2 Precambrian Basement of the Congo Basin and Its Flanking Terrains

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2.1 Introduction

Africa is the world's second largest continent, with just over 30 million km^2, almost entirely underlain by Precambrian crystalline basement. The geology of this basement, particularly in central Africa, however, is generally not well-described and is poorly constrained by geochronology because of an extensive cover of Phanerozoic rocks, recent sediments, laterites and vegetation; and because of an extended period of socio-political instabilities that continues to make it difficult to explore and study this region.

Until 30 years ago, the Precambrian history and geochronology of central Africa's basement was based primarily on geologic and low resolution Rb/Sr analyses essentially carried out and synthesized by Louis Cahen and Norman Snelling, and their collaborators, in their iconoclastic book '*The Geochronology and Evolution of Africa*' (Cahen et al. 1984). Since then there has been a slow exponential increase in more precise U-Pb dates on zircons and hence improved understanding of Africa's crustal evolution, particularly in the regions of central Africa: in Gabon, Cameroon, Central African Republic (CAR) and Chad (e.g. Feybesse et al. 1998; Toteu et al. 2006, 2014; Nkoumbou et al. 2013; de Wit et al. 2014, under review); in Uganda, Democratic Republic of Congo (DRC), Rwanda and Burundi (e.g. Link et al. 2010; Tack et al. 2010; Fernandez-Alonso et al. 2012; Lawley et al. 2013, 2014); in Tanzania (e.g. Boniface et al. 2012; Kabette et al. 2012a, b; Kasanzu 2014); Mozambique (e.g. Bingen et al. 2009); in northern Zambia (e.g. Master et al. 2005; de Waele et al. 2006; Lawley et al. 2013, 2014) and in central-northeast Angola (e.g. Carvalho et al. 2000; Delor et al. 2006; Jelsma et al. 2011, 2012), amongst others.

Here we briefly review and summarize some of these results to provide a framework of the Precambrian basement underlying and flanking the Congo Basin (CB), in particular because this constitutes the upper lithosphere foundation to this very large (ca. 1.8 million km^2) and poorly understood Phanerozoic sedimentary basin that is the focus of this book.

2.2 Cratons and Shields in Africa

The African continent can be subdivided into four major Precambrian Shields that amalgamated along Neoproterozoic orogens (Fig 2.1, inset B), and each of which in turn comprises assemblages of Archean cratons further embedded within Meso- and Paleo-Proterozoic mobile belts. However, in the literature, the terms Craton and Shield are not always clearly defined. For example, geologic terrains in central Africa are often used indiscriminately and sometimes interchangeable: Congo Craton, Congo Shield and Central African Shield or Craton; Kasai Craton or Shield and Lunda Shield; Angola-Kasai Craton, Angola Craton or Shield, and NE Angolan Shield, or Cuango Shield or Craton, and southern Congo Craton; Greater Congo Shield, etc. To clarify our nomenclature here, we follow the definitions of Stankiewicz and de Wit (2013), and specifically refer to 'cratons' as Archean blocks (e.g., stabilized >2.5 Ga), and to 'shields' as stabilized, post-Archean continental domains that formed and/or amalgamated at specified times during the Proterozoic-Phanerozoic, and within which Archean cratons (or deformed Archean blocks) are embedded.

We refer collectively then to a number of relatively small Archean cratons that underlie, or in part underlie, the CB

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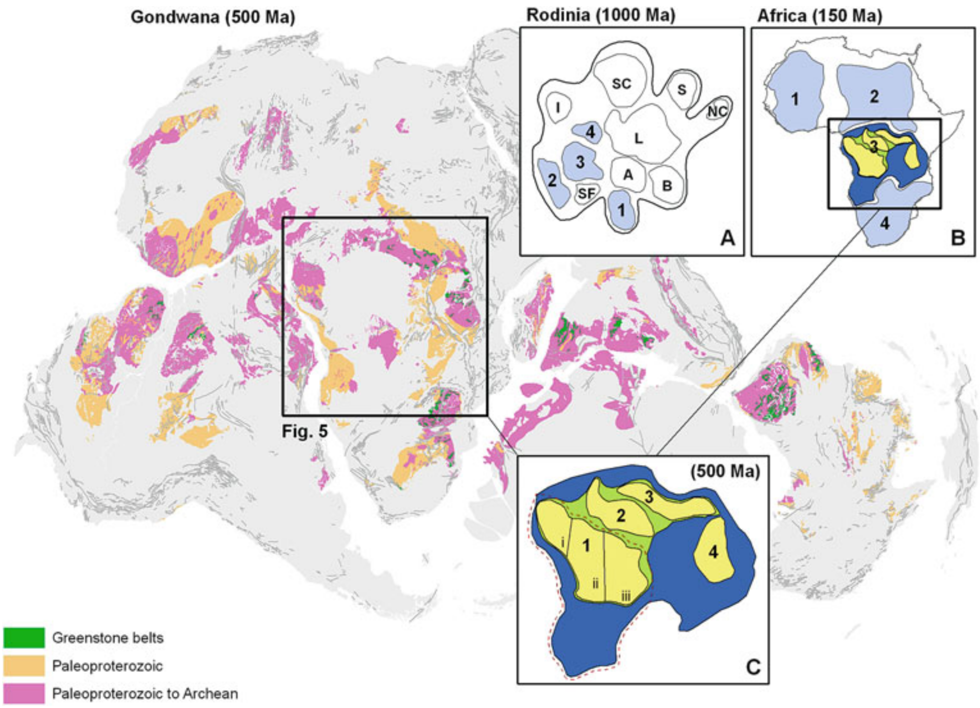

Fig. 2.1 Simplified early Precambrian map of Gondwana (GIS from de Wit et al. 1988; modified). Inset (A and B) Four major African Precambrian Shields (*pale blue*): 1 = West African Shield; 2 = Saharan Shield; 3 = Central African Shield; 4 = Southern African Shield, and other fragments of Rodinia (~1 Ga): A = Amazonia; B = Baltica; L = Laurentia; I = India; S = Siberia; SC = South China; NC = North China (simplified from Li et al. 2008 and Lindeque et al. 2011). Inset (C) crustal domains of central Africa with four cratons (*yellow*): $1_{i,ii,iii}$ = Ntem, Cuango, Kasai = SouthWest Congo Craton (SWCC); 2 = Cuvette [Central] Congo Craton (CCC); 3 = Mboumou-Uganda = NorthEast Congo Craton (NECC), forming the Congo Shield (CS, *green*), and enlarged in Proterozoic to form the Central African Shield (CAS, *dark blue*). *Red dotted outline* is the SouthWest Congo Shield (SWCS)

(e.g. Kasai, Cuango, Ntem, Bouca, [Bomu] Mboumou-Uganda) and some of which amalgamated before the end-Archean into three larger cratons: 'the Southwestern, Cuvette [or Central], and Northeastern Congo Cratons (SWCC, CCC, NECC, respectively), but the detailed tectonic history of which still remains largely unknown (Fig 2.1, inset C). We use 'Congo Shield' (CS) for a larger lithospheric region that comprises those three cratons that cannot be directly correlated beneath the present CB for lack of appropriate geophysical data, but which likely amalgamated during the Proterozoic and which all lie inboard of surrounding Pan-African (ca. 0.8–0.5 Ga), Kibaran (ca. 1.0–1.4 Ga) or Eburnian (ca. 1.9–2.3 Ga) orogenic belts and related inferred suture zones that surround the CB (Fig. 2.1, inset B; Fig. 2.2).

For simplicity, here we specifically separate the Congo Shield (CS) from potential conterminous shield areas in Brazil. Even though parts of a larger central African shield area, which we here term the Central African Shield (CAS), may have been linked to the greater São Francisco Shield (mostly referred to in the literature as a Craton) in a Rodinia framework (Fig. 2.1, inset A), there is still considerable uncertainty about the detailed timing and accretion processes that may have linked these two shields into a larger Paleoproterozic Shield in Eburnian times (circa 2.0 Ga; e.g. Pedrosa-Soares et al. 2008, and references therein). Suffice it to say that it has been argued, for example, on the basis of paleomagnetism and undeformed Mesoproterozioc sedimentary sequences found on both shields (dated between 1.7–1.8 Ga (Pedreira and de Waele 2008) that the two continental terrains may have been connected at that time (e.g. Trompette 1994), but also that the age correlations are far from detailed enough to substantiate this correlation from one continent to another (e.g. McCourt et al. 2004; Pedreira and de Waele 2008). Whilst we will briefly refer to this potential connectivity below, it is beyond the scope of this chapter to explore this in further detail here.

As early as the mid-Paleoproterozoic, the eastern and northern margins of the CS were convergent margins that experienced Eburnian subduction-obduction of ca. 2.0–2.3 Ga oceanic lithosphere, and accretion of Archean continental fragments, over a period of at least 150 Ma, between ca. 2050–1880 Ma (e.g. Boniface and Schenk 2012; Boniface et al. 2012; Nkoumbou et al. 2013; Lawley et al. 2013, 2014; and see below). By contrast, the southern margin of the CS is defined by the Central Shield Zone of Angola (cf. Carvalho et al. 2000), a wide transition zone of Eburnian granitoid magmatism and high grade tectonism that also embodies a

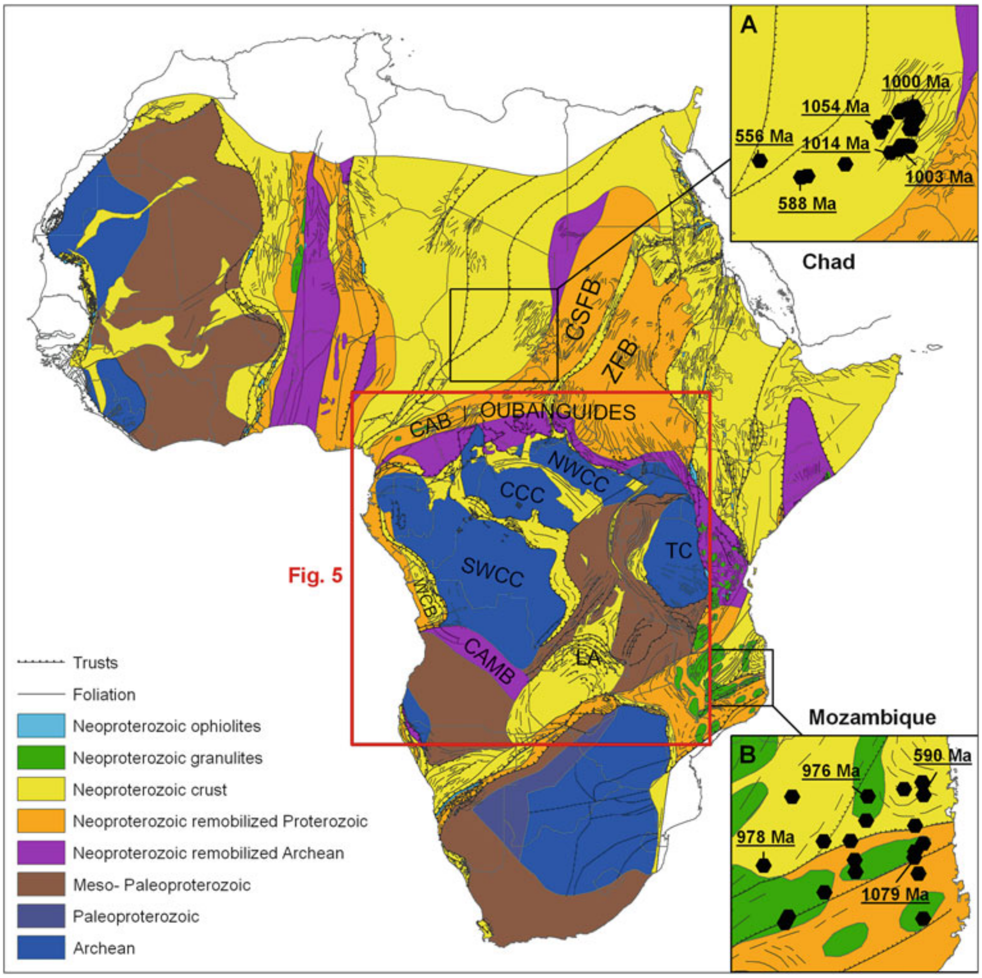

Fig. 2.2 Geological map of the Precambrian basement of Africa (GIS from de Wit et al. 2008; updated), locating the studied area in central Africa. Black rectangles detail adjacent regions with recent data: (A) in Chad (de Wit et al. under review) and (B) in Mozambique (Jamal, PhD thesis 2005)

