Geology and mining at the Panasqueira W-Sn deposit

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Abstract:

The importance of exploration geology in an active mine must always be highlighted. Exploration geology will invariably be a strong part of the present and especially of the future of mines. The Panasqueira mines are a good example of how a very small technical team can deal with a heritage of more than a century. The professional and personal relationship amongst all the technical people is probably one of the keys to the success. The Panasqueira mines have a good, daily coexistence between conventional and non-conventional geology mine working, from the exploration to the evaluation of the resources/reserves, finalizing in grade control. The exploration geology work in the Panasqueira mines does not finish with just the core drill holes and is mixed with mining engineering that has to systematically open exploration adits named "inclines", still in an exploration phase. Panasqueira is one of the few mines worldwide which has been working for more than 130 years, producing the best wolframite concentrate in the world, as well as cassiterite and chalcopyrite concentrates, and furthermore crystal specimens of several minerals much appreciated all around the world.

Resumen:

La importancia de la exploración geológica en una mina activa siempre debe ser siempre destacada. La geología de exploración será invariablemente una parte importante del presente y especialmente del futuro de las minas. Las minas de Panasqueira son un buen ejemplo de cómo un equipo técnico muy reducido puede gestionar una herencia de más de un siglo. La relación profesional y personal entre todos los técnicos es probablemente una de las claves del éxito. Las Minas de Panasqueira tienen una buena coexistencia diaria entre el trabajo de geología en mina, convencional y no convencional, desde la exploración hasta la evaluación de recursos/reservas y el control de leyes. Los trabajos de exploración en las Minas de Panasqueira no finalizan con los sondeos, sino que van en paralelo con la ingeniería de minas, que tiene que abrir de una forma sistemática galerías -llamadas "inclines"-, aún incluso en la fase de prospección. Panasqueira es una de las pocas minas en el mundo que ha estado trabajando desde hace más de 130 años, produciendo el mejor concentrado de wolframita del mundo, así como concentrados de casiterita y calcopirita, además de muestras de cristales de diversos minerales, muy apreciados en todo el mundo.

Palabras Clave: Exploración, Minas de Panasqueira, Wolframita. **Key Words:** Exploration, Panasqueira Mines, Wolframite.

INTRODUCTION

The Panasqueira mines are located in the Covilhã Municipality in the Centre of Portugal, in the south of the Serra da Estrela Mountain (the highest point of Continental Portugal) (Fig.1). The topography is mountainous with difficult accessibility; the drive by car to the mine is around 30-40 km on a twisty road.

The name of the Panasqueira mine refers not only to one isolated mine but to a cluster of small ancient mines, located in the same region, which have changed their location depending on the mining activity.
There are recordings of the exploration work, both underground and at the surface, continuously and diversified throughout all the exploitation of the Panasqueira mines.

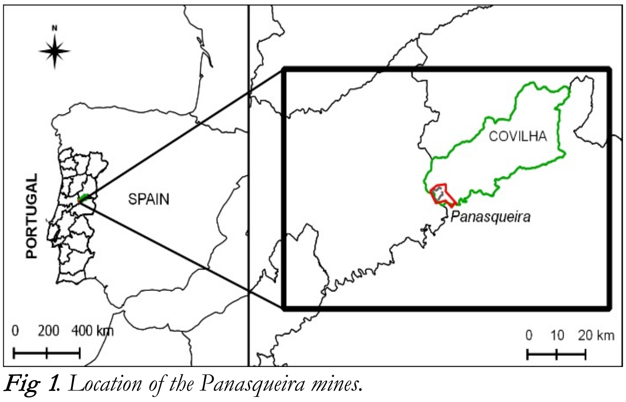

Fig 1. Location of the Panasqueira mines.

The first references to the Panasqueira mines are from 15 September 1881 when Manuel dos Santos went to the Covilhã Town Hall to register the mining activity rights of the Vale de Ermida zone.

During the history of the Panasqueira mines there have been several different owners, usually British or South Africans, with the Japanese company Sojitz being the exception.

GEOLOGY

The Panasqueira deposit is located in the Central Iberian Zone (CIZ) in a monotonous series of schists named "Xistos das Beiras" that cover a big area of the Centre of Portugal. These schists are part of a complex geological unit known as the Schist Greywacke Complex.

In the surrounding area of the mines, the influence of a magmatic intrusion found at depth, which generated a metamorphic contact aureole, can be noted (Kelly, 1977; Kelly and Rye, 1979). This aureole is expressed by spotted schist, observed on the surface and in underground excavations. It is also possible to see acid and basic magmatism manifestations, represented by aplite and pegmatite veins and dolerite dykes, respectively (Thadeu, 1951; Reis, 1971).

