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Geochimic Study of Geological Formations of Sake (Kibarian) In North-Kivu, R.D.Congo

K.W. Kavyavu[a], A. Simba[b], M.L. Nathati[b]

[a]*Geology/University of Nature Conservation and Development of Kasugho, Goma, DRC.*
[b]*Independents Geologists researchers, Goma, RDC.*

[*]*Corresponding author.* *wisdomkambale@gmail.com*

Abstract. The geochemical study of the facies of Sake in the Masisi Territory is as for any area a preliminary concept that may serve as a preliminary level for the valuation of the mining anomalies that can have this region. Our study focused on the trace elements to find their concentration in the petrography diversity and allows to have an idea on the metalogeny model of this anomaly trace establishment, in our case, is veinous given the gold content in the units may belong to the hydrothermal concentrations in the breaks. It's just demonstrated from the standardized contents that Sake is highly stano-auriferous and poorly in Niobite- Tantalum parageneses.

Keywords. Geochemistry, Tracer elements, Sake.

INTRODUCTION

The contemporary metallogenic and metallurgical industry uses adequate scientific and technical activities to meet the various demands made by the galloping needs of society. Sheet metal, automobile mechanics, food processing, medicine and / or army, using respectively Copper, Zinc, Tin, Uranium taking only these, which are use full in the upstream phases of Mining productions. Gold plays in our days as in the olden times an economic heritage for nations (kingdoms) that for individuals, paragenesis Ta-Nb-Sn plays a more important role as for the Rare Earths Elements in the manufacture of green technology tools (NTC, army ...) the (Tin) intervene in the agro-food industry. Thus, it is difficult to find in the world a single area where the products of the mining industry are not used.

Finally, currently, various developing countries, including the Democratic Republic of the Congo, are the countries that are endowed with very high mineral resource potential that require intense geological and mining research. The study of wealth and concentration (indices) requires the scientific knowledge and many other parameters that are used in setting up the deposit. The scarcity of documents in some Congolese regions, including Masisi in North-Kivu, is not good for researchers and leads to geological ambiguity.

The Sake city is an agglomeration in the Masisi Territory, in North-Kivu Province in its Southern part, East of the Democratic Republic of the Congo. It is located 27 km North-West far of the Goma city and 7 km North of Kirotshe village. It shares the coastal cities of Kivu Lake. Sake is a roundabout crossroads crossed by the National Highway 2 connecting it to Bukavu and Goma. Here you can see the junction taking the axis Masisi center-Walikale. (www.wikipedia.com).
The geology of Sake is predominantly metamorphic with some acidic plutonic points and scoriaceous projectiles; the map N°1 gives an idea. The presence of the thermal spring waters resurgences confirms the actualism of the Rifting in these faults and not only the meteoric infiltrations warming up to the perpendicular magmatic chamber of the volcanic field of Virunga. Before the colonial era, Kivu Lake was in direct communication with the Kihira Estuary and Ndakoleka, today, a tholeïtic pot creates a bay called Small Lake of Sake in the north of the lake as seen on the map of figure 1. We observe here and there regressed beds and even disappearances on the surface to reappear in downstream flow, the river Kataka and Mubambiro are cases.

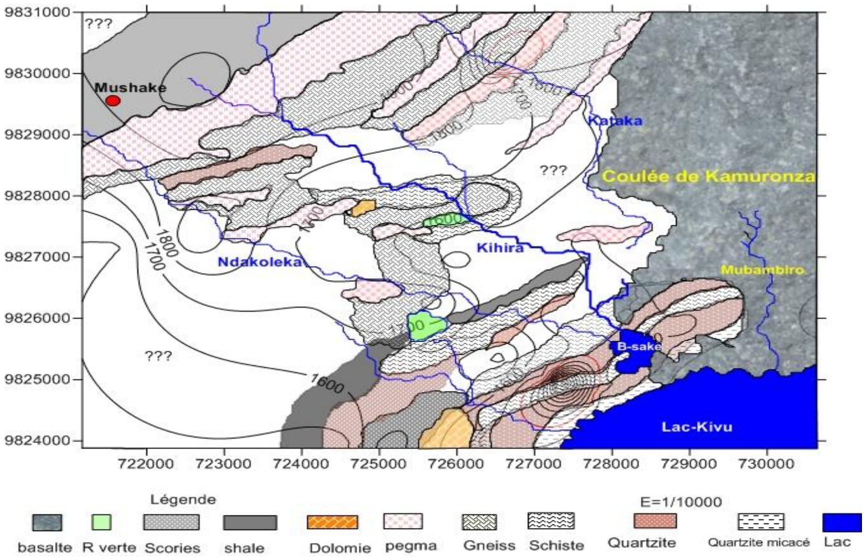


Fig.1. Lithology of Sake Sector, Our lithologic surveys.

MATERIALS AND METHODS

Field work

The macroscopic recognition of the formations was carried out following the surveys of the Geological outcrops according to the geological servey of map N°1. Proceed with the sweeping by routes (geological sections) oriented perpendicular to the preferential direction of the region. Lithological and structural observations caused by plutonic islands, followed by a mineralogical description, have been added to macroscopically name the outcrops.
In the case of scarcity of outcrops as a result of pyroclastic cover, as with any survey, we used the bottoms of the beds and their abrupt slopes as a continuation of buried outcrops. The sampled outcrops have undergone macroscopic in-situ identification and a number of representative samples of certain lithological units (amphibolites, shales, granitoids,) are taken for a lame lithogical and geochemical study.

