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BORON DEPOSITION IN GEOTHERMAL WELLS OF COPAHUE, ARGENTINA

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ABSTRACT

Deposition of boric acid, sassolite, in the pipes of geothermal wells of the Copahue field is described. This mineral was studied by means of optical microscopy, scanning electron microscopy and X-ray diffraction. The corrosive effects on wells and the pollution problems of this material on the environment arising from the utilization of the geothermal resource are analyzed.

INTRODUCTION

The object of this work is to expose the mineralogical characteristics of the sassolite precipitate as inlays and scaling in the pipes of the geothermal well COP-1, in the Copahue geothermal field. This material, whose chemical composition corresponds to the boric acid, (H_3BO_3) was originally found in the fumaroles of Sasso, Toscania, Italy.

The Copahue geothermal field is located to the west of the Neuquén Province, approximately at the 37º30' of south latitude and 71º10´ west longitude, in the border with the Chile Republic. It is about 70 km to the northwest of the town of Loncopué and to 200 km of the city of Zapala, through the Prov. Route Nº 231 (Fig.1).

Four deep wells have been drilled in this geothermal field, in an area located about 6 km to the NE of the Copahue Volcano. These wells confirm the presence of a vapor-dominant type reservoir below about 800m of depth. The four wells constitute an area of one km of side, located on a WNW-ESE fault that link ChanchoCo manifestation in Chile with Las Máquinas

In the well COP-1, a pilot scale geothermal plant of 640 KW/h, which was the first one of South America, was operating from 1986 to 1998. In the pipes of this plant, during winters months, a porous white material, fragile and very soft to the tact, identified as sassolite or boric acid, have been found.

Fig.1: Location map of the Copahue Geothermal Field

GEOLOGY

The Copahue Geothermal Field is a volcanic complex of Tertiary-Quaternary age, formed by a great caldera of about 15x 20 km, that would have originated from a big stratovolcano, in which several extrusive centers have developed, associated to the major structures related to the former caldera. Some of these centers would have evolved to explosion craters.

A characteristic geomorphologic feature in the field is the presence of small basins, formed by the differential erosion of the hidrothermally altered areas. These areas constitute the active geothermal manifestations denominated Termas de Copahue, Las Máquinas, Las Maquinitas and El Anfiteatro, in Argentina (fig.1, inset), and Chancho Co in Chile. These active geothermal manifestations are closely related with the faulting structures of the area, since the faults would have acted as passages of the geothermal fluids (Mas, 1993). Several fractures are present in the area, being predominant those of NE-SW and WNW-ESE strike.

The relationship of these fault systems with the surficial geothermal manifestations and with the presence of subsurficial geothermal fluids was confirmed during the development of the exploration wells COP 1, COP 2 and CO P 3. (JICA-EPEN, 1992; Mas, 1993; Mas *et al*. 1993, Nakanishi *et al.* 1995).

MINERALOGY

Sassolite has precipitated as inlay and scaling in the pipes of the geothermal well COP-1. This mineral was analyzed by means of X-ray diffraction, optic microscopy and scanning electron microscopy.

X Rays Diffraction

A Rigaku D/max IIIC diffractometer was used in this study, operated under standard conditions, with CuK-α = 1.5405Å anticatode; Ni filter; 1°/min scanning speed; 0.01° sampling step; 1° of divergence and reception slits and 0,15 mm dispersion slit, and a graphite monochromater. The fig.2 shows the x ray diffractogram of sassolite from Copahue.

The most conspicuous characteristics of this diffractogram are:

- A notable difference of intensities among the reflection 002 and all the remaining ones, because of the preferred orientation of the plane 00l; and
- The great number of recognizable reflections, although masked by the mentioned intensity difference, due to the triclinic character of the mineral.

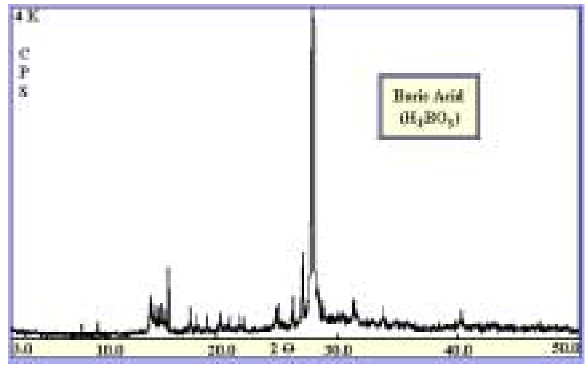


Fig.2: Sassolite diffractogram

In some of the analyzed samples sassolite is accompanied by very subordinate amounts of hidroboracite.

Optic microscopy

Under transmitted light this mineral is observed as colorless, very thin pseudo hexagonal sheets, with almost parallel extinction, near long-slow orientation and negative biaxial optic character.

Electron scanning microscopy

Figs. 3 and 4 show SEM images of the material from the COP-1 well pipes. These images were obtained with a JEOL JSM 35CP microscope, equipped with a microprobe EDAX DX4 with ultrathin window. Fig.3 shows the general texture of the mineral, botryoidal, very cavernous, and with numerous holes and vesicles.

