REE AND SOME OTHER TRACE ELEMENTS DISTRIBUTION IN THE MINERALS OF THE PALLASITES. Lavrentjeva Z.A., Lyul A.Yu. V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, RAS, Moscow, E-mail: lavza@mail.ru

Introduction: Pallasites are among the most enigmatic of meteorites. They are of special interest because of information they provide about the interiors of asteroidal bodies and the differentiation processes that occurred within them.

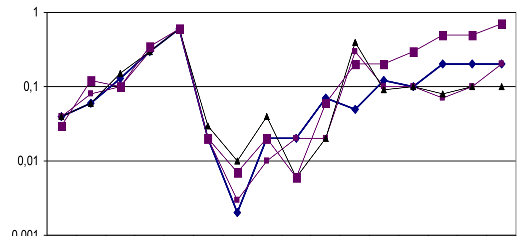
Olivine and metal, the major constituents of pallasites, have vastly different densities and chemical behaviors, which would suggest both physical and chemical incompatibility and belie their coexistence. Finding them coarse-grained intergrowths adds to the puzzle of pallasite origin and how these minerals could have formed in this way, but there are disappointingly few clues [1]

Based on the chemical composition of metal and silicates [2] pallasites are subdivided into main, main anomalous, Eagle Station, and pyroxene bearing groups.

The origin of pallasites is also controversial. In our opinion, the most substantiated hypothesis is that pallasite were formed at the core-mantle boundary in the differentiated parent bodies [2, 3]. The new results suggest pallasites are derived from several, different parent bodies, perhaps as few as 5 – 7 [4]. This work reports new data on the composition of mineral fractions of the Omolon pallasite, which are considered from the viewpoint of cosmochemical history of pallasites.

Samples and methods. The Omolon pallasite (250 kg weight) was found in 1982 near the Omolon River in the Magadan district. This meteorite belongs to the main group of pallasite family. Pallasite contains rounded olivine grains (about 60 vol %, up to 3 cm in size, 12.3 mol % Fa). Olivine often contains metallic spherules from 10 to 500µm in size. Kamasite is observed around olivine. We studied the following fractions of minerals: olivine, trydimite and four fragments from the Omolon pallasite. The element composition of fractions was analyzed at the Central Laboratory of GEOKHI RAS using optimized version of neutron-activation analysis developed for analyzing extraterrestrial material [5]

Discussion: The major REE sources in the pallasites are olivine (dominant phase) and phosphates (REE carrier). Pallasite olivines are essentially free of REE_s (Fig.1). Pallasite olivine cannot be produced by a single stage differentiation from the starting material with an unfractionated REE abundance pattern. The simplest model [6] to explain the observed REE pattern in pallasite olivine needs two steps; the LREE-enriched phase is removed at first and the olivine crystal is formed as a cumulate later.



	Na	Ca	Cr	Sc	Fe	Co	Ni	Au	Ir	Zn	Cs	La	Sm	Eu	Yb	Lu
A	0,04	0,06	0,13	0,3	0,6	0,02	0,002	0,02	0,02	0,07	0,05	0,12	0,1	0,2	0,2	0,2
B	0,04	0,08	0,1	0,3	0,6	0,02	0,003	0,01	0,02	0,02	0,3	0,1	0,1	0,07	0,1	0,2
C	0,04	0,06	0,15	0,3	0,6	0,03	0,01	0,04	0,006	0,02	0,4	0,09	0,1	0,08	0,1	0,1
D	0,03	0,12	0,1	0,35	0,6	0,02	0,007	0,02	0,006	0,06	0,2	0,2	0,3	0,5	0,5	0,7

Fig.1. CI chondrite- normalized of trace elemenrs in the olivine fractions from the Omolon pallasite 1 – pure olivine (A); 2 – yellow olivine (B); 3 –olivine with rounded inclusions of opaque minerals. (C); 4 –olivine with rims of opaque minerals (D).

The presence of phosphoran olivine is consistent with more recent minor and trace element research [7, 8] which suggests fast cooling through high temperatures, but slow cooling through lower temperatures has been interpreted as subsolidus Fe-Ni metal in pallasites exhibits Widmanstätten structure indicative of slow cooling, and cooling rates inferred from zoning profiles in metal are ~1°C /My [2]. However, pallasite olivines show chemical diffusion profiles that suggest cooling rates of a few to tens of degrees per year, roughly a million times faster [2, 9]. Metal and olivine do not seem to be telling the same story. The phosphates display a wide range of REE abundances (0.001 to 100 x CI) with distinct patterns. Within a given phosphate grain, REE_s are generally homogenous. REE_s of phosphate may vary from grain to grain within the same meteorite by a factor of 10 to 100 [7]. The Omolon pallasite contains four fragments with high contents of refractory lithophile elements (Fig 2.).

