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GEOCHEMISTRY OF UPPER PROTEROZOIC ROCKS OF THE SVOJŠÍN VOLCANIC STRIP (WESTERN BOHEMIA) AND PROBLEM OF THE SOURCE MATERIAL OF METASEDIMENTS

(Figs. 2, Tabs. 5)

Abstract: From the determination of trace elements in 21 samples of metasediments and metabasics it can be stated, that in comparison with available literature data metamorphosed sediments of the Svojšín area are strongly enriched in V and Cr, having, considerably lower Co and light REE contents. Also an increased content of Sc is quite in character. Graphitic phyllites represent an individual group, being enriched in U, V, Ni, heavy REE and to the contrary deficit in Th and light REE. Tholeiitic metabasics have low REE contents and a primitive REE distribution. The studied rocks display a conspicuous positive correlation between Sc and Co.

In addition to predominant tholeiitic volcanics the source material of the Svojšín metasediments includes also abundant rocks generated from an area with a developed continental crust, presumably corresponding to recent continental margins (60 % of rocks of a tholeiitic composition, 15 % of rocks representing calc alkaline andesites and dacites of the And type, 25 % of rocks of a rhyolitic composition).

Резюме: На основе определений редких элементов в 21 пробах метаосадков и метабазитов можно установить, что метаосадки свойшинского региона сильно обогащены V и Cr, и они имеют содержания Co и легких р. з. э. значительно ниже по сравнению с величинами приводимыми в литературе. Для них характерно также повышенное содержание Sc. Графитовые филлиты, которые по сравнению с «нормальными» филлитами обогащены U, V, Ni и тяжелыми р. з. э. и, на другой стороне, обеднены Th и легкими р. з. э., представляют отдельную группу. Толеитовые метабазиты выделяются низкими содержаниями и примитивным распределением р. з. э. Исследованные породы обнаруживают выразительную положительную корреляцию Sc и Co.

В исходном материале свойшинских метаосадков были кроме преобладающих толеитовых вулканитов в значительной мере замещены также породы из региона с развитой континентальной корой, вероятно соответствующей нынешним окраинам континента (60 % толеитовых вулканитов, 15 % известково-щелочных андезитов и дацитов андского типа, 25 % риолитов).

Introduction

The studied area is situated in the western and northwestern vicinity of Stříbro (Western Bohemia) and geologically has been studied in detail by Pertold (1966). In it, Upper Proterozoic sedimentary rocks metamorphosed in the epizone predominate. The Svojšín volcanic strip, streching NE-SW, is

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built of metamorphosed volcanics, prevailingly pyroclastics (F i a l a, 1977). In this area P e r t o l d (1966) distinguished 2 groups- the older, so-called roofing slate group and the younger, spilite group. The roofing slate group includes epizonally metamorphosed sediments: phyllites, phyllites with rounded pebbles and phyllitized metagraywackes. Spilite rocks absent. The spilite group is represented by sediments interbedded by products of the spilite-keratophyre volcanism. The rocks are epizonally to mesozonally metamorphosed, the group being mostly intensively folded. From metasediments phyllites are mostly abundant, less metagraywackes and rarely also graphitic and sulphide phyllites occur (P e r t o l d, 1966.) According to H o l u b e c (1966) the whole area ranges among the lower Rabštejn group (A).

Samples were taken from boreholes LS 40, LS 44, LS 46, Vv 5 provided by GPUP Příbram and from a mapping borehole V 16b/65 (P e r t o l d, 1966). Their localization is given by M a t ě j k a (1980, 1987). 21 samples were analysed in Central laboratories ČSUP in Stráž pod Ralskem using the instrumental neutron activising analysis in order to determine Sc, Cr, Co, La, Ce, Sm, Eu, Tb, Yb, Lu, Hf, Th, U; Ni and V were determined in the laboratory of the Dept. of Mineralogy, Faculty of Natural Sciences using the emission spectral analysis. In this laboratory also silicate analyses of 5 samples were made.

Petrography

The studied samples include metagraywackes phyllites and metabasics (M a t ě j k a, 1980, 1987).

