Peñas Blancas: An historic Colombian emerald mine

Ron Ringsrud and Edward Boehm

Abstract: The Peñas Blancas emerald mine is part of Colombia's Muzo mining region, an 800 km^2 area that encompasses the famous Muzo, Coscuez and La Pita mines. This is the largest emerald district in Colombia, and it is the most productive and well-known emerald mining region in the world. Peñas Blancas has a fascinating and turbulent history, which sheds light on that of the entire Colombian emerald industry. Just as important, Peñas Blancas is finally accessible after more than 20 years of being closed to outsiders. This article describes the history, geology and gemmology of Peñas Blancas emeralds, and compares this historic mine to other famous producers in the region.

Keywords: Colombia, emerald, geology, inclusions, Peñas Blancas, RI, SG, trapiche

Introduction

From ancient artisanal beginnings with the Chibcha and Muzo Indians, the emerald mines of Colombia have supplied the world with fine material for hundreds of years. When the Spaniards, led by Hernán Cortés, conquered Mexico almost 500 years ago, legend has it that Aztec ruler Montezuma was adorned in gold and emeralds. The Spanish conquistador Francisco Pizarro also found emeralds, now known to be from Colombia, as far south as what are now Ecuador, Peru and Chile. After the conquered treasures made their way to Spain, the Spanish traded the emeralds with the Persians for gold. Thus, Colombian mines have been supplying the world with emeralds since the mid-1500s.

A relatively unknown Colombian emerald deposit is Peñas Blancas, located in the famous Muzo mining district. This mine has rarely been mentioned in gemmological literature except as an historical footnote. Long thought to be depleted, Peñas Blancas closed in the early 1980s because of a decades-long conflict between the two controlling families of the area. This conflict was finally resolved in late 2003, and by March 2004 the Peñas Blancas mine was producing high-quality rough. The authors are aware of one parcel yielding 270 carats of faceted emeralds that sold for US$810,000 ($3,000/ct). The authors first visited the mine in late 2004, and subsequent trips by one of us (RR) revealed good potential for future production, although mining continues slowly in the absence of investment and technology.

Peñas Blancas emeralds are known among local dealers for their exceptional colour and transparency. Although Peñas Blancas is hosted by a geological formation that is somewhat different from the three other Muzo-region mines, the fine quality of the emeralds (e.g., *Figure 1*) is similar to its more famous neighbours. The history of the mine has had a significant impact on the development of the entire Muzo district, and eventually Peñas Blancas may be partially responsible for the revival of this important mining region.

Figure 1: This superb mineral specimen taken from Peñas Blancas in February 2004 beautifully displays a cluster of emeralds that surround a quartz crystal. Quartz is more common in the emerald-mineralized zone at Peñas Blancas than at other Colombian localities. The specimen measures 55×65×90 mm and is courtesy of the Roz and Gene Meieran Collection; photo by Harold and Erica Van Pelt.

Early history

According to general understanding in Bogotá's emerald trade, Peñas Blancas attained significance in 1959 when a large emerald pocket started a bonanza that revived a dormant national industry and launched the careers of many of its principal players. Formerly known as *Peña Blanca*, the mine first appeared on a sketch map published by J. Pogue (1916; see *Figure 2*). At the turn of the 20th century, Pogue along with Charles Olden and Robert Sheibe (Sinkankas, 1981), were among the few geologist-explorers who were adding to the published knowledge about gem occurrences in Colombia. After World War II, Victor Oppenheim was the first of many geologists assessing petroleum and coal deposits in South America, and he briefly mentioned the Peñas Blancas mine: "...Tambrias or Peña Blanca mine — This mine is located some 25 km northeast of Muzo but as is the case of the La Chapa mine, very little is now known of the emeralds there, as the mine has not been worked for a considerable time" (Oppenheim, 1948, p. 37). Apparently, after the passage of many decades and two World Wars, the Peñas Blancas prospect was nearly forgotten.

The rediscovery of Peñas Blancas as a source of fine emeralds is now legendary. Since 1955, San Pablo de Borbur has been the closest town to the Peñas Blancas mine. From Borbur, mules would take locals to the Peñas Blancas area once a week for agricultural work. Those *campesinos* would sometimes find emeralds on the ground and, not knowing what they were, simply give them away. According to a local legend, in 1958 a mule driver showed a Peñas Blancas emerald to one of his relatives in Muzo, and within a few months the rush began.

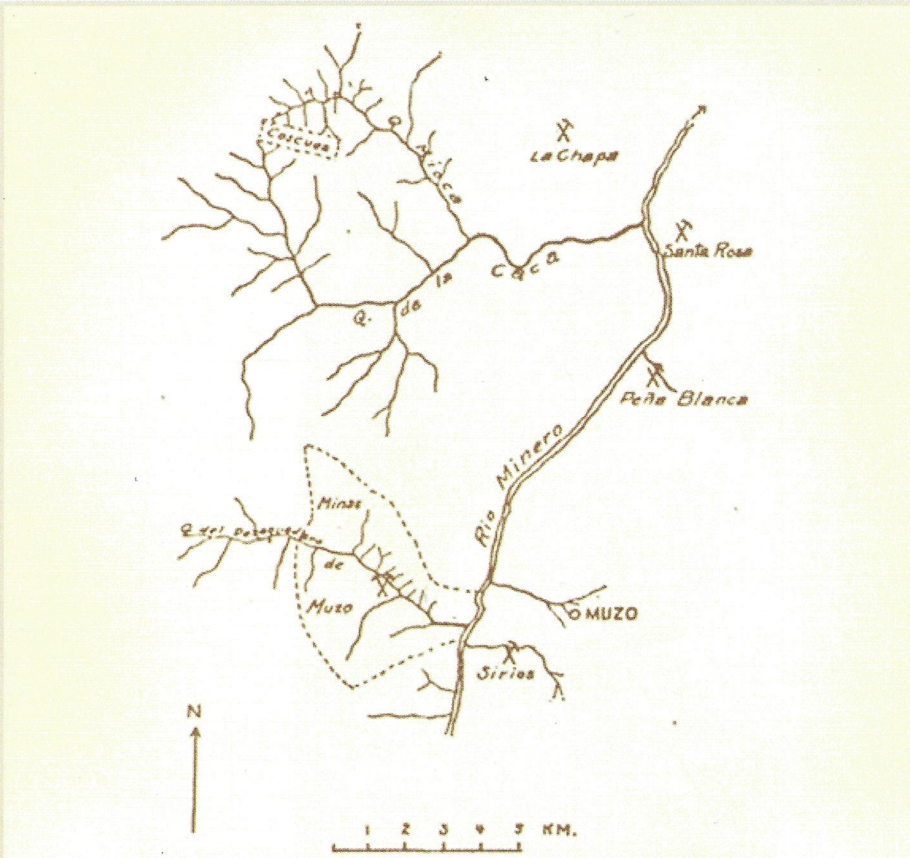


FIG. 2.—SKETCH MAP SHOWING THE MUZO AND ADJACENT EMERALD DEPOSITS. (The Muzo preserve, the property of the Colombian government, is inclosed by broken lines.)

