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The Precambrian rift-related metamagmatic rocks of the Southern and Western Lithuania

The main geological unit of the Archaean–Early Proterozoic crust of Southern Lithuania is Dzukia greenstone belt. The metamagmatic sequence of this greenstone belt is composed of mafic and ultramafic rocks sometimes with komatiitic-like and tholeiitic affinities and was emplaced at about 2.5 Ga ago. The uprising of a mantle diapir initiated the breaking of the preexisting sialic crust and induced the formation of the greenstones in a proto-oceanic rift geodynamic environment. We consider that imbricated thrusts are the main structural feature of greenstone belt.

The volcano-sedimentary supracrustal Vidmantai complex is part of the Western Lithuanian Precambrian basement, which was formed by extensive mantle-derived crustal growth during the Early Proterozoic. The rocks range from medium and high-K tholeiitic dacites to high-Ti shoshonites resemble those of present-day mature volcanic arcs or arcs near or at active continental margins. The high-Ti shoshonites may mark the existence of temporal or local extensional environments. This is in agreement with the models assigning the Svecofennian province to convergent plate margin environments.

The basalts and lamprophyres were found almost in the each borehole of the Southern and Western Lithuania. The dyke swarm includes tholeiitic continental basalts and kersantites, which clearly suggest a continental rift setting. Our results suggest that the Translithuanian dyke swarm represents an abortive attempt at the Early Riphean break up the Archean–Lower Proterozoic thick continental crust, which was continued a little later by formation of the Veivirzhenai volcano-sedimentary sequence in the graben-synclines.

It must be pointed out that, in course of time, petrogenetic processes in Precambrian have changed from ensimatic to ensialic, implying a major reworking of the preexisting crustal materials.

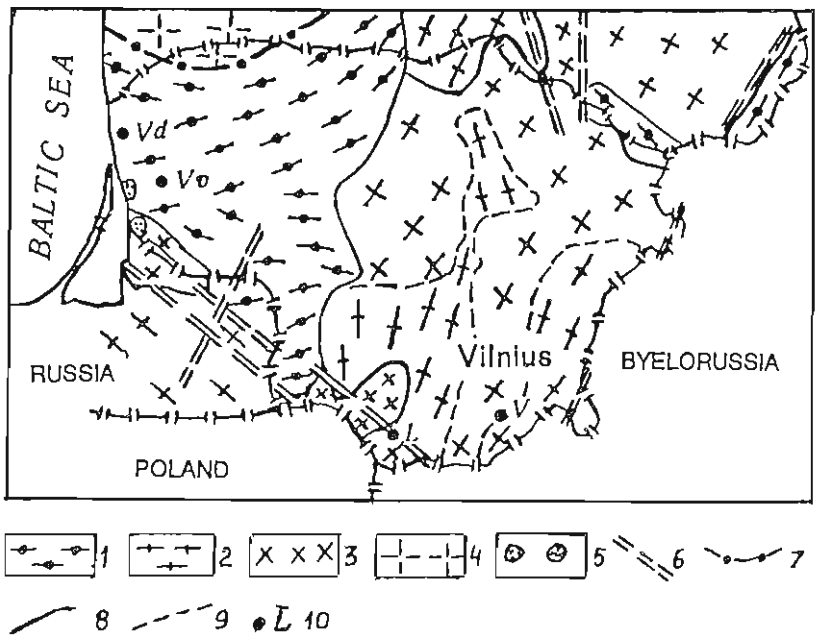

Fig. 1. Schematic geological map of the crystalline basement of Lithuania (*Baltic tectonics*, 1979) with additions of authors

1 — the Archacan metamorphic rocks of granulitic facies, forming sometimes and imbricate structures with PR_1 medium- and low-temperature metamorphic complex; 2 — the Archaean–Early Proterozoie complex (biotite-amphibole and biotite plagiogneisses and schists, amphibolites, metagahbro, dolomitic marbles): the Eastern Lithuanian foldbelt with the remnants of the imbricated thrusts of the Dzukia greenstone belt; 3 — the mainly Lower Proterozoic granite-gneisses and granite-migmatite with relicts of the Archaean metamorphic rocks; 4 — the Early Proterozoic Riga anorogenic pluton; 5 — fragments of the Early Riphean Veivirzhenai sequence; 6 — preplatform faults; 7 — thrusts; 8 — proved geological boundaries; 9 — supposed ones; 10 — boreholes: Vd — Vidmantai–1, Vv — Veivirzhenai–3 and 1 (Pabalve–1, Sakuchiai–4, Krazhante–26, Plunge–2 and 3, Maldunai–1 and 2, Degliai–3, Vilkichiai–2, 4 and 14, Gargzhdai–3, 12 and 17 boreholes are situated near and eastern from the first two), L — Lazdijai–29; V — borehole no. 348; the boreholes nos. 403, 423 and 987 are located to south and east from borehole no. 348

Schematyczna mapa geologiczna podłoża krystalicznego Litwy (*Baltic tectonics*, 1979) z uzupełnieniami autorów