number of remobilized Archean fragments, and which we here rename the Central Angola Mobile Belt (CAMB). This belt separates the rest of the Angola basement to the south, comprising predominantly Eburnian-Kibaran (mid-Proterozoic) crust, from the SWCC. We suggest these two blocks collided along the CAMB at ca. 2 Ga to form the 'Southwestern Congo Shield' (SWCS, as first termed by S. Masters in 2004; see Chap. 1 in this Book).

To the west of the CS lies a wide region of Proterozoic basement, including Eburnian (Ubendian), Kibaran and Pan-African segments that separate it from the Tanzanian Craton. This intervening region has a complex geologic history that is still under reconnaissance investigation, and the details of which are beyond the scope of this chapter. Suffice it to mention that an Eburnian orogenic belt/suture zone (the Rwenzori Fold Belt of Tanner, 1974), and the Buganda-Toro system, e.g. Nagudi et al. 2003, and references therein separates the Tanzanian Craton from the NWCC (Mboumou-Uganda Craton). It is not clear how this Eburnian suture links up southwards across central Africa, from Uganda and western DRC through Rwanda, Burundi, western Tanzania to Zambia and Angola. We show here two likely Eburnian terrain boundaries directly flanking the CS and the Tanzanian Craton, respectively (Fig. 2.3). This leaves the central Proterozoic block (including the Paleoproterozoic Bangwuelu Block), with occasional Archean fragments, as a separate accretionary region that first amalgamated between the CS and the Tanzanian Craton during Paleoproterozoic (Eburnian) times. This terrain was subsequently in part re-melted during the Mesoproterozoic (e.g. the 'Kibaran Event' [s.s.] in the Karagwe-Ankole region; Tack et al. 2010; Fernandez-Alonso et al. 2012) and again deformed within the Kibaran Belt (e.g. de Waele et al. 2006, 2008). Along the Ubendian Belt flanking the southwestern margin of the Tanzanian Craton, Eburnian oceanic crust was metamorphosed at low T/high P to eclogite during subduction at around 1866–1868 Ma, and was subsequently re-metamorphosed and re-deformed during Kibaran and Pan African tectonism (Boniface et al. 2012; Kabette et al. 2012a; Lawley et al. 2013, 2014). The complexity of this vast 'Kibaran Shield' is yet to be resolved.

Subsequent accretion of other crustal blocks along a number of orogenic belts surrounding the Congo Shield during the formation of Gondwana in the late Neoproterozoic-Early Cambrian created the still larger 'Central African Shield'

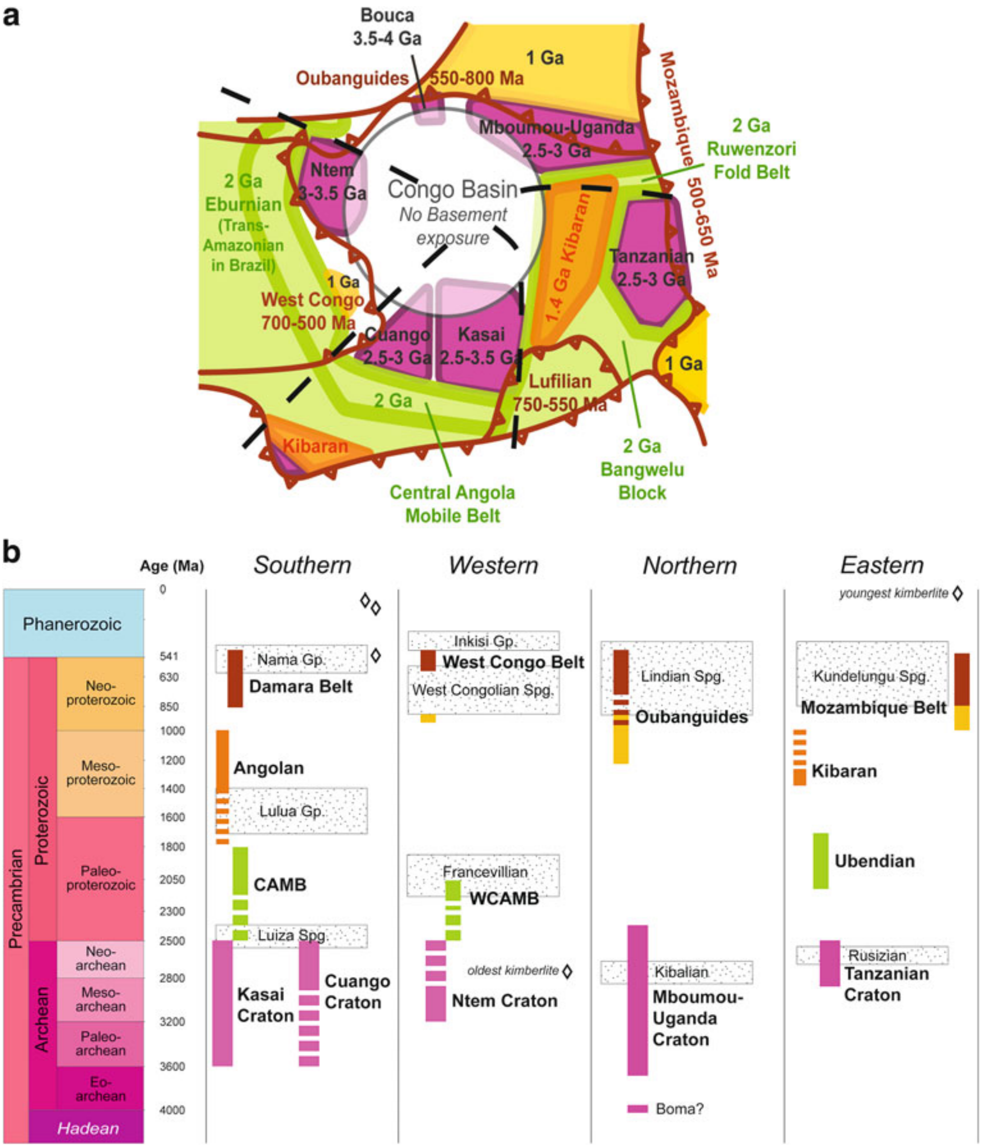

Fig. 2.3 (**a**) Sketch map of Precambrian basement surrounding the CB, showing the six Archean cratonic blocks (*purple*); Eburnian (*green*) and Kibaran terrains (*orange* and *yellow*), and tectonic fronts of Pan African fold-and-thrust belts (*brown*). Possible Pan African structures below the basin are not shown. (**b**) Time–Space diagram of Precambrian of central Africa. The four regions are shown in (**a**) (*dashed lines*) and described in detail in the text. Dotted rectangles in b = sedimentary sequences

(CAS) that stabilized by ca. 540 Ma (Fig. 2.1, inset B). CAS incorporates: the West Congo Belt of Gabon, western DRC and northwestern Angola; the Oubanguides (or sometimes called the Central African Fold Belt) of northern Gabon, Cameroon and CAR; the Mozambique Belt (as part of the southern East African Orogen) from southern Sudan, eastern Tanzania, Kenya and Mozambique; the Lufilian Belt (Arc) in Zambia and its extension into northwest Botswana and Namibia (as the Damara Belt) and from there north through the Kaoko Belt back to a link with the West Congo Belt in northwest Angola, via parts of the Braziliano Araçuaí Belt (now) of eastern Brazil (e.g. de Wit et al. 2008; Fig. 2.3). The precise connections between these Pan African Belts and their Brasiliano counterparts are still under scrutiny (e.g. Pedrosa-Soares et al. 2008; IGCP-628 project, and draft Gondwana Geological Map 2014, Renata Schmitt Personal communications, 2014).

Thereafter, this lithosphere of central Gondwana experienced prolonged and complex long-wavelength perturbations during multiple compression and then multiple rifting events as it became covered by Paleozoic and Meso-Cenozoic sedimentary basins—of which the CB is a prime and globally unique example (e.g. Linol, 2013; Linol et al., Chap. 12 of this Book). Unlike its early-linked Paraná Basin (now in Brazil), and unlike the Michigan Basin of North America to which an over-simplified history of the CB has been frequently compared (e.g. Hartley and Allan 1994), Gondwana break-up led to a CB that evolved further into a continental basin surrounded by rifts, except along its southern margin, where it is flanked by the southern (Kalahari) African high Plateau underlain by the Southern African Shield (e.g. Fig. 2.4).

