U-Pb AND Lu-Hf ISOTOPIC CONSTRAINTS ON THE PROVENANCE OF PERMIAN DETRITUS IN METASEDIMENTARY ROCKS OF SOUTHERN CHILE AND LIVINGSTON ISLAND, ANTARCTICA

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INTRODUCTION

The provenance of sedimentary rocks has been revolutionised through the application of isotopic methods, in particular U-Pb zircon dating of detrital zircon grains. Such studies reveal not only the age spectrum for the source of the zircon, but invariably one finds a young age component that places significant constraints on, and in some cases may redefine the time of deposition of the sediment. In many cases this young age component is derived from a magmatic source (invariably volcanic) that is effectively coeval with deposition.

Whilst U-Pb detrital zircon age spectra have been used to correlate sedimentary rocks (and basins), in many cases the age spectra are not unique. For example along the Palaeozoic Proto-Pacific margin of Gondwanaland, extending from Australia, through Antarctica to South America and Africa, once one crosses to the active or subduction-related tectonic phase of that margin, the detrital zircon signature is well known to be equivalent and dominated by Pan African and Grenville ages. It is within such non-unique age spectra that Lu-Hf isotopic analyses of previously U-Pb dated zircon are likely to define unique isotopic sources and so enable more refined correlations and plate tectonic reconstructions (for example Millar *et al.*, 2003).

The Hf isotope signature of an individual zircon age component will provide, grain by grain, a characteristic signature of the protolith and information as to crustal residence time. This is akin to Sm-Nd whole rock isotopic studies that paint a somewhat broader-brush picture of isotopic signatures and crustal residence times. The advantage of Lu-Hf analysis on parts of single zircon grains, means that one can characterise the initial Hf isotope signature for a specific age range within a detrital zircon suite and so significantly refine correlations, or the lack thereof.

GEOLOGIC SETTING

Within the Late Palaeozoic accretionary wedge of the western margin of South America and Antarctic Peninsula there are significant packages of metasedimentary rocks that lie outboard of the long-lived southern Patagonian Batholith. The provenance of these sediments is important in refining Gondwanaland configuration.

In Patagonia, the Duque de York Metamorphic Complex (DYC) is a turbiditic succession that was deposited on an accreted oceanic island complex comprising pillow basalt, red and white cherts (Denaro Complex) and Early Permian pelagic fusulinid limestones (Tarlton Limestone). Key outcrops of the DYC occur, from north to south, in the Madre de Dios Archepelago, Diego de Almagro archipelago and Isla Desolacion at the western entrance to Estrecho Magallenas (see Hervé *et al.*, 2003, and Hervé and Fanning, 2003 and references therein).

Further south, on the Antarctic Peninsula, the Trinity Peninsula Group (TPG) is a pre-Middle Jurassic turbiditic sequence and a correlative of the DYC (see Millar *et al.*, 2003; Hervé *et al.*, 2006 and references therein). The Miers Bluff Formation (MBF) crops out at Hurd Peninsula on Livingstone Island, South Shetland Achipelago to the north of the Antarctic Peninsula. The MBF comprises turbiditic sandstones, mudstones, conglomerates and sedimentary breccias, and has been correlated with the TPG. However, recent U-Pb detrital zircon age determinations have shown that the MBF is no older than Middle Jurassic, whereas the TPG is pre-Middle Jurassic (Hervé *et al.*, *in press*).

The detrital zircon age spectra from the turbiditic sequences outlined above all have a significant and anomalous Permian age peak. The source of these Permian zircons is speculative. Whilst some may have come from proximal sources, say for example in the Antarctic Peninsula, the preponderance of Permian-aged zircons in Patagonia suggests that there are significant Permian rocks yet to be identified in Argentina, or that the grains are from a long travelled drainage system, or that Patagonia and the Antarctic Peninsula were juxtaposed along the Gondwana margin. The purpose of this study is to characterise the Hf isotope signature of these detrital zircons and to assess the possible sources.

ANALYSED SAMPLES

Sample MD3 is a meta-sandstone from the turbiditic succession cropping out on Isla Santa Rosa, Madre de Dios Archipelago (Hervé *et al.*, 2003). Of the 50 grains analysed for U-Pb, excluding the interpreted discordant two Triassic grains, 36 grains have U-Pb ages between ~255 and ~305 Ma, that is ~72% of the grains analysed are from a Permain aged source.

Sample AL1 from Isla Diego de Almagro, is a massive, medium-grained sandstone within a turbiditic succession that has thin continuous pelitic interbeds (Hervé *et al.*, 2003, Hervé and Fanning, 2003). From the 56 grains analysed, 38 have U-Pb ages between ~255 and ~305 Ma, that is ~68% are Permian in age.

Simple FO0203 is a metasandstone from the turbiditic DYC on Isla Desolación. Our unpublished SHRIMP U-Pb zircon data for this sample show a prominent age peak in the Permian (~265-310 Ma) with scattered, subordinate peaks within the age range from ~465-615 Ma and isolated ages in the range ~900-1165 Ma, and older to ~1550 Ma. There are 22 of 58 grains in the range ~265 to ~310 Ma, comprising ~38% of the zircon grains analysed.

