SEG – Student Chapter – Universidade Federal de Ouro Preto

UFOP SEG Student Chapter Field Trip 2022

Brasília Orogen, Minas Gerais

July 17th – 22nd

Ouro Preto, February of 2023

SUMMARY

FIGURE INDEX

TABLE INDEX

1. INTRODUCTION

The UFOP SEG Student Chapter (SC) is a student entity formed by students from the Federal University of Ouro Preto (UFOP) who are interested in the area of economic geology. Linked to the Geology Department of the Escola de Minas and the Society of Economic Geologists (SEG), the chapter aims to develop activities related to the Economic Geology subject at UFOP, through the scientific investigation of mineral deposits in conjunction with the mineral industry and research centers. For this purpose, technical visits to mineral deposits, short-courses, workshops, lectures, study groups, research and publications in periodicals are promoted.

In this context, the UFOP SEG SC, subsidized by SEG and with the support of the Escola de Minas, organized a six-day field trip activity on the Brasília Orogen region, in the eastern and northeastern portion of Minas Gerais, aiming for a better understanding of the orogen by an Economic Geology perspective. It is a region of considerable importance for economic geology, as it hosts mineral deposits of phosphate, zinc, lead, gold, in addition to the largest niobium reserve in the world and occurrences of diamonds.

The field trip group was composed by three UFOP SEG SC students and our Professor Dr. Emilio Evo Magro Correa Urbano, who was responsible for guiding the group during the field trip, through his knowledge about the evolution of the Brasília Orogen and its importance on the control of the mineralizations. In addition, the other members of the committee were also essential in organizing the project, raising funds and contacting the companies visited.

Regarding the preparation for the field trip, during the months prior to departure, bibliographic research was carried out to better understand the occurrence of mineralizations and their geological contexts. Presential meetings were also frequent in order to define the best routes and logistics. Finally, this field trip proved to be an excellent opportunity for interaction and networking among the participants and industry professionals.

2. LIST OF PARTICIPANTS

NAME	POSITION	INSTITUITION	SEG MEMBERSHIP
Bianca Morais Ferreira	Undergratuated Student Member	UFOP SEG S.C	919635
Emilio Evo Magro Correa Urbano	Geologist Professor	UFOP SEG S.C	
Flávia Compassi da Costa	PhD student Member	UFOP SEG S.C	919386
Ivan Batista Lisboa	Undergratuated Student Member	UFOP SEG S.C	920132
Lucas Medeiros da Silveira	Undergratuated Student Member	UFOP SEG S.C	
Victor Fagundes Carvalho Melo	Undergratuated Student Member	UFOP SEG S.C	920092
Vitória Bruschi Nelvam	Undergratuated Student Member	UFOP SEG S.C	919634

Table 1: List of participants

3. VISITED AREAS

The visited points of the field trip are located in the state of Minas Gerais – Brazil (Figure 1). The field trip started on the P1, which represents the Federal University of Ouro Preto and is followed by the points on the interest areas. The second visited point (P2) is the Companhia Brasileira de Metalurgia e Mineração (CBMM) - Niobium and REE mine - in Araxá city. The third point represents the kimberlites outcrops (P3) and is followed by Mosaic Phosphate Mine in Lagamar city (P4). The final visited point was the Kinross Gold mine, nearby the city of Paracatu (P5).

Figure 1: Location of the visited areas during the field trip.

4. GEOLOGICAL SETTINGS

The Brasília Orogen is part of the system of orogens that developed towards the São Francisco Craton (CSF) during the Neoproterozoic and formed by folding and thrusting belts. This tectonic unit borders the west margin of the CSF and is divided into a north segment, with a NE-SW orientation, and a south segment, with a NW-SE orientation (Figure 2). In the southern segment there are three regions with different levels of deformation and metamorphism: the cratonic zone, formed mainly by the Bambuí Group and corresponds to the part least affected by deformation and metamorphism; the folds and thrusts zone, formed in the external domain by the Paranoá, Canastra and Ibiá groups and metamorphosed under the greenschist facies; and the Nappes Complex, constituted by the Araxá Group and with rocks that record metamorphic grade up to granulite facies (Valeriano, 2017). The northern region, on the other hand, registers the interaction between the São Francisco and Amazonian Cratons. According to Uhlein et al (2012), this orogenic process also involved other tectonic units, such as the Goiás Massif, Neoproterozoic magmatic arcs and Meso-Neoproterozoic sedimentary sequences.

