EVIDENCE FOR HYDROUS MAGMATISM ON THE NORTHWEST AFRICA 011 PARENT BODY.

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Introduction: Hydrous magmatism is a widespread process on Earth, and evidence supporting hydrous magmatic processes has been presented for Mars [1] and the Moon [2]. At present few known examples of hydrous magmatic rocks from asteroidal bodies are known. The basaltic achondrite Northwest Africa (NWA) 4587 is paired with NWA 011 (as well as NWA meteorites 2400, 2976, 2400, 2976, 4587, 5644, 7129, 8545, 13274). This group of meteorites is unusual in several respects. While the NWA 011 group superficially resemble basaltic eucrites, they are isotopically distinct, and in particular show oxygen, chromium, and titanium stable isotopic compositions consistent with accretion from materials resembling carbonaceous chondrites [3]. The NWA 011 group meteorites consist of pyroxene (pigeonite with exsolved augite), plagioclase, and numerous minor and accessory phases including merrillite, quartz, olivine, troilite, and oxides [3]. All members of the NWA 011 pairing group show evidence for substantial post-crystallization thermal annealing similar to equilibrated eucrites. Cystallization ages for the NWA 011 group meteorites are ancient (~4.565-4.560 Ga) consistent with an asteroidal origin [4].

Methods: Doubly-polished grain mounts of NWA 4587 pyroxene were prepared by embedding hand-picked pyroxene grains in epoxy resin. Initial polishing was done by hand with successively finer diamond grit lapping film (400, 800, 1000 grit) while monitoring the sample surface in a reflected light petrographic microscope. Final polishing was done on a lapping wheel with cotton polishing paper and diamond paste (first 3 μm grit, then 1 μm). The mounts were then polished on the reverse side in the same manner, until the sections were IR-transmissive, ~100-200 μm thick. To monitor any potential introduction of water into the sample, pyroxene grains from the diogenite NWA7831 and the ungrouped achondrite NWA 6693 (probable impact melt [5,6]) were prepared in the same manner. Transmission spectra were collected with a JASCO Fourier Transform Infrared Spectrometer at the Institute for Planetary Materials (IPM) with a nominal spot size of 20×20 μm covering 400-10000 cm^{-1} (1.0-25 μm) with 4 cm^{-1} spectral resolution. Following FTIR analysis, the grain mounts were coated with 5 nm of amorphous carbon and elemental maps of Ca, Al, Si, Fe, and Mg were collected using a JEOL 8900 electron probe microanalyzer at IPM using wavelength-dispersive spectroscopy (Figure 1).

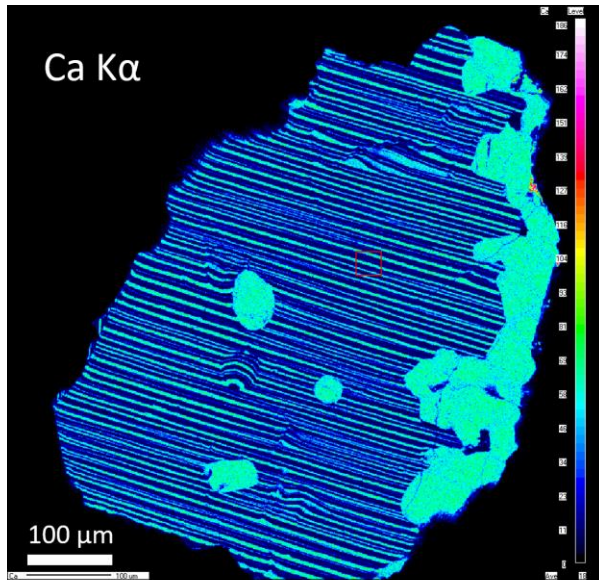

Figure 1: Calcium X-ray map of an NWA 4587 pyroxene grain showing typical equilibrated texture featuring prominent exsoluton of augite lamellae within the original pigeonite host. The small red box shows the area of FTIR analysis, 20×20 μm. The presence of fine exsolution textures greatly complicates the quantification of hydrogen from FTIR spectra.

Results: All NWA 4587 pyroxene grains analyzed showed clear evidence for hydrogen incorporation (Figure 2A). In contrast, pyroxene grains from the NWA 7831 diogenite and NWA 6693 ungrouped achondrite, though subjected to identical sample preparation methods, showed no evidence of hydration (Figure 2B-C). In detail, the hydration features observed for NWA 4587 pyroxene are variable (Figure 3) but consistently show a maximum in absorption near 3200 cm^{-1} with shoulders near 3500 cm^{-1} and 2900 cm^{-1}.

