

Characterization of secondary deposits of columbite-tantalite minerals found in the city of Rorainópolis (RR), Brazil

Anna Caroline Andrade Pinto

Department of Geosciences, Institute of Exact and Earth Sciences, Federal University of Amazonas, Brazil

annacaroline1504@gmail.com

Tiago Felipe Arruda Maia

Department of Geosciences, Institute of Exact and Earth Sciences, Federal University of Amazonas, Brazil

tiagotmaia@ufam.edu.br

Abstract

Many of the studies about mineral deposits are bringing great information to the scientific community, providing, for example, general characteristics of these deposits, possible source areas and its used in some cases as prospective tools to help in geological mapping. In this way, this study aimed to characterize the alluvial secondary deposits of columbite-tantalite that were found near vicinal 12, about 50km north/northeast of Rorainópolis city, between the BR-174 and BR-210 roads, in the state of Roraima (Brazil), bases on 4 samples that were brought by a resident of the region. To fulfill these objectives, some chemical and mineralogical methods were performed: magnetic separation, X-ray diffraction, X-ray fluorescence and petrographic description. The deposits of the region end up being characterized by having a large amount of Fe and Ti (mostly), containing in some places also a large concentration of Niobium and Tantalum. Not all samples have columbite-tantalite, showing that their concentration in some areas of the deposit is quite low. There are samples with less than 1% Nb and Ta and also samples with more than 20% Nb and 6% Ta concentration. These minerals were poorly transported, being identified by the degree of roundness and granulometry of the samples. A weathering cap on some minerals could also be verified. This research work turned out to be relevant, as it provides new data that add to the knowledge of the mineral potential, which has not been fully explored yet.

Keywords: Columbite-tantalite; Geochemical characterization; Chemical elements; Secondary deposits.

1. Introduction

Freitas (2017) made a series of geochemical maps of Roraima, focusing on the chemical anomalies of each region of the state. This is a work focused on deposits of columbite-tantalite in Rorainópolis city, so the main chemical elements of interest are niobium and tantalum. Freitas (2017) states that, about niobium, higher levels (element in soils) were found in an NW strip that runs from the southern part of Rorainópolis to the center of the state. The author also explains that in this region, these high levels are related to

metamorphic and granitoid rocks. The niobium found in placers also occurred in the east of this city, due to the influence of granitic bodies. Now, about tantalum, it did not have as many results in the state as niobium, but there are stream-sediments on metamorphic rocks of the Martins Pereira Suite and also on soils derivative from granitoids of Água Branca Intrusive Suite (Freitas, 2017).

At the end of 2018, a resident of vicinal 12 (near Rorainópolis) with the name Angelo, handed over to this research, about four samples that were collected along this vicinal road in four different Mr. Beterre properties. All samples were concentrated (pan-concentrate) and placed in sealed bags. The resident has brought these with the objective of obtaining results about what minerals and chemical elements have in this area and whats the percentage of each, to obtain information about these secondary deposits.

A series of geochemical and petrographic methods were then applied to the four samples, to characterize these deposits of probable columbites-tantalites in this region, conclude possible source rocks of these deposits, based on mineralogy, chemical signature, and local geology, providing new data that add to the mineral potential knowledge of the region.

1.1 Location Area

The work was made in alluvial deposits, in the Mr. Beterre properties, vicinal 12, located on the right side of the BR-174 (north direction), about 50 km from Rorainópolis (figure 1).

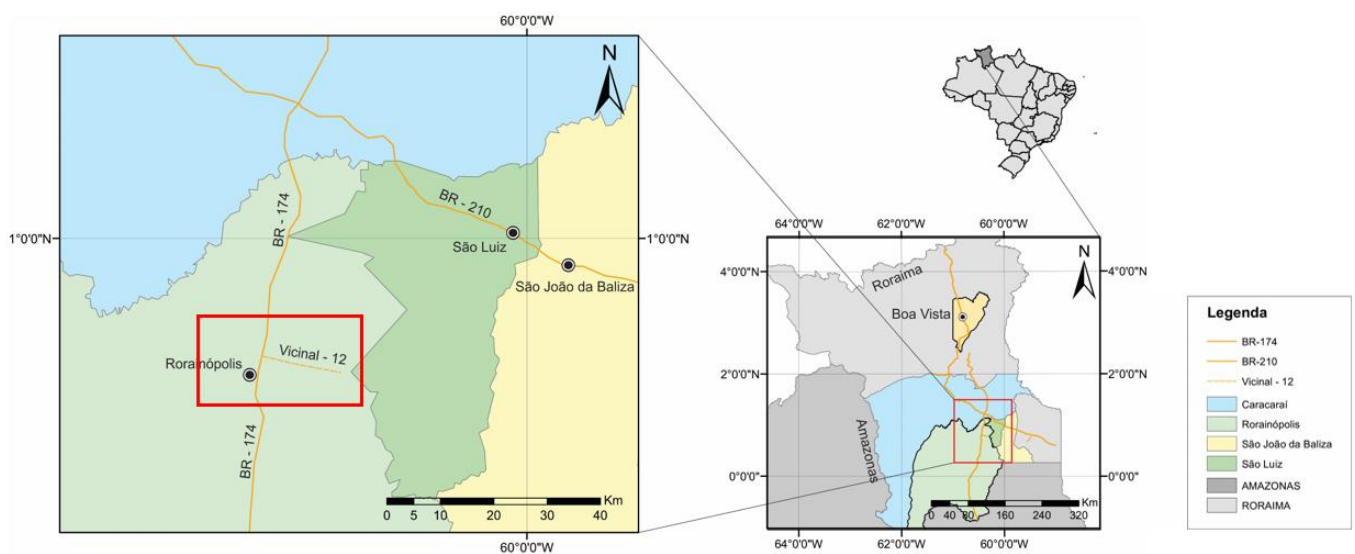


Figure 1. Location map of the study area. Map made with CPRM shapefile.

2. Theoretical Reference

2.1 Regional Geology

The State of Roraima occupies the south-central portion of the Shield of Guyana, the northern portion of the Amazonian Craton, which includes large expanses of tropical forests and constitutes one of the geologically least known regions on earth (Fraga, 2002). The state has an area of around 230,104 km² in the extreme north of Brazil and maintains border boundaries with Venezuela and Guyana (Reis et. al. 2003). Also according to Reis, the recent geological surveys and academic studies allowed a considerable advance

to the regional geological knowledge, offering to the study, its synthesis and approach to the state of the art of the geology of Roraima.

2.1.1 Amazonian Craton

This extensive tectonic entity is centered on the northern portion of the South American Platform, subdivided into two main Precambrian areas, based on lithological and structural data, related to the Guiana Shield to the north, and the Central Brazil Shield to the south, separated by the Phanerozoic basins from Acre, Solimões, Amazonas, and Alto Tapajós (Almeida, 1967).

The knowledge of the evolutionary history of the Amazonian Craton is explored through proposals of tectonic compartmentalization, based on geological, structural, geophysical and geochronological studies, and the subdivision of the craton is based on geophysical and geological information, forming a mosaic of crustal blocks gathered through increased diachronic collisions during the Archean and the Paleoproterozoic (Hasui et al. 1984 and Costa & Hasui, 1997 apud Souza, 2012). These blocks are called provinces. The parameters that will be used in this work will be based on recent data according to Santos et al. (2006) and CPRM (2006), in which, the study area is inserted in the geochronological province: Tapajós-Parima.

2.1.1 Tapajós-Parima Province

Located to the west of the Central Amazon Province, with an orogenic band-oriented to NW-SE, this province has Paleoproterozoic isotopic ages, pointing to rejuvenation from east to west (CPRM, 2006). With the collection of developed works, field reports, geological maps, and remote sensing works, four main domains are proposed for the section of Roraima (Fraga and Reis, 1998, 2000 apud Reis et al. 2003): Urariquera, Parima, Uatumã- Anauá and Central Guiana, where these domains are characterized by geological associations, ages, and specific structural features. The research area is part of the Uatumã-Anauá domain, nicknamed by CPRM (2006), north of the Amazonas Sedimentary Basin.

