The Panasqueira Mines

Covilhã, Portugal

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Panasqueira, an extensive complex of orebodies and mines, was discovered and worked for tin by the ancient Romans, and was opened to modern mining in 1885. Since then it has become famous as a source of superb specimens of green and purple fluorapatite, arsenopyrite, cassiterite, ferberite and other minerals, and is the type locality for panasqueiraite and thadeuite. The mines have been consistent suppliers of specimens for several decades and continue to yield fine minerals today.

INTRODUCTION

The Panasqueira mining district is well known as encompassing one of the world's biggest tungsten deposits, and one of Europe's most important tin deposits. The mining works have been under more or less continuous development for over a century, and remain active today.

Panasqueira has become famous, not only for the richness of its ores, but also for its magnificent mineral specimens, representing a large number of species. For many decades, thousands of specimens from Panasqueira have joined collections worldwide. The classic crystals of fluorapatite, cassiterite, ferberite, siderite and arsenopyrite—to name just the more notable species—are outstanding for their sharpness, size, and varied morphologies.

During the last few years, however, the production of collector-quality specimens from Panasqueira has diminished somewhat. This is mainly because of changes in corporate ownership of the mines, and increased levels of vigilance to prevent the collecting of specimens by the miners. But over the same period an increased demand for tin and tungsten has generated projects to open new mining at Vale da Ermida and some other areas of the district; these new operations offer the possibility of new specimen wealth in the near future.

In any case, keen interest in the Panasqueira deposit, both by mining professionals and by collectors, has given rise to an extensive Spanish-language literature describing the history, geology and mineralogy of Panasqueira, as summarized in an excellent monograph by Azevedo (1997). But the English-language literature thus far has been confined to a single six-page article by Gaines and Thadeu (1971) in the sixth issue of the then-new *Mineralogical Record.*

HISTORY

"Panasqueira," the name first conferred on the mining district at the beginning of the 20th century, comes from the term "panasco," denoting an orchard grass (*Dactylis glomerata hispanica*) native to the area. A little more than a century ago the region of the present mines was almost uninhabited, although vestiges of very ancient mining works could be seen. These vestiges testify to surficial mining of tin ore during the time of Roman rule (very probably) and during the period of Arab occupation.

The beginning of modern mining at Panasqueira came in 1885.

Figure 1. **Location map.**

For some time before this year the area had been visited regularly by *carboneros*—people who harvested thickets of the "panasco" in order to burn the plant material to make charcoal which they then sold in nearby villages and cities. One of these charcoal-makers, known by the nickname of *O Pescão de Casegas* ("the fisherman of Casegas": his real name is not known), found a black rock whose heaviness surprised him. He showed it to his friend Manuel dos Santos, a businessman and adventurer, who understood that the black rock was probably valuable ore of some kind. Dos Santos visited the area and concluded that the ore sample had come from a nearby deposit. Smelling a juicy business opportunity, Dos Santos went to Lisbon to show the ore sample to the professor of mineralogy at the university, an engineer named Silva Pinto, who judged that it was "wolframite." Dos Santos constructed a little house at Panasqueira and began a small mine, as well as buying for high prices all samples of the mineral which herders carried to him.

Soon Silva Pinto arrived and acquired considerable land, including the parcel which had been occupied by Dos Santos. Pinto registered the first mining claims and built some bunkhouses for workers. But a short time later, needing more capital, Pinto took on two partners: Estevão Almeida from Lisbon and Raúl Dória from Covilha. At this time, only small, surficial ore veinlets were being exploited and the milling was manual and very rudimentary, but almost 100 people were being employed.

According to Vaz Leal (1945) and Azevedo (1997), the first written reference to the Panasqueira mine appears in the *Catálogo Descritivo da Secçao de Minas da Exposiçao da Lisboa* ("Descriptive Catalog of the Mining Section at the Lisbon Exposition") (1889). The passage describes mining at Panasqueira in the few foregoing years, and implies that during this early period the mine was small and of little economic importance.

The first official mining concession, registered in the *Diario do*

Figure 2. **The Barroca Grande mine area, ca. 1920s. Photo courtesy of Rui Nunes.**

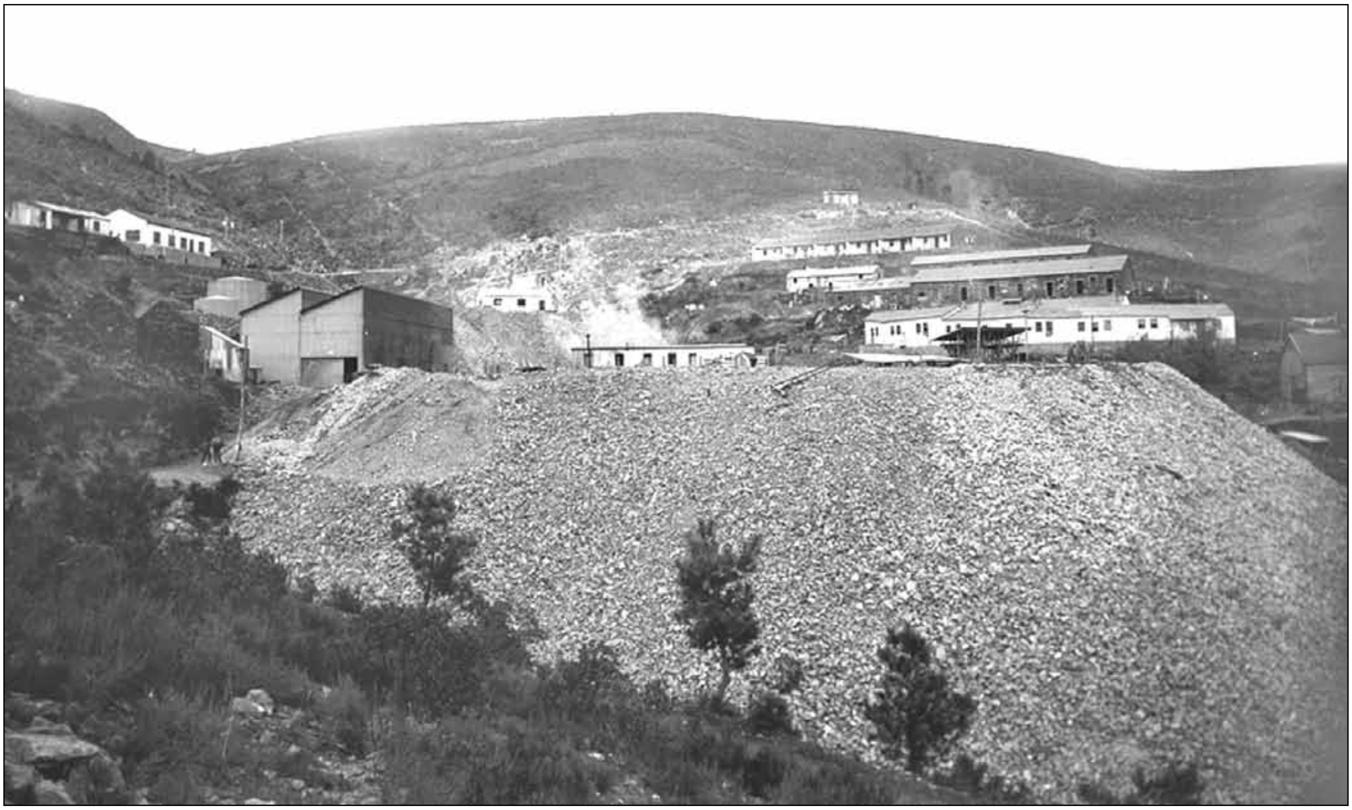


Figure 3**. The Barroca Grande dump area, ca. 1920s. Photo courtesy of Rui Nunes.**

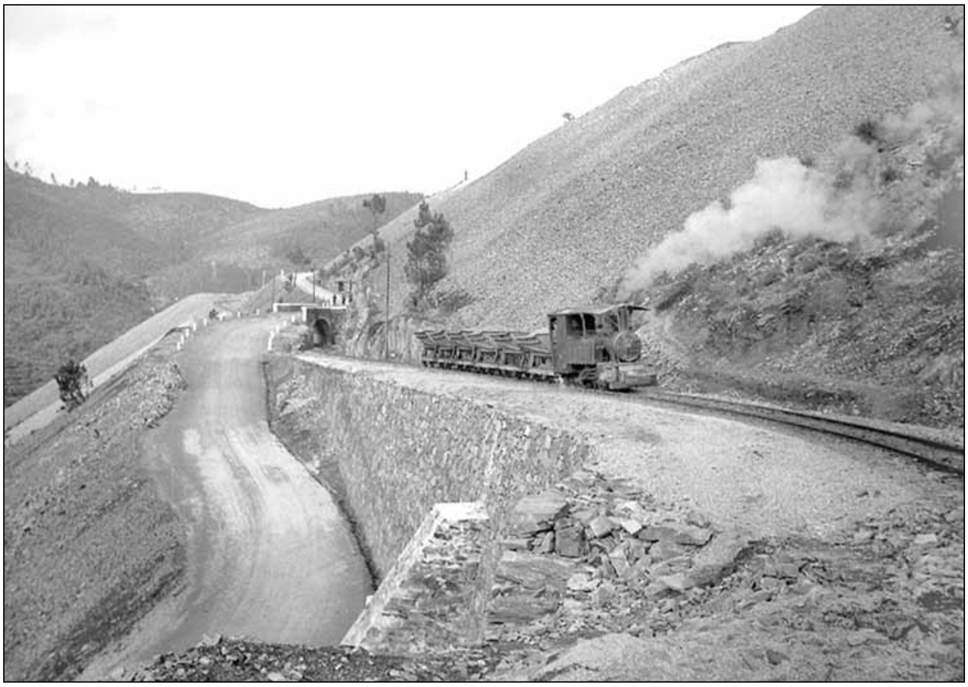


Figure 4**. Ore train at the Cabeço do Pião mine, ca. 1920s. Photo courtesy of Rui Nunes.**

Governo, was granted to the *Sociedade de Minas de Volfram em Portugal Lisboa por a firma Almeida, Silva Pinto and Comandita, Exploradora de Minas de Volfram existentes no Fundão e Covilhã, com sede en Lisboa* ("Society of tungsten mines in Portugal, for the Almeida, Silva Pinto and Comandita Corporation, developer of the existing tungsten mines at Fundão and Covilha, with headquarters in Lisbon"). The concession is dated 1898, the year when significant tungsten mining at the Panasqueira and Cabeço do Pião mines began.

In 1901 the Count of Burnay purchased the concession, which had shortened its name to *Firma Almeida Silva Pinto and Comandita*. In 1904 the first mechanized mill was constructed on a bank of the Zêzere River. The richness of the mine attracted the interest of an English company, and Burnay sold the mining concession to this company, but when the company did no mining for a year the concession reverted to Burnay, who held it until 1911. In that year the concession passed to Wolfram Mining and Smelting Company Ltd.; in 1928 this company was renamed Beralt Tin and Wolfram, Ltd.

Between the First and the Second World Wars the company suffered some difficulties, and in 1918 and 1919 the mines went almost completely inactive (except for maintenance and some repair work). In 1920, 300 new workers were hired and a new mill was built, but the revival was short-lived: mining almost stopped again in 1923, and in 1926 the mines closed.

Always short of financing, the company maintained itself precari-

***Figure 5*. Ore milling and washing facilities at Panasqueira, ca. 1900. Photo courtesy of Rui Nunes.**

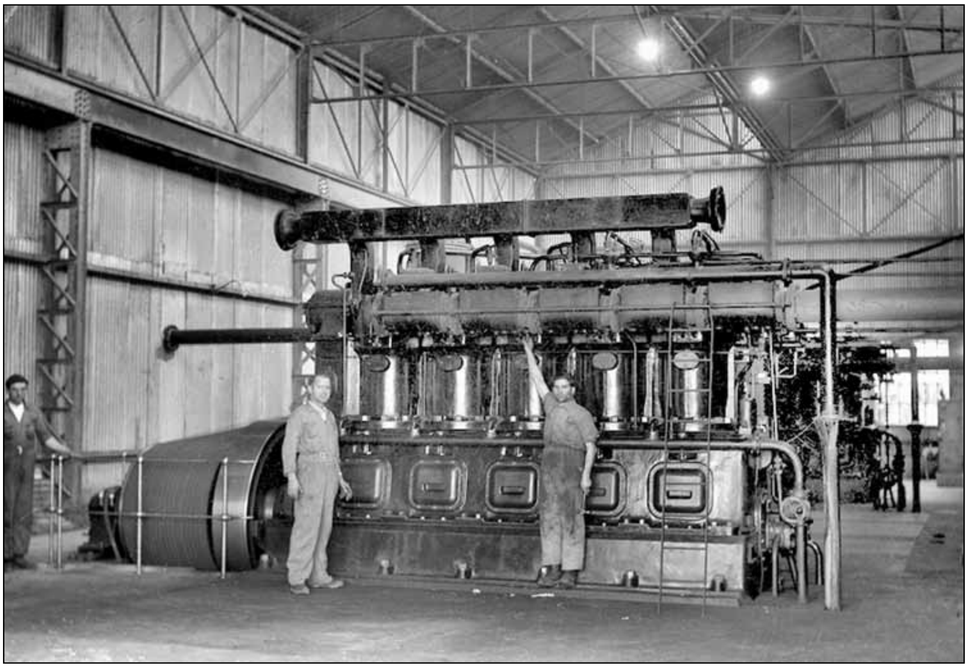


***Figure 6*. Diesel-powered mill engine at the Cabeço do Pião mine, ca. 1920s. Photo courtesy of Rui Nunes.**

ously until 1934, when new English investment and the increasing price of tungsten provided new impetus to mining at Panasqueira. During the late 1930s and early 1940s, 5,800 miners and 4,880 more people from local villages were employed. Many of these workers were women, children and elderly people. They formed groups of four or five and combed areas near the shafts and on the dumps to find ore which they brought to the mine owners. They were paid a fixed per-kilogram amount for the ore—a practice called *exploraçõ do quilo* ("mining by the kilogram") (Lourenço, 2008; Vaz Leal, 1945). Sometimes the people who did this kind of work matched or even exceeded the ore output of the more conventional miners. Because of the high price of tungsten, many of them soon became wealthy, and even the less productive among them were able to build new "houses and walls, put glass in the windows and iron verandas on their houses" (Vaz Leal, 1945), although the constant work forced many to abandon necessary social tasks. Alarmed at the social disruption which was resulting from this kind of mine development, the Portuguese government decided in June 1944 to close all Portuguese tungsten mines.

Just after World War II the price of tungsten climbed quickly and the company's fortunes improved, but production declined again in the late 1940s. In the early 1950s, mainly as an effect of the Korean War, tungsten prices rose very quickly for a short time, but then fell again just as quickly.

