Untying the Kibaran knot: A reassessment of Mesoproterozoic correlations in southern Africa based on SHRIMP U-Pb data from the Irumide belt

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ABSTRACT

The Irumide belt is part of a network of late Mesoproterozoic Kibaran-age orogens in south-central Africa. Sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages for gneisses, migmatites, and granitoids indicate that peak Irumide metamorphism was ca. 1020 Ma and that this was associated with widespread granitic magmatism at 1050–950 Ma. Pre-Irumide protoliths are dominated by 1650–1519 Ma granitic gneisses. These data provide the first robust constraint on the timing of Irumide tectonism and show that previous estimates of ca. 1350 and 1100 Ma are incorrect, thereby negating previously proposed correlations of the Irumide belt with nearby Kibaran-aged tectonism. The correlation between the Irumide belt and Choma-Kalomo block of southern Zambia has had a major influence on models for the tectonic assembly of southern Africa because it required that the intervening Neoproterozoic Zambezi belt was intracratonic and associated with minimal horizontal displacements. Our data indicate that both terranes have distinct histories, consistent with lithologic and metamorphic evidence of Neoproterozoic ocean closure along the Zambezi belt. This implies that the Kalahari and Congo cratons assembled during the Neoproterozoic and not during Kibaran-age tectonism, as previously believed. This new outlook on regional African tectonics supports a configuration of the Rodinia supercontinent that places the Congo craton well away from the Kalahari craton ca. 1000 Ma.

Keywords: Kibaran orogeny, correlation, southern Africa, Mesoproterozoic, SHRIMP data, Zambia.

INTRODUCTION

The use of relative structural timing and isotope geochronology as means of correlating Precambrian orogenic belts and testing the role of global drift in continental assembly was first proposed by Holmes (1951), using south-central Africa as an example. Subsequent work in this region defined a network of Paleoproterozoic to Neoproterozoic orogenic belts (Cahen et al., 1984) that overprinted the margins of older cratons (Fig. 1) and are commonly grouped into three orogenic cycles (Kröner, 1977) known as the Eburnian (2200–1800 Ma), Kibaran (1350–950 Ma), and Pan-African (800–500 Ma). Although some workers have interpreted all of these belts in terms of plate tectonics and ocean closure (Burke and Dewey, 1972), others emphasized that the older belts occur on both sides of younger crosscutting belts with no apparent offset, a spatial relationship more consistent with ensialic rejuvenation (Kröner, 1977; Shackleton, 1973).

Perhaps the best known of these crosscutting relationships is that between the Irumide and Zambezi belts (Fig. 1). The Zambezi belt is part of an east-west–trending zone of Neoproterozoic tectonism that extends southwestward into the Damara orogen. It is associated with eclogite relics, reworking of older basement blocks including possible island arc and ophiolite terranes, and significant north-south shortening (Dirks and Sithole, 1999; Goscombe et al., 2000; Oliver et al., 1998). The northeast-trending Irumide belt is widely believed to continue along strike across the Zambezi belt, where it is exposed as the Choma-Kalomo block (Hanson et al., 1988; Shackleton, 1973). Preliminary age data confirmed that both terranes developed during the Mesoproterozoic (Hanson et al., 1988) and both are considered part of a single Kibaran orogen. This correlation precludes the closure of a large Neoproterozoic ocean basin along the Zambezi belt and requires that the Kaapvaal-Zimbabwe and Congo cratons were juxtaposed before or during Irumide tectonism.

In this paper we present new sensitive high-resolution ion microprobe (SHRIMP) U-Pb zircon ages from the Irumide belt and demonstrate that previous age estimates of Irumide tectonism are incorrect. We argue that there is no isotopic evidence for any Mesoproterozoic correlation across the Zambezi belt, making it likely that the major cratons of southern Africa did not assemble until the Neoproterozoic.