2.2 Local Geology

Uatumã-Anauá Domain comprises the south-southeast region of Roraima and the northeast of Amazonas, which is limited to the northeast with the Guianas. Reis & Fraga (2000) and Reis et al. (2003) named the south-southeast portion of the state of RR “Anauá-Jatapu Domain” characterized by structural control and arrangement of lines with NW-SE to NE-SW directions and determinedly EW. Faria et al. (2005) designates the northeast portion of Amazonas as the “Uaimiri-Anauá” domain. The units associated to Uatumã-Anauá domain that belongs to the study region are Anauá Complex, Granite Martins Pereira, Água Branca Intrusive Suite, Igarapé Azul Intrusive Suite, Mapuera Intrusive Suite and Modern Granite (figure 3).

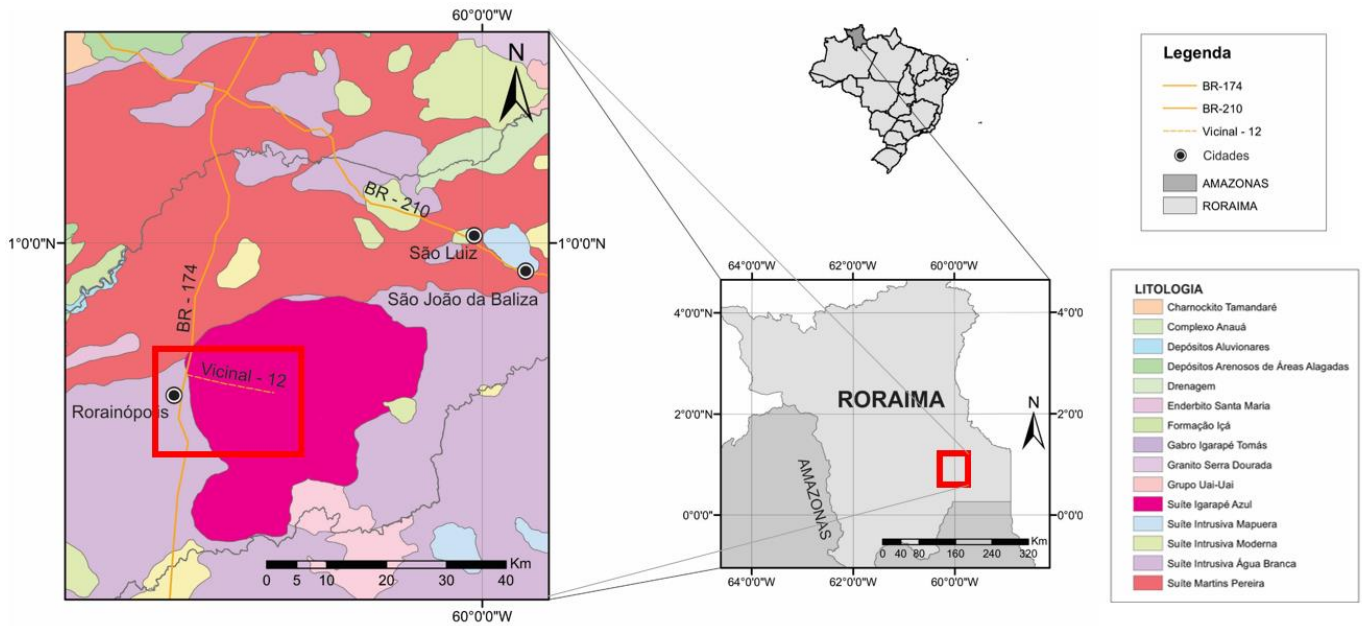


Figure 2. Local geology map of the area. Focus on the vicinal 12 region. Map made with CPRM shapefile.

2.2.1 Anauá Metamorphic Complex

The name Anauá Metamorphic Complex is used by Faria et al. (2000, apud Vedana, 2010) to gather as low to high-grade metamorphic rocks and signs of subordinate acid and ultrabasic, outcrops in the south-southeast region of the state of Roraima. This complex represents the oldest set of metamorphic rocks in the region, being represented by migmatites, granites, charnokites and some metabolites and amphibolites, in addition to orthoderivated gneisses with granulite enclaves (Muller & Carvalho, 2005).

2.2.2 Martins Pereira Granite

Martins Pereira Granite is formed by alkaline, metallic and peraluminous rocks, high K and pointed as type I granite, showing enrichment in LILE (K, U, and Th, for example) and ETR (Almeida, 2006), aged 1,99 Ga (Almeida et al., 2002). According to Almeida et al. (2007), it consists of rocks that have anatexis, probably generated in the collisional phase of the tectonic evolution of the orogenic arch of Anauá. In terms of mineralization, the primary occurrences of gold are hosted by Martins Pereira granitoids (Almeida, 2006).

2.2.3 Água Branca Suite

It is appointed as type I Cordillera granite, a metaluminous to slightly peraluminous origin and calcined specificity (Almeida et al., 2002; Faria et al., 2000), which indicates a geochemical affinity for granitoids originating from the partial part of the mantle and/or crustal, tending to mark subduction attributes. Almeida et al. (2002) recorded geochronological data in recent research, showing granite crystallization averages of 1.90-1.89 Ga. CPRM (2006) individualizes these granitoids through gray, equigranular to porphyritic types, with a predominance of granodiorites composed of hornblende and biotite, in addition to monzogranites, tonalites, monzodiorite quartz and diorite quartz, with accessory minerals mostly containing titanite, epidote, apatite, allanite, and zircon.

2.2.4 Igarapé Azul Suite

Igarapé Azul Granite is divided into three main facies (Vila Catarina, Saramandaia and Cinco Estrelas) and is essentially composed of monzogranites with a low content of mafic minerals that are generally hydrothermalized (Almeida, 2006). Also according to the author, these granitoids occupy in the QAP diagram the field of crustal granites and are chemically calcium-alkaline rocks, pointed out as type I granites with high K, rich in SiO₂ and slightly peraluminous, showing enrichment in LILE and varied patterns of ETR. They are also characterized by a wide range of enclaves: 1) rich in biotite (surmicaceous); 2) metagranitic (Martins Pereira); 3) para-gneissic (Cauarane type); 4) tonalitic-granodioritic micro granular (Almeida, 2006). Alluvial occurrences of Nb-Ta are found in the Igarapé Azul Granite (Almeida, 2006).

2.2.5 Mapuera Suite

The petrographic analyzes made by Lombello et. al. (2009) and Lombello (2011), show that Granite Abonari has a syenogranitic to monzogranitic composition, with alkali-feldspar granites and quartz-alkali subordinate syenites and which also has many accessory minerals such as titanite, allanite, epidote, apatite and zircon, with three different facies, a microgranitic, a sieno-monzogranitic and another alkali-feldspar granite. They have a meta-peraluminous composition, high K sub alkaline, with characteristics of type A granites (Araújo Neto & Moreira, 1976).

2.2.6 Modern Granite

Moderna Granite (Moderna-Madeira magmatic event, 1.81Ga) and Madeira Granite are characterized by type A and peralkaline granites (Elias, 2018). Moderna granite, monzogranite with variations for sienogranite, is housed with NE-SW elongation in the contact zone between the calc-alkaline granites Martins Pereira (1.96 Ga) and Caroebe (1.89 Ga) and is in transitional contact with these units, marked by features of hydrothermal alteration associated with plastic deformation, responsible for its characteristic red color, which does not affect the magmatic orientation of the rock (Elias, 2018). Pegmatites with amethyst are present in bodies related to Modern Granite (Almeida, 2006).

