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Microchemical signature of alluvial gold from two contrasting terrains in Cameroon

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ABSTRACT

The microchemical signature of alluvial gold particles has wide application in constraining their primary sources. In this study, we apply this concept to investigate the composition of gold-bearing alloys from alluvial samples draining two geologically distinct terrains in southern and eastern Cameroon where the search for primary gold has remained elusive. The first set of gold grains (Lom grains) are from the Lom river drainage system with predominantly metasedimentary Pan-African rocks in the catchment region while the second set of grains (Nyong grains) are from the Mbal and Ebap tributaries of the Nyong river draining over a Paleoproterozoic complex comprising metamorphosed ultramafic rocks, amphibolites and granulitic gneisses. The gold grains recovered from these fluvial networks after panning were first studied under an electron microscope in order to evaluate their morphological features and subsequently embedded in epoxy resin, polished, and their compositions determined by both electron microprobe (EMPA) and laser ablation (LA-ICP-MS) techniques. The Lom grains are irregular to sub rounded with extensively pitted surfaces while the Nyong grains are predominantly rounded, oblong and with smooth surfaces. Nyong grains are devoid of inclusions while galena and pyrite are entombed in the Lom grains. Both set of grains are essentially Au–Ag alloys although the Ag content of the cores of the Nyong grains from both EMPA and LA-ICP-MS analytical techniques are significantly lower (0.05–6.07 wt% Ag; 93.54–99.29 wt% Au) than for Lom gold (0.06–22.75 wt% Ag; 78.76–99.86 wt% Au). X-ray element distribution maps do not show any zonal variation in core composition suggesting the gold grains derived from lode sources with single episode of hydrothermal gold deposition. Also the Nyong grains have significant amounts of Pt, Pd and Cr suggesting a link with ultramafic rocks while the Lom grains have substantial Sb and Zn levels pointing to hydrothermal quartz veining as the possible primary mineralization system. The grains from both localities have Ag-depleted rims. The results demonstrate that the microchemical signature of gold is useful to study the hypogene environment of a given area and a field for hydrothermal-orogenic gold is proposed on the ternary Au–Ag–Hg and Au–Ag–Cu plots.

1. Introduction

The composition of gold grains from alluvia and the inclusions they host are widely and increasingly used to determine the source of the primary gold mineralization, the style of mineralization and the potential host rock. Several studies in this line of research using mainly electron microprobe analysis (EMPA) technique have been completed in different terrains around the world with commendable successes (e.g. Leake et al., 1992; Chapman et al., 2000a,b; Chapman and Mortensen, 2006; Chapman et al., 2009, 2011; McLenaghan and Cabri, 2011; Hancook and Thorne, 2011; Moles et al., 2013). Microchemical signature of alluvial gold is of great significance in areas where gold is won from active stream sediments yet the primary mineralization has not been discovered. This approach allows for the identification of populations of placer gold

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derived from different sources and in several cases permits a correlation of inclusions mineral assemblage with specific alloy compositions (e.g. Chapman et al., 2009). In Cameroon alluvial gold is mined from the Lom river drainage system and its tributaries (Fon et al., 2012; Embui et al., 2013) and from tributaries of the Nyong river (see www.legendmining.com, for example). Despite intensive mapping, ground geophysical surveys and soil geochemical programmes in the catchment regions of these rivers, the primary mineralization that is the source of gold in the alluvia has not been uncovered. The Nyong catchment area is made up of a plethora of metamorphic rocks of Paleoproterozoic age while the Lom catchment comprises much younger Pan-African rocks. In this study we investigate the microchemical signature of gold grains from both catchments in the hope of finding subtle but significant differences in their composition that can suggest the mineral system from which the gold was sourced and hence enhance the search for the primary mineralization itself. The novelty of this study is that both EMPA and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) techniques are employed in the analysis of the same gold grains. To facilitate the presentation, the first set of grains derived from the Lom drainage are hereafter referred to as Lom grains and those from the Nyong drainage referred to as Nyong grains. Here, we report on the morphology of the Lom and Nyong grains and show that the elevated concentration of Pt, Pd, Se and Cr in the Nyong grains suggests an ultramafic source rock while the Lom grains with slightly elevated Sb–Zn values are likely derived from hydrothermal quartz veins.

2. Geology and reconnaissance gold investigations in the regions

The geology of the two areas from which the gold alloys investigated were derived is presented in Fig. 1. The Lom grains are derived from a tributary draining a catchment dominated by rocks of the lithostructural unit locally referred to as the Lom Series (Toteu et al., 2006). The Lom series is a pull-apart basin with meta-volcanic and metasedimentary rocks that are Pan-African in age (600 ± 50Ma; Ngako et al., 2003; Toteu et al., 2006). The metasedimentary basement rocks comprise schistose units of amphibolite to greenschist facies intercalated with quartzite and metaconglomerate (Fig. 1b). These units are intruded by late largely S-type granitic plutons. Hydrothermal alteration around these plutons resulted in the development of tourmaline of dravite-schorl composition in association with pyrite. Structurally, the Lom Series has NE–SW, NNE-SSW and ENE-WSW faults that are related to the Central Cameroon Shear Zone (CCSZ; Soba, 1989; Dane, 1998; Ngako et al., 2003; Toteu et al., 2001, 2006; Kankeu et al., 2012). Hydrothermal alteration here is expressed by the ubiquitous occurrence of sulfide-bearing quartz veins in the area. Although gold has been reported in quartz veins within the Lom Series, a significant primary deposit is yet to be reported (Fon et al., 2012; Suh, 2008). Gold is commonly disseminated in quartz stringers associated with pyrite, sphalerite, rare pyrrhotite, chalcopyrite, galena and colloidal hematite. Freyssinet et al. (1989) identified Au–Mo–W–Pb–Bi element association in the host rock and overburden as pathfinder elements for gold in the Lom area.

