Xenon Isotope Systematics in Kapoeta and Ancient Solar Activity; M.N. Rao[1], D.H. Garrison[2], D.D. Bogard, NASA Johnson Space Center, Houston, TX 77058 (also [1]P.R.L. Ahmedabad, India; [2]Lockheed-ESC)

Neon isotope studies of solar flare irradiated grains (1) from Kapoeta and etched mineral separates from Kapoeta (2,3) revealed significant ^{21}Ne excesses which were attributed to an intense solar flare (SF) irradiation in the early solar system. This view has been questioned by other investigators (4) who attribute such an excess to long galactic cosmic ray (GCR) exposure rather than to an enhanced solar cosmic ray (SCR) proton flux. To address this problem differently, we resolve the Xe isotopic system from lightly etched (LE) and heavily etched (HE) feldspar and pyroxene grain separates from (L)ight and (D)ark phase Kapoeta. This approach is based on the use of Xe isotopes 129, 131 and 132 which are considered to be mixtures of trapped solar wind (SW), GCR and SCR spallation, and fission; 126, 128 and 130 which are considered to be mixtures of SW and GCR spallation; and 134 and 136 which are considered to be mixtures of trapped and fission, and free from spallation. We have adopted procedures given by (5,6) for the decomposition of these Xe isotopic mixtures. Each isotope is corrected by successive subtractions of appropriate compositions to account for the trapped, cosmogenic (GCR) and fission components. Using this procedure, we find significant excesses at isotopes 129, 131 and 132, which are attributed to SCR spallation.

First, $[130]_c$ is calculated from $(128/130)_m$, $[130]_m$ abundances, and an assumed SW composition (SUCOR). $[130]_{SW}$ is obtained by subtraction of $[130]_c$ from $[130]_m$ (m = measured; c = cosmogenic; f = fission; [] signifies concentration; () signifies ratio). All other isotopes are renormalized to $[130]_{SW}$; subtraction of the SUCOR SW composition removes the SW component. The residual mixtures of cosmogenic and fissiogenic Xe components are further corrected for GCR spallation in [129], [131] and [132] using a high-energy Ba spallation Xe spectrum (7). A substantial excess of [129] remains in the D-Feld and D-Pyx samples and is considered to be SCR produced (Table 1). A negligible excess of [129] is found in the L-Feld and L-Pyx samples after GCR correction. Finally, fission corrections must be made to [131] and [132]. For both L-Feld and L-Pyx samples, the $(134/136)_f$ ratio and overall fission spectrum is close to that of ^{244}Pu fission produced Xe (Fig. 1) and accounts for the remaining [131] and [132]. However, the fission contribution to the D-Feld and D-Pyx samples cannot be accounted for by ^{244}Pu alone because, observed $[136]_f$ contents are much higher in these samples than expected from ^{244}Pu (Table 1). After ^{244}Pu correction, the $(134/136)_f$ ratios in these samples are close to the H-Xe fission value of 0.7 (Table 1). Hence, we use the H-Xe composition to correct for additional fission contributions to [131] and [132] in the dark phase samples.

