MINERALOGIA POLONICA
Vol. 17, No 2 — 1986

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PRELIMINARY TRACE ELEMENT EVIDENCE FOR AN OCEANIC DEPLETED MANTLE ORIGIN OF THE ŚLĘŻA OPHIOLITIC COMPLEX, SW POLAND

Abstract. Detailed studies of the first author (A. Majerowicz) have shown that the largest occurrence of basic and ultrabasic rocks in SW Poland in the Ślęża (Mt.) Group represents typical ophiolitic association. It consists of serpentinized metamorphic peridotites, metagabbros including cumulates, amphibolites and siliceous radiolaria-bearing shales. Moreover, pediform chromites, plagiogranites and recently described rodingites occur in subordinate amounts.

Two representative samples of amphibolites, being the only preserved volcanic or hypabyssal member of this association and 3 of various metagabbros were analyzed by the second author (Ch. Pin) for *REE* and other petrogenetically diagnostic trace elements. The obtained geochemical data confirm earlier suggestion on predominantly *OFB* character of metabasites in question. However, some incompatible trace element ratios indicate them to be formed not in mid-ocean ridge but rather in back-arc or marginal basin setting.

GENERAL CHARACTERISTICS OF THE ŚLĘŻA OPHIOLITIC COMPLEX

Detailed petrologic studies of the largest complex of basic and ultrabasic rocks in Lower Silesia, SW Poland, occurring within the Ślęża (Mt.) Group, have shown them to represent typical ophiolite association (Majerowicz 1979, 1981). This group is situated on the Foresudetic block, on N margin of the oldest Precambrian element in this region — the Sowie Góry (Mts) Block forming a distinct morphological elevation. It consists of serpentinized peridotites, metagabbros, amphibolites and granitoids (Fig. 1). Further to E, near Pustków Wilczkowicki, there occur feebly metamorphosed siliceous shales and phyllites containing radiolaria of *Spumellina* group what indicates their Lower Paleozoic age. Their contact with the above ophiolitic members is covered but, most probably, tectonic, suggesting Paleozoic displacement of this complex. Till now there are no data on the age of basic and ultrabasic rocks in question. The only rock dated — Variscan granitoid — shows with all the rocks of the Ślęża (Mt.) Group and with gneisses of the Sowie Góry (Mts) Block intrusive-thermal contacts.

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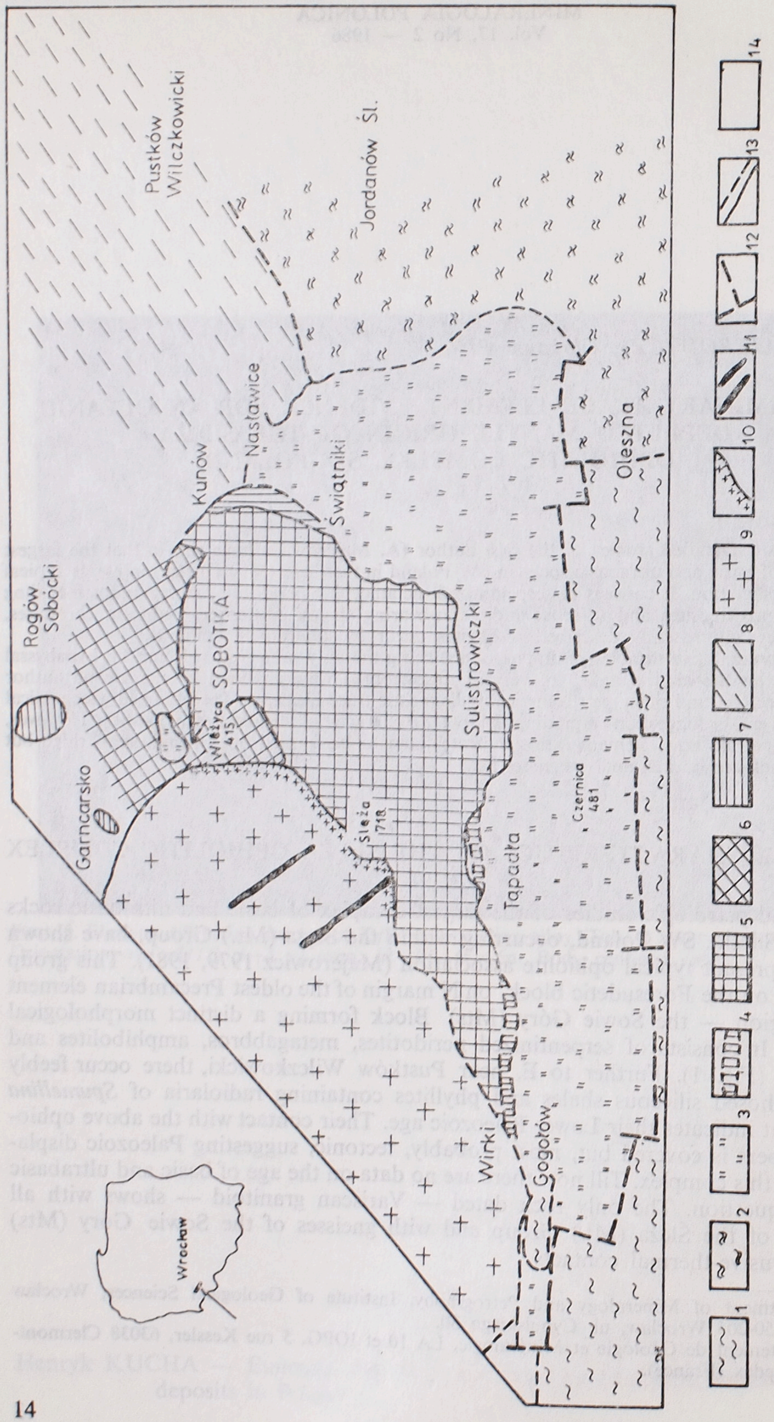


