
Introduction: MIL 05035 is a 142.2 g lunar meteorite found on the Miller Range Ice Field, Antarctica, during the 2005 meteorites season [1]. A polished thin section, MIL 05035,6 (~0.75 cm², Fig. 1), was used for the petrographic and mineralogic study. Results suggest that this new lunar meteorite is derived from a highly fractionated, low-Ti magma.

Petrography: MIL 05035,6 is conspicuous for the abundant break-down assemblages (~1.4 vol%) and the large grain size. It has a holocrystalline texture and is mainly composed of coarse-grained pyroxene (>2 mm, ~66 vol%) and maskelynite (>1 mm, 29 vol%). The rest of the sample consists of interstitial minerals (fayalite, troilite, ulvöspinel intergrown with ilmenite, and SiO₂), Fe-rich pyroxene break-down assemblages (intergrowths of olivine, SiO₂, and ferroaugite), and mesostasis (K-rich glass, fayalitic olivine, merrillite, baddeleyite, and SiO₂). Mesostasis accounts for <1 vol% of the section. Also present is a small section of highly vesiculated, heterogeneous fusion crust. All minerals are subhedral to anhedral.

Mineral Chemistry: Pyroxene: Primary pyroxenes have augite cores (En₃₅₋₄₀Fs₃₀₋₄₂) and grade toward Fe-rich rims (Fig. 2). The extreme Fe-enrichment of pyroxene rims places these compositions in the “forbidden zone” for terrestrial pyroxenes, and they are, therefore, metastable [8]. Secondary pyroxenes in the break-down regions are close to hedenbergite (En₁₁₋₁₂Fs₅₂₋₅₃Wo₃₇₋₃₃).

Maskelynite: Maskelynite is zoned from An₉₄ in cores to An₉₁ in rims. However, rims in contact with the mesostasis have An₈₅₋₈₆.

Olivine: All olivines are fayalitic in composition. The most extreme composition is that of two large (>1 mm) fayalite grains (Fa₉₈) associated with late stage phases (e.g., K-rich glass, Cr-rich usp, baddeleyite). Small fayalite grains in mesostasis have a composition of Fa₉₀. Secondary olivine, in the break-down textures, has composition Fa₉₄₋₁.

Oxide Phases: Interstitial ulvöspinel (>1 mm) contains 5-7 wt% Cr₂O₃, and ilmenite contains ~0.2 wt% Cr₂O₃. Ilmenite has detectable ZrO₂ (~0.2 wt%).

Miscellaneous Phases: Silica occurs as lath shaped grains (~1 mm long), as well as small grains (<20 µm) in the break-down assemblages. K-rich glass contains up to 8.5 wt% K₂O and ~0.9 wt% BaO.

Bulk Composition: The bulk composition of the rock was estimated using the modal analyses of minerals, mineral compositions, and density. The estimated composition is low Ti basalt: 47.2 wt% SiO₂, ~1 wt% TiO₂, 10.5 wt% Al₂O₃, 0.4 wt% Cr₂O₃, 5.9 wt% MgO, 13.7 wt% CaO, and 20.7 wt% FeO.

Discussion: MIL 05035,6 has an unusually high proportion of break-down assemblages (~1.4 vol%). Most...
assemblages contain a uniform distribution of minerals (Fig. 3a). However, a few assemblages have distinctive myrmekitic textures (Fig. 3b).

This intergrowth feature of augite, fayalite, and SiO$_2$ is indicative of the break-down of pyroxferroite [9-10] or pyroxenes with compositions in the “forbidden zone” (Fig. 4) [8]. The pre-break-down pyroxenes or pyroxinoids were reconstructed using the modal percentage of minerals (analyzed on the BSE image using image analysis software, ImageJ from NIST), the composition of minerals, and their corresponding densities.

For the uniformly distributed texture (Fig. 3a), the reconstructed composition (Fig. 4) lies near the range of lunar pyroxferroite [8]. Pyroxferroite can form metastably at low P and then break-down during slow cooling [9]. In this sample, the lack of pyroxenes with pyroxferroite composition (Fig. 4) suggests that all pyroxferroites broke down due to a homogeneous process affecting the entire rock e.g., cooling.

For the myrmekitic break-down, the reconstructed Fe-rich pyroxene, in the “forbidden zone” (Fig. 4), is similar in composition to the rim of primary pyroxenes. The preferential alignment of olivine and SiO$_2$ suggests the pyroxene (En$_{12}$Fs$_{65}$) decomposed to ferro-augite and metastable “ferrosilite”, and the “ferrosilite” subsequently broke down to fayalite + SiO$_2$.

The textual and chemical differences between the two types of break-down suggest a different process may have been involved in the formation of the myrmekitic assemblages. An obvious candidate to provide the activation energy required to initiate this process would be the impact shock that launched this lunar rock into space. The full conversion of plagioclase to maskelynite involves pressures in the upper end of the vitrification range (30 – 45 GPa [11]), and the mosaicism of pyroxenes involves pressures of 30 – 75 GPa [12]. This may have been sufficient energy to cause the breakdown. That not all pyroxenes with this composition broke down is further evidence for the mechanical nature of the activation of this process.

Comparison with Other Lunar Meteorites: Compared to other lunar gabbroic meteorites (Asuka-881751 [6], Yamato-791369 [7]), MIL 05035 is similar to Asuka-881751 in that primary minerals have similar compositions. However, MIL 05035 contains more Fe-rich pyroxenes and less ilmenite than Asuka-881751. The break-down textures have been reported for other lunar meteorites, but not to the degree observed here.