THE GEOLOGICAL EVOLUTION OF AFRICA

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Summary

Seven Archaean cratonic nuclei characterized by granite-greenstone terrains form the foundation of Africa. During the Neoarchean and Paleoproterozoic these Archean nuclei merged into three major cratons referred to as the West Africa, Central Africa (Congo-Tanzania) and Southern Africa (Zimbabwe-Kaapvaal) cratons.

The Paleoproterozoic geology of the African Plate is dominated by sedimentation, volcanism, and tectonism between 2.3 and 1.8 Ga. These events are collectively known as the Eburnian orogeny and have been recognized in the Southern, Central and West Africa cratons.

The worldwide 1.35-0.9 Ga cascade of continental collisions that constructed the supercontinent Rodinia is known in Africa as the Kibaran orogeny. Effects of this can be found along the margins of the Central and Southern Africa Cratons. Kibaran events did not affect the West African Craton.

The break-up of Rodinia at 0.85 Ga led to a fan-shaped aggregation of pre-Gondwana continental blocks including East Gondwana, West Gondwana and the intervening African cratonic blocks. These blocks were separated by oceanic basins, which were consumed and closed between 0.85-0.55 Ga during events referred to as the Pan-African Orogeny.

By 0.55 Ga the Gondwana Supercontinent had formed with Africa at its center. For the next 350 Ma this continent remained in existence and Africa only experienced sedimentation along the Gondwana margin or in intra-continental rift-sag basins. Orogenic activity during this period was limited to the NW and S extremities of the continent. From the late Jurassic onwards, Gondwana rifted resulting in the African plate as we now know it, with most tectonic activity controlled by extension and hot spot activity.

1. Introduction

The African continent preserves evidence for major crust-forming events dating back to 3.8 Ga. These events represent cycles of continental break-up and growth, which have been recognized worldwide and can be largely explained in a plate-tectonic context, within the confines of partly overlapping Wilson cycles. In Africa the main orogenic episodes are shown in Table 1.

Orogeny	*Age*	*Main outcome*
Paleoarchean	3.55-3.15 Ga	Formation of early Archean cratonic cores (Kaapvaal, Tokwe)
Mesoarchean	3.15-2.75 Ga	Accretionary growth of Kaapvaal, Zimbabwe, Congo, Tanzania cratons and the Man and Reguibat shields
Neoarchean	2.75-2.55 Ga	Stabilisation of Kaapvaal, Zimbabwe, Congo, Tanzania cratons and the Man and Reguibat shields; merging of Kaapvaal and Zimbabwe cratons as Southern Africa Craton
Eburnian	2.2-1.8 Ga	Growth of the West Africa Craton along an active accretionary margin (Birrimian). Merging of the Congo and Tanzania cratons in the Central Africa Craton. Passive margin development and orogenesis along the W margin of Central and Southern Africa cratons.
Kibaran	1.4-0.85 Ga	Merging of Southern and Central Africa cratons as part of the Rodinia supercontinent
Pan-African	0.85-0.5 Ga	Merging of all cratonic fragments to form the Gondwana supercontinent to which Africa is central
Hercynian	0.45-	Limited collision and tectonic activity along the NW

	0.25 Ga	and S margins of the African plate
Alpine	0.12-0 Ga	Subduction of African plate under Eurasia and formation of the Atlas mountains

Table 1: Summary of the main orogenic episodes in Africa
All figures with this text have been largely adapated from Choubert & Faure-Muret (1990).

2. The Archean between 3800-2550 MA: Formation of Cratons

Seven major cratonic nuclei form the foundation of Africa: the Kaapvaal craton, the Zimbabwe Craton, the Tanzania Craton, the Congo Craton, the Man Shield, the Reguibat Shield and the elusive (largely covered and reworked) East Sahara or Nile Craton. During the Neoarchean and Paleoproterozoic these Archean nucleii merged into three major cratons which will be referred to as the West Africa, Central Africa (Congo-Tanzania) and Southern Africa (Zimbabwe-Kaapvaal) cratons (de Wit and Ashwal, 1997; Trompette, 1994; Thomas et al., 1993). Archean terranes in Africa are shown in Fig. 1.

