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INCLUSIONS IN OLIVINE OF THE OMOLON PALLASITE: A PRELIMINARY STUDY

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Introduction

The Omolon meteorite (250 kg) was found in 1982 (it fell in 1981) near the Omolon river (Magadan district, Russia). This meteorite belongs to the main group of the pallasite family. It contains rounded olivine grains (about 60 vol. %, sizes – up to 3 cm, Fa content – 12.3 mole %) in nickeloan iron matrix consisting of kamacite, taenite and plessite (Plyashkevich et al., 1991; Desrousseaux et al., 1997). In addition, troilite, chromite, schreibersite, nikelphosphide (former rhabdite) and stanfieldite were found in the meteorite (Plyashkevich et al., 1991; Bondar et al., 1997). The irradiation time of this meteorite was determined to at 78±7 Ma (by noble gases); the K-Ar age for olivine crystallization was assessed as 4.6 Ga, i.e., close to the starting time for formation of protoplanetary system (Shukolyukov et al., 1992). The calculation of atmospheric trajectory and orbit showed that the Omolon meteorite was probably a fragment of an Apollo M-type asteroid and its preatmospheric mass was approximately 390-490 kg (Bronshten et al., 1999). According to fossil track studies the depth of ablation for the Omolon pallasite does not exceed 8.2±2.1 cm out of the preatmospheric surface (Bondar et al., 1997). Kolyasnikov and Savva (1997) suggested the presence of forsteritic glass in melting rim of the meteorite. The aim of this work is to study the inclusions occurring in olivine grains of the Omolon pallassite.

Inclusions in olivine

We studied individual olivine grains from the outer zones of the Omolon pallasite. In general, inclusions form planar arrays associated with fractures in the host olivine. Coexisting metal-sulfide blebs, fluid and crystal inclusions and their combinations were found in some arrays. The sizes of individual inclusions range from 5 to 200 μm (Fig. 1). In addition, olivine hosts large metal-sulfide blebs and oriented needle-like isolations of unidentified Cr-rich phase, unrelated to the arrays described above (Fig. 1A-C). Metal-sulfide and fluid inclusions are most common. Typical phase composition of large metal-sulfide blebs is troilite + kamacite. Nickelphosphide, taenite, stanfieldite, whitlockite, chromite, and unidentified Si-rich and Cr-S-rich occur as minor phases. Taenite and nickelphosphide are predominantly located on the boundary between troilite and kamacite (Fig. 1A-B). Fluid inclusions contain low-density fluid and sometimes metal-sulfide isolations. Colorless transparent phase (phosphate?) rarely occurs in large fluid inclusions (>100 μm). Some mineral associations from the arrays have an appearance of the silicate melt inclusions; microprobe analyses have demonstrated, however, that they are assemblages of stanfieldite, metal-sulfide blebs, and gas bubbles (Fig. 1F). The individual euhedral chromite (up 20 μm) with adhered metal-sulfide bleb and Si-rich phase occurs rarely (Fig. 1D).

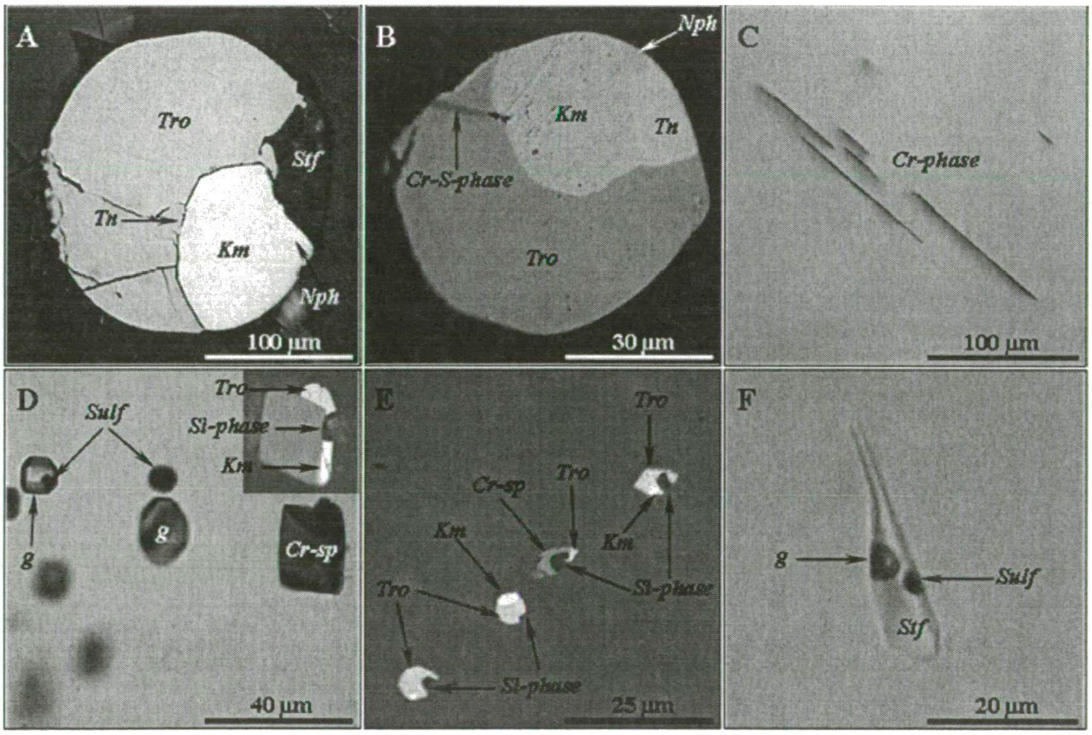

Figure 1. Different types of inclusions in olivine of the Omolon pallasite.

