IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Environmental and Earth Sciences Research Journal
Vol. 10, No. 2, June, 2023, pp. 41-51
Journal homepage: http://iieta.org/journals/eesrj

Geochemical Assessment of Mineral Occurrences in the Karibumba Region in the Territory of Beni, Democratic Republic of the Congo

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https://doi.org/10.18280/eesrj.100202

Received: 25 January 2023
Accepted: 3 March 2023

Keywords:
Karibumba, geochemical analysis, copper, tin, gold

ABSTRACT

The Karibumba region, in the Mesoproterozoic Kibaran chain, is one of the least geochemically and metallogenically known regions of Kivu. Moreover, the Kibaran chain is geochemically characterized by valuable content of tin (Sn), tantalum (Ta), niobium (Nb), tungsten (W), lithium (Li), gold (Au), and rare earth elements (REE). With the belonging of Karibumba in this chain, it is likely that valuable occurrences of these elements can be found in this entity. In addition, these metals and rare earth elements are largely used nowadays by modern industries and green technologies. This increases even more and in an exponential way the demand for these metals. It is to constrain the geochemical and metallogenic aspects that this study was carried out in the Karibumba area in the territory of BENI, eastern Democratic Republic of Congo (DRC). To achieve this, geological studies and fieldwork allowed to collect samples which were geochemically analysed for trace element. These samples were selected based on petrographic facies variation. Trace elements were determined by a combination of X-ray fluorescence spectrometry (XRF) and inductively coupled plasma mass spectrometry (ICP-MS). Results revealed that, the only mineralization identified with certainty in the Karibumba area is gold. The other elements analyzed showed grades lower than or comparable to the Clarkes and constitute the geochemical background of the area. The anomalous tin content in sample JM01 and the significant negative correlation between gold and silver raise the need for further study in the area. This would identify the nature of the stanniferous anomaly found and cross-check the surprising negative correlation between gold and silver.

1. INTRODUCTION

The subsoil of the Democratic Republic of Congo (DRC) is endowed in geological and energy resources as mentioned in the study [1-5]. This abundance of mineral resources, with more than 1100 different mineral substances, for a value estimated at 3700 billion dollars by the World Bank in 2008, gives the DRC the pseudonym of a "geological scandal" [6].

For Muhigirwa, in addition to minerals, it also has forest resources (with 145 million hectares, or 56% of Africa's forests, which ranks it as the second largest forest in the world after the Amazon), energy (Inga Dam, whose hydroelectric power production capacity represents 15% of the world's capacity), oil (with a reserve of 180 million barrels) and gas (with a reserve of 55 billion m³ in Lake Kivu) [7].

In addition, studies conducted by Mupepele Monti in 2012 show that the DRC ranks first in the world for cobalt reserves (with almost half of the world's reserves) and industrial diamonds (80%), as well as second for iron (5.8% of the world's reserves) and pyrochlore (6.6% of the world's reserves). It also ranks 5th in the world for coltan, 8th for cassiterite, 4th for copper and 7th for gold reserves [7].

These geological resources consist of six main mineral groups: the copper group (copper, cobalt, uranium, zinc, lead, cadmium), the chromium and nickel group, the diamond group, the tin group (tin, wolfram, columbite-tantalite, beryl, monazite), the iron and manganese group, and the hydrocarbon group (coal, oil shale, petroleum, gas) [8-10].

Indeed, the same findings were made by Villeneuve and his team during their work on the review of the G4 "tin granites" and associated mineral occurrences in the Kivu belt (eastern DRC) and their relationship with the latest Kibaran tectonic-thermal events. Thus, they found that the Mesoproterozoic Kibaran belt contains large quantities of mineral resources such as cassiterite, wolframite, gold and columbite group minerals, all of which are highly sought after by modern green technologies [11]. However, the concentrations of these metals are not proportionally distributed throughout the country.

The spatial distribution of metallogenic and geological provinces in DRC shows that there is gold, tantalum, niobium, tin, oil and natural gas in the North Kivu province [12, 13]. Considering that Karibumba area belongs to this part of the country, could this potential be represented in the Karibumba region? And what would be the chemical species present in the Karibumba region that could be the subject of mining research? The answers to these questions will be the subject of this study. This is why this study provides a geochemical constraint of the Karibumba area to identify specific metals which could potentially be enriched in the geological formations in this place. There are two reasons for this study. Firstly, the mining sector today constitutes one of the major pillars of the DRC's budget with an estimated contribution of more than 30% each year. Thus, research that is related to the discovery of new mining potential or that tends to add to the Congolese government's budget would be very beneficial not only for the authors but also for the entire republic. Secondly, the Kivu region in general, due to its position in the Kibaran region, is potentially rich in mineral resources as mentioned above. Nevertheless, these mineral resources have never been the subject of an in-depth geochemical study for certain entities in this province. This is the reason for this study.

