AFRICA

Contents

Pan-African Orogeny

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Introduction

The term 'Pan-African' was coined by WQ Kennedy in 1964 on the basis of an assessment of available Rb–Sr and K–Ar ages in Africa. The Pan-African was interpreted as a tectono-thermal event, some 500 Ma ago, during which a number of mobile belts formed, surrounding older cratons. The concept was then extended to the Gondwana continents (**Figure 1**) although regional names were proposed such as Brasiliano for South America, Adelaidean for Australia, and Beardmore for Antarctica. This thermal event was later recognized to constitute the final part of an orogenic cycle, leading to orogenic belts which are currently interpreted to have resulted from the amalgamation of continental domains during the period ~870 to ~550 Ma. The term Pan-African is now used to describe tectonic, magmatic, and metamorphic activity of Neoproterozoic to earliest Palaeozoic age, especially for crust that was once part of Gondwana. Because of its tremendous geographical and temporal extent, the Pan-African cannot be a single orogeny but must be a protracted orogenic cycle reflecting the opening and closing of large oceanic realms as well as accretion and collision of buoyant crustal blocks. Pan-African events culminated in the formation of the Late Neoproterozoic supercontinent Gondwana (**Figure 1**). The Pan-African orogenic cycle is time-equivalent with the Cadomian Orogeny in western and central Europe and the Baikalian in Asia; in fact, these parts of Europe and Asia were probably part of Gondwana in pre-Palaeozoic times as were small Neoproterozoic crustal fragments identified in Turkey, Iran and Pakistan (**Figure 1**).

Within the Pan-African domains, two broad types of orogenic or mobile belts can be distinguished. One type consists predominantly of Neoproterozoic supracrustal and magmatic assemblages, many of juvenile (mantle-derived) origin, with structural and metamorphic histories that are similar to those in Phanerozoic collision and accretion belts. These belts expose upper to middle crustal levels and contain diagnostic features such as ophiolites, subduction- or collision-related granitoids, island-arc or passive continental margin assemblages as well as exotic terranes that permit reconstruction of their evolution in Phanerozoic-style plate tectonic scenarios. Such belts include the Arabian-Nubian shield of Arabia and north-east Africa (**Figure 2**), the Damara–Kaoko–Gariep Belt and Lufilian Arc of south-central and south-western Africa, the West Congo Belt of Angola and Congo Republic, the Trans-Sahara Belt of West Africa, and the Rokelide and Mauretanian belts along the western part of the West African Craton (**Figure 1**).

The other type of mobile belt generally contains polydeformed high-grade metamorphic assemblages, exposing middle to lower crustal levels, whose origin, environment of formation and structural evolution are more difficult to reconstruct. The protoliths of these assemblages consist predominantly of much older Mesoproterozoic to Archaean continental crust that was strongly reworked during the Neoproterozoic. Well studied examples are the Mozambique Belt of East Africa, including Madagascar (**Figure 2**) with extensions into western Antarctica, the Zambezi Belt of northern Zimbabwe and Zambia and, possibly, the little known migmatitic terranes of Chad, the Central African Republic, the Tibesti Massif in Libya and the western parts of Sudan and Egypt (**Figure 1**). It has been proposed that the latter type of belt represents the deeply eroded part of a collisional orogen and that the two types of Pan-African belts are not fundamentally different but constitute different crustal levels of collisional and/or accretional systems. For this reason, the term East African Orogen has been proposed for the combined upper crustal Arabian-Nubian Shield and lower crustal Mozambique Belt (**Figure 2**).

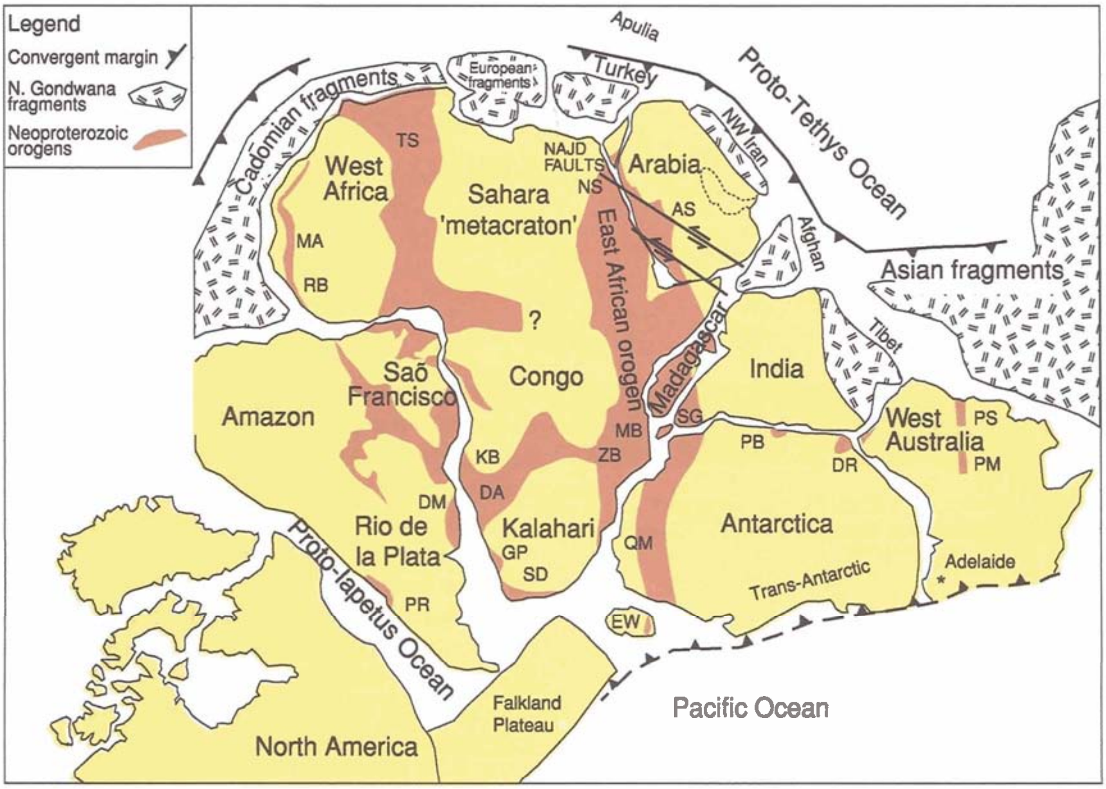

Figure 1 Map of Gondwana at the end of Neoproterozoic time (~540 Ma) showing the general arrangement of Pan-African belts. AS, Arabian Shield; BR, Brasiliano; DA, Damara; DM, Dom Feliciano; DR, Denman Darling; EW, Ellsworth-Whitmore Mountains; GP, Gariep; KB, Kaoko; MA, Mauretanides; MB, Mozambique Belt; NS, Nubian Shield; PM, Peterman Ranges; PB, Pryolz Bay; PR, Pampean Ranges; PS, Paterson; QM, Queen Maud Land; RB, Rokelides; SD, Saldania; SG, Southern Granulite Terrane; TS, Trans-Sahara Belt; WB, West Congo; ZB, Zambezi. (Reproduced with permission from Kusky *et al.*, 2003.)