Beralt Tin and Wolfram, Ltd. continued to operate the mines until 1973. In that year, after the Portuguese government had contributed

Figure 7. **The Barroca Grande mining area in 2012.**

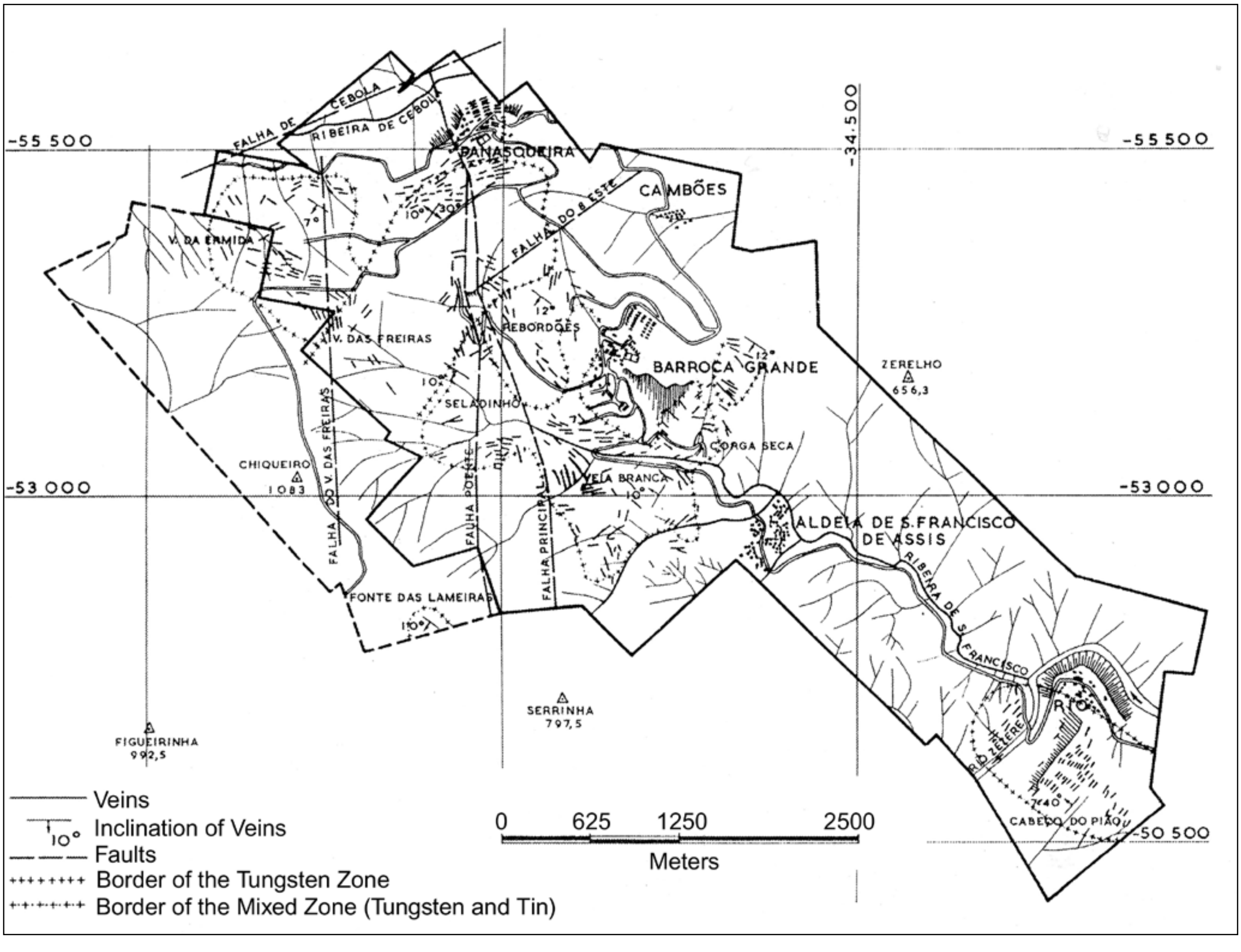


Figure 8. **Map of the major veins in the Panasqueira and Vale da Ermida mining areas. Beralt Tin & Wolfram, Ltd.**

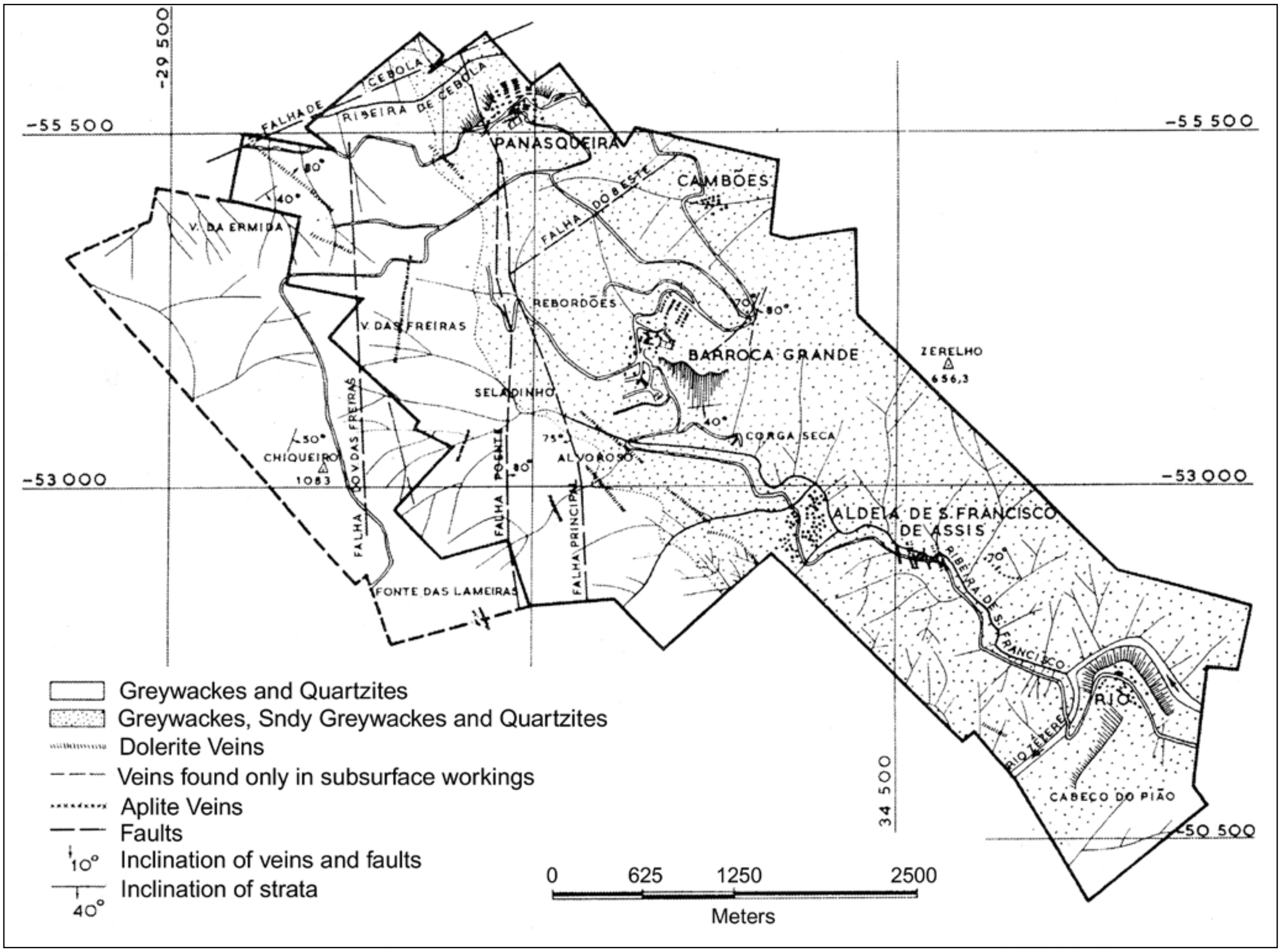


***Figure 9*. Geologic map of the mining areas of Panasqueira and Vale da Ermida. Beralt Tin & Wolfram, Ltd.**

significant funding, the company's name was changed to Beralt Tin and Wolfram Portugal, S.A.; by that time the Canadian firm of Primary Metals controlled the majority of the company's shares. Also in 1973, when tungsten prices were very low, the company began to recover copper from chalcopyrite ore.

One year later, Beralt Tin began underground mechanized production, followed inevitably by a reduction in the number of miners. At the end of the 1970s the company opened a second underground level in the Barroca Grande mine, and by 1982 this new mining zone was yielding more ore than any other part of the mining concession.

The decade of the 1990s was a good one for Panasqueira. The mines closed between 1993 and 1995, but a new mill opened at Barroca Grande in 1996, a new mechanized shaft brought on better working conditions and increased ore production, and the mines in general were economically profitable.

The new millennium has also been a good time for the mines so far. Since before 2004, tungsten prices have remained high, and ore production at Panasqueira has been more or less continuous. In 2007–2008, the Japanese firm of Sojitz gained control of the Beralt Tin Company, renaming it Sojitz Beralt Tin and Wolfram (Portugal) S.A. The Japanese company took over via a public acquisition offer to Primary Metals, the previous majority shareholder.

Since 2008, most ore production, as well as new exploration, has taken place on level 3 of the Barroca Grande mine.

GEOLOGY

Panasqueira is one of the largest and best-known tungsten-tin deposits in the world. Lying in Beira Baixa Province in east-central Portugal, 300 km northeast of Lisbon, the deposit belongs to one of the most important European metallogenic regions, the so-called "tin arch," characterized by large granitic plutons flanked by metal-bearing greisens. The Panasqueira deposit has been exhaustively studied and described (Cotelo, 1944; Thadeu, 1951; Bloot and De Wolf, 1953; Reis, 1971; Orey, 1967; Conde *et al.*, 1971; Kelly and Rye, 1979; Bussink, 1984; Foxford *et al.*, 1991; Azevedo and Sáinz de Baranda, 1997; Ascençao Guedes, 2002)—a general summary is offered here, with emphasis on the mineralization.

The original sedimentary rocks at the site of the deposit were formed during the Upper Precambrian and Cambrian, then altered successively by the Caledonian, Hercynian and Alpine orogenies, when intrusions of granitic batholiths generated a low-grade regional metamorphism partially overprinted by later contact metamorphism. The metamorphosed country rocks have a marine sedimentary origin (in many areas the rocks clearly preserve this character); most of the rocks began as clayey shales, and in areas affected by the regional metamorphism the shales were altered to graywackes and quartzites rich in biotite and chlorite and to a lesser extent andalusite and cordierite. Later metamorphic processes around the granitic intrusions produced sulfide-poor greisens. Mineralization was most intense in the associated "silica caps" of hydrothermally deposited quartz; these silica caps, which reach thicknesses of 14 meters in some places, contain the highest density of mineralized veins.

The granite batholiths are highly fissured and crossed by dikes of two basic kinds: subvertical dolerite dikes which generally strike north-south, and younger aplite dikes which are obviously related, both genetically and compositionally, to the granite of the batholiths. Lenticular veins and veinlets of quartz locally known as *seixo bravo* ("rough stones") infuse the meta-shales, which are oriented, in most cases, parallel to the bedding planes of the shale.

MINERALIZATION

A dense network of more than 1,000 quartz veins and veinlets (from a few millimeters to more than 1 meter thick) crisscrosses the ore deposits and has been a controlling factor in the mineralization. The veins, which formed when the batholiths cooled and contracted, show sub-horizontal structures mineralized by ferberite and cassiterite with a secondary enrichment in sulfides. Other, smaller veins, also mineralized, cross the major veins at oblique angles.

The tungsten-bearing and tin-bearing quartz veins are of Carboniferous age, having formed during the final phase of the Hercynian Orogeny when ascending magma released the mineralizing fluids. The details of the process are not yet completely understood (Kelly and Rye, 1979), but it is evident that the mineralization began when fluids migrated from the granitic dome, and that the composition of the ore was later affected by meteoric waters impinging on the deposit.

The mineralization within a typical vein forms successive parallel layers from the periphery to the center, corresponding to several well differentiated phases: (1) a first, "quartz seam" phase, with quartz and some tourmaline (schorl-dravite); (2) a muscovite selvage formation phase, with quartz, schorl-dravite, muscovite, arsenopyrite, topaz and fluorapatite; (3) a main oxide-silicate stage, rich in tin and tungsten, with quartz, schorl-dravite, muscovite, arsenopyrite, cassiterite, ferberite and fluorapatite; (4) a main sulfide stage, with quartz, schorl-dravite, muscovite, arsenopyrite, fluorapatite, other phosphates, sphalerite, pyrrhotite, pyrite, chalcopyrite and cassiterite; and (5) a pyrrhotite alteration stage, with siderite, pyrite, marcasite, chalcopyrite, stannite, galena and As-Bi sulfides (Polya *et al.*, 2000; Ascençao Guedes, 2002). After these main mineralizing phases there was a terminal phase, known as the late carbonate stage, characterized by the appearance of dolomite, calcite and Ni-As sulfides forming coatings. Ferberite, the major ore mineral, is concentrated in the main oxide-silicate parts of the veins, i.e., near their centers, while most of the ore sulfides are found in the main sulfide stage and the pyrrhotite alteration zones.

In veins of this kind there are commonly open spaces (cracks, fissures, vugs) in which crystals can form. In such open spaces in the Panasqueira deposit, crystals of ferberite, fluorapatite, cassiterite and arsenopyrite are often found resting on layers of small acicular crystals of tourmaline (schorl-dravite) and/or leafy muscovite. In turn, layers and scattered crystals of later sulfides (marcasite, pyrite and chalcopyrite) and carbonates (siderite, calcite and dolomite) commonly rest on the crystals of ferberite, fluorapatite, etc. Mineralization in larger cavities is similar, being characterized by the presence of well crystallized quartz and by large, well developed crystals of fluorapatite, siderite, arsenopyrite and marcasite.

Thadeu (1951) described seven areas of the deposit, each with its own geological, tectonic and mineralogical features; these areas have all been mined, but to different extents and during times which are not necessarily coincident. The areas are (1) Panasqueira-Barroca Grande, (2) Gorga Seca-Alvoroso-Veia Branca-Giestal, (3) Lomba da Cevada, (4) Rebordões-Seladinho, (5) Fonte das Lameiras, (6) Vale das Freiras-Vale da Ermida, and (7) Cabeço do Pião. Most of the best collector-quality mineral specimens have come from Vale das Freiras-Vale da Ermida and—in particular—from Panasqueira-Barroca Grande. In all seven areas the distribution of mineralization is irregular, but clearly the mineralization at Panasqueira and Vale da Ermida is richest—although it becomes much sparser in the deeper levels of Barroca Grande (Azevedo and Calvo, 1997).

