BULK MINERALOGY, WATER ABUNDANCE, AND H ISOTOPE COMPOSITION OF UNEQUILIBRATED ORDINARY CHONDRITES.

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Introduction: Unequilibrated ordinary chondrites (UOCs) represent some of the most pristine early Solar System materials available, having undergone minimal aqueous and thermal alteration. Low petrologic subtype UOCs record evidence of hydration, for example in the form of secondary phyllosilicates [1-3], which appear to host water with some of the highest D/H ratios of any Solar System objects [4-7]. D/H ratios are used as a tracer for the origin and distribution of H and water in the protoplanetary disk, with most models suggesting a H_2-rich, low D/H environment in the warm inner Solar System, with H_2O/H_2 abundance and D/H ratios increasing with heliocentric distance [8]. Despite having formed in the inner regions of the asteroid belt, water in some UOCs has D/H ratios at least as high as those typical of outer Solar System comets [4-7]. Therefore, UOC sample data seem at odds with existing models for D/H evolution in the protoplanetary disk, which warrants further investigation. Obtaining homogenized bulk data on UOC samples allows us to investigate trends across different groups and petrologic subtypes, and will help interpretation of mineralogical and isotope variations seen at the micron scale in individual samples.

Methods: Small chips (< 100 mg) of 21 UOCs (15 falls and 6 finds) from the H, L, and LL groups, and spanning between petrologic subtypes 3.00 to 3.9, were finely ground to provide homogeneous bulk powders. Their bulk water abundances and H isotope compositions were determined using the Thermo Scientific EA IsoLink – deltaV IRMS System at the CRPG in Nancy, following the method detailed in [9]. In addition, bulk mineralogical compositions of 14 of the falls were determined on the remaining powders using a Rigaku Rapid 2 Micro-XRD (X-ray diffraction) instrument at the Natural History Museum in London.

Results and Discussion: While hydrated phases such as phyllosilicates are predominantly found in the fine-grained matrix in UOCs of the lowest petrologic subtypes [1-3], we find that it is still possible to observe evidence of these hydrated minerals from homogenized bulk powders using XRD. XRD data show that olivine is the dominant mineral, at ~50% abundance, and that it has a wide spread of compositions ranging from at least Fo20 to Fo100 in UOCs of the lowest subtypes, becoming more homogeneous with increasing metamorphism. The remaining ~50% of mineral phases is comprised of ortho- and clinopyroxene, sulfides, metals, and in some cases low abundances of plagioclase and phyllosilicates (up to ~10 wt. %). With increasing subtype, XRD peaks become sharper and more intense, reflecting increasing equilibration. Bulk water measurements range from 0.05 wt.% for the most equilibrated samples up to ~1.0 wt.% (when excluding finds) for the least equilibrated. Assuming all the water is contained in phyllosilicates, and based on estimated phyllosilicate water contents of ~10 wt.% [10], this would imply bulk phyllosilicate abundances of ~10 wt.% for the most H_2O enriched, least equilibrated samples. We also find large variations in bulk chondrite D/H ratios between low and high petrologic subtypes, with falls of the lowest subtypes such as Semarkona (LL3.00) and Bishunpur (LL3.15) having δD values >750‰. On the other hand, petrologic subtypes 3.6 and above tend to be characterized by a narrow range of δD values between -60 and -120‰. Interestingly, Tieschitz and Ngawi, both classified as subtype 3.6, have unexpectedly high δD values of 420‰ and 1140‰. These samples present some peculiar features, such as the presence of amphiboles in Tieschitz [11], and some characteristics corresponding to lower petrologic subtypes than their currently assigned subtype of 3.6 [12]. The lowest petrologic subtype UOCs have D/H ratios higher than those measured in water-rich CI, CM, and CR carbonaceous chondrites (CCs), despite UOC parent bodies having formed closer to the Sun than CC parents. Such elevated D/H ratios in the least metamorphosed UOCs suggest greater addition of D-rich interstellar ices, which may imply that OC parent bodies accreted later than CC parent bodies, or were supplemented with additional material post formation [13]. OC with petrologic subtypes >3.6 have much lower bulk D/H ratios, suggesting that low degrees of thermal metamorphism on the OC parent bodies destroyed this D-enriched primordial component.

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