The results of these analyses would be compared with Clarke's contents for each analyzed element to determine the enrichment or the depletion of each analyzed element.

Apart from the introduction and conclusion, this article is subdivided into four parts including the study area, materials and methods, results and discussion.

2. STUDY AREA

2.1 Location of the study area

The locality of Karibumba is located in the south of the village of Kabasha, in the Ruwenzori sector, in Beni territory (Figure 1).

The study area is bounded to the northeast by the village Muomo, to the north by the village of Kabasha, to the south by Mount Kiowe and the west by the village of Mahungu [14].

The Karibumba area is under the equatorial climate [15-18]. There is an alternation of dry and wet season [19]. The wet season lasts about nine months. The relief is dominated by hills and mountains (Figure 2).

The nature of the soil in the Karibumba area varies according to the distance from the ancient volcanic edifice. Thus, as one moves away from the volcano, there is a presence of sandy soil, clay-sandy soil and finally clay soil as described by Denaeyer and Petitjean [14]. The vegetation consists of pteridophytes (Figure 3).

The Karibumba area is drained by numerous rivers that flow through the valleys bordered by hills and mountains. The major rivers in the area are the Lombe and Mohe Rivers [20]. Among the well-known rivers in the region, there are Lingito, Lungu, Tshikolokolo, Kaheri, and Kiabikere rivers.

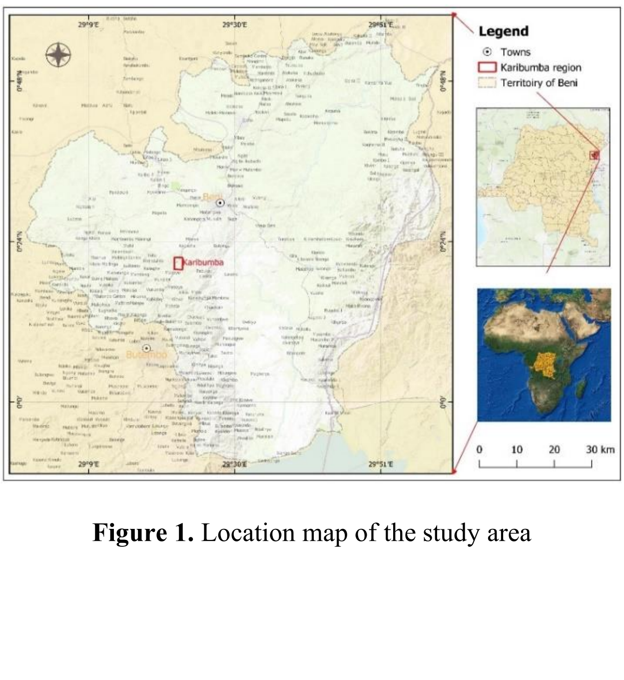

Figure 1. Location map of the study area

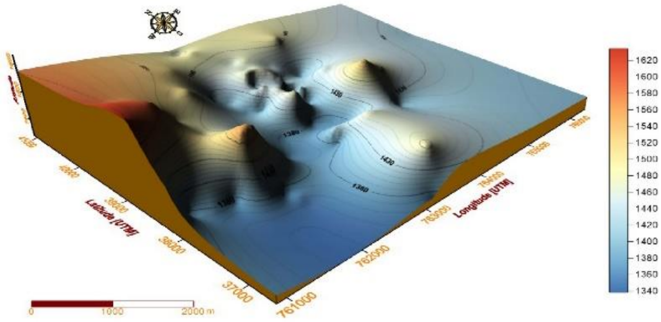

Figure 2. 3D view of the relief of the study area

Figure 3. Vegetation of the Karibumba area

2.2 Geological setting and minerals resources in the territory of BENI

The Beni region, corresponds, for the most part, to a complex basement zone of age ranging from Archean to Middle Proterozoic, cut into two units that are difficult to correlate by a vast tectonic trench filled in by fluvial-lacustrine and continental series of Tertiary to present age [21, 22]. The basement zones of BENI are locally overlain by sedimentary formations of the Upper Proterozoic (Figure 4). We rarely find witnesses of fluvio-glacial deposits. These deposits are Paleozoic in age and outcrop in the Ibina, Biakatu and Ituri valleys northwest of Beni [23].

