Digital Images and Commentary courtesy of Wolf Kuehn

Canadian Institute of Gemmology (Vancouver)

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Research pulled from various sources including:

- *Green Fever: The Colombian Emerald* (video from Discovery Channel's *Stones of Fate & Fortune* series)

- ed. Brooks, John. *The South American Handbook*

- Smithsonian. *Rock & Gem*

- *The Emerald Deposits of Muzo, Colombia*, by Joseph E. Pogue, PhD., Evanston. Illinois, Transactions of the American Institute of Mining Engineers, Vol. LV, 1917 (Arizona Meeting, September 1916.)

Additional Commentary and Post Presentation Discussion by Holger Hartmaier

Maps provided by:

Map of South America: Honor the Earth website – www.honorearth.org

Map of Colombia: Information Please website – www.infoplease.com

Map of Colombia

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Introduction

Emeralds are found in relatively few countries around the world. Recent deposits have been found in Canada's north. Historical sources are few and far between -- Pakistan, Russia's Ural Mountains, Zambia & Zimbabwe in Africa, and Brazil & Colombia in South America.

Colombia reputedly boasts the best emeralds in the world, at one time producing 80-90% of the world's production. Current production is estimated to be about 60%. Most of the emeralds come from two major mining districts Muzo and Chivor located respectively north and east northeast of Bogotá. The images we will be seeing here are from the mines near Muzo; Colombia's largest and most famous mine. It is located in the province of Boyaca, north of Bogotá, Colombia's capital. All images were taken by Wolf Kuehn of the Canadian Institute of Gemmology in Vancouver during a trip to Colombia in the summer of 2005.

Colombia, South America

Colombia is the fourth largest country in South America, with coast lines on both the Atlantic and Pacific. Its lowlands are largely uninhabited, whereas the narrow valleys and high basins between its mountains support over 90% of the population. The climate is hot, resulting in a daily cycle of evaporation from the marshy lands, followed by torrential rainfalls and fog. The lushly forested landscape is punctuated with crops such as maize, potatoes, sugar cane, coffee, and cacao (from which chocolate is derived).

Butterflies of Colombia, South America

The human population in Colombia is almost as colourful as its butterflies. You will find descendants of the indigenous Indian population, along with those of the conquistadors and black slaves. Intermarriage adds to this rainbow.

Fauna of Colombia, South America

The flora and fauna of Colombia are also colourful and exotic. This is a land of parrots, lizards, and the occasional jaguar.

Quartz Crystal

Mineral treasures also abound. Quartz may occur as well formed, colourless to greenish (rare) crystals in the emerald veins. Inclusions of pyrite and emerald have been noted, indicating that the quartz crystals formed after the emeralds.

History of Colombia, South America

Emeralds were prized by the natives of Colombia, long before the Conquistadores arrived. The Indians treasured them as symbols of fertility and immortality, incorporated them into their gold work, and used them as currency in barter. Over the years these stones have caused much strife. The Muzo area came under Spanish control in 1567, when the natives were enslaved by the Conquistadors and put to work in the mines. The power struggle for control of this resource continues to this day.

Let's take a look at the last half of the 20th century. Up until 1947, the mines of Muzo were administered by the Bank of the Republic. Looting was rampant. In 1968, the state created a mining corporation (Esmeralda of Colombia) to take control. They doled out claims and contracts to private families, but the robberies and violence continued until the army was forced to close the mines in 1973. In 1976, private consortia picked up the reins, but a free-for-all ensued, featuring rival guerrilla groups, and even drug cartels. (Note: per gram, uncut emeralds are worth fifty times more than drugs. Even on the streets of Bogotá, 1,500 carats of rough crystals will fetch a quarter million dollars). The ensuing "Green Wars" claimed thousands of lives. It wasn't until 1991, when Pablo Escobar and another big drug lord were killed by the army, that "relative peace" returned to the region. That said,

security remains tight around Muzo today. And while this may discourage outside attacks, it does little to address the problem of workers swallowing stones to smuggle them offsite.

