A comparative provenance study of the late Mesoproterozoic Maud Belt (East Antarctica) and the Pinjarra Orogen (Western Australia): implications for a possible Mesoproterozoic Kalahari-Western Australia connection

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Summary The Maud Belt (East Antarctica) and the Pinjarra Orogen (Western Australia) are both late Mesoproterozoic orogens which formed during continent-continent collision. Based on palaeomagnetic data, recent Rodinia models suggest a collision between Kalahari and Western Australia along a combined Maud Belt/Pinjarra Orogen. Although attempts have been made to support this model with geochronological data, the size of the available data sets is as yet insufficient to allow statistically sound conclusions. In this contribution, we present ca. 950 new detrital zircon ages (LA-ICPMS and SHRIMP) from the Maud Belt and Pinjarra Orogen. While the samples from the Maud Belt show a clear Kalahari signature, the metasediments of the Northampton Complex (Pinjarra Orogen) were probably derived from sources within Australia and the adjacent Mawson Craton. A direct comparison between both regions shows significantly different age distributions and no clear evidence for a Kalahari-Western Australia connection was found.

Citation: Ksienzyk, A. K., J. Jacobs, J. Kosler, and K. N. Sircombe (2007), A comparative provenance study of the late Mesoproterozoic Maud Belt (East Antarctica) and the Pinjarra Orogen (Western Australia): implications for a possible Mesoproterozoic Kalahari-Western Australia connection, in Antarctica: A Keystone in a Changing World – Online Proceedings of the 10th ISAES X, edited by A. K. Cooper and C.R. Raymond et al., USGS Open-File Report 2007-1047, Extended Abstract 090, 4 p.

Introduction

The position of the Kalahari Craton within Rodinia is still actively debated and two contrasting palaeogeographic models have recently been proposed: (1) Dalziel et al. (2000) and Jacobs et al. (2003) interpreted Kalahari as the "southern continent" that collided between ca. 1090-1060 Ma with south-eastern Laurentia to form the Llano and Namaqua-Natal-Maud orogens. (2) Powell et al. (2001a) found that palaeomagnetic data require Kalahari and Laurentia to be separated by an ocean at least 1600 km wide at 1105 Ma and positioned Kalahari to the southwest of Laurentia. Powell et al. (2001b) and Pisarevsky et al. (2003) combined this new position with a revised fit for Australia and proposed that Kalahari might have collided with Western Australia during the Pinjarra Orogeny at ca. 1080 Ma (Bruguier et al. 1999).

Fitzsimons (2002) summarised geochronological data in support of a Kalahari-Western Australia connection. He argued that the metasedimentary rocks of the Pinjarra Orogen (Bruguier et al., 1999; Cobb et al., 2001) and the Maud Belt (Arndt et al., 1991; Harris, 1999) display essentially the same age spectra and thus must have been derived from the same sources and belong to the same orogenic belt. These arguments, however, are questionable, as the data sets used for this comparison are too small to reliably detect small zircon populations (e.g. Vermeesch, 2004). Therefore, this contribution aims (1) to provide a larger number of detrital zircon ages from the Maud Belt and the Pinjarra Orogen, (2) to review available geochronological data for potential source regions for the metasediments, and (3) by comparison of these data sets, to test a Kalahari-Western Australia connection from a geochronological perspective.

Samples and Methods

The locations of seven samples from the Northampton Complex (Pinjarra Orogen, Western Australia) and three samples from Dronning Maud Land (Maud Belt, East Antarctica) are shown in Fig. 1. In the Northampton Complex, a thick unit of garnetiferous paragneisses, representing the main rock type in the complex, was sampled. Two samples from the Maud Belt are also paragneisses, while the third sample (W30014) is part of a quartzite unit. Zircons were extracted from these samples using standard mineral separation techniques. Prior to analysis, cathodoluminescence images of all samples were obtained to reveal the internal structures of the grains. U-Pb ages of the detrital cores of the zircons were then determined using LA-ICPMS (University of Bergen) and SHRIMP (Curtin University of Technology, Perth) techniques.

