NÉDLI ZSUZSANNA

PETROGRAPHY, GEOCHEMISTRY AND PETROGENESIS OF THE BASIC SUBVOLCANIC ROCKS IN THE VILLÁNY MTS (SW HUNGARY)

PhD thesis

Tutor

DR. M. TÓTH TIVADAR

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GOALS OF STUDIES

This thesis has the aim of the petrographical, geochemical description of the Villány Mts basalt outcrops, determination of petrogenesis and petrotectonic setting of the generated melt. I also attempt to clarify the geodynamic relationship between the studied basalts and the neighbouring Mesozoic volcanics. The thesis in special deals with the following topics.

1) The Villány Mts basic magmatics was generally thought to be in magmatic relation with the well described Mecsek Mts volcanics. In the first description of the Beremend dyke (Molnár & Szederkényi, 1996) this relationship was questioned. I aimed to study the petrogenesis of all Villány Mts magmatics (dykes of Beremend and Máriagyűd, sill of Babarcszőlős, magmatics in Turony-1 borehole) and clarify the magmatic relationship with the neighbouring Mesozoic volcanics.

2) Upper mantle xenoliths from Mesozoic volcanics are rarely known from the region (Szabó, 1984; 1985; Embey-Isztin et al., 1989; Downes et al., 1995) and only the dyke of Beremend carries upper mantle xenoliths in the Hungarian part of Tisza Unit. With the description and study of upper mantle xenoliths I aimed to reveal the physical, chemical characteristics of the Mesozoic subcontinental mantle beneath the region and insert these information into the model of evolution of the Pannonian Basin.

3) All Villány Mts magmatics contain large variety of round, felsic structure, ocelli. I studied these ocelli with the aim of interpreting the formation of ocelli, as well as physical condition of stability of rhönite in ocelli, taking also into account that these studies and related publications are the first report of rhönite from the Hungarian part of Tisza Unit. Rhönite is also important because previously it was described only in one publication from ocelli (Sabatier, 1999) worldwide.

The final aim of the studies is the inserting all the results into the model of the Cretaceous evolution of the Tisza Unit and of the mantle beneath the Pannonian Basin.

ANALITICAL METHODS

I collected several samples from the Beremend, Máriagyűd magmatics between 1997 and 2003. Once the Babarcszőlős sill was sampled systematically in each 5 cm. The petrography of the samples is based on more than 100 thin section. In cases when the samples were too altered to prepare thin sections, I used X-ray diffractometry for determining the mineral phases.

Major and some trace elements were determined on representative Beremend, Babarcszőlős and Turony-1 basalt samples by X-ray fluorescence spectrometry (XRF) at the Department of Mineralogy and Petrology of the University of Padua (Italy). Some minor and trace elements including rare-earth elements were determined on pressed pellets by Instrumental Neutron Activation Technique at XRAL Laboratories, Ontario (Canada).

Quantitative mineral chemical analyses of basalt and their mantle xenoliths from Beremend were performed on an ARL-SEMQ 30 electron microprobe at Montanuniversität, Leoben (Austria).

X-ray single crystal diffraction measurements were performed on spinel single crystals from the ultramafic xenoliths of Beremend basalt at the University of Trieste (Italy), by an automated KUMA-KM4 diffractometer. These data served for using intracrystal thermometers.

NEW RESULTS OF THE STUDIES

1. All studied Villány Mts magmatics are similar to lamprophyres petrographically but some lamprophyre characteristics are missing because of alteration. On the other hand, it is difficult to discriminate between lamprophyres and high volatile-bearing basalts, so the Villány Mts basic volcanics can be classified as lamprophyre-like alkali basalts. Geochemically, however they are more similar to the lamprophyres than to alkali basalts. Based on incompatible, immobile trace element ratios and the composition of clinopyroxenes, the basalts are alkali in character and are related to an intraplate magmatic activity.

