PETROGRAPHIC DESCRIPTION OF THE MAFIC AND ULTRAMAPHIC ROCKS OF THE OURO FINO UNIT, OF THE NOVA GROUP LIMA, IN CAETÉ AND SANTA BÁRBARA, MG

PETROGRAPHIC DESCRIPTION OF THE MAFIC AND ULTRAMAFIC ROCKS OF THE OURO FINO UNIT, NOVA LIMA GROUP, IN CAETÉ AND SANTA BÁRBARA, MG

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SUMMARY
The petrographic study of the rocks of the Ouro Fino Grupo Nova Lima Unit, Greestone Belt Rio das Velhas, within the iron quadrangle, includes samples little affected by alteration processes. Several rocks preserve primary features such as pillow lavas, amygdalae and variolas. Petrographic analysis classifies the rocks as tholeiitic basalts and magnesian tholeiites. The metabasalts of the Ouro Fino Unit come from an ocean floor environment, evidenced by structural features (pilow lavas) and lithological associations (banded iron formations and Metachert). Several minerals were identified in petrographic slides, thus allowing the characterization of their mineral paragenesis and a more precise classification. The geochemical characteristics consulted in the bibliography indicate that part of the metabasalts was formed by mantle plumes (P-MORB). These characteristics infer a submarine plateau environment.
Key words: Iron Quadrangle. Ouro Fino Unit. Igneous Rocks.

ABSTRACT
The petrographic study of rocks of Ouro Fino unit's Nova Lima group, Greenstone Belt Rio das Velhas, in interior of Quadrilatero Ferrifero, cointains few samples affected by alterations processes. Many rocks have the primary features like lavas in pillow, tonsils and pox. The petrographic analysis classifies the rocks in tholeiitic basalt and magnesium tholeiite. Ouro Fino Unit's metabasalts are from ocean bottom environment shown by

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structures (pillow lava) and lithologic associations (banded iron formation and metachert). A few minerals were recognized in petrographic thin section allowing the description of its mineral paragenesis and a needed classification.The geochemical characteristics consulted in the literature indicate that part of the metabasalts was formed by a mantle plume (P-MORB). These characteristics infer a submarine plateau environment.
Keywords: Ferrifero Quadrilateral. Ouro Fino Unit. Igneous rocks.

1. INTRODUCTION

The Ouro Fino Unit belongs to the Archean volcanosedimentary sequence of the Rio das Velhas Supergroup, located in the northeast region of the Iron Quadrangle (MG). This lithostratigraphic unit is one of the subdivisions given to the Nova Lima Group corresponding to its basal portion and, together with the ultramaphytes of the Quebra Osso Unit, corresponds to an ancient ocean floor where other related units were deposited. Its best exposures occur along the Conceição River near the district of Vigário da Vara and along the Córrego Ouro Fino south of Serra da Piedade (CPRM, 1996).

The Ouro Fino Unit is made up of tholeiitic, massive, locally cushioned, variolitic and amygdaloidal metabasalt, with a diverse degree of alteration. In subordinate proportions, metaperidotite, komatiite metabasalt, basic metatuff, acid metavolcanic, metachert, iron formation and carbonaceous shale occur. The metamorphism is of greenschist facies. (SCHRANK et al., 1993).

1.1 OBJECTIVE

1.1.1 GENERAL OBJECTIVE

The present work seeks to associate the research of bibliographies of the area with petrographic analyzes of the rocks that belong to the Ouro Fino Unit. The interpretation of this research is developed by microscopic descriptions together with the creation of a phase diagram.

1.1.2 SPECIFIC OBJECTIVES

The specific objectives of the work are:

- Generate location and geological maps of the study area.

- Create petrographic slides with the samples collected and later donate them them to the collection of the Mineralogy laboratory at the University Center of Belo Horizonte, in order to contribute to the studies of our colleagues.

1.2 LOCATION AND ACCESS

The outcrops visited were divided into two regions, Caeté and Santa Bárbara, both within the Iron Quadrangle. In the Santa Barbara region, around 70km from Belo Horizonte, a total of three outcrops were visited, the first two being located in the district of Vigário da Vara, 26km from the center of Santa Barbara. Access to the outcrops is via a dirt road, known as Rua de Baixo, which connects the district of Brumal to Vigário da Vara.

