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# A Unified Structural Framework for Major Shear Zone in the Ntem-Chaillu-Ivindo Blocks: Case of Tectonic and Structural Evolution of the Ivindo Basement, Northern Republic of Congo, Congo Craton

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**Abstract:** ***The Ivindo Basement primarily outcrops within the Souanké and Bomalinga Provinces of the Republic of Congo and is part of an Archean Ntem-Chaillu-Ivindo block, in the western part of a greater Central African Congo Craton. Geological studies in the Ivindo Basement have focused on rock sample petrography, geochemistry and geochronology, revealing different supracrustal sequences (also referred to as greenstone belts) and granite-gneiss complexes, cross-cut byyounger mafic to ultramafic dykes. The supracrustals consist of metamorphosed volcano-sedimentary chlorite-sericite-schist sequences, banded iron formations and amphibolites. This paper offers an additional structural analysis of a reactivated regional shear zone across the Ivindo Basement. Our structural identifies three distinct phases of deformation, labelled D1-3. D1 was associated with horizontal NNW-SSE compression and is exposed at both Souanké and Bomalinga. This phase developed a ductile to brittle shear zone systems, with dextral WNW-ESE to NNW-SSE and E-W faults, together with sinistral N-S and NE-SW Riedel shears. D2 was only observed in Bomalinga and is mainly comprised of sinistral WNW-ESE and dextral NE-SW trending brittle shear zones; i.e., with an opposite sense of shear to D1. The transition between D1 and D2 is marked by changes in the kinematics of blocks and in-filling granitic intrusions. The D2 phase resulted from E-W horizontal shortening under an extensional strike-slip regime. Both D1 and D2 shear zones were reactivated as normal faults during a third, D3, deformation phase, experiencing E-W horizontal shortening and N-S radial extension. On a more regional scale, the mapped shear zones within the Ivindo Basement correlate with normal faults along the edge of the Proterozoic Sembé-Ouesso basin, as interpreted from a topographic map of ALOS as 500 m in depth surface rupture.***

**Keywords:** Congo craton, Ivindo basement, shear zones, Archean, Republic of Congo

## 1 Introduction

The Precambrian cratons exhibit well-documented tectonic-magmatic activity worldwide (Santosh et al., 2015; Smithies and Champion, 2000; Wang et al., 2017, 2012) and are among the most metallogenically important regions on the planet, making these some of the world's major mineral provinces (Goldfarb et al., 2001; Turnbull et al., 2021). The study of the tectonic history of these cratons has not only elucidated the evolution of the Archean continental crust, but also helped us understand the global history of the Earth (Armstrong et al., 1981; Taylor and McLennan, 1995, 1985). Thus, the Archean cratons of northern China (Wang et al., 2017, 2012), Dharwar in India (Jayananda et al., 2015; Ranjan et al., 2020; Santosh et al., 2015), Pilbara in Australia (Smithies and Champion, 2000) and Africa's Congo craton (Akame et al., 2020b; Djama, 2018; Loemba et al., 2022a; Shang et al., 2010a; Tchameni et al., 2000) represent indispensable witnesses to the understanding of Precambrian earth history. However, the geodynamic history of some Archean cratons is still unclarified and debated (Bédard, 2018; Chardon et al., 2009; Condie, 1994; Condie and Benn, 2006; De Waele et al., 2008; Thiéblemont et al., 2018), not only for the accretionary stages of Archean rock stages (Martin et al., 2014), but also in the definition of tectonic processes that these underwent. These cratons mainly show large shear zones and foliations that affect a carton's common tonalite-trondhjemite-granodiorite (TTG) and charnockite suites and granodiorite-granite-monzogranite (GGM) suites, as well as greenstone belts (Akame et al., 2020b; Pouclet et al., 2007; Thiéblemont et al., 2018; Toteu et al., 1994).

Unraveling the tectonic histories of these cratons will assist mineral exploration, particularly in less-explored African countries, as well as increase knowledge of the processes involved in the establishment of these cratons. In addition, investigation aids our understanding of ancient structures across some cratons, which are currently associated with neotectonic processes (Ambraseys and Adams, 1986; Assumpção et al., 2004; Assumpção and Veloso, 2020; Ayele, 2002; Bazebizonza Tchiguina et al., 2020; Miyouna et al., 2018; Ngatchou et al., 2018; Nkodia et al., 2020). Cratons thus represent key areas for understanding, predicting, and explaining ancient or modern geological processes. The Congo Craton, for instance, has witnessed the establishment of several structural units from the Paleoproterozoic to the Phanerozoic (Alkmim et al., 2006; Boudzoumou, 1986;

Boudzoumou and Trompette, 1988; Bouenitela, 2019; Delvaux et al., 2020; Ganwa et al., 2016; Ngako et al., 2008; Tack et al., 1994; Thiéblemont et al., 2018; Vaughan and Pankhurst, 2008). The Congo craton constitutes therefore an ideal area for clarifying Precambrian geological processes.

In this paper, we present data from the Archean Ivindo basement, in the northwestern corner of the Republic of Congo, which constitutes the north-eastern corned of a larger Ntem block, which, in turn, forms a north-western part of a greater Congo craton. To date, a few studies have been devoted to the granitoids and geodynamic history of the Ivindo basement (Gatsé Ebotehouna et al., 2021; Loemba et al., 2022b) and their interpretations are based largely on correlations with the Ntem Archean complex (Nedelec et al., 1990; Tchameni, 1997; Tchameni et al., 2000) in Cameroon and the North Gabonese Massif Archean complex (Thiéblemont et al., 2011, 2009). However, the lack of detailed structural data obscures the full history of the Ivindo basement and results in differing assessments.

