CHANGES IN THE NOBLE GAS PATTERN OF HOT DESERT METEORITES CAUSED BY WEATHERING - CORRELATION WITH TERRESTRIAL AGE AND WEATHERING GRADE.

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Abstract: We present new noble gas data on 11 ordinary H-chondrites from the Acfer region and one from Roosevelt County that confirm earlier results and provide additional information about the coherence of atmospheric noble gas contamination with the degree of weathering and terrestrial age. To study the compositional variations in heavily weathered meteorites in more detail, noble gases in four of these chondrites are determined from interior and exterior sections of the same specimen.

Introduction: The recent gain in importance of hot desert meteorites is mainly due to the enormous influx of interesting specimens collected in arid and semiarid areas around the globe, with Australia, Africa and North America contributing the bulk of desert finds. Weathering of meteorites is an important aspect for the study of noble gases in extraterrestrial matter. It is well established that these meteorites have experienced considerable changes regarding their original physical and chemical records. The effect on the noble gas composition is twofold. The light noble gases He and Ne are depleted in extensively alterated parts of the chondrites and Ar, Kr and Xe show an additional contamination with atmospheric gases that is roughly correlated with their weathering grade [1].

Experimental Techniques: Isotopic composition and concentration of He, Ne, Ar, Kr and Xe were determined with the MAP 215 mass spectrometer "Alfred". All samples were preheated in vacuo for at least 48 hours at 140°C to remove any lightly bound adsorbed atmospheric gases, in particular Kr and Xe. A detailed description of the apparatus and the experimental procedures is given by Loeken [2].

Observations: It has been shown earlier [1] that different meteorite "populations", namely Antarctic meteorites, hot desert meteorites and modern falls are separated in a ^{132}Xe /^{84}Kr versus 1/^{84}Kr plot (Fig.1). The typically moderate to severely alterated meteorites from hot deserts are characterized by an additional contribution of atmospheric ^{84}Kr. This excess of ^{84}Kr (by a factor of up to ten for the investigated H-chondrites) is due to the high ^{84}Kr/^{132}Xe ratio of about 28 in the terrestrial atmosphere. Ordinary chondrites with high contamination scatter predominately around the value of atmospheric gases dissolved in liquid water (^{132}Xe/^{84}Kr ~ 0.073). This is one indication that the heavy noble gases are carried into the meteorite by liquid water and are then incorporated in hydrous secondary minerals. All investigated Acfer samples and RC037 plot within the cluster of hot desert meteorites. For Acfer 206, 212, 292 and RC037 additional measurements were performed in an exterior and interior section of the sample. While it is macroscopically not possible to distinguish two separate alteration zones for the Acfer samples, RC037 shows a distinct zoning pattern with a more severely alterated outer rim. RC037 has a considerable smaller concentration of He and Ne in the exterior rim probably caused by chemical leaching while buried in the soil. The depletion factor for He and Ne is more than a factor of two. This result was confirmed by a second series of measurements. The fact that the weathering history for RC037 is completely different compared to the Acfer samples (more intensive chemical weathering because buried in soil and exposed to liquid water for thousands of years) explains why the Algerian meteorites Acfer 206, 212 and 292 show only small depletions for He in the exterior part of the specimen and within errors of ± 5% for concentrations they are even negligible. The difference of the weathering grade in both zones is small and the contribution of aggressive chemical weathering is much less for the Acfer samples. Surprisingly, the heavy noble gases are not always enriched in the outer zones (which might be expected especially for RC037 with weathering index W6) indicating that alteration products alone are not the only source for atmospheric Kr and Xe excess, but also mechanical weathering processes [1]. However, the ^{84}Kr/^{132}Xe ratio for all Acfer samples is always higher in the exterior zone compared to the interior. The relative amounts of the dominant Kr and Xe carrier in meteorites, ferric iron (Fe^{3+}), are used as an indicator for the degree of weathering [3]. Jull and Wlotzka [4,5] have successfully attempted to correlate terrestrial ages and weathering grade for meteorites collected in selected desert areas like Acfer and Roosevelt County. In Fig. 2 we show the concentration of ^{84}Kr and the ^{84}Kr/^{132}Xe ratio for the Acfer H-chondrites versus their weathering index and terrestrial ages, respectively. It is possible to identify a trend for noble gas data and weathering grade. The terrestrial ages, however, correlate reasonably well with the excess ^{84}Kr.