The Pan-African system of orogenic belts in Africa, Brazil and eastern Antarctica has been interpreted as a network surrounding older cratons (**Figure 1**) and essentially resulting from closure of several major Neoproterozoic oceans. These are the Mozambique Ocean between East Gondwana (Australia, Antarctica, southern India) and West Gondwana (Africa, South America), the Adamastor Ocean between Africa and South America, the Damara Ocean between the Kalahari and Congo cratons, and the Trans-Sahara Ocean between the West African Craton and a poorly known pre-Pan-African terrane in north-central Africa variously known as the Nile or Sahara Craton (**Figure 1**).

Arabian-Nubian Shield (ANS)

A broad region was uplifted in association with Cenozoic rifting to form the Red Sea, exposing a large tract of mostly juvenile Neoproterozoic crust. These exposures comprise the Arabian-Nubian Shield (ANS). The ANS makes up the northern half of the East African orogen and stretches from southern Israel and Jordan south as far as Ethiopia and Yemen, where the ANS transitions into the Mozambique Belt (**Figure 2**). The ANS is distinguished from the Mozambique Belt by its dominantly juvenile nature, relatively low grade of metamorphism, and abundance of island-arc rocks and ophiolites. The ANS, thus defined, extends about 3000 km north to south and >500 km on either side of the Red Sea (**Figure 3**). It is flanked to the west by a broad tract of older crust that was remobilized during Neoproterozoic time along with a significant amount of juvenile Neoproterozoic crust, known as the Nile Craton or 'Saharan Metacraton'. The extent of juvenile Neoproterozoic crust to the east in the subsurface of Arabia is not well defined, but it appears that Pan-African crust underlies most of this region. Scattered outcrops in Oman yielded mostly Neoproterozoic radiometric ages for igneous rocks, and there is no evidence that a significant body of pre-Pan-African crust underlies this region. The ANS is truncated to the north as a result of rifting at about the time of the Precambrian–Cambrian boundary, which generated crustal fragments now preserved in south-east Europe, Turkey and Iran.

The ANS is by far the largest tract of mostly juvenile Neoproterozoic crust among the regions of Africa that were affected by the Pan-African orogenic cycle. It

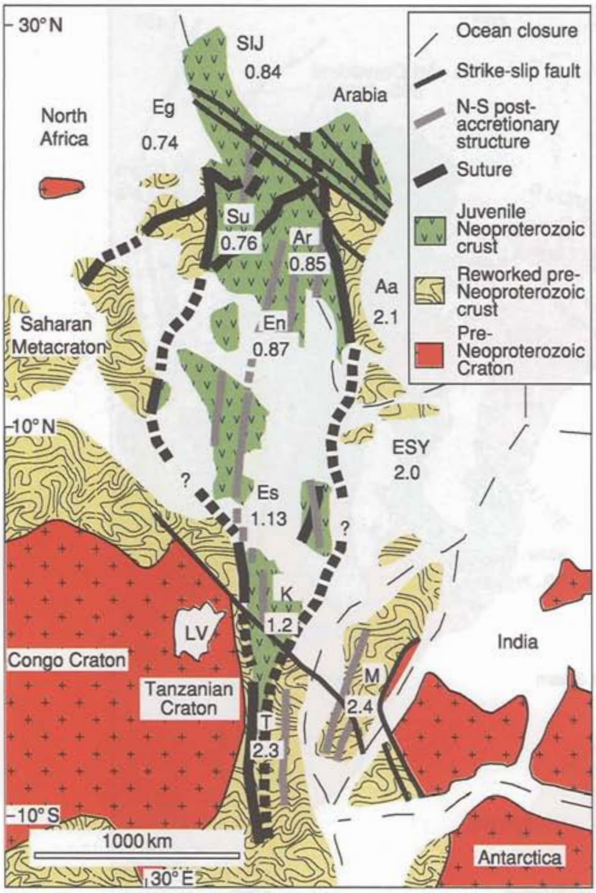

Figure 2 Pre-Jurassic configuration of elements of the East African Orogen in Africa and surrounding regions. Regions include Egypt (Eg), Sudan (Su), Sinai–Israel–Jordan (SIJ), Afif terrane, Arabia (Aa), rest of Arabian Shield (Ar), Eritrea and northern Ethiopia (En), southern Ethiopia (Es), eastern Ethiopia, Somalia, and Yemen (ESY), Kenya (K), Tanzania (T), and Madagascar (M). Numbers in italics beneath each region label are mean Nd-model ages in Gy.

formed as a result of a multistage process, whereby juvenile crust was produced above intra-oceanic convergent plate boundaries (juvenile arcs) and perhaps oceanic plateaux (*ca.* 870–630 Ma), and these juvenile terranes collided and coalesced to form larger composite terranes (**Figure 4**). There is also a significant amount of older continental crust (Mesoproterozoic age crust of the Afif terrane in Arabia; Palaeoproterozoic and Archaean crust in Yemen, **Figure 2**) that was overprinted by Pan-African tectonomagmatic events. ANS terrane boundaries (**Figure 3**) are frequently defined by suture zones that are marked by ophiolites, and the terranes are stitched together by abundant tonalitic to granodioritic plutons. Most ANS ophiolites have trace element chemical compositions suggesting formation above a convergent plate margin, either as part of a back-arc basin or in a fore-arc setting. Boninites have been identified in Sudan and Eritrea and suggest a fore-arc setting for at least some ANS sequences. Sediments are mostly immature sandstones and wackes derived from nearby arc volcanoes. Deposits that are diagnostic of Neoproterozoic 'snowball Earth' episodes have been recognized in parts of the ANS, and banded iron formations in the northern ANS may be deep-water expressions of snowball Earth events. Because it mostly lies in the Sahara and Arabian deserts, the ANS has almost no vegetation or soil and is excellently exposed. This makes it very amenable to study using imagery from remote sensing satellites.

