ResearchOnline@JCU

This file is part of the following work:

McCarthy, Michael (1996) ***SS Xantho: towards a new perspective. An integrated approach to the maritime archaeology and conservation of an iron steamship wreck*****. PhD thesis, James Cook University of North Queensland.**

Access to this file is available from:

https://doi.org/10.25903/5d8d88a721af4

Copyright © 1996 Michael McCarthy.

If you believe that this work constitutes a copyright infringement, please email
researchonline@jcu.edu.au

SS *Xantho*: Towards a new perspective.
An integrated approach to the maritime archaeology and conservation of an iron steamship wreck

Thesis submitted by
Michael McCarthy Dip. P. Ed., B. Ed., Grad. Dip. Mar. Arc., M. Phil.
in January 1996

For the degree of Doctor of Philosophy
in the Department of Archaeology and Anthropology
James Cook University of North Queensland

ABSTRACT

The assessment and excavation of the wreck of the iron-hulled SS *Xantho* (1848-72) has shown that otherwise unobtainable information about both materials and people can be found in the archaeological study of iron and steamship wrecks.

One important development has been the initiation of full pre-disturbance studies of a shipwreck's biological and electrochemical properties, giving insights into the condition of the site and its materials of value to both the archaeologist and conservator. Conducted by diving conservation specialists at the request of the archaeologist, this was the first such comprehensive study to be performed on any underwater site. It is now recognised as an essential element in any modern maritime archaeological project.

Site inspection revealed that *Xantho* was powered by a former Royal Navy gunboat engine, of a type that was evidently the first high pressure, high revolution and mass produced marine engine made. Despite these advances, they were suitable only for use in a naval context. The ship itself was a former paddle-steamer built in the formative years of iron shipbuilding. After 23 years of service it was sold to a scrap metal merchant who joined the hull to the second-hand screw-engine and offered the revamped hybrid for sale.

That the ship appeared on the sparsely populated and poorly serviced Western Australian coast, far from coal supplies and marine engine repair facilities, posed an immediate question; what sort of person would use it in this manner? Thus the *Xantho* program came to focus on Charles Edward Broadhurst and how he came to make the apparently strange decision to purchase such an odd and apparently unsuitable vessel. Archival study and an excavation of the stern section of the wreck were conducted for these purposes.

The study of Broadhurst was completed in 1990, the subject of the author's Masters thesis, resurrecting and analysing the entire business career and life of one of Western Australia's forgotten, but most active and controversial colonial entrepreneurs.

This thesis centres on the excavation of Broadhurst's ship and describes the recovery of the ship's engine from a highly-oxygenated salt-water environment. The recovery of the engine was followed by conservation treatment and an archaeologically-based 'excavation' of the heavily concreted engine in the laboratory. Begun in 1985 the deconcretion was completed by mid 1995 with the opening up of the last of the internal spaces and the freeing of all working parts in preparation for the engine's reassembly and exhibition.

The successes of the two 'excavations' have confirmed both the place of the conservator on the sea-bed and the archaeologist's place in the conservation process. In the disassembly of the engine, where nearly two tonnes of concretions were removed, evidence was found of technical significance and of the way Charles Broadhurst, the vessel's owner operated the ship.

I also describe commonalities evident in the formation of iron and steamship wreck sites. This enables anomalies noted at the *Xantho* site to be assessed and quantified against a broader sample, leading to a focus on the behaviour of steamship owners in a frontier environment and the postulation of a number of testable propositions about the material residues of such behaviours.

Statement of Access

I, the undersigned, the author of the thesis, understand that James Cook University of North Queensland will make it available for use within the University library and, by microfilm or other means, allow access to users in other approved libraries. All users consulting this thesis will have to sign the following statement:

> In consulting this thesis, I agree not to copy or closely paraphrase it in whole or part without the written consent of the author; and to make proper public written acknowledgment for any assistance which I have obtained from it.

Beyond this, I do not wish to place any restriction on access to this thesis.

23/1/1996.
....

(................)   (Date)

STATEMENT ON SOURCES

Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

23/ . /1996.

(................) ....

(Date)

TABLE OF CONTENTS

ACKNOWLEDGMENTS

A great number of people have been involved in the *Xantho* project and the assistance rendered to me over the past years has been most generous and multi-faceted.
Before recognising that assistance, through the attached list, I wish to thank a number of key contributors without whose assistance the project would not have proved such a success. The first of these are my family, Debbie, Kim, Katie, Ellen and Phillip, whose support has been unwavering.

The key personnel on a technical level are diver/rigger Geoff Kimpton, corrosion specialists and Heads of the Department of Materials Conservation and Restoration, Dr Neil North and Dr Ian MacLeod and finally conservator/restorer Dick Garcia. These four specialists provided not only the solutions to very difficult problems but have shown a deep commitment to the project. Without their assistance the project could not have succeeded.
Special thanks must also be rendered to my steam engineer/adviser, the late Noel Miller, to model-maker Bob Burgess, to John Riley, iron and steam shipwreck specialist and to Charles Broadhurst's grand-daughter, the late Marjorie Darling.
The unwavering support of my family is also acknowledged.
On an academic level, Associate Professor John Campbell of the Department of Archaeology and Anthropology at James Cook University provided the backing necessary for my enrolment within the School at a most opportune time. Dr Peter Veth, from the same Department, was my thesis supervisor. He provided not only the necessary support, advice and editorial assistance in abundance and with deep commitment, but also the academic and philosophical climate needed to help me develop, through this thesis, a belated but much-needed bridge between terrestrial and maritime archaeology in Australia.
I am indebted also to Professor Richard Gould and to Dr Paul Johnston for their interest in the *Xantho* project.
Finally, I thank my past and present colleagues at the Departments of Maritime Archaeology and Conservation at the Western Australian Maritime Museum for their assistance through the years. To my colleague and Head of Department, Jeremy Green, to the former Director of the WA Museum, John Bannister, and Head of Division, Dr Ian Crawford, I give special thanks for allowing me to use the results of work on behalf of the Museum for this thesis. I thank the present Executive Director of the Museum Andrew Reeve and Graeme Henderson, Director of the Maritime Museum, for continuing that support. In doing so they have all recognised the need to expose maritime archaeological excavation, especially that of a relatively new class of site, to the most rigid external academic scrutiny possible.

Following is a list of those who have assisted me in this project.

THE *XANTHO* TEAM (1983-1995)

Personal Field Assistants

Geoff Kimpton
Dena Garratt
Brad Duncan
Bob Richards

Field Conservators

Neil North
Jon Carpenter
Fairlie Sawday
Ian MacLeod
Paul Mardikian
Nancy-Mills-Reid

Assistant Field Archaeologists

Steve Cushnahan
Nic Clarke
Mark Staniforth
Brunhilde Prince
Dena Garratt
Peter Harvey
Shirley Strachan

Biologist

CJ Beegle

Deconcretion Team

Ian Macleod
Geoff Kimpton
Bob Richards
Michelle Berry
Nancy Mills-Reid
Brad Duncan
Jan Davies
Ian Godfrey
Stéphane Pennec
Vicki Richards
Louella Doran
Dick Garcia
Jon Carpenter
David Kelly
Kolam Gaspar
Paul Mardikian
Alan Kendrick
Pat Baker
Carmela Corvaia
Fairlie Sawday
Alex Elliott
Rhonda Wozniak

Engineers

Noel Miller
Harvey Watson
Bob Burgess
Geoff Hewitt

Model-maker

Bob Burgess
Noel Miller (drawings)

Engine Rigging and cutting

Geoff Kimpton
Bob Richards
Brian Marfleet
Colin Powell

Diving Specialists

Geoff Hewitt (Engineer)
Sally May (Archaeological Assistant)
Mike Lorimer (Archaeological Assistant)
John Riley (Archaeological Assistant)
Jon Carpenter (Photographer)
Lyall Mills (Video operator)
Pat Baker (Photographer)

Artwork and Diagrams

Ian Warne
Geoff Kimpton
Colin Cockram
Fairlie Sawday
Peter Correy
John Riley
Geoff Hewitt
John Moffett
Chris Buhagiar
Paul Mardikian

Site-conditions Study

Peter Worsley (MAAWA)
Jill Worsley (MAAWA)

On-site Photography

Pat Baker (WAMM)
Nic Clarke (VAS)
Jon Carpenter (WAMM)
Lyall Mills (MAAV)

Technical and Professional Advice and Assistance

Paul Mardikian (Conservation)
Maria Pitrun (Metallurgy)
David Lyon (Research)
Graeme Henderson (Archives)
Richard McKenna (Research)
D. I. Moor (Archives)
Chris Dixon (Photogrammetrist)
Peter Veth (Archaeological theory))
Laurie White (Photogrammetrist)
Paul Johnston (SS *Indiana*)
Richard Gould (Archaeological theory)
Malcolm Tull (Broadhurst)
Ken MacPherson (Previous supervision))
Myra Stanbury (Artefact Management)
Colin Christie (Glasgow University)
John Dell (Strathclyde Archives)
Lucy Burrow (Artefact Registrar)
Nick Burningham [Editorial]
Tom Vosmer [Editorial]
Roland Webb (Engineering)
Stephane Pénnec (Conservation)
Olaf Envig (SS *Hansteen*)
Jeremy Green (Computers)
Richard Tomlin (Engineering)
Tim Willings (Botanist)
Harvey Watson (Engineering)
Joe Roone (Science Museum)
Pat Baker (Photography)
Antonia MacArthur (Researcher)
Richard McKenna (Researcher)
Edwin Punchard (Researcher)
Brian Doherty (Engineer)
Laurent Mezin (Translation)
Sue Cox (Secretarial)
P Duffy (Glasgow Archive)
K Langrish (Lloyd's Register)
F Sawday (Artefact Registrar)
Lindsay Hill [Drawings]
Ray Sutcliffe (Photographs)

Corporate Assistance

ALCOA
Main Roads Department
Target Minerals
Perth Diving Academy
Department of Home Affairs
CIG
AIMA
Ansett
TAA
State Engineering Works
United Transport
Coates hire
Bill Busby (Budget)
Canberra TV
Queensland Museum
SUHR

General Conservation Staff

Neil North
Richard Garcia
Michelle Berry
Nancy Mills-Reid
Nikki King-Smith
David Kelly
Rinske Car
Ian MacLeod
Jon Carpenter
Ian Godfrey
Vicki Richards
Lucy Burrow
Alan Kendrick
James Pang

The Broadhurst family

Marjorie Darling
Jenny Davies
Penny Cocks
Margaret Brinsden
Jan Brummitt
Gwen Thomas

General Field Assistants

T Beaver
J Greenlees
J Mercer
K Hoffmann
L Simmons
M Moffett
P O' Toole
J Paskulich
M Clarke
B Williams
P Boardman
E Boogard
R MacLeod
J Sewell
C Martindale
D Gilroy
D Hardstaff
M McKay
J Dobbin
J Gloriod
J Turner
M Hewitt
S Cunningham
J Banfield
D McKenzie
D McCarthy
B Martindale
M Jesser
B Busby
S McKenzie
R Garcia
G Wallace

MUSEUM SUPPORT STAFF

Directorate

John Bannister (Director WAM to 1994)
Ian Crawford (Head of Division WAM to 1994)
Andrew Reeves (Executive Director WAM 1994-)
Graeme Henderson (Director WAMM 1994-)

Administration

Robin Reid and staff (Accounts WAM to 1992)
Sieg Praxl and staff (Accounts from WAM 1992)
Mike Lefroy and Education staff
Ann Ousey and staff (Publications)
Barry Bishop and attendant staff
Dan Boyes and staff (Accounts WAMM)

Exhibition and Design

Annie Chandler
Darrell Hick
Jacques Maissin
Carol Anne-Cassidy
Allan Roe
Rod Van Der Merwe

Library

Margaret Triffitt
Joanne Valley

The Maritime Archaeology Advisory Committee
The Australian Institute for Maritime Archaeology
The State Library of Western Australia

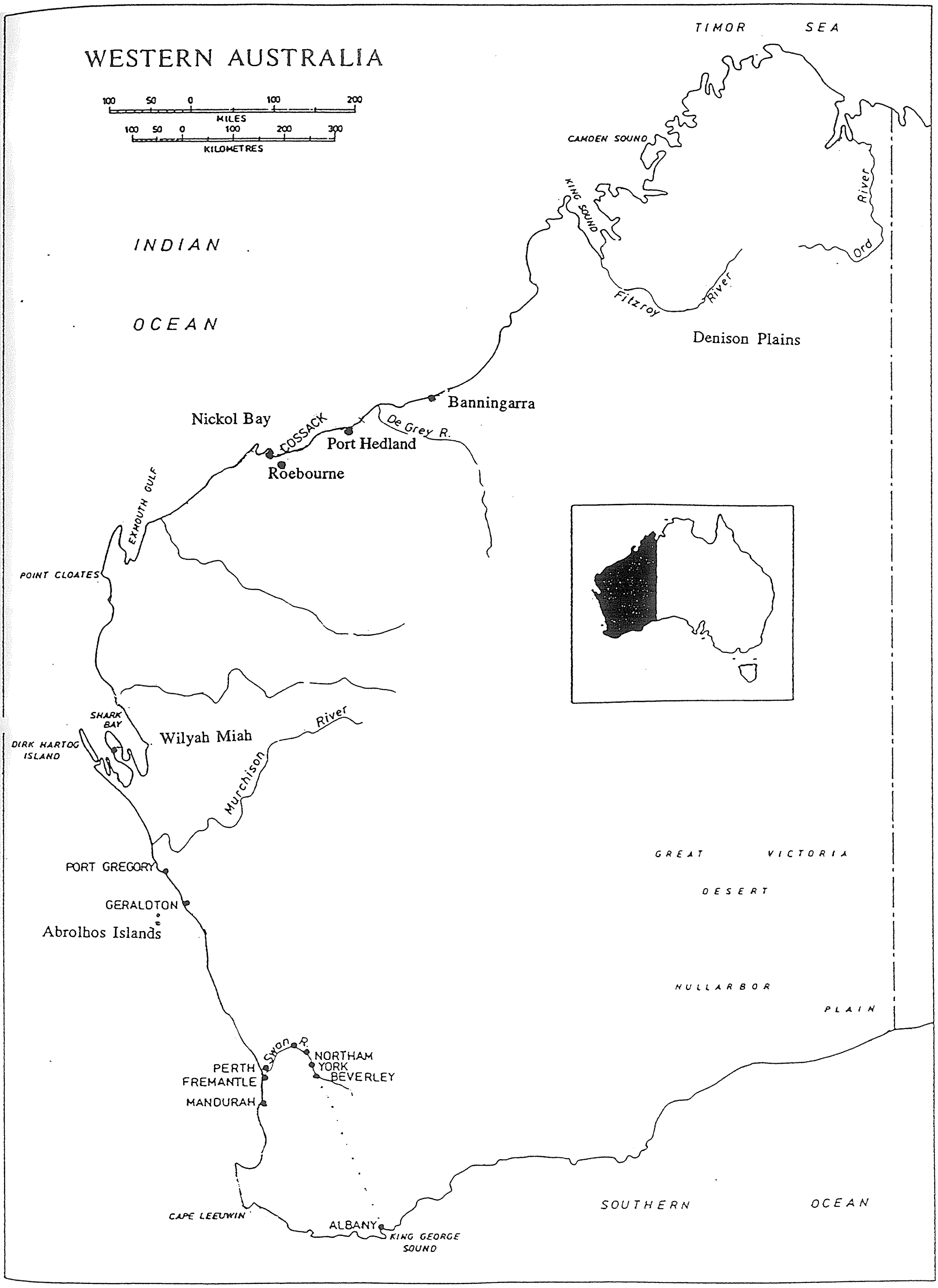
LIST OF ILLUSTRATIONS AND TABLES

Figure **Page**

ABBREVIATIONS

A&M	Agricultural and Mechanical
AICCM	Australian Institute for the Conservation of Cultural Material
AUS	Australian chart
BA	British Admiralty chart
Co.	Company
CSO	Colonial Secretaries Office
CSR	Colonial Secretary Received
CSS	Confederate Steamship
FPA	Fremantle Port Authority
ft.	foot
HMAS	Her (His) Majesties Australian Ship
HP	Horse Power
ICCM	Institute for the Conservation of Cultural Material
IHP	Indicated Horse Power
IJNA	The International Journal of Nautical Archaeology
kg.	Kilograms
lb.	Pound (Weight)
m.	Metres
MAAV	Maritime Archaeological Association of Victoria
MAAWA	Maritime Archaeological Association of WA
MANSW	Maritime Archaeological Association of NSW
mm.	Millimetres
MV	Motor Vessel
nd	No Date
NHP	Nominal Horse Power
NMM	National Maritime Museum
NSW	New South Wales
P&O	Peninsular and Orient Steam Navigation Company
PRO	Public Records Office
PS	Paddle Steamer
psi	Pounds per square inch
RN	Royal Navy
RPM	Revolutions per minute
RWAHS	Royal Western Australian Historical Society
SA	South Australia
SAWA	State Archive of Western Australia
SS	Screw Steamer
SUHR	Society for Underwater Historical Research (SA)
TSS	Twin Screw Steamer
USS	United States Ship
V&P	Votes and Proceedings of the WA Legislative Council
WA	Western Australia
WAM	WA Museum
WAMM	WA Maritime Museum
WWI	World War 1
WWII	World War 2

Figure 1: Western Australian European centres in the 1870s (WA Maritime Museum)



INTRODUCTORY NARRATIVE

Setting the scene

The carriage of lead ore along the vast Western Australian coast in November 1872 appeared to be a good sideline for entrepreneur, Charles Edward Broadhurst.[1] He was a pearler based in the north-west and he had a steamship; the iron-hulled SS *Xantho*. All that was required on the very long voyage down to Fremantle with an empty ship was to call into Port Gregory, load with ore and transport the cargo 30 nautical miles south to Geraldton (Figure 1). At Geraldton, or Champion Bay as it was then called, the ore would be off-loaded into lofty wool-clippers for the long voyage to England as paying ballast, a substitute for the worthless rocks that were usually taken by sailing ships for that purpose. From there, the *Xantho* would continue south to Fremantle and Broadhurst would have a handsome profit to show for little effort and virtually no additional expenditure.

So; 'fill the holds and cram every space with ore' was apparently the order given to Captain Ernest Denicke. Hundreds of bags of lead at the rate of 12 to the ton, were loaded on-board and manoeuvred into every available space. By mid-evening 83 tons had been stowed, putting the ship noticeably down at the bows, well out of trim and clearly over-loaded. To make matters worse, the south-easterly breeze was freshening, lifting the sea into a heaving mass that would fight the ship every inch of the way on the voyage down the coast. The sails which the steamer carried would have been a hindrance in the head-wind and were probably stowed away.

It was November 1872, at the beginning of the Western Australian summer and the vessel had just arrived at Port Gregory from the newly named Port of Cossack, then home of Australia's pearling industry (Figure 1). It had been very hot in the north-west and the yellow pine planking of the decks had opened up in the sun, allowing water to find its way below.

The leaking decks and the heavy load did not unduly worry the first mate, who was at the wheel. Though the ship was a former paddle-steamer built almost a quarter of a century earlier, it had three watertight bulkheads and recently had repair work done on its ageing hull. Around midnight, Denicke came up on deck and relieved the mate who went below. After a quick glance the skipper was satisfied that, though the ship was sluggish and the bows were lying deeper than normal in the water, the *Xantho* was coping with the seas. All was well, he believed, and his thoughts would have drifted away as he stood, wheel in hand, legs braced against the comforting regularity of the ship's movement.

Denicke's mind probably flitted across the year that had elapsed since he had left Britain as Broadhurst's pearling adviser and master of the newly purchased ship. No one else was pearling in such a grand fashion as Broadhurst. He had become a virtual king in the sparsely populated north with his small steamer, the first to be used on the coast and the first used in the pearling industry. As a result he was tremendously influential in a Colony hungry for steam transport, technology and the chance to profit from its nascent primary industries.

Quite the English gentleman to people like Denicke, Broadhurst found little difficulty in dealing to his satisfaction with Government bureaucrats and sundry officials and was used to having his way. Despite his 'breeding', he was also a hard worker who expected nothing less from his crew. He was controversial too, not only being hard on his men, but he had been involved in some questionable enterprises. One was the Denison Plains Pastoral Company which had planned to

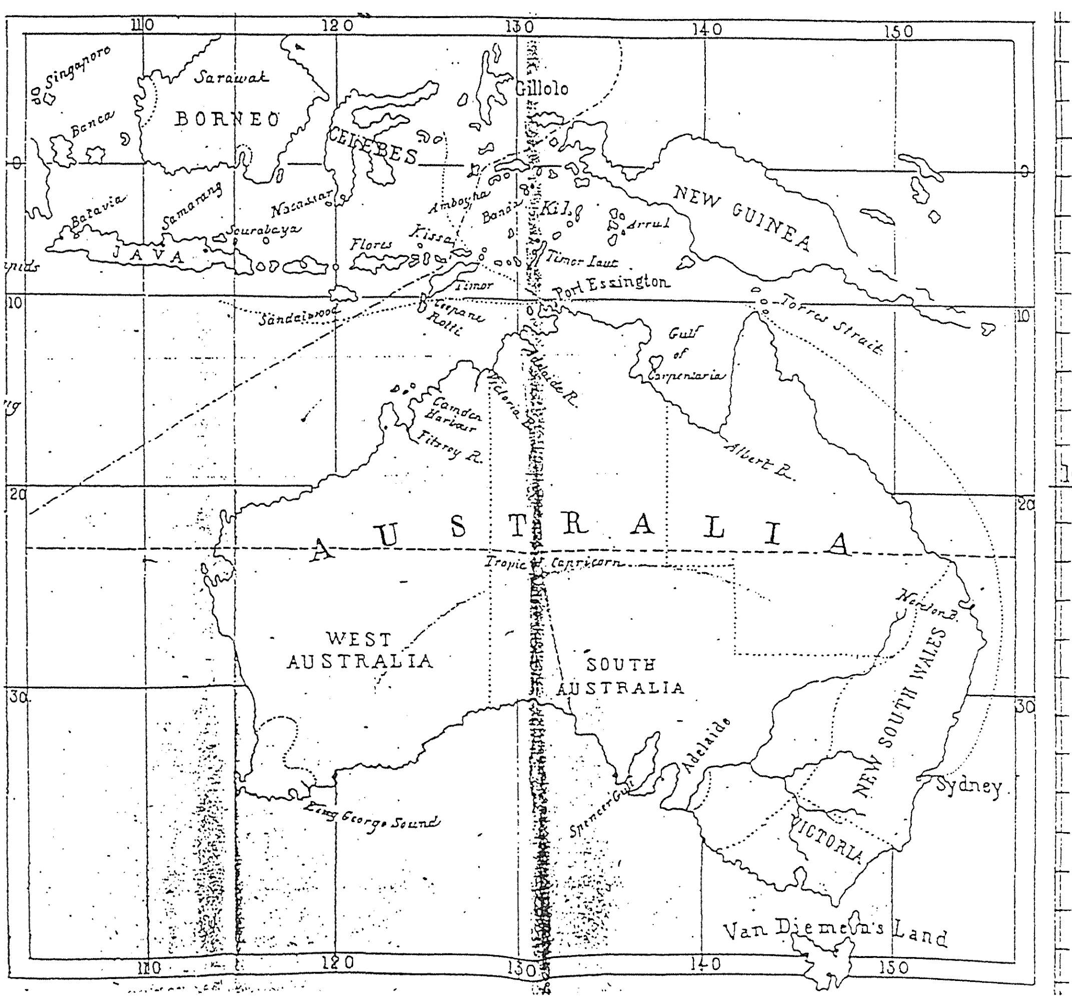
---

[1] Entrepreneur: In defining the term economists have stressed innovation, risk bearing, organisation and leadership. The entrepreneur organised production, capital and labour, selected the site, the most appropriate technology, bargained for raw materials and found outlets for the finished product. (cf., Payne, 1974:13-14).

settle the far north of Western Australia; the other was its sister company, the Camden Harbour Pastoral Association. Both hoped to form a new gateway into Australia from India and Singapore, by allowing mariners a safe alternative to the difficult sea-lanes into Melbourne and Sydney via the Bass or Torres Straits. It was all a pipe-dream and Broadhurst had been badly tainted by the inevitable collapse of both companies. He had also proved controversial as a pastoralist and pearler; but still Denicke had travelled far and wide with him and had amassed a considerable amount in wages that would be paid in a lump sum at the end of the voyage.

Much had happened since Denicke, Broadhurst and the *Xantho* left England in October 1871. They had passed through the newly opened Suez Canal, across to Galle, then onto Batavia (now Jakarta) and Surabaya to recruit a new breed of pearl divers, then generically called 'Malays'.[1] Around April 1872, when the onset of cold weather signalled the end of the pearling season, they travelled down the long Western Australian coast-line to Fremantle. There they off-loaded and spent a short period ashore while Broadhurst attended to business and visited his family. Then they turned around and travelled back up the coast carrying passengers and a general cargo. In the north they went pearling for the season and then headed across to Surabaya and Batavia.

Figure 2: Chart showing the Western Australian coast, Batavia (Jakarta) and Surabaya (Camden Harbour Pastoral Association Prospectus, 1864)



[1]Malay: A term, generally but incorrectly, used in the nineteenth century to denote indentured labourers from the islands to the north of Australia. Often found as divers in the pearling industry, the labourers came from Timor, the Philippines, Singapore, present-day Indonesia, Borneo and Malaysia.

After these few voyages, the proximity of the north coast of Western Australia to Batavia and Surabaya, ceased to surprise Denicke. Travel down the length of the vast unpopulated coastline between the pearling grounds and Fremantle took far longer. It was even further still to King George Sound (Albany) and the regular steam-ship connections with Adelaide, Melbourne and the outside world. Denicke soon appreciated the fact that Broadhurst's pearling bases, and the entire 'North District' of the Swan River Colony, as it was called, was closer to Surabaya, Batavia and the outside world than to any other major settlement on the Australian coast, including Fremantle (See Figure 2).

The formation of the Xantho site

A rapid change in the motion and the feel of the ship would not have caught Denicke unawares. Like any experienced sailor, he would have felt the ship become more sluggish and the bows not rising to the seas. In fact the entire vessel seemed to be gradually sloping down into the seas and was not rising at all. The first mate was roused out of the cabin and sent forward with orders to report back on the problem. On arrival he was astounded to find that the entire fore-part of the ship was awash and was down by the bows at least seven feet. They were sinking. He scrambled aft, shouting at Denicke who immediately spun the wheel calling for all hands to rouse themselves and jettison the sacks of ore. The other crew hurried up on deck, already alerted by the commotion and the change in motion.

Broadhurst also hurried up into the night, his mind undoubtedly on the profits rapidly disappearing overboard with every heave of the frightened crew. He quickly summed it all up. On the one hand, the pumps were useless being in the elevated stern of the ship. On the other, the bulkheads were watertight and the ship was just holding its own. They might just make it back.

Characteristically, he ordered a halt to the dumping of the ore, saying he would rather save the ore than the ship. The crew were incredulous, but he was such a forceful character they could only obey. They did as they were ordered and stopped work, taking stock of their perilous situation as they rested. Though poised dangerously for a final plunge into the depths, the ship was just under control and they were still underway. Perhaps Broadhurst was right.

For four long hours they watched in fear as they slowly crept back north, this time with the swell and the wind assisting them in their flight. Soon the crashing reefs that protect Port Gregory from the seas loomed white before them. It was 4 am. They crept slowly in towards the coast; the vessel, with most of its rudder exposed, the propeller thrashing out of the water on every turn and the helm almost useless. On they went north, until slowly they turned into the passage. Behind the reefs the waves ceased their incessant pounding and then they were safe. Here the water was very shallow, the sea-bed lying only a few feet below the *Xantho's* keel. They only had to negotiate the last set of surge and swells opposite a small gap in the reef and they were in the harbour proper.

Their joy was short lived however, for ten minutes later the sunken bows ground into a sand-bar opposite the gap and the ship came to a sudden jarring halt. In the engine room, the men recovered from the impact and swung the engines into mid-gear, awaiting further orders. As they glanced around, checking that all was in order, they became horrified as seawater surged up through the stokehold floors to eddy around their feet. For around 15 minutes they sweated and shovelled coal into the furnaces, keeping up steam to work the pumps in an attempt to keep water from the fires. But still it rose. As the sea crept beneath the boiler to the furnace grates, they slammed the furnace doors shut and opened the relief valves on the boiler. With a violent hissing and spattering of ash, the fires were extinguished and all of the machinery, including the pumps, slowly ground to a halt.

Fearful of being trapped below as the vessel sank, the men rushed onto the deck to join in an attempt to manually bail water from the ship. It was a forlorn hope and they watched the *Xantho* slowly settle beneath them and come to rest in only five metres of water. Above their heads, against the black sky, they could see the vessel's tall funnel, the masts and the rigging; below their feet the decks were awash. Timber, cabin fittings and loose items were already bubbling past them on the tide.

Dawn soon began to break and as the sky brightened the crew saw that the shore, in the form of a small sand-bar, was only a stone's throw away. When the sun rose, they could still see the sacks of lead ore that they had left on the beach only hours before. Perhaps they should have left much more behind.

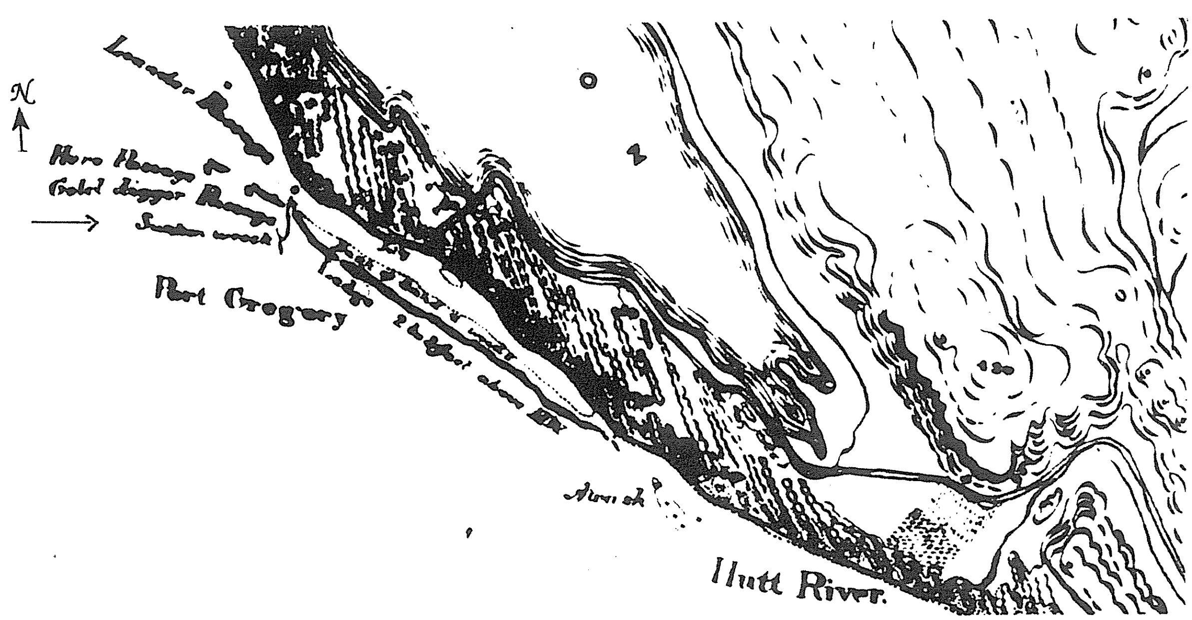
It was all an anticlimax and each man would have been resigned to his own thoughts as they prepared to leave the ship. Broadhurst then remembered that the insurance on the ship had lapsed only two weeks previously. The SS *Xantho* had cost him a great deal to buy and he had no money to pay the men. He was effectively ruined, but he said nothing.

Wasting no time, he set the men about removing everything that they could from the wreck. The sails, fittings, rigging and everything moveable were quickly taken from the wreck and stored on the beach opposite. Denicke was sent south to Champion Bay see if a buyer could be found for the wreck and Broadhurst took passage to Fremantle to salvage as much of his business empire as he could.

The ship soon proved to be a total loss. Divers reported that it had sunk into the sea-bed and the shifting sand had quickly filled the vessel's holds, preventing them from salvaging all of the ore. They retrieved the loose bags, personal effects, goods and fittings that still lay strewn inside the ship, or were fixed by their buoyancy to the roof of the cabin and crew's quarters. What was not loose they would have attempted to lever off the deck or cabin walls. They did their work well and sent everything they could to be stacked safely on the beach.

Thus the short colonial career of the SS *Xantho* had come to an abrupt end. Broadhurst's attempts to salvage it came to naught and, being a total loss of no further use, it was soon forgotten. A few years later the Royal Navy charted the entrance to the port and noted that an unidentified wreck, which was found on the edge of the channel, would soon become engulfed by the sand-bar (Figure 3). It was Broadhurst's ship, but this fact soon became lost to living memory.

Figure 3: Excerpt from the Royal Navy chart showing a wreck at the entrance to Port Gregory (Archdeacon, 1879, Admiralty Chart No: 2. Western Australian Coast)[1]



---

[1]From a low density photograph of the original.

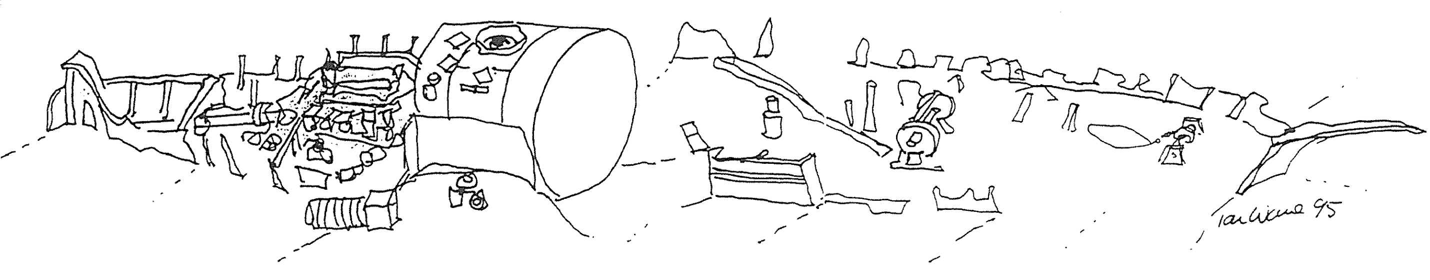
Inspection, pre-disturbance survey and excavation

In 1979 the wreck was found and *Xantho* was acknowledged to be of a regional importance. Following reports of looting at the wreck I was assigned responsibility to ascertain whether interference was likely to continue. If so, the option of a controlled salvage archaeological excavation was to be considered. Though an ostensibly mundane task, it had occurred to me that we were breaking new ground, for until then, the vast majority of maritime archaeologists had concentrated on wooden shipwrecks. It was assumed at the time that iron shipwrecks would last as long as a comparable wooden wrecks and, as a result, work on them was considered a low priority. In reality these were untested assumptions. Questions, such as how an iron wreck behaves in an underwater environment, or what the processes of iron ship disintegration were, remained to be answered.

The archaeological evidence

In May 1983, I attended to these and other questions with the assistance of biologists, corrosion scientist and other specialists. After facilitating and assisting in a pre-disturbance study, my attention turned to the technical features of the ship and a number of anomalous features that were identified. The engine was an inefficient piece of machinery with a huge appetite for coal. It was of a type primarily used in the naval context due to its configuration and compact nature. Its use was virtually unheard of in a merchant steamer, let alone one operating in a remote part of the world with very few repair facilities and poor coal supplies. This posed many questions about the *Xantho*, the manner in which it was engined, its mode of operation and its apparently ill-advised owner. Little was known of Broadhurst, however, as he had been dismissed historically as an unsavoury character and a failure in most of his business enterprises.

Figure 4 : A sketch of the SS *Xantho* as it appeared in 1983. By project artist Ian Warne.



(Not to scale)

It soon became apparent that the engine of Broadhurst's ship was not only anomalous but technologically important and in danger of destruction by natural and human forces. Covered in a rock-hard layer of marine growths, its recording and conservation necessitated a re-assessment of traditional maritime archaeological and conservation methods and philosophies. Protective anodes were applied to the engine and later to a part of the hull to slow the corrosion processes. A decision was then made to raise the engine in the context of a total excavation of the stern section of the wreck.

The engine was bought to the surface in 1985 after more than a century on the seabed. It was the first attempt to raise a steam engine from a highly oxygenated, salt water environment.

Concurrent research was conducted in the archives and oral histories were recorded in order to better understand Broadhurst (McCarthy, 1990). Questions remained unanswered, however. As a result excavation continued, both at the site and in the laboratory, all in order to answer the questions arising from both the examination of the ship and the archival analysis of Broadhurst.

In April 1995, the excavation and analysis came to a finish. The conservation of the engine is in its final stages and an exhibition centring on Broadhurst and his ship is in preparation.

This thesis presents the results of over a decade of archaeological work including a behavioural analysis based on maritime material remains. It is the culmination of a project that began with the preliminary assessment of what was expected to be a relatively modern, mundane iron-hulled steamship wreck holding few, if any, surprises.

CHAPTER 1:

THE CASE FOR THE ARCHAEOLOGY OF IRON STEAMSHIPS

The study of iron and steamship wrecks has been seen by many as an unnecessary duplication of information appearing in archives and museums. Alternatively, it can be argued that it constitutes an important element in the general study of maritime history, culture and engineering. The *Xantho* study represents an opportunity to address this debate and to firmly demonstrate that the study of iron and steamship wrecks is a valid part of maritime archaeology and of archaeology as a whole.

In order to place this particular study, and that of iron and steam shipwrecks generally, into an historical and theoretical context, it will first be necessary to examine the nature of maritime archaeology itself and to briefly examine it's place as an accepted part of the discipline of archaeology.

I begin with archaeology practised underwater, so-called underwater archaeology, and then proceed to shipwreck archaeology and finally to maritime archaeology.

The evolution of underwater archaeology

Underwater archaeology, sometimes called marine archaeology, is archaeological investigation practised underwater. The vast research potential of underwater archaeology is only now being fully realised, even though in the mid-nineteenth century while the discipline of archaeology itself was becoming established, its potential was recognised. Over a century ago, the following observation was made

> It is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean than will exist at any other time on the surface of the continents (Lyell, 1832:258)

The veracity of those words is increasingly becoming evident. Submerged Paleo-Indian sites have been located in Florida; Maori settlements in New Zealand; crannogs (lakeside villages) in Scottish lochs (Dixon, 1991:1-8); Greek, Roman and Phoenician ports and cities are found in the Mediterranean sea and inundated townships (such as Port Royal) have been studied in Jamaica (Cockrell *et al.*, 1980:132-175). Major inroads are now being made into the systematic location and mapping of submerged terrestrial sites reflecting past human activity along paleocoastlines and the modelling of population movement across land bridges (Masters and Flemming, 1983). Within mainland Australia, submerged Aboriginal sites are also being found (Dortch and Godfrey, 1990:28-33).

It has been argued for over thirty years that 'archaeology underwater... should simply be called *archaeology*' and that it should not necessarily be considered a separate branch of the parent discipline purely because the material under examination has become inundated (Bass, 1966:15). As a result it has been claimed that the only valid subdivisions that can be made between the study of terrestrial and underwater sites are those based on topics and perhaps the dominant classes of material which are the subject of study (Muckelroy, 1980:9). Obviously the philosophical basis and inferential logic with which a terrestrial archaeologist may approach a terrestrial excavation equally applies if that site becomes inundated mid-excavation, say due to a flash flood. Similarly, when presented with an inundated site adjacent to, or connected with, an existing terrestrial site, the terrestrial archaeologist merely needs to adapt the necessary techniques and methods in order to proceed with a terrestrially-driven research strategy. An inundated site is no less an archaeological site because it is underwater.

The submerged environment presents logistical and technical challenges which need to be mastered by the archaeologist before the required standard of recording and recovery can be reached. Often those who do not dive misunderstand the nature of these challenges. Influential terrestrial archaeologists Renfrew and Bahn, for example, recently noted (1991:11) that for an archaeologist to proceed underwater demands 'great courage as well as skill', thereby setting those who take the plunge apart from the mainstream. This does not stand up well to objective scrutiny. As a very experienced underwater archaeologist once noted, diving is just a 'minor skill that can be learned by almost anybody' (Throckmorton, 1987:24).

It has long been argued that the skills needed for effective inundated work are generally a part of any qualified and experienced archaeologist's training and can be transferred underwater with time, knowledge, good teaching and experience. There is ample proof of the truth in the simple axiom that it is 'far easier to teach diving to an archaeologist than archaeology to a diver' (Goggin, 1964:299-309). One documented example, that of George Bass' evolution from a terrestrially-bound student of Classics is well recognised (Frey, 1993:18-22). Bass is now widely recognised as one of the founders of underwater archaeology, even in the popular literature (Bahn, nd:49). There are many more, undeniably successful examples of this phenomenon, though Ivor Noel Hume (1975:191-2), a well known proponent of historical archaeology, has called for the teaching of underwater archaeology as a separate subject; rather than see archaeology and anthropology graduates precipitously take the plunge without proper training.

Shipwreck archaeology

The relatively easy transport of terrestrial archaeologists and their research agenda into the water, after suitable induction to the marine environment, has not been easily extended to the case of shipwreck studies. There are many reasons for this phenomenon.

In the late 1960's Bass (in association with Peter Throckmorton) made considerable progress in bringing the shipwreck, as a useful inundated archaeological site, to the attention of his peers. He began what is now termed underwater archaeology through his series of benchmark excavations of Bronze Age, Roman and Byzantine wrecks in the Mediterranean (Bass, *et al.*, 1967).

Bass was followed by many others in realising the value of the shipwreck as an archaeological site. Most had no formal training in archaeology, however. As a result, and in contrast with Bass, much was done to an unsatisfactory standard (Bass, 1981:x). Questions were subsequently raised about those professing to be shipwreck archaeologists due to their lack of academic standing, their sometimes crude methods and the very public involvement of some in what were essentially treasure seeking expeditions.

Mainstream archaeologists pointed to these elements as proof that the study of shipwrecks, even when performed in ideal conditions to high standards, was at best a cataloguing of the existing resource, or the collection of objects for museums and other purposes. To them, only low level empirical generalisations were resulting from the work and the investigations had little archaeological value. This served inevitably to tar even those working to high standards with the same brush. The endeavours of workers such as Bass, Throckmorton and others across the Atlantic, such as Frédéric Dumas and Joan Du Plat Taylor (Du Plat

Taylor, 1965), were seen by some in the 1960's as a 'silly business' (Bass, 1983:91).

One of the early impediments to mainstream acceptance of shipwreck archaeology was the fact that Bass and others did not apply stratigraphic techniques to their excavations. It can be argued that they did not need to, however. In Bass' case each of the sites quickly proved to be quite discrete and related to only one incident in time or what Noel Hume termed 'an unimpeachable *terminus ante quem*' (1975:189-190). The often cataclysmic deposition of a single ship-borne culture in one place at one point in time is a characteristic of most large wreck sites. While many practitioners viewed a firm handle on chronology as one of the strengths of shipwreck research, to many and especially to anthropologists, the shipwreck presented a weakness in its apparent inability to provide the diachronic perspective of culture change. The scepticism was broadly felt. In noting that artefacts had 'lost' their stratigraphy in a scattered wreck Noel Hume, for example, reiterated the concerns of many of his peers

> Picking up the pieces from the bottom is essentially a salvage rather than an archaeological project because it requires none of the archaeologist's techniques of revealing, studying, and recording the relationship between objects and their stratigraphy (1975:190).

In claiming on the one hand that the ideal wreck, such as the famous *Wasa* (1628-1628) which was raised intact from the waters of Stockholm Harbour in 1961, may be a 'miniature Pompeii' and therefore deserves to be treated accordingly and on the other, that there is little to be gained from the painstaking plotting of material from scattered sites, it is apparent that Noel Hume did not appreciate, or agree with, the assemblage concept, as defined and widely accepted in his time (cf. Champion, 1980:11-12).[1]

The first step by shipwreck archaeologists in overcoming concerns about stratigraphy and association were attempts by Bass and others at improving the standards of recording and reporting from within the field of shipwreck archaeology itself. In 1970, for example, Colin Martin wrote to the editor of the newly produced, *International Journal of Nautical Archaeology and Underwater Exploration* (IJNA) questioning the 'general standards of competence'. He called for the appropriate qualification of practitioners and for standards of excavation, recording and reporting that were 'acceptable in conventional archaeological practice' (Martin, 1972:246-247). The call clearly indicated that standards within the field of underwater and shipwreck archaeology were often not generally acceptable at that time. Twenty-five years later this issue has largely been addressed by legitimate practitioners. In 1983, for example, Watson stated

> A great many terrestrial archaeologists and other scholars do not regard underwater archaeology as a legitimate part of the profession because they fail to realize that excavation and recording at underwater sites has attained a completely professional level (1983:29).

New underwater recording methods and equipment come to underwater archaeology almost yearly from the oil and mineral industry. The general level of technical recording by underwater archaeologists is, as a result, more than satisfactory (cf. Green 1990). The same can be said for the conservation of materials raised from the

---

[1] Assemblage: A set of objects found in association with each other and therefore assumed to belong to one phase and one group of people. An assemblage can be made up of objects of different type...An assemblage may reflect the totality of artefacts available to a particular group of people at one time.
Association: Objects are said to be in association with each other when they are found together in a context which suggests simultaneous deposition. Associations between objects are the basis for relative dating...The association of undated objects with artefacts of known date allows the one to be dated by the other (Champion, 1980:11-12).

sea-bed; an area where breakthroughs are also continually being made (e.g. Pearson, 1987).

In response to the criticism that stratigraphic approaches cannot be applied underwater, it should be noted that stratigraphic interpretation can be employed, where conditions are conducive to the development of a depositional sedimentary regime. Successful recording and analysis of inundated cultural layers has now been clearly demonstrated. Excavations at the former town of Phanagoria, and other cities along the Black Sea and at prehistoric villages built over water in Switzerland both revealed chronostratigraphic units (Blawatsky, 1972:115-121; Ruoff, 1972: 123-133).

Of significance, Robert Grenier's excavation of a Basque whaler in Red Bay, Labrador, provides an example where 'well-defined layers of cultural deposition' were recovered through the use of a 'stratigraphic technique'. The main cultural horizon contained datable organic materials such as crushed barnacle shells, providing 'important analytical statements' about the stratigraphy of the excavation (Stevens, 1982:17-18; Ringer, 1983:119). The potential of stratigraphic approaches to wrecks and other maritime archaeological sites is clearly high. In late 1994, for example, I led an excavation which examined the possibility of locating defined cultural layers at 19th century underwater sites adjacent the land, such as jetties and other port-related structures. These were located and successfully recorded (Garratt, McCarthy, Richards and Wolfe 1995: 29-40).

The major impediment to mainstream acceptance of shipwreck archaeology, however, was the perception that the growing number of underwater archaeologists after Bass, were theoretically depauperate, ranging from 'minutely particularist in scope...to broader historiography' (Watson, 1983:25). Thus shipwreck archaeology was isolated from mainstream archaeology at the time of rapid philosophical change associated with the advent of 'New Archaeology' with its emphasis on explanation. Though the *IJNA* was an international publication, it is indicative of the academic isolation of underwater archaeology that a full seven years after its initial publication one American author, professing to be examining trends in historical archaeology, stated that 'no journal for underwater archaeology papers has yet been established' (South, 1977:21). This isolation led to a situation where, in the mid-to late 1970's, Bass and leading practitioners such as Jeremy Green, in Australia, pursued what was in effect a crusade to legitimise their field in the face of a two pronged attack; one from fellow academics and the other from the treasure-hunters. These two influential workers were ardent historical particularists, unashamedly 'artefact oriented...concerned with the artefacts and their functions' (Bass, 1983:91-104). Green and Bass' *raison d'étre* can be summed up in Green's words, thus

> Historical particularists are artefact orientated and are concerned with artefacts and their functions. This approach is particularly appropriate for the archaeology of shipwrecks, because being a new field of study, the material artefacts are not well understood. It is important, therefore, to build up a clear understanding of the material before constructing the deeper hypothesis (Green, 1990:235).

Many of Bass' and Green's colleagues and students naturally followed their approach. When new graduates in maritime archaeology did not enter the debate with their terrestrial colleagues, this added further to the difficulty in having underwater archaeology broadly accepted within the ranks of a parent discipline engaged in a rigorous questioning of particularist approaches through what has been termed the hypothetico-deductive logic of New Archaeology.

Maritime archaeology

Moves towards the development of an explanatory base in maritime archaeology reached a zenith with the publication of Muckelroy's *Maritime Archaeology* (Muckelroy, 1978). Although young, he had by then become one of the best known of the 'British School'[1] of underwater archaeologists (Lenihan, 1983:49). He defined maritime archaeology as the scientific study of the material remains of humans and their activities on the sea, including not only shipwrecks, but 'everything connected with seafaring in its broadest sense' (Muckelroy, 1978:4). This included the study of port-related structures, shipwreck archaeology, *nautical archaeology,* or the specialised study of maritime technology and other elements of maritime endeavour.

In an arguably conscious effort to establish the academic validity of underwater and maritime archaeology, Muckelroy wrote

> ...the moment has come to consider the value and purpose of this sub-discipline...With a clear definition of its scope and potential, it will have come of age and can take its place within the modern discipline of archaeology (1978:vii).

Whilst well on the way to achieving that aim with a well-argued and logical attempt to propose a theoretical framework which he hoped would be 'applicable to all responsible and scientific underwater work', Muckelroy tragically drowned.[2] His theoretical contribution was recently described (Gibbins, 1992:82-85) as a 'most productive focus' on data characterisation and site formation analyses. He also clearly

---

1 'British School' or 'English School of nautical archaeologists' : a term used generally by American underwater archaeologists to describe those such as Muckelroy, who are accepted in that country as *bona fide* archaeologists but who as yet are still to come to terms with the notion of 'research design' or problems of an 'anthropological nature.' Lenihan, for example, stated that

> The only exceptions [in this] have been recent. A few of the British School, most prominently the late Keith Muckelroy, have begun to raise some very germane theoretical issues (1983:49).

2 Muckelroy was 29 when he died.

defined maritime archaeology, nautical archaeology and underwater archaeology, removing a stumbling block, even for those in the field (1978:1-10).

Across the Atlantic, an American anthropologically-based movement was gathering in strength, calling for other reforms. In deliberately taking a social science approach, it questioned the historical particularist basis of the 'British' maritime archaeological school. The movement also questioned the lack of explicit research design or well defined research objectives, the failure to test hypotheses and the general lack of emphasis on human behaviour (e.g. Lenihan and Murphy, 1981; Gluckman 1981).

Debate about archaeological reasoning has rarely been entered into between the shipwreck anthropologists and historical particularists. As noted by Gibbins (1992) 'a problem since Muckelroy has been the failure of theorists to address the main problems of wreck archaeology'.

Many maritime archaeologists and especially those from the British School, did not join in philosophical debates raging in mainstream archaeology and anthropology, citing (with some justification), an excessive use of jargon as part of the reason (Green, 1990:240-241).

The lack of dialogue clearly changed with the convening of the advanced seminar on shipwreck anthropology and the presentation of papers under the title *Shipwreck Anthropology* (Gould 1983). This volume was influential in paving the way for a broader acceptance of the shipwreck as an archaeological site and in widening the debate about the validity of shipwreck studies amongst anthropologists generally. In the volume Lenihan noted the importance of the wreck in both technical and historical terms and to archaeology and anthropology generally. He stated that

> The actual remains of a shipwreck offer much that is not known from the literature about ship construction, material culture and unique events in history...shipwrecks present an extraordinary data base for investigation by anthropologically oriented archaeologists (Lenihan, 1983:42, 63).

Watson (1983:31), in agreeing, also argued that a change of emphasis should occur in shipwreck archaeology, bringing it into line with 'processual' or new archaeology. Murphy summed up the potential of the 'shipwreck anthropology' argument in the following manner

> The archaeology of shipwrecks should not be merely the embellishment of the maritime historical record, but the elucidation of otherwise unattainable aspects of human behavior. The combination of shipwreck archaeology with the methodologies of other disciplines will result in the authentic reconstruction of behavior patterns, and will permit the formulation of generalities regarding marine lifeways and human social processes (1983:69).

Shipwreck Anthropology also served to illustrate the traditional bias in maritime archaeology up to the early 1980's. For example Cockrell notes

> The bulk of the literature of shipwrecks has concerned itself with studies of method and technique...an approach designed to transcend simple description and explanation and address processual topics with scientific explanation has been rare or non-existent (1983:207-9).

Despite this critique, it must be reiterated that Muckelroy had earlier recognised the need to study submerged remains in order to derive insights into the organisational strategies of the people and the societies which produced them. For example, he emphasises

> Above all, it should be noted that the primary object of study is man...and not the ships, cargoes, fittings or instruments with which the researcher is immediately confronted (Muckelroy, 1978:4) .

As the only non-anthropologist present at the shipwreck anthropology seminar following Muckelroy's untimely demise, Bass (1983:103) defended the value of what had gone before. In so doing, he found it necessary to present, what he termed a 'plea for historical particularism' in what he admitted was a 'biased case'.

It is evident in the discussion above that, with the exception of Australia where there is but one published instance (Effenberger, 1987), the questioning of the descriptive approach and the strengthening of the theoretical base, are indisputably on-going elements in maritime archaeology where mature programs exist (cf. Carrell, 1990). As a result of the general trend towards the development of both practice and theory over the last thirty years, it is generally accepted that maritime archaeology is responsive to change and development within the wider discipline of archaeology. It can also claim with considerable justification that it is a specialised, sometimes highly scientific, part of archaeology as a whole and that is capable of shedding what was termed 'new light' on life on land as well as at sea (Renfrew and Bahn, 1991:11).

The archaeology of iron and steam shipwrecks

It was argued earlier that a number of areas within maritime archaeology require substantive validation. One area is the study of iron-hulled steamship wrecks. The need to pursue this issue stems in part from comments made by Muckelroy in 1980, when he stated that studies based on early steamships and the like, while interesting and sometimes furnishing useful displays for museums, were not archaeology. He argued that

> As an academic discipline, archaeology interprets the past on the basis of surviving objects; it becomes redundant at that point in the past after which surviving records, descriptions, plans and drawings of contemporary objects can tell us more about the culture of the time than we can learn from digging up a few relics...(Muckelroy (1980:10)

Further, Muckelroy stated that the 'onset of industrialization and modern style bureaucracies in the early 1800s marks the cut-off point' for underwater archaeological studies (1980:10). David Lyon, of the National Maritime Museum at Greenwich, has also noted that aspects of archaeology become redundant where historical records appear (cf. Henderson, 1988a : 10-11; Lyon, pers. comm).

Interestingly the Muckelroy/Lyon position is primarily a British viewpoint in the English-speaking maritime archaeological world. It is also a view that would find little support amongst terrestrial historical archaeologists. Australian maritime archaeologists studying predominantly colonial and historical period wrecks, have not accepted this position (cf. Henderson, 1986; Green, 1977a). Equally, Bass (1972:10) noted 'the value of archaeological research on ships recent enough for photographic records to be available'. Gould and other anthropologists argue strongly for a cross-temporal and cultural approach; one that is not encapsulated in a specific period of the past (cf. Gould, 1983; Peron, 1988).

I aim to demonstrate through the medium of the SS *Xantho* excavation, that there is much to be learnt from an examination of post-1800 sites. This is obviously not a new claim and it could be argued, with respect to the *Xantho* and other similar sites, that the study of the iron and steam shipwreck is akin to what is referred to as industrial archaeology, itself a sub branch of historical archaeology and a field of study well-recognised in its own right.

Industrial archaeology is described by some as the study of the physical remains of industry in the recent past, particularly the products of the industrial revolution. It is clearly modern, as Renfrew and Bahn note

> For more recent technologies, such as those of the last 200 or 300 years, the growing field of *industrial archaeology* can also make use of eyewitness accounts by living craftspeople or verbal descriptions handed down from one generation to the next, as well as historical and photographic records (1991:271).

Though the abundance of archival material is at the root of their disclaimers, it is the propinquity of these objects to contemporary material cultures that may have alarmed some prehistorians and possibly Muckelroy so much.

Muckelroy's (1978:196-214) acceptance of the validity of studies into 17th and 18th century wrecks and his rejection of those of a more recent period on the basis of the availability of historical data (1980:10) is not a sustainable position. Muckelroy's earlier comment that excavation 'becomes archaeological if it is problem orientated' (1978:250) is more universally acceptable.

The systematic study of iron and steam shipwrecks can satisfy the purported aims of historical, industrial and general archaeology.

Though it is obvious that in many cases the study of iron and steam shipwrecks can add to a body of technological and historical knowledge, the question remains whether it can add to our knowledge of the people who once owned, operated, serviced and sailed them, and to their social context.

The *Xantho* study will answer that question in the affirmative through a marriage of traditional historical particularist studies, technological and historical documentation and modelling and in the deliberate use of problem oriented anthropologically-based enquiry in both the underwater excavation and in the excavation conducted in the conservation laboratory (cf. Peron, 1988).

Having proposed that the archaeological study of iron and steamship wrecks is a valid one, it is now my intention to examine the development of this field of enquiry up to the commencement of the *Xantho* project in 1983.

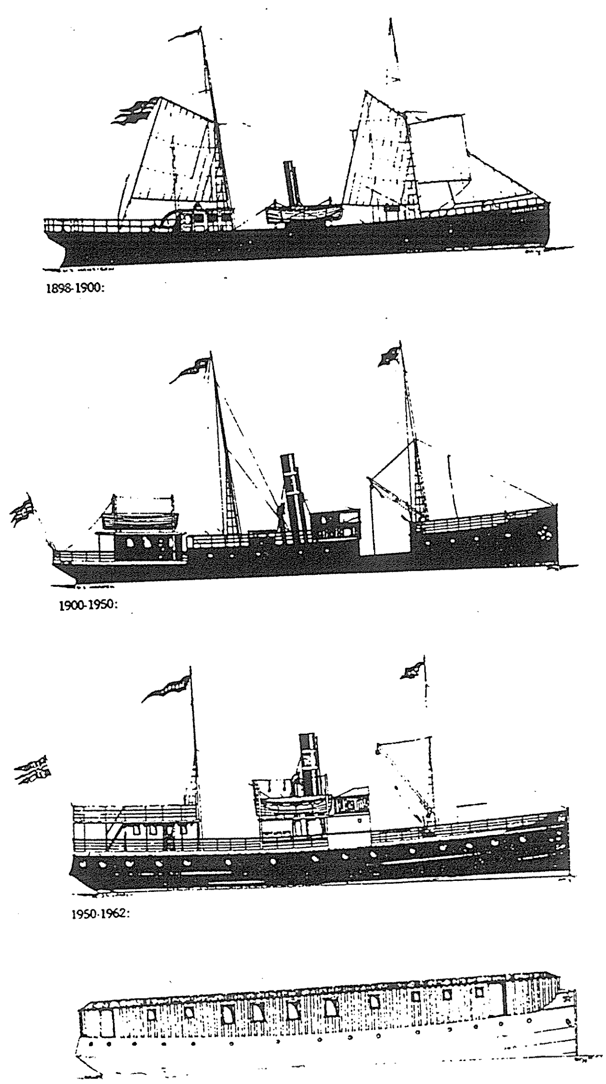
....

From the time iron ships were first manufactured, there has been a great deal of interest in the study of the technology involved and of the marine engines that powered them. Because the ship represents one of the largest and most complex expressions of human manufacturing expertise, a fascination with them and a willingness to expend vast sums of money on their remains, in contrast to other equally significant remains on-shore, is to be expected (cf. McCarthy, 1994). As a result, ship societies and ship and marine engine preservation societies abound throughout the world. Old ships and marine engines can be found in virtually every maritime museum on the globe. In Norman Brouwer's *International Register of Historic Ships*, which was first published in 1985, details appear of over 700 historic ships surviving in 43 different countries. A high percentage of these are built of iron or steel with many being propelled by steam.

Museum ships survive today as the outcome of many refits, and they are often far removed from their original context. Like the wreck, little of the original structure remains, however, often for different reasons. Historic engines can be similarly affected through re-use over decades and by the restoration process. A wreck then is the primary and unbiased source of information relevant to the *terminus ante quem*.

In being removed from their working context and by being significantly altered from their original state, much useful information is lost with museum vessels. This is not to deny the importance of what survives for the study of iron-founding, metallurgy, engineering or shipbuilding. Historic vessels such as the Russian cruiser *Aurora* (built 1900) and the Chilean monitor *Huascar* (built 1865), to name but two examples, are clearly important (Brouwer, 1985). The fact that they have been subject to cultural transformations (before and after the recent recording of their structures) creates both strengths and weaknesses. This diachronic element of the ex-hulk/museum ship has been recognised by anthropologists. Murphy (1983:75), for example, noted that 'the life of a ship and its use will be reflected in material remains'. Though a self-evident statement, this is a useful insight often forgotten by those who see the ship primarily as a monochronic unit. A case of a vessel that has been used in numerous configurations is the schooner-rigged SS *Hansteen*, which was built in 1866 (Figure 5). This was a common occurrence. SS *Xantho* (1848-1872), for example, was first a paddle-steamer and then a screw-steamer and this change is clearly reflected in the physical remains, as will be shown. Of itself, that is an interesting phenomenon, relevant to notions of artefact modification and re-use before abandonment; a theme common in terrestrial archaeology (cf. Schiffer, 1976). Abandoned hulks such as Brunel's *Great Britain,* built in 1843 and recovered in 1970 after many years in service under steam, sail and then as a hulk, are important on three levels: historical, technical and anthropological. Their detailed recording over all these phases is essential. *Hansteen*, for example, was built in 1866 for use as a Government research vessel/royal yacht. It was converted in 1898 to a passenger steamer, in which service it underwent a number of refits (5a-b). It was altered in 1950 for use in the herring fishery (5c) and was stripped in 1962 for use as a hostel for homeless men (5d). In 1978 it was restored to the original (Envig 1984).

Figure 5 a-d : SS *Hansteen* from 1898 to the present day, showing its various configurations (Envig, 1993).



In many cases, such as *Great Britain*, the recording of existing vessels is to a very high standard (e.g. Corlett, 1970). Unfortunately in many significant cases, little has been done about other existing remains. For example, hulks such the monitor *Cerberus* (launched 1870), now lying in Melbourne waters, are in danger of imminent collapse and may be lost before the recording process is completed (Maritime Archaeology Association of Victoria, 1983).

Research into iron and steam shipwrecks, as opposed to abandoned hulks or museum ships, can be traced in the Northern Hemisphere mainly to North Carolina in the United States and, in the Southern Hemisphere, to Western Australia. A summary of these parallel developments provides an insight into the research orientation of early iron and steamship studies pre-*Xantho* and the evolution of protective legislation for such wrecks.

In the Australian case, early shipwreck legislation enabled the Western Australian Museum to potentially exercise a controlling function over historic wrecks lying within State territorial waters. This legislation followed on from the location and subsequent looting of the rich wooden-hulled seventeenth century Dutch East India Company (VOC) wreck, the *Vergulde Draeck* (1628-1656) in 1964 (Green, 1977b). Soon after, a party from the Western Australian Museum examined a number of iron wrecks with a view to 'obtaining first hand knowledge of the early colonial wrecks' (Advisory Committee Minutes, 11/5/1965). The sites were not considered worthy of addition to a schedule of historic wrecks being prepared, however, as academic and political focus was on the bullion carrying 17th and 18th century East Indiamen. At the time the comment was made that 'nineteenth century wrecks were mainly of importance from the material recovered, rather than of their structure' (Advisory Committee Minutes, 29/10/1970).

Other East India wrecks were found around this time, notably the VOC ship *Batavia* (1628-1629) and the English East India Company (EEIC) ship *Trial* (?-1622) (Green, 1989; 1977c). There was further looting of these wrecks (cf. Henderson J., 1993), and given that only one curator with a small technical support staff was assigned to the job, it proved a near impossible task to investigate and stop the damage that was occurring. As a result, the question was put whether the wrecks would best be managed by the University of Western Australia or another specific purpose group that was yet to be developed (Williams, 1971; Tyler, 1970).

The issue was resolved when the Department of Maritime Archaeology was formed under the direction of Jeremy Green, who was brought from Britain in 1971. Green arrived from underwater archaeological work in Europe and the Mediterranean, and was arguably of the almost universally-held belief that wrecks of the recent past were of lesser significance to those of greater antiquity and, that as a general rule, little of significance would be found in shallow water (cf. Muckelroy, 1978: 60). Green's examination of the wooden hulled *Trial* tended to confirm these claims (Green, 1977c).

Green was directed by the Museum to halt rampant looting of the VOC sites through the systematic recovery of accessible material and bullion. After inspecting a number of iron sites he noted that, though the iron wrecks were of value as an underwater classroom useful for the teaching of mapping and survey, they were 'of no further historic interest' (Advisory Committee Minutes 20/8/1971)

Given that the European community of Western Australia had a settlement-history only dating back to the early nineteenth century, however, mid-to late nineteenth century iron and steamship wrecks were intrinsically of interest. These popular sentiments influenced

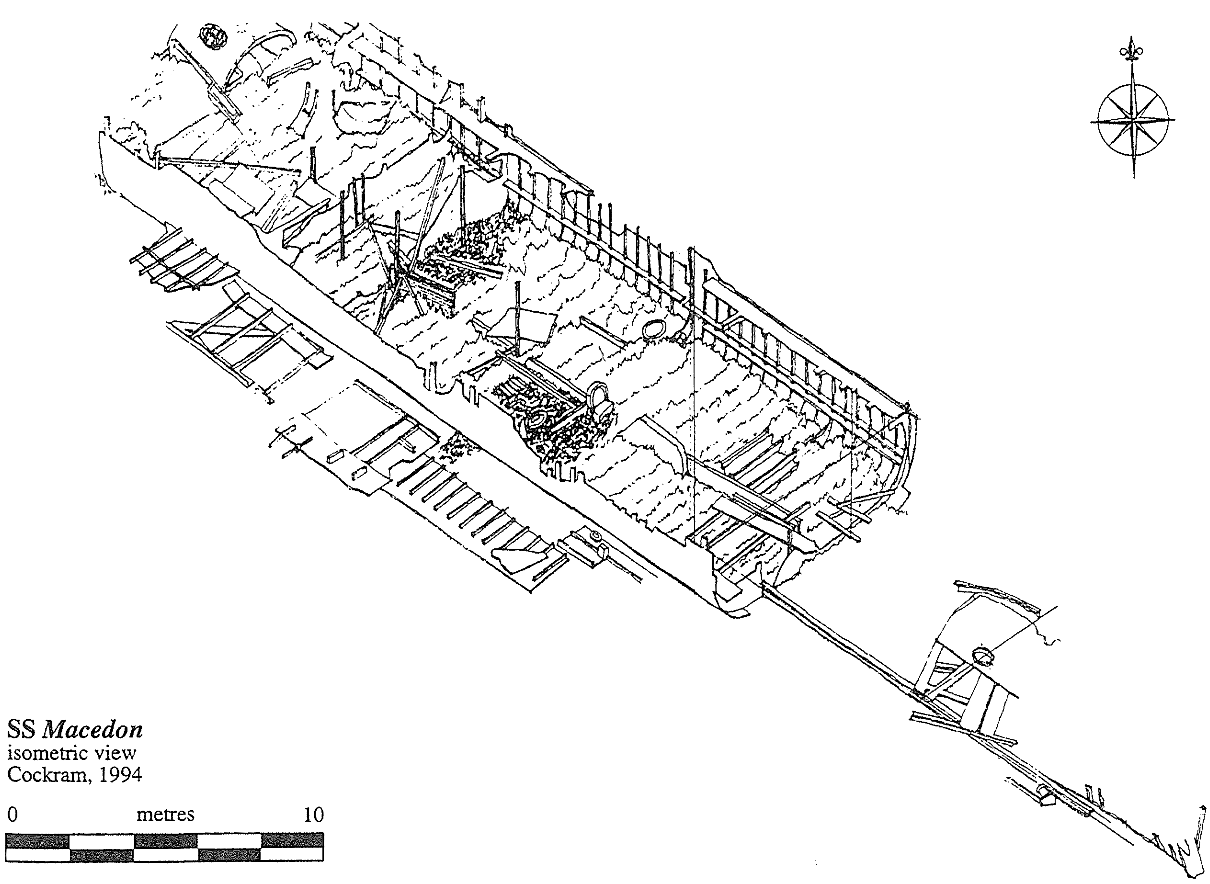
Green and in 1972 he recommended to the Advisory Committee that they consider the declaration of the iron Barque *Mira Flores* (1867-1886) as an historic wreck, chiefly because of its local historical significance to the diving community (Advisory Committee Minutes, 27/1/1972). Considerable debate ensued as to whether the Museum Act should be used to protect wrecks which, in the words of one of Green's historical advisers, had 'only marginal historical interest'. In that context, a position paper entitled '*The Problem with Colonial Wrecks*' was debated at length (Advisory Committee Minutes, 1/6/1972).

At this time Green was assisted by Graeme Henderson, who brought strong research interests in shipping and wrecks of the colonial period. By the end of 1972 five late nineteenth century iron wrecks, including one streamer, were declared historic sites. The vessels included the nineteenth century iron barques *Mira Flores* (1867-1886), *Sepia* (1864-1898), *Denton Holme* (1863-1890), the ship-rigged *City of York* (1869-1899) and the SS *Macedon* (1870-1883), shown in Figure 6, below (Advisory Committee Minutes, 30/8/1972). The State then enacted the Maritime Archaeology Act, 1973 which protected all wrecks lost before 1900, whether built of iron or wood or driven by sail or steam (O'Keefe and Prott, 1984:172-174).

Colonial period wrecks then became firmly established as potential historic sites (Henderson, 1977a). In order to manage the growing resource a wreck inspection program, in which all wreck sites were routinely inspected and reported on, was formally put in place in the mid 1970s (Sledge, 1977).

In the face of a High Court challenge to the State Maritime Archaeology Act 1973, the Commonwealth Historic Shipwrecks Act 1976 was introduced (Green, Henderson and McCarthy, 1981:145-160). This Federal Act applies to Australian waters and resulted in the inspection and declaration of many iron and steel-hulled shipwrecks around Australia. By 1983, of the total of 77 wreck sites inspected in Western Australia, 14 were iron-hulled sailing vessels and 12 were iron-hulled steamers, such as the SS *Macedon*, shown below.[1]

Figure 6 : The midships section of the SS *Macedon* (1870-1883). The deck beams have disintegrated, leaving the sides of the hull unsupported and ready to collapse. The stern was apparently demolished to allow the salvage of the engines, shaft and propeller. By Colin Cockram, MAAWA (Kenderdine, 1995: 52).



[1]As yet, Western Australia has no historic wooden-hulled steamship wrecks. The only available wreck of this type is the SS *Dolphin* (1882-1919), a small coastal steamer that was converted to a floating accommodation platform for sea-scouts after being stripped of all its fittings. Only sections of the hull remain in shallow water (Lapwood, 1991).

Following the enactment of the Federal legislation, voluntary research groups were formed in most Australian states. Examples include the Underwater Archaeology Research Group of New South Wales, the South Australian Society for Underwater Historical Research and The Maritime Archaeology Associations of Western Australia, Victoria and Tasmania. These groups facilitated the involvement of divers in site inspection and recording with professional guidance. This work, in turn, led to the inspection and declaration of more iron and steamship wreck sites, such as the PS *Ballina* (1865-1879) and the screw steamer *Royal Shepherd* (1853-1890).

The Western Australian based Post-graduate Diploma Course in Maritime Archaeology began in 1981 under Green. This course and the resulting graduates facilitated the creation and growth of regional maritime archaeological units throughout Australia. These were located in museums (Queensland and Northern Territory) and in Government heritage management bodies (Victoria, South Australia, Tasmania and New South Wales). This has resulted in the inspection and declaration of many more sites, such as the wooden-hulled SS *Monumental City* (1850-1853) and the wooden-hulled PS *Clonmel* (1836-1841). These two early colonial sites were inspected and declared historic (Harvey, 1985, Staniforth, nd). Many more sites, the majority of which are iron and steam shipwrecks, have since been declared historic. Comparatively modern vessels have also been included, notably the German WWI cruiser *Emden* (1909 -1914) and the diesel driven WWII Japanese Submarine *I 124* (1927-1942) (McCarthy, 1991a: 10-52). Many of these studies are on-going. The HMAS *Sydney* (1934-1942) project, for example, is a major research program (McCarthy, 1991b) and is of relevance here in that, though it is a modern steel-hulled[1], screw-driven

[1] Steel, a derivative of iron, is included in these discussions.

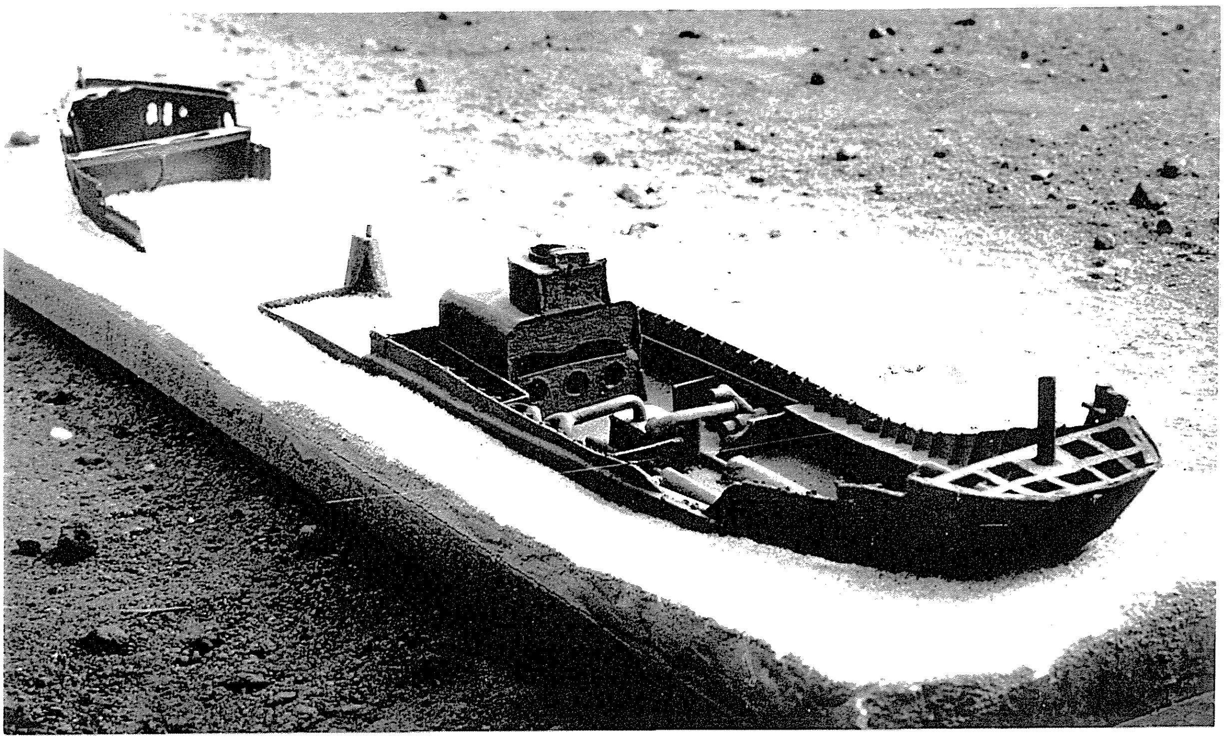
vessel, the archaeological record is expected to be a major element in illuminating one of Australia's major war-time disasters.

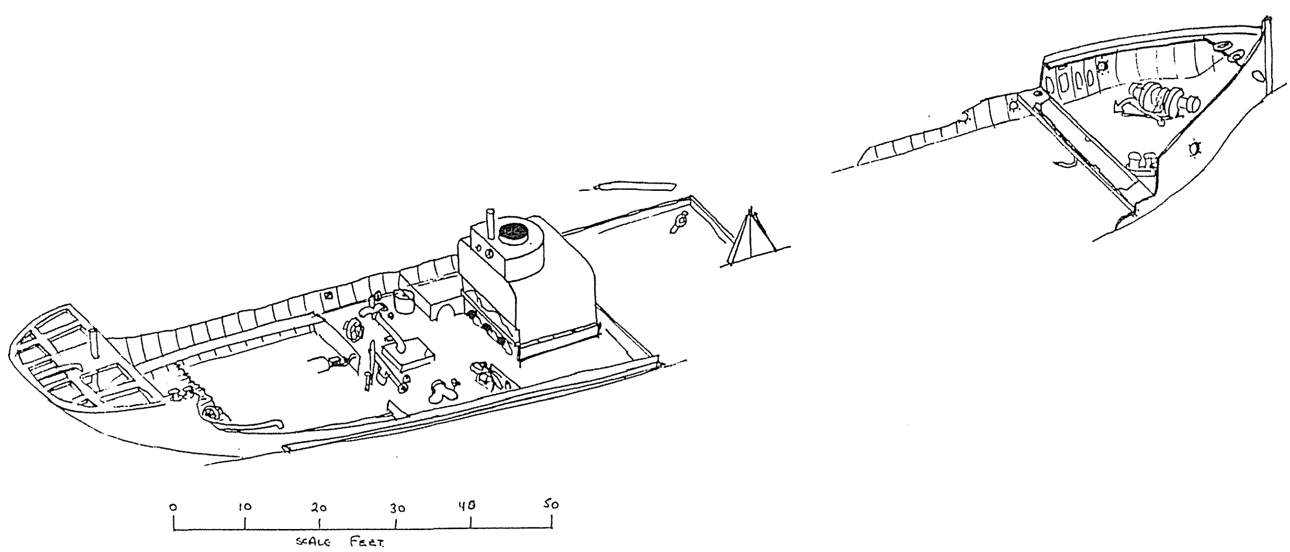
The majority of declared maritime archaeological sites in Australia are iron or steamship wrecks. Despite this fact, little more than site inspections or regionally-based surveys occurred before the *Xantho* study began in 1983. The only exception was the test excavation of the iron hulled SS *John Penn* (1867-1879) off the coast of New South Wales. This site had been located in 1979 and following the declaration of the site as an historic wreck, volunteer amateur archaeologists Mike Lorimer and John Riley conducted fourteen days of work over a period of seven months between January and August 1983. Their initial aim was to test the application of Riley's proposition, that when iron ships sink onto a soft substrate, they come to rest at around the level they float on water (Riley, 1988a). This phenomenon is illustrated in Figure 7 below using a model and isometric projection of the wreck of the *John Penn.*

Finding the use of recording grids impractical due to the configuration of the vessel, Riley and Lorimer took measurements from prominent features of the site by trilateration and by using angle/distance techniques.

Through the use of a water dredge to recover artefactual assemblages, they uncovered three distinct layers of sediment in their excavation. The upper layer comprised mobile, clean sand, the middle, an anaerobic black mud and the lower unit, in which most of the artefacts appeared, a fine anaerobic silt. The salient features of the ship, including a characterisation of the artefact assemblages, its engines and other machinery, were recorded and published (John Penn Team, 1984). Lorimer and Riley assisted considerably in the development of iron and steam shipwreck studies within Australia through the application of isometric projections, wreck site models, and in the describing of layering within the hull.

Figure 7: John Riley's model and isometric projection of the wreck of the TSS *John Penn*, illustrating the state of burial of the hull and the value of the isometric projection and wreck site models (Lorimer, 1988).





Other former British colonies, such as Canada, New Zealand and America, also developed an interest in iron wrecks and steamships of the nineteenth century, probably also due to their relatively recent settlement by Europeans.

New Zealand, for example, is able to protect all sites over 100 years old under the Historic Places Amendment Act 1975. The first survey of the wreck resource, including iron and steel vessels, was conducted in 1977 and though limited in scope, was conducted as an 'exercise in archaeological research' by an anthropologist (Campbell, 1977).

Canada, on the other hand, has seen considerable research activity on iron and steamship wrecks. In 1983 the Nippising University of Ontario conducted a survey of the remains of the wooden-hulled, SS *John Fraser* (1888 -1893). The results of the survey, carried out under very difficult conditions, were published locally and later internationally in summarised form through the pages of the *IJNA*. Further work was planned there, including the establishment of conservation facilities (Vandenhazel, 1987). In the same year an Ottawa volunteer conservation group surveyed the remains of the 252 foot (76m) long wooden-hulled 'propeller' *Conestoga* (1919-1922)[1]. This large, and extensively damaged wreck, proved difficult to record and the survey was not completed (Gregory, 1984).

In the United States, the location of the wooden-hulled, steam powered gunboat USS *Cairo* (1861-1862) in 1956 had the potential to provide a benchmark for studies into wooden-hulled steamship wrecks (Bearss, 1963). Being extraordinarily well preserved in the cold muddy waters of the Yazoo River in the State of Mississippi, it received considerable attention. It was subsequently salvaged at a time when the

---

[1]Propeller: The term 'propeller' is a contemporary one now regularly appearing in American literature. It was used on the North American continent to signify a screw or propeller-driven vessel. In British and other literature it refers solely to the screw.

call for archaeologists to 'develop diving skills and take over the responsibility for underwater remains' was still in its infancy (de Borhegyi, 1963). The adverse results, centring on an ill-conceived hull recovery program, were a useful lesson for the future and much has been done since to remedy the situation. (McGrath, 1980; 1981).

At around the same time, the State of North Carolina became actively interested in its nineteenth century shipwreck resource. Survey and excavation work was conducted on the British blockade runner SS *Modern Greece* (?-1862) and ten other Civil War wrecks (Watts, 1972, 1988). In 1967, State legislation was enacted protecting all historical and archaeological material lying unclaimed in state waters for ten years or more. In 1972 a formal underwater archaeology program was established with professional staff. Work was immediately begun on a comprehensive site survey of a section of the coast and from that a considerable amount of work has flowed (Watts and Bright, 1973).

Two wooden-hulled steamers also came to the attention of the archaeological community in America. These were the side-wheel cotton packet *Black Cloud* (1864-1873) and the inland stern-wheel steamboat *Bertrand* (?-1865). *Black Cloud* was surveyed and part-excavated by students at the Texas A&M University, under George Bass. A report was published, complete with artefact catalogue, description of conservation techniques and recommendations for future work (Adams, 1980). The *Bertrand* was located by prospective treasure salvors and was excavated with the participation of qualified archaeologists in the period 1968-9. The excavation was later considered of importance to the study of the type and of the cargoes carried (Simmons, 1988, Ch. 10). In both cases the majority of the machinery had been removed in earlier years.

Attention then came to focus on the iron-hulled USS *Monitor* (1862-1862) which was located in 1973 and declared as the United States' first 'National Maritime Sanctuary' two years later (Watts and Still, 1982). The location of the *Monitor* can be seen, from a national perspective, to have marked a turning point in the study of iron and steamship wrecks (Edington *et al*., 1978). At a depth of 70 metres, it initially proved too deep for study by any but remote-sensing methods. In bringing its potential to the attention of the world's underwater archaeological community, the archaeologist in charge, Gordon Watts, firmly established the notion that iron and steam shipwrecks were worthy of study. In 1975, the following comment was made by the editors of the *IJNA* with respect to Watt's report (1975). It was the first recognition by the 'British School' of the new field of study into iron and steamship wrecks

> Contributions to the Journal have maintained their high standard and we welcome the important paper on the discovery of the USS *Monitor* (*IJNA*, 1975, 4.2:171).

In some respects the importance of the *Monitor* program is reflected in the composition of the Technical Advisory Committee and the Governmental Review Committee formed to '...maximise output into the decision making process' (Watts, 1987: 128-139). Members included underwater archaeologists, historians, conservators, engineers, oceanographers, museologists, geologists and representatives of government agencies and institutions, including the Smithsonian Institution, the National Trust and the US Navy. In 1979 a master planning document was produced which identified basic research goals and developmental options. Two primary goals were identified; one to ensure the scientific recovery and dissemination of the historical and cultural information at the site, and the other the preservation of the remains in a manner cognisant of its historical significance and its scientific and educational potential.

Due to the depth of the site, equipment from the oil exploration industry was used to perform non-disturbance investigations. The study included still and video photography, detailed measurement of the magnetic field of the site, sub-bottom profiling and sediment sampling. A photogrammetric survey was also conducted. Mini-submarines with lock-out facilities were deployed, allowing diver access for the first time. Artefactual material was recovered, allowing conservation scientists to physically test the materials in the laboratory and to consider the major conservation issues (Watts, 1975: 321-322)

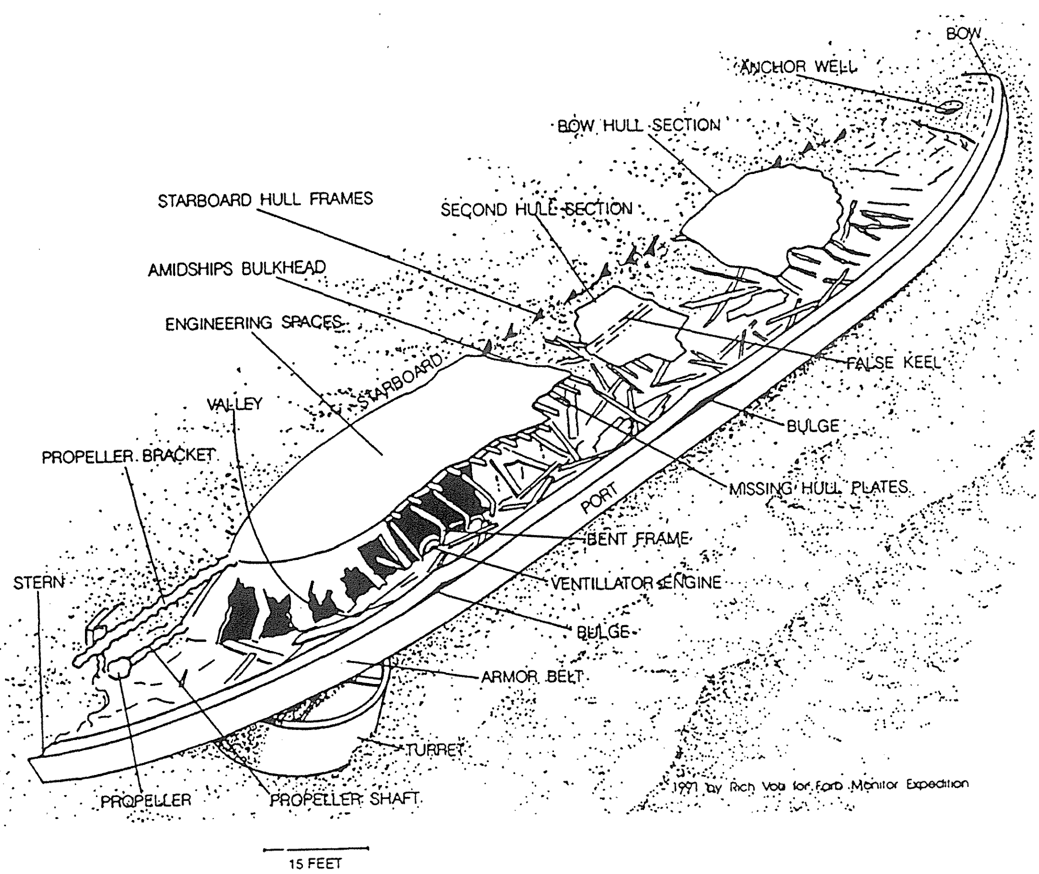
Later, in 1979 an extensive and complex research project was initiated at the *Monitor* site. This included a limited test-excavation, designed partly to further define the conservation requirements for material to be recovered in the future. First priority was the establishment of what were termed 'on site datum stations' to strictly control data collection. It was later justifiably described by Watts as

> ...a highly regimented sequence including mapping and photography, excavation, additional mapping and documentation, artifact recovery and additional excavation (Watts, 1987: 135).

Wood, leather, rubber impregnated fabric, glass, ceramics, iron, brass and other materials were raised and successfully conserved. Wooden structures, some part-buried by sediment, within and around the iron hull, were also noted. Where visible above the sea floor, the structural deterioration of the iron hull was considered to be of an advanced nature and the wreck itself was believed to be in a fragile state (See Figure 8). It was postulated that deterioration of the iron hull would be significantly less where it was buried in sediment in contrast to the exposed iron-work (Watts, 1987). The studies of the sediment layer showed that the upper layers were extremely active and mobile and it was proposed that they could be removed without compromising the archaeological integrity of the site.

On receiving the reports, the Technical Advisory Committee recommended that the recovery, conservation, and display of the wreck be adopted as a major goal. This recommendation was adopted in November 1982 and an expedition was planned for the following year.

Figure 8 : The inverted hull of the USS *Monitor,* showing extensive corrosion. By R. Volz (Farb, 1992)



The program was designed, in Watts' words, to

> ...generate all of the additional archaeological, historical, technological, conservation, and fiscal data determined to be essential for formulating and evaluating plans for the in-situ stabilization of the *Monitor's* remains and the recovery of as much of the ship as determined to be technologically and fiscally feasible (1987:135).

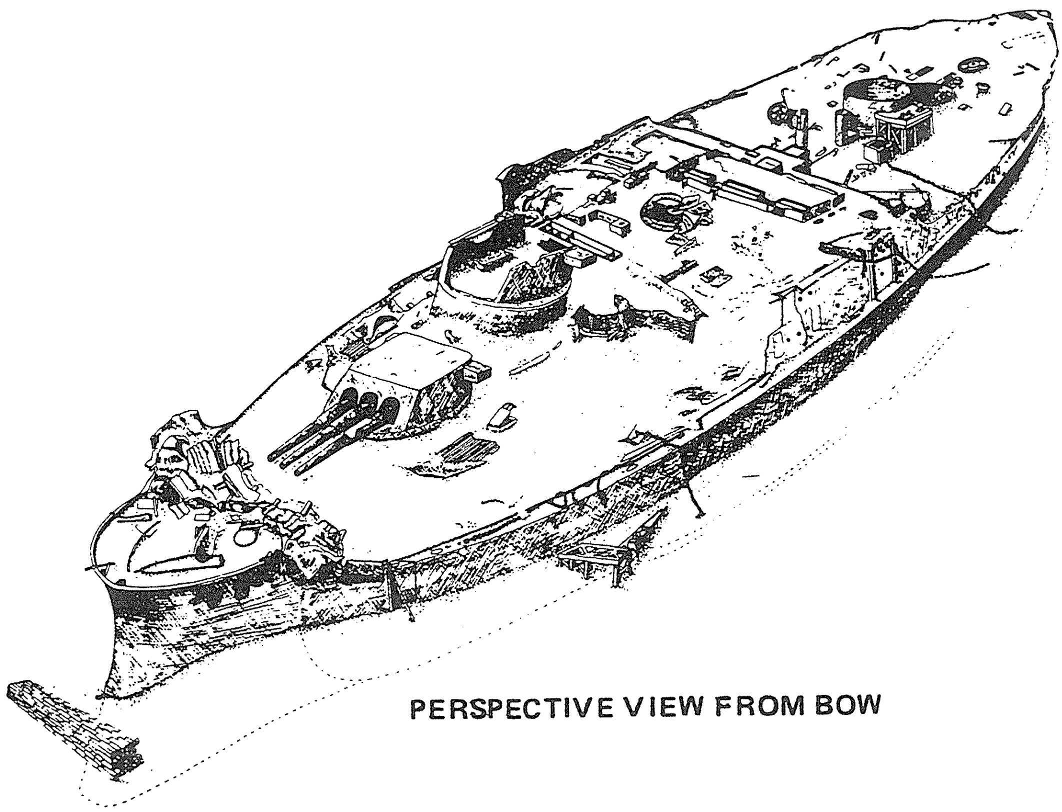
The study has provided an insight into both the condition of the wreck and the nature and scope of the archaeological record preserved at the site (Watts, 1987:135). For a number of reasons, the *Xantho* project did not have the benefit of this research and, as a result, it operated in isolation for several years.[1]

Around the time the *Xantho* project commenced, work also began on an assessment of the steel-hulled USS *Arizona* (1915-1941), now a well-known national monument and memorial at Pearl Harbour (Murphy, 1987; Lenihan, 1989). The first assessment dives on *Arizona* were conducted in 1983. Given the immense size of the wreck, the initial site survey was a protracted process, resulting in the completion of site plans and a video record (Figure 9, below). In 1986 a biofouling and corrosion study, similar to that conducted on the *Xantho* in 1983, was conducted (Henderson, 1989: 117-156). These developments allowed the site managers to develop an 'action plan' based on an informed understanding of the degradation processes at the site (Lenihan, 1989:6). It was acknowledged that corrosion and other data would facilitate a decision as to whether to attempt to modify the natural degradation processes at the site (Cummins and Dickinson, 1989:167-168).

---

[1] Unpublished data on the *Monitor* program was not available and the report was not widely disseminated until 1987 (Watts, 1987).

Figure 9: The *Arizona* site. The hull appears intact, though the upperworks have been substantially altered by bombing and salvage. By J. Livingstone (Lenihan and Murphy, 1989: 83).



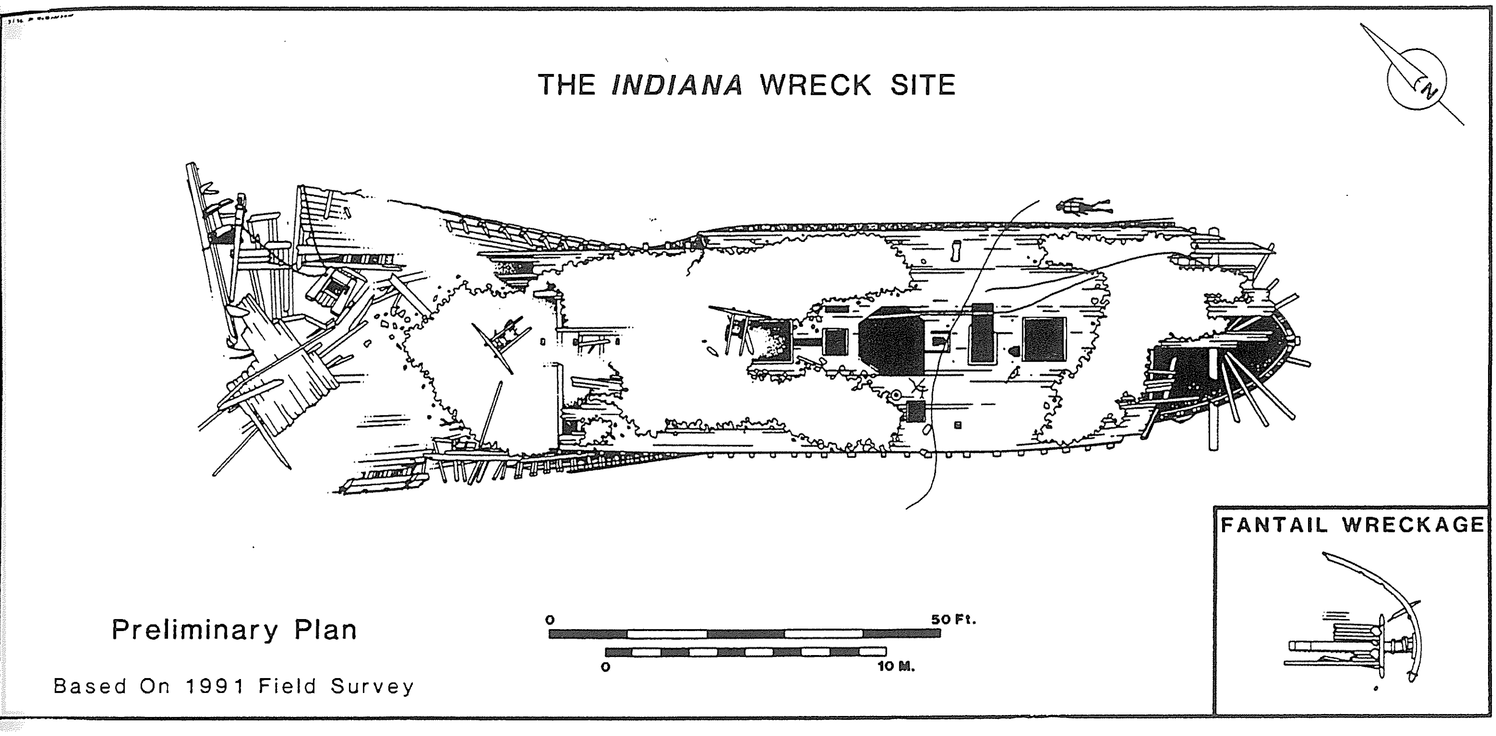
Clearly the study of iron and steamship wrecks was an established component of North American underwater archaeology by the time the *Xantho* project commenced in Australia. From the beginning, groups from the United States proceeded to examine a large number of iron and steamship wreck sites and to declare a considerable number of them historic under both State and Federal legislation, for example (Gisecke, 1985:138-141).

A number of thematic studies were also undertaken as the *Xantho* project got underway. One such study reassessed the California Gold Rush through maritime archaeology (Delgado, 1986). Others have concentrated on the phenomenon of 'blockade running', providing a detailed analyses of the fast steamers involved (Bright 1985; Watts, 1972; Wilde-Ramsing, 1985; Wise 1985). These studies have links to manufacturing in Britain, for many of these vessels were built there, causing considerable contemporary interest in engineering circles due to their speed and power. The SS *Tallahassie,* for example, was described in Britain as a 'most efficient instrument of maritime warfare' (*The Engineer*, 3/6/1898:527). More recently the theme of 'American Naval Archaeology' has risen (Dudley, 1990). The broad acceptance of the validity of such thematic studies can be seen in the diversity of topics included in the 1989 edition of the American periodical *Archaeology* (Watts, 1989).

I do not deal with the wooden-hulled steamer at any length in this thesis as it is subsumed through the study of wooden-hulled vessels and the study of iron and steamship wrecks. An exception is the wooden-hulled 'propeller' SS *Indiana* (1848-1858), as it represents an important development in the field of steamship archaeology (Figure 10, below).

In 1979 the Smithsonian's National Museum of American History recovered all of the machinery of the *Indiana* which had sunk 121 years earlier in 37 metres of fresh water in Lake Superior (Jacobs, 1979). An early Great Lakes Steamer, it was powered by what is acknowledged as one of the earliest examples of a power plant from a commercially successful screw vessel (Simmons, 1988:192).

Figure 10: The *Indiana* site, an early wooden-hulled steamship wreck (Johnston and Robinson, 1993). Drawing by D. S. Robinson.



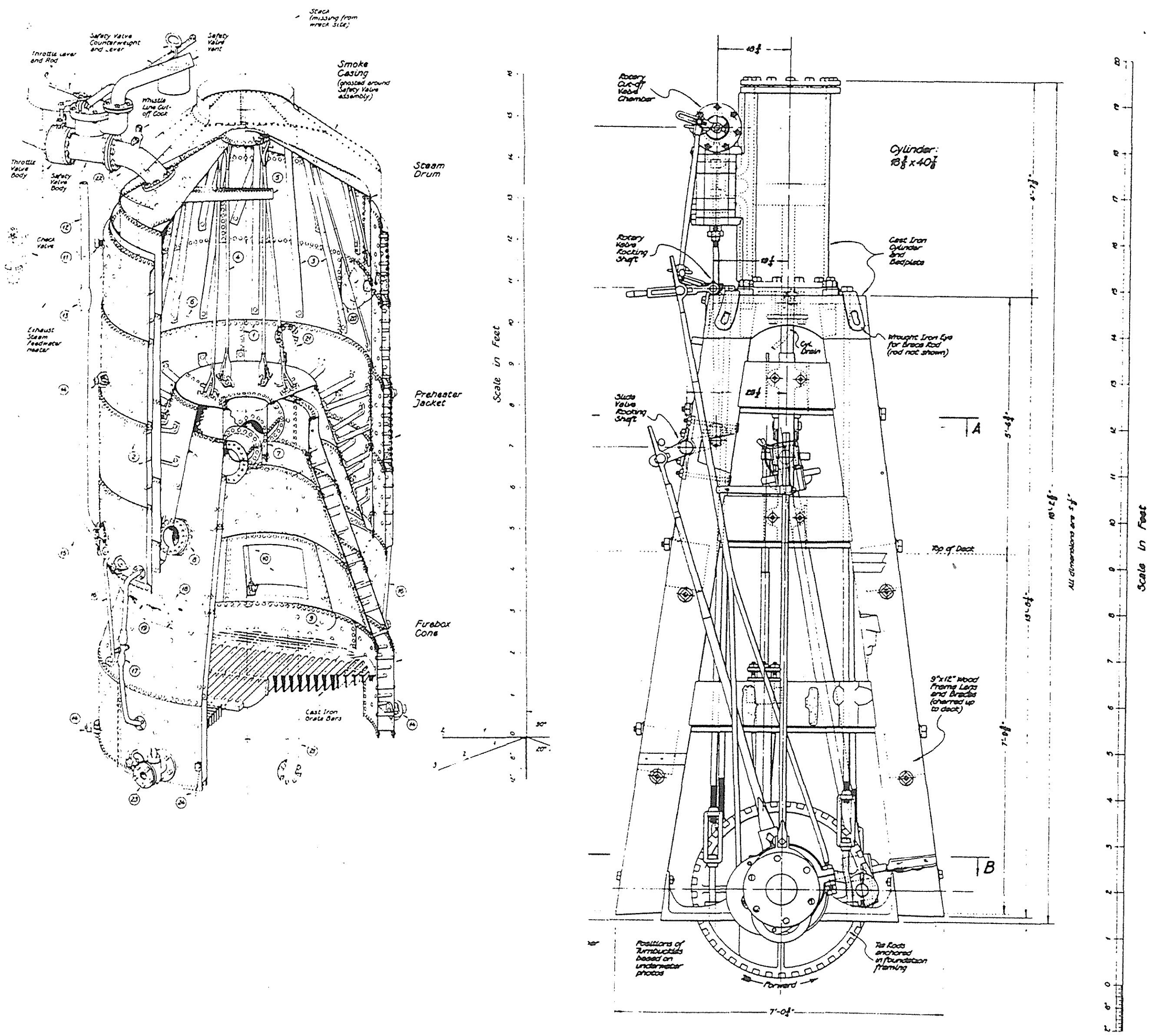
The recovery project was clearly a massive undertaking, resulting in the recovery of around 20 tonnes of machinery, including a boiler, a single cylinder (5.5m high by 1.2m diameter) vertical engine and a 3m diameter propeller (*Society for Industrial Archaeology Newsletter*, 1979).

After raising, the ancillary machinery was cleaned, coated with lacquer and placed on exhibition, being remarkably stable and in excellent condition due to the cold, deep fresh-water environment. The engine, also being similarly stable, has undergone passive conservation and is in good condition. The boiler is described as 'stable' and is stored in ambient conditions (Johnston pers. comm.). These appear below in Figure 11.

Paul Johnston, the present Curator of Maritime History at the Smithsonian Institution, eventually became responsible for the remains and recently joined with David Robinson of the Nautical Archaeology Program at Texas A&M in an examination of the site (Johnston and Robinson, 1993).

The *Indiana* provides a useful comparative study for the *Xantho* project, especially as I come to focus in later chapters on the treatment and complete dismantling of the machinery raised from the *Xantho* after 113 years on the sea-bed.

Figure 11: The boiler and engine from the *Indiana.* (Johnston and Robinson, 1993). Both have created considerable interest as primary sources of information on marine engineering. Drawings by R.K. Anderson, Jr.



In comparison to the efflorescence of maritime archaeologists in the former British Colonies, Europe still has few professional workers and most countries have considerable difficulty managing or studying sites of antiquity, let alone modern wrecks. Israel, where one of the earliest courses in maritime archaeology was established, has produced few if any studies on wrecks of the recent past (Raban and Gertwagen, 1980).

Notable exceptions outside former colonies such as USA, Canada and Australia have been site-specific French studies on the CSS *Alabama* (1862-1864), a Confederate raider found off Cherbourg in 1988 (Enault, 1988; Guérout, 1988), English interest in the raising and exhibition of the early submarine *Holland I* in 1985 (Preston and Batchelor, nd: 20) and Swedish work on the SS *Eric Nordewall* (1836-1856), a well preserved paddle steamer (Cederlund, 1987). In all of these cases interest has centred on the remains, their background, descriptive-oriented recording and management needs.

Thus the *Xantho* (1848-1872) study, is best located in the context of late 1970's to mid 1980's research on iron and steam shipwrecks in the USA, Canada and Australia. As the study represents a departure from the mainstream on a number of levels, I will now examine the philosophical basis and research orientation employed for the *Xantho* study.

CHAPTER 2:

AIMS AND RESEARCH ORIENTATION

Introduction

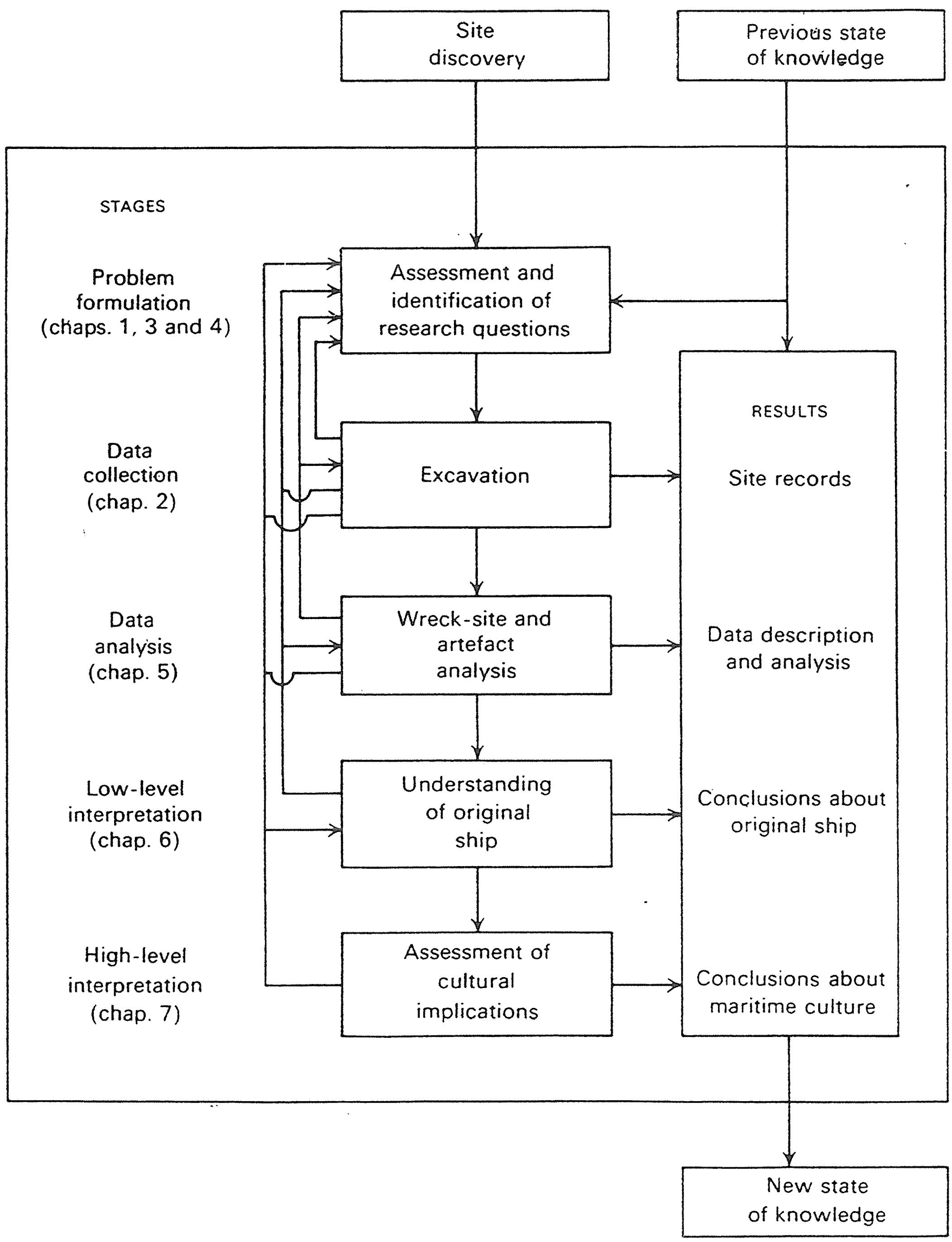
In this chapter I outline the aims and research orientation developed for the *Xantho* investigation. Before doing so, it needs be noted that the study of iron and steamship wrecks was clearly in its infancy when the project began and there were few 'ready theoretical formulations' (Renfrew 1982:3) to prescribe an obvious way to proceed with the investigation.

The May 1983 inspection of SS *Xantho* was not on traditional maritime archaeological lines. It was part-driven by questions aimed at investigating an iron-hulled steamship, rather than the wooden-hulled vessels generally the object of research in shipwreck archaeology. Questions included, whether iron hulls generally behaved in the underwater environment like their wooden counterparts? Did iron hulls pose any new problems to maritime archaeologists? Were traditional recording methods suitable?

As a result of these and related issues, I requested and co-ordinated pre-disturbance surveys of the physical, biological and electro-chemical properties of the wreck in addition to the traditional wreck-inspection method (e.g., McCarthy, 1982a).

By the time the *Xantho* project began, the generally-accepted processes for the study of wrecks in maritime archaeology were well described by Muckelroy (1978:249). Of importance is his crystallisation of the research stages contained in Table 1 below. According to Muckelroy, the process begins with the location of the site, its assessment and identification, the formulation of problem domains, data collection and then data analysis in the light of that problem. From there comes an understanding of the original ship, or what Muckelroy describes as 'low-level interpretation'. This then leads on to explanation or his 'high-level interpretation'.

Table 1 : Muckelroy's model of the research stages in maritime archaeology (1978:249)



As indicated above, in the *Xantho* case, the 1983 site assessment was driven by research questions which reflected the fact that a new class of site was being examined. Subsequent to the 1983 inspection, there has been a deliberate attempt to actively explore the 'cultural implications' of material patterning at the site to be more than an inductively-driven study. Here my purpose has been to explore the role of the individual, Charles Broadhurst, through an archaeological investigation of a material record at the site of the SS *Xantho*. I have then sought to examine possible cross-cultural and cross-temporal nautical behaviours.

The 1983 inspection gave rise to a number of alternative possibilities. It was evident that *Xantho* could be viewed, on the one hand, as a badly-engineered, worn-out vessel, apparently unsuited for the poorly serviced coast of Western Australia; or on the other, a ship purchased primarily with a view to overcoming the problems associated with steamship operation in a frontier environment. As a result, its owner and operator, Charles Edward Broadhurst (1826-1905), could be viewed equally as a misguided, apparently naive and possibly eccentric colonial entrepreneur, or as a visionary acting with considerable fore-thought and imagination; a man beaten only by bad luck. Subsequent research and excavation has been oriented towards an examination of these initial propositions.

It is useful to view the *Xantho* project within the general research design for archaeology as articulated by Renfrew and Bahn in 1991. They describe

> 1) the formulation of a research strategy to resolve a particular question or idea;
> 2) the collecting and recording of evidence against which to test that idea, usually by the organization of a team of specialists and conducting of fieldwork;
> 3) the processing and analysis of that evidence and its interpretation in the light of the original idea to be tested;
> 4) the publication of the results in journal articles, books (1991:61).

Having posed a range of problems above in both pre- and post-site assessment stages, a series of excavations were carried out both at the wreck and on the engine in the laboratory during the period 1985-1995. These combined with a detailed archival study conducted in the period 1984-1990, focussing on Broadhurst (McCarthy, 1990), to encompass Renfrew and Bahn's first and second steps. The results of these inquiries were gradually synthesised and appraised against alternative reconstructions as each phase of excavation came to a close, to culminate in Renfrew and Bahn's third step; the equivalent of Muckelroy's stage of data analysis and low-level interpretation. The articulation of the cultural implications of the study satisfies Renfrew and Bahn's stage three, or what Muckelroy describes as 'high-level interpretation'. Publication, Renfrew and Bahn's stage four, has been on-going, commencing in 1985. As an indication of progress in this stage; publications (including popular offerings, film and video) are reproduced in Appendix 1.

Notwithstanding the on-going process of publication, the re-working of the *Xantho* problem domains through time is consistent with the notion that 'feed-back and constant reassessment' is required over the life of any archaeological project (Binford 1972:159). It is also generally recognised that each of the stages above can be 'repeated and re-worked in the light of subsequent investigations' (Muckelroy, 1978:249). Where logistical problems and conservation processes serve to ensure the longevity of a complex project, this will eventually prove to be one of the strengths of shipwreck excavations (Muckelroy, 1978:249).

Description and analysis

As the first iron steamship to be systematically analysed and excavated in a combined maritime archaeological/materials conservation study, the *Xantho* investigation arguably provides an important springboard for future shipwreck studies; whether of wood, iron or its derivative, steel. With respect to what I believed must be an essential link between maritime archaeologists and material conservators in the inspection and analysis, surveying, excavation and management of iron and steam shipwrecks (and maritime archaeological sites generally), I advocated that

> If you accept that we are the temporary custodians of the artefacts under our care, i.e. the ships, vessels, coinage and everything else that comes under our control, then there is no room for a dichotomy between conservators and archaeologists when dealing with the same material... [they]... should be involved together on the excavation underwater and in the conservation process above water...[in order] to extract the greatest possible amount of data from the artefact, not just archaeological and historical, but physical, chemical and biological. ...With this in mind, archaeologists and conservators are bound to be a group together from the beginning to the end of a project.... The work that we have done on the SS *Xantho* is very much a reflection of these philosophies (McCarthy, 1987:9).

The *Xantho* project represents a linking of conservation specialists and archaeologists underwater at an iron shipwreck, not just for environmental or artefact conservation purposes, but also with archaeological aims in mind. The pre-disturbance survey and the successful recovery of the heavily-concreted *Xantho* engine, the first attempted from a saline, heavily oxygenated warm-water, environment, are significant developments in maritime archaeology and conservation science.

Another feature of the *Xantho* program, in the wake of others such as Bass (1967), has been the number of specialists that have been drawn together to generate information from the site. These include practising steam engineers, model engine-makers, corrosion specialists, biologists, naval architects and other technical specialists. This 'maximisation strategy' is a feature of any modern complex maritime archaeological study e.g., the *Monitor* project (Watts, 1987). It has also been employed in my research at the wreck of the wooden-hulled VOC ship *Zuytdorp* (1702-1711) and its adjacent land sites, where is believed that the survivors intermingled with local Aboriginal people. On the *Zuytdorp*, for example, I have developed and facilitated (in association with Phillip Playford) a team involving a geologist, conservators, pre-historians, anthropologists, geneticists, cartographers, surveyors and a specialist in-water team. (e.g. Bowdler 1990; Playford 1959; McCarthy, 1993; Morse, 1988:37-40; Weaver, 1994). The same approach characterises my excavation of the less-complex Albany Town Jetty (Garratt, McCarthy, Richards and Wolfe, 1995).

Though a commonsense approach, the strategy has been slow to receive the general recognition it requires. In 1983, for example, it was noted that the '...multidisciplinary approach is long overdue. Little is known about the environmental impact on wrecks...' (Murphy, 1983:80). The following comment, published only a few years ago in the *IJNA*, attests to the sad fact that it was still not standard-practice by 1992. It also illustrates the reasons why a 'maximisation strategy' is essential in maritime archaeology generally

> No one individual has sufficient knowledge to identify precisely all the interconnections represented in the complex archaeological site environments, so specialists from other disciplines must be enlisted. Initiatives taken to involve other disciplines in archaeology underwater are to be applauded as, although there is a recognized need, it is not always achieved effectively (Oxley, 1992:108).

In utilising the interdisciplinary work of the specialists in the team, I will also focus on site formation processes at the *Xantho* and on iron ships generally. This builds on Keith Muckelroy's site formation analyses (1978:157-214) and on John Riley's 'waterline' theory of iron ship disintegration (Riley, 1988a).

With respect to the *Xantho* engine, it will be shown that it is possible to obtain useful technical information from heavily-concreted marine engines. This is an important development, as it was once believed that only machinery recovered from a relatively non-corrosive environment would yield such information. Excavated ship's engines will be shown to match hull form or rigging details in the breadth of technical detail that they can provide. Finally, in leading into the next section dealing with explanation in maritime archaeology, it will become evident that when analysing the behaviour of those who owned and operated ships of the past, attention can now be paid, not only to the hull, fixtures, fittings and contents of each ship (e.g. its cargo, personal items, the crew's accoutrements and the like) but also to the form of propulsion. It will be shown that an examination of the interior of a ship's machinery has the potential to provide unbiased information on how a particular ship was operated and maintained, in comparison to how it was believed to be.

Explanation

Much of human 'achievement' over the last few thousand years has been associated with sea transport. Over the last one hundred and fifty years, a large portion of this has been through the use of iron vessels and steamships.

Though iron and steam shipwrecks like the *Xantho* are sites of considerable complexity, consistent behavioural patterns may be inferred, for example about the owner Charles Edward Broadhurst. Patterns are suggested from evidence in the archives; these can be tested with the evidence taken from the wreck and further refined with evidence from the conservation laboratory.

I attempt to keep the general aims of processual archaeology foremost in my strategy and additionally to make the processes of archaeological reasoning more explicit to reach a clearer view of explanation (cf. Renfrew, 1982:1).

The period covered by the *Xantho* study has seen the consolidation of processual archaeology, a vigorous fight-back from some historical particularists (e.g. Courbin, 1988) and the growth of the 'shipwreck anthropology' movement (e.g. Gould, 1983). More recently we have seen the application of post-processual approaches in maritime archaeology (as noted by Gibbins, 1992: 82-4), in some of the papers prepared for the 1990 Society for Historical Archaeology Conference in Tucson, Arizona (Carrell, 1990).

It is clear that agreement may not be reached about explanation, no matter how clear the processes of explanation are. This is well articulated by Renfrew, who notes

> An essential characteristic of what is today called "processual archaeology" is the intention to seek explanations for the archaeological record of the past in terms of valid general statements, which manage to avoid the particularism of some schools of historical explanation. Yet despite these widely acknowledged aims, there is very little agreement about explanation itself, about what constitutes a meaningful explanation, or about appropriate ways of validating or testing explanations that have been offered (1982:5).

Richard Watson summarised the dilemma faced by those operating on anything but a descriptive/analytical level when he noted that

> The harder it is to confirm or disconfirm hypotheses about a subject matter, the more interpretations can be given of it (1990:73).

This is an important issue, because the difficulty experienced by anthropologists in coming to a consensus about research strategies, validation and processes of explanation (e.g. Bintliff, 1992: 111-113; Courbin, 1988; Gould, 1990:225-226; Thomas and Tilley, 1992: 106-

110) has led many in maritime archaeology to spurn theoretical debate (e.g. Green, 1990:240).

To point to the transient nature of theoretical approaches, however, and to then dismiss them as passing fashions, will inevitably have a 'dampening effect on the growth of knowledge within archaeology in general', however (Binford, 1989: xiii). As Bintliff stated of the progress of archaeological debate in contemporary times

> Rather than proceeding in a cumulative fashion, deepening our theoretical perspective's, we seem instead to write off the research aims and achievements of each preceding decade (1991: 274).

Understanding the debate is important; engaging in it is useful provided we can build upon what has gone before. I therefore reject the 'traditional' maritime archaeological position on the lack of value of debate in archaeology. As a result, I will attempt to move beyond the relatively safe ground of particularist description and analysis in maritime archaeology to actively seek explanation.

Terminology is an important issue. In a self-evident, but little-heeded statement, Renfrew (1982:8) stated that 'the aims of explanation may be described, without initial reference to any explicit methodology, as to make intelligible'. Lack of credibility occurs (as identified by practitioners like Gould (1990:15-16) when counter-productive and jargon-ridden, epistemological argument is overtly used. The question 'how can alternative groups have access to a past that is locked up both intellectually and institutionally' (Hodder, 1991:9) is well put with respect to the need to avoid cabbalistic language, the 'disease of immature and growing disciplines' (Clarke, 1968:24).

The need to make debate 'open' in future maritime archaeological discourse is essential given that so many specialists seek access to our data; e.g. historians, historical archaeologists, site managers, economists, conservators, biologists and not the least anthropologists. In maritime archaeology, because of the 'traditionalist' legacy, we have a unique opportunity to keep language simple and the discourse 'open' in the future.

With respect to explanation, it has become apparent that the emergence of anthropologically-based shipwreck studies, without a large data base on which to build, is a potential stumbling block for iron and steam shipwreck studies specifically, and for maritime archaeology generally. Bass (1983:103) was particularly adamant about this

> Based on... [restrictive research designs]..., as well as on the excavation reports published by anthropologically oriented archaeologists who must hire archivists and historians to interpret their catalogues of finds, I suggest strongly that wrecks of all periods be left to particularist archaeologists who have a proven record of gaining the most knowledge from wrecks.

Green is of a similar opinion (1990:235) and Noel Hume has noted

> There are two essential requirements, the ability and experience to dig correctly and a thorough knowledge of the history and objects of the period of the site being dug (1975:15).

In a sense, traditional or particularist archaeology is thereby defended and is seen to be of the utmost value as a necessary foundation for explanation.

The need for a broad artefactual and technological data base generated by particularist approaches regularly surfaces. It is especially evident when scholars attempt to make general conclusions from too small a sample. An example includes the anthropologically-based discussion about the hull fastenings on the wreck of the wooden-hulled *La Trinidad Valencera* (?-1588). This built on earlier conclusions about the 'mass-produced' nature of the ship, the processes of corrosion and the deterioration in hull strength that led to the loss of the ship (cf. Gould, 1983:126-128). Studies on ship's fastenings (e.g. McCarthy, 1983), are arguably too few for maritime archaeologists or anthropologists to generalise with safety on this subject. Indeed as Gould noted (1990:56-59), there was a lack of sufficient data on which to establish a base to validate the general inferences. He states that

> The problem with explaining the wreck of *La Trinidad Valencera* is that we have too many competing ideas about how it may have come about and no clear framework yet for choosing the most convincing of them (Gould, 1990:59).

This aside, given that the full spectrum of a ship's activities are deposited initially as a discrete unit on a sea-bed matrix, a wreck site provides a unique opportunity to infer related behaviours when adopting the anthropological approach. If relevant controls are used to control for post-depositional effects, the behavioural systems can be successfully identified (Schiffer, 1976:12-19; Muckelroy, 1978:157-214).

I now address the problem of using historical documentation alongside the archaeological record (cf. Little, 1992). It is acknowledged that the available historical record for people like Broadhurst is biased towards success, as a result of individual and familial forces and possibly to Victorian and post-Victorian perceptions of respectability. A useful concept which aims to come to grips with subjective skewing of the record is the notion of '*organizational behavior*'. This is the 'conceptual category for the activities that have structured the ethnographic record, the documentary record and the archaeological record' (Potter, 1992:10). Here we focus on, and take note of, the reasons why documents were created in the first place and the role of 'organisational behaviour' in structuring or preserving documents.

With respect to the need to use archaeological evidence and written material as both complementary and potentially conflicting data bases, the following truism is kept in mind

> The archaeological record and the documentary record are both imperfect representations of the same underlying reality... (Potter, 1992: 10).

As a result of these understandings, I will use the archival record as both an independent data base and as a source for generating alternative hypotheses about nautical behaviours and about Broadhurst (the individual) which may be tested through the application of archaeological data. To a lesser extent, I will also refer to oral histories as a useful insight into Broadhurst and his activities.

The application of low, middle and high level theory to data gathering and analyses, is required in shipwreck studies. Muckelroy (1978: 249) and Trigger (1989:19-24) categorise low level theory as 'empirical research with generalizations'. This includes the examination and analysis of the physical features of a site and the analyses of the artefactual assemblages. These are the descriptive studies that provide the data base. Much of the work conducted by the conservators, engineers, biologists and myself in the pre-1987 period at the *Xantho* may be categorised as such.