Figure 2: A sketch map of the Muzo mining region by J. Pogue (1916) depicting Peña Blanca (Peñas Blancas) a few kilometres north of the small town of Muzo.

Emeralds were initially found on the surface underneath an overgrowth of vegetation, in a rich vein more than 60 m long (Claver Téllez, 2011). During the initial years of the boom, shallow trenches provided miners with significant quantities of gem-quality rough.

Emeralds from this find eventually reached the Gemological Institute of America (GIA), then located in Los Angeles. An unattributed two-page article titled 'A new emerald find in Colombia' appeared in the Spring 1961 issue of *Gems & Gemology*. The article states (pp 142, 158):

> "Each of the clear, deep-green stones showed prism faces and the two or three with basal pinacoids also had very small bipyramid faces of the same order as the prisms. We understand that production has ranged in size from one carat to about thirty carats. The rich, velvety color of the few we saw was reminiscent of the Muzo product.
>
> "The new find … has been the scene of a wild rush of perhaps fifteen hundred miners. At this writing, the government has not yet determined who should be granted the right to work the property; the army, however, has surrounded the area, to keep order and prevent robbery."

It would be two decades until Peñas Blancas was cited again in the gemmological literature, when John Sinkankas included it in his 'Chronology of Colombian Emerald' section of *Emerald and other Beryls* (Sinkankas, 1981, p. 412). Sinkankas mentioned a new Colombian agency called *Empresa de Esmeraldas* (Emerald Company), formed by the Banco de la República to control the emerald region and to mine emeralds on behalf of the government, "including recently discovered deposits in Boyacá Province" (referring to Peñas Blancas). The government attempt to control the mining region was unsuccessful, and in 1968 the Colombian Ministry of Mines and Petroleum formed the *Empresa Colombiana de Minas* or ECOMINAS (Sinkankas, 1981). ECOMINAS ran the region more efficiently by granting mining concessions to private companies (Keller, 1981).

Recent history

The vast wealth produced by Peñas Blancas during the 1960s and 1970s allowed aggressive and entrepreneurial leaders not only to launch themselves into the emerald business but also to gain influence in the entire region. In those years, Muzo and Coscuez were stagnating under government control while Peñas Blancas was a relatively new find, uncontrolled by the government, and yielding gems only 6 ft (1.8 m) below the surface. The 1960s were dominated by the irascible Isauro Murcia, whose son Jaime *El Pekinés* later assumed control at Coscuez during the infamous Emerald Wars of 1985–1990 (see below). A powerful syndicate composed of Palermo and Gilberto Molina, Victor Carranza and Juan Beetar consolidated their control of the Colombian emerald industry in the 1970s and 1980s, initially at Peñas Blancas and then at Muzo.

Gilberto Molina is credited with instigating the development in 1986 of a much-needed road from Muzo to Otanche (near the Coscuez mine) and an airstrip in Quípama (near Muzo). Molina was known on occasion to dump quantities of *moralla* (lower-quality emerald rough) into Muzo's Itoco River streambed just before religious holidays like Christmas and Easter. He wanted to assure that the thousands of *guaqueros* (independent diggers) had stones to trade and thereby enjoyed the holidays. In contrast, during the 1970s, the legendary *El Ganso* (The Goose) Humberto Ariza ruled his dominion from horseback, exercising his power daily with a small squadron of armed men based in Coscuez. In the 1980s, Ariza's enemies and rivals were so numerous that he would never stay more than 30 minutes in one location to avoid assassination attempts. Ariza ultimately died in a blaze of bullets. Later, the folklore and history of Peñas Blancas was further embellished by the menacing presence of scar-faced Pacho Vargas and the fearless Quintero brothers.

During the 1980s, the Muzo and Coscuez mines enjoyed strong production while Peñas Blancas was essentially closed and intermittently yielded only small amounts of rough. The Muzo region, while accessible, was strongly territorial with a violent rivalry between groups from Muzo and Coscuez (Angarita and Angarita, 2013). In 1985, the entry of the personal army of drug-lord José Gonzalo Rodríquez Gacha, a partner of Medellín Cartel leader Pablo Escobar, escalated this rivalry into what became known as the Emerald Wars.

This conflict lasted until 1990, with most of the violence localized in the Muzo mining region. Occasionally, shootings would occur in downtown Bogotá in the famous emerald district of Avenida Jiminez and 7th Avenue. Nevertheless, abundant emerald production from the region continued throughout those years, especially at Coscuez (Ringsrud, 1986). To avoid areas of fighting and danger, the routes taken by the gem couriers as they made their way to the cutting centres in Bogotá were extremely circuitous and laboured. Due to the violence, a road between the village of Santa Barbara and the Coscuez mine was closed for more than four years. It became known locally as *El Muro de Berlin* (The Berlin Wall) because no one could cross it and live to tell about it. Curiously, the actual Berlin Wall fell on 9 November 1989, the same week the road to the Coscuez mine was re-opened.

While federal forces of the Colombian government dealt with drug-lord Rodríquez, it was the emerald miners and guards associated with Carranza who finally secured the emerald region. The end of the Emerald Wars was so significant that on 7 November 1989 the Archbishop of Colombia presided over a peace accord that was signed in Chiquinquirá, a major city and religious centre in the province of Boyacá. With Gilberto Molina a casualty of the violence, Carranza and Beetar continued to consolidate their regional power in the 1990s, and controlled the region until Carranza's death in April 2013.

Although Colombia's emerald mines have been quite productive over the past 15 years, the region has remained uninviting to foreign buyers. However, as of this writing, the locals and many of the newer mine owners have expressed a strong desire to replace the violent past with forward-looking openness, productivity and planning. Many locals still remain armed, but there is improved accessibility to the region and a pride in talking about the relative safety of the roads and the lack of fighting during the past decade. There has been a major military presence since 2008, and strongly enforced gun laws. Government-mandated accountability and control at the mines has added to their accessibility. As a result, foreign-owned mining operations have entered the region; Muzo International (known in Colombia as Minería Texas Colombia) now controls the Muzo mine, while additional international companies are actively creating alliances in other districts.

Because the Emerald Wars were prolonged and escalated by groups involved in the drug trade, there remains an on-going regional enmity toward guerrilla- or drug-related groups who try to enter the mining areas. Not only the emerald miners and their families, but also the *campesinos* are vigilant in their efforts to keep out paramilitary groups and guerrillas. In 2004, fields of coca (used for making cocaine) were discovered just 15 km from the villages of Borbur and Otanche. They were uprooted with great fanfare through the cooperation of local emerald miners and the Colombian national police. The talk among farmers of the region is that lucrative crops like stevia (a sugar substitute) and cocoa (for chocolate) will eventually provide better and equally profitable alternatives for export. Fedesmeraldas, the umbrella organization that encompasses the organizations of emerald miners, dealers and exporters, as well as the Colombian Ministry of Mines and Energy, has completed several multi-year projects building clinics, schools and co-ops in the region (see, e.g., www.emeraldmine.com/2012Archive.htm).