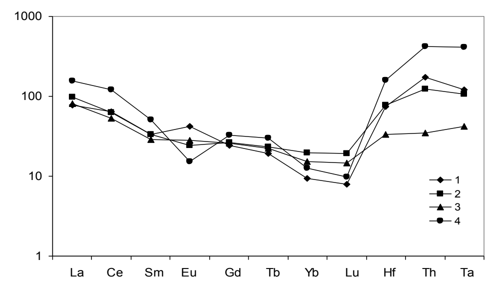
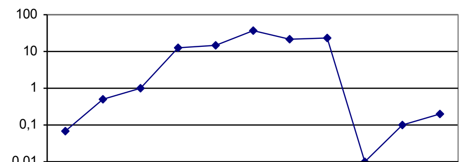


Fig.2. CI chondrite- normalized of trace elemenrs in the N, O, P, and R fragments from the Omolon pallasite. (*1*) fragment N [(brown red glass), (*2*) fragment O (dark brown glass), (*3*) fragment P (semitransparent greenish-gray rock), (*4*) fragment R (light dense rock).

The degree of LREE enrichment in all fragments of the Omolon pallasite is higher that in the coarse-grained CAI_S of Allende chondrite [10] and in the fragments of the Kainsaz CO chondrite [11]. The fragments N,O,P , and R show significant fractionation between LREE and HREE $(La/Lu)_N$ / $(La/Lu)_{CI}$= 9.7; $(La/Lu)_O$ / $(La/Lu)_{CI}$ =5.2; $(La/Lu)_P$ / $(La/Lu)_{CI}$=6.6; $(La/Lu)_R$ / $(La/Lu)_{CI}$ =16.2 with positive anomalies of Eu in the N fragment and negative, in O and R fragments. In the fragments of the Omolon pallasite, the HREE/LREE increases with increase of Na content in them. Obviously, the LREE, Na were incorporated in the same mineral. In the pallasites, the carriers of such elements as Na, K, U, and Th are phosphates [12]. The Omolon pallasite contains two phosphates: stanfieldite and withlockite. Withlockite in this case is of geochemical interest as accumulator of small amounts of alkalis available in pallasites.

Tridymite (Fig 3) is enriched in REE with the prominent predominanceof heavy REE $(Lu/La)_{tridymite}$ /$(Lu/La)_{CI}$ =1.97 and positive Eu anomaly $(Eu/Sm)_{tridymite}$ / $(Eu/Sm)_{CI}$ = 2.37. The element distribution in the tridymite indicates that this mineral accumulates HREE.



	Na	Ca	Sc	La	Sm	Eu	Yb	Lu	Cr	Fe	Co
M	0,07	0,5	1	12,2	15,1	35,8	20,8	24	0,01	0,1	0,2

Fig 3. CI chondrite- normalized contents of elements in tridymite from Omolon pallasite.

Despite the simplicity of the mineralogy, the origin of pallasites has remained largely controversial. The mineralogy and slow metallographic coolig rates support a core-mantle origin for pallasites. In a chondritic magma, density differences will results in the separation of iron metal from the silicate melt to form a planetary core. An olivine similar to pallasite olivines, then, would be the first mineral to crystallize from the silicate melt. In this model, pallasite would originate from a layer or interface where the core metal and the lower mantle silicate are mixed. Such a layer is assumed to be deep in the interior of asteroids, allowing pallasites to cool very slowly, as indicates by the Widmanstätten structures in Fe-Ni alloys. However, fragmented and angular olivines are not predicted by such a model. Pallasite olivines could not come from a boundary between a Fe-Ni core and silicate mantle. The olivines must have been produced by an independent mechanism and then be immersed in or intruded by a molten iron body [7].

Preliminary data on chemical composition of four fragments from the Omolon pallasite that is very difficult to reconcile with a deep-seated origin at the core-mantle boundary. The high concentrations of rare-earth elements in their phosphates suggesting they once contained small amounts of residual silicate magma, which should have been concentrated near the crust, not the core.

It is assumed that Omolon pallasite body was formed as impact-brecciated mixture of material of asteroid core with material of mantle in the result of the large impacts between asteroids.

References: [1] Stevens M and Buseck (2008) *LPS XXXIX,* Abstract # 2157 [2] Wasson J. T. and Choi B. G. (2003) *GCA,* 66, 3079 - 3096. [3] Scott E. R. D. (1977) *Mineral. Mag*., 41, 265 – 272. [4]. Boesenberg J. et al. (2000) *Meteoritics & Planetary Science,* 35, 757 – 769. [5] Kolesov G.M. et al. (2001) *I. Anal. Chem.,* 56, 1022 – 1028. [6] Minova H. and Ebihara M.(2002) *LPS XXXII*I, Abstract #1386. [7] Hsu W. (2003) *Meteoritics 38*, 1217-1240. [8] Miyamoto, M. (1997) *JGR* 102, 21613-21618. [9] Mittlefehldt D.W. et al. (1998) *In: Planetary Materials, Papike J.J. (Ed)*, p. 195. [10] Grossman L. et al. (1977), *GCA,* 41,1647-1664. [11] Lyul A. Yu. Et al. (1990), *Geokhimiya,* 10, 1467 - 1475. [12] Buseck P. R. And Holdsworth E. (1977) *Mineral. Mag.,* 41, 91 - 102.