2.3 Niobium and Tantalum

Niobium and Tantalum are transitional metals with very similar physical and chemical properties, and are commonly grouped. They do not occur naturally as free metals, but are essential components in a range of mineral species, the majority of which are oxides (Shaw et.al., 2011). The most common ore minerals containing Nb and Ta are minerals from the pyrochloric supergroup, minerals from the columbite-tantalite, struverite, loparite and euxenite series (Mackay and Simandl, 2015).

About primary deposits, those of Nb and Ta are often associated with igneous rocks, including granites, pegmatites, syenites and carbonatites. These deposits can be divided into three main types, based on the igneous rocks with which they are associated: carbonatites and associated rocks; alkaline to peralkaline granites and syenites; and granites or pegmatites present in the LCT family (enriched in lithium (Li), Cesium (Cs) and tantalum) (Shaw et.al., 2011).

The secondary deposits that are known are those in which the minerals that have Nb and Ta have been

concentrated through weathering and other sedimentary processes (Shaw et.al., 2011).

3. Materials and Methods

The work was carried out following the methodology model used in works of geological nature, which consists of the division of the methods in the following stages:

3.1 First Stage

3.1.1 Bibliographic Search

A survey of geological information about the work area was carried out. Theoretical studies were also carried out on geochemical methods, igneous rocks, niobium and tantalum deposits and general concepts on geology. The data obtained in this stage consisted of research and readings carried out in publications of articles, books, dissertations, classes and periodicals that involve the geological knowledge of Roraima. At the current stage, samples brought by resident Angelo were also received. The collect context was not specified by the resident.

3.2 Second Stage

3.2.1 Sample Preparation

Stage where the samples were prepared for laboratory analysis. Four samples were used with the following names: A01 - R, A02 - R, A03 - B and TF04 -R. Part of them was removed (quartering) to be sprayed for X-ray fluorescence and diffraction. The materials used were: the samples, a mortar and pistil of both agate and porcelain and a spray mill from the Pavitest brand. The mortar was used to spray samples of smaller granulometry, while the mill was used to spray larger samples more quickly. In the mill, the material to be sprayed is inserted into the grinding pan (in which it has several cylinders inside), the pan is selected according to the purpose of the sample. After that, the pan is placed inside the mill which then, through predominantly horizontal vibratory movements, the material is reduced/pulverized by impact and friction, having used a sample time of approximately 30s.

3.2.2 X-Ray Fluorescence (XRF)

X-ray fluorescence spectrometry is a non-destructive technique that allows the identification of chemical elements that are present in a sample, thus establishing the concentration of each element in the referred sample (UFRG, 2017). The chemical elements of the main interest that were analyzed, are niobium and tantalum, elements found in columbite-tantalite. As material, all four samples and the Epsilon 3 XL model X-ray fluorescence spectrometer, brand Malvern Panalytical, were used. It can quickly and accurately analyze the most diverse materials, which can be liquids, solids, etc.

3.2.3 X-Ray Diffractometry (XRD)

This analytical technique of X-ray diffraction was used to obtain data from the interpretation of the spectra emitted by the XRD. It has the purpose of validating the mineralogical identification of the samples, emphasizing to the columbite-tantalite, and to solve any doubts. The analysis was done with the part of the

samples previously sprayed. The materials in this phase were all the four samples and the X-ray diffractometer, Shimadzu - model XRD 6100. It allows analysis of solid crystalline materials (phases that compose rocks, which is the objective of this work) as well as industrial materials (for example: ceramics, cements, slag, among others).

3.2.4 Magnetic Separation

It is used to separate mixtures containing minerals with a magnetic character. This separation is achieved by changing the flow of particles, using in this case the FRANTZ magnetic separation equipment. In this process, an electromagnetic field is applied to the samples that, due to the different magnetic susceptibilities that the minerals have, it is possible to separate them precisely, as they are affected in a different way and intensity, resulting in the intended separation (Lopes, 2014). The materials were: samples, magnet, sieve (0.84mm) and FRANTZ separator. In this separation phase, only three samples were used, which were those with lower particle size: A02 - R, A03 - B and TF04 - R. The current intensities used were from 0.1A to 0.5A, as the columbite-tantalite is attracted to a current intensity of 0.5A. Finally, samples were obtained attracted by the magnet, attracted to amperages less than 0.5A, to amperages greater than 0.5A and those attracted only in a current of 0.5A. These samples can be seen in figure 3.



Figure 3. Samples already separated by the FRANTZ Magnetic Separator.

3.2.5 Mineralogical Description

Use of binocular loupe to identify minerals present in samples with a focus on columbite-tantalite. The materials were: petri dish, watch glass, tweezers and spatulas. The samples used were only three, which were those with lower particle size: A02 - R, A03 - B and TF04 - R. The sample A01 - R, being larger, was

analyzed unaided eye.

3.3 Third Stage

3.3.1 Data Interpretation and Integration

This stage consisted of joining all the data previously collected for the interpretation and elaboration of a result/report/final work, integrating rationally and completely all the results obtained in the analyzes and the literature review.

4. Results and Discussions

4.1 X-Ray Fluorescence

After all samples were sprayed in the first stage, they were sent to XRF, obtaining the results in relation to the oxides / chemical elements that can be analyzed in table 1.

Table 1. Comparison of the concentrations of the main oxides and chemical elements of the samples identified by XRF.

	A01 – R (%)	A02 – B (%)	A03 – R (%)	TF04 – R (%)
Al ₂ O ₃	0,881	0,629	1,038	1,012
SiO ₂	1,139	2,183	6,685	6,911
P ₂ O ₅	0,394	0	0,401	0
K ₂ O	0	0	0,107	0
CaO	0,105	0,328	0,130	0,273
Ti	13,640	46,156	33,821	42,537
V	0,087	0	0	0,345
Cr	0	0	0,025	0
Mn	0,398	1,020	4,927	0,634
Fe ₂ O ₃	82,720	16,803	52,267	21,239
As	0	0,003	0	0,003
Se	0	0,031	0	0,022
Y	0	0,242	0,004	0,755
Ni	0,013	0	0	0
Cu	0,001	0	0	0
Zn	0,031	0	0,047	0
Rb	0	0	0,006	0
Zr	0,002	0,205	0,010	0,456
Nb	0,074	22,397	0,193	17,807
Ag	0,119	0,257	0,143	0,256
Sn	0,070	0,233	0	0,593
Nd	0	0,667	0,046	0,493
Sm	0	0	0	0,002
Ta	0,011	7,128	0,093	5,993
W	0	0,209	0,034	0,217
Pb	0	0,103	0	0,070

Bi	0,049	0	0,019	0
Th	0	0,241	0	0,206
U	0	0,073	0	0,054
Sc	0,010	0,084	0	0,038
Pd	0	0,007	0	0
Eu	0,254	0	0	0
Lu	0,002	0	0	0
Pt	0	0	0,003	0
Yb	0	0	0	0,084

Also making a comparison between the samples in terms of the concentrations of the main chemical elements of this research (Nb and Ta) and the most abundant (Fe, Ti and Mn), table 2 was prepared.

Table 2. Comparison of the concentrations of the main chemical elements of the samples identified by XRF.

Samples \ Elements	Nb (%)	Ta (%)	Fe (%)	Ti (%)	Mn (%)
A01 - R	0,105	0,016	79,101	17,827	0,538
A02 - B	24,234	7,693	12,675	49,600	1,100
A03 - R	0,250	0,120	46,564	41,813	6,252
TF04 - R	20,102	6,740	16,680	47,466	0,711

It is noticed that there are the same chemical elements in the four samples analyzed (table 2), but with different percentages of occurrence. As a result, the sample with the highest concentration of Fe is the first (A01 - R) and the value of Ti concentration in the three other samples is similar and high. Finally, it should be noted that samples A02 - B and TF04 -R have high values for Nb and Ta in relation to the other samples, so they are likely to have more columbite-tantalite (figure 4).

