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ANCHIMETAMORPHISM OF PERMIAN SANDSTONES OF THE STRUŽENÍK GROUP IN THE NÍZKE TATRY MTS. (WESTERN CARPATHIANS)

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Abstract: Permian sandstones, as the cover of the Veporic Nappe of tonalites in the Central Western Carpathians, were anchimetamorphosed during Middle Cretaceous folding events (at T up to 320 ^{o}C). This is shown by the presence of metastable phases (half-disintegrated clastogenic biotites and muscovites) as well as by the difference in the composition of clastogenic (muscovite) and authigenic (Ti-phengite, phengitic sericite) micas. The authors discuss the criteria for anchi- and epimetamorphism, as well as the possibilities of Alpine diaphtoresis of the crystalline basement.

Key words: Cretaceous folding, anchimetamorphism, sandstone, Veporicum, Western Carpathians.

Introduction

The determination of intensity and P-T parameters of Alpine metamorphism in the Western Carpathians is of a great importance for the development of a general geodynamic model for this region. The temperature parameters of the Alpine cycle can be best determined when studying progressive metamorphism of Permian - Triassic and Mesozoic rocks of the cover, especially where this complex is strongly dislocated, and together with rocks of the crystalline complex taking part in the system of Alpine tectonic nappes. In such tectonically strained zones we can expect maximal Alpine thermal flow and metamorphism.

In the presented paper, the authors discuss as an example low-temperature alterations of sandstones of the Struženík Group, representing the cover of a tonalite nappe on the northern slopes of the Kráľova hola Hill (Nízke Tatry Mts.).

Geological setting of Permian sandstones

The eastern part of the Nízke Tatry Mts. crystalline complex, east of the Čertovica line (Fig. 1) is formed by several tectonic units (Putiš 1981, 1982, 1987, 1989).

1 - The partial nappe of the Predná hoľa Hill (Bajaník et al. 1979), composed of the Predná hola complex (green schists, metakeratophyres, phyllites, marbles and metasandestones of Devonian age), related to the Rimavica Nappe (Maheľ 1986) thrusted from the southern Veporicum.

2 - The Kráľova hoľa series of nappes:

2.1 - the upper partial nappe of Vápenica (blastomylonitized tonalites);

2.2 - the lower partial nappe of Kráľova hoľa formed by the Kráľova hola complex (Klinec 1966, 1976) (augen K-feldspar-plagioclase blastomylonitized granites).

3 - The Hron series of nappes of the crystalline complex, which is represented in the studied region by the partial Hron Complex Nappe (Klinec 1976).

The Permian arkose metasandstones studied in the presented paper represent the basal part of the cover of the Kráľova hoľa nappe series crystalline complexes and they belong to the Struženík Group in some places here with Middle to Upper Triassic metalimestones, metadolomites and dark shales. They are confined between the tonalite nappe and the overlying Lower Triassic rocks of the Veľký Bok Group (Krížna Nappe).

U-Pb age determination of the age of magmatic zircons have shown that intrusion of tonalites took place 303 Ma ago (Bibikova et al. 1990) and intrusion of granites 268 - 274 Ma ago (unpublished data of the authors). Thus, they belong to the Upper Paleozoic magmatic complex. Gneiss xenoliths in granites contain andalusite and sillimanite (Putiš 1987).

Although the tonalites and granites preserve their magmatic structure and primary-magmatic minerals (brown magmatic biotites, microcline, plagioclase), they are strongly blastomylonitized. Low-temperature minerals are present: secondary biotite, muscovite, sericite, epidote, chlorite, albite, which are oriented along the mylonitic schistosity planes.

The first data on Alpine metamorphism of the Veporicum, on the example of the Foederata Group (analogy of the Struženík Group) and granitoids in its basement, have been presented by Vrána (1966, 1980).

Permian arkose sandstones, gritstones and phyllites

Psammites

The sandstones and gritstones wchich underwent low-temperature alterations belong to the class of typical arkoses with feldspar contents of over 25 %. Their structure is blastopsammitic (Fig. 2). The fragments are represented by regenerated grains of quartz, plagioclase, K-feldspar, biotite and muscovite. There are no signs of volcanic material.

The principal authigenic mineral of the sandstones is newly-formed fine-flaked sericite with very slight admixture of individual flakes of chlorite and in one case of carbonate. The cement is in most samples well-schistose, usually in a plane coinciding with the primary bedding. It is difficult to say how large a portion of the cement formed from primary aluminous material and how much as a result of the disintegration of clastogenic biotite and muscovite. Signs of such disintegration and "dissolution" of fragmental micas in the sericite mesostasis can be seen in each sample, however, with different intensity.

The clastic fraction contains:

1. Large angular or rounded grains of quartz, plagioclase and K-feldspar of clearly granitic origin. Quartz and plagioclase are predominant, K-feldspar occurs less frequently. Inside some quartz fragments there are preserved relics of brown magmatic biotite.

