Cuprian Elbaite
from the
Batalha Mine, Paraíba, Brazil

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Copper-bearing “Paraíba tourmaline,” a geochemical
oddity, was discovered in Brazil in 1988. Its rich and
unique colors have given it extraordinary gemstone
value, resulting in the preservation of very few good
crystal specimens. Renewed exploration and
mining were initiated in 1999.

INTRODUCTION
The tourmaline group consists of 13 species, elbaite, liddicoatite
and uvite being among the most colorful. Until the discovery of the
Batalha occurrence in the state of Paraíba, northeastern Brazil,
however, none were known to be colored by copper. Cuprian
elbaite from the Batalha pegmatite veins, unrecognized until the
1980's, has become the most valuable and sought-after of all
tourmalines, and remains the rarest in mineral collections. The
extraordinary colors resulting from the presence of copper (and, to
a lesser extent, manganese), especially an incredibly bright and
rich turquoise-blue, are the reason for its fame and popularity.

Although copper is not an element typical of complex pegmatites,
the association is not unique to the Batalha deposit. Other pegmatites
in the region have been found to contain tourmaline colored by trace
amounts of copper, though not of such high quality; and the Khan
pegmatite near Rössing, Namibia, is also high in copper content,
although it has thus far yielded no tourmalines colored by copper
have reported the presence of copper-bearing elbaite from the Edeko
mine near Ilorin in the state of Ojo, Nigeria, which is very similar in
color and in main and trace element contents to Batalha mine elbaite.

The cuprian elbaites from the Batalha mine would be merely a
mineralogical curiosity were it not for the stunningly beautiful and
deply saturated colors that have resulted from the copper (and
manganese) “contamination.” That feature has elevated Batalha
crystals, now known widely as “Paraíba tourmaline,” to the strato-
sphere of gemological value. Unfortunately for mineralogy, that
high value (in some cases exceeding $20,000/carat) has caused
nearly all good crystals to be immediately faceted into gemstones.
Another factor contributing to the scarcity of good display speci-
mens is the typically broken and/or heavily etched condition of the
crystals. This, combined with the tendency for crystals to be found
completely embedded instead of in open pockets, has meant that
sharp, well-formed, transparent or semi-transparent crystals have
been found only very rarely, and good matrix specimens not at all.
Surviving uncut crystals are treasured by the few collectors and
museums fortunate enough to own one.
Figure 1. Location map showing the Batalha mine at the southern end of the Seridó pegmatitic province (adapted from Sinkankas, 1981).

Figure 2. Location of the Batalha mine and two other mines known for cuuprian elbaite, in the Seridó Fold Belt (SFB) (after Rodrigues Soares et al., 2000).
Because these rare crystals have such significance as specimens for the mineralogist and collector, and because virtually all that has been written about them has appeared only in the gemological literature, the following summary is provided for Mineralogical Record readers. Except as noted, all of the information presented here has been taken from Fritsch et al. (1990) and from Karfunkel and Wegner (1996).

LOCATION

The Batalha mine ("Mina da Batalha," pronounced "Bat-tal-ya") is situated in the Serra das Queimadas mountain range, on the side of Frade Hill ("Serra da Frade"), very near the village of São José da Batalha, and about 4.5 km northeast of the town of Salgadinho in the state of Paraíba, Brazil. The full name of the mine is "Mina da Batalha a Nova Era" ("Mine of the Battle of the New Era") but "Mina da Batalha" is in general use, and some cite the name of the village (São José da Batalha) as also being the mine name. The harsh and dry scrubland of the area supports little agriculture, but for decades a small local mining industry has focused on industrial pegmatite minerals, especially tantalite. Access is via a good highway west from the town of Campina Grande through Soledad and Juazeirinho, and from there about 42 km more due west to Salgadinho.

