ILLITE-PARAGONITE LAYER INTERGROWTHS FROM THE GEMERICUM NAPPE IN THE NE PART OF THE ČIERNA HORA MTS. VEPORICUM (WESTERN CARPATHIANS)

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Abstract: In anchimetamorphosed Upper Carboniferous metapsammites of the Gemericum Nappe thrusted onto the Mesozoic mantle of the Čierna Hora Mts. crystalline complex, there are authigenic mixed-layer illite-paragonite micas or their disintegration products - a mixture of discrete illite and paragonite flakes. Clastogenic biotites have been replaced by metastable brown Ti-biotite. Phase equilibria of anchimetamorphism of these rocks have been determined on the basis of electron microanalyses and diffractograms of authigenic as well as clastogenic micas. According to mineral indicators, the recrystallization temperature of these rocks corresponds to the boundary of medium and high grade of anchizone and it did not exceed 250 °C.

Key words: Paleo-Alpine nappes, Upper Cretaceous upthrust zones, anchimetamorphic conditions, authigenic mixed layer and clastogenic micas, incomplete equilibrium.

Introduction

Veporicum of the Čierna Hora Mts. belongs to regions where geological conditions allow to solve such important problems of the Western Carpathian Internides as the one concerning the equal or different intensity of Alpine metamorphism related to thrusting of paleo-Alpine (lower Cretaceous) nappes, or to the formation of Upper Cretaceous upthrust zones of Čertovica, Pohorelá or Margecany type.

On the Upper Paleozoic – Mesozoic mantle of the Čierna hora Mts. crystalline complex there are preserved nappe fragments of the Carboniferous and Permian of Gemericum, which are together with the underlying sequences rhytmically cut by regional upthrust zones having NW-SE direction, medium to steep inclination predominantly to NW (Jacko 1979). The most prominent one - the Margecany upthrust zone - is at the same time the boundary between the eastern margin of the Gemericum unit and Veporicum of the Čierna hora Mts.

In this contribution the authors present the results of a study of metamorphism of Upper Carboniferous metapsammites forming the basal part of Gemericum Nappe fragments lying on Jurassic limestones near the SW margin of the Čierna hora Mts. Veporicum (Fig. 1) - however, outside the relevant upthrust zone (i.e. the Bujnisko upthrust zone, Jacko 1979). The study of minerals from anchimetamorphic rocks of various regions has shown that the composition and structural features of authigenic as well as clastogenic micas allow to distinguish the thermal stages of anchimetamorphism (Frey 1987; Hunziker et al. 1986; Kisch 1983; McDowell & Elders 1983; Merriman & Roberts 1983). Important indicators of temperature are: the sum of alkalies and the ratio Na/Na+K in authigenic white mica, the presence or absence of mixed-layer phases in them, the recrystallization grade of 1 Md polytypes in $2M_1$, authigenic replacement of clastogenic biotites by equilibrium or inequilibrium phases etc.

Slightly regenerated biotite and muscovite flakes have been preserved in the clastogenic fraction of the studied Upper Carboniferous metapsammites. A microcrystalline aggregate of authigenic phengite micas is predominant in the matrix, the sum of K+Na in the group X varying from 0.78 to 1.0 formula units. The alkali deficiency in some of them (0.77 – 0.85 form. units) points to illite character of phengites (Robinson & Bevins 1986; Frey 1986; Hunziker et al. 1986; Eberl et al. 1986) and to the thermal boundary of medium and high grade of anchizone.

Petrographic composition of rocks

Predominant rocks of the Gemericum Nappe fragments lying on the mantle sequences of the Čierna hora Mts. Veporicum are Upper Carboniferous metapsammites and metaaleurites (Jacko 1978). The studied metasediments have been collected in the area of Spálený Hill, where the most extensive relics of the Gemericum Nappe has been preserved.

The medium- to fine-grained metapsammites have a not very markedly developed schistosity subparallel to bedding. Semi-oval to sub-angular clastogenic material mostly consists of quartz and plagioclases, rarely of K-feldspar flakes or only slightly altered muscovite and strongly regenerated biotite. Metapsammites have the composition of sandstones, and often also of typical arkoses (Fig. 2). Authigenic minerals of the matrix are predominantly represented by sericite, less by quartz and albite. The metapsammites are in schistose deformation zones and they contain thin diagonal quartz veinlets.

Metaaleurites frequently contain subparallelly deposited clastogenic mica, less feldspars, which are often missing altogether (Fig. 4). The sericite-quartz matrix of many aleurites contains a considerable portion of bituminous component. The distinctly crystalline sericite aggregate contains flakes having a size of up to 0.01 *mm*.

Composition of clastogenic and authigenic minerals

Two typical samples - of a mataaleurite (Fig. 4) and of a metasandstone (FIg. 2) - have been selected for the study by electron microanalyser.

Clastogenic muscovites (Tabs. 1, 2) have a composition typical of muscovites from granitoids, or of muscovites of high-temperature two-mica gneisses (Guidotti 1981). Their characteristic features are the variable and generally low grade phengicity (Mg, Fe contents), low Na/Na+K ratio - up to 9 %, the sum of Na+K in the crystallochemic formula being 0.9 – 1.0. If it should be proved that they are identical with muscovites of two-mica gneisses from the Rakovec Formation of Gemericum, it would be a further argument in favour of Variscan nappe position of the formation (Grecula 1982).

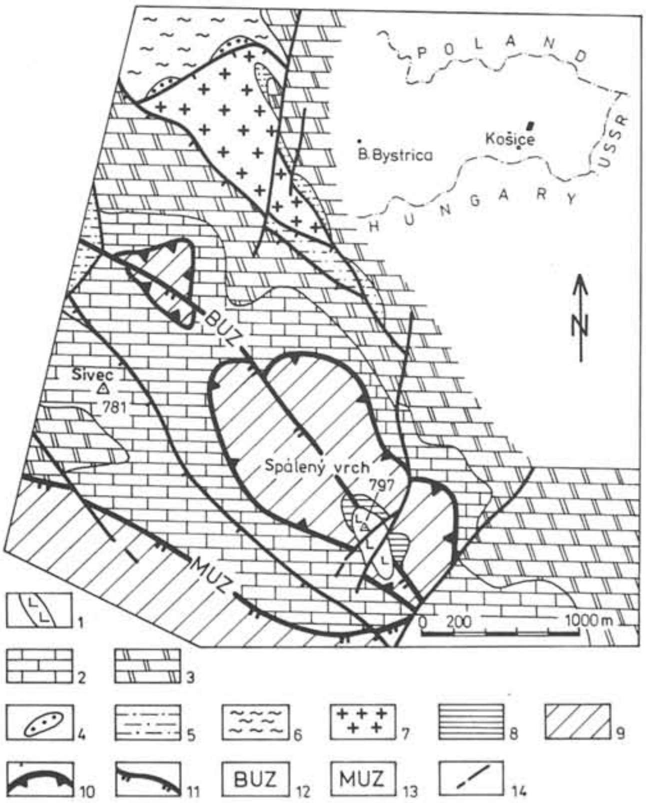

Fig. 1. A schematic geological-structural map of the Spálený Hill region.
1