

WATER CONTENTS OF ANGRITES, EUCRITES, and UREILITES AND NEW METHODS FOR MEASURING HYDROGEN IN PYROXENE USING SIMS. J. M. Dudley¹, J. P. Greenwood¹, N. Sakamoto², K. Abe.^{1,2}, M. Kuroda², and H. Yurimoto², ¹Dept. Earth & Environmental Sciences, Wesleyan University, 265 Church St., Middletown, CT 06457, ²Natural History Sciences, Hokkaido University, Sapporo, Japan 060-0810.

Introduction: The origin of Earth's water remains a topic of debate, with comets [1] and chondrite meteorites [2] as favored sources. Recent advancements have led to a growing hypothesis that Earth represents a mix of volatile sources accreted both during and after its formation [3].

A series of studies interpreted magnetization in CV carbonaceous chondrites as evidence of planetesimal core dynamos and re-examined models linking the chondrite and achondrite meteorites to a common parent body [4-5]. If the stony-meteorites are as interrelated as this work suggests, the volatile contents of achondrites may supplement existing chondrite research and provide useful constraints to the amount of water delivered during planet-forming processes. Here, we study the water contents of the angrite, eucrite, and ureilite achondrite meteorites to estimate the volatile contents of differentiated planetesimals incorporated by the terrestrial planets during their formation.

Volatile studies of achondrites are limited and present a range of water concentrations in phosphates [6, 7], pyroxene [8, 9], olivine [7, 10-12], and whole rock [13]. We measured hydrogen in pyroxene in Juvinas, Pasamonte, D'Orbigny, Northwest Africa 4590 (NWA 4590), and Pecora Escarpment 82506 (PCA 82506) using SIMS with live SCAPS (Stacked CMOS-type Activated Pixel Sensor) ion imaging and compared new methods for sample preparation of low-water samples (<20 ppm).

Methods: New reference materials have been established for measuring hydrogen in pyroxene using SIMS [14]. Grains of 6 standards, Suprasil 3002 glass (1 ppm H₂O certified by Heraeus Quarzglas), and standard mount were provided by K. Kumamoto [14]. A second standard mount was prepared to develop a calibration curve reflective of the mounting techniques described below.

Sample preparation. 200-300 mg chips were requested for each sample. Pyroxene grains were separated from Pasamonte under an optical microscope, mounted in a disk of low-temperature metal, and placed in an 80 °C oven under vacuum. Remaining meteorite chips were divided among 3 additional disks and mounted directly. For calibration purposes, 2-4 grains of the pyroxene reference materials were included in mounts containing meteorite chips.

Each mount was smoothed with a sequence of silicon carbide papers and absolute ethanol. For the final polish, D'Orbigny and NWA 4590 were polished with 1 µm, and 0.05 µm alumina powder and absolute ethanol. The new standard mount, and 3 mounts containing Juvinas, Pasamonte grains, and PCA 82506 were polished with 3 µm, and 1 µm diamond paste and oil.

SEM. The JEOL 6390-LV SEM at Wesleyan University was used to identify pyroxene in each chip and confirm Pasamonte pyroxene grains. The JEOL FEG SEM (JSM-7000F) at Hokkaido University was used to develop BSE maps of each sample to locate target grains for the remaining analyses.

SIMS. The modified Cameca ims 1270 at Hokkaido University with live SCAPS ion imaging was used for the hydrogen analysis. Target grains were monitored with SCAPS to avoid cracks and areas of adsorbed water contamination. Spots were pre-sputtered for 30 sec with a 10keV Cs+ primary beam over a 20x20 µm area. ¹H and ³⁰Si were determined from a central 5x5 µm area in 20 cycles. Analyses were collected on multiple days for Juvinas, D'Orbigny, NWA 4590, and PCA 82506. Pasamonte grains were analyzed in a single day.

EPMA. The JEOL JXA-8530F FEG Hyperprobe at Yale University was used to collect compositional data for each grain analyzed via SIMS

Results: Using each sample's final measurements, eucrite pyroxene ranged 1-3 ppm H₂O (n=6), angrite pyroxene 3-12 ppm H₂O (n=7), and ureilite pyroxene 11-13 ppm H₂O (n=3) with 10% error due to counting statistics (Fig. 1).

Discussion: As others have noted [8], SIMS analysis of hydrogen in NAMs is challenging at low concentrations. Measurements are highly dependent on analytical background and can therefore only be interpreted as maximum estimates.

