UNESP SEG - STUDENT CHAPTER

FIELD TRIP REPORT 2022

Goiás, Brazil

FIELD TRIP 2022

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Introduction

This field trip, promoted by the SEG UNESP Student Chapter, took place from August 28th to September 6th, 2022, having as destination different municipalities in the northern part of the State of Goiás, Brazil. The main objective of this field trip was to visit some companies in the mining industry, in order to get to know and deepen the concepts and practices that involve the knowledge of economic geology applied to mining, linked not only to the geology of exploration, but also to the geology of the mine, production and metallurgy. Furthermore, the itinerary also included a touristic part heading to the Chapada dos Veadeiros National Park, an important bioconservation unit of the Brazilian Cerrado, which was declared Natural Patrimony of Humanity by UNESCO in 2001.

The script was organized in 2020 but due to the COVID-19 pandemic it had to be postponed. In May 2022, we started contacting the companies via e-mail and whatsapp, to schedule the visit. We need to send the personal documents, the results of the COVID test and other information.

The trip began in the early morning of August 28, with the group leaving from the city of Rio Claro, São Paulo. Departing Rio Claro by the Anhanguera Highway (SP-330), we drove to the city of Uberlândia, in the state of Minas Gerais. In Uberlândia, we took an access road to the Transbrasiliana Highway (BR-153), by which we drove to our destination, the city of Uruaçu, in the State of Goiás. We arrived in Uruaçu at about 6:00 pm, a total of 16 hours of travel.

The six-day stay in Uruaçu was strategically chosen to facilitate the commute each morning to the other cities we visited. This is because this city is centrally located in relation to the visiting destination cities, which are located nearby Uruaçu. Besides the question of strategic location, we also took into consideration the easy access to the highway that took us to all the visited cities.

The first day of the field trip, August 29, began with a visit to Lundin Mining's Chapada Mine, which operates in the copper and gold exploration area of Alto Horizonte - GO. On the second day of the trip, August 30, we did a field work in the vicinity of the Chapada Mine, recognizing in outcrops some of the lithotypes of the local geology. On the third day, August 31, we visited the Pilar Mine of Pilar Gold Inc., in Pilar de Goiás - GO.

The fourth field day, September 1st, was dedicated to visiting Anglo American's Barro Alto Mine, which operates extracting lateritic nickel in Barro Alto, GO. On the fifth day, September 2nd, we visited AngloGold Ashanti's Serra Grande Unit, which operates in gold exploration in underground mines, in Crixás - GO. Finally, on the sixth and last field trip day, September 3nd, we went to Campos Verdes (GO) to visit some places that work with emerald mining (gold-digging) and commercialize this ore.

The next two days (September 4th and September 5th) were reserved for the geotourist part of the trip. At this stage of the trip we stayed in the city of Alto Paraíso de Goiás - GO, which is located in the Chapada dos Veadeiros. On the first touristic day we went to Vale da Lua to observe the conglomerates of the Paranoá Group. On the second day, in the morning, we hiked to the “Mirante da Janela”, and in the middle of this hike we saw some quartz crystal extractions; in the afternoon we went to the “Catarata dos Couros”.

The field trip ended on September 6th, and the return to Rio Claro began at 2:00 a.m. on the same day, leaving from Alto Paraíso de Goiás. Leaving this city, we headed towards the city of Brasília - DF, where we made a brief stop. Leaving Brasília via the BR-040 highway, we continue until the city of Cristalina - GO, from where we take the BR-050 highway. On this highway we followed all the way to the state of São Paulo. Once in São Paulo, in the city of Araras - SP, we took a road that leads to Rio Claro. We arrived at UNESP around 7:30pm on September 6th.

Day 1 - August 29

Chapada mining, Alto Horizonte (GO) - Lundin Mining

<u>Guides</u> Geologists: Tais Pian, Letícia Kwong, Filipe Machado and Juliana Monteiro
Geologists intern: Ana Flávia Araújo, Bruna Sampaio and Julio Neto
<u>Schedule</u> 8am - 4pm

The first company to be visited by the group was Lundin Mining, located in Alto Horizonte - GO. The visit started around 8 am, when we met with Taís Pian who accompanied us throughout the visit.

At the entrance of the company, we received guidance on what our walk would be like and we also watched a safety video, where all the information and alerts were passed on how to act within the operation and the precautions that must be taken in order to keep the environment safe.

Then we went to the meeting room to watch a presentation on the geology of mining and how the mineral discovery cycle works. Here, mineral exploration concepts such as Greenfield and Brownfield were addressed. Other very interesting topics that were addressed also concern mine geology, project design and planning, whether short or long term.

After geological contextualization of the mine, we went to the shed where the holes for all operations are located. A previous explanation was provided by Taís so that we could understand the drill cores of the mineralized layers and how these samples are described. In addition to telling us how the day-to-day works in the company.

The mine was built in 2007 by Yamana Gold and in 2019 Lundin bought it from Yamana. They discovered these occurrences by soil sampling and another prospective guide are the kyanitites hills (in the region of Mara Rosa Arc).

The Cu-Au occurrence

The Chapada Mine is an open pit copper-gold mine and the sulfide mineralization is hosted in a structural, metamorphosed and deformed system with ore grades and mineralogy comparable to porphyry/skarn copper deposits. These rocks are part of the Mara Rosa Magmatic Arc from Brasília Belt.

The main rocks that occur in this region are orthogneiss, metavolcanic and metasedimentary (Mara Rosa sequence); late intrusives and mafic metavolcanics and metatuff as host rocks. The main fault that occurs in this region is the Rio dos Bois fault from Campinorte Sequence.

