# Provenance connections between Late Neoproterozoic and Early Paleozoic sedimentary basins of the Ross Sea region, Antarctica, southeast Australia and southern Zealandia

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**Summary** U-Pb detrital zircon age patterns are reported for latest Neoproterozoic, Cambrian and Ordovician greywackes in tectonostratigraphic terranes, formerly contiguous in the present-day Ross Sea region: southern Zealandia, Marie Byrd Land, West Antarctica, and Northern Victoria Land, East Antarctica. The youngest age components are commonly coincident with depositional ages. Latest Neoproterozoic-early Paleozoic recycled zircons have major component(s), at about 525, 550, and 595 Ma, about 40-80 million years older than depositional ages, suggesting active-margin depocentres with minor, contemporary volcanic sources, and older, exhumed plutonic equivalents, becoming volumetrically more important in the Ordovician. Late Mesoproterozoic age components, at 1030 and 1070 Ma, probably originate from igneous/metamorphic complexes in the Gondwanaland hinterland, and evolve into more polymodal patterns in the early Ordovician. The detrital zircon provenances reflect the evolution of plutonic/metamorphic complexes of the Ross Fold Belt, Transantarctic Mountains, and Delamerian Fold Belt, South Australia, as sediment sources to depocentres at the Gondwanaland margin.

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## Introduction

Late Precambrian to Early Paleozoic greywacke-dominated turbidite successions are a persistent feature of the eastern margin of the Gondwanaland supercontinent, and today form outcrops over extensive areas (500-1000km scale) in Northern Victoria Land, East Antarctica (Tessensohn et al., 1981), Marie Byrd Land, West Antarctica (Bradshaw et al., 1983, 1987; Pankhurst et al., 1998), Victoria and New South Wales, southeastern Australia (VandenBerg et al., 2000, Birch 2003, Glen 2005), and the southern part of the greater New Zealand region, Zealandia (Cooper and Tulloch, 2002, Adams 2004, 2007). With the exception of the Bowers terrane in Northern Victoria Land (Laird and Bradshaw 1983) and Takaka terrane in New Zealand (Cooper, 1989 Cooper and Tulloch 1992), their regional monotony and structural complexity, allows very limited lithostratigraphic subdivision, and rare fossil occurrences are frequently confined to tectonically isolated enclaves (chert, limestones etc). With some minimum age estimates from metamorphic ages of slates (Adams 1981, 1986, 1997, 2004, 2007), depositional ages of the main greywacke sequences could be latest Neoproterozoic, late Early–Late Cambrian, and Early Ordovician. On Gondwana reconstructions these depocentres appear to be grouped closely in the present-day Ross Sea region, and parallel to the Mesoproterozoic-Neoproterozoic margin of Australia-Antarctica. Very limited Early Paleozoic semi-schist outcrops on Campbell Island (Oliver 1950, Adams et al., 1979) in southernmost Zealandia offer a connection between the Australasian and Antarctic sectors. However, in New Zealand and Northern Victoria Land at least, and possibly also in southeast Australia (Glen 2005), these successions form the main part of tectonostratigraphic terranes (Tessensohn et al., 1981, Bishop et al., 1985, Cooper and Tulloch et al., 1992), allowing the possibility of the large-scale lateral translation to their final position of amalgamation (mainly in the Late Paleozoic). In to explore this possibility, we summarise here detrital zircon age studies of latest Neoproterozoic, Cambrian and Ordovician greywackes from terranes in southern Zealandia and Antarctica, to study their sediment provenance and confirm a former contiguity. These provide an extension to previous studies (Ireland 1992a, b) which demonstrated a surprising uniformity of detrital zircon age patterns, and in the Australian sector at least, reflecting a gradual uplift evolution of the Ross–Delamerian Fold Belts of East Antarctica and South Australia, at a stabilised Paleo- and Mesoproterozoic cratonic margin (Ireland et al., 1998, Fergusson and Fanning, (2002).

## Detrital zircon studies

Detrital zircon U-Pb age patterns were obtained for 11 greywacke samples (Fig.1) from Zealandia (*localities 1-5*), West Antarctica (*6,7*) and East Antarctica (*8-10*), comprising latest Neoproterozoic (*9,11*), Cambrian (*2,5,10*) and Ordovician (*1,3,6,7,8*) groups. Data from localities *6,8,9,10,11* are SHRIMP ages (RSES, Australian National University, Canberra), and from localities *1,2,3,4,5,7* are ICPMS ages (GEMOC, Macquarie University, Sydney). Full age datasets and probability density curves (using ISOPLOT) for individual samples, and an age data compilation for component peaks of the total sample set, are available from the authors, and will be published in detail elsewhere.

