# REHABILITATION OF MINED BAUXITE LANDS AT POÇOS DE CALDAS, MINAS GERAIS STATE, BRAZIL[1]

by

Don Duane Williams[2]

Abstract. Since 1979, Alcoa Alumínio S/A has rehabilitated 85 hectares of mined bauxite lands on its mineral concessions on the Poços de Caldas Plateau in Minas Gerais State, Brazil, 180 km north of the City of Saõ Paulo. The Plateau is an alcaline ring structure, 30 km in diameter with elevations of 1200 to 1600 meters. Bauxite occurs on steep mountain ridges and flanks and on lower rolling hills, in orebodies that range from several thousand up to, uncommonly, one million tonnes. Ore thickness is erratic, but averages 4.5 meters, and is covered by a soil layer 20 to 80 centimeters thick with natural grasses or sub-tropical rain forest. Presently 10 hectares are mined annually. Rehabilitation consists of pre-mining soil stripping and storage, post-mining terracing, drainage works, topsoil replacement, grass and legume hydroseeding, and tree planting with native species. The common size of a rehabilitation unit is 100 by 300 meters. Vegetation growth is fast, plus native vegetation quickly invades the areas. The average cost of rehabilitation has been 6.5 cents per crude tonne of bauxite mined, or $4,075 per hectare, or 18 cents per tonne of aluminum oxide produced in Alcoa's local plant.

Additional Key Words: mine reclamation, surface mining, bauxite, Brazil.

## The Local Setting

The Poços de Caldas Plateau is located 180 km due north of the City of Saõ Paulo, Brazil. The Plateau is an uplifted alkaline ring complex (nepheline syenites, phonolites, and tinguaites) in the form of a circle 30 km in diameter. Elevations on the Plateau range from 1200 to 1600 m, with the entire Plateau some 400 m above the surrounding areas. The average annual rainfall is 1700 mm, concentrated in the summer months of October through March. Summer daytime temperatures rarely go above 32°C. In the winter (May through August) several frosts occur with nighttime temperatures falling as low as -6°C. Steep, intermittent ridges form the circumference of the Plateau with base elevations of 1200 m and rising to as high as 1600 m on the ridge tops. The interior of the Plateau consists mainly of low rolling hills whose base elevations are at 1200 m elevation and rise some 100 m. Natural vegetation is indigenous grasses and scrub both in the interior of the Plateau and on some of the circumventing mountain ridges.

[1]Paper presented at the 1986 National Meeting of the American Society for Surface Mining and Reclamation, Jackson, Mississippi, March 17-20, 1986.

[2]Don Duane Williams is mining manager at Alcoa Alumínio S/A in Poços de Caldas, State of Minas Gerais, Brazil.

Proceedings America Society of Mining and Reclamation, 1986 pp 111-114
DOI: 10.21000/JASMR86010111

Semi-deciduous, sub-tropical rain forests border streams and cover some of the Plateau's border ridges, though the latter are not primary forests. Major land uses are dairy cow raising on indigenous and improved species grasslands, potato and corn crops, and commercial fire and pulp wood plantations of eucalyptus. The soils are shallow, 15 to 80 cm deep, and poor, as they are low in nutrients, with pH values of 4.0 to 5.5. There is no hard cap; bauxitic gravel is common in the soil. Kaolinite is the major mineral in the soils and underlying subsoils. Alkaline pebbles, rocks, and boulders in a kaolinitic matrix, or again, rarely, as massive bedrock, can be found at depths from 2 to 20 m. Poços de Caldas (110,000 population—32 $km^2$ urban area), located on the northern edge of the Plateau, is its only town. It is Brazil's largest inland resort center, and known for its hot mineral springs, scenic mountain setting, and subtropical climate.

## Bauxite

The bauxite occurs mainly on the northern half of the Plateau on the tops and flanks of the circumventing mountain ridges and on the tops of some of the rolling hills in the interior of the Plateau. It is either massive and friable, or as pebbles and cobbles in a clayey matrix. The topsoil itself may be commercial grade ore. The average depth is 4.5 m from the surface, but can go as deep as 15 m. Kaolinitic/clay veins commonly cut across the ore section in varying directions and thicknesses. Orebodies range in size from several thousand tonnes to, rarely, one million tonnes. The sum of the Plateau's orebody areas was some 12 $km^2$ before bauxite mining began in the 1930's.

