SEG STUDENT CHAPTER

Escuela Politécnica Nacional
(Quito - Ecuador)

September 24\textsuperscript{th} – September 28\textsuperscript{th}, 2018
International Field-Trip Report
Medellín – Chivor, Boyacá, Colombia

PREPARED BY
ALEJANDRO PASQUEL, SANTIAGO ALMAGOR, ERICK GUERRERO & ROMEL AMANTA
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**Sumary**

The SEG Student Chapter – National Polytechnic School, organized an international fieldtrip to visit Gramalote and Quebradona deposits in Medellin, Colombia and the Esmerald mines in Chivor, Boyacá. The field trip took place during September 24th through 28th of 2018. Fifteen people participated in the field trip including eleven students of geological Engineering of Escuela Politécnica Nacional of Quito Ecuador, and four geologists of the mining and exploration industry. The financial support for the students was provided by Stewart R. Wallace Funding.

The personal of the mining companies visited gave us an induction where they explained to us the geological and ore deposits settings. In Quebradona and Gramalote deposits we were able to review and analyze the cores of intrusive bodies with their principal mineralization also we could identify the mineral association and the rock textures. In Esmerald mines we could learn all the geochemical processes occurred in the mineralized series. The field trip was very important to better understand how intrusive systems work, their alterations and their mineralization.

**Figure (1).** Quebradona project. Left to right (first line): Anglogold Ashanti worker, Anglogold Ashanti worker, Anglogold Ashanti worker, Santiago Almagor (EPN), Mayelin Cabascango (EPN), David Cadena (EPN), David Lopez (EPN), Erick Guerrero (EPN), Luis Navarrete (Cornestone), Milton Gonzaga (Soldgold), Diego Vinueza (Cornestone), Patricio Aguilar (G.M. Buenaventura), Alejandro Pasquel (EPN), Michel Toro (EPN), Juan Pablo Noriega (Anglogold Ashanti worker), Anglogold Ashanti worker. Left to Right (Second Line): Alejandro Chavarria (EPN), Belén Vela (EPN), Jhonny Lozada (SEG-EPN Student Chapter President).
1. Introduction

Objectives

- Acquire specific field experience and new skills for field exploration of porphyry deposits and intrusions related gold system.
- Visit different types of deposits to know their main characteristics and apply it within the mining industry.
- Provide facilities to students to access big projects.
- Access to geological information that allow us to conduct studies in ore deposits.

Participants

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<tr>
<th>Name</th>
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<tbody>
<tr>
<td>Mayelin Cabascango</td>
<td>SEG Student Chapter - Escuela Politécnica Nacional</td>
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<td>Jhony Lozada</td>
<td>SEG Student Chapter - Escuela Politécnica Nacional</td>
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<td>Alejandro Pasquel</td>
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<td>Romel Amanta</td>
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<td>Michel Toro</td>
<td>SEG Student Chapter - Escuela Politécnica Nacional</td>
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<td>Santiago Almagor</td>
<td>SEG Student Chapter - Escuela Politécnica Nacional</td>
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<td>Escuela Politécnica Nacional</td>
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<td>David Cadena</td>
<td>SEG Student Chapter - Escuela Politécnica Nacional</td>
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<td>Milton Gonzaga</td>
<td>SoldGold</td>
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<td>Edgar Aguilar</td>
<td>Grupo Minero Buenaventura</td>
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<td>Luis Navarrete</td>
<td>Cornerstone Resources</td>
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<td>Diego Vinueza</td>
<td>Cornerstone Resources</td>
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Itinerary