The first outcrop (645920.00 m E 7775758.00 m S) is close to the bridge at the junction with the access road to Samarco's Capanema Mine. The second outcrop (645920.00 m E/7774570.00 m S) is in an area of difficult access and is accessed via 1.5km of trails that border the Conceição River. The third outcrop (671130.00 m E 7797865.00 m S) visited is on the banks of the Peti Reservoir, approximately 8km from the center of Santa Barbara, accessed via Rua Jose Malaquias, where you take secondary roads to the dam with the outcrop located at its extreme east.

Figure 1: Location map. Source: Authors (2018)

In the Caeté region, around 50km from Belo Horizonte, two outcrops were visited, the first (638515.00 m E 7803075.00 m S) on the banks of the Ouro Fino stream. Access is via MG-435, close to the urban perimeter of Caeté, where you take the road to the Quintas da Serra condominium for 2 km to the outcrop near the headquarters of Fazenda Ouro Fino. The second outcrop (638516.00 m E 7797102.00 m S) is located on the edge of the access road to the Morro Vermelho district, close to the Casa da Vovó hotel, 2.7km from the center of Caeté.

Figure 2: Points taken during fieldwork. A, D, E: Caeté. B and C: Santa Bárbara Source: Authors (2018)

2 THEORETICAL FOUNDATION

2.1 REGIONAL GEOLOGY

According to Dorr (1969), the Iron Quadrangle is located on the southern edge of the São Francisco Craton, comprising an area of approximately 7000 km². This geographic space resembles a square, characterized by the accommodation of synclines where sediments from the Minas Supergroup emerge, of Paleproterozoic age, separated by irregular antiform structures with Archean terrains of the greenstone belt type of the Rio das Velhas Supergroup, and domes of Archean and Proterozoic (ROSIÈRE et al., 2000), including granite-gneisses, metatonalites, syenogranites, pegmatites, amphibolites, and ultramafic rocks, in addition to supracrustals metamorphosed on the amphibolite faces.

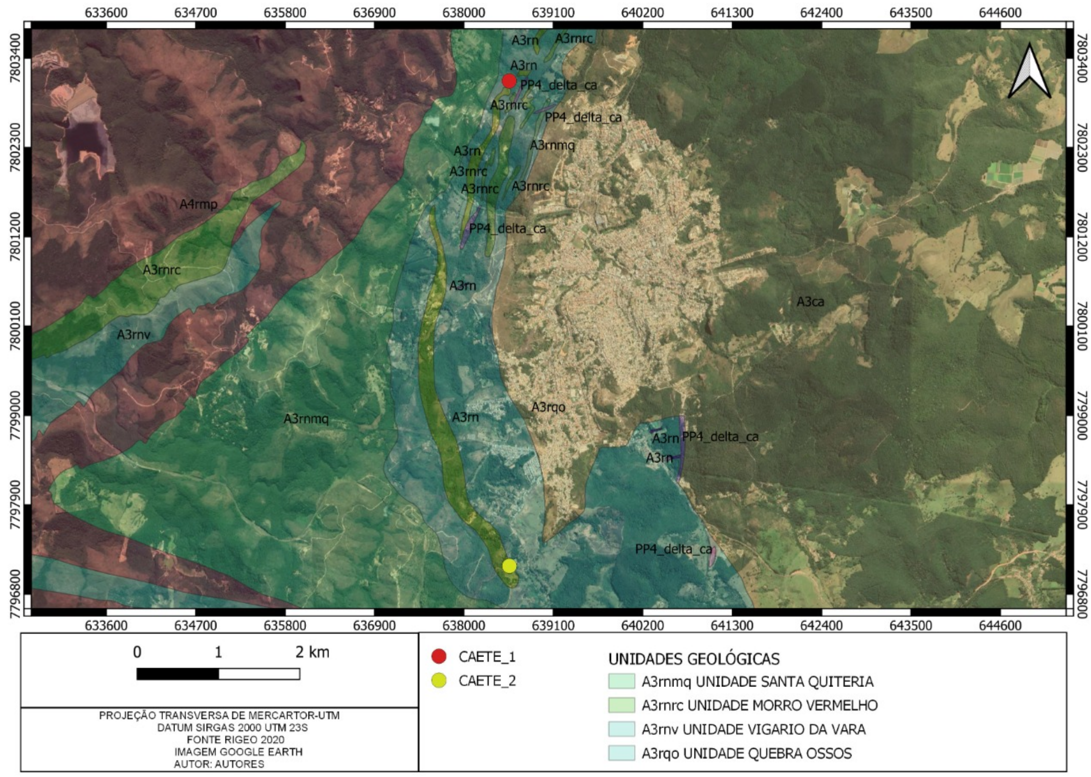

Figure 3: Geological map with points made in the city of Caeté. Source: Authors,2021

