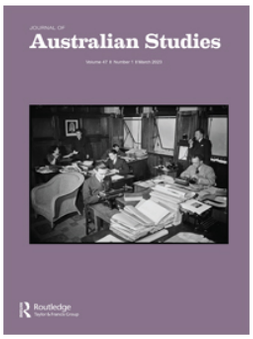

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Untangling Maralinga: Spatial and Temporal Complexities of Australia's Atomic Anthropocene

Lianda Burrows [a], Darren Holden [b] and Elizabeth Tynan [c]

[a]College of Arts, Society and Education, James Cook University, Townsville, Australia; [b]School of Arts & Sciences, The University of Notre Dame, Fremantle, Western Australia; [c]Graduate Research School, James Cook University, Townsville, Australia

ABSTRACT

Reflecting on the atomic test sites in the South Australian desert, this article analyses the bisociation of cultural and historical spaces with geographical and geological formations. We expand Michel Foucault's concept of heterotopias to include complex intersections with natural environments. Given the close association of human intervention and landform, these atomic test sites are also important indicators of the Anthropocene, marking transitional geo-spaces influenced by both human and pre-human geological action. Crossing dimensions of colonial contest, tourism, atomic science and geology, we demonstrate that temporal and physical intersections of multiple human cultures at atomic test sites both influence and are influenced by deep-time geological history.

KEYWORDS

Maralinga; atomic history; Australia; Anthropocene; geology

Introduction

In the mid-20th century, an Australian surveyor was tasked with finding suitable atomic weapons testing areas for the British. Len Beadell located Maralinga (South Australia) in 1953. Before then, in June 1952, Beadell scoped out Emu Field—193 kilometres north of Maralinga—for two highly secretive tests. Operation Totem, as it was named, was held in October 1953.[1] Emu Field was abandoned abruptly after Totem, deemed unsuitable because of its remoteness, lack of water, and inadequate transport infrastructure. Moreover, Emu Field is subject to unpredictable winds and sandstorms. The atomic tests held there are notable for the harm they caused to inhabitants of the lands, partly because the British authorities had a poor understanding of the site's meteorological conditions.[2] When the British sought to create a permanent atomic weapons test site, Beadell was given a new set of requirements: the site had to be within the expansive boundaries of the Woomera Prohibited Area;[3] it needed to be

CONTACT Lianda Burrows lianda.burrows@my.jcu.edu.au

[1]Len Beadell, *Blast the Bush* (Adelaide: Rigby Limited, 1967), 13–23.

[2]Elizabeth Tynan, *The Secret of Emu Field* (Sydney: NewSouth Books, 2022), 96.

[3]The Woomera Prohibited Area was proclaimed in 1947 as part of the Anglo-Australian Joint Project. This range, which takes up one-eighth of the state of South Australia, was used to test British rocket technology between 1947 and 1980: Elizabeth Tynan, *Atomic Thunder: The Maralinga Story* (Sydney: NewSouth Books, 2016), 12.

generally flat, close to rail, climatically better than Emu Field, and isolated enough to be secured.[4] Beadell had undoubtedly spotted the Maralinga Plain by air and perhaps had heard of the failed well-digging exploits of English explorer William Tietkens in 1879 in an area north of Ooldea.[5]

Beadell's mission heralded monumental changes. For those familiar with their significance to 20th-century history, Maralinga and Emu Field conjure images of towering atomic mushroom clouds rising from desert plains—and of Aboriginal dispossession. But Maralinga is more: it is a complex, multidimensional location that invokes a range of cultural and scientific responses. By turns, South Australia's atomic test sites have been celebrated and vilified in historical, political, scientific and public debate. Making the sites available for atomic testing (1953–1963) was arguably Australia's greatest sacrifice to the Cold War arms race, although at the time the Australian government did not foresee the loan of land as a 200,000-plus-year commitment. The main contaminant at Maralinga, the radioactive isotope plutonium-239, has a half-life of 24,400 years, which means that radiation at Maralinga "will be present in the environment so far into the future that it might as well be called forever".[6]

Drawing upon our understanding of Michel Foucault's "heterotopia",[7] with its inverted worlds within worlds, our observations have led to two main conclusions. Firstly, Maralinga is a distinctive site that meets the definitive criteria for a heterotopia—and surpasses it. That is, Maralinga's complexities make it more than a heterotopia. From an ancient land traversed for tens of thousands of years by Aboriginal people, through to the desecration of atomic testing, and its subsequent role as a contemporary tourist site and a natural environment undergoing renewal, Maralinga is multilayered. Unlike standard heterotopias, these human layers are both heaped upon and informed by the geological history of the region. For example, the special features of the landscape at Maralinga initially suggested it to surveyors and scientists as a suitable arena for atomic testing. In turn, this testing left indelible marks on the land itself, and beyond. At other times, the apparent contradictions of the landscape have occurred spontaneously, or at least without scientific or colonial intervention. Moreover, the natural and human-made alterities in the land, from its history as a place of crisis and displacement, to current limitations on public access, involve more than the "temporal transition" that Foucault's definition, as we will see, demands. Maralinga contains the kind of alterity or paradox that simultaneously captures deep time and distant futures, through geological relics of ancient marine life through to the perpetuity of radiation. In this regard, its status as a "heterotopia" is all-encompassing, including geology, geography, culture, atomic science, and time itself. Not simply the product of human intervention like a burial site or carnival, Maralinga exhibits simultaneous impasses of human and geological origins.

Secondly, many of the features that make Maralinga a unique heterotopia provide support for an atomic-era Anthropocene. Various valid starting times have been proposed for the Anthropocene.[8] One candidate is the arrival of the atomic age,[9] and

[4]Beadell, *Blast the Bush*, 186–202.
[5]Neville Collins, *Tietkens-Explorer and Pioneer* (Adelaide: self-pub., 2016), 73–91.
[6]Tynan, *Atomic Thunder*, 24.
[7]Michel Foucault, "Of Other Spaces," *Diacritics* 16, no. 1 (1967; trans. 1986): 22–27.
[8]C. Soriano, "On the Anthropocene Formalization and the Proposal by the Anthropocene Working Group," *Geologica Acta* 18, no. 6 (2020): 1–10.
[9]Soriano, "On the Anthropocene Formalization".

evidence from the Maralinga lands supports this suggestion. At this extraordinary site, we see a profound gesture at futurity—an acknowledgment that certain human actions have irrevocably shaped the Earth, surpassing what was possible in earlier human epochs. These culminate in an answer to our original question—what can an interdisciplinary approach add to our understanding of Maralinga? The Anthropocene is of central interest to diverse disciplines in the sciences and humanities, but an interdisciplinary approach has suggested Maralinga especially as a compelling site for engaging with the concept. In its complexity, we found the various precursors to the Anthropocene, including colonisation, atomic science, and the visible geological effects of both.