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<th>Night at</th>
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<tr>
<td>Monday, September 24th, 2018</td>
<td>17h00</td>
<td>First meeting at Bolivariano Plaza hotel (logistic issues)</td>
<td>Medellín</td>
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<td>Tuesday, September 25th, 2018</td>
<td>All day</td>
<td>Visit to the Quebradona mine</td>
<td>Medellín</td>
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<td>Wednesday, September 26th, 2018</td>
<td>All day</td>
<td>Visit to the Gramalote mine</td>
<td>Medellín</td>
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<td>Thursday, September 27th, 2018</td>
<td>9h00 – 10h00</td>
<td>Visit to the museum of mineralogy of Medellín</td>
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<td>11h00 – 16h00</td>
<td>Travel Medellín – Chivor, Boyacá</td>
<td>Chivor, Boyacá</td>
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<td>Friday, September 28th, 2018</td>
<td>8h00 – 17h00</td>
<td>Visit to the Emerald mines</td>
<td>Chivor, Boyacá</td>
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<td>20h00</td>
<td>End of field trip</td>
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2. Geological Settings

The geological settings we will analyze three different zones. Quebradona is a project which is located in the Middle Cauca river region and it appears between the Central and Western Cordilleras of the Colombian Andes. The Cambia Formation comprises a large part of the local geology of Quebradona, which is about volcanosedimentary rocks of the late Miocene, which are intruded by hypabyssal intrusives and breccias similar age (Fig. 2). (Pujol N. et al., 2012).

![Geological map of the Quebradona area, from Leal-Mejia 2011, in Pujol N. et al., 2012](image)

The Gramalote project is located in the northern part of South America, in the Central Cordillera of Colombia, between the Magdalena Valley to the East and the Cauca-Patia Graben to the West. It has been exploited discontinuously in shallow workings since pre-Colombian times. The Antioquia batholith is the host rock of Gramalote Au deposit. The area of this intrusive is 7200 km2 (fig. 3), and composes the core of the Central Cordillera at the Antioquia Department (Gonzalez, 2001). The Antioquia Batholith is constituted by tonalites and granodiorites and two subordinate rock types: granodiorites to quartz–monzonites and gabros. The host rock composition of the Gramalote Deposit is restricted to a narrow area in the tonalitic composition field (Rodriguez, 2009), which is composed by 40 to 60% of cuarzo, 30 to 50% of plagioclase and 10% potassic felderspat. In the zone even tough has been recognized dioritic dikes (fig. 3).
The **Emerald deposits** are located in the Eastern Cordillera, within two narrow bands on the west side (western zone, Muzo and Coscuez deposits) and on the east side (eastern zone, Chivor and Gachalá deposits). The Eastern Cordillera is considered to have acted since the middle Miocene (Andean phase) as a fold and thrust belt, squeezed between and thrust over its two foreland basins, the middle Magdalena basin to the west and the Llanos basin to the east (Branquet et al., 1999). Our study area is the east side specifically the Chivor area. In the east side there is sedimentary series, corresponds to the upper part of the Guavio Formation (Berriasian), which unconformably overlies the Paleozoic basement and is overlain by the shales of Valanginian Macanal Formation (Branquet et al., 1999) (fig. 4). The series hosting the emerald bearing veins and the hydrothermal breccias are composed of, shales and siltstones, stratiform brecciated level largely made of hydrothermal breccia, an albitized and carbonatized sequence and shelly limestones grading vertically and laterally into black shales (Branquet et al., 1999).
3. Gramalote gold deposits

The Gramalote project is located in San Roque, in the Department of Antioquia, in the northern Central Cordillera of Colombia, between the Magdalena Valley to the East and the Cauca- Patía Graben to the west, 230 km NW of Bogotá and 80 KM of Medellin (fig. 5).

The Central Cordillera is built on a Pre-mesozoic polymetamorphic basement which consists largely on a Paleozoic metamorphic belt of continental and oceanic origin. This basement also includes isolated Precambrian remnants and is intruded by numerous Mesozoic batholiths and stocks (McCourt, 1984) in (Rodriguez, 2009).