Recently the construction of an Ouesso-Ntam road allowed more thorough observations of the granitoid rocks within quarries and along road embankments that were once inaccessible due to dense vegetation. Building on previous work, this study proposes structural data in order to define the geodynamic context of the placement of the Ivindo Basement granitoids and the tectonic evolution of this cratonic block. Next, we present the types of deformation that affected these rocks at both a regional and outcrop scale, including their palaeostrain axes. Finally, we discuss the structural context of the granitoids of the Ivindo Basement in relation to other blocks within the Congo craton.

## 2 Geological Overview

The Congo Craton consists of distinct Archean blocks and terranes (i. e., Kasai, Angola and Chaillu-Ntem-Ivindo block across Gabon, Cameroon and Congo; Boumou in Democratic Republic of Congo and Tanzanian) amalgamated during Paleoproterozoic orogenic collages (e.g., De Waele et al., 2008; Shang et al., 2010b; Thiéblemont et al., 2018). In Congo, the Chaillu-Ntem-Ivindois represented by the Ivindo Basement to the north and Chaillu Massif to the south (Kessi, 1992; Gourcerol et al., 2022). The Ntem-Chaillu-Ivindoblock (Fig. 1) can be compartmentalized into two different basement suites; i.e., supracrustal sequences and granite-gneissic complexes (e.g., Gatsé Ebotehouna et al., 2021; Meloux et al., 1986). The supracrustal rocks in the Ivindo region consist of volcano-sedimentary sequences formed by chlorite-sericite-schists, banded iron formations and amphibolites (greenstone belts), whereas the magmatic intrusions are represented by mafic to ultramafic (dolerites) and granitic plutons (Desthieux, 1993; Loemba et al., 2022b).

The Ivindo basement in the northwestern part of the Congo (Fig. 2) has been little studied and in particular very few structural studies have been carried out. Only the work of Desthieux (1993) reports field observations of N-S and NNE-SSW trending strike-slip faults. However, quite relevant studies in the Northern Gabonese Massif reveal major E-W to WSW-ESE trending zones dextral shear zones, coupled with N-S trending sinistral shears. These deformations have been associated with a demonstrated Neoarchean orogeny (Thiéblemont et al., 2009). On the other hand, the Ntem complex exhibits a vertical foliation that is NW to NNE and ENE-WSW to E-W trending and incorporates a sub-horizontal stretching lineation. This foliation has been linked to D1 deformation during the intrusions of Mesoarchean granitoids (Tchameni et al., 2000). A second D2 phase is related to an Eburnean orogeny, which developed N-S to NE-SW trending sinistral and ESE-WSW trending dextral shear zones (Akame et al., 2013, 2020b; Feybesse et al., 1987; Maurizot et al., 1986; Toteu et al., 1994). The D2deformationcoincides with a metamorphic event at ~2050 Ma (Toteu et al., 1994). Incorporating previous studies in literature, the present work clarifies the context and structural evolution of granitoids in the Ivindo basement and discusses the implications for the evolution of the Congo Craton.

## 3 Methodology

Visible structural lineaments were extracted from a mosaic of 30 m SRTM ALOS-type radar interferometric DEM images (Downloaded from ALOS' Global Digital Surface Model https://www.eorc.jaxa.jp/ALOS/en/aw3d30/data/index.htm) and imported into a geographic information system (GIS). Two complementary approaches were used; the first applied an automatic lineament extraction on previously processed images, enhanced by the application of Sobel directional filters along NE-SW, E-W, N-S and NW-SE directions. The LINE module of the PCI Geomatica software enabled this automatic extraction. The second method, judged to be more efficient, consisted of manually extracting lineaments through visual photo interpretations. Lineaments were manually extracted under four different main azimuth directions of sunlight (NE-SW, E-W, N-S and NW-SE), where different hill slopes were enhanced. Thus, all surface structures (slope breaks, mountain ridges, depressions, structural features) were clearly identified. Finally, the automatically identified lineaments were compared to the manually identified lineaments in order to retain only those lineaments that had a structural significance in relation to the geomorphological criteria described in Burbank and Anderson (2011).

Structural data were obtained from detailed field observations within a former quarry, near the village of Souanké, and along the Bomalinga river. We used a kinematic approach for our fault-slip data to determine paleo-strain axes viathe Win-Tensor program (Delvaux, 2012) and using an approach described in the work of Delvaux et al. (1997), and Delvaux and Sperner (2003). Strain axes were determined on a fault population that was grouped on the basis of field criteria (overlap, conjugate fault, age of the deformation, etc.). The program determines the PBT kinematic axes for each fault plane, constituting the axes of symmetry of the contraction and extension quadrants.

The distribution of PBT axes for a fault population is associated with two orthogonally orientated strain ellipse surfaces. Y (referred to as S2), constitutes the intermediate strain axis and represents the intersection between these two strain ellipse surfaces, while the Z axes (referred to as S1) is the axis of shortening and X (referred to as S3) is the axis of extension and are located in the middle of quadrants P and T, respectively.

## 4 Results

### 4.1 Structural analysis

#### 4.1.1 Lineaments and field analysis

Extracted lineament analysis presents a network of structural lineaments within the Ivindo basement and its surroundings. The analysis provides a new perspective, compared to previous studies, and highlights a less-suspected structural scheme. Based on our analysis of the mapped lineaments, we observe an E-W trending major dextral shear zone of about 130 km in length that we call the North-Ivindo shear (Fig. 3), which is an extension of the North Gabon shear zone (Thiéblemont et al., 2009). In addition, a 160 km-long normal fault system, developing a NNW-SSE to N-S trending horst, is identified within the study area. This normal fault system coincides with the border between the Ivindo basement and the Sembe-Ouesso basin. These results corroborate field observations.