IRUMIDE BELT

The Irumide belt of Zambia preserves an increasing intensity of Mesoproterozoic tectonism from its northwestern foreland, where undeformed quartzite and pelite of the Muva Supergroup unconformably overlie 2000–1800 Ma granites and volcanics of the Bangweulu block, through a fold-and-thrust belt into an internal zone, characterized by syntectonic to late tectonic plutons, amphibolite facies gneisses, and migmatites (Andersen and Unrug, 1984; Daly, 1986a, 1986b; Daly and Unrug, 1982; Drysdall et al., 1972). The southeastern margin of the belt is not preserved; the Irumide gneisses are progressively overprinted in southeastern Zambia and Malawi by high-grade Neoproterozoic structures of the Zambezi and Mozambique belts. The Irumide belt is truncated to the northeast by Neoproterozoic shear zones along the Ubendian belt.

Lithologies within the internal zone of the orogen include the metasedimentary Manshya River Group and a range of granitoid units (Fig. 2). In the northeastern part of the belt, the granites and orthogneisses are classified as pre-, syn- or late-tectonic, depending on the intensity of ductile fabrics observed in the field. This subdivision was supported by limited Rb-Sr data that identified ca. 1800 Ma gneissic basement, correlated with the Bangweulu block, ca. 1400 Ma pretectonic to early tectonic foliated granitoids collectively called the Mutangoshi gneissic granite, and ca. 1000 Ma posttectonic plutons comprising the Bemba batholith and Chilubanama granite (Daly, 1986b) (Fig. 3). Despite the fact that textural differences and contrasting field relationships allow such subdivision in the southwest, the

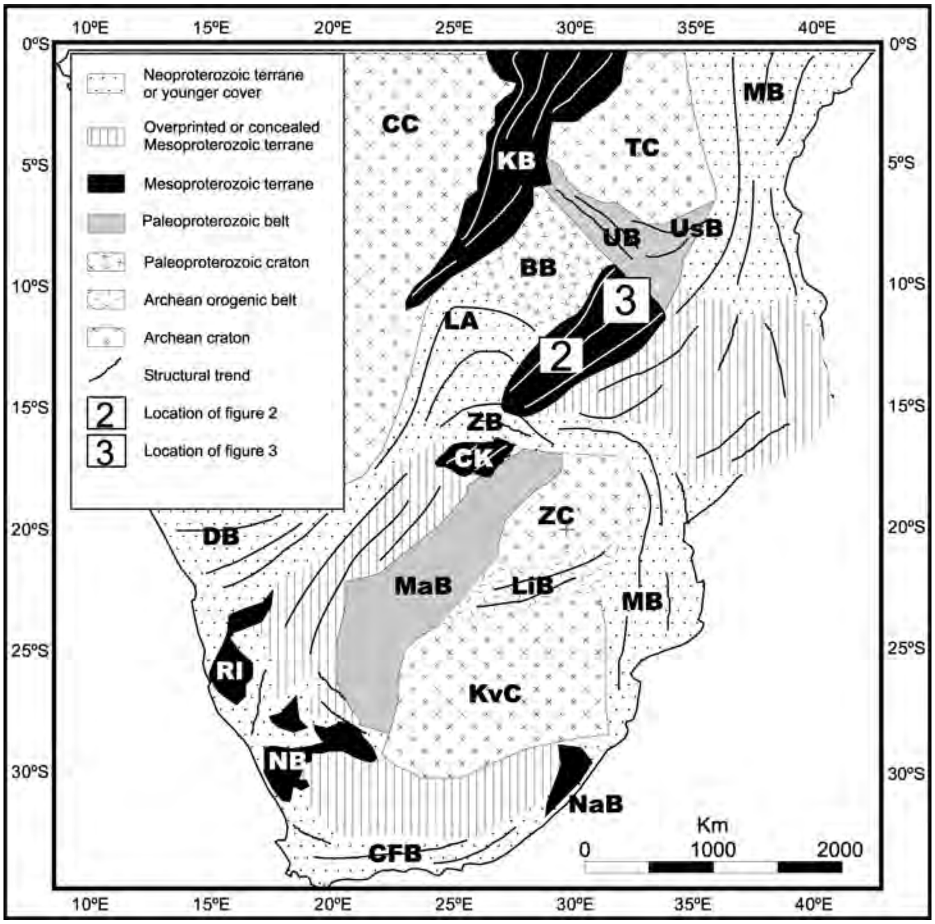

Figure 1. Tectonic provinces of central and southern Africa. Abbreviations: BB—Bangweulu block; CC—Congo craton; CFB—Cape fold belt; CK—Choma-Kalomo block; DB—Damara belt; KB—Kibaran belt; KvC—Kaapvaal craton; LA—Lufilian Arc; LiB—Limpopo belt; MaB—Magondi belt; MB—Mozambique belt; NaB—Natal belt; NB—Namaqua belt; RI—Rehoboth inlier; TC—Tanzania craton; UB—Ubendian belt; UsB—Usagaran belt; ZB—Zambezi belt; ZC—Zimbabwe craton.