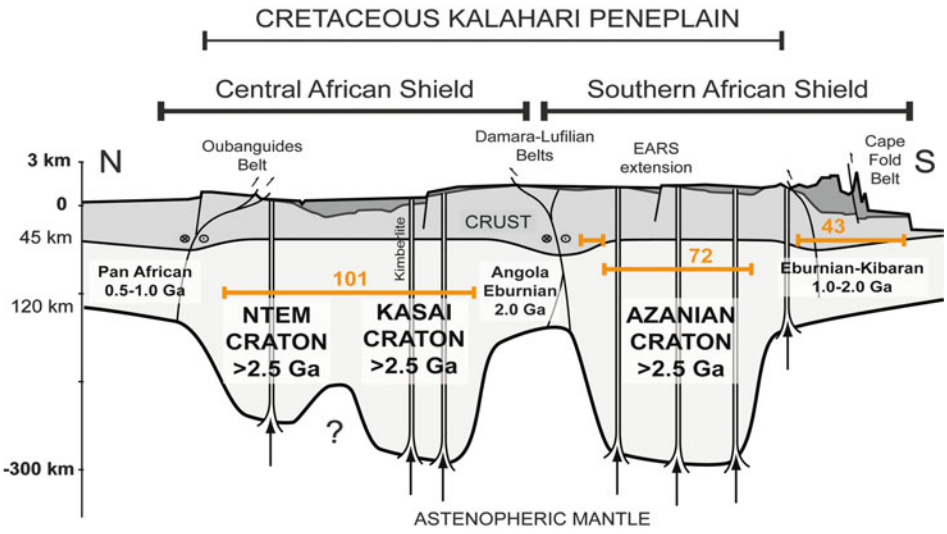

Fig. 2.4 Lithospheric model (in *pale grey*) N–S cross-section from southern Africa (Agulhas Fault) to Sahara (Chad), showing the Central and Southern African Shields capped by a sub-continental Cretaceous Kalahari peneplain. Effective elastic thicknesses of the lithosphere (Te; in km), shown in orange lines, are taken from Hartley and Allan (1994) and Doucoure and de Wit (1996), derived using the same techniques through spectral analysis

Shortly after Africa emerged out of Pangea/Gondwana, over a period of some 80 million years (ca. 200–120 Ma) that heralded the opening of the Indian and South Atlantic Oceans, the conterminous Central and Southern African Shields were uplifted during the Kalahari epeirogeny (de Wit 2007), and then peneplained to form the Kalahari Plateau (Fig. 2.4). During the end-Mesozoic to Cenozoic this plateau became covered by sands and a hard-cap of calcretes and silcretes (the Kalahari Group). Above the CB, this surface collapsed in the Eocene (Linol et al., Chap. 11, this Book), but across the Southern African Shield this surface remains mostly intact, probably because, largely, it is directly underlain by Precambrian basement rocks.

Whilst a large amount of deep local geophysical and geochemical data has enabled a firm understanding of the 3-D structure beneath the Southern African Shield (e.g. Evans et al. 2011; Bell et al. 2003; Stankiewicz and de Wit 2013, and references therein), including variations in depth to Moho and the bottom of the lithosphere, this is not the case for the CAS (e.g. Begg et al. 2009; Buiter et al., 2012; see also Raveloson et al., Chap. 1, this Book). Geophysical data is particularly scarce across the CS. Beneath the CB, there is no hard information about variations in depth to Moho or the lithosphere structure and its thickness, other than by inference from (mostly) Cretaceous diamondiferous kimberlites that have intersected the mantle lithosphere below the CS (Fig. 2.4; de Wit and Jelsma, Chap. 18, this Book); and from low resolution seismic tomography that suggest the thickness of the lithosphere beneath the cratons embedded in the CS varies between 130–200 km (e.g. Raveloson et al., Chap. 1, this Book) and is thus thick enough to contain the transition into the general lithospheric mantle stability field of diamonds (ca. >120 km). But the geophysics has not as yet tested potential lithospheric variations across the boundaries between, for example, the three central Congolese Cratons of the CS.

2.3 Regional Geology and Geochronology of Central Africa

The CB of central Africa is completely surrounded by peneplained Precambrian basement, including Archean cratonic blocks and numerous Paleo- to Meso-Proterozoic mobile belts (Figs. 2.2, 2.3, 2.4 and 2.5). This complex assemblage comprises the Kasai, Cuango, Ntem, Bouca, Mboumou-Uganda and Tanzanian Cratons (ca. 2.5–3.5 Ga; Cahen et al. 1984), the CAMB (ca. 2.0–2.3 Ga; Carvalho et al. 2000), and the West Central African Mobile Belt (WCAMB; ca. 2.0–2.5 Ga; Feybesse et al. 1998).

These oldest blocks apparently all amalgamated during Eburnian (in Africa; Trans-Amazonian in South America) orogenesis, ca. 1.8–2.2 Ga, along: an east–west suture in southern Uganda, cutting across the central Rwenzori Mountains, and collectively known as the Rwenzori Fold Belt (Tanner 1973); the Rusizian and Ubendian-Usagaran Belts in Uganda and western Tanzania (Lenoir et al. 1995; Tack et al. 2010; Link et al. 2010; Fernandez-Alonso et al. 2012; Boniface et al. 2012; Lawley et al. 2013, 2014), across central Angola (Doucoure et al. 1999; de Carvalho et al. 2000; Jelsma et al. 2012), and north–south along the South Atlantic margin where it forms the basement to the Neoproterozoic West Congo Belt and its Braziliano counterpart in Brazil (Feybesse et al. 1998; Tack et al. 2001; Toteu et al. 2001; Pedrosa-Soares et al. 2008).

We have drawn roughly defined Eburnian sutures along the CAMB and WCAMB, where major continental accretion may have occurred to consolidate the SWCS (Figs. 2.3 and 2.6). There are widespread areas in the CAMB (e.g. Central Shield Zone of Carvalho et al. 2000; Jelsma et al. 2012) where regions of Eburnian deformation, granulite-grade metamorphism and crustal melting have significantly affected Archean granite-greenstone fragments. This broad

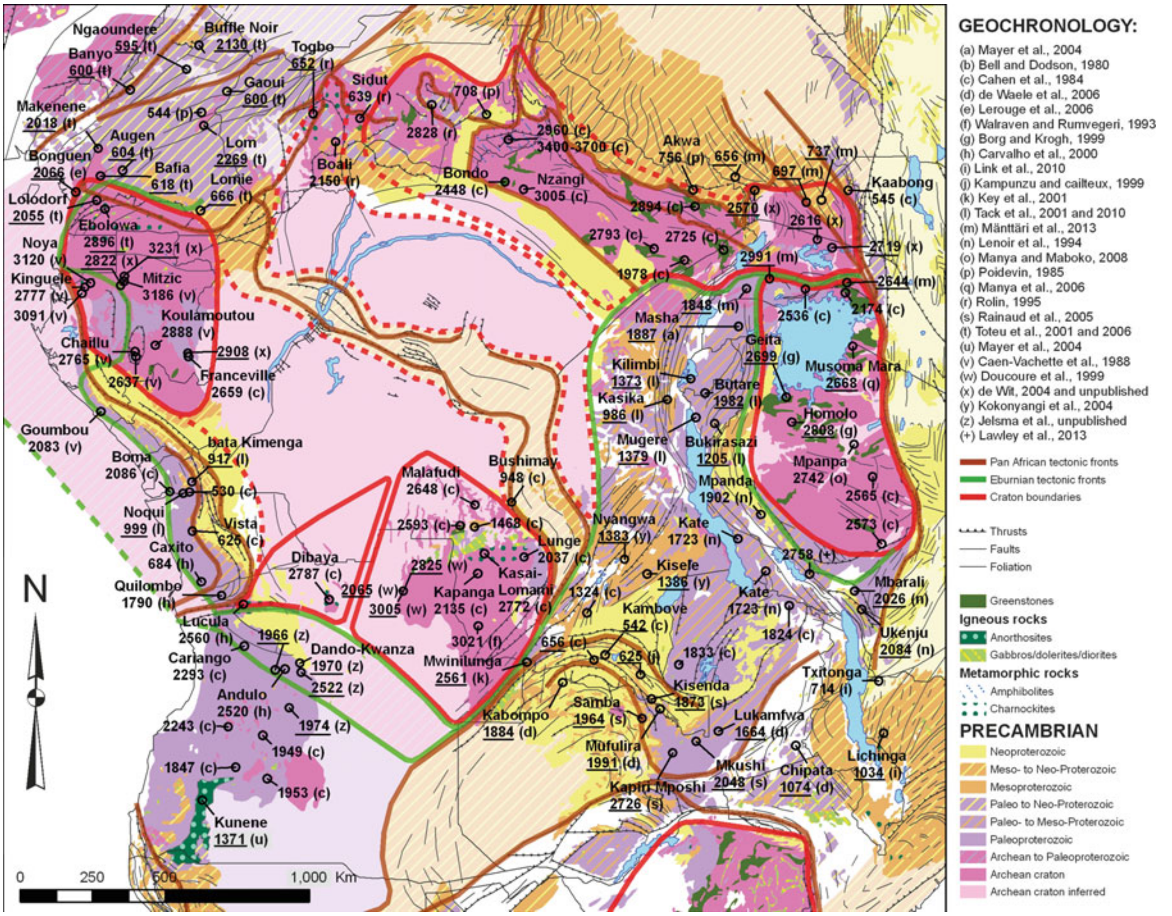

Fig. 2.5 Detailed Precambrian map of basement surrounding the CB (GIS database from de Wit et al. 1988, modified), with selected dates from the literature. *Underlined numbers* are U-Pb zircon dates, in millions of years (Ma)

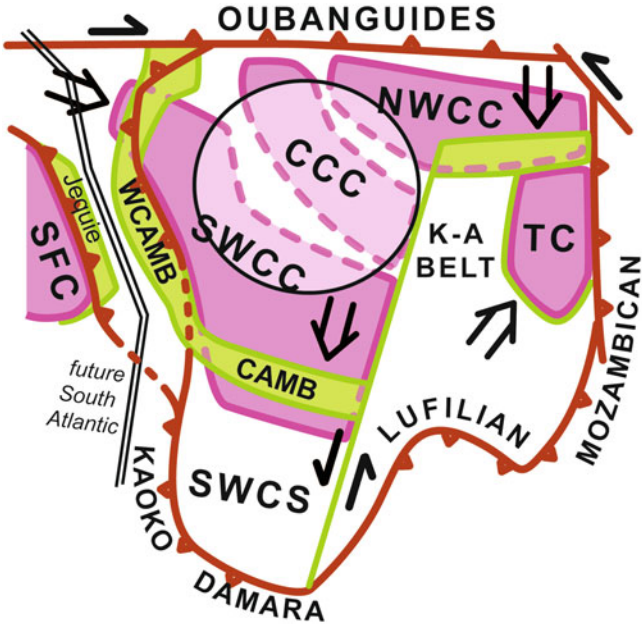

Fig. 2.6 Schematic diagram of the formation of the Central African Shield (CAS)

boundary zone (200–250 km wide) between the SWCC and the Angola region to the south may represent an Eburnian exhumed 'Alpine-Himalaya' type-zone, formed during prolonged southward under-thrusting of the Kasai Craton beneath the Angola basement, forming an Eburnian paleo-Tibet like Plateau with low pressure granulite formation and prolonged alkaline magmatism (2300–1300 Ma) and widespread rapakivi granites as old as 2065–2068 Ma (U/Pb zircon TIMS dates; Doucoure et al. 1999). The Angola region stretches ca. 1,000 km south towards its tectonic contact with the Kaoko-Damara Belt in Namibia, a contact boundary that contains slivers of Archean gneisses (ca. 2580–2620 Ma) within the Eburnian-Kibaran granitoids of the Angola basement (e.g. Miller 2008). Near its southern margin this Angola basement is overlain unconformably by relatively undeformed Paleo-Mesoproterozoic sedimentary rocks (Chela Group, ca. 1790 Ma McCourt et al. 2004), and intruded by the vast Mesoproterozoic mafic-anorthosite complex of Kunene at 1371 Ma (U-Pb zircon date; Mayer et al. 2004) associated with widespread red granites and syenites dated around 1400–1300 Ma (Carvalho et al. 2000).