The Maralinga atomic test sites have profound human importance, but they are also sensitive ecosystems within an extraordinary natural landscape. Here, the Earth's physical processes have produced local anomalies that contradict the wider landscape, presenting a boundary zone that is at times both (and neither) sea and land. Maralinga offers a parallel to the ambivalent bothness of modern constructs built upon ancient sites and lands. For example, remnants of a former life under water—as fossilised seashells—are scattered across a sandy desert floor. At the same time, the Maralinga lands are significant Aboriginal cultural sites that have undergone colonial and scientific, or atomic, interventions. This process is bidirectional, with many natural aspects of the local environment influencing its cultural legacy and its selection for atomic testing in the first place.

Maralinga can be seen anew as an intricate place with geological, cultural and technological dimensions all due for a unifying cross-disciplinary investigation. During a research trip to Maralinga in April 2021, a unique way of looking at the site emerged through such interdisciplinary observation and discussion. Arriving from different corners of the country, we three authors brought diverse proficiencies from fields as seemingly disparate as atomic history, journalism, geology, and the literary history of the Australian landscape. Accompanied by two Australian army veterans with links to Maralinga and guided by the Oak Valley Ranger Coordinator and the Maralinga caretaker, our group was notable for the various motivations that prompted the journey. As scholars, however, our key purpose was to establish whether an interdisciplinary approach could disentangle some of the spatial and temporal complexities of the landscape at Maralinga, both natural and artificial: to observe Maralinga through a new—albeit colonial-settler—lens and understand it more comprehensively. After discussion, we decided that we were not qualified or entitled to write extensively about the deep history and cultural landscape of the Anangu, and we respectfully confined ourselves to our areas of expertise. The harms conferred on Anangu by the weapons testing at Maralinga are unambiguous, however, and cannot be overstated.

Methodological Framework: Heterotopic and Bisociative Investigations

In "Of Other Spaces", Foucault introduces "heterotopia" with a set of criteria for human-created spaces that seemingly sit within normality but are also at odds with it, incompatible and disturbing. His examples are predominantly urban and include cemeteries, prisons, brothels, museums and fairgrounds.[10] Many scholars have since demonstrated that heterotopias are not restricted to individual sites like these. Fiona Allon, for

[10]Foucault, "Of Other Spaces," 22–27.

example, convincingly argues for the consideration of an entire Australian suburb as a heterotopia: "with its juxtaposition of identities and the coexistence of divergent iconographies, contemporary Earlwood appears as something of a heterotopia of competing spatialities".[11] Expansive definitions characterise the secondary literature on heterotopias.

While ideas of heterotopias and spatial poetics more generally have been thoroughly addressed in scholarship across the humanities,[12] scant attention has been paid to the way that natural environments also function as heterotopias. This reluctance may come because "heterotopia" has already suffered enough scrutiny, and as Peter Johnson explains, it is a "rather sketchy idea" with spatio-temporal-cultural dimensions open to almost endless interpretation and deployment.[13] Johnson does, however, acknowledge its productive potential in interdisciplinary work, citing Matthew Gandy as an exemplar for future scholarship.[14] In "Queer Ecology: Nature, Sexuality, and Heterotopic Alliances", Gandy discusses a London cemetery so overgrown with "wild urban nature" that it usurped the human site and became part of a heterotopic profusion of uses.[15] Yet can a natural site, even before human intervention, inform or alone be considered a heterotopia? Perhaps it is precisely heterotopia's broad application that lends itself to use in an interdisciplinary project about the human-nature-culture continuum.

Like humanities scholars, geologists are familiar with contradictions, although they typically call them "anomalies". The term describes instances where the slow processes of the Earth are suddenly and locally interrupted. For example, hot geothermal water may be forced through a rupturing fault into a spectacular geyser, or the granular deposition of strata may be interrupted by a moment of climatic cataclysm. In the current geological age of the Anthropocene, it is increasingly difficult to distinguish natural and human-made anomalies given their vast and temporally transcendent nature. Timothy Morton describes these events, such as climate change, pollution, geopolitics, capitalism and radiation, as "hyperobjects".[16] While too massive to see, hyperobjects produce observable effects on the Earth as geological-geographical-cultural anomalies. Such anomalies disturb and unnerve human senses in much the same way as traditional Foucauldian urban heterotopias.

As atomic test sites in the Australian desert, the Maralinga lands are heterotopias of both cultural and natural import. Foucault himself set a precedent for our combining of natural and human-made "other spaces", albeit one made in passing. In "Of Other Spaces", Foucault used a geological analogy to explain the formation of cultural places, "history: with its themes of development and of suspension, of crisis and cycle, themes the ever-accumulating past, with its preponderance of dead men and menacing glaciation

[11]Fiona Allon, "Translated Spaces/Translated Identifies: The Production of Place, Culture and Memory in an Australian Suburb," *Journal of Australian Studies* 26, no. 72 (2002): 99–110.
[12]For example, consider Michiel Dehaene and Lieven De Cauter, eds., *Heterotopia and the City* (Abingdon: Taylor & Francis, 2008); Gareth A. S. Edwards and Harriet Bulkeley, "Heterotopia and the Urban Politics of Climate Change Experimentation," *Environment and Planning D: Society and Space* 36, no. 2 (2017): 350–69; Allon, "Translated Spaces/Translated Identifies," 99–110.
[13]Peter Johnson, "The Geographies of Heterotopia," *Geography Compass* 7, no. 11 (2013): 790–803.
[14]Johnson, "The Geographies of Heterotopia," 790–803.
[15]Matthew Gandy, "Queer Ecology: Nature, Sexuality, and Heterotopic Alliances," *Environment and Planning D: Society and Space* 30, no. 4 (2012): 727–74.
[16]Timothy Morton, *Hyperobjects: Philosophy and Ecology after the End of the World* (Minneapolis: University of Minnesota Press, 2013), 1–7.

of the world".[17] It was perhaps not sheer coincidence or poetic virtue that prompted Foucault to draw on a geological metaphor to describe history—the two are irrevocably entwined. Nowhere is this reality more apparent than in the dawning Anthropocene. Like history, geology is underlaid by themes of crisis and cycle, and Maralinga's accumulating strata are a striking example of this.

