Águas Claras Mine – A successful dewatering story

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Abstract

The Águas Claras Mine is an important mine of the "Quadrilátero Ferrífero", a major iron ore producing area in the southeast of Brazil. The mine is located south of the city Belo Horizonte, capital of the Minas Gerais State and belongs to the mining company Minerações Brasileiras Reunidas S/A – MBR.
The production started in 1973 and since that time, the mine has produced about 300 million tons of iron ore. The average annual production was about 12 million tons. The mine will be depleted by the year 2002.
The dewatering of this mine started in 1981 by drains and in 1988 several wells started to operate. In 2000 the water level was located at about 275 m below its original position. After the depletion of the mine, the pit will be flooded, generating a deep lake. This will be the first large pit to be flooded with water in Brazil.

Key words: dewatering, environmental impact, iron ore mine, lakes

Introduction

The Águas Claras Mine is located south of the city Belo Horizonte, capital of the state Minas Gerais, Brazil (fig. 1). The mine belongs to the mining company Minerações Brasileiras Reunidas S/A MBR. The production started in 1973 and since then has produced about 300 million tons of high-grade iron ore. The Águas Claras is a tabulated ore body of soft hematite (with small lenses of hard hematite), 1600 m long, 250m wide and 500 m deep. The dewatering of the mine started in 1981. At that time the water level was about 1,165 meters and in 2000 the water level was about 890 meters. After 28 years of mining activities the mine will be exhausted, the last two years, 2001 and 2002, with a reduction production. Since 2001 the lowest levels of the pit has been filled with water in order to form a lake.

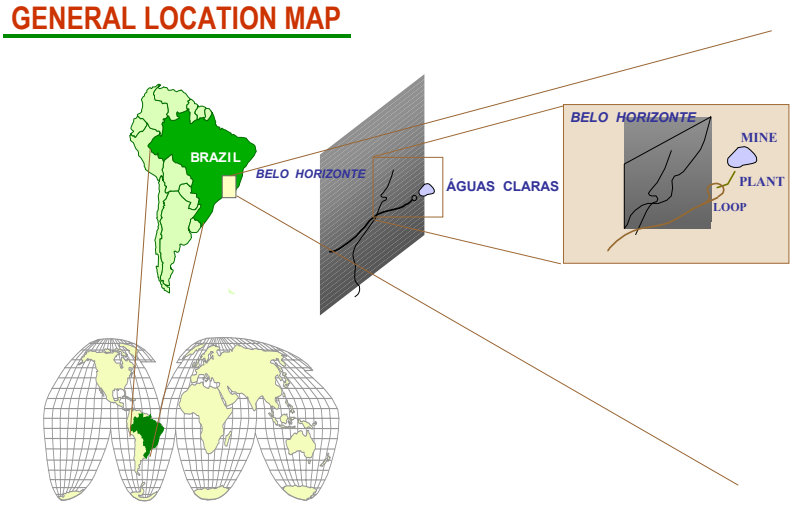


Fig - 1

Geology

The Quadrilátero Ferrífero is a mineral province holding mainly reserves of gold and iron ore. Because the iron ore this province is called Iron Ore Quadrangle. The oldest sequence of rocks corresponds to the Archean basement, represented by the Rio das Velhas Supergroup, subdivided into two groups: Nova Lima and Maquiné. The Nova Lima Group is composed by metavolcanic and clastic and chemical metasediments, while the Maquiné Group is dominantly composed by clastic rocks. The Minas Supergroup lies over the Rio das Velhas Supergroup. It is a Protherozoic sequence composed by the Caraça, Itabira, Piracicaba and Sabará groups (Figure 2).