Juvenile crust of the ANS was sandwiched between continental tracts of East and West Gondwana (**Figure 4**). The precise timing of the collision is still being resolved, but appears to have occurred after ~630 Ma when high-magnesium andesite 'schistose dykes' were emplaced in southern Israel but before the ~610 Ma post-tectonic 'Mereb' granites were emplaced in northern Ethiopia. By analogy with the continuing collision between India and Asia, the terminal collision between East and West Gondwana may have continued for a few tens of millions of years. Deformation in the ANS ended by the beginning of Cambrian time, although it has locally continued into Cambrian and Ordovician time farther south in Africa. The most intense collision (i.e. greatest shortening, highest relief, and greatest erosion) occurred south of the ANS, in the Mozambique belt. Compared to the strong deformation and metamorphism experienced during collision in the Mozambique belt, the ANS was considerably less affected by the collision. North-west trending left-lateral faults of the Najd fault system of Arabia and Egypt (**Figures 1** and **2**) formed as a result of escape tectonics associated with the collision and were active between about 630 and 560 Ma. Deformation associated with terminal collision is more intense in the southern ANS, with tight, upright folds, steep thrusts, and strike-slip shear zones controlling basement fabrics in Eritrea, Ethiopia, and southern Arabia. These north–south trending, collision-related structures obscure the earlier structures in the southern ANS that are related to arc accretion, and the intensity of this deformation has made it difficult to identify ophiolitic assemblages in southern Arabia, Ethiopia, and Eritrea. Thus, the transition between the ANS and the Mozambique Belt is marked by a change from less deformed and less metamorphosed, juvenile crust in the north to more deformed and more metamorphosed, remobilized older crust in the south, with the structural transition occurring farther north than the lithological transition.

The final stages in the evolution of the ANS witnessed the emplacement of post-tectonic 'A-type'

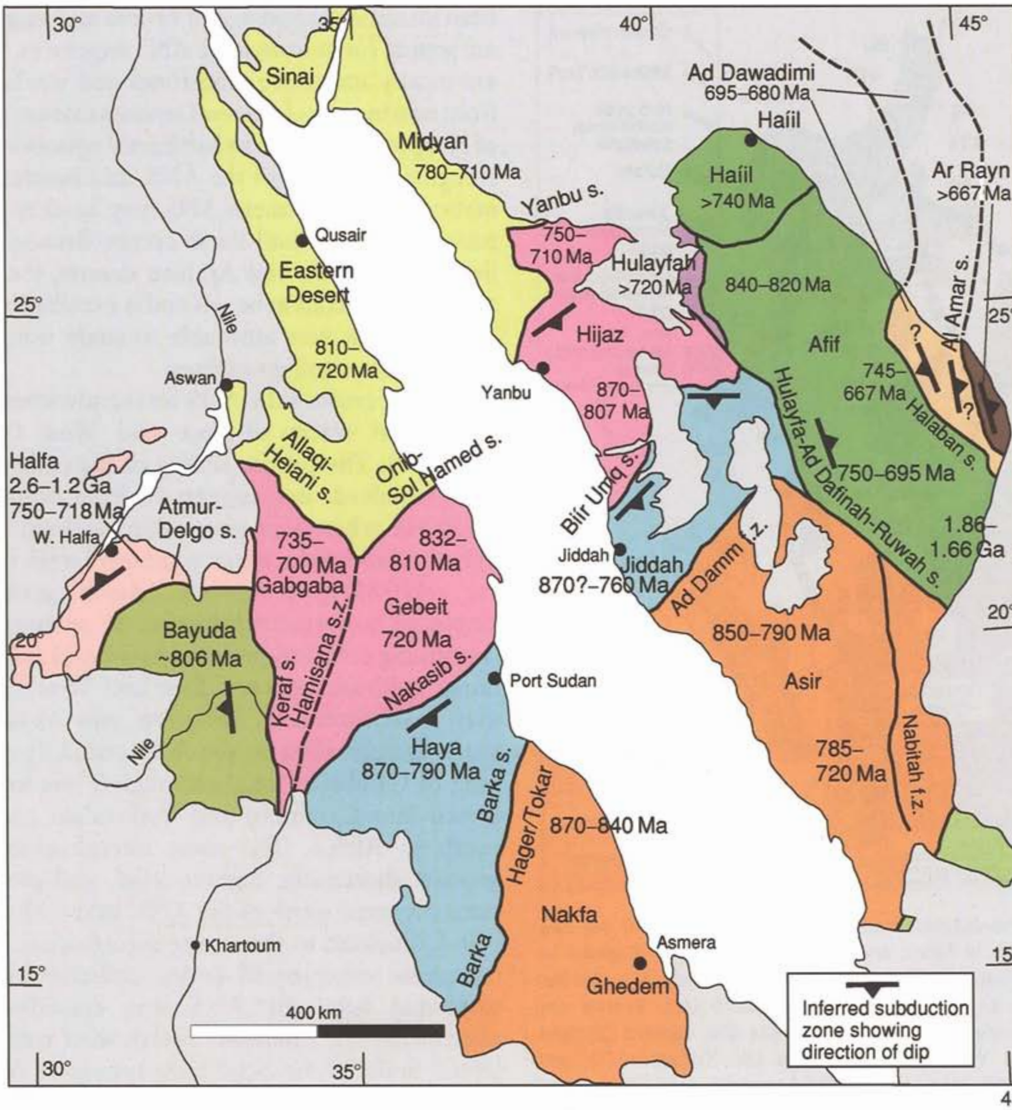

Figure 3 Terrane map of the Arabian-Nubian Shield. (Reproduced with permission from Johnson PR and Woldehaimanot B (2003) Development of the Arabian-Nubian Shield: perspectives on accretion and deformation in the northern East African Orogen and the assembly of Gondwana. In: Yoshida M, Windley BF and Dasgupta S (eds.) *Proterozoic East Gondwana: Supercontinent Assembly and Breakup*. Geological Society, London, Special Publications 206, pp. 289–325.)

granites, bimodal volcanics, and molassic sediments. These testify to strong extension caused by orogenic collapse at the end of the Neoproterozoic. Extension-related metamorphic and magmatic core complexes are recognized in the northern ANS but are even more likely to be found in the more deformed regions of the southern ANS and the Mozambique Belt. A well developed peneplain developed on top of the ANS crust before basal Cambrian sediments were deposited, possibly cut by a continental ice-sheet.

The ANS has been the source of gold since Pharaonic Egypt. There is now a resurgence of mining and exploration activity, especially in Sudan, Arabia, Eritrea, and Ethiopia.