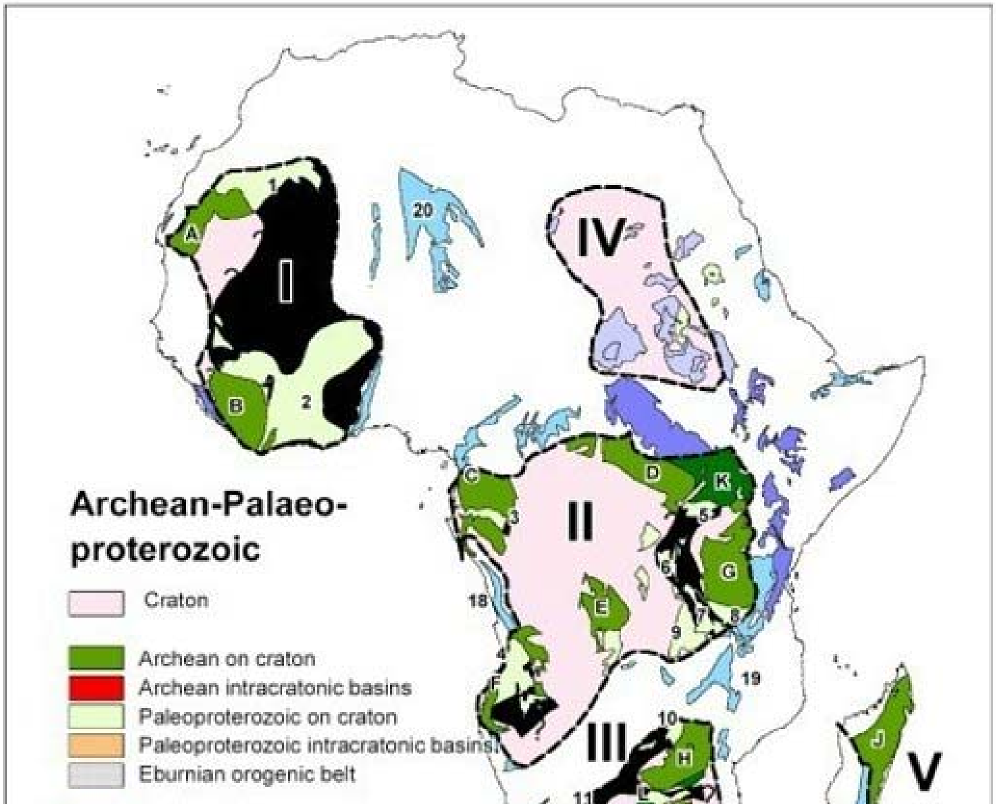

Figure 1: Archeaen and Paleoproterozoic (Ubendian) terranes (3800-1750 Ma)

2.1. The West Africa Craton

The West Africa Craton (1.5 million km^2 Archean; 3.0 million km^2 Paleoproterozoic) in NW Africa consists of the Reguibat and (Leo-) Man Shields in the N and S of the craton, respectively, that are separated by the Neoproterozoic to Paleozoic Taoudeni basin. In both shields, Archean rocks are exposed in the western parts and separated from Paleoproterozoic rocks to the east by major shear zones, referred to as the Sassandra Fault in the Man Shield (Ivory Coast) and the Zednes Fault in the Reguibat Shield (Mauritania) (Attoh & Ekwueme, 1997).

Age dating and paleomagnetic reconstructions suggest that the West Africa Craton and the Guyana Shield (Amazonian Craton) in South America formed a single domain in the Palaeoproterozoic. A possible Archean suture may be found along the SW margin of the craton (Sierra Leone, Liberia) where a linear belt of Archean granulite-facies supracrustal and meta-igneous rocks (Kasila Group) occurs, marked by a shallowly W-dipping mylonite zone. This area has been overprinted by deformation related to the Pan-African Rokelide Belt (Williams & Culver, 1988).

The Archean rocks of the **Reguibat Shield** include TTG-type migmatitic orthogneiss and metavolcanic and metasedimentary belts with ironstones, marbles, ultramafic rock, and amphibolite (e.g. Tasiast belt, Amsaga area in Mauritania), greywacke and pelite. The gneisses have ages of 3.52 Ga, 3.42 Ga and 2.84 Ga and are intruded by 2.99-2.83 Ga charnockitic gneiss. The shield has been affected at 2.74 Ga by polyphase folding and high-grade metamorphism followed by the emplacement of late-tectonic granites at 2.73-2.72 Ga. Retrograde amphibolite-grade mineral assemblages occur near the main shear zones (Attoh & Ekwueme, 1997; Potrel et al., 1998).

