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# Geometry and kinematics of brittle deformation in the Central Cameroon Shear Zone (Kékem area): Implication for gold exploration within the Central Africa Fold Belt in Cameroon

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ABSTRACT

The Central Africa Fold Belt (CAFB) is a collision belt endowed with gold deposits in Batouri area mined for about 50 years. However, favorable areas for gold exploration are poorly known. This paper presents (1) the kinematics of the brittle deformation in the Kékem area form the SW portion of the Central Cameroon Shear Zone and (2) constraints gold mineralization events with respect to the collisional evolution of the CAFB. The authors interpret that the conjugate ENE to E and NNW to NW trending lineament corresponds to the synthetic (R) and the antithetic (R') shears, which accompanied the dextral slip along the NE-ENE striking shear. The latter coincides with the last 570–552 Ma $D_3$ dextral simple shear-dominated transpression, which is parallel to that of Batouri area hosting gold deposits. Gold mineralization, which mainly occurred during the last dextral shearing are disseminated within quartz veins associated to Riedel's previous structures reactivated due to late collisional activities of the CAFB as brittle deformation. Gold mineralization occurred mainly during the 570 –552 Ma D3 event. The reactivation, which might be due to dextral simple shear during mylonitzation, plausibly remobilized the early gold deposits hosted in syn-compressional rocks and/or possibly focused deep-sourced fluid mixed with those released by dehydration. Therefore, the Central Cameroon Shear Zone where Kékem is located, and which, shows a similar petrographical and structural features that controlled Batouri gold district, is target area for gold exploration.

## 1. Introduction

The Central African Fold Belt (CAFB) in Cameroon (Toteu SF et al., 2001), a part of the vast Brasiliano-Pan-African fold belt (Fig.1a) in the pre-drift reconstruction (Archanjo CJ et al., 2013) is a typical collisional belt developed in a subduction-collisional setting (Owona et al., 2010; Bouyo MH et al., 2013). Its evolution is characterized by an early crustal thickening followed by transpression with a sinistral- and then by a dextral shear along about NE-ENE striking Central Cameroon Shear Zone (CCSZ, Ngako V et al., 1991) and the Bétaré Oya Shear zone (Kankeu B et al., 2009). A complex network of fault system characterized by a N70°E parallel en-echelon shear zones inter-connected by a N40°E directed S-type restraining bend exists in the Magba area (Njonfang E et al., 2008). This S-type bend, extending southward up to the Foutoni and the Kékem areas (Tchaptchet TD et al., 2009), is associated with a network of secondary fault and fractures around Foumban (Njonfang E et al., 2008), Kékem (Tchaptchet TD, 2017) and the Tombel plain (Njome MS and Suh CE, 2005). Although Simeni NAW et al. (2017) linked secondary fractures with the Pan-African structures, their geometry and kinematics remained poorly documented. Interestingly, some of these transpressional shear zones (Tchollíré Shear Zone: TSZ, Betaré Oya Shear Zone: BOSZ) and associated subsidiary shears in their adjacent areas host gold deposits (Suh CE et al., 2006; Tchameni V et al., 2013).

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E.g. vein-type gold deposits (0.04 to 30 g/t and even 66 g/t Au) are associated to NE-SW trending shear zone within 620 Ma metagranite and in altered wall rock up to 18.5 gt$^{-1}$Au (Asaah VA et al., 2014; Suh CE et al., 2006, Vishiti A et al., 2019) are reported in Batouri and adjacent areas, which are affected by Betaré Oya Shear Zone (Kankeu B et al., 2009). The reserve of this gold which is mined in Cameroon for more than 50 years (Asaah VA et al., 2014) is estimated to be at least 15 t (Mélisi JP et al., 2006).

This study performs geometric and kinematic analyses of the lineaments in the Kékem area, located at SW of the CCSZ. These analyses are based on (1) lineaments identification by combining geomorphological parameter, (2) digital elevation model, and (3) field data. CCSZ parallels the gold-enriched BOSZ. The gold mineralization processes and their plausible timing with respect to the tectonic evolution of the CAFB are discussed. The Kékem area at SW of the CCSZ is assessed for the suitability for gold exploration following its comparison with the Betaré Oya Shear Zone. The area displays similar tectonic evolution and lithogic features that apparently controlled gold mineralization at the BOSZ.

## 2. Regional geology

The Kékem area (Fig. 1b) is located at the SW of the about NE striking Central Cameroon Shear Zone (CCSZ, Ngako V et al., 1991; Njonfang E et al., 2008; Tchaptchet TD et al., 2009) of the CAFB in Cameroon (Fig. 1b). The CAFB is divided into three geodynamic domains (Toteu SF et al., 2004). (1)The northern domain is made up of the Poli, the Léré and the Mayo Kebbi meta-sedimentary series all intruded by pre-, syn- and post-tectonic (750-680 Ma) calc-alkaline rocks emplaced in an Early Neoproterozoic back-arc or a continental magmatic arc basin (Toteu SF et al., 2006; Bouyo MH et al., 2015). These intrusions define an NNE –SSW corridor marking the southern limit of the northern domain. (2) The southern domain is monocyclic with granulitic nappes made up of Neoproterozoic metasedimentary units (Mbalmayo, Yaounde and Ntui-