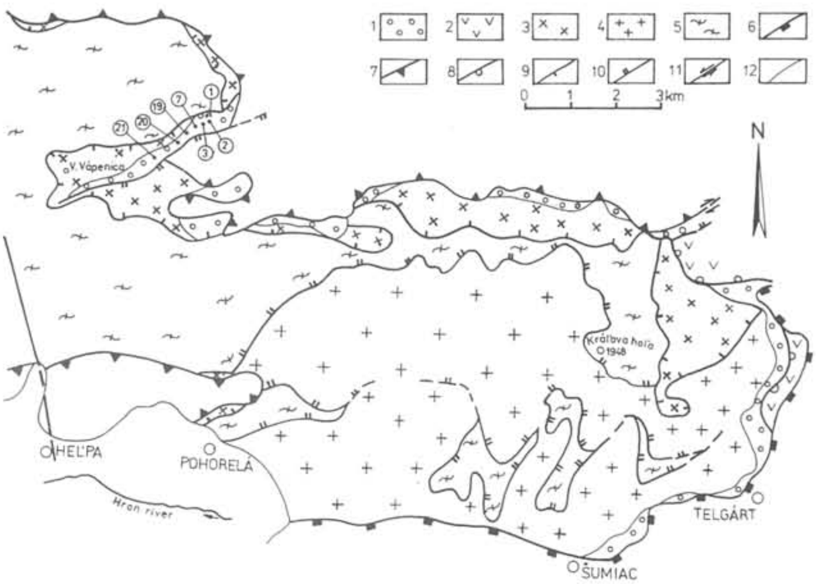

Fig. 1. Schematic sketch-map of the eastern part of the Nízke Tatry Mts.; contact area between Supra-Tatricum (in the N) and Veporicum (Putiš 1981, 1989).
Legend: 1 - Struženík Group (Permian - Triassic cover of Veporic granitoid nappes); 2 - Veporic Predná hoľa Nappe (Devonian basement rocks: greenschists, porphyroids, phyllites, metapsammites, and Struženík - type cover); 3 - metatonalites of Veporic Vápenica Nappe; 4 - metagranites of Veporic Kráľova hoľa Nappe; 5 - Supra-Tatric Hron Nappe (micaschists to gneisses, amphibolites, locally metagabbros, metaperidotites, serpentinites); 6 - overthrust plane of Choč Nappe; 7 - overthrust plane of Krížna Nappe (Supra-Tatricum); 8 - overthrust plane of Veporic Kráľova hoľa Nappe; 9 - overthrust plane of Veporic tonalite nappe; 10 - secondary thrusts; 11 - faults, strike-slips, tectonic boundaries; 12 - primary geological boundary.
Numbers in circles - localities of sampling.

Fig. 2. Permian sandstone texture. Locality 1, enlargement 45x, microscale - 0.5 *mm*.

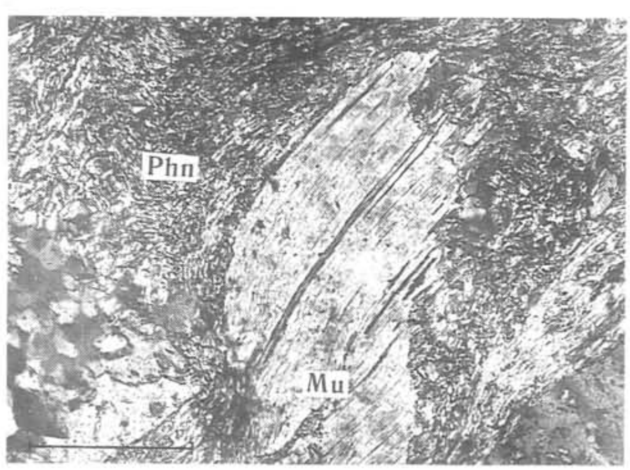

Fig. 3. Clastogenic muscovite in fine-grained sericite-phengite mesostasis. Loc. 3, enlargement 120 x, microscale - 0.5 *mm*.

2. Clastogenic flakes of coarse- and medium-grained muscovite, which are as to their shape and size identical with muscovites in granites, tonalites and augen-gneisses. Many flakes are kinked. In peripheral parts we can observe the disintegration of clastogenic muscovites and their resorbtion by fine-flaked sericite forming the mesostasis of arkoses (Fig. 3).

3. Clastogenic fragments of magmatic brown biotite, strongly recrystallized and decomposed. In the initial stage of resorbtion biotite flakes are corroded by colourless sericite only at their margins or along cleavage planes (Fig. 4a). Biotites at the same time become darker, almost black, acquiring isotropic properties and preserving not very marked pleochroism only inside the flakes. When more strongly regenerated, biotite plates disintegrate along cleavage into a series of thin fibres alternating with newly-formed sericite, but generally preserving the contours of primary biotite grain (Fig. 4b). During this process biotite fragments lose pleochroism and become opaque. As we shall show later, such biotite is almost totally substituted by metastable Ti-phengite.

