RHÖNITE IN ALKALI BASALTS: STUDIES OF SILICATE MELT INCLUSIONS IN OLIVINE PHENOCRYSTS

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Introduction

Rhönite, $Ca_2(Mg,Fe^{2+})_4Fe^{3+}Ti[Al_3Si_3O_{20}]$, is an uncommon phase in alkali basalts. It scarcely occurs as phenocrystal or groundmass mineral in silica-undersaturated basalts (Cameron et al., 1970; Magonthier, Velde, 1976; Olsson, 1983; Kunzmann, 1999; Seghedi et al., 1995; Prestvik et al., 1999). In some basalts and their deep-seated xenoliths rhönite is observed in reactionary rims around amphibole (Kyle and Price, 1975; Gushchin et al., 1991). However, recent studies of silicate melt inclusions showed that rhönite is a common daughter phase of silicate melt inclusions in olivine phenocrysts of most alkali and subalkali basalts (Ananiev, Okrugin, 1991; Kuz'min et al., 1999; Golovin et al., 2000; Kóthay et al., 2001), whereas it may be absent as phenocrystal or groundmass mineral in these rocks. This work is a present-day compilation of all data we collected concerning to rhönite from silicate melt inclusions.

Rhönite from inclusions

To study crystallization conditions of rhönite in alkali basalts, we used silicate melt inclusions hosted by olivine phenocrysts from different localities (Table 1). It should be noted that rhönite-bearing inclusions occur relatively rarely and are mainly confined to the central zones of host olivine, whereas silicate melt inclusions from the outer zones are generally free in rhönite. Besides rhönite, silicate melt inclusions usually contain Ti-rich augite, apatite, Al-spinel, sulfide blebs, amphibole, Ti-magnetite, ilmenite as daughter phases, and Cr-spinel and sometimes Cr-diopside as trapped crystals. A halo of small inclusions around large silicate melt inclusions with rhönite is typical of some olivines (Fig. 1) that might indicate high pressure for trapping of inclusions and their subsequent leakage. According to petrography of inclusions, rhönite is one of the earliest daughter phases. It crystallized after trapped Cr-spinel and daughter Al-spinel and before Ti-Al-rich clinopyroxenes, apatite and ilmenite. Thermometric data for rhönite-bearing inclusions are available only for some occurrences. According to these data, during heating apatite disappeared at 1060-1100°C, ilmenite – at 1030-1130°C, Ti-rich augite – in the range of 1130-1210°C, rhönite – at 1180-1245°C, and Al-spinel – at 1270°C (the Pécskő basalts). Homogenization temperatures of inclusions are in the range of 1250-1355°C, and possible pressure of their trapping estimated on coexisting CO_2 inclusions is higher than 2 kb. Oxygen fugacity estimated on the olivine-Cr-spinel pair (the Hegyestű basalts) is higher in 1-2 order than the QFM buffer.

Table 1. Rhönite occurrences in olivine-hosted silicate melt inclusions from some alkali basalts of the world.

Locality	Rock	Phase composition of inclusions	$T_{melting}$ for Cpx	$T_{melting}$ for Rhö	T_{hom}, °C	P, kb estim.	Reference
Kamchatka, Russia	high-Al basalt	Gl+Opx+Cpx+ Al-sp±Rhö±Amph+g			1250-1350	2-3	Ananiev, Okrugin, 1991
Tsagan-Khurtei ridge, Transbaikalia, Russia	trachybasalt	Gl+Cpx+Rhö±Mgnt ±Al-sp+Ap+Sulf+g			1280-1320	0.8-1	Kuz'min et al., 1999
Lurbun volcano, Udokan Volcanic Field, Transbaikalia, Russia	olivine nephelinite	Gl+Cpx+Rhö+ Ap+Sulf+g			>1250	>3	
Tergesh and Bele pipes, Khakasia, Russia	basanite	Gl+Cpx+Rhö±Ilm ±Mgnt+Sulf+g	1130-1190	>1200	1280-1310	>3	Golovin et al., 2000
Makhtesh Ramon, Southern Israel	basanite	Gl+Cpx+Rhö+Sulf+g	1140-1180	1180-1230	1310-1355	>3	
Hegyestű, Kabhegy, Badascsony, Haláp volcanoes, Bakony-Balaton Highland Volcanic Field, Hungary	basanite	Gl+Cpx+Rhö+ Al-sp+Ilm+Sulf+g	1190-1210	1220-1245	1270-1310	>3	Kóthay et al., 2001
Pécskő, Eresztvény, Magyarbánya, Terbelény, Nógrád-Gömör Volcanic Field, Hungary-Slovakia	hawaiite basanite	Gl+Cpx+Al-sp± Rhö±Amph+Sulf+g	1165-1235		1300-1350	2-3	