Fig. 1 Geologic sketch map of the Ślęża (Mt.) Group (after Majerowicz 1981, simplified)

1 — gneisses of the Sowie Góry (Mts.) Block, *2* — gneisses of the Niemcza dislocation zone, *3* — serpentinites (metamorphic peridotites), *4* — amphibole-pyroxene rocks (ultramafic cumulates), *5* — metagabbros, *6* — amphibolites, *7* — epimetamorphic siliceous shales, *8* — metamorphic rocks of NE cover of granitoid body, *9* — Variscan granitoids, *10* — contact leucogranites, *11* — quartz veins, *12* — faults (found and probable), *13* — lithostratigraphic boundaries, *14* — Tertiary and Quaternary deposits

Ultrabasic rocks display variable degree of serpentinization, the best preserved being wehrlitic and dunitic varieties. Recently, the first author have found and examined rodingitic enclaves occurring within serpentinites in boudinaged forms and dikes coming from overlaying gabbros (Majerowicz 1977, 1979, 1985). Plagiogranites are represented by subordinately occurring albitite dikes. Pediform-type concentrations of chromite, characteristic of ophiolite associations, are known at Czarna Góra near Tąpadła.

All the petrographic and chemical features of serpentinized peridotites indicate (them to represent the lowermost member of an ophiolites association — metamorphic peridotites (Majerowicz 1981, Narębski and Majerowicz 1985). Between serpentinites and metagabbros there occurs a zone generally defined as consisting of pyroxene-amphibole rocks (bore-hole data of Niemczynow 1966). Similar zone with rocks containing relics of olivine grains was found by the first author at the Tąpadła pass and in the region W of Nasławice. Detailed petrographic study of these rocks has shown them to represent ultramafic cumulates, characteristic of central parts of ophiolite associations (Coleman, 1977). Above these cumulates, there occurs their parent rock — metagabbro, also showing distinct differentiation. In its bottom part we observe irregular cumulative concentrations of uralitized pyroxenites, composed of crystals of altered diallages up to 30 cm long and several cm thick. Metagabbros consist predominantly of dark green coarse-grained rock composed of uralitized diallage crystals intergrown with diablastic strongly saussuritized plagioclases. These rocks are overlain by fairly diversified amphibolites (Majerowicz 1971). At the Wieżyca hill, NE of Ślęża (Mt.) Group, aphanitic, fine-grained, medium-grained and blastoporphyric varieties of these rocks are alternating with each other, resembling a series of sheeted dikes. Their contacts with metagabbros in the environs of Kunów are very complicated showing mutual interpenetration. Preliminary geochemical data interpreted by means of some discrimination diagrams have shown that amphibolites in question display tholeiitic trend and essentially correspond geochemically to ocean-floor (OFB) or middle-ocean ridge basalts (MORB) (Majerowicz 1981, Narębski *et al.* 1982, Narębski and Majerowicz 1985).