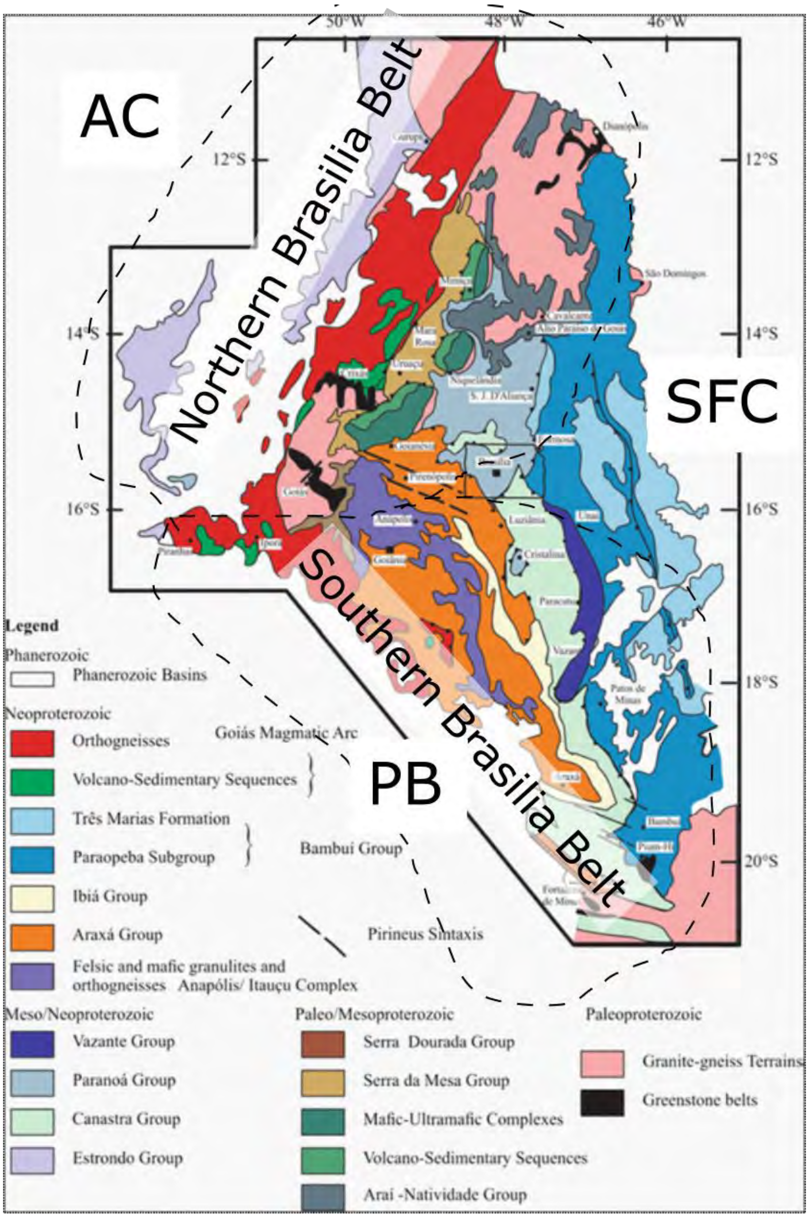

Figure 2: Brasilia belt location. The Northern and Southern Brasilia belts as orogenic domains developed by the indentation of the western São Francisco paleocontinental margin against accretionary terranes during the Brasiliano orogeny (modified from Valeriano et al.2008). SFC: São Francisco Craton; AM: Amazon Craton; PB: Paraná Basin.

4.1. STRATIGRAPHY

According to Hasui et al. (2012), the basement of the Brasília Belt is represented by two Archean units, located in the southern portion: one of gneissic-granite composition, known as the Campos Gerais Complex, and a greenstone belt unit, the Fortaleza de Minas Group.

Of Paleoproterozoic age, gneissic units belonging to the Jurubatuba Suite (central portion) and Andrelândia Group were identified, the latter represented by granitic and granodioritic gneisses, banded and migmatized gneisses, quartzites, graphite schists, tourmalinites. Also of Paleoproterozoic age, located in the central portion of the Belt, the Silvânia Complex consists of a metavolcanosedimentary sequence comprising amphibolites, metandesites, metadacites, talc-schists, actinolite-schists, chlorite-schists, ferruginous quartzites, marbles, garnet-micaschists, cyanite , sillimanite and staurolite.

Up in the stratigraphy, the Paranoá Group, of Mesoproterozoic age, is composed by a metasedimentary sequence with metaconglomerates at the base, covered by rhythmites, followed by platform quartzites, pelites, limestones and stromatolitic dolomites, from varied environments (Dardenne, 2000). Next, the Canastra Group is mainly represented by formations of phylitic rocks, greenish calciferous schists, quartzites, carbonaceous phyllites, metarenites and metasiltites. At the top of the rocks of Mesoproterozoic age, we have the Vazante Group (approx. 1,100 – 990 Ma) of pelitic-dolomitic nature, with conglomeratic quartzites, slates, diamictites and phosphate deposits (Figure 3).

