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A Review of Granitoid-Related Gold Mineralization Styles and Characteristics of the Neoproterozoic Eastern Gold Districts, Cameroon and the Role of Fluid Inclusion Studies in Elucidating the Genesis

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Abstract Geophysical, structural and geochemical data have been used to study the relationships between magmatism, tectonics, fluid circulation and gold mineralization in eastern Cameroon, and to provide pressure-temperature-composition-time paths constrained by the available dating. Primary gold mineralization displays spatial and temporal relationship with felsic to intermediate I-type granitoids emplaced in the 620-635 Ma period, in a volcanic arc setting at 625°C to 775°C. These granitoids were probably generated by partial melting of hydrated lower mafic crustal rocks, under oxidizing to moderately reduced conditions, where global permeability and tectonic regime allowed vertical fluid exchanges to be established. Mantle-derived, gold-enriched alkalic magmas are postulated as the ultimate source of gold enrichment in the crust. The Pan-African orogeny, and associated regional metamorphism and magmatism, generated large-scale movements of gold- and base metal-bearing fluids in the crust, channelized along complex fractures into regional NE-trending shear zones in Cameroon (e.g. Central Cameroon Shear Zone). However, these gold-rich alkalic magmas are so modified by crustal processes that evidence of their genetic relationship with gold become obscured. The primary ore mineral assemblage of quartz veins and veinlets within these shear zones consists of pyrite, galena, chalcopyrite, specular haematite, and gold. Preliminary fluid inclusion data from these auriferous quartz vein indicate that gold was probably transported predominantly as a bisulfide (HS^-) complex and deposited from low salinity (<1 to 8 wt% eq. NaCl) H_2O–CO_2 ($\pm CH_4 \pm N_2$) fluids that have total homogenization temperatures of 245-355°C. Desulfidation of hydrothermal fluids by Fe-bearing minerals in the wall-rock triggered the main gold precipitation phase. The major and trace element composition of ore-forming fluids from the mineralized vein, barren and granitic intrusion is still largely unknown, yet could provide important and more direct evidence for the fluid source(s). This is vital in establishing a direct genetic link between granitoids and gold mineralization.

Keywords: *neoproterozoic, granitoids, gold mineralization, hydrothermal alteration, fluid inclusion, Cameroon*

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1. Introduction

The geology of Cameroon has favoured the emplacement of several mineral deposits such as gold (Au), cobalt and nickel, diamond, rutile, iron ore and bauxite. Au mineralization is usually spatially and temporally related to granitoids [1,2,3,4]. Gold mineralization in Cameroon ranges from Archean to Proterozoic (Figure 1) during or postdating granitic intrusion. Therefore, several questions arise concerning the chronology and the role of geological events, the source of metal and the mechanisms which have led to the ore deposition. In the north part of the country, gold mineralization is associated with the Neoproterozoic Poli Series and coincident with the NE-SW trending Tcholliré shear zone [5]. In the south, gold mineralisation is associated with Archean to Palaeoproterozoic greenstone belts, BIF, and ultramafic rocks [6,7,8], which have been deformed by NNE-SSW and E–W (Djoum-Akonolinga), as well as N–S-trending (Ntem), shear zones and faults [5]. The Neoproterozoic Lom Series in Eastern Cameroon has been focus terrains for artisanal gold mining for several decades [9]. Artisanal gold mining activities in Batouri, Bétaré Oya and Colomine Districts around the 50s, recorded a production peak of 717 kg [10]. Au mining in these Au districts till the 70s remained basically artisanal and constituted the main source of livelihood for the indigenous community. This gradually changed due to the increase in gold price around the 1970s. The constant increase in this commodity price led to a cooperation between the United Nations Development Programme (UNDP) and Cameroon Ministry of Mines, Water and Energy, on a project aimed at evaluating the mineral potential of gold in this part of Cameroon, from 1981 to 1986. Batouri, Bétaré Oya and Colomine gold districts were areas of great interest, due to high gold contents. This coupled with the favorable Cameroon mining code of 2001 which offers mining companies a 5-year tax holiday and free transfer of capital out of the country, led to renewed foreign interest (particularly from Korea and China) and began the recent gold mining boom in these districts. Milési et al. [11] proposed resource estimates for these gold districts as follows: ~15t Au at Batouri, ~20t Au in Bétaré Oya and ~12t Au in Colomine. The 2009 "Gold Rescue Programme" put in place by the Cameroon government following the construction of the Lom-Pangar dam project expected to cause flooding of several tons of gold reserves along the Lower and Upper Lom series, intensified mining activities in these areas. This led to an annual gold production estimated at 1,500 kg through open pits and local underground shafts [12]. However, no reliable historical gold production data exist till date, but figures from http://www.24hgold.com (access on the 11/01/2018 at 9:37 am) shows a drop in production to 600 kg from 2010 to 2014.