Tro – troilite;
Km – kamacite;
Tn – taenite;
Nph – nickelphosphide;
Stf – stanfieldite;
Sulf – metal-sulfide bleb;
Cr-sp – chromite;
g – gas.
A, B, E – reflected light;
C, D, F – ordinary light.

Chemistry of minerals from inclusions

Troilite is the major phase of metal-sulfide blebs. Its composition is uniform: Fe – 63.3-63.5; S – 36.4-36.7 (all compositions are in wt. %) and similar to sulfide from metallic part of the pallasite (Plyashkevich et al., 1991). Compositions of *kamacite* are somewhat variable: Fe – 90.3-94.9; Ni – 4.2-8.9; Co – 0.3-0.8, Si, P and S - <0.02. Compositions of *taenite* are highly variable: Fe – 85.9-59.6; Ni – 13.1-40.1; Co – 0.05-0.6. The similar variations are also typical of taenite from metallic part of the meteorite (Plyashkevich et al., 1991). *Nickelphosphide* $(Ni,Fe)_3P$ (recently accepted as a new mineral (Britvin et al., 1999); initially was named rhabdite, Ni-rich variety of schreibersite) occurs rarely in metal-sulfide blebs in olivine. Its composition is: Fe – 31.9-32.8; Ni – 52.1-53.4; Co – 0-0.03; P – 14.3-14.8; Cu, S and Si - <0.15. This mineral is different from schreibersite $(Fe,Ni)_3P$ and similar to nickelphosphide from metallic part of the meteorite (Plyashkevich et al., 1991). *Chromite* is virtually free in TiO_2 (<0.05 wt.%) that is typical of Cr-spinels from other pallassites (Buseck, 1977). Based on microprobe analyses, compositions of individual chromite crystals in olivine are homogeneous. The chemical variations of this mineral are: SiO_2 – 0.04-0.2; Cr_2O_3 – 53.5-61.8; Al_2O_3 – 5.6-8.8; FeO – 25.3-32.6; MgO – 3.9-5.5; MnO – 0.6-0.8. Two different phosphates were observed in olivine: *stanfieldite* $Ca_4(Mg,Fe^{2+},Mn)_5(PO_4)_6$ and *whitlockite* $(Ca,Mg,Fe^{2+})_3(PO_4)_2$. Stanfieldite is a common phosphate mineral, while whitlockite is rare. Chemical composition of stanfieldite: P_2O_5 – 46.2-49.2; SiO_2 – 0-1.45; FeO – 2.8-7.8; MnO – 0.35-0.55; MgO –19.9-21.2; CaO – 23.5-28; Na_2O – 0.02-0.1. Whitlockite is SiO_2-rich (n=2): P_2O_5 – 38.4; SiO_2 – 16.7; FeO – 2.95; MnO – 0; MgO – 2.7; CaO – 37.9; Na_2O – 0.95.

Unfortunately, we could not identify some minerals from inclusions because of their very small sizes and the possible presence of light elements that cannot be determined by microprobe technique (O, N and C). *Si-rich phase* forms 1-5 μm grains in association with chromite and metal-sulfide bleb in the arrays. Microprobe analysis and EDS showed that this phase contains up to 40 wt.% of Si (in these analyses the diameter of the microprobe beam was greater than the size of the analyzed mineral). This phase could be a SiO_2 polymorph or nierite Si_3N_4 (Lee et al., 1995) or sinoite Si_2N_2O (Andersen et al., 1964). In one metal-sulfide bleb we have found a Cr-S-rich phase (<1 μm) in troilite. According to EDS, this mineral contain Cr, Fe and S (in this analysis again the diameter of the beam was greater than the size of the analyzed mineral). This phase could be daubreelite $FeCr_2S_4$ (extremely rare in other pallassites; Buseck, 1977), or brezinaite Cr_3S_4, or carlsbergite CrN.

Discussion

The petrography of the Omolon meteorite, i.e., general recrystallization kamacite, the appearance of fine-grained kamacite with boundary of migration growth, the redistribution of rabdite (nickelphosphide), kink banding in olivine, shows that this meteorite has undergone at least two shock deformations (Plyashkevich et al., 1991). The presence of planar arrays of inclusions in olivine seems to indicate post-deformational annealing for the meteorite (Buseck, 1977). Possibly, the inclusions originated in response to penetration of the meteorite into the Earth's atmosphere and subsequent impact.

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