GEOCHEMICAL INVESTIGATION OF THE ATACAMAITES, A NEW IMPACT GLASS OCCURRENCE IN SOUTH AMERICA.

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Introduction: A recently described glass occurrence has been reported from the Atacama desert, Chile, by [1]. The glasses were named atacamaites and initially classified as tektites. However, [2] suggested them to be impact glasses based on magnetic properties and redox state. A similar nature has been suggested by [3], based on Mössbauer spectra. Currently, the true nature of the atacamaites remain undefined, whether tektites or impact glasses, as well as the nature of the impactor. We present the results of a geochemical investigation of the atacamaites, focusing on major and trace elements coupled with the determination of highly siderophile elements, with the purpose of contributing towards the elucidation of their nature.

Current knowledge: More than 3000 pieces of atacamaite were collected over an area of 20 km^2 in 2012 and 2013 [1]. These authors described them as aerodynamically shaped black glasses with minor vesicles, ranging in size from 4 to 35 mm, with a mean weight of 500 mg (Fig. 1). Using scanning electron microscopy (SEM-EDS) they observed Fe-poor (ca. 5 wt% FeO) and Fe-rich (15 wt% FeO) varieties, both with inclusions of lechatelierite (> 99 wt% SiO_2). FTIR analysis indicated water contents of ca. 0.013 wt%. Bulk, REE and Sr-Nd isotopic compositions reported by [1] showed the glasses to be compatible with locally occurring volcanic rocks. A positive correlation between Ni and Fe contents was interpreted by them as an indication of possible contamination by an iron impactor.

Figure 1 Atacamaites exhibiting aerodynamical shapes and containing small vesicles. The coin, for scale, is ~1.8 cm wide (specimens provided by P. Rochette).

The magnetic properties of specimens from the four known tektite strewn fields (Australasian, Ivory Coast, Central European, North American) and impact glasses (e.g., Libyan Desert, Darwin, Aouelloul glass) were compared by [2]. They concluded that the magnetic susceptibility of impact glasses, including the atacamaites, shows a wider range of values than that of the tektites. Preliminary Mössbauer analyses [3] of two samples of atacamaites, one Fe-poor and the other Fe-rich, confirm their distinction from tektites (=distal ejecta) and their similarity with proximal impact glasses.

Geochemical analyses: Geochemical analyses of major and minor element abundances were conducted using electron micro probe analysis (EMPA) and trace element contents were determined via neutron activation analysis (INAA). EPMA, including mineral analysis by energy-dispersive spectrometry (EDS) and by wavelength-dispersive spectrometry (WDS), was performed at the Natural History Museum of Vienna using a JEOL JXA 8530-F electron microprobe (EMP) equipped with an EDS and WDS detector (11.5 mm working distance, 15-20 kV). Spot sizes varied between 10 and 20 m depending on the magnification and the required analysis. Images were produced by secondary-electron imaging (SEI) and back-scattered electron detectors (BSE). The abundances of major (Na, K, and Fe) and the majority of the trace elements (including rare earth elements, REEs) were determined by Instrumental Neutron Activation Analysis (INAA) at the Department of Lithospheric Research at the University of Vienna [5]. For the siderophile elements, ca. 50 mg of the atacamaite was cleaned in an ultrasonic bath prior to crushing and powdering in an agate mill. About 30 mg of the so obtained homogeneous sample powder was used for the determination of highly siderophile elements (i.e., Re, Os, Ir, and Pt) by isotope dilution, and ^{187}Os isotope composition measurements by thermal ionization mass spectrometry (TIMS). Solvent extraction, micro-distillation and anion exchange techniques were performed following the methods described in [5-7]. Mass spectrometric measurements were carried out using a Thermo Element XR SF-ICP-MS in single collector mode at the Steinmann-Institute at the University of Bonn, Germany, using methods described in [8] and using a Thermo Finnigan Triton TIMS (operating in negative mode) at the Department of Lithospheric Research at the University of Vienna, Austria.