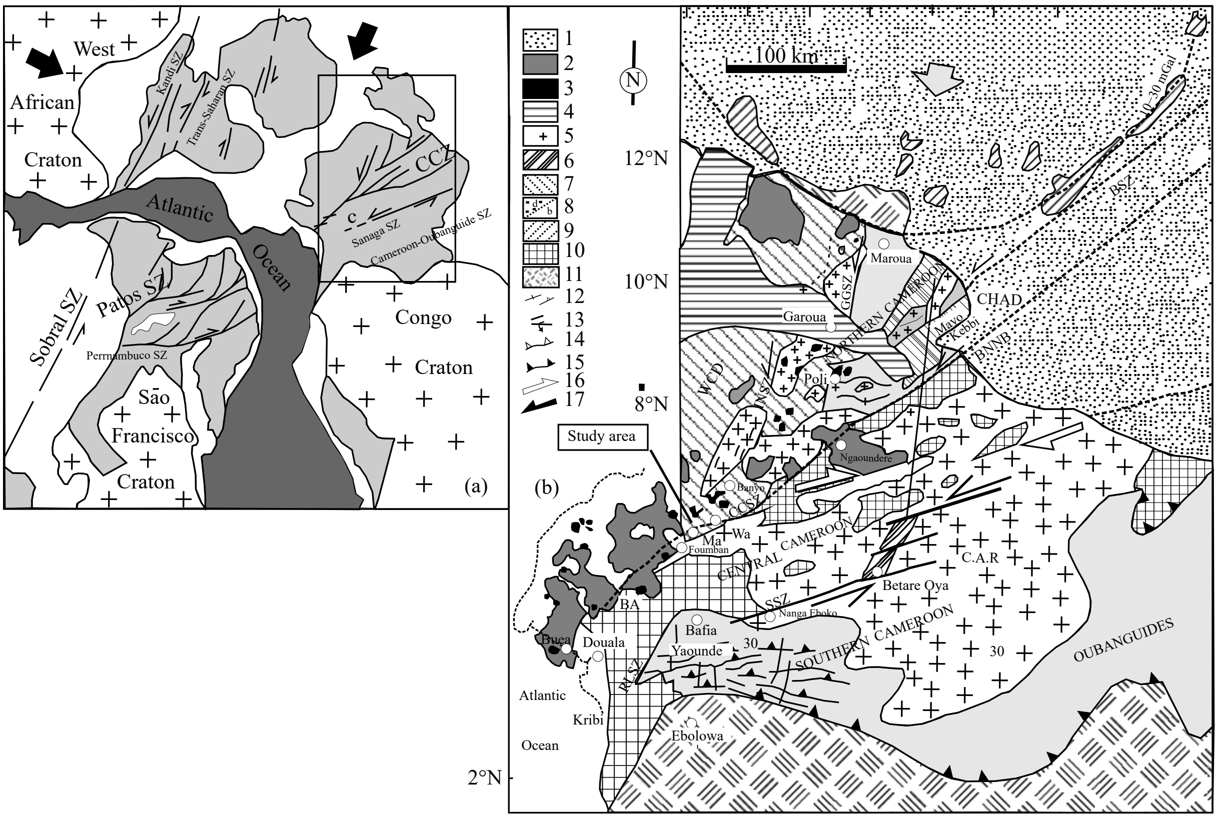

**Fig. 1.** **a**. Pan-African shear zone network in pre-Mesozoic reconstruction (after Caby R, 1989). SZ = Shear Zone: C = Cameroon area. **b**. Pan-African structural map of Cameroon from Njonfang E et al. (2008) and location of the study area. 1–Quaternary sediments; 2–Cameroon Line volcanism; 3–Cameroon Line plutonism; 4–Mesozoic sediments (Benue through); 5–Late syntectonic sub-alkaline granitoids; 6–Lom syntectonic basin (meta-sediments, conglomerates, volcanic ashes and lavas); 7–Western Cameroon Domain (WCD: early syntectonic basic to intermediate calc-alkaline intrusions, 660-600 Ma); 8a–Poli Group (active margin Neoproterozoic supracrustal and juvenile intrusions); 8b–Yaounde Group (intracratonic deposits); 9–Massenya-Ounianga gravity highs (10-30 mGal); 10–Adamawa-Yadé and Nyong Paleoproterozoic remnants; 11–Craton and inferred craton; 12–S$_2$ foliation and L$_2$ lineation trends; 13–F$_2$ upright and overturned antiforms; 14–syn-D$_2$ Main frontal thrust zone; 15–syn-D$_1$ thrust zone (separates the LP to MPzone in the North from the HP zone in South); 16–Syn-D$_3$ sense of shear movement; 17–Syn-D$_2$ sense of shear movement. Large grey arrow:syn-D$_{1-3}$ regional main stress direction. Thick lines- shear zones (SZ): BSZ = Balché SZ; BNMB = Buffle Noir - Mayo Baléo SZ; CCSZ = Central Cameroon SZ; GGSZ = Godé - Gormaya SZ; MNSZ = Mayo Nolti SZ; RLSZ = Rocher du Loup SZ; SSZ = Sanaga SZ; Ma = Magha; Wa = Wakaa. Small squares: Ba = Bandja complex; Fo = Fomopéa complex.

Betamba). These units, consisting of schists, garnet-kyanite-bearing mica-schists and garnet-kyanite gneisses, formed originally in either a passive margin (Mvondo H et al., 2003) or an active margin (Standal H et al., 2006) at the northern edge of the Congo craton. They are associated with alkaline magmatic rocks and the entire unit thrusts onto the Archean Congo craton towards South (Ngako V et al., 2008).

The Pan-African tectonics is characterized by three main deformation phases. The significance of these deformations is interpreted differently. According to Mvondo H et al. (2007), the southern domain is characterized by two compressive events, $D_1$ and $D_3$, with E-W to NW-SE maximum stress direction. These two phaseshad an intermediate $D_2$ event of extension parallel to the orogen synchronous with the peak metamorphism. This evolution is consistent with a magmatic-arc collision setting (Mvondo H et al., 2007). $D_1$ and $D_3$ are compressive tectonics with nappe stacking during $D_1$-$D_2$ interphase coeval with the 620 ± 10 Ma granulitic metamorphic peak and anatexis (Penaye J et al., 1993) defining a suture zone following collision between the Congo craton to the south and the Paleoproterozoic crust to the north. These two domains are separated by Adamawa-Yadé domain, which is transected by the CCSZ and is sandwiched between the N70°E striking Tchollіré-Banyo Shear Zone (TBSZ) to the N and the Sanaga shear zone (SSZ) tothe south (Fig. 1b; Toteu SF et al., 2004). These transcurrent CCSZ faults are regarded as possible continuation of the major shear zones of NE Brazil in the pre-drift Gondwana reconstruction (Archanjo CJ et al., 2013). This polycyclic domain is made up of an assemblage of about 2100 Ma remnants of Paleoproterozoic rock with an Archean heritage (Penaye J et al., 2004; Toteu SF et al., 2001; Ganwa AA et al., 2016) and Neoproterozoic meta-sedimentary rocks recrystalized in upper amphibolite to granulites facies metamorphism during 630–600 Ma of crustal thickening (Tchaptchet TD et al., 2009; Tchaptchet TD, 2011; Bouyo MH et al., 2013). These formations are further intruded by Pan-African granitoids whose emplacement age in Kékem isabout 576–560 Ma Ma (Kwékam M et al., 2013, Tchaptchet TD, 2011) and 640–620 Ma at Batouri gold district (Asaah VA et al., 2014). Subsequently in this article $D_4$ phase will denote the brittle deformation.

