POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 24, 2004; Volume 24, 2004

Jacek PUZIEWICZ[1]

PETROLOGY OF THE KSIĘGINKI NEPHELINITE (CENTRAL EUROPEAN TERTIARY MAGMATIC PROVINCE): A REAPPRAISAL OF EXISTING DATA AND PRELIMINARY RESULTS OF A NEW STUDY

Abstract: The Księginki nephelinite (olivine, clinopyroxene, nepheline) is one of the largest occurrences of Tertiary primitive mafic volcanics in NE part of the Bohemian Massif. Its parental magma comes from the upper part of garnet-peridotite zone of the litospheric mantle (~ 20 kbar) and contains peridotite enclaves representative of the overlying upper mantle.

Keywords: nephelinite, Lower Silesia, enclaves, mantle.

INTRODUCTION

The nephelinite lava flow in Księginki near Lubań (Sudetes, SW Poland) belongs to the numerous occurrences of Tertiary volcanic rocks of similar composition (basanites, nephelinites, alkali basalts) in SW Poland. Three lava flows, separated by pyroclastic rocks, and their feeder are exposed in Księginki (Kozłowski, Parachoniak 1960). The upper flow is thickest (up to 15 meters) and has largest lateral extension of few kilometers. The nephelinite carries numerous peridotitic enclaves and rare megacrysts of augite of size up to several centimeters.

The microscopic study of Kozłowska-Koch (1981) shows the nephelinite to consist of Ti-augite + nepheline + magnetite matrix (≥ 79 vol. %) with olivine and clinopyroxene and extremely rare orthopyroxene porphyrocrysts. Apatite, biotite and analcime occur scarcely. Two kinds of olivine and clinopyroxene porphyrocrysts are described by Kozłowska-Koch (1981): the smaller ones, interpreted as a product of host magma crystallization, and the larger ones, supposed to be derived from disintegrated peridotitic enclaves.

In this paper the preliminary results of recent study of the Księginki nephelinite are presented and discussed.

PETROGRAPHY AND MINERAL CHEMISTRY

The detailed microprobe chemical and BSE (back-scattered electron) image study shows the nephelinite to consist of porphyrocrysts of olivine and clinopyroxene of various sizes embedded in the nepheline matrix (Fig. 1). Spinel and rhombohedral oxide phase are opaques. Very small interstitial grains of

[1] *Institute of Geological Sciences, University of Wrocław, Cybulskiego 30, 50-205 Wrocław, Poland; jpuz@ing.uni.wroc.pl*

analcime occur locally, small grains of plagioclase and needles of apatite are very scarce.

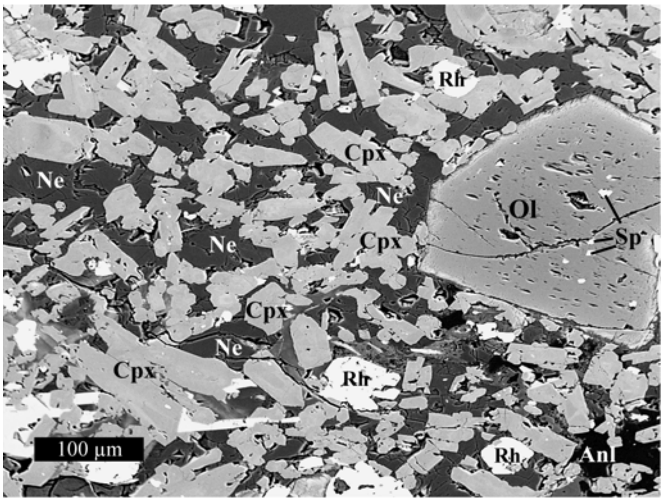

Fig. 1. BSE image of the Księginki nephelinite.
Ol - olivine; Sp - spinel; Rh - rhombohedral oxide phase; Cpx - clinopyroxene; Ne - nepheline, Anl - analcime.
The reaction fringe at the margin of the olivine porphyrocryst is

The olivine grains are (1) euhedral to subhedral ranging in size from microns to millimeters, and (2) anhedral, closely resembling those occurring in the enclaves. The euhedral crystals contain from 79% of forsterite in the margins to 86 in centers (Kozłowska-Koch 1981, reports 81-83% basing on optical 2V measurements). The thin (<10μm) marginal parts of larger grains have the structure indicative of their melting. The large anhedral crystals contain 86% of forsterite (Kozłowska-Koch: 90%).

