

# Stream Sediment Geochemical Survey of Gouap-Nkollo Prospect, Southern Cameroon: Implications for Gold and LREE Exploration

Soh Tamehe Landry<sup>1</sup>, Ganno Sylvestre<sup>1,\*</sup>, Kouankap Nono Gus Djibril<sup>1,2</sup>, Ngnotue Timoleon<sup>3</sup>, Kankeu Boniface<sup>4</sup>, Nzenti Jean Paul<sup>1</sup>

<sup>1</sup>Laboratory of Petrology and Structural Geology, University of Yaoundé I, Cameroon

<sup>2</sup>Department of Geology, HTTC, University of Bamenda, Cameroon

<sup>3</sup>Department of Geology, University of Dschang, Dschang, Cameroon

<sup>4</sup>Institut de Recherches Géologiques et Minières, Yaoundé, Cameroon

\*Corresponding author: [sganno@uy1.uninet.cm](mailto:sganno@uy1.uninet.cm); [sganno2000@yahoo.fr](mailto:sganno2000@yahoo.fr)

Received April 23, 2014; Revised May 07, 2014; Accepted May 07, 2014

**Abstract** Stream sediments play a significant role in geochemistry exploration by identifying possible sources of anomalous element concentration. This work is the baseline stream sediments geochemical study which brings general information on the geochemical dispersion of the metal elements (especially gold) at Gouap-Nkollo prospect (SW Cameroon) with the aim of providing a useful guide for future exploration strategies. For this study a concentration of 47 elements was measured in 10 stream sediment samples using BLEG and ICP-MS methods, but emphasis was given to the following 21 chemical elements: Al, Ca, Fe, K, Mg, Na, P, Ag, Au, B, Co, Cr, Cu, Mn, Ni, Ti, Zn, Ce, La, Th, U and Zr. Averaged elemental concentration for each samples obtained by statistical analysis showing patterns of enrichment and depletion which may relate to localized mineralization conditions or local lithological changes. Results showed that the stream sediments have high concentrations of Au, Ce and La with average values of 314.85ppm, 19081ppm and 11808ppm respectively for gold, cerium and lanthanum. Cerium and Lanthanum have considerably high concentrations when compared with other Rare Earth Elements (REE) analyzed. These concentrations represent interesting indices for Au and LREE mineralization's. The geochemical dispersion of the metal elements (especially gold) reveals that high concentrations are recorded in the northern part of the prospect, close to the quartz-tourmaline vein within the quartzite. This result indicates that the Au and other metal elements probably originated from the quartz-tourmaline veins hosted by surrounding rocks. Detailed exploration work including geochemical soil sampling and geophysical survey is highly recommended in the northern part of the Gouap-Nkollo prospect, where anomalous concentrations of Au were observed, for further investigation.

**Keywords:** stream sediments geochemistry, anomalous concentrations, Gouap-Nkollo, Cameroon

**Cite This Article:** Soh Tamehe Landry, Ganno Sylvestre, Kouankap Nono Gus Djibril, Ngnotue Timoleon, Kankeu Boniface, and Nzenti Jean Paul, "Stream Sediment Geochemical Survey of Gouap-Nkollo Prospect, Southern Cameroon: Implications for Gold and LREE Exploration." *American Journal of Mining and Metallurgy*, vol. 2, no. 1 (2014): 8-16. doi: 10.12691/ajmm-2-1-2.

## 1. Introduction

One of the most widely used methods in regional geochemical approaches is the stream sediments sampling. Stream sediment geochemistry is extensively used in mineral exploration and environmental studies. Active sediments in the channels of streams and rivers can contain low levels of metals derived from weathering of mineralized rocks within the upstream catchment [1]. Natural concentrations of heavy metals as a result of the weathering processes of mineral deposits can be quite high in stream sediments close to the deposit, but decrease with increasing distance downstream, due to dissipating energy and dilution of sediments from other unpolluting sources [2]. Geochemical maps have been constructed using

stream sediment geochemical data over the world to identify possible sources of anomalous element concentrations [3]. Ore deposits form when a useful commodity is sufficiently concentrated in an accessible part of the Earth's crust so that it can be profitably extracted [4]. The stream sediment technique has played a major part in the discovery of many ore bodies around the world. A good example being the discovery of the Panguna porphyry copper/gold deposit on Bougainville Island, Papua New Guinea [1,5].

Gold prospecting in Cameroon using stream sediments has been by large receiving little attention. The recent work of Embui et al. [6] investigating the concentrations of gold and associated elements in stream sediment samples from the Vaimba-Lidi drainage system in northern Cameroon represents the only published works on the use of stream sediment in gold exploration in

Cameroon. It's worth noting that alluvial gold exploitation commenced in the early 1940s and continues till date. Most of these small-scale alluvial gold mining operations are located in the eastern part of country, especially in the Betare Oya and Batouri gold district [7]. Also, others but not more active alluvial gold mining operations are located in southern and southeastern Cameroon, respectively around Akom II and Mintom areas, but little or no exploration works have been carried out in these areas. In an attempt to discover new gold potentials in the southern part of the country, we designed a stream sediment survey targeting the Gouap-Nkollo area. The selection of this area is based on two main factors: (i) the lithology which consists of quartzite crosscut by pegmatite tourmaline-quartz vein. Gold ore deposits with tourmaline in wall rocks and sometimes in the ore vein itself have been fully documented around the world [eg. [8-13]]; (ii) the presence of visible gold grain in pan concentrate and the existence of small-scale alluvial gold mining in Nkollo site.