Metagraywackes (samples 30, 31, 32, 33, 35, 38, 43, 45) are light-grey to dark-grey rocks, mostly of a good foliation. In all of the samples quartz and feldspar were found, also biotite muscovite (mostly sericite), in places chlorite, Fe-hydrooxide and a graphitic substance are present. Zircone, tourmaline, pyrite and other ore minerals represent current accessories. In 2 samples actinolite, forming spherolitic aggregates, was observed. The texture of theses rocks is blastopsammitic, in places a laminar structure can be recognized.

Phyllites (samples 26, 29, 34, 44) are dark-grey fine-grained schistose rocks. In all samples quartz and sericite were found, a graphitic substance is also abundant. Chlorite, feldspar, muscovite, pyrite, biotite, Fe-hydrooxide and ore minerals also take part in the rock composition. Accessories are made up of apatite, tourmaline and zircone. The rock texture can be characterized as blastoaleuritic.

Biotite-muscovite hornfels (sample 36) is of a similar mineral composition as the phyllites, it differs in its appearance and mainly in the presence of a great amount of poikilitic muscovite porphyroblasts, a more considerable proportion of biotite, and in having expressionless spots. The groundmass is of a pavement character and is made up mainly of fine-flaky muscovite, biotite and chlorite, less of quartz and feldspar. The rock texture is porphyroblastic.

Graphitic phyllites (samples 15, 37) are made up of the following mineral association: Q + graphitic substance + pyrite, which forms parts of casted sulphides in sample 15. Sporadically or in accessory amount muscovite has been found. Both samples are of a heterogranoblastic texture.

Table 1

Silicate analyses of rocks of the Svojšín area

	40	31	35	45	36
SiO_2	50.96	65.60	70.41	67.82	62.39
TiO_2	1.30	0.94	0.56	0.52	0.69
Al_2O_3	15.90	15.96	13.44	14.55	17.16
Fe_2O_3	1.83	1.63	0.68	1.40	
FeO	5.60	4.39	3.87	3.94	6.62$^+$
MnO	0.12	0.06	0.05	0.06	0.06
MgO	5.95	2.20	1.71	2.13	2.22
CaO	9.76	0.66	1.00	0.71	0.86
Na_2O	3.96	2.62	2.92	2.82	3.09
K_2O	0.20	2.98	2.13	2.70	3.32
P_2O_5	0.25	0.13	0.62	0.08	0.70
H_2O	2.45	3.05	2.24	2.67	2.86
CO_2	2.19	0.24	NS	NS	NS
S	NS	NS	0.25	0.28	0.29
	100.47	100.46	99.88	99.68	100.26
Na_2O/K_2O	19.8	0.88	1.37	1.04	0.93

Note: Sample 40 — metabasics; 31, 35, 45 — metagraywackes; 36 — biotite-muscovite hornfels.
$^+$ total Fe as FeO, NS — not determined.

Metabasics (samples 28, 39, 40, 41, 42) are dark-greenishgrey to black fine--grained rocks, regularly without obvious foliation. Frequently they are penetrated by carbonate veinlets. In these rocks following minerals have been determined: actinolitic amphibole, feldspar, carbonate, in some cases muscovite (and/or sericite), biotite, chlorite, quartz, pyrite, and ore minerals. The most often accessories are klinozoisite and titanite; further ilmenite, epidote and Fe-hydrooxide were found. Nematoblastic, granoblastic, lepidoblastic and fibroblastic rock textures combine. Sample 27 represents an in detail undeterminable volcanosedimentary rock with a predominance of the volcanic component.

It appears, that all of the studied rocks suffered contact metamorphism within the aureole of the Kladruby massif, although in many cases the contact metamorphism is impossible to distinguish from the regional metamorphism.