Middle level theory describes 'generalizations that attempt to account for the regularities that occur between two or more sets of variables in multiple instances' (Trigger, 1989:20). This largely involves the archaeologist making behavioural-material correlates. It should be noted that Muckelroy made no provision for mid-level theory in his schematic analysis (1978:249). It is at this point that the paucity of genuine behavioural modelling in maritime archaeology becomes most apparent. The term has also come to encompass the study of site formation processes (e.g. Gibbins, 1992:82-85; Anuskiewicz, 1990: 93-99). This is of relevance to the study of the regularities of ship disintegration that I will build on in succeeding chapters (cf. Riley 1988; Muckelroy 1978: Ch. 5).

Trigger's high level theory describes 'abstract rules that explain the relationships among the theoretical propositions that are relevant for understanding major categories of phenomena' (1989:21). Bass has argued that social scientists rarely have the required command of lower order data on which to build higher order inferences in maritime archaeology, let alone to tap into competing theories of 'social order'. To remedy this, I believe that expertise in shipwreck studies at the descriptive and analytical levels, should be augmented by a broader grounding in the behavioural sciences and the forging of strong links with the appropriate specialists. This would ensure in terms of research orientation that anthropologically-oriented analyses would be articulated early on as part of the original research design so that data recovery may be relevant to the questions and hypotheses raised.

Finally, it must be noted that the *Xantho* project is museum-based, causing it to have a strong public emphasis and to encompass the collection, research, education and exhibition ethos of museum studies, generally.

CHAPTER 3:

XANTHO IN HISTORICAL AND TECHNOLOGICAL CONTEXT

In order to explain the significance of any historic archaeological site it is necessary to place it in its social, economic and technological context. The site then also needs to be compared with similar sites in order to qualify and quantify any variance found.

In the *Xantho* instance it is necessary to examine the state of marine engineering and iron shipbuilding up to, and just beyond, the period when *Xantho* was built and when it was re-fitted as a screw-steamer. These two analyses will enable us to form a picture of what is to be expected at the wreck of any iron ship of the period. Shipping on the Western Australian coast will then be examined in order to place the features found on the wreck into a regional economic and colonial framework and again to account for any variance found. An examination of Charles Broadhurst's entrepreneurial activities taken from evidence in the archives will then follow in order to ascertain the place of *Xantho* within his business empire and also to gain some insights into his operations.

In a later chapter, these various findings will be tested with the evidence taken from the wreck and further refined with evidence from the conservation laboratory.

The iron ship

An iron hull can be expected on any wrecksite formed in 1872 when *Xantho* was lost; for iron had been in use as a shipbuilding medium for over a half a century and it was soon to be superseded by steel (cf. Corlett, 1970; Grantham, 1859; Thearle, 1886). What is of significance is the reason why Broadhurst would opt for an iron hull in preference to the traditional wooden hulls then in use on the Western Australian colonial frontier.

Though there are examples of iron boat-building dating to the late 18th century (cf. Grantham, 1859: 6), the first self-propelled iron vessel was the 32 metre long, side paddle-steamer *Aaron Manby,* fabricated in Staffordshire, England. It appeared in 1820 and was sent to London in parts where it was constructed on the dock. From there it steamed to Le Havre and from there on to Paris with a cargo. More vessels were built for use in British waters and in 1823 one was sent for use on the 1832 Niger expedition. In 1832 Maudslay Sons and Field constructed four 36 metre long (270-ton) iron steamers for use on the River Ganges in India.[1] This was followed by the launch of a c. 250-ton steamer, which was sent to America in pieces. The first iron vessel in which water tight bulkheads were fitted was produced in 1834 for use in Ireland. This was an important development, keeping some sections of the vessel dry when others were holed or began to leak. In 1838 the 260-ton ship-rigged sailing vessel *Ironsides* became the first large iron sailing vessel to be employed for sea voyages (Grantham, 1859:13-14).

Of significance in this attempt is the fact that many of these early vessels were heavily built, mainly because the properties of iron in sheet form were not well understood. Of equal significance was the early appearance of water tight bulkheads and the rapid spread of the practice of building quite large vessels in widely dispersed regions of the world.

A considerable amount of research was undertaken at the time on the benefits of the new technologies. One report examined the possibilities of applying the new technology in the construction of the *Great Britain* which was launched a few years before *Xantho*. This report (Corlett,

---

[1]Tonnage Appendix 2 contains a distillation of the term as it applies to shipping. The term ton can refer to space and weight in a maritime context. With respect to weight or mass, the ton=1016 kg. One tonne=1000 kg=0.984 tons. The unit is left as per the original and a metric equivalent is not given.

1970: 27-28) indicated that iron afforded better strength, buoyancy and capacity at less expense than wood. Other advantages such as freedom from dry rot, less upkeep, reduced damage on grounding and the elimination of bilge water stench were also mooted. In being stronger, yet less bulky, much more space was available for cargo. It was estimated, for example, that the use of iron instead of wood increased the potential carrying capacity of the *Great Britain* by 600 tons or 24,000 cubic feet (Corlett, 1970: 27-28). It has been also estimated that the weight of an unladen wooden ship amounted to between 46-50% of its displacement, whereas in iron it amounted to only half that figure (Doeffer, 1981:326). The greatest disadvantage was seen to be fouling with weed and animal growth, a phenomenon which dramatically reduced the vessel's speed. The *Great Britain* report under-estimated this factor and the length of time it would take to solve the problem.

Though the iron hull theoretically presented a large number of advantages to those willing to experiment with it, when the decision was taken to use iron in the *Great Britain* its builder, Brunel, knew little of the practicalities required for its construction (cf. Corlett, 1970). Despite this, the eventual success of the *Great Britain*, and its publicised prolonged stranding and eventual salvage in 1846/7, helped cement the place of the iron hull as a viable shipbuilding medium. With iron shipbuilding establishments busy on the Clyde, Thames, Mersey, the Baltic and probably throughout the Continent, it becomes difficult to follow the history of individual iron ships. We can note that when *Xantho* was built in 1848, this was still a period of considerable technological experimentation in iron shipbuilding.

In August 1843 Lloyd's, the British Association of Underwriters, began to collect information from their surveyors on iron ships. In January 1844 Lloyd's issued a notice stating that iron ships would be entered into the register with the character A1 provided that they were built under the supervision of the Society's surveyors (*Annals of Lloyd's Register*, 1884: 76). They also had to be of good workmanship with 'substantial materials' and were to be surveyed on an annual basis. This enabled the vessels, and equally importantly their cargoes, to be insured. The first iron vessel classified thus was the Marseilles owned, iron steamer *Sirius,* which was built in London in 1837 (*Annals of Lloyd's Register*, 1884:76).

It was soon realised that, with a few exceptions, the iron ship was superior to equivalent vessels built of wood (Fincham, 1851: 78).

The iron ship of this experimental period generally had a series of transverse frames in the form of single angle iron and later Z shaped bars which carried the deck beams. This was, in effect, the application of European wooden shipbuilding tradition to the medium of iron. Lengthwise strength was provided by skin plating, decks, stringers and the keel (Figure 12 a). They were built, as a result, in the same fashion as a wooden ship, with ribs (frames) onto which the deck beams and longitudinal planks were attached. Plates were small and in many cases, including the *Xantho*, these were applied in clinker (clincher) fashion. In the best circumstances tapered liners were used to fill the ensuing gap between the plate and the frames (Figure 12b, 3rd from left). This contrasts with wooden ships where planks were fitted against each other, flush to the frames, with only smaller vessels being clinker-built.

Figure 12a: Framing systems on early nineteenth century iron ships (Westcott Abell, 1948;124).

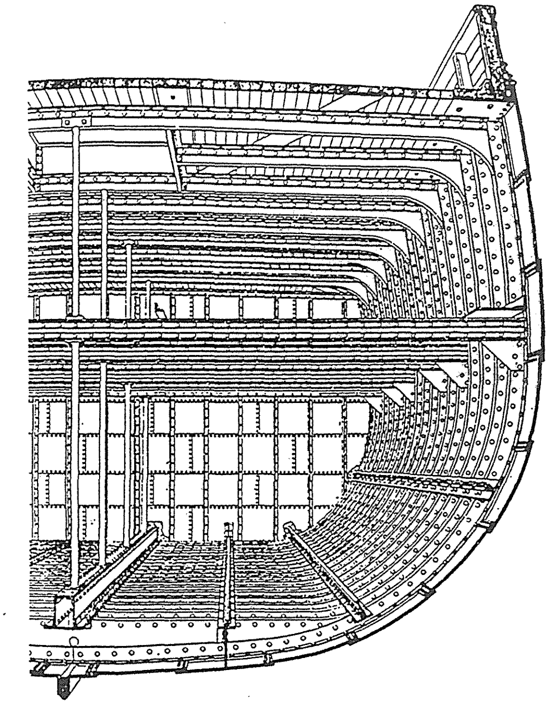
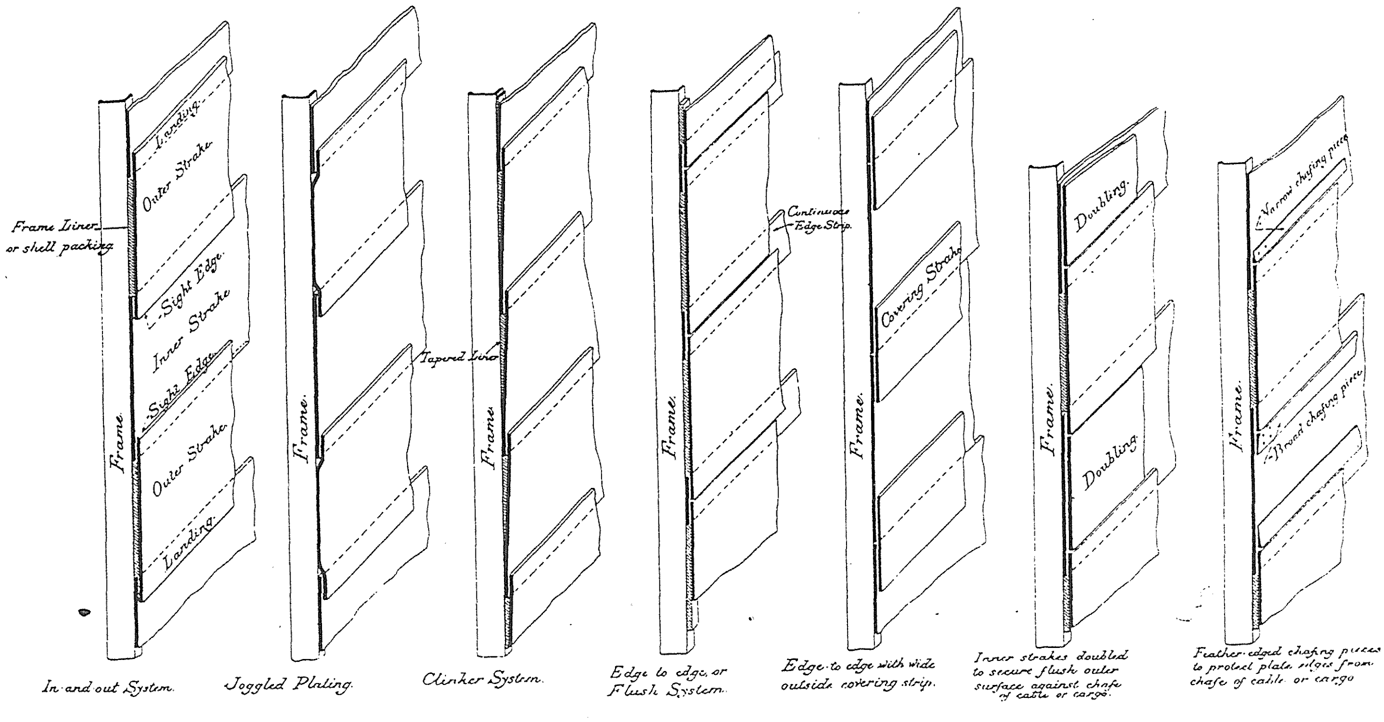


Figure 12b: Plating systems on early nineteenth century iron ships (Thearle, 1886: Plate 11). The Clinker System is third from the left.



Experimentation continued and much of it was scrutinised by other shipbuilders and the insurance industry, generally. Though the underwriters (insurers) had established a series of standards for type and scantlings (sizes) of materials used in wooden shipbuilding over the years, by 1855 (seven years after the *Xantho* was built) Lloyd's had still not specified scantlings or mode of construction for iron ships. The following excerpt from the Register Book for 1855 illustrates this point

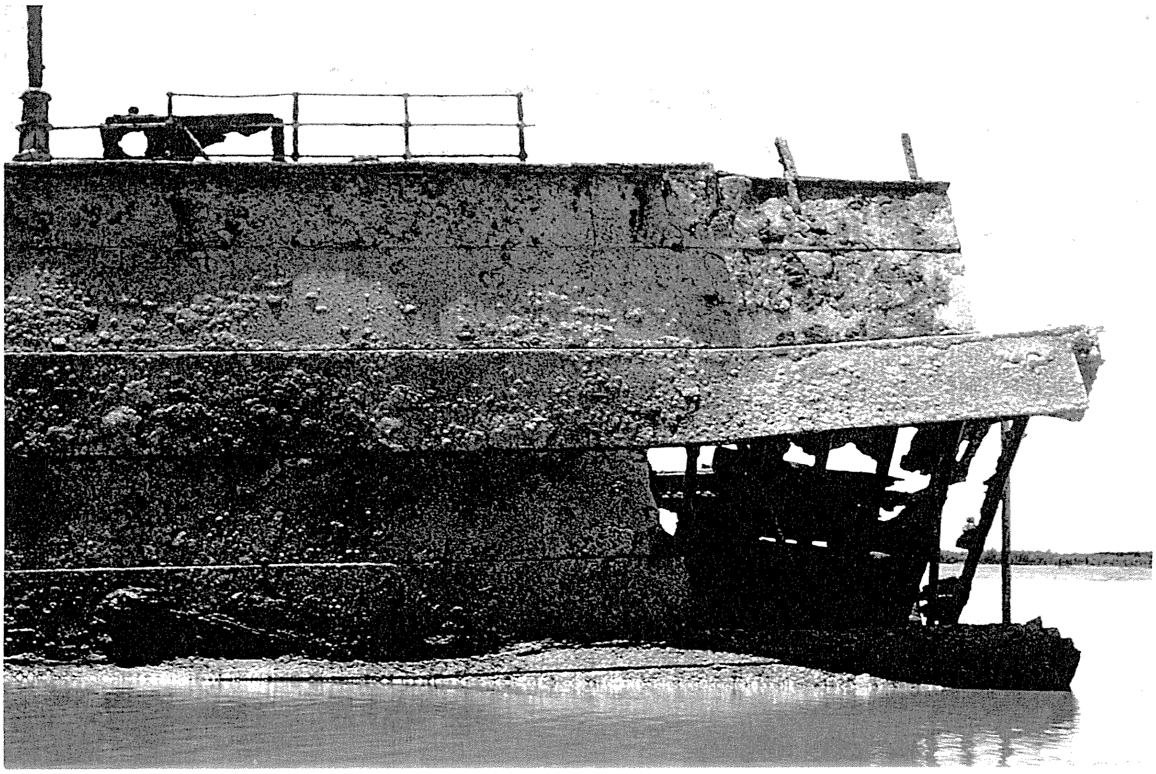
> Considering that iron shipbuilding is yet in its infancy and that there are no well-understood general rules for building Iron Ships, the Committee have not deemed it desirable to frame a scheme compelling the adoption of a particular form or mode of construction... (Reproduced in *Annals of Lloyd's Register*, 1884:77).

The clinker system of applying hull plating, as used on the *Xantho*, was superseded by the 'in and out' or 'alternative' plating system shown on the SS *Colac* (1886-1910) in Figure 13, below. There were obvious reasons for the rapid acceptance of the latter method as can be gauged from the following comment

> There was however, a serious objection to clinker-plating. Between each plate and the frame running across it there was a triangular gap which had to be filled before the rivets joining the outer plate and the frame could be hammered up; a rivet can be made good only if there is no 'spring' between the parts to be connected. On occasion, ill-fitting washers were fitted in the gap around the rivets, but more usually a tapered 'liner' (a narrow strip of plate to fill in between a frame and an outer strake), was used. Such liners were difficult to make, and commonly not very well made (Robb, 1978: 357).

On the other hand, the longitudinal system of lengthwise girders and partial and main bulkheads, which became a feature of 20th century shipbuilding (Figure 12a), was less quickly accepted (Westcott-Abell, 1948: 87-111).

Figure 13 a &b: Hull plating on SS *Colac* (1895-1910). The 'in and out' system is clearly visible. Photographs by M. McCarthy.



Xantho was built at a time before enough data was available to allow the iron shipbuilding industry to specify hull thicknesses and building method. It was, as a result, a product of mid-nineteenth century experimentation with metallic hulls. Being clinker built the hull had an acknowledged inherent weakness should it be subject to inordinate stresses during its working life.

There were clearly distinct advantages in Broadhurst purchasing a ship built of iron. These were enumerated by the engineer John Grantham thus

1. strength combined with lightness
2. great capacity for stowage
3. safety
4. speed
5. durability
6. economy in repairs
7. cost
8. draught of water (1859:86)

The question still remains, however, whether *Xantho* was suitable for the purposes intended by Broadhurst.

In order to address this question and to be able to characterise the scantlings of the iron used in the building of the *Xantho* and other ships constructed in the period before rules for iron hulls were promulgated, we need to examine the evidence available from both extant contemporary hulls and from the builder's specifications described in the early literature.

SS *Great Britain* (built 1843) was clinker-built and had relatively thick garboard plates of 11/16 of an inch (17mm),[1] bilge and side plates of 10/16 of an inch (15mm) and upper decks and gunwales of 6/16 inch thickness (9.5mm). Another museum ship, *Star of India* (built 1863), was also very heavily built. Its entire bottom to the turn of the bilge was built of 1 inch (25mm) thick plates and from there the plates ranged from 12/16 (19mm) to 10/16 inch (16mm) plating (Wall, 1978:33; Reynard, 1979). Partly due to this over-building, far in excess of the

[1]An inch is 25.4 mm. Where a vessel is built in feet or inches, the original term is used traditionally in maritime archaeology, with the notation of the type of foot or inch; e.g. the Amsterdam or British foot. Metric equivalents are given when necessary. In this thesis the British foot of 12 inches (12") is used.

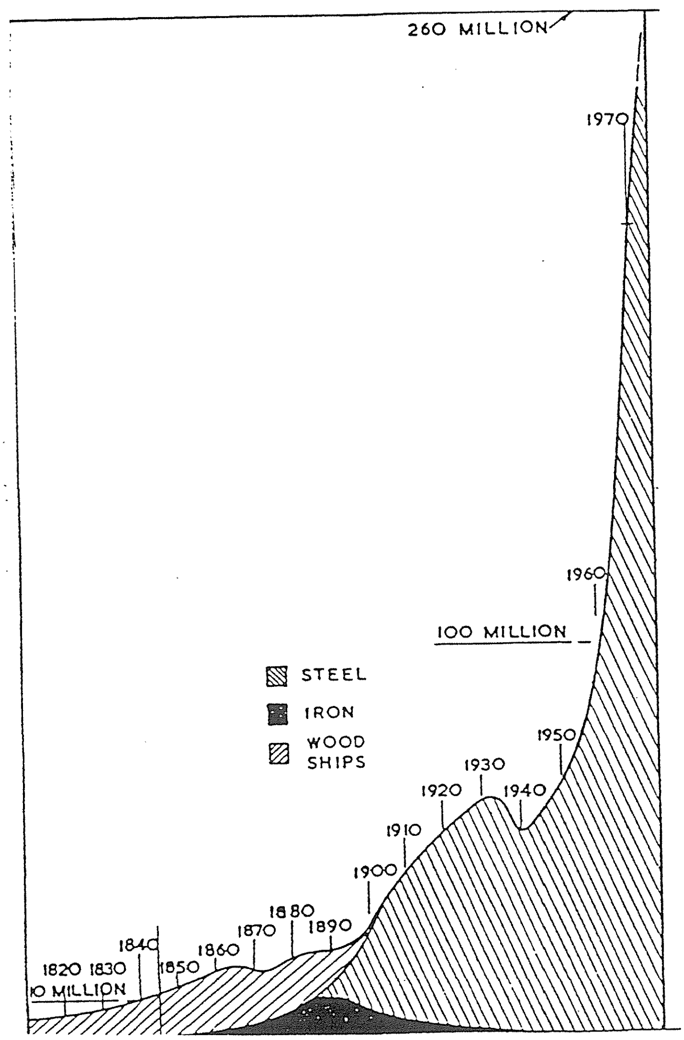
sizes later recommended, both of these ocean-going vessels are extant and in fact the *Star of India* is still afloat.

At the opposite end of the scale at the time, were the small river steamers described by Grantham (1859:187-191). Some of these had hull plating of only a maximum of 4/16 inch (6mm) thick (see scantlings for two London river steamers reproduced in Appendix 3). Though Lloyd's rules were in operation by 1855, there was considerable variation in the scantlings of vessels built in the period. This was not only as a result of differences in the overall size of the vessels, but was also due to their operating parameters. Grantham, for example, actually advises that variations to Lloyd's new rules were justifiable and gives examples of successful vessels and their scantlings to support his argument. In some instances, notably river steamers, he advocates scantlings lighter than those sanctioned by Lloyd's (e.g. Grantham, 1859:186-187).

In general, ocean-going steamers were normally of heavy construction due to their size and operating parameters. River-steamers were noticeably of smaller scantlings, due again to their smaller size and operating parameters. Sometimes these scantlings were less than those advocated by Lloyd's. This is of relevance when we come to examine the *Xantho.*

Steel began to replace iron as a shipbuilding medium after the invention of the Bessemer converter in 1856 and more rapidly after the Siemens process was initiated in 1866 (Tylecote, 1976: Chapter 10). It allowed for a further reduction of scantlings and hence weight, with a subsequent rise in carrying capacity. Though initially proving expensive, by 1880 it was only 50% more expensive than iron and by 1891 down to 10%, with Lloyd's first rules appearing in 1888 (Corlett, 1970:219). Showing considerable economic efficiencies due to the reduction in scantlings and vessel weight, steel replaced iron as a shipbuilding medium and iron ships were not built in quantity after that time. Figure 14 illustrates the peak in iron shipbuilding, as measured by tonnage at around 1890, with a rapid falling off after that time. The figure also illustrates the fact that the iron-hulled vessels like the *Xantho,* represented only a very small percentage of the tonnage of European shipping, making them of further interest.

Figure 14: A graph of the tonnage of wooden, iron and steels ships built in the period 1820-1970 (Corlett, 1979:281).



Therefore, a ship built during the period 1840-1880 can be expected to be built of either of iron or wood, but not of steel. If built early in the iron period (i.e. before 1850), it can be expected to differ from ships built after the advent of general rules for iron shipbuilding. This may include hull plating techniques, frame, keel and support structure form, hull thicknesses and general scantling sizes. Early river or inland-water steamers were generally built with small scantlings due to their operating parameters and they are expected to differ from Lloyd's rules, if the recommendations of influential iron shipbuilders such as John Grantham were followed. An analysis of his recommendations shows that they were often built to smaller scantlings than those allowed by the underwriters in later years. Their suitability for prolonged use at sea is then clearly bought into question.

Engines and ancillary machinery

The *Xantho* was first built as a paddle steamer and was then converted to screw propulsion. It was powered by a number of boilers, marine engines and ancillary machinery throughout its 23-year career.

In understanding the machinery found on the wreck it is necessary to put its machinery into its engineering context (cf. Bourne, 1858; Jamieson, 1897; Guthrie, 1971)

Xantho was built forty years after the first successful attempt to operate commercially viable steam vessels in America and Britain (Fincham, 1851: 288; Guthrie, 1971:37). Early marine engines were a bulky and heavy apparatus which reduced the capacity to carry cargo. The numerous working parts made the engines difficult to operate and expensive to maintain. Reduction of the weight and the space required for the engine-room became a prime consideration for early marine engineers. The disadvantages of early engines, such as the side-lever type, saw the development of the direct-acting marine engine with cylinders placed in various configurations immediately below the paddle shaft. The forerunner of this configuration, the Gorgon engine, though reducing space and weight, had problems due to the short connecting rods acting at an angle to the piston movement. Increased wear was a major problem. To remedy this situation types such as the steeple engine (as originally fitted to paddle steamer (PS) *Xantho* in 1848) were built.

The steeple engine employed a long connecting rod passing vertically out of the cylinder, up past the crankshaft and then vertically back down to connect with it, thus avoiding the problems of angular thrust as in the case of the direct acting Gorgon Engine.[1] Open-top cylinders were also introduced at this time, allowing the attachment of long connecting rods close to the pistons themselves. These were all vertical engines, with the paddle shaft above the cylinder(s).

Other variations such as the Oscillating Engine also came into vogue. With this engine the cylinders swung (oscillated) on trunnions (bearers) keeping the angle of the piston constant to the line of the connecting rod. This eliminated the need for the long connecting rod used to reduce angular thrust. Being compact, these became a very popular engine, especially for paddle steamers. One of the earliest known sets of Oscillating Engines was fitted in the first iron steamer, the *Aaron Manby* in 1822 (Grantham, 1859:9). The oscillating engine was perfected for use in paddle propulsion by the firms Maudslay, Field and Son, of London and John Penn and Son of Greenwich. The diagonal direct acting engine was added in the late 19th century and the two became the dominant types which took paddle propulsion into the 20th century (Yeo, 1894:4)

Thus though *Xantho* was built in the formative years of iron shipbuilding, its paddle engines were of a common and proven form. It

---

[1]Engine: One cylinder was usually referred to as an 'engine'. If a particular piece of machinery had two cylinders it was often referred to as being or having 'two engines'. Later a machine with two or more cylinders was referred to as a ship's 'engines'. Gradually the term 'engine' referred to a piece of machinery with any number of cylinders.

was altered from paddle-propulsion to screw-propulsion in 1872 and it is to that transition in form of propulsion we now turn.

The successful demonstration of the use of a screw (propeller), by the Ship Propeller Company's SS *Archimedes* in 1839, attaining a speed of 9 knots,[1] sparked an interest in the screw as a viable means of ship propulsion. It was not, however, until after the Admiralty trials in 1845 that the mechanical efficiency of the screw over the paddle was conclusively proved. From a naval point of view the advantages of the screw for war vessels were acknowledged at once, clearly illustrating the influence of warfare on technological innovation. Paddles had the disadvantage of causing reduction in the deck space available for the mounting of cannon. Roll in heavy seas posed considerable problems. Additionally a ship was less vulnerable to shot with the screw located below the water line as opposed to paddles exposed above it. The entire side of a screw-propelled vessel could be placed alongside a jetty or wharf in comparison with a 'side wheeler' and there was less danger while there of damaging the paddles against those structures. Finally, in placing the engines at the stern and not amidships, as was the case with the paddle-driven vessel, there were considerable gains to be made with the location of cargo holds amidships and the reduction in the number of cranes and derricks needed (Smith, 1937:217).

Until Rankine produced his theory of propeller action in the mid-1860s, thereby providing the basis for understanding the operation of the screw, the development of the screw was described as being 'totally empirical, intuitive and in some cases fortuitous' (Corlett, 1993: 102). After then it was based on scientific principles. The following quote illustrates this process

---

[1]The knot refers to the number of nautical miles travelled per hour. The nautical mile (1853m.) is fixed at a minute of latitude and hence the knot is a term still in use today.

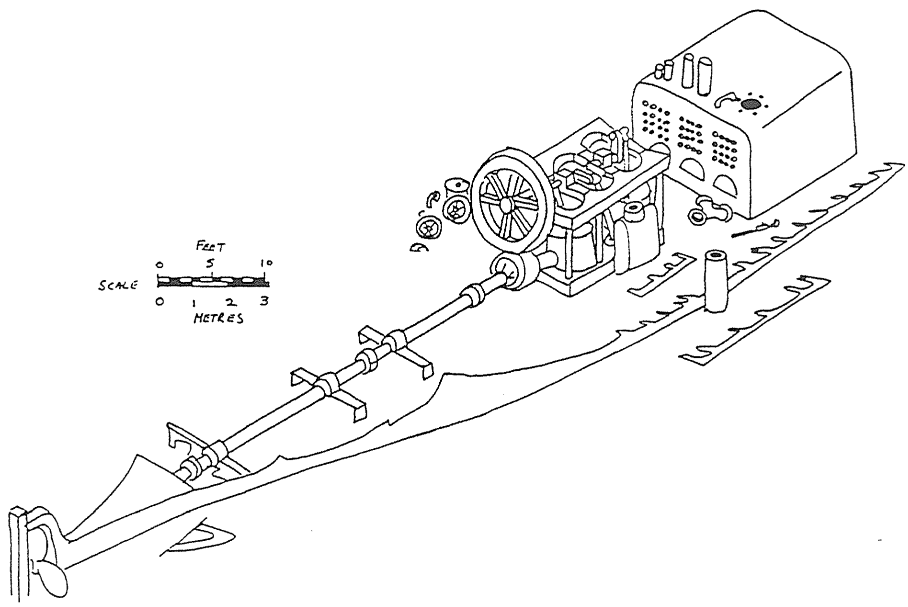
> By 1865, as far as the propulsive side was concerned, there was little to be done with screw propulsion except to refine it...1840-1865 was truly a golden age for the development of the modern ship and for screw propulsion in particular. (Corlett, 1993: 104)

Early steamships invariably carried masts and spars on which to carry sails, allowing their masters to revert to sail propulsion in favourable conditions. Drag of the propeller then became a major concern. In these cases, an arrangement could be made whereby the screw could be disconnected and raised out of the water to counteract the resultant drag. On the other hand, a 'dog-clutch' (enabling the propeller to be disconnected from the engine, and thereby 'freewheel' in the vessel's wake), was often fitted if the screw was to be left immersed. Sometimes engines were fitted on sailing vessels for use as auxiliary propulsion where the wind was fickle or contrary. Thus a nineteenth century steamship could be found fitted with auxiliary sails, and sailing vessels, notably private 'yachts' or other specialist craft, could be found with auxiliary engines. All can be found in the literature, registers and archives under the designation 'steamer', however.

In order to drive the new breed of screw-driven ships, engineers originally attempted to adapt existing paddle engines to drive the screws.[1] This caused considerable problems, as the screw required a greater speed of rotation (revolutions) than the paddle. To obtain the higher revolutions, engineers employed a system of gearing to increase the speed of the slow running paddle engines. The system was noisy, inefficient and prone to failure. Figure 15 shows the gearing on the engine of the SS *Royal Shepherd* (1853-1890) and the positioning of the direct-acting engine immediately below the crankshaft.

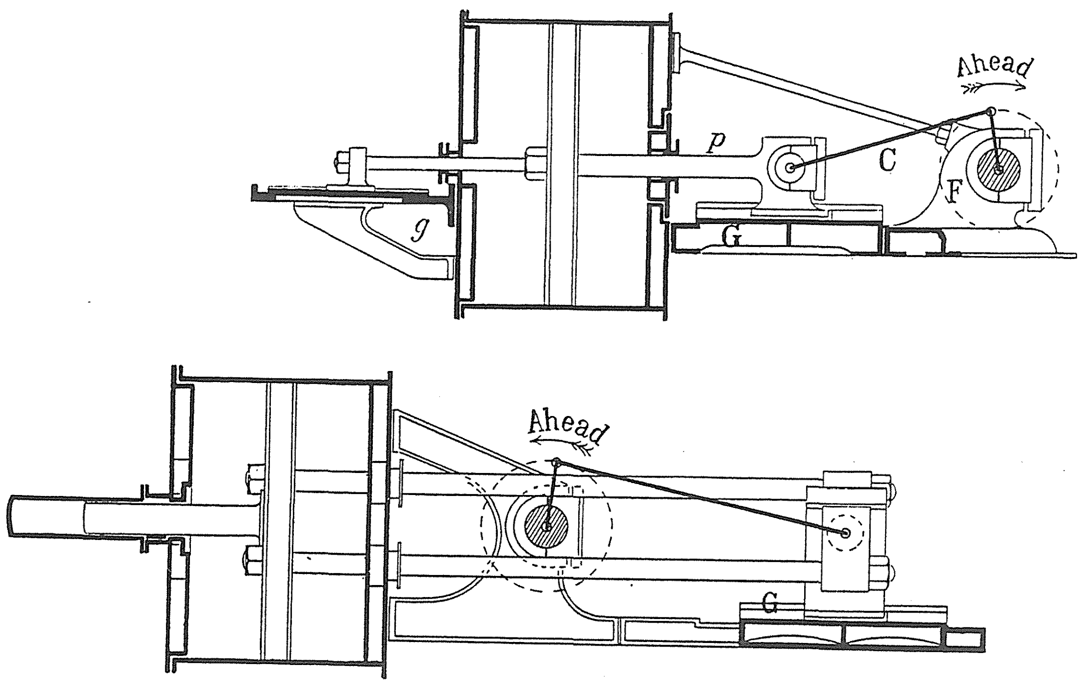
[1]The term SS is generally used to indicate a screw steamer. TSS indicates a twin screw steamer. MV indicates an engine driven vessel. The term 'propeller' as used in contemporary North American literature is defined on page 31.

Figure 15: The stern section of the wreck of the SS *Royal Shepherd* showing gearing and the vertical oscillating engine. By John Riley (Riley, 1988b: 144).



A gradual trend away from low pressure, low revolution, geared screw engines to specifically built, high revolution screw engines then occurred. Although not without problems, an early tendency towards horizontal engines was reinforced in 1858 when an Admiralty Committee, seeking to find a satisfactory engine for naval purposes, decided in favour of horizontal engines because they could be kept low in the ship away from enemy fire. The horizontal types that the committee identified as being superior to the older types were the direct-acting engine, the double trunk engine, patented by a consortium including John Penn (Patents for Inventions, 1855) and the return-connecting-rod engine made by Maudslay, Son and Field (Smith, 1937:146). The return-connecting-rod Engine was, in effect, a vertical steeple engine in horizontal form.

Figure 16: A schematic representation of two horizontal screw engines. The upper diagram shows the arrangement of a direct-acting engine and the lower, a return-connecting-rod engine. Note the direction of rotation (Yeo, 1894:54).



The advantages of the new engine types were summarised by professional marine engineers Sennett and Oram, thus

> The majority of steamers, both war and mercantile, built during the years 1850-60, were fitted with horizontal screw propeller engines working with steam of from 20-25 pounds pressure per square inch. The engines had jet injection condensers and were not remarkable for economy and fuel, but were much lighter and occupied considerably less space than the paddle wheel engines that preceded them (1918:10) .[1]

[1]Pressure was generally referred to as pounds per square inch (psi). In order to effect a conversion, one atmosphere is c. 15 psi. 2.2 pounds equals one kilogram (kg). The units are kept as per the originals.

Indicating a personal preference for the trunk engine, the engineer Burgh noted

> The horizontal arrangement for screw engines has many originators, many friends, and of course, naturally the usual amount of enemies. The object sought after with the type in question is compactness of arrangement, with free space above the cylinders and condensers. The double trunk engines...... (as built by Messrs. Penn) combines simplicity of connection (piston to crank) and access for repair, with superlative design and arrangement (1869:41).

The trunk engine (Figure 17, below) was a very compact, direct-acting type. It was designed to allow for the use of a relatively long connecting rod joined directly to the piston via a hollow trunk, which projected through both ends of the cylinder. By the end of the century, the engineer Andrew Jamieson noted that the engine was then outmoded partly as a result of the excessive friction at the stuffing-boxes and heat losses on the exposed trunks (Jamieson, 1897: 214-215). He also noted that the engine was designed to rotate in a particular direction in order to minimise wear on the under-surface of the piston. His comments are reproduced in full in Appendix 4.

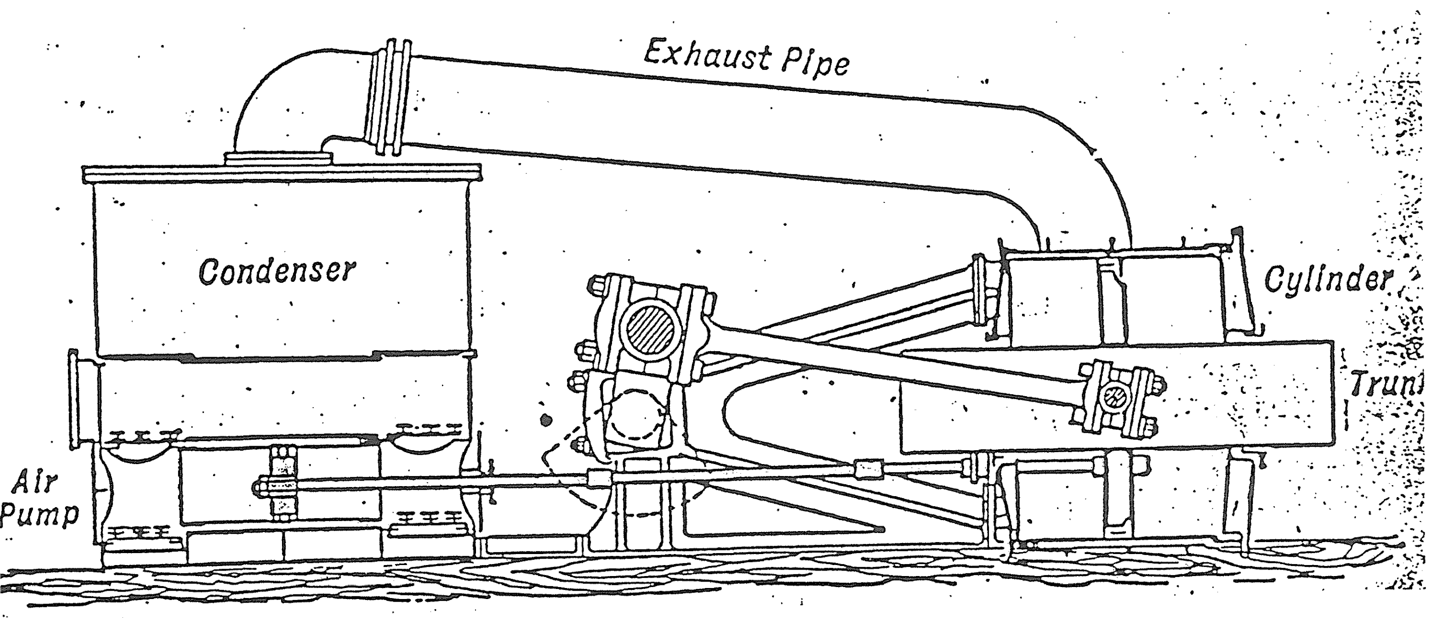
The trunk engine type was built from 1846 to 1875. It proved very expensive to operate due to the inefficiencies noted above, using an average of 4-5 pounds (2-2.5 kg) of coal per indicated-horsepower-hour (Corlett, 1993: 97).[1] This was a high rate of energy consumption and the only real niche for an engine of this type was in naval service due to its ability to be built as a compact unit able to be kept below the water-line, away from shot and shell (Banbury, 1971: 227-229). For example the *Himalaya,* which was built for mercantile use in 1853 with a 2500

---

[1] Horsepower: is a measure of the engine's capacity for work and it is recorded as Horsepower, (HP), Indicated Horsepower (IHP) or Nominal Horsepower (NHP). Rivett, (nd: 52-5), reproduced in Appendix 2 provides a useful synthesis of these three indicators of engine capacity.

horse power trunk engine, soon reverted to naval service as a troop ship having strategic (as opposed to economic) value by virtue of its size and mode of engineering (Guthrie, 1971:112-115; Engineer, 1898: 254, 350).

Figure 17: A trunk engine, showing the cylinder, trunk, condenser and air-pump (Jamieson, 1897: 214). Note the long rods from the piston crossing the mid-line of the vessel to the condenser air pump.



The trunk engine and the return-connecting-rod Engine eventually fell out of use due to their inefficiencies. Engines then came to be aligned in the vertical position, especially in the merchant marine, where there was no need to keep the engine below the waterline. Being vertical and easily accessible on all sides, they became favoured for their ease of maintenance. They were soon fitted to numerous ships, becoming known as the vertically-inverted engine. This name refers to the fact that though in the earlier vertical engines the cylinders were located below the crankshaft at the bottom of the ship (as shown in Figure 15 above), in later engines the cylinders were located above the shaft. Although the vertical engine was immediately seen to possess many practical advantages for merchant vessels, it was not introduced readily into the Royal Navy due to the necessity to keep machinery below the water line. Thus the horizontal screw engine experienced its last popular usage within the framework and requirements of the Royal Navy and other major sea-powers. It was still found in that context up until the late nineteenth century, when it was rendered redundant partly due to the development of the armoured hull.

Three other developments were necessary before the screw engine was able to achieve its full potential. The first was the invention of the *Lignum vitae.* stern gland in 1854. This device, based on the use of adjustable wooden inserts made from a very hard and self-lubricating timber called *Lignum vitae.*, solved the problem of keeping watertight the tube through which the rapidly rotating propeller shaft passed from inside the vessel's hull outside to the screw (Barnaby, 1904: 283). Before the device was perfected there were many problems with wear on the metal to metal surfaces and near sinking's occurred (see Figure 18, below).

The production of an efficient thrust block of the multi-collar type solved the problem of transferring the forward pushing force generated by the screw back along the propeller shaft. Without an efficient device to take the strain, the engine and other components were subject to very destructive forces. The thrust block, which consisted of a series of adjustable collars in an oil filled container, effectively transferred the thrust from the rotating shaft via the enmeshing collars to a stationary 'block' and then to strong bearers on the vessel's hull (see Figure 19, below).

Figure 18: The stern of an iron ship, showing the stern tube (10-14), joining flanges (9) and a plummer block (or stool) (4-5) supporting the propeller shaft(13) (Paasch, 1890; Plate 25).

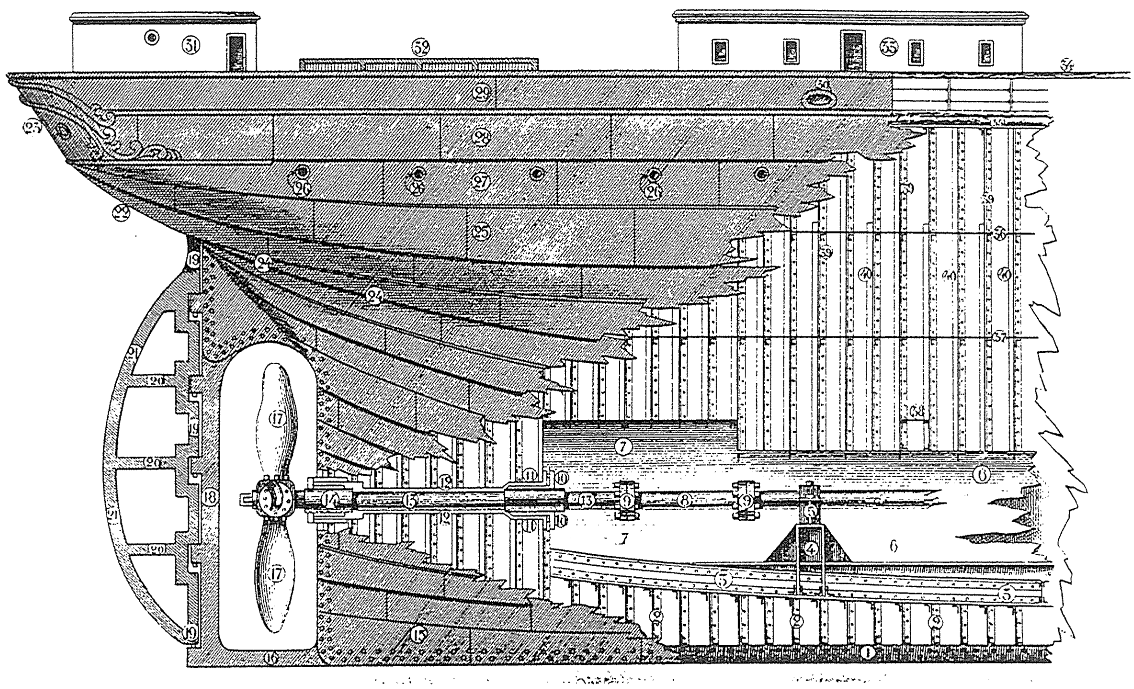
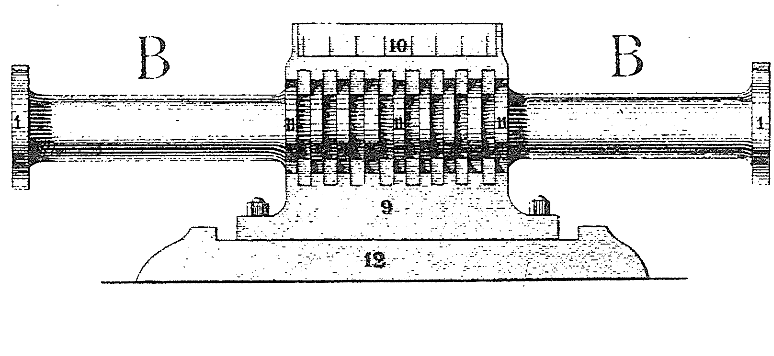


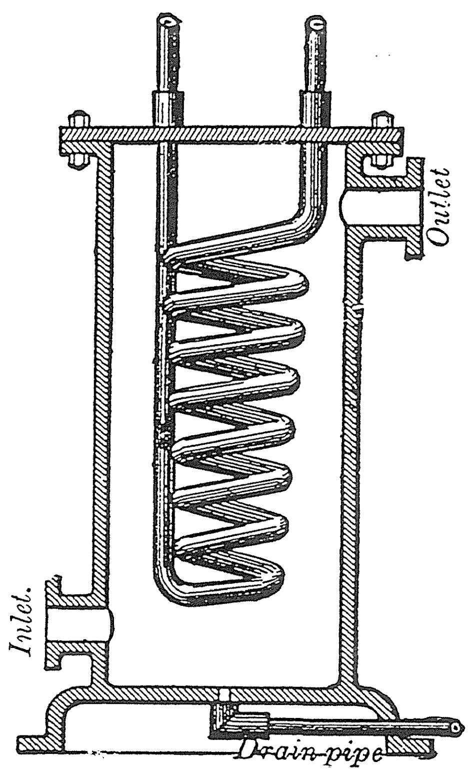
Figure 19: A multi-collar thrust block. The base (9) is attached to the vessel (12), the shaft (B) to the propeller and engine respectively at a flange (1). An oil reservoir is shown above (10). (Paasch, 1890; Plate 59 (B)



Advances in boiler-making were another prime consideration at this time. Though the production of steam for land engines and pumps dates back to at least 1663, significant developments occurred in the evolution of boilers and boiler making in the latter half of the working life of *Xantho*. These are well documented, especially with respect to boilers (cf. Burgh, 1873: Ch. 1). Relevant to the *Xantho* is the fact that marine boilers initially used salt water as opposed to fresh water. Though the steam emanating from salt water was itself free of impurities, sea-water requires more energy to be brought to boil. At one atmosphere, or 15 pounds per square inch, a temperature of 213.2°F is required to boil seawater, as compared to 212°F for fresh water. As boiling continues and fresh water was taken off as steam to drive the engines, the remaining water in the boiler becomes progressively more saline. Unless an attempt was made to replace the water, its density increases and the required boiling point would also progressively rise, thereby requiring more coal. One simple method of achieving the best possible thermal efficiency, was to note the temperature at which the water began to boil and if it was too high, to remedy the situation by replacing it with unused sea-water. It was recommended that if the boiling point of water reached a temperature of 215° F due to the increased salts, then it should be replaced with water from the ocean (Main and Brown, 1855:28). Cold water as a boiler feed was undesirable and thermally inefficient in itself, a factor that could only be reduced if the water was preheated in a special vessel, called a feed-water heater (Figure 20, below).

Pressure was also a consideration, in that the higher the pressure in the boiler, the higher the boiling point of the water and hence the more salt precipitated. At 15-20 pounds (gauge) pressure (i.e. up to 5 pounds per square inch above atmosphere (15 psi), the boiling point was relatively low and precipitation was minimal. As a result the use of sea-water was not a real problem at low pressures, though there was a slow depositing of scale which required cleaning at regular intervals.

Figure 20 : A feed-water heater (Hutton, 1903 :523)



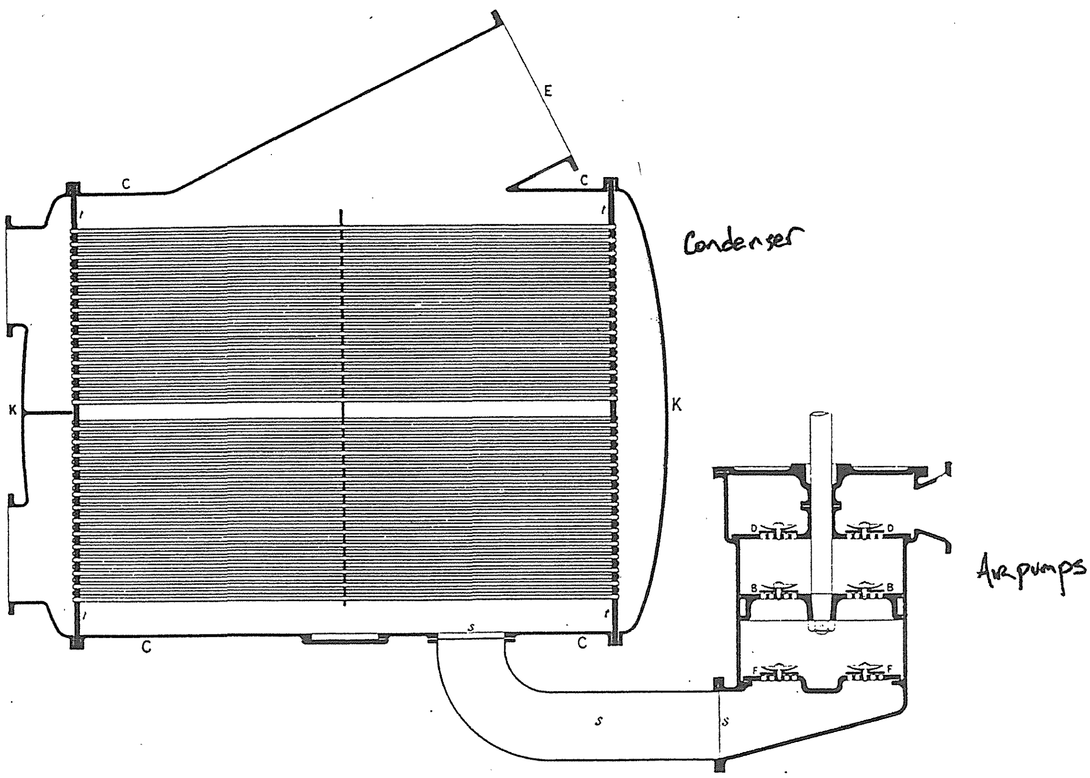
Being soluble over a wide range of operating parameters, the sodium chloride in sea-water (though it contributed to scale formation) was not as much a problem as was the sulphate of lime, or calcium sulphate, in sea-water. As boiler temperature rose, either through increased density of the salt water or through the use of higher boiler pressures, the solubility of calcium sulphate decreased and it readily precipitated on the fire tubes, grates and other internal surfaces. The precipitate produced a hard, poorly conducting scale obstructing heat transfer within the boiler itself, requiring more heat and therefore more coal to attain boiling point. In order to remove this encrustation, the boiler needed to be regularly shut down and cooled to enable the deposit to be physically removed from the interior.

Thus sulphate of lime in sea-water was a major factor keeping boiler pressures down where salt water feed was used. It was also well recognised in the mid-nineteenth century that marine boilers using salt water feed had a life expectancy of four or five years in comparison to a similar fresh water fed land boiler which was expected to last eighteen to twenty years (Bourne, 1858: 83). Marine engineers conducted experiments as to the cause of the problem and on the possible use of fresh water for the purposes of producing steam in the marine environment. Agreement could not be reached on the causes of the corrosion, however (Burgh, 1873: 356).

Another important device dependent on, and linked to, this problem was that of the condenser. This device facilitated the recycling of exhaust steam in the form of fresh water condensate by passing a jet of cold sea-water on it (a jet condenser) or by passing the steam through, or over, tubes cooled by circulating sea-water (a surface condenser). The jet condenser resulted in a mixing of the fresh water condensate with sea-water. The surface condenser kept the sea-water and fresh water separate. As a result, salt water was not introduced into the system, with obvious thermal efficiencies.

There were problems with surface condensers, however, in that the surfaces of the cooling tubes became clogged by tallow and other lubricants which entered the system through the steam chests and cylinders of the engine. These fats also decomposed at high temperatures into an acidic state with obvious ramifications for the life of the boiler.

Figure 21: A surface condenser with air pumps (Yeo, 1894:152)



Initially these problems limited the choice of condensers to the jet condenser which sprayed sea-water on the exhaust steam, cooling it so that the mixture of salt and fresh water from the recycled steam could be collected and re-used. As coal consumption in a non-condensing engine of the time was calculated at 4 pound weight (lbs) of coal per indicated-horsepower-hour (Jarvis, 1993:156), a jet condenser was clearly better than having no condenser at all.[1]

There was another advantage in the use of condensers and one that eventually led to the re-use of high pressure steam. The rapid cooling of

[1] The pound is the equivalent of 453 grams or 0.453kg. The consumption figure of 4 pounds of coal per indicated-horsepower-hour, incidentally is the same as that quoted earlier for a trunk engine fitted with a condenser, giving some indication of the relative inefficiencies of that type of machinery.

the exhaust steam caused a near vacuum in the condenser and in the pipes leading to it from the engine cylinders. This was a phenomenon that was used to advantage in reducing the back pressure of the exhaust steam on the pistons by one atmosphere, or 15 psi. Conversely, where steam exhausted straight to atmosphere, it immediately encountered a back pressure of 15 psi. To remove it by use of a vacuum resulted in an increase in useable power and a saving in coal. On the negative side, a supply of fresh water was required and pumps were needed to circulate the cooling water and to assist in maintaining or increasing the required vacuum (Yeo, 1894:152). Despite the need to power the pumps, an engine fitted with a condenser still proved far more thermally efficient than an equivalent engine without one. In recognition of this advance, the following comment was made in 1855

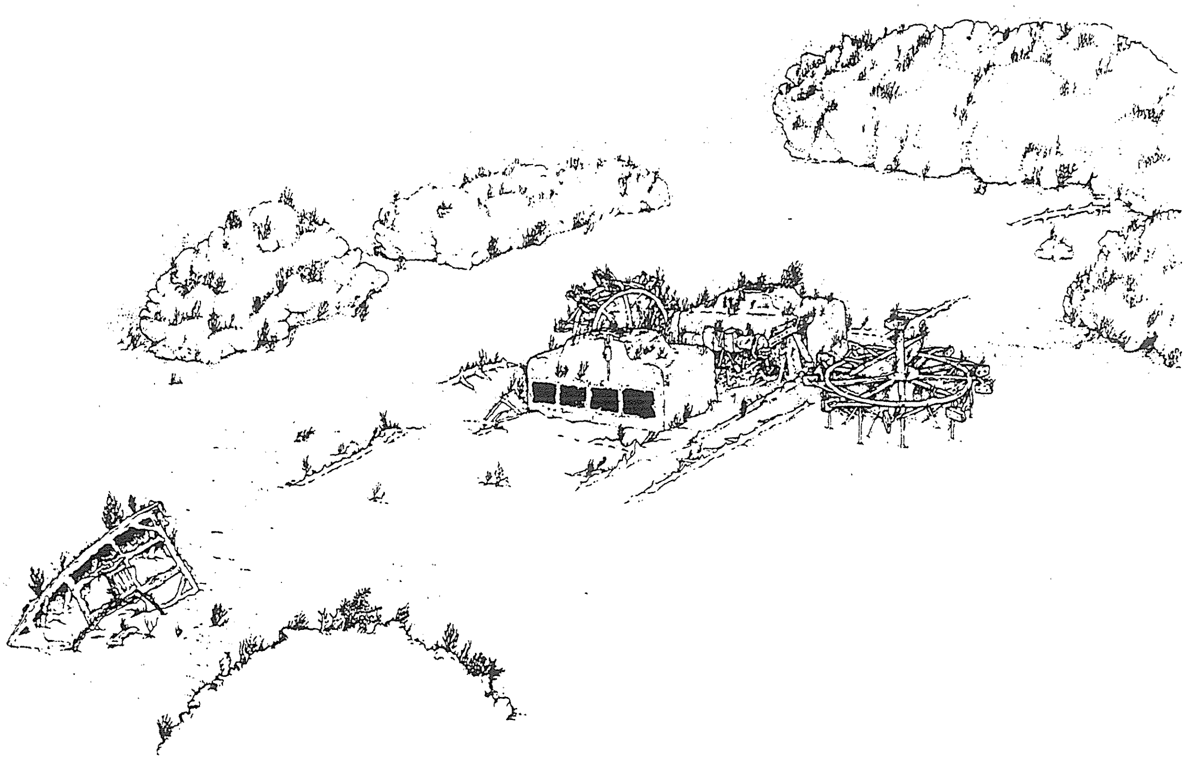
> A non condensing engine... will only be used where fuel is readily obtained and it is important to save space and weight...[they] are serviceable for very short voyages in steamers...especially river navigation...[the] condensing engine is more economical...(Main and Brown: 50, 67).

Thus a condenser of some sort was vital if long journeys were to be considered, if space was at a premium and if coal supplies were at a premium. Jet condensers were fitted until the 1860s, due to the problems earlier mentioned with the deposition of fats and their breakdown into acidic compounds. The development of temperature stable mineral oil lubricants in the USA in 1856 (Corlett, 1993:98) provided the breakthrough necessary for the further development of the surface condenser and the replacement of the jet condenser and salt water feed. The transition proved quite rapid, so that by the end of the 1860's surface condensers (Figure 21) were becoming widely adopted.

With some exceptions, boiler pressures rose in unison with these advances from 5 lbs per square inch in the 1830's, to 10 lbs per square inch in the 1840's, 20 lbs in the 1850's and finally to over 100 lbs per square inch in the 1880's (Smith, 1937:133)[1].

The boilers that produced the steam themselves altered physically from the rectangular flue boilers of the 1840's to the rectangular multi-tubular boilers of the 1850's and then the cylindrical multi-tubular type of the late 1860's. Examples of rectangular boilers appear on the American blockade runner *Mary Celestia* (1864-1864) shown in Figure 22 below.

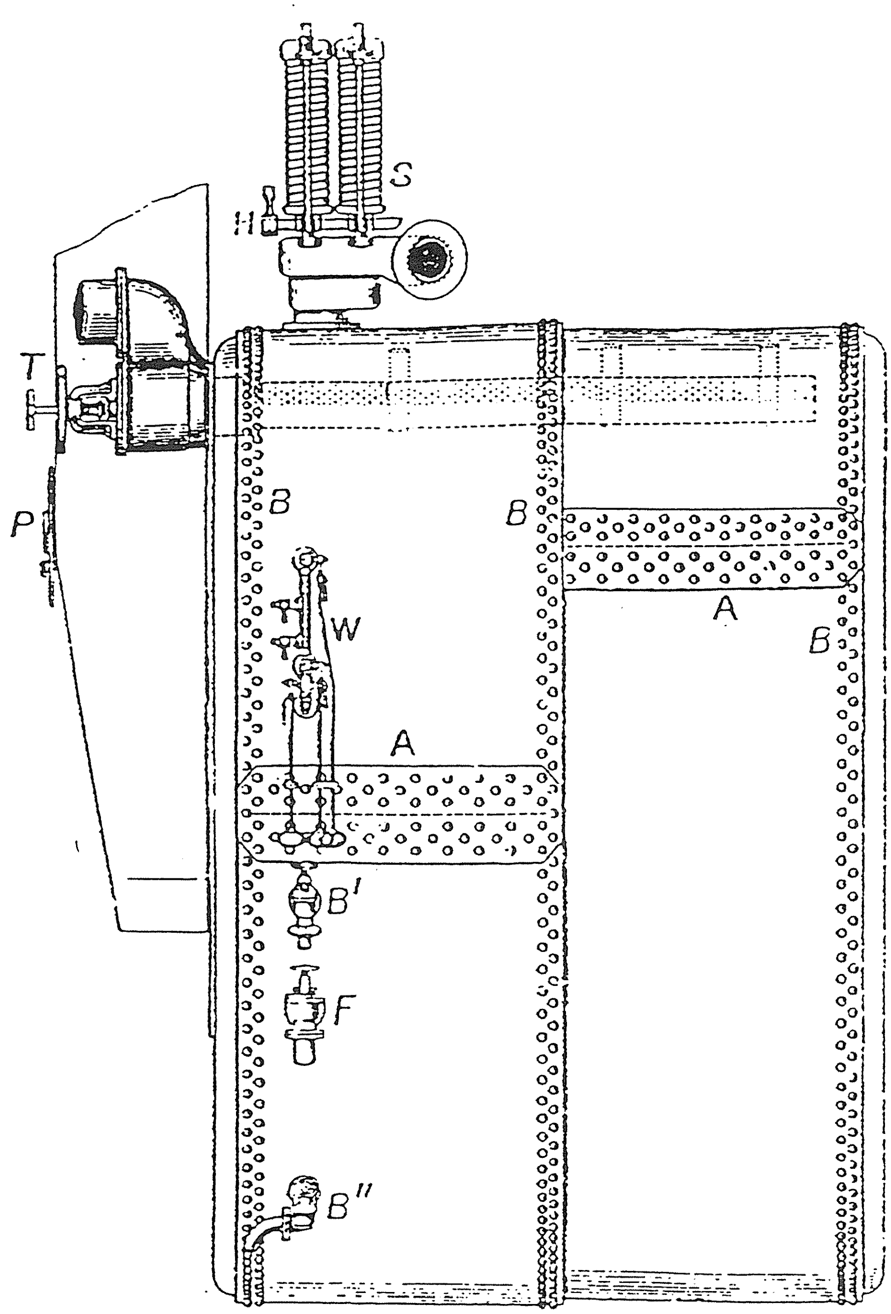
Figure 22: A pair of rectangular marine boilers on an 1860s paddle-wheeler , by Julie Melton (Watts, 1988: 163).



By the late 1860's, the cylindrical boiler, later to become known as the Scotch boiler, had proved so superior in regards to simplicity, reliability and ease of maintenance that most other types became out-moded. (Figure 23).

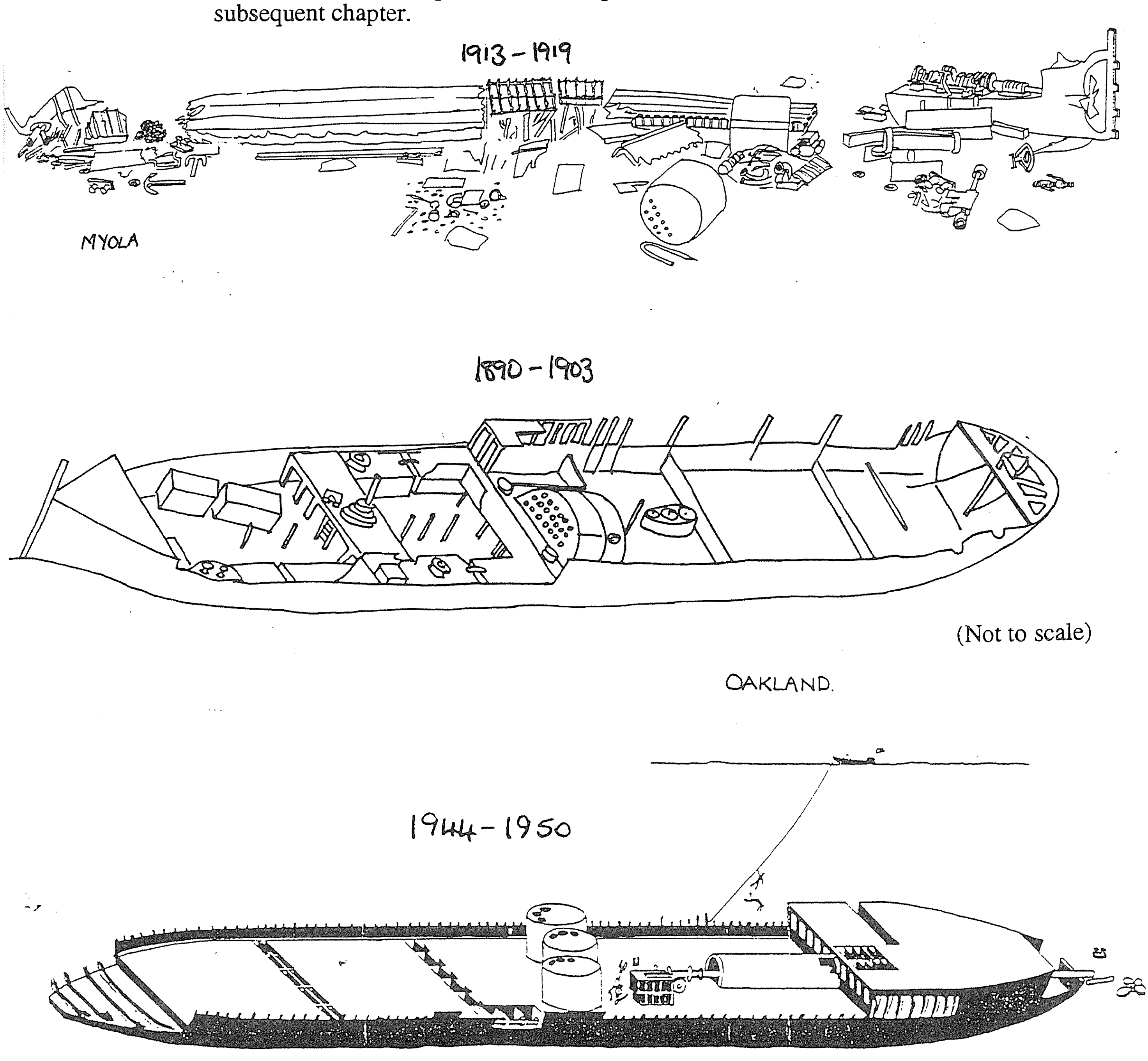
[1]The *Indiana's* boiler pressures were around 80PSI in 1848 (Johnston, pers. com.) See pp 38-9.

Figure 23
A Scotch marine boiler with a spring operated safety valve (S) (Yeo, 1894:39).

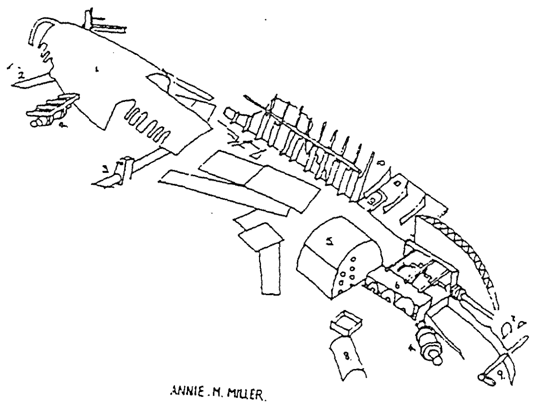


Thus though rectangular boilers could still found long after the 1860s on vessels such as *Mary Celestia*, *Royal Shepherd* and *John Penn* (Figures 8, 15 and 22, above), the Scotch boiler became the dominant marine-steam producing vessel of the latter half of the nineteenth century. A selection of vessels utilising these boilers is shown in Figure 24, below.

Figure 24: A compilation of isometric projections showing a variety of sites ranging from 1863-1950 showing Scotch boilers in-situ. Prepared for this study by John Riley, the illustrations also provide evidence of commonalities in iron and steamship wreck disintegration which will be discussed in a subsequent chapter.

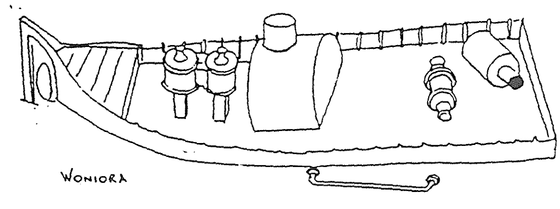


1928-9



ANNIE. M. MILLER.

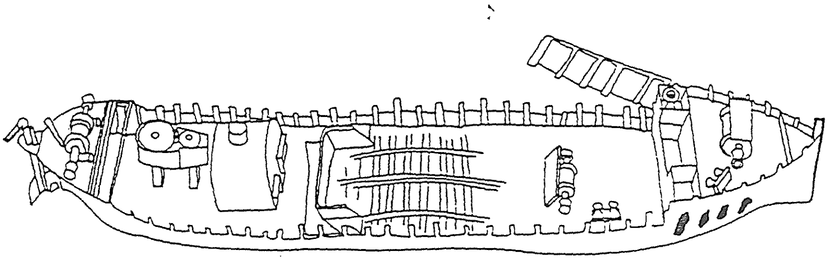
1863 - 1882



WONIORA

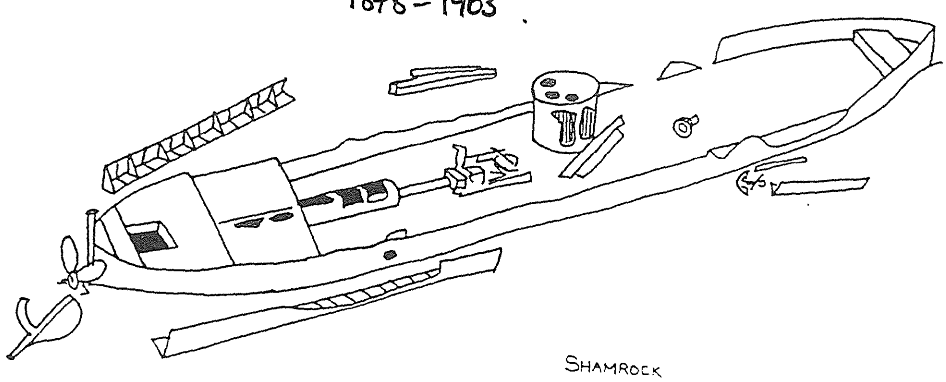
(Not to scale)

1909 - 1918



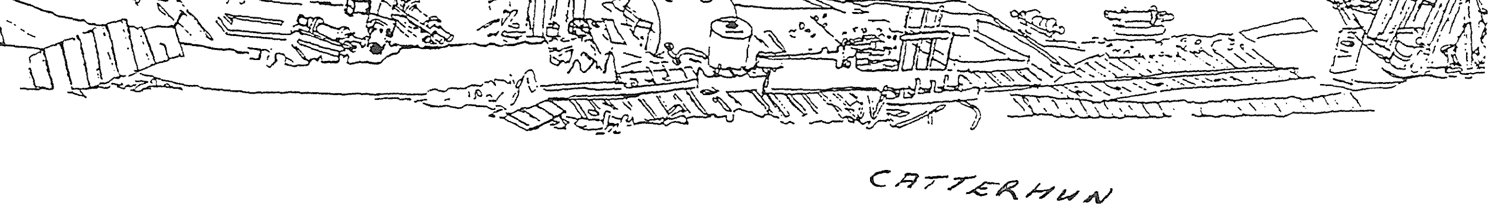
UNDOLA

1878 - 1903



SHAMROCK

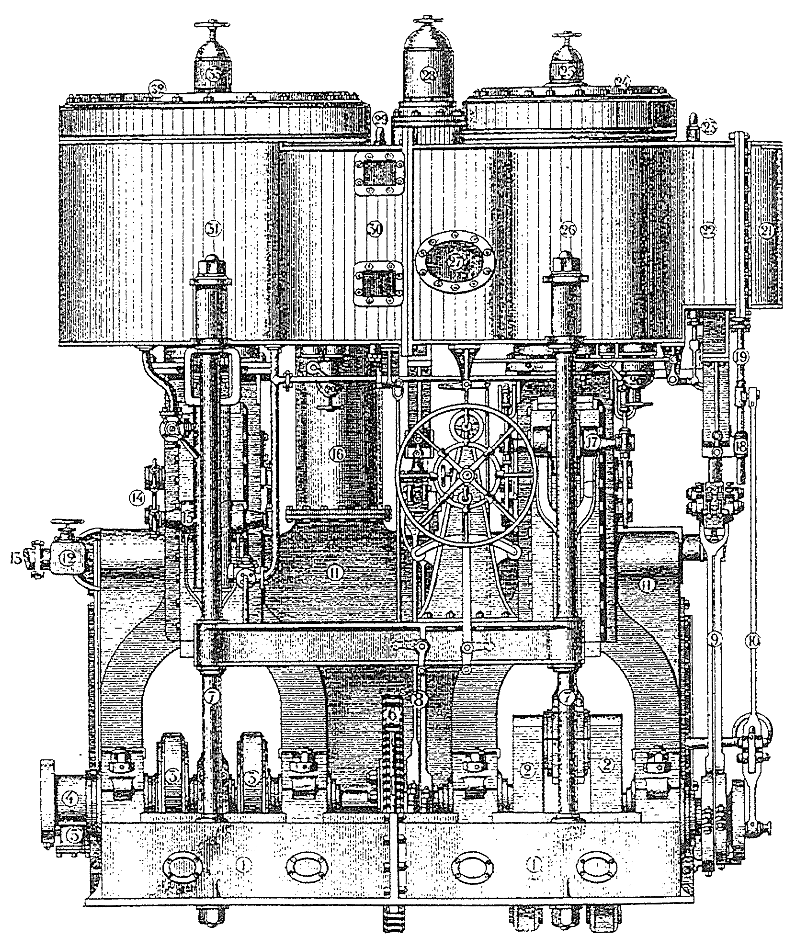
1881 - 1895



CATTERHUN

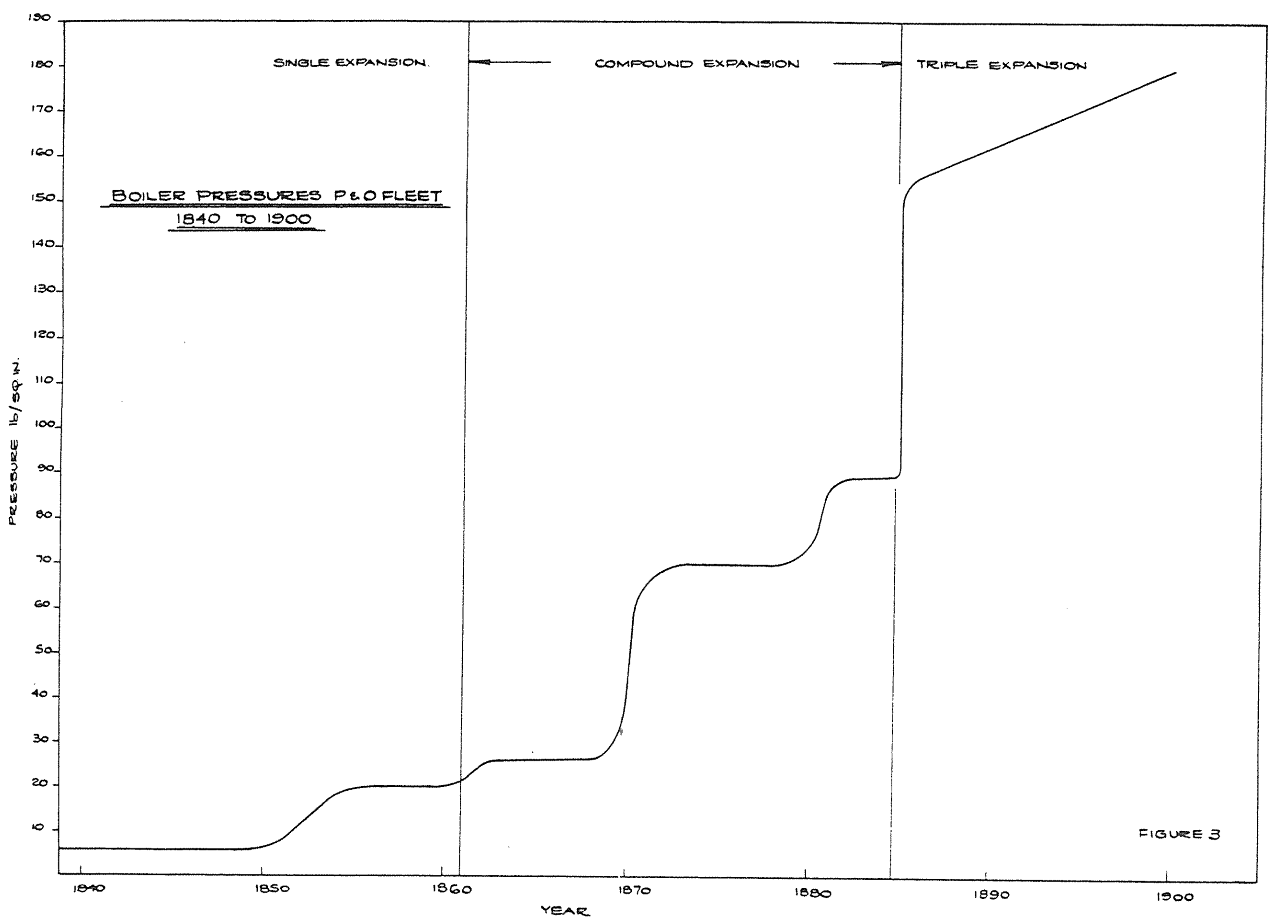
The advent of much higher boiler pressures saw the development of efficient compound engines (Guthrie, 1971, Ch. 6). These engines allowed high pressure steam from the boiler to be expanded in stages; first in a high pressure cylinder from where it was exhausted to a lower pressure cylinder and from there to the condenser for re-circulation back to the boiler (Figure 25). This type of engine allowed for a substantial saving in fuel due to its thermal and mechanical efficiency, reducing consumption to as low as 2 lbs per indicated-horsepower-hour (Jarvis, 1993:156; Griffiths, 1993: 168-170). Less coal had to be carried, more space was available for cargo and fewer stokers were required.

Figure 25: A compound engine (Paasch, 1890: Plate 49) The columns, the low-pressure and high-pressure cylinders are shown, as is the condenser, bedplate and crankshaft.



The rises in boiler pressures in one field of operation, the Peninsula and Orient Steam Navigation Company (P&O), are shown in Figure 26 below. With the exception of the Crimean War gunboats of 1854-5, the link between the rise of pressure and the advent of compounding is evident.

Figure 26: The rise of boiler pressures in the P&O fleet and the advent of compounding (Corlett, 1981:284)



Compound engines in their latest stages not only used less coal, but also operated at a higher speed, weighed less and occupied less space. These advances and the opening of the Suez Canal in 1869, through which the SS *Xantho* was soon to pass, heralded the great age of the trans-oceanic steamship and the complete passing of the clipper ship era (MacGregor, 1973:270).

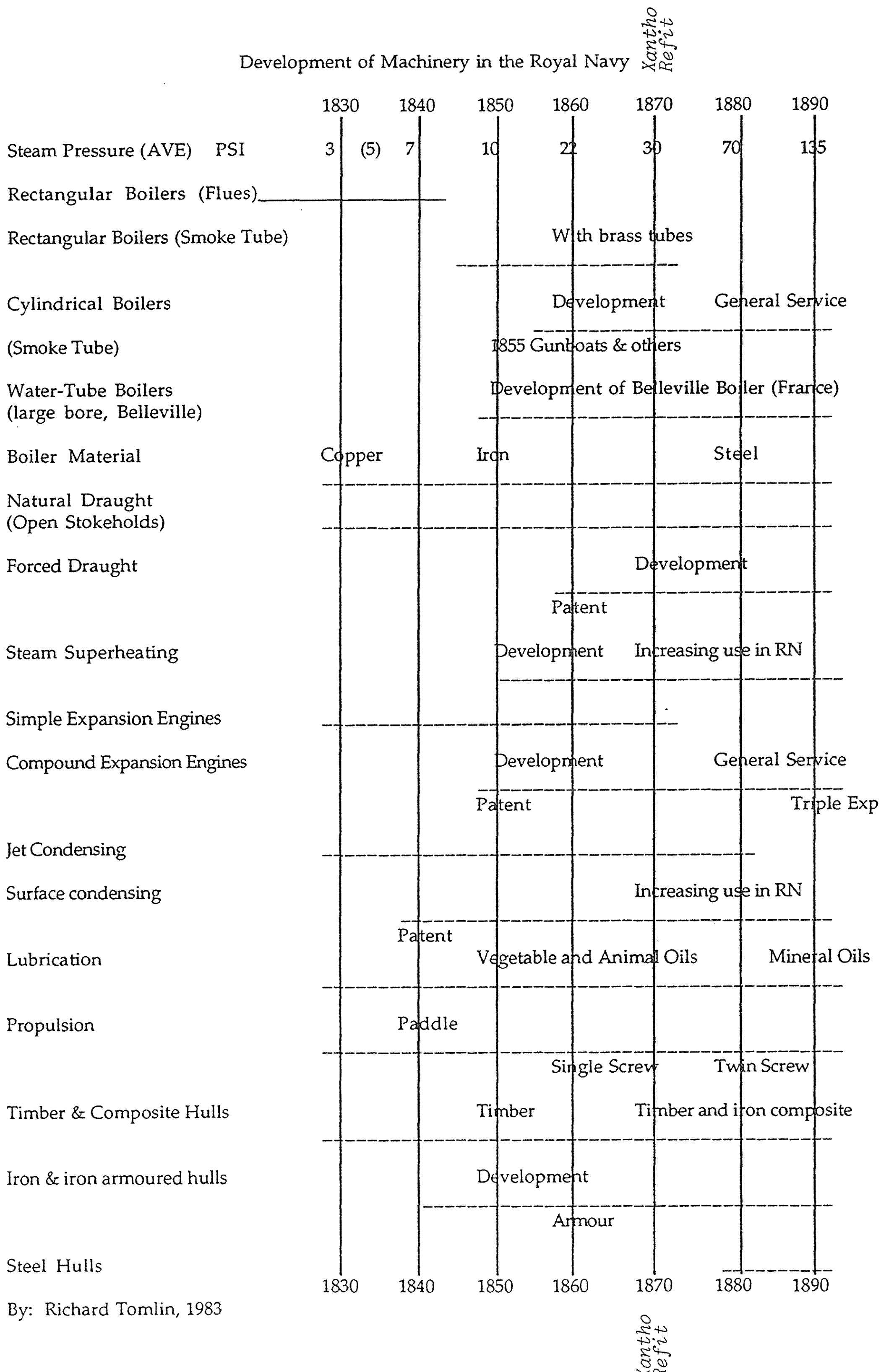
With the Royal Navy convinced of the advantages of compound engines and of the value of the twin screw vessel, it became an obvious and almost necessary step for it to change from horizontal to vertical engines and to protect them with side armour. This allowed naval engineers the luxury, realised many years previously in the merchant marine, of tending to a vertical engine. Thus the replacement of the horizontal engine (whose only saving grace was the ability to be kept below the water line for tactical reasons), with vertically inverted compound engines was assured. The compound engine in its two, three, and quadruple cylinder forms took marine steam propulsion into the twentieth century.

It is reasonable to expect therefore that a newly-engined, or substantially re-fitted vessel of the early to mid 1870's, which was designed to be operated over long distances, or where coal supplies were at a premium, would be fitted with a Scotch boiler, a surface condenser and a two-cylinder compound engine connected to a propeller via a multi-collar thrust block and a stern tube lined with *lignum vitae.*

Out-moded, though still useable, simple expansion engines and inefficient rectangular boilers were still to be found (as in the three cases mentioned above) but normally only where coal was cheap, distances were short, or if the capital needed to upgrade or purchase suitable machinery was lacking.

Figure 27, below, schematically presents the developments in marine engineering discussed above, albeit from a conservative perspective, that of the Royal Navy and it indicates the engineering characteristics one might expect of a ship, like *Xantho,* built or totally refitted in the early 1870s.

Figure 27: Marine engineering developments in the RN (after Tomlin, 1983; cf. Warsop and Tomlin, 1990). 1871 is marked in italics, illustrating the characteristics generally expected of a vessel built or substantially re-fitted around that time.



Having addressed the developments in marine engineering that would have influenced the design and configuration of a ship built or substantially refitted in 1871, like *Xantho,* I will now examine the regional factors which may have had an influence on its configuration and operation.

SS *Xantho* in the Western Australian context

By 1865, when Broadhurst decided to go to west Australia as a prospective settler, the Swan River Settlement (present day Perth and Fremantle) was the administrative centre for a European population of approximately 20,000 people located within an area in excess of 1,000,000 square kilometres (Knight, 1870).[1] The colony had a coastline of approximately 4,350 nautical miles (8,066 kilometres) containing few safe or reliable harbours. Communications and conditions in the colony were relatively primitive when *Xantho* arrived in 1872. Conditions in the northern part of the state, to where Broadhurst and his family were bound, were even more primitive and communication was much more irregular than in the south. Movement on the west Australian coast (Figure 1) was so slow that the colonial Government was allowing a maximum of fourteen days for a one way coasting voyage from Fremantle to Geraldton (250 nautical miles away) and twenty one days from Fremantle to Albany (300 nautical miles). Voyages from Fremantle to Cossack (nearly 1,000 nautical miles away) were allowed a maximum of 50 days (*Government Gazette*, 14/8/1862).[2]

---

[1]The European population in 1859 was 14,837 and in 1869 was 24,785.

[2] Fremantle to Champion Bay, 10 days in summer and 14 days in winter, Return 14 days in summer and 10 days in winter. Fremantle to King George Sound, 21 days summer and 14 days winter. Return, 10 days in summer and 21 days in winter. Fremantle to Nickol Bay, summer 30 days and winter 50 days. Return, summer 50 days and winter 30 days. It also needs be noted that sailing vessels often had to travel far greater distances than those shown on the maps and charts due to unfavourable winds.

In this context Broadhurst and many of his contemporaries wereforced to spend a great deal of time in travel or in waiting for replies to requests for information or instruction. This latter consideration characterised European settlement in the north of Western Australia in the 1860's (McCarthy, 1990: Ch. 3; Clement, 1991).

Isolation, poor communications and vast coastlines dictated a reliance on the judgement of distant others; a major influence on what are often portrayed as examples of very poor decision-making.

Vast distances, poorly serviced harbours and a tiny European population are some of the reasons why regular steam transport on the Western Australian coast was a very late phenomenon indeed. Dutch-owned steamers, for example, were in service in the East Indies by 1825. A regular service between Batavia (Jakarta) and Surabaya was in operation by 1827 and a 236-ton wooden paddle-steamer was built in Surabaya under British supervision around that time (Roff, 1993: 30-31). The first steam vessel to run on the Australian Coast operated between Sydney, Melbourne and other local ports on the eastern coast towards the end of 1831. It was followed in 1832 by an Australian-built ship. Both of these early colonial steamers had imported engines, though five years later, one was launched with an Australian-built engine (Richards, 1987). Western Australia proved much tardier than even South Australia, an equivalent colony, where vessels were delivered from places such as Glasgow in parts and assembled there as early as the 1850s. Ship and engine building flourished soon after (Cumming, 1988; Sexton, 1992: 1-31).

Though the advent of steam transport on the western coast of Australia was still a long way off in the mid-nineteenth century, there was the occasional visitor. The first passenger steamer visited Fremantle in 1852 as part of a feasibility survey by the P&O Company, for example (Bulbeck, 1969: 103-7). The P&O had just been awarded an eight-year mail contract from Southhampton to Eastern Australia via intervening ports. One of those ports was to be on the west or south-west coast. Unfortunately for those in Perth and its port of Fremantle, King George Sound (Albany), with its ideal sheltered harbour, was chosen. Being even further away from the geographical centre of the colony on the south coast, this decision provided of little advantage to the majority of settlers. Mail and passengers had to be sent to Albany overland or on small coastal sailing vessels. In 1870 the road from Albany to Perth had yet to be completed (Figure 1). Thus the south-western, western, north-western and northern coasts of Western Australia were without steam power until well over half a century after its advent elsewhere.

Aware of the benefits of steam power from their experiences elsewhere and by the visits of steam vessels, settlers wanted access to a steamship. The technology was commonplace elsewhere and it appeared in the colony, on the land and in industry as well as on the river. In 1855 a successful steamship service was begun on the Swan River with the arrival from England, via Melbourne and South Australia, of the newly-built *Les Trois Amis*. This was an iron-hulled, 29-tonne, 20-metre long, schooner-rigged screw steamer. Unfortunately the owner drowned and the ship was sold in 1856 for £840 (see a contemporary schedule of wages and salaries in Appendix 5 for a comparison). It was then put back on river service while the new owner tried to sell its apparently unsuitable engines before placing the ship on the run from Fremantle to Champion Bay as a sailing vessel. *Les Trois Amis* began a run from Fremantle to Champion Bay as a schooner (*Perth Gazette*, 29/5/1957; Dickson, 1993: 56-62). In the meantime a number of wooden paddle steamers were built and were successfully operated on the Swan River.

The presence of all these steam vessels on the Swan added to the mounting pressure for similar vessels in the coastal trade. There were also a number of serious, but unsuccessful, attempts to form companies in order to raise the estimated £3,000 required to for a steamship on the west coast (Dickson, 1993). The Governor and Colonial Secretary supported the establishment of steam communication and were prepared to do all that they could to induce someone to bring a steamer to the colony. Despite this, the government was not in a position to assist those willing to enter the industry. In 1862 a request for a subsidy to run a steamer out of the newly-proposed settlement at Camden Harbour in the far north received encouragement but a polite refusal. The prospectuses of the Camden Harbour Pastoral Association and the Denison Plains Pastoral Company, both of which involved Broadhurst, were published in 1864 and both referred to the intention of purchasing a steamer, for £3,000, to ply between Camden Harbour and the Straits Settlements. These settlement schemes were the brainchild of William Harvey, another of Broadhurst's future associates (McCarthy, 1990:64-90).

In 1867, following an inquiry from the manager of the Australasian Steam Navigation Company, the government indicated that it was prepared to offer every assistance to those intending to establish a steamship service, but was still unable to offer the subsidy required to make such a venture profitable (Colonial Secretary to Manager, ASN Co, 14/2/1867). In February 1869 a north-west pastoralist, L.C. Burges, yet another of Broadhurst's colleagues, publicly indicated his desire to float a steamship company. In June 1870, a prospectus was issued by a group of unnamed businessmen wishing to operate one or two steamships on the coast. The matter was debated in the Legislative

Council, where concern was raised about the isolation of the Nickol Bay settlement where Broadhurst was a pastoralist. Due to its proximity to Surabaya and Singapore and its distance from Fremantle, it was perceived that the area could become economically separated from the south by its being eventually forced to deal entirely with those centres on the basis of transport costs alone (*Inquirer*, 26/4/1871).

A regular steamer run, linked to Singapore, India and eventually Europe, was then operating between Timor, Surabaya and Batavia, making a link with the north west of Australia a matter of economic common sense. It soon became obvious that if steamers could be induced to link with that run from Western Australia's north west, Fremantle would be by-passed on the basis of savings in transport costs alone.

The government realised that it had to become involved to stave off this eventuality and finally, in August 1871, the Legislative Council proposed a subsidy of £2,000 pounds per annum for a steamer to run between Albany and Champion Bay (Geraldton) on a monthly basis. They were not prepared to extend the subsidy further north however.

This is an important issue. One analysis of the maritime economy of Western Australia, just prior to Broadhurst's purchase of the SS *Xantho* in late 1871, indicates that a critical shortage of capital was the likely cause of the inordinate delay in the development of the Western Australian merchant fleet (Broeze, 1982:108-9). Another reason for the delay in the development of the coastal trade was the failure of the Swan River Colony to grow appreciably in population. Consequently, the volume of trade was not sufficient to justify the considerable expense of operating a steamship on the vast and sparsely populated coast, especially in regions north of Geraldton. Another major drawback to the establishment of a coastal steam trade was the lack of coal. In late 1872, coal could not be bought in a reliable quantity even in Fremantle.

There were also no suitable repair facilities on this coast, the nearest being at Surabaya in present day Indonesia and at Adelaide and Melbourne on the south-east coast of Australia. For these reasons the coastal trade in Western Australia was awaiting the advent of steam propulsion twenty years after steamships had captured over 30% of the traffic around Europe (Hartley, 1971:221). Thus, experienced and prospective colonial ship-owners, such as Walter Padbury and J.W. Bateman, found themselves unwilling to enter the relatively expensive and complex business of steamship operations without governmental and logistical support in the form of a substantial subsidy. It has been claimed that they '...may have shown sound business sense...' in doing so (Hartley, 1982:97).

As Henderson notes

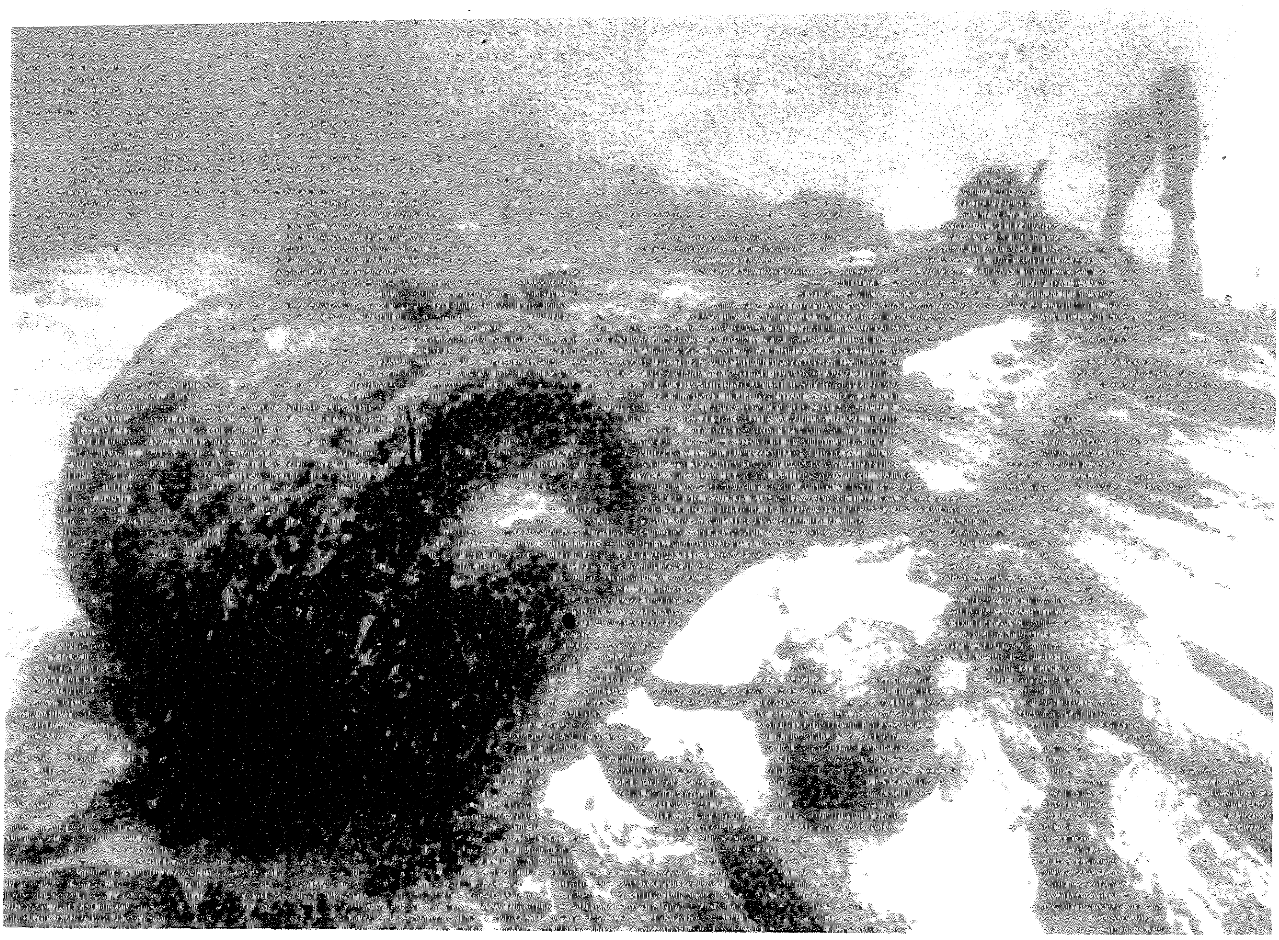
> There were enormous difficulties to be overcome in opening up a commercially successful steam service on such a long sparsely populated coastline, where ports were widely separated and facilities for steamers did not exist (1977a:191).

Thus, when the SS *Xantho* arrived at the colony in April 1872, it was almost half a century after the introduction of steamships in other parts of the world (Jamieson, 1897:187-200). The small European population ensured that coal and engineering facilities were also in short supply. It would therefore be expected that engineering characteristics of the *Xantho* would accomodate those considerations. Its machinery and hull should have been characteristic of sound, efficient and easily maintained steamers of the period.

In bringing *Xantho* to a colony without the infrastructure required of steamship operation, Broadhurst appears, at a superficial glance, to have made the greatest of his many mistakes as a colonial entrepreneur. The subsidy required to effectively operate a steamer to a timetable was estimated to be at least £4,000 per annum and even that figure would represent a loss for the first three years (Henderson, 1977:191). Despite these projected losses, Messrs Connor and Mackay of New Zealand decided to embark on the venture and in September 1872, they entered into a three-year contract with the government to establish a fixed steamer service on the south-west coast. They expended £14,000 on the purchase of a near-new 211-ton, 46-metre, iron screw steamer *Georgette*. Built in 1872 at Dumbarton for use as a collier, it arrived on the coast in September 1873 complete with masts, sails and a spare propeller which was stowed onboard (McCarthy, 1980). It was also fitted with a modern two-cylinder, condensing, 48-horsepower compound engine (Henderson and Henderson, 1988a:211). It also had a large cargo-carrying capacity, estimated by its owners at 460 tons deadweight, and had two steam-operated winches to assist in its handling (Colonial Secretary's Office, 757, 12/6/1873). *Georgette* appears to have been a wise choice, one that was engineered as expected, being newly-built with a two-cylinder compound engine, a Scotch boiler, spare propeller and a surface condenser. Despite this, Connor and Mackay's enterprise was dogged by misfortune and labour problems and *Georgette* was lost in 1876. The remains (Figure 28, below) provide a useful physical comparison to *Xantho*.

As a result of its failure, *Xantho* has usually been totally overlooked (cf. Dickson-Gregory, 1928; Parsons, 1973; Henderson, 1977b), or at best, viewed in the context of attempts to establish a commercially successful steam service on the west coast of Australia. Henderson's analysis of the transition of shipping from sail to steam in Western Australia, for example, argues that, because of its failure and Broadhurst's apparent lack of business acumen, *Xantho* was of little significance in comparison to *Georgette*.

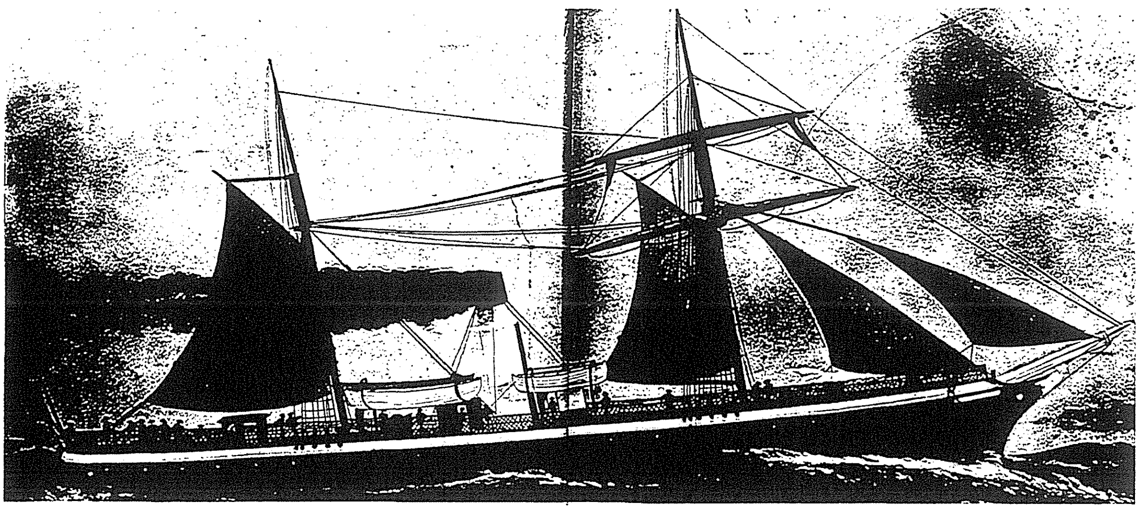
Figure 28: The wreck of the *Georgette*. In the foreground are the remains of the two cylinder compound engine. The diver (the author) is alongside the high pressure cylinder. See Figure 25 for a comparison. The boiler is missing (Photo Scott Sledge, WA Maritime Museum).



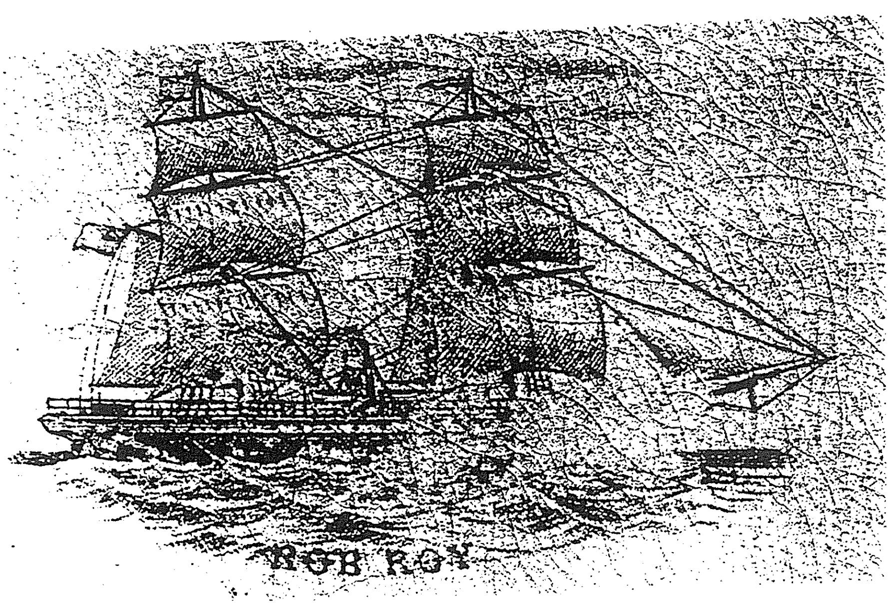
In focussing on the provision of a service to a fixed timetable, Henderson attaches little import to the pearling and entrepreneurial elements of the *Xantho* venture, arguing that little need be said about it and its operations and that 'the significance of this experiment lies in its failure' (Henderson, 1977b:191)

In looking beyond the *Georgette* for other examples of how other early steam vessels on the Western Australian coast were engineered in this period, the 163-foot (49.6m) long, 267-ton, iron hulled SS *Rob Roy* needs to be examined.

Figures 29a: A contemporary illustration of the *Rob Roy* (Page, 1975:46-7).



Figures 29b: A stylised illustration of the same vessel on its own china[1].



[1]The upper view is apparently reliable, being a representation of *Rob Roy* as it actually appeared, with auxiliary sails. The other, showing it as a full-rigged sailing ship and steamer, is designed to romanticise the vessel and portray it in a better light. There is a clear danger in accepting the lower illustration as fact.

Figure 29a above, shows the *Rob Roy* at work and Figure 29b is a depiction of it found on a ship's plate recovered during an excavation I conducted at the Albany Town Jetty which was one of the vessel's frequent ports-of-call (Garratt, McCarthy, Richards and Wolfe, 1995). In showing the ship under full sail it the figures illustrate the dual mode of propulsion used by steamers in those days.

Owned by the Melbourne-based partners Marshall, Robinson, Anderson and Lilly, *Rob Roy* was larger but older than the *Georgette.* It had been earlier considered by the government for the coastal run but was rejected in favour of the *Georgette,* being too deep in the water and heavy on coal consumption due in part to its apparently 'bulky' hull (Henderson, 1977b:226). Built in Scotland in 1867, it was originally powered with what appears to be a two-cylinder, simple-expansion, low pressure 50 HP engine operating at quite a low pressure. In 1872, it was lengthened and refitted with a two-cylinder, 60 HP compound engine, and in this mode *Rob Roy* proved such a great success that it replaced the *Georgette* when that vessel sank.

To broaden the sample of vessels examined against the *Xantho,* we can include three examples from 1878 when the shipping schedule was expanded to include an inter-colonial service to Adelaide and Melbourne. To service the run, Marshall, Robinson, Anderson and Lilly purchased the SS *Otway,* a 180-feet long (54m) 271-ton iron ship built in 1872 at Glasgow with a two-cylinder compound engine. At this time the service on the Western Australian coast was increased to fortnightly runs between Albany, Champion Bay and intervening ports. Pressure to establish a regular run to the north-west, mainly Shark Bay and Nickol Bay, also grew. This was partly based on the few successful *ad hoc* trips that *Georgette* had made to Shark Bay in earlier years and possibly those of the *Xantho.* The contractors resisted, however, and indicated that they were only willing to commence if the Government bore the expected financial losses. By 1881 a contract for three trips to the north-west per year, calling at Shark Bay and Cossack, was agreed to by Government. In late 1882 the SS *Otway* was sent to Melbourne for lengthening in anticipation of its use on the run extending to Beagle Bay. SS *Otway* continued active service to 1913 after which time it was used as a coal hulk, a term used to describe an otherwise redundant vessel that was stripped down for use as a floating storehouse. These hulks, somewhat ironically, helped overcome the problem with the supply of coal on the Western Australian coast. Coal was imported in great quantity in sailing ships, often from Newcastle in New South Wales and then transferred to hulks moored in harbours frequented by the steamers (McKenna Notes; Bulbeck, 1969; Parsons, 1980:26).

While awaiting a refit of the *Otway*, the Company chartered the 220-foot long (67m) iron-hulled SS *Macedon,* which was built in 1870 at Liverpool with a two cylinder 100 HP engine (Figure 7). It was wrecked near Fremantle in March 1883 on the day it left for Beagle Bay. Marshall, Robinson, Anderson and Lilly then entered into discussions with the well-established Adelaide Steamship Company for the purchase of the *Claud Hamilton,* a 200-foot (61m) long iron steamer built in Britain in 1862 with a 100 NHP simple expansion engine. Not having a compound engine, and though otherwise well suited, the ship was considered unsuitable for their needs having had what was described as a '...healthy appetite for coal...' (Parsons, 1980:26). It was not used and the ship was later re-engined with a compound engine to make it more competitive. Seeing an opportunity for expansion, the Adelaide Steamship company sent over their newly-built, 210-foot (64m) long SS *Investigator* with an efficient 97 HP compound engine and large cargo carrying capacity. They entered into discussions with

Marshall and Company and eventually purchased the *Rob Roy* and *Otway*. They also obtained three coal hulks and other accoutrements for £35,000, taking over the Western Australian colonial and inter-colonial trade and effectively ending the frontier phase of steamship operation on the western coast, an era arguably pioneered by the *Xantho*. Further details of these vessels and those that followed on the coast up until 1900 are contained in Appendix 6.

Thus, the engineering expectations for a newly-purchased ship that was designed to be operated on such a remote and vast coastline and its economic context have been established. An iron-hulled vessel, not more than ten years old, with sails and with a two-cylinder compound engine and surface condenser is to be expected.

In completing this section of contextual analyses before dealing with the *Xantho* site itself, it now remains to examine Charles Broadhurst's business activities in order to determine whether he exhibited a behavioural pattern that will prove useful as a pointer to the evidence found at the wreck of his ship.

Broadhurst in historical context

In 1983 when I began the search for archival material that would help in an understanding of the man largely responsible for the wreck of the *Xantho*, little other than a number of short resumes and transcripts were available (Kimberly, 1897: 97; Drake-Brockman, 1969: 233-234; Weldon, nd).

The reasons for this paucity of sources are many. One is the tendency for people to destroy or suppress records about ventures in which they have failed, something Broadhurst did with remarkable regularity. Another was the tendency amongst post-Victorian authors and historians to write only about those characters and activities that could be re-cast and resurrected in an aura of success and respectability. The following discussion helps set the context for questions I pose about anomalous features recorded on the *Xantho* site. A full and detailed description of the social and economic context in which Broadhurst operated may be found in my Masters thesis, entitled *Charles Edward Broadhurst 1826-1905: a remarkable nineteenth century failure* (McCarthy, 1990). In beginning the precis of that work, I present the results of oral historical enquiries made over the past decade to illustrate the immediacy and importance of such programs to historical archaeology generally (cf. Purser, 1992).

When I first met Marjorie Darling, she was a remarkable 94-year old lady. She could still remember her grandparents Charles and Eliza Broadhurst and was interested in talking about them. With her hand shaking gently on the arm of the settee, rattling the cup in its saucer, she told of what she knew of them, of their children, her mother and father and of the many relatives. Some were in the east, one held a scrapbook, another had photographs, some had donated items to the Museum. Strangely, none held any property. "There was Jenny, Gwen, David, Margaret, and many more", she said to me. I eventually contacted all of them, each leading to another family member and another insight into their extraordinary past. It was slow yet satisfying work, especially as the family found a common link to Charles and Eliza Broadhurst through the *Xantho* and their 'Aunt Marjorie', my informant. Born in 1894, she was the daughter of Charles and Eliza's eldest son Florance and was the last surviving member of the family to have a direct link with Broadhurst. To Marjorie Darling and her relatives, Charles Edward Broadhurst was a virtual stranger. In her words he was "never home" being always away off in search of wealth, leaving her grand-mother Eliza to cope with her family and the problems Charles continuously caused.

There was even an odd stroke of amazing fortune which presented itself in a hospital room. "That's my great, great grandfather's letter you've got there," one nursing Sister exclaimed, pointing to a copy of a letter that lay at the foot of my bed. I had found it in the State Archives and the letter bore Broadhurst's name. It was an unbelievable coincidence. The sister was named Penelope and she had even more to add to the story; a will, documents and more contacts.

Broadhurst, the gentleman farmer and pastoralist

Charles Edward Broadhurst was born in 1826 in Manchester, England, into a very well-known and financially-established textile merchant family. It was a privileged position, providing useful social contacts and the best possible education. One of Charles Broadhurst's sisters married the famous and very wealthy engineer Sir Joseph Whitworth in the same year that the *Xantho* was purchased, for example. This is doubly of significance, as will be seen.

In 1843 Broadhurst emigrated to Victoria, in Australia, joining his elder brother on a vast pastoral holding at Kilmore, north of Melbourne (Hamilton, 1914:9). Despite owning considerable amounts as freehold, the majority of the land was occupied on a *de facto* or 'squatter' basis (Roberts, 1935:66-68). Again it was a privileged position and Broadhurst's emigration at 17 years of age into this wealthy pastoral context, surrounded by servants and labourers, would have further accustomed him to the life of a Victorian gentleman of considerable social standing and influence. Broadhurst was notably hard-working, however, and soon became a considerable success as a pastoralist and grazier in his own right.[1]

At thirty four years of age and concerned by growing demands for land by newly-displaced gold miners (Dingle, 1984:54), Broadhurst and his young wife, Eliza Howes, turned their attention to newly-opened land in the North of Western Australia; an area that had been described by explorers as a 'pastoralist Eldorado' (Richardson, 1909:37).

Marjorie Darling could never really understand why the Broadhursts left Kilmore. "Eliza was so happy in Victoria surrounded by her socially well-placed family and friends," she told me. Having endured hardship and adversity as one of fourteen children born to a schoolteacher, Eliza apparently contrasted with her husband, having developed a great love for the bustle of family life and the warmth of everyday society. She also appears to have been practical and somewhat hard-headed. "She loved teaching," Marjorie Darling said, "and she was a very talented musician with a good singing voice." Strangely, both of these seemingly unconnected references are relevant in that they directly affected Broadhurst's career, as will be seen.

The Broadhursts became attracted to what is now known as the Murchison, Gascoyne, Pilbara and Kimberley regions of Western Australia. Then called the *North District*, it encompassed the entire area of Western Australia north of the Murchison River (Figure 1). It was a vast region and had no European inhabitants when land settlement regulations were promulgated in 1862. Many settlement schemes were formed as a result of the land offer, which in essence allowed the settler 100,000 acres of land rent free for eight years should they land 200 sheep or 20 cattle or horses in the district. Many could not afford the

---

[1] Pastoralists and graziers in Australia tend to hold most of their 'runs' or 'stations' on a lease from the government. Some actually own part or all of the property as 'freehold'.

financial outlay required to charter vessels and joined, or formed, companies with the intention of spreading the costs. The best known of these were the Melbourne-based Camden Harbour Pastoral Association and the Denison Plains Pastoral Company. They were in effect, sister companies formed with the intention of establishing a new 'gateway' to Australia at Camden Harbour. This was to be linked by a series of pastoral and telegraphic stations running through the Denison Plains and on to Sturt's route which ran to embryo settlements in the north of Australia (near present-day Darwin) from Adelaide (See Figure 30). In this fashion overland links would be forged from Camden Harbour to the major Eastern States capitals. On paper it was a sound notion which would shorten the route to Singapore, India and Britain and obviate the need for mariners to navigate the difficult Torres and Bass Straits to access Sydney and Melbourne (See Figure 2).

As part of the Denison Plains Pastoral Company, the Broadhursts were to land at Camden Harbour and proceed overland on an untried route to the fabled Denison Plains. This area, near present-day Halls Creek, had been much praised by earlier explorers unaware that they had traversed the country just after exceptional rains (cf. Grey, 1843; Gregory, 1884).

The Denison Plains Company was somewhat of a mystery to Marjorie Darling before my study began. The family had told her and the other children very little about Broadhurst and his business ventures. Clearly, it was not the sort of thing one wanted to recall, let alone pass on to children. My delving into what proved to be a scandal did not worry her, however, because a few details had filtered through to her as a small girl as she played around her parents' table and she had always had an interest in it. "Grand-father was somewhat of a dark horse," she would say. It appears that the family did not discuss him much when the children were around and preferred instead to concentrate on the more successful elements of their family history. Most of these were apparently embodied in Eliza Broadhurst and her activities. Herein lies one of the major problems of relying solely on historical documentation biased by the subjective weeding out of what is considered socially acceptable by family and society generally.[1]

Though it is not detailed in any of the archives, it is evident that Broadhurst needed to re-build, financially and socially, after the collapse of the Denison Plains Company. Given his background, the setbacks and the resulting physical and mental hardships probably would have hardened his resolve to succeed. Though impossible to accurately assess, it is likely that Charles and Eliza's attitudes towards others, and possibly to life itself, would have been considerably affected by the Denison Plains fiasco.

The Denison Plains venture and its effect on their social standing was perhaps the driving force behind Charles and Eliza Broadhurst's subsequent Western Australian colonial career and their ensuing thirty-year search for regained wealth and social position. I would argue that it was a major influence in Broadhurst's decision to purchase the *Xantho* and to operate it in conditions so foreign to an English-born gentleman-pastoralist. For this reason, I will briefly examine Broadhurst's involvement in the Company as follows.

The explorer's glowing reports of Camden Harbour and Denison Plains regions were seized on by Government, the land-hungry and speculators alike. The Western Australian Government expended an estimated £5,000 in sending a Resident Magistrate (Robert Sholl) and his

---

[1]As indicated earlier, this selective process filtering the documentary record is described as '*organizational behaviour*' or the 'conceptual category for the activities that have structured the ethnographic record' (Potter, 1992: 10). It has obvious ramifications for the analysis of people like Broadhurst and needs to be constantly kept in mind.

entourage to Camden Harbour, for example. Given the isolation and the distances involved, Sholl was in effect the Governor of the region, having broad powers that ranged from the judiciary through to day-to-day government functions and the collection of customs dues.

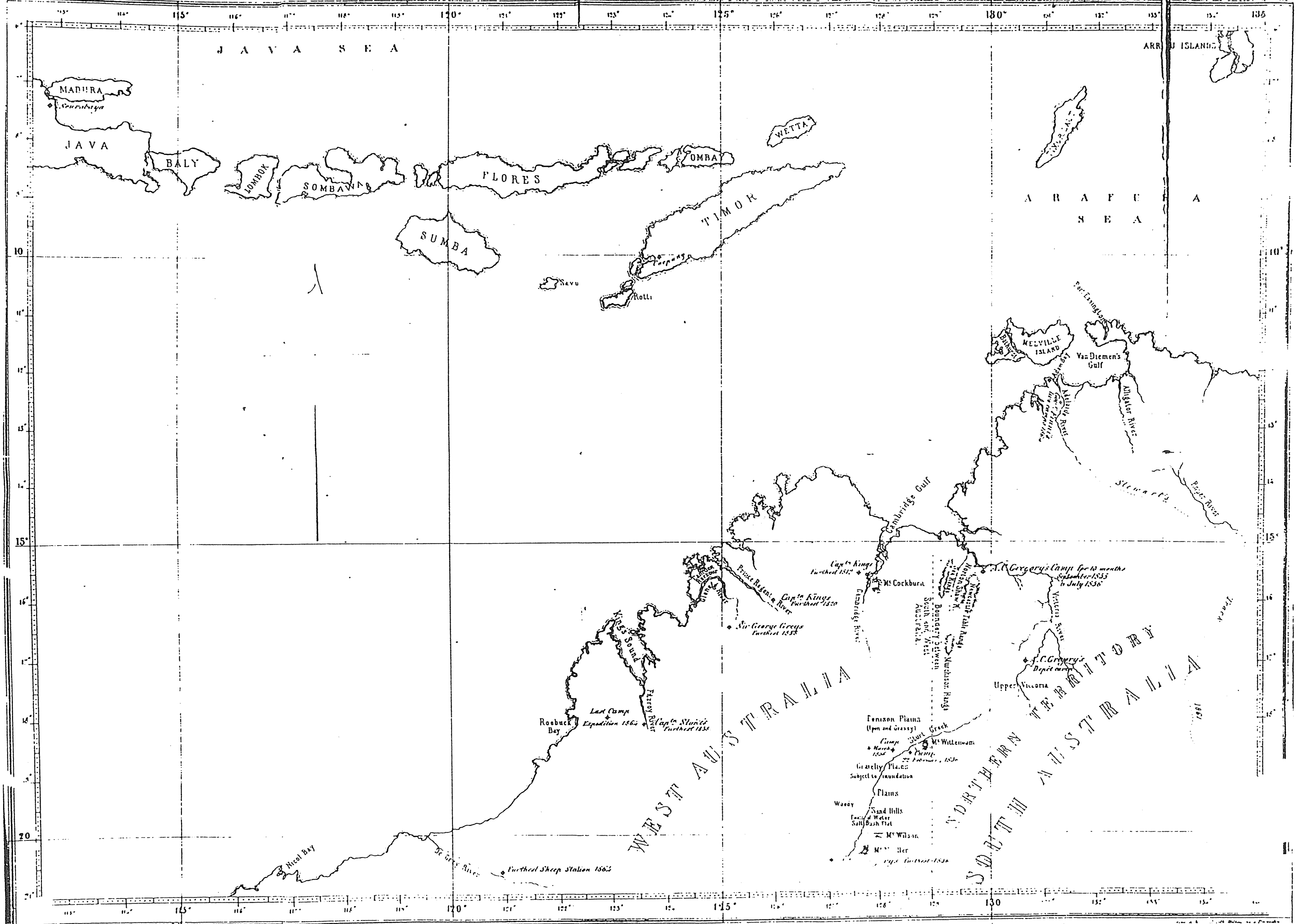
Once a decision was made to proceed to the 'North District' to settle, it took between a month to six weeks to transit news from there to Melbourne via Fremantle, under favourable circumstances. In unfavourable circumstances the delays were much longer. This helps explain one of Broadhurst's chief problems in his colonial career; that of making an informed decision at great distance based on what often eventually transpired to be unreliable information.

The pastoral companies looked very good on paper. One of the promotional pamphlets which accompanied the Camden Harbour Company prospectuses (*Description of Camden Harbour*, 1864), for example, contained a chapter detailing the benefits of Camden Harbour and its proximity to Kupang, Surabaya, Batavia and a pool of cheap labour at Calcutta, Singapore and China. Indications of this geographical advantage appear in Figures 2 and 30.

The inspiration for *Xantho* may have stemmed from the Camden Harbour and Denison Plains Company pamphleteer, who suggested that the Company might purchase a small steamer for £3,000. It was claimed that this hypothetical vessel would provide shorter and cheaper transit to Europe from Camden Harbour than from any other part of the Australian continent. Here, clearly spelt out, was the fact that north-western Australia was closer to the trade centres of Timor, Batavia, Surabaya and Singapore than it was to Melbourne, Sydney or even Fremantle. This realisation may well have inspired Broadhurst to operate his ship away from colonial officialdom in a remote part of the

Northwest that linked more with what is now the Indonesian Archipelago and Singapore than with settled parts of Australia.

Figure 30: A contemporary map, showing Camden Harbour (on the coast at c. 125° E, the Denison Plains to the south-east, Stewart's Route [sic], Roebuck Bay, Nickol Bay and the proximity of the region to Surabaya and Kupang. Broadhurst later based *Xantho* at Banningarra Creek, situated at around 120° E on the coast a few kilometres from the De Grey River (McKay, 1864, Denison Plains Pastoral Company Prospectus).



115°
120°
125°
130°
135
10°
15°
20
JAVA SEA
MADURA
Sourabaya
JAVA
BALY
LOMBOK
SOMBAWA
FLORES
OMBAY
WETTA
TIMOR
Coepang
SUMBA
Savu
Rotti
ARRU ISLANDS
ARAFURA SEA
Port Essington
MELVILLE ISLAND
Van Diemen's Gulf
Alligator River
Adelaide River
Cambridge Gulf
Capt. Kings Furthest 1819
Mt. Cockburn
Cambridge River
Prince Regent River
Capt. Kings Furthest 1820
Sir George Greys Furthest 1838
Kings Sound
Fitzroy River
Capt. Stokes Furthest 1838
Roebuck Bay
Last Camp Expedition 1864
A. C. Gregory's Camp for 10 months September 1855 to July 1856
Victoria River
Upper Victoria
Newcastle Table Range
Murchison Range
Boundary between South and West Australia
Denison Plains (Open and Grassy)
Sturt Creek
Mt. Wittenoom
Gravelly Plains Subject to inundation
Plains
Woody
Sand Hills
Mt. Wilson
WEST AUSTRALIA
NORTHERN TERRITORY
SOUTH AUSTRALIA
Nicol Bay
De Grey River
Furthest Sheep Station 1863

Grand plans, lies and exaggerations were part of the various company notices appearing in the Melbourne press. One claimed, for example, that the Company had obtained permission to occupy 5,000,000 acres extending from the Camden Harbour settlement to Sturt Creek including the Denison Plains (*Geelong Advertiser*, 84/1865). The Company was actually entitled to only 100,000 acres and this was clearly stated in the Western Australian Government's Regulations which appeared on the Company prospectus itself. For Broadhurst and his colleagues to have missed this point begs the question about their gullibility or attention to detail, at the least.