#### 4.1.2 Field analysis from Souanké

Field observations at Souanké showed mainly brittle and ductile shear zones with steep dips (70-90°) (Fig. 4d). These zones are organized into a corridor of Riedel fractures that are orientated WNW-ESE to NNW-SSE, E-W, N-S and NE-SW (Figs. 4a, b). The shear zones are orientated WNW-ESE to NNW-SSE define dextral (R) brittle and ductile corridors, which are synthetic to the principal deformation zone (PDZ) oriented E-W. This zone corresponds well to the E-W lineament that on the basis of satellite imagery was interpreted as a dextral shear zone (Fig. 3). In addition, these zones are sometimes filled with granodiorite (Fig. 6b).

Dextral R shear zones also define a conjugate system with sinistral brittle R' shear zones, essentially oriented N-S and NE-SW, respectively. In addition, the system as a whole appears to be a large NE-SW trending brittle sinistral shear corridor. This corridor corresponds to R' fractures also. These shear zones locally develop relay zones that are often connected by extension fractures or form both extensional and compressional duplexes (Figs. 9a, d).

#### 4.1.3 Field analysis from Bomalinga

Out crops along the Bomalinga River also expose a few brittle and ductile shear zones with steep dip angles (70-90°) (Fig. 5d). These zones occur as corridors of Riedel fractures with orientations WNW-ESE, N-S to NNE-SSW and NE-SW (Fig. 5a). The WNW-ESE trending shear zone defines dextral (R) brittle and ductile corridors, which are possibly synthetic to the principal deformation zone (PDZ) oriented E-W observed at Souanké. The R shear zones also define a conjugate system with the sinistral R’ shear zones oriented N-S and NE-SW. They materialised also as a large NE-SW trending brittle sinistral shear corridor. This corridor corresponds to R’ fractures.

In the field, there are similarities and differences observed in the types of shear zones. The brittle shear zones mainly show polished surfaces with subhorizontal to oblique striae (Fig. 4e and Fig 5e). They mostly display left relays. The striae develop either on crushed surfaces covered with chlorite at Souanké, or with calcite fibers sometimes arranged in steps, and sometimes with muscovite flakes (Fig. 6e). These areas form anastomosing traces on the surfaces or even connection areas with extension fractures (Fig. 6b, a) or duplexes (Fig. 6d), into which veins of quartz or granodiorite are sometimes injected. These characteristics are only associated with N-S to NE-SW trending shears. In contrast, ductile shear zones essentially display right step overs and several asymmetric structures which allow us to determine the sense of movement. They also host east verging asymmetric folds with, C / S structures, and σ-type to φ-type porphyroblasts (Fig. 7). The maximum thickness of such a shear zone reaches 13 m in the field. While such ductile shear zones are only WNW-ESE to NNW-SSE trending, some brittle shear zones are likewise WNW-ESE to NNW-SSE trending.

A period of reactivation of shear zones tends to follow their establishment. We have observed evidence of this in the field in the form of subvertical grooves and striations overprinting subhorizontal striations (Fig. 8c) across the surfaces of both NE-SW and NW-SE trending shear zones. Such striations are either imprinted on steps of euhedral calcite or on polished planes of chlorite.

#### 4.1.4 Kinematic analysis for Paleostrain reconstitution

Stress inversion using a PBT method of kinematic axes allowed us to distinguish two kinematic stages for 145 and 46 faults, measured at Souanké and Bomalinga, respectively. The first stage occurred through NNW-SSE shortening while the second stage manifested itself as radial extension, oriented E-W and N-S. However, a group of 35 (24, 13%) faults could not be classified within any of these two stress stages, because of either not displaying a surface lineation or kinematic interpretations being inconsistent with either stage. The determination of their tensor is therefore imprecise and consequently ignored.

- **The first kinematic stage** at Souanké was identified from 67 out of 145 fault-slip data (Fig. 9a). A remaining 11 faults were rejected for not fitting this stage. All of these 67 structures can be generated through horizontal shortening along an almost horizontal (4°) plunge towards 164°, or roughly NNW-SSE. Its corresponding extension was horizontal, along 254°, or roughly E-W.

- **The second kinematic stage** at Souanké was interpreted from 28 out of 43 measured faults, which conform to radial extension regime around a subvertical shortening axis (plunging 74° towards 133°) and least compressive stresses plunging 12° towards 273°, or roughly E-W, and with lesser extension in a N-S direction.
- **The first kinematic stage** at Bomalinga was identified from 13 fault-slip data out of 46 fractures recorded (Fig. 9a). All the structures originated from a horizontal shortening (06/347) oriented NNW-SSE in a strike-slip regime. The extension of the structures mainly occurs in the E-W direction (05/256).

**The second kinematic stage** at Bomalinga was interpreted from 19 fault-slip data out of 46 faults recorded. They formed in an extensional strike-slip regime with subvertical shortening (11/261) and dominant extension towards the SSW-NNE (03/351), with minor extension in the N-S direction.

## 5 Discussion

### 5.1.1 Structural interpretation to geodynamic evolution

Satellite and field observations in the Souanké and Bomalinga areas show that the Ivindo basement is affected by strike-slip tectonics, followed by extension. The strike-slip tectonics developed large shear zones that are organized in Riedel structures. Subhorizontal to shallow dipping striae record strike-slip movements (Dooley and Schreurs, 2012; Sylvester, 1988). The dextral WNW-ESE to NNW-SSE and sinistral N-S to NE-SW trending shear zones are all orientatedat angles less than 60 °, which satisfies the criterion that these are R and R' fractures, respectively (Fig. 9a), consistent with analog models (Naylor et al., 1986; Tchalenko, 1970; Wilcox et al., 1973).