The eastern region of Cameroon is the most prospective area for gold in the country [11,12]. Primary gold mineralization in this area is related to a series of quartz sulphide veins occurring within the NE-SW-trending brittle–ductile shear zones, associated to the large-scale Central Cameroon Shear Zone (CCSZ) system [3,13]. This mineralization extends beyond its border into Chad and the Central African Republic [14]. In the last decades, efforts have been made to improve the understanding of primary gold mineralization and tectonic evolution in this Neoproterozoic terrains of eastern Cameroon [3,4,13-21]. These results provided constraints on: (1) the nature of the hosting structures of lode gold mineralization; (2) their mineral chemistry; (3) the geochemistry and geochronology of associated granitic rocks; and (4) the source(s) of the ore fluids. Research on the orogenic or mesothermal lode gold mineralization style [3] has been particularly important for recent exploration successes in the Lom Series. An integration of these studies is presented in this review, which attempts to link geological processes documented at regional scale with those documented in individual gold districts in Eastern Cameroon: Batouri, Bétaré Oya and Ngoura-Colomine. This paper specifically intends to place gold mineralization related to granitic intrusions into the framework of crustal evolution deciphered so far. Extensive research hinge to the formation of gold deposits, aimed at proposing a range of genetic exploration models applicable to the Cameroon geologic context is necessary.

2. Regional Geological Overview

Geologically, Cameroon is characterised by Archean basement, Proterozoic volcano-sedimentary packages (similar to that of the auriferous Birimian belt of West Africa) and several late stage intrusive phases (Figure 1a, b). The Neoproterozoic Pan African-Brasiliano tectonic belt underlies NE Brazil, central Africa and much of Saharan Africa (Figure 1a). This belt formed as the West African and Congo-Sao Francisco Cratons converged during the assembly of West Gondwana [22,23,24]. An example of continental collisional tectonics with accretion-amalgamation of terrains, between converging older (Archean, Palaeoproterozoic) continental blocks. Final collision induced thrusting towards the cratonic forelands, anatexis, shearing, and doming. In the course of orogenic activity, major deformational zones originated all across the belt (Borborema province of NE Brazil, Hoggar, Nigeria, and Central Africa) as strike-slip tectonics or other transtensional or transpressional episodes. This is the case of the large-scale transcurrent Pre-Mesozoic Central African Shear Zone (CASZ) which extends from central Africa, across the Atlantic, into NE Brazil, as the Pernambuco shear zone [22,25,26,27]. The location of Cameroon within this Pan-African network provides an opportunity to understand shear zone related gold mineralization, and eventually correlating it to northern Brazil and other parts of the world.

In Cameroon, the CASZ forms two branches (Figure 1b): the central Cameroon Shear zone (CCSZ) to the north, and the Sanaga fault (SF) and the Betaré-Oya shear zone (BOSZ) to the south [16,17,28,29,30]. These shear zones generally follow a NE–SW trend (Figure 1b). Gold deposits in Eastern (Bétaré Oya, Batouri and Colomine) and Northern Cameroon are confined to these NE–SW trending shear zones and associated well-rock and volcano-sedimentary formations or schist belts locally referred to as the Lom series and Poli Group (Figure 1b), belonging to the Adamawa Yade Domain (AYD). The AYD (Figure 1) is dominated by 640–610 Ma, syn- to late-collisional high-K calc-alkaline granitoids [31,32]. These granitoids intrude high-grade gneisses that represent a Palaeoproterozoic basement, which was likely dismembered during the Pan-African assembly of western Gondwanaland [31,32,33]. Toteu et al. [17,31] classified the rocks of the AYD into three main groups, viz. (a) large supracrustal blocks of Palaeoproterozoic metasedimentary rocks and orthogneiss with assimilated Archean crust similar to the Ntem Complex, (b) 612-600 Ma, low- to medium-grade metasedimentary and metavolcaniclastic rocks, and (c) 640-610 Ma syn- to late-tectonic granitoids of transitional composition and crustal origin [32]. Similarities in chemical composition and ages of granitic intrusions reported throughout the AYD [4,17,21,34-41] may suggest an underlying regional scale batholith.