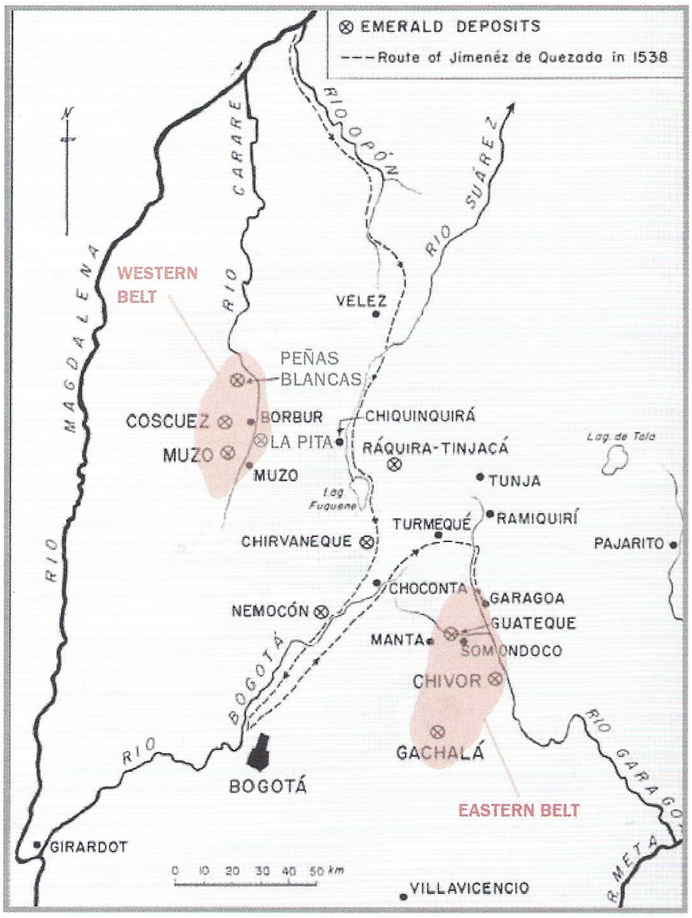


Figure 3: Emerald deposits in Colombia are situated in two belts within a mountain range known as the Eastern Cordillera. The western belt hosts the Peña Blancas, Muzo, Coscuez and La Pita mines, while the Chivor mine is located in the eastern belt. After Sinkankas (1981).

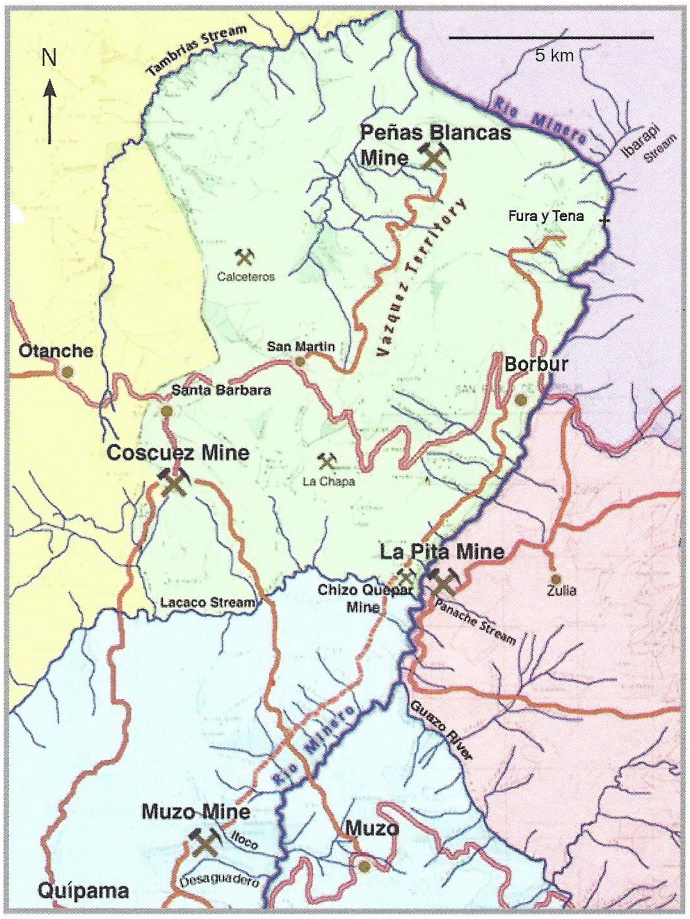


Figure 4: This map depicts the current active mines in the Muzo mining region. Peñas Blancas can be seen at the top, and the Muzo mine is at the bottom of the map. The town of Borbur is located just southeast of Peñas Blancas. Compiled by R. Ringsrud.

Location and access

Colombia's emerald deposits are situated in two belts that are hosted by a mountain range known as the Eastern Cordillera or Cordillera Oriental (e.g., Cheilletz *et al.*, 1994). Within this range, the Peñas Blancas, Muzo, Coscuez and La Pita mines are located in the western belt, while Chivor and others are situated in the eastern belt *(Figure 3)*. All of the mines are located within the state of Boyacá, about a day's drive from Bogotá. Peñas Blancas and the other western-zone mines can be reached by a challenging journey that descends from the capital city of Bogotá (2,600 m) in the central highlands through the lush, semitropical forest to the western flanks bordering the Andes Mountains. After five to six hours of driving on paved and unpaved roads, one reaches the mining region at an altitude of approximately 1,150 m. The area is marked by the twin peaks known as *Fura y Tena* (see Box A). The Peñas Blancas mine (5°43.0'N, 74°4.9'W) is located approximately 40 minutes by off-road vehicle from the town of Borbur (*Figures 4* and *5*). The name *Peña Blanca* that appears on older maps means 'white outcrop', in reference to the limestone layers where emeralds were first discovered. Today locals refer to the mine as *Peñas Blancas*, or simply as *La Peña*.

The village of Borbur lies at about 980 m above sea level, and is still principally a farming and mining town with a population of just over 1,000. The entire municipality surrounding Borbur has a population of almost 11,000. This area, bordered to the east by the Río Minero (Minero River), encompasses Peñas Blancas, Coscuez and part of the La Pita mine. A new road completed in 2011 along the western flank of the Río Minero valley extends from Borbur to the Muzo mine. This road provides direct access through Chizo Quepar to the Muzo mine rather than through the town of Muzo, which is on the other side of the river (see *Figure 4*). Another recent development in this formerly inhospitable region is the arrival of mobile phone coverage to many parts of the mining area. The rapid access to information about new finds enables buyers from Bogotá to respond quickly, making it more difficult and competitive to acquire top-quality gem rough at the mines.

Overall, the Muzo emerald region is rather small; the mines of Muzo, Coscuez, La Pita and Peñas Blancas could all theoretically be visited within a half-day's driving. However, access to any of the emerald mines is impossible without also having an invitation from a manager, operator or owner of that mine, and visits must be made in the company of locals from each particular mine.

The major mines of Muzo and Coscuez are government-owned, and today access is provided to private companies in 10-year renewable leases from INGEOMINAS, an affiliate of the Colombian Ministry of Mines and Energy. Legal mining claims and filings must be accompanied by environmental permission from two agencies. Peñas Blancas is privately owned, and prospecting of its tunnels is negotiated individually with local strongmen and families from the region, as at other small mines such as Chivor and Gachalá.

Figure 5: The Borbur Cathedral tower is seen here, with the peaks of Fura y Tena in the distance. Photo © Robert Weldon.

