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TECHNOLOGICAL CHARACTERIZATION OF THE PEGMATITE LITHIUM ORE AT THE CBL MINE, ARAÇUAÍ – MG

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ABSTRACT

Lithium is a considerably light metal relative to other metals. Due to its high specific heat, it has several applications related to heat transfer, while its remarkable electrochemical potential and high energy density make it widely used in batteries. Due to its high reactivity, it is not found in nature in its elemental form, occurring mainly in lithium brines and pegmatites. In Brazil, the presence of lithium is observed in pegmatite deposits, with important mineralized bodies located in the Jequitinhonha Valley, in the state of Minas Gerais. This work aims to carry out a survey of information through chemical, mineralogical and granulometric analysis of the litiniferous pegmatite from the Companhia Brasileira de Lithium (CBL), located in the municipality of Itinga/MG, comparing with information available in the literature. The results showed that the main mineralogy consists mainly of spodumene and quartz, also presenting fractions of apatite and pyrite, among other

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minerals. Following the growth in demand in the national and international market for lithium minerals, especially for use in technological systems, such as batteries, it is increasingly necessary to understand the natural disposition of exploitable ores for better use in mining.

Keywords: Granulometry. X-ray diffraction. SEM. Mining.

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INTRODUCTION

Lithium reserves in South America are predominantly concentrated in continental brines and pegmatite bodies, driving the global economy due to the growing demand in the battery industry and clean technologies [1]. Being the lightest of the metals, lithium has atomic number 3, atomic mass of 6.939 u, and abundance in the earth's crust of 12 ppm [2]. Although about 150 minerals contain lithium, only four are economically viable for the production of lithium compounds, they are: spodumene, lepidolite, petalite, and amblygonite. The main products traded are lithium carbonate (Li_2CO_3) and lithium hydroxide (LiOH), with variations in properties according to their specific applications [2].

The pegmatites developed in granitic intrusive igneous rocks are composed of quartz, feldspar, biotite, muscovite, afrisite and minerals such as beryl, cassiterite, amblygonite, spodumene, tantalite columbite and colored tourmalines. In addition to granitic varieties, there are definitions that cover ultramafic, mafic, and syenitic compositions. The term "pegmatite" is also used to describe late residual melts with a high concentration of dissolved volatiles. These pegmatites are important sources of mineral resources, including rare elements and gemstones such as morganite and aquamarine, as well as minerals such as hiddenite and kunzite [3].

Lithium stands out as a rare element present in pegmatites, driven by high demand due to rapid technological development. The element lithium (Li) is an alkali metal with distinct physical and chemical characteristics. With exceptionally low density and the lowest molar weight of all metals, as well as high electrochemical potential surpassing that of the standard hydrogen electrode [4], make this element an input of paramount importance for the world industry, especially with regard to the battery production sector.

Spodumene, with the chemical composition LiAlSi2O6, is a lithium aluminosilicate. Belonging to the group of pyroxenes, however, it does not form isomorphic series with other species of this group [5]. The mineral is colorless in its pure state, although there are colored varieties according to the impurities present, of which the best known are kunxite, pink in color due to manganese and hiddenite, green in color attributed to the element Chromium [6].

Continental brines and hard rocks are main sources for lithium exploration, with some countries, such as Australia, focusing on production from rocks, especially spodumene [1]. South America, especially the triangle of Argentina, Bolivia and Chile, accounts for 57% of the world's lithium deposits [7]. Brazil has occurrences associated with

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pegmatite rocks in the states of Minas Gerais, Ceará, Rio Grande do Norte and Paraíba, with minerals such as amblygonite, spodumene, petalite and lepidolite [2]. In Brazil, the main reserves of lithium ores are located in the Jequitinhonha Valley, in Minas Gerais, specifically in the municipalities of Araçuaí and Itinga [8]. The Araçuaí Orogen developed at the end of the Neoproterozoic, marked by the end of the Brasilian cycle and with the amalgamation of Western Gondwana, located between the São Francisco Craton and the Atlantic Continental Margin on the eastern Brazilian margin with ages ranging from 630 to 480 Ma [9].