2. Using crust enriched and highly incompaible element ratios (Th/La, Ta/Yb vs. Th/Yb) I estimated the measure of the crustal assimilation. In the Villány Mts magmatites presence of a small amount of crustal material is proved petrographically and chemically, but the origin of the crustal material is uncertain. Comparing the samples in study to the lamprophyres from borehole Alcsútdoboz-2 (North Transdanubia), based on the very similar chemical composition with a significant negative Nb-Ta anomaly and a petrogenesis from an enriched, subduction component bearing source material (Szabó et al., 1993), I suppose that a small amount of fossil subduction-related material was present in the mantle source of both magmatic activities. On the other hand, contamination during ascent was negligible.

3. Several quartz xenocrysts are present in all outcrops, carrying important information about the crust beneath the region and about the physical conditions of the magma ascend. I estimated the velocity of the ascending magma from petrographic observations by measuring the thickness of the glassy zone around the xenocrysts and using experimental data on the dissolution rates of quartz.

Based on calculations of the time, the magma passed in the crust (28-83 hours), the ascent velocity of the basaltic magma feeding the Villány Mts sill and dykes was approx. 10-30 cm/s.

4. The Beremend basalt contains a large amount of variably altered mafic and ultramafic xenoliths. Upper mantle xenoliths from Mesozoic volcanics are rarely known from the region (Szabó, 1984; 1985; Embey-Isztin et al., 1989; Downes et al., 1995), and have not been described from the Hungarian part of Tisza Unit before my studies, so they are the unique source of information about the Mesozoic mantle beneath this area. With petrographic and chemical studies I proved that the variety of xenoliths from one outcrop shows a heterogeneous mantle; the OH-bearing minerals are evidence of the modal metasomatism. I found that the xenoliths belong to the Cr-diopsidic suite (Wilshire & Shervais, 1975) or I. type lherzolites (Frey & Prinz, 1978), they have LREE-enriched character and high LREE/HREE ratios. Their porphyroclastic texture proves that the xenoliths are deformed. I also found that the spinel of xenoliths record a low grade depletion of the mantle.

I established the magmatic story of xenoliths: recrystallized enstatite porphyroclasts represent the former stage of mantle evolution, with a temperature estimate about 1190-1250 °C. The equilibrium temperature of the later, recrystallized, equigranular olivine - clinopyroxene - orthopyroxene paragenesis is about 800-900 °C. Because of the highly altered character of the xenoliths in study and the few co-existing phases in equilibrium, I used the rarely applied spinel intracrystal thermometer and crystal structure analogies too. These methods also support an equilibrium temperature about 900 °C. I found that similarly low temperatures are characteristic among the specially textured, deformed xenoliths from other parts of Pannonian Basin and are in agreement with the lowest temperature of the xenoliths of the Tisza Unit in the Pannonian Basin (Szabó et al., 1995).

5. I found that based on trace element data, the melt of the Villány Mts basic magmatics originated from an enriched (more similar to EM II-type) garnet lherzolite mantle source by very low degree (<1%) partial melting. The very high enrichment in LRE and LIL elements and high LREE/HREE ratios prove a very low degree melting and garnet content of the source material. It is not possible to discriminate between EM I and EM II type sources because of the alteration, caused mobility of the discriminant LIL elements. The significant negative Nb-Ta anomaly and moderate enrichment in HFS elements suggest the subduction-related origin of the EM component of the source.

We have known little abut the Mesozoic mantle beneath the Tisza Unit and before my studies there was no evidence of an EM-type mantle component. I found that the described HIMU component from Mecsek Mts (Harangi et al., 2003) was not detectable in the Villány Mts samples. Similarly enriched, subduction-related mantle source is known from Upper Cretaceous lamprophyres in the North Transdanubia (Alcsútdoboz-2 borehole - Szabó et al., 1993). I detected a significant chemical, petrographic, petrogenetic similarity of the Villány Mts lamprophyre-like alkali basalts to the lamprophyres from the Alcsútdoboz-2 borehole, but these localities lies on two different microplates (the Villány Mts on Tisza Unit, the lamprophyres of North Transdanubia on Pelso Unit or ALCAPA) so further studies are required for evidence of the same mantle source.