This work was undertaken at a time of renewed interest in the gold potential of Gouap-Nkollo prospect for which G-Stones Resources Ltd has exclusive exploration rights (see [www.g-stonesresources.com/php.index](http://www.g-stonesresources.com/php.index)). The current paper is the baseline geochemical study which brings general information on the geochemical dispersion of the

metal elements (especially Gold), REE, and the relationship of this distribution to the geology of the area to provide a useful guide for future exploration strategies.

## 2. Geographical and Geological Settings

### 2.1. Geographical Location and Drainage Pattern

The Gouap-Nkollo prospect is located between latitudes 3°08'N and 3°15'N and longitudes 10°13'E and 10°18'E and covers an area of 120Km<sup>2</sup>. The area is covered by the tropical rain forest. The local climate is equatorial climate with two dry seasons (mid-November to mid-March; mid-June to mid-August) and two rainy seasons (mid-August to mid-November; mid-March to mid-June). Annual average rainfall is 563 mm and the annual average temperature is 27°C. The relief of the site is quite plain with hills. The detail geomorphology could be divided into two topographical units including a lower unit made up of plains with low altitude (<200 m) and a higher unit formed of hills with elevations ranging from 200 to 400 m. There is no major river in Gouap-Nkollo prospect. However, the drainage system over the areas is a dendritic network with the proliferation of many smaller stream channels.

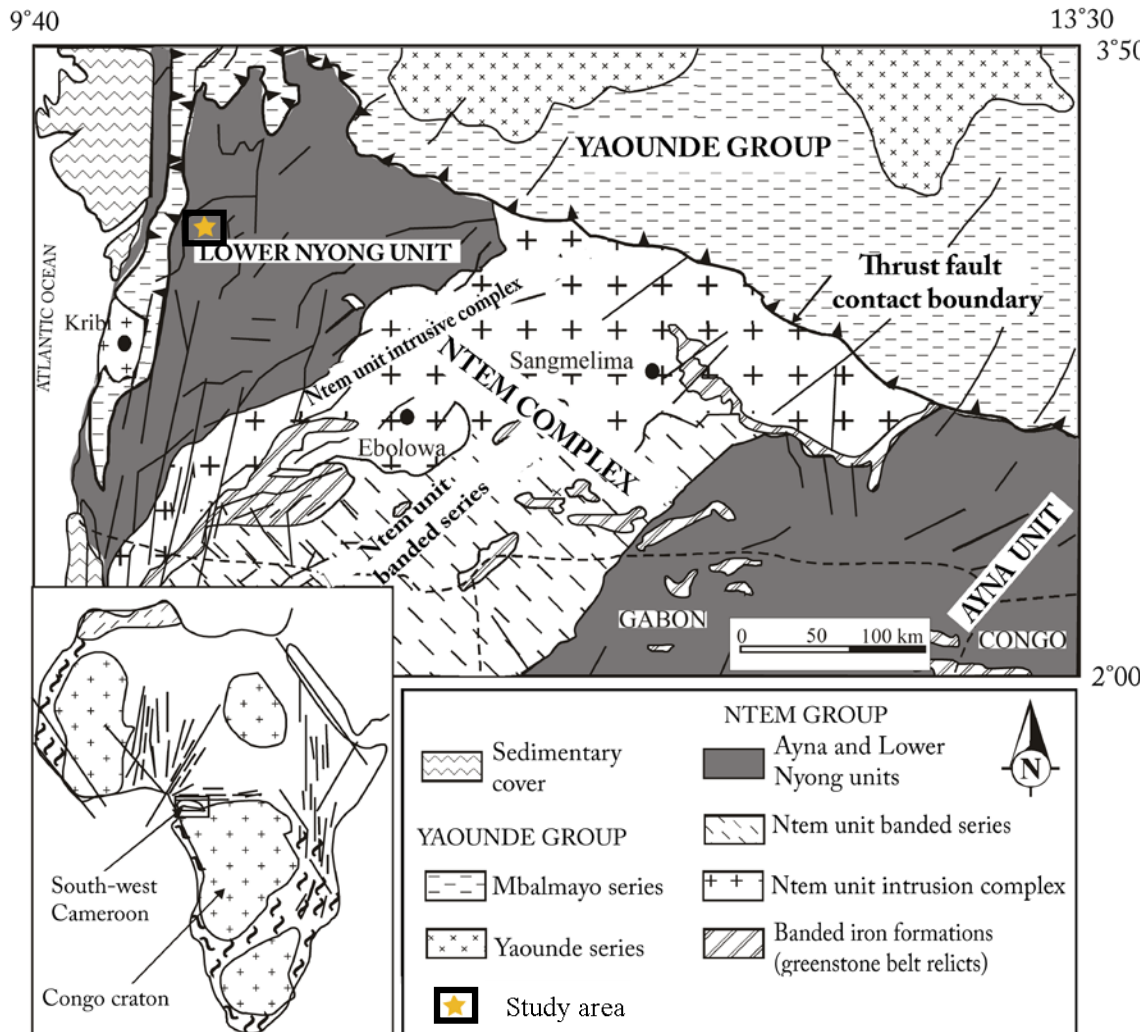


Figure 1. Geological map of South-West Cameroon after Maurizot et al. [20] showing the location of Gouap-Nkollo prospect within the Lower Nyong Unit

