TWO NEW ACHONDRITIC INCLUSIONS IN THE L5 CHONDRITE TSAREV.

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Introduction: The ordinary chondrite Tsarev (found in 1968, Russia) is an impact melt breccia containing variably shocked chondrite fragments within the network of highly shocked chondrite material and impact melt veins [1]. Several achondritic inclusions (AI) of different texture and composition were found in the meteorite [2-4]. All of the AIs are similar to L chondrites by silicate compositions. It was proposed that one AI could be a product of igneous differentiation on the Tsarev parent body [2, 3]. Here we report mineralogical and geochemical features of two large AIs (AIs #1 and #2) recently discovered in Tsarev.

Results: The AI#1 is a light-gray rock fragment of 2x4 cm in size. It has a porphiritic texture formed by sub- and unhedral grains of olivine $Fa_{23.5\pm1.2}$ (N=15, Fe/Mn=51, at.) up to 500 μm in size, minor pyroxene $Fs_{20.7\pm1}Wo_{2.2\pm0.6}$ (N=4, Fe/Mn=31, at.), settled within a main mass of Na-Ca-Al-Si glass containing the grains of pyroxene $Fs_{8\pm0.5}Wo_{45\pm0.8}$ (N=10) and fine inclusions of troilite, FeNi metal, accessory chromite, silica, Ca-phosphate. The largest olivine grains systematically contain thin veinlets of FeNi metal terminating on the grains boundaries, and rare large inclusions of the metal, troilite and chromite. These features could indicate that the olivine grains are relicts. The glass compositions vary from approx. $Ab_{80}An_{14}$ to $Ab_{25}An_{75}$ forming a linear trend on the plagioclase composition diagram. The bulk chemical composition (XRF) of the AI#1 corresponds to that of L chondrites except for Na, Al (2xL ch.) and P (3xL ch.) enrichment and Fe, Ni and S depletion. The REE distribution of the AI#1 is also similar to that of L chondrites. It shows only a small LREE enrichment that can be related to the Ca-phosphate presence in the AI#1.

The AI#2 is a dark-grey isometric inclusion of 2 cm in diameter containing gas voids. The AI#2 has heterogeneous, fine- to medium-grained porphiritic texture and contains a small amount of large silicate inclusions and xenoliths (up to 2 mm in size). The subhedral and skeletal grains of olivine $Fa_{25.4}$ (Fe/Mn=44, at.) and pyroxene $Fs_{10.2}Wo_{44.1}$ (Fe/Mn=21.5, at.) up to 300 μm in size are settled in the ground mass of devitrified glass with inclusions of small pyroxene grains and fine-grained inclusions of troilite, chromite and Ca-phosphate. The glass compositions are in the range $Ab_{77}An_{19}$ - $Ab_{60}An_{29}$. The mineral inclusions are represented by olivine grains of 200-400 μm in size showing undulatory and in some places mosaic extinction without pronounced planar deformation features suggesting shock pressures <35 GPa [6]. One of the xenoliths is similar to a fragment of barred olivine chondrule and consists of olivine $Fa_{25.8}$ (Fe/Mn=41, at.) and glass or feldspar ($Ab_{78.9}An_{16.1}$). Another xenolith is an isometric object mainly composed of merrillite with minor inclusions of olivine $Fa_{26.2}$ (Fe/Mn=56, at.), pyroxene $Fs_{22.3}Wo_{2.7}$ (Fe/Mn=30, at.) and glass heterogeneous in composition ($Ab_{53}An_{45}$ –$Ab_{73}An_{23}$). The bulk chemical composition (XRF) of the AI#2 is very enriched in lithophile elements (Na, Al, Ca, K, P, Ti) and depleted in Mg, Fe, Ni, S relatively to L chondrites.

Discussion: Similar to other Tsarev AIs, the AIs #1 and #2 are close to L chondrite silicate compositions and most probably originate from the L-chondrite parent body. Both inclusions are depleted in Fe, Ni and S possibly indicating a segregation of FeNi-FeS liquid from the melts during AIs' formation. The metal and troilite depletion is a feature of some L chondrite related melt rocks [5]. The segregation of the metal-sulfide and silicate liquids in the L-chondrite melts could occur during the melt movement based on the observation of strong directional flow orientation of the metal-sulfide assemblages in the L-chondrite melt rock Northwest Africa 4286 [5]. As REEs are not fractionated in the AI#1 we suggest that the latter is most possibly a melt rock of impact origin. The bulk composition of the AI#2 is distinct from the chondritic one and except for K, Ca, P and Ti resembles that of the inclusion described by [2, 3]. However, the texture and the presence of olivine distinguish AI#2 from that inclusion.

Conclusion: The AI#1 and AI#2 are different from the AIs described before in Tsarev and represent new types of achondritic inclusions in this chondrite. The presence of various AIs in the Tsarev chondrite assumes that the L-chondrite asteroid has been affected by a number of different processes including melting and partial fractionation.

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