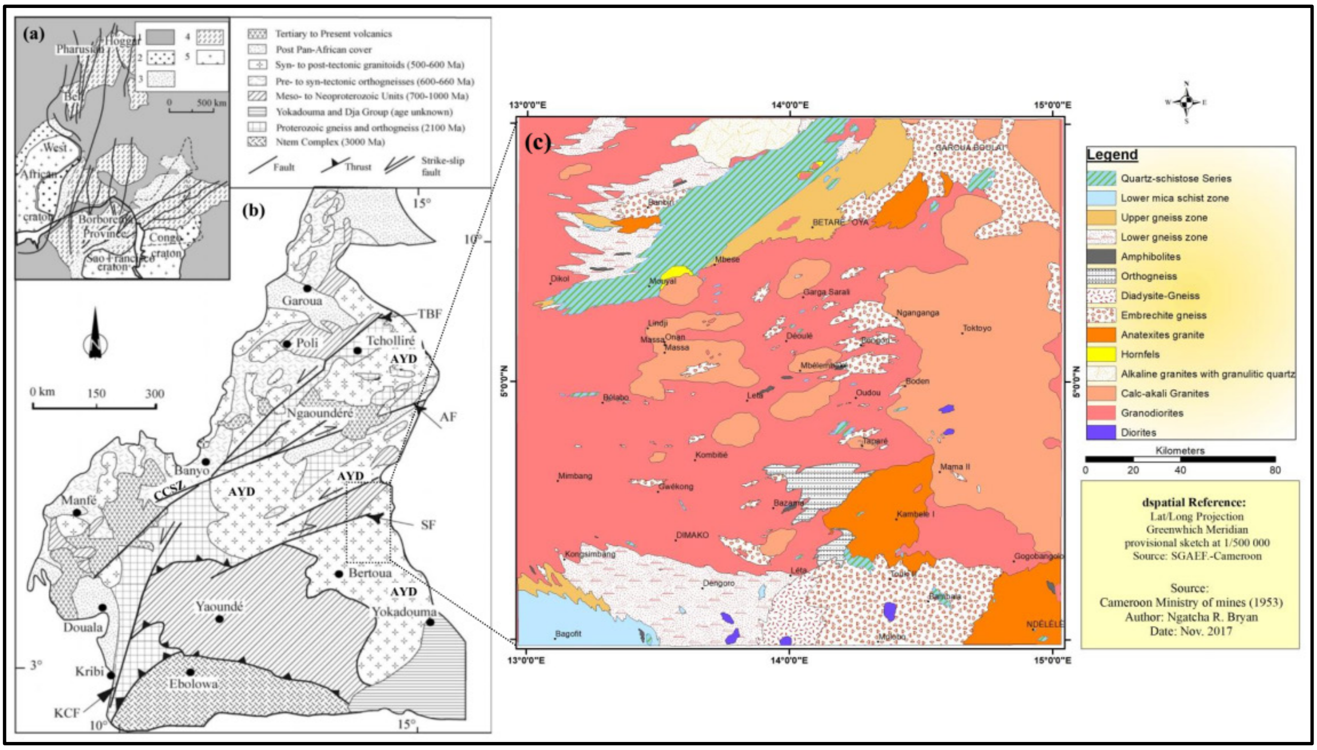

Figure 1. (a) Geology of West-central Africa and northern Brazil in a Gondwana (pre-drift) reconstruction (modified from [25,42]. Dashed line boundary of Cameroon. Thick line, boundary of the two continents: (1) Phanerozoic cover; (2) Neoproterozoic formations; (3) Regions of Brasiliano/Pan-African deformation in which Paleoproterozoic basement is absent or only present as small isolated blocks; (4) Regions of Brasiliano/Pan-African deformation with large amounts of reworked Paleoproterozoic basement; (5) cratons; (6) faults. **(b)** Simplified geological map of Cameroon showing the main lithostratigraphic domains of the Neoproterozoic Pan-African orogenic belt, adapted from Soba [43] and Toteu et al. [41]. AYD, Adamawa Yadé Domain; KCF, Kribi-Campo fault; AF, Adamaoua fault; SF, Sanaga fault; TBF, Tcholliré-Banyo fault; CCSZ, Central Cameroon Shear Zone. Dashed line represents the assumed geophysical limit of the Congo craton after Toteu et al. [31]. **(c)** Geologic map of Batouri east, sheet No. NB.33 S.W. E.31 (modify from [9])

This review focuses on gold mineralisation in the eastern region of the country. Three main gold districts are recognized. (1) The Bétaré-Oya gold district is located within the Lom Series (Figure 2). This series is well known for its gold mineralization and other mineral occurrences associated with granitic intrusions: Pb, Bi, and Mo [3,19,20,35,44]. Primary gold mineralization in the district is related to a series of quartz–sulphide veins that define a steeply dipping NNE-SSW-trending brittle-ductile shear zone [13]. The primary ore mineral assemblage of the quartz veins consists of pyrite, galena, chalcopyrite, specular haematite, and gold [20]. The veins transect metasedimentary sequences in the vicinity of small granitic intrusions 635 Ma [21]. The host rocks are biotite schists, sericite and chlorite schists, quartzites and shales that constitute a rock sequence locally known as the Lom series [30,43]. (2) In the Batouri district primary gold mineralization is related to structurally controlled discordant quartz veins/veinlets [4,45], weathering profiles and altered wallrock restricted to NE-SW trending shear zones [3] that cut across Pan-African 620 Ma I-type granites [4]. The mineralized veins form a network of anastomosing veinlets composed of quartz ± gold hematite ± sulphide ± carbonate ± goethite and few selvages of wallrock bearing sericite [4]. (3) The Ngoura-Colomine district is characterised by a large complex of late-to post-tectonic calc-alkaline to alkaline granite plutons. The early granite plutons are deformed at their margins. Gold is found in the NE-SW trending quartz veins along zones of shearing and pegmatitic veining that transect the plutons [46].