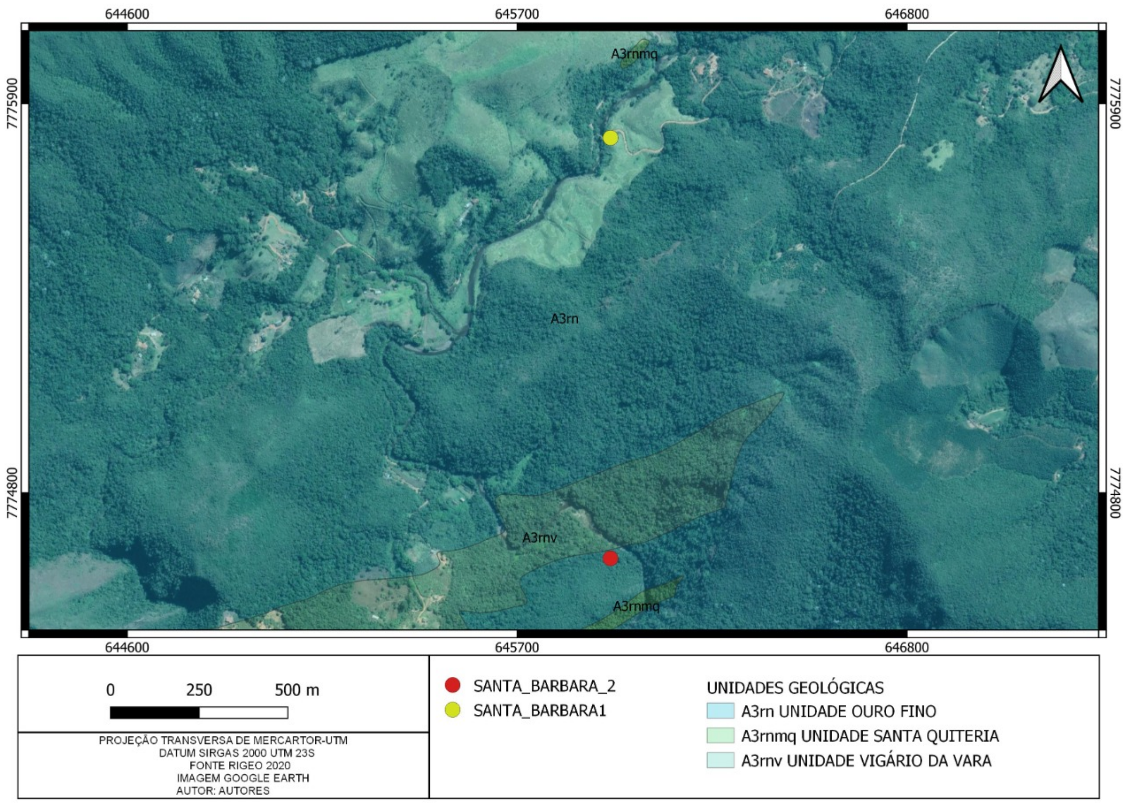

Figure 4: Geological map with points made in the city of Santa Bárbara. Source: Authors,2021

