PREVENTION OF ACID MINE DRAINAGE AT NEVES-CORVO MINE, PORTUGAL

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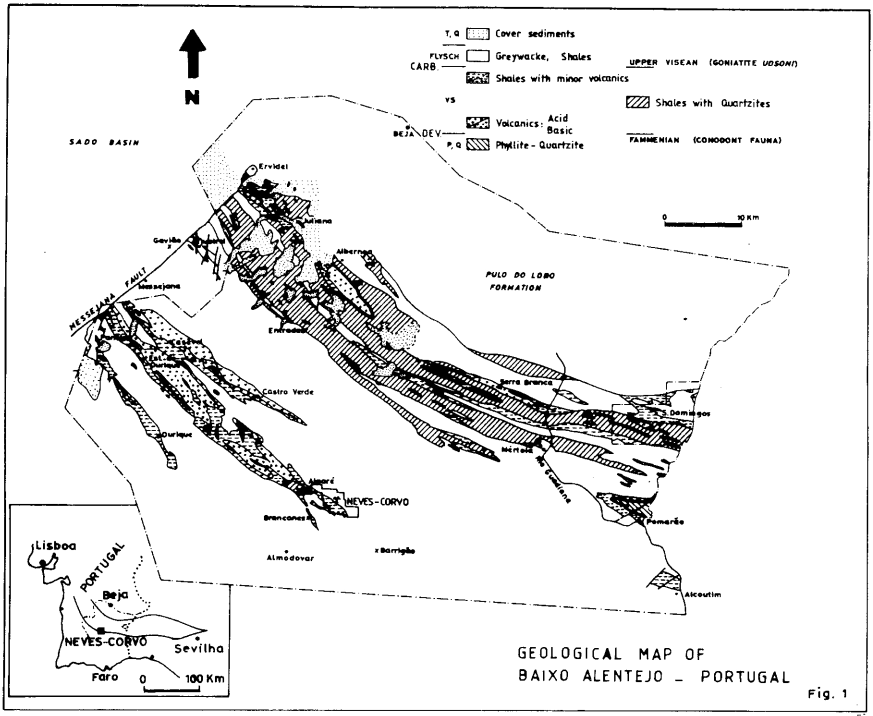
REGIONAL DISTRIBUTION OF ACID WATER

ıe Neves-Corvo mine, in southern Portugal, has been developed to ĸploit polymetallic sulphide deposits which were discovered in 1977. ıe mine started production of copper ores in 1988 and tin ores in 1990.

ıe mine is located in the Iberian Pyrite Belt Metallogenic District, :igure 1) which has been exploited for thousands of years and from ındreds of orebodies of varied size and tonnage. Production dates back ɔ Phoenecian times, and continued through Roman and Moorish periods to ıe present day.

ıis history of mining activity has been closely associated with acid ıter production, giving this region one of the most spectacular ĸamples of its action. In many cases these acid water effects are seen ɔt only in the mining site, waste dumps and tailings, but have also, ɔr hundreds of years, affected surface waters and river systems. The ɘst example is the Red River (Rio Tinto), so called because of the high :on hydroxide content of its water, derived from leached pyritic and ıne waste piles.



GEOLOGICAL MAP OF
BAIXO ALENTEJO _ PORTUGAL
Fig. 1

The problem has reached such a state that there is no doubt that even by suspending all mining activities in the Rio Tinto area, hundreds or even thousands of years with the same uncontrolled acid water generation would pass before acceptable conditions could be restored. All this, and the fact that acid water conditions exist at Aljustrel and S. Domingos mining areas in Portugal, together with concern for environmental standards, made Somincor aware of the considerable mine water problems which it could face, and how it could avoid them in all its operations and sensitive areas.

Action can be taken in several different areas to achieve the same target of predicting and eliminating short term problems as well as considering the future abandonment of the mine.

In this paper we will describe the preventive drainage installed in the mine as a contributing technique to reducing acid groundwater generation.