Box A: Fura y Tena

Presiding over the lush valley of the Río Minero are the imposing monoliths known as *Fura y Tena (Figure A1)*. These twin peaks dominate the topography of the emerald region, and are visible from Borbur and Coscuez as well as locations close to Muzo and La Pita. The higher peak, Fura (850 m from base to peak), looks like an irregular pyramid topped by a pointed cone, while Tena is a shorter obelisk that reaches only to Fura's shoulder. Río Minero, another significant feature common to all the mines in the Muzo district, runs between the two peaks.

The Fura y Tena are subjects of an indigenous legend dating back to the time of the Muisca and Muzo Indians that dwelled in the area before the Spanish Conquest. The legend speaks of a creator named Ar-e who formed Tena, the first man, and Fura, the first woman, out of the earth. Their life in that land was paradise until Zarve, represented by the Río Minero, tempted and seduced Fura. The infidelity angered the creator, who condemned them to death. Tena, ordained to die first, was turned into stone. Three days later, Fura died at his feet and the god Ar-e sent the torrents of the Zarve River, now called the Minero, to separate them forever. After centuries, the waters purified them and the murmurs of Fura's sadness were converted into the millions of blue butterflies *(Morpho didius)* that populate the region, while her tears became the emeralds. Fura and Tena then became minor deities presiding over the sun's rays, the winds and the underworld.

Figure A1: The peaks of the Fura y Tena dominate the emerald mining region and are visible from the Coscuez mine, Borbur and the La Pita mine. Río Minero, another prominent feature in the mining region, flows between the two peaks. Photo by R. Ringsrud.

Box B: Formation of Colombian emerald deposits

By Terri Ottaway, Museum Curator, Gemological Institute of America, Carlsbad, California, U.S.A.

Colombia's emeralds, arguably the finest in the world, are geologically unique, occurring in organic-rich shales and limestones without the usual association of beryllium-bearing pegmatites. The absence of a well-defined source of Be, the key ingredient in emerald, has long been a perplexing problem for geologists.

In contrast, elsewhere in the world emeralds have formed in environments where pegmatites and related solutions have transected ultramafic country rocks such as serpentinites or amphibolites. Subjected to heat and fluids from the intruding pegmatite, the surrounding country rocks underwent metasomatism to form mica or amphibole schists. Within the schists a mixing zone of pegmatite solutions containing Be, Al and Si, and local solutions containing Cr, V and Fe, resulted in the crystallization of emeralds. For a thorough description of metamorphic emerald environments, see Kazmi and Snee (1989).

Emeralds formed in pegmatite-schist environments are frequently heavily included with mica or amphibole, which reduces the transparency of the crystals and lowers their value as gems. Additionally, Fe can substitute into the emerald structure and negatively affect the colour. Chromium and vanadium not only give the characteristic beautiful blue-green colour to emerald, but they also impart a strong red fluorescence (Nassau, 1983). Although not visible to the naked eye, it may act to enhance the perceived blue-green colour. The presence of Fe in the beryl structure quenches the fluorescence, causing the emerald's colour to appear less intense. Iron can also impart a yellow tinge, resulting in a more 'grass-green' colour. Colombian emeralds are renowned for their intense, velvety blue-green colour and are devoid of inclusions of mica and amphibole, which signifies that their environment of formation differed from the conventional schist-related model.

Despite the lack of evidence, early researchers attempting to explain the formation of emeralds in the black shales of Colombia proposed that emerald-bearing solutions were derived from some hidden igneous activity at depth (Pogue, 1916; Scheibe, 1933; Oppenheim, 1948; Campbell and Bürgl, 1965). Then an intriguing observation was noted that there was a strong spatial association between emerald deposits and evaporites (Oppenheim, 1948; Roedder, 1963; McLaughlin, 1972). Evaporites form through the evaporation of seawater to form large beds of gypsum (hydrous calcium sulphate) and halite (sodium chloride). Their relationship to emeralds becomes all the more evident when one examines the fluid inclusions inside emerald crystals. Fluid inclusions are tiny pockets of the actual solutions from which the emeralds formed that became trapped in tiny cavities during the crystallization process. Over time as the temperature and pressure surrounding the emerald decreased, gases and elements came out of solution to form three-phase (gas-liquid-solid) inclusions. Thus, fluid inclusions represent a geological 'fingerprint'. The presence of halite (salt) crystals within fluid inclusions in all Colombian emeralds indicates the extremely high salinity of the emerald-forming solutions. Perhaps brines from evaporites leached sufficient key elements from the shales and limestones and precipitated them as emeralds (Beus, 1979; Kozlowski *et al.*, 1988; Giuliani *et al.*, 1993).

A geochemical study of the fluid inclusions, isotopes and organic matter of the emeralds, veins and shales at Muzo points to emeralds having formed at approximately 330°C through the interaction of sulphate from incoming evaporitic solutions with the organic-rich shales and limestones (Ottaway, 1991; Ottaway *et al.*, 1994; Giuliani *et al.*, 1995). At certain locations, the sulphate was thermochemically reduced and the organic matter was oxidized to carbon dioxide, releasing organically bound Be, Cr and V. The resulting pressurized solutions were forced into the fractured shales and limestones where they precipitated pyrite, calcite, albite and emerald. The reaction sites where this occurred are distinctively bleached in contrast to the rest of the black shales due to the absence of organic matter. Miners refer to these areas as *cenicero* (ashtray). The abundance of native sulphur in the cenicero further enhances this descriptive term. The peculiar, hexagonally patterned trapiche emeralds are found in the shale surrounding the cenicero. The black shale adjacent to the cenicero also records exposure to a high-temperature event through the elevated reflectance levels as compared to the rest of the shales (Ottaway, 1991).

The removal of Fe from the system in the form of pyrite was critical to the colour of Colombian emeralds. With just Cr and V as chromophores, the emeralds show the renowned intense blue-green colour we value so much.

Emeralds from the Cosquez mine contain fluid inclusions almost identical to those studied at Muzo (Ottaway, 1991; Ottaway *et al.*, 1994). A site visit also confirmed that the greatest concentrations of emeralds were from zones close to bleached areas of shale rich in native sulphur. Indeed, evidence points to the same processes having occurred at the Chivor mine on the eastern flank of the Cordillera Oriental (Ottaway, 1991). Thus, given a favourable environment, the processes of emerald formation presumably occurred over and over, producing all of the known deposits in Colombia, including the emeralds at the Peñas Blancas mine. Although rocks matching the description of the cenicero have not been reported there, it may be that weathering, erosion or mining activity have removed all traces of their existence. Alternatively, it is likely that large emerald-producing areas indicated by reaction sites such as the cenicero are waiting to be discovered.

Geology

The diverse geology of Colombia gives rise to a wealth of varied mineral resources. Petroleum, coal, nickel and emerald are the most important minerals to the Colombian economy. In addition, the Western Cordillera and Central Cordillera are known for gold deposits in granitic rock. The Eastern Cordillera, where the emerald mines are located, consists mainly of sedimentary rock, principally limestones and shales with minor igneous and metamorphic rocks. The major emerald deposits, found as hydrothermal deposits in sedimentary rock, are limited to the western margin (Muzo region) and the eastern margin (Chivor region) of the Eastern Cordillera (again, see *Figure 3*).