It should be emphasized that in the Ślęża ophiolitic complex we observe the lack of the uppermost member of this association — submarine volcanics, usually represented by pillow lavas. It is supposed that these rocks were either completely eroded or tectonically displaced.

Mineral composition and structural features of amphibolites and metagabbros in question suggest that they were subjected to metamorphism connected with penetration of sea water into the rift zone (Majerowicz 1981). It is supposed that these alterations took place under conditions of lower stage of amphibolite facies for metagabbros whilst amphibolites were metamorphosed at *pt* conditions corresponding to greenschist facies. These conclusions were confirmed recently by the studies of oxygen isotopes carried out by J. Jędrysek in the Institute of Geological Sciences, Wrocław University (unpublished M. Sc. thesis).

Thanks to fruitful cooperation of the Universities in Wrocław and in Clermont-Ferrand, seven representative samples of typical rocks of the Ślęża ophiolite complex were selected for determination of REE and other petrogenetically important trace elements occurring in very small amounts.

ANALYTICAL METHODS AND RESULTS

Trace elements have been determined by the Ch. Pin using the following techniques:

1) Zr and Nb — wavelength dispersive X-ray fluorescence spectrometry at École Nationale des Mines d'Alés;

2) Rare earth elements — inductively coupled plasma (ICP) optical emission spectrometry, at CRPG (Nancy);

3) Ni, Cr and V — atomic absorption spectrometry at LA 10 (Clermont-Ferrand).

The obtained results are detailed in table 1 and presented in figures 2, 3 and 4.

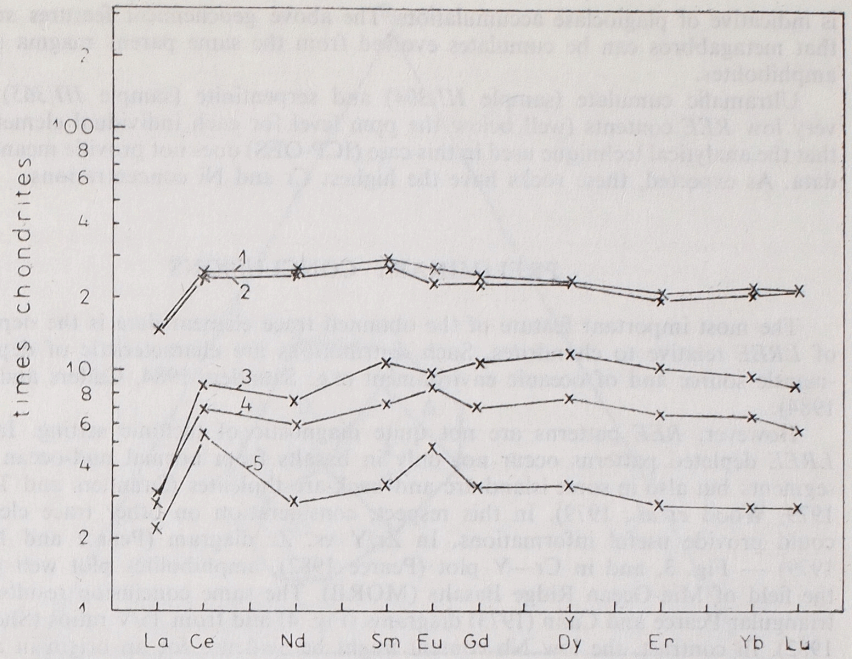
Amphibolites (2 samples) are characterized by fairly high contents of incompatible elements (Zr, Y, Lanthanides) with rare earths at about 25 times chondrites.

Table 1

Trace element contents in metabasic rocks of the Ślęża ophiolite complex (in ppm)