While exceptional, a scholarly precedent exists for extending the idea of heterotopias to larger areas and concepts, such as Maralinga. Here, a settler-storied landscape was superimposed on a natural geographical anomaly and pre-existing culturally mapped homeland. Maralinga was selected for atomic testing based on environmental features that corresponded with narratives about barren Antipodean space. The failures of this decision—partly predicated on errant narratives about the Australian environment—had grave material and scientific consequences.

The atomic test sites, while more expansive than traditional heterotopias, similarly meet Foucault's criteria. Here, Arthur Koestler's notion of bisociation—the mutually illuminating role of otherwise disparate discursive practices—integrates our cultural and historical investigation with geographical and geological studies.[18] We propose that a discussion of a corrupted natural environment as a heterotopia, and in reference to our interdisciplinary background bridging natural and human worlds, necessitates a bisociative approach.

This article makes two key submissions: firstly, that Maralinga is a special kind of heterotopia,[19] and secondly, that a bisociative understanding of its unique human-landform makes it an important indicator of the Anthropocene. The Anthropocene is an area of extensive research in many disciplines across the sciences, social sciences and humanities. The word itself implies a conflation of human and geological processes, an explicit acknowledgment of our prevalence and potential demise. By structuring this article according to both the human and geological processes at the atomic test sites, we describe the test sites as expansive heterotopias as well as suggesting their scientific and symbolic complexity.

As various scholars, including Arthur Koestler, have asserted, the beginning of the atomic age marked a new era and a sharp break from what came before: "Before the thermonuclear bomb, man had to live with the idea of death as an individual; from now onward, mankind has to live with the idea of its death as a species … Every age has had its Cassandras and Get-Ready men, and mankind has managed to survive regardless of their sinister prophecies. But this comforting argument is no longer valid, as no past age, however convulsed by war and pestilence, had possessed our newly acquired power over life on the planet *as a whole*."[20]

By placing Maralinga in the context of geological time, we can begin to decode one of humanity's existential crises and its conflation with hard, inanimate rock. This is, as Koestler wrote, a "bisociation"—where two seemingly unrelated observations can inform each other, with no special priority afforded to objective science or elegant aesthetic because both are ultimately informed by a personal experience of reality: "The artist and the scientist each projects his experience of reality into his chosen medium

[17]Foucault, "Of Other Spaces," 22–27.
[18]Arthur Koestler, *The Act of Creation* (London: Hutchinson, 1964), 35.
[19]Foucault, "Of Other Spaces," 22–27.
[20]Arthur Koestler, *The Ghost in the Machine* (New York: The Macmillan Company, 1967), 321.

of expression. They do not inhabit separate universes, but occupy the two extremes of a continuous spectrum—a rainbow stretching from the infrared of the physicist to the ultra-violet of the poet, with many intermediary ranges such hybrid vocations as architecture, photography, chess playing, cooking, psychiatry, or the potter's craft. There is nowhere a clear boundary where the kingdom of science ends and that of art begins; and the uomo universale of the Renaissance was a citizen of both."[21] The landforms of the South Australian atomic test sites and the cultural experiences of its inhabitants and colonists collided and influenced each other, leaving a unique legacy to untangle.

Dimensions of Colonial Contest and Tourism: Infinite Deserts and Infinitesimal Atoms

Since 2014, a small tourist operation managed by Maralinga Tjarutja Council has provided public access to the atomic test sites through a system of permits, the most restrictive being for Emu Field. As in any heterotopia, access is prohibited but penetrable. When entering Maralinga, the visitor proceeds through a security gate into an area that was closed for more than 50 years, including during the period of the atomic tests under the strict provisions of the *Defence (Special Undertakings) Act 1952*. This Act, established especially for British atomic testing in Australia, carved out the test sites from the rest of Australia and excluded anyone without security clearance, creating instant heterotopias. Inside the fence are the ruins of a village that was once a transitory home to thousands of scientists and military personnel, offering basic huts, a hospital, church, swimming pool and theatre. In the 1950s, the expansive airfield, arguably the best remote strip in Australia, was also one of the busiest, as aircraft carrying scientific and military equipment, and a steady stream of politicians, journalists and others, landed around the clock. Today, the airfield is comparatively dormant. This fact satisfies the criteria of temporal transition and emplacement and displacement of a standard heterotopia.

The "Forward Area" to the north of Maralinga Village hosted seven full-scale atomic weapons tests and more than 500 "minor trials", some of which did more harm than the mushroom cloud tests and made complete restoration of the sites impossible.[22] Heterotopian crises abounded. These supposedly minor trials, so named to play down their risks, included perilous experiments conducted using radioactive materials and toxic chemicals.[23] The British failed to clean up the site, despite two desultory attempts during the 1960s. A more thorough, but still controversial and disputed, clean-up in the late 1990s by Australian authorities eventually made it possible to hand back the territory to its Traditional Owners and left features on the landscape that will endure beyond living memory.[24]

The Traditional Owners of Maralinga and Anangu Pitjantjatjara Yankunytjatjara (APY) lands refer to themselves as Anangu in both Pitjantjatjara and Yankunytjatjara,

[21]Arthur Koestler, "The Truth of Imagination," *Diogenes* 25, no. 100 (1977): 103–10.
[22]Tynan, *Atomic Thunder*, 137–38.
[23]Tynan, *Atomic Thunder*, 313.
[24]B. W. Church et al., *Rehabilitation of Former Nuclear Test Sites at Emu and Maralinga (Australia)* (Canberra: Department of Education Science and Training, Maralinga Rehabilitation Technical Advisory Committee, 2003).