The Pan-African tectonic evolution of this domain is characterized by an early $D_1$ deformation (630–600 Ma: Bouyo MH et al., 2013) of crustal thickening followed by 620–585 Ma $D_2$ phase (Ngako V and Njonfang E, 2011) with N-S to ENE-WSW striking sinistral transcurrent/transpressional shear zones (e.g., the Mayo Nolti shear zone, the Gordé Gormaya shear zone and the Rocher du Loup shear zone: Ngako V et al., 2008) developed during amphibolite facies metamorphism (Njonfang E et al., 2008). The about 585-583 Ma $D_3$ event (Ngako V et al., 2008) is marked by a about NE to ENE trending dextral strike slip faults (e.g., CCSZ, Fig. 1b, Ngako V et al., 2008) that transect the central domain- locally known as the Foumban Shear Zone (FSZ: Njonfang E et al., 2008) or the Fotouni-Foumban Shear Zone (FFSZ, Tcheumenak Kouémo J et al., 2014). It is about 500 km long and 5-12 km wide (Njonfang E et al., 2008).

The Kékem area (Fig. 2), at the SW of the central domain, comprises Paleoproterozoic magma-derived migmatitic gneiss (Dumort JC, 1968; Tchaptchet TD 2009; Tchaptchet TD, 2011), displaying 2.7–1.5 Ga Archean to Paleoproterozoic ages (Penaye J et al., 1993; Toteu SF et al., 2001; Tchaptchet TD, 2011). The rocks consist of garnet-bearing pyroxene gneiss dated at 2100 Ma (U/Pb on zircon: Penaye J et al., 1993; Toteu SF et al., 2001) and biotite-amphibole gneiss. The rocks recrystallized at granulites facies metamorphic conditions and subsequently retrogressed into amphibolite facies during the Pan-African orogeny (Penaye J et al., 2004). They are associated with lenses of Neoproterozoic metasedimentary rocks, garnet-biotite gneiss and sillimanite-garnet-biotite gneiss (Tchaptchet TD et al., 2009) that recrystallized under the upper amphibolites-facies metamorphic condition about 580 Ma (U-Th-Pb on monazite, Tchaptchet TD et al., 2009) or 600 Ma (U-Pb on zircon, Tchaptchet TD, 2011) during crustal thickening, following a continental collision (Tchaptchet TD et al., 2009). These migmatitic gneisses have been intruded by high-K calc-alkaline to shoshonitic post-collisional magmatic rocks (biotite granite with enclave of diorite, amphibole granite, muscovite-biotite granite, gabbro and norites) at 570–560 Ma (Dumort JC, 1968; Tchaptchet TD et al., 2009; Tchaptchet TD, 2011; Kwékam M et al., 2013). This magmatism is coeval with the activity of the N40°E striking high temperature shear zone constrained at 570–552 Ma (U-Th-Pb dating of monazite (Tchaptchet TD et al., 2009).

The shear zone is associated to secondary fractures filled in by sheet-like granite and tholeiitic basalt dykes originated from the melting of subcontinental lithospheric mantle by early fragmentation of the West Gondwana (Tchaptchet TD et al., 2017). Migmatitic gneisses and magmatic rocks are covered partially by the 10–5 Ma alkaline basalts (Tchuimegnie Ngongang NB et al., 2015) of the Cameroon Volcanic Line.

## 3. Methodology

This work uses combined methodologies of Ganwa AA et al. (2007) and Akam JM et al. (2014) to identify lineaments. According to Ganwa AA et al. (2007) the analysis of geomorphologic parameters is very useful for identifying lineaments in the pan-African setting. River flow can be tectonic controlled (e.g. Misra AA et al., 2014), and hence, can help in deciphering lineaments. Not all drainage patterns are tectonics-controlled. Any specific drainage pattern (e.g., the rectangular pattern) was not observed in the study area (Dasgupta S and Mukherjee, 2019). The hydrological network as in the 1:50000 scale topo-sheet (Fig. 3) was used and the lineaments identified are shown as black lines in Fig. 3. Then, this first lineament map is superposed on a second one obtained from digital elevation model of the Shuttle Radar Topography Mission (SRTM) following the methodology of Akam JM et al. (2014). This operation is based on 2001