Several authors have described the geology of the Muzo district, including Pogue (1916), Schiebe (1933) and Oppenheim (1948). This work is summarized in Keller (1981), Sinkankas (1981) and Ringsrud (1986). A thick layer of black carbonaceous shales and minor amounts of limestone underlies the emerald mining areas. Fossils in these rocks indicate that they are from the Cretaceous Period (approximately 120 million years old). The shales are intensely folded and transected by a number of north-northeast-trending faults that are accompanied by zones of brecciation (fracturing). Mining geologist Cesar Agusto Valencia, working at the Peñas Blancas and La Pita mines, found that fault zones are often rich in emerald, particularly where they intersect and are deformed (C.A. Valencia, pers. comm., 1998). The fault zones can sometimes be identified by changes in the colour or texture of the surrounding rock, or by water seepage. Ottaway *et al.* (1994) state that these fractures in the shales are weaknesses that allowed hydrothermal fluids to infiltrate and deposit calcite, dolomite, emerald, pyrite, quartz and other accompanying minerals such as albite, fluorite, parisite and baryte (for more details, see Box B). This deposition occurred in several episodes involving heat and sometimes violent pulses of pressure (Cheilletz *et al.*, 1994; Ottaway *et al.*, 1994; Giuliani *et al.*, 1995, 2000; Branquet *et al.*, 1999).

Figure 6: The Peñas Blancas mining area is visible in this photo. The green foliated area below and above the mining camp (centre-right) is where past mining yielded many fine-quality trapiche emeralds. At present this area is not being exploited. Photo by R. Ringsrud.

Two rock units are of significance to the emerald deposits: the Paja Formation, in which the mines of Muzo, Coscuez and La Pita are situated; and the Rosablanca Formation, which hosts Peñas Blancas (*Figure 6*; INGEOMINAS, 2005). (The Villeta Formation is also cited by some authors as the host of the emerald deposits.) In contrast to Colombia's other emerald mines, the prominent geological feature of the Rosablanca Formation at Peñas Blancas is its compact and blocky shale. This carbonaceous, fine-grained, argillite shale is penetrated by intersecting white calcite and quartz veins in which the emerald mineralization occurs (*Figure 7*). By comparison, the Muzo, Coscuez and La Pita areas are characterized by softer, coarser grained, carbonaceous black shales that are highly fractured (*Figure 8*). Peripheral to the Peñas Blancas exploitation zone, cavities and fissures in the shales give rise to many small, white stalactites of calcium carbonate, which are collected by the locals. Most shops in Borbur have at least one on display, which the locals call *gangas de agua* (water minerals).

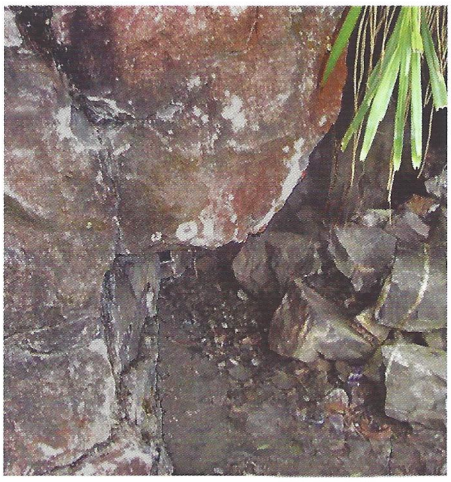


Figure 7: The host rock at Peñas Blancas (Rosablanca Formation) is comprised of blocky fine-grained carbonaceous shale penetrated by intersecting white calcite and quartz veins that locally host emerald mineralization. Note the solid compactness of the rock. Photo by R. Ringsrud.

As with other areas in the Muzo mining region, pyrite formation preceded the crystallization of emerald and is one reason for the superior colour of Colombian emerald (see Box B). At Coscuez and Peñas Blancas, pyrite seems to form in thin veins and stock works running through the shales. The pyrite also weathers to form orangy brown iron

Figure 8: All other emerald mines in the Muzo region are located within the Paja Formation, which is characterized by more highly fractured and softer carbonaceous shales (here, being examined by Dr Peter Keller). Compare this with the blocky nature of the shale at Peñas Blancas in Figure 7. Photo by R. Ringsrud.

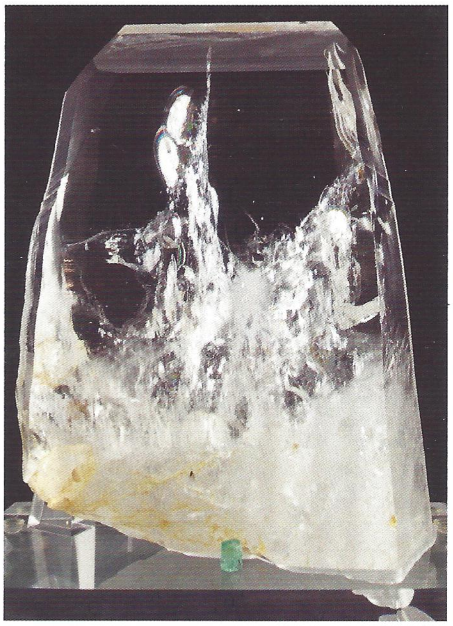


Figure 10: This large transparent quartz crystal (probably half of a Japan-law twin, 23 cm long) and accompanying emerald crystal were found at Peñas Blancas in 2004. Photo by E. Boehm.

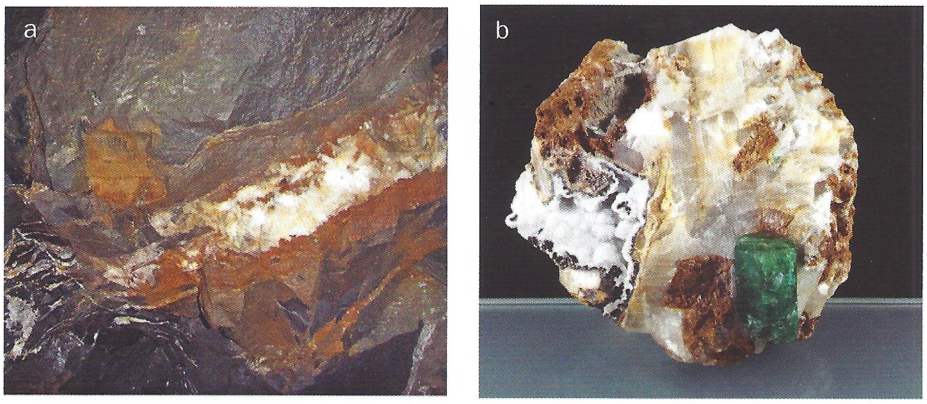


Figure 9: (a) Deep within the tunnels at Peñas Blancas, a white calcite vein (approximately 9 cm wide) shows typical orangy brown iron staining. (b) This mineral specimen from Peñas Blancas features a 2.5-cm-long emerald crystal embedded in the typical matrix of iron-stained calcite with a later secondary coating of botryoidal white calcite. Photos by E. Boehm.

stains along the veins, which are common at Peñas Blancas *(Figure 9)*. In Muzo and La Pita, the pyrite more often forms nodules in the veins or is found as crystals in the shales and veins.