An Alcoa Aumínio S/A mining subdidiary supplies bauxite to an Alcoa alumina refining and aluminum smelter complex which began production in 1970. This is located 10 km south of the town of Poços de Caldas. The mining subsidiary's bauxite concessions, granted by the federal government, are in 72 orebodies scattered throughout the northern half of the Plateau at a 20-km average distance from the refinery. The subsidiary controls some 30 per cent of the Plateau's bauxite reserves and owns the surface rights on three-quarters of the land area where its orebodies occur. Initially 2 to 3 ha were mined annually. Currently 8 to 10 ha are mined per year (600,000 crude tonnes). Heterogenous ore grades require simultaneous selective mining at four different sites. Some 10 mine sites are always kept open so that equipment may be moved in to satisfy ore blending requirements. Mining is on 2-m high contour benches by 900-liter capacity bucket backhoes. These load into dump trucks with a payload capacity of 10 tonnes. The bauxite's average specific gravity is 1.6 in situ and 1.3 on a dry basis.

## Rehabilitation

### Background

Mining leaves a moonscape effect on the surface. The bauxite's erratic posture produces an end result of deep potholes, high banks, loose clayey subsoil, rock cobbles and boulders up to 40 $m^3$ in volume. Some of the mine sites can be seen from the town and many more are visible from public highways and roads. It was obvious that Poços de Caldas' scenic mountain landscape, which is so important to its tourist-resort area tradition of the town, should not suffer the effects of abandonment and aesthetic degradation from mining.

In late 1978, rehabilitation work began. The following year an agronomist with experience in highway, railroad, and oil line revegetation of disturbed lands was hired to direct the job. By March 1986, 85 ha of mined out bauxite land had been rehabilitated. Some 240 ha still remain to be mined. This will take 22 years at the current mining rate.

### Final Land Use Objective

Partial deforestation of mountain ridges and flanks began in the mid 19th century to turn those lands into grazing areas through a natural succession of native grasses. In this century natural grasslands used for grazing in the interior of the Plateau are gradually being plowed up to be replaced with improved species grazing grasses, and more recently with eucalyptus for fire or paper pulp wood, with the planting of several crops of potatoes before the planting of eucalyptus seedlings. This pauperizing of the natural, native vegetation has led Alcoa to take a posture of implanting native wood species with an adequate understory of grasses and forbs to control soil erosion. These rehabilitated lands from then on will be considered as areas of permanent preservation with final donation to a government agency for the

continuation of their preservation. It is believed that this use will be appreciated by future generations rather than their sale for agricultural uses, or in some areas, even for urban development to which some of the lands are suitable. It is judged that there are sufficient other lands that will satisfy urban development needs.

Pre-mining Drainage Works

Prior to stripping and mining, runoff water drainage ditches are dug around the area to collect fines. These are directed into gullies where sedimentation ponds are built. Many of the ponds cannot hold a large volume of fines, but can be cleaned out with a backhoe and hauled to deep depressions in mined out areas that have not undergone post-mining grading and shaping.

Pre-mining Soil Stripping

The soil is stripped to a minimum depth of 15 cm and stored at a nearby location for post-mining replacement. Mining usually advances in 25 m by 25 m increments. Stripping is normally done a few months before mining begins. If the area contains woody species, these are cut and sold as firewood before stripping. Fortunately, the major part of the orebodies are on grasslands, and not in native forests.