In the underground excavations, the magmatic intrusion is expressed by a greisen cupola found at elevations of 620m, 560m and 530m, located in the northern part of the mine. Thadeu (1951) was the first author who described this. The deposit is limited to the north by a regional E-W shear fault called the "Cebola". No exploitation work is known to the north of it; therefore, the mineralization is considered confined by this structure.

The Panasqueira ore is constituted by a dense swarm of horizontal quartz veins with several different minerals, some of them in economic concentrations, allowing their underground exploitation.

The following mineral paragenetic sequence (Table 1), globally accepted (Kelly and Rye, 1979), shows the most frequent minerals in the Panasqueira veins.

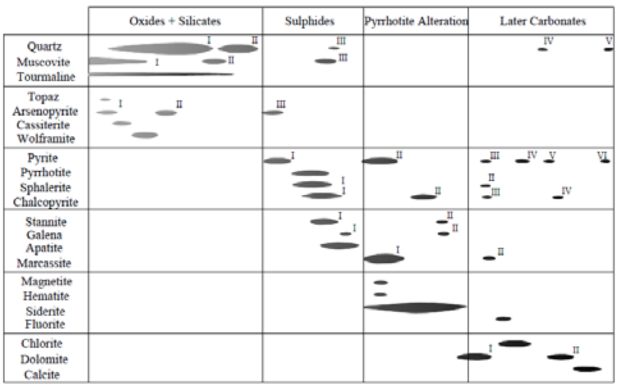

Table 1. *Paragenetic mineral assemblage from Kelly and Rye (1979). Roman numbers represent different stages of the same mineral.*

The economic minerals exploited in the Panasqueira mines are wolframite (*var.* ferberite), cassiterite and chalcopyrite. Other useful minerals, such as sphalerite, siderite and topaz, are present but unfortunately are not economic even as a by product due to the difficulties to extract them at the concentration/separation plant. Even when separated, the small quantities produced place them below any industrial economic interest.

The Panasqueira sub-horizontal veins are commonly 18-30 centimetres thick, but can reach up to 100 centimetres, which is why the stopes are only about 2.2 meters high. As all the mineralization is limited to the veins, any other material taken out would represent dilution. The morphology of the veins is not always continuous and/or homogeneous.

It is very common to see veins ending in an "*eel tail*". Frequently, a vein that closes in an *"eel tail"* will begin some centimetres or metres ahead and/or above or below another "*eel tail*" (Fig. 2). In reality this geometry is apparent and frequently the termination is only a 2D apparent effect and the tails are part of the same vein.

Fig 2. *Example of a mineralized vein ending as an "eel tail". (Source: photography from the authors).*

HISTORIC EVOLUTION OF THE MINES

The exploitation work is dispersed along a hill. The first mining work began over the quartz veins outcropping at elevations around of 1,000 metres, from the top of the hill to elevations of around 500 metres, at the bottom of the hill side (Vaz Leal, 1945).

The work followed those veins and the mine has been growing up until the present day. Nowadays, the main structure is located near the Barroca Grande locality. This small village is located on the south side of Panasqueira (the village where all the mining work began) and to the east of the Vale de Ermida village.

For several years, the mines have been growing to lower elevations, exploring deeper veins. Before 1946, the mine exploited veins up to the elevation of 740 metres (above level 0), from 1946 to 1978 up to the 620 metre elevation (levels 0 and 1), from 1978 to 1989 up to the 560 metre elevation (level 2) and from 1989 to 2005 up to the 470 metre elevation (level 3).

From 2005 up to the present day the mines have begun to exploit in the opposite way, that is, from 2006 to 2008 the mine returned to exploiting previously worked levels, returning from level 3 to level 2, in 2009 the exploitation returned to level 1 and in 2013 level 0. Therefore, from 2014 till the present, the veins mined are from all the levels (level 0 to level 3).

The mining activity is returning to the old and still not mined veins or at least to the borders of the old mined ones. This means that the ore that is being mined usually has lower grades than the historical ones. As the work returned to previously mined zones, the access to information obtained in those years has become a powerful ally of the exploration geologist.

The historic stope data constitute a very important part of the mining exploration at Panasqueira. This is essential not only to know where the veins have been previously mined but also how it was done and what have been found as wolframite grades in the borders of those old exploitations. This research also allows us to get information about some characteristics of the stopes, such as vein inclination, thickness, expected grades, and, in some cases the lithology and structural mapping (eg. presence of faults).

