P-BEARING OLIVINES FROM THE LUNA-16 SITE.

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Introduction: P-bearing olivine is an extremely rare phase in lunar rocks. Its presence was recently noted in lunar samples of Luna-16 and -20, Apollo-14 and in Dhofar 025, 961, 287 lunar meteorites [1,2]. Here we report about Luna-16 rocks containing P-bearing olivine and its trace element composition.

Methods: Polished thick sections containing 60 fragments of Luna-16 (L-16) soil (sample 1639, soil fraction >200 µm) were studied using optical microscopy. The chemical composition of mineral phases was measured using a JEOL JXA-8530F (Vienna) and a Cameca SX-100 (Moscow) microprobe. LA-ICP-MS (Element-XR with UP-213) (Moscow) was used to measure trace and some major elements. Laser pulse frequency of 4 Hz and beam diameter of 30 µm were used for the analyses. NIST 610 glass was used as an external standard.

Results: Nine rock fragments of mostly anorthositic – noritic(gabbro-noritic) – (spinel) troctolitic (ANT) composition contain P-bearing olivine. It is commonly present as mineral fragments in fragmental or impact melt breccias. Olivine-bearing clasts with rather coarse-grained granulitic and igneous texture are present, too.

Clast #5008 is an olivine anorthosite with a porphyritic intersertal texture. It contains coarse plagioclase laths (An_{95-97}) and a glassy or partly crystalline matrix in the interstitions. Rare rounded relics (up to 50x80 µm in size) of P-bearing olivine (Fo_{69-76}, <0.26 wt.% P_2O_5) are surrounded by a 3-10 µm zone of skeletal Mg-rich and P-poor olivine (Fo_{84-86}, <0.05 wt.% P_2O_5). Glass contains (wt.%): 51.6 SiO_2, 13.5 Al_2O_3, 0.26 Cr_2O_3, 2.04 TiO_2, 10.8 CaO, 8.2 FeO, 0.13 MnO, 9.7 MgO, 0.47 K_2O, 0.53 Na_2O, 0.18 P_2O_5. Accessory minerals are Fe,Ni-metal, troilite and silica.

Clast #5002 has a coarse-grained subophitic texture and a Fe-rich composition. Fayalite (Fo_{4-5}, <0.31 wt.% P_2O_5) silica and minor Ca-Fe pyroxene (En_2Wo_{35}) fill interstitions between plagioclase laths (An_{87-93}). Accessories are Fe,Ni-metal, troilite, ilmenite, apatite and K-Si-rich glassy mesostasis.

The studied brecciated fragments show a wide range in mineral compositions: plagioclase An_{82-98}, pyroxene $En_{8-71}Wo_{4-39}$, olivine Fo_{6-86}. P-bearing olivines are also variable in composition similar to that of igneous rocks, however Mg-rich ones (Fo_{82-87}, 0.06-0.18 wt.% P_2O_5) are present as well.

We measured the trace element contents of P-bearing olivines of clasts #5008 and #5002. Both Mg- and Fe-rich olivines are enriched in REE, Zr, Hf, Sc and Ti in contrast to P-free olivines of L-16, however Fe-rich olivines are more enriched in HREE (10-100xCI) than Mg-rich (1-6xCI). First ones are also higher in Ti and Sc content but lower in Cr, V and Co (Fig.1).

Discussion: The composition of P-bearing olivines in L-16 soils points to the presence of at least two different sources. The Mg-rich one has an ANT composition similar to that of L-20 [1], however the relict and fragmental occurrence of P-bearing olivines suggests that their parent rocks experienced disintegration, partial assimilation and possibly are of different origin. The high amount of incompatible elements in the olivines suggests a KREEP-enriched parent melt composition. KREEP rocks are not typical in Luna-16 rocks, however their possible presence was predicted in the coarse fraction of L-16 soils [3]. Low Co and Cr contents in the olivines point to a possible relation to the highland Mg-suite rocks which often contain abundant olivine. In contrast, the fayalite - Ca-Fe-pyroxene - silica assemblage of #5002 could have crystallized stably from the late-stage, Fe-enriched portions of mare basalt melts [e.g. 4]. However, Co and Cr contents in #5002 fayalites are surprisingly low similar to olivines of the Mg-suite rocks but not like the mare basalt ones which are higher in these elements [5,6]. The reason for that could be an influence of S and/or C at high temperature and low fO2 which made these elements siderophile in late-stage basaltic melts [5]. Otherwise, an evolved differentiation of the Mg-suite melts would be required.

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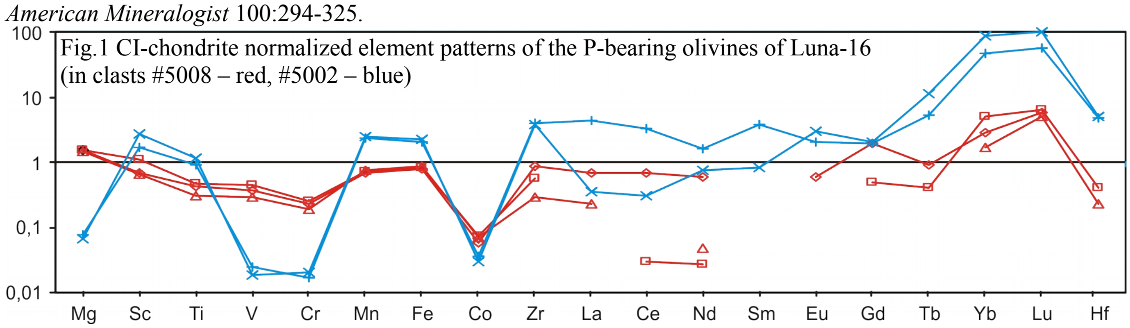

Fig.1 CI-chondrite normalized element patterns of the P-bearing olivines of Luna-16 (in clasts #5008 – red, #5002 – blue)