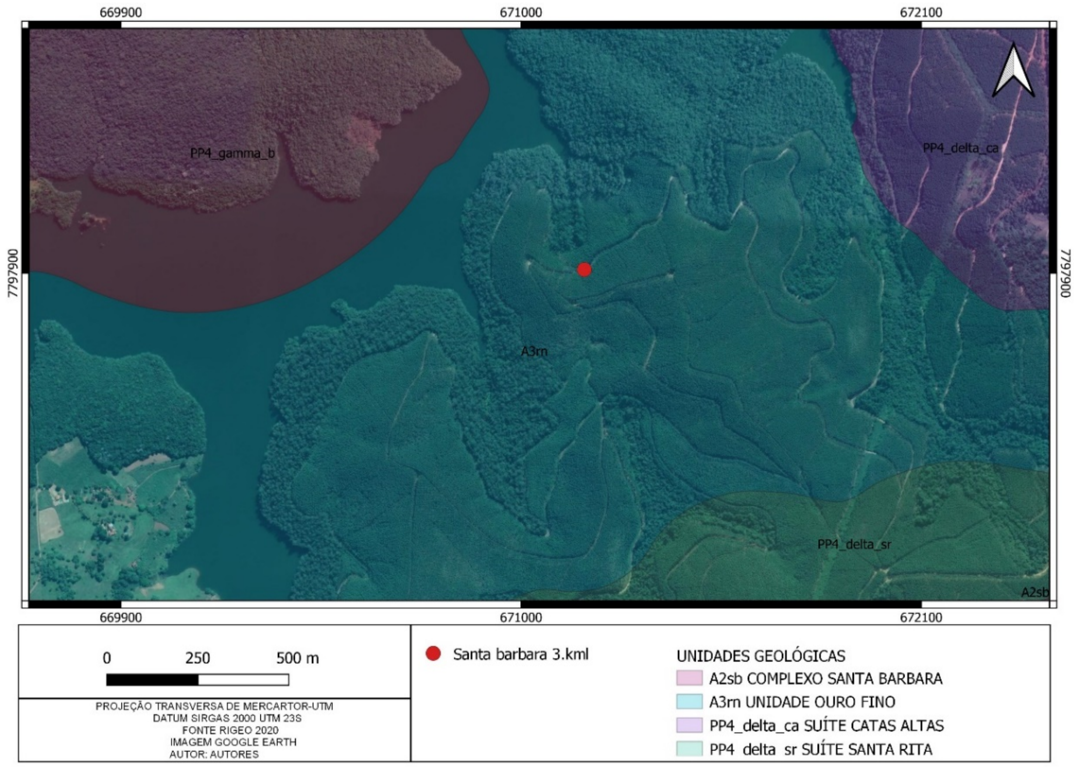

Figure 5: Geological map with a point made in the city of Santa Bárbara, close to the Peti Reservoir. Source: Authors, 2021

2.1.1 RIO DAS VELHAS SUPERGROUP

The Rio das Velhas Supergroup (LOCZY & LADEIRA, 1976), originally defined as the Rio das Velhas Series (DORR et al., 1957), is made up, from base to top, of the groups Quebra Osso (SCHORSCHER, 1978), Nova Lima and Maquiné (DORR et al., 1957). Its base is defined by the Nova Lima Group and its top by the Maquiné Group and is composed of green basalt and komatiite rocks, rhyolitic lava and an intercalation of sedimentary rocks at the top, in the form of a belt (ALKMIM; MARSHAK, 1998).

Schorscher (1978) defined the Quebra Osso Group as an association of rocks lying beneath the Nova Lima Group, to which he gave the formal name of the Quebra Osso Group. The type section is located in the Quebra Osso stream valley. It is made up of peridotite komatiites with thick cumulate horizons, in addition to thin levels of iron-poor iron formation, fuchsitic metachert, tourmalinite and carbonaceous phyllite, with greenschist facies metamorphism.

The Nova Lima Group was defined by Dorr et al., (1957) as a succession of mica schists with beds, lenses and zones of iron formations, greywackes and sub-graywackes, quartzite, conglomerate, metavolcanic rocks, graphitic schists and phyllites, quartzankerite schist and other metasediments.

Ladeira (1980), Oliveira et al., (1983), Vieira and Oliveira (1988) informally and locally divided the Nova Lima Group into basal, middle and upper units. The classification of its stratigraphic units were subdivided based on the cartography of the Rio das Velhas Project (1996), from base to top, into: Ouro Fino, Morro Vermelho, Santa Quitéria, Ribeirão Vermelho, Mestre Caetano, Córrego do Sítio, Mindá, Catarina Mendes, Fazenda Velha, Córrego da Paina and Pau d'Óleo. Along with this classification, the Córrego dos Boiadeiros Complex is also included, which is characterized by a basic-ultrabasic sequence intrusive in the basal units of the greenstone belt.