The copper mineralization of the Chapada and Sucupira deposits is mainly chalcopyrite with small amounts of bornite spread and/or folded. Copper content is highest in the central zone of the Chapada deposit along the anticline axis, although copper mineralization is widespread over a wide area. Gold occurs associated with sulfide mineralization and is also spatially uneven, which reinforces the idea that it has been remobilized by low-temperature change events. The copper content is approximately 0.24.

Regarding the geology of the mine, there are a total of 6 operations that occur as a result of a metamorphosed porphyry deposit (Au-Cu-Ag), formed during the Neoproterozoic (0.88 Ga). It is estimated that from 900 to 770 Ma, the porphyry and the mineralization was formed; from 770 to 750 Ma the plates collided that caused the metamorphism in the amphibolite facies; from 635 to 625 Ma the Rio dos Bois fault was formed and triggered the greenschist facies; and at 625 Ma the configuration of domes and basins was formed. The porphyry system was altered hydrothermally and the evidence are the potassium, sericitic and clayey alterations that they find in the rocks.

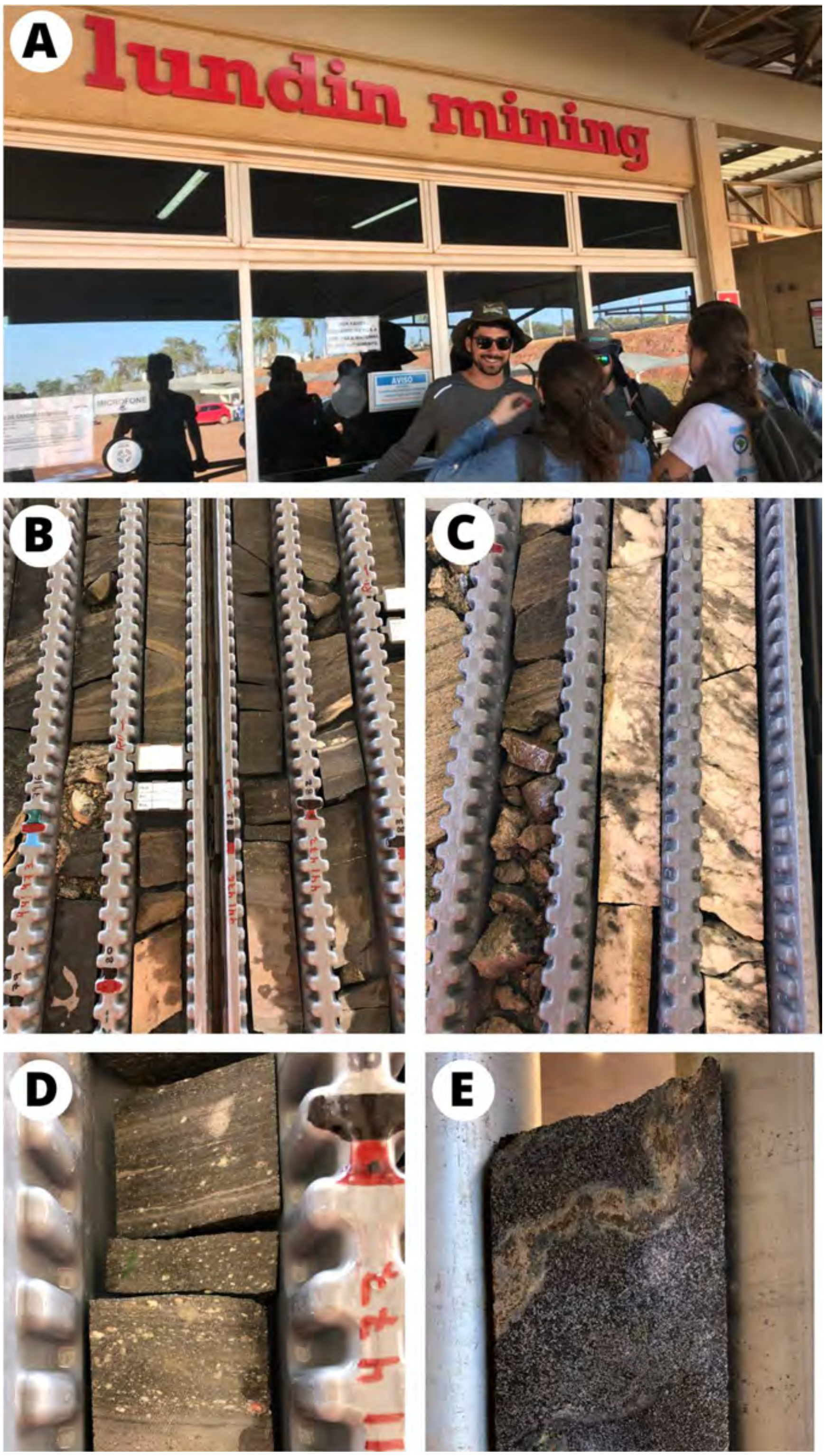

Fig. 1: A: Photograph taken by the group at the entrance of the company. B, C. D, E: drilling cores of mineralized layers.

Day 2 - August 30

Fieldwork near Alto Horizonte (GO) - Lundin Mining

Guides Geologist: Tais Pian
Geologist intern: Julio Neto
Schedule 8am - 2pm

On the morning of the second day, we continued our visit to Lundin Mining, this time in an external field activity, in the vicinity of the Chapada Mine operations area. Upon arrival at the site, the individual protection equipment necessary for the activity was delivered by the geologists who accompanied the group. There, we made a brief field, climbing to the top of a hill to observe in outcrops some of the lithologies that are part of the local geology of the mine. We were able to recognize some metamorphic rocks from the hydrothermal alteration zones, such as hydrothermalite. Some samples were collected. These hydrothermal rocks that we observed were the same used as guides in the prospect that gave rise to the exploration of copper and gold ore in the region.