Locally, the geology of the Karibumba sector is made up of granites, gneiss and diorite which form the basement of the sector (Figure 5). On these bedrock formations, quartzites, conglomerates and volcanic ashes are found. These surficial rocks rest on the bedrock in an unconformable manner [24].

From a metallogenic point of view, the tin and gold group mineralization found in the Kibaran formations is related to granites [25-30].

However, some gold deposits are not related to the granite. But Kabete et al. [31] have shown that these gold deposits are often contained in metamorphic formations.

These deposits have attracted the attention of many firms and actually, research in Kivu are mainly oriented on gold and metals associated with stratiform basic intrusions such as nickel (Ni), cobalt (Co), copper (Cu), and platinum group minerals especially titanium (Ti), vanadium (V) and iron (Fe) [32].

In addition, the Kibaran Range contains resources of industrial minerals such as andalusite, feldspar, kaolinite, muscovite, quartz and wollastonite [33]. Besides some evidence of minerals from sedimentary deposits are also found in, cassiterite, columbite-tantalite, wolframite, monazite and gold.

Table 1. Geological resources of North Kivu Province [34]

N°	Beni	Lub.	Rut.	Go.	Mas.	Wal.	Ny.
01	Au	Au	Au	-	Au	Au	-
02	Sn	-	-	-	Sn	Sn	-
03	Nb	Nb	-	-	Nb	Nb	-
04	Ta	Ta	-	-	Ta	Ta	-
05	W	W	W	-	W	W	-
06	-	Diamond	-	-	-	Diamond	-
07	-	-	-	-	-	Pb	-
08	-	Saphir	-	-	-	-	-
09	-	Zr	-	-	-	-	-
10	-	-	NaCl	NaCl	-	-	-
11	Oil	Oil	Oil	-	-	-	-
12	-	-	-	CH_4	CH_4	-	-
13	REE	-	REE	-	REE	-	-

Notes:

1. (-) Resources not yet prospected but unlikely in the region.
2. Except for the abbreviations, the symbols used in this table are those of the periodic table of elements. As abbreviations we have: Lub. (Lubero), Rut (Rutshuru), Go (Goma), Mas (Masisi), Wal. (Walikale), Ny (Nyiragongo) and REE (Rare Earth Element).

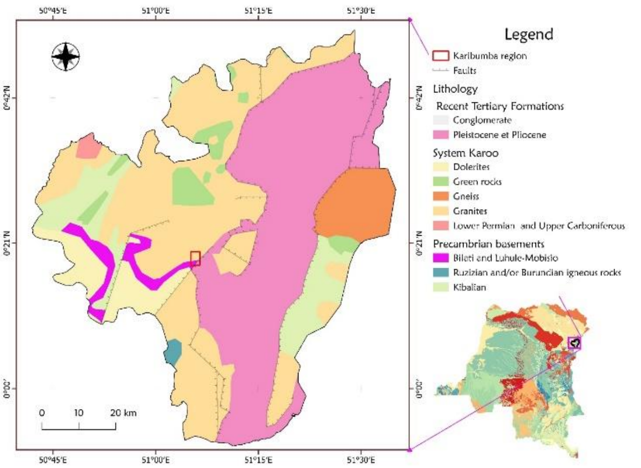

Figure 4. Geological map of the territory of BENI after [35, 36]