Figure 3 shows an example of an old section drawn by hand, where it is possible to see the information present in these old documents (the galleries have 2,2m height).

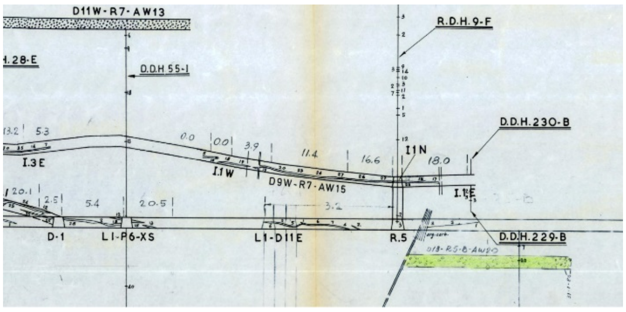

Fig 3. Old section image from Drive D11. (Source: Beralt Tin and Wolfram Portugal).

Furthermore, a survey from the historic drill holes done in the Panasqueira mines shows thousands of old drill holes that in 2004 were still only available in paper reports. In the last 15 years, the technical staff of the mine has created and updated a global digital database with all this historical information. All the sections were included and updated using specialized software.

The information about previously mined zones is also very useful regarding the safety issues. The risks of being very close to an old stope must be minimized in order to prevent accidents that could be very serious. If there is not enough thickness of rock between stopes, the roof could fall causing injuries or damaging equipment, for example, a machine falling some metres to a stope located below.

For several years only some statistic data from 1946 to the present was recorded; the research work has allowed us to recover 12 years of history and get data from 1934 onwards. Before that, there were no known records about the exploitation or exploration done…anyway it is 85 years of history recovered.

STRUCTURE OF THE PANASQUEIRA MINES

During many years the mines did not have a well-defined plan, with the size and direction of the galleries being defined by the geometry of the veins that were being exploited. This is visible in the old parts of the mine where their distribution takes more random forms (Fig. 4).

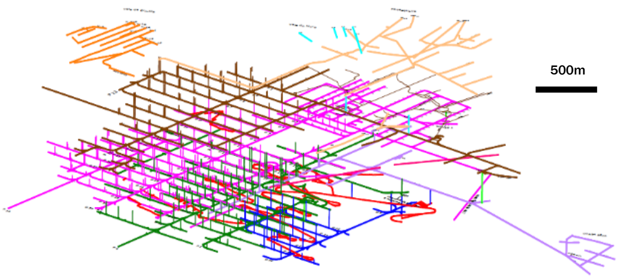

Fig 4. Global structure of the Panasqueira Mines. Note that different colours represent different mine levels. (Source: Beralt Tin and Wolfram Portugal).

The concession area had several different and separated zones and entrances, but their exploitation zones connected with each other in underground (Vale de Ermida-Panasqueira-Corga Seca). The old exploitations were done with the "Long wall" method. The veins were exploited following the ore along a gallery and, while it was depleted on one side of the adit, the produced waste and wood were used to make the wall in the exploited zone on the other side of the adit.

Since at least 1960, the mines have been developed further to the south of the original galleries and their geometry became regular with the definition of "drives" (D) (E-W galleries) separated by 100 metres and "panels" (P) (N-S galleries) 50 metres apart. All the mine structure follows an azimuth of N30º.

As stated above, the "old mine" is located at the north side and until 2015 the new mine was developed essentially to the south. The mine is now growing back towards the north, below the "old mine" level, that stopped near the base of level 1 (620m). Figure 4 presents a general picture of the mine works where the different exploited zones are represented, from Vale de Ermida (900m) to Fonte do Masso (614m), Rebordões (650m) Salgueira (530m) and Corga Seca (520m).

The current exploitation is dispersed over a huge area, once there are stopes in the north, south, east and west sides of the mine, as well as mining from level 3 (470m elevation) to level 0 (above 680m elevation). From a base level to another base level, ramps are planned and executed in order to intersect the maximum of veins possible, previously defined by drill holes. When those veins are intersected, "inclines" are opened up, these are galleries opened following the vein in a typical mesh of 100mx50m.

These galleries ("inclines") expose the veins allowing the geology team to measure the grade, *in situ*. The WO_3 grade measured is decisive whether to make or not a stope there. If the measured grades show a good possibility of producing an economic exploitation, a gallery is opened (5 metres wide) defining an almost square mesh with 11mx11m pillars until the vein disappears or turns out to be systematically uneconomic, usually below 18 cm.

