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SOLAR COSMIC RAY EFFECTS IN HEAVY NOBLE GASES OF LUNAR SOILS AND BRECCIAS,

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Lunar surface is subjected to solar cosmic ray bombardment over long periods of time and Walton et al. (1) showed convincing evidence for solar cosmic ray produced Ne in lunar fines 67701. Previously Rao et al. (2) pointed out that low energy solar cosmic rays induce nuclear reactions in barium in lunar and meteoritic materials and the resultant Xe^{132}excess correlates positively with solar cosmic ray produced fossil tracks in lunar soils(3). In this communication, we present evidence regarding solar cosmic ray produced krypton excesses for Kr^{84}, Kr^{83} and Kr^{82} isotopes by 10-60 MeV proton reactions on strontium in lunar soils and breccias and compare these results with the surface exposure ages calculated for lunar soils using track systematics (4, 5, 6).

We have plotted Kr^{84}/Kr^{86} against Kr^{80}/Kr^{86} in Fig. 1 for several lunar soils and breccia (7-11). Kr^{80} is mainly contributed by the galactic cosmic rays whereas $Kr^{84}$is produced by both galactic and solar cosmic rays. Fig. 1 shows for most of the lunar soils and breccia that the 84/86 values are greater than 3.24 and the values for this ratio go up to 3.35 for the component denoted by C. For this component the variation in the 80/86 values is only between 0.13 and 0.14, indicating that the galactic contribution is small. The solar cosmic ray component discussed here is similar to the lightly-bound krypton component found in Apollo 14 soils (7, 8) and it has a composition 82:83:84 = 1:1:3.5. The 84/86 and 80/86 values for both lunar trapped xenon and terrestrial atmosphere are considered to be same in the following calculations.

When Sr in lunar soils is bombarded with 10-60 MeV solar cosmic ray protons, Kr^{84} is produced by $Sr^{88}(p, \alpha n)$ and $Sr^{87}(p, \alpha)$ reactions. Excitation functions for these low energy reactions on Sr isotopes have been measured radiochemically (12) and we estimate a σ_{max} of 35 and 27 mb for the above reactions at E_{max} of 25 and 16 MeV respectively. Using solar cosmic ray energy spectrum given by Lal (13) and Walton et al. (1), we calculate an average Kr^{84} production rate of about 6×10^{-12}cc STP per gm per m.y., in soils exposed to solar cosmic rays within depths of 0-5 mm on the lunar surface. In principle, the measured Kr^{84} is corrected for galactic cosmic ray contribution and from the residual Kr^{84} excess, we calculate the solar cosmic ray exposure ages for lunar soils and breccias, using the Kr^{84} production rate obtained above. In suitable cases, these Kr^{84} ages are compared with the surface exposure ages calculated

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using fossil track techniques (4, 5, 6).

The stepwise-heating measurements for lunar soils and breccia(7-11) are analysed using the above procedure and the results are given in Table 1. The errors are possibly upto 50 percent in these ages, because the small SCR-component is masked by the huge solar wind contribution in case of soil rare gas measurements. For Apollo 12 double core sample 12025, we obtain a SCR-exposure age of about 110 m.y. and for 12028, about 60 m.y. Using fossil track (FT) methodology, Arrhenius et al. (4) obtained surface exposure ages of 35 m.y. for 12025 and 10 m.y. for 12028. Within experimental errors, the Kr^{84} SCR-exposure ages and the FT surface exposure ages seem to agree well. However, it should be pointed out that the Kr^{84} SCR-exposure ages are usually higher than the FT surface exposure ages and this could be partly due to the contribution from higher solar cosmic ray activity in the past. Results on some lunar soils and selected breccias with specific orientation will be presented.

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Table 1. Solar cosmic ray exposure ages for some lunar soils and breccias.

	Ne^{21}age (m.y)	SCR age(m.y)	FT surface exposure age(m.y)
12025	350^{*}	110	35
12028	350^{*}	60	10
65315	1.5	7	--
14301	(102+30)	4	8
15601	380	20	10

Ne^{21} ages (7-11) and FT ages (4-6). * Xe^{126} age (14)

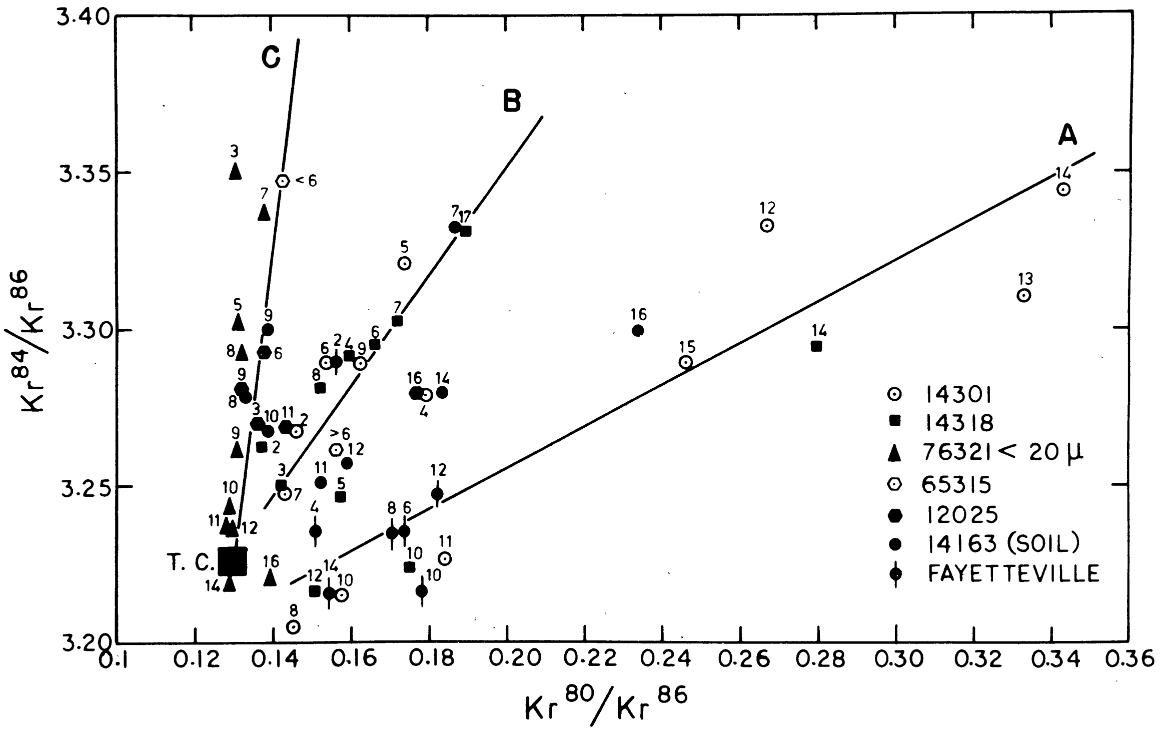

Fig. 1 : Correlation diagram of Kr^{80} and Kr^{84} normalized to non-spallagenic Kr^{86} in lunar soils and breccia.