two dialects of the Western Desert.[25] As Eve Vincent notes, the arid inland of South Australia, particularly Anangu Country, has long sustained life, culture and art.[26] Anangu are attuned to their environment and knowledgeable about its resources. For example, the location of water holes, in places such as Ooldea, and the paths between them, form part of Anangu cultural knowledge handed down to the initiated.[27] As settlers slowly learned, the Great Victoria Desert has stands of black oak providing shade and firewood, acacia roots holding tasty witjuti grubs, and kangaroo or emu to hunt. To the first human residents, Maralinga was not "deserted"; it was home. The racism of the atomic test era was so ingrained that the notion of holding dangerous tests on the homelands of Anangu was not considered an impediment. The only initial measure taken to protect the people of the land was to assign one person, Walter MacDougall, to the task of keeping people away from the sites.[28] A second patrol officer was assigned in 1956, but until then, MacDougall was the only person warning and deterring Anangu —across lands that stretch hundreds of thousands of square kilometres—from the atomic tests.[29]

The most intractable impact on the land from atomic testing is undoubtedly radiation itself—an energy that inhabits the inanimate stone, swaying grasses and bounding animals of Maralinga.[30] Despite piecemeal efforts by the Australian and British governments to decontaminate the area, there is no unassailable method for removing radiation. No amount of environmental exorcism can completely rid the Maralinga lands of the spectres of a nuclear past. Ultimately, time is the only assured solution as each subatomic particle of energy dissipates into the space above and below. The British knew the catastrophic consequences of atomic weapons tests on people and environments and outlawed such tests on their own homeland. They chose Maralinga (and Emu Field) knowing what their planned tests would do and gave hollow assurances to a naïve Australian government. The results were devastating. As a senior Anangu woman, Mima Smart, wrote in the foreword to a special issue of *Unlikely: Journal for Creative Arts*, "That poison has killed so many of our people. Through that atomic bomb. And radiation on everything … sand, trees, animals, buildings and other things."[31]

The decision to use an Australian desert landscape for atomic testing was shaped by imperial notions of both Australia and the desert. The combination of ulterior motive and the lackeyism of the Australian government reflected a wider disregard held by settler-colonial Australians for their own hinterlands as they clung to the coasts of their ancient continent.[32] The British did not have to make strong demands to Australia to hand over territory for atomic testing. The Australian government hastily obliged, filled with ambitions for an Australian atomic future that these testing agreements

[25]Tynan, *The Secret of Emu Field*, 3.
[26]Eve Vincent, "Taking Care of the Country: The Irati Wanti Campaign Is Working Hard to Protect the Australian 'Desert' from its New Enemy, the Remote Dumping of Radioactive Waste," *Arena Magazine* (2002).
[27]Ronald Berndt, "Tribal Migrations and Myths Centred on Ooldea, South Australia," *Oceania* 12, no. 1 (1941): 1–20.
[28]Tynan, *Atomic Thunder*, 80, 178–88.
[29]Tynan, *Atomic Thunder*, 184.
[30]A 2021 study showed evidence that particles of plutonium left behind by some minor trials are even more unstable than previously assumed. The aftermath of the minor trials is the ongoing release of radioactivity that can mix with dust and water and continue harming the environment indefinitely: Megan Cook et al., "The Nature of Pu-Bearing Particles from the Maralinga Nuclear Testing Site, Australia," *Scientific Reports* 11 (2021).
[31]Mima Smart, foreword in "Reimagining Maralinga," *Unlikely: Journal for Creative Arts* 5 (2018).
[32]Tynan, *Atomic Thunder*, 64.

might presage. Another former British colony approached by Britain to host atomic weapons testing, Canada,[33] had a better developed concern for the dire environmental consequences of British atomic testing and declined to participate.

The idea of desert regions as a "hideous blank"[34] that did not require protection was common to settler-colonial as well as British culture. The strange combination of both a romanticised and overlooked "outback" is one way of understanding how the British came to be given almost completely free rein over huge swathes of sovereign territory for lastingly destructive activities. From the first recorded descriptions of *Terra Australis* and well into British settlement, Australia was portrayed as an arid land of exiles—a place "without rice or many fruits" and only "poor, naked people" peppering its shoreline.[35] Colonisers saw the local environment as infelicitous and lacking providential direction. While the coast eventually yielded to human needs, the outback's empty immensity seemed an insurmountable challenge. Within the cultural-geographical conception of the Antipodes, the desert was already "other" for its colonial settlers. Agricultural and geographic remoteness were translated, throughout Australian and British culture, into depictions of the desert that often foregrounded death, hardship and nullity.[36]

Unsurprisingly, both settler Australians and the English regarded deserts as futile and barren plains.[37] The reality, of course, is that Australian deserts are far from empty. The Great Victoria Desert teems with flora and fauna. From spinifex, desert pea and acacia through to dingoes, kangaroos and other macropods and a large variety of birds, the Australian inland is far from lifeless. The idea that the Great Victoria Desert was an empty wasteland should have been dispelled within days of arriving.

The British atomic scientists who came to the desert were truly gods of small things. While their work was predicated on neutrons, subatomic particles invisible to the unaided eye, they were also more accustomed to small spaces. Research laboratories or quaint pubs filled with pipe smoke, like at the Aldermaston base of the UK Atomic Weapons Research Establishment in southeast England, were more familiar territory than the plains of Australia's inland.[38] From the bucolic countryside of England, the Great Victoria Desert would have conjured Hebraic notions of the desert as a sandy frontier, a waterless and lifeless vacuity—a place, perhaps, to endure self-sacrifice, and test oneself against the temptation of Faustian bargains enacted for the sake of scientific progress.[39] These hopes were undoubtedly tempered by the lived experience of the Australian desert. The "Bridge of Sighs" at the Maralinga Airfield stands as a testament to overwhelmed Brits. This unimpressive bridge straddling a gutter is named for the standard reaction of British soldiers and scientists as they walked across it. As journalist John

[33]John Clearwater and David O'Brien, "'Oh Lucky Canada': Radioactive Polar Bears; the Proposed Testing of British Nuclear Weapons in Canada," *Bulletin of the Atomic Scientists* 59, no. 4 (2003): 60–65.

[34]Roslynn Haynes, *Seeking the Centre: The Australian Desert in Literature, Art and Film* (Cambridge: Cambridge University Press, 1998), 291.

[35]Early explorer Abel Tasman cited in Stuart Macintyre, *A Concise History of Australia* (Cambridge: Cambridge University Press, 2009), 25.

[36]For example, refer to Henry Handel Richardson, *The Fortunes of Richard Mahony* (Melbourne: Allen & Unwin, 1930).