4. Micro-pebbles (5 - 10 *mm*) of K-feldspar-plagioclase-quartz and muscovite-K-feldspar-quartz granites and plagioclase-quartz tonalites with normal hypidiomorphic texture.

5. Fragments of blastomylonitized quartz-feldspar augen-gneisses.

The structure of gritstones and arkose sandstones is various. In some thin-sections clastogenic muscovites and biotites are randomly distributed, at various angles to sedimentary banding. In other thin sections we can observe subparallel orientation of large muscovite fragments along bedding. The strongly discordant position of many clastogenic micas in relation to mesostasis and signs of their "dissolution" in authigenic sericite aggregate clearly prove pre-sedimentary, clastogenic and non metamorphic origin of large mica grains.

Aleurolites and phyllites

Sericite-quartz and chlorite-sericite-quartz aleurolites and phyllites is a minor group of rocks. They are composed mainly of sericite-chlorite-quartz mesostasis, in which small isolated grains of quartz, plagioclase, K-feldspar, clastogenic muscovite and half-decomposed biotite are predominant. The contrast between very fine-grained, even microcrystalline mesostasis and grains of clastogenic muscovite is in such rocks especially great.

Many aleurolites have good schistosity, usually consistent with bedding, or fine plication, but sometimes schistosity is entirely absent.

Mineralogy of arkose sandstones

Regenerated clastogenic minerals and newly-formed sericites from mesostasis of sandstones were analysed using the microprobe "CAMECA MS-46" at IGEM, Russian Acad. Sci. The results are presented in Tabs.1 - 5. The numbers of samples (localities) are according to the collection of M. Putiš.

Regenerated clastogenic biotites

We have analysed the inner, homogeneous parts of regenerated brown biotite flakes with residual pleochroism as well as without it. The results proved to be wholly unexpected (Tab. 1).

Note: The following abbreviations are used in the paper: Ab - albite, Act - actinolite, An - anorthite, Bi - biotite, Chl - chlorite, Cs - celsian, Ep - epidote, Ksp - K-feldspar, Leuc - leucoxene, Mgn - magnetite, Mu - muscovite, Ort - orthoclase, Phn - phengite, Q - quartz, Ser - sericite, Sld - seladonite.

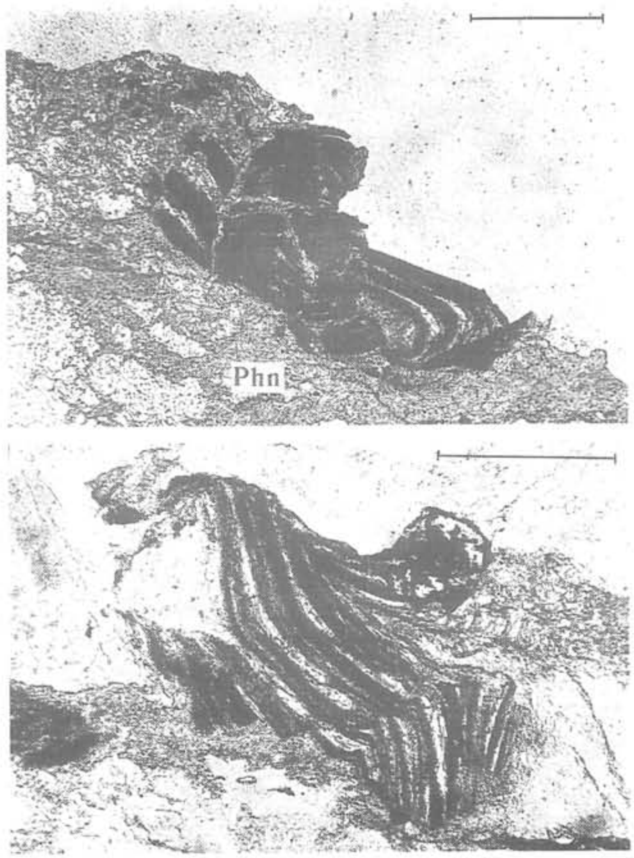

Fig. 4. Disintegration of clastogenic biotite (replaced by brown Ti-phengite) in fine-grained sericite-phengite mesostasis. Loc. 1: **a** - middle-stage disintegration, enlargement 100x, microscale 0.5 *mm*; **b** - high-stage disintegration, enlargement 140x, microscale 0.5 *mm*.

Table 1. Composition (wt.%) of clastogenic regenerated "biotites" (Ti-phengites).

Sample No.	1				21
Analysis No.	1	2	3	4	
Oxids					
SiO_2	49.77	47.19	53.92	52.17	50.50
TiO_2	2.64	4.04	3.69	2.35	2.47
Al_2O_3	22.36	21.28	20.75	21.02	21.36
FeO	6.04	5.46	4.35	5.01	4.90
MnO	-	-	-	-	0.04
MgO	4.38	3.80	2.49	2.98	3.35
CaO	-	-	-	-	-
K_2O	10.29	9.83	8.65	10.58	10.41
Na_2O	N.D.	N.D.	N.D.	N.D.	0.15
Total	95.48	91.60	93.85	94.11	93.18

Note: All studied samples, above and in the following tables (Nos. 1,2,3,7,19,20 and 21) are medium- and coarse-grained arkose sandstones with clastogenic grains of quartz, plagioclase, muscovite, regenerated biotite, sometimes K-feldspar, and newly-formed sericite cement. The samples were collected (Fig. 1) from a belt of arkose metasandstones northeast from the Priehyba saddle (N of Heľpa), between the valleys Vápenica and Dikula.

