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Relics of ophiolite-bearing accretionary wedges in NE Brazil and NW Africa: Connecting threads of western Gondwanaś ocean during Neoproterozoic times

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ABSTRACT

Neoproterozoic breakup of Rodinia resulted in the formation of several oceanic realms between dispersing cratons, which were later consumed during the assembly of Gondwana. In its western portion, the interior orogenic belts of Gondwana formed during the Brasiliano-Pan African Orogeny in the late Neoproterozoic-early Cambrian. Available geophysical, structural and petrological data suggest that the complex network of shear zones that once connected the Borborema province (NE Brazil), Tuareg shield (Hoggar) and Central African domain (NW Africa) likely represent ancient sutures that mark collisional episodes between Archean-Paleoproterozoic paleocontinents such as Amazonian-West African and São Francisco-Congo. Mafic, ultramafic and sedimentary sequences associated with this set of structures represent dismembered ophiolite slices interpreted as oceanic remnants (*sensu lato*) that were emplaced during the late stages of the Gondwana assembly. For instance, the composite Transbrasiliano-Khandi-In-Tedeini-Silet shear system crosscuts rock assemblages preserving a complex history of oceanic-crust-transition development (Novo Oriente complex) in association with primitive to evolved magmatic arcs and UHP rocks both in the Borborema province and NW Africa. In the central Borborema province, preserved ophiolitic slices are strongly overprinted by ductile and brittle deformation events, but partially preserved MORB-like amphibolites are akin to subduction-related-types that crystallized in early- and late Neoproterozoic times docked via terrane accretion and dispersed by strike-slip shear zones. In the southern Borborema province, an example of a Neoproterozoic ophiolitic assemblage is the Monte Orebe complex, that encompasses T-MORB mafic rocks, ultramafic lenses, and exhalative sedimentary rocks akin to early to late stages of oceanic basin spreading, emplaced during convergent plate motions between the Pernambuco-Alagoas superterrane and the São Francisco craton. Correlative units are found in Cameroon, including the strongly hydrothermalized ultramafic rocks of the Lomié and Boumnyebel complexes, that are structurally controlled by top-to-the-south verging nappes found in the N-NW margin of the Congo craton. In all scenarios, the ophiolitic complexes are related to intra-oceanic and continental magmatic arcs as well as to geophysical signatures comparable to Phanerozoic suture zones. Although strongly

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dismembered, scrapped off Neoproterozoic oceanic crust partially preserved within the major belts of western Gondwana demonstrate the role of accretion-collisional orogenesis during its assembly.

1. Introduction

Ophiolitic complexes are composed of mafic and ultramafic rocks emplaced in modern and ancient mountain belts and interpreted as relics of oceanic crust/upper mantle sections. A complete ophiolite complex can contain (i) ultramafic tectonites, including harzburgites and serpentinites in the base, (ii) gabbro layers with interleaved fragments of dunites and trondhjemites, and (iii) sheeted dikes, breccias, pillow basalts and pelagic sediments including chert and turbidites at its upper portion (Dilek and Furnes, 2011 and references therein).

The site of initial generation of ophiolitic complexes includes the diversity of environments associated with modern oceans (*e.g.*, mid-oceanic ridges, ocean islands, island arcs) with subsequent emplacement on land related to interaction between the ocean lithosphere and accretionary-collisional zones (*e.g.*, Furnes et al., 2014; Ishizuka et al., 2014; Whitmarsh et al., 2001). Phanerozoic examples include the Oman (United Arab Emirates), Ligurian (Italy), Shergol (India) and Bay of Islands complexes (*e.g.*, Cawood and Suhr, 1992; Renna and Tribuzio, 2011; Coleman, 2014; Manas et al., 2021, among others).

In Precambrian orogenic belts, ophiolitic complexes are often incomplete, occurring as strongly reworked, metamorphosed, and deformed slices preserved in suture zones (Cawood et al., 2009; Furnes et al., 2014). Nevertheless, once identified, Precambrian ophiolite relics have contributed to understanding pre-Phanerozoic tectonic process on Earth (Kusky et al., 2013 and references therein). A well-studied example is the Mona Complex of Anglesey, North Wales, UK, which comprises strongly deformed mafic and ultramafic tectonic slices scrapped off from the oceanic slab, marking the onset of accretionary stages of the Avalonian-Cadomian orogeny in late Neoproterozoic times (*e.g.*, Kawai et al., 2006 and references therein). Further in the geological past, mafic-ultramafic rocks representing embryonic oceans have also been recognized in sequences such as greenstone belts, providing glimpses for possible plate interactions during the Neoarchean (*e.g.*, Van Kranendonk et al., 2007; Furnes et al., 2015).

It has long been proposed that Gondwana's peripheral and interior orogens preserve relics of complex accretionary-collisional histories (*e.g.*, Caby, 1994; Castaing et al., 1994; Oriolo et al., 2017; Cawood et al., 2021; Caxito et al., 2021a, 2021 b), and in the case of western Gondwana, are mostly related to the Neoproterozoic to early Paleozoic Brasiliano (South American side) and Pan African (African side) orogenies ($\sim$ 800-500 Ma; Brito Neves et al., 2014 and references therein). Despite widespread deformation and medium- to high-grade metamorphic overprints, relics of mafic-ultramafic sequences within mélanges containing deep-sea sedimentary rocks have been interpreted as ophiolite-related in several portions of Brazil and western Africa, and are at least in part related to the closure of the long-lived Adamastor and Goiás-Pharusian oceanic basins (*e.g.*, Cordani et al., 2013; Ganade de Araújo et al., 2014a; Basei et al., 2018; Hodel et al., 2019; Amaral et al., 2020; Brown et al., 2020a, 2020 b; Massuda et al., 2020; Werle et al., 2020; Caxito et al., 2022).

Lying at the heart of western Gondwana, the Borborema province of northeastern Brazil (Almeida et al., 1981) is a highly deformed orogenic system that, in paleogeographic reconstitutions, presents crustal continuity to several orogenic belts in northwestern Africa, including the Dahomeydes, Pharusides-Gourma (Togo, Benin and Mali), Central African or Oubanguides orogens (Cameroon, Central African Republic and Chad), and the Tuareg and Benino-Nigerian shields (Algeria, Niger, Mali, and Nigeria; Caby, 1989; Castaing et al., 1994; Toteu et al., 2001; Brito Neves et al., 2002; Arthaud et al., 2008; Santos et al., 2008; Van Schmus et al., 2008; Kalsbeek et al., 2013). This large set of composite orogenic belts is interpreted as the result of tectonothermal events on the margins of the São Francisco-Congo, Amazonian-São Luis-West Africa and Saharan paleoplates during Neoproterozoic and Cambrian times.

The presence of possible ophiolitic remnants in NE Brazil and NW Africa (Caxito et al., 2020a and references therein) emphasizes the importance of accretionary episodes on the peripherial segments of Archean-Paleoproterozoic continental blocks in western Gondwana. In this contribution, we provide an overview of possible ophiolitic slices preserved in the Borborema province and inferred equivalents in NW Africa orogenic belts, reviewing their field relationships and their petrographic and geochemical-isotopic character, with the aim of evaluating spatial and temporal linkages, as well their role in the continental assembly of Gondwana during the Neoproterozoic.

2. Interior orogens of western Gondwana: NE Brazil-NW Africa

Proposed crustal correlations between Brazil and Africa commenced in the late 1960ś and were based on regional-scale structures and comparison of tectono-magmatic records (*e.g.*, Hurley et al., 1967; Almeida and Black, 1968). Over the last thirty years, the expansion of geological mapping and growth of geochemical and isotopic datasets have shown that systematic and complex convergent events grouped within the Brasiliano-Pan African Orogen occurred between the Archaean-Paleoproterozoic blocks (*e.g.*, São Francisco-Congo, Saharan and Amazonian-West Africa paleocratons) as a consequence of the Gondwana assembly (*e.g.*, Caby et al., 1991; Trompette, 1994, 2000; Brito Neves et al., 2000; de Wit et al., 2008a, 2008b) (Fig. 1a).

Despite variations in the published isotopic/geochronological results that have accumulated over the last several decades, it is generally accepted that the major period for the Gondwana assembly was concentrated in the 620-500 Ma interval (*e.g.*, Caby, 2003; Collins and Pisavervsky, 2005; Cawood and Buchan, 2007; Ganade de Araújo et al., 2014b). In the west of Gondwana, it is assumed that such collisional episodes followed the closure of large oceanic realms developed between *ca.* 900 and 720 Ma (*e.g.*, Caby et al., 1981; Stern, 1994; Cordani et al., 2013; Bechiri-Benmerzoug et al., 2017), as in the case of the Goiás-Pharusian ocean, marked by a 2500-km-long suture zone crosscutting both the South American and African continents (*e.g.*, Jahn et al., 2001; Agbossoumondé et al., 2001; Ganade de Araújo et al., 2014a; Santos et al., 2015a, 2015b).

Several regional-scale ductile shear zones are used to divide these orogenic belts in NE Brazil (*e.g.*, Brito Neves et al., 2000; Van Schmus et al., 2011) and NW Africa (*e.g.*, Black et al., 1994; Toteu et al., 2004; Liégeois 2019). Along these structures, geophysical, field, and geochemical-isotopic studies have demonstrated that several mafic-ultramafic sequences, including ophiolite

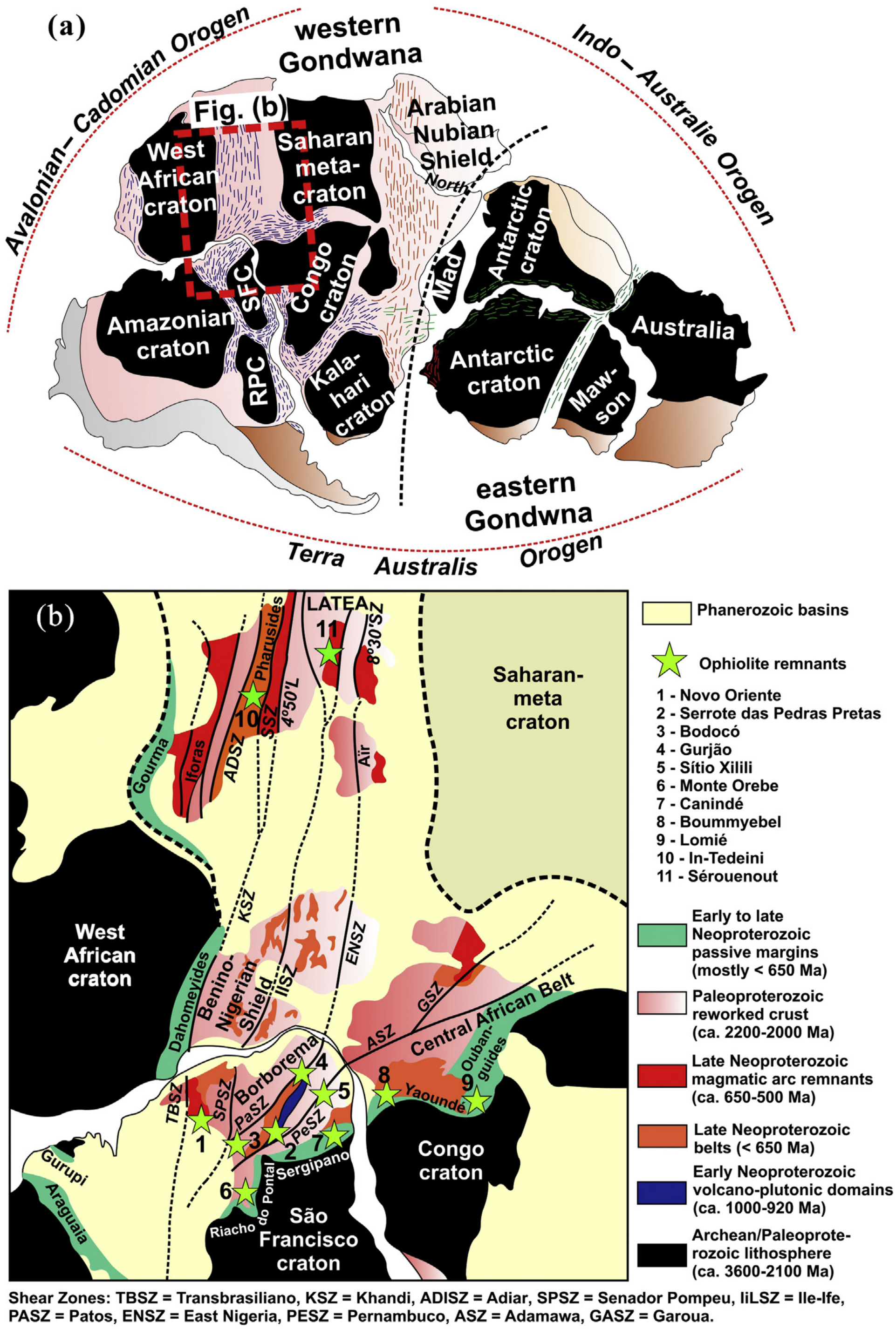

Fig. 1. (a) Gondwana map at ca. 500 Ma showing the position of major cratons and orogenic belts according to Cawood et al. (2021); (b) Geodynamic context of NE-Brazil and NW Africa showing the location of the ophiolitic complexes discussed herein.

remnants and HP/UHP rocks, might represent ancient hidden suture zones within the inner portions of western Gondwana (*e.g.,* Padilha et al., 2014, 2017; Santos et al., 2014; Brahimi et al., 2018; Oliveira and Medeiros, 2018; Deramchi et al., 2020; Araïbia et al., 2022) (Fig. 1b).

2.1. NE Brazil – Borborema Province

The crustal record of the Borborema Province comprises dominantly Paleoproterozoic gneissic-migmatitic basement sequences (*ca.* 2.2–2.0 Ga; *e.g.,* Santos et al., 2013a, 2013b, 2015a, 2017a, 2022; Lages et al., 2019; Brito Neves et al., 2020), local Archaean nuclei (*ca.* 3.5–2.6 Ga; *e.g.,* Dantas et al., 2013; Pitarello et al., 2019; Ferreira et al., 2020), and Neoproterozoic supracrustal-dominated terranes (*ca.* 1.0–0.6 Ga; *e.g.,* Van Schmus et al., 2003; Santos et al., 2010; Brito Neves et al., 2014; Brito Neves and da Silva Filho, 2019; Lima et al., 2018; Caxito et al. 2020b). Several early- to late Neoproterozoic pre-, syn-, late- and post-orogenic granitic suites intruded both basement and supracrustal-dominated regions, which are mostly aged between 0.9 and 0.5 Ga (*e.g.,* Santos and Medeiros, 1999; Santos et al., 2010; Guimarães et al., 2011;

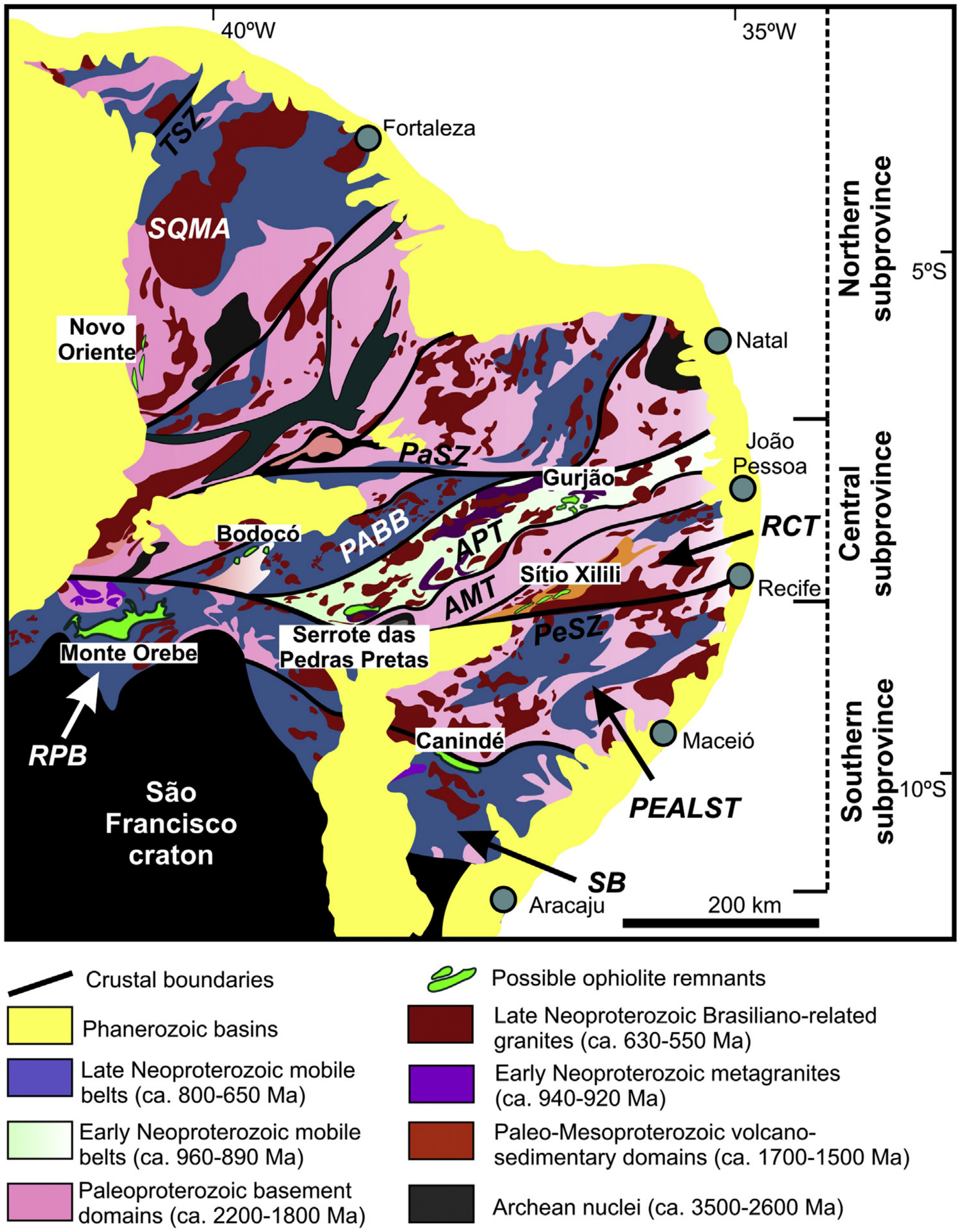

Fig. 2. Simplified geological map of the Borborema province with the location of the documented ophiolite complexes in NE Brazil. Major shear zones: TSZ = Transbrasiliano, PaSZ = Patos, PeSZ = Pernambuco. Major domains described here: SQMA = Santa Quitéria magmatic arc, PABB = Piancó-Alto Brigída belt, APT = Alto Pajeú terrane, AMT = Alto Moxotó terrane, RCT = Rio Capibaribe terrane, PEALST = Pernambuco-Alagoas superterrane, RPB = Riacho do Pontal belt, SB = Sergipano belt. The grey circles represent major cities.

Nascimento et al., 2015; Silva et al., 2015; Brito Neves et al., 2016; Sial and Ferreira 2016).

One of the prominent features of the province is the dense network of up to several hundred-kilometer-long shear zones (*e.g.,* Vauchez et al., 1995) of which the E-W Patos and Pernambuco divide the province into northern, central, and southern subprovinces (Van Schmus et al., 1995, 2008). Distinct models have been proposed to describe the Borborema province's evolution. Santos (1996) and Brito Neves et al. (2000) have proposed that the province corresponded to an accretionary orogen, like those described in the North American Cordillera by Coney et al. (1980). According to this model, thrust-related and strike-slip shear zones are, at least in part, remnants of suture zones agglutinating several terranes during the Cariris Velhos (*ca.* 1000-920 Ma) and Brasiliano orogenies (Caxito et al., 2020a, 2020b, 2021a; Santos and Caxito, 2021; Santos et al., 2021a). In contrast, evidence against the terrane accretion model has emphasized an intracontinental setting for deformation in the region (*e.g.,* Neves, 2021 and references therein).

Apart from the end-member orogenic styles of accretionary and intracontinental, intermediate settings have emerged. Ganade de Araújo et al. (2021) proposed the Borborema lithosphere was pulled away from the São Francisco Craton during 1000 and 650 Ma decratonization events, then inverted to a dominant transpressive phase, also incorporating exotic Paleoproterozoic fragments via strike-slip tectonics. Alternatively, extroversion tectonics (*i.e.,* accretion of continental margins that were not previously conjugated) have been proposed to have acted on the province's borders while introversion phases occurred in its internal oceanic domains, with typical Wilson cycle rift-drift-subduction-collision events separating and then joining back again the reworked basement blocks (Caxito et al., 2016, 2020a, 2021a).

3. Ophiolite wedges in NE Brazil

3.1. General outline

The role of obducted ophiolitic wedges in the orogenic history of the Borborema province has been recognized since the 1980-1990s, and they are mostly interpreted as relics of oceanic realms that were accreted to the dominant Paleoproterozoic continental lithosphere during the Neoproterozoic (see Brito Neves et al., 2000 and references therein). For instance, in the central Borborema province, Santos (1995) described a series of ultramafic rocks, including relics of picritic melts and gabbros/amphibolites with MORB-like signature, grouped as the Serrote das Pedras Pretas suite (Floresta/PE), and interpreted as oceanic floor relics that crystallized *ca.* 1025-920 Ma (Lages and Dantas, 2016). Also, remnants of eclogitic rocks associated with Cr-Fe-Ti mineralization have been described in the same region (Beurlen et al., 1992). Another important example includes the mafic, ultramafic and pelitic rocks of the Monte Orebe complex in the southern Borborema Province, formerly interpreted by Moraes (1992) as tholeiitic rocks of oceanic affinity that were thrusted over the northern margin of the São Francisco craton, which was later confirmed by Caxito et al. (2014a) through the interpretation of field, geophysical, elemental and isotope geochemistry data.

