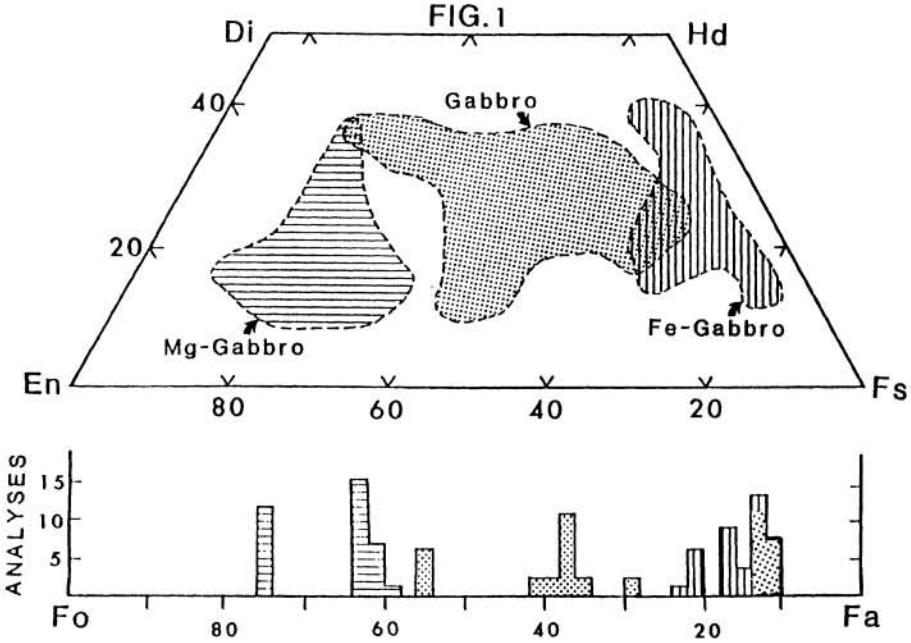
COARSE-GRAINED BASIC IGNEOUS SAMPLES FROM MARE CRISIUM: MINERALOGY, PETROGRAPHY, AND PETROGENESIS. Fengxiang LU, Lawrence A. TAYLOR, and Yuequn JIN, Dept. of Geological Sciences, Univ. of Tennessee, Knoxville, TN 37996.

As part of the continuing exchange program in planetary science between the U.S.S.R. and the U.S.A., the Soviets have recently made available new lunar samples from the Luna Missions for research in the U.S. program. We have received polished grain mounts of >250 micron particles from the 88 and 105 cm portions of the Luna 24 core, namely samples 24088,14 and 24105,15. We have examined 47 particles with igneous textures using petrographic and electron microprobe techniques in an attempt to delineate the relationships between the different lithic types and their petrogenesis.

Although modes on samples as small as these are suspect, it was still possible to distinguish five (5) kinds of lithic fragments. They are Mg-rich Ol-gabbro, Ol-gabbro, ferrogabbro, troctolite, and an Ilm-Qtz-fayalite-whitlockite rocklet. The three gabbros were found in both slides, but the others were found only in 24105,15. There is little real difference between the two samples from the different depth within the Luna 24 core. However, the troctolite and Ilm-Qtz-fayalite-whitlockite fragments are rare; only four particles were found.



Mg-RICH Ol-GABBRO: Six fragments, ranging from 310x230 to 780x460 um, of Mg-rich Ol-gabbros were found in the two thin grain mounts. This gabbro is essentially composed of 3 minerals: olivine, pyroxene, and plagioclase. Euhedral chromite-ulvöspinel, the only opaque mineral found in this gabbro, occurs in the pyroxene. This type of gabbro is richer in Mg than the others, as reflected in the compositions of Ol (Fo60-75) and pyroxene (Wo10-37, En46-70, Fs 10-34). Plag compositions range from An92-98. This rock has poikilitic, subhedral granular, & intergrowth textures. Some early-formed olivines (50-100 microns) are rounded and enclosed in large pyroxenes (320 microns), and some are subhedral (100-120 microns) and interstitial with Cpx. Most of the pyroxenes are subhedral, but an intergrowth of Cpx with Plag also occurs. Deformation features in the Cpx and Plag are abundant, where undulatory extinction and kink bands (21-30 microns) are developed. The average mode of this gabbro is 50% Plag, 41% Cpx, 8% Ol, and 1% opaque minerals.