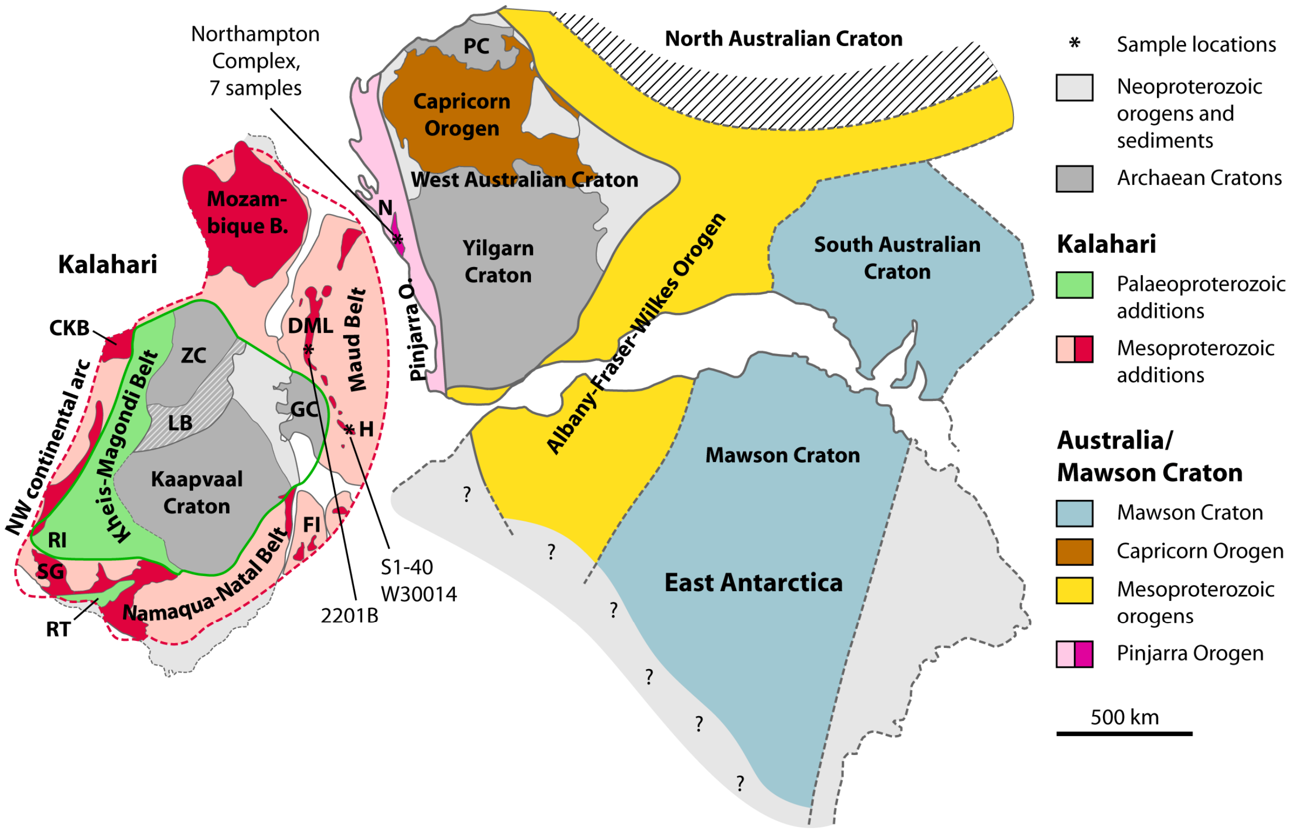

Figure 1. Possible palaeogeographic situation at the end of the Mesoproterozoic: Kalahari lies to the west of Australia, with the Maud Belt and Pinjarra Orogen facing each other. Palaeomagnetic data suggest that the Grunehogna Craton and Maud Belt, today parts of East Antarctica, belonged to Kalahari during the late Mesoproterozoic (e. g. Peters et al., 1991). The West Australian Craton is joined to the Mawson Craton (South Australia and parts of East Antarctica) along the Albany-Fraser-Wilkes Orogen. Sample locations are indicated. CKB – Choma-Kalomo Block, DML – Dronning Maud Land, FI – Falkland Islands, GC – Grunehogna Craton, H – Heimefrontfjella, LB – Limpopo Belt, N – Northampton Complex, PC – Pilbara Craton, RI – Rehoboth Inlier, RT – Richtersveld Terrane, SG – Sinclair Group, ZC – Zimbabwe Craton. Palaeogeography modified from Fitzsimons (2003) and Pisarevsky et al. (2003).

