LUNAR SILICA-BEARING DIORITE: A LITHOLOGY FROM THE MOON WITH IMPLICATIONS FOR IGNEOUS DIFFERENTIATION. T. J. Fagan[1*] and S. Ohkawa[1], [1]Dept. Earth Sci., Waseda Univ., 1-6-1 Nishi-waseda, Shinjuku, Tokyo, 169-8050, Japan ([*]fagan@waseda.jp).

Introduction: Silica-rich igneous ("granitic") rocks are rare on the Moon, but have been detected by remote sensing on the lunar surface [e.g., 1], and in Apollo samples and lunar meteorites [e.g., 2-5]. To date, lunar granitic samples have been characterized by high concentrations of incompatible elements and/or mafic silicates with high Fe# (atomic Fe/[Fe+Mg]x100) [2-5], both features consistent with origin from late-stage residual liquids or very low degree partial melting. Furthermore, silica-rich rocks detected by remote sensing often combine the Christiansen feature in infra-red spectra with high incompatible element concentrations (e.g., Th detected by gamma-ray spectroscopy [1]), again reflecting a correlation between silica content and incompatible elements.

In this study, we describe a silica-bearing lunar igneous rock, tentatively classified as a diorite, that is not enriched in incompatible elements. The silica-bearing diorite occurs as a clast in lunar meteorite Northwest Africa 773 (NWA 773). The diorite requires a mechanism for silica-enrichment decoupled from incompatible elements, and has implications for remote sensing detection of silica-rich rocks on the Moon.

Methods: The diorite clast was discovered during characterization of thin sections from the NWA 773 clan of lunar meteorites [5,6]. The clast was identified from petrographic microscope observations and wide-scale elemental mapping of the polished thin section shown in Fig. 1. Detailed (2x2 µm step size) back-scattered electron (BSE) and X-ray elemental maps of the clast were collected using a JEOL JXA-8900 electron probe micro-analyzer (EPMA) at Waseda University. Elemental maps were mosaicked together, saved as jpg-files and then input as layers in an Adobe Illustrator file. A grid was overlain on the elemental maps in the computer file. The elemental maps were used to manually identify the mineral present at each grid node. Color-coded circles were digitally overlain on the grid. The color-coded mode map was then input into a spreadsheet file as a number-coded map. Spreadsheet commands were used to tally the mode.

Quantitative analyses of pyroxene, plagioclase feldspar, silica and ilmenite were collected by EPMA using wavelength dispersive spectroscopy, well-characterized standards, and the following beam conditions: 15 kV, 20 nA, focused beam scanning at 100,000X (effective spot size ~ 1 µm diameter). Most EPMA analyses of Ca-phosphate grains yielded low totals, however Ca/P ratios and relatively high F concentrations indicate that the analyzed grains are apatite (not merrillite).

Results: The silica-bearing diorite (Sil-Di) is dominated by pyroxene (55 mode%), plagioclase feldspar (36%), silica (4.4%), ilmenite (3.9%) and K-feldspar (0.3%) (Fig. 2). Apatite and troilite also occur. The Sil-Di exhibits interlocking, igneous textures with elongate plagioclase feldspar (Fig. 2). Plagioclase feldspar has nearly constant composition of $An_{88}Ab_{11}$, but pyroxene has a wide range of zoning (Fig. 3).

The modal composition of the Sil-Di is plagioclase-rich compared to many silica-bearing igneous rocks from the Moon (Fig. 4). Based on the modal classification of [7] for terrestrial rocks, the Sil-Di could be classified as a quartz diorite or quartz gabbro. Most terrestrial diorites have hornblende, but hornblende has not been identified in rocks native to the Moon; however, unlike silica- and/or K-feldspar-bearing gabbroic rocks in the NWA 773 clan, the silica and K-feldspar in the Sil-Di are not limited to late-stage magmatic pockets with Fe# ~ 100. Therefore, we refer to the Sil-Di clast as a diorite in our preliminary classification.

Discussion: The Sil-Di has only minor Ca-phosphate, and the only Ca-phosphate identified is apatite, which typically has lower concentrations of incompatible rare earth elements compared to merrillite in lunar rocks. Furthermore, no Zr-rich phases were identified. Thus the Sil-Di is not enriched in incompatible elements and is distinct from Apollo 15 quartz monzodiorite. Origin by fractional crystallization from KREEP basalt followed by immiscibility [5,8] does not explain the Sil-Di. Mafic silicate of the Sil-Di is Mg-rich relative to alkali-rich phase ferroan (ARFe) lithology of the NWA 773 clan [5] and the Apollo 12 granite described by [4], ruling out crystallization from extensively fractionated silicate liquid. Zoning of pyroxene in Sil-Di indicates that in situ fractionation occurred, but correlative zoning in feldspar has not been identified.

In any case, from the Sil-Di we infer that silica-enrichment on the Moon may have occurred without extreme enrichment in FeO or incompatible elements. If so, silica-rich igneous rocks might not be restricted to incompatible element-rich locations on the Moon.

