Petrography and bulk composition of Miller Range 05035: a new lunar VLT gabbro

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PETROGRAPHY AND BULK COMPOSITION OF MILLER RANGE 05035: A NEW LUNAR VLT GABBRO. K. H. Joy1,2,3, M. Anand2,4, I. A. Crawford1, and S. S. Russell2. k.joy@ucl.ac.uk 1 UCL/Birkbeck Research School of Earth Sciences, UCL, Gower Street, London, WC1E 6BT, UK. 2The Natural History Museum, Cromwell Road, London SW7 5BD, UK. 3RAL, CCLRC, Didcot, Oxon, OX11 0QX, UK. 4 Department of Earth Sciences, CEPSAR, The Open University, Milton Keynes, MK7 6AA,UK.

Introduction: Miller Range (MIL) 05035 is a crystalline lunar mare gabbroic meteorite collected in Antarctica in 2005 [1]. It is an important new sample in the lunar meteorite (LM) collection as it is only one of ~8 to be classified as basaltic in nature. MIL 05035 is coarsely grained with large pyroxene grains (<8mm) subophitically enclosing plagioclase grains (<6mm), and accessory ilmenite, spinel, silica and sulphide phases.

Methods: Minerals in MIL 05035.31 and MIL 05035.34 were investigated using a Cameca SX50 Wavelength Dispersive electron microprobe. Mineral X-ray maps were made using a LEO 1455VP SEM fitted with Oxford Instruments INCA energy dispersive X-ray spectrometer and bulk major- and trace-element chemistry was obtained using ICP-AES and ICP-MS techniques on 140 mg chip of MIL 05035.19 (Table 1).

Lunar Origin: Fe to Mn ratios in the bulk rock (62), and in pyroxene (average: 60) and olivine phases (average: 80), bulk rock Co/Cr (0.014), and a typical lunar anhydrous mineralogy confirm lunar origin for this meteorite. We will report the results on ongoing oxygen isotope analysis at the LPSC 2007 meeting.

Petrography: MIL 05035 is an unbrecciated, holocrystalline lunar gabbroic meteorite. Its coarse-grained nature suggests a slow cooling history in a thick lava flow.

Pyroxenes: are the dominant mineral phases in MIL 05035 (~54% of sample 31 by mode). They are typically large with compositional zoning from calcic-augite and pigeonite cores to Fe-rich calcic-augite rims: Fs59.68,Wo14.41,En2.42 (Fig.1a,2).

Extreme fractionation is evident in terms of Fe-rich rims associated with late stage crystallization products. Ferrosilite breakdown symplectic assemblages (silica + fayalitic olivine + hedenbergitic pyroxene) occur at the rims of many pyroxene grains in a similar texture observed in LM Asuka-881757 [2,3,4,5,6]. These aggregates in places cover broad areas of MIL 05035 (~6% by mode: Fig.2), and suggest that the sample may have crystallized at low-pressure [4].

Plagioclases: are generally large (500μm – 6mm: Fig. 2) sub-rounded grains (36% by mode) with a typical mare basaltic compositional range: An76.95,Or5.5 (Fig.1c). The vast majority of grains appear to have been completely shock metamorphosed to maskelynite.

Olivine: grains are fayalitic in composition (Fig.1b: Fo1–Fo11) and form anhedral aggregates of varying sizes (<500μm – 2μm) as part of the late-stage mineral assemblage (<1% by mode: Fig.2).

Ilmenite: is rare in MIL 05035 (<1%) and found in association with pyroxene-rim compositions and

![Fig. 1. Mineral compositional variation in MIL 05035 (a) pyroxene variations where the melt evolution is tracked with the black arrow, (b) olivine, and (c) plagioclase compositional variations.](1867.pdf)
symplectite assemblages. It occurs as euhedral elongate crystals (10μm – 500μm), and also as smaller anhedral aggregates in proximity to mesostasis areas. The very low modal abundance of ilmenite is evidence that this sample crystallized from a melt poor in TiO2.

Spinels: occur occasionally as large grains (<700μm) that have a limited compositional range of late-stage crystallizing ulvöspinel (2*Ti77-90,Al4-7,Cr4-16). These large anhedral grains occupy an intergrowth with host ilmenite and fayalite phases. Smaller grains also occur as intergrowths in mesostasis regions.

Mesostasis: areas are found adjacent to evolved pyroxene rims and associated with the symplectite assemblage described above. Associated with these regions is fayalitic olivine, silica phases (occurring as elongate laths (<1mm) and smaller (<300μm) grains), anhedral troilite (Fe 61-63S 33-37) blebs,apatite, whitlockite, and occasional aggregates of small Si-rich and K-rich glass intergrowths.

Bulk composition and Lunar context: according to our measurements (Table 1) MIL 05035 can be classified as a VLT (0.9 wt. % TiO2) low-Al (8.85 wt. % Al2O3), low-K (124 ppm K) mare gabbro meteorite (Fig.3b) following the scheme proposed by [7]. It has a very high Sc-content (109 ppm) and is evolved (Mg# 40), but has low bulk ITE concentrations, and a very low Th-content (0.28ppm Th; Fig.3c) implying that it was likely crystallized distally to the Procellarum KREEP Terrane [8].

Our sample of MIL 05035 does not have a negative Eu-anomaly (Fig.3a) typical of the majority of mare basalts. It also has a low REE content, with a C1-normalised profile [9] typical of being dominated by pyroxene phases (positive LREE slope, and a relatively flat HREE profile: (La/Lu)N=0.4. (Tb/Lu)N=1.4). This profile is similar to that measured in the LM Yamato-793169 and Asuka-881757 [3,5] (Fig.3a), although in comparison MIL 05035 is depleted in REE concentration and also notably lower in bulk TiO2 content (Y and A are reported to have 1.5-2.5 wt. % TiO2 [3,5]). MIL 05035’s bulk REEs are also much lower than those in Apollo and LM low-Ti samples, but are akin to concentrations measured in A17 and Luna 24 VLT mare basalts.

Mineralogically, pyroxene and symplectite textures in MIL 05035 are similar to those reported in Asuka-881757 and to some large monomict pyroxene fragments and symplectite assemblage clasts observed in the LM regolith breccia MET 01210 [11,12].

Summary: MIL 05035 is an unusual holocrystalline, coarsely grained VLT mare gabbro sample. We propose that it is possibly paired with A-881757 and Y-793169 in terms of petrography, mineral chemistry and bulk composition.

Table.1. Bulk chemical composition of MIL 05035, 19 measured using ICP-AES and ICP-MS (elements denoted with a *). Elements from Li onwards are listed in ppm. Errors are reported as 2 sigma.