Materials

For the realization of fieldwork we used the primary materials of the prospecting geologist which we quote the most commonly used.

- GPS: used for taking geographic coordinates which helped us to have the lithological facies of figure 1,
- The compass: indispensable, having a referential orientation the geographical North. Apart from the orientation to the wind rose it serves for the geometrical positionnement of Geological formations and/or tectonic elements (slop and dip), the orientation of watercourses and access tracks. But also the situation or location in relation to North are its uses. For a Geologist, it must have a bubble level to ensure horizontality and a sighting system to make targeted cuts.
- The less: substituting the human eye because the latter is not enough to detect and recognize the singular crystals of the rocks except if they are particularly large.
- The hammer: It is used to bleed in the end to have a particle of diminished dimension coming from the rock. He is manipulated to make the least possible damage; it is through him that the rock samples are detached.
- The decameter: tool to measure the extension of geological formations during the execution of the cuts to specify their thickness and in case of lithological change.
- Sulfuric acid: tester for the specification of carbonated rocks such as limestones and dolomitic rocks and well expected their intermediaries.

Data processing

The spatial analysis of field data was done firstly from Google Earth 2010 and completed by the UN mapping. After macroscopic descriptions leading to a macroscopic nomination, we proceeded to geochemical analysis followed by the interpretation of traces elements to appreciate the anomalous traces of metals. This geochemistry allowed us to construct the correlation matrix to get an idea of the exploitability of the lithologies of the environment (Fig. 2).

Fig.2. Localization of study place.

DISCUSSION

The Virunga volcanic chains located inside the Western branch of the African Rift tectonic ditch, have aroused, since their discovery, the attention of petrographers and volcanologists by the particular composition of their lava. Apart from their differentiated, these are poor in silica and rich in alkalis, especially potash. On the other hand, small masses of nepheline syenite outcrop at different points in the basement, not far from the volcanic apparatuses. These syenites

have similar chemical characters: alkalinity and silica deficiency, but in contact with the lavas, they are more sodic than potassium.
The same author adds that, further east, halfway up the south exit of Shasha, on the Sake-Bukavu road, outcrops of gray shale follow each other, generally mediocre and superficially disturbed.
According to Paul PASTEEL, 1961 it is to the knight Josué Henry De Lalindi that is due the first geological observations made in the region of Kirotshe. During rapid reconnaissance, this author notices the formation of travertines in the Sake stream, and recognizes the existence of important limestone formations in Nyamakubi, about 50 km further south. But the presence of dolomites at Kirotshe seems to have escaped him. While the acid intrusions of the region are recognized as none leave by the colonial works even those flush under their bases.
In South of the lava flow of the Tshambene volcano, which in 1939 isolated Sake Bay as a small lake, Quartzophyllades gave way to Quartzites, generally altered and diaclasticated.
The small hydrothermal source of Sake, whose geochemistry is absent here, reported by G. PASSAU, 1935 is certainly related to the fault.
For the whole Territory of Masisi, the find mineralizations are the following: the Cassiterite of Mumbe, Idambo, Ikese, kamzoro, Nzubu, Nkenge, Kasenda, Bishasha; Wolframite, Kasangula (Mumba); Colombo-Tantalite in Mumba-Numbi; Pyrolusite; Gold for Ngungu-center; Pyrite and Mispickel in Mumba. The same author adds that we can meet in the sector of Sake the Limestone which is seen around Sake, Mount Mushekera, Murambi, Chanzole, Male, Kanyachoa, Shebuseke estimated in 2350000 tons) Tourmaline, gold, Pyrite and mispickel, ...

GEOCHEMICAL STUDY OF FACIES

Until recently, the geologist had to be satisfied with the information he could draw from outcrops for deposit finding. The applications of geophysics then gave him a way to "penetrate" deeper into the Earth's crust. Just recently, applied geochemistry has been added to his baggage. The geochemical analyzes carried out us make it possible by comparison to appreciate the concentration of the tracer elements only in the rocks analyzed because for us the concerned is not to know the enrichment but the metalliferous enrichment in the region.

PRESENTATION OF GEOCHIMIC DATA OF TRACE ELEMENTS

Raw geochemical data of trace elements in ppm (g/tonne)

After analysis of the different samples collected and described macroscopically in situ, followed by petrographic microscopy, we went to a geochemical stage to obtain a Quantitative idea whose table 1 reveals us without modification the raw result.
From the data in table 1, no interpretation emanates from the raw values to attest to enrichment or depletion. To judge the presence or absence of the positive anomaly of interest, standardization is an asset. It is here used the Clarke, metalliferous contents in the earth's crust. This normalization will allow us a conclusion on the metalliferous concentration in the facies analyzed in the Sake region.
Normalized data is obtained by the ratio between the content of an element in the sample and it's Clarke, which is the average content of an element in the Earth's crust. Table 2 on metals' Clarke in the crust is worth for reference. For any metal having more Clarkes, the metal standard quantity in the crust we made an arithmetic mean. The ratio of the actual contents gives us a calculated content which is repeated in table 3.

