ACTIVITY OF THE ANCIENT SUN BASED ON NOBLE GAS STUDIES OF ETCHED KAPOETA MINERAL SEPARATES; M.N. Rao[1], D.H. Garrison[2], D.D. Bogard, NASA Johnson Space Center, Houston, TX 77058, A.V. Murali, and D.C. Black, Lunar & Planet. Inst., Houston, TX 77058, (also [1]P.R.L. Ahmedabad, India; [2]Lockheed-ESC)

Effects of an enhanced solar cosmic ray particle flux in the early solar system seem to have been permanently preserved in the silicate crystals of gas-rich meteorites. Earlier studies of Kapoeta grains irradiated by solar flares (2) and pyroxene mineral separates from Kapoeta (1) found ^{21}Ne excesses that were attributed to intense solar flare irradiation of the early Kapoeta parent body regolith. This interpretation has been questioned by (3) who attributed the excess ^{21}Ne in the pyroxenes to a very long exposure to galactic cosmic rays (GCR), rather than an intense irradiation by solar cosmic rays (SCR).

In order to study this problem in detail, we have conducted additional measurements of noble gas components in acid-etched pyroxene and feldspar mineral separates from Kapoeta, a howardite known to contain significant amounts of solar-implanted noble gases. Samples from dark (gas-rich) and light (gas-poor) portions of Kapoeta were separately disaggregated, and separated into pyroxene- and feldspar-enriched mineral fractions using heavy liquids. Mineral fractions were further separated into 35-125μm and 125-200μm size fractions. Aliquants of these separates were then chemically etched in two steps to remove the solar wind component contained in grain surfaces; this resulted in one lightly etched (l) and one heavily etched (h) sample of each size fraction of both the pyroxene and feldspar separates. All of these fractions were measured for the isotopic composition of their noble gases by standard mass-spectrometric procedures, using three temperature extractions of 600^{o}C, 1200^{o}C and 1600^{o}C.

Figs. 1 and 2 show all neon isotopic data for the pyroxene and feldspar samples, as well as the compositions of Ne in the solar wind (SWC and Lunar), the Earth's atmosphere, carbonaceous chondrites (Planet.) and Ne produced by nuclear reactions in feldspar and pyroxene (GCR and SCR). Ne data for both pyroxenes and feldspars each define a linear array which indicates mixing between a cosmogenic (GCR and/or SCR) component and a second component that lies along the general trend defined by solar wind, terrestrial, and carbonaceous chondrite Ne. This second Ne component, which we interpret to have been implanted by solar flares, has a ^{20}Ne/^{22}Ne ratio of 11.6$\pm$0.1, which is similar to values previously derived (2,3).

The cosmogenic Ne end-member does not agree exactly with either the GCR or SCR compositions, but appears to be a mixture of the two. To decompose the three component system (SF-Ne, SCR-Ne and GCR-Ne), we use the lever rule to calculate the fraction of ^{21}Ne that is solar flare (SF) produced and the fraction that is cosmogenic. For Kapoeta light phase, cosmogenic ^{21}Ne, which is mostly, if not entirely GCR-produced, comprises 89% and 92% of the total ^{21}Ne for pyroxene and feldspar, respectively. These concentrations of GCR-^{21}Ne for Kapoeta light pyroxene and feldspar are given in Table 1, and correspond to a GCR exposure age of 3My, which is consistent with the age determined by other workers for Kapoeta. We assume that Kapoeta dark phase contains a comparable GCR ^{21}Ne component to that determined in Kapoeta light phase in order to derive the SCR-^{21}Ne component in the dark phase samples. Independently for pyroxene and feldspar samples, subtracting the GCR-$^{21}Ne_c$ in the light fraction from the total (SCR+GCR) cosmogenic Ne in the dark material gives those concentrations of SCR ^{21}Ne in the various separates shown in Table 1. The SCR-Only concentrations of ^{21}Ne in Table 1 have had a correction applied to compensate for the observation in Kapoeta dark material that only 3% of the silicate grains have been irradiated by solar flares.

