The Tsarev meteorite is the largest meteorite shower on the USSR territory that fell in December 1922 but was found only in 1979. Now there are 30 samples with total weight more than 1000 kg. The study of large areas of internal surface of the meteorite (about 1600 cm²) makes it possible to observe some peculiarities that are impossible to see during usual meteorite research.

The meteorite is partly-melted shock-breccia of L-group chondrite composition. There are two distinct lithologic types of matter of the meteorite: (1) the light grey areas with well-preserved chondritic texture, and (2) more dark portions that are cement-like in relation to the first (Fig. 1). The light grey areas are the products of prolonged, intense recrystallization in solid. Highly recrystallized texture suggests that the Tsarev meteorite belongs to the petrologic type 5 with some portions belonging to types 4 and 6.

The dark portions are the products of shock partial melting and are saturated in finely dispersed opaque. The width of such zones varies from very fine branchy veinlets up to 4–5 cm, and their quantity is 30–55 vol.% of matter in the various meteorite samples. They consist of cryptocrystalline silicate matrix with relics of chondrules and of olivine grains.

Mineral composition of the meteorite is usual for ordinary chondrites: olivine, ortho- and clino-pyroxenes, maskelynite, calcium phosphates (apatite and whitlockite), nickel-iron, troilite, chromite, ilmenite, and rutile. All silicate minerals contain the shock signs namely development of maskelynite on plagioclase, presence of planar features and recrystallization of olivine with display mosaic extinction.

The Tsarev meteorite must be referred to highly-shocked chondrites of facies e-f, in connection with Dodd and Jarosewich criteria of shock intensity [1]. Recrystallization of olivine permits to estimate peak pressure near 800 kbar in according to data of Carter et al. C21.

Electron microprobe analyses show that the compositions of olivines (Fa 24.6) and orthopyroxenes (Fa 20.6) are almost uniform in all samples of the meteorite and do not transpose compositions of L-chondrite group. At that it is necessary to note rather high contents of CaO in olivines (0.07–0.35 wt.%), and orthopyroxenes (0.85–2.3 wt.%) in comparison with other chondrites of types 5 and 6 [13]. The clinopyroxenes corresponds in composition to diopside with reduced calcium content Ca40Mg40Fe12. The temperature of equilibrium of coexistence pyroxenes is estimated as <40°C [14].

The cryptocrystalline silicate matrix of dark portions corresponds in composition to orthopyroxene of light areas but with some higher contents of FeO (15.7 wt.%) as well as Al2O3 (1.5 wt.) and MgO (0.6 wt.%) also.

The distribution of nickel-iron in meteorite matter is very non-uniform not only among various individual samples but also within the individual samples, and varies from 1 to 8 vol.% (count areas 10 cm²). Such variation is connected predominantly with loss of metal iron during the Earth oxidation [53].

Metallographic study shows that predominant component of nickel-iron is plessite (Fig. 2, 3). The morphology of this structure (av. Ni 14 wt.% av. Co 0.9 wt.%) under small magnifications is similar to a2 martensite, the product of non-diffusion transformation in Ni-Fe alloys. But under large magnifications one may see that martensite-like structure consists of smallest plates of taenite (Ni 24 wt.%) which decorate the boundaries of kamacite (Ni 9 wt.%). Such plessite was described in some iron meteorites [6] and was formed by a2 + a + γ transformation (plessite of I11 type). The plessite fields of mono- and polycrystalline grains are surrounded by borders (width 1–25 mcm of secondary kamacite (Ni 7 wt.% Co 1.2 wt.%). The latter was formed from γ-iron.

On the whole the Tsarev meteorite is the shock-breciated chondrite of L 5 e-f group of rather homogeneous composition. On the peculiarities of composition and structure one must refer to the limited group of highly-shocked chondrites of type of Shaw, Farrington, Ramsdorf, Genicke and other [7–9]. High degree of shock is confirmed by (1) large percentage of melted portion, (2) olivine recrystallization, (3) higher CaO contents in olivine and orthopyroxene with presence of low-Ca diopside, (4) nature of metal transformation.

Principal structure component of metal iron is plessite. We have observed similar structures also in metal grains in Farrington, Ramsdorf and Genichesk chondrites. Earlier such structure in these meteorites was described as martensite [8,9].

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References:
Fig. 1 The surface of section of Tsarev meteorite sample 15384: 1 -- light grey areas; 2 -- dark portions; 3 -- large grains of nickel iron; 4 -- vesicles; 5 -- fractures.

Figs. 2, 3. The structure of nickel iron grains: $k_1$ -- kamasite, $k_2$ -- secondary kamasite, $t$ -- taenite.