1 — archaiczne skały metamorficzne facji granulitowej oraz struktury imbrykacyjne z PR_1 średnio- i niskotemperaturowymi kompleksami metamorficznymi; 2 — kompleks archaiczno-wczesnoproterozoiczny (plagiognejsy biotytowo-amfibolitowe i biotytowe, łupki, amfibolity, metagabra, marmury dolomityczne): wschodniolitewski pas fałdowy z ostańcami zimbrykowanych nasunięć zieleńcowego pasa Dzukia; 3 — głównie dolnoproterozoiczne granitognejsy i granitomigmatyty z reliktami archaicznych skał metamorficznych; 4 — wczesnoproterozoiczny anorogeniczny pluton Rygi; 5 — fragmenty wczesnoryfejskiej sekwencji Veivirzhenai; 6 — uskoki preplatformowe; 7 — nasunięcia; 8 — pewne granice geologiczne; 9 — przypuszczalne granice geologiczne; 10 — otwory wiertnicze: Vd — Vidmantai–1, Vv — Veivirzhenai–3 i 1 (otwory: Pabalve–1, Sakuchiai–4, Krazhante–26, Plunge–2 i 3, Maldunai–1 i 2, Degliai–3, Vilkichiai–2, 4 i 14, Gargzhdai–3, 12 i 17 są zlokalizowane tuż obok i na wschód od dwu wymienionych wcześniej), L — Lezdijai–29; V — otwór nr 348; otwory nr 403, 423 i 987 są położone na południe i wsehód od otworu nr 348

Table 1

Rare Earth element concentrations (ppm) in the metamagmatic rocks from the Dzukia greenstone belt

Sample number	Borehole	Depth [m]	Rocks	La	Ce	Nd	Sm	Eu	Gd	Er	Yb
1		471.0	Ta–Hb–Cumm–Antoph–schist	14	66	58	20	1.20	16	12	9.6
2		451.0	Hb–Ca–Pl–Q–Ta–schist	9.7	42	37	14	1.30	10	6.60	5.4
3	348	453.3	Antoph–Cumm–Act–Ta–Q–schist	3.9	18	16	4.2	0.36	6.2	2.20	2.6
4		437.9	Hb–Ca–Ta–Q–schist	5.5	16	14	7.6	0.62	5.8	4.00	2.8
5	423	387.3	Metabasite	16	42	22	2.0	1.40	4.8	1.30	2.2
6	403	575.5	Bi-plagiogneiss	42	110	67	18	1.40	15	3.80	3.0
7	403	585.0	Bi-plagiogneiss	18	37	15	0.8	0.48	1.9	0.75	0.4

REE concentrations were determined by ICP–AES techniques on a Hilger Analytical MONOSPEC 1000 instrument using the preliminary concentration of rare Earth's with ion-exchange resins; abbreviations used in the text and Table 1: Antoph — antophyllite, Act — actinolite, Bi — biotite, Cumm — cummingtonite, Ca — calcite, Hb — hornblende, Pl — plagioclase, Ta — talc, Q — quartz; locations of the main boreholes are shown on Fig. 1

THE METAMAGMATIC ROCKS OF THE LATE ARCHAEAN DZUKIA GREENSTONE BELT (SOUTHERN LITHUANIA)

It is composed by different pyroxene-bearing gneisses, biotite plagiogneisses, charnockites, amphibolites, mafic-ultramafic suite rocks, including gabbro, serpentinites and "komatiite-like" strongly altered rocks, tonalitic-trondhjemitic-granodioritic (TTG) gneisses, fine-grained, substantially migmatised rocks and plagioclase and microcline granites (Fig. 1). In respect to structural, petrological, geochemical and partially geochronological data this belt (K. B. Kepezhinskas, 1988) resembles another representative of the Late Archaean greenstone belts such as Lublin, Podlasie, Ciechanów and Kaszuby in Poland (W. Ryka, 1984, 1985), Kuhmo — Suomussalmi of the Eastern Finland (H. Martin et al., 1984), Karasjok — Kittila in the Scandinavia (G. Gaál et al., 1989), Norseman — Wiluna, Yilgarn Block, Western Australia (D. I. Groves, R. D. Gee, 1980; W. Compton et al., 1986) etc.

We have studied mainly mafic-ultramafic sequence and partly their wall-rocks. REE abundances of these rocks are listed in Table 1. The strongly altered mafic-ultramafic rocks on the REE patterns normalized to average ordinary chondrite exhibit well-pronounced negative Eu anomaly and other characteristic, which are typical for the talc-serpentine, carbonate, chlorite and tremolite-actinolite schists of the Archaean granulite-gneiss belts of Stanovoj region of the Aldan Shield, the Pallavaram, Madras, India; Lewisian, NW Scotland; and for komatiitic and tholeiitic metabasalts of the Late Archaean greenstone belts of Africa: Barberton Mountain Belt, Nimini Hills (Sierra Leone), Bandas and Bogoin etc. (K. B. Kepezhinskas, 1988). At the same time the REE pattern of the "komatiite-like" strongly altered rocks of the Southern Lithuania quite differ from strongly altered, but preserved spinifex texture rocks of the komatiite flows of the Kambalda district of Australia.

The most similar with Lithuanian "komatiite-like" ultramafic-mafic talc-carbonate-chlorite and chlorite-cummingtonite-actinolite rocks are discovered in the Late Archaean Olondo greenstone belt of the Aldan Shield among typical komatiite flows (N. L. Dobretsov et al., 1988, Tab. 4). In our opinion geochemical anomalies in both cases are caused by contact — metasomatic action of the later acid intrusions, which existed in the Southern Lithuania and Olondo.