SCAPS and vacuum effects. The live SCAPS ion imaging minimized the effects of adsorbed water and allowed us to determine concentrations <20 ppm. Fractures within shocked meteorites can become filled with polishing residue and are difficult to avoid during SIMS analysis. With the SCAPS detector we were able to image ¹H along each sample's surface and center our measurements over low signal areas. As the analysis proceeded, we observed that the hydrogen signal in standards and samples decreased with time. Calibration

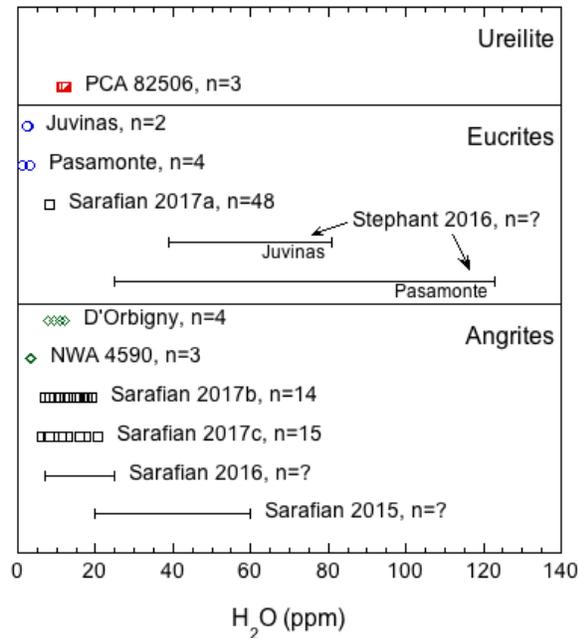


Fig 1. H_2O contents of angite, eucrite, and ureilite olivine and pyroxene. Results of this study shown in color (n=# of measurements, ?=unknown).

curves were re-generated each day to account for this variation and samples were analyzed until water contents plateaued. Juvinas, D'Orbigny, and NWA 4590 spent 10 days under vacuum before the measurements were completed. The ureilite mount was left in the instrument for an additional 2 weeks (Fig. 2). A minimum of 1-2 weeks of pumping time may be appropriate for future analysis of mounts containing thick-section samples. Less pumping time may be required for grains mounted individually.

Sample Preparation. Two samples were polished with ethanol and three were polished with oil. We cannot compare these techniques as they were used for different samples. However, $^1\text{H}/^{30}\text{Si}$ was lowest in Pasamonte grains that were polished with oil and analyzed on the first day of the experiment. Sample size may have a greater effect on hydrogen measurement than polishing technique.

Water contents of differentiated bodies. Our sample selection covers a range of thermal histories. The eucrites experienced different stages of metamorphism (Type 1-6) with unequilibrated (Pasamonte=2) and equilibrated (Juvinas= 5) textures [15], yet have similar water contents. The volcanic Angrites cooled rapidly and have quenched textures with zoned olivine and pyroxene, while the plutonic Angrites cooled slowly and have cumulate-like textures with equilibrated minerals [16].

We compare ~10 ppm H_2O (n=4) in volcanic angrite D'Orbigny to ~4 ppm H_2O (n=3) in plutonic angrite

NWA 4590 and conclude that the difference between the water contents of these samples may reflect the dichotomy of the cooling history in the angrite suite.

The ureilites have coarse textures that are likely the result of extensive processing before fast cooling upon the UPB's disrupt [17]. Water content of PCA 82506 overlaps with that of angites and eucrites (Fig. 1) and implies that similar amounts of water were retained within the highly-processed materials of differentiated planetesimals. Estimates of the total water contents of the angrite, eucrite, and ureilite parent bodies will be discussed at the meeting.

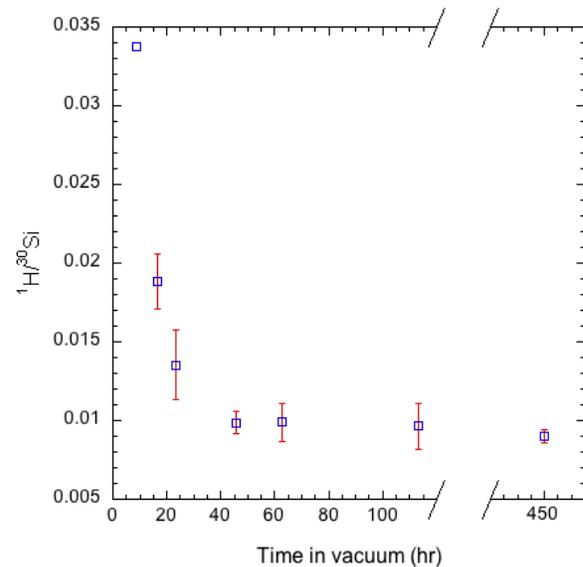


Fig 2. Vacuum effect on ~62 ppm [14] standard SC-J1 in PCA 82506 mount.

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