**K-Ca AND Rb-Sr DATING OF LUNAR GRANITE 14321 REVISITED.** J. I. Simon, C.-Y. Shih, and L. E. Nyquist, NASA Johnson Space Center, Houston, TX 77058 (Justin.I.Simon@NASA.gov), JE-23 Jacobs Technology/ESCG, P.O. Box 58477, Houston, TX 77058.

**Introduction:** K-Ca and Rb-Sr age determinations were made for a bulk feldspar-rich portion of an Apollo rock fragment of the pristine lunar granite clast (14321_1062), an acid-leached split of the sample, and the leachate. K-Ca and Rb-Sr data were also obtained for a whole rock sample of Apollo ferroan anorthosite (FAN, 15415). The recent detection [1] of widespread intermediate composition plagioclase indicates that the generation of a diversity of evolved lunar magmas may be more common and therefore more important to our understanding of crust formation than previously believed. Our new data strengthen the K, Ca, Rb, and Sr abundances in samples and therefore more important to 

The new K, Ca, Rb, and Sr data were obtained on a Thermo Finnigan Triton TIMS instrument. Standard mass spectrometry procedures for Sr were used. Rb and K measurements were run sequentially on the same filament and Ca analyses follow methods developed by [3]. The K abundances in samples were calculated from their $^{40}$K/$^{41}$K ratios, normalized to $^{39}$K/$^{41}$K = 13.9448. A mean $^{40}$K/$^{41}$K value of 0.001739±7 (2 sd, n=8) was obtained for the NBS985 K standard mixed with the Rb standard NBS984. The Ca abundances in samples were calculated from their $^{40}$Ca/$^{44}$Ca ratios, normalized to $^{42}$Ca/$^{44}$Ca = 0.31221. An average value of $^{40}$Ca/$^{44}$Ca = 47.160±5 (2 sd, n=8) was obtained for SRM915a and used to correct the sample $^{40}$Ca/$^{44}$Ca values accordingly based on the UC Berkeley value of 47.153 [3, cf. [5]. The Rb abundances in samples were calculated from the $^{87}$Rb/$^{86}$Rb ratios, normalized to the average $^{87}$Rb/$^{86}$Rb value of 2.6036±77 (2 sd, n=9) for NBS984 mixed with the K standard. The Sr abundances in samples were calculated from their $^{87}$Sr/$^{86}$Sr ratios, normalized to $^{87}$Sr/$^{86}$Sr = 8.37521 and corrected to $^{87}$Sr/$^{86}$Sr = 0.710250, according to the measured average $^{87}$Sr/$^{86}$Sr value = 0.710238±10 (2 sd, n=10). Uncertainties of elemental concentrations largely reflect weighing errors for individual samples and uncertainty in spiking.

**Results:** Granitic material processed in this study was derived from several small chips originally characterized by [6]. The initial sample handling done and described by [2]. In order to increase the spread in the K-Ca and Rb-Sr isochrons reported by [2], we processed an additional 2.9 mg aliquot of the feldspar-rich bulk rock (14321 FR), 4.15 mg of acid-washed residues of the sample (14321 FR), and a 0.7 mg leachate derived from the washing (14321 FR). A split of 15415 was also characterized to allow direct comparison to the initial Ca and Sr compositions of pristine lunar highland rocks.

