



ENVIRONMENTAL HERITAGE OF OIL SHALE MINING IN BRAZIL



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Introduction

After 34 years of oil shale mining activities in Brazil, 5.0 million square meters of a total of 6.8 million square meters of mined areas have been reclaimed.

Continuous environmental evaluations helps to establish the criteria of reclamation methods developed in order to assure appropriate residue disposal, including city garbage, and restoration of soil fertility, basic conditions required for agricultural use or forestry purpose.

Natural Landscape



The relief of the region is characterized by undulating elevated area, about 800 meters above of the sea level.

The climate is of pluvial temperate type, with average annual precipitation of 1400 - 1700 mm. The temperatures varies from 0°C in the winter time, and 35°C in the summer time.

The economic geological section of the Permian Irati Formation, known as Assistencia Member, is composed by two layers of oil shale, almost horizontal with a deep of 1 degree, separated by a sterile intermediate bed of marlstone and siltstone. The overburden is constituted by siltstone of the Serra Alta Formation. The upper layer is 6,0 meters thick with a oil content of 7 wt%, and the lower layer is 3,0 meters thick with an average oil content of 9,0 wt%. Reserves of about 717 million barrels have been measured only in that area near the project.

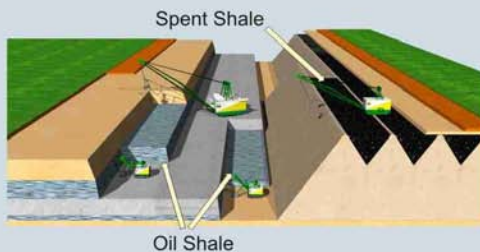
The oil shale beds are black, very fine grained, laminated, constituted by silicates (quartz, k feldspar and albite), hematite, pyrite and a high content of organic matter, as querogen. Those marlstone are dark rocks, constituted of dolomite and calcite, beyond magnetite, hematite, k feldspar, albite, quartz and organic matter.



Open pit mine and oil shale industrialization are potentially environment impacting, especially with respect to land expropriation, soil degradation, residue generation and the potential of ground water contamination.

Old mines could be integrated to the natural ecosystems or even to support economic land use, minimizing social and visual impacts. A permanent environmental heritage of post mining landscape, including the structure of rocks, their geotechnique state, relief elements and water regime, the new technogenic morphology, will stay longer, and need to be evaluated.

Post Mining Landscape



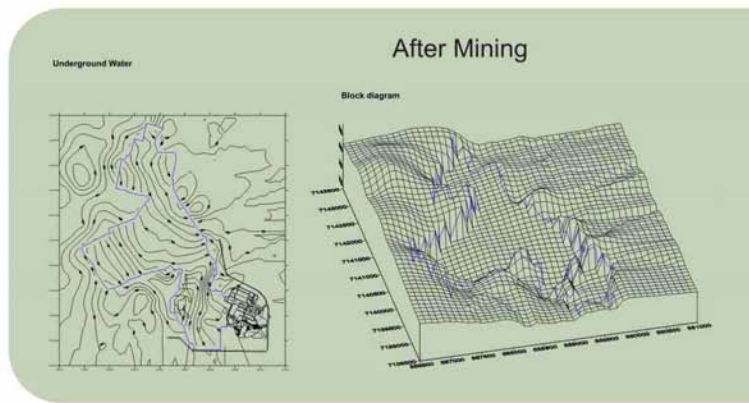
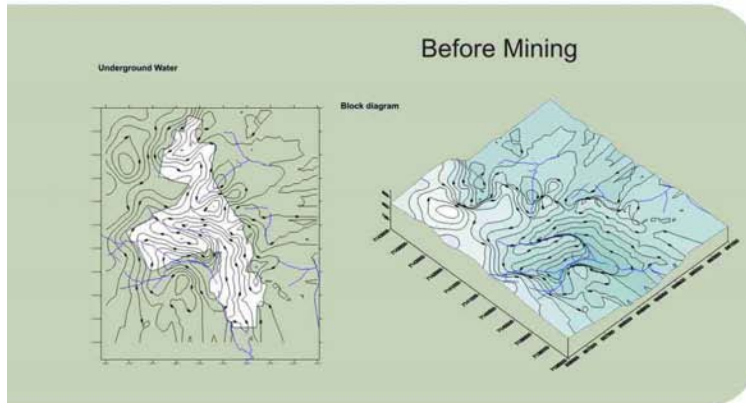
After processed, the spent shale returns to the mine, covering the piles of barren materials. In spite of the increase in volume by the fragmentation of the rocks, at about 35 %, the relief tend to be similar to the original area, preserving the pattern of the regional drainage. After the surface regularization, the residues are covered by a layer of clay (weathered rock) of 1.2 meter of thickness and 0.5 meter of a top soil bed, from the areas to be mined, in order to allow vegetation to grow. The spent shale must be covered as soon as possible because it still has a content of piritic sulfur and could produce a spontaneous combustion by oxidation.





In the natural areas where the oil shale deposits are located, the presence of a simple water table (phreatic) aquifer was identified near the surface in the overburden, limited by the bed rock composed of impermeable Permian sediments. The behavior of the potentiometric surface is quite similar as the topographic surface, almost 8 meters deep. The map illustrates the previous situation of the area, indicating the directions of groundwater flow.

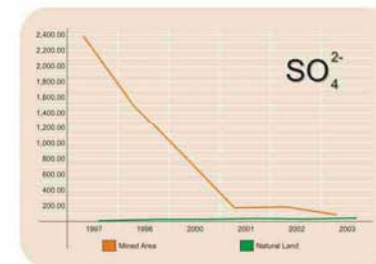
One of the permanent disturbance in the water system is related to the subsidence of the water table level, that do not returns to the original state after reclamation, due to the high permeability of the restored profile, that can varies from 10^{-3} to 10^0 cm²/s.



Water Quality

When the rain water passes through the soil and substratum of the natural areas, it acquires pH of 4.3 and sulfate concentration of 95ppm, as observed in monitoring wells. In reclaimed area the ground water is characterized by the pH 6.3-7.0, and high content of dissolved substances, that comprise 3519 mg/l of sulfate, 669mg/l of calcium, 99mg/l of magnesium, 199.3mg/l of sodium and 211mg/l of total iron.

Most of the constituents of the ground water are considered essential plant nutrients, suggesting the use of biochemical barriers in order to create conditions for immobilization of the excess of dissolved substances. It will work in the forests and lakes, but will be especially efficient in the supra-aqual landscape, or wetlands.



Conclusion

After 34 years of oil shale mining all environmental evaluations carried out indicate that it is possible to develop economical exploration leaving an appropriate environmental heritage for new coming generations.



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