At the top of the stratigraphic column, Neoproterozoic units occur, which in turn comprise metavolcanosedimentary rocks such as the Araxá Group, composed of schists, quartzites, marbles, amphibolites, garnet, serpentinites and chlorite-schists and the Rio do Peixe Group, comprising amphibolites , meta-hornblendites, calcium-silicate rocks, quartzites, schists and marbles. There are also metasedimentary rocks of the Ibiá Group, such as metadiamictites, quartzites, phyllites, diamictites considered to be deposited in a glaciomarine environment and the Bambuí Group, composed of pelite-carbonate sequences deposited in a foreland basin (Figure 3).

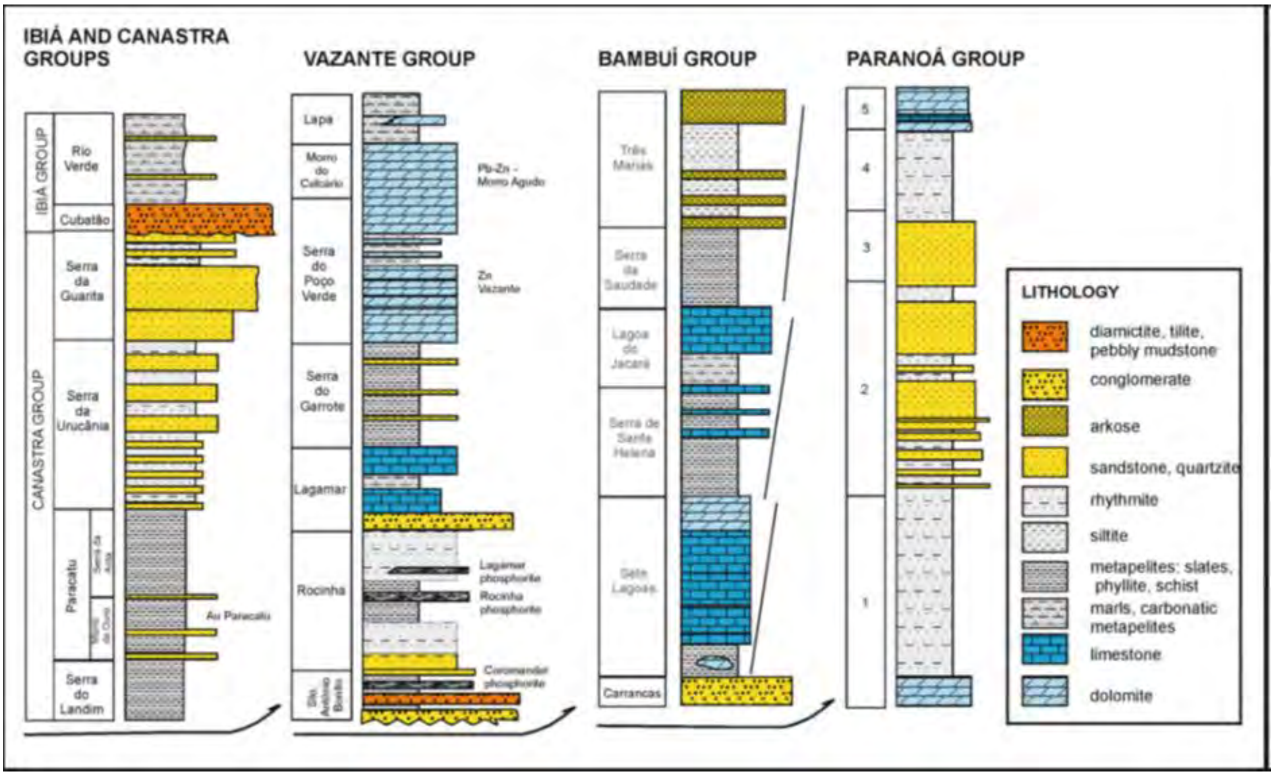

Figure 3: Representative lithostratigraphic columns for the metasedimentary units of the Southern Brasilia: Ibiá and Canastra groups (Dias et al. 2011); Vazante, Bambuí (Dardenne 2000) and Paranoá (Alvarenga et al. 2012) groups.