Plutonism in Colombia present five events of plutonic activity. These are Triassic (c.240-210 Ma), Jurassic (c. 200-140Ma), Cretaceous (c. 125-70Ma), and two Tertiary (c.60-30Ma and 30-0 Ma) events. Recent U-Pb dating in magmatic zircon (Ibañez-Mejía et al. 2007; Ordoñez et al., 2007) restricted crystallization ages of the Antioquia Batholith to a spam between 76 ± 2 and 88.5 ± 0.6 Ma. In addition, AngloGold Ashanti Colombia Ltd. performed U-Pb in magmatic zircon analyses in host rocks of gold occurrences in the Antioquia Batholith, obtaining similar crystallization ages of 79.5 ± 1.3 Ma (La Floresta de Yolombo) and 87.4 ± 1.3 Ma (La Maria sector, in Gramalote) (fig 6). Additional U-Pb zircon analyses of Gramalote host rock in selected drill-cores and surface samples yielded the youngest crystallization ages obtained for the Antioquia Batholith, in a well constrained spam between 59.2 ± 1.2 and 60.7 ± 1.0 Ma, (Rodriguez, O. 2009).
The Antioquian Batholith has a trapezoidal shape, with a maximum north-south extension of 110 km and maximum width of 80 km. It is located between two important regional fault systems: the San Jerónimo (to the west) and Otú-Pericos (to the east), intruding Paleozoic low to medium-grade polymetamorphic rocks of the Cajamarca Complex (Feininger et al. 1972).

According Rodriguez, O. (2009), the deposits of Gramalote is hosted by medium to coarse grained tonalite and granodiorite comprising the main phases of the Antioquian Batholith, which occupies an area of ca. 7800 km$^2$. In general the batholith is crosscut by dykes of aplite, k-spar-quartz pegmatite, porphyritic granodiorite and fine grained diorite.

According Rodriguez, (2009), alteration and mineralization style show that Gramalote Project is an Intrusion Related Gold System because Au in Gramalote occurs in open filling veins up to 10 or 15 cm wide, thin sheeted veins 0.5cm wide and stockworks. These veins yield gold assays greater than 80 ppm Au, the alteration is restricted to, halos of about a few centimeters around the veins and veinlets and is not auriferous. We can see that the hidrothermal alteration present at Gramalote area is entirely structurally controlled, in form of alteration selvages around fractures, veinlets and veins. The intensity of the hydrothermal alteration is closely related to the abundance of the structures present within the rocks; therefore, zones with high density of structures will show a more pervasive hydrothermal alteration, product of the coalescence of several adjacent alteration haloes. Three principal types of hydrothermal alteration haven been identified within the deposit area: potassic, quartz – sericitic, and carbonate – sericitic (Cepeda, F., et al. In prep) in (Rodriguez, O, 2009).

4. Quebradona Project
Quebradona project is located in Jericó, department of Antioquia, 110 km southern of Medellin, between the central and western cordilleras of Colombia in a pull-apart basin with N-S fault systems. The Project has been developed by Sociedad Kedahda S.A, B2
Gold Corp. and now a days by AngloGold Ashanti (fig. 7). The project actually began the prefeasibility step.

**Figure (7).** New Chaquiro regional setting and location.

Consists in a Cu-Au Porphyry-type mineralization, where is host in a Miocene volcanic rocks affected by a pervasive sericitic alteration and important silicification. All the district is located in Combia formation that consists mainly in andesitic tuffs, breccias, agglomerates, and lava flows intruded by dikes and diorite and quartz diorite intrusions (Porphyry Cu-Au (Mo)). The Cambia Formation presents an age between 6 and 11 Ma, the intrusion bodies have an age between 7 and 8,5 Ma and the age of mineralization is 7,147 Ma.

In the camp of Minera Quebradona Colombia we could see the well 50. The analysis of this well was very interesting and didactic. We could see the philic alteration with sericite, pirtyte and quartz like key minerals, this alteration persists until the 350 meters approximately, the veins type B are frequently. The potassic alteration appears to the 350 m approximately, with secondary biotite and magnetite like key minerals, in this section of the core the rock has a dark brown hue and the Cupper percent start to increase, veins type A and B are frequently. Under the 450 meters appears a dome with massive silification, this zone present high laws of Copper and Gold. The final part of the well the intrusive is brecciated and presents an extensive potassic alteration with high values of Copper and Gold. All these features indicate that the thermal gradient increases and therefore to such depths we find the most enriched area of the deposit (fig. 8).
5. Emeralds mines