Ol-GABBRO: The most abundant of the coarse-grained fragments are Ol-gabbro. It contains Ol (Fo11-55), Cpx (Wo11-37, En12-48, Fs21-61), subhedral or lath-shaped Plag (An85-96), and opaque minerals (chromite-ulvöspinel, ilmenite, troilite, and native FeNi). The compositions of the ferromagnesian minerals vary greatly between different rock fragments, as well as from grain to grain within the same particle. Elongated, Fe-rich olivines (Fo11-12; 300x110 to 270x100 microns) are larger than the rounded Mg-rich Ol (Fo42-54; 100-120 microns). The interstitial or subhedral Plag is associated with Fe-rich pyroxene, whereas lath-shaped Plag is associated with Mg-rich Cpx. This implies that the Fe-rich ferromagnesian minerals were crystallized earlier than the Plag. Deformation features are also seen in Plag and Px, which are similar to those in the Mg-rich Ol-gabbro. In general, the Ol-gabbro has subhedral granular texture. The average mode is 40% Plag, 43% px, 12% Ol, and 5% opaque minerals.

FERROGABBRO: A 1x0.5 mm fragment of ferrogabbro occurs in 24105,15 and consists of pinkish pyroxene (Wo21-39, En5-19, Fs60-82), colorless pyroxene (Wo14-16, En5-7, Fs79-81), Plag (An79-90), and ilmenite, which is included in Px. This texture is typical subhedral granular, and the lengths of Cpx and Plag are 1 mm and 300 microns, resp. Thin sections reveal that the Ca-poor, Mg-poor, and colorless pyroxene appears to replace the Mg-poor pinkish pyroxene. This feature is also found in monomineral fragments in both samples. The modal composition is 60% pinkish Cpx, 18% colorless Cpx, 21.5% Plag, and 0.5% Ilm.

TROCTOLITE: Two troctolite rocklets (350x250 & 300x270 microns) consist of Ol (Fo12-30), Pl (An90-96), euhedral spinel, and ilmenite. In one fragment, Ol and Cpx are intergrown with each other, but they are subhedral granular in the other particle. The average mode is 62% Ol, 35% Plag, 3% Cpx, and 3% opaque minerals.

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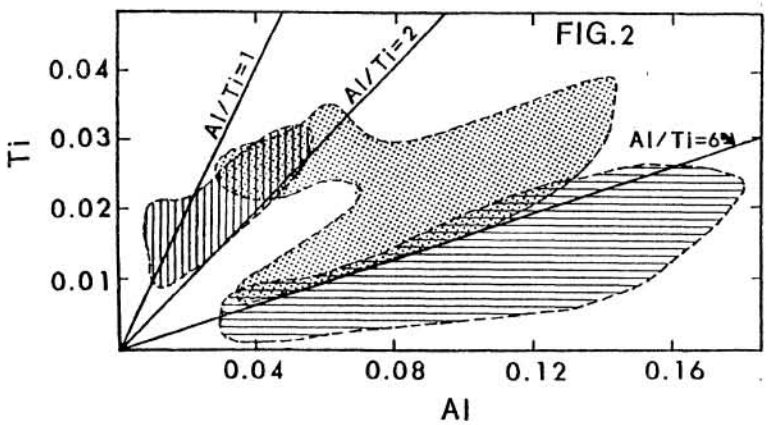
ILM-QTZ-FAYALITE-WHITLOCKITE: A very interesting type of rock chip that has never been reported in Luna 24 [1,2,3] or any other lunar sample is Ilm-Qtz-fayalite-whitlockite. Two such particles occur in 24105,15. One particle (300x250 microns) has only Qtz and Ol (Fo2.6-2.8); another (400x470 microns) has 20% Ilm, 30% Qtz, 49% Ol (Fo6-7), and <1% whitlockite, in which the Ilm and Qtz are lath-shaped, and the Ol occurs interstitially.