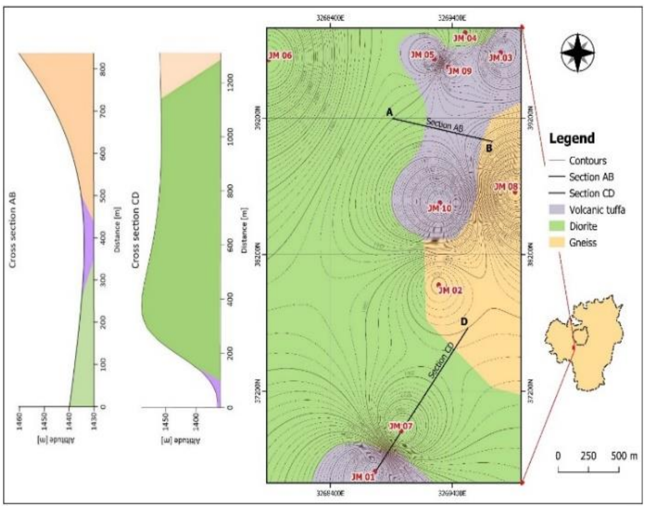

Figure 5. Geological map of the Karibumba region

2.3 Regional mineralization of the north kivu province

The North Kivu province has a low mining potential compared to the ex-provinces of Katanga, Kasai and Oriental Province [37]. However, this potential is not negligible (Table 1). Indeed, since colonial times, cassiterite, columbite-tantalite (Coltan), monazite and gold have been extracted from the underground in this part of the country [38-42].

Besides, in the North Kivu province, there are two large pyrochlore deposits. The first is located in Bingo, 25Km west of the town of Beni [43, 44], and the second is in Lueshe, 80Km north of Goma [45-47]. The latter has been operated by SOMIKIVU since 1986. On the other hand, the Lake Kivu contains nearly fifty billion cubic meters of methane gas (CH_4) that is still unexploited [48-51]. In addition, diamond occurences are reported in the territory of Lubero (Mukene, Kinyavuyiri, Kilau, Kasisi and Kimbulu) and the territory of Walikale (Angoa, 119 Amapima, Tchungu, Kasangano, Makwatima, Apiti, Tunisie/Muswane and Kabombo) [52-56]. Other Platinum and Silver occurences and some semi-precious gemstones such as tourmaline, and amethyst exist in several locations in North Kivu Province [57, 58].

3. MATERIAL AND METHODS

3.1 Materials and field work

The rocks studied and sampled during fieldwork were mostly outcropping in stream beds and on road slopes. Access to the outcrops was difficult because firstly the terrain is rugged (Figure 2), and secondly because of the absence of outcrops on the hillsides and mountains.

During fieldwork, accessible samples were directly observed, and briefly described macroscopically using a lens to identify the sampled rock. The sampling was done on rocks in place (fresh rocks) with the help of a geological hammer. And the estimated weight of a sample was between 1 and 1.5kg depending on the variation in lithological features. Outcrop locations were recorded using GPS in UTM geographic coordinates.

3.2 Description of the samples

Samples were labeled and packed in plastic bags and then transported in the raffia bag for shipment to the analytical laboratory. Ten samples (Table 2), selected based on variations in lithological and mineralogical characteristics were sent for geochemical analyses at the University of Lubumbashi laboratory.

Table 2. Location and identification of samples analyzed at the laboratory

Easting	Northing	Elevation	Samples no	Lithology
763106	36628	1364	JM 01	Volc. tuff
763629	37995	1471	JM 02	Orthogneiss
764138	39698	1391	JM 03	Volc. tuff
763846	39842	1441	JM 04	Diorite
763592	39652	1470	JM 05	Volc. tuff
762231	39647	1520	JM 06	Diorite
763320	36922	1490	JM 07	Diorite
764256	38677	1544	JM 08	Gneiss
763708	39591	1410	JM 09	Volc. tuff
763639	38596	1372	JM 10	Volc. tuff

Volc. means volcanic.

3.3 Sample analysis in the laboratory

The analysis of samples was performed at the Geological Laboratory of the University of Lubumbashi using a combination of X-ray fluorescence spectrometry (XRF) and inductively coupled plasma mass spectrometry (ICP-MS) [58-61], for analyzing the trace elements. ICP-MS was used to identify and quantify trace elements present in our samples.

3.4 Data processing

For data processing, the normalization of the contents of the elements in ppm based on the Clarke (Table 3) of each element was done in MS Excel to deduce the enrichment or the depletion of the collected samples like used by the study [62, 63].

Field maps were produced by QGIS (version 3.16) and Surfer (version 21.1.158) software. The three-dimensional relief map and the geological sections were elaborated by Surfer 21. Statistical parameters were assessed using Past (version 3). Hierarchical classification of samples and principal component analysis (PCA) were carried out with the "vegan" package of R software (version 3.2.1).

Table 3. Clarke of analyzed trace elements in ppm

Elements	Au	Ag	Cu	W	Sn	Mo	Bi	As	Nb	Ta
Clarke	0.05	0.1	55	1.5	2	1.5	0.2	5	20	2

4. RESULTS

4.1 Trace elements content

Table 4 and Table 5 show respectively the raw content and the normalized values of trace elements analyzed in the laboratory. In the 10 samples analyzed, gold was enriched in nine. With the exception of tin in sample JM01, the other elements were depleted in the analyzed samples, with contents lower than or comparable to Clarkes.