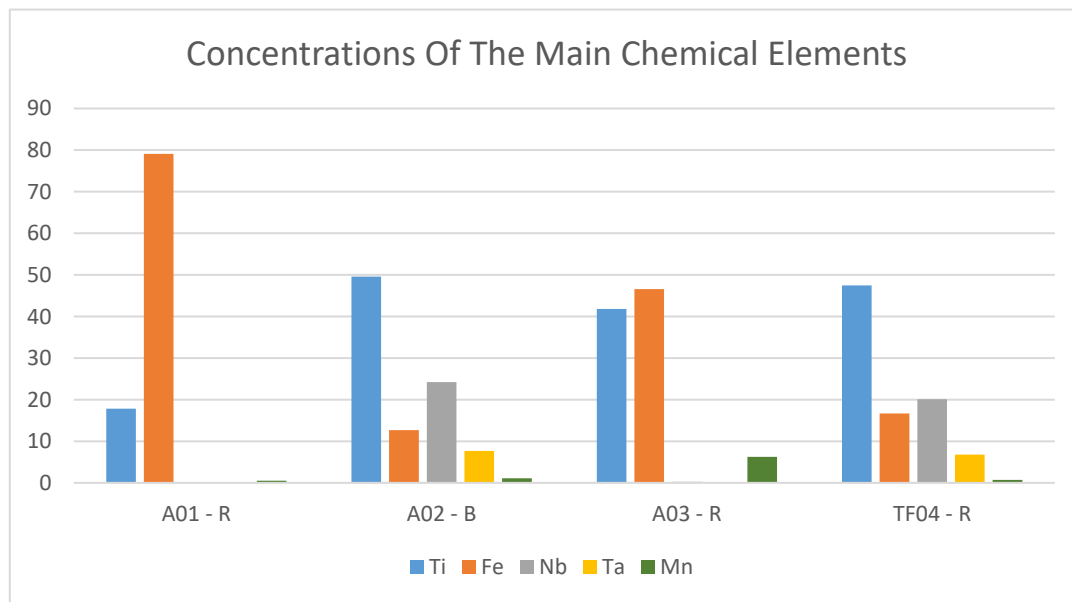


Figure 4. Comparison of the concentrations of the main chemical elements found in the four samples.

4.2 X-Ray Diffractometry

A01 - R

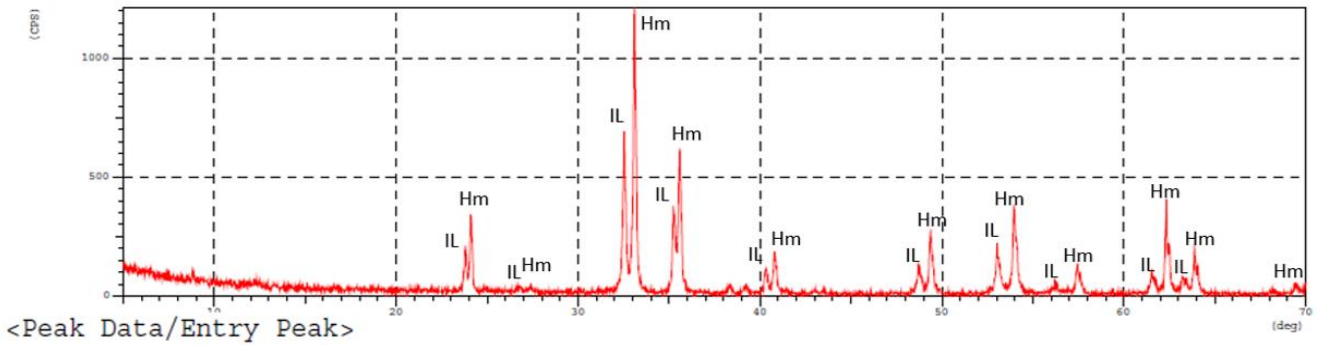


Figure 5. Diffractogram of sample A01 - R, two main minerals were found, hematite (Hm) and ilmenite (IL).

Two main minerals were found, hematite (Fe₂O₃) and ilmenite (Fe₂ + TiO₃). Hematite had the highest peaks, while ilmenite had high peaks, but smaller than those of hematite. This is a sample with a high content of Fe and Ti.

A02 - B

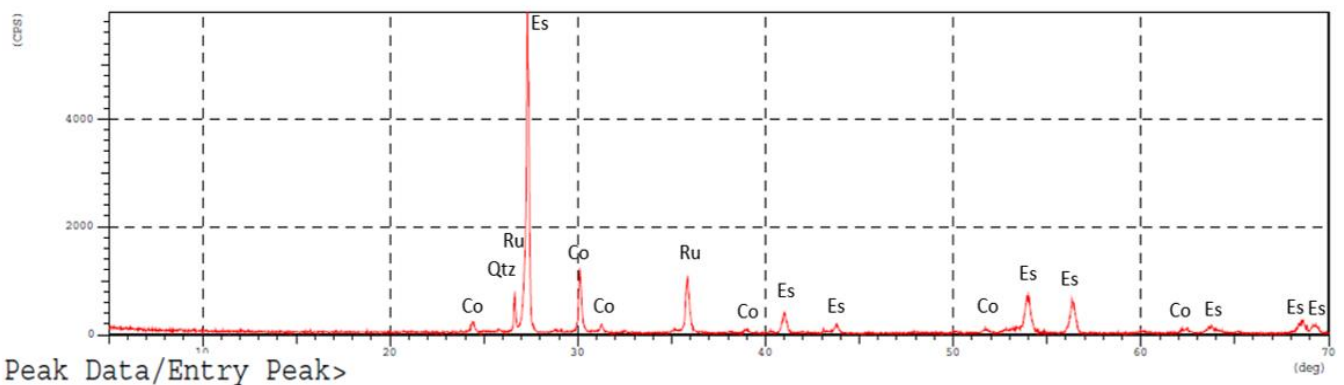


Figure 6. Diffractogram of sample A02 - B, four main minerals were found, rutile (TiO₂), titanium oxide, tantalum, niobium and iron (struverite - Es), ferrocolumbite with manganese (Co) and quartz (Qtz).

Four main minerals were found, rutile (TiO₂), struverite ((Ti, Nb, Ta, Fe) ₂O₄), ferrocumbite with manganese (Fe, Mn) (Nb, Ta) ₂O₆ and quartz (SiO₂). The highest peaks belong to titanium oxide, tantalum, niobium and iron. It is clear that this sample has high levels of Fe, Ti, Ta and Nb.

A03 - R

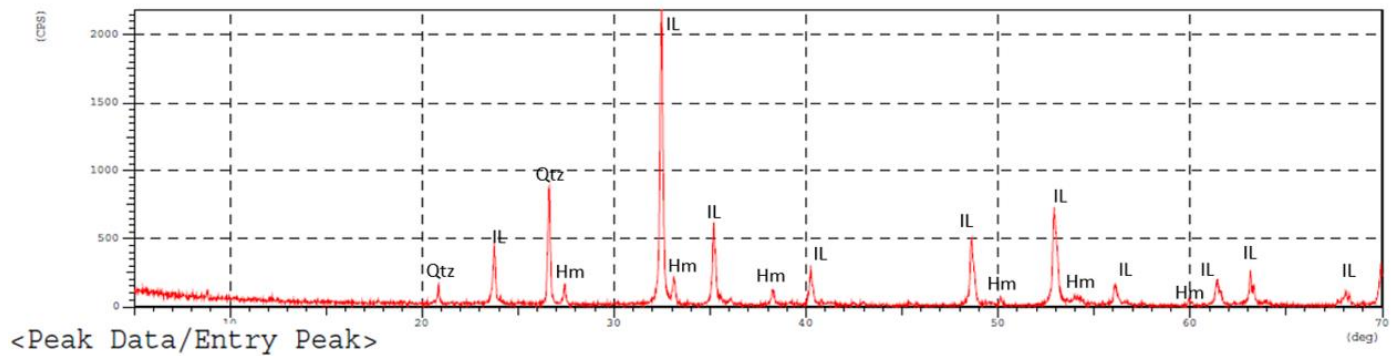


Figure 7. Diffractogram of sample A03 - R, three main minerals were found, quartz (Qtz), hematite (Hm) and ilmenite (IL).