According to their SiO_2 contents, as well as the sum of FeO and MgO, the analysed micas correspond to phengite (the sum of FeO and MgO in biotites is approx. equal to 25 wt.%). Al_2O_3 contents in a number of micas (21 - 22 wt.%) are several times lower than in genuine phengites (compare with data in Tab. 3), however, a high content of TiO_2 compesates for this.

The main and very unusual feature of these phengites is the unusually high TiO_2 content reaching 3.7 - 4 wt.%, which is typical for high-temperature magmatic biotites and absolutely uncharacteristic for muscovites. Since we have not observed any fine inclusions of rutile or leucoxene inside the mica, we can only assume that biotite is substituted by phengite in which the Ti content is wholy inherited from the primary biotite.

These results show that during anchimetamorphic decomposition of biotite only the contours of its clastogenic flakes are preserved and biotite itself is pseudomorphologically substituted by fine-crystalline titanium-rich phengite. The dark-brown or black colour of the mica is caused by high titanium content and maybe by high oxidation grade of iron. A part of the surplus Fe released during phengitization of biotite remains in the pseudomorph in the form of iron hydroxide inclusions.

To prove the above mentioned conclusion, brown mica from sample 1 has been studied by S.V. Soboleva using electronographic method. The results have shown that the mica has a muscovite structure diagnosed above all by the reflexes 060, corresponding to b = 0.904 *nm*. With great difficulty have been detected the hardly discernible 060 reflexes with b = 0.922 *nm*, indicating sporadic relic packets of biotite in newly-formed phengite. The latter is represented by the modification $2M_1$, giving distinct reflexes on the ellipse I of the electronogram of textures ($\bar{1}14$, 024, $\bar{1}14$, 025 and others). The grade of completion is low. The parameters of the monoclinic lattice $2M_1$ of muscovite are: a - 5.22, b - 9.04, c - 19.80, β - 96°. Biotite is not represented by reflexes of the type $\overline{11l}$, 02l on ellipse I, which indicates its spatial disorder during the substitution. Only on ellipse II there is a clear reflex 133 (204) with d $\approx$ 0.244 *nm*, corresponding to biotite and superposed on the reflex 133 (202) of muscovite. No reflexes of independent Ti oxides of rutile type could be detected.

Thus, electronography confirmed the data obtained by microprobe analysis indicating that during anchimetamorphism biotite has been substituted by a special type of titanium-rich phengite with a low grade of structural completeness.

Clastogenic muscovites

Table 2 lists the compositions of large clastogenic muscovite flakes from arkoses and gritstones. They contain a small admixture of the phengite molecule (low amount of Mg and Fe) and vacancies in the group X are almost completely filled by alkalies, predominantly by K (the sum of cations in the group X is over 0.9). Thus, clastogenic muscovites are, as far as their composition is concerned, similar to the muscovite end member of the muscovite-phengite series, which is characteristic for micas formed in granitoids in early stages of the post-magmatic process (Spear 1984). Judging from the shape of the grains, they formed as a result of the erosion of large muscovitized granite and tonalite massifs exposed in the southern part of the region (Fig. 1).

Fine-flaked newly-formed sericite from cement

Analysed of fine-flaked sericites from mesostasis of arkoses and gritstones are listed in Tab. 3. The predominant majority of micas proved to be typical phengites enriched by Fe and Mg.

It is important to note that the grade of filling of vacancies in the group X in newly-formed phengites generally exceeds 0.9.

Table 2. Composition (wt. %) of large clastogenic muscovite flakes.

Sample No.		1				3	20
Analysis No.		6	7	8	9	10	11
Oxids							
	SiO_2	47.14	46.93	46.97	46.57	46.76	48.77
	TiO_2	1.57	0.72	0.58	0.48	0.77	0.40
	Al_2O_3	29.45	32.98	32.13	30.90	31.41	32.72
	FeO	4.16	4.03	4.20	4.21	4.04	3.76
	MnO	0.03	0.08	0.05	0.05	0.05	0.03
	MgO	1.18	0.81	0.88	1.14	0.75	1.62
	CaO	-	0.01	0.01	-	-	-
	K_2O	10.65	10.29	10.91	10.59	10.93	11.19
	Na_2O	0.20	0.47	0.43	0.26	0.40	0.20
Total		94.38	96.32	96.16	94.20	95.11	98.69
Crystallochemic formulae calculated to 6 cations of the groups Z+Y							
Z=4	Si	3.05	3.10	3.13	3.16	3.16	3.14
	Al_{IV}	0.95	0.90	0.87	0.84	0.84	0.86
Y=2	Al_{VI}	1.29	1.66	1.65	1.63	1.66	1.62
	Ti	0.08	0.04	0.03	0.02	0.04	0.02
	Fe	0.22	0.22	0.23	0.24	0.23	0.20
	Mn	-	-	-	-	-	-
	Mg	0.41	0.08	0.09	0.11	0.07	0.16
X	Ca	-	-	-	-	-	-
	Na	0.02	0.06	0.06	0.03	0.05	0.02
	K	0.88	0.86	0.92	0.92	0.94	0.92
	$\sum$ X	0.90	0.92	0.98	0.95	0.99	0.94