Table 1. Raw Geochemical Data for Trace Elements in ppm (g/tonne). (Geochemical analysis at the laboratory of the University of Lubumbashi).

Sample	Au	Cd	Sn	W	Nb	Ta	As	Ag
AN 001	0.03	0.055	58	0.43	0.36	0.043	0.01	0.84
AN 002	0.35	0.043	37	0.28	0.24	0.01	2.35	0.88
AN 003	0.42	0.03	64	1.24	0.29	1.36	2.91	0.74
AN 004	0.05	0.02	44	0.002	0.07	0.004	0.38	0.59
AN 005	0.03	0.068	47	0.011	0.013	0.074	0.47	0.68
AN 006	0.02	0.076	54	1.73	15.2	0.82	3.2	1.38
AN 007	0.01	0.016	12	0.056	0.43	0.001	0.31	2.02
AN 008	0.05	0.012	24	0.004	0.51	0.007	0.03	0.48
AN 009	0.02	0.01	25	0.001	0.05	0.054	0.22	0.28
AN 010	0.52	0.032	58	0.66	10.4	1.23	0.11	0.31
AN 011	0.44	0.024	57	1.01	22.4	1.03	3.45	1.35
Min	0.01	0.01	12	0.001	0.013	0.001	0.01	0.28
Max	0.52	0.076	64	1.73	22.4	1.36	3.45	2.02
Moyenne	0.176	0.035	43,636	0.493	4,542	0.421	1,221	0.868
Somme	1.94	0.386	480	5,424	49,963	4,633	13.44	9.55

Table 2. Clarke trace elements in ppm.

Au	cd	Sn	W	Nb	Ta	As	Ag
0.05g /t	0.15g/t	2 - 3g/t	5 g/t	20 - 24 g/t	2g/t	5g/t	0.1 g/t

Table 3. Standard geochemical data for trace elements in ppm.

Sample	Au	Cd	Sn	W	Nb	Ta	As	Ag
AN 001	0.6	0.36	19.3	0.28	0.016	0.021	0.002	8.4
AN 002	7	0.28	12.3	0.18	0.01	0.005	0.47	8.8
AN 003	8.4	0.2	21.3	0.82	0.013	0.68	0.582	7.4
AN 004	1	0.13	14.6	0.001	0.003	0.002	0.076	5.9
AN 005	0.6	0.45	15.6	0.007	0.0005	0.037	0.094	6.8
AN 006	0.4	0.5	18	1.15	0.69	0.41	0.64	13.8
AN 007	0.2	0.1	4	0.037	0.019	0.0005	0.062	20.2
AN 008	1	0.08	8	0.002	0.023	0.0035	0.006	4.8
AN 009	0.4	0.06	8.3	0.0006	0.002	0.027	0.044	2.8
AN 010	10.4	0.21	19.3	0.44	0.472	0.615	0.022	3.1
AN 011	8.8	0.16	19	0.67	1.018	0.515	0.69	5.274

Based on these normalized values, we find a significant enrichment in Au decreasing in samples **AN011, AN 010, AN 003**. In addition to gold, we come from this standardized table that the Sn made record in samples **AN003, AN010, AN001, and AN011**. Apart from these two metals, we retain a slight concentration of Nb-Ta in **AN011**. These analyzes of the tracers are undoubtedly revealing that Sake is Gold-stanniferous. It must be recognized as Sn-Nb-Ta; Au-Ag paragenesis. The presence of metals brings us back to the dominant cassiterite riches of Niobite-Tantalite. Also, we recognize the gold that is carried by Quartz veins of magmatic origin (hydrothermalism) filling the weak areas in the materials.

Distribution of traces in analysed samples

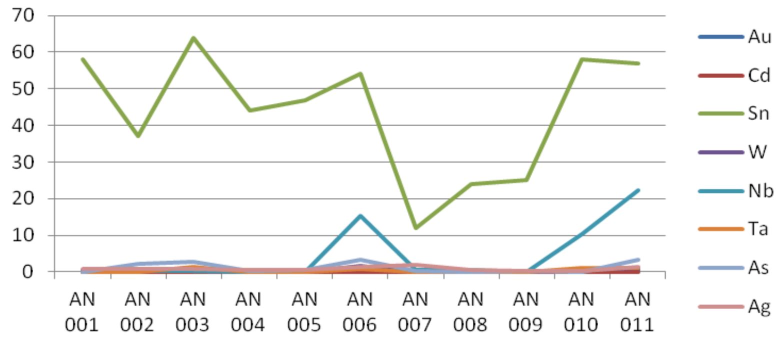


Fig. 3. Distribution of the elements in traces in the samples before normalization.

Using the raw data, we report a single recognizable metal in Sake region, Sn with a slight Nb concentration. The remains being inferiors in the facies, it is necessary to resort to standardized data to apprehend the riches. Figure 4 gives an overview.