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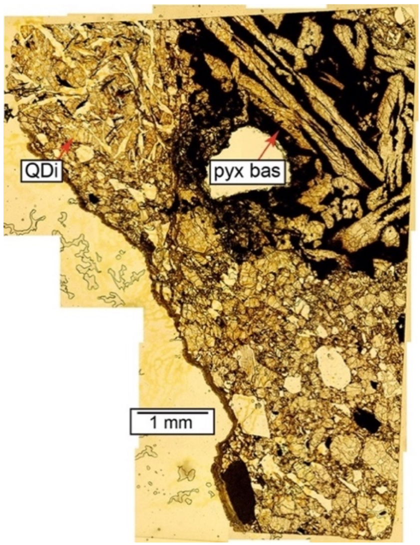
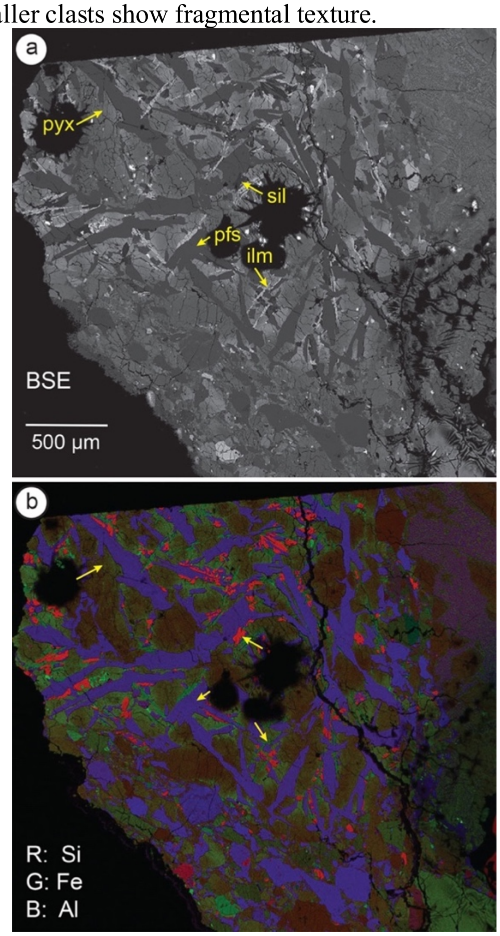


Fig. 1. Plane-polarized light mosaic of thin section of NWA 773 with silica-bearing diorite (QDi) clast. A pyroxene-phyric basalt (pyx bas) also is present. Smaller clasts show fragmental texture.



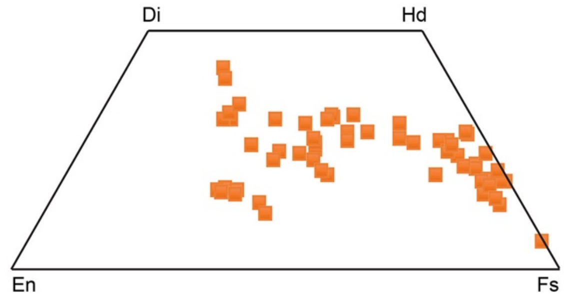


Fig. 3. Quadrilateral compositions of pyroxene in silica-bearing diorite from NWA 773.

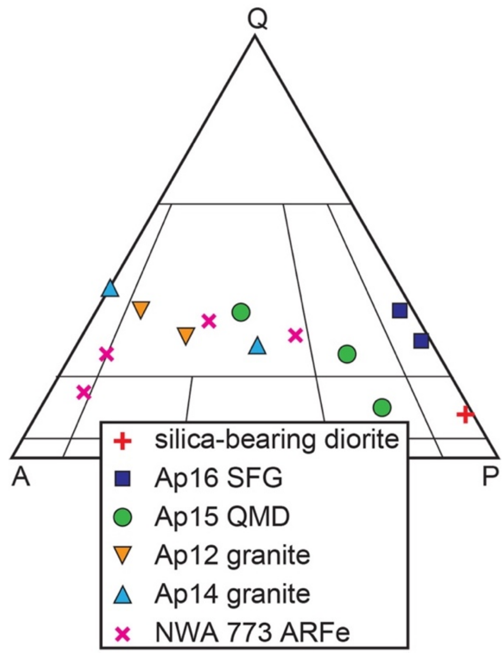


Fig. 4. Quartz-Alkali Feldspar-Plagioclase (QAP) plot [7] of modes of NWA 773 silica-bearing diorite and selected granitic rocks from the Moon. Abbreviations and sources: Ap16 SFG = 67915 sodic ferrogabbro [2]; Ap15 QMD = 15405 quartz monzodiorite [2,5]; Ap12 granite = 12032,366-19 [4]; Ap14 granite = Apollo 14 granitic clasts [3]; NWA 773 ARFe = alkali-rich phase ferroan clasts [this study].

← Fig. 2. Silica-bearing diorite clast in BSE (a) and combined red:green:blue = Si:Fe:Al Ka X-ray intensities (b). Black splotches in clast are from bumpy surface of the thin section. Abbreviations: ilm = ilmenite; pfs = plagioclase feldspar; pyx = pyroxene; sil = silica.