Table 3. Composition (wt. %) of fine-flaked sericite from newly-formed parts of the cement of arkoses.

Sample No.		2		3		7	20	1
Analysis No.		12	13	14	15	16	17	18
Oxids								
	SiO_2	51.12	49.86	48.47	50.52	49.54	48.64	49.03
	TiO_2	0.25	0.35	0.50	0.43	0.77	0.18	0.30
	Al_2O_3	28.88	24.12	24.21	25.38	23.47	27.39	24.80
	FeO	3.90	6.02	5.71	5.44	8.34	5.39	5.02
	MnO	0.04	0.04	0.03	0.03	0.04	0.04	0.03
	MgO	1.77	3.56	3.15	3.40	3.56	2.59	3.15
	CaO	-	0.03	0.04	0.11	-	-	-
	K_2O	11.12	10.88	10.81	11.07	10.36	11.59	10.60
	Na_2O	0.09	0.42	0.09	0.09	0.04	0.07	0.05
Total		96.76	95.28	93.01	96.47	96.12	95.89	92.98
Crystallochemic formulae calculated to 6 cations of the groups Z+Y								
Z=4	Si	3.38	3.36	3.36	3.36	3.31	3.27	3.28
	Al_{IV}	0.62	0.64	0.64	0.64	0.69	0.73	0.72
Y=2	Al_{VI}	1.63	1.28	1.33	1.35	1.15	1.43	1.23
	Ti	0.01	0.02	0.02	0.02	0.04	0.01	0.02
	Fe	0.19	0.34	0.33	0.30	0.46	0.30	0.28
	Mn	-	-	-	-	-	-	-
	Mg	0.17	0.36	0.32	0.33	0.35	0.26	0.31
X	Ca	-	-	-	0.01	-	-	-
	Na	0.01	0.05	0.01	0.01	-	0.01	0.01
	K	0.94	0.94	0.95	0.94	0.88	0.99	0.90
	$\sum$ X	0.95	0.99	0.96	0.96	0.88	1.00	0.91

This means that newly-formed micas in the cement of psammites are not represented by illites with a deficit of alkalies (Hunziker et al. 1986), but by common phengite-muscovite micas characteristic of the epizone determined for the Nízke Tatry Mts. cover rocks on the basis of Kübler's index (Plašienka et al. 1989).

To check if at least partly mixed-layer phases with expandable interlayer packets, typical for low grades of anchimetamorphism, have not been preserved in cement of the arkoses, the most fine-grained mica fraction (0.001 *mm*) was separated from sample 1. Three diffractograms were made for this fraction: 1 - of natural mica; 2 - of mica saturated by glycerine and 3 - of mica subsequently heated at 550 °*C*. As we can see from Fig. 5, there was no mixing or distortion of basal reflexes, confirming thus the total absence of mixed-layer micas even in the most fine-grained fraction of arkoses.

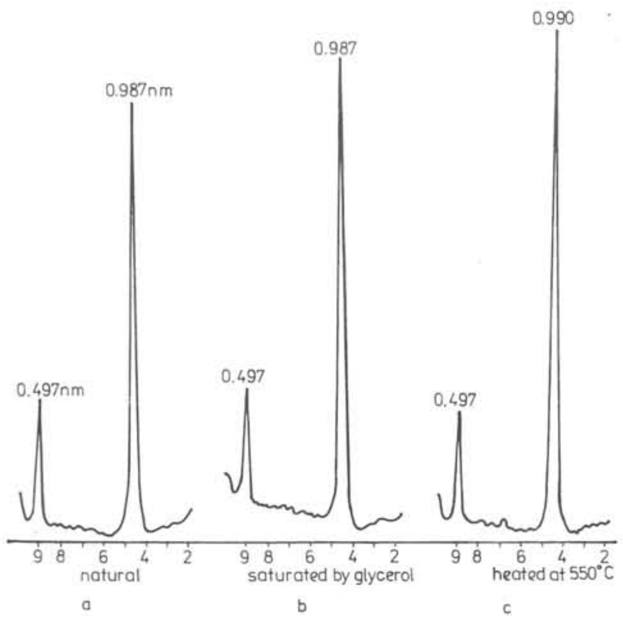

Fig. 5. Basal reflexes of sericite-phengite fraction *mm* on diffractogram: **a** - natural mica; **b** - saturated by glycerol, **c** - heated at 500 °*C*.