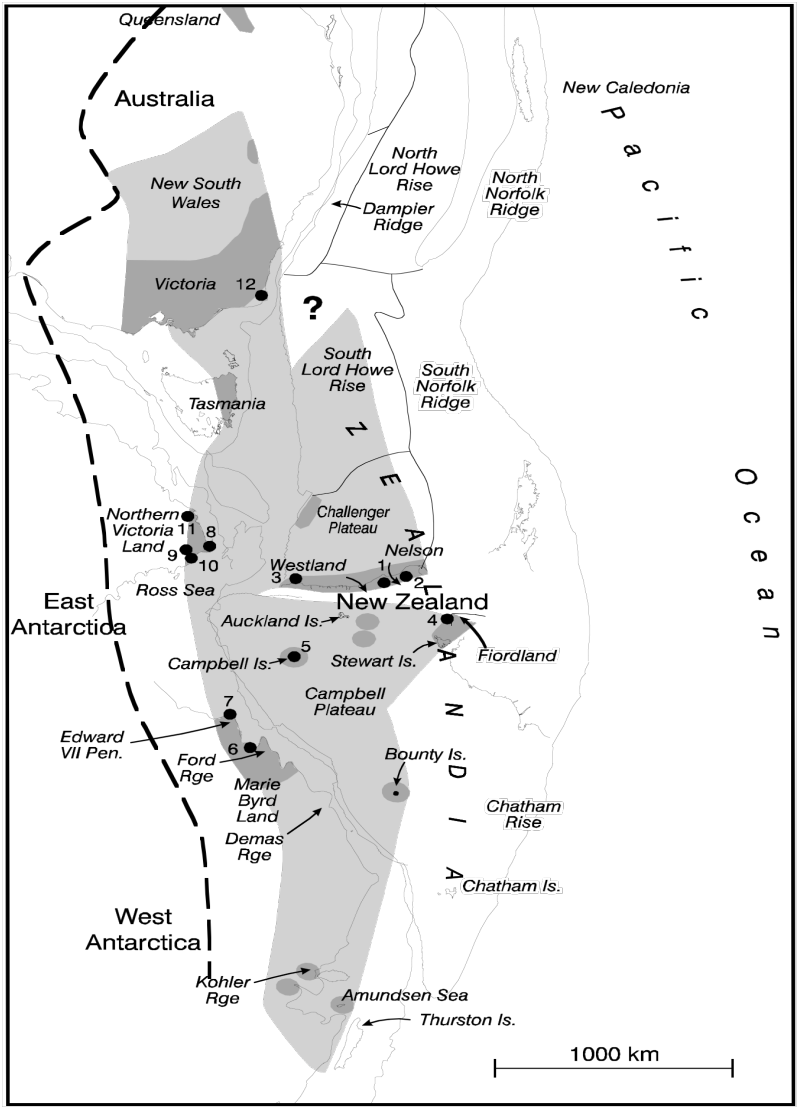


**Figure 1.** Late Paleozoic reconstruction of Pacific margin of Eastern Gondwanaland (after Sutherland 1999) showing the Late Precambrian continental margin (dashed line) and the probable extent of the subsequent latest Late Neoproterozoic to Ordovician sedimentary successions (grey), and probable continuations (pale grey), of the Lachlan Fold Belt of southeast Australia, and equivalents in Antarctica (Wilson, Bowers and Robertson Bay terranes) and Zealandia (Buller and Takaka terranes in the Western Province of New Zealand) . Numbers and dots indicate sample sites and other localities discussed in text: 1 Waitahu River, Buller (Buller terrane); 2 Takaka River and Wangapeka River valleys, Nelson (Takaka terrane); 3 Martins Bay, Westland (Buller terrane), 4 Cape Providence, Fiordland; 5 Complex Point, Campbell Island; 6 Swanson Mountains, Ford Ranges; 7 Drummond Peak, Edward VII Peninsula; 8 Robertson Bay (Robertson Bay terrane), 9 Priestley Glacier, Terra Nova Bay (Wilson terrane);10 Molar Range, Evans Névé (Bowers terrane); 11 Berg Mountains, Oates Coast (Wilson terrane), 12 Mallakoota, Victoria (Adaminaby terrane)

Technical procedures are given in Ireland et al., 1998, and Jackson et al., 2004. The significant age components (and their errors) in the probability density curves (comprising at least 4 analyses, and >4% of total), and their proportion of the total dataset, are summarised in Fig.2, with the sample datasets grouped, from bottom to top, in descending stratigraphic age order (where known).

The zircon age patterns have persistent, but rarely major, youngest components, almost coincident with estimated time of sediment deposition; the oldest examples are latest Neoproterozoic Berg Group (*11*) and Priestley Formation (*9*) of Wilson Terrane of North Victoria Land (NVL), Cambrian examples are from Bowers Terrane, NVL (*10*) and Takaka Terrane (*2*), and probably Campbell Island (*5*), Zealandia, and Early Ordovician examples are from Robertson Bay Terrane, NVL (*8*), Marie Byrd Land, MBL (*6,7*), Antarctica, and Buller Terrane, Zealandia (*1,3*).