6. I made the systematic petrographic description as well as stable isotope analysis of several ocelli types in the Villány Mts magmatics. I found that in the formation of ocelli, because of petrographic evidences, the formation as low-temperature filling or as precipitation of secondary minerals after alteration of primary magmatic minerals could be excluded. In fact, petrographically and chemically the ocelli derived by late stage segregation from the basaltic melt,

but it is not proved whether the segregation occurred between primary magmatic carbonates and silicate melt or between assimilated sedimentary material and the basaltic melt. According to several studies on origin of ocelli (Lucido et al., 1980; Bogoch & Magaritz, 1983; Demény & Harangi, 1996; Demény, 1992; 1999) the later is more acceptable. Due to similarity of stable isotope composition, it is probable that the internal fluid of the magma caused strong autometasomatism, what also is represented in the entire alteration of olivine phenocrysts.

7. My studies are the first petrographic and chemical description of rhönite from ocelli and also from the Hungarian part of the Tisza Unit. The amphibole thermometer in ocelli records formation temperature around 980 °C as a minimum estimation through co-existing with another Ti-phase (rhönite). Composition of co-existing amphiboles of the ocelli confirms formation at high temperature; however it excludes crystallization under extremely low pressures. Similarly high temperature but significantly lower pressure (<600 bar, Kunzmann, 1989; 1999) was supposed before for rhönite stability. I found that rhönite could form in the late stage segregation melts in elevated temperature and pressure, so the stability of rhönite is larger than previously supposed. No similarly high temperatures for ocelli formation was suggested before: stabile isotope data of carbonates have shown approx. 400-500°C, 7 kbar (Demény, 1999; Azbej, 2002) suggesting a high cooling rate in ocelli. However my results agree with recent rhönite-bearing silicate inclusion studies (Kóthay & Szabó, 1999; Kóthay et al., 2001, 2003; Sharygin et al., 2003) showing a higher temperature stability for rhönite.

8 This study shows that the Babarcszőlős sill, the Beremend dyke, the Máriagyűd dyke and the magmatics of the Turony-1 borehole, are similar both in petrographic and geochemical characteristics as well as in pertogenetics, so

they are related to the same Late Cretaceous volcanic activity. This is the reinterpretation of the age of the Babarcszőlős sill and magmatics in the Turony-1 borehole, which were thought to be of Early Cretaceous in age (Fülöp, 1966; Harangi & Árváné, 1993).

9. Regarding the magmatic relationship I found that the Mecsek Mts volcanics (Harangi, 1993; 1994; Harangi & Árváné Sós, 1993; Harangi et al., 2003) are different from the studied ones concerning age, volume of the magmatic products and their petrography. Neither the Mecsek Mts, nor the Slavonian volcanics show strong chemical similarity to the Villány Mts magmatics. The magmatic relationship with the Slavonian basalt (Pamić, 1993; 1997; Pamić et al., 2000) cannot be excluded, but a firm proof would require further studies. Significant petrographic, chemical and petrogenetic analogies can be observed between the studied rocks and the lamprophyres from the North Transdanubia (Kubovics et al., 1989; Szabó et al., 1993).

10. In the case of the Babarcszőlős sill I made systematic sampling, making possible the study of all the section of the sill. I established, based on mineralogical and chemical variations in the section, that two intrusions are probable, with moderately different chemical compositions. The major intrusion exhibits symmetrical segregation of the magma. This can be traced by variations in trace element and rare earth element concentrations: the gravitational differentiation caused the concentration of heavy element bearing minerals (olivine, pyroxenes) in the lower part of the sill, whereas the volatile-rich melts, segregated in the late stage of the solidification, containing amphibole, biotite, plagioclase, carbonate minerals, occur in the central part of the sill, in two separated sheets.

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