Recent contributions have sougth to unravel the setting of possible remnants of ophiolite wedges (Fig. 2) and in investigating high-grade mafic-ultramafic complexes, including unique occurrences of HP and UHP rocks in the northern Borborema province (*e.g.,* Ganade de Araújo et al., 2014a; Santos et al., 2015a; Amaral et al., 2015; Pitombeira et al., 2021). These rocks are closely related to the Transbrasiliano shear zone and to granitic rocks of the Santa Quitéria magmatic arc, representing the markers of tectonic inversion and closure of the Goiás-Pharusian oceanic basin at *ca.* 600 Ma (Cordani et al., 2013). In addition, studies have summarized the characteristics of mafic-ultramafic sequences throughout the province and in its African counterpart (Caxito et al., 2020a and references therein), indicating Neoproterozoic oceanic realms/accretionary complexes that might be hidden in other portions of the province (*e.g.,* Santos and Caxito, 2021; Santos et al., 2021a).

3.2. Northern subprovince

3.2.1. Novo Oriente

Mafic and ultramafic rocks of the Novo Oriente Group (Cavalcante et al., 2003) occur in the Acaraú sub-domain in the southwestern portion of the northern Borborema province (Fig. 3a), which is delimited by the Transbrasiliano and Tauá shear zones. The Novo Oriente Group contains two distinct stratigraphic sequences (Cavalcante et al., 2003): (i) the proximal coastal Bonsucesso Formation that comprises quartzite and minor basic metavolcanic rocks and (ii) the distal Caraúbas Formation that constitutes a metapelitic–volcanic-carbonate sequence, including metabasic rocks with pillow structure and sheared serpentinized ultramafic rocks (Fig. 3b).

The ultramafic rocks are dominantly composed of deformed and undeformed serpentinites, chloritites, actinolitites, talc-chlorite schists, serpentine-talc schists, talc-rich siliceous rocks and subordinated listwänites (Pitombeira et al., 2017). The deformed (sheared) serpentinites are characteristically green to purple and are composed of stretched serpentine and Cr-magnetite. The undeformed (isotropic) serpentinites are greenish, massive textured and composed of serpentine, Cr-magnetite and crosscut by late quartz veins. Subordinate actinolitites, talc-chlorite schists, serpentine-talc schists, chloritites, and talc-rich siliceous rocks occur as lenticular bodies associated with the serpentinites. The metamafic rocks of the Novo Oriente Group occur interspersed in metapelitic (Caraúbas Formation) and metapsamitic (Bonsucesso Formation) sequences.

The mafic members are represented by gabbros, hornblende gabbros and basalts (Pitombeira et al., 2017). The gabbros are of greenish gray color, dominantly isotropic and medium- to locally coarse-grained. The hornblende gabbros show grano-nematoblastic texture, marked by incipient foliation and intense recrystallization of plagioclase and amphibole. The basalts, represented by fine-grained amphibolites, crop out as tabular and concordant bodies interspersed in the eastern portion of the quartzite package. Locally, they show oriented ellipsoidal concentrations of quartz and feldspar akin to deformed amygdales that indicate the top of the basaltic flows (Fig. 3b).

Ganade de Araújo et al. (2010) proposed two distinct tectonic settings for the Novo Oriente Group: (1) an evolved extensional basin that formed during the Mesoproterozoic (*ca.* 1.5–1.3 Ga); or (2) part of a rift-passive margin system that developed during the break-up of the Rodinia supercontinent (*ca.* 0.95–0.8 Ga), associated with the Goiás-Pharusian ocean. Isotopic analysis indicates crustal assimilation with negative εNd(t) and Paleoproterozoic T_{DM} ages (Fig. 3c) whereas available geochemical data of the ultramafic rocks suggest that they represent altered dunites depleted in HREE, similar to observed patterns in classical subduction-zone-related serpentinites, generally generated from exhumed subcontinental peridotites hydrated during ocean-continent transition rifting (Pitombeira et al., 2017). The metamafic rocks show tholeiitic affinity with signatures between E- and N-MORB and variable contamination by crustal components, as shown in Fig. 3d and 3e.

3.3. Central subprovince

3.3.1. Bodocó and Serrote das Pedras Pretas

Rocks of the Bodocó occurrence consist of highly deformed mafic-ultramafic lenses with general geochemical signatures typical of oceanic tholeiitic magmas and occur close to the tectonic contact between late Neoproterozoic supracrustal rocks and Paleoproterozoic terranes within the Piancó-Alto Brígida belt (Fig. 4a; Beurlen et al., 1992; Lages and Dantas, 2016). They enclose Cr-Ti-Fe mineralized chromitites (Fig. 4b) within mafic-ultramafic host-rocks (Fig. 4c,d) in association with low temperature/C type eclogites (*sensu* Coleman et al., 1965) interpreted as the record of subduction events in the region (Fig. 4e–g; Beurlen and Villarroel, 1990; Beurlen et al., 1992).

The Serrote das Pedras Pretas Suite was described by Santos (1995) as slightly- to strongly deformed mafic and ultramafic rocks in the western Alto Pajeú terrane and were later interpreted as an important marker of its boundary with the Archean-Paleoproterozoic Alto Moxotó terrane (Lages and Dantas, 2016; Santos et al., 2017b, 2018, 2021b). Available zircon U-Pb ages suggest initial magma crystallization of the suite at *ca.* 1.0 Ga during early stages of the Cariris Velhos event and were later submitted to eclogitic facies metamorphism at *ca.* 620 Ma (Lages and Dantas, 2016).

Field relationships suggest that rocks from this suite might occur in allochthonous contact with metasedimentary rocks of the São Caetano Complex (Santos et al., 2019) or as roof pendant xenoliths within the Brasiliano Riacho do Icó granite, dated at 608 ± 5 Ma (Santos et al., 2020). This suite comprises garnet amphibolites (Fig. 5a), garnet hornblendites (Fig. 5b), tremolitites, chlorite-actinolite schists, pyroxenites and cumulate members such as olivine cumulates. Several clusters of small mafic to ultramafic host rocks associated with this unit are commonly mineralized by massive Fe–Ti–V oxides and minor disseminated Ni–Cu sulfides. A tholeiitic-picritic oceanic character was described by Beurlen et al. (1992). In addition, the rocks display positively frac-

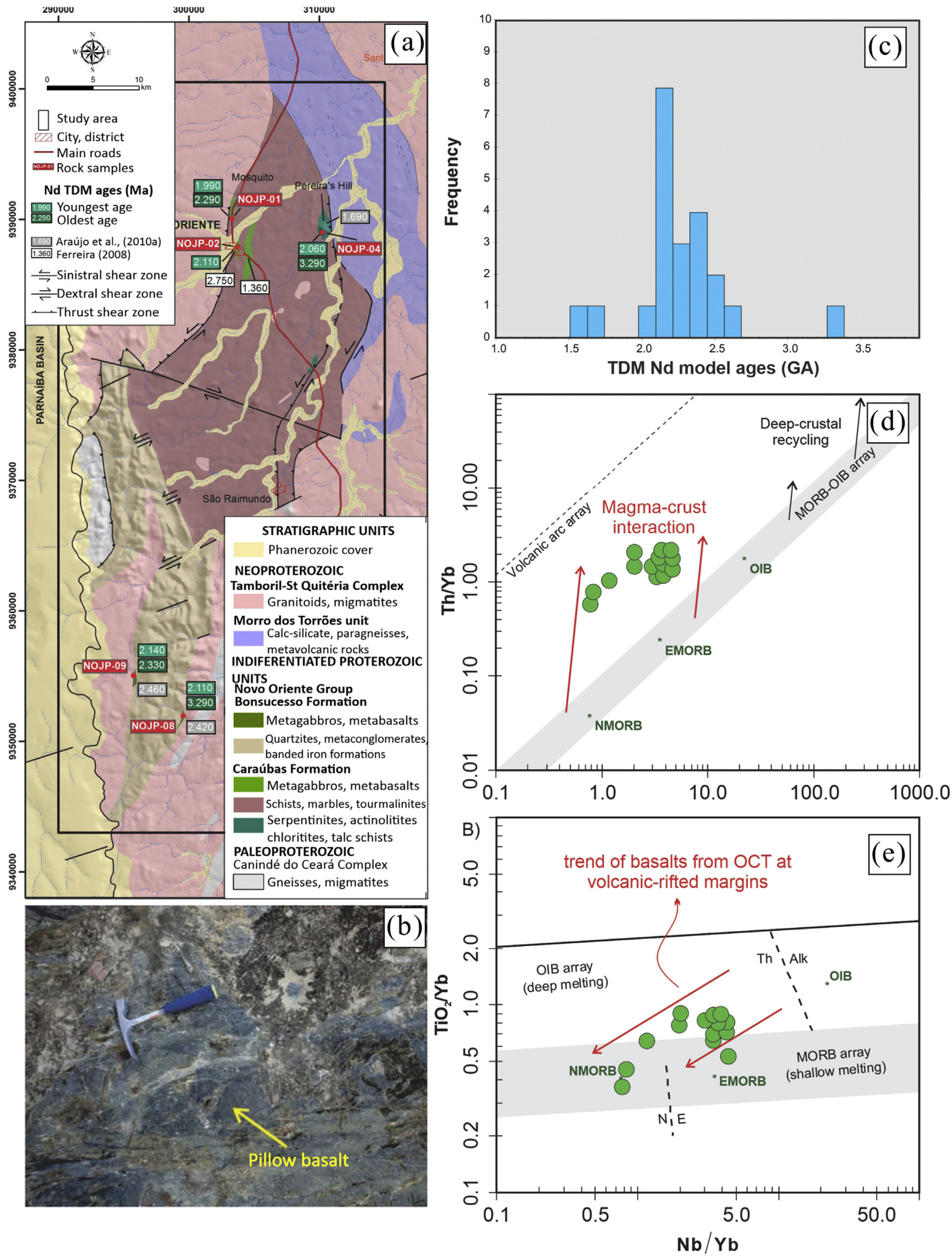

Fig. 3. (a) Simplified geologic map of the Novo Oriente area showing the main occurrences of metaultramafic and metamafic rocks and isotopic data location and values of T_{DM} model ages, modified after Ganade de Araújo et al. (2012). (b) Stretched and moderately altered pillowed metamafic rock. (c) Histogram showing the distribution of T_{DM} Nd ages for the metaultramafic and metamafic rocks of the Novo Oriente region. (d) Plots in the Nb/Yb x Th/Yb and (e) Nb/Yb x TiO_2/Yb diagrams for the Novo Oriente metamafic rocks. Geochemical diagrams are from Pearce (2008). Geochemical data are from Pitombeira et al. (2017).

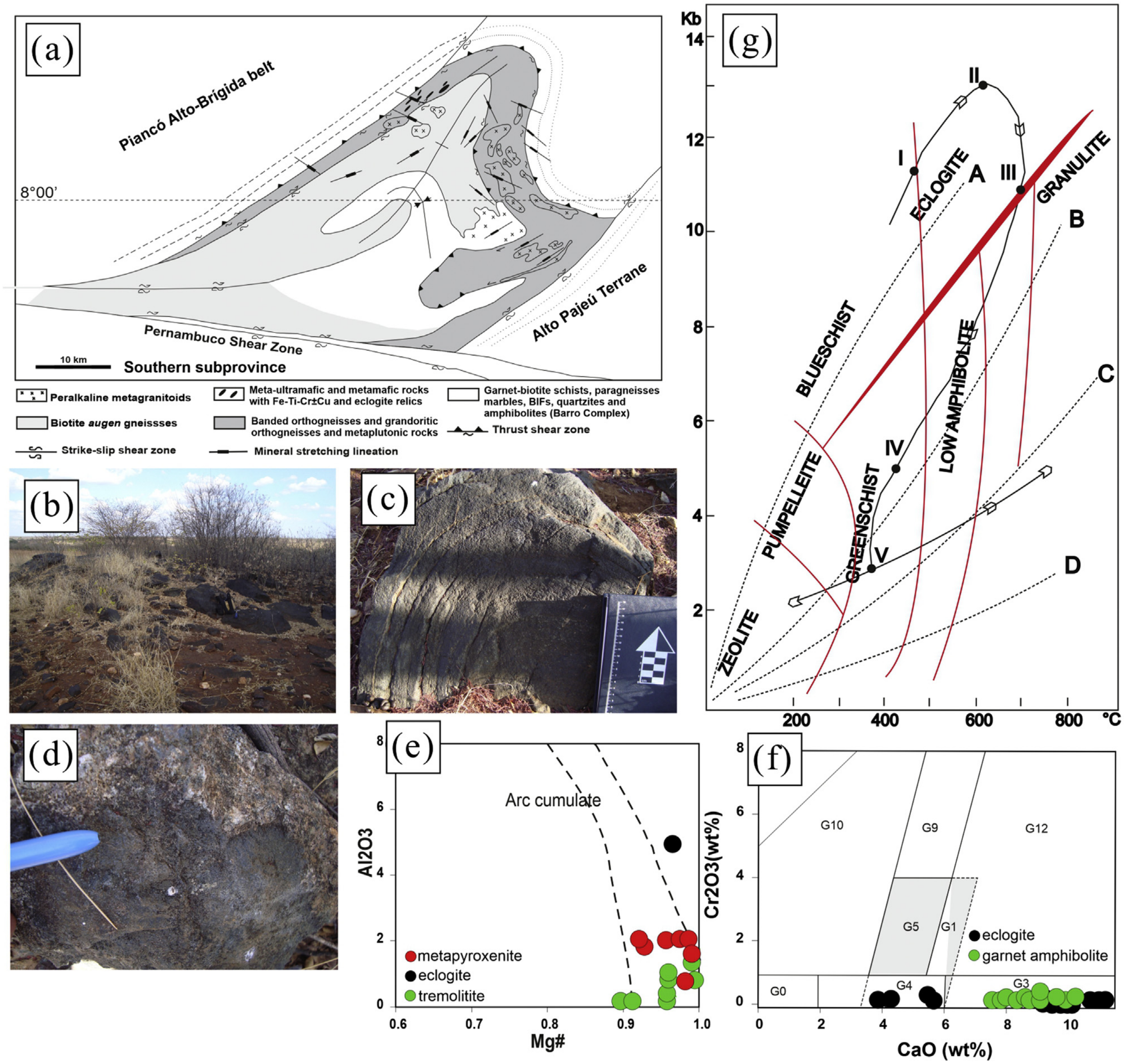

Fig. 4. Simplified geological map of the Bodocó Mafic-Ultramafic Complex with stratigraphic column modified after Lages and Dantas (2016); (b) massive Cr-Fe-Ti chromitites from Bodocó; (c) folded metapyroxenite from the Bodocó mafic-ultramafic Complex; (d) garnet + melts in metaultramafite; (e) Plots of Al_2O_3 vs. Mg/(Mg + Fe^{2+}) of clinopyroxenes from the Bodocó mafic-ultramafic complex. The compositional range for arc cumulate is from Debari and Coleman (1989); (f) Cr_2O_3 vs. CaO garnet diagram of Grütter et al. (2004) with G-number nomenclature of the classification scheme: G0 – unclassified, G1- low-Cr megacrysts, G3 - eclogitic, G4 and G5 - pyroxenitic, websteritic and eclogitic, G9 – lherzolitic, G10 – harzburgitic and G12 – wherlitic; (g) metamorphic pressure/temperature (P/T) trajectory with solid lines indicating the mafic-ultramafic rock evolution from the Bodocó Mafic–Ultramafic Complex (Beurlen et al., 1992). A–D represent subduction zones, plutonic and volcanic complexes, and accretional margins, respectively. Geochemical data are available in Lages and Dantas (2016) and Beurlen et al. (1992).

tionated $\varepsilon Nd_{(1.0\ Ga)}$ values, reaching up to +4.84 (Fig. 5c), which is in accordance with a depleted mantle source that coupled with initial ratios of $^{87}Sr/^{86}Sr$ and fractionation of light rare earth elements (LREE) relative to heavy rare earth elements (HREE), suggests metasomatization by subduction-related melts/fluids (Lages and Dantas, 2016).

3.3.2. Gurjão

The Gurjão rocks occur in the eastern part of the central subprovince, in association with the crustal boundaries between the Pajeú and Alto Moxotó terranes, as well as between the Piancó Alto Brígida belt and the northern subprovince (Fig. 2). They include schists, chlorite to talc-chlorite-amphibole schists, serpentinites, listwanites, fine-grained amphibolites, actinolitites, gabbros, cherts and iron formations. These lithotypes are in contact with mid- to late Neoproterozoic biotite-muscovite gneisses and schists apparently over-thrusted in an apical folding zone on biotite-amphibole migmatite gneisses (Fig. 6a) aged at *ca.* 1.0 Ga (Lages et al., 2014).

Alteration products within these rocks are recorded by centimetric to decimetric fibrous veins of anthophyllite, chrysotile and antigorite. Talc schists (Fig. 6b) are composed of talc, Fe-chromite, phlogopite and anthophyllite. Associated listwanites (Fig. 6c) have a gossanous texture and a reddish-brown color, probably due to the preferential breakdown of the ferromagnesian carbonates. A typical process along this occurrence is the widespread laterization mainly formed through microcrystalline silica infiltration (dissolution of carbonates and reprecipitation of silicious fluid). The amphibolites and talc-chlorite schists are melanocratic and exhibit a

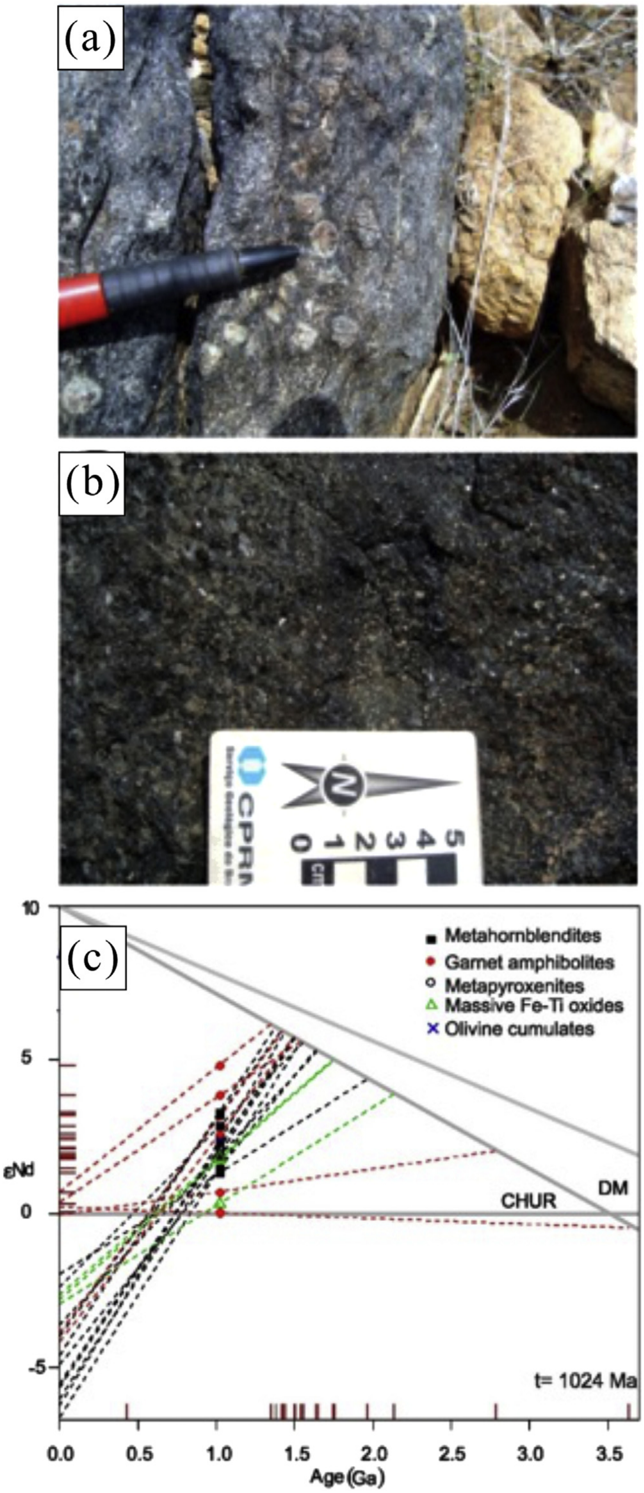

Fig. 5. (a) Plagioclase symplectite in garnet in a metamafite from Serrote das Pedras Pretas Suite; (b) contact between coarse-graned hornblendite and garnet amphibolite; (c) Positive Nd evolution diagram of the Serrote das Pedras Pretas Suite with calculated age of 1024 Ma (Lages and Dantas, 2016).

dark green color with milky submillimetric plagioclase dots. They have a well-developed schist structure, besides an incipient mineral lineation marked by aligned subhedral to anhedral chlorite crystals.

Available U-Pb ages were obtained on metamorphic zircon crystals and grain overgrowths from a fine-grained amphibolite of the sequence (*ca.* 0.6 Ga; amphibolite facies metamorphism age), suggesting that the precursor magma must be older than that (Lages et al., 2017). Obtained $\varepsilon Nd_{(0.6\ Ga)}$ values up to +3.7, indicate juvenile upper mantle inputs in the genesis of these rocks (Lages et al., 2017). Geochemical aspects of the ultramafic members include the Ti content, Yb enrichment and low LOI values, typical of obducted ophiolitic cumulates (Deschamps et al., 2013). In contrast, rare earth element patterns observed in the mafic rocks are similar to those observed in boninites from arc-retro-arc settings. In addition, the #Cr and #Mg of the chromites are like those from serpentinites generated in supra-subduction zone mantle wedge (Lages et al., 2017).

3.3.3. *Sítio Xilili*

Mafic-ultramafic rocks mapped as the Sitio Xilili unit crop out in the western portion of the Rio Capibaribe terrane (Fig. 7a). This terrane comprises an early Paleoproterozoic (*ca.* 2.1 Ga) basement formed of metagranites and banded orthogneisses (Brito Neves et al., 2013 and references therein) crosscut by isolated occurrences of mafic-ultramafic and fine-grained late Paleoproterozoic orthogneisses (*ca.* 1.7-1.6 Ga; Accioly, 2000; Sá et al., 2002). Early Neoproterozoic units (*ca.* 0.92 Ga) are also described, represented mainly by volcanosedimentary sequences, including schists and garnet amphibolites, that were possibly intruded by ultramafic rocks, including inferred ophiolite members (Accioly and Santos, 2010; Santos et al., 2017c).

