Igneous Differentiation Mechanisms in Mafic Rocks from the Moon and Earth: Comparing the NWA 773 Clan of Lunar Meteorites with the Murotomisaki Gabbroic Sill

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Introduction: The Northwest Africa 773 (NWA 773) clan consists of several petrologically similar mafic lunar meteorites [1,2]. A characteristic lithology of the NWA 773 clan is an olivine cumulate gabbro (OCG, Fig. 1a,b), which has been interpreted as an early stage of igneous crystallization in a magmatic sequence [1,3]. As such, many clasts of the NWA 773 clan represent an igneous crystallization sequence that gives us a view of magmatic processing on the Moon.

In this study, we compare the inferred igneous sequence of the NWA clan with the Murotomisaki gabbroic sill (MGS), where field relations have been combined with geochemical and petrologic studies to determine the crystallization sequence and mechanisms of differentiation that occurred during crystallization of the sill [4-7 among others].

Methods: Collection of samples in the MGS was guided by a field report kindly provided by T. Hoshide. Polished thin sections were prepared from samples of the MGS and of the NWA 773 clan (NWA 773, NWA 2727, NWA 2977, NWA 6950), and were studied using petrographic microscopes, a secondary electron microscope (SEM, Hitachi 3-3400) and an electron probe micro-analyzer (EPMA, JEOL JXA-8900) at Waseda University.

Results and Discussion: The NWA 773 OCG can be divided into at least two varieties based on textures, and olivine and pyroxene compositions: one with higher mode of pyroxene vs. olivine+feldspar, Fo_{70} olivine compositions, and olivine crystals mostly enclosed by pyroxene ("pyx-rich OCG") and the other variety with lower pyroxene/olivine+feldspar and slightly but consistently more ferroan (Fo_{69}) olivine ("olv-rich OCG") (Fig. 1a). In NWA 6950, the pyx-rich OCG is enclosed within the olv-rich OCG (Fig. 1a). Thus, the texture and olivine compositions both indicate that the pyx-rich OCG preceded olv-rich OCG. Subsequent lithologies include olivine-absent gabbros with variable abundances of pyroxene and plagioclase, followed by fayalite-hedenbergite-silica symplectite and ferroan clasts with inclusions of alkalic glass and/or K-Ba-feldspar+silica (alkali-rich phase ferroan or "ARFe" clasts) [1,3]. The glass and K-Ba-feldspar+silica inclusions apparently formed by silicate liquid immiscibility from Mg-depleted, ferroan liquid [3]. In the MGS, two distinct varieties of olivine-bearing gabbro also occur: a stratigraphically lower, more magnesian gabbro that formed by gravitational settling of olivine and a later unit with coarser-grained, more ferroan olivine that was dominated by crystal growth [5]. Feldspar-rich layers in the gabbro formed by physical segregation, and have bulbous stratigraphic tops suggesting diapiric rise during formation of the sill (Fig. 1c, see [6]). A later stratigraphic layer in the MGS consists of feldspar-pyroxene-rich gabbro, occasionally with veins of feldspathic glass.

Comparisons with the MGS indicate that the following mechanisms should be considered for igneous differentiation of the NWA 773 clan: (1) an early stage dominated by crystal growth of magnesian olivine and pyroxene; followed by (2) crystal settling and growth of olivine, pyroxene and plagioclase feldspar; (3) formation of pyroxene-feldspar gabbros by a combination of (3a) depletion of Fe and Mg from liquid by olivine crystallization and (3b) segregation and mixing of plagioclase layers.

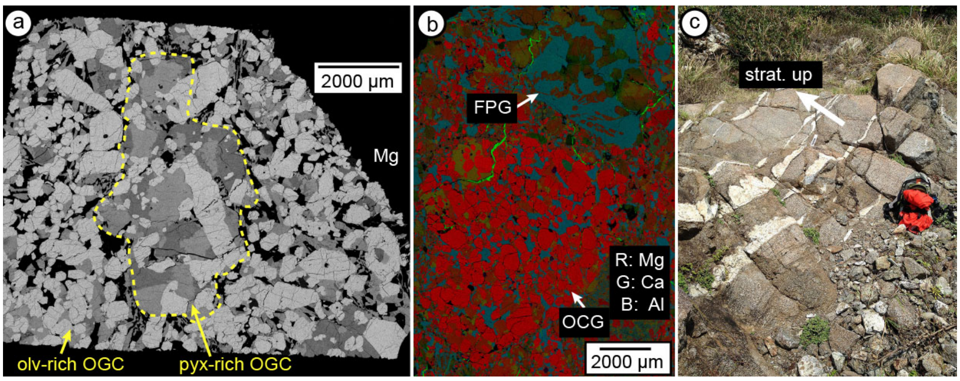

Figure 1. (a) Mg Kα X-ray map of pyx-rich and olv-rich varieties of OCG in NWA 6950; (b) R:G:B Mg:Ca:Al map of clasts of OCG and feldspar-pyroxene gabbro (FPG) in NWA 2727; (c) photograph of gabbro with feldspar-rich layers (white) in MGS. Arrow points toward stratigraphic top. Red backpack at right is ~0.5 m tall.

References

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