[37]The myth of empty desert wastelands was further perpetuated in the early 2000s when Prime Minister John Howard attempted to set up a nuclear waste dump in South Australia. See Eve Vincent, "Knowing the Country," *Cultural Studies Review* 13, no. 2 (2007): 138–52.

[38]For example, see reference to William Penney and poetry in Steve Grant, "Soccer Pitches Pop Up in Landrover Mystery," *Fremantle Herald*, 8 June 2018, 2.

[39]Suggested reading: Gino Segre, *Faust in Copenhagen: The Struggle for the Soul of Physics* (London: Penguin Books Ltd, 2007).

Keane wrote, "Last rites—a sigh of trepidation by those arriving; a sigh of relief by those departing—were often performed on that spot."[40] The echoes of that more famous bridge in Venice, where prisoners saw the canals of that city for the last time before they were incarcerated, are palpable.

Today, the settlement built on Anangu land, Maralinga Village, is a relic being turned into a tourist attraction. Its rudimentary but growing museum features an eclectic mixture of artefacts. Juxtaposed with scientific, medical and military equipment, vintage Barossa wine bottles and crockery hint at an attempt to impose British gentility on the remote outpost. Recalling Gothic tropes of the Australian outback, images of the unheimlich abound. Weird discordant artefact arrangements and signs of "unhousedness" and dispossession are offset by striking Aboriginal art and piercing fluorescent lighting. Small rooms of vintage steel medical equipment are abutted with radioactive warning signs, while a rusted gear stick sits next to a cupboard of aged soft drink bottles. Far from misrepresenting the site, this eerie installation captures a history of discord, loss and faded colonial victories. In many ways, the museum at Maralinga is a palimpsest of a fallen world.

The Maralinga test sites themselves continue this impression of the uncanny. To the north of the village, the main test sites are marked with simple frustums, 1.5-metre tall topless concrete pyramids with recessed letters stating the name of the site and when the atomic test took place. The names—One Tree, Marcoo, Biak, Wewak, Taranaki and others—are themselves arrestingly vivid. The frustums were erected in the 1990s, during the most recent clean-up, when the area was still closed to the public, and are functional, inelegant structures. While some twisted steel remains, the old Land Rovers and pill-box observational posts are buried in the pits. The creepy mannequins deliberately placed into the blast zone are long gone, joining other contaminated detritus in the 21-metre-deep bomb crater at Marcoo. For a place with such historical drama, what is left of these sites may appear a little underwhelming to anyone oblivious to the reality of the atomic hellfire unleashed there. Such visitors want more, so we are told,[41] as the deepest secrets are buried in strata.

Dimensions of Geology: Maralinga by the Sea

Geology is traditionally classified as a physical science. However, geologists rarely involve themselves in experimentation the way that physicists or chemists do. Instead, geologists look for subtle clues in the contemporary exposure of rocks to detect and elucidate a past—a geological "history". The use of the term "history" is perhaps not as metaphorical as it may seem. As in history generally, ancient evidence—for geologists, rocks—offers scant data compared to more recent events. The oldest age of the Earth, the Precambrian, covers the first 3.5 billion years of the 4.5 billion years of the planet—a lot of time for primary sources to be subsumed, metamorphosed, re-exposed and weathered. As geologists work forward, evidence of change is easier to deduce, and epochs become shorter as lines of demarcation are more pronounced. The Holocene epoch, being

[40]John Keane, "Maralinga's Afterlife," *Age*, 11 May 2003.

[41]The Maralinga caretaker reported that he had considered mounting a television in the tour bus so that he could replay footage of the bombs as he pulls into each test site. Foucauldian heterotopias, like old prisons or red-light districts, have become modern tourist sites.

only the past 12,000 years, concluded with the recent start of the Anthropocene. The kind of history that geology brings to light is seldom joined with cultural history and geography; however, in contemplating Maralinga, we found that it offers otherwise inaccessible insights. Geology is in essence a storytelling and knowledge-making practice that links the deep past to our contemporary Earth environment. As the description below shows, the geology of the Maralinga region is in fact central to the cultural history that has been indelibly etched into it.

Mirroring its distinctive colonial history, the Maralinga Plain is a modern-day topographic anomaly, an enclave of divergent winds[42] and salty water among the sand ridges and sandstone ranges of the Great Victoria Desert. To the south, the Nullarbor Plain contains deep caves of abundant fresh water, eroded from the limestone and containing petrified remains of animals.[43] The surrounding rock of the Nullarbor is fossil too, showcasing embedded pieces of shell that contain clues to the origins of Maralinga landforms.[44] These physical features show that the temporal transition of Maralinga as a heterotopia does not simply pertain to its cultural history, but also its geological past.

Around 55 million years ago, only 10 million years after the dinosaurs died out, the Earth's climate was much warmer than now. Even in the high-Arctic, sea temperatures were an estimated 23°C, equivalent to tropical seas today.[45] Earth had no ice, and the sea levels were much higher. Geoscientists, such as Baohong Hou, deduced that at this time the Great Australian Bight cut much deeper into the continent.[46] As the planet cooled, the water gradually receded, and a warm shallowing sea allowed for corals and shell beds to grow on the sea floor; these would become the Nullarbor limestone. This grand bay was approximately the size of the Gulf of Mexico, more than 1,000 kilometres from east to west, and 500 kilometres from north to south. Indeed, driving across the flat Nullarbor Plain today, the ghost of the ancient seabed, feels like zipping in a boat across the water. Feeling the shape of the Earth this way, with the natural horizon on all sides on land, can be disorienting. Here, the natural landforms alone, quite distinct from the eerie tourist centre attached to the north, produce a sense of "otherness", of the uncanny.

The diverse topography surrounding the Maralinga test sites includes sandy desertscapes. Just as the human infrastructure is penetrable, but beset by obstacles limiting and complicating entrance, the landscape presents its own access challenges. In the late Eocene (around 37–34 million years ago), the ancient northern shoreline of the bay was a long red sandy dune, perhaps more than 100 metres high. Long-shore currents, driven by the same prevailing westerly winds of today, carried sand from the eroding cratons of Western Australia along the coastline. These ancient currents formed dunes along the coast, influenced by both long-shore and offshore Aeolian action, the same way winds now form longitudinal dunes.