Results

Maud Belt

Altogether 130 new zircon ages were obtained from the three samples from the Maud Belt. The samples show quite different age distributions, but all are dominated by ages between ca. 1250 and 1000 Ma and contain older age groups between ca. 1450 and 1250 Ma and between ca. 2000 and 1650 Ma (Fig. 2). Ages between 1650 and 1450 Ma are extremely rare and are represented only by a single age in one of the samples. Young ages between 1100 and 1000 Ma are particularly dominant in sample W30014 and are interpreted as corresponding to metamorphic or magmatic events during continent-continent collision along the Maud Belt. Sample 2201B additionally contains ages younger than 1000 Ma which are attributed to a metamorphic overprint during a later Pan-African event. These age distributions are in good agreement with data from Arndt et al. (1991) and Harris (1999), who also found dominant age populations between ca. 1250 and 1000 Ma, with smaller populations at ca. 1400 Ma and between 2050 and 1850 Ma, and only a single age with a very low probability of concordance between 1850 and 1400 Ma.

Northampton Complex

A total number of 815 new zircon ages were derived from the Northampton Complex and all seven samples show similar age distributions with the majority of ages between 1300 and 1050 Ma, other prominent zircon populations between 1500 and 1400 Ma and at ca. 1600 Ma, and only few ages older than 1800 Ma (Fig. 2). The age of regional metamorphism in the Northampton Complex has been constrained at ca. 1080 Ma (Bruguier et al., 1999) and the youngest ages are therefore attributed to a metamorphic overprint during this or possibly an as yet unrecognised later event.

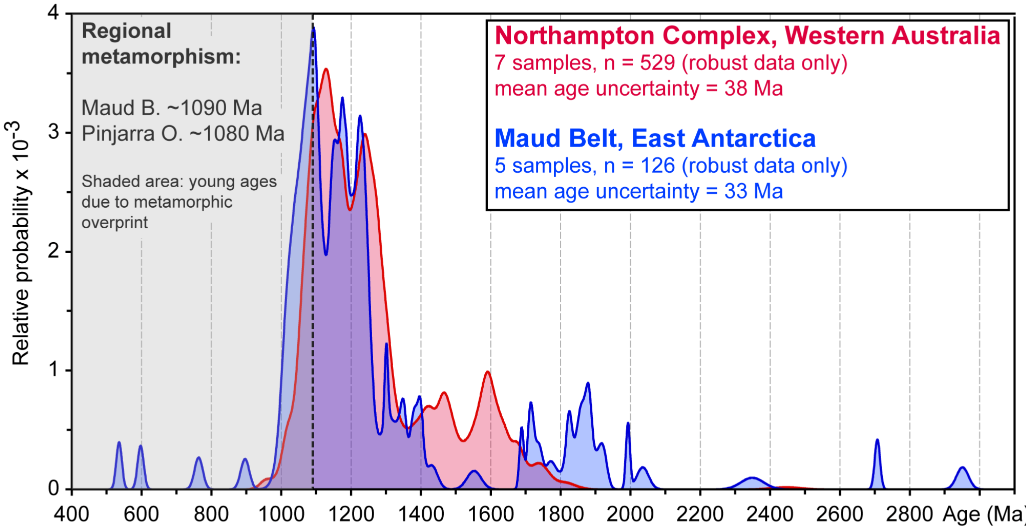

Figure 2. Probability density distributions (PDDs) of detrital zircons ages from the Maud Belt (blue) and Northampton Complex (red). The data were filtered for robustness and only ages with 1σ errors of the measured isotope ratios ≤ 5 % and a probability of concordance ≥ 0.05 are shown (including the less robust ages results in slightly wider peaks but very similar PDDs). To increase the number of analyses, the PDD for the Maud Belt includes both the new data from this study (3 samples; 100 robust ages) and detrital zircon ages from Arndt et al. (1991) and Harris (1999).

Discussion

Limitations

With orogens as poorly exposed as the Maud Belt and the Pinjarra Orogen and many of the potential source regions not accessible for direct sampling, the task of positively identifying the sources of detrital zircons is clearly a difficult one. The quantity and quality of available data varies considerably between regions and makes a direct comparison problematic. Moreover, prominent sediment sources at the time of deposition might not be preserved or exposed today.

Additional limitations arise from the samples themselves: Two samples from the Maud Belt show significant Pan-African overprinting, resulting in many discordant ages. In the Northampton Complex, there is no stratigraphic control on the samples, and it cannot be considered certain that all samples contain detrital zircons derived from the same sources. However, the samples all come from the same metasedimentary gneiss unit, were taken less than 100 km apart from each other, and must have been deposited within a relatively short time, as ages not significantly older than the age of regional metamorphism (1080 Ma; Bruguier et al., 1999) were found in all samples. They are therefore considered here to represent the same provenance, an assumption tentatively supported by a qualitative assessment of the data.