By early 1865 Broadhurst's name headed the list of Company Directors in advertisements, as he apparently assumed an increasing role in the venture. As a pointer to the controversies and suspicion that were later to dog Broadhurst's entire career, the Directors were later decried as 'self elected and irresponsible' and were accused of making a number of very questionable decisions (Baynton to his father, reproduced in the *Perth Gazette*, 23/11/1866). One was the issue of whether men, pregnant women and small children, with their cumbersome wagons and stock, could actually make the untried journey from Camden Harbour to the Denison Plains. A glance at a modern topographical map shows that it was a near impossible journey, and at no stage does the question of whether the trek was feasible appear to have been raised by the settlers before they departed Melbourne. It seems that a letter received by the Directors on the impossibility of the trek was considered at a meeting of the Board and then suppressed (Baynton to the Editor, *Perth Gazette*, 23/11/1866). As a Board member, there are strong suspicions that Broadhurst was involved in the deception. Further, his decision to risk himself, his pregnant wife and two very young sons on the trek, attests to an apparent lack of commonsense and the prevailing attitude of

Victorian-era men to their wives and families. Thus began Broadhurst's involvement in one of the great, almost forgotten, scandals in the history of the settlement of Western Australia. In April 1865, members of the Company began loading their ship at Melbourne for the Denison Plains via Camden Harbour. On the very day they were due to leave port, the first hint of problems at Camden Harbour surfaced. That particular settlement had failed dramatically many months earlier, but the delays in communication ensured that news had not yet filtered south. Disillusioned shareholders sent a message ahead in the form of a public letter, cautioning the Denison Plains contingent and urging them to wait. The newspaper containing this letter was withheld from the shareholders in Melbourne, as was the fact that only 45 of the 500 available shares in the Company had been sold. So they sailed to the North-west on the very day that the letter was published in the Melbourne press. Broadhurst appears to have been implicated in the deception and in other doubtful transactions which are dealt with in full elsewhere (McCarthy, 1990: Ch. 3).

At the same time accounts of the debacle at Camden Harbour were published in Western Australia, causing great concern in Government circles. Thus, when the Denison Plains Company finally arrived at Fremantle in May 1865, Broadhurst was met by the Colonial Secretary who accompanied him to Perth for interviews with the Governor and Surveyor General. There he was advised to make a change of destination to Roebuck Bay where the Government-backed settlement was struggling to become established (Figure 30). As a result, Charles Edward Broadhurst became a well known figure in the press and in the offices of the colonial administration, within hours of first setting foot on these shores. He also featured in the Western Australian press as the leader of the much-publicised Denison Plains Pastoral Company; the largest and apparently best organised contingent of prospective settlers to pass through Fremantle on their way north. Well-educated, influential and leading a large, well equipped group of men and women, he could not have helped but create a considerable impression. His influence was such that the Government assigned to him an Aboriginal convict labourer they called 'Harry'. The allocation of convict labour to him began Broadhurst's involvement in another of the dominant and most controversial themes in his future life; his ill-treatment of labourers and staff.

Due to adverse weather conditions, they landed not at Roebuck Bay but further south at Nickol Bay (Figures 1 and 30), where there was a thriving European settlement, good traversable land and friendly Aborigines on whom to depend for labour and assistance. The earlier settlers also provided great assistance to the new arrivals, however ill-prepared they may have appeared. Mrs Emma Withnell, the best known of the women settlers then in residence, passed down vivid memories of the Company women's fine clothes which, in her words, were 'similar to those illustrated in the magazines' (Withnell-Taylor, 1987:73). Her thoughts on seeing the seven months pregnant Eliza Broadhurst landing in her finery with two young boys and her piano, are unfortunately not recorded. That the Broadhursts transported the piano to the north and apparently intended hauling it across the north of Australia on an untried route is a statement in itself. Either the explorers' glowing accounts of the north and the Government's support for settlement generally had lulled them into a false sense of security, or they were of the opinion that even in the most difficult of conditions, good graces, the retention of the bulky accoutrements of culture, and the maintenance of appearances would be a factor in their eventual success. Equally Eliza may have refused to go without it!

Under Broadhurst's direction, the people of the Denison Plains Company went about their business at Nickol Bay with every intention of eventually proceeding to the Denison Plains and in complete ignorance of events in Melbourne. Newly arriving settlers eventually brought information that the Company had completely folded in Melbourne. Despite this, Broadhurst refused to wind up the venture in Western Australia, causing considerable disquiet amongst his colleagues. To make matters worse, a drought set in, supply ships did not come, and in an aura of despair, food supplies began to dwindle. Pressure was then applied on Broadhurst to release some animals for food. He resisted stoutly, creating great dissension amongst the group. As the drought deepened the remaining shareholders hardened in their resolve and exerted even more pressure on Broadhurst to break up the Company and to distribute stock and equipment. Still Broadhurst resisted their demands and he held out for exactly eleven months until a meeting resolved to wind up the Company and distribute the stock to pay outstanding wages and salaries. His actions in resisting calls for winding up the Company and his refusal to allow the goods and flocks under his control to be dispersed, or to be used for food understandably engendered considerable ill feeling. News of the confrontation filtered south when the first members of the failed Company landed there. To many in the tiny settlements of Perth and Fremantle, Broadhurst was the person responsible for the debacle. Thus the collapse of the Denison Plains Company was to be the beginning of Western Australia's long lasting suspicion of Charles Edward Broadhurst.

The following excerpt taken from an exchange of letters penned nearly three years later by two prominent Perth merchants illustrates this point

> Mr Broadhurst is certainly a smart man ... but if success be the test of ability he has certainly not proved himself superior having made a pretty mess of the Denison Plains Company... there is certainly a great distrust of him here (Barker and Gull letters, State Archive, 2423a, 16 May, 1868).

Robert Sholl, the Resident Magistrate, had transferred from Camden Harbour to Nickol Bay in the meantime and a growing European settlement developed at Withnell's station, becoming the township of Roebourne. As Broadhurst was one of the few educated men in the area, Sholl appointed him as a Justice of the Peace and later, quite surprisingly given the prevailing attitudes towards him, as acting Resident Magistrate. It was an even more remarkable appointment when it is noted that Broadhurst had tendered for the defunct Denison Plains Pastoral Company, a matter which caused his colleagues occupying land and holding stock or equipment considerable concern. On his return to the North in the following February, Sholl advised his superiors that Broadhurst had acquitted himself discreetly in a difficult situation (State Archive, CSR, 603/8-24). When Broadhurst finally took possession of the former Company in June 1867, however, he wasted no time in ruthlessly claiming everything it had once owned including stock, equipment and blocks of land occupied by his colleagues.

In contrast, Eliza Broadhurst emerges as a much loved personality; one whose company was much more sought after than her husband in the private diaries of Robert Sholl and his adult son, who was in effect the Resident Magistrate's private secretary (Diary and Occurrence books, R.J. Sholl; Diary of T.C. Sholl). On one occasion, for example, Charles Broadhurst was observed busily digging up and actually 'spoiling' young Sholl's block of land in Roebourne. He was searching for building material (probably clay) for his own holding, on which he had built a house. In finding it on Sholl's property, Broadhurst commenced excavation immediately and without permission. The younger Sholl dryly notes this transgression in his diary, yet on the very next night, and for many nights after, we find the Sholls in both of the Broadhurst's company, playing cards and chess, singing and listening to Eliza on the piano.

It is of significance that Charles and Eliza Broadhurst became close personal friends of the Resident Magistrate and his son; the two men who were, in effect, responsible for Government in the entire 'North District'. In this way, Charles and Eliza Broadhurst built a very strong link with Government in the North-west. This stood them in good stead, especially when Broadhurst turned his mind from pastoral activities to pearling (McCarthy, 1990: Ch. 3).

Pearling from Nickol Bay

Broadhurst purchased the SS *Xantho* primarily for use in pearling, an industry in which he became one of the most innovative practitioners.

Pearl shell, or 'mother of pearl', fetched very high prices per ton; often as high as £100 landed at London (Bain, 1982: 18, 46). This was equivalent to a mid-level government servant's annual wage (see Appendix 5). It was however a brutal industry. Suffering and slavery were the lot of the 'coloured' workers who were 'recruited' to provide the labour force for the white pearlers.

Though engaged in lucrative 'dry-shelling' (harvesting pearl shell at low water spring tides) using local Aborigines, Broadhurst left the North-west for Victoria in late 1867. As a result, he missed out on the very valuable experiences gained by others in this formative period. Those who stayed learnt more about the location of shell beds and the most efficient (though not necessarily the most humane) means of utilising Aboriginal men and women in the industry. More importantly, the Aborigines were learning at a rapid rate how to make the transition from dry shelling or wading, into naked diving (i.e. diving without any aids such as goggles or fins). This development began at the time Broadhurst left at the end of 1867 and he was apparently in ignorance of it. The transition was in full swing by the middle of the following year and by the end of 1868 divers were descending to depths of 6 fathoms, or around 10 metres (*Perth Gazette*, 31/1/1868; *Herald*, 6/6/1868; *Inquirer*, 31/3/1869).

Broadhurst returned to Western Australia in April 1868 with plans to introduce diving apparatus to the pearling industry in a partnership with three others (Figure 32). Though the use of this equipment was commonplace outside of Australia (cf. Davis, 1955), through sheer inexperience, they chose a far too large vessel, in the form of a 27-metre long wooden two-masted schooner *Mary Ann*. They then compounded the problem by commencing diving in the narrow Flying Foam Passage at Nickol Bay (Figure 31). Though a rich source of shell, the passage was subject to very strong currents, sometimes in excess of 3-4 knots. They had great difficulty manoeuvring the boat and even with heavy lead boots, their diver was lucky not to be swept off his feet. The chances of an accident were very great indeed. After a short while they gave up, having failed dismally in the attempt. Broadhurst and his colleagues had attempted to apply unnecessarily complex technology with inexperienced operators using a ship that proved far too large for the local conditions. They were doomed to failure from the outset.

Figure 31: The Flying Foam Passage at Nickol Bay. From Approaches to Dampier, AUS 741, 1: 150.000

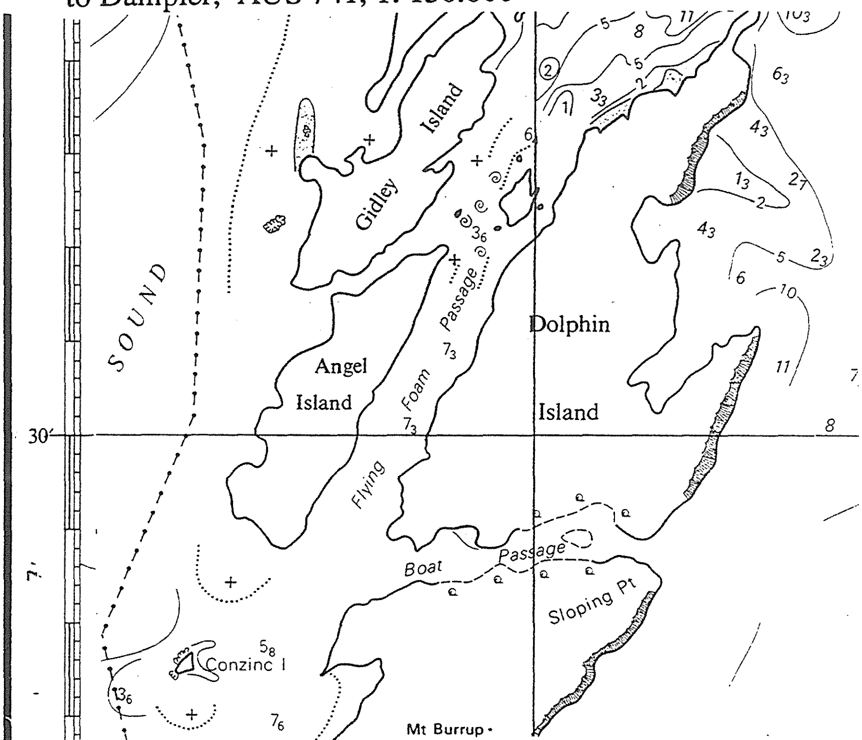
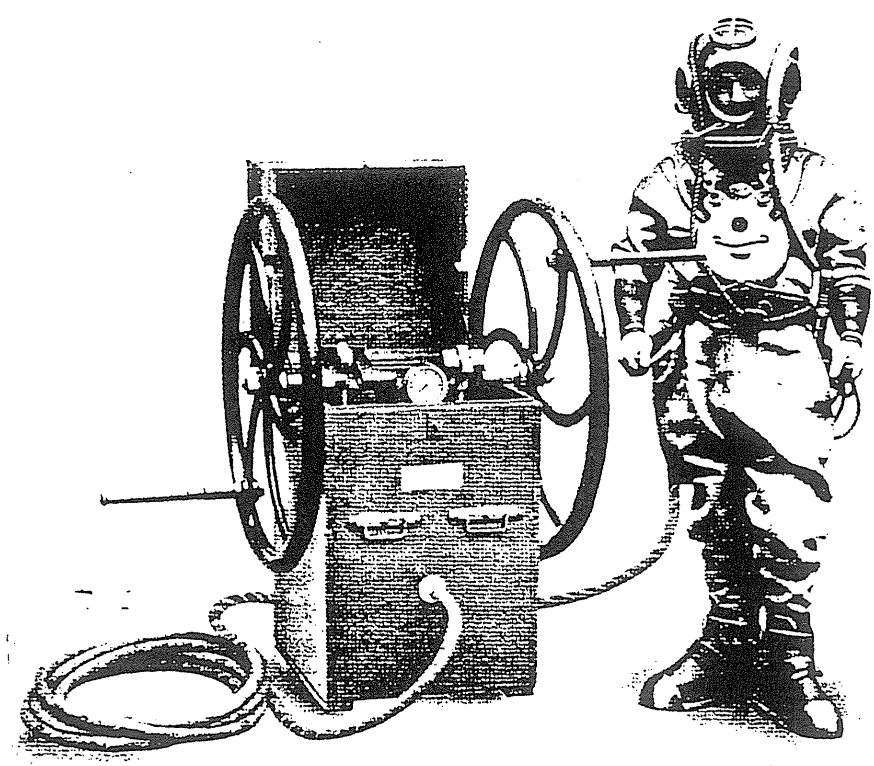


Figure 32: A diver in a 'standard dress' or 'hard hat', with hoses and air compressor. The apparatus is bulky and expensive, requiring considerable space in the diving boat and paid operators (Michel, 1980:77).



On the other hand, the Aborigines in rowing boats were proving most successful, even in the Flying Foam Passage. Here they actually used the current to advantage by allowing themselves to be carried along over vast areas of seabed without having to unduly exert themselves. Though they were without protective clothing, goggles and swimming aids, the availability of cheap and plentiful labour made this a most productive exercise-one that is still practised today by Indonesian fishermen (McCarthy, 1991a: 10-52).

Despite the failure of this first known attempt to use diving apparatus on the Australian pearl fishery, Broadhurst correctly realised that the equipment had potential. He was twenty years ahead of his time in introducing it to the region, however, and there was a great deal to be learnt to adapt methods to the tides and waters of the North-west. Broadhurst clearly had vision in realising the value of technological advances, but he did not realise that a great deal of experimentation was required before the technology could be efficiently applied.

He retained the diving apparatus when the partnership folded and entered a new diving venture, apparently with both the 'hard-hat' and a more complex and untried form of diving technology, the French *Aerophore* system (See McCarthy, 1990, Ch. 4, for an expansion). He and his partner, Mr. Hughan, travelled great distances in attempting to prove the venture a success. An examination of the plant specimens recovered by Mrs. Hughan, for example, shows that the partners travelled as far afield as the Camden Harbour region, King's Sound, Beagle Bay and La Grange Point, home of the Broome pearl industry which later proved hugely successful in other hands (Willing to McCarthy, 9/10/1991). But still Broadhurst failed. Though he had learnt that fast currents were to be avoided, he had still not discovered efficient means of diving for pearls in tidal waters or even how to find submerged beds when out at sea.

On the other hand, Aboriginal divers were getting excellent results. And so, despite their obvious capacity for experimentation, hard work and willingness to range far and wide in search of shell, Broadhurst and Hughan did not succeed. Hughan left the industry and Broadhurst tried again. By this stage pearlers were finding it difficult to acquire Aboriginal labour due to the increasing number of operators and the ravages of smallpox. Characteristically, Broadhurst looked elsewhere for labour and applied to the Government to interview Aboriginal prisoners from Rottnest Island, near Fremantle, with a view to enticing them to volunteer for service in the North-west pearl fishery. Attesting again to his powers of persuasion with Government, he received permission to do so and was successful in obtaining 18 volunteers for the 1870/71 season.

Despite public opposition, Broadhurst gained official support and embarked on his latest venture in a much smaller and more suitable wooden, two-masted schooner. He based himself at Banningarra Creek, just east of the De Grey River (Figures 30 and 37) and there he employed both Aboriginals and a European apparatus as the conditions suited. This was an innovative, but misguided, last attempt to combine the use of Aborigines and the diving apparatus.

Mainly southern people without a swimming tradition, the Rottnest convicts proved hopeless in the sea and were a stark contrast to the local Aborigines. Unfortunately, just as they found good pearling beds, the weather turned foul, becoming a series of gales that continued throughout the season. His use of the volunteer southern Aboriginal convict labour out of Banningarra was, in Broadhurst's own opinion, another failure (Broadhurst to Sholl, 14/4/1871, CSR, 697/110).

Obviously, the idea of using the 'hard hat' and volunteer convicts appeared sound to Broadhurst on paper, but in reality both had proved impractical. Though these ventures were a failure, Broadhurst felt that the pearl beds they had found in the previous season were extensive and rich. He noted that only 'labour and capital' were required to develop the newly found beds (Broadhurst to Sholl, 14/4/1871). In an attempt to locate the required labour and to raise the capital for the industry, he left for Europe and soon after, Asia.

Xantho and the 'Malays'

The labour and capital that Broadhurst had in mind included a paid labour force of Asian divers (then called 'Malays') a string of managers and agents and the SS *Xantho*. The prospect of importing Malays, a practice that began around 1871, was a logical progression given that the supply of Aboriginal labour was drying up and the Malays had been operating as divers for centuries in the islands to Australia's north.

In comparison to the Aborigines, however, the Malays required to be housed, fed, paid and then repatriated at the end of their employment. In an attempt to provide his men with a reasonable diet, and no doubt reduce his costs and profit from the supply of the food, Broadhurst successfully applied for land at Mt. Blaze, near Banningarra Creek. There he established a 300-tree coconut plantation. In principle it was a sound notion. A Captain Tucker, who operated on the eastern seaboard of Australia in the late 1880's, hoped to secure a return of £6,000 per annum from a plantation of 40,000 coconut trees, for example (Bain, 1982: 66).

As with most of Broadhurst's projects, his idea was innovative and the plan was good, but things started to go wrong. One of his divers drowned, some of his men stole one of his boats from another base at

Port Hedland and set off for home. Others stole a boat from one of his bases at the Flying Foam Passage and also departed for home. Whether they were successful is not known, but in the case of the Port Hedland theft it is worth noting that their manager claimed that the workers left without rations or stores. These incidents led to official concern and the police subsequently made an inspection of the pearling camps in November 1872. This occurred while Broadhurst was away on the *Xantho* on its last voyage. The police report stated

> The Malays have not the slightest idea of either swimming or diving being completely out of their element in the water. I witnessed a specimen of their diving... in 2 and a half fathoms of water..[I was]...not the least surprised at their getting drowned (V&P, 1874-5, 714/57:168).

The same, almost singular, failure to perform in the water also beset Broadhurst's Malays in the Flying Foam Passage in Nickol Bay, further south. By this time Broadhurst had landed 140 Malays on the coast at a cost of over £10 per head.

If they were as inexperienced as the reports indicate, the costs of transportation and their wages would have represented a great loss. Broadhurst's decision to employ them without first ensuring that they could dive appears very ill-considered and it parallels the venture with diving apparatus and the Rottnest Island convicts.

For Broadhurst, the 1872/3 pearling season was a disastrous one. The *Xantho* was lost, he could not pay the crew and the Malays had proved useless as divers. These failures, combined with the inappropriateness of the diving apparatus and the Aboriginal volunteer convicts, caused him to abandon the northern pearling grounds and concentrate solely on the pearling industry at Shark Bay. There pearls could be had in a place where diving skills in the work force were useful, but not essential to success.

Much can be learnt from Broadhurst's behaviour in these instances and the insights gained help us understand anomalous evidence gleaned from an examination of the wreck of his ship. He clearly had vision and was prepared to experiment with ideas and technology. He was equally prepared to risk himself and to travel great distances in the search for wealth and lost social status. He was persuasive and influential with the Government, partly through his own attributes and from his and Eliza's friendship with the Sholls, and from the position he had inherited by virtue of his family name.

Broadhurst unfortunately appeared to lack attention to detail and did not have the skills or experience required to bring his visions to fruition. In not having an eye for detail, or demonstrable commonsense, he appears to have regularly made poor technical decisions at distance and, as a result, depended greatly on others for advice.

I will now briefly examine his career after the loss of the *Xantho* in 1872 to ascertain if the behaviours that led to the purchase and operation of the vessel are consistent with those that follow.

Pearling at Shark Bay

Pearl shells at Shark Bay were noted for the pearls they provided, rather than for the shells and Broadhurst quickly followed others there. Most notable was the notorious 'black-birder', ship-owner and explorer, Captain Francis Cadell (Bain, 1982: 28-9). Broadhurst initially intended to work the Shark Bay, Nickol Bay, Port Hedland and Banningarra fisheries simultaneously. All of these places, especially Shark Bay, had confined and difficult waters that were a trap for sailing vessels, but ideal for a small steamship like *Xantho*. The difficulty experienced in navigating in Shark Bay under sail, for example, is referred to by Broadhurst's contemporary, Julius Brockman, who describes having a 'terrible beat' against the wind up the harbour to the pearling beds (Brockman, 1987:42). The situation was the same at Broadhurst's bases near Port Hedland, Banningarra, and the Flying Foam Passage.

When the *Xantho* (which was to be the link between these centres) sank, as described in the introductory narrative (pp. 1-4), Broadhurst was placed in a difficult financial position without the means to link his widespread endeavours. By having allowed his insurance on *Xantho* to lapse, he did not have the funds to purchase another steamship, let alone a suitable sailing vessel with which to re-establish the links. On the other hand he had a large work-force of Malays at his disposal, and was able to muster some small boats that would prove suitable for shallow water work. Given the problems resulting from the loss of the steamer, the answer lay in concentrating in one location; at Shark Bay (Figure 1) and abandoning everything further north.

A short time after Broadhurst and his men arrived at Shark Bay, there was a rush of pearlers centred on the very productive area called 'Wilyah Miah' (Place of the Pearl). By January 1873 there were over 400 men at work there. Broadhurst, with some undisclosed access to funds, soon established a well-stocked wooden store, one of only two operating in the entire fishery. Described as 'the most imposing looking structure in the place' (*Inquirer*, 8/10/1873, 3/12/1873), it was run by a nephew of Eliza's and proved to be most lucrative. Broadhurst saw the potential and began to supply merchandise, liquor and food. Always on the lookout for ways of diversifying and cutting costs, Broadhurst entertained ideas of establishing a fish-curing works on the beach at nearby Dirk Hartog Island. It was to be managed by a European with five Malays and was, like his coconut plantation, a logical progression.

In the meantime the rest of his men were hard at work on the pearl beds. Initially the venture was a great success, and soon Broadhurst was eulogised in language reminiscent of the effusive tones used to describe the heroes of a gold rush

> And now we are startled by the announcement of one gentleman-Mr. Broadhurst- receiving as the proceeds of one month's fishing, no less than one hundred ounces of pearls worth at least £2500. Than Mr. Broadhurst no man better deserves his present success. He has been an energetic speculator, undaunted by adverse results (*Inquirer*, 8/10/1873).

Alongside Cadell, who had recently purchased a former steamship, the iron-hulled *Les Trois Amis* for use as a pearling and trading schooner, Broadhurst was clearly the best organised operator and had the most boats. By the end of 1873 there were 46 vessels in Shark Bay, ranging in size from fifteen tonnes to less than one tonne. Broadhurst owned at least eight small cutters. The largest, at two tons, was *Shenandoah* and the others *Alabama, Florida, Talahassy, Stonewall, General Lee* and *Jefferson Davis* were each of one ton. One boat, *Sir Joseph*, was of an unstated size. He also had two other pearling vessels, the dinghies *Xantho* and *Pearler.*[1]

What were the reasons for this unaccustomed success? Broadhurst, with about 75% of the Malays at Shark Bay at his disposal had the largest work-force. He had also bought a mariner from Batavia as his manager, a Mr Smith. Smith obviously knew how to get the best from his charges without resorting to violence and, as a result, received his

---

[1]The size of his *Sir Joseph,* (named apparently after Sir Joseph Whitworth, his illustrious brother-in-law) and the reasons behind his obvious propensity for American 'Southern' names is not known. There is certainly more than a coincidence in it, for many years later he was described by his peers as having 'all the decisive action of a typical American'(Kimberly, 1897:8). By not choosing a broader range of names it does appear that in the American Civil War his sympathies lay with the pro-slavery States and their officers. On this evidence one could assume that he was in favour of slavery and that this propensity was a significant factor in Broadhurst's notoriously poor labour relations. These are discussed in depth in my earlier work (McCarthy, 1990).

fair share of the adulation when news of their success spread to the local press.

Smith, was described by the press as an 'enterprising and indefatigable' manager. He built a small jetty and stone breakwater and spared 'neither labour nor trouble' in improving the condition of the Malays in regard to their housing, health and work practices. The 'substantial wooden houses' that he built for them, were contrasted with the usual 'dirty low hovel termed a Malay hut' (Inquirer, 8/10/1873; 29/10/1873). Another factor was the technology employed. It was arguably simple, being small sailing vessels dragging a triangular dredge in which the shells were harvested.

As Broadhurst expanded his fleet and travelled further afield, accidents began to occur and there was loss of life. One of his new cutters sank in South passage and another capsized, almost drowning Broadhurst and his assistant. His capacity for hard work and his willingness to risk himself in his search for wealth, is again evident.

Broadhurst's primary mode of operation was apparently to set up a base himself, work there for a while alongside his men, appoint a manager and then set off in search of other enterprises and activities.

Such was the case in Shark Bay where he not only diversified his maritime pursuits (pearling, fishing and so on) but also submitted a tender to sink wells on the stock route (or commonly-used droving track) from Tamalee Well at the south end of the bay to the Murchison River. In this instance, he showed his considerable vision in searching for a wide range of opportunities to deploy his men and resources to advantage. A further indication of his entrepreneurial flair is his attitude to the supposedly worthless pearl shell, of which nearly a thousand tons was lying abandoned in mounds throughout the camps. Broadhurst sent trial shipments of this Shark Bay shell to Europe and while awaiting the returns, the following optimistic comments appeared in the press, reflecting the prevailing attitude towards Broadhurst

> The speculation is a bold one...and on Mr Broadhurst's account alone, who for enterprise and determination is a man out of 10,000, we sincerely hope the venture will turn out as profitable as Mr Broadhurst could desire and make up in some measure for the heavy losses he has sustained in other undertakings... (*Inquirer*, 2/9/1874).

In this comment we find that Broadhurst was on his way to being socially resurrected as a colonial benefactor after the Denison Plains fiasco and his much publicised failure to pay the crew of the *Xantho* when it sank (See Chapter 4). From a financial perspective however, he still had a long way to go to make up the financial losses incurred as a result of the vessel's loss.

The trial shipment of shell was purchased by an intermediary who did well out of it. In contrast Broadhurst just covered his costs. As usual, he continued on undaunted, noting in his own revealing words that with 'careful management' he would eventually realise a profit (*Herald*, 17/6/1876; *Inquirer*, 27/1/1875). Though he appeared to have a talent at seeing opportunities, Broadhurst again exhibits an inability to turn hard work to advantage through appropriate management skills. Despite these failings, all looked promising at Shark Bay, until again things started to go drastically wrong following the departure of his much praised manager, Mr Smith and the arrival of his replacement, Daniel, Broadhurst's nephew.

Charles Broadhurst left the fishery soon after his nephew arrived and went to Perth attending to the sale and transport of the shell from Shark Bay. While in Perth, he was approached by the Governor to sit in Parliament. In nominating him, the Governor cited Broadhurst's first hand knowledge of the North-west coast and the settlers there, and claimed that he was 'the only person in the position who has the abilities and leisure to represent them' (Drake-Brockman, 1969:234). Broadhurst accepted the nomination and sat in the Chamber for the first time in late October 1874. His social and political elevation set the scene, however, for the very public humiliation that was soon to befall him.

Figure 33: The Broadhursts and their 'Malay' servant in the early 1870s, (WA Maritime Museum).[1]

[1] Marjorie Darling and the Broadhurst family believed that the servant was Indian. As there was less of a stigma attached to being Indian as opposed to being 'Malay' or Aboriginal, this apparently became a common process (cf. Morgan, 1987)

In short, Cadell and Daniel Broadhurst failed to pay and repatriate the 'Malays' at the end of their contracts and Charles Broadhurst was held responsible. He was summonsed soon after he took his seat in Parliament and all his boats, huts and equipment were sold at a public auction in order to pay the money owed. Broadhurst then resigned from parliament. He and his entire family had received another severe social and financial set-back. Summonsed six times in Perth during this period for non-payment of debt by a cross-section of the European merchants in the Colony, his finances were obviously in a very bad state.

Broadhurst left the Colony, making another voyage with a cargo of pearl shell at the end of 1875, arriving back in April 1876, having failed to realise a profit. On landing back in the Colony he wrote to the Colonial Secretary stating that he had 'lost so much in this colony in endeavouring to develop its resources'. His fortunes and morale were at a very low ebb and he requested to be appointed to the first available Government position, that of Sheriff (Broadhurst to Colonial Secretary, 21/4/1876).

As a scapegoat and no longer held in high regard by the Government, Broadhurst failed in his attempt to enter government service in order to obtain a relatively small, but secure income after years of hard work and tribulation. Eliza then announced her intention to open a school for day scholars and boarders. While a lady of standing could be expected to teach school subjects, especially music, it is doubtful that she would have taken in boarders unless forced to do so. Forced to make the most of any opportunity, Charles then left for London with another cargo of Shark Bay shell.

Broadhurst's other enterprises

Eliza was not to see her husband for over a year. When he did return in October 1877 his mind had turned to canning fish. Backed by a successful merchant firm, he successfully pursued this venture south of Fremantle (Figure 1) as the Mandurah Fish Canning and Preserving *Company*. Broadhurst set it up, obtained finance, established buildings and erected machinery. When at full capacity, the works employed about 50 people from a total population in the town of 200.

Ever restless and searching for opportunities, he sold the canning business in 1882 and proceeded to the Abrolhos Islands near Geraldton (Figure 1). There he discovered previously unknown guano beds of great significance,[1] clearly demonstrating that he was 'a capitalist and trader who would go out of the ordinary grooves in search of wealth' (Kimberly, 1897: 90).

The Government again became interested in his initiatives and decided to grant him a lease to the guano deposit. In December 1883, at 57 years of age during a time of life when most people would have ceased their struggle for security and wealth, Broadhurst settled at the Abrolhos Islands in order to work the deposits. That he left Perth at this age to embark on the establishment of an industry noted for its isolation and harsh conditions is astounding in itself and a comment on his strength of character and physical resilience. It is also a reflection on his financial state and his desire to succeed after so many setbacks.

Eliza, at 44 years of age, was still struggling to make ends meet. An advertisement announced her intention to open a girls school again and a preparatory school for boys under twelve, with a few boarders at a 'reasonable rate' (*West Australian*, 4/3/1884). She was noted as being ill

[1] Guano, a rich organic substance consisting of the remains of birds, their droppings and other material. It was much sought after throughout the world as a fertiliser (cf. Stanbury, 1993: 7-14).

and looking 'quite fagged and worn out', being overworked from school and music lessons (Hillman Diaries, 7/10/1883). Life was certainly tough for them both and they still did not own a home, for in January 1884 Eliza sought to rent a cottage for £50 per annum plus rates and taxes (Hillman Diaries, 21/1/1884). As a further indication that money was tight, or as further proof of his attitude towards creditors, Broadhurst was summonsed for non-payment of debt by his former backers in the fish canning industry. Further evidence of his lack of finance appears in Broadhurst's difficulty in finding surety for the guano lease.

In following what by now can be seen to be a consistent behavioural pattern, Broadhurst, the entrepreneur, was to seize on any opportunity with flair and vision, but without the capital, infrastructure and organisational ability required to profit from the venture.

Broadhurst struggled on and, as is often the case today, the small entrepreneur was forced to take on a backer. This time it was the well-known colonial merchant W. J. Bateman. Facilities were established on Rat Island in the Abrolhos Islands, including a storeroom and a stone landing to load the lighters used to ship the guano in sacks to the much larger vessels waiting off-shore. In 1885 Broadhurst received further capital by taking in another partner, William Brown MacNeil, forming the firm of Broadhurst, MacNeil and Company. His indebtedness to Bateman, who did not become a partner in the business, also grew. Broadhurst mortgaged his share in the Company and all the goods, chattels and improvements to him. While Broadhurst was totally and absolutely in debt in the Abrolhos, Eliza was still working hard to make ends meet in Perth.

Somewhat typically, for he looked forever to greener pastures, Broadhurst re-applied for a lease to unused portions of the pearling banks at Shark Bay at £1000 per annum around this time. His bid was refused, however.

By the middle of 1886, he and his men had succeeded in constructing accommodation huts, a stone enclosure to hold over a thousand tonnes of guano, tramways and a stone jetty 77 metres long with a depth of two metres of water at its extremity. There was fifteen fathoms of water within 100 metres of the jetty and all was in readiness for an expansion of the enterprise to take oceangoing ships. Despite the hard work and increased scale of the venture, many mistakes were made due to inexperience and some cargoes failed to make a return at all because they contained little saleable guano.

There was also little profit margin in the business at the time and with his personal finances still in disarray Broadhurst was again summonsed for non-payment of debt. He was in effect a complete bankrupt.

The scene changed dramatically in 1886 when his son, Florance Constantine Broadhurst, was brought into the partnership. Recognising his own deficiencies as a business manager and seeing that his son, who had received a mercantile education and had been a success in the banking industry, was to be the key to the future success of the business, Charles Broadhurst retired. Under article 9 of the agreement under which Florance was brought into the Company, it was stated that

> The management of the firm shall be exclusively in the hands of the said William Brown MacNeil and Florance Constantine Broadhurst as joint managers ... and the said <u>Charles Edward Broadhurst shall in no way interfere in the management of the said partnership business</u> (Broadhurst, Family Papers).[1]

These words are a clear indication that Broadhurst senior, though capable of seeing opportunities and grasping them, was a bad business

[1]My emphasis.

manager and a poor administrator. A further indication of this is the statement that proper books were to be kept and that a general accounting was to be made at the end of each calendar year.

Thus it was not Charles who turned guano mining to his advantage, but his son Florance and it was he who finally became an acknowledged financial giant and 'pillar of society'. Ahead of his time, Charles Broadhurst had again seen an opportunity, seized it and then found that he lacked the knowledge or expertise to bring it to fruition. This scene had repeated itself so many times in Charles Broadhurst's life. Florance, in contrast, was a man later noted for his 'clear sighted methods and organising power' and soon achieved remarkable results which need no elucidation here (Kimberly, 1897:98; *West Australian*, 24/10/1887).

The family became extremely wealthy and in May 1890, at the age of 64, Charles Broadhurst gave formal notice of his retirement from the firm. MacNeil had earlier retired from the partnership and Bateman was paid out. A family trust to the amount of £10,000 was then formed in order to secure the future of Eliza and their children and so they returned to England, very wealthy. Charles Edward Broadhurst's remarkable thirty year Colonial career, which culminated in the Abrolhos Islands guano industry, finally came to a satisfactory close.

Eliza died soon after her return to England; worn out from her exertions, leaving an as-yet unwritten, yet truly remarkable, story to be told. When Charles died in 1905, aged 86, news of his death was quickly relayed to the former Colonies. He received a suitable eulogy in the Victorian and Western Australian press, which in summing up his career, read

> Mr Broadhurst was one of the most indefatigable and persevering exploiters of the infant industries of Western Australia in his day (*West Australian*, 1/5/1905).

Even from the grave he was to cause confusion and concern. The executors of his will found themselves unable to fulfil the conditions in the manner specified due to there being insufficient funds to attend to his wishes; indicating once again and for the last time, his lack of attention to detail in such matters.

Summary

In this precis of my detailed analysis of Broadhurst which began soon after I visited the wreck of his ship, I have discussed numerous examples of behaviour which can be used to understand anomalies in the archaeological record at the *Xantho* site.

It is clear that Broadhurst was a 'gentleman' accustomed to position and wealth; an entrepreneur with access to some funds, but never quite enough to properly cater for all his needs. He had a propensity for grand schemes and untested technology. He also precipitously embarked on speculative ventures without the capital, experience or common-sense required to make them a success.

He consistently failed, primarily due to his lack of experience, poor advice and his consistent lack of attention to detail. A key is found in his managers. Where they were good, he succeeded; where they were bad, or where they gave poor advice, he failed. This may be related to his traditionally poor labour relations, in that by alienating his workforce Broadhurst may have set the scene for his ultimate demise in business ventures.

He was remarkably resilient. Each time he failed he rebounded through flair, vision and hard work, only to fail again. When he did achieve some measure of success, he immediately looked elsewhere for other opportunities. His continued failure, his background and his desire to restore himself and his family, may have been the catalyst for his propensity to gamble with grand schemes and unnecessary technology.

Again this is relevant to the specifics of the SS *Xantho*.

CHAPTER 4:

IRON STEAMSHIPS, THE CASE OF THE SS *XANTHO*

Construction and operation as a paddle-steamer

Data on the *Xantho* and its operators was located in three places: the seabed, the archives and oral histories. In this section I will focus on archival sources, beginning with the ship's construction. As noted earlier in the contextual studies, the history of iron shipbuilding and the marine engine is well documented (Corlett, 1971; Bourne, 1858; Burgh, 1869; Grantham, 1859; Fincham, 1851; Guthrie, 1971). My discussion therefore will be limited to information relevant to analysis of the archaeological record.

Xantho was originally built as a paddle steamer by the well-known Denny shipbuilding company which operated out of Dumbarton in Scotland (Denny and Brothers, 1932). *Xantho* was the eighth steamer and only the twenty-second vessel built by the Denny Brothers (Lyon, 1975:18). It was, therefore, one of their early products. Much of the original material relating to the Company is still housed in the 'Moor Collection', a privately held compilation of documents and papers rescued after the failure of the Company in 1963. An unexpected find was the location of the contract and specifications for the building of the vessel together with a letter of acceptance from the purchasers (See Table 2 below). These documents illustrate the manufacture of the vessel and indirectly the acquisition and modification of the raw materials needed to do so.

Table 2: A summary of the specifications for the PS *Xantho*[1]

Length between perpendiculars: 101.3 feet (30.8 m)
Length overall: 121 feet. (36.8m)
Breadth of Beam: 17.6 feet. (5.3m)
Depth of Hold: 8.4 feet. (2.5m)

Keel: Of Bar iron, 3 inches x 1 inch [in section][2] (76.2mm x 25.4mm)
Frames: For 40 feet (12m) in midships, 3 x 2x $^5/_{16}$ [inch] (c. 8mm) angle iron. Fore and abaft that 3 x 2 x $^1/_4$ [inch] (c. 6mm) to be placed 21 inches (533 mm) from centre to centre.
Floors: Of plates, 9 inches (228 mm) deep by $^3/_{16}$ inch (c. 5mm) thick with $2^1/_2$ (c. 64mm) x $2^1/_2$ x $^3/_{16}$ inch angle iron, rivetted on top edge, with extra strength of floors for fastening engine.
Plates: Bottom to 2 feet (610 mm) waterline $^5/_{16}$ inch from 2 to 5 feet (1524 mm) $^1/_4$ inch to gunwale $^3/_{16}$ inch to be overlapped longitudinally with flush butts and rivets.
Stringers: Of 2 $^1/_2$ x $2^1/_2$ x $^1/_4$ inch angle iron and plates 12 inches (c. 305 mm) broad x $^3/_{16}$ inch thick the angle iron to be rivetted to the outside plates and stringers.
Bulkheads: To have three of these full depth of vessel, all of $^1/_8$ inch (3 mm) plates. To be stiffened with angle iron and made perfectly water tight. The plates to be all of one length, and neatly rivetted with snap headed rivets.
Coal bunkers same thickness, size as required.
Deck Beams: To have one on every alternate frame of angle iron 4 x 2 x $^1/_4$ inches, to be single kneed with triangular plate knees, 12 inches long in the arm by $^5/_{16}$ inch thick, with 3 rivets in each arm, and rivetted to frame with one $^3/_4$ rivet in each beam end.
Paddle Beams: To be framed of plates 12 inches deep, with 6 x 3 x $^3/_8$ inch angle. iron, rivetted back to back.
Decks: Deck plank of Quebec Yellow pine, 5 x $2^1/_4$ inch tapered
Holds: To have hold fore and abaft engine and boiler space size as may be required. Two cargo derricks for use of holds, and a small winch to each derrick capable of lifting $1^1/_2$ tons.
Sails: Foresail or square sail, mainsail and jib.
Cabins: Main cabin and steerage to be finished complete, in a neat but plain manner. To have hair cloth sofas in main cabin and in captain and mates room.
Carving: Figure-head and trail boards, trail boards to be hatched with gold.
Cooking Apparatus: To cook for 8 men.
Paintings: As iron boats usually are done.
Sundries: 2 anchors and 2 chain cables. 2 cork fenders, 1 Ensign, 1 Union Jack, 1 burgee and ferry flag, 1 long sweeping broom, one deck scraper, 3 brooms, 1 paint scrub and mop, 2 long brushes for funnel, 2 deck lanterns, 2 holly stones, bell and belfrey, 4 wooden fenders with hooks and chains, passengers gangways with ladders, 2 hand poles and limber chains. To have an iron knee inside on gangway stanchions, hawsers and warps, water cask, 3 pails, axe and saw,
Water closet in main cabin, and one in steerage - cabin store, tables and mirrors, 12 camp stools, life buoys according to act, compass to be adjusted,
Engine: To have a 60 horsepower Staple [sic] engine, with a tubular boiler, capable of generating a sufficient quantity of steam for the same. Diameter of cylinder 43 inch The engine and boiler to be upheld for 6 months by the Contractors in the event of materials or workmanship giving way.

---

[1]Where vessels were measured in tons and built to feet and inches, it is customary to quote the original figures; for often they show a pattern that is not otherwise evident in a metric conversion; e.g. 21 inch frame spacings as opposed to the metric equivalent (533.4 mm).

Being of direct relevance to this discussion, the summary is prepared from a hand-written copy of the original which is housed on SS *Xantho* file 9/79, Department of Maritime Archaeology, WA Maritime Museum. The measurements given are as per original documents. Metric equivalents appear in parenthesis throughout this work, except where the tons are specified.

[2]1 inch =2.54 cm.

It can be seen from this data that *Xantho* had hull plate thickness of a maximum of 5/16 of an inch (c. 8 mm) and that it had other scantlings similar to those recommended by the contemporary iron shipbuilder John Grantham (1859:186-187). These appear in Appendix 3a. He recommended that river steamers of the same size as *Xantho* had hull plating a maximum of 4/16-5/16 of an inch (c. 6-8 mm) thick, for example. The *Xantho* frame spacing of 21 inches (533 mm), centre to centre, was greater than Grantham suggested, however; his recommendations generally being 18 inches (457 mm), at most. Grantham's work was published in 1859, eleven years after the *Xantho* was built and it is to be expected that there were some differences. Being built before the advent of Lloyd's Rules in 1855, it is expected that *Xantho* would also differ from those requirements. These are reproduced in Appendix 3b, reflecting Lloyd's standards around that time. An examination of this data indicates that *Xantho* was lightly built in comparison to an equivalent seagoing steamer. Its hull, below the water-line, was over 1/16 inch (1.5 mm) less than that specified if it were to receive even a six year certificate for use at sea. Its watertight bulkheads, at 2/16 inch (3 mm) thick, were only half that required by Lloyd's. Equally significant, its frame spacings were greater than Lloyd's requirements, which were uniformly set at 18 inches (457 mm). This made *Xantho* weaker in comparison to a vessel built according to rules later devised by Lloyd's for ocean-going steamers. The same can be said with respect to Grantham's recommendations for river steamers, on the basis of frame spacings alone.

The PS *Xantho's* total building costs were £3,270; divided almost equally between the machinery and the hull. (Lyon, 1975:118). The name *Xantho* appears derived from the use of yellow pine (*Pinus strobus)* on the deck timbers (Greek *Xanthos*). This softwood occurs naturally in the south-eastern parts of the Northern American continent and is recognised for its qualities in shipbuilding. It is especially noted for its ease of working, small shrinkage in drying and its stability in use. It is not resistant to rot, however (Bramwell and Palmer, 1979:273).

At the time of launching *Xantho* measured 106.8 feet (32.5m.) in length by 16.8 feet (5.1m.) in breadth and was 8.4 feet (2.6m.) deep, with a length between perpendiculars of 101.25 feet (30.8m).[1] It was also schooner-rigged with two masts and it had one deck (*Register*, 4/1848, Anstruther). The engine was a 60 horse power, steeple engine built by Twingate and Company and it was powered by steam from a tubular boiler, most likely of a rectangular form. The engine room was 31.6 feet (9.6m) long, taking up a considerable percentage of the length of the vessel. Designed for paddle propulsion, the engine was located amidships, resulting in two cargo holds, one fore and the other aft of the machinery space, each served by separate winches and other attendant machinery.

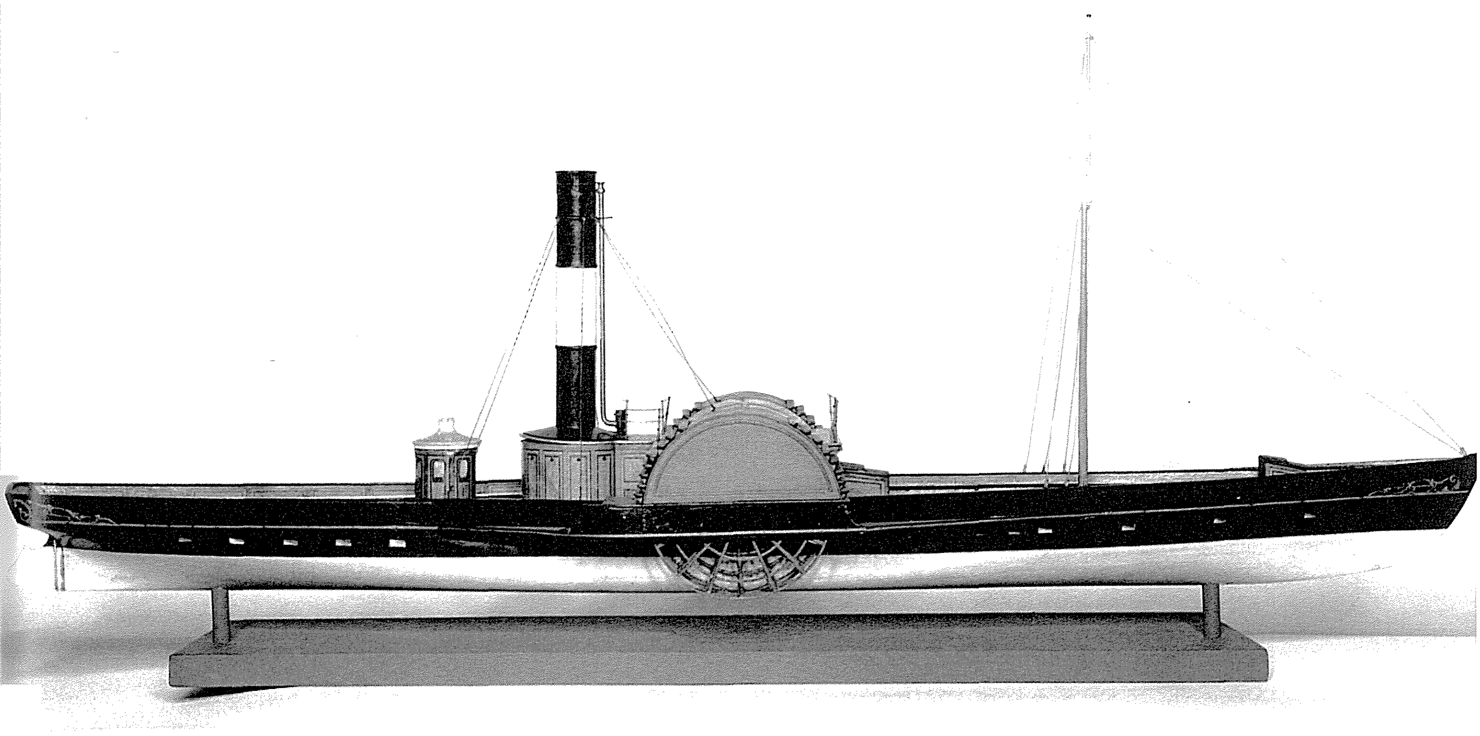
Plans, photographs or contemporary illustrations of *Xantho* do not appear in the Denny List or Moor Collection. Mentioned in the specifications for the building of *Xantho*, however, is Denny's iron paddle steamer *Loch Lomond* (Figure 34). Having been built in 1845 it is expected to bear some resemblance to the *Xantho,* which was comparable in length.

Xantho's first certificate of British registry (No. 41 of 1848) was issued at the Port of Anstruther, Scotland. It shows that *Xantho* was given the official number of 7802 and its first owners were the elected trustees of a joint stock company called the Anstruther and Leith

[1] Fractions of a foot were expressed in tenths or decimals and not inches in these registers, as one would expect.

Steamship Company. *Xantho* was used in this period as a pleasure steamer operating on the Forth between Leith and Aberdour (Records, Scottish Maritime Museum).

Figure 34: A side view of paddle steamer *Loch Lomond,* showing the hull configuration (Photograph, National Maritime Museum, Greenwich).



After twelve years in this service, *Xantho* was sold and transferred to Scarborough (*Certificate of British Registry*, 21/5/1860).[1] The details in this register were basically the same as those previous, with the additional information that its tonnage was 97.3 tons and its length was 114 feet (34.7m). These various, and often conflicting, tonnage and length figures reflect measurements and formulae often quite different from the previous or subsequent Acts (MacGregor, 1973:248). The

[1] The new owners were William Strong, a hotel proprietor, Samuel Bailey, a 'gentleman', Michael Hick, a shipowner, and Edwin Broomhead, also a shipowner. Hick, incidentally was a well-known figure in Western Australia having operated vessels into Port Gregory, the site of *Xantho's* eventual loss. He also had been heavily involved in the Geraldine Mine from which lead ore, which was on board *Xantho* when it was lost, was also mined. The Hick family was also involved in the Barque *Arabella* shown in Figure 39.

engine room also differed slightly at this time, being recorded as 32 feet (9.75m.) in length and of 53.04 tons capacity.[1]

While tonnage figures can be the source of considerable difficulty, confusion rarely arises over type of propulsion. We can note that, in comparison to *Loch Lomond,* the *Xantho* was topsail-schooner rigged and therefore was capable of carrying sails either as an assistant to the steam engine or as a substitute where conditions, or operating parameters, required.

The in-water propulsion system in the two registers, quoted above, is recorded as being paddles driven by one engine of 60 horsepower (HP).[2] The *Xantho* was sold again, on 25 July in 1864, and its register transferred to Wick. The ship was recorded in the Mercantile Navy list of that year as being permitted to take excursions to sea (Henderson and Henderson, 1988:119-124). In the following year it is described in the *Glasgow Herald* (7/6/1865), as a 'smart iron, passenger-cargo, paddle steamer'.

Thus, the *Xantho* had an apparently uneventful career as a general-purpose paddle-steamer, operating first in inland waters for a period of 16 years and then at sea around Scotland for a further 6 years. In undergoing a number of refits during this period and in order to prepare it for a sea-going role, re-engining and perhaps some alterations to deck structures and minor fittings are to be expected.

---

[1]Tonnage: As indicated, tonnage could both be a unit of space or weight and be expressed in a variety of forms each with a completely different meaning, such as 'Register Tons', 'Net Tons', 'Gross Tons', 'Displacement Tons' and the like. Often the type of tonnage being referred to in a particular document or report was not specified at the time, adding further to the confusion. An analysis (MacGregor, 1973: 283-5) of the various tonnages mentioned here appears in Appendix 2b.

[2](i) Horsepower is a complex rating. It is explained in Appendix 2a.

(ii) Often the engine type is not specified and in most cases only the barest details are given. As indicated previously, the word 'engine,' for example also is often used to refer to the term 'cylinder', thus one engine can mean one cylinder and the word 'engines', where found in the literature of this time, can indicate two or more cylinders in any one piece of machinery.

The question that arises is whether the ageing *Xantho* with such relatively small scantlings and quite thin watertight bulkheads should have been put back into service on the open ocean ?

Alteration of the PS *Xantho* to screw propulsion

The First Transformation

In dealing with the transformation of a site and assemblages, Schiffer developed the important distinction between changes that occur as a result of human versus natural actions. These he referred to as 'cultural formation processes' and 'natural formation processes' (Schiffer, 1976:12-19). In applying Schiffer's concepts to an entire ship, in this case the *Xantho*, it can be seen that both cultural and natural transformation processes occur, independently or together, over the active life of a vessel and following abandonment. These effects can be corrosion, damage at sea, refit, abandonment behaviour, salvage, or natural processes at the wreck or on the sea-bed.

If material is raised from a site, changes occur both within it and around the disturbed site itself. Transformations also occur later in the conservation laboratory or in the exhibition gallery. Excavation by cultural resource managers or museum-based archaeologists for the purposes of exhibition, for example, result in the remains being returned to a systemic context, to become again a part of the cultural process. These are all significant processes.

We are fortunate that the cultural transformations to the *Xantho's* form wrought by its owners, or later by its salvors, are fairly well documented. Some of these were quite dramatic; altering the vessel not through periodic refit by re-engining, repairs or maintenance of the hull, but by completely changing its configuration and physical characteristics.

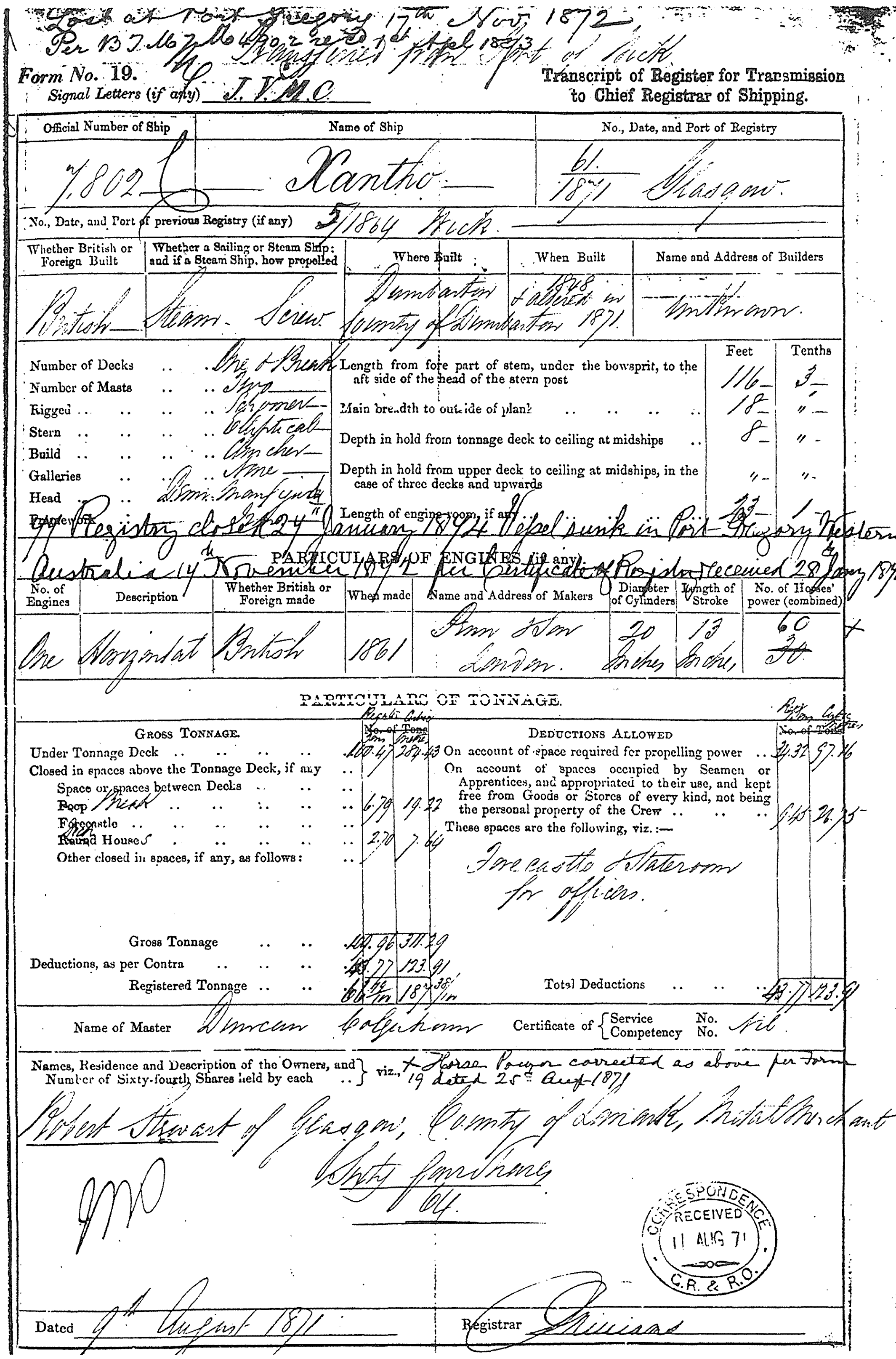
In 1871 for example, *Xantho* was sold to a 'metal merchant,' or scrap metal dealer, Robert Stewart of Glasgow (See Figure 35). Seeing an opportunity for profit, Stewart refitted the ship and altered it from paddle to screw propulsion.

Xantho's stern and figurehead also were altered and the ship was substantially lengthened to 116.3 feet (35.4m.). The cumbersome paddle engines were replaced with what was initially recorded in its register documents as a 30 HP horizontal engine built in 1861 by John Penn and Son (1871, Certificate of Registry).[1]

In making the transition from a large paddle engine housed around midships to a compact horizontal screw engine housed aft, the engine room length was reduced from 32 feet (9.7m) long to 23 and 1/10th feet (7.04m). This represented a considerable saving in space, with a resultant gain in cargo or coal carrying capacity. These alterations resulted in the relocation of all the machinery (including the pumps) aft, giving an increased cargo space. By relocating the cargo space forward, all the holds could be serviced by one deck winch. The economies of space, time and man-power resulting from such a re-arrangement resulted in an otherwise commercially unattractive vessel appearing quite viable. Through this particular transformation process, a redundant artefact (the *Xantho*) was modified and re-used, rather than being broken-up in order to retrieve useful materials before deliberate scuttling or abandonment, as was the norm.

[1]Here is an example of the confusion caused by the term 'engine' noted earlier, for though each cylinder developed 30 HP, the two cylinders combined produced 60 HP in total and the register was subsequently altered in recognition of this. In one contemporary register *(Liverpool Underwriter's Register*, 1872: 381), the vessel appears as having 'one horizontal 30 HP engine'.

Figure 35: The 1871 Register of the SS *Xantho* (Certificate of Registry, Glasgow 61/1871: showing the details of the refit and tonnage figures.



Lost at Port Gregory 17th Nov 1872
Per 137 M ... Registry closed 1st Apl 1873 Port of Wick

Form No. 19.
Signal Letters (if any) J. V. M. C

Transcript of Register for Transmission to Chief Registrar of Shipping.

Official Number of Ship	Name of Ship	No., Date, and Port of Registry
7802	Xantho	61 / 1871 Glasgow

No., Date, and Port of previous Registry (if any) 5/1864 Wick

Whether British or Foreign Built	Whether a Sailing or Steam Ship; and if a Steam Ship, how propelled	Where Built	When Built	Name and Address of Builders
British	Steam. Screw	Dumbarton County of Dumbarton	1848 altered in 1871	Unknown

			Feet	Tenths
Number of Decks .. One & Break		Length from fore part of stem, under the bowsprit, to the aft side of the head of the stern post	116	3
Number of Masts .. Two				
Rigged .. Schooner		Main breadth to outside of plank	18	"
Stern .. Elliptical		Depth in hold from tonnage deck to ceiling at midships	8	"
Build .. Clencher				
Galleries .. None		Depth in hold from upper deck to ceiling at midships, in the case of three decks and upwards	"	"
Head ..				
Framework		Length of engine room, if any	22	1

Registry closed 24th January 1894 Vessel sunk in Port Gregory Western Australia 14th November 1872 per Certificate of Registry received 28 Jany 1874

PARTICULARS OF ENGINES (if any).

No. of Engines	Description	Whether British or Foreign made	When made	Name and Address of Makers	Diameter of Cylinders	Length of Stroke	No. of Horses' power (combined)
One	Horizontal	British	1861	Penn & Son London.	20 Inches	13 Inches	60 ~~30~~ +

PARTICULARS OF TONNAGE.

GROSS TONNAGE.	No. of Tons (Register)	(Cubic Metres)	DEDUCTIONS ALLOWED	No. of Tons (Register)	(Cubic Metres)
Under Tonnage Deck ..	100.47	284.43	On account of space required for propelling power ..	34.32	97.16
Closed in spaces above the Tonnage Deck, if any			On account of spaces occupied by Seamen or Apprentices, and appropriated to their use, and kept free from Goods or Stores of every kind, not being the personal property of the Crew ..	9.45	26.75
Space or spaces between Decks ..			These spaces are the following, viz.:—		
Poop Break ..	6.79	19.22	Forecastle & Stateroom for officers.		
Forecastle ..					
Round House ..	2.70	7.64			
Other closed in spaces, if any, as follows:					
Gross Tonnage ..	109.96	311.29			
Deductions, as per Contra ..	43.77	123.91	Total Deductions ..	43.77	123.91
Registered Tonnage ..	66 19/100	187 38/100			

Name of Master Duncan Colquhoun Certificate of {Service / Competency} No. Nil.

Names, Residence and Description of the Owners, and Number of Sixty-fourth Shares held by each .. viz., + Horse Power corrected as above per Form 19 dated 25th Aug 1871

Robert Stewart of Glasgow, County of Lanark, British Merchant
Sixty four shares
64.

CORRESPONDENCE RECEIVED 11 AUG 71 C.R. & R.O.

Dated 9th August 1871 Registrar

It is interesting to note that the tonnage figures shown on the register appear in both tons and cubic metres. This was apparently with an eye to the continent where the metric system was in place, especially in France. Here is an example of an object of little use to one group being offered for trade and presented in such a way to appear attractive to another group.

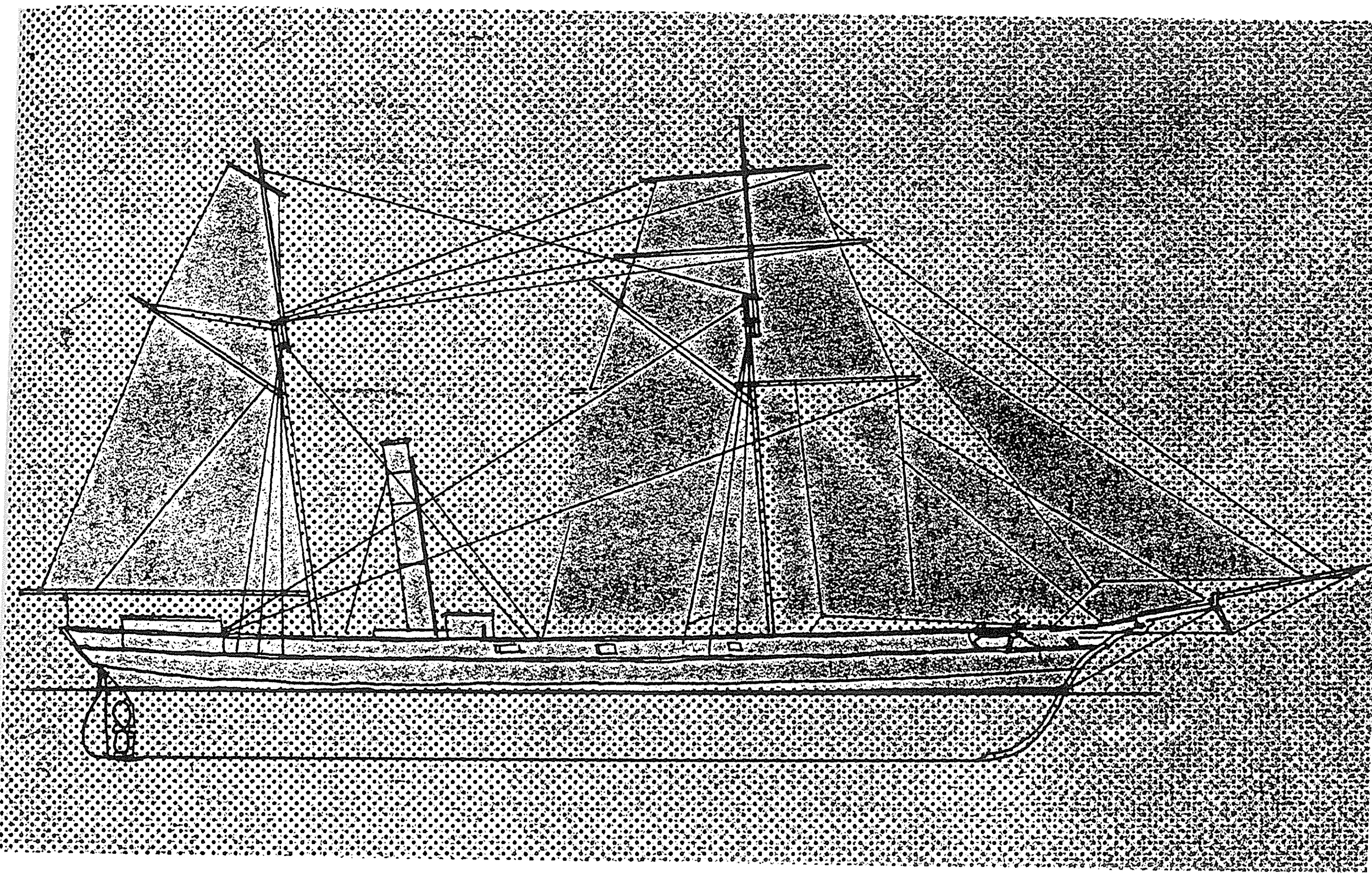
In its late 1871 configuration, *Xantho* may indeed have been an attractive proposition for operations on rivers or sheltered waters such as the well-serviced River Seine. Its re-fit and mode of engineering may also have made it eminently suitable for use in semi-saline or fresh waters, as will be seen in a later chapter.

The efficient use of sails would have represented a considerable saving in coal, but these savings were reduced in part by the windage or resistance of the masts, rigging and spars that were carried. The schooner rig, with its predominantly fore and aft configuration, had less windage and was also easier to handle than a rig with square sails and therefore required a smaller crew. An impression of the appearance of *Xantho* in its 1872 configuration is shown in Figure 36 below. This is based on a comparison of plans and illustrations of similar steamers, from descriptions of Broadhurst's ship and from the evidence on the sea-bed (Chapter 5).

Broadhurst and the operation of the SS *Xantho*

As indicated, Broadhurst travelled to Scotland with intentions of revolutionising pearling in Western Australia by introducing steam power to the industry. When he left, thirty one sailing vessels, ranging from one to fifty six tons, were in operation on the pearling grounds along with fifty two smaller boats or dinghies. All were wooden-hulled and not one was a steamship.

Figure 36: An impression of the SS *Xantho* in 1872 under Broadhurst's ownership: By Ian Warne. The hachuring is to emphasise the sail configuration.



Broadhurst does not appear to have adequately investigated the economics of the steamship industry before he purchased *Xantho*. He apparently did not make any formal enquires of Government, nor did he make public any prior intention of purchasing a steamer when he left for England in 1871. No mention of his scheme appears in any known official, private or family records where one would expect such things to appear. In addition, Broadhurst's subsequent letters to the Colonial Government on the matter show that he was, in his own words, 'entirely on... [his]... own account'; i.e. he was not in partnership with anyone else (Broadhurst to Colonial Secretary, 25/10/1871). To make the risk even greater, he planned to work the ship on a coast where other operators had demanded a subsidy to ensure their operations would be viable. Finally, the sum of £4,500 which Broadhurst eventually expended in the purchase and fitting out of the *Xantho* with boats and whaling gear, coal and stores (Broadhurst to Colonial Secretary, 25/10/1871), was twenty times that of a mid to upper-level government servant's annual salary at the time and would be measured in the millions of dollars today (See Appendix 5 for a schedule of contemporary wages and salaries as a comparison).

Where Broadhurst got the money is somewhat of a mystery. Pearling for him in the seasons before he purchased the ship appears to have been one series of disasters after another. The sale of his pastoral interests at Nickol Bay may have part-financed the purchase of the vessel, as could the sale of his stock and land in Victoria. He may also have been a beneficiary in his recently deceased sister's will and his family in England may have assisted in the purchase and even in the choice of vessel. When in England in 1871, for example, he would have visited his newly-married sister, Mary Louisa who had just wed the famous engineer, Sir Joseph Whitworth (Lee, 1900:169). Whitworth may have advised his new brother-in-law that Glasgow, a noted shipbuilding region, was the best place to get a second-hand steamer. On being consulted on the options available for operation on a remote coast, he could have also volunteered the information that anything engineered by John Penn of Greenwich, Engineer to the Royal Navy, was bound to be good (for reasons that will later become apparent).

Though he was to have only one steamer, Broadhurst intended to diversify his activities by using it as a 'mother boat', servicing a number of smaller dinghies that he had working at distant bases in the pearling industry on the north-west coast. He was carrying five boats on the vessel's deck, together with 120 tons of coal, 30 tons of stores, whaling gear and everything that his experience suggested was useful in order to pursue as many and diverse a range of maritime pursuits as possible. This included whaling and turtle shell collecting. If one were to deduct the estimated cost of these five boats, the coal, stores and whaling gear from the stated cost of £4,500, a figure not unlike the £3,000, flagged as the potential cost of a steamer by the Camden Harbour Association and Denison Plans Company, is approached.

Finally, when not required for pearling, he intended to use *Xantho* as a trading vessel or 'tramp' carrying goods and people as the occasion allowed.[1] Thus the relatively high costs of obtaining coal, employing qualified masters and officers and the many other expenses incurred by operating the SS *Xantho* could potentially be recouped. It was a maximising strategy, common and identifiable through much of human endeavour in a difficult frontier environment or an untried economic context. Herein lies the difference between what Broadhurst was attempting and what steamship owners, prepared to operate only with a subsidy to a fixed timetable, had in mind. It clearly was a gamble, even under the best of circumstances.

As also indicated earlier, the prospect of importing Malays in this period also was another logical progression, given that they had been operating as divers for centuries in the islands to Australia's north and that the available pool of Aboriginal labour had been over-stretched by mistreatment and the introduction of European diseases. In comparison to the Aborigines, who were in effect slaves, Malays required to be

[1]Tramp: A freight vessel that does not run on any regular line but takes cargo wherever shippers desire...Tramp vessels are hired to carry cargo of any kind not requiring vessels of special design. They are operated singly over any ocean route and to any destination not prohibited by physical conditions such as insufficient harbour depth (de Kerchove, 1984:853).

paid and had to be transported back home at the end of their period of employment.

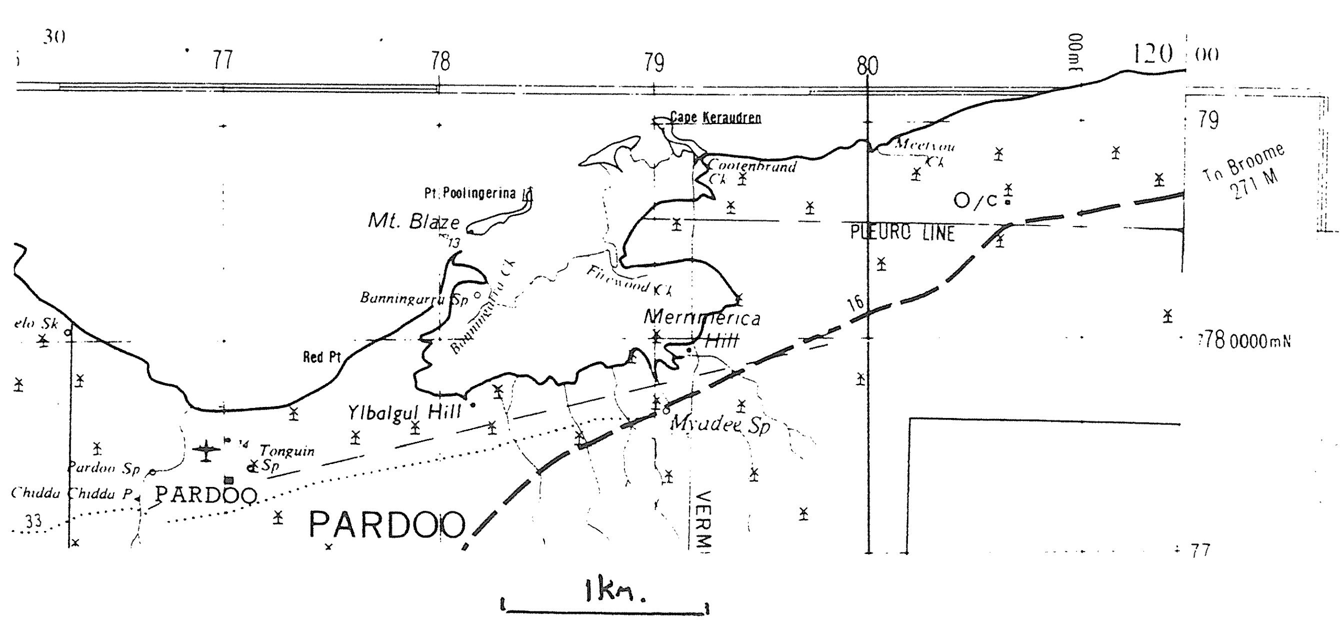
Apart from being harvested, the pearl shell also had to be transported from the pearl beds to a suitable location for sale and manufacture. These places were as far afield as the Australian north coast and the continent of Europe. Thus a string of agents and managers and a good vessel were crucial for an enterprise so geographically widespread. The managers and agents Broadhurst selected were connected to his family at Singapore and Batavia (Jakarta). To complete the chain, Broadhurst had one of the largest shell buyers in England willing to purchase, by telegraph, sight unseen, any shell he could land in Singapore.

As noted in Chapter 3, the inspiration for the scheme may have come from the Camden Harbour and Denison Plains Companies. These companies had flagged the use of a small steamer (costing around £3,000) between their settlements on the north coast of Australia, Batavia and the Straits Settlements (McCarthy, 1990:64-84). There was already a monthly steamer run across the island chain from Kupang in Timor to Batavia and, from there, direct links could be had by telegraph and steam-ship to India and London. It was a regular trading route to tap into for the carriage and disposal of harvested shell. Clearly if one were to use this network, pearl shell could be sold direct to the buyer, transport costs could be lowered and the government revenue charges levied out of Western Australian ports could be reduced. Indeed, if one were to bypass those ports, the charges could be avoided altogether.

Broadhurst's intention to use a steamship to satisfy the dual aims of harvesting and transporting shell and labourers between north-west Australia, Batavia and Surabaya and operating against time and tide in difficult pearling harbours was a well-founded strategy. Port Hedland, where he established one of his pearling bases, for example, was considered a beautiful harbour; completely land-locked but not suitable for sailing vessels in anything but perfect conditions. The fact that he was taking an extraordinary gamble with unproven technology and that his Achilles Heel was potentially the ship itself, went unnoticed in the euphoria surrounding the news of the impending arrival of *SS Xantho* in the Colony, however.

En route to Australia with the vessel, Broadhurst called in to his agents in Singapore, Batavia and Surabaya. There he obtained coal, engaged forty Malay divers and continued onto Banningarra, or Mt. Blaze, arriving around April 1872.

Figure 37: Mt. Blaze, or Banningarra, where Broadhurst maintained his base. Access to Banningarra spring was via Banningarra Creek. Note Firewood Creek, a possible source of substitute fuel for *Xantho*. An excerpt from De Grey, WA 1: 500,000, SF 50-E. See also Figure 30.



Banningarra was a safe, virtually landlocked harbour with two and a half fathoms of water (5m) at low tide (See Figure 37). Near a small fresh water lagoon not far from shore, Broadhurst established a camp with a substantial wooden house and 'sick-bay' for his 'Malays'. Firewood, from dead mangrove trees, was (and still is) in plentiful supply.

The arrival of the steamer on the coast strengthened Broadhurst's position with Government immeasurably. Even the Governor, who was then planning his first official visit to the north, intended to welcome Broadhurst and the steamer when it arrived at Nickol Bay, such was his improved standing in bringing the vessel to these shores.

SS *Xantho* arrived a month late to find the Governor gone and it progressed on down the coast to Champion Bay, now Geraldton, arriving there to a populace clamouring to view the vessel.

> The Xantho a small steamer recently purchased by Mr C.E. Broadhurst and intended for the pearl fishery, called at the Bay yesterday on her way to Fremantle. Such a novelty as a veritable steamer in our waters attracted crowds to the jetty, and as the little vessel lay alongside for several hours, the curious had ample time to inspect her. The Xantho is a small Clyde built screw steamer of about 120 tons, with powerful engines for her size. She is stated to be a good sea boat and apparently can steam with ease 7-8 knots per hour (*Inquirer*, 22/5/1872)[1].

Public euphoria does not necessarily translate into things material, however, and Broadhurst had difficulty obtaining coal at a reasonable price. The only fuel available was offered at £4 per ton, an exorbitant figure, which was attacked in sardonic prose by the local papers. Undeterred, the ship carried on down to Fremantle and was greeted enthusiastically. Broadhurst, for his part, was eulogised as 'our enterprising speculator' (*Inquirer*, 15/5/1872). It appears, however,

[1]There is a discrepancy between the tonnage figure quoted by the press and the registers.

that Government officials became worried when they learnt of his plans to carry shell direct from his bases to Singapore and sought to cater for his every demand in order to minimise potential revenue losses. After completing business Broadhurst and his ship departed Fremantle for Batavia via Champion Bay and Nickol Bay, carrying passengers, Aboriginal prisoners and assorted cargo.

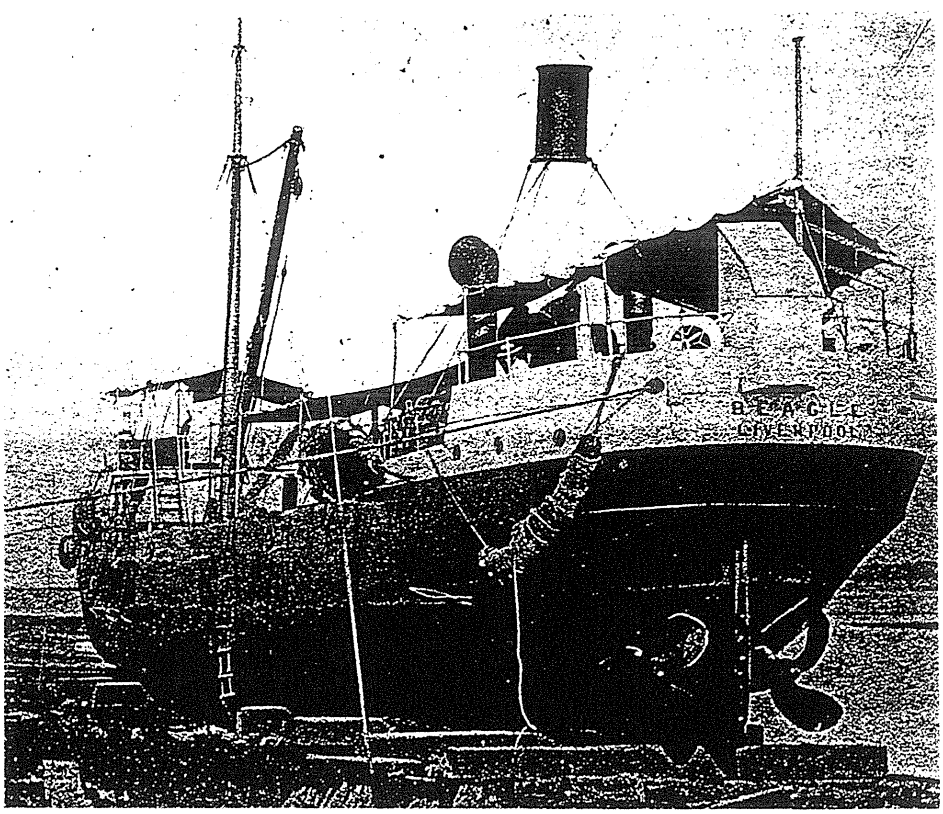
At Champion Bay they ran into a fierce storm and at one stage, *Xantho* was forced to steam at half speed with two anchors set to prevent it being wrecked. In the process of doing so the engines consumed over £100 pounds worth of coal. The capstan and the best anchor were also badly damaged. Of significance, in this instance, is the high cost of operating the vessel when steamed even at half speed over a prolonged period.

After the storm, which lasted nearly a week, they proceeded north to the pearling grounds. There, they would have loaded the vessel with every available shell collected in the season. They then sailed north to Surabaya and Batavia where the shell was off-loaded for consignment to Broadhurst's buyer in London. While at Batavia Broadhurst replenished the ship's coal supplies and loaded with saleable goods, including some that were later classed as contraband (McCarthy, 1990: 267). Clearly Broadhurst exploited every conceivable opportunity for financial gain.

After taking on more 'Malay' divers, the vessel returned from Batavia to Broadhurst's pearling bases, first Banningarra, then Port Hedland and finally the Flying Foam Passage at Nickol Bay (Figure 32). At the Flying Foam Passage, SS *Xantho* was allowed to rest on the bottom at low tide, like all the other vessels in the vicinity and it would have remained in that position until the next high tide (See Report of Inquiry into the loss of the *Xantho,* following).

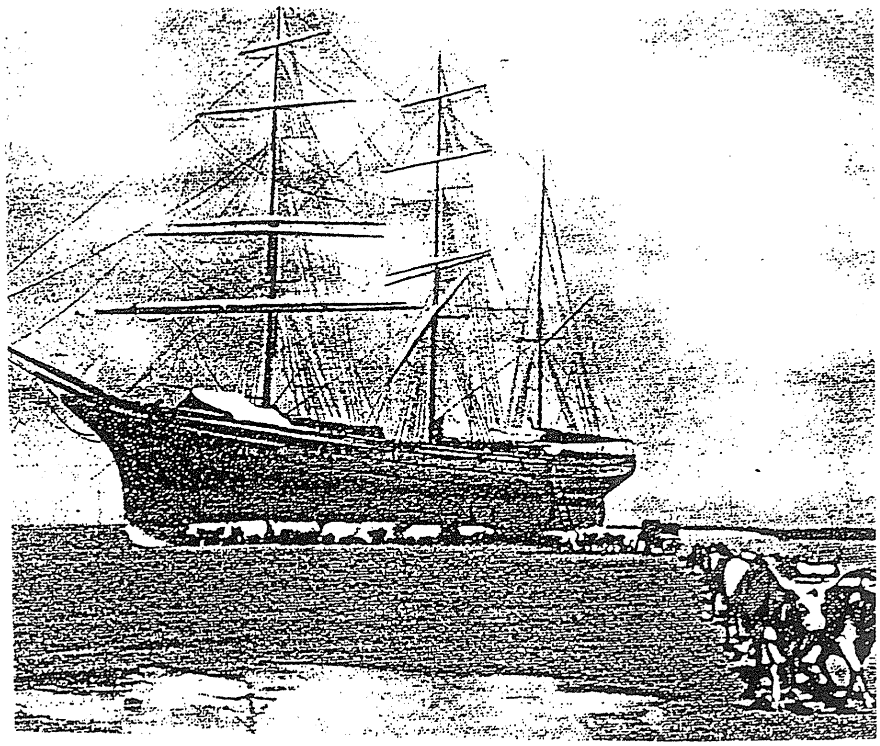
The tides of Nickol Bay are often in excess of 4 metres (*Australian Tide Tables*, 1994: 202-203). These tides, when combined with a coastline with little declination in its off-shore profile, often resulted in vast areas of the sea-bed drying at low water. This presented a severe problem when moving cargo, stock and passengers to and from large ships. One solution was to allow the vessel to rest on the sand or mud at low tide and then perform all the cargo and passenger handling functions (See Figures 38 & 39 below).

Figure 38: A late 19th century steamer, the SS *Beagle*, aground at low tide in Nickol Bay. Xantho would not have had the specially prepared blocks (State Archive, Battye Library, 21613P).



Stresses and strains on the vessels involved could be expected and the practice was common with both iron and wooden vessels on the north-west coast until a few decades ago. When a vessel is old or vulnerable, as appears to have been the case with the *Xantho,* damage can occur.

Figure 39: The wool barque *Arabella* ashore at Condon near Banningarra in the 1900s (Simmer, nd: 373)



Complex, untried, or lightly-built technology often fails in a frontier environment. In not having enough capital to afford a relatively new, strongly-built iron ship, like those shown above, Broadhurst was taking a considerable risk and may have been better served with a traditional wooden-hulled sailing vessel.

When the tide rose at the Flying Foam Passage *Xantho* was floated off and they departed for Geraldton as planned. Nothing appears to have been pre-arranged for the journey down to Fremantle and Broadhurst instructed his agents to look out for a paying cargo. While at Geraldton, Broadhurst heard of a good sideline and immediately took the ship back north to nearby Port Gregory to load a cargo of lead ore for a waiting sailing ship.

Though an outport for lead mines, bay whaling operations, and the pastoral industries in the area, Port Gregory was a narrow harbour with very strong currents, and was notoriously dangerous for sailing vessels (Totty, 1986). It was, however, admirably suited for use by a small steamer such as the SS *Xantho*.

The Loss of *Xantho*

The Second Transformation

Apart from on-going deterioration due to age, the next transformation operating on *Xantho* was what Schiffer would identify as a cultural formation process.

While operating in the Geraldton area, on what was to prove to be its last voyage, *Xantho* had a crew of fifteen. This included the Captain, Ernest Denicke, an unspecified number of 'Malays', Joseph Taquer, late Master of a vessel wrecked in the storm discussed earlier acting as pilot, and William Smith, also a Master Mariner acting as second mate.

At Port Gregory, the ship was chartered to load a cargo of 100 tons of lead ore from a nearby mine and to return it to Geraldton for tran-shipment to the barque *Zephyr* which was then waiting at Geraldton ready to load for Europe. Once the cargo was off-loaded, the intention was to take *Xantho* on to Fremantle and to continue in the carrying trade until it was needed back at the pearling grounds.

Eighty three of the intended 100 tons of lead ore were loaded onto *Xantho* from small boats and this cargo was then topped with wool and whale oil from the nearby district and bay whaling establishments (Trenaman, 1934:1-5). *Xantho* left Port Gregory for Champion Bay at 9:40 p.m. on the night of 16 November, heading into a strong south-easterly breeze and a heavy sea. It was then lost in the manner described in the introductory narrative. At a subsequent Court of Inquiry, the first mate, Augustus Thistleton described the events leading up to the loss of the vessel (Table 3). Some of the detail is included here as an example of the information available and as important clues to the analysis of the archaeological record. Relevant sections are underlined.

Table 3: Excerpts from the evidence given at the Court of Inquiry

...We shipped at Port Gregory 83 tons of lead ore. We left Port Gregory for Champion Bay on the night of the 16th at 9.00 pm. The wind was SE. It was a strong breeze and a heavy sea. The *Xantho* was not deeper in the water than I had before seen her. ...The cargo was stowed under the captain's direction. We expected to take 100 tons on board and the vessel was stowed with that expectation. Had the 100 tons been taken on board a considerable proportion of the deadweight would have been in the after part of the ship. The captain said he would only take 1 boat load more. Part of the cargo of ore was removed to the after part of the vessel. When we had finished taking cargo on board the *Xantho* she was about 5 or 6 inches by the head, her usual loading trim is about 2 inches by the stern. She was then 7 or 8 inches out of her proper trim. ... It was my watch until twelve that night. During my watch the vessel was not taking in water more than I had before seen her do in a head sea. I was down in the fore compartment about half past eleven I did not notice any water in the fore compartment. The *Xantho*'s decks leaked a good deal. I went to see if any of the crew were asleep in the forepart of the ship as [indecipherable].... I was relieved at twelve by the Captain. I didn't make any report to the Captain as to the water the vessel was taking in. I did not consider it excessive. I had before seen her taking as much water....The fore hatch was battened down. The swinging doors of the forecastle were closed and the side also. I went to my berth on being relieved. At five minutes past I was called by the Captain. He told me he wanted me on deck to look after the hands as the forepart of the ship was full of water. I went on deck and passed the Captain at the wheel. He told me to go forward as the ship was in a sinking position the *Xantho* had two watertight compartments in her. On going forward I found the whole of the forepart of the ship under water it being level with the combings of the fore hatch, there was as near as possible a difference of elevation between the stem and the stern of 7 feet. Part of the lead was thrown overboard to lighten the vessel. At the time the vessel was heading SE by S being her course towards Champion Bay. I went aft and recommended to the Captain to return to port. He put the stern around. After the vessel was put around I observed he was going out to sea and I requested the pilot to go to the helm and steer for the port for the purpose of saving lives, which he did. Until then the Captain had the helm in his own hands. The engine pumps were going but were of no use, the water being all forward. There were no pumps in the forepart of the ship. We reached Port Gregory at a quarter to four in the 17th. We went in the *Hero Passage*. She took the ground about 10 minutes after entering the passage when abreast the Gold Digger Passage. The water then began to go aft. It was not more than 15 or 20 minutes after the water began to run aft that the fires in the engine room were put out by it. The vessel then settled down. The pumps were then useless. The vessel did not sink immediately. Attempts were made to free her by bailing but it had no effect on her....At any rate the bailing had not the slightest effect in resolving the quantity. I cannot account how the water got from the fore compartment. ... the Captain...gave no orders. He did not appear to be competent to give orders. He had lost the presence of mind altogether....*Xantho*'s port of registry was Glasgow, she is an iron vessel rigged as a topsail schooner ...by the vessel being down by the head the water that came in overall could not get out of the scupper holes. In the same way, it would had she been in proper trim. The *Xantho* was ashore in the Flying Foam Passage on the voyage from Point Walcott. I did not think she received injury there to account for leakage on the night of the 16th. We had a very heavy head sea while rounding the West Cape she then had about 18 ins in her fore compartment. It was bailed out at the time. The fore compartment was sound. The bulkhead of the fore compartment was about 15 ft from the stem'.

Joseph Taquer stated that he would not have taken the vessel to sea in the trim that it was in as it had no chance to rise to the sea. As it was originally designed and licensed for use in inland waters, it most likely had bows common to river and lake steamers; i.e. without what is termed 'flare' or the resultant ability to thrust aside or rise above an oncoming wave or swell. As a result, the bows would have tended to bury into the sea and most of the water would have surged on-board instead of being hurled aside, as was usually the case with a ship designed for open water. Thus the vessel's design may have been unsuitable for the persistent, short seas of this coast. Though Broadhurst stated that they 'had a good trial' of the vessel out of Scotland (Broadhurst to Colonial Secretary, 25/10/1871), the heavy cargo taken on at Port Gregory may have exacerbated the failings inherent in a vessel which was not only leaking badly, but was also originally designed for use in sheltered waters and a cold climate.

Alexander Maquis, the first engineer, also gave evidence. He revealed that he had previously examined the hull when the ship lay aground at low tide and found that about a metre up from the keel, amidships, rivets had 'gone'; i.e. were corroded or had popped out of the hull. He replaced them, but thought that the rest of the hull was in good order. He also indicated that the *Xantho* always leaked forward in a head sea, partly in the hull and partly in the deck.

Captain Denicke, in his defence, explained that the method of stowage of the ore was not at fault and stated that Broadhurst had prevented him throwing any more from the vessel on the way back to Port Gregory (Minutes of the Inquiry). Worth reiterating here is the fact than when *Xantho* was on the verge of sinking, Broadhurst called a halt to the jettisoning of the lead ore, and was recorded later as having stated that he preferred to 'save the cargo rather than the ship' (Minutes of the Inquiry, Geraldton, 1872).

Denicke added that when they were cleaning the hull at Batavia three of the plates in the fore part of the hull were scraped through and required replacement.

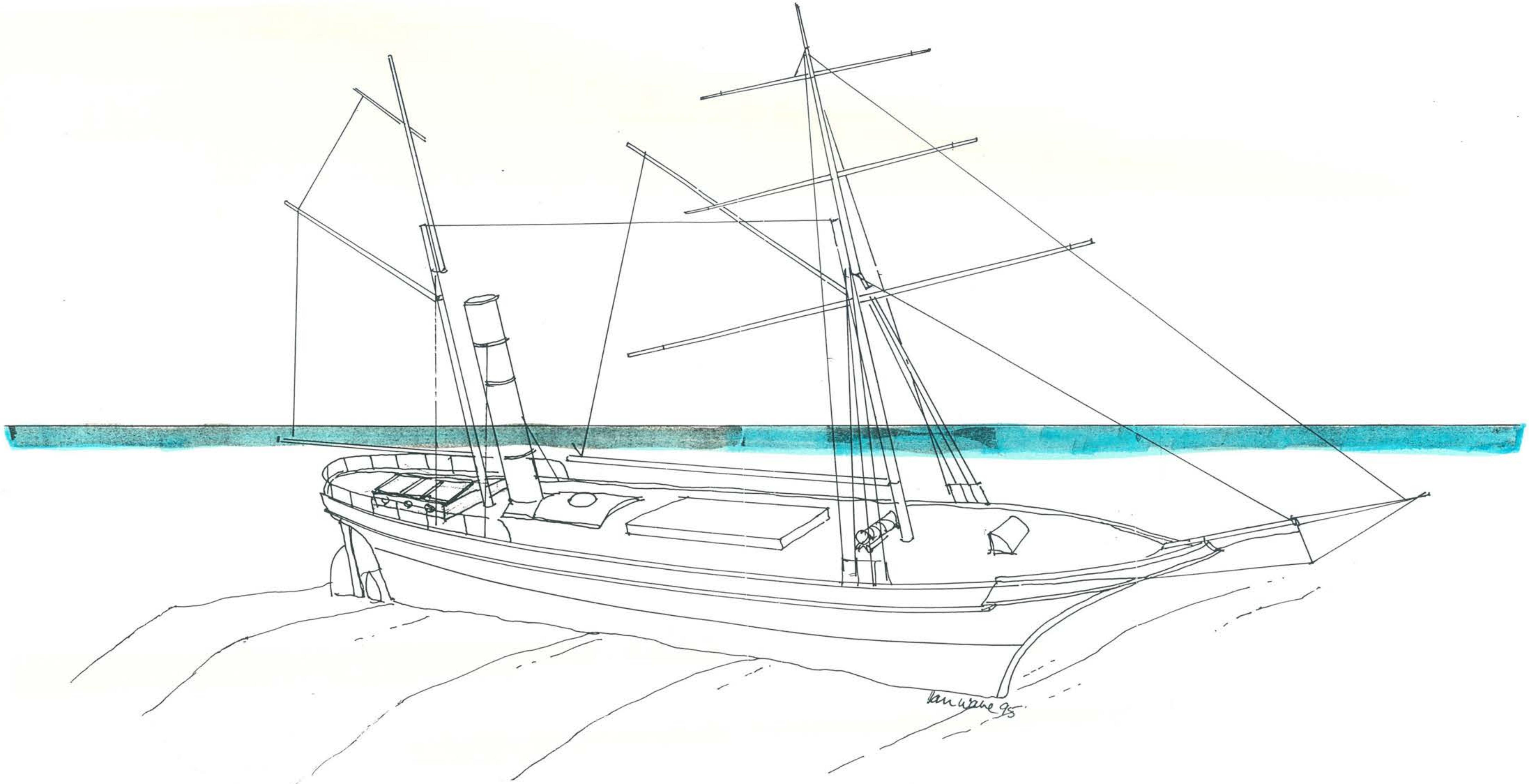
On the basis of the evidence, the Court found that the steamer was not lost by any default, neglect of duty or incompetence on the part of the Master and his certificate was duly returned. At the inquiry, Broadhurst revealed that he had forgotten to renew the ship's insurance. Realising this about a fortnight before the ship sank, he had sent an urgent letter home to rectify the situation, but it was too late, the mails were so slow and the telegraph to Europe was not connected (Minutes of the Inquiry).

Thus, on the basis of the historical evidence alone, it appears that the SS *Xantho* was lost through old age, hull failure and incorrect loading. In purchasing this particular vessel, Broadhurst had made a very costly error. This modern assessment matches that of the local press, which claimed that

> Her hull is weather beaten and worn out... The vessel was simply swamped through her unfitness from age, service and other causes to carry the freight with which she was laden (Herald, 25/1/1873).

Taking note of the evidence presented in the discussions above, project artist, Ian Warne presented my impressions of the *Xantho* as it would have appeared on the day it was lost. These impressions appear in Figure 40 below. This is the beginning of a continuum illustrating projected disintegration stages at the *Xantho* site. The other hypothetical stages appear in Figures 41, 44 and 72.

Figure 40: An impression of the *Xantho* on the seabed, the day it was wrecked. Based on contemporary accounts. Sketched by project artist Ian Warne. The sea-surface is emphasised.



Break-up and Early Salvage

The Third Transformation

Once a shipwreck has occurred, the vessel is subject to both cultural change through the processes of immediate post-wrecking salvage and then to natural transformation. The latter occurs, firstly, by the action of the seas and swell and then by the wreck's interaction with the sea-bed and its environment. All of these process will produce quite dramatic changes in the vessel, leading eventually to the formation of a wreck site as we know it today.

Of importance to the archaeological record is the speed and process of the abandonment and salvage process itself. The loss of *Xantho* eventually proved not to be a life-threatening event, occurring in shallow water within the approaches to an existing port. As a result, abandonment was not hurried. The crew also had ample opportunity to return to the ship. Eventually all accessible valuable or re-usable loose material, and most likely all available personal effects, would have been retrieved and sent ashore to be sorted and reclaimed.

There is in fact a continuum in abandonment processes generally, ranging from circumstances like that described, through to people being unexpectedly and abruptly cast ashore on a hostile coast, or into raging seas (e.g. the VOC ship *Zuytdorp*, mentioned earlier). Clearly the archaeological record is markedly affected by these variables and they must be taken into account before conclusions are made about the significance of the remaining assemblage.

Broadhurst was keen to salvage ore from the wreck and as a preliminary a close examination of the wreck was made from the surface. It appears that the fore deck was three to four metres underwater and the afterdeck about one metre below the surface. The engine room, cabin skylights and cabin companion had all been washed overboard. Within a few weeks, the main deck had partly lifted and washed away, as had the bulwarks. The reports concluded that the vessel was a total wreck and should be sold (Colonial Secretaries Office, Records, 727/268).

By December diving apparatus had been obtained and Broadhurst would have then been set to work salvaging the lead ore and gear from the wreck. From a logistical perspective, it was a very difficult undertaking and in January 1873 negotiations were still under way for the hiring of other divers and more diving apparatus. The salvage of the loose gear and equipment within the wreck proved quite successful, however, and the list of gear landed on the beach and later sold at auction was substantial (*Inquirer*, 5/2/1873). This included a complete set of sails with running gear, anchors, 81 fathoms of chain, boat davits, lifebuoys, a barometer, thermometers, salinometers, navigation lights, fenders, a large ship's bell, a portable forge, three compasses, a 'patent' log, engine room tools, two clocks, lamps, a telescope, and a 13-foot (4m) dinghy.

The list indicates that the vessel was stripped of everything that could be obtained, including material from the engine-room. This apparently left the ship virtually an empty shell, bar the machinery that was fixed to the hull and much of the lead ore.

The processes of salvage that occur after the wreck is sold or abandoned by its original owners must also be accounted for. Where undertaken by the owners, insurers or their agents, I refer to this as 'primary salvage'. When the Captain eventually proceeded with the sale of the wreck in order to obtain funds with which to pay the crew, the auction was poorly attended and was subsequently described as a 'complete sacrifice'. Items such as the dinghy on the beach at Port Gregory, fetched only £1. As a result, the total sum raised was only

£180. Of significance was the fact that the hull and engines were also sold, as one lot, fetching £110. Interestingly, the purchaser refused to pay for the engines and hull until he was guaranteed that the sale was authorised by Broadhurst. There was considerable confusion on this issue, for Broadhurst had not yet relinquished ownership. In March and April 1873, for example, he was still calling for tenders for the raising of the steamer (*Inquirer*, 19/3/1873; *Herald*, 5/4/1873).

That the wreck was still salvable and accessible is of importance. Equally of importance is the fact that the purchaser did not complete the deal or exercise his options as expected. As a result, the engine and hull remained on-site.

Strangely, one of the reasons for this fortuitous outcome was Broadhurst's consistently poor labour relations, which are dealt with elsewhere (McCarthy, 1990). The reasons for his engines remaining on the wreck, though they were a saleable proposition, can be traced partly to Broadhurst's abandonment of his crew soon after the loss of the ship and their claim that all the proceeds of any sale were to go to them to pay their arrears in wages. Broadhurst naturally countered these claims, adding further to the confusion. In examining the evidence from the papers, letters and the various government offices, it appears that Broadhurst did not pay his men off in the belief that, as the vessel was salvable, they were still in his employ. With this understanding he went off south to recover what he could of his faltering business empire. On the other hand, Denicke and the crew, left without instructions or money, believed that as the vessel had sunk they were entitled to be discharged and to be paid their dues, as was the custom. They then pursued Broadhurst up and down the coast, seeking their arrears in wages. In the meantime four 'Malays' were left destitute, wandering the streets of Geraldton. They were forced onto the government for help and the matter became a great scandal in which Broadhurst was roundly criticised (Government Resident's Office to Colonial Secretary, 31/12/1873). He eventually repaid the Government the money owing for the accommodation and feeding of the 'Malays', but it is doubtful that he ever paid out the rest of his men. In selling the vessel without his authority the crew would, in his eyes, have given him just cause to totally ignore any further demands. It was a scene that destroyed the respect and position that he had re-built in bringing the steamer to these shores.

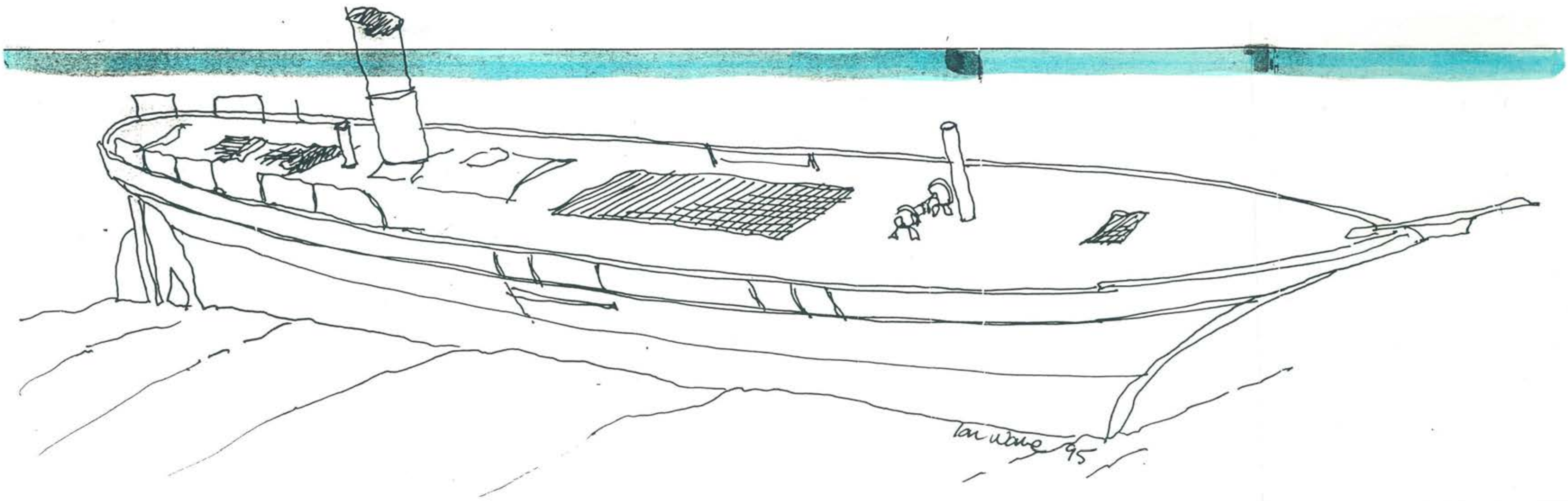
In noting the cultural and natural changes recorded above, such as the extent of the salvage, the lifting of the decking, the loss of the skylights and the inevitable removal of the valuable masts, spars and rigging, I was able to conclude that the wreck would have been transformed within a few months of its loss to a form similar to that shown in Figure 41, below.

Little is known about cultural transformations that may have followed at the site and it appears that the *Xantho* was quickly forgotten by all except those navigating the narrow channel in which it lay. In 1875, for example, Port Gregory was surveyed and the site was examined and marked with the notation, 'submerged wreck' (Figure 3, above and Figure 42, below). The surveyor, Commander, W.E Archdeacon RN, does not name the vessel, but describes the location exactly

> One third of a cable [c. 70 m] off the point a small coasting steam vessel foundered and her remains not having been removed it is probable the point will eventually work out to it (Archdeacon, 1879:16.)

It is clear that by Archdeacon's time the wreck had been abandoned by all, including Broadhurst and his unfortunate crew, and soon it became lost to living memory. Of equal importance was Archdeacon's belief that the point (or sand-bar) would 'work out' to the wreck and that it would, by inference, become engulfed in it.

Figure 41: A sketch of the of ship a few months after its loss. The illustration is based on the historical evidence and the removal of the masts and spars. By Ian Warne.

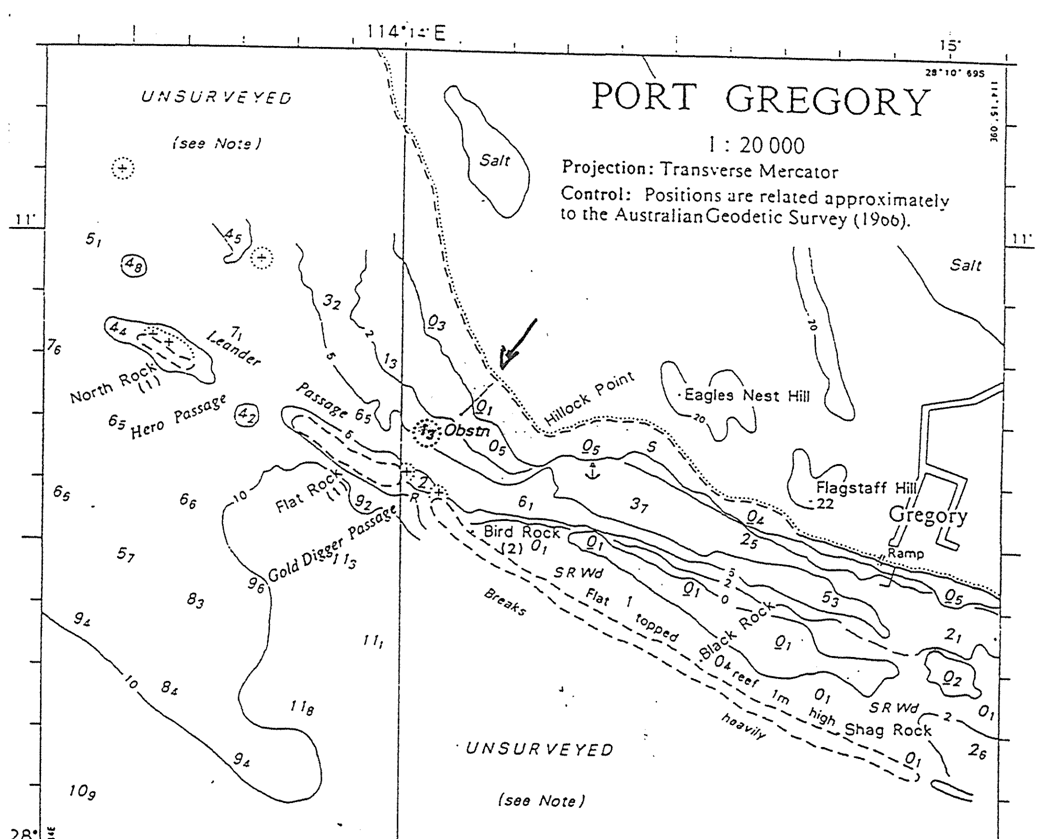


From Archdeacon's time on, we know little of what occurred at the site, but on days of complete calm and clear water sailors could not have missed seeing the wreck as they tacked into Port Gregory. It was also a distinct and quite noticeable hazard to navigation, with the boiler and upper-works barely a metre below the surface (See Figure 42). Pearling craft *en-route* Fremantle and the north for example, would have utilised

Port Gregory. With divers on-board, they may have investigated the site, removing anything that still appeared useful![1]

In the early twentieth century, salt was harvested from inland lakes and it was shipped from Port Gregory. It appears that we are fortunate in having anything at all to examine at the site, for when the SS *Kurnalpi* called into Port Gregory in February 1918 to take on a cargo, the master requested that the wreck be removed as it constituted a hazard to navigation.

Figure 42: Port Gregory, in modern times, showing the location of an obvious navigation hazard (the *Xantho*) at the entrance to the Port (AUS 751, Houtman Abrolhos & Geelvinck Channel.[2]



---

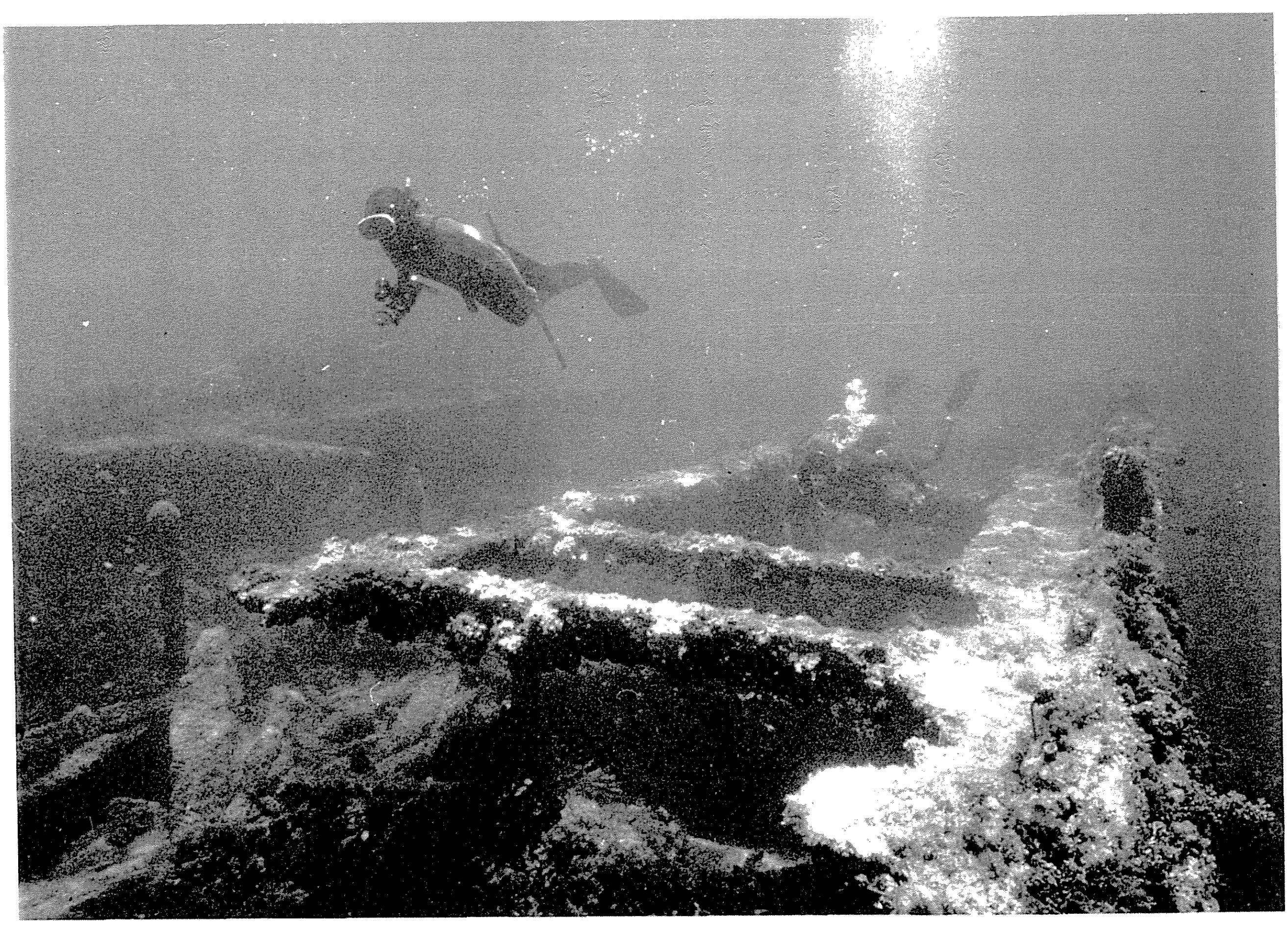
[1]Indonesian trochus shellers, for example, are known to have dived on many wrecks further north, reducing them to sterile sites (See McCarthy, 1991). Pearl divers can be expected to have done the same (See Figure 64).

[2]The vessel's name appears on more modern maps and charts (See Figure 73).

Fortunately it was decided to mark it with a permanent beacon instead of destroying it with explosives, as was usually the case. (Suckling nd: 42-6). Though the nature and form of the beacon on the wreck is not known, it is expected that the marker would have been held in place by chains fastened to a portion of the wreck itself, further hastening its destruction in times of bad weather.

In the interim, disintegration would have continued as a result of natural processes. We know from experience that wooden decking quickly disintegrates and that iron deck-beams, flexing with each heavy swell, gradually weaken to the point where they fail and the sides of the vessel no longer have any support (Figure 43).

Figure 43: The author inspecting the midships section of the SS *Macedon*. The deck beams have disintegrated and the sides of the hull are only a few years off collapsing. Photograph by P. Baker (See also Figure 6).



At this point, the sides of the hull are totally vulnerable to the seas and as they corrode or are exposed to heavy swells across the hull, they collapse, especially around the cargo holds. The direction in which they fall is dependent on the direction of the seas at the time of near-collapse, the current, and the angle of heel of the hull itself.

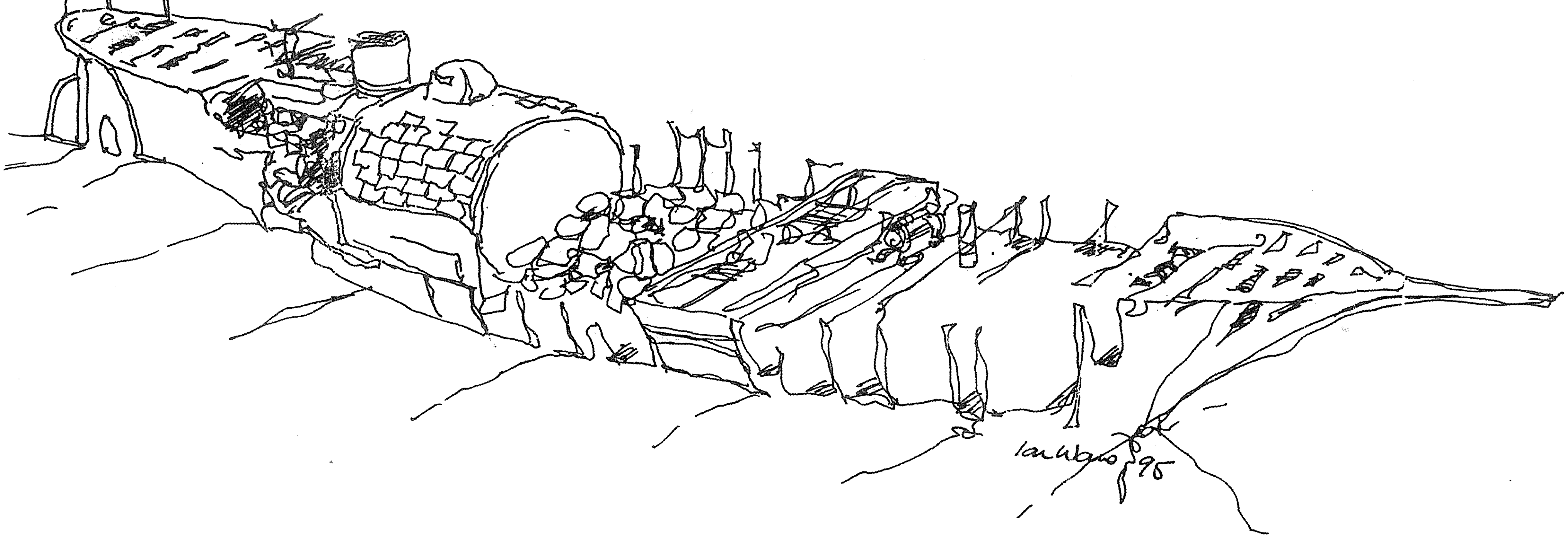
In contrast, the stronger, better-supported area around the boiler, coal bunkers, stokehold and engine-room often form a unit and remain intact for a considerably longer period. The bow and stern triangles, which are immensely strong structures, still remain upright and they often remain so for some time. These phenomena have been observed in contemporary photographs and illustrations of ships in similar situations and they are now believed to be a common process, notwithstanding salvage or other cultural transformations, such as the effect of war. This, somewhat surprisingly, is an issue which had to be considered at the *Xantho* site, for the area was shelled by a Japanese submarine in 1943 (Hashimoto, nd). Investigations subsequently showed that the site was not damaged (MacDonald, 1994).

On the basis of an examination of the remains of many similar sites, the projected appearance of *Xantho* as it began to collapse is shown in Figure 44, below. What is illustrated here is what I now believe is a standard slow midships-collapse for vessels of this type in similar conditions.

There are a number of assumptions inherent in the production of the three illustrations of how *Xantho* would have appeared in the years between its abandonment in 1873 and its relocation and inspection in modern times (Figures 40, 41 & 44). They revolve around the notion of commonalities in iron ship disintegration through the processes of natural disintegration, an issue which will be discussed at length in

Chapter 6. Before examining this phenomenon, I will examine the wreck, as found in modern times.

Figure 44: An impression of the appearance of the *Xantho* in the process of collapse. Sketch by Ian Warne. See also Figures 40 & 41



CHAPTER 5:

THE WRECK OF THE SS *XANTHO*

Discovery, inspection and protection of the site

Station-hands living in the area of the wreck claimed to have known of its existence since the 1930's, but kept it to themselves (McLoughlin to McCarthy, pers. com.). An amateur historian and member of the Underwater Explorer's Club of Fremantle, Bruce Melrose, first brought Commander Archdeacon's unnamed wreck at Port Gregory to the attention of the general public (*Underwater Explorer's Club Newsletter*, 16/10/1966). He found the site while perusing early charts and modern aerial photographs for the purposes of locating new wrecks. Little was done about his report, however, and the exact location and identification of the wreck still remained a mystery for many years. This was probably fortuitous, for when the Underwater Explorer's Club found the wreck of the *Georgette* (1872-1876) during the same period, they removed everything possible and dismantled the engine for souvenirs, leaving it broken on the sea-bed (Figure 28). In an attempt to remove its propeller with explosives, they blew it to pieces and, though they dragged the spare ashore, it was lost in the sand.

There was no official reaction to this site destruction or the Melrose report. Western Australian academics and politicians were preoccupied with decisions as to how best stop the systematic plundering of newly found 17th and 18th century English East India Company and Dutch East India Company ships, as discussed earlier. Later, in the mid-1970s, an interest in iron and steamship wrecks grew due to the work of Graeme Henderson, Curator of Colonial Wrecks, and Scott Sledge, then Curator responsible for the wreck inspection program (Henderson, 1977; Sledge, 1977). Knowing *Xantho* to be located in the vicinity of Archdeacon's wreck, Henderson requested that the Maritime Archaeological Association of Western Australia (MAAWA) mount an expedition to locate the site. The Association searched the Port Gregory area, but initially failed to locate the wreck partly due to the prevailing strong current.

Eventually the assistance of local fishermen was sought and as it eventuated, the wreck was well known to them as a navigational hazard. They promptly directed members to the site. The Association conducted a preliminary survey of the wreck, locating a boiler, iron frames, a windlass, propeller, other machinery and lead ore. A report with sketch plans was prepared that left no doubt that the wreck was that of the *Xantho* (Hall, Hill and Warne, 1979). The wreck was officially inspected by Sledge in October 1979. He was accompanied by a team of volunteers, including members of the original MAAWA team. Further sketches were made and compass bearings and transits were taken to facilitate its re-inspection at a later date. Five artefacts were located, recorded and raised.

An excerpt of the 1979 report appears below, with elements significant to this project highlighted.

> The wreck lies in 5.5 m of water with a large boiler rising to within 3 m of the surface. The axis of the keel is directly NS on sand bottom. Overall length between stern and stem post 34.05 m (110.7 ft) with a measured breadth of 5.2 m (16.9 ft) at 10 m abaft the stern. The stump of the foremast is located 9.9 m abaft the stem and a large tubular boiler (2.8 m diameter) is located slightly abaft amidships. A two cylinder engine lies immediately abaft the boiler but has fallen over to port. The boiler is held in position by a wooden cradle, at least partly surrounded by an iron box. Small artefacts including a copper porthole ring and broken glass thereof, a small leather shoe sole and blue transfer ceramics sherds were recovered from the area to starboard engine. Several pieces of whalebone and deck skylight and samples of lead ore, found abundantly in the fore section of the wreck were recovered. A 16 cm diameter drive shaft with 40 cm connecting flange links an iron screw propeller to a confusion of rubble just aft of the engine. The whole construction is of thin iron plate (no more than 1 cm thick) over iron frames, with tongue in groove 3 cm wooden ceiling planking. Wooden dunnage[1] was noted

[1]Dunnage: A term applied to loose wood or other material used in a ship's hold for the protection of cargo (DeKerchove, 1948:250).

> amongst the lead ore in the fore section. A mild to northerly current was encountered which did not shift with the change of tide. Visibility remained poor to moderate at 4.5 m. The five artefacts XA 2417-2421 were transported to Fremantle for conservation. A rough site plan and drawing and other drawings were also made (Sledge, 1979) .

The inspection report was then presented to the Maritime Archaeology Advisory Committee of Western Australia (MAAC). This committee included academics, archivists, divers, professional staff and others who advised the Director of the Western Australian Museum on maritime archaeological issues. After the report was received and the identification accepted, the wreck was submitted to the Trustees (Board) of the Western Australian Museum for declaration as an historic site. From there the nomination went to the Western Australian State Government for protection under the terms of the 1973 Maritime Archaeology Act (Minutes, Maritime Archaeology Advisory Committee: Resolution 4/1980)

In January 1980 a further visit was made by members of the Geraldton Branch of the MAAWA. Measurements and sketches were made, photographs of the site were taken and an intact boiler gauge was noted lying 70 cm from the aft starboard corner of the boiler. In October 1980, the Geraldton MAAWA again visited the site of the wreck and found that some items, including the boiler gauge, had been removed. Concern was formally expressed by this group for the safety of loose artefacts on the site and they recommended that all be removed as soon as possible (Totty, 1982).

Having become responsible for the wreck inspection program, I attempted to visit the site in February 1981 with the intention of assessing the reported damage. Diving was not possible, however, due to extremely poor conditions. It was decided that a detailed survey of the site should be conducted at a later date and I was requested to lead the project and conduct a test excavation.

The 1983 Expedition

In 1983, I prepared a submission for funding in order to assess the effect of the looting. A statement of aims, and proposals for a test excavation to a budget of $3,700 AUS were also presented.

The problems and methods of effectively recording a site, such as *Xantho* with substantial relief were important considerations. Inspection, recording and excavation philosophies and techniques were to be re-examined and modified where necessary. My objective was also to record the propulsion system, to comment on the research potential of the hull, propulsion system and cargo remains and to assess and report on physical conditions affecting the wreck and its future stability. The aims, as set in 1983, are reproduced below.

