

## ANALYSIS OF WEATHERING IN ANTARCTIC H5 AND CR CHONDRITES USING MÖSSBAUER SPECTROSCOPY

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**Introduction.** Mössbauer spectroscopy is a very useful tool for identifying weathering products in meteorites because of the capability to quantify the relative amounts of ferric iron. Mössbauer measurements were made of thirty-three Antarctic H chondrites [1] and two paired CR chondrites to try to determine if a weathering sequence can be derived from Mössbauer analyses and if the relative amount of ferric iron correlates with the terrestrial age of the meteorite.

**Experimental Procedure.** A sample mount for each specimen was prepared by mixing 15 to 110 mg of powdered meteorite with 300 to 400 mg of sucrose. A Mössbauer spectrum for each meteorite was obtained at room temperature using a  $^{57}\text{Co}$  source in Rh foil at a  $\pm 5$  mm/s velocity range, which cut off the outermost peaks of any magnetic sextets that were present. The total area of all the iron peaks was computed by adding the areas of each of the peaks in the spectrum plus the areas of the two metallic iron and two troilite peaks (when present) outside the  $\pm 5$  mm/s velocity range and whose areas were calculated from the 3:2:1:1:2:3 area ratio for peaks in magnetic sextets. The relative area for iron in a particular mineral (or oxidation state) is calculated by dividing the area of the peaks (including peaks outside the  $\pm 5$  mm/s velocity range) associated with that mineral by the total area of all iron peaks. The relative area for each mineral is proportional to its amount in the sample, its iron content and its parameter  $f$  (recoil-free fraction).

**Mössbauer Results.** To try to determine if Mössbauer spectroscopy can be used in deriving a weathering sequence for ordinary chondrites, the relative areas of the peaks assigned to metallic iron, troilite, olivine and pyroxene were compared to the relative areas of the peaks assigned to  $\text{Fe}^{3+}$  for both the samples (predominately H5) in this study and the samples in a study of Shinonaga *et al.* [2]. (Petrographic studies [3] of ordinary chondrites support a sequence of weathering that affects first the metal grains, then the troilite and finally the silicates.) Shinonaga *et al.* did a similar Mössbauer study of thirteen H chondrites and one L chondrite that was mistakenly labeled in their paper as an H chondrite. Ordinary chondrites should have negligible amounts of ferric iron when they fall to earth. If the samples have the same initial (before weathering) relative amounts of iron in different minerals and no iron is lost nor added to the sample during weathering, then the creation of ferric iron should decrease the relative areas of peaks associated with minerals that are weathering. Minerals that are not weathering should show no decrease in the relative areas of their peaks with increasing amounts of ferric iron. In our study, the relative areas of the peaks assigned to metallic iron show no real decrease with increasing relative area of the ferric iron peaks. The relative areas of peaks assigned to troilite, olivine and pyroxene do appear to show a slight decrease with increasing relative area of the ferric iron peaks, however there is a large amount of scatter among the points. The reason for this lack of any apparent decrease in the relative amounts of metallic iron with increasing ferric iron content may be due to the problems in preparing meteorite powders that initially had the same abundances of metallic iron, troilite, olivine and pyroxene. These heterogeneous compositions make it very difficult to determine which minerals are weathering since the relative iron content of minerals in each H chondrite sample will be functions of both the initial relative iron content and the amount of weathering of that mineral.

This interpretation is different from the conclusions of Shinonaga *et al.* Although they concluded that there was no correlation between the relative abundances of metallic iron and ferric iron, they stated that the decrease in relative amounts of troilite and silicate minerals (olivine and pyroxene) with increasing relative amounts of ferric iron was indicative of weathering of these minerals to produce ferric oxide products. The reason for this different interpretation is that the relative areas of the peaks of metallic iron in the study of Shinonaga *et al.* are relatively constant (4-12%) while the relative areas of the peaks assigned to metallic iron in the samples analyzed in this

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study tended to be more varied (7 to 39%). For some unknown reason, the samples of Shinonaga *et al.* had relative amounts of metallic iron that tended to be relatively constant for different amounts of weathering while the samples in this study had relative amounts of metallic iron that varied considerably for specimens even with the same amount of weathering.

Mössbauer measurements were also done on two paired Antarctic CR chondrites (EET87747 and EET87770). EET87747 was found to have higher relative amounts of ferric iron and lower relative amounts of metallic iron than EET87770. (In CR chondrites, the ferric iron is found in both pre-terrestrial phyllosilicates and the weathering products of metallic iron.) The sum of the relative areas for the iron peaks assigned to metallic iron and ferric iron for both samples was approximately 87%. This data indicates that EET87747 is more heavily weathered than EET87770 and that ferric iron is being produced from the weathering of the metallic iron, which keeps the sum of these two relative areas constant. These analyses also contradict with the results of the Mössbauer study by Shinonaga *et al.*, who found no evidence for the production of ferric iron by the weathering of metallic iron.

**Terrestrial Ages.** To try to determine if there is any correlation between terrestrial age and amount of weathering in the H chondrite samples, the  $^{14}\text{C}$  [4] [5] [6] and  $^{36}\text{Cl}$  [7] terrestrial ages for twenty-five of the meteorites with calculated ages were compared to the relative areas of their ferric iron peaks. No correlation was evident between the terrestrial ages and the relative amounts of ferric iron in the H chondrites. The absence of any apparent correlation firmly supports the scenario that the amount of weathering of an Antarctic meteorite is indicative of the amount of time the meteorite has spent on the surface and not the total time that it has resided on the earth.

One of the H chondrites (ALHA77294) had  $^{14}\text{C}$  dating done on extracted  $\text{CO}_2$  from carbonates in the meteorite [8]. The percent of modern carbon corresponded to an age of  $135 \pm 200$  years before present (BP), where present is 1950 AD. The short  $^{14}\text{C}$  age of the carbonates from ALHA77294 implies a relatively short time that this meteorite has been exposed on the surface. This "weathering age" is supported by the Mössbauer measurements of ALHA77294, which determined that this meteorite had one of the lowest relative areas of ferric iron (8%) of all meteorites in the study. One inconsistency in this argument is that liquid water should be a major factor in carbonate formation on a meteorite, which would imply that a meteorite with carbonates should also have relatively high amounts of ferric iron.

**Conclusions.** Comparisons of relative amounts of ferric iron in meteorites can easily be done using Mössbauer spectroscopy. However, determining the sequence of weathering for different minerals in ordinary chondrites appears very difficult due to the samples not initially having the same exact compositions. The analyses of the two paired Antarctic CR chondrites show that the metallic iron is weathering before the silicate minerals. No correlation is evident between relative amounts of ferric iron and terrestrial age for Antarctic H chondrites.

**Acknowledgments.** This paper is dedicated to Roger G. Burns (1937-1994) and represents the completion of a line of investigation that was in progress at the time of his death. The authors would like to thank Tim Jull and Mike Lipschutz for use of their unpublished terrestrial ages. This research was sponsored by NSF grant EAR-9117857.

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