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PETROGENESIS OF AMPHIBOLITES FROM THE SZKLARSKA PORĘBA BELT (WEST SUDETES): INFERRENCES FROM GEOCHEMICAL MODELLING

Abstract: Amphibolites from the Szklarska Poręba belt despite their polymetamorphic history have preserved primary, magmatic concentrations of trace and major elements. Geochemical modelling showed that the parental melt was presumably formed due to limited fusion (~3%) of the primitive mantle garnet lherzolite. Subsequent differentiation of the melt governed by fractional crystallisation (X=42%) led to extraction of cpx-opx-oliv-plag-ilm cumulate probably in more shallow conditions yet with no evidence for coeval contamination from crustal rocks. The fractionated melt was then emplaced in an environment of initial continental rift formed above the extending lithosphere.

Keywords: amphibolite, trace elements, geochemical modelling, contact zone.

INTRODUCTION

Unlike metabasites and amphibolites of the northern part of the Izera-Karkonosze block (IKB), amphibolites cropping out within the Szklarska Poręba metapelites have been subjected to contact metamorphism imposed on the whole belt by thermal activity of the Karkonosze granite (Borkowska 1966, Oberc-Dziedzic 1985). Due to this episode metapelites were turned into biotite-cordierite-andalusite hornfelses, while amphibolites underwent textural and mineralogical changes in the hornblende-hornfels facies conditions resulting in appearance of cummingtonite + anorthite LP/HT assemblage (Ilnicki 2002). Thus amphibolites of the Szklarska Poręba belt provide an extraordinary object for geochemical studies of metabasites exposed to intensive thermal influence of the nearby intruding pluton. Preliminary results (Ilnicki 2003) shown that these rocks despite their polymetamorphic history have preserved primordial geochemical features. Presented in this contribution newly obtained data for these rocks allowed more comprehensive and quantitative insight into their magmatic history.

RESULTS

Samples of amphibolites were collected in Mniszy Las, Zakręt Śmierci, Wysoki Kamień and Rozdroże Izerskie area. Twelve of them were crushed, powdered in tungsten carbide mill and fused with lithium borate, then analysed by means of XRF in the Mineralogical Institute of Würzburg University for concentration of

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major elements. A subset of 7 representative samples was selected for further trace element analysis by means of ICP-MS in the ALS laboratory, Val d'Or, Canada.

The studied rocks are characterised by rather wide range of Mg-number (#Mg) changing from 68 to 46 and usually noticeable linear trends on Harker diagrams. Although some of major and LIL elements underwent certain degree of mobility probably under metamorphic conditions, concentration of almost all HFSE and transition elements seems to remain unchanged since magmatic stage. Contents of incompatible elements systematically increase with an increase of differentiation index at constant inter-element ratios, as evidenced by single linear trends on bivariate diagrams. Moreover, variations of compatible versus incompatible elements are characterised by subvertical trends, what suggests that differentiation of the suite was governed by mechanism of fractional crystallisation and thus trends observed on Harker diagrams for major elements could approximate liquid line of descent.

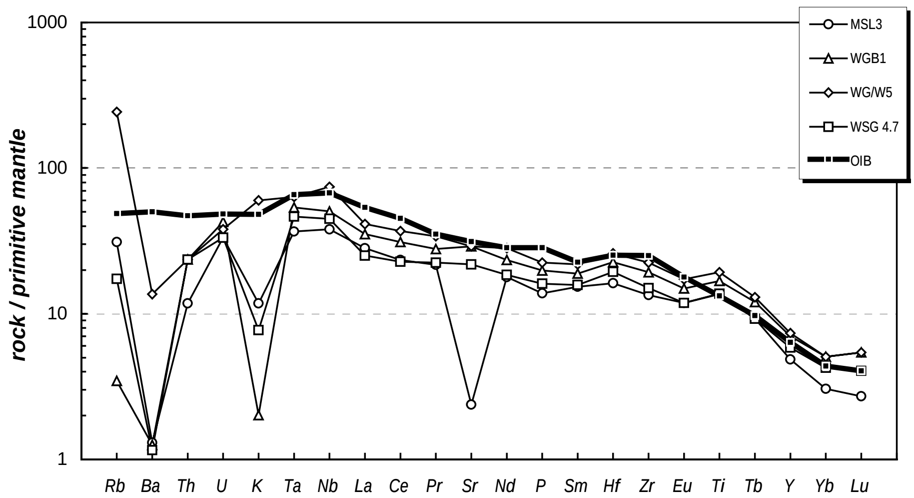

Fig. 1. Trace element variation diagram for selected samples of amphibolites from the Szklarska Poręba belt. The ocean island basalt (OIB) pattern is shown for comparison. Normalisation values and OIB data are taken from Sun and McDonough (1989).