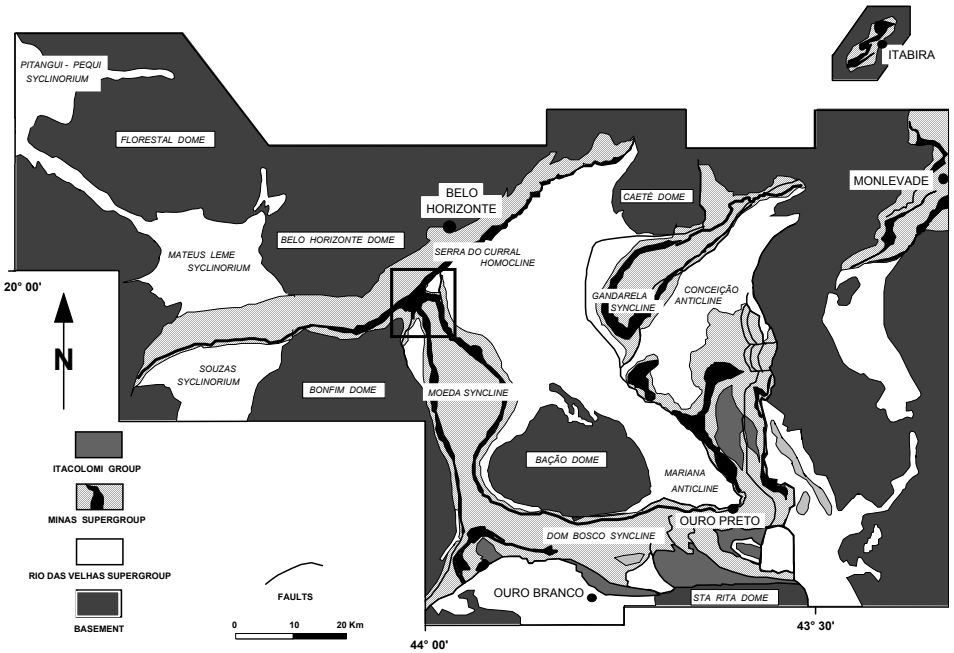


Fig. 2 – Simplified geological map of Quadilatero Ferrífero (Alkmim, 1998)

The Águas Claras Mine is located in the southeastern flank of the Curral Ridge, where occur the Nova Lima, Caraça and Itabira groups. The Nova Lima Group outcrops in the southeastern part of the mine site and is composed by red colored chlorite-schist. The Caraça Group is represented by the Moeda and Batatal formations, respectively composed by quartzite and phyllite, occupying the southeastern part of the mine. The Itabira Group is subdivided in the Cauê and Gandarela formations. Itabirites and hematite and the Gandarela formation compose the Cauê Formation, by dolomites. The ore itself is a product of the supergenic enrichment of the dolomitic itabirites of the Cauê Formation (figure 3).

From the structural point of view, the Curral Ridge is an overturned homoclinal oriented on the N 52º E, dipping 42º SE.

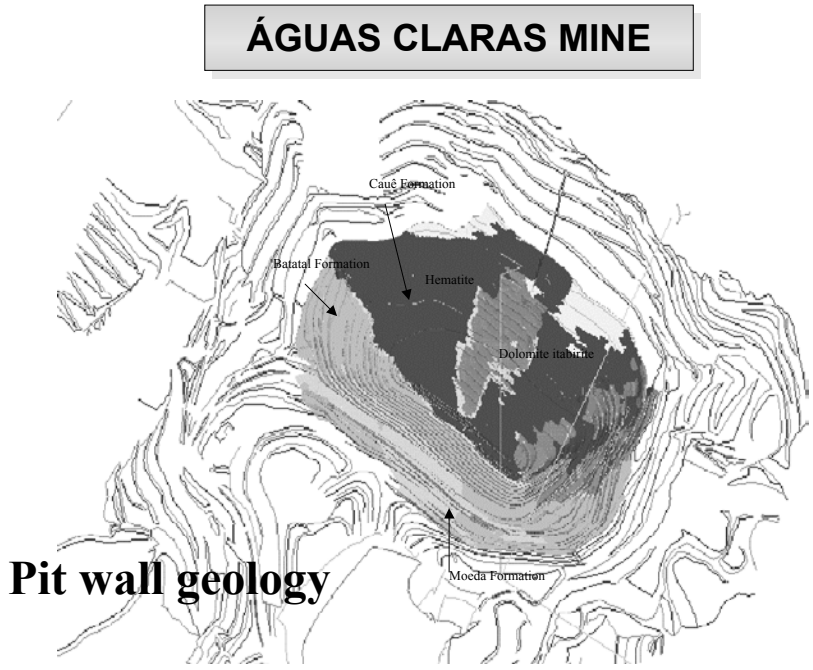


Fig- 3

The aquifers

Two independent aquifers can be pointed out in the mine site: the quartzite of Moeda Formation and the iron or of the Cauê Formation. The quartzite forms a minor aquifer confined between schist and phyllite of respectively the Nova Lima Group and the Batatal Formation. In intensely fractured areas, the transmissivity is about 600 m^2/day and the effective porosity is about 5%. The electrical conductivity is about 66 μΩ/cm; the pH is 7.6; the major anion is bicarbonate and the major cations are calcium and magnesium.