Mozambique Belt (MB)

This broad belt defines the southern part of the East African Orogen and essentially consists of medium- to high-grade gneisses and voluminous granitoids. It extends south from the Arabian-Nubian Shield into southern Ethiopia, Kenya and Somalia via Tanzania to Malawi and Mozambique and also includes Madagascar (**Figure 2**). Southward continuation of the belt into Dronning Maud Land of East Antarctica (**Figure 1**) has been proposed on the basis of geophysical patterns, structural features and geochronology. Most parts of the belt are not covered by detailed mapping, making regional correlations difficult. There is no

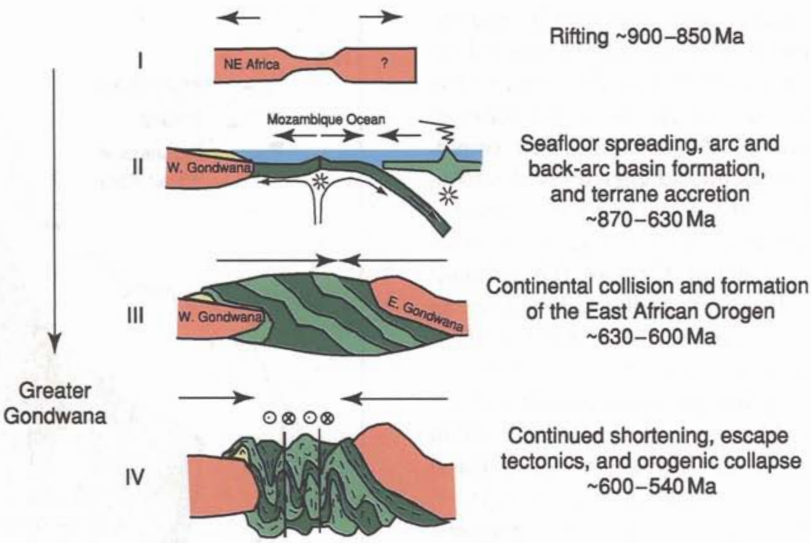

Figure 4 A diagram of the suggested evolution of the Arabian-Nubian Shield.

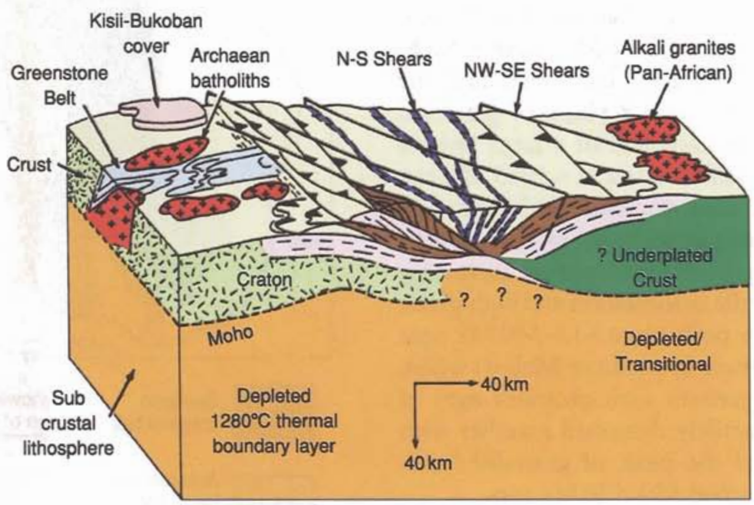

Figure 5 A schematic block diagram showing tectonic interdigitation of basement and cover rocks in the Mozambique Belt of Kenya. (Reproduced with permission from Mosley PN (1993) Geological evolution of the Late Proterozoic 'Mozambique Belt' of Kenya. *Tectonophysics* 221: 223–250.)

overall model for the evolution of the MB although most workers agree that it resulted from collision between East and West Gondwana. Significant differences in rock type, structural style, age and metamorphic evolution suggest that the belt as a whole constitutes a Pan-African Collage of terranes accreted to the eastern margin of the combined Congo and Tanzania cratons and that significant volumes of older crust of these cratons were reconstituted during this event.

Mapping and geochronology in Kenya have recognized undated Neoproterozoic supracrustal sequences that are structurally sandwiched between basement gneisses of Archaean and younger age (**Figure 5**). A ~700 Ma dismembered ophiolite complex at the Kenyan/Ethiopian border testifies to the consumption and obduction of marginal basin oceanic crust. Major deformation and high-grade metamorphism is ascribed to two major events at ~830 and ~620 Ma, based on Rb–Sr dating, but the older of these appears questionable.

A similar situation prevails in Tanzania where the metamorphic grade is generally high and many granulite-facies rocks of Neoproterozoic age show evidence of retrogression. Unquestionable Neoproterozoic supracrustal sequences are rare, whereas Late Archaean to Palaeoproterozoic granitoid gneisses volumetrically greatly dominate over juvenile Pan-African intrusives. These older rocks, strongly reworked during the Pan-African orogenic cycle and locally migmatized and/or mylonitized, either represent eastward extensions of the Tanzania Craton that were structurally reworked during Pan-African events or are separate crustal entities (exotic blocks) of unknown origin. The significance of rare granitoid gneisses with protolith ages of ~1000–1100 Ma in southern Tanzania and Malawi is unknown. From these, some workers have postulated a major Kibaran (Grenvillian) event in the MB, but there is no geological evidence to relate these rocks to an orogeny. A layered gabbro-anorthosite complex was emplaced at ~695 Ma in Tanzania. The peak of granulite-facies metamorphism was dated at 620–640 Ma over wide areas of the MB in Tanzania, suggesting that this was the major collision and crustal-thickening event in this part of the belt.

In northern Mozambique the high-grade gneisses, granulites and migmatites of the MB were interpreted to have been deformed and metamorphosed during two distinct events, namely the Mozambican cycle at 1100–850 Ma, also known as Lurian Orogeny, and the Pan-African cycle at 800–550 Ma. Recent high-precision zircon geochronology has confirmed the older event to represent a major phase of granitoid plutonism, including emplacement of a large layered gabbro-anorthosite massif near Tete at ~1025 Ma, but there is as yet no conclusive evidence for deformation and granulite-facies metamorphism in these rocks during this time. The available evidence points to only one severe event of ductile deformation and high-grade metamorphism, with a peak some 615–540 Ma ago. A similar situation prevails in southern Malawi where high-grade granitoid gneisses with protolith ages of 1040–555 Ma were ductilely deformed together with supracrustal rocks and the peak of granulite-facies metamorphism was reached 550–570 Ma ago.

The Pan-African terrane of central and southern Madagascar primarily consists of high-grade ortho- and paragneisses as well as granitoids. Recent high-precision geochronology has shown that these rocks are either Archaean or Neoproterozoic in age and were probably structurally juxtaposed during Pan-African deformation. Several tectonic provinces have been recognized (**Figure 6**), including a domain consisting of low-grade Mesoproterozoic to Early Neoproterozoic metasediments known as the Itremo group which was thrust eastwards over high-grade gneisses. A Pan-African suture zone has been postulated in eastern Madagascar, the Betsimisaraka Belt (**Figure 6**), consisting of highly strained paragneisses decorated with lenses of mafic–ultramafic bodies containing podiform chromite and constituting a lithological and isotopic boundary with the Archaean gneisses and granites of the Antongil block east of this postulated suture which may correlate with similar rocks in southern India.