The fact that the noble gas data correspond much better with the terrestrial age than with the weathering index might be due to the fact that the latter is only a subjective and relative measure while the calculated ages are a more accurate measurement of the actual time they have spent on Earth. Assuming that weathering in these desert areas is a relatively linear process over thousands of years, which is most likely not always the case [6], and that the amount of pre-terrestrial ferric iron is negligible, this trendline could lead to an additional method to measure a relative time of terrestrial residency for ordinary chondrites collected in hot deserts.

Conclusions: Noble gas data obtained from weathered meteorites have to be scrutinized closely when calculating cosmogenic and radiogenic ages or when correcting for the atmospheric contribution of heavy noble gases. The concentrations of light noble gases in ordinary H-chondrites are depleted in severely altered meteorites by up to a factor of two and heavy noble gases are often enriched by a factor of up to ten. With some constraints it is eligible to use the excess concentration of contaminated Kr and Xe in chondrites from specific hot desert regions as a tool to obtain a rough estimate of their time of terrestrial residency. There are, of course, numerous limitations to this method that might complicate or even distort an interpretation, e.g. an unknown and complex - probably non-linear - climate and weathering history over thousands of years, different microclimatic conditions at a particular finding site (e.g. ridges and depressions) or substantial variations of the ^{84}Kr concentration within the same meteorite [1].

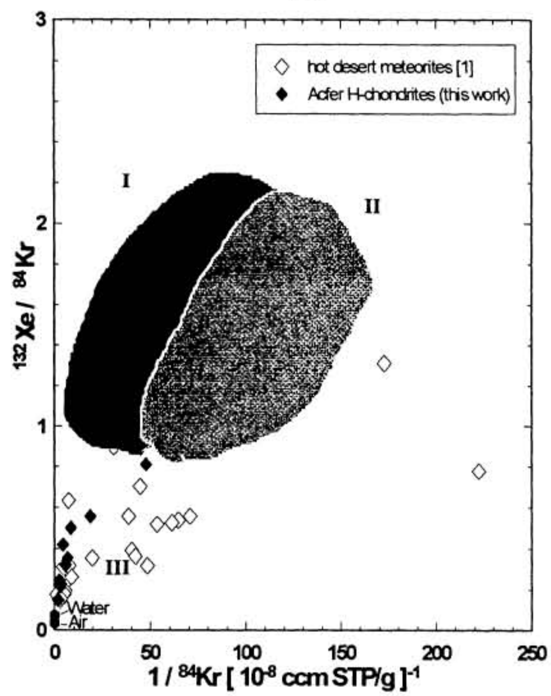

Fig.1: Distribution of three different meteorite "populations" according to their heavy noble gas composition. Cluster I symbolizes H-chondrite falls [7] and cluster II Antarctic H-chondrites [8]. The hot desert meteorites scatter in sector III close to the atmospheric value.

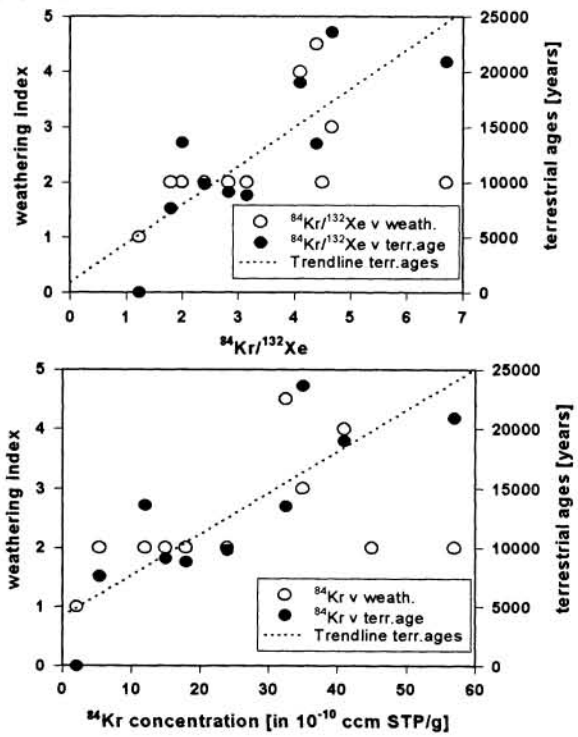

Fig.2: Correlation attempt of the $^{84}Kr/^{132}Xe$ ratio and the concentration of ^{84}Kr respectively with the weathering index [1,9] and terrestrial ages [5,10] for the Acfer samples.

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