[42]Paul Hesse, "The Australian Desert Dunefields: Formation and Evolution in an Old, Flat, Dry Continent," in *Australian Landscapes*, ed. P. Bishop and B. Pillans (London: Geological Society, 2009), 141–64.
[43]"Cave: Searching for Australia's Forgotten Beasts," Western Australian Museum, http://www.museum.wa.gov.au/cave/ (accessed 10 January 2022).
[44]Alice Gorman, "Trace Fossils: The Silence of Ediacara, the Shadow of Uranium," *Griffith Review* 55 (2017).
[45]James C. Zachos, Gerald R. Dickens, and Richard E. Zeebe, "An Early Cenozoic Perspective on Greenhouse Warming and Carbon-Cycle Dynamics," *Nature* 451 (2008): 279–83.
[46]Baohong Hou et al., "Evolution of Beach Placer Shorelines and Heavy-Mineral Deposition in the Eastern Eucla Basin, South Australia," *Australian Journal of Earth Sciences* 50 (2003): 955–65.

Meanwhile to the north, central Australia was wet and subtropical, its great rivers draining from the interior into the gulf. Hou and colleagues have names for these river valleys, such as the "Tallaringa paleo-valley", although they existed before any human. Near present-day Mamungari (west of Maralinga), a notch-like smaller bay disrupted the sweeping shoreline and allowed the sand dune to be pushed into a sandbar. This sandbar grew to over 200 kilometres long before it was halted by an alluvial channel of similar sand, and behind it formed a large swampy lagoon.

As evidenced by some carbonaceous layers, at times this lagoon had vegetation and trees, and at others was inundated with colonies of molluscs growing in the tidal zone. Like the juxtaposition of artefacts at the Maralinga museum, the land has a tumbling multitude of anomalies. Over time, the lagoon filled with anoxic rotting vegetation, dead shells and silt washed down from inland. Oolites, rounded concretions of calcium carbonate the size of gobstoppers, grew slowly like snowballs, rolling back and forth on the lagoon bed in the mineral-rich water. These oolites are not fossils of biota, but fossilised tides created when the gravitational tug of the moon pulled on the silky blanket of sea millions of years ago.

This ancient marine history ensured that the present-day region, with its deep red sand and intermittent rolling dunes, was also awash with salt. In the present day, the sandbar has been remoulded into a series of east-to-west-running dunes of the Ooldea Range, so that the access road to Maralinga rises and falls like waves on a slow sea. Maralinga Village sits atop this range on the recent dune field, but also upon the ancient one that, some 35 million years ago,[47] would have commanded great views across the coral-filled gulf to the south. To the north, the view would have looked across the lagoon, to the distant ranges from where the silty rivers flowed. The important water holes at modern Ooldea and Palinga are a result of permeable terrestrial dune sandstone directing rainwater, safe from the evaporating sun, into the near-surface aquifers. The old lagoon, where the main atomic test sites were positioned, is still a depression, a lowland between the sandstone ranges. The rare rain that falls is channelled into the depression. It mixes with salty sediment, runs underground to Carle Thulka (Lake Maurice) and evaporates. Unlike the Nullarbor, the salt here cannot be washed to the sea but instead leaves behind a brine that, as Aboriginal people knew and Tietkens learned, is saltier than the sea itself. The hall of mirrors in Foucault's essay provides a ready parallel to this geological reality in which appearances are deceptive to the untrained eye of a colonial explorer.

The apparently contradictory combination of terrestrial and marine forms further suggests the Maralinga region as a geological or topographic anomaly, a heterotopia, containing naturally occurring deviation, juxtaposition, illusion, prohibition, deviation and temporal shifts. The Nullarbor limestone is clearly marine, and the Ooldea and Paling sandstones of the old red dunes are clearly terrestrial. Yet what geologists call the Garford Formation, beneath the Maralinga Plain, consists of layers of lagoonal sediments that are classified as both terrestrial and marine.[48] Geomorphologically, this ephemeral boundary proves that the seams between the two obvious states of the planet—sea and land—are not hard and precisely marked (coast) lines, but are transitional zones

[47]Hou et al., "Evolution of Beach Placer Shorelines," 955–65.
[48]Hou et al., "Evolution of Beach Placer Shorelines," 955–65.

intermittently fluctuating between being submerged by the sea and exposed to the air. The result is what we now see as the Maralinga Plain—a flattish depression fortified by natural mottes of sand.

An in-between space, neither land nor sea, the Maralinga Plain is a topographic heterotopia, a place of human as well as geological otherness. The geological influence of deep subterranean space and deep time informs the elements that today dictate the nature of the earth, wind and water. Far from coincidental, the historical trajectory of Maralinga is entwined with its geological roots: a bad-water spirit place of the mamu for Anangu[49] and a secured site—bulwarked by geological processes and as flat and protected as the ancient lagoon itself—perfect for Beadell, the British scientists and the bomb.

Maralinga and the Australian Anthropocene?

Australian geology and its landforms are famously ancient. Vast tracts of the landmass are horizon-to-horizon peneplains of erosional surfaces and red-rusted earth. Unlike all other continents, Australia does not stand astride major active faults and wrenching tectonism. This is geologically a quiet place with unearthed erosional surfaces and strata being formed gently over time. Despite the sparse human habitation in the outback, signs of our presence easily accumulate on this slow-changing land.

The idea of an Anthropocene demands both a cultural and a geological framing to place planet-changing humanity within the vastness of geological time. Doing so requires at once an arrogant assertion of our power, a humbling realisation of the smallness of our existence, and an awed acknowledgment of how deep "deep time" really is. Nevertheless, geoscientists tend to agree that a permanent marker of recent human industry will inevitably be fossilised within the Earth's strata.[50] Perhaps, after the current version of humanity burns out, a few layers of sediment will enable a future intelligent lifeform evolving on (or returning to?) Earth to deduce our long-gone presence and prevalence.

Debate continues over which particular human impact will define the start of the proposed Anthropocene era.[51] James Taylor Carson has addressed the Australian Anthropocene with a well-posited argument for both colonisation and our contribution of coal to the Carbon Age.[52] Indeed, the industrial revolution and the burning of coal mark the great acceleration of human impact and is the most favoured time to consider the start of the Anthropocene.[53] Various other dates, however, have been proposed as a way to compartmentalise time in the Anthropocene and its sub-ages. Of the possible choices, only one specifies a single moment: 16 July 1945, at 5:29 a.m., when British scientist Ernest Titterton turned the dial, and the Trinity atomic test exploded over the New

[49]The Maralinga caretaker told us that the Maralinga Plain is "mamu", meaning a place of the mamu monster, a dangerous shapeshifter to be avoided. Refer to Christine Judith Nicholls, "Dreamings and Place-Aboriginal Monsters and their Meanings," Artark, https://artark.com.au/blogs/news/dreamings-and-place-aboriginal-monsters-and-their-meanings (28 February 2023).