Late Neoproterozoic units within this terrane include low- to medium-grade supracrustal sequences (Neves et al., 2008; Brito Neves et al., 2013) and calc-alkaline to alkaline plutonic rocks dated at *ca.* 0.59 Ga and deformed by several NE-SW trending strike-slip shear zones that crosscut the terrane (*e.g.,* Santos and Medeiros, 1999; Mariano et al., 2001; Neves et al., 2006). In its central portion, mafic-ultramafic rocks have been studied since the 1970ś mainly due to their association with anthophyllite asbestos. Ultramafic rocks include serpentinites and anthophyllite-talc schists with picritic-peridotitic protoliths, whereas mafic rocks include gabbros and amphibolites that crop out as lenses along the NE-SW trend of the Rio Capibaribe terrane (Lira Santos et al., 2022).

No geochronological data have been obtained in the plutonic rocks. U-Pb ages associated with volcanic lenses that occur concordant with the mafic/sedimentary pile suggest crystallization ages of *ca.* 0.92 Ga (Santos et al., 2017c). Ultramafic rocks are strongly altered, marking a dark-brown clayish soil with iron caps of magnetite-rich mafic rocks (Fig. 7b). Serpentinites within the ultramafic sequence are composed of antigorite, serpentinite, talc, magnesite, chlorite, and magnetite that form a xenoblastic aggregate, with antigorite showing interpenetrating textures. The anthophyllite-talc schists are inequigranular porphyroblastic (given by the anthophyllite prisms) (Fig. 7c) with a lepidoblastic matrix composed of talc, anthophyllite, antigorite, chlorite, and magnetite concentrations. The mass- and slip-fiber asbestos form brownish masses composed of anthophyllite fibers and magnetite (Santos et al., 2022). The gabbros are equigranular, consisting of amphibole (Fig. 7d), clinopyroxene, and plagioclase, with minor sphene, quartz, epidote, and oxides.

Few geochemical and isotopic data have been documented, which is primarily due to the difficulty in mapping and collecting these rocks that have been buried since ca. 2017, when exploration for asbestos in Brazil was prohibited. However, the few analyzed samples of amphibolites (Santos et al., 2022) present geochemical signatures akin to N-MORB and E-MORB (Fig. 7e) magmas as testified, for instance, by the low fractionation pattern between LREE and HREE compared with the chondrite (Fig. 7f), that in addition with the occurrence of primitive melts and strongly hidrotermalized rocks (litswanites?), opens the possibility of ophiolitic rocks

Fig. 6. (a) Migmatized biotite-amphibole gneiss with closed folds pattern of the Stenian/Tonian Sítio Icó basement; (b) Talc schist exhibiting crenulation lineation from Gurjão rocks sequence; (c) Oxized listwanite with mega pseudomorphs filled with white mica.

obliterated by the intense deformation recorded in the central subprovince of the Borborema province.

3.4. Southern subprovince

3.4.1. Monte Orebe and Canindé

Mafic, ultramafic and sedimentary sequences grouped in the Monte Orebe Complex were recognized as possible ophiolite remnants (Moraes, 1992; Caxito et al., 2014a) exposed in the Riacho do Pontal orogen, southern subprovince (Brito Neves, 1975). The orogen is divided into three sectors: internal, central and external (Fig. 8a; Oliveira, 1998; Caxito and Uhlein, 2013; Caxito et al., 2014b, 2016) and the Monte Orebe complex crops out in the central sector of the orogen. The complex comprises several occurrences of actinolite schists, amphibolites and metatuffs, commonly interleaved with sedimentary rocks interpreted as deep-sea pelagic remnants, exhalative rocks such as metric-thick chert layers (Fig. 8b), and ultramafic lenses. Massive basalts are widespread, mostly interleaved with actinolite-plagioclase greenschists, also exhibiting well-preserved amygdaloidal textures (Fig. 8c).

The available whole-rock Nd isochronic age of *ca.* 819 ± 120 Ma (Fig. 8d) and the initial calculated eNd(t) values at around +4.4, along with the petrographic, stratigraphic, structural, elemental geochemistry and metamorphic characteristics as well as geophysical signatures led Caxito et al. (2014a) to suggest that the Monte Orebe Complex marks a Neoproterozoic suture zone within the central portion of the Riacho do Pontal belt. Despite the high uncertainty of the calculated Sm-Nd isochron, inherent in whole-rock isochrons of homogeneous oceanic crust samples with similar, homegeneous Sm/Nd ratios, this is so far the best estimation for the crystallization of the Monte Orebe metavolcanic rocks. Geochemical data obtained in metamafic rocks of the Monte Orebe Complex point to a tholeiitic (Fig. 8e) subduction-related (Fig. 8f) continental margin (Fig. 8g) setting, and the trace element distribution patterns including REE, suggest affinities with T-MORBs (Caxito et al., 2014a). This interpretation concurs with the early proposition of Moraes (1992) and is reinforced by the detected paired positive-negative linear Bouguer anomaly observed in the region (Oliveira, 1998), typical of ancient suture zones where lithospheric blocks of distinct age and composition are juxtaposed.

Zircon data from the metasedimentary succession supports the interpretation of an accretionary prism setting, including both cratonic-sourced and hinterland-sourced successions tectonically interleaved with scraps of obducted oceanic crust (Caxito et al., 2016). Southward, towards the northern São Francisco craton margin, platformal successions including carbonate ramps and quartzites of the Barra Bonita formation represent the shallow marine correlatives of this deep-sea succession (Caxito et al., 2016).

Further east, the Canindé Domain is one of a series of crustal segments that compose the Sergipano belt of the Southern subprovince. Similar to the Riacho do Pontal belt, it represents a strongly deformed Neoproterozoic crustal piece that borders the N-NE region of the São Francisco craton, presenting direct linkage to the Oubanguides orogen in Cameroon (Davison and Santos, 1989; Silva Filho, 1998; D'el-Rey Silva, 1999; Trompette, 2000). Several accretionary markers are described within this orogenic region, including arc-related granites, basic to acidic volcanic rocks and several plutonic and sedimentary sequences (*e.g.*, Oliveira et al., 2006, 2010, 2017; Lima et al., 2019). The latter represent remnants of platformal and oceanic sequences that were strongly reworked and deformed/disrupted during collisional episodes between the Pernambuco-Alagoas superterrane and the São Francisco craton during the Brasiliano Orogeny (Brito Neves and Silva Filho, 2019).

The major domains/terranes of the Sergipano belt are bounded by several regional-scale shear zones, from which airborne geophysical investigations suggest that they might represent relics of ancient sutures, marking the onset of accretionary phases between the Borborema province and the São Francisco craton (*e.g.*, Almeida et al., 2021). Among them, the Canindé domain occurs in the northernmost portion of the Sergipano belt and comprises volcanic-sedimentary rocks (Novo Gosto and Gentileza units), the Canindé gabbroic intrusion and several pre-, syn and post-collisional late Neoproterozoic granites (Passos et al., 2022 and references therein).

Jardim de Sá et al. (1986) described within this domain relics of island arcs, in addition to the early proposition of Silva Filho (1976), that gave more emphasis on ophiolite-related settings. Furthermore, Davison and Santos (1989) suggested that contrasting domains of the Sergipano belt, including Canindé, might represent relics of accreted terranes on the margins of the São Francisco craton. Based on a vast number of geochemical and isotopic data, Oliveira et al. (2010) suggested that rocks from the Canindé domain were generated in a continental rift setting that later evolved to an oceanic basin.

Recently, Passos et al. (2021) obtained the first Tonian ages of the Canindé Domain (*ca.* 0.74 Ga) in amphibolites and granitic rocks, which are directly related to pre-collisional stages of the Brasiliano Orogeny. Although no clear evidence for an ophiolite complex has been identified within this domain, the evolution of the belt including two orogenic stages (Cariris Velhos and Brasiliano; Carvalho et al., 2005; Oliveira et al., 2010, 2017) as supported by geochemical and isotopic data, strongly suggest that an ocean might have existed between the Tonian and Ediacaran periods.

4. Ophiolites of NW Africa

4.1. Central African geological domain

The complex evolution of Central Africa extends over more than 3.0 Gy and records formation, reworking and juxtaposition of

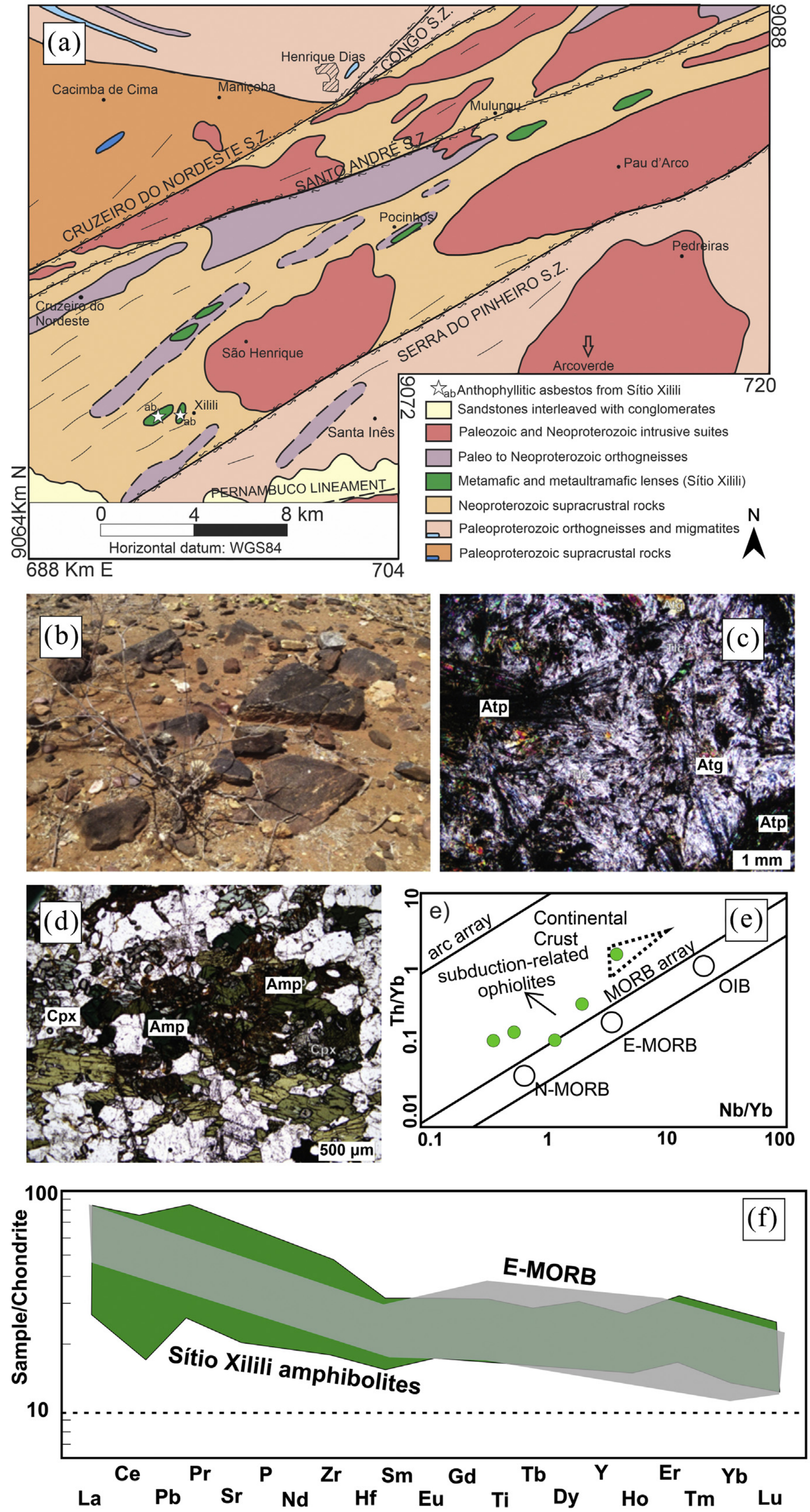

Fig. 7. (a) Geological map of the central portion of the Rio Capibaribe terrane showing the occurrences of the mafic-ultramafic rocks of the Sítio Xilili unit, modified from Accioly and Santos (2010); (b) scattered blocks of altered meta-ultramafic and metamafic rocks, including iron-rich members; (c) anthophyllite-antigorite aggregate in a strongly altered sample of anthophyllite-talc schist; (d) amphibole and clinopyroxene crystals suggesting uralitization processes in a nematoblastic amphibolite sample; (e) Nb/Yb x TiO_2/Yb plot of the metamafic rocks on the Pearce (2008) diagram; (f) Chondrite-normalized (Sun and Mcdonough, 1989) REE patterns for the metamafic rocks of the Sítio Xilili unit as well as average E-MORB distribution extracted from Schiling et al. (1983). Geochemical data are from Santos et al. (2022).

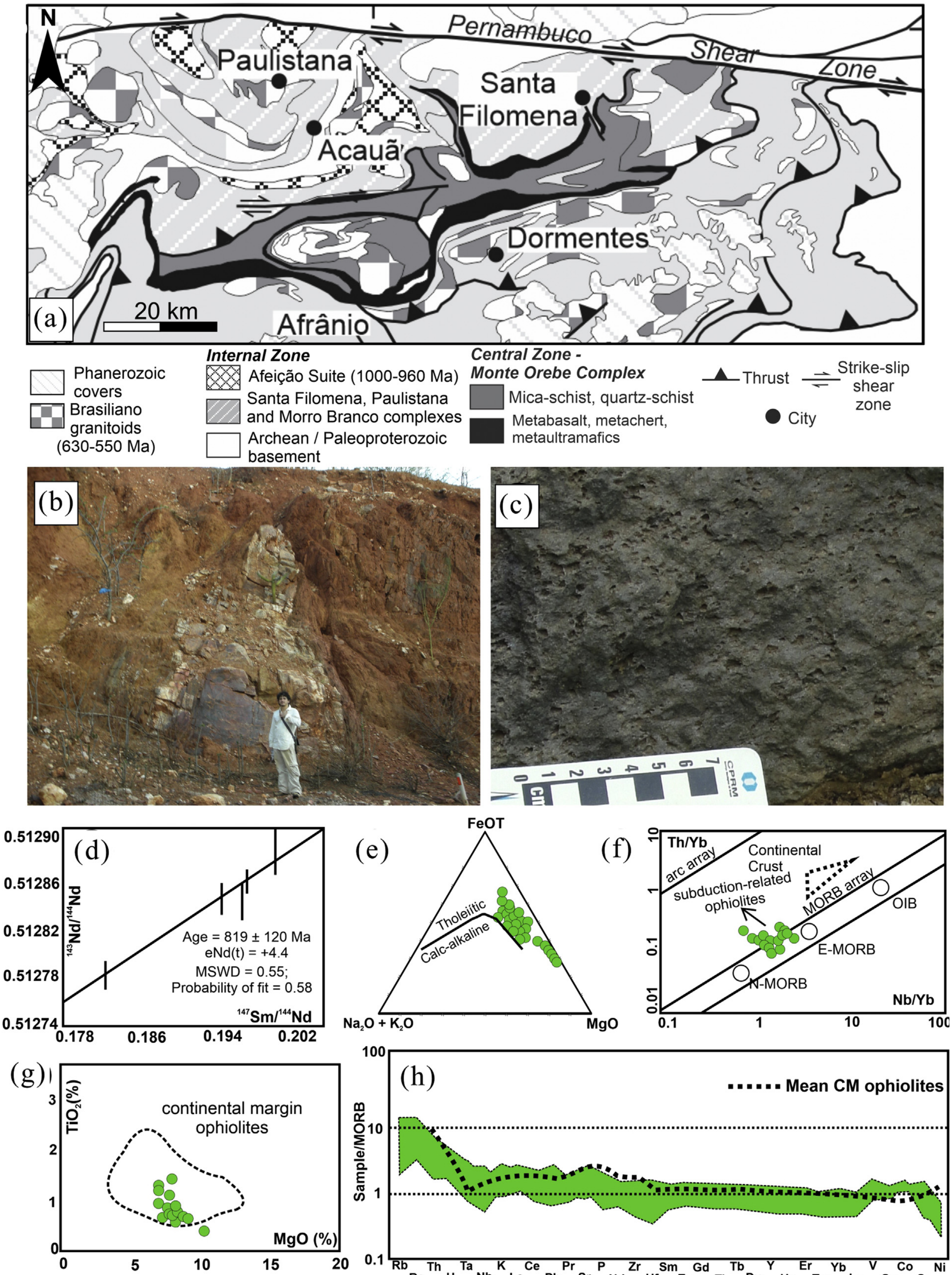

Fig. 8. (a) Geologic map of the Riacho do Pontal fold belt (extracted from Caxito et al., 2014a); (b); decametric chert layer; (c) greenish amygdaloidal metabasalt; (d) Sm-Nd isochron of Monte Orebe metabasalts (Caxito et al., 2014a); (e) plots of the metamafic rock samples of the Monte Orebe Complex on the AFM diagram from Irvine and Baragar (1971); (f) TiO_2-MgO and (g) Th/Yb-Nb/Yb diagrams from Pearce (2008); (h) chondrite normalized diagram of the metamafic samples of the Monte Orebe Complex. MORB values are from Dilek and Furnes (2011). Isotopic and geochemical data are from Caxito et al. (2014a).

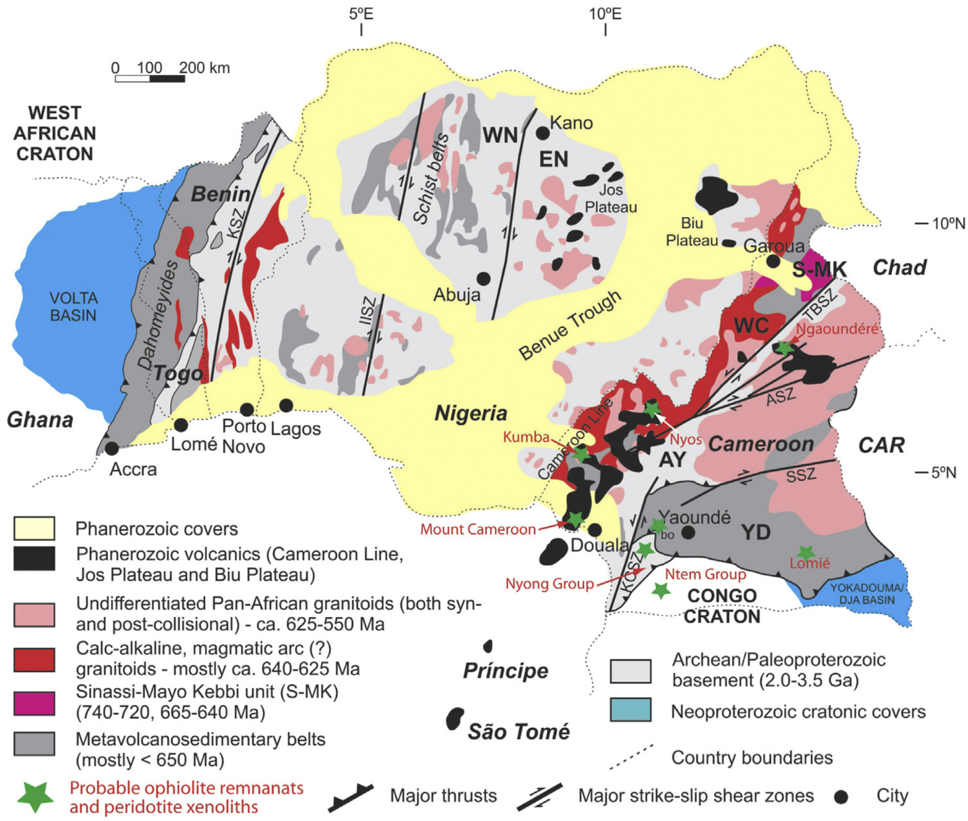

Fig. 9. Geological map of the Benino-Nigerian Shield and Cameroon, including the location of the Lomié serpentinites and the Boumnyebel (bo) mafic to ultramafic complexes. From Caxito et al. (2020a).

Archean to Paleoproterozoic terrains followed by accretion of Neoproterozoic arc successions and volcanosedimentary basins to the Archean Congo craton during the Pan-African continental collision in the late Neoproterozoic (~ 600 Ma; Toteu et al., 2001, 2004, 2022; Shang et al., 2004, 2010; Penaye et al., 2006; Van Schmus et al., 2008; Bouyo Houketchang et al., 2009, 2013; Tchameni et al., 2010; Owona et al., 2011, 2021; Nkoumbou et al., 2014; Tchakounté et al., 2017; Blades et al., 2021; Djerossem et al., 2021). These Precambrian units are overlain by Phanerozoic intra-cratonic sedimentary basins and cut by recent volcanic rocks of the Cameroon volcanic line.

Based on the available geological, geochemical, geochronological and airborne geophysical data, several bodies of mafic to ultramafic rocks have been identified, mainly within the Neoproterozoic Yaoundé Group or domain in Cameroon, the southern part of the Central African fold belt (CAFB). Rocks from this domain mostly include several low- to high-grade Neoproterozoic sedimentary members and orthogneisses that were accreted to the northern margin of the Congo craton (Toteu et al., 2006a, 2006b and references therein) in addition to early to post-orogenic granitoids. Although significantly altered, the best-known examples of mafic to ultramafic rocks are grouped in the Lomié and Boumnyebel complexes interpreted as remnants of oceanic crust or ophiolite-related rocks obducted during the onset of the Pan-African orogeny (Fig. 9).

4.1.1. Boumnyebel and Lomié

In the Boumnyebel region, decametric lenses of metamafic-ultramafic rocks occur interleaved with the metasedimentary rocks of the Yaoundé Group, which were metamorphosed under high-pressure conditions at *ca.* 620-610 Ma (Penaye et al., 1993; Toteu et al., 2004). The available crystallization age of the sequence is inferred from U-Pb zircon age of gabbro at Mamb near Boumnyebel of 618 ± 7 Ma (Toteu et al., 2006a). These deformed and highly altered sequences (Fig. 10a–c) include talc schists, amphibolites, pyroxenites, serpentinites, hornblendites, chlorite schists and gabbros. They are interpreted as slices of dismembered ophiolite complexes of Neoproterozoic oceanic basins, related to accretionary events of the Pan-African orogeny (Nkoumbou et al., 2006; Kundu et al., 2022). In addition, mafic and ultramafic rocks within the CAFB are also linked to subduction-related rocks including those of the Sinassi magmatic arc in northern Cameroon, where small scale intrusions or discontinuous xenoliths of gabbros, hornblendites, amphibolites are reported (Bouyo Houketchang et al., 2016).