Mineral extraction at the Araçuaí unit by Companhia Brasileira de Lithium (CBL) is carried out through underground mining in the pegmatites using the method of *sublevel stoping*, from where the ore is transported to the crushing by wheel loaders, at the Cachoeira Mine in the lower valley of the Piauí River, a tributary of the Jequitinhonha [2,10]. After extraction, the ore undergoes a beneficiation process, resulting in spodumene and feldspar being obtained as products. The spodumene is transported to the factory located in Divisa Alegre/MG, where the production of lithium carbonate and hydroxide takes place. The processing of the mined ore begins with the classification/comminution stages, conducted by jaw and cone crushers. The circuit is closed by vibrating screens. The mineral concentration stage is carried out with the ore in the granulometry of 6.35 to 19.05 mm, with a content of 1.5% of Li2O. This process occurs in a circuit using dense medium cyclone [8]. Lithium hydroxide (LiOH) and lithium carbonate (Li2CO3) are the main industrial forms of lithium, obtained from lithium-rich minerals and brines [11]. Lithium carbonate has been the main production from brines. Lithium hydroxide is second in consumption, and can be obtained directly from brines, concentrates or from lithium carbonate [12].

Thus, South America is crucial due to the vast reserves of lithium, playing a key role in the development of the new energy standard and presenting significant potential. Investing in this strategic resource can bring important benefits to the continent and contribute to future well-being and prosperity. In this context, the main objective of this work was to evaluate the mineralogical and chemical characteristics of the lithium ore from the municipality of Araçuaí/MG, from the mining carried out by the Brazilian Lithium Company (CBL), bringing results acquired in the laboratory of the technological characterizations in order to expand the information associated with the litiniferous ore.

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MATERIALS AND METHODS

The lithiniferous pegmatite samples were kindly made available by a company located in the municipality of Itinga (CBL - Companhia Brasileira de Lítio), in the northeast region of Minas Gerais, which extracts the litiniferous pegmatites at the Cachoeira Mine, where spodumene ore is dominant.

SAMPLE PREPARATION

The material was submitted to mineral processing by the crushing operation, at the Mineral Operations Laboratory of the Federal Institute of Northern Minas Gerais – IFNMG. The procedure aimed to fragment ore blocks from the *Run Of Mine* - ROM, which is the ore from the mine, taking them to the desired granulometry for direct use in subsequent processes. First, the lithiniferous pegmatite sample was positioned in the opening of the Brastorno Tormax 18x13 (BT. BMB) for crushing. The crushed material was bagged in a clean plastic bag, to avoid contamination, and sent for the proper procedures and subsequent analysis.

PARTICLE SIZE ANALYSIS

The screening tests were used in order to classify the material coming from the crusher according to the size of the particles present in the sample, in this case, in order to know the particle size distribution of the litiniferous pegmatite after primary crushing. This analysis was carried out at the Laboratory of Mineral Operations of the Federal Institute of Northern Minas Gerais – IFNMG. For the tests, the sample from the crushing stage with a total weight of 3430 grams, was placed in an Abronzinox sieve shaker to follow the dry sieving for 5 minutes with a frequency of 5 Hz; using Tyler series sieves with 4.75 mm (4#) openings; 2.36 mm (8#); 1.70 mm (10#); 1.40 mm (12#); 1.118 mm (14#); 0.297 mm (48#); and the last retained classified as 0.250 mm (60#), as exemplified in Figure 1.