It must be pointed out that in spite of differences in the REE patterns between "komatiite-like" talc, carbonate, chlorite, anthophyllite, actinolite-tremolite rocks of Lithuania and similar rocks of the Kambalda komatiitic flows in Australia, they are identical in respect to Au and Ag contents.

The atomic-absorbtion analysis of the Au and Ag made in the Institute of Geology and Geophysics (Novosibirsk) by G. N. Anoshin of the 34 samples of different altered rocks of the Dzukia greenstone belt from 10 boreholes revealed that concentrations of Au and Ag ranged in the interval 1.3×10^{-7}–1.1×10^{-6}%. In the one case (borehole no. 987, depth 377.4 m) concentration of the Au in amphibole-clinopyroxene-sulphide rock reaches up to 1.6×10^{-5}%. These concentrations of the Au are comparable with those in the altered rocks of komatiite flows with the preserved spinifex texture in the Kambalda: 1.1×10^{-7}–2.5×10^{-6}% (12 samples). The Ag contents in the same samples of the Southern Lithuania ranges from 1.1×10^{-6} to 9.3×10^{-5}% The concentrations

of Ag in the altered komatiite flows of the Kambalda ranges in the similar interval: 3.6 x 10^{-7}–7.3 x 10^{-5}%.

These data once again stress that the Southern Lithuanian Precambrian basement belongs to typical greenstone belts and points to important meaning of these rocks in the metallogenic aspects.

The wall-rocks of the mafic-ultramafic sequence represent different gneisses. Some of them are biotite plagiogneisses. Their REE pattern (Tab. 1, samples nos. 6 and 7) are similar to those of many granulite gneisses and greenstone belts mentioned above.

Thus, taking into account the geologic setting of the Precambrian basement of the Dzukia region (Southern Lithuania), including mafic-ultramafic sequence, geochemistry (first of all REE abundances of the rocks), age and low-grade metamorphism of a latter one, we regard that this part of East-European Platform belongs to the representative greenstone belt such as greenstone belts in the Precambrian basement of the neighbour areas of Poland (W. Ryka, 1984, 1985).

Imbricated thrusts represent in our opinion the main tectonic feature of this and other greenstone belts. Frequently they form allochthonous slices and represent remnants of paleooceanic crust generated mainly by proto-rifting of the preexisting crustal materials.

THE METAVOLCANIC ROCKS OF THE EARLY PROTEROZOIC, THE VIDMANTAI VOLCANO-SEDIMENTARY COMPLEX (WESTERN LITHUANIA)

The Early Proterozoic (PR_1) volcano-sedimentary supracrustal Vidmantai complex is a part of the Precambrian basement of Lithuania, which was formed by extensive mantle-derived crustal growth during the Early Proterozoic.

Most of the volcanic rocks of the Vidmantai supracrustal complex are porphyroblastic rocks of lava origin. Porphyroblasts have been composed by distinctly zoned feldspars. The groundmass represents fine- and medium-grained schistose aggregate which consists of quartz, plagioclase, biotite and accessories.

The supracrustal rocks of this complex were metamorphosed under low-pressure greenschist and epidote-amphibolite facies conditions (K. B. Kepezhinskas, 1977).

The volcanic rocks of the complex range in chemical composition. Part of the variation is possibly due to alteration and reworking, but the main control is primary compositional characteristics. The rocks range from medium- and high-K tholeiitic dacites to high-Ti shoshonites (Figs. 2 and 3; P. K. Kepezhinskas et al., 1988, Figs. 4 and 5). The medium- and high-K tholeiitic dacites are the most common type, and there are general similarities to present-day mature volcanic arcs or arcs near or at active continental margins. Some shoshonites relatively high in TiO_2 may indicate the existence of temporal or local extensional environments (P. K. Kepezhinskas et al., 1988).

A representatives of this rift-related type volcanic rocks are also shoshonites of the Mount Lamington, marking present-day rift, intersecting the Papua — New Guinea ophiolite complex, high-K lavas of the Avacha Graben at Kamchatka, shoshonites

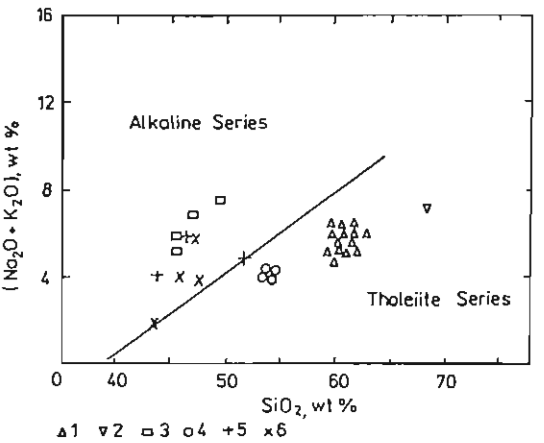

Fig. 2. Total alkali-silica diagram

The metamagmatic rocks of the PR_1 Vidmantai complex: 1 — augen gneisses, 2 — leucocratic gneisses, 3 — orthoclase-biotite-apatite-amphibole-clinopyroxene gneisses; the volcanics of the R_1 Translithuanian dyke swarm: 4 — plagioclase-clinopyroxene aphyric basalts, 5 — plagioclase-biotite (±pyroxene) medium-grained rocks; the dolerites of the Hällefors composite dyke (R. Lopez-Montano, 1986): 6 — rocks of marginal border group

Diagram krzemionki w stosunku do alkaliów

Metamagmatyczne skały kompleksu PR_1 Vidmantai: 1 — gnejsy oczkowe, 2 — gnejsy leukokratyczne, 3 — gnejsy ortoklazowo-biotytowo-apatytowo-amfibolowo-klinopiroksenowe; wulkanity translitewskiego zespołu dajek R_1: 4 — afirytowe bazalty plagioklazowo-klinopiroksenowe, 5 — plagioklazowo-biotytowe (±piroksenowe) skały średnioziarniste; doleryty złożonej dajki Hällefors (R. Lopez-Montano, 1986): 6 — skały grupy brzeżnej

from Puerto Rico, forming dyke-sedimentary complex in the troughs of NW extension, intersecting all of the Pre-Senomanian structure of the island (P. K. Kepezhinskas et al., 1988), etc.