3. Crustal Evolution, Gold Mineralization Features and Implications

The Lom Basin is associated with low-pressure metamorphism defined by garnet–staurolite–andalusite–sillimanite. This metamorphism involved a high thermal gradient related to widespread crustal melting that produced the dominant S-type granitoids in the region (Sr- and Nd isotopes, [15,42,47,48]. The best known S-type granites are the Ndokayo and Wakasso leucogranites, which are affected by strike slip faults, and numerous late-to post-tectonic intrusions (Tina, Borguene, Kongolo, and Nyibi), some of which developed thermal aureoles in the host rocks. Recent studies highlighted, high K calc-alkaline to sub-alkaline I-type granitoids (620 – 635 Ma) emplaced within a volcanic arc setting at temperatures that varies between 625°C and 775°C, to be mainly associated with gold mineralization in the Lom series [4,21]. Contradictory, this temperature bracket is consistent with temperatures for S-type granitoids according to Chappell and White [49] classification of granitoids. However these temperatures have been linked to high K-calc alkaline I-type granitoids in the northern parts of the CASZ using hornblende in plagioclase [40]. According to Asaah et al. [4] the Lom series granitoids were probably generated by partial melting of hydrated lower mafic crustal rocks, under oxidizing conditions (Figure 3). On the other hand, Ateh et al. [21] reported Ce/Sm ratios range of 0 to 3 associated with variable Yb/Gd ratios up to 76 in zircons from the Bétaré Oya granitoid, which is a characteristic feature of crustal derived melt in a reducing environment. Ateh et al. [21] suggested a metasedimentary contribution during magma generation based on zircon morphology (the existence of dark rounded cores with magmatic overgrowths is clear evidence of inherited zircons) and chemistry. However, intrusion-related gold deposits (IRGD) may vary from oxidized to moderately reduced environments in regions where I-type character is dominant [50]. Magmatic sources have actually been unequivocally established in deposit types related to alkaline magmatism such as gold-rich porphyry [51,52] and epithermal systems [51,53], as well as intrusion-related [54] and gold-bearing skarn deposits [55]. One possible connection between magma and gold deposits supposes that igneous intrusions serve as a source of heat that drives ore-forming hydrothermal systems [2]. According to Hronsky and Groves [56] gold-rich alkalic magmas are so modified by crustal processes that evidence of their genetic relationship with gold become obscured in many cases. It is believed that the Pan-African orogeny, and associated regional metamorphism and magmatism, generated large-scale movements of ore bearing fluids in the crust. These fluids were channelized along complex fractures into regional NE-trending shear zones and were responsible for gold and base-metal mineralisation along these structures throughout the Pan-African mobile belt [57,58]. Accordingly, during magmatic–hydrothermal evolution, Au partitions into exsolved magmatic fluids, under suitable physiochemical conditions and geological environment. Consequently, a gold deposit originating from magmatic fluids may form within the intrusion or peripheral country rocks [1]. The factors that control the concentration of gold in these deposits, as well as the wide range of physico-chemical environments in which they occur, poses challenges to unequivocally constrain the source(s) of ore fluids [59].

