METEORITES AS INDICATORS OF PALEOCLIMATIC CONDITIONS.

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Abstract: A study of ordinary chondrites from three hot deserts suggest that highly weathered samples resulted when the meteorites involved fell at times when the rainfall was high. A mechanism for the weathering process consistent with this observation is proposed, and we forsee an exciting new use for thousands of high grade ordinary chondrites recovered by collection programmes.

Meteorites have the valuable property that their arrival on the surface of the Earth can be dated from the subsequent decay of cosmogenically produced radionuclides. The vast majority of them (ca. 90%) are ordinary chondrites, whose classification scheme is based on the abundance of reduced iron (Fe^0) and Fe^{2+} containing minerals. Once chondrites are present in the natural environment, their iron containing minerals begin a gradual change to the Fe^{3+} valence state through weathering until the samples either become "finds" or erode away completely. The ages of samples discovered in temperate environments compared to those found on Antarctica suggests the lifetime of a meteorite on Earth may be from a couple of thousand to over a million years, (1, 2). It has often been stated that meteorites have the potential to record paleoclimatic events during this sojourn (3, 4) but up to now this has not been realised.

To investigate the possibility of using meteorites as paleoclimatic indicators, we have studied suites of ordinary chondrites from the Nullarbor region of Australia, Roosevelt County, New Mexico, the Daraj locality of the Libyan Sahara and the Allan Hills, Antarctica. All the specimens are of known terrestrial age, determined by ^{14}C measurement. To monitor the rate of weathering, we acquired Mössbauer spectra which can be interpreted in respect of the absolute and relative abundance of various distinct minerals present in the sample. However for the purposes of discussion here, we consider only two parameters: the percentage of the total spectral area due to Fe^{3+} and the percentage of the spectral area accounted for by ferromagnesian silicates (olivine and pyroxene); these are almost, but not quite, complimentary estimates of the state of preservation of meteorite samples.

In common with others (2) we have found that there is no clear correlation between the extent of weathering and age of the material for Antarctic meteorites. Presumably chondrites only begin to be destroyed, when their fabric is affected by liquid water at a sufficient temperature for the chemical reactions involved in weathering to proceed. As a direct contrast to the above however, we have found in all three instances, that chondrites from hot deserts have a direct relationship with their terminal age and environmental history. The increased abundance of Fe^{3+} (loss of silicates) does not show a simple time dependency. Rather, it was observed that some samples, which apparently fell relatively recently, were more weathered than those with much longer residence times and vice versa. The key to understanding this phenomenon is the realisation that deserts are not deserts all of the time. During the timespan covered by the samples investigated, the regions where the meteorites fell have gone through several climatic cycles. The deviations, from a linear trend of weathering with time, match with periods of significant climatic change independently measured by a variety of other techniques. For example, palynological evidence indicates that the Nullarbor Plain was very arid from 20000 to 10000 BP (5) but at its wettest (peak lake levels) at 8000 BP (6). Speleothem studies indicate another wet period between 37000 and 20000 BP (7). During the periods when the Nullarbor Plain was wetter than today weathering as measured by Fe^{3+} was at a maximum. The Daraj and Roosevelt County samples also reveal times when more or less weathering corresponds to fluctuations in rainfall. Although the data coverage is incomplete, the fact that three hot desert sites are in agreement cannot be coincidental. A correlation which strengthens our case. Fe^{3+} abundance data emerges if Fe^{3+} from all the sites are combined and plotted against age, with the H and L (LL) chondrites separated. The complex patterns are in fact very similar with L(LL) chondrites showing slightly less weathering. The agreement between the two sets of samples verifies that the trends seen in for the individual sites are probably real and not simply because different types of chondrites were weathered differently.

For meteorites to record the climatic conditions prevailing at their time of fall, weathering must be at least a two stage process with the most significant phase occurring in the period immediately after the samples arrive on Earth. We propose that during this period, when the meteorite is fresh and its porosity greatest, weathering is rapid. Newly formed weathering products block the pores and armour the mineral grains against further degradation which is consequently much slower. Thus meteorites which fell originally in dry periods can survive subsequent wet ones.

The ideas put forward here are at an early stage of development but if they prove to be correct they create a valuable scientific rôle for the hundreds to thousands of high petrologic type ordinary chondrites recovered by the collection programmes of ANSMET, EUROMET and NIPR, especially if a way can be found to include the Antarctic samples thus extending climatic coverage to 10^6 years. It should also be appreciated that a better understanding of the fate of meteorites is essential for the evaluation of models which might show whether the meteorite flux has varied with time.

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