The Maquiné Group, defined by Dorr et al. (1957), consists mainly of quartzites, phyllites and conglomerates. In the type area it was divided into the Palmital Formation (O'ROURKE, 1957 apud DORR, 1969) and the Casa Forte Formation (GAIR, 1962).

OKbeautiful 1: Stratigraphic column of the Nova Lima Group. Source: Modified from VIEIRA et al. (1991)

Nova Lima Group	
Clastic Unit: Metapelito with felsic tuffite, quartzite, conglomerate	Catarina Mendes Unit
	Mindá Unit
	Córrego Do Sítio Unit
Metavolcanic Unit Sedimentary: Andesitic breccia, felsic tufite and metapelite	Mestre Caetano Unit
	Ribeirão Vermelho Unit
	Santa Quitéria Unit
Metavolcanic Unit: Basalt and andesite with BIF, ultramafic rocks	Córrego Dos Boiadeiros Unit
	Morro Vermelho Unit
	Ouro Fino Unit

2.1.2 FINE GOLD UNIT

It constitutes, together with the Quebra Osso Group, the ocean floor on which the other units of the Rio das Velhas Supergroup were deposited. The Ouro Fino Unit is made up of tholeiitic, massive, locally cushioned, variolitic and amygdaloidal metabasalt, with a diverse degree of alteration. In subordinate proportions, metaperidotite, komatiite metabasalt, basic metatuff, acid metavolcanic, metachert, iron formation and coal shale. The metamorphism is of greenschist facies (MEDINA et al., 2005). Tholeiitic metabasalt has a dark gray and greenish gray color that turns reddish yellow to reddish due to weathering. The grain is fine and the dominant structure is schist, locally not very pronounced. In these places, there are preserved primary structures and textures such as pillow lavas, tonsils and smallpox (MEDINA et al., 2005).

Metaperidotite constitutes intercalations in the tholeiite metabasalt, from which it differs in its silky appearance to the touch, its light green color and its mineral composition. With weathering it becomes yellowish, contrasting with the reddish color of the metabasalt. The structure is schist and laminated, or massive and fractured in serpentinite. Mafic metatuff occurs in rare thin lenses among basaltic flows. They are pyroclastic interflows of laminated, dark green, fine-grained schist rocks. Acid metavolcanic occurs interspersed in metabasalts, with thickness varying from a few centimeters to tens of meters (MEDINA et al., 2005).

Metachert and iron formation occur in a subordinate manner. The banded iron formation has centimeter-thick mesobands made up of quartz and martite/magnetite. Carbonate may be present, but in general, on the surface, it is completely leached, which gives the rock a friable appearance. Metachert, carbonate or not, has a massive structure and presents crystals. equigranular quartz in polygonal arrangement. Carbonaceous shale is mainly characterized by the presence of chlorite, sericite, carbonaceous material and quartz (MEDINA et al., 2005).

3 METHODOLOGY

Firstly, a bibliographical research was carried out where the articles Medina et al., (2005) and CPRM et al., (1996) were reviewed and served as a basis for beginning the work. After deciding on the study site, a cartographic survey was carried out, using the topographic maps of Acuruí (1:50,000) and Caeté (1:50,000) along with the geological maps of Santa Bárbara (1:50,000), Gandarela (1:50,000) and Caéte (1:50,000). From the theoretical basis, it was possible to recognize the area to define collection points, aiming for fresh samples, in good condition and possible access.

4 RESULTS AND DISCUSSIONS

4.1 PRODUCTION AND ANALYSIS OF PETROGRAPHIC SHEET

To make the slides, three samples collected from fieldwork were chosen: Rio Conceição I (collected from the outcrop on the banks of the Rio Conceição), Ponto 5 and Ponto 7. The analyzes of these slides were carried out using the Eclipse E200 Polarazing Nikon microscope, available in the geosciences laboratory of the Centro Universitário de Belo Horizonte (UNIBH), on July 8, 2018. The identification of mineralogy in percentage, grain size, granulometric homogeneity, types of contact and texture were the concepts for classifying the sheets produced . Other concepts used for possible characterizations were the types of changes and structures.