> AIM: To examine the *Xantho* wreck site and assess the feasibility of a future site excavation.
>
> **Methods:**
>
> 1. **Conduct a surface level survey** resulting in a site plan produced by physical measurement and photography.
>
> 2. **Assess and report on site conditions**, notably current, turbulence and visibility.
>
> 3. **Comment on the most appropriate excavation procedures** and plant required in view of (1) and (2) above.
>
> 4. **Comment on the research potential** of the hull, propulsion system and cargo remains.
>
> 5. **Conduct trial trenches** to ascertain the orientation of the keel and the extent of hull remains for future grid positioning and recording techniques.
>
> 6. **Recover and conserve artefacts from the trial trench** and forward them suitably conserved and photographed through to the laboratory and into the conservation.
>
> 7. **Record and report on the propulsion system.**

8. **Report on the problems and methods of effectively recording** a site such as *Xantho* with substantial relief.

In expectation of a successful submission, a preliminary study of the weather and on-site conditions prevailing in the Geraldton/Port Gregory region was commissioned of Peter Worsley of the Geraldton MAAWA. In short, it recommended that the best time for a fieldwork program would be the period commencing late March through May. This pre-winter period was selected due to the expected easing of the prevailing southerly winds which are normally experienced in the months before. During the southerlies and winter storms, seas breaking over the southern end of the reef cause stronger currents than those which normally run up the channel. These could attain speeds of up to 3 knots. The tidal range was little over one metre and was not seen to be a significant factor. It was recommended that small vessels could be used in the proposed fieldwork due to the proximity of the wreck to the launching ramp and caravan park at Port Gregory.

My proposals and budget were accepted and fieldwork was planned for the coming month of May.

Earlier, I had published a number of guidelines for conducting wreck inspection programs in the *IJNA*. These included the non-disturbance recording of biological, physical and chemical parameters of relevance to the conserving and managing of artefacts taken from wrecks (McCarthy, 1982a: 47-52). They are presented below,

(a) **Temperature:** water temperature is an important variable in determining the rate of marine growth, corrosion of metal objects and the biodeterioration of organic materials.

(b) **Salinity:** water salinity has a pronounced effect on the stability of metal objects, ceramics and biological growth, e.g. bacteria and fungi which have a marked effect on the deterioration of wood. Salinity, therefore, is an important factor to be considered and measured.

(c) **pH and dissolved oxygen content:** both should be measured on site where possible as they are major factors in determining the stability of both inorganic and organic materials.

(d) **Water movement and purity:** wave action, water movement and non-marine water sources nearby, e.g. rivers, sewers, etc., should be recorded in view of their effect on a–c above.

(e) **Bottom-type analysis:** this variable also needs to be recorded since it has chemical as well as immediate physical effects on the wreck material and on the site itself. Samples of bottom sediment should be taken with a view to analysing micro-organisms present and mainly the sulphate-reducing bacteria content with a view to their effect on organic material and artefacts.

(f) **Corrosion products and marine concretions:** these are best initially retained where practical, due to their protective coatings which help prevent damage of artefacts in transit and also for the information conservators can gain from an analysis of the corrosion products and marine concretions. Some marine concretions, however, harden considerably on artefacts such as ceramics and experience has shown that these are best removed soon after being taken from the site.

Having expanded the brief to acknowledge that *Xantho* was the first iron and steam shipwreck to be studied by maritime archaeologists in Australia, I extended it further so that it might accommodate what I perceived were some new directions in underwater archaeology. One of these was the study of iron and steamship wrecks.

My intention was to make no *a priori* assumptions about the *Xantho* site, how it should be treated or how it behaved in an underwater environment in comparison to the wooden-hulled wreck. Therefore, I decided that a full pre-disturbance survey had to be carried out prior to the main recording/excavation program. There was, unfortunately, little precedent on which to base the pre-disturbance work. All earlier examples of corrosion monitoring in Australia were undertaken post or mid-excavation, centring on the analysis of discrete metallic artefacts such as cannon, anchors, brass fittings, rigging and the like from wooden vessels (MacLeod, 1981:291-303; North, 1982:77).

The results of work conducted overseas was not available to us at the time. A detailed examination the wreck of the iron hulled USS *Monitor* which was conducted in 1979, for example, was not made available. On reading that study in later years, it appears that it involved a 'limited amount of structural testing' that was based on in-laboratory work and on a physical examination of the site (Watts, 1987:128-139). The other study I located on hull material recovered in 1967 from the USS *Tecumseh* (? -1864), is noted in Watts' earlier account of the *Monitor* (1975:322; Edington, 1978; Friend, 1978). It also appears the subject of an in-laboratory corrosion study (cf. Baker, Bolster, Leach and Singleterry, 1969). Thus it was not known whether the results obtained in either of these two cases mirrored what was happening on the site itself, as was the intention of the proposed *in-situ* recording of parameters (a-f) above.

The most appropriate people to conduct the proposed pre-disturbance survey were specialists with experience in the handling of scientific equipment and in interpreting these results. Though comparatively new to work in the underwater environment, some of these normally laboratory-bound specialists were trained to dive and could operate their equipment underwater with a degree of confidence. The following comment places this development in perspective

> Prior to the excavation of the iron steamship *Xantho,* the project leader (McCarthy, 1985) decided that a pre-disturbance biological, chemical and electrochemical survey should be made of the site since it was the first iron shipwreck to be systematically studied (MacLeod 1987:50).

The decision to involve these specialists from the beginning, and throughout all subsequent phases of archaeological investigation, provided an opportunity to study not only the physical state the hull, boiler, engine and fittings, but also the biological growth and electrochemistry of the site. As we expected there to be a considerable number of galvanic couples (bonding of dissimilar metals around the site and especially on the engine) this study also presented an opportunity to conduct the first underwater (as opposed to in-laboratory) study of corrosion on a composite structure which had been submerged for more than a few years.

As a result, an addition was made to the *Xantho* research design

> 9) **To conduct a pre-excavation study of the site conditions**, biological factors and electrochemical state of the wreck and its engine, fittings and cargo.

Clearly the study had to be performed before the site was transformed in any way. This was to be the other new direction. It is a strategy that has worked well, as will be seen, and as a result I was later to make the following comment with respect to what I now consider to be an inextricable link between conservation and excavation

> There appears a need (almost a requirement) to have trained, experienced and capable conservators working, not only on-site at the expedition camp, but on-site underwater on the excavation itself (McCarthy, 1986c: 21-25).

The pre-disturbance survey

By arrangement, local divers re-located and buoyed the site prior to our arrival. After a short familiarisation dive, corrosion potential measurements were taken and an assessment of the physical and chemical status and the biological growth on the wreck was made. The rationale for the study was that

> ...very little is known about the rate and manner in which the ship's material decays and corrodes, what type of problems are likely to be encountered when attempting to excavate or raise artefacts, or how to protect any significant sections which have to remain *in situ* after the excavation is completed. Our aim in carrying out this preliminary survey was to collect enough data to answer some of these questions, or at least pinpoint where further work is needed... The type of information which can be obtained from the *Xantho* is applicable, in part, to other marine problems such as the formation of artificial reefs and protection of long term off-shore facilities (Beegle, North and MacLeod, 1983:1).

A precis of the pre-disturbance survey report by Neil North, Head of the Conservation Department at the Maritime Museum, assisted by Ian

MacLeod and biologist, Ms CJ. Beegle follows (Beegle, North and MacLeod, 1983). (See original in Appendix 7).

The conservator's work shows that the depth over the site ranged from between 3 to 6 metres and at the time of recording the sea water temperature was 23°C with no thermal gradient. The current, which ran from the port forward quarter of the hull across the site to the starboard quarter astern, was approximately 3 knots. This and the storms that preceded the inspection produced a mass of weed and sea-borne grit which gave a turbidity (visibility) of 2.5 to 3.0 metres at best, often falling to less than one metre. The salinity of the water was measured at 37.53 parts per thousand. No direct measurements on dissolved oxygen were made, but due to the strong current and shallow depth over the wreck, it was estimated at 100% saturation. The pH of the water at 23°C was 8.1.

Compared to the nearby barrier reef and benthic communities, the ecosystem of the *Xantho* appeared to be an anomaly. The surrounding areas comprised eel-grass communities with a large herbivore population which feed on the organisms seeking shelter and protection amongst the eel-grass fronds. The *Xantho* itself, however, was a tunicate-dominated community of primarily sedentary filter feeders. These served to camouflage much of the remains and possibly to protect them from wave action. Also present were tube worms and a single crinoid. Of all the structures of the ship, the most interesting area was the boiler. It was found that this large cubic structure located in such a strong current allowed higher rates of colonisation in comparison to successively more sheltered areas on the rest of the wreck.

At the top of the boiler, the wave surge was found to be at right angles to the current and approximately 0.5 m in amplitude on the day of the study. Within the shelter of an opening, on the upper surface of the boiler, tunicates were found. These were generally smaller forms of 7-10 cm overall length. On the top of the boiler, which was 2.9 metres from the sea surface, encrusting sponges occurred with small green algae. Where the upper surface sloped down towards its corners, large brown algae were present. A distinct demarcation of growth along the boiler surface was noted at a depth of 4.1 metres. Below this line, large tunicates (10-15 cm overall length), large upright sponges (5-10 cm high) and a few scattered red algae appeared. On the port side, above a depth of 3.7 metres, the full force of the south-west swell was felt, but below this depth there was only a mild surge along the plane of the face. The biology reflected each of these area's exposure to current and swell. Above 3.7 m biota was associated with that found on the upper surface. However, from 3.7 m to 4.2 m depth, a band of large brown algae occurred. From 4.2 m to the seabed (at 4.9 m depth) were encrusting sponges and red algae. The species of the lower areas were the same as on the forward side except for the lack of tunicates.

The water column was also sampled for contaminants and high quantities of lead sulphide were found downstream of the lead ore (PbS) cargo.

In highly oxygenated warm water and saline environments, such as that on *Xantho*, concretion occurs (See Chapter 6 for an expansion). This natural transformation process (Schiffer, 1976: 12-19) is a matrix formed through the combined effects of chemical processes, animal life and the accretion of sand and shell. It gradually covers iron and some other metallic surfaces (cf. North, 1982). Called concretion, due to its rock hard characteristics, it was seen to have formed a layer over the boiler, the engine and all other iron surfaces. On the engine it appeared to be up to 50 mm thick; on the boiler it was less. Animal matter often grew on top of this layer of concretion.

In comparison to the thick layers found on the iron, the concretion layer observed on brass and copper fittings (e.g. oil cups and lubricators) on the engine was only a few millimetres thick and consisted of a dense white calcareous deposit. The mechanism for the development of this concretion is of significance and is briefly discussed here (cf. MacLeod, 1982).

Galvanic protection provided by the corroding iron on the engine allowed the copper based alloys in the fittings to act as cathodic sites in the corrosion cell. This caused the surface pH to increase and inorganic calcium carbonate precipitated on the metal. Once this protective layer covered the toxic metal corrosion products, the surface was then subject to normal colonisation by marine organisms. The carbonate layer was fairly dense and under it some of the copper oxides on the metal surface had been converted to copper sulphates, through the action of sulphate-reducing bacteria.

It has long been acknowledged that to deconcrete an object underwater, in order to ascertain its stability or to record data from its surface, leaves it unprotected and liable to accelerated corrosion and abrasion from sand movement. It is not a justifiable process. As a result, artefact markings and detailed features are rarely visible, often frustrating those wishing to use a concreted object for dating or identification purposes. These problems applied to the entire *Xantho* wreck and were a major factor in the design of the pre-disturbance survey.

The corrosion specialists minimised the impact of their study by a procedure which consisted of clearing the loose plant and animal growth from the area to be examined and then by drilling a 6mm diameter hole through the concretion down to the metal itself. This procedure was performed using a using a masonry bit and a hand drill. A platinum electrode connected to a high impedance digital multimeter, housed in an epoxy body, was then inserted into the hole. A reference electrode was placed adjacent to the hole and the voltage measured. For the resistance survey the reference electrode was replaced with a stainless steel probe (See Figure 45). The procedure was repeated elsewhere on the wreck, allowing the depth of the concretion layer on each feature to be tested. More importantly, the instruments allowed the corrosion specialists to ascertain the electrochemical environment and the physical state of the metal beneath. From there they were able to make predictions on its stability. Thus the corrosion potential of the iron work and other metallic surfaces were measured across the site.

Figure 45: Neil North and Ian MacLeod at work on the engine during the pre-disturbance survey. MacLeod is using a hand-drill. on North is holding the multimeter. The electrode is visible in the foreground. Photograph by M. McCarthy.

Results of the pre-disturbance survey

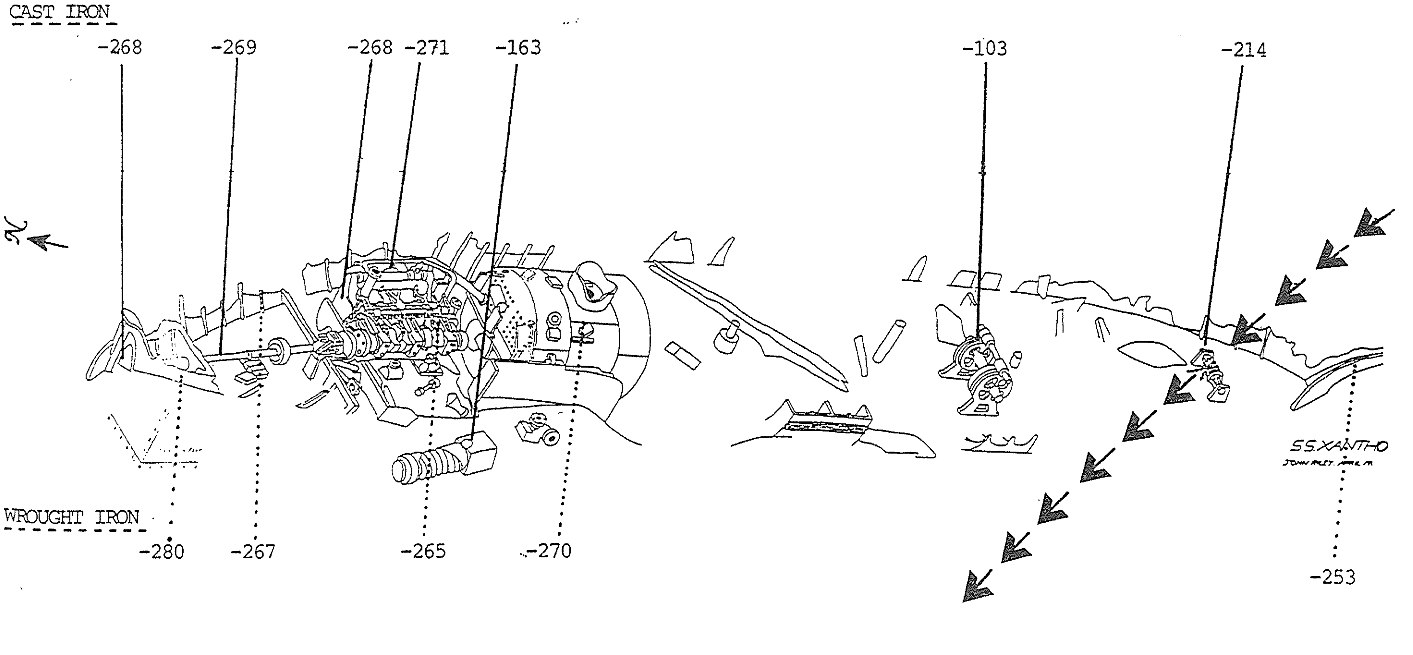
The analysis of marine organisms on-site and other ambient conditions provided some evidence of burying which had apparently killed colonising plants and animals.

It also became apparent that the hull plates remaining beneath the concretion were extremely thin and that some appeared only as hollow casts with no original metal at all, especially up current in the forward, port section of the ship. The ironwork on the boiler varied in thickness with some robust metal remaining in parts, especially on its aft face. In comparison to the coppers and bronzes, which appeared to be in excellent condition, there was no solid iron left in the winch or windlass, each being in effect hollow concretions.

Only the engine, drive shaft, propeller and part of the starboard quarter at the stern appeared to have some solid metal, though Neil North, the senior conservator was of the opinion that the engine had a life-span of sixty to one hundred years at most; even if left totally undisturbed on the sea-bed (North to McCarthy, pers. com., SS *Xantho* Expedition, 1983). North advised that after this period the engine would be reduced to mere shells of concretion or would collapse under the force of the heavy seas and swell which sometimes affect the site. This observation was based on measurements of what proportion of the original metal remained on the engine and by predicting rates of corrosion in an underwater environment for areas that could not be assessed. This are discussed briefly in what follows, being of considerable importance to this study.

Studies conducted before the *Xantho* project began showed that the rate for underwater corrosion of discrete steel and some iron objects in an anaerobic environment averaged 0.10 mm per year (ranging from 0.02 -0.195 mm/yr) (LaQue, 1975:383-9). These results were supported in a subsequent study, where a mean rate of 0.08 mm per year was recorded after 16 years of measurement (Southwell, Bultman and Alexander, 1976). Studies on corrosion and galvanic coupling had also been conducted (North, 1984). As a result of these findings, North initially applied a corrosion rate of 0.08-0.10 mm/year to the *Xantho* in his predictive studies; noting that it could be expected to vary greatly, both below and above that figure (North to McCarthy, 23/1/1984). As indicated, North's predictions led, in part, to the belief that the *Xantho* engine had a short projected life, even if left undisturbed beneath its layer of concretion on the sea-bed. The rates were found to vary considerably across the wreck and across the engine itself, as North had forecast.

Figure 46: The SS *Xantho*, showing the points at which the corrosion potential measurements were taken and the readings obtained. The prevailing current is shown by the arrows. Adapted from an isometric projection by John Riley.

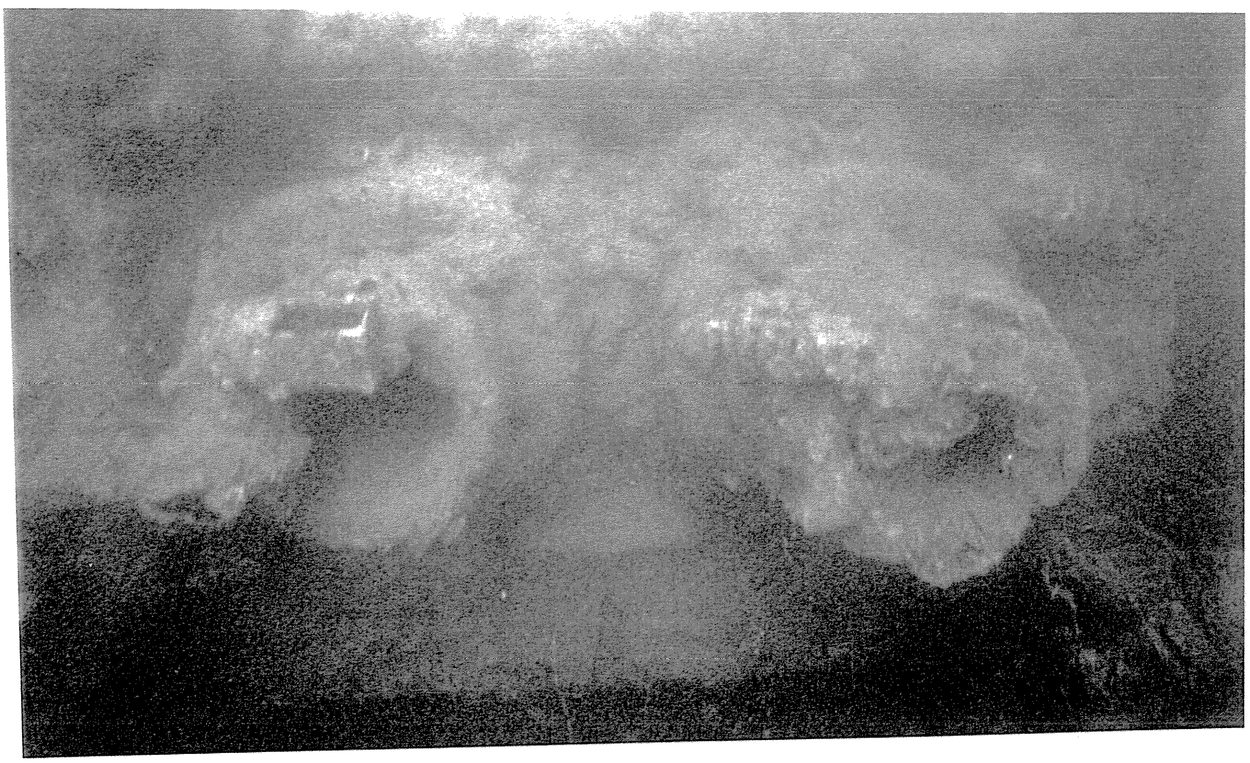


The results are discussed at length in Appendix 7 (Beegle, MacLeod and North 1983). In summary, the trend to more negative corrosion potentials of cast and wrought iron moving from bow to stern indicates a slower corrosion rate. The 168-millivolt difference between the windlass and the trunk is equivalent to the windlass corroding three times faster than the trunk. The 27-millivolt difference between the bow plate and the counter stern means that the former is corroding 20% faster than the latter. Differences in corrosion rate are primarily dependent on the flux of dissolved oxygen to the metal surface. The arrows show the dominant direction of the water flow over the site which indicates that the windlass is in the most exposed environment. This is directly reflected in the voltage of the fitting (MacLeod pers. com.).

In summary, the wreck and its features, including the engine, were actively degrading and were not expected to last intact much more than another half a century (Beegle, MacLeod and North, 1983). The predicted short life of the hull and machinery was a surprise, contra-indicating extensive excavation, for most had assumed that iron wrecks with considerable relief and apparent structural integrity would last for a considerable time even above the sea-bed. Reports on this phase were subsequently published (MacLeod, North and Beagle, 1986; McCarthy, 1986a-c; 1987; 1988a: 339-347; 1989a-c; MacLeod, 1986; 1989a-b; 1992a).

While escorting the conservators around the site, it became apparent that the engine was not, as originally reported by Sledge, lying on its side. This suspicion was confirmed when heavily camouflaged brass oil cups with lids opening upwards towards the surface of the sea were identified. Clearly they would not function on a vertical engine. This was, instead, a horizontal engine. More importantly, two hollow cylinders projected out of the engine block, indicating that the unit was of the trunk engine variety, a favourite with the Royal Navy from the mid-1840's to the mid-1870's, as discussed earlier. Protruding trunks were a feature of this design and were unique to this form of marine engine. They were, in fact, used almost entirely in the naval context (Banbury, 1971:227).

Figure 47a-b: The SS *Xantho* engine on the sea-bed, clearly showing the oil cups and the trunks. Note the concreted boiler tube brushes on the right-hand (aft) trunk. Photographs by M McCarthy.



The following contemporary description provides the rationale for the trunk engine

> The difficulty of obtaining a sufficiently long stroke from a direct-acting horizontal engine in the case of a man-of-war, where the engines had to be placed as near the keel of the ship as possible, was solved by Mr. John Penn of Greenwich. He hinged the connecting rod direct to the centre of the piston by means of a gudgeon, surrounded by a brass cylindrical case or trunk as seen in the following figure. The trunk was fixed to the piston, and protruded from each end of the cylinder through stuffing boxes... (Jamieson, 1897: 214-215).

The only other trunk engine known to be in existence is in the Chilean Monitor *Huascar,* now a museum ship at Talcahuano, Chile (Brouwer, 1985: 35). Though research conducted later confirmed that the *Xantho* engine was referred to in the 1871 Register as a 'horizontal engine' (Figure 35), its identification as one of the rare trunk engine variety came as a complete surprise.

As the pre-disturbance survey continued it became apparent that the engine was even more significant as all its fittings, copper piping, brass taps, cocks, valves and tallow pots were intact, albeit heavily camouflaged. This was unexpected, for every other steamer in shallow water close to a centre of population, like Port Gregory, had long since been stripped of all its brasses and copper-work by salvors and recreational divers.

Alerted by the Museum and MAAWA presence, fishermen and sports divers were showing an unwelcome and renewed interest in the wreck and it was feared they would attempt to recover material as soon as we left. The wreck had not yet been declared historic and the options for its preservation were broadly canvassed. They ranged from not clearing it further of animal growth for recording, to the post-recording removal of items that were attractive to divers, to covering parts of the wreck, especially the engine, with sand and rocks and even to doing nothing.

It was eventually decided to record the engine and other features manually and by photographic means after removing loose sedentary colonising marine life from the concretion layer. This would at least give some record of the still-concreted structure. A covering of rocks placed on the engine, after recording was complete, would serve to further camouflage the engine and other features and would also serve to deter idle looters.

The engine was also found to be functioning as a 'discrete electrochemical entity', electrically isolated from the remains of the hull, including the stern and propeller shaft (MacLeod, 1992a:46). As a result, the possibility of applying anodes to it to render the copper pipes and brasses cathodic was also mooted. It was hoped that this conservation technique would reduce the toxicity of the copper and allow a relatively rapid secondary colonisation by marine organisms after the concreted engine had been examined in detail (North to McCarthy, Expedition Daybook, 9/5/1983:15). This re-growth was considered a priority. The anodes would also begin the process of preservation of the metal itself and should prolong the life of the engine on the sea-bed. The technique was standard practice in underwater environments on working vessels, steel jetty piles, oil rigs and the like, but its application to a shipwreck had still to be tested; though it had been mooted for use at the wreck of the USS *Monitor* (The National Trust for Historic Preservation in the United States, 1978: 99, 123).

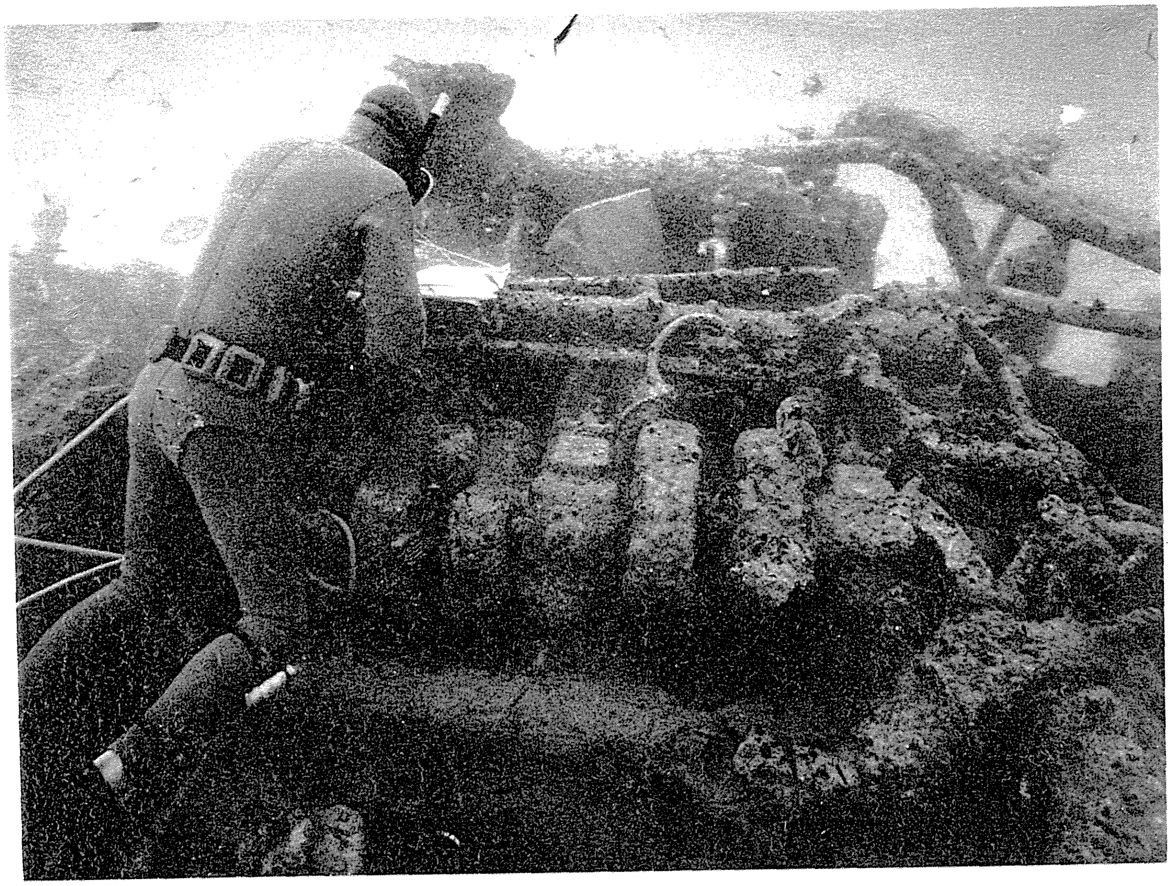
Site Survey and test-excavation

While the three-day pre-disturbance survey was under way, the site survey process was commenced in traditional fashion with the laying of a grid around the exterior of the site. This was constructed using graduated stainless steel wire attached to star pickets (or galvanised steel fence supports) driven at 4 m intervals along each side of the wreck. A plastic tag indicating position along the wire (e.g. 2m, 4m , 8m, 12m, and so on) was placed at each 2m interval. With the grid set and the pre-disturbance survey finished, work began to address the remainder of the aims of the project; i.e., the production of site plans, the excavation of the perimeter of the site and trenches across the wreck at 4 metre intervals; the examination and recording of the machinery, the assessment of the natural forces at work on the wreck and the production of a two-dimensional and three-dimensional photographic record, including a photomosaic.

Each experienced member of staff was allocated one of these aims as their specific responsibility which, in view of the still less than ideal conditions, became their sole task in the remaining ten days of the excavation. Chief assistant Geoff Kimpton spent all this time recording the engine, for example, while another senior diver, a maritime archaeology course graduate Steve Cushanahan, was to produce a site plan. Jill Worsley of the Geraldton MAAWA, was to examine the physical forces at work on the wreck following on from the predictive analysis conducted in the previous year by her husband.

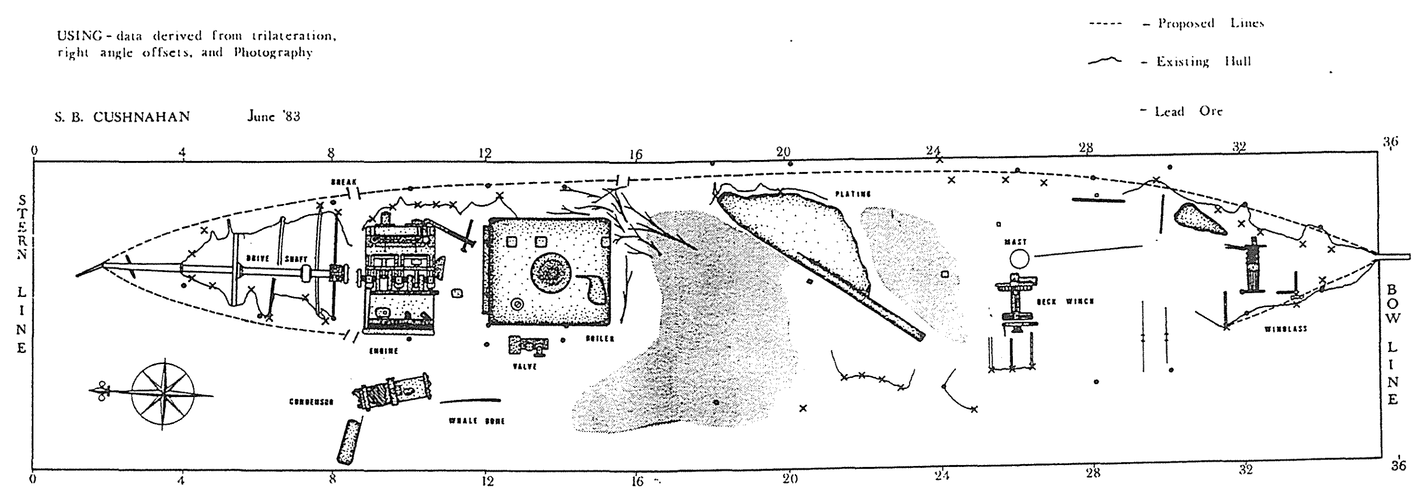
The air supply chosen for this phase was hookah, or compressor-driven surface supply type, which in the shallow waters on the *Xantho* allowed unlimited dive time. Given the strong currents and poor visibility, the hookah hoses also acted as a useful lifeline and recall system. With an unlimited air supply at shallow depth, divers were able to work for four hours or more per day when conditions were favourable. Obviously when conditions deteriorated, the time spent underwater lessened. On some days 20 knot SW winds, moderate seas and a swell added to poor visibility and the strong current on the site. The combination of these factors made conditions for work underwater less than ideal.

Figure 48: Geoff Kimpton recording the *Xantho* engine using manual methods and the hookah system. The crankshaft , oil cups and piping are clearly visible. Photograph by M. McCarthy. The results appear in Figure 74.



Current was by far the most trying factor, negatively affecting diving and making normal anchoring sometimes impossible. The strong current also resulted in equipment loss when gear was not properly secured. Thus visibility on site varied between excellent with half the site visible to very poor; i.e. one metre or less, with water turbulence throwing clouds of sand and weed fragments around the site. Days of strong current were invariably days of moderate to poor visibility with large banks of weed moving throughout the site and especially on tidal change. Though the *Xantho* lies on a sandy bottom, the weed (mainly Poseidonia fragments) reduced visibility and collected on grid wires, tapes and diver's gear. On occasions a cloud of weed would suddenly descend upon the wreck site cutting visibility to less than one metre within only a few minutes. In most cases work would then have to cease until conditions cleared with the turning of the tide. Often the anticipated clearing did not occur. The grid used is shown in the site plan above as the port, starboard, bow and stern lines and lines across the site at 4m intervals (Figure 49, below).

Figure 49: SS *Xantho,* site plan. By Stephen Cushnahan.



When measurements were able to be taken, graduated metric tapes were attached to star pickets marking distance (e.g. 2m, 4m, 12m) along each side of the wreck in a one, two, or three tape configurations. This allowed measuring distance along a marked line or directly across the wreck from picket to picket or by trilateration from two or three fixed positions. Where suitable, tapes could also be stretched from one picket to another and left for continuous monitoring. It was soon evident that masses of weed collected on the wires, tapes and pickets, however. While the stainless wire grid withstood the pressure, tapes could not be left in position for any length of time.

Measurement at times of strong current was precluded due to the catenary or stretching effect on the longer tapes. Retractable builder's tapes proved suitable over short distances, though unless thoroughly cleaned and desalinated at the end of each day they had a very limited life span. Holding cameras and other recording materials steady during adverse conditions was also difficult.

The integrity of the hull was examined at some length as it appeared disarticulated or at best twisted around its longitudinal axis. Builder's levels and steel carpenter's tapes were used to assess this. After lateral and longitudinal measurements were taken at a number of locations it was found that the hull was broken in three places. Under the engine the hull drops 3° towards the stern and inclines 8° to starboard. Aft of the engine, it drops 11° towards the stern. Resulting forces appeared to have caused the propeller shaft to break away from the engine at its coupling with the thrust block. By contrast, the boiler forward of the engine drops 8-9° towards the bow and is inclined 6° to starboard. Forward of the boiler and on its starboard side there is a significant scour pit which has exposed the bottom of the boiler and its wooden bearers. Measurement of a wooden deck stanchion (or mast section found) forward of the boiler indicates a lean to starboard of 14° in the fore part of the ship.

The wreck therefore, appears to have broken into four parts. One section is that aft of the engine, broken under its coupling with the propeller shaft. Another appears to be that section of hull under the engine itself. Both of these lie on an angle to starboard and have adopted an angle down towards the stern. The rest of the hull, from the boiler forward, slopes down towards the bow and is also in two parts. The section of hull on which the boiler rests, and the majority of the hull forward of the boiler, is also leaning to starboard on the sea-bed, itself sloping from port to starboard. All bar a few unsupported parts of the hull have collapsed downhill to starboard in the direction of the prevailing current and not to port in the direction of the seas and swell.

Though broken into four sections, each has moved only centimetres apart, thus remaining in close proximity to other sections. The hull therefore could be recorded as a single unit.

Test-Excavation Method

The sampling method employed for testing the wreck was based initially on a visual examination of the exposed surface remains and then by the examination of buried deposits after conducting an initial test trench. The test trenches were excavated along the length of the ship outside the hull, across the site at the bow and stern, and then through the hull at four-metre intervals. This particular sampling technique is cognisant of both the disintegration processes that often result in the spread of artefactual material outside of the hull remains as the wreck collapses or opens up, and of the traditional compartmentalisation of shipboard activity.

On iron sailing ships and early steamers, officers were usually housed aft and the crew forward in the forecastle, as also appears to be the case with the *Xantho*. (See, for example, Evidence at the Court of Enquiry into the loss of *Xantho* on page 152). The quarters of the officers, passengers and crew in a large ship are usually separate compartments. The separation was an almost rigid feature of shipboard life based on centuries of European seafaring tradition. The boundaries are usually crossed where officers and/or passengers require service, where work is to be performed, or by invitation to functions. On smaller ships, officers and passengers would dine together. Even more rigid conventions are seen on large naval vessels where entire classes of sailors ate and lived in separate compartments and where a ship's master could have completely separate accommodation, eating alone and served by a personal steward.

Accommodation, machinery and cargo spaces themselves are also discrete, specific-purpose compartments within a ship. These are separated by barriers deliberately designed to minimise unauthorised or unwanted access by people or materials, especially noxious engine wastes and sea-water. Though the movement of water through a wreck and the collapse of decks down onto lower ones can markedly affect this compartmentalisation, the artefact distribution and structural remains can reflect specific uses or classes of activities. With iron and steamship wrecks an opportunity emerges to structure research design around this element, enabling the researcher to target specific areas, leaving others untouched. Where structural elements such as bulkheads, decks or other features still exist, an excavation of one discrete area need not necessarily impinge on another. Area excavation, once the norm in Western Australia, is not necessary, nor should it be considered a valid procedure on large, compartmentalised iron or steel wrecks.

The excavation tool used on *Xantho* was a water-dredge, an excavating system common to most underwater archaeological work. It operates on the venturi principle and relies on high-pressure water being forced through a small diameter opening at an angle past a much larger pipe, thus creating a suction at its entrance (Green, 1990:135-137). On *Xantho*, high pressure water was produced from an eleven kilowatt petrol engine driving a common fire pump, delivering 500 litres per minute at a pressure of 700 kilopascals. With a total weight of 91 kg, the unit was portable and took up relatively little space on the expedition's work boat. A 100-mm diameter fire hose supplied water to the dredge below. The dredge itself was constructed from a five-metre length of 125-mm PVC sewer piping. A five metre length of clear flexible pipe was mounted to the intake, giving greater mobility and enabling blockages to be monitored and to be removed. The excavated overburden was ejected from the water dredge on the downstream side of the wreck and was taken away by the currents.

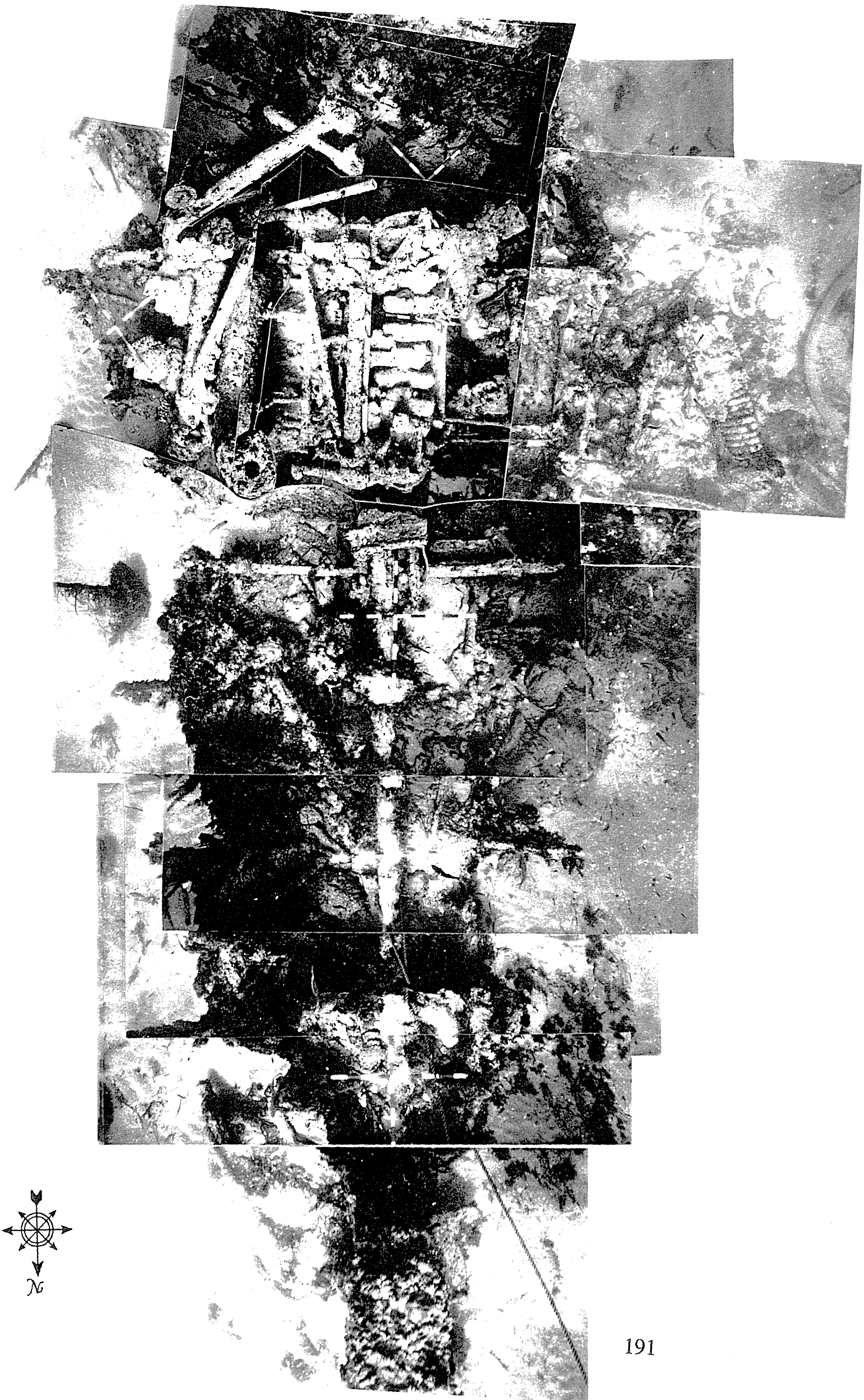
In this particular phase, overburden was removed from defined areas. Initially this comprised a one-metre wide trench along the survey lines delineating the site (Figure 49). The sensitivity of the dredge depends on both proximity of the dredge inlet to the seabed and the occlusion, or otherwise, of the inlet by the operator's hand. Where little sensitivity is required the inlet is fully opened and applied directly to the overburden, which is then sucked away in considerable quantities and with considerable force. Where sensitivity is required, the inlet is partly closed, or more frequently is positioned away from the excavation surface. Material was often exposed by 'hand fanning', with the dredge used to remove only the suspended particles in the water column. Once a section was exposed to the depth required, it was possible to proceed along the trench, allowing material to be first exposed and then carefully removed. Where excavation was conducted through a layer of mobile sand and loose clay, the customary backfilling of trenches after excavation and recording was not necessary due to the rapid ingress of sand. This was of such a speed that within a few hours after excavation the trenches were again filled. All visible indications that an excavation had taken place disappeared overnight, such was the mobility of the sea-bed in the prevailing current. Recovered artefacts recovered were recorded *in-situ*, tagged and handled in the accepted manner before being raised for cataloguing, on-site conservation and further recording.

Results of the site survey and test excavation.

As indicated, the aims of the 1983 season were to examine the site and the forces acting on it, to conduct a sea-bed survey, assess and report on site conditions, comment on the most appropriate excavation procedures, comment on the research potential of the hull, propulsion system and cargo remains, conduct sampling trenches and recover and conserve those surface artefacts found in a salvage archaeological context. I also aimed to record the propulsion system, conduct a pre-disturbance survey and report on the problems and methods of effectively recording a site such as *Xantho* which had substantial relief. All these purely descriptive aims were satisfactorily addressed in 1983.

The drawing, measurement and inspection of the hull, boiler, engine, drive shaft windlass, deck winch and other machinery were successfully completed. A site plan was produced by trilateration and by taking of right-angle offsets (Figure 49). Standard three-dimensional photographic techniques, allowing the relief of wreck to be viewed in the laboratory, were also successfully applied, though the relief of the wreck posed considerable problems. Common two-camera or stereo overlap photogrammetric techniques, or manual three-dimensional methods were suitable. Due to their sheer size and dominant nature the engine, boiler, stern and stem of the *Xantho* proved problematic, however. Eventually a combination of manual recording and photographic methods was applied resulting in a plan of the wreck, a plan view photomosaic of the stern section, a port elevation photomosaic of the entire site, a manually recorded three-dimensional drawing of the engine and other machinery and two-dimensional and three-dimensional photography throughout, including the engine.

Figure 50: A photomosaic of the stern section. By J. Buchanan and M. McCarthy. The scale is one metre in length



Photomosaics provide not only single photographic illustrations of a large section of the site, but are also a reference allowing post- and pre-disturbance comparisons. Figure 50 above, shows from top to bottom, the edge of the boiler, the main steam pipe to the engine, the engine and its trunks, a condenser(?) to starboard, the thrust block and stern shaft.

The test excavation along the perimeter of the site, and across it at four-metre intervals, indicated a one-metre thick mobile sea-floor of soft sand overlaying a thin band of hard clay, which in turn overlaid a thick weed mat on a sand bottom. The latter proved almost impossible to penetrate and no further attempts were made to examine the deposits below it. Excavations in only one area, the region abaft of the boiler produced artefacts in any quantity.

The plan view of the site (Figures 49 and 80) show the vessel has opened out down current and this is highlighted by the spread of lead ore and the presence of machinery outside the remains of the hull to starboard. The ore provides a near impenetrable and clearly protective mass for material and structure lying below. The presence of an almost-impenetrable weed mat below the mobile layer of sand leads to the conclusion that the wreck forms a barrier to the movement of weed in the current. Consequently, weed would have quickly filled the spaces inside the vessel and under the hull. Mobile sand would have helped compact this deposited weed and, as a result, preserved material could be expected to lie buried beneath it.

No artefacts were seen on the surface. Excavations along the perimeter of the wreck on both sides and through the bow and stern compartments also revealed few artefacts. In total, thirty-five items were located and raised, to add to the six artefacts raised on the 1979 inspection.

The artefacts are listed in the artefact catalogue in Appendix 7. In general, they can be categorised as material common to nineteenth-century European seaborne life, such as ship's fittings, cargo items, personal items (such as the sole of a shoe) and glass and ceramics from the galley or cargo. At variance from items usually recovered from wooden hulled wrecks were iron hull fragments and a boiler water gauge glass. Evidence of site contamination was noted deep in the mobile sand layer in the form of modern material, such as light globe fragments and a motor vehicle oil filter.[1] A coconut husk and whalebone may represent contamination from Port Gregory's early days as a whaling station (Trenaman, 1934; Heppingstone, nd.), or simply reflect galley supplies and cargo from Broadhurst's activities further north. The lead ore and some of the bagging in which it was stowed was still visible in the cargo-hold forward of the boiler and samples of both were recovered. Rough cut branches were found throughout the cargo spaces, possibly representing the dunnage (or softeners on which cargo was laid to prevent damage to the vessel's hull) mentioned in the Court of Enquiry into the loss of the ship.

No evidence was found of the compartmentalisation of the ship into two accommodation areas. The forecastle, traditionally the crew's quarters, was not closely examined or excavated, partly due to the weed mat. An accommodation section above the engine (which had collapsed down onto the machinery) was indicated by material later found in the engine spaces consistent with those activities. These included a salt cellar (XA 115).

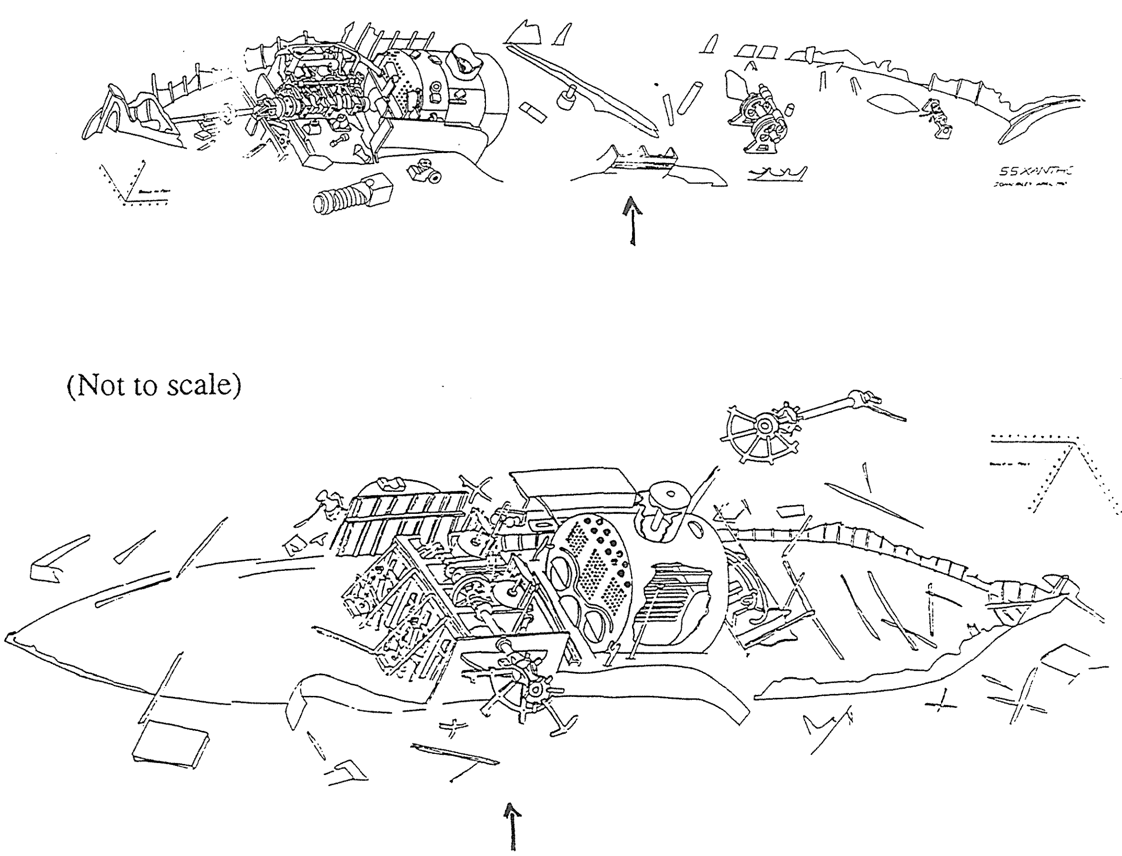
Sections of the hull have considerable relief, especially the bow and stern sections, or triangles. Much of the hull has collapsed, however, and missing sections of the port side of the vessel appear to have collapsed into the ship. In contrast, with the exception of a small section of the hull near the stern and just forward of the boiler, the entire starboard side has

[1] Electric light was yet to become a feature of such vessels and oil burning lamps were used. The saloon of the Inman liner *City of Berlin* was lit by electricity in 1879 and represents one of the first instances of the use of that technology (Smith, 1937: 229).

collapsed outwards and down-current. It too has disintegrated in all but the stern section.

The inner and aft walls of a coal bunker were located on the starboard side of the boiler and a heavily built section consisting of a small number of heavily built hull frames was also noted just forward of the boiler on the starboard side. This proved to be the support for the starboard sponson that held the bearing of the starboard paddle wheel. The sponson also served to transmit the thrust of the paddle to the hull and needed to be stronger and thicker than the surrounding frames and hull plates (See Figure 51).

Figure 51: Isometric projections of the SS *Xantho* and the PS *Commodore* by John Riley, with the paddle sponsons highlighted. The coal-bunker on *Xantho* is also shown on the starboard side of the boiler. The isometric projections represent an idealised view in a concretion-free state (Riley, 1988a: 194).

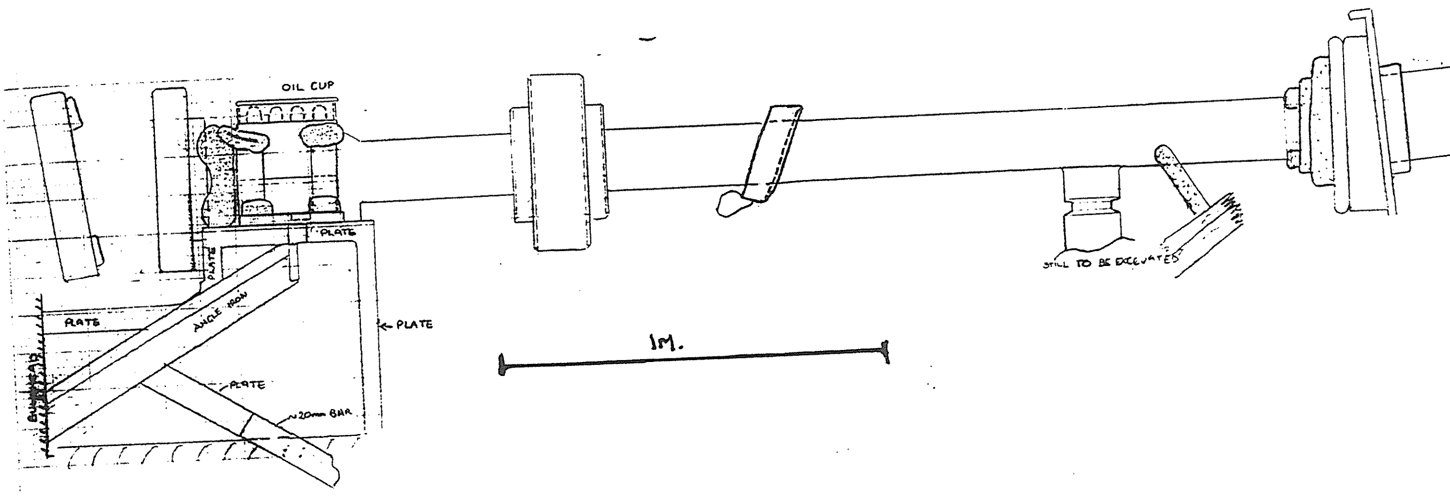


In contrast to expectations, the *Xantho* hull was fragile above the sea-bed. Corrosion also appeared to be continuing within covering concretions. In the mid 1980s, it was generally considered that where iron hulls are buried and covered in concretion, they are strong and likely to last indefinitely unless exposed to excessive physical forces. It was estimated that the remaining hull was buried to a depth of a least 1.5 to 2 metres forward and slightly less aft.

It soon became evident that the boiler and machinery were the most intact part of the vessel. The engine was identified as a small, simple expansion horizontal trunk engine, but it required considerably more research in order to identify its type conclusively. Being of a type normally found in a naval context, its presence on the *Xantho* also required some explanation. Like the remainder of the site it proved difficult to record in the conditions and under its thick layer of concretion. On the positive side, the engine appeared to be supported on a system of lateral iron bearers that served to keep it above the floor of the engine room, and in this instance clear of the sand inside the vessel's hold. This allowed access to most of its features, including those on its undersurface.

The 16-cm in diameter propeller shaft extended from the thrust block to the propeller for a distance of 5.5 m. What appeared to be a dog-clutch or disconnecting device appeared on the shaft, though it proved difficult to confirm due to concretion. The shaft was supported in three places on thrust block bearers, on one separate stool and by the stern tube itself (Figure 52). An examination of the shaft, bearings, stern tube and propeller details was not made in detail due to concretion. The thrust block did appear similar, however, to that referred to by contemporary engineers as a common small thrust block (Jamieson, 1897: 286). This type had wick lubricators to each collar, each positioned on an open oil box which was mounted on top of the thrust block.

Figure 52: A working drawing of the propeller shaft, showing from left to right, the flanges coupling the shaft to the engine, the thrust block and its bearers, the 'dog-clutch, a stool or plummer block and the beginnings of the stern tube. By John Moffett. (See Figures 18 and 19 for comparison).

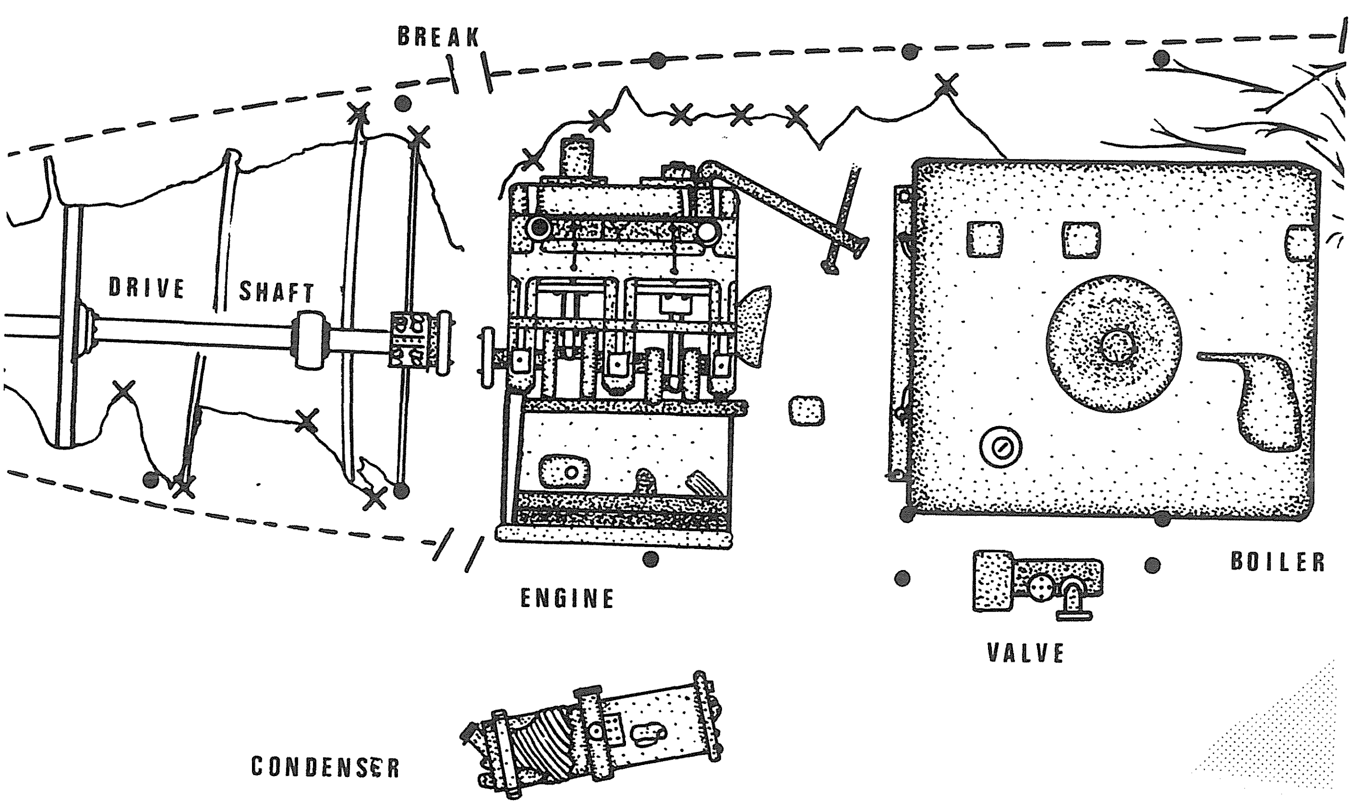


The propeller was an iron screw of approximately 1.8 metres (6 ft) diameter, situated inside a stern aperture constructed, as usual, forward of the stern post. Only one blade was visible. Detailed measurements of size and pitch were prevented by the sand build-up and strong currents which prevented accurate usage of a plumb-bob.

The single-ended, two-furnaced, return tube boiler measured 3.2 metres (10.5 feet) in length by 2.2 metres (7.2 feet) in diameter. It appeared to have a slightly elliptical shape. Both the furnace doors were shut, precluding an inspection of the interior. An aperture on the upper surface of the boiler appeared to be for a steam dome or for a relief valve. A number of concreted and heavily camouflaged brass fittings were noted on the forward face. These were left undisturbed. A large unidentified valve, probably a relief valve, which appears to have been knocked off the boiler, was noted lying on the sea-bed on the starboard side.

Also lying to starboard of the engine, and apparently having fallen from a position on the starboard hull in the engine-room, was what appeared to be a condenser. As indicated in the section on marine engineering earlier, condensers were used to re-cycle expended steam. Its presence was expected on the *Xantho*. Its form in this instance was a puzzle, however, and no driving-rods connecting it to the engine were found.

Figure 53: The condenser (?) and boiler valve on the starboard side of the wreck.[1] By S. Cushnahan.



The application of anodes to the engine and stern shaft

It soon became apparent that the engine and the ship were of considerable regional importance. The engine was an uncommon type, it was physically degrading and was also in danger from recreational divers.

---

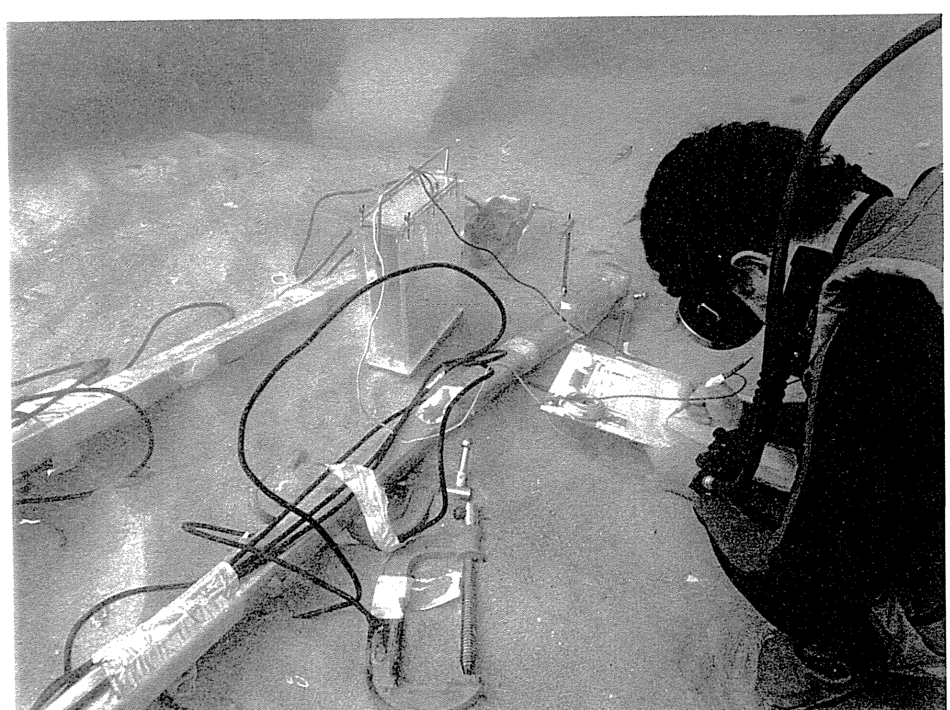
[1]The condenser was later identified as a feed-water heater.

It clearly needed some form of protection. Conservator North's proposal to experiment with anodes and cover the engine with rocks was adopted after some discussion. In his instructions for the application of the anodes North, wrote

> The engine of the *Xantho* is in surprisingly good condition considering its age, the presence of many galvanic couples and the underwater environment. The attachment of sacrificial anodes, in May 1983, will prevent any further decay and should actually start in the preservation treatment by encouraging the release of chloride salts from the corrosion products (North to McCarthy, May 1983, SS *Xantho* file, 9/79).

The anodes were subsequently attached to a counterweight on the crankshaft and to the propeller shaft aft of the thrust block. A circuit was made by winding down a pointed screw, held in a bracelet, through the concretion to the original metal.

Figure 54: The anodes before being attached to the vessel.
Photograph by J. Carpenter.



After the anodes were attached to the engine, it was covered with rocks obtained from a nearby creek bed. After the removal of all grid wires, and other equipment, bar a small number of pickets at each extremity, the site was closed.

In the process of this first study, 200 operator-hours had been spent underwater over a total of 76 operator-days worked on the ten-day expedition (including travel).[1]

An analysis of the natural site formation processes at *Xantho*

During the May 1983 season, natural processes contributing to site-disintegration were monitored and the data was compiled and assessed by Jill Worsley of the Geraldton MAAWA (SS *Xantho* file, 9/79). A brief discussion of her conclusion that land form, swell, current, weed, tide and wind were the main visible forces follows.

The land form at the wrecksite, combined with ambient weather conditions, such as south-west winds and swell crashing over the southern part of the barrier reef, cause a fast current to run up the natural channel between the reef and the shore.

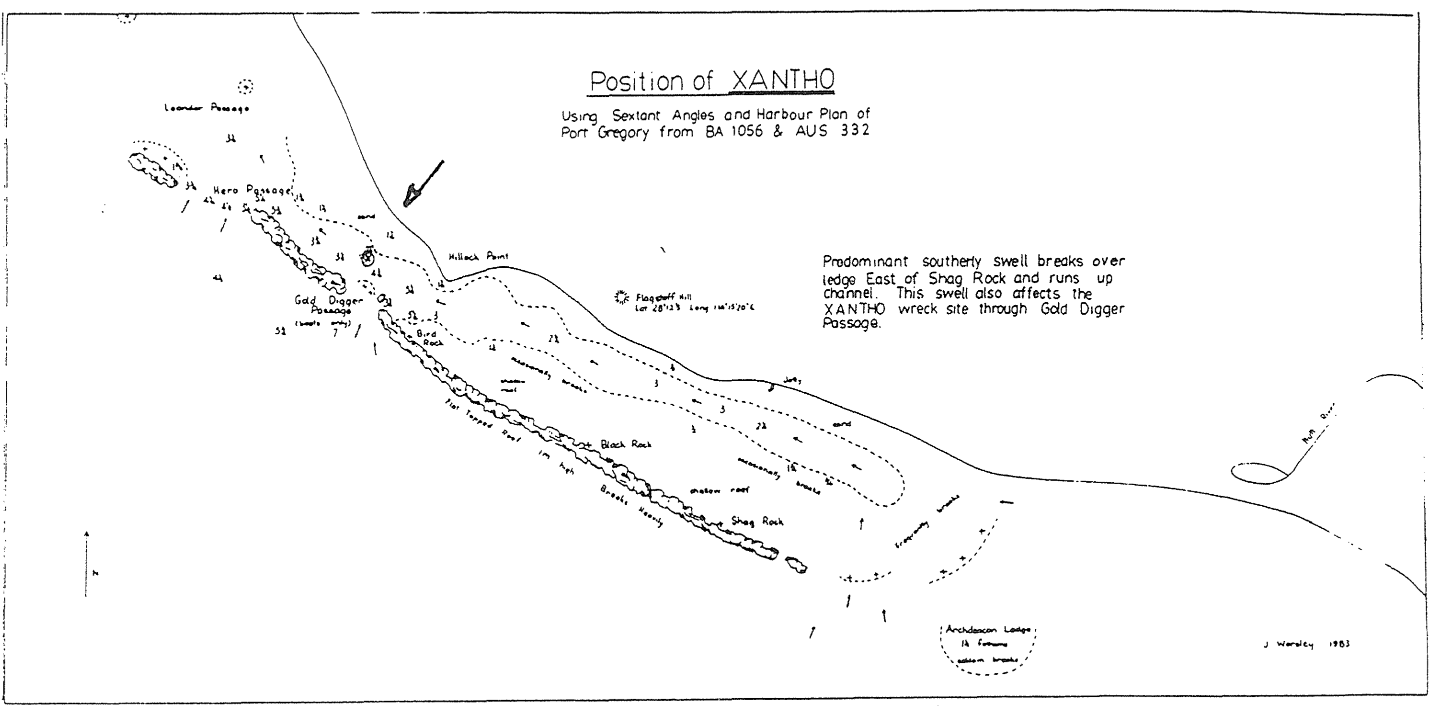
The prevailing swell has two main effects on the *Xantho* site; one generating a current travelling up the reef system and out over the *Xantho* site from the port to the starboard quarters, the other refracting around reefs into Gold Digger Passage which lies opposite the site. This impinges at right angles to the starboard side of the wreck. There are sufficient gaps in the reef, opposite and to the north of the wreck to allow

[1]The 1983 team had been reasonably small consisting of a small full time core comprising chief assistant, ex oil-industry diver and museum boat skipper and diver, Geoff Kimpton, Steve Cushnahan, a maritime archaeology course graduate, Jill and Peter Worsley of the Geraldton MAAWA, Bob Richards, a departmental diver/skipper and myself.
Part-time assistance was rendered by 11 people including Brian Marfleet of the South Australian equivalent of MAAWA, Conservators, Neil North, CJ Beegle and Ian MacLeod. Scott Sledge and his wreck inspection team joined us *en route* an inspection tour for the second half of the season at the site.

the swell to impact on the *Xantho* site in all conditions except an offshore breeze.

The tides are diurnal and in the order of up to one metre maximum, having a direct influence on current and weed banks. The current was strongest just after high tide, and then for an hour or more after (Figure 56).

Figure 55: The position of the SS *Xantho* at Port Gregory, showing prevailing forces. By Jill Worsley, MAAWA.



It appears then that the major sea-borne effects at the *Xantho* site are seas and swell pushing in from the south-west into shallow water, and a current running from south-east to north-west across the wreck, often in excess of 3 knots. These combine to produce both strong lateral forces on the wreck, one a steady current across the site from the port bow to the stern aft and the other a pulsating wave and swell action at right angles from starboard to port. These forces also had an effect on the sea-bed around the site.

An early account of the magnitude of these forces in the same locality comes from the experiences of those aboard the American whale ship *Iris* which was nearly wrecked at Port Gregory in the winter of 1855 (Totty, 1979:111-112)

> A gale started to blow hard from the north. During it, a strong current swept the *Iris* out towards the open sea stern first, against the wind. Captain Davok had three anchors out, one of which became fouled up with a government mooring buoy. They were all swept away together. ...the anchors seemed to drift faster than as the vessel as if the whole bottom of the anchorage lifted bodily four ways (*Inquirer*, 11/7/1855).

The position of the *Xantho* in the current and across the direction of the prevailing seas and swell, may also have had a localised effect in causing the movement of the sand-bar out to the wreck which was noted by Commander Archdeacon. The resultant accretion of sand around and under the wreck would have continued over the years, producing additional forces on the site as the sand itself moved. This appears to have caused the wreck to break up into four parts, as described earlier.

When these forces are combined with on-going corrosion processes, they are likely to have been sufficient to have caused the rapid disintegration of the hull. It is also possible that loose material left in the hull, after it was opened up by the seas, would have been swept off the site or buried under the hull on the downstream side.

CHAPTER 6:

THE *XANTHO* SITE FORMATION MODEL

Introduction

Before attempting to account for the anomalous features of the *Xantho* site, this chapter aims, firstly, to consider the effects of transformation processes acting on iron and steamship wrecks, generally. This attempt to control for (properly account for) post-depositional process will examine iron and steamship wrecks as a class of similar sites and formulate statements which will make an analysis of individual remains at *Xantho* more valid. These are necessary steps, for as Gould (1990: 48) has noted

> In looking at general relationships between behaviour and material residues, the first thing to consider is the total ecosystem in which this behaviour takes place.

Attempts to control for post-depositional processes in maritime archaeology represent an extension of work by Muckelroy, who attempted to identify features common to all shipwrecks, including disintegration processes. He noted, for example, that

> The phenomenon of the shipwreck must involve certain regular features common to all instances. If these can be described, then their implications for any analysis of sea-bed remains can be ascertained...The validity of any conclusions reached in maritime archaeology depends fundamentally on the understanding of these processes....(1978:157).

Muckelroy examined the general processes which lead to the disintegration of a wreck and the movement of artefactual and other material from, and around, the site. The identification and description of these processes could 'amplify the evidence regarding the ship itself' (Muckelroy, 1978: 167) and were labelled 'extracting filters'. They include, the process of wrecking, salvage operations and the disintegration of perishables.

In identifying the three process above, Muckelroy noted that (a) unless the hull is pinned down by the weight of cargo, fittings or other objects, it will float away in the process of wrecking; (b) where people are present or in transit, some salvage of accessible sites is to be assumed; and (c), most 'perishables' on the site will disintegrate (Muckelroy, 1978: 167).

Post-depositional processes and the iron wreck

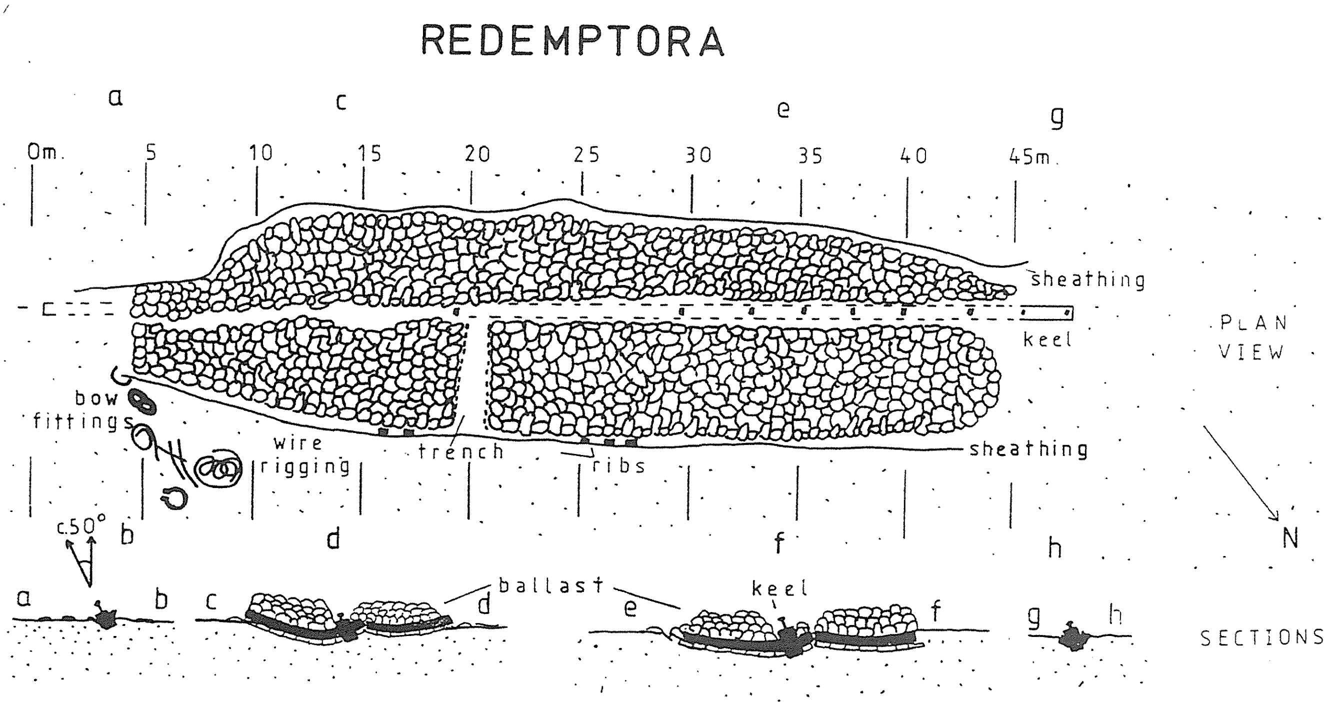
In contrast to Muckelroy's first example, it would be noted that iron or steel vessels, unless they contain a very buoyant cargo, or large airtight spaces, will usually sink straight to the bottom once they are substantially holed. With respect to derelict or floating, yet abandoned hulks, the following has long since been noted

> Steel ships that have been abandoned by their crews usually sink to the bottom of the ocean within a few hours at the most, but a wooden vessel, especially when carrying a buoyant cargo such as timber, will remain afloat for months, possibly years...(Rogers, 1945: 10).

Where an iron or steel shipwreck lies in deep water it will remain virtually as it came to rest on the sea-bed, until the sea and corrosion processes destroy it. Until the hull is broached the artefacts within it will remain there, albeit in a confused form. When the hull is broached then they may spill out or collapse down through the decks, though often they will remain *in situ,* cemented as a result of their often rapid encapsulation in concretion (cf. North, 1976).

Sections of 19th century iron or steel hulls are often found with considerable relief, even in shallow water. This feature, common to many iron and steamship wrecks today, represented an acknowledged departure from the usual situation at 19th century wooden-hulled sites in high-energy waters. In the case of wooden vessels, though they are occasionally exposed due to sea-bed movement, the hull is normally found buried beneath ballast, sediments, cargo, or similar protective materials. Though there are notable exceptions, relief above the sea-bed is usually minimal. One example is the wreck of the 1235 ton wooden-hulled ship *Redemptora* (1853-1888), shown in Figure 56a buried in ballast.

Figure 56a: The hull of the wooden-hulled, ship-rigged *Redemptora*, beneath a protective mound of ballast. Four sections through the remains are also shown. By the author, from McCarthy (1981a: 239-252).



The projected process of disintegration of such sites is illustrated using the case of one particular wooden wreck, believed to be the 318 ton brig *Gemma* (1868-1893). This site was found buried in sediments, near the *Redemptora*, but with only a series of iron knees visible. In this instance an iron knee midships is used to follow the collapse of the wreck onto the sea-bed.

Figure 56b: A plan view of a wreck believed to be the wooden-hulled brig *Gemma*. Five test-excavations are shown, together with three sections through the remains (A-B, C-D, E-F). By the author, from McCarthy, 1983b: 242-252).

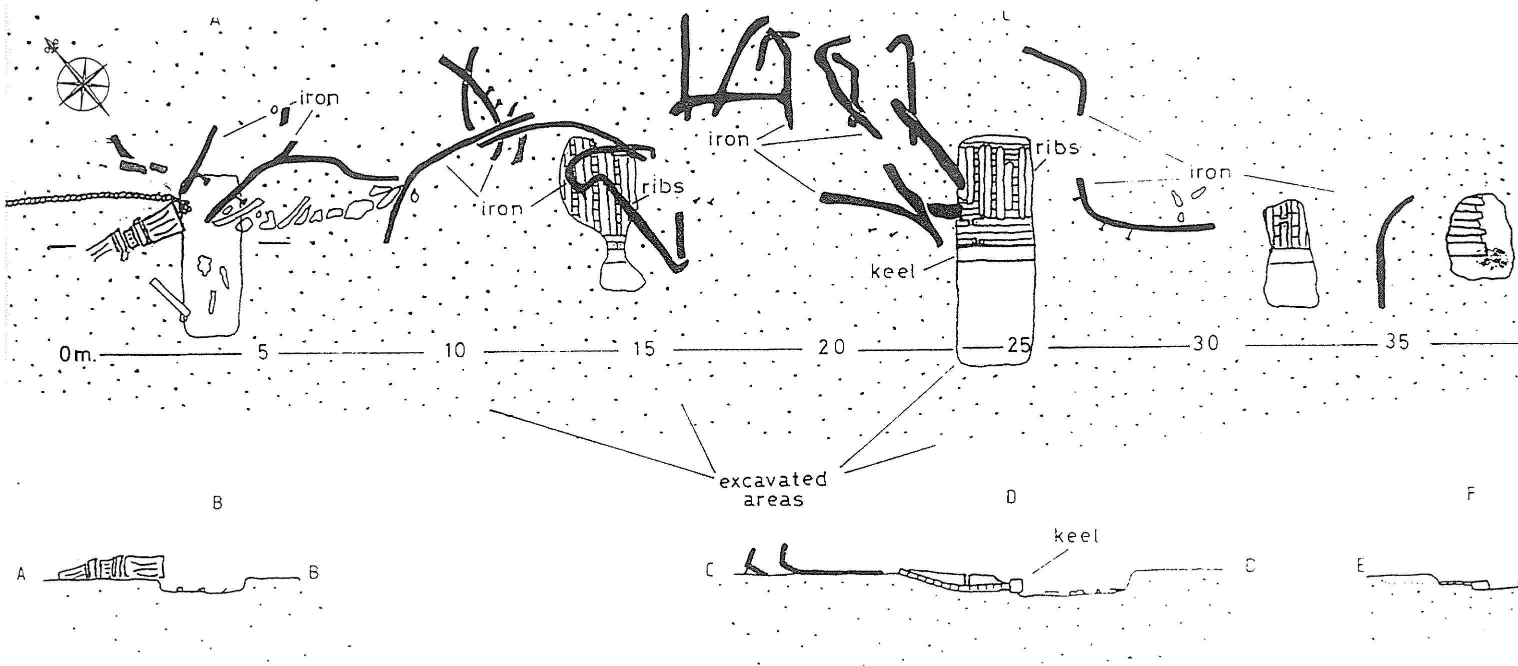
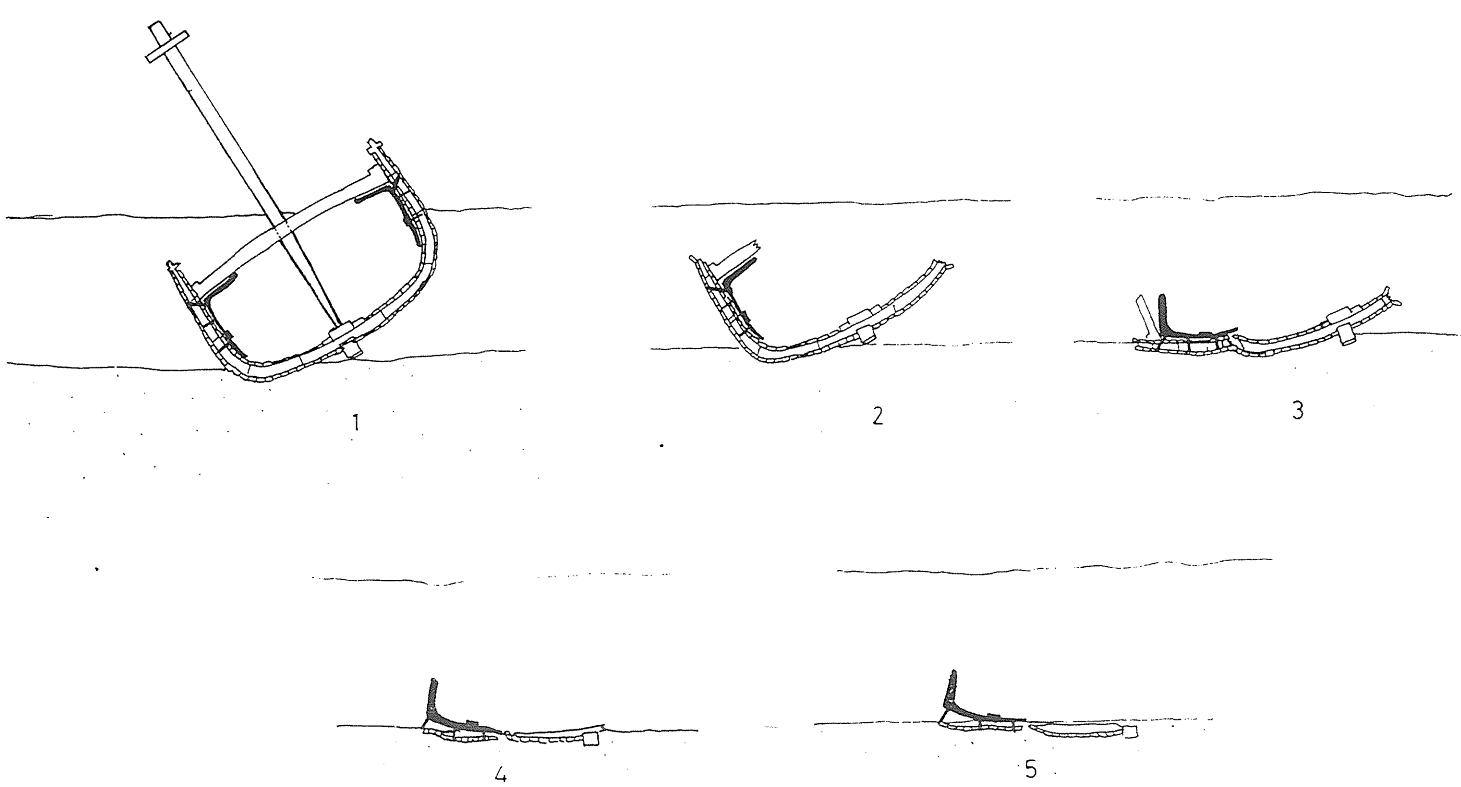


Figure 56c: The proposed stages of disintegration of the *Gemma* wreck using the section through points C-D and an iron knee as the focus. By the author.



In shallow waters and in very violent conditions, wave action can also destroy an iron or steel hull in a very short time and can move entire parts of the ship, including boilers and hull considerable distances from the parent wreck (See Figures 65 and 66 below, for example). Muckelroy identified these phenomena in general terms, as 'scrambling devices', or factors which served to rearrange the elements of the vessel and to alter the ship after it is wrecked.[1]

A wooden- or iron-hulled ship, afloat or sailing on the surface, is transformed from a highly organised unit whose constituent parts are arranged so as to ensure desirable qualities, including efficient cargo stowage, seaworthiness and ease of handling into one, which at best, has some semblance of order on the sea-bed. Elements such as the nature and topography of the sea-bed, the type of hull, its integrity at the moment of sinking, the type and weight of cargo and/or ballast carried are of relevance in that process.

The effect of corrosion and concretion

With reference to corrosion (one of the major scrambling effects) Muckelroy noted (1978: 167) that it can vary across short distances over a site, depending on sea-bed type, marine growths, the presence of dissimilar metals and other chemical and electrical phenomena. The *Xantho* study allows us to quantify these complex processes for the first time.

Concretion is also a considerably complex phenomenon, appearing on most metallic surfaces underwater, especially where the water is

---

[1] Muckelroys' distillation of wreck-site formation processes into 'extracting filters' or 'scrambling devices' is useful, for though the choice of phraseology could cause semantic debate, invariably any other choice of words in turn is eventually brought into question. The term 'maritime archaeology' itself, for example, can be seen to have unfortunate connotations for those who profess to be purely 'nautical archaeologists' or 'shipwreck archaeologists'; a debate which Muckelroy himself foreshadows (1978: 1-23). Quite recently the term 'hydroarchaeology' was coined for underwater archaeology in general, adding further to the possibilities and to the scope for semantic debate (Fenwick, 1993: 1). Few will find the term attractive, however logical it may appear.

comparatively warm and the wreck and its contents lie in a predominantly aerobic environment. Once it was believed that the concretion protected iron from further corrosion, as the following comment shows

> Iron corrodes in the presence of both oxygen and water and on the sea-bed this is usually a relatively slow process, particularly as iron objects often soon become covered with a concretion of calcium carbonate and iron compounds which protects the iron from further corrosion (Oddy, 1975:367).

Oddy was writing before the first major study on shipwreck concretion was conducted (North, 1976: 253-258). North found that concretions were formed within the first few months of wrecking initially from coralline algae which, unlike soft algaes, had a partial exoskeleton of calcium carbonate (CaCO3). This concretion formed on a thin layer on stationary and biologically non-toxic material, such as iron. As the coralline algae died their exoskeletons remained and were subsequently overlaid by later growths of the same substance. These build-ups merge progressively with adjacent objects, often forming a large mass on which a secondary growth of seaweed, soft corals, molluscs and other biota occurs. The rough outer surface of the concretion provides a trap for sand particles, coral fragments and other debris being moved around the site. Material can become completely covered with coralline algae and secondary growths within about 12 months. It was also found that though the concretions found on iron were externally indistinguishable from those formed on natural materials, they formed a layer of low porosity on the surface of the iron which retarded the movement of corrosion products away and resulted in the production of an acidic iron rich solution. These chloride concentrations can rise by a factor of three and the pH can drop from around 8.2 to 4.2, thereby increasing acidity considerably (North, 1976: 253-258).

Comments on the complex corrosion and concretion processes operating at sites such as the USS *Arizona* in Pearl Harbour, Hawaii, highlight the need to involve the appropriate specialists on archaeological sites. The anthropologist Larry Murphy has noted, for example, that

> Experience with materials from historical marine shipwrecks indicates that most ferrous materials are protected from continual corrosion by the formation of encrustation, a complex interaction of chemical and biological processes. Encrustation substantially reduces or stops active corrosion (Murphy, 1987:57).

We now know that corrosion can continue, though it is most often at a reduced rate, within layers of concretion. It can do so until the last of the oxygen bound in the form H_2O is consumed and hydrogen is given off. This leaves, in most cases, nothing of the original iron after a few hundred years. We also now know that the process is not uniform across a site and that it is affected by a large number of variables. At the *Xantho,* for example, the conservators showed that corrosion was not proceeding at a uniform rate, and that it was continuing, even in an anaerobic environment under the concretions. Apparently intact, heavily concreted iron structures were shown to be merely hollow shells, for example.

It could be claimed that we should have been well aware of these possibilities, even before North's study. The excavators of the seventh century wreck at Yassi Ada, for example, examined the encrusted remains of around 150 iron objects. They found that the iron had completely corroded away (Van Doorninck, 1972:156-7).

North and MacLeod also found iron and copper sulphides in the concretion matrices examined at the *Xantho* site. These indicated biological action by sulphate-reducing bacteria which were in the process of rendering sulphates to sulphides within some concretions. In finding evidence for the bacteria at work during some of the excavation phases, they were able to conclude that corrosion was also continuing in the sediments in which the vessel was buried (MacLeod, pers. com.). This is an important issue, for it was once believed that iron hulls buried in sediment would be relatively well preserved. Again this could reasonably be inferred from earlier excavations, such as the wooden-hulled *Wasa* (1628) where it was noted that the wrought iron fastenings had suffered heavy corrosion (Barkman, 1977:127). Of a total of 800 iron objects recovered from the previously buried ship, those of cast iron were often corroded right through. Even the bolts that modern divers placed into the hull of the *Wasa* to replace those lost prior to its being raised, were rapidly attacked by corrosion. One was reduced to a third of its original diameter within a short time (Arrhenius, Barkman and Sjostrand, 1973:14-16). These findings have obvious ramifications for both archaeologists and conservators.

Despite these well-published findings, it was believed until recently that burial in sediments would assist the preservation of iron hulls in a stable anaerobic environment. The following statement was made following visual observations at the *Monitor* in the period up to 1986. The comments could be correct, but in awaiting analysis by appropriate microbiologists, they are an example of the dangers of purely visual observation by archaeologists

> Examination of the iron armour and lower hull plating confirmed that the interface between plates and fastenings had deteriorated through electrochemical galvanic action...While this deterioration will probably prove to be significantly less where the wreck has been protected by the accumulation of sediment, areas exposed to the water column have deteriorated extensively (Watts, 1987:136-7).

That is not to imply that some degree of protection might not occur as a result of sedimentation processes, but rather to acknowledge that protection will not necessarily result from burial in sea-bed sediments.

Microbiological corrosion is a process defined as '...the deterioration of metal by corrosion processes which occur, either directly or indirectly, as a result of the metabolic activity of micro-organisms' (Evans, 1973:469). It is not always a visible phenomenon; a factor that has considerable ramifications for the archaeologist, as the following comment shows

> Iron can corrode rapidly in the absence of oxygen if sulfate-reducing bacteria are present. These bacteria are commonly found in deep wells, in soils, and in seawater. The bacteria by their metabolic processes, reduce dissolved sulfates to sulfides in the course of which they are able to depolarize cathodic areas of iron. Corrosion thereupon, proceeds as rapidly as bacterial action permits. Galvanized pipe carrying cold water has failed from this source within two years time (Uhlig, 1948:126).

These bacteria can be categorised as either aerobic or anaerobic micro-organisms, depending on their viability in relatively high or virtually zero oxygen levels. Both types require organic and inorganic chemical compounds from which to obtain oxygen, carbon, nitrogen, hydrogen or sulphur. Other factors such as pH, oxygen concentration and temperature are also crucial to their growth.

The implications of the presence of sulphate-reducing bacteria, for the survival of iron are profound. It was shown nearly a half century ago, for example, that even non-corrosive, washed silica sands can be rendered corrosive by the combination of environmental factors. That is corrosion can and does occur beneath an apparently sterile sea-bed (cf. Hadley, 1948: 466-470).

There is still much research to be carried out in this area, as the following comment illustrates

> ...one of the major limitations in studies of microbial corrosion has always been the lack of valid experimental procedures allowing the independent measurement of both the electrochemical and biological components of the system in such a manner that the nature of their interdependence is made manifest (Sequeira and Tiller, 1988:17).

A useful summary is provided by marine corrosion scientist Francis LaQue. He noted that on the one hand, heavy growths of marine organisms can reduce corrosion partly by eliminating the 'acceleration' of corrosion produced by a high velocity of water flow over bare metal, and on the other (by acting as barriers to the diffusion of oxygen) the growth of anaerobic bacteria is promoted (1975:116).

Corrosion is clearly a major transformational process operating on iron and steamship wrecks, though its effects are not always visible. As a result of the misconceptions that can result where specialists are not involved, archaeologists should become more aware of the processes. Corrosion specialists should become a fundamental part of iron shipwreck research. They, in turn, should be followed down onto the site by diving microbiologists. Recently, microbiologists conducted a survey of post-depositional micro-biological effects on the wooden-hulled HMS *Pandora* (1779-1791), heralding an important recognition of the process (Guthrie, Blackall, Moriarty and Gesner, 1994).

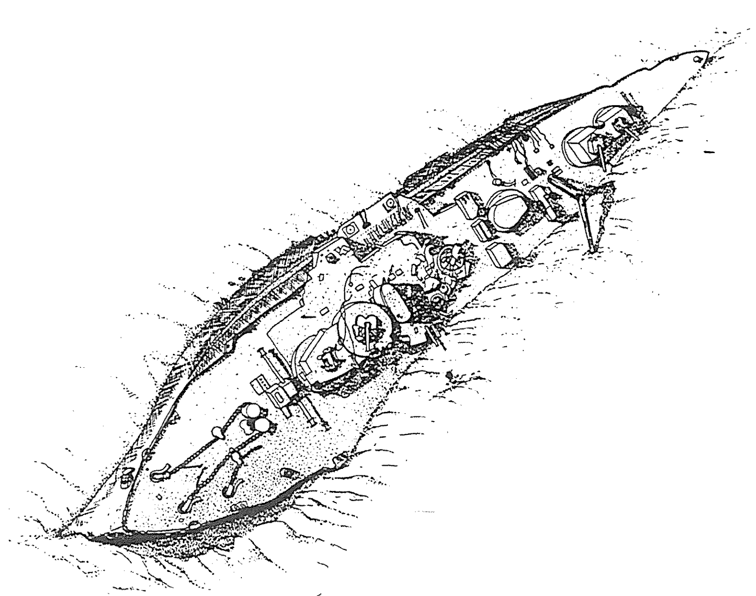
A classificatory index and the 'water-line theory'

In examining the end result of corrosion and other natural transformational factors, such as sea-bed topography, bottom slope and fetch, Muckelroy provided a useful five-stage site-classificatory index (1978:164-165). This is based on the degree of hull and material survival, ranging from his Class 1 sites, with extensive structural, organic and other remains in a coherent distribution, down to Class 5 sites with no structural and few if any other remains, all scattered in an apparently disordered fashion over the sea-bed.

In utilising his classificatory index, iron wrecks would range down from Class 1 sites, such as *Titanic* (1911-1911) and the USS *Monitor* (Figure 8). Until recently, these were inaccessible, relatively intact hulls that had not been subject to what I call 'primary salvage', or the recovery of materials by their owners, operators or agents soon after the vessel was lost.

Sites similar, yet subjected to 'primary salvage', are the USS *Utah* (1909-1942), a vessel sunk at Pearl Harbour (Figure 57), and the former USS *Arizona,* which was also bombed (Lenihan, *et al.,* 1989) (See Figure 9).

Figure 57: The USS *Utah.* By J. Livingstone, from Lenihan and Murphy, (1989:104).



Arizona is now inaccessible to divers by legislation and has not been affected by 'secondary salvage', or the action of professional salvors or sports divers in recent times. *Titanic* is an interesting case in that, while its hull is being left undisturbed, its debris field is now being regularly harvested by commercial and museological interests, i.e. secondary salvage is occurring at the site.

The SS *Yongala* (1903-1911), an intact, but much more accessible wreck located off Townsville in Queensland (Figure 58), could be considered similar to the much-visited war-time wrecks of Truk Lagoon. Though protected by legislation, secondary salvage by sports divers does occur, albeit on a small scale.

Though they fit Muckelroy's highest classification, all of these sites, bar *Monitor,* have been subject to uncontrolled post-depositional transformations and would therefore form part of a number of sub-classes within the highest category (e.g. Class 1(b)-(c)).

The equally intact wreck of the SS *Sunbeam* (1861-1892), off the Kimberley coast of Western Australia (Figure 59), would fall into a lower class entirely (possibly Class 2) because there are few organic materials and the site generally has been picked clean of all material that is not buried or heavily encrusted (Sledge 1978:70-71; Henderson and Sledge, 1984). A lower category again would be given to the remains of the MV *Uribes* (1868-1942), a former iron barque which was converted to a schooner and then a motor-ship before being wrecked against a very accessible shoreline reef. There it was subject to heavy primary salvage and, being close to a popular holiday resort, to secondary salvage with the onset of sports diving. Though now a 'sterile' site, in recent years it has become a part of a popular 'wreck trail' concept (McCarthy, 1983c) (Figure 60).

Figure 58: SS *Yongala* from 1973 to 1993. Illustrations by L. Zahn and J. Riley, (Riley, 1994: 8). Note the changes in the sea-bed astern, near the forward cargo-hold and at the bow between 1973 and 1986. Between 1986 and 1993, the davits and deck-rails have been destroyed, probably by vessels anchoring to the wreck. This procedure has since ceased. When visited by the author in 1994, the scour pit at the bow was very marked, leaving much of the forward section unsupported and it is possible that the wreck will soon break in that region. The sand cover inside the ship extended from the main deck on the starboard side, through the mid-line of the vessel to the top of the engine and across to the port bilge. Thus, though lying on its starboard side, there are expected to be considerable artefactual remains within the hull. Skeletal material, fittings and fixtures were still visible in 1994, for example.
Though the site is one of the tourist drawcards in the region, 'secondary salvage' or looting by sports divers is reasonably well controlled by the dive industry itself, leaving considerable amounts of loose artefactual material to be viewed in what I refer to as an 'underwater display case' mode (McCarthy, 1981b).

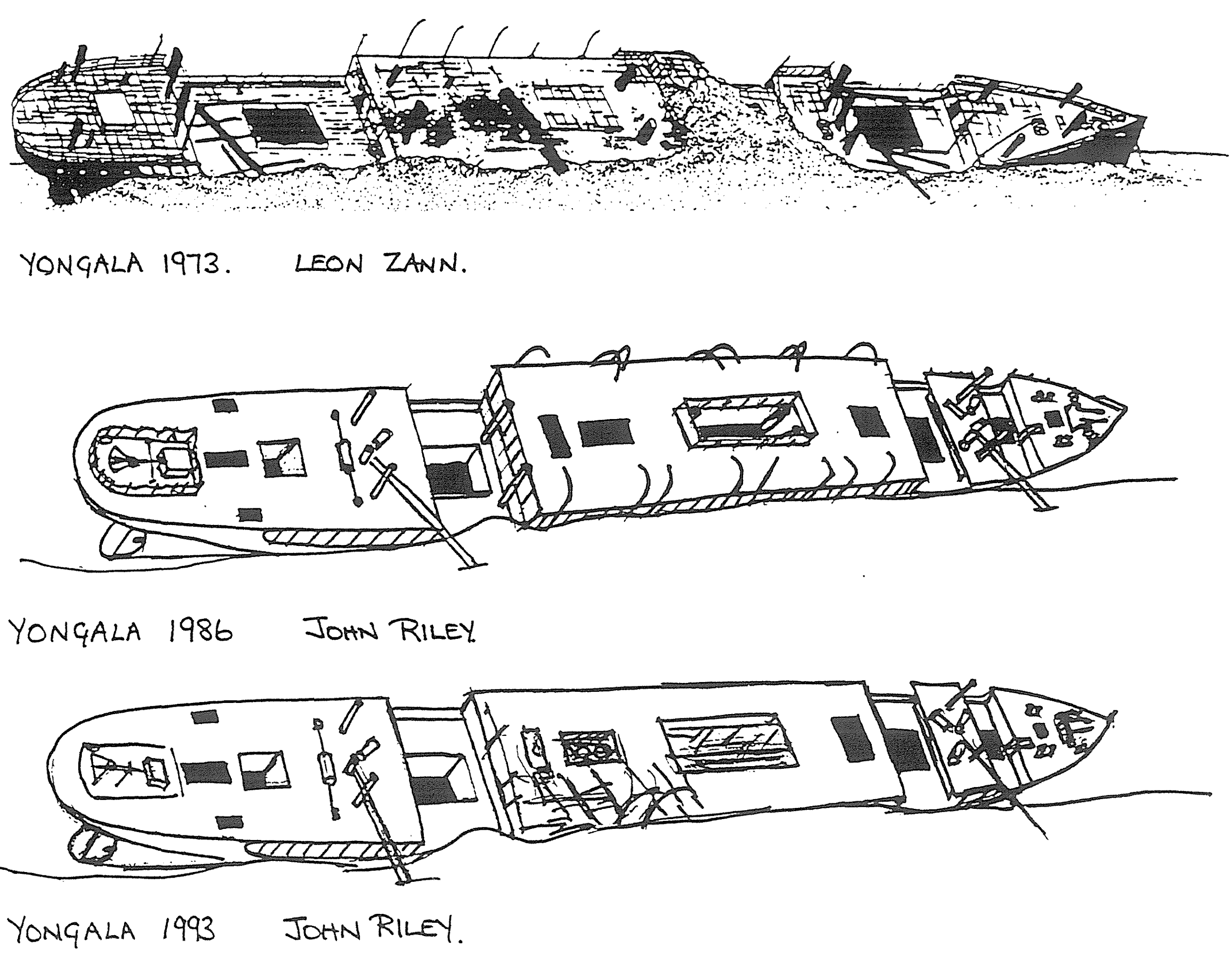


Figure 59: The SS *Sunbeam,* showing an apparently intact hull minus its wooden decking. Photograph by R. Coulter, Australian Customs Service. (See discussion p. 356).

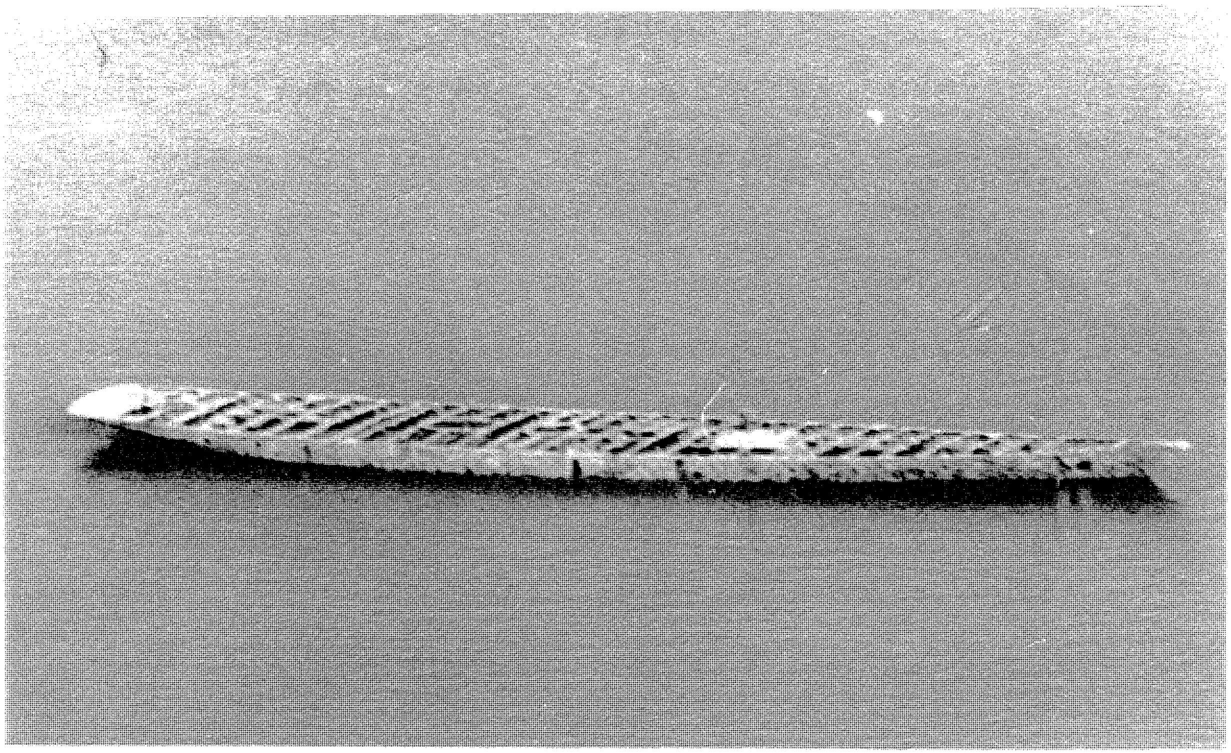
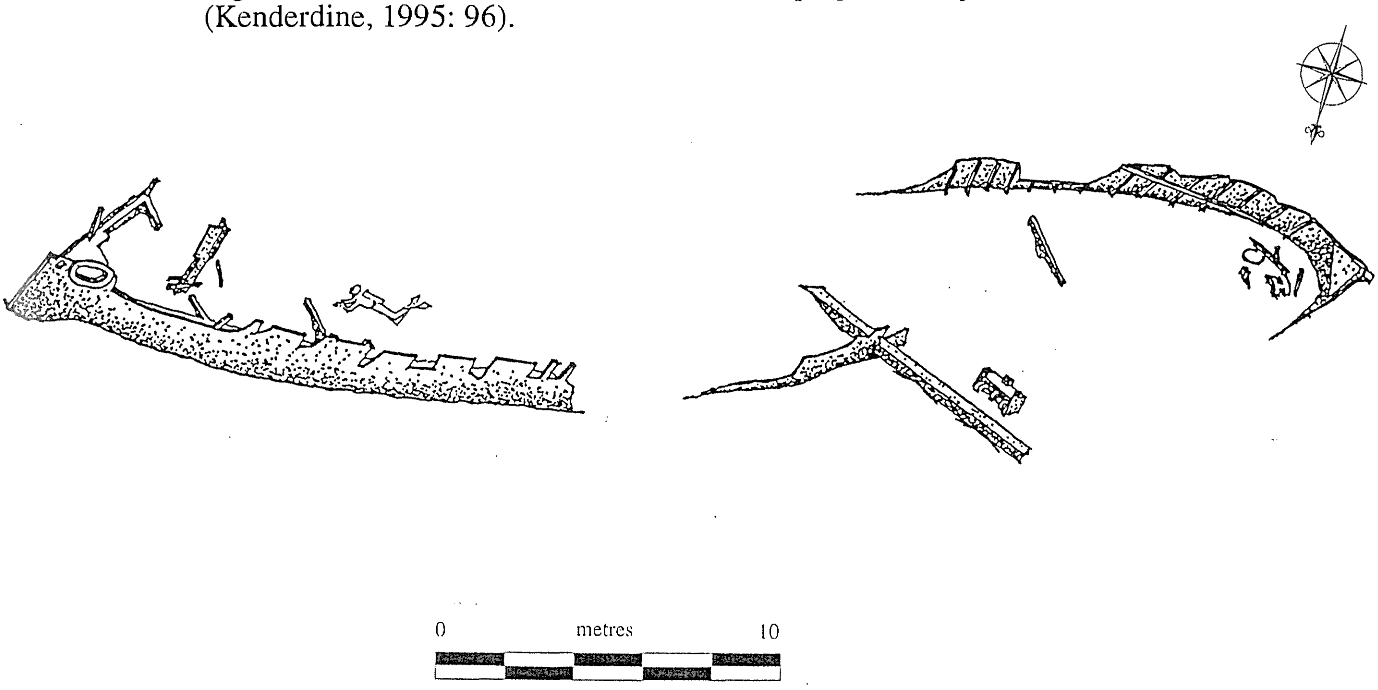


Figure 60. The MV *Uribes*. An isometric projection by Colin Cockram, (Kenderdine, 1995: 96).



Less intact sites ranging through to totally disintegrated ships, such as the iron barque *Ann Millicent* (?-1890), or the SS *Windsor* (1890-1908), lying on hard shallow reefs and subject to considerable seas and swell, would form the remainder of Classes 4-5 proposed by Muckelroy (1978: 157-169) (See Figures 64-66).

It is not intended to dwell on his classificatory scheme other than to note the possibilities for further study and its ability to assist in descriptive and analytical studies of iron and steam shipwreck sites. Of importance is the need to assess a number of iron and steamship wreck sites and to view them as a category of archaeological site capable of being analysed as a suite and, from there, to progress in a comparative fashion to the *Xantho*.

An examination of the illustrations below and those previous (e.g. 6-9, 22, 24) shows that the extent of burial of a wreck in sediment or other matrix is clearly a major factor in physically limiting the movement of fixtures, fittings and artefactual material from the hull.

Commonalities in hull burial were first enunciated by John Riley following a decade of study of over one hundred wrecks off the coast of New South Wales (Riley, 1988a:191-197). As indicated earlier, his sample indicates that ships generally sink to the waterline when they come to lie upright on a sea-floor of sand. Riley also illustrated other commonalities in iron ship disintegration, such as the fact that boilers eventually roll out of steamships lying in the surf zone or come to rest as upright cylinders in heavy conditions, thus presenting least resistance to seas and swell. These patterns are illustrated in figures throughout this thesis, most notably Figure 24).

By moving further afield than the waters of New South Wales and the British coasts, as I have done in this dissertation, we can expand and test Muckelroy's and Riley's propositions, by examining their applicability to the study of iron, steel and steam shipwrecks in general. We are then able to avoid some of the generalisations made from earlier studies in the Mediterranean; the birthplace of maritime archaeology. Until as late as 1972, scholars described the special characteristics of that sea and made erroneous assumptions about wreck disintegration and survival of archaeological material on the sea-bed for the world. It was claimed, on the basis of studies conducted in the Mediterranean for example, that 'nothing of significance' would be found in shallow water for 'the sea smashes everything in shallow waters, and such scattered wreckage is of scant interest to the archaeologist' (Dumas, 1972:160). Honor Frost, an equally influential underwater archaeologist, agreed (Muckelroy, 1978:160). Though this destructive process certainly occurs, we now know that this is not a sustainable position. Work at the iron and steamship sites noted above e.g. Watts (1988); Bright (1985); Delgado (1986); at the wooden-hulled VOC ship *Batavia* (1622-1629) (Green, 1987); the American China trader *Rapid* (1807-1811) (Henderson, 1986:105-114) and the iron-hulled SS *Xantho* (1848-1872) clearly show that archaeology in shallow water environments can produce significant results. This is especially so if the hull has time to act as a receptacle and becomes part-buried before being broached by the seas or destroyed by transformation processes (See Figure 61a-b below).

Other commonalities become evident in an examination of the broader sample and it is now clear that iron and steamship wrecks generally appear to disintegrate in a common fashion, depending on how the wreck came to rest and on other relevant factors, such as depth, exposure to wave and swell action and sea-bed composition.

Figure 61a): The SS *Kakapo* (1900-1900), a beached wreck in South Africa (Wexham, 1984: 72-3). Its role in acting as a receptacle for artefactual material while the hull disintegrates is evident.

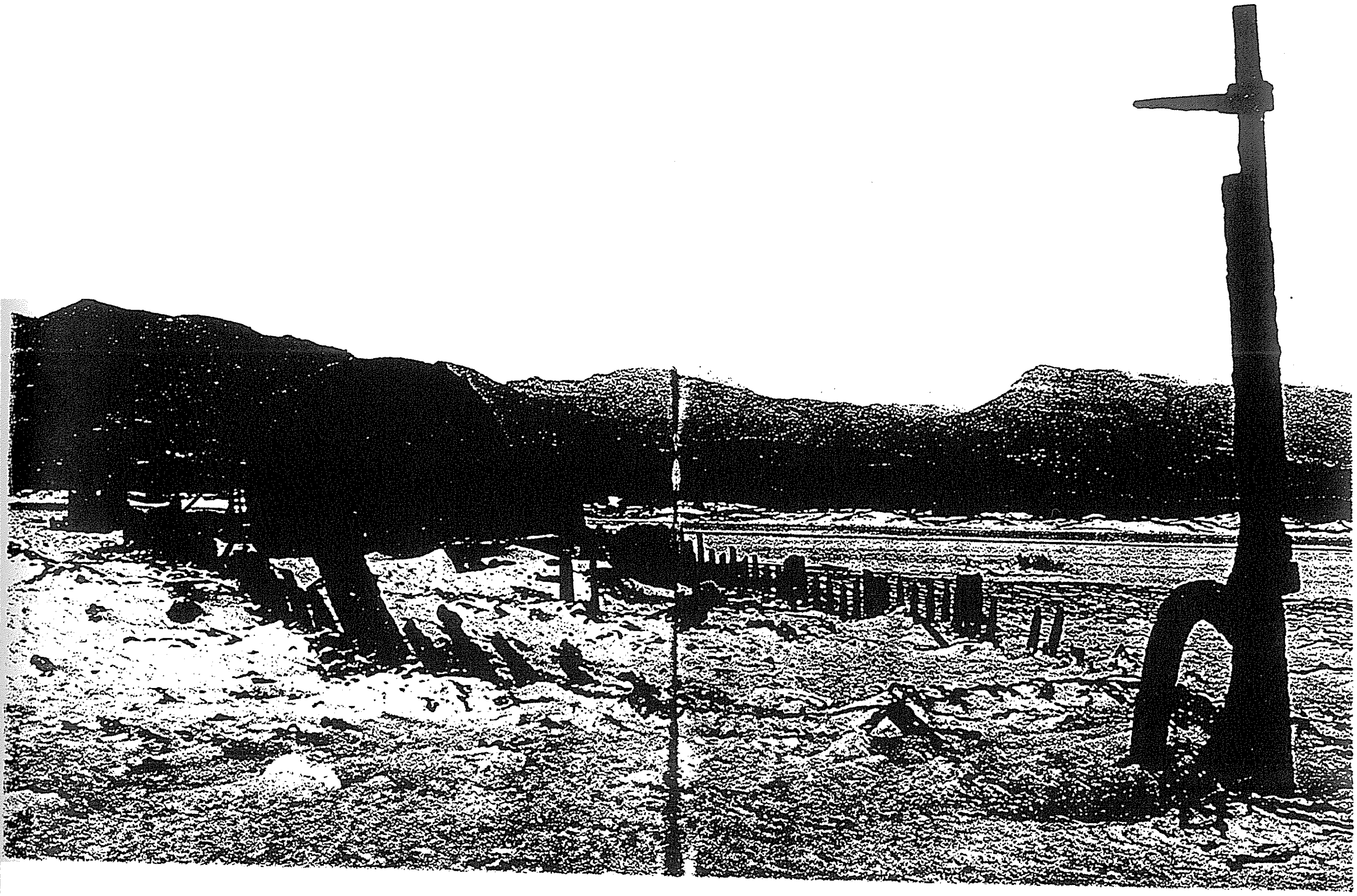
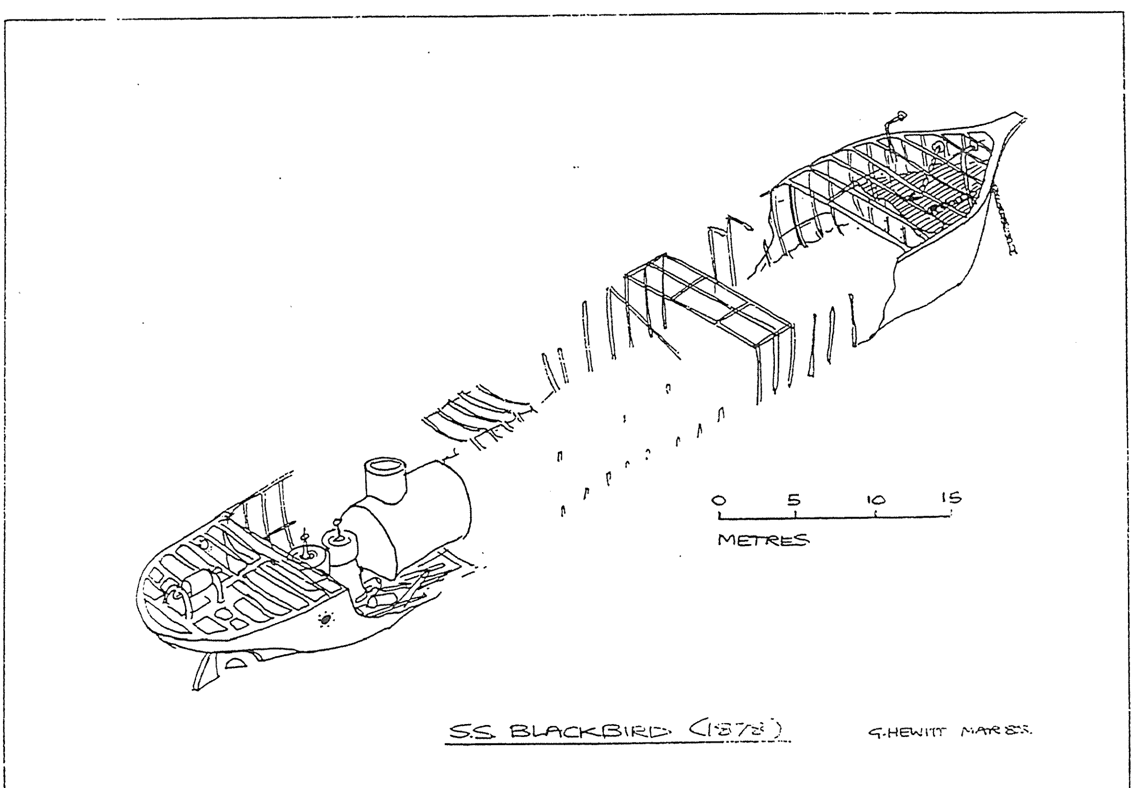


Figure 61 (b): The blockade-runner, *SS Nola* (1863-64) off Bermuda. By K. Morris (Watts, 1988). It has also acted as a receptacle. Note the rectangular boilers and the relatively intact bow and stern sections. The engines are missing in both these instances.

In comparison to the two examples above, iron hulls tend to flatten out as they disintegrate, when lying upright on a hard unyielding sea-bottom, again leaving a characteristic pattern. The hull floors break where they are not supported by the sea-bed, to lie flat, surmounted by engines and boilers with fittings and fixtures lying either side (or on the hull), depending on the direction of the prevailing seas.

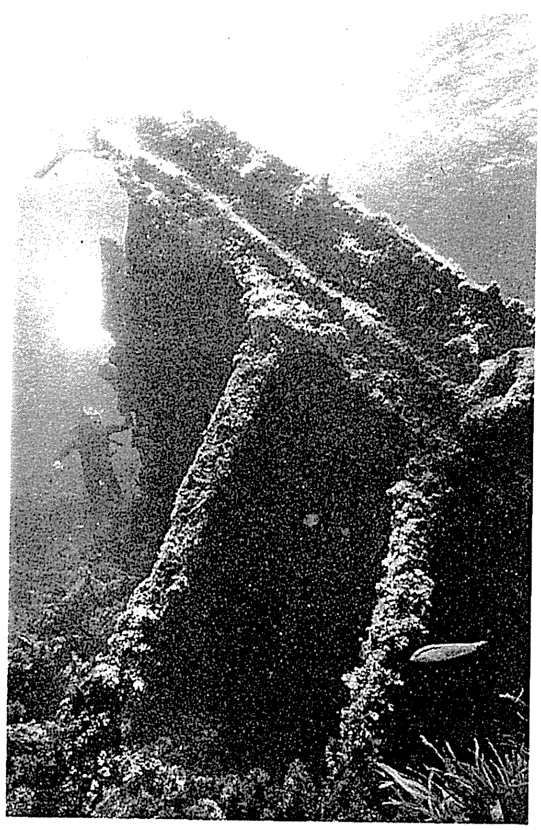
The relative longevity of the forecastle or poop (the bow and stern triangles) in comparison to cargo sections is another common feature. Eventually an exposed iron vessel comes to assume a characteristic appearance; i.e. bow and stern triangles lying on their side, separated by flattened cargo holds and a midships section surmounted by engines and boilers (if present). A progression to this stage is seen in the wreck of the SS *Blackbird* (1863-1878), shown below

Figure 62: The SS *Blackbird*, By Geoff Hewitt, MAAV (1988: 147).



The *Blackbird* site will eventually be characterised by isolated bow and stern triangles separated by machinery and a collapsed hull section between. Eventually those triangles will also fall to the sea-bed, in similar fashion to the bow of the iron barque *Denton Holme* (1863-1890) (Figure 63). The bow of the *Ann Millicent* (?-1890), which dries at low-water spring tides (Figure 64) and the stern of the *Ben Ledi* (?-1879) (Figure 65) are examples of a similar phenomenon. See also SS *Marie Celeste* in Figure 22 and the SS *Nola* in Figure 61b.

Figure 63: The bow of the iron barque *Denton Holme,* Photograph by P. Baker.



The angle on which sections of a particular hull fall will not necessarily be consistent with those other parts of the site which collapsed at a different time. Their angle of repose will be dependent on such factors as the sea conditions as they reached the point of collapse and the movement of the sediments on which each section may lie.

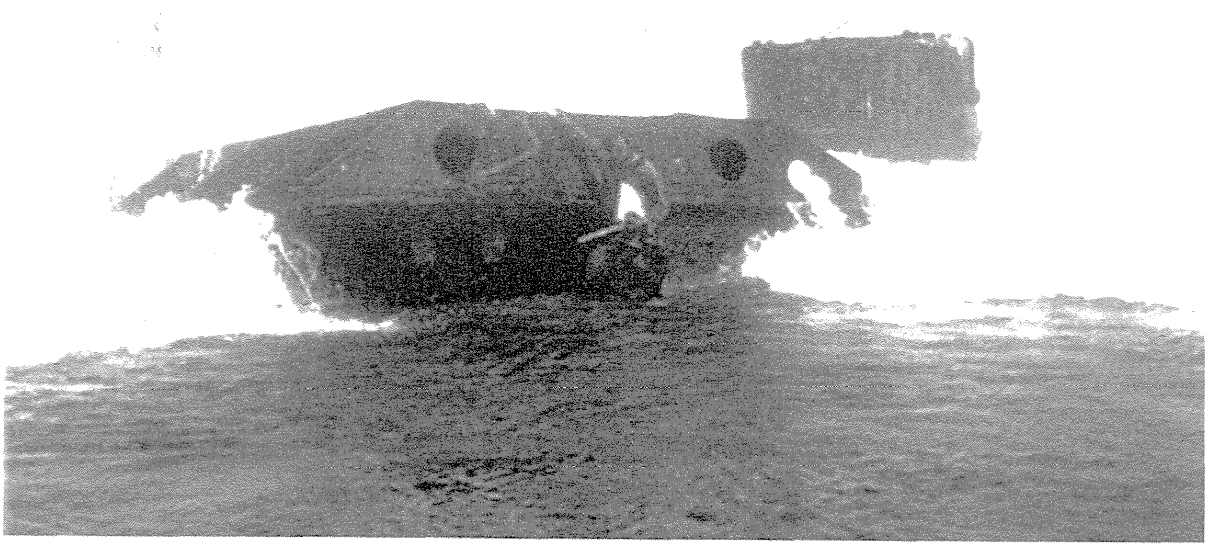
Figure 64: The bow of the iron barque *Ann Millicent.* Note the Indonesian fishermen searching for trochus shell. Having visited the area for over two centuries, the fishermen have subjected the wreck to heavy 'secondary salvage'. Despite that, material such as a large array of anchors, a cannon and other heavy material of interest remain (McCarthy, 1991a). Photograph by J. Carpenter

Figure 65: The author inspecting the stern of the iron barque *Ben Ledi.* The illustration shows the integrity of the unit.