4.2 Compositional similarity

This dendrogram divides the samples into three groups (Figure 6). There are sample groups JM07 (Diorite), JM02 (Orthogneiss), JM06 (Diorite), and JM08 (Gneiss). The second group includes samples JM05 (Volcanic Tuff), JM09 (Volcanic Tuff), and JM10 (Volcanic Tuff). The last group is represented by samples JM03 (Volcanic Tuff), JM04 (Diorite) and JM01 (Volcanic Tuff).

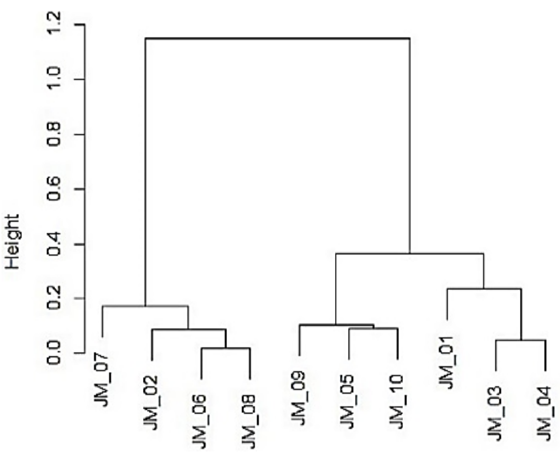

Figure 6. Hierarchical classification of samples based on their geochemical composition

4.3 Principal component analysis (PCA)

The principal component analysis allows apprehending the real values of the coexistence of elements (variables) through the correlations observed during axis construction and the relationship existing between these variables and individuals (samples).

Referring to our result in Figure 7, we find that samples JM09, JM07, JM06 have anomalously high Gold contents.

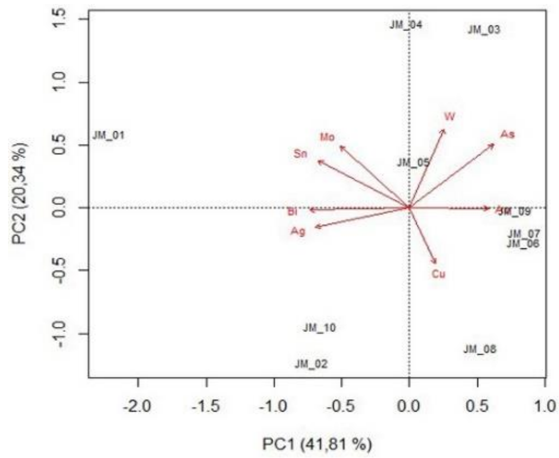

Figure 7. Principal component analysis (PCA)

Table 4. Raw content (in ppm) of the elements analyzed in the samples

Samples No	Au	Ag	Cu	W	Sn	Mo	Bi	As
JM01	0.08	0.07	28.00	0.02	8.60	0.06	0.10	0.04
JM02	0.16	0.07	60.01	0.05	1.47	0.05	0.05	0.09
JM03	0.56	0.04	31.52	0.15	2.23	0.04	0.03	3.28
JM04	0.05	0.04	31.52	0.07	2.90	0.06	0.03	4.30
JM05	0.08	0.02	25.03	0.02	2.15	0.05	0.02	2.10
JM06	0.72	-	55.00	0.02	1.05	0.04	0.04	3.50
JM07	1.28	0.01	44.99	0.03	1.90	0.03	0.05	2.80
JM08	0.24	0.05	55.00	0.03	0.78	0.03	0.02	2.00
JM09	0.98	-	21.01	0.02	2.10	0.03	0.02	1.80
JM10	0.01	0.06	22.99	0.01	1.38	0.03	0.06	0.11

Table 5. Normalized values of analyzed elements in samples

Samples No	Au	Ag	Cu	W	Sn	Mo	Bi	As
JM01	1.60	0.70	0.51	0.01	4.30	0.04	0.50	0.01
JM02	3.20	0.70	1.09	0.03	0.74	0.03	0.25	0.02
JM03	11.20	0.40	0.57	0.10	1.12	0.03	0.15	0.66
JM04	1.00	0.40	0.57	0.05	1.45	0.04	0.15	0.86
JM05	1.60	0.20	0.46	0.01	1.08	0.03	0.11	0.42
JM06	14.40	0.04	1.00	0.01	0.53	0.03	0.20	0.70
JM07	25.60	0.10	0.82	0.02	0.95	0.02	0.23	0.56
JM08	4.80	0.50	1.00	0.02	0.39	0.02	0.08	0.40
JM09	19.60	0.02	0.38	0.01	1.05	0.02	0.10	0.36
JM10	0.20	0.60	0.42	0.01	0.69	0.02	0.30	0.02