Colombian Emerald Mining District

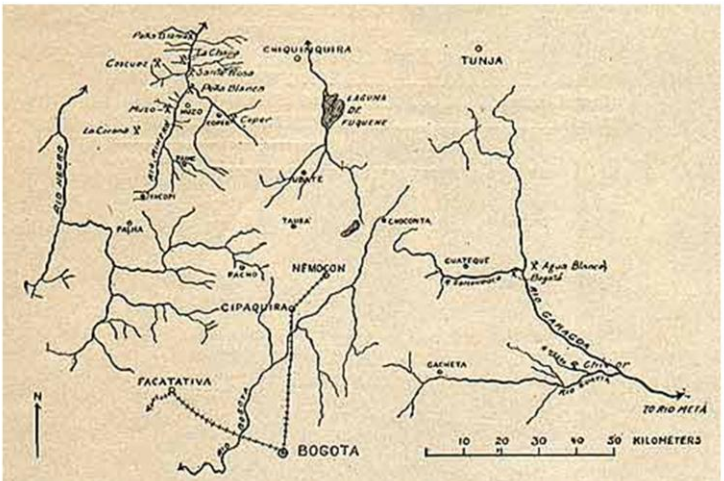


FIG. 1.—SKETCH MAP SHOWING APPROXIMATE LOCATIONS OF ALL IMPORTANT EMERALD MINES AND PROSPECTS IN COLOMBIA.
(Data in part supplied by Robert Scheibe, July, 1915.)

The Muzo emerald mining district covers an area of about 360 square km, centered about 105 km north-northwest of Bogotá, in the western foothills of the eastern branch of the Andes at about 700 metres above sea level. Local relief is less than 500 metres. It consists of three major mining centres, Muzo, Coscuez and Penas Blancas. The Muzo mine is located about 8 km west of the village of Muzo.

The Chivor district is located on the eastern slopes of the Andes about 75 km east-northeast of Bogotá. The district occupies about 100 square km in very rugged country, cut by canyons 1000 metres or more deep. The Chivor mine is located at an elevation of 2300 metres above sea level. The two currently active and most important mines in the Chivor district are the Chivor and the Gachala.

Muzo and Adjacent Emerald Deposits

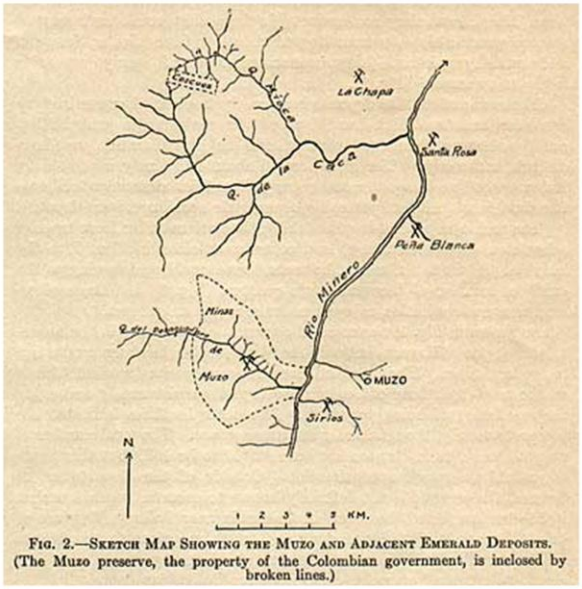


FIG. 2.—SKETCH MAP SHOWING THE MUZO AND ADJACENT EMERALD DEPOSITS. (The Muzo preserve, the property of the Colombian government, is inclosed by broken lines.)

The town of Muzo is located along the valley of Rio Minero. The mine is located within a steep walled valley of Quebrada del Desaguadero. The dashed area outlines the Muzo mining preserve. The mining area is composed of many individual “cortes” or mines which are on long term leases from the Colombian government.