Electronographic study of this sericite fraction from cement has shown that it belongs to the modification $2M_1$, with considerably higher completeness of structure than the Ti-phengite substituting clastogenic biotite (see above). The parameters of the sericite lattice are: a - 5.20, b - 9.00, c - 19.97, β - 95.8°.

Fig. 6 shows well the difference between clastogenic muscovites and newly-formed phengites. High alkali contents in the group X (0.9 form. units) show that temperature of crystallization of both lies above the stability field of illites, however, the phengicity grade (the value of $Mg+Fe+Mn+Ti/\Sigma Y_{VI}$) of sericite micas is various and at low temperatures it depends only on the comosition of the rock.

Table 4. Composition (wt. %) of clastogenic K-feldspars from arkoses.

Sample No.		19				
Analysis No.		19	20	21	22	23
Oxids						
	SiO_2	65.32	65.22	64.45	63.85	63.11
	Al_2O_3	18.43	18.28	18.71	18.82	18.17
	CaO	0.01	-	0.01	0.03	0.06
	Na_2O	0.47	0.38	0.47	0.53	0.43
	K_2O	16.35	16.23	16.12	15.92	16.44
	BaO	0.25	0.23	0.47	0.93	0.36
Total		100.83	100.34	100.23	100.08	99.07
	Ort	94.90	95.80	94.30	92.30	95.00
	Ab	4.20	3.40	4.10	4.60	3.80
	Cs	0.90	0.80	1.60	3.10	1.20

Potassium feldspars

All clastic grains of potassium feldspar (Tab. 4) contain a small admixture of albite - not exceeding 4.6 %, and a considerable amount of celsian - up to 3 %. The presence of Ba-feldspar indicates the primary granitic character of K-feldspars. However, the low Na content makes them different from common granitic microclines and orthoclases. This is connected with anchimetamorphic recrystallization as a result of which high-temperature K-feldspars tend to change into Na-poor low-temperature adularia (Fig. 7).

Plagioclases

Plagioclases are clearly predominant and often the only feldspars in arkoses. They all belong to almost pure albites

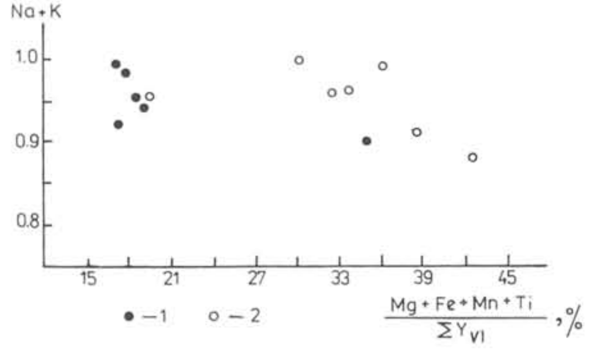

Fig. 6. Alcali content in the group X and phengicity grade in white micas of arcosses: 1 - clastogenic muscovites; 2 - newly-formed sericites-phengites from mesostasis (according to data in Tabs. 2 and 3).

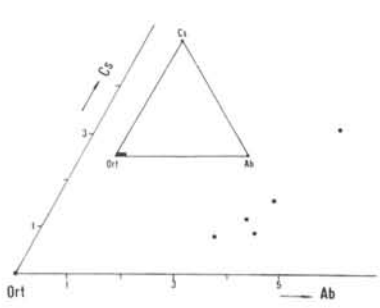

Fig. 7. Components of clastogenic K-feldspars on Ort-Ab-Cs diagram (according to data in Tab. 4).

Table 5. Composition (wt. %) of clastogenic plagioclases from arkoses.

Sample No.		1					3				19				
Analysis No.		24	25	26	27	28	29	30	31	32	33	34	35	36	37
Oxids															
	SiO_2	68.42	68.48	67.50	69.21	68.34	68.67	69.35	68.27	68.61	68.58	68.19	68.49	68.51	68.90
	Al_2O_3	19.50	19.87	20.13	19.29	19.22	19.81	19.38	19.34	19.65	19.,66	19.52	19.77	20.04	19.69
	CaO	0.06	0.34	0.99	0.06	0.01	0.04	0.08	0.03	0.01	0.17	-	0.03	0.76	0.01
	K_2O	0.21	0.10	0.08	0.09	0.06	0.34	0.07	0.04	0.09	0.07	0.04	0.05	0.05	0.05
	Na_2O	11.10	11.00	10.31	10.92	11.19	11.20	11.17	11.55	11.28	111.16	10.88	10.74	11.09	11.40
Total		99.29	99.79	99.01	99.57	99.82	100.06	100.05	99.23	99.64	99.64	98.63	99.08	100.45	100.05
	Ab	98.5	97.7	94.6	99.0	99.6	97.8	99.2	99.7	99.4	98.8	99.8	99.6	96.0	99.6
	An	0.3	1.7	5.0	0.3	0.1	0.2	0.4	0.1	0.1	0.8	-	0.1	3.7	0.1
	Ort	1.2	0.6	0.4	0.5	0.3	2.0	0.4	0.2	0.5	0.4	0.2	0.3	0.3	0.3

(Tab.5), with anorthite molecule contents not exceeding 5 % and orthoclase contents not over 2 % (Fig. 8). The K-admixture shows that plagioclases as well as K-feldspars are of primary magmatic origin. The loss of Ca is connected with recrystallization of clastic oligoclases into low-temperature albite.