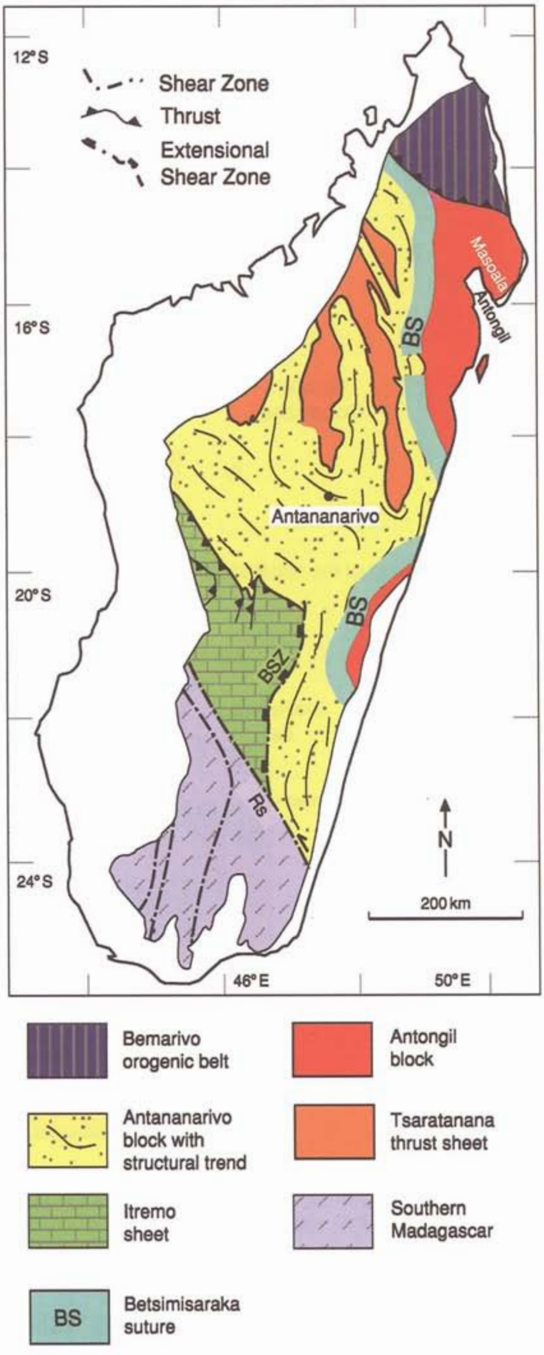

Figure 6 A simplified geological map showing the major tectonic units of the Precambrian basement in Madagascar. Rs, Ranotsara Shear Zone; BSZ, Betsileo Shear Zone. (Reproduced with permission from Collins and Windley 2002.)

Central and northern Madagascar are separated from southern Madagascar by the Ranotsara Shear Zone (**Figure 6**), showing sinistral displacement of >100 km and correlated with one of the major shear zones in southern India. Southern Madagascar consists of several north–south trending shear-bounded

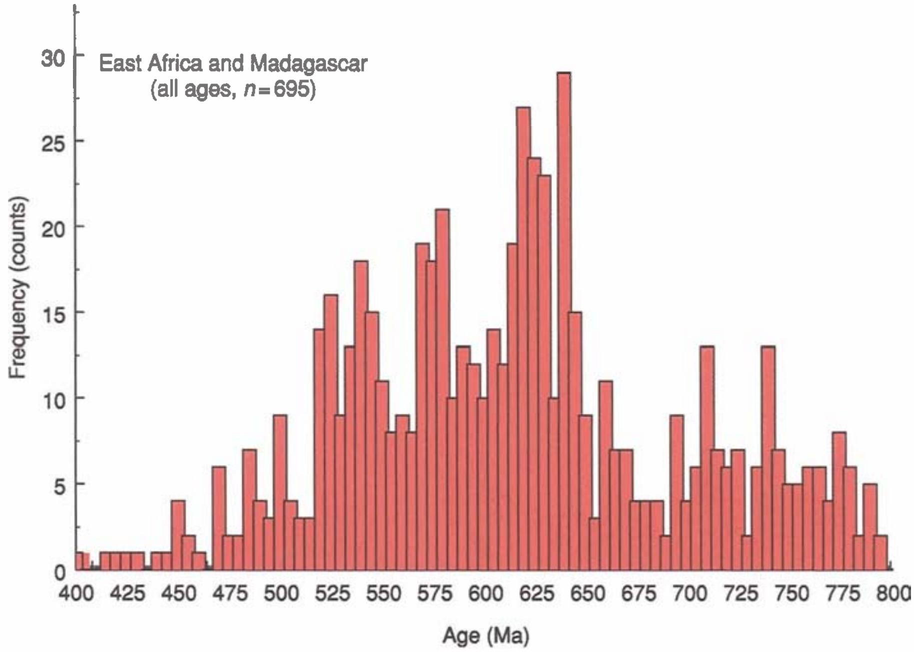

Figure 7 Histogram of radiometric ages for the Mozambique Belt of East Africa and Madagascar. Data from Meert JG (2003) A synopsis of events related to the assembly of eastern Gondwana. *Tectonophysics* 362: 1–40, with updates.

tectonic units consisting of upper amphibolite to granulite-facies para- and orthogneisses, partly of pre-Neoproterozoic age. The peak of granulite-facies metamorphism in central and southern Madagascar, including widespread formation of charnockites, was dated at 550–560 Ma.

The distribution of zircon radiometric ages in the MB suggests two distinct peaks at 610–660 and 530–570 Ma (**Figure** 7) from which two orogenic events have been postulated, the older East African Orogeny (~660–610 Ma) and the younger Kuunga Orogeny (~570–530 Ma). However, the are no reliable field criteria to distinguish between these postulated phases, and it is likely that the older age group characterizes syntectonic magmatism whereas the younger age group reflects post-tectonic granites and pegmatites which are widespread in the entire MB.

Zambezi Belt

The Zambezi Belt branches off to the west from the Mozambique Belt in northernmost Zimbabwe along what has been described as a triple junction and extends into Zambia (**Figures** 1 and 8). It consists predominantly of strongly deformed amphibolite- to granulite-facies, early Neoproterozoic ortho- and paragneisses which were locally intruded by ~860 Ma, layered gabbro-anorthosite bodies and generally displays south-verging thrusting and transpressional shearing. Lenses of eclogite record pressures up to 23 kbar. Although most of the above gneisses seem to be 850–870 Ma in age, there are tectonically interlayered granitoid gneisses with zircon ages around 1100 Ma. The peak of Pan-African metamorphism occurred at 540–535 Ma. The Zambezi Belt is in tectonic contact with lower-grade rocks of the Lufilian Arc in Zambia along the transcurrent Mwembeshi shear zone.

Lufilian Arc

The Lufilian Arc (**Figure** 8) has long been interpreted to be a continuation of the Damara Belt of Namibia, connected through isolated outcrops in northern Botswana (**Figure** 1). The outer part of this broad arc in the Congo Republic and Zambia is a north-east-verging thin-skinned, low-grade fold and thrust belt, whereas the higher-grade southern part is characterized by basement-involved thrusts. The main lithostratigraphic unit is the Neoproterozoic, copper-bearing Katanga succession which contains volcanic rocks dated between 765 and 735 Ma. Thrusting probably began shortly after deposition, and the main phase of thrusting and associated metamorphism occurred at 566–550 Ma.