granites and gneisses in this region are collectively known as the Mkushi gneiss complex and are believed to represent reworked Bangweulu block, on the basis of limited Rb-Sr and U-Pb isotopic data (Ng'ambi et al., 1986; Rainaud et al., 2002). Recent work in the southwestern part of the belt, however, distinguished a suite of predeformational granitoids known locally as the Lukamfwa Hill granite gneiss (Fig. 2), and a suite of syntectonic to posttectonic porphyritic granites (De Waele and Mapani, 2002).

In the past, there have been two estimates for the timing of Irumide tectonism. Cahen et al. (1984) argued that tectonism occurred at 1355 ± 28 Ma, using a Rb-Sr whole-rock isochron from the phyllonitized Nyika granite in northern Malawi. Daly (1986b) obtained a similar Rb-Sr whole-rock isochron age of 1407 ± 34 Ma for the Mutangoshi gneissic granite of northern Zambia, but he interpreted this granite as a pretectonic to early tectonic intrusion that preceded the Irumide event. He estimated the age of peak metamorphism and tectonism to be ca. 1100 Ma, based on Rb-Sr whole-rock isochron ages of 1005 ± 71 Ma and 947 ± 89 Ma, and a U-Pb upper-intercept discordia age of 970 ± 5 Ma for porphyritic late tectonic granites that were assumed to have been emplaced during the waning stages of the event. Similar ages of 1016 ± 55 Ma and 964 ± 34 Ma were obtained from foliated porphyritic granites and migmatites in central Malawi (Haslam et al., 1983, 1986). Schenk and Appel (2001) dated metamorphic monazite from a gneiss in eastern Zambia, placing peak metamorphism in the eastern part of the Irumide belt at 1046 ± 3 Ma.

SHRIMP GEOCHRONOLOGY

We collected 15 samples of granitoid and gneiss from the Irumide belt[1] for SHRIMP U-Pb geochronology in order to bracket the timing of Irumide tectonism (Figs. 2 and 3). In addition, two migmatites from the Serenje region were sampled to provide a direct constraint on the age of Irumide metamorphism. All measured compositions, corrected for common Pb using measured ^{204}Pb, are less than 5% discordant, and each age component is reported here as a weighted mean ^{207}Pb/^{206}Pb age.

A single sample of inferred pre-Irumide basement from the northern part of the belt was dated in this study (Fig. 2) and yielded a poorly constrained age of 1519 ± 19 Ma. Seven samples of assumed pretectonic to early tectonic granitoids were dated. Three of these were examples of the Lukamfwa Hill granitic gneiss from the southwest of the belt, which yielded ages of 1664 ± 9 Ma, 1653 ± 7 Ma, and 1639 ± 14 Ma (Fig. 2). The remaining four are samples of the equivalent Mutangoshi gneissic granite from the northern Irumide belt, one of which yielded a comparable age of 1592 ± 43 Ma, but the other three gave significantly younger ages of 1046 ± 77 Ma, 1028 ± 8 Ma, and 953 ± 19 Ma (Fig. 3). Samples of porphyritic late tectonic granite yielded consistently young ages of 1034 ± 12 Ma, 1033 ± 13 Ma, 1030 ± 16 Ma, 1024 ± 9 Ma, and 1021 ± 16 Ma in the southwest (Fig. 2), and 1022 ± 8 Ma and 1005 ± 21 Ma in the northeast (Fig. 3). Low Th/U metamorphic overgrowths in the two migmatite samples yielded ages of 1020 ± 7 Ma and 1004 ± 20 Ma, whereas the cores yielded ca. 2000 Ma ages not discussed in detail here.

