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GEOLOGY

The Role of "Postore" Basaltoids in the Formation of Ore-Bearing Hydrothermal Solutions

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The study of numerous epithermal deposits ranging in age from Paleozoic (Omolon Craton) to Late Mesozoic (Okhotsk–Chukot volcanogenic belt) and Miocene–Pliocene (Kamchatka) revealed that nearly all ore fields incorporate postore dikes (sills and stocks) of basaltic andesites. Dikes of dolerites, microgabbro, and other basic rocks are developed in some places. Subvolcanic bodies show a wide range of variation in size. Thin dikes (0.3–1 m) in sedimentary rock fields extend from a few meters to 5 km or more. Domal, stratiform, and semicircular dikes in volcanogenic rock fields range from 10 to 200–300 m in diameter. The central part of subvolcanic bodies is usually composed of holocrystalline rocks (up to monzonites), while the periphery consists of vitreous varieties enriched in clinopyroxenes. In some places, the rocks (particularly, stratiform varieties) have a botryoidal structure with chalcedony, opal, quartz, calcite, and chlorite botryoids ranging from 1.5–2 cm to 0.5 m in size. The rocks have a porphyritic texture with phenocrysts up to 2–3 mm in size. The content of phenocrysts varies from 50–60 vol % in the central part of subvolcanic bodies to 5–10 vol % at the margin (average 20–25 vol %). The phenocrysts are composed of euhedral plagioclase crystals (5–30 vol %) varying in composition from andesine to labradorite-bytownite. Colorless clinopyroxene (diopside) and orthopyroxene (enstatite) are subordinate components (1–20 vol %). The pyroxenes are often associated with Fe-biotite flakes (up to 5 vol %). Quartz is a rare mineral. The micromonzonitic, micropoikilitic, or andesitic groundmass is composed of plagioclase (andesite–labradorite) laths, xenomorphous K-feldspar grains (up to 50 vol % in trachyandesitic varieties), pyroxenes, and moderately acid glass. Zircon, magnetite, and apatite are accessory minerals. The apatite grains (0.03 mm) account for up to 1 vol % in some places. The SiO_2 content is as much as 50–55% (K_2O/Na_2O varies from 2 : 3 to 2: 1). The absolute age of two-pyroxene trachyandesites in ore fields of the Okhotsk–Chukot volcanogenic belt varies from 60 to 100 Ma, whereas the age of adular–quartz veins is estimated at 50–90 Ma [1]. In Kamchatka, the age of basaltic andesites and adular–quartz veins is estimated at 0.6–0.8 Ma (Mutnov deposit) and 7.4–7.9 Ma (Agin deposit) [2].

In general, basaltic andesite dikes intersect ore bodies (Figs. 1, 2). In some cases, bonanza ores are developed near such postore dikes (within ore bodies in rare cases). The abundance and prominence of unaltered basaltic andesite dikes within ore fields have attracted the attention of researchers, because such dikes allegedly testify to the abyssal and homogeneous nature of ore-generating sources of epithermal deposits. However, ore formation and stable isotope data on ore elements indicated that crustal sources of ore material range from the relatively deep variety to the near-surface regeneration type. The cognation of ores and metasomatites at various epithermal deposits in global volcanogenic belts is convincingly demonstrated by the development of similar near-surface physicochemical processes in hydrothermal solutions during their mixing with meteoric waters [3].

The role of basaltic andesite dikes in the formation of ore-bearing hydrothermal solutions is an interesting issue. Judging from the absolute age data, the dikes intruded ore zones at the final stage of hydrothermal processes. The basic dikes actually terminate ore processes and foster the "boiling" (according to Korzhinskii [4]) of hydrothermal systems. Study of volcanic rocks on the Okhotsk coast and Kamchatka revealed a specific mode of explosive (ignimbritic) volcanism accompanied by vigorous hydrothermal processes along the periphery of volcanic structures [3, 5]. This type of volcanism and associated hydrothermal processes gave way to the intrusion of various basaltic bodies and even the emplacement of plateau basalts (acid-to-basic succession). Researchers naturally attributed the ignimbritic volcanism and associated hydrothermal processes to the ascent of a basaltic magma front in the Earth's crust of the study region. This seemed even more evident because postore basalts and basaltic