Table 2

Contents of trace elements in rocks of the Svojšín area (ppm)

	metabasics					
	39	40	41	42	28⁺	27⁺⁺
Sc	42	66	54	74	26	34
V	320	220	350	220	190	200
Cr	340	67	320	83	350	31
Co	33	40	52	50	47	21
Ni	95	65	75	85	140	55
Th	ND	ND	ND	ND	2.7	0.82
U	6.2	ND	ND	ND	ND	5.6
Hf	1.6	1.5	1.7	1.9	3.0	2.9
La	1.8	1.8	2.2	3.3	13	8.4
Ce	9.4	2.3	9.8	4.6	31	2.6
Sm	0.60	2.5	2.1	2.9	3.9	1.7
Eu	0.78	1.5	0.90	1.4	1.6	1.2
Tb	0.52	0.86	0.58	0.76	0.60	1.0
Yb	2.1	3.3	1.6	1.8	1.3	0.85
Lu	0.48	0.40	0.15	0.14	0.16	0.12
La_N/Yb_N	0.6	0.4	0.9	1.2	6.7	6.7
Ce_N/Yb_N	1.2	0.2	1.6	0.7	6.2	0.8
Eu_N/Eu_N^*	1.86	1.40	1.09	1.25	1.24	1.27
Th/U	—	—	—	—	—	0.15

Geochemistry

Results of analyses are given in Tab. 1. and Tab. 2. and are discussed in detail in the paper by Matějka (1987). It can be stated, that metagraywackes display low Na_2O/K_2O values. They are intensively enriched in V and Cr and strongly impoverished in light REE in comparison with graywackes of an average composition (Wedepohl, 1968). An increased content of Sc is also characteristic. In chemical composition phyllites are very similar to metagraywackes. The trace-element distribution in these rocks even more emphasizes the fractionational trend of sedimentary rocks of this area. REE normalized curves of the Svojšín metasediments (Fig. 1) show a negative Eu anomaly ($Eu_N/Eu_N^+ = 0.81 \pm 0.12$). The graphitic phyllites represent a special group, in comparison with "normal" phyllites they are enriched in U, V, Ni and heavy REE, but on the other hand they have reduced contents of Th and light REE. This results in extremely low Th/U and La/Yb, and/or Ce/Yb values (Tab. 2).

Metabasics are characteristic by particularly low TR contents and by their considerably primitive distribution (Fig. 1). Obtained data do not allow an unambiguous decision whether they represent tholeiitic rocks of the ocean floor or island-arc tholeiites (Matějka, 1980).

1st continuation of Tab. 2

	metagraywackes							
	30	31	32	33	35	38	43	45
Sc	11.5	20	13	18	15	9.6	15	18
V	130	150	200	210	200	170	190	160
Cr	200	83	420	97	54	190	43	80
Co	4.4	12	7.0	10	8.0	6.0	9.4	11
Ni	25	45	40	45	40	40	20	35
Th	8.0	9.6	8.6	10.5	9.6	7.2	8.4	11
U	2.7	ND	2.7	2.1	2.7	ND	3.2	4.7
Hf	3.5	3.5	3.1	4.0	4.0	3.5	3.8	3.5
La	19.5	16.5	17	9.8	15	12	15	21
Ce	49	40	42	36	41	32	40	44
Sm	3.2	3.2	2.8	2.3	2.6	2.6	1.9	3.0
Eu	0.94	1.0	1.0	0.80	0.92	0.70	1.1	1.1
Tb	0.86	0.96	1.0	0.62	1.3	0.90	1.1	1.0
Yb	2.4	2.6	2.6	2.0	2.5	2.2	2.4	2.9
Lu	0.44	0.40	0.44	0.33	0.46	0.29	0.35	0.48
La_N/Yb_N	5.5	4.3	4.4	3.3	4.1	3.7	4.2	4.9
Ce_N/Yb_N	5.3	4.0	4.2	4.7	4.2	3.8	4.3	3.9
Eu_N/Eu_N^*	0.75	0.77	0.82	0.89	0.69	0.63	1.05	0.87
Th/U	3.0	—	3.2	5.0	3.6	—	2.6	2.3

The Svojšín metasediments display a pronounced positive correlation between Sc and Co (Fig. 2). The coefficient of serial correlation for 15 samples of the Svojšín metagraywackes, phyllites and graphitic phyllites reaches a high value — $R = 0.906$. This relation seems to be empirically very good for the Svojšín metabasics. Inclusion of 4 samples of metabasics (i.e. ommiting s. 28 hydrothermally altered) to the mentioned set raises the serial correlation coefficient to the value $R = 0.949$. Therefore, the mutual close relationship of the both elements seems to be a primary feature of the original basic rocks and its transition into metasediments is due to a considerable proportion of metabasics on the composition of these rocks. The revealed relationship thus represents a significant geochemical feature, enabling to characterize Proterozoic rocks of the studied area.