### 2.2. General on Local Geological Setting

The Gouap-Nkollo prospect belongs to the Lower Nyong unit which corresponds to the NW corner of the Congo Craton in South-Cameroon (Figure 1). This unit is of Palaeoproterozoic age and is a well-preserved granulitic unit of the West Congo craton resting as an Eburnean nappe on the Congo Craton [14,15]. The Lower Nyong unit underwent high-grade tectono-metamorphic event at 2117–2045 Ma [15,16,17]. It is associated with charnockite formation [18]. This led to the assertion that the Nyong Group is a reactivated portion of the Archean

Ntem complex [14,19,20]. It is constituted of both Archean and Paleoproterozoic materials associated with iron formation or BIF (Banded Iron Formation), plutonics (TTG, charnockites, dolerites, alkaline syenites), greenstone (serpentinites, ...) and biotite hornblende gneisses, which locally appear as grey gneisses of TTG composition, orthopyroxene–garnet gneisses (charnockites), garnet–amphibole–pyroxenites, and banded iron formations (BIF). The metamorphic evolution is polycyclic with Paleoproterozoic granulitic assemblages overprinted in the western part of the group by Pan-African high-grade recrystallization [15].

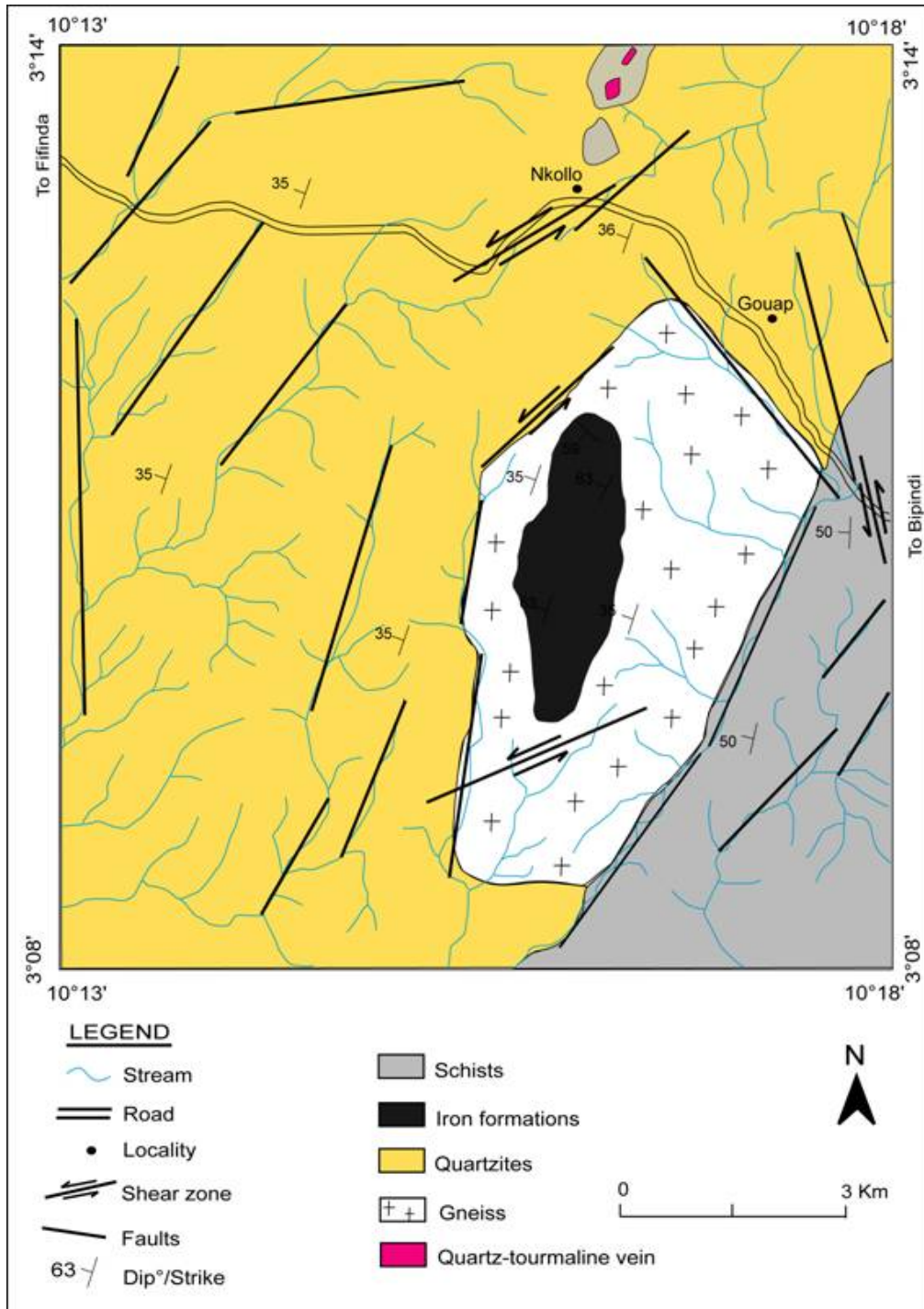


Figure 2. Geological sketch map of Gouap-Nkollo prospect, modified from [21]