Further southeastward, in the Lomié area (southeast Cameroon), low- to medium-grade schists, amphibolites and highly deformed ultramafic bodies crop out in a series of nappes that border the NE portions of the Congo craton. The ultramafic rocks of Lomié (Fig. 10d) were mapped for the first time during the United Nations Development Programme exploration work in 1987. They comprise four main rock masses (Kongo, Nkamouna, Mang and Messea) covering several tens of square kilometers each and, despite systematic investigations on the cobalt-nickel-PGE mineralization in this sequence, associated lithotypes generally crop out very poorly and usually lateritized (Yongue-Fouateu et al., 2006; Ndjigui et al., 2009; Ndjigui and Bilong, 2010). The best-preserved ultrabasites are mainly serpentinites (serpentinized peridotites) with antigorite, having undergone low-grade regional metamorphism and/or significant silicification. In addition to serpentine (sometimes 90% of ultrabasites), rare relics of olivine and orthopyroxene (± talc, magnesian carbonates, chlorite, magnetite, tourmaline, sulfides) have been described, which suggest that the original rock would be a harzburgite-type peridotite. The presence of facies richer in talc

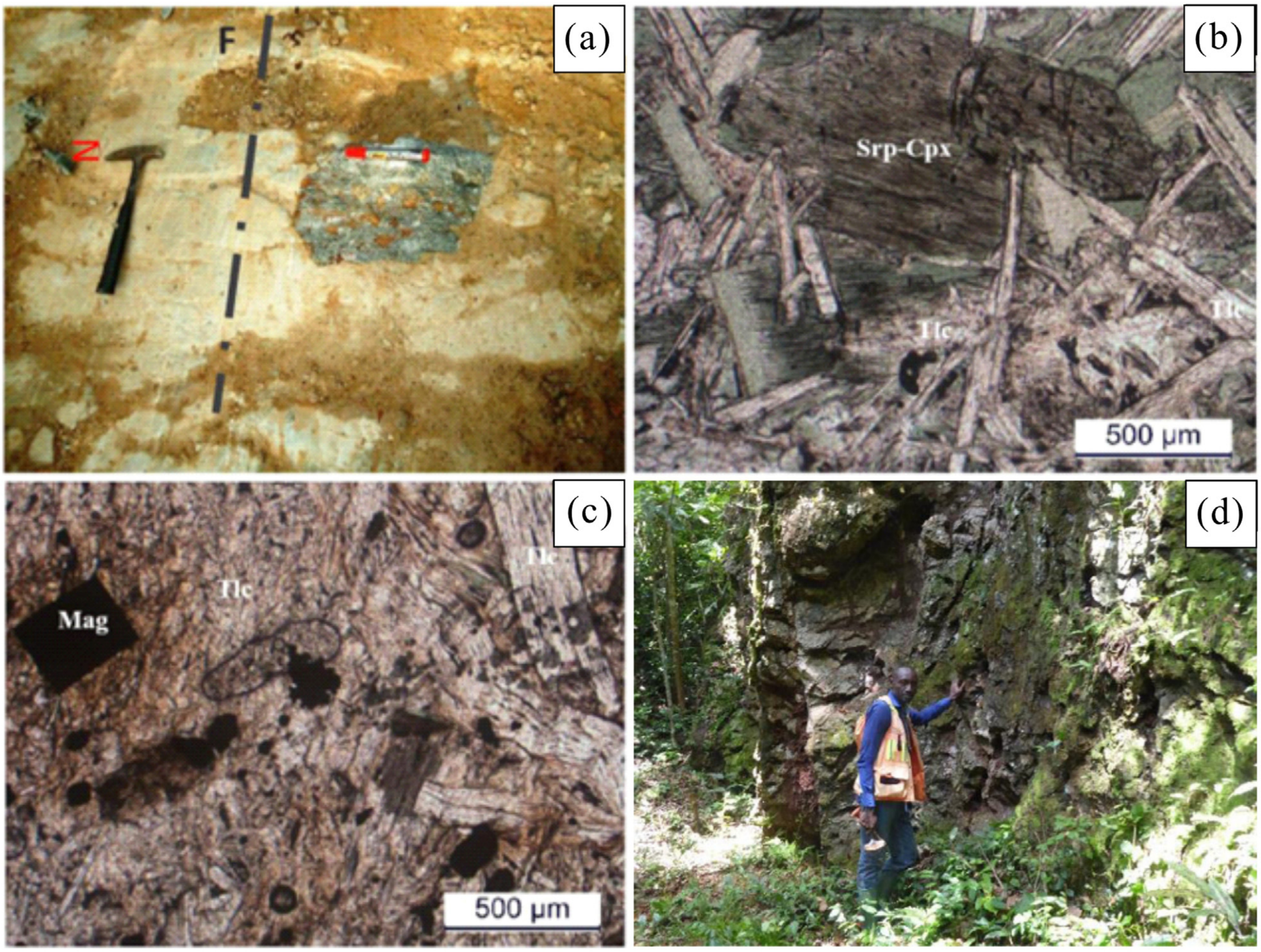

Fig. 10. (a) Talc-schist flagstone cropping out on the Mapan-Mémel road; (b) strongly serpentinized mesh-like texture and prismatic ghost pyroxene crystals; (c) idiomorphic disseminated magnetite crystals in strongly altered talc-schists; (d) domed serpentinite at Kongo-Kamouna, Lomié area. (a)–(c) are from the Boumnyebel and (d) refers to Lomié.

(60 %) and carbonates suggests a protolith of the pyroxenite type. According to Seme Mouangue (1998), their emplacement and subsequent alteration are linked to later stages of the Pan-African Orogen, which is in agreement with the *ca.* 666 ± 26 Ma age obtained in an associated gabbro at the Masins region (Toteu et al., 2006a).

4.2. Tuareg shield

The Tuareg shield represents part of the Pan-African orogenic belt that extends over the Aïr in Niger, Iforas in Mali and mainly in the South of Algeria, where it is referred as Hoggar shield (Fig. 11). The crustal arrangement of this complex orogenic area results from the amalgamation of 25 terranes due to the closure of early Neoproterozoic paleo-oceans, followed by accretion of island arcs and collisional events of continental domains between the West African craton and the Saharan metacraton (Caby, 1989; Trompette, 1994; Liégeois et al., 1994; Black et al., 1994; Abdelsalam et al., 2002; Santos et al., 2008).

These terranes were formed during Archean and Paleoproterozoic times and strongly reworked within the Pan-African Orogeny, mostly between ~870 and 520 Ma, also including the growth of juvenile terranes. These crustal blocks show contrasting lithostratigraphic, tectonometamorphic and magmatic features, and have been welded together along major thrust-related and strike-slip shear zones, often in a sub-meridian direction (Liégeois et al., 2003, 2019; Caby, 2003; Deramchi et al., 2020; Araïbia et al., 2022; Ouadahi et al., 2022).

The major trending sub-meridian-trending shear zones at ∼ 4°50'E and ∼ 8°30'E divide the shield into western, central and eastern Hoggar (Bertrand and Caby, 1978). These structures have been considered (Caby, 1989; Arthaud et al., 2008; Cordani et al., 2013) as the main suture zones within the Tuareg shield connected with those of the northern Borborema Province on the reconstruction of western Gondwana (Caxito et al., 2020a and references therein).

Remnants of Neoproterozoic oceanic lithosphere are described between the Archean-Paleoproterozoic blocks in the Tuareg shield, mainly associated with the bonding shear zones (Black et al., 1994). However, only a few have been investigated, mainly those on both sides of the LATEA unit, which belongs to the central Hoggar (Bertrand and Caby, 1978; Vialette and Vitel, 1979; Caby et al., 1981). The former is an acronym of five constituting terranes having similar general features: Laouni, Aouilène, Tefedest, Egéré-Aleksod, Azroun'Fad. It is bounded in the west and east by oceanic Neoproterozoic domains, the Pharusian belt and the SAA domain (Sérouenout, Aghefsa and Aguendis), respectively (Fig. 11).

4.2.1. The Pharusian belt

The Pharusian belt (Gravelle, 1969; Bertrand, 1974; Bertrand and Caby, 1977, 1978; Caby et al. 1981; Black et al., 1994; Caby, 2003; Caby and Monié, 2003) is composed of the Silet, In-

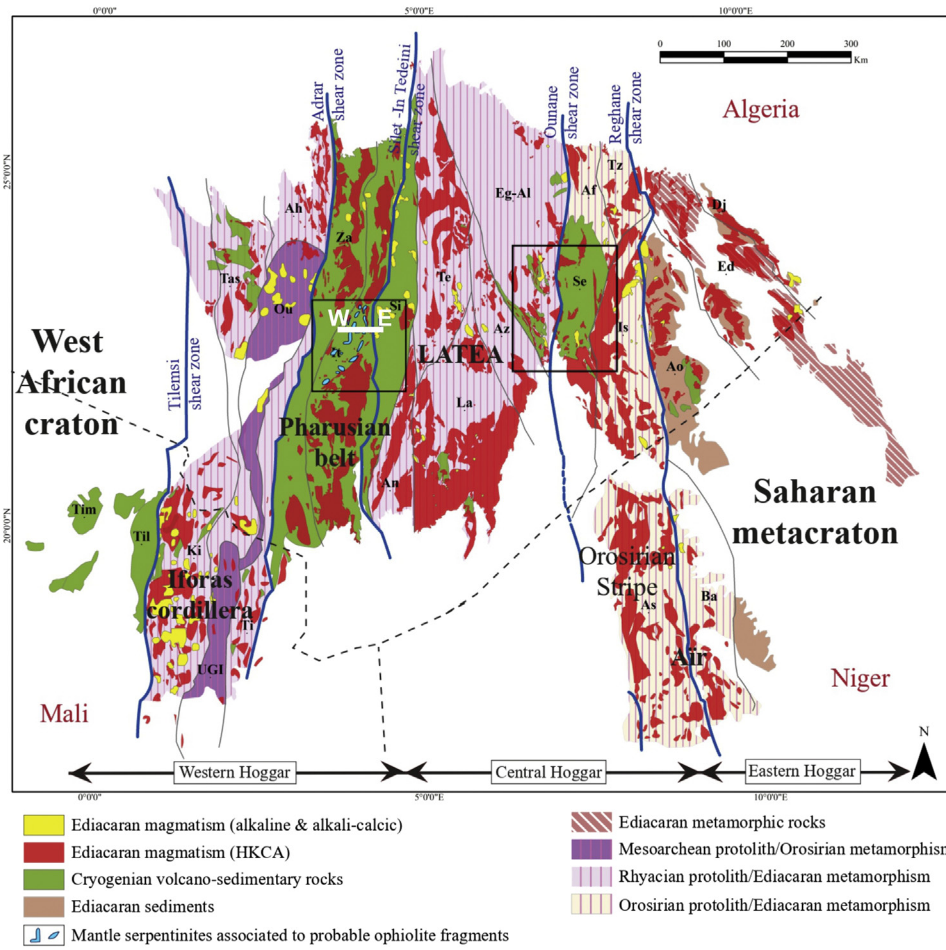

Fig. 11. Simplified Tuareg Shield geological map after Liégeois (2019). From east to west, 25 terranes are indicated: Afara (Af), Ahnet (Ah), Aouilène (An), Aouzegueur (Ao), Assodé-Issalane (As-Is), Azrou N'Fad (Az), Barghot (Ba), Djanet (Dj), Edembo (Ed), Egéré-Aleksod (Eg-Al), Iforas granulitic unit (UGI), In Ouzzal (Ou), In Teidini (It), Iskel (Isk), Kidal (Ki), Laouni (La), Sérouenout (Se), Tassendjanet (Tas), Tazat (Ta), Tchilit (Tch), Tefedest (Te), Tilemsi (Til), Timétrine (Tim), Tin Zaouatene (Za), Tirek (Ti). The highlighted boxes on the figure represent the regions where ophiolite rocks crop out and the E-W white line delineates the croos-section presented in Fig. 12.

Tedeini and Tin Zaouatene domains, interpreted to represent a Cordillera-like crustal collage of island arc and oceanic rock units formed in the interval 870 – 640 Ma (Caby et al., 1981; Caby, 2003; Bechiri-Benmerzoug et al., 2011, 2017).

The belt's history started with rifting related to the break-up of the Rodinia supercontinent (*ca.* 1000-900 Ma; Dupont et al., 1987; Bouchachi, 1993; Caby, 2003; Caxito et al., 2020a). This period accompanied the generation of transitional-type volcanic rocks associated in part with mafic-ultramafic (Abed, 1983; Boukhalfa, 1987) and metasedimentary lithotypes. This set overlays a Paleo-Mesoproterozoic basement, defined in the eastern and western parts of the Pharusian belt (Gravelle, 1969; Boukhalfa, 1987, 2002; Bouchachi, 1993; Black et al., 1994; Haddoum et al., 1994; Caby, 2003; Bosch et al., 2016).The expression of the Pan-African orogen in the belt is mainly characterized by conspicuous late Neoproterozoic arc magmatism consisting of calc-alkaline volcanics and TTG suites, including associated sedimentary sequences that reached greenschist metamorphic conditions (*e.g.*, Bertrand and Caby, 1978; Chikhaoui et al., 1980; Bechiri-Benmerzoug et al., 2017).

Eastern In-Tendei domain. Serpentinite lenses, as well as mafic and associated sedimentary rocks with chromitite pods (Augé et al., 2012), crop out in the Eastern In-Tedeini domain (Fig. 11). Structural analysis conducted by Ouadahi et al. (2022) has suggested that these rocks underwent coeval horizontal and vertical movements, in NNW to NNE direction, and reflect eastward steeply dipping transpressive sinistral structures (Fig. 12a–d) developped during collision-related episodes of the Pan-African Orogeny.

In addition, based on the integration of whole-rock geochemical, mineral chemistry and geochronological data, these authors suggested a harzburgitic-mantle wedge origin for the In-Tedeini serpentinites, later involved in an accretionary-collisional-related setting. This interpretation is based, for instance, on the overall geochemical parameters of these rocks, including variably depleted and correlated LREE and HFSE, typical of intense dynamic melting in the upper mantle (Fig. 12c), influenced by fluid influx and melt refertilization by island arc products, typical of intra-oceanic subduction-settings. Furthermore, preserved Cr-spinel strongly suggests oceanic affinities, whereas the Cr# for low to intermediate Mg# point to high degrees of melt depletion likely in a subduction zone context (Fig. 12e,f). In the same way, tholeiitic N-MORB and E-MORB geochemical signatures have also been identified in associated amphibolites. These may represent massive mantle wedge serpentinites subjected to complete serpentinization under static amphibolite-facies conditions, which were then enveloped in talc-schist caps that localize intense deformation and favored their exhumation from the mantle wedge.

Few zircon crystals recovered from metasomatic chloritite dikes provided ages that were interpreted by Ouadahi et al. (2022) as recording the subduction-related arc melts (770 ± 5 Ma) and emplacement (631 ± 10 Ma) of mantle wedge serpentinites within the

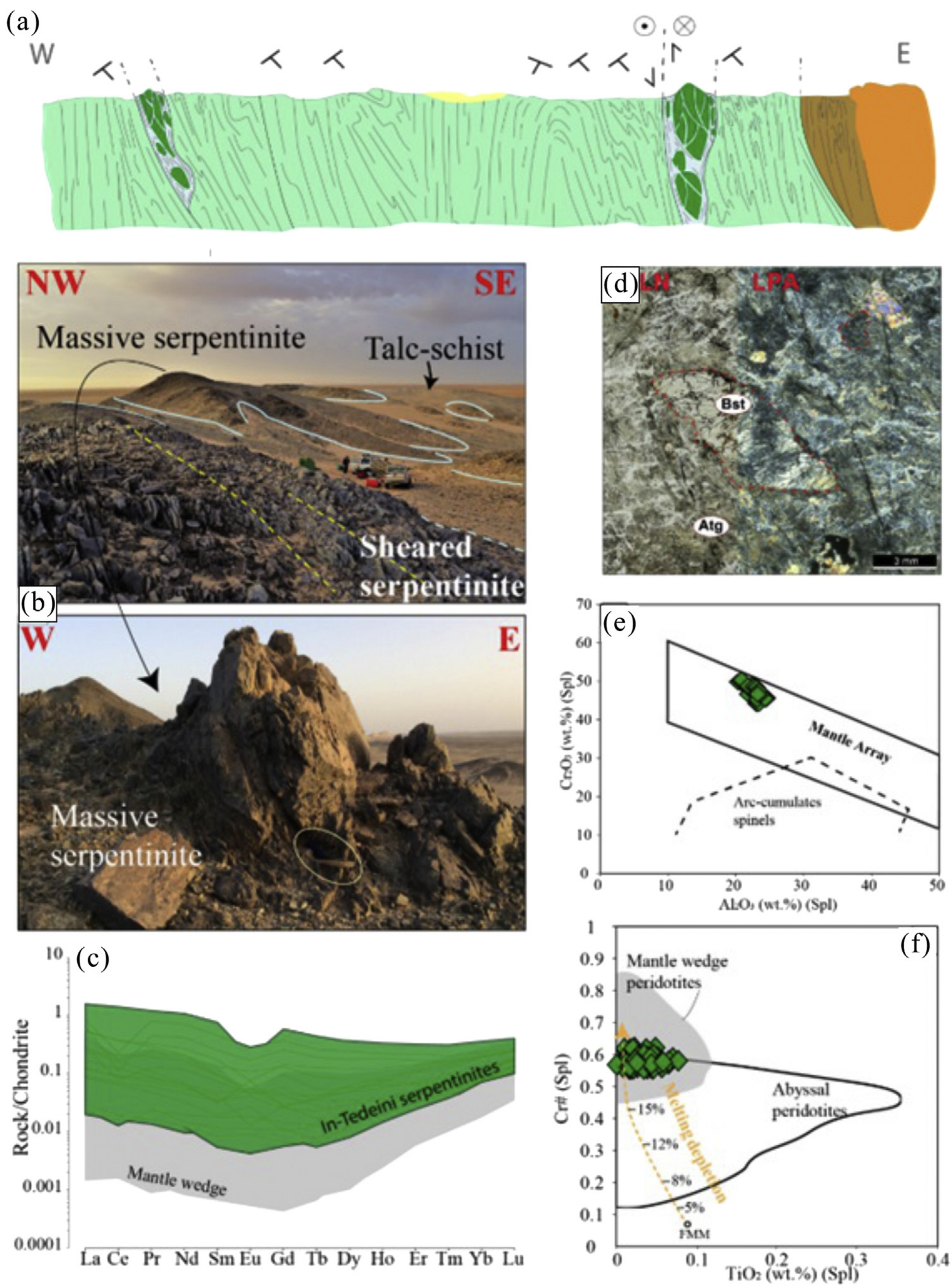

Fig. 12. (a) E-W cross-section through the North of In-Tedeini area, Pharusian belt; (b) View on the structuration of the In-Tedeini serpentinite outcrops; (c) Chondrite normalized REE patterns of the In-Tedeini serpentinites (green field). Estimated chondrite values are from Barrat et al. (2012); gray field for mantle wedge serpentinites and peridotite pattern; (d) Pseudomorphic texture of the In-Tedeini serpentinite matrix; Cr-spinel data of the serpentinites plotted on (e) Cr_2O_3 vs. Al_2O_3 contents (wt%) diagram and (f) Cr# ratio vs. TiO2 content (Wt%) diagram. FMM is Fertile Mid-ocean-ridge Mantle (Pearce and Parkinson, 1993). Modified after Ouadahi et al. (2022).

crust; or alternatively recording hydrothermal events endured by In-Tedeini serpentinites, which are compatible with island arc rock ages previously recorded in the belt (Bechiri-Benmerzoug et al., 2017 and references therein). Additionally, previous geophysical investigations in this area (*e.g.,* Brahimi et al., 2018; Liégeois, 2019; Deramchi et al., 2020) have suggested the presence of a main Pan-African suture zone that likely corresponds to the In-Tedeini-Silet shear zone instead of the boundary at 4°50’E.

4.2.2. Wadi Takalous

The Wadi Takalous area represents a key region for the understanding of the polycyclic history in central Hoggar, Algeria (Fig. 11). It comprises parts of the composite LATEA, SAA and TAI (Tazat, Assodé-Issalane) terranes (Araïbia et al., 2022 and references therein) and includes continental and oceanic rock-assemblages, bounded by multi-kilometric lithospheric submeridian shear zones (Fig. 13a).