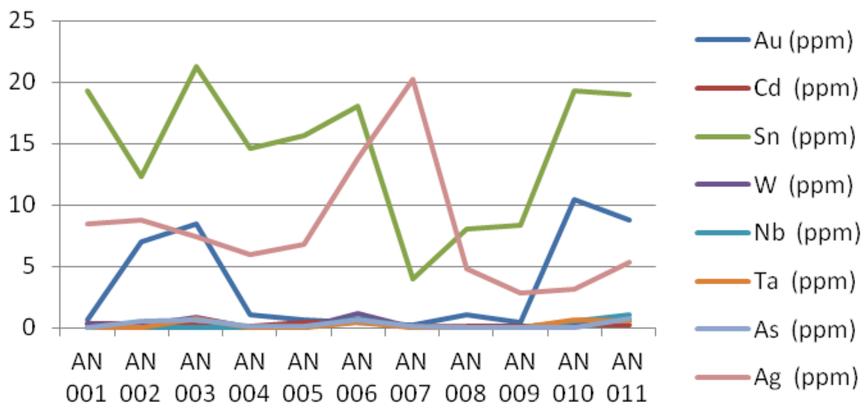
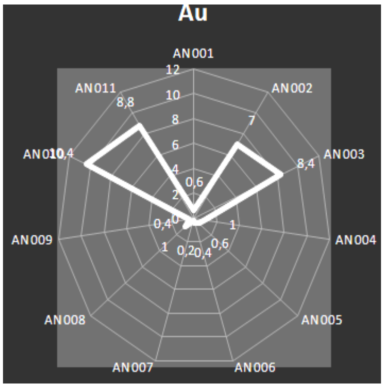


Fig. 4. Distribution of the elements in traces in the samples after normalization

After normalization, by dividing the detected Quantity by the clarkes for verifying the real rich of the field we deduce from this that the repartition is abnormal in the facies, some have a peak for Tin **(AN001, AN003, AN010 and AN006),** others for Gold in **AN003 , AN010, AN011** and still others for silver, playing an intermediate concentration (AN001, AN002, AN007). In some cases, no correlation between gold and its attendant silver.

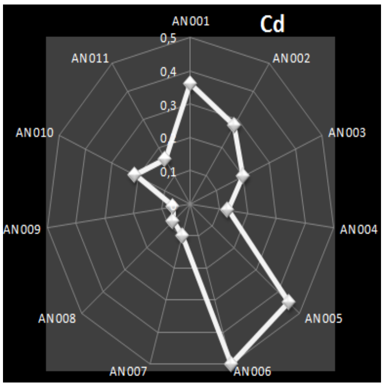
Data presentation

Due to the laboratory in the region, we use to begin by eight elements. These are target of artisanal workings. In this part of the research, we illustrate the contents of the different metals of the petrographic facies of the Sake region with the aim of knowing the anomalies that can be targeted from the work coming for the mining researches.



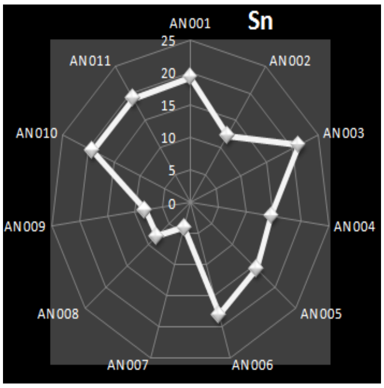
a- gold.

From this graph, we find that the gold is more abundant in the sample AN010 with a content of 10.4ppm, taken from a vein of pegmatitic nature hosted in granite, followed by the sample AN011 also taken from a vein. Ferruginous Quartzite with a content of 8.8ppm, followed by the AN003 sample with a grade of 8.4ppm, after that comes the sample AN002 with a content of 7ppm. This content is insignificant in the other samples.



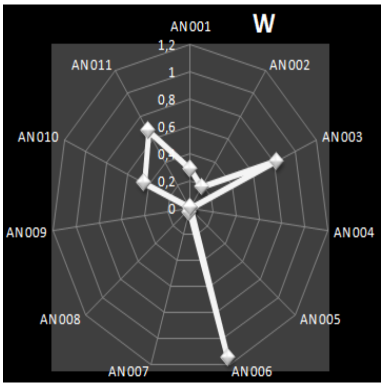
b- Cd.

We can see from this curve that the cadmium is at maximum content in the sample AN006 with a value of 0.5 ppm, followed by the sample AN005 with a content of 0.45 ppm and then comes the sample AN001 with a content of 0.36 ppm. He geochemistry serves as behave like gold contamination



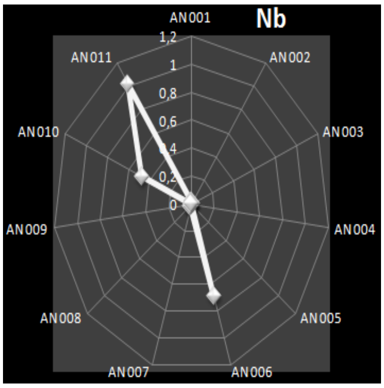
c- Tin.

