occur. The fluid inclusion study was done on khondalite, leptynite, quartzite and granulite in this area. CO_2-bearing fluid inclusions occur in quartzite, leptynite and khondalite. CO_2-H_2O and H_2O inclusions are also seen. The CO_2 inclusions in quartzite yield moderate to low densities (0.86-0.88g/cm^3). On the contrary CO_2 inclusions are relatively rare in the granulite, which contains many H_2O inclusions, which show decrepitation textures. Although the EGMB is considered to have followed an anti-clockwise P-T path (Dasgupta, 1995), a clockwise path can be assumed on the retrograde process at lower temperature after metamorphic peak from the estimation of temperature-pressure condition of fluid inclusions in quartzite.

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Assembly and Break-up of Rodinia - No Link With Gondwana Assembly

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Our understanding of the processes involved during the formation of supercontinents is still limited. The assembly and dispersal of Rodinia and Gondwana supercontinents are currently among the most debated topics in geology. The timing and processes involved during the assembly of Gondwana are still a matter of debate, although there is a substantial amount of multidisciplinary constraints for this event. The configuration, timing, and processes involved during the assembly and fragmentation of Rodinia are much less constrained, partly because Mesoproterozoic crustal provinces are poorly preserved in several continents. Africa is unique because it preserves ca. 35% percent of the world's exposed Precambrian crustal provinces, providing the best region in the world for the investigation of Precambrian evolution processes. Here I will present relevant geological, geochemical and geochronological data constraining the geodynamic evolution of Africa during the Mesoproterozoic and the Neoproterozoic. The data are then used to constrain the assembly, break up, and dispersal of Rodinia and to show that there is no link between Rodinia break-up and dispersal and the assembly of Gondwana.

Rodinia Assembly

The most important orogenic events during the construction of Rodinia occurred between ca. 1.4-0.95 Ga, e.g. in the Kibaran orogenic system (Africa) and the Grenvillian orogenic belt (North America).

The Kibaran belt is the oldest Mesoproterozoic orogenic system identified in the world, seven decades ago (Robert, 1931). The first common Pb isotopic age dating performed five decades ago on Kibaran rocks yielded Mesoproterozoic ages in the range 1.2-1.0 Ga. In the sixties and seventies, Rb-Sr whole rock, mineral isotopic data and multigrain U-Pb zircon dating established that the Kibaran orogenic system was formed between ca. 1.4–0.95 Ga (Mounteyne-Pouleart et al., 1962; Cahen et al., 1967, 1984). In contrast, it is only in the nineties that this age range was accepted for the evolution of the Grenvillian orogenic cycle of North America (e.g. Mc Lelland and Chiarenzelli, 1990; Davidson, 1995, 2000; Mc Lelland et al., 1996; Van Schmus, 2000). Compared to the Grenvillian, the Kibaran orogenic system is better preserved and thus, since the forties, its evolution was described using models based on Phanerozoic orogens, viz. the "geosyncline" evolutionary model (Robert, 1944; Cahen, 1954).

The pre-Rodinia evolution of Africa is characterised by a major Paleoproterozoic orogen which formed the ~2.1–1.8 Ga Eburnean-Ubendian belt. There is no record of orogenic events in the interval 1.8–1.5 Ga (Geons 18–15) which is inferred to be a time of break-up and development of an oceanic basin, which will be closed during the assembly of Rodinia. This interpretation is supported by the discovery of a 1.6 Ga passive margin sedimentary sequence in the Palapye Group in Botswana (Mapeo et al., 2000).

The earliest Kibaran orogenic event is ca. 1.4 Ga. In central and eastern Africa, the Kibaran orogenic system extends for more than 3000 km and is in average 400 km wide. Kibaran supracrustal metasedimentary and metavolcanic rocks were affected by several deformation episodes (e.g. Burg et al., 1986) grouped into two major tectonic events (D_1-D_2), with a minor third event (D_3). They display metamorphic parageneses indicating equilibration in a large range of P-T values, from subgreenschist to granulite facies. The most abundant early Kibaran granitoids and related orthogneisses have geochemical features of continental arc magmas (Kampunzu et al., 1986). The early Kibaran granitoids (~1.4–1.25 Ga; Kampunzu et al., 1998a) yielded SHRIMP U-Pb zircon ages indicating a peak of magmatic activity between ~1.39–1.35 Ga (e.g. Kokonyangi et al., 2001). The age of these granitoids is, within the margin of errors, similar to the U-Pb zircon age of 1393± 22 Ma for a remnant of Mesoproterozoic ophiolitic assemblage forming a basement inlier in the Neoproterozoic Zambezi belt of northern Zimbabwe. Geochemical data suggest that this ophiolitic complex formed along an oceanic convergent plate margin (Johnson and Oliver, 2000).