In the case of the SS *Windsor* (1890-1908), on the Abrolhos Islands in Western Australia, I have observed another interesting phenomenon; the gradual sinking of the wreck, or some of its parts, into apparently hard reef platforms.

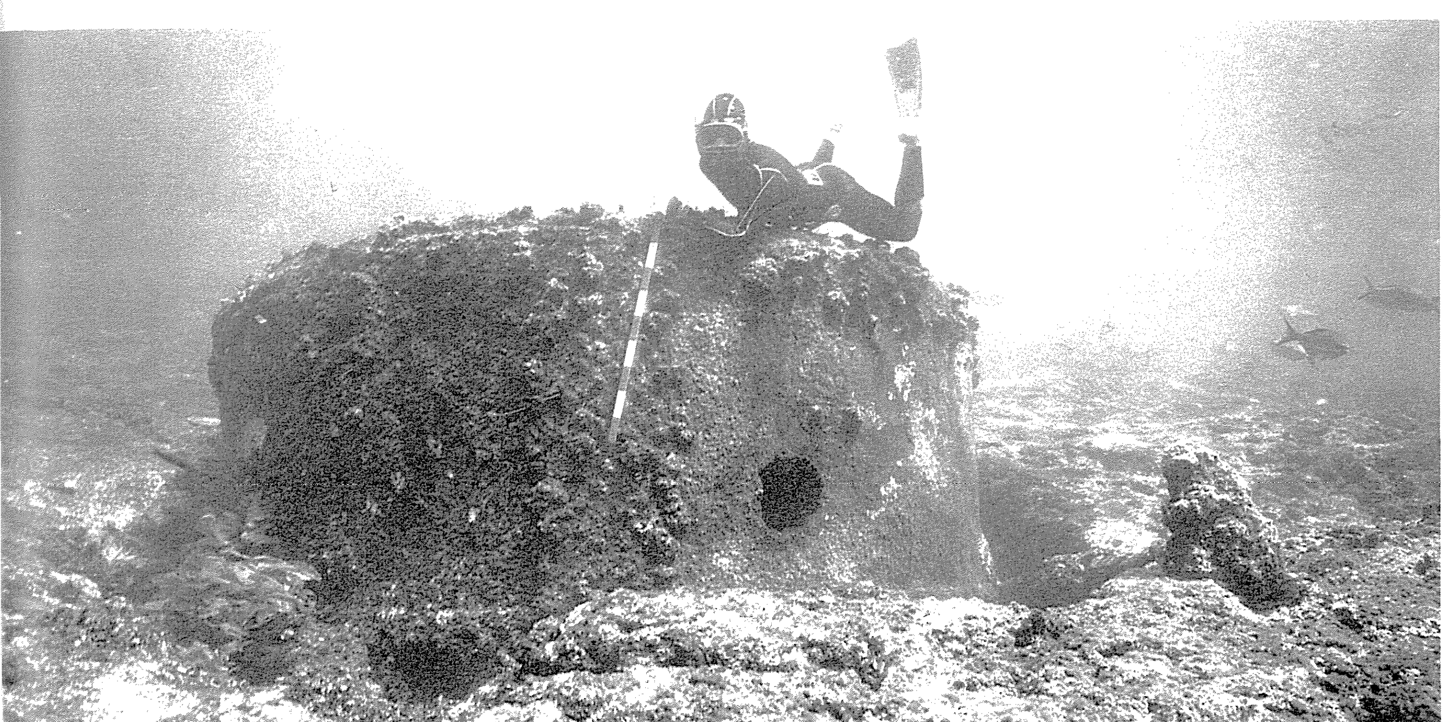
Lying in shallow water against a drying reef and subject to very heavy seas, the hull has completely disintegrated. The engine, shaft and propeller lie disjointed on the sea-bed near a submerged boiler. The hull has totally disintegrated, apart from the vessel's floors lying inverted on top of the drying reef adjacent to another boiler. These are shown in Figure 66a. The stern section lies even further inshore.

Figure 66a: The *Windsor* boiler and a section of its floors on a drying reef. Photographs by the author (McCarthy, 1982b).



The boiler, shown underwater in Figure 66b, lies only metres from the one shown in Figure 66a on the drying reef-top. Both lie on their end; one has sunk into the reef, the other has not, posing obvious questions about the site-disintegration processes and the substrate on which the separate parts of the wreck lie. Though there was considerable discussion and disagreement on this phenomenon when it was first seen, the tight fit of the boiler and the finding of the rudder in a rudder-shaped hole were considered conclusive (McCarthy, 1978a, 1978b). Diving geologist R.J. Brown was also consulted and he agreed, after examining the evidence, that the boiler and the rudder had worked their way down through the reef and that they had not fallen into an existing hole (pers. com.).

Figure 66-b: Burial in reef structures. A view of the *Windsor* boiler underwater. Photograph by the author (McCarthy, 1982b). The question was put whether the boiler could have fallen into the hole? Given that the hole in which the boiler lies is almost perfectly cylindrical and given the tight fit, it became evident that the boiler had gradually sunk into the reef. The finding of the ship's rudder deep within a rudder-shaped hole, provided conclusive proof.



In examining Riley's 'waterline' theory in soft sediments, or the cases noted above where material becomes embedded in a hard, but yielding, sea-floor it appears that the sea or swell initially impinges rhythmically against an object, or around a hull that comes to rest upright on a relatively soft bottom, causing it to slowly subside. The wooden three-masted American-built schooner *Abemama* (1918-1927), shown below in Figure 67, is one example of this phenomenon.

Illustrations (Figure 68a-c) of the French-built iron-hulled tug-boat *Alacrity* (1893-1931), lost within a few years of *Abemama* and now lying seven metres from it, show that the process applies as much to an upright wooden wreck as it does to the iron hull in the same environment.

Figure 67: The wooden-hulled *Abemama* soon after it came ashore (Sawday collection). See Figure 51a and 68 for its appearance today .

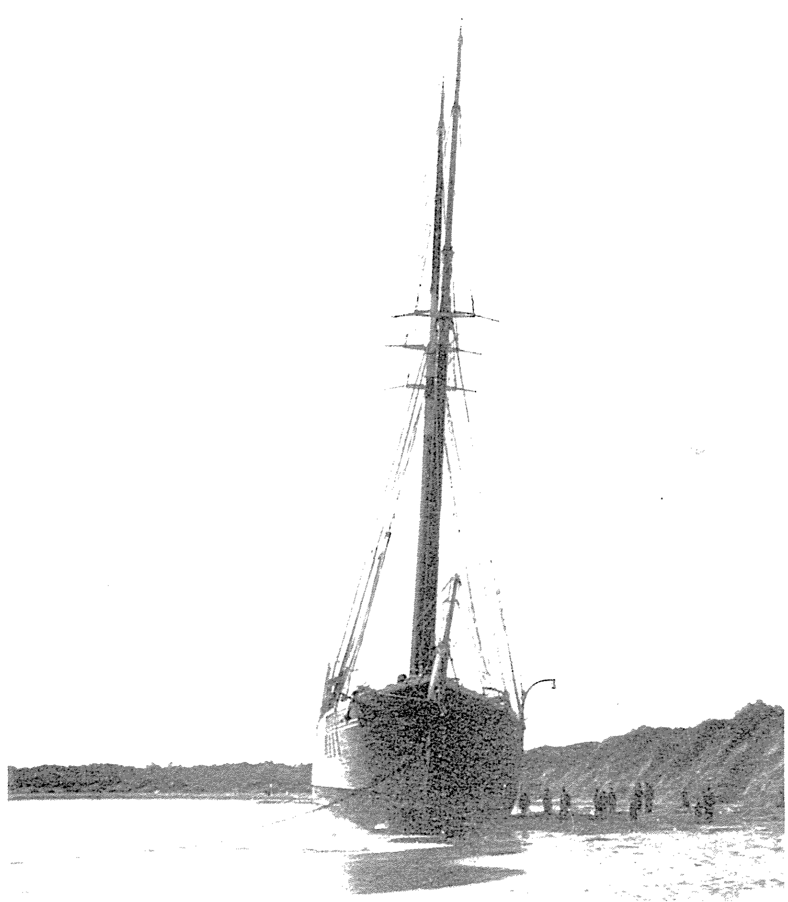
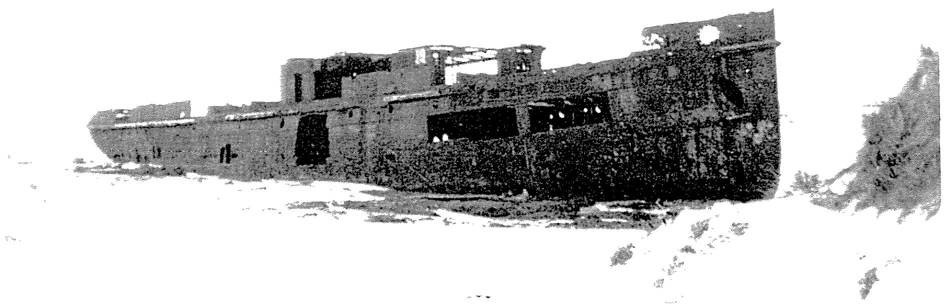
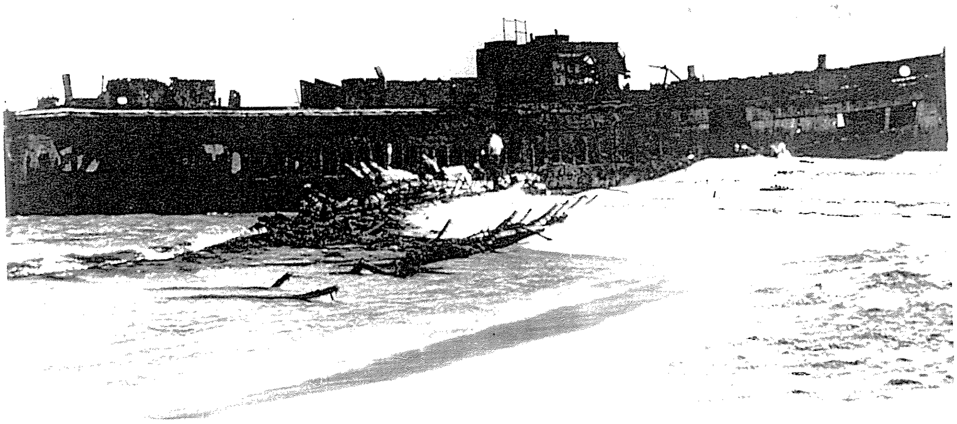


Figure 68*:* The iron-hulled *Alacrity* in the process of disintegration over a period of about 20 years up to around 1975. *Abemama* can be seen inshore on the aft quarter of *Alacrity.* The uncovering of the two sites is due to dredging nearby. Note the varying angles of the *Abemama* hull to the *Alacrity*. Photographs by D. Gilroy and D. Robinson.[1]





[1]It is useful to note at this juncture that wrecks can move, even after many years. The evidence appears above in the case of the *Abemama*.

It is noted at this juncture, however, that where the seabed is very soft, hull burial can proceed beyond the turn of the bilge; e.g. the VOC ship *Amsterdam* (1748-1748) (Marsden, 1974: 72).

Where wooden-hulled or iron-hulled vessels come to rest at an angle on a soft yet unyielding seabed, such as the well-known *Mary Rose,* (1509-1545) (Rule, 1982), HMS *Pandora* (1782-1791 (Gesner, 1991) or the USS *Utah* and SS *Yongala* (shown above) they settle to an area that often encompasses a line drawn laterally between the top of the keel (on one side), to the sheer strake (on the other) and in a longitudinal direction between the first and last of the cant frames (cf. McCarthy, 1984). This leaves all else unsupported above the sea-bed until it degrades through natural forces such as water movement and wood borers (cf. Florian, 1987:15). Where the sediments are less yielding or underlaid by much harder formations the extent of settling is obviously much less. Where the seabed is mobile, or where there are sufficient currents or water movement to create localised scour-pits, variations must be expected. Sometimes these are seasonal. Where the sea-bed is hard and the water shallow, with rapid movement the extent of site degradation is much more marked and the hull and other fragile remains much less preserved.

The commonalities of iron wreck disintegration

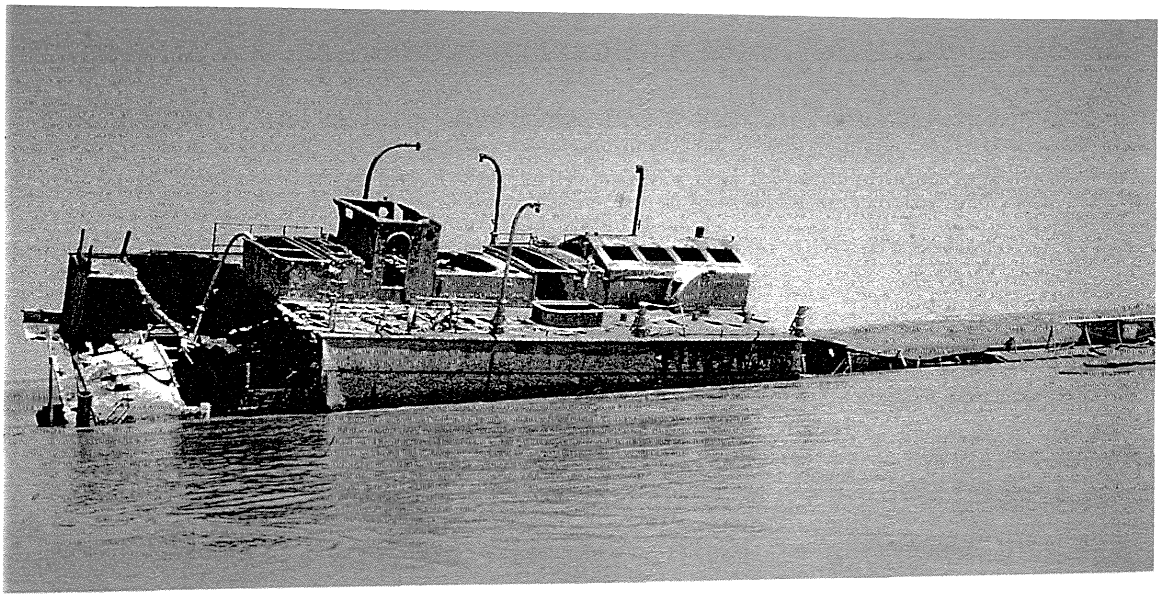
Following both Muckelroy and Riley, it is my contention that there are a number of commonalities to be observed in the disintegration of iron and steam shipwrecks. When joined with a more informed appraisal of the on-going processes of metallic corrosion, both above and below the encapsulating sediments, these commonalities will enable archaeologists to properly control for a variety of depositional and post-depositional factors and effects, before commenting on the remains before them.

I have identified some of these common patterns as a) survival of the bow and stern triangles, b) variable hull settlement, with consequences for the degree of preservation and c) the flattening of the hull, especially in cargo holds amidships.

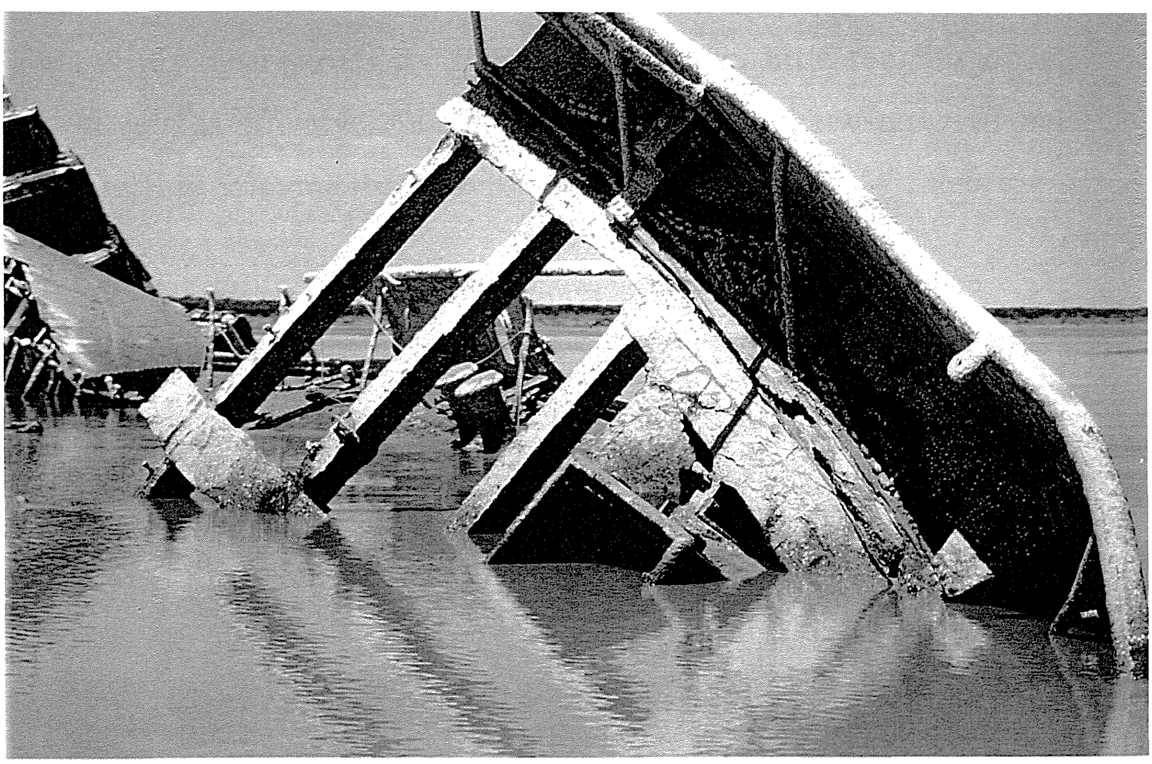
The following illustrations of the *SS Colac* (1895-1910) in King Sound near Derby (Figure 69a-c) show not only some of the patterns noted, such as the disjointed but otherwise intact bow and stern triangles and collapsed cargo sections, but also an apparent anomaly; a completely intact midships hull section after nearly a century of inundation.

Figure 69a: Views of the SS *Colac* at low water spring tides near Derby on the Western Australian coast. Photographs by M. McCarthy, October 1995. See also Figure 13.

69b: The engine-room, boiler-room and stokehold showing surprising integrity[1].



69c: The stern, showing the integrity of the section in comparison with the cargo-hold.

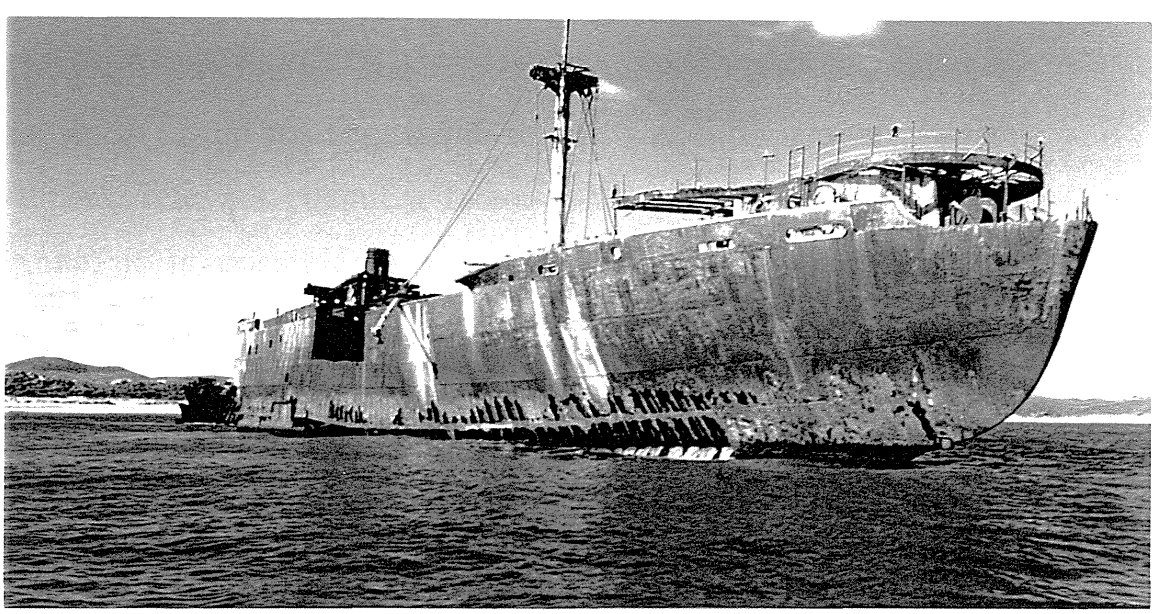


[1] After being damaged and rendered unseaworthy, this vessel was run aground on a sand-bar and abandoned after heavy salvage in 1910. Though subject to diurnal tides, sometimes in excess of 10 metres, with strong currents, the wreck does not experience heavy swells (*Australian Tide Tables*, 1994: 212-213). The ship has sunk to near the waterline in its own scour-pit and the bow and stern triangles and cargo holds are as expected. The engine and boiler -rooms together with the coal bunker have formed a very strong unit and are intact due to their substantial construction. Corrosion specialists are yet to visit the site, which lies in similar waters to the SS *Sunbeam* in Figure 59. I suspect that the colonising inter-tidal shellfish are an important element in these two instances in that they protect the hull from the effect of wind and wave.

On inspection it became evident that the relative longevity of the midships section is apparently due both to the longitudinal and lateral strength of the engine, bunker and boiler rooms. These form a very strong unit which is heavily braced both horizontally and vertically in traditional fashion and by a heavily-built coal chute at an angle of around 45° from the vertical in the bunker room. The prevailing site conditions of strong, but directionally constant, tidal currents and the absence of the constant pulsing action of seas and swell represent other major factors.

An interesting comparison to the SS *Colac* is the former Liberty Ship SS *Alkimos* (1943-1963) (Stewart, 1992). This steel-hulled vessel lies a few miles north of Fremantle in an area having a tidal range between 1-1.5m (*Australian Tide Tables*, 1994: 174-5). Though lost nearly half a century after *Colac*, little remains of its hull in what is effectively a constant 'splash-zone' between wind and wave, as it is colloquially known.

Figure 70: The SS *Alkimos*, showing extensive corrosion in the splash-zone. Photograph by J. Clarke.



Highly oxygenated saline water at the sea surface has constantly impinged on this small (c. 2m high) inter-tidal zone on *Alkimos*, with an obvious and well-recognised effect (cf. LaQue, 1975:113-116). This is in stark contrast to *Colac*, which is subject to 10m tides. Being in a Mediterranean climate in comparison to *Colac*'s tropical location, the biofaunal colonisation of *Alkimos* also appears markedly different, requiring some attention by the appropriate specialists.

Variations to the patterns noted above are expected and must be accounted for before any comment is made about natural or cultural depositional and post-depositional effects. The wreck of the iron barque *Moltke* (1867-1913), located in a rich coralline environment off Magnetic Island, North Queensland for example, provides an interesting example of a class of site yet to be analysed. In this instance it appears that an iron hull will eventually be totally colonised by coral. In this context, it is interesting to note that, after being jettisoned from HMB *Endeavour* in 1770, the explorer Lt. James Cook's anchors and cannon gradually became buried in coral and were found nearly 200 years later only with the aid of magnetometers (Knuckey, 1988; Callegari, 1994).

Thus by examining the many variables involved, such as composition of the sea-bed, depth of the wreck, the extent of water movement, relevant chemical factors and the nature of colonising biofauna, it is possible to make informed comment about the appearance of an iron wreck site. More importantly, in identifying deviations from the expected, we can identify anomalies and try to account for the variance. One of the masts on *Moltke*, for example, lies at an angle inconsistent with the original angle of heel of the wreck. It transpires, that in being used as a practice-target for WWII bombers, the wreck was not only heavily transformed by the explosions, but the mast was hit by one low-flying aircraft, causing it to lie at an angle incompatible with the remainder of the wreckage.

An interesting example of the need to control for post-depositional effects is again found on the SS *Alkimos*. The following illustration (Figure 71) shows an apparent collapse in the forward cargo hold and an intact bow triangle, as expected.

Figure 71: An aerial view of SS *Alkimos* showing the collapse of the forward cargo hold. Photo by R. Gould, 1995.

Though fitting the expected mould for natural transformation processes at iron and steamship sites, these features are actually the result of cultural transformations in the form of secondary salvage over a number of years (Nairn and Sue, 1975); making it essential to account for all post-depositional factors before making comment on the processes involved. The process of site disintegration in the case of such vessels is on-going and occasionally quite dramatic. The derrick and fore-deck shown in Figure 71, above have now totally collapsed, leaving only the fore-peak above the waves ahead of the bridge (Veth, pers. com. 1996).

In summary, part of my preceding discussion has centred on hulls which were rapidly buried in sediments to around the turn of the bilge or the waterline, providing long-term remaining receptacles and closed systems for the materials and artefacts held within them. Over time they were transformed by both natural and cultural processes in the form of corrosion, wave action and salvage to one that is more a feature around or on which material lies or is fixed by the processes of concretion or sedimentation. This is apparently what has happened at the *Xantho* wreck.

The formation of the *Xantho* site

It can be seen from the discussion above that the fabric of *Xantho* fits the expected patterns of an iron wreck submerged for over a century, in that in 1983 it appeared to be buried to its water-line. The bow and stern triangles were essentially intact, as were the engine and boiler and some of the hull structure around them. Contrary to expected patterns, however, is the fact that although the wreck lies in shallow water opposite a break in the barrier reef protecting Port Gregory, the boiler has remained *in situ*. This suggests that the seas at the site have not been as destructive as first thought, and/or that the sand-bar encroaching onto the wreck from the port side has had some effect in serving to help hold the boiler against the forces of seas and swell from the starboard quarter.

Given its part-burial in soft sediments, the *Xantho* constitutes a hull which has apparently remained intact for a time, acting as a repository for a range of materials. In contrast to wrecks which have been cast onto hard reefs or hard shallow sea-floors and are rapidly torn apart, *Xantho* would have probably remained an intact 'vessel' for a period. It may have appeared for a while like *Sunbeam* (Figure 59), containing much of its unsalvaged cargo, fittings and fixtures within the hull itself. By coming to lie on a mobile sand bottom in the surf zone and in the path of a strong current running diagonally across the site from port to starboard, the *Xantho* has opened up over the years to starboard, allowing material to spill out down slope. Being exposed to the full force of the current, the port side of the ship has collapsed inward. Corrosion specialists have advised that, being in aerated water directly in the path of the current, the port sections have experienced a corrosion rate in excess of the starboard side, especially the area aft of the boiler (MacLeod, pers. com.). Thus the potentially protective effects of concretion and animal growth as argued by LaQue in the discussion above, appear to have been less than expected.

The south-west seas impinging on the wreck from starboard to port appear to have had some effect in hastening the break up the hull through their rhythmic action. Seas and severe storms from the north-west would have been partly broken by the Abrolhos Islands and a barrier reef just off-shore, leaving only a refracted wave effect and a broken swell to impinge on the site. As a result, a wreckage plume following the prevailing current and not the prevailing seas is to be expected, with some materials undoubtedly lying under the hull along the starboard side.

The moving sand has caused the wreck to break up into four distinct parts; i.e. forward of the boiler, under the boiler, under the engine and aft of the engine. This disarticulation appears to have been solely due to natural forces. On the other hand, the position of the wreck has caused it to be a navigation hazard and some elements of the site, such as the valve once atop of the boiler, has been either knocked off by a passing vessel or deliberately torn from its housing and allowed to fall to the sea-bed. Further, it appears from historical accounts that a considerable amount of primary salvage took place and much of the loose material was removed soon after the ship went down.

By virtue of the hull having opened up laterally in the intervening years, and by being initially heavily salvaged, the wreck has slipped from an intact hull (say Class 1-2) in its earliest configuration to a lesser category, as the processes of site disintegration have continued and the hull has been affected by periodic burial and uncovering (See Figures 40, 41, 44 and 72 for the predicted continuum).

Figure 72: A sketch of the SS *Xantho* in 1983, by Ian Warne.


A. 1983
SEA LEVEL

The archaeological evidence from *Xantho* shows, however, that what occurred since it sank was not a form of 'secondary salvage' as is the norm on most accessible wrecks. Most of the brass-work remains on the engine and boiler, where normally explosives and equally robust methods would have been used by professional salvors and 20th Century sports divers to remove such fittings.

Having attempted to control for post-depositional effects and to come to an informed opinion as to why the wreck appears as it does, it is now relevant to ask whether behaviour consistent with the circumstances of a vessel experiencing sudden hull failure and going down in an unsuccessful attempt to return to port is indicated by the remains at the site?

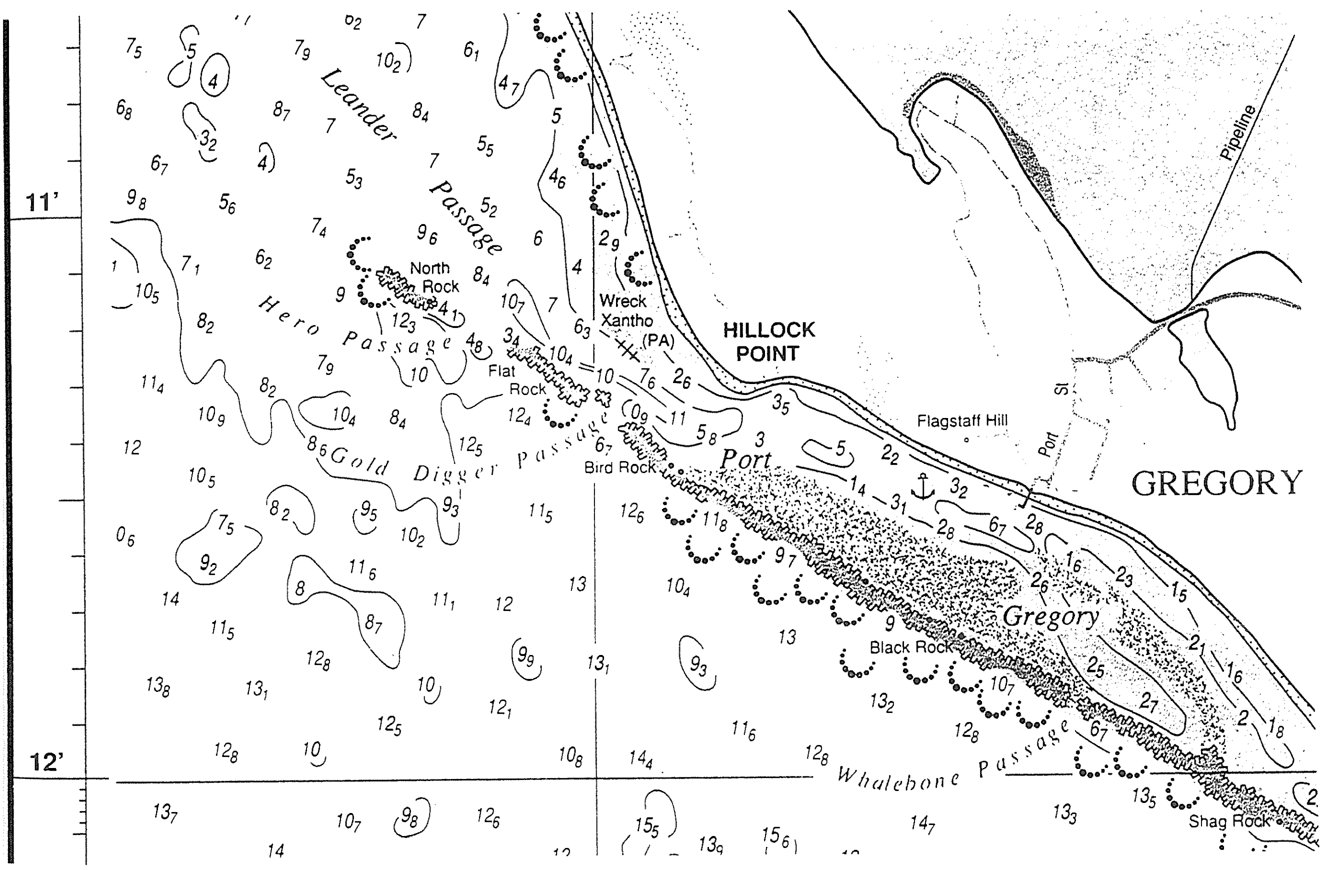
The answer appears to be yes.

The wreck lies on a direct course into Port Gregory from the open sea via the main channel, Leander Passage (Figure 73).

Despite attempts at salvage, much of the vessel's cargo of lead ore remains in the hold, indicating that it represented a loss to the owner, Broadhurst. The bow lies at an angle that suggests an attempt to turn to seaward after the vessel struck; i.e. it was not run ashore. On the other hand, this configuration could be due to movement caused by shifting sands. The former analysis is supported by the fact that the rudder is hard to starboard. This would be expected of a vessel that abruptly struck a sand-bar on its port quarter. The fire-doors of the boiler are firmly shut, indicating that they were deliberately closed as the vessel slowly succumbed to inrushing water. The stern is in shallow water with the boiler coming to within two metres of the surface.

From the material evidence, it appears that abandonment was slow and that the grounding was accidental; i.e. the vessel was not deliberately run ashore for insurance purposes or for some other gain. There is independent confirmation of this interpretation from the testimony at the inquiries held after the loss of the vessel (Table 3).

Figure 73: The position of the *Xantho* in relation to Port Gregory, the reefs and the beach. Note Whalebone Passage upstream of the wreck (Department of Land Administration)



Having accounted for both cultural transformations wrought by primary and secondary salvage and natural transformations in the form of corrosion, current, seas and swell, we are now able to recognise anomalies and begin to account for them through archival and other analyses.

Though apparently fitting the norm for iron-hulled steamship wrecks, the *Xantho* presented engineering and technological anomalies. It was powered by a horizontal trunk engine, a type expected only in a naval context, with steam apparently provided by a slightly elliptical boiler of an apparently early type and not the vertical compound engine and Scotch boiler that could be expected. Ancillary machinery such as a 'condenser' was visible, although it did not appear connected to pumps, as expected. These anomalies must now be accounted for.

The investigation continues, in the archives

Some of the early conclusions about the wreck were not necessarily supported by subsequent research. The local press recorded, for example, that the boiler was new when it was fitted to the vessel in 1871. It was described thus

> The boiler, a multi-tubular one, also new and in perfect order, was manufactured by Davidson & Co., Boiler Makers, of Glasgow, and bear a steam pressure of 50 to the square inch (*Herald*, 25/1/1873).

This firm operated the Union Boiler-works out of Union Street, Glasgow, from 1867-1871 (*Glasgow Post Office Directory*, 1872). This cast some doubt on our preliminary analysis at the wreck, where indications were that it was an earlier type of low pressure boiler and not the high pressure cylindrical, tubular 'Scotch' boiler that became common in the later 1860s. A re-examination was clearly necessary.

The pumps which fed the boiler, powered the condenser and cleared water from the ship's bilges, were also described in the local press as new

> The feed pump, bilge pump, and steam-pipes are all copper and new. The cost of all this machinery [plus the boiler] and the extra gear could not have been less than 1500 pounds in Glasgow when purchased, and at present would be worth in that town almost half as much more, when the rise in the price of iron is considered (*Herald*, 25/1/1873).

The pumps appeared to be part of an amorphous mass on the fore-side of the engine itself and were, if those impressions were correct, an integral part of the engine. Being located in the stern of the vessel, they could not have been easily deployed to clear water from the bows or cargo spaces. These impressions fitted the archival evidence well. On the other hand, the specifications for the building of the ship and the Court of Inquiry evidence also contained references to watertight bulkheads, yet reports of the loss of the vessel show that the bulkheads allowed water from the bows to rush aft and extinguish the boiler fires when the vessel struck the sand-bar at Port Gregory. The bulkheads were not visible in the pre-disturbance survey and they were not apparent in the transects or the trenches cut through the wreck. Here were additional problems requiring resolution and further recording of the hull and excavation on the site. No evidence of the clincher (clinker) construction of the hull was observed due to the layers of concretion encountered.

What was thought to be the condenser lying to starboard of the engine was also an anomaly that required further examination. All available illustrations of trunk engines show that they were fitted with condensers and that these were located on the opposite side of the engine room to the engine itself. Condensers were in general use at that time and were to be expected on a vessel built or re-fitted in the early 1870's, as indicated earlier (*The Engineer*, 1898:574; Burgh, 1869:46).

They were normally driven by the engine itself, but being located on the opposite side of the vessel, long pump-rods were required (See Figure 17). The location of what was originally thought to be the *Xantho* condenser opposite the engine, where it had apparently been attached to the starboard hull, corresponded to these expectations. On the other hand, the expected pump-rods, or their remains, were not visible. Advice on trunk engine configuration was received from various sources, notably Noel Miller, our steam engine adviser, Richard Tomlin, part of the team refitting the HMS *Warrior* (built 1860) (*The Engineer*, 1898: 444-446) and Joe Roone of the Science Museum in Kensington. The *Warrior* had been originally fitted with a 1250 NHP trunk engine which no longer existed (Warsop and Tomlin, 1990). As a result, a professional research assistant, Antonia MacArthur, was employed to comb British holdings at the National Maritime Museum in Greenwich for evidence of the engine type (pers. com., 1994). This led to the accumulation of a mass of information about the trunk engine type.

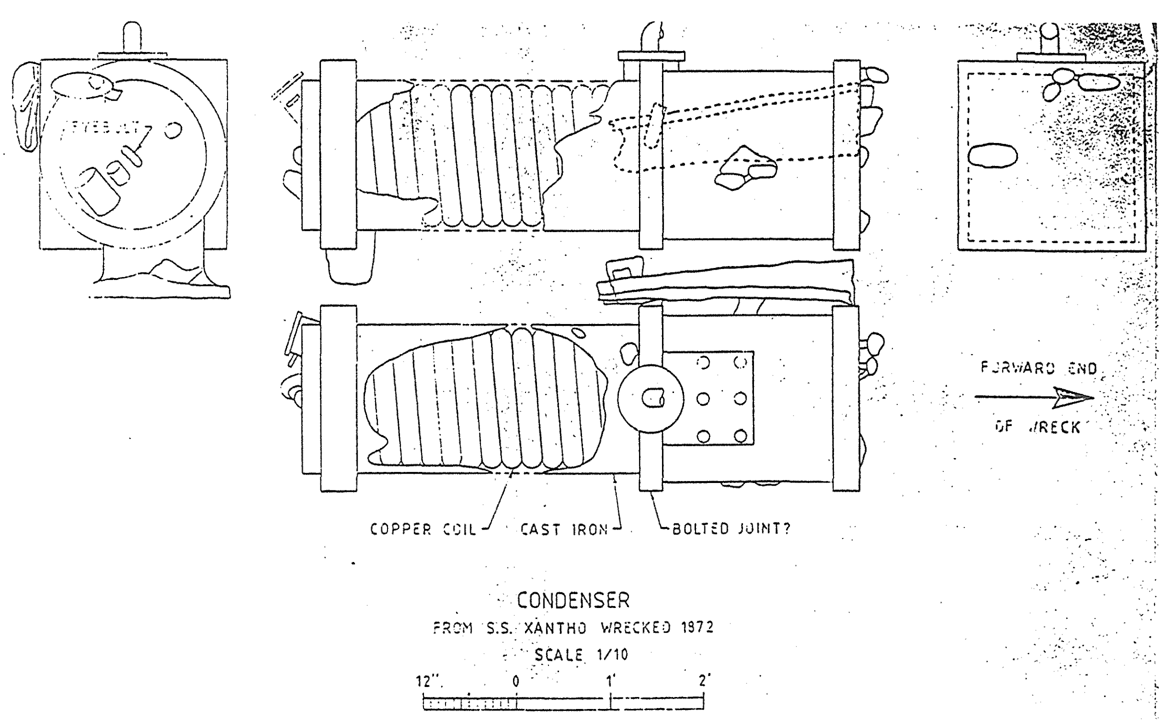
After consulting this material, consensus of opinion was that a large amount of cylinder lubricant was required for a trunk engine and this would have precluded the use of a surface condenser. This was because tallow or animal fat lubricants would have insulated it and rendered it ineffective. It was generally agreed that if a condenser had been fitted to *Xantho,* it would have been a jet condenser (Miller to McCarthy, pers. com.; Tomlin to McCarthy, 29/9/1983).

Further examination of the drawings and photographs from the wreck suggested that the unit was not like condensers of either the jet or surface type, however. Given the absence of piston rods to drive the 'condenser' pumps, it was reasoned that the *Xantho* most likely had a non-condensing engine and that it exhausted to atmosphere, like a common steam locomotive. This was most unexpected for a vessel re-fitted in late 1871, when condensers were common. The absence of a condenser meant that salt water had to be used to top up the boilers. The 50 psi boiler pressures on *Xantho* (quoted in the newspaper report above) would have caused heavy precipitation insulating the heating surfaces and requiring more coal to attain boiling point. As a result, coal consumption could be expected to be inordinately high. As Main and Brown have noted

> A non condensing engine... will only be used where fuel is readily obtained and it is important to save space and weight...[they] are serviceable for very short voyages in steamers...especially river navigation... [the] condensing engine is more economical... (1855: 50, 67).

After some deliberation it was eventually decided that the 'condenser' was most likely a feed water heater designed to heat cold sea-water before it was fed into the hot boiler (Figure 20 and Figure 74, below).

Figure 74: The feed water heater. By John Moffet, MAAWA (Note that it is incorrectly labelled, reflecting our original thoughts).



A non-condensing, high pressure, salt water feed arrangement was clearly unsuitable for a vessel which had to steam considerable distances and was operating on a coastline notorious for length, poor facilities and lack of coal supplies.

Attempts to identify the type of trunk engine located at the wreck initially posed problems, in that conflicting comments were found in the contemporary press. The engine was described thus

> ...these were made by Payne [sic], the Government machinist, of London, and are a masterpiece of workmanship having been originally intended for a Government gunboat. They have only been 18 months in work in the Xantho which consequently at the time of that vessel's founding they were as good as new. Their nominal horsepower is 30 with the capability of working up to 50. (Herald, 25/1/1873).[1]

Thus, my impressions about the naval origins of the engine were confirmed, though given the unreliability of the press, and in this instance their motives in writing this piece, more concrete evidence was required.[2]

A reading of the contemporary press and the *Liverpool Underwriters' Register* of 1871 gives the power of the engine variously as 30 HP, 33 HP, 40 HP and capable of up to 80 HP (*Inquirer*, 8/2/1873). The engine was recorded in the Register as being built by John Penn of London in 1861 and, in this respect, the register and the local press (though some got the spelling of his name wrong), were in agreement. All agreed that the average speed of the vessel under steam was 7 knots, though there was disagreement as to the

[1]Not the plural 'these' referring to the earlier use of the term engines to mean cylinders.

[2]As an example of 'organisational behaviour' in creating what eventually becomes archival material, in this case the press are expected to exaggerate, being motivated by their desire to see the wreck of the *Xantho* sold off to pay the arrears of wages owing to the crew when Broadhurst abandoned them. See discussion on page 158.

suitability of the engines for the *Xantho* (e.g. *Inquirer*, 29/5/1872; *Herald*, 25/1/1873).

In the 1871 *Xantho* register (Figure 35), the engine is described as a horizontal engine, built by Penn and Son of London in 1861, with 20 inch diameter cylinders and a 13 inch stroke. It can be seen that whilst originally recording the horsepower as 30, it was amended two weeks later to read 60 HP. This alteration helped resolve a number of problems. By combining the written sources with the evidence from the wreck itself, the engine was finally identified as a non-condensing, two cylinder 60 HP trunk engine built in 1861, most likely for the Royal Navy, by Penn and Son of London.

The ability to resolve the difficulty experienced here attests to the value of the artefact as an primary historical source in its own right and clearly illustrates both the complementary and conflicting nature of the documentary record. The perils of accepting the written word *verbatim* are clearly indicated here, as is the need to take considerable care where the archaeological record is the sole source of information. Though there is room for debate on the extent to which the documentary and material evidence is expected to complement each other, or even which of the two takes primacy, the following comment by James Deetz, with respect to combining these two sources in historical archaeology generally, is clearly relevant in the *Xantho* case.

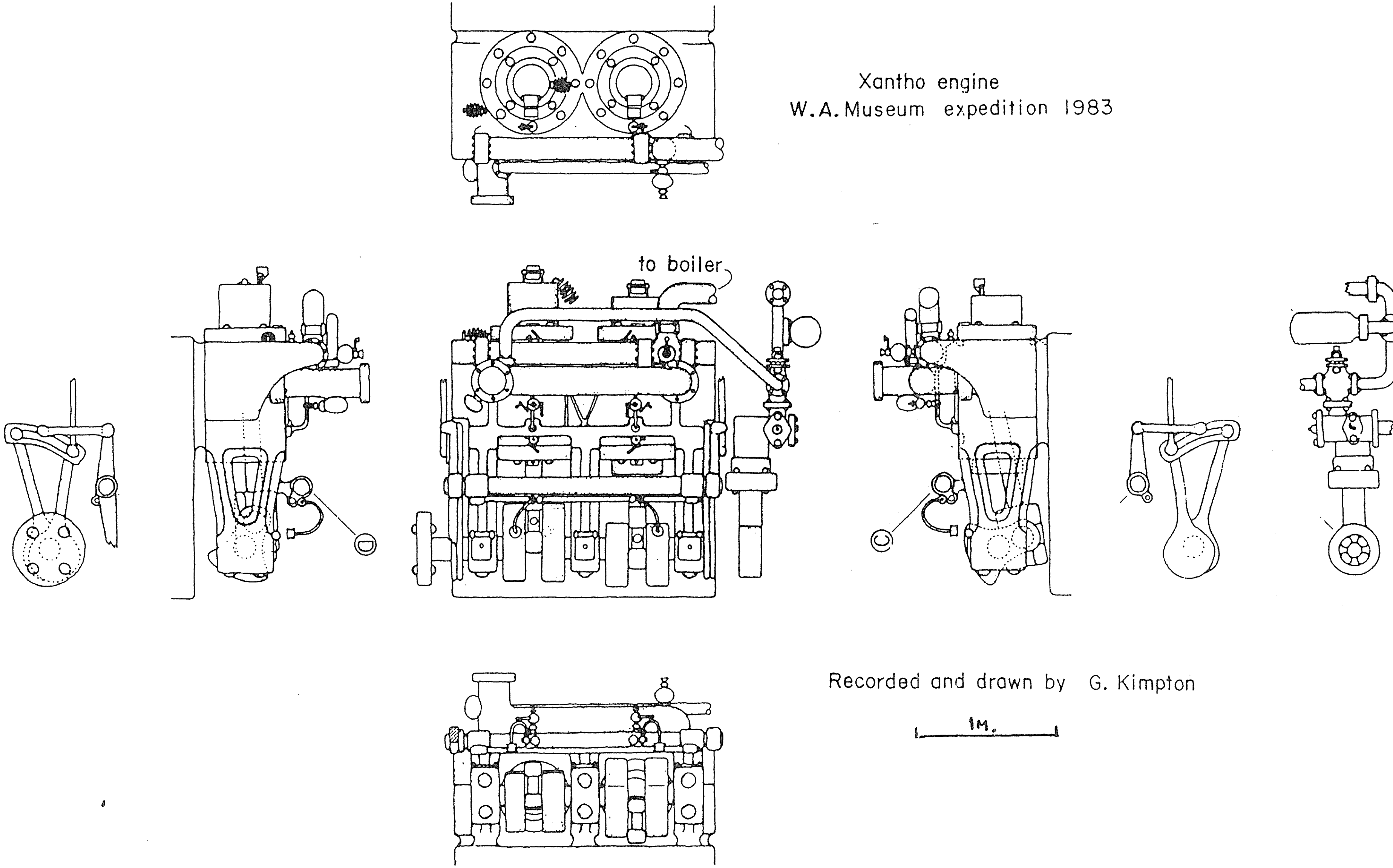
> In the nonexperimental [sic] sciences (if archaeology is indeed a science), precise certainty is rarely achieved. Rather, research takes the form of a gradual refinement of explanation, as more and more factors are incorporated into the construction of the past that one is attempting to create. In historical archaeology, this refinement is best accomplished by maintaining a balance between the documentary and material evidence, being always mindful that, to be a productive exercise, the results should provide a more satisfactory explanation than would be forthcoming from either set of data alone (Deetz, 1988:367).

The drawings of the *Xantho* engine in its concreted state (Figure 75) were sent to Britain and were examined by the *Warrior* team. With access to British Admiralty records they advised that the unit appeared similar to those described as the 40/60 NHP trunk engines built by John Penn for the Crimean War gunboats of 1854/5.[1]

Figure 75: The SS *Xantho* engine as recorded in its concreted state. By G. Kimpton, WAMM.

[1]Nominal horsepower (NHP) and Indicated horsepower (IHP) are defined in Appendix 2

Xantho engine
W.A. Museum expedition 1983



Recorded and drawn by G. Kimpton

The gunboat engines were described as having a cylinder diameter of 21 inches, a stroke of 12 inches and a computed trunk diameter of 11 inches, producing 60 HP. They developed 270 IHP which drove the gunboats at approximately 7 knots (Preston and Major, 1965: 107; Osbon, 1965:106). They were non-condensing for reasons that now become evident. Firstly, they were designed to have a very shallow draught to enable them to safely negotiate shallow waters, as a matter of priority. This required that weight be kept to a minimum and clearly condensers were heavy. (See Main and Brown's comments above). Being compact vessels, with gunnery the other main priority, space was also at a premium. This was another factor which mitigated against the fitting of a condenser. The specific factor that enabled the designers to dispense with the condenser, in their efforts to save weight and space and attain the required operating parameters, was the nature of the Black Sea, their intended field of service, however. It had a salinity of 16-18 parts per thousand, being only half that of the major oceans of the world (Russian Ministry of Defences, 1974; Florian, 1987:4). The salinity of the ocean around Port Gregory, and much of the Western Australian coast, was double that of the engine's original intended operational conditions.

A contemporary source, *The Engineer,* noted that these 60 HP, non-condensing, double-acting, double-trunk engines, exhausted to atmosphere and drove a two-bladed Smith's screw measuring six feet (1.8m) in diameter (*The Engineer*, 11/2/1898:124-5). It appears that over 150 of these small 60 NHP engines were built for gunboats in the course of two years; half by the firm of John Penn of Greenwich and half by the firm of Maudslay, Son and Field of Lambeth. Penn used his well-known trunk design; Maudslay, the return-connecting-rod type (See Figures 16 and 17). Both allowed for the required compactness required for the engine to be kept below the water-line for strategic purposes. Of additional interest was that some form of sub-contracting was needed for such a large order in such a short space of time. As a result, it appears that engineering firms elsewhere produced items such as the cranks and connecting-rods and that, on delivery, the two firms completed only the final assembly and installation phases (Preston and Major, 1965:29). As a result, the Crimean War gunboat engine is recorded as 'probably the first recorded instance of mass production being applied to marine engineering' (Preston and Major, 1965; Osbon, 1965:106).

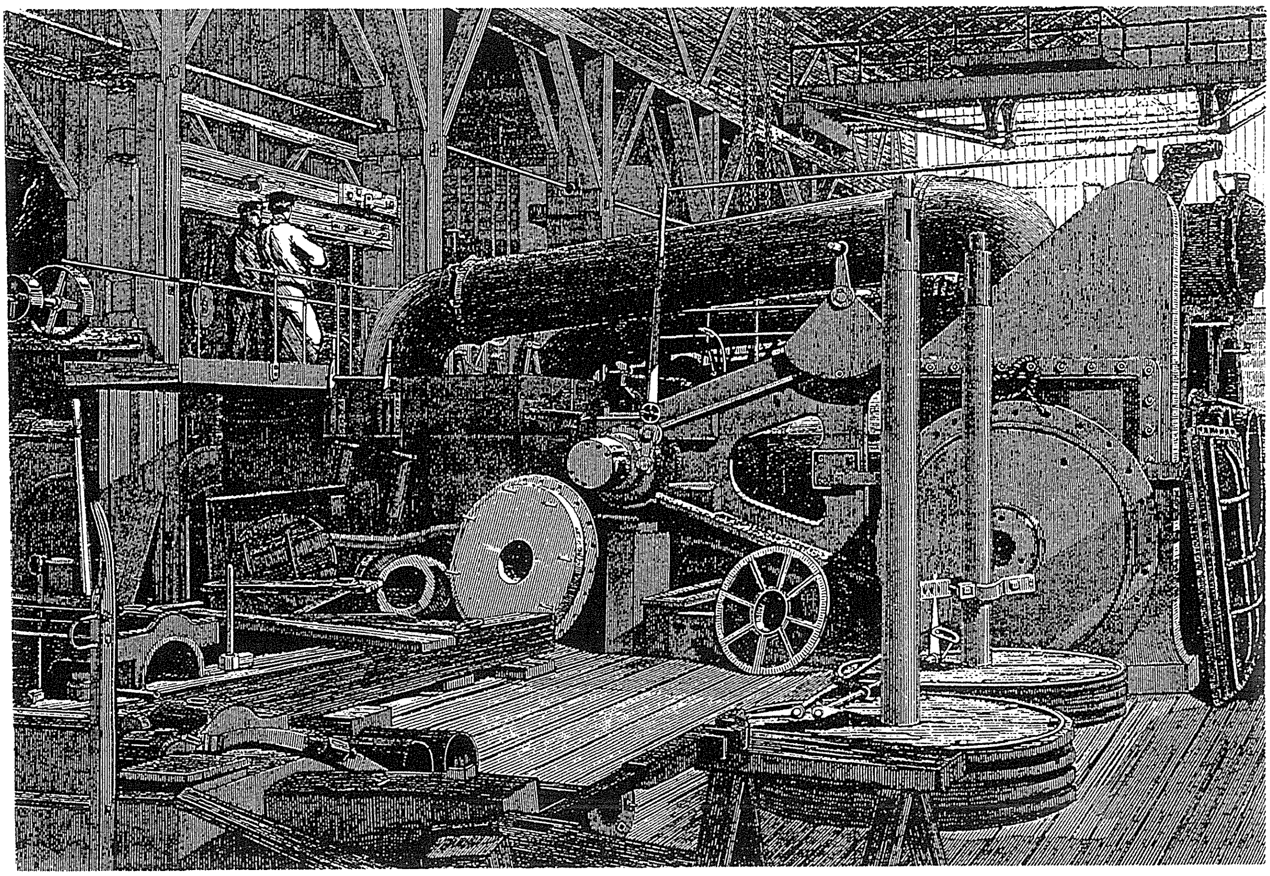
With respect to the apparently mass-produced nature of the Crimean War gunboat engine, the following comment is perhaps relevant

> Credit is nowadays usually given to the Americans for the pioneering of standardized mass-production and assembly line manufacture... there is evidence, however, that in some fields they were preceeded in the application of such methods by certain British engineering firms (Musson, 1969: 473).

On the basis of historical evidence it appears that Penn and Son need be credited, jointly with Maudslay Son and Field, for producing the first mass-produced marine engines in the form of these Crimean War gunboat types. Though built after that conflict, the *Xantho* engine appears to be one of this type. Of interest is the question whether this claim is supported by archaeological evidence. This will be discussed in Chapter 8.

As with the large trunk engines, such as that shown in Figure 76 below, there was an apparently very high standard of workmanship in the construction of the relatively small gunboat engines. Not only were high standards a hallmark of Penn's workshops, but the gunboat engines represented a watershed in marine engineering; operating at high speed (190 revolutions per minute) when other marine engines of the time were rotating at only 60 revolutions per minute at most.

Figure 76: A large trunk engine being constructed at Penn's Workshop (Illustrated London News, 7/10/1865).



The engine shown in Figure 76 revolved at around 60 revolutions per minute at most, while the gunboat engines were almost three times that speed. Resultant lubrication difficulties caused excessive wear, overheating of bearings and other problems for the engineers. They were also high-pressure engines, using steam at 90 pounds per square inch, or six atmospheres (Bar). This represented a quantum leap forward both in the pressure applied and in the speed of the engine (Preston and Major, 1965:108; *The Engineer*, 11/12/1898). The success of this type of engine represents the overturning of what had been described as the '...foolish prejudice against the use of high pressure engines or boilers at sea...' and the removing of restrictions placed on steam which, up to 1853, kept it to 30-45 pounds pressure or 2-3 atmospheres (*The Engineer*, 11/12/1898). It was considered an 'enormous leap' compared with practices of only a few years earlier. These engines, described as having cylinders 'no larger than that of the land locomotive of the time,' were thus apparently the first high-pressure, first high-revolution and first mass-produced marine engines made (*The Engineer*, 11/12/1898).[1]

Problems created by the high pressures and high speed forced the Royal Navy to keep a floating workshop on the China Station to service the engines (Preston and Major, 1965:108). Despite their limitations, some units remained in service for many years and a number lasted into the late nineteenth century and beyond (Osbon, 1965: 211-218), leading to the possibility that others still exist on the sea-bed. Despite this, the combined problems of heat losses from the internal and external surfaces of the exposed trunks, the dangers of ash and other abrasive substances coming in contact with the trunks, the power losses caused by friction at the trunk packing glands and the associated large appetite for coal (even when fitted with a condenser), all served to see the trunk engine, no matter how well-engineered, uneconomic in comparison to the compound engine developed in the 1860s (Guthrie, 1971: 112-115). Unfortunately plans and detailed descriptions of the 'gunboat type' have not yet been found.

Thus the 23 year-old, former paddle-steamer *Xantho* had been fitted with a ten year-old gunboat engine during the refit that took place in 1872 at the hands of the scrap 'metal merchant' dealer Robert Stewart. The first question requiring answering was how or why did this occur and what was its significance in general terms?

---

[1]There is room for debate on the claims made about pressure, as the SS *Indiana* and other American engines operated at 80 pounds per square inch. Johnston, pers. com., November 1996

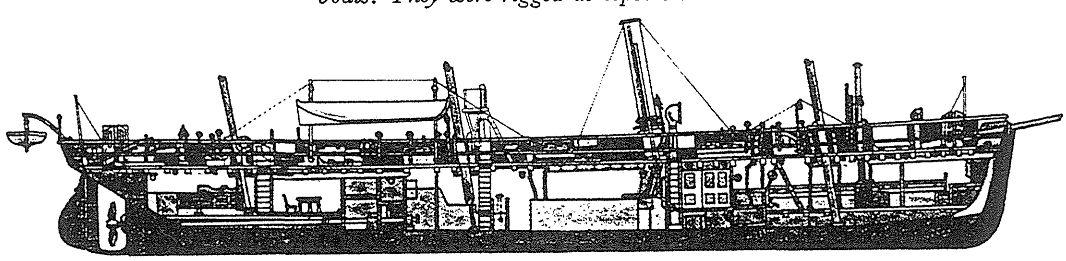
How one of these engines would appear in the hands of a scrap metal dealer and then be good enough to be put back into service in the merchant marine, ten years after it was built, needed to be examined, before Broadhurst's behaviour could be analysed in detail. The answer was found firstly in the shortage of seasoned oak which occurred in the mid 1850's. This resulted in permission being given to the builders of the 1854/5 gunboats to use a variety of woods, some of which were known to be 'green'; i.e. unseasoned and liable to warp (Osbon, 1965, Preston and Major, 1965; Archibald, 1968 : 91). The gunboats ordered for the Crimean conflict and later posted to foreign stations (for example China, the Mediterranean, North America, the West Indies) achieved notoriety when some of them literally fell apart within years of their launching. Even those built after the Crimean War were in some cases hastily constructed. After the war, for example, three quarters of those vessels found rotting away in shipyards were the 60 HP gunboats and there was a great scandal as a result (*The Engineer*, 3/1/1862:7). When these gunboats were being disposed of their machinery had seen little service, and 56 engines were fitted into the larger *Plover* class of twin-engine gunboats, for example (Preston and Major, 1965:93). Recycling of gunboat engines then became the norm as the excerpt in Figure 77 shows.

Assuming the 1861 date for building (or final assembly) of the *Xantho* engine is accurate, it appears that it may have been part of a subsequent batch of gunboat engines designed for one of the *Britomart* class of post-Crimean War gunboats, illustrated below in Figure 77.

These vessels were 120 feet (36m) in length, of 330 tons and had wooden hulls. A total of 20 were ordered; ten in 1859 from private shipyards and a further 10 in 1861 from Portsmouth. These included the vessels *Bramble, Crown, Danube* and *Protector,* which were laid down (or ordered) in 1861 and cancelled on the stocks (building yard) on 12 December 1863 (Colledge, 1969:14, 87, 152, 441). Though not conclusive, the chances of the *Xantho* engine coming from one of these four vessels is reasonably high, especially given that its known date of manufacture (or assembly) is 1861 (*Xantho* Register, 61/1871).[1]

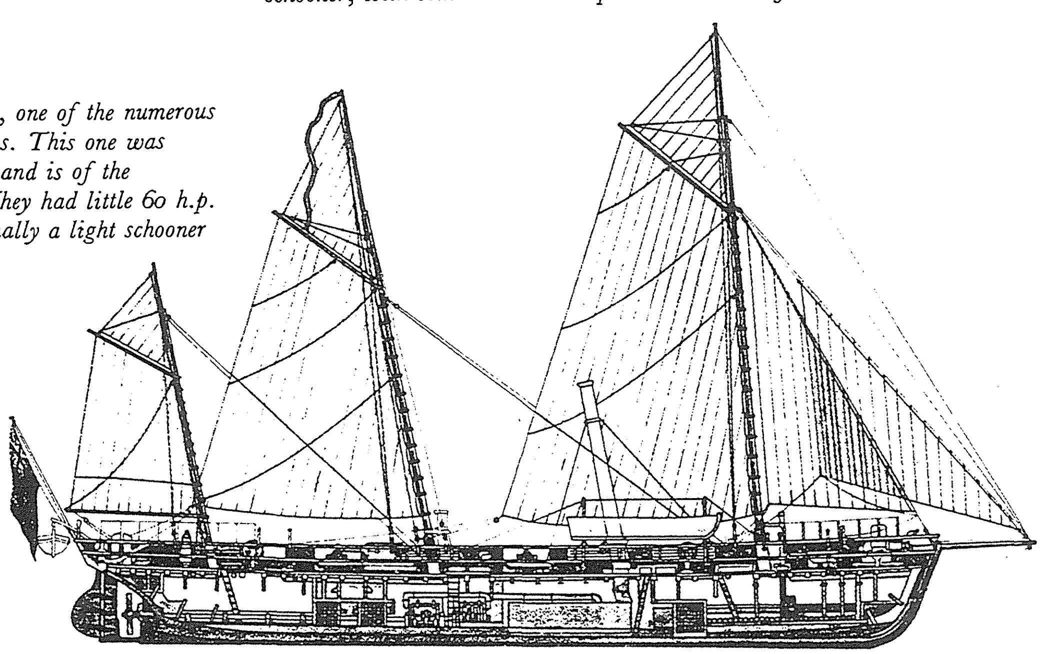
Figure 77: An excerpt from Archibald, (1968: 89), showing the *Britomart* Class of RN Gunboats and commenting on the use of the Crimean gunboat engines in vessels of 1867 designed for the China Station.

H.M.S. Beacon, *launched 1867, the name ship of a class of composite built, twin-screw gun vessels built for service in China. They were shallow-draught, their two engines were taken from the hulls of unused and rotten Crimean gun boats. They were rigged as topsail schooners.*



H.M.S. Tyrian *of 1861, one of the* Britomart *class of wooden gun boat designed as an improvement on the Crimean gun boats. She was rigged as a three-mast schooner, with some additional square sails on the foremast.*

H.M.S.,Skylark, *one of the numerous Crimean gun boats. This one was launched in 1855 and is of the* Dapper *class. They had little 60 h.p. engines and originally a light schooner rig.*



[1] There is some conjecture here. A vessel built in 1861 could have been fitted with an engine built and assembled entirely in that year or one that was built earlier and assembled in 1861. Equally, where mass-production techniques were used it could have had an engine that was built and assembled earlier and stored until required.

Conclusion

Having accounted for the wreck and its antecedents, the behaviour of those involved comes into focus in examining this instance of nineteenth century recycling. Was the scrap-metal merchant, Robert Stewart, dishonest; the marine equivalent of today's crooked used car dealer? These, indeed were my original thoughts (McCarthy, 1985; 1986).

In highlighting the difficulty of attaining agreement on explanation for motivational behaviour, it should be noted that Stewart may not have been dishonest, but may have assumed that a prospective buyer would operate the ship around Britain or on the Continent in sheltered waters, close to engineering, repair and coaling facilities. Given that the ship was old and originally designed for use in inland waters, it was a reasonable expectation that it would be operated where the stress on the hull would be kept to a minimum such as on inland or coastal waters where shelter could easily be obtained. Stewart may also have assumed that it would be operated in waters that were fresh, or nearly so, and over short distances to compensate for the lack of the relatively expensive and bulky condensers. As indicated, the 1871 register recorded the *Xantho* tonnage and carrying capacity in both tons and cubic metres. This was apparently with a view to its sale to either British or Continental interests or at least to countries such as France, where the metric system was then in operation and where steamships had long been in service on the coast and river systems. Though freshly painted, with increased cargo space resulting from its conversion to screw propulsion and with efficient cargo handling facilities, the vessel's age, comparatively small scantlings and its mode of engineering could not have escaped the attention of any knowledgeable buyer. An intent to defraud was not necessarily in Stewart's mind. On the other hand, perhaps he did not care and his interests were only on profit. In recognition of the latter possibility I proposed in 1988 that '...the refit, re-engining and sale of the SS *Xantho* in 1871 was not in the best interests of the unfortunate purchaser' (McCarthy, 1988a:347).

I also believed that Broadhurst had been duped in purchasing the vessel and that the decision was ill-conceived at best and I was clearly viewing Broadhurst's behaviour as evidence of naiveté and poor judgement. That the ship appeared on the very distant Western Australian coast naturally posed the question; what sort of person would purchase it for use on the sparsely-populated, poorly-serviced, Western Australian coast, far from the nearest marine engine repair facilities at Adelaide and Surabaya? Was he an impulsive individual with vision and access to capital, yet lacking the necessary experience of practical, frontier capitalists such as his contemporaries Walter Padbury, Charles Harper and others (cf. McCarthy, 1990)? Worse still, was he a rich fool, or a gentleman eccentric, given to grand and poorly though-out schemes?

Thus, a fundamental change of emphasis occurred in my research soon after I inspected the wreck and my attention came to focus on Broadhurst and how he came to make the apparently strange decision to purchase this odd vessel, a hybrid refugee from the scrapheap (McCarthy, 1985). By shifting emphasis to include the social context, the project ceased having the purely descriptive focus of traditional maritime archaeology and came to have an additional analytical/explanatory focus, eventually evolving into the *Xantho*/Broadhurst project. Elements of cognitive and behavioural approaches to archaeology were clearly called for.

I had also come to the realisation that the engine was of considerable historical and technological importance, not just as an intact example of the rare trunk engine type, but as an example of one of the earliest high-pressure engines used in the British Empire and the first mass-produced, high-revolution engines used at sea. It was physically degrading, however, and also was in danger from recreational divers. As noted, it was camouflaged with rocks and sediment to keep salvage divers at bay. Sacrificial anodes were also attached in order to hasten the regrowth of animal matter and to slow the processes of corrosion.

I then examined the possibility of raising the entire engine and discussed with Conservator North the feasibility of raising the engine and of conserving it. He indicated that, if raised, it would have to be treated as one piece and that the main problem was simply one of size. He advised that a large specific-purpose treatment tank was not then available and would have to be obtained were the engine to be raised. Failing the provision of a tank, it could be left in its concreted state and placed in a safe underwater environment near Fremantle. There a sacrificial anode system could be attached to protect the engine against corrosion. North also indicated that, if the engine were to be raised and placed in a treatment tank with appropriate infrastructure, the external surfaces of the engine could be readily deconcreted and treated by electrolysis, a common technique successfully applied to large iron objects (North, 1987: 207-231).

North felt that the internal cavities in the engine would be a much more difficult proposition, and that the only feasible approach would be to clean them as well as possible and then electrolyse them using insulated rod anodes. He predicted this would be a slow process. The main costs were the tank, the provision of space for the tank, treatment chemicals and labour costs based on staff-time. These he estimated at 200 operator hours for one person spread over a two-year period. In summary, he stated that '...the treatment of this engine will be difficult but there is no reason to believe it could not be done successfully' (North pers. com., May 1983, SS *Xantho* file, 9/79, Department of Maritime Archaeology, WA Maritime Museum).

When all of this was considered, I came to favour the option of raising the engine for conservation, further examination and eventual display. The matter was taken to the Maritime Archaeology Advisory Committee (MAAC) and their support was obtained. Thus the project aims were further amended and a decision was made to examine the possibility of raising the engine in more detail (MAAC Minutes, 22/6/1983).

As a result of these developments, the SS *Xantho* research design was markedly changed to include three further considerations; one, an intensive study of Charles Broadhurst based on the archival evidence; another, the further examination and excavation of his ship in order to address the questions posed by the site; and thirdly, the possibility of raising the engine for conservation, study and eventual display in the context of an excavation of the stern section of the ship (McCarthy, 1988c: 189).

The archivally-based study of Broadhurst began in 1983 and came to a satisfactory conclusion in 1990 (McCarthy, 1990; pages 100-131, above).

The excavation of the stern section (accommodation and engine room spaces) of the ship and the removal of the engine, in the context of that excavation, began in mid-1985 and will be the subject of the next chapter.

In the intervening decade, further analyses and excavations have occurred, both on-site and in-laboratory; leading to the retrieval of further data relevant to the ship and Broadhurst. These will be described in following chapters and the results will be drawn together in the concluding chapter.

CHAPTER 7 :

ON-SITE EXCAVATIONS, 1984-1994

The cutting free of the Xantho Engine

The SS *Xantho* engine was clearly a significant historic and technological relic at risk from natural and human forces. These considerations together with various conservation reports, led to the decision to assess whether the engine could be successfully raised, transported and conserved for the purposes of exhibition and further study. Broadhurst's grand-daughter, Marjorie Darling, was told of the plan and received the idea with enthusiasm, thereby giving a final seal of approval.[1]

The feasibility study required that appropriate conservation facilities be developed to accommodate the largest and most complex artefact raised after a century in a heavily-oxygenated saline environment.[2] The means of removing the engine from the wreck and of transporting it to the beach at Port Gregory and then to Fremantle were assessed, both with favourable results.

Test cuts of the bearers holding the engine to the hull were proposed, as part of the study, in preparation for the eventual recovery operation. The problems identified in this exercise were routine salvage procedures governed by engine size and water depth. On the other hand, the weight of the engine and hence the number of lifting bags required was difficult to predict. Eventually an estimation formula was obtained from practicing engineers, producing a range from 7-10 tonnes (allowing for the unknown weight of concretion).[3]

---

[1]Though the wreck had been declared historic and therefore the property of the State, I believed that her opinions needed to be taken into account before removing the engine.

[2]The SS *Indiana* engine was recovered from a more benign environment.

[3] Pers. com., Brian Doherty, ex works Engineer, Cheynes Beach Whaling Station, to Miller and McCarthy, 22/2/1984. The formula used: Weight (in tons) equals length, by breadth by height (in feet) divided by 27 and multiplied by 1.3.

In cutting the engine free of the ship, standard methods, such as the use of hacksaws, were expected to be unserviceable given the size of the engine bed and the cramped conditions under the engine. As a result, the possibility of employing other underwater cutting equipment was assessed.

It was eventually decided to use a thermal lance, an oxygen/steel powered, high temperature cutting tool used in many above water applications.[1]

An underwater trial was conducted in January 1984 on the sea-bed adjacent the wreck of the steel-hulled SS *Lygnern* (1920-1928), which lies in shallow water just off Fremantle.[2] A clean eight mm thick sheet of scrap steel was lowered to the sand bottom adjacent to the wreck in an attempt to emulate site conditions at the *Xantho*. A test-cut was satisfactorily conducted, proving that a defined line could be followed with a neat cut of around 1.5 to 2 centimetres width resulting.

With the benefit of this knowledge and attention to safety issues pertaining to the use of high-temperature cutting tools in a petrol-driven 5.5m aluminium work-boat, the test was extended to a portion of the wreck of the *Lygnern* itself. Abandoned in 1928 after running aground, the wreck was partially destroyed with explosives in 1970 (Hall, 1975:18-21). The submerged remains had accumulated corrosion products and a substantial layer of marine growth and concretion over the years. This mirrored, to an extent, the state of the iron-work on the *Xantho*. The results were similar to those with the clean scrap steel. It was decided to apply the method to the *Xantho*, in a pre-lifting survey

---

[1] The thermal lance consists of a hollow steel tube measuring 2 m in length and 18 mm in diameter, filled with 2 mm diameter steel rods. The working end of the lance is pre-heated to very high temperatures using oxy-acetylene equipment and when oxygen under pressure is passed through the rod to the red-hot tip, it ignites to produce a cutting flame. Its application underwater was not well documented, though previous experience in the oil and salvage industries had shown that it could work under water.

[2] By Museum staff Geoff Kimpton (an ex-oil industry diver) and myself, assisted above water by Colin Powell and Bob Richards.

and test-cutting program, that was to be followed by a longer season at the site should the trial prove successful.

A one week field trip was allocated to the pre-lifting/test-cut survey. Having ascertained that the April/May period was not suitable, summer months were selected instead.

A team of conservators, led by North, was again included in order to examine the success of the anodes previously fixed to the engine and drive shaft and to monitor the extent of biological re-growth in the nine months since the first pre-disturbance survey was conducted. The remainder of the team was to conduct test-cuts and examine the best means of removal, lifting and transporting the engine to shore and, from there intact, to Fremantle.[1]

The aims set of this part of the project were to

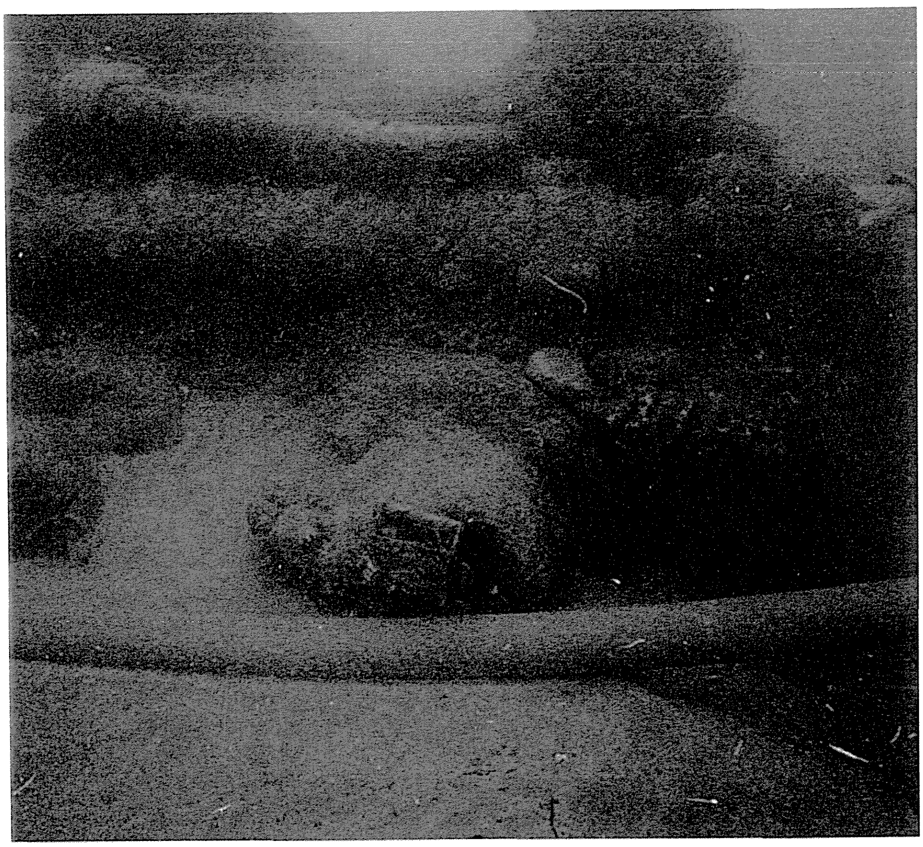
1. Relocate the site and buoy it ready for diving.
2. Analyse the effectiveness of the conservation techniques used in 1983.
3. Clear the engine of sand and rock.
4. Continue recording details of the engine.
5. Examine methods of engine removal and locate cutting positions.
6. Undertake some test-cutting to ascertain,
    a. Problems
    b. Time
    c. Gases needed.
7. Strop engine to examine lifting problems (then remove strops).
8. Re-cover engine with sand and rocks.
9. Examine how the engine is to be manoeuvred to the jetty, ashore then to transport (e.g. a truck).

On arrival at the site in mid-January 1984, the team were startled to discover that though diving conditions were generally good, the visibility was poor and the wreck was almost totally covered in sand (Figure 78). The boiler, which nine months earlier stood almost clear of the seabed, had only 1.5m of its upper surfaces protruding from the sea-bed. The engine was buried up to the top of its trunks. Apart from the

[1] The team comprised Conservators North and MacLeod and the cutting team of Kimpton, Powell, Richards and and myself.

top 20 centimetres of the stern post, the remainder of the site was not visible. Despite this severe, yet informative, set-back, the strong currents and poor general conditions present in the April 1983 study were not in evidence.

Figure 78: The extent of the sand cover on the engine. Photograph by M. McCarthy.



The newly-deposited sand around the engine was quickly cleared. Even so the anodes were re-located only after considerable effort, being totally buried. When tested, the anodes were found to have had only a limited effect, due to their burial in sand and clay in the intervening months. After being excavated they were placed on a higher level on the understanding that they would begin protecting the engine once they were returned to an oxygenated environment. The sand cover had also effectively killed all marine growth on the engine and boiler, bar the upper surface, leaving only newly colonised weed and dead molluscs on the concretions. This gave the divers clear access to the remains without the need to remove any of the living animal and plant matter as had been the case on the previous expedition. Some of the dead bivalves, for example, were still articulated.

Here were clues to the bands of marine growth seen on the boiler in April 1983. Accretion of sand had apparently killed marine growth on the boiler over the previous summer months. When we arrived at the wreck in April 1983, just before winter, the seas had begun to carry the sand away. The growths were apparently only a few months old.[1]

North concluded at the time that

> Sometime between May '83 and January '84 there had been a tremendous deposition of sand onto the *Xantho* site and this had [negated] nearly all our experiments...My interpretation was that, for some reason, the site has been completely covered with sand so that none of the wreck protruded above the sea-level. Approximately 3 weeks ago some of the sand was swept away to reveal the top 3 feet of the boiler and colonisation started again. In the last 1 to 2 weeks a second sand shift has exposed the boiler for a further 2 feet.... We had a further disappointment with the anode system. The potential measurements indicated that it wasn't working and I felt this may have been due to the anodes being buried under the sand... About 3 feet below the present seabed we ran into a mixture of fine sand and clay. I estimated that there would have been 3 feet of this material overlying the anodes... and above that another 10 feet of sand...so it is not surprising they were not giving out much current (North to Beegle, pers com., February 1984, SS *Xantho* file 9/79).

Having been filled with mobile sand since the 1983 program, the area immediately beneath the engine was excavated in a gross manner (i.e. without recording). The space was then examined with underwater torches in order to ascertain the size and strength of the engine bearers and other engine supports.

---

[1] A disadvantage in 1984 was that the rate of re-colonisation and re-growth of biological organisms over the 9 month period was obviously not able to be monitored and this element of the project was then shelved until our next visit.

North had earlier predicted a 0.08 to 0.10 mm corrosion rate per year; i.e., 8-10mm or 5/16-6/16ths (3/8th) inch per hundred years. The examination of the wreck in May 1983 confirmed that what were originally 3/16ths inch (5 mm) and 5/16th inch (8 mm) thick hull plates and their supporting frames had become mere shells.[1] In similar fashion it was found that the one inch or 25 mm thick bearers, which supported the engine, and which were much thicker then the hull or its frames, also contained little residual metal. As the bearers had been exposed on both surfaces to the elements, corrosion had occurred simultaneously on each side. Thus, at a rate of 8-10 mm of corrosion per hundred years it was predicted that 16-20 mm of the original 25 mm thick engine supports would be severely corroded. When test-holes were drilled through the concretion into bare metal, it was found that in some cases corrosion rates had been higher and that in many cases the iron-work had totally disintegrated, leaving hollow shells filled with corrosion products.

Though heavily concreted, it was ascertained that the engine was originally bolted to a rudimentary box frame consisting of riveted plate iron, originally one inch or 25 mm in thickness and approximately 18 inches or 500 mm deep. The frame, in turn, was riveted to lateral supports or beams of I-section iron, running laterally across the engine room. These were attached by rivets to the hull and frames on the vessel's side. Supporting the fore lateral bearer and fixing it to the keelson was a vertical iron plate measuring one foot (10 cm) wide and one inch (25 mm) thick. This was further braced to the keelson with a similar sized diagonal bearer. The engine bearers were almost totally corroded and were extremely fragile. The vertical supports fore of the

[1]Corrosion occurs on both sides of the hull plates. Thus a predicted rate of 8-10mm per one hundred years would see plates double that thickness consumed, if predictions were correct.

engine, attaching it to the keelson, had substantially more original metal left.

The extent of the corrosion confirmed the conservator's prediction that the engine would begin to disintegrate after a few decades, or at best it would collapse intact into the ship's bilge. There it would be increasingly susceptible to sand abrasion. Copper piping was also found passing from the engine, under an iron decking, into the bilges underneath.

As indicated earlier a large, four-bolt, flange on the aft section of the crankshaft, which was originally connected to another similar in size and construction on the propeller shaft forward of the thrust block, had parted from its mate as the hull of the *Xantho* broke up. This left the engine disconnected from the stern shaft and thrust block (See Figures 53 and 82).

After exploratory work in the bilge and around the engine, it became apparent that due to the rudimentary construction of the engine-bed and its advanced state of decay, very few points needing cutting in order to free the engine. A suitable location for the test-cut was identified and marked and large timber bearers were wedged under the engine should it collapse during this exploratory work.

Following the techniques tested on the *Lygnern,* the cut was carried out. More corrosion products than those experienced on the *Lygnern* were lifted towards the surface in a cloud by the gas bubbles produced by the cutting process. When the bubbles burst, the corrosion products descended in a cloud, obscuring visibility and covering the operators with detritus. Deafening noise was also generated by the escaping gases and the two factors made the cutting a very difficult process, indeed. In the enclosed spaces under the engine, visibility was further reduced by a combination of the noise from the escaping gases and the glare from the cutting tool (Figure 79).[1]

Though planned as a test-cut, there was so little original metal holding the engine and its box frame to the vessel that within the space of a few hours, the engine was cut free (Kimpton and McCarthy, 1988).

Figure 79: Cutting in progress. Photograph M. McCarthy.

At the conclusion of the cutting process the engine remained fixed in place, however. Apart from the copper piping, nothing solid could be seen or felt in the spaces underneath. A vehicle jack was then positioned on the under-surface of the engine and pressure was carefully applied in order to examine the orientation in which the engine was held. Having ascertained that the engine was held only by a small number of copper pipes running vertically through the engine-room deck, into the bilges,

[1] In the *Xantho* case the resultant gases had a free exit to the surface and the effectiveness and safety of the tool in an enclosed underwater space was not assessed. Were it to be used in an enclosed environment, considerable care would be needed due to the build up of gases which have the effect of producing an upward force on the ceiling of the space; additionally they could become explosive.

these were cut using a hacksaw. As the last cut was completed and the jack was lowered, the engine slowly settled downwards onto the large timber baulks previously placed underneath it. It was free and ready to be lifted at a later date.

Where the freeing of the engine was expected to be a lengthy process, requiring large quantities of cutting equipment applied over a number of seasons, instead the whole operation took just a few hours spent over a four day period.[1]

The excavation of the stern and the removal of the engine.

Briefings on the 1983 and 1984 phases of the SS *Xantho* project were regularly made to Maritime Advisory Committee (MAAC) of the Western Australian Maritime Museum. As indicated earlier, this group of academics and representatives of the community at large advised the Director of the WA Museum, who in turn advised the Trustees, who were then legally responsible for the Museum and its operations. In receiving various reports on the merits of the project, discussions were held on the question of a reward to the finders of the wreck. The justification for the reward took into account the vessel's pioneering role, its links to Broadhurst and its importance to the history of marine engineering (Sledge, to Director, WA Museum, 2/10/1984). Letters of support from the HMS *Warrior* team and from the Water Transport Department of the Science Museum in London were also provided. These indicated that the *Xantho* engine was an 'exciting and unique find', one which would be (in their words) 'invaluable' in order to 'fill in the gap' for a period were no records had been found (Tomlin to McCarthy 28/12/1983; Roone to McCarthy 18/5/1984).

---

[1]The expedition left Fremantle on 14 January and returned on 20 January 1984.

Eventually it was decided to present to the finders a reward of $3,000-the largest sum ever given under the terms of the State Maritime Archaeology Act of 1973. Until late 1994, when rewards were retroactively paid to the finders of the Dutch and English East-Indiamen, it was the third largest reward paid in Australia under either State or Federal shipwreck legislation.[1] This was a fair indication of the changing perception that, though built of iron, the SS *Xantho* had become one of the most significant wrecks found in the waters off Western Australia. It was also a major change in direction for research in maritime archaeology within Australia.

In addition to the reward, a budget of $7,200 was allocated to the next phase of the project; the excavation of the stern and the recovery of the engine. Being a relatively small sum in comparison to that then allocated to the excavation of wooden wrecks, I elected to augment the funds with sponsorships, tax incentives and other schemes. Being a new element in Australian underwater archaeology, it was also decided to maximise the returns from the excavation by involving graduates from the Post-graduate Diploma Course co-ordinated by the Department of Maritime Archaeology and by volunteers and professionals from other maritime archaeological units in Australia. As a result, calls for expressions of interest in participating in both the excavation and a proposed seminar on iron and steamship wrecks were made through the Australian Institute for Maritime Archaeology (AIMA).[2]

In the briefing notes the participants were given logistical and other information common to large expeditions. Summaries on the philosophy behind the practical and theoretical seminar, project aims and a

[1]The finders of the wooden-hulled American China Trader *Rapid* (1807-1811), in Western Australian waters, received a total of $30,000, mainly in recognition of the bullion recovered and the finders of HMS *Pandora,* (1783- 1791), in Queensland waters, received an interim reward of $5,000.

[2]The seminar was to be the first conducted under the umbrella of AIMA. AIMA also gave its official support to the program as a recognised project ensuring that all donations, or support in kind, became tax deductible.

background to the excavation, in the form of a paper presented earlier in the Steamship Archaeology Section of the Annual Council for Underwater Archaeology Conference at Boston, USA (McCarthy, 1985) were also disseminated (McCarthy to Participants, SS *Xantho* excavation and seminar, File 9/79/5, WA Maritime Museum).

The expedition was planned for mid-April through mid-May 1985 with the knowledge that, although the summer months presented far more amenable diving, they also resulted in the covering of the wreck in mobile sand. The aims of this section of the project were

1. The relocation and re-examination of the site.
2. Familiarisation dive for all divers.
3. Re-examination of the chemical state of the wreck and assessment of the effectiveness of the anodes set in 1983.
4. Conducting the seminar on practical and theoretical aspects including recording and conservation objectives.
5. Practical demonstration of the methods used in measuring the electropotential of the wreck.
6. The setting of site grids, excavation of the forecastle, under the hull and stern. Attempted recovery of some cargo in the original sacks. Detailed examination and recording of hull, boiler and machinery mounts. Removal and recovery of the engine propeller, shaft, rudder , thrust-block.
7. The re-photographing of the site in colour and black and white, mosaic of the plan view, port and starboard elevation. Stereo photogrammetry of engine, boiler, stokehold and other fittings. General photography, including video coverage above and below water.
8. The production of an isometric view of the site and the machinery

A considerable amount of sponsorship had been obtained in the interim, ranging from equipment such as buses, cranes, other transport, machinery, a large treatment tank for the engine, underwater video systems, machinery, dive gear, air-fares and other items including boats. The on-site equipment was standard; a 6m aluminium work boat as the chief dive-boat, smaller vessels, caravans, trucks, 4WDs and the Museum's marquee as expedition meeting and victualling hall.

Shortly before the expedition got under way, senior conservator Dr. Neil North left the Museum. In believing the conservation project possible, North was the key element in the decision to go ahead with the raising of the engine. His replacement was Dr. Ian MacLeod, North's assistant in the pre-disturbance survey. Macleod's conservation team included an organics conservator and a specialist on-site conservator who were to replace him when he returned to Fremantle at the mid-expedition change-over.[1] The organics conservator was to attend to timber, leathers etc., and to examine the biology at the site in a effort to ascertain whether it had altered since 1983. The on-site conservator's task was to conduct conservation and stabilisation required of the artefacts on-site, in the water column, on board the work-boat and ashore. At the field-station the artefacts were to be catalogued, photographed, drawn and then packed, loaded and then transported to the laboratories at Fremantle. Also present was the Museum's artefact (finds) manager, whose task was to co-ordinate the management of artefacts after they were delivered to the field laboratory.[2] The finds manager was also to be responsible for tracking each item through the conservation process at the Museum's laboratories, and from there eventually into storage or onto the exhibition floor. All conservators were divers. The diving contingent also included 1981/2 Maritime Archaeology Course graduates, some of whom were then staff of the various maritime archaeological site management units burgeoning throughout Australia, such as the Victoria Archaeological Survey.[3] Other staff were technical officers from Museums, such as the State facility in Queensland and Western Australia.[4] Representing the many volunteer archaeological groups interested in iron and steam shipwrecks throughout Australia were other specialist or volunteer staff.[5] Added to

---

[1]Nancy Mills-Reid and Jon Carpenter, respectively.

[2]Fairlie Sawday.

[3] The maritime archaeologists present for the excavation and seminar were Mark Staniforth, Shirley Strachan, Peter Harvey, Nick Clarke, Jill Worsley, Brunhilde Prince, Steve Cushnahan and Dena Garratt.

[4] Sally May, Patrick Baker, Geoff Kimpton and Bob Richards.

[5] John Riley from the Maritime Archaeology Association of NSW, Geoff Hewitt (diver/marine architect) and Lyall Mills (underwater video camera-operator), both from the Maritime Archaeology Association of

this skilled group were many local volunteer divers, medical practitioners, sponsors, partners and others. A mid-season changeover of all participants, bar a core team of five, was also planned.

The excavation season opened in mid-April 1985 with our arrival at Port Gregory, settling into the caravan park, and setting up in readiness for the seminar and excavation. The wreck was re-located after a very difficult 45 minute search hampered by poor visibility, swell, suspended weed and currents similar to those experienced in 1983. When located, it was buoyed after a perfunctory examination to await better conditions. In the meantime the skills of new divers were tested and improved where required while experienced personnel set about preparing equipment, field laboratories and other gear.

The seminar was brought forward in the face of the bad weather and began with a letter of welcome *in-absentia* from Jeremy Green, the AIMA president. Graeme Henderson, Curator responsible for the Museum's Colonial Wreck Program, attended the seminar briefly and presented another introductory address. In recognising that archaeologists had only recently begun to contemplate iron and steam shipwrecks as a truly significant part of the nation's cultural heritage, Henderson stated that

> We archaeologists (and conservators) must expect to be surprised by iron steamships sites. There has been so little (properly published) work done underwater on this type of site that we hardly know what to expect in terms of their preservation underwater (1988b: 10-12).

On the other hand in reflecting current thought in British circles Henderson quoted the well-known David Lyon of the National Maritime

---

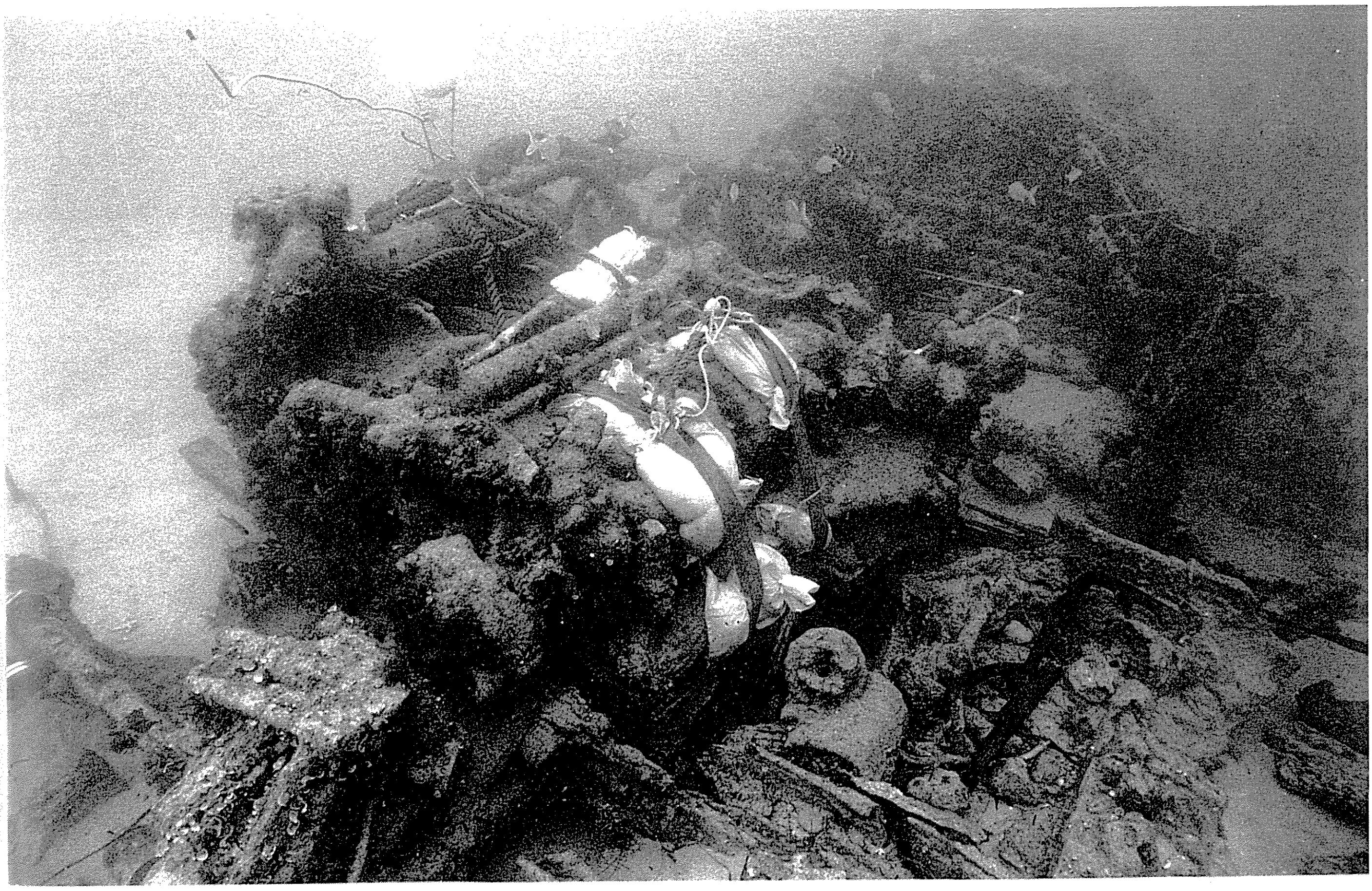
Victoria, Brian Marfleet, (professional police diver) from the Society for Underwater Historical Research in South Australia, Phil Clegg (professional oil industry diver), Chris Buhagiar (diver/artist) both from the Fremantle MAAWA and Peter and Jill Worsley from the Geraldton MAAWA.

Museum (Greenwich), who doubted the wisdom of spending what he believed were great sums of money to make inferior plans on the sea-bed. Henderson then echoed the commonly-held belief that iron wrecks would survive better than wooden wrecks in many environments and argued that, due to their mode of construction, they would not constitute, what he termed, the 'individual expression of creativity' which he believed was to be found on the wooden wreck. In questioning whether anything other than what was readily available in engineering books and plans would result from the study of iron and steamship wrecks, Henderson also suggested that '...no further engines be raised at least until the *Xantho* engine has been successfully conserved' (1988b:11).

As conditions improved work began on-site. On inspection, the wreck site was found to be in similar condition to May 1983, with the stern post, tip of the propeller, all of the engine, most of the boiler, deck winch, windlass, stem-post and sections of the port hull were exposed. A copper cable attached to an anode connected to the engine had a sulphide patina, indicating that it had been buried under sediment in the summer months previous to our visit. The anode itself was found to have been partly working, resulting in a reconstituted layer of calcium carbonate on previously cleared copper and brass fittings. The anode attached to the stern shaft also appeared to have also worked only partially, due to its having been buried. MacLeod and his team continued the corrosion study, proceeding to measure the temperature at the site and to take corrosion potentials at points on the wreck earlier ear-marked for comparative study (Conservation Daybook, 15-25 April, 1985).

An external site grid (a reconstruction of the 1983 external grid) was set up while the engine was carefully stropped (sandbagged and bound with wide webbing straps to spread the pressure) in preparation for lifting by a rigging team.

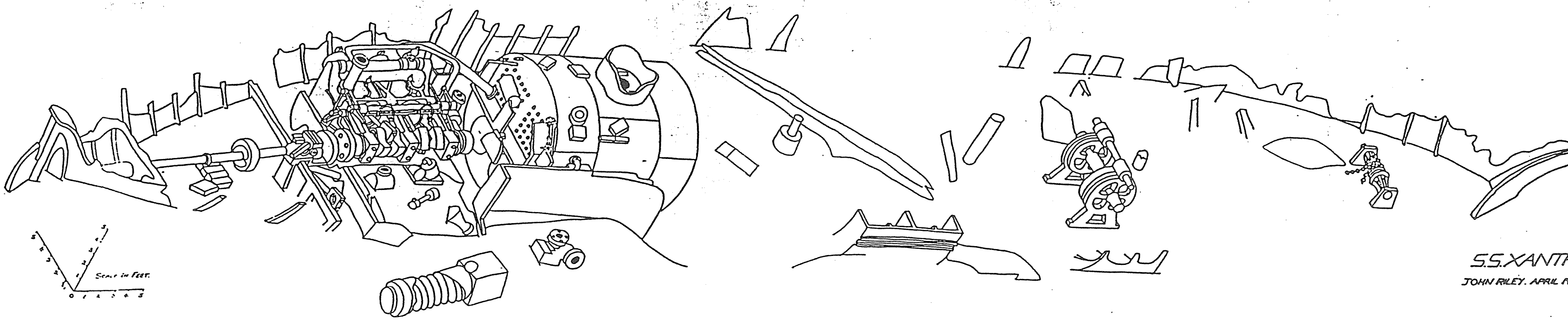
Figure 80: The engine ready for lifting. The strops and sandbags protecting the engine are clearly evident. To the right of the engine are oil and other containers. The break between the flanges joining the engine and the thrust-block is visible in the bottom left-hand corner. Photograph by P. Baker.



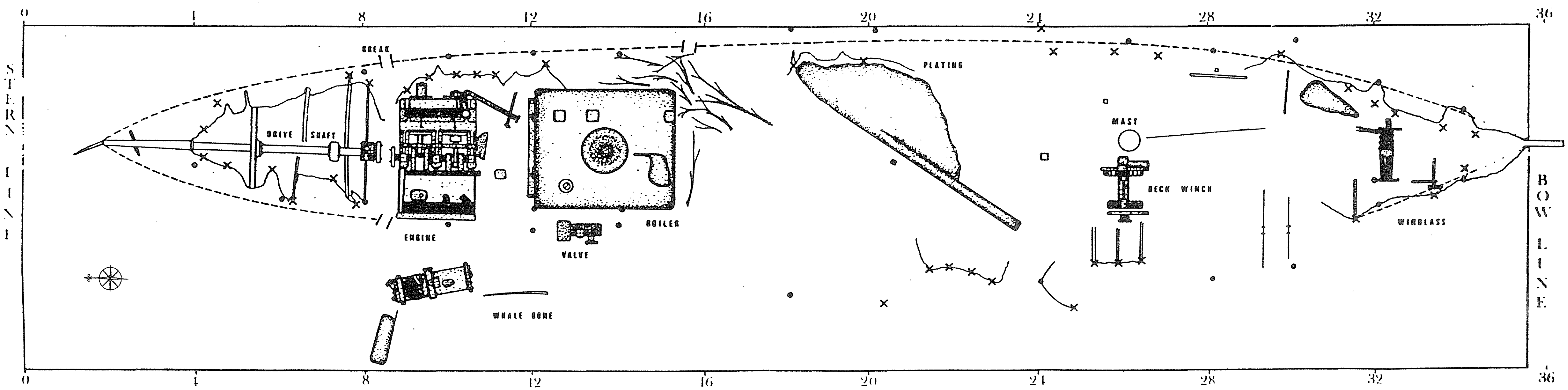
John Riley, whose work on iron shipwrecks was discussed earlier, commenced the production of an isometric projection of the site.

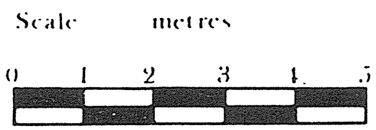
Figure 81: An isometric projection and plan view of the SS *Xantho,* by John Riley and Steve Cushnahan, respectively.[1] See also figures 52, 54 and 80.

[1]Where sites are large, extending beyond the limits of diver visibility, the isometric projection allows areas chosen for detailed excavation or examination to be conceptualised as part of the whole. They are also very useful as a briefing tool, as were the site models produced by Riley for the *John Penn* (Figure 7).



S. B. CUSHNAHAN June '83





XANTHO
SITE PLAN 1:100

Throughout the excavation, the stereoscopic system shown in Figure 81 was deployed. It comprised a twin 15 mm underwater camera system mounted on a one metre-long bar and a double grid frame which allows the diver to locate the cameras vertically above the target. Intended as a three dimensional supplement to manual recording, it provided a very useful cross reference where the manual recording required checking or augmentation in the laboratory (cf. Green 1990: Ch. 5).

Figure 82: Photographer Pat Baker employing two Nikonos III cameras with 15mm Nikonos lenses and a double grid square used for keeping the cameras in a horizontal plane. Photograph by N. Clarke.[1]

[1]When correctly in position above the dual grid frame, only one of the pair can be seen through the view-finder.

Underwater and above water video recording successfully augmented the traditional 2D and 3D colour and black-and-white still photography, common to most underwater excavations. As the recording program continued, a late-season cyclone was identified slowly progressing down the coast. This had the effect of holding the off-shore wind pattern, making the conditions ideal for work, although the prognosis was bad. As a result, it was decided that the engine lift would have to be brought forward.

Work then began on attaching and part filling lifting bags to ascertain the security of the strops and to test the system. All went well and a decision was made to proceed. The wreck was then cleared of all but the rigging team and camera operators in preparation for the lift (Figures 83a-c).

Figure 83a: Riggers Geoff Kimpton and Brian Marfleet adjusting the lift bags. Photograph by P. Baker.

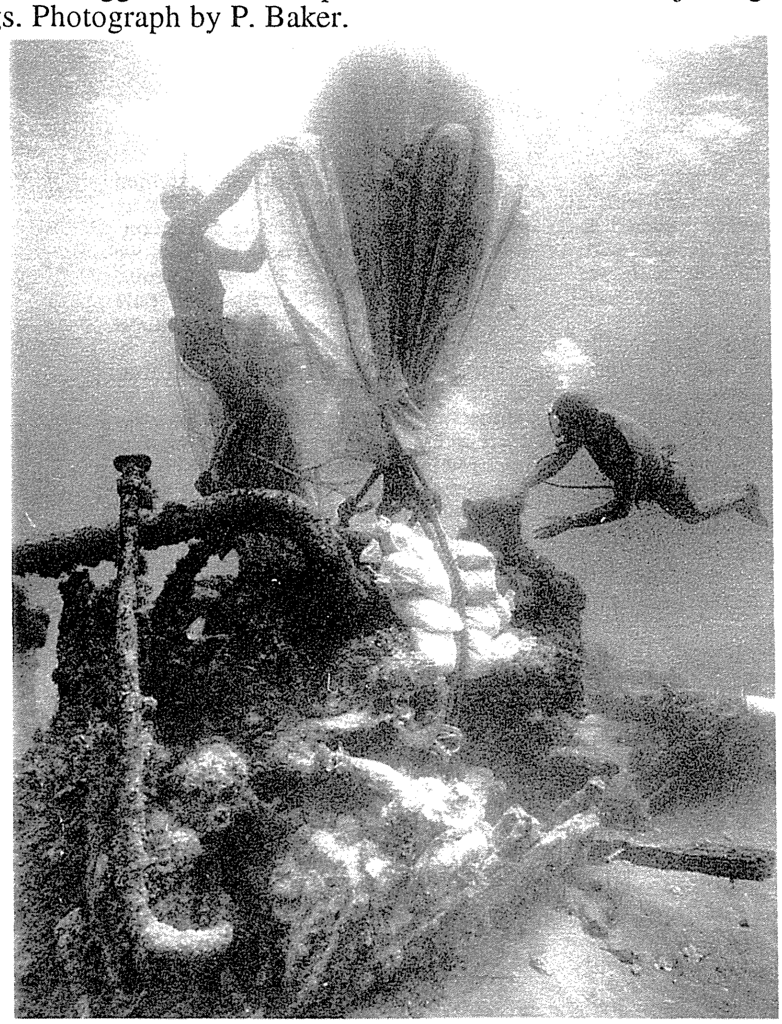


Figure 83b: Geoff Kimpton and the author making final checks. Photograph by P. Baker.

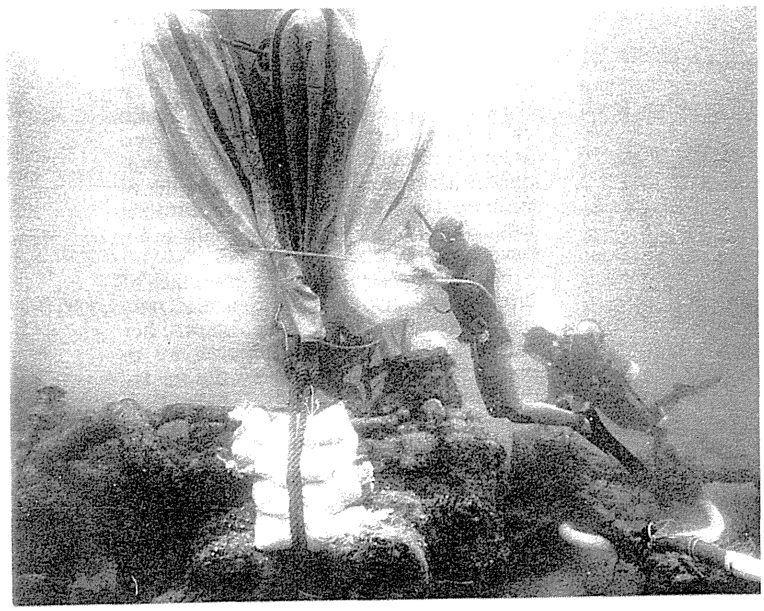
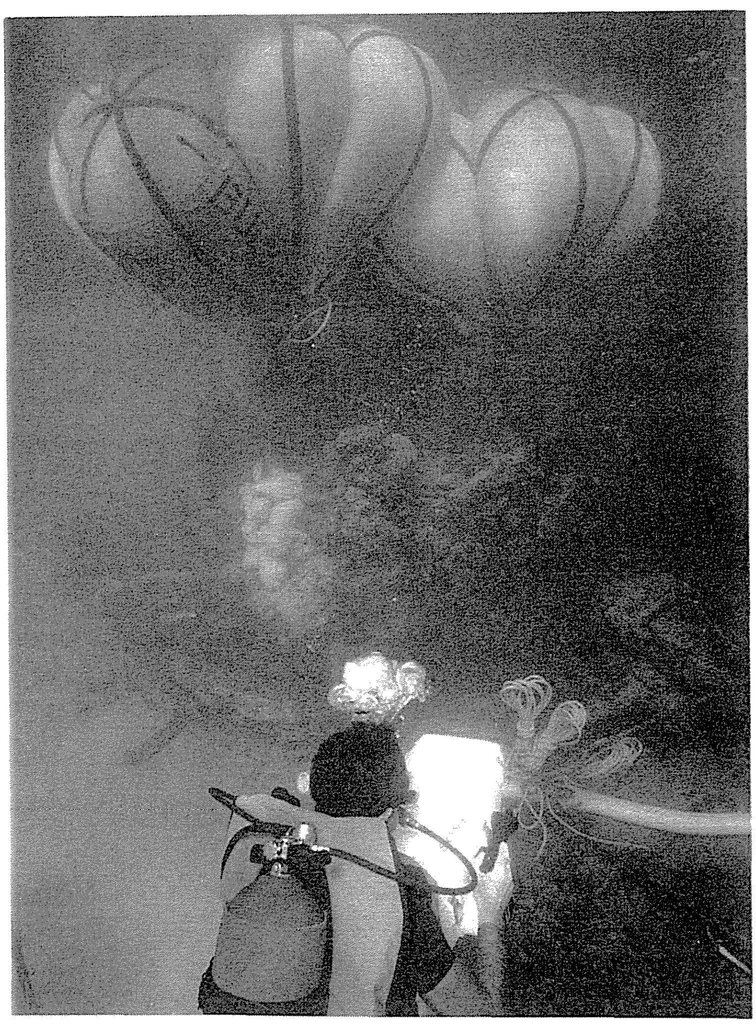


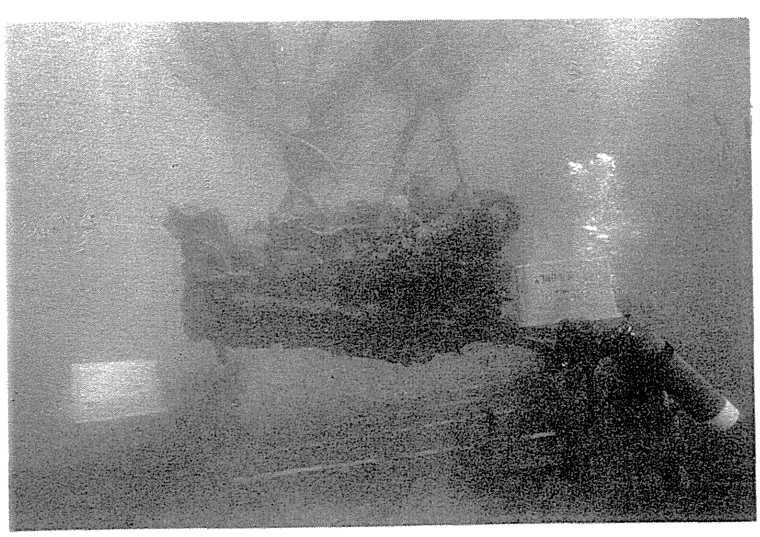
Figure 83c: Video-operator Lyall Mills recording the engine at the point of neutral buoyancy. Photograph by P. Baker.



Air was slowly fed into the lifting bags and as they filled they commenced to pull towards the surface putting tremendous strain on the strops. More were added to obtain maximum lift, bringing the engine closer to neutral buoyancy. As it approached that point (with 27 lifting devices ranging from one-tonne bags to inverted tubs) the engine began rocking gently and then with some force in the almost imperceptible swell. The on-coming cyclone had produced flat-calm conditions and an imperceptible swell on the surface, but on the sea-bed, with a neutrally buoyant engine, the swell was quite noticeable and was proving potentially damaging. As a result, the engine was returned back to the sea-bed for re-stropping. The lift recommenced and the engine, on its bearers, rose vertically from the seabed.

The tow was then taken up by the work boat and the engine was pulled to the starboard side of the ship. From there, the engine with divers monitoring the tow, began a slow voyage behind the work-boat back to the beach near Port Gregory where a pre-fabricated iron sled was waiting. The engine was then run in towards the shore until it was located just centimetres above the sled.

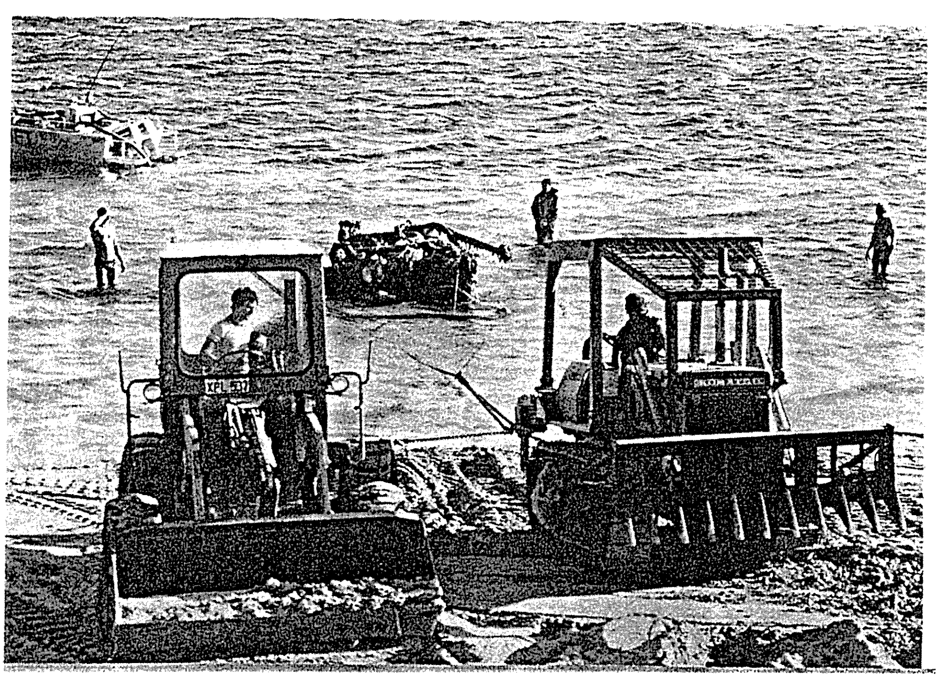
Figure 84: The engine in position above the sled prior to the two being joined. Photograph by P. Baker.



The sled was then lifted up to the engine using upturned tubs filled with air and when the two had met, they were firmly lashed together, as the chief rigger Geoff Kimpton had planned. The sled, with engine attached, was then pulled further into the beach until it grounded in shallow water (3 metres), approximately 30 metres from shore. Air was slowly released from the tubs and bags and the engine was returned to the seabed. The remaining lifting devices were slowly emptied and removed.

The underwater slope ahead of the sled was modified by excavating with the water dredge. A bulldozer and front-end loader were then shackled to the chains on the sled which was then slowly towed into progressively shallower water, until the top of the engine greeted air after 113 years on the sea-bed.[1] The sled was then towed along the shore and up the slope to a parking zone overlooking Port Gregory.

Figure 85: The engine being dragged ashore on the sled. Photograph by P. Baker.



[1]This description does not adequately reflect the difficulties experienced both at the site or with the earth-movers. Details appear in the day-book.

Once the engine and sled were secured on the land, the earth-movers were unhitched and the photographers and conservators went about their business recording and preparing the engine for transport south. This included 3D recording of the engine by photogrammetrists from Curtin University using a special-purpose camera with glass negatives so that an accurate record could be obtained, should the engine not survive the journey intact.[1]

Having been brought ashore ahead of schedule due to the onset of the cyclone, the engine required temporary storing. Large iron objects, such as cannon and anchors, are usually covered in hessian and kept wet with sprinklers or are preferably inundated in a 5% solution of sodium hydroxide (caustic soda) to keep them from further corrosion.

Water was at a premium at Port Gregory, however, and the engine was a composite of cast and wrought iron, coppers and brasses. In this instance it was decided to use Erosel, combined with a solution of 1% sodium bicarbonate and 5% sodium carbonate soaked into hessian (Conservation Daybook, 19/4/1985: 34).

This technique had been used a few years before to help preserve and pack material raised from HMS *Pandora* (Carpenter, 1987). Before the treatment was finished the engine received its artefact number; XA 57. Though completely covered with Erosel, wet hessian, black plastic and ropes, by night-fall a roster had to be set up to monitor the engine and guard until dawn. [2]

---

[1]By Chris Dixon and Laurie White of the WA Institute of Technology, now Curtin University.

[2]An attempt had been made earlier that day, while staff were busy elsewhere, to lever off one of the copper pipes. Around 1.30 AM the next morning, a car noisily pulled up and its totally inebriated occupants attempted to hitch up their 4WD to the sled and proceed to drive off with the engine and sled in tow. Angry words and threats were exchanged. There were offers of fisticuffs but nothing further transpired and they noisily departed. Thankfully they did not return, though later they were to apologise for their actions, while at the same time indicating that if they had known there was so much sellable scrap metal on the wreck they would have removed it long before.

Figure 86: The engine ashore, in its coating of Erosel. Photograph by P. Baker.

With the engine removed from the site, the excavation of the stern of the *Xantho* aft of the boiler began in earnest. Each of the archaeologists present was allocated a small team and a two-metre-wide section of trench to excavate across the hull. It was each group's responsibility to excavate their allotted rectangle down to the engine room floor to the set recording parameters. In the process of excavating each of the rectangles they were to record all the features and artefacts in three co-ordinates and annotate that information on a pre-prepared underwater tag. The latter was a system designed to minimise discrepancies that often occur in transition from recording underwater to entering the data in the artefact catalogue. Spatial (non-photographic) recording involved standard techniques, such as builder's levels to maintain the horizontal, plumbobs to gauge vertical separation and two and three-tape systems for horizontal fixing.

Figures 87 a-c: The excavation and recording process.

Figure 87a: Using a builder's level and plumbob to record the feed-water heater and its surrounds. Photograph P. Baker.

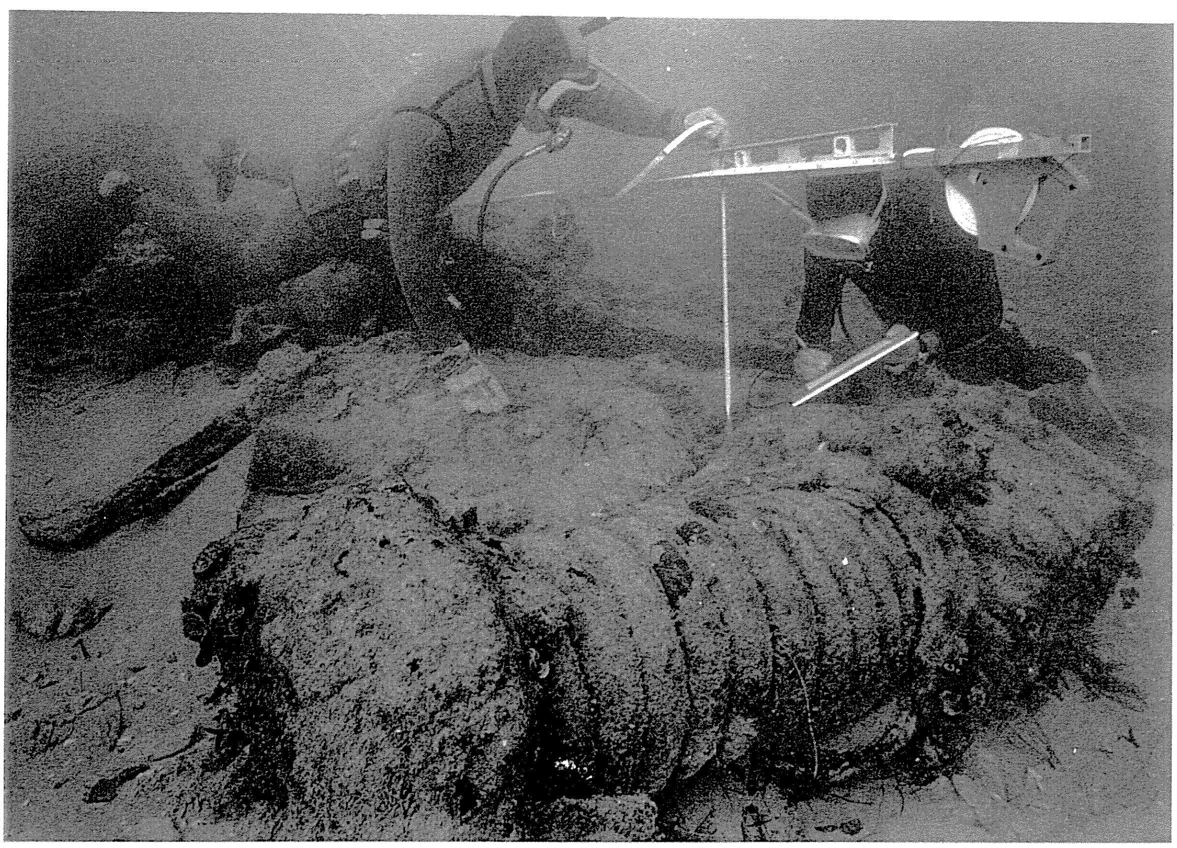


Figure 87b: An excavation team utilising a water-dredge in a grid aft of the thrust block. A 'dog-clutch' or device which enables the propeller shaft to be disconnected from the engine is visible on the shaft. Photograph P. Baker.