The dextral ductile and brittle shear zones that trend WNW-ESE to NNW-SSE forms a small angle with the E-W shear zones, with similar sense of shear. Thus E-W trending dextral shear zones can be considered as principal within the region. This finding corroborates a large E-W lineament (Fig. 3), interpreted as a dextral North Ivindo shear zone, according to geomorphological criteria. Such an angular relationship between R and R' shears is also verified by an analogic experiment by Bartlett et al. (1981) . However, the angular variation between the R and R' fractures could be explained by the fact that the R shear zone was associated with a ductile deformation phase, which probably caused a slight rotation of structures.

Furthermore, the coexistence of ductile and brittle shear zones could be questioned. Indeed, some studies claim that brittle shears develop during the late phases of deformation or during exhumation after the collision phase (Fossen and Cavalcante, 2017). What is interesting to note is that in the field, ductile WNW-ESE to NNW-SSE trending shear zones also show aspects of brittle shearing in some places (Figs. 6 and 7). This indicates that these shear zones would have an evolutionary character and would probably have initiated as brittle fractures which evolved into ductile fractures. This change from brittle to ductile has been widely demonstrated in literature (Austrheim, 1987; Goncalves et al., 2016; Guermani and Pennacchioni, 1998; Pennacchioni, 2005; Pennacchioni and Mancktelow, 2007; Pennacchioni and Zucchi, 2013; Segall and Simpson, 1986), and is often due to the intervention of fluids in the earth's crust. Since the granitoids of the Ivindo basement that intruded the shear zones show a geochemical subduction-zone signature (Loemba et al., 2022b), the intervention of fluids seems more plausible explanation. This argument strengthens the theory that the brittle and ductile shear zones can develop during a deformation event and through the intervention of fluids in the Earth's crust. In addition, shear zones are large lithospheric structures that can locally show several “rheological facies”, either ductile or brittle in places (Tikoff et al., 2013; Vauchez et al., 20212).

Rock surfaces in shear zones display a bimodal distribution of striation plunges; (1) subhorizontal striae that indicate strike-slip movement, which are overprinted by (2) sub vertical striae (Fig. 8c) that indicate dip-slip movement. This suggests that normal faults reactivated by strike-slip shear zones. In addition, normal fault striations are sometimes found on calcite veins, post-dating their emplacements. Later development of large normal faults is also confirmed by the lineaments interpreted on a regional scale, which show a topographic break of nearly 500 m (Fig. 3).

At Souanké, our kinematic analysis show that shear zones originated from a strike-slip tectonic regime during NNW-SSE shortening (Fig. 9a), while later normal faults were associated with radial extension, dominantly in the E-W direction to a lesser extent in the orthogonal N-S direction (Fig. 9b). The shear zones constitute our first phase of NNW-SSE shortening (D1 deformation) in the Souanké zone, and the radial extension constitutes our D2 phase.

In addition, along the Bomalinga river, our kinematic analysis show that shear zones originated from strike-slip tectonic regime with NNW-SSE shortening (Fig. 9a) and an E-W extensional strike-slip regime (Fig 9b). The shear zones at the Bomalinga river constitute the first phase of NNW-SSE shortening (D1 deformation), and the E-W extensional constitute the D2 phase of deformation. Finally, the combined D1 deformation phase observed at Souanké and the Bomalinga river showed a NW compression followed by ENE-WNW extension system (Fig. 9c).

These deformations affect TTG-type granitoids in the Ivindo basement, which share similar geochemical signatures to 2.9-2.5 Ga North Gabon granitoids (Thiéblemont et al., 2018a, 2009) and other granitoids of the Ntem complex (Akame et al., 2020a, 2018, 2013; Pouclet et al., 2007; Shang et al., 2010a; Tchameni et al., 2010, 2000). Consequently, the D1deformations correspond to a described episode of Neoarchean collision due to oceanic subduction (~ 2700Ma) (Akame et al., 2020a; Thiéblemont et al., 2009). There are two reasons for supporting this idea: (i) At the regional scale, the shear zones described in the Ivindo basement clearly extend into the North Gabonese Massif complex through the dextral shear corridors of Nkol and North Gabon (Fig. 3) (Thiéblemont et al., 2009). This is the case with the North Ivindo shear, which is an extension of the North Gabon shear zone. These shear zones have the same sense of movement (dextral) and similar stepovers (right). Likewise, the shear zones of the North Gabonese Massif complex affect granitoids contemporary to the Neoarchean orogen (2750-2680 Ma) (Thiéblemont et al., 2009). These shear zones show facies similar to those encountered in the Souanké and Bomalinga areas. (ii) In the Ntem complex in Cameroon, particularly in the Sangmelima region which shows a granitoid-gneiss complex, a greenstone belt and metagabbros that were affected by a horizontal compressive phase at around 2850 Ma and 2750 Ma (Akame et al., 2020a). This compression phase has been linked to two stages of deformation, D2and D3 (Akame et al., 2020b).