The Neoproterozoic SAA domain consists of a strongly deformed thrust-sheet dominated crustal segment encompassing sedimentary rocks in association with serpentinized peridotites, eclogite-facies rocks, white schists and omphacite-garnet-bearing rocks, interpreted as remnants of Neoproterozoic oceanic lithosphere submitted to high- to ultra-high-pressure conditions (Fig. 13b; Black et al., 1994; Liégeois et al., 2003; Caby, 2003; Bitam-Derridj et al., 2010; Adjerid et al., 2012, 2015). The eastern margin of the LATEA superterrane is composed of a Paleoproterozoic

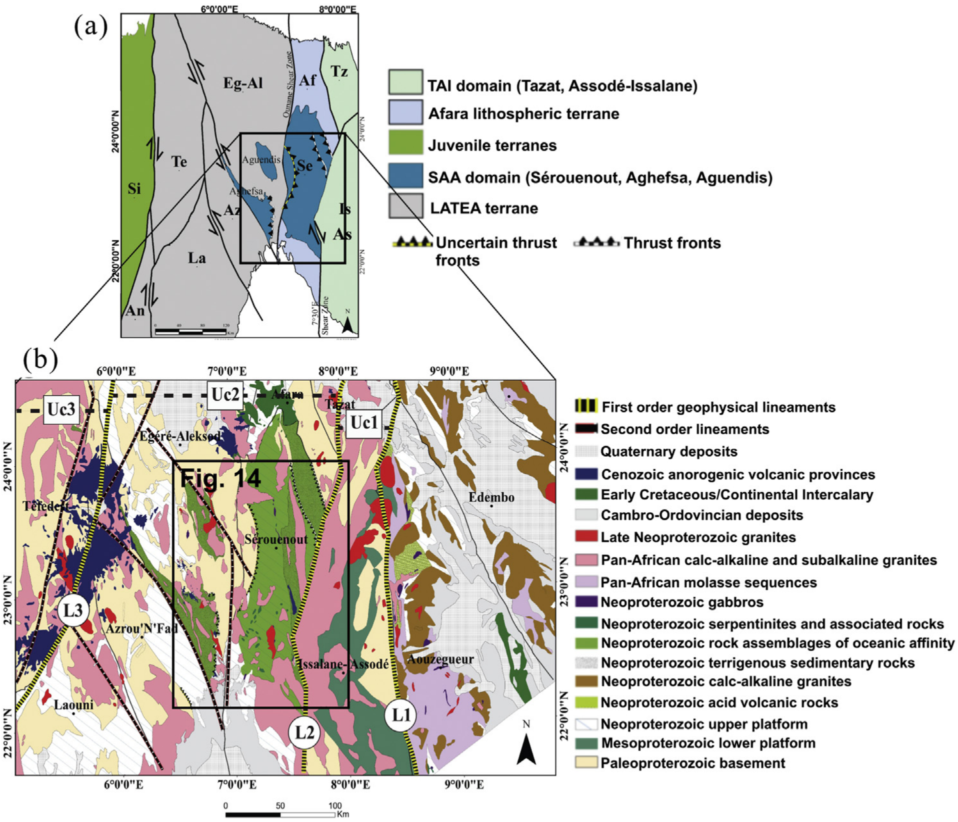

Fig. 13. (a): Sketch map of terranes from the Central Hoggar (modified after Liégeois et al., 2003) showing the location of Wadi Takalous; (b): A synthetic geological map made after Bertrand and Caby (1977), Brahimi et al. (2018) and Liégeois (2019) in agreement with the airborne gamma-ray spectrometry data. Uc1-Uc3: magnetic and gravimetric units; L1-L3: first order geophysical lineaments (after Brahimi et al., 2018) with L2 representing the major 7°30'E Shear Zone. The rectangle represents the region where ophiolite rocks crop out. The black rectangle in Fig. 13b represents Fig. 14.

granulite–amphibolite facies basement (*ca.* 2.1-1.9 Ga), interpreted as a passive margin overthrust by the SAA thrust system (Black et al., 1994; Liégeois et al., 2003). Finally, the TAI domain is known for its high-temperature metamorphism, including the occurrence of anatectic leucogranites and high-K calc-alkaline granitoids (630 and 570 Ma, respectively; Bertrand et al., 1978; Liégeois et al., 1994, 1998).

Recent advances in airborne geophysical (airborne magnetometry and gamma-ray spectrometry data) studies carried out in the Wadi Takalous area revealed the occurrence of several expressive magnetic lineaments separating the SAA and TAI domains represented by distinct magnetic and gamma spectrometric domains. Brahimi et al. (2018), using potential field methods, defined the occurrence of first-order geophysical lineaments delineating the 7°30'E dextral shear zone separating two contrasting gravimetric and magnetic units (Figs. 13b, 14); Uc1 (TAI domain) and Uc2 (LATEA and SAA domains). This observation suggests that these lineaments constitute a suture zone for the Enachat ocean as suggested by Liégeois (2019 and references therein). This generated the SAA domain and is associated with the growth of an oceanic island arc edifice and obduction of the tectonic slices of metamorphosed ophiolitic mafic-ultramafic and ultra-high-pressure rocks toward the lithospheric Afara terrane and the LATEA eastern margin.

5. Geodynamic considerations and final remarks

The overall crustal evolution of the interior orogenic belts of western Gondwana is contentious due to the strong early to late Neoproterozoic and Cambrian tectonothermal events imprinted on both the basement terrains and overlying sequences, as well as the lack of regional integrated geochrological-isotopic studies. This complex history has led to the contrasting models of orogenic development for the Borborema province, including: (i) systematic episodes of terrane assembly (*e.g.*, Santos, 1996; Brito Neves et al., 2000; Santos et al., 2010, 2017b, 2018, 2021a), (ii) a sequence of rift-drift-subduction-collision akin to the Wilson cycle (*e.g.*, Oliveira et al., 2010; Caxito et al., 2014b, 2016); (iii) widespread crustal reworking of a Paleoproterozoic stable lithosphere via intracontinental deformation (Neves, 2015, 2021); and, (iv) combined models including two or more of those above (*e.g.*, Caxito et al., 2020a, 2021a; Ganade de Araújo et al., 2021).

Over the last thirty years, several studies have provided petrological, geochemical (both elemental and isotopic), geophysical and structural arguments in favor of the existence of oceanic basins, rock sequences of which later obducted in magmatic arc-trench systems during collisional stages of the Brasiliano-Pan African orogeny (Brito Neves et al., 2014 and references therein). Indeed, terrane assembly or subduction-collision events have been proposed since the 1990's, especially with respect to the Tuareg shield (*e.g.*, Black et al., 1994; Caby et al., 2003) and in the northern and central Borborema province (*e.g.*, Santos, 1995; Fetter et al., 2003). Significant advances have been achieved by multi-method characterization of lithospheric sutures, as in the case of the Transbrasiliano lineament/shear zone in Brazil (*e.g.*, Cordani et al., 2013) and the submeridian shear zone within the Sérouenout terrane, western/central Hoggar (*e.g.*, Zerrouk et al., 2017; Araïbia et al., 2022).

The petrographic, geochemical and isotopic data of partially preserved mafic-ultramafic sequences reviewed herein provide important information necessary to unravel the history of the (cryptic) suture zones in NE Brazil and NW Africa. For instance, serpentinized rocks of the Novo Oriente Group (northern subprovince,

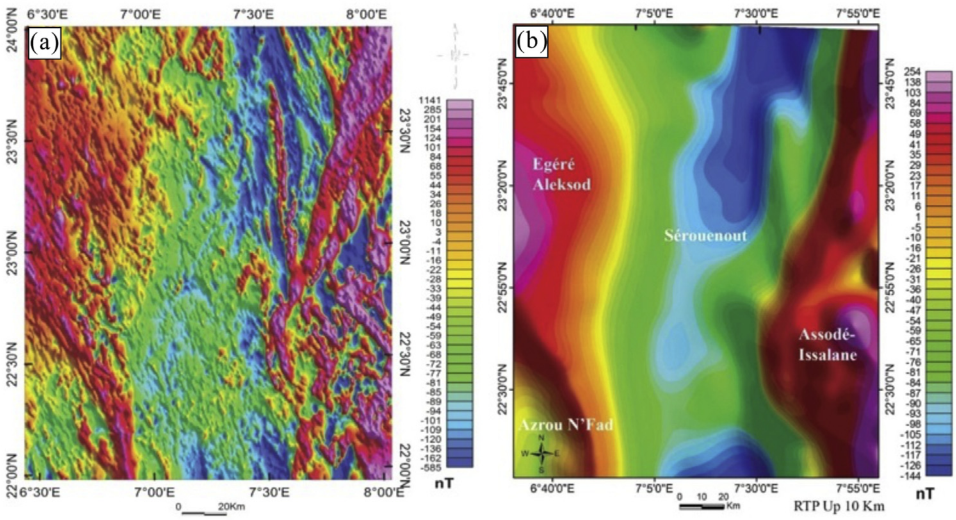

Fig. 14. Geophysical magnetic maps of the Wadi Takalous area. (a) reduced to the pole magnetic anomaly map; (b) 10 km upward continuation map of the reduced to pole map.

Borborema province) are akin to subduction-zone derived upper mantle rocks, that have experienced hydration at an oceanic-continental transition (OCT), representing a continental margin-type ophiolite (Pitombeira et al., 2017). Evidence for continental suturing in this region is reinforced by the occurrence of HP to UHP rocks in association with subduction-related granites and orthogneisses, suggesting the development of a complete accretion-collision zone that marks the Goiás-Pharusian ocean closure (Ganade de Araújo et al., 2014a, 2014b, 2016; Santos et al., 2015a; Pitombeira et al., 2021).

In west/central Hoggar, different types of early to late Neoproterozoic (∼ 870-638 Ma) juvenile to crust-related granites were identified through geochemical and geophysical (mostly gamma-spectrometric) signatures, providing evidence of primitive to evolved stages of plate-margin magmatic arcs (Caby et al., 1981; Liégeois et al., 1994, 1998; Liégeois, 2019; Béchiri-Benmerzoug et al., 2011; Zerrouk et al., 2017). They are believed to be emplaced during the island arc stage of the Silet terrane and the whole set can be interpreted as an accretionary complex tectonically extruded towards the west onto the LATEA passive margin. In addition, several geochemical and isotopic data obtained in serpentinized rocks within the In-Tedeini area (Pharusian belt) led Ouadahi et al. (2022) to propose an updated geodynamic model for the central-western Tuareg shield, in which the In-Tedeini mantle wedge serpentinites constitute key markers of a Neoproterozoic NNW-SSE oriented suture zone, partially contrasting with the available early interpretations (*e.g.*, Liégeois et al., 2003; Caby, 2003). According to Ouadahi et al. (2022), this suture would connect the western and central domains (*i.e.*, LATEA block), as the result of an east dipping intra-oceanic subduction (*e.g.*, Deramchi et al., 2020 and references therein) followed by transpressive and sinistral strike-slip tectonics related to collisional to post-collisional phases of the western Gondwana assembly, marking the last stages of the closure of the Goiás-Pharusian ocean in NW Africa.

A comprehensive overview of events documented in central Hoggar has been presented by Araïbia et al. (2022), and suggests three main evolutionary stages: (i) closure of a paleo-ocean realm that probably correlates with the Conceição Ocean in NE Brazil, implying east dipping intra-oceanic subduction (? - 650 Ma), including the development of an oceanic magmatic arc represented by the SAA domain that later evolved to a continental arc stage of the TAI terranes; (ii) amalgamation of exotic terranes and accretion of oceanic material on the eastern part of the LATEA and Afara terranes, followed by collision between the LATEA and TAI, and exhumation of HP rocks (*ca.* 650 - 630 Ma); and, (iii) post-collisional (*ca.* 630 - 575 Ma) lithospheric delamination that produced a large volume of elongated granitic plutons along regional-scale shear-zones (the HKCA plutons). In spite of the lack of correlative ophiolitic rocks in the Brazilian counterpart, a wide spectrum of ca. 630-580 Ma granitic rocks including early, syn and post collisional derived magmas have been documented and interpreted by Brito Neves et al. (2016) as a major accretionary marker that are geochemically and isotopic correlated with those described along the LATEA and TAI crustal boundary (Liégois, 2019).

In the central subprovince of the Borborema province, the real significance of the Cariris Velhos mafic-ultramafic sequences (*e.g.*, Serrote das Pedras Pretas and Bodocó suites) is still an open question. These rocks are aged at *ca.* 1.0 Ga and interpreted as arc-roots and ophiolite remnants that were possibly obducted by the early Neoproterozoic Cariris Velhos orogenesis between *ca.* 960 and 920 Ma (Brito Neves et al., 1995; Kozuch, 2003; Santos et al., 2010, 2019; Lages and Dantas 2016). Tonian ages at ca 1.0 Ga were until now only known in Cameroon as detrital sources (Toteu et al., 2006b), but a very recent national-wide geological mapping programme (Precasem) reports for the first time the initiation of early Tonian magmatism in NW Africa.

Based on the geochemical-isotopic evidence presented by Lages and Dantas (2016) for the mafic-ultramafic rocks of Bodocó and Serrote das Pedras Pretas, we suggest that such primitive magmas represent relics of an early Neoproterozoic short duration ocean, later dismembered and obducted during the compressive stages of the Cariris Velhos Orogeny (Santos et al., 2010; Van Schmus et al., 2011; Caxito et al., 2014b, 2020b). Alternative options include their development in an arc-back-arc system such as the Yamato basin (Japan sea; Sato et al., 2020) or retro-arc foreland basins, comparatively to the western Argentinian Cordillera (Capaldi et al., 2020) as a result of ancient slab roll backs or flat-slab subduction. In addition, these rocks are involved in the top-to-the-south Serra de Jabitacá nappe deformation system that bounds the allochthonous early Neoproterozoic Alto Pajeú terrane and the Archean-Paleoproterozoic autochthonous Alto Moxotó terrane (*e.g.*, Santos et al., 2017a, 2018), that in addition to the associated late Neoproterozoic eclogitic assemblage described

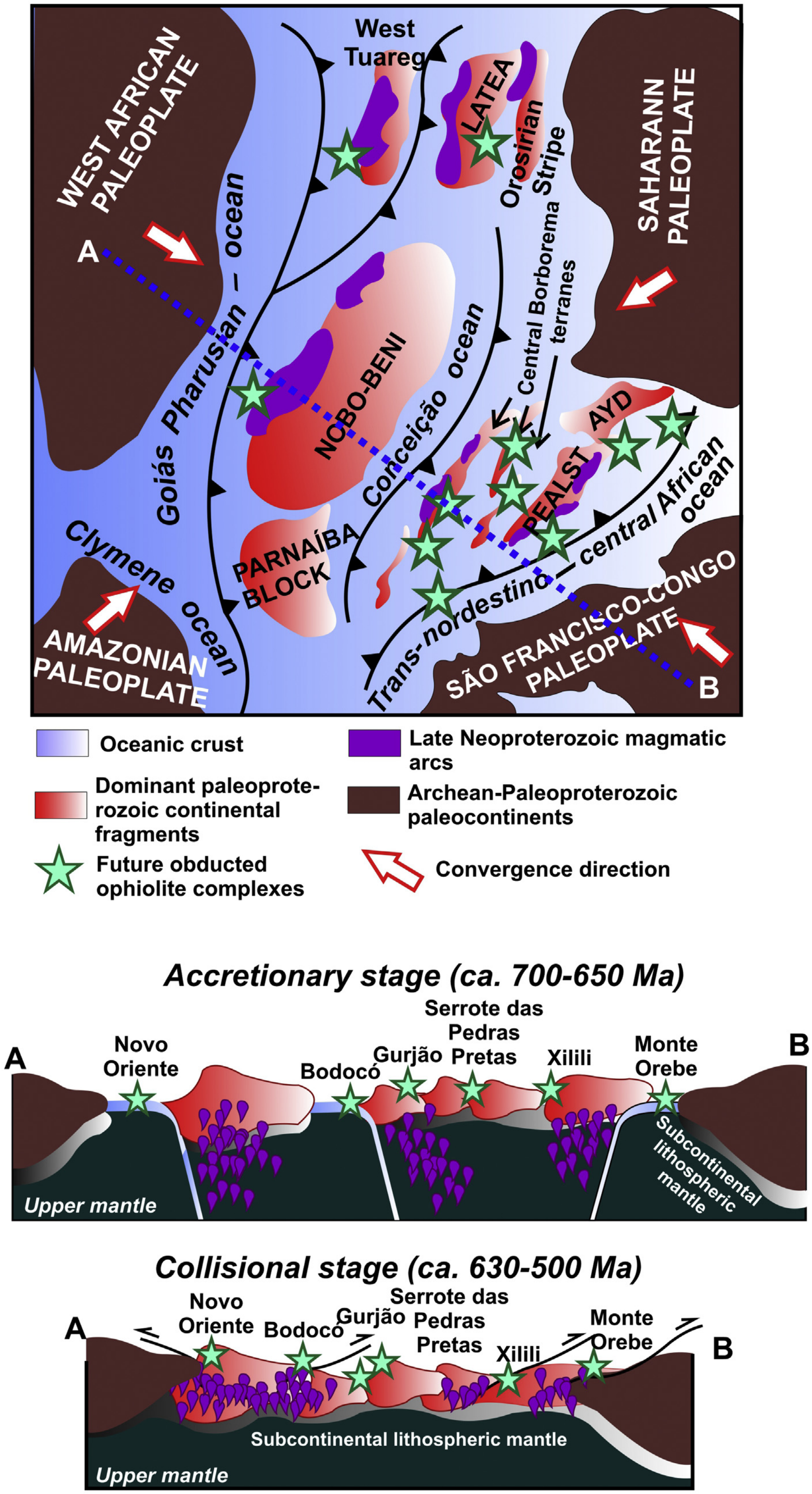

Fig. 15. Envisaged geodynamic model for the assembly of Western Gondwana with the location of the described ophiolite complexes.

by Beurlen et al. (1992) and Lages and Dantas (2016) are typical features of accretionary-collisional systems.

Although not yet investigated properly, other occurrences of mafic-ultramafic sequences in the central Borborema province are associated with strike-slip and thrust-related shear zones such as Gurjão and Sítio Xilili. Available geochemical data of both units include pristine deformed cumulatic sections as well as serpentinites and talc-schist, indicating hydratation of the upper mantle as well as metamafic rocks such as metagabbros and amphibolites that present typical signatures of N- to E-MORBs, possibly representing deformed and metamorphosed remnants of obducted upper layers of the ophiolite strata (*sensu* Furnes and Dilek, 2022 and references therein).

In Cameroon, metamafic and meta-ultramafic rocks of the Yaoundé Group are also related to nappe tectonics, representing markers of continental collision episodes between the Congo-São Francisco Craton and different blocks and dispersed microcontinents during the Brasiliano/Pan-African Orogeny (Oliviera et al., 2006; Van Schmus et al., 2008; Toteu et al., 2022). Equivalent of the Canindé rocks of the Sergipano belt in NE Brazil, the Yaoundé Group records oceanic crust consumption as well as a complete spectrum of arc-related to syn-collisional granites marking the closure of the Transnordestino-Central African oceanic basin (Caxito et al., 2020a and references therein). This ocean and its closure history is considered an equivalent of the Goiás-Pharusian ocean further south bounding the São Francisco-Congo craton and minor microcontinents/blocks in the north such as the Pernambuco-Alagoas superterrane (Brito Neves and da Silva Filho, 2019).