MINERALS

Acanthite $Ag2S$

Acanthite microcrystals are rare and are usually associated with the intrusive rocks (Kelly and Rye, 1979; Wimmers, 1983). Acanthite also forms inclusions in some siderite crystals (Azevedo and Calvo, 1997; Ascençao Guedes, 2002).

Althausite $Mg_4(PO_4)_2(OH,O)(F,\square)$

Massive althausite is among the phosphates found in the main sulfide zone. Very rare, it is associated with, and difficult to distinguish from, scorodite, wagnerite, isokite, thadeuite, panasqueiraite and wolfeite (Kelly and Rye, 1979).

Amblygonite $(Li,Na)Al(PO_4)(F,OH)$

Massive white and greenish white amblygonite is one of the phosphates found in the main sulfide zone. Like most of these, it is very rare and difficult to detect when mixed with thadeuite, panasqueiraite, scorodite, wagnerite, isokite and wolfeite (Kelly and Rye, 1979).

Ankerite $Ca(Fe^{2+},Mg,Mn)(CO_3)_2$

Not a significant species at Panasqueira, ankerite is one of the carbonates of the late carbonate stage. In most cases it is a component of zoned crystals of dolomite-ankerite; individual ankerite crystals are difficult to identify.

Antimony **Sb**

Native antimony is very rare at Panasqueira. It is genetically associated with the intrusive rocks but also occurs as inclusions in galena and chalcopyrite (Wimmers, 1983; Azevedo and Calvo, 1997; Ascençao Guedes, 2002).

Arsenic As

In 1978, spherical nodules of native arsenic from 5 to 8 cm in diameter were found between the 60 and 124 veins at San Agustín (Azevedo and Calvo, 1997; Ascençao Guedes, 2002).

Arseniosiderite $Ca_2Fe^{3+}_3(AsO_4)_3O_2\cdot 3H_2O$

The occurrence of arseniosiderite at Panasqueira requires confirmation. Vague citations of the species refer to microscopic, white, fibrous masses that could be products of supergene alteration; these masses could also contain pharmacosiderite and symplesite (Azevedo and Calvo, 1997).

Arsenopyrite $FeAsS$

Arsenopyrite is one of Panasqueira's most important collector species, occurring there as specimens rivaling those from any other locality. The dominant forms are the {101} prism, commonly striated, and the {120} prism; other forms, especially the {001} pinacoid, are present, but generally are very poorly developed. Most crystals are doubly terminated prisms elongated on [101], but this shape can vary: faces and edges are sometimes slightly curved, and there may be polycrystalline growth on the faces. Penetration twins on the (012) plane are also found. Very commonly, arsenopyrite forms aggregates of more or less flattened crystals showing parallel growth in both vertical and horizontal directions (Orey, 1967; Gaines and Thadeu, 1971; Azevedo and Calvo, 1997; Ascençao Guedes, 2002). Individual crystals have an average size between 1 and 3 cm, but crystals measuring 8 to 10 cm are not especially rare, and exceptionally the crystals reach 16 cm.

One of the most distinctive habits of arsenopyrite at Panasqueira is the so-called "key shape," consisting of an epigenic bipyramidal crystal showing the {110} and {014} prisms (faces of the latter form being very smooth and finely striated) attached perpendicularly to a long edge of an elongated crystal showing dominant {110} prism

and {101} pinacoid. The morphological differences between the two attached crystals of the same species, plus the fact that the epigenic crystals can be greenish or iridescent, can cause arsenopyrite in "key-shaped" aggregates to be confused with marcasite.

Bertrandite $Be_4Si_2O_7(OH)_2$

Bertrandite was identified by Clark (1965) in specimens from Rebordões, as clusters of submillimetric (maximum 0.3 mm) crystals on surfaces of beryl and fluorapatite. The tiny bertrandite crystals are oval-shaped, transparent and colorless, with pearly luster; heart-shaped twins are seen rarely.

Beryl $Be_3Al_2Si_6O_{18}$

Beryl has been noted from Corga Seca (Thadeu, 1951), Rebordões and Barroca Grande (Bussink, 1984). It forms white to bluish, deeply striated and strongly channeled, opaque, crystalline masses.

Figure 10 **(*top left*). Arsenopyrite with fluorapatite and sphalerite, 12.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 11 **(*above*). Arsenopyrite, 5 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 12 **(*left*). Arsenopyrite with quartz, 9.7 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

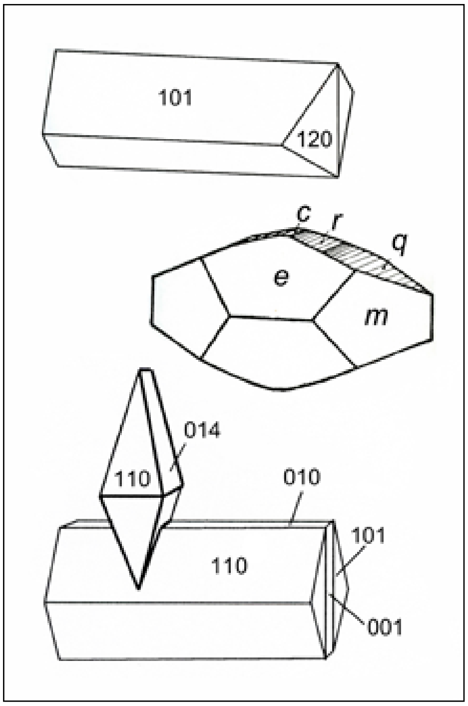


Figure 13. **Crystal drawings of arsenopyrite habits from Panasqueira (Azevedo and Calvo, 1997; Niggli, 1948; Curto, 2013).**

***Figure 14* (*top right*). Arsenopyrite with siderite, 7.6 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

***Figure 15* (*above*). Arsenopyrite with iridescent oxidation coating, on quartz, 8.6 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

***Figure 16* (*left*). Arsenopyrite with quartz, 11 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 17. **Arsenopyrite with iridescent oxidation coating, 14.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 18. **Cassiterite with quartz, 6 cm, from Panasqueira. Jordi Fabre collection and photo.**

Bismuth Bi

Native bismuth is present in the hypogenic rocks, and it occurs fairly commonly as microscopic inclusions in arsenopyrite and chalcopyrite, especially when these are associated with pavonite, matildite and bismuthinite (Orey, 1967; Azevedo and Calvo, 1997; Ascençao Guedes, 2002).

Bismuthinite Bi_2S_3

Bismuthinite occurs at sites in the veins which are rich in bismuth which has displaced tin in the sulfides (Bloot and De Wolf, 1953; Azevedo and Calvo, 1997; Ascençao Guedes, 2002). Stibnite is found at the same sites, and the two species are impossible to distinguish except by analysis. Bismuthinite can also occur with native bismuth, and as inclusions in or overgrowths on arsenopyrite.

Calcite $CaCO_3$

Calcite is an uncommon species at Panasqueira, having formed during the late, carbonate-rich stage of mineralization. It generally occurs as milky white, pinkish white or transparent brown, small, rhombohedral crystals, in some cases lenticular, showing the $\{10\bar{1}0\}$ second-order prism and the $\{10\bar{1}1\}$ second-order rhombohedron as dominant forms. It is sometimes seen as aggregates to 1 cm of strongly flattened, tabular or even laminar crystals of a "poker chip" appearance, with dominant {0001} pinacoid and small $\{01\bar{1}2\}$ prism. In many specimens, calcite crystals have grown along the edges of isolated crystals of other species, or may coat them completely. Calcite pseudomorphs after fluorite have been observed (Kelly and Rye, 1979; Azevedo and Calvo, 1997; Ascençao Guedes, 2002).

Canfieldite Ag_8SnS_6

Microscopic grains of canfieldite have been noted in a few specimens from Panasqueira; the grains are associated and intergrown with pyrite, chalcopyrite and stannite. Some canfieldite grains have a significant tellurium content, and these occur with native bismuth, matildite, sphalerite and galena (Wimmers, 1985). When intergrown with stannite the Te-bearing canfieldite can be distinguished by its slightly bluish tint.

Figure 19. **Cassiterite, 9.7 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 20. **Cassiterite, 4.9 cm, from Panasqueira. Jordi Fabre collection and photo.**

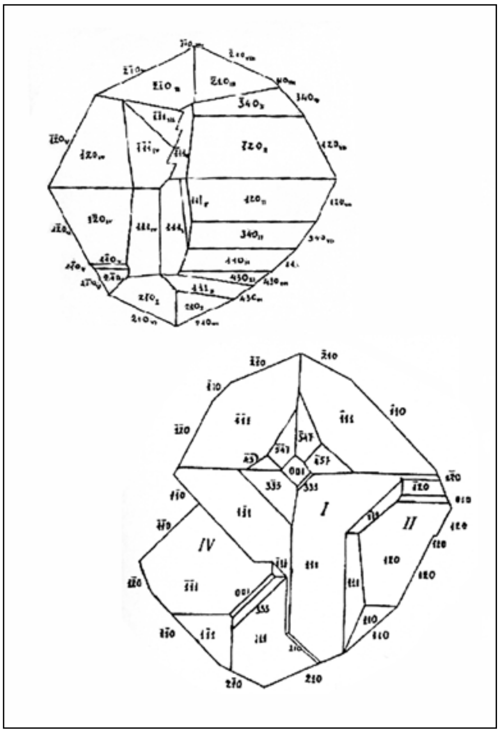


Figure 21. **Crystal drawings of cassiterite habits from Panasqueira (Niggli, 1948; Candel, 1926).**

Figure 22. **Chalcopyrite with pyrite, 7.4 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 23. **Chalcopyrite with arsenopyrite, 4.8 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Cassiterite SnO_2

Cassiterite is the main tin ore at Panasqueira as well as one of the major species occurring in collector-quality specimens. It is found in the quartz veins, primarily at Vale da Ermida, Corga Seca, Barroca Grande and Das Guerras (Ascençao Guedes, 2002), as crystalline masses and euhedral crystals associated with ferberite, quartz, fluorapatite and siderite. The cassiterite crystals range generally between 1 and 3 cm, rarely larger. Crystals found in several areas of the deposit are dipyramidal cyclic twins composed of three individuals. Such twins show a dominant {111} dipyramid, a less well developed {210} prism, and secondary faces including a {110} prism: such crystals are typically sharp, lustrous and black. The characteristic "elbow twin" shape is commonly masked by complex twinning aggregates of three, four, eight or even ten individuals, with dominant {111} dipyramid and {110} prism and other less well developed faces including the {001} pinacoid, {210}, {230}, {340} and {350} prisms, and {223}, {231}, {335}, and {457} dipyramids (Candel, 1926). Cyclic "star" twins are also found, but rarely. Many of these more complex crystals are brown and translucent with some transparent areas and with luster varying between greasy and adamantine.

Typically, in these crystals, the color and transparency vary in parallel, darker and lighter bands, the darker bands being richer in Nb, Ta and Fe while the lighter bands consist of nearly pure SnO_2 (Neiva, 2008). This zoning is especially strong in cassiterite crystals associated with quartz crystals from Vale da Ermida.

Chalcanthite $Cu^{2+}SO_4 \cdot 5H_2O$

Chalcanthite is a secondary species formed as post-mining crystallizations over some of the copper minerals, especially on the second level at Rebordões, where it forms small stalactitic growths.

Chalcocite Cu_2S

At Vale da Ermida (Thadeu, 1951; Bloot and De Wolf, 1953; Azevedo and Calvo, 1997; Ascençao Guedes, 2002), chalcocite forms small, partially rounded crystals with the distinguishable forms of the {111} pyramid, the {001} third-order pinacoid and the {110} prism. It is associated with the main sulfides which replace bismuthinite: pyrite (Thadeu, 1951), arsenopyrite, chalcopyrite and sphalerite. Because the chalcocite crystals are very small (1 mm or less) and are dark gray, with matte luster, they may easily be confused with other metallic sulfides. At Vale da Ermida also, very small, inconspicuous chalcocite crystals occur in and on crystals of fluorapatite.

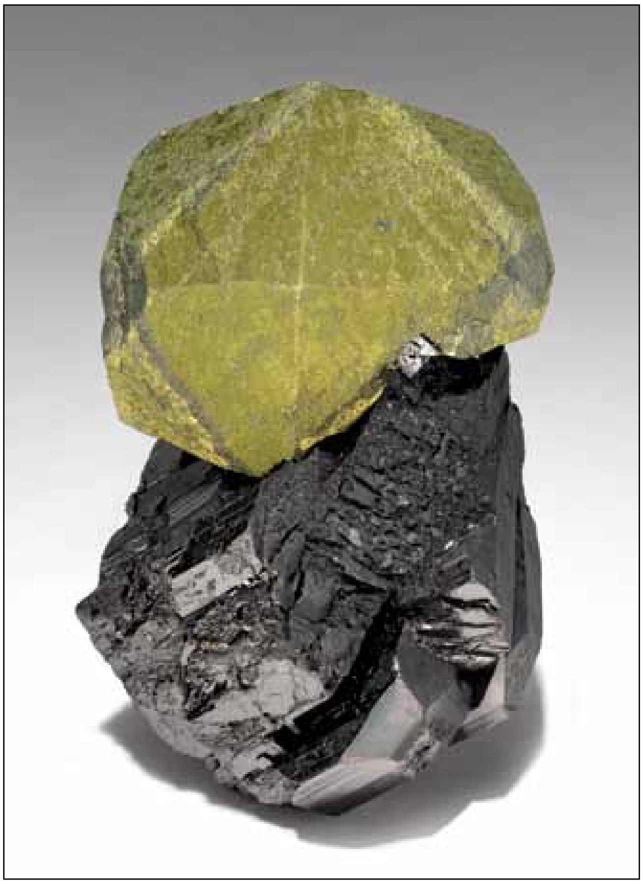


Figure 24. **Chalcopyrite crystal on ferberite, 10 cm, from Panasqueira. Jordi Fabre collection and photo.**

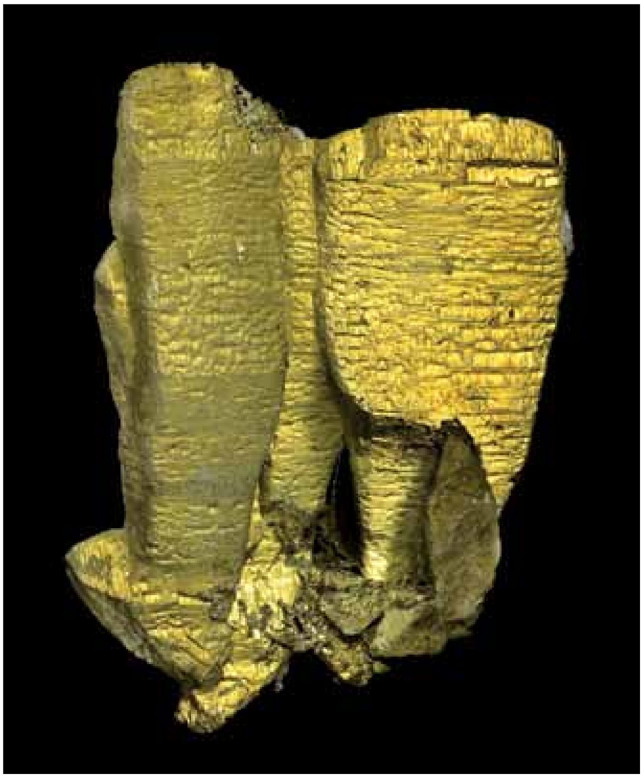


Figure 25. **Chalcopyrite, 5.8 cm, from Panasqueira. Jordi Fabre collection and photo.**

Chalcopyrite $CuFeS_2$

At Panasqueira, chalcopyrite ore is economically important, inasmuch as considerable copper and silver are recovered from it (Azevedo and Calvo, 1997). The mineral occurs throughout the mining area but is especially abundant in the veins at Vale da Ermida; in some other areas it is found in the greisens (Thadeu, 1951). It is generally massive and intergrown with other massive sulfides, such as sphalerite.

