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Clay Composition and Particle Size of the Canterbury Drifts - Climatic, Oceanic, and Tectonic change in the SW Pacific

Thesis submitted by
Marissa Land
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Thesis committee:

Dr Raphael Wust, School of Earth and Environmental Sciences, James Cook University
Professor Bob Carter, Marine Geophysical Laboratory, James Cook University
Dr. John Luly, School of Earth and Environmental Sciences, James Cook University

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Eddie Ness, Advanced Analytical Centre, James Cook University
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Abstract

Marine sedimentary records provide valuable information for reconstructing ancient environmental and climatic change, and by doing so, also contribute knowledge critical for better understanding future climate change. Records from mid-latitude locations, such as New Zealand (Southern Hemisphere), are particularly important for paleoenvironmental research because they provide information on potential climatic teleconnections between equatorial and polar regions. In reality, however, paleoclimatic and paleoceanographic research on mid-latitude records has received limited attention, particularly in the Southern Hemisphere.

This thesis focuses on Neogene-Pleistocene drift deposits in the Canterbury Basin, also known as the Canterbury Drifts, SE New Zealand. The Canterbury Drifts are recognised as important paleoclimate and paleoceanographic archives of the SW Pacific because they record intrinsic signals of variability in South Island climatic conditions (glacial erosion), of tectonic uplift of the Southern Alps (western South Island), and of the flow of intermediate depth water masses and associated currents that originate from Antarctica (i.e. Sub-Antarctic Mode Water, Antarctic Intermediate Water, Antarctic Circumpolar Current). Despite previous research on the Canterbury Drifts, crucial aspects of their history remain unknown, including details of sediment source and supply dynamics relative to climatic, oceanographic and/or tectonic processes, and how SW Pacific climatic and oceanographic conditions have responded to Milankovitch cycles and high latitude conditions. The aim of this thesis was to address these issues by using clay mineralogy, clay geochemistry (trace elements and Nd, Sr isotopes), and particle size analysis of Canterbury Drift deposits recovered from Plio-Pleistocene Ocean Drilling Program (ODP) Site 1119 and the Early Miocene Bluecliffs Silt (BCS) Formation.

The principal objectives of this thesis were to identify:

1. Changes in South Island weathering regimes and detrital sediment supply relative to Plio-Pleistocene climatic conditions.
2. Change in onland source for shelf sediments relative to environmental conditions, including distinct tectonic events during Plio-Pleistocene drift sedimentation.
3. Connectivity between the Southern Alps ice cap and Antarctic temperatures prior to MIS 11, and Milankovitch (orbital) cycles in Late Pleistocene drift sediments.

4. Changes in climatic, tectonic, oceanic conditions during the Early Miocene-Pleistocene Canterbury Drift succession, and Milankovitch cycles in Early Miocene drift sediments.

Plio-Pleistocene changes in South Island weathering regimes and detrital sediment supply are identified from the clay mineralogy of Site 1119 sediments. The abrupt replacement of smectite with higher chlorite and illite contents at ~3.5 Ma is coincident with the global Early-Late Pliocene transition and reflects the onset of a glacially modulated physical weathering regime, which accompanied abrupt global cooling at that time. Chlorite and illite remain abundant through the Late Plio-Pleistocene, consistent with persistent glacial erosion and continually cooling climate. A glacial control on physical weathering is also seen at high resolution (~4 ka resolution sampling between ~650-260 ka) as increased chlorite and illite deposition during cold glacial phases. Changes in clay mineralogy of ODP Site 1119 therefore reflect changes in onland weathering regimes associated with global climate events.

The high-resolution record (back to at least MIS 16) also shows close ties between the behaviour of the Southern Alps ice cap and Antarctic atmospheric temperatures. Periods of reduced Antarctic temperature are concurrent with increased glacial erosion on the South Island and increased supply of detrital sediments (chlorite, illite, Th, Rare Earth Elements) directly to Site 1119 during periods of lowered sea level. Cold phases were also a time of reduced Southland Current flow as determined by the fine mean sortable silt and low sand content proxies. Conversely, warm Antarctic temperatures (interglacial and glacial-interglacial transitions) are concurrent with reduced glaciation on the South Island, reduced detrital sediment supply to Site 1119 and faster Southland Current flow. Previous evidence of a connection between SW Pacific climate and Antarctic conditions has been strengthened in this study by using numerous proxies and by providing spectral evidence. Spectral analysis of the clay and particle size data indicates high latitude influence on New Zealand climate and oceanography during the Plio-Pleistocene and highlights complex heat distribution in the Southern Hemisphere.