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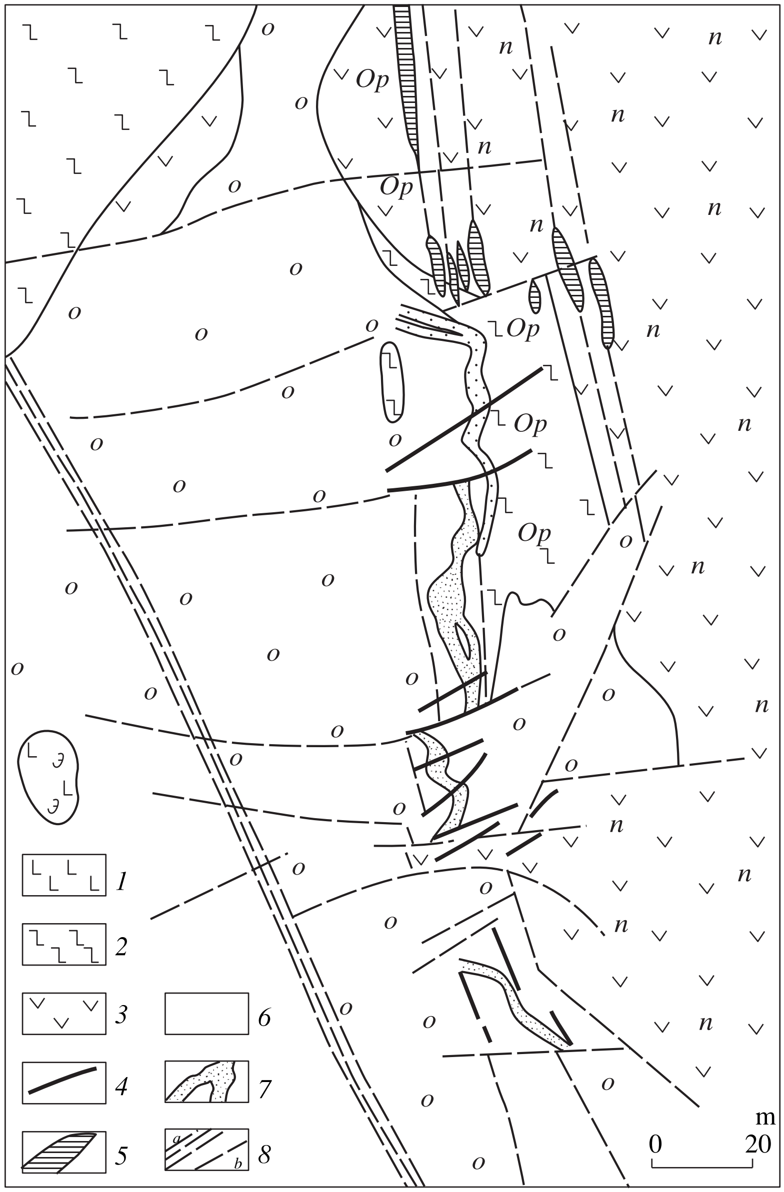

Fig. 1. Schematic geological setting of the Khandzha gold–silver deposit (Okhotsk coast) [1]. (*1*) Upper Cretaceous andesites; (*2*) Upper Cretaceous dacites and rhyolites; (*3*) Lower Cretaceous andesites; (*4*) postore basaltoids; (*5*) granite and granosyenite porphyry dikes; (*6*) subvolcanic rhyolites; (*7*) ore body; (*8*) faults: (*a*) crush zone, (*b*) fractures.

andesite also frequently include numerous geodes filled with chalcedony, agate, and quartz (amethyst inclusive). The structural and geochemical characteristics of the geodes and epithermal veins show several common features.

Thus, the postore basaltoid dikes mark certain segments of the ascending basaltic magma front. Their clusters within ore fields of epithermal deposits can be considered a "microplume," which was responsible for late preore (granitoid and rhyolite) volcanism and epithermal ore formation. Judging from data on large deposits, the intensity of ore deposition was primarily governed by the type of crustal sources of ore material. The role of abyssal sources in the formation of hydrothermal solutions is evident for the layered basic–ultrabasic plutons and oceanic black smokers. In other words, ore material of volcanogenic deposits is derived from various sources. This is confirmed by isotope datings of lead, sulfur, and other elements in ores, as well as by ore formation analysis [6].

Thus, bimodal (rhyolite–basalt) volcanism is typical of volcanogenic ore-bearing zones. Nevertheless, contrast volcanism was not considered a prospecting criterion, because the basaltoid member turned out to be a postore formation. However, materials discussed in the present paper suggest that the subvolcanic (postore)