Rock type	Amphibolites		Metagabbros leucocratic	Metagabbros melanocratic	Meta-diallagite
Sample No	*II/21x*	*IV/21x*	*7 G*	*18 G*	*I/PEG*
Zr	157	166	30	12	—
Nb	2.0	1.9	<1	<1	—
Y	51	53	19	8	29
Cr	340	170	95	400	600
Ni	100	80	65	135	130
V	450	460	270	160	540
Ti[1]	15780	15900	nd	nd	nd
Sr[1]	126	117	nd	nd	nd
La	4.57	4.86	1.01	0.71	0.93
Ce	20.68	21.93	5.92	4.60	7.48
Nd	15.20	16.45	3.69	1.75	4.74
	(15.67)	(16.65)	(4.04)	(1.36)	
Sm	5.52	5.84	1.48	0.67	2.18
	(5.25)	(5.79)	(1 82)	(0.62)	
Eu	1.77	2.03	0.65	0.36	0.74
Gd	6.37	6.74	1.93	0.89	3.03
Dy	7.87	8.08	2.60	1.12	4.11
Er	4.49	4.71	1.46	0.61	2.30
Yb	4.64	4.88	1.40	0.59	2.10
Lu	0.73	0.74	0.19	0.09	0.29
$(La/Sm)_N$	0.51	0.51	0.40	0.63	0.25
$(La/Yb)_N$	0.58	0.58	0.43	1.73	0.26
Zr/Nb	79	83			
Zr/Y	3.1	3.1	1.6	1.5	
La/Nb	2.3	2.6			
Ti/V[1]	35	34			
Ti/Zr[1]	100	96			

[1] Data after Narębski and Majerowicz (1985).
In brackets: isotope dilution mass spectrometric results for REE.
nd — not determined, — below detection limit.



REE data are

		La	Ce	Nd	Sm	Eu	Gd	Dy	Er	Yb	Lu
1	IV/21X	4,86	21,93	16,45	5,84	2,03	6,74	8,08	4,71	4,88	0,74
2	II/21X	4,57	20,68	15,20	5,52	1,77	6,37	7,87	4,49	4,64	0,73
3	I/PEG	0,93	7,48	4,74	2,18	0,74	3,03	4,11	2,30	2,10	0,29
4.	7G	1,01	5,92	3,69	1,48	0,65	1,93	2,60	1,46	1,40	0,19
5.	18G	0,71	4,60	1,75	0,67	0,36	0,89	1,12	0,61	0,59	0,09

Fig. 2. Chondrite-normalized REE patterns of amphibolites and metagabbros (including cumulates) of the Ślęża ophiolitic complex. Rock types and sample numbers as in Figure 1

This is in good agreement with their origin as meta-basaltic liquids. Their chondrite-normalized *REE* pattern (Fig. 2) shows a distinct light rare earth elements (*LREE*) depletion ($(La/Yb)_N = 0.58$, $(La/Sm)_N = 0.51$). The lack of noticable *Eu* anomaly suggests that plagioclase fractonation did not play a major role during petrogenesis of these rocks.

Metagabbros (2 samples) and metadiallagite sample have lower and variable incompatible element contents (between 3 and 10 times chondrites for *REE*) what is due to significant role of cumulus processes in their origin (Dal Piaz *et al.* 1981). Their chondrite-normalized *REE* patterns (Fig. 2) exhibit similar *LREE* depletion as the amphibolites and, besides, distinct Ce and Eu anomalies. The former can be due to variable redox conditions during the origin of these rocks whilst the latter is indicative of plagioclase accumulation. The above geochemical features suggest that metagabbros can be cumulates evolved from the same parent magma as the amphibolites.

Ultramafic cumulate (sample *III/304*) and serpentinite (sample *III/365*) have very low *REE* contents (well below the ppm level for each individual element) so that the analytical technique used in this case (ICP-OES) does not provide meaningful data. As expected, these rocks have the highest Cr and Ni concentrations.

PRELIMINARY CONCLUSIONS

The most important feature of the obtained trace element data is the depletion of *LREE* relative to chondrites. Such distributions are characteristic of depleted--mantle source and of oceanic environment (e.g. Saunders 1984, Cullers and Graf 1984).

However, *REE* patterns are not quite diagnostic of tectonic setting. Indeed, *LREE* depleted patterns occur not only in basalts from normal mid-ocean ridge segments but also in some island-arc and back-arc tholeiites (Saunders and Tarney 1979, Wood *et al.*, 1979). In this respect, consideration on other trace elements could provide useful informations. In Zr/Y vs. Zr diagram (Pearce and Norry, 1979) — Fig. 3, and in Cr—Y plot (Pearce 1982), amphibolites plot well within the field of Mid-Ocean Ridge Basalts (MORB). The same conclusion results from triangular Pearce and Cann (1973) diagrams (Fig. 4) and from Ti/V ratios (Shervais, 1982). In contrast, the low Nb content might be evidence for an origin in a subduction-related back-arc setting. Zr/Nb rations (ca 80) are distinctly higher than in N-type MORB (ca 40; Erlank and Kable, 1976). In the same way, La/Nb at about 2.4 is much higher than in MORB (ca 1.0) but quite comparable to island-arc

