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ScienceDirect

Russian Geology and Geophysics 58 (2017) 541–550

RUSSIAN GEOLOGY AND GEOPHYSICS

www.elsevier.com/locate/rgg

Modeling of the formation of nonisothermal zoning in magnesian skarns in the ore-magmatic fluid systems of intrusive traps of the southern Siberian Platform

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Received 1 December 2015; received in revised form 14 September 2016; accepted 20 October 2016

Abstract

Using the Selector PC application, we studied the process of formation of magnesian skarns at the contact of dolerites with carbonate-salt deposits. The physicochemical parameters of metasomatic processes were estimated by studying the localization of skarn ore shoots and mineral assemblages in the deposits of the Angara–Ilim type. The action of magmatic fluids on the system dolerite–magnesian salt deposits and dolerite–carbonate-salt deposits resulted in zonal columns of infiltration magnesian skarns. The computation was carried out using a dynamic multireservoir model of a flow reactor with a constant temperature gradient and a uniform pressure. We have established that changes in the C/H ratio and Cl content in the fluid source affect the composition of the produced mineral assemblages. Depending on the temperature during the formation of skarns, different mineral assemblages are produced: diopside, enstatite, anorthite, quartz, ilmenite, hercynite, and pyrrhotite at 1040–1010 ºC; monticellite, forsterite, magnetite, geikielite, periclase, spinel, calcite, and graphite at 980–740 ºC; and calcite, dolomite, phlogopite, halite, and graphite at 710–380 ºC. Wollastonite is observed in the rear zone of magnesian skarns. We examined the temperature-dependent sequence of formation of different types of silicates, spinels, and Ti-containing minerals in the metasomatic column. The computation results show that during crystallization, the tholeiitic magma releases a fluid phase with C/H = 0.1–1.0, amounting to 1.5–2.0 wt.%.

Keywords: magnesian skarns; dolerites; metasomatism; numerical modeling

Introduction

The intrusion and reactionary interaction of basic magma with the rocks of the sedimentary cover of the Siberian Platform are accompanied by different assimilation processes, liquation, and metasomatism of the rocks (Sharapov et al., 2009a). There are scarce data on the high-temperature mass exchange between trap bodies and the host carbonate–salt deposits of the platform cover during the formation of iron deposits in the Angara–Ilim ore district (Antipov et al., 1960; Pavlov, 1975; Pukhnarevich, 1986; Vakhrushev, 1985). Study of the mineral zoning of these deposits (Antipov et al., 1960; Mazurov and Bondarenko, 1997) showed two possible types of sources of magmatogene fluids: (1) magmatic fluids separated from liquid fractions during the breakup of primary basic melt after the assimilation of dolomites and salt deposits and (2) magmatic fluids formed during the retrograde boiling of crystallizing trap bodies intruded into the above deposits without melt liquation. Among the known quantitative models of the intrusion–host-rock interaction (Sharapov et al., 2009a), the model of fluid separation during the retrograde boiling of magma (Sharapov et al., 2012) has been best elaborated. Therefore, in this paper we dwell on the formation of magnesian skarns following this model.

Although mineralogy of the contact zones of the regional deposits was studied earlier (Vakhrushev, 1985), the physicochemical conditions of formation of magnesian skarns and the sources of major rock components in magmatogene fluids are still debatable. Therefore, we performed a special research into the structure, composition, and occurrence of skarn ore shoots (Mazurov, 1991; Mazurov and Titov, 1999; Mazurov et al., 2004, 2007; Shabynin et al., 1984), which served as the geologic and mineralogical basis for the elaboration of a

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1068-7971/$ - see front matter
http://dx.doi.org/10.1016/j.rgg.2016.10.012