After applying the SW, GCR and fission component corrections, the resulting excess Xe [129], [131] and [132] in the D-Feld and D-Pyx samples are much larger than the GCR spallation Xe contributions, and are attributed to low-energy SCR proton spallation on Ba received on the Kapoeta parent-body regolith ~4.5 Gy ago. Table 1 lists the GCR spallation [129] (similar GCR [131] results are not shown) and SCR spallation contents determined for 129, 131 and 132. [The D-Pyx HE samples show lesser GCR and SCR contents than the LE samples, which may indicate that the target element concentrations in the HE samples were depleted relative to the LE samples by the degree of chemical etching, which differentially attacks the mineral sites (phosphates) bearing the target elements Ba and REE (10).] The Ba content of these Feld samples is 80ppm, while that of the pyroxene samples is 40ppm. Using GCR production rates, i.e. $129 = 2.8E^{-15}$ ccSTPxppm $Ba^{-1}xMy^{-1}$ (5) and the calculated [129], [131] and [132] GCR concentrations we calculate GCR exposure ages for both Feld and Pyx samples from Kapoeta light and dark phases (Table 1). The GCR ages for the L-Feld and L-Pyx samples (which are unetched) agree with the 3 My exposure age for Kapoeta determined by several workers using ^{21}Ne isotope. We next determined the apparent SCR exposure ages using the corrected SCR-Xe lunar production rates, i.e. $129 = 1.5 \times 10^{-15}$ ccSTPxppm $Ba^{-1}xMy^{-1}$ (7), and the [129], [131] and [132] SCR excesses given in table 1. Because these derived SCR produced Xe excesses are from samples containing mixtures of SF irradiated and unirradiated grains in Feld and Pyx separates, we have normalized the SCR concentrations to 100% irradiated grains based on the known 3% fraction of irradiated to unirradiated grains in the Kapoeta dark phase. Further, the SCR production rates at 3 A.U. will be down by a factor of 10 compared to those determined for the moon. The apparent SCR exposure ages for 129, 131 and 132 are then found to be 10^3-10^4My (Table 1). Even though there are large errors in the SCR contents and their ages, our results indicate that the minimum apparent SCR exposure ages for Kapoeta Feld and Pyx samples are a few thousand million years or greater.

Based on asteroidal regolith dynamics models (11,12), the precompaction exposure ages to protons in the Kapoeta parent body regolith are expected to be a few million years in which these grains accumulate the observed SCR proton spallation effects. The SCR 129 and SCR 131 ages obtained for these samples are much

larger than expected. An explanation may be that the SCR Xe production rates, or in particular the SCR proton fluxes used in our calculations, are too low. If, at the time and place (~4.5 Gy and 3 A.U.) of precompaction irradiation on the Kapoeta parent body, the SCR-proton fluxes were ~10^3-10^4 times higher than today then the calculated SCR ages become a few million years. This interpretation is consistent with the present understanding of the regolith dynamics models on asteroid-size parent bodies. These results provide evidence for a highly-active ancient sun and are consistent with the SCR ages based on excess ^{21}Ne determined earlier by (1,2,3) and ^{38}Ar excesses determined by (2) in Kapoeta.

Taking an initial $^{244}Pu/^{238}U$ ratio of 0.0068 (Hudson et al., 1982), $[136]_f$ = 1.6x10^{-12} ccSTP/g and the U content of these samples of 51 ppb, we estimate ~70 My for the time-interval between the cessation of nucleosynthesis and the formation of the Kapoeta meteorite parent-body. These results are consistent with those obtained in the case of the Bholghati howardite (8,9). Furthermore, the observed ^{244}Pu fission Xe in these Kapoeta samples indicates that this intense SF-irradiation had to take place on the meteorite parent-body regolith during the first 100 My after the formation of the solar system.

Table 1.

		$[132]_m$[1]	$\left(\frac{134}{136}\right)_f$	$[136]_f$[2]	$[129]_c$ GCR	GCR[3] AGE My	$[129]_c$ SCR	$[131]_c$ SCR	$[132]_c$ SCR	SCR[3] "AGE" My
Feld (L)										
35-125μ		8.96	0.82	1.74	0.44	2.0	0.0	0.0	0.0	0
		±0.40	±0.15	±0.35	±0.04	±0.2				
Feld (D)										
35-125μ	VLE	249.32	0.82	11.34	2.18	9.7	11.68	10.02	12.74	32000
		±1.67	±0.21	±2.31	±1.10	±5.2	±7.51	±6.83	±6.98	±21000
125-200μ	VLE	343.70	0.67	14.51	3.19	14.2	18.98	8.17	14.40	52700
		±1.52	±0.17	±1.83	±1.60	±8.6	±5.01	±4.16	±6.19	±13900
Pyx (L)										
125-200μ		6.57	0.96	1.53	0.24	2.1	0.0	0.0	0.0	0
		±0.20	±0.16	±0.31	±0.03	±0.3				
Pyx (D)										
35-125μ	LE	50.63	0.77	4.18	0.75	6.6	6.41	3.70	7.33	35600
		±0.38	±0.24	±0.84	±0.19	±1.7	±3.07	±2.10	±2.96	±17100
35-125μ	HE	31.72	0.64	2.63	0.19	1.7	2.46	3.01	4.53	13700
		±0.27	±0.16	±0.53	±0.06	±0.6	±2.09	±1.93	±2.90	±11600
125-200μ	LE	42.11	0.71	5.86	1.49	13.3	6.30	4.57	7.12	35000
		±0.26	±0.18	±1.17	±0.63	±8.6	±3.17	±2.48	±3.06	±17500
125-200μ	HE	32.51	0.67	2.26	0.25	2.2	1.69	1.99	3.04	9400
		±0.18	±0.20	±0.45	±0.09	±0.7	±1.38	±1.14	±1.46	±7500