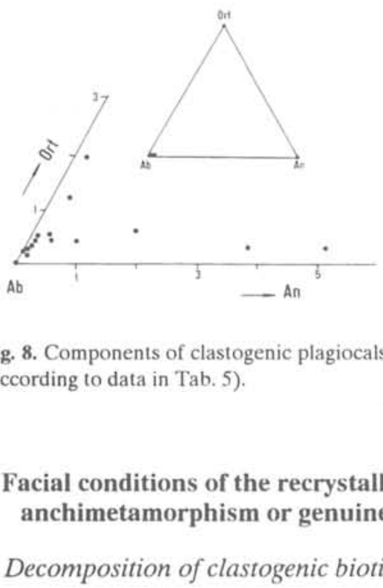

Fig. 8. Components of clastogenic plagiocalses on Ab-An-Ort diagram (according to data in Tab. 5).

Facial conditions of the recrystallization of arkoses - anchimetamorphism or genuine metamorphism?

Decomposition of clastogenic biotites

The substitution of biotites by titanium-rich phengites is a quite unusual process. However, analogous processes have already been described in petrological literature. McDowell & Elders (1983), in a work dealing with anchimetamorphic alteration of Neogene psammites in a borehole of the geothermal field Salton Sea in California, studied for the first time titanium chlorites substituting clastogenic biotites. They are of dark-brown colour, with high birefrigence and very high Ti contents identical to amounts of Ti in substituted clastogenic biotites of high-temperature genesis. According to McDowell & Elders, this anomalous chlorite is a transitional metastable phase formed only in anchimetamorphic conditions, and with the transition from epizone to the chlorite-sericite subfacies of metamorphism it is substituted by common, low-titanium greenish chlorite with ingrowths of leucoxene or rutile.

Thus, formation of transitional Ti-phengites in place of biotite is also possible. The metastable character of the phase and the reaction itself is indicated by the low grade of structure completeness of these phengites (see above). In thin sections (Fig. 4) we can see very well the transitional character of Ti-phengite, since continually there are discovered further substitutions by an aggregate of colourless sericite (phengite) in which TiO_2 content already does not exceed 0.77 wt.% (Tab. 3). The forming of fine-grained sericite aggregate in mesostasis reflects the progressive trend of anchimetamorphism in the Struženík Group, since colourless sericite is the final product of the substitution not only of clastogenic biotite, but also of clastogenic muscovite.

Mineralogical indicators of the grade of anchimetamorphism of Permian arkoses

The analyses of authigenic sericites (Tab. 3) have shown that they are not represented by illites, but by normal phengites of $2M_1$ modifications with a sum of alkalies not below 0.9 form. units. According to present criteria (Hunziker et al. 1986) this can mean that the grade of metamorphism of arkoses corresponds either to the epizone (the highest grade of anchimetamorphism), or the sericite-chlorite subfacies of metamorphism. However, it is not possible to determine solely on the basis of the composition and polytypes of authigenic white micas to which one of these two grades the metaarkoses belong, since they are identical in the epizone and in the chlorite-sericite subfacies (Frey 1986). The same can also be said of such signs as complete albitization and adularization of clastogenic feldspars and high grade of cleavage and fine plication.

Thus, in this case the most important criterion are data on the character of disintegration and composition of clastogenic biotites and muscovites. It is well known that in metapsammites and metapelites of the chlorite-sericite subfacies (Brown 1967; Mather 1970; Frey et al. 1988) there is full equilibrium between all minerals and any metastable phases or metastable equilibria between minerals disappear. Clastogenic biotites definitively disintegrate leaving practically no relics. Clastogenic muscovites can remain preserved, however, their compositions equalize with the composition of the surrounding mesostasis (Hunziker et al. 1986).

According to these characteristics, metaarkoses of the Struženík Group do not correspond to the criteria of the sericite-chlorite subfacies. The compositions of clastogenic muscovites and authigenic sericites in them are at immediate contacts even different (see Tabs. 2 and 3, and Fig. 6), which indicates an absence of equilibrium in the rocks. The second characteristic feature is the substitution of clastogenic biotites by metastable Ti-phengites, originating, like Ti-chlorites, only in anchimetamorphic conditions (McDowell & Elders 1983).

Thus, the joint study of the compositions of authigenic and clastogenic micas shows that reworking of Permian arkoses of the Struženík Group took place in the conditions of epizone of anchimetamorphism.