The model of geotectonic setting proposed for the Vidmantai volcano-sedimentary complex is in agreement with those assigning the Svecofennian province to convergent plate margin environments (A. Hietanen, 1975; G. Gaál, 1982, etc.).

The percentage of medium- and high-K dacites mostly exceeds 50, which suggests that the crust was more than 20 km thick during the eruption of most of the studied rocks. This is also applicable many Svecofennian volcano-sedimentary belts.

When compared with recently studied Svecofennian volcano-sedimentary belts (the Bergslagen supracrustal complex, the Tampere Schist Belt, etc.), the Vidmantai supracrustal volcano-sedimentary complex shows some similarities but also differences.

The Bergslagen supracrustal complex has bimodal frequency distributions of silica and are dominated by rhyolites. The Bergslagen district exhibits features interpreted as to suggest episodes of extensional tectonics (I. S. Oen, 1987). In this respect the Vidmantai complex resembles the Tampere Schist Belt (Y. Kähkönen, 1987) rather than the Bergslagen district. The volcanic rocks of the Tampere Schist Belt range from

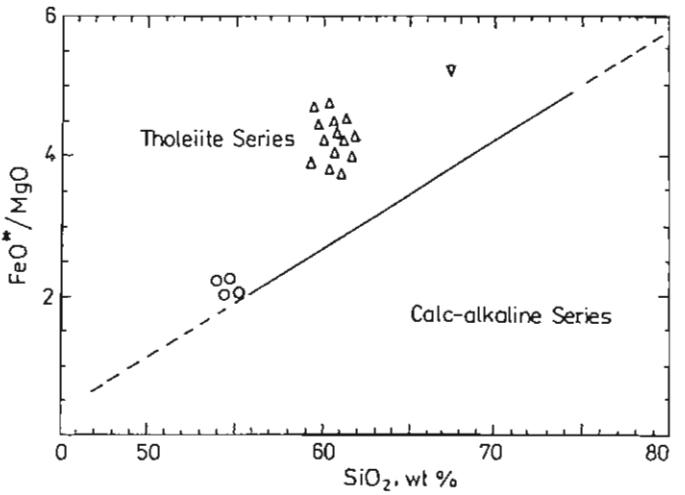

Fig. 3. The SiO_2 (weight %) — total FeO/MgO diagram for discrimination tholeiitic and calc-alkaline series (A. Miyashiro, 1975)

Explanations as in Fig. 2

Diagram funkcji dyskryminacyjnej SiO_2 w stosunku do FeO/MgO (% wag.) dla tolcilitów i serii wapniowo-alkalicznej (A. Miyashiro, 1975) .

Objaśnienia jak na fig. 2

low-K tholeiitic units to shoshonitic and trachytic units resembling those of present-day volcanic arcs. Some units are exceptional by exhibition of non-arc affinities; they are high in Ti and may mark extensional tectonic events.

THE EARLY RIPHEAN RIFT-RELATED MAGMATIC ROCKS

There exist two main stages of magmatic activity at the time of rifting. Both of them are related with the begining of general processes of the reworking of the continental crust formed in the Archaean–Early Proterozoic.

These two rift-related magmatic stages in Lithuania are represented by the Translithuanian basalts and lamprophyres dyke swarm and the Veivirzhenai volcano-sedimentary complex of northwest Lithuania (Fig. 1).

The volcanic rocks of the Early Riphean Translithuanian dyke swarm. The dykes are found as frequently as at the two from every three boreholes among some hundred ones. For this reason we ascribe them to the separate geological unit — dyke swarm like the Blekinge — Dalarna or Sarv dolerites dyke swarms in Scandinavia (Z. Solyom et al., 1984).

The dyke swarm in Western Lithuania is represented mainly by basaltoids, rarely lamprophyres and perhaps also acid rocks. The fragments of the latter ones were found

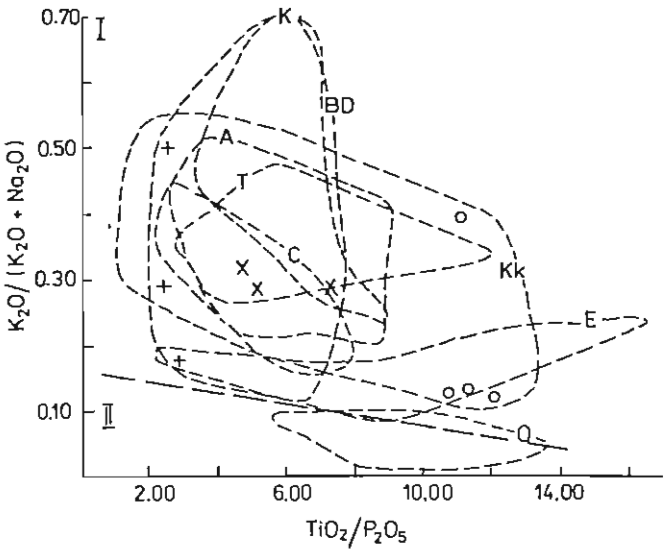

Fig. 4. The discriminant diagram for continental (I — plateau and dyke swarms) and oceanic (II — middle oceanic ridges) rift-related basaltoids