After this activity, we went to visit an old open pit mine in the municipality of Mara Rosa, which is now a deactivated and flooded pit. In this place we also observed some metamorphic rocks of hydrothermal alteration.

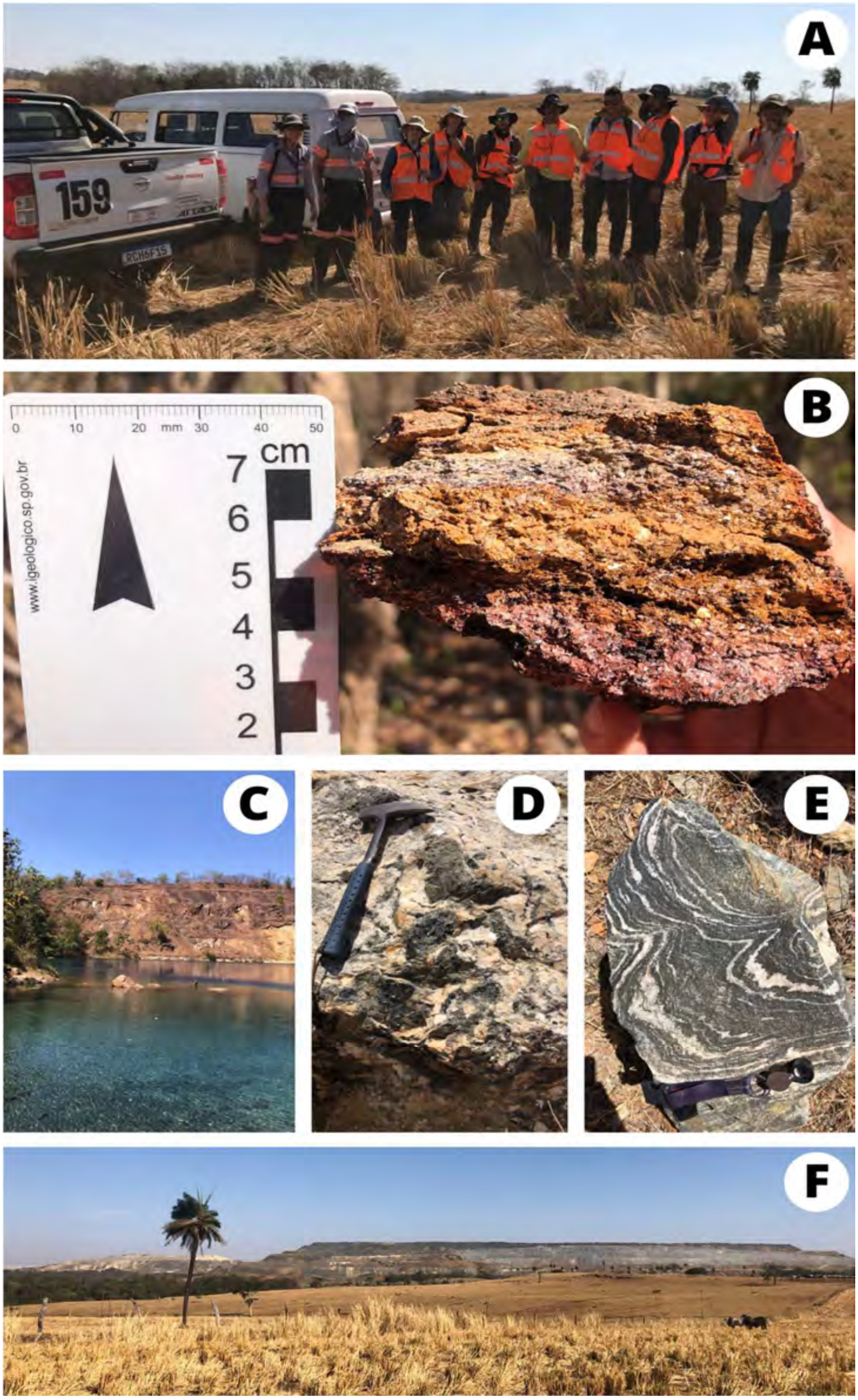

Fig. 2: Photos taken during the external field activity. A **-** The group of students; B **-** Hidrothermalite sample; C **-** Deactivated open pit mine at Mara Rosa; D **-** Giant biotites concentrated by hydrothermal action; E **-** Gneiss; F **-** Distance view of Lundin Mining.

Day 3 - August 31

Pilar Gold mining, Pilar de Goiás (GO) - Pilar Gold

Guides Geologist: Roberto Cobra
Geologist intern: Isadora Munari and Jordanna Brenda
Schedule 8am - 4pm

On the third day of the trip, we left Uruaçu - GO at 7 am to Pilar de Goiás - GO. The visit started at 8 am, and we were greeted by intern Isadora Munari, who introduced herself and led us to the visiting room, where we were introduced to intern Jordanna Brenda and geologist Roberto Cobra. All of them accompanied us throughout the visitation day.

In the living room, we were introduced to Vanessa, who showed us a video with safety and behavior guidelines during the visit. Then, Vanessa presented a video that showed the entire history of gold mining in the municipality of Pilar de Goiás, from its discovery in the 18th century, to the present day, with Pilar Gold.

Afterwards, Roberto Cobra and Jordanna Brenda made an introduction about the regional and local geological context in which the mine is inserted. There was also a presentation on the formation of the gold deposit in the region and a brief presentation of the underground mine.

After the presentations, we took a break for lunch and, after lunch, we went by minibus to the warehouse where Pilar Gold's drill cores are stored. The interns explained to us how the description of the drill cores is made and showed us some beautiful mineralized specimens, coming from different points of the mine.

After visiting the testimony shed, we went by minibus to the old mine, where it was possible to observe the entrance of some of the old galleries, through which the miners entered, before the area was required and protected by the mining companies.