Akame et al. (2020b) argue that theirD2 phase created dextral NNW-SSE and sinistral NE-SE trending, brittle-ductile shear zones that post-date crustal accretion, inflicted byroughly horizontal E-W shortening (Akame et al., 2020b). As a result of NNW-SSE shortening, their D3 phase essentially developed fracture cleavages and brittle shear zones that are oriented parallel to D2, as well as a refolding of pre-existing D2 structures (Akame et al., 2020b, 2018). With regard to the structures described in the Sangmelima region, our structural observations on the shear zones are identical to the descriptions for D2 and D3structures except for the foliation, which has not been noted in the Souanké quarry. The Akame et al. (2020) interpretations of phases D2 and D3 could have primarily resulted from NW-SE oriented progressive deformation. In Gabon, the Nkol shear zone, which is parallel to the Ivindo shear zone, displays a dip-slip component towards the NW (Thiéblemont et al., 2009), which corresponds very well to a NNW-SSE shortening that we support with our field observations in Ivindo.

Alternatively, these shear zones could also have reactivated during the Rhyacian orogeny (Eburnian event) period (2.10-2.04 Ga) when the Sao-Francisco craton and the Ntem-Chaillu-Ivindo block collided (Baldim and Oliveira, 2021; Feybesse et al., 1998, 1987; Maurizot et al., 1986; Toteu et al., 1994). Baldim and Oliveira (2021, pp.16; Fig. 17) clearly describe, via a cross-section, a NW-SE shortening with the development of large N-S trending sinistral shears.

The shear zones of the Souanké quarry showed reactivation by normal faults. This D2 phase could correspond to a Neoproterozoic extension which established the Francevillien basin across Gabon and the Sembe Ouesso basin in the Republic of Congo (Thiéblemont et al., 2009). Indeed, these normal faults are oriented parallel with the shear zones. They form large corridors which affected both Neoproterozoic formations and granitoids of the cratonic blocks. However, in the absence of dating, care should be taken against any hasty interpretation of cross cutting relationships, since these only offer maximum ages and there have been many tectonic events follow one another in the Neoarchean and Paleoproterozoic Eras. Thus, the Cretaceous opening of the Atlantic Ocean could also have reactivated these shear zones, as observed alongPan-African shear zones across the Borborema province in Brazil (Miranda et al., 2020). Dating of granitoids, shear zones in particular, and minerals that grew within and during shearing and faulting is required to better define their absolute chronology.

### 5.2 Comparison with other Archean cratons

Most of the structural patterns recorded in other cratons are also very similar to what has been described above, for the Ntem craton block. The Archean rocks and their related felsic intrusions have undergone a complex deformation. As in the Ivindo Basement, Archean cratons show large crustal-scale shear zones. The D2 phase of deformation described in the Abitibi greenstone belts, in the Superior Province in Canada, (Zhang et al., 2014) exhibits a shortening that resulted in a large ductile dextral shear zone, containing gold deposits. This D2 phase is very similar to our findings compared to D1 phase of deformation. The same shear zone pattern and their kinematics are also described in the Dharwar craton in southern India, where large NW-SE to E-W trending dextral shear zones, with high grade mylonites, cut across granitic plutons (Chardon et al., 2009, 2008; Chetty et al., 2012). Large NW-SE trending ductile shear zones have been also described in the North Craton of China (Faure et al., 2007; Trap et al., 2009) and in the Pilbara Craton (Pawley et al., 2002) where a similar regional shortening is reported. Even though, there are some quite noticeable differences in orientation ranges of the shear zones, they all share the same structural style. All these similarities in large shear zones thoroughly imply that these blocks of cratons could have been part of a super craton during the Archean. Such a hypothesis has also been coined by Turnbull et al. (2021), from their detailed investigations of the NE Congo Craton in the Democratic Republic of Congo.

## 6 Conclusion

This study finds that the Ivindo Basement has been affected by two phases of deformation.

1. D1 is a horizontal shortening episode with NNW-SSE direction. This phase has developed large brittle and ductile shear zones. It probably started coincided with Neoarchean subduction and was likely reactivated by a Rhyacian orogen (Eburnian event) from 2.10 to 2.04 Ga.
2. D2 is a radial extension primarily oriented E-W that might have commenced in the Neoproterozoic. This second phase is manifested by the development of large basins across margins of the Congo craton.
3. D1 and D2 shear zones were reactivated as normal faults during a third, D3, deformation phase.
4. The D2 phase described in the Abitibi greenstone belts is very similar to radial extension primarily oriented E-W in the Ivindo basement compared to D1 phase of deformation.

5. The same shear zone pattern and their kinematics are also described in the Dharwar craton in southern India, in the North Craton of China and in the Pilbara Craton.