Three main minerals were found, quartz (SiO₂), hematite (Fe₂O₃) and ilmenite (Fe₂ + TiO₃). The biggest peaks belong to the ilmenite. The sample presents high levels of Fe and Ti.

TF04 - R

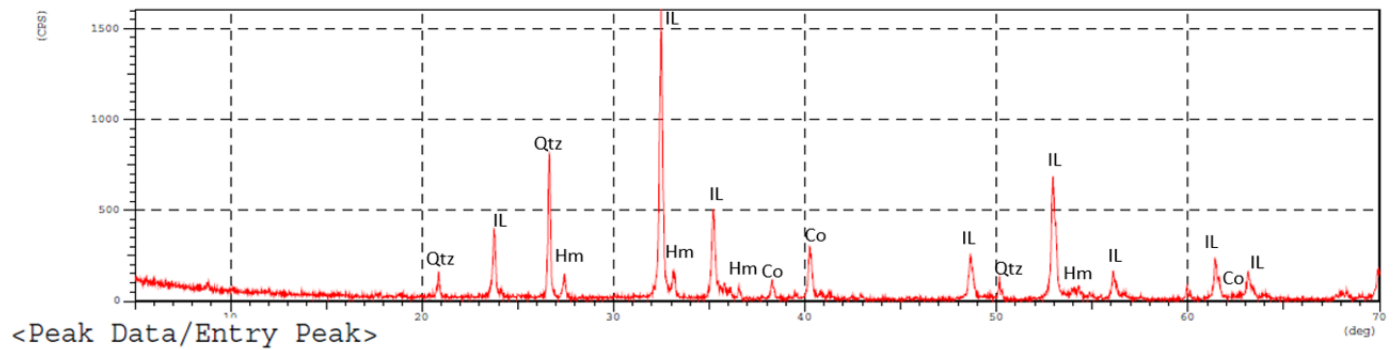


Figure 8. Diffractogram of sample TF04 - R, four main minerals were found, quartz (Qtz), hematite (Hm), ferrocolumbite with manganese (Co) and ilmenite (IL).

Four main minerals were found, quartz (SiO₂), hematite (Fe₂O₃), ferrocolumbite (Fe, Mn) (Nb, Ta) ₂O₆ and ilmenite (Fe₂ + TiO₃). The biggest peaks belong to the ilmenite. It is noticed that this sample has high levels of Fe, Ti, Ta and Nb, and may also contain struverite.

4.3 Mineralogical Descripton

4.3.1 First Sample



Figure 9. Angular minerals belonging to sample A01 - R.

A01 - R: Analyzed with the naked eye, as they have sizes ranging from 0.5 to 3.5 cm. Most of the grains in the sample are sub-angular and few are very angular (figure 9), indicating little transport. Were identified: quartz (figure 10A), hematite (figure 10B) and ilmenite (figure 10C).



Figure 10. A. Quartz grain. B. Hematite. C. Ilmenite. All from sample A01-R.

4.3.2 Second Sample

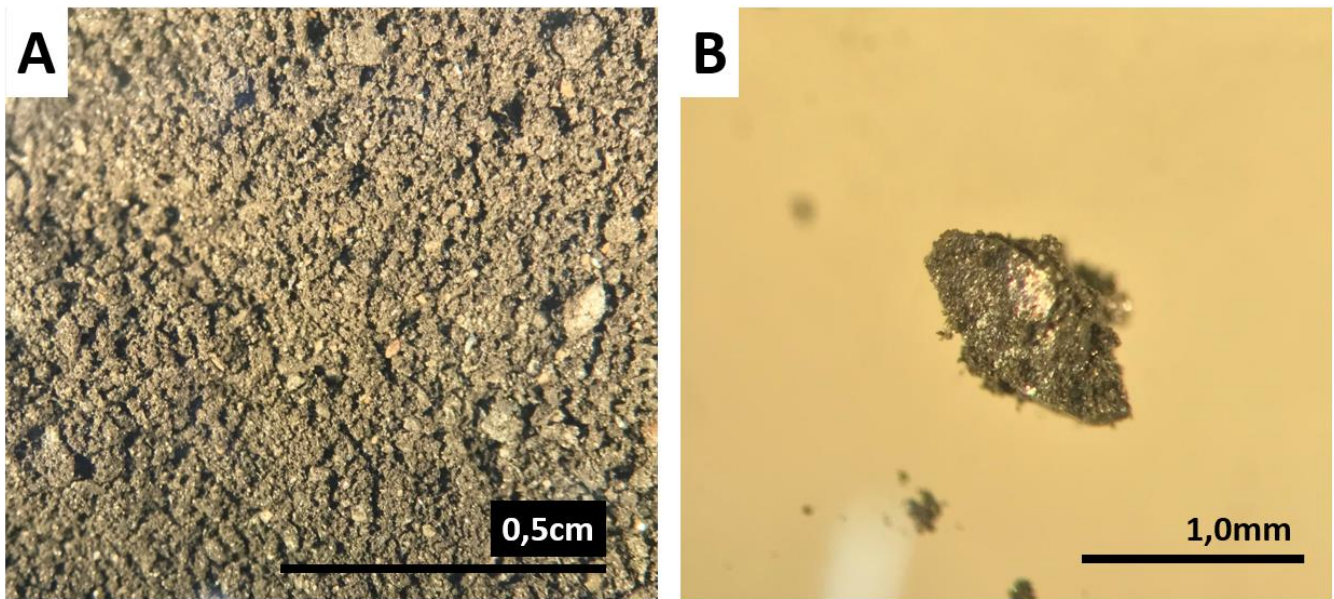


Figure 11. A. Binocular magnifier view of partially pulverized minerals. **B.** Columbite-tantalite. All from sample A02-B

A02 - B: Analyzed in the binocular loupe, as they have sizes less than 1mm. Regarding the rounding of minerals, it was not possible to be analyzed because all samples were partially pulverized (figure 11A), leaving only a few grains that could be identified: quartz and columbite-tantalite (figure 11B).

4.3.3 Third Sample

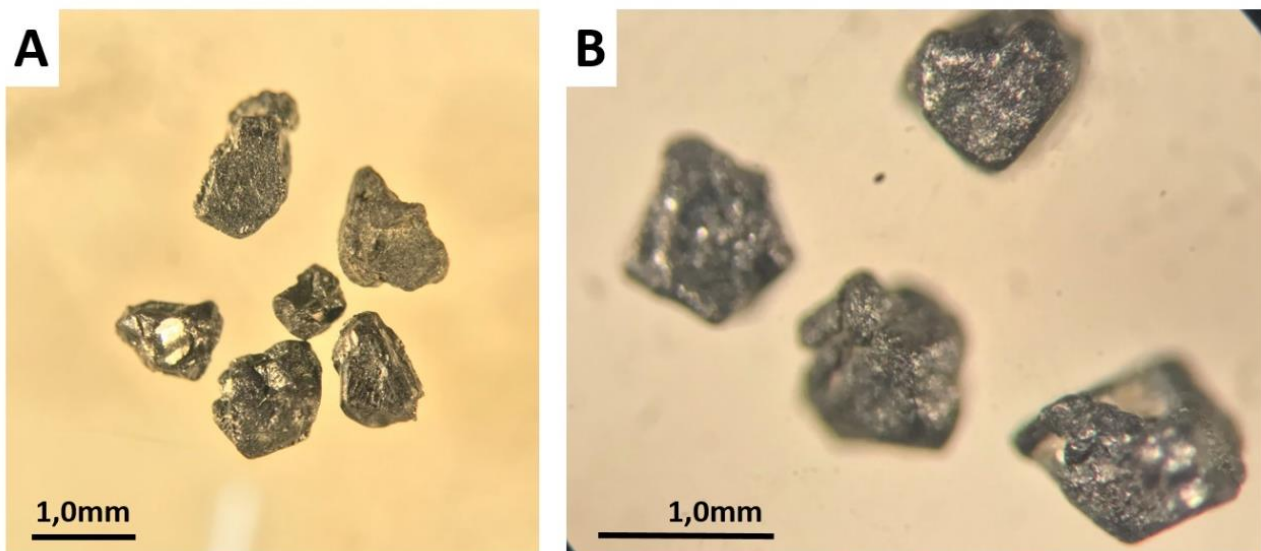


Figure 12. A. Possible columbite-tantalite. **B.** Probable Ilmenites. All belonging to sample A03-R.

