NEW PIECES OF THE LUNAR GRANITE-QUARTZ MONZODIORITE PUZZLE. Ursula B. Marvin, Beth B. Holmberg, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, and Marilyn M. Lindstrom, NASA Johnson Space Center, Houston, TX 77058.

Three coarse fines particles with quartz monzodiorite related components were separated from soil 15403 which was collected from a crevice in a boulder sampled as rock 15405. One of the particles was made into thin section 15403,71which contains a single 5mm fragment with three clasts rich in silica, K-feldspars, and phosphates but having markedly different modes and textures. We classified two of the clasts (A and B) as quartz monzodiorites (QMD) and the third (C) as granite (G). The remaining two particles were analyzed by INAA. They show extraordinary enrichments in K, REE, and other incompatible elements over and above those in the KREEP basalts and melt rocks that make up the bulk of the 15403 soil.

Our new QMD and G clasts have certain similarities and some distinct differences from those in 15405, the rock that contained the original QMD and some granite clasts [1]. However, with all characteristics considered together they show a very close family relationship.

The mode of QMD Clast A, 2mm across, is about 33% of silica and K-feldspar (Or_{89-94}) in granophyric intergrowths, 29% plagioclase ($An_{50-80}Ab_{20-45}Or_{0.3-5}$) about 4% of which occurs in a plagioclase-silica intergrowth, 18% phosphates, 14% of pyroxenes with exsolution lamellae of ferroaugite and ferropigeonite, 5% SiO_2 in separate grains, and accessory ilmenite, baddeleyite, troilite, and metallic Fe with 0.0-0.5% Ni. The pyroxene compositions are spanned by the following exsolution pairs: $En_{26}Fs_{69}Wo_5$ and $En_{23}Fs_{33}Wo_{44}$; $En_{38}Fs_{54}Wo_8$ and $En_{33}Fs_{34}Wo_{33}$. The strikingly high abundance of phosphates in the clast reflects the presence of two grains 0.8 and 1.2 mm long. The larger phosphate lath is an intergrowth of apatite with whitlockite (Fig. 1a). The apatite is essentially the pure mineral with <1 wt% of major element impurities, undetectable trace elements, and little space for halogens, as the electron microprobe analyses sum to between 98.9 and 100.6 wt%. The whitlockite contains 1.7-2.3 wt% MgO and 2.7-4.4 wt% FeO, but the probe analyses consistently sum to only about 90 wt%, indicating 10 wt% of additional components. We have not yet performed quantitative analyses, but element scans indicate the presence of Y, Ce, La, Gd, and Nd.

Clast A displays some shock-induced randomization of optical extinctions, and along its border with the matrix there is a thin zone of mineral fragments and vesicular glass with crystallites. Some of the pyroxenes in that zone run higher in MgO than those in the clast proper, but have values similar to those of the pyroxenes in the matrix.

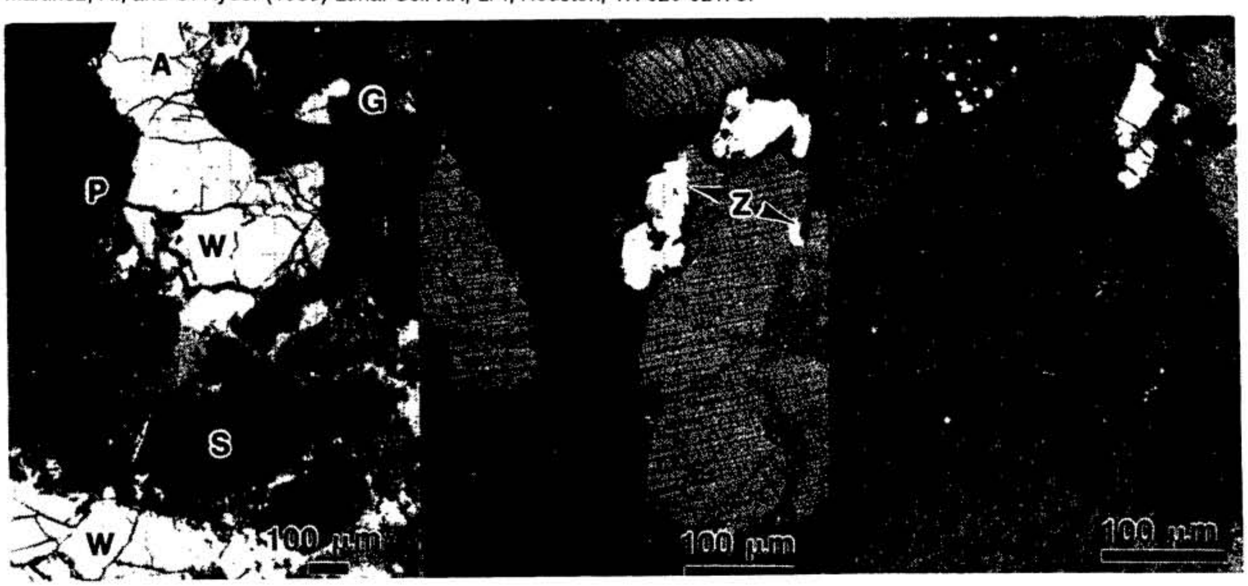
QMD Clast B (Fig. 1b) is a 530 x 420 µm fragment consisting of 54% exsolved ferropyroxenes, 42% of an intergrowth of silica and K-feldspar (Or_{90-95}), 4% whitlockite similar to that in Clast A, 1% ilmenite, and traces of baddeleyite, FeS and metallic Fe. The pyroxene compositions overlap with those in Clast A, but the most Fe-rich pairs range up to $En_{23}Fs_{73}Wo_4$ and $En_{20}Fs_{38}Wo_{42}$.