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## Figures

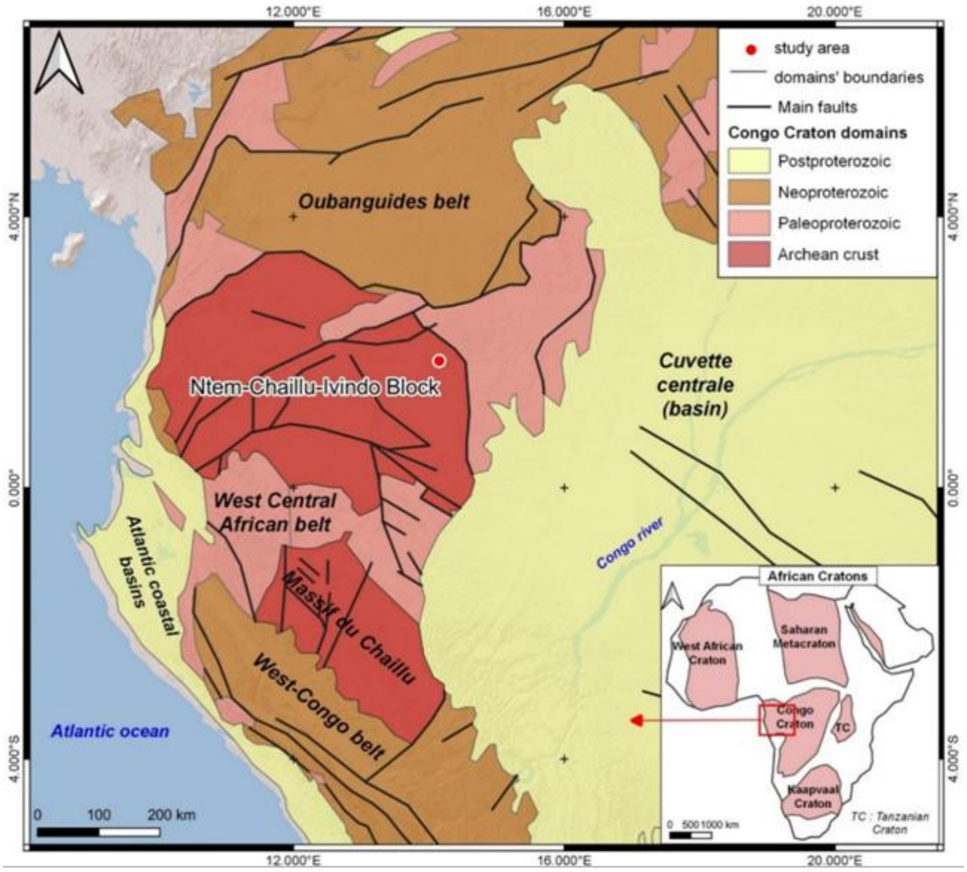


**Figure 1:** Simplified tectonic map of Central Congo Craton adapted from Thiéblemont et al. (2018).

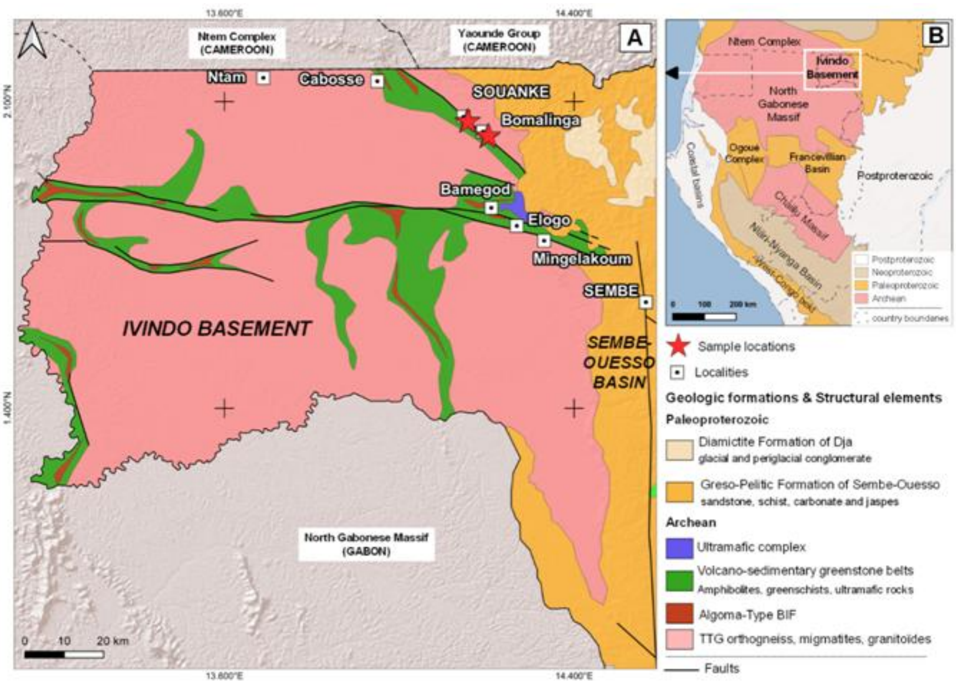


**Figure 2:** Geological map of Archean Ntem-Chaillu-Ivindo blocks showing: A-Simplified geological map of the Ivindo basement with sample locations; B-Presentation of the Ivindo basement in the Ntem-Chaillu Archean domains adapted from Desthieux. (1993) and Gourcerol et al. (2022).