Post-mining Grading

Further rehabilitation work must wait until mining is completed on a "rehabilitation unit". This is a land unit that usually has a minimum of 200 m along the contours and 100 m along the slope component. It is chosen to adjust the area's topographical form and landscape characteristics. Grading is done by a D-6 of D-8 tractor. If the final slope has to be greater than 10 to 15 per cent, contour benches will have to be built for erosion control. Some final slopes have to be as great as 35 to 40 per cent. The difference in elevation between contour benches is usually no greater than 5 m. If sufficient clayey subsoil is not present in the unit to cover up any rock boulders, it can be trucked in from a nearby mined area. Deep ripping to 1.75 m is required at parts of some sites to further break up fractured rock and create better conditions for surface water penetration and plant growth. The inner edge of the contour bench is built to be slightly lower than the outer or crest edge. The bench is sloped ideally no more than 2 per cent along the contour to points of rain runoff discharges that may require drainage works or down slope runoff conduction.

Replacement of Topsoil

The stored topsoil is trucked in and spread along the bench and down the slope by a front-end wheel loader if the slope is low. Hand spreading by hoe is done on steep slopes. Dolomitic agricultural limestone is spread if the pH is below 5.0. Inorganic fertilizer is added if required. A 12-disk (66-cm diameter) plow hitched to a D-6 incorporates the topsoil on benches and shallow slopes.

Post-mining Drainage Works

Surface water drainage ditches lined with cobble rock in a cement and sand matrix are built at the foot of bench walls near down slope water conduction points. Cascades are built with these same materials for down slope conduction at these points. Underground concrete pipe is layed under roads that must be kept if they cross the area. A larger ditch may be required at the foot of the area to conduct water to a gully that has the sediment pond built before stripping and mining.

Revegetation

Slopes between benches are hydroseeded with grasses and legume forbs. Mulching is not used. Little steps 3 cm wide are made with hoes on the slopes between benches. They dip slightly into the slope. These are to retain seeds until germination. Shallow slopes are hand seeded. Benches usually do not require seeding as the undercover growth is fast and spreads onto the benches within a year or two. The hydroseeder is equipped with a 200-m length hose that usually can cover the entire area from its base bench or road. Cow manure or organic fertilizer, inorganic fertilizer, shreaded cardboard boxes, and Curasol are used in the hydroseeder mix. Unfortunately, native grass and forb seed production does not exist yet. Species used are annual rye grass, grease grass (Melenis minultiflora, an exotic grass from Aftica that has spread widely over eastern Brazil), perennial soybean, and Desmodium intortum. Ground coverage is fast, and native species quickly invade the area.

Initially, Eucalyptus saligna (Sydney blue gum) seedlings were planted in one

row along the bench crests and a mixture of exotic and native tree seedlings in one row along the center of the benches. Present practyice is to plant bracatinga (Mimosa scabrela—a woody legume native to the three southern states of Brazil, but not to the Plateau) tree seedlings along the bench crests and a mixture of hardwood tree species native to the Plateau along the center of the bench. The reason to plant the fast growing (1 to 2 m per year) eucalyptus, and now bracatinga, is to reduce the visual effects of the benches on the landscape while the hardwoods grow. The fast growing species are gradually thinned out and eventually eliminated as the hardwoods attain heights of 4 to 5 m. This is quite effective, as the benches cannot be seen at 500 m away from the area.

If the land surface rights do not belong to Alcoa's mining subsidiary, the owner is given the choice of type of revegetation. They usually choose a eucalyptus plantation or an improved species grazing pasture. These are installed at no cost for the owner.

## Cost of Rehabilitation

The average cost of rehabilitation since 1979 has been 6.5 cents per crude tonne of ore mined, based on the actual tonnage mined from each site, or $4,075 per ha, or 18 cents in the cost of a tonne of alumina produced at the refinery. These per tonne costs of course vary from one rehabilitation unit to the other because of differences in ore depths and with the type of work done on the site. These costs are rather insignificant when compared to the total cost of mining.

## Conclusions

To date there are no specific legal requirements for rehabilitation of surface mined areas in Brazil. The federal government mining agency has been preparing material for several years that may lead to legal requirements or regulations. Alcoa's initiative to begin rehabilitation in 1979 has given time for the company to develop techniques and methods wich have proved successful for site specific requirements, and whose implementation is done at a low, reasonable cost. At the same time it has placed Alcoa among the small group of companies that, on their own initiative, are Brazil's minerals industry pioneers in applying mine environmental control and rehabilitation.