These data indicate that peak Irumide metamorphism occurred ca. 1020 Ma, which is the first direct estimate of the timing of this event, and also demonstrate that this event was associated with widespread granite plutonism at 1050–950 Ma. It is significant that these Irumide-age plutons exhibit a range of tectonic fabrics, and that a gneissic lithology, previously regarded as a pretectonic to early tectonic intrusion due to its intense foliation, yielded the youngest crystallization age. It is apparent that Irumide deformation was heterogeneous, with high strain developed locally in rocks emplaced as late as 950 Ma. Degree of strain is clearly not a reliable indicator of crystallization age in granitic rocks of the Irumide belt, and the existing field-based classification of lithologies should be revised.

Our data show that Irumide tectonism reworked older protoliths dominated by a previously unrecognized 1660–1519 Ma granitoid suite, together with some evidence of older ca. 2000 Ma rocks comparable to the Bangweulu block foreland. There is no evidence of granite emplacement at 1400–1350 Ma, and we interpret 1400–1350 Ma Rb-Sr whole-rock data from the northern Irumide belt (Cahen et al., 1984; Daly, 1986b) to be due to incomplete isotopic homogenization of

[1]GSA Data Repository item 2003074, U-Pb data for granitoids and gneisses of the Irumide belt, is available from Documents Secretary, GSA, P.O. Box 9140, Boulder, CO 80301-8140, editing@geosociety.org, or at www.geosociety.org/pubs/ft2003.htm.

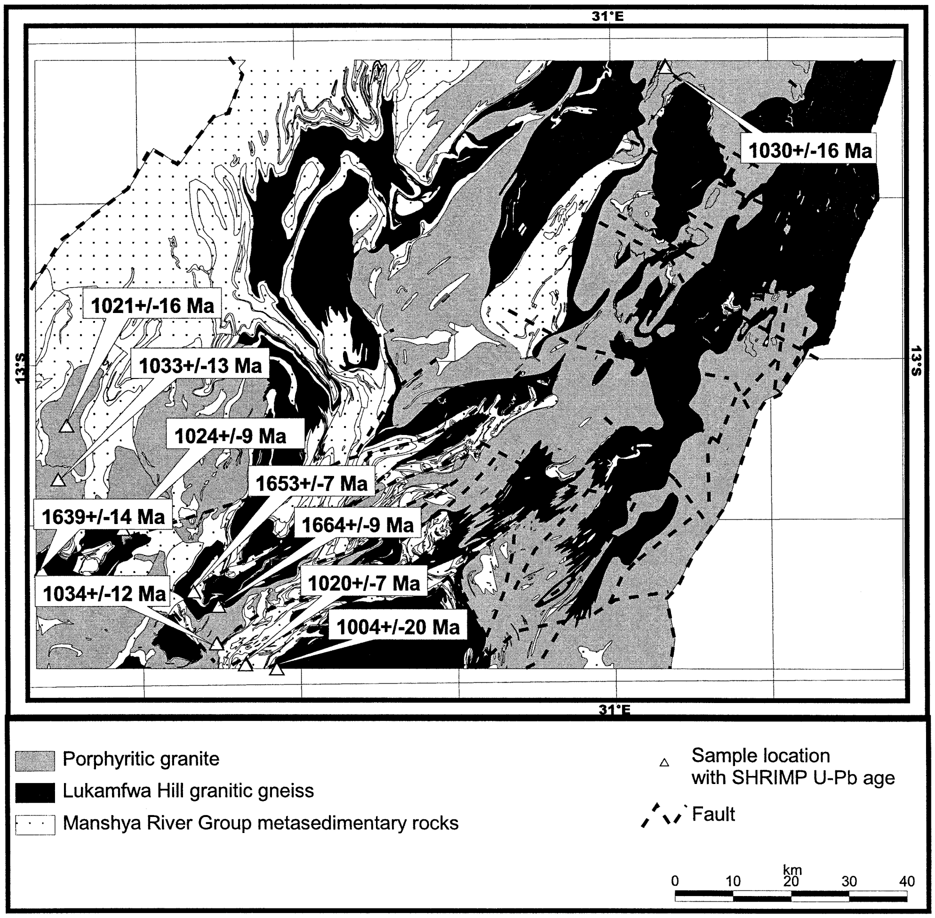

Figure 2. Overview of sample locations in southwestern portion of Irumide belt. Ages are based on sensitive high-resolution ion microprobe (SHRIMP) U-Pb data.

ca. 1660–1590 Ma protoliths, tectonized at ca. 1020 Ma.