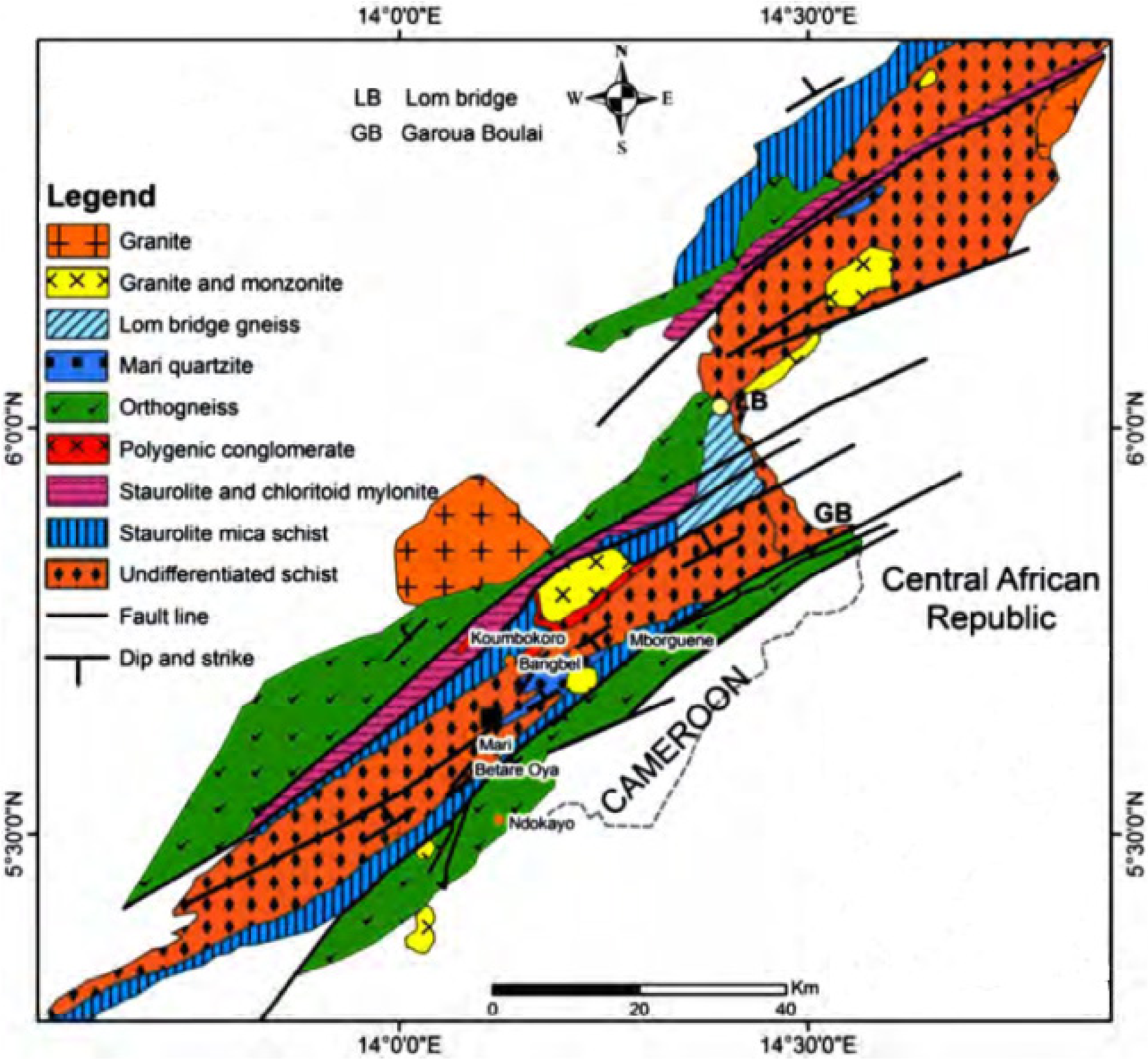

Figure 2. Geological sketch map of the Lom unit modify from Ngako et al. [16], Toteu et al. [17] and Fon et al. [13]. **(d)** It is characterized by a predominant NE-SW trending shear zone