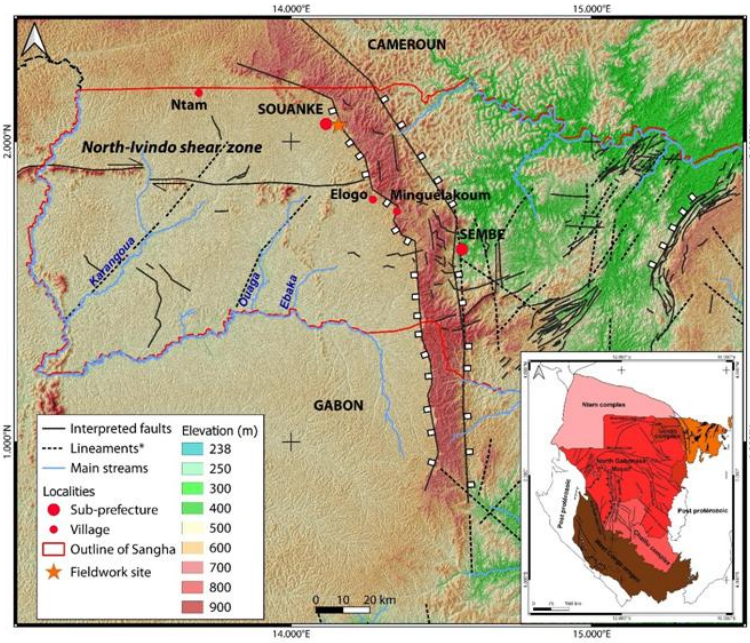


**Figure 3:** Map of lineaments extracted in the Ivindo basement.

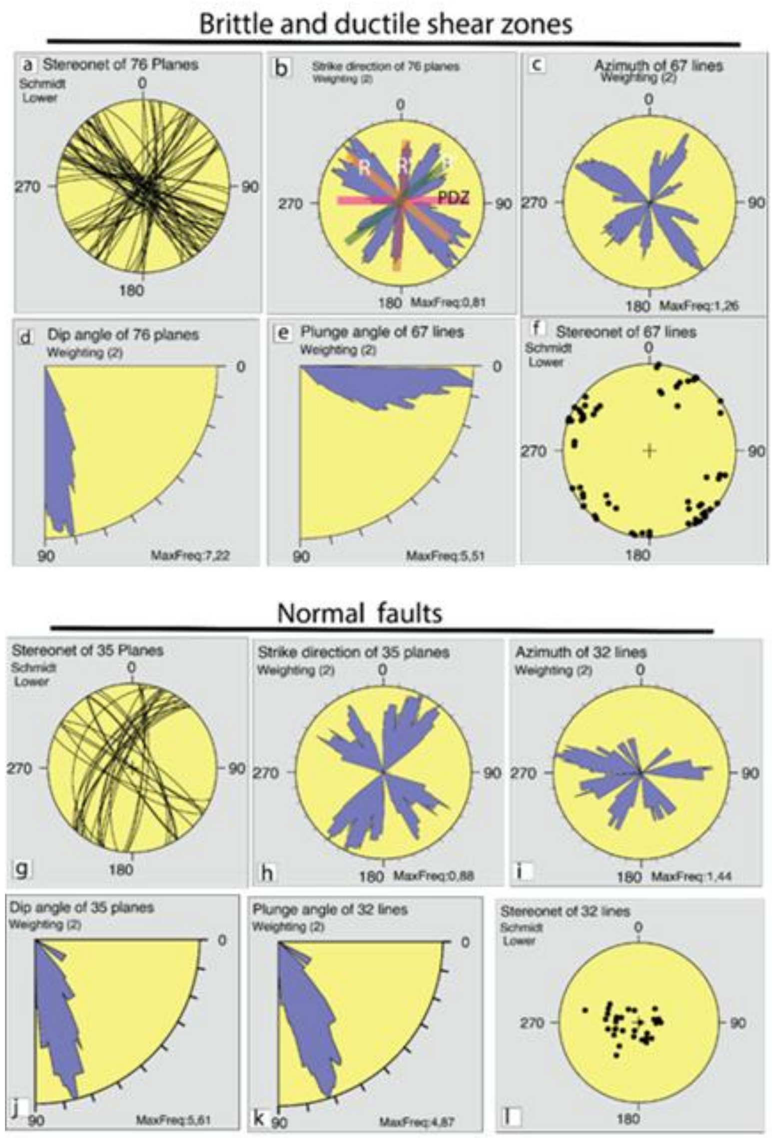


**Figure 4:** Geometric analysis of structural data observed at Souanké.

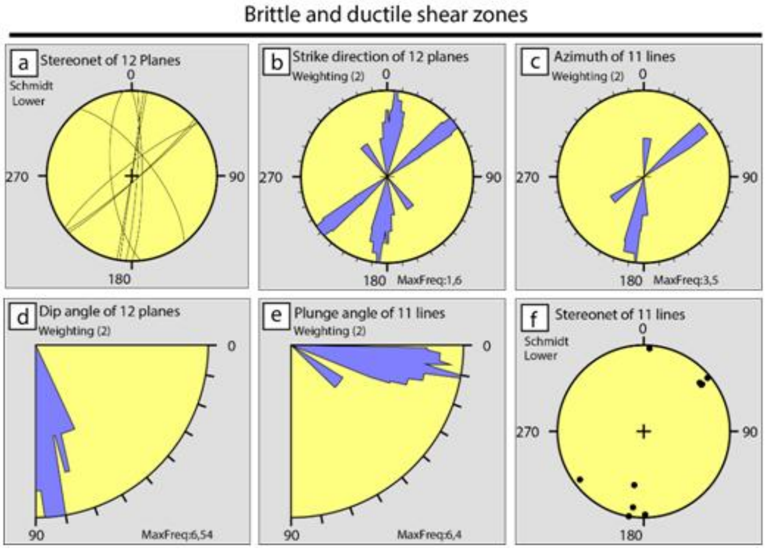


**Figure 5:** Geometric analysis of structural data observed at Bomalinga.


**Figure 6:** Brittle faulting within the Souankéquarry. (a) X-Y trending sinistral shear zone corridor with extension fractures. (b) X-Y trending dextral shear zone corridor with an anastomosing fracture network, associated with granodiorite injections. (c) X-Y trending sinistral shear zone corridor (d) Compressive duplex developed along the shear corridor (e) A shear zone surface with subhorizontal striae defined by muscovite.

