STUDYING THE MAIN MINERALOGY AND SHOCK OF THE BOLIVIAN H5 CHONDRITE AIQUILE.

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Introduction: The first meteorite fall recognized in Bolivia occurred on 20 November 2016 at 21:57 UTC in Aiquile, Cochabamba district [1]. The meteorite was immediately recovered by casual witnesses and classified at Museu Nacional, Quinta da Boa Vista, Rio de Janeiro, as a H5 ordinary chondrite [1]. We obtained a fresh meteorite specimen from a dealer, with the aim of performing a careful study of the level of shock experienced by this meteorite as well as its specific mineralogy. For this purpose, we have obtained SEM-EDS images and performed powder x-ray diffraction (XRD) measurements on the available material. Quantitative phase analysis (QPA) using the Rietveld method has allowed us to evaluate the concentration of the major minerals in Aiquile as well as the composition of the olivine (ol) and pyroxene (px) phases.

Experimental methods: For the present work, a thin section from IEEC-CSIC collection has been employed. SEM images and EDS spectra were obtained with a Hitachi TM4000Plus tabletop microscope equipped with a Bruker EDS detector. XRD measurements were performed on a small chip of the meteorite that was carefully grinded with mortar and pestle. The XRD measurements were performed with a D8-A25 Bruker TWIN-TWIN diffractometer equipped with a Cu X-ray source and a Lynxeye position sensitive detector. Given that Fe-rich samples like meteorites usually exhibit strong X-ray fluorescence signal when XRD is performed with Cu X-ray radiation, long integration times were employed in order to improve the signal-to-background ratios. Phase identification was carried out with the DIFFRAC.EVA software, using the Powder Diffraction File (PDF-2) and the Crystallography Open Database (COD). The program TOPAS 4.2 from Bruker was used to perform the Rietveld analyses [2]. From the refined lattice parameters and the results of Ref. [3], information about the Fe/Mg composition of ol and px minerals was also gained.

Results and discussion: It is well known that most chondritic meteorites reaching the Earth have experienced significant collisions during their histories, some of which were responsible for the detach from their parent asteroids. Thus, different levels of shock-induced facies and minerals can be appreciated in meteorites due to high-velocity impacts [4]. Texturally, Aiquile appears through the petrographic microscope as an equilibrated ordinary chondrite, dominated by porphyritic chondrules and with the presence of opaque minerals (fresh metal grains and troilite). Radial pyroxene chondrules and barred olivines, which are the result of very rapid cooling, are also observed across the thin section.

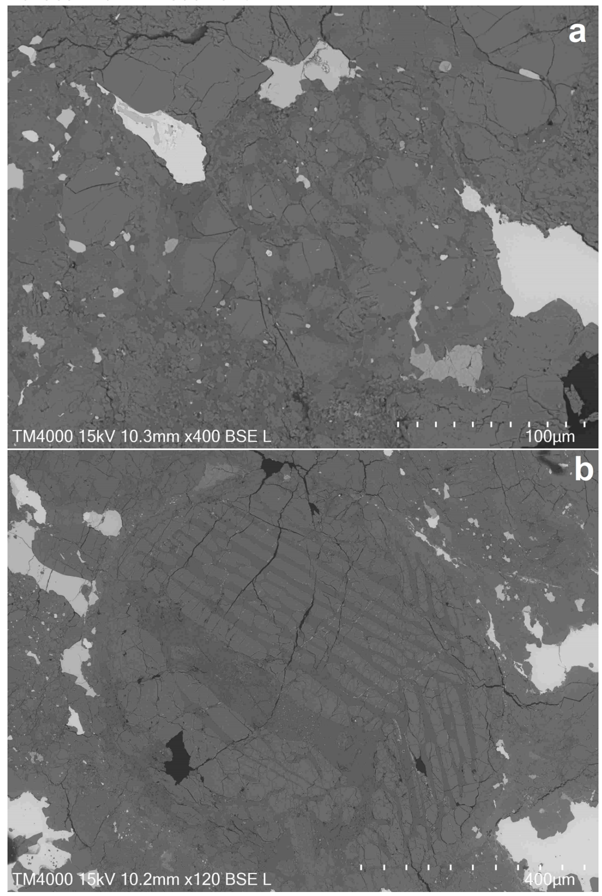

Figure 1. SEM-EDS images of two different regions of interest of the Aiquile meteorite.

Figures 1a and 1b show two different SEM images (backscattered electrons) from the thin section, which help illustrate the recrystallized texture of Aiquile. Evident fractures are visible in the interior of the chondrules. Kamacite (white) and troilite (gray) are the brightest phases. The central chondrule in Fig. 1a exhibits a typical porphyritic texture, while that of Fig. 1b corresponds to a barred olivine chondrule which, as revealed by EDS mappings (not shown), is embedded in an oligoclase ($Ab_{80}An_{20}$) matrix. Extinction in cross-polarized light suggests that this plagioclase phase may be non-crystalline (maskelynite).