A03 - R: They were analyzed in the binocular loupe as they were smaller than 2mm. Most of the grains in the sample are sub-angular and a few are angular (figures 12A and B), already containing a greater degree of sphericity than the other samples, indicating little transport. Some show a weathering cover. Ilmenite

and columbite/tantalite were identified.

4.3.4 Fourth Sample

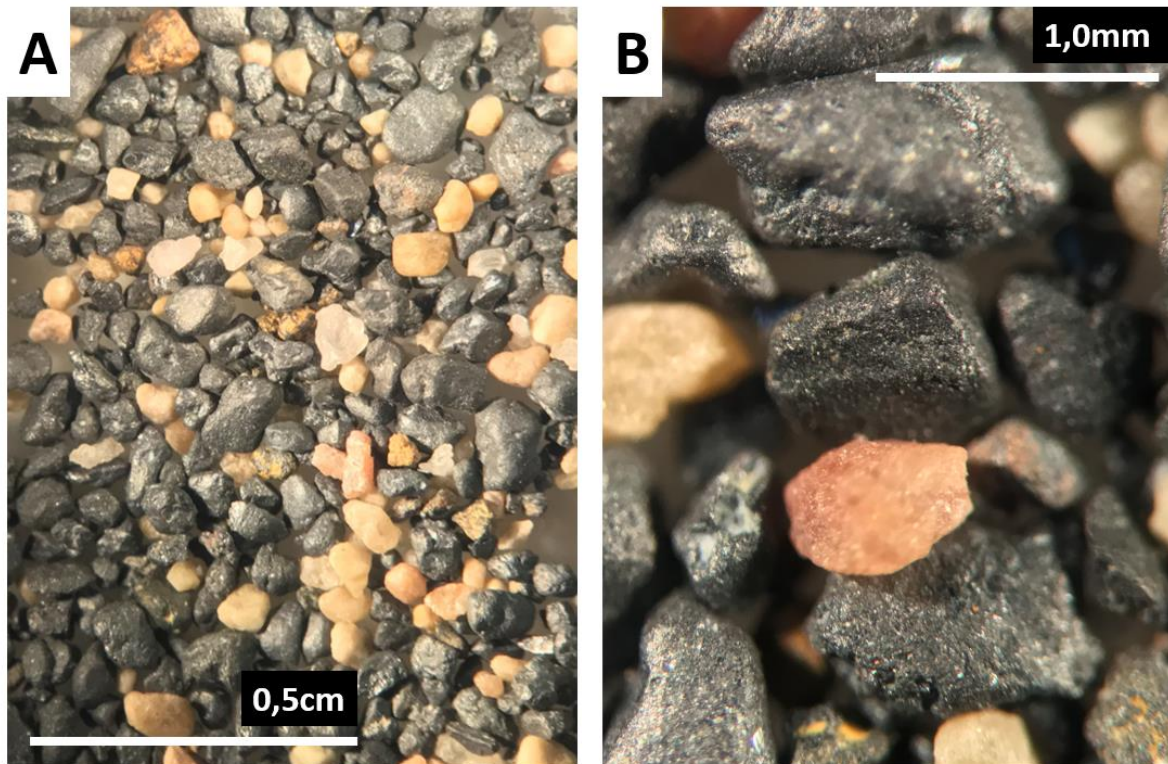


Figure 13. A and B. Overview in the binocular magnifying glass of minerals. All of the sample TF04-R.

TF04 - R: Analyzed in the binocular loupe, as they have sizes smaller than 3mm. Most of the grains in the sample are sub-angular to angular (figure 13), indicating little transport, with some grains having a greater sphericity than others. Some show a weathering cover. Were identified: quartz (figure 14) and columbite-tantalite (figure 15).

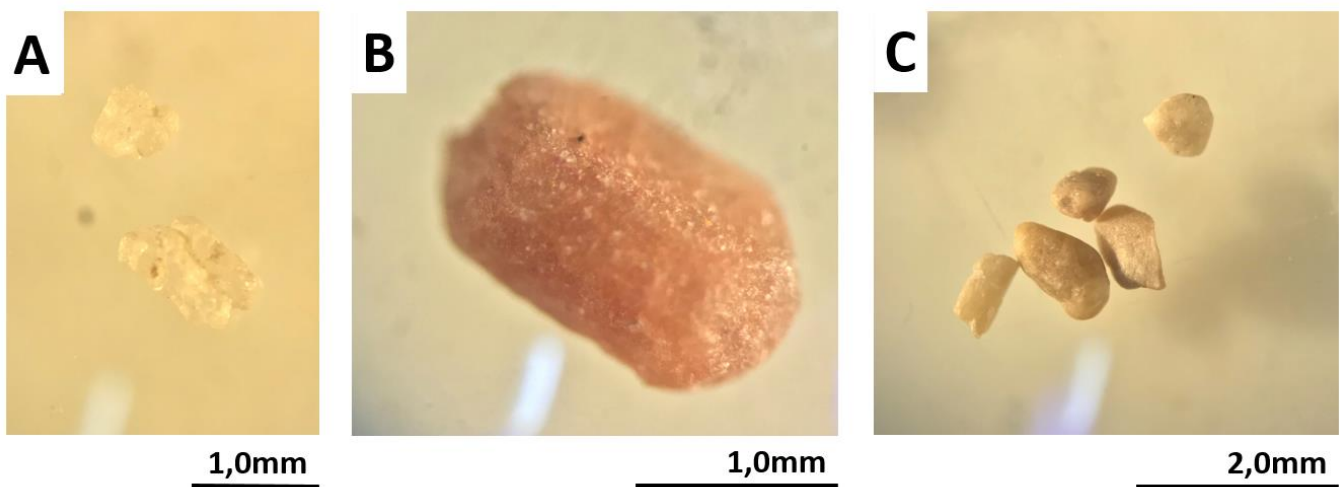


Figure 14. A, B and C. Overview of the quartz crystals found in the binocular loupe. All of the sample TF04-R.