GEOLOGY

The Neves-Corvo deposits consist of five lenses of massive sulphides, with associated mineralisation of the wallrocks, amounting to approximately 200 million tonnes of sulphide material. The most common sulphide is pyrite (Fe S2), but strong base metal zonation within the lenses has produced high-grade copper and tin ores, and other areas of polymetallic zinc-lead-copper ore. The mining operation is currently based on the reserves of copper and tin ore, which are being mined at rates of 1.3 million and 0.3 million tonnes per year respectively, from Corvo and Graça orebodies.

The orebodies are buried beneath 250 to 750 metres of barren rock, and are located at the top of a pile of distal volcaniclastic material of late Devonian age (Figure 2). The rocks underlying the ores are phyllites and quartzites, and the ore level is capped by Flysch sequences of greywackes and shales. The contacts between units are apparently conformable, and the deposits are thought to have formed by the accumulation of sulphides precipitating in restricted seafloor basins, close to sources of metal-rich hydrothermal fluid vents related to late stage volcanic activity.

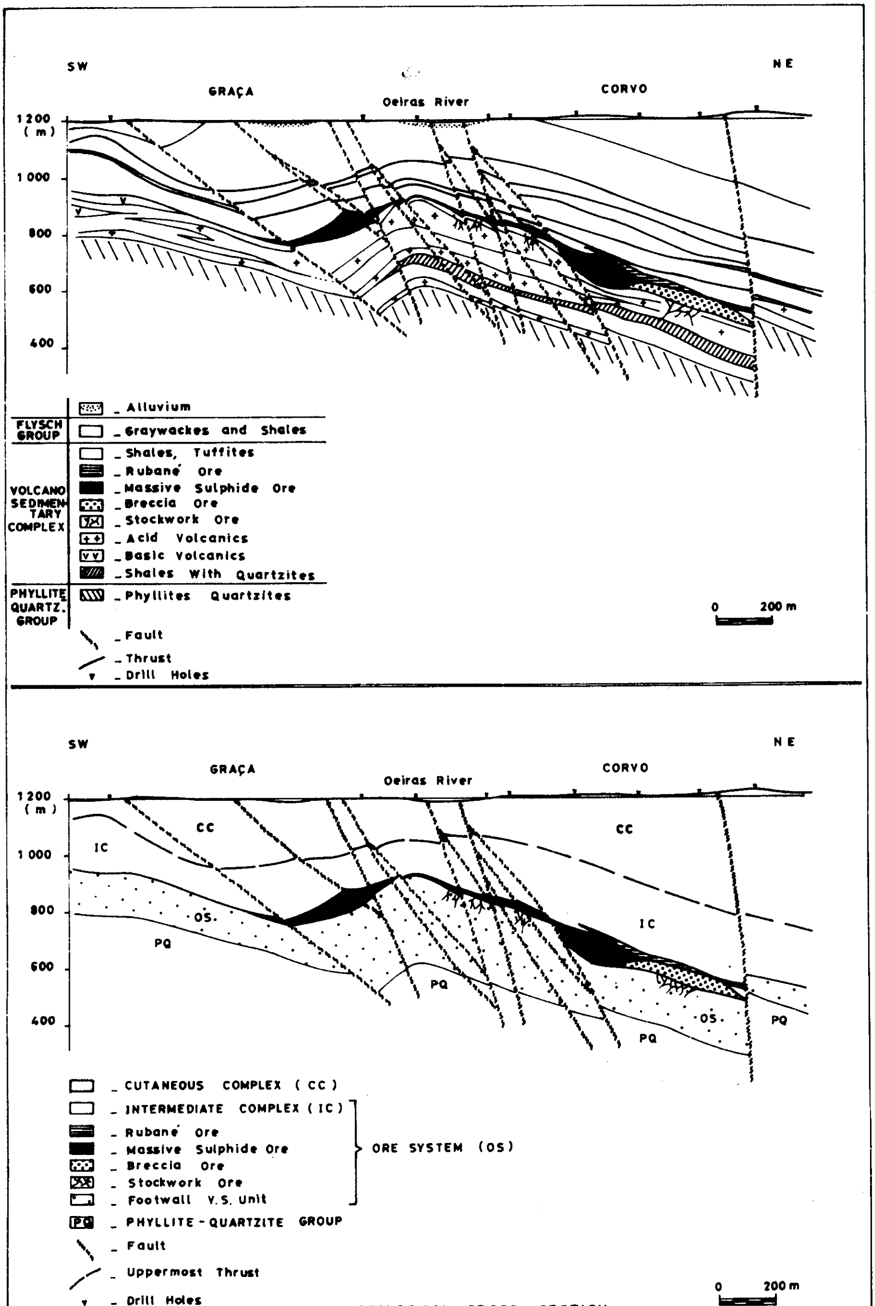
Since their deposition, the orebodies and surrounding rocks have been affected by several phases of tectonic activity. These have resulted in gentle open folding, (including a plunging anticline across which the lenses now lie), thrusting, faulting, pervasive jointing and a regional cleavage.

