

MINERALOGICAL AND CRYSTALLOGRAPHIC CHARACTERISTICS OF APATITES FROM THE ALKALINE/CARBONATITIC ARAXÁ PHOSPHATE DEPOSIT, BRAZIL

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INTRODUCTION

Chemical, morphological and crystallographic characteristics of apatites from the Araxá deposit were studied to define apatite features, which may affect their behavior in the flotation process.

Braga & Born (1988) described the main characteristics of the Araxá weathered apatite mineralization, overlying carbonatitic and glimmeritic rocks. The alteration profile, up to 180 meters thick shows an upper non-apatitic waste layer, followed by a phosphate enriched level, containing apatite, goethite, magnetite, hematite, other phosphates, barite and vermiculite-hydrobiotite. In the lower part of the profile and in decomposed rocks, phlogopite, carbonates and some pyroxene/amphibole have been partially preserved.

Although apatite is relatively stable in the supergenic environment, some alteration occurs due to weathering. Some free P_2O_5 reacts with other elements originating new minerals, as gorceixite, goyazite, and monazite/rhabdophane. Under favorable circumstances another part of the free P_2O_5 moves down in the alteration mantle originating a new generation of secondary apatite.

Most of the primary apatite remains as an eluvial mineral, of the same grain size as in the original rocks, with its prismatic or granular habit, but with somewhat rounded edges. These grains may be partially or totally covered by iron oxide coatings, secondary apatite crusts or other secondary phosphates.

When covering primary apatite grains, or filling its fractures, the microcrystalline secondary apatites occur as fine prismatic aggregates with irregular or radial structure. A particular portion of the deposit is constituted almost only of pure phosphate crusts, composed of eluvial apatite grains and iron oxides, cemented by secondary microcrystalline apatite and with late barite veins.

GEOLOGICAL SETTING

The Barreiro do Araxá Carbonatitic Complex, Minas Gerais State, Brazil, covers an area of about 16 Km². The circular intrusion is constituted mostly by glimmeritic and carbonatitic rocks, with some radial and concentric dikes of sovitic and beforstic composition. Most glimmerites are admittedly derived from previous pyroxenitic and peridotitic rocks. Issa Filho et al (1984) described the most important features and lithologies of the complex.

The apatite deposit occupies some 2.5 Km² of the northwestern portion of the complex. Several samples representing the most important apatite bearing materials, according to previous mining experience and geological criteria, were collected for this study.

METHODOLOGY

The standard procedure to obtain almost pure apatite concentrates, involved crushing below 48 mesh, low and high intensity magnetic separations (Frantz) and heavy-liquid methods (TBE and DIM). Analytical techniques included chemical analysis, optical microscopy, X-ray diffraction, infrared Fourier transform spectroscopy and preliminary scanning electronic microscopy.

MORPHOLOGICAL AND OPTICAL CHARACTERISTICS

Detailed studies on nine different samples revealed the main characteristics of the apatites:

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Primary Apatite - Ovoid or prismatic habit, medium to coarse grain size; crystal faces are generally smooth, without surficial alteration, although sometimes sulcate, striated or corrugated features indicate partial dissolution. Some grains present an alteration rim with higher birefringence, but with the same optical orientation, probably of carbonate-apatite. In some samples, frequent ovoid to rod-shaped inclusions occur.

Secondary Apatite - The reprecipitated apatite are divided into sub-groups according to morphological features:

- **Prismatic** - Aggregates of fine hexagonal prisms with radial orientation, grown around an iron oxide nucleus or as late crusts over primary apatite grains. Extinction is radial-ondulating or incomplete according to the orientation of the aggregates;
- **Crystallite Aggregates** - Fine crystallites forming rugous or micro-folded rough aggregates, generally associated to iron oxides or criptocrystalline apatites. Optical extinction is incomplete;
- **Criptocrystalline Aggregates** - Criptocrystalline apatite, associated to fine iron oxides, occurs as irregular masses of 'snowy' aspect, covering or cementing primary apatite grains.

X-RAY DIFFRACTION

Crystallinity and unit cell dimensions were determined on almost pure or mixed samples of the different apatite types.

The crystallinity was measured by the relation between the area and height of the (211) and (112) peaks, according to the methodology proposed by Norman & Murata (1976). The highest level was verified on samples constituted only by primary apatite (Samples 8 and 9), while the lowest level was obtained for a sample constituted almost only by secondary apatite (Sample 5). The other six samples present intermediate levels of crystallinity according to the proportions among the primary and secondary phases (Figure 1).

Unit cell parameters defined the primary phase as fluor-hidroxy-(carbonate)-apatite and the secondary phase as fluor-carbonate-(hidroxyl)-apatite, indicating a phosphate replacement and carbonate enrichment, followed by hidroxy decrease in reprecipitated apatite (Table 1). The slight decrease of the 'c' parameter of secondary apatites, from samples containing a mixture of the two apatite phases, might indicate either replacements in cation positions or simply reflect an insufficient number of these ancillary peaks used to define the parameter. More precise measurements should be obtained on pure secondary apatites.