When all the vein has been covered by the 11mx11m pillars and the vein has become uneconomic, the stope expansion finishes and the splitting of the 11mx11m pillars with 5m adits begins, leaving at the end, in a similar process, only 3mx3m pillars (Fig. 5). At this point it is likely that the stope is close to the safety limits, only remaining the work to clean the finest material with high WO_3 grade that is still on the floor. Finally, the area is abandoned.

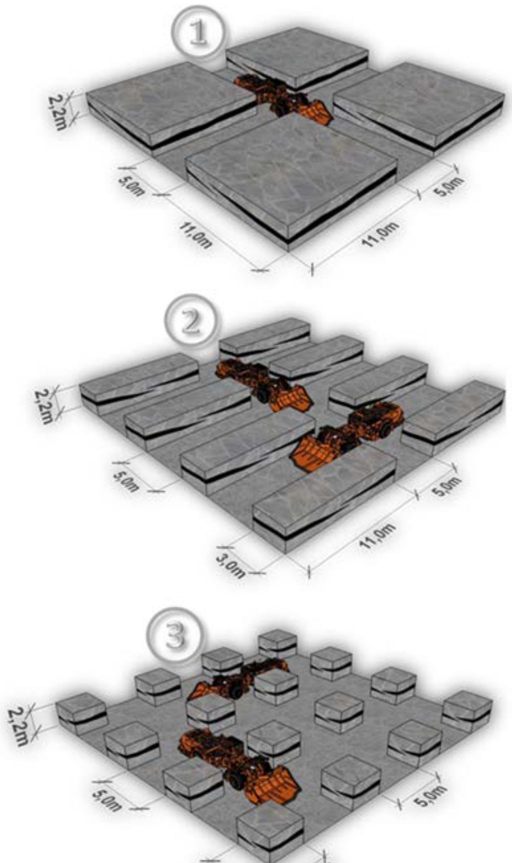

Fig 5. *Stope structure. (Source: Beralt Tin and Wolfram Portugal).*

Currently the mine is making fifty to sixty blasts per day to get a usual ROM (run of mine) of three to four thousand tonnes per day. The mine is usually functioning five days per week in two shifts. The third-shift time is used to ventilate. The air goes inside by many points, some of them not even known, once there were many entrances and shafts made and then later abandoned. Usually the mining engineers "only" have to drive the air, which is pumped in through a shaft in Vale de Ermida, closing and opening the different galleries.

EXPLORATION

The exploration work is always the first and fundamentally, a task that can drive a mining project to become a mine. This type of work is also the only one that can maintain and extend the life of any working mine.

Usually, when the exploration work finishes, it means that the end life of that mine is being prepared. Panasqueira is not an exception but as usual there are some specific characteristics that turn these mines into very special ones.

The main exploration in Panasqueira is the core drill holes and the "inclines". The core drill holes are usually done in intersections of drives with panels, making a mesh with about 50x100 metres, and occasionally inside strategic stopes.

The normally regular length of core drill holes is usually 60 metres to investigate the level below and/or above. The exception was the study of level 3 of the mine that is 90 metres and so the drill holes were longer.

As it has indicated previously, "inclines" are galleries opened up inside a vein, following intersections of the veins by the drill holes. These galleries ("inclines") allow a visual contact with the vein, making possible to measure grades and to do a detailed evaluation of it to support a decision about whether to open a stope (pillars of 11x11 meters) or if the area is declared non-economic and it's abandoned immediately.

The core drill-hole records have been carried out since 1946, throughout the Panasqueira/Barroca Grande area, as can be seen in Table 2.

YEAR	METERS DRILLED
1946 - 1950	4.707,71
1951 - 1960	17.673,70
1961 - 1970	17.772,06
1971 - 1980	32.839,36
1981 - 1990	41.590,26
1991 - 2000	3.987,07
2001 - 2010	7.600,96
2011 - 2018	21.221,56
TOTAL	147.392,68

Table 2. *Drill holes done in the Panasqueira/Barroca Grande area. (Source: Beralt Tin and Wolfram Portugal).*

The exact location of these drills holes as well as their technical results were systematically measured by the topographic team and registered in books. This information was then used to make the plans and sections.

As already mentioned, the information obtained over the lifetime of the mines is an important key for the current mines. During many years Beralt Tin and Wolfram Portugal had a large "Studies Department" where many people worked to give form to accurate paper records, plans and sections. This information is vital when taking decisions about the best plan to mine. These documents have been preserved, and it is possible to access them even now.