MESOPROTEROZOIC CORRELATIONS IN SOUTHERN AFRICA

There are four main regions of Mesoproterozoic Kibaran-age tectonism exposed in Zambia and adjacent parts of south-central Africa (Fig. 1): the Irumide and Kibaran belts on the southeastern and northwestern margins of the Bangweulu block, the Choma-Kalomo block to the west of the Zimbabwe craton, and Mesoproterozoic gneisses within the southern part of the Mozambique belt, adjacent to the eastern margin of the Zimbabwe craton. Many previous studies have assumed that all these are broadly equivalent and developed during a single Kibaran orogenic cycle, but our data indicate that tectonism in the Irumide belt cannot be correlated with events elsewhere in the region.

Tectonism in the Irumide belt has previously been linked with Mesoproterozoic events in the Mozambique belt (Daly, 1986b; Pinna et al., 1993), although the boundary between both belts is uncertain and obscured by extensive Neoproterozoic reworking. Mesoproterozoic granitic orthogneisses are exposed in northern Mozambique, where they were reworked during Neoproterozoic thrusting, and in northwestern Mozambique immediately adjacent to the eastern edge of the Zimbabwe craton. The former yield Pb-Pb zircon evaporation ages of 1150–1040 Ma (Kröner et al., 1997), whereas the latter yield SHRIMP U-Pb ages of 1150–1100 Ma (Mahnica et al., 2001). Although the timing of Mesoproterozoic magmatism in both areas is similar to the ca. 1100 Ma age proposed by Daly (1986a, 1986b) for Irumide tectonism, our data indicate that Irumide magmatism and tectonism occurred at 1050–950 Ma. The data indicate that the Irumide belt, which developed along the margin of the Bangweulu block, does not relate to the Lurio-Mozambique belt in northern Mozambique, which formed along the eastern side of the Kalahari craton. Both terranes, which developed independently of each other, were juxtaposed during Neoproterozoic Zambezi and east African tectonism. Similarly, based on our new data, correlations between the Irumide and Kibaran belts cannot be maintained. Extensive syncollisional granite magmatism in the Kibaran belt at 1370 Ma was followed by postcollisional magmatism at 1205 Ma; a second metamorphic event at 1080 Ma preceded posttectonic emplacement of tin granites at 1000–970 Ma (Kokonyangi et al., 2002; Tack et al., 2002). None of these events are recorded in the Irumide belt.

The correlation most critical for tectonic reconstructions is that across the Neoproterozoic Zambezi belt between the Irumide belt and the Choma-Kalomo block, because it was used to argue that the Zambezi belt was intracratonic and accommodated limited lateral displacements. This correlation is based on the apparent alignment of the Irumide and Choma-Kalomo terranes, their similar northeasterly structural trends, and isotope geochronology (Drysdall et al., 1972; Hanson et al., 1988). U-Pb zircon ages of 1352 ± 14 and 1343 ± 6 Ma date the emplacement of the main phases of the Choma-Kalomo batholith (Hanson et al., 1988), whereas a porphyritic granite with a U-Pb zircon age of 1198 ± 6 Ma is believed to postdate the main deformation and provide a lower age limit on the timing of Mesoproterozoic tectonism. The older ages correspond closely to the Rb-Sr ages for early to syntectonic plutons in the northern Irumide belt (Daly, 1986b), prompting Hanson et al. (1988) to suggest that the Irumide belt and Choma-Kalomo block represent a single orogen that occurs on both sides of the Zambezi belt. Our ages show that previous Rb-Sr whole-rock data for the gneissic granites of the Irumide belt do not provide reliable constraints on the timing of granite emplacement nor the timing of deformation. Neither the 1650–1590 Ma nor 1050–950 Ma magmatic events in the Irumide belt have been identified in the Choma-Kalomo block and, conversely, there is no reliable evidence for 1370 Ma magmatism in the Irumide belt.