New K data for a rock fragment and leachate along with previously reported data [2] for mineral separates and several fragments of the granite clast 14321 are shown in Fig. 1. These data correspond to an isochron age of 4031±74 Ma (2 se, MSWD=0.24, n=7, for $\lambda(^{40}\text{K})=0.5543 \text{ Ga}^{-1}$) with an initial $^{40}\text{Ca}^{44}\text{Ca}=47.163±12$ (2 se). This age is within error of the previously reported K-Ca age of 4059±120 Ma (2 se, MSWD=0.07, n=5). Fig. 2 contains new Rb-Sr data that along with previously reported Rb-Sr data [7] collectively correspond to an isochron age of 4052±81 Ma (2 se, MSWD=1.3, n=8, for $\lambda(^{87}\text{Rb})=0.01402 \text{ Ga}^{-1}$) with a relatively impure initial Sr/Sr = 0.7021±65 (2 se). This age is within error of the previously reported Rb-Sr age of 4055±110 Ma (2 se, MSWD=1.8, n=6). The primitive FAN 15415 yields a $^{40}\text{Ca}^{44}\text{Ca}$ value of 47.145±6 (2 se) that is within error of the initial value accepted for Earth and other differentiated planetary objects [3, 4], but slightly lower than the mean lunar value of 47.155±2 (2 se, n=7) reported by [2]. An estimate for the initial Sr/Sr value of the ancient lunar highlands based on Apollo FAN sample 15415 yields a value of 0.69925±10 that is consistent with the previously reported value of 0.69925 by (8).

**Discussion:** Granite 14321 is one of the youngest and most evolved silicic rocks collected from the Moon (6). It has been dated previously by Sm-Nd, Ar/Ar (7), and U-Pb (zircon) methods (9). As expected the precision of the K-Ca and Rb-Sr ages has been improved. Both new ages are slightly younger than previously reported. These ages are now within error of the existing mean U-Pb zircon age (3965±50 Ma).
The total release Ar/Ar age of a feldspar-enriched split of 14321 yields a slightly younger age of $3.88 \pm 0.03$ Ga (2 se). The concordancy of K-Ca, Rb-Sr, Sm-Nd internal isochrons and (now) the U-Pb model age strongly indicate that the granite formed ~4000 Ma ago. The apparent Ar/Ar age suggests that it was brecciated and excavated from near the surface about 100 Ma later.

The initial Ca isotopic ratio provides a constraint on the K/Ca ratio of the source of 14321 (Fig. 3). Using the measured composition of 15415 (this study) or a combination of this and previous estimates for the initial $^{40}$Ca/$^{44}$Ca of the Moon (2), a more precise estimate for K/Ca of ~0.7 is determined. This value is significantly higher than previous estimates and largely due to the new low K/Ca 14321 FR.I datum near the origin in the K-Ca isochron (Fig. 1). This calculated mean K/Ca value is well above the upper range for the values (0.2-0.5) found in known lunar quartz monzodiorites, e.g., (10) and suggests that 14321 (that has an K/Ca value of ~5) was probably generated from an earlier episode of intermediate magmatism.


**Figure 1.** K-Ca internal isochron for lunar granitic clast 14321,1062. New feldspar-rich bulk and sample-leachate data (this study) are combined with two bulk samples and 3 color-sorted mineral separates (2). The isochron age and initial $^{40}$Ca/$^{44}$Ca ratio are calculated using Isoplot (11). The error envelope represents the 95% confidence interval of the regression. The bulk measurement of FAN 15415 is representative of primitive lunar highland rocks.

**Figure 2.** Rb-Sr internal isochron for lunar granitic clast 14321,1062. Two new bulk samples (one that is acid-washed, 14321 FR.r) are combined with data from a bulk sample, 3 feldspar mineral separates and 2 magnetic fractions (7). The isochron age and initial $^{87}$Sr/$^{86}$Sr ratio are calculated using Isoplot (11). The error envelope represents the 95% confidence interval of the regression. FAN 15415 plots off scale.

**Figure 3.** Plot of $^{40}$Ca/$^{44}$Ca evolution against time. Growth curves are shown for basaltic (K/Ca=0.02), intermediate, and evolved (K/Ca=1) crustal sources. The initial $^{40}$Ca/$^{44}$Ca composition of Apollo granite 14321 when compared to primitive lunar crust (e.g., FAN 15415) indicates that it was derived from a relatively enriched source that has a K/Ca ratio (~0.7) that is equivalent to terrestrial andesite.