Keeping these limitations in mind, a number of conclusions can still be drawn from the data presented here. It has to be pointed out that these are based on a visual, qualitative assessment of the data, while a statistical approach and its limitations are briefly discussed below.

Potential source regions

The samples from the Maud Belt show a clear Kalahari signature: The group of older peaks in the age distribution (2100-1700 Ma) can be correlated with the Kheis-Magondi Belt, the Bushveld Igneous Province, the Richtersveld Terrane, the Rehoboth Inlier, and the reactivation of the Limpopo Belt (Fig. 1). Peaks between ca. 1400 and 1250 Ma correspond to ages of the Sinclair Group and Kgwebe-Opdam Formation of the north-western continental arc as well as the Choma-Kalomo Block, and the peaks at ca. 1230 Ma and 1150-1180 Ma represent island arc magmatism and arc accretion in the Namaqua-Natal-Maud Belt. The prominent peak at ca. 1090 Ma is interpreted as corresponding to the main metamorphic event in the Maud Belt during continent-continent collision. Except for one robust age at 1552 Ma and another age at ca. 1595 Ma with a very low probability of concordance, no ages fall between 1650 and 1450 Ma which is in very good agreement with the potential source regions currently exposed in Kalahari, none of which could have supplied zircons in this age range. This 1650-1450 Ma gap in the age distribution is, on the other hand, inconsistent with a contribution of the Australian Craton to the metasediments of the Maud Belt, as significant magmatic and metamorphic activity occurred in the Albany-Fraser Belt and South Australian Craton within this time frame and is also recorded in the detrital zircon population of the Northampton Complex. The source regions for the metasediments of the Northampton Complex are most likely the Albany-Fraser Orogen and the South Australian Craton (Fig. 1). Counterparts of the Albany-Fraser Belt in East Antarctica, the Mawson Craton, and possibly the Capricorn Orogen in north-western Australia might also have contributed to the zircon population of the samples studied here.

Comparison between regions

The Maud Belt and Pinjarra Orogen show quite distinct zircon populations (Fig. 2) and the argument that they are part of the same sedimentary sequence and thus belong to the same orogenic belt (Fitzsimons, 2002) is not supported by the new data. Although the dominant age groups (ca. 1300-1000 Ma) show a close agreement between both regions, older ages do not. Young ages (1300-1000 Ma) are to be expected in a Grenville-age orogen and, as the latter occur worldwide, these ages are not considered strong evidence for a correlation between the Maud Belt and Pinjarra Orogen. More importance is therefore attributed to the older zircon populations, and here the Maud Belt is characterised by ages between ca. 2050 and 1650 Ma and a characteristic absence of data between ca. 1650 and 1450 Ma, while the samples from the Northampton Complex, quite to the contrary, yielded a number of ages between ca. 1500 and 1400 Ma and show a prominent peak in the age distribution at ca. 1600 Ma, but contain very few ages older than 1800 Ma.

Statistics

A statistical approach (Sircombe and Hazelton, 2004) was applied to the samples from the Northampton Complex and two samples from the Maud Belt (S1-40 and W30014) and gives somewhat different results than the qualitative assessment of the data. Similarity analyses between the samples suggest that there are two different clusters of samples in the Northampton Complex with slightly different provenances, and that the two samples from the Maud Belt are each more closely related to one of these clusters than to each other. It has to be pointed out, though, that due to relatively large uncertainties in some of the data, the age distributions were strongly smoothed prior to comparison and that the similarity between sample S1-40 and the Northampton Complex samples is very weak. Although we present a large number of new data from the Northampton Complex, the number of ages from the Maud Belt (16 to 58 robust ages per sample) is still insufficient for reliable statistical analyses, and the results should be regarded with extreme caution.

Conclusions

New detrital zircon ages from the Maud Belt (East Antarctica; 130 ages) and the Pinjarra Orogen (Western Australia; 815 ages) are presented here and compared to each other and their potential source regions. The samples from the Maud Belt show a clear Kalahari signature and the samples from the Pinjarra Orogen were most likely derived from sources within Australia or from the adjacent Mawson Craton. Both regions show distinct and significantly different zircon age distributions, and no unequivocal evidence for a Kalahari-Western Australia connection could be found. While a Western Australia-Kalahari connection is therefore permissible from a palaeomagnetic perspective, it receives no support from the geochronological data presented here.

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