4.4 Paragenesis between elements

On the matrix (Table 6), at 95% confidence, there are three significant correlations. That is between Au-Ag, Mo-Sn and Bi-Sn. These correlations are obtained by comparing the calculated correlation coefficients with the theoretical coefficient read from the table of Rollinson (1993). The value of this theoretical coefficient is 0.632. Thus, are considered as significant correlations, all values greater than or equal to 0.632 taken in absolute value.

To get a good understanding of the connections between these elements, we will try to bring special attention to the discussion.

Table 6. Inter-element correlation matrix

	Au	Ag	Cu	W	Sn	Mo	Bi	As
Au	1.00							
Ag	-0.75	1.00						
Cu	0.13	0.09	1.00					
W	0.03	0.12	-9.00	1.00				
Sn	-0.25	0.38	-0.38	-0.08	1.00			
Mo	-0.44	0.29	-0.14	0.15	0.65	1.00		
Bi	-0.25	0.55	-0.11	-0.25	0.76	0.43	1.00	
As	0.37	-0.63	0.10	0.45	-0.32	0.04	-0.59	1.00

5. DISCUSSION

As previously mentioned, the spatial distribution of metallogenic and geological resources in eastern DRC, highlights the existence of gold, tantalum, niobium, tin, oil and natural gas Cahen [64] and Fernandez-Alonso et al. [65] in the notice of the geological map of the DRC; as well as demonstrated by Rusembuka [7] or Villeneuve et al. [11] while assessing the opportunities to invest in mineral resources development in DRC. This potential is real and not negligible in this part of the country as reconsidered in previous work already carried out in the region. It is the case in the studies of [1, 45, 46] on the occurrences of REE in carbonatite complexes respectively around Lueshe, Kirumba, and Bingo in the eastern DRC.

To ensure the existence of this potentiality in the region of Karibumba, ten samples were taken for geochemical analysis. In these samples, ten elements were analyzed (Table 4), two of which: Tantalum (Ta) and Niobium (Nb) were found to be absent in the samples (perhaps due to the selection of samples for analysis or due to the sampling method). The remaining eight elements show a very irregular distribution of values. These include Gold (Au), Silver (Ag), Copper (Cu), Tungsten (W), Tin (Sn), Molybdenum (Mo), Bismuth (Bi), and Arsenic (As).

The dendrogram (Figure 6) classifies the samples into three groups. These are sample groups JM07 (Diorite), JM02 (Orthogneiss), JM06 (Diorite), and JM08 (Gneiss). The second group includes JM05 (Volcanic Tuff), JM09 (Volcanic Tuff), and JM10 (Volcanic Tuff). The last group is represented by JM03 (Volcanic Tuff), JM04 (Diorite) and JM01 (Volcanic Tuff). After interpretation, this classification was made based on the copper grade. It shows that the first group of samples has a very high copper grade, the second group is very poor in copper and the third group has an average content. Unfortunately, these are insignificant grades (Table 5) because they are isolated (Figure 7). The anomalously high grades in some samples can be interpreted as nugget grades like previously interpreted by Dewaele et al. [66] while performing the satellite image interpretations and petrographic and fluid inclusion analyses on samples from the stratiform mineralization of Kamoto and Musonoi.

After normalization, there is an enrichment in gold (Au) in all samples (Table 5), unlike the other elements. This result suggests that only gold can be the subject of geological and even mining research in the Karibumba area. In addition, how can the presence of gold in a Kibaran context be explained? Indeed, it is not magical to find gold in the Karibumba area. Referring to the local geology, the anomalously high gold content may be due to the metamorphic basement of the Ante-Kibaran age. Besides, precious metals are concentrated in formations of the Ante-Kibaran age, probably the Kibalian as mentioned in the study [11, 25, 27, 67, 68]. This is because the Karibumba area is dominated by these Ante-Kibaran age formations (represented by the granites, diorites and gneisses that form the basement of Karibumba). But also because most of the samples were taken on fresh rocks. The reason why this gold mineralization is believed to be syngenetic.

