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BRIEF COMMUNICATIONS

On Two Types of Metalliferous Carbonaceous Rocks

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Abstract—Two types of metalliferous carbonaceous rocks that differ in associated metals are considered. One of them is characterized by gold occurring in finely dispersed arsenopyrite and arsenic-bearing pyrite, and the other, by finely impregnated native metals in carbonaceous matter. Rocks of the first type also contain elements of the platinum group, while those of the second type bear rhenium, silver, iron, molybdenum, and other metals. Graphitic mineralization is usually localized in the shear zone associated with alkaline basalts.

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Large gold deposits associated with carbonaceous rocks were discovered over recent decades. Metalliferous black shales enclosing deposits of base and noble metals are among these rocks (Sidorov and Tomson, 2000). The deposits are usually localized in shear zones.

It was established that shales contain both biogenic and endogenic carbon and are accompanied by platinum mineralization. Such compositional properties imply penetration of mantle-derived metalliferous hydrocarbonaceous fluids into sedimentation basins along shear zones during formation of these rocks (Konstantinov *et al.*, 2000).

Most of the gold in shales occurs in form of submicroscopic inclusions in acicular fine-grained arsenopyrite and arsenic-bearing pyrite. The economic significance of the deposits enclosed in these rocks is largely determined by the content of arsenopyrite and pyrite with finely dispersed gold (Konstantinov *et al.*, 2000). In this connection, we can mention the Maiskoe deposit in Chukotka, the Nadezhdinsk deposit in Yakutia, and the Natalkinsk deposit in the Kolyma region, where ores are mostly represented by similar metalliferous rocks. All of them are enclosed in black shale sequences of the Verkhoyansk complex and located in the perivolcanic zone of the Okhotsk–Chukotsk volcanogenic belt (Konstantinov *et al.*, 2000).

Metalliferous carbonaceous metasomatites represent another type of carbonaceous rocks, which was established in ore regions (Tomson *et al.*, 1984a, 1984b, 1995). In distinction from gold-bearing black shales, native metals in metasomatites occur in aggregates of free carbon.

The metasomatites are controlled by thick shear, boudinage, and brecciation zones and constitute cement of explosive breccias. They are found in ore regions with various hydrothermal and skarn mineralization. Among the best studied are carbonaceous metasomatites of the Dal'negorsk ore district. The latter includes the Bor deposit, one of the largest skarn boron–silicate deposits and numerous skarn polymetallic, vein-type polymetallic, and other deposits. Skarn boron–silicate and skarn polymetallic deposits formed in the period of 74–56 Ma, while others are younger. Their isotopic age determined by the Rb–Sr method is 115 ± 6 Ma (Tomson *et al.*, 2001).

Carbonaceous metasomatites are the most widespread in the central part of the district, which comprises three grabens crossed by a system of NW-trending faults.

The metasomatites are dark-colored to black in the case of very high carbon content and well manifested against the background of light metamorphic shales and carbonate rocks.

The main minerals in metasomatites are graphite and ilmenite accompanied by common rutile, sericite, rare muscovite, carbonates, and sulfides such as pyrrhotite, arsenopyrite, and pyrite. Accessory minerals are native metals, intermetallides, and carbides. Native metals are largely represented by iron associated with gold, zinc, lead, tin, copper, and aluminum (Fig. 1). Intermetallides include zinc copper and tin–lead and zinc–aluminum mixtures. Cogenite is established among carbides. Native metals and their mixtures are observed immediately within graphite. Such an association could form in a reducing endogenic environment. All the accessory minerals occur mainly in the form of nannoinclusions and, to a lesser extent, platy, spherical, and other aggregates hundredths and tenths of a millimeter across.

The study of metasomatites using neutron activation, atomic absorption, chemical, and other methods revealed that they formed under the input of C, V, Ti, Fe, Au, Ag, Mn, Mg, Cu, Zn, Pb, Co, Ni, Mo, Cr, Se, Re, and other elements including typical mantle-derived ones such as Ti, Cr, Co, Ni, Pt, et al. The pres-