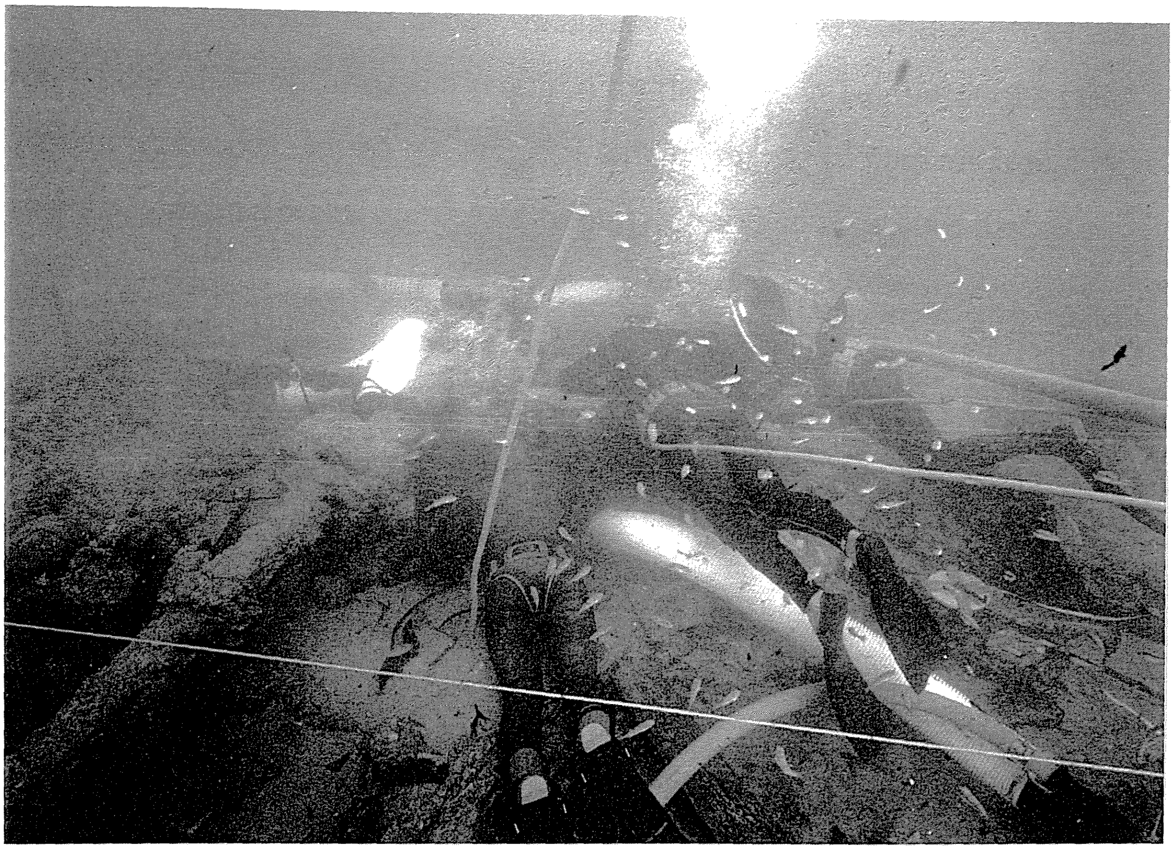
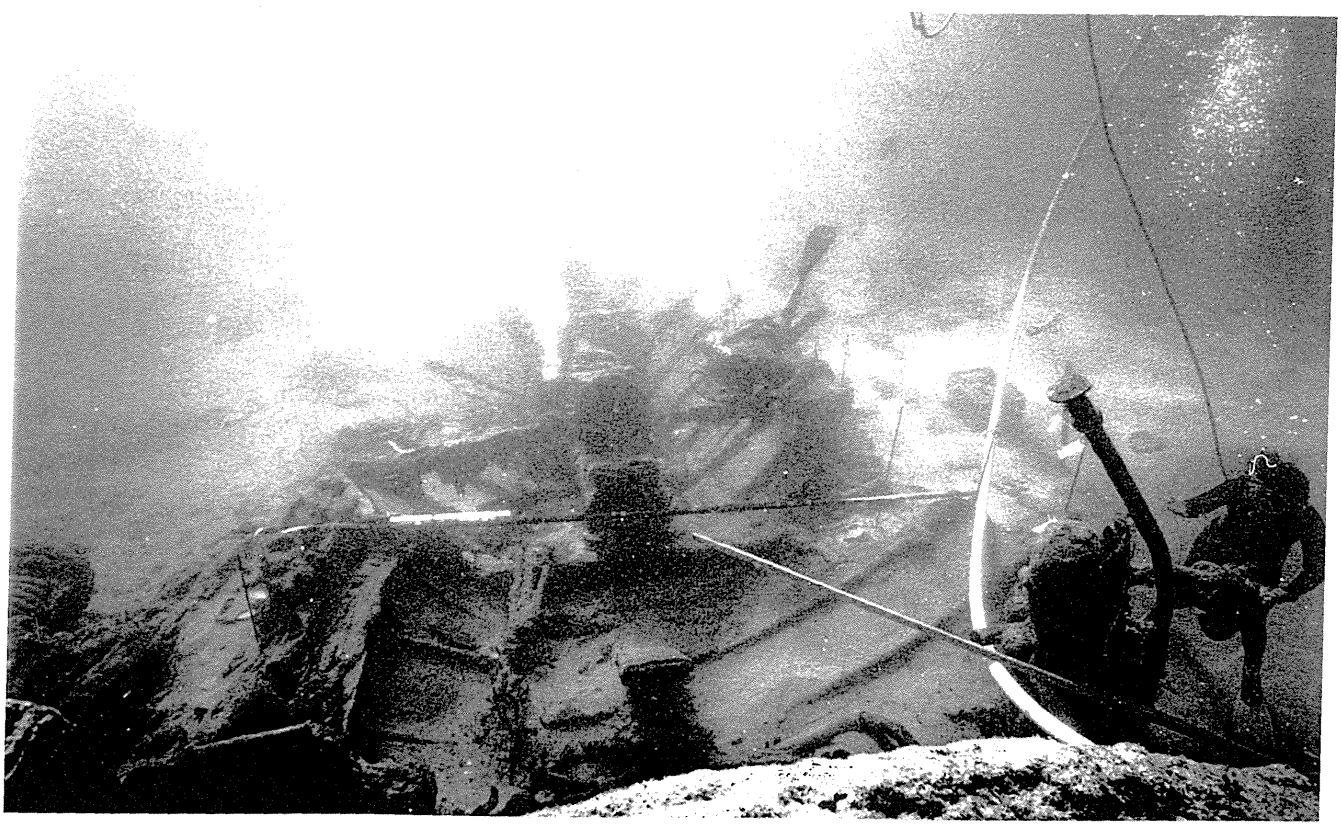


Figure 87c: A view of the excavated stern section from the top of the boiler. Photograph P. Baker



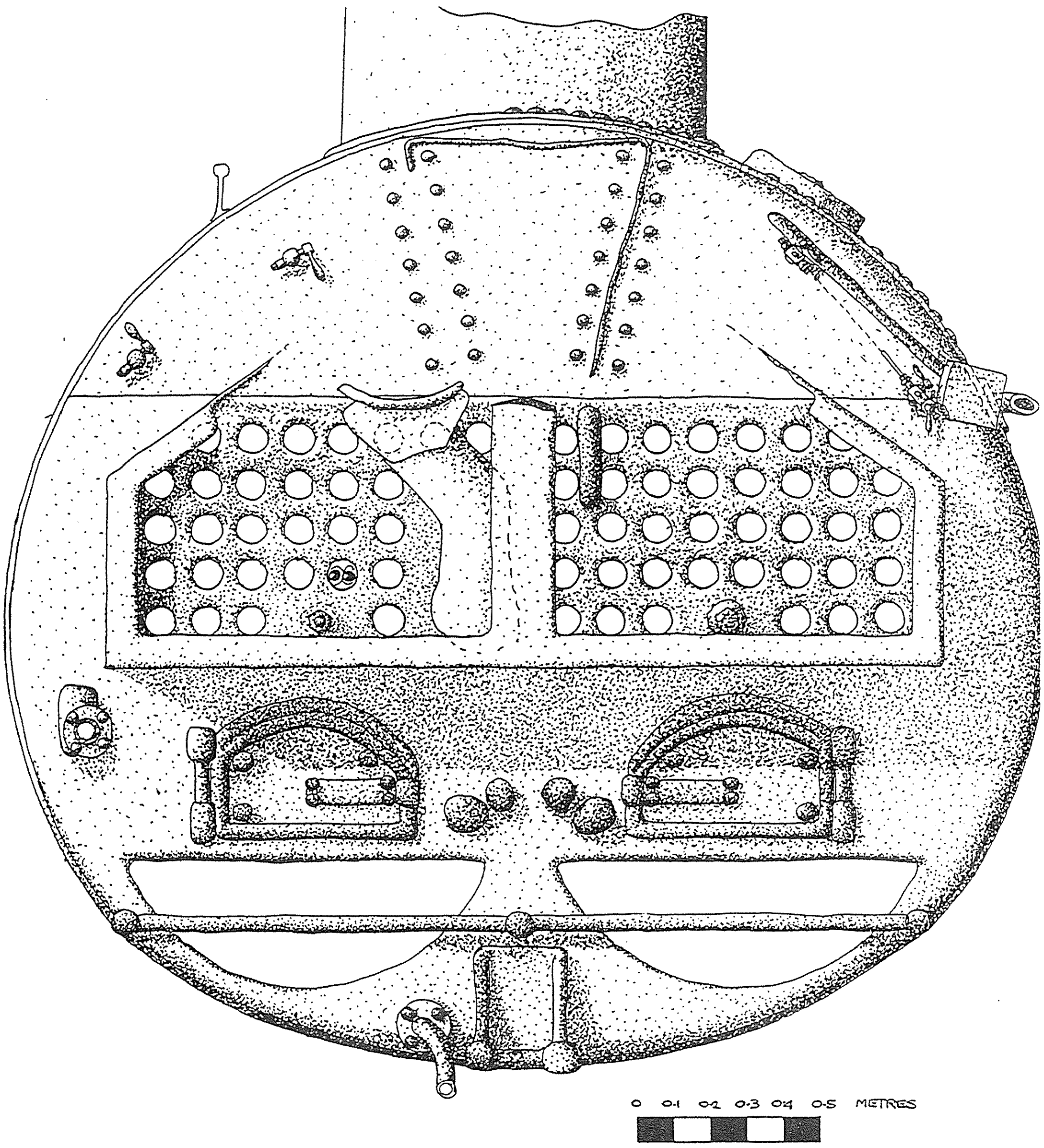
Tagged artefacts were transferred to the conservation facility at the base camp. There the finds manager took over, completing the remainder of the information required on the tag and beginning the field artefact catalogue. In the evening the archaeologists plotted each feature and find on a 1:10 site plan. Additionally, they had to ensure that every artefact was correctly passed, complete with its identifying tag, to the conservators and finds manager. On the following day the conservators would remove the underwater tags, check the details and transfer them to the artefact catalogue and replace the tag with a more permanent plastic or stainless steel dymo tape type. Plastic was used where water was the conserving solution and steel where treatment was in a caustic or other chemical solution.

Given our belief that the boiler was not cylindrical, diving naval architect Geoff Hewitt from the Maritime Archaeological Association of Victoria (MAAV), spent considerable time re-examining and redrawing it in detail (Figure 88).

The illustration shows both the anomalous shape of the boiler and the fact that the furnace doors were firmly shut before the ship went down. The brasswork for the gauge glasses is visible on the upper face at each side as are the return tubes which are visible within the remains of the uptake to the funnel. The base of the steam dome is also visible.

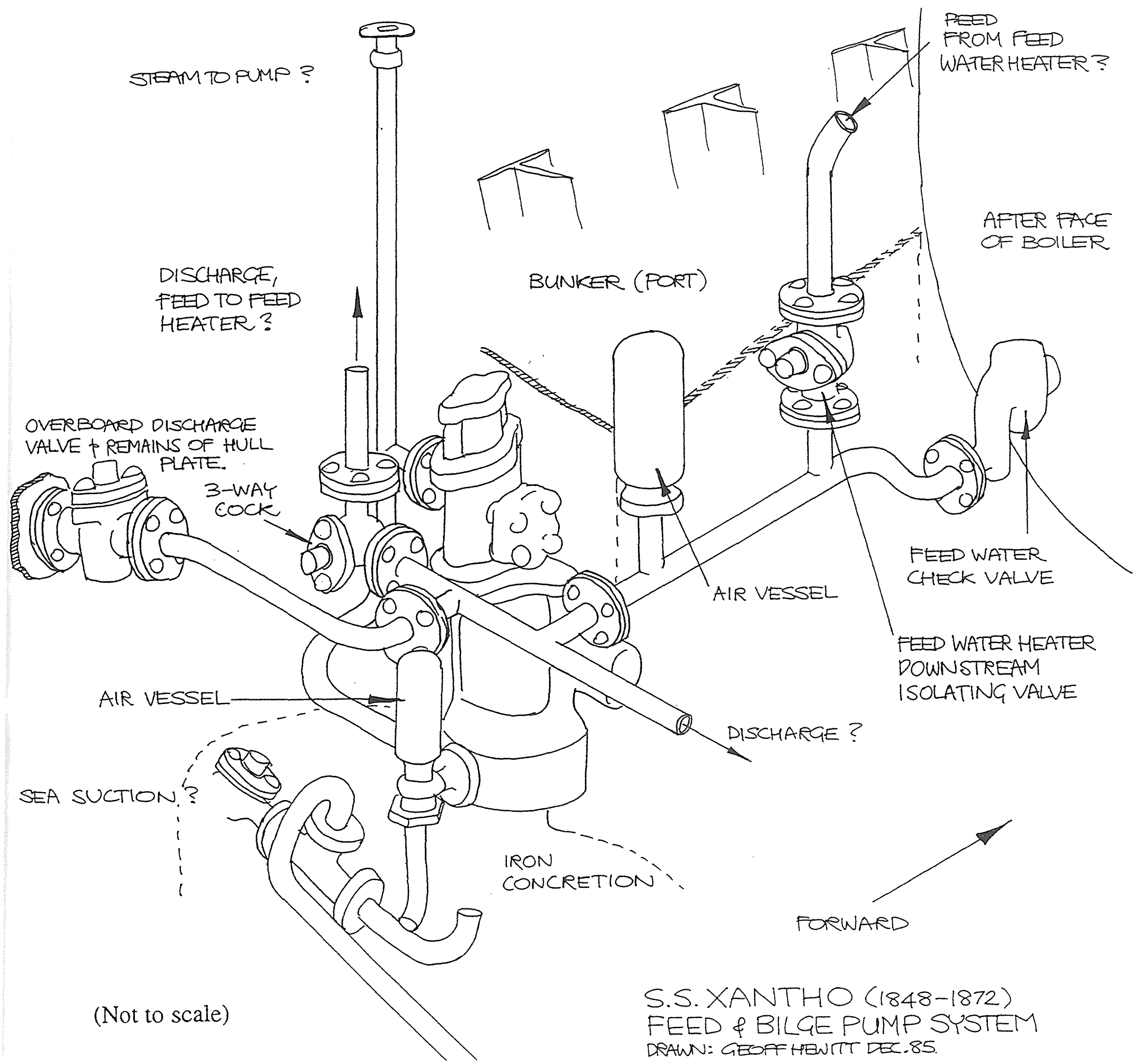
Though slightly elliptical, the boiler was once cylindrical, its anomalous shape being due to distortion on the sea-bed caused by the ingress of sand, corrosion and other forces. It was the type now generally known as the Scotch boiler (Figure 23). The brasswork on the aft face of the boiler was removed, catalogued and sent for conservation.

Figure 88: The aft face of the *Xantho* boiler, by G. Hewitt. The fire doors are shut.



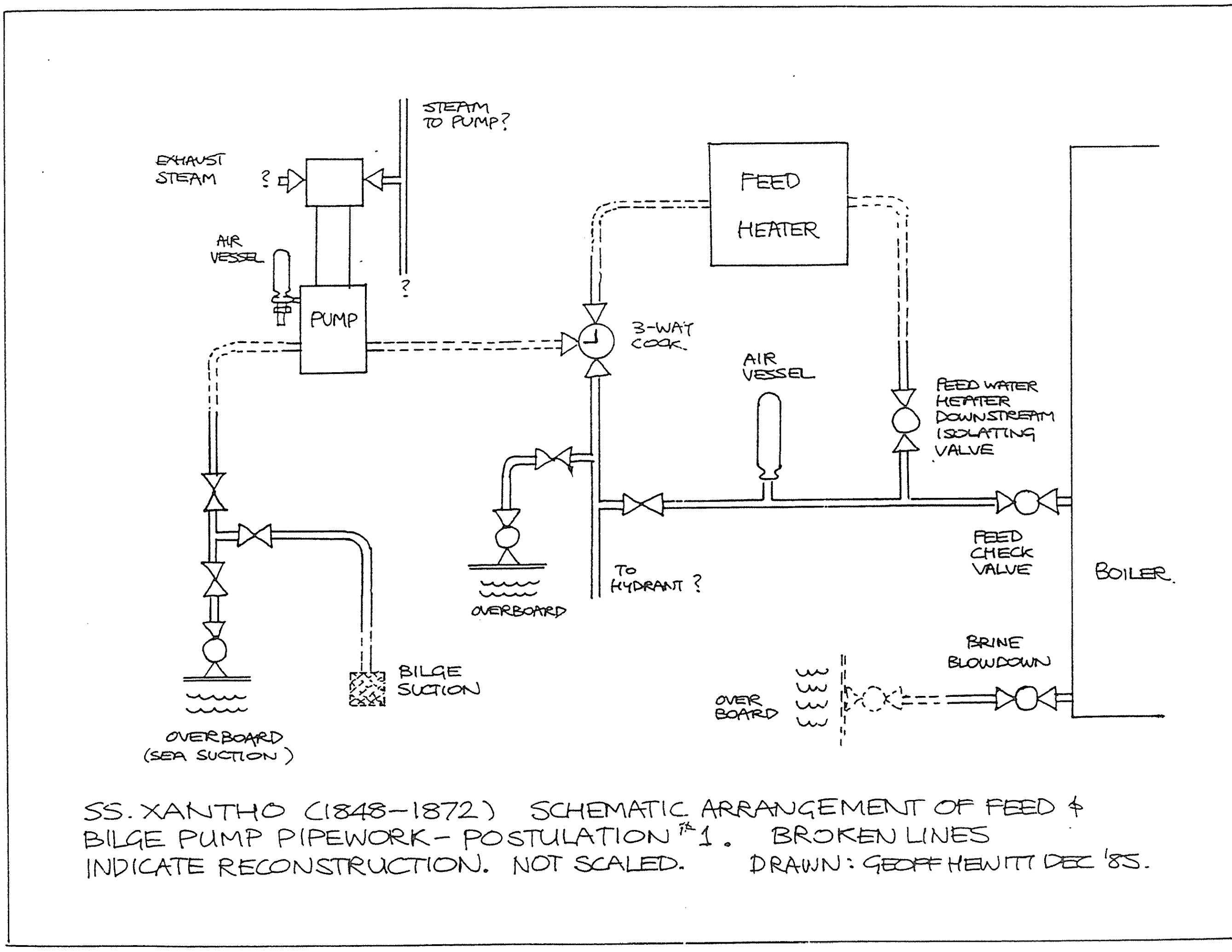
Hewitt then recorded the piping arrangement between the boiler and the engine (Figure 89, below) and produced a schematic analysis of the function of each component part (Figure 90). Though conjectural, the arrangement is based both on marine engineering knowledge and his experience of design in modern naval vessels (cf. Hewitt, 1988b). Hewitt's representations have provided a useful basis on which to develop an understanding of the operation of the *Xantho* machinery.

Figure 89 : The piping arrangement in the stokehold. By G. Hewitt (MAAV).



(Not to scale)

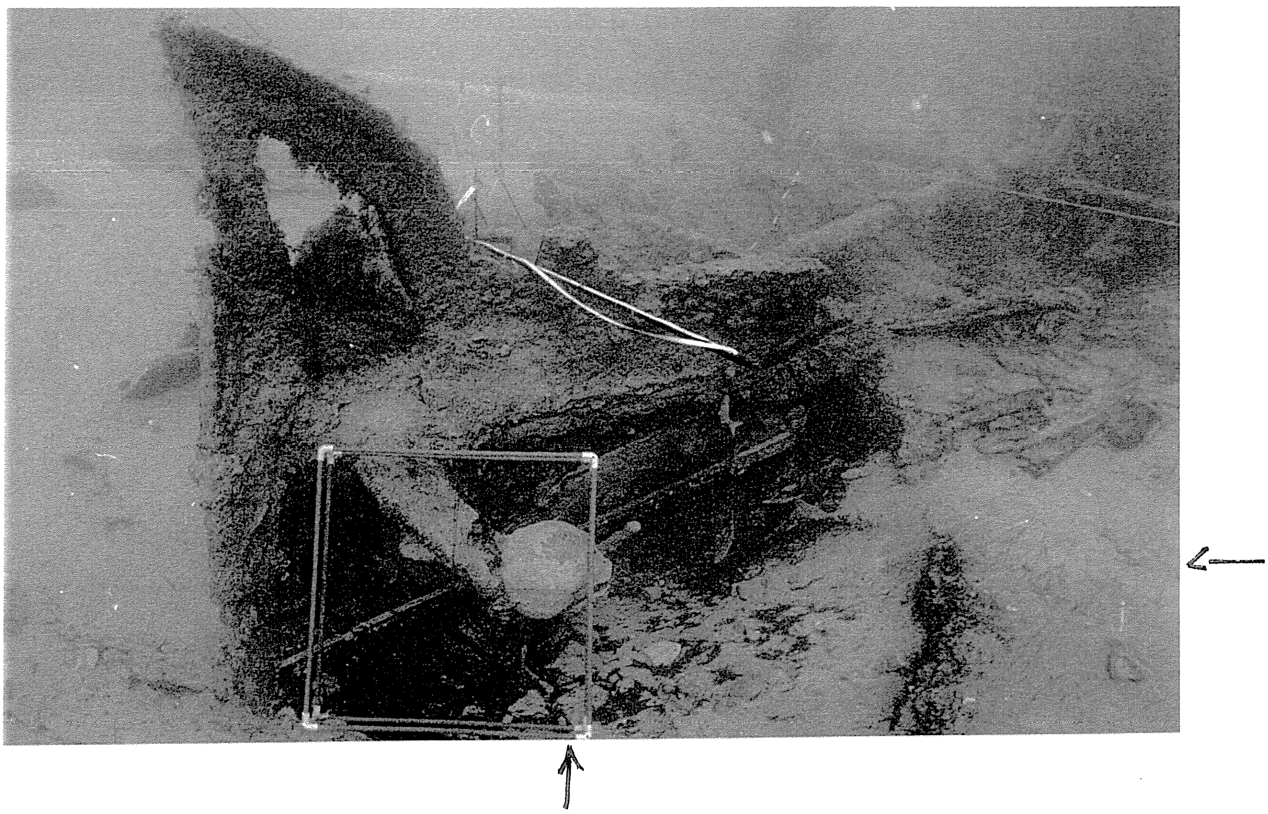
Figure 90 : A schematic analysis of the *Xantho* piping. By G. Hewitt (MAAV).



Hewitt and the other seminar delegates were replaced, in turn, by other course graduates and then by volunteers from MAAWA. While the crew changeover was in progress, the engine arrived in Fremantle and was immersed in the newly built conservation tank, to await the end of the excavation and the beginning of the deconcretion phase.

The excavation continued at the site until the cyclone crossed the coast, bringing work to an abrupt halt. As numerous whalebones had been found on the wreck, including one firmly cemented to what proved to be the ship's three bladed propeller, the lost days were spent searching for a whaling station near the wreck (Figure 91, below).

Figure 91: The whalebone found cemented to the tip of *Xantho* propeller . Photograph by P. Baker.
A piece of wood has lodged under the propeller on the starboard side. Both it and the whalebone are an indication of the sand movement around the hull. Note the paucity of the hull remains. (See discussion following).



Evidence of a previously unknown whaling station was found immediately opposite and just upstream of the site. Surface indications were that it pre-dated the *Xantho* (*Xantho* Excavation Daybook). The site was recorded in a non-disturbance fashion and a selection of surface material was recovered and catalogued for further study. The belief that it was a whaling camp from the 1840-50s was later confirmed in a separate study (Gibbs, 1994). Other evidence of whaling activities were also noted (e.g. Whalebone Passage upstream of *Xantho* in Figure 73).

When conditions allowed, the excavation and 3D recording of the site continued, eventually finishing with the entire inside of the hull, from the boiler to the stern tube.

When the conservators were not acting as part of the excavation or recording teams, they conducted further corrosion potential and hull thickness measurements. One series of measurements showed that on the starboard side of the stern, opposite the thrust block just above the sea-floor, the plates were 0.25-0.4 mm thick under the concretion layer, which averaged around 40mm in thickness. When measured for its electro-potential, even the original metal was found to be very corroded. The rear section of the hull on the starboard side aft of the thrust block appeared in uniformly good condition, measuring a minimum of 4 mm thick (See Figure 91). No original metal was found on the port, or upstream side of the hull, however. Forward of rib 5 (on the 1:10 plan), there was virtually no metal left beneath the concretion on the the ship's hull.

The area from which the engine had been removed (the stokehold/engine room) had been cleared to the deck and corrosion potentials were recorded (Conservation Daybook: 40-42) (See Figure 87c). The stokehold was lined not just with concretion but also with cement, as was often the case with the bilge of iron ships. There, beneath the cement, original metal remained though not of uniform thickness. At best, some plates were 4 mm thick. The exterior of the hull under this section was not recorded, for fear of damaging the structure.

In the only attempt to excavate under the hull, a one-metre-wide trench was excavated down and under the starboard side of the hull immediately aft of the thrust block. This was conducted in order to ascertain the state of the iron-work and to gauge the depth to which the hull was actually buried. This trench showed that the hull on the starboard side of the stern, aft of the thrust block and adjacent to rib 3, was still strong, projecting 700 mm above the sea-floor. Below the sea-floor a band of 200-400 mm was covered by weed mat, leaving a further 800 mm of well-preserved hull in sand down to the keel. Thus a two-metre-high section of hull remained in the vicinity of the propeller aperture in the aft section of the ship on the starboard side (See Figure 91 above).

This section contained much original metal and appears to be the only intact part of the ship. After discussion with corrosion specialists and other conservators, I then came to favour the recovery of this stern section and commissioned diving-artist Chris Buhagiar to produce a conceptualisation of an exhibition that could combine both the engine and the stern section (See Appendix 8).

The thermal lance was then used to cut this section of the stern free, in preparation for its future raising as a unit together with the propeller, stern tube, shaft and thrust block. This was effected over a period of four days, resulting in the remaining two metres of the stern of the ship, aft of the thrust block (from Rib 3 aft), being cut free from the rest of the hull. Even when cut, it would not move, however. Eventually two 70 mm diameter limestone pinnacles were found holding the stern section fast to the limestone reef underneath the mobile sand. These were subsequently cut. The section was stropped for a trial lift, which proved successful to the point of near neutral buoyancy. The bags were then deflated and the stern section allowed to settle firmly back on to the seabed. All rigging materials, bar one strop were removed and anodes were applied, beginning *in-situ* treatment. A small section of exposed hull, consisting of a butt-plate covering a clincker joint and frame, all attached with rivets (XA 517), was cut free and raised after its corrosion potentials were measured. It was conserved in the field station and sent to the laboratory in Fremantle for further analysis (Figure 95).

The feed-water heater, boiler valve and the remainder of the unidentified pump were subsequently covered with rocks and work began on the cleaning up of the site and the finalisation of recording. The expedition had deployed a total of 55 people for a total of 605 operator days, with a total of 603 diving hours spent on the wreck over a one-month period from mid-April to mid-May 1985.

Subsequent on-site excavations

In February 1988 a visit was made to *Xantho en route* to the author's season of excavation on the VOC ship *Zuytdorp*. Our intention was to monitor the anodes which were attached to *Xantho* stern in 1985.[1] Conditions were suitable, though the site was covered in sand to just above the level of the top of the furnace doors. During the inspection, the boiler relief valve and feed-water heater that had been left *in-situ* were further examined and a decision was made to recover them after the planned corrosion measurement study was completed. The finding of an eccentric strap buried under the feed-water heater indicated that the area could still contain material of interest. A surface search of the depression from which the heater came, and the downhill slope to starboard of it. revealed a brass tap and some unidentified tools. These were recorded, catalogued and recovered for conservation.

The scour pit on the fore part of the starboard side of the boiler was deeper than previously seen, illustrating the mobile nature of the sand. It also exposed the wooden bearers on which the boiler lay.

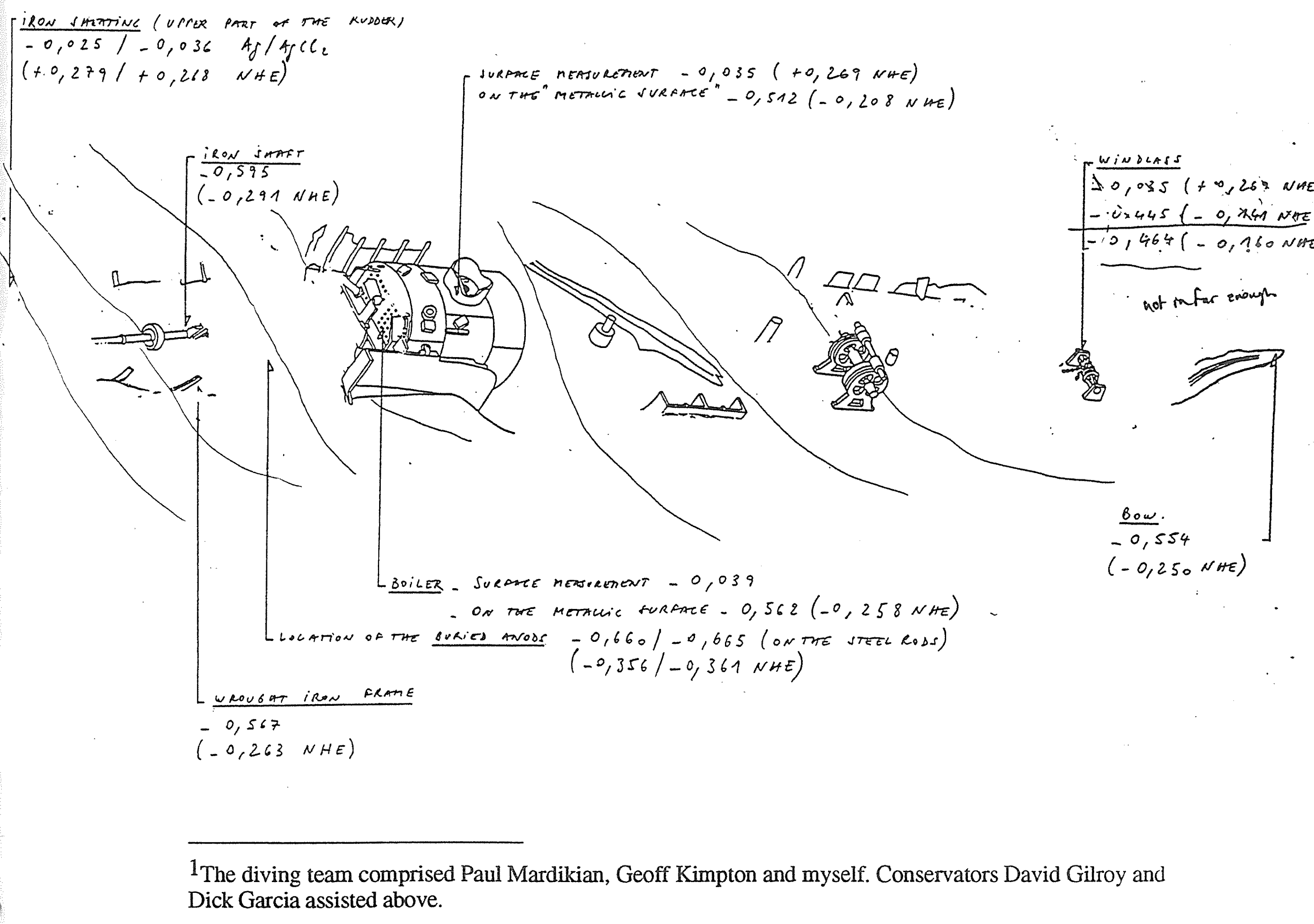
In March 1992, with the aim of further monitoring the site and removing the air-pot and auxiliary pump assembly previously recorded by Hewitt (Figure 89), the *Xantho* was visited again *en route* to the *Zuytdorp* excavation. By then interest in the *Xantho* project had spread and we were joined by M. Paul Mardikian, a Paris-based diving

[1] The visit to the site in this instance was in two parts, each of approximately two days duration separated by a month of fieldwork at the *Zuytdorp* excavation. The team comprised conservators, Ian MacLeod, Jon Carpenter, Geoff Kimpton and myself.

conservator, working on both the artefacts from the iron hulled steamers SS *Titanic* and CSS *Alabama.* Mardikian was on an internship at the Museum's conservation laboratory and had come partly to familiarise himself with the site and the techniques of on-site corrosion study. Having had a very difficult season on the *Zuytdorp,* it was to be a short, one day visit to Port Gregory, however.[1]

The stern of *Xantho* was covered by sand to the level of the counter and to the top of the fire boxes on the boiler (Figure 92). The bow area had less cover than normal, considerably exposing the starboard side from the bow to the boiler.

Figure 92: A working diagram, showing the site as found in 1992 and the electro-potentials measured. Based on an adaptation of J. Riley's isometric by P. Mardikian



[1]The diving team comprised Paul Mardikian, Geoff Kimpton and myself. Conservators David Gilroy and Dick Garcia assisted above.

The electro-potentials Mardikian recorded for all points previously measured, bar those buried, are shown in Figure 92. When analysed in the conservation laboratory, these measurements showed that when compared with the 1983 data, there was no change in corrosion on the upper part of the stem-post. On the other hand, there was a 44% increase at the windlass and a 50% increase on the boiler. The propeller shaft, on the other hand, showed a 15% decrease. The air-pot and pump assembly were also recovered. The anodes fixed in 1985 were found to have worked well, being totally consumed and in need of replacement.

In the following months an inventory of the data and results of the previous excavations was made, leading to the conclusion that no useful data had yet been obtained on the clincher-built construction of the hull, bar that which was evident from the small section removed in 1985. The presence of concretions, cement layers and the fragile state of the hull had rendered little data in this area. It was decided to make one final attempt to address this issue and to comb the site for evidence of hull construction technique. To facilitate the work, a small water dredge with an outlet nozzle designed to produce both gentle suction and a jet of water was obtained.

In March 1994 the last visit took place with three aims in mind: 1) to re-record and examine the site; 2) to further examine the construction of the hull, and 3) to attach new anodes to the stern.[1] Conditions for the study were excellent. A video and colour/black and white stills record was obtained for comparison with that produced in 1985. Using newly obtained equipment, the GPS position of the wreck was fixed for the first time.[2]

---

[1] The team in this instance was Jon Carpenter, Pat Baker, Geoff Kimpton and myself. The expedition took place over two days on 23-25 March.

[2] 28° 11.28' S, 114° 14.07' E, SD 24.1, Satellites 17, 21, 28, PDOP 9s)

When located, the wreck was seen to be in what can now be referred to as its summer configuration. The tip of the propeller was exposed by only about 30 cm, the boiler was visible aft to just below the furnace doors and the fore part was completely exposed on the starboard side at the scour pit. Midships was totally covered in sand, as expected, though the stem was exposed more than before, allowing it to be examined closely for the first time. We also found that the starboard plating at the bow had collapsed outwards and that the forepeak was being totally opened up by the current. This revealed much more of the timber ceiling and other fittings than had been accessible in earlier years.

The anodes were uncovered by excavation, one lying alongside the starboard hull at the stern, the other inside the hull at a higher level. The upper one had been consumed and the lower was in original form. It had apparently ceased working soon after it was fitted, due to a break in its connections.

A corrosion potential study was completed by Carpenter to add to the data obtained by North, MacLeod and Mardikian since the first application of anodes to the site in 1983. These have proved the basis for a long-term comparative study (cf. MacLeod, 1992; 1995).

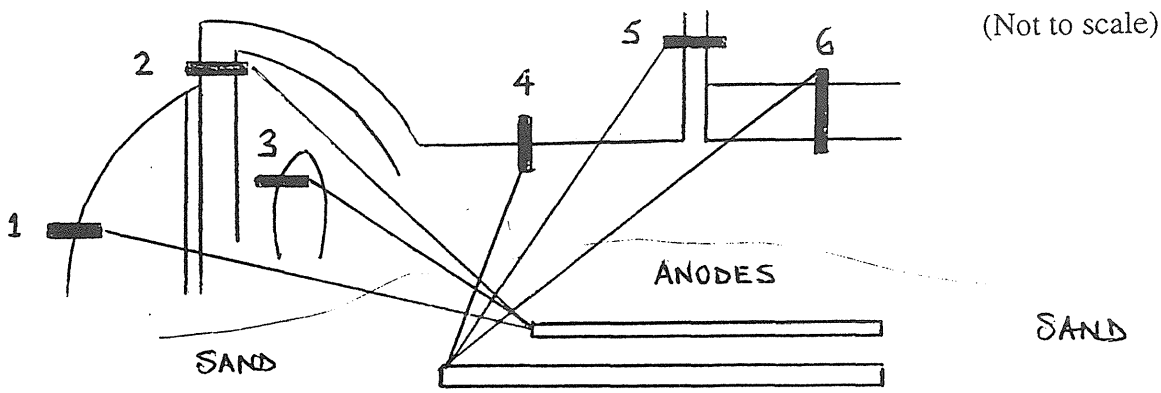
In returning to the 1848 hull for clues to its construction, eventually four exposed areas were selected for examination; the port bow, a section of frame projecting on the port side of the boiler aft, a collapsed section of hull forward of a set of heavy frames and the heavy frames themselves. The newly-exposed bow plates and the paddle-wheel sponson bearers were very heavily concreted and nothing of value could be ascertained from a visual inspection. One frame alongside the boiler on the port side appeared more suitable for inspection and animal growth was removed to reveal the concreted surface of the frame and the various hull plates remaining on it. Again nothing of value could be obtained from a non-destructive examination of the external surfaces due to their physical state and the concretion layer. On the internal surface there was not only concretion, but also possibly cement, further obscuring the details of the original plating.

Particular attention was paid to the collapsed section of hull forward of the boiler near the starboard paddle-wheel sponson. Lying flat and totally exposed on the sea-bed, it consisted of three frames and a two metre square section of hull plate. Loose detritus was cleared using suction, hand fanning and the water jet. Again the concretion/cement layer made an attempt to obtain data by physical means or by photography impossible. When a stream of water was applied to the water column above the opening in order to develop a gentle suction, clouds of black corrosion products streamed out into the column. This left a totally hollow and very fragile thin shell from which no information could be obtained. The procedure was not continued.

These experiences further highlighted the problem of taking an accurate record of concreted surfaces. Where the corrosion is advanced and the concretion fragile, as was the case in this instance, the difficulty of obtaining useful data on the sea-bed in a non-destructive mode is extreme. The interstices of the concretions were too thin to produce latex, polysulphide rubber or similar casts traditionally produced in such cases (e.g. Murdock and Daley, 1982).

It was also decided that, as the conservation and analysis of the engine and ancillary machinery still had to be completed in the laboratory at Fremantle, nothing further of the hull, including the stern section, would be raised at this stage. The remaining anode was then reconnected, a new one was fitted and further potential measurements were taken (Figure 93).

Figure 93: A sketch of the position and fixing points for the anodes. By J. Carpenter



On this, the last dive on the *Xantho* to date, a plastic handled, steel-bladed diving knife was seen projecting from the sea-floor three metres from the starboard paddle-wheel sponson. It was recognised as one lost by the author in 1985 by a roll of blue electrical tape carried on the handle. It was very heavily concreted, far more than had been expected.

The knife was recovered and preserved intact as a comparative specimen. It shows the results of a decade of concretion growth and corrosion on modern steel at the *Xantho* and provides an insight into what may have happened over quite a short period on the wreck itself. It also provides a useful example of the rapidity of the concretion process (cf. North, 1976). It has proved a most useful comparison and is currently being used for such purposes in other studies (cf. MacLeod, 1995: 58). It will also be referred to in an ensuing discussion of the formation of concretion on the *Xantho* engine and in its interstices.

Figure 94: A diver's knife after nearly a decade on the sea-bed alongside the *Xantho*. Photograph J. Carpenter.

Results of the 1984-1994 on-site excavations

The interior of the stern section of the *Xantho* wreck up to and including the boiler face was totally excavated. The vessel's engine and most of its auxiliary machinery, bar the boiler, were raised in the context of that excavation. The interior was recorded in three dimensions down to the cement lining in the stokehold and in the areas aft of the thrust block. So too were the rudder, stern post and propeller. The exterior of the hull was not excavated below the weed mat in any but the aft-most stern section on the starboard side. Where excavated, on the outside of the hull, the disturbance was limited to within a metre of the hull proper. The area around and forward of the boiler face was not excavated, though a surface inspection in the forecastle area revealed that iron and organic material remained and that some material, such as a rope fender, was occasionally exposed by the currents and then subsequently reburied.

The small section raised from the stern (XA 517) was analysed by Maria Pitrun, a metallurgist with considerable experience in the analysis of shipwreck materials (cf. MacLeod and Pitrun, 1986). As indicated, it comprised a double riveted butt-plate over two strakes of clincher hull plating with part of a frame (rib) attached. The section, through one of the rivets holding the butt-plate (top layer), two strakes of plating, and a frame (bottom layer) together, shows considerable interseam corrosion (Figure 95 a-b below).

Figure 95a : A magnified (X2) photographic section of XA 517, by Maria Pitrun, showing a rivet passing through four layers of iron plate:
1 top) an external butt plate
2) & 3) two strakes of clincher style hull-plating
4 bottom) a hull frame.

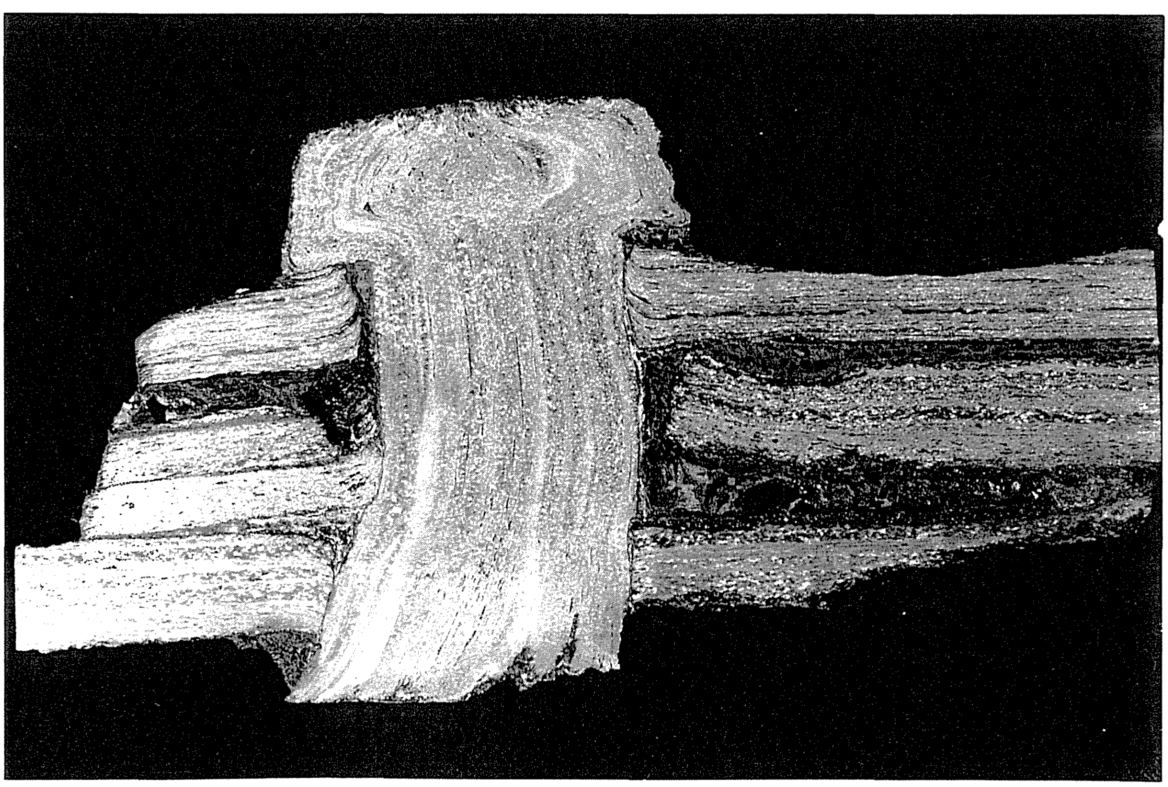
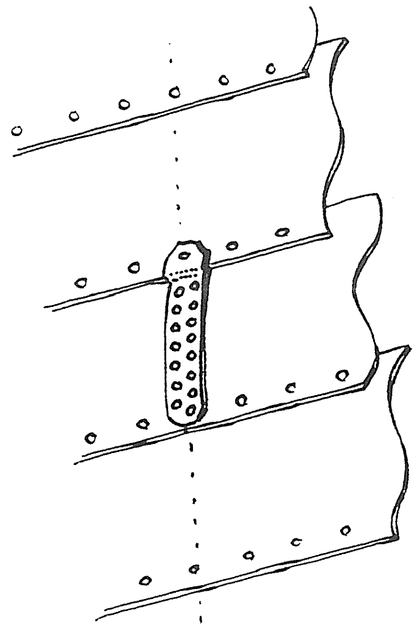


Figure 95b : A sketch showing the location of a similar butt-plate on an iron clinker-built hull. The dotted line in the diagram indicates the centre-line of a frame or rib beneath the strakes of plating and the butt-plate itself. By Geoff Kimpton.



(Not to scale)

In addressing the question whether corrosion, or other associated problems, had contributed to the sinking of the vessel Pitrun advised as follows

> The chemical analysis is typical of a wrought iron of that period... Although there are no traces of cold deformation in the grains, the microhardness measurements show major differences in their average values... Examination of the section showed that significant corrosion had occurred in the crevice-like spaces in between the sheets...It is impossible to determine how much of the overall corrosion had taken place prior to the vessel's demise. However, given that preferential corrosion occurred along the lines of extensive working adjacent to areas of greater hardness, it is not inconsistent to blame extensive interseam and stress corrosion. Since the wreck site is subject to periodic burial and exposure from under two metres of sediment, the overall corrosion phenomenon are complicated by differential aeration and the presence of tons of lead ore galena (PbS) (Pitrun to MacLeod, pers. com., SS *Xantho* file, 9/79).

Thus, though the extent of the corrosion can be measured at the *Xantho*, its use as a comparative tool is complicated by the periodic burial of the wreck and by the excessive amounts of lead sulphide contaminant (from the lead ore PbS) in the water column. The lead sulphide levels were later found to be 11,500 times higher than that found upstream of the wreck (MacLeod, 1992a: 46). It is therefore impossible to calculate the extent to which corrosion had occurred before the vessel was lost.

Despite the problems caused by the presence of lead sulphide and the possible refurbishment of the section of hull analysed, a beginning is being made on which to build a comparative study of 19th century metallurgy from primary sources. Some of the results are presented below, in Table 4.

Table 4: Analyses of *Xantho* ironwork from the stern plating, a rivet, the forward valve chest, the starboard pump and an inspection plate on that pump.

Element	Stern Plating	Rivet	Forward valve chest	Starboard pump	Inspection Plate starboard pump
Carbon equivalent	0.395	0.24	3.59	4.06	3.42
C	0.165	0.030	2.65	2.95	2.42
S	0.03	0.01	0.13	0.06	0.07
Mn	0.022	0.045	1.05	0.81	0.709
P	0.33	0.25	1.10	0.92	0.58
Si	0.36	0.38	1.73	2.42	2.43
Ni	0.053	0.035	0.015	0.017	0.016
Cu	0.022	0.048	0.045	0.011	0.013
Cl	0.02	0.02	0.0175	0.0175	<0.01

The results show the expected difference in carbon equivalent between the cast irons of the pump and valve chest and the wrought irons of the stern section. The pump inspection plate and its parent body appear to be of the same casting, as expected, while the valve chest is not of the same composition, giving rise to the belief that the pumps and engine were cast in separate workshops.

A total of 178 artefacts (XA 43-XA 219), including the engine XA 57, were recovered in the various excavation phases; 14 before the engine was raised and the remainder after it had been moved off-site. The assemblage was consistent with the location of the engine-room and accommodation spaces in the stern of the ship. These, of necessity, were on two levels or decks and the artefact spread reflects the contents of an accommodation section which has collapsed down onto an engine room below. The artefacts ranged from numerous concretions, glass and ceramic sherds, tools, oil containers, engine spares (such as a connecting rod, XA 139), boiler fittings, cup hooks, metal cabin fittings, fire bricks, door keys, a lamp glass, a box of matches, a salt cellar, brass taps, whalebone (on the propeller and alongside the hull), some timbers (possibly wooden cabin fittings), tree branches (possibly dunnage), hessian fragments (ore sacks), a small portion of the hull and modern contamination.

Small fragments of lead ore were found around the engine, indicating that some of the ore had been stored in the aft section of the ship. This would most likely have been between the boiler and the stern, in the accommodation spaces and on the deck above the engine. This spatial patterning is consistent with the evidence given at the inquiry into the loss of the ship.

As indicated, the fore section of the ship was not excavated, beyond the test trenches dug in 1983.

The source of the whale-bone attached to the vessel's propeller appears to have been the early whaling station adjacent to the wreck, though the location of 'Whalebone Passage' upstream of the wreck (Figure 73) provides another possibility. Either way, having been disposed of in the sea, the bone appears to have been carried by the currents or swell onto the site, where it remained lodged, to become concreted to the wreck. The position of the bone also provides an insight into the periodic covering and uncovering of the wreck (Figure 91).

With respect to the anodes, it was shown that, even when they were not working to capacity in the early stages of the experiment, the anodes produced a drop of 120 millivolts on the engine, causing a reduction in corrosion rate of approximately 90% (MacLeod, North and Beegle, 1986:123).

The surface pH of the stern section. to which anodes were also applied, had reduced after 20 months of treatment indicating a sixty-fold reduction in acidity (MacLeod, 1986:78; MacLeod, 1992:47). It was later estimated that, in using the anodes, a one-hundred-fold decrease in corrosion rate from about 0.08 to about 0.008 mm/year has been achieved (MacLeod, 1986:87). Thus the stern is undergoing conservation treatment *in situ* in preparation for the time when a decision is made to return and recover it for further conservation, study and eventual exhibition. MacLeod has reported in detail on this work and on its subsequent application to other sites where *in-situ* treatment is desirable (MacLeod, 1987: 49-56; MacLeod, 1992:45-51).

Despite the skewing effects of periodic burying and the presence of excessive amounts of lead sulphide from the lead ore cargo, the decade of work that has been completed at the wreck of the *Xantho*, together with various underwater corrosion studies, has provided a firm basis for comparative studies into iron and steam shipwrecks, generally.

Finally, though it is often buried to the water-line, it is now known that the *Xantho* does not completely fit Riley's expected model in that the wreck has a dual configuration; one the effect of the accretion of sand over the Western Australian summers, and the other the effect of winter scouring. This has had both a protective and disintegrating effect on the wreck. The moving sand has subjected the hull to strong forces, causing it to break at a number of points. On the other hand, the boiler, being in the wave-line, should have rolled out of the wreck, yet this has been prevented due to the much shallower and relatively steep sand-bar on the shore-side of the wreck. The severe current and suspended weed at *Xantho* has had a negative effect, serving to hasten the disintegration of the site, but not in a uniform fashion. On the other hand, both the current and suspended weed have had a protective effect, serving to make the site often undiveable, thereby reducing the extent of the salvage and looting that would have resulted had the wreck been more easily accessed by sport-divers. This is in direct comparison to the contemporary SS *Georgette,* which was lost in 1876 and lies buried to near its waterline in a wave zone on a gently sloping beach 50 kilometres north of Cape Leeuwin (Figure 1). In this instance, the boiler has totally disappeared due to wave action. Being easily accessible on a clean sand bottom, the wreck has also been subject to heavy cultural transformation, including the removal of both its working and spare propellers and the total dismantling of its engine.

Though providing information of technological significance, nothing substantial was found in the excavations following the 1985 season that shed new light on Broadhurst and the way he operated his ship. Data relevant to these issues were recovered from further excavation of the engine and fittings in the laboratory. This is the subject of the following chapter.

CHAPTER 8:

THE EXCAVATION CONTINUES IN THE LABORATORY (1985-1995)

Introduction

I have argued that the process of deconcreting or disassembling an artefact in the laboratory or field station and the entering of its internal spaces, for the purposes of examining its contents or structure, is no less an excavation than that conducted on a site (McCarthy, 1989:21-27). Clearly important are the surface inscriptions and markings covered by the concretion, clues to an object's identity, construction and, in the case of the *Xantho,* its mass-produced nature and mode of assembly. It is doubly important where one of the specific purposes of deconcretion is to reveal information about the behaviour of those who owned and operated the object before it acquired its covering layer. Accurate, archaeologically-based observations and recording, with hypotheses and technical questions in mind, are just as important in the process of deconcretion as in the excavation, recording and removal of the artefacts from their matrix on the sea-bed.

Before *Xantho,* deconcretion was seen to be in the domain of the conservator, albeit assisted and advised by the archaeologist (Green, 1990: 161-167; Pearson, 1987:107-109). I have treated the deconcreting process and disassembly of the *Xantho* engine, not as an exercise in traditional materials conservation, but as a modern, problem-oriented archaeological excavation; addressing the hypothesis that Broadhurst was naive, ill-advised and eccentric. Deconcretion was to me an excavation in its own right, requiring the archaeologist and conservator to work side by side throughout the process. As a result, since work began on the *Xantho* engine, conservators, corrosion scientists, technical staff and volunteers have worked successfully with me as a team as they did in the water, analysing and deconcreting the engine as if it were an excavation.

The final stage of the *Xantho* project has illustrated that with appropriate facilities, expertise and care a heavily concreted engine can be successfully recovered, dismantled and studied after being submerged for a century in a heavily oxygenated, salt-water environment. Techniques have been devised or modified in the process, giving those who follow a foundation on which to build.

Graeme Henderson's statement that '...no further engines be raised at least until the *Xantho* engine has been successfully conserved...' was delivered in April 1985, on the eve of the removal of the *Xantho* engine from the sea-bed (1988a:11). In making the comment, he correctly noted the experimental nature of this project. He also indirectly highlighted the risk involved. This is a pertinent observation, for though a conservator might be excused for having failed to satisfactorily treat an object due to its complexity or the experimental nature of the treatment strategies, the archaeologist who raises it bears full responsibility for the ultimate failure in these two instances. Currently we are in the final stages of conservation.

It is not intended to dwell at length on the technical elements of the conservation of the *Xantho* engine or its *in-situ* treatment; for that is the arena of the specialists involved (cf. Carpenter, 1987; Carpenter, 1990; Garcia, in prep; MacLeod and Pitrun, 1986; MacLeod, North and Beegle, 1986; MacLeod, 1989a; MacLeod, 1989b; MacLeod, 1990; MacLeod, 1992b; North, 1976; North, 1982; North, 1984; North 1987; Pénnec, 1990). A brief explanatory note is required, however, in order to illustrate how the deconcretion and disassembly of the *Xantho* engine represents a new development in maritime archaeology.

When iron objects are submerged they corrode at a rate dependent on a wide range of factors; notably water movement, biological activity, temperature, dissolved oxygen, the presence of dissimilar metals and salinity. In essence, the corrosion results in the inward diffusion of chloride ions through the concretion into the corroding metal and the outward diffusion of metal ions back out through the concretion to the sea. The treatment process is designed to speed up the diffusion of chloride ions from the metal into the treatment solution. The accepted methods used to achieve this involve the stabilisation of the iron, using a solution of alkalis (5% sodium sesqui-carbonate, 5% sodium carbonate or 2% sodium hydroxide) in water. It is a lengthy process. Where artefacts are small, hydrogen reduction is performed. This procedure involves the heating of corroded iron up to at least 400°C in a current of hydrogen gas, reducing the corrosion products back to iron and giving off the chlorides as hydrogen chloride gas. There are some dangers involved and the metallographic structure of the uncorroded iron can be altered at temperatures above 450°C. Electrolytic reduction, a process part-pioneered and refined by Neil North and his predecessor Colin Pearson, is performed where possible (North and MacLeod, 1987:68-98). This entails making the iron object a cathode within a tank of 2% sodium hydroxide or 5% sodium sesqui-carbonate. The anode is a sheet of mild steel and electrolysis occurs when a current is passed through to the metals. By these three means, salt is released from deconcreted iron. The main danger is the risk of losing surface detail if the current is too high (cf. Oddy, 1975:367-370).[1]

The deconcretion process not only reveals the structure for subsequent recording, but also allows chlorides to escape from the surface of the iron. As a result, the levels of chloride in solution in which a deconcreted object is placed will rise to a point where they match that of the chlorides in the

[1]Excessively high currents cause an evolution of gases near the surface of the metal being treated. This can cause considerable damage by lifting off the fragile surfaces.

deconcreted iron and at that point the diffusion of the salts across the surface of the iron stops. When this occurs, or when it is slowed to a marked extent, the tank is emptied and deconcretion work begins again.

Following the arrival of the *Xantho* engine at the Conservation laboratory at the Western Australian Maritime Museum in late April 1985 it was lowered into a treatment tank containing a solution of 40 kilograms of sodium bi-carbonate ($NaHCO_3$) and 60 kilograms of sodium hydroxide (NaOH), to inhibit further corrosion.

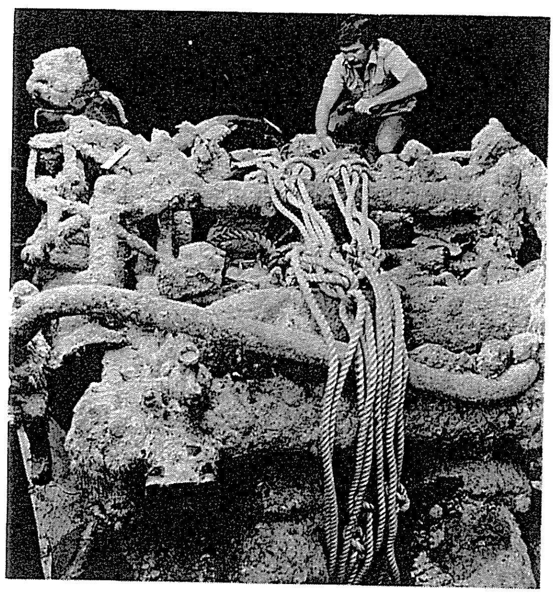
Figure 96: The engine before placement in the treatment tank at Fremantle. The flange is on the right, radius link centre and valve chest and trunks left. The remains of the engine bed is visible beneath. Photograph P. Baker.

Deconcretion of the engine: stage 1, the external surfaces

The gradual disintegration of the engine bearers on the underwater sled continued in the tank. This necessitated the engine being re-shored so that it rested on timbers.

In May the tank was drained and the first deconcretion session began. Not having been attempted on such a large and complex artefact before, considerable experimentation was required.

Figure 97: The author examining the concretion on the *Xantho* engine. Photograph P. Baker.



Firstly the obvious shapes, such as two iron-haired cylindrical boiler tube brushes, (XA 222 a and b), were examined and chipped free. These are visible in Figure 47, but required X-ray analysis to confirm their identification. Concreted rope, tools, lead ore, boiler sight glass fragments, screws and other smaller objects were also found amongst amorphous concretions on, and around, the engine. Copper pipes that had fallen onto the engine as the ship disintegrated were also chipped free. These finds and their locations indicated that they had collapsed onto the engine as the ship disintegrated.

Brasses, copper, wrought and cast irons are typically found on marine engines. Wood is often found as lagging (or insulation) around the cylinders. A surprise find was a engineer's foot-rest; a shaped baulk of timber that was fixed onto the engine-bed and ran parallel to the crankshaft, though only centimetres below it (Figure 98). This prevented the engineer's foot from slipping as he attended to the engine. Of additional interest was the fact that it was located very close to the crankshaft and that it had to be scalloped out to avoid being in contact with the big-ends of the connecting-rods. Being wood, it had to be removed for separate treatment (XA 273).

Figure 98: A view and close-up of the partly-deconcreted engine showing the wooden foot-rest and the scalloping-out to cater for its proximity to the crankshaft. Photograph by J. Carpenter.

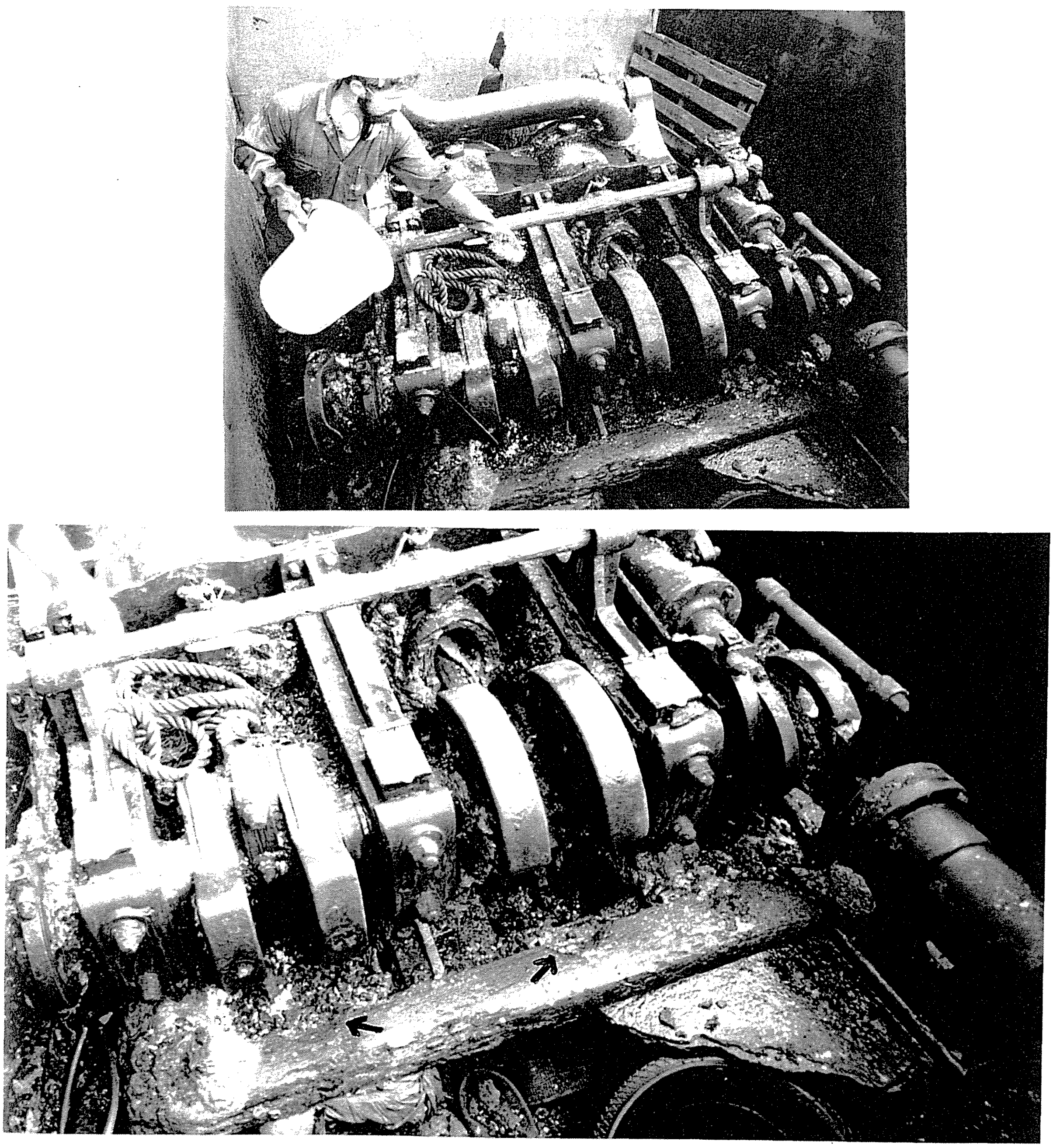
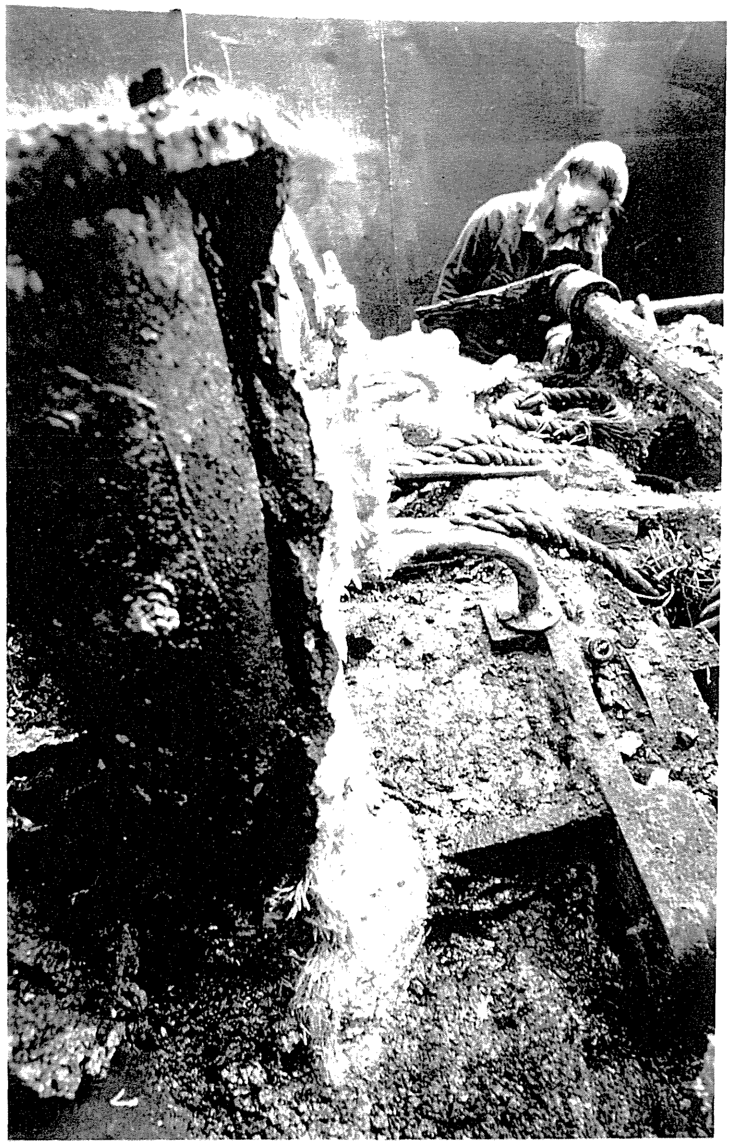
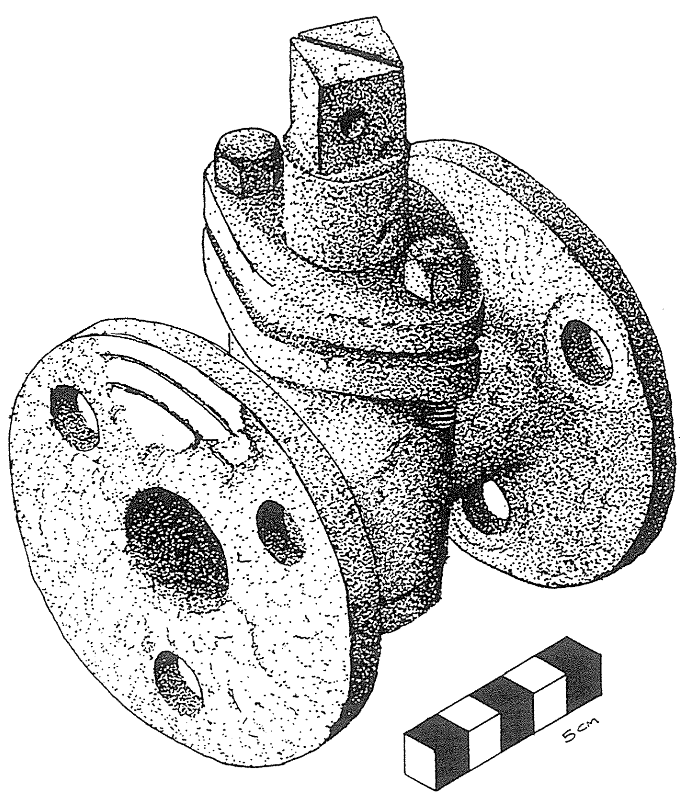


Figure 99: Deconcretion in progress Photographs by P. Baker



Removing the numerous brass lubricators, tallow pots, tap, nuts and bolts screwed onto the engine presented little difficulty, as the layer of concretion on them was only a few millimetres thick and their threads were in pristine condition. These components were unscrewed in the same fashion they were fitted a century before (See Figure 100). They were then treated using 5% citric acid and thiourea, in the deconcretion phases, and then de-salinated in a solution of sodium sulphate and sodium hydroxide in order to remove the chlorides. After cleaning they were prepared for storage or exhibition (Berry, Treatment notes and conservation report; 6/10/1993, XA 444, Butterfly Valve).

Figure 100: A brass plug cock (XA 69), showing the excellent condition of the brasses on the engine. By G. Hewitt.



The wrought and cast iron structures, such as the cylinders, cranks, valve chests, pipes, main-frame, and the trunks were far more difficult to treat. These were covered totally with a layer of concretion ranging from 25-50 mm in thickness. Often the layer was thicker than the object buried within. The principal method used initially to remove the concretion was by hammering and chipping in the traditional 'percussive' mode (Pearson, 1987:107-109; Carpenter, 1990:25). This involved the use of tools such as hammers, geopicks and chisels; the principle being that it is possible to separate the concretion and artefact at their junction by applying compressive or shearing forces. A trial application of what appeared to be more 'acceptable' techniques, such as chemicals and ultra-sound methods had earlier proved unsuccessful given the size of the engine and the thickness of the concretions. It was frustrating, backbreaking, dirty and difficult work. To an archaeologist, especially one not having been exposed to such a large concretion, the methods used were initially frightening though undeniably effective.

As is the norm in excavation, progress was recorded manually, photographically and by video; engine parts were catalogued as they were removed, systematic day books were kept, in addition to field and laboratory catalogues. As each engine component was sent for treatment it was labelled and tracked through the conservation process for storage or exhibition for eventual reassembly in years to come.

Ninety-two kilograms of concretion were removed in the first week. Over the weekend the engine was kept wet with sprinklers and continually monitored. On the first day of the following week a total of 350 kilograms of concretion and corrosion products were removed, revealing the upper surfaces of the trunks, the pumps, the tops of the cylinders and cranks.

After the first week of experimentation, work progressed from 9-a.m. to 5-p.m., averaging six operators in the tank at any one time (including

Ian MacLeod and myself full-time). We shared responsibility for progress of the deconcretion and for the safety of the artefact itself, acknowledging the fact that the deconcretion process was a threat to its integrity. It is recognised that damage does occur, especially on thin projecting surfaces

> The concretion that is formed both in aerobic or anaerobic conditions can be exceedingly tough so that when conservators and archaeologists attempt to remove the marine growth, a significant amount of damage occurs, often with the loss of archaeological information (MacLeod, 1987:49).

A halt was called to the work at the end of this week. The engine was washed, the floor of the tank cleaned and all of the loose concretion removed to be weighed. The engine was once again returned to a bath of chemicals. After two weeks, 1,250 kilograms of concretion had been cleared from the upper surfaces of the engine (see Figure 100). The tank was then filled with a clean solution.

During a week in July a further 555 kilograms of concretion was removed. The drop in weight by over 50% is an indication that, after the initial period of rapid deconcretion of large objects and their surfaces, attention was diverted to finer work.

At the end of October 1985, the salt levels in the tank were 727 parts per million (ppm). The tap water originally used to make the solution had 105 ppm salt content, indicating that a six-fold increase in salt content had occurred since the tank was filled after the last deconcreting session. As little change occurred in the salt level over the next week, the time had come to again drain the tank (Engine Deconcretion Book 23/5/1991: 30).

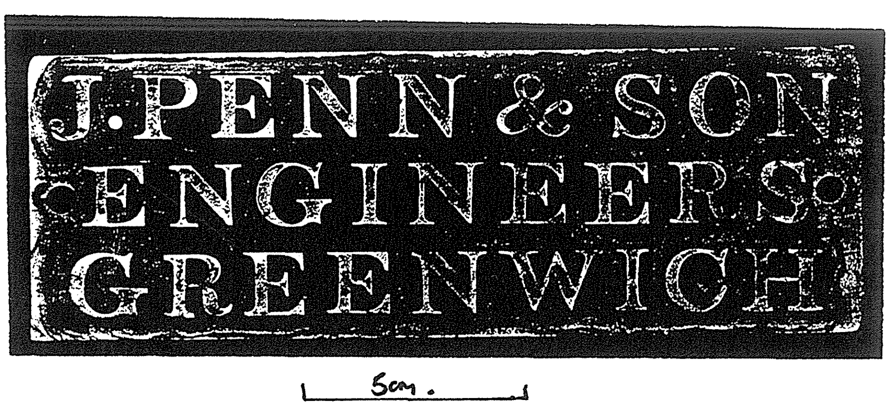
The core deconcretion team was joined at odd times throughout the next ten years by visiting conservators, some on internship from a number of countries throughout the world.

Figure 101: A deconcretion team in the tank, showing the engine after its upper surfaces were deconcreted. From the left: Dick Garcia, (WA Museum), Kolam Gaspar (Brunei), Alexandra Elliott (Canada), the author, Paul Mardikian (France), Ian MacLeod (WA Museum). The wooden foot-rest was bolted to the bearer under MacLeod's left foot

As the excavation progressed, it became apparent that corrosion rates over the engine were not uniform. In some places iron nuts and bolts had totally disintegrated or were present merely as hollow shells; in others they were intact. The fore side wrought iron radius link, for example, was found to be a mere hollow concretion due to its being preferentially corroded by the cast iron. Its concretions were kept to be moulded as casts for reconstruction in the future. The corresponding link on the aft side of the engine was in far better condition, however. The wrought iron weigh shaft, which joined the two, was similarly badly affected and it soon became evident that all of the wrought iron on the engine, including the heavy engine bearers, had suffered in a similar fashion. In the latter instance some parts had totally corroded away. This contrasted with the brass-work and copper, which as one would expect from their place in the electrolytic table were uniformly in good condition. For example, the maker's nameplate was further deconcreted and found to be in perfect condition (Figure 102).

The nameplate was removed for treatment as the centrepiece of a proposed exhibition featuring the *Xantho* brasswork. The written record noting the maker of the engine was thus corroborated, and in part corrected, by the physical evidence.[1]

Figure 102: The maker's nameplate, J. PENN & SON ENGINEERS GREENWICH. Photograph J. Carpenter.



The surfaces of the cast iron structures, though extensively corroded and graphitised, were uniformly intact, although very fragile. A series of numbers and letters were visible and eventually a pattern was seen to emerge. The majority comprised the letters **58 30 F** or **58 30 A** on the

[1]One newspaper referred to the engines as built by 'Payne, the government machinist' (Herald, 25/1/1873)

valve chests, the end of the trunks and the brass-work (Figure 103). They were eventually located on every discrete part of the engine, indicating that each unit carrying part number 58 30 F was to be attached to the fore cylinder and that those with the number 58 30 A were to be attached to the aft cylinder. Occasionally the numbers 1-4, and identifying or position fixing dots, were located. On the eccentric straps, of which there were two on each side of the engine, the figures FB and FT (fore bottom and fore top) and correspondingly AB and AT (aft bottom and aft top) appeared. More inscriptions were found as the 'excavation' continued.

Figure 103: A close-up of a valve chest, showing some of the markings found in the deconcretion process. Photograph P. Baker

The markings attested to the possibility that the engine was number 58:30 and that it was capable of being readily assembled and disassembled, with interchangeable parts suitably identified and marked to ensure their correct order and place of application. This led to the belief that this was the 30th engine produced by Penn and Son in 1858. As the engine is recorded in the *Xantho* register as having been built in 1861, the question was put whether it had been stored for the intervening three years before being fully assembled for its fitting into a gunboat.

In looking for evidence as to how the engine and the *Xantho* were operated, evidence of hasty repair was sometimes found. What was described in the artefact book as a 'rough rubber gasket with wire' (XA 288) was in fact a very crude attempt to stem the leakage of steam between the inlet valve attached to the fore valve chest and the chest itself. Other instances of crude repair were found, as discussed below.

The next deconcretion session, which began in early June 1986, resulted in our steam engineer, Noel Miller making an amazing discovery. While recording an oil cup on the crankshaft he noted that it was designed to take lubricant on each rotation from an oil impregnated wick suspended above the crankshaft (Figure 104, below).

This in itself was not unusual. The surprising feature was that the cup was open to the starboard side of the ship. This indicated that, when viewed from astern (as in Figures 104 and 105 below), the crankshaft and hence the propeller rotated in a clockwise direction and the top of the propeller and crank moved from left to right, i.e. the propeller and the engine had a right-handed rotation (Engine Deconcretion Book, 23/5/1991: 31).

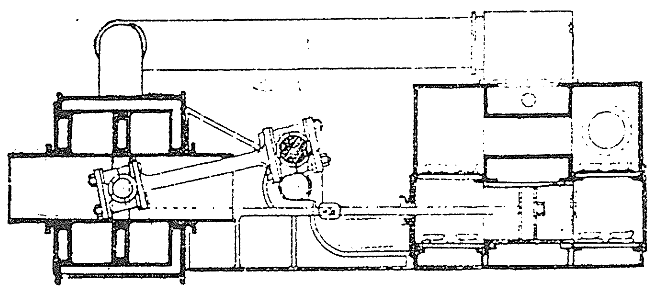
Figure 104: Noel Miller recording the upper surfaces of the engine. The oil cup is in the foreground, right. Photograph by P. Baker.

In stark contrast, John Penn had designed all his trunk engines fitted to the port side of the ship (like *Xantho)* to rotate anti-clockwise, in order to counteract the force of gravity on the cylinders and to thus reduce their wear (Seaton, 1911:74). A discussion of this appears in Figure 105 below.

Figure 105: An excerpt from (Sothern, 1923: 299); explaining the direction of rotation[1]

Trunk Engines.

A trunk engine has no piston rod, but simply a connecting rod extending between the crank-pin and the piston. The trunk passes



No. 20.—Trunk Engine and Double-Acting Air Pump.

through both ends of the cylinder, and is bolted by a flange to the piston. For a right-handed propeller this type of engine is placed on the starboard side of the engine-room, so that when going ahead the stress will be thrown on the top side of the trunk and piston; for a left-handed propeller the engine would be placed on the port side to obtain the same result.

The air pump shown on the sketch is of the double-acting type, and has foot and head valves at either end, and a solid piston; the condenser suction is below, and the hot-well above. When the engines are of the inverted type, the pump is worked from the main shaft by an eccentric, or by a pin on the crank web.

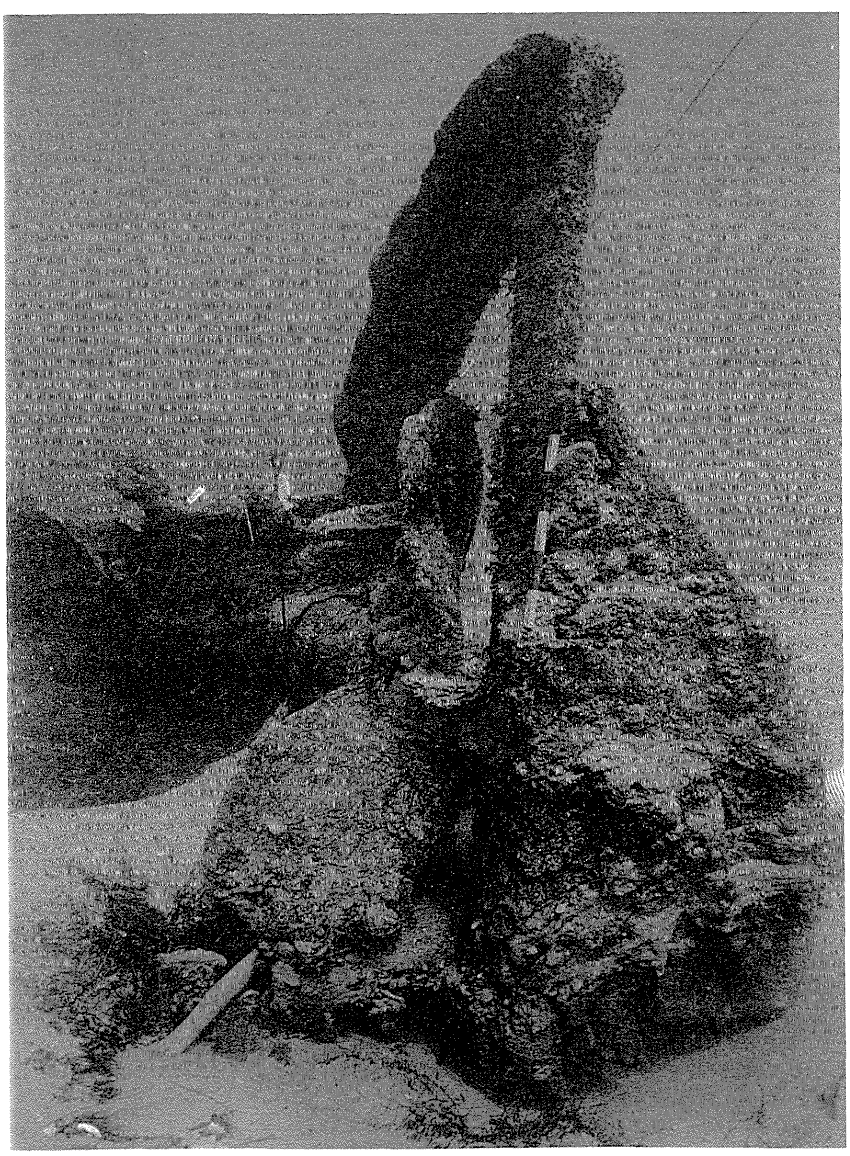
The *Xantho* engine, therefore, appeared to be rotating in the opposite direction to that which its maker had designed. In order to confirm this observation, the photographic and video record was consulted, and it clearly showed that the propeller was also right-handed and rotated clockwise when viewed from astern (Figure 106).

This was a most anomalous find as the direction of rotation on the *Xantho* engine served not to lift the piston up from the cylinder floor on

[1] See also the excerpt from Jamieson, (1897) reproduced in Appendix 4.
It should be noted that Figure 16 shows two other horizontal engine types with an opposite rotation. Neither suffers from angular thrust on the piston by virtue of the cross-head utilised, however, and as a result direction of rotation is not a major issue.

each rotation, as Penn had designed in order to reduce wear (cf. Jamieson, 1897: 215), but to force it downwards adding to the gravitational force and thus increasing engine wear markedly. This made complete engine failure only a matter of time, raising further questions about Broadhurst's decision to purchase the *Xantho*. Was he aware of the problem? When had the propeller been fitted? Why did *Xantho* not carry a spare, when we know *Georgette* carried a spare propeller for use on a run far closer to engineering facilities. (cf. McCarthy, 1985: 22-25; McCarthy, 1986a: 54-59, McCarthy, 1988c: 179-190).

Figure 106: The propeller on the *Xantho*. When viewed from astern the upper blade rotates from left to right. Photograph by J. Carpenter. Note that the rudder is hard to starboard.



Very hard concretions were also encountered during this phase, necessitating experimentation with an air compressed needle gun, with little success. In late October 1986, the tank was again drained for another week of work and, in view of the hardness of the concretion, an air driven chisel (A two speed Zytek model with changeable heads) and an air driven drill were utilised to some effect. Though the potential for damage was noted, these tools were considered more suitable than the percussive methods used earlier due to their efficiency in cramped spaces.

In order to speed up the removal of salts from the iron, deionised water was used after the tank was drained. Eventually, few artefacts remained attached to the engine structure, leaving mainly nuts bolts and a few remaining oil cups and other brasswork pieces to be removed. It was slow work, however, and in 1986 only nine objects ranging from an iron bolt to rubber and wood fragments (XA 304-5) were removed compared to the total of 345 recovered up to that time.

The next stage of deconcretion was conducted over a two and a half week period in late September to early October 1987. It involved the raising and re-shoring of the engine with baulks of timber to allow work to begin underneath. Three hundred kilograms of concretions varying from 30-50 mm thick were removed from the underside of the engine reflecting the fact that work was being performed in this previously inaccessible area. A halt was eventually called to this phase due to safety considerations.

While this work was in progress, the recording of the upper surfaces continued. Deconcretion of the spare connecting rod, which was found in the engine room of the *Xantho* also began. On its surface was the legend SPARE FITTED 58 30, the first indisputable proof of the existence of interchangeable parts. This artefact was sent to the hydrogen furnace for treatment and this proved so effective that it was placed on display almost immediately after the application of a layer of microcrystalline wax. This was a standard procedure designed to protect conserved objects from the atmosphere and from the effects of handling.

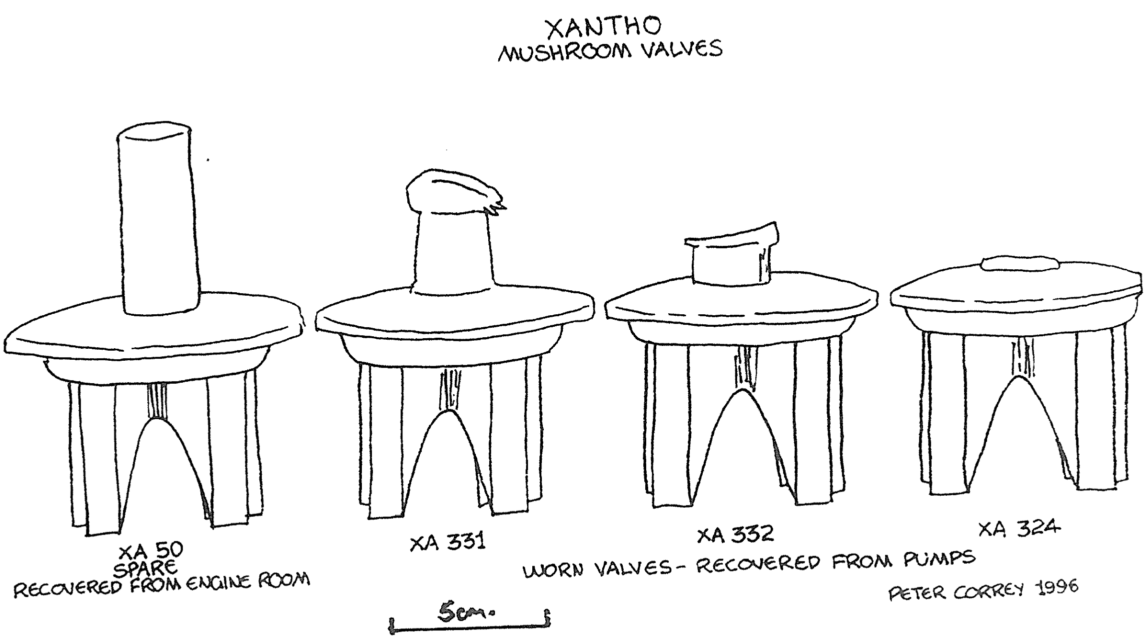
Figure 107: One end of the spare connecting rod, showing the markings, SPARE FITTED 58.30. The connecting rod is shown *in-situ* beneath the thrust-block and flanges in Figure 80. Photograph, J. Carpenter.

More importantly the spare connecting rod, when combined with the ubiquitous markings 58:30 F and 58:30 A, indicated that the engine was designed to be easily assembled and that it was of a mass-produced type which would potentially allow the use of interchangeable parts from other similar engines. Broadhurst's decision to purchase this particular ship, fitted with a very simple, easily-worked engine that had easily fitted spares and interchangeable parts, came to assume another dimension. Was his decision based on logic after all? Was it wrong to hypothesise he was a naive English Gentleman duped through his lack of business-sense? Would a smart entrepreneur planning to operate a ship in a remote part of the world with poor coal supplies, few engineering facilities, little water and little else besides, opt for a vessel that was cheap, multi-purpose and, in effect, an auxiliary steamer i.e. a vessel which used its engine as a secondary source of propulsion? Was this decision more appropriate than purchasing a steamship proper, with auxiliary sails, thus obviating the need for coal supplies and to some extent mitigating against the thermal inefficiencies of the engine? Would he have looked for a vessel fitted with compact, easily-repaired machinery? Should the engine be considered separate to the ship, which was a unit that Broadhurst may have been forced to buy because his capital was limited? Was the decision to purchase the *Xantho* a good one after all? The interpretations were conflicting, but new possibilities had been established.

Attention then turned to the deconcretion and opening up of the pumps, one of which (the starboard pump) was completely dry. The two pumps were attached to a 'Scotch yoke' arrangement, a form of eccentric attached to the crankshaft causing them to be always in operation (i.e. they could not be disconnected). The iron that had been used to manufacture the pumps was analysed and the results showed that it was poorly cast, resulting in their being in very poor condition in comparison to the rest of the ironwork examined and leading to the belief that they were not part of the original engine (MacLeod to McCarthy, pers. com.).

Inside each pump were two non-return 'mushroom' valves, each of which originally had a c. 50 mm stem (Figure 108). These were adjusted by a nut on the top of the pump case. In a number of instances the stems had been worn flat as could be expected through their continual use (XA 325 & 324, XA 331 & 332). A poorly cast, previously unidentified spare (XA 50) had been located during the excavation of the stern of the ship, providing an interesting comparison.

Figure 108: A sketch of three of the mushroom valves recovered from the pumps, showing the extent of wear on those in use in comparison to the spare on the left. By P. Correy.



The dismantling of the inlet and exhaust pipes and other piping, that once linked the boiler to the engine and it to the pumps, also began. In the meantime a special purpose heavy metal frame with lifting eyes had been constructed on which to rest the engine and, where necessary, on which to raise it without further stropping. Being of solid construction, it also allowed work to continue under the engine. The deconcretion of the area inside the trunks began at this time. This involved the use of traditional percussive methods with the addition of air tools and masonry drills. A total of 547 kilograms of concretion was removed in this phase making a total 2469 kilograms removed up to that point.[1]

Finer deconcreting amongst the interstices of the engine resulted in the removal of a number of brass fittings. A kitchen knife (XA 366) was also recovered from one of the concretions, again providing some insight into the disintegration of the accommodation spaces above the engine room and adding to the evidence found during on-site excavation. Work also continued on the removal of all of the trunk gland tightening nuts (XA 349-362) and on the deconcretion of the inside of the trunks.

The tank was again drained in December 1990 and in May 1991 a further week of extensive deconcretion was carried out. This proved most successful, and it included much fine work and engineering-based recording by Miller.

Before he was forced to discontinue work due to ill-health, Miller noted that the engine was in 'mid-gear'; i.e., it was stationary and was not driving the propeller either forward or in reverse. A slowly sinking vessel can be expected to have its engines in mid-gear, in order to facilitate an orderly abandonment by reducing the danger from a rotating propeller and in order to bring the vessel to a halt so that lifeboats can be launched. Steam is still needed to drive auxiliary machinery, however. Where the vessel is hard aground, and cannot be got off, the engines are also expected to be in mid-gear for the same reason. Only where a ship is rapidly sinking

---

[1] There were also a number of unexpected problems. In August 1988, for example, the edges of 14 discrete surfaces on the engine and especially the pumps, were found to have fractured and cast iron fragments had fallen off between treatments. It was eventually ascertained that the exfoliation had been caused partly by an inability to maintain a uniform field of current throughout an angular object (without the surface symmetry of the iron cannons usually treated) and by the application of more current than was necessary. The combination of these two factors produced an evolution of hydrogen at stress sites. The evolution of the gas caused the fragile metal to spall off, especially at corners where it was most at risk from external forces. Advice was sought on the exfoliation problem from both Dr North (then in private practice) and M. Stephane Pénnec (a conservator on internship from France) involved with the treatment of *Titanic* material. Eventually it was decided that deconcretion could continue but that the monitoring process should be stepped up. The phenomenon is described at some length by Pénnec (1990). After the problem was rectified, the tank was again filled and treatment continued.

or where abandonment is abrupt, or panic-driven, are the engines expected to be found in forward or reverse gear.

Further deconcretion work was conducted in March and October 1992 and, by the end of seven years, the engine lay almost completely deconcreted with all but the internal parts of the trunks, cylinders and valve chests, as clean as the day the *Xantho* was lost. The engine looked as if it could run again. In the process, 2,544 kilograms of concretions had been removed from its surfaces and 48 kilograms of chloride ions had been released from within the actual metal of the engine itself (MacLeod, 1992:49). The visible parts were stable and looked as if all they needed was a coating of wax and the engine could go onto the exhibition floor (See Figures 104 and 106).

On the negative side, the area inside the trunks had proved too difficult and work in these spaces had been halted. Due to the difficulties of dealing with the thin (10-25 mm thick) cast iron piping removed earlier and the fact that the thin cylinder and valve chest walls and cover plates apparently had no original metal left in them, work in the internal cavities had also not been envisaged. The deconcretion of the internal spaces was not considered possible and the use of corrosion inhibitors and internal coatings was planned. The excavation and analysis could only be considered part complete as a result and an examination of the interior and deconcretion of the trunks was necessary in order to complete the archaeological analysis of the engine. Earlier, there had been an unexpected effusion of gasses from a number of internal spaces when drainage taps and indicator cocks were removed. This indicated that the opened sections were dry. An endoscope was applied to these spaces revealing, in some instances, previously unseen areas that had not been flooded when the ship went down. This led to the possibility that the interior could be recorded using cameras mounted on the endoscope. My day book of the time (*Xantho* Engine Deconcretion Book 23/5/1991: 71) reads thus

> Both the valve chests and the cylinders were examined and proved remarkably free of concretion with surface corrosion only and very sharp edges to all surfaces. This is a wonderful boost to us all and the light at the end of the tunnel now looms large :- with vapor phase inhibitors it is clear that the cylinders and valve chests will not become a source of continued corrosion in the future and we can concentrate instead on existing concretion in the trunks themselves.

Thus it was initially decided that the interior would be examined with endoscopes, recorded with cameras and filled with vapour phase inhibitors, as would the trunk cavities. When rendered internally and externally stable, the engine would be coated in microcrystalline wax and placed on exhibition. Further recording work could be conducted in the public gallery itself, including the completion of the engineering drawings and the recording of the various oil-cups, nuts, bolts and studs and their threads.

We were prepared to halt at this juncture, in the belief that corrosion inhibitors would most likely protect the internal workings and that to proceed further with the deconcretion could result in the destruction of the engine.

The engine model

The philosophy behind the production of working models or replicas of ships and boats, their construction and their use in testing alternative ideas has been covered at length by a number of authors (e.g. Claasen, 1983:189-205).

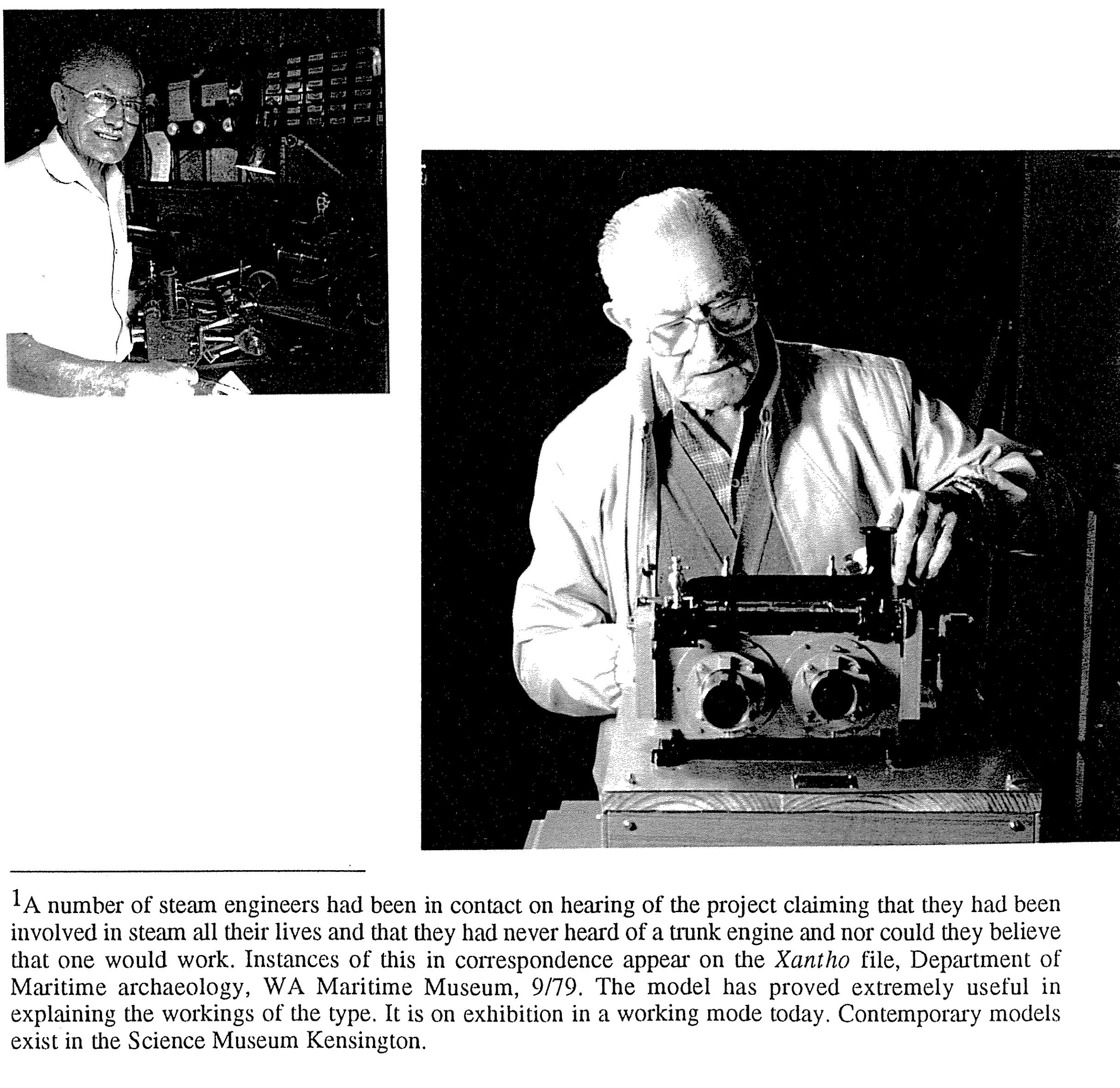
In the *Xantho* case, excavation of the hull for the purposes of obtaining the ship's lines, even at considerable intervals, was contraindicated due to its fragility (Beegle, North and MacLeod, 1983); see Appendix 7. As a result the production of lines for the underbody of the ship and a resulting hull model or replica capable of being used for tank tests and other experimental purposes, was not attempted.

Once it was decided to raise the *Xantho* engine, the production of a working scale replica, based on the resulting engineering drawings, became desirable in order to assess specific engineering features. It was to be the first model of a marine steam engine recovered from the sea. Miller, a practising steam engineer and model maker, had spent a great deal of time measuring and recording each section of the engine as it emerged from its layer of concretion, partly with that aim in mind. He became gravely ill, however and the part-finished engineering drawings were given to a colleague, accomplished model maker C.E. (Bob) Burgess. After a number of years and thousands of working hours he completed both a wooden mock-up and a 1:6 working scale model of the engine which was presented to the Museum in May 1991 (Burgess and McCarthy, 1994). A suitable hand-over ceremony was held and in turn he was presented with one of two replicas of the engine name-plate, the other going to the HMS *Warrior* in England. Soon after this ceremony both Marjorie Darling and Noel Miller died.

The working model (Figure 109) has enabled us to examine the engine over what is now an extended period of time. By reproducing each external part faithfully, Burgess has enabled us to understand the engine as a unit and to visualise how it appeared statically and in motion. Insights were also gained into its compact and easily accessed nature, its change from forward to reverse or mid-gear, how it was supported on the engine bed and compactly housed within the vessel.

What Miller and Burgess could not do, however, was reproduce the internal workings. Up until that time our only glimpse of what was inside the engine was through the lens of an endoscope and that had proved inconclusive, except to confirm that some of the interstices were still in a very good condition. As Burgess assembled the model progress was recorded until finally it was ready to receive compressed air, an accepted alternative to steam in the model world. Not having dealt with a trunk Engine before, Burgess was not sure that the engine would work. It did, however, and from a technical point of view the model has been an undeniable success, proving to those who doubted that a trunk engine could work (or that it even existed) that they were functional and even possessed a number of engineering advantages.[1]

Figure 109a-b: Model engineer Bob Burgess with the model in his workshop and in the exhibition gallery. Photographs by D. Elford and P. Baker.



[1]A number of steam engineers had been in contact on hearing of the project claiming that they had been involved in steam all their lives and that they had never heard of a trunk engine and nor could they believe that one would work. Instances of this in correspondence appear on the *Xantho* file, Department of Maritime archaeology, WA Maritime Museum, 9/79. The model has proved extremely useful in explaining the workings of the type. It is on exhibition in a working mode today. Contemporary models exist in the Science Museum Kensington.

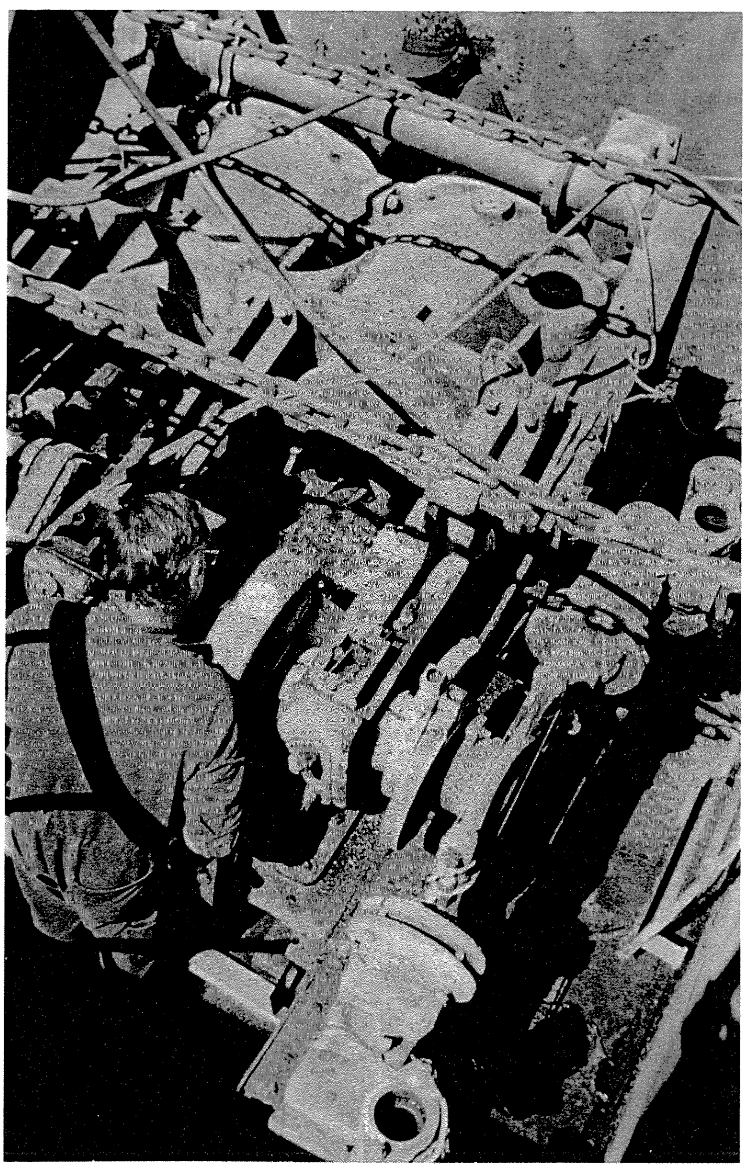
The model demonstrated that the *Xantho's* engineer was in grave danger of being crushed between the rotating crankshaft and the wooden rest. With the engine rotating in a contrary fashion to that designed by Penn and Son, the counter-weights and crankshaft were moving down towards the engineer's foot-rest and not up and away from it, as planned. These dangers are clearly illustrated in Figure 101 above, where one of the deconcretion team has his left boot where the foot-rest was located before it was removed for conservation. A counter-weight is poised just above his foot, showing that there was no margin for error in the circumstances described above. Here was another clear example of shoddy engineering practice.

Deconcretion of the engine: stage 2, the internal spaces

Another change in direction for the *Xantho* project came when Richard (Dick) Garcia, a conservator with extensive experience in refurbishing munitions and armaments, vehicles and other heavy equipment provided us with the benefit of his extensive experience. He had found that the internal parts of fire-arms and munitions buried for over half a century in the mud of battlefields, could be freed and the corrosion products loosened using direct heat. He had also applied the method to small-arms, which were in effect composite iron and brass objects, with considerable success. Having successfully applied an oxy-acetylene flame to the deconcretion of a pair of fragile iron trypots recovered from a wooden-hulled wreck (Carpenter, 1990: 31-34), Garcia suggested the method could be applied to the *Xantho*.

In March 1992, mindful of the results with trypots, Garcia was authorised to conduct a test on a heavily concreted brass tap from the *Xantho*. The experiment proved successful and the method was tested on the area inside the trunks, where deconcretion had earlier proved impossible. The 'direct flame method' causes differential expansion of the matrix in addition to the production of steam at the metal/concretion interface. This causes the concretion to break its grip and the surface of the metal does not suffer undue heating if the method is correctly applied.

Figure 110: Dick Garcia using the 'direct-flame' method. The long tip of the oxy-acetylene equipment allowed the heating of previously inaccessible areas inside the trunks. The photograph shows the cramped space between the crankshaft counterweight and the trunk aperture in front of Garcia. Traditional percussive deconcreting methods were rendered practically impossible in the circumstances. The chain above the space in question was used to prevent the sides of the tank bowing.
The two pumps are shown on either side of the crankshaft on the right of the picture. The pump valves shown in Figure 108 were recovered from the chambers, which appear without their covers in this illustration. Photograph J. Carpenter.



← flame

↑ flame

Work proceeded successfully and a total of 75 kilograms of otherwise immoveable concretion was removed from within the confined spaces. Eventually I concluded that the method was superior to percussive methods, especially in confined spaces or where the concretion was difficult to remove (Engine Deconcreting Book, 3/1992: 73).

The percussive and direct-flame techniques were then applied to a very fragile container that had been recovered from *Xantho* in 1985 and had been considered impossible to treat, (See Figure 82), the feed-water heater (which was recovered in 1988), and to the boiler valve and the pump (which was recovered form the port side of the stokehold in 1992). The percussive technique resulted in the usual surface chips, while the flame method showed little visible damage at all; though its long-term ramifications are still to be observed and much work still needs to be done before the method is universally accepted.

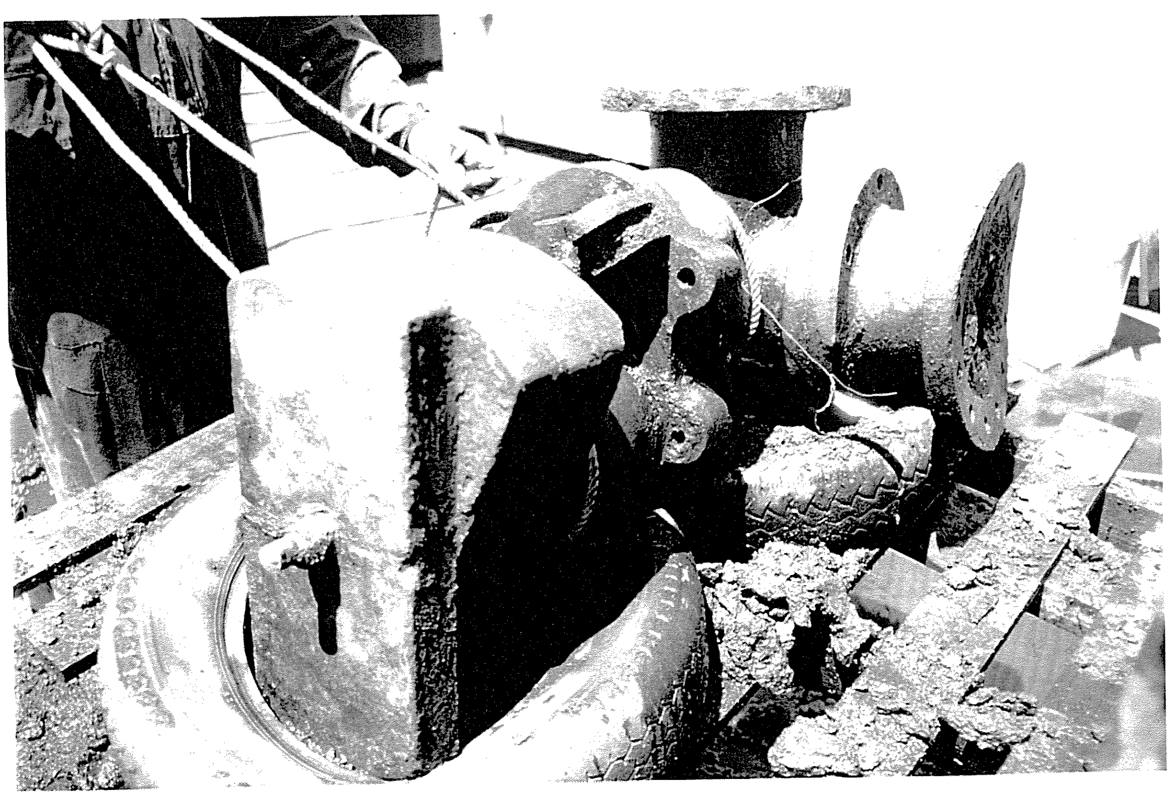
While deconcreting the feed-water heater, a nameplate was located bearing the inscription

Chaplin's Patent
Alexr Chaplin & Co
Cranstonhill Engine works
Glasgow

This information was recorded and work has begun on tracing the company involved and examining its patent documents.

The boiler 'valve' (XA 339) proved to be a safety valve designed to release steam when the boiler pressures exceeded those considered safe for normal operation. Onboard ocean-going ships, where pitching and rolling in heavy seas is the norm, boiler safety valves are usually the spring-loaded type as shown in Figure 23. The spring provides a constant force in any plane, independent of gravity. When fitted on land-based stationary engines and boilers, the valves often had a counter-weight or 'dead weight' system where the steam had to overcome only the gravitational forces exerted by weight on a valve-seat. Where more steam pressure was required more weights were attached and vice-versa. The dead weight safety valve worked well where boilers are kept in one plane e.g. on land or on rivers or still waters. If fitted to boilers on ocean-going steamships, the valve seat would be subject to varying pressures as the vessel pitched or rolled. It has been stated that 'this type of valve is not suitable for marine practice' (Sothern, 1923: 960). Contrary to expectations, *Xantho* was fitted with a dead weight safety valve. Though suitable for use on rivers and sheltered waters, the valve was considered inappropriate for use at sea and its appearance on the *Xantho* was intially considered anomalous.[1]

Figure 111: The *Xantho* boiler relief valve. It is a 'deadweight' type. Photograph by J. Carpenter.



[1]In enquiring further it was ascertained that *Royal Shepherd* (1853-1890) lost of the NSW coast was also fitted with a counterweight type (J. Riley, pers com., January, 1997). See page 69. I was also advised, after this thesis was submitted, that 'equal space' is given to lever and spring-operated valves in *The Practical Engineer's Handbook* (Hutton, 1890), while in *A Manual of Marine Engineering* (Seaton, 1904), it was stated that the lever type or dead weight type were no longer in use by then. (R.H. Webb, pers. com., November 1996) (RWebb56467@aol.com).

At this stage, it is relevant to follow on from an earlier comment about the categories of archaeological information that can result from an examination of a ship's engine. In order to do so, it is reasonable to make analogy and point to the sort of information that would be required by any informed observer today in order to judge the state or condition of machinery and to answer the question whether an engine was suitable for the purposes intended. I take this step because much of what follows recognises that the reader will have some experience with machinery, and especially with engines both new and used.

In attempting to answer questions raised about any particular machine, an inquirer would turn from the records and verbal statements given by a former owner, to an examination of the engine itself. This would first be performed externally by visual observation, then with the machine running. (With the substitution of a working model for the original, we have done this in the *Xantho* project). An external examination and compilation of technical data and oral histories would be followed by an examination of the internal state of the engine through the use of cylinder pressure gauges and other sensory aids. Where vital indications are not positive or conclusive, an analysis of the interior of the engine, by the removal of the cylinder heads, or the covers is likely. If further information is required, or standards are more rigid, such as in the aircraft industry, then the engine could be disassembled and its parts subjected to minute structural analysis, maybe even by metallurgists. In combining all of these approaches, answers could be provided to questions such as, was the engine new or recently reconditioned, had it been modified in any way, were those modifications suitable, was it well maintained, how long would it last, etc.

These interpretations, when applied to an engine recovered from a past context, have both technical and behavioural dimensions. Firstly a statement can be made about whether the engine is of a suitable design or whether it was well maintained and, importantly, conclusions can be made about those who owned and operated it. Thus, though conservation of the *Xantho* engine was still a major aim in this final stage, archaeological considerations came to the fore.

Having proved that the flame deconcretion system was effective in removing very hard or inaccessible concretion, Garcia was requested to begin work on a feasibility study by first removing one bolt on the engine. Heat and lubricant were applied, followed by spanners. The method proved successful. Garcia was then authorised to remove the bolts on the crankshaft. The big end nuts and assemblies (XA 387-8) were removed, followed by the end caps, pumps, radius links, eccentric straps (XA 396-9) and weigh shaft.

The corrosion exposed under the nuts and bolts was greater than had been expected and it is likely that it would have eventually destroyed these components from the inside. Consequently Garcia continued, removing as many nuts and bolts as possible, exposing many previously joined surfaces.

At the end of March 1993 the tank was again drained and work continued, with such success that Garcia proposed the engine be dismantled into its component cylinders and main frames. Again a small-scale feasibility study was conducted. Starting with the fore starboard side, all bolts holding the engine to the bed plate were carefully heated and removed for cataloguing and conservation. This was followed by removing the bolts holding the cylinders to the main-frame, the pump to its bed bolts and those bolts holding the cylinders together. Then the engine was carefully lifted using specially built hydraulic jacks. Under each of the three webs of the main frame were a series of rough wooden wedges and iron spacers used to align the engine with the crankshaft. The use of spacers is standard practice in engineering, but in this instance they appeared particularly crude. Similar wedges were found under the cylinders. After being recorded and numbered in the usual fashion these too were removed for conservation. Each part was then separated using hydraulic jacks and levers and tiny rollers inserted under each part. Thin wedges were then inserted at the breaks, pressure applied and the engine slowly separated into its component parts, just as John Penn had designed.

Eventually the cylinders were split into each unit (XA 445 and 446) and with the main treatment tank near the end of its life (ironically due to corrosion), the smaller engine sections were removed from the tank and placed into other tanks in December 1993. Further disassembling of the numerous, mass-produced and interchangeable component parts then began. The cylinder covers were removed after hundreds of hours of work and the cylinders themselves were entered. Their state reflected the fact that one side of each cylinder was open to atmosphere via the valve chests and the other was steam and watertight. Sand had been deposited in the 'open' cylinders together with corrosion products and other detritus. Samples were taken and sent for analysis. The 'closed' cylinders were in exceptional condition. The wrought iron engine bed was also dismantled, revealing that it was in a very eroded and fragile state and that it was barely strong enough to hold the engine. This supported North's analysis in 1983.

Then, using heat, lubrication and force, Garcia was able to turn the crank-shaft for the first time in over a century and the end caps, bearings and finally the crank was removed from its frames. These, in turn, were separated and placed in a treatment tank for further electrolysis. Then work started on removing the glands from the pistons. This required the construction of special purpose mechanical 'pullers' and miniature jacks which were applied, along with heat, to surfaces seized for over a century. After months of work, involving cleaning minute channels of concretion, applying heat with tension and lubricants, success was achieved and the first steam glands and their packings were removed. In late June the cylinder head was also removed, allowing the packing glands and internal spaces to be recorded and analysed. The trunk, with its piston attached, was seized inside the piston. Garcia then set about its removal by systematically applying heat, lubricants, percussion and then tension in the form of a specially constructed 'puller'.

Figure 112 a-c: The disassembly of the engine. Photographs by Ray Sutcliffe

Figure 112a: The separation of the cylinders began with the insertion of a hydraulic jack.

Figure 112b: The fore cylinder and valve chest assembly, showing concretion that had earlier proved impossible to remove.

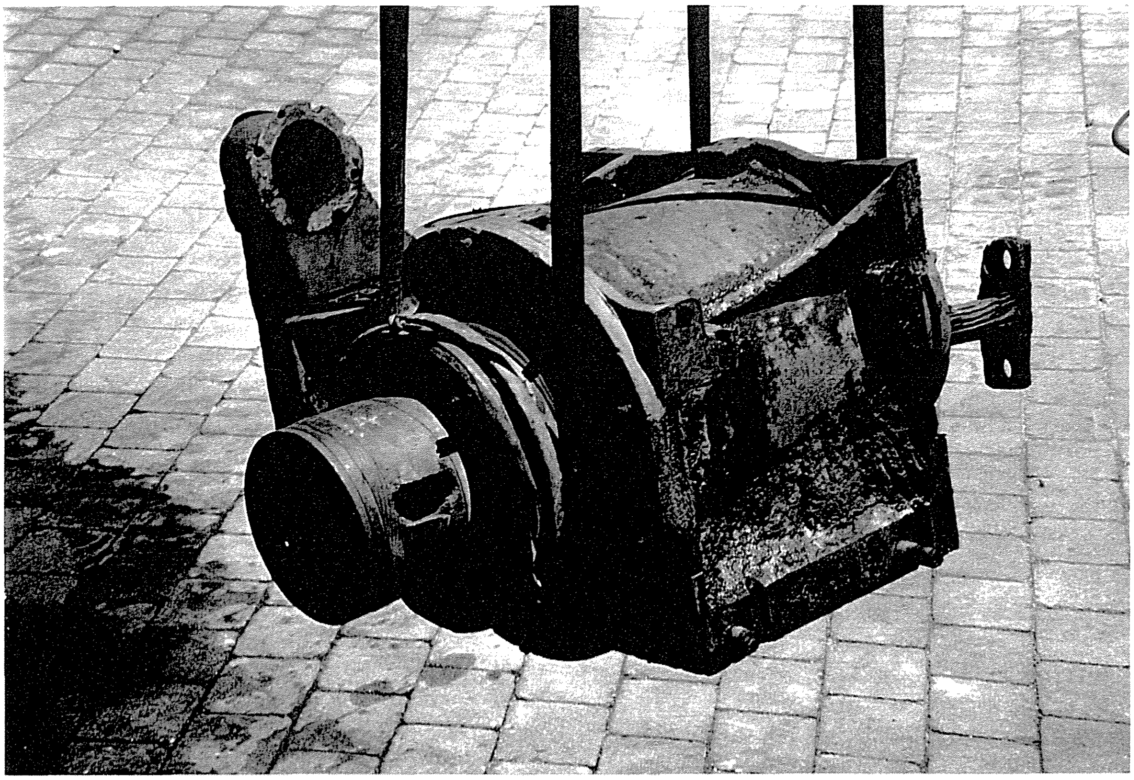
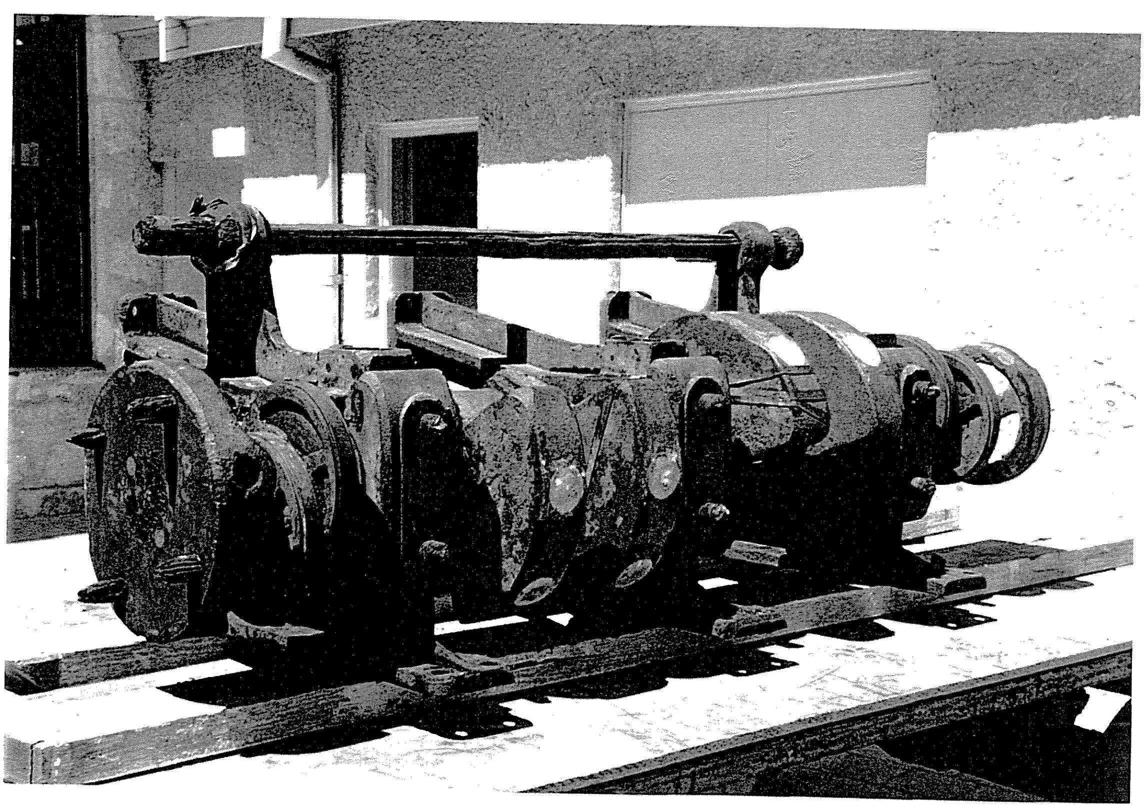


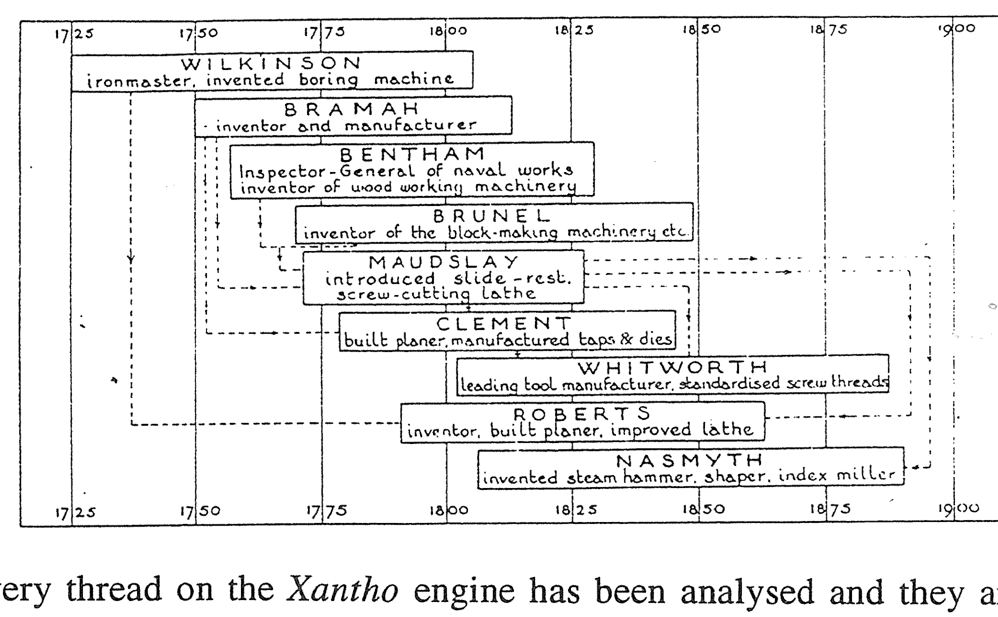
Figure 112c: The crankshaft and web assembly. The light-coloured circles on the counterweights are lead, which was poured while molten into the recesses to prevent the bolts loosening.



The deconcreting of the interstices of the *Xantho* engine has allowed the engine to be examined from a technical and archaeological perspective down to its last nut and bolt-setting the scene for similar studies in a area of inquiry once considered to be impossible.

One of the important observations that resulted from this 'excavation' relates to the threads found on the engine, providing an interesting link to Broadhurst and his family. In 1841 Sir Joseph Whitworth, Broadhurst's future brother-in-law, proposed a standard for the screw thread which was quickly adopted and now bears his name, the British Standard Whitworth (BSW) thread (Lee, 1900:166-170; Gilbert and Galloway, 1978: 431-5, 637-638). His role in the development of engineering is illustrated in Figure 113, clearly straddling the *Xantho*/gunboat period. As indicated earlier, I would argue it is likely that Whitworth would have influenced Broadhurst in his decision to purchase *Xantho*, in that he would have been well aware of the pedigree of the gunboat engine type; for we now know that he was a part of its development.