Reading this curve, we notice that tin is very far from being negligible, except in the sample AN007, AN008 and AN009 where the content seems to decrease with the values of 4 ppm, 8 ppm and 8.5 ppm, respectively. Remarkable abundance in the other samples, I.e 72%, with a maximum value in the sample AN003 taken from a ribbonized gneiss grading 21.3ppm



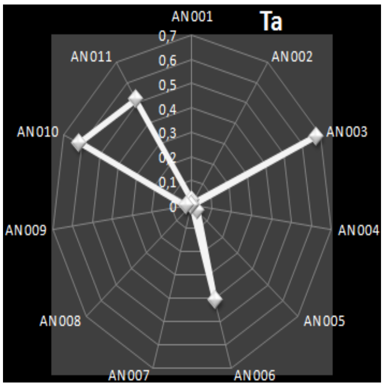
d- Tungsten.

It can be seen from this graph that the W content is maximum in sample AN006 followed by sample AN003 and then sample AN011 with values of 1.15ppm, 0.82ppm and 0.67ppm, respectively. The content is low in the other samples. This joins as in some corners an evolution with Sn.



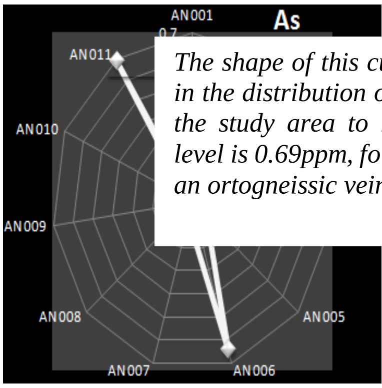
e- Nb.

From this curve we find that the Nb is at maximum value in the sample AN011, with a content of 1.018ppm, followed by the sample AN006 with a content of 0.69ppm. For this element, the content is below the norm in all samples except sample AN011. This last rock allowed concluding black spots like cassiterite.



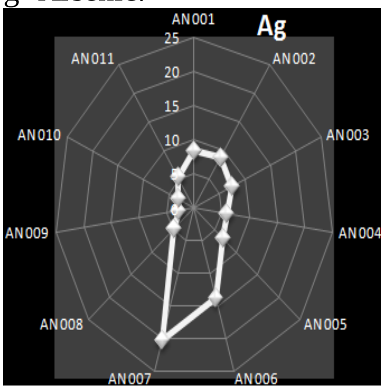
f- Tantalum.

From this curve, we notice that tantalum is below the norm in all the samples, no presence of tantalum is easily conceivable, nevertheless the maximum content is found in the sample AN003. The metal is probably related to the oxides, the most common of which is formational tantalite in the granitoids. The sample concluded paragenesis Sn-Ta associate.



The shape of this curve shows us a certain irregularity in the distribution of arsenic levels in the formations of the study area to insignificant values. The maximum level is 0.69ppm, found in the AN011 sample taken from an ortogneissic vein encased in granite.

g- Arsenic.



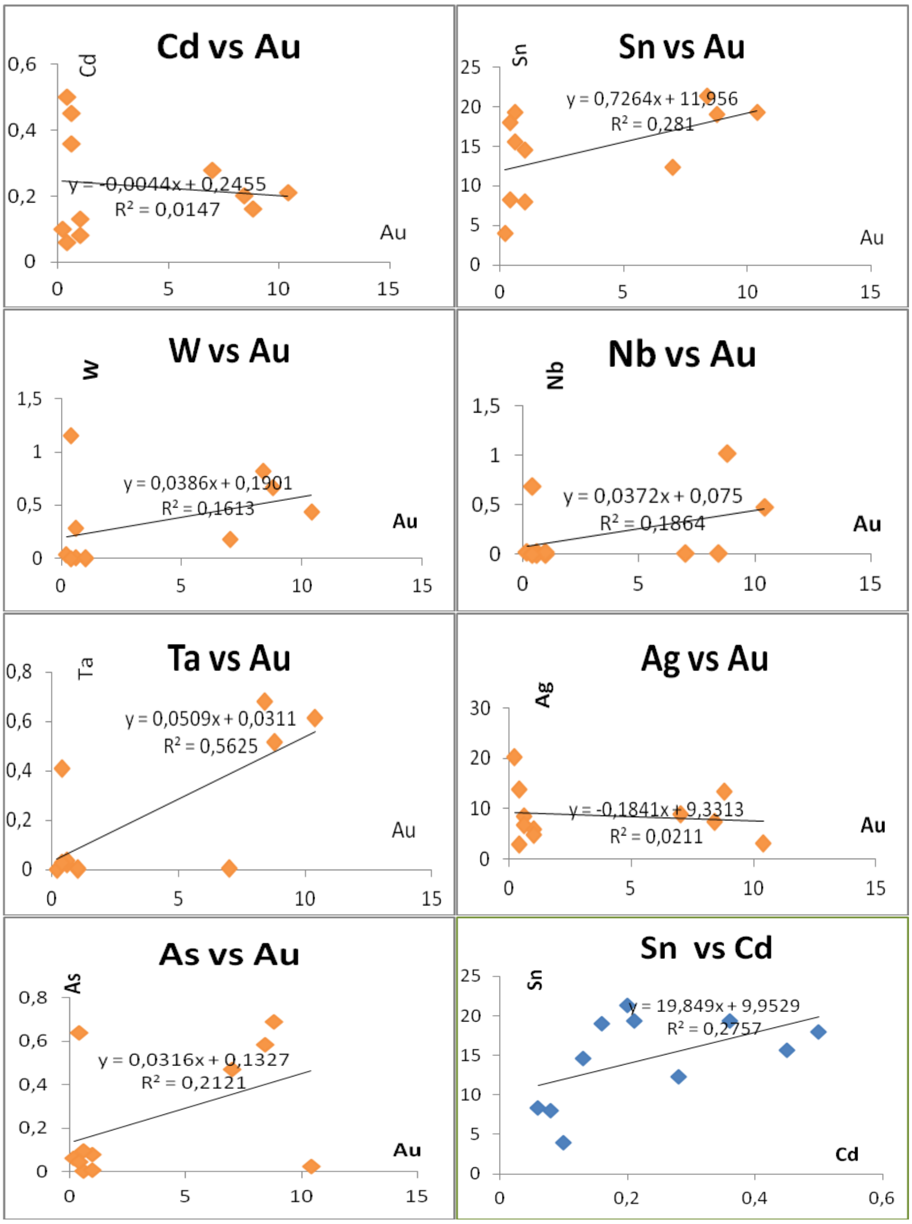
By examining this curve we can easily see the abundance of silver in all samples, but to different degrees of course. Sample AN007 embodies the maximum content, which reaches 20.2 ppm, followed by samples AN006 and AN002 with 13.8pmm and 8.8ppm, respectively. The minimum content is down to 2.8ppm in samples AN009 and AN010.