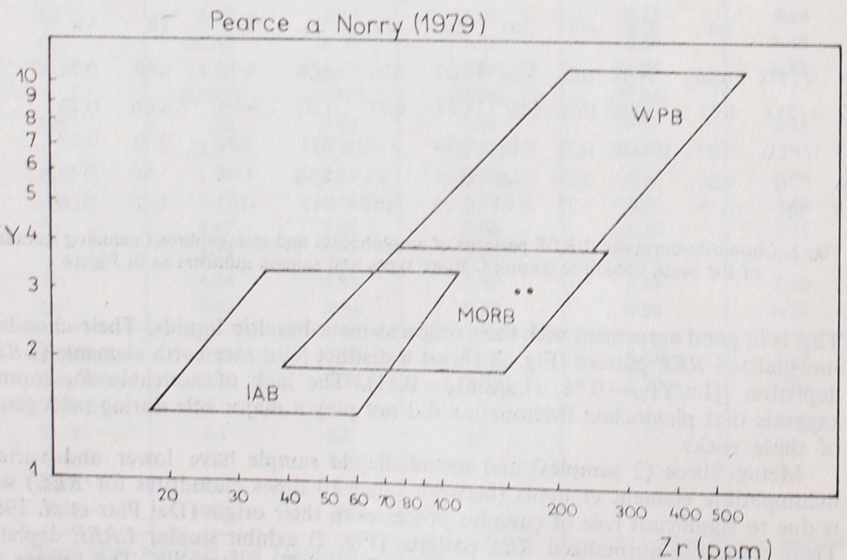


Fig. 3. Zr/Y vs Zr diagram (Pearce and Norry 1979) for amphibolites of the Ślęża ophiolitic complex, plotting in the *MORB* field. *WPB* — within-plate basalts, *IAB* — island-arc basalts