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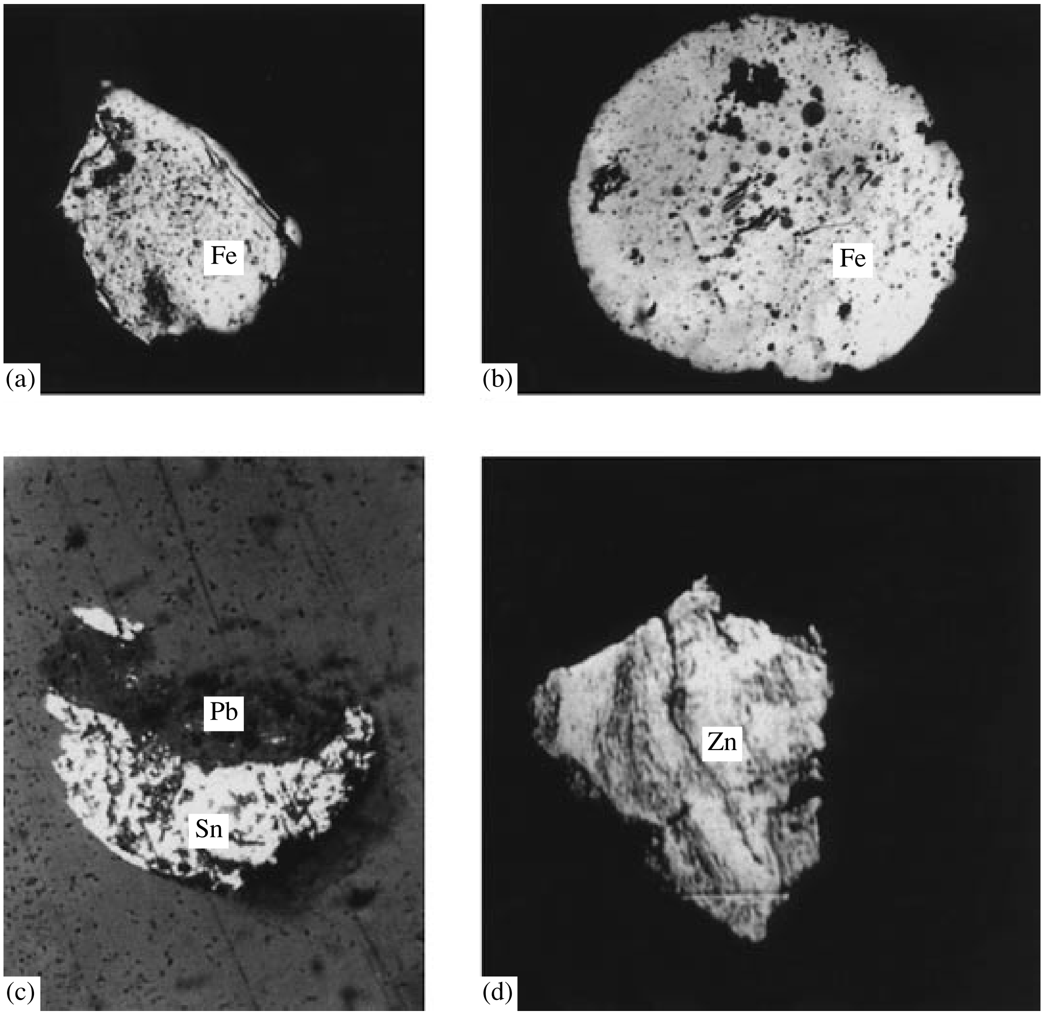

Fig. 1. Native metals and their associations. (a) native iron, polished thin section, magn. ×250; (b) spherical iron aggregate, magn. ×250; (c) native tin and zinc associations, magn. ×160; (d) plate of native zinc, polished thin section, magn. ×160.

ence of mantle-derived elements indicates a deep source of fluids responsible for metasomatosis. It should be emphasized that the content of many elements correlates with the concentration of free carbon in rocks.

The study of gases from closed pores carried out at the laboratory of gases and bitumen of the Kola Scientific Center of the RAS under the supervision of S.V. Ikorskii revealed that they are dominated by methane, hydrogen, and nitrogen. Such a composition is characteristic of gases from diamond-bearing kimberlite pipes and minerals associated with diamonds, the deep origin of which is beyond doubt.

It was established that zones of NE-trending faults controlling distribution of metasomatites host coeval alkaline basic bodies. The composition of these rocks suggests that they formed with the participation of upper mantle plumes (Baskina *et al.*, 2004).

The similar age and structural position of alkaline basic rocks and carbonaceous metasomatites indicate that the latter formed under the influence of plumes.

The structural setting, association with basalts of plume type, mineral composition, geochemical properties, and composition of gases from closed pores of rocks unambiguously indicate that metasomatites formed under the action of reduced deep-sourced metalliferous carbonaceous fluids.

Endogenic carbonaceous metasomatites formed most likely above the frontal part of deep plumes. The close association of native metals and carbon in metasomatites implies migration of gold and other metals in the form of metalloorganic compounds. E.Yu. Buslaeva found metalloorganic compounds of gold, iron, and arsenic in metasomatites of the Dal'negorsk district (Tomson *et al.*, 1995).

Inasmuch as carbonaceous metasomatites served as a source for some metals in areas of later mineralization, they deserve particular attention. In addition, elevated concentrations of noble metals, rhenium, and other elements in metalliferous carbonaceous metasomatites are promising with respect to nontraditional ore types (Tomson *et al.*, 2003).

The data help to discriminate two types of metalliferous carbonaceous rocks. In black shales, gold forms mainly microinclusions in arsenopyrite and arsenic-bearing pyrite. This type can be termed as gold–carbonaceous–arsenic. In carbonaceous–ilmenitic metasomatites, native metals are present as nannoinclusions in graphite, which give grounds to term this type as carbonaceous–native metallic.

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