The oldest component of the **Man Shield** consists of banded TTG gneiss (> 3.0 Ga) overlain by greenstone belts with (ultra)mafic metavolcanics, banded ironstone, phyllite, greywacke and quartzite (e.g. Sula and Nimini belts in Sierra Leone) and intruded by 2.97-2.78 Ga granites (Attoh & Ekwueme, 1997).

2.2. The Central Africa (Congo-Tanzania) Craton

The Congo-Tanzania Craton is a region of pre-2.5 Ga continental crust, located in central Africa and includes the Tanzania and Congo cratons, linked by the Archean Uganda Basement Gneiss and West Nile Complex (> 2.8 Ga Kilo-Moto Terrane).

The **Tanzania Craton** (0.5 million km^2; Tanzania, SW Kenya, SE Uganda) consists of the >2.9 Ga Dodoma Terrane in the south and the younger Lake Victoria Terrane in the north. The Dodoma Terrane comprises high-grade TTG-type orthogneiss, mafic-ultramafic rocks, quartzite and phyllite.

The Lake Victoria Terrane consists of tectonized greenstone belts intruded by large amounts of granite. The greenstones consist of 2.81-2.70 Ga bimodal volcanics and flysch (Nyanzian Group) overlain by 2.68-2.63 Ga volcanics and clastic sediments (Nzega and Kakamega Groups). Basalt, andesite, shoshonitic rhyolite and conglomerate (Rongo Group) unconformably overlie the older sequences. Granite was emplaced during several stages at 2.72-2.68 Ga (early-syntectonic), 2.64 Ga (late-syntectonic) and 2.58-2.56 Ga (the post tectonic Western Granite Complex). A 2.53 Ga platform sequence was deposited on the NE and N parts of the craton (Kisii, Buganda Groups) (Borg & Krogh, 1999; Pinna et al., 1996, 2000).

Archean outcrops in the **Congo Craton** include the Chaillu - Gabon blocks (SW Cameroon, Equatorial Guinea, Gabon, Congo), the Zaire Block (NE DR Congo, W Uganda), the Angola Block and the Kasai Block (NE Angola, S DR Congo).

The **Chaillu - Gabon blocks** contain 3.19-3.12 Ga granite-greenstones deformed and metamorphosed at high metamorphic grades at ~ 3.15 Ga. They are intruded by 2.95-2.85 Ga calc-alkaline tonalites and granites, associated with intermediate to felsic volcanics (2.97-2.94 Ga), metamorphosed at low metamorphic grades. Ultrabasic rocks intruded at 2.78 Ga, followed by late-orogenic granites between 2.8-2.5 Ga before stabilization of the block (Feybesse et al., 1998).

The **Zaire Block** can be divided into the Bomu (amphibolite-gneiss) Complex and Ganguan greenstone belts in the far W, the West Nile Complex in the N, and the Upper-Zaire Granitoid Massif with Kibalian greenstone belts in the S. The Kibalian Group greenstones are thought to rest unconformably on older gneiss and consist of a mafic volcanic-dominated lower portion intruded by 2.8 Ga tonalite, and a bimodal volcano-sedimentary upper sequence intruded by 2.45 Ga old granite, similar to greenstones found in the Tanzania Craton. The West Nile Complex consists of high-grade gneiss with remnant mafic greenstone segments. The gneiss complex can be traced across S Sudan and central Uganda into the Tanzania craton and may form a link (orogenic belt ?) between both cratons. The > 3.0 Ga Ganguan Group greenstones are thought to rest unconformably on still older gneisses of the Bomu Complex. The Ganguan greenstones form distinct belts of slightly metamorphosed quartzite, slate, jaspilite, talc schist and dolerite. The 3.4-3.0 Ga Bomu Complex extends into the Central African Republic and is composed of migmatitic gneiss with mafic and metasedimentary schist inclusions. Deformation has been recorded at ~ 3.3-3.0 Ga and 3.0 Ga (Borg & Shackleton, 1997; Lavreau, 1982, 1984).