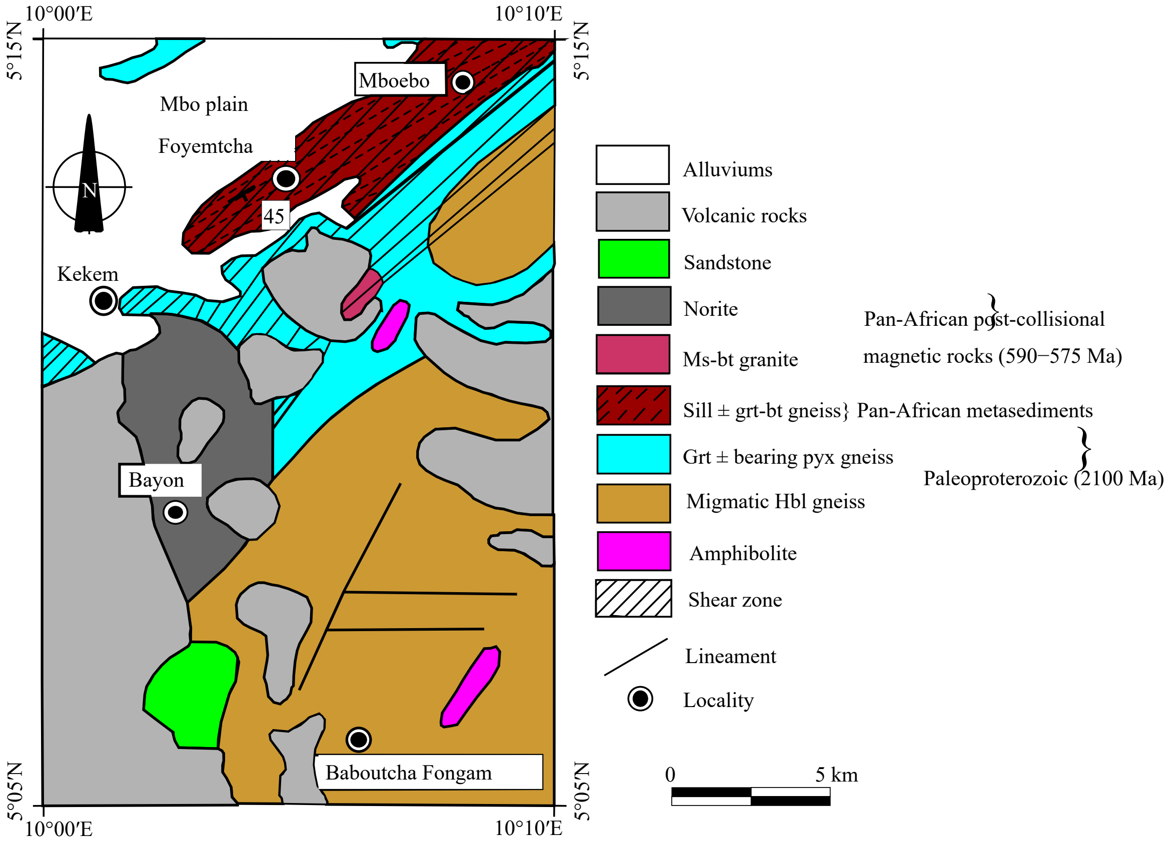

**Fig. 2.** Sketch of the geological map of the study area, extracted from Dumort JC (1968).

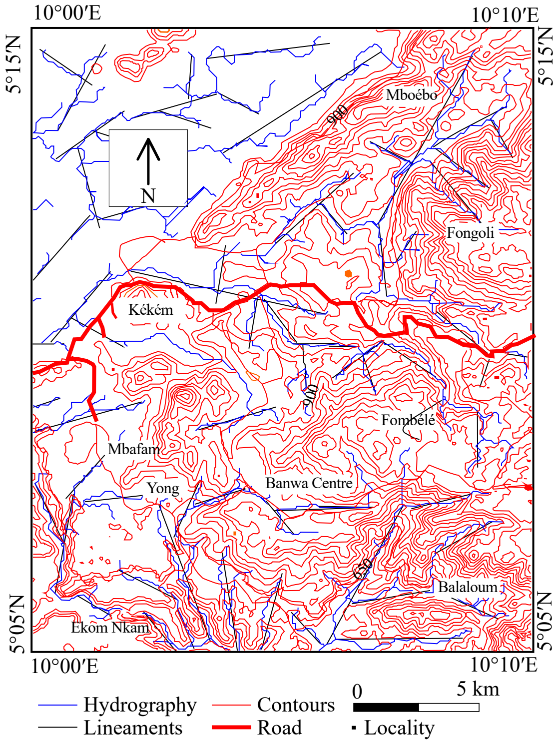

**Fig. 3.** Topographic map of the studied area with lineament identified from hydrographic network. This figure is generated from the SRTM DEM. Alternately, hillshade data derived from DEM may also be used.

(SRTM_ffB03_p186r057) satellite images (downloaded from internet and expressed in 3D on previously geo-referenced digital data; Fig.4). This SRTM DEM has a better resolution and image enhancement entails selection of subset of information to be displayed (Neawsuparp K and Charusir P, 2004). The shaded relief method, as an enhancement technique, discriminates structural features indicated by homogeneously colored area, corresponding to lineaments that are different from the background colour. These lineaments are extracted manually, and only the natural lineaments are taken. This operation is performed by using the Global Mapper software (version 10). Fig. 4 is superposed on Fig. 3 to obtain the lineament map of the study area (Fig. 5). In other words, lineaments extracted have been overlain on the SRTM DEM of the area. Only regional lineaments were selected for interpretation (Fig. 6a). SRTM images were downloaded and were worked on.

## 4. Results and discussion

### *4.1. Geometrical analyses*

As per Fig. 6b, five fractures sets striking ENE, E, NW, NNE and NE are distinguished. The ENE fractures are most numerous (Fig.7a). Some of them deflect earlier foliation through dextral shear (Fig.7a). The E-W trending fractures are the second predominant that are commonly expose in the SE portion the Kékem area (Fig.7b). Some of them dextrally

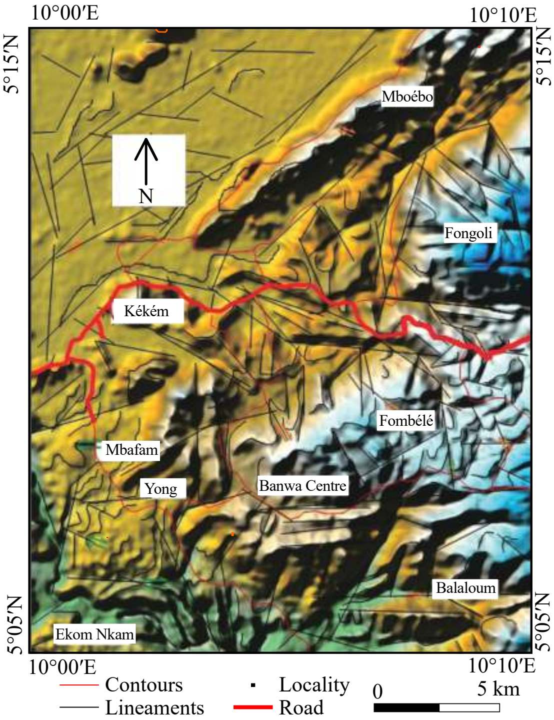

**Fig. 4.** Digital elevation model from the Shutter Radar Topography-Mission (SRTM) with identified lineaments. Black curved lines show curved foliations.