HYDROGEOLOGY

Following combined geological and hydrogeological investigations it was possible to distinguish three main hydrological units (figure 2).

- Surface complex (SC). Aquifer or aquitard, relatively heterogeneous, with permeability decreasing with the depth. Free or semiconfined. The SC Unit includes the alluvial terrace, and the weathered zone, and it is limited in depth to the uppermost thrust plane.

- Intermediate Complex (IC). Aquifugous assemblage crossed by vertical pervious faults, thus providing secondary heterogeneous permeability. Semiconfined or confined. The IC Unit is limited by the Flysch Group just above the deposits.



GEOLOGICAL CROSS SECTION AND HYDROGEOLOGICAL UNITS

Fig. 2

- Ore system (OS). Aquifers and aquifuges. Permeability is provided by microfissures in the orebodies. Confined. The OS Unit groups together the deposits plus the footwall formations.

Before mining works the only ground water flow was restricted to the SC Unit with small rain water infiltration and subsequently a slower discharge to the river and its small tributaries. The water pumped for irrigation and domestic consumption was very small.

MINE WATER INFLOW

The mining infrastructure for access to the orebodies, consisted of a ramp 3.5 Km long (started in 1981) and a shaft 570 m deep (collared in 1982). There are many other mine infrastructures such as ramps or ore access galleries. (Figure 3)

During the excavation of these mine workings, almost since the beginning groundwater inflow was encountered via subvertical faulting or associated competent fractured lithologies, and along the thrust surface between the two upper complex systems.

The impact of water inflow on mining advance rates was reduced by cement injection of fans of short percussion holes drilled around the mining face. This classic technique reduced the inflow of water in fractured and sheared zones associated with subvertical faults.

As these fault systems were intersected by progressively deeper mine workings, flow rates and water pressures in the upper inersection points decreased, an effect caused by water reporting to the lowest drainage point.

However, in a general sense, the total water inflow increased with the growth of underground workings (Figure 4) (Fernandez-Rubio & Associates, 1985).

In the main shaft, on the other hand, the inflow of water occurred preferentially at the bottom of the excavation. Here a subvertical fan of holes for grouting was drilled as well as short horizontal holes at the bottom of the shaft. However there was a small increase in the inflow with depth.