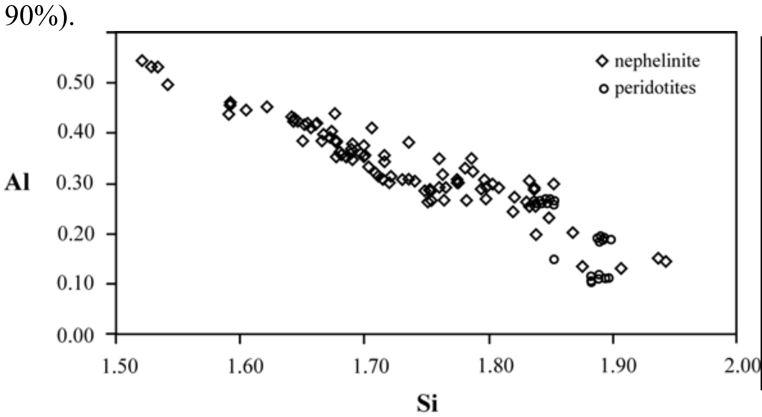

Fig. 2. Points representing clinopyroxene from the Księginki nephelinite and its peridotitic enclaves on the Al vs. Si diagram.

The clinopyroxene forming small crystals is usually subsilicic titanian diopside (sensu Morimoto et al. 1988). It contains down to 1.53 atoms of Si (Fig. 2) and up to 0.18 atoms of Ti pfu (per formula unit, O^{2-} = 6). The same refers to marginal parts of large porphyrocrysts. Their inner parts have the composition of chromian augite (Cr up to 0.03 atoms pfu). The aluminium content reaches 0.55 atoms pfu and is positively correlated with Ti and negatively – with Si contents. Central parts of porphyrocrysts contain up to 0.10 atom of Na pfu. The zoning patterns of larger porphyrocrysts are irregular and intricate.

Two kinds of oxides occur in the Księginki nephelinite. The spinel phase has composition close to $(Mg_{0.5}Fe^{2+}_{0.5})(AlCr_{0.6}Fe^{3+}_{0.4})O_4$ and occurs as intergrowths in some of the olivine porphyrocrysts. The rhombohedral phase is later in the crystallization sequence (cf. Fig. 1) and has the composition of approximately $Fe^{3+}_{1.1}Fe^{2+}_{0.3}Mg_{0.10}Ti_{0.40}Al_{0.10})O_3$ (Fe^{3+} and Fe^{2+} proportions calculated by the method of Stormer 1983).

Nepheline has constant chemical composition close to $Na_{3.0}(K_{0.4}Ca_{0.15})Al_{3.6}Si_{4.3}O_{16}$. Analcime and plagioclase (An 14-18, Or 12-18) are interstitial and very late-magmatic or post-magmatic phases.

ENCLAVES

The enclaves occurring in the Księginki nephelinite vary in diameter from first centimeters to approximately 1 meter. Most of them have the composition of olivine-rich harzburgite; lherzolites and wehrlites are much less common, whereas dunites, websterites and pyroxenites occur sporadically (Kozłowska-Koch 1981). Scarce gabbroic enclaves occur as well (Bakun-Czubarow, Białowolska 2003).

The Mg/(Mg+Fe) ratio of olivine varies between the enclaves, its value ranges from 0.86 to 0.91 in the three studied in detail enclaves of harzburgitic composition. The Mg/(Mg+Fe) ratio of orthopyroxene is identical to that of olivine in the studied samples. Most of the clinopyroxene grains have Cr/(Cr+Al) ratio above 0.15 (typical for refractory peridotites), but some grains of ratio close to 0.10, typical of fertile peridotites (Zheng et al. 2004), are also present. The spinel (Mg/(Mg+Fe) ratio 0.60 – 0.69 and Cr/(Cr+Al) ratio of 0.26 – 0.47 is also characteristic for refractory to transitional mantle. Part of the enclaves experienced incipient partial melting, with plagioclase, olivine and clinopyroxene formed from the new melt.