Based on proton reaction cross sections, Hohenberg et al (4) derived SCR $^{21}Ne_c$ production rates at 3 A.U.of 0.044x10^{-8} ccSTP/g-My for pyroxenes and 0.0146x10^{-8} ccSTP/g-My for feldspars. Dividing the SRC-Only 21Ne concentrations of Table 1 by these SCR production rates, we obtain the apparent SCR ^{21}Ne exposure ages listed in the last column of Table 1. These SCR "ages" for various Kapoeta samples are all relatively similar at ~1700-2700 My, and are much greater than the 3My GCR exposure age for Kapoeta. Because it is unlikely that the true GCR and SCR exposure ages for Kapoeta could differ significantly, the much higher apparent SCR ages actually indicate a much higher flux of solar cosmic rays during irradiation of Kapoeta compared to irradiation of lunar materials, which presumably occurred at a much later time. The very large differences in SCR and GCR exposure ages imply an SCR particle flux in the early solar system that was enhanced by approximately a factor of 600-800 over the later flux.

The observation from Ne data from pyroxenes that the cosmogenic end-member lies close to the GCR component (Fig.1), led (3) to question the suggestion of an enhanced SCR particle flux as the cause of excess cosmogenic ^{21}Ne in Kapoeta and Fayetteville. For example, it might be assumed that Kapoeta dark phase

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grains were given an extra irradiation by galactic cosmic rays when they acquired their solar gases, compared to Kapoeta light phase, If true, then the subtraction process we used to derive the SCR-Only ^{21}Ne concentrations of Table 1 might not be correct, and an irradiation with a much higher SCR flux might not be required. We believe that neon isotopic data in Figs. 1 & 2 refute such an inference. Neon data from feldspar is better suited for distinguishing between SCR- and GCR-^{21}Ne, because of better separation of these components on the three-isotope Ne diagram (Fig 2). Dark and light feldspar samples from both grain-size fractions define a line clearly different from a SF-Ne and GCR-Ne tie-line. The feldspar data, to a greater extent than the pyroxene data, define a definite third component due to SCR ^{21}Ne production (Fig.2). Thus, we believe that a significant excess SCR ^{21}Ne component exists in Kapoeta dark material and that this component suggests an early irradiation with an enhanced SCR flux.

Being a howardite, Kapoeta is a brecciated mixture of basaltic eucritic and diogenitic material, which is presumably derived from deep within the parent body. Radiometric studies of eucrites suggest that they may have formed over a time period of ~10^{-8} years (5). Time would also be required for major impacts on the parent object to form a regolith, comminute some material down to a fine grain size, and irradiate some grains on the parent body surface while other material remained deeper in the regolith and unirradiated. If an enhanced SCR source existed in the early solar system and produced the excess SCR ^{21}Ne in Kapoeta, it apparently either occurred considerably after the sun and planetary objects accreted, or it existed for a period of time of the order of ~10^{8} years. Neither inference appears compatible with a brief, early T-Tauri phase of the sun (6) to explain a greatly enhanced flux of solar cosmic rays.

Table 1. ^{21}Ne concentrations (10^{-8}ccSTP/g) and calculated exposure ages (My) for Kapoeta phases

	GCR Only	GCR AGE	SCR +GCR	SCR Only	SCR "AGE"
Pyroxene:					
Light, 35-200μm, Lightly Etched	0.72	3My	--	--	
Dark, 35-125μm, Lightly Etched	--		3.09	2.37	1790My
Dark, 125-200μm, Lightly Etched	--		2.92	2.20	1780My
Dark, 35-125μm, Heavily Etched	--		3.09	2.37	1797My
Dark, 125-200μm, Heavily Etched	--		3.07	2.35	1650My
Feldspar:					
Light, 35-200μm, Lightly Etched	0.54	3My	--	--	
Dark, 35-125μm, Lightly Etched	--		1.70	1.16	2750My
Dark, 125-200μm, Lightly Etched	--		1.59	1.05	2400My

(1) Padia and Rao, G.C.A. 53, 1461 (1989); (2) Caffee et al. J.G.R. 88, B267-273 (1983); (3)Wieler et al., G.C.A. 53, 1441 (1989); (4) Hohenberg et al., Proc.LPSC, 2311-2344 (1978); (5) Nyquist et al J.G.R. 91 #B8, 8137 (1986); (6) Giampapa and Imhoff, Protostars and Planest II, 386-404 (1985).