HISTORY

Attractive elbaite was first noticed in the area by Marcus Amaral, a geologist with the Mining and Geology Department of the Federal University of Paraíba in the late 1970’s, but the potential of the deposits was not immediately recognized. In 1982, Jose Pereira of Patos, a local Paraíba garimpeiro and dealer in "black minerals" ( columbite-tantalite), found a tantalite specimen containing tiny grains resembling colored sugar. Eventually he offered the specimen to another miner, Heitor Dimas Barbosa, who suspected that the colorful grains (later shown to be cuprian elbaite) might indicate the presence of gem minerals. With Pereira as his guide, Barbosa began exploring the mine dumps and tailings of the area’s industrial pegmatites (normally exploited for tantalum, industrial beryl, kaolinite, quartz and mica). In 1983 they finally relocated the source of the specimens, a small, abandoned manganotantalite prospect (Koivula and Kammerling, 1990).

Over the next few years a team of 10 to 16 garimpeiros headed by Barbosa excavated shafts and galleries in the decomposed pegmatite, finding primarily tourmaline of various common shades of green. In August of 1988, however, they encountered strikingly colored “electric” blue and sapphire-blue tourmaline: these were the first of what came to be known as “copper tourmaline,” or “Paraíba tourmaline.”

Barbosa and his associates filed a claim on the deposit in 1988, and formed a mining cooperative (COGASBRA) which they registered with the DNPM (Brazilian National Department of Minerals). Nevertheless, the mining rights were disputed and lengthy litigation ensued, during which time little productive mining activity took place. The controversy was finally resolved in 1998, a consequence of the settlement being that the deposit was broken into three more or less equal pieces, of which Barbosa got one. Heitor and Sergio Barbosa then reactivated their portion of the property (Austin, 2001). Land adjacent to the mine was also opened up for exploration and mining (Cook and Barbosa, 1999). When Laurs and Shigley (2000) visited the mine in August of 2000, mining was proceeding carefully under the guidance of Heitor Barbosa; two teams of miners had begun working new areas of the pegmatite, and underground fluorescent lighting had just been installed. Barbosa was also constructing facilities to process the old mine tailings, and another group, T.O.E. Mineração Ltda. (a subsidiary of Treasures of the Earth, a Nevada corporation), had recovered considerable quantities of gem rough by processing alluvial sediments down-slope from the mine. In February of 1999 the T.O.E. group signed a 7.5-year agreement to mine the de Souza property, which includes part of Serra da Frade itself and some of the flat land surrounding the hill where alluvial deposits have
developed; the operation has been very successful. Removal and processing of alluvial/eluvial material has also uncovered additional tourmaline-bearing pegmatite veins (Austin, 2001). The Batalha mine is a labyrinth consisting of shafts 50 to 60 meters in depth connected by several kilometers of hand-dug drifts and adits exploiting the complex system of pegmatite dikes. The narrow tunnels (originally only about 60 x 180 cm, though some have now been significantly enlarged to around 2 meters high and 1.5 meters across) were all worked solely by candlelight, under conditions of poor ventilation, during the 1980’s and early 1990’s, but have been modernized somewhat in recent years.

It was estimated in 1990 that approximately 10,000 carats (2 kg) of rough crystals and cut stones had been produced from the mine before legal difficulties restricted mining activity. Additional pockets were discovered underground in 1993 and 1998, but since then the bulk of production of gem rough has come from the processing of alluvial material (Austin, 2001).

GEOLOGY

The Batalha occurrence is situated within a large, well-known pegmatite province containing hundreds of pegmatite bodies that have produced feldspar, quartz, mica and columbite-tantalite. At Batalha the geology consists of a parallel to sub-parallel system of steeply dipping, thoroughly decomposed granitic pegmatite dikes cutting across a hard muscovite-quartzite country rock. This rock unit, known as the Ecuador Formation of the Mid-Proterozoic Serido Group, is part of the Borborema geologic province (Almeida et al., 1981). The dikes are thought to have formed during the Upper Proterozoic (650–600 ma) Brazilian thermotectonic cycle. Feldspars in the pegmatites have all been completely altered to white, chalky kaolinite. Gem-quality tourmaline crystals are found embedded in this clay, and within small clay-filled pockets in the core zones of the pegmatites. Most tourmaline crystals have been broken by natural tectonic forces, and show moderate to severe etching. Some crystals have also been partially or completely altered to lepidolite. Associated minerals include quartz, lepidolite, schorl, dark green non-cuprian elbaite and Nb-Ta oxides.
The vein-like pegmatite bodies measure 20 to 140 cm in thickness. One area that has been particularly productive of gem cuprian elbaite is known as the "Heitorita trend," especially at a depth of about 35 meters (Barbosa and Cook, 1991). The main dikes in the trend are generally referred to by number, one through five.