The iron ore forms the main local aquifer, being a semi-confined, heterogeneous and anisotropic with interstitial porosity and fractures. The total porosity determined in laboratory is 50% for the soft hematite and field determinations leaded to an effective porosity of 15%. The semi-confinement is due to the anisotropy of the permeability controlled by the ore banding and by the textural variation. The permeability of coarse hematite is about 3 m/day and the permeability of fine hematite is about 0.3 m/day. The electrical conductivity is about 10 μΩ/cm, the pH is about 5 to 6, the major anions are bicarbonate and cloride and the major cations are calcium and sodium.

The mine dewatering

In 1981 the water level of the Águas Claras Mine in the Cauê aquifer reached the altitude of 1,165 meters. From that date up till 1990, the drainage was done by open channels, while the mine was in flank. The hydrogeological studies to project the dewatering started in 1986 and recommended the previous dewatering through tubular deep wells. The drilling of the wells started in 1988 and, since that time up till 1999, a group of wells have been operating with a total average outflow of 73 L/s. In the beginning of the dewatering process the outflow was about 100 L/s to 150 L/s. After February 2.000, the wells started to be closed and, by the end of 2000, the

last one was closed. The temporal evolution of the water level in the iron formation is presented in the figure 4.

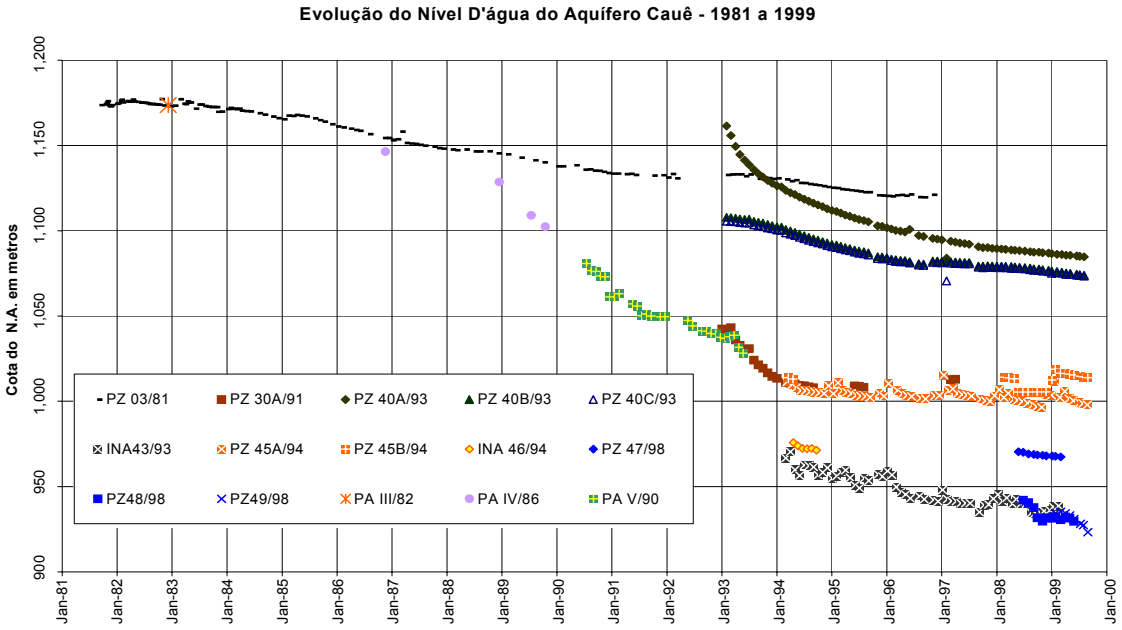
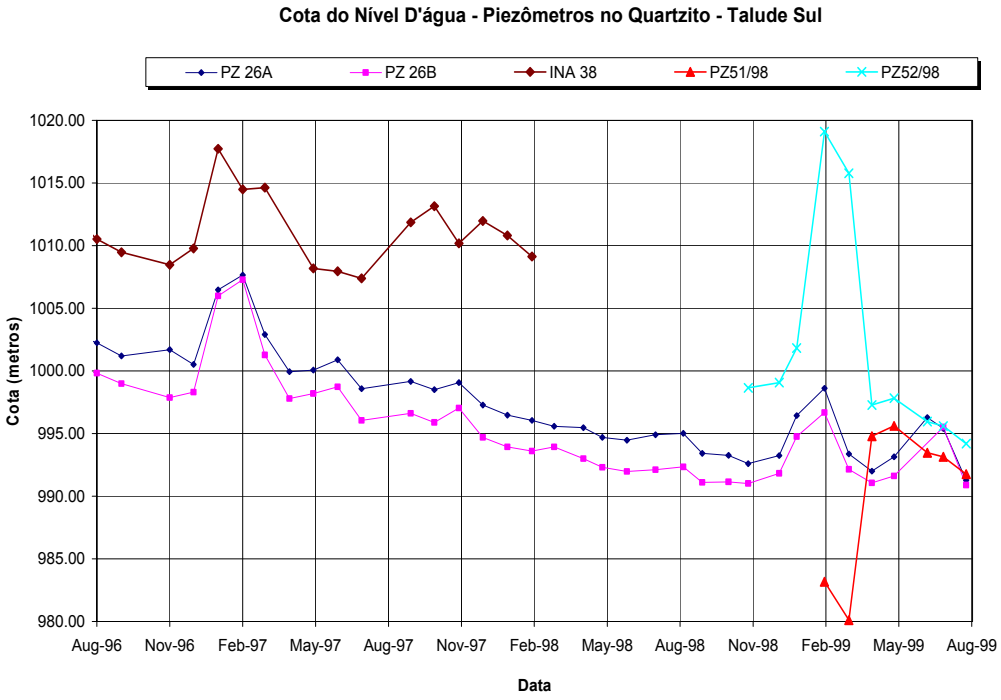