Discussion

Problems concerning source material of the Bohemian Upper Proterozoic rocks were solved so far on the basis of petrological studies. Cháb and Pelc (1973) studied Proterozoic graywackes of the NW part of Barrandien and considered them as typical eugeosynclinal. They regard acid to intermediate volcanics of an unclear provenience, interbasinal basic volcanics and sediments, extrabasinal crystalline schists and plutonites as principal sources of clastic material of these sediments. Jakeš et al. (1979) consider mainly ande-

2nd continuation of Tab. 2

	phyllites					graphitic phyllites	
	26	29	34	36+++	44	15	37
Sc	19	24	20	22	21	10	15
V	120	160	200	170	290	2900	1300
Cr	190	48	110	80	99	290	300
Co	16	16	14.5	13	14	7.5	11
Ni	45	45	45	50	45	270	150
Th	12.5	11	11.5	11	11	2.0	5.6
U	5.4	2.8	4.0	5.2	2.0	20.0	11.5
Hf	4.2	3.6	4.0	3.8	2.8	1.4	2.9
La	15.5	20	29	22	20	5.4	7.6
Ce	48	61	76	48	51	16	13
Sm	3.3	3.1	5.6	3.1	3.8	1.1	0.78
Eu	1.2	0.86	1.6	1.2	1.2	0.61	1.1
Tb	1.1	1.0	1.5	1.0	0.70	0.50	1.0
Yb	3.5	2.1	3.0	3.1	2.0	4.0	4.4
Lu	0.47	0.23	0.48	0.50	0.30	0.50	0.72
La_N/Yb_N	3.0	6.4	6.5	4.8	6.7	0.9	1.2
Ce_N/Yb_N	3.6	7.5	6.6	4.0	6.6	1.0	0.8
Eu_N/Eu_N^*	0.86	0.66	0.73	0.93	0.91	1.14	1.54
Th/U	2.3	3.9	2.9	2.1	5.5	0.1	0.5

+ altered metabasic; ++ in detail unspecified volcanosedimentary rock with predominance of the voicanic component; ND — the element was not determined; +++ biotite-muscovite hornfels.

sites and dacites of the calc alkaline suite (subordinately tholeiitic and shoshonite rocks) of island arcs as source material of the Upper Protezoric graywackes and metagraywackes of the Tepelsko—Barrandien region. Further calc-alkaline andesites (the And type) of the continental provenience and their depth equivalents (i.e. tonalites and granodiorites), then sporadically (in small amounts) alkaline basalts follow. Metamorphites are represented by rocks of the greenschist facies, being originally rather volcanics and their metamorphic equivalents than pelitic schists (J a k e š et al., 1979). From geochemical data these authors conclude, that graywackes of the Teplice—Barrandien Proterozoic do not contain ultrabasic or strongly basic material, they originated predominantly from geochemically undifferentiated material and include only a small amount of material of the continental granitic crust. Majority of geochemical features of these graywackes can be explained by the contribution of synsedimentary or presedimentary volcanism or its metamorphic equivalents (J a k e š et al., 1979).

Influence of synsedimentary (resp. presedimentary) volcanism conspicuously affects also the chemical composition of the Svojšín metasediments, but it concerns rocks of a tholeiitic character. From comparing the TR distribution in the Svojšín metabasics and metasediments it results, that these tholeiitic metabasics could not be the only source material of the metasediments. Even a component with a higher degree of TR differentiation must have taken part in the generation of these rocks. The established Th and U contents also correspond to this fact. On the basis of investigation of J a k e š et al. (1979) it is necessary to presume also the presence of rocks of andesite composition within the source material. If we consider an average composition of andesites (T a y l o r, 1968), then even a simple mixing of the tholeiitic and andesite component cannot explain low contents of Sc, Co, raised Hf, Th and U concentrations and finaly neither the TR distribution in some samples of the Svojšín metasediments.

