A New Lunar Meteorite MET 01210: Mare Breccia with a Low-Ti Ferrobasalt. T. Arai, K. Misawa and H. Kojima, [1]Antarctic Meteorite Research Center, National Institute of Polar Research, 1-9-10 Kaga Itabashi Tokyo 173-8515, Japan (tomoko@nipr.ac.jp; misawa@nipr.ac.jp; kojima@nipr.ac.jp).

Introduction: MET01210 is a new lunar meteorite, weighing 22.8 g, recently found at Meteorite Hills in Antarctica [1]. Although it is tentatively classified as an anorthositic regolith breccia [1], a provided thin section of this meteorite is a mare breccia with basalt clasts and mineral fragments of mare derivation. We present mineralogy of this new lunar meteorite to discuss the petrogenesis and to assess the likelihood of pairing with known lunar-meteorite mare breccias/basalts.

Sample and Method: A polished thin section MET01210,19 is provided by NASA JSC. Mineralogical analyses were done by JEOL 8200 Electron Microprobe at National Institute of Polar Research.

Results: MET 01210 is a polymict regolith breccia, consisting of dominantly mineral fragment, 100 - 600 μm in size, of apparent mare derivation with basaltic clasts, opaque-rich clasts, plagioclase-rich clasts, hedenbergite - fayalite - silica symplectite, fine-grained dark melt clasts and Anorthositic impact glass spherules / fragments of 60 - 500 μm across, embedded in a dark matrix. The dark matrix is heterogeneous with fine-grained, fragmental materials. Mafic mineral fragments are mainly pyroxene and Ca-rich plagioclase (An = 92 – 96) with Fe-rich olivine (Fo = 30, 20, 4 - 7, 0 for each grain), ilmenite, Cr, Al-bearing ulvöspinel (Chr5-10Her4-7Ulv84-90), troilite, Fe metal and silica minerals. Ilmenite grains of 100 μm across are scattered through the thin section. Pyroxene compositions are shown in Fig.1a. Note that some fragments show compositions of an extreme enrichment of Fe and Ca close to pyroxferroite. Most of the pyroxene fragments are exsolved in a few micron scale. No pyroclastic glass is found in this thin section. Brown-colored vesicular fusion crusts 100 to 400 μm in width, are found at one side of the thin section. The average composition of the homogeneous outer portion (100 - 150 μm from the crust rim) is SiO_2 = 44.3 wt%, TiO_2 = 1.6 wt%, Al_2O_3 = 16.2 wt%, FeO = 16.6 wt%, MgO = 6.0 wt%, CaO = 12.7 wt%. Mineralogy of lithic clasts are shown below:

Basaltic clasts: A coarse-grained basaltic clast (Basalt 1), 2.7 mm × 4.7 mm in size, is composed mainly of pyroxene and plagioclase (An =91 – 95) with ilmenite, ulvöspinel, and fayalite. This clast preserves the primary igneous texture and chemical zonings with minor shock effect. Pyroxene grains show extensive and complex compositional zoning trend (Fig. 1b). In the case of a pyroxene grain 1 (Px 1), starting from a augite core of (Wo36En42Fs32), the Ca content cyclically decreases and increases with the lowest Ca point of a pigeonite (Wo12En50Fs38) and the gradually rises to a Fe-rich augite (Wo25En9Fs66). A pyroxene grain (Px 2) has a core composition is more Fe-rich than Px 1, but instead, an extremely Fe-rich pigeonite rim (Wo14En8Fs78). A pyroxene grain 3 (Px 3) shows a similar zoning trend to Px 1, but the rim composition Wo37En8Fs55 is close to pyroferroite and the rim is mantled by a 100 – 300 μm-thick fayalite (Fo = 6). Hedenbergite – fayalite - silica symplectites are present in the Fe-rich augite portion which is indicative of break-down of pyroxferroite. The pyroxenes are finely exsolved in a few micron scales. Another fine-grained subophitic basaltic clast (Basalt 2), 520 × 350 μm size, includes mainly pyroxene and plagioclase (An = 93) with ulvöspinel (Her4Ulv96) and hedenbergite - fayalite - silica symplectite. The pyroxene compositions are similar to those of Basalt 1 Px 2, but the rim is more Fe-rich with an extremely Fe-rich augite of Wo28En2Fs70 (Fig. 1c). The pyroxenes show exsolution of a few micron scales.

***Plagioclase-rich clasts*:** Three clasts with high modal abundances (60 – 85 vol. %) of plagioclase and medium grain size (100-500 μm) are found. These clasts consist of plagioclase (An = 95 – 96) and pyroxene, and the grain boundary is smooth-curved, indicative of subsolidus annealing. The pyroxenes are co-existing augite and pigeonite in heterogeneously exsolved within a grain. Both augite and pigeonite are finely exsolved in a few micron scale. The vertically distributed compositions in the pyroxene quadrilateral (Fig. 1c) reflect these pyroxene occurrences.