Chalcopyrite crystals are rare at Panasqueira. In most cases they show the simple forms of the short positive {111} and negative $\{1\bar{1}1\}$ disphenoids, with a tetrahedral shape and commonly with curved edges. More rarely the crystals are elongated, flattened and strongly deformed. They can reach 2 or 3 cm, rarely more; exceptional crystals to 5 cm are known. Chalcopyrite crystals are typically associated with quartz crystals and with sphalerite, arsenopyrite, siderite, muscovite and late-stage carbonates such as dolomite and calcite.

Clinochlore $(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$

The occurrence of clinochlore at Panasqueira has not been thoroughly studied and requires confirmation (Azevedo and Calvo, 1997); in the literature it has been denoted mainly as "chlorite." Green coatings of clinochlore formed, very probably, during the late carbonate stage, contemporaneously with calcite and dolomite (Kelly and Rye, 1979; Azevedo and Calvo, 1997). This "chlorite" has also been called cookeite (Bancroft, 1984), but superficial analysis suggests that it is *diabantite*, an iron-rich variety of clinochlore.

Covellite CuS

Occasionally, covellite has been noted as a component of the mixture of sulfides formed during the pyrrhotite alteration stage, with siderite, pyrite, marcasite, chalcopyrite, stannite, galena and As-Bi sulfosalts (Polya *et al.*, 2000).

Cubanite $CuFe_2S_3$

Detailed studies have identified cubanite as a component of the mixture of sulfides formed during the pyrrhotite alteration stage. Microscopic grains of cubanite are intergrown with other sulfides and sulfosalts, including covellite, stibnite, gudmundite, mackinawite, pentlandite, tetrahedrite and freibergite (Thadeu, 1951; Bloot and De Wolf, 1953; Clark, 1965; Orey, 1967; Kelly and Rye, 1979; Wimmers, 1983).

Dolomite $CaMg(CO_3)_2$

Dolomite is found occasionally as white crystals rarely exceeding 1 cm. The smaller crystals are translucent, the larger ones opaque, with recrystallized surfaces. The crystals are rhombohedral, some distorted in typical "saddle" shapes, and some showing minor, almost indistinguishable crystal forms (Azevedo and Calvo, 1997; Ascençao Guedes, 2002). One of the late-formed carbonates, it also forms coatings on quartz, fluorapatite, ferberite, siderite and chalcopyrite.

Ferberite $Fe^{2+}WO_4$

Ferberite is the most important ore species at Panasqueira. Traditionally it has been called "wolframite," but Dunn (1977b) found a composition of 90–92% ferric tungstite, that is to say, nearly pure ferberite. The species has been profusely described in both scientific and popular mineralogical literature (Clark, 1965; Orey, 1967; Gaines and Thadeu, 1971; Voileau, 1975; Bussink, 1984; Azevedo and Calvo, 1997; Ascençao Guedes, 2002; Neiva, 2008).

Ferberite occurs ubiquitously at Panasqueira, forming masses of considerable volume and crystals which range from less than 2 cm to more than 15 cm; quite commonly the isolated crystals are doubly terminated. Tabular to leafy ferberite crystals form groups which are jumbled, parallel, radial or "book"-shaped and can reach

Figure 26. **Dolomite crystals 8.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 27. **Ferberite with quartz and arsenopyrite, 6.8 cm, from Panasqueira. Jordi Fabre collection and photo.**

more than 30 cm (Bussink, 1984). Typically the thicker crystals are found nearer to the walls of the veins. Their color varies from grayish black to deep black, with the deep black crystals in general showing the brighter luster.

The dominant crystal form is the {100} front pinacoid, typically finely striated, accompanied by the second-order and third-order pinacoids ({010} and {001} respectively) and sometimes by prisms ({110} and {102}, and more rarely {104}; {121} and/or {$\bar{1}$21} prisms may also be present in very different sizes and degrees of development. The length-width ratios of the crystals is generally around 2:1 (the most common) to 1:1, but some crystals have ratios exceeding 3:1—in these, the {$\bar{1}$21} face is severely elongated. Contact twins, with the twinning plane parallel to the {100} front pinacoid, are not rare; this twinning is commonly visible on the thicker crystals.

In general, ferberite crystals from Panasqueira show two different shapes (Azevedo and Calvo, 1997). Those which grew perpendicular to the cavity walls are thick-tabular, with dominant {100} first-order pinacoid and {110} third-order prism, both deeply striated. These two forms are combined with the {010} second-order pinacoid, coinciding with cleavage surfaces. Such surfaces where natural cleaving has already occurred are commonly recrystallized and may be coated by later minerals, most commonly chlorite, siderite and calcite.

The other, much less common habit is seen most frequently on crystals which have formed in groups in the veins, such groups having often been found as floaters. On these crystals the {010} second-order pinacoid is absent or nearly so; the most conspicuous forms are the {100} front pinacoid and the positive and negative fourth-order prisms ({121} and {$\bar{1}$21}).

Another morphological curiosity in ferberite from Panasqueira is the presence of bending. In some cases, a slight displacement of neighboring parallel crystals creates an appearance of bending in the aggregate group, but real bending also occurs when the crystals are broken and displaced by tectonic forces, then recrystallized.

Ferberite is found associated with almost all of the other species from Panasqueira, the most common of which are muscovite, siderite, quartz, fluorapatite and cassiterite. Complete ferberite crystals may be included in quartz.

Panasqueira ferberite is very sensitive to temperature changes and cleaves readily when exposed to the sun on the dumps, when being cleaned in excessively warm water, or even when kept too long under hot lights in exhibit cases.

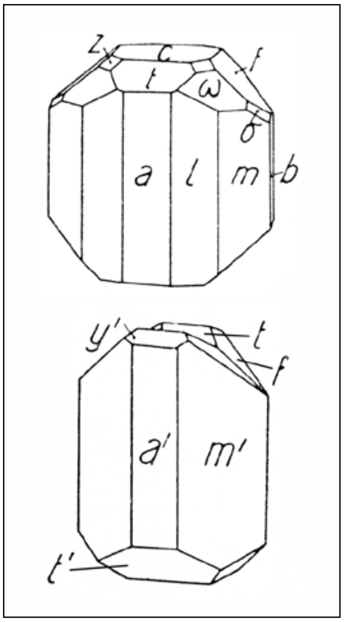
Fluorapatite $Ca_5(PO_4)_3F$

Clearly, fluorapatite is the "star" mineral from Panasqueira. First described by Bloot and De Wolf (1953), it has since then been the object of numerous genetic, morphological and chemical studies (Orey, 1967; Gaines and Thadeu, 1971; Voileau, 1975; Dunn, 1977a; Lagerwey, 1977; Bancroft, 1984; Bussink, 1984; Knutson *et al*., 1985; Azevedo and Calvo, 1997; Ascençao Guedes, 2002; Hochleitner and Weiss, 2005; Curto and Fabre, 2013).

Figure 28. **Ferberite on muscovite, 10 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Figure 29. **Ferberite and quartz crystals rimmed by tiny siderite crystals, 11.8 cm, from Panasqueira. Jordi Fabre collection and**

Figure 30. **Ferberite with quartz and siderite, 7.6 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**



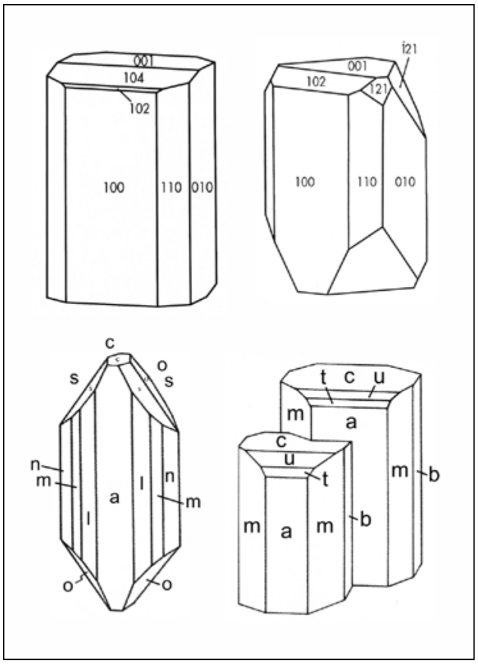


***Figure 31-34*: (*top left*). Ferberite crystals in parallel growth, 17 cm, from Panasqueira. Jordi Fabre collection and photo. (*top right*). Crystal drawings of ferberite crystal habits from Panasqueira (Niggli, 1927) (*above right*). Crystal drawings of ferberite crystal habits from Panasqueira (Ascensao, 2002; Azevedo and Calvo, 1997) (*above left*). Ferberite crystals on quartz, 10 cm, from Panasqueira. Rob Lavinsky (*The Arkenstone*) specimen; Joe Budd photo.**

At Panasqueira, fluorapatite forms crystals which generally measure between 1 and 3 cm (of length if prismatic, of width if tabular), but prismatic crystals exceeding 10 cm long are not especially rare. Their habits vary widely, but tabular and short-prismatic are most common; length:width ratios between 1:1 and 2:1 dominate, but in rare cases this ratio exceeds 3:1. In a few cases the dipyramid predominates over the prism, so that sloping or (less commonly) pointed terminations result. Doubly terminated crystals are common, these often appearing pseudo-hemimorphic when different faces are developed on the two ends of the *c*-axis. In other cases, parallel crystal growths make for complex polycrystalline terminations. Acicular, and even fibrous, fluorapatite crystals also occur.

In appearance the crystals are morphologically simple, with the $\{10\bar{1}0\}$ second-order prism and $\{0001\}$ pinacoid more developed than are other faces. In some cases the $\{11\bar{2}0\}$ first-order prism is developed equally with the second-order prism.

Less common than the pinacoid and the $\{10\bar{1}0\}$ second-order prism are the dipyramid forms that modify crystals of simple habit, becoming dominant forms in rare cases. The steeper $\{10\bar{1}1\}$ and

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Figure 35 **(*above*). Prismatic fluorapatite crystal, 8.5 cm, from Panasqueira. Rob Lavinsky (*The Arkenstone*) specimen; Joe Budd photo.**

Figure 36 **(*top left*). Brown fluorapatite crystals with arsenopyrite and siderite, 5.8 cm, from Panasqueira. Jerry Rosenthal collection; Jeff Scovil photo.**

Figure 37**. Fluorapatite (nearly colorless) on muscovite, 3.2 cm, from Panasqueira. *Kevin Ward* specimen and photo.**

Figure 38**. Yellow-green fluorapatite on ferberite, 8.9 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

Figure 39. **Fluorapatite crystals stacked in parallel growth, 6.5 cm, from Panasqueira. Frédéric Escaut (*Escaut Minerals*) specimen; Jeff Scovil photo.**

Figure 40. **Fluorapatite crystals stacked in parallel growth, 7.7 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 41. **Fluorapatite crystals with arsenopyrite, 6.2 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

***Figure 42*. Dark green fluorapatite crystal cluster, 5.6 cm, from Panasqueira. Jordi Fabre collection and photo.**

***Figure 43*. Green fluorapatite on quartz crystals, 7 cm, from Panasqueira. Jordi Fabre collection and photo.**

***Figure 44*. Green fluorapatite with quartz crystals on muscovite, 8.6 cm, from Panasqueira. Scott Rudolph collection; Jeff Scovil photo.**

Figure 45. **Blue-green fluorapatite on quartz, 7 cm, from Panasqueira. Jordi Fabre collection; Jeff Scovil photo.**

Figure 46. **Fluorapatite with arsenopyrite, muscovite and siderite, 4.5 cm, from Panasqueira. Scott Rudolph collection; Jeff Scovil photo.**

Figure 47. **Blue-green fluorapatite with siderite, 11 cm, from Panasqueira. Jordi Fabre collection and photo.**

***Figure 48*. Large slab of matrix with green fluorapatite crystals, about 40 cm, from Panasqueira. This specimen and others from Panasqueira were exhibited at the 1991 Tucson Gem and Mineral Show by the Portuguese National Museum of Natural History in Lisbon. Wendell Wilson photo.**

***Figure 49*. Fluorapatite crystals with quartz, 10.4 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 50 (*left*). **Green fluorapatite crystals, 4.9 cm, from Panasqueira.** ***Rock Positive*** **specimen; Jeff Scovil**

Figure 51 (*below left*). **Blue fluorapatite crystals with muscovite, 4.1 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Figure 52 (*below*). **Blue-green fluorapatite with siderite crystals, 11.4 cm, from Panasqueira.** ***Stuart Wilensky*** **specimen and photo.**

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{$10\bar{2}1$} dipyramids are more common, although some crystals exhibit shallower {1121} and {$21\bar{3}1$} dipyramid faces. Of course, nothing is ever totally simple: close inspection of some crystals can reveal rich and complex crystallography that includes more uncommon dipyramids (positive and negative) with very different inclinations (Lagerwey, 1977; Azevedo and Calvo, 1997; Curto and Fabre, 2013).

Fluorapatite is found as sharp, isolated crystals as well as aggregates of numerous individuals. Jumbled aggregates sometimes form "nests" of crystals coated on their undersides, and bordered in part, by calcite or siderite. Aggregates consisting of parallel scepters and inverse scepters, or of curious sheaf-like or "mushroom" shapes, have been observed (Azevedo and Calvo, 1997; Ascençao Guedes, 2002; Curto and Fabre, 2013).