CONCLUSIVE REMARKS

The Księginki nephelinite belongs to the extensive area of occurrences of primitive mafic alkaline volcanic rocks of Tertiary and Quaternary age in central and western Europe. The exact nature of that volcanism varies depending on the character of hosting crustal block (Wilson, Downes 1990). The characteristic features of Tertiary volcanic rocks occurring in SW Poland are (1) absence of garnet peridotite and plagioclase peridotite xenoliths (none were mentioned by Białowolska 1980) and (2) absence of potassic types.

The Księginki nephelinite REE distribution pattern (Bakun-Czubarow, Białowolska 2003) is characterized by strong enrichment of light REEs and depletion of heavy REEs, suggesting the presence of garnet in the source and low degree of its melting (cf Hanson 1980). Since no garnet-bearing peridotite enclaves occur in the nephelinite, the magma melting took probably place in the uppermost part of garnet-bearing mantle, ie. at pressures close to 20 kbar. The petrographic diversity of enclaves occurring in the nephelinite are thus supposedly because they were collected from the upper mantle profile of thickness of ca. 30 km. At present the upper mantle in the area below Księginki is characterized by two significantly different P-wave velocities (Grad et al. 2003), which suggests its heterogeneity.

The velocity of magma flow in the conduit feeding the Księginki extrusion must have been high, as suggested by large size of peridotite enclaves. The magma evolution in the conduit was governed by rapid pressure decrease from 20 kbar to surface pressure and concomitant temperature decrease. This is demonstrated by the clinopyroxene compositions, ranging from those typical of partially molten peridotites in the source region to those extremely impoverished in silica, typical of low-pressure crystallization in magma of low silica activity (Fig. 2). The Księginki nephelinite, is thus a potential source of information on the upper mantle composition in the times of volcanic activity.

REFERENCES

BAKUN-CZUBAROW N., BIAŁOWOLSKA A., 2003: Gabbroic enclaves from basaltoids of the Lubań and Złotoryja regions, Lower Silesia. Prace Specjalne PTMin. 23: 32-34

BIAŁOWOLSKA A., 1980: Geochemical features of some Lower-Silesian basaltoids and their ultramafic inclusions. Arch. Mineral. 36: 107-163 [in Polish, English summary].

GRAD M., JENSEN S. L., KELLER G. R., GUTERCH A., THYBO H., JANIK T., TIIRA T., YLINIEMI J., LUOSTO U., MOTUZA G., NASEDKIN V., CZUBA W., GACZYŃSKI E., ŚRODA P., MILLER K. C., WILDE-PIÓRKO M., KOMMINAHO K., JACYNA J., KORABLIOVA L., 2003: Crustal structure of the Trans-European suture zone region along POLONAISE'97 profile B4. Jour. Geophys. Res. 108(B11): 2541.

HANSON G. N., 1980: Rare earth elements in petrogenetic studies of igneous systems. Ann. Rev. Earth. Planet. Sci. 8: 371-406.

KOZŁOWSKA-KOCH M., 1981: Petrography of ultramafic nodules in the nephelinites from Księginki near Lubań (Lower Silesia). Arch. Mineral 37: 33-58.

KOZŁOWSKI S., PARACHONIAK W., 1960: Products of weathering of basalts in the area of Lubań in Lower Silesia. Acta Geolog. Polon. 10(3): 285-324.

MORIMOTO N., FABRIES J., FERGUSON A. K., GINZBURG I. V., ROSS M., SEIFERT F. A., ZUSSMAN J., AOKI K., 1988: Nomenclature of pyroxenes. Miner. Mag. 52: 535-550.

STORMER J. C. Jr., (1983): The effects of recalculation on estimates of temperature and oxygen fugacity from analyses of multicomponent iron-titanium oxides. Amer. Miner. 68: 586-594.

WILSON M., DOWNES H., 1990: Tertiary-Quaternary extension related alkaline magmatism in Western and Central Europe. Jour. Petrol. 32: 811-849.

ZHENG J., O'REILLY S., GRIFFIN W. L., ZHANG M., LU F., LIU G., 2004: Nature and evolution of Mesozoic-Cenozoic litospheric mantle beneath the Cathaysia block, SE China. Lithos 74: 41-65.