All this huge amount of information started to be gathered in an informatic database in 2004, a challenge for the people that worked on it due to its dimension.

Currently, only an update on a monthly basis with the performed work and the results is required. The most important technical characteristics registered by the geology department are the lithology, vein intersections and their thickness, vein mineralogy, with reference to the amount of minerals presented and structural aspects. An empirical classification from 0 to 6 referring to all the observed minerals was created, in the core vein intersections with the purpose of quantifying it.

The geological exploration work at the Panasqueira mines was always very complicated. If, on the one hand, the presence of quartz veins is a very good guide and represents the possibility of finding wolframite, on the other hand the presence of quartz is not a guarantee that the wolframite will be also be present and so there can be "good" or "bad" quartz veins as far as the wolframite content is concerned.

This means that only when galleries ("inclines") are opened will it be possible to get an idea about the economic quality of that vein.

EXPLORATION UNTIL THE 1950s

It is certain that at the beginning the exploration was done at the surface and consisted essentially on the visual discovery of the vein outcrops.

Most of the information from this period was lost and from that time what happened can only be estimated from the waste piles dispersed in front of the old gallery entrances all along the mountain with very different sizes and volumes (Fig. 6).

Nevertheless, the history of the Panasqueira mines demonstrates that it always had surface and underground exploration.

Fig 6. *Waste piles over the old gallery entrances – Panasqueira Village. (Source: photography from the authors).*

Most of the waste rock stayed inside the exploitations, filling the walls and supporting the roofs (2 meters height) of the mined area (Fig. 7).

Fig 7. *Old adit with rock wall made of waste. (Source: photography from the authors).*

The waste volume amounts produced are a good unit of measurement of the quantity and/or quality of the exploited vein and will usually give us a good idea about the success of each exploitation.

As most parts of the veins are sub-horizontal, the vertical ventilation shafts were, during many years, a powerful way of exhibiting the quartz and were consequently an exploration method to find new veins in the proximity of the stopes being exploited. These shafts allow us to check in situ the veins and to obtain a better definition of their probable WO_3 productivity.

EXPLORATION IN THE 1950s - 1990s

During this period there was a big development of the exploration work, not only by the described drill holes and "inclines" but also by some traditional methods (geological mapping, stream sediments, soil geochemistry and rock sampling) in a much larger area than the Panasqueira zone.

It was also during these years that the "Glory Holes" of Vale de Ermida were dug, in a successful attempt to increase the production of cassiterite concentrates (Fig. 8).

***Fig 8**. Glory Holes – Vale de Ermida area. (Source: photography from the authors).*

The company acquired core drill-hole machines and has operated them during many years, not only underground but also on the surface. One good example of this is a Longyear 44 that still exists, although no one today knows how to operate it, since it works with a tripod.

Apart from the exploration work done to find new areas, the exploration operations inside the mine have never stopped. This approach has a high relevance for the mine development work as it was always recognised by the technical teams of the Panasqueira mines. This has shown to be a correct vision of the future and allowed the Panasqueira mines to survive in the darkest periods of low concentrate prices at the end of this time period.

Another piece of evidence of this correct vision from the future was the acquisition in 1979 of a Raise Borer Robbins 44 that is still working at the mine and that gave versatility to the mine exploitation and mine management. This acquisition also allowed the teams to finish one of the most dangerous jobs in the mine – the opening of vertical shafts, which were made by hand, with hydraulic hammers, from bottom to top.

RECENT EXPLORATION

From the 90's to the present day and in addition to the traditional drill holes, there was other exploration work done with the aim of getting a better understanding, not only of the ore distribution, but also of finding and understanding the genesis and to obtain new guides to increase the life of the mine.

These methods include lithogeochemistry, geophysics and exploration drill holes in green-field zones, were carried out, not only within the area of the mining license but also in an exploration area that surrounded the mining license area.

This exploration work was based on the knowledge acquired throughout the life of the mine, not only by several technical and scientific studies carried out in the Panasqueira mines but also by all the observations and field data, collected daily from the mine.

One of the facts that can be observed in the mine is that there are clearly different zones richer in SnO_2 or in WO_3 (D'Orey, 1967; Kelly and Rye, 1979; Lourenço, 2002, 2006).