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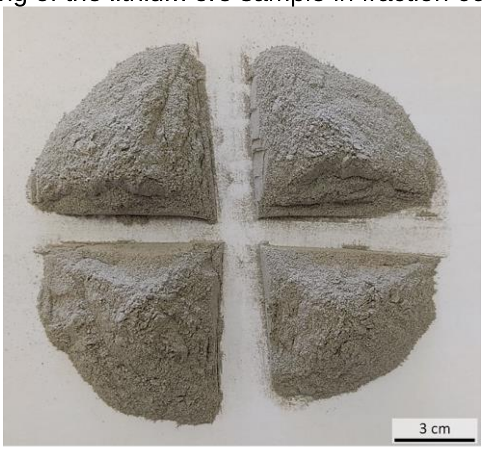
Figure 1: Macroscopic view of lithium ore after screening on a scale of 4# to 60# (Tyler series).

MINERALOGICAL ANALYSIS

First, the selected sample (0.250 mm or 60 #) was homogenized by the quartering process, to reduce the amount of mass, obtaining a fraction of 145 g by weight, as exemplified in Figure 2. Three aliquots of the lithiniferous pegmatite sample of the chosen particle size range were removed and sent to the laboratory for mineralogical analysis, using the X-ray diffraction technique. The crystallographic structure was determined using the powder method, , with a Shimadzu diffractometer model XRD-6000 using CuKa monochromatic radiation (λ = 0.15406 nm - 40 kV and 30 mA), analysed at a scan rate of 2.0 degree/min covering the 2θ range of 10-80°. This analysis was carried out in partnership with the Multiuser Laboratory of Advanced Microscopy (LMMA), at the Diamantina campus of UFVJM. For the treatment of the data obtained, the X'Pert HighScore Plus program was used.

Figure 2: Quarrying of the lithium ore sample in fraction 60 # (Tyler series).



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CHEMICAL ANALYSIS

The separate aliquots for mineralogical analysis were also subjected to chemical and morphological analysis in a HITACHI Scanning Electron Microscope (SEM) model TM-3000 with an EDS analyzer from OXFORD model SWIFT ED 3000. This analysis was also carried out in partnership with the Multiuser Laboratory of Advanced Microscopy (LMMA), on the Diamantina campus of UFVJM. Figure 3 exemplifies the samples sent.

Figure 3A: Separate fraction 60# aliquots for mineralogical analysis

RESULTS AND DISCUSSION

Figure 4 shows the granulometry of the dry sieving performed in the laboratory, showing a higher percentage (27.12 %) in the coarser range, above 4.75 mm, while the finer granulometry showed around 5 % retained below 0.250 mm. According to Braga *et al.* [12] the mineral processing carried out at the Cachoeira Mine by CBL uses ore in the granulometry of 6.35 mm to 0.8 mm with a content of 1.5% Li_2O after secondary crushing, which goes to the dense medium cyclone generating a concentrate with about 5% Li_2O, corresponding to an enrichment of 3.3 times. The work proposed here already demonstrates that it is possible to achieve similar results in the granulometry cited by Braga *et al.,* with primary crushing. The granulometry below 0.8 mm represents 9.33 % in the analyses carried out here, this fine unused material presents an opportunity for the development of flotation, which can add significant value to the beneficiation process [13].