The paroxysmal deformation event in the Kibaran belt (D_2) formed the ca. 1.2–1.1 Ga NE-trending fold-and-thrust belt, defining the main physiographic feature of the belt extending for more than 2000 km from Katanga (Congo) to Uganda. Syn-D_2 Barrow-type metamorphic parageneses record clockwise P-T-t paths, indicating a major crustal thickening during this tectonic

event. The D_2 tectonic event and associated metamorphism signal the collision between the Congo and the East African cratons. The latter included the Kalahari, Bangweulu, Tanzania and West-Nilian pre-Kibaran crustal blocks. Syn-to late-collisional S-type granites and related pegmatites are widespread in the Kibaran orogenic system and host the tin-group ore deposits (Caron et al., 1986; Pohl, 1994). This crustal felsic magmatism coincides with the development of a LP-HT late-kinematic metamorphism. The crystallisation ages of the late to post-kinematic granitoids is ~1.0–0.95 Ga, although Ar-Ar muscovite and biotite ages of several early and post-kinematic granitoids is in the range 0.95–0.90 Ga (e.g., Ikingura et al., 1990,1992).

Thus, Rodinia assembly started at ~1.4 Ga in Africa, with the development of a continental active margin, culminating in a continental collision at ca. 1.2 Ga. The final amalgamation was at ca.1.1–0.95 Ga, and the post-orogenic exhumation is shown by Ar-Ar muscovite and biotite ages of ca. 0.95–0.90 Ga.

Rodinia Break-up

A number of workers indicate that the break-up and rifting of Rodinia started at ca. 750 Ma, during Geon 8 (e.g., Powell et al., 1993). This interpretation is backed-up by palaeomagnetic reconstructions (e.g., Meert et al., 1994; Weil et al., 1998), although some African paleomagnetic poles used in these studies were either poorly dated or attributed to cratonic blocks on which the rocks did not belong at the time of emplacement. Thus, the position of Africa in Rodinia supercontinent is still speculative.

In central and eastern Africa, anorogenic granitoids, carbonatites and related alkaline silica-undersaturated rocks (e.g., Kampunzu et al., 1998b; Tembo et al., 2000) marking the earliest stage of post-Kibaran Neoproterozoic extension and widespread mafic rocks marking various stages of this extension yielded ages between 880–750 Ma (e.g., Kampunzu et al., 1998b, 2000; Armstrong et al., 1999). Therefore, we infer that this period dates the break up of Rodinia supercontinent in subequatorial Africa.

Gondwana Assembly

The break-up of Rodinia and Neoproterozoic rifting and drifting of Rodinian blocks was inferred to lead to the amalgamation of east and west Gondwana at ~0.65–0.5 Ga, with paroxysmal continental collision during the Geon 6 (e.g., Rogers et al., 1995; Wilson et al., 1997). Some of these interpretations were biased by data from the Damaran, Katangan and Zambezi belts in southwestern and central Africa. We currently know that these three segments of the Pan African belt were outside the areas of major Gondwana crustal assembly (Kampunzu et al., 2000). A number of critical evidence reviewed below indicates that the assembly of Gondwana was not controlled by drifting crustal fragments dispersed during the break-up of Rodinia.

In Africa, there are two major suture belts formed during the assembly of Gondwana. The first major Panafrican suture track is the Trans-Sahara Pan African belt of West Africa (Caby et al., 1981). This north-south-trending orogenic system is more than 1000 km wide and runs for more than 2000 km in West Africa. It extends southwards into Brazil (pre-drift position), where it is part of the Brasiliano belt. The continental collision in this orogenic system is well constrained between ca. 700-500 Ma (e.g., Liegeois et al., 1994). However, critical for the evaluation of the linkage between Rodinia break-up and Gondwana assembly is the timing of the earliest oceanic closure which culminated into the Tibetan-type continental collision documented by several authors. Igneous rocks marking the active margin stage of this Pan-African belt include island arc and continental arc igneous associations (e.g. Chikhaoui et al., 1978; Dostal et al., 1994) yielding crystallisation ages between 880-700 Ma, with the oldest island arc rocks preserved in Hoggar (Caby, 1987).

The second major Pan-African suture track is the East African orogenic system (Stern, 1994), including the Mozambique belt in East Africa and Madagascar and the Arabian-Nubian shield in northeast Africa and Arabia. It is a north-south-trending belt, more than 5000 km long and ca.1000 km wide in northeast Africa where abundant juvenile Neoproterozoic crustal rocks coexist with accreted older basement blocks and ca. 500 km wide in east Africa where predominate reworked pre-Neoproterozoic crust (e.g., Maboko, 2000). The climax of continental collision in the Mozambique belt is ~650–550 Ma and this is usually taken for the timing of East and West Gondwana assembly. However, plate convergence in the East African orogen started much earlier. The oldest Neoproterozoic arc igneous associations yielded U-Pb zircon ages of ~880–800 Ma (e.g., Tucker et al., 1999; Kroner et al., 2000; Yibas et al., 2000).