The same happens with several other minerals and it expectable relations between minerals assemblages can be observed (Conde *et al.,* 1971) such as topaz and fluorite with cassiterite, which have spatial relationships that are very well defined. It was verified that the Panasqueira mines have: (i) a rich tin zone in the Vale de Ermida, (ii) the northern area of the mine, around the well-known greisen intrusion, and (iii) the SW part of the actual mine.

The study of old data, such as the WO_3 grades mined, has allowed us to verify that the central zone of the actual mine, around D19 and level 1-2, has higher grades than the average of the mine. To understand how the WO_3 distribution is in the mine, several studies were carried out indicating, in many opinions, that another greisen/granite cupola must be present (Pinto, 2014; Pinto *et al.,* 2014) but that has not yet been found.

In order to obtain a surface geochemistry signature of the lithologies present in the underground, a large surface lithogeochemistry sampling and magneto-telluric geophysics campaigns was made.

Some electric and electromagnetic exploration in underground was also tried. This work was done during the weekends to have the least anthropogenic influence possible, but anyway the water, rails and some electric cables that cross the galleries made the methods inappropriate.

Based on the acquired knowledge, some deep drill holes were made to try to find any evidence of the "new" greisen or at least a package of veins. These three drill holes, in total 1.732,10 meters, were negative.

Not even spotted schist was intersected and the existing veins were scarce and small, usually less than 10 centimetres.

GEOLOGY IN RELATION WITH MINING

In a mine where the geology team only has one full time geologist, it is very important to have a good work team and a great relationship with the mining engineers and miners.

It is only possible to manage a profitably work at the Panasqueira mines if a very small technical team has strong, good communication skills and if the problems are correctly shared between the different areas. It is normal to see the geologist talking with the mining engineer about any mine problem or about any geological problem. It is also very common to see the geologist or the mining engineer exchanging their ideas and plans to facilitate some work of the other departments.

These very good relationships do not stop at the end of the working day therefore it is common that some of the technical team have dinner together or organize barbecues in their houses or promote social activities with other workers (Fig. 9). Nowadays, the investment by the mining companies in social and cultural purposes is crucial and, in some cases, the key for success.

Fig 9*. Mining friends "meeting". (Source: photography from the authors).*

Only with this strong union it's possible to keep the mine going forward. The relationships are usually more than just work relationships.

To remark, that sharing these active discussions and issues with different technical areas, give to the geologist a much greater knowledge about common mine problems that many times help to understand what might be more useful for the geology teamwork, saving time and money.

It also works as a continuous formation for a geologist in areas that, even if they are not exactly about geology, they are very close and make the geologist better prepared to get useful information and to have a greater productivity.

These kinds of relationships are responsible for the survival of a such big mine as the Panasqueira with so small technical team (i.e. one full time geologist).

GEOLOGY IN RELATION WITH THE PLANT

Equally important as the relationships with the mine are the ones with the plant. This is a point that the geologist usually tends to forget and not give so much importance to, but for the success of a mine, it is very important that the geologist understands the plant processes and that he/she makes the metallurgists understand the details of the ores existing in the mine.

In the Panasqueira mines, the geologist and the plant manager usually talk about ore feed and plant results, working together to achieve a good performance. If something strange or different happens in the ore treatment it is certainly discussed with the geologist, as well as if the geologist finds something different in the mine, he/she will communicate it to the plant manager responsible for preventing eventual issues.

A good example is what happened with the cassiterite concentrate, when it was verified that it was lighter than normal. At that moment, normally the cassiterite would not come separately from another white mineral that visually, at the shacking tables, might be identified as quartz. The chemical analysis was not much help either since it only gave a high Si content.

The discussions with the mine staff and some quick studies were able to identify the mineral as topaz, which appears at the end of the gravity plant process together with cassiterite due to hydrostatic forces. To break these hydrostatic forces, a fast solution was used with success, something as simple as a washing up detergent.

GEOLOGY TASKS IN THE PANASQUEIRA MINES

The geology tasks in the Panasqueira mines are quite diverse. They can be divided between the exploration and the support to the exploitation.

The exploration tasks have already been partly explained before and comprise surface exploration, but also the underground exploration that usually is more related with the near future.

The Panasqueira mines have two small drill rigs working now, one is an Atlas Copco – Diamec 252 core drill rig that can drill more than 100 metres (Ø46mm) per hole (Fig. 10).

Fig 10*. Atlas Copco – Diamec 252. (Source: photography from the authors).*

This machine tries to find new exploitable areas detailing previous scarce existing information. Usually these drill holes try to upgrade resources from inferred to indicate or to give indications regarding veins that are currently being exploited.