5. VISITED SITES/DAILY REPORT

DATE	ACTIVITIES
Sunday – July 17th	**Trip from Ouro Preto to Araxá. Geological cross-section through the southern Brasilia Belt**
Monday – July 18th	**Visit to CBMM Mine**
Tuesday – July 19th	**Visit to Mosaic Mine**
Wednesday – July 20th	**Visit to Kimberliths Outcrops**
Thursday – July 21st	**Visit to Kinross Mine**
Friday – July 22nd	**Return to Ouro Preto**

Table 2: Itinerary of the UFOP SEG Field Trip 2022.

5.1. 1st DAY: SUNDAY, July 17

The first day of our trip was mainly dedicated to travel inform Ouro Preto to Araxá, where it is located the mine operated by CBMM (Carbonatite with Nb, P and REEs mineralization). During this trip we performed a geological cross-section through the transition between the São Francisco craton and the southern Brasília Orogen. This allowed us to observe deformational structures (Figure 4), possibly related to the opening of the Atlantic Ocean, and an angular uncorformity related to the São Francisco Basin, Areado Group and Bambui Group (Figure 5).

Figure 4: Contact of a schist with a mature soil, marked by a curved normal fault.

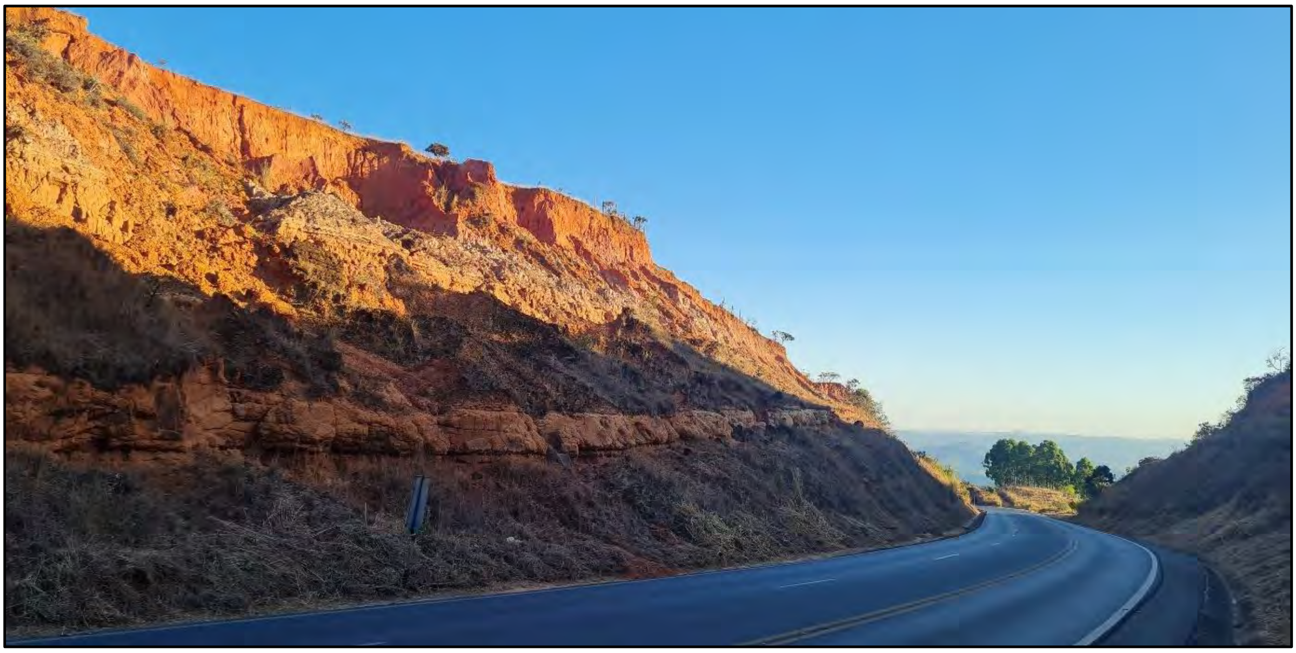

Figure 5: Angular unconformity between Serra da Saudade formation (siltstone slightly green due to the presence of glauconite), Bambui Group (lower part of the photo), and Areado Group composed by reddish brown sandstone with tabular cross stratification (superior part of the photo).

5.2. 2rd DAY: MONDAY, July 18

On our second day of fieldtrip, we visited the CBMM Niobium Mine (Figure 6). CBMM (Companhia Brasileira de Metalurgia e Mineração) is a Brazilian company, world leader in the production and supply of niobium products, produced from pyrochlore extracted in Araxá, Minas Gerais.