Considering a broader scenario, we suggest the existence of extensive oceanic realms developed after the break-up of the Rodinia supercontinent (Fig. 15). Despite the poor preservation, the association of the described complexes is generally associated with continental-scale shear zones that are herein interpreted as the record of oceanic basin closure such as the Goiás-Pharusian and Transnordestino-Central African oceans as proposed by Caxito et al. (2020a, 2021a). The available geochronological dataset indicates that the major accretionary phases took place between *ca.* 750 and 650 Ma followed by collisional events in the *ca.* 630-500 Ma interval (Caxito et al., 2020a, 2021a and references therein). During this timespan, crustal growth and reworking took place in intraoceanic and continental settings followed by the welding of several ophiolitic complexes onto the continental margins of the major continents and terranes during the development of western Gondwana interior orogens. Evidence of Neoproterozoic suturing is also reinforced by several regional geophysical surveys including magnetic, gravimetric, seismic and magnetotelluric based studies (Lima et al., 2015; Correa et al., 2016; Padilha et al. 2017; Oliveira and Medeiros, 2018) and accretionary orogenesis should be considered as a plausible model to rearrange distinct crustal pieces of western Gondwana.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abdelsalam, M.G., Liegeois, J.-P., Stern, R.J., 2002. The Saharan Metacraton. J. Afr. Earth Sci. 34, 119–136. doi:10.1016/S0899-5362(02)00013-1.
Abed, H., 1983. Paléosuture à caractètes ophiolitiques du Protérozoïque supérieur dans la région de Silet, Hoggar Occidental (Algérie). PhD Thesis, Nancy University 1, France, 172p.
Accioly, A.C.A., 2000. Geologia, geoquímica e significado tectônico do Complexo Metanortosítico de Passira: província Borborema, nordeste brasileiro. PhD Thesis, São Paulo University, Brazil, 230p.
Accioly, A.C.A., Santos, C.A., 2010. Carta Geológica Folha SC-24-X-B-II Pesqueira. Recife, CPRM (Brazilian Geological Survey, SUREG Recife): Scale 1/100.000.
Adjerid, Z., Ouzegane, K., Godard, G., Bitam-Derridj, A., Kiénast, J.R., 2012. Le Sérouènout: Un fragment de lithosphère océanique subducté à haute pression, exhumé, puis granulitisé à haute température. Bull. Natl. Geol. Serv. Alger. 23 (3), 199–217.
Adjerid, Z., Godard, G., Ouzegane, K., 2015. High-pressure whiteschists from the Ti-N-Eggoleh area (Central Hoggar, Algeria): a record of Pan-African oceanic subduction. Lithos 226, 201–216. doi:10.1016/j.lithos.2015.02.013.
Agbossoumondé, Y., Ménot, R.-P., Guillot, S., 2001. Metamorphic evolution of Neoproterozoic eclogites from south Togo (West Africa). J. Afr. Earth Sci. 33 (2), 227–244. doi:10.1016/S0899-5362(01)80061-0.
Almeida, F.F.M., Black, R., 1968. Geological comparison of northeastern South America and Western Africa. An. Acad. Bras. Ciênc. 40, 317–319.
Almeida, F.F.M., Hasui, Y., Brito Neves, B.B., Fuck, R.A., 1981. Brazilian structural provinces: an introduction. Earth Sci. Rev. 17 (1/2), 1–29. doi:10.1016/0012-8252(81)90003-9.
Almeida, G.M., Fuck, R.A., Lima, D.P.D., Dantas, E.L., 2021. Accretion tectonics in Western Gondwana highlighted by the aeromagnetic signature of the Sergipano Belt, NE Brazil. Tectonophysics 2 (5), 228742. doi:10.1016/j.tecto.2021.228742.
Amaral, L., Caxito, F.A., Pedrosa-Soares, A.C., Queiroga, G., Babinski, M., Trindade, R., Lana, C., Chemale, F., 2020. The Ribeirão da Folha ophiolite-bearing accretionary wedge (Araçuaí orogen, SE Brazil): new data for Cryogenian plagiogranite and metasedimentary rocks. Precambrian Res. 336, 105522. doi:10.1016/j.precamres.2019.105522.
Amaral, W., Santos, T.J., Ancelmi, M.F., Fuck, R.A., Dantas, E.L., Matteini, M., Moreto, C.P., 2015. 1.57 Ga protolith age of the Neoproterozoic Forquilha eclogites, Borborema Province, NE-Brazil, constrained by U–Pb, Hf and Nd isotopes. J. S. Am. Earth Sci. 58, 210–222. doi:10.1016/j.jsames.2014.10.001.
Araïbia, K., Amri, K., Amara, M., Bendaoud, A., Hamoudi, M., Pedrosa-Soares, A., Caxito, F.A., 2022. Characterizing terranes and a Neoproterozoic suture zone in Central Hoggar (Tuareg Shield, Algeria) with airborne geophysics and Landsat 8 OLI data. J. Afr. Earth Sci. 187, 104455. doi:10.1016/j.jafrearsci.2022.104455.
Arthaud, M.H., Caby, R., Fuck, R.A., Dantas, E.L., Parente, C.V., 2008. Geology of the Northern Borborema Province NE Brazil and its correlation with Nigeria. Geological Soc. Lond. Spec. Publ. 294, 49–67. doi:10.1144/SP294.4, NW Africa.
Augé, T., Joubert, M., Bailly, L., 2012. Typology of mafic–ultramafic complexes in Hoggar, Algeria: implications for PGE, chromite and base-metal sulphide mineralization. J. Afr. Earth Sci. 63, 32–47. doi:10.1016/j.jafrearsci.2011.10.002.
Barrat, J.A., Zanda, B., Moynier, F., Bollinger, C., Liorzou, C., Bayon, G., 2012. Geochemistry of CI chondrites: major and trace elements, and Cu and Zn isotopes. Geochim. Cosmochim. Acta 83, 79–92. doi:10.1016/j.gca.2011.12.011.
Basei, M.A.S., Frimmel, H.E., Campos Neto, M.C., Araujo, C.E.G., Castro, N.A., Passarelli, C.R., 2018. The tectonic history of the Southern Adamastor ocean based on a correlation of the Kaoko and Dom Feliciano Belts. Reg. Geol. Rev. 63–85. doi:10.1007/978-3-319-68920-3_3.
Béchiri-Benmerzoug, F., Liégeois, J.P., Bonin, B., Azzouni-Sekkal, A., Bechiri, H., Kheloui, R., Matukov, D.I., Sergeev, S.A., 2011. The plutons from the cryogenian Iskel composite oceanic island arc (Hoggar, Tuareg Shield, Algeria): U-Pb on zircon SHRIMP geochronology, geochemistry and geodynamical setting. In: Proceedings of the Hutton Symposium on Granites and Related Rocks, 7, Spain, p. 17 Annals.
Bechiri-Benmerzoug, F., Bonin, B., Bechiri, H., Khéloui, R., Talmat-Bouzeguela, S., Bouzid, K., 2017. Hoggar geochronology: a historical review of published isotopic data. Arab. J. Geosci. 10, 351. doi:10.1007/s12517-017-3134-6.
Bertrand, J.M.L., 1974. Evolution polycyclique des gneiss du Preecamb-rien de l'Aleksod (Hoggar central, Sahara algeerien). In: Aspects structuraux, peetrologiquee, geeochimiques et geeochronologiques. Centre National de la Recherche Scientifique, Paris, France, p. 350 Seerie Geeologique 19.
Bertrand, J.M., Caby, R., 1978. Geodynamic evolution of the Pan-African orogenic belt: a new interpretation of the Hoggar shield (Algerian Sahara). Geol. Rundsch. 67, 357–388. doi:10.1007/BF01802795.
Bertrand, J.M., Caby, R., 1977. Carte geeologique du Hoggar, Algerie. Direction des Mines et de la Geeologie, SONAREM, eechelle1:1 000 000, 2 sheets.
Bertrand, J.M., Caby, R., Ducrot, J., Lancelot, J., Moussine-Pouch-kine, A., Saadallah, A., 1978. The late Pan-African ensialic foldbelt of eastern Hoggar (Algeria): geology, structural development, U/Pb geochronology, tectonic implications for the Hoggar Shield. Precambrian Res. 7, 349–376. doi:10.1029/TC005i007p00955.
Beurlen, H., Silva Filho, A.F., Guimarães, I.P., Brito, S.A., 1992. Proterozoic C-type eclogites hosting unsual Ti-Fe±Cr±Cu mineralization in Northeastern Brazil. Precambrian Res. 58, 195–214. doi:10.1016/0301-9268(92)90119-9.

Beurlen, H., Villarroel, H.S., 1990. Petrografia de duas ocorrências de provável eclogito em Bodocó e Floresta no estado de Pernambuco, Brasil. Braz. J. Geol. 20, 111–121. doi:10.25249/0375-7536.1990111121.

Bitam-Derridj, A., Ouzegane, K., Adjerid, Z., Godard, G., Kiénast, J.R., 2010. Les éclogites granulitisées de Ti-N-Eggoleh (terrane du Sérouënout, Hoggar central): étude métamorphique et conséquence géodynamique. Bull. Natl. Geol. Serv. Alger. 21 (2), 117–136.

Black, R., Latouche, L., Liégeois, J.P., Caby, R., Bertrand, J.M., 1994. Pan-African displacedterranes in the Targui shield (Central Sahara). Geology 22, 641–644. doi: 10.1130/0091-7613(1994)022%3C0641:PADTIT%3E2.3.CO;2

Blades, M.L., Collins, A.S., Foden, J., Payne, J.L., Stüwe, K., Abu-Alam, T., Makroum, F., Hassan, M., 2021. Age and hafnium isotope evolution of Sudanese Butana and Chad illuminates the Stenian to Ediacaran evolution of the south and east Sahara. Precambrian Res. 362, 106323. doi:10.1016/j.precamres.2021.106323, 1-24.

Bosch, D., Bruguier, O., Caby, R., Buscail, F., Hammor, D., 2016. Orogenic development of the Adrar des Iforas (Tuareg Shield, NE Mali): new geochemical and geochronological data and geodynamic implications. J. Geodyn. 96, 104–130. doi:10.1016/j.jog.2015.09.002.

Bouchachi, M.A., 1993. Géologie de la région Timgaouine-Abankor (Hoggar, Algérie). Caractérisation géochimique du paléomagmatisme du bassin d'Abankor et implications géodynamiques. PhD Thesis, University of Paris, France, 168p.

Boukhalfa, L., 1987. Diversité et signification géodynamique des complexes ultrabasiques/basiques d'âge protérozoïque supérieur du rameau oriental pharusien de la chaîne panafricaine (Hoggar, Algérie). PhD Thesis, University of Nancy 1, France, 339p.

Boukhalfa, L., 2002. Les formations volcano-sédimentaires néoprotérozoïques de la branche orientale de la chaîne pharusienne (Hoggar occidental, Algérie): lithologie et géochimie. Mém. Serv. Géol. Algér. 11, 9–31.

Bouyo Houketchang, M., Toteu, S.F., Deloule, E., Penaye, J., Van Schmus, W.R., 2009. U-Pb and Sm-Nd dating of high-pressure granulites from Tcholliré and Banyo regions: Evidence for a Pan-African granulite facies metamorphism in northcentral Cameroon. J. Afr. Earth Sci. 54, 144–154. doi:10.1016/j.jafrearsci.2009.03.013.

Bouyo Houketchang, M., Penaye, J., Barbey, P., Toteu, S.F., Wandji, P., 2013. Petrology of high-pressure granulite facies metapelites and metabasites from Tcholliré and Banyo regions: Geodynamic implication for the Central African Fold Belt (CAFB) of north-central Cameroon. Precambrian Res. 224, 412–433. doi:10.1016/j.precamres.2012.09.025.

Bouyo Houketchang, M., Penaye, J., Njel, U.O., Moussango, I.A.P., Sep, N.J.P., Nyama, A.B., Wassouo, W.J., Abaté, E.J.M., Yaya, F., Mahamat, A., Ye, H., Wu, F., 2016. Geochronological, geochemical and mineralogical constraints of emplacement depth of TTG suite from the Sinassi Batholith in the central African Fold belt (CAFB) of northern Cameroon: implications for tectonomagmatic evolution. J. Afr. Earth Sci. 116, 9–41. doi:10.1016/j.jafrearsci.2015.12.005.

Brahimi, S., Liégeois, J.P., Ghienne, J.F., Munschy, M., Bourmatte, A., 2018. The Tuareg shield terranes revisited and extended towards the northern Gondwana margin: magnetic and gravimetric constraints. Earth Sci. Rev. 185, 572–599. doi:10.1016/j.earscirev.2018.07.002.

Brito Neves, B.B. 1975. Regionalização geotectônica do Precambriano nordestino. PhD Thesis, São Paulo University, Brazil, 198p.

Brito Neves, B.B., Fuck, R.A., Pimentel, M.M., 2014. The Brasiliano collage in South America: a review. Braz. J. Geol. 44 (3), 493–518. doi:10.5327/Z2317-4889201400030010.

Brito Neves, B.B., Santos, E.J., Fuck, R.A., Santos, L.C.M.L., 2016. A preserved early Ediacaran magmatic arc at the northernmost portion of the Transversal Zone central subprovince of the Borborema Province, Northeastern South America. Braz. J. Geol. 46 (04). doi:10.1590/2317-4889201620160004.

Brito Neves, B.B., Santos, E.J., Van Schmus, W.R., 2000. Tectonic history of the Borborema Province, northeastern Brazil. In: Cordani, U., Milani, E.J., Thomaz Filho, A., Campos, D.A. (Eds.), Proceedings of the Thirty-first International Geological Congress, Rio de Janeiro, Brazil, pp. 151–182 Tectonic Evolution of South America.

Brito Neves, B.B., da Silva Filho, A.F., 2019. Superterreno Pernambuco-Alagoas (PEAL) na Província Borborema: ensaio de regionalização tectônica. Geol. USP Sér. Cient. 19 (2), 3–28. doi:10.11606/issn.2316-9095.v19-148257.

Brito Neves, B.B., Spröesser, W.M., Petronilho, L.A., Souza, S.L., 2013. Contribuição à Geologia e à Geocronologia do Terreno Rio Capibaribe (TRC, Província Borborema). Geol. USP Sér. Cient. 13 (2), 97–122. doi:10.5327/Z1519-874X2013000200006.

Brito Neves, B.B., Van Schmus, W.R., Fetter, A.H., 2002. North-western Africa-North-eastern Brazil. Major tectonic links and correlation problems. J. Afr. Earth Sci. 34, 275–278. doi:10.1016/S0899-5362(02)00025-8.

Brito Neves, B.B., Van Schmus, W.R., Santos, L.C.M.L., 2020. Alto Moxotó Terrane, a fragment of Columbia supercontinent in the Transversal Zone interior: Borborema Province, Northeast Brazil. Braz. J. Geol. 50 (2). doi:10.1590/2317-4889202020190077.

Brito Neves, B.B., Van Schmus, W.R., Santos, E.J., Campos Neto, M.C., Kozuch, M., 1995. O evento Cariris Velhos na Província Borborema: integração de dados, implicações e perspectivas. Revista Brasileira de Geociências 25 (4), 279–296.

Brown, M.T., Fuck, R.A., Dantas, E.L., 2020a. Isotopic age constraints and geochemical results of disseminated ophiolitic assemblage from Neoproterozoic mélange, central Brazil. Prec. Res. 339, 105581. doi:10.1016/j.precamres.2019.105581.

Brown, M.T., Fuck, R.A., Dantas, E.L., 2020b. Provenance of neoproterozoic ophiolitic mélange sediments in the brasilia belt, central Brazil. J. S. Am. Earth Sci. 104, 102825. doi:10.1016/j.jsames.2020.102825.

Caby, R., 1989. Precambrian terranes of Benin, Nigeria and Northeast Brazil and the late Proterozoic South Atlantic fit. In: Dallmeyer R.D. (Ed.). Terranes in the Circum-Atlantic Paleozoic Orogens. Special Paper Geological Society of America, 230, pp. 145-158. doi: 10.1130/SPE230-p145

Caby, R., 1994. Precambrian coesite from northern Mali: first record and implications for plate tectonics in the Trans-Saharan segment of the Pan African belt. Eur. J. Mineral. 6 (2), 235–244.

Caby, R., 2003. Terrane assembly and geodynamic evolution of central western Hoggar: a synthesis. J. Afr. Earth Sci. 37 (3), 133–159. doi:10.1016/j.jafrearsci.2003.05.003.

Caby, R., Bertrand, J.M., Black, R., 1981. Pan-African ocean in the Hoggar-Iforas segment, Central Sahara. In: Developments in Precambrian Geology, 4. Elsevier, pp. 407–434. doi:10.1016/S0166-2635(08)70021-5.

Caby, R., Monié, P., 2003. Neoproterozoic subductions and differential exhumation of Western Hoggar (Southwest Algeria): new structural, petrological and geochronological evidence. J. Afr. Earth Sci. 37 (3-4), 269–293. doi:10.1016/j.jafrearsci.2003.01.001.

Caby, R., Sial, A.N., Arthaud, M., Vauchez, A., 1991. Crustal evolution and the Brasiliano orogeny in Northeast Brazil. In: The West African Orogens and Circum-Atlantic Correlatives. Part of the IGCP-Project 233 book series (IGCP 233), pp. 373–397. doi:10.1007/978-3-642-84153-8_16.

Capaldi, T.N., Horton, B.K., McKenzie, N.R., Mackaman-Lofland, C., Stockli, D.F., Ortiz, G., Alvarado, P., 2020. Neogene retroarc foreland basin evolution, sediment provenance, and magmatism in response to flat slab subduction, Western Argentina. Tectonics. 39 (7). doi:10.1029/2019TC005958.

Carvalho, M.J., Oliveira, E.P., Dantas, E.L., McNaughton, N., 2005. Evolução tectónica do Domínio Marancó - Poço redondo: Registro das orogeneses cariris Velhos e Brasiliana na margem norte da Faixa Sergipana. Anais da Sociedade Entomológica do Brasil, Short Papers – III Simpósio sobre o Cráton São Franscisco, pp. 204-207.

Castaing, C., Feybesse, J.L., Thiéblemont, T.C., Chevremont, P., 1994. Paleogeographical reconstructions of the Pan-African/Brasiliano orogen: closure of an oceanic domain or intracontinental convergence between major blocks. Precambrian Res. 69, 327–344. doi:10.1016/0301-9268(94)90095-7.

Cavalcante, J.C., Vasconcelos, A.M., Medeiros, M.F., Paiva, I.P., Gomes, F.E.M., Cavalcante, S.N., Cavalcante, J.E., Melo, A.C.R., Duarte Neto, V.C., Benevides, H.C., 2003. Mapa Geológico do Estado do Ceará. Escala 1:500.000. Serviço Geológico do Brasil, Fortaleza. CPRM.

Cawood, P.A., Buchan, C., 2007. Linking accretionary orogenesis with supercontinent assembly. Earth Sci. Rev. 82, 217–256. doi:10.1016/j.earscirev.2007.03.003.

Cawood, P.A., Kröner, A., Collins, W.J, Kusky, T.M., Mooney, W.D., Windley, B.F., 2009. In: Accretionary Orogens through Earth History, 318. Geological Society London, Special Publications, pp. 1–36. doi:10.1144/sp318.1.

Cawood, P.A., Martin, E.L., Murphy, J.B., Pisarevsky, S.A., 2021. Gondwana's interlinked peripheral orogens. Earth Planet. Sci. Lett. 568, 117057. doi:10.1016/j.epsl.2021.117057.

Cawood, P.A., Suhr, G., 1992. Generation and obduction of ophiolites: constraints from the Bay of Islands Complex, western Newfoundland. Tectonics 11, 884–897. doi:10.1029/92tc00471.

Caxito, F.A., Basto, C.F., Santos, L.C.M.L., Dantas, E.L., Medeiros, V.C., Dias, T.G., Barrote, V., Hagemann, S., Alkmim, A.R., Lana, C., 2021a. Neoproterozoic magmatic arc volcanism in the Borborema Province, NE Brazil: possible flare-ups and lulls and implications for western Gondwana assembly. Gondwana Res. 92, 1–25. doi:10.1016/j.gr.2020.11.015.

Caxito, F.A., Hartmann, L.A., Heilbron, M., Pedrosa-Soares, A.C., Bruno, H., Basei, M.A., Chemale, F., 2022. Multi-proxy evidence for subduction of the Neoproterozoic Adamastor Ocean and Wilson cycle tectonics in the South Atlantic Brasiliano Orogenic System of Western Gondwana. Precambrian Res. 376, 106678. doi:10.1016/j.precamres.2022.106678.

Caxito, F.A., Heilbron, M., Valeriano, C.M., Bruno, H., Pedrosa-Soares, A., Alkmim, F.F., Basei, M.A.S., 2021b. Integration of elemental and isotope data supports a Neoproterozoic Adamastor ocean realm. Braz. J. Geol. 44, 493–518. doi:10.7185/geochemlet.2106.

Caxito, F.A., Santos, L.C.M.L., Ganade de Araújo, C.E., Bendaoud, A., Fettous, E.-H., Bouyo Houketchang, M., 2020a. Toward an integrated model of geological evolution for NE Brazil–NW Africa: the Borborema Province and its connections to the Trans-Saharan (Benino-Nigerian and Tuareg shields) and Central African orogens. Braz. J. Geol. 50 (2), 1–38. doi:10.1590/2317-4889202020190122.

Caxito, F.A., Santos, L.C.M.L., Uhlein, A., Dantas, E.L., Alkmim, A.R., Lana, C., 2020b. New U-Pb (SHRIMP) and first Hf isotope constraints on the Tonian (1000-920 Ma) Cariris Velhos event, Borborema Province, NE Brazil. Braz. J. Geol. 50 (2). doi:10.1590/2317-4889202020190082.

Caxito, F.A., Uhlein, A., Dantas, E.L., Stevenson, R., Salgado, S.S., Dussin, I.A., Sial, A.N., 2016. A complete wilson cycle recorded within the Riacho Do Pontal Orogen, NE Brazil: implications for the Neoproterozoic evolution of the Borborema Province at the heart of West Gondwana. Precambrian Res. 282, 97–120. doi:10.1016/j.precamres.2016.07.001.

Caxito, F.A., Uhlein, A., 2013. Arcabouço tectônico e estratigráfico da Faixa Riacho do Pontal, divisa Pernambuco-Piaui-Bahia. Geonomos 21 (2), 19–37. doi:10.18285/geonomos.v21i2.269.

Caxito, F.A., Uhlein, A., Stevenson, R., Uhlein, G.J., 2014a. Neoproterozoic oceanic crust remnants in Northeast Brazil. Geology 42 (5), 387–390. doi:10.1130/g35479.1.

Caxito, F.A., Uhlein, A., Dantas, E.L., 2014b. The Afeição augen-gneiss Suite and the record of the Cariris Velhos Orogeny (1000–960 Ma) within the Riacho do Pontal fold belt, NE Brazil. J. S. Am. Earth Sci. 51, 12–27. doi:10.1016/j.jsames.2013.12.012.