Fig. - 4

Since the quartzite is an independent aquifer, it was necessary to proceed its dewatering with a specific group of wells, in order to maintain the slope stability of the south walls of the mine.

Figure 5 presents the temporal evolution of the water level in the quartzite.



Environmental aspects

The goal of this project was not only to obtain the operational advantages and the safety in the pit proportioned by the efficiency of the dewatering. The major aspect was the non-interference on the streams around the mine site, due to the knowledge of the groundwater behavior and the maintenance of an extensive monitoring program. Similar care will be adopted in the flooding of the pit, as discussed below.

Formation of the lake

The water for the formation of the lake comes from three main sources: surface water, rain water and Groundwater. The most significant morphometric features of the lake are as follows. It should be emphasized that the Aguas Claras Lake will be so far the deepest lake in the country.

Area: 0,67 km^2
Volume: 58 million m^3
Shoreline: 3772 m
Maximum depth: 234 m

It can be seen from the morphometric data that the future lake is characterized by a very high surface area to depth ratio. This can be conveniently expressed by the morphometric parameter known as *relative depth*. It is calculated dividing the maximum depth by the mean diameter of the lake, i.e. the diameter of a circle that has the same area as the lake. In the case of the Aguas Claras Lake the relative depth will be 25 %, which is actually a very high value, This means that the lake will have difficulties with performing complete vertical circulation. Such water bodies with partial circulation are called *meromitic*. Moreover the lake will be steep sided and well sheltered from winds. With regard to the water quality this meromitic condition means that the lake will have a permanent anaerobic layer at its bottom. Nevertheless the general water quality of the lake will be pretty good, since, due to its depth, the eventual phosphorus remobilization will not reach the euphonic zone. Hence eutrophication problems will probably not

appear in the Aguas Claras Lake. A summary of the main physical, chemical and biological processes and their influences on the Aguas Claras Lake is given in Table 1.

TABLE 1

Exposure to solar radiation	Small area – 0.67 km2
Assimilation capacity	High volume relationship Hypoliminiun / Epiliminiun
Hydrology	Precipitation higher than evaporation
Circulation pattern	Meromitic
Biological productivity	Low
Trophic degree	Oligotrophic
Hydrodynamics	Limited horizontal and vertical circulation
Silting	Controlled by a peripheric drainage system and by a slow filling rate
Water residence time	High
Recreational conditions	Very good

Monitoring program

The monitoring program for the flooding of the Aguas Claras Lake encompasses the main physical, chemical and biological parameters. The sampling frequency will be monthly.

TABLE 2: Parameters of the monitoring program

Water temperature	Soluble and total phosphate	Lead
Air temperature	Ammonium nitrogen	Copper
Secchi depth	Nitrate	Chrome
pH	Soluble and total iron	Mercury
Dissolved oxygen	Soluble and total	Zinc
Color	manganese	Fecal cloakrooms
Turbidity	BOD	Fecal streptococci
Suspended, dissolved and	Chloride	Phytoplankton
total solids	Sulfates	Zooplankton
Conductivity	Oil	Zoobenton
Total alkalinity	Phenol	Chlorophyll
Total hardness	Aluminum	
Soluble and total phosphate	Arsenic	
	Cadmium	

The here presented monitoring program is able to identify eventual pollution problems and allows a very detailed assessment of the water quality of the lake. This project has a pioneer character in Brazil, since there is in this country no limnological information available about lakes deeper than 200 m. The formation of the lake, besides being an environmentally sound technique for the rehabilitation of the area, leads to the creation of an extreme scenic water body.

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