Niobium is considered fundamental to the advanced technology industry and is used in several sectors of essential technological applications. In addition of having superconducting properties, it is used to improve the strength of alloys, particularly at extreme temperatures. World production is dominated by CBMM. In 2020, for example, it supplied more than 90% of the niobium consumed in Brazil and met between 75% and 80% of world demand.

The CBMM mine operates on the alkaline-carbonatitic complex named Barreiro which is part of the Alto Paranaíba Igneous Province (Almeida 1983). Besides the Barreiro carbonatitic complex, there are several other carbonatitic intrusions with variable areas, between 15 km² and 65 km², circular to oval shape and crosscut in Neoproterozoic metamorphic rocks of the Brasília Belt. They are called Serra Negra, Salitre I, II and III,and Tapira.

From a genetic point of view, they are associated with ultrapotassic alkaline magmatism, composed of varying proportions of rocks from the bebedouritic, phoscorite and carbonatitic differentiation series. The evolution of these rocks starts from primitive magmas of kamafugitic affinity under the action, in different proportions, of liquid immiscibility and/or fractional crystallization (Brod et al. 2004).

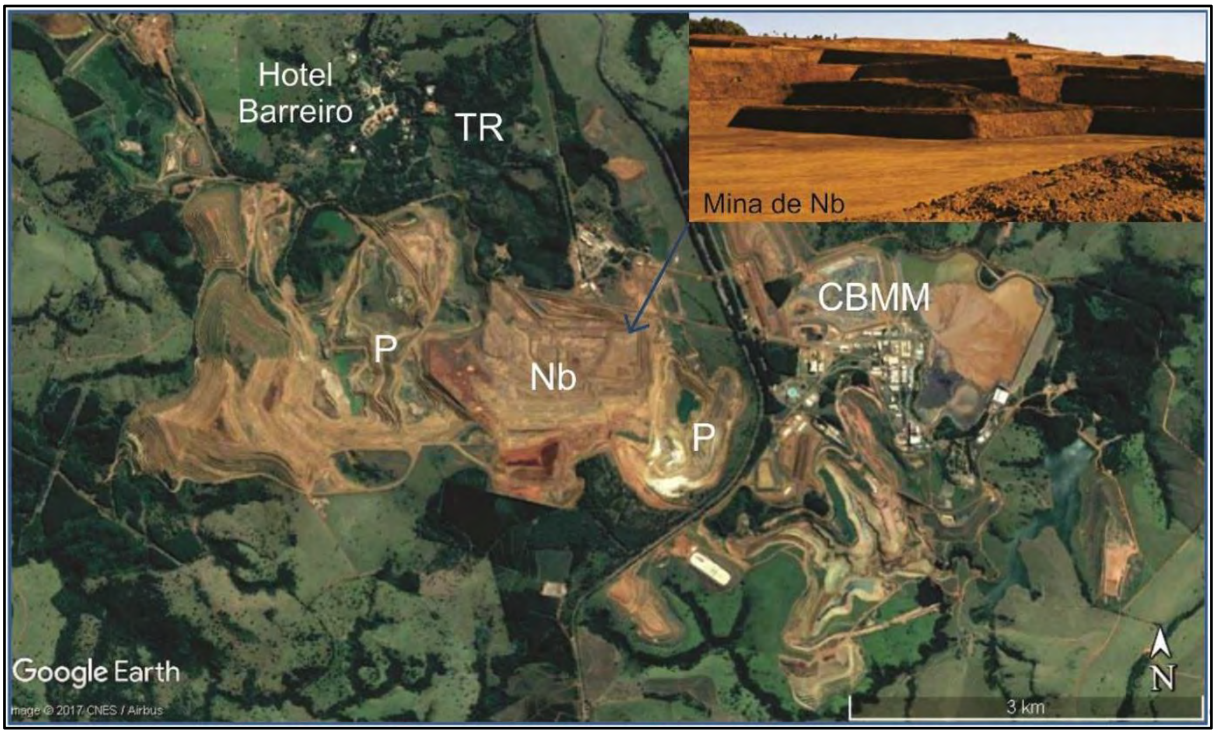

Figure 6: Satellite image illustrating part of the area occupied by phosphate (P) and niobium (Nb) mining in the Barreiro Alkaline-Carbonatitic Complex, with emphasis on the CBMM (Map data: Google, Google Earth, CNES/Airbus).

The Araxá Alkaline-Carbonatitic Complex is one of the most important in the world due to the mineral resources it contains. The niobium deposit was developed on dolomite carbonatite and phoscorite rich in baryopyrochlore, in the central portion of the structure, composing a circular area with a diameter of 1,800 meters. It stands out for being the world's largest niobium reserve, reaching 461.75 Mt of ore with 2.5% Nb2O5 on average (CODEMGE, 2018).