[50]Simon L. Lewis and Mark A. Maslin, "Defining the Anthropocene," *Nature* 519, no. 7542 (2015): 171–80; Soriano, "On the Anthropocene Formalization," 1–10.

[51]Soriano, "On the Anthropocene Formalization," 1–10.

[52]James Taylor Carson, "Decolonisation and Reconciliation in the Australian Anthropocene," *Journal of Australian Studies* 45, no. 1 (2021): 4–17.

[53]Soriano, "On the Anthropocene Formalization," 1–10.

Mexico desert.[54] In the Great Victoria Desert, the atomic age arrived some 3,012 days later, on 15 October 1953, with the early-morning detonation of Totem I at Emu Field. Titterton, who migrated from Britain to Australia in 1950 to head the nuclear physics department at The Australian National University, was present at Totem, and he can be seen as a connective thread in the atomic Anthropocene tapestry.

Geological processes are ongoing and will continue to shape the region. Consider, for example, that the Paleocene-Eocene thermal maximum, which placed Maralinga beneath the sea, coincided with high carbon levels. At that time, worldwide volcanism bellowed carbon dioxide into the atmosphere. Human-induced climate change arises from the same greenhouse effect, with one prediction indicating we may reach levels of atmospheric CO_2 like those seen in the early Eocene by the year 2400.[55] If that happens, the Maralinga Village area may again be on the coast, and the "Forward Area" will be a lagoon.

Similarly, the radiation at Maralinga is still detectable and contaminates soil and plants, despite attempts to contain it. The heterotopic crisis at Maralinga is detectable in strata. The evidence of the blasts themselves is more subtle, and post-test-era rehabilitation endeavoured to sweep up the debris and bury it. The heat of an atomic blast peaks at over 5,000°C, as hot as the surface of the sun, and has littered some of the sites at Maralinga with a substance known by geologists as trinitite. Technically, trinitite is not a mineral because it lacks crystal structure. Instead, it is melted sand that forms an amorphous green to black glass. Geologically, it is a radioactive cousin of the volcanic glass obsidian, which forms when lava rapidly cools. Over time, the radiogenic properties of this rock and the surrounding area dissipate. The trinitite, however, will remain, essentially fossilising the split-second detonation of each atomic blast. This accidental by-product of the atomic explosions, inert to chemical reaction and impermeable to rainwater, is scattered around the ground zeroes like broken bottles at an old campfire—evidence of departure without tidying up.

The perfunctory clean-up efforts by British and Australian governments may have comparably long-lasting effects. The main burial pit of radioactive waste sits near the Taranaki test site in the far northwestern reaches of the Forward Area. Taranaki became the most contaminated site at Maralinga. Scientific surveys eventually revealed about three million loose fragments of plutonium at Taranaki, a finding that prompted consternation at the highest levels of the Australian government and helped make the case for the Royal Commission in the mid-1980s.[56] The final mushroom cloud explosion took place there as part of the 1957 Antler test series, but the contamination caused by the infamous Vixen B trials of the early 1960s left the worst legacy, spreading over 22 kilograms of "fiendish toxic" plutonium-239 across the landscape, to be found much later in those millions of fragments.[57] During the most extensive clean-up at Maralinga in the late 1990s, diggers with hermetically sealed cabs excavated huge pits for the radioactive material, including fragments of unfissioned plutonium from the minor tests.[58] A jumble

[54]Becky Alexis-Martin, "Nuclear Warfare and Weather (Im)mobilities," in *Weather: Spaces, Mobilities and Affects*, ed. Kaya Barry, Maria Borovnik, and Tim Edensor (London: Routledge, 2020), 236–49.
[55]Zachos, Dickens, and Zeebe, "An Early Cenozoic Perspective," 279–83.
[56]Tynan, *Atomic Thunder*, 122.
[57]Tynan, *Atomic Thunder*, 24.
[58]Church et al., "Rehabilitation of Former Nuclear Test Sites," 182.

of detritus and soil filled the pits, which was then subjected to "in-situ vitrification", in which electrodes sent strong electric currents through the buried debris, raising it to temperatures up to 2,000°C.[59] Just as the heat of the bomb forms trinitite, this process was intended to turn the dangerous material into a solid lump of glass. While this glass is no less radioactive, it is less likely to react with the surrounding rock and groundwater. However, the in-situ vitrification apparatus exploded midway through, and the remaining debris was capped with concrete, leaving questions over its efficacy.[60]

Even the formal demarcations of these clean-up areas suggest an ominous legacy. The frustum at the Taranaki burial pit, however, is different from those at the other ground zeroes. Rather than marking a point in space, it marks an area. The raised writing on the concrete states, "DO NOT DIG IN THIS AREA", and it includes the Universal Transverse Mercator coordinates (a metric global coordinate system uniquely describing every point on the planet) detailing a trapezoidal area 228 by 157 metres. At first sight, this frustum is perplexing: why is it marked differently, so permanently, and with UTM coordinates? Presumably, government bureaucrats have systems in place to maintain records and closely control access and excavation of the site. Upon reflection, the purpose of the monuments becomes clear: they are designed to become artefacts themselves, fossilised remains of catastrophic human error. Just as the pharaonic Egyptians left warning signs of cursed tombs in another desert, the markings at Maralinga are a warning to be deciphered by a far-future archaeologist or palaeontologist contemplating a dig for the sake of history, science or curiosity. The Anthropocene will certainly record our ruinous mistakes and environmental impact, and we are already implicitly acknowledging this state of affairs and leaving intentional messages to future enquiring minds.

While burying nuclear materials ensures their place in strata, it is perhaps also, as Morton explains, "untenable" to discard waste by "shunting it under the rug".[61] The contrarian views of the Nuclear Guardianship movement, as presented by Morton, advocate for radioactive materials occupying social spaces, stored above ground where they become obvious parts of society and can be managed into the future. Morton seeks to remove the boundary between humans and "Nature" and instead binds humanity's hyperobjects into our new Anthropocene environment. After all, radiation is inherently uncontainable and has already been released from the confines of intentional or accidental storage.