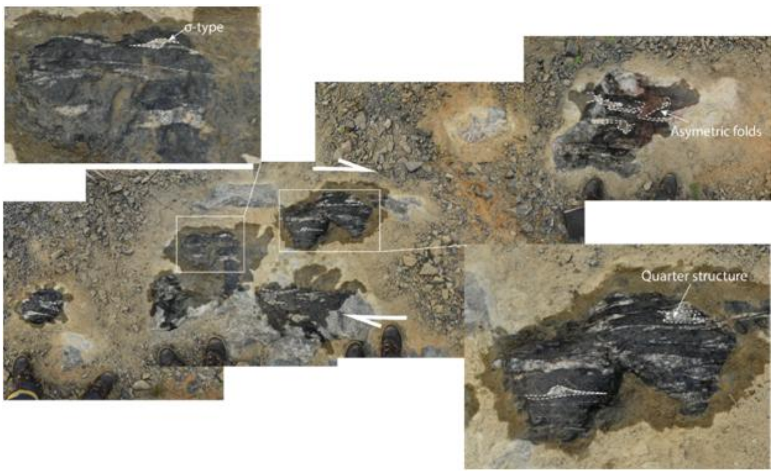


**Figure 7:** Ductile shear zone outcropping across the floor of the Souankéquarry (cf., feet for scale), showing asymmetric folds.

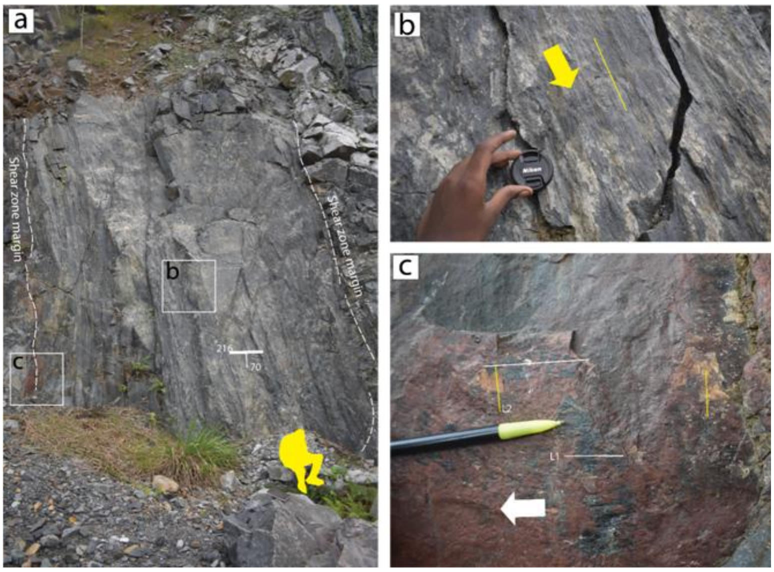


**Figure 8:** Striae evidence of reactivation along shear zones. (a) Normal fault with subvertical striae, across fault surfaces with fault grooves. (b) View of subvertical striae, across fault surfaces with fault grooves (c) A ductile shear zone surface cutting a normal fault. Its surface shows subvertical striae on calcite steps overprinting subhorizontal striae of the shear zones.

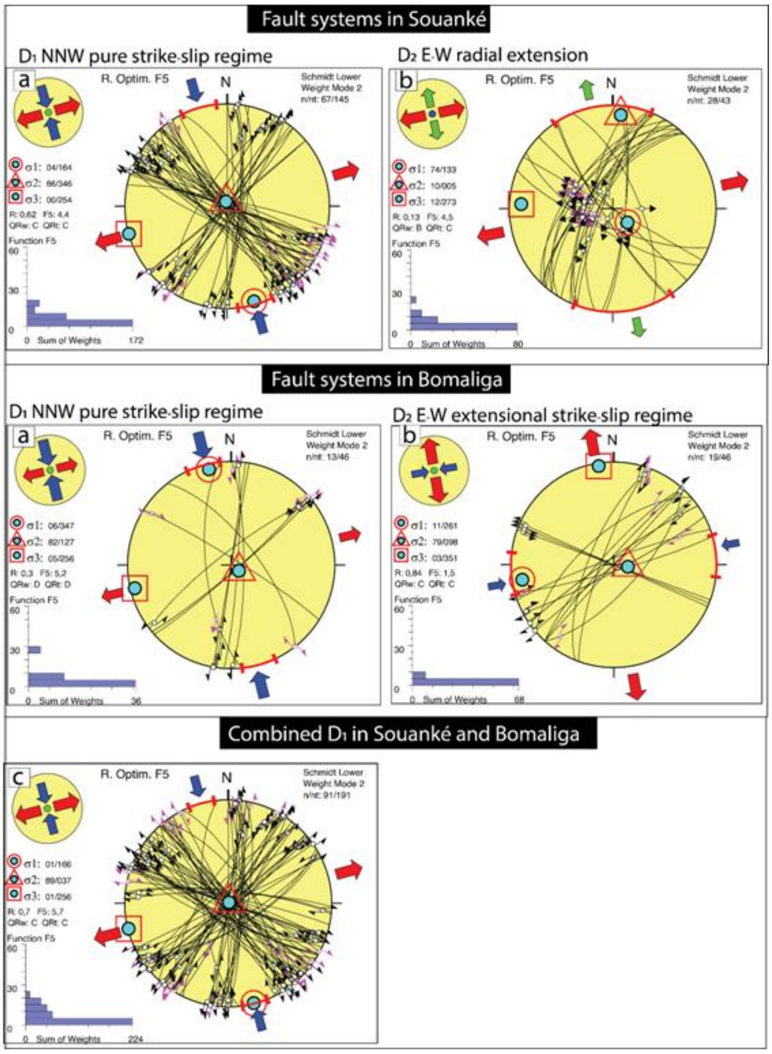


**Figure 9:** PBT kinematic axes results for both D1 and D2 at (a); (b) Souanké and Bomalinga, as well as (c) D1 in both Souanké and Bomalinga, combined.



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