Previous geological investigations have recognized four rock types in the area, namely muscovite quartzites, gneiss, tourmaline micaschists and tourmalinites [21,22] (Figure 2). All these rocks have heterogranular granoblastic

microstructures with mineral assemblages' characteristics of plurifacial prograde metamorphism from greenschist facies to medium grade amphibolite facies [22]. Tourmalinization, sericitization and silicification are the main observed wall rock alteration processes. These processes are probably related to the circulation of hydrothermal fluids in felsic to mafic rocks (sericitization and silicification) and shale, slate and schist (tourmalinization) [23].

### 3. Methodology

#### 3.1. Sampling and Preparation

Systematic stream sediment sampling was carried out using topographic maps with 1:5,000 scales. For this study, a total of forty-five stream sediments were sampled. The location coordinates and the position of each sample were quickly recorded with a global positioning system (GPS). Active stream sediments were collected along stream beds of the area using a pick, a panning dish, a stainless steel sieve and collection pan (a -80 mesh sieve size). They were sampled mostly at a depth of 30-45 cm and sieved on site in order to provide a sample of suitable weight for assay (2 kg of <1.2 mm fraction). Since some tributaries of the seasonal streams have had no water flow for many months, their stream bed was dogged and the samples were collected with extreme care. For the technique to work with maximum effectiveness, sieving has been done by washing the sample through the mesh of the sieve. Clean polyethylene bags were used in storing stream

sediment samples before it was transported to the laboratory. The sample bags were carefully labeled with permanent markers to avoid mix up. During the sampling process, simultaneous site surveys carried out in order to provide specific information relating to the geology of the sampling point.

#### 3.2. Analytical Methods

Forty-five stream sediments were sampled in the whole study area and ten samples yielded visible gold in pan concentrate were selected for chemical analysis. The analyses were performed at OMAC Laboratories (Alex Stewart Assayers Group), Ireland. The chemical analysis involved the use of BLEG (Bulk Leach Extractable Gold) and ICP/MS (Inductively Coupled Plasma/Mass Spectrometry) following a lithium metaborate/ tetraborate fusion and nitric acid digestion of 0.2g sample. BLEG-ICP/MS involves weighing a 1-2 kg sample into a polyethylene bottle, adding an appropriate cyanide solution (0.25% to 1% NaCN) and bottle rolling for a determined period of time [24]. A pH of 10 or greater is maintained during leaching. The gold is dissolved through formation of its cyanide complex [24]. The resultant cyanide solution is diluted and analyzed by Perkin Elmer Sciex ELAN 6000, 6100 or 9000 ICP/MS [24]. After dilution, solutions were analyzed for a series of 47 elements. In this study, emphasis was given on the following chemical elements: Al, Ca, Fe, K, Mg, Na, P Ag, Au, B, Co, Cr, Cu, Mn, Ni, Ti, Zn, Ce, La Th, U and Zr.