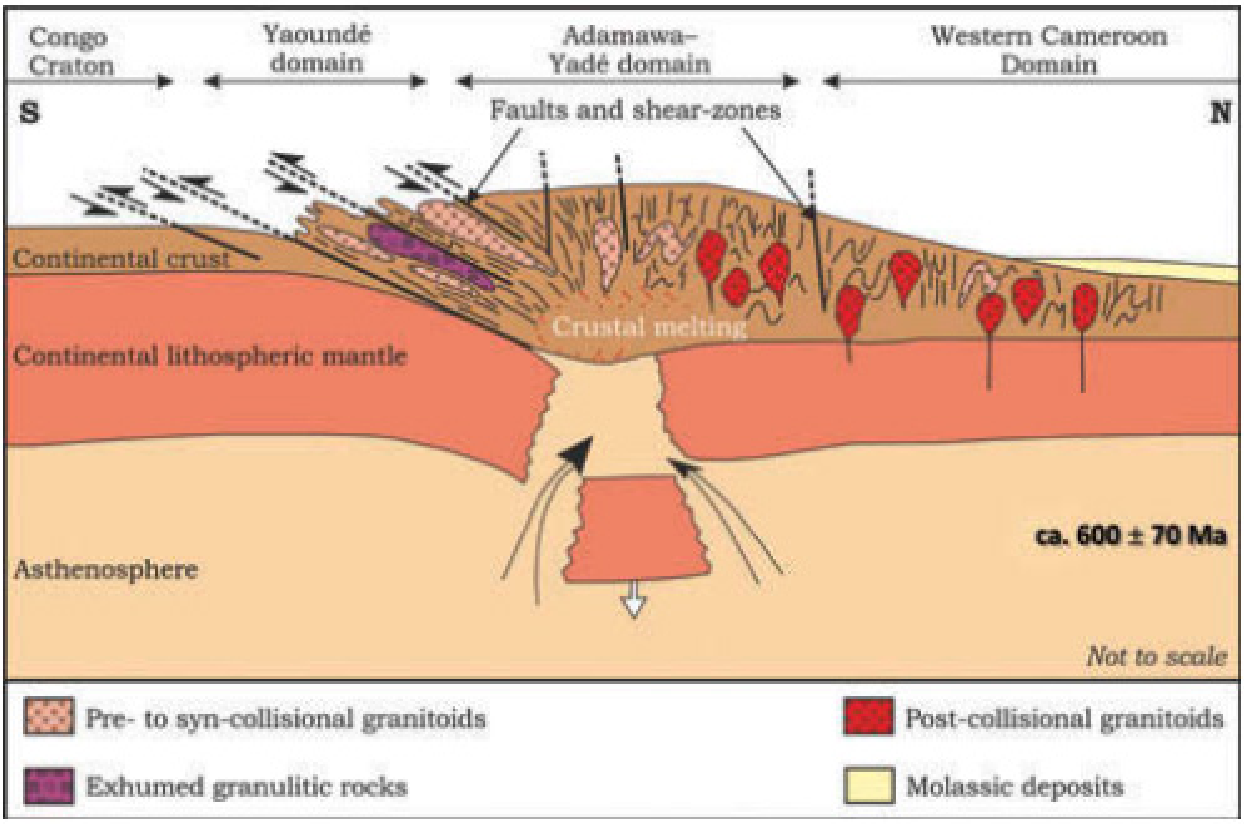

Figure 3. Model of the post-collisional stage of the Central African Fold Belt and the Congo Craton. The upwelling asthenosphere supplied excessive heat to the lower crust, which melted crustal rocks to generate high-K calc-alkaline granitic magmas. After Asaah et al. [4]

Gold deposits in plutonic environments usually consist of simple veins that occupy fissures, second- or third-order structures linked to crustal discontinuities notably along shear zones in plutonic level granitic rocks and associated metamorphosed wall rock [60]. Gold bearing quartz veins and veinlets in eastern Cameroon are structurally controlled and show a general NE-SW orientation (Figure 2; [3,13,20]. These quartz veins and veinlets extend from the plutons into the brecciated and locally silicified metavolcanic and metasedimentary rocks [3]. They range from barren (massive quartz) to mineralized, with foliated, sheared, vuggy, fractured, and sugary to brecciated textures. Inclusions (selvages) of altered wall rock are common within the mineralised veins. This is diagnostic of shear zone system [20]. Micro-shear and fault zones within the vicinity of these granitic plutons, thus, constitute favourable sites for primary gold exploration. Similar structurally controlled mineralization styles have been reported in the Pala region, south-western Chad [14] and in the Seridó Mobile Belt (SMB) in the Borborema Province north-eastern Brazil [61]. This confirms the hypothesis that gold mineralized shear zones runs from NE Brazil through Cameroon to Chad. Alterations associated with primary gold mineralization in eastern Cameroon include silicification, sulphidation, sericitization, K-feldspar alteration, alkali metasomatism with muscovite/sericite formation, haematitization, carbonatization and pyritization [3,20]. Pyrite, arsenopyrite, galena, chalcopyrite, specular haematite, and gold are the primary ore mineral assemblages of the quartz veins and veinlets. In addition to hydrothermal ore minerals, pre-hydrothermal stage minerals from the wall-rock, such as magnetite, titanomagnetite and ilmenite are also reported in the veins [62]. Because gold- and As- bearing minerals (pyrite and arsenopyrite) correlate positively, [3,20], As is considered to play an important role in the concentration of Au in hydrothermal systems. When the S content is extremely low, native As would form, such as the case in the Baogutu gold deposit [63], where native As is the predominant gold carrier. The modes of occurrence of ore minerals in these veins vary from single-grain disseminations to randomly distributed clusters, and concentrations along fractures in laminated quartz [3,19,62]. Laminations in quartz veins are defined by sulfide-bearing or barren foliations along which quartz was fragmented. The foliations run parallel to the strike direction of the veins and are restricted to the peripherial regions of the veins. Vishiti et al. [20] elucidate the presence of interstitial and corroded specular haematite in pyrite and interpreted it as indicative of a hypogene hydrothermal alteration stage, which implies an oxidized hydrothermal fluid probably of magmatic origin. This is in line with the magmatic and oxidizing environment advocated for the source of mineralizing fluids in the Batouri gold district [4]. Moreover, the occurrence of Au as well as elevated Pb and Zn in quartz veins from Betare Oya, further advocates for a granitic source for the ore-bearing fluid [20]. This is also supported by the alloy relation of Au with Ag and the geochemical association of Au±Cu±Bi±As±Pb. However, evidence from the $\delta^{34}S$ of auriferous quartz veins from the Betare Oya gold district points to multiple sources of sulphur in the system, perhaps a mixture from metasedimentary and granitic rocks [20]. Although these hydrothermal ore deposits formed within or at some distance from felsic to intermediate igneous intrusions, establishing a direct genetic link with these intrusions, in this case gold is not always clear.