At Peñas Blancas, the mineralized veins range in width from 1 to 30 cm and are usually filled with calcite, dolomite, pyrite and quartz. The emerald crystals occur most frequently attached to the walls of the vein, and are embedded in the vein material. Where the veins are wide enough to form cavities, the emeralds may be larger. Field observations indicate that the best emerald crystals usually occur in the narrower veins (~5 cm thick) and that quartz crystals increase in transparency toward emerald mineralization. Quartz crystals, some quite large and transparent *(Figure 10)*, are commonly found in association with the emeralds (see also *Figure 1*). Quartz found in or near emerald veins is referred to as *cuarzo de veta* (vein quartz), and is typically transparent and very clean, while the more common quartz found elsewhere is known as *cuarzo de tierra* and is not as transparent. The abundance of quartz as a vein mineral differentiates Peñas Blancas from other emerald mines in the area.

Mining

During the bonanza years of 1958–1965, emerald mining at Peñas Blancas consisted of uncovering the surface of *La Culata* (Spanish for gun breech [opening] or a mound, referring to landforms at the mining site) and following productive veins. Miners eventually dug down over 10 m, with intersecting trenches that were subsequently widened with a bulldozer into gullies. What remains of these workings today are four steep mounds separated by wide gullies. The mounds are perforated by prospecting holes and are overgrown with vegetation *(Figure 11)*. One tunnel, *El Tunel de los Dos,* was started in this time period above La Culata and was extremely productive for many years.

When the surface mining operations predominated, terms like *capas buenas* (emerald-bearing layers), *cambiado* (barren zones) and *cama* (breccia-like masses) were used to describe the rocks. These terms helped to orient the miners as they worked the faces of the slopes. Later, such terms fell out of use as mining moved underground, following productive veins with shafts and drifts. After the depletion of the surface-reaching deposits at Peñas Blancas in the early 1970s,

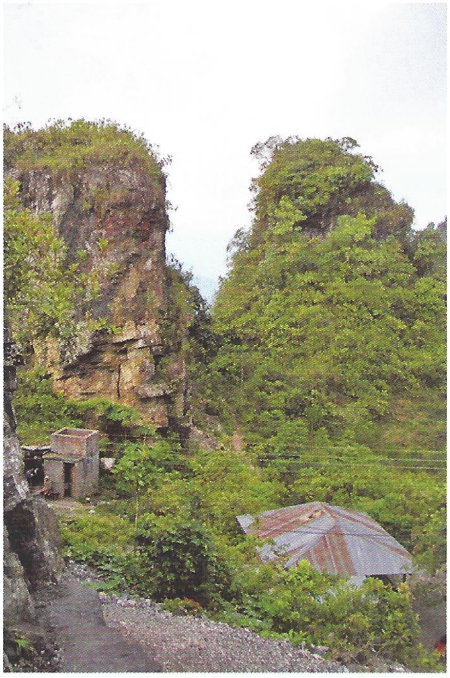


Figure 11: Mining at Peñas Blancas began 50 years ago at the top of these mounds, in an area known as La Culata. Emeralds found at the surface started a bonanza. The miners dug trenches that eventually reached a depth of over 10 m. Photo by E. Boehm.

Figure 12: The authors (RR on left and EB on right) and mine foreman Edilfo Ramírez inspect emerald crystals on matrix from Peñas Blancas. Photo by Willington López.

tunnelling became the only means of following the emerald-rich veins.

At the well-known mines of Muzo, Coscuez, La Pita and Chivor, the brecciated shale host rock provided little resistance to the use of dynamite, and sometimes the force of the explosions passed into the veins, thus damaging the emeralds. Rough stones from these localities sometimes show an indicative whitish percussion mark at the surface that may or may not have accompanying fissures emanating into the stone.

The harder, more blocky shale at Peñas Blancas requires the use of more dynamite than at the other emerald mines, but the uniform compactness of the shale helps insulate the veins from the force of the explosions. If well placed, the dynamite clears away the hard shale without damaging the actual veins, which are then worked manually. The emeralds mined by this process are generally free from percussion fractures caused by dynamite use. They are commonly recovered still embedded in the vein material *(Figure 12)*.

Because of the independent and artisanal nature of the mine workings at Peñas Blancas, there is little money to invest in infrastructure. Even the best-equipped tunnels have only one pump for ventilation and a generator for an electric hammer-drill.

Gemmology

In the authors' experience, Peñas Blancas emeralds are very slightly bluish green (e.g., *Figure 13*), like most Colombian emeralds, but they generally contain less colour zoning and possess a velvety appearance that is highly prized. Also like most Colombian emeralds, the crystals form first-order prisms with flat terminations. However, a unique characteristic of the Peñas Blancas rough material is called *cascocho* by some cutters and dealers. It refers to the tendency of the crystals to have numerous pits and cavities, which hinder the cutting of large stones. They are most likely due to secondary chemical etching after emerald formation.

While visiting Bogotá's downtown emerald market, the authors were fortunate to see two large pieces of rough from Peñas Blancas prior to cutting *(Figure 13)*. The larger crystal weighed 22 g and was faceted into nine stones weighing 32.90 ct (a 30% yield), with the largest being a ~9 ct heart shape *(Figure 14)*. Much sawing was required to remove the cavities from the rough. However, the attraction of Peñas Blancas emerald rough is that beneath the zone of cavities and pits there is sometimes fine material of exceptional purity. The hope of uncovering that fine material, which is not always evident when viewing the surface of the rough, is what often entices cutters and dealers to take risks on emerald

Figure 13: The colour and clarity of some Peñas Blancas emeralds make them highly prized. The 22 g crystal on the left yielded higher-quality material than the smaller crystal on the right. Photo by E. Boehm.

Figure 14: These nine emeralds, faceted from the larger Peñas Blancas crystal in Figure 13, weigh 32.90 carats in total. The large heart shape weighs ~9 ct. Photo by E. Boehm.

crystals from this mine. The cutters equate them to the seed of a peach, whose pitted and gnarly exterior *(cascocho)* covers an inner seed or nodule *(la almendra)* that is pure and fine.

The authors studied 10 rough or partially polished emerald samples that they purchased during their late-2004 trip to Peñas Blancas. The emeralds were obtained from an intermediary who bought them at the mine camp. Refractive indices (taken from at least one polished surface or crystal face) obtained with a GIA Duplex II refractometer were consistent with emeralds from the Muzo region (n_o=1.578–1.580, n_e=1.569–1.572; see *Table I*, cf., O'Donoghue, 2006). With the exception of sample 6 (SG=2.68), the hydrostatic specific gravity values were somewhat lower than reported for emeralds from this region (i.e., 2.63–2.67 vs. 2.70; O'Donoghue, 2006). These lower values may be due to the stones' higher 'porosity', resulting in trapped air bubbles, because of etch cavities present in the rough material. Faceted gems without

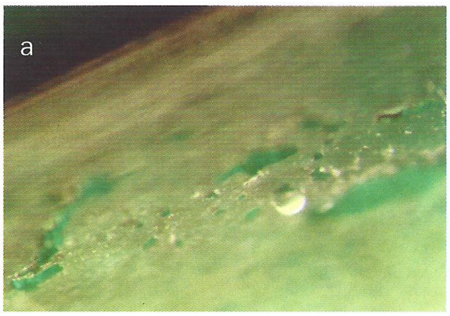
Table I: RI and SG values of 10 rough emerald samples from Peñas Blancas, Colombia.