These dates also confirm Kibaran (s.s.) mafic and granite magmatism and crustal melting along the southern margin of the SWCS, similar to the Karagwe-Ankole Belt east of the CB; both predated by Paleo-Mesoproterozoic sedimentation across a large region of the CAS, including the Kibaran Supergroup sequences flanking the western margin of the Tanzania Craton (e.g. Pedreira et al., 2008).

Extensive Archean areas north of the CAMB have also been affected locally by Eburnian tectono-metamorphic remobilisation. In parts of the Kasai and Cuango Cratons, the 2.0–2.2 Ga Mubindji Event deformed Paleoproterozoic metasediments (Luiza Group) and possibly related low-grade metabasaltic with pillow lavas (Lulua Group), which unconformably overlie Archean charnockites and enderbites (Cahen et al. 1984; Carvalho et al. 2000). Neither accurate field relationships nor precise geochronology are available to establish a more detailed geologic history.

If the Kasai, Cuango and Ntem Cratons are in fact connected beneath the CB (as the SWCC), then the flanking Eburnian high-grade mobile belt (CAMB) to the south may have stretched all the way from Zambia in the southeast (terminating along a NE-trending Eburnian-Kibaran transcurrent suture) to Gabon, where, as the WCAMB, it forms basement to the younger, overlying West Congo Belt (Figs. 2.2, 2.3 and 2.4). The westernmost tectonic margin of the (CAMB-WCAMB) Mobile Belt is exposed in Brazil between the Trans-Amazonian suture (containing the fold and thrust belt, and gold mineralisation in the Jacobina metasediments) that separates the eastern margin of the Sao Fransisco Craton from the Archean-Eburnian Jequie granulites along the east coast of Brazil (e.g. Feybesse et al. 1998; Lerouge et al. 2006).

Finally the CS was again strongly tectonized during the Pan-African (Brasiliano) orogenesis (ca. 650–540 Ma; e.g. de Wit et al. 2008 and references therein) during accretion of continental blocks along peripheral suture zones, now manifested by a number of well-studied fold-and-thrust belts, including: the West Congo, the Oubanguides (Central African Fold Belt), the Mozambique, and the Irumides-Lufilian-Damara-Kaoko Belts (Figs. 2.2, 2.3 and 2.4). These belts all verge tectonically into the CB, and provided sediment detritus to late Neoproterozoic-early Paleozoic foreland basin sequences that cover the basement rocks and/or the Cryogenian Carbonate sequences exposed along the outer margins of the CB (e.g. Delpondor and Préat, Chap. 3 this Book), and which likely also cover the basement of all of the three Congolese Cratons as shallow marine carbonates, with possibly evaporites (e.g. Kadima et al., Chap. 6, this Book; Selley et al. 2005; Jackson et al. 2014). Evaporite minerals have been recorded in these sequences where they outcrop near the southern and western margins of the CB (e.g. Mbuji-Mayi and Gabon; see Delpomdor et al., and Kolo et al., Chaps. 4 and 5, this Book, respectively), However, major salt sequences have not been observed anywhere in the deep drill holes through the central CB or along the peripheral Neoproterozoic basins (e.g. Tait et al., 2011; and, respectively, Kadima et al., and Linol et al., Chaps. 6 and 11, this Book).

Regionally, 'Redbeds' unconformably overlie the folded Neoproterozoic (carbonate) sequences of the Pan-African Belts and in cores through the CB (Kanda et al. 2011). These Redbeds can no longer be considered as only Precambrian, as frequently argued, because ca. 540 Ma detrital zircons have been found in the Redbeds of the Inkisi Group (Jelsma et al. 2011). At least the upper parts of the CB Redbeds are thus younger than earliest Cambrian; however, the general stratigraphy of these and younger Redbeds remains poorly constrained as there is no reliable chronostratigraphy to correlate them accurately (e.g. Tait et al. 2011).

It has been suggested that the CCC and SWCC amalgamated along an NW-SE trending Pan African deformation zone (Daly et al. 1992; de Wit et al. 2008; Figs. 2.2 and 2.5), but the age of this deformation, indeed even the existence of such a Neoproterozoic deformation zone is still in dispute (Linol et al., Chap. 12, this Book) and will require new high resolution reflection seismology to clarify this (e.g. Kadima et al. 2011; Kadima et al., Chap. 6, this Book). Similarly, the CCC and NECC may have amalgamated along a NW-SE trending deformation zone during the Mesoproterozoic (Kibaran) (as suggested by S. Master in 2004, see Raveloson et al., Chap. 1, this Book), or during Neoproterozoic (Pan African) as suggested by de Wit et al. (2008; see Fig. 2.2). Again there is no hard data, geologically or geophysically, to refute or substantiate these working models.

Below we briefly summarize the most reliable geology and geochronology of some of the cratons and shield regions, referred to above, surrounding the CB.

2.4 Local Geology and Geochronology of Cratonic Domains and Their Cover Sequences Surrounding the CB

The Precambrian basement of the Congo Shield and relevant parts of the CAS is described below in four sub-regions: (1) southern, (2) western, (3) northern, and (4) eastern central Africa (Fig. 2.3a, b). A detailed map with selected (most robust) radiometric dates summarized from the literature and our own unpublished data, is presented (Fig. 2.5; Table 2.1).

In almost all of the basement areas directly flanking the CB, thick (~5–10 km) sequences of Cryogenian (850–635 Ma) siliciclastics and carbonates, with excellently preserved, albeit sedimentologically complex, glacial deposits (diamictites and tillites; also sometime named 'mixites') and cap carbonates rest directly on the

Table 2.1 Selected dates of the Precambrian Central African Shield

Long		Lat		Rock name	Dates (Ma)		Method	Author
22°48′ 31″	E	7°44′42″	S	Musefu	2772	±28	Rb-Sr whole-rock	Cahen et al. (1984)
23°39′54″	E	6°8′13″	S	Bushimay basalt	948	±20	K-Ar whole-rock	Cahen et al. (1984)
17°58′11″	E	9°10′6″	S	Dibaya migmatite	2787	±164	Rb-Sr whole-rock	Cahen et al. (1984)
28°30′4″	E	2°56′38″	S	Kasika granite	986	±10	U-Pb zircon	Tack et al. (2010)
29°23′44″	E	3°29′55″	S	Mugere granite	1379	±10	U-Pb zircon	Tack et al. (2010)
29°58′51″	E	3°41′11″	S	Bukirasazi granite	1205	±19	U-Pb zircon	Tack et al. (2010)
29°40′37″	E	2°44′23″	S	Butare orthogneiss	1982	±6	U-Pb zircon	Tack et al. (2010)
29°14′1″	E	2°18′13″	S	Kilimbi Muzimu	1373	±6	U-Pb zircon	Tack et al. (2010)
13°1′21″	E	5°49′1″	S	Boma	2086	±64	Rb-Sr whole-rock	Cahen et al. (1984)
15°20′1″	E	10°37′2″	S	Cariango	2293	±43	Rb-Sr whole-rock	Cahen et al. (1984)
15°18′11″	E	9°19′0″	S	Lucala migmatite	2560	±50	Rb-Sr whole-rock	de Carvalho et al. (2000)
14°38′4″	E	9°2′36″	S	Quilombo gneiss	1790	±32	Rb-Sr whole-rock	de Carvalho et al. (2000)
13°59′48″	E	8°37′25″	S	Caxito migmatite	684	±20	Rb-Sr whole-rock	de Carvalho et al. (2000)
22°31′17″	E	6°13′29″	S		2648	±22	Rb-Sr whole-rock	Cahen et al. (1984)
22°3′18″	E	6°52′17″	S		2593	±92	Rb-Sr whole-rock	Cahen et al. (1984)
22°30′14″	E	6°55′10″	S		1468	±30	K-Ar whole-rock	Cahen et al. (1984)
24°2′40″	E	7°50′44″	S		2037	±30	U-Pb	Cahen et al. (1984)
22°36′17″	E	8°21′40″	S	Kapanga	2135	±100	Rb-Sr whole-rock	Cahen et al. (1984)
20°17′39″	E	8°54′14″	S		2825	±3	U-Pb zircon	Doucouré et al. (1999)
16°35′42″	E	11°19′40″	S	Andulo migmatite	2520	±36	Rb-Sr whole-rock	de Carvalho et al. (2000)
16°2′58″	E	14°45′13″	S		1853	± 74	Rb-Sr whole-rock	Cahen et al. (1984)
14°49′60″	E	13°8′3″	S		2243	±94	Rb-Sr whole-rock	Cahen et al. (1984)
15°54′54″	E	13°23′50″	S		1949	±30	Rb-Sr whole-rock	Cahen et al. (1984)
15°4′15″	E	14°23′36″	S		1847	±62	Rb-Sr whole-rock	Cahen et al. (1984)
21°9′59″	E	6°13′46″	N	Ippy	2828	±70	Rb-Sr whole-rock	Rolin (1995)
17°28′26″	E	5°57′30″	N	Togbo	652	±19	U-Pb zircon	Rol(1995)
13°36′2″	E	1°37′0″	S	Franceville granite	2659	±30	Rb-Sr whole-rock	Cahen et al. (1984)
13°59′57″	E	6°0′3″	N		544	±40	Rb-Sr whole-rock	Poidevin (1985)
10°51′18″	E	4°0′52″	N	Bafia metamonzodiorite	618	±7	U-Pb zircon	Toteu et al. (2006)
11°32′33″	E	4°11′56″	N	Augen metagranite	604	±3	U-Pb zircon	Toteu et al. (2006)
13°56′2″	E	8°5′6″	N	Buffle Noir amphibolite	2130	±20	U-Pb zircon	Toteu et al. (2001)
10°47′1″	E	4°52′4″	N	Makenene gneiss	2018	±9	U-Pb zircon	Toteu et al. (2001)
14°4′59″	E	5°35′1″	N	Lom metavolcanite	2269	±100	U-Pb zircon	Toteu et al. (2001)
11°47′6″	E	6°42′5″	N	Banyo charnockite	600	±10	U-Pb zircon	Toteu et al. (2001)
13°32′58″	E	7°20′12″	N	Ngaoundere granite	595	±10	U-Pb zircon	Toteu et al. (2001)
14°48′5″	E	6°39′4″	N	Gaoui granite	600	±10	U-Pb zircon	Toteu et al. (2001)
13°26′4″	E	5°52′2″	S	Noqui granite	999	±7	U-Pb zircon	Tack et al. (2001)
13°42′23″	E	5°30′47″	S	Bata Kimenga granite	917	±14	U-Pb zircon	Tack et al. (2001)
13°37′12″	E	5°49′45″	S		530	±12	Rb-Sr whole-rock	Cahen et al. (1984)
29°21′26″	E	3°4′12″	N		2894	±67	Rb-Sr whole-rock	Cahen et al. (1984)
23°27′19″	E	3°50′4″	N		2448	±28	Rb-Sr whole-rock	Cahen et al. (1984)
28°5′42″	E	1°45′8″	N		2793	±66	Rb-Sr whole-rock	Cahen et al. (1984)
32°48′4″	E	0°29′33″	N		2536	±24	Rb-Sr whole-rock	Cahen et al. (1984)
24°2′6″	E	3°36′5″	N	Nzangi gneiss	3005	±64	Rb-Sr whole-rock	Cahen et al. (1984)
29°2′20″	E	1°23′59″	N		1978	±72	Rb-Sr whole-rock	Cahen et al. (1984)
30°15′0″	E	1°43′14″	N		2725	±77	Rb-Sr whole-rock	Cahen et al. (1984)
30°43′32″	E	0°39′57″	S		1887	±245	Rb-Sr whole-rock	Cahen et al. (1984)
31°33′45″	E	8°17′30″	S	Kate granite south	1723	±41	Rb-Sr whole-rock	Lenoir et al. (1994)
34°19′49″	E	8°54′17″	S	Mbarali granite	2026	±8	U-Pb zircon	Lenoir et al. (1994)
31°24′ 21″	E	6°31′23″	S	Mpanda gneiss	1902	±73	Rb-Sr whole-rock	Lenoir et al. (1994)
32°13′4″	E	2°51′39″	S	Geita rhyolitic volcanite	2699	±9	U-Pb zircon	Borg and Krogh (1999)
32°22′52″	E	3°39′15″	S	Homolo rhyolitic volcanite	2808	±3	U-Pb zircon	Borg and Krogh (1999)
34°16′35″	E	1°17′24″	S	Musoma Mara granite	2668	±11	U-Pb zircon	Manya et al. (2006)
34°18′38″	E	4°20′12″	S	Mpanpa volcanite	2742	±27	Sm-Nd whole-rock	Manya and Maboko (2008)