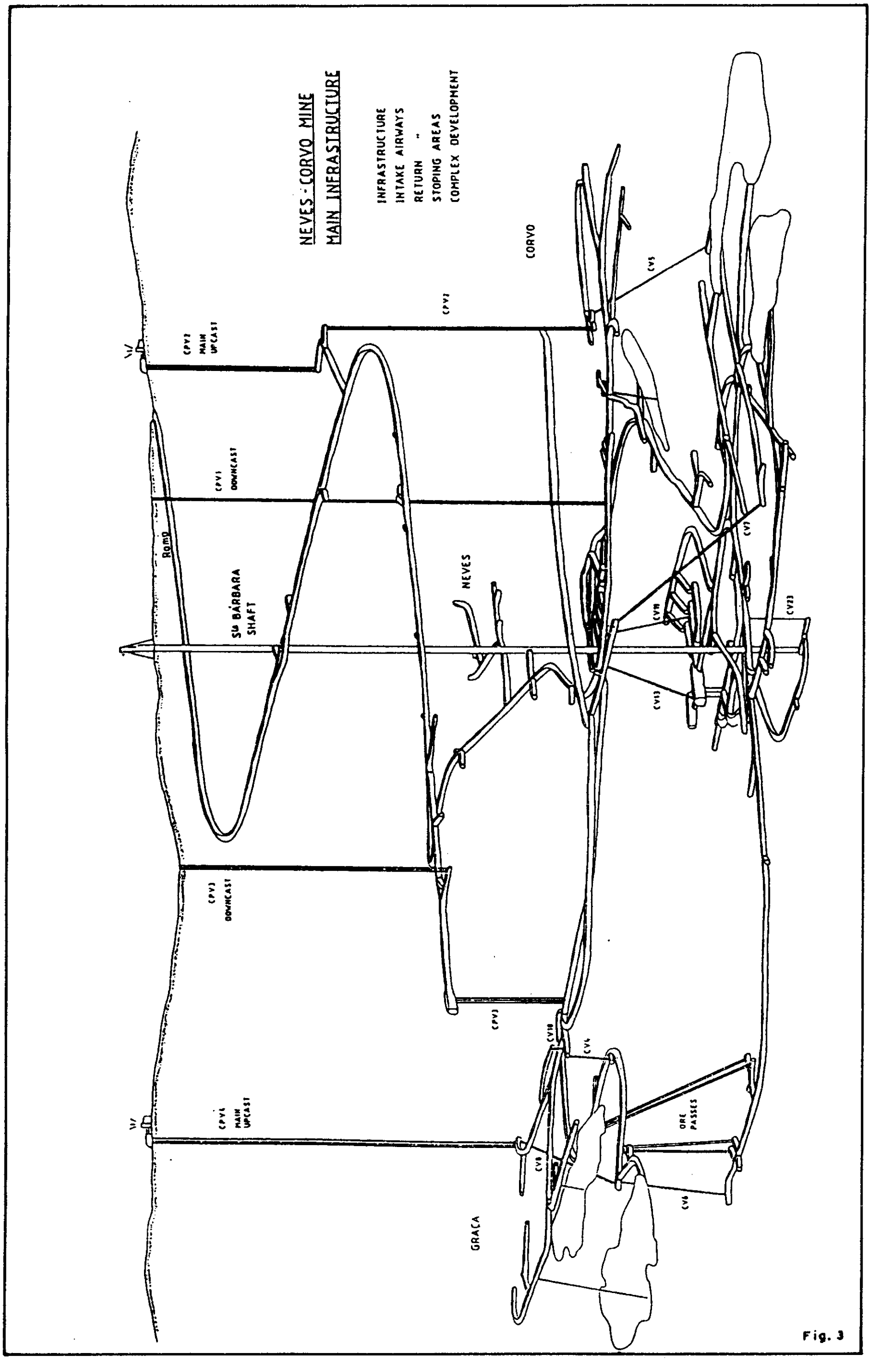
