K-Ca AGE OF LUNAR GRANITES; C.-Y. Shih and H. Wiesmann, Lockheed Engineering and Science Co., 2400 NASA Road 1, Houston, TX 77258; L. E. Nyquist, NASA Johnson Space Center, Houston, TX 77058.

In an ongoing study of dating lunar rocks by the $^{40}$K-$^{40}$Ca chronometer, we have presented preliminary K-Ca isotopic results for a suite of lunar igneous rocks (1). Here, we present K-Ca mineral isochrons for two lunar granitic clasts: 14321,1062 and 12033,576. $^{40}$Ca/$^{44}$Ca and $^{40}$K/$^{44}$Ca data: The Ca and K isotopic data were obtained on a Finnigan-MAT 261 multi-collector mass spectrometer following the data-acquisition procedures described in (1). The mean value of $^{40}$Ca/$^{44}$Ca=47.134, normalized to $^{42}$Ca/$^{44}$Ca=0.31221 (2), was obtained for a set of ten measurements of the JSC Ca standard made during the course of this study. This value is about 0.010 higher than that reported in (1). The external precision ($\sigma_{\text{m}}$) for these measurements is $\pm 0.004$ ($\pm 1 \epsilon$-unit), which is normally greater than their internal precisions ($\sigma_{\text{i}}$). Using a mixed $^{40}$K-$^{48}$Ca spike, high precision K abundances were determined from the $^{40}$K/$^{41}$K ratios, normalized to $^{39}$K/$^{41}$K=13.8566 (3). The accuracies for K/Ca ratios reported in this study are $\pm 0.1\%$.

K-Ca mineral isochron for granitic clast 14321,1062: Granitic clast 14321,1062 is the largest pristine sample so far identified in lunar samples (4). We have dated this clast by the Rb-Sr, Sm-Nd and $^{39}$Ar-$^{40}$Ar methods (5). The magnetic fraction of the sample was completely consumed by this previous study. The current K-Ca isotopic study was conducted using the remaining non-magnetic fraction of the sample. After a bulk sample (WR1) and the clear feldspar separate (CF) were taken from this fraction for an earlier study (1), a second bulk sample (WR2) was taken. Two additional mineral separates, clear and gray phases (C+G) and dark and gray phases (B+G) were separated by handpicking. The distribution of K and Ca in the bulk samples and mineral separates of the granite, shown in Fig. 1a, clearly indicates at least three phases were obtained for this age study. $^{40}$Ca/$^{44}$Ca and $^{40}$K/$^{44}$Ca ratios for the two bulk samples and three mineral separates define a line corresponding to a K-Ca isochron age of 4.06$\pm$0.07 Ga ($2\sigma$) for $\lambda$($^{40}$K)=0.5543 Ga$^{-1}$ and decay parameters recommended in (6,7), and low initial $^{40}$Ca/$^{44}$Ca of 47.141$\pm$0.002 (see Fig. 1b) when the data are regressed by the Williamson program (8). The $2\sigma$ uncertainties of the age and the initial ratio are reduced to $\pm 0.03$ Ga and $\pm 0.004$ respectively, when the data are regressed using the York program (9). The K-Ca isotopic age is in excellent agreement with the Rb-Sr age of 4.09$\pm$0.03 Ga for $\lambda$($^{87}$Rb)=0.01402 Ga$^{-1}$ (10) and the Sm-Nd age of 4.11$\pm$0.20 Ga for $\chi$($^{147}$Sm)=0.00654 Ga$^{-1}$ obtained previously for this granite (5). These ages are slightly older than the U-Pb age of 3.96$\pm$0.021 Ga for zircons from 14321,1027 (11). The concordancy of K-Ca, Rb-Sr and Sm-Nd isochron ages strongly suggests that the granite crystallized from a melt $\sim 4.1$ Ga ago. The brecciation event at 3.88$\pm$0.03 Ga recorded by the $^{39}$Ar-$^{40}$Ar age (5) seems to have had little effect on these three isotopic systems.

K-Ca mineral isochron for granitic clast 12033,576: Granitic sample 12033,576 was identified from an inner core of a dimict breccia from a collection of 4-10mm KREEP-rich soil particles.
(12). A gray feldspar–rich sample (G) and a dark sample containing brownish glasses of possible shock melting origin (12) and mafic minerals (B) were separated by handpicking from a bulk sample of <149 μm. The non-linear distribution of K and Ca abundances in two bulk samples (WR1 and WR2) and two mineral separates, shown in Fig. 2a, suggest samples of at least three phases were obtained for the study. The K–Ca isotopic data for two bulk samples and two mineral separates define an isochron age of 3.62±0.11 Ga(2s) and a high initial 40Ca/44Ca of 47.160±0.006 (see Fig. 2b) using the Williamson fit program (8). This age is slightly younger than the U–Pb zircon age of 3.898±0.010 Ga (11), but is considerably older than the 39Ar/40Ar age of 800±15 Ma determined from an aliquot of the sample (13). The discordancy of these ages and high initial 40Ca/44Ca value for the granite indicate that the K–Ca isochron could be partially reset. If so, the crystallization age for this granite would be significantly older and could probably be close to its K–Ca model age of ∼4.2 Ga. The 800 Ma age has been interpreted as the age of Copernicus (13), suggesting that the K–Ca age was partially reset by the Copernicus impact.

** Petrogenetic implications:** Ages and initial 40Ca/44Ca ratios for these two granitic samples are represented by two error parallelograms in Fig. 3. The 40K/44Ca ratio for the source of granite 14321 is calculated to be ~0.0025, similar to the values found in quartz monzodiorites (14–16). A large K/Ca fractionation (F_{K/Ca}= -11) for the granite seems to be required during granite formation. Large enrichments of K/Ca are expected from the silicate liquid immiscibility (SLI) process (17,18). The present K–Ca and the previous Rb–Sr and Sm–Nd isotopic results (5) are all in agreement with granite genesis involving the SLI process (e.g. 4,5,18). The initial 40Ca/44Ca ratio for granite 12033 defined by the K–Ca isochron is so radiogenic that this granite must have either derived from very high K/Ca sources (themselves granitic) or have assimilated ancient granitic materials prior to its crystallization. However, assuming a similarly large F_{K/Ca}= -11 for this granite as for 14321, it could be derived from sources with reasonably low K/Ca ∼4.14 Ga ago, probably via SLI. The 39Ar/40Ar studies (13) suggests an origin near the crater Copernicus.