The Archean of the **Angola Block** was largely reworked during the Eburnian event. Archean gneiss was metamorphosed at ~2.8 Ga and intruded by granite between 2.83-2.60 Ga. They are covered by volcano-sedimentary rocks (Jamba Group in the N; Utende-Chela Supergroup in the S) of poorly constrained age (2.8-2.2 Ga). In the SW, Archean granite-greenstone terrains occur (de Carvalho, 1983). De Wit (2001, unpublished data) reports 3.5 and 2.7 Ga ages and a 2.0 Ga overprint, indicating that the Angola Block is more complicated than previously known.

The **Kasai Block** consists of tonalitic gneiss and old granodiorite (3.5-3.3 Ga) associated with supracrustals, gabbro-norite-anorthosite complexes and amphibolite, metamorphosed at granulite facies around 2.8 Ga during emplacement of 2.9-2.8 Ga charnockite and 2.83 Ga granite. A second event is associated with widespread calc-alkaline granite emplacement and migmatisation between 2.7-2.6 Ga.

2.3. The Southern Africa Craton

The Southern Africa Craton comprises the Zimbabwe Craton to the N and the Kaapvaal Craton to the S, merged across the high-grade gneisses of the Limpopo Belt.

The 3.55-2.58 Ga **Zimbabwe Craton** (0.3 million km^2, Zimbabwe, NE Botswana, W Mozambique) contains a 3.55-3.35 Ga, central gneissic nucleus (Tokwe Segment) affected by regional deformation (N-S grain) > 3.35 Ga. After it stabilized, ~3.0 Ga stable shelf sedimentation occurred along its W margin. Subsequent tectono-magmatic events added granite and greenstones including clastic and deep-water sediments at ~2.9-2.8 Ga (Belingwean, Lower Bulawayan Groups) and ~2.72-2.64 Ga (Upper Bulawayan, Shamvaian Groups). Greenstone forming events are either explained in continental rift- or flood basalt settings with deposition on older basement, or in active continental margin settings involving subduction-accretion and back-arc rifting. Important Archean unconformities have been described at the base of greenstone sequences in the Belingwe greenstone belt (Wilson et al., 1995; Jelsma & Dirks, 2002).

Thermal and isostatic stabilization of the craton occurred at 2.6 Ga with the emplacement of late-orogenic monzogranite (Chilimanzi Suite) followed by crustal relaxation, and emplacement of the Great Dyke layered mafic-ultramafic complex at 2.58 Ga. A 2.62-2.56 Ga granulite terrane occurs along the N margin of the Zimbabwe Craton. The terrane represents Archean lower crust brought to the surface during Kibaran and Pan-African events in the adjacent Zambezi belt (Jelsma & Dirks, 2002).
The **Kaapvaal Craton** (1.2 million km^2, South Africa, Botswana, Lesotho, Swaziland) originated from an early nucleus that contains the Barberton greenstone belt, Natal Terrane and Ancient Gneiss Complex with the oldest known crustal fragment in Africa (Ngwane Gneiss, 3.64 Ga).

In the Barberton greenstone belt, oceanic, 3.49-3.46 Ga (ultra)mafic volcanic and plutonic rocks experienced 3.45-3.42 Ga deformation-metamorphism and TTG-type plutonism as oceanic crust and 3.55-3.52 Ga tonalitic gneiss were obducted onto an active arc-trench-like terrain. An early continental margin may have formed to the S (3.4 Ga, Mkhondo-Mahamba Groups, Swaziland). At 3.3-3.2 Ga, renewed tectono-magmatism resulted in crustal thickening with clastic sedimentation (Fig Tree-Moodies Groups), evolving to late strike-slip shear and post-tectonic granite emplacement between 3.15-3.07 Ga (Brandl & de Wit, 1997).

By 3.1 Ga, a large part of the Kaapvaal Craton had stabilized and a thick volcano-sedimentary pile accumulated on this proto-cratonic block. Along its N margin, the ~3.2-2.97 Ga Pietersburg-Giyani and Murchison Terranes represent juvenile oceanic- and island-arc crust that accreted with the proto-craton between 3.2-2.8 Ga. West of the proto-craton, the ~3.1-2.9 Ga Amalia, Colesburg and Kraaipan Terranes accreted along the Colesberg Lineament (Brandl & de Wit, 1997; McCourt, S., 1995).