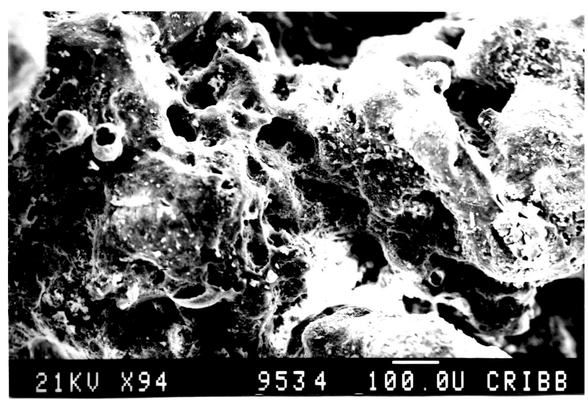
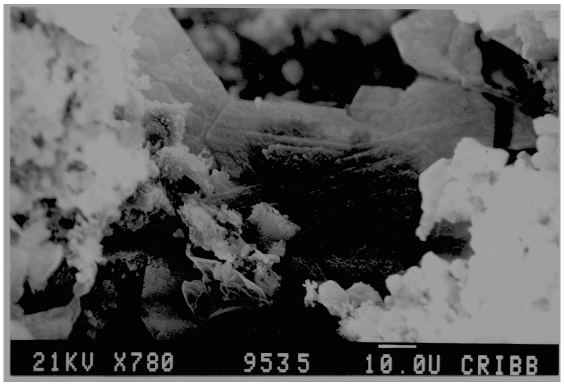


Fig.3: SEM image of sassolite

Fig.4 shows a detail, with great amplification. It is clearly observed the very thin, pseudo hexagonal sheets, also observed by optic microscopy. These sheets are responsible of the conspicuous orientation that this material presents in the diffractometric analysis.

Fig.4: SEM image of sassolite



CONSIDERATIONS

Mas (1993) pointed out that the gaseous phase of the geothermal fluid of the different hot springs and geothermal wells of Copahue area, is constitute predominantly by vapor, with a vapor: gas ratio of about 95:5. The gas is predominantly CO_2 (more than 90% of total) with variable, but generally low contents (about 1%) of H_2S. The boron amount in this phase varies from 1 mg/l in COP-2 to < 0,1 mg/l in COP-1.

The hot water, on the other hand, has isotopic relationships ^2H and ^{18}O that coincide closely with the average world line for the meteoric water, although the relationship N_2/Ar and the fluctuating proportion of H_2S indicate the existence of an important magmatic contribution. The boron in this fluid is present in a proportion of 40 mg/l.

These boron concentrations, although low, are high enough as to precipitate boron compounds under appropriate environmental conditions.

Ozol (1974) describes the presence of boron minerals levels inserted in the travertine of the Pamir region, in the alpine-Himalayan boron province, formed by the volcanic activity of several hot springs with CO_2 and sodium bicarbonate waters. The boron is irregularly distributed in the travertine, with concentrations that vary from 0,001 to 0,1%. The boron content of the thermal waters varies among 10 to 20 mg/l and the relationship B/∑bulk salts varies from 0,002 to 0,009. Ozol (*op.cit)* attributes the presence of boron in these sediments to the extremely arid conditions that facilitate the quick evaporation of the solutions. As a consequence, the boron concentration in the solutions abruptly increase, and at sufficiently high concentrations, the complex B $(OH)_3$ and B $(OH)_4$ (that are the forms under which the boron is present in the water) form the strongly dissociant boric acid.

Allegrini and Benvenuti (1970) analyzed the main phases condensed from the overheated vapor in geothermal energy plants and their corrosive characteristics. The overheated vapor used for the production of geothermal energy condenses partially, in its way toward the turbines, in the pipes of the well. These condensed phases contain soluble components such as H_3BO_3, NH_3, chlorides and sulfates in higher concentrations than the fluid average. Despite these condensates have usually a pH of 6.5 to 7.0, their oxidization-reducing properties can cause corrosion processes comparable with those produced by a sulfuric solution with much lower pH. On the other hand, the precipitation of solid phases because of the oversaturation of these condensates causes internal scaling in the pipes that reduces the efficiency of the plant.

Between the different environmental effects that the utilization of the geothermal resources can cause, they can be mentioned:

- The human environment, including changes in the noise level, local climate and landscape;
- Water contamination, since the geothermal fields usually emit saline fluids with fluorine, boron, arsenic and small quantities of heavy metals; and
- Air pollution, for the emission of CO_2 and SH_2.

The boron (almost the same as silica or other salts) can destroy the vegetation of the region, if the vapors and geothermal condensed are liberated to the atmosphere without previous treatment; or it can inhibit the use of the geothermal effluent for agriculture watering; but it is not a critical element from the health point of view, since the normal diet includes 10-20 mg of boron per day and concentrations up to 20 ppm are accepted in the potable water (Ellis, 1978).

Most of the boron in the total discharge remains in the water phase during phase separation of the geothermal water. There are no extraction processes reported, which have been tested beyond a laboratory scale (Brown, 2000). One of the most effective ways to remove boron selectively is to use boron specific ion exchange resins. These are successful in removing up to 98% of the boron and releasing it again on addition of acid. However, the capital cost of the resins is high, and the operational costs would also be expected to be high with large quantities of acid being required. More over, silica has a detrimental effect on the resin and would need to be removed before the boron extraction phase. On the other hand, the soluble elements in the vapor condensates, as the boron, may be easily reinjected with the condensate to the reservoir, just as it is made in Larderello (Italy) and in The Geysers (USA).

All the mentioned inconveniences have possible technical solutions, but they affect the cost of production and therefore they should be known and considered from the earlier stages of the development of the field.

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