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Shonkinites and minettes of the Ryabinovyi massif (*Central Aldan*): composition and crystallization conditions

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Abstract

Dikes of biotitic shonkinites and minettes of the complex Ryabinovyi alkaline massif (Central Aldan) have been studied. The dikes are localized in a neck of K-picrites in the northeast of the massif, which intrudes gold-bearing microcline–muscovite metasomatites (Muscovitovyi site). The obtained data on the chemical and trace-element compositions of the rocks and minerals and study of melt inclusions in clinopyroxenes indicate that the biotitic shonkinites and minettes crystallized from the same deep-seated high-pressure alkaline ultrabasic magma during its evolution. Apparently, at the early stage of crystallization of diopside in the biotitic shonkinites, homogeneous carbonate–silicate melt was separated into immiscible fractions of silicate, carbonate–salt, and carbonate melts. The temperature of melt immiscibility was >1120–1190 ºC, i.e., higher than the homogenization temperature of silicate inclusions in the diopside. The contents of trace elements in the biotitic shonkinites and rock-forming clinopyroxenes were one or two orders of magnitude higher than the mantle values. The Eu/Eu* ratios of both the considered rocks and the clinopyroxenes were close to those of chondrites, which testifies to their crystallization from mantle magma. The HREE/LREE ratio indicates that the magma source was localized at the depths where garnet-spinel assemblages existed. The negative Nb and Ti anomalies in the trace-element spectra and the high (>5) La/Nb ratios in the rocks and clinopyroxenes point to the influence of crustal material on the parental magma. Crystallization of magma took place in reducing conditions, which is evidenced by the low (4–7) Ti/V ratios in clinopyroxenes and the presence of chloride–sulfate inclusions in them. Since gold in the Ryabinovyi massif is associated with late sulfate–chloride and sulfate–carbonate fluids, it might have been transported by alkaline chloride–sulfate and carbonate (carbonatite) melts, found as inclusions in clinopyroxenes of the biotitic shonkinites, at the early stages of Mesozoic magmatism.

Keywords: shonkinites; minettes; silicate and carbonate–salt inclusions; immiscibility; geochemistry of rocks and minerals; sources of magmatism and mineralization; gold; alkaline complexes of the Aldan Shield; Ryabinovyi massif

Introduction

The largest area of Mesozoic alkaline magmatism and diverse mineralization in southern Yakutia is located in the Central Aldan region. This area includes a wide spectrum of igneous rocks: ultra-alkaline, alkaline, subalkalic, and rare-earth (from ultrabasic to acid). The magmatism is related to (Kochetkov et al., 1981) the tectonomagmatic activity of the Mongol-Okhotsk Fold Belt, which gave rise to ring volcanoplutonic polyformational alkaline complexes. There are more than 20 alkaline and subalkalic massifs (stocks, laccoliths, and ring volcanoplutonic complexes) in this region: Tommot, Yakokut, Yllymakh, Ryabinovyi. They are often accompanied by ore occurrences and placers of gold and, sometimes, platinum. It is assumed (Bilibin, 1958; Kochetkov et al., 1989) that the polyformational structure of Mesozoic igneous complexes is due to the repeated magmatic activity in the same areas, the existence of several magma chambers at different depths, which generated melts of different alkalinity, and the temporal and spatial correlation between the melt intrusion products. Three rock associations are related (Kochetkov and Lazebnik, 1984) to the Mesozoic magmatism: (1) leucitite–alkali-syenite, formed from K-alkali-basaltic magma and being most widespread in the Ryabinovyi massif; (2) monzonite–syenite, formed within the Earth's crust or as a result of the assimilation of crustal material by alkali-basaltic magma; and (3) shonkinite–alkali-picrite, produced in the deepest-seated mantle chambers at different stages of the

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Mesozoic magmatism, including the latest ones, after the formation of most of metasomatic and ore deposits.

The shonkinite–alkali-picrite association differs from the rest. Its rocks have a specific chemical composition (wt.%): 40–50 SiO_2, 5–12 MgO, and 5–10 K_2O. Some researchers (Bogatikov et al., 1991; Makhotkin et al., 1989) refer part of its rocks to lamproites. However, the later detailed mineralogical, petrological, and fluid inclusion studies (Sharygin, 1993) did not confirm the presence of lamproites in the Ryabinovyi massif. A specific feature of the rocks of this association is the almost permanent presence of carbonate-containing minerals and its co-occurrence with carbonatite veins. The rocks are rich in ore components Ti, Cr, Co, Ni, P, Mn, and Cu and are poor in Mo, W, U, and Th (Kochetkov et al., 1989).

However, the genesis of rocks of this association has been poorly investigated. Only the origin of the alkali picrites of the Ryabinovyi massif was studied (Sharygin, 1993). These rocks were assigned by Makhotkin et al. (1989) to lamproites. The aim of our research was to elucidate the physicochemical conditions of formation of biotitic shonkinites and minettes from the shonkinite–alkali-picrite association of the Ryabinovyi massif. We planned to study their specific features and crystallization temperatures as well as the chemical composition of initial melts and their enrichment in trace elements, evolution, and magmatic source. For a complex investigation, we invoked fluid inclusion study methods, which are used to investigate the mineral-forming environment conserved in minerals during their crystallization.