Opaque-rich clasts: An opaque-rich clast (clast 1)350 × 250 μm includes co-existing extremely Fe-rich augite and pigeonite with about 15 vol.% of opaque phases which are dominant troilite with minor ilmenite and fayalite (Fo =5). The Fe-rich augite is slightly zoned from Wo28En10Fs62 to Wo20En6Fs74, while the Fe-rich pigeonite is homogeneous (Wo14En6Fs80) with patches of zoned augites (Wo25En27Fs47 to Wo31En6Fs63) (Fig. 1c). These pyroxene compositions are close to the rim compositions of Basalt 1 Px 2 (Fig. 1b and 1c). Another clast (clast2), 250 × 230 μm, consists of about 50 vol.% of ulvöspinel (Chr5-6He5-7Ulv88-90) Fe-rich pyroxene, and plagioclase (An = 92 - 93). The pyroxene is slightly zoned from Mg-rich augite (Wo29En33Fs40) to Fe-rich augite (Wo16En16Fs67) which falls within the compositional range of Basalt 1 Px 2 (Fig. 1b).

***Pyroxene with Mg-rich olivine*:** A single pyroxene, 500 × 400 μm, contains a partly smooth-curved euhedral Mg-rich olivine (Fo = 52) , 110 × 130 μm in size. Pyroxene irregularly exsolved with augite and pigeonite domains and each pyroxene exhibit the micron-scale exsolution. The pyroxene compositions are vertically distributed in the quadrilateral between Wo40En40Fs20 to Wo6En55Fs39, reflecting the fine exsolution.

Discussions:

Petrogenesis of MET01210: Among the observed breccia clasts and mineral fragments, non-mare components are rare except aluminous impact glasses. The symplectite and pyroxene fragments with similar compositions of the basalt clast in the breccia matrix are apparently originated from the Fe-rich basalts. The opaque-rich clasts with pyroxenes more Fe-rich than those of the basalt clasts indicate that they are the late-stage product of fractional crystallization following after crystallization of the basalt clast. Pyroxene compositional variation in the plagioclase-rich clasts and the pyroxene with Mg-rich olivine imply that these clasts are relatively slowly cooled from the common parent magma with the basalt clast. Thus, all the mare components are derived from the common parent magma, relatively slowly cooled in shallow intrusion.

Connection to other lunar mare meteorites

Taking the composition of fusion crust as a rough estimate of the bulk-rock composition, what distinguish MET 01210 from other Antarctic lunar mare breccias (Y793274/Y981031, QUE94281, EET87521/96008, YYQEETs hereafter) are enrichment of TiO2. While the YYQEETs have 0.6 -0.7 wt% TiO2 [e.g., 2, 3], MET 01210 shows 1.6 wt.% TiO2. The bulk TiO2 of the basalt clasts estimated from the empirical correlation of bulk TiO2 and pyroxene Fe# vs Ti# trend [2] is ≈ 2 wt %, equivalent of A881757/Y793169 basalts [4], while those of YYQEETs ≈ 1 wt %. Thus, the basalt clast in MET01210 is low-Ti basalt, while YQEETs which are all Very-low-Ti (VLT) basalts. The pyroxene compositions are more Fe-rich, especially in highly fractionated rim, compared to YYQEETs [e.g.,2, 5, 6]. In contrast, pyroxene crystallization trend of A881757 is remarkably similar to those of MET01210 with the narrower compositional range (Fig. 2) [7]. Remarkable similarity of MET 01210 and A 881757 in the bulk-rock TiO2 of the basalt clast, coarse-grain texture, pyroxene crystallization trend strongly support the inference that basalt clasts in MET 01210 are petrogenetically related to A881757 (and probably Y793169). Pyroxene compositions of MET01210 is also extremely similar to those of Luna24 VLT ferrobasalts [8], implying a possible connection of lunar meteorite Low-Ti basalt suites with Mare Crisium. Further discussion regarding pairing with other lunar meteorite breccias is pending the outcome of the CRE launch age study.

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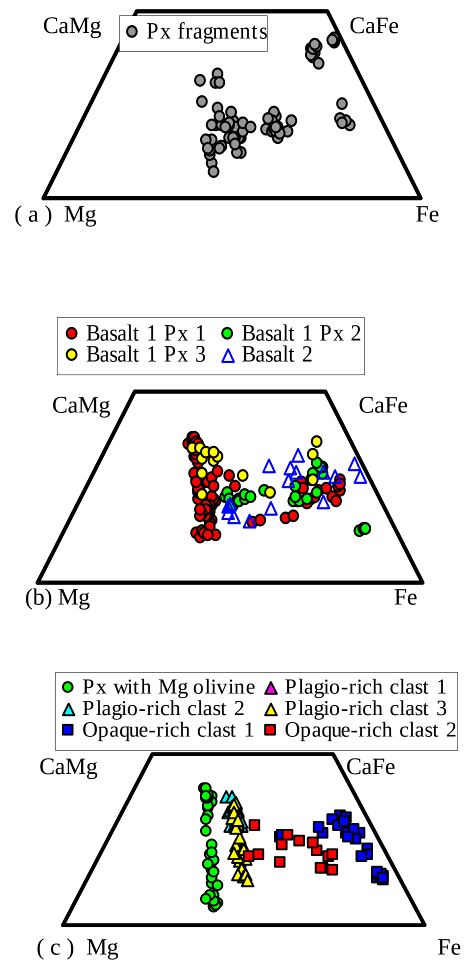

Fig.1 Pyroxene composition in the quadrilateral.