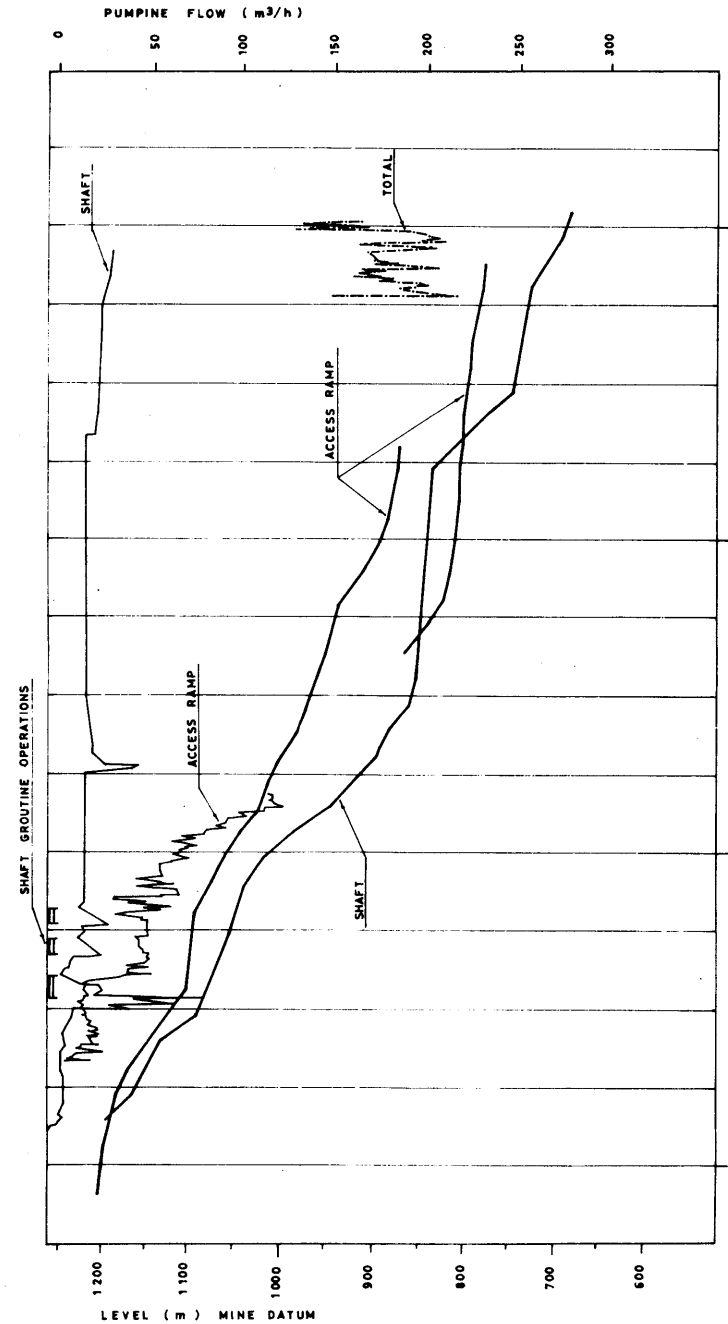

