DETRITAL ZIRCON PROVENANCE AGES OF THE "DWYKA TILLITE" IN SOUTH AFRICA AND THE FALKLAND ISLANDS

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Introduction

Reconstructions of Gondwana show that the Falkland Islands lie on a rotated microplate that originally lay off the Eastern Cape-Kwa-Zulu Natal (KZN) provinces of South Africa (e.g. Marshall, 1994). This implies that the Permo-Carboniferous tillites (diamictites) of South Africa and the Falklands were once contiguous. In the Western Cape, South Africa, thin tuff layers within the Dwyka Group have been precisely dated at ca 290 Ma, close to the Permian-Carboniferous boundary (Bangert et al., 1999). In our study, U-Pb dates from detrital zircons, extracted from five samples of the tillite, have been dated by ICP-MS laser ablation at the University of Arizona (approximately 100 zircons per sample). The samples were taken from the Western Cape Province (near Laingsburg), the Eastern Cape (east of Oudtshoorn) , northern and central KZN (near Vryheid and Pietermaritzburg respectively), and from East Falkland (west of Port Stanley). In South Africa, the samples were taken from the "southern facies" of the Dwyka Group, known as the Elandsvlei Formation (Johnson et al., 2006), whereas in the Falklands, the equivalent unit is known as the Fitzroy Tillite Formation of the Lafonia Group. All the samples analysed were composed of massive tillite (diamictite). Published models of ice sheet flow directions in South Africa, show ice movements generally from NE to SW across the area (e.g. Isbell et al., 2008)

Geochronology

Age probability curves for the four analysed samples are shown in Fig. 1. and can be summarized as follows:

- Western Cape sample has major age peaks at ca 550 and 1100 Ma, with minor peaks between 600 and 900 Ma and 1600, 1800, 2100, 2600 and 3200 Ma (youngest zircon ca 498 Ma). Heavy minerals are dominated by pyrope (80%), andradite and almandine garnets.
- Southern cape sample has a major peak at ca 550 Ma, with minor peaks between 600 and 800 Ma, 1000 to 1100 ma and 1400 and 1700 Ma (youngest grain ca. 507 Ma).
- The central KZN sample has major peaks at 550 Ma, 1100 and 2700 Ma, with minor peaks at ca 800, 1700 and 2100 Ma (youngest grain at ca. 499 Ma)
- Northern KZN sample has major peaks at 550 Ma, 1100 and 2000 Ma, with minor peak at ca 800 Ma and a cluster of Archaean ages between 2600 and 3500 Ma (youngest grain at ca. 499 Ma)
- The Falkland sample has major peaks at 550 Ma and 1100 Ma and minor peaks 600 to 900 Ma and at ca 2000 and 2700 Ma (youngest grain ca. 499 Ma)

Discussion

All samples have a major peak at 550 ± 50 Ma. This reflects provenance from the extensive late Neoproterozoic "Pan-African" mobile belts which surround the Kalahari Craton (e.g. Saldania Province), and Palaeozoic sediments also derived there from, such as the Cape Supergroup (Western, Southern Cape), Natal Group (KZN) and the West Falkland Group (East Falkland). Considering the generally N and NE ice flow directions of the tillites, this also introduces the possibility of zircons derived from the Pan-African high-grade terrains of the East African Orogen and its continuation into East Antarctica. The link is strengthened by palaeocurrent directions from the Ordovician Natal Group, which was also derived from fluvial systems flowing from the NE in KZN (Thomas et al., 1992). The NE flow direction from the Dwyka and Natal Groups can also explain the minor peaks in all samples between 600 and 900 Ma: rocks with this range of ages is common in the southern part of the East African Orogen (e.g. Bingen et al., 2009). The major peak at 1000 to 1100 Ma in all samples is a reflection of zircons derived from the erosion of the Mesoproterozoic Namaqua-Natal belt, which wraps around the southern part of the Kaapvaal-Grunehogna Craton. Minor peaks of zircons with a range of Palaeoproterozoic ages support the findings of Eglington and Armstrong (2003) of hidden crust of this age from beneath the central Karoo cover. The large single peak at ca 2050 Ma in the northern KZN sample presumably represents derivation from rocks of the

Bushveld Complex and related igneous rocks. Minor Archaean peaks are seen in the samples from the western Cape and East Falkland, while the northern KZN contains a large concentration of zircons between 2600 and 3500 Ma, representing the range of typical Kaapvaal Craton ages of that area and northwards. The single large 2700 Ma peak in the central KZN sample indicates derivation from a far more restricted Archaean source.