Other pegmatites in the general area which have been found to contain cuprian elbaite (always of lower quality) plot within a narrow north-northeast-trending band extending for some 90 km. They include the Capoeira pegmatite (where the cuprian elbaite is typically strongly color-zoned pink, blue, purple, green and gray), also known as the Boqueirãozinho pegmatite and the CDM or Mulungu mine. However, erroneous localities for cuprian elbaite have also been circulated, apparently to deter and confuse competing interests; these include names such as Salgadinho, the Pedra Bonita spessartine occurrence near Carnaúba dos Dantas, Cajazeiros, Riach do Pingo, Junco do Seridó, Pedra Lavrada, and Serra dos Quintos, none of which have actually produced any cuprian elbaite.

Serra dos Quintos, however, should not be confused with the productive Quintos pegmatite, also known as the Wild mine (Laurs and Shigley, 2000). Traces of copper have also been found in tourmaline from the Gregório pegmatite near Parelhas (Soares et al., 2000; Adusumilli et al., 1994).

The high copper content of the pegmatites was apparently derived from underlying Cu-bearing sediments during chemical mobilization associated with the Brasiliano thermotectonic cycle. Veins containing copper sulfides have been found nearby at Serra Negra, at a site between Parelhas and Pedra Lavrada, at an
occurrence near Nova Palmeira, in the scheelite skarns of Currais Novos, and very near the Capoeira/Boqueirãozinho pegmatite (see Falster et al., 2000, and the article on the latter occurrence by Robinson and Wegner, 1998). Other metallic elements which have also been found locally in pegmatites (U, W, Ta, Sn, Nb, Mn) have been perceived by some authors to be arrayed in broad concentric zones radiating outward from the center of the pegmatite field, the copper-containing tourmaline band being parallel to these zones and therefore presumably genetically related to the core pluton (Cook and Barbosa, 1999); this theory still requires confirmation.

MINERALOGY

Batalha-mine cuprian elbaite occurs in a range of rich colors, from yellow-green to emerald-green, blue-green, turquoise-blue, tanzanite-blue, sapphire-blue, “electric” blue, Bluish purple, purple, purplish pink, pink and gray—each color valued differently by the gem market. Many individual crystals are concentrically zoned in several colors. High concentrations of copper (1.5 to 2.3 weight % CuO) plus some manganese are responsible for the turquoise-blue color, whereas lower copper (< 0.6 wt.%) in the presence of manganese results in the purple color. Low manganese (<0.1 wt.%) and high copper produce a green color. Pleochroism is usually distinct, from medium blue to pale greenish blue. The highest concentration of manganese (2.99 wt.% MnO) was found in a greenish gray crystal. Some colors are produced or enhanced by heat treatment, such treatment not always being determinable after the fact.

Indices of refraction are typical of elbaite (1.618–1.612 and 1.638–1.646); specific gravity (3.03–3.12) is slightly higher than usual. The crystals are unresponsive to longwave and shortwave ultraviolet light. The X-ray diffraction pattern is closely similar to that of standard elbaite, yielding a unit cell of $a = 15.883$ and $c = 7.111$ Å.

Numerous yellowish specks have been found included in some crystals; X-ray fluorescence analysis indicated the presence of Mn, Fe, Cu, Zn, Bi and S, suggesting a complex sulfide. However, Brandstätter and Niedermayr (1993, 1994) investigated the metallic...
inclusions noted earlier by others and found them to be native copper; inclusions of black tenorite were also found in elbaite. The copper appears to have formed by epigenetic exsolution from elbaite.