NEVES - CORVO MINE
MAIN INFRASTRUCTURE
INFRASTRUCTURE
INTAKE AIRWAYS
RETURN
STOPING AREAS
COMPLEX DEVELOPMENT
CORVO
NEVES
GRAÇA
ORE PASSES

Fig. 3



GROUND WATER INFLOW EVOLUTION, DURING ACCESS RAMP AND SHAFT CONSTRUCTION

Fig. 4

The only unexpected water influx occurred during the mining of the first orebody access in Corvo. The massive sulphide ore was intensely fractured, the effect of tectonic processes of folding, faulting and thrusting on a very competent, brittle rock. As the access crosscut reached the orebody, there was a rapid drainage of stored water from this confined aquifer via diamond drillholes and blastholes.

Thereafter, each successively lower ore crosscut also experienced high flows which caused rapid reductions in the water reporting at higher intersections. This phenomenon has been confirmed for Corvo and Graça orebodies, and shows the extraordinary degree of hydraulic communication which exists in the ore by virtue of interconnected microfracturing.

Thus, almost all water make in the mine at its deepest points, with the upper elevations being effectively drained.

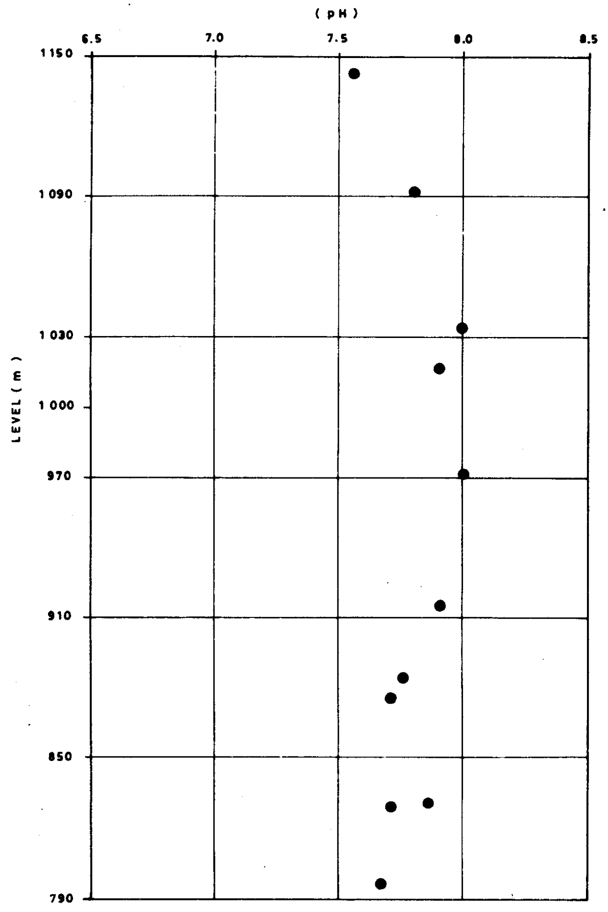
PRODUCTION METHOD

The ore bodies are blocked out and stoped using a method of cut and fill mining known as drift and fill which is more suitable for the complex nature of the ore bodies at Neves-Corvo. Haulage levels are cut in the footwall at vertical intervals of 20m and from these horizontal crosscuts at intervals of between 50m and 80m are then made into the orebody. Mining then proceeds along the hanging wall contact with drifts of about 40 square metre section.

Once each drift has been excavated along the stike of the ore body it is backfilled and then the next cut is worked. Tests are under way to see which is the best method for retreat extraction of the remaining pillars.

EVOLUTION OF PH WITH DEPTH

The first set of pH measurements for water inflow in the access ramp (12 samples) and the shaft (1 sample taken at the bottom), were made in February 1985 (Fernandez-Rubio & Associates, 1985), and are shown in figure 5.



WATER pH DISTRIBUTION THROUGH THE ACCESS RAMP IN FEBRUARY / 1985

Fig. 5

At this stage, which was almost the natural state, all the water was found to be alkaline (pH between 7.55 and 8.00). Detailed inspection shows a slight increase of pH with depth, in the surface complex (as far as sampling point PH 7). There follows a section with constant pH values, corresponding to the Intermediate complex (down to point PH 11).

At greater depths the pH decreases with depth, as a consequence of the oxidation of pyrite in the presence of air and water, caused by mine dewatering.

On reflection, the most notable fact is that although the waters were still alkaline, a slight trend was present in the decrease of pH and the increase of sulphate content.

To limit the future development of acid mine waters it was proposed (Fernandez-Rubio e Associates, 1985) to reduce the water make into the mine, and to dewater the orebodies. Both proposals have been carried out with success, at least up to the present time.

ADVANCE DEWATERING

The hydrological behaviour of pyrite orebodies is controlled by their aquiferous nature, owing to their high degree of fracturing. Initially, the ore zone should behave as a confined aquifer, practically without external influence.