The colors of the fluorapatite crystals show no correlations with their morphologies. The most common hues are bottle-green and olive-green, but pale green and grayish green crystals are fairly common (Knutson *et al.*, 1985; Curto and Fabre, 2013). Also widespread are crystals in a palette of violet hues. These range from lilac to blue-violet and violet-blue; they are generally pale but may be deeply saturated (Gaines and Thadeu, 1971; Bancroft 1984; Azevedo and Calvo 1997; Ascençao Guedes, 2002; Curto and Fabre,

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Figure 53 (*above*). **Blue fluorapatite with arsenopyrite, 6.8 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Figure 54 (*above right*). **Blue-green fluorapatite crystals on quartz, 6 cm, from Panasqueira. José Ramon Garcia collection; Jeff Scovil photo.**

Figure 55. **Blue-green fluorapatite crystals, 13.5 cm, from Panasqueira.** ***Marcus Budil*** **specimen; Jeff Scovil photo.**

Figure 56. **Blue-green fluorapatite with quartz, 6.8 cm, from Panasqueira. John Rakovan collection; Jeff Scovil photo.**

Figure 57. **Blue-green fluorapatite crystal cluster, 5.8 cm, from Panasqueira. Martin Zinn collection; Jeff Scovil photo.**

Figure 58. **Blue fluorapatite, 2 cm, from Panasqueira. Keith and Mauna Proctor collection; Jeff Scovil photo.**

Figure 59. **Fluorapatite crystals on muscovite with siderite, 7.8 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Figure 60. **Blue fluorapatite with quartz and siderite, 6 cm, from Panasqueira. Kyle Soller collection; Jeff Scovil photo.**

Figure 61. **Blue/purple fluorapatite crystals with muscovite, 17.5 cm, from Panasqueira. Pinnacle collection; Joe Budd photo.**

Figure 62. **Blue/purple fluorapatite crystals with quartz and siderite, 15.2 cm, from Panasqueira.** ***Stuart Wilensky*** **specimen and photo.**

***Figure 63*. Fluorapatite, 5.1 cm, from Panasqueira. *Rock Positive* specimen; Jeff Scovil photo.**

***Figure 64*. Fluorapatite with siderite and arsenopyrite, 5.2 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

***Figure 65*. Fluorapatite with quartz and ferberite, 7.6 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

***Figure 55*. Fluorapatite with quartz, pyrite and muscovite, 6.1 cm, from Panasqueira. Luis Miguel Fernandez Burillo (*Luis Burillo Minerales*) specimen; Jeff Scovil photo.**

Figure 67. **Fluorapatite with siderite, 10.3 cm, from Panasqueira. Gail and Jim Spann collection; Tom Spann photo.**

Figure 68. **Fluorapatite with siderite, 7.1 cm, from Panasqueira. Jordi Fabre collection and photo.**

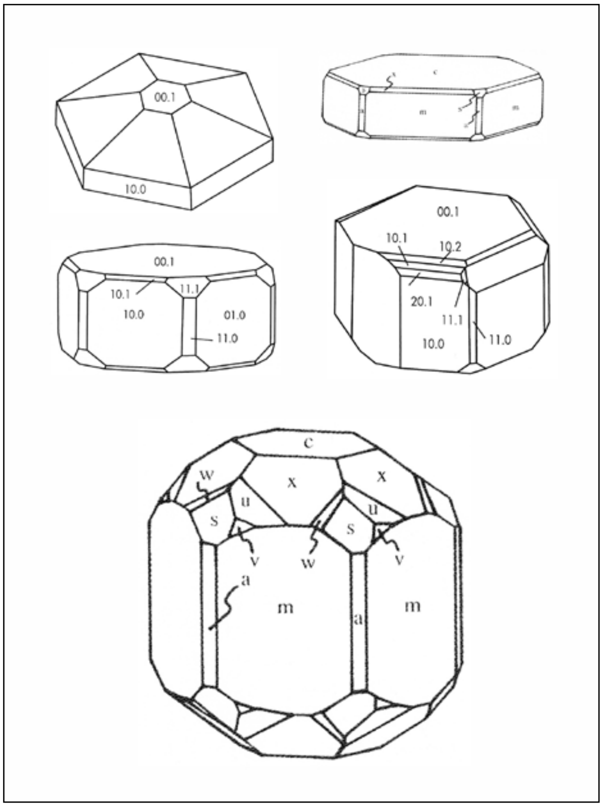

Figure 69. **Crystal drawings of fluorapatite crystal habits from Panasqueira. (Ascensao, 2002) (*top and middle*), (Azevedo and Calvo, 1997) (*bottom*).**

Figure 70. **Fluorapatite (zoned purple and colorless) with siderite, 4 cm, from Panasqueira.** ***Dan Weinrich*** **specimen; Jeff Scovil photo.**

Figure 71. **Fluorapatite (zones purple and colorless, in parallel growth) with siderite, 3.9 cm, from Panasqueira. Carles Millán collection; Jeff Scovil photo.**

Figure 72. **Fluorapatite (V-shaped pair of prismatic crystals), 5.1 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

Figure 73 (*left*). **Fluorapatite (prismatic crystal), 4.7 cm, from Panasqueira. Rob Lavinsky (*The Arkenstone*) specimen; Joe Budd photo.**

Figure 74. **Fluorapatite (zoned purple and colorless) on quartz, 6.4 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

***Figure 75* (*top left*). Fluorapatite crystals to 8.5 cm with siderite, from Panasqueira, Portugal. Houston Museum of Natural Science collection; Jeff Scovil photo.**

***Figure 76* (*above*). Fluorapatite crystal (zoned green to purple), 3.8 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

***Figure 77*. Fluorapatite with siderite, 8.3 cm, from Panasqueira. *Stuart Wilensky* specimen and photo.**

Figure 78. **Fluorite on quartz with siderite and pyrite, 13 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Figure 79. **Fluorite crystal with muscovite, 5.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

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2013). Colors in the violet spectrum, unlike those in the green, are usually concentrated at the intersections of the {0001} pinacoid and $\{10\bar{1}1\}$ pyramid so that the outer edges of thin-tabular, violet crystals tend to be more deeply saturated than their cores. Other colors of fluorapatite found at Panasqueira include pale shades of blue and pink, both of which are rare, as well as white and yellow. Colorless crystals are relatively abundant but are generally small. A few crystals exhibit different colors (green and violet) under incandescent and fluorescent light sources.

Color zoning is also seen in Panasqueira fluorapatite. Tabular to short-prismatic crystals commonly exhibit concentric color bands, while prismatic crystals tend to exhibit "phantoms" of color. At times the color near the centers of crystals, particularly the violets and pinks, is more intense than toward the peripheries. Crystals with alternating opaque, matte and pale-colored faces, bright white

Figure 80. **Galena crystal with quartz and sphalerite (?), 7.8 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 81. **Fluorite with fluorapatite, 6.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

faces, and dark green faces are sometimes found. Color zoning concentric around the *c*-axis is frequently seen and is most striking in tabular and short-prismatic examples. Crystals that exhibit this zoning, locally known as *olho de boi* ("porthole"), almost always show just two or three dominant bands.

The presence of other members of the apatite group at Panasqueira has been a subject of speculation, as characteristics such as the fibrous appearance and/or the yellow to almost white color of some crystals have been thought to indicate chlorapatite or hydroxylapatite, but analyses have repeatedly shown every sample to be fluorapatite (Dunn, 1977a; Kelly and Rye, 1979; Hochleitner and Weiss, 2005).

Fluorite CaF_2

Fluorite is the only identified halide at Panasqueira, where it is not especially rare, but is found only rarely as well-developed crystals. The crystals occur in cavities in the veins, associated with quartz crystals and with fluorapatite, pyrite and late-stage carbonates (Azevedo and Calvo, 1997). Fluorite crystallized after fluorapatite (Kelly and Rye, 1979) and sometimes coats the fluorapatite prism faces (but not the pinacoid faces); a second generation of fluorite is probably present as well (Bussinsk, 1984).

Euhedral cubic crystals of fluorite reach 3 cm on edge, and groups of parallel crystals reach 8 cm. The {100} cube is occasionally modified by the {110} dodecahedron and/or by the {111} octahedron; some small crystals are unmodified octahedrons. In general the crystal faces are smooth, but polycrystalline growths, especially on the {100} faces, are common. Isolated, unmodified dodecahedral crystals approaching 1 cm are also known.

Most commonly the fluorite crystals are translucent and uniformly lilac to deep lilac-purple in color, but some are green. Others are color-zoned, with a green nucleus, a colorless or white intermediate zone, and violet faces; or the core may be deep violet while the bulk of the crystal is almost colorless, or vice versa (Thadeu, 1951). Some rough, slightly deformed, octahedral brownish white fluorite crystals resemble scheelite crystals.

In 2012 and 2013, exceptional new finds of fluorite at Panasqueira have changed our perception of this species at the locality. A relatively small number of specimens with isolated and grouped, sharp cubic crystals, in some cases beveled by the dodecahedron, with a very deep violet color has been recovered. They are associated with siderite, calcite, arsenopyrite, ferberite, quartz and muscovite. These fluorites can be considered the best ever found at the locality

Freibergite $Ag_6Cu_4(Fe,Zn)_2Sb_4S_{13}$

Freibergite occurs sparsely at Panasqueira, associated with native silver, acanthite and galena (Kelly and Rye, 1979; Wimmers, 1983, 1985; Ascençao Guedes, 2002). Also, very small freibergite crystals rest on surfaces of some carbonates in the veins (Azevedo and Calvo, 1997).

Galena PbS

Galena is uncommon and very irregularly distributed at Panasqueira. It is usually found filling Alpine-type fractures and faults, as exfoliated masses and as crude crystals to 5 cm. The most common crystal forms are the {111} octahedron, {100} cube, and combinations of the two.

Gold Au

Gold, like the other noble metals at Panasqueira, occurs rarely and sporadically in the granitic rocks (Wimmers, 1983; Azevedo and Calvo, 1997; Ascençao Guedes, 2002) and as inclusions in pyrite and native silver associated with galena and the silver sulfosalts.

***Figure 82*. Botryoidal marcasite, 9.3 cm, from Panasqueira. Jordi Fabre collection and photo.**

***Figure 83*. Pyrite crystal group, 5.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

Gudmundite FeSbS

Detailed studies (Thadeu, 1951; Bloot and De Wolf, 1953; Clark, 1965; Orey, 1967; Kelly and Rye, 1979; Wimmers, 1983) have identified microscopic grains of gudmundite intergrown with other sulfides and sulfosalts.

Gypsum $CaSO_4 \cdot 2H_2O$

Small quantities of gypsum formed by supergene alteration are present in the veins. The elongated, prismatic gypsum crystals, rarely larger than 3 mm, form “swallowtail” twins; the dominant forms are the {010} second-order pinacoid and the {110} third-order and {111} fourth-order prisms.

Hematite Fe_2O_3

Massive, granular hematite is seen occasionally as an alteration product of other iron-bearing minerals (Ascençao Guedes, 2002).

Isokite $CaMg(PO_4)F$

Isokite occurs as microgranular, easily cleavable aggregates. It resembles thadeuite, with which it shares genetic conditions and mineral associations, being found with wolfeite, topaz, althausite and quartz (Isaacs *et al.*, 1979; Ascençao Guedes, 2002).

Löllingite $FeAs_2$

Löllingite has been identified in some specimens from arsenopyrite veins, as granular masses intergrown with arsenopyrite. At Vale da Ermida it occurs as small crystals showing a dominant {100} first-order pinacoid and some other, poorly developed forms (Thadeu, 1951). The occurrence with arsenopyrite has not been well studied, but, very probably, this löllingite is an alteration product of arsenopyrite. Löllingite must be considered rare at Panasqueira, but it is possible that it often passes unnoticed because of its close resemblance to arsenopyrite in color and luster.

Mackinawite FeS

Like gudmundite, cubanite, canfieldite and other sulfides, mackinawite exists only microscopically at Panasqueira, as one of the sulfides and sulfosalts formed during the pyrrhotite alteration stage (Clark, 1965; Orey, 1967; Wimmers, 1983).

Magnetite $Fe^{2+}Fe_2^{3+}O_4$

Magnetite was identified by Clark (1965) as a rare constituent of the main quartz veins at Rebordões, where it is associated with cassiterite, ferberite and chalcopyrite. Granular magnetite (the grains never larger than 1 mm) may fill fractures in chalcopyrite or occur interstitially in ferberite.

Marcasite FeS_2

Marcasite, an alteration product of pyrrhotite (Kelly and Rye, 1979), is associated with pyrite. It is not common at Panasqueira, but at Barroca Grande it is well crystallized, forming coxcomb-shaped groups to 3 cm or, more rarely, smaller pseudohexagonal

***Figure 84.* Pyrite crystals with quartz, 12.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

cyclic twins resembling pointed spears (in German, *Speerkies*). The dominant forms are the {010} lateral pinacoid and the {110}, {101} and rarely {140} prisms. Less common than the forms cited above are sharp, ax-shaped twins of three individuals, with well developed {011} prisms and the {001} pinacoidal and {013} prism faces delineating fine striations. Also, in this twin the minor forms of the {111} dipyramid are visible on the vertices.

Having crystallized during a late stage, marcasite is associated with calcite, dolomite and recrystallized siderite. Some thin, iridescent arsenopyrite crystals, as well as epitactic growths of second-generation on first-generation arsenopyrite, have been confused with marcasite (Thadeu, 1951).

Matildite $AgBiS_2$

Very small amounts of matildite occur as anhedral grains or veinlets in most samples of arsenopyrite and chalcopyrite, and as microscopic intergrowths with native bismuth, bismuthinite and stannite, sometimes enclosing them. Matildite is difficult to recognize because it closely resembles galena in color and luster (Wimmers, 1985).

Molybdenite MoS_2

Molybdenite is a rare species at Panasqueira (Thadeu, 1951), practically unrecognizable in hand specimens but occurring in the veins of Rebordões and Barroca Grande as small spots or very thin sheets included in arsenopyrite, milky quartz and muscovite. Clark (1964) identified the rhombohedral polytype (3R) of molybdenite in irregular veinlets of sugary quartz in the greisenized granite, where the polytype forms flakes of less than 1 mm associated with ferberite and cassiterite.

Muscovite $KAl_2\square AlSi_3O_{10}(OH)_2$

Muscovite is the only mica species occurring at Panasqueira, although some specimens have erroneously been called zinnwaldite because of the bronze-brown color of some crystal aggregates.

Muscovite is very abundant at Panasqueira, occurring throughout the deposit as a first-formed phase lining the veins. It forms leafy aggregates and small, rosette-shaped crystal groups, these commonly forming complete coatings on crystals of other species such as quartz, sphalerite, arsenopyrite and fluorapatite. The rosette groups are most commonly brown, sometimes with bronze reflections (Thadeu, 1951; Gaines and Thadeu, 1971; Kelly and Rye, 1979; Wimmers, 1983; Bussink, 1984).