There is a more complex assemblage of latest Neoproterozoic-early Paleozoic recycled zircons in all examples, with major component(s), each representing 15-30% of total, at about 525, 550, and 595 Ma, and mostly commonly these are 40-80 million years older than their depositional age. This suggests that an active, long-lived, continental margin is providing a minor, but continuous contemporary zircon supply via volcanic igneous rock sources, and in addition, with time, their exhumed plutonic equivalents, which become volumetrically more important in the Early Paleozoic. The recycled zircons also include persistent and important late Mesoproterozoic age components, most commonly at about 1030 and 1070 Ma. Like the latest Neoproterozoic-early Paleozoic components above, these evolve in a similar way, with younger components (early Neoproterozoic, 900-1000 Ma), and more polymodal patterns (1000-1300 Ma), becoming significant only in the early Ordovician greywackes. This suggests that their provenance is in more deep-seated igneous and metamorphic complexes of the Gondwanaland hinterland, with erosion gradually revealing an increasing variety of older, and long-persistent, zircon sources.

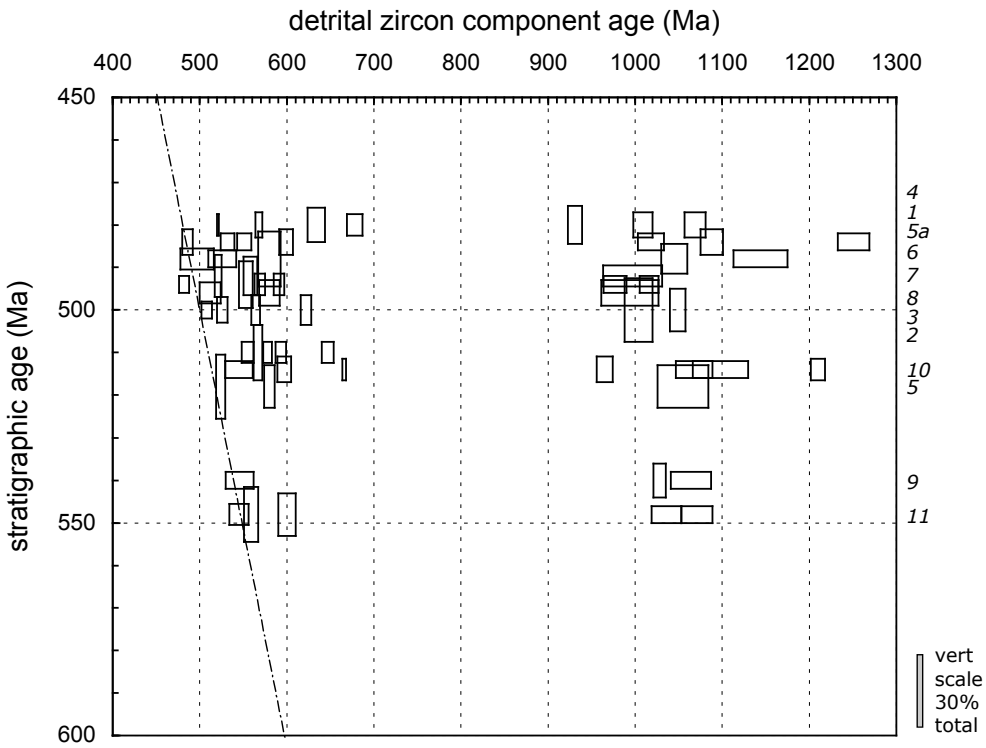


**Figure 2.** Detrital zircon U-Pb age components in latest Neoproterozoic, Cambrian, and Ordovician greywackes at the Eastern Gondwanaland continental margin, in the present-day Ross Sea region, viz., Northern Victoria Land (East Antarctica), Marie Byrd Land (West Antarctica), and southern Zealandia. Component age peaks are calculated from $^{206}Pb/^{238}U$ data for ages <1000Ma, and from $^{207}Pb/^{206}Pb$ data for ages >1000 Ma. Error box widths are the age error at 95% confidence limits, and the error box heights represent the proportion of that component as a percentage of the total (see scale bar at right). Age data are stacked from bottom to top in latest Neoproterozoic, Cambrian, and Ordovician groups, and in approximate descending stratigraphic age order (where known), The dot-dash line is the stratigraphic limit which ideally forms the younger age boundary to the detrital zircon age data. The sample locality numbers (*italic*) from Fig.1 are shown at right.

Geographically, the zircon provenance patterns confirm the conclusions of Ireland et al., (1998) and Fergusson and Fanning (2002), and reflect the evolution of plutonic/metamorphic complexes of the Ross Fold Belt of the Transantarctic Mountains, NVL and Delamerian Fold Belt of southeast Australia, as the main sediment supply to depocentres developing at the Gondwanaland margin. This continued from the late Neoproterozoic, at a relatively inboard location in the Wilson Terrane of NVL, to the early Ordovician, at the most outboard position, in the Takaka Terrane of Zealandia.

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