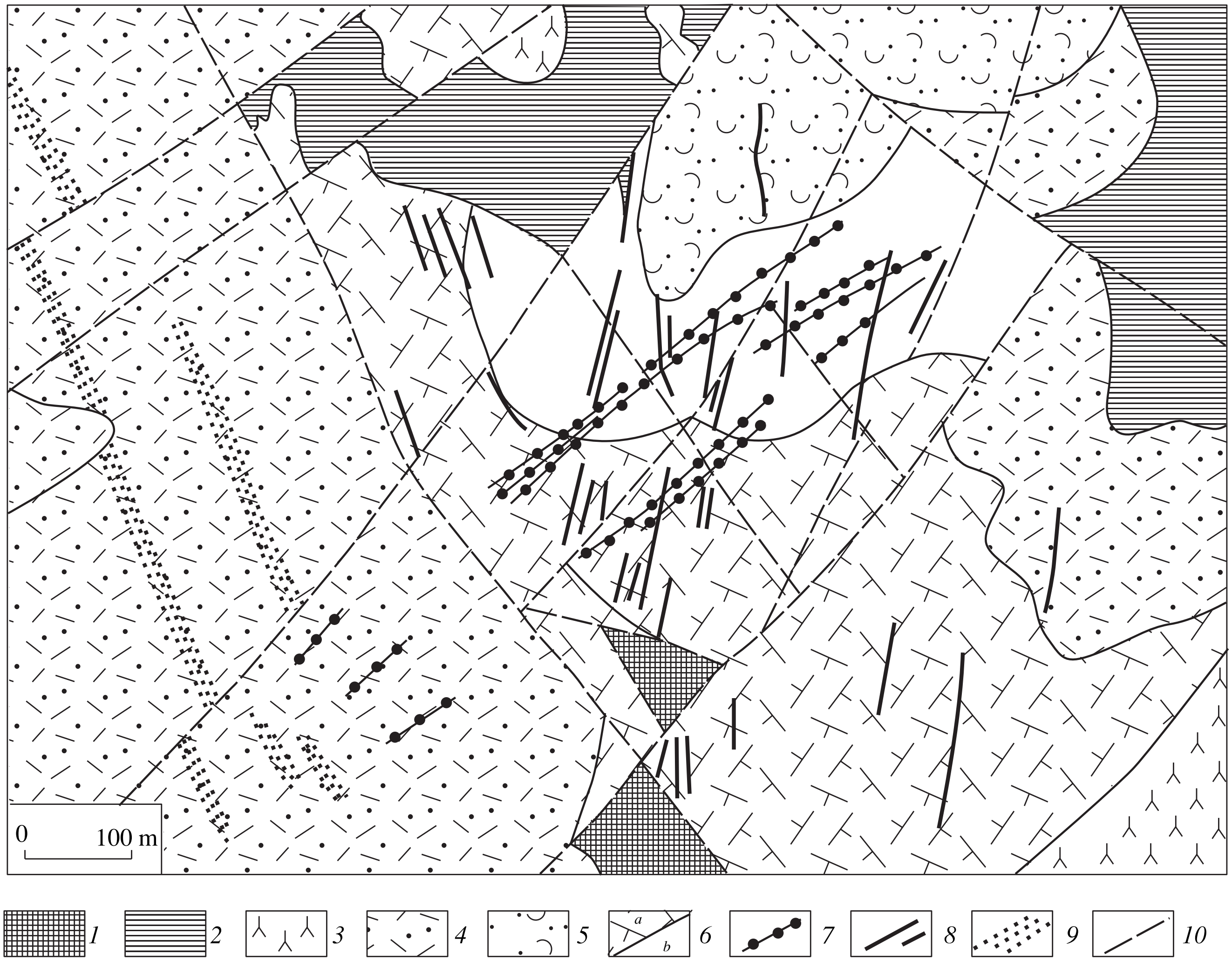

Fig. 2. Schematic geological setting of the Dukat silver deposit (Okhotsk–Kolyma watershed) [1]. (*1*) Triassic sandy–shaly sequences; (*2*) Lower Cretaceous terrigenous sequences; (*3–5*) Upper Cretaceous volcanogenic sequences: (*3*) andesite, (*4*) rhyolite, (*5*) felsite; (*6*) complex effusive–subvolcanic rocks: (*a*) stratified andesites, dacites, and rhyolites, (*b*) fluidal felsitic rhyolites; (*7*) basaltic andesite dikes; (*8*) ore bodies; (*9*) Sn-bearing chloritization zones; (*10*) faults.

basaltoid bodies represent the latest (terminal) product of the ascending basic magma front, which was responsible for the upper crustal granitoid magmatism and hydrothermal anomalies. The termination of volcanic processes after basaltic eruptions naturally promoted the gradual disappearance of hydrothermal systems. In some cases, relicts of such systems are well preserved as geodes in basaltic andesite sheets and dikes.

REFERENCES

1. A. A. Sidorov, *The Gold–Silver Formation of Volcanogenic Belts in East Asia* (Magadan, 1978) [in Russian].
2. I. D. Petrenko, *The Gold–Silver Formation of Kamchatka* (S.-Peterb. Kartograf. Fabrika VSEGEI, Petropavlovsk-Kamchatskii, 1999) [in Russian].
3. A. A. Sidorov, *Analysis of Ore Formations and Evolution of Noble Metal Mineralization* (DVO RAN, Magadan, 1998) [in Russian].
4. D. S. Korzhinskii, Dokl. Akad. Nauk **122**, 267 (1958).
5. V. V. Aver’ev, in *Recent Volcanism* (Moscow, 1966), Vol. 1, pp. 118–129 [in Russian].
6. A. A. Sidorov and A. V. Volkov, Dokl. Earth Sci. **397**, 611 (2004) [Dokl. Earth Sci. **397**, 72 (2004)].