The second drill rig working is a small Hilti DD750 that gives support to the mining work as it can drill until about 12 metres with a diameter of Ø46mm. This machine allows the miners to do a quick search for veins that have disappeared or have been displaced by faults or for some other reason in the exploitation front. It also allow the miners to investigate the existence of other veins immediately above or below the stopes in order to optimize the exploitation and not miss eventual possible veins existing in the proximity of the stopes.

All the drill-hole data is added to the database and represented in plans and sections. These documents are the base of the daily work at the mine and the resource/reserve calculations done every six months.

The Panasqueira mines have an extreme nugget effect, which is the reason why a normal front sampling with chemical analysis, and/or classification when the mine is advancing, is not effective. The following picture shows how this nugget effect can be tricky and lead to wrong decisions if based only on chemical analysis (Fig.11).

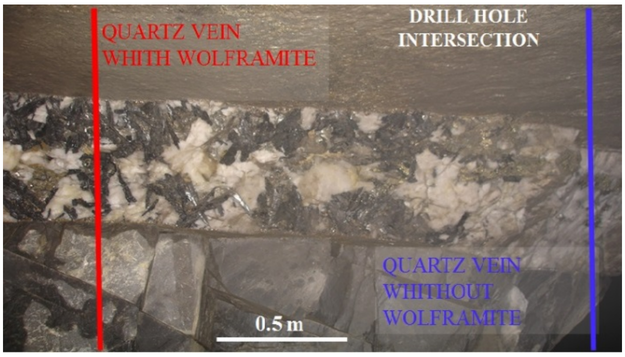

Fig 11. *Distinct possible drill hole intersections. (Source: photography from the authors).*

This is the reason why it is so important to have a clear description of the veins and define the real thickness of the vein.

Other aspects are also very important to drive the mine forward, and the present and past geological knowledge is essential for developing the different work. Some decades before a formula was developed, called the "D9 formula", which correlates the thickness of the veins with an expectable grade.

The last attempt to provide a reliable prediction of grades from intersected veins by drill holes was done around 2014-2015 when an academic approach was developed to determine a formula to predict grades. Many factors had been integrated but it did not perform as expected. When tested to check this study, the expected grades did not correspond to the ones found when an "incline" was opened.

So, at this moment the Panasqueira mines still work with the old "D9 formula" not as a correct number but as an indication to be added with to other geographic and geological indications. This still seems to be the best approach to reality.

Notwithstanding, if the chemical analysis is not effective, some other way must be found to get a good idea of the grade control in the exploited fronts.

The solution was a grade calculation by a formula that uses the area of the visible crystals of wolframite and the height and width of the stope. There is a team of two workers from the geology department that goes daily to the mine to do this work, reporting the results found twice a month, by stope, as shown in Table 3.

This is called the measure of "pintas" that means something close to wolframite points.

JANUARY										
STOPE ID.				1st Sampling (1st + 2nd weeks)						
L.	D.	R.	AW.	m^2	Linear meters	Grade (Kg/m^2)	Vein Thickness (cm)	Height (m)	Width (m)	Med.
0	22	13	AW02	184	106	14,0	32	2,1	4,7	18
0	13	15	AW06							
LEVEL 0				184	106	14,0	32	2,1	4,7	18
1	25	13	AW11	1062	544	8,3	27	2,3	4,7	109
1	5	7	AW15	2576	1368	25,3	27	2,4	4,7	262
LEVEL 1				3638	1912	20,5	27	2,3	4,7	371
2	29	13	AW21	200	110	20,5	57	2,5	5,0	18
2	29	5A	AW23	402	219	15,1	23	2,1	4,6	42
LEVEL 2				601	329	16,9	34	2,2	4,7	60
3	15	0	AW32	322	177	7,5	21	2,3	4,3	35
LEVEL 3				322	177	7,5	21	2,3	4,3	35
TOTAL				4746	2524	18,8	28	2,3	4,6	484

INCLINE ID.	m^2	Linear meters	Grade (Kg/m^2)	Vein Thickness (cm)	Height (m)	Width (m)	Med.
L0 D13 R23 I.5	139	54	2,7	17	2	5	15
L2 D1 MDW I.1	182	73	17,0	25	3	5	19
TOTAL	321	127	10,9	22	2	5	34

PILLARS ID.				Grade (Kg/m^2)	m^2	Vein Thickness (cm)
L.	D.	R.	AW.			
0	13	15	AW06	10,5	464	31
1	13	13	AW11	9,3	102	24
TOTAL				10,3	566	30

Table 3. *Example of "pintas" results. (Source: Beralt Tin and Wolfram Portugal).*

CALCULATION OF THE RESOURCES

The calculation of the resources in the Panasqueira mines is not done with any geological software, not because the ALMONTY group does not have it (Los Santos, Valtreixal or Sangdong use it), but due to the specific characteristics of the mineralization of the Panasqueira mines and the historical good approaches achieved throughout the years.