Conceição I River: calcite minerals ($CaCO_3$) (19%), chlorite ((Mg, Fe)3(Si,Al)4O10 (OH)2(Mg,Fe)3(OH)6) (40%), quartz (SiO_{two}) (10%), rutile (TiO_{two}) (1%) and titanite ($CaTiSiO_5$) (30%). The granulometric homogeneity is inequigranular from medium to fine grain. The minerals make serrated contacts and have a hypidiomorphic texture. It was possible to observe two foliations;

Point 5: the minerals present in this slide are muscovite ($KAl_{two}(Yes_3Hello_{10}(OH,F)_{two})$ (20%), oxides (25%), plagioclase((Na,Ca)Al(Si,Al)Si2O8) (25%) and quartz (30%). The granulometric homogeneity is inequigranular from medium to fine grain. The oxides make contact in the globular type and the other minerals in the serrated type, presenting a hypidiomorphic texture;

Point 7: at last blade, he was observed minerals in actinolite (Ca2(MgFe)5(OH)2(Si4O11)2) (20%), chlorite (30%), oxides (4%), quartz (15%), rutile (1%) and serpentine (Mg3(Si2O5) (OH)4) (30%). The granulometric homogeneity is inequigranular from medium to fine grain. The mineral texture is hypidomorphic and the types are globular in the few existing oxides and serrated in the other minerals. It is possible to observe chloritization and serpentine changes, which are the product of metamorphism in olivines.

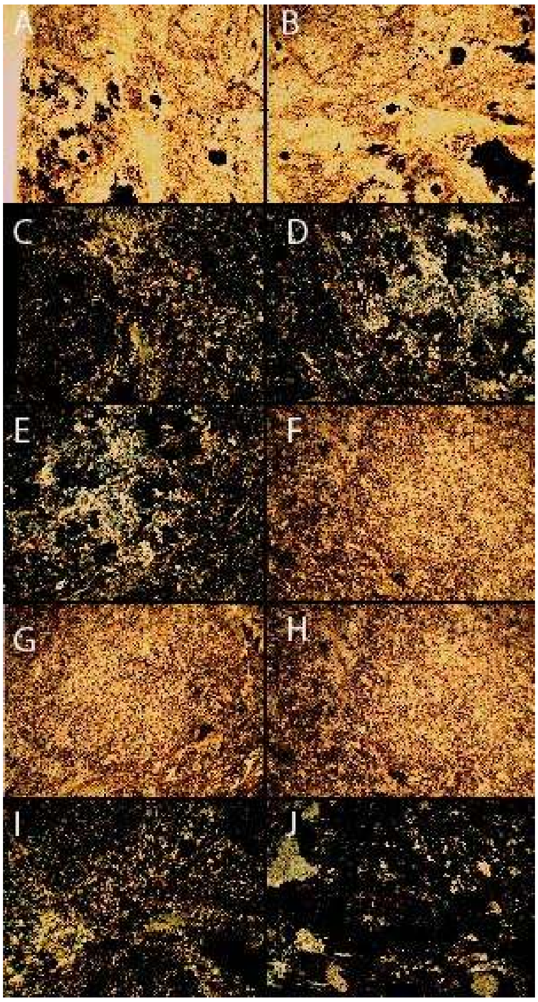

Figure 5: Photos of the prepared slides. A, B, C: Point 5; D, E, F, G, H: Point 7; I, J: Rio Conceição. Source: Authors (2018)

4.2 MINERAL PARAGENESIS

The metavolcanic rocks of the Greenstone Belt Rio das Velhas are metamorphosed and affected by hydrothermal alteration and shear that modify the fabric of the rocks, therefore all samples are affected in the greenschist facies, the main constituents are Chlorite (metamorphic mineral and product of alteration of the Mafics such as Biotite (pyroxenes and amphiboles) Actinolite (metamorphic mineral, product of alteration of pyroxenes rich in Mg) and Quartz (polymorphous silicate of SiO_2) and Serpentine (metamorphic mineral of hydrothermal alteration rich in magnesium such as Olivines) (ZUCCHETTI AND BALTAZAR, 1998).

Secondary minerals such as Titanite, Rutile and oxides participate in the magma fabric and define, together with alteration minerals (calcite and muscovite), the thermodynamic conditions for rock formation and the processes of metamorphism and hydrothermal alteration throughout geological time (ZUCCHETTI E BALTAZAR, 1998).