Granite Clast C (Fig. 1c) is an angular fragment, 640 µm across, of silica and K-feldspar in a granophyric intergrowth. The only other minerals are 2 grains of whitlockite and some small rounded masses of FeS and metallic Fe. A marked change in texture occurs in the midst of the clast where the delicate optically-continuous lamellae of silica, 5 to 20 µm wide, give way to a zone with bands up to 100 µm wide. The silica has a wormy, porous texture that tends to yield low analysis totals. The feldspar consists mainly of Or_{90-93}, which clusters with the K-feldspars in the QMD clasts, but it also includes ternary compositions ($An_9Ab_8Or_{83}$ to $An_{18}Ab_{17}Or_{65}$), not observed in the QMD. Ternary feldspars, mostly of compositions different from these have been described in numerous lunar granites [2]. They also occur in other alkali-rich rocks [e.g. 3,4].

The dark colored breccia matrix has an igneous microtexture consisting of plagioclase, pyroxene, and ilmenite laths 1 to 6 µm wide. It contains many small clasts of granites, exsolved pyroxenes similar to those in the large clasts, and other minerals. Not surprisingly, microprobe scans across the matrix at 10 µm intervals show fairly consistent values for a felsic and a mafic component (aside from clast analyses which are easily identifiable). Averaged together, the two matrix components show a normative composition of 48 wt% plagioclase ($An_{78}Ab_{19}Or_{2.4}$), 42% pyroxene ($En_{44}Fs_{45}Wo_{12}$), 3.8% quartz, 1.9% apatite, 2.7% ilmenite, 0.22% chromite and 0.07% pyrite. The matrix is siliceous, KREEPy, and moderately ferroan, but it is 10 to 15 wt% richer in magnesium than the most Mg-rich pyroxenes of the QMD clasts. We conclude that the matrix is an impact melt made up chiefly of a rock that was somewhat less evolved than QMD but closely related to the QMDs and granites that make up most of the clast population.

Comparisons of QMD clasts show that ours contain apatite, baddeleyite, troilite, and plagioclase-silica intergrowths which were not observed by Ryder [1] in the QMD of 15405. However, Ryder found zircon and chromite, of which we saw none, and he described ilmenite in large, twinned crystals sometimes intergrown with Si-K-rich phases. In the granite clasts of 15405, and also of 15434 Ryder [1,5] found exsolved pyroxene grains similar in major and minor element contents to those in the QMD. He also noted plagioclases, silica in platy grains, and chains of small ilmenites with euhedral pyroxenes, glass and phosphates. We found none of these components, but we identified K-rich ternary feldspars. On the assumption that the small clasts of granite in 15403 and 15404 come from the same source, we can visualize a parent rock rich in silica-orthoclase intergrowths, plagioclase, ferropyroxenes, and phosphates, plus a few common accessories. The same minerals, in different proportions and with somewhat different compositional ranges, make up the quartz monzodiorites. In 1989 Martinez and Ryder [5] asked if a granite fragment from the Apennine front could be a brother of quartz monzodiorite. Although certain aspects of this puzzle defy an immediate solution, we predict that continued investigation will show that indeed they are brothers--blood brothers.

REFERENCES: [1] Ryder, G. (1976) Earth and Planet. Sci. Letts. 29:255-268. [2] Ryder, G., *et al.*, (1975), PLSC 6th, GCA Suppl. 6, 435-449. [3] James, O.B., *et al.*, (1987) PLSC 17th, JGR 92, E314-E330. [4] Lindstrom, M.L. *et al.*, (1987) LPSC 18th, 169-185. [5] Martinez, R., and G. Ryder (1989) Lunar Sci. XX, LPI, Houston, TX 620-621. 3.



a b c

Figure 1. Backscattered electron images of clasts in 15403,71. **a.** Clast A, quartz monzodiorite with two large phosphate grains. Whitlockite [W], apatite [A], silica K-feldspar granophyre [G], silica-plagioclase granophyre [P], silica [S]. **b.** Clast B, quartz monzodiorite with exsolved ferropyroxenes and granophyric silica and K-feldspar. Whitlockites (white) are associated with ilmenite (gray) and baddeleyite [Z]. **c.** Clast C, an uncomplicated granite with two whitlockites and small grains of Fe metal and FeS.