Muzo in the province of Boyaca
Colombia, South America

These next few shots are of the town of Muzo, in the province of Boyaca. They'll give you an idea of the Colombian landscape. The emerald mining district is within 16 km of the town.

Muzo in the province of Boyaca
Colombia, South America

The emerald deposits around Muzo were originally worked by the Incas up to 2000 years ago and were “rediscovered” by the Spanish in 1559. There has been a long history of intermittent production from these mines continuing to the present day.

Muzo in the province of Boyaca
Colombia, South America

The mines have been owned by the government since 1871 and have been leased to various operators since then. Five year leases were instituted in 1977 and discontinued in 1982 due in part to poor recovery brought about by rapid mining techniques (dynamite and bulldozers). Ten year leases were most recently held by two companies Tecminas and Coesminas, who developed underground workings.

Road to Muzo Mine

While the best way to avoid ambush enroute to the mine is to travel by helicopter, this just isn't an option for most workers. Here we have a shot taken along the road to the Muzo mine, located about 8 km west of the town of Muzo.

Emerald Country

We are now in emerald country.... The region around the deposits is characterized by intense tropical jungle and excessive heat. Jungle growth quickly obscures abandoned workings and makes exploration very difficult and costly.

“It is a 4 hour gruesome four-wheel drive for the 80 kms from Chiquichira at 2,200 m down into the valley. I was the only "tourist" and many of the locals on the jeep got sick. The scenery is absolutely spectacular. But most emerald dealers use the helicopter and "miss out" on the adventure.” – Wolf Kuehn

Muzo Mine Entrance

…and have arrived at the mine.

Panorama View of Muzo Mine

While the Muzo mine covers an area the size of a small city, this shot will give you an idea of the traditional open-cast mine, in combination with newer technologies (if you look part way up the slope, perhaps you will note a shaft). The Muzo Mine was worked long before the arrival of the *conquistadors*. Little is known about the early history of the mine. Local lore states that it was found by the Spanish when a horseman riding around the town of Muzo noticed a green stone wedged between the hoof and shoe of his steed. Upon investigation and questioning the local Indians he learned that these green stones could be found just outside of town.

Mining Methods

FIG. 13.—PHOTOGRAPH SHOWING HOW ACCUMULATED DÉBRIS IS CLEARED FROM WORKING FACE BY WATER LET IN FROM ABOVE.

FIG. 11.—PHOTOGRAPH OF BANCO CENTRAL, ONE OF THE PRINCIPAL OPEN CUTS, SHOWING THE TERRACES BY MEANS OF WHICH THE EMERALD FORMATION IS WORKED.

Traditional mining methods are used that differ little from those used by the Spaniards in the 16th century. Nearly all work is by hand. The bedrock is a soft shale and explosives are rarely used to break the rock, only when it is free of emerald bearing veins. The emerald bearing strata on steep mountainsides are cut into steps about 2 m high and 3-4 m wide by gangs of miners using picks and crowbars. Using this open cut method, literally every cubic metre of rock is examined and emerald recovery approaches 100%. The broken waste rock is removed mostly by flushing with water. Large reservoirs are located in the hills above the workings and are filled directly by streams or by water diverted long distances by dug canals. The force of the water effectively washes away all the broken rock into the valley below.

Working the Tailings

The broken waste rock washed from the mine accumulates in the valley bottom below the mine. Here there is no shortage of peasant "shovellers" eager to eke out a living in the sludge. They sift through thousands of tons of rock, and if they are lucky may find a few handfuls of emeralds per day.

Working the Tailings

It has been estimated that the grade of the emerald bearing rock is about 1 carat for every 15 cubic metres of rock. Assuming a bulk density of 2.2 g/cubic cm, the ratio of emerald to rock is 1:165 million, making the overall emerald grade of the ore 0.0000006%! This is more than 10 times leaner than the grade of South African diamond bearing kimberlites.