4.3 GEOCHEMICAL ANALYSIS

To demonstrate the geochemical aspects and thus verify the paragenesis of one of the samples, the sample database of the author Zuccheti and Baltazar (1998) was used. The authors have a sample collected in the same location where the current work covered. The sample data was used in the GCDkit (The GeoChemical Data ToolKIT) 4.1 software, and classification diagrams were generated for the sample.

Table 2: Table of geochemical data from samples from Zuccheti and Baltazar (1998) used in generating the diagrams.

SiO_{two}%	TiO2	$Al_{two}O_3$	$Faith_{two}O_3$	FeO	MnO	MgO	Dog	$At_{two}O$	$K_{two}O$
55.00	1.40	14.60	2.30	6.50	0.12	4.80	7.90	4.90	0.19
$P_{two}O_5$	$H_{two}O^+$	$H_{two}O^-$	CO_{two}	s	FEDERAL POLICE	mg	F(ppm)	To the	Sb
0.35	0.96	<0.10	0.17	<0.01	1.30	49.95	255.00	<5.00	3.22
Ba	**Rb**	**Mr.**	**CS**	**Cr**	**Ni**	**co**	**V**	**Ass**	**Pb**
93.00	3.50	115.0	0.30	120.0	34.0	37.00	254.0	53.0	11.0
Zn	**OK**	**Nb**	**Hf**	**Zr**	**Y**	**Th**	**There**	**Ce**	**Pr**
75.00	0.54	7.00	3.60	130.00	36.0	3.83	17.90	35.90	4.42
Nd	**Sm**	**I**	**Gd**	**Also**	**Dy**	**Ho**	**Er**	**TM**	**Yb**
19.70	4.99	1.32	5.02	0.95	5.97	1.20	3.62	0.55	3.56
Lu									
0.54									

The MORB diagram of Pearce (1983) is based on the ETR diagrams, the same is used for mid-ocean ridge basalts. The order in the diagram is defined by the mobile elements (Sr, K, Rb, Ba) are arranged in increasing incompatibility mode from left to right. For real estate, the incompatibility grows from right to left. The plotted sample is a tholeitic basalt, the high Th content is notable.

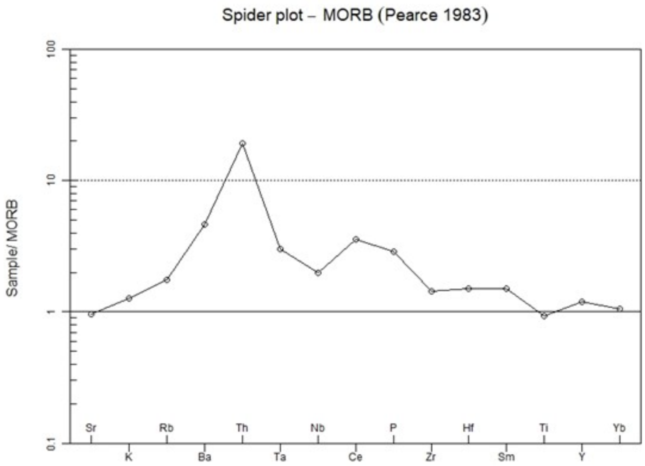

Figure 6: Sample analysis results on the diagram *MORB* by Pearce, highlighting the high content of Th.
Source: Authors (2018)

The Wichest and Floyd diagram (1977) was used as an indicator of alkalinity where the sample is classified as having a low content of Zr/TiO2 and Nb/Y, falling within the field of Subalkaline rocks.