Fields: BD — Blekinge — Dalarna dyke swarm dolerites; K — Karroo plateau lavas; Kk — Kokchetav dyke swarms metabasites, northern Kazakhstan; A — Antarctica basalts; E — Ethiopian rift basalts; O — MORB; the fields A, C, E, K, O and T — after D. Chandrasekharam and A. Parthasarthy (1978), BD — after Z. Solyom et al. (1984); Kk — this study; other explanations as in Fig. 2

Diagram dyskryminacyjny dla kontynentalnych (I — zespoły dajek i plato) i oceanicznych (II — grzbiety śródoceaniczne) bazaltoidów ryftogennych

Pola: BD — zespół dajkowych dolerytów Blekinge — Dalarna; K — lawy pokrywowe Karroo; Kk — zespoły dajkowych metabazytów Kokczetaw, północny Kazachstan; A — bazalty Antarktyki; E — ryftowe bazalty Etiopii; O — MORB; pola A, C, E, K, O i T według: D. Chandrasekharam i A. Parthasarthy (1978), BD — według: Z. Solyom i in. (1984); Kk — materiały badane; pozostałe objaśnienia jak na fig. 2

by A. D. Stirpeika (1987) in the Veivirzhenai sedimentary rocks. The dykes in the southern part of Lithuania are represented as a rule by lamprophyres. Such bodies are also known in Kaliningrad region and Poland (M. Juskowiakowa et al., 1963).

We consider that in spite of the different petrochemistry of the volcanics of the Translithuanian dyke swarm they belong to the same rift, but mark its different stages. Such features are characteristic to many dyke swarm in other places.

The Translithuanian dyke swarms occur in the Precambrian basement and have not been found in its covering sequences. At a time the dykes have not been undergone regional metamorphism and deformations. So the most likely time of their intrusions is the Early Riphean (R_1). The fragments of volcanic rocks of the Veivirzhenai volcano-sedimentary complex in the Veivirzhenai, Gargzhdai and Vilkichiai areas of the Western Lithuania are similar to basaltoids, which are discovered in the veinlets or cement of the veined or tectonic breccias. In the Plunge area they are similar with basalts of the Veivirzhenai dyke (sill) and veinlets of the Pabalve–1 borehole. Therefore, the dykes have not been regarded as a magmatic channel for a lava-breccias and

ash tuffs of the Veivirzhenai complex and represent more early the Preveivirzhenai formation, belonging to the very early of R_1. In the Southern Lithuania lamprophyre dykes together with rocks of the Precambrian basement were a target in a meteor crater (Lazdijai–29 borehole), which shortly after were covered with V–e_1 fossiliferous sediments (G. B. Motuza, R. P. Gailius, 1978). Therefore, in the southern part of Lithuania the emplacement of the lamprophyre dykes took place in the Pre-Vendian time. Taking into account the geological setting and petrochemical relationships we regard them as the different magmatic stages of one and the same rifting, which took place at the beginning of the Early Riphean.

In order to classify and assess the evolution of the dyke swarm magmatic rocks, we use frequently employed discrimination methods. We focus our attention to following elements: Ti, P, Zr, Y (Z. Solyom et al., 1984, Figs. 5, 11 and 12), which are considered as imobile and discriminative. However, in some cases the more mobile elements such as Na, K, Si, Mg, Fe, can be used to verify specific magma characteristics (Figs. 2–4). The basaltoids of the Translithuanian dyke swarms are typical continental high-Al tholeiites (Figs. 2 and 3). The lamprophyres of the same dyke swarm in correspondence discrimination diagrams coincide with compositional field of kersantites and dolerites of marginal border group of the composite Hällefors dyke (Figs. 2–4). On the diagram $K_2O/(K_2O + Na_2O)$ versus TiO_2/P_2O_5 (Fig. 4) the basalts of dykes and sills are consistent with compositions of the continental tholeiitic Ethiopian rift basalts, the Early Riphean basaltic dyke swarms of the Archaean–Lower Proterozoic Kokchetav Massif, northern Kazakhstan and the continental high-Al tholeiites of the marginal border of a strongly differentiated Hällefors dyke which was emplaced ca. 1550 Ma ago in gneisses of the Svecocarelian (1950–1750 Ma) orogenic belt in south of central Sweden (R. Lopez-Montano, 1986). The lamprophyres of the Translithuanian dyke swarm (TDS) are analogues with calc-alkaline lamprophyres (kersantites) of the main R_1 rift stage of the A:PR_1 Kokchetav Massif in the Central Asian foldbelt of Kazakhstan.

The mineralogical variations of the TDS are consistent with their chemistry.

Taking into account the petrochemistry of volcanics mentioned above and their geological setting we consider that the Translithuanian dyke swarm is the most early signal of the A:PR_1 continental crust rifting and reworking.

