ISOTOPIC STUDIES OF SHOCK METAMORPHISM: II. Sm-Nd. L. Nyquist[1], B. Bansal[2], H. Wiesmann[2], C.-Y. Shih[2], and F. Horz[1] ([1]SN4, NASA Johnson Space Center, Houston, TX, 77058; [2]Lockheed, 2400 NASA Rd. 1, Houston, TX, 77058).

We have undertaken a series of experiments to define the effect of shock metamorphism on the Rb-Sr and Sm-Nd isotopic systems. Some Rb-Sr results for artificially shocked samples of Apollo 11 high-K basalt 10017 have been presented already (1). Sm-Nd results for some of the same samples used for the earlier Rb-Sr study and additional Rb-Sr data are presented here.

Five target disks (7mm x 0.5mm) of 10017 were shocked to 35 GPa ($\pm$3%) and combined for isotopic analysis. Control samples of unshocked basalt processed in the same manner as the shocked materials were also analyzed. Modal abundances of the major minerals in the group of High-K basalts to which 10017 belongs are px: 48-59%, ol: <0.1%, plag 18-27%, opaques (ilm): 15-24%, cristob./tridym.: 1.1-1.6%, and "mesostasis": 6-9% (2). Because 10017 is a fine grained basalt, and because the isotopic data are heavily influenced by phases present in the very fine grained, polymineralic mesostasis, it has proven difficult to obtain subsamples which are clearly representative of specific phases, especially for the shocked samples. However, numerous Rb-Sr analyses of mineral fractions obtained using a variety of techniques, combined with data from the previous study of 10017 by (3), permit the identification of end member phases which are important in determining the Rb-Sr and Sm-Nd isotopic systematics. Thus, the Rb and Sr concentration data are presented in Figure 1 for aid in discussion of the host phases for Rb, Sr, Sm, and Nd. End member (Rb,Sr) coordinates in ppm for px, plag, ilm, and "mesostasis" are at or near (0.8,84), (0.7, 521), (1.2,14), and (24.5,410), respectively. The position of the mesostasis point was calculated from the visually estimated proportions of mesostasis, pyroxene, and ilmenite in a density fraction of 2.96-3.2 g/cm^3 from the unshocked basalt. Its coordinates are, thus, rather uncertain. However, there is a pronounced convergence of the (Rb,Sr) data of other mineral separates towards the estimated mesostasis coordinates, indicating the presence of a high-Rb phase in the vicinity of the estimated Rb and Sr values. Furthermore, electron probe analyses show that the mesostasis is an area of high K concentration; it must also, therefore, be an area of high Rb concentration. We have so far not isolated a "pure" separate of either the polymineralic mesostasis or the high-Rb carrier phase within it. However, the latter is enriched in the low density phases and we tentatively identify it as tridymite, which can be significantly enriched in alkalies (4). The "ilmenite" and "pyroxene" fractions of the shocked samples, which were obtained by magnetic

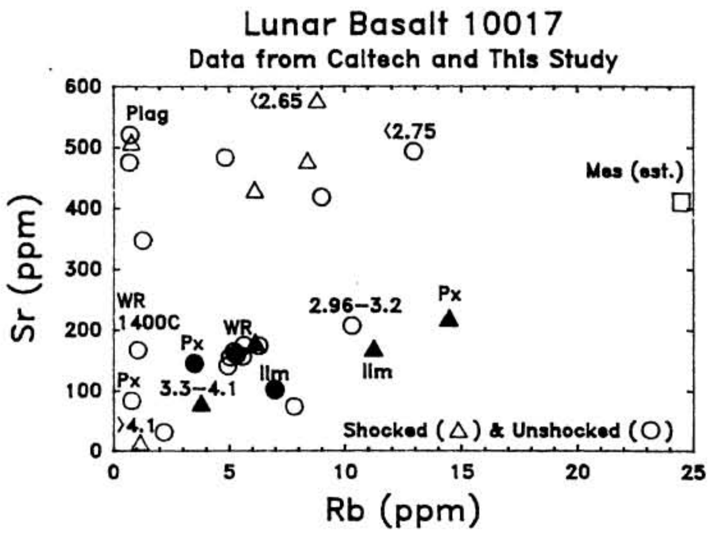

Figure 1.

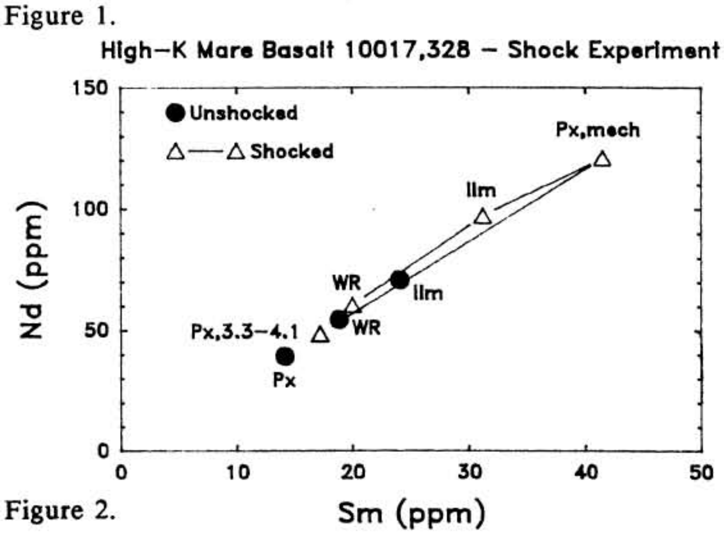

Figure 2.