Sample	Weight (ct)	n_o	n_e	SG
1	1.28	1.580	1.570	2.64
2	1.41	1.580	1.572	2.67
3	1.57	1.580	1.572	2.60
4	2.05	1.580	1.570	2.63
5	2.18	1.580	1.572	2.63
6	2.54	1.578	1.569	2.68
7	4.38	1.58	1.57	nd*
8	4.99	1.578	1.570	nd
9	6.88	1.580	1.570	nd
10	22.52	1.578	1.570	nd

* Abbreviation: nd = not determined.

cavities would likely yield higher SG values. Samples 7–10 contained significant fractures and surface cavities that were filled with oil and epoxy resin (e.g., *Figure 15*). These samples would have therefore rendered inaccurate specific gravity readings.

Inclusions in emeralds from this mining area were first described by Dr E.J. Gübelin and J.I. Koivula (1986, p. 250) in samples coming from the 'Burbar' mine which we know today as Borbur, the closest village to Peñas Blancas. Those authors described the "greatly distorted and distended form of the secondary three-phase inclusions" as typical hallmarks of these emeralds *(Figure 16a)*. Similar secondary three-phase inclusions were also observed in the samples examined for this article *(Figure 16b,c)*. Primary or syngenetic three-phase inclusions are also seen in emeralds from Peñas Blancas. Some protogenetic inclusions of pyrite, calcite and quartz were noted, but such crystals are more commonly found as associated minerals within the gem-bearing veins or attached to the surface of the emerald crystals.



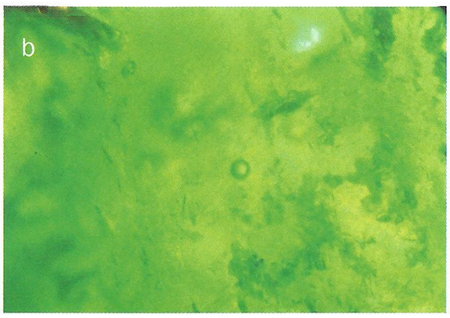


Figure 15: Rough emeralds from Peñas Blancas are sometimes fracture-filled with oil, resin or a combination of these. (a) The pitted surface etching typical of Peñas Blancas emeralds is shown, along with an air bubble that appeared on the surface as a result of the heat generated from the incandescent bulb of the microscope. The heat caused oil in the sample to expand, forcing a bubble and then some oil to the surface. (b) Air bubbles trapped in this emerald's filler could possibly be mistaken for two-phase inclusions. Photomicrographs by E. Boehm, magnified 66× (a) and 50× (b).

Trapiche emeralds

Most gemmologists are familiar with trapiche emeralds from Muzo, in which inclusions of carbonaceous matter form spokes radiating from a hexagonal centre, creating six black 'rays' in the emerald crystal (e.g., Ringsrud, 2009, pp 344–6).

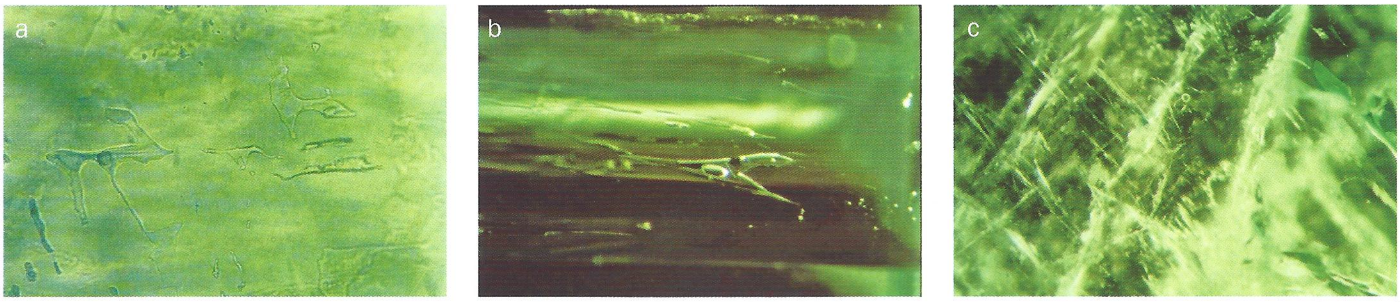


Figure 16: Secondary three-phase inclusions in Peñas Blancas emeralds. (a) Irregular shapes photographed by Dr E.J. Gübelin, magnified 50× (from Gübelin and Koivula, 1986, p. 250). (b) A classic inclusion scene containing a halite crystal, CO_2 gas, and liquid in a 1.41 ct emerald crystal from Peñas Blancas; photomicrograph taken by Dr E.J. Gübelin in 2004; magnified 66×. (c) View parallel to the basal plane of an emerald crystal with a small three-phase inclusion in the top-centre; photomicrograph by E. Boehm, magnified 50×.

The Spaniards called these peculiar emeralds *trapiche* because of their resemblance to the cogs and gears with which sugarcane was crushed. Trapiches are usually cut into cabochons to show off this cog-wheel pattern.

In the 1960s and 1970s, many well-formed large trapiches from Peñas Blancas with white (albite) or black (carbonaceous) interstitial material found their way into collections all over the world (e.g., *Figure 17*). Unfortunately, their size and abundance was also the cause of their destruction: the rays of the trapiche were often sawn through and the six transparent gem segments were then cut into calibrated stones. Rare chatoyant sections were polished into cabochons to form cat's-eyes. Trapiches are no longer being mined at Peñas Blancas. During our visit in 2004, the locals indicated the 'trapiche zone' was found in a steep area overgrown with vegetation (again, see *Figure 6*).

Conclusion and future potential

Since its rediscovery in 1958, the turbulent history of the Peñas Blancas mine demonstrates the necessity of not only solving the geological and engineering aspects of emerald extraction but also understanding the inherent social factors at play in the area. After the initial bonanza, the best emerald production at Peñas Blancas occurred during the presence of loyal, trained security forces headed by strong, undisputed leaders. The current trend of pacification, organization and investment in Boyaca's rich emerald region may allow Peñas Blancas to once again become a significant emerald producer.

Recent exploration at Peñas Blancas has consisted of little more than locals digging shallow test pits, of which only a few have shown potential. The lower trapiche zone could provide additional production, along with the upper area known as La Culata. However, as is the case elsewhere in the subtropical Boyacá mining region, heavy overgrowth has inhibited proper geologic exploration. Prospecting also has been hindered by the area's remoteness, steep topography and challenging social climate. However, it seems probable that more sources of fine Colombian emeralds will be found. One example is provided by the La Pita mine *(Figure 18)*. After two decades of dormancy, in 1998 the La Pita mine suddenly became a major producer in the region (Michelou, 2001). This gives an indication of the possible future of Peñas Blancas and the surrounding region.

