ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 415A, No. 6, pp. 866–868. © Pleiades Publishing, Ltd., 2007.
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GEOLOGY

Plumes and Their Influence on the Formation of Noble Metal Mineralization in Carbonaceous Rocks

P. V. Komarov† and Corresponding Member of the RAS I. N. Tomson

Received February 16, 2007

DOI: 10.1134/S1028334X07060086

Increasingly more data on the role of mantle plume in various geological processes have begun to appear in the geological literature. The study of the influence of plumes on the formation and localization of ore deposits is also of keen interest. Before discussing specific examples, let us recall briefly the meaning of a plume and its derivatives. As follows from numerous publications of Russian and foreign scientists, the term *plume* commonly implies giant batches of outer liquid core of the Earth that reach the Earth's surface [1, 2]. The currently discussed models of origination and evolution of plumes are diverse and remain hypothetical to a great extent. The outlines of plumes at the surface are often uncertain.

Our interpretation of plumes, more exactly of their derivatives, is based on the age of igneous rocks and ore deposits established in Russia. The numerous determinations of isotopic ages of rocks and orebodies have shown a zonal distribution of ore magmatic systems (OMS) in terms of their chronology. Such a zoning is displayed in contouring of coeval and monoperiodic OMS using isotope data on minerals in endogenic deposits and igneous rocks related to the youngest phases of magmatism and ore mineralization in each region (figure). The delineated domains extend to thousands of kilometers and correspond to giant igneous provinces. Therefore, they are most likely related to formations recognized as plumes and superplumes [2–4]. In this connection, let us define the zone of plume manifestation. If a vast territory (hundreds and thousands of kilometers across) is distinguished by coeval and monoperiodic endogenic deposits and/or igneous rocks, then such a territory is considered a zone of plume manifestation or, more precisely, a zone of occurrence of derivatives of the plume of a certain period localized at upper horizons of the crust.

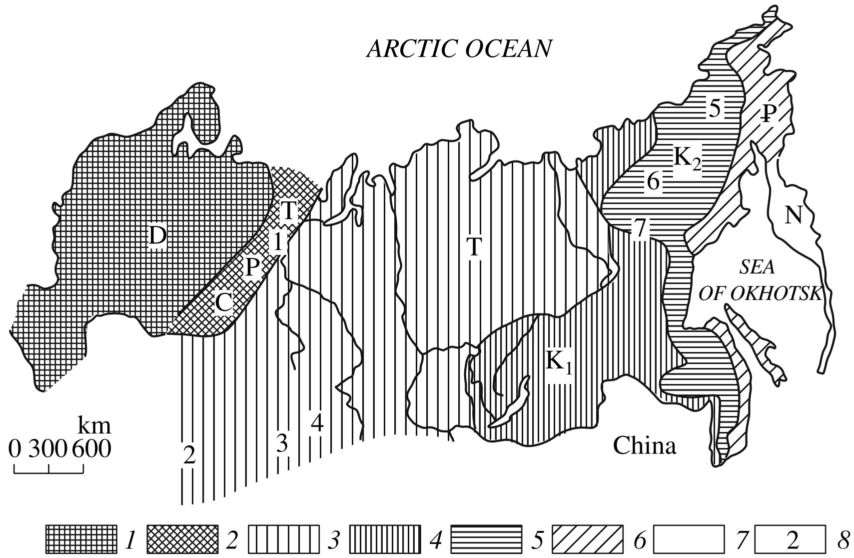
Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences, Staromonetnyi per. 35, Moscow, 119017 Russia

†Deceased.

Such a zone spreads in the latitudinal direction to the boundary of the neighboring zone with the OMS of a different age. In the longitudinal direction, the plume-tectonic zones are traced so far up to the Eurasian segment of Tethys. The zonal arrangement of igneous rocks and ore deposits in northern Eurasia distinctly corresponds to the periods of the geochronological scale. The zones of monoperiodic OMS become progressively younger in the eastern direction from the Devonian to the Neogene–Quaternary. This fact also indicates the eastward migration of the parental plumes (figure). Igneous derivatives of plumes could intrude the crystallization zone along sectors subjected to the most intense tectonic reworking. In addition to the zonal, coeval, and monoperiodic igneous rocks and ore deposits in Eurasia, the OMS of each period is also traced over the entire planet as intermittent stages. Each zone of periodic zonal series may be regarded as global onset of the OMS stage of the given period. The volcanism is accompanied by the accumulation of sediments and periodic growth of the Earth's crust in several stages. The intrusive magmatic activity promotes the overlapping or replacement of older rock complexes by younger igneous rocks.

Each coeval and monoperiodic OMS or igneous rock zone represents an autonomous plume-tectonic structure with high potential of the discovery of new deposits related to the given period. We shall call these units geochronoperiodic plume-tectonic or plume-metallogenic zones of the first order (figure). The much smaller (in comparison with plume-tectonic zones of the first order) OMS and monoperiodic igneous rocks are defined as plume-tectonic zones of the second or lower orders. Exposures of the OMS, fields of igneous rocks, and plume-tectonic zones of the second or lower order related to other periods are regarded as manifestations of the global stage of the respective period.