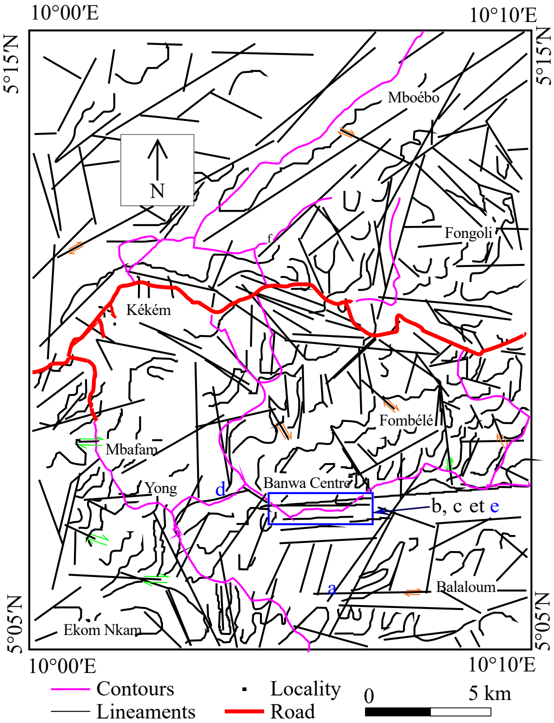

**Fig. 5.** Lineaments map from the hydrographic network and the SRTM image: Notice that red colored fractures are from hydrographic network and dark colored fractures from SRTM.

deflect the earlier foliation planes (Fig. 7c). A few sets of such fracture are filled with basalts (presumably dykes) and granites in the Banwa locality (Figs. 7b, c). Few fractures cut across sheet like igneous bodies (Fig. 7d). The NNE-striking planes are less abundant and are marked by sinsitral shear affecting the earlier foliations (Fig.7e). The NE-trending fractures are least numerous (Fig.7f). Fig. 8 presents synoptically the geometrical arrangement of these secondary fractures. The ENE fractures make about 15° with the NE and the E trending fracture sets. Moreover, ENE and NW trending fractures constitute conjugate sets at about 60°.

The geometry of the fault plane and the type of faulting depend on the internal angle of friction, strain rate, stress state (Ahlgren SG, 2001), vorticity and rheological properties of the rocks (Misra S et al., 2009; also see Mukherjee S and Khonsari, 2018). The complex fault pattern is also characterized by the Riedel conjugate set- comprising of synthetic Riedel fractures (R) and conjugate antithetic Riedel fractures ($R^{/}$). This conjugate fracture set, most conspicuous as per the Anderson’s model, is accompanied sometimes by synthetic P-shear fractures and tensional T fractures at about 45° with the primary shear Y-planes.

Fig. 8 is deduced based on the brittle planes’ orientations for the Kékem area (Fig. 8). This resembles those given in Simeni NAW et al. (2017) reported from Bafia and Maham areas, respectively, about100 km SE of Kékem. A dextral shear along the NE to ENE striking shear zone as the main fault is suggested. This implies that the NNE/NE, ENE, E-W and NW fractures correspond most plausibly to P, Y, R and $R^{/}$ in the complex fault pattern recorded in a strike slip shear zone (Simeni NAW et al., 2017).

### *4.2. Kinematics of fault-network in the Kékem area*

As discussed in the previous section, the synoptic map of the Kékem area (Fig. 4) shows a fault pattern consistent with a right-handed Riedel shear with an ENE striking primary shear zone. This fault pattern matches with the dyke offsets of Simeni NAW et al. (2017) from the southern domain of the Cameroon Volcanic Line. The strike of the main shear zone coincides with that of the dextral regional CCSZ recorded geophysical from the basement rocks of the central domain (Noutchogwé et al., 2010).

Brittle deformation modeling shows that the maximum principal stress axis ($\sigma_1$) bisects the 60° angle between conjugate R and $R^{/}$planes (Davis GH et al., 2000). Following this, $\sigma_1$ should trend E-W in our study area (Fig. 8). This orientation is compatible with the E-W to NW-SE maximum stress field direction ascribed to the $D_3$ folding in the southern domain (Mvondo H et al., 2003) or that of the NW-SE to WNW-ESE of the last dextral simple shear dominated transpression along the CCSZ in the central domain (Ngako V et al., 2008; Kankeu B et al., 2009; Ngako V and Njonfang, 2011; Bella Nké BE et al., 2018) in the CAFB. The maximum stress field direction and the $D_3$ simple shear-dominated transpression are compatible, and this rotated the $\sigma_1$-axis clockwise (Ngako V et al., 2008; Ngako V and Njonfang, 2011; Bella Nké BE et al., 2018). The fractures system is coeval to the simple shear-dominated transpression. This hypothesis is consistent with Davis GH et al., (2000). As per

