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Linking alteration of noble gas inventories with secondary petrographic features in Antarctic meteorites – An analogue

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Abstract

Dolerite samples taken from Sandford Cliffs, Antarctica were used as meteoritic analogues for cold desert residence and studied to investigate subsequent alteration of noble gas inventories. The $^{84}Kr/^{132}Xe$ and $^{36}Ar/^{132}Xe$ ratios were seen to decrease with increased amounts of weathering, the $\delta^{15}N$ showed little change. The most weathered dolerite showed a signature close to Martian interior.

1. Introduction

Noble gas inventories of meteorites have many uses: from ascertaining points of origin [1] to measuring the compositions of solar matter [2], thus the understanding of how and why the noble gas inventories have been altered on Earth is of critical importance. There is special pertinence to Martian meteorites as the Martian signature is so intrinsic to the diagnosis and the Chassigny interior signature has been found to be close to elementally fractionated air [3] (Fig. 1). Noble gas inventories have been found to be compromised through Antarctic residence [4], but no clear relationship to other weathering indicators could be established to date. Here we present a combination of petrographic observations and heavy noble gas results to investigate into their relationships.

2. Samples

The samples used in this study are Antarctic dolerites collected by the 2003/2004 ANSMET team from a moraine at Sandford Cliffs. The samples consist of i) a 15 cm diameter boulder, ii) a half fist sized piece of rock and iii) gravel and fines from a freeze thaw zone. Samples from the interior of the boulder have been designated as fresh 1 and 2, the weathered exterior – weathered 1-3, and the gravel – moraine.

3. Petrography

The dolerite boulders primary minerals consist of pigeonite (En_{20-40}, Fs_{20-40}, Wo_{8-20}), augite (En_{15-50}, Fs_{10-50}, Wo_{30-45}) and plagioclase with minor amounts of myrmekite, ilmenite and ulvöspinel. Secondary products formed are smectites (Fe rich montmorillonites and Fe rich saponites) and minor Fe oxides (less than 1 um across).

The outer, weathered rim of the boulder can be seen to be fractured pervasively with the largest cracks following mineral boundaries. The most weathered pyroxenes' compositions were seen to be pushed towards more iron rich ferrosillite and away from enstatite. The myrmekite consisted of silica and K feldspar that preferentially alters to clays, leaving behind patches of silica (Fig. 2). The mineral boundary fractures suggest thermal stress may be an important mechanical break up mechanism [5]. The contacts between pyroxenes and myrmekite were exploited by fluids precipitating through the sample, as were the smectites whose micro-porosity allows water access to the reaction front [6].

The moraine samples consisted of dolerite fragments (82.3%), limestone (12.5%) and siltstone (5.2%). The fragments of dolerite were fractured throughout with small open cracks.

4. Noble gas results

The fresh and weathered samples appear similar in their low-T step release of ^{36}Ar and ^{132}Xe, however they can be differentiated on their $^{36}Ar/^{132}Xe$ and $^{84}Kr/^{132}Xe$ ratios [7]. The fresh samples were both similar with $^{36}Ar/^{132}Xe$ of 815±80 and 848±81and $^{84}Kr/^{132}Xe$ = 14±1, whereas the weathered samples $^{36}Ar/^{132}Xe$ varied between 247 and 381 and $^{84}Kr/^{132}Xe$ = 10.2±1. The moraine sample has $^{36}Ar/^{132}Xe$ = 27 and $^{84}Kr/^{132}Xe$ = 1.8. The fresh samples and weathered 2 and 3 show a wide range of $\delta^{15}N$, moraine and weathered 1 show $\delta^{15}N$ with the terrestrial air ratio within error.

5. Discussion

With increased weathering, the ratios of Ar and Kr to Xe decrease. This is possibly due to adsorption and desorption cycles, with Xe being adsorbed more favourably than Kr, which itself is more favourably adsorbed than Ar. At the same time, desorption favours Ar over Kr over Xe [8]. The nitrogen is less conclusive in the boulder, but the negative values of $\delta^{15}N$ in the moraine sample are similar to low values found in Antarctic soils [9]. When plotted with the Martian interior signature of Chassigny and Elementally Fractionated Air (EFA), the most weathered materials are close to the Chassigny signature. Also there is no consistent steady decrease in the $^{84}Kr/^{132}Xe$ ratio as the samples are increasingly weathered (see Fig. 1), therefore links between noble gas contamination and weathering are not simple but, rather, are likely related to the amount of fracturing within the samples.

6. Conclusions

Whilst an increasing grade of weathering is correlated to the noble gas signatures of samples being increasingly more similar to EFA, the relationship is not simple and can be related to mechanical failure caused by freeze thaw cycles and mineral boundary thermal stress. Therefore the relationship observed between the amounts of fracturing within samples and the morphology of the secondary products could provide a mineralogical indicator for the noble gas contamination.

References

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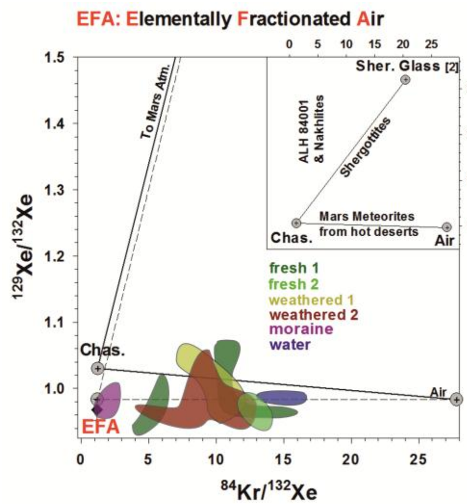

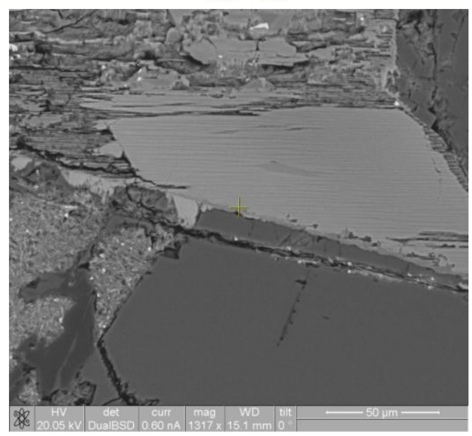

Figures 1 + 2. Figure 1: Three isotope diagram with water and EFA marked on. **Figure 2**: BSE image of needles of Fe nontronite with small Fe oxides forming. K feldspar has been exclusively replaced, leaving behind silica.