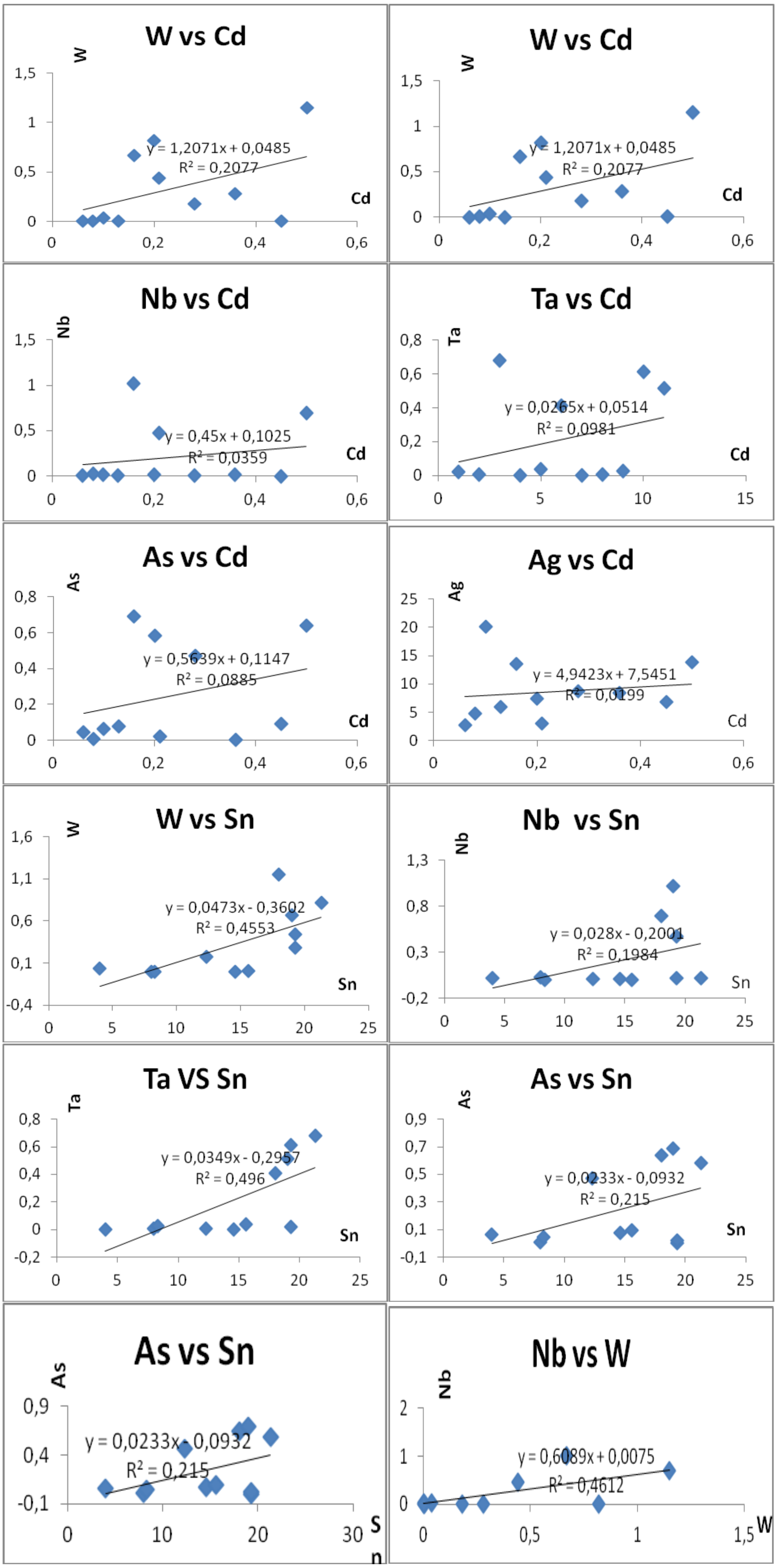
h- Silver.