In the view of the geological context of the study area, gold mineralization in the Karibumba area can have two possible origins. First, it can be assimilated to belong to the hypozonal orogenic type, forming in high metamorphic conditions (T>475°C), and are very often in equilibrium with the metamorphic conditions of the host rock or are slightly retrograde as assumed by Dubé and Mercier-Langevin [69]. The characteristics of these deposits defined by Pohl [70], and Thomas et al. [71] take into account: high-temperature alteration minerals (like biotite, garnet and pyroxene); pyrrhotite, arsenopyrite, loellingite, and chalcopyrite metallic mineral assemblage; ductile structural control; and country rocks that are mostly bounded by iron-rich lithologies such as amphibolites, BIFs, ultramafic rocks, and diorites. This phenomenon explains the concentration of gold in the diorite (see sample numbers JM04, JM06 and JM07).

On the other hand, the gold mineralization in the Karibumba area is believed to belong to the mesozonal orogenic type often retrograded for the highly metamorphosed host rocks, and are characterized by alterations compatible with greenschist facies (sericite-ankerite-chlorite-albite) see the consideration of the study [72-75]. Gold mineralization of this type can be found in orthogneiss, paragneiss, or granites according to Pitcairn et al. [76]. For these deposits, the metallic minerals associated with gold are mainly pyrite, arsenopyrite and chalcopyrite [11, 25]. They typically form during late phases of orogenic episodes, characterized by extensional tectonics and exhumation of deep rocks [32, 77]. For our study region, this would explain the gold enrichment in the diorite up to a concentration factor of 25.6. This is the case in the world of the mesozonal orogenic deposits of the Abitibi in Canada where gold deposits are found in the archean green belts [69, 73, 75-81].

There was a significant negative correlation between gold and silver (Figure 8). This seems contradictory with reality because gold and silver are generally associated in hydrothermal veins [25]. Indeed, geochemically, these two elements have similar charges and ionic radii and can substitute each other in the crystal lattice [82-85].

This negative correlation between gold and silver can have two reasons: first, we believe that the linear regression between gold and silver is due to the sampling. Maybe the rocks we sampled were not vein-like. This seems obvious because orthogneiss, diorite and gneiss are plutonic rocks. Secondly, perhaps it is because the study area is located in a volcanic context, dominated by volcanic tuffs (see Samples

JM01, JM03, JM05, JM09 and JM10). Moreover, the volcano with its very particular thermodynamic conditions (very high temperature and pressure) and a rather brutal cooling, can be the origin of this negative correlation like previously mentioned in the works [28, 67, 86-92].

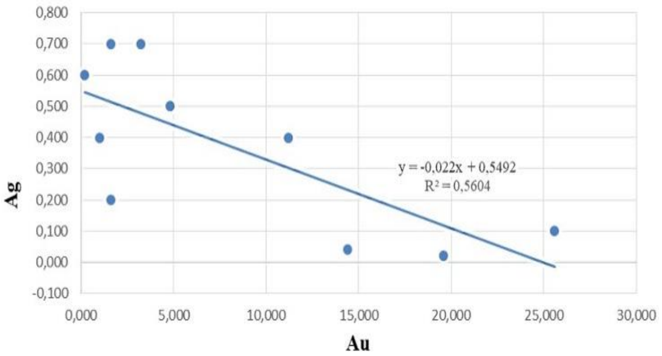

Figure 8. Linear regression between silver and gold

Furthermore, by making a careful examination of the normalized results (Table 5), another element that attracts attention is tin. Indeed, tin is one of the characteristics of the mineralization of the Kibaran formations [93]. It would be anomalous not to find it in an area located in the middle of the Kibaran facies. Statistical studies show strong correlations between tin: Mo-Sn (Figure 9) and Bi-Sn (Figure 10).