Working the Tailings

The great value of the emerald makes security at the mines a problem. Members of the National Police guard and oversee operations at all legally worked emerald mines. Bonuses are paid to miners who spot smears of emerald (moralla) in the rock that lead to discovery of a productive vein or pocket.

Working the Tailings

In the mines, a month or more of mining commonly separates discoveries which may contain in volume not more than a soft ball, gems worth from a few thousand to several million dollars.

Working the Tailings

Annual production of emeralds from Colombia is not known with any degree of accuracy due to clandestine operations. Average yearly production from 1964-1967 was 325,000 carats, much of it low grade stones.

Underground Mining

New technologies, such as underground mining, have been introduced by players such as Rio Verde (Green River), a Vancouver company. Further up the mountain we can see what looks like power generators, probably for the pneumatic drills that will be used to dig into the thin white calcite veins that contain the emeralds, when a pocket can be found.

Underground Mine Entrance

The advantage of underground mining is that the amount of waste rock mined may be reduced, assuming that a productive vein can be followed. The disadvantage of this method is the need to use explosives, which damage the emeralds. Also the underground openings need to be supported and ventilated. As you can see, mining methods are rather primitive and potentially unsafe.

Entering the Underground Mine

...and these next few shots are inside the hot muggy mine. In the dark, it is difficult to see much at all. The large pipes deliver ventilation to the working face.

Underground Conditions

Here we can see the poorly lit and wet conditions in the adit leading to the working face.

An “adit” is a mining term for a horizontal opening into the ground that only has one entrance, as opposed to a tunnel which is open at both ends. In mining terms a shaft is a vertical opening into the ground.

Underground Conditions

Relatively few timbers are noted here, indicating good ground conditions.

Calcite Veins

Here we see one of the calcite veins that emeralds are often found in. The host rock is a black carbonaceous and calcareous shale. The calcite vein material would be brought to the surface and broken up by hand to remove any emerald crystals present.

Fruits of an entire day's labour…

…and here we see a miner with a handful of stones – probably the fruits of an entire day's labour. Only the most trusted employees are allowed near the working face of the mine. In some mines, the best stones are placed into leather pouches for protection after extraction.

Raw Emeralds

Here we get a closer look at some raw emeralds.

Wolf Kuehn and Jesus Tajeado (right)

...and this is Wolf Kuehn on the left (Director of the Canadian Institute of Gemmology, the gentleman who took these photos) and Jesus Tajeado, his Muzo guide.

“I will say the trip was one of my greatest adventures and I will go back as soon as I can. However, I would not recommend an excursion to Muzo for group travel or inexperienced tourists. Spanish and familiarity with local customs are an absolute must.” - Wolf Kuehn

J. Wolf Kuehn, C.I.G. Director of Education, is a Fellow of the Gemmological Association of Germany. He is a professional member of the "British Columbia College of Teachers" and holds a Master's degree in Marketing (University of Augsburg). As the founder of the Canadian Institute of Gemmology (Instituto de Gemologia del Pacifico - Pacific Institute of Gemology) he has been involved in gemology for over 30 years. Among his publications the Gem Colour Manual and the Gemstone Inclusion Library has been widely recognized as a valuable tool for colour grading and serious gem identification

Leaving the Muzo Mine

At last we leave the mine behind.

Back to Muzo and a much earned Cerveza!

…and return to Muzo. But let's have a closer look at some emeralds.

Emeralds of Muzo Mine
Colombia, South America

Here we can see a lovely emerald crystal in calcite. Note the prismatic crystal, which is hexagonal in structure. Emeralds are a member of the beryl family, obtaining their unique colour from trace amounts of chromium and vanadium. They can be green or blue green, but Colombian emeralds are unique in that they exhibit a complete lack of iron. (The pyrite often found nearby seems to have attracted it all.)

Emeralds of Muzo Mine
Colombia, South America

Again – another specimen

Emeralds can be transparent to translucent. Their value is primarily in their colour, which is enhanced by their natural fluorescence in daylight. The famous “emerald cut” further enhances a stone’s colour and richness.