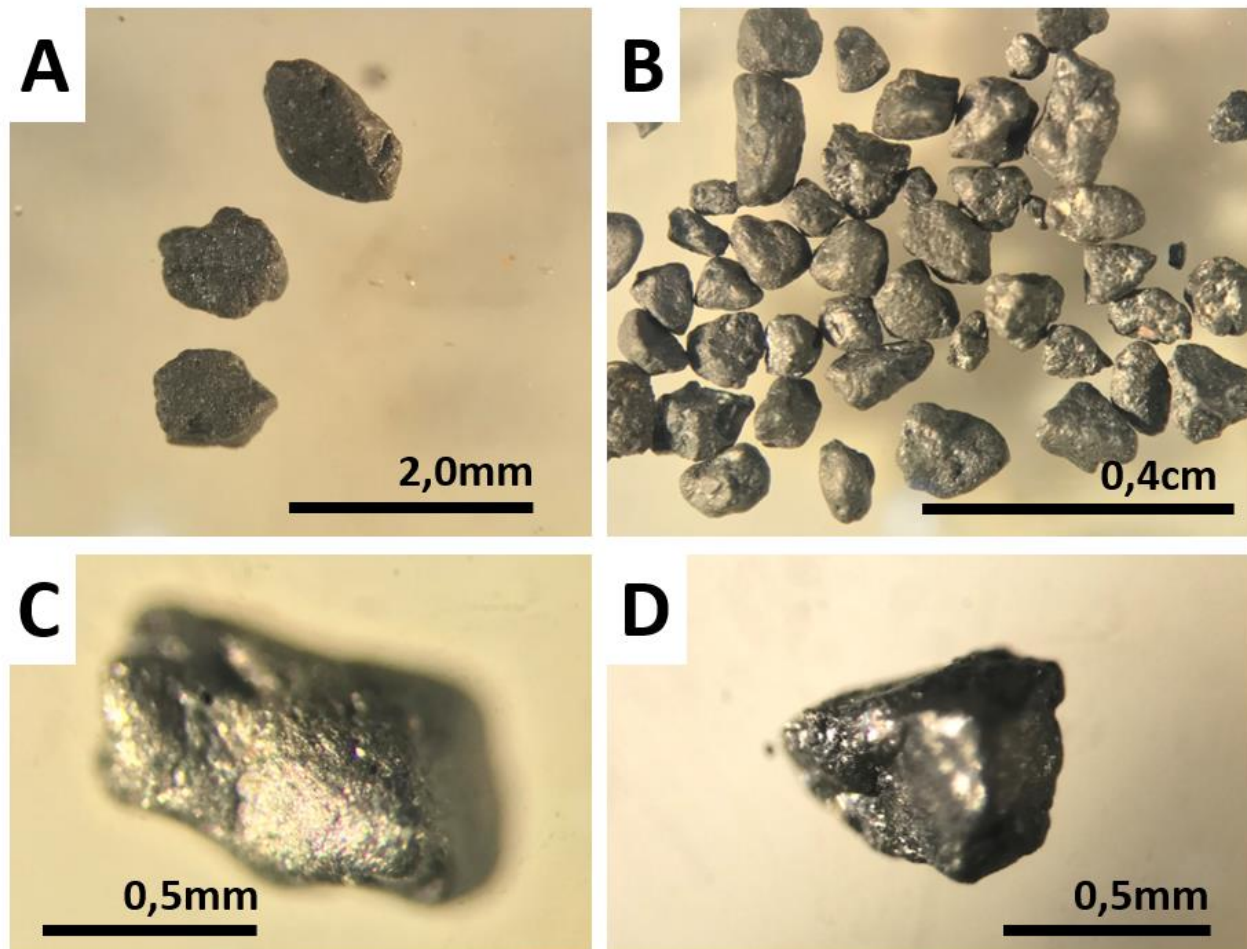


Figure 15. **A.** Presence of streaks in columbite-tantalite. **B.** Overview in the binocular magnifying glass of minerals. **C and D.** Metallic shine of the mineral. All of the sample TF04-R.

4.3 Discussions

The X-Ray Fluorescence allowed us to identify the chemical elements present in the samples. With this, it was possible to identify a large amount of iron and titanium in all these samples, as well as a significant amount of niobium and tantalum in some of these. In addition to the main elements identified, some other elements are associated with the anomalies of Nb and Ta. Some of these are the Rare Earth Elements (RET), more precisely scandium (Sc), yttrium (Y), neodymium (Nd), ytterbium (Yb) and samarium (Sm), the last two appearing in only one of the samples containing columbite-tantalite. All probably concentrated in their secondary form in the alluvial deposits of the area. Among the RET, monazite (Ce, La, Di) PO₄ and xenotime (YPO₄) are usually associated with columbite-tantalite in pegmatites, showing that these are rocks that should be explored in this area because they are probably the source rocks. According to Freitas (2017), he states that: high levels of scandium appear sporadically in isolated areas on gneissic and migmatitic rocks in the regions of Rorainópolis, Caracaraí and Urariquera river; about the yttrium, the most striking area of high levels is east of Rorainópolis (upper Anauá river basin), where these levels are related to the orthoderivative metamorphic rocks of the Martins Pereira Suite and granitoids of the Mapuera Intrusive Suite. Associated with regional geology, it can also be said that they are probably associated with

Martins Pereira Suite, Igarapé Azul Suite or the Modern Granite, as these, contain RET, in addition to the presence of pegmatites. In addition to the RET, there is also the presence of some actinides, such as thorium (Th) and uranium (U), both with radioactivity, also probably associated with the Martins Pereira or Igarapé Azul Suite, due to the regional geology affirming the enrichment in LILE and RET.

X-ray diffractometry allowed the identification of the minerals found in each of these samples, more specifically showing the presence of titanium oxide, tantalum, niobium and iron ((Ti, Nb, Ta, Fe) $2O_4$), also known as struverite, and ferrocombite with manganese (Fe, Mn) (Nb, Ta) $2O_6$). With this, almost all the minerals found are oxides, among them ilmenite (Fe₂ + TiO₃), hematite (Fe₂O₃) and rutile (TiO₂), obtaining columbite-tantalite in two of the four samples.

The methods used, also including petrography, allowed not only to identify the chemical and mineral elements that make up these deposits, but also made it possible to advance the discussion regarding the transport processes that acted on these minerals.

With all the analyzes, it can be said that the minerals from this secondary deposit were little transported, being identified by the low degree of selection of the samples. However, there was a tractive transport causing alluvial deposits. Not all samples had fine granulometry, showing that it varies throughout the deposit. It was possible to verify a weathering layer in some minerals, being more characteristic in the ilmenites, identified through the binocular loupe.

The study region (vicinal 12) is located exactly in the Igarapé Azul Suite and, because little transport was also identified in the samples, it can be inferred that somewhere nearby there may be pegmatites or other igneous rocks in this suite, which may come to be the source rock of these deposits. Or the source rock may also be associated with the Martins Pereira Suite due to the presence of ETRs and actinides (Th and U). According to Freitas (2017), through the geochemical atlas of the region of Roraima (CPRM), he states that in the region they may have placer deposits.

5. Conclusion

The deposits in this area are characterized by having high percentages of Fe and Ti (mostly), containing, in some places, large concentrations of niobium and tantalum, finding minerals such as struverite. Not all samples had columbite-tantalite, showing that their concentration in some places of the deposit is very low. There are samples with less than 1% Nb and Ta and there are also samples with more than 20% Nb and more than 6% Ta.

A primary deposit of niobium and tantalum present in the northern region, is the Pitinga Mine. This mine has a content of niobium of 0.202% and tantalum of 0.028%, showing that in comparison with these deposits of Rorainópolis, it has a very high content (vicinal 12), which can also infer that its primary source probably also has elevated content of niobium and tantalum.

All methods proved to be quite suitable for the analysis of alluvial deposits found in this location. They made it possible to advance in the discussions about the deposit and also about the transport processes that occurred in these minerals, concluding that they were little transported, being identified by the low degree of selection and rounding of the samples, and it can also see a layer of weathering in some of these deposit minerals, allowing better identification of some grains such as ilmenites.

X-ray diffractometry showed that in the samples there are up to two types of niobium and tantalum minerals: struverite and ferrocombite with manganese. Samples that contain a high content of niobium and tantalum are probably closer to each other than the two samples that do not have a high content.

The Nb and Ta were probably originated from some igneous rock (pegmatite, for example) close to the region, containing a lot of RET, which may be from the Igarapé Azul Suite itself or the Martins Pereira Suite. The regional geology states that there is the presence of pegmatites in the Martins Pereira and Granito Moderna Suite, being potential areas for future prospecting.