Fig. 5. Evolution of contents of the different metals of the petrographic facies of the Sake region (in ppm).

Correlation lines and inter-element correlation coefficients

The correlation lines
We present to figure 6, the inter-element correlations lines in trace with their equations as well as the corresponding correlation coefficients. However, we present here only those whose correlation is significant and especially positive ones. In addition, it should be understood from this section that the correlation is positive for elements taken two by two when their geochemical behaviors are similar and thus make a paragenesis and not an exsolution in magmatic crystallization processes. They can thus be found in a polymetallic deposit.





W vs Cd
W
y = 1,2071x + 0,0485
R² = 0,2077
Cd
1,5
1
0,5
0
0
0,2
0,4
0,6
W vs Cd
W
y = 1,2071x + 0,0485
R² = 0,2077
Cd
1,5
1
0,5
0
0
0,2
0,4
0,6
Nb vs Cd
Nb
y = 0,45x + 0,1025
R² = 0,0359
Cd
1,5
1
0,5
0
0
0,2
0,4
0,6
Ta vs Cd
Ta
y = 0,0265x + 0,0514
R² = 0,0981
Cd
0,8
0,6
0,4
0,2
0
0
5
10
15
As vs Cd
As
y = 0,5639x + 0,1147
R² = 0,0885
Cd
0,8
0,6
0,4
0,2
0
0
0,2
0,4
0,6
Ag vs Cd
Ag
y = 4,9423x + 7,5451
R² = 0,0199
Cd
25
20
15
10
5
0
0
0,2
0,4
0,6
W vs Sn
W
y = 0,0473x - 0,3602
R² = 0,4553
Sn
1,6
1,1
0,6
0,1
-0,4
0
5
10
15
20
25
Nb vs Sn
Nb
y = 0,028x - 0,2001
R² = 0,1984
Sn
1,3
0,8
0,3
-0,2
0
5
10
15
20
25
Ta VS Sn
Ta
y = 0,0349x - 0,2957
R² = 0,496
Sn
0,8
0,6
0,4
0,2
0
-0,2
0
5
10
15
20
25
As vs Sn
As
y = 0,0233x - 0,0932
R² = 0,215
Sn
0,9
0,7
0,5
0,3
0,1
-0,1
0
5
10
15
20
25
As vs Sn
As
y = 0,0233x - 0,0932
R² = 0,215
Sn
0,9
0,4
-0,1
0
10
20
30
Nb vs W
Nb
y = 0,6089x + 0,0075
R² = 0,4612
W
2
1
0
0
0,5
1
1,5