Emeralds of Muzo Mine
Colombia, South America

Another shot... Emeralds have a hardness of 7 ½ to 8, with imperfect cleavage. Fractures are uneven to conchoidal.

Emeralds of Muzo Mine
Colombia, South America

Here we have multiple specimens...

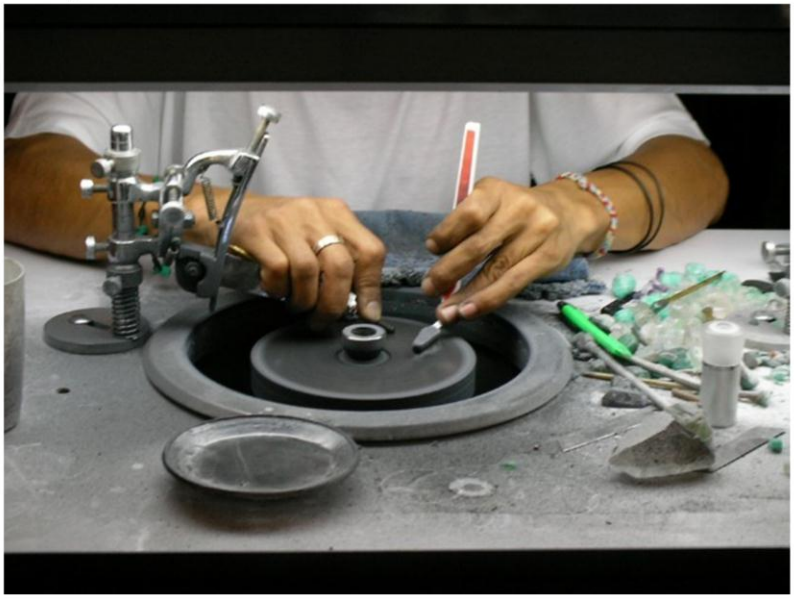
Emeralds of Muzo Mine
Colombia, South America

...and more of the same, with a finished faceted stone.

Emeralds of Muzo Mine
Colombia, South America

…the same thing again, and a word about inclusions. The inclusions in emeralds add to their interest. These “growth features” tell us how the stones grew in nature, and provide us with information on what temperatures they were formed at, what solutions they were formed from, and so on.

Faceting an Emerald
Muzo, Colombia



Here we see a faceter at work. As most of you know, a cutter can add to the value of a stone -- or take it away in one false move! Emeralds are usually cut in the…guess what… the emerald cut!

Emeralds of Muzo Mine
Colombia, South America

Here we have a lovely sampling of cut stones. Emerald is the birthstone for May. Colour and clarity are highly variable and are major factors in valuation. Nearly all stones have inclusions, and the best coloured usually have the most inclusions. The term “jardin” (meaning garden) is used for mossy appearing, densely included stones. Good stones of high clarity and colour are extremely rare in sizes above 2-3 carats. Colour is highly prized with large carat, but weakly coloured stones up to five carats being worth less than smaller included stones of better colour. Most natural stones are “oiled” to improve clarity. Traditional oils include Canada Balsam and cedarwood oil. This treatment is used to seal the cracks in the crystals. Seven times rarer than diamonds, these stones will fetch a small fortune once they leave the country. Commercial grade emeralds will cost buyers approximately $1,000/carat in Colombia. Exceptional stones of 5 carats or more have been sold for as much as $25,000/carat! Before they leave the country, these stones must be registered, appraised, and approved for export (for a fee, of course). Moving emeralds is still risky business. The possibility of Colombian gangs following a dealer to Canada or the US is not unheard of, but unscrupulous customs agents enroute can be equally devastating to a gem dealer. Perhaps that is one justification for the twenty-fold price jump that occurs between the Colombian emerald mine and the North American jewellery store.