Panasqueiraite $Ca(Mg,Fe)(PO_4)(OH,F)$

Panasqueiraite is a monoclinic calcium-magnesium phosphate, a hydroxyl-bearing analog of isokite (Isaacs and Peacor, 1981). At Panasqueira, its type locality, it is found intergrown in massive, fine-grained accumulations with other phosphates (fluorapatite, thadeuite, wolfeite, althausite and vivianite) and with topaz, quartz and sulfides (arsenopyrite, pyrrhotite, chalcopyrite and sphalerite) in the hydrothermal veins. Panasqueiraite closely resembles thadeuite and wolfeite, but the naked eye can distinguish the three species by their slightly different colors: orange-yellow for thadeuite, rose-salmon for wolfeite and rose-orange for panasqueiraite. Crystals of panasqueiraite are not known, but {010} cleavage surfaces are always present, as also for thadeuite.

Pavonite $AgBi_3S_5$

Pavonite has been detected as intergrowths with bismuthinite in massive chalcopyrite (Wimmers, 1985). Pavonite from Panasqueira is characterized by its trace-element contents of Pb and Cu.

Pentlandite $(Fe,Ni)_9S_8$

Pentlandite is present as microscopic intergrowths with other sulfides and sulfosalts formed during the pyrrhotite alteration stage (Thadeu, 1951; Bloot and De Wolf, 1953; Clark, 1965; Orey, 1967; Kelly and Rye, 1979; Wimmers, 1983).

Pharmacosiderite $KFe^{3+}_4(AsO_4)_3(OH)_4\cdot 6–7H_2O$

Of doubtful occurrence at Panasqueira, pharmacosiderite has been cited (Azevedo and Calvo, 1997) as a supergene alteration

Figure 85 (*above*). Quartz with ferberite and siderite, 14.7 cm, from Panasqueira. Ed and Teri Lopez collection; Jeff Scovil photo.

Figure 86 (*top right*). Quartz crystal with muscovite and pyrite, 5 cm, from Panasqueira. Luis Miguel Fernandez Burillo (*Luis Burillo Minerales*) specimen; Jeff Scovil photo.

Figure 87. Quartz with muscovite, 7 cm, from Panasqueira. Jordi Fabre collection and photo.

product forming microscopic, fibrous aggregates with symplesite and arseniosiderite.

Pyrargyrite Ag_3SbS_3

Pyrargyrite occurs rarely as microscopic grains in arsenopyrite and chalcopyrite, associated with native silver, stephanite and freibergite (Kelly and Rye, 1979; Acevedo and Calvo, 1997).

Pyrite FeS_2

Pyrite formed originally as marcasite by the hypogenic alteration of pyrrhotite. It is common in some areas of the district, usually as granular masses filling small veins and interstices between crystals of other species (it occurs with arsenopyrite and chalcopyrite crystals at Barroca Grande). Pyrite crystals to 3 cm are also found (Thadeu, 1951; Orey, 1967).

Commonly, crusts of pyrite crystals coat crystals and masses of other species. The pyrite crystals show predominant {100} cubic forms; many of these crystals have pronounced curving on faces and edges, and {111} octahedral faces sometimes appear on crystals smaller than 5 mm. Very rarely, {110} dodecahedron and {201} pyritohedron forms are also noted.

In some quartz veins the crystals of pyrite can "stack" along a single axis, with prominent echelons, forming the so-called "inca pyramid" aggregate shape. Pyrite also can form spectacular botryoidal or roughly spherical aggregates of microcrystals coating other species.

Pyrrhotite $Fe_{1-x}S$ $(x=0.1–0.2)$

Pyrrhotite was formed during the main sulfide stage and disappeared during the following pyrrhotite alteration stage, when it altered to marcasite and pyrite; it is therefore never found with these other iron sulfides. Pyrrhotite is intergrown with arsenopyrite, chalcopyrite and sphalerite at Vale da Ermida and Barroca Grande, where very small pyrrhotite crystals associated with or included in quartz have been noted (Thadeu, 1951; Orey, 1967).

Figure 88. **Siderite crystals on a quartz crystal, 12 cm, from Panasqueira. Jordi Fabre collection and photo.**

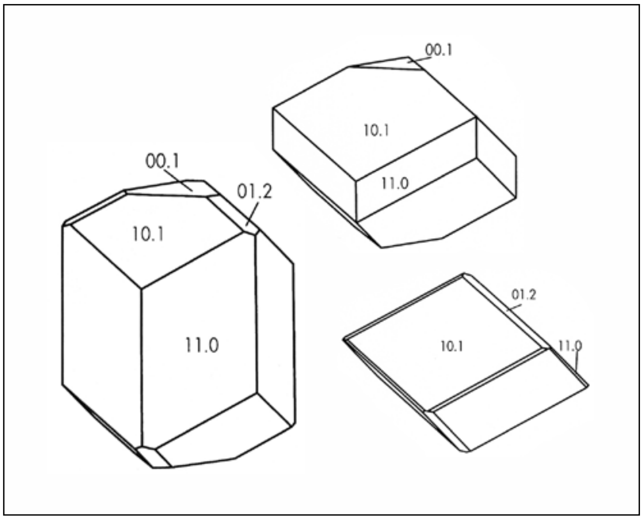

Figure 88. **Crystal drawings of siderite crystal habits from Panasqueira (Ascensao, 2002).**

Figure 90. **Siderite crystal perched on a quartz crystal, 10.4 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

***Figure 91*. Siderite crystal with quartz, 6 cm, from Panasqueira. Jordi Fabre collection and photo.**

***Figure 92*. Siderite crystals perched on arsenopyrite, 5.6 cm, from Panasqueira. Joan Massagué collection; Jeff Scovil photo.**

Quartz SiO_2

Massive and crystallized quartz is present in most of the veins. The crystals, typical for the species, show a dominant $\{10\bar{1}0\}$ prism with the $\{10\bar{1}1\}$ positive rhombohedron and $\{01\bar{1}1\}$ negative rhombohedron, the $\{11\bar{2}1\}$ right trapezohedron being less common. Massive quartz is opaque and milky white, but the crystals are colorless and transparent; Thadeu (1951) notes the occurrence of amethyst at Vale da Ermida. Doubly terminated quartz crystals are not rare, and can reach lengths to 70 cm and more.

In many cases, inclusions of other species occur in the quartz crystals. The most commonly included species are muscovite, tourmaline (schorl-dravite), pyrite, fluorapatite, and, in the most

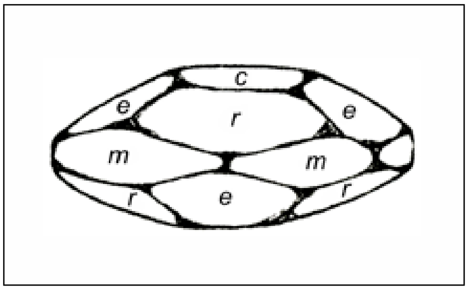

***Figure 93*. Sketch of a siderite crystal showing the same habit as in Figure 92 (Azevedo and Calvo, 1997).**

***Figure 94*. Siderite crystal, 8.2 cm, from Panasqueira. Jordi Fabre collection and photo.**

Figure 95. **Sphalerite crystal on muscovite, 6.5 cm, from Panasqueira. Jordi Fabre collection and photo.**

gorgeous specimens of this kind, complete crystals of ferberite, cassiterite and arsenopyrite (Thadeu, 1951; Kelly and Rye, 1979).

Rutile TiO_2

Rutile is found at Panasqueira as minute acicular crystals enclosed in molybdenite and as corroded grains in cassiterite, the latter at Vale da Ermida, Rebordões and Panasqueira proper. Rutile inclusions in quartz and in late fluorapatite have also been noted (Bloot and De Wolf, 1953; Bussink, 1984; Neiva, 1996).

Scheelite $CaWO_4$

Scheelite was noted by Thadeu (1979) at a point where a quartz vein crosses a large dolerite dike at Rebordões. In this metasomatic occurrence the scheelite has replaced ferberite. Scheelite formed by supergene alteration is a rare component of quartz veins, where it is associated with ferberite and scorodite (Clark, 1965). In the latter case, scheelite forms cream-colored coatings and (very rarely) sharp dipyramidal crystals to 1 cm. Because of its pale color scheelite can easily go unnoticed, but its strong fluorescence makes it easy to spot with the aid of an ultraviolet lamp.

Scorodite $Fe^{3+}AsO_4{\cdot}2H_2O$

Scorodite is a fairly common secondary species at Panasqueira, generally forming small, very thin, friable, blue to blue-green coatings on weathered arsenopyrite (Clark, 1965). In very recent years some sharp, prismatic, transparent blue-green scorodite crystals with very acute terminations, approaching 1 cm, have been identified at Panasqueira.

Siderite $FeCO_3$

Siderite is one of the most common species at Panasqueira, occurring in crystals to more than 20 cm on edge. The crystal habits are diverse: tabular, lenticular, equant, short-prismatic and (much more rarely) long-prismatic habits all occur. The most commonly dominant forms are the $\{10\bar{1}1\}$ positive rhombohedron (sometimes with deep horizontal striations) and the $\{11\bar{2}0\}$ third-order pinacoid. Many siderite crystals, especially the flattened lenticular ones, have strongly curved edges.

The color varies from white (in some small crystals) to cream-colored to dark brown, sometimes with slightly greenish tints. Siderite crystals are associated with most other major species at Panasqueira, especially ferberite, chalcopyrite, fluorapatite and quartz; coatings of crystallized siderite on these minerals are found commonly.

Silver Ag

Very rarely, granular native silver occurs in granite (Wimmers, 1983; Ascençao Guedes, 2002), and as an accessory in galena and chalcopyrite (Pirard, 1987; Azevedo and Calvo, 1997). Silver has been noted particularly at Vale da Ermida (Orey, 1967).

Sphalerite ZnS

Sphalerite is not one of the better known species occurring in collector-quality specimens at Panasqueira: crystals are generally crude and rounded, and the commonly seen exsolution blebs of stannite impart a grayish color and silky luster. Yet sphalerite occasionally does form very good, bright crystals to 2 cm, most of them deep black (the variety called *marmatite*) because of their high iron content.

The morphologies of Panasqueira sphalerite crystals are highly variable. Some have simple forms, with a dominant $\{111\}$ positive tetrahedron and smaller faces of the $\{1\bar{1}1\}$ negative tetrahedron. Many crystals show a spectacular triangular striation pattern per-

***Figure 96*. Acicular brown schorl/dravite crystals, 9.2 cm, from Panasqueira. Jordi Fabre collection and photo.**

pendicular to the ternary axis (Thadeu, 1951; Orey, 1967). Other crystals are more complex, with more rounding and twinning and more secondary forms. In general, crystallized sphalerite is found in veins in the higher levels of the deposit, where it is associated with quartz crystals and with some ubiquitous species such as siderite, fluorapatite and pyrite.

Stannite Cu_2FeSnS_4

Stannite specimens from Panasqueira have long been known, although they very seldom reach the collector market. Especially common at Barroca Grande, stannite is one of the deposit's main secondary ores of tin (Ascençao Guedes, 2002). It is typically found between "leaves" of muscovite, associated with cassiterite, pyrite, sphalerite and chalcopyrite.

The sharpest crystals, all measuring 1 mm or less, show the forms of the {112} positive and {112} negative disphenoids; some are epitactic on chalcopyrite or sphalerite but most are simply intergrown with these two species, or have directly replaced sphalerite.

On some specimens, larger stannite crystals—approaching 1 cm—are isolated and clearly visible. They may appear either tetragonal or isometric, as the disphenoids are so short that they look like tetrahedrons; moreover the crystals may be strongly curved, and polycrystalline growths are always present.

Some stannite crystals, thanks to broken areas that expose exfoliation and fresh surfaces, can appear to be intergrown with sphalerite, but other crystals are different: platy to thickly lenticular, uniformly dark gray and without exfoliation. Analysis indicates that these crystals are indeed stannite, but broken areas always reveal brassy intergrowths of chalcopyrite. The stannite crystals might be primary, but more likely they are pseudomorphs after chalcopyrite. In any case the crystals (or pseudocrystals) are very common and are associated with crystals of fluorapatite, arsenopyrite, sphalerite and chalcopyrite. Since, in general, the collector community (including museums) is not familiar with stannite of this kind from Panasqueira, excellent and interesting specimens of the material have remained unnoticed in many collections.

A sporadic occurrence of microscopic silvery stannite associated with chalcopyrite has been noted at Barroca Grande (Wimmers, 1985).

Stephanite Ag_5SbS_4

Stephanite occurs in very small quantities associated with native silver, pyrargyrite and freibergite, and as microscopic grains in arsenopyrite and chalcopyrite (Kelly and Rye, 1979; Acevedo and Calvo, 1997).

Stibnite Sb_2S_3

Stibnite has been cited (Thadeu, 1951; Clark, 1965; Orey, 1967) as occurring very sporadically in the Rebordôes area, as felted aggregates and as acicular and elongated-platy crystals forming irregular patches to 1.5 cm across in the quartz veins, associated with the ferberite-cassiterite-quartz paragenesis. Visual identification of stibnite is not always easy since the crystals are small and since, in some areas of the deposit, the antimony has been replaced by bismuth, creating bismuthinite, a species closely resembling stibnite.

Tetrahedrite $Cu_6Cu_4(Fe,Zn)_2(Sb,As)_4S_{13}$

Tetrahedrite is rare at Panasqueira, occurring only in grains of microscopic or sub-millimetric size, typically dispersed in the hypogenic rocks (Clark, 1965; Orey, 1967; Wimmers, 1983; Bussink, 1984). It can easily be confused with freibergite.