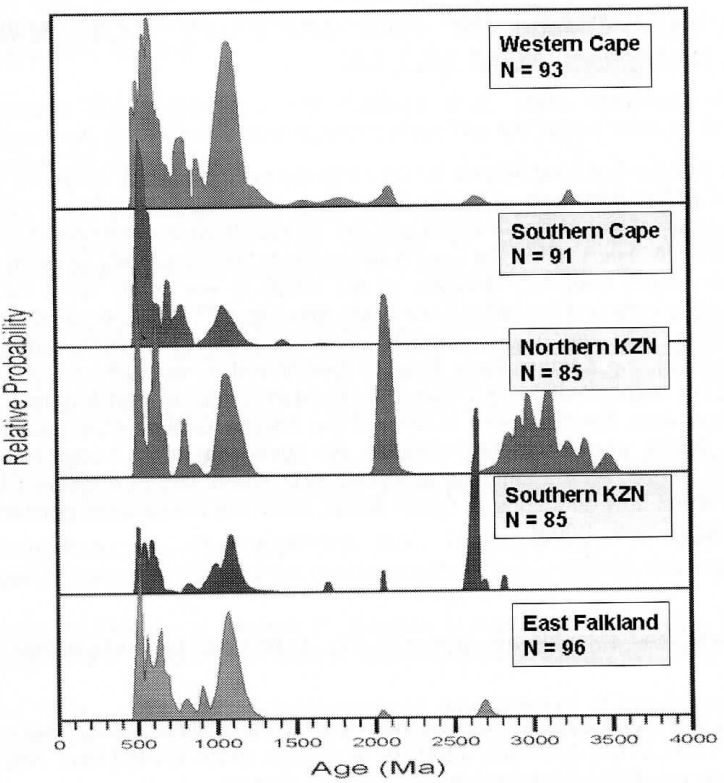

Figure 1. Detrital zircon age spectra for the five analysed samples.

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GEOCHRONOLOGICAL CONSTRAINTS ON THE EASTERN MARGIN OF THE TANZANIAN CRATON IN THE MPWAPWA AREA, CENTRAL TANZANIA

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Introduction

The position and nature of the eastern margin of the Tanzanian Craton in central Tanzania is poorly understood, especially with regard to its relationships with the Palaeoproterozoic Usagaran Belt and the Neoproterozoic Western Granulites of the East African Orogen (e.g. Reddy et al., 2003; Cutten et al., 2006; Fritz et al., 2009). Transects have been undertaken across a ca. 45 km N-S crustal section east of Dodoma, Central Tanzania, in order to ascertain the position, nature and geochronology of the eastern margin of the Tanzanian Craton and its relationship with a sequence of high-grade supracrustal gneisses to the east, known as the Mpwapwa Group.

Geology and geochronology

The rocks of the eastern part of the craton are uniformly composed of coarse-grained, grey, migmatised granodiorite orthogneisses which are heterogeneous at outcrop scale but are regionally homogeneous. U-Pb zircon data from a typical orthogneiss sample (DOD8) show a multi-phase history with all grains discordant to various degrees and clusters at 2.7 and 2.8 Ga with evidence of inherited zircons at ca 3.0 Ga. Generally, the orthogneisses have no regionally consistent fabric and foliations are variably oriented at outcrop scale. However, there is a gradual increase in strain eastwards of about 36°12'E, manifest as an increasingly strong, regionally consistent, E to SE-dipping pervasive foliation. This strain increase eventually leads to mylonitic and porphyroclastic planar fabrics and strong, uniformly SE-plunging, linear fabrics. In most structural domains planar fabrics are predominant, but these alternate with minor domains dominated by linear fabrics, with fold mullions locally developed. The kinematics of the high-strain mylonites show a consistent, oblique top-to-the-NW sense of movement. The frontal thrust zone steepens laterally into sinistral and dextral oblique strike-slip shear zones to the north and south respectively. The contact is a single wide deformation zone in the northern and southern segments of the study area, with a more complex imbricate belt up to about 2 km wide in the central part. The thrust zone contains slivers of mylonitised tonalitic orthogneisses, petrologically unlike those of the craton, but similar to gneisses in the SW part of the area, around Msagali, where they are associated with charnockite. A mylonitised tonalite sample (DOD11) yielded unzoned, very low U zircons with a range of concordant ages from 2.4 to 2.0 Ga. We interpret these data to give the age of shearing at ca 2.0 Ga of Neoarchaean igneous rocks with a minimum age of ca 2.4 Ga.