The Zimbabwe and Kaapvaal cratons were juxtaposed at ~2.6 Ga across the ENE trending **Limpopo Belt** that is separated from the cratons by major thrusts (North Limpopo Thrust Zone in the N; Hout River Shear Zone in the S). The Limpopo Belt has been interpreted as an Archean collisional orogen and comprises the North Marginal

Zone (reworked Zimbabwe craton), Central Zone and South Marginal Zone (reworked Kaapvaal Craton). The marginal zones have been interpreted as metamorphosed deep-crustal equivalents of granite-greenstones in the adjacent cratons. The Central Zone is separated from the marginal zones by the dextral Triangle Shear Zone to the north and the sinistral Palala shear zone to the south. The Central Zone preserves no evidence of greenstone precursors, but is characterized by platform sediments (provenance 3.8-3.3 Ga) deposited on a basement of 3.25-3.17 Ga orthogneiss (Sand River gneiss). Deformation occurred at high-grades at ~3.2-3.1 Ga (Central Zone only), 2.65-2.55 Ga (collision) and 2.05-1.95 Ga (transpression).

2.4. An Archean Passive Margin Sequence and Foreland Basin

A large section of the Kaapvaal craton stabilized by 3.1 Ga, and acted as basement to the thick volcano-sedimentary sequences of the co-evolving (> 2.94 Ga) Pongola and (3.12-2.71 Ga) Witwatersrand basins. In the Witwatersrand basin, the sequence comprises the lowermost 3.12-3.07 Ga Dominion Group volcanics, overlain by the Witwatersrand Supergroup sediments. Sedimentation took place during two cycles, with rocks of the lower cycle forming on a passive continental margin.

Sediments of the upper cycle are rich in gold and accumulated between 2.84-2.71 Ga in a foreland basin. Early rifting evolved to post-rift subsidence and flexural loading due to thrusting along the SE and NW margins of the basin. The evolution of the Witwatersrand Basin came to an end with the vast outpouring of the Ventersdorp Group rift-basin volcanics at ~ 2.71 Ga (Brandl & de Wit, 1997; Coward et al., 1995).

2.5. East Sahara or Nile Craton

The poorly known East Sahara or Nile Craton stretches E-W from the Hoggar Massif (Algeria) to the Western Desert (Egypt). It is largely covered by younger rocks and reworked by Pan-African events. Rocks from the Uweinat Massif (Egypt) are as old as 2.63 Ga, but the bulk of the pre-Pan-African Nd model ages reported for the craton are Proterozoic. Provenance ages and xenocryst ages from Egypt and Sudan indicate significant episodes of crustal growth during the Proterozoic at 2.5-2.4 Ga, 2.1-1.9 Ga, 1.7-1.2 Ga and 1.0-0.8 Ga (Stern et al., 1994).

2.6. Malagasy Shield

The Malagasy Shield (Madagascar) is divided in two parts by the NW-SE trending Bongolava-Ranotsara shear zone with high-grade Pan-African gneiss affecting Mesoproterozoic and possibly Archean protoliths to the S. To the N of the shear zone, low- and medium-grade greenstone-gneiss terrains occur separated by metasedimentary rocks and granitoid.

The greenstone belt stratigraphy has been divided into metasedimentary/paragneiss dominated (Androyen, Graphite Systems), and greenstone dominated (Vohibory System) sequences. A migmatite tonalite gneiss in the sequence is dated at 3.19 Ga, whilst 2.52-2.49 Ga, granitic orthogneiss intruded the greenstone (Tucker et al., 1997).

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Hielke Jelsma obtained his PhD at the Free University Amsterdam, working on greenstone belts in Zimbabwe. From 1990 until 2000 he lectured at the University of Zimbabwe after which he moved to the Department of Geological Sciences at the University of Cape Town, where he worked as a research associate on problems related to the evolution of the Kaapvaal Craton including kimberlite genesis. In 2003 he took up a position in the Exploration Division of De Beers Consolidated Mines. His main research interests are the tectonic evolution, structural geology and metallogeny of Archean cratons and orogenic belts.