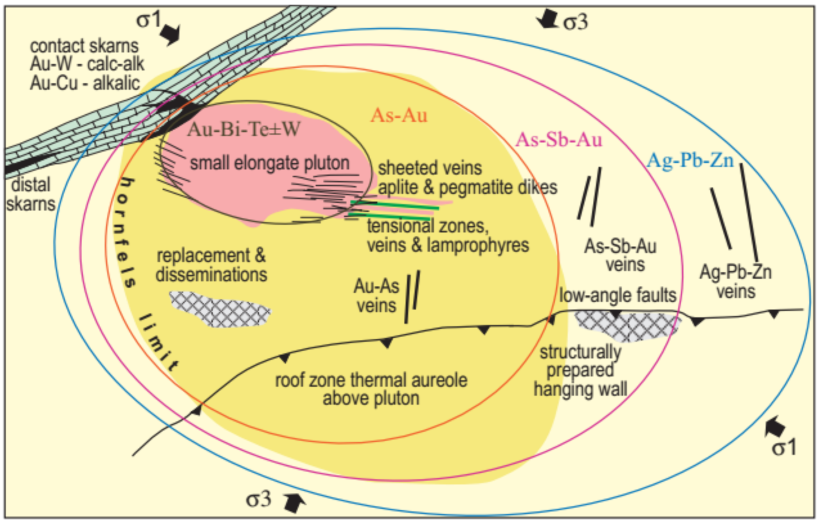

Figure 4. General plan model of intrusion-related gold systems from the Tintina Gold Province. Note the wide range of mineralization styles and geochemical variations that vary predictably outward from a central pluton [64]

4. Fluid Inclusions Studies and Relevance

So far, preliminary fluid inclusions have been documented for the Batouri gold district from gold-bearing quartz vein samples [3,62]. Two dominant type of fluid inclusions, $H_2O–CO_2$ fluids (Type I) and $H_2O–CO_2$ (±CH4±N2) (Type II) were distinguished. Type I inclusions are rare and occur as single inclusions or scattered clusters within individual quartz grains not related to any discernible fractures or crystal growth defects. These fluid inclusions mostly exist in two phases, liquid and vapour, at room temperature, although there also exist three-phase inclusions, containing two immiscible liquids, aqueous and carbonic, and a vapour phase. However, most of the three-phase inclusions are only recognized as such, at temperatures below 16°C. They reported an average total homogenization temperature value of 299° ± 36°C with low salinity (<1 to 6.5 wt% eq. NaCl) for these Type I inclusions. Type II inclusions occur most commonly as linear arrays or trails healing fractures that run across grain boundaries (transgranular trails). These inclusions were also dominantly two-phase (liquid, L, and vapour, V) of low-salinity (<1 to 8 wt% eq. NaCl) and highly variable CO_2 densities (0.65 g/cm^3 to 1.09 g/cm^3). Total homogenization temperatures (T_h total) are 275° to 333°C. On the basis of their mode of occurrence and microthermometric data, Suh et al. (2006) interpreted Type II inclusions as CO_2-rich inclusions resulting from CO_2 trapping, following strain-induced leakage of H_2O from mixed H_2O+CO_2 Type I precursor fluids. Asaah [62] within the same gold district also documented similar aqueous-carbonic inclusions [H_2O-CO_2(±CH_4±N_2)] with T_h range from 291 to 355°C (Figure 4) for vein quartz, with emplacement temperature of ~300°C. Homogenization temperature for quartz veinlet range from 245 to 270°C, indicating entrapment temperatures were >250°C. The presence of Nitrogen ± carbonic inclusions [N_2±CO_2] in the quartz veins were further documented. These N_2±CO_2 inclusions portray several low-density, ~9 to ~13 µm-sized, gas inclusions, sometimes containing aqueous films. These inclusions homogenized into the liquid or vapor phases at temperatures of about -150.2°C. According to Asaah [62] carbon dioxide in these inclusions probably came from the hypogene fluid while nitrogen was most likely derived from the alteration of wall-rock minerals such as feldspars and micas, which usually contain traces of ammonium [65]. The dominant occurrence of aqueous-carbonic fluid inclusions in quartz from gold-bearing veins at Batouri indicates that mixed aqueous-carbonic hydrothermal fluids are responsible for gold transport in hydrothermal systems. In solution, gold occurs either as Au(I) or Au(III), and can form stable complexes with such ligands as bisulfide (HS^-) or chloride (Cl^-) depending on the prevailing physico-chemical conditions of the solution [66,67]. According to Asaah [62] gold in the Batouri area is transported predominantly as a bisulfide complex. Several experimental studies have led to the conclusion that, in terms of stability and concentration, Au(I) bisulfide complexes predominate in mildly oxidizing to reducing hydrothermal fluids over a wide range of temperature and pH. On the other hand, Au(I) chloride complexes are more important in hydrothermal fluids with high chlorine activity, under moderately to highly oxidizing acid conditions [67,68]. According to Gammons and Williams-Jones [69] gold mostly occurs as $AuCl_2^-$ in a system with temperature higher than 400°C. Zajacz et al. [70] showed that gold hydrosulfide complexes supersede gold chloride complexes, and more importantly, that the stability of gold hydrosulfide complexes is greatly increased by the presence of minute concentrations of KCl or NaCl (0.1-0.5 mol/kg H_2O). The amplifying effect of alkali chlorides on the solubility of gold in H_2S-bearing volatiles may explain the preferential association of many giant hydrothermal gold deposits with alkaline mafic to intermediate igneous rocks, which exsolve volatiles that simultaneously contain both H_2S and alkali chlorides in significant concentrations. However, even with the association of these giant hydrothermal gold deposits with alkaline mafic to intermediate igneous rocks, it is still difficult to determine the source of gold bearing fluids. This may explain scarcity of models that reflects the complexities related to possible variations of gold speciation in IRGDs environment.