The Au occurrence:

In the southern Goiás Archean Block, the Faina greenstone belt forms an elongated, NW-trending synform with, from the bottom to top, metamorphosed ultramafic, mafic and sedimentary rocks, culminating with chemically precipitated sedimentary rocks.

Five greenstone belts occupy the midwest portion of Goiás state. These greenstone belts are hosted in an allochthonous fragment of Archean, known as the Goiás Archean Block. The latter Archean crustal fragment was amalgamated during the Brasiliano/Pan-African orogeny onto the western margin of the Brasília fold belt. The belt comprises one of three fold belts of the Tocantins Province, formed during the Neoproterozoic convergence between the Amazonian, São Francisco-Congo and Paranapanema cratons.

The Goiás Archean Block comprises Archean TTG granite-gneiss complexes with inliers of Archean/Paleoproterozoic greenstone belt sequences and rare Neoproterozoic intrusion.

The gold ore explored by Pilar Gold is associated with the Archean Faina greenstone belt, in the southern Goiás Archean Block. The Faina greenstone belt consists of metasedimentary rocks unconformably overlaying metavolcanic rocks. The metasedimentary sequence is represented by detrital clastic rocks, with local carbonate lenses, overlain by pelites, followed by carbonaceous schist and banded iron formation (BIF).

The bulk of the gold is hosted in carbonaceous schist and banded iron formation and is controlled by a D_3 shear zones including gold-bearing shear veins and surrounding hydrothermally altered wallrocks.

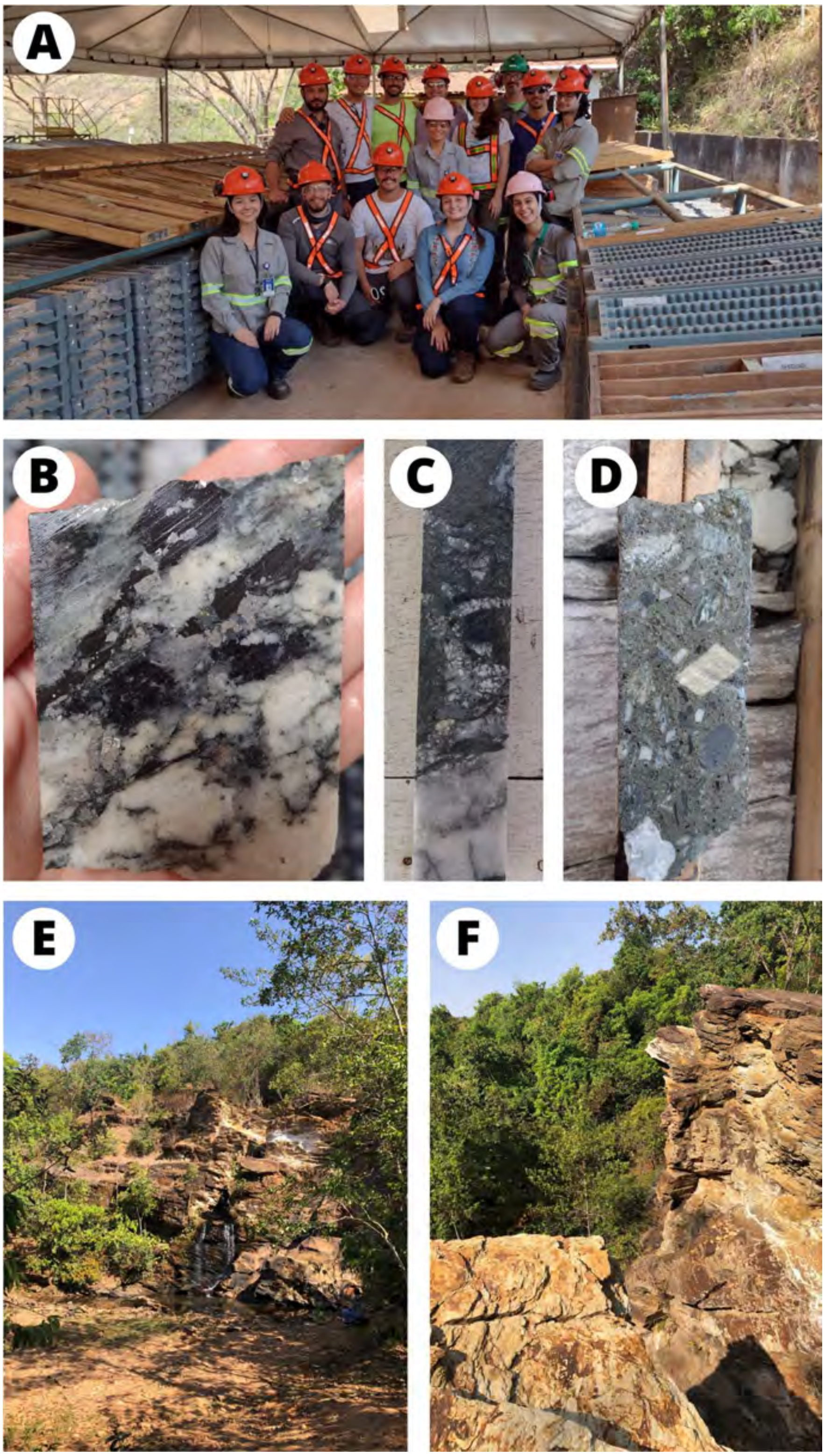

Fig. 3: Photos taken during the visit. A - The group of the students and the employees of Pilar Gold; B and C - Testimonies from drilling of rocks containing gold ore; D - Testimony from lamproite; E and F - Outcrops and waterfall with access to the old mining site.