Damara Belt

This broad belt exposed in central and northern Namibia branches north-west and south-east near

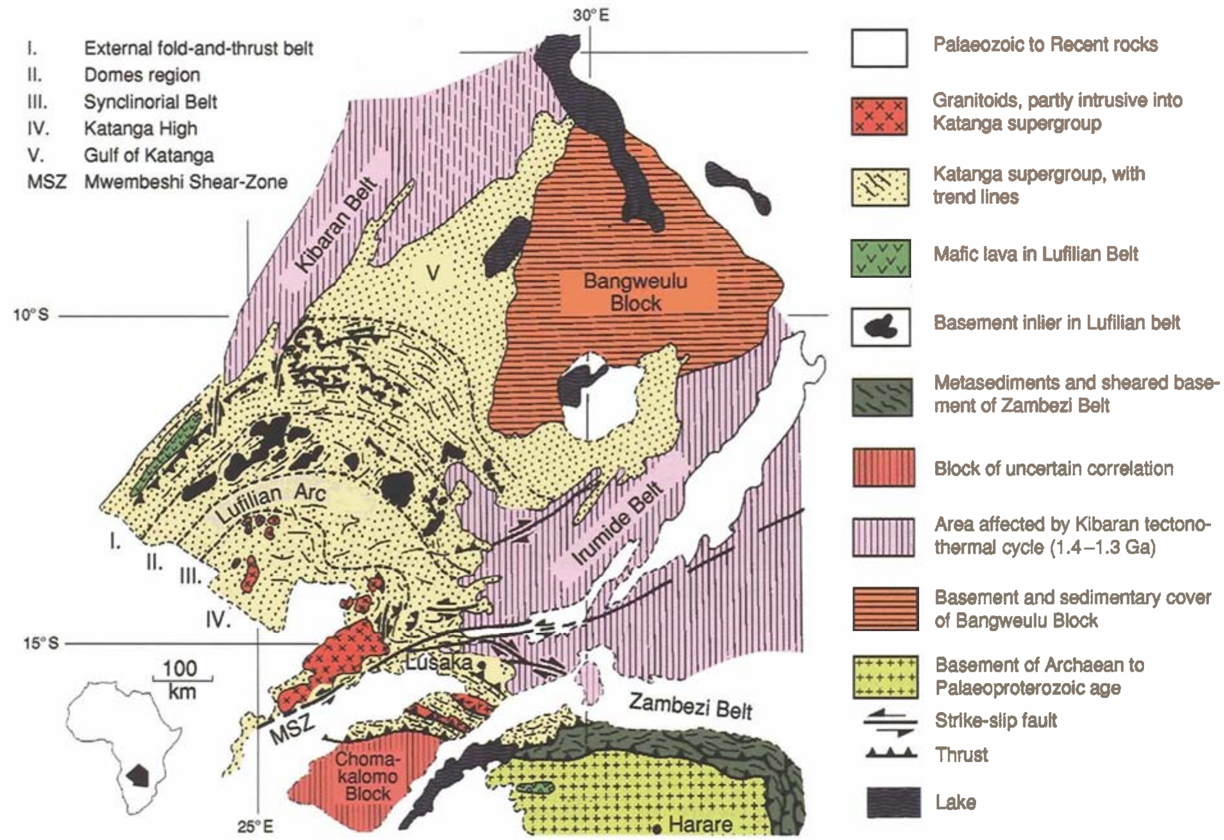

Figure 8 A simplified geological map of the Lufilian Arc and Zambezi Belt. (Reproduced with permission from Porada H and Berhorst V (2000) Towards a new understanding of the Neoproterozoic-early Palaeozoic Lufilian and northern Zambezi belts in Zambia and the Democratic Republic of Congo.)

the Atlantic coast and continues southwards into the Gariep and Saldania belts and northwards into the Kaoko Belt (**Figure 1**). The triple junction so produced may have resulted from closure of the Adamastor Ocean, followed by closure of the Damara Ocean. The main lithostratigraphic unit is the Damara supergroup which records basin formation and rift-related magmatism at ~760 Ma, followed by the formation of a broad carbonate shelf in the north and a turbidite basin in the south. The turbidite sequence contains interlayered, locally pillowed, amphibolites and metagabbros which have been interpreted as remnants of a dismembered ophiolite. Of particular interest are two distinct horizons of glaciogenic rocks which can probably be correlated with similar strata in the Katanga sequence of south central Africa and reflect a severe glaciation currently explained by the snowball Earth hypothesis.

The Damara Belt underwent north- and south-verging thrusting along its respective margins, whereas the deeply eroded central zone exposes medium- to high-grade ductilely deformed rocks, widespread migmatization and anatexis in which both the Damara supracrustal sequence and a 1.0–2.0 Ga old basement are involved. Sinistral transpression is seen as the cause for this orogenic event which reached its peak at ~550–520 Ma. Voluminous pre-, syn- and post-tectonic granitoid plutons intruded the central part of the belt between ~650 and ~488 Ma, and highly differentiated granites, hosting one of the largest open-cast uranium mines in the world (Rössing), were dated at 460 Ma.

Uplift of the belt during the Damaran Orogeny led to erosion and deposition of two Late Neoproterozoic to Early Palaeozoic clastic molasse sequences, the Mulden group in the north and the Nama group in the south. The latter contains spectacular examples of the Late Neoproterozoic Ediacara fauna.

Gariep and Saldania Belts

These belts fringe the high-grade basement along the south-western and southern margin of the Kalahari craton (**Figure 1**) and are interpreted to result from oblique closure of the Adamastor Ocean. Deep marine fan and accretionary prism deposits, oceanic seamounts and ophiolitic assemblages were thrust over Neoproterozoic shelf sequences on the craton margin containing a major Zn mineralization just north of the Orange River in Namibia. The main deformation and metamorphism occurred at 570–540 Ma, and post-tectonic granites were emplaced 536–507 Ma ago. The famous granite at Sea Point, Cape Town, which was described by Charles Darwin, belongs to this episode of Pan-African igneous activity.

