LIGHT NOBLE GASES IN AGGLUTINATES: A RECORD OF THEIR EVOLUTION?
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Recently (1, 2) we reported about He, Ne, and Ar analyses in constituents in the 150-200 \(\mu\)m grain size range for a variety of lunar soils. We found that composite, secondary soil particles contain higher concentrations of trapped solar gases than primary mineral particles and rock fragments. Here we concentrate on the following questions:
* Are the handpicked agglutinates and the magnetically separated agglutinitic glasses comparable in their noble gas concentrations and abundances?
* Do agglutinates of all grain sizes contain high concentrations of trapped noble gases?
* What is the distribution of trapped gases within agglutinates (surface/volume and glassy/crystalline material)?
* Is it possible to delineate a correlation between vitrification and gas fractionation in agglutinates?

In this context we report on exploratory experiments with separates from the mature highland soil 61501.

To investigate the gas concentration and composition in agglutinates and agglutinitic material, a 150-200 \(\mu\)m grain size fraction of the bulk soil was magnetically separated. The magnetic and nonmagnetic phases were then handpicked for agglutinates and breccias as defined in (2). Elemental ratios and gas concentrations are given in Figs. 1 and 2 (①). The agglutinitic separate ① can be viewed as a mixture of magnetic agglutinates and magnetic breccias, datapoints labelled 3 and 5, respectively. Datapoint 1, handpicked structural agglutinates (2) coincides reasonably well with that for the agglutinitic separate. Thus, our first question is, at least for agglutinates from

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**Fig. 1.** Element abundance ratios of trapped rare gases in various 150-200 \(\mu\)m agglutinate and breccia concentrates (①, 1 = handpicked structural agglutinates, see Ref. 2; 2 = agglutinitic concentrate; 3 = magnetic agglutinates; 4 = nonmagnetic agglutinates; 5 = magnetic breccia; 6 = nonmagnetic breccia), in eight grain size fractions ranging from 25 to 300 \(\mu\)m, of plagioclases and agglutinates as well as scolecitic (⑤) and dendritic (⑥) agglutinates and their constituents. The mode of preparation is indicated.
soil 61501, answered affirmatively. In addition we prepared concentrates in the 300–500 μm grain size range of scoriaceous (○, Figs. 1 and 2) and dendritic (⊗) particles which we regard as endmembers of the continuous agglutinate population, whereby the dendritic particles were about twice as abundant. Scoriaceous particles conform with “textbook” agglutinates; the very friable dendritic particles, however, consist of mineral and rock debris welded together by very small amounts of glass.

The two sets of analyses of agglutinates of similar size, but of different nature, revealed that the range of trapped gas concentrations and compositions is larger than anticipated from our previous study (2). This may indicate that different types of agglutinates have different histories. For intercomparison of trapped gases in agglutinates a knowledge of the preparative procedure is of utmost importance.

In an other experiment we measured eight grain size fractions of magnetically separated agglutinates and plagioclases, covering the range of 25 to 300 μm. Results are given in Figs. 1 and 2, for sake of clearness by cross-hatched fields only. In both figures, smaller grain sizes plot at larger values. Two features are apparent: A) Gas concentrations in agglutinates are much higher than in plagioclases for all grain size fractions. This is in accord with the conclusion in (2) that secondary particles are the dominant carriers of rare gases in bulk soils. B) In Fig. 1 agglutinate datapoints spread more than plagioclase datapoints, in accord with the spread noted above for agglutinates in the narrow grain size range. Perhaps increasing amounts of light nonmagnetic agglutinates (datapoint labelled 4) are present in finer grain sizes. In fact an anticorrelation of feldspathic material with grain size was detected in agglutinates of soil 15601 (3, 4). Alternatively, it is possible that the larger the agglutinates are, the more intense are the effects of reworking and hence the fractionation (see below).

To evaluate the distribution of trapped gases within agglutinates we etched scoriaceous (○) and dendritic (⊗) fractions thereof. Datapoints • and ★ refer to the etched residuals. The gas amounts in the removed material were calculated (symbols ○ and ★, respectively). The two types of agglutinates differ with regard to their surface and volume correlated trapped rare gases. Upon etching about 10% by weight of the scoriaceous and 15% of dendritic agglutinates are removed, whereas the amounts even of 36-Ar in these materials differ by a factor of about 5. Most likely this is due to the differences in minera-
LIGHT NOBLE GASES IN AGGLUTINATES

Etique et al.

logical compositions and glass content. We note that the 36-Ar surface concentrations of the unetched scoriaceous agglutinates and of the 300–500 μm plagioclases, as extrapolated from our grain size suite, agree within 50%. This indicates that the mean integrated surface exposure times of primary and secondary particles are similar.

The etched scoriaceous particles were further treated to delineate the trapped gas concentrations and compositions in the crystalline and glassy phases of the agglutinates. These particles were crushed, sieved, magnetically separated and handpicked for glass-rich (glass) and mineral-rich (min.) fragments as indicated in Fig. 1. The residue from handpicking was also analyzed (res.). Crushing and sieving led to two subsamples of slightly different trapped gas concentrations and abundances. Smaller particles have higher gas concentrations and higher 4-He/36-Ar ratios. The reason for this is unclear. The magnetic separation yielded a nonmagnetic, predominantly glassy sample, maske-lynite and some plagioclase. Its datapoint in Fig. 1 is shifted towards that of the nonmagnetic agglutinates (labeled 4). The handpicking of the magnetic fraction for separates enriched in matrix glass (>80%) or minerals (>70%), respectively, yielded two samples both containing noble gases, but with distinct concentrations and abundances.

Thus, it is shown that all the different phases within the agglutinates, even the glass, contain trapped gases. The noble gas concentrations and elemental abundances are host specific and the element fractionation appears to increase with the degree of vitrification.

In summary, the present investigation answers the raised questions and confirms some of the expectations set out in our earlier paper (2). Agglutinitic materials contain trapped gases in varying concentrations and compositions whereby a large fraction is volume distributed as are other volatile trace elements (3, 5). The depletion of He and Ne relative to Ar in magnetic agglutinates may correlate with the degree of vitrification. The smaller degree of trapped gas fractionation observed in nonmagnetic agglutinates and in the nonmagnetic fraction of the magnetic agglutinates might be due to the lower degree of reworking. Trapped light noble gases in agglutinates show more widely varying concentrations and composition patterns than mineral soil constituents. This clearly reflects the often complex history of secondary particles.

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References

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