The carbonatites are mainly dolomite carbonatite, with subordinate calcite and ankerite, as well as barite, apatite, magnetite, perovskite, phlogopite, pyrite, amphibole sodium, isokite, strontianite, and baryopyrochlore. The geological map shows the effect of magmatic fluids on the host rocks of the complex, producing a phenitization halo –phenitized quartzites and phenitized schists – that can reach 2.5 km in width (Figure 7 - A). The original rocks are completely transformed by the leaching of soluble elements, by the accumulation of iron in the form of laterites and by the concentration of minerals resistant to alteration. This process led to the formation of mineral deposits and was so intense that the weathering profile can reach 250 meters depth.

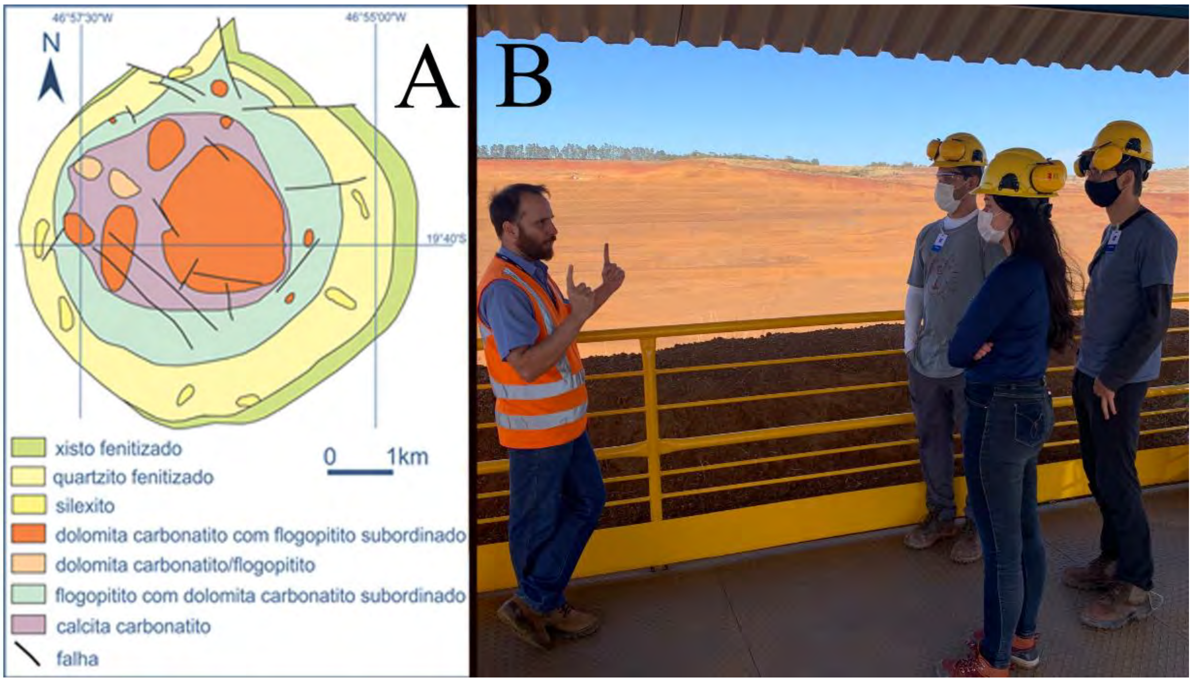

Figure 7: A – Geological map of the The Araxá Alkaline-Carbonatitic Complex; **B** – Lecture by a CBMM geologist employee.

The phosphate deposit is also significant, with reserves of 460 Mt of ore, and an average content of 15.07% P2O5, in the form of apatite. Barite reserves – ranging from hydrothermal veins, disseminated ore and concretions of supergenic origin – add up to 463 Mt of ore reserves with an average content of 20.67% BaSO4. The values of the Rare Earth reserves are not yet available, but it is known that the presence of silexite veins rich in monazite and disseminated monazite is significant in the Barreiro Carbonatitic Complex.

5.3. 3th DAY: TUESDAY, July 19

On our third day of fieldtrip, we visited Mosaic Mine which is located Alto Paranaíba region, this deposit was acquired by Mosaic in the year of 2016 and is the largest sedimentary phosphorite deposits in Brazil (Figure 8). This deposit is located between the cities of Patos de Minas and Presidente Olegário.