CONCLUSIONS

SHRIMP U-Pb zircon ages for a range of granitic lithologies in central and northern Zambia indicate that tectonism in the Irumide belt was focused in the interval 1050–950 Ma and affected earlier ca. 2000 Ma and 1650–1590 Ma granitic basement terranes. This history is distinct from that of other Mesoproterozoic terranes in the Kibaran and Mozambique belts and the Choma-Kalomo block, and it is apparent that correlations made in the past between these belts are no longer supported. As a result, previous models for the assembly of southern Africa, relying largely on these Kibaran correlations to indicate that Neoproterozoic tectonism had little effect on the spatial arrangement of earlier cratons and metamorphic belts, have to be reconsidered.

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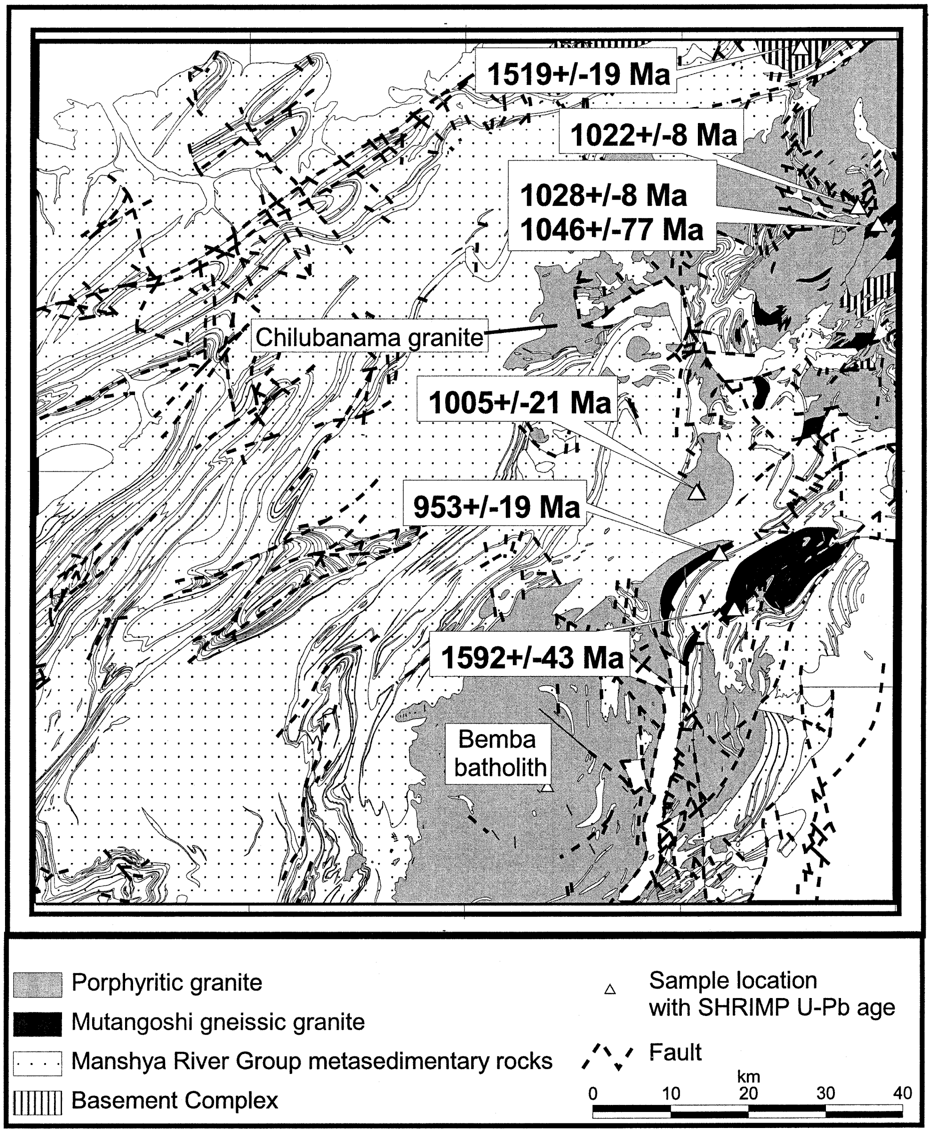

Figure 3. Overview of sample locations in northeastern portion of Irumide belt. Ages are based on sensitive high-resolution ion microprobe (SHRIMP) U-Pb data.

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