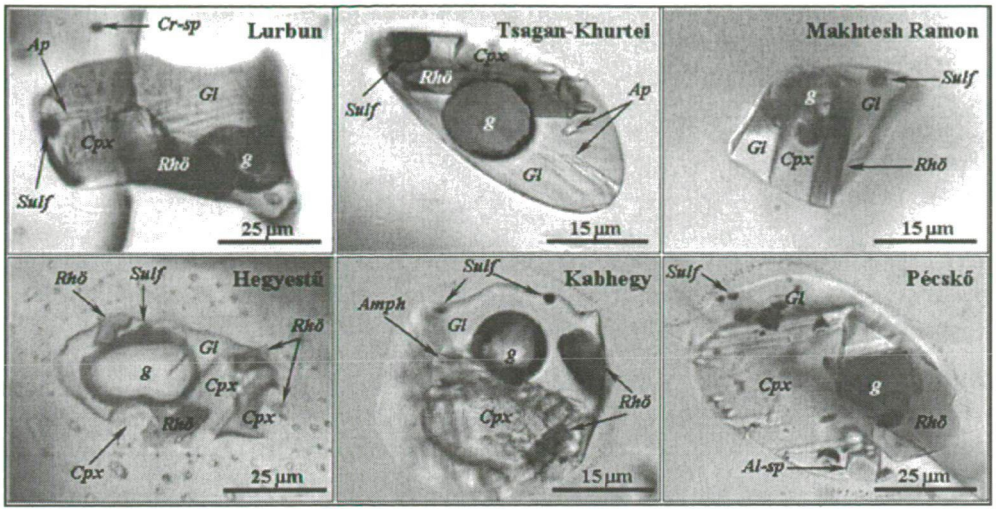

Figure 1. Rhönite as daughter phase of silicate melt inclusions in olivine phenocrysts from alkali basalts around the world.

Discussion

The data obtained show that rhönite in olivine-hosted silicate melt inclusions crystallized in a narrow temperature range (1180-1245°C) and at pressure less than 3-5 kb based on CO_2 microthermometry. The petrography of studied inclusions indicates the following sequence to crystallize minerals: (Cr-spinel, sometimes Cr-diopside) -> Al-spinel -> rhönite -> Ti-Al-clinopyroxene – Ti-magnetite (ilmenite). According to Bonaccorsi et al. (1990), the rhönite structure represents an alternation of "pyroxene" and "spinel" slabs. In this sense, rhönite is not only a transitional member between Al-spinel and Ti-Al-augite in a crystallization sequence but also an intermediate member of a polysomatic series having spinel and pyroxene as the end-members. Our data somewhat contradict with conclusions of Kunzmann (1999) who suggests that stability of rhönite in alkali silica-undersaturated basalts is restricted to pressures less than 0.6 kb, and temperatures from 840 to 1200°C without any limitations on oxygen fugacity. Apparently, some contradictions may be related to the chemistry of rhönite because this mineral is highly variable in the contents of Fe^{2+}, Fe^{3+}, and other components due to isomorphic substitutions. In addition, the chemical and physical conditions of solidification in olivine-hosted melt inclusions and in the rock groundmass might be different.

This work is supported by the Russian Foundation for Basic Research (grant no. 02-05-64620) and the Hungarian National Scientific Foundation (OTKA): grants T034922 to Török, K. and T030846 to Szabó, Cs.

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