APOLLO 14321 LUNAR BRECCIA – CLUE TO THE UNDERSTANDING OF P-BEARING OLIVINE SOURCE.

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Introduction: P-bearing olivine is an extremely rare phase in lunar rocks but it was found in some lunar samples and meteorites [1,2]. Apollo 14 breccias are complex impact breccias dominated by KREEP and high-Al basalts with great diversity of pristine highland rocks ranging from ultramafic to highly evolved compositions. Apollo 14321 lunar sample has been extensively studied using a wide range of analytical approaches (The Lunar Sample Compendium and references therein). Detail study of 14321 P-bearing olivine and its associated minerals allows characterizing its source rock affinities.

Methods: Two polished thin sections of lunar sample 14321 (14321,34 and 14321,35) were studied using optical microscopy. Chemical composition of mineral phases was determined using Cameca SX100 microprobe (Moscow). LA-ICP-MS (Element-XR with UP-213) (Moscow) was applied for measuring 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: A large stone sample 14321 (8998 g) was collected from near the edge of Cone Crater during Apollo 14 mission and it is thought to be a piece of the Fra Mauro Formation. The sample is represented by fragmental breccia containing variety of lithic clats of both mare and nonmare origin. It contains 3 principal lithologic components: 1) rounded fragments of dark microbreccia, comprising mineral and rock fragments in a fine-grained matrix; 2) a rich variety of low-Ti, aluminous mare basalts; 3) a light-colored matrix dominated by comminuted basalt fragments with minor dark microbreccia fragments [3]. Rare olivine phenocrysts of low-Ti basaltic lithology contain no phosphorus but P-bearing olivine was found in a dark microbreccia clast (area of 11 mm^2). It is present in a rounded rock fragment of olivine-noritic anorthosite (180x700 µm) with granulitic-like texture; in a plagioclase-olivine intergrowth (200x300 µm) and as coarse mineral fragments (from 40x60 to 280x400 µm in size) in the matrix of the clast. Olivine Fo_{76-88} contains up to 0.4 wt.% P_2O_5, up to 0.1 wt.% Cr_2O_3 and up to 0.2 wt.% CaO. Some of them are concentrically zoned in MG# that is not connected with unevenly distributed P. Associated pyroxene is enstatite ($En_{87-88}Wo_{1-2}$), plagioclase is anorthite ($An_{94-96}Or_{0.4-0.8}$).

Trace elements composition of P-bearing olivines and associated pyroxene and plagioclase were studied in present work. Most olivines are enriched in REE (especially HREE (1-9xCI)), Zr, Hf and Ti. Some olivines contain inclusions of possibly REE,Y-rich Ca-phosphate or Zr- and Ti- rich phases which were identified by LA-ICP-MS. Preceding microscopical study discovered that tiny inclusions (<1 µm) are distributed along cracks or form patches in some olivine grains, while others are free of visible inclusions. Plagioclase is enriched in LREE (5-15xCI), Ba (~250 ppm) and Y (~2 ppm). Low-Ca pyroxene is enriched in HREE (10-40xCI) and Y (~30 ppm).

Discussion: Dark microbreccia clasts represent the pre-existing component of breccia 14321 which contains different highland lithologies [3-5]. P-bearing olivine source has ANT composition enriched in incompatible elements similar to that of Luna-20 and Luna-16 samples [1,2]. High MG# and low Cr and Co content in olivine as well as trace element chemistry of the coexisting phases point out the relation with high-Mg suite rocks [6]. Magnesian anorthosites and associated troctolites and dunites recognized by Lindstrom and coworkers in breccia 14321 as possible derivatives from differentiated troctolite intrusion [4] are the best candidates for P-bearing olivine source rocks. The rocks are surprisingly enriched in REE that is thought to be resulted from high modal abundance of REE-rich phosphates [4,5]. Apatite or merrillite are the late-stage phases which cannot be formed simultaneously with early liquidus Mg-rich olivine and occurrence of Ca-phosphate inclusions in some olivine grains in 14321 is surprising. The inclusions could be formed by segregation impurities during annealing of the olivine crystallized from the P, REE-rich melt. However P has slow diffusion rate in olivine and Ca content should be high as well that is not common for lunar olivines. Another possibility is an infiltration of P, Zr, Ti, REE-rich impact melt as it was suggested for some olivines from VHK basalts [7] and for origin of phosphates in primitive lunar highland rocks [8].

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References: [1] Demidova S. I. et al. (2017) *LPSC 48th,* Abstract #1409. [2] Demidova S. I. et al. (2018) *Petrology* 26:317-332. [3] Grieve R. A. et al. (1975) *Geochimica et Cosmochimica Acta* 39: 229-245. [4] Lindstrom M. M. et al. (1984) *Proc. 15th LPSC. in Journal of Geophysical Research* 89:C41-C49. [5] Warren P. H. et al. (1981) *Proc. 12 LPSC. 21-40.* [6] Shearer C. K. et al. (2015) *American Mineralogist* 100:294-325. [7] Gawronska J. W. et al. (2018) *LPSC 49th,* Abstract #1821. [8] Neal C. R. and Taylor L. A. (1991) *Geochimica et Cosmochimica Acta* 55:2965-2980.