Results: The BSE image (Fig. 2) shows that the atacamaite is relatively heterogeneous. Ni and Co contents were found to be 3085 and 237 ppm, respectively, from INAA. FeO has an average of 10.15 wt% FeO, with a minimum of 8.1 wt% FeO and a maximum of 14.9 wt% FeO. This is equivalent to ~6-11 wt% Fe.

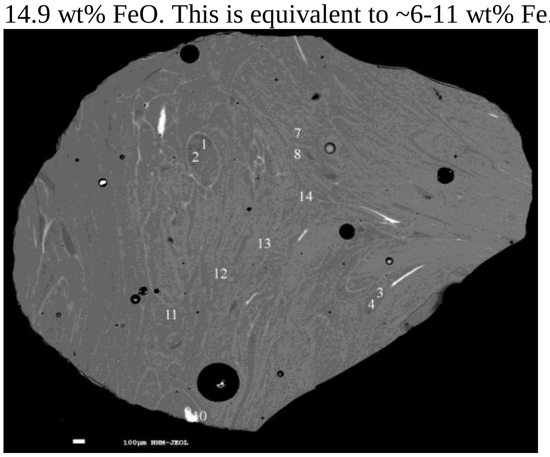

Figure 2 BSE image of the atacamaite sample showing the spots where microprobe measurements were taken.

Concentrations for selected highly siderophile elements range from 1.22 ppb for Re and 5.58 ppb Ir to 10.34 ppb for Pt. The Re, Ir, and Pt concentrations are several orders of magnitude higher compared to the average upper continental crust (UCC; ~198 pg/g Re, ~22 pg/g Ir and ~510 pg/g Pt [10]) and only comparable to ultramafics (komatiites or basalt protoliths with up to several ppb Ir and Pt [11].

In terms of water contents, the presence of 0.013 wt% H_2O reported by [1] falls into the range of typical values for tektites (from 0.002 to 0.02 wt% H_2O), although close to the lower limit of the range for impact glasses (0.02 to 0.06 wt% H_2O) [12].

Discussion: The heterogeneous composition of the atacamaite is similar to that of impact glasses, whereas tektites tend to be more homogeneous [4]. Fe contents are high, even assuming that part of the Fe is terrestrial. Ni is also very high: 0.27-0.61 wt% NiO (equivalent to 0.21 - 0.48 wt% Ni) from the microprobe data, and around 0.30 wt% Ni from INAA. Likewise, Co is very high, at 237 ppm, as well as Re (1.22 ppb), Ir (5.58 ppb) and Pt (10.34 ppb).

Re/Ir and Pt/Ir ratios are 0.22 and 1.85, respectively, comparable to carbonaceous chondrites, which typically exhibit ratios of ~0.09 and ~2 [13], respectively. Ratios for the UCC are distinctly different with ~9 for Re/Ir and ~23 for Pt/Ir. Possible iron meteoritic admixtures to the tektite cannot be ruled out based on the current dataset. However, while Re/Ir ratios for iron meteorites are nearly indistinguishable from those of carbonaceous chondrites, values ranging from ~2 to ~10 are reported for Pt/Ir [14,15], in part significantly higher compared to the ratio measured in the atacamaite.

The Ni/Co ratio is 12.7, compatible with iron meteorites [16] (in particular with IIAB-type irons) and significantly lower than the typical Ni/Co ratios of carbonaceous chondrites [17].

Assuming the atacamaites originated from a chondritic meteorite would require that approximately <50% of the iron, 1/3 of the Ni and <50% of the Co would be meteoritic. This would, in turn, require ~150 ppb Ir, a far higher figure than the ca. 5 ppb found in the atacamaite.

Conclusions: Our results confirm the presence of a meteoritic component in the atacamaites, and thus their formation in an impact event. The compositional heterogeneity and water content suggest them to be impact glasses, rather than tektites, thus confirming previous suggestions by [2] and [3]. As to the nature of the parent body, an iron composition appears more seemingly than a chondritic one, as suggested by our overall geochemical results.

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