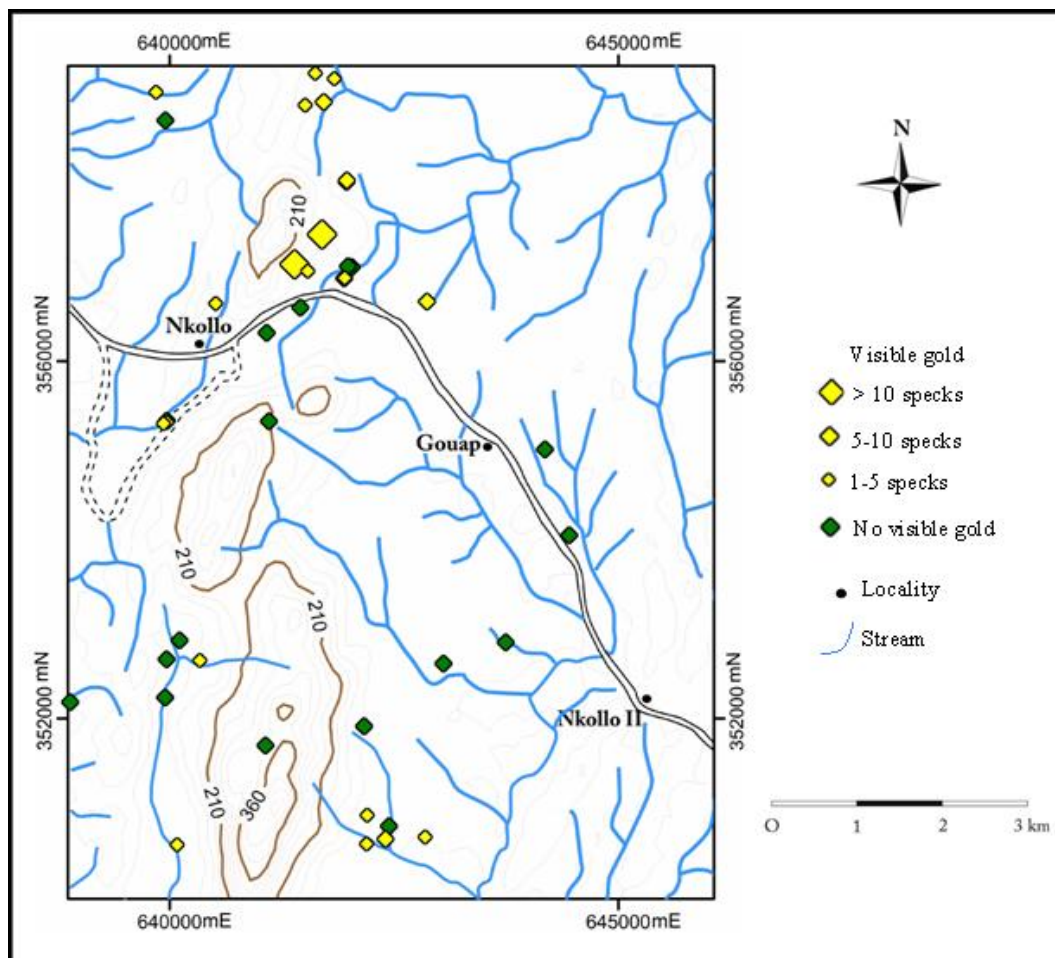


Figure 3. Stream sediment sampling map showing gold field survey results

## 4. Results and Discussion

### 4.1. Field Survey

The results of the field investigation are presented in Figure 3. On this map, twenty (20) sampling sites showed visible gold grain in pan concentrate. These sites are predominately located in the Northern part of the study area and few in the southern part. Twenty-five (25) samples didn't show visible gold in the concentrate. The sampling sites with visible gold in pan concentrate are

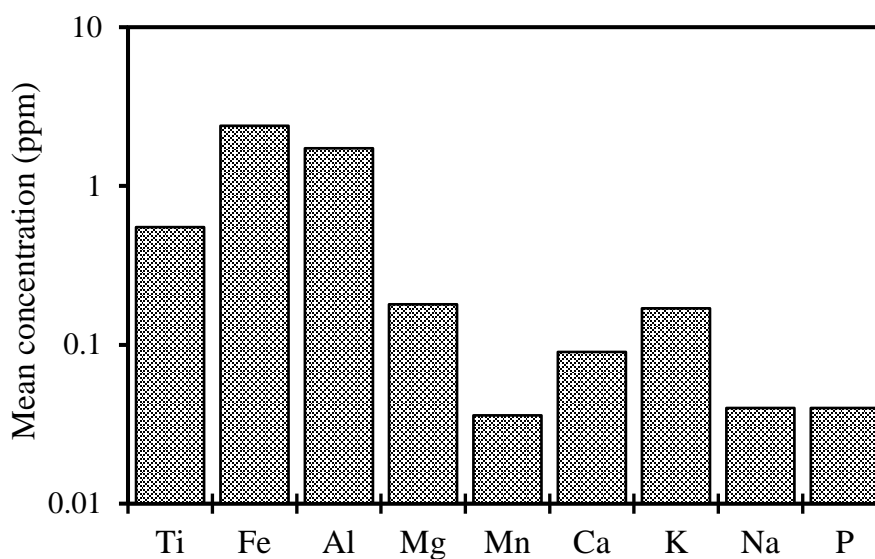
located downstream of quartzite with quartz-tourmaline vein, dominated by silification and sericitization hydrothermal alteration. This results shows that the gold mineralization in Gouap-Nkollo prospect could be related to the quartz-tourmaline vein.

### 4.2. Geochemical Survey

Chemical composition of the studied stream sediment samples is presented in Table 1 and Table 2.

**Table 1. Statistical distribution of major elements (wt%)**

Samples	Ti	Fe	Al	Mg	Mn	Ca	K	Na	P
BPS002	0.5078	2	2.7	0.34	0.0286	0.38	0.15	0.08	0.059
BPS003	0.3511	1.72	1.7	0.05	0.0196	0.02	0.11	< 0.01	0.08
BPS004	0.2462	1.69	1.18	0.12	0.0178	0.03	0.17	< 0.01	0.049
BPS004B	0.131	3.59	3.51	0.96	0.0303	0.04	0.89	< 0.01	0.042
BPS005	0.3729	1.56	0.84	0.12	0.0312	0.05	0.05	< 0.01	0.012
BPS005B	0.3038	0.88	0.82	0.01	0.0207	0.01	0.03	< 0.01	0.034
BPS006	1.7941	7.74	1.62	0.08	0.096	0.1	0.04	0.01	0.039
BPS006B	0.86	2.02	0.89	0.04	0.0544	0.09	0.06	0.02	0.009
BPS007	0.5498	1.33	1.02	0.05	0.0373	0.09	0.07	< 0.01	0.031
BPS007B	0.3847	1.35	3.01	0.05	0.024	0.07	0.14	< 0.01	0.029
Minimum	0.131	0.88	0.82	0.01	0.0178	0.01	0.03	< 0.01	0.012
Maximum	1.7941	7.74	3.51	0.96	0.096	0.38	0.89	0.08	0.08
Mean	<b>0.55014</b>	<b>2.39</b>	<b>1.73</b>	<b>0.18</b>	<b>0.03599</b>	<b>0.09</b>	<b>0.17</b>	<b>0.04</b>	<b>0.04</b>
Standard deviation	0.47987	2.01	0.99	0.29	0.02365	0.11	0.257	0.04	0.021