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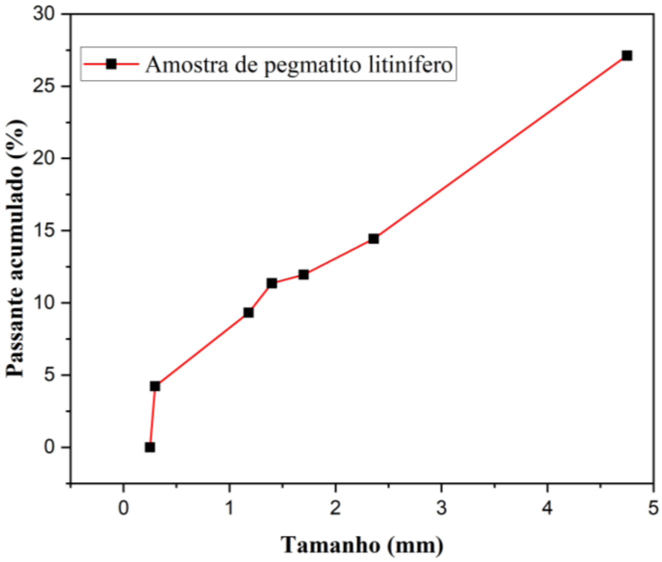
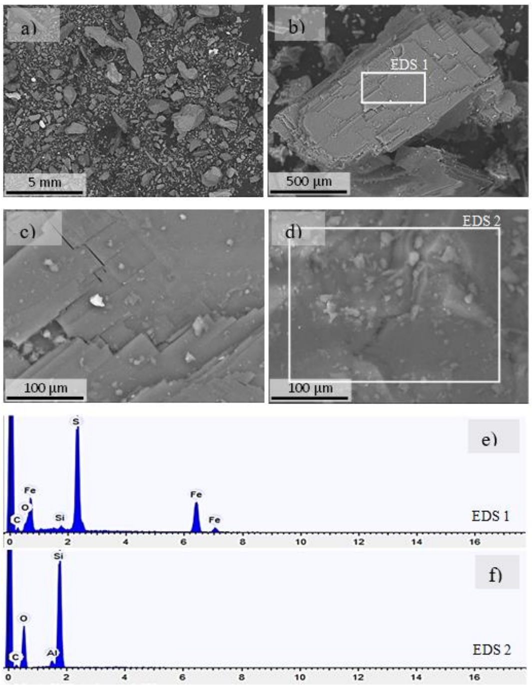
Figure 4: Particle size distribution curve.



After the quadruping of the selected particle size range (60 #; 0.250 mm), 3 samples were taken, numbered and taken to characterization by SEM and EDS, where Figure 5, 6 and 7 present images for the microregions of samples 1, 2 and 3 respectively. The SEM/EDS analyses aimed to analyze the morphologies and particle size distributions. In the image of backscattered electrons, particles with varying particle size and difference in shades of gray are noticeable.

Figure 5: SEM images of lithium ore sampling 1 (a-d), and EDS analyses of the identified microregions (e-f).



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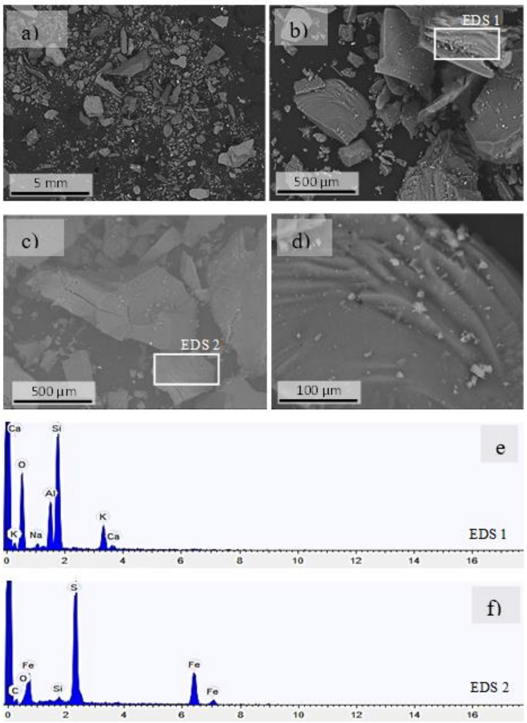
It is possible to observe in the images of Figure 5, sample 1, varied granulometries that do not exceed the size of 5 mm, as already expected by the granulometric analysis performed. Some minerals stood out with a lighter shade of gray, and the EDS analysis observed the presence of iron and sulfur, which preliminarily suggests that there may be the presence of an iron sulfide.

Figure 6: SEM images of lithium ore sampling 2 (a-d), and EDS analyses of the identified microregions (e-f).



For sample 2, in Figure 6, the particle size results as well as the elements identified in the EDS are as expected due to the similarity of the samples. However, it showed some traces for elements such as Sodium, Calcium and Potassium, indicating the formation of a possible Feldspar for the mineral studied.