Rare earth elements (REEs) in Site 1119 sediments identify a dominant Torlesse Terrane provenance during the Plio-Pleistocene. Trace element ratios (Th/Sc, Nd/Sc, Rb/Ba) could not confidently identify sediment source and question the conventional use of immobile elements to fingerprint sediment source. Neodymium and Sr isotope data demonstrate intervals of distinct provenance change, alternating between a central Torlesse Terrane source and more a more volcaniclastic-rich sediment input from terranes further south. Specific shifts in the geochemical record between 2.7-2.3 Ma and 0.7-0.6 Ma coincide with previously recorded Australian-Pacific plate rotation events, and suggest distinct episodes of tectonic control on sediment supply to the Canterbury Basin.

Identification of tectonic control on drift sedimentation highlights the importance of considering tectonic activity when interpreting paleoclimatic signatures in basin environments.

Early Miocene BCS drift sediments are dominated by smectites, indicating a prevailing chemically dominated weathering regime during times of low topographic relief in New Zealand, and warm global climatic conditions. Change from a dominantly chemical weathering regime in the Early Miocene to a dominantly physical regime in the Plio-Pleistocene occurred in parallel with the rapid and continuing uplift of the Southern Alps mountain range since the Late Miocene, and with deteriorating climatic conditions from the Late Plio-Pleistocene. The particle size of BCS samples is coarser than Site 1119 sediments and demonstrates long-term fining through the Canterbury Drift succession. This trend is consistent with the widening of eastern shelf areas, continual uplift of the Southern Alps, formation of a mountain glacial cap that accompanied the global Late Cenozoic cooling, and possibly diminishing current flow through a deepening basin environment. Spectral analysis of BCS samples reveals Milankovitch cycles (eccentricity and obliquity) in Early Miocene drifts, and a high latitude influence on New Zealand climatic and oceanographic conditions since the Early Miocene.

This research demonstrates that paleoenvironmental studies of mid-latitude sedimentary records, such as the Canterbury Drifts, are integral to piecing together changes in global climatic and oceanographic conditions through time. Understanding how the Earth's climate has changed in the past, and what has driven these changes, in-turn provides valuable insight into the prediction of, and potential effects of, future climate change.

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Publications produced during my PhD candidature

Publications

Land. M., Wust, R.A., Robert, C., Carter, R.M. (2010) Plio-Pleistocene Climate and Oceanography of the SW Pacific; clay mineralogy and particle size of ODP Site 1119, SE New Zealand. *Marine Geology*, **274**, 165-176 (Chapter 2)

Land, M., Wust, R.A.., Kemp, A.I.S., Carter, R.M. *in prep*. Trace elements of ODP Site 1119 – Unravelling Environmental Change in the SW Pacific (Chapter 3)

Land, M., Robert, C., Wust, R.A., Carter, R.M. *in prep*. Pleistocene sediment advection, climate, and oceanography in the New Zealand sector of the SW Pacific: connectivity with global climate and Antarctic conditions. (Chapter 4)

Land, M., Kemp, A.I.S., Wust, R.A., Mass, R. *in prep.* Isotopic Fingerprinting of New Zealand terranes in offshore drift deposits: implications for paleoclimatic implications? (Chapter 5)

Land, M., Wust, R.A.J., Robert, C., Carter, R.M. *in prep.* Changes in climate and oceanography through the Canterbury Drfit succession (Early Miocene-Pleistocene), SE New Zealand. (Chapter 6)

Conference Presentations

Land, M., Wust, R.A., Robert, C., Kemp, A.I.S., Carter, R.M. (2009) Clay Mineralogy and Clay Geochemistry of ODP Site 1119 – Climatic and Oceanographic history of the SW Pacific since ~3.9 Ma. Australian National Network in Marine Science Inaugural Conference, 1-2 December

Land M., Wust, R.A., Carter, R.M., and Robert, C. (2008) Clay Mineralogy and Clay Geochemistry of ODP Site 1119 – Paleoclimatic and Paleoceanographic History of the SW Pacific for the last 3.9 Ma. *EOS Trans. AGU,* 89 (53) Fall Meet. Suppl. Abstract PP11A-1363