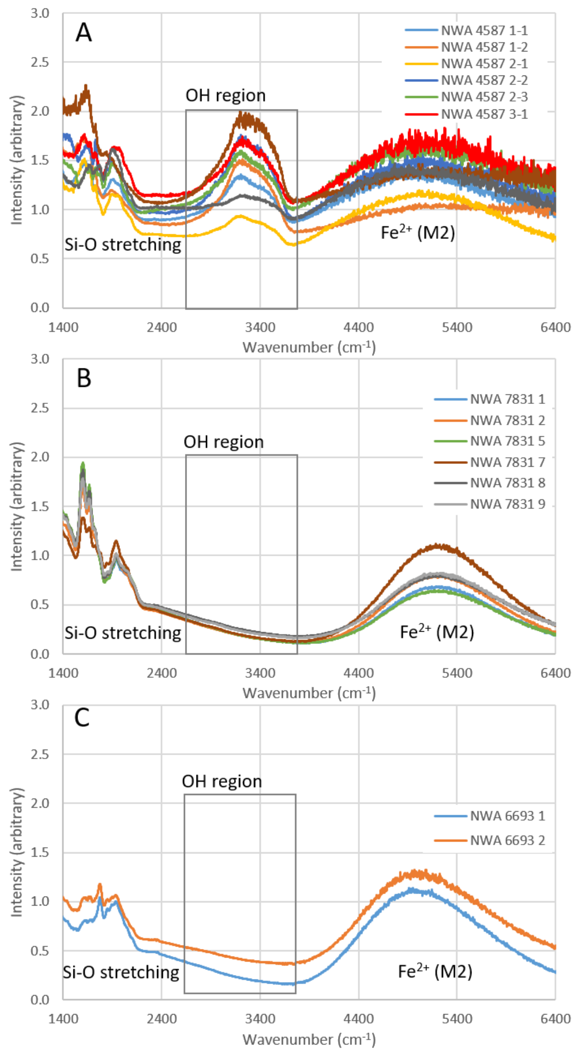

Figure 2: Transmission FTIR spectra of NWA 4587 pyroxene compared with NWA 7831 iogenite and NWA 6693 ungrouped achondrite (impact melt). Hydration was observed only in the spectra of NWA 4587. Other features are due to fundamental Si-O stretching vibrations and crystal field transtions of Fe^{2+} in the pyroxene M2 sites.

Discussion and Conclusions: The presence of hydrous pyroxene in NWA 4587 demonstrates that the parent magma of the NWA 011 basaltic achondrites was hydrated. This is broadly consistent with accretion of the NWA 011 parent body from outer solar system materials at least somewhat similar to hydrated carbonaceous chondrites. Because the identically-treated diogenitic pyroxene showed no evidence of hydration, we are confident that the signature detected here was not introduced during sample preparation. Similarly, both NWA 4587, NWA 7831, and NWA 6693 have experienced broadly similar hot-desert terrestrial weathering, yet only NWA 4587 shows clear evidence of hydration, therefore we conclude that the hydration signature is not due to terrestrial weathering. There is some variability in the hydration feature region in the NWA 4587 spectra, due to a complex interplay of crystallographic orientation and variable optical path length through the two pyroxene phases.

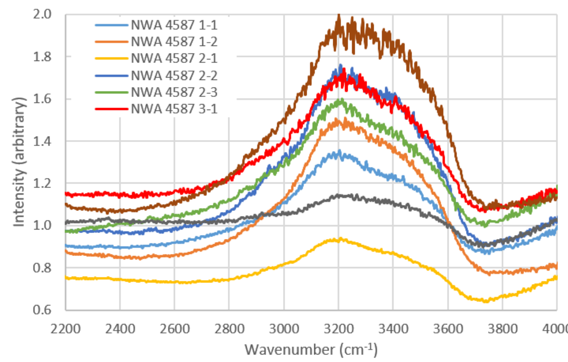

Figure 3: Detail of the hydration feature region for spectra of NWA 4587. A maximum in absorption near 3200 cm^{-1} with shoulders near 3500 cm^{-1} and 2900 cm^{-1} are consistenly observed. Variations in crystallographic orientation and differences in optical path length in the two pyroxene phases present are the most plausible cause of the observed variability.

At present, quantification of the hydrogen content and speciation in the NWA 4587 pyroxenes is hampered by the fine-scale exsolution textures present. Nevertheless, these results demonstrate that hydrous magmatic processes took place on differentiated asteroids, perhaps originally close to Vesta in size. Hydration has significant effects on the physical and chemical behaviour of magmas and should be considered in the context of planetesimals formed from precursors with carbonaceous chondrite affinity. Such bodies may once have been common prior to disruption and removal froms stable orbits, and their remanants may still exist, for example in outer-belt basaltic asteroids.

References: [1] F.M. McCubbin et al., Geology (2012) 40 (8): 683–686. [2] E. Hauri et al., Science, 333 (2011), pp. 213-215. [3] C. Floss et al., MAPS 40(3) 343–360 (2005). [4] M. H. Huyskens 50th LPSC abstract 2132 (2019). [5] Hibiya et al., GCA 245 597-627 (2019). [6] Izawa et al., JpGU-AGU Joint Meeting 2020 abstract PCG23-01 (2020)