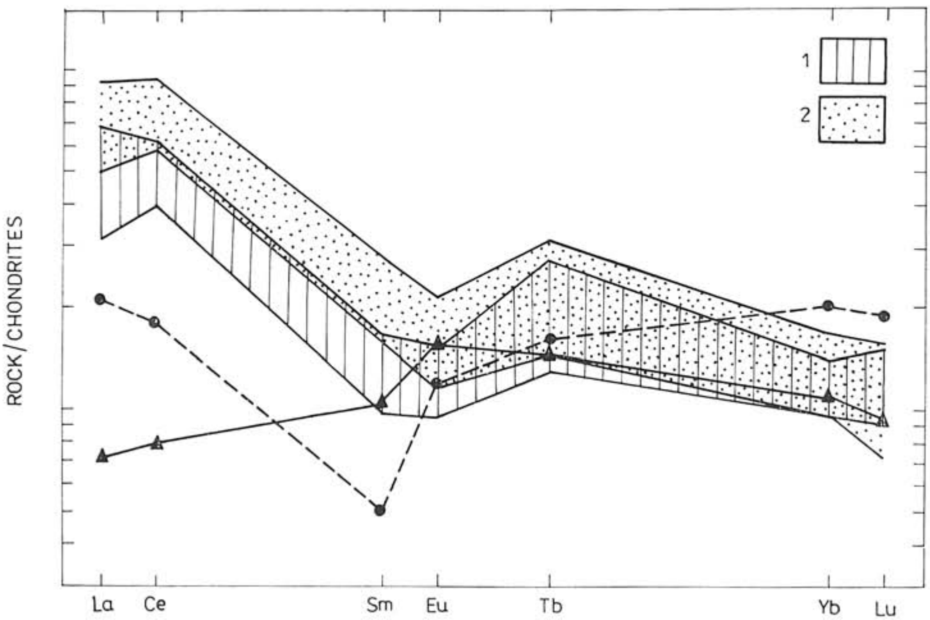

Fig. 1. REE distribution in rocks of the Svojšín volcanic strip.

Explanations: 1 — metagraywackes; 2 — phyllites; triangles — average of metabasics, circles — average of graphitic phyllites.

Hence, it is necessary to consider a third component, such, that would have low Sr, Co contents and raised Hf, Th, U and TR concentrations. This is best fulfilled by granitoid rocks or by their effusive equivalents. Also this aknowledgement is in agreement with conclusions of J a k e š et al. (1979). The mentioned authors, however, assign only little importance to this component. Likewise they point out, that typical eugeosynclinal graywackes of the Baldwin formation (NS Wales, eastern Australia) have a lower SiO_2 content than graywackes and metagraywackes of the Bohemian Upper Proterozoic. Source material of the Baldwin graywackes was prevailingly represented by rocks of the calc alkaline association of Island arc (N a n c e — T a y l o r, 1976, 1977).

Also J a k e š et al. (1979) and M a t ě j k a (1980) report a chemical similarity between the Barrandien Upper Proterozoic graywackes and metagraywackes with sediments of the Fig Tree group (S Africa) on whose composition also granitic rocks take part considerably (C o n d i e et al., 1970). Considering data of C h á b — P e l c (1973) it can be suggested, that also acid volcanics considerably participated in the origin of the Svojšín Upper Proterozoic metasediments.

