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Studies of light noble gases in mineral grains from lunar soils; a status report. R. Wieler, Ph. Etique, and P. Signer, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland.

Among the lunar soil constituents, monomineralic grains deserve special attention. Our group has concentrated since several years on noble gas studies of carefully prepared mineral separates from lunar bulk soils. Here, we summarize the major results and conclusions of these investigations in the context of both, the regolith evolution and the history of the solar corpuscular radiation. With regard to the most abundant noble gas component in regolith samples - the solar gases - the mineral grains have mainly two properties giving these particles among all soil constituents the best characteristics as sensors for solar gases, despite the fact, that the noble gas concentrations in a mineral separate are 10 - 60 times lower than those in a bulk sample of the same grain size. The first of these properties is the mineral dependent retentivity of the light gases He and Ne, the second property concerns the relatively short time during which a mineral grain acquires its solar gases. In the following, these two points are discussed:

Retentivity of solar He and Ne: The table shows the ranges of He/Ar and Ne/Ar in various constituents (refs 1 & 2) and the solar values (3):

	ilmenite	oliv./pyro.	plagioclase (highl.)	solar
4-He/36-Ar	5000 - 11000	300 - 600	40 - 80	20000
20-Ne/36-Ar	15 - 30	6 - 16	1 - 2	26

In sharp contrast to the He and Ne amounts, the solar Ar concentrations in all mineral separates in a given grain size range from the same bulk soil always agree to within +-25%, as was shown for about 20 soils (1,2). It was concluded that the implanted solar wind Ar (SW Ar) is retained to better than 70% in all mineral grains of the lunar regolith, and that diffusional losses and not sputtering cause the low abundances of solar He and Ne. The good retentivity of all lunar soil constituents for SW Ar seems to disagree with the Ar/N ratios in bulk soils and mineral separates. These ratios are about 20+-10 times lower than the assumed solar value (cf. 4-6). This important problem is discussed further in a companion abstract (7).

Lifetime of minerals: Primary particles are constantly admixed to the regolith by erosion of rocks and pebbles. Conversely, these particles are also constantly broken up and/or incorporated into secondary particles like microbreccias and agglutinates. In contrast to the latter particles, minerals therefore acquire their solar gases during a relatively short time interval. We estimate the mean lifetime of a population of clean mineral grains (150 - 200 um) in the reworking zone of the regolith to be on the order of 50 Ma. (8). This estimate is based on the noble gas and track record in plagioclases of North Ray Crater soil 67601. The material of this soil was added to the regolith only about 50Ma. ago. Despite this, the minerals from 67601 have among the highest observed solar Ar concentrations as well as among the highest track densities of all surface soils studied (2). Nevertheless, the plagioclase grains in this or in any other soil are not saturated with solar wind Ar, as our analyses of He and Ar concentrations in nearly 100 single grains each from a gas poor and a gas rich mineral population showed. Evidently, for mineral grains in the 150 - 200 um grain size range, residence times of more than 50Ma. near the regolith surface lead to destruction of these grains. The results of Monte Carlo computations for the regolith turnover rate (9) can be used to estimate that the time between the first and the last surface exposure of a population of clean minerals in many cases is not longer than 100Ma. Of interest in this context is the observation that the 38-Ar GCR exposure age and the SW Ar concentrations of "dirty" plagioclase grains of soil 61501 in a relatively large grain size (200 - 300 um) are both nearly a factor of two higher than the respective values of clean grains in the same size range of the same soil. At least for this soil, the dirty mineral population must have had a longer evolutionary history than the clean minerals (10).

The solar corpuscular radiation in the past and today: A large number of separates of olivine, pyroxene, and ilmenite - minerals fairly retentive for SW Ne - was investigated (8). Comparison of the Ne data of surface soils on the one hand, and drill core samples and soil breccias on the other hand revealed that the 20-Ne/22-Ne ratio of SW Ne has not changed drastically with time. A possible secular increase of this ratio over the past 2 - 3 Ga. is smaller than 2%.

Studies of aliquots of a plagioclase separate etched to various depths revealed a Ne component with a 20-Ne/22-Ne ratio of about 11.3 in the first several ten microns below the grain surface (11). This component is most plausibly interpreted as solar flare implanted Ne (SF Ne). Due to the strong depletion of SW Ne in plagioclases by diffusion, the SF Ne can amount to as much as 20 - 50% of the total solar Ne in this mineral. The 20-Ne/22-Ne ratio of this flare component differs from the value of 7.6 +- 2 measured in a few contemporary flares by satellite borne instruments (12, 13).

The SF Ne detectable in mineral grains of the lunar regolith opens up new possibilities - besides the SW gases and the SF tracks - to trace back the history of the solar activity over the last few billion years. For this purpose, we need data on etched mineral separates from early and recently exposed samples.

So far, no etching experiments on early irradiated samples have been made. At present, the SF component in plagioclase must therefore be calculated from the 20-Ne/22-Ne ratio of the solar component (superposition of SW Ne and SF Ne), by assuming a constant composition of spallogenic Ne in each sample. A low $(\text{20-Ne/22-Ne})_{sol}$ is then indicative for a relatively high SF Ne contribution. This approach is justified because the $(\text{20-Ne/22-Ne})_{sol}$ correlates inversely with the 20-Ne/36-Ar ratio. This is expected, because the retained SF Ne is likely to have a larger Ne/Ar ratio than the retained SW Ne in plagioclases. The $(\text{20-Ne/22-Ne})_{sol}$ also correlates with the Mean Track Density/36-Ar ratio, which is another and independent flare/wind flux measure. The drill core and soil breccia samples investigated have on average a two times higher MTD/36-Ar ratio than surface soils. This indication for an about two times higher flare/wind flux ratio 1 - 3 Ga. ago is supported by the inverse correlation of $(\text{20-Ne/22-Ne})_{sol}$ in plagioclases and the 40-Ar/36-Ar ratio in mafic minerals of the same soils. The latter ratio is thereby taken as a rough indicator of the time when a sample was exposed at the regolith surface.

Ref: (1) Signer et al. (1977), PLSC. 8th, 3657; (2) Wieler et al. (1981), LPSC. 11th, 1369; (3) Cameron (1982), in: Essays in Nuclear Astrophysics, Cambr. Univ. Press; (4) Clayton & Thiemens (1980), Ancient Sun, 463; (5) Norris et al. (1983), 46th Ann. Meeting Met. Soc., Mainz (6) Frick and Pepin (1983) in prep.; (7) Signer et al. (1983), this volume; (8) Wieler et al. (1983), LPSC. 13th, A713; (9) Borg et al. (1976), EPSL 29, 161; (10) Etique (1982), PhD Thesis, ETH Zurich; (11) Etique et al. (1983), to be publ. in GCA; (12) Dietrich & Simpson (1979), Astrophys. J., 231, L91; (13) Mewaldt et al. (1979), Astrophys. J., 231, L97.

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