(*continued*)

Table 2.1 (continued)

Long		Lat		Rock name	Dates (Ma)		Method	Author
34°54′7″	E	5°21′3″	S		2565	±40	Rb-Sr whole-rock	Cahen et al. (1984)
35°10′22″	E	7°26′16″	S		2573	±34	Rb-Sr whole-rock	Cahen et al. (1984)
34°2′55″	E	0°23′9″	N		2174	±69	Rb-Sr whole-rock	Cahen et al. (1984)
27°10′28″	E	7°54′59″	S	Nyangwa monzogranite	1383	±5	U-Pb zircon	Kokonyangi et al. (2004)
27°52′38″	E	8°22′21″	S	Kisele monzogranite	1386	±8	U-Pb zircon	Kokonyangi et al. (2004)
25°59′53″	E	9°35′9″	S		1324	±71	Rb-Sr whole-rock	Cahen et al. (1984)
28°0′24″	E	12°16′3″	S	Kinsenda trachyandesite	1873	±8	U-Pb zircon	Rainaud et al. (2005)
27°43′44″	E	12°52′32″	S	Samba metavolcanite	1964	±12	U-Pb zircon	Rainaud et al. (2005)
26°34′20″	E	10°53′35″	S	Kambove uranite	542	±10	U-Pb zircon	Cahen et al. (1984)
26°13′34″	E	11°3′38″	S		656	±20	U-Pb zircon	Cahen et al. (1984)
27°40′22″	E	11°30′33″	S		625	±5	U-Pb zircon	Kampunzu and Cailteux (1999)
32°17′20″	E	9°21′40″	S		1824	±75	Rb-Sr whole-rock	Cahen et al. (1984)
28°51′40″	E	11°11′40″	S		1833	±9	Rb-Sr whole-rock	Cahen et al. (1984)
22°52′36″	E	5°56′7″	N		708	±11	Rb-Sr whole-rock	Poidev(1985)
18°10′54″	E	5°4′26″	N	Boali	2150	±30	Rb-Sr whole-rock	Rolin (1995)
18°56′16″	E	5°48′19″	N	Sidut	639	±3	Rb-Sr whole-rock	Rolin (1995)
34°8′10″	E	3°34′57″	N	Kaabong	545	±30	Rb-Sr whole-rock	Cahen et al. (1984)
31°12′60″	E	3°34′17″	N	U03-6B	2570	±3	U-Pb zircon	de Wit (2004)
33°10′11″	E	2°2′21″	N	U03-12	2616	±1	U-Pb zircon	de Wit (2004)
13°58′25″	E	2°56′23″	N	Lomie metagabbro	666	±26	U-Pb zircon	Toteu et al. (2006)
10°22′36″	E	0°32′51″	N	Kinguele bronzite	2777	±83	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
12°34′6″	E	1°15′33″	S	Koulamoutou gneiss	2888	±40	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
11°35′32″	E	0°44′46″	N	Mitzic gneiss	3186	±75	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
10°52′34″	E	3°19′7″	S	Goumbou granite	2083	±26	U-Pb zircon	Caen-Vachette et al. (1988)
10°5′36″	E	3°31′26″	N	Bonguen metagranodiorite	2066	±4	U-Pb zircon	Lerouge et al. (2006)
10°44′39″	E	3°15′32″	N	Lolodorf metasyenite	2055	±5	U-Pb zircon	Lerouge et al. (2006)
10°33′14″	E	0°41′24″	N	Noya charnockite	3120	±67	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
11°57′49″	E	1°37′3″	S	Chaillu K-granite	2637	±33	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
11°55′36″	E	1°27′13″	S	Chaillu dioritic granite	2765	±39	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
10°16′49″	E	±0°22′7″	N	Kinguele gneiss	3091	±53	Rb-Sr whole-rock	Caen-Vachette et al. (1988)
11°0′0″	E	2°58′59″	N	Ebolowa charnockite	2896	±7	U-Pb zircon	Toteu et al. (1994)
13°43′43″	E	7°2′35″	S	Vista Alegre granite	625	±25	Rb-Sr whole-rock	Cahen et al. (1984)
29°18′14″	E	3°35′47″	N	Akwa mylonite	756	±40	Rb-Sr whole-rock	Poidevin (1985)
24°7′37″	E	11°7′19″	S	Mwinilunga granite	2561	± 10	U-Pb zircon	Key et al. (2001)
25°14′31″	E	11°45′22″	S	Kabompo granite	1884	±10	U-Pb zircon	de Waele et al. (2006)
28°16′23″	E	12°35′32″	S	Mufulira granite	1991	±3	U-Pb zircon	de Waele et al. (2006)
28°40′10″	E	13°57′10″	S	Kapiri Mposhi granite	2726	±36	U-Pb zircon	Rainaud et al. (2005)
29°24′13″	E	13°35′13″	S	Mkushi gneiss	2048	±6	U-Pb zircon	Rainaud et al. (2005)
30°5′18″	E	13°16′43″	S	Lukamfwa Hill granite gneiss	1664	±6	U-Pb zircon	de Waele et al. (2006)
32°29′51″	E	13°42′45″	S	Chipata porphyritic granite	1074	±3	U-Pb zircon	de Waele et al. (2006)
14°1′37″	E	15°25′21″	S	Kunene mangerite vein	1371	±3	U-Pb zircon	Mayer et al. (2004)
34°33′14″	E	9°28′36″	S	Ukenju gneiss	2084	±86	U-Pb zircon	Lenoir et al. (1994)
30°42′8″	E	7°16′54″	S	Kate granite north	1723	±41	Rb-Sr whole-rock	Lenoir et al. (1994)
22°36′53″	E	9°59′50″	S	Sandoa granodioritic granite	3021	±48	Rb-Sr whole-rock	Walraven and Rumvegeri (1993)
32°55′39″	E	8°22′19″	S		2758	±9	U-Pb zircon	Lawley et al. (2013)
35°14′10″	E	13°19′48″	S	Lichinga	1034	±14	U-Pb zircon	Link et al. (2010)
35°5′36″	E	11°42′19″	S	Txitonga	714	±17	U-Pb zircon	Link et al. (2010)
30°58′9″	E	0°30′22″	N		1848	±6	U-Pb zircon	Mänttäri et al. (2013)
34°5′37″	E	0°42′9″	N		2644	±10	U-Pb zircon	Mänttäri et al. (2013)
31°41′0″	E	1°49′38″	N		2991	±9	U-Pb zircon	Mänttäri et al. (2013)
16°44′26″	E	12°32′40″	S		1974		U-Pb zircon	Jelsma et al. (unpublished)
16°17′39″	E	11°21′58″	S		1966		U-Pb zircon	Jelsma et al. (unpublished)
17°6′55″	E	11°26′15″	S	Dando-Kwanza	2522		U-Pb zircon	Jelsma et al. (unpublished)
17°3′42″	E	11°9′7″	S	Dando-Kwanza	1970		U-Pb zircon	Jelsma et al. (unpublished)

Precambrian crystalline basement. In many places at least two glacial sequences are recognized and commonly linked to the Marinoan and Sturtian Glaciations, ca. 635–650 Ma and 720–750 Ma, respectively (e.g. Poidevin 2007; Tait et al. 2011). However, because these sections are not conterminous around the CB and because in many places Pan-African tectonism has tectonically repeated and/or strongly deformed these sequences (e.g. in the Lufilian Arc of Zambia and northwest Botswana; the Oubanguides of northern DRC, CAR and Cameroon), and because radiometric data are scarce and often imprecise, accurate correlations across the CS remain wanted (e.g. Frimmel et al. 2006; Tait et al. 2011; Delpomdor and Préat, Chap. 3, this Book).

An angular unconformity across the Neoproterozoic carbonates in central Africa is considered to represent the base of the CB (although some researchers place it beneath the deformed carbonates; e.g. Daly et al. 1992; Kadima et al. 2011). It is overlain by ubiquitous Cambrian Redbeds, which are often tentatively correlated across the entire CB; however other (similar) formations of red quartzites, conglomerates, sandstones and red siltstones are very common within the stratigraphic record of this large basin (e.g. the Triassic Haute Lueki Group; Lombard 1961) and may often have been misidentified.

2.4.1 Southern Central Africa

At the southern margin of the CB, the Precambrian basement corresponds to the Kasai and Cuango Cratons (Kasai and NE Angola Cratons of Cahen et al. 1984), which essentially comprise Meso- to Neo-Archean grey tonalitic to granodioritic gneisses (TTG), high-grade metamorphic granite gneisses (including extensive charnockites and enderbites) and migmatites (e.g. the Dibaya and Kasai-Lomami Complexes), as well as large mafic-ultramafic complexes, all intruded by widespread Neoarchean granites. Diamondiferous kimberlites of late Precambrian (582 Ma) to late Phanerozoic (110–140 Ma [Alto Cuilo]; 70 Ma [Mbuji-Mayi]; 32 Ma [Kundelungu]) intrude these two cratons (Batumike et al. 2009; Jelsma et al. 2009; de Wit and Jelsma, Chap. 17, this Book), attesting to the deep cratonic mantle-lithosphere characteristics of this region (e.g. Fig. 2.4).