The volcano-sedimentary rocks of the Early Riphean Veivirzhenai sequence, north-west Lithuania. The most ancient postcratonic volcano-sedimentary formations of the Baltic region resemble the Hogland sequence (M. I. Niin, 1976). In 1975 A. D. Stirpeika called similar rocks in the Western Lithuania the Veivirzhenai complex (Fig. 1) and compared it with the Subjotnian-Jotnian rocks. In the 1987 he subdivided this complex into two sequences: the Veivirzhenai (PR_1sjt) and the Baubliai (PR_2jt).

In 1992 we made revision of borehole materials and also different literature data to show that the discussed formation had possesed complex structure and composition. It is composed mainly of volcano-sedimentary rocks thickness up to 23 m (Veivirzhenai–3 borehole, depth 2182–2159 m).

We would like to stress such significant moments, which allow us to interpret a genesis and tectonic setting of this formation in a new way:

1. As we mentioned above the fragments of basaltic volcanics in the sedimentary rocks of the Veivirzhenai complex are similar to those of the Translithuanian dyke swarm by their structures and composition. Therefore, the dyke swarm can not represent the channels for volcanogenic material of the Veivirzhenai complex, but belongs to more early magmatic stage of the same rift.

More rarely the fragments of an acid dacite-like rocks have been discovered in the Veivirzhenai complex. Therefore, we do not exclude that the R_1 dyke swarm was composed by bimodal rift series like those of the R_1 Kokchetav dyke swarms in the Central Asia foldbelt of Kazakhstan.

2. The composition and volume of fragments of the effusive rocks in the Veivirzhenai complex testify to the denudation of a dyke swarm volcanics and not of plateau-basalts as regarded A. D. Stirpeika (1987).

3. In single cases the basaltoid lava-breccias (Sakuchiai–4 borehole), the basaltic ashes (Krazhante–26 borehole), tuffites and tufaceous sandstones (boreholes: Plunge–2, Maldunai–1) were discovered among the rocks of the Veivirzhenai sequence. The lava-breccias seem to mark an ascent channel through which an eruption of tuffs and formation of tuffites took place.

4. Basal horizons of the Veivirzhenai complex and its equivalents are represented by different rocks in the different regions. At the Suursaar island a basal horizon is represented by thin isolated bodies of quartzites and quartzite-like conglomerates (M. I. Niin, 1976). In its analogues of the Los-Hamra region, Central Sweden (T. Lundqvist, 1968) an the Northern Lithuania (Maldunai–1 borehole, A. D. Stirpeika, 1987), a basal level is represented by conglomerate-breccias, the fragments of which are composed of quartzites. That is, one and the same thin complex covers the A:PR_1 basement by different horizons. Moreover, in the some plases a "basal" level contains fragments of a "basal" horizon in an other place. The stratigraphical contact is unlikely to be in this case. We deal with the thrusts in all cases mentioned above.

5. The Hogland sequence and its equivalents, in particular the Veivirzhenai complex in some cases lay on the folded basement horizontally (boreholes: Veivirzhenai–3, Degliai–3, Vilkichiai–14), whereas in the other cases (Suursaar island, the Los-Hamra region of Central Sweden; Gargzhdai–3, 12, 17 and Vilkichiai–2, 4 boreholes of the Western Lithuania) they cover the besement by angle up to 20–60°.

Taking into account the distinguished differences of the metamorphic grade and character of the deformations between the A:PR_1 basement and the Hogland sequence and its analogues it is easy to explain such contacts by thrusting. The influence of such thrusting is expressed in the formation of tectonic breccias — so-called "basal" horizons, which is best examplified by breccia of the Maldunai borehole, which is composed from fragments of dyke swarm basaltoids (80%) and quartzites (20%).

6. The age of thrusting is Pre-Jotnian because the Jotnian sequence (1500 Ma) covers the Hogland and Veivirzhenai complexes horizontally.

7. The scale of thrusting discussed above is not too large, because the fragments of "underlying" dyke swarm are brecciated but not deformed. This is in an agreement with estimation of A. Berzin who established overthrusting of the Precambrian basement in the West Baltic region up to 20 km by geophysical methods.

Thus, it is reasonable to relate the intrusion of the Translithuanian dyke swarm and formation of the Veivirzhenai volcano-sedimentary complex in the graben-synclines to the same rifting regime of the Archaean–Early Proterozoic continental crust in the Early Riphean but to its different stages.

CONCLUSIONS

Our investigations of the three main metamagmatic units in the Precambrian basement of Southern and Western Lithuania recognized two major regional peculiarities, which seems to bear a general character.

The first one consists in establishment of the fact that the rifting was characterized of the inheritable and directional features due to the uprising of a mantle diapir. This peculiarity was expressed by the following succession of events:

1. A protooceanic rifting of the continental crust marked by mafic-ultramafic rocks of the Dzukia greenstone belt in the Archaean.

2. The temporal or local extensional environment in a mature island arc setting indicated by high-Ti shoshonites of the Vidmantai volcano-sedimentary complex probably in the Early Proterozoic.

3. The intracontinental rifting of a thick crust in the Early Riphean marked by the Translithuanian dyke swarm composed of tholeiitic basalts and calc-alkaline lamprophyres and the Veivirzhenai volcano-sedimentary complex, which was originally deposited in graben-synclines.

