

THE EFFECT OF AQUEOUS ALTERATION IN ANTARCTIC CARBONACEOUS CHONDRITES FROM COMPARATIVE ICP-MS BULK CHEMISTRY. J. Alonso-Azcárate¹, J.M. Trigo-Rodríguez², and C.E. Moyano-Camero², ¹Universidad de Castilla-La Mancha (UCLM), Campus Fábrica de Armas, 45071 Toledo, Spain. (jacinto.alonso@uclm.es), ²Meteorites, Minor Bodies, and Planetary Sciences Group, Institute of Space Sciences (CSIC-IEEC). Campus UAB, Fac. Ciències, C5-p2, 08193 Bellaterra (Barcelona), Spain (trigo@ice.csic.es).

Introduction: Terrestrial ages of Antarctic carbonaceous chondrites (CC) indicate that these meteorites have been preserved in or on ice for, at least, tens of thousands of years [1]. Due to the porous structure of these chondrites formed by the aggregation of silicate-rich chondrules, refractory inclusions, metal grains, and fine-grained matrix materials, the effect of pervasive terrestrial water is relevant [2]. Our community defends that pristine CC matrices are representing samples of scarcely processed protoplanetary disk materials as they contain stellar grains, but they might also trace parent body processes [3-5]. It is important to study the effects of terrestrial aqueous alteration in promoting bulk chemistry changes, and creating distinctive alteration minerals. Particularly because it is thought that aqueous alteration has particularly played a key role in some CC groups in modifying primordial bulk chemistry, and homogenizing the isotopic content of fine-grained matrix materials [2,6]. Fortunately, the mineralogy produced by parent-body and terrestrial aqueous alteration processes is distinctive [7-8].

With the goal to learn more about terrestrial alteration in Antarctica we are obtaining reflectance spectra of CCs [8], but also performing ICP-MS bulk chemistry of the different CC groups. A direct comparison with the mean bulk elemental composition of recovered falls might inform us on the effects of terrestrial alteration in finds. With such a goal, in the current work we have analyzed some members representative of CO and CM chondrite groups.

Experimental procedure: The meteorites analyzed in our ICP-MS analyses that we include in this preliminary work are members of the CM and CO chondrite groups. We first discuss the CM group members: Cold Bokkeveld, Murchison, Murray, LEW 87148, and QUE99355; and later the CO group ones: Kainsaz, ALHA 77307, ALH 82101, ALH 83108, and ALHA 77003. The samples were analyzed by an ICP-AES (Inductively coupled plasma atomic emission spectroscopy) ICAP 6500 ThermoElectron for major elements and an ICP-MS (Inductively coupled plasma mass spectrometry) Thermo Electron X Series II for minor and trace elements.

Solutions were prepared from ~0.025 g of each sample fluxed with 0.05 g of Li-metaborate and dissolved in 30 ml HNO₃ 1N and 1 drop of HF. Four standard US Geol. Survey reference materials were

used for external calibration; internal calibration was made before the measurements using Rh as standard.

Results and discussion: Elemental mobilization of water-soluble and reactable elements was first described in CC finds related to loss of Na [9]. Motivated by such results obtained by other techniques and the review given in [2] we decided to test our ICP-MS analyses. Fig. 1 compiles the mean bulk chemical compositions (in weight %) obtained for the main rock-forming elements of the analyzed CM chondrites. It is remarkable how the concentrations of Na and K are highly variable compared to the other elements. The lowest Na abundance corresponds to Cold Bokkeveld, QUE 99355, and LEW 87148. On the other hand, Murray and Murchison have Na abundances closer to the bulk group “CM” value given by [7]. It has been suggested that Na concentrations decrease due to the loss of this element by leaching of sulfates during weathering. Obviously, if this is the case the observed pattern indicates that terrestrial weathering has been more extensive in the Antarctic CMs and Cold Bokkeveld. The later is a (quite old) meteorite fall, and many specimens may have been subjected to significant weathering. In reference with the measured K abundance, a similar underabundance is found suggesting a similar action of water. It is important to remark that although K is non-water soluble it does react with water producing potassium hydroxides. Moreover potassium compounds may be water soluble.

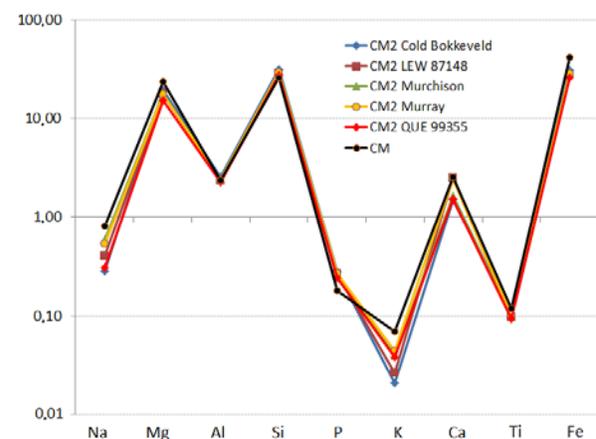


Figure 1. Mean bulk chemical compositions of CM chondrite group members analyzed here. The bulk group “CM” value was taken from [6].