Thadeuite $Mg(Ca,Mn)(Mg,Fe,Mn)_2(PO_4)_2(OH,F)_2$

Thadeuite is a complex orthorhombic hydroxyl phosphate of calcium, manganese, and magnesium for which Panasqueira is the type locality. At first it was mistaken for triplite, and some confusion persisted even after thadeuite was described as a species by

Table 1. **Minerals of Panasqueira.**

Elements	
Antimony	Sb
Arsenic	As
Bismuth	Bi
Gold	Au
Silver	Ag
Sulfides and Arsenides	
Acanthite	Ag_2S
Arsenopyrite	FeAsS
Bismuthinite	Bi_2S_3
Canfieldite	Ag_8SnS_6
Chalcocite	Cu_2S
Chalcopyrite	$CuFeS_2$
Covellite	CuS
Cubanite	$CuFe_2S_3$
Galena	PbS
Löllingite	$FeAs_2$
Mackinawite	FeS
Marcasite	FeS_2
Molybdenite	MoS_2
Pentlandite	$(Fe,Ni)_9S_8$
Pyrite	FeS_2
Pyrrhotite	$Fe_{1-x}S$ (x=0.1–0.2)
Sphalerite	ZnS
Stannite	Cu_2FeSnS_4
Stibnite	Sb_2S_3
Sulfosalts	
Freibergite	$Ag_6Cu_4(Fe,Zn)_2Sb_4S_{13}$
Gudmundite	FeSbS
Matildite	$AgBiS_2$
Pavonite	$AgBi_3S_5$
Pyrargyrite	Ag_3SbS_3
Stephanite	Ag_5SbS_4
Tetrahedrite	$Cu_6Cu_4(Fe,Zn)_2(Sb,As)_4S_{13}$
Halide	
Fluorite	CaF_2
Oxides	
Cassiterite	SnO_2
Hematite	Fe_2O_3
Magnetite	$Fe^{2+}Fe_2^{3+}O_4$
Rutile	TiO_2
Carbonates	
Ankerite	$Ca(Fe^{2+},Mg,Mn)(CO_3)_2$
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Siderite	$FeCO_3$
Sulfates	
Chalcanthite	$Cu^{2+}SO_4\cdot 5H_2O$
Gypsum	$CaSO_4\cdot 2H_2O$
Phosphates and Arsenates	
Althausite	$Mg_4(PO_4)_2(OH,O)(F,\square)$
Amblygonite	$(Li,Na)Al(PO_4)(F,OH)$
Arseniosiderite	$Ca_2Fe_3^{3+}(AsO_4)_3O_2\cdot 3H_2O$
Fluorapatite	$Ca_5(PO_4)_3F$
Isokite	$CaMg(PO_4)F$
Panasqueiraite	$Ca(Mg,Fe)(PO_4)(OH,F)$
Pharmacosiderite	$KFe_4^{3+}(AsO_4)_3(OH)_4\cdot 6–7H_2O$
Scorodite	$Fe^{3+}AsO_4\cdot 2H_2O$
Thadeuite	$Mg(Ca,Mn)(Mg,Fe,Mn)_2(PO_4)_2(OH,F)_2$
Vivianite	$Fe_3^{2+}(PO4)_2\cdot 8H_2O$
Wagnerite	$(Mg,Fe)_2(PO_4)F$
Wolfeite	$Fe_2^{2+}(PO_4)(OH)$
Tungstates	
Ferberite	$Fe^{2+}WO_4$
Scheelite	$CaWO_4$
Tungstite-Hydrotungstite	$WO_3\cdot H_2O - H_2WO_4\cdot H_2O$
Silicates	
Bertrandite	$Be_4Si_2O_7(OH)_2$
Beryl	$Be_3Al_2Si_6O_{18}$
Clinochlore	$(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$
Muscovite	$KAl_2\square AlSi_3O_{10}(OH)_2$
Quartz	SiO_2
Topaz	$Al_2SiO_4(F,OH)_2$
Tourmaline (Schorl-Dravite)	

Isaacs *et al.* (1979). A further detailed article about the structure of the mineral (Isaacs and Peacor, 1982) definitively established it as a new species.

At Panasqueira, the mineral was found at two narrowly circumscribed sites in two veins (Isaacs *et al.*, 1979), where it occurs as fine-grained masses (the largest known is just under 2 cm across) and as intergrowths with fluorapatite. Thadeuite has a vitreous luster and an orange-yellow color by which it may be distinguished (with difficulty) from wolfeite, which is salmon-colored. Other associated species are topaz, quartz, muscovite, chalcopyrite, sphalerite, siderite, arsenopyrite and, much more rarely, althausite and vivianite. Thadeuite is a very rare species, present only in a very few of the Panasqueira veins. It is possible that the orange inclusions in some quartz crystals are thadeuite.

Topaz $Al_2SiO_4(F,OH)_2$

Although not very well known in specimens from Panasqueira, topaz is relatively common there, particularly in the western part of Barroca Grande and at Rebordões, where is intimately associated with quartz and muscovite on the borders of the veins. The topaz masses are grayish white and translucent to opaque, with corroded surfaces (Gaines and Thadeu, 1971).

Good short-prismatic, fairly thick topaz crystals were found in a small dump at Vale da Ermida. They are translucent to transparent and white to pale blue; some are tinted yellowish by inclusions. These crystals are very well developed, with dominant {110} and {120} third-order prisms, the {001} pinacoide and the {111} pyramid; secondary faces show the {112} pyramid, the {021} first-order prism and {010} second-order prism, and the {010} second-order pinacoid. These crystals from the dump are rarely larger than 1 cm, but crystals over 2 cm have been found in underground workings.

Tourmaline (Schorl-Dravite)

Tourmaline-group minerals occur abundantly at Alvaroso, Das Guerras and especially at Corga Seca (Gaines and Thadeu, 1967). The tourmaline is associated with muscovite and ferberite in the basic ore, where it forms black veins 1 to 2 cm thick, and is dis-

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Wild Panasqueira—A Memoir

Jordi Fabre

The title of this small memoir, "Wild Panasqueira," may seem strange to readers, but when I remember all of the many trips I have taken to that famous classic locality, what I recall most vividly isn't the beauty of the fluorapatites, the variety of the "combination" specimens, or the huge sizes of the crystal pockets in the ferberite veins, but rather the wildness of the landscape, the character of the people, and the hard dealing that was necessary in order to get fine specimens. I will try to set forth why I often enjoy remembering my many tough, challenging, sometimes dangerous trips to Panasqueira in search of minerals.

The Panasqueira mine exploits tungsten ore, and tungsten is a "war" element. By this I mean that because of its resistance to friction, tungsten is used to build rockets, tanks and many other things of use to military forces. During the Second World War, tungsten was considered a strategic metal, and because the Portuguese government was "neutral" during that war the Nazis bought much tungsten from Portugal. Knowing this, the Allies forced Portugal to stop supplying tungsten to the Nazi government.

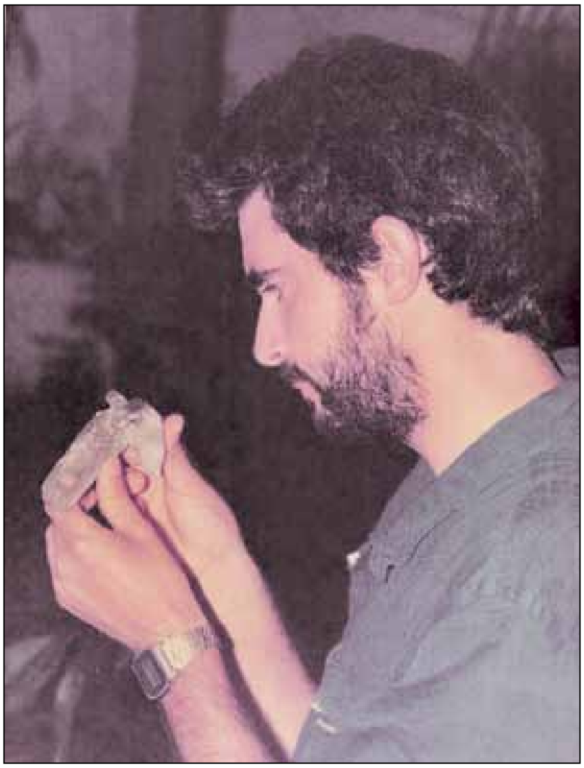
All problems involving money tend to find solutions, and in this case the Portuguese government found a good solution, namely selling the tungsten through Spain—also a "neutral" country during the war but then much friendlier to the Nazis than Portugal. Much contraband tungsten was shipped from Portugal through Spain to Germany until the Allies forced the Portuguese government to stop the traffic. Today, these historical facts remain in the minds of everybody in the Serra da Estrela—the mountains surrounding the Panasqueira mines—and every "terra" (small village) stores in its genome the feeling that minerals from Panasqueira are associated with some kind of prohibited business, so all dealings involving those minerals must be extremely secret and dark.

I used this "war story" to try to explain why really good specimens from Panasqueira have always been so scarce, and why, when they do appear on the market, their prices are so high, even when they were newly found. I'm familiar with the backstories of dealings in Moroccan minerals, and in Romanian minerals during the Ceauşescu dictatorship, and believe me, neither of these can compare with tales about Panasqueira minerals.

One example is the story of what is probably the best extant cassiterite specimen from Panasqueira, currently in the Folch collection. Señor Folch always explained that this cassiterite was offered to him in the *escritorio* (office) of the mine, where it had been used as a paperweight, but that to smuggle it out of Portugal he had hidden it under his hat. Imagine the scene at the customs office at the Portuguese/Spanish border: Señor Folch, well known, wealthy and always dapper, sitting in his luxury car (a Rolls-Royce, I believe) with a heavy cassiterite under the hat on his head!

When I visited Panasqueira for the first time, on a trip with my brother Francesc, I was 14 years old. I would visit many more times, but already, during that first trip, I learned the importance of seeming very self-confident when searching for minerals there. Although persistent in making inquiries, we had seen no specimens until, luckily, someone who pitied us (or had gotten bored with us) suggested that we try Senhor X (sorry, I can't give his name), who seemed to have access to good specimens. After several more unsuccessful trips to the mines we learned that Senhor X lived in a "terra" about 20 km from the mining area. After a few more trips I finally met him: he was a funny man with a permanent smile and a playful personality.

The country home of this man can be described—generously—as "chaotic," and strongly suggestive of the presence of "easy ladies." Sex moves the world, people say, and in this case sex moved the good minerals to Senhor X by way of the going rates for the "ladies." That country home was very peculiar: there were a lot of chickens running around in complete freedom, pieces of mountain cheese on the tables (especially fragrant because it was a hot summer), and a lot of used glasses which apparently had come from elsewhere. The bedrooms were not especially clean. Senhor X, with traditional mountain hospitality, always offered the arriving visitor a piece of cheese and a *copo* (drink)



The author in 1978 (21 years old), admiring a specimen of quartz and fluorapatite from Panasqueira.

in one of the well-used glasses, but usually I refused these generous offers. I was less than 20 years old, and all I sought in this "paradise" was mineral specimens "distinguished by their scientific importance."

Senhor X was always very friendly to me, and he always offered good specimens. After we had made a few low-level deals (for cheap, inferior specimens that I bought just to maintain my relationship with Senhor X), he offered me a large lot which included some very fine pieces. I was interested in that lot, and after a typically lengthy discussion we agreed on a price; the remaining problem was how to move it into Spain, considering how large the lot was and how difficult it would be to get through customs. Senhor X offered a solution: another person, Senhor Y, would bring the specimens to Fuentes de Oñoro, the first Spanish town after the Portuguese customs station in Vilar Formoso. I was naïve enough to accept his proposal, and to *pay for the lot in advance*! Yes, twenty-something is a nice age, when we still suppose that everyone's intentions are good.

I paid for the whole lot but not did make a list of the specimens, or even count them, so huge was my stupidity. I went to Fuentes de Oñoro at the day and hour which had been fixed between Senhor X and me. No one was there, and after waiting for two hours I felt that all my money had vanished because of my stupidity. But . . . a miracle! two hours after the arranged time an old, very battered Lada car appeared with Senhor X (smiling, as always) and Senhor Y (looking much more serious) inside. They had brought the lot through! Of course, some specimens, including the best one, a superb ferberite with quartz, were no longer there, but despite this annoyance I had the lot, and the possibility of making money from it.

Many years after this transaction I met Senhor Y in his home. I knew he was there because in front of his home I saw his really old Lada, which inexplicably seemed to be still in use. I visited with him, I drank with him several *copos* (an unavoidable Serra da Estrela habit), and then he opened his heart to me and we remembered together the Fuentes de Oñoro transaction. He explained to me that, at first, he and Senhor X had decided not to waste time delivering the lot to me. As the lot had already been paid for, and they could make money selling it again to someone else, while avoiding the costs of getting it into Spain, they decided just to cheat me. But then, after several *copos*, they began wondering how I could have been so stupid as to order a lot like this, to be delivered as contraband, and paying for it beforehand. They tried to consider all possibilities but couldn't find any plausible reason for my behavior. So finally they decided that the whole deal was too strange: I must have had powerful reasons to think that (against any logic) they would fulfill the agreement. At last they decided to bring the lot to me after all, just to be sure that nothing bad happened to them if they didn't. So I got the minerals simply because I had been ignorant beyond belief. When, during my visit years later, Senhor Y realized that I had simply, innocently, acted out of faith in human goodness, he became very regretful for having lost a good chance to pocket good money. He was ashamed of himself for not having recognized at the time that I was just a fool.

Over the years I kept dealing with Senhor X, who always showed me respect, ignoring the memory of the Fuentes de Oñoro episode. One day in his home (not the home with the "easy ladies" but his family home), I was talking with his Spanish wife about minerals. (His wife was not as kind, funny, or hospitable as he was, but she was much more realistic: with her, price negotiations always dragged out because, although I was willing to pay a great price, she would want to charge a fantasy price.) We were in the middle of a discussion when I heard people running, and unusual noises; then suddenly someone came into the house to sound an alarm about "*guardilhas, guardilhas!*" (cops, cops!). The Portuguese police were outside, looking all around my car. Immediately the wife of Senhor X assumed that the police had recognized the car (after all my visits here to buy minerals) and were looking for me. She said that she would take care of me. She brought me to the roof of her home by way of a very narrow staircase covered by drapes. When I reached the roof she said "jump!"

"What? jump to where?" I said.

Excitedly she explained to me that the police must not be allowed to find me in Senhor X's private home, and that the only way to escape their notice was to jump down to the patio. So, at the risk of bodily injury, I leaped down to the inner patio, where I waited for further news from the wife of Senhor X. Luckily I had not been physically hurt by my leap, but I kept imagining detention, long periods in jail, torture . . . and I waited for four or five hours to hear from my hosts. At last Senhora X opened the door of the patio and explained to me that the reason why the police were interested in my car had nothing to do with minerals—I had parked badly in the street!

The police, since they hadn't found me, took down the car's license plate number, and so, of course, when I returned to Barcelona (without any minerals) I sold that car and bought another. The written record of that car from Spain, belonging to an unknown driver, should still be there in the files at the Sierra da Estrela police station, among other unsolved mysteries.