However, for Peñas Blancas to realize its full potential, it must first become attractive to outside investment. A decade after the authors' initial visit, the road to Peñas Blancas is still barely passable. The original bonanza left behind a mining

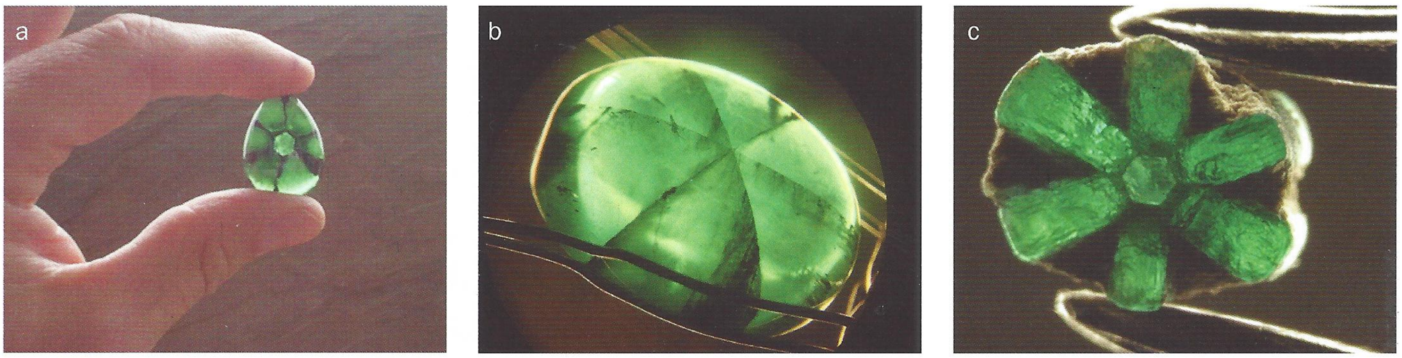


Figure 17: Trapiche emeralds from Peñas Blancas entered the market in the 1960s and 1970s. (a) The most common trapiche variety consists of emerald material intersected by spokes of dark carbonaceous inclusions (28 ct; courtesy of RareSource, photo by E. Boehm). (b) This 25 ct trapiche cabochon displays chatoyant segments, although any cat's-eye emeralds cut from them would be rather small; photomicrograph by E. Boehm, magnified 8×. (c) A 'reverse trapiche' example in which the spokes are formed by straight segments of emerald with albite or shale in between (here, 7 mm in diameter; photo by R. Ringsrud). This type of trapiche, now quite rare in the market, has been found in relatively large sizes (up to 20 ct).

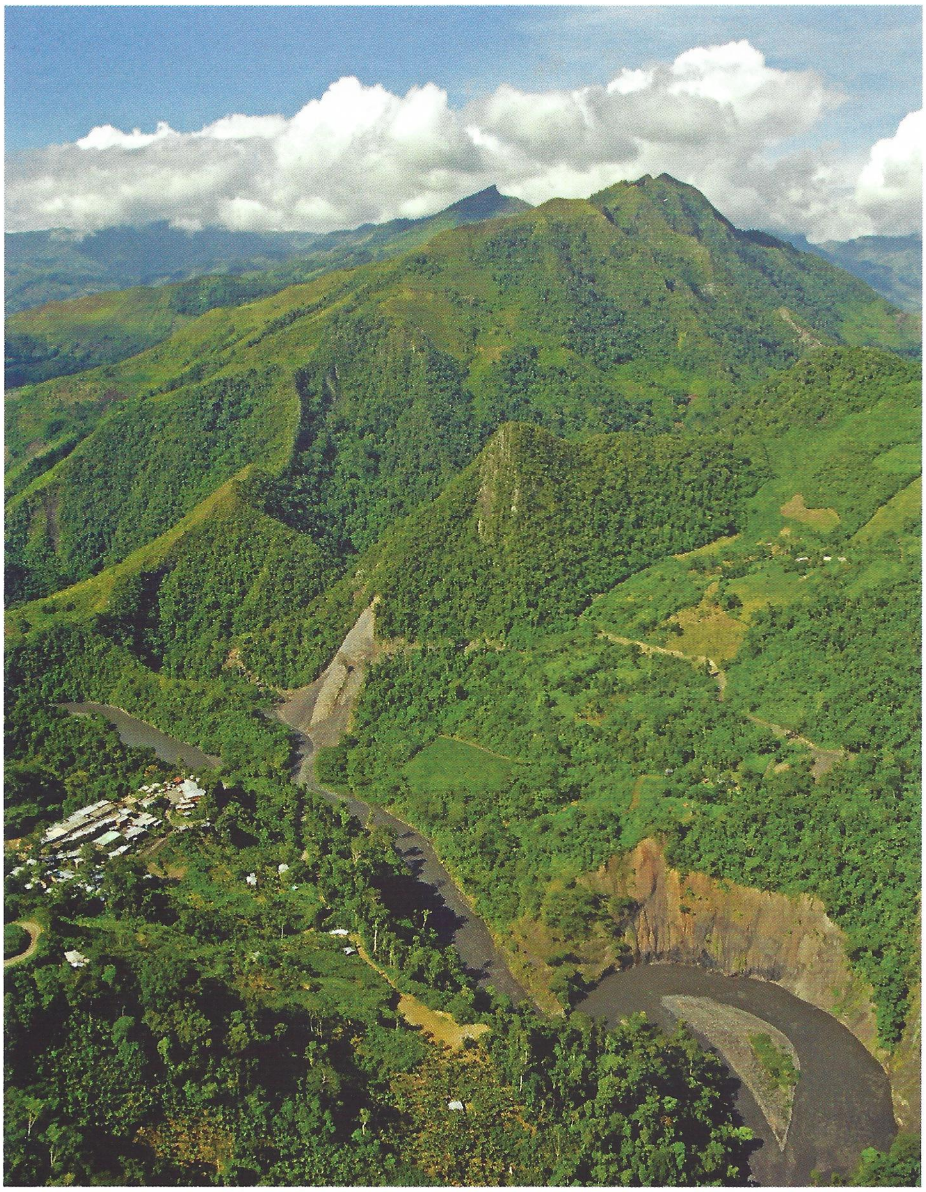


Figure 18: The La Pita emerald mine (left-centre) had its own bonanza in the late 1990s. Continued steady production has elevated the La Pita to the legendary status of Muzo and Coscuez as one of the premier mines in the Muzo region. Photo by R. Ringsrud.

area full of potential but needing serious infrastructure improvements to make it worthy of exploitation.

Even after almost five centuries of supplying fine emeralds to the world, the Muzo region still shows no signs of exhaustion. World emerald demand will only increase, and it is expected that exploration and production in Colombia's premier mining region will grow to meet the demand. With the colour green in fashion and Hollywood actresses wearing more and more emeralds, the future importance of Peñas Blancas, and all emerald mines, will only grow.

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The Authors

Ron Ringsrud
Muzo International, 40 Rue du Rhone, Geneva, Switzerland
email: ronald.ringsrud@muzoemerald.com

Edward Boehm
RareSource, P.O. Box 4009, Chattanooga TN 37405 USA
email: edward@raresource.com