2.4.1.1 The Kasai Craton

In the central core of the Kasai region of southern DRC, small regions of Mesoarchean TTG gneisses (c. Luanyi; Fig. 2.5) were dated at 3490 ± 170 Ma (Rb/Sr microcline date; in Cahen et al. 1984), and granodiorites (Kanda-Kanda gneisses; c. Sandoa) at 3021 ± 49 Ma (Pb/Pb whole-rock date; Walraven and Rumvegeri 1993). These rocks are flanked to the north and south by an extensive region of Neoarchean granulites and gabbro-norites (e.g. the charnockites and enderbites of the Kasai-Lomami Complex), dated between 2.76 and 2.89 Ga, and which, in turn, are in tectonic contact with Eburnian granites and gneisses to the south and metasediments to the north (e.g. the Lulua Group). The age of granulite metamorphism is estimated at ca. 2.78 Ga and generally referred to as the Musefu event (Cahen et al. 1984). Farther north and east are late Neoarchean granites and migmatites (the Dibaya Complex), dated between 2.58 and 2.69 Ga (Cahen et al. 1984; Delhal 1991). These granites and migmatites of the Kasai Craton may extend southeast as far as NW Zambia where granites have also been dated recently at 2561 ± 10 Ma (Key et al. 2001). Migmatisation and metamorphism of this age was referred to as the Moyo event by Cahen et al. (1984).

More recent U-Pb zircon (TIMS) analyses yielded an oldest date of 2825 ± 3 Ma on a TTG in the Lunda area of northeast Angola (and a range between 2.9–2.5 Ma in the same general region; Doucoure et al. 1999; Fig. 2.5), and of 2684–2520 Ma (SHRIMP) on biotite gneisses of the Dando-Kwanza area (Jelsma et al. 2012), suggesting an extension of the central Kasai region into northeast Angola as far south as the CAMB. Whilst a number of dates on charnockitic gneiss in the Lunda area have yielded the oldest zircon dates of the Kasai Craton yet (3.4–3.6 Ga) overprinted by metamorphic U/Pb zircon of ca. 3.25 Ga (H. Jelsma personal communication, 2012), the early geological history of the Kasai Craton is still to be resolved.

Farther south, the Angola basement is swamped by Eburnian granites (e.g. at Jamba and Cutenda, dated at 1.8 Ga by Cahen et al. 1984), and younger rapakivi granites and syenites ('red granites' dated by Rb/Sr between 1302–1411 Ma; de Carvalho et al. 2000). Recently, precise U/Pb zircon analyses re-date these granites between 2065 and 2068 Ma (U/Pb TIMS by S. Bowring, in Doucoure et al. 1999). Nevertheless, there is a great apparent range of granites and syenites from Paleo- to Meso-Proterozoic based on Rb/Sr dates and low resolution U/Pb zircon dates (between 1300–1960 Ma, and in one case as young as 1027 Ma; in Cahen et al. 1984; Carvalho et al. 2000). More precise petrology and geochronology is clearly wanted.

The Kasai Craton is overlain by a sequence of Paleoproterozoic metasediments (the Luiza Supergroup), intruded by granitoids (e.g. Kapenda and Lunge) dated between 2.0 and 2.2 Ga, and covered by younger basaltic volcanics (with pillow lavas) of the Lulua Group dated at 1.9 Ga (Delhal 1991; Andre 1994). To the NE, it is overlain by Late Mesoproterozoic carbonate platform metasediments (the Mbuji-Mayi Supergroup), with basalts in the upper part dated at 948 ± 20 Ma (K/Ar whole-rock date; in Cahen et al. 1984; see also Delpomdor et al. Chap. 4, this Book).

2.4.1.2 The Cuango Craton

In the adjacent Cuango and Malange regions of northern Angola and southern DRC (Fig. 2.5), granite gneisses and migmatites similar to the Dibaya Complex were dated near Lucala at 2560 ± 50 Ma, and at Andulo at 2520 ± 36 Ma (Rb/Sr whole-rock dates; de Carvalho et al. 2000). Thus, the reason for subdividing the Cuango from the Kasai Craton is not based on geology but because the dated (and thus exposed) regions are separated geographically by substantial distances, and two different cratonic blocks are discernable on low resolution seismic sections (e.g. Linol et al., Chap. 8, this Book).

2.4.2 Western Central Africa

The western margin of the CB is bound by a NNW-trending mobile belt, more than 1,000 km long that includes, respectively, an external and internal east-verging Eburnian Belt (WCAMB), and the east-verging Pan-African West Congo Belt with folds and thrusts of thick sequences (~10 km) of Neoproterozoic volcanic and carbonate rocks of the West Congolian Supergroup. To the north and east this Pan African belt tectonically overlies the Archean Ntem Craton and its Paleoproterozoic platform cover (Cahen et al. 1984; Feybesse et al. 1998; Tack et al. 2001; Tait et al. 2011). Farther north still, flanking the Cameroon border, the degree of Eburnian thrusting is sometimes difficult to distinguish from the Pan-African thrusts (Feybesse et al. 1998; Toteu et al. 2001, 2006 and 2014 in preparation; Kalsbeek et al. 2013; Nkoumbou et al. 2013; Ndema Mbongue et al. 2014).

2.4.2.1 The Ntem Craton

In the north-central section of the Ntem Craton, in the Mont Crystal region of northern Gabon, TTG gneisses were dated at Mitzic at 3186 ± 75 Ma and charnockites (c. Noya) at 3120 ± 67 Ma (Rb/Sr whole-rock dates; Caen-Vachette et al. 1988; Fig. 2.5). More recently, a series of TTG and charnockites (11 sites in total) close to Mitzic, also yielded an age range between 2775.2 and 3056.2 Ma; and close to Zamoho at 3231 ± 0.7 [TIMS and U/Pb zircon and monazite dates; S. Bowring, in Doucouré et al. (1999) and de Wit (2004)], and with Mesoarchean TDM dates as old as 3.2 Ga. Near the northern margin of the Ntem Craton, in southwestern Cameroon, charnockites (c. Ebolowa) have been dated at 2896 ± 7 Ma (TIMS U-Pb zircon date, Toteu et al. 1994; Nkoumbou et al. 2013). These Late Archean dates within the Ntem Craton characterize an episode of high grade metamorphism. Yet, ca. 100 km farther along to the northwest, is the Eburnian high-grade Nyong terrain of Cameroon, whose sequences are thrust across the margin of the Ntem Craton (Toteu et al. 2001, 2006; Nkoumbou et al. 2013; Ndema Mbongue et al. 2014). These Eburnian high-grade metasediments and charnockites include 2093 Ma eclogites with MORB-like chemistry that represent relics of the oldest subducted Paleoproterozoic oceanic crust that were subsequently emplaced across the northeast margin of the CS (Schenk et al. 2006; Boniface et al. 2012). Thus, subduction and obduction processes mark this northern boundary of the Ntem Craton as an Eburnian convergent margin, which has since been extensively overprinted again by the Pan-African tectonism of the Oubanguides-Sergipano Belts (e.g. Toteu et al. 1994 and 2014, in preparation; Nkoumbou et al. 2013; see below), possibly linking for the first time the CAS with the Sao Francisco Shield of Brazil (Toteu et al. 2006; Kalsbeek et al. 2013).

The geology and new dates of the Ntem Craton are consistent with the synthesis of Feybesse et al. (1998) of a complex Archean Craton comprising Mesoarchean granite-greenstone-BIF and high grade terrains dated between ca. 3.2 and 2.9 Ga, and a subsequent Neoarchean history of widespread granites and granodiorite intrusions followed by tectono-metamorphism at ca. 2.7–2.8 Ga, and then Late Archean granite activity.

Near Mitzic, the Ntem Craton is locally cut by a substantial number of Archean meta-kimberlites, emplaced at 2848-2862 Ma (U-Pb zircon; LA-ICP-MS) and metamorphosed (^{40}Ar/^{39}Ar) at ca. 2615–2550 Ma (at amphibolite grade) and ca. 2000–1940 Ma (at greenschist grade). These are the world's oldest known diamondiferous kimberlites; and together with the chemistry of these kimberlites, attest to the presence of Archean depleted mantle lithosphere beneath the SWCC at that time (Henning et al. 2003). However, since no younger diamondiferous kimberlites have yet been discovered on the Ntem Craton, it is not known if the Archean mantle lithosphere here has retained its original structure and thickness.

To the south, the Ntem Craton also includes extensive younger Archean granites of the Chaillu Massif, dated between 2.63 and 2.76 Ga (Caen-Vachette et al. 1988), very similar to that of the Kasai and Cuango Cratons (e.g. the Moyo event of Cahen et al. 1984).

The Archean basement of the Ntem Craton is tectonically and unconformably overlain in the west by the Eburnian metavolcanic sedimentary rocks of the Oguoué orogenic domain (2235–2040 Ma) and to the east by the Francevillian platform/foreland basin sequences (2150–1780 Ma), respectively. Metasediments of the Francevillian Supergroup (Mossman et al. 2005; Ossa Ossa et al. 2013), include black shale and uranium-rich deposits with the Eburnian natural nuclear reactors at Oklo, dated at 2050 ± 30 Ma (U-Pb uraninite date, Cahen et al. 1984).

2.4.2.2 The West Congo Belt

Precambrian basement to the West Congo Belt includes Eburnian-age granites (c. Goumbou) dated at 2083 ± 26 Ma

(U-Pb zircon date; Caen-Vachette et al. 1988), and migmatites dated near Boma at 2086 ± 64 Ma (Rb/Sr whole-rock date; in Cahen et al. 1984; Fig. 2.5). This Paleoproterozoic basement is locally intruded by younger granites (c. Noqui) dated at 1.0 Ga, and capped by 5–6 km thick basalts and rhyolites of the Zadinian and Mayumbian Groups, dated between 912 ± 7 Ma and 920 ± 8 Ma (U-Pb zircon dates; Tack et al. 2001). These early Neoproterozoic magmatic sequences are, in turn, unconformably overlain in the eastern part of the belt by relatively thick (~5 km) carbonate platform and foreland metasediments of the West Congolian Group (Frimmel et al. 2006; Delpomdor et al., Chap. 3; Kolo et al., Chap. 5, this Book). Recent U-Pb and Ar/Ar geochronology within these sequences shows that Pan-African orogenesis occurred during two main episodes, at ca. 490 Ma and 540 Ma (Monié et al. 2012). This Early Cambrian (Tardive) phase of deformation is very similar to that of the Araçuaí Orogen in eastern South America (e.g. da Silva et al. 2005).

The deformed Neoproterozoic West Congolian Group includes in the lower part two formations of diamictites (the Lower and Upper Mixtites), linked to the Sturtian (710–750 Ma) and Marinoan (635–650 Ma) glaciations, respectively. This is only supported, however, with Sr-isotope dates of 575 Ma from overlying cap carbonates (Poidevin 2007). This sequence terminates upward with molasse-type deposits (the Mpioka Subgroup) unconformably overlain by southward prograding fluvial-delta red sandstones and conglomerates of the Cambrian Inkisi Group that might best be interpreted to reflect the final exhumation and erosion of the West Congolian orogenic Pan-African mountains (Alvarez et al. 1995; Tack et al. 2001; Tait et al. 2011).

2.4.3 Northern Central Africa

In northern Central Africa, the vast E–W trending and S-verging fold-and-thrust belt of the Oubanguides is more than 3000 km long, extending from Cameroon (where it has sometimes been called the Central African Fold Belt), and farther west into northeast Brazil as the Sergipano Belt), through the CAR, to northeastern DRC and Uganda, where it is tectonically thrust across the Bouca and Mboumou-Uganda Cratons (Fig. 2.5). No diamondiferous kimberlites have been discovered across this region.