Day 4 - September 1st

Barro Alto mining, Barro Alto (GO) - Anglo American

Guides: Geologists: Francisca Souza and Viviane Oliveira
Environment Engineer: Mariza Guerzoni
Production coordinator: Rafael Carias
Institutional relations and corporate affairs specialist: Cândida Bicalho

Schedule: 8am - 4pm

On the fourth day of the field trip, we left Uruaçu - GO at 7 am towards Barro Alto - GO. The visit started at 8 am, and we were welcomed by Candida Bicalho, who guided us throughout the day.

After the reception, we were instructed on the safety factors in force at the mine; the geologists explained some of the local geology; the mining engineer talked about the construction of the mine; the environmental engineer Mariza explained about the existing environmental problems and how to solve them; and Rafael introduced us to how Ni ore is processed.

After the instructions, the tour began, first going through the Anglo American Workplace Safety Museum. In the museum, it was possible to go through each work area of the Barro Alto operations, knowing the risks, correct norms of conduct and the personal protective equipment (PPE), necessary for each activity. The second point of visit was the mine office, where we could see a little of the work routine of geologists and engineers.

Afterwards, we went by van to the mine, passing the beneficiation plants, mining pits and stopping at a viewpoint to observe the mine. Before lunch, we stopped near the beneficiation plant to observe the calcining furnaces and also entered the operational control room of the beneficiation plant, where we learned how the processing steps are carried out. After lunch, we went to Anglo American's core shed, located in the city of Barro Alto, and the geologist could show us the drilling holes of the rocks that occur in the region of the mine.

Fig. 4: Photos taken during the visit. A - The group of students at the entrance; B - Calciner model at the Workplace Security Museum; C - Anglo American office in Barro Alto; D - Operational control room.

The Ni occurrence:

In the open pit mine of Barro Alto, is extracted lateritic nickel. The first discoveries of mineral occurrences in the region were made between 1930 and 1940 and the production of Fe-Ni alloy by Codemin (now Anglo American) started in 2011. The Barro Alto Ni deposit is part of the Brasília Belt and consists of one of the largest set of mafic-ultramafic layered rocks of tholeiitic affiliation in Brazil, with preferential NNE direction. The main composition consists of gabbros and norites which had supergene enrichment, forming lateritic Ni deposits. The geochemical models take into account the mobility of elements in the soil.

The Ni deposits form an arc with a concavity to the NW and present about 126 km long and 8 km wide to the north and 25 km wide to the center; the deposits are divided into 6 areas. At the pit they usually work with small equipment and the depth is low, but the lateral extension is large.

The cut grade of the mine is 1.4% Ni. The differentiation of Ni content is made between sterile, acidic and basic and this is estimated by geochemistry, aided by high precision GPS. Approximately 80% of the plant becomes slag, which has a greenish color due to the presence of chromium.

As a final product, the Fe-Ni alloy is produced through the Bulk Ore Sorter (BOS) enrichment process, whose main objective is to remove the sterile part; and the metallurgical process.

The main steps consist of: extraction and screening in the mine (and enrichment - BOS); then the metal is taken to the calciners, where the water is reduced; the very homogeneous material is taken to the electric ovens; and finally the alloy is dispatched via ports. The main customers are the producers of special steel and stainless steel.