It should be noted that, similarly to processes of the formation of plume-tectonic zones and discontinuous global stages, the process of plume manifestation commonly bears a periodic character and strictly corresponds to the periods of the geochronological scale in the Phanerozoic. This process demonstrates the spa-



Spatiotemporal zoning of the OMS in the northern Eurasian continent (periodicity of ore mineralization and plume tectonics from the Devonian to the Neogene). Zones: (*1*) Devonian (D); (*2*) juxtaposed Carboniferous (C), Permian (P), and Triassic (T) OMS zones of the Urals; (*3*) Triassic (T); (*4*) Early Cretaceous (K_1); (*5*) Late Cretaceous (K_2); (6) Paleogene (₽); (*7*) Neogene. Noble metal deposits hosted in carbonaceous rocks (numerals in figure): (1) Vorontsovka; (2) Muruntau; (3) Kumtor; (4) Bakyrchik, (5) Maisk; (6) Natalka; (7) Nezhdaninsk.

tiotemporal distribution of ore mineralization. In the taxonomy of tectonic units, the periodic plume-tectonic zones of the first order are subordinate relative to continents, oceans, and global fault zones of the MOR type or the Eurasian segment of Tethys. They are the largest metallogenic units that embrace the zones of coeval OMS related to different epochs of the given period, as well as ore clusters and ore districts.

The concept of plume-tectonic zones and monoperiodic global OMS stages allows us to reveal the effects of plumes on the formation of various ore deposits, in particular, on the noble metal deposits hosted in carbonaceous rocks. The concept formulated above was checked for the following Phanerozoic deposits: Maisk (Chukchi Peninsula), Natalka (Magadan district), Nezhdaninsk (Yakutia), Vorontsovka (Urals), Bakyrchik (Kazakhstan), Muruntau (Uzbekistan), and Kumtor (Kyrgyzstan). It should be noted that all the aforementioned deposits are large structures. Thus, the investigation of relationships of the deposits hosted in carbonaceous rocks with plumes can also make it possible to estimate the relationships between plumes and large deposits.

First, let us ascertain the relationship between these deposits and plume-tectonic zones (figure). The Carboniferous Vorontsovka deposit (Urals) is located in the Carboniferous plume-tectonic zone, which is juxtaposed here with the Permian and Triassic zones. However, the Triassic zone, the youngest in the package, is observed as the uppermost unit. In the Urals, gold mineralization related to derivatives of the Triassic plume (e.g., Mindyak deposit) has a Permian age, whereas gold mineralization related to derivatives of the Triassic plume (e.g., Kumak deposit) has a Triassic age [2, 8]. Thus, the available geological materials indicate that endogenic ore deposits, which are derivatives of specific plumes, characterize not only types and formation conditions of mineral resources, but also their geological structures and metallogenic potential. They also distinctly outline the studied space in time. The zones of juxtaposed periods extend from the Urals to the south and east. The Muruntau, Bakyrchik, and Kumtor deposits localized in such zones are confined to specific periods, because each deposit is related to the derivatives of a certain plume or several plumes juxtaposed in one tectonic zone. For example, the Kumtor deposit is related to derivatives of the Permian plume [6]; the Muruntau deposit, to derivatives of the Permian and Triassic plumes [5]; and the Bakyrchik deposit, to derivatives of the Carboniferous and Triassic plumes [7].

Thus, the ages of the noble metal mineralization and carbonaceous ore zones correspond to ages of the respective plumes. The Maisk, Natalka, and Nezhdaninsk deposits are hosted in different (in composition and age) rocks, but all these deposits are located in the zone affected by the Cretaceous plume. Therefore, they have a Cretaceous age. Since noble metal deposits in carbonaceous rocks are related to the plumes of certain periods, they depend on periodicity of the plumes expressed in both time and space. The periodicity is reflected in the eastward migration of plumes and their activity in the Urals (in the Carboniferous, Permian, and Triassic) and the eastern part of Russia (in the Cretaceous and Paleogene) [2, 4, 9] in accordance with the periodicity of magmatism, mineralization, manifestation of plumes, and their eastward migration.

Thus, we can conclude that the influence of derivatives of plumes on noble metal mineralization is expressed in the following regularity: the host carbonaceous rocks may be of any age, but the age of noble metal mineralization always fits the age of the plume, i.e., the age of ore-generating igneous rocks.

Since the noble metal deposits in carbonaceous rocks are related to the plumes of certain periods, these deposits depend on the periodicity of plumes in the given territory. The periodicity is manifested in both time and space.

The relationships established by the study of zoning and multistage structure of the derivatives, periodicity, and polychronous nature of plumes (based on isotopic dating of minerals in OMS) are the basis for a new line of plume-tectonic and metallogenic zonal-stage analysis of ore deposits.

ACKNOWLEDGMENTS

This work was supported by the Division of Earth Sciences, Russian Academy of Sciences (Program of Basic Research no. 2).

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