OPAQUE-RICH LITHOLOGY IN THE DIVNOE ACHONDRITE: PETROLOGY AND ORIGIN

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An opaque-rich lithology (ORL) makes up to ~9 vol.% of the Divnoe achondrite. It is characterized by enrichment of troilite and pyroxene compared to bulk Divnoe, the presence of tiny remnants of olivine in low-Ca pyroxene and low minor element concentrations in pyroxene. The ORL was formed by local reaction between gaseous sulfur and olivine in the Divnoe.

INTRODUCTION The Divnoe meteorite is an olivine-rich achondrite with subchondritic chemistry and mineralogy [1-4]. It has a granoblastic coarse-grained olivine groundmass (CGL: coarse-grained lithology) with relatively large (2-10 mm) poikilitic patches (PP) of pyroxene and, rarely, plagioclase. The groundmass also contains an opaque-rich fine-grained lithology (ORL) which comprises ~9 vol.% of the meteorite, displays reaction boundaries with the groundmass, and differs in mineral chemistry from it. Numerous μm- to mm-thick veins of troilite and, rarely, metal cross all the lithologies found in the meteorite. The Divnoe itself appears to represent a sample of an igneous source region.

PETROLOGY The opaque-rich lithology has been found only within granoblastic CGL. It is often located at boundaries between olivine grains, or along preexisted cracks filled now by ORL. The types of occurrence of ORL vary from roughly equidimensional irregular areas ranging from tens to hundreds μm in size, to long (several mm) branching veins of varying thickness (100 - 900 μm). Sometimes ORL is associated with large metal or troilite grains. Texture of ORL depends upon its content of opaque minerals, changing from granoblastic to micrographic as the content of opaques and the troilite/metal ratio increases. The grain size of ORL rarely exceeds 100 μm, and varies from area to area from several μm to tens μm, being relatively constant within an area.

Major minerals are low-Ca pyroxene or, rarely, even two pyroxenes with slightly different compositions and very low birefringence; sulfide, usually troilite; metal; and olivine, the abundance of which varies considerably. Compared to the bulk meteorite, ORL is enriched in pyroxene and opaques (Table 1). Two modes of occurrence of olivine have been found in ORL: (1) relatively large anhedral grains similar in size to the other minerals, and (2) small relict grains inside pyroxene. The second type of olivine, characteristic for ORL, always shows reaction relations with the host pyroxene, implying a substitution of the latter for the former. In several cases, large anhedral olivine grains surrounded by pyroxene and opaque intergrowths, and small olivine relicts within pyroxene, display the same optical orientation. Opaque minerals also occur in two types of grains: (1) relatively large grains of metal and troilite, and (2) very small troilite grains along the boundaries between large grains of olivine and pyroxene inside ORL as well as at the boundary between ORL and CGL. The metal/sulfide ratio varies considerably, and, as a rule, the higher troilite content the higher the pyroxene/olivine ratio is in ORL. In two areas, where ORL is associated with large metal grains, it contains euhedral or subhedral whitlockite grains as a major mineral. The only grain of high-Ca pyroxene found is in such an area.

Characteristic of practically all occurrences of ORL is the presence of microcopy of it - finer-grained domains, even richer in opaques, inside ordinary ORL. These domains often concentrate at peripheries of ordinary ORL, near its boundary with olivine, and consist of pyroxene and sulfide, the latter comprising up to 70 % of the domains. The sulfide is often pyrrhotite. No olivine has been found in the micro-ORL.

The chemical composition of silicates in ORL differs slightly in major elements (Fig. 1) and considerably in minor (Fig. 2). Olivine and pyroxene are more magnesian then these minerals in CGL. The pyroxene in ORL is depleted in all minor elements relative to the pyroxene in PP. This appears to be a reason of very low birefringence of ORL pyroxene. The metal is often replaced by terrestrial oxides. Previous studies [1,3] revealed similar compositions of metal in CGL and ORL, with minor enrichment of ORL metal in Ni and Co. The troilite, phosphate, and high-Ca pyroxene are identical in composition to minerals in CGL.