Chikhaoui, M., Dupuy, C., Dostal, J., 1980. Geochemistry and petrogenesis of late pro-

terozoic volcanic rocks from north-western Africa. Contrib. Mineral. Petrol. 73 (4), 375–388. doi:10.1007/BF00376630.
Coleman, R.G., Lee, D.E., Beatty, L.B., Brannok, W.W., 1965. Eclogites and eclogites: their differences and similarities. GSA Bull. 76 (5), 483–508. doi:10.1130/0016-7606(1965)76[483:EAETDA]2.0.CO;2.
Coleman, R.G., 2014. The Ophiolite Concept Evolves, in: 'PERSPECTIVE. Elements 10 (2), 82–84. doi:10.2113/gselements.10.2.82.
Collins, A.S., Pisarevsky, S.A., 2005. Amalgamating eastern Gondwana: the evolution of the Circum-Indian Orogens. Earth Sci. Rev. 71 (3-4), 229–270. doi:10.1016/j.earscirev.2005.02.004.
Coney, P., Jones, D., Monger, J., 1980. Cordilleran suspect terranes. Nature 288, 329–333. doi:10.1038/288329a0.
Cordani, U.G., Pimentel, M.M., Araújo, C.E.G., Fuck, R.A., 2013. The significance of the Transbrasiliano-Kandi tectonic corridor for the amalgamation of West Gondwana. Braz. J. Geol. 43 (3), 583–597. doi:10.5327/Z2317-48892013000300012.
Correa, R.T., Vidotti, R.M., Oksum, E., 2016. Curie surface of Borborema Province, Brazil. Tectonophysics 679, 73–87. doi:10.1016/j.tecto.2016.04.037.
D'el-Rey Silva, L.J.H., 1999. Basin infilling in the southern-central part of the Sergipano Belt, NE Brazil, and implications for the tectonic evolution of the Pan-African/Brasiliano cratons and Neoproterozoic sedimentary cover. J. S. Am. Earth Sci. 12, 453–470. doi:10.1016/S0895-9811(99)00034-6.
Dantas, E.L., Souza, Z.S., Wernick, E., Hackspacher, P.C., Martin, H., Xiaodong, D., Li, J-W., 2013. Crustal growth in the 3.4–2.7 Ga São José de Campestre Massif, Borborema Province, NE Brazil. Precambrian Res. 227, 120–156. doi:10.1016/j.precamres.2012.08.006.
Davison, I., Santos, R.A., 1989. Tectonic evolution of the Sergipano Fold Belt, NE Brazil, during the Brasiliano orogeny. Precambrian Res. 45 (4), 319–342. doi:10.1016/0301-9268(89)90068-5.
de Wit, M.J., Brito Neves, B.B., Trouw, R.A.J., Pankhurst, R.J., 2008a. In: Pre-Cenozoic Correlations Across the South Atlantic Region: (The Ties That Bind), 294. Geological Society, London, Special Pub, pp. 1–8. doi:10.1144/SP294.1.
de Wit, M.J., Stankiewicz, J., Reeves, C., 2008b. In: Restoring Pan-African-Brasiliano connections: more Gondwana control, less Trans-Atlantic corruption, 294. Geological Society, London, Special Publications, pp. 399–412. doi:10.1144/SP294.20.
DeBari, S.M., Coleman, R.G., 1989. Examination of the deep levels of an island arc: Evidence from the Tonsina Ultramafic-Mafic Assemblage, Tonsina. Alsk. J. Geophys. Res. Solid Earth 94 (B4), 4373–4391. doi:10.1029/JB094iB04p04373.
Deramchi, A., Bouzid, A., Bendaoud, A., Ritter, O., Hamoudi, M., Cruces-Zabala, J., Meqbel, N., Boukhalfa, Z., Boughchiche, S.S., Abtout, A., Boukhlouf, W., 2020. Neoproterozoic amalgamation and Phanerozoic reactivation of Central/Western Hoggar (Southern Algeria, Tuareg Shield) lithosphere imaging using magnetotelluric data. J. Geodyn. 139, 101764. doi:10.1016/j.jog.2020.101764.
Deschamps, F., Godard, M., Guillot, S., Hattori, K., 2013. Geochemistry of subduction zone serpentinites: a review. Lithos 178, 96–127. doi:10.1016/j.lithos.2013.05.019.
Dilek, Y., Furnes, H., 2011. Ophiolite genesis and global tectonics: geochemical and tectonic fingerprinting of ancient oceanic lithosphere. Bulletin 123 (3-4), 387–411. doi:10.1130/B30446.1.
Djerossem, F., Zeh, A., Isseini, M., Vanderhaeghe, O., Berger, J., Ganne, J., 2021. U-Pb-Hf isotopic systematics of zircons from granites and metasediments of southern Ouaddaï (Chad), implications for crustal evolution and provenance in the Central Africa Orogenic Belt. Precambrian Res. 361, 1–15. doi:10.1016/j.precamres.2021.106233, 106233.
Dupont, P.L., Lapierre, H., Gravelle, M., Bertrand, J.M., 1987. Caractérisation du magmatisme Protérozoïque supérieur en Afrique de l'ouest et implications géodynamiques: des rifts intracratoniques au Panafricain? Can. J. Earth Sci. 24 (1), 96–109. doi:10.1139/e87-008.
Ferreira, A.C.D., Dantas, E.L., Fuck, R.A, Nedel, I.M., 2020. Arc accretion and crustal reworking from late Archean to Neoproterozoic in Northeast Brazil. Sci. Rep. 10, 7855. doi:10.1038/s41598-020-64688-9.
Fetter, A.H., Santos, T.J.S., Van Schmus, W.R., Hackspacher, P.C., Brito Neves, B.B., Arthaud, M.H., Nogueira, J.A., Wernick, E., 2003. Evidence for Neoproterozoic continental arc magmatism in the Santa Quitéria Batholith of Ceará State, NW Borborema Province, NE Brazil: implications for the Assembly of West Gondwana. Gondwana Res. 6 (2), 265–273. doi:10.1016/S1342-937X(05)70975-8.
Furnes, H., de Wit, M., Dilek, Y., 2014. Four billion year of ophiolite reveal secular trends in oceanic crust formation. Geosci. Front. 5, 571–603. doi:10.1016/j.gsf.2014.02.002.
Furnes, H., Dilek, Y., de Wit, M., 2015. Precambrian greenstone sequences represent different ophiolite types. Gondwana Res. 27 (2), 649–685. doi:10.1016/j.gr.2013.06.004.
Furnes, H., Dilek, Y., 2022. Archean versus Phanerozoic oceanic crust formation and tectonics: Ophiolites through time. Geosyst. Geoenviron. 1 (1), 100004. doi:10.1016/j.geogeo.2021.09.004.
Ganade de Araújo, C.E., Cordani, G.U., Agbossoumounde, Y., Caby, R., Basei,, M.A., Weinberg, R.F., Sato, K., 2016. Tightening-up NE Brazil and NW Africa connections: New U–Pb/Lu–Hf zircon data of a complete plate tectonic cycle in the Dahomey belt of the West Gondwana Orogen in Togo and Benin. Precambrian Res. 274, 24–42. doi:10.1016/j.precamres.2016.01.032.
Ganade de Araujo, C.E., Cordani, U.G., Basei, M.A.S., Castro, N.A., Sato, K., Sproesser, W.M., 2012. U–Pb detrital zircon provenance of metasedimentary rocks from the Ceará Central and Médio Coreaú Domains, Borborema Province, NE-Brazil: tectonic implications for a long-lived Neoproterozoic active continental margin. Precambrian Res. 206-207, 36–51. doi:10.1016/j.precamres.2012.02.021.
Ganade de Araújo, C.E., Pinéo, T.R.G., Caby, R., Costa, F.G., Cavalcante, J.C., Vasconcelos, A.M., Rodrigues, J.B., 2010. Provenance of the Novo Oriente Group, southwestern Ceará Central Domain, Borborema Province (NE-Brazil): a dismembered segment of a magma-poor passive margin or a restricted rift-related basin? Gondwana Res. 18 (2-3), 497–513. doi:10.1016/j.gr.2010.02.001.
Ganade de Araújo, C.E., Rubatto, D., Hermann, J., Cordani, U.G., Caby, R., Basei, M.A.S., 2014a. Ediacaran 2,500-km-long synchronous deep continental subduction in the West Gondwana Orogen. Nat. Commun. 5, 5198. doi:10.1038/ncomms6198.
Ganade de Araújo, C.E., Weinberg, R.F., Caxito, F.A., Lopes, L.B.L., Tesser, L.R., Costa, I.S., 2021. Decratonization by rifting enables orogenic reworking and transcurrent dispersal of old terranes in NE Brazil. Sci. Rep. 11, 5719. doi:10.1038/s41598-021-84703-x.
Ganade de Araújo, C.E., Weinberg, R.F., Cordani, U.G., 2014b. Extruding the Borborema Province (NE-Brazil): a two-stage Neoproterozoic collision process. Terra Nova 26 (2), 157–168. doi:10.1111/ter.12084.
Gravelle, M. 1969. Recherches sur le géologie du socle précambrien de l'Ahaggar centro-occidental dans la région de Silet-Tibehaouine — Contribution à la reconnaissance géochronologique, géochimique et structurale des terrains cristallins du Sahara central. PhD Thesis, University of Paris, France, 360 p.
Grütter, H.S., Gurney, J.J., Menzies, A.H., Winter, F., 2004. An updated classification scheme for mantle-derived garnet, for use by diamond explorers. Lithos 77 (1-4), 841–857. doi:10.1016/j.lithos.2004.04.012.
Guimarães, I.P., Silva Filho, A.F., Almeida, C.N., Macambira, M.B., Armstrong, R., 2011. U–Pb SHRIMP data constraints on calc-alkaline granitoids with 1.3–1.6 Ga Nd TDM model ages from the central domain of the Borborema province, NE Brazil. J. S. Am. Earth Sci. 31 (4), 383–396. doi:10.1016/j.jsames.2011.03.001.
Haddoum, H., Choukroune, P., Peucat, J.J., 1994. Evolution of the precambrian In-Ouzzal block (Central Sahara, Algeria). Precambrian Res. 65 (1-4), 155–166. doi:10.1016/0301-9268(94)90103-1.
Hodel, F., Trindade, R.I.F., Macouin, M., Meira, V.T., Dantas, E.L., Paixão, M.A.P., Rospabé, M., Castro, M.P., Queiroga, G.N., Alkmim, A.R., Lana, C.C., 2019. A Neoproterozoic hyper-extended margin associated with Rodinia's demise and Gondwana's build-up: the Araguaia Belt, central Brazil. Gondwana Res. 66, 43–62. doi:10.1016/j.gr.2018.08.010.
Hurley, P.M., Almeida, F.F.M., Melcher, G.E., Cordani, U.G., Rand, J.R., Kawashita, K., Vandoros, P., Pinson, W.H., Fairbarn, H.W., 1967. Test of continental drift by means of radiometric ages: a pre-drift reconstruction shows matching geologic age provinces in West Africa and Northern Brazil. Science 157 (3788), 495–500. doi:10.1126/science.157.3788.495.
Irvine, T.N., Baragar, W.R.A., 1971. A guide to the chemical classification of the common volcanic rocks. Can. J. Earth Sci. 8, 523–548. doi:10.1139/e71-055.
Ishizuka, O., Geshi, N., Kawanabe, Y., Ogitsu, I., Taylor, R.N., Tuzino, T., Sakamoto, I., Arai, K., Nakano, S., 2014. Long-distance magma transport from arc volcanoes inferred from the submarine eruptive fissures offshore Izu-Oshima volcano, Izu–Bonin arc. J. Volcanol. Geotherm. Res. 285, 1–17. doi:10.1016/j.jvolgeores.2014.08.006.
Jahn, B.M., Caby, R., Monié, P., 2001. The oldest UHP eclogites of the world: age of UHP metamorphism, nature of protoliths and tectonic implications. Chem. Geol. 178, 143–158. doi:10.1016/S0009-2541(01)00264-9.
Jardim de Sá, E.F., Moraes, J.A.C., Silva, L.J.H.D.R. 1986. Tectônica tangencial na Faixa Sergipana. Anais XXXIV Congr. Bras. Geol. 3, 1246-1256.
Kalsbeek, F., Ekwueme, B.N., Penaye, J., Souza, Z.S., Thrane, K., 2013. Recognition of early and late Neoproterozoic supracrustal units in West Africa and North-East Brazil from detrital zircon geochronology. Precambrian Res. 226, 105–115. doi:10.1016/j.precamres.2012.12.006.
Kawai, T., Windley, B.F., Terabayashi, M., Yamamoto, H., Maruyama, S., Isozaki, Y., 2006. Mineral isograds and metamorphic zones of the Anglesey blueschist belt, UK: implications for the metamorphic development of a Neoproterozoic subduction-accretion complex. J. Metamorph. Geol. 24 (7), 591–602. doi:10.1111/j.1525-1314.2006.00656.x.
Kozuch, M., 2003. Isotopic and trace element geochemistry of Early Neoproterozoic gneissic and metavolcanic rocks in the Cariris Velhos orogen of the Borborema Province, Brazil, and their bearing on tectonic setting. PhD Thesis, University of Kansas, USA, 192p.
Kundu, M.O., Minyem, D., Tamen, J., Nkoumbou, C., Fuh, G.C., Tchakounté, J.N., 2022. Petrology of ophiolites of Mémel, Nsimè-Kelle and Mapan (Yaoundé Group): Evidence of the geodynamic evolution of the Pan-African orogeny in south Cameroon. J. Afr. Earth Sci. 191 (104537), 1–24. doi:10.1016/j.jafrearsci.2022.104537.
Kusky, T.M., Windley, B.F., Safonova, I., Wakita, K., Wakabayashi, J., Polat, A., Santosh, M., 2013. Recognition of ocean plate stratigraphy in accretionary orogens through Earth history: A record of 3.8 billion years of sea floor spreading, subduction, and accretion. Gondwana Res. 24 (2), 501–547. doi:10.1016/j.gr.2013.01.004.
Lages, G.A., Dantas, E.L., 2016. Floresta and Bodocó Mafic–Ultramafic Complexes, western Borborema Province, Brazil: geochemical and isotope constraints for evolution of a Neoproterozoic arc environment and retro-eclogitic hosted Ti-mineralization. Precambrian Res. 280, 95–119. doi:10.1016/j.precamres.2016.04.017.
Lages, G.A., Dantas, E.L., Oliveira, R.G., Santos, L.C.M.L., 2017. A sequência ofiolítica de Gurjão/Pb: caracterização geoquímica e isotópica, Província Borborema. In: A sequência ofiolítica de Gurjão: caracterização geoquímica e isotópica, Província Borborema. Abstract. 27° Simpósio De Geologia Do Nordeste.
Lages, G.A., Dantas, E.L., Santos, L.C.M.L., 2014. Sítio do Icó Orthogneiss, east of Transversal Zone, Borborema Province. Stenian Orthogneiss with Juvenile caracteristics. In: Proceedings of the 9th South American Symposium on Isotope Geology, p. 113.

Lages, G.A., Santos, L.C.M.L., Brasilino, R.G., Rodrigues, J.B., Dantas, E.L., 2019. Statherian-Calymmian (ca. 1.6 Ga) magmatism in the Alto Moxotó Terrane, Borborema Province, northeast Brazil: implications for within-plate and coeval collisional tectonics in West Gondwana. J. S. Am. Earth Sci. 91, 116–130. doi:10.1016/j.jsames.2019.02.003.

Liégeois, J.P., 2019. A new synthetic geological map of the tuareg shield: an overview of its global structure and geological evolution, in: Bendaoud, A., Hamimi, Z., Hamoudi, M., Djemai, S., Zoheir, B. (eds) The Geology of the Arab World - An Overview. Springer Geology. Springer, Cham. doi: 10.1007/978-3-319-96794-3_2

Liégeois, J.P., Black, R., Navez, J., Latouche, L., 1994. Early and late Pan-African orogenies in the Aïr assembly of terranes (Tuareg shield, Niger). Precambrian Res. 67 (1-2), 59–88. doi:10.1016/0301-9268(94)90005-1.

Liégeois, J.P., Latouche, L., Boughrara, M., Navez, J., Guiraud, M., 2003. The LATEA metacraton (Central Hoggar, Tuareg shield, Algeria): behaviour of an old passive margin during the Pan-African orogeny. J. Afr. Earth Sci. 37, 161–190. doi:10.1016/j.jafrearsci.2003.05.004.

Liégeois, J.P., Navez, J., Hertogen, J., Black, R., 1998. Contrasting origin of post-collisional high-K calc-alkaline and shoshonitic versus alkaline and peralkaline granitoids. Lithos 45, 1–28. doi:10.1016/S0024-4937(98)00023-1.

Lima, H.M., Pimentel, M.M., Fuck, R.A., Santos, L.C.M.L., Dantas, E.L., 2018. Geochemical and detrital zircon geochronological investigation of the metavolcanosedimentary Araticum complex, Sergipano fold belt: Implications for the evolution of the Borborema Province, NE Brazil. J. S. Am. Earth Sci. 86, 176–192. doi:10.1016/j. jsames.2018.06.013.

Lima, H.M., Pimentel, M.M., Santos, L.C.M.L., Dantas, E.L., 2019. Isotopic and geochemical characterization of the metavolcano-sedimentary rocks of the Jirau do Ponciano Dome: A structural window to a Paleoproterozoic continental arc root within the Southern Borborema Province, Northeast Brazil. J. S. Am. Earth Sci. 90, 54–69. doi:10.1016/j.jsames.2018.12.002.

Lima, M.V.A.G., Berrocal, J., Soares, J.E.P., Fuck, R.A., 2015. Deep seismic refraction experiment in northeast Brazil: New constraints for Borborema province evolution. J. S. Am. Earth Sci. 58, 335–349. doi:10.1016/j.jsames.2014.10.007.

Lira Santos, G., Santos, L.C.M.L., Araújo Neto, J.F., 2022. Um olhar sobre os minerais de asbesto: aspectos históricos e geológicos e estudo de caso do Sítio Xilili (PE), porção central da Província Borborema. Rev. Geocienc. UNESP 41 (1), 63–73. doi:10.5016/geociencias.v41i1.16327.

Manas, M., Mukherjee, B.K., Dubey, R.K., 2021. Non-silicate needles and metals in peridotites from Himalayan ophiolite, Western Ladakh, India: evidence of deep Earth origin. Int. J. Earth Sci. (Geol. Rundsch) 110, 2849–2862. doi:10.1007/s00531-021-02086-w.

Mariano, G., Neves, S.P., Da Silva, A.F., Guimarães, I.P., 2001. Diorites of the high-K cale-alkalic association: geochemistry and Sm-Nd data and implications for the evolution of the Borborema province, northeast Brazil. Int. Geol. Rev. 43 (10), 921–929.

Massuda, A.J., Hartmann, L.A., Queiroga, G.N., Castro, M.P.de, Leandro, C.G., Savian, J.F., 2020. Mineralogical evolution of the northern Bossoroca ophiolite, São Gabriel terrane. Braz. J. Geol. 50. doi:10.1590/2317-4889202020190120.

Moraes, J.F.S., 1992. Petrologia das rochas máficas-ultramáficas da seqüência vulcanosedimentar de Monte Orebe, PE-PI. Federal University of Bahia, Master Thesis, Salvador, 98 pg.

Nascimento, M.A.L., Galindo, A.C., Medeiros, V.C., 2015. Ediacaran to Cambrian magmatic suites in the Rio Grande do Norte domain, extreme Northeastern Borborema Province (NE of Brazil): current knowledge. J. S. Am. Earth Sci. 58, 281–299. doi:10.1016/j.jsames.2014.09.008.

Ndjigui, P.-D., Bilong, P., Bitom, D., 2009. Negative cerium anomalies in the saprolite zone of serpentinite lateritic profiles in the Lomié ultramafic complex, South-East Cameroon. J. Afr. Earth Sci. 53, 59–69. doi:10.1016/j.jafrearsci.2008.09.002.

Ndjigui, P.D., Bilong, P., 2010. Platinum-group elements in the serpentinite lateritic mantles of the Kongo–Nkamouna ultramafic massif (Lomié region, South-East Cameroon). J. Geochem. Explor. 107, 63–76. doi:10.1016/j.gexplo.2010.06.008.

Neves, S.P., 2015. Constraints from zircon geochronology on the tectonic evolution of the Borborema Province (NE Brazil): widespread intracontinental Neoproterozoic reworking of a Paleoproterozoic accretionary orogen. J. S. Am. Earth Sci. 58, 150–164. doi:10.1016/j.jsames.2014.08.004.

Neves, S.P., Bruguier, O., Bosch, D., Silva, J.M.R., Mariano, G., 2008. U–Pb ages of plutonic and metaplutonic rocks in southern Borborema Province (NE Brazil): Timing of Brasiliano deformation and magmatism. J. S. Am. Earth Sci. 25 (3), 285–297. doi:10.1016/j.jsames.2007.06.003.

Neves, S.P., Bruguier, O., Vauchez, A., Bosch, D., Silva, J.M.R., Mariano, G., 2006. Timing of crust formation, deposition of supracrustal sequences, and Transamazonian and Brasiliano metamorphism in the East Pernambuco belt (Borborema Province, NE Brazil): Implications for western Gondwana assembly. Precambrian Res. 149 (3-4), 197–216. doi:10.1016/j.precamres.2006.06.005.

Neves, S.P., 2021. Comparative geological evolution of the Borborema Province and São Francisco Craton (eastern Brazil): Decratonization and crustal reworking during West Gondwana assembly and implications for paleogeographic reconstructions. Precambrian Res. 355, 106119. doi:10.1016/j.precamres.2021.106119.

Nkoumbou, C., Yonta-Ngouné, C., Villiéras, F., Njopwouo, D., Yvon, J., Ekodeck, G.E., Tchoua, F.M., 2006. Découverte des roches à affinité ophiolitique dans la chaîne panafricaine au Cameroun: les talcschistes de Ngoung, Lamal Pougue et Bibodi Lamal. C. R. Acad. Sci. Paris 338, 1167–1175. doi:10.1016/j.crte.2006.07.008.

Nkoumbou, C., Barbey, P., Yonta-Ngouné, C., Paquette, J.L., Villiéras, F., 2014. Precollisional geodynamic context of the southern margin of the Pan-African fold belt in Cameroon. J. Afr. Earth Sci. 99, 245–260. doi:10.1016/j.jafrearsci.2013.10.002.

Oliveira, E.P., Toteu, S.F., Araújo, M.N.C., Carvalho, M.J., Nascimento, R.S., Bueno, J.F., McNaughton, N., Basilici, G., 2006. Geologic correlation between the Neoproterozoic Sergipano belt (NE Brazil) and the Yaoundé belt (Cameroon, Africa). J. Afr. Earth Sci. 44 (4-5), 470–478. doi:10.1016/j.jafrearsci.2005.11.014.

Oliveira, E.P., Windley, B.F., Araújo, M.N.C., 2010. The Neoproterozoic Sergipano orogenic belt, NE Brazil: a complete plate tectonic cycle in western Gondwana. Precambrian Res. 181, 64–84. doi:10.1016/j.precamres.2010.05.014.

Oliveira, E.P., Windley, B.F., Mcnaughton, N.J., Bueno, J.F., Nascimento, R.S., Carvalho, M.J., Araújo, M.N.C., 2017. The Sergipano Belt. Springer International Publishing doi:10.1007/978-3-319-01715-0_13.

Oliveira, R. G., 1998. Arcabouço geotectônico da região da faixa Riacho do Pontal, Nordeste do Brasil: dados aeromagnéticos e gravimétricos. Master Thesis. Geoscience Institute, São Paulo University, São Paulo, 157p.

Oliveira, R.G., Medeiros, W.E., 2018. Deep crustal framework of the Borborema Province, NE Brazil, derived from gravity and magnetic data. Prec. Res. 315, 45–65. doi:10.1016/j.precamres.2018.07.004.

Oriolo, S., Oyhantçabal, P., Wemmer, K., Siegesmund, S., 2017. Contemporaneous assembly of Western Gondwana and final Rodinia break-up: Implications for the supercontinent cycle. Geosci. Front. 8 (6), 1431–1445. doi:10.1016/j.gsf.2017.01.009.

Ouadahi, S., Bendaoud, A., Bodinier, J-L., Dautria, J-M., Vauchez, A., Fettous, E-H., Alard, O., 2022. A suture related accretionary wedge in the Gondwana assembly: Insights from serpentinites in the Hoggar shield, Algeria. Precambrian Res. 369, 106505. doi:10.1016/j.precamres.2021.106505.

Owona, S., Ratschbacher, L., Nsangou Ngapna, M., Gulzar, A.M., Mvondo Ondoa, J., Emmanuel Ekodeck, G., 2021. How diverse is the source? Age, provenance, reworking, and overprint of Precambrian meta-sedimentary rocks of West Gondwana, Cameroon, from zircon U-Pb geochronology. Precambrian Res. 359, 106220. doi:10.1016/j.precamres.2021.106220.