6. Acknowledgment

We would like to thank the Laboratory of Mineralogical Techniques, more specifically, technician Alfredo for always being kind, approachable and helping in some stages of this work, and also the residents of the neighborhood who collected and brought the samples. To CPRM for offering logistical support in some stages of this work, in particular to Wiane Silva, Nelisson Leão, and Heitor Grazziotin.

7. References

- [1] ALMEIDA, F. F. M. de, 1967, Origem e Evolução da Plataforma Brasileira, Boletim 241, DNPM / DGM.
- [2] ALMEIDA M.E., MACAMBIRA, M.J.B., FARIA, M.S.G. de 2002. A granitogênese paleoproterozóica do sul de Roraima. In: SBG, Cong. Bras. Geol., 41, João Pessoa, PB, Anais, p. 434.
- [3] ALMEIDA, M. E.. Evolução geológica da porção centro-sul do escudo das guianas com base no estudo geoquímico, geocronológico e isotópico dos granitoides paleoproterozoicos do sudeste de Roraima, Brasil. Belém-Pará, 2006, 241p.
- [4] ALMEIDA, M.E., MACAMBIRA, M.J.B., OLIVEIRA, E.C. 2007. Geochemistry and zircon geochronology of the I-type high-K calc-alkaline and S-type granitoid rocks from southeastern Roraima, Brazil: Orosirian collisional magmatism evidence (1.97–1.96 Ga) in central portion of Guyana Shield. In: Precambrian Research 155 69 – 97Almeida et.al 2002;
- [5] ARAÚJO NETO, H., MOREIRA, H.L. 1976. Projeto Estanho de Abonari. MME/DNPM/CPRM. Brasília, Vol. 1, 232p.
- [6] COSTA, J.B.S & HASUI, Y. 1997. Evolução geológica da Amazônia. In Contribuições à Geologia da Amazônia. Belém: FINESP/SBG. Núcleo Norte. p. 15-90.
- [7] CPRM, 2006. Geologia e Recursos Minerais da Amazônia Brasileira, Região Cratônica, Sistema de Informações Geográficas – SIG. Mapa na escala de 1:1000000. CD-Rom.
- [8] ELIAS, M. E. V., O Registro de Petrogramas do Granito Moderna e dos Granitos Adjacentes, São Luiz do Anauá, Roraima. 2018, 72f.:il. Color; 31 cm

- [9] FARIA M.S.G. de, LUZARDO R. 2000. Complexo Metamórfico Anauá. In: CPRM (ed.) Programa Levantamentos Geológicos Básicos do Brasil. Caracará, Folhas NA.20-Z-B e NA.20-Z-D (integrais), NA.20-Z-A, NA.21-Y-A, NA.20-Z-C e NA.21-Y-C (parciais). Escala 1:500.000. Estado de Roraima. CPRM Superintendência Regional de Manaus. Capítulo 3 – 3.4.
- [10] FARIA M.S.G., FARACO M.T.L., REIS N.J. e OLIVEIRA M.A. 2005. Folha NA.21-Tumucumaque. In: Schobbenhaus, C., Gonçalves, J.H., Santos, J.O.S., Abram, M. B., Leão Neto, R., Matos, G.M.M., Vidotti, R.M., Ramos, M.A.B., Jesus, J.D.A.de. (eds.) Carta Geológica Brasil ao Milionésimo, Sistema de Informações Geográficas-SIG. Programa Geologia do Brasil. CPRM, Brasília. CD-ROM.
- [11] FRAGA, L.M.B. 2002. A Associação Anortosito–Mangerito–Granito Rapakivi (AMG) do Cinturão Guiana Central, Roraima e Suas Encaixantes Paleoproterozóicas: Evolução Estrutural, Geocronologia e Petrologia. Tese de Doutorado, CPGG/CG, Universidade Federal do Pará. 386 p.
- [12] FREITAS, A. F. Atlas geoquímico do estado de Roraima / Aurélio Figueiredo Freitas, José Luiz Marmos. -- Recife: CPRM, 2017. 227 p.
- [13] HASUI Y.; HARALYI, N. L. E.; SCHOBHENHAUS, C. 1984. Elementos geofísicos e geológicos da região Amazonica: subsídios para o modelo geotectônico. In: Anais do 2º Symposium Amazonico, DNPM/CNPq, Manaus, p.129-141.
- [14] LOMBELLO, J. C., TRINDADE, I. R., SOUZA, V. S., ALMEIDA, M. E., MALTA, J. V., VERAS, R. S., NEVES, M. P., SILVA, D. P. B. Caracterização Petrográfica do Granito Abonari, Município de Presidente Figueiredo (AM). Manaus, 2009.
- [15] LOMBELLO, J. C., Petrogênese do Magmatismo Abonari, escudo das Guianas, município de Presidente Figueiredo (AM) - Orientador Profº. Dr. Valmir da Silva Souza – (IG/UnB), Co- Orientador Profº. Dr. Ivaldo Rodrigues da Trindade – (DEGEO – UFAM) - Manaus UFAM/Instituto de Ciências Exatas - Departamento de Geociências, 2011. 98p.
- [16] LOPES, M.. Separação Magnética do Beneficiamento Mineral. Disponível em: <<https://tecnicoeminerao.com.br/separacao-magnetica-beneficiamento-mineral/>> 2014 Acesso em: 03/12/2018.
- [17] MACKAY, D. A. R.; SIMANDL, G. J. Niobium and tantalum: Geology, markets, and supply chains, [in]. In: Symposium on Critical and Strategic Materials. 2015. p. 13.
- [18] MULLER, A. J., & CARVALHO, A. D. S. (2005). Uso de produtos CERBS para o zoneamento geoambiental de Presidente Figueiredo, no Amazonas. In XII Simpósio Brasileiro de Sensoriamento Remoto. Goiânia: INPE.
- [19] REIS N.J., FRAGA L.M.B. (1998) - Geologia do Estado de Roraima. Publicação Interna, Inédito, CPRM, Manaus, 24 p.

- [20] REIS N.J., FRAGA L.M.B. 2000. Geologic and tectonic Framework of Roraima State - Guiana Shield. In: Int. Geol. Congr., 31, Rio de Janeiro, Expanded Abstract. CD-ROM.
- [21] REIS, N.J.; FRAGA, L.M.; FARIA, M.S.G.; ALMEIDA, M.E. Geologia do Estado de Roraima, Brasil. Géologie de La France, n. 2-3-4, 2003. pp.121-134.
- [22] SANTOS, J.O.S., HARTMANN, L.A., FARIA, M.S.G DE., RIKER, S.R.L., SOUZA, M.M., ALMEIDA, M.E., MCNAUGHTON, N.J. (2006) A Compartimentação do Cráton Amazonas em Províncias: Avanços ocorridos no período 2000-2006. Em: SBG-Núcleo Norte, Simpósio de Geologia da Amazônia, 9, Belém.
- [23] SOUZA, A. C. S. Litogeoquímica e química mineral das rochas félsicas e máficas aflorantes entre os Km 151-155 da BR 174, Município de Presidente Figueiredo (AM). 2012. 99 f. Dissertação (Mestrado em Geociências) - Universidade Federal do Amazonas, Manaus, 2012.
- [24] SHAW, R., GOODENOUGH, K., 2011. Niobium-tantalum : April 2011. British Geological Survey, 27pp.
- [25] UFRG, Geoquímica – Fluorescência de Raio-X e Difração de Raio-X (FRX). Disponível em: <<https://www.ufrgs.br/geoquimica/frx-2/>> 2017. Acesso em: 04/12/2018
- [26] VEDANA, L. A. (2010). Balanço geoquímico de massa entre as fácies do Granito Madeira-Pitinga (AM). Luiz Alberto Vedana, Porto Alegre, RS.