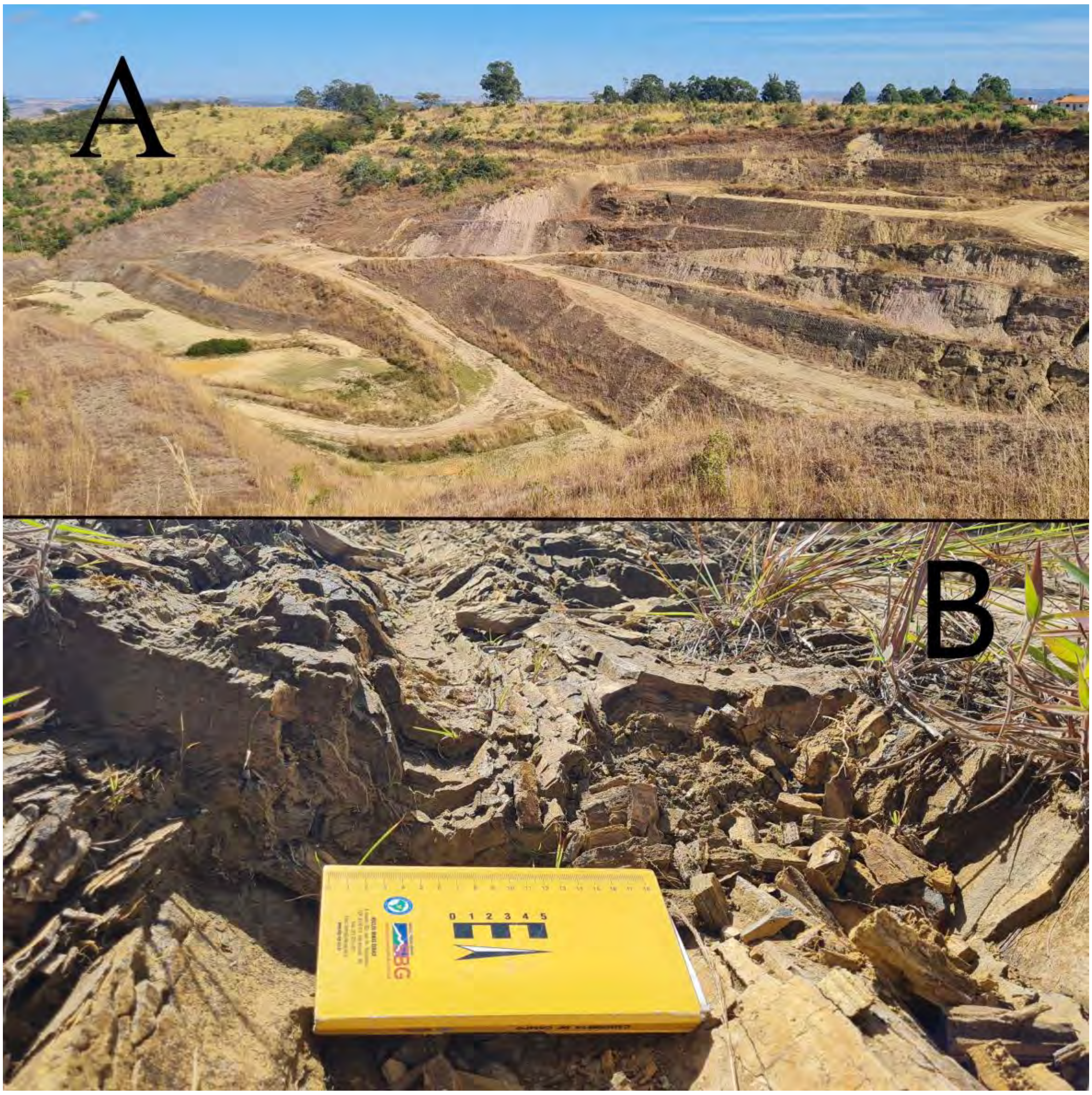

Figure 8: A – Photo of the open pit mine; **B** - apatite rich levels with approximately 5 cm of thickness (dark brown) and barren metasiltites.

The ore body mined by Mosaic is related to the Rocinha Formation, part of the Mesoproterozoic Vazante Group. The Vazante group is mainly composed by metapelites (slates) and meta-dolomites, which host the widely known mineral deposits of Vazante (Zn), Morro Agudo (Zn-Pb) and Lagamar (phosphate). In the Precambrian, phosphorites were deposited in very shallow waters in continental margin environments or continental seas (Riggs 1986). These could be enriched in phosphate by bacterial contribution from reef environments and/or iron oxides under anoxic conditions that would aid in the precipitation of apatites (Föllmi, 1996).

