KREEP basalt in lunar meteorite Yamato 983885

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KREEP, an acronym reflecting the high concentration of K, REE, P and other incompatible elements, is very important in discussing the lunar crustal / thermal evolution because it is a major reservoir of heat-producing elements. The KREEP is considered to be a last dreg of the global magma ocean lying between the mafic mantle and anorthosite crust [e.g. 1]. Although the KREEP is a major chemical component of the upper lunar crust especially at Apollo12 - 14 landing sites, igneous pristine KREEP basalts or fragments have been rarely found [e.g., 2]. Due to the limited number and size of the KREEP basalts, the petrogenesis of KREEP magmatism / volcanism is still poorly understood.

A lunar meteorites Yamato (Y) 9838855 is a polymict regolith breccia with a KREEP basalt, a Mg-rich troctolite, a Mg-rich norite, a high-Al basalts, a very low-Ti basalt, and a granulite originated from ferroan anorthosite and Si, Na-rich impact spherules. An igneous KREEP basalt is first reported in this lunar meteorite. The KREEP clast, 0.8 x 0.4 mm in size, preserves a primary igneous texture with medium grain size. It consists of 64 vol. % ternary plagioclase, 20 vol. % pyroxene (pigeonite and augite), 2.8 vol. % REE-rich whitlockite, 2.1 vol. %, ilmenite, 11 vol. % Si, Al, K-rich glass, and trace of Ba-rich potassium feldspar. Three grains of pyroxenes consist of high-Ca pyroxene and low-Ca pyroxene respectively, and the compositions fall within a similar range, but vary between grains. The most Mg-rich grain (Px 1) includes co-existing pigeonite with an enrichment of Fe and Ca (Wo8Fs37En55, mg# = 60 to Wo13Fs51En36, mg# = 41) and augite with a Fe enrichment and Ca depletion (Wo37Fs17En46, mg# = 63 to Wo20Fs42En38, mg# = 47). The most Fe-rich pyroxene grain (Px 2) contains low-Ca pyroxene (pigeonite and augite) (Wo19Fs45En36, mg# = 44 to Wo12Fs54En34, mg# = 39) and augite (Wo35Fs33En32 mg# = 49 to Wo28Fs39En33 mg# = 46). The Px 2 is found in a direct contact with the extremely Na-rich plagioclase and the Si, Al, K-rich glass. The largest pyroxene grain (Px 3) of 200 micron-across, consists of an augite with Ca-depletion and Fe-enrichment (Wo37Fs17En46, mg# = 73 to Wo26Fs35En39, mg# = 53) mantled by a low-Ca pyroxene with Ca and Fe enrichment (Wo10Fs45En45, mg# = 50 to Wo22Fs46En32, mg# = 41). Exsolution lamellae in the three pyroxene grains are resolved both in pigeonite and augite in submicron to a few micron scales. The Si, Al, K-rich glass is compositionally heterogeneous (SiO_2 = 76.4 - 80.1 wt.%, K_2O = 5.14 - 6.46 wt.%, Al_2O_3 = 10.7 - 12.7 wt.%) and contains up to 5 wt. % of BaO.

The KREEP basalt is mineralogically distinct from Apollo KREEP basalts: (1) lack of the typical Ca zoning from orthopyroxene to pigeonite instead, the presence of the co-existing pigeonite / augite and augite core /pigeonite rim, both of which show chemical zonings and micron-scale exsolution and (2) the extremely Na and K-enriched plagioclase (An68Ab29Or3 – An61Ab36Or3), which is more evolved than that in KREEP basalt (An = 70 – 90), and comparable to that in quartz monzodiorites (An = 60 – 80) [2], and (3) lack of silica, fayalite, troilite, FeNi metal in the late stage product. With these mineral characteristics, the KREEP basalt is probably cooled slightly slower than the Apollo KREEP basalts, under the subsurface condition such as hypabyssal setting or lava pond.

Simultaneous occurrence of a KREEP basalt and a genetically KREEP-related, high-Al basalt, a Mg-rich troctolite / norite and the Si, Na-rich impact glasses constrains the source region of Y983885 to the KREEP-rich Procellarum terrane in the northwestern hemisphere of the lunar nearside.

References: [1] Warren and Wasson (1979) Rev. Geophys. Space Phys 17, 73-88. [2] Papike et al. (1998) Lunar samples. In Reviews in Mineralogy, Vol. 36.