Table 1. Summary of Kapoeta Xenon, concentrations in 10^{-12}ccSTP/g. (L) = Light phase; (D) = Dark phase; VLE = very lightly etched (< 1μ); LE = lightly etched (1-2μ); HE = Heavily etched (8-10μ)
1 Note that D-Feld show much larger concentrations of Xe than D-Pyx, while Xe concentrations in L-Feld and L-Pyx are similar. Total (D Feld + D Pyx) Xe abundances are similar to previous Kapoeta values (8).
2 D-Feld and D-Pyx values are corrected for ^{244}Pu fission.
3 Exposure ages are calculated from $[129]_c$, similar values are obtained using $[131]_c$ and $[132]_c$.
Notes: Listed uncertainties are propogated from measured, cosmogenic and fission correction uncertainties. While the SW correction introduces by far the largest uncertainty, the residual concentrations obtained using the Pesyanoe (Marti, 1969) SW composition agree within ~5% to those obtained using SUCOR. Large uncertainties in the D-Feld samples are due to large amounts of SW Xe remaining after only very light etching.

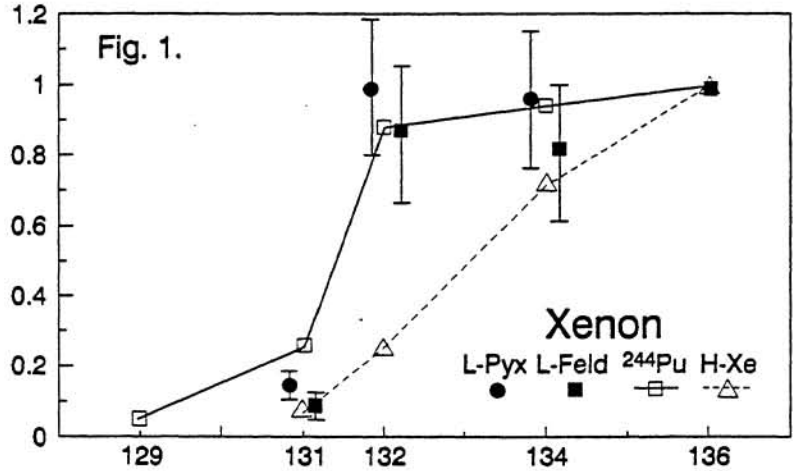

Fig. 1. Fission Xe spectum of L-Pyx and L-Feld normalized to 136.

(1) Caffee et al., Proc.LPSC B267-B273 (1983); (2) Rao et al., LPSC (abs) 996-997 (1990); (3) Padia and Rao, GCA 53, 1461-1467 (1989); (4) Wieler et al., GCA 53, 1441-1448 (1989); (5) Hohenberg et al., GCA 45, 1909-1915 (1981); (6) Podosek and Huneke, EPSL 12, 73-82 (1971); (7) Prescher et al., Nucl.Instr.Meth.Phys.Res. 13, submitted (1990); (8) Swindle et al., GCA 54, 2183-2194 (1990); (9) Nyquist et al., GCA 54, 2195-2206 (1990); (10) Delaney et al., LPSC XV (abs), 208- (1984); (11) Housen & Wilkening Ann.Rev.EPS 10, 355-376 (1982); (12) Langevin and Maurette LPSC (abs), 602-604 (1980)