4. We assume also the existence of the fourth extensional crust regime indicated by signs probably of the Vendian basaltoid volcanism of the Volhynian suite (580-620 Ma), expressed by the Merkys sequence in the Southern Lithuania and probably similar formation in the Vidmantai–1 borehole in the Western Lithuania. But these formations need additional special investigations.

This regularity seems to be carried global characteristic. Rifts are frequently regenerated with respect to tectonic and magmatic activity. A nearby example is provided by the Permian Oslo Graben, which was partly controlled by Late Precambrian rifting (J. B. Ramberg, E. R. Neumann, 1978). The Late Precambrian Reelfoot (Mississippi embayment) rift was active in Mesozoic time and is today the site of seismic activity (G. R. Keller et al., 1983).

The second major peculiarity interconnected with the first one concerns directional character of the Earth crust evolution in the Precambrian of the Southern and Western Lithuania. As a matter of fact a paleooceanic crust formed in the Archaean time has been reworked practically to a continental one at the end of the Early Proterozoic — to the very beginning of the Early Riphean. The first signs of such reworking were shown already in the Late Archaean. The closure of the paleooceanic basin resulted in considerable crustal thickening, indicated by lower crustal hydrous melting and widespread intrusion of granodiorites, tonalites and trondhjemites. Their emplacement marks the initial reworking of an oceanic crust to a continental one.

This process was continued in the Early Proterozoic time. The most prominent tectonic feature of the Western Lithuania is the occurrence of the Vidmantai complex

of Early Proterozoic metavolcanic and metasedimentary rocks that have been subjected to strong compressional regimes along major zones of faulting with only temporal or local extensional event. This suggests the closure of the Early Proterozoic depositional basins once situated above or between segments of Archaean continental crust and sets the scene for plate tectonic modelling. For the formations of the Early Proterozoic Vidmantai volcano-sedimentary complex we assume the mature island arc or arc near at active continental margin settings.

The process of the formation of a continental crust terminated at the end of the Early Proterozoic time by the emplacement of strongly differentiated Riga pluton. The rapakiwi-granite among the different Riga pluton rocks signs a high level of maturity of a continental crust.

The intracontinental rifting of the Earth's crust of Southern and Western Lithuania in the Early Riphean marked by the Translithuanian dyke swarm begins new epoch of its evolution, which was continued in the Vendian (580–620 Ma) time.

Our model of evolution of Earth's crust in the Precambrian of Southern and Western Lithuania is in agreement with those assigned for the Svecofenian province (G. Gaál et al., 1989; H. Martin et al., 1984) etc.

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REFERENCES

BALTIC TECTONICS. TRANSACTIONS (1979) — Vol. 33. Mokslas. Vilnius.

CHANDRASEKHARAM D., PARTHASARTHY A. (1978) — Geochemical and tectonic studies on the coastal and inland Deccan Trap Volcanics and a model for the evolution of Deccan Trap volcanism. Neues Jb. Miner. Abh., **132**, p. 214–229.

COMPTON W., WILLIAMS J. S., CAMPBELL J. H. et al. (1986) — Zircon xenocrysts from the Kambalda volcanics: age constraints and direct evidence for older continental crust below the Kambalda—Norseman greenstones. Earth Plan. Sci. Let., **76**, p. 299–311.

DOBRETSOV N. L., DOBRETSOV N. N., POPOV N. V. et al. (1988) — Mineralogy and geochemistry of the Olondo komatiites, Aldan shield. In: Geochemistry of the volcanics of the different geodynamic settings. Nauka, p. 34–49. Novosibirsk.

GAÁL G. (1982) — Proterozoic tectonic evolution and late Sveeocarelian plate deformation of the Central Baltic Shield. Geol. Rdsch., **71**, p. 158–170.

GAÁL G., BERTHELSEN A., GORBATSCHEV R. et et al. (1989) — Structure and composition of the Precambrian crust along the POLAR Profile in the northern Baltic Shield. Tectonophysics, **162**, p. 1–25.

GROVES D. I., GEE R. D. (1980) — Regional geology and mineral deposits of the Kalgoorlie — Norseman region — Perth. Geol. Soc. Australia.

HIETANEN A. (1975) — Generation of potassium-poor magmas in the northern Sierra Nevada and the Svecofennian of Finland. J. Res. U. S. Geol. Surv., **3**, p. 631–645.

JUSKOWIAKOWA M., JUSKOWIAK O., RYKA W. (1963) — Jotnian in North-Eastern Poland (in Polish with English summary). Biul. Inst. Geol., **197**, p. 23–58.

KÄHKÖNEN Y. (1987) — Geochemistry and tectonomagmatic affinities of the metavolcanic rocks of the Early Proterozoic Tampere Schist Belt, Southern Finland. Precambrian Research, **35**, p. 295–311.

KELLER G. R., LIDIAK E. G., HINZE W. J. (1983) — The role of rifting in the tectonic development of the midcontinent, USA. In: Processes of continental rifting. Tectonophysics, **94**, p. 394–412.

KEPEZHINSKAS K. B. (1977) — Paragenetic analysis and petrochemistry of the middle-temperature metapelites (in Russian). Nauka. Novosibirsk.

KEPEZHINSKAS K. B. (1988) — Pre-Riphean mafic-ultramafic metamorphic complexes and their bearing on the origin of cratonic greenstone belts. In: The mafic complexes of activization zones at different stages of lithosphere evolution (in Russian), p. 7–22. Nauka. Novosibirsk.