Discussion

This discussion will focus on the relationships between the final assembly and the break-up of Rodinia, and the earliest stage of Gondwana assembly. According to several authors, the break up of Rodinia at ~750 Ma lead to rifting-drifting and, subsequently, the dispersed Rodinian blocks were re-assembled in a different configuration, within Gondwana. *The data presented in this paper show that the break-up of Rodinia at ~750 Ma is 150 Ma younger than the earliest stages of Gondwana assembly, which started at ~900 Ma.* Furthermore, the final assembly of Rodinia at ~1–0.95 Ga (cf. Kibaran and Grenvillian belts), with the exhumation history extending to ca. 0.9 Ga, show that *the earliest stages of Gondwana assembly coincide with, instead of post-dating, the final amalgamation of Rodinia.*

These observations preclude any link between Rodinia break-up and Gondwana assembly, although a number of rift basins opened during the Rodinia break-up (e.g., Damaran, Katangan, Zambezi) underwent contractional deformation for the first time during the Pan-African collision. The voluminous Neoproterozoic oceanic and continental arc assemblages emplaced between ca. 880–700 Ma in West and East Africa (*Af*), South America (*am*), Arabia (*ar*) and Antarctica (*an*) require the existence of a large pre-900 Ma oceanic basin (hereafter *Afamaran ocean*), which closed between 900–700 Ma, during the early Panafrican orogenesis.

I propose a model in which the opening and drifting within the Afamaran Ocean is part of a worldwide Mesoproterozoic plate divergent system compensating the plate consumption along active margins during the assembly of Rodinia. The change of plate motions at the end of Rodinia assembly (~1–0.9 Ga)

induced the closure of the Afamaran ocean, through oceanic and continental arcs (~900–700 Ma), culminating in the Pan African collision (~700–550 Ma). In some areas, the collision involved continental blocks (e.g. Mozambique belt) whereas in others arc assemblages represent a major component during the Panafrican collision (e.g. Arabian- Nubian shield)

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Evidence of Structural Reworking in the Eastern Ghats Granulite Belt, India: Implication for a Contiguous Supercontinent in the Proterozoic

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The Eastern Ghats granulite belt, skirting the east coast of India records complex deformation. Study area around Jenapore, Orissa, situated near the northern boundary of the belt, primarily exposes khondalite and massif-type charnockite. Three phases of folding is recorded from the area. Minor quartzite bands in the khondalite host and hornblende rich mafic granulite bands in the charnockite host define rootless, isoclinal and reclined F_1 folds; these bands are designated as S_0. The pervasive gneissosity of the khondalite and streaky gneissic foliation of the charnockite are axial planar to these folds and are designated as S_1. Intersection of S_0 and S_1 generates striping lineation, L_1. F_2 folds, generally developed on S_1, are characterised by the development of axial planar leptynitic foliation, S_2. A stretching lineation is developed on S_2 plane and is designated as L_2. F_3 folds are broad warps.

Poles of S_1 in charnockite plot on a great circle with a point maximum and the mean cluster of poles to S_0 plane also plot close to this point maximum. This indicates that the regional F_2 fold is highly asymmetrical and the northerly dipping short limb is much less represented. Pole to the great circle lies well within the cluster of the L_2 lineation. The deviation of S_1 poles from the great circle as also L_2 lineation from the pole of the great circle may be the effect of late F_3 warp. The L_1 lineation is highly variable, although distributed on mean S_2 and their clustering near L_2 maximum, can only be explained as the effect of shearing along S_2 in the direction of mean L_2. In the khondalite, most of the S_1 gneissosity is steep, and the mean S_0 plane is also parallel to it. Minor F_1 and F_2 fold axes and L_1, L_2 are steep and variably oriented unlike that in the charnockite. Shear component is differently manifested here; stretching along L_2 might have resulted in F_1-F_2 coaxial relationship.

Combined structural analyses can be interpreted with the help of a schematic diagram. Regional F_1 folds are steep and asymmetric with reclined geometry and regional F_2 folds are also asymmetric, upright and have gentle plunge. The hinge region of F_1 folds, here represented by khondalite, produces F_1-F_2 coaxial relation, while the limb region of regional F_2 folds, represented by charnockite, produces F_1-F_2 non-coaxial relation. Such geometry can be interpreted as a result of break in the deformation history. Also, the progressive rotation of earlier material line (L_1) during late simple shear confirms this break. This is in sharp contrast to the proposal of continuous progressive deformation (Dobmeier and Raith, 2000).

Recent studies on metamorphism and geochronology of the Eastern Ghats belt emphasizes the hypothesis of tectonic reworking in the Proterozoic (Dasgupta and Sengupta, 1998; Sarkar and Paul, 1998). Also, from palaeomagnetic studies it is clear that east coast of India was juxtaposed with Antarctica before Rodonia breakup in the Mesoproterozoic time (Yoshida et al., 1992; Yoshida, 1995). Notably, evidence of structural reworking during Mesoproterozoic in the east Antarctica was also proposed (Clarke, 1988).

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