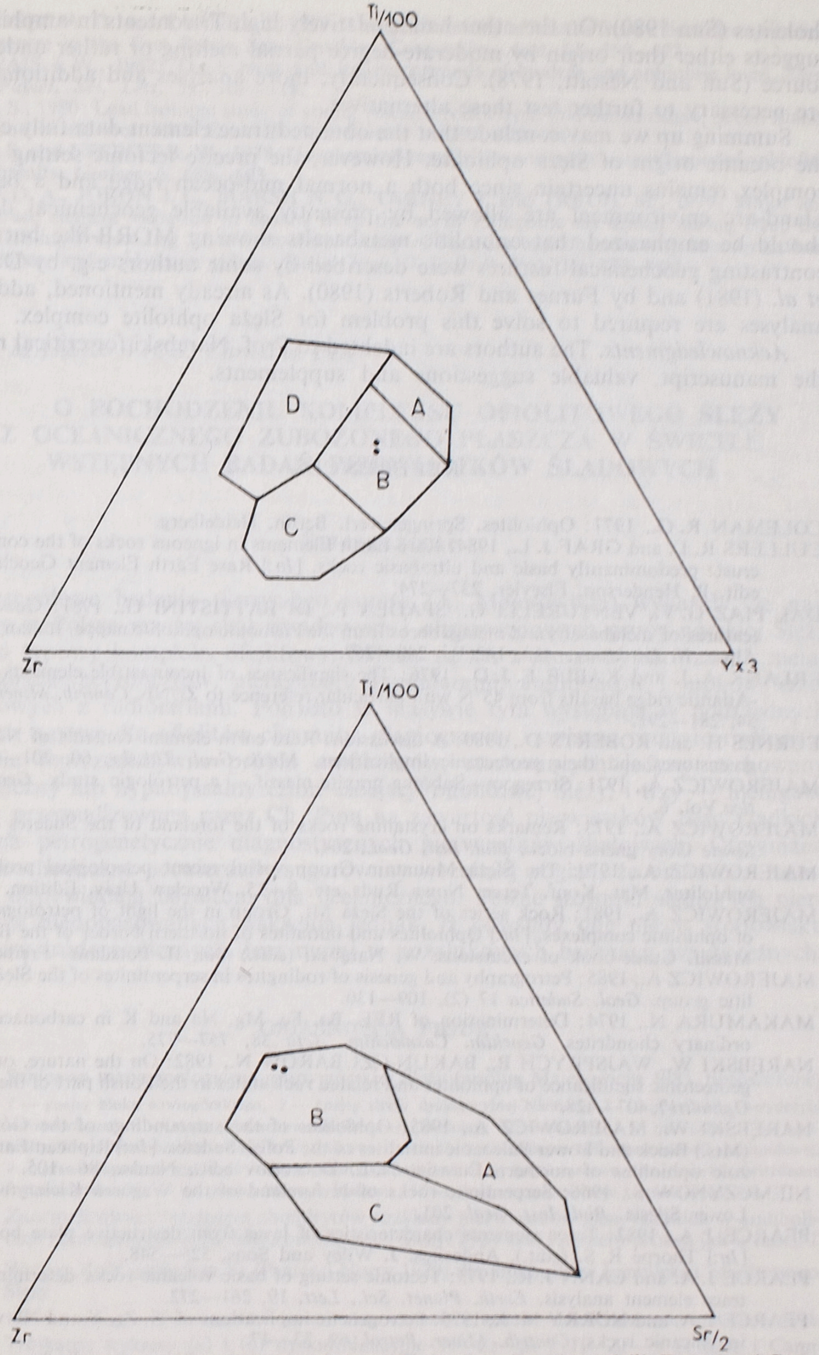


Fig. 4. Triangular Ti—Zr—Sr and Ti—Zr—Y discrimination diagram (*a*) and (*b*) (Pearce and Cann 1973) showing the position of the Ślęża (Mt.) Group amphibolite plots within the *OFB*=*MPRB* fields

tholeiites (Sun 1980). On the other hand, relatively high Ti contents in amphibolites suggests either their origin by moderate-degree partial melting or rather undepleted source (Sun and Nesbitt, 1978). Consequently, more analyses and additional data are necessary to further test these alternatives.

Summing up we may conclude that the obtained trace element data fully confirm the oceanic origin of Ślęża ophiolite. However, the precise tectonic setting of this complex remains uncertain since both a normal mid-ocean ridge and a back-arc island-arc enivironment are allowed by presently available geochemical data. It should be emphasized that ophiolitic metabasalts showing MORB-like but rather contrasting geochemical features were described by some authors e.g. by Dal Piaz *et al.* (1981) and by Furnes and Roberts (1980). As already mentioned, additional analyses are required to solve this problem for Ślęża ophiolite complex.

Acknowledgments. The authors are indebted to Prof. Narębski for critical reading the manuscript, valuable suggestions and supplements.

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O POCHODZENIU KOMPLEKSU OFIOLITOWEGO ŚLĘŻY Z OCEANICZNEGO ZUBOŻONEGO PŁASZCZA W ŚWIETLE WSTĘPNYCH BADAŃ PIERWIASTKÓW ŚLADOWYCH

Streszczenie

Szczegółowe badania pierwszego autora (A. Majerowicza) wykazały, że największy w Polsce masyw skał zasadowych i ultrazasadowych grupy górskiej Ślęży stanowi typowy kompleks ofiolitowy. Składa się on z zserpentynizowanych metamorficznych perydotytów, metagabr z kumulatami, amfibolitów i łupków krzemionkowych z radiolariami. Ponadto w masywie tym występują w podrzędnych ilościach typowe dla ofiolitów chromity, plagiogranity i opisane ostatnio rodingity.

Dwie reprezentatywne próbki amfibolitów, stanowiących jedyny zachowany wulkaniczny lub hypabyssalny człon asocjacji ofiolitowej Ślęży, i trzy — metagabr zostały przeanalizowane przez Ch. Pina na zawartość pierwiastków ziem rzadkich i innych petrogenetycznie diagnostycznych pierwiastków śladowych. Otrzymane dane geochemiczne potwierdziły sugerowany wcześniej pogląd, że omawiane metabazyty odpowiadają bazaltom dna oceanicznego. Pewne stosunki śladowych pierwiastków niedopasowanych wskazują jednak, iż powstały one nie w środowisku grzbietów śródoceanicznych, lecz raczej w pozałukowych basenach przybrzeżnych.