With this approach, the task is easier to do with less specific software such as AutoCAD and Excel.

In Panasqueira, the resource reconciliation is done every six months. This work recalculates the inferred, indicated and measured resources.

During many years this work was done with the database referring to 30 June and 31 December. From two years ago until the present, and because the financial year of the Almonty Group ends at 30 September, this work is done with the data from 31 March to 30 September.

To sum up, inferred resources are obtained with one vein drill intersection over 18 cm and have an influence of a square with 34m if the vein is between 18-30 cm or 50m if the vein is wider than 30cm. Indicated resources are all the areas where the influence areas of two or more drill holes give any superposition.

The measured resources are defined by an influence area of a vein exposed by a gallery with a measured grade over the cut-off grade of the mine – the Virgin Area, or Pillars. Each pillar has an area and an average grade, and thickness calculated by the surrounding measures made.

During many years, Panasqueira only had three different types of resources (inferred, indicated and measured) and did not do any table with reserves, rather assuming measured resources as proved reserves.

From 2006 onwards, there has been the first competent person who has changed the criteria and decided to create probable resources which are also probable reserves.

More recently, and with the same known criteria from several decades, it was decided to obtain the usual tables of resources and create an independent table with reserves. The reserve table produced has two categories, proved and probable reserves.

Therefore, the current reconciliation work done in the Panasqueira mines is in accordance with the Canadian National Instrument 43-101 (Wheeler, 2016).

The proved reserves are defined by pillars and the probable by what we call a "Virgin Area" constituted by the advance of the mine where a pillar has not yet been formed.

This means that to obtain the proved reserve a grade control over four sides of the pillars with 11m side is needed, and to obtain the probable reserve only the visual access to the sides and face of a gallery is needed.

All the results are presented multiplied by 0.84, which represents the really mined volume of a stope once it has the 3x3m pillars that will "never" be exploited. 16% remains at this stage of the stope.

MONTHLY RECONCILIATION

All the geology, mine and plant numbers are checked monthly with the elaboration of a "Survey Report". This "Survey Report" shows and compares all the numbers defined by the different departments, presenting a number that corresponds to a relationship between them at the end of each month. This number is called the "Mine Call Factor".

This value will be preferentially near 100 but, if it shows a trend to be higher or lower, it needs to be checked in order to understand the reasons why and to get a logical explanation for this different behaviour.

When this happens, some corrections must be proposed. Nevertheless, nothing changes until the problem is understood and so we always need to have a strong tendency to implement changes.

CONCLUSIONS

The Panasqueira mines are very old mines that have always successfully tried to keep innovation side by side with tradition.

It is not possible for the present staff to think they are cleverer than the previous ones who worked there. Essentially, there are only more tools and accumulated knowledge than at the beginning of the mines.

The 43-101 rules, based on the history of the mine, is proof that this is the correct approach, nowadays there is an acceptance of the many special characteristics of the Panasqueira mines.

Moreover, it is not possible to forget the technical evolutions and that mines must be always open to new methods and approaches.

Nowadays some projects are being attempted, such as the one that is testing an increase in the recovery from waste by the use of ore sorters, or another one that is trying to recover metals from the tailings by bio methods.

The environmental problems are also a big concern and priority for the Panasqueira mines. The work is being carried out not only to solve the ones that arise from the actual exploitation as well as trying to reduce the ones that come from the past.

Unfortunately to keep the mine running profitably and allow the payment of the salaries to almost 300 people, it is important to not lose focus on the production, which is why it is difficult to get general visits to the mines.

Finally, and as always, it is important to mention the well known mineral crystals from the Panasqueira mines. The mines have a store that sells them and is open on working days. The profits of these sales go entirely to all the workers as a gift, at Christmas time. However, the illegal sale of these minerals is still a big issue at Panasqueira, not only because of the injustice created between the people who take them and the people who do an honest job but also because of the high number of work hours lost when miners are looking for crystals and not working. The cavities of the crystals are usually "cleaned" even if the safety conditions in the area are still not assured.

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