**Figure 4.** Histogram of mean values against major elements (wt%)

Table 1 presents the statistical analysis of major elements occurring in the stream sediments while Figure 4 indicates the histogram of distribution of these elements against their mean values. The result of the analysis of major elements (Table 1) revealed that these samples yielded weak to very strong Na, P, Ca, K, Mg, Fe Al, Ti and Mn contents (Figure 4). Fe and Al are the mean major element with mean values of 2.39% and 1.73% respectively (Table 1). The abundance of iron (0.88-7.74%) in the stream sediments indicates that these sediments are highly ferruginous and should come from a rock rich in ferromagnesian minerals such as biotite, pyroxene, and iron oxide. Fe has its highest concentration in BPS006 and its lowest concentration at BPS005B. The highest content of Fe in stream sediment could be attributed to the

leaching of banded iron formation which crops in the central part of the studied prospect. The weathered materials enriched in iron oxide are transported by water towards the stream bed situated downstream. The second major element with high content is Aluminium (Al) which ranges from 0.82% to 3.51%. The abundance of Al in the stream sediments indicates the presence of disintegrated aluminosilicate minerals such as feldspars and muscovite. Al values in the stream sediment are higher in BPS004B and lower in BPS005B (Table 1). The presence of aluminosilicate minerals in the stream sediments might be as a result of solubility of some minerals caused by the action of running water on the surrounding rocks. Titanium (Ti) has average concentration value of 5501.35ppm. Higher Ti content is

observed in sample BPS006 and the lowest content in sample BPS004B (Table 1). These strong concentrations in Ti indicate that the sediments come from a rock rich in titanohematite such as ilmenite. Due to more resistivity of Ti to weathering, this accessory mineral can be concentrated in stream sediments. Mn concentration ranges from 178-960ppm with higher concentration in BPS006 and lowest in sample BPS004 (Table 2). Calcium (Ca), Potassium (K), Magnesium (Mg), Sodium (Na) and Phosphor (P) are low in concentration. Their values range as follows: Ca (0.01-0.38)%, K (0.03-0.89)%, Mg (0.01-0.96)%, Na (<0.001-0.08)%, P (0.012-0.080)% and their averages are 0.09, 0.17, 0.18, 0.04 and 0.04 respectively.

The trace elements and LREE geochemical composition of stream sediment samples at Gouap-Nkollo prospect is presented in Table 2 while Figure 5 presents the histogram of distribution of these elements against their mean values. Stream sediment geochemical sampling anomalous values

ranging from 2 to 3278ppm Au, 368 to 719ppm Cr. Gold (Au), and chromium (Cr) are the most abundant trace elements with mean concentration values of 468.90ppm and 493.10ppm respectively (Table 2, Figure 6A). Au has its highest concentration in BPS003 and its lowest in five samples (BPS002, BPS004, BPS005, BPS006 and BPS007). Their values range from 2 to 3278 ppm. Cr records its maximum concentration in BPS004 and its minimum in BPS006, and their value range from 368 to 719ppm (Table 2). These concentrations are indicative for the presence of precious metal such as Au and Cr in the studied area. Cobalt (Co), Copper (Cu), Nickel (Ni), zinc (Zn), thorium (Th), lead (Pb) and Zirconium (Zr) have low concentrations with mean concentration values of 6.39ppm, 9.85ppm, 19.52ppm and 50.33ppm respectively. Their values range from 2-14ppm, 2-29ppm, 5-48ppm, 17-210ppm, 8-263ppm, 6-43ppm and 11-88ppm respectively for Co, Cu, Ni, Zn, Th, Pb and Zr.

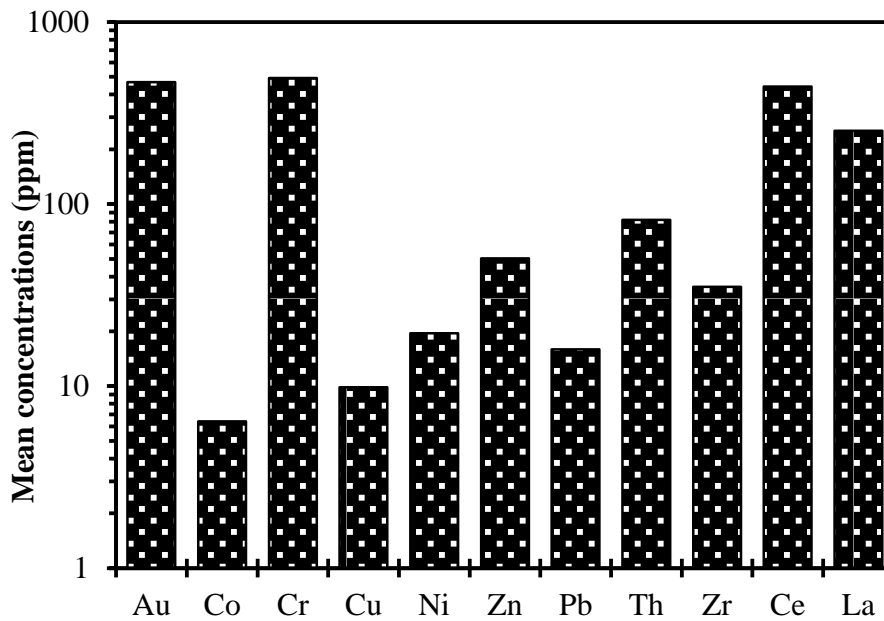


Figure 5. Histogram of mean values against the trace elements (ppm)