Chemically the Batalha cuprian elbaites are typical of other elbaites in their low Ti (< 0.11 wt.% TiO₂) and Fe (< 0.34 wt.% Fe₂O₃) contents and the virtual absence of V and Cr. The high concentration of Cu is, of course, quite unusual. Small amounts of Bi, Pb, Zn and Au were also detected in many specimens: these trace elements apparently have no influence on color. Site-occupancy and charge-balance considerations indicate that the copper and manganese are present in the Y crystallographic site, substituting for aluminum. Therefore the formula can be written as: Na(Li,Al)₃(Al,Cu,Mn)₆(BO₃)Si₆(OH)₁₈. Heat treatment of the crystals is said to be commonly practiced; the affect is the reduction of Mn³⁺ to Mn²⁺, removing the pink and purplish colors to leave a pure turquoise-blue. Heat treatment has no effect on the absorption attributable to copper, although blue and green colors can be influenced by heat treatment because of the presence of trace amounts of Mn.

Morphologically the Batalha mine elbaites are roughly trigonal in cross-section but are somewhat irregular in outline. Zoning in some crystals shows that etching has not significantly affected their overall shape, whereas other crystals appear more heavily etched. Terminations, where present, are usually trigonal rhombohedrons or a flat pedion. Terminated crystals, however, are much rarer than broken fragments. One heavily fractured crystal would have measured about 30 cm, had it been recovered intact (Wilson, 1991). Surviving crystals are usually in the 1 to 3-cm size range. Koivula
and Kammerling (1989) reported a “specimen quality” crystal (presumably meaning that it had no gem value) weighing 100 grams (about a quarter of a pound). Koivula et al. (1993) reported seeing an exceptional 4.8-gram bicolored crystal (violet-blue to blue-green) with no eye-visible inclusions and with well-formed, striated prism faces. They also reported seeing dark yellowish green crystals with metallic inclusions which were said to have been found below the level where the brightest blue crystals occur; further down only black schorl is said to be found.

The Natural History Museum of Los Angeles County has an interesting specimen consisting of fractured and mostly unterminated non-gem-grade crystals of good color embedded in white quartz matrix and showing partial alteration to lepidolite. According to curator Anthony Kampf, several hundred such specimens, purportedly from the Batalha mine, were available in Brazil from Emilio Frois (New Gems Ltda. and Color Gemas company) at his warehouse in Governador Valadares in 2000 and 2001, and some of these later appeared among the stock of other dealers at the 2001 Denver Gem and Mineral Show. These specimens provide systematic collectors and museum curators with an opportunity to acquire study-grade examples of cuprian elbaite at a price well below that of gem-grade crystals. However, it is not at all certain that this material is from the Batalha mine; similar cuprian elbaite specimens sold in Tucson a few years ago came from the Wild mine (the Alto dos Quintos, or just Quintos, pegmatite), owned by Paul Wild of Idar-Oberstein, located about 60 km northeast of Batalha in Rio Grande do Norte state (Brendan Laurs, personal communication, 2001).

Figure 11. Cuprian elbaite from the Batalha mine, 5-cm crystal with 1.3-cm (4-carat) cut stone. Michael Scott collection; Van Pelt photo courtesy of Michael Scott.
Figure 12. Cuprian elbaite, 2.3 cm, from the Batalha mine (ca. 1989). Brian Cook specimen; Wendell Wilson photo.

Figure 13. Cuprian elbaite, 1.7 cm, from the Batalha mine (ca. 1989). Wendell Wilson collection and photo.

Figure 14. Cuprian elbaite crystal section, 3 cm, turquoise-blue with purple core, from the Batalha mine (ca. 1989). Brian Cook specimen; Wendell Wilson photo.
Finally, it should be noted as a warning that some marketers have been offering blue-to-green copper-free tourmaline as Paraíba tourmaline in order to obtain a much higher price.

CONCLUSIONS

Although the area in northeastern Brazil where occurrences of cuprian elbaite have been found is fairly large, none of the localities has produced crystals equal to those found at the Batalha mine. Furthermore, almost all good crystals of any size tend to be shattered, and the remainder are generally embedded, non-gemmy and not of good collector quality. As long as mining continues in the area, the possibility of more good crystals being found exists, but their extremely high gem value probably means that most will continue to be cut as gemstones rather than saved as crystal specimens. Consequently, even very small crystals of good color, form and transparency will probably remain very rare in collections and on the market.

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