To the east of the thrust zone, the typical cratonic orthogneisses are in contact with a high-grade supracrustal succession, termed here the "Mpwapwa Group" in the light of uncertain regional correlations. The Mpwapwa Group consists of a thick sequence of semi-pelitic, two mica-kyanite-garnet schists/gneisses, quartzites, marbles and calc-silicate rocks, leucocratic pink quartzo-feldspathic gneisses and migmatites and abundant metabasic layers ± garnet. There appears to be an east-west zonation of the Mpwapwa Group lithological units, with most of the quartzites, calcareous rocks and pelitic schists/gneisses tending to occur close to the craton margin, with semi-pelitic gneiss/migmatite to the east, along with interlayered bimodal repetitions of acid quartzo-feldspathic leucogneisses and mafic gneisses (amphibolite, garnet amphibolite). Mineral assemblages, as evidenced by garnet-kyanite in pelitic rocks and garnet-clinopyroxene in some metabasites suggest metamorphism under moderate to high pressure amphibolite facies conditions, as might be expected at the base of a thrust stack and resulting crustal thickening.

The age of the Mpwapwa Group is unknown. A felsic gneiss sample (DOD16), thought to represent a meta-rhyolite within the bimodal gneiss sequence yielded a population of unrounded, subhedral, high U-zircons (U = ca 3000 ppm) with concordant ages of ca. 1.94 Ga. A second population of small, euhedral zircons with sector zoning gave an age of ca 2.7 Ga. Detrital zircons were separated from two quartzite samples of the Mpwapwa Group. A clean glassy quartzite (DOD1) gave a unimodal population of zircons with ages clustered around 2.7 Ga (youngest grain 2607 ± 17 Ma) and a few grains at ca 3 Ga. A layered quartzite (DOD4) gave broadly comparable results, but with important clusters of data at ca 2650 and 2770 Ma and smaller clusters between 2.9 and 3.2 Ga. The youngest concordant grains gave an age of 2642 ±

8 Ma. No metamorphic overgrowths were observed. The maximum age of deposition of the Mpwapwa Group quartzites is thus ca 2.6 Ga

The Mpwapwa Group outcrop area contains outcrops of largely unfoliated biotite granite. Intrusive contacts were not seen, but the undeformed nature of the granite suggests that it has not undergone the deformation and metamorphism seen within the Mpwapwa Group. It is thus probably intrusive. The granite (Sample DOD7) gave a U-Pb zircon age of 1880 ± 20 Ma, with some evidence of Archaean inheritance. Some zircons have thin metamorphic overgrowths dated at ca 560 Ma.

Towards the southern part of the area, around Msagali, the eastern margin of the craton is indistinct and the rocks characterised by high-grade paragneisses (lithologically unlike the Mpwapwa Group), tonalitic orthogneisses (like those found and dated in the thrust zone), and intrusive charnockite. From the field evidence it is thus unclear to which tectonic domain the rocks belong. Zircons from a sample of unfoliated two-pyroxene charnockite (DOD19) gave clusters of concordant data around 2.7 and 2.65 Ga respectively. Core-rim relationships of these ages are not consistent, but point to crystallisation and/or metamorphism of the charnockite within this period. This implies that the rocks of the Msagali area belong to an Archaean high-grade domain distinct from the Tanzanian cratonic rocks seen further north.

Conclusions

- The granodiorite orthogneisses from the western part of the area are typical in lithology and age (2.7 to 2.8 Ga) for the central Tanzanian craton;
- High grade gneisses in the SW part of the area, around Msagali, include tonalitic orthogneisses and were intruded by charnockite at ca 2.7 Ga, suggesting the presence of a second, distinctive, Archaean block.
- Quartzites of the Mpwapwa Group contain only Archaean detritus (youngest zircon = 2607 ± 17 Ma);
- A meta-rhyolitic felsic gneiss from the Mpwapwa Group contained two populations of zircons dated at ca 1.9 and 2.7 Ga respectively;
- The lithological zonation of the Mpwapwa Group suggests it represents a parauthochthonous succession;
- The Mpwapwa Group were intruded by biotite granite at 1.88 Ga
- The Archaean blocks and the Mpwapwa Group are juxtaposed along a low-angle ductile thrust zone with an oblique top-to-the NE sense of movement and associated metamorphism which is probably Palaeoproterozoic (ca 2.0 Ga) in age, and part of the Ubendian-Usagaran orogenic system;
- There is no evidence for Neoproterozoic ("Pan-African") activity from the East African Orogen, other than thin metamorphic zircon rims in the post-tectonic granite.

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