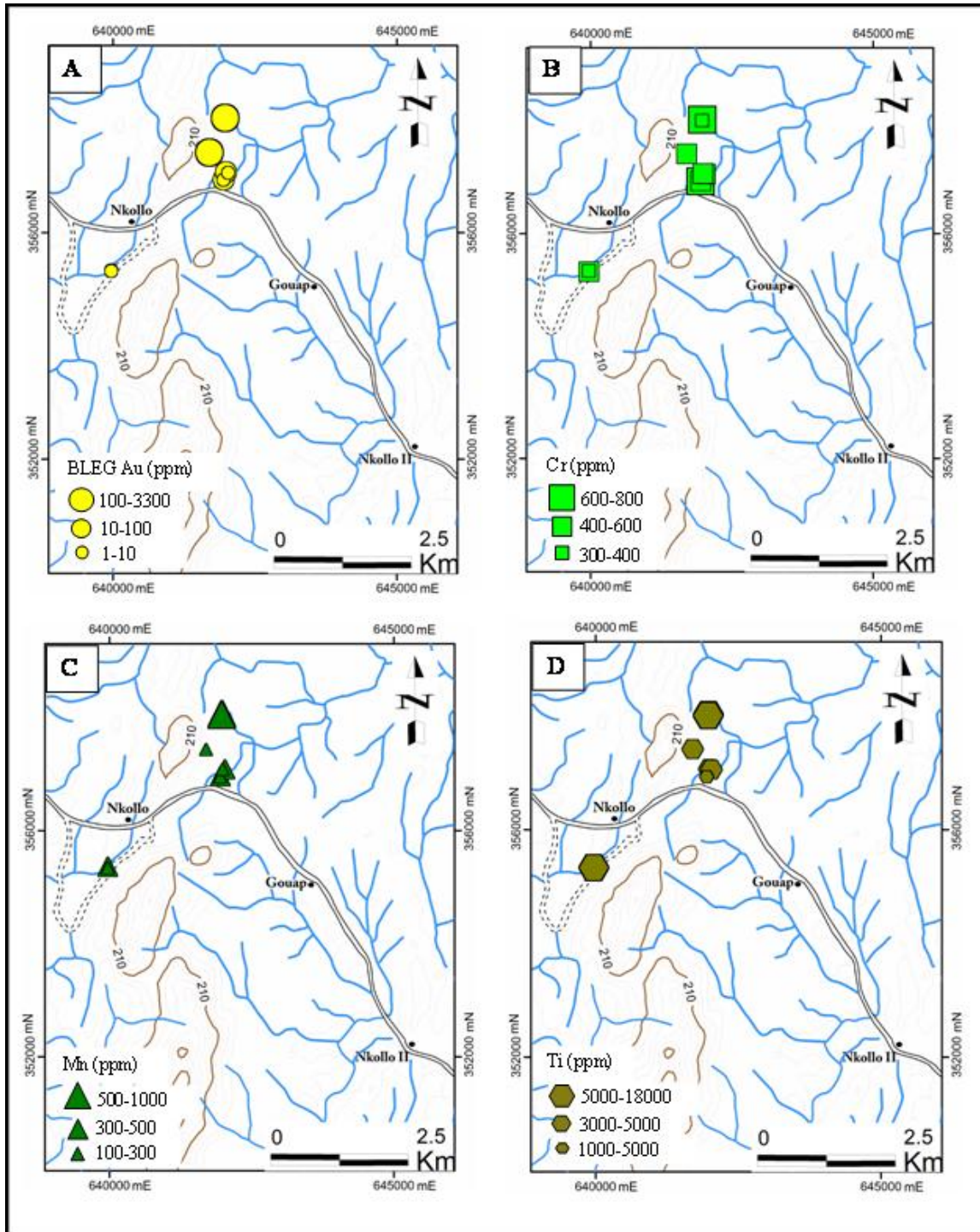
Table 2. Statistical distribution of trace and REE elements (ppm)