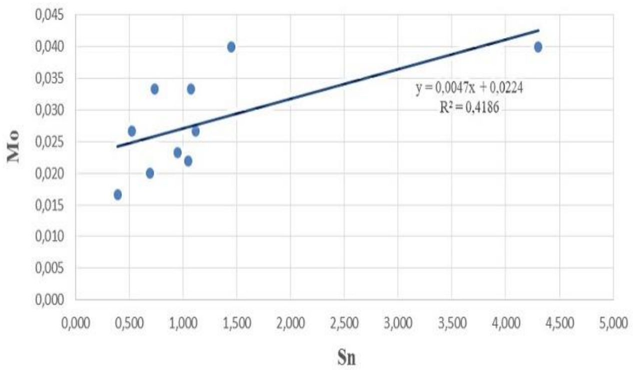

Figure 9. Linear regression between molybdenum and tin

Molybdenum (Mo) and bismuth (Bi) are extracted mainly from hydrothermal concentrations of fairly high temperature in the form of wulfenite ($PbMoO_4$) and Bismuthite ($(BiO)_2CO_3$) [94-98]. In this formula of wulfenite ($PbMoO_4$), lead and tin being all elements of the 4th family on the geochemical table of elements (same valences and very close ionic radii), these elements can easily be substituted according to the Ringwood rule defined in [82-85]. Thus, instead of $PbMoO_4$, after substitution and under very particular thermodynamic conditions, there is the crystallization of $SnMoO_4$ clearly shown in [99-102]. It is the same with bismuthite ($(BiO)_2CO_3$). Bismuth (Bi) is a chemical element of the 5th family but it has almost the same charges and the same ionic radius as tin (Sn) [72, 103-107]. This can lead to the replacement of bismuth (Bi) by tin (Sn) in the formula of bismuthite ($(BiO)_2CO_3$), for having ($(SnO)_2CO_3$). These types of paragenesis are however extremely rare and their existence requires very particular thermodynamic conditions [92, 108, 109].

Like gold, tin deposits are found in geological formations of all ages, from the Precambrian to the Quaternary [110-112]. Despite the existence of many tin minerals, this metal is mainly produced from cassiterite [11, 38, 40, 113]. Its deposits can be associated with granites crystallizing at very different depths and under very varied geological, geochemical and structural conditions: they are found either in or around granitic domes associated with pegmatite veins and quartz veins [11, 28, 40].

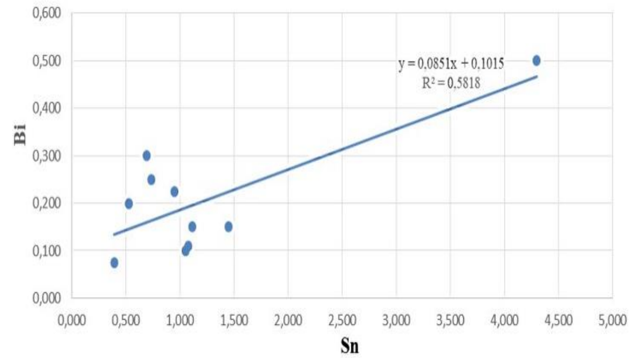

Figure 10. Linear regression between bismuth and tin

6. CONCLUSION

It is obvious that the mineral wealth of the DRC in general and of its eastern part in particular is more important and partly poorly described, thus confirming its qualification as a geological scandal. The results of this study confirm this point of view by highlighting the presence of gold mineralization in the Karibumba area. Other elements analyzed had grades lower than or comparable to the clarkes, with the exception of tin in sample JM01. Based on these data, until proven otherwise, only gold can be prospected for in the study area. However, the enrichment of tin in one of the samples justifies the need to conduct further research in the area to determine the nature and potential extension of this anomaly. In addition, the evolution of gold and silver grades deserves to be studied in the background at Karibumba and its surroundings in order to verify whether the negative correlation observed between these two elements was due to sampling error/insufficiency or not, as in most hydrothermal veins, these two elements are always positively correlated. For finalizing, this study has identified the mineral resources of the Karibumba region. In addition, the metals that can be mined have also been identified. However, due to our limited resources and the lack of funding for the research, the number of samples was very small. This is why we recommend that anyone interested in investing in the Karibumba area should deepen this study by multiplying the number of samples to ensure the validity of our findings.

ACKNOWLEDGMENT

We thank the Faculty of Science and Technology of the “Université Officielle de Ruwenzori” for providing us with the field materials. We extend our warmest thanks to the laboratory of the University of Lubumbashi, for the geochemical analysis of samples. We would also like to thank the various reviewers for their insightful remarks which enabled us to improve this article.

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NOMENCLATURE

GPS	Global Positioning System
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
JM01	Sample number 01, named using the initials of the co-authors: Justin Mireille
QGIS	Quantum Geographic Information System
SOMIKIVU	SOcieté MInière du KIVU (Kivu Mining Company)
XRF	X-Ray Fluorescence Spectrometry
UTM	Universal Transverse Mercator