Mineral	Weight (%)	Composition
Forsterite	45	Fa=20%
Enstatite	42	Fs=18%
Troilite	5	
Kamacite	3	
Plagioclase	< 5	

Table 1. Concentration of the main rock forming minerals of Aiquile and molar composition of the two major minerals as determined by XRD.

Figure 2 shows an XRD scan of Aiquile. The major minerals that can be identified, together with the QPA results obtained with the Rietveld method, are displayed in Table 1. The XRD reflections from the olivine phase are relatively narrow, which is a consequence of compositional homogeneity due to equilibration. The main low-Ca px phase is orthorhombic enstatite, in agreement with the petrological type 5 classification of the meteorite. Although weak signal from clinoenstatite may show up in the XRD scans, it is not taken into account in the present analyses. Small amounts of crystalline plagioclase, with a composition close to andesine, are also detected.

The second column of Table 1 shows the Mg/Fe composition (in mol%) of the two main silicate phases, as obtained from the refined lattice parameters. The values thus obtained agree well with those reported in Ref. [1] (Fa=18.3%±0.5 for ol and Fs=15.7%±0.7 for px), showing the usefulness of the XRD technique for the characterization of both the mineralogy and composition of the chondrites.

Conclusions and future work: The study of our thin section and the XRD results confirm the significant shock stage of this H5 meteorite. The present data are compatible with the S3 shock stage reported in Ref. [1]. However, the presence of glassy plagioclase and possible planar fracturing might point toward larger shock effects. An additional search for shocked minerals using Raman spectroscopy will be performed in order to further constrain the degree of shock of this meteorite.

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References: [1] Gattacceca J. et al. (2018), The Meteoritical Bulletin no 106, 10.1111/maps.13215. [2] The Rietveld Method, ed. by Young R.A. IUCr Monographs on Crystallography, vol. 5. Oxford University Press. [3] Morrison S. M. et al. (2018), American Mineralogist 103, 848–856. [4] Stöffler D. et al. (1991), Geochimica et Cosmochimica Acta 55, 3845-3867.

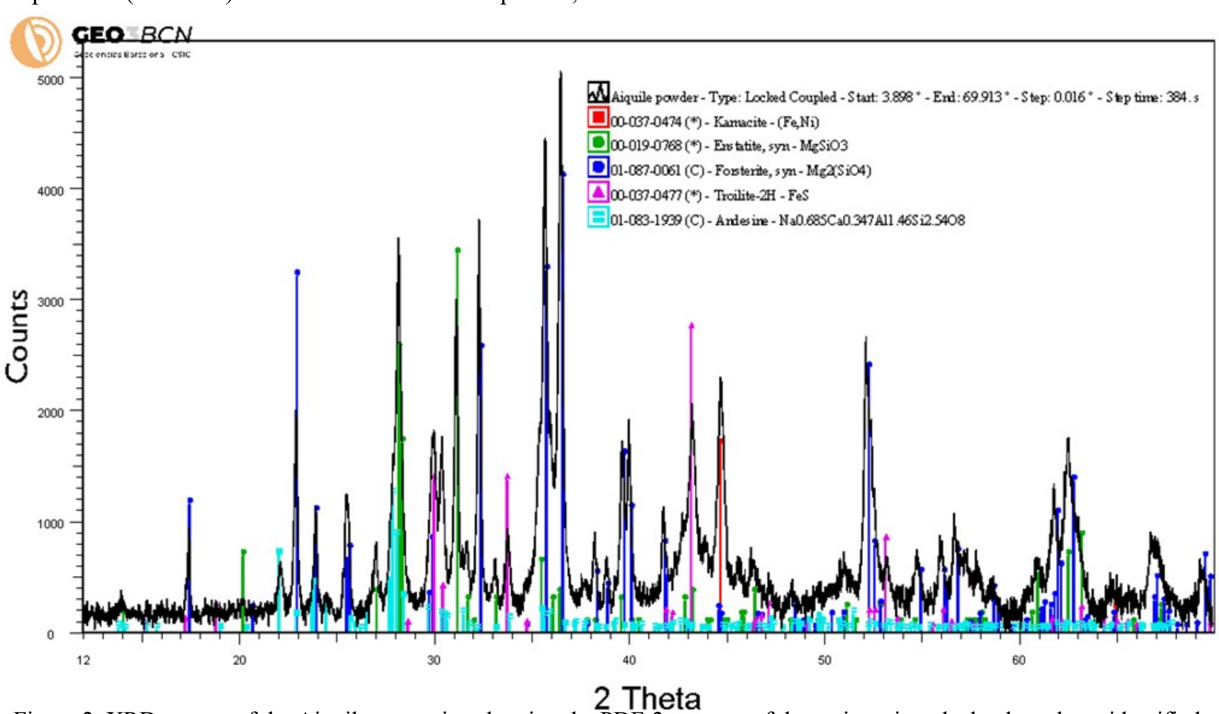

Figure 2. XRD pattern of the Aiquile meteorite, showing the PDF-2 patterns of the major minerals that have been identified.