To the North of the Oubanguides lies a region in the Sahara often referred to as the Sahara Metacraton, but which in fact as far north as Darfur mostly comprises Mesoproterozoic basement, with extensive Kibaran granitoids (ca. 1000–1100 Ma) deformed during the Pan-African orogenesis at ca. 625 Ma along the Central Saharan and Zalingai Fold Belts (CSFB and ZFB, respectively; Fig. 2.2, inset A; de Wit et al. 2005 and 2014, under review).

2.4.3.1 The Mboumou-Uganda Craton

The central section of this craton (also referred to as the Congo-Uganda Block by Tait et al., 2011), in northeastern DRC, is predominantly a classic low-grade granite greenstone terrain (de Wit and Ashwal 1997). The oldest TTG gneisses (c. Nzangi), dated at 3005 ± 64 Ma (Rb/Sr whole-rock date, in Cahen et al. 1984), are intruded by undeformed tonalites (e.g. Moto and Kilo) dated between 2.7 and 2.8 Ga, and relatively younger granites dated between 2.4 and 2.6 Ga (Cahen et al. 1984). These Neoarchean dates are similar to those of the Kasai and Cuango Cratons. However, high grade mafic gneisses (Bomu and Monga) that define the northwestern margin of this craton have been dated at 3.4–3.7 Ga (Cahen et al. 1984); and in one report the Boma rocks were speculated to be ca. 4.0 Ga, based on a Rb/Sr errorchron; Lavreau and Ledent 1975), which would make these the oldest mafic gneisses in Africa and some of the oldest in the world. Clearly new precise geochronology of these Boma gneisses is sorely needed.

The eastern extremity of the Mboumou-Uganda Craton contains Neoarchean high-medium grade TTG and paragneisses exposed over a wide area of north-central Uganda. This is supported by more recent (TIMS) U-Pb zircon dates of 2570 ± 3 Ma and 2616 ± 1 Ma obtained from basement rocks in central Uganda (S. Bowring, in de Wit 2004, unpublished), and several others between ca. 2550–2650 Ma (Link et al 2010; Mänttäri et al. 2013). In two other localities, flanking either side of the Uganda-DRC border, Mesoarchean dates have been recorded (2991 and 3079 Ma, respectively, Mänttäri et al. 2013). The easternmost boundary of this craton is defined by NW-SE trending Neoproterozoic mylonite shear zones (of which the Aswa shear zone is the best known, and dated around 700–680 Ma; S. Bowring, in de Wit 2004, unpublished).

2.4.3.2 The Oubanguides Belt

The northern margin of the CAS and the southern margin of the Central Sahara Shield is marked by the poorly studied, E–W striking Oubanguides, an orogenic belt that stretches from Cameroon through the CAR and southernmost South Sudan to northeast Uganda (Poidevin 1985; van Schmus et al. 2008; de Wit et al. 2008; Toteu et al. 1994, 2001, 2006, and 2014 in preparation). High-grade granitic gneisses and charnockites are widespread, some of which are Neoarchean in age (U/Pb zircon dates between 2.56–2.64 Ga; Toteu et al. 1994, 2001, 2006, and 2014 in preparation) whilst most others are Neoproterozoic (U/Pb zircon dates; Toteu et al. 1994, 2001, 2006, and 2014 in preparation). Many K/Ar and Rb/Sr whole rock dates on paragneisses and associated batholitic granitoids, and U/Pb dates on their zircons, cluster in the range of ~800–1200 Ma and between 480–655 Ma. The latter ages relate to dextral strike-slip and south-directed thrusting of the Oubanguides over the Archean rocks and its overlying Cryogenian sequences (Poidevin 1985; Toteu et al. 2001, 2006, and 2014, in preparation). Farther south scarce Archean dates mark the diffuse tectonic transition between the northern margin of the Archean Bouca and Mboumou Cratons and the allochthonous southern margin of the Oubanguides (Cahen et al. 1984; Poidevin 1985; Toteu et al. 2014, in preparation). Apart from its western extension in Cameroon (e.g. Nkoumbou et al. 2013), this tectonic transition has not been studied with modern structural and radiometric analysis in the central section of the belt.

In Cameroon and western CAR, the Oubanguides comprise both Eburnian and Pan-African thrust sheets with high grade allochthons of Archean (e.g. 3072 Ma), Eburnian (2372 Ma) and Pan-African juvenile volcanogenic rocks (1100–625 Ma; Nkoumbou et al. 2013; Toteu et al. 2006; Toteu et al. 2014, in preparation; de Wit et al. 2014 under review) emplaced across a ~3 km thick Neoproterozoic platform sequences known as the Lindian Supergroup (Lepersonne 1974; Poidevin 1985). Pan-African tectonism has been dated, for example at Akwa at 756 ± 40 Ma, at Boukouma at 708 ± 11 Ma (Rb/Sr whole-rock dates, in Poidevin 1985), near Sidut at 639 ± 3 Ma (U-Pb zircon dates, in Rolin 1995) and in southwestern Cameroon between 640–600 Ma (Nkoumbou et al. 2013). This is comparable with gabbros (c. Lomie) dated at 666 ± 26 Ma in the western part of the belt, and slightly younger monzodiorites in western Cameroon (c. West of Bafia) dated at 619 ± 4 Ma (U-Pb zircon dates, Toteu et al. 2006). More recent dates from western and central CAR includes extensive granite activity between 640–660 Ma, with magmas derived from melting of Kibaran crust (1020 Ma), as well as Archean granitoids with Neoproterozoic overprints; and ca. 800 Ma metasediments with metamorphic overprints at ca. 650 Ma (LA-ICP-MS; K. Drost and M. de Wit, unpublished; Toteu et al. 2014 in preparation). In general, the Pan-African dates of this northern region of central Africa seems to represent orogenic events that apparently young westward across this vast and understudied belt; but this is poorly constrained.

The deformed Lindian Supergroup comprises carbonate metasediments (the Ituri and Lokoma Groups) including dolomites with spectacular stromatolites (Plate 5; Robert 1946). This sequence is dated at 730–755 Ma (Rb/Sr dates, Poidevin 2007) and includes a tillite (the Akwokwo Tillite) that may represents either the Sturtian or Marinoan glaciation. These sequences are overlain by about 1,500 m thick red quartzites, schists, and arkoses (the Galamboge, Alolo, and Banalia Formations) of the late Neoproterozoic-lower Paleozoic Aruwimi Group (Lepersonne 1974). Based on lithostratigraphy, the uppermost Banalia Redbeds unit is now considered to be Cambrian in age (Tait et al. 2011).

2.4.4 Eastern Central Africa

Along the eastern margin of the CB, the 300 km wide, NNE-trending Kibaran Belt (s.s.) separates the Tanzanian Craton from the CS (Figs. 2.2, 2.3 and 2.5), and is tectonically overlain to the south by the late Neoproterozoic (Pan African) Lufilian-Damara Belts.

2.4.4.1 The Tanzanian Craton (TC)

The Tanzanian Craton (>3.8–2.6 Ga) comprises a complex amalgamation of Archean blocks (seven super-terranes and twelve or so terranes as defined by Kabette et al. 2012a) in which Neoarchean granitic gneisses and a number of classic greenstone belts predominate; but Mesoarchean dates have also been sporadically reported (Borg and Shackleton, 1997; Kabette et al. 2012a, b; Kasanzu 2014).

In the northern section of the Tanzanian Craton (TC), volcanics of the Nyanzian and Kavirodian Supergroups have been dated, for example at Homolo (2808 ± 3 Ma) and at Geita (2699 ± 9 Ma; U-Pb zircon dates; Borg and Krogh 1999; Fig. 2.5), and near Mpampa at 2742 ± 27 Ma (Sm/Nd whole-rock date; Manya and Maboko 2008). These dates represent a significant episode of volcanism within the TC that clearly differs from that of all Congolese Cratons.

In the central TC, Meso- to Paleoarchean TTG gneisses have been reported (Kabette et al. 2012a), and basement to juvenile greenstone rocks in the Central Tanzania Region includes orthogneisses with enclaves of ~ 3600 Ma fuchsitic quartzite with detrital zircons as old as 4013 Ma (Kalsbeek et al. 2013).

In the south, the TC includes late Neoarchean gneisses and migmatites of the Dodoman Complex dated at 2573 ± 34 Ma (Rb/Sr whole-rock date; in Cahen et al. 1984), and granites (e.g. Singida) dated at 2535 ± 30 Ma (Rb/Sr whole-rock date; Bell and Dodson 1981), and between 2660 to 2850 (U/Pb Zircon SHRIMP, Kabette et al. 2012a).

The southern and western margins of the TC are poorly defined and includes a number of remobilized Archean endogenous and exogenous terranes within a broad zone, known as the Ubendian-Usagaran Belt, of long-lived Proterozoic tectonism that lasted over a period of ca. 300 million years between 2.1–1.8 Ga (Boniface et al. 2012; Lawley et al. 2013, 2014). The zone includes sheared Paleoproterozoic (Eburnian) metasediments of the Rusizian Supergroup dated between 1.9 and 2.1 Ga, and younger granitoids dated around 1.7–1.8 Ga, that form the Ubendian Belt (Cahen et al. 1984; Lenoir et al. 1995; Lawley et al. 2013, 2014 and references therein). The complex series of allochthonous terranes of the Ubendian Belt are in turn overlain by Mesoproterozoic metasediments that, in turn, were deformed during the Kibaran Orgogeny. Due to lack of reliable geophysical data, there is no agreement about the origin of the allochthonous fragments in the Ubendian Belt, and whether or not the TC lithosphere may originally have extended as far south as the Bangweulu Block (e.g. Lawley et al. 2013 and references therein; and see below).

The eastern margin of the TC comprises mainly Archean blocks remobilized during the Neoproterozoic at high grades within the central zone of the Pan African Mozambique belt (e.g. Fritz et al. 2013; Kabette et al. 2012a; Fig. 2.2).

Across the Tanzanian Craton, repeated diamondiferous kimberlite activity (at 189 Ma [Mwadui] and 53 Ma [Nzoga]) and young Quaternary volcanoes with magmatic rocks characteristic of kimberlite (c. Iqwisi), as well as geochemistry of lithospheric mantle xenoliths, attest to a cratonic lithosphere with a thickness in excess of 120 km (e.g. Dawson 1994; Rudnick et al. 1998; Begg et al. 2009; Brown et al. 2012a, b).