Considerig several chemical parameters (e.g. Nb/Y, Zr/Y, V/Ti, Zr/P_2O_5), it is concluded that the Szklarska Poręba amphibolites are similar to within-plate alkaline rocks. Their geotectonic emplacement setting is further confirmed by position of these rocks on the diagrams La-Nb-Y of Cabanis and Lecolle (1989) and Nb-TiO_2-Th of Holm (1985). Particularly in the latter case, the studied rocks clearly reveal affinity with an initial continental rift environment.

Analysed samples are enriched in incompatible elements, including light rare earth elements. Both $(La/Yb)_N$ and $(Tb/Yb)_N$ ratios are high, 7.8±1.1 and 2.6±0.3 respectively, which is indicative of presence of residual garnet in the source. Primitive mantle-normalised patterns are convex-shaped, which is typical for rocks derived from OIB-like enriched asthenospheric mantle (Fig. 1), a conclusion also confirmed by Th/Yb and Ta/Yb ratios. Absence of Nb-Ta negative anomaly on one hand, and values of Ti/Yb and Nb/U ratios on the other, suggest lack of magma contamination with crustal rocks. Observable on the diagram negative anomalies for Ba, K and Sr for different samples are most probably the result of mobility of these elements during metamorphism.

In order to assess the processes and their role in genesis and evolution of the magma of the investigated suite geochemical modelling was performed. Four models describing partial melting process were tested, among which the non-modal batch melting one seems most appropriate (Fig. 2a). Independently of the applied

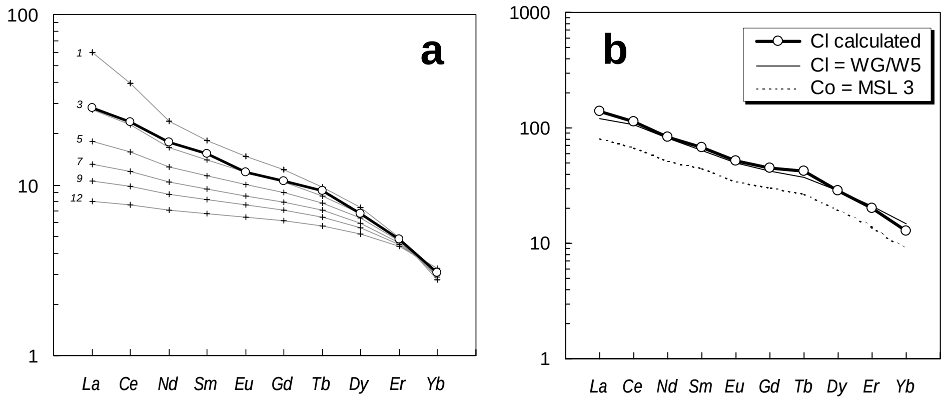

Fig. 2. Primitive mantle- (a) and chondrite- (b) normalised REE diagrams showing the results of modelling. **a.** Model of non-modal batch melting of primitive mantle (60% oliv, 22% opx, 10% cpx, 8% ga). Fine lines and numbers denote melt increments, heavy line is for the most primitive sample (MSL 3) of the studied suite. **b.** Model of fractional crystallisation of the studied amphibolites. Co – composition of the most primitive melt, Cl – composition of the most differentiated melt. See text for details. Normalisation values as in Fig. 1.

model, it was calculated that parental melt could have been derived from lherzolite with trace element concentrations similar to that of primitive mantle (Sun, McDonough 1989). The maximum amount of modal garnet in the mantle source was about 8%, whilst the degree of melting of ~3%. It appears that garnet mode in the source gradually dropped to ~4% with the increase of the melt fraction.

Following the assumption that chemical composition of the melt was further differentiated by fractional crystallisation, the relevant modelling based on both major and trace elements was performed. Major elements model was obtained by means of Genesis ver. 1.1 program (Teixeira 1996) and yielded the degree of fractionation of 42% and modal composition of the extracted cumulate: 54% clinopyroxene, 37% orthopyroxene, 4% olivine, 3% plagioclase and 2% ilmenite. Subsequently calculated trace element model confirmed the above results, as evidenced by an excellent fit of calculated and real sample REE patterns (Fig. 2b).

CONCLUSIONS

Alkaline parental melt for protolith of amphibolites from the Szklarska Poręba belt was probably formed as a result of limited fusion of primitive mantle lherzolite. The process took place within asthenospheric mantle at depth corresponding to the beginning of garnet-spinel transition zone and conceivably was brought about by decompression of upwelling mantle plume, as suggested by decreasing garnet mode in the source. Presumably the rate of extension was rather low (β factor ~1.5–2) for the studied rocks clearly bear geochemical signatures of LREE-enriched, OIB-like mantle and no significant change in the source composition is observable. However, involvement of subcontinental lithospheric mantle cannot be ruled out. Further chemical evolution of the melt was governed by fractional crystallisation process, which probably took place at more shallow level producing cumulate of websterite composition. More importantly, the magma virtually did not suffer from contamination from crustal rocks, what might account for short magma storage within the crust. Finally, the fractionated melt was displaced upwards in an environment of developing continental rift formed above the concurrently extended lithosphere.

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