Currently, the Rocinha Mine is not in operation due to a strategic reorganization of Mosaic Company. However, taillings with approximately 10% of P2O5 is being sold on the local market, which, in turn, helps in the decommission process of local tailing dams. During regular operations, the beneficiation plant from Rocinha Mine produces 7 varieties of fertilizers (Figure 9. Our visit was conducted by Guilherme Giorgi and Kliver Peixoto Santos, the latter of which is an UFOP geologist alumnus (Figure 10).

Figure 9: Photo of the 7 varieties of fertilizers that Mosaic sells to agroindustry.

Figure 10: Chapter members in front of the phosphorite mine and Mosaic employees, Guilherme and Kliver.

5.4. 4th DAY: WEDNESDAY, July 20

On this day, we traveld to Paracatu, where a important gold mine operated by Kinross is located. During this trip, we made several stops aiming to locate some kimberlites, which coordinates are available in the website of the Brazilian Geological Survey (CPRM). We were sucessful to find two outcrops of ultramafic volcanic rocks, on of which presented several limestone xenoliths incorporated from the host geological units. The presence of these xenoliths in this kimberlite produced an uneven surface caused by the diferential erosional process (Figures 11, 12 and 13).

Figure 11: Ultramafic volcanic rock (Kimberlite) with limestone xenoliths.

Figure 12: Ultramafic volcanic rock (Kimberlite) with strong magnetism.

Figure 13: Limestone xenoliths reacting with the acid (HCl).

5.5. 5th DAY: THURSDAY, July 21

On the last and final day of the field trip, we visited the gold mina known as Morro do Ouro operated by Kinross (Figure 14). The visit began with a historical contextualization of the gold exploration which began on the XVII century. Next, we visit the mine office, where we ere introduced to the mine staff, and then a diamond drilling rig. This drilling was part of a geotechnical investigation campaign with the purpose of slope stability analyzes. The slopes are 12 m high.

The gold mineralization is hosted in a regional sub-horizontal thrust fault (Córrego Rico Fault) which crosscut the Paracatu Formation, a Mesoproterozoic stratigraphic unit is formed by carbonaceus philites. Boudinaged quartz vein control the gold mineralization, which is commonly associated to arsenopyrite, chalcopyrite, galena, pyrite and others sulfides (Figure 15). The mineralized hydrothermal fluids percolated the Córrego Rico Fault zone, which presents a ENE-WSW trend and is laterally limited by E-W to NE-SW late faults. The Paracatu Formation was tectonically transported over the Vazante Formation during the Neoproterozoic Brasiliano Event, which promotated the gold depois formation.

Regarding the technical activities performed by the geological staff, we had the opportunity to get to know part of the sampling process, application of QA-QC, geological mapping of mining fronts and part of the geological modelling process.

Figure 14: Kinross Gold Mine – Morro do Ouro – Paracatu.

Figure 15: Gold grain associated to quartz boudin found on a drill core sample – Mina Morro do Ouro, Paracatu.

At the end of the day, we had a barbecue at the house of one of the geologist of Kinross, who warmly welcomed us.

5.6. 6th DAY: FRIDAY, July 22

During this day we traveled by car 600 km back to Ouro Preto.

6. FINANCIAL REPORT

The expenses of this field trip are related to vehicle rental, accommodation, materials required for lectures and field activities, totaling the amount of US$880.78. All structure, logistic and hosting of the SEG SC members was planned to cost as low as possible, without jeopardizing the quality of the field trip. The participants were responsible for their own meals, so there was no cost for food. Dollar was quoted at R$4.58 by the donation time, totalizing a total amount of R$3.667,56. Therefore the Chapter financed $80,78 to support the field trip costs. Below follows a detailed description of incomes and expenses.

Income		
Stewart Wallace Fund - bank tax	R$ 3.667,56	$800,00
UFOP SEG SC contribution	R$ 366,39	$80,78
Total	**R$ 4.033,95**	**$880,78**
Expenses		
Accommodation for field participants	R$ 1.569,20	$342,62
Car rent and fuel	R$ 2.464,75	$538,16
Total	**R$ 4.033,95**	**$880,78**

Table 3: Description of incomes and expenses.

7. ACKNOWLEDGMENTS

UFOP SEG SC is deeply thankful for the all the institutions, companies and people who helped to make this field trip possible, specially to:

- SEG International financial contribution through the Stewart Wallace Fund;
- Professor Emilio Urbano for the lecture and field guidance;
- Professor Edson Tazava, our mentor;
- CBMM for all the support in receiving the group at their mine and guidance;
- Mosaic Fertilizantes for all the support in receiving the group at their mine and guidance;
- Kinross for all the support in receiving the group at their mine and guidance;
- UFOP and the School of Mines for the support;
- All the participants who took part on the field trip.

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