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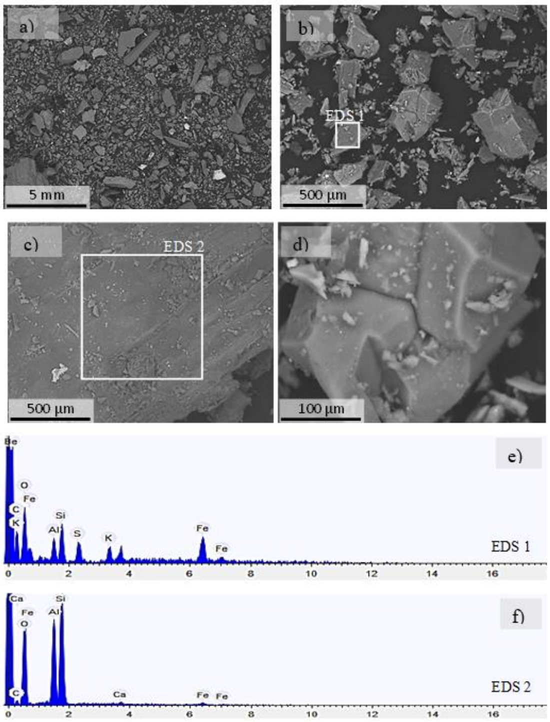
Figure 7: SEM images of lithium ore sampling 3 (a-d), and EDS analyses of the identified microregions (e-f).



Sample 3, in Figure 7, showed a result close to sample 2, also denoting the same chemical elements already mentioned above. The ore studied here carries Li2O, however the presence of Li, due to its low atomic mass (6.941 ± 0.002 u), is not detected by EDS. The identification of the mineral phases present in the different samples was determined by X-ray diffractometry, as shown in the diffractograms in Figures 8, 9 and 10. As expected, Spodumene is the predominant mineral phase in both.

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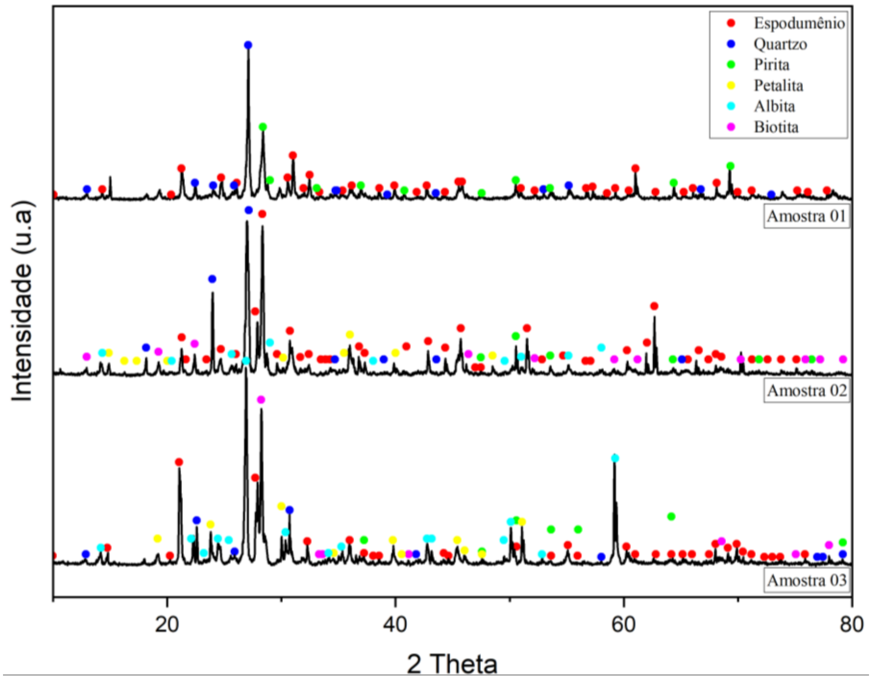
Figure 8A: X-ray diffraction spectra of lithium ore sample 1.