Anchimetamorphic reactions between clastogenic micas in the arkoses

To show the general reactions of decomposition of clastogenic muscovites and biotites, the following parameters have been plotted on the diagram Al-(K, Na) - (Mg, Fe) (Fig. 9): theoretical composition of granite biotites and real compositions of clastogenic muscovites, Ti-phengites (pseudomorphs after biotites) and sericite phengites from mesostasis of the arkoses (Tabs. 1 - 3).

On the diagram we can see that compositions of Ti-phengites and phengite authigenic micas are almost identical as far as Al(K+Na) and (Mg+Fe) are concerned. At the same time,

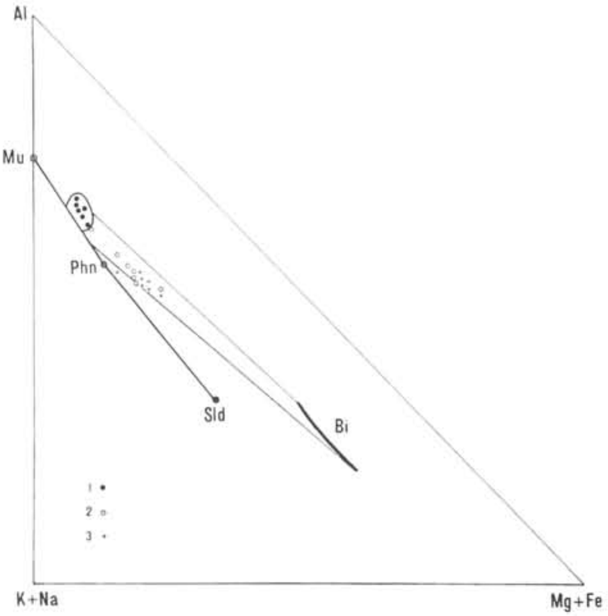

Fig. 9. Al-(K+Na) - (Mg+Fe) diagram of mica composition from metasandstones of the Struženík Group.
1 - clastogenic muscovites; 2 - newly-formed sericites and phengites from mesostasis; 3 - regenerated clastogenic biotites replaced by brown Ti-phengite.

they are lying on the connode Mu+Bi. This means that both types of newly-formed phengites could originate as a result of a simple reaction between clastogenic muscovites and biotites during their progressive decomposition, e.g.:

$$Bi_{clast} + Mu_{clast} \rightarrow Phn_{Ti}$$

$$Bi_{clast} + Mu_{clast} \rightarrow Phn_{Ser} + Leuc$$

In this process metastable browm Ti-phengites and stable light-coloured sericites in mesostasis form simultaneously. With further temperature increase metastable Ti-phengites are in turn substituted by light-coloured sericite and leucoxene:

$$Phn_{Ti} \rightarrow Phn_{Ser} + Leuc$$

After the conclusion of these anchimetamorphic reactions, clastogenic muscovites and biotites should be completely substituted by an aggregate of colourless fine-grained sericite, which would mark the transition to the chlorite-sericite subfacies of metamorphism. However, this stage has not been reached in the Alpine cycle of recrystallization of Permian psammites.

The temperature of anchimetamorphism of the studied Permian rocks can be estimated only approximately, on the basis of an analogy with other objects with well determined temperature. Thus, in the geothermal field of Salton Sea (McDowell & Elders 1980, 1983), the appearance of the isograd of newly-formed biotite corresponds to 320 °C, the decomposition of clastogenic biotite in the interval from 200 to 300 °C.

The low-temperature character of Alpine progressive anchimetamorphism proves that the synchronal as far as temperature and parageneses are concerned - diapthoresis of crystalline rocks was hardly of great extent and apparently it was limited to zones of uong tectonization and crushing, permeable for low-temperature fluids.

However, the reaching of the 300 °C isotherm during Alpine tectonogenesis should have led to regional loss of radiogenic Ar from high-temperature micas in rocks of the crystalline fundament. The related K-Ar rejuvenation of granitoids and metamorphic rocks of the Western Carpathians can be very well registered by radiological methods (Burchart et al. 1987).

Conclusions

1 - Microprobe study of the compositions of authigenic and clastogenic minerals from Permian metasandstones of the northern slopes of the Kráľova hoľa Hill has shown that conditions of their recrystallization correspond to an epizone of anchimetamorphizm with temperatures of 250 - 30° C.

2 - Authigenic sericites do not belong to illites, but to Mg- and Fe-rich $2M_1$ phengites with the sum of alkalies not lower than 0.88 - 0.9 form.units.

3 - Metastable Ti-phengites, with a low grade of structural completenes, have been identified for the first time, as products of the decomposition of clastogenic biotite, during anchimetamorphism.

4 - Clastogenic muscovites are not changed; their composition corresponds to Mg- and Fe-poor muscovites from mica granites. Plagioclases are almost completely albitized and K--feldspars are substituted by low-natrium adularia.

5 - Anchimetamorphic reactions of the decomposition of clastogenic phases have isochemic character.

Translated by K. Janáková

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