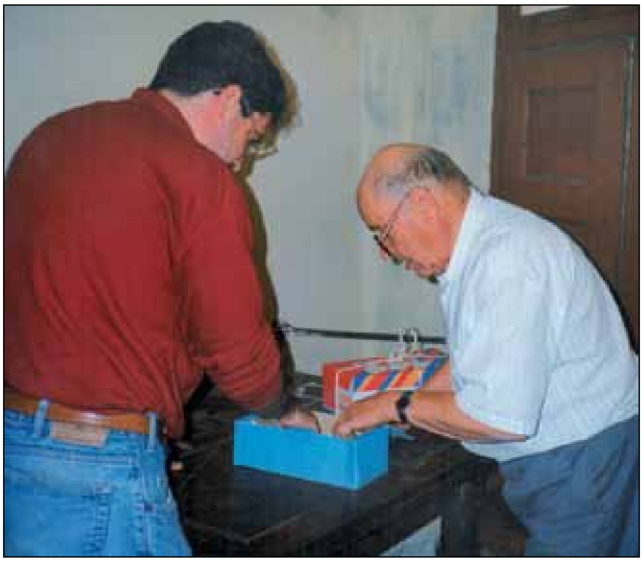
The state of the roads in Serra da Estrela was (and still is) not the best. The roads are narrow, even those that are paved are in very bad shape, and road signs are few. Lights visible in the night offered some hope, but only a few very dim ones marked where small villages were located in the middle of nowhere. For several years, a supplier in the village of Meãs often had good specimens to sell, so a visit to him was mandatory. However, he was hard to find because he never arranged meetings in advance, and his working hours in the mine frequently changed, so I wasted many trips to his house when he wasn't there. On one of those trips I rolled into Meãs very late, in the dark of night, when only a single 60-watt bulb was working to illuminate the whole village. Trying to find the supplier's home in the dark, I crossed a small bridge several times. During one of these crossings I turned the steering wheel and heard a big noise, and I felt the earth vanish below the car. When I recovered my breath I carefully, slowly, got out of the car, discovering that, as in a Hollywood movie, the car was half on the road and half in the air, suspended above the river just off a corner of the bridge. I could think of nothing to do but to walk to the home of the supplier, and I was very lucky to find him at home. At this time my Portuguese was very poor; I couldn't find enough vocabulary to tell him what had happened. Desperate, and worried that at any time my car could fall into the river, I just kept saying to him "*o carro, o carro*" (the car, the car). Since he didn't grasp what I wanted to say, I finally took his arm and guided him to my suspended car. When he saw my car with one half in the road and the other half in the air, he started to laugh and he never

A photo taken in July 1991, as I sat outside a very small village store in Panasqueira where the best specimens were changing hands.

stopped; I have never seen anyone laugh for so long at a time. Still laughing, he went to some neighbors to explain my trouble, and of course when *they* saw my car they, too, laughed like crazy people. I think that for some reason my words "o carro, o carro" made the situation still more hilarious to them.

They fixed the trouble quickly: two or three people formed a kind of "human tower" from the river (which didn't have much water in it), and pushed the car up and onto the road in correct position. My final image of Meãs as it was on the night of my incident is of all the people laughing and screaming "o carro, o carro." I'm sure that afterwards they created a new festivity named "O Carro-O Carro," and that every year they celebrate the funniest thing that ever happened in Meãs. Anyway I should say that I consider myself lucky, because at around this same time another courageous dealer tried to ford the nearby Zezere River and was not successful; the car got caught up in the river's current, and the dealer could only save his life by jumping out. The Zezere River delivered his rental car to the larger Tajo River, and later maybe to the Atlantic Ocean.

Of course not all of my memories of Panasqueira are so funny. I should mention one bad situation when on a very dark night a car appeared behind mine, blinking its lights furiously. The road was very bad, and there were high canyons on my left. I tried to escape this strange persecution, but rapid acceleration was too risky, so I decided to stop, take my chances, and confront the situation. The driver behind me was a very uneasy Portuguese part-time dealer involved in some very dirty business, and he "suggested" that I purchase from him a broken specimen (very good, but broken). When I told him that I wasn't interested in buying broken specimens he explained to me patiently that he needed money. He reminded me that we were alone in the night in Serra da Estrela, and said that if I would look carefully at the specimen I would see that it wasn't broken. Considering everything, and remembering that, luckily, I didn't have much money on me just then, I decided to buy that broken rock, offering him all the money I had. The transaction turned out all right for the Portuguese dealer since, for some stupid reason, I told him that he could keep my money as credit toward future business,



The author in 1990 with Senhor Barroca Gill, the main supplier during the early history of the Panasqueira mine. He sold thousands of specimens over the years, first to the prominent Barcelona dealer Joaquin Folch-Girona and later to many other collectors and dealers. His little store, called *Miudezas* ("Small Things"), had a very modest "showroom" where he would pull out hidden shoe boxes containing minerals, in extreme secret. I always had to wait a long, long time, sometimes hours, until the situation in his store allowed him to invite me inside to see his hidden secrets. My memories of my dealings with Senhor Gill will always be associated with darkened rooms and an intense smell of old, cheap cheese.

that I didn't need the broken rock. Of course I never recovered my money, and I never saw again that broken specimen that I'd foolishly decided not to keep.

One of the best specimens of violet fluorapatite from Panasqueira that I know of, with a sharp, well individualized fluorapatite crystal in a bed of muscovite, was mined by someone with whom at this time I had an excellent relationship, because over many years I had trained him to recognize quality and to know prices. But, unfortunately for me, another dealer arrived in Panasqueira before me and, knowing that this young man had a great specimen he was saving for me, invited the young man to have a drink with him, then another drink and then another, and another, etc., until finally the young man had gotten so drunk that he sold the fluorapatite on the spot to the other dealer, instead of holding it for me. I heard this story later from the young man himself: was it the truth or a lie? I don't know, but when I later saw this fluorapatite specimen in the hands of different collectors I always saw it as a kind of "lost prodigal son."

On the other hand, another great specimen was saved for me while other dealers attempted to buy it, simply because the fellow who owned it had worked so hard to bring it out of the mine that he wanted to sell it to someone who would really love it. He wrapped it in a lot of paper, bubble wrap, wood chips, etc., and hid the package inside the wheel of an enormous jumbo bulldozer working in the mine. The specimen isn't small; it measures 12 × 17 cm. Imagine what a careful wrapping job this fellow must have done in order to protect a cabinet-sized fluorapatite specimen inside a wheel of a jumbo bulldozer which would be negotiating the very rough roads inside the mine.

I have used "wild" in my title because my memories of Panasqueira are wild, and the history of any great specimen from Panasqueira is likely to be wild as well. Every miner who has ever worked in the great mine, and every dealer who has ever gone there surely has stories of his own like these. Many other stories come to mind, but my task here is to present to readers just a few reasons why Panasqueira is special, and to point out how proud every collector with a really fine Panasqueira specimen should be. The really fine ones are very scarce, and they tend to have complicated histories.

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seminated in the wall rock. Very thin to acicular, black to bronze-colored tourmaline crystals to 1 cm form druses in these settings. Gaines and Thadeu (1967) identified the $\{10\bar{1}0\}$ first-order trigonal prism and the $\{11\bar{2}0\}$ second-order pyramid, but these forms are indistinguishable to the naked eye.

The tourmaline species was called schorl by Conde *et al.* (1971), but unpublished analyses have shown that both schorl (black) and dravite (bronze-brown) are present. Pure end-members are absent. In the absence of analytical determinations in every case, this tourmaline can be referred to as schorl-dravite.

Schorl-dravite in the veins forms infillings in vugs, and has crystallized around the bases of crystals other species. Most commonly it is associated with muscovite, but it is also common as inclusions in quartz and fluorapatite; Kelly and Rye (1979) noted tiny fluorapatite crystals resting on acicular crystals of schorl-dravite.

Tungstite-Hydrotungstite $WO_3\cdot H_2O - H_2WO_4\cdot H_2O$

Tungstite is the product of the dehydration of hydrotungstite. The two species together appear as yellow and green, powdery aggregates on altered ferberite (Clark, 1965). They are visually distinguishable in that tungstite tends towards yellow, hydrotungstite towards pale apple-green. Tungstite also appears at Panasqueira as sharp, elongated orthorhombic prisms closed by basal pinacoids—in size these crystals are between 5μ and 90μ. Hydrotungstite crystals from Panasqueira do not exceed 40μ.

Vivianite $Fe^{2+}_3(PO_4)_2\cdot 8H_2O$

Vivianite from Panasqueira was described by Kelly and Rye (1979) as blue-green cleavable masses formed, with other minor phosphates, during the main sulfide stage. The usual phosphate associations are scorodite, wagnerite, isokite, thadeuite, panasqueiraite and wolfeite; this suite occurs in association with quartz, tourmaline (schorl-dravite), muscovite, arsenopyrite, fluorapatite, pyrrhotite, pyrite, chalcopyrite and cassiterite.

Wagnerite $(Mg,Fe)_2(PO_4)F$

Wagnerite formed, with the other minor phosphates, during the main sulfide stage (Kelly and Rye, 1979). It is massive, very rare, and typically associated with thadeuite.

Wolfeite $Fe^{2+}_2(PO_4)(OH)$

Wolfeite is one of the rarest phosphates at Panasqueira, where it is found as very small, earthy aggregates, always associated with thadeuite and panasqueiraite. It is distinguishable from associated species by its color: wolfeite is salmon-colored whereas thadeuite is orange-yellow and panasqueiraite is rose-orange (Isaacs*et al.*, 1979).

MINERAL ASSOCIATIONS

In the Panasqueira orebody, attractive "combination" specimens showing two or more well crystallized species are very common; the species occurring together may have formed either syngenetically (simultaneously) or paragenetically (at different times). The species most commonly seen in such specimens are fluorapatite, ferberite, siderite and arsenopyrite. Cassiterite, quartz, sphalerite, chalcopyrite, marcasite and pyrite may also occur with other species, producing specimens of special beauty and mineralogical interest (Gaines and Thadeu, 1971; Orey, 1967; Foxford *et al.*, 1991; Azevedo and Calvo, 1997; Ascençao Guedes, 2002). Specimens in which fluorapatite, ferberite, siderite and arsenopyrite are associated with quartz crystals are particularly aesthetic; such specimens are typically found in the quartz veins. Typically the crystals of the species named above rest on the quartz crystals and are partially covered, in turn, by later sulfides, carbonates or muscovite.

In quartz-poor areas of the deposit dominated by ferberite, fluorapatite crystals commonly rest on crystals of ferberite, although there are known cases in which the original ferberite has leached away, then recrystallized on the fluorapatite. Something similar can occur with other species such as cassiterite, arsenopyrite and siderite. In some areas of the district, all of these species, as well as chalcopyrite and sphalerite, may be seen occurring together. Nor is it especially rare to find crystals of several of these species coated or underlain by muscovite and accompanied by tourmaline (schorl-dravite), with later coatings of sulfides and carbonates.

At Panasqueira, each separate stage of the paragenesis is dominated by a single species, but in each case, crystals of the dominant species may be accompanied by crystals of any minerals which are generally common in the district. In many specimens, macrocrystals of three or more species are present, although the most aesthetic "combination" specimens have only two. The most prominent of such specimen types are briefly described below.

Arsenopyrite-cassiterite. This is not a common association, but in the late 1970s and early 1980s abundant specimens emerged in which isolated, complexly twinned cassiterite crystals rest on clusters of arsenopyrite crystals, sometimes with small crystals of siderite and/or with muscovite coatings.

Arsenopyrite-chalcopyrite. Since chalcopyrite crystals are rare at Panasqueira, arsenopyrite-chalcopyrite specimens are also rare, but the known examples are very noteworthy.

Arsenopyrite-siderite. In this common association, arsenopyrite is almost always earlier than siderite.

Cassiterite-quartz. These two species can appear together without macrocrystals of other species, but siderite is seen fairly commonly also on cassiterite-quartz specimens.

Cassiterite-siderite. In this association, typically, tight groups of twinned cassiterite crystals rest in "nests" composed of flattened or lenticular crystals of siderite.

Ferberite-quartz. In specimens with ferberite and quartz crystals predominating, macrocrystals of other species including arsenopyrite, fluorapatite, siderite, cassiterite, chalcopyrite, sphalerite and (rarely) marcasite may be present as well.

Ferberite-cassiterite. Specimens of this uncommon association show complex, twinned cassiterite crystals directly implanted on ferberite crystals.

Ferberite-fluorapatite-siderite. This is a very common association in some areas at Panasqueira: fluorapatite crystals are implanted on ferberite and siderite crystals of considerable size. Arsenopyrite crystals also are commonly present.

Ferberite-muscovite. Ferberite and muscovite are commonly found together, as both species are major components of the orebody. In the most aesthetic specimens, muscovite forms rosette-shaped aggregates of leafy crystals partially coating the ferberite faces.

Ferberite-siderite. This association is also very common. The siderite associated with ferberite forms lenticular crystals or rhombohedrons with curved edges; rarely the siderite crystals are prismatic.

Ferberite-quartz. This association is very common in the quartz veins.

Fluorapatite-cassiterite. In this uncommon association, individual cassiterite crystals or groups of complex cassiterite twins are implanted on the fluorapatite.

Fluorapatite-quartz. In this association, fluorapatite crystals rest on quartz. Other species which may also be present include muscovite, arsenopyrite, ferberite, siderite (common), cassiterite, chalcopyrite, sphalerite and marcasite (rare).

Fluorapatite-muscovite. In specimens which are found commonly at the margins of the orebody, muscovite partially coats fluorapatite crystals.

Fluorapatite-siderite. In most fluorapatite-siderite specimens the fluorapatite is earlier than the siderite.

Fluorapatite-ferberite. Fluorapatite is commonly implanted on ferberite as isolated crystals or as irregular clusters.

Siderite-quartz. In the quartz veins it is common to find siderite crystals implanted on quartz crystals. The siderite may take a variety of habits, and crystals of both species commonly reach 10 cm or more.

COATINGS AND INCLUSIONS

The larger crystals in crystal-lined cavities are commonly coated by other species, e.g. siderite, muscovite and/or late-forming carbonates and sulfides, especially calcite, pyrite, marcasite and, less frequently, dolomite and sulfides. The sulfide coatings are mixtures typically dominated by löllingite and chalcocite. In most cases the coatings only partially cover the crystals, but in other cases they completely cover and hide them. The contact surfaces between the coatings and the underlying crystals are rarely smooth, and when the coatings are removed the crystal faces beneath appear rough and corroded.

Inclusions are very common, and they are easily visible when the host crystal is transparent quartz or fluorapatite. Crystals of cassiterite, arsenopyrite, sphalerite and chalcopyrite may also have inclusions, but these are not always easy to distinguish at first glance.

Muscovite inclusions are clearly visible in many crystals, where it forms small, silvery or brownish flakes or mossy aggregates. Other common Panasqueira species can also be seen as inclusions, frequently as small but sharp, isolated crystals or groups; such inclusions may be completely enclosed by the surrounding crystal or may reach and extend beyond that crystal's boundary faces. The species most commonly found as inclusions of this kind are sharp, platy ferberite crystals; acicular crystals or mossy aggregates of tourmaline (schorl-dravite); highly lustrous, deformed crystals of arsenopyrite; and small twinned crystals of cassiterite.

ACKNOWLEDGMENTS

Special thanks to Tom Moore for his fine and accurate editing and his interesting comments. My thanks also to Jordi Fabre, simply for all, and to Wendell E. Wilson, who has enriched this article with his gathering of new illustrations and his eye for graphic design. Thanks are also due in memory of the late Joan Viñals (1949-2013), who studied and widely reported on the sulfides from Panasqueira with special attention to the fascinating transitions of the stannite-chalcopyrite-sphalerite suite; to the Folch family and Francesc Riquelme, curator of the Folch collection; and, finally, to Josep (Pep) Gorgas, who kindly allowed access to their stannite and other Panasqueira specimens.

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