Kaoko Belt

This little known Pan-African Belt branches off to the north-west from the Damara Belt and extends into south-western Angola. Here again a well developed Neoproterozoic continental margin sequence of the Congo Craton, including glacial deposits, was overthrust, eastwards, by a tectonic mixture of pre-Pan-African basement and Neoproterozoic rocks during an oblique transpressional event following closure of the Adamastor Ocean. A spectacular shear zone, the mylonite-decorated Puros lineament, exemplifies this event and can be followed into southern Angola. High-grade metamorphism and migmatization dated between 650 and 550 Ma affected both basement and cover rocks, and granitoids were emplaced between 733 and 550 Ma. Some of the strongly deformed basement rocks have ages between ~1450 and ~2030 Ma and may represent reworked material of the Congo Craton, whereas a small area of Late Archaean granitoid gneisses may constitute an exotic terrane. The western part of the belt consists of large volumes of *ca.* 550 Ma crustal melt granites and is poorly exposed below the Namib sand dunes. No island-arc, ophiolite or high-pressure assemblages have been described from the Kaoko Belt, and current tectonic models involving collision between the Congo and Rio de la Plata cratons are rather speculative.

West Congo Belt

This belt resulted from rifting between 999 and 912 Ma along the western margin of the Congo Craton (**Figure 1**), followed by subsidence and formation of a carbonate-rich foreland basin, in which the West Congolian group was deposited between *ca.* 900 and 570 Ma, including two glaciogenic horizons similar to those in the Katangan sequence of the Lufilian Arc. The structures are dominated by east-verging deformation and thrusting onto the Congo Craton, associated with dextral and sinistral transcurrent shearing, and metamorphism is low to medium grade. In the west, an allochthonous thrust-and-fold stack of Palaeo- to Mesoproterozoic basement rocks overrides the West Congolian foreland sequence. The West Congo Belt may only constitute the eastern part of an orogenic system with the western part, including an 800 Ma ophiolite, exposed in the Aracuaí Belt of Brazil.

Trans-Saharan Belt

This orogenic Belt is more than 3000 km long and occurs to the north and east of the >2 Ga West African Craton within the Anti-Atlas and bordering the Tuareg and Nigerian shields (**Figure 1**). It consists of pre-Neoproterozoic basement strongly reworked during the Pan-African event and of Neoproterozoic oceanic assemblages. The presence of ophiolites, accretionary prisms, island-arc magmatic suites and high-pressure metamorphic assemblages makes this one of the best documented Pan-African belts, revealing ocean opening, followed by a subduction- and collision-related evolution between 900 and 520 Ma (**Figure 9**). In southern Morocco, the ~740–720 Ma Sirwa-Bou Azzer ophiolitic mélange was thrust southwards, at ~660 Ma, over a Neoproterozoic continental margin sequence of the West African Craton, following northward subduction of oceanic lithosphere and preceding oblique collision with the Saghro Arc.

Farther south, in the Tuareg Shield of Algeria, Mali and Niger, several terranes with contrasting lithologies and origins have been recognized, and ocean closure during westward subduction produced a collision belt with Pan-African rocks, including oceanic terranes tectonically interlayered with older basement. The latter were thrust westwards over the West African Craton and to the east over the so-called LATEA (Laouni, Azrou-n-Fad, Tefedest, and Egéré-Aleksod, parts of a single passive margin in central Hoggar) Superterrane, a completely deformed composite crustal segment consisting of Archaean to Neoproterozoic assemblages (**Figure 9**). In Mali, the 730–710 Ma Tilemsi magmatic arc records ocean-floor and intra-oceanic island-arc formation, ending in collision at 620–600 Ma.

The southern part of the Trans-Saharan Belt is exposed in Benin, Togo and Ghana where it is known as the Dahomeyan Belt. The western part of this belt consists of a passive margin sedimentary sequence in the Volta basin which was overthrust, from the east, along a well delineated suture zone by an ophiolitic mélange and by a 613 My old high-pressure metamorphic assemblage (up to 14 kbar, ~700°C), including granulites and eclogites. The eastern part of the belt consists of a high-grade granitoid–gneiss terrane of the Nigerian province, partly consisting of Palaeoproterozoic rocks which were migmatized at ~600 Ma. This deformation and metamorphism is considered to have resulted from oblique collision of

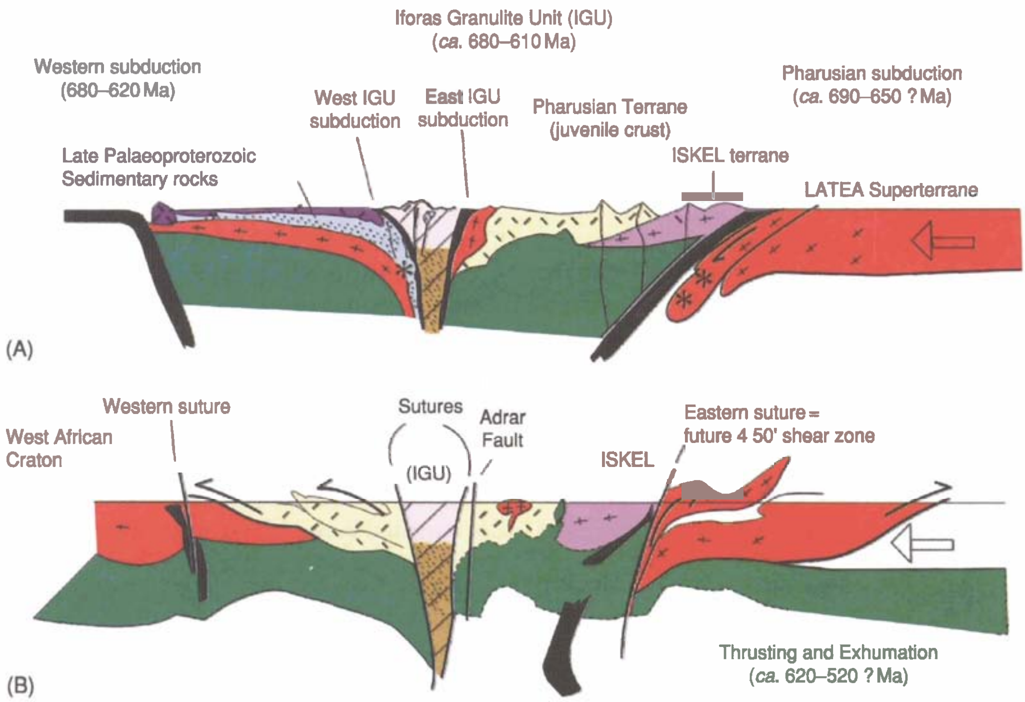

Figure 9 Diagrams showing the geodynamic evolution of western central Hoggar (Trans-Sahara Belt) between ~900 and ~520 Ma. Stars denote high-pressure rocks now exposed. (Reproduced with permission from Caby R (2003) Terrane assembly and geodynamic evolution of central-western Hoggar: a synthesis.)

the Nigerian shield with the West African Craton, followed by anatectic doming and wrench faulting.