Figure 113: Joseph Whitworth's place in 18th and 19th century engineering (Gilbert, 1978: 418)

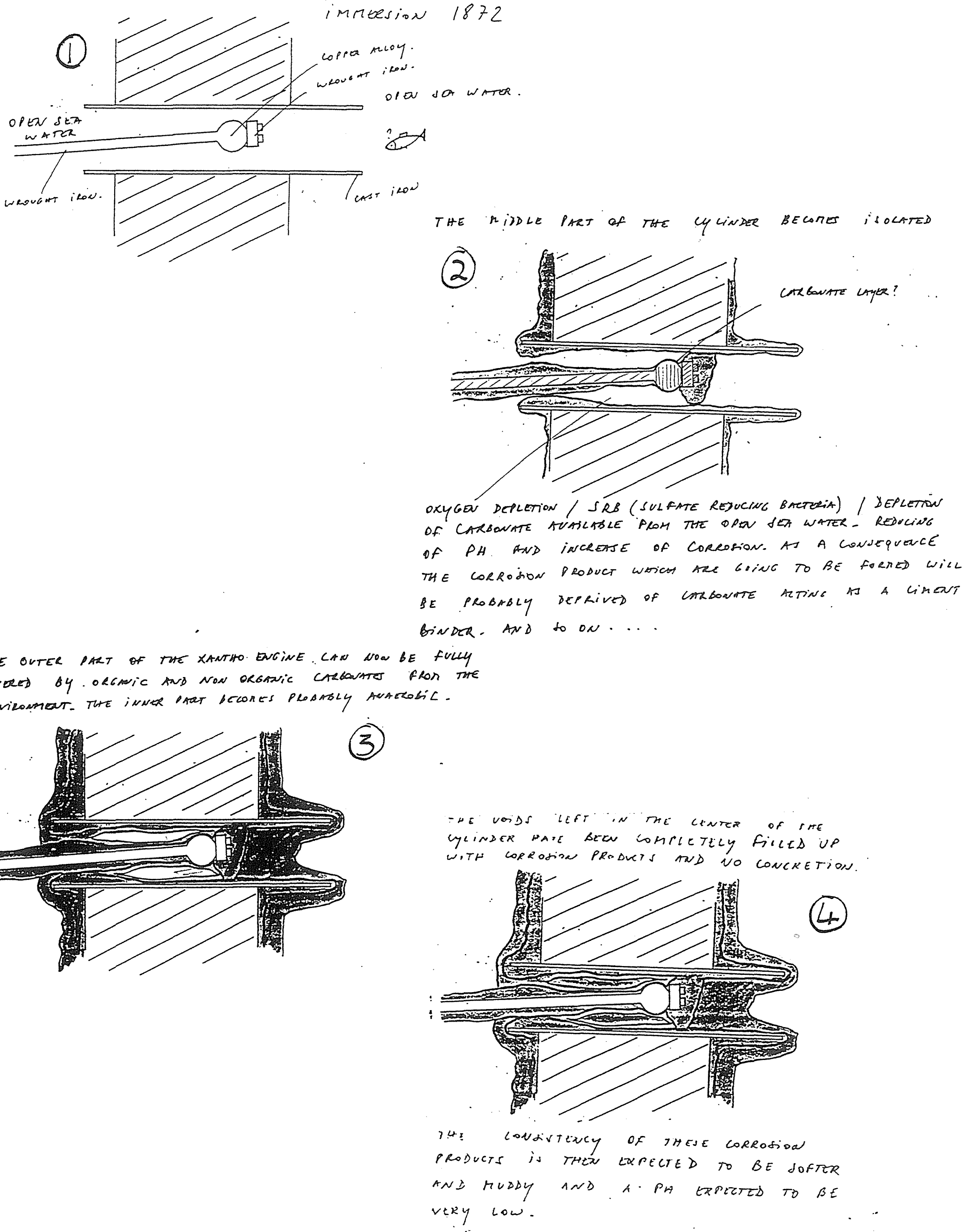


Every thread on the *Xantho* engine has been analysed and they are all British Standard Whitworth (BSW) threads (Garcia and McCarthy, in prep). In contrast threads found on the new boiler and in other locations on the ship are not BSW, showing on the one hand that this standard was used by Penn in his mass production, but that it was not universally used in Britain at the time. The threads found on the pumps were also found to be Whitworth standard threads. This was a surprise, giving rise to the belief that they may have not have been an afterthought added in an unsatisfactory manner to the original engine as suggested by the metallurgic studies mentioned previously.

There are many other potential studies of a technical nature to be conducted and most, being peripheral to Broadhurst, are outside the scope of this particular dissertation. Of immediate importance to maritime archaeology, however, is the analysis of the concretions found within the trunks. These were not uniform in composition, thickness or hardness, posing questions about their formation and the ramifications of this phenomenon for the materials preserved inside. This caused me to seek the advice of M. Paul Mardikian. Mardikian was able to make a number of observations, with respect to the formation of concretions in the months and years following the sinking of the *Xantho* (See Figure 114). In doing so, he provided a preliminary model for the formation of concretions and corrosion-products within interstices, like the trunks that are rapidly sealed (Engine Deconcreting Book, 1992:77-78).

Though Mardikian's reconstructions are of a preliminary nature, they provide a useful schematic representation assisting maritime archaeologists to understand concretion processes, one of the greatest post-depositional effects on iron and steamship wrecks. The reconstructions are also important in illustrating that within concretions there are regions with differing micro-environments.

Figure 114: Paul Mardikian's analysis of the growth of the concretions in the trunks.
(Working sketches: Not to scale)



In his stage 1, for example, the trunk, a composite metal structure with numerous galvanic couples, is open to the sea. In stage 2, the middle section of the trunk is becoming isolated due to the accumulation of concretion and detritus. The heavily-concreted diver's knife found in 1994 gives some indication of the speed of this process (Figure 94).

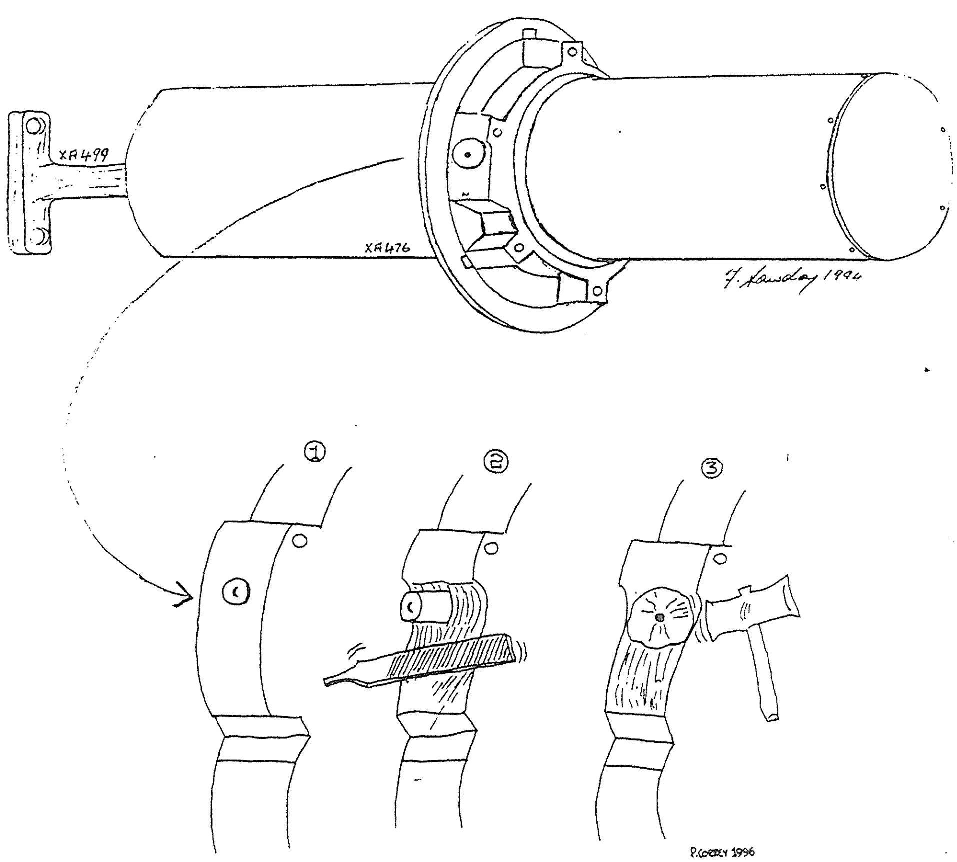
In this preliminary analysis, Mardikian has identified the operation of sulphate-reducing bacteria, oxygen and carbonate depletion in the water column, a reduction in pH and a subsequent increase in corrosion. In stage 3, the engine itself is totally concreted, in part protecting, yet at the same time rendering the inner part of the trunk anaerobic, leaving it part-filled with soft, highly acidic corrosion products. Stage 4 sees the area totally filled, though the corrosion products are still relatively soft.

Thus the formation of concretion has both a positive and negative post-depositional effect on iron and steamship wrecks. It is only recently that concretions have been shown to be more than just an impediment to archaeological studies, however. It is now known that they can contain information of archaeological importance. For example, microscopic examination of concretions from *Xantho* has also shown that approximately 16 separate bands occur in the matrix, indicating that the wreck seems to have been exposed and buried 16 times since 1872 (MacLeod, North and Beegle 1986:122; MacLeod, 1992:46). The timing of these cycles is not known and this avenue of inquiry is, as yet in its infancy. Despite this, the information obtained is of importance, not just to conservators and site managers, but also to archaeologists in providing information about post-depositional effects and conditions.

Finally in the deconcretion process, we are taken back to Broadhurst and the way he and his men operated the *Xantho*. When the aft cylinder was opened and dismantled, the 'little-end' crank-pin in the aft cylinder was found to have been exposed at each extremity, by roughly grinding down the casting of the little-end itself. The exposed pin was then apparently heated and hammered over using extreme force at each end; like a rivet (See Figures 115 and 116).

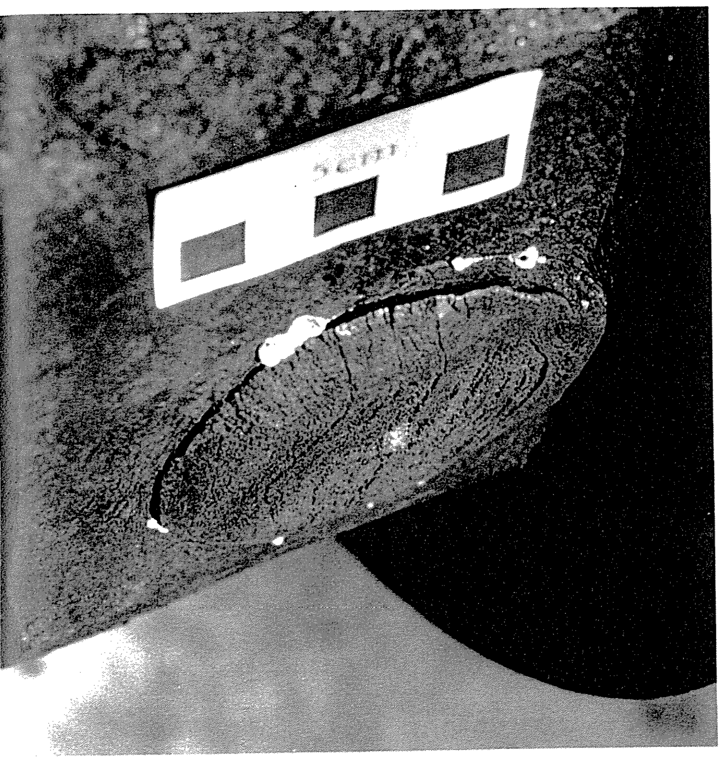
It appears that the pin had become loose during operation, causing 'slap' at the little-end on each stroke, vibrating the engine and causing obvious problems to the engineers. In order to alleviate the problem, a crude attempt was made to expand the pin *in-situ* and to take up the slack, thereby reducing vibration and wear. The engineers had shaved down the metal sleeve through which the pin was fastened to the little-end, thereby exposing around 1-2 centimetres of the pin at each end. The exposed pin was then heated until malleable and 'peened over', using heavy hammers.

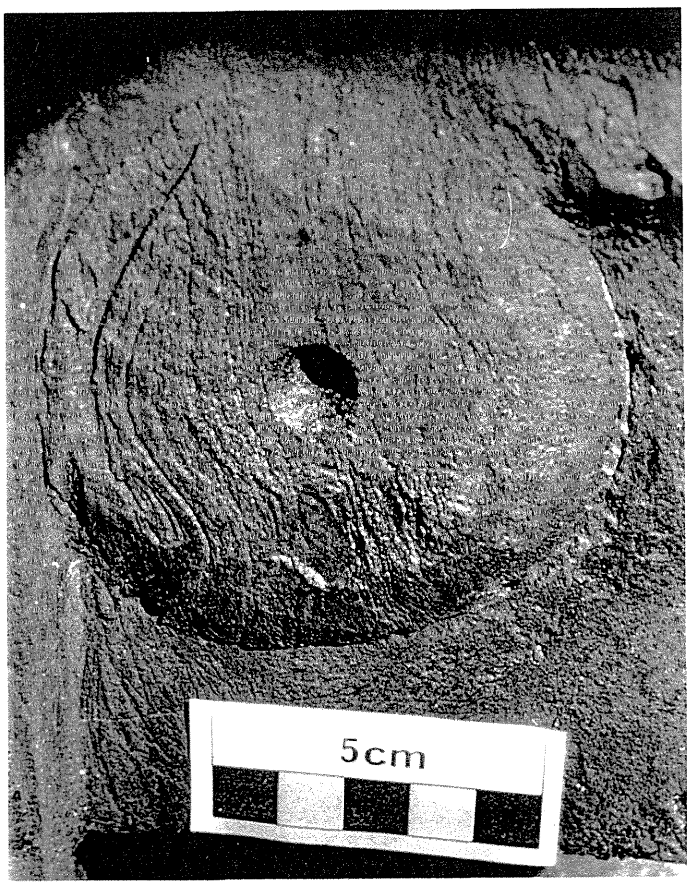
Figure 115, Sketches of the trunk assembly, showing the position of the little-end gudgeon pin and the three stages in the 'peening over' of the pin using hammers and heat. By F. Sawday and P. Correy respectively. (Not to scale)



The procedure was apparently unsuccessful, for in dismantling the piston and removing the rings, we found that one of the nuts holding a locking ring in place on the face of the piston had worked loose and had fallen into the drain plug at the bottom of the cylinder. The locking ring, was also in the process of working loose and, had it done so, the rings and piston would have separated, component parts would have been released into the cylinder and the engine would have eventually seized.

Figure 116: Detail of the gudgeon pin and its surrounds. By J. Carpenter.





Thus the *Xantho* engine was apparently succumbing to the combined effects of high speed, high working pressures and poor maintenance. These were precisely the kinds of problems that caused the Admiralty to station a special-purpose, properly-equipped floating machinery workshop in the Crimea to service the gunboat engines. Technology essential for one context can easily fail in another, due to the absence of ancillary support facilities or to the presence of factors outside its normal operating parameters. Broadhurst and his crew could not have been unaware of the fact that their engine was in dire need of expert repair and refurbishment. Their problem was where and how.

Results of the deconcretion

The *Xantho* engine was mass-produced, as shown by the spare connecting rod bearing the legend SPARE FITTED 58:30 and the appearance of the numbers 58:30 F and 58:30 A on surfaces throughout. The only exceptions to this were four cylinder indicator-cocks.

Indicator-cocks connect an instrument (an indicator-gauge) to the cylinders. The indicator-guage itself is used to assess the performance of an engine by measuring the pressure of steam throughout its entire cycle. The indicator-gauge produces the data in diagrammatic form (an indicator-diagram). The indicator-cocks recovered (XA 311-314) bear the inscriptions 44 3F 30 (MACK); 44 T 30; 64 3A 30 and 44 A 30. They are all marked with the Government-issue broad arrow, which is not found on any other part of the engine. They may not be part of the original machine and could have come supplied with the indicator-gauge itself. Engineers tend to keep tools of their own, especially precision instruments.

The shared markings, including those on the indicator-cocks, and the various aligning dots, attest to the acknowledged fact that the engine was easily assembled and disassembled, and that it was undeniably simple and easy to operate. There appears to be some logic in Broadhurst purchasing a vessel fitted with a simple, compact, mass-produced engine, with an apparent abundance of spare parts. Though there was some justification for the employment of such an engine in a remote setting far from engineering facilities, there were enough flaws in the concept to cast doubt on Broadhurst's powers of judgement.

At the time of its loss, the hull of *Xantho* was worn out, the engine was falling apart and the repairs that had been performed on it were poorly conducted, at best. The pumps were on the verge of breakdown due to constant operation and the resultant wear on the mushroom valves. The boiler was of high enough pressure to cause heavy precipitation of its salt-water feed. The engine was running in reverse, as a result of the fitting of an incorrect propeller, causing both excessive wear and safety problems. Related to this failing, the fact that *Xantho* did not carry a spare propeller, as did *Georgette* its successor on this coast, is a major oversight on Broadhurst's part.

CHAPTER 9:

CONCLUSIONS

The multi-faceted nature of the *Xantho* study requires that it be concluded as it began; firstly as a traditionally-based descriptive/analytical maritime archaeological project designed to examine a relatively new class of site from a technical perspective and then, as an anthropologically-based study designed to examine its owner and operator, Charles Edward Broadhurst.

Description and analysis

It has been argued that the *Xantho* was a vessel of regional social, historical and economic significance. It is also of technological and general maritime interest as an example of re-cycling and abandonment in the latter half of the nineteenth century. The description and analysis of its remarkable engine provides clear material evidence of the introduction of standardisation, mass-production, the use of high pressure steam and high-revolution engines in the Royal Navy as a result of the pressures of war. The re-use, modification and abandonment of the engine after the conflict is also of interest in that it parallels many past and modern processes.

Contrary to opinions expressed by Keith Muckelroy and David Lyon, to name but two influential authors, it is clear that the iron and steamship wreck is capable of adding to the body of technical and historical knowledge in archives and museums. The *Xantho* project has unequivocally shown that, in using the material evidence as a primary source, the study of iron and steamship wrecks can add to both the body of knowledge about the owning and operation of iron steamships and about marine engineering generally.

The relevance of iron and steel wreck research has been firmly established at the wrecks of the USS *Monitor,* SS *Xantho* and the USS *Arizona*, providing useful comparative studies for the future.

Beyond this, the *Xantho* project has also broken new ground at technical level. An experimental steam engine, the product of a strategic need on the part of the warring British Government, became redundant and was unsuccessfully re-used in a remote colonial context. Lost in warm, highly-oxygenated waters off Western Australia, the heavily-concreted engine was recovered from a saline environment after a century on the sea-bed. It has since been successfully deconcreted, disassembled and is in the final stages of electrolysis in preparation for reassembly and exhibition. The engine has been examined (both internally and externally) and has provided information of technical, historical and archaeological importance. This is a unique development in modern maritime archaeology; one which could be repeated elsewhere if there were sufficient justification.[1]

The SS *Xantho*, USS *Monitor* and the USS *Arizona* excavations show beyond doubt that iron and steamship wrecks are a degrading archaeological resource and that where time and funds can be made available, their recording and in some cases their protection, should be a high priority. The following comment reveals that others are now beginning to realise that fact

> The discovery of the *Titanic,* an iron wreck, is given greater significance when one realizes that the iron will not last forever, and that the vast hull will probably crumble within a further 75-100 years (Flemming, 1988: 198-200).

[1] Apart from the SS *Indiana* machinery, there are two other engines which could conceivably be disassembled in order to extract archaeological (as opposed to purely technical) information about the manner in which they were operated and maintained. These are the machinery from the steamer *Arabic* (1853-1856), which was salvaged in 1988 and is now on exhibit in Kansas City (Hawley, 1989) and the crosshead engine of the Steamboat (PS) *Columbus* (1828-1850 recovered from the waters of Chesapeake Bay in May 1993 (Holly, 1996). (Johnston pers. com.).

In noting that '...iron will not last forever...', Flemming echoes one of the major reasons why the study of iron wrecks, even modern steel ones, is presently warranted.

Though far more manageable as a cultural resource than either *Monitor* and *Arizona*, the *Xantho* has provided a number of scientifically-based working models for those interested in the problem of assessment and future management of degrading iron or steel shipwrecks. This is partly because the *Xantho* study has been acknowledged by conservators and corrosion scientists (in Australia at least) as the first iron steamship to be systematically examined by diving corrosion specialists (MacLeod, 1986:71).

It was argued over a decade ago that a wreck inspection assessment strategy must include a pre-disturbance recording of biological, physical and chemical parameters by appropriate specialists to enable an informed opinion to be made about the state of the wreck and to better facilitate the management of both it and the artefacts from it (McCarthy, 1982). The procedure did not become standard practice, however, even where facilities, funding and infrastructure existed. As a result some projects have suffered from a lack of attention to this need. The following was noted of the *Monitor,* for example.

> In comparing data from archaeological expeditions in 1979, 1983, 1987 and 1990, it is apparent that the rate of deterioration of the wreck of the *Monitor* is increasing... The management philosophy of a "hands off" policy (the best preservation being no destruction) used until recently is now seen to be misguided. This philosophy has been rendered outdated by the rapid progression of deterioration (Arnold, Fleshman, Peterson, Stewart, Watts and Weldon, 1992: 47-56).

The process of routine pre-disturbance analysis by corrosion specialists was begun at *Xantho* in 1983 at the archaeologist's request

(MacLeod, 1987:50). The following statement, attesting to the value of the strategy, was made by the conservators after that survey was complete

> By having the opportunity to carry out this work before the shipwreck was disturbed we were not only able to provide information on the condition of artefacts before they are excavated but we will also be able to document exactly the effects of partial cleaning of marine growth and cathodic protection on an iron shipwreck. Neither of these has been previously studied and indeed, cathodic protection has never previously been applied to an historic shipwreck. In scientific terms the data obtained to date are highly significant (Beagle, MacLeod and North, 1983:11).

The *Xantho* study has shown that the presence of corrosion specialists, biologists and conservators on an underwater site, *ab initio* and throughout a particular project, is fundamental if an informed opinion on the state of a site is required. It was said of *Xantho,* for example, that

> The *Xantho* project has lead to a new understanding of the interaction of iron shipwrecks with their micro-environment...(MacLeod, 1992 :49).

While the use of on-site conservators in maritime archaeology is not new,[1] the involvement of conservation specialists in *ab initio* underwater analyses is a progression from these earlier developments. The practice has become more prevalent in recent years on iron and steamship wrecks, at wooden-hulled sites and lately at port-related structures such as jetties (e.g. Carpenter and Richards, 1994; Garratt, McCarthy, Richards and Wolfe, 1995; Gould, 1991; Guthrie, *et. al.*, 1994; Kenderdine and Jeffery, 1992; Lenihan *et. al.*, 1989; MacLeod, 1992; McCarthy, 1993; and Murphy, 1987).

---

[1]Archaeologists such as Bass, Hamilton, Piercy, the Smithsonian, Rule, Green, Henderson *et. al.* have all used on-site conservators in varying degrees for decades.

In utilising the services of these specialists, the *Xantho* project has demonstrated that predictions about the corrosion rates on shipwrecks are an unreliable management tool. On the other hand, the principle of applying anodic protection devices, or impressed current, has been shown to have considerable merit. First applied to the *Xantho* engine in 1983 and initially a failure due to burial in sediments, the anodes were re-applied to the engine in 1984 and to the stern in 1985. They have been continually monitored over the ensuing decade, proving a success in slowing corrosion rates and in beginning the *in-situ* conservation of the stern, should it be raised in the future. The process has since been repeated elsewhere on anchors and cannon and lately at the hulk of the iron barque *Santiago* (Kentish, 1995). Most recently, a dive charter operator and member of the MAAC applied anodes to the deliberately-scuttled wreck of the barge *WH Gemini,* in order to prolong its life on the sea-bed and thereby increase revenue from dive tourism (J. Clarke, pers. com.).

By involving metallurgist Maria Pitrun in the analysis of the material raised from the *Xantho* wreck, archaeologists have begun to address the question first posed by Murphy (1983:75) whether it is possible to show that pre-depositional corrosion or stress had led to the loss of a particular ship. Other studies, specifically on the metallurgy of the *Xantho* engine, have also been published (e.g. MacLeod and Pitrun, 1986; MacLeod, 1992: 48-49).

On these bases, it been argued that, from a purely archaeological perspective alone, the traditionally-accepted dichotomy between maritime archaeology and conservation is an out-moded position. Formal research links between the two must be increasingly facilitated so that iron and steamship wrecks (and wrecks generally) will come to be properly understood and better managed. This is even more important as we have come to appreciate the vast amounts of archaeologically-relevant information that even rust stains contain. Indeed, as Turgoose notes with respect to corrosion products and the information they contain about site formation processes

> [With respect to]... the types of evidence that may be preserved in corrosion products... it could be said that removal of corrosion products, when necessary, should be carried out with an awareness that potential information about the artifact and its burial environment are being lost (1989:30-31).

Archaeologists must now involve specialists directly in underwater work, in order to properly understand one of the major natural transformation processes that occurs on all metal wrecks, the corrosion of iron. In following this theme through, there is a reciprocal need for these specialists to be aware of the history of technological evolution, or at least to avail themselves of specialists who do. Considerable importance, for example, needs to be attached to the methods by which metals were forged, welded and otherwise produced. Thus, a conservator or corrosion specialist dealing with archaeological material must be exposed to some materials history as well as material cultural science. Tylecote's 'Metallurgy in Archaeology' (1962) and 'A History of Metallurgy' (1977: 269-287), provide invaluable data with which corrosion scientists of today can develop an understanding of ancient metalworking practices fundamental to the conservation of archaeological materials.

In summary, by combining archaeologists and conservators on the sea-bed from its beginnings in 1983 and by treating the two as a single team for archaeological (as well as conservation) purposes in all subsequent stages, the *Xantho* project has provided a new direction in the study of iron wrecks. It has been claimed that

> The wreck site of the iron steam-ship *Xantho* has provided a model for how an underwater archaeological site can be managed. Pre-disturbance surveys of the marine biology and electrochemical and physical environment of the site established reference criteria for monitoring changes in the site conditions (MacLeod, North and Beegle, 1986:113).

Not only must conservators become part of the underwater archaeological process, but the *Xantho* deconcreting program has shown that the archaeologist must also be prepared to become a part of the in-laboratory conservation process. This is especially true where shipwreck concretions are of considerable size and contain a wide variety of artefacts. The deconcretion of the *Xantho* engine has shown clearly that the 'excavation continues in the laboratory' and that to perceive maritime archaeology and conservation science as completely dichotomous is an outmoded position (cf. McCarthy, 1986a:21-25; McCarthy 1989a: 21-29; McCarthy, 1989b: 9-13).

Finally, with respect to description and analysis, the *Xantho* wreck has allowed us to focus on the development of general models for iron and steam shipwreck disintegration in the wake of Muckelroy and Riley and to examine these against the case of the *Xantho*. In establishing these commonalities in iron ship disintegration, we have been able to identify anomalous features such as the configuration of the boiler and the presence of paddle-sponson bearers on a screw steamer. Evidence of important post-depositional effects, such as the periodic covering and uncovering of the site, were also found at *Xantho*. This had ramifications for the survival of the engine and its fittings, for the retention of the boiler *in situ* and appears to have led, at least in part, to the breaking of the wreck into four parts on a mobile bed of sand.

By controlling for such post-depositional effects, we are able to comment in a more informed manner on both the abandonment processes and such fundamental questions as whether the loss of the vessel was deliberate or accidental. Eventually we may also be able to make comment on the effect of corrosion in that process.

Analysis and explanation

I now wish to proceed beyond the descriptive mode of empirical generalisation and address some of the anthropological issues raised by this thesis. The complementary nature of particularist and generalist examinations are well described by Lenihan (1983:43), who notes

> The questions the marine historians and marine architects ask of shipwrecks are different from, but every bit as valid as, those an anthropologist would ask.

Though acknowledging the importance of both approaches, Patty Jo Watson summarised the underlying tension between historical particularism and anthropologically-based approaches to maritime archaeology when she noted that

> ...the logical response to the debate between generalists and particularists is always the same : both are essential and both are present in everyone's work, although individual scholars usually stress one more heavily than the other (1983:310).

In answer to the question of whether an iron or steamship wreck is capable of providing an understanding of the social context and behaviour of its owners and operators, it is now also clear that the answer can be in the affirmative. The potential relevance of iron and steamship studies to anthropology has, I believe, been established in the *Xantho* project, where I have attempted to define physical parameters before analysing the behaviour of Broadhurst.

The anomalous material remains found at the wreck and in the deconcretion laboratory can be seen to be the product of the activities of a 'frontier gentleman' accustomed to privilege and command; someone with access to finance, with ideas on which to build, but without the necessary experience to succeed. The ideational gulf between Broadhurst and his contemporaries, such as the very successful colonial entrepreneurs Walter Padbury, an orphan child (Nairn, 1984) and Charles Harper (Mercer, 1958), a local boy who grew up with Aborigines, is stark. Broadhurst was markedly different in both his approach and methods.

From a processual perspective, the *Xantho* can be seen as a component of entrepreneurial expansion on a major frontier underwritten, though sometimes impeded, by bureaucracy and the legislature. The vessel spearheaded an ambitiously broad range of economic enterprises, including pearling, whaling, fishing and the carriage of passengers and general cargo, over a vast geographical area ranging from Fremantle on the south-western Australian coast to Batavia (Jakarta) in Indonesia. Such diverse endeavours required a non-specialised craft capable of optimising returns on any potential commodity. Given the frontier setting, the craft would have had to be simple, robust, of low maintenance with available spare parts and be capable of operation, repair and refit with a paucity of resources. That is, its use-life might potentially be long and it would need a minimum of infrastructure. One hypothesis, then, could be that such optimising strategies are a feature of entrepreneurial, maritime groups in the initial colonisation of coastal frontiers.

In failing to realise the temporal limitations of the ageing hull and the already 10-year-old experimental engine, Broadhurst may have been illustrating the commonly-acknowledged failings of those born into 'landed' privilege and power; with a surfeit of ideas, but without the practical skills required to bring them to fruition. Further, his training was in the pastoral and farming industries, a background that would hardly lent itself to success in pearling and steamship operation.

A cognitive processual critique might view the numerous anomalies identified at the wreck of the *Xantho* as symbolic of, or representing, the unconventional and idiosyncratic approach of Charles Broadhurst, the unpredictable individual. A post-processualist might seize upon Broadhurst's curious behaviour with the *Xantho* as a real example, supported by the historical record, of the impossibility of applying or trying to apply general rules or semi-quantitative analyses to the human situation, especially where enough funds exist to fuel capricious whims.

Despite this, Broadhurst's behaviour may be seen as consistent with philosophies about the place of the Victorian-era individual within the 'landed' class and within mercantile capitalism, generally. Broadhurst was singularly obsessed by a search for wealth, security and position, and was especially so after his failure with the Denison Plains Pastoral Company.

To illustrate this point we may look at the technology found at the *Xantho*. There, a curious marriage was found of a hull designed for inland waters with a mass-produced, non-condensing, sea-water fed, high compression, high revolution, energy-expensive, steam engine running in reverse (due to an incorrect propeller). The engine was showing evidence of very shoddy maintenance in the form of the pump valves and the little-end gudgeon. This makes sense if we see the purchase of the vessel as the product of poor advice and possibly Broadhurst's own naivete and eccentricity. As the archival sources show, when he had good advice and good managers, he succeeded; when he did not he failed (McCarthy, 1990).

He also attempted to apply otherwise useful technology out of its context. Though his brother-in-law, the noted engineer, Sir Joseph

Whitworth may have advised that the gunboat engine was an excellent one and that it could provide a useful source of auxiliary steam, he could not have envisaged that Broadhurst or his engineer would operate it in reverse, or maintain it as badly as they did.

On the other hand, Broadhurst was an undoubted visionary, continuously attempting to apply new ideas and technology in frontier environments, with an undeniable capacity to interest others and to raise some of the funds necessary to pursue his dreams. With the *Xantho* his object in acquiring a multi-purpose carrier capable of operating in the face of all kinds of material shortages, with a very simple engine, having interchangeable parts, capable of operating without fresh-water and away from engineering facilities, can be seen as a result of an identifiable process. The idea of using a steamer in the north-west is traceable to his earlier involvement in the Camden Harbour Pastoral Association and the Denison Plains Pastoral Company. Both of these endeavours flagged the benefits of an independently-operated small steamer that would link the far north-west coast of Australia with the outside world and thereby provide a new gateway to this continent.

Broadhurst's role as an innovator may be examined at this point. For example, anthropologist Daniel Lenihan, proposed that

> The phenomenon of inventions having to "wait their time" is another aspect of technological innovation which might be the subject of an interesting study by anthropologists. Certainly shipwrecks over time offer an excellent data base for getting at this question (Lenihan, 1983: 56).

This concept is relevant both to an examination of Charles Broadhurst's personal propensity for innovative methods and new ideas and to the technology evident at the wreck of the *Xantho*. Broadhurst consistently applied technology well ahead of its time (e.g. the application of diving apparatus and the use of steam power in the pearling industry).

Broadhurst, the Victorian-era gentleman born into wealth and command, had vision but clearly lacked the practical focus and common-sense necessary to translate ideas into a viable enterprise. He clearly exhibited the same 'misplaced confidence in engineering' discussed by Gould as common amongst men of the 'Victorian-era' (Gould, 1990: 55).

One major failing, in the context of his visionary zeal, can be attributed to his failure to pay attention to the minutiae required for successful steamship operation in such a remote setting. These details might include the inappropriateness of the scantlings and operating parameters of the vessel, the availability of repair facilities and coal supplies and, ironically, the maintenance of his insurance cover.

Larry Murphy's 'one-more-voyage' hypothesis is also of relevance in this instance (Murphy, 1983:75). Broadhurst could not have been unaware that his ship was ailing. The engine would have been vibrating badly, the hull was disintegrating before his eyes; yet he carried on, even to the point of knowingly overloading the ship on its last voyage. He either saw that its loss was inevitable, and was going to squeeze out the last ounce of use from it before it sank (risking crew, cargo and himself), or he had a misplaced confidence in engineering in abundance. What clouds Murphy's analysis of shipowner behaviour in this instance is, not the loss of the ship and its cargo, but the failure to re-insure it, as he had intended. Arguably one basis for the 'one-more-voyage' syndrome is the availability of insurance, in that the taking of risk can be directly related to access to insurance in its various forms.[1]

---

[1]In contrast, Gould indicates that this phenomenon is also one of the manifestations of the Murphy's 'one more voyage' syndrome and that '[o]perating uninsured vessels was just another form of high-risk behavior' on the part of unscrupulous shipowners. Research currently being conducted at Fort Jefferson in the Dry Tortugas (Gould, 1995) indicates that shipowners generally operated vessels to that port even after they had been condemned and the insurance cover withdrawn (Gould, pers. com.).

Broadhurst also exhibited what Gould (1990:54) has identified in other circumstances, as 'social and cultural factors' which help account for particular 'high risk behaviour'. As a result of his personality and background and his fall from grace and social position, following the dramatic failure of his foray into the Denison Plains Pastoral Company, Broadhurst's personal failings were dramatically bared. As a result, they did not remain cloaked in a veneer of Victorian respectability. His precipitate and well-publicised social demise may be seen as the major driving force behind his subsequent high risk behaviour. This manifested itself in his acknowledged propensity to 'go out of the ordinary grooves in search of wealth' (Kimberly, 1897: 97), to travel vast distances, to risk himself and his family, and most pertinently, to experiment with untried technology and ideas in a frontier environment. One could also argue that this represents a pattern where a wealthy and socially well-placed individual is driven to perform extraordinary feats in order to resurrect a destroyed career or social position. Broadhurst performed phoenix-like resurrections too often for them to be a coincidence. The only alternative for him was an unaccustomed and much despised mediocrity, embodied in the government position sought when at his lowest ebb.

In searching for behavioural generalisations from a broad-based study of iron and steamship wrecks, as generated by the SS *Xantho,* I make the following propositions which could be tested through further analyses using a broader sample (cf. McCarthy and Veth, in prep.).

1. Vessels used by individual entrepreneurs in frontier contexts were non-specialised, simple and robust.[1]

2. In frontier settings engines and general mechanical fittings were selected for low maintenance and ease of interchangeability of parts, rather than for efficiency.

[1] In this instance *Xantho* was not robust, partly due to the effects of corrosion and an unsuitable design.

3. The 'robustness' of such vessels is a reflection of deliberate redundancy, in that numerous aspects of the *Xantho's* engine (as one example) were aimed towards replication and interchangeability. The vessel (and therefore the system) is less likely to fail should a single component fail.

4. Craft owned by individual entrepreneurs, as opposed to corporations, had higher rates of failure.

5. Frontier craft were designed in such a way that they could be used for a wide range of carrying functions and specifically for a variety of functions that might not be envisaged at the time of initial use of the craft. For example the layout of the interior of the hull *Xantho* allowed for radical re-design of the internal configuration of cargo space. As has been noted, the location of the compact, high-pressure engine on the *Xantho* allowed for maximum use of cargo space.

6 When vessels are owned by individual entrepreneurs there may be a greater potential for innovation and, therefore, discard of inefficient features following failure. The opposite case would be the continuing presence of obsolete features such as ramming devices on ironclads well after they were demonstrated to be ineffectual, because corporate groups (such as the Admiralty) were locked into what has been described elsewhere as 'trend innovation' (cf. Gould, 1990: 170 *et seq.*).

As an example, we can examine similarities to the *Xantho* instance in the wreck of the iron-hulled SS *Sunbeam* (1861-1892), illustrated in Figure 59. The wreck lies in shallow, protected waters off the Osborne Islands in the Admiralty Gulf on the north Kimberley coast of Western Australia.

Sunbeam was built of iron in 1861 on the Thames and was a 92.1-foot long (28m), 72-ton, clincher-built, one-deck, three-masted schooner. Its engine was originally a vertical single-cylinder annular engine built by John Penn's chief competitor, Maudslay, Son and Field (*Register*, 34/1878). After twenty-five years on the coast of Britain under numerous owners, the vessel was re-engined with a two-cylinder 18 HP compound engine and the ship was placed on the market. The newly-refitted

Sunbeam was purchased by the well-known pearler and entrepreneur Edwin Streeter for use in the Australian pearling industry (Streeter, 1886; Stanbury, 1995).

Like *Xantho* it had only one successful season, in this case 1891. When lost in March 1892, it was operating with a crew of four Europeans and 35 'Asiatics' (as they were called), utilising four boats with diving apparatus. While at anchor near Osborne Islands a leak was discovered and the vessel was run ashore to be patched up. It was refloated after the repairs were effected, but twelve hours later the first mate reported that it was again making water. The master, on going down into the engine room, found a 14 centimetre gash in the hull caused by corrosion. The torrent was quickly plugged and they tried to run the vessel back ashore, but they struck a sand-bank *en-route* and the ship became firmly embedded in it. The *Sunbeam* slowly settled down to the sea-bed, coming to rest in the sediments at or around its water-line (Sledge, 1976). There it remains today, looking (but not necessarily being) completely intact.[1]

Being in such a remote frontier situation the crew were forced to make the journey to Broome in a small boat.

In 1984 the following was noted of *Sunbeam*

> The *Sunbeam* added an important element to the [pearling] industry-steam power...If the *Sunbeam* had not been wrecked, it might well have set the pace and led to earlier mechanisation of the industry-at least for the mother-ships operating in the most remote high tide areas (Henderson and Sledge, 1984: 28-32).

We now know that these words actually apply to startlingly similar events which took place two decades earlier centring on *Xantho* and Broadhurst. They also indirectly illustrate a commonality of behaviour

[1]Corrosion potential measurements have yet to be taken.
It is interesting to note that the wreck has also become part of Aboriginal legend, in that the local people believe that the wreck was sunk by a Spirit in retribution for the sailors keeping Aboriginal women on-board for longer than the agreed period (Crawford, pers. com.).

on the part of two wealthy frontier steamship owners and two acknowledged pioneers in the pearling industry.

What is interesting in these remarkably similar events is that both men were noted entrepreneurs and that both had training and experience elsewhere; Streeter as a jeweller, Broadhurst as a pastoralist. Both were 'Victorian-era' gentlemen, with access to finance, and both had some prior involvement in the pearling industry.

Finally, with reference to attempts to identify trends on a regional level, it should be noted that what is found at sea, must eventually be linked to what is found on land. Towards that end, I facilitated the beginnings of a survey of Broadhurst's Abrolhos Islands guano sites (Stanbury, 1993). I am also assisting in the historical archaeological study of pearling bases at Shark Bay with emphasis on *Wilyah Miah*, the place Broadhurst was once based, (McGann, in prep). A preliminary examination of Miaree Pool, where Charles and Eliza Broadhurst were once based during their pastoral phase, has been made (McCarthy, 1990: 99-118; and in prep). Broadhurst's pearling base at Banningarra, east of Nickol Bay, was recently examined as part of a study into port-related structures in Western Australia (Cumming, Garratt, McCarthy and Wolfe, 1995). The study of Broadhurst's fish canning industry at Mandurah is also mooted here (McCarthy, 1990:295-7). By these means the physical remains of one person's entrepreneurial endeavour can be examined in order to conduct a pattern recognition study. The evidence from remains, both on land and at sea, can be combined to cover a considerable period of time and to reflect different circumstances, so that valid generalisations can be made.

Finally, in treating the iron-hulled steamship wreck as a new element in maritime archaeology, I join conservators, corrosion scientists and biologists as one in the archaeological team. In the deconcretion of materials raised from the excavation, especially the engine, I maintain this unity of purpose and new light has been cast on *Xantho* and its owner, Charles Edward Broadhurst. Modern maritime archaeology must acknowledge the complexity of both the materials on the shipwreck and the behaviour of those who owned and operated them. It must provide for, and facilitate, the involvement of specialists throughout all phases from inspection and evaluation, through to excavation, analysis and finally explanation. It is clear that a maximisation strategy is essential and that the active endorsement of the anthropological approach is one part of that strategy.

BIBLIOGRAPHY

Books and Articles

Adams, R.M., *et. al.*, 1980, *Survey of the steamboat Black Cloud.* Department of Anthropology and Nautical Archaeology, Texas A&M.

Albright, A.B., 1987, (ed.) *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference, Tucson.* Society for Historical Archaeology, Tucson, Arizona.

Archibald, E.H.H., 1968, *The wooden fighting ship in the Royal Navy, AD 897-1860.* Blandford Press, London.

Arnold, J. B., 1978, (ed.) *Beneath the waters of time: The Proceedings of the Ninth Conference on Underwater Archaeology.* Texas Antiquities Commission, Publication No 6, Austin Texas.

Arnold, J. B., 1989, (ed.) *Underwater Achaeology Proceedings from the Society for Historical Archaeology Conference, Baltimore Maryland.* The Society for Historical Archaeology: 111-119.

Arnold, J. B., Fleshman, G. M., Peterson, C.E., Stewart, K.W., Watts, G.P., & Weldon, C.P., 1992, USS *Monitor*: Results from the 1987 Season. In Barto Arnold, J., (ed.), Advances in underwater archaeology. In *Historical Archaeology: Journal of the Society for Historical Archaeology,* **26** (4), University of Pennsylvania, Pensylvania, 1992 : 47-56.

Arrhenius, O., Barkman, L., & Sjostrand, E., 1973, *Conservation of old rusty iron objects: reduction of rust with hydrogen gas.* Korrosionsinstitutet, Stockholm.

Bahn, P., nd, *The bluffer's guide to archaeology.* Ravette Books, Horsham.

Bain, M. A., 1982, *Full fathom five.* Artlook, Perth.

Baker, Bolster, Leach and Singleterry, 1969, Examination of the corrosion and salt contamination of structural metal from the USS *Tecumseh. Naval Research Laboratory. Memorandum Report.* Washington, D.C.

Banbury, P., 1971, *The shipbuilders of the Thames and Medway.* David and Charles, Newton Abbott.

Barkman, L., Preservation of large iron objects. Treatment of waterlogged finds, & conservation of finds. In Green, J.N., (ed.), 1977, Papers from the *First Southern Hemisphere Conference on Maritime Archaeology.* Ocean's Society, Melbourne: 119-128.

Barnaby, N., 1904, *Naval development of the century.* Chambers, London.

Bass G. F., 1966, *Archaeology underwater.*Thames and Hudson, London.

Bass, G. F., (Ed), 1972, *A History of seafaring based on underwater archaeology.* Thames and Hudson, London.

Bass, G. F., 1967, with the collaboration of Throckmorton, P., Du Plat Taylor, J., et. al., 1967 Cape Gelidonya: A Bronze Age Shipwreck. In *Trasnsactions of the American Philosophical Society,* **57**.(8), The American Philosophical Society, Philadelphia.

Bass, G. F., 1981, Is money the root of all evil? Keynote Address. In Watts, G. P., (ed.), *Underwater archaeology: The challenge before us. The Proceedings of the Twelth Conference on Underwater Archaeology,* Fathom Eight, California.

Bass, G. F., 1983, A plea for historical particularism in nautical archaeology. In Gould, R. A., (ed.), 1983, *Shipwreck Anthropology.* University of New Mexico Press, Albuquerque: 91-104.

Bass, G., (ed), 1988, *Ships and shipwrecks of the Americas : A history based on underwater archaeology.* Thames and Hudson, London.

Bearss, E.G., Underwater archaeology at the *Cairo*. In Holmquist, J.D., & Wheeler, A.H., 1963, (eds.), *Diving into the past. Theories, techniques and applications of underwater archaeology.* Minnesota Historical Society and the Council of Underwater Archaeology, Minnesota: 12-18.

Beegle, C.J., Macleod., I. D., & North, N. A., 1983, *Preliminary survey of Xantho and installation of cathodic protection system.* Report, Department of Materials Conservation and Restoration, WA Maritime Museum.

Bickersteth, J., (ed.), 1989, *The Bulletin of the Australian Institute for the Conservation of Cultural Material.* AICCM, Canberra, 1989.

Binford, L.R., 1972, *An archaeological perspective,* Seminar Press, New York.

Binford, L. R., 1989, *Debating archaeology.* Academic Press, New York.

Bintliff, J., 1992, Comments on Thomas, J., & Tilley, C., 'TAG and 'post modernism' : a reply to John Bintliff'. In *Antiquity 66:* 110-114.

Blawatsky, V.D., 1972, Submerged sectors of towns on the Black Sea Coast. In UNESCO, 1972, *Underwater archaeology: A nascent discipline.* UNESCO, Paris: 115-121.

Bowdler, 1990, *In search of the Zuytdorp survivors: Report on an archaeological reconnaissance of a site in the Shark Bay area,* 1990. Unpublished report, UWA, *Zuytdorp* File 460/71, Department of Maritime Archaeology, WA Maritime Museum.

Bourne, C.E., (ed), 1858, *A Treatise on the steam engine in its application to mines, mills, steam navigation, and railways. By the Artizan Club.* Longman, London.

Bramwell, M., & Palmer, J., (eds), 1979, *The international book of wood,* Mitchell Beazley, London.

Bright, L.S., 1985, Wrecked Blockade Runners of the Lower Cape Fear: Site environment and physical condition. In Johnston, P.F., (ed.), 1985, *Proceedings of the Sixteenth Conference on Underwater Archaeology.* Special Publication Series, No 4., The Society for Historical Archaeology, Tucson, Arizona.

Brockman, J., (ed.), 1987, *He Rode Alone, being the adventures of John Brockman from his diaries.* Artlook, Perth.

Broeze, F. J. A., 1982, Western Australia until 1869 : the maritime perspective. *Early Days : Journal of the Royal Western Australian Historical Society*, Vol VIII, parts 5 & 6, RWAHS, Perth.

Brouwer, 1985, *International Register of Historic Ships.* Anthony Nelson, Shropshire.

Bulbeck, D., 1969, The P&O Company's establishment at King George's Sound 1850-1880. *The Journal of the Royal Western Australian Historical Society,* Vol VIII, RWAHS, Perth: 103-130.

Burgess, R., & McCarthy, M., 1994, SS *Xantho,* The engine model. *Model Engineer*, **172**, (3970), Argus Specialist Publications, Hemel Hempstead: 676-79.

Burgh, N.P., 1869, *Modern marine engineering illustrated.* E. & F.N Spon, London.

Burgh, N.P., 1873, *A practical treatise on boilers and boiler-making.* E. & F.N Spon, London.

Callegari, D., 1994, *Cook's cannon and anchors: The recovery and conservation of relics from HMB Endeavour.* Kangaroo Press, Kenthurst.

Campbell, J., 1977, Historic wrecks at the Chatham Islands. *Working Papers in Chatham Islands Archaeology,* Anthropology Department, University of Otago, Dunedin, N.Z.

Carpenter, J., 1987, The uses of soil stabilizing gel media in the conservation of large and small shipwreck artifacts. *The International Journal of Nautical Archaeology,16 (2),* The Nautical Archaeology Society, Academic Press, London: 95-107.

Carpenter, J., 1990, A review of physical methods used to remove concretions from artefacts, mainly iron, including some recent ideas. *Bulletin of the Australian Institute for Maritime Archaeology, 14(1): 25-42.*

Carpenter, J., and Richards, V., 1994, *Conservation in Galle.* Report, Department of Conservation, WA Maritime Museum, Fremantle.

Carrell, T.L., 1990, (ed.), *Underwater Archaeology Proceedings from The Society For Historical Archaeology Conference, Tucson.* The Society for Historical Archaeology, Tucson, Arizona.

Cederlund, C.O., 1987, The *Eric Nordewall.* An early Swedish paddle steamer. *The International Journal of Nautical Archaeology and Underwater Exploration, 16(2),* The Nautical Archaeology Society, Academic Press, London : 109-133.

Champion, S.,1980, *A dictionary of terms and techniques in archaeology.* Phaidon Press, Oxford.

Claasen, C., Answering our questions with experiments. In Gould, R.A., (ed.), 1983, *Shipwreck Anthropology.* University of New Mexico Press, Albuquerque: 189-206.

Clarke, D. L., 1968, *Analytical archaeology.* Methuen, London.

Clement, C., 1991, *Australia's North-West: A study of exploration, land policy and land acquisition, 1644-1884.* Unpublished, Ph.d. Thesis, Murdoch University.

Cockrell, W.A., Flemming, N. C., Morrisson, I. A., 1980, Structures underwater. In Muckleroy, K., (ed.),1980, *Archaeology under water. An atlas of the world's submerged sites.* McGraw-Hill, New York: 132-177.

Cockrell, W.A., 1983, A Trial Model for the Analysis of Shipwrecks, Gould, R.A., (ed), 1983, *Shipwreck Anthropology,* University of New Mexico Press, Albuquerque: 207-218.

Colledge, J.J., 1969, *Ships of the Royal Navy : An historical index.* David & Charles, Newton Abbott.

Commissioner of Patents, 1862, *Patents for inventions.* Eyre and Spottswoode, London.

Corlett, E.C.B., 1970, *The iron ship, the history and significance of Brunel's Great Britain.* Moonraker Press, London.

Corlett, E.C.B., 1981, Iron, steel and steam: review paper. In Howse, D., 1981, (ed.) *Five hundred years of nautical science 1400-1900.* National Maritime Museum, Greenwich, London: 278-291.

Corlett, E.C.B., 1993, The screw propeller and merchant shipping: 1840-1865. In Gardiner, R., & Greenhill, B (eds.), 1993, *The advent of steam: The merchant steamship before 1900.* Conway Maritime Press, London: 83-105.

Courbin, P., 1988, *What is archaeology: An essay on the nature of archaeological research.* University of Chicago Press, Chicago.

Cumming, D.A., 1988, *Some aspects of shipbuilding and navigation on the River Murray.* South Australian Division of the Institution of Engineers, Australia, Goolwa.

Cumming, D., Garratt, D., McCarthy, M and Wolfe, A., 1995, *Port related structures on the coast of Western Australia.* Report, Department of Maritime Archaeology, WA Maritime Museum, Fremantle, No. 100.

Cummings, C. R., (ed.), 1980, *Underwater archaeology, The Proceedings of the Eleventh Conference on Underwater Achaeology,* Fathom Eight, Special Publication. #4, San Marino, California.

Cummings. C. R., (ed.), 1983, *Underwater archaeology, The Proceedings of the Fourteenth Conference on Underwater Archaeology, Denver,* Fathom Eight, Special Publication, San Marino, California.

Cummins, G & Dickinson, B., 1989, The management experience.In Lenihan, D. J., (ed.), 1989, *Submerged cultural resources study: USS Arizona Memorial and Pearl Harbor national historic landmark.* Southwest Cultural Resources Center Professional Papers, No. 23. Santa Fe, New Mexico: 157-168

Davis, R.H., 1955, *Deep diving and submarine operations. A manual for deep sea divers and compressed air workers.* Siebe Gorman and Co., London.

De Kerchove, R., 1948, *International maritime dictionary.* Second Edition, 1961,Van Nostrand, New Jersey, de Borhegyi, S.F., 1963, Tribute to J. M., Goggin. In Holmquist, J.D., & Wheeler, A.H., (eds.), *Diving into the past. Theories, techniques and applications of underwater archaeology,* Minnesota Historical Society and the Council of Underwater Archaeology, Minnesota.

Deetz, J., 1988, American historical archaeology: methods and results. In *Science, (Articles),* **239**: 362-367

Delgado, J.P., 1983, Underwater archaeological investigations of gold rush era steamships on the Californian coastline. In Cummings, C.R., (ed.), 1983, *Underwater archaeology, The Proceedings of the Fourteenth Conference on Underwater Archaeology, Denver.* Fathom Eight, Special Publication San Marino, California.

Delgado, J. P., 1986, Tasting champagne: Reassessing the California gold rush through maritime archaeology. In Foster, J.W., & Smith, S.O., 1988, (eds.) *Archaeology in solution, The 1986 Proceedings of the Seventeenth Annual Conference on Underwater Archaeology, Sacramento California.* Coyote Press, Salinas, California: 104-107.

Delgado, J.P., (ed.), 1988, *Underwater Archaeology Proceedings from the Society For Historical Archaeology Conference, Reno, Nevada.* The Society for Historical Archaeology, Tucson, Arizona.

Delgado, J.P., 1992, Recovering the past of USS *Arizona*: Symbolism, myth and reality. In Barto Arnold, J., 1992, (ed.), Advances in underwater archaeology, *Historical Archaeology: Journal of the Society for Historical Archaeology,* Vol 26: 4, University of Pennsylvania, Pensylvania: 69-80.

Denny and Brothers, Ltd, 1932, *Denny Dumbarton, 1844-1932.* 2nd ed., Burrow and Co., Printers, Cheltenham.

Dickson, Gregory, 1928, *Australian steamships past and present.* The Richards Press, London.

Dickson, R., 1993, *Steam whistles on the Swan.* Report, Department of Maritime Archaeology, WA Maritime Museum, No. 70.

Dingle, T., 1984, *The Victorians and settling.* Fairfax, Melbourne.

Dixon, N., 1991, The history of Crannog survey and excavation in Scotland. *The International Journal of Nautical Archaeology,* **20** (1) The Nautical Archaeology Society, Academic Press, London: 1-8.

Doerffer, J. W., 1979, Impact of the application of iron and steel as a structural material upon the development of science and technology in shipbuilding in the XIX century. In Howse, D., 1981, (ed.) *Five hundred years of nautical science 1400-1900.* National Maritime Museum, Greenwich, London: 322-345.

Dortch, C.E., & Godfrey, I.M., 1990, Aboriginal sites in a submerged landscape at Lake Jasper, Southwestern Australia. *Australian Archaeology,* No 31, 1990: 28-33.

Drake-Brockman, H., 1969, Broadhurst, Charles, Edward. (1826-1905). In Pike, D., (ed.), *Australian dictionary of biography, Vol. 3, A-C, 1851-1890.* Melbourne University Press, 1969: 233-234.

du Plat Taylor, J., 1965, (ed.) *Marine archaeology: developments during sixty years in the Mediterranean.* Hutchinson, London.

du Plat-Taylor, J., 1975, Editorial, *The International Journal of Nautical Archaeology,4(2).* The Nautical Archaeology Society, Academic Press, London.

Dudley, W.S., 1990, American naval archaeology: past and prologue. In Carrell, T.L., 1990, (ed.), *Underwater archaeology proceedings from the Society For Historical Archaeology Conference, Tucson, Arizona.* The Society for Historical Archaeology, Tucson, Arizona: 88-90.

Dumas, F., 1972, Ancient wrecks. In UNESCO, *Underwater archaeology, a nascent discipline.* UNESCO, Paris.

Edington, R.S., Friend., J.H., Pineau, R., *et al.*, 1978, Some past and present shipwreck recovery projects. In *The Monitor, its meaning and future, papers from a national conference.* National Trust for Historic Preservation in the United States, The Preservation Press, North Carolina : 47-61.

Edington, R.S., 1978, The USS *Tecumseh.* In *The Monitor: Its Meaning and Future,* The National Trust for Historic Preservation in the United States, The Preservation Press, Washington, D.C.

Effenberger, S., 1987, Where land meets sea: The merging Australian archaeologies. *Bulletin of the Australian Institute for Maritime Archaeology*, **11**(1):11-13.

Enault, P., 1988, *Alabama-Kearsage:* Duel devant Cherbourg. In *Le Chasse Mareé, 3:* 44-57.

Envig., O. T., 1984, Offwatch: Sole surviving steam/sail ship being restored. *Marine Propulsion International,* February 1984: 36-38.

Envig., O. T., 1993, *Skonnertrigget dampskip "Hansteen" under seil og damp på ny.* Den Norske stats første forstningsfartøy, Hansen, Oslo.

Erickson, R., 1978, *The Dempsters.* UWA Press, Nedlands.

Evans, U. R., 1973, *An introduction to metallic corrosion.* Edward Arnold, London.

Farb, R. M., 1992, Computer video image digitilization on the USS *Monitor,* a research tool for underwater archaeology in, Keith, D.H., & Carrell, T.L., 1992, 1492-1992, *500 years of change, Underwater Archaeology Proceedings for the Society for Historical Archaeology*, Kingston Jamaica:

Fenwick, V., 1993, Editorial, *The International Journal of Nautical Archaeology,* **22.** (1), The Nautical Archaeology Society, Academic Press, London:

Fincham, J., 1851, *A History of Naval Architecture.* Scholar Press, London, 1979 Edition.

Flemming, N.C., Book Review. *The International Journal of Nautical Archaeology, 17(2),* The Nautical Archaeology Society, Academic Press, London: 198-200.

Florian, M.L.E., 1987, The underwater environment. In Pearson, C., 1987, (ed.) *Conservation of marine archaeological objects.* Butterworths, London: 1-20.

Foster, J.W., & Smith, S.O., 1988, (eds.), *Archaeology in solution: The Proceedings of the 17th Annual Conference on Underwater Archaeology, Sacramento California, 1986*. Salinas, California.

Frey, D. A., 1993, Treasures of the sponge divers. In *Sea History. The Art, literature, Adventure, Lore & Learning of the Sea.* **68**, Winter, National Maritime Historical Society : 68.

Friend, J.H., USS *Techumseh*: child of the *Monitor*. In, The National Trust for Historic Preservation in the United States, 1978, *The Monitor: Its Meaning and Future.* The National Trust for Historic Preservation in the United States, The Preservation Press, Washington, D.C.

Gardiner, R., & Greenhill, B (eds.), 1993, *The advent of steam: The merchant steamship before 1900.* Conway Maritime Press, London.

Garratt, D., McCarthy, M., Richards, V., and Wolfe, A., 1995, *The Albany Town Jetty excavation report.* Department of Maritime Archaeology, WA Maritime Museum, No 96.

Gesner, P., 1991, *Pandora: An archaeological perspective.* Queensland Museum, Brisbane.

Gibbs, M., 1994, *An archaeological, conservation and management study of 19th century shore-based whaling stations in Western Australia.* Report, National Trust for the Australian Heritage Commission.

Gibbins, D., 1992, Reviewing the Underwater Archaeology Proceedings from the 1990 Society for Historical Archaeology Conference. *The International Journal of Nautical Archaeology,* **21** (1), The Nautical Archaeology Society, Academic Press, London: 82-5.

Gilbert, K.R., & Galloway, D.F., 1978, Machine Tools, (1&2), in Singer, C., et al., 1978, (eds.), *A history of technology.* Oxford, Clarendon Press.

Gisecke, A.G., 1985, The best in State historic shipwreck programs. In Johnston, P.F., (Ed.), 1985, *Proceedings of the Sixteenth Conference on Underwater Archaeology , Boston.* The Society for Historical Archaeology, Special Publication Series, No 4, Tucson, Arizona: 138-141.

Gluckman, S.J., 1981, Some thoughts about research designs and underwater archaeology. In Watts, G.P., (ed.), 1981, *Underwater archaeology: The Challenge before us. The Proceedings of the Twelth Conference on Underwater Archaeology,* Fathom Eight, Special Publication, #2, San Marino, California: 232-4.

Goggin, M., 1964, *Underwater archaeology: Its nature and limitations.* University of Miami Press.

Gould, R. A., (ed.), 1983, *Shipwreck Anthropology.* University of New Mexico Press, Albuquerque.

Gould, R. A., 1983, Getting off the gold standard. In Cummings. C. R., (Ed.), 1983, *Underwater archaeology, The Proceedings of the Fourteenth Conference on Underwater Archaeology, Denver.* Fathom Eight, Special Publication #7 San Marino, California: 1-3.

Gould, R.A., 1990, *Recovering the past.* University of New Mexico Press, Albuquerque.

Gould, R.A., 1991, The archaeology of the HMS *Vixen,* an early ironclad ram in Bermuda. *The International Journal of Nautical Archaeology,* **20** (2), The Nautical Archaeology Society, Academic Press, London: 141-153.

Gould, R.A., 1995, The Bird Key Wreck: Dry Tortugas National Park, Florida. in *The Bulletin of the Australian Institute for Maritime Archaeology,* **19**(2), AIMA, Fremantle: 7-16.

Grantham, J., 1859, *Iron shipbuilding: with practical illustrations.* 2nd. ed., Lockwood & Co., London.

Green, J.N., (ed.), 1977a, *Papers from the First Southern Hemisphere Conference on Maritime Archaeology.* Ocean's Society, Melbourne.

Green, J.N., 1977b, The A.V.O.C. Jacht *Vergulde Draeck,* wrecked Western Australia, 1656. *British Archaeological Reports,* Supplementary Series **36,** Oxford.

Green, J.N., 1977c Australia's oldest wreck: The loss of the *Trial,* 1622. *British Archaeological Reports,* Supplementary Series **27**, Oxford.

Green, J.N., Henderson, G.J., and McCarthy, M, 1981, Maritime archaeology and legislation in Western Australia. *The International Journal of Nautical Archaeology,* **10**(2), The Nautical Archaeology Society, Academic Press, London: 145-160.

Green, J.N., 1989, The AVOC Retourschip *Batavia* wrecked Western Australia, 1629: An excavation report and catalogue of artefacts. *British Archaeological Reports,* Supplementary Series, No 489., Oxford.

Green, J.N., 1990, *Maritime archaeology. A technical handbook.* Academic Press, London.

Gregory, A.C., & F.T., *Journals of Australian explorations:1846-1858,1884.* Hesperian Press, Perth, 1981 Facsimile Edition.

Gregory, D., 1928, *Australian steamships past and present.* London, The Richards Press.

Gregory, F.G., 1984, *A report of the marine archaeological survey conducted by an Ottowa conservation group, SOS Conestoga during the summer of 1983.* Ontario Heritage Branch, Ministry of Citizenship and Culture.

Grey, G., 1843, *Journals of two expeditions of discovery in the North West of Western Australia, 1843.* 1983 Facsimile Edition, Hesperian Press, Victoria Park.

Griffiths, D., 1993, Marine engineering development in the Nineteenth Century. In Gardiner, R., & Greenhill, B (eds), 1993, *The advent of steam: The merchant steamship before 1900.* Conway Maritime Press, London: 160-178.

Guthrie, J., 1971, *A History of marine engineering.* Hutchison, London.

Guthrie, J.N., Blackall, L.L., Moriarty, D.J.W., and Gesner, P., 1994, *Wrecks and marine microbiology: a case study from the Pandora.* The Bulletin of the Australian Institute for Maritime Archaeology, **18**, 2 :19-24.

Guérot, M., 1988, The engagement between the CSS *Alabama* and the USS *Kearsage,* 19 May 1864,: The archaeological discovery, 1984-1988. *The Mariner's Mirror, 74(4):355-359.*

Hadley, R.F., Corrosion by micro-organism in aqueous and soil environments. In Uhlig, H.H., (ed.), 1948, *The Corrosion Handbook.* Ninth Edition, John Wiley & Sons, New York: 486-410.

Hall, C., 1975, The Unlucky Lygnern. *Port of Fremantle Quarterly*, Spring, FPA, Fremantle: 18-21.

Hall, L., Hill, L. J., Warne, I., *et al.*, 1979, *The Xantho, Western Australia's First Steamship: Report of the MAAWA Expedition, May 1979.* MAAWA, Fremantle.

Hamilton, J.C., 1914, *Pioneering days in Western Victoria. A narrative of early station life.* Exchange Press, Melbourne.

Hartley, C., 1982, Western Australia, *The decline of the Colonial merchant shipping industry, 1870-1890: A critical biography.* Unpublished Honours thesis, Murdoch University.

Harvey, P., 1985, *The earliest steamship wreck in Australia: Paddle Steamer Clonmel.* Victoria Archaeological Survey Unit, Melbourne.

Hashimoto, Mochitsura, (ND), *Sunk: the story of the Japanese submarine fleet, 1942-1945.* Cassell, London.

Hawley, D., 1989, *The raising of the shipwreck Arabia.* Arabia Steamboat Museum, Kansas City.

Henderson, G. J., 1977a, *From sail to steam: Shipping in W.A. 1870-1890.* Unpublished M.A. Thesis, UWA.

Henderson., G., 1977b, Developing a Colonial wrecks programme in Western Australia. In Green, J.N., 1977, (ed.), *Papers from the First Southern Hemisphere Conference on Maritime Archaeology*, Ocean's Society, Melbourne: 69-72.

Henderson, G.J., & Sledge, S.D., 1984, *Sunbeam*: Solving the mystery. *Western Way, 13,* October-December, Ansett, Perth.

Henderson, G, 1986, *Maritime archaeology in Australia.* UWA Press, Nedlands.

Henderson, G., 1988a, The archaeological value of iron vessels and steamships. In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988): 1-12.

Henderson, G. J., & K. J., 1988b, *Unfinished Voyages, 1850-1880, Vol. II.* UWA Press, Nedlands.

Henderson, J., 1993, *Phantoms of the Tryall.* St. George Books, Perth.

Henderson, S., 1989, Biofouling and corrosion study. In Lenihan, D. J., (ed.), 1989, *Submerged cultural resources study: USSArizona Memorial and Pearl Harbor national historic landmark.* Southwest Cultural Resources Center Professional Papers, No. 23. Santa Fe, New Mexico: 117-155.

Heppingstone, I.D. *Whaling at Port Gregory.* Unpublished manuscript, PR 7666, State Archives of Western Australia.

Hewitt, G., 1988a, *The SS Blackbird (1863-1878)- Wrecked at Port Albert Victoria.* In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988: 145-152.

Hewitt, G., 1988b, How a steam engine works: a simple account as delivered to the first iron and steamship seminar. In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988: 224-228.

Hillman, B., 1990, (Comp.), *The Hillman Diaries : 1877-1884.* Private Publication, Perth.

Hodder, I., 1991, Interpretive archaeology and its role. *American Antiquity,* **56**(1), Society for American Archaeology: 7-18.

Holly, D. C., 1996, Recovery of the crosshead engine of the Steamboat *Columbus. in The American Neptune: a quarterly journal of maritime history and arts.* **56**(1), Spring: 163-166.

Holmquist, J.D., & Wheeler, A.H., 1963, *Diving into the Past. Theories, Techniques and Applications of Underwater Archaeology.* Minnesota Historical Society and the Council of underwater Archaeology, Minnesota.

Howitt, W., 1855, *Land Labour and Gold.* 1972 facsimile edition, Sydney University Press, Sydney.

Howse, D., 1981, (ed.) *Five hundred years of nautical science 1400-1900.* National Maritime Museum, Greenwich, London.

Hutton, W.S., 1890, *The practical engineers handbook. 3rd. Edition,* Crosby Lockwood, London.

Hutton, W.S., 1903, *Steam-boiler construction. A practical handbook for engineers, boiler-makers & steam-users.* Crosby Lockwood, London.

International Congress of Maritime Museums, 1979, *Third Conference Proceedings, 1978.* Mystic Seaport Museum, Mystic, Connecticut.

Jacobs M., 1979, From the bottom of Lake Superior...and off to Silver Hill. *The Smithsonian Torch,* (September, 1979) & *Superior Evening Telegram,* 7/8/1979.

Jamieson, A., 1897, *A text-book on steam and steam engines: Specially arranged for the use of Science and Art, City and Guilds Of London Institute and other engineering students. 12th Ed.,* Charles Griffin And Co. London.

Jarvis, A., 1993, Alfed Holt and the compound engine. In Gardiner, R., & Greenhill, B (eds.), 1993, *The advent of steam: The merchant steamship before 1900.* Conway Maritime Press, London: 156-159.

Jeffery, W., and Amess, J., 1983, *Proceedings of the Second Southern Hemsiphere Conference on Maritime Archaeology.* South Australian Department of Environment and Planning, Commonwealth Department of Home Affairs and Environment, Adelaide and Canberra.

John Penn Project Team, 1984, *John Penn project report.* Underwater Archaeological Research Group of NSW.

Johnston, P.F., (ed.), 1985, *Proceedings of the Sixteenth Conference on Underwater Archaeology, Boston.* Special Publication Series, No 4., The Society for Historical Archaeology, Tucson, Arizona.

Johnston, P.F., & Robinson, D.S., 1993, The wreck of the 1848 Propeller *Indiana:* Interim report. *The International Journal of Nautical Archaeology,* 22(3), The Nautical Archaeology Society, Academic Press, London: 219-235.

Keith, D.H., (ed.)., 1982, *Underwater archaeology, The Proceedings of the Thirteenth Conference on Underwater Archaeology, Philadelphia,* Fathom Eight, San Marino, California.

Keith, D.H., & Carrell, T.L., 1992, (eds.), 1492-1992, *500 years of change, Underwater Archaeology Proceedings for the Society for Historical Archaeology*, Kingston, Jamaica.

Kenderdine, S., & Jeffery, B., 1992 (eds)., *Muddy waters: Proceedings of the First Conference on the Submerged and Terrestrial Archaeology of Historic Shipping on the River Murray, Echuca, September, 1992.* State Heritiage Branch, Dept. of Environment and Natural Resources, Adelaide.

Kenderdine, S., 1995, *Shipwrecks 1656-1942: A guide to historic wrecksites of Perth.* WA Maritime Museum, Fremantle.

Kentish, P., 1995, *Stablisation of Santiago, Report No: Met, 291 Part 1.* University of South Australia, Gartrell School of Mining Metallurgy and Applied Geology.

Kimberly, W.B., (Comp.), 1897, *History of Western Australia: A narrative of her past, together with biographies of her leading men.* Niven, Melbourne.

Kimpton, G., and McCarthy, M., 1988, The freeing of the SS *Xantho* engine using a thermal lance. In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988: 73-4.

Knuckey, P.J., 1988, *An anchor form HMB Endeavour: restoration and other aspects.* Materials Research Laboratory, DSTO, Melbourne

Lapwood, M., 1991, *A History of the Steamship Dolphin (1882-1972).* Report, Department of Maritime Archaeology, WA Maritime Museum,

La Que, F.L., 1975, *Marine corrosion, causes and prevention.* John Wiley & Sons, NY.

Lee, S., 1900, (ed.), *Dictionary of national biography, Vol LXI.* Smith Elder, London.

Lenihan, D. J., & Murphy, L, 1981, Considerations for research designs in shipwreck archaeology. In Watts, G.P., (ed.), 1981, *Underwater archaeology : The challenge before us. The Proceedings of the Twelth Conference on Underwater Archaeology, New Orleans.* Fathom Eight, Special Publication #2, San Marino, California: 69-75.

Lenihan, D.J., 1983, Rethinking shipwreck archaeology: A history of ideas and considerations for new directions. In Gould, R.A., 1983, (ed.) *Shipwreck Anthropology.* University of New Mexico Press, Albuquerque: 37-64.

Lenihan, D.J., (ed.), 1989, *Submerged cultural resources study: USS Arizona Memorial and Pearl Harbor national historic landmark.* Southwest Cultural Resources Center Professional Papers, No. 23. Santa Fe, New Mexico.

Lenihan, D. J., 1989, Introduction. In Lenihan, D. J., (ed.), 1989, *Submerged cultural resources study: USSArizona Memorial and Pearl Harbor national historic landmark.* Southwest Cultural Resources Center Professional Papers, No. 23. Santa Fe, New Mexico: 1-12.

Lenihan, D.J., and Murphy, L.E., 1989, Archaeological record. In Lenihan, D. J., (ed.), 1989, *Submerged cultural resources study: USSArizona Memorial and Pearl Harbor national historic landmark.* Southwest Cultural Resources Center Professional Papers, No. 23. Santa Fe, New Mexico: 75-113.

Little, B., 1992, Text-aided archaeology. In Little, B., 1992, (ed.), *Text Aided Archaeology.* CRC Press, Ann Arbor : 1-6.

Lloyd's Register of British Shipping, 1884, *Annals of Lloyd's Register.* Wyman and Sons, London.

Lorimer, M., 1988, Field techniques in the study of TSS *John Penn.* In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988: 176-178.

Lyell, C. 1832, *Principles of geology.* London. (Quoted in Muckelroy, 1978: 11)

Lyon, D.J., 1975, *The Denny List.* National Maritime Museum, London.

MacDonald, G., 1994, *The little boat harbour at Port Gregory.* Private publication, Port Gregory.

MacGregor, D. R., 1973, *Fast sailing ships 1775-1875: their desgin and construction.* Nautical Publishing Co., Lymington.

Macleod, I.D., 1981, Shipwrecks and applied electrochemistry. *Journal of electroanalytical chemists,* **118**: 291-303.

MacLeod, I.D., North, N.A. & Beegle, C.J., 1986, The excavation, conservation and analysis of shipwreck sites. In *Preventative measures during excavation and site protection-second ICCROM Conference on Conservation and Archaeological Excavation, Ghent, 1985.* ICCROM, Ghent: 113-131.

Macleod, I.D., 1986, Conservation of the Iron Steam Ship *Xantho.* In Mansell, H., (ed) Towards 200, Conservation in an Australian context, Perth Conference 1985. *The Bulletin of the Institute for the Conservation of Cultural Material,* **12**, (3&4): 67-94.

Macleod, I.D. and Pitrun, M., 1986, The effects of microstucture on long-term corrosion. *Australiasian Corrosion Association Proceedings Conference 26*, Adelaide 1986. Vol II-Symposium, II.

Macleod, I.D., 1987, Conservation of corroded iron artefacts-new methods for on-site preservation and cryogenic deconcreting. *The International Journal of Nautical Archaeology,* **16** (1) The Nautical Archaeology Society, Academic Press, London: 49-56.

Macleod, I.D., 1989a, The Application of corrosion science to the management on maritime archaeological sites. *The Bulletin of the Australian Institute for Maritime Archaeology, 13:2,* AIMA, Fremantle: 7-16.

Macleod, I. D., 1989b, Marine corrosion on historic shipwrecks and its application to modern materials. *Corrosion Australia,* **14**: 3: 8-14.

Macleod, I. D., 1990, Conservation report on iron shipwrecks: SS *Xantho* (1872), *The Bulletin of the Australian Institute for Maritime Archaeology, 14:2,* AIMA, Fremantle: 1-8.

Macleod, I.D., 1992a, Conservation Management of Iron Steamships-The SS *Xantho* (1872). *Multi-Disciplinary Engineering Transactions,* G.E. No. 1: 45-51.

MacLeod, I. D., 1992b, Report on the corrosion of iron shipwrecks in South Australia: with particular reference to the River Murray. In Kenderdine, S., & Jeffery, B., 1992 (eds.), *Muddy Water: Proceedings of the First Conference on the Submerged and Terrestrial Archaeology of Historic Shipping on the River Murray, Echuca, September, 1992.* State Heritage Branch, Dept. of Environment and Natural Resources, Adelaide: 1-14.

MacLeod, I. D., 1995, Technical Communication: *In situ* corrosion studies on the Duart Point wreck, 1994. *The International Journal of Nautical Archaeology,* **24** (1) The Nautical Archaeology Society, Academic Press, London: 53-59.

Main, T. J., and Brown, T., 1855, *The marine steam engine. Designed chiefly for the use of the officers of Her Majesty's Navy.* 3rd ed., Longmans, London.

Mansell, H., 1986, Towards 200, Papers from the Institute for the Conservation of Cultural Material Conference, Perth, 1985. *ICCM Bulletin, 12. 3&4* ICCM, Canberra.

Maritime Archaeology Association of Victoria, 1983, *The Cerberus.* MAAV, Melbourne.

Martin, C., 1972, Letter to the Editor. *The International Journal of Nautical Archaeology and Underwater Exploration,* **1**, Council for Nautical Archaeology, London: 246-7.

Marsden, P., 1974, *The wreck of the Amsterdam.* Hutchinson, London.

Masters, P. M. & Flemming, N.C., (eds.), 1983, *Quaternary coastlines and marine archaeology: Towards the prehistory of landbridges and continental shelves.* Academic Press, NY.

McCarthy, M., 1979, SS *Windsor*. Unpublished wreck inspection report, Department of Maritime Archaeology, Western Australian Maritime Museum.

McCarthy, M., 1980, SS *Georgette*. Unpublished wreck inspection report, Department of Maritime Archaeology, Western Australian Maritime Museum.

McCarthy, M., 1981a, Jervoise Bay: a case study in the management of endangered wrecksites, *The International Journal of Nautical Archaeology,* **10**(3) The Nautical Archaeology Society, Academic Press, London: 239-252.

McCarthy, M., 1981b, The underwater display case. *Bulletin of the Australian Institute for Maritime Archaeology,* **5**: 42-45, AIMA, Fremantle.

McCarthy, M., 1982a, A Wreck inspection programme as an aid to the co-ordinated management of a large number of wrecksite., *The International Journal of Nautical Archaeology,* **11**(1) The Nautical Archaeology Society, Academic Press, London: 47-52.

McCarthy, M., 1982b, *Colonial wrecks in the Abrolhos Islands.* Report, Department. of Maritime Archaeology, WA Maritime Museum, No. 27.

McCarthy, M., 1983a, Ship's Fastenings: a preliminary study. *Bulletin of the Australian Institute for Maritime Archaeology, 7(1):* 1-25.

McCarthy, M., 1983b, Shipwrecks in Jervoise Bay. *Records of the Western Australian Museum,* **10**(4), WA Museum, Perth: 335-372.

McCarthy, M., 1983c, Wrecks and Recreation. In Jeffery, W., and Amess, J., 1983, *Proceedings of the Second Southern Hemsiphere Conference on Maritime Archaeology.* South Australian Department of Environment and Planning, Commonwealth Department of Home Affairs and Environment, Adelaide and Canberra: 381-390.

McCarthy, M., 1984, *Fastenings analysis, HMS Pandora excavation, 1983-4.* Unpublished Report: Department of Martime Archaeology, WA Maritime Museum.

McCarthy, M., 1985, Treasure from the scrapheap : *Xantho* engine recovered after 113 Years on the Sea Bed. *Australian Sea Heritage* : 22-25.

McCarthy, M., 1986a, SS *Xantho*: A 19th Century lemon turned sweet. In Johnston, P.F., (Ed)., *Proceedings of the Sixteenth Conference on Underwater Archaeology.* Society for Historical Archaeology Special Publication, No.4 : 54-59.

McCarthy, M., 1986b, The excavation and raising of the SS *Xantho* engine and Australia's first practical and theoretical seminar on iron and steamship archaeology. *The International Journal of Nautical Archaeology,* **15** (2), News, The Nautical Archaeology Society, Academic Press, London: 73-6.

McCarthy, M., 1986c, The protection of Australia's underwater sites. *Papers from the Conference on Preventative Measures During Excavation and Site Protection.* ICCROM Ghent, 1985: 133-145.

McCarthy, M., 1986d, Conservators underwater, (and archaeologists above). In Mansell, H., 1986, Towards 200, *Papers from the Institute for the Conservation of Cultural Material Conference, Perth, 1985.* ICCM Bulletin, **12** (3&4) ICCM, Canberra: 21-26.

McCarthy, M., 1987, The SS *Xantho* project: management and conservation. In Macleod, I.D., (ed.), *Conservation of wet wood and metal, The Proceedings of the ICOM Conservation Working Groups on West Organic Archaeological Materials and Metals, Fremantle 1987,* WA Museum, Perth: 9-13.

McCarthy, M., 1988a, SS *Xantho*: The pre-disturbance, assessment, excavation and management of an iron steam shipwreck off the coast of Western Australia. *The International Journal of Nautical Archaeology,* **17** (4) The Nautical Archaeology Society, Academic Press, London: 339-347.

McCarthy, M., (ed.), 1988b, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988.

McCarthy, M., (ed.), 1988c, SS *Xantho* excavation. In McCarthy, M., (ed.), 1988, Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks.* W.A. Museum, Perth, 1988: 179-180.

McCarthy, M., 1989,The Excavation Continues... in the laboratory, in Bickersteth, J., (ed.), 1989, *The Bulletin of the Australian Institute for the Conservation of Cultural Material,* AICCM, Canberra, 1989: 21-28.

McCarthy, M., 1990, *Charles Edward Broadhurst, 1826-1905, A Remarkable 19th. Century Failure.* Unpublished, M. Phil. Thesis, Murdoch University.

McCarthy, M., 1991a, *The Flamingo Bay Voyage, including reports on the Japanese Submarine, I124, The iron Barque, Ann Milicent, Indonesian Divers at Cartier Island and the inspection of a site believed to be the SS Koombana.* Report, Department of Maritime Archaeology, WA Maritime Museum, no. 45: 10-52.

McCarthy, M., 1991b, HMAS Sydney, an archaeologist's view of the situation. in Kirsner, K., and McCarthy, M., (Comp.), *Papers from the HMAS Sydney Forum, Fremantle, 21-23 November, 1991.* Report, Department of Maritime Archaeology, No 52: 1-19.

McCarthy, M, (Comp), 1993a, *From the Inside: Shipwrecks and the Western Australian Museum, 1957-1972, Minutes of: 1) The Historical Materials Advisory Committee. 2) The Joint Committee on Maritime History and Archaeology.* Report, Maritime Archaeology Department, WA Maritime Museum.

McCarthy, M., 1993b, *Zuytdorp:* The search continues. *Landscope: Western Australia's Conservation, Forests and Wildlife Magazine,* Autumn: 43-48.

McCarthy, M., 1994, Western Australia's maritime industrial heritage: Why we are here today. *Sailing ships to microchips, Papers from the Inaugural Engineering Heritage Conference*, Fremantle: 31-34.

McCarthy M., 1995, Before Broome. *The Great Circle: Journal of the Australian Association for Maritime History,* **16**(2): 76-89.

McGann, S., (in prep), Wilyah Miah, *Place of the pearl.* MA Thesis, Department of Archaeology, University of Western Australia, in preparation.

McGrath, H.T., 1980, The Preservation of the USS *Cairo*. In Cummings. C. R., (Ed.), 1980, Underwater archaeology, *The Proceedings of the 11th Conference on Underwater Archaeology, Albuquerque*. Fathom Eight, San Marino, California : 97-106.

McGrath, H.T., 1981, The eventual preservation and stabilization of the USS *Cairo*. *The International Journal of Nautical Archaeology,* **10**(2), The Nautical Archaeology Society, Academic Press, London: 79-94.

McKee, A., 1968, *History under the Sea.* Hutchison, London.

Melrose, B., 1966, *Underwater Explorer's Club Newsletter.* October.1966.

Mercer, F. R., 1958, *The Life of Charles Harper.* Westralian Farmers Co-op Printing, Perth.

Michel, J., 1980, *Trois Inventeurs Méconnus. Benoit Rouquayrol. Auguste et Louis Denayrouze. De prestigieuses découvertes et l''Histoire du premier Scaphandre Autonome une invention bien Francaise 1865.* Editions Musée, Joseph Vaylet, Paris.

Morgan, S., 1987, *My Place*. Fremantle Arts Centre Press, Fremantle.

Morse, K., 1988, The archaelogical survey of midden sites near the *Zuytdorp* wreck, Western Australia. *Bulletin of the Australian Institute for maritime archaeology, 12 :1,* 37-40.

Morris, P.M., 1986, *Applications of isometric projection for archaeological drawing and wrecksite plans.* Unpublished paper produced for the Post-graduate Diploma Course in Maritime Archaeology, 1986. Department of Maritime Archaeology, WA Maritime Museum.

Muckelroy, K., 1978, *Maritime archaeology.* Cambridge University Press, Cambridge.

Muckelroy, K., (ed), 1980, *Archaeology underwater: An atlas of the world's submerged sites.* McGraw-Hill, New York.

Murdock, L.D., and Daley, T., 1982, Progress report on the use of FMC, polysulfide rubber compounds for recording archaeological ship's features in a marine environment, *The International Journal of Nautical Archaeology,* **11**, (4), The Nautical Archaeology Society, Academic Press, London: 349-353.

Murphy, L., 1987, Recent preservation efforts on USS *Arizona*, Pearl Harbor. In Albright, A.B., 1987, (ed.), *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference, Tucson.* Society for Historical Archaeology, Tucson, Arizona:57-59.

Murphy, L., Shipwrecks as data base for human behavioral studies, in Gould, R. A., (ed), 1983, *Shipwreck Anthropology.* University of New Mexico Press, Albuquerque: 65-90.

Musson, A.E., 1969, The growth of mass-production engineering. In Musson, A.E., and Robinson, E., (eds.), 1969, *Science and technology in the Industrial Revolution.* Manchester University Press, Manchester: 473-509

Nairn, N.B., et. al., 1969, (Section eds), *Australian Dictionary of Biography, (Vol 3, A-C).* Melbourne University Press, 1969.

Nairn. J., 1984, *Walter Padbury. His life and times.* North Stirling Press, Padbury.

Nairn, J., and Sue, J., 1964, *The ghost of the Alkimos.* WA Skindivers, Perth.

National Trust for Historic Preservation in the United States, 1978, *The Monitor: Its Meaning and Future,* The Preservation Press, Washington, D.C.

Noel Hume, I., 1975, *Historical Archaeology: A comprehensive guide for both amateurs and professionals to the techniques and methods of excavating historical sites/* Norton, New York.

North, N.A., 1976, Formation of coral concretions on marine iron. *The International Journal of Nautical Archaeology,* The Nautical Archaeology Society, Academic Press, London: 253-258.

North, N. A., 1982, Corrosion products on marine iron. *Studies in conservation,* 27 (1982): 75-83.

North, N. A., 1984, The role of galvanic couples in the corrosion of materials on shipwrecks. *The International Journal of Nautical Archaeology, 13* The Nautical Archaeology Society, Academic Press, London: 133-6

North, N.A., and MacLeod, I.D., 1987, Corrosion of metals. In Pearson, C., (ed.), 1987, *Conservation of marine archaeological objects.* Butterworths, London: 68-98.

O'Keefe, P.J., &Prott, L.V., 1984, *Law and the cultural heritage: Volume 1, discovery and excavation.* Professional Books, Oxford.

Oddy, W.A.,1975, A review of procedures for the conservation of cast and wrought iron found on the sea-bed. *The International Journal of Nautical Archaeology,* 4(2), The Nautical Archaeology Society, Academic Press, London: 367-370.

Osbon, G. A 1965,. The Crimean War Gunboats. Part. 1. *The Mariner's Mirror, The Journal of the Society of Nautical Research.* Vol. 51, Cambridge, University Press: 103-116.

Oxley, I., 1992, The investigation of the factors which affect the preservation of underwater archaeological sites. In Keith, D.H., & Carrell, T.L., 1992, 1492-1992, *500 years of change. Underwater Archaeology Proceedings for the Society for Historical Archaeology*, Kingston Jamaica.

Paasch, H., 1890, *Illustrated marine encyclopaedia.* 1977 repr., Model and Allied Publications, Argus Books, London.

Page, M., 1975, *Fitted for the voyage: the Adelaide Steamship Company 1875-1975,* Rigby, Adelaide.

Parsons, R., 1980, *Steamships in Colonial Western Australia,* revised 1973 edition, Private Publication, Magill, S.A.

Patents for Inventions, 1855, A.D. 1845... No 11,017, *Specification of John Penn, William Hartree the Younger, John Matthew the Younger. Steam engines, propulsiuon of vessels, &c. Eyre and Spottiswoode.* The Greater Patent Office, Holborn, London: 1-18.

Payne, P.L., 1974, *British entrepreneurship in the nineteenth century: Studies in economic history.* Macmillan, London.

Pearson, C., 1987, (ed.) *Conservation of marine archaeological objects.* Butterworths, London.

Pearson, C., 1987, On-site storage and conservation in Pearson, C., (ed.)., *Conservation of marine archaeological objects.* Butterworths, London: 105-109.

Pénnec, S., 1990, *La Conservation des métaux provenant de fouilles sous-marines, Rapport du stage effectué au laboratoire conservation du Western Australian Maritime Museum Fremantle, Septembre 1990.* Unpublished report, Department of Conservation, WA Museum: 85-164.

Peron, R., Anthropological perspectives in nautical archaeology. In Delgado, J.P., (ed.), 1988, *Underwater Archaeology Proceedings from the Society For Historical Archaeology Conference, Reno, Nevada, 1988.* The Society for Historical Archaeology, Tucson, Arizona: 53-55.

Pike, D., (ed.), 1969, *Australian dictionary of biography, Vol., 3, A-C, 1851-1890.* Melbourne University Press.

Playford, P. E., 1959, *The wreck of the Zuytdorp: On the Western Australian coast in 1712.* Royal Western Australian Historical Society, Perth.

Potter, P.B., 1992, Middle-range theory, ceramics, and capitalism in 19th-century Rockbridge County, Virginia. In Little, B., 1992, (ed.) *Text Aided Archaeology.* CRC Press, Ann Arbor: 9-21.

Preston, A., & Major, 1967, J., *Send a gunboat.* Longmans, London.

Preston, A., and Batchelor, J., nd, *The Submarine, 1587-1919.* Phoebus, London.

Purser, M., Oral History and historical archaeology. In Little, B., 1992, (ed.) *Text Aided Archaeology.* CRC Press, Ann Arbor: 25-28.

Raban, A., & Gertwagen, R., 1980, *Selected bibliography.* University of Haifa, Centre for Maritime Studies, Marine Archaeology and Nautical Technology.

Renfrew, R. C., 1982, Explanation revisited. In Renfrew, R.C., Rowlands, M.J. and Segraves, B.A., 1982, (eds.) *Theory and explanation in archaeology: the Southhampton Conference.* Academic press, London: 1-23.

Renfrew, R. C., Rowlands, M.J. and Segraves, B.A., 1982, (eds.) *Theory and explanation in archaeology: the Southhampton Conference.* Academic press, London.

Renfrew, C., & Bahn, P., 1991, *Archaeology, theories, methods and practice.* Thames and Hudson, NY.

Reynard, K. D., Restoration of an iron Star. In *International Congress of Maritime Museums, 1979, Third Conference Proceedings, 1978.* Mystic Seaport Museum, Mystic, Connecticut: 16-27

Richards, M.P., 1987, *Workhorses in Australian waters: A history of marine engineering in Australia.* Turton and Armstrong, Wahroonga.

Richardson, A.R., 1909, *Early Memories of the Great Nor-West and a Chapter in the History of Western Australia.* E.S. Wigg, Perth, 1909.

Riley, J., 1988a, The Waterline Theory of Iron Ship Disintegration. In McCarthy, M., 1988, (ed.), Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks*. W.A. Museum, Perth, 1988: 191-197.

Riley, J., 1988b, The SS *Royal Shepherd*. In McCarthy, M., 1988, (ed.), Iron ships and steam shipwrecks. *Papers from the First Australian Seminar on the Management of Iron Vessels and Steam Shipwrecks*. W.A. Museum, Perth, 1988: 143-4.

Riley, J., 1994, *SS Yongala: Site inspections, 5/12/1993*. Private publication, Sydney.

Ringer, R., 1983, The marine excavation of the 16th Century Basque whaling vessel *San Juan* in Red Bay, Labrador: A summary of the 1982 field season. In Cummings. C. R., 1983, (ed.), *Underwater archaeology, The Proceedings of the Fourteenth Conference on Underwater Archaeology*. Fathom Eight, Special Publication #7, San Marino, California: 119-121.

Rivett, N., ND, *The naval steam reciprocating engine*. The Naval Historical Society of Australia, Sydney.

Robb, A. M., 1978, Shipbuilding. In Singer, C., Holmyard, E.J., Hall, A.R., & Williams, T.L., (eds.), 1978, *A history of technology, Vol III: From the Renaissance to the Industrial Revolution c.1500-c.1750*. Oxford, Clarendon Press: 350-390.

Roberts, S. H., 1935, *The squatting age in Australia, 1835-1847*. Melbourne University Press, Melbourne.

Rodgers, B.A., 1989, Technical communication: The case for biologically induced corrosion at the Yorktown shipwreck archaeological site. *The International Journal of Nautical Archaeology*, **18** (4) The Nautical Archaeology Society, Academic Press, London: 335-340.

Roff, W.J., Early steamships in eastern waters. In Gardiner, R., & Greenhill, B (eds.), 1993, *The advent of steam: The merchant steamship before 1900*. Conway Maritime Press, London: 28-43.

Rogers, R., c. 1945, *Derelicts of the sea*. Blackie and Son, London.

Royal Australian Navy, Department of Defence, 1994, *Australian national tide tables*. Australian Hydrographic Publication: **11**, Australian Government Publishing Service, Canberra.

Ruoff, U., 1972, Palafittes and underwater archaeology. In UNESCO, 1972, *Underwater archaeology : A nascent discipline*, UNESCO, Paris: 123-133.

Rule, 1982, *The Mary Rose: the excavation and raising of Henry VIII's flagship*. Conway Maritime Press, London.

Schiffer, M. B., 1976, *Behavioral Archaeology*. Academic Press, New York.

Seaton, A.E., 1904, *Manual of marine engineering*. Chas. Griffin and Co., London.

Seaton, A.E., 1911, *Manual of marine engineering*. Chas. Griffin and Co., London.

Sennett & Oram, 1918, *The Marine steam engine*. Longmans Greer & Co., London.

Sequeira, C.A.C., & Tiller, A.K., 1988, *Microbial corrosion- 1.* Elsevier Applied Science, London.

Sexton, R. T., 1992, The Goolwa shipbuilding industry. In Kenderdine, S., & Jeffery, B., 1992 (eds.), *Muddy Waters: Proceedings of the First Conference on the Submerged and Terrestrial Archaeology of Historic Shipping on the River Murray, Echuca, September, 1992.* State Heritiage Branch, Department of Environment and Natural Resources, Adelaide:1-31.

Simmer, G. L., (nd.), "Arabella" a woolship of the 'Nineties'. In *Journal of the Honourable Company of Master Mariners*, London: 372-4.

Simmons, J.J., 1988, Steamboats on inland waterways: Prime movers of manifest destiny. In Bass, 1988, *Ships and shipwrecks of the Americas : A history based on underwater archaeology.* Thames and Hudson, London: Chapter 10.

Singer, C., Holmyard, E.J., Hall, A.R., & Williams, T.L., (eds.), 1978, *A history of technology, Vol III: from the Renaissance to the Industrial Revolution c.1500-c.1750.* Oxford, Clarendon Press.

Sledge, S., 1977, The wreck inspection programme at the Western Australian Museum: Responsibilities, aims and methods. In Green, J.N., (Ed), 1977, *Papers from the First Southern Hemisphere Conference on Maritime Archaeology.* Ocean's Society, Melbourne: 80-90.

Sledge, S.D., 1978, *Wreck Inspection North Coast.* Report, Department of Maritime Archaeology, WA Maritime Museum.

Sledge, S., 1979, *Wreck inspection report, SS Xantho*, Unpublished wreck inspection report. Department of Maritime Archaeology, WA Maritime Museum. Reproduced in Hall, *et al.*, 1979.

Smith, E.C., 1937, *A short history of marine engineering.* Bablock and Wilcox, Cambridge.

Society for Industrial Archaeology, 1979, *Indiana* salvage: Oldest American marine engine recovered. *Society for Industrial Archaeology Newsletter.* **8**(5), Society for Industrial Archaeology, Washington, DC:

South, S., 1977, *Method and theory in historical archaeology.* Academic Press, New York.

Sothern, J.W.M., 1923, *'Verbal' notes and sketches for marine engineer officers: A manual of marine enginering practice.* 11th edition, Crosby Lockwood and son, London.

Southwell, C.R., Bultman, J.D., & Alexander, A., 1976, Corrosion of metals in tropical environments: Final report of 16 year exposures. *Materials Performance,* July, 1976:9-26.

Stewart I.G., 1992, *Liberty Ships in peacetime and their contribution to world shipping history.* Ian Stewart Marine Publications, Rockingham Beach, Perth.

Stammers, M. K., Review of the Papers from the First Australian Seminar on Iron and Steamship Archaeology, *The International Journal of Nautical Archaeology.* The Nautical Archaeology Society, Academic Press, London, **18**(1): 87-88.

Staniforth, M., nd., SS *Monumental City, the first steamship to cross the Pacific.* Victoria Archaeological Survey Unit, Melbourne.

Stanbury, M., 1993, *Historic sites of the Easter Group, Houtman Abrolhos, WA: Report prepared for the Abrolhos Islands Consultative Committe.* Report, Department of Maritime Archaeology, WA Maritime Museum, No 68.

Stanbury, M., 1995, Mother-of-Pearl cultivation: an early 20th century experiment in the Montebello Islands, Western Australia. *Great Circle: Journal of the Australian Association for Maritime History,* 16(2): 90-120.

Stevens, W., 1982, Underwater stratigraphy at Red Bay: A methodological approach to explain past events. In Keith, D.H., 1982, *Underwater Archaeology, The Proceedings of the Thirteenth Conference on Underwater Archaeology.* Fathom Eight, Special Publication, # 5, San Marino, California:17-18.

Streeter, E.W., 1886, *Pearls and pearling life.* Bell and Sons, London, 1886.

Suckling, A.J., *The history of the Northampton district.* Unpublished, Teachers Higher Certificate Thesis, State Archive of Western Australia.

Thearle, S.J.P., 1886, *The modern practice of shipbuilding in iron and steel.* Collins, Glasgow.

The Maritime Archaeology Association of Victoria, 1983, *The Cerberus.* MAAV, Melbourne.

Thomas, T., and Tilly, C., 1992, 'TAG and post-modernism: a reply to John Bintliff'. *Antiquity,* 66, 1992:106-110.

Throckmorton, P., (ed),1987, *The sea remembers. Shipwrecks and archaeology from Homer's Greece to the rediscovery of the Titanic.* Artist's House, London.

Totty, D., 1979, *Wrecks of W.A's central mainland coast-Jurien Bay -Port Gregory.* Unpublished Report, Department of Maritime Archaeology, WA Maritime Museum.

Totty, D., 1982, *SS Xantho, Unpublished Report.* SS *Xantho* file, 9/79/1, Dept. of Maritime Archaeology, WA Maritime Museum.

Totty, D., 1986, *Wrecks of Western Australia's Central Mainland Coast.* Private Publication, Perth.

Trenaman, H.R., 1934, Port Gregory and Lynton. *Journal and Proceedings of The Western Australian Historical Society,* Vol.II, Part XVI, RWAHS, Perth:1-5.

Trigger, B., G., 1989, *A history of archaeological thought.* Cambridge University Press, Cambridge.

Turgoose, S., 1989, Corrosion and structure: Modelling the preservation mechanisms, *Evidence Preserved in Corrosion Products: New Fields in Artifact Studies,* The United Kingdom Institute for Conservation, Occasional Papers # 8.

Tylecote, R.F., 1962, *Metallurgy in Archaeology.* Edward Arnold, London.

Tylecote, R.F., 1976, *A History of Metallurgy.* The Metals Society, London.

Tylecote, R.F., 1977, Durable metals for sea water: The archaeological evidence. *The International Journal of Nautical Archaeology, 6:4,* The Nautical Archaeology Society, Academic Press, London : 269-287.

Tyler, P., 1970, The wreck of the *Batavia*: Insights into the relationship between bureaucracy and Government in Western Australia. *Westerly,* **2**, July.

Uhlig, H.H., (Ed), 1948, *The corrosion handbook.* Ninth Edition, John Wiley & Sons, New York.

USSR, Ministry of Defence, 1974, *Atlas of the Oceans-Pacific Ocean.* USSR Naval Branch.

Van Doorninck, F., 1972, Byzantium, mistress of the sea. In Bass, G. F., (ed.), 1972, *A history of seafaing based on underwater archaeology.* Thames and Hudson, London, 1972: 330-641.

VandenHazel, B.J.,1987, The wreck of the side paddlewheel steamer *John Fraser,* Lake Nipissing, Ontario, Canada, *The International Journal of Nautical Archaeology,* **16**(4) The Nautical Archaeology Society, Academic Press, London: 331-341.

Walker, F.M., 1990, Precision construction: Iron's contribution to modern shipbuilding. *Metals in shipbuilding. Papers presented at the March 1990 Conference of the Historical Metallurgy Society,* Historical Metallurgy Society, London.

Wall, R.D., 1979, Commentary on Reynard. *International Congress of Maritime Museums, 1979, Third Conference Proceedings, 1978.* Mystic Seaport Museum, Mystic, Connecticut: 31-35.

Warsop, J.C., & Tomlin, R.J., 1990, *HMS Warrior 1860- A Study of machinery installation, operation and performance.* The Institute of Marine engineers, London.

Watson, P.J., 1983, Method and theory in shipwreck archaeology. In Gould, R.A., (ed.), *Shipwreck Anthropology,* University of New Mexico Press, Albuquerque: 23-36.

Watson, R.A., 1990, Ozymandias, King of Kings. Post-processsual radical archaeology as critique. *American Antiquity,* **55**(4), The Society for American Archaeology: 673-689.

Watts, G.P., 1972, Bermuda and the American Civil War: a reconnaissance investigation of archival and submerged cultural resources. *The International Journal of Nautical Archaeology,* **17**(2), The Nautical Archaeology Society, Academic Press, London:159-171.

Watts, G.P., & Bright, L.S., 1973, Progress in underwater archaeology in North Carolina 1962-72. *The International Journal of Nautical Archaeology,***2**(1), The Nautical Archaeology Society, Academic Press, London: 131-6.

Watts, G.P., 1975, The Location and identification of the Ironclad USS *Monitor. The International Journal of Nautical Archaeology,***4**(2), The Nautical Archaeology Society, Academic Press, London: 301-329.

Watts, G.P., (ed.), 1981, *Underwater archaeology: The challenge before us. The Proceedings of the Twelth Conference on Underwater Archaeology,* New Orleans, San Marino California

Watts, G.P., & Still, W.N., (eds.), 1982, *Cheesebox, Monitor National Maritime Sanctuary Activities Report,* Program in Maritime History and Underwater Archaeology, Department of History, Carolina University, Vol 1 No 1, December 1982.

Watts, G.P., 1987, A Decade of research: Investigation of the USS *Monitor.* In Albright, A.B., *Underwater Archaeology Proceedings from the Society for Historical Archaeology Conference, Savannah.* The Society for Historical Archaeology, Tucson, Arizona: 128-139.

Watts, G.P., 1988 Bermuda and the American Civil War. *The International Journal of Nautical Archaeology,* 17(2), The Nautical Archaeology Society, Academic Press, London : 160-171.

Watts, G.P., 1989, Runners of the Union. *Archaeology* September/October, 1989: 32-39.

Weaver, F., 1994, *Report of the excavations of previously disturbed land sites associated with the VOC ship, Zuytdorp wrecked 1712, Zuytdorp cliffs Western Australia.: A report to the Western Australian Maritime Museum.* Report-Department of Maritime Archaeology, Western Australian Maritime museum, No. 90.

Weldon Athole c.1960. *The life and work of C.E. Broadhurst.* Unpublished Typescript, PR 4257, Battye Library.

Westcott, Abell, 1948, *The shipwright's trade.* Conway Maritime Press, 1981 Edition.

Wexham, B., 1984, *Shipwrecks of the Western Cape*, Howard Timmins, Citadel Press, Capetown.

Wilde-Ramsing, M., 1985, National register districts as a management tool for underwater resources. In Johnston, P.F., (Ed), 1985, *Proceedings of the Sixteenth Conference on Underwater Archaeology.* Special Publication Series, No 4., The Society for Historical Archaeology, Tucson, Arizona.

Williams, T.A., 1971, The historic wrecks of Western Australia: A study in the administrative politics of preservation. *Public Administration, The Journal of the Australian Regional Groups of the Royal Institute of Public Administration,* (Vol, 30, 1971)

Wise, S.R., 1985, Confederate trade and blockade running during the American Civil War. In Johnston, P.F., (Ed), 1985, *Proceedings of the Sixteenth Conference on Underwater Archaeology.* Special Publication Series, No 4.,The Society for Historical Archaeology, Tucson, Arizona: 120-133.

Withnell-Taylor, N. E., 1980, *A saga of the North-West. Yeera-Muk-a-Doo. The first settlement of North-West Australia told through the Withnell and Hancock families 1861-1890.* Hesperian Press, Carlisle W.A.

Yeo, J., 1894, *Steam and the marine steam engine.* Macmillan & Co., London.

Official Documents

Correspondence relating to the loss of the steamship Xantho, and evidence at the court of enquiry. CSO, 727/233-275, SAWA.

Glasgow Post Office Directory, Glasgow.

Government Gazette, 14/8/1862.

Government Resident Officer's Reports, (GRO) in Exploration Diaries, Volumes 5 & 6, SAWA.

Journals and Occurance Books, R.J. Sholl, Acc 194, QB SHO, SAWA.

Knight, W., Comp., 1870, *Census. Census of the Colony of Western Australia, taken on 31, March 1870 and also the general statistics of the Colony for the ten years ending 31/12/1869.* Perth, Government Print.

Proclamation, 14/3/1862, Government Gazette & Superintendent of Water Police to the Colonial Secretary, 10/7/1872.

Liverpool Underwriter's Register, 1872, Liverpool.

Votes & Proceedings of the Legislative Council, (V&P) *Correspondence relative to the State of Affairs on the North west Coast and the treatment of Malay and other labourers employed in the Pearl fishery, Votes and Proceedings of the Legislative Council, 1874-1875.*

Xantho, Certificate of British Registry. (Steamers), 4/1848, Port of Anstruther, 1/11/1848, PRO: BT 107/453.

Xantho, Certificate of British Registry. 21/5/1860, PRO, BT 108/67

Xantho, Certificate of Registry, Glascow, 61/1871, BT 108/250, PRO, London.

Unpublished diaries

Sholl, R. J., *Diary and Occurance Books, R.J. Sholl*, RJS, QB SHo., SAWA.

Sholl, T.C., *Diary T.C. Sholl,* TCS, QB SHo., SAWA

Maps and Charts

Archdeacon, Cmdr., W. E., RN, *Australia West Coast, OD 97, Shoal Point 28° South to Flinder's Bay, Archdeacon* 1879: 16 & on Admiralty Chart No. 2. Western Australian Coast.

DeGrey, WA , 1:500,000, SF, 50 NE.

AUS 751, Houtman Abrolhos and Geelvinck Channel, 1: 20, 000.

Company Documents

Broadhurst, C.E., and Broadhurst, F.C., *Deed of Dissolution of Partnership,* Broadhurst Family Papers, SAWA.

Camden Harbour Pastoral Association, 1864, *Description of Camden Harbour, its climate and adjoining country. with map*, Fergusson and Moore, Melbourne, 1864. University of Melbourne Company Archives.

McKay, D., 1864, *North Western Australia. It's soil, climate and capacity for pastoral enterprise,* Robert Mackay, Glascow Book Warehouse, Melbourne, 1864, Q 333.7, NQR, SAWA. (Denison Plains Pastoral Company).

Moor Collection, *SS Xantho specifications and builder's contract.* Hertsfordshire, England. Copy on Department of Maritime Archaeology, WA Maritime Museum, file, 9/79.

Letters

Baynton to his father from the Nicol River Station, N.W Australia, 20/2/1866. Reproduced in the Perth Gazette and W.A. Times, (Perth Gazette), 23/11/1866.

Broadhurst, C., to the Directors 27/5/1865, reproduced in the Perth Gazette, 1/9/1865.

Broadhurst to Colonial Secretary. 1/7/1872, CSR 727/76, SAWA.

Broadhurst to Sholl, 14/4/1871, CSR 697/110, SAWA.

Broadhurst to Colonial Secretary 25/10/1871, CSR 1885/1182, SAWA.

Broadhurst to Colonial Secretary. 21/4/1876, CSR 488, Vol 20, SAWA.

Colonial Secretary's Office to Manager ASN Co., Sydney 14/2/1867, in response to an inquiry of 9 January. Letters forwarded to Settlers, Vol 39, SAWA.
Gull to Barker, March 1868, Barker and Gull papers, Acc No. 2423a, BL.
Government Resident's Office to Colonial Secretary, 31/12/1873, CSR 727/254.
Government Chemsitry Centre to MacLeod, 19/5/1995, Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*
North, N. A., To Beegle, C.J., 1984. Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*
Tomlin to McCarthy, 28/12/1983, Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*
Tomlin to McCarthy, 29/9/1983, Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*
Roone to Mccarthy, 18/5/1984, Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*
Willing to McCarthy, 9/10/1991, Maritime Archaeology Dept., WA Maritime Museum file, *SS Xantho, 9/79.*

Statutes
Statutes of Western Australia, Museum, No. 90 of 1969. *An ACT to make provision for the re-establishment, control and management of the Western Australian Museum, the Preservation of Historic Wrecks and for incidental and other purposes.* 13° Elizabeth II., No. LVIII, No 58 of 1964, An Act to amend the Museum Act, 1969.
Statutes of Western Australia. Maritime Archaeology, No 66 of 1973. *An ACT to make provision for the preservation on behalf of the community of the remains of ships lost before the year nineteen hundred, and of relics associated therewith, and for other purposes incidental thereto.*
Australia. Historic Shipwrecks Act 1976. No. 190 of 1976. *An ACT relating to the protection of certain shipwrecks and relics of historic significance.*

Newspapers and Periodicals
Geelong Advertiser, 1864-7
Glasgow Herald, 1865
Herald, 1870-3
Illustrated London News, 1865
Inquirer and Commercial News, 1864-1880
Perth Gazette and W.A. Times, 1865-1876
Superior Evening Telegram, 7/8/1979.
The Engineer, Shipbuilding and Marine Enineering on the Thames in the Victorian Era, 3/1/1862; 11/2/1898; 3/6/1898, London.
Sea-history, the art, literature, adventure, lore and learning of the sea, No 68, winter, 1993-4
UEC Newsletter, The Underwater Explorer's Club, Fremantle
West. Australian, 1886-1890, 1988,1989

Daybooks and Minute books
Berry, M., 1993, *Treatment notes and conservation report, 6/10/1993, XA 44, Butterfly Valve,* Conservation Department, WA Maritime Museum.
McCarthy, M., (Comp), 1993, *From the inside: Shipwrecks and the Western Australian Museum. Minutes of the Historical Materials Advisory Committee and the Joint Committee on Maritime history and Archaeology.* Maritime Archaeology Department, WA Maritime Museum.
Xantho Conservation Book. Department of Materials Conservation and Restoration, WA Museum,
Xantho Engine Deconcretion Book, 1985-1995. Department of Maritime Archaeology, WA Maritime Museum.
Xantho Expedition Daybook, 1983-1994. Department of Maritime Archaeology, WA Maritime Museum.

Appendices

(1) Publications emanating from the Xantho study

(2) Tonnage and horsepower defined

(3) Scantlings for river steamers and iron ships

(4) A description of the Trunk Engine type and its failings

(5) Wages and salaries in the 1870's

(6) Notes on steamships in WA Waters

(7) The Xantho pre-disturbance survey report

(8) a. The 1985 concept for the exhibition of the engine
b. Xantho artefact catalogue

Appendix 1

Books, chapters, articles and film emanating from the *Xantho* study.

(a) Books, Articles and Reports - Historical/Archaeological/Conservation/Technical
(b) Museum information series
(c) News Articles
(d) Film and video

Renfrew and Bahn have described four stages in a modern research design

> 1) the formulation of a research strategy to resolve a particular question or idea;
> 2) the collecting and recording of evidence against which to test that idea, usually by the organization of a team of specialists and conducting of fieldwork;
> 3) the processing and analysis of that evidence and its interpretation in the light of the original idea to be tested;
> 4) the publication of the results in journal articles, books (1991:61).

Publication, their stage four, has been on-going, commencing in the *Xantho* case in 1985. As an indication of the progress in this stage, the publications, including popular offerings, film and video, emanating from this study are reproduced below

(a) BOOKS ARTICLES & REPORTS (in chronological order)

Beegle, C.J., MacLeod, I.D. & North, N.A., (1983)
Preliminary Survey of Xantho and Installation of a Cathodic Protection System.
Report, Department of Materials Conservation, WA Maritime Museum.

Andrews, G., (1984)
Australia's Maritime Heritage.
Royal Press, Sydney: 52.

Australian Corrosion Association, (1984)
Work in a Natural Laboratory.
Chemistry Industry and Laboratory Management, October 1984:13.

Australian Corrosion Association, 1984 (Dec.)
Oceans Provide Valuable Available Examples of Corrosive States.
Chemistry and Industry and Laboratory Management, December 1984:18-21.

Evans, V., (1985)
SS *Xantho* .
Australian Association for Maritime History Newsletter, Vol. 2:5.

Evans, V., (1985)
Maritime Archaeology.
Australian Association for Maritime History Newsletter , Vol.24:4.

Hansen, R., (1985)
SS *Xantho* Expedition.
Maritime Archaeological Association of Western Australia Newsletter, Vol.3:13,14.

Marfleet, B., (1985/6)
Xantho Revisited 1985.
S.U.H.R. Annual Report , 1985/6:32-38.
McCarthy, M., (1985)
SS *Xantho* Excavation and Seminar.
Australian Institute for Maritime Archaeology Newsletter, 3(2):7-9.
McCarthy, M., (1985)
Treasure from the Scrapheap : *Xantho* Engine Recovered After 113 Years on the Sea Bed.
Australian Sea Heritage , No.7:22-25.
Strachan, S., (1985)
SS *Xantho* Expedition - April 12-10 May 1985.
In K. Atherton, (ed) *Maritime Archaeological Association of Tasmania Newsletter* , May:9 & 10.

"Basilisk", (1986)
The Maritime Museum, Fremantle WA.
Corrosion Australasia , 11(3), June.
Carpenter, J., (1986)
Soil Stabilizing Gel Media - their uses in Conservation of Shipwreck Artefacts.
ICCM Conference , Towards 200, Perth 1985.
Deith, C.L., (1986) (Editorial)
SS *Xantho.*
Engineering in Miniature , 7(10):289.
Henderson, G., (1986)
Maritime Archaeology in Australia, UWA Press, Nedlands: 124-5.
MacLeod, I.D. & Pitrun, M., (1986)
The Effects of Microstructure on Long Term Corrosion.
Australian Corrosion Association Proceedings :26, Adelaide 1986. Vol. II, Lead Paper, Symposium 11.
MacLeod, I.D., North, N.A. & Beegle, C.J., (1986)
The Excavation, Analysis and Conservation of Shipwreck Sites.
In Preventative Measures During Excavation and Site Protection. ICCROM Conference, Ghent, 1985:113-131.
MacLeod, I.D., (1986)
Conservation of the Steam Ship Xantho.
ICCM Conference, Perth 1985.
McCarthy, M., (1986)
SS *Xantho* : A 19th Century lemon turned sweet.
Proceedings of the 16th Conference on Underwater Archaeology:54-59. Society for Historical Archaeology Special Publication No.4.
McCarthy, M., (1986)
The Excavation and Raising of the SS *Xantho* Engine and Australia's First Practical and Theoretical Seminar on Iron and Steamship Archaeology.
International Journal of Nautical Archaeology , News, 15(2):173-6.
McCarthy, M., (1986)
Conservators Underwater, Maritime Archaeologists Above.
ICCM Conference Towards 200 , Perth 1985:21-26.
McCarthy, M., (1986)
SS *Xantho* Excavation.
ICCM Conference Towards 200 , Perth, 1985:63-66.
McCarthy, M., (1986)
The Protection of Australia's Underwater Sites.
Papers from the Conference on Preventative Measures During Excavation and Site Protection, ICCROM Ghent, 1985.
Morris, P.M., 1986, *Applications of isometric projection for archaeological drawing and wrecksite plans.* Unpublished paper produced for the Graduate Diploma Course in Maritime Archaeology 1986. Department of Maritime Archaeology, WA Maritime Museum.

Carpenter, J., (1987)
The Uses of Soil Stabilizing Gel Media in the Conservation of Large and Small Shipwreck Artefacts.
MacLeod, I.D., (1987)
Conservation of Corroded Iron Artefacts - new methods for on-site preservation and cryogenic deconcreting. *International Journal for Nautical Archaeology,* 16(1):49-56.
McCarthy, M., (1987)
The SS Xantho Project: Management and Conservation,
In Macleod, I.D., 1987, *Conservation of Wet Wood and Metal, Proceedings of the ICOM conservation working groups on wet organic archaeological materials and metals,* Fremantle 1987, WA Museum, Perth 1989: 9-13.

Carpenter, J., (1988)
Iron Ship Concretion Wreck.
In M. McCarthy, (Ed.) *Papers from the first Australians seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar Series No.1. : 88-90.
Henderson, G.J., (1988)
The Archaeological Value of Iron and Steam Ships.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar Series No.1. : 88-90.No.1:10-12.
Kimpton, G. and McCarthy, M., (1988)
The Freeing of the SS *Xantho* Engine.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar Series No.1: 73-74
MacLeod, I.D., (1988)
On Site Conservation. The SS *Xantho* Engine.
In M. McCarthy, (ed), *Papers from the First Australian Seminar on the Management of Iron Ships and Steam Ship Wrecks* , Australian Institute for Maritime Archaeology Seminar, Series No.1:91-92.
MacLeod, I.D., (1988), Conservation of Corroded Metals Recovered from Shipwrecks.
In M. McCarthy, (ed), *Papers from the First Australian Seminar on the Management of Iron Ships and Steam Ship Wrecks* , Australian Institute for Maritime Archaeology Seminar, Series No. 1: 93-103.
McCarthy, M., (1988)
The Excavation of the SS *Xantho.*
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1: 179-190.
McCarthy, M., (1988)
The Management of Iron and Steam Shipwreck Sites.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1 :21-23.
McCarthy, M., (1988)
SS Xantho: The pre-disturbance, assessment, excavation and management of an iron steam shipwreck off the coast of Western Australia. *International Journal Of Nautical Archaeology and Underwater Exploration.* 17.4: 339-347.
Miller, N.A., (1988)
Description of SS *Xantho* Engines from Pre Excavation Drawings.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1 : 208-214.
Miller, N.A., (1988)
A General Description of Trunk Engines as Designed and Built by John Penn and Sons.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1 : 215-218.

Mills-Reid, (1988), Organic Materials and Iron Shipwrecks - The *Xantho* Case Study- Suggestions for Future Research. In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1: 86-87.

Richards, M., (1988)
Work Horses in Australian Waters.
Australian Institute of Marine Engineers, Sydney:31, 47.

Riley, J., (1988)
Isometric Drawing of High Profile Sites.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1: 68-69.

Riley, J., (1988)
Iron Ship Disintegration: The Waterline Theory.
In M. McCarthy, (Ed.) *Papers from the first Australian seminar on the management of iron ships and steamship wrecks.* Australian Institute for Maritime Archaeology Seminar, Series No.1: 191-199.

Macleod, I.D., (1989)
The Application of corrosion science to the management on maritime archaeological sites, in Green, J., & Stanbury, M., (eds), *The Bulletin of the Australian Institute for Maritime Archaeology, 13:2,* AIMA, Fremantle: 7-16.

Macleod, I. D., (1989)
Marine corrosion on historic shipwrecks and its application to modern materials,
Corrosion Australia, 14: 3: 8-14.

McCarthy, M., (1989)
The SS *Xantho* Project, Management and Conservation,
in Macleod, I.D., & Grattan, D.W., *Conservation of Wet wood and Metal :Proceedings of the ICOM Conservation working Groups on Wet Organic Archaeological Materials and Metals, Fremantle 1987,* WA Museum, Perth, 1989 : 9-13.

McCarthy, M., (1989)
The Excavation Continues... in the laboratory,
in Bickersteth, J., (ed)., 1989, *The Bulletin of the Australian Institute for the Conservation of Cultural Material,* AICCM, Canberra, 1989: 21-28.

Carpenter, J., (1990), A review of physical methods used to remove concretions from artefacts, mainly iron, including some recent ideas, *Bulletin of the Australian Institute for Maritime Archaeology, 14(1): 25-42.*

Henderson, G.J., & Henderson, K, J., (1990)
Unfinished Voyages 1850-1880.
University of Western Australia Press, Perth: 119-124.

McCarthy, M., (1990)
Charles Edward Broadhurst, 1826-1905, A Remarkable 19th. Century Failure,
Unpublished, M. Phil. Thesis, Murdoch University.

Pénnec, S., (1990)
La Conservation des métaux provenant de fouilles sous-marines,
Rapport du stage effectué au laboratoire Conservation du Western Australian Maritime Muuseum Fremantle, Septembre 1990, pp. 85-164.

Macleod, I.D., (1992)
Conservation Management of Iron Steamships-The SS *Xantho* (1872),
in *Multi-Disciplinary Engineering Transactions,* G.E. No. 1: 45-51.

Griffiths, G., (1993)
West Australia's first coastal steamer gives up her engine,
Sea Breezes, Feb. 1993.

Burgess, R., & McCarthy, M., (1994)
SS *Xantho,* The Engine Model.
Model Engineer, 3 June, 1994: 676-79.
Gill, J., and McCarthy, M., (1995)
The *Xantho*: Goes on Exhibition in Geraldton.
Destinations, Skywest In Flight Magazine, January to February, 1995, pp. 9-11.

MUSEUM INFORMATION SERIES

(i) YOUR MUSEUM

Your Museum (1983)
Xantho, June:1.
Your Museum (1984)
Museum Restores Rare Engine , March:3.
Your Museum, (1985)
Success Smiles on Xantho *Expedition* . May:4.
Your Museum. (1985)
Towards 200 Conservation Conference , September:4-5.
Your Museum.(1985)
Visitors Enjoy Fremantle Day. November:4.

(ii) INFORMATION SHEETS

McCarthy, M., 1985, *SS* Xantho *Western Australia's First Coastal Steamer.*

NEWS ARTICLES

Sunday Times (1979)
Wreck Recalls Nightmare Run. 24 June, 1979.
Geraldton Guardian (1983)
Excavation of Shipwreck Uncovers Old Steam Engine 26/5/1983.
Geraldton Guardian , (1983)
Society to Visit Site of Wreck. April.
Geraldton Guardian , (1983)
Work to Start on 109 Year Old Wreck. 6 May 1983.
Western Farmer , (1983)
Experts Seek Clues on Geraldton Wrecks. 12 May 1983.
West Australian , (1983)
Study on Steamship Wreck. 9 May:34.
Daily News , (1983)
Museum Team at Shipwreck. 6 May.

Geraldton Telegraph , (1985)
Historic Relic from the Deep. 24 April:1&2.
West Advertiser , (1985)
Old Steamer Hits Top. 12 June.
Western Mail , (1985)
Chipping at a Piece of Sea History. 25 May.
West Australian , (1985)
New Look for Ancient Engine. 3 August:5.
Fremantle Gazette , (1985)
Relic from the Days of Steam. 1 May and Vol.9:16.
West Australian , (1985)
Rescued After a Century at Sea. 25 May.
West Australian , (1985)
(a) Attractions At Museum. 1 November.
(b) Saved from the Wreck. 1 November.