MINERAL CHEMISTRY: The compositions of the pyroxenes (Figs. 1 & 2) reveal trends for the different gabbro types. Variations of the Cpx from Mg-rich pigeonite and Mg-rich augite through the pigeonite, augite and ferroaugite to the ferropyroxene is correlable with rock type from Mg-rich Ol gabbro through Ol gabbro to the ferrogabbro. The pyroxene compositions vary greatly from grain to grain and from core to rim as well. Generally, the pyroxenes display an evolutionary trend towards Fe-rich. However, there are small but significant distinctions between the rock types. Some trends become Fe-rich with increasing Ca, whereas others with decreasing or constant Ca. Core to rim compositional zoning can be towards Ca increase or decrease. The ferrogabbro appears to have fractionated to such an extreme that "pyroxferroite" has formed, albeit metastably. The Ti vs. Al diagram also shows the progressive differentiation of Ti/Al from 1/6 to 1/2 during early fractionation, to greater values for the ferrogabbro. To some extent, these trends are probably a function of Plag crystallization. The Ol compositions also become increasingly Fe-rich, but there is an overlap in the Ol histogram between Ol-gabbro and ferrogabbro. (The compositions of Ol in troctolite and in Ilm-Qtz-fayalite-whitlockite plot in the field of ferrogabbro.) Plag compositions (An78-98), detailed above, are typically lunar values. The distribution peak is around An94-96; however, the differences between the various types of rock are not significant.



DISCUSSION: According to the mineral compositions of the pyroxenes in the various rock fragments, the predominant evolution trend of the suite is one of increasing FeO and TiO_2, with decreasing MgO, CaO, Al_2O_3, and Cr_2O_3. Obviously, Fe and Ti play a role as incompatible elements in the differentiation, and Mg, Ca, Al, and Cr are compatible. K_2O and Na_2O only increased slightly, as reflected in the plagioclase, with K_2O up to 0.25% (Or1.1-1.5) and Na2O up to 2.5% (Ab20-22.2) in the later stages. Because the olivine occurs almost in every rock-type, it may indicate that Si is not a very important incompatible element in the process. Compared with the trend of Fe-rich terrestrial tholeiite, this lunar process could be called a **"short range differentiation"**, and it corresponds to a part of tholeiitic trend from M to F in the A-F-M diagram.

The presence of "pyroxferroite" replacing ferropyroxene is another sign of the advanced stage of evolution of these rocks. Even though this phase is metastable at the low pressures prevailing during the formation of these gabbros, it nevertheless only occurs during late-stage fractionation of Fe-rich basalts/gabbros.

The rock fragments consisting of coarse-grained (2-300 microns) **Ilm + Qtz + fayalite + whitlockite** are significant. Neal and Taylor [4, this volume] have presented a scenario for KREEP wherein further fractionation of KREEP will produce silicate liquid immiscibility (SLI) with one of the two melts forming a granitic assemblage. The other, Fe-rich melt would probably crystallize to Ilm + Qtz + Fa + whitlockite. Effectively, the KREEP is separated into a K-fraction and a REEP-fraction. It is possible that these Luna 24 particles represent **the crystallized products from this REEP-fraction.** Although this assemblage is common as the mesostasis in many basalts, this is the first reported occurrence of such a well-crystallized, coarse-grained mineral assemblage into a rock.

CONCLUSION: The Mg-rich Ol-gabbro, Ol-gabbro, troctolite, ferrogabbro, and Ilm-Qtz-fayalite-whitlockite assemblages represent the products of magmatic differentiation of a Mg-rich basaltic magma. **The Mg-rich Ol-gabbro, the least-evolved magma, may be representative of the primary melt, and the Ilm-Qtz-fayalite-whitlockite rock is an end member of the differentiation.** This process, controlled mainly by Mg-rich Ol and Cpx fractionation, can be called "short-range differentiation". It is possible that silicate liquid immiscibility (SLI) is also a mechanism of this differentiation.

REFERENCES: **[1]** Coish & Taylor, 1978, Mare Crisium: The View from Luna 24, 403-417; **[2]** Nielsen & Drake, 1978, Mare Crisium: The View from Luna 24, 419-428; **[3]** Laul et al., 1978, Mare Crisium: The View from Luna 24, 537-568; **[4]** Neal & Taylor, LPSC XIX, this volume.