The Nyong grains are derived from tributaries running over the Paleoproterozoic rock unit termed the Nyong Series. This unit is regarded as the northwestern corner of the Archean Congo Craton in Cameroon (Lasserre and Soba, 1976; Maurizot et al., 1986; Toteu et al., 1994; Van Schmus et al., 2008; Feybesse et al., 1998; Penaye et al., 2004). The basement rocks are high-grade charnockitic gneisses (Fig. 1c) 2423 ± 4Ma in age (Lerouge et al., 2006). These are mainly biotite-hornblende gneiss, biotite-amphibole gneiss, orthopyroxene gneiss, garnet gneiss, amphibole-pyroxene gneiss and amphibole-garnet-pyroxene gneiss that are associated with amphibolites and magnetite-bearing gneisses. These units are intruded by multiple late granitic plutons present as metadiorites, granodiorites and metasyenites (Lerouge et al., 2006). Early ultrabasic bodies are defined by amphibolites (Bayiga et al., 2011) and pyroxenite rocks (Ebah Abeng et al., 2012). Tectonically, the Nyong unit has suffered several episodes of deformation with a granulite metamorphic facies reported in the Eburnean (Toteu et al., 1994). An early flat lying foliation accentuated by N–S strike slip faults has been truncated by late NE-SW-trending shear zones. Silicification, chloritization, sulfidization and carbonitization are the main wall rock alterations observed. No visible lode gold has been reported in the Nyong unit rocks. However, Ebah Abeng et al. (2012) reported Au assay values of 25.1–120.9 ppb within pyroxenites and amphibolites in the Eseka area. In 2013, Legend Mining Limited (www.legendminging.com.au) exploring for iron and gold in the Nyong Series reported gold grades of up to 8 g/t from stream sediments. The significant presence of gold within the stream beds is substantiated by wide spread artisanal workings in some parts of the area indicative of potential economic mineralization in the rocks that has remained undiscovered to date.

3. Sampling sites and analytical methods

Stream sediment samples used in this study were collected at sites shown on Figs. 2 and 3. The Nyong area (Fig. 2) is characterized by a continuous chain of topographic highs and deeply incised valleys. This provides most parts of the area with a dendritic drainage pattern that runs in rapids and falls over the steep flanks and in quiet and gentle flows at the foot of the hills (Fig. 2). The Lom region is characterized by a gentle topography (Fig. 3) with vast alluvial plains and isolated hills. Both semi-mechanized and rudimentary artisanal mining are carried out in the streams of the Lom alluvial plains (Fig. 4) but sampling for the purposes of this work avoided such areas where the sediments are extensively disturbed. All the sampling sites were located using a GPS and coordinates were introduced into a GIS platform. At each sampling site ~3 kg of active stream sediment sample were collected, panned, and the heavy mineral fraction retained and stored in a clearly labeled self sealing plastic bag. The heavy mineral fraction was dried and the gold grains handpicked under a binocular microscope. Considering the reconnaissance nature of this study, 15 Nyong grains and 20 Lom grains selected based on grain size (>50 μ), diversity of grain shape and color were studied further and data from the grains eventually analyzed are reported in this study.

The morphology of the gold grains recovered was studied under a scanning electron microscope (SEM) equipped with an energy dispersive spectrometer (EDS). SEM analysis was performed at Rhodes University in South Africa (courtesy of A.R. Cabral) and the Technical University of Clausthal, Germany. Gold grains were subsequently embedded in epoxy resin, polished, and viewed under reflected polarized light. Backscattered electron (BSE) imaging, mapping and chemical analysis on the polished gold grains were obtained using a CAMECA SX100 electron microprobe operated at 20 kV and 40 nA at the Technical University of Clausthal, Germany. The following elements were analyzed: Ag, As, Au, Cu, Fe, Hg, Pb, S, Sb, Se, Sn, Zn with counting times of 20 s for each element. Pure metals (Ag, Au, Cu, Pd, Se, Pt), pure galena (Pb, S), sphalerite (Zn), HgTe (Hg), GaAs (As), InSb (Sb), cassiterite (Sn), and hematite (Fe), were used as standards. The electron beam size was 5μ and detection limits in the 10–100 s ppm range. The fineness for Au was calculated using the formula Au*1000/Ag +Au (Hallbauer and Utter, 1977).

Reconnaissance laser ablation-inductively coupled plasma mass spectrometry (LA-ICP-MS) was performed at GeoZentrum