ORIGIN The enrichment of ORL in opaques, especially troilite, and its variable but high pyroxene/olivine ratio, suggest the operation of a process involving redox reactions between silicate(s) and a reducing agent. In the case of Divnoe, such the reducing agent could be sulfur. Reaction between sulfur, with a fugacity was buffered by a troilite-metal assemblage in the source region, and CGL olivine at high temperature could results in the formation of pyroxene-troilite intergrowths associated with as yet unreacted olivine. This could occur during the final stages of partial melting when all other minerals except olivine and metal, were exhausted from a source region. In a microchambers represented now by ORL, reaction between olivine and gaseous sulfur resulted in the extraction of Fe_{2+} from the silicate and formation of troilite. The residual silicate assemblage had a lower (Mg+Fe)/Si ratio and, consequently, a lower melting temperature. Since the temperature was fixed, the decrease of (Mg+Fe)/Si resulted in increasing of melt/olivine ratio in the microchamber, with silicate melt being of pyroxenic composition.

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Simultaneously the amount of troilite increased, if sulfur was the only reducing agent. If another reducing agent, e.g. C-bearing gas species, played a role in this process, the amount of metal in the microchamber would increase. Such a melting event could also explain low minor element contents in pyroxene of ORL as a result of the dilution of the microchamber's melt with almost pure enstatite.

REFERENCES [1] Zaslavskaya N.I. et al. (1990) *Meteoritika*, **49**, 10-27 (*in Russian*) [2] Zaslavskaya N.I., Petaev M.I. (1990) *21st LPSC*, 1369-1370 [3] Zaslavskaya N.I. et al. (1990) *21st LPSC*, 1371-1372 [4] Petaev M.I. et al. (1990) *21st LPSC*, 948-949

Table 1. Mineralogy of Divnoe lithologies (vol.%)

	Bulk*	PP-rich	ORL
Pyroxene	14.3	27.6	41
Olivine	74.6	57.9	32
Plagioclase	1.5	-	-
Opaques	9.5	6	13
ORL	-	8.5	14**

* Mineral norms converted to vol.%

** Very fine-grained ORL

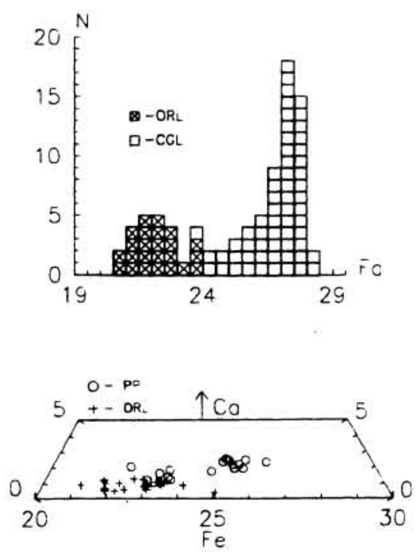

Fig. 1. Chemical variations in olivine (top) and pyroxene (bottom).

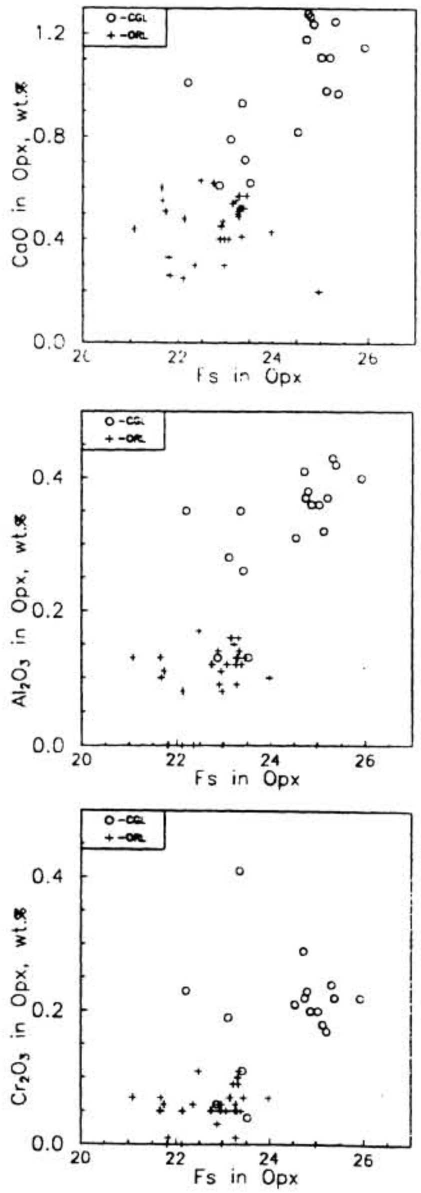

Fig. 2. Minor elements in low-Ca Px.