Emerald - Mineralogy

- A deep green gem variety of **BERYL**
- Beryllium aluminum silicate $Be_3Al_2Si_6O_{18}$
- Hexagonal (trigonal) crystal system
- Hardness 7.5- 8.0 (Harder than Quartz)
- S.G. 2.67- 2.78

Emerald is the gem variety of beryl.

Emerald - Mineralogy

- Green colour due to trace amounts of Chromium
- Other gem varieties of Beryl include:
  - Aquamarine (blue- Fe)
  - Heliodor (yellow- Fe)
  - Morganite (pink- Mn)
  - Red Beryl or Bixbite (red- Mn)
  - Goshenite (colourless)

The gem varieties of beryl are all the same composition, but owe their colours to trace amounts of different elements that substitute for the Aluminum in the crystal lattice and act as chromophores.

Geology and Origin of the Muzo Emerald Deposits

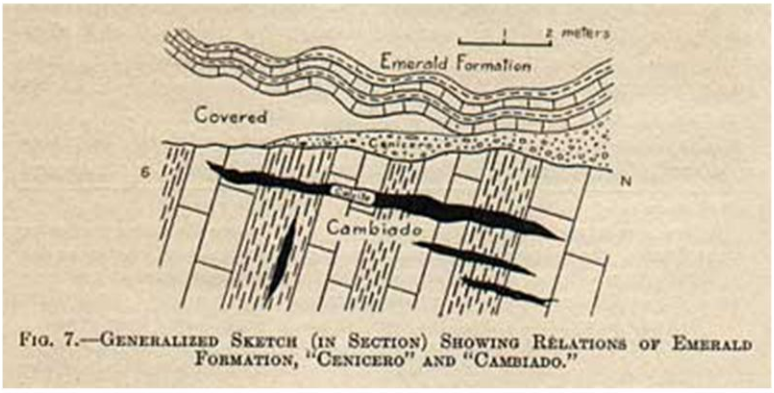


FIG. 7.—GENERALIZED SKETCH (IN SECTION) SHOWING RELATIONS OF EMERALD FORMATION, "CENICERO" AND "CAMBIADO."

The rocks hosting the Muzo emerald deposits are of middle Cretaceous age, based chiefly on the abundant ammonites that are found with them.

The geology of the Muzo emerald deposits is still poorly understood, due to its checkered history and poor exposures of bedrock in the region. The best exposures are in the working mine faces, as abandoned workings are quickly covered by jungle vegetation. The emerald formation (see slide) consists of thin beds of carbonaceous shale and limestone. There is an angular unconformity between the emerald bearing rock units and the barren rock units of early Cretaceous age below. It is believed that the younger emerald bearing rock units were thrust on top of the older, steeply dipping strata by large scale tectonic displacements. At the same time as this deformation was taking place, hydrothermal fluids were being injected along the fault zone, bringing in the emerald bearing solutions. Calcite veins were formed in both the barren and emerald bearing rock units, however, it is believed that gases emanating from the solution rose into the rock units above the fault and were responsible for depositing the emeralds preferentially. The barren rock units called the “cambiado” (Spanish for changed-metamorphosed) were only subjected to the hot hydrothermal fluids and were not affected by the gases. The rock units between the emerald formation and the cambiado were literally cooked to a crumbly ash-like unit called the cenizero (Spanish for ash), which forms a marker between the emerald and non-emerald bearing rocks. Obviously, more investigative work is required to fully understand the geology of these deposits.

Associated Minerals

- Calcite
- Dolomite
- Ankerite
- Pyrite
- Parasite
- Quartz
- Fluorite
- Apatite
- Fuchsite
- Gypsum
- Albite
- Barite
- Anthracite
- Marcasite
- Chalcophyllite
- Native sulphur
- Pyrophyllite
- Allophanite

Here's a list of the other minerals that are found in association with the emeralds at Muzo. Many of them are well formed and good specimens in their own right. They are no doubt of particular chemical interest in understanding the origin and formation of the emerald deposits.

Thank You

- Questions???