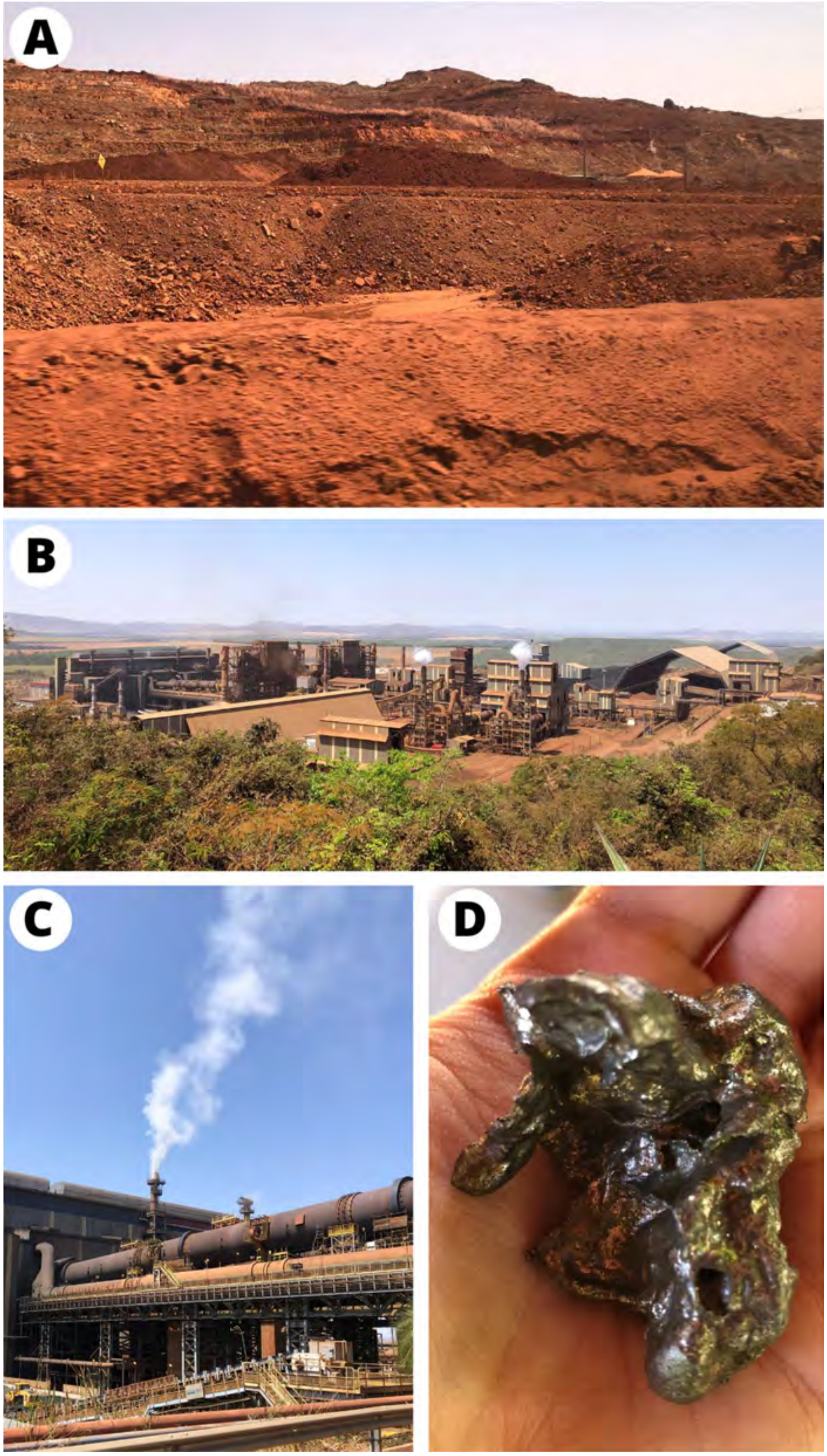

Fig. 5: A - Part of the mine visited; B - Processing plant seen from the viewpoint; C - The calciners; D - Final product to export = Nickel iron alloy pellets.

Day 5 - September 2nd

Serra Grande mine, Crixás (GO) - AngloGold Ashanti

Guides Geologists: Lucas Siqueira and James Schroeder
Schedule 8am - 4pm

On the fifth day of the field trip, we visited the Serra Grande Unit of AngloGold Ashanti, in the municipality of Crixás - GO. The visit began at 8 am at the reception, where we were welcomed by geologist Lucas Siqueira, who accompanied us throughout the day.

First, we received the company's uniforms with reflective strips and some of the PPE required to visit the underground mine. Next we went to a room where there was a presentation of the AngloGold Ashanti company and its Serra Grande Unit, which has three underground mines (Mine III, New Mine and Palmeiras), one open pit mine (Open Pit Body V) and a metallurgical plant. They were also given safety rules and instructions for the visit, in addition to a brief introduction to the local geology, which also covered the exploration and production geology. Afterwards, the rest of the mandatory PPE was distributed and the visit proceeded to the Underground Mine III.

The access to the Underground Mine III was made in a minibus, which went down the access roads towards the galleries. When reaching about 500 m underground, we stopped for 15 minutes to go down and get to know the structure of the gallery, as well as to recognize, with the help of geologist Lucas, the main features in which the gold ore is found. It was possible to see in the middle of the schist the many quartz veins that contain the gold ore. These veins present themselves in different thicknesses and directions. In this mine, the mining method is chambers and pillars, although the sublevel stoping method is already in use.

After the underground visit, we went back to the Unit. After lunch, in the afternoon, we started the second part of the visit, in which we got to know the poll testimony shed. There we got to know the structure of the place that stores these testimonies and saw some of these that were selected for characterizing the rocks that contain the ore. After some explanations by Lucas, the visit was concluded and we left the Serra Grande Unit.

The Au occurrence:

The gold ore explored in the Serra Grande Mine is hosted in rocks of the Crixás greenstone belt, which is inserted in the geological and geotectonic context of the Tocantins Province, more specifically in the portion of the Goiás Massif. The Goiás Massif (Barbosa et al., 1969) is composed of granite-greenstone belts of Archean age and Paleo-mesoproterozoic volcano-metasedimentary complexes and sequences.

The Crixás greenstone belt is characterized as a volcano-sedimentary sequence, named Crixás Group, elongated in N-NW and S-SE direction. Its lithotypes are divided in Córrego Alagadinho Formation, characterized by metakomatiites; Rio Vermelho Formation, with metabasalts; and Ribeirão das Antas Formation, represented by metasediments.

The mineralization found in Mine III, controlled by Structure III (low-angle thrust fault), is found in three distinct zones, and can be recognized as lenses of massive sulfides (Upper Zone) hosted in rocks such as carbonaceous shales and chlorite shales; in quartz veins (Lower Zone), being discontinuous and concordant to the foliation of the carbonaceous shales, submitted to hydrothermal alteration; or as disseminated ore (Intermediate Zone), being gold-rich zones hosted in the carbonaceous shales.

The Ore Body Ingá, also belonging to Structure III, is currently the main producing body of the mine. It is subdivided into two distinct mineralized zones: upper, where mineralization occurs in massive sulfide lenses hosted in dolomites; and lower, where auriferous mineralization occurs associated with a thick discontinuous quartz vein.

As for the grades at Mine III, the massive sulfide type mineralization consists of 12 g/t gold on average, while the quartz vein type mineralization averages 8 g/t gold.