The Colombian emeralds deposits are located in the Eastern Cordillera of Colombia in northwestern South America, within two narrow bands on the west side (Muzo and Coscuez deposits) and on the east side (Chivor and Guachalá deposits) (fig. 9). According to Branquet et al., (1999) during Andean phase (Middle Miocene) the Eastern Cordillera of Colombia is considered to have acted as a fold and thrust belt, squeezed between and thrust over its two foreland basins, the middle Magdalena basin to the west and the Llanos basin to the east.
Emerald deposits in Colombia are very interesting because after detailed geological and geochemical studies undertaken in 1988 have led to an entirely different and original model involving hot basinal brines (Cheilletz and Giuliani, 1996 in Branquet et al, 1999). Also, the emerald mineralization in the Eastern Cordillera have a very peculiar aspect because its formation at two different ages measured by $^{40}\text{Ar}/^{39}\text{Ar}$ and K-Ar dating of syngenetic green muscovite crystallized on esmerald-bearing vein wall rock. Eastern zone presented Cretaceous-Tertiary boundary age and the second at the time of Eoceno-Oligoceno boundary in the western zone.

Emerald mines-Chivor-Boyacá is located in the Eastern zone of the Eastern Cordillera where Andean thick-skinned tectonics are responsible for the main deformation observed on regional cross sections through the Eastern Cordillera and adjacent Llanos foothills. As the result of these Andean thick-skinned tectonics, the Chivor emerald deposit is located on a gently northwest dipping monocline situated on the western flank of a large, N30°E-trending, upright fold, devoid of cleavage. Branquet et al, (1999) (fig. 10).

In the next figure 11, we can see a representation where these are black shales folded or broken up with breccias of carbonates, albite and/ or pyrite and fractured bits of black shale (fig 10). Beryllium, vanadium and chromium leached out of the black shale and concentrated as emeralds in cavities left by the relief of confining pressure.
Figure (11). Emerald in vugs with carbonates, pyrite and albite. Taken from Emeralds of the world.

Figure (12). Common vein whit emplacement of emerald. Foto taking in the museum of Chivor.

In the mine we can also distinguish veins of pyrite and some of evaporites, who crystallizes in stalactite and stalacnite shapes (fig. 13).
Figure (13). a) Veins of pyrite whitin shales whit carbonates. b) Stalactites of evaporates in the principal veins.

6. Conclusions

- The Quebradona project is a deposit type porphyry Cu – Au, presents phyllic alteration, potassic alteration and a dome zone which is silicified. Vein type A, type B and type D were observed, which presented chalcopyrite pyrite quartz and in point zones molybdenite and bornite. The deposit doesn’t present an important structural control.

- The Gramalote deposit is a IRGS (Intrussion related gold deposit), which is related to the Antioquia batholith of Cretaceous. This deposit presents 3 important features, the content of sulfides is less than 5, the structural control is preferentially NE and present aplitic and pegmatitic dykes. The hydrothermal alteration is present in the veins, alteration is observed quartz calcite pyrite and a slight potassic alteration.

- In the eastern zone (Emerald mines-Chivor), all the geochemical processes occurred in the mineralized series, which contained an evaporitic level, in relation to an extensional deformation, the regional structures are Andean and obviously postdate the emerald mineralization. Also in the eastern zone (Emerald mines-Chivor) the deposits are scattered along a regional brecciated level.

7. Acknowledge

The Society of Economic Geologist - Escuela Politécnica Nacional (SEG - EPN) Student Chapter would like to express their sincere thanks to the respective people to make
this fieldtrip happen. Thanks for the financial support was provided by Stewart R. Wallace Funding. The EPN-SEG Student Chapter also would like thank to all Anglogold Ashanti team for receiving us in their projects and to B. Eng. Pablo Noriega (Anglogold Ashanti Geologist) for an excellent explanation from the Quebradona Project, and to B. Eng. Julian Orozco (Anglogold Ashanti Geologist) for introducing us the Gramalote Project. Furthermore, the especially invaluable help made by Mr. Hugo Sanchez and Ms. Sonia Zoraida in making possible the Emerald mine visit is warmly thanked.

8. References