A similar plot has been made for the analyzed CO chondrites. The results are compiled in Fig. 2. It is noticeable that the elemental abundances of the main rock-forming elements are consistent with the values given in [7]. Little data dispersion is found for Fe, Mg and Si. On the other hand, it is widely known that different degrees of aqueous alteration are well established as petrological subtypes, from 3.0 to 3.7 [7]. For example, the CO 3.0 ALHA77307 is usually considered one of the most pristine CCs. Despite of this, we have found that ALHA77307 exhibits the lowest Na abundance, with large difference from the other analyzed COs that are far closer to Hutchison's bulk elemental value for this chondrite group [7]. A clear difference is found for the K depletion that was found to be similar in our study to the four analyzed Antarctic COs. It seems consistent that a quite fresh fall, the CO 3.2 Kainsaz, is closer to the Hutchison's bulk elemental value [7]. The clear differences between the Na and K abundances seems to point towards a distinctive mechanism to explain the measured underabundance of Na and K. Then, it is plausible that ALHA77307 experienced an exposure to the action of water, that participated mobilizing its Na content.

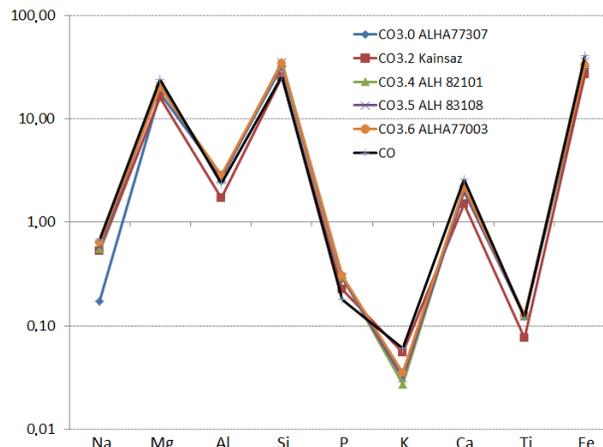


Figure 2. Mean bulk chemical compositions of the CO chondrites analyzed here. The bulk group "CO" value was taken from [6].

Conclusions: CCs have suffered significant weathering in Antarctica, but clearly below the degree of alteration found in CC falls, or finds in dry deserts [2]. Consequently, we think that our ICP-MS measurements are capable to test the influence of water in the elemental abundances of highly-porous CCs. A significant influence on the Na, and K concentrations measured in Antarctic chondrites has been found. This confirms that Na and K depletions are mostly due to terrestrial alteration during their long residence in Antarctica's ices as was suggested previously [10].

We plan to perform a more comprehensive study of the bulk elemental chemistry of CC groups. One key question is the determination of the extent of terrestrial alteration and contamination experienced by these meteorites. This is certainly challenging as these effects could be specimen-dependent as consequence of the preservation policies and handling strategies. Due to the porous nature of these primitive materials these terrestrial alteration processes could be at work even for falls (as previously reported for CMs [11]) or finds.

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References: [1] Jull A. J. T. (2006) in *Meteorites and the Early Solar System II*, D.S. Lauretta & H.Y. McSween Jr. (eds.), Univ. Arizona Press, Tucson, 889-905. [2] Bland P. et al. (2006) in *Meteorites and the Early Solar System II*, D.S. Lauretta & H.Y. McSween Jr. (eds.), Univ. Arizona Press, Tucson, 853-867. [3] Zolensky M.E. et al. (1993) *Geochim. Cosmochim. Acta* 57, 3123. [4] Brearley A. and Jones R.H. (1998) In *Planetary Materials*, ed. Papike J.J., Washington, D.C.: Min. Soc. of America, 1-398. [5] Zinner E. (2003) In *Meteorites, Comets and Planets*, ed. Davis A.M., Treatise on Geochemistry, vol. 1, Elsevier, pp.17-39. [6] Trigo-Rodríguez J.M., and J. Blum (2009) *Publ. Astron. Soc. Australia* 26, 289. [7] Hutchison R. (2004) in *Meteorites: A Petrologic, chemical and isotopic synthesis*, CUP, Cambridge, UK. [8] Trigo-Rodríguez J.M. et al. (2013) *MNRAS*, 437, 227-240. [9] Kallemeyn G.W. et al. (1994) *GCA*, 58, 2873-2888. [10] Brearley A.J. (2006) in *Meteorites and the Early Solar System II*, D.S. Lauretta & H.Y. McSween Jr. (eds.), Univ. Arizona Press, Tucson, 587-624. [11] Benedix G.K. and Bland P.A. (2004) 67th Ann. Meteorit. Soc. Meeting, abstract #5184.