CHRONOLOGY OF LUNAR GRANITE 12033,576: RESETTING OF Rb-Sr AND K-Ca ISOCHRONS; C.-Y. Shih, H. Wiesmann and D. H. Garrison, Lockheed Engineering and Science Co., 2400 NASA Road 1, Houston, TX 77058; L. E. Nyquist and D. D. Bogard, NASA Johnson Space Center, Houston, TX 77058.

Lunar granite 12033,576 is a subsample of the "large" (~1 g) felsite 12033,507 which was identified from a collection of 4-10 mm particles from the 12033 soil sampled from the north rim of Head Crater in the eastern part of Oceanus Procellarum. Discordant ages of ~3.6, ~0.8, ~3.9 and ~2.2 Ga for this lunar granite were obtained, respectively, by the K-Ca, ^{39}Ar-^{40}Ar and U-Pb zircon methods in previous studies and by the Rb-Sr method in this study. Assuming the granite crystallized ~3.9 Ga ago (zircon age), and was shocked by meteoritic impacts at 0.8 Ga ago (^{39}Ar-^{40}Ar age), the intermediate apparent ages by the Rb-Sr and K-Ca methods can be interpreted as reset by diffusion of the parent and daughter nuclides. The Rb-Sr age is less resistant to resetting than the K-Ca age, but more resistant than the ^{39}Ar-^{40}Ar age.

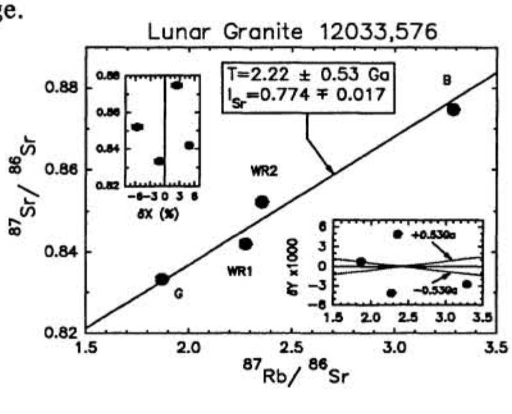

Figure 1. Rb-Sr mineral isochron of granite 12033.

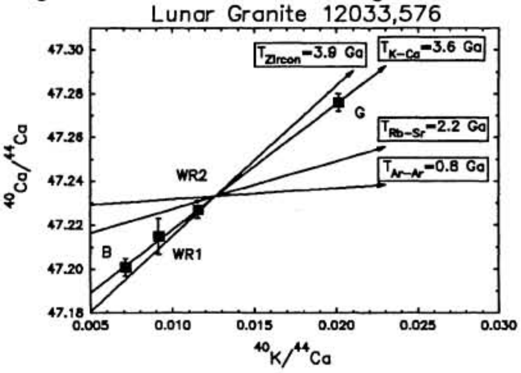

Figure 2. Discordant ages for granite 12033,576, shown on the K-Ca isochron diagram.

__Rb-Sr mineral isochron for granite 12033,576:__ Rb and Sr isotopic data for this subsample of large felsite 12033,507 [1] were obtained with procedures described in [2]. Two bulk samples, WR1 and WR2, and two mineral separates, G and B, handpicked from the whole rock sample crushed to <149 μm were analysed. G is a gray feldspar-rich sample and B is a dark sample containing brownish glasses of possible shock origin [1] as well as mafic minerals. K-Ca isotopic data for these samples yield a well-defined isochron age of 3.62$\pm$0.11 Ga [3]. Rb-Sr isotopic results are reported here for the same samples, and do not define a good isochron (Fig. 1). The best-fit line for the disturbed Rb-Sr system yields a young and imprecise age of 2.22$\pm$0.53 Ga (2σ) and a high initial $^{87}Sr/^{86}Sr$ of 0.774$\pm$0.017 (2σ) using the York program [4]. Both K-Ca and Rb-Sr ages are younger than the upper concordia intersection age of 3.898$\pm$0.010 Ga obtained from the U-Pb data for zircons [5]. All these ages are considerably older than the ^{39}Ar-^{40}Ar age of 800$\pm$15 Ma, interpreted as the age of Copernicus, determined from an aliquot of the bulk sample [6]. The high initial $^{87}Sr/^{86}Sr$ and $^{40}Ca/^{44}Ca$ values for the granite indicate that both the Rb-Sr and K-Ca isochrons could have been partially reset by the Copernicus impact. If so, the crystallization age for this granite could be significantly older than the K-Ca isochron age and probably close to the U-Pb zircon age of ~3.9 Ga, but not older than the K-Ca model age of ~4.2 Ga.