KEPEZHINSKAS P. K., KRAVCHENKO-BEREZHNOY, GULKO N. I. (1988) — The Cenozoic shoshonites from North Kamchatka: implications for the tectonic interpretation of island arc shoshonitic series. In: The mafic complexes of activization zones at different stages of lithosphere evolution (in Russian), p. 98–114. Nauka. Novosibirsk.

LOPEZ-MONTANO R. (1986) — Origin and composition of the Hällefors composite dyke, central Sweden. Meddelanden från Stockholms Univ. Geol. Inst., no. 267. Stockholm.

LUNDQVIST T. (1968) — Precambrian geology of the Los-Hamra region Central Sweden. Stockholm.

MARTIN H., AUVRAY B., BLAIS S. et al. (1984) — Origin and geodynamic evolution of the Archaean crust of Eastern Finland. Bull. Geol. Soc. Finland, **56**, p. 135–160, no. 1–2.

MIYASHIRO A. (1975) — Volcanic rock series and tectonic setting. Ann. Rev. Earth Planet. Sc., **3**, p. 251–269.

MOTUZA G. B., GAILIUS R. P. (1978) — About proposal astroblemes of the Lithuania. In: Local structures of the Byelorussia and Pribaltica. Vilnius.

NIIN M. I. (1976) — Stratigraphy of the Middle Proterozoic Hogland sequence Northern Baltic region. In: Publications on stratigraphy of the Baltic region. Vilnius.

OEN I. S. (1987) — Rift-related igneous activity and metallogenesis in SW Bergslagen, Sweden. Precambrian Research, 35, p. 367–382.

RAMBERG J. B., NEUMANN E. R. (1978) — Palaeorift systems — Introduction. In: Petrology and geochemistry of continental rifts. Reidel Publishing Company. Dordrecht.

RYKA W. (1984) — Precambrian evolution of the East-European Platform in Poland. Biul. Inst. Geol., **347**, p. 17–28.

RYKA W. (1985) — The evolving of old Precambrian structures in the marginal zone of the East-European Platform. Publ. Inst. Geophys. Pol. Acad. Sc., **A-16** (175), p. 29–42.

SOLYOM Z., ANDREASSON P. G., JOHANSSON I. et al. (1984) — Petrochemistry of late Proterozoic rift volcanism in Scandinavia. In: The Blekinge — Dalarna Dolerites (BDD) — volcanism in a failed arm of Iapetus? Lund Publications in Geology, **23**.

STIRPEIKA A. D. (1987) — Volcano-sedimentary formations of Hogland and early Riphean of the Baltic region. In: Tectonic, facies and formations western part of the East European Platform. Minsk.

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PREKAMBRYJSKIE SKAŁY METAMAGMATYCZNE O GENEZIE RYFTOWEJ Z POŁUDNIOWEJ I ZACHODNIEJ LITWY

Streszczenie

Główną jednostkę litologiczną archaiczno-wczesnoproterozoicznej skorupy na obszarze południowej Litwy stanowi zieleńcowy pas Dzukia. Na metamagmatyczną sekwencję tego pasa, powstałą ok. 2.5 mld lat temu, składają się maficzne i ultramaficzne skały, zawierające czasem komatiitopodobne i toleityczne odmiany. Wznoszenie się diapiru w obrębie skał płaszcza zainicjowało rozpad wcześniejszej skorupy sialicznej i stymulowało powstanie zieleńców w geodynamicznym środowisku przedoceanicznego ryftu. Autorzy są zdania, iż obecność zimbrykowanych nasunięć jest główną cechą strukturalną pasa zieleńcowego.

Wulkaniczno-osadowy suprakrustalny kompleks Vidmantai, nazwany tak od jednego z otworów wiertniczych w okolicy Palangi, stanowi część zachodniego prekambryjskiego podłoża Litwy, utworzonego we wczesnym proterozoiku wskutek intensywnego rozrostu skorupy, mającego swe źródło w procesach zachodzących w płaszczu Ziemi. Powstałe skały, obejmujące spektrum od średnio- i wysokopotasowych tolcitycznych dacytów po wysokotytanowe szoszonity, przypominają skały, formujące się w obrębie współczesnych, dojrzałych łuków wulkanicznych lub łuków w pobliżu czy też na aktywnych krawędziach kontynentów. Wysokotytanowe szoszonity mogą wskazywać na obecność okresowych lub lokalnych środowisk z dominacją zjawisk ekstensyjnych. Fakt ten jest zgodny z modelami, wiążącymi prowincję svekofińską z środowiskami konwergencyjnej krawędzi płyt kontynentalnych.

Bazalty i lamprofiry stwierdzono niemal w każdym z odwierconych otworów na obszarze południowej i zachodniej Litwy. Zespół dajek obejmuje toleitowe kontynentalne bazalty i kersantyty, sugerujące wyraźnie obecność ryftu kontynentalnego. Wyniki badań autorów wykazują, iż translitewski zespół dajek reprezentuje poronioną próbę przerwania we wczesnym ryfeju grubej skorupy kontynentalnej A:PR_1, kontynuowaną nieco później w formie wulkaniczno-osadowej sekwencji Veivirzhenai w obrębie rowo-synklin.

Należy podkreślić, iż w miarę upływu czasu, procesy petrogenetyczne w prekambrze zmieniały się od śródsimatycznych do śródsialicznych, powodując znaczącą przebudowę wcześniejszych skał pokrywy.

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