The location and geologic structure of the Ryabinovyi massif

The Ryabinovyi massif is located near the city of Aldan (Fig. 1). It is irregular ellipsoid in shape, with a long axis of NE strike. The total area of the massif (with apophyses) is ~50 km^2. The massif is formed by more than 20 varieties of intrusive, volcanic, and veined rocks of high and elevated alkalinity (mainly potassic). It is an intricate volcanoplutonic structure with a subsidence caldera filled with alkali and

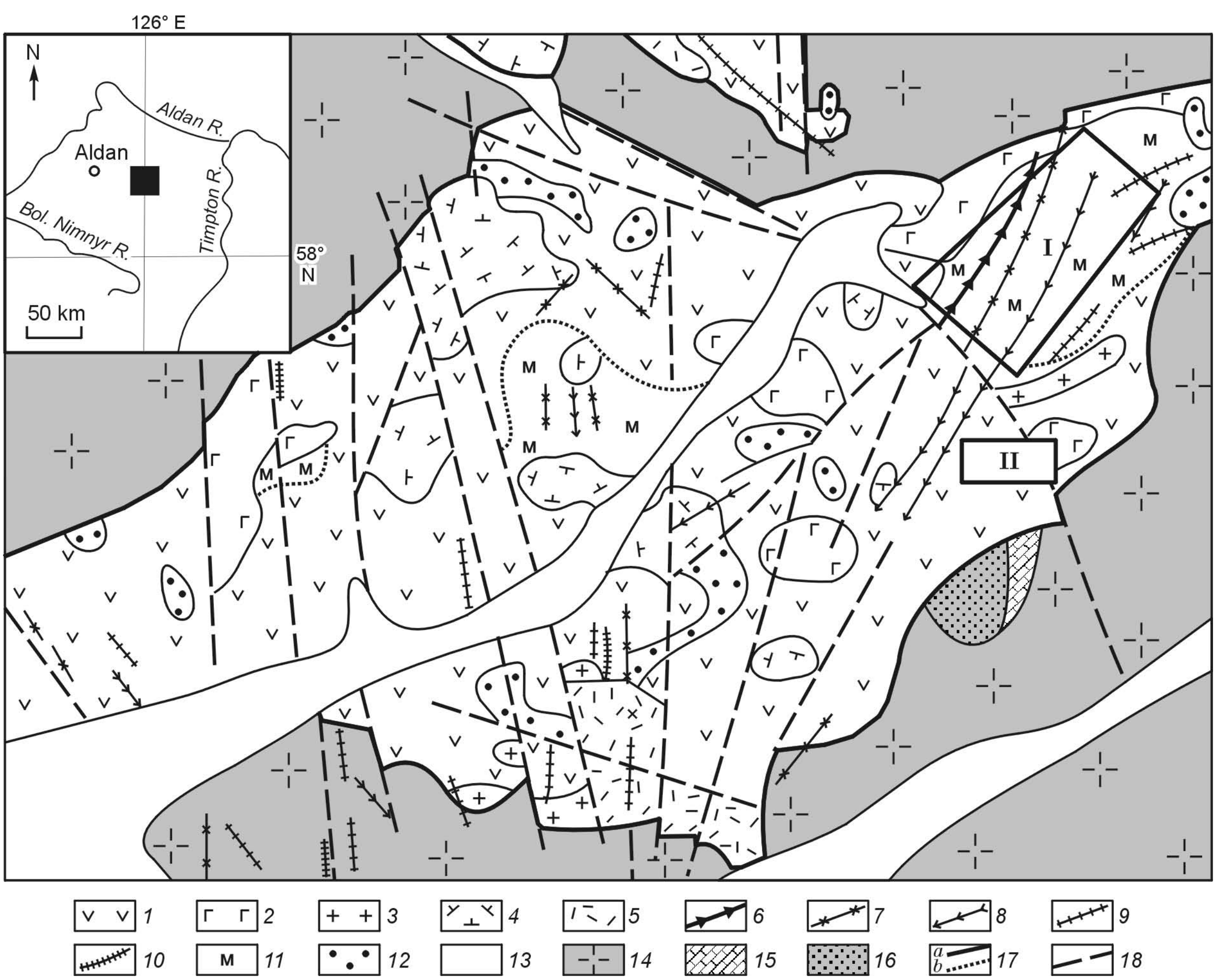

Fig. 1. Locations and schematic geologic structure of the Ryabinovyi alkaline massif (Kochetkov et al., 1989). *1*, aegirine syenites, pulaskites; *2*, malignites and melanocratic nepheline syenites; *3*, alkali granites; *4*, alkali trachytes; *5*, lava breccias of alkali trachytes; *6*, K-picrites, shonkinites, and aegirinites; *7*, syenite-porphyry; *8*, minettes; *9*, grorudites and sölvsbergites; *10*, alkali aplites; *11*, muscovitized syenites and muscovite–microcline rocks; *12*, skarns and skarnoids; *13*, alluvium. Host rocks: *14*, Archean granites and granite-gneisses; *15*, Vendian–Cambrian dolomites; *16*, Jurassic sandstones. *17*, contacts of intrusive (*a*) and muscovitized (*b*) rocks; *18*, faults. Gold-ore loci: I, Muscovitovyi; II, Novyi.