OBJAŚNIENIA FIGUR

Fig. 1. Szkicowa mapa geologiczna grupy górskiej Ślęży (według Majerowicza 1981, uproszczone)
1 — gnejsy bloku sowiogórskiego, *2* — gnejsy strefy dyslokacyjnej Niemczy, *2* — serpentynity (perydotyty metamorficzne), *4* — skały piroksenowo-amfibolowe (kumulaty ultramaficzne), *5* — metagabra, *6* — amfibolity, *7* — epimetamorficzne łupki krzemionkowe, *8* — skały metamorficzne NE osłony intruzji granitoidowej, *9* — granitoidy waryscyjskie, *10* — leukogranity kontaktowe, *11* — żyły kwarcowe, *12* — uskoki (stwierdzone i prawdopodobne), *13* — granice litostratygraficzne, *14* — osady trzeciorzędowe i czwartorzędowe

Fig. 2. Znormalizowane względem chondrytów rozkłady pierwiastków ziem rzadkich w amfibolitach i metagabrach kompleksu ofiolitowego Ślęży. Typy skał i numery próbek jak w tabeli 1

Fig. 3. Wykres Zr/Y względem Zr (Pearce i Norry 1979) dla amfibolitów kompleksu ofiolitowego Ślęży
WPB — bazalty śródpłytowe, *IAB* — bazalty łuków wyspowych, *MORB* — bazalty grzbietów śródoceanicznych

Fig. 4. Trójkątne wykresy (*a*) i (*b*) dyskryminacyjne Ti—Zr—Sr i Ti—Zr—Y (Pearce i Cann 1973) wykazujące położenie punktów projekcyjnych amfibolitów Ślęży w polu bazaltów dna oceanicznego (*OFB = MORB*)

Альфред МАЕРОВИЧ, Кристьян ПИН

О ПРОИСХОЖДЕНИИ ОФИОЛИТОВОГО КОМПЛЕКСА СЬЛЕНЖИ ИЗ ОБЕДНЕННОГО ОКЕАНИЧЕСКОГО СЛОЯ В СВЕТЕ ПРЕДВАРИТЕЛЬНОГО ИЗУЧЕНИЯ ЭЛЕМЕНТОВ-ПРИМЕСЕЙ

Резюме

Детальные исследования, проведенные первым автором (А. М), доказали, что наиболее крупный в Польше массив основных и ультраосновных пород группы горной Сьленжи представляет собой типичный офиолитовый комплекс. Он состоит из серпентинизованных метаморфических перидотитов, метагаббро с кумулатами, амфиболитов и кремнистых сланцев с радиоляриями. Кроме того, в этом массиве в подчиненном количестве присутствуют типичные для офиолитов хромиты, плагиограниты и, описанные в последнее время, родингиты.

Два представительных образца амфиболитов, представляющих единственный сохраненный вулканический либо гипабиссальный член офиолитовой ассоциации Сьленжи, и три образца метагаббро были проанализированы вторым автором (К. П) на содержание РЗЭ и других в петрогенетическом отношении диагностических элементов-примесей. Полученные геохимические данные подтвердили предполагаемый раньше взгляд, что обсуждаемые метабазиты соответствуют базальтам океанического дна. Некоторые соотношения несовмещающихся элементов-примесей однако указывают на то, что они образовались не в зоне срединных океанических хребтов, а скорее всего в обрамляющих бассейнах ближе островных дуг.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Эскизная геологическая карта группы горной Сьленжи (по А. Маеровичу 1981, упрощено)

1 — гнейсы Совьегорской глыбы, *2* — гнейсы дислокационной зоны Немчи, *3* — серпентиниты (метаморфические перидотиты), *4* — пироксен-амфиболовые породы (ультрамафитовые кумулаты), *5* — метагаббро, *6* — амфиболиты, *7* — эпиметаморфические кремнистые сланцы, *8* — метаморфические породы СВ обрамления гранитоидной интрузии, *9* — варисские гранитоиды, *10* — контактные лейкограниты, *11* — кварцевые жилы, *12* — сбросы (установленные и предполагаемые), *13* — литостратиграфические границы, *14* — третичные и четвертичные отложения

Фиг. 2. Стандартизованное по отношению к хондритам распределение РЗЭ в амфиболитах и метагаббро офиолитового комплекса Сьленжи. Типы пород и номера образцов как в табл. 1

Фиг. 3. График соотношения Zr/У к Zr (Пирс и Норри 1979) для амфиболитов офиолитового комплекса Сьленжи

WPB — континентальные базальты, *IAB* — базальты островных луг, *MORB* — базальты океанических хребтов

Фиг. 4. Треугольные дискриминационные диаграммы (a) и (b) Ti-Zr-Sr и Ti-Zr-У (Пирс и Канн 1973), показывающие положение проективных точек амфиболитов Сьленжи в поле базальтов океанического ложа (*OFB* = *MORB*)