WEATHERING OF H-CHONDRITE ROOSEVELT COUNTY 037. J. Levine[1], M. A. Segreti[1], and K. D. Heylman[1], [1]Department of Physics and Astronomy, Colgate University, Hamilton, New York 13346, USA (jlevine@colgate.edu).

Introduction: The H-chondrite meteorite Roosevelt County 037 has an unusually long terrestrial age, even for meteorites found in this desert locality [1,2]. From the lack of cosmogenic ^{14}C above terrestrial backgrounds, Jull et al. [1] inferred a lower limit on the terrestrial age of this meteorite of 46,000 years. We seek to constrain more precisely how long this meteorite has survived in the terrestrial environment, by determining abundances of the longer-lived cosmogenic nuclides ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{59}Ni.

Weathering of any meteorite poses potential problems for terrestrial age dating. Only if a meteorite has remained a chemically closed system for its entire residence on Earth can cosmogenic nuclide abundances be simply interpreted in terms of the terrestrial age. Because loss of cosmogenic nuclides by processes other than radioactive decay potentially compromises our ability to use nuclear systems as clocks, we have investigated the effect of weathering on the chemical composition of Roosevelt County 037.

Observations: A polished thick section of Roosevelt County 037 (Fig. 1) reveals sub-centimeter areas that are alternately dark and light in color. The dark areas are reddish brown and contain a few mm-sized metal grains. By contrast, the light areas are tan to golden orange in color, and have no evident metal. We infer, on the basis of their rusty color and lack of metal, that the light-colored areas are more heavily weathered than the dark areas. Relict chondrules are visible in both kinds of area, with one >1 mm chondrule in a heavily weathered area (lower left of Fig. 1) and several smaller chondrules throughout the section, exhibiting both porphyritic and barred olivine textures.

The division of the meteorite into domains of distinct weathering affords us an opportunity to assess quantitatively the extent to which weathering compromises the chemical integrity of the sample, and ultimately the retention of cosmogenic nuclides. We used the JEOL JSM-6360LV scanning electron microscope at Colgate University to examine the polished section of Roosevelt County 037, imaging the sample in backscattered electrons and measuring the abundances of major elements by energy dispersive x-ray spectroscopy. The lightly weathered areas have subhedral crystals that are cut by thin fractures that appear bright in backscattered electrons (Fig. 2, left). The heavily weathered areas have a stucco-like texture: the few large crystals are embedded in a densely pitted filamentary matrix (Fig. 2, right).

Generally, the heavily weathered areas appear brighter in backscattered electron images than do the lightly weathered areas, implying a gross chemical difference between the two kinds of area. We sought to determine whether weathering caused the chemical difference we observed, or whether the spatial pattern of weathering of this meteorite was controlled by pre-existing chemical heterogeneities. This question has important implications for interpreting cosmogenic nuclide abundances. If weathering significantly changes the chemical composition, one must expect substantial exchange of atoms between the meteorite and its environment, possibly including loss of cosmogenic nuclides. In such a scenario, relatively unweathered regions of the meteorite could more faithfully retain their cosmogenic nuclides and record the true terrestrial age of the meteorite. On the other hand, if weathering preferentially affects certain regions of the meteorite because of pre-existing compositional differences, one could possibly determine a terrestrial age by normalizing the abundances of cosmogenic nuclides to the concentrations of target nuclides in the lightly weathered region alone, rather than in the bulk meteorite [3].

Figure 1: Polished section of Roosevelt County 037 photographed in true color, showing heavily and lightly weathered areas. Section is 15 mm long.

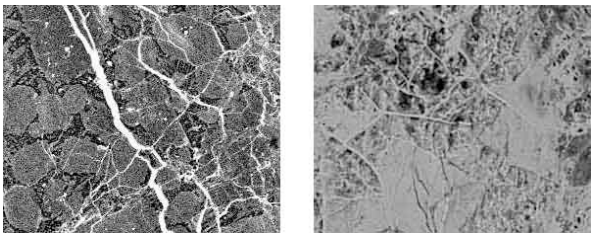

Figure 2: Backscattered electron images of lightly (left) and heavily (right) weathered areas. Fields of view are ~150 μm.