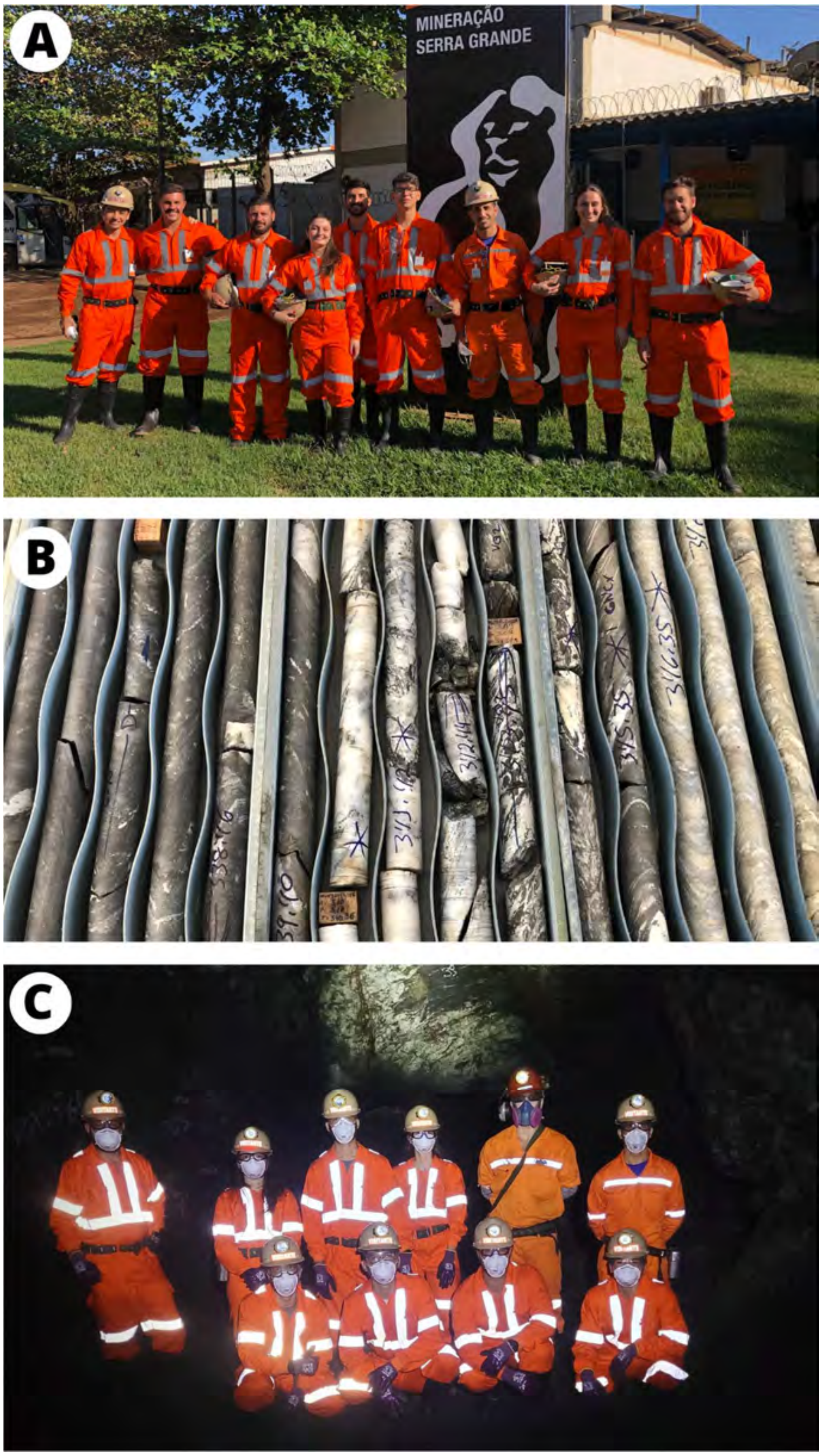

Fig. 6: Photos taken during the visit. A - The group of students at the entrance; B - Bore hole test samples from rocks containing gold ore; C - The group during the visit to the underground mine.

Day 6 - September 3rd

Emeralds, Campos Verdes (GO)

Guides Manager of the emerald extraction site: Tarcisio José
Emerald separation and customer salesman: Antônio Campos
Emerald polishers: João da Gama and Pedro Theodoro

Schedule 8am - 2pm

At 8am, the group arrived in the small city of Campos Verdes - GO and went to the emerald separation site. We were received by the owner Antônio, who accompanied us during the visit. He explained the entire "picking" process, in which he manually selects emerald crystals from a pile of crushed stone to send to the polishers.

At 10:30am, the group arrived at the talc-schist exploration site and the manager Tarcisio received the students. The talc-chlorite schist is the rock where the emerald crystal occurs in the Santa Therezinha Sequence, a low metamorphic grade rock, whose mineralization is controlled by the surrounding rocks, as the São José do Alegre granite. The first formed mineral is beryl, but with the inclusion of $Cr2+$, from the metamorphosed basic-ultrabasic rocks, on its inner structure, it receives the name of emerald, according to Lariucci (1990). The underground mine is accessed by the employees through a schaft system and the ore comes to the surface using that system as well. Then the ore is classified using a sampling method, and priced by its emerald inclusions.

The group arrived at the emerald polishing site at 1 pm, where we were met and guided by João da Gama and Pedro Theodoro. First, they introduced a little about the polishing technique and then showed the group the equipment used in the whole process, such as the wooden sticks that hold the emerald; the polishing discs, which have diamonds on their surface to "cut" the gems, and the disc used to polish the piece. They then showed the group the final results and discussed how the pieces are traded.

Fig. 7: A - Piles of emerald ore; B - Emerald before "picking" process. C - Emerald selected by the "picking" process; D - Antônioshowing the process to the students; E - João da Gama polishing the emerald pieces; F - Talc-chlorite schist sample.

Day 7 - September 4th

Vale da Lua, Alto Paraíso de Goiás (GO)

Schedule 2pm - 5pm

On Sunday, SEG visited the Vale da Lua (Moon Valley), a very traditional tourist spot located at Alto Paraíso de Goiás - GO. The place gets its name due to the characteristics of the surface, forming circular and smooth erosion where the river passes.

Ribeirão São Miguel Formation is the major rock group that occurs at that place. This Formation is composed by matrix-supported conglomerates, with sandy matrix and carbonate cements. The clasts are made of fine or medium quartzite, fine marble, and metasiltite, with diameters ranging from millimeters to decimeters, and blocks of up to 1 meter.