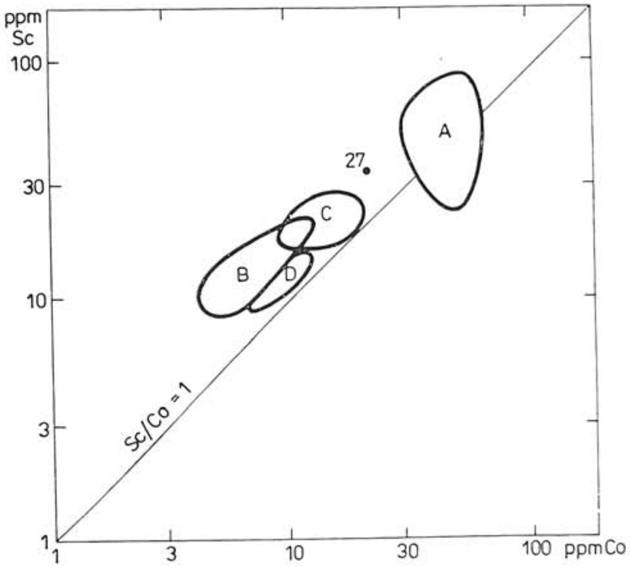

Fig. 2. Rocks of the Svojšín volcanic strip in the correlation diagram Sc vs.

Explanations: Co: A — metabasics (5 samples); B — metagraywackes (8 samples); C — phyllites (5 samples); D — graphitic phyllites (2 samples); 27 — volcano-sedimentary rock (see text).

Mixing models

The proportional representation of individual types of source material of the composition of Svojšín metagraywackes was verified on models based on a simplified presumption that the studied metagraywackes originated from mixing of following material: synsedimentary tholeiites, andesites and dacites of the calc alkaline island arc suite, calc alkaline andesites of the continental margins (the And type) and acid volcanics (C h á b — P e l c, 1973; J a k e š et al., 1979; M a t ěj k a, 1980).

An average of the Svojšín metabasics stands for the tholeiitic component in the model. These metabasics represent synsedimentary (and probably also presedimentary) volcanic material, directly taking part on the formation of the studied metasediments (Tab. 3).

Table 3

Contents of selected elements in initial rocks of models

	1	2	3	4
SiO_2 (%)	50.94	62.43	62.56	74.0
TiO_2	1.33	0.75	0.57	0.25
Al_2O_3	15.30	17.48	17.78	13.3
FeO^{tot}	7.71	4.46	3.97	1.7
MgO	5.59	2.01	3.06	0.3
CaO	10.15	5.34	4.93	1.5
Na_2O	4.57	3.94	4.63	4.0
K_2O	0.28	2.29	2.00	3.5
V (ppm)	260	115	136	8.5+
Cr	230	26	40	2
Ni	90	17	13	1
La	2.7	32	12.7	30
Ce	6.5	70	22.2	70
Yb	2.2	2.0	1.7	3.5

+ value according to Ewart et al. (1968)

Explanations: 1 — metabasics of the Svojšín area (Matějka, 1980) — the essential elements are represented by sample 40, the trace elements by an average value of the Svojšín metabasics; 2 — andesites of the Chilenian and Argentinian Ands (Dostál et al., 1977 — average of groups 3 and 4); 3 — andesites and dacites of the calc-alkaline island-arc group (Jakeš and White, 1971, 1972); 4 —average recent rhyolite (Condie, 1976).

Andesites and dacites of the calc-alkaline island arc suite are characterized by values available from recent island arcs. These data (Tab. 3) were calculated according to mutual proportional representation of both rock types mentioned in papers by Jakeš — White (1971).

Andesites of continental margins are represented by values refered by Dostál et al. (1977-group 3 and 4) for Miocene to Quaternary andesites of the Chilenian and Argentinian Ands (Tab. 3). In agreement with criterions of Jakeš — White (1972) these rocks can be assigned to typical andesites of continental margins. According to criterions of Gill (1981) they stand for calc-alkaline rocks of a medium to high K content, according to SiO_2 contents some of the samples represent even dacites.

An average recent rhyolite was chosen as representative of acid volcanics (Condie, 1976) (Tab. 3). Element selection for models was influenced mainly by the spectrum of gained data, availability of literature data and sensibility of individual elements towards metamorphism. On the basis of these criterions V, Cr, Ni and La, Ce Yb from the rare earth elements were chosen as most suitable. The behaviour of these elements was studied by much authors. but their results are not unambiguous. Transit metals are commonly considered as little mobile up to considerable degrees of regional metamorphism (e.g. Makrygina — Glazunova, 1978; Ronov et al., 1977). Garcia

(1978) regards only Cr as little mobile, while according to him V and Ni display mobility in dependance on increasing regional metamorphism. REE are usually considered as unmobile, at least up to the hornblende facies (Cullers et al., 1974; Garcia, 1978; Jakeš, 1984; Makrygina et al., 1980). According to Ronov et al. (1977) raising metamorphism can lead to a slight removal of heavy TR. As to the low-grade metamorphism of the studied metagraywackes, from this point of view, the mentioned elements can be considered as convenient with the given aim.