Later, access galleries in the orebodies caused not only the dewatering of the pyrite masses, but also preferential downward flow in faults which cut the orebodies. In this way, the mineralised system is linked to the Oeiras River system as well as the surface complex, mainly in rainy seasons. This results in an input of recent calcium bicarbonate rich water, which circulates down through the Intermediate complex via fault systems, and flows out through the orebodies. At deep inflow sites, high flow-rates of cold recent waters have been detected alongside slower-flowing warm fossil water inflows, which are gradually being replaced by cold surface water.

In all cases, a slight reduction in the fossil water component has been observed, due to the progressive depletion of the amounts stored in the hydrogeological units (Fernandez-Rubio a Assiciates, 1987).

However, the development of mine infrastructure has led to an increase in the total quantity of water pumped, especially in deep dewatering. All surface hydrological studies: piezometry, water chemistry, temperature, isotopic dating, water inflow and pressure measurements have confirmed this model.

The mining method used has allowed access to the deeper parts of the orebodies, and the installation of instruments and drainage apparatus in these galleries. In this way, the use of geological evaluation drill holes for advance dewatering has been possible. An example of the evolution of this advance dewatering can be seen from the measurements taken from boreholes in the 704 level, in Corvo orebody (Figure 6).

The dewatering by boreholes and mine workings resulted in a reduction in the water make, and a decrease in pressure, always conditioned by the elevation of the lowest drainage gallery (Figure 6). This exploitation-dewatering system avoids the risk of inrushes, sudden or gradual, of important quantities of water, causing reduced productivity, and allows the over-design of mine sumps and pumps to be minimized. Moreover, it allows the deeper parts of the orebody to be kept flooded, intact (without the development of acid water), and the upper parts to be practically dewatered and dry for mining, with the exception of the rapid downflow of surface waters through sub-vertical faults. This flow is conducted away from pyrite-water-air interaction.

SEALING OF THE OEIRAS RIVER

A sequence of hydrogeological investigations proved that the major source of water reaching the underground workings comes from infiltration through the river-bed at surface. (Fernandez-Rubio & Associates, 1985, 1987, 1988, 1990).