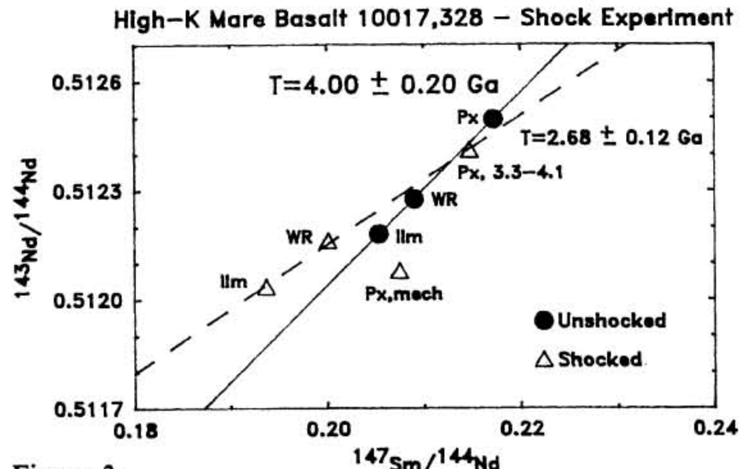

Figure 3.

separation, were apparently even more enriched in mesostasis than was the 2.96-3.2 g/cm^3 fraction of the unshocked material.

Figure 2 shows Sm and Nd concentrations in those samples indicated by solid symbols in Figure 1. No plagioclase or other low density phases were included because small sample sizes and/or low REE concentrations made Sm-Nd analyses of these samples unfeasible. Samples which are enriched in Rb are also enriched in Sm and Nd and in the same order. In particular, those samples which are interpreted as most enriched in mesostasis, the magnetically separated shocked "ilmenite" and "pyroxene" also have the highest Sm and Nd concentrations. We have not identified the carrier of the REE within the mesostasis, but Reid et al. (5) reported the presence of yttrium-bearing calcium phosphate in the mesostasis. Thus, it is probable that such phosphates are also carriers of the REE.

The Sm-Nd isotopic data are presented in Figure 3. Isotopic data for the unshocked samples (solid symbols) are collinear well within error limits. The age as calculated by the Williamson method (6) is 4.00±0.20 Ga, in satisfactory agreement with the Rb-Sr age. The range in Sm/Nd ratio among the unshocked separates analyzed to date is only ~6% and is inadequate to precisely define the Sm-Nd age of 10017; however, definition of the age is not the primary purpose of this report. The more important observation is that, whereas the data for the unshocked samples are precisely collinear, the data for the shocked samples are shifted away from the isochron defined for the unshocked basalt. The disturbances are greatest for the shocked ilmenite and pyroxene and are equivalent to shifts in the Sm/Nd ratio of ~3% for the shocked ilmenite and pyroxene and ~2% for the shocked whole rock sample. The mostly pyroxene, shocked, 3.3-4.1 g/cm^3, density separate is nearly concordant with the isochron defined by the unshocked basalt, but is displaced from it in excess of error limits, which are smaller than the size of the symbols in the figure. The shocked ilmenite, whole rock, and pyroxene define a pseudoisochron of T = 2.68±0.12 Ga illustrating that the relative error in the age can be much larger than the apparent fractional disturbance in the Sm/Nd ratio because the range in Sm/Nd ratios is much less than their absolute values. In this sense, Sm-Nd ages can be more sensitive to disturbances in the Sm/Nd ratio than Rb-Sr ages are to disturbances in the Rb/Sr ratio, because the range in Rb/Sr ratios used to define an isochron is usually comparable to the highest ratio. Thus, for 10017 a 3% shift in the Rb/Sr ratio of an ilmenite separate would also produce a 3% shift in the calculated age, whereas, in this (unfavorable) illustration a 3% shift in the Sm/Nd ratio has produced an ~30% shift in the calculated age. It should be noted that the Rb-Sr data of the shocked "ilmenite" and "pyroxene" show no detectable (<1%) evidence of disturbance (1).

The disturbance of the Sm-Nd system can be interpreted as limited to the mesostasis. The shocked "ilmenite" and mechanically separated shocked "pyroxene", both enriched in mesostasis, have nearly identical $^{143}Nd/^{144}Nd$ ratios, but Sm/Nd ratios which differ by ~6%. These two samples would define an "isochron" of ~0.5±0.2 Ga, i.e., the isotopic system of these two samples was nearly, but not completely, reset. It is reasonable that isotopic resetting should be greatest for those samples containing the greatest proportion of mesostasis. Mesostasis, being a highly compressible phase, should be most disturbed by shock and, indeed, incipient melting of mesostasis occurred in many areas of the shocked sample.

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