Sample VF15 is a submature medium-grained quartzofeldspathic sandstone from the MBF turbiditic sequence on the Hurd Peninsula of Livingston Island (Hervé *et al., in press*). This sample has a small but significant Triassic component in the detrital zircon U-Pb age spectrum. Minor Siluro-Devonian grains are present together with scattered Grenville ages, and 3 older Proterozoic-Archaean grains. Significantly, 27 of the 60 grains analysed have Permian U-Pb ages between ~250 to ~300 Ma; that is ~45% of the population is Permian.

Hf ISOTOPE RESULTS

The Hf isotope analyses have been carried out using by laser ablation, multi collector ICP MS (Neptune) at the Research School of Earth Sciences, ANU (Yaxley and Eggins *in prep.*).

For the purposes of this study, Hf isotopic analyses have only been made on the Permian aged zircons. Note that the areas analysed are those previously used for the ~1μm deep SHRIMP U-Pb analysis. Only those grains which were seen to be optically clear and free of inclusions could be analysed by laser ablation, as the laser pit burns through the sectioned zircon grain and consumes all material in its path. Thus not all Permian aged grains analysed by SHRIMP were suitable for laser Hf isotope analysis. For comparative purposes, initial Hf isotope values (ε_{Hf}) have been calculated at an arbitrarily assumed, common magmatic crystallisation age of 280 Ma.

For sample MD3, 27 of the 36 Permian grains could be analysed. The ε_{Hf} values range from -5.5 to -19.5, with 24 of the 27 grains having ε_{Hf} in the more restricted range of -5 to -10. For sample AL1, 27 of the 29 grains analysed have ε_{Hf} in the range of -5 to -11.5. The two other grains record approximately -14 and -18.5 respectively. Only 10 grains could be analysed from sample FO0203, with 9 having ε_{Hf} ranging from -3.5 to -10. The data from sample VF15 is more diverse, though 12 of the 16 grains analysed have ε_{Hf} ranging from -4 to -10.5. There is one grain with an ε_{Hf} of -28.5 with three others between -11 and -13.5.

DISCUSSION

The Hf isotope data for Permian aged zircons from the 4 samples of turbiditic sandstones all yield dominant ε_{Hf} values between about -5 to -10. This indicates that the source for these Permian zircons has had a significant crustal residence time and that the zircons are not derived from a juvenile magmatic source. Other grains from the same suite record more enriched Hf isotope signatures indicating derivation from older crustal sources, or at least mixtures of less and more enriched sources.

The fact that all 4 samples in this N to S transect from about 50°S to 60°S record a similar range in ε_{Hf} at 280 Ma suggest that they all have a similar source of turbiditic detritus. The Hf isotope data reinforces the conclusions from the U-Pb age spectra in terms of a common provenance. Further it indicates that juvenile crust was not dominant, but that in the zircon source regions there may have been mixing between an older continental crust, say Pan African and Grenville in age, together with a minor but significant subduction-related magmatic input.

The similarity in Hf isotope signatures, together with the U-Pb age spectra adds support to the premise that the Antarctic Peninsula was side by side with Patagonia during the Jurassic, receiving detritus from the same source as suggested by Hervé *et al.* (2006).

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RESUMO

O estudo de proveniência de rochas sedimentares tem sido revolucionado pela aplicação de métodos isotópicos, especialmente, a datação U-Pb de zircão detrítico. Tais estudos revelam não somente o espectro de idades da fonte do zircão mas, invariavelmente, um componente mais jovem que estabelece ou redefine um limite significativo no tempo de deposição. Análises Lu-Hf em ICP-MS com multi-coletor e abrasão a laser de zircão previamente datado pelo método U-Pb podem limitar as fontes isotópicas. A assinatura isotópica de um grupo de idades fornecerá uma assinatura característica do protolito e informação sobre o tempo de residência crustal permitindo, assim, correlações e reconstruções mais refinadas.

Na cunha de acreção do Paleozóico Superior da margem oeste da América do Sul e Península Antártica há expressivos pacotes de rochas metassedimentares sobre a borda sul do Batólito Patagônico. Dados isotópicos de Hf foram determinados em zircões detríticos permianos de 4 amostras de arenitos de uma seção N-S entre 50°S e 60°S. Em todas as amostras, os valores dominantes de ε_{Hf} estão entre -5 e -10. Isto indica que a fonte desses zircões permianos tem tido um tempo de residência crustal significativo e que eles não são provenientes de um arco magmático juvenil. Outros grãos apresentam assinaturas isotópicas de Hf mais enriquecidas indicando derivação de fontes crustais mais antigas. Essa similaridade nas assinaturas isotópicas de Hf, junto com o espectro de idades U-Pb é consistente com a premissa de que a Península Antártica esteve ao lado da Patagônia no Jurássico, recebendo detritos da mesma fonte.