The Vale da Lua rocks were buried and subjected to an increase in pressure and temperature, being metamorphosed and cemented by calcite precipitation. The presence of the matrix with calcite facilitates the dissolution of the rocks forming the "pans" that give the "lunar" appearance.

The relief is formed by the meeting of Paranoá Group (base) and the Traíras Group (represented by the Chapada dos Veadeiros National Park) and the Vale da Lua was formed between these groups.

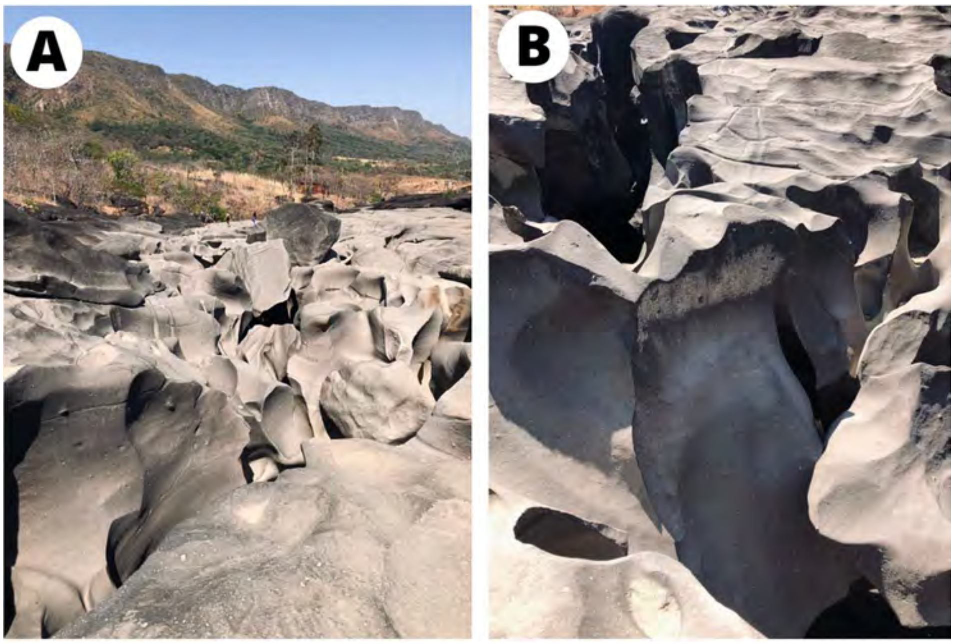

Fig. 8: Matrix-supported conglomerates, from São Miguel Formation.

Day 8 - September 5th

Quartz extraction, Alto Paraíso de Goiás (GO) and Couros Waterfall

Schedule 9am - 12am and 2pm - 6pm

The last day consisted of a visit to a village formed by ex miners. At the site, the old entrances to the galleries where the ore was removed were seen. The main occupation of the people of Vila de São Jorge was the mining of quartz rock crystal, manually extracted with rudimentary tools, seeking survival and social and economic reproduction. In addition, a 6km trail was carried out along the outskirts of the national park. During the trail, several waterfalls and quartzite outcrops were observed.

According to Barbosa (2008), the crystal gained value in the international market, especially in the period between the first world war and the Korean war. The ore was used as raw material for radio transmitters and land mines, equipment for military use, attracting successive waves of prospectors to Chapada dos Veadeiros, giving rise to several villages.

In the afternoon, a waterfall belonging to the river "Rio dos Couros" was visited. This waterfall runs in metasedimentary rocks belonging to the “Faixa Brasilia” event. It is also inserted in the eastern portion of the Tocantins Structural Province, of Neoproterozoic age.

The main rocks that occur in that place are yellowish quartzites, fractured by many faults that give rise to the waterfalls. The place is used as a tourist spot in the region, attracting many people from all over the country. Although abundant, there is no history of quartzite exploration.

Fig. 9: A - Morro da Baleia (Whale Hill), composed by quartzites; B - Old mine at São Jorge village; C - Quartz crystal taken from ancient mines; D - Couro's Waterfall; E - Mirante da Janela, an outlook from the Chapada dos Veadeiros National Park; F - Faults that give rise to the waterfalls at Couros Waterfall.

Financial Report

Due to the COVID-19 pandemic, this field trip that should have happened in 2020, was postponed until august 2022. We were mostly sponsored by the SEG "Stewart R. Wallace Fund", that gave us 1250 $; and the "Institute of Geosciences and Exact Sciences" from UNESP (IGCE), that provided a vehicle from the university (kombi) and daily for a teacher to accompany us. The food was considered a personal expense.

The total field expenditure was R$ 7.639 = US$ 1488,31, detailed at Table 1.

FINANCIAL REPORT - Goiás Field Trip		
EXPENSES	**R$ (BRL)**	**$ (USD)**
Accomodation (for 9 people per 9 nights)	4.020	860,17
Fuel	2.980	628,14
Total Expenditure	7.639	1488,31
FINANCIAL SUPPORT	**R$ (BRL)**	**$ (USD)**
SEG/Stewart R. Wallace Fund Grant	5.579	1250
Vehicle and tolls	IGCE - UNESP	IGCE - UNESP
Contribution from SEG UNESP Members	2.060	238,31

Table 1: Total expenses and financial support. When we received the funding from SEG (2020), with a total amount of US$ 1250,00, the exchange rate from dollar to real was US$ 1,00 = R$ 4,46. When the field trip occurred, the exchange was US$ 1,00 = R$ 5,40.

ACKNOWLEDGEMENT

We are grateful for the financial support from SEG Stewart R. Wallace Fund, that helped us with 1500 dollars.

We also thank IGCE for providing us with the vehicle used during the trip and for allowing a teacher to accompany us.

Finally, we would like to thank the companies that welcomed and provided us with so much knowledge.