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METAVOLCANIC ROCKS FROM ŁOMŻA, NE POLAND: GEOCHEMISTRY, AGE AND GEOTECTONIC INTERPRETATION

Abstract: The 1802±9 Ma Łomża metavolcanic rocks are characterized by high incompatible element contents e.g. Rb: 30–60 ppm, Ba: 256–660 ppm, Zr: 60–85 ppm and Nb: 5–11 ppm and high REE contents, e.g. La: 31–68 ppm and Yb: 4,74 ppm. La-Y-Nb, Zr-Nb/Zr and Zr-Nb-Y tectonomagmatic discriminants suggest that the metavolcanics formed in a subduction setting, possibly within an island arc.

Keywords: Palaeoproterozoic, East European Craton, metavolcanics, geochemistry, island arc, subduction

INTRODUCTION

The major gravity and magnetic anomaly near Łomża in northeastern Poland forms an isolated structure, the stratigraphic and tectonic setting of which remains poorly understood. Three deep boreholes (Łomża 1, 2 and 3) were drilled on the anomaly in 1974. Several distinct volcanogenic rock units were encountered, but their stratigraphic relationships were not closely investigated.

Geochemical studies of both low and high grade igneous rocks have helped to identify the different geodynamic environments for magmatic activity and the plate-tectonic processes that might have operated as the East European Craton (EEC) evolved. The Łomża amphibolites, in the western part of the EEC, have previously been interpreted as part of a young metamorphic structure, the so-called Kampinos Complex (Kubicki 1995; Ryka 1995)

The Łomża Precambrian basement rocks are dominantly amphibolites (56–75% of the drilled sequence), amphibolite gneisses (3–18%) and schists (17–22%). The amphibolites range from fine- to medium-grained, with very well preserved magmatic structures. Large euhedral grains of amphibole with inclusions of calcic plagioclase and ilmenite predominate. Patchy pleochroism reflects changes in chemical composition. It has been argued that the metamorphic grade reached epidote- amphibolite subfacies (Ryka 1995).

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RESULTS

The Łomża amphiboles have a wide range of chemical composition from pargasite and edenite (Mg# = 51–53) and sometimes magnesiohornblende (Mg# = 63) in the grain cores, to ferro-edenite (Mg# = 42–48) in the rims. Small ilmenite inclusions occur in profusion. The plagioclase grains are zoned, An_{53-87}, and plagioclase inclusions in amphibole are even more calcic, An_{77-82}.

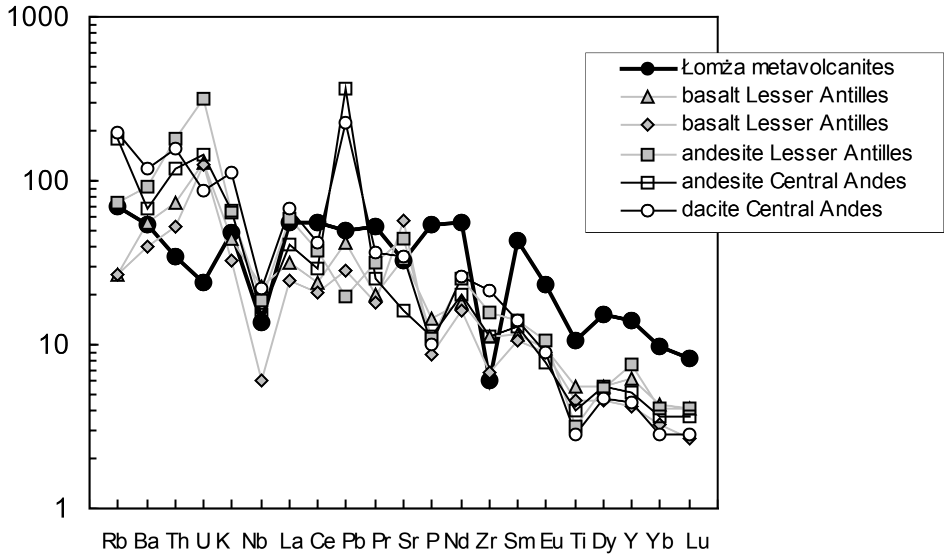

Fig. 1. Incompatible element variation (primitive mantle normalized) in the Łomża metavolcanics, with arc basalt compositions (Lesser Antilles and Central Andes) for comparison.