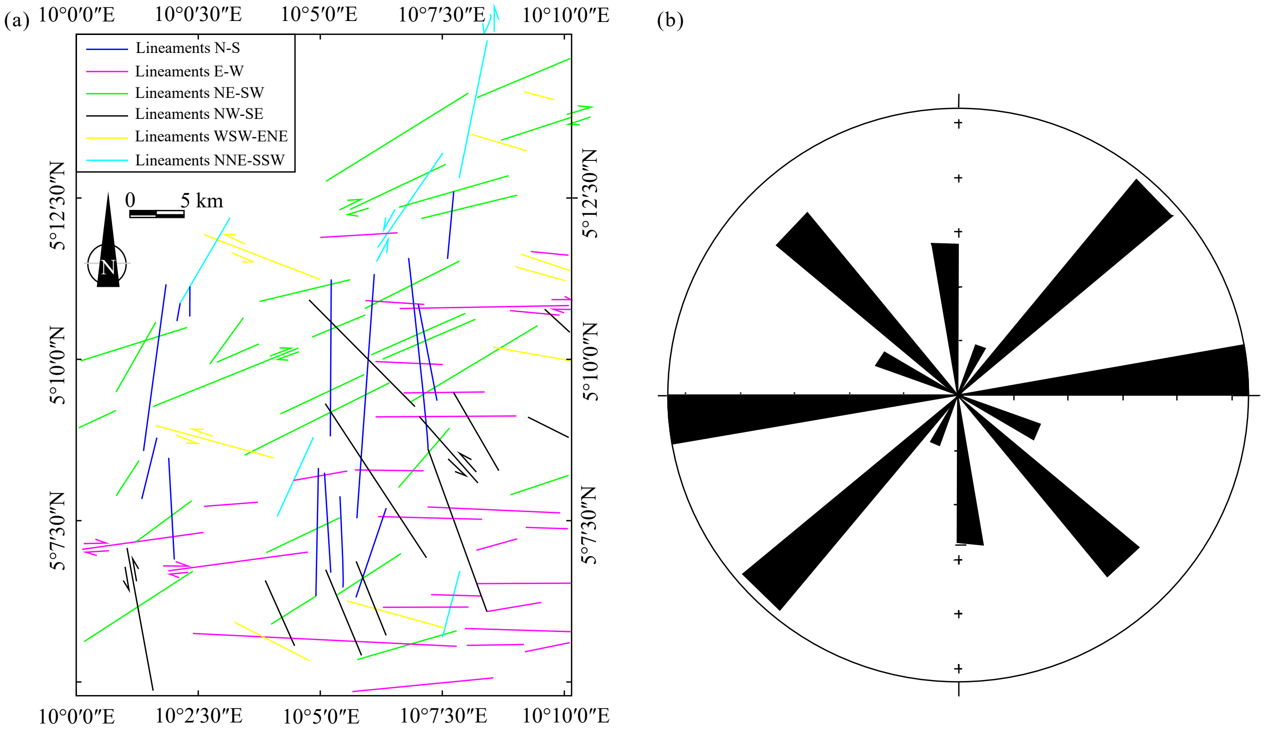

**Fig. 6.** Synthetic lineaments map from the hydrographic network (a) and the SRTM image (b). Only regional lineaments selected.

Davis GH et al. (2000), shear zone experiencing simple shear is accompanied by Riedel 's fractures kinematic model. Therefore, the reactivation of previous structures ascribed to $D_3$ transpression (Ngako V et al., 2008) can be envisaged for fracture systems recorded along the CCSZ (Njome MS and Suh CE, 2005) as well as the BOSZ (Takodjou WJD et al., 2016).

## 5. Implication for the evolution of the CCSZ in Cameroon

The CAFB (Cameroon) witnessed a tectonic indent collision between the East Sahara Block (ESB) and the Sao-Francisco - Congo and West African cratons (Ngako V et al., 2008). This collision is characterized by an early crustal thickening that existed during thrust and nappes tectonics (NgakoV et al., 2008; Owona S et al., 2010; Tchaptchet TD et al., 2009; Bouyo MH et al., 2013), followed by a 620-585 Ma sinistral shear (Ngako V et al., 2008; Tcheumenak Kouémo J et al., 2014) coeval with the emplacement of calc-alkaline to high K calc-alkaline granitoids. Finally, a $D_3$ dextral simple shear-dominated transpression (Ngako V et al., 2008, Njonfang E et al., 2008; Kankeu B et al., 2009; Bella Nké BE et al., 2018) at 585-538 Ma (Ngako V et al., 2008; Njonfang E et al., 2008) or 570-552 Ma (Tchaptchet TD et al., 2009) happened. These shear zones constitute a complex network of fault system characterized by a N70°E parallel en-echelon pattern, presumably a “step-over” indicating intense shearing (reviewed in Mukherjee S 2013), inter-connected by a N40°E directed S-type restraining bend around Magba (Njonfang E et al., 2008), which extend southward up to the Foutoni and the Kékem areas (Tcheumenak Kouémo J et al., 2014; Tchaptchet TD et al., 2009).

The reactivation characterizing the late collision (Ngako V et al., 2008) operate dominantly through simple shear (Bella Nké BE et al., 2018) inducing strike-slip (Misra S et al., 2009) follow the Riedel model of kinematic fractures. Simulation of faulting in zone of continental transpression by Schreurs G and Colletta B (1998) show that as deformation intensifies, the transverse component of the transpression increases the strike-slip leading to rocks failure. These fractures widespread along the CCSZ in Manjo (Njombe MS and Suh CE, 2005), Magba (Njonfang E et al., 2008), and the Betaré Oya shear zone (Som Mbang MC et al., 2018) are associated with sub-vertical sheet-like granitic veins and sub-continental mantle-derived tholeiitic basalt dykes characteristic of extension (Tchaptchet TD et al., 2017). Simple shear within the CCSZ could be the main mechanism that initiated the transition from ductile to brittle deformation marking the onset of extensional tectonics corresponding to the $D_4$ event. The later postdates the 570-552 Ma dextral shear along the CCSZ. This timing is compatible with the extensional tectonics-related 550 Ma alkaline granites within the fold belt (Toteu SF et al., 2001).

## 6. Tectonic setting and gold mineralization in the CAFB (Cameroon)

The Central Africa Fold Belt (CAFB) in Cameroon is endowed with orogenic gold deposits (Tchameni R et al., 2013; Asaah VA et al., 2014) associated with compression and transpression. Indeed, the gold-bearing syenogranite in Batouri yielded an age of 620 Ma (U-Pb on zircon: Asaah VA, 2014. As per the deformation chronology of Li et al. (2017) and Ngako Vet al. (2008), this corresponds to a $D_1$-$D_2$ event interpreted as the peak of the granulitic metamorphism in the south domain of the CAFB. In addition, transpressional shear zone-related gold mineralization is reported from the Tchollíré Shear Zone (TSZ), the Betaré Oya shear zone (BOSZ) and in subsidiary shear zones in the adjacent areas (Tchameni R et al., 2013; Asaah VA et al., 2014). In the TSZ, gold lode is associated with NE-trending shear zones and subsidiary fractures related to dextral shear (Tchameni R et al., 2013). In Batouri and Dimako-Mboscosso adjacent to the BOSZ, the lode gold deposit is found in quartz veins in steeply dipping brittle-ductile shear zones in foliated biotite meta-granite, wall rock, and in NNW to WNW trending faults inside the alkali-feldspar granites (Vishiti A et al., 2017). However, the gold-bearing quartz veins are more frequently recorded within the NE-trending shear zone, which is about 13 km-long and 100 m to 1 km wide (Vishiti A et al., 2017). Minor anastomosing shears with gold-bearing quartz veins