Thus the X-ray diffraction studies identified the two distinct types of apatites indicated by optical microscopy, although even less conspicuous varieties of secondary apatites may still remain to be identified, as suggested by 'c' parameter measurements.

INFRARED FOURIER TRANSFORM SPECTROSCOPY

Further corroboration of X-ray diffraction results were obtained by infrared analysis, indicating carbonate substitutions for phosphate radicals in the secondary apatite. That kind of replacement characterizes the B-type fluor-carbonate-(hidroxyl)-apatite (bands in 860-flexure, 1430 and 1460 cm^{-1} - stretch). The spectrums also illustrate a hidroxy decrease in the secondary phase and the low participation of the carbonate radical in primary phase (Figure 2).

The decrease in P_2O_5 and increase in F and CO_2 contents indicated chemical analysis results (Table 1) also support this interpretation.

RESULTS

The optical microscopy studies were useful to identify the presence of different, closely associated, apatite varieties and their relation with alteration process. XRD and FTIR results indicated fluor-hidroxy-(carbonate)-apatite as the only primary phase and fluor-carbonate-(hidroxyl)-apatite as the main reprecipitated secondary phase, forming individual aggregates or covering primary grains. Carbonate substitutions for the phosphate radical

and fluorine for hydroxyl were established for the secondary apatite.

The secondary prismatic to cryptocrystalline apatite has low crystallinity and is normally associated to iron oxides.

Behavior for the 'a' parameter values for primary and secondary apatites is consistent. The cause of the detected variations in the 'c' parameter of the secondary phase from several mixed apatite samples, may be suggestive of additional differences among the reprecipitated apatites, probably explained by cations substitutions, or simply reflect an insufficient number of data for the definition of the parameter.

The existence of several apatite types, with particular characteristics, is an important clue to understand the different technological behavior of some Araxá phosphate ores. As a practical approach for mine planning and estimation of the technological behaviour of ores - recovery and grades - an appropriated routine was established for the Araxá phosphate ore. The procedures consist of WHIMS laboratory tests on ground ores to define their technological behavior.

REFERENCES

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 Issa Filho, A. et al, 1984 - In: Complexos Carbonatíticos do Brasil: CBMM, p. 19-44.
 Norman, M.B. & Murata, K.J., 1976 - American J. of Science, 274, p. 201-211.

TABLE 1: Unit cell dimensions (Å) and some chemical analysis results

<i>Sample/Specie</i>	<i>ore type</i>	<i>a</i>	<i>c</i>	<i>%P₂O₅</i>	<i>%F</i>	<i>%CO₂</i>	<i>%CaO</i>
MN-1 /Primary	normal	9.39986	6.89046	40.1	1.9	0.61	53.9
MC-2 /Primary	cemented	9.39605	6.88996	39.6	2.6	1.0	53.0
MC-2 /Secondary		9.36608	6.86788				
MM-4/Primary	micaceous	9.40052	6.88932	39.6	2.1	1.2	52.9
MM-4/Secondary		9.36613	6.87002				
MC-5 /Secondary	cemented	9.35822	6.8939	37.7	3.1	2.2	52.2
MG-8 /Primary	pyroxenitic	9.3981	6.89181	40.6	1.9	0.25	55.0
MF-3 /Primary	friable	9.3931	6.89165				
MF-3 /Secondary		9.36421	6.85612				
MM-6/Primary	micaceous	9.40704	6.89017				
MM-6/Secondary		9.35588	6.86952				
MM-7/Primary	micaceous	9.40233	6.88971				
MG-9 /Primary	pyroxenitic	9.40107	6.88956				



FIGURE 1: Apatite crystallinity by XRD

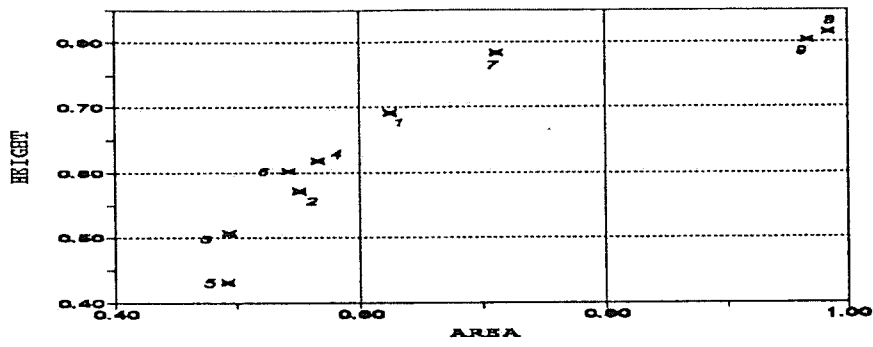


FIGURE 2: Apatites infrared spectrums