The physico-chemical conditions of the hydrothermal fluids during Au deposition at Batouri were deciphered from features of the deposit such as: the dominantly sulfide hydrothermal ore mineralogy; highly sericitized wall-rock; and mineralization temperatures, to be >250°C. These features match those of reducing mesothermal fluids at near-neutral pH [67,71,72], in which Au is likely transported mainly as a bisulfide complex [67,68,73]. According to Zhu et al. [74] $Au(HS)_2^-$ is the dominant phase at lower temperature and maximum solubility exists in the vicinity of the H_2S-HS^--SO_4^{2-} equilibrium point. With the decline of oxygen fugacity, the Au–S complex breaks down, leading to gold precipitation [53,75]:

$$2Au(HS)_2^- + H_2O \rightarrow 2Au + HS^- + 2H^+ + 0.5O_2$$

$$2Au(HS)_2^- + 8H_2O \rightarrow 2Au + 4SO_4^{2-} + 4H^+ + 8H_2$$

$$FeCO_3 + Au(HS)_2^- = FeS_{2\,pyrite} + CO_2 + H_2O + Au.$$

However, desulfidation of hydrothermal fluids by Fe-bearing minerals in wall-rocks in the Batouri gold district has been advocated as the main trigger to the gold precipitation phase [62]. Late deposition of electrum on gold in this district indicates another gold deposition mechanism during the late stages, which favoured the deposition of both gold and silver.

5. Conclusion

Extensive research on the formation of gold deposits, to produce a range of genetic exploration models applicable to the Cameroon geologic context is necessary. Establishing a genetic link between gold and granitic intrusions is pivotal in this case. Detail fluid inclusion studies on granitoid-related gold mineralization in eastern Cameroon could provide an answer to the obscured genetic relationship of gold with crustal processes known to modify gold-rich alkalic magmas. Studying fluid inclusions in quartz grains from the gold-bearing veins, barren veins and the non-mineralized part of the granitic pluton to determine the temporal relationship between inclusions hosting gangue phases and Au ore mineral, by assessing the composition of the mineralizing and non-mineralizing fluid/melt, is an unexploited avenue which could be used to establish this genetic link. Advances in analytical techniques using fluid inclusions trapped in quartz grains from gold bearing veins/rocks provide a means of elucidating the factors controlling gold concentration and ultimate source, by studying the properties of these fluids which hold evidence of ore formation. The major and trace element composition of ore-forming fluids related to intrusion-related gold mineralization is still largely unknown in the eastern goldfields of Cameroon, yet could provide important and more direct evidence for the fluid source(s). Advances in laser-ablation inductively coupled plasma-mass spectrometry (LA-ICPMS) now permit complete analysis of individual fluid inclusions including rock-forming elements, ore metals, sulfur, boron and the halogens [76,77,78,79,80]. This multi-element in situ technique has been applied to hydrothermal fluids from a diverse range of geological environments including magmatic-hydrothermal, unconformity-related and metamorphic fluids [80-86]. However, very little data is available for intrusion-related and orogenic gold systems [87,88,89]. Thus, detail fluid chemistry studies will be very relevant in eastern Cameroon.

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