__Diffusion model for resetting internal isochrons:__ Discordant ages for the granite are summarized in a K-Ca isochron diagram (Fig. 2). Assuming that the granite crystallized at ~3.9 Ga and underwent shock metamorphism at 800 Ma, fractional exchanges (loss or gain), F(Sr) and F(Ca), of ^{87}Sr and ^{40}Ca, respectively, by diffusion in partially reset isotopic systems can be defined as $F=(R_{3.9}-R_t)/(R_{3.9}-R_{0.8})$ where R is $^{87}Sr/^{86}Sr$ or $^{40}Ca/^{44}Ca$ for points on isochrons representing ages of 3.9 Ga, 0.8 Ga and the observed age t at a given parent/daughter ratio. Thus defined, F is given by the relative degree of isochron rotation, and can be calculated by a lever rule [7]. The calculated F(Sr) and F(Ca) for mineral separates B

AGE OF LUNAR GRANITE 12033,576: Shih C.-Y. et al.

and G are 0.58-0.60 and 0.18-0.16, respectively. These values can be used to calculate the diffusion parameter $\alpha=(Dt/a^2)^{1/2}$ for Sr and Ca, using procedures analogous to those developed by [8] for the diffusion of Ar. The results for α(Ar), α(Sr) and α(Ca) are >0.8, ~0.2 and ~0.05, respectively, as presented in Fig. 3. The three solid lines represent the anticorrelation between diffusion time and diffusion coefficient for the three isotopic systems: K-Ar, Rb-Sr and K-Ca. Petrographic evidence suggests that the granite had experienced a shock-related thermal event at ~700°C [1]. The D/a^2 value for the K-Ar system at this temperature is determined from an Arrhenius diagram of temperature release ^{39}Ar data to be ~10^{-6} sec^{-1}. This temperature and D/a^2 value correspond to an Ar diffusion time of several days needed to totally reset the K-Ar chronometer. The Rb-Sr and K-Ca isotopic data indicate that diffusion in the Rb-Sr and K-Ca system is, respectively, ~10x and ~400x slower than in the K-Ar system. These differences are in good agreement with the relative values of experimentally determined diffusion coefficients for Sr and Ca in granitic melts recommended by [9]. At 700°C, it would have required months to totally reset the Rb-Sr system in the granite, and years to toally reset the K-Ca system.

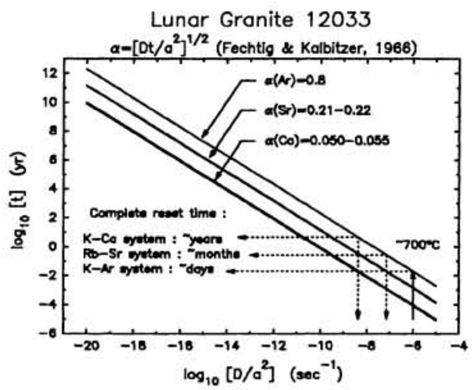

Figure 3. Diffusion time (t) vs. parameter (D/a^2).

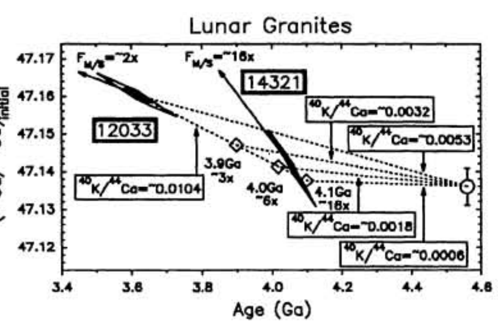

Figure 4. Age vs. I(Ca) for lunar granites.

Crystallization age and petrogenetic implications: Ages and initial ^{40}Ca/^{44}Ca ratios of lunar granites 14321 and 12033 [3,10] are represented by error parallelograms in Fig. 4. Dotted lines represent ^{40}K/^{44}Ca growth curves. For a simple two-stage model, the ^{40}K/^{44}Ca ratio in the source of granite 14321, which has concordant ages [10,11], was calculated to be ~0.0018, similar to values found for quartz monzodiorites [12-14], suggesting large K/Ca fractionations ($F_{M/S}$~16x) during granite formation. Large enrichments of K/Ca can be produced by silicate liquid immiscibility (SLI) processes [*e.g.* 15,16]. The ^{40}K/^{44}Ca ratio calculated for the source of granite 12033 formed at the K-Ca isochron age of 3.6 Ga is so high that it either must have been derived from an already granitic source, or have assimilated a large amount (~40%) of ancient granitic materials prior to its crystallization. Assuming a similarly large $F_{M/S}$~16x for this granite as for 14321, the 12033 granite could have been derived from a low K/Ca source similar to that for granite 14321 ~4.1 Ga ago in a plutonic environment perhaps associated with the parental magma of some Mg-suite rocks.

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