Models were made employing a method according to Bryan et al. (1969). Individual element contents in the consequent graywacke are marked Y_i ($i = 1, n$), where n is the number of studied elements. Element contents in source rocks are marked x_{ij} where i ($i = 1, n$) is the number of elements and j ($j = 1, k$) is the number of source rocks. The consequent amount of the individual elements in the mixture (in the consequent graywacke) is marked b_j $j = 1, k$).

The linear model is as follows:

$$\begin{array}{l} b_1x_{11} + b_2x_{12} + b_3x_{13} + \ldots\ldots\ldots\ldots + b_kx_{1k} = y_1 \\ b_1x_{21} + b_2x_{22} + b_3x_{23} + \ldots\ldots\ldots\ldots + b_kx_{2k} = y_2 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ b_1x_{n1} + b_2x_{n2} + b_3x_{n3} + \ldots\ldots\ldots\ldots + b_kx_{nk} = y_n \end{array} \tag{1}$$

This can be described by matrices

$$_nX_k\,{}_kB_1 = {}_nY_1 \tag{2}$$

By multiplying both sides of equation (2) by a transposed matrix X′ from the left, we obtain the expression

$$X'XB = X'Y \tag{3}$$

By multiplying both sides of equation (3) by a matrix $(X'X)^{-1}$ from the left, we obtain the wanted column vector B, representing an approach to the real vector B:

$$\hat{B} = (X'X)^{-1} . X'Y \tag{4}$$

Equation (4) gives one solution only if $n \geqq k$ (in the case of the studied models it was always fulfilled). If we substitute vector $\hat{B}$ for B in equation (2) hypothetical values $\hat{y}_i$, of minimal $S = \sum_{i=1}^{n} (y_i - y_i)^2$ with regard to original y_i values, can be calculated (Bryan et al., 1969).

More complicated models turned out to be unsuitable, models of 3 components proved most competent. We failed to make a model where besides

Table 4

Model composition of the Svojšín metagraywackes (ppm)

Model I	1	3	4	TMD	SMD
	62 %	4 %	34 %		
V	260	136	8.5	170	175
Cr	230	40	2	145	150
Ni	90	13	1	57	35
La	2.7	12.7	30	12	16
Ce	6.5	22.2	70	28	41
Yb	2.2	1.7	3.5	2.6	2.5
Model II	1	2	4	TMD	SMD
	59 %	17 %	24 %		
V	260	115	8.5	175	175
Cr	230	26	2	141	150
Ni	90	17	1	56	35
La	2.7	32	30	14	16
Ce	6.5	70	70	33	41
Yb	2.2	2.0	3.5	2.5	2.5

Note: Indication of source rocks given in Tab. 3, TMD — theoretical (model) metagraywacke, SMD — average of Svojšín metagraywackes.

calc-alkaline andesites and dacites of island arcs also andesites (and dacites) of the And type would take part in the composition of the final graywackes. The following 2 models, differing in their intermediate member, best correspond to the used data:

I. tholeiite 62 % + calc-alkaline andesites and dacites of island arcs 4 % + rhyolite 34 %.

As to limited occurrence of acid volcanics in the island-arc rock association thic model is little acceptable.

II. tholeiite 59 % + calc-alkaline andesites and dacites of the And type 17 % + rhyolite 24 %.
In regard to the representation of rock types in the continental margin rock association this model seems to be convenient.

Theoretical values calculated after both models are given in Tab. 4. By means of the gained proportions it was possible to calculate the representation of those main elements, that could be considered as distinctly resistent towards metamorphism of presumed degrees in a theoretical graywacke (Tab. 5). A disproportion in SiO_2 contents resists a good agreement with the average of the Svojšín metagraywackes — this disproportion together with differences in TiO_2, FeO^{tot} and MgO contents represent another argument for a high proportion of acid volcanic material in the studied rocks.

