Northwest Africa 8409: hydrogen abundance and isotope composition in the Mercury-like meteorite

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Introduction: Over the past decade, a number of studies have measured a range of achondrites and primitive achondrites from the non-carbonaceous (NC) region to quantify the water abundance of parent bodies that accreted in the inner Solar System, as well as to infer their hydrogen isotopic composition (δD signatures) [e.g., 1-3]. The aim of such studies is to answer one of the greatest unknowns in cosmochemistry, i.e., the source of water in inner Solar System planetesimals. So far, most NC achondrites present a similar δD value of about −300 to −250‰ [e.g., 1-3]. Because most NC achondrites might have formed at or beyond the snowline [4], it is difficult to conclude whether the main source of water could have been water ice (e.g., mantling chondrules) similar to how CM chondrites acquired water [5], or if their hydrogen was somehow acquired (in an isotopically fractionated way) from H gas in the nebula [e.g., 6]. Northwest Africa (NWA) 8409, paired with NWA 7325, could be a key witness in the search for the H source in the innermost region of the Solar System. NWA 7325/8409 is a unique reduced, FeO-poor gabbroic achondrite [e.g., 8]. NWA 7325/8409 was initially proposed to sample Mercury, yet this has been discredited due to its ancient crystalisation ages. However, the possibility that it derived from a Mercury building block cannot be ruled out [9]. Here, we analysed hydrogen abundance and isotope composition of nominally anhydrous minerals (NAMs) in NWA 8409 to better understand the source of water in bodies in the innermost region of the Solar System.

Materials and Methods: A 15 x 7 mm chip of NWA 8409 was studied using scanning electron microscope (SEM), followed by chemical characterization of pyroxene, plagioclase, olivine and sulfides using an electron probe microanalyser (EPMA) at the Department of Earth Sciences, University of Firenze. The chip was then pressed into indium for the measurements of D^-/H^-, expressed in δD ratios, and $H^-/^{16}O^-$ ratios, calibrated as H_2O concentrations, using the NanoSIMS 50L at the Open University following established procedures [1-2]. Subsequently, the sample was removed from indium and embedded in resin to be polished for investigation by electron backscatter diffraction (EBSD) at the Open University. As the CRE age of NWA 7325 has been estimated to range from 13.5 to 18 Myr due to some noble gas heterogeneities [10], the noble gas (Ne-Ar) abundances and isotope ratios will be determined by CO_2 laser extraction static mass spectrometry at the CRPG noble gas analytical facility [11].

Results: Our section of NWA 8409 contains 54 vol.% of calcic plagioclase ($An_{89.5\pm1.0}$ $Ab_{10.5\pm1.0}$), 41 vol. % of diopside ($En_{54.1\pm0.2}Wo_{45.1\pm0.2}$ $Fs_{0.8\pm0.1}$), 5 vol.% of forsteritic olivine ($Fo_{97.8\pm0.1}$) and traces of sulfides. Inverse pole figure maps of NWA 8409 reveal no evidence of recrystalisation, while grain reference orientation deviation maps reveal moderate strain within both olivine and pyroxene. Olivines and pyroxenes contain, on average, 1.9±0.6 and 3.0±0.3 µg/g H_2O, respectively. While the extremely low H_2O content of olivines restrict an estimate of an associated δD value, the δD upper limit of NWA 8409 pyroxenes, corrected from spallation contribution of D considering the younger CRE age of its paired sample, is −315±90‰ (n=6; 2se), while the lower limit using the older CRE age is −490±90‰ (n=6; 2se).

Discussion: We estimate a water content for the parent body of 30 µg/g H_2O, similar to estimates made for Vesta, the ureilite parent body and the acapulcoite-lodranite parent body [e.g., 1]. Since EBSD maps of NWA 8409 are consistent with shock events on the parent body, the H_2O/δD systematics of this sample and its parent body have to be seen as upper limits due to potential H loss. As a result, an even lower δD value can only be reached if gaseous H from the nebula is the principal contributor to the H budget of NWA 8409. This could be achieved by various processes, such as direct nebular ingassing [12] or incorporation of phases or minerals bearing this H component [e.g., 13], that need to be evaluated with respect to the NWA 7325/8409 parent body.

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