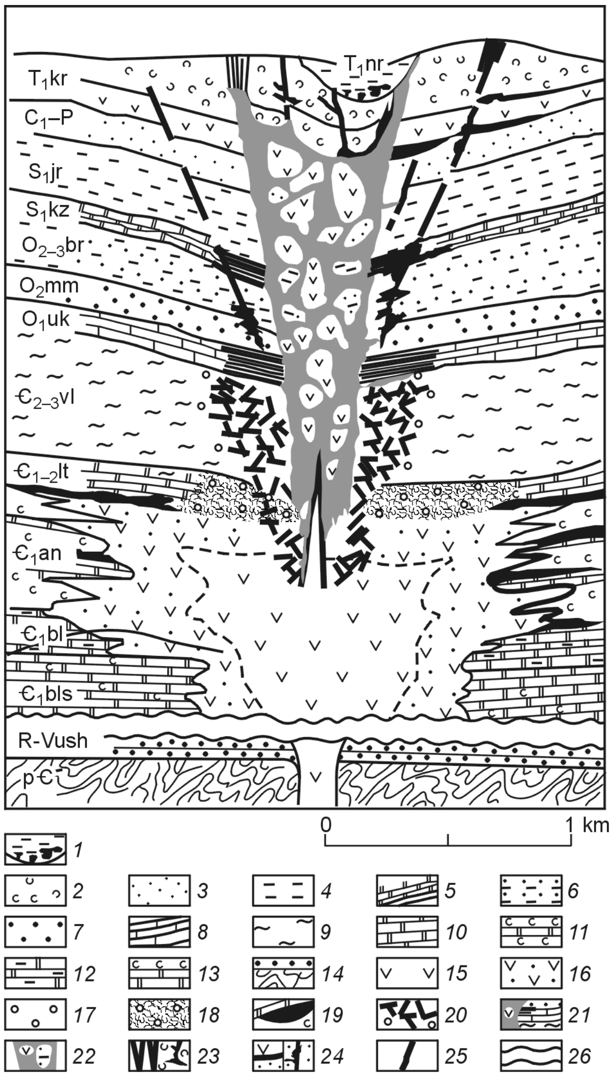

Fig. 1. Schematic section of ore-bearing volcanotectonic structure of the Angara–Ilim type, after Mazurov and Bondarenko (1997), supplemented. Vertical and horizontal scales are equal. *1*, volcanomictic sediments of crater lakes, Neryunda Formation (T_1nr); *2*, explosive breccias, flows, covers, and pyroclastic strata, Korvunchan Formation (T_1kr); *3*, poorly lithified carbonaceous deposits (C_1–P); *4*, red mudstones, siltstones, and marls with scarce sandstone intercalates, Yar Formation (S_1jr); *5*, sandstones with carbonate–clay intercalates, Kezhem Formation (S_1kz); *6*, red mudstones and marls with scarce sandstone intercalates, Bratsk Formation ($O_{2–3}$br); *7*, quartz sandstones, Mamyr Formation (O_2mm); *8*, limestones, Ust'-Kut Formation (O_1uk); *9*, marls with intercalates of fine-grained calcareous sandstones, siltstones, gypsum, and limestones, Upper Lena Formation (Є$_{2–3}$vl); *10*, dolomites, Litvintsevo Formation (Є$_{1–2}$lt); *11*, dolomites and rock salts with mudstone and siltstone intercalates, Angara Formation (Є$_1$an); *12*, massive dolomites, Bulai Formation (Є$_1$bl); *13*, dolomites, anhydrites, and salt intercalates, Bel'sk Formation (Є$_1$bls); *14*, sandstones, siltstones, and mudstones of the platform cover basement, Ushakovka Formation (R–Vush), and basement schists (pЄ); *15*, intrusive bodies of trap complex (sills, laccoliths, dikes, and dolerite tongues); *16*, skarnized dolerites of the zone of mixing of dolerites with evaporites; *17*, magnesian and calcareous skarns, skarnoids, and calciphyres; *18–24*, iron deposits: *18*, conform bodies in magnesian skarns and calciphyres, *19*, halite–magnetite ores in the Angara Formation, *20*, ore stockwork in the Upper Lena Formation, *21*, stratified calcite–magnetite ores in the limestones of the Ust'-Kut and Kezhem Formations, *22*, polychronous ore shoots in diatremes, *23*, subvertical banded, oölitic, and breccia ores in effusive–pyroclastic deposits, *24*, vein ores of subsill shoots and filling of late fracture zones; *25*, dislocations; *26*, deep part of the platform cover with unstudied ore mineralization.

physicochemical model of the interaction of magmatogene fluids separated from intrusive body with the carbonate–salt deposits of the platform cover (Mazurov et al., 2007). The obtained results helped to refine the qualitative schemes of infiltration metasomatism of limestones and dolomites at the magmatic and postmagmatic stages (Pertsev, 1977; Zharikov and Rusinov, 1998). At present, the physicochemical evolution of real geologic objects is studied by computer modeling of complex natural and experimental heterogeneous systems. The Selector C application is the most advanced tool for this research (Karpov et al., 1994). The theory, technique, and facilities of the modern version of this application are reported by Chudnenko (2010). Examples of its most reasonable use for modeling of endogenous systems are given by Avchenko et al. (2009) and Sharapov et al. (2009b, 2010, 2012).

Sharapov et al. (2009a) formulated the general problem of the dynamics of nonisothermal infiltration metasomatism for a stationary fluid flow from a magmatic source in the framework of the model of a multireservoir flow reactor and reported the first results of its study. The present paper continues this research. We consider the specifics of the metasomatic formation of zoning in magnesian skarns at the contacts of dolerites with carbonate–salt deposits.

Geological and mineralogical knowledge of metasomatic processes accompanying the formation of subvolcanic trap intrusions

Parameters of the starting and boundary conditions for metasomatic processes were evaluated by analysis of the localization of magnesian skarns in the structure of real deposits, from data on the mineral composition of skarnification zones, and by study of the composition and homogenization temperatures of inclusions in forsterite, halite, carbonates, and sulfates and the occurrence of intrusive bodies in the platform cover section (Mazurov et al., 2007). The geologic conditions in the areas of such processes were best studied at the Korshunovskoe deposit, where a large dolerite laccolith with branched stratified and cutting tongues was stripped beneath the central ore-bearing diatreme among Lower Cambrian deposits (Fig. 1). The main stages and steps of skarn ore formation were synchronous with the formation of this laccolith (intermediate magma chamber) among carbonate–evaporite and carbonate–salt deposits beneath screening terrigenous-sedimentary strata. Two genetic types of magnesian skarns, magmatic and postmagmatic, were recognized (Mazurov and Titov, 1999, 2001), which formed at the contacts of magmatic bodies with dolomites, rock salt, and heterogeneous carbonate–salt formations (Mazurov et al., 2004, 2007). Infiltration ore shoots of magmatic magnesian skarns, up to 200 m in thickness, are confined to the apical zone of the contact between the intrusion and Middle–Lower Cambrian massive dolomites.

In its central part the intrusion is more than 500 m in thickness, and some tongues are longer than 1500 m (Fig. 1). The intrusive bodies of the stratified tongues lack sharp contacts. Their marginal zone is composed of disintegrated