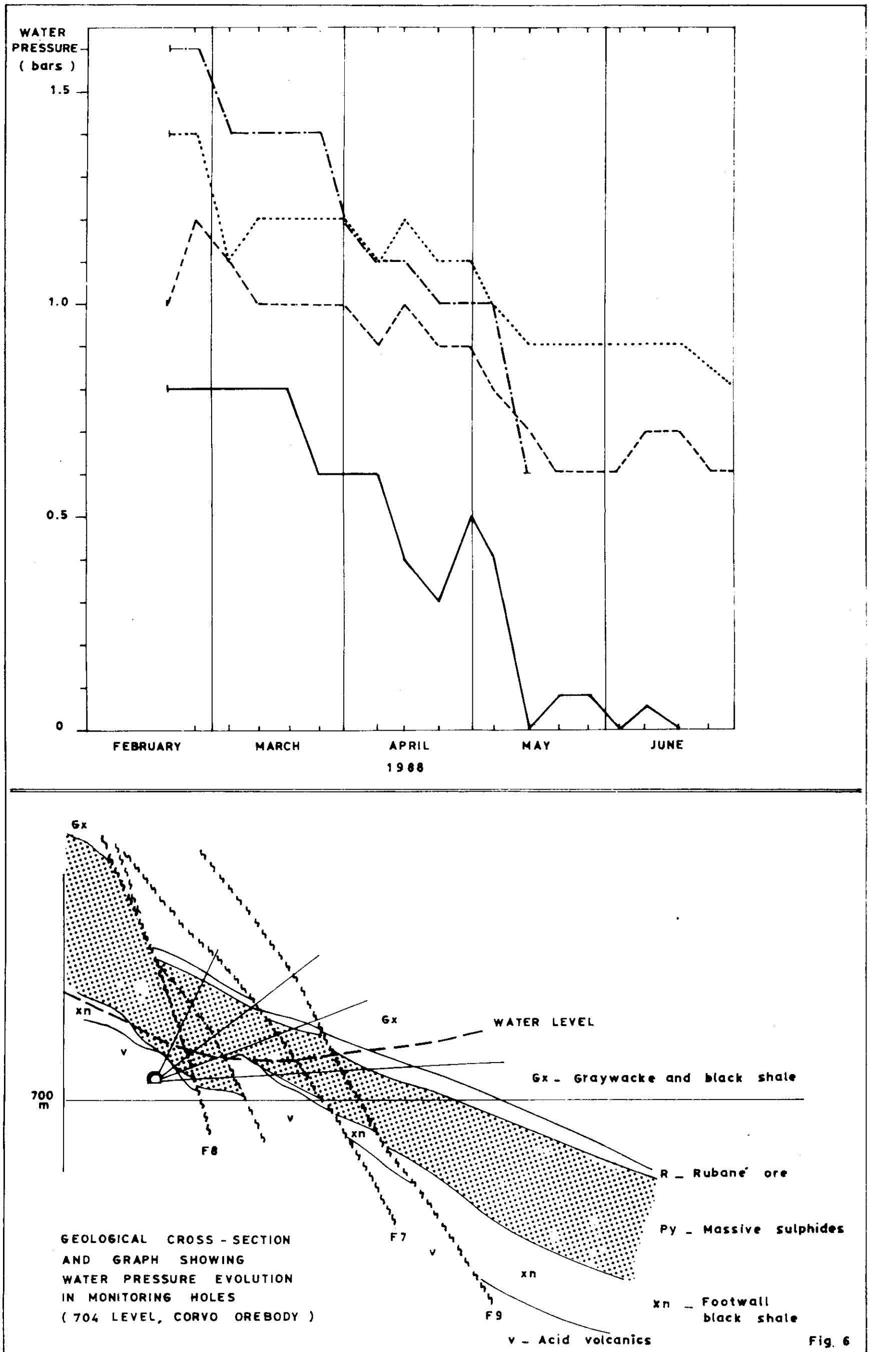
Possible actions were studied to achieve a reduction of this flow, consisting of: diverting the River, grouting of deep faults, constructing a pipe or conduit, and sealing the river-bed. (Fernandez-Rubio & Associates, 1990).

Because of economic and technical considerations the last solution was adopted.

First, geophysical surveys (electrical and seismic) were carried out, and these, together with a geological study, allowed many faults to be accurately located in the river-bed.

The work consisted of:

- Regularising and smoothing a single course for the river, six metres wide; cleaning the river bed, removing irregularities in the floor, and reaching solid rock whenever possible.



GEOLOGICAL CROSS - SECTION AND GRAPH SHOWING WATER PRESSURE EVOLUTION IN MONITORING HOLES (704 LEVEL, CORVO OREBODY)

Fig. 6

- Sealing the new river course with concrete, reinforced with steel mesh and anchors, with the river banks protected by shotcrete.

After this work of regularising and sealing the surface, water inflows in the mine have decreased appreciably, although it is not possible to quantify this reduction.

CONCLUSIONS

The discovery of deep high-grade massive sulphide copper and tin ores at Neves-Corvo, and the subsequent planning and development of a mining project, presented a technical challenge in the prediction of mine water volumes and acid water potential.

Hydrogeological work has accompanied every phase of the project, and today it is possible to reach a number of conclusions concerning its role:

- The conceptual model of three hydrogeological systems has been confirmed by experience of mine development and production;

- The priority to drain fossil water from the sulphide orebodies reduced the potential for acid water formation early in the life of the mine.

- The identification, analysis, and treatment of the problem of infiltration of rain and river water through the Oeiras River has reduced the volume of water entering the mine.

- Hydrogeological monitoring of surface and underground sites and hydrogeological interpretation, will continue to assess the evolution of the mine's impact on the conceptual model of the hydrogeological systems, and acid water potential.

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