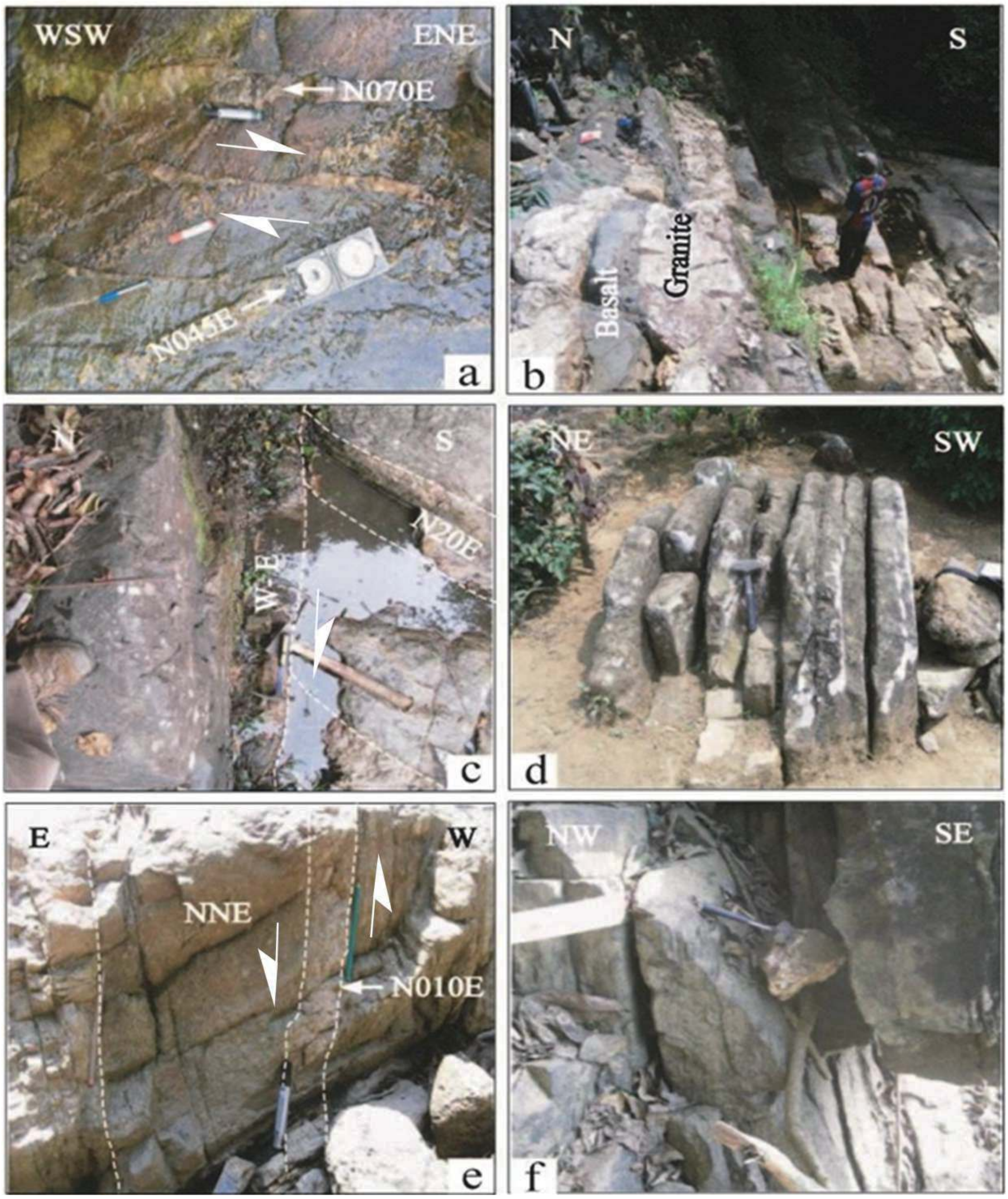

**Fig. 7.** Field photograghs of faults associated to N40 to N50° E shear zones. Location of snaps for the below sub-figures are indicated in Fig. 5. a–A network of fractures (N70° E and N45° E) filled up with quartz cross cutting the N45°E striking mylonitic band in the area of Fotsi Sud. Notice that the N70°E striking fracture cross-cut that of N450°E.b–Sub-vertical E-W striking fault plane filled up with sheet-like granite and basalt in the northern Fotsi. c–W-E striking sub-vertical sheet-like granite transposing N30°E striking mylonitic foliation in the northern Fotsi. d–NW-SE trending sheet-like granite in the Banwa town. Fractures can be found after zooming the image. e–Parallel NNE-trending sheet-like cross cutting the N30°E trending mylonitic gneiss. On zooming the image one sees few P-planes defining the slip sense. The Y-plane is parallel to the half arrows. f–N45°E striking fracture associated with N45°E striking mylonitic gneiss in the Kékem area.

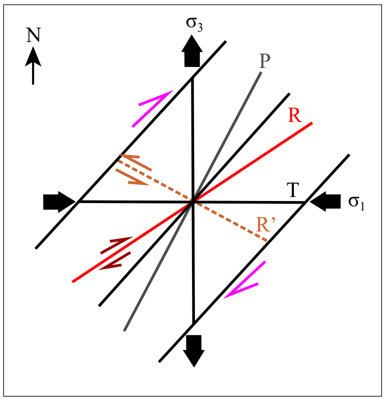

**Fig. 8.** Stress regime and shear planes in the study area. This is also as per Passchier and Trouw (2005).

trend NNE-SSW, NE-SW, and ENE-WSW with steep dip towards NW (Asaah VA et al., 2014).

The geometric distribution of these gold-bearing quartz veins is consistent with the Riedel shear model following a dextral slip along the main NE- ENE striking Betare Oya Shear Zone (Vishiti A et al., 2017). This gold bearing quartz veins system, which cross cuts variably deformed granitoids, formed during the pan-African orogeny in a volcanic-arc setting, are composed principally of quartz ± calcite and Mg-rich ankerite. This mineral assemblage is associated with major hydrothermal ore minerals such as arsenopyrite, chalcopyrite, pyrrhotite and galena.