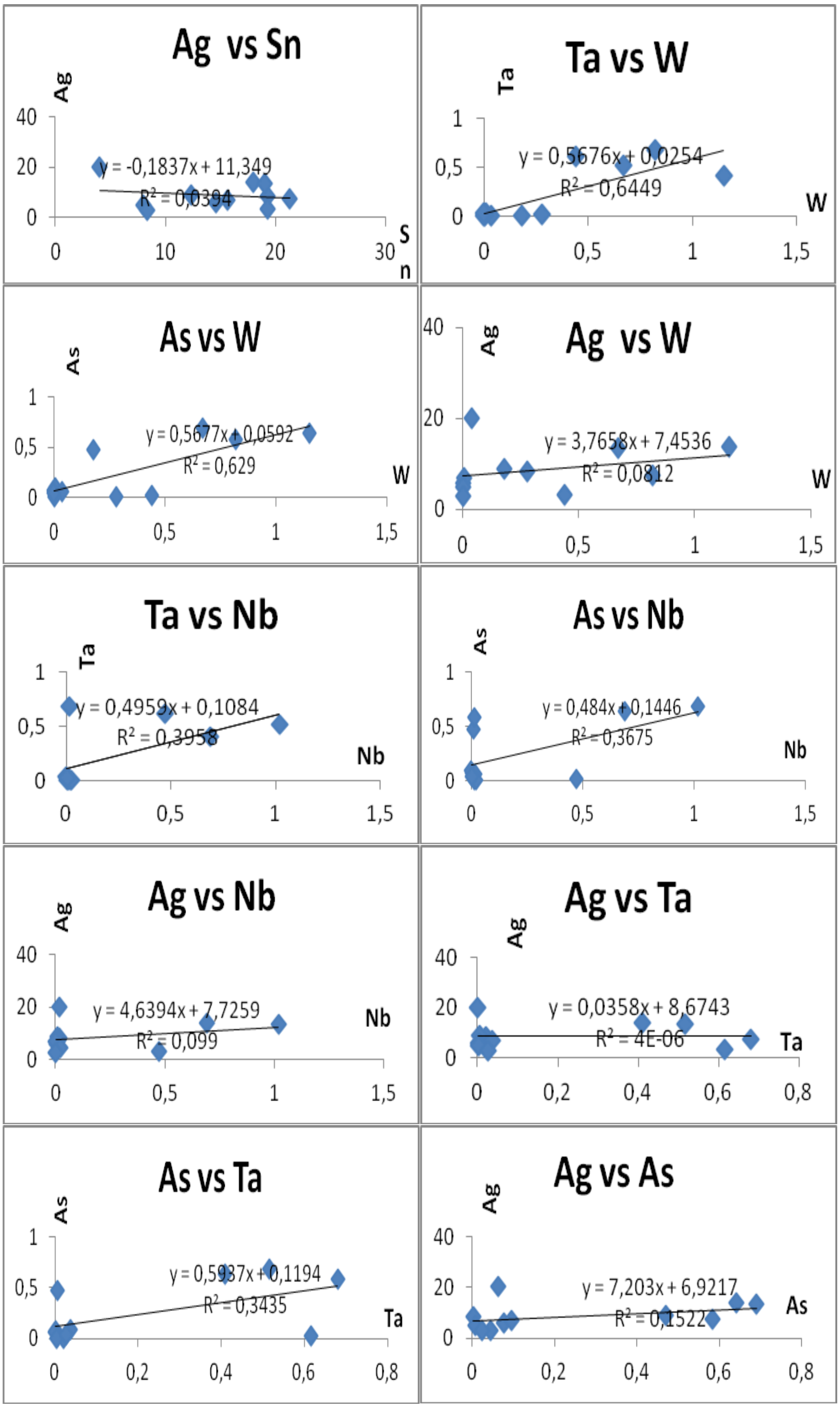


Fig.6. Inter-element correlations lines in trace with their equations

Correlation coefficients

From these different curves and correlation coefficients obtained on the sequence of the graphs, we have to build the correlation matrix. We refer to r, having r^2 as the coefficient of the line, extracting its root amounts to finding the value sought.

According to the geologist Rollinson (1995), who put a table of his name to the public, from this table we appreciate the inter-elemental correlation, for our case we work at the threshold

of 5% of uncertainty that is to say the degree of freedom of 95 %. The significant value of the correlation coefficient found according to the mathematical notation D = value read at n-2 where D is the value considered significant at the considered threshold (Rollinson, 1995).
In our type, having 11 samples, D is the value read at 11-2 = 9. Looking at the table, the value corresponding to 9 is 0.603 and is therefore considered significant any value of r greater than or equal to D. In our matrix table, the shaded bottom values are those of significant correlation.

Table 4. Correlation matrix.

Au	1							
Cd	0.118	1						
Sn	0.530	0.524	1					
W	0.401	0.454	0.674	1				
Nb	0.431	0.187	0.444	0.678	1			
Ta	0.749	0.313	0.704	0.802	0.628	1		
As	0.460	0.296	0.463	0.793	0.605	0.585	1	
Ag	0.144	0.137	0.197	0.284	0.314	—	0.389	1
	Au	Cd	Sn	W	Nb	Ta	As	Ag

RESULTS INTERPRETATION

In examining the results obtained we may find that:

- For the significant coefficients, all are positive, which implies the compatibility between these elements, as for the case of the Nb/Ta pair which constitutes an isomorphic series due to their neighboring ionic rays which allow them to substitute each other in the Colombo-Tantalite being that we work from the mobile belt of the eastern part of the Democratic Republic of the Congo,the Sn / W couple whose similar geochemical behaviors allow assimilation to other couples.
- For metals with scatter plots concentrated on the x-axis, it implies the low values of the contents of the element taken up on the ordinate and vice versa, as in the case of Ta / Cd, As / Cd, W / Cd, Nb / Cd, the scatterplots are concentrated on the y-axis, which leads us to understand that the cd is in abundance compared to most metals in the samples.
- For some correlation diagrams the scatterplot is lengthened and the shape of the curve is increasing, which means that the dispersion of the values is small, that the connection between the elements is good.
- Regarding to the dispersion of the scatterplots with respect to the carrier line, it can be seen that the dispersion is variable, which materializes the quality of the correlation coefficient.
- A feature that stands out instead of the correlation coefficient between Ta and Ag, because of the impossibility of calculation because the value of r^2 for these two metals, was doped with numbers and letters.

Of all that, a geochemical appreciation comes down to criticizing for the metals that come out better in this region. Making a ratio between average facies and Clarke, if greater than 1, there is confirmation of an index. Starting with gold, 0.176 / 0.05 = 3.52 "to 1 justifies a wealth; tin is, 43.636 / 2.5 = 17.454 »1, Ag 0.868 / 0.1 = 8.68» »1 three terms justifying an occurrence to be sought by works with commercial interests.

CONCLUSION

At the end of the work of the survey combined with the analysis of the geochemical powders attests that the geological formations of at least belonging to the facies studied with Sake carry significant indices for the Tin whose host is the Cassiterite, followed by and his companion, the

silver. The paragenesis Sn-Nb-Ta remained insignificant by a single metal; the 2nd paragenèse is Au-Ag.
The two parageneses are explicable not only by their geological units of belonging but also by volcanogenic manifestations, we have assimilated these indices to metamorphosed magmatic bodies; the granites and a hydrothermal model attested by Quartzitic and Pegmatitic veins in the surrounding areas of diversified natures.

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