Pan-African Belt in Central Africa (Cameroon, Chad and Central African Republic)

The Pan-African Belt between the Congo Craton in the south and the Nigerian basement in the north-west consists of Neoproterozoic supracrustal assemblages and variously deformed granitoids with tectonically interlayered wedges of Palaeoproterozoic basement (**Figure 10**). The southern part displays medium- to high-grade Neoproterozoic rocks, including 620 Ma granulites, which are interpreted to have formed in a continental collision zone and were thrust over the Congo Craton, whereas the central and northern parts expose a giant shear belt characterized by thrust and shear zones which have been correlated with similar structures in north-eastern Brazil and which are late collisional features. The Pan-African Belt continues eastward into the little known Oubanguide Belt of the Central African Republic.

Pan-African Reworking of Older Crust in North-Eastern Africa

A large area between the western Hoggar and the river Nile largely consists of Archaean to Palaeoproterozoic basement, much of which was structurally and thermally overprinted during the Pan-African event and intruded by granitoids. The terrane is variously known in the literature as 'Nile Craton', 'East Sahara Craton' or 'Central Sahara Ghost Craton' and is geologically poorly known. Extensive reworking is ascribed by some to crustal instability following delamination of the subcrustal mantle lithosphere, and the term 'Sahara Metacraton' has been coined to characterize this region. A 'metacraton' refers to a craton that has been remobilized during an orogenic event but is still recognizable through its rheological, geochronological and isotopic characteristics.

Rokelide Belt

This belt occurs along the south-western margin of the Archaean Man Craton of West Africa (**Figure 1**) and is made up of high-grade gneisses, including granulites (Kasila group), lower-grade supracrustal sequences (Marampa group) and volcano-sedimentary rocks with calc-alkaline affinity (Rokel River group). Pan-African deformation was intense and culminated in extensive thrusting and sinistral strike-slip deformation. The peak of metamorphism reached 7 kb and 800°C and was dated at ~560 Ma. Late Pan-African emplacement ages for the protoliths of some of the granitoid gneisses contradict earlier hypotheses arguing for extensive overprinting of

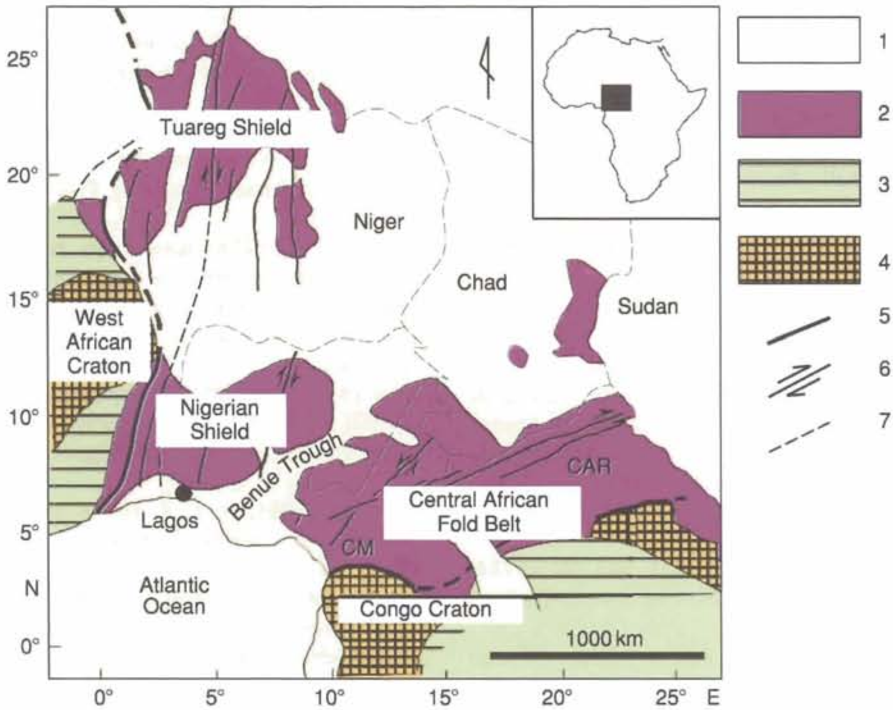

Figure 10 A sketch map showing Pan-African domains in west central Africa. 1, Post-Pan-African cover; 2, Pan-African domains; 3, pre-Mesozoic platform deposits; 4, Archaean to Palaeoproterozoic cratons; 5, craton limits; 6, major strike-slip faults; 7, state boundaries. CAR, Central African Republic; CM, Cameroun. (Reproduced with permission from Toteu SF, Penaye J and Djomani YP (2004).)

Archaean rocks. The Rokelides may be an accretionary belt, but there are no modern structural data and only speculative geodynamic interpretations.

Gondwana Correlations

The Pan-African orogenic cycle was the result of ocean closure, arc and microcontinent accretion and final suturing of continental fragments to form the supercontinent Gondwana. It has been suggested that the opening of large Neoproterozoic oceans between the Brazilian and African cratons (Adamastor Ocean), the West African and Sahara–Congo cratons (Pharusian Ocean) and the African cratons and India/Antarctica (Mozambique Ocean) (**Figure 1**) resulted from breakup of the Rodinia supercontinent some 800–850 Ma, but current data indicate that the African and South American cratons were never part of Rodinia. Although arc accretion and continent formation in the Arabian-Nubian shield are reasonably well understood, this process is still very speculative in the Mozambique Belt. It seems clear that Madagascar, Sri Lanka, southern India and parts of East Antarctica were part of this process (**Figure 1**), although the exact correlations between these fragments are not known. The Southern Granulite Terrane of India (**Figure 1**) consists predominantly of Late Archaean to Palaeoproterozoicc gneisses and granulites, deformed and metamorphosed during the Pan-African event and sutured against the Dharwar Craton. Areas in East Antarctica such as Lützow-Holm Bay, Central Dronning Maud Land and the Shackleton Range, previously considered to be Mesoproterozoic in age, are now interpreted to be part of the Pan-African Belt system (**Figure 1**). Correlations between the Pan-African belts in south-western Africa (Gariep–Damara–Kaoko) and the Brasiliano belts of south-eastern Brazil (Ribeira and Dom Feliciano) are equally uncertain, and typical hallmarks of continental collision such as ophiolite-decorated sutures or high-pressure metamorphic assemblages have not been found. The most convincing correlations exist between the southern end of the Trans-Saharan Belt in West Africa and Pan-African terranes in north-eastern Brazil (**Figure 1**). Following consolidation of the Gondwana supercontinent at the end of the Precambrian, rifting processes at the northern margin of Gondwana led to the formation of continental fragments (**Figure 1**) which drifted northwards and are now found as exotic terranes in Europe (Cadomian and Armorican terrane assemblages), in the Appalachian Belt of North

America (Avalonian Terrane assemblage) and in various parts of central and eastern Asia.

See Also

Arabia and The Gulf. **Australia:** Proterozoic. **Brazil**. **Gondwanaland and Gondwana**. **Palaeomagnetism**. **Tectonics:** Mountain Building and Orogeny. **Tertiary To Present:** Pleistocene and The Ice Age.

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