The gold mineralization associated with transpression has been addressed widely (e.g., Araújo FJOD and Kuyumjian, 2000; Araújo FJOD et al., 2005; Tchameni R et al., 2013; Groves DI et al., 2018; Silva FW et al., 2018). Both the BOSZ and TSZ, parallel to CCSZ, are simple shear-dominated zones of transpression (Njonfang E et al., 2008; Kankeu B et al., 2009; Bella Nké BE et al., 2018) of lithospheric-scale (Njonfang E et al., 2008) constrained at 570 –552 Ma (Tchaptchet TD et al., 2009). Those are also the zones of fluid flow (Groves DI et al., 1988) sourced from (1) asthenospheric upwelling (Bierlein PF et al., 2006), (2) dehydration metamorphic reaction of carbonaceous metasedimentary rocks, and/or (3) fluid released during felsic and intermediate magma crystallization (Silva FW et al., 2018). In these shear zone, as the deformation intensifies, the transverse shortening component increases the strike-slip that deviates from the simple shear. The strike slip deformation originated vertical mylonitic foliations with sub-horizontal lineations on them. Plastic deformation and dynamic recrystallization of sub-grain modified the permeability of the deforming rocks resulting in fluid accumulation leading to micro-cracks (Zhu J et al., 2014) and favorable environment for gold deposits (Zhu J et al., 2014).

When the transpression/shear zone is associated with genetically linked subsidiary shear zones, the latter are referred also as the first-order/second-order brittle planes. The first order shear zone is characterized by higher temperature commonly containing gold dissolved as reduced sulphide with respect to the gold occurring at the secondary fractures. Contrasting fluid-pressure and/or temperature promotes fluid flow and gold deposition. This hypothesis can be applied for the gold deposits in Cameroon because the last dextral shear of the transpressional tectonics occurring at high temperature (Njonfang E et al., 2008) is susceptible to rehomogenize gold in 620 Ma-aged syn-collisional granitoids into subsidiary Riedel shears along the main shear zone. This hypothesis matches with Araújo FJOD and Kuyumjian (2000). As per Araújo FJOD and Kuyumjian (2000), the gold deposits in the NE Brazil are probably due to the reactivation during $D_3$ strike-slip deformation, which remobilized gold of the Pre S-granitoids into Riedel's fractures kinematic models.

Summarily, the main gold mineralization is presumably associated with the last $D_3$ transpressional shear about 570–552 Ma. This is even though the gold-bearing 640–620 Ma syn-collisional granitoids is recorded in Batouri (summary from Asaah VA et al., 2014). These transpression shear zone-related gold mineralizations are probably coeval with the reactivation of the early structures during the last collisional activities amongst the Congo craton, West African Congo craton and Saharan Metacraton, as suggested by Ngako V et al., (2008).

## 7. Potential targets for gold exploration within the CAFB

As discussed, crustal environment favorable for gold deposits is apparently controlled by the structural setting and the lithology. Lithospheric-scale transpression/shear zones characterized by the association of pure- and simple shear followed by mylonization can result in fluid focusing and gold deposition. Greenschist facies metasedimentary rocks and high K alkaline to alkaline granite are gold hosting rocks, suggesting gold-enriched fluid (Asaah VA et al., 2014) to be present in the past. These geological features are reported from Kékem by Tchaptchet TD, 2009; Tcheumenak Kouémo J et al., (2014). According to these authors, the Kékem area forms the SW prolongation of the CCSZ. In addition, metasedimentary rocks experienced a clockwise PT path with a retrograde loop characterized by an early $D_1$, $D_2$ deformations during the upper amphibolite facies metamorphism and mylonitization between 570 –552 Ma. These metamorphic rocks are intruded by Pan-African felsic to intermediate magmatic rocks (Tchaptchet TD et al., 2009). Both events can generate gold- enriched fluid (Tomkins GA et al., 2013; Silva FW et al., 2018) that flow through the fractures. Also, the reactivation process ascribed to $D_3$ event (Tcheumenak Kouémo J et al., 2014), which operates at high temperature are able to rehomogenize the gold-enriched fluid that move to low strain zones i.e., fracture with Riedel kinematic model (this study). This argument is strengthened by numerous quartz veins associated to fractures that connote fluid activity (Groves DI et al., 1988). These quartz veins hold gold grains / lode as in Betaré-Oya.

The similarities in lithological association, metamorphism facies (greenschist facies) and structural evolution between the Batouri and Betaré Oya area where gold-bearing quartz veins are reported and the Kékem area that forms the SW of the CCSZ, suggests that the CCSZ as well as the subsidiary shear fractures in the adjacent areas, are crustal environment favorable for gold deposits. Accordingly, the central domain of the CAFB bounded by transpression/shear zone associated with subsidiary Riedel’s shear fractures kinematic model can be the potential target for further gold exploration.

## 8. Conclusions

(i) The Kékem area forms the SW prolongation of the CCSZ. Evolution of this segment of the CCSZ is characterized by an early $D_1$crustal thickening, followed by $D_2$ sinistral shear and a $D_3$ dextral simple shear-dominated transpression and then a $D_4$ brittle deformation. This brittle deformation, presumably no older than 550 Ma, is the onset of the extensional tectonics as illustrated by associated granites and tholeiitic basalts.

(ii) The main gold mineralization is associated with 570 –552 Ma $D_3$ simple shear-dominated transpression (Tchollirè and Betaré Oya shear zone) and secondary fractures of their adjacent regions. However, syn-collisional (syn-$D_2$ granitoids) gold lodes exist in Batouri. The reactivation of the early structures during late collision activities through simple shear rehomogeneized the syn-collisional granitoid-related gold.

(iii) The deep-sourced fluid might have mixed with the component released from dehydration metamorphic reaction and felsic magma crystallization. These $CO_2$-enriched fluids contain gold dissolved as reduced sulphide at high temperature, and deposited gold in dilation zone where mylonitization operated under greenschist to amphibolite facies conditions.

(iv) The similarity in structural evolution and lithologies of the gold-bearing Betaré Oya transpressional shear zone with that the Kékem area that forms the SW prolongation of the CCSZ, and suggests a regional setting controlling the gold mineralization within the CAFB. Therefore, the CCSZ as well as its adjacent areas with secondary fractures could be a suitable spot for gold exploration.

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## CRediT authorship contribution statement

Tchaptchet Tchato is the one who has carried out field study, conceived and initiated the paper in collaboration with Professor Soumyajit Mukherjee. In addition, the latter reorganise the paper, redraw some figure with corel draw software according to editor ’ requirements. Numbem has actively participated in writting the manuscript and has highly improved the english language quality. Ngamy has contributed in the methodology section and has produced original figures for the paper. Tchouankoue upgrade the manuscript by reviewing it.

Declaration of competing interest

We have approved the manuscript and agree with submission to China Geology.

There are no conflicts of interest to declare.

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