The Łomża metavolcanics are characterized by low SiO_2 and Ti contents: 40–49 wt.% and 1–2 wt.% respectively, and a high Al_2O_3: 16–20 wt.%. The Mg number is relatively constant (44-49). The potassium content ranges between 0.92 and 1.5 wt.%. Phosphorus is anomalously high (0.74–1.33 wt.%). The 12 analysed samples have a narrow range of incompatible large ion lithophile element (LILE) contents: Rb, 30–40 ppm, and Ba, 256–660 ppm. Nb contents (5–11 ppm) are particularly low, as is Zr (60–85 ppm). The high field strength element (HFSE) contents are high. Sr ranges from 690 to 1142 ppm. Rare earth element contents are also high, La: 31–68 ppm, Yb: 4,74 ppm.

The primitive mantle normalized multi-element patterns for the Łomża metavolcanics show similar enrichments in HFSE and LREE, and depletion in Nb to island arc volcanics. The strong negative Nb anomaly is a consistent feature of arc basalts associated with subduction zones. High LILE/HFSE and LREE/HREE ratios are not common in oceanic basalts, however. They indicate some involvement of continental crust (Hooper, Hawkesworth, 1993).

Several geochemical features point to an island arc setting. All projections of the Łomża amphibolites on a La-Y-Nb diagram (Cabanis, Lecolle 1989) fall only within the 1A field of calc-alkaline island arc basalts. The Zr and Nb contents, especially of the Łomża amphibolites, are typical of subduction zones, as indicated by the Zr-Nb/Zr diagram (Thieblemont, Teggeyey 1994). On a Zr-Nb-Y diagram (Meschede 1986), however, the Łomża amphibolite compositions straddle two fields; field D, the island arc basalts (including N-MORB), and field B, containing enriched E-MORB.

It is useful to compare the compositions of the Łomża rocks directly with those of modern rocks from similar tectonic settings to those indicated by these tectonomagmatic diagrams. The Lesser Antilles, for example, is an Eocene island arc formed above a subduction zone, but with some chemical features indicating crustal contamination of the magmas (van Soest et al. 2002, Woodland et al. 2002). Compared to the Łomża amphibolites, the basalts and andesites of the Lesser Antilles are more enriched in the mobile LILE. The high-K calc-alkaline lavas from the Antilles, in particular, are much more potassic than the Łomża rocks. Other elements compare more closely, with abundances tracking the arc basalt curve. The stronger positive Pb anomaly in the Łomża rocks probably reflects a higher level of crustal contamination. The REE patterns are very similar: Łomża 110 x chondrites, the Lesser Antilles 80–120 x chondrites.

One classic example of continental-margin arc magmatism is the Central Andes arc on the west coast of South America. The basaltic andesite lavas from the Chilean volcanoes of El Guadal and Puyehue, which represent the fore-arc, have been contaminated by continental crust (Feeley et al. 1998). They have very similar LILE to the Łomża amphibolites, and a similar negative Nb anomaly. The principal difference is that the Łomża amphibolites are more enriched in the LREE. Nonetheless, the trace element abundances are sufficiently similar in the rocks from the two regions that they seem to confirm formation of the Łomża amphibolites in an island arc setting in association with subduction processes. The enrichments in LILE and LREE are probably the result of some contamination by continental crust.

The island arc basalts are produced by partial melting of mantle wedge that has been modified by the addition of relatively mobile LILE derived from the subducted plate. The volcanic rocks associated with subduction zones are commonly enriched in LILE relative to HFSE and LREE, but the degree of enrichment differs widely on a regional scale. These differences are a function of several factors, including differences in the ages of the converging plates, differences in the amount of sediment involved in the magma-forming process, and differences in the extent to which back-arc magmatism has previously impoverished the mantle wedge (Patino et al. 2000). The striking resemblance between the compositions of the Łomża rocks and rocks from the Central Andes arc provides strong evidence that the former were produced in the vicinity of a continental arc subduction zone with a clear involvement of some continental crust. Zircon recovered from one orthoamphibolite consists of simple melt-precipitated grains with no visible inherited cores or metamorphic overgrowths. Their SHRIMP $^{207}Pb/^{206}Pb$ age of 1802±9 Ma is interpreted as the emplacement age of the orthoamphibolite's igneous protolith.

CONCLUSIONS

The PM-normalized incompatible element contents of the metavolcanic rocks from Łomża closely resemble those of island arc basalts. The strong negative Nb anomalies, in particular, are a consistent feature of arc basalt produced in association with subduction. The location of the compositions of the Łomża rocks in discrimination diagrams such as La-Y-Nb, Zr-Nb/Zr and Zr-Nb-Y points unequivocally to an island arc tectonic setting involving subduction. Close comparison of these compositions with those of rocks from modern arcs such as the Lesser Antilles and the Central Andes arc suggests that the Łomża rocks were formed as a result of subduction close to a continental margin.

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