2.4.4.2 The Kibaran Belt (s.s.)

Across most of eastern DRC, Rwanda, and Burundi, Precambrian basement is widely intruded by Mesoproterozoic granites and these represent the type area of the famous ca. 1.0 Ga Kibaran Belt defined by Cahen et al. (1984). Several generations of these granites were recently re-dated, ranging between 986 ± 10 Ma and 1383 ± 17 Ma, but the majority of the granites are ca. 1375 Ma in age (U-Pb zircon dates; Tack et al. 2010). In the southern part of the belt, granites (e.g. Kisele and Nyanga; Fig. 2.5) have been dated similarly at 1385 Ma (Kokonyangi et al. 2004). Thus, this 1370–1385 Ma age characterizes the main episode of Mesoproterozoic magmatism and crustal melting in eastern central Africa, the original type area of the Kibaran (as defined by Cahen et al. 1984, but now referred to as the Kibaran Karagwe-Ankole Belt). Whether the general term Kibaran should be applied to the younger, near 1.0 Ga, rocks elsewhere in Africa (e.g. the Irumide, Mozambican, Namaquan belts) remains an as yet unanswered question. This is a debate that has not yet been resolved (e.g. Tack et al. 2010; Fernandez-Alonso et al. 2012), and is similar to earlier misunderstandings about the Pan African, which was originally defined around ca. 500 ± 50 Ma (Kennedy 1964), but is presently mostly used for rocks in the range between 500–800 Ma (e.g. see discussion in de Wit et al. 2001).

In the type area, the Kibaran Belt is unconformably overlain by late Mesoproterozoic to Neoproterozoic platform metasediments of the Bukoban Supergroup, with basalts in the upper part dated at 815 ± 14 Ma (K/Ar whole-rock date, in Cahen et al. 1984).

2.4.4.3 The Lufilian Arc

In Zambia and southeastern DRC, basement consists of Paleo- to Meso-Proterozoic granite gneisses of the Bangweulu Block, dated at ~2050 Ma, and with a widespread volcanic arc sequence (c. Lubufu) that yield U-Pb SHRIMP zircon ages ranging between 1874 ± 8 Ma and 1980 ± 7 Ma and granites (e.g. Mufulira; Fig. 2.5) dated at ca. 2 Ga (de Waele and Mapani 2002; Rainaud et al. 2005). This deformed (Eburnian) basement is locally intruded by younger granitoids at 1.6 Ga and between 1000–1050 Ma (c. Serenge; de Waele et al. 2008). It is tectonically overlain by the Lufilian Arc: a convex Pan-African northward-verging fold and thrust belt with two principal tectonic nappes that contain about a 10 km thick Neoproterozoic sequence of metasediments, known as the Katanga Supergroup (formerly Kundelungu Supergroup; Lepersonne 1974), and famous in Zambia and DRC for its high-grade Cu-Co mineral deposits. The deformation style is believed to have been influenced by evaporites, since the structures resemble salt-tectonism (e.g. Jackson et al. 2003; Selley et al. 2005). However, no salt deposits are preserved, and if this tectonic interpretation is correct, the evaporites have all been dissolved during the Pan African deformation and related fluid activity, perhaps inducing the base-metal mineralization (c.f. El Desouky et al., 2010, and references therein).

The Lufilian tectonism has been dated between about 700 Ma and 530 Ma, similar to that of the Damara Belt of southern Namibia (Kampunzu and Cailteux 1999; Miller 2008), and to which it is likely linked via northwestern Botswana (de Wit 2010). Here, in northwest Botswana, a thick Neoproterozoic sequence of sediments (ca. <541–750 Ma) comprises medium-grade metamorphosed and deformed Cryogenian rocks, including diamictites and substantial carbonates interbedded with intermittent BIF. These metasediments overly a complex granitoid Archean and Proterozoic basement (recently dated at ca. 2.6 and 2.0 Ga, respectively; U/Pb zircon LA-ICP-MS; de Wit 2012; Unpublished Report for Tsodilo Resources Ltd.). Any affiliation with the Archean block below the Lufilian Fold Belt remains unknown.

In the Lufilian Arc of southeastern DRC and northern Zambia, the Katanga (formely Kundelungu) Supergroup comprises Cryogenian carbonate platform metasediments (the Roan and Nguba Groups), which locally include volcanics dated at 760 ± 5 Ma (U-Pb zircon date, in Master et al. 2005), and with two glacial conglomerates (Grand and Petit Conglomerates) basically attributed to the Sturtian and Marinoan glaciations (e.g. Selley et al., 2005; Poidevin 2007). At the top, the Supergroup terminates with a relatively thick (~5 km) Redbed foreland basin sequence (e.g. Wendorff 2003), in turn unconformably overlain by about 1 km thick red siltstones of the Biano Group (Master et al. 2005). The latter may be correlated to the (Cambrian) upper Nama Group covering the Damara Belt of Namibia (e.g. Grotzinger and Miller 2008), and the Cambrian Redbeds across the CS discussed earlier (the Inkisi and Banalia sequences).

2.4.4.4 The Mozambique Belt

The Mozambique Belt of northeastern Mozambique flanks the eastern margins of the CAS and the Southern African Shield at Africa's southernmost extent of the Pan-African East African Orogen. Details of this orogen are beyond the scope of this chapter, but the interested reader is referred to Fritz et al. 2013, and references therein). Suffice it to mention that the Mozambique Belt yielded the first 1.0 Ga Kibaran (Mozambican) dates on orthogneisses and high grade granulites in Africa (Holmes 1918, 1951), an age which has since been recorded by Rb/Sr analyses (e.g. Cahen et al. 1984), and more recently confirmed by precise zircon and monazite dating (e.g. Jamal 2005; Bingen et al. 2009; Fritz et al. 2013). For example, the Mozambican orthogneisses of the Unango and Marrupa complexes date between ca. 946 Ma and 1062 Ma, overprinted by the extensive Pan-African high grade granulite-facies metamorphism with charnockitization between 700–525 Ma (Fig. 2.2, Inset B; Jamal 2005). These lower crustal rock types and ages have strong affinities with similar rocks of southern India and Madagascar. All these regions are similarly overprinted by extensive Pan-African deformation dated between 530–620 Ma. Whilst in detail the Kibaran/Pan-African history is complex (Jamal 2005; Bingen et al. 2009; Fritz et al. 2013), there is justified reason here for mentioning these Kibaran/Pan-African dates of the Mozambique Belt, because in many of the Phanerozoic sequences of the CB, detrital zircon analyses invariably yield both abundant ca. 1.0 Ga and 0.6 Ga dates (Linol et al., Chaps. 7 and 8, this Book). To date, the source of this bimodal detrital zircon population has been controversial. Since the age of crystalline rock-types of the Mozambique Belt is similar to parts of the Oubanguides flanking the northern margin of the CAS, and the regions to the north (in Central Sahara), the detritus may have been sourced from either north of the CB (Fig. 2.2, Inset A; e.g. Linol et al. 2014, submitted) or southeast of the CB (Fig. 2.2, Inset B; e.g. Roberts et al., 2012). Only when integrated with sedimentology data (paleocurrent directions) can a conclusive interpretation for a northerly source of many CB sequences be verified (see Linol et al., Chaps. 8, 9 and 13, this Book).

2.5 Summary and Conclusions

The CB of central Africa is underlain and completely surrounded by Precambrian basement that spans a history of up to 3.8 Ga, including Archean cratonic blocks, with rocks along its northeastern edge possibly as old as 4.0 Ga (and detrital zircons of similar age on the Tanzanian Craton), separated and surrounded by numerous Paleo- to Neo-Proterozoic mobile belts. Diamondiferous kimberlites span a range of almost 3.0 Ga billion years. This complex assemblage inculcates peripheral (outcropping) Archean nuclei: the Kasai, Cuango, Ntem, Bouca and Mboumou-Uganda cratonic blocks that constitute three larger Congolese Cratons largely unexposed beneath the CB: the SouthWest-, the Cuvette- or Central- and the NorthEast- Congo Cratons (SW-, C- and NE -CC) and that in turn, together, constitute the Congo Shield (CS). Subsequently these three aggregated along the Central Angola Mobile Belt (CAMB; ca. 2.0–2.3 Ga; Carvalho et al. 2000) and the West Central African Mobile Belt (WCAMB; ca. 2.0–2.5 Ga, Feybesse et al. 1998) to form the SouthWestern Congo Shield (SWCS). In the east, the CS enlarged further to form the Central African Shield (CAS) during the Proterozoic along Eburnian, Kibaran and Pan-African orogenic belts (Fig. 2.6), but the details of the accretion processes of these continental domains remain uncertain. The working model we provide here serves only to open discussions and encourage renewed field work and radiometric dating across this region, as that catalysed by Arthur Holmes, William Kennedy, Luiz Cahen and Norman Snelling in the last century. There is much work to be undertaken before a robust model for the formation of the CAS can emerge.

The basement beneath Phanerozoic CB is clearly complex. The oldest Archean cratons may have amalgamated in the Proterozoic, although the precise age of amalgamation is in dispute, and may even have occurred in the Archean. Parts of these cratons are exposed along the northern, southern and eastern margins of the CB, where they are flanked by Eburnian and Pan-African sequences; and the Tanzanian Craton (with its remobilised Archean crust to the west, within the northern Mozambique belt), which collectively is referred to here as the CAS.

The southern margin of the CS is defined by the Central Shield Zone of Angola, a wide transition zone of Eburnian granitoid magmatism and high-grade tectonism that also embodies a number of Archean fragments, and which we have named the CAMB, inferred to represent a deep, exhumed Himalayan-style Eburnian orogenic belt. This belt separates the rest of the Angola basement to the south, comprising predominantly Eburnian-Kibaran (mid-Proterozoic) Tibetan-like crust, from the SWCC. These two blocks collided along the CAMB at ca. 2 Ga to form the SWCS.

Between the Tanzanian Craton and the CS, a complex Eburnian-Kibaran tectonic history includes large scale melting of Eburnian crust between 1.3–1.5 Ga. Near the southern margin of the Angola basement, the vast Mesoproterozoic mafic-anorthosite complex of Kunene associated with widespread red granites and syenites dated around 1.3–1.4 Ga Ma confirm Kibaran (s.s.) mafic and granite magmatism and large scale crustal melting along the southern margin of the CS that may link along a continental shear zone to the type Kibaran of the Karagwe-Ankole Belt (Fig. 2.6). Subsequent accretion of other crustal blocks, along a number of orogenic belts surrounding the CS in the Mesoproterozoic, including the Tanzanian Craton during the formation of Rodinia, and Gondwana in the late Neoproterozoic-Early Cambrian, created the still larger CAS that stabilized by ca. 540 Ma.

The Precambrian rock sequences were regionally peneplained during and following formation and exhumation of the Pan-African orogenic Mountain systems that lasted until at least 540 Ma, and possibly 490 Ma (e.g. de Wit et al. 2001); and the unconformities were covered by marine carbonate-quartzite platform rocks as early as the Cryogenian and, in turn unconformably overlain by Cambrian Redbeds. These fluvial-lacustrine and aeolian Redbeds, which generally characterize hot and arid continental environments, form the basal units of the CB, recording marked extreme climate changes across the CB (and the CAS) during the Neoproterozoic-Cambrian transition.

In summary, the basement of the CB has a highly varied geological history with a complex mantle lithosphere that dates back to the Early Archean. Whilst detailed geophysics and mantle petrology across the CAS are mostly lacking, the variable ages of diamondiferous kimberlites, or the lack thereof, from its varied cratonic blocks illustrates that a simple 'one-fits all' lithospheric mantle structure cannot be used to model the evolution of the CB.

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