Owona, S., Schulz, B., Ratschbacher, L., Mvondo Ondoa, J., Ekodeck, G.E., Tchoua, F.M., Affaton, P., 2011. Pan-African metamorphic evolution in the southern Yaounde Group (Oubanguide Complex, Cameroon) as revealed by EMP monazite dating and thermobarometry of garnet metapelites. J. Afr. Earth Sci. 59, 125–139. doi:10.1016/j.jafrearsci.2010.09.003.

Padilha, A.L., Vitorello, Í., Pádua, M.B., Bologna, M.S., 2014. Electromagnetic constraints for subduction zones beneath the northwest Borborema province: Evidence for Neoproterozoic island arc–continent collision in northeast Brazil. Geology 42 (1), 91–94. doi:10.1130/G34747.1.

Padilha, A.L., Vitorello, I., Pádua, M.B., Fuck, R.A., 2017. Cryptic signatures of Neoproterozoic accretionary events in northeast Brazil imaged by magnetotellurics: Implications for the assembly of West Gondwana. Tectonophysics 699, 164–177. doi:10.1016/j.tecto.2017.01.022.

Passos, L.H., Fuck, R.A., Chemale Jr., F., Lenz, C., Pimentel, M.M., Machado, A., Pinto, V.M., 2021. Neoproterozoic (740-680 Ma) arc-back-arc magmatism in the Sergipano Belt, southern Borborema Province, Brazil. J. S. Am. Earth Sci. 109, 103280. doi:10.1016/j.jsames.2021.103280.

Passos, L.H., Fuck, R.A., Chemale Jr,, F., Lenz, C., Porcher, C.C., Pinto, V.M., Santos, L.C.M.L., 2022. Neoproterozoic pre-collisional events recorded in the Sergipano belt, Southern Borborema Province, West Gondwana. Int. Geol. Rev. doi:10.1080/00206814.2022.2054029.

Pearce, J.A., 2008. Geochemical fingerprinting of oceanic basalts with applications to Ophiolite classification and the search for archean oceanic crust. Lithos 100, 14–48. doi:10.1016/j.lithos.2007.06.016.

Pearce, J.A., Parkinson, I.J., 1993. In: Magmatic Processes and Platetectonics, 76. Geological Society, Special Publications, pp. 373–403.

Penaye, J., Toteu, S.F., Van Schmus, W.R., Nzenti, J.P., 1993. U–Pb and Sm–Nd preliminary geochronologic data on the Yaoundé series, Cameroon: reinterpretation of the granulitic rocks as the suture of a collision in the "Centrafrican belt". C. R. Acad. Sci. Paris 317, 789–794.

Penaye, J., Kroner, A., Toteu, S.F., Van Schmus, W.R., Doumnang, J.-C., 2006. Evolution of the Mayo Kebbi region as revealed by zircon dating: an early (ca. 740 Ma) Pan-African magmatic arc in southwestern Chad. J. Afr. Earth Sci. 44, 530–542. doi:10.1016/j.jafrearsci.2005.11.018.

Pitarello, M.Z., Santos, T.J.S., Ancelmi, M.F., 2019. Syn- to post-depositional processes related to high grade metamorphic BIFs: Geochemical and geochronological evidences from a Paleo to Neoarchean (3/5-2.6 Ga) terrane in NE Brazil. J. S. Am. Earth Sci. 96, 102312. doi:10.1016/j.jsames.2019.102312.

Pitombeira, J.P.A., Amaral, W.S., Santos, T.J.S., Dantas, E.L., Fuck, R.A., 2021. A new record of continental arc magmatism in the Ceará Central Domain, Borborema Province (NE Brazil): evidence from the Pacatuba-Maranguape Complex. Precambrian Res. 359, 106192. doi:10.1016/j.precamres.2021.106192.

Pitombeira, J.P.A., Amaral, W.S., Uchôa Filho, E.C., Fuck, R.A., Dantas, E.L., Parente, C.V., Costa, F.G., Veríssimo, C.U.V., 2017. Vestiges of a continental margin ophiolite type in the Novo Oriente region, Borborema Province, NE Brazil. J. S. Am. Earth Sci. 73, 78–99. doi:10.1016/j.jsames.2016.11.007.

Renna, M.R., Tribuzio, R., 2011. Olivine-rich Troctolites from Ligurian Ophiolites (Italy): evidence for impregnation of replacive mantle conduits by MORB-type melts. J. Petrol. 52 (9), 1763–1790. doi:10.1093/petrology/egr029.

Sá, J.M., Bertrand, J.M., Leterrier, J., Macedo, M.H.F., 2002. Geochemistry and geochronology of pre-Brasiliano rocks from the Transversal Zone, Borborema Province, Northeast Brazil. J. S. Am. Earth Sci. 14 (8), 851–866. doi:10.1016/S0895-9811(01)00081-5.

Santos, A.C.A.L., Padilha, A.L., Fuck, R.A., Pires, A.C.B., Vitorello, I., Pádua, M.B., 2014. Deep structure of a stretched lithosphere: magnetotelluric imaging of the southeastern Borborema province, NE Brazil. Tectonophysics 610, 39–50. doi:10.1016/j.tecto.2013.10.008.

Santos, C.A., Accioly, A.C.A, Leite, P.R.B., Lins, C.A.C., Santos, R. B., Mendes, V.A., Bezerra, D.R.S., 2017. Geologia e Recursos Minerais da Folha Sertânia, Estados de Pernambuco e Paraíba. CPRM, Recife, 158 p.
Santos, E.J., 1995, O Complexo Granítico Lagoa das Pedras: Acresção e colisão na região de Floresta (Pernambuco), Província Borborema. PhD Thesis, São Paulo University, Brazil, 219p.
Santos, E. J., 1996. Ensaio preliminar sobre terrenos e tectônica acrescionária na Província Borborema, in: Anais do 39°Congresso Brasileiro de Geologia. Salvador, SBG. 6, 47-50.
Santos, E.J., Medeiros, V.C., 1999. Constraints from granitic plutonism on proterozoic crustal growth of the Transverse Zone, Borborema Province, NE-Brazil. Rev. Bras. Geocienc. 29 (1), 73–84. doi:10.25249/0375-7536.1999297384.
Santos, E.J., Van Schmus, W.R., Kozuch, M., Brito Neves, B.B., 2010. The Cariris Velhos tectonic event in northeast Brazil. J. S. Am. Earth Sci. 29 (1), 61–76. doi:10.1016/j.jsames.2009.07.003.
Santos, E.J., Souza Neto, J.A., Carmona, L.C.M., Armstrong, R., Santos, L.C.M.L., Mendes, L.U.D.S., 2013a. The metacarbonate rocks of Itatuba-PB: a record of sedimentary recycling in a Paleoproterozoic collisional zone of the Borborema Province, NE Brazil. Precambrian Res. 224, 454–471. doi:10.1016/j.precamres.2012.09.021.
Santos, L.C.M.L., Caxito, F.A., 2021. Accretionary models for the Neoproterozoic evolution of the Borborema Province: advances and open questions. Braz. J. Geol. 51 (2), 1–9. doi:10.1590/2317-4889202120200104.
Santos, L.C.M.L., Dantas, E.L., Cawood, P.A., Lages, G.A., Lima, H.M., Santos, E.J., 2018. Accretion Tectonics in Western Gondwana Deduced from Sm-Nd Isotope Mapping of Terranes in the Borborema Province, NE Brazil. Tectonics 37 (8), 2727–2743. doi:10.1029/2018TC005130.
Santos, L.C.M.L., Dantas, E.L., Cawood, P.A., Lages, G.A., Lima, H.M., Santos, E.J., Caxito, F.A., 2019. Early to late Neoproterozoic subduction-accretion episodes in the Cariris Velhos Belt of the Borborema Province, Brazil: Insights from isotope and whole-rock geochemical data of supracrustal and granitic rocks. J. S. Am. Earth Sci. 96, 1–22. doi:10.1016/j.jsames.2019.102384.
Santos, L.C.M.L., Dantas, E.L., Cawood, P.A., Santos, E.J., Fuck, R.A., 2017a. Neoarchean crustal growth and Paleoproterozoic reworking in the Borborema Province, NE Brazil: Insights from geochemical and isotopic data of TTG and metagranitic rocks of the Alto Moxotó Terrane. J. S. Am. Earth Sci. 79, 342–363. doi:10.1016/j.jsames.2017.08.013.
Santos, L.C.M.L., Dantas, E.L., Santos, E.J., Santos, R.V., Lima, H.M., 2015b. Early to late Paleoproterozoic magmatism in NE Brazil: the Alto Moxotó Terrane and its tectonic implications for the pre-West Gondwana assembly. J. S. Am. Earth Sci. 58, 188–209. doi:10.1016/j.jsames.2014.07.006.
Santos, L.C.M.L, Dantas, E.L., Vidotti, R.M., Cawood, P.A., Santos, E.J., Fuck, R.A., Lima, H.M., 2017b. Two-stage terrane assembly in Western Gondwana: insights from structural geology and geophysical data of central Borborema Province, NE Brazil. J. Struct. Geol. 103, 167–184. doi:10.1016/j.jsg.2017.09.012.
Santos, L.C.M.L., Lages, G.A., Caxito, F.A., Dantas, E.L., Cawood, P.A., Lima, H.M., Cruz Lima, F.J., 2021b. Isotopic and geochemical constraints for a Paleoproterozoic accretionary orogen in the Borborema Province, NE Brazil: implications for reconstructing Nuna/Columbia. Geosci. Front., 101167 doi:10.1016/j.gsf.2021.101167.
Santos, L.C.M.L., Lages, G.A., Lima, H.M., Araújo Neto, J.F.A., Lira Santos, G., Paixão, M.S., 2022. An overview on the Rhyacian-Orosirian (ca. 2.1-2.0 Ga) granitic magmatism of the Alto Moxotó Terrane and its implications for the crustal evolution of the Borborema Province, NE Brazil. J. Iber. Geol. 48, 225–239. doi:10.1007/s41513-022-00191-6.
Santos, L.C.M.L., Lima, H.M., Lages, G.A., Caxito, F.A., Araújo Neto, J.F., Guimarães, I.P., 2020. Petrogenesis of the Riacho do Icó Stock: evidence for Neoproterozoic slab melting during accretion tectonics in the Borborema Province? Braz. J. Geol. 50 (2), 1–17. doi:10.1590/2317-4889202020190127.
Santos, L.C.M.L., Oliveira, R.G., Lages, G.A., Dantas, E.L., Caxito, F., Cawood, P.A., Fuck, R.A., Lima, H.M., Santos, G.L., Araújo Neto, J.F., 2021a. Evidence for Neoproterozoic terrane accretion in the central Borborema Province, West Gondwana deduced by isotopic and geophysical data compilation. Int. Geol. Rev. 64 (11), 1574–1593. doi:10.1080/00206814.2021.1944332.
Santos, R.V., Santos, E.J., Souza Neto, J.A., Carmona, L.C.M., Sial, A.N., Mancini, L.H., Santos, L.C.M.L., Nascimento, G.H., Mendes, L.U.S., Anastácio, E.M.F., 2013b. Isotope geochemistry of Paleoproterozoic metacarbonates from Itatuba, Borborema Province, Northeastern Brazil: evidence of marble melting within a collisional suture. Gondwana Res. 23, 380–389. doi:10.1016/j.gr.2012.04.010.
Santos, T.J.S., Amaral, W.S., Ancelmi, M.F., Pitarello, M.Z., Fuck, R.A., Dantas, E.L., 2015a. U-Pb age of the coesite-bearing eclogite from NW Borborema Province, NE Brazil: Implications for western Gondwana assembly. Gondwana Res. 28 (3), 1183–1196. doi:10.1016/j.gr.2014.09.013.
Santos, T.J.S., Fetter, A.H., Nogueira Neto, J.A., 2008. Comparisons between the northwestern Borborema Province, NE Brazil, and the southwestern Pharusian Dahomey Belt, SW Central Africa. Geol. Soc. Spec. Pub 294 (1), 101–119. doi:10.1144/SP294.6.
Sato, T., No, T., Arai, R., Miura, S., Kodaira, S., 2020. Transition from continental rift to back-arc basin in the southern Japan Sea deduced from seismic velocity structures. Geophys. J. Int. 221 (1), 722–739. doi:10.1093/gji/ggaa006.
Schiling, J-G., Zajac, M., Evans, R., Johnston, T., White, W., Devine, J.D., Kingsley, R., 1983. Petrologic and geochemical variations along the Mid-Atlantic Ridge from 29° N to 73°N. Am. J. Sci. 283 (6), 510–587. doi:10.2475/ajs.283.6.510.
Seme Mouangue, A.C., 1998. Géochimie, métamorphisme et métallogénie des formations ultrabasiques du secteur est de Lomié (Sud-Est Cameroun). PhD Thesis, Yaoundé University, Cameroon, 3e cycle, 155p.
Shang, C.K., Liégeois, J.P., Satir, M., Frisch, W., Nsifa, E.N., 2010. Late Archaean high-K granite geochronology of the northern metacratonic margin of the Archaean Congo craton, Southern Cameroon: evidence for Pb-loss due to non metamorphic causes. Gondwana Res. 18, 337–355. doi:10.1016/j.gr.2010.02.008.
Shang, C.K., Satir, M., Siebel, W., Nsifa, E.N., Taubald, H., Liegeois, J.P., Tchoua, F.M., 2004. TTG magmatism in the Congo craton; a view from major and trace element geochemistry, Rb-Sr and Sm-Nd systematics: case of the Sangmelima region, Ntem complex, southern Cameroon. J. Afr. Earth Sci. 40, 61–79. doi:10.1016/j.jafrearsci.2004.07.005.
Sial, A.N., Ferreira, V.P., 2016. Magma associations in Ediacaran granitoids of the Cachoeirinha–Salgueiro and Alto Pajeú terranes, northeastern Brazil: forty years of studies. J. S. Am. Earth Sci. 68, 113–133. doi:10.1016/j.jsames.2015.10.005.
Silva, T.R., Ferreira, V.P., Lima, M.M.C., Sial, A.N., Silva, J.M.R., 2015. Synkinematic emplacement of the magmatic epidote bearing Major Isidoro tonalite-granite batholith: Relicts of an Ediacaran continental arc in the Pernambuco–Alagoas domain, Borborema Province, NE Brazil. J. S. Am. Earth Sci. 64, 1–13. doi:10.1016/j.jsames.2015.09.002.
Silva Filho, M.A., 1998. Arco vulcânico Canindé-Marancó e a Faixa Sul-Alagoana: sequências orogênicas Mesoproterozóicas, in: XL Congresso Brasileiro de Geologia, Belo horizonte, SBG. p. 16.
Silva Filho, M.A., 1976. A suite ofiolítica da geossinclinal de Propriá. Anais 29°Congresso Brasileiro de Geologia. 4, 51-58.
Stern, R.J., 1994. Arc assembly and continental collision in the Neoproterozoic East African Orogen: implications for the consolidation of Gondwanaland. Annu. Rev. Earth Planet. Sci. 22, 319–351. doi:10.1146/annurev.ea.22.050194.001535.
Sun, S., McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Geol. Soc. Lond. Spec. Pub. 42 (1), 313–345. doi:10.1144/GSL.SP.1989.042.01.19.
Tchakounté, J., Eglinger, A., Toteu, S.F., Zeh, A., Nkoumbou, C., Mvondo-Ondoa, J., Penaye, J., de Wit, M., Barbey, P., 2017. The Adamawa-Yadé domain, a piece of Archaean crust in the Neoproterozoic Central African Orogenic belt (Bafia area, Cameroon). Precambrian Res. 299, 210–229. doi:10.1016/j.precamres.2017.07.001.
Tchameni, R., Lerouge, C., Penaye, J., Cocherie, A., Milesi, J.P., Toteu, S.F., Nsifa, N.E., 2010. Mineralogical constraint for metamorphic conditions in a shear zone affecting the Archean Ngoulemakong tonalite, Congo craton (Southern Cameroon) and retentivity of U-Pb SHRIMP zircon dates. J. Afr. Earth Sci. 58, 67–80. doi:10.1016/j.jafrearsci.2010.01.009.
Toteu, S.F., de Wit, M., Penaye, J., Drost, K., Tait, J.A., Bouyo Houketchang, M., Van Schmus, W.R., Jelsma, H., Moloto-A-Kenguemba, G.R., da Silva Filho, A.F., Lerouge, C., Doucouré, M., 2022. Geochronology and correlations in the Central African Fold Belt along the northern edge of the Congo Craton: New insights from U-Pb dating of zircons from Cameroon, Central African Republic, and south-western Chad. Gondwana Res. 107, 296–324. doi:10.1016/j.gr.2022.03.010.
Toteu, S.F., Penaye, J., Poudjom Djomani, Y., 2004. Geodynamic evolution of the Pan-African belt in central Africa with special reference to Cameroon. Can. J. Earth Sci. 41, 73–85. doi:10.1139/e03-079.
Toteu, S.F., Van Schmus, W.R., Penaye, J., Michard, A., 2001. New U-Pb and Sm-Nd data from north-central Cameroon and its bearing on the pre-Pan African history of central Africa. Precambrian Res. 108, 45–73. doi:10.1016/S0301-9268(00)00149-2.
Toteu, S.F., Yongué-Fouateu, R., Penaye, J., Tchakounte, J., Seme Moungue, A.C., Van Schmus, W.R., Deloule, E., Stendal, H., 2006a. U-Pb dating of plutonic rocks involved in the nappe tectonic in southern Cameroon: consequence for the Pan African orogenic evolution of Central Africa fold belt. J. Afr. Earth Sci. 44, 479–493. doi:10.1016/j.jafrearsci.2005.11.015.
Toteu, S.F., Penaye, J., Deloule, E., Van Schmus, W.R., Tchameni, R., 2006b. Diachronous evolution of volcano-sedimentary basins north of the Congo craton: Insights from U-Pb ion microprobe dating of zircons from the Poli, Lom and Yaoundé Groups (Cameroon). J. Afr. Earth Sci. 44, 428–442. doi:10.1016/j.jafrearsci. 2005.11.011.
Trompette, R., 1994. Geology of Western Gondwana (2000-500): Pan-African-Brasiliano Aggregation of South America and Africa. Balkema, Rotterdam, p. 350.
Trompette, R., 2000. Gondwana evolution; its assembly at around 600 Ma. C. R. Acad. Sci. Ser. IIA Earth Planet. Sci. 330, 305–315. doi:10.1016/S1251-8050(00)00125-7, Paris Sciences de la Terre et des planètes.
Van Kranendonk, M.J., Smithies, R.H., Hickman, A.H., Champion, D.C., 2007. Review: secular tectonic evolution of Archean continental crust: interplay between horizontal and vertical processes in the formation of the Pilbara Craton, Australia. Terra Nova 19 (1), 1–38. doi:10.1111/j.1365-3121.2006.00723.x.
Van Schmus, W.R., Brito Neves, B.B., Hackspacher, P., Babinski, M., 1995. U/Pb and Sm/Nd geochronologic studies of eastern Borborema Province, northeastern Brazil: initial conclusions. J. S. Am. Earth Sci. 8, 267–288. doi:10.1016/0895-9811(95)00013-6.
Van Schmus, W.R., Brito Neves, B.B, Williams, I.S., Hackspacher, P.C., Fetter, A.H., Dantas, E.L., Babinski, M., 2003. Seridó Group of NE Brazil, a Late Neoproterozoic pre- to syn-collisional flysch basin in West Gondwanaland? insights from SHRIMP U-Pb detrital zircon ages. Precambrian Res. 127, 287–327. doi:10.1016/S0301-9268(03)00197-9.
Van Schmus, W.R., Oliveira, E.P., Silva Filho, A.F., Toteu, S.F., Penaye, J., Guimarães, I.P., 2008. Proterozoic links between the Borborema Province, NE Brazil, and the Central African Fold Belt. Geol. Soc. 294, 69–99. doi:10.1144/SP294.5.
Van Schmus, W.R., Kozuch, M., Brito Neves, B.B., 2011. Precambrian history of the Zona Transversal of the Borborema Province, NE Brazil: insights from Sm–Nd and U–Pb geochronology. J. S. Am. Earth Sci. 31 (2-3), 227–252. doi:10.1016/j.jsames.2011.02.010.

Vauchez, A., Neves, S.P., Caby, R., Corsini, M., Egydio-Silva, M., Arthaud, M., Amaro, V., 1995. The Borborema shear zone systems, NE Brazil. J. S. Am. Earth Sci. 8, 247–266. doi:10.1016/0895-9811(95)00012-5.

Vialette, Y., Vitel, G., 1979. Geochronological data on the Amsinassene-Tefedest Block (Central Hoggar, Algerian Sahara) and evidence for its polycyclic evolution. Precambrian Res. 9 (3-4), 241–254. doi:10.1016/0301-9268(79)90005-6.

Werle, M., Hartmann, L.A., Queiroga, G.N., Lana, C., Pertille, J., Michelin, C.R.L., Remus, M.V.D., Roberts, M.P., Castro, M.P., Leandro, C.G., Savian, J.F., 2020. Oceanic crust and mantle evidence for the evolution of Tonian-Cryogenian ophiolites, southern Brasiliano Orogen. Prec. Res. 351, 105979. doi:10.1016/j.precamres.2020.105979.

Whitmarsh, R.B., Manatschal, G., Minshull, T.A., 2001. Evolution of magma-poor continental margins from rifting to seafloor spreading. Nature 413 (6852), 150–154. doi:10.1038/35093085.

Yongue-Fouateu, R., Ghogomu, R.T., Penaye, J., Ekodeck, G.E., Stendal, H., Colin, F., 2006. Nickel and cobalt distribution in the laterites of the Lomié region, South-East Cameroon. J. Afr. Earth Sci. 45, 33–47. doi:10.1016/j.jafrearsci.2006.01.003.

Zerrouk, S., Bendaoud, A., Hamoudi, M., Liégeois, J.P., Boubekri, H., El Khaznadji, R.B., 2017. Mapping and discriminating the Pan-African granitoids in the Hoggar (southern Algeria) using Landsat 7 ETM+ data and airborne geophysics. J. Afr. Earth Sci. 127, 146–158. doi:10.1016/j.jafrearsci.2016.10.003.