Geraldton Telegraph, (1986)
Our Wreck Revisited. 11June:4.
The Times of the West, (1986)
Museum Restores Steam Engine. 10 November:5.
West Australian, (1986)
Old Lady Emerges from Beauty Bath. 4 November:5.

West Australian, (1987)
Relics Under Scrutiny. 27 August.

Fremantle Focus (1988)
Old Steamship in Display April/ May
West Australian, (1988)
Steamer's fatal past kept for the future 22 April:6

Eastern Suburbs Reporter (1991)
Bob's an Engine Whiz at 81. 5 February, 1991.
Eastern Suburbs Reporter (1991)
Historical Swap. 17 September, 1991.

West Australian, (1992)
Engine gets Shipshape 16 March 1992.

West Australian, (1994)
Museum Enters Age of Steam 12 February 1994.
Geraldton Guardian, (1994)
Display centres on pioneer steamer 2 November, 1994.
Geraldton Guardian, (1994)
Sunken Ship an Historic Treasure. 2 December, 1994

FILM AND VIDEO

ABC News.
TVW Seven News.

Appendix 2.

Horse-power and tonnage defined (from Rivett, nd: 52-55)

HORSE-POWER

Early steam engines were often employed on various haulage tasks previously performed by horses. It was therefore natural that comparison should be made between their relative power, and to express the power of a steam engine in terms of equivalent horses. The unit of work had long been the foot-pound, that is, a force of one pound moved through a distance of one foot. A very small unit for practical purposes. As power is the 'rate' of performing work, the power of a steam engine, like that of a horse could be measured in foot pounds of work performed in one minute. Although this was the scientific way to describe the power of an engine, the resulting value was usually a large meaningless figure. More importantly the power of an engine expressed in foot pounds per minute failed to provide a means of comparison with the power of a horse, which was an unknown quantity. Watt established the unit of horse-power by a series of experiments conducted at the London brewery of Barclay and Perkins. A heavy dray horse pulling on a rope passed over a pulley suspended above a deep well, was found to be capable of lifting a load of 100 lbs at a rate of 2.5 miles per hour. This is the equivalent of 22000 foot pounds per minute. As horses vary considerably in strength, Watt added 50 per cent to the determined value in order to give his customers good measure, and as a concession to sceptics. Thereafter he rated his engines on the basis of a HORSE-POWER (HP) of 33000 foot pounds per minute.
HP remained the legal Imperial unit of mechanical power until the introduction of the 'SYSTEME INTERNATIONAL' (SI) metric units.

Appropriately, the universal unit of power then adopted was the 'Watt' (W).

NOMINAL HORSE-POWER

Watt found that the mean effective pressure usually obtained in the cylinders of his atmospheric engines throughout the working stroke, was 7 lbs per square inch absolute.
He also held firm opinions regarding the optimum piston speed for his steam engines, and set the value at $128X \sqrt{3}$ stroke feet per minute.
Watt thereafter determined the power of his engines from the formula:-

NHP=AREA OF PISTON (sq.ins) x EFFECTIVE PRESSURE (lbs.sq.ins) x SPEED OF PISTON (FT.MIN.)÷ 33000 FT.LBS.MIN.

NHP=AREA OF PISTON X 7 X $128\sqrt{3}$ stroke ÷ 33000

Power so calculated was designated 'nominal' horse-power, because the engine was denominated as being of that power, and in practice was the power actually obtained from a Watt atmosphere engine.
This simple rating system was short lived as a means of conveying the true power of a steam engine.
Some manufacturers considered Watt's rating to be too conservative, and assumed an effective pressure of $7^1/_2$ lbs. per sq.in., and adopted higher piston speeds, thereby gaining a commercial advantage.
When improved boiler manufacturing techniques permitted the use of steam in excess of atmospheric pressure, the concept of 'nominal' horse-power became meaningless and should logically have been abandoned.
Unfortunately the term continued to be used for commercial convenience, as it defined with tolerable accuracy the physical size of an engine and its commercial value in so far as these were dependent upon cylinder dimensions.
In an attempt to make provision for the increasing number of variables introduced in the course of steam engine development, various authorities made numerous amendments to the original formula for nominal horse-power.

The Admiralty initially adopted an arbitrary rule for the speed of the piston, which was presumed to vary with the length of stroke as shown in the following table:-

Stroke	Speed of Piston	Stroke	Speed of Piston
Ft. In.	Ft per min	Ft. In.	Ft. per min
3 0	180	6 0	221
3 6	188	6 6	226
4 0	196	7 0	231
4 6	204	7 6	236
5 0	210	8 0	240
5 6	216	9 0	248

Events quickly rendered these values obsolescent, and it became the normal practice for purchasers of steam engines to insert a clause in the contract binding the manufacturers to specify the 'indicated' horse-power. (HP)

Eventually the Admiralty came to regard the value of the nominal horse-power as being in the order of one sixth of the indicated horse-power, before finally abandoning the use of the term in 1871.

The British Board of Trade and its successor The Ministry of Transport, Lloyds Register and engine manufacturers, each continued to use their own formulae for nominal horse-power, covering a wide range of engine variants, until the end of the steam reciprocating era.

REGISTERED HORSE-POWER

In Lloyds Register the nominal horse-power calculated from Lloyds formula was recorded in the official register of a merchant vessel as Registered Horse-Power. (RHP)

INDICATED HORSE-POWER

The indicated horse-power (IHP) of an engine is determined with the aid of a small instrument called an indicator, the original of which was invented circa 1780 by James Watt, who was appropriately a scientific instrument maker by profession.

The indicator produces a diagram, the vertical ordinates of which represent to scale the pressure in the engine cylinder at all positions of the piston during a cycle, or engine revolution.

The mean height of the diagram therefore indicates the average, or 'mean effective pressure' (m.e.p.) in the engine cylinder throughout the stroke.

IHP is determined by substituting the m.e.p. derived from the indicator diagram, and other relevant engine data in the formula,

$$IHP = \frac{PLAN}{33000}$$

where:- P. = mean effective pressure in lbs. per sq.inch.
L. = length of piston stroke in feet
A. = area of cylinder in sq. inches.
N. = of working strokes per minute.
33,000 = one horse-power in foot lbs.

This is virtually the same formula as that originally used to determine nominal horse-power (NHP), but uses different expressions and actual values for piston speed and effective pressure.

IHP represents the power developed internally by an engine, and includes the power expended in overcoming internal frictional resistance, generally referred to as frictional horse-power.
All the power indicated is therefore not available for performing useful work, but because IHP is relatively easy to determine it is the most practical means available for monitoring performance and comparing engines.
Occasionally in engine design work, or for purposes of comparison, use is made of calculated, or approximated IHP.
This is determined from calculations made using given dimensions, and some calculated figures approximating those likely to be obtained from an indicator, or selected from the vast accumulation of tabulated engine data available.

DEFINITIONS OF MEASUREMENTS FOR TONNAGE, 1854 RULE.[4]

Length — This is the distance between the extreme ends of the hold, below the tonnage deck. For the sake of convenience it is measured on top of the tonnage deck, and allowance has to be made at each end for the rake of the stem and sternpost, which if not deducted could increase the length somewhat. The transverse areas are set out along this length. It was found that in vessels with normal sheer, i.e. 3ft-0in in 250ft-0in, the length could be measured along the deck, rather than in a dead-straight line or chord between the extremities, and that the ultimate difference in the under deck tonnage was about .01%. But in vessels with great sheer, such as 5ft-0in in 100ft-0in the difference would be 1%, which meant that the length had to be measured 'by means of a tape or line stretched tightly from end to end of the deck'.[5]

Breadth — Taken at heights given in the rule, between inner faces of the ceiling, or battens in an iron ship; or to inner surfaces of frames if there is no ceiling or battens.

Depth — This is depth of hold, which is taken from below the underside of the deck to top of ceiling at the limber strake beside the keelson, from which is deducted one-third of the deck camber or 'round of beam'. If there is a water-ballast tank, the depth is measured to the upper edge of the ordinary floor plate.

Under deck tonnage — This is the figure obtained from all spaces below the tonnage deck. No deductions are made from it. It is sometimes used as a basis for block coefficients of fineness.

Gross tonnage — The volume of all enclosed spaces above the tonnage deck was added to the under deck tonnage, to produce this gross figure and it is from this total that deductions can be made for the various crew and store-room allowances. Before 1867 when crew accommodation *above* the tonnage deck was exempted from measurement, small flush-decked vessels with only a deckhouse for the crew had similar figures for under deck and gross tonnage, and as there was nothing to deduct, the net tonnage was also similar.

Net Register tonnage — Any allowances were deducted from the gross tonnage to give the net tonnage. Before 1867, the only allowable deduction was the engine room in steamships, but after that year crew accommodation was *deducted* from the gross total rather than *exempted* from it. Other allowances have since been added. The net tonnage is also the 'register tonnage' (never 'registered') on which is assessed light, pilot and harbour dues and which is the official tonnage entered for registry.

B.M. or B.O.M. tonnage — Builder's Measurement or Builder's Old Measurement tonnage. These were synonymous terms for the pre-1836 old measurement rule which many builders used until the mid-sixties for quoting the price for a new ship, as it only required a simple calculation to obtain the tonnage figure.

Due to the divisor of 100, easy arithmetical sums resulted without any of the awkward fractions that occured when 3500 was the divisor, as in the years 1836–54.

DEFINITIONS OF MEASUREMENTS FOR REGISTRY, 1854 ACT

These are the dimensions normally seen in descriptions of ships which appeared in the Certificate of Registry and survey reports. The length is often the most difficult to measure for the layman when confronted by a sheer elevation, and it is hoped that this description and sketch will elucidate the matter. (See figure 161).

Length — 'Length from the forepart of the stem under the bowsprit to the aftside of the head of the sternpost'. So runs the description in the Certificate. The length was measured along the deck, although in craft with considerable sheer it was probably taken in a dead-straight line. (See above under 'tonnage length' for 1854). The aftside of the sternpost at deck level is easy to locate, but the forward point presents difficulties, which are intensified in iron ships. In wooden ships, it is frequently necessary to project the line of the stem parallel to the stem rabbet to a point below the bowsprit, to obtain the forward termination of the length. But in iron ships, the stem and cutwater are the same and the stem curves away rather as in an Aberdeen bow until it is running almost parallel with the steeve of the bowsprit. A practical article in the magazine *Naval Science* contained an explanatory drawing upon which figure 161 is based, which shows that in iron ships the length was measured from the stem where it stopped against the bottom block of the figurehead.[6] It will be obvious from the drawings that length for registry will often be longer in sailing ships of normal design than length for tonnage.

The forward termination of the length reverted to that in use before 1836, which some shipyards had continued to use.

Breadth — 'Main breadth to the outside of plank'. This was the maximum external breadth sometimes called 'extreme breadth outside'.

Depth — 'Depth in hold from tonnage deck to ceiling at midships'. This is fairly straight-forward, the upper point of measurement being the underside of the deck and the lower point being taken beside the keelson; it is *never* the draught of water.

Other measurements encountered:

Length between perpendiculars — This is a term used by shipbuilders and varied from yard to yard, but in many cases it lay between the afterside of the stem at deck level and the afterside of the heel of the sternpost, perpendiculars being drawn through these points and projected down to the half-breadth plan.

Length aloft — 'Aloft' indicates a length measured along the deck as opposed to the keel and probably lies between the same points as for the register length.

Length overall — Usually measured from foreside of figurehead to afterside of taffrail.

Moulded breadth — This is identical to the description for the old measurement rule.

The above detailed comments, if read in conjunction with the drawings, will go some way to prevent those anomalies which frequently cause confusion over a ship's length and tonnage.

APPENDIX 3

Grantham's scantlings for river steamers and iron ships (Grantham, 1859:186-7)

186 SPECIFICATIONS OF

SPECIFICATIONS.

Having endeavoured to illustrate the plain and ordinary modes of Iron Ship-building, I reserve for the conclusion a few Specifications of various Steam and Sailing vessels. One of these is strictly in accordance with the last published regulations of Lloyd's, and by following the rules there laid down, it is not difficult to discover the correct scantling required for different sized vessels which are to be classed at Lloyd's. The remainder are chosen rather to show instances of vessels which, though differing from Lloyd's rules in many essential points, have nevertheless stood well, and may therefore be useful guides to those who have occasion to construct vessels for peculiar purposes, and wish for examples to guide them.

I could wish to have enlarged this section of my work, but, without the permission of either the owners or the builders, I did not feel myself at liberty to insert some examples that would have been valuable for the objects above-named: other cases, which it was in my power to give, did not afford sufficient interest or variety.

Iron Work of a London River Steamer.

Dimensions, &c.—Length on deck, 126 ft.; breadth, 13 ft.; depth of hold, 7 ft.; draught of water to be 2 ft. 6 in., with machinery and coals on board.

Keel and Stems of $6 \times \frac{1}{2}$ in. bar iron.

Plating.—Garboard strake, $\frac{1}{4}$ in. thick; bottom and bilges,

PADDLE STEAMERS. 187

$\frac{3}{16}$ in.; sides, $\frac{1}{8}$ in.; all to be flush-jointed and countersunk, riveted. A bar of half-round iron to run all round the gunwale strake and along the sponsons.

Frames to be of 2×2 in. angle-iron, spaced 18 in. apart in centre of the vessel, widening out at both ends of the vessel to 24 inches.

Engine Sleepers to be 12 in. deep and $\frac{1}{4}$ in. thick; and of sufficient length to distribute the weight of the engines and boiler over 30 ft. length of vessel.

Bulkheads and Coal Bunkers.—Bulkheads to be made of $\frac{1}{8}$ in. plates bare in thickness, and the coal bunkers to be $\frac{1}{8}$ in. full.

Iron Work of the Paddle Steamer, "Vernon," built for River Work by Messrs. S. Vernon & Son, 1849.

Dimensions.—Length on the water line, 130 ft.; breadth, 16 ft. 6 in.; depth from skin to underside of deck, 8 ft. 6 in.

Keel Plate to be $\frac{3}{8}$ in. thick, to be made hollow and form a waterway under the flooring plates; the keel plate to be single riveted to the garboard strakes, and to be made of best Staffordshire iron.

Stern Posts to be formed of solid bar iron, $\frac{3}{4}$ in. thick at the fore-part; the after-part to correspond with the lines of the vessel, to be 4 in. wide, with a projection to cover the edges of the plates. The posts to be bent, or worked round to suit the form of the rudder, and to run in upon and be securely fastened to the keel plate, and to have holes for the rudder post and locking bolt, brace for lower part of rudder, and shoe for it to work on. The rudder guards to be $5 \times 1\frac{1}{4}$ in. iron.

Plates to be of best Staffordshire iron, clincher built, with flush butts and rivets. Thickness of garboard strake, fore-and-aft, $\frac{5}{16}$ in.; bottom, up to bilge, for 30 ft. amidships, $\frac{5}{16}$ in.; bottom, up to bilge, for 8 ft. fore-and-aft of this, $\frac{1}{4}$ in.; sides, for 30 ft. amidships, $\frac{1}{4}$ in.; remainder of plating, $\frac{3}{16}$ in. The whole to be single riveted.

Frames to be of $2\frac{1}{2}$ in. angle-iron, $\frac{1}{4}$ in. thick, 2 ft. from centre to centre amidships, and widening to $2\frac{1}{2}$ ft. fore-and-aft; each frame to be in two pieces, and the ends to be connected in the centre of the vessel by a reversed angle-iron, 4 ft. long in the midships, and gradually reduced fore-and-aft; to be securely riveted together, with the flooring plate between them. The frames fore-and-aft of the engine room to be $\frac{3}{16}$ in. thick.

Flooring Plates to be 9 in. deep at the centre by $\frac{1}{4}$ in. thick

Lloyd's scantlings for iron ships (Grantham, 1859:180)

IRON SHIPS.—*Table of Minimum Dimensions of Frames, Plating, Rivets, Keels, Keelsons, Stem and Stern Posts, Floor Plates, Beams, Bulkheads, Stringers, &c.*

Gross Tonnage.	Keel, Stem and Stern Posts for all Grades.*	Distance of Frames or Ribs from Moulding edge to Moulding edge all fore-and-aft for all Grades.	FRAMES OR RIBS. Dimensions of Angle-Iron for all Grades.	Dimensions of Reversed Angle-Iron on Frames and Bulkheads for all Grades.	THICKNESS OF PLATES.† Garboard Strakes. Years. 12	9	6	From the Garboard to the upper part of Bilge, and the Sheer-strakes. Years. 12	9	6	From Bilge to Sheer-strakes, thickness of Beams ‡, Stringer § Plates upon Beam Ends, Hooks, Crutches, Floor Plates ‖, and Keelsons. Years. 12	9	6	BULK-HEADS. Thickness of Plates throughout for all Grades.	Dimensions of Angle-Iron on Beam Stringers or Keelsons for all Grades.	RUDDER for all Grades. Diameter at the Head.	Diameter at the Heel.	Thickness of Wood, Flat of Upper Deck.	Gross Tonnage.
	Inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	inches.	
100	5½×1½	18	6/16×2½×2½	5/16×2¼×2¼	8/16	7/16	6/16	7/16	6/16	5/16	6/16	5/16	5/16	4/16	6/16×2½×2½	2½	2	2¼	100
200	6×2	18	6/16×3×2½	5/16×2¼×2¼	9/16	8/16	7/16	8/16	7/16	6/16	7/16	6/16	5/16	4/16	6/16×3×2½	3	2	2½	200
300	6¼×2¼	18	6/16×3¼×2¾	5/16×2½×2½	10/16	9/16	8/16	9/16	8/16	7/16	8/16	7/16	6/16	5/16	6/16×3½×2¾	3¼	2¼	3	300
400	6½×2½	18	7/16×3½×2¾	6/16×2¾×2½	10/16	9/16	8/16	9/16	8/16	7/16	8/16	7/16	6/16	5/16	6/16×4×3	3½	2½	3	400
500	6¾×2½	18	7/16×3¾×2¾	6/16×3×2½	11/16	10/16	9/16	10/16	9/16	8/16	9/16	8/16	7/16	6/16	7/16×4¼×3¼	3¾	2¾	3½	500
600	7×2¾	18	7/16×4×3	6/16×3×2¾	11/16	10/16	9/16	10/16	9/16	8/16	9/16	8/16	7/16	6/16	7/16×4½×3½	4¼	2¾	3½	600
700	7¼×2¾	18	8/16×4¼×3	7/16×3×2¾	12/16	11/16	10/16	11/16	10/16	9/16	10/16	9/16	8/16	6/16	8/16×4¾×3¾	4½	3	3½	700
800	7½×3	18	8/16×4½×3	7/16×3×3	12/16	11/16	10/16	11/16	10/16	9/16	10/16	9/16	9/16	6/16	8/16×5×4	4½	3	3½	800
900	8×3	18	8/16×4¾×3	7/16×3¼×3	13/16	12/16	11/16	12/16	11/16	10/16	11/16	10/16	9/16	7/16	9/16×5×4¼	4¾	3	3½	900
1000	8½×3	18	9/16×5×3	8/16×3½×3	14/16	12/16	11/16	12/16	11/16	10/16	11/16	10/16	9/16	7/16	9/16×5×4½	5	3	4	1000
1200	9×3	18	9/16×5×3½	8/16×3½×3	15/16	13/16	12/16	13/16	12/16	11/16	11/16	10/16	9/16	7/16	9/16×5½×4½	5	3¼	4	1200
1500	10×3	18	10/16×5½×3½	9/16×4×3½	16/16	14/16	13/16	14/16	13/16	12/16	12/16	11/16	10/16	8/16	9/16×6×5	5½	3½	4	1500
2000	12×3	18	10/16×6×4	9/16×4½×3½	17/16	15/16	14/16	15/16	14/16	13/16	13/16	12/16	11/16	8/16	10/16×6½×5½	6	3¾	4	2000
2500	12×3¼	18	11/16×6¼×4	10/16×4½×3½	17/16	16/16	15/16	16/16	15/16	14/16	14/16	13/16	12/16	9/16	11/16×6½×5½	6½	4	4	2500
3000	12×3½	18	11/16×6½×4	10/16×4½×3½	17/16	16/16	15/16	16/16	15/16	14/16	14/16	13/16	13/16	9/16	10/16×6½×5½	6¾	4½	4	3000

RIVETS. Diameter of Rivets required for Thickness of Plates . . .	⅝ of an inch.			¾ of an inch.			⅞ of an inch.			1 inch.			Rivets to be ¼ of an inch larger in diameter in the stem, stern post, and keel.
	5/16	6/16	7/16	8/16	9/16	10/16	11/16	12/16	13/16	14/16	15/16	16/16	

* When Hollow Plate Keels are adopted, their thickness should not be less than one and a half that of the Garboard Strake. For Keels of other Forms, see Sect. 2.

† Plating not to be reduced in thickness forward or aft, except in the sheerstrake and strake next below it, which may be reduced 1-16th of an inch in Vessels of 1000 Tons and under, and 2-16ths of an inch in Vessels above 1000 Tons, for a distance not exceeding one quarter of the length of the Vessel from each end.

‡ All Beam Plates to be in depth one quarter of an inch for every foot in length of the Midship Beam; to have double Angle-Iron upon upper edge. Siding and Moulding together of each to be not less than three-fourths the depth of Beam Plate, and to be in thickness 1-16th of an inch for every inch of the two sides of the Angle-Iron.

§ Stringer Plates upon ends of Beams not to be less in breadth than three times the depth of Beams, and to be of the thickness given in the Table, the said Stringer Plates to be fitted home and riveted to the outside plating at all Upper Decks, and at the Middle Deck in Vessels having three decks, with Angle-Iron of the dimensions given in the Table above. Tie Plates ranging all fore-and-aft upon Beams on each side of Hatchways, or from side to side diagonally, to be half the width, and of the same thickness as the Stringer Plates upon ends of Beams. Each arm of Knee Plates not to be less in length than twice and half the depth of the Beams.

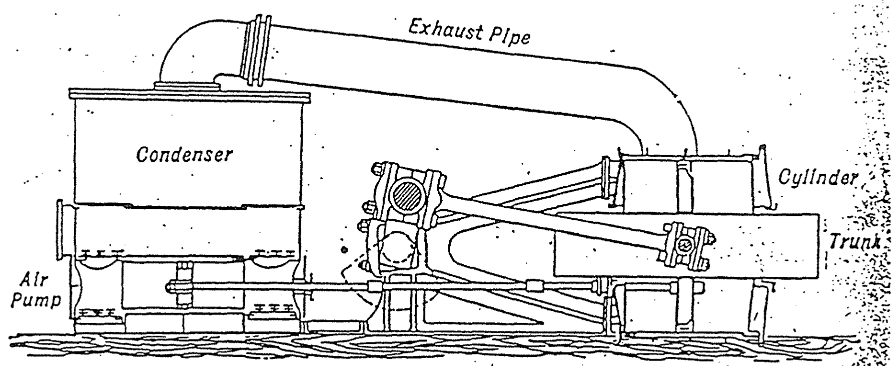
‖ Depth of Floor Plates at the middle line not to be less than one inch for every foot of the Vessel's depth, measured amidships from the top of the Floor Plates to the top of the Upper or Spar Deck Beams, to extend beyond the Bilge Keelsons, and not to be less in depth at the Bilge Keelsons than the Moulding of the Frames.

The Rivets to be of the best quality, and to be in diameter as per Table; the rivet holes to be regularly and equally spaced and carefully punched opposite each other in the laps and lining pieces, or strips; to be countersunk all through the Outer Plating, the rivets not to be nearer to the Butts or edges of the Plating, Lining Pieces to Butts, or any Angle-Iron, than a space not less than their own diameter, and not to be further apart from centre to centre than four times their diameter, or nearer than three times their diameter, and to be spaced through the Frames and outside Plating a distance equal to eight times their diameter apart. When riveted up, they are completely to fill the holes, and their points, or outer ends, are to be round or convex, and not to be below the surface of the Plating through which they are riveted. *All edges or horizontal joints of outside plating to be double riveted in vessels intended for the 12 years' grade, of 700 Tons and upwards, and from Keel to the height of upper part of Bilges all fore-and-aft in vessels intended for the 9 years' grade, and for the 12 years' grade under 700 Tons.* The Stem, Stern Post, Keel, Edges of Garboard Strakes and Sheerstrakes, and Butts of outside Plating, and Butts of Floor Plates, Breasthooks, Transoms, and Plates of Beams; also butts of Keelsons, Stringers, Shelf Plates, and all other longitudinal ties, to be double riveted in all Vessels. The overlaps of Plating where double riveting is required, to be not less in breadth than five times the diameter of the rivets, and where single riveting is admitted, the overlaps to be not less in breadth than three times the diameter of the rivets. If double riveting be adopted where single riveting is allowed by the Rules, the diameter of the rivets may be reduced 1-16th of an inch below that prescribed by the Rules, provided that in no case the diameter be reduced below 5-8ths of an inch.

APPENDIX 4

Descriptions of the Trunk Engine (Jamieson, 1897: 97)

Penn's Trunk Engine.—The difficulty of obtaining a sufficiently long stroke from the direct-acting horizontal engine in the case of a man-of-war, where the engines had to be placed as near the keel of the ship as possible, was solved by Mr. John Penn of



Greenwich. He hinged the connecting-rod direct to the centre of the piston by means of a gudgeon, surrounded by a brass cylindrical case or trunk, concentric with the steam cylinder, as seen in the following figure. This trunk was fixed to the piston, and protruded from each end of the cylinder through stuffing boxes, thereby not only giving additional support to the piston, but also permitting access for oiling the gudgeon and connecting-rod end, and preserving an equal area to the pressure of the steam on both sides of the piston.

Seaton, in his *Manual of Marine Engineering*, says—"This engine is the lightest and most compact of all the forms of marine screw engines, when constructed of the same materials; and for large sizes with the *lower steam pressures*, has been unsurpassed by any other type of engine. The length of stroke is considerably more than that of the ordinary direct-acting engine, and the connecting-rod much longer than that of any other form, being from two and a half to three times the length of the stroke; the weight of the piston is taken by the trunks in a great measure, and there are no piston-rod guides. But with the increase of pressure the defects of this form become more apparent, and lie with the very part that distinguishes it—viz., the trunk.

"The friction of the large stuffing-boxes is very great; in fact, may be so great by unduly tightening the glands as to stop the engine. The loss of heat from the large surface of the trunks being alternately exposed to steam and to the atmosphere, is very great, as is also that from their inner surfaces. The gudgeon brasses are exposed to a very high temperature and liable to become heated, and when heated cannot easily be cooled, as from their position they are not readily adjusted."

Penn arranged his engine so that the direction of motion of its crank when going ahead caused the thrust of the connecting-rod to be upward, and thus, as far as possible, to relieve the bottom of the cylinder from the tear and wear due to the weight of the piston. Some of the largest and most powerful ships in the British Navy have been engined with this Trunk form, such as—H.M.S. *Neptune*, 9000 I.H.P., H.M.S. *Sultan*, *Hercules*, *Minotaur*, *Northumberland*, *Warrior*, *Black Prince*, *Devastation*, &c.*

APPENDIX 5

Wages and Salaries 1872 (Knight, 1879)

Colonial Surgeon	£400
Post Master General	£350
Chief Clerk	£300
Harbour Master (Fremantle)	£250
Crown Solicitor	£250
Headmaster (Perth Boys)	£200
Draughtsman	£200
Surveyor (Roebourne)	£200
Harbour Master (Albany)	£150
Doctor	£150
Cooper and Warehouse Keeper	£130
Teacher (Perth Boys)	£100
Teacher, Girls School	£100
Post Master	£100
Caretaker of the Public Gardens	£70
Hospital Matron	£50
General House Servant	£16

APPENDIX 6

Steamships in Western Australian waters:
the sample used to analyse *Xantho* on a regional basis. (Parsons, 1980, Dickson, 1993)

Albany

Iron single screw steamship, ON 44865, (ex *Claud Hamilton* Feb.1886) 668g,529n, B.1862 (3) Chas. Mitchell & Co Low Walker/Tyne. 3 m barque rig, 200.2 x 28.2 x 16.5: Simple steam engine, 100nhp, by Morrison & Co, Newcastle/Tyne, Lengthened & rebuilt 1886 - 878g 794n, 231.4 x 16.5. Engine: compound surface condensing type, 120nhp, by D & W Henderson Ltd. Glasgow 1900 - alterations 889g: Built for Intercolonial Royal Mail S. P Co, reg. London name of owners changed 1866 to Panama, New Zealand & Australian Royal Mail S.P. Co: April 1869 to McMeckan, Blackwood & Co, reg. Melbourne: March 1880 Nipper & See: Dec. 1881 The Adelaide S.S. Co. Ltd: Wrecked off Nambucca Heads, NSW, March 28, 1905, under charter to AUSN.

Colac

Iron, single screw steamship, ON89469, 1,479g, 958m. B.1884 (1) E. Withy & Co, West Hartlepool. 245.2 x 34.2 x 17.2: Compound surface condensing direct acting steam engine. 140nhp, T. Richardson & Sons, Hartlepool 1 deck, well deck. Owners:- J. Huddart & Partners, reg. Melbourne: Oct. 1886 The Adelaide Steam Ship Co. Ltd, reg Port Adelaide. Stranded in the vicinity of Derby WA, Sept 17, 1910 and subsequently dismantled and abandoned.

Croydon

Steel, single screw steamship, ON101625, 68g, 38n: B.1896 Riley, Hargraves & Co, Singapore: 76.0 x 16.0 x 6.7: Compound surface condensing steam engine, 25nhp by shipbuilder. Owners: not registered until 1899 but reputedly owned by J.W. Bateman & Sons, Fremantle: 1899 H. Osborne & Partners, reg. Fremantle: 1901 The Adelaide S.S. Co Ltd: In 1905 tried to get to South Australia but got such a buffeting that she had to be towed from Point Malcolm by *Tarcoola*. On arrival at Pt Adelaide 1905 she was slipped and was found to be so strained that she was abandoned to the Underwriters. Sold to W.R. Cave & C., reg. Port Adelaide August 1913: Oct. 1918 sold Huon Shipping & Logging Co.: Sunk, Savage River, west coast Tasmania, May 13, 1919. Adelaide Company used the vessel in lightering operations at Cossack, but she was also the mail steamer between Albany and Esperance for some years, and for 12 months ran the mails to Houptoun.

Eddystone

Iron single screw steamship, ON91942, 2040g, 1313n, B.1886 (6) M. Pearse & Co, Stockton 275.0 x 36.0 x 20.0: Raised qtr dk,103:1 deck, Three cylinder, compound steam engine, 200 nhp, blr 160psi, by Blair & Co Ltd. Stockton. Owners: Farrar, Groves & Co, reg. London: 1893 McIlwraith, McEacharn Ltd., reg Melbourne: Wrecked Depuch Is, West Aust. Sept 8, 1894 (about 40 miles east of Cossack - Port Walcott).

Franklin

Iron single screw steamship, ON79328m 730g, 395n.: B1880 (8) D. & W. Henderson, Patrick, Glasgow 200.1 x 26.3 x 19.4: 1 dk & awning deck. Compound steam eng, 280nhp, by shipbuilder. Owners:- Spencers Gulf S.S. Co. Ltd reg. Port Adelaide: Dec. 1882 The Adelaide Steam Ship Co. Ltd. Wrecked, Point Malcolm, Western Australia, April 18, 1902.

Georgette

Iron single screw steamship, ON68004, 337g. 212n. 151.5 x 22.5 x 11.5, B.1872 (10) McKellar, McMillan, Dumbarton, Compound vertical direct acting steam eng, 50 hp, Smith Bros & Co, Glasgow: Owner: Thos. Connor Wrecked at Calgardup, WA Dec 1, 1876.

Though *Georgette* had established regular trade connections between Albany, Champion Bay and intervening ports, it was dogged by problems with the crew and concerns about its suitability for the trade. Human error resulted in the ship being stranded on a reef near Fremantle soon after it arrived, causing considerable structural damage such that stanchions and faremes were bent and plates sprung. It appears that the vessel was lucky not to be lost on the voyage home (Inquirer 29/10/1873). Tensions between the contractors and the government grew and as a result the Government found itself unwilling to renew their contract with Connor and McKay and advised the owners accordingly in September 1876 (Henderson, 1977:197). Two months later the vessel was lost on a voyage from Fremantle to Adelaide where it was to receive an overhaul· It appears that a heavy baulk of timber fell into the vessel's hold while they were loading ship. Nothing untoward was noticed at the time, but eventually a leak, apparently caused by the falling timber, was discovered around midnight while in the vicinity of Hamelin Bay on the south-west coast. In attempting to stem the influx neither the ship's pumps nor the auxiliary steam pumps could be made to function properly. This left the unfortunate passengers and crew to bail out the vessel out with buckets. They proved only partly successful and the captain took the ship in towards the coast while the water slowly rose inside the hull. Eventually the fires were extinguished by the sea and the main engines stopped. The *Georgette* then drifted ashore and was wrecked (Henderson, 1988:212).

Such a series of coincidences would have roused considerable suspicions amongst ship's underwriters in modern times when the deliberate scuttling of redundant or unsuitable vessels in order to claim insurance money is a not unknown occurrance. It appears co-incidental and no hint of impropriety surfaced in this instance however.

Karrakatta

Steel, single screw steamship, ON102212, 2091g, 1271n: B.1897 John Scott & Co, Kinghorn. 300.0 x 42.2 x 17.6:2 masts, 2 decks. Triple expansion steam eng, 1800 ihp, 300 nhp, rated $12^{1}/_{2}$ knots, by shipbuilder. Owners:- West Australian S.N. Co. Ltd., reg. Fremantle. Totally wrecked, march 26, 1901, near Swan Point, North West coast, Western Australia, on a voyage Fremantle to Singapore.

Les Trois Amis

Iron single screw steamship, ON 40477, 42.2 g, 28.7n. Built in 1854 by Pitchers at Northfleet Dockyard. 65.7x12.9x10.1. One direct-acting steam engine, 9HP. Arrived Melbourne on 6 December 1854, Campbell and Co agents, arrived Swan River from Adelaide on 15 March 1855. Masts and ballast removed for use as a river steamer, carrying passengers and goods, often to a timetable. Campbell drowned in November and the vessel was mothballed pending settlement of his estate. The vessel was sold to George Shenton in December 1856 who attempted to sell its engine, which had proved unsuitable. Sold to George Green, the vessel was re-rigged to run from Fremantle to Champion Bay as a sailing schooner. Its first voyage was in July 1857 on what was to become a regular run. Described in the press as a 'steam schooner', it appears the engines were used as auxiliary power only and the vessel had a narrow escape in May 1858 when, in the face of a severe gale, the crew had to resort to chopping up the fittings for fuel in order to 'get up steam' to keep the ship off a reef.. The machinery was removed in the following November to be used in a flour mill. Its plates were noted as being worn out in October 1872 and the hull was planked over with Jarrah (hardwood) boards. In December 1873, the vessel was sold to Broadhurst's colleague Francis Cadell for use in the pearl shell industry and for carriage of passengers and general goods. The vessel was apparently lost off the coast of Timor in 1884.

Lubra

Iron single screw steamship, ON29368, 246g, 167n: 1877 - 320g, 224n. B. 1860 (11) Laurance Hill & Co, Pt. Glasgow: 147.0 x 22.2 x 10.5: Lengthened 1877. 167.3 x 22.2 x 10.4: Single 50 hp steam engine. Compound engine, 60hp by D & W. Henderson installed 1877: Owners:- W.Ward, reg. Glasgow: 1862 A.L. Elder reg London: 1863 Thos Elder & Rbt. Barr Smith & Others reg. Port Adelaide: Feb. 1877 Spencers Gulf SS Co. Ltd: Sept 1882 The Adelaide SS Co. Ltd. Wrecked Jurien Bay, West Australia, Jan 9, 1898.

Macedon

Iron, single screw steamship, ON63253m 826g 532n, B.1879 (2), W.H. Potter & Co. Liverpool, 220.6 x 29.8 x 15.8, 3 m bq. 2 cylinder inverted direct acting, steam engine, 100hp, James Jack & Co., Liverpool: Owners: Wm Howard Smith & Partners, reg Melbourne: Wrecked Kingston Reef, near Rottnest Island, WA March 21, 1883. (Press reports and other sources say that the vessel was sold to Anderson & Marshall in Sept. 1881. This does seem to have been recorded on her official papers).

Otway

Iron single screw steamship, ON64783, 446g, 271n: 1883 - 563g 352m, B.1872 (6) Blackwood & Gordon, Port Glasgow. 180.0 x 25.0 x 12.0: Lengthened 1883 - 203.0 x 25.2 x 12.0: Compound inverted direct acting steam eng, 93hp, by shipbuilder: Owners:- Warrnambool Steam Packet Co, reg. Warrnambool, May 1878 C.V. Robinson & Partners, reg. Melbourne: Nov. 1878 Lilly & Marshall May 1883 The Adelaide Steam Ship Co. Ltd: Jan 84 transferred to Port Adelaide Sept 1892. A. Jouve & Co, Noumea: June 1897 E.F.A. Knoblauch, reg. Sydney: Oct. 1897 Illawarra S.N. Co. Ltd: June 1901 North Coast S.N. Co. Ltd. and renamed *Nymbodia* hulked 1913.

Perth

Iron, single screw steamship (ex *Penola* March 1885) ON48408, 499g, 298n. B.1863 (6) Laurance Hill & Co. Ltd, Pt. Glasgow rebuilt & lengthened at Port Adelaide 1884/5 - 192.1 x 22.5 x 12.6, 2 mast, NE 1885 - Compound direct acting steam engine, 70 nhp, D & W Henderson, Ltd. Glasgow. Owners:- The Adelaide Steam Ship Co. Ltd, reg. Port Adelaide. Wrecked at Point Cloates on North West coast of West Australia, September 13, 1887. (When rebuilt she lost her clipper bow).

Rob Roy

Iron single screw steamship, ON60331, 309g. 200n: Nov. 1872 - 393g 231n. B.1867 (12) T. Wingate & Co., Whiteinch. 148.2 x 21.5 x 15.1. Lengthened Nov. 1872 - 163.0 x 21.5 x 15.1: Original engine 2 cylinder 50hp, 26 psi, by ship builder, replaced 1..5 by Compound, 60hp, by D. & W. Henderson Ltd, Glasgow. Owners:- C.V. Robinson & Partners, reg Melbourne: Nov 1878 Marshall & Lilley: Register closed after vessel stranded at Cossack, N.W. of West Australia Feb. 1882 *Rob Roy* suffered severe damage and workmen were despatched from Melbourne to repair the stricken ship and make it seaworthy for the lengthy trip back to Melbourne were it was repaired and lengthened to 203 feet (61m) at a cost of £6,000, to re-enter service in September, thereafter operating up to 1893 when it was 26 years old (Parsons, 1973:70).

Re-registered upon production of a new certificate of seaworthiness, in Melbourne by Marshall and Lilly. May 1883 The Adelaide S.S. Co. Ltd, and registration transferred to Adelaide, January 1884. Register closed April 1904 and vessel hulked. She was used as a coal hulk in Melbourne until at least 1910 Engine and boiler went into the tug *Uraidla*. *Rob Roy* was usually in the Albany-Geraldton run, but in 1893 she was replaced by *Flinders*. By February 1896 *Rob Roy, Lubra* and *Flinders* were maintaining a twice-weekly service from Pt Adelaide to Esperance supplying the Norseman and Dundas goldfields. By 1898 *Flinders* alone maintained the run and *Rob Roy* was on standby in Port Adelaide until hulked.

Rodondo

Iron single screw steamship, ON79508, 1119g, 715n. B.1879 (Lloyds - 1873 (12)) W.H. Potter & Sons, Liverpool. 239.8 x 30.2 x 21.3. 1 dk & awning deck. Compound inverted direct acting steam eng, 150hp, blr 75 psi, by James Jack & Co, Liverpool. Owners:- W.H. Smith & Partners, reg. Melbourne Oct 1883 W. Howard Smith & Sons Ltd: registry transferred to Sydney 1885. Foundered after striking Pollock Reef, Western Australia Oct 7, 1894, vide Sydney Customs records.

APPENDIX 7

The 1983 predisturbance Survey

PRELIMINARY SURVEY OF XANTHO AND

INSTALLATION OF A CATHODIC PROTECTION SYSTEM

C.J. Beegle, I.D. MacLeod and N.A. North

W.A. Maritime Museum
Cliff Street
FREMANTLE
AUSTRALIA

Introduction:

The history of the Xantho and its present visible remains have been described earlier in this report. As the Xantho was an undisturbed shipwreck, it presented an excellent opportunity to examine the physical, chemical and biological status of an iron shipwreck in its stable long-term state. Studies of this nature are important both in terms of pure scientific research and in the application of that knowledge to the excavation and conservation of historic shipwrecks.

The Xantho was a steam powered iron hulled ship, typical of the first years of marine steam. Ships of a similar type are receiving increasing attention world wide as maritime archaeologists are starting to devote more attention to marine industrial archaeology. However, very little is known about rate and manner in which the ships material decays and corrodes, what type of problems are likely to be encountered when attempting to excavate or raise artefacts, or how to protect any significant sections which have to remain in situ after the excavation is completed. Our aim in carrying out this preliminary survey was to collect enough data to answer some of these questions, or at least pinpoint where further work is needed.

In terms of basic marine research, the Xantho is an ideal long term experiment in marine corrosion fouling and artificial reef formation. The shipwreck, although completely submerged at all times, stands 3 metres above the seabed for a considerable length in the stern and engine room sections. This area contains large quantities of cast iron, steel, copper, brass and some white metal. As this section is well above sand level it is freely available for colonization and growth of marine organisms. From the combined data on metal corrosion and the marine growth, it was hoped a better understanding could be obtained on how these effect each other. The significance of this interaction, particularly as regards metal corrosion, is often overlooked. This neglect is partially due to the long experimental times, of several years, before results of these interactions become apparent. The Xantho is a ready made test site which has been running for over 100 years. The type of information which can be obtained from the Xantho is applicable, in part, to other marine problems such as the formation of artificial reefs and protection of long term off shore facilities such as oil producing platforms.

Marine Growth:

Compared to the nearby barrier reef and benthic communities, the ecosystem of the Xantho appears to be somewhat of an anomaly. From personal observation and conversation with local divers the surrounding areas are all eel-grass communities with a large fauna of herbivores feeding on the eel-grass organisms seeking shelter and protection among the fronds. The Xantho, however, is a tunicate dominated community. The organisms colonizing the wreck were primarily sedentary filter feeders, particularly solitary ascidians, with upright and encrusting sponges and a few encrusting bryozoans. The algae present were small chrophytans on the upper light-rich areas (2.9 - 3.3m) and large phacophylans in deeper water (below 3.3m). Also observed present were several tube worms and a single crinoid. A complete list of macroscopic identified species will follow later.

Of the remaining structures of the ship, the most interesting area for study was the boiler. It's cubic structure (l(3.2m) x w(2.8m) x h(2.6m)) placed into such a strong current (3-5 knots) set up an interesting situation. The colonization in areas exposed to the current could be compared with successively more sheltered areas.

The orientation of the wreck and the current is illustrated in figure 1. The water conditions at each face will be described with reference to figure 1. The biological areas referred to in the description below are drawn in figure 2.

Top of Boiler

The surge was perpendicular to current, approximately 0.5m in amplitude.

Only within the shelter of the opening were tunicates found. These were generally smaller forms of 7-10cm overall length. On the exposed top (depth 2.9m) were generally encrusting sponges and small green algae. As the top sloped down towards its corners, large brown algae were present.

Forward Side

The current was only periodic along this face. There was a distinct demarcation of growth at the depth of 4.1m. Above this mark the life forms were like those at the edges of the top. However, below this line there were large tunicates (10-15cm overall length), large upright sponges (5-10cm high), and a few scattered red algae.

Port Side

Above 3.7m the prevailing current was full force, but below this depth there was only a mild surge along the plane of the face. The biology reflected the areas exposure to the current. Above 3.7m the biology was that of the top surface. However, at 3.7m down to 4.2m depth was a band of large brown algae. Then from 4.2m down to the bottom at 4.9m depth were encrusting sponges and some red algae. The species of this lower areas were the same as on the forward side except for the lack of tunicates.

Starboard Side

The current on this side was periodic but along the plane of the face toward the stern rather than from above, as one would expect. A band of large tunicates (10-15cm) with small upright sponges (5cm) and large brown algae was present from a depth of 3.3m down to 4.0m. There were a few scattered individuals of the above fauna from 4.0m down to the sandy bottom at 4.7m

Aft Side

The complicated structure of the aft side of the boiler caused more unusual water flow and more varied fauna. The current flowed along the plane of this face as one would expect. However, there was a periodic backflow of water in the other direction caused by extensions from the boiler to the engine. The area was covered with large brown algae from its upper extension of 2.9m down to its lower structural limit of 3.7m. The boiler endplate has a series of boiler tube holes of approximately 7cm in diameter. A few of the holes were utilized by crinoids and feather worms.

...emical Environment

The on-site sea water temperature during May 5th - 9th was 23°C ...d no thermal gradient was observed in the 3m-6m range. Because of the ...evailing strong current, approximately 3 knots, and storms that ...eceeded our inspection a mass of weed and sea borne grit gave a ...rbidity of 2.5 to 3.0 metres at the best but this often fell to less ...an one metre. The salinity of the water was measured by conducitivity ...d by coulometric titration (for chlorinity) and gave the value of ....53 parts per thousand. No direct measurements on dissolved oxygen ...re made, however, it is reasonable to assume that because of the strong ...rrent and shallow depth it was 100% saturation. The pH of the water at ...°C was 8.1 .

...rrosion Potentials

When metals are placed in oxygenated sea water they will begin to ...rrode. Positively charged ions are produced as the metal corrodes and they ...nd to diffuse away from the solid metal where they are either precipitated ... the surface or dissolve in the sea. Each metal corrodes at a rate that ...pends on variables such as temperature, dissolved oxygen, salinity, water ...vement and the inherent reactivity of the metal in relation to water. ...e reactivity of a metal is determined by the relative rates of reactions ... the metal and its ions with water. A reactive metal such as iron has a ...eater tendency to give off electrons than it has to accept them from ...ter under standard conditions; this is reflected in the relatively ...pid rate of corrosion that is found for unprotected iron surfaces. For ...tals such as copper the rate of accepting electrons from water under ...andard conditions is much faster than the rate of giving them up and ... much metals are deemed 'noble' since the overall tendency is for the ...tal not to corrode. A convenient way of comparing the reactivity of ...tals in aqueous media is gained by a comparison of the logarithm of the ...tios of the rates of forward (corrosion of metal) and reverse (reduction ... ions) reaction using the relationship

$$E^\circ = \frac{2.303RT}{nF} \log \frac{K-}{K+}$$

...ere K- is the rate of the reduction reaction and where K+ the rate of the ...idation reaction defined under standard conditions.

$$M^{n+} + ne^- \underset{K+}{\overset{K-}{\rightleftarrows}} M$$

... E° is called the standard potential and n is the number of electrons ...olved in the process (normally two for iron corrosion and one for copper ...sea water).

...s data is summarised as tables of standard potentials (E°'s) for metal/metal ion couples. Noble metals such as gold, silver and copper have positive E°'s while reactive metals such as iron, zinc and aluminium have negative values of E°.

Copper has an E° of +0.34 volts (it accepts electrons faster than it donates them to an acid solution) while iron has an E° value of -0.41 volts (iron has a greater rate of giving off electrons to a standard acid solution than it has of accepting electrons).

Since we are concerned with metals in a marine environment the solutions under consideration pertain more to sea water than to standard acid conditions. Because chloride ions alter the rates of many electrode processes (e.g. metal oxidation - metal reduction) the E°'s of the metals in "standard sea water" are different to those in ordinary water. Iron and less commonly copper and its alloys are often covered with a layer of marine growth which effectively places the metal in an environment which is different to normal sea water. Such environments tend to have a higher chloride concentration and lower pH and much lower oxygen concentration than ambient sea water since the concretions act in many ways as a semi permeable membrane which inhibits rapid transport of some ions and gases. Not surprisingly the voltages associated with the metals under such conditions are different to those found in reference tables.

When a metal is corroding one of two processes limits the rate of the dissolution/corrosion reaction; it is either the rate of the cathodic (reduction) process - which is commonly oxygen reduction or the rate of the anodic (oxidation) process (metal dissolution). For most cases involving concreted metals the rate reduction of oxygen is the controlling factor that determines how fast the object will corrode. The voltage of a metal object in the sea, will be dependent on how fast the metal is corroding and this is interdependent on the pH of solution adjacent to the corroding object. If we have a knowledge of the pH and the voltage of the corroding metal (commonly called the corrosion potential, Ecorr) we can tell whether the metal is immune (not corroding) passive or if it is actively corroding. Since the voltage is dependent on both the metal oxidation and cathodic reduction process the voltage is also known as a "mixed" potential.

The corrosion potentials were measured in situ using a high impedence digital multimeter (Fluke 8010A), a platinum electrode (0.8mm thick) housed in an expoxy body and a silver/silver chloride reference electrode (Titron model No. 211). Sea water was used as the reference solution. The procedure consisted of drilling into the concretion (using a ¼" masonary bit and a hand drill) and placing the platinum electrode into the hole while pressing firmly to establish good electrical contact; the reference electrode was placed adjacent to the hole and the voltage measured. For the resistance survey the reference electrode was replaced with a stainless steel probe.

The results of the survey are shown in Table I and also shown in a diagramatic way in figure which shows the Pourbaix diagrams for iron and copper in sea water. A Pourbaix or voltage/pH diagram is a convenient way of summarising thermodynamic data pertaining to metal in aqueous solution. An immune area is a region of pH and Eh (voltage relative to the normal hydrogen electrode) in which the metal will not corrode, an active region is one where the metal is undergoing corrosion and passive zones are areas where the corrosion has been inhibited by the formation of a passive film/corrosion product. Although in situ pH measurements were not done on the wreck material we have estimated the pH of the metal under concretion on the basis of our previously published data on iron and copper based concretions. When the iron concretion was being drilled bubbles of escaping gas were occasionally observed - the gas is mainly hydrogen and light weight hydrocarbons that are formed as a result of the corrosion process.

Inspection of the Pourbaix diagram shows that the potential of the frame plates lies on the hydrogen discharge line viz. at such potentials and pH water is in equilibrium with one atmosphere of hydrogen gas. Seventeen of the twenty-five sites measured had a corrosion potential of -0.268±0.006 V vs NHE (or -0.539 vs AgCl seawater); in effect this shows that they are all in essentially the same corrosion microenvironment. From the observed relationship between corrosion currents and voltage in laboratory experiments the standard deviation of ±6 mV means that the rates of corrosion are within fifty percent of each other. The difference of 113 mV between the corrosion potentials of the deck winch and the frame plates near the stern reflects a ten fold difference in their relative corrosion rates. The value of -0.113 volts for the windlass is typical of potentials where no solid metal remains and this was indicated when the drill bit penetrated to a depth greater than 10cm.

All the potentials observed or the non ferrous fittings show that they are all in the immune (for copper and brass) or passive zones (white metal on crankshaft bearings) - see the copper Pourbaix diagram. The corrosion potentials of the brass/bronze oil cups and valves are largely determined by the iron corrosion potentials since the objects are in electrical contact with the iron metal which has a much larger surface area. Although the copper and iron fittings have the same potential the results are different; copper/brass will not corrode and iron is actively corroding. The concretion layer observed on the brass and copper fittings was a few mm thick and consisted of a dense white calcareous deposit. Because of the galvanic protection provided by the corroding iron the copper based alloys act as cathodic sites in the corrosion cell and this causes the surface pH to increase and inorganic calcium carbonate as calcite/aragonite precipitates on the metal. Once this "protective" layer of $CaCO_3$ covers the biologically toxic metal corrosion products the surface is then subject to normal colonization by marine organisms. The $CaCO_3$ layer is fairly dense since under its protection some of the Cu_2O on the metal surface had been converted to Cu_2S through the action of sulphate reducing bacteria. The less negative potential for the copper tubes and case on the condensor is simply due to the different corrosion rate of the condensor to which it is still connected.

Although the corrosion potential of the white metal bearings on the crankshaft is -0.268 volt vs NHE is outside the immunity range for lead it is in a region of stability of passivation through lead sulphate (anglesite) formation. On site inspection suggested that the 2.5mm film covering the bearings was a mixture of anglesite and calcite ($PbSO_4$ and $CaCO_3$ respectively).

TABLE I

Corrosion potentials[1] recorded on the Xantho wrecksite

Object	Potential	Notes
Propellor blade, shaft and shaft bearing	-0.269	iron fitting, rapid gas evolution on shaft.
Frame plates hr. stern	-0.280	gas bubbles escaping
Plating near stern	-0.267	iron
Crankshaft; bearings, crank and oil cup	-0.267	bearings white metal oil cup is a copper alloy
Connecting rod, "A" frame trunk and engine block	-0.265	very solid
Trunk stuffing block	-0.271	
Boiler	-0.270 to -0.283	concretion approx. 4mm thick
Deck winch	-0.214	gas on wheel, conc. approx. 50mm thick. Measured centre axle also.
Stem post	-0.253	
Condensor, case end	-0.163	copper case, iron end
Windlass	-0.103	no solid metal, drill in > 100mm
Large copper piping	-0.202	near boiler
Small copper piping	-0.244	engine fittings
Oil cups and brass valves	-0.268	piston cup

[1]Voltages were measured using a Ag/AgCl sea water reference electrode which was calibrated using the Pt electrode in a Quinhydrone solution at pH 4.0 . Voltages have been converted to the NHE scale.

Mineralogy of Ore Cargo

One possible explanation for the lack of gross concretion on the engine was that the sea water may have leached out biologically toxic material from the galena (lead sulphide, PbS) cargo in the hessian bags. The lode from the Geraldine mine, situated on the Northampton river, was almost pure galena and the associated minerals were lead carbonate, zinc blende, iron pyrites, a blue slatey clay and quartz. There were no arsenic or mercury minerals present and so the possibility that poisoning from such sources could be ruled out. Examination of some of the remaining galena showed some oxidation of the PbS to lead sulphate ($PbSO_4$) and some laurionite (Pb OH Cl). The approximate solubility of lead from $PbSO_4$ in sea water is 0.4 ppm but at this level it is unlikely to have had any significant effect on the colonization or growth of the marine organisms - see section III on colonization and speciation.

Cathodic Protection

To make detailed drawings of the historically important engine, it was necessary to remove a lot of the living marine growth from the engine. In this clearing only loosely attached material was removed. The hard calcareous concretions which covered the steel and cast iron were deliberately not disturbed as removal of this material produces accelerated corrosion of the underlying metal.

The clearing of the engine area caused a considerable quantity of copper and brass fittings to become readily visible to any casual diver, and hence an obvious target for pilfering. Some minor damage had also occurred to the protective iron concretions through accidents and by holes drilled into it during the potential survey (see above). In order to accelerate the regrowth of marine organisms on the copper alloys and to protect the iron from corrosion attack, a sacrificial cathodic protection system was attached to the engine.

In broad terms a sacrificial cathodic protection system consists of a highly reactive disposable metal which is in electrical contact to a less reactive metal. This forms a galvanic couple with the more reactive (and expendible) metal suffering increased corrosion attack with the less reactive metal, usually steel, being protected against corrosion. Detailed explanations of cathodic protection are readily available with several standard text books on this subject.

Apart from corrosion control there are some side effects of cathodic protection which made it desirable for use on the Xantho engine. Firstly the action of the cathodic protection generates alkali at the surface of the protected metal and thus raises the pH of the seawater at this surface. This rise in pH causes a white deposit, mainly calcium and magnesium carbonate, to precipitate out of the seawater. This deposit coats the protected surface and thus hides the metal under a paint-like layer. It was hoped that this white coating would camouflage the copper alloys and render them less obvious to a casual diver. On the iron sections, the white deposit will block up and fill in any holes in the concretion which were produced during the survey work.

Under normal conditions the copper alloys are unsuitable sites for marine growth as the copper corrosion products are toxic. With cathodic protection no new copper corrosion products are formed and those already present are slowly converted back to metallic copper. This eliminates the biological toxicity of the copper and thus allows normal colonization and growth of marine organisms, which further obscures the copper artefacts from casual divers.

Design and Installation

For a metal to be cathodically protected it must be in electrical contact with the anode; that is, metal to metal contact. Whilst it is a relatively simple matter to attach anodes to a point on the engine, this will not give protection to the rest of the engine if that is not electrical continuous to the point of anode attachment.

Electrical continuity was determined before attaching anodes. This was done by measuring the electrical resistance between different points on the engine and associated metalwork. On land it is easy to determine if two points are in electrical contact from resistance values between those points; a contact gives zero resistance, no contact gives infinite resistance. In seawater this is complicated by the ability of seawater to conduct electricity. In seawater, a metal to metal contact will show zero resistance but a metal/seawater/metal pathway may only show a few ohms resistance. In practise a further problem arises due to the difficulty in making a good contact between components. For convenience most of the resistivity survey was carried out using one, or both, resistance probe in contact with either copper or white metal.

The resistivity survey showed that the engine formed a single conducting unit which was also electrically bonded to the propellor shaft. Most of the copper pipework attached to the engine was also in electrical contact with the engine but there was no metal-metal contact from the engine to the hull remains or to the boiler and condensor.

Following the resistivity survey it was decided to install two protective anodes on the engine remains. Each anode consisted of a 2kg magnesium anode welded to a 25kg aluminium anode. Sufficient cable was used to place the anodes outside the hull remains, and at sufficient distance from the engine to give a good current spread (see diagram 1). The anode cables were welded to a clamp system which was then clamped onto an engine component (see diagram 2). Each clamp was individually designed to fit that particular attachment point. The points chosen for attachment were the propellor shaft and a white metal bearing. These points were chosen on the basis of ease of attachment and suitability for forming a good electrical contact. Before attaching clamps each point was deconcreted back to the residual metal. No apparent problems occurred during installation.

Discussion

Marine Biology:

One might assume that after 110 years of submersion the ecosystem set up on the Xantho site would be stabilized. A comparison of the present-day flora and fauna with that far in the future would be the only way to tell for certain. The striking difference between the wreck site and the surrounding areas point toward some twist in development. Two possibilities seem most likely. The first possibility is that the Xantho community has not fully "matured". In time the wreck site may be the same as the surrounding areas are now. This would mean that these other areas went through a similar stage, and evidence may be present.

Another hypothesis is that the structure of the substrate affects the colonization more than is currently believed. In natural systems, new substrates generally become available only slowly as by the rise in sea level after an ice age. Such new areas are generally continuous with the old ecosystem so the colonization is more an expansion of the old ecosystem's boundaries than a new invasion. At a shipwreck site, the situation is markedly different. Suddenly a large area of fresh substrate, spanning a range of depths, is available for colonization. The colonization of such large areas would not feel the pressure of the surrounding life forms as much as the natural system would. Once a foothold was gained, the new life forms might be able to keep the local ecology out. Hence, the differences in biology. Evidence for this is found when comparing wrecks in different situations.

The Lygnern (1928) and Samuel Plimsoll (1948) are in a similar situation to the Xantho. The two lie in Cockburn Sound, one atop the other, on a sandy bottom. The only structure close by is a shipping channel masker with its mussel community. The vessels are not intact, but structures several metres high off the bottom are still evident. The ecosystem here is very similar to Xantho. High light areas are covered by large phaeophytans (brown algae) and darker areas show the same tunicate dominated community as seen on the Xantho. Another wreck which appears to be developing the same way is the Cheynes III (1982) located in Albany [illegible]. However, it is much too early to really tell in which direction the Cheynes III will develop.

Such wrecks as the Lady Elizabeth (1878), the Rapid (1811), and the Batavia (1629) show a very different development. These wrecks are located on rocky bottom where the wreck is in contact with the local flora and fauna. Also the structures have collapsed so very little material extends more than a metre or two off the bottom. The wooden wrecks have assimilated the local ecosystem quite well. It is also possible with these wrecks that a tunicate community existed up until the time of collapse, at which point the local community took over. Observing the development of a shipwreck beyond its collapse would be the only way to solve this mystery.

These findings raise some questions about the current practices in building artificial reefs to promote the local biology. Today artificial reefs are built as a final complete units much as an intact shipwreck. It would appear that a better way to build these would be in layers perhaps not more than a metre in height. Each new layer could be added after the previous layer had developed the local flora and fauna. These structures would be more like the low lying reefs which do pick up the local ecosystem.

Corrosion:

The potential survey on the metal structures of the shipwreck gave three items which can be related to the condition of the underlying metal. These are potential, presence of entrapped gases and depth to solid metal. From these we can estimate the condition of the underlying metal.

The engine and boiler are in relatively good condition and show low potentials, no significant gas evolution and metal close to the original metal surface. The non-ferrous components of the engine and boiler are all in excellent condition with potentials too low for active corrosion.

The hull remains are in fair condition with the amount of corrosion attack being higher in the forward areas than in the stern. These are a doubtful proposition for excavation and a large amount would be lost due to the already advanced state of corrosion.

The windlass appears to be very badly corroded and, although its shape is well preserved by concretions, there is unlikely to be any solid metal remaining. Similarly with the condensor, the potentials indicate that iron is very heavily corroded but the copper components should be in good conditions beneath the concretions.

Conclusion:

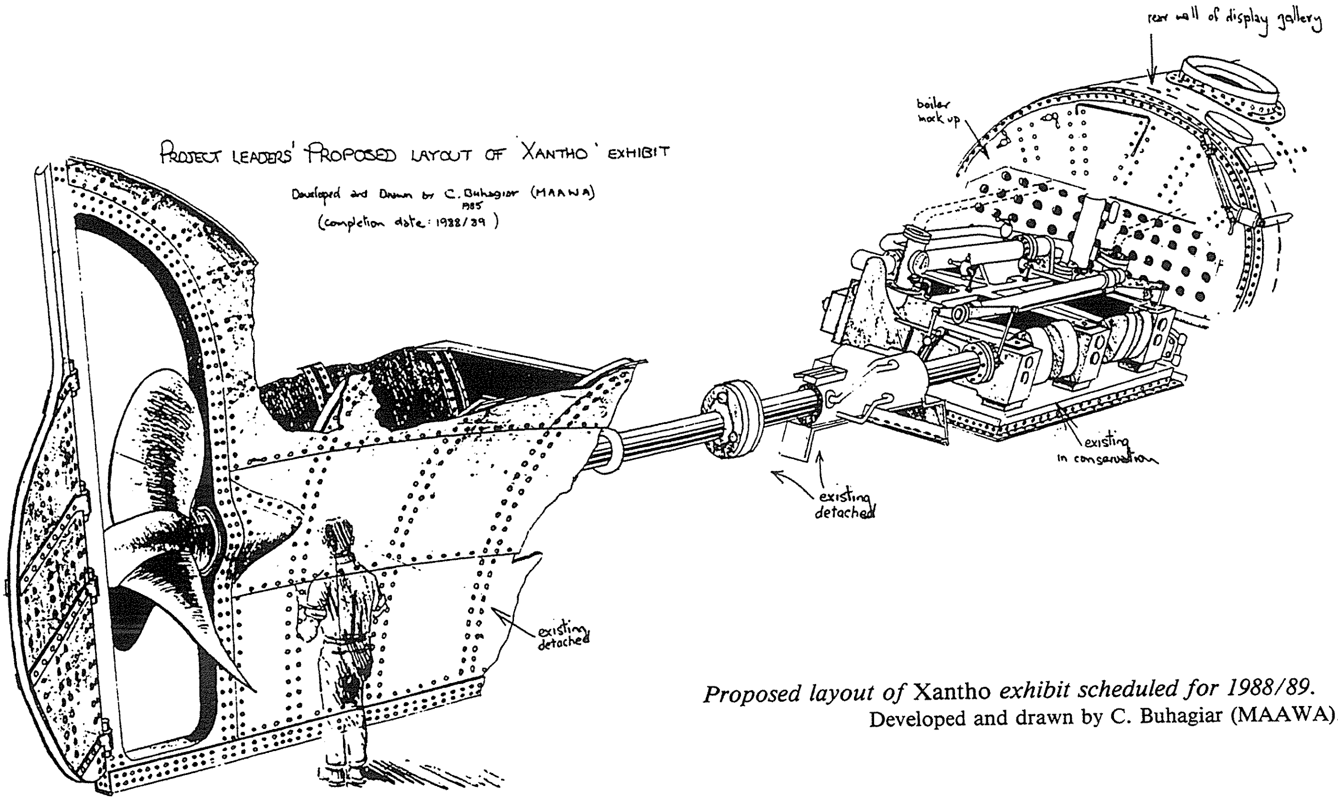
As a result of this initial survey the boiler and engine had been cleaned of the bulk of the marine growth and a cathodic protection system had been installed on the engine. In the next site inspection the main aims will be examination of the biological regrowth and monitoring of the cathodic protection effects.

As the initial survey was carried out before the site was disturbed, we have virtually unique data from which to assess changes in the wrecksite. The biological data provides a baseline against which the regrowth can be compared. The potential survey provided the baseline against which we can determine exactly the extent of cathodic protection being achieved on each part of the wrecksite. The resistivity survey showed there was no electrical contact between the engine and the boiler. If the forthcoming potential survey confirms this then we will be able to compare the biological regrowth in the presence (engine) and absence (boiler) of cathodic protection.

By having the opportunity to carry out this work before the shipwreck was disturbed we were not only able to provide information on the condition of artefacts before they are excavated but we will also be able to document exactly the effects of partial cleaning of marine growth and cathodic protection on an iron shipwreck. Neither of these has previously been studied and indeed, cathodic protection has never previously been applied to an historic shipwreck. In scientific terms the data obtained to date are highly significant.

APPENDIX 8:

The 1985 concept plan for the exhibition of the Xantho engine and stern.[1]
and
The *Xantho* artefact catalogue



Proposed layout of Xantho *exhibit scheduled for 1988/89.*
Developed and drawn by C. Buhagiar (MAAWA).

[1] By Chris Buhagiar, MAAWA. The boiler is to be a mock-up McCarthy (1988c : 189).

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 1

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA0	CW	TUB 15 WET ROOM	82 1	Hull plate		
XA0	CW	TUB 65 WET ROOM	84 1	Drum		
XA0	0		32 2	Lubricator box,+ 1screw, brass		1 NOV 88
XA0	CW	TUB 14 WET ROOM	84 1	Cast iron steam dome-deconc. inside.		
XA0	CW	TUB 61 WET ROOM	86 3	Concretion unid.		
XA1	MAX	Check this location.	32 4	Ring 17cm, brass + a piece of its glass; case gin bottle + stopper.		1 NOV 88
XA2	MAX	Check location?	22 0	Blue transfer ware ceramics, sherds		
XA3	MAX	Check location.	46 1	Boot sole		
XA4			44 1	Deck skylight		
XA5	CL	JC ROOM	8 3	Graphitised pieces No.1		
XA5	CL	JC ROOM	8 1	Graphitised pieces No.2		
XA5	CL	JC ROOM	8 1	Graphitised pieces No.3, corners		
XA5	CL	JC ROOM	8 1	Graphitised pieces No.4		
XA5	CL	JC ROOM	8 1	Graphitised pieces, Crank webs and flanges No. 5		
XA5	CL	JC ROOM	8 1	Graphitised pieces,Edges scotch yoke-port pump No.6		
XA7	MME	X3?? MAX	32 1	Knob, [handle], brass	10 AUG 83	
XA8	MME	X7? MAX	32 1	Screw plug, brass, w/ cork inset ?	12 MAR 83	
XA9	MAX		44 1	Light globe, part only - the center. Composite of glass and metal.	13 MAR 83	
XA10	MAX	Organic	46 1	Rope frags.Found on a large concretion w/ wood and iron.	13 MAR 83	
XA11	MAX	23/6/92	61 1	Lining from forepeak, ceiling-for analysis.	13 MAR 83	
XA12	MAX		68 1	Coconut husk section	13 MAR 83	
XA14	MAX		41 1	Bone	13 MAR 83	
XA15			49 1	Clay, grey	13 MAR 83	
XA16	MAX		67 0	Twigs, loose - contamination or dunnage	14 MAY 83	
XA17	MAX		44 1	Sherd, thick clear glass, fractured,feathered pattern	15 MAY 83	
XA18	MAX		44 2	Sherds, thin green glass- case bottle frags ?	15 MAY 83	
XA19	MAX		86 1	Iron concretion - Xray. Treated in furnace = 2 nails.	16 MAY 83	
XA20	MAX		61 1	Screws, wood -a piece of stick returned this no'.	16 MAY 83	
XA21	CL	21	25 1	Fire brick, from boiler insulation.	16 MAR 70	
XA22	MAX		41 1	Bone- large vertebrae	18 MAY 83	
XA23	MAX		61 2	Timber pieces ; hull underneath stbd side stern block.	18 MAY 83	
XA24	MAX		44 0	Glass frags; very thin, clear, some darkened. probably part of light bulb + shade.	19 MAY 83	
XA25	MAX		44 0	Sherds, clear glass, green tint 1111 pattern- striated window glass.	19 MAY 83	
XA26	MAX		44 1	Sherd, very thick clear glass, green tint	19 MAY 83	
XA27	MAX		44 1	Sherd, clear glass, green tinge - 4mm	19 MAY 83	
XA28	MAX		44 2	Sherd, green glass, thin clear- 3mm	19 MAY 83	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 2

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA29	MME	X2	44 1	Sight glass- water gauge from boiler	19 MAY 83	
XA30	MAX		61 1	Timber w. tonque	19 MAY 83	
XA31	MAX		64 3	Timber scraps	19 MAR 83	
XA33	MAX		49 1	Rubber strip	19 MAY 83	
XA34	MME	X7. MAX?	14 1	Sharpening stone, part only	19 MAY 83	
XA35	MAX		44 1	Sherd- thin dark green glass-case bottle	19 MAY 83	
XA36	MAX	23/6/92	68 1	Stick, small piece	18 MAY 83	
XA37	MAX		34 7	Flange, lead + 6 brass nails	20 MAY 83	
XA38	CFG	Tank J	41 1	Whale bone, long	20 MAY 83	
XA39	MAX		32 1	Ring possibly from guage cover, brass. See 346	20 MAY 83	
XA40	MAX		41 1	Teeth set in part of jaw.	20 MAY 83	
XA41	MME	MA X organic	47 1	Hessian. Sacks contained galena ?		
XA43	MAX		44 2	Bottle frags,dark green glass. Square, Seal w/ an eagle and mark.Round one seam	15 JAN 84	
XA44	MME	X3	86 1	Can(oil), concretion, flat	15 JAN 84	
XA45	MAX		44 0	Glass frags, thin white	16 JAN 84	
XA46	MAX		44 0	Glass frags, thick	16 JAN 84	
XA47	MAX		61 1	Wood	16 JAN 84	
XA48	MME	X3	32 1	Cylinder w/ diamond hole, brass	16 JAN 84	
XA49			32 1	Hook, brass	16 JAN 84	
XA49	MAX		32 1	Cup hook, brass.	16 JAN 84	
XA50	MME	X2	31 1	Mushroom valve, bronze	16 JAN 84	
XA51	MAX		41 1	Bone, jawbone	16 JAN 84	
XA52	MAX		44 0	Glass frags, striated	16 JAN 84	
XA53	MAX		64 1	Pulley block iron /wood	16 JAN 84	
XA54	CWJ	TUB 64 WET ROOM	86 4	Iron conc.	16 JAN 84	
XA55	CWA	TUB 63 WET ROOM	86 0	Composite, Glass/iron/wood	16 JAN 84	
XA56			66 1	Wood frag		
XA57	CC		88 1	Steam Engine - composite = brass,bronze, wood...	18 APR 85	
XA58			32 2	Oil cans in flat tray-concreted	18 APR 85	
XA59	MME	X2	44 1	Sight glass- boiler guage for water levels	19 APR 85	
XA60			44 1	Sheet glass, ribbed	19 APR 85	
XA62			44 2	Sheet glass, flat, rubbed + dark bottle glass frag	19 APR 85	
XA63			1	Bar section, rounded, concreted to iro	19 APR 85	
XA64			88 1	Unid. - soft flat layered sheet-for analysis	19 APR 85	
XA65	CWJ	TUB 60 WET ROOM	86 1	Scissor concretion	19 APR 85	
XA66			49 1	Concrete piece- broken	19 APR 85	
XA67			44 1	Sherd, striated glass	19 APR 85	
XA68	CW	Glass tub 6	44 1	Sherd, clear glass	19 APR 85	
XA69			1	Valve small, brass/ plug cock in 4 se	20 APR 85	
XA69A-D	CWJ	WET ROOM/TUB 1	82 4	Bolts/nuts	19 APR 85	
XA70			44 1	Case bottle base	20 APR 85	
XA70C	CWJ	TUB 9 WET ROOM	8 3	Bolt threaded/loose washer/ cast iron frag.		
XA71			44 2	Sherds, clear glass. Thickness = 10mm; 7mm.	20 APR 85	
XA72			88 1	Unid. soft flat layered sheet. See XA 64	20 APR 85	
XA73			88 1	Unid. possibly part fish bone	20 APR 85	
XA74			44 1	Boiler guage, glass, part only	20 APR 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 3

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA75			44 2	Glass frags. thickness - 10mm for one the other is rubbed.	20 APR 85	
XA76	MME	X7	32 1	Lid w/ screw cap, brass	20 APR 85	
XA77	MME	X3	32 1	Hook, large, brass	20 APR 85	
XA78	MA		32 3	Hooks, brass for cups ?	20 APR 85	
XA79	MME	X3	32 2	Hook, brass, for cups ?	20 APR 85	
XA80	MAX		34 1	Fishing sinker,spoon type	20 APR 85	
XA81			44 1	Flat, thin glass frag	20 APR 85	
XA82			44 1	Glass frag, fine curved and clear	20 APR 85	
XA83			44 1	Flat glass - 4mm	20 APR 85	
XA84			32 1	Hand rail support, bracket, brass	20 APR 85	
XA85	CWJ	tub 60	83 1	Scissor concretion`	20 APR 85	
XA86	MAX		32 1	Sheet piece, brass,sections cut out.	20 APR 85	
XA87			26 1	Paving stone, fire brick-broken	20 APR 85	
XA88	CWA		64 1	Unid. length of wood	20 APR 85	
XA89			32 1	Tube w/ flange. copper	20 APR 85	
XA90			34 1	Tube? Bar inside, possibly wood too. Investigate	20 APR 85	
XA91			11 1	Slate frags - concretion	20 APR 85	
XA92	MME	X3	32 1	Handle, brass- coat hook	20 APR 85	
XA93			44 3	Flat glass, fine	20 APR 85	
XA94			44 3	Glass, striated - 2 pieces + 1 curved piece	20 APR 85	
XA95			44 1	Fragment, glass- 6mm thick	20 APR 85	
XA96			44 1	Bottle glass frag, green	21 APR 85	
XA97	MME	X3	32 2	Keys, brass	21 APR 85	
XA98	MA	Storage	32 1	Butterfly catch, brass	21 APR 85	
XA99	0		32 1	Lid w/ ring, brass, screw each side	21 APR 85	
XA100	MA	Storage	32 1	Eyelet, brass w/ thread	21 APR 85	
XA101			0			
XA101			44 2	Glass frags, clear and striped	21 APR 85	
XA102			44 3	Glass frags, clear	21 APR 85	
XA103	MA	Storage	32 2	Screws, brass	21 APR 85	
XA104			46 1	Hessian frag	21 APR 85	
XA106			32 3	Boiler guage - brass, w/ hand and conc seperate	21 APR 85	
XA107			49 1	Rubber piece	21 APR 85	
XA108			44 4	Glass frags- striped, thick, case bottle + plain	21 APR 85	
XA109			44 1	Lamp glass, complete	21 APR 85	
XA110			44 0	Glass frags, large, thin	21 APR 85	
XA111			32 1	Plate w. rivets, brass + soft material on reverse.	21 APR 85	
XA112	MAX	organic	67 0	Box + matches	21 APR 85	
XA113			32 1	Hand rail w/ part bracket w/ pitch inside	21 APR 85	
XA114	CWA		64 1	Unid wood, part furniture or fitting, could have putty or paint in it.	21 APR 85	
XA115			44 3	Salt cellar, rectangular glass, + 2 small frags	21 APR 85	
XA116			32 1	Key, brass in conc	21 APR 85	
XA117	CFG	Tank J	44 7	Bevelled glass	21 APR 85	
XA118			44 1	Ribbed glass piece	21 APR 85	
XA119	MMX		32 3	Spigot, brass- tap center valve + 'washer /pipe'		1 NOV 88
XA119A	MMX		32 1	Cylinder with diamond hole, brass		1 NOV 88
XA120	MMX		32 1	Knob, [handle] brass	21 APR 85	1 NOV 88
XA121	CLV		32 1	Oil can,brass- incomplete	21 APR 85	
XA122			44 1	Glass- 90mm	21 APR 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 4

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA123			44 1	Boiler guage, glass	21 APR 85	
XA124			44 1	Ribbed glass	21 APR 85	
XA125			44 6	Striated glass frags	21 APR 85	
XA126			44 1	Striated glass `	21 APR 85	
XA127	CWJ	TUB 61 WET ROOM	86 1	Bar	21 APR 85	
XA128			26 1	Tile section - 70mm wide. Similar to 87	22 APR 85	
XA129			61 2	Wood pieces, pine - 40 mm thick	22 APR 85	
XA130	CWA		34 1	Strip, w/ nails ?	22 APR 85	
XA131			44 1	Glass pieces, part of bottle or lamp glass	22 APR 85	
XA132			44 1	Glass frag- 70mm thick	22 APR 85	
XA133			44 2	Glass frag 70 mm thick + dark glass frag.	22 APR 85	
XA134			44 4	Bottle frags, dark glass	22 APR 85	
XA135			44 1	Glass piece, large - 10 mm thick	22 APR 85	
XA136	MMX		32 4	Tap, brass- 'valve/ handle ' washer /nut	22 APR 85	1 NOV 88
XA137			44 1	Glass piece, 100 mm.	22 APR 85	
XA138	MME	X1	32 1	Valve, brass- includes 3 screws, 1 cu pipe, 1 valve= 5 sections - main part. C+ D holes are flange for 2 screws, E = valve centre.	23 APR 85	1 NOV 88
XA138A-D	CWJ	TUB 8 WET ROOM	32 4	Nut/bolt		
XA139			32 1	Spare con rod (+ surroundng conc. - crank shaft) containing glass boiler guage. brass	23 APR 85	
XA140			48 1	Whale vertebrae	23 APR 85	
XA141			25 1	Brick	23 APR 85	
XA142	CWA		64 1	Wood, part of furniture? - Jarah?	23 APR 85	
XA143			0 1	Unid. layered sheet- for analysis	23 APR 85	
XA144			46 1	Hessian frag (bag corner)	23 APR 85	
XA145			49 1	Clay sample (greyish color)- unid. sand w/ stuff from anodes	23 APR 85	
XA147			46 1	Rope and matting	2 MAY 85	
XA148			21 1	Bowl section w/ wide rim-asiatic pheasant	2 MAY 85	
XA149			44 0	Case bottle frags, green - falcon seal + mark.	2 MAY 85	
XA150			2 1	Plate frag, white w/ blue rim-shipware	2 MAY 85	
XA151			2 1	Fragment, transferware, blue and white	1 MAY 85	
XA152			0 1	Unid white gel, possibly in assoc. with anodes	2 MAY 85	
XA153			44 0	Glass fragments, approx 3/8 " thick	2 MAY 85	
XA154	MA	Storage	32 1	Strap w/ screw fastening, brass w/ lead core	2 MAY 85	
XA155			0 1	Unid, similar to 64 and 72	2 MAY 85	
XA156			86 1	Conc. iron		
XA157			67 8	Wood w/ lead covering and copper aloy nails- 7	1 MAY 85	
XA158	CWJ	TUB 61 WET ROOM	8 1	Flange??? and Rod.	1 MAY 85	
XA159			32 1	Pipe, copper 2" diam and pprox 1.7 m long	2 MAY 85	
XA160	MAWG		67 1	Tree branch, bark removed, light yellow brown	2 MAY 85	
XA161			86 1	Conc. w/ metal pipe	2 MAY 85	
XA162	MAWG		67 1	Tree branches w/ dark brown bark	2 MAY 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 5

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
A163	MAWG		67 1	Tree branches w/ dark brown bark	2 MAY 85	
A164	CWA		67 1	Branch section, w/ dark brown bark, reddish color	2 AUG 85	
A165			44 11	Glass pieces, striped texture	3 MAY 85	
A166			44 1	Glass piece, plain	3 MAY 85	
A167			44 1	Tube glass frag	3 MAY 85	
A168	CWA		6 1	Unid. piece of wood w/ white paint, 2 holes	3 MAY 85	
A169ABCD	CFG	MAX	64 6	T-piece, softwood - possibly from carling or deck w/ some concretion and metal ring & 4 large nails	3 MAY 85	
A170	CWA		6 8	Wood, reddish brown	3 MAY 85	
A171	CWJ	TUB 61 WET ROOM	86 2	Conc.		
A172	CWJ	TUB 61 WET ROOM	86 1	Plate Cast iron		
A173			44 1	Glass frag, clear	3 MAY 85	
A174	CWJ	TUB 73 WET ROOM	82 1	Flange. Register reads concretion, wood, glass. Drum = 174 only	3 MAY 86	
A175			29 1	Fragment, white glazed, curved w/ 2 ridges.Porcelain.	6 MAY 85	
A176			32 1	Rivet type object	6 MAY 85	
A177			41 1	Whale bone rib	6 MAY 85	
A178	MME	X3	32 1	Hinge, brass		
A179	MME	X2	32 1	Valve, brass and sight glass tube	7 MAY 85	
A180	MA	Storage	32 4	Valve, brass- for engine glass - some glass in situ.		
A180	CLV		32 4	Sight glass, pieces	6 MAY 85	
A181			34 1	Pipe, lead	7 MAY 85	
A182	MAX		34 2	Collar sections w/ nail holes	7 MAY 85	
A183			86 1	Concretion - rock	7 MAY 85	
A184	MME	X3	32 1	Spigot tap, brass	7 MAY 85	
A185	CWJ	TUB 59 WET ROOM	86 1	Flange- Concretion w/ lead plate and copper nails	7 MAY 85	
A186			32 1	Pipe, copper or conc of iron rod	7 MAY 85	
A187	CWJ	TUB 61 WET ROOM	82 3	Bar	7 MAY 85	
A188	CWJ	TUB 21 WET ROOM'	82 1	Bar w/ looped ends	7 MAY 85	
A189	MME	X1,X9	32 1	Pipe, copper- Engine room (pump) Port - check register description pp13. + gasket Approx 3"	8 MAY 85	
XA190	MME	X2	32 1	Valve, brass	8 MAY 85	
XA191AB			32 2	Valve, brass. Nails x4	8 MAY 85	
XA192			34 5	Flange, lead + 4 alloy nails	8 MAY 85	
XA193			44 4	Pane glass, clear	8 MAY 85	
XA194			1 1	Stone ? slag?	8 MAY 85	
XA195			25 5	Bricks, 4 white 1 red. E= red	8 MAY 85	
XA196	CWJ	TUB 9 WET ROOM	82 1	Nut, from pump, port engine room	8 MAY 85	
XA197			44 5	Glass frags w/ striped texture	7 MAY 85	
XA198			2 1	Ceramic frag, white glaze w/ blue line - shipware	7 MAY 85	
XA199			44 1	Sheet glass, plain, 10 mm thick	7 MAY 85	
XA200			0 1	Unid. probably cement	7 MAY 85	
XA201			8 1	Propeller piece ?	7 MAY 85	
XA202			44 1	Glass frag, striped texture.	7 MAY 85	
XA203			6 1	Wood frag - burnt. Possibly fuel.	7 MAY 85	
XA204	CWJ	TUB 61 WET ROOM	84 1	Can, oil, large. ??? in concretion	10 MAY 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 6

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA205			44 1	Glass frag	10 MAY 85	
XA206	CW	Tub 4?	44 0	Glass frags	10 MAY 85	
XA207	MA	Storage	82 1	Bar, bent	10 MAY 85	
XA208			32 1	Plate section w/ rivets. copper ?	10 MAY 85	
XA209			44 0	Glass frags,	10 MAY 85	
XA210	MA	Storage	46 1	Leather frag, tiny	10 MAY 85	
XA211A			46 1	Rope frag	10 MAY 85	
XA211B	MAX		32 1	Sheathing tack	10 MAY 85	
XA212			32 1	Sheet frag, copper	10 MAY 85	
XA213	MAWG		25 13	Brick = 6 ; 7 tiles + frags	10 MAY 85	
XA214	CFG	Tank J	41 1	Whale bone, large lump, in conc?	10 MAY 85	
XA215	MAX		32 6	Flange, wood with lead sheathing, in concretion w/ 5 alloy nails	10 MAY 85	
XA216			46 1	Rope w. knot= modern ??	2 MAY 85	
XA217			32 7	Valve, brass. See 179	14 MAY 85	
XA219	CWJ	TUB 64 WET ROOM	86 2	Concs. (2 bags)assoc with engine	14 MAY 85	
XA220			61 1	Plank, wood = 18 " assoc. w/ engine conc. and 221	4 JUN 85	
XA221			61 1	Plank, wood = 3ft. associated w/ engine conc.	4 JUN 85	
XA222	CWJ	TUB 24 WET ROOM	32 1	Brushes, composites. Copper. Not part of the engine.	17 MAY 85	
XA223			46 1	Rope frags	17 MAY 85	
XA224			46 1	Rope frags	17 MAY 85	
XA225			46 1	Rope frags	17 MAY 85	
XA226	CWJ	TUB 51 WET ROOM	82 1	Aft slide valve spindle	17 MAY 85	
XA227	CWJ	BLUE RACK	82 1	Nut frags, hexagonal	17 MAY 85	
XA228			86 1	Shackle conc. Holes attached to rope ??	17 MAY 85	
XA229	MME	C6	32 1	Steam Pipe, copper	15 MAY 85	
XA230			46 1	Rope frags	15 MAY 85	
XA231A	CWJ	BLUE RACK- 12 = rope /11= iron.	46 1	Rope frag	20 MAY 85	
XA231B	CWJ	BLUE RACK	82 1	Thimble, iron	20 MAY 85	
XA232	CWJ	TUB 51 WET ROOM	86 2	Nut casts- forward pump- 6 sided, neat circular centre- from aft handle.	20 MAY 85	
XA233			2	Casts from spare con rod- complete flange in	20 MAY 85	
XA234	MA	Storage	82 1	Steam pipe flange frags	20 MAY 85	
XA235	CWJ	TUB 24 WET ROOM	32 1	Brushes, copper	20 MAY 85	
XA236			32 1	Handle (tool) w/ thread, brass - transverse, iron section erroded away.	20 MAY 85	
XA237AB	MME	X4	32 4	Oil cup, aft, brass(A); tube, copper (B) + 50 mm copper wire (twisted) + folded lead 10 mm sq.	20 MAY 85	
XA238			44 0	Site glass frags and flat frags.	20 MAY 85	
XA239			86 1	Fore suspension link - cast	20 MAY 85	
XA240			82 1	Bar, cast iron -square	20 MAY 85	
XA241			88 2	Unid iron w/ nuts - possibly shackle conc.	20 MAY 85	
XA242	MA	Storage	32 1	Pipe frag, copper	25 APR 85	
XA243	MME	C6	32 1	Pipe, copper- ex pump port	20 MAY 85	
XA244			86 2	Wiperarm cast, shaft cast	20 MAY 85	
XA245	MME	X4	32 1	Lid of oil cup, brass	21 MAY 85	
XA246	MME	X7	32 1	Cooling pipe brass	22 MAY 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 7

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
246L	MME	X7	32 1	Tap from cooling pipe brass	22 MAY 85	
246R	MME	X7	32 1	Tap from cooling pipe brass	22 MAY 85	
247			46 1	Rope w. cu wire	22 MAY 85	
248	MME	X5	32 10	Cylinder aft. pipe, brass- 10 pieces each - main pipe, top section, middle, top screw plug, 2 sets handle, washer + nut	23 MAY 85	
249	MME	X5	32 10	Cylinder fwd. pipe, brass- 10 pieces - main pipe, top section, middle, top screw plug, 2 sets handle, washer + nut.	23 MAY 85	
250			32 1	Screw, brass from ??	24 MAY 85	
251	CWJ	TUB 58 WET ROOM	32 2	Aft wiper arm + suspension link.	24 MAY 85	
252			86 1	Rubber in conc	24 MAY 85	
253	MME	X8	32 4	Cog, ratchet, & 2 screws, brass. Listed as glass- thick, flat and on top of forward cylinder.	24 MAY 85	
A254			82 1	Bar part only, iron	24 MAY 85	
A255	CWJ	TUB 51 WET ROOM	86 1	Concretion casts for display- dry	24 MAY 85	
A256			86 1	Cast from spare con rod.	24 MAY 85	
A257			32 1	Inch ruler, brass, section only - from spare crank shaft conc.	24 MAY 85	
A258			32 1	Lid, hinged, brass- rectangular. From oil container.	17 MAY 85	
A259			2 1	Tile, complete	17 MAY 85	
A260	CWJ	TUB 30 WET ROOM	82 1	Flange (to deconc.)- frags exhaust pipe + engine nic ?, trunk	29 JUL 85	
A261	CWJ	TUB 9 WET ROOM	8 1	Locking nut from camshaft	29 JUL 85	
A262	CLV		32 2	Gasket mat, 2 pieces and brass wire from front valve chest	30 JUL 85	
A263	CLJ	JC ROOM	8 2	Wear plates from expansion links - brass	30 JUL 85	
A264			82 1	Angle iron	30 JUL 85	
XA265	MME	X8	32 2	Cogs, aft & fwd., brass- from fore cylinder. The one w/ a stud is the foremost.	30 JUL 85	
XA266	CWJ	TUB 64 WET ROOM	86 3	Concs. (2 bags)		
XA266	MME	X4	32 1	Lubricator, little end, brass. w/ tube- fore cylinder	1 AUG 85	
XA267			47 2	Canvas and filling from exhaust pipe	1 AUG 85	
XA268			6 2	Wood and rubber (gasket)?	1 AUG 85	
XA269	MME	X1	47 2	Gaskets, fabric/canvas	30 JUL 85	
XA270	MME	C5	32 3	Makers Name Plate, brass + 2 screws	1 AUG 85	
XA271	MA	Xa Storage	32 7	Tallow cup, brass- consists of body + 2 sets each- pipe, washer, nut.	2 AUG 85	
XA272			86 2	Concs + engine bearer frags = 2 + pieces	29 JUL 85	
XA274	MME	X7	32 3	Lubricator cup lids, (E,M,F) brass- tallow cup	1 AUG 85	
XA274F	CWJ	TUB 9 WET ROOM	8 1	Bolt fragment		
XA275	MME	X8	32 4	Indicator cocks, brass. FP, FS, AP, AS. 4 parts each- cock, handle, washer, nut.	1 AUG 85	
XA276			44 1	Glass,under pumps attachted to bearers	1 AUG 85	
XA277			86 5	Conc. samples + putty	1 AUG 85	
XA278	CWJ	TUB 72 WET ROOM	82 1	Radius arm link iron + brass	1 AUG 85	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:00 : 8 JAN 96 Page 8

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA279			83 1	Tool, iron, square section	29 JUL 85	
XA280	MME	X4	32 4	Lubricator box, + 3 screws, brass- forward valve spindle guide.	29 JUL 85	
XA281	MME	X4	32 1	Lubricator box, brass- aft valve spindle guide lubricator + 1 screw.	12 NOV 85	
XA282	MME	X5	32 1	Inboard trunk gland, brass, aft feed pump - 1 screw	12 NOV 85	
XA283	MME	X5	32 1	Inboard trunk gland, brass- forward feed gland	12 NOV 85	
XA284	MME	X7	32 1	Pet cock, brass, from inboard feed pump	12 NOV 85	
XA285	MME	X4	32 1	Die block lubricator box, brass, from fore radius link arm	12 NOV 85	
XA286			67 2	Cork + piece of wire from forward main bearing lubricating box.	12 NOV 85	
XA287			32 1	Die block lubricator box, brass, from aft radius	12 NOV 85	
XA288			49 1	Rubber gasket, rough w/ wire - wire preventing leak between fore butterfly + fore valve chest- wrapped around flange - wire wrapped around butterfly spindle.	12 NOV 85	
XA289			82 1	Stop valve flange from main steam pipe (came apart during treatment)	12 NOV 85	
XA290	MME	X4	32 1	Lubricator box, brass- aft outboard gland - 1 screw only	12 NOV 85	
XA291	MME	X4	32 2	Lubricator box + 1screw brass- forward outboard gland	12 NOV 85	
XA292			3	Ratchet & 2 screws, brass- from aft outboar	12 NOV 85	
XA293			47 1	Canvas from gasket	12 NOV 85	
XA294			44 1	Bottle neck,light green glass	12 NOV 85	
XA295			32 1	Rivet head, brass	12 NOV 85	
XA296			34 1	Lead ore sample		
XA297			86 1	Conc, from conc. between cylinders	5 JUN 86	
XA298	CWJ	WET ROOM/TUB 1	82 2	Bolts- 55 mm	5 JUN 86	
XA299			32 1	Plate, brass- possibly drip tray	5 JUN 86	
XA300F	CWJ	TUB 9 WET ROOM	8 1	Nut	29 OCT 86	
XA301			32 1	Pipe, copper - 50 mm wide x 1.60 m long	29 OCT 86	
XA302			86 1	Trunk concretion	29 OCT 86	
XA303			86 1	Webbing concretion	29 OCT 86	
XA304.12	CWJ	TUB 8 WET ROOM	32 1	Rivet. Registered as rubber frag.	29 OCT 86	
XA305			6 6	Wood frags	29 OCT 86	
XA306			2	Valves (holes M, & R) brass. Valve M= 5 secti	25 SEP 87	
XA306	LO	Various locations for individual parts.	32 1	Pump discharge live air vessel & attached pipes. Air pot complex includes - 3 pipes + 3 valves also a cover (join) with 1 1/2 " small section pipe + 6 fabric gaskets from joins. There are 7 joins : a-d;e-h(valve) ;i-l;m-p (valve) ;q-t (valve) ;u-x- Appl joint (heads towards air pot pipe with valve Q to T); y-z = 2 iron bolts. AA-DD= 4 iron	25 SEP 87	

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				bolts + 2 washers only which fit onto air pot join. Concerning joins - 2 holes on joins are numbered, 2holes on gaskets are numbered, all the iron bolts, some bolts have nuts and washers. The seperate parts have individual entries following this.		
XA306			47 6	Gaskets, fabric, from joins - 306 APP1, APP2, 306 (A&B), 306 (E & F), 306 (I&JJ), 306 (M&N).	25 SEP 87	
XA306			32 4	Pipe UV,OP - 5 openings with flanges ; pipe UV,EF, 3 openings,2 flanges, opening broken; pipe AB, NM, 2 openings w/ flanges, complete; pipe - 3 flanges labelled A, inscribed T B.	25 SEP 87	
XA306	MME	X1X	32 1	Flange w/ pipe, brass/ copper	25 SEP 87	
XA306A-D	CWJ	TUB 8 WET ROOM	32 4	Nut/bolts.	25 SEP 87	
XA306E-G	CWJ	TUB 14 WET ROOM	82 3	Nut/bolts. This should include H as part of the valve. Valve 'E'= appears more coppery + smaller than 'm'. Center of valve has three openings. There are 4 sections - main part, valve center, washer (sq hole) + nut (no top).	25 SEP 87	
XA306H-J/L	CWJ	TUB 8 WET ROOM	32 4	Nut/bolts	25 SEP 87	
XA306M-P	CWJ	TUB 8 WET ROOM	32 4	Nut/bolts= part of valve M	25 SEP 87	
XA306Q-T			32 4	Nut/bolts = Valve	25 SEP 87	
XA306U-X	CWJ	TUB 8 WET ROOM	32 4	Nut/bolt/fibre+ APP1 joint - heads towards air port pipe with valve Q to T.	25 SEP 87	
XA306Y/Z	CWJ	TUB 9 WET ROOM	8 3	Nut/Bolt/Washer. Question as to whether these pieces from this complex.	25 SEP 87	
XA307	MME	X1	32 1	Pipe, [hole A], copper= 2 flanges + broken end AB ?		
XA307			32 3	Pipe sections (3) from port pump, down feed pump, discharge + suction valve chamber, 2 joins A-D, E-H. Plus iron bolts and washers and gaskets (6). Seperate entries follow...		
XA307			32 2	Flange opening EF + broken pipe.		
XA307			32 2	Flange openings (2) AB-EF + plain end.		
XA307			47 6	Gaskets- A-D = Hemp?, 3 seperate sections only B,C,D. Gasket E -H = Rubber ?, 1 only. Plus 2 other gaskets (which belong where?)		
XA307A-D	CWJ	TUB 8 WET ROOM	32 4	Nut/bolt/washers		
XA307E-H	CWJ	TUB 8 WET ROOM	32 5	Nut (1)/ bolts (4)		
XA308	LO	L. Hill for drawing 29/ 9/95	0	Valve, brass, from port pump		
XA308			32 0	Down fuel pump discharge + suction valve chamber. 308 = 1 pipe + 1 valve from port pump		

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				side. There is one joint w/ rubber gasket - 1 4" ?. Plus 4 iron bolts A-D, E-F iron bolts with washers, nuts and bolts (from valve). G section = center of valve.		
XA308A-D	CWJ	TUB 8 WET ROOM	32 4	Nut/bolts		
XA308E,F	CWJ	TUB 8WET ROOM	32 2	Nut/bolt/washer		
XA309	MME	X7	32 1	Valve chest drain, aft, brass		
XA310	MME	X7	32 1	Valve chest drain, fwd, brass		
XA311	MM		32 1	Cylinder drain Port Aft brass		
XA312	MME	X6	32 1	Cylinder drain Port Fwd brass		
XA313	MME	X6	32 1	Cylinder drain Aft Fwd brass- piston		
XA314	MME	X6	32 1	Cylinder drain Starb Fwd brass		
XA315			32 4	Forward cylinder flange, adjusting nuts + block = Cog, brass w/ 2 nuts + a lock. = 11 o'clock.		
XA316			32 4	Forward cylinder flange, adjusting nuts + block = Cog, brass w/ 2 nuts + a lock. = 4 o'clock, Port Forward.		
XA317			32 4	Forward cylinder flange, adjusting nuts + block = Cog, brass w/ 2 nuts + a lock. = 2 o'clock.		
XA318			32 4	Forward cylinder flange, adjusting nuts + block = Cog, brass w/ 2 nuts + a lock. = 7 o'clock.		
XA319	MME	X3	32 1	Crankshaft lubricator, brass		
XA320	CWJ	TUB 8 WET ROOM	82 1	Threaded shaft- adjusting bolts for gland on forward port cylinder - 4 o'clock.		
XA321	CWJ	TUB 8 WET ROOM	82 1	Threaded shaft- adjusting bolts for gland on forward port cylinder - 11 o'clock		
XA322	CWJ	TUB 14 WET ROOM	32 1	Flange cover w/ brass threaded bolt- port feed pump discharge + suction chamber - iron. TOP plate w/ spindle. Spindle has brass end + gasket still in place keeping broken plate on place. Gasket in organic storage.		
XA323	CWJ	TUB 8 WET ROOM- nut / bolts only	32 2	Port feed pump discharge + suction chamber SIDE plate. Iron (brass section on shaft) + 2 iron bolts + nuts w/ square heads (possibly brass nut removed earlier) gasket in place.		
XA324			31 1	Mushroom valve, bronze- top. From inside		
XA325	MME	X2	31 1	Mushroom valve, bronze- Bottom		
XA326	CWJ	TUB 8 WET ROOM- nut/ bolts only	32 11	Port pump flange bolts X 4, 4 nuts + 3 washers. Also stbd pump frags		
XA327			32 7	Starboard pump outer pipe, copper. w/ flange + broken end		
XA328			32 1	Pipe w/ flange copper= starboard pump o		
XA328	CWJ	TUB 8 WET ROOM	32 4	Bolt(1), nuts (3)		

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA329	CWJ	TUB 14 WET ROOM	8 1	Flange cover		
XA329	CWJ	TUB 8 WET ROOM	8 3	Frags. cast iron from engine??		
XA329AB	CWJ	TUB 8 WET ROOM- nuts/ bolts.	32 3	Starboard feed pump discharge and section chamber - iron. TOP plate. Bolts AB(2), nut (1) B has nut. + gasket.		
XA330			82 1	Starboard feed pump discharge + suction chamber - iron - SIDE plate, has gasket - bolts ???		
XA331			31 1	Mushroom valve, bronze. STBD, TOP		
XA332	MME	X2	31 1	Mushroom valve, bronze. STBD, BOTTOM.		
XA333			82 1	Port /Stbd pump covers, small frag.		
XA334			82 22	Right angle support plates from under engine. 1,4,5,6,7,8,9,10 small + 12 reverse + part plate. 2 large pieces in engine tank.		
XA336			3	Plate, square, on stbd pump- Frags. cast iron from engine.		
XA337	CWJ	TUB 9 WET ROOM	8 4	Nut/bolt/washers - all bolts w/ nuts and washers. Possibly incorrectly marked XA 307.		
XA339	CFJ	CONCRETE TANK B	82 1	Pump, boiler valve= pressure relief valve- concreted	19 FEB 88	
XA340			47 1	Gasket, possibly from XA 338 B, definetly from one of the above		
XA341	MME	X6??	31 4	Eccentric strap, bronze- spare - 2 little pieces fit on one end, broken off. 1 bit in storage X4.		
XA341B	MAX	3 frags CONS JON 4/85	82 4	Conc of bolt heads w/ washers.+ 3 iron frags		
XA341B	MAX	3 frags CONS JON 4/85	82 4	Conc of bolt heads w/ washers.+ 3 iron frags		
XA342	CWA		82 1	Bar, in conc,	19 FEB 88	
XA343	CWA	WET ROOM TUB 1.	83 1	Tool handle -Metal file in concretion w/ wood and brass		
XA344	MA	Organic Storage	47 1	Gasket material- from aft port side piston flange- main exhaust pipe	26 JUN 88	
XA345			47 1	Gasket - from main aft exhaust	26 JUN 88	
XA346			32 1	Bore, brass, for instrument ' like compass'- Xantho boiler pieces 322 gm treated wt- 15 cms diam.		
XA347			32 11	Oil box from Xa 258 (no' XA 57/ 7)- aft piston trunk Tallow Box. Includes section of brass pipe- 480 mm, this fits at the back of the box; tack (modern?); 8 soldered frags (from round pipe - check?).		
XA348			32 1	Plate, brass, curved - plate fom 8" in from "2 o' clock' on inside forward piston trunk. INscribed on brachet-58,38,1; screw section- 2.		
XA349			32 3	Ratchet/ lock & 2 screws, brass- cog nut i		
XA350	MME	X8	32 4	Cog/ ratchet, & 2 screws, brass, lock is missing - 2o'clock. Stbd Forward.		

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA351	MME	X5	32 3	Cog, & 2 screws, brass= 7 o'clock. Stbd Forward.		
XA351	MME	X8	32 4	Cog, ratchet, & 2 screws, brass		
XA352	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, =4 o'clock. Stbd forward.		
XA353	MME	X8	32 4	Cog, ratchet, & 2 screws, brass. 11 o'clock. Stbd aft.		
XA354	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, 2 o'clock. Stbd aft		
XA355			32 4	Cog, ratchet, & 2 screws, brass- 7 o'clock. Stbd		
XA356			32 3	Ratchet, & 2 screws, brass, 4 o'clock. Stbd a		
XA357	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, 11 o'clock. Port aft		
XA358	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, 2 o'clock. Port aft.		
XA359	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, 7 o'clock. Port aft.		
XA360	MME	X8	32 4	Cog, ratchet, & 2 screws, brass, are 292. 4 o'clock. Port aft.		
XA361			32 10	Nuts, cylinder fastenings, brass, from port side forward piston, 1F to 10 F, larger flange.		
XA362			32 10	Nuts- cylinder fastenings, brass, from portside aft piston (see 361) 1A to 10 A, larger flange.		
XA363			34 2	Oil wick crimp and screw	15 AUG 88	
XA364			32 2	Lower lubricator + 1 screw- fore radious link, brass	23 DEC 88	
XA365			86 1	Conc. from cast iron pipe in treatment	10 MAR 89	
XA366	MA	Storage+CWA, CWJ	83 1	Knife, brass ferrule, iron blade, wood handle.	23 SEP 89	
XA366	CLV		8 1	Ferrule, brass, from knife		
XA366	CLV		32 1	Ferrule from knife, brass		
XA367			88 1	Sample, metal from trunk	23 SEP 89	
XA368			88 1	Sample, metal from valve chest	23 SEP 89	
XA369			88 1	Sample, metal from Pump.	23 SEP 89	
XA370			47 1	Gasket material, unlabelled	27 MAR 90	
XA371			6 2	Wood frags for samples	23 MAY 91	
XA372	MAX		3 1	Oval cover, tin	23 MAY 91	
XA373	MA	Storage	32 1	Copper fragment - cut	23 MAY 91	
XA374			8 1	Bolt head	23 MAY 91	
XA375	MA	Storage	32 1	Lubricator pipe guide ; inscribed 58,30,1	23 MAY 91	
XA376	MA	Storage	32 2	Lubricator pipe guide, larger w/ hexagonal treated extension, inscribed 58,30, 2.	23 MAY 91	
XA377			8 2	Screws, from 376	23 MAY 91	
XA378			8 1	Flange fragment, part of	23 MAY 91	
XA379	CO	Con	87 1	Model of engine, working- 1to 6 working model	28 MAY 91	
XA380	MAB2	CWA	32 1	Pipe, lubricating guide - brass/bronze	6 MAR 92	
XA381	CLJ	JC ROOM	82 2	Locking screw, on little nut w/ section of this nut ??	6 MAR 92	
XA382	MAX		32 1	Pipe, lubricating guide section - brass/bronze, 1 1/2 screw holes	11 MAR 92	
XA383	CWJ	JC ROOM	8 4	Cast iron frags	11 MAR 92	
XA384			32 1	Flange - br/cu- diam: 130mm	18 MAR 92	
XA385			32 1	Pump from engine, cast iron base, lower cylinder iron, upper section copper, + copper tubing.	18 MAR 92	

No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				Iron side section		
36	MAX		32 1	Wire, brass, holding lubricating wick?	20 OCT 92	
37	CWA		32 9	Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
37A	CWA		32 1	Shell, brass. From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
37B	CWA		82 1	End plate, iron. From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
37CH	CWA		82 2	Bolts, iron.From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
87DI	CWA		82 2	Nuts, iron.From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
387EJ	CWA		82 2	Nuts, each nut with locking ring, iron, grub ring..From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
87G	CWA		82 1	Locking pin. From Big End assembly, from fore connecting rod. Big end comprises 2 brass shells - one is still attatched to the engine + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
8A	CWA		32 1	Shell, brass, Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly	20 OCT 92	

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				erroded as to remain in situ + the same for grub screws + locking pins.		
XA388B	CWA		82 1	End plate, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388C	CWA		82 1	Bolt, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388DI	CWA		82 2	Nuts, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388EJ	CWA		82 2	Locking rings, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388F	CWA		82 1	Grub screw, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388G	CWA		82 2	Locking pins, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA388K	CWA		82 1	Grub screw, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA388L	CWA		82 2	Locking pins, iron. Big End assembly- section still on engine. From aft connecting rod. Big end comprises 2 brass shells -one is still attatched to engine, + in some cases nuts are so badly erroded as to remain in situ + the same for grub screws + locking pins.	20 OCT 92	
XA389	MAX		32 2	Pipes, oil, from lubricator cut, removed previously from Fore Big END, brass	20 OCT 92	
XA390			32 3	Lubricator cup - complete w/ pipes + studs from aft Big End. Br/Cu + lead	20 OCT 92	
XA391			82 1	Fore radius link- iron. (lubricating cup Cu attatched) w/ excentric rod attached. which is attatched to executive strap (398 C)	20 OCT 92	
XA392			32 6	Die block assembly from fore radius link. PArt of 2 iron screws still insitu. 4 brass sections, 1 bolt - threaded (iron) screw; length. 30mm; 1 copper circle which has had a surround	20 OCT 92	
XA393AB			82 2	Crank supports - top and bottom of mid crank support. Bottom bolt, B, is more eroded	20 OCT 92	
XA394			82 1	Crank support, aft, TOP. Bottom bolt totally eroded, to be analysised	20 OCT 92	
XA395AB			82 2	Crank support, fore, Top and Bottom. Tallest and most eroded is the bottom one - B	20 OCT 92	
XA396			32 12	Eccentric strap assembly "AB". Consists of 2 brass straps, each w/ 2 bolts + spaces w/ wood seperation to complete a circle. They are inscribed- FB - fore bottom; FT fore top; AB aft bottom; AT aft top. Iron rod attached w/ 2 bolts + nuts. Cu shin seperating this section.	20 OCT 92	
XA396AB			31 2	Circle, 1/2, top, and bottom. bronze.Bottom marked 58,30.	20 APR 93	
XA396C			82 1	Eccentric rod, iron.	20 APR 93	
XA396D			82 2	Bolt w/ nut. Left side joining rod - stamped 12. D angled to fit flush in ring.	20 APR 93	
XA396E	MAX		32 1	Shim, copper. Left side joining rod.	20 APR 93	
XA396F			82 1	Bolt, right side joining rod. Stamped 12. F angled to fit flush in ring.	20 APR 93	
XA396G	MAX		32 1	Shim, copper, right side joining rod. Chopped off on angle, labelled 12.	20 APR 93	
XA396H			82 1	Bolt joining rings. Left - nut on side of A	20 APR 93	
XA396I			64 1	Spacer, wood, left.	20 APR 93	
XA396J			82 1	Bolt, right - nut on side of A. Labelled 11	20 APR 93	
XA396K			64 1	Spacer, wood, Right - hole incomplete.	20 APR 93	

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA397			32 11	Eccentric Strap assembly 'FB'	20 APR 93	
XA397AB			31 2	Circle, 1/2, top, and bottom. bronze.	20 APR 93	
XA397C			82 1	Eccentric rod, iron.	20 APR 93	
XA397D			82 2	Bolt w/ nut. Left side joining rod - stamped 15	20 APR 93	
XA397E	MAX		32 1	Shim, copper. Left side joining rod.	20 APR 93	
XA397F			82 1	Bolt, right side joining rod. Stamped 16	20 APR 93	
XA397G	MAX		32 1	Shim, copper, right side joining rod.	20 APR 93	
XA397H			82 1	Bolt joining rings. Left -head towards B - has pin in situ.	20 APR 93	
XA397I			64 1	Spacer, wood, left.	20 APR 93	
XA397J			82 1	Bolt, right - joining straps. Remains of head on B side.	20 APR 93	
XA397K			64 1	Spacer, wood, Right	20 APR 93	
XA398			32 1	Eccentric Strap assembly 'FT'. Includes A-D,F,H-K.	20 OCT 92	
XA398AB			31 2	Circle, 1/2. top and Bottom, Bronze. 3/4.	20 OCT 92	
XA398C			82 1	Eccentric Rod - attached to 391.	20 APR 93	
XA398D			82 1	Bolt- erroded. Above no' stamp 398 C	20 APR 93	
XA398F			82 1	Bolt - eroded - no stamp.	20 APR 93	
XA398H			82 1	Bolt - joining straps left - thread. On side of A	20 APR 93	
XA398I			64 1	Spacer, wood - left	20 APR 93	
XA398J			82 1	Bolt, joining straps. right thread. On side of A.	20 APR 93	
XA398K			64 1	Spacer, wood, right- incomplete	20 APR 93	
XA399			32 1	Eccentric Strap assembly 'AT'. Includes A-H J-L. 39/40.	20 OCT 92	
XA399AB			31 2	Circle, 1/2. top and Bottom, Bronze. 39/40	20 OCT 92	
XA399C			82 2	Eccentric Rod - small section only.	20 APR 93	
XA399D			82 2	Bolt- left side - joining rod and nut. Stamped 40.	20 APR 93	
XA399E	MAX		32 1	Shim copper, left side. Joining rid and nut.	20 APR 93	
XA399F			82 2	Bolt, right side, rod + 1/2 nut. Stamped 39	20 APR 93	
XA399G	MAX		32 1	Shim, copper, right side + rod	20 APR 93	
XA399H			82 1	Bolt - joining straps left - screw towards A. Hole for cocking pin.	20 APR 93	
XA399J			82 1	Bolt, joining straps. right thread- thread on side A, hole for pins?. Stamped 39.	20 APR 93	
XA399K			64 1	Spacer, wood, right	20 APR 93	
XA399L			84 1	Locating pin (oblique locking), right. This fits into threaded region of Bolt J. into locating heel (?) in A.	20 APR 93	
XA400			61 0	Timber frags from on top of fore cylinder.	20 OCT 92	
XA401	MAX		8 3	Spaull (?) pieces- replace on engine when cons complete	20 OCT 92	
XA402A-H			32 8	Pump (from 385). A. cylinder - cu; B.flange, brass; C. Gasket to B;D.flange, brass; E. Gasket to D; F. fitting to pipe (G);G. pipe cu; H. locking nut-cu.	20 OCT 92	

itime Archaeology Department Database printed by SITE
ed as of: 09:01 : 8 JAN 96 Page 17

No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
03			46 1	String - knotted. From pump concretion.	20 OCT 92	
04			64 2	Wedge, wooden. From pump concretion.	20 OCT 92	
05	MAX		32 1	Plug, threaded brass. From pump concretion	20 OCT 92	
06	CWA		32 3	Maker's plates, brass w./ 2 screws	12 NOV 92	
07	MA	Storage	0 0	Fillings from Forward valve chest	20 OCT 92	
08	MA	Storage	0 0	Fillings from Aft valve chest	20 OCT 92	
09			82 1	Flange, mainly conc	23 MAR 93	
10			6 1	Wood piece, large w/ conc and glass	23 MAR 93	
11			44 0	Flat glass sherds- from Drum 174	23 MAR 93	
12ABC			82 3	Bolt- no head (A); BC bolts.	1 APR 93	
13ABC			82 3	Bolt (A); BC nut.	1 APR 93	
14ABCD			82 3	Bolt + nut (A + B); CD bolts	1 APR 93	
15A-D			82 4	Bolts. C - long; D bolt + nut > long	1 APR 93	
16A-D			82 4	Bolts	1 APR 93	
17A-D			82 5	Bolts. D= Bolt and nut	1 APR 93	
18A			82 0	Aft web- iron nuts and bolts - holding frame to bed.	1 APR 93	
19A-H			82 8	Center web?	1 APR 93	
20A-H			82 0	Web. See 418, 419. ??????	1 APR 93	
21A-D			82 7	Pump bolts- port. Viewed from side overlooking.. A- bolt and nut remains. B- bolt and but. C- bolt. D- nut and bolt remains.	1 APR 93	
22A-D			82 6	Pump bolts - starboard. A- remains of bolt. B- nut remains. C- nut and bolt remains.D-nut and bolt.	1 APR 93	
423			82 1	Packing slipper "V" under center web, cast iron. See 432. "V" is top.	1 APR 93	
424			82 1	Scotch yoke bolt- top. Remains of nut each end - larger + seperated Port end. CAst iron surrounds are in frags	1 APR 93	
425			82 1	Scotch Yoke Bolt - Bottom, has eroded surface on stbd half.	1 APR 93	
426			82 1	Pump right.	1 APR 93	
427			82 1	Pump left.	1 APR 93	
428			31 1	Scotch yoke bearing block, stbd, lubricating tube at top.	1 APR 93	
429			31 1	Scotch yoke bearing block, port, wire in lubricating tube at top.	1 APR 93	
430			32 1	Spacer, brass fits between con rod + big end. Top is where tag is tied scores on big end side.	1 APR 93	
431A			82 1	Wedge- tapered	2 APR 93	
431B-G			64 10	Spacers- wooden wedges. B- wedge. C-2 wood wedges, on top of B, w/ bolt hole. D- wood wedge w/ bolt hole, appears to fit over E. E-wood wedge. F. 3 wood wedge. G- 3 wood wedges, fits over F.	2 APR 93	
431H			82 1	Spacer, iron, marked VII. From forward web. Label tied on top.	2 APR 93	
431I-O			64 7	Spacers- from forward web.I- wood wedge. J- wood wedge, fits over I.K- wood wedge. L- wood	2 APR 93	

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:01 : 8 JAN 96 Page 18

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				wedge, fits over K. M- 2 wood wedges. N-wood wedge, fits over M.		
XA431O			82 1	Spacer, iron- rectangle	2 APR 93	
XA431PU			64 9	Spacers- from forward web. P- wood wedge.Q- 2 wood wedges. RST- wooden wedge. U- 3 small wooden wedges, fits over T.	2 APR 93	
XA432A-T	CLV		64 23	Spacers- Center web. A- 2 wedge w/ bolt hole, on top of B. B- wood wedge w/ bolt hole. C-wedge w/ bolt holes. D- 2 wedges, goes on top of C. E- small thin wedge goes on top pf D. GH- wood wedges w/ lug impressions. H fits on top of G. I - 3 small slithers of wood under H. JK wooden wedges, these 2 go together. K over J, 2 small wedges under K. LM wooden wedges, M fits over L. OP wedge, p fits over O. QR wedge- R fits over Q. ST wedge, T fits over S.	5 APR 93	
XA432FN	CWJ		82 2	Spacers, iron. F- 'VI' with lugs. N- spacer 'VII'	5 APR 93	
XA433AGN	CWJ		82 4	Wedges from aft web,Iron. A. wedges (2), IV. G. Spacer III- two lugs. N. Spacer II	5 APR 93	
XA433B-F	CLV		64 7	Wedges from aft web. B. 2 wooden wedges w/ bolt holes. C. 2 wooden wedges w/ bolt holes. D. small wood wedge - shaded area of D fits under cover of B. E. wooden wedge. F. wooden wedge sits over E.	5 APR 93	
XA433H-M			64 7	Wedges from aft web. Wood. H. wooden wedge. i. Wedge - H fits over I. J. Wooden wedge. K wooden wedge - J fits under K. L Wooden wedge. M. 2 wedges.	5 APR 93	
XA433O-V			64 8	Wedges/spacers from aft web. O. Wedge. P. Wedge- O fits over P. Q. wedge. R. wedge- fits Q over R. S. wedge. T. wedge -S over T. U. narrow wedge. V. narrow wedge - V fits over U.	5 APR 93	
XA434			82 1	Bolt, upper aft big end bearing. Head = port end.	5 APR 93	
XA435			31 1	Big end - Forward. Top has lettering and oil holes.	5 APR 93	
XA436			31 1	Big end - Aft. Top has lettering and oil holes.	5 APR 93	
XA437A-D	CWJ		82 7	Bolts holding cylinder block to frame under valve chest. Forward end. A- bolt, nut fixed. B. Bolt, nut in pieces- free. C Bolt and nut - free. D nut only- bolt still in situ.	6 APR 93	
XA438A-D			82 7	Bolts holding cylinder block to frame under valve chest. Aft end. A- 2 bolt frags + 1 washer frag. B. Bolt only. C Bolt and washer. D bolt only.	6 APR 93	
XA439A-G			64 8	Wedges, wooden spacers under cylinder block Aft. AB. wedge- b fits on top of A. CD. wedges- D	6 APR 93	

ritime Archaeology Department Database printed by SITE
ted as of: 09:01 : 8 JAN 96 Page 19

. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
				fits under C. E wood wedge - appears to be one piece. F. 2 wedges-F fits over G. G wedge.		
439H			82 1	Spacer, iron. "I"	6 APR 93	
440AJ			82 2	Spacer, iron. From under cylinder. Block forward. A. spacer XI (probably 11 but could be 9??). J. Spacer- still in situ.	7 APR 93	
440B-I			64 21	Spacers, from under cylinder Block forward. B. wedge (wider blocks than previously). C. wedges (3) fits over B. D. wedge- wide. E. wedge, small piece fits right of D. F. 2 wedges, fits over D. G. 7 small sections - fits somewhere between D + H. H. wedge- wide. I 5 wedges, sections fit over H.	7 APR 93	
441			82 1	Rivet from deck - starb aft..; just inside 433 A+C.	7 APR 93	
442			82 2	Nut from cylinder connecting Bolt - TOP	7 APR 93	
443			82 1	Nut from cylinder connecting bolt- BOTTOM	7 APR 93	
444	MA	BOTTOM DISPLAY CUPBOARD	31 1	Butterfly valve, bronze	7 APR 93	
445	CF		32 1	Forward trunk. 58.30 F		6 DEC 93
446	CF		32 1	Aft trunk. 58.30 A		6 DEC 93
447	MAX		32 1	Crank assembly		6 DEC 93
448A	CLJ		32 14	Plate + angle plate. Ass rivets - 15 mm diam. From engine frame.		7 DEC 93
449	CLJ		32 5	Plate (parallel to 448). Ass rivets 15mm diam.		7 DEC 93
450A	CLJ	More to come	32 28	Angle plate (rt angles to 448 + rivet). A = flat plate w/ ass. rivets 15mm in diam. 26 rivet sections		7 DEC 93
451A			32 2	Angle plate (parallel to 450 (centre)). A = flat plate.		7 DEC 93
452			32 1	Angle plate from engine frame. Parallel to 451		7 DEC 93
453			32 1	Plate parallel to 448 (440 spaces on this(?))		7 DEC 93
454	CLJ		32 3	Plate- has connecting holes A-F (next to 455). Parallel to 448. A-F are gussets, angles & assoc. plates holes are marked accordingly. Ass rivets 15mm diam. 2 rivets -more to come.		7 DEC 93
A455	CLJ		32 25	Plate: between 453,454, vertical has hole A for angle support 457. Hole D for angle support- 455 which connects to 454 D. Ass. Rivets 15mm diam. 24 rivet section, 1 plate frag- more to come.		7 DEC 93
A456	CLJ		32 1	Angle bracket fits side 455 at hole 456 X.		7 DEC 93
A457			32 1	Angle bracket, section, fits on 455 at hole A.		7 DEC 93
A458	CLJ		32 13	Gusset rivet, removed from frame.		7 DEC 93
A459	MAX		8 1	Spall(sections conc) from crank assembly. Location unknown.		6 DEC 93

Maritime Archaeology Department Database printed by SITE
Printed as of: 09:01 : 8 JAN 96 Page 20

Reg. No.	Mus.Co.	Mus. Loc.	No.		Date reg	Date collect
XA484	CWA		32 1	Flange		
XA823	CWJ	TUB 8 WET ROOM	8 1	Flange cover.		
XA2387	MME	X4	32 1	Oil cup brass		19 DEC 90
XA2417			32 2	Porthole ring, copper, + some glass.		18 OCT 79
XA2418	MAX		22 1	Plate frag, blue/white -asiatic pheasant.		18 OCT 79
XA2419			34 1	Galena ore, sample, lead		18 OCT 79
XA2420			44 2	Neck and shoulder case bottle + cork.		18 OCT 79
XA2421			32 1	Skylite vent w/ screw, brass, glass and rubber.		18 OCT 79
XA2422	CLG		46 1	Shoe sole, leather		18 OCT 79
XA2525	MAB2	CWA - on top of cupboard	32 1	Pipe		9 FEB 80
XA2526	MAB2	CWA- on top of the cupboard	34 1	Lead fittimg w/ copper nails.		9 FEB 80
XA3205	MAH	T4	32 1	Sheathing, brass w/ makeup stamp M.S.		
XA4169	CWJ	TUB 16 WET ROOM	82 1	Stanchion??		
XA4215A-G			86 7	Concretions to be excavated. To go into seperate registrations.		

T 1996 MACC C.C

JAMES COOK UNIVERSITY LIBRARY
6942514