Data: We acquired 10 energy dispersive X-ray spectra of ~0.2 mm^2 fields of view in a lightly weathered area and another 10 in a heavily weathered area of the meteorite, and we determined the abundances of major elements in each field. To assess whether the chemical differences between the two kinds of area were controlled by weathering or vice versa, we compared each of our analyses with bulk compositions of H-chondrites from [4,5,6]. Because fresh H-chondrites are chemically similar [e.g., 6], we assume that the bulk composition of fresh H-chondrites represents the bulk composition that Roosevelt County 037 had when it arrived on Earth. If the weathering of Roosevelt County 037 were controlled by pre-existing chemical heterogeneities, we would expect the compositions of the heavily and lightly weathered areas to be displaced by nearly equal amounts in opposite directions from the assumed bulk composition (the two weathering domains represent nearly equal amounts of material). On the other hand, if the chemical compositions of the two kinds of area differ as a result of weathering, the composition of the heavily weathered regions should differ greatly, and the composition of the lightly weathered region only slightly, from the bulk composition of the other H-chondrites. We find that the latter is more consistent with our observations.

Relative to the H-chondrite bulk composition, the heavily weathered areas of Roosevelt County 037 are depleted in Si and less so in Mg, but enriched in Al and especially Fe (e.g., Fig. 3). This pattern of element enrichments and depletions is typical of leached soils [e.g., 7]. The less weathered areas of the meteorite are slightly depleted in Fe and Ni, and contain the other major elements Mg, Al, Si, and Ca in nearly their chondritic proportions to one another (Fig. 3). This pattern suggests that even the lightly weathered areas

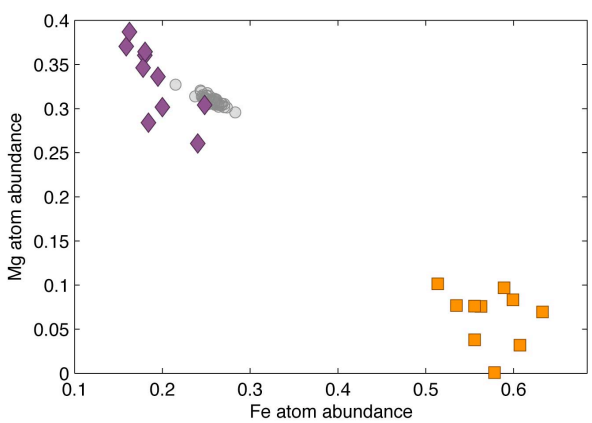

Figure 3: Atomic abundances of Fe and Mg in heavily (squares) and lightly (diamonds) weathered areas of Roosevelt County 037. For comparison, bulk analyses of 53 H-chondrites from [6] are shown as light circles.

of the meteorite have undergone oxidation of metal in these areas to oxides and hydroxides [8], with overall loss of Fe and especially Ni.

Implications: The oxidation of metal that has affected the lightly weathered areas of the meteorite presumably affected the entire rock. The main difference between the heavily and lightly weathered areas seems to be that soluble cations such as Si and Mg have been leached from silicate minerals in the heavily weathered areas, but not yet in the lightly weathered areas. In the heavily weathered areas, the alteration products left behind after removal of the mobile elements are strongly enriched in Fe and Al

The weathering history of this meteorite suggests that cosmogenic ^{36}Cl (mostly produced by spallation of Fe) may largely have been lost during the oxidation of the metal grains that had hosted it. (Measured $^{36}Cl/Cl$ ratios could also have been corrupted by incorporation of terrestrial Cl during oxidation [9].) Some cosmogenic ^{59}Ni (produced by neutron capture on ^{58}Ni) has presumably been lost as well, but oxidation should not have fractionated Ni isotopes, so the $^{59}Ni/^{58}Ni$ ratio should be relatively insensitive to weathering. Cosmogenic ^{41}Ca (produced by both neutron capture on ^{40}Ca and spallation of Fe) has likely been retained in the silicate fraction of the lightly weathered areas, and so can yield useful information for terrestrial age dating. Cosmogenic ^{26}Al (produced by spallation of Al and Si) is likely to have been retained in all regions of the meteorite. We will test these hypotheses by measuring the cosmogenic nuclide abundances separately in the lightly and heavily weathered areas. This will allow us both to find the terrestrial age of Roosevelt County 037 and to quantitatively assess the extent to which weathering compromises terrestrial age determinations.

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