The results that the X-ray diffractograms exhibit in the figures confirm that the studied samples have the same majority mineralogical composition, containing Spodumene and Quartz. The X-ray diffractogram of sample 1, Figure 8, showed characteristic peaks that made it possible to verify the presence of Spodumene [Li4Al4Si8O24] and Quartz [SiO2], as well as characteristic peaks for Pyrite [FeS2], the latter being attributed to minerals with light color highlighted in the SEM images.

The results of samples 2 and 3, Figures 9 and 10 respectively, obtained peaks similar to those of sample 1, confirming the presence of Spodumene, and also showing the presence of Quartz and Pyrite as the main minerals. It is observed that these samples obtained peaks for Biotite of the type Annite [Si5.18Al3.82Fe5.14K1.87O24], Petalite [Si8Li4Al4O21] and Albite [Na2Al2Si6O16], which is in line with the elements Ca, Na and K obtained in his EDS analyses. In his work Romero *et al.* [10] mentions that the pegmatites of the Cachoeira Mine are essentially made up of spodumene, albite and quartz.

By means of X-ray diffractometry, it is also possible to visualize the percentage composition by the number of characteristic peaks, as shown in Table 1. Thus, in the XRD analysis, the majority composition of the mineral Spodumene was verified, followed by the others already mentioned.

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Table 1: Mineralogical content by the ratio of the peaks found in the XRD.

Mineral	Sample 1 (Content)	Sample 2 (Content)	Sample 3 (Content)
Spodumene	76%	33%	44%
Quartz	7%	12%	1%
Pyrite	17%	18%	10%
Biotite	-	9%	13%
Petalite	-	7%	11%

The technological characterization used here made it possible to confirm that the ore to which the Brazilian Lithium Company (CBL) is working in the Jequitinhonha Valley in Minas Gerais is a Spodumene with occurrences in lower content of another lithium aluminosilicate, Petalite [14]. Spodumene is a lithium mineral that occurs in pegmatites, almost always associated with other minerals such as Quartz and Feldspars such as Albite [15]. The presence of Biotite shales in analyses of the Araçuaí pegmatites had already been elucidated in the work of Chaves and Dias (2022).

Spodumene has a density of 3.2 g/cm3 while quartz, feldspar and petalite have densities in the range of 2.4 to 2.6 g/cm3 [16]. The concentrate of CBL is obtained by separation in a dense medium, so minerals that do not have a density close to that of spodumene are not effectively separated by this process, without using a lot of energy or a polluting medium. Lithium miners have an environmental commitment to use clean media, where the pyrite found can be an aggravating factor in existing mining, as the wet oxidation of pyrite can generate acid drainage, a challenging environmental concern of mining activities [17].

CONCLUSION

The application of a characterization such as the one described here makes it possible to optimize the use of the natural resource, resulting in greater reliability, increased productivity and economic gains in all phases, from the initial mining to the transformation of the productive asset. This study focused on the mineralogical characterization of litiniferous pegmatites from the Jequitinhonha Valley region of the state of Minas Gerais, aiming to expand the knowledge about the properties of this mineral resource, especially due to the growing interest in lithium minerals.

The specific objectives were achieved by identifying and quantifying the mineral phases present in the lithium ore and the particle size range after passing through the primary crushing. Lithium ore from CBL stood out for the predominance of feldspar gangue and quartz, in addition to the presence of iron sulfides. The significant pyrite content (Fe_2S)

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can be mitigated through the implementation of processes such as gravitational separation, which separates minerals based on their density, or fine grinding, where the differentiated particle size of pyrite relative to value minerals allows separation by mechanical methods. The fine granulometry presented in the analyses carried out also goes back to the potential for the development of flotation. The improvement of these methods produces effects on economic gains, as well as on the environment with a possible use of less waste and processes without the use of much energy or a polluting environment. Further work will be considered in order to study the possibilities of optimizing the processing of lithium ore in the region of Araçuaí/MG.

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