The atomic test sites in the South Australia desert are four-dimensional microcosms of an Anthropocene principle of human intervention in global systems. Some hints of the point in time when that principle became reality are discernible in an answer given by the architect of the British bomb, William Penney, when questioned by the mid-1980s Royal Commission into the British Nuclear Tests. The question was: "[In the] planning stage, did you harbour concerns in relation to the fact that the fallout from those [Emu Field] tests would necessarily pass across a significant part of Continental Australia?" Penney answered: "They would pass around the world."[62] The events at the test sites placed

[59]Church et al., "Rehabilitation of Former Nuclear Test Sites," 221.
[60]Church et al., "Rehabilitation of Former Nuclear Test Sites," xlv.
[61]Morton, *Hyperobjects*, 17.
[62]William Penney, "Transcript of Evidence to the Royal Commission into British Nuclear Tests in Australia," Reference A6448, Item 9, 1985, 4341, National Archives of Australia.

marks on the whole planet, satisfying another criterion—global record—to establish a geological age.

This assertion is backed by an international collaboration known as Project Sunshine, which sought to establish a signal, a pulse, from atomic testing. This project originated when the United States Atomic Energy Commission contracted the Rand Corporation in 1953 to undertake measurement of strontium-90 in human bones. If the Anthropocene, or a sub-category/age, can indeed be dated from the start of the atomic age, Project Sunshine is one way the line of demarcation can be established. The project arose from scientific fears about increased atmospheric testing of atomic and thermonuclear weapons, with 1954 being a particularly big testing year by the US and USSR.[63] Global atmospheric strontium-90 levels were projected to rise 10-fold during 1954. The British government, and by extension the Australian government, came into the project in 1957, as the tests in Australia were contributing to strontium in the atmosphere, and from there into the food chain, then into humans. A signal from the strontium was detected, and soon atmospheric testing was banned.[64]

While the Anthropocene is explicitly marked geologically at Maralinga, radiation markers from all atmospheric atomic blasts will also find their way into the Earth's whole geological record[65] and, as Project Sunshine showed, into human and other animal bones. If the International Commission on Stratigraphy ultimately settles on the atomic age being a marker of the Anthropocene, our current era began on 16 July 1945. A single moment in time defining the start of a geological age is not without precedent. Geologists combine the last major era, the Mesozoic, with the end of the Cretaceous, 65.95 million years ago. This shift was not transitionary; the boundary was a single moment on a single day when an asteroid slammed into Earth. That split second doomed 80 per cent of the Earth's species to extinction. The most definitive evidence we have of this day is a thin layer of sediment containing elevated levels of the rare metal iridium.[66] Just like plutonium and fission products from an atomic blast, iridium atoms were cast into the sky from the asteroid impact and circulated in the stratosphere before drifting down to the land and sea, there to be found as a subtle global monument of a momentous day.

Conclusions

The Anthropocene is marked clearly and definitively at Maralinga: in the filled-in bomb crater, trinitite, haunting radiation, and in the intentionally durable and descriptive frustums warning of danger. Although the area has several ground zeroes from where the Anthropocene artefacts were hurled into the atmosphere, the atomic age is recorded in earth, air and water around the world. As a heterotopia, the military-industrial and micro-urban remnants at Maralinga are still visible. For the visitor, the artefacts are a sobering reminder of the Cold War and emblematic of reconceived conquests and

[63]Ralph E. Lapp, "Sunshine and Darkness," *Bulletin of the Atomic Scientists* 15, no. 1 (1959): 27–29.
[64]Paul Rubinson, "'Crucified on a Cross of Atoms': Scientists, Politics, and the Test Ban Treaty," *Diplomatic History* 35, no. 2 (2011): 283–319.
[65]A. Kudo et al., "Global Transport of Plutonium from Nagasaki to the Arctic: Review of the Nagasaki Pu Investigation and the Future," *Radioactivity in the Environment* 1 (2001): 233–50.
[66]J. Brittan, "Iridium at the K/T Boundary—the Impact Strikes Back," *Astronomy & Geophysics* 38, no. 4 (1997): 19–21.

colonialisation by the British and Australian governments of (not so) empty deserts. Even the radiation is a testament to the cavalier approach of mid-20th-century atomic scientists, harnessing and mobilising the fundamental energies of the universe. The place has been returned to Anangu in a powerful act of reterritorialisation. Under the aegis of this care and nature itself, the Maralinga lands are gradually being ecologically and culturally restored.

Scientists today can predict the future rate of decay of radioactive energy, and peer deep into the past through layers of sediment that speak of movements of water, wind and even the gravitational pull of the moon on the long-gone tidal lagoons. At Maralinga, the geological history of a space that was both land and sea transitions to human history in the making of this novel heterotopia—both a secure site for atomic testing and an ancient homeland rich with life and legend, unseen by Western eyes during its 60,000-year human occupation. Here, markers of the Anthropocene, traceable moments of humanity's folly crystallising from untouchable and ethereal Mortonian hyperobjects, have been created through the intersection of geological action with mid-20th-century geopolitics. We visiting scholars saw in the Maralinga lands a confluence of rivers, carrying the atomic history, the literary imagination and the depths of geological time, and ultimately the meaning of the place, to the unifying ocean of our understanding of this continent in all its shifting dimensions.

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ORCID

Lianda Burrows http://orcid.org/0000-0002-6593-4803
Darren Holden http://orcid.org/0000-0003-2336-9698
Elizabeth Tynan http://orcid.org/0000-0002-7696-678X

[67]South Australian atomic test sites at Maralinga and Emu Field are part of the lands managed by Maralinga Tjarutja (MT) Council, known more broadly as the Maralinga lands. The 10.6-million-hectare MT territory in the central far west of South Australia is cared for by the Oak Valley Rangers, a team of Traditional Owners who enact various land-management plans. During our visit to Maralinga and Emu in April 2021, no Traditional Owners were present, owing to cultural business. See *Oak Valley Rangers, What, Who, How, Why, Where: A Brief Summary of the Ov 2020/21 Oak Valley Ranger Work Program* (Maralinga: Maralinga Tjarutja Council, 2020).