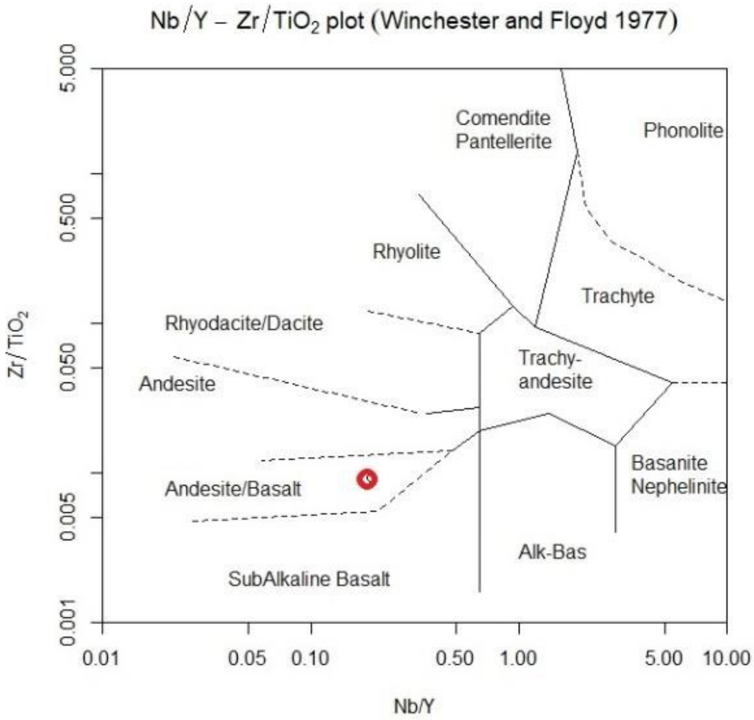

Figure 7: Result of sample analyzes on the diagram
Wichest and Floyd. Source: Authors (2018)

And the Jensen diagram (1976) is used to classify subalkaline rocks, using only larger elements that are not very mobile. The sample studied was defined as Basalt.

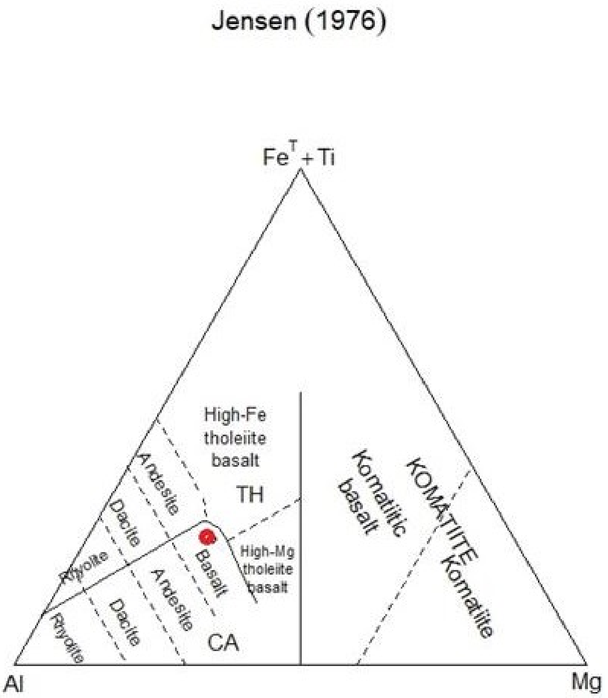

Figure 8: Result of the analysis carried out in the diagram*Jensen* (1976) Source: Authors (2018)

FINAL CONSIDERATIONS

Based on petrographic analyzes and with the bibliographical assistance of geochemical analyzes referring to the area carried out by Zucchetti and Baltazar (1998), it is possible to classify the rocks of the Ouro Fino Unit as actinolite schists and chlorite schists, indicating greenschist facies metamorphism. Chemical analyzes carried out by Zuchetti (1998) reveal two types of metabasalts, one less magnesian and the other more magnesian. Metabasalts are divided into tholeiites and magnesian tholeiites depending on the Mg of actinolite and the MgO content of the total rock analysis. The geochemical and structural characteristics (cushion lavas) and textural characteristics (tonsils) and the associations of banded iron formations and Metachert) indicate that the metabasalts of the Ouro Fino Unit are from the ocean floor. This fact, combined with geochemical characteristics, allows us to characterize a submarine plateau environment. In relation to mineralogy, the most common petrographic type is albite-chlorite-actinolite schist, other minerals observed are quartz, titanite, white mica, biotite, rutile and opaque minerals. Actionlite occurs in thin oriented prisms, chlorite appears constantly in the form of oriented reeds marking the metamorphic foliation. Regarding the tonsils, they occur in a lenticular shape and are filled with well-developed and idioblastic crystals.

of quartz, carbonate, chlorite and epidote. The amounts of each mineral vary and do not necessarily all appear in the same amygdala.

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