The elevated acidity of Teplice—Barrandien Proterozoic graywackes and metagraywackes in comparison with typical eugeosynclinal graywackes was

Table 5

Aplication of models to essential elements (%)

Model I	1	3	4	TMD	SMĎ
	62 %	4 %	34 %		
SiO_2	50.94	62.56	74.0	59.25	67.94
TiO_2	1.33	0.57	0.25	0.93	0.67
Al_2O_3	15.30	17.78	13.3	14.72	14.65
FeO^{tot}	7.71	3.97	1.7	5.52	5.18
MgO	5.59	3.06	0.3	3.69	2.01
Model II	1	2	4	TMD	SMD
	59 %	17 %	24 %		
SiO_2	50.94	62.43	74.0	58.43	67.94
TiO_2	1.33	0.75	0.25	0.97	0.67
Al_2O_3	15.30	17.48	13.3	15.19	14.65
FeO^{tot}	7.71	4.46	1.7	5.72	5.18
MgO	5.59	2.08	0.3	3.72	2.01

Note: Indication of individual columns is given in Tabs. 3, 4.

pointed out by Jakeš et al. (1979). Cháb — Pelc (1973) represent the approximate composition of detrite of the Upper Proterozoic graywackes of the NW part of Barrandien as follows: fragments of basic to intermediate volcanics 16 %, fragments of acid (to intermediate) volcanics 20 %, fragments of plutonites under 1 %, sedimentary detritus 5 %, metamorphic 3 %, undefined fragments 15 %, feldspars 23 %, quartz 15 %, accessories 2 %. As posible source of quartz mainly metamorphites, granitoides and acid volcanics are presumed. By distributing these 15 % of quartz between all of the 3 groups we obtain 10 % of pure SiO_2, with which the produced model does'nt count.

The greatest problem of the models is the selection of appropriate data. From this point of view synsedimentary metabasics, present directly in the studied area, are most reliable. Jakeš et al. (1979) — note above — succeeded in indifying the origin of intermediate volcanics. This should partly indicate also the origin of acid volcanics. However, a considerable variability of data exists even in terms of in this way specified source rocks (see e.g. Dostál et al., 1977). Yet, on the basis of the presented models, it can be concluded, that calc-alkaline rocks of continental margins played a much greater part in the generation of metagraywackes of the Svojšín area than the calc-alkaline rocks of island arcs. Also the TR distribution in the Svojšín metasediments supports this theory. The REE display only an unconspicuous positive Eu-anomaly in comparison with NASC (Haskin et al., 1966, 1968; Gromet et al., 1984), namely only in some samples ($Eu/Eu^{+} = 1,11 \pm 0,16$). This hardly gives an argument for a considerable representation of island-arc rocks according to Jakeš — Taylor (1974).

Conclusion

The Svojšín tholeiitic metabasics are characterized by low REE contents and by a distinctly primitive REE distribution. The metasediments are strongly enriched in Sc, V and Cr and strongly depleted in Co in comparison with average literature data. Graphitic phyllites display distinctly high U, V, Ni and heavy REE contents and are deficit in Th and light REE. All studied rocks display a conspicuous positive correlation between Sc and Co so characteristic of Proterozoic rocks of this area.

From trace-element distribution in the Svojšín metasediments it results, that these rocks are mainly made up of material of synsedimentary (ev. presedimentary) tholeiites with a substantial contribution of granitoid material, brought from an area of a developed continental crust. Material of calc-alkaline volcanics is also substantialy present, in its case the model of generation of a mean metagraywacke based on material mixing of the Svojšín tholeiites, rhyolites and intermediate volcanics strongly prefers calc-alkaline andesites and dacites of continental margins (the And type) instead of andesites and dacites of the island-arc calc-alkaline suite. The proportional representation of acid volcanics in the composition of the Svojšín metagraywackes after this model reaches approximately 25 %, yet it could be also higher.

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