Samples	Au	Co	Cr	Cu	Ni	Zn	Pb	Th	Zr	Ce	La
BPS002	2	8	400	9	26	51	29	171	88	875	497
BPS003	3278	3	560	5	8	23	43	263	64	1307	771
BPS004	2	5	719	9	10	44	17	84	51	618	308
BPS004B	22	10	407	29	25	210	19	68	16	548	276
BPS005	2	7	494	4	48	22	7	11	14	47	34
BPS005B	86	2	538	2	5	19	16	100	35	472	236
BPS006	2	14	368	11	27	65	16	77	22	224	169
BPS006B	1290	5	659	7	9	23	6	8	29	30	25
BPS007	2	3	376	4	8	17	11	31	21	257	183
BPS007B	3	7	410	17	31	30	14	9	11	54	36
Minimum	2	1.71	368	2	5	17	6	8	11	30	25
Maximum	3278	14	719	29	48	210	43	263	88	1307	771
<b>Mean</b>	<b>468.90</b>	<b>6.39</b>	<b>493.10</b>	<b>9.85</b>	<b>19.52</b>	<b>50.33</b>	<b>15.93</b>	<b>82</b>	<b>35.19</b>	<b>443</b>	<b>253</b>
Standard deviation	1065.55	3.65	123.61	8.03	14.016	58.29	17.62	81.48	25.01	413	233

The REE content of studied stream sediment samples is ranging from 30 to 1307ppm Ce, 25 to 771 ppm La (Table

2). Cerium (Ce) and Lanthanum (La) have considerably high concentrations when compared with other Rare Earth

Elements (REE) analyzed (Table 2). Ce, La and Th concentrations might indicate the presence of monazite.



**Figure 6.** Graduated symbol plot for (a) Au, (b) Cr, (c) Mn and (d) Ti scores (ppm) superimposed on the drainage map of the Gouap-Nkollo prospect. High positive scores (large symbols) indicate locations with anomalous concentrations

### 4.3. Source of the Stream Sediment and Mineralization Potential

To enhance the data presentation and interpretation, we generated point symbol maps for Au, Cr, Mn, and Ti (Figure 6). The data for each element were then superimposed on a georeferenced drainage map of the study area. These plots show four elements (Au, Cr, Mn and Ti) with high values in the same sampling site, located at the northern of Nkollo village (Figures 6A, 6B, 6C and 6D). The sample with high Au values corresponds to that collected just some few meters down of the tourmaline-

quartz vein crosscutting the quartzite which is the main lithology of the area. Overall, the collected stream sediment samples present ferromagnesian, aluminosilicate minerals, precious and ferrous metals reflecting the lithological composition of the area comprising quartzite, gneiss, tourmaline bearing micaschist and iron formations [21]. So, the element distribution patterns and chemical composition of stream sediments of Gouap-Nkollo are greatly influenced by the local geology of the area. The geochemistry of the stream sediments has revealed that the source of sediments collected in the stream bed is the surrounding rocks. The recorded high concentrations of

titanium probably indicative of ilmenite mineralization while the presence of manganese and chromium might indicate the potential of ferrous metals mineralization. Cerium, Lanthanum and Thorium concentrations are indices of monazite mineralizations. Fe is associated with Co, Mn, and Ti in BPS006 while Au is in relation with Ce, La and Th in BPS003. Ce concentration might indicate the presence of an unusual distinctive form of monazite [25], the cerium and lanthanum phosphate is the major commercial source of cerium.

#### 4.4. Recommendation for Future Exploration Strategies

Owing to the high concentrations of Fe and Al as the dominant major elements, as well as high concentrations of Mn, P and Ce as the dominant trace and rare earth elements in the stream sediments analyzed from Gouap-Nkollo prospect, it is recommended that a more comprehensive survey of stream sediments should be carried out. However, the present result provides baseline geochemical information needed to carry out a more detailed investigation on the occurrence of heavy minerals in stream sediments of the region. Due to high concentrations of elements (major, trace and LREE) recorded in the northern part of the prospect, especially at the vicinity of Nkollo area, it is recommended that more detailed geophysical and geochemical surveys are needed in this area for possible mineralization of gold. We also recommend detailed geological mapping of the study prospect to evaluate the possible mineralization zones and potential mineable areas as this will help in determining the level, quantity and quality (tonnage) of mineralization in place.

### 5. Conclusion

A stream sediment survey was undertaken in the Gouap-Nkollo area. Considering the geochemical analysis of the stream sediments as well as its interpretation, the following conclusions can be drawn.

1. Fe and Al are the dominant major elements in the stream sediments. Fe indicates the possible occurrence of ferromagnesian minerals while Al indicates that the stream sediments are enriched in aluminosilicate minerals such as feldspar and mica.

2. High concentrations of titanium probably indicative of ilmenite mineralization while the presence of manganese and chrome might indicate the potential of ferrous metals mineralization. Cerium, Lanthanum and Thorium concentrations are indicators of monazite mineralization's.

3. Occurrences and indicators of Fe, Co, Mn, Ti, Au, Ce, La, Pb and Th mineralization's were discovered. Gold has some interesting concentrations which merit more detailed investigation.

4. The element distribution patterns and chemical composition of stream sediments of Gouap-Nkollo is greatly influenced by the local geology of the area and the geochemistry of the stream sediments originated from their surrounding rocks.

5. Future exploration work will be focused on the northern part of the Gouap-Nkollo prospect, where some anomalous concentrations of Au were observed.

### Aknowledgements

The data presented here form a part of the first author's Ph.D thesis supervised by J.P. Nzenti at the University of Yaoundé I, Cameroon. We gratefully acknowledge the mineral exploration company 'G-Stones Resources SA' for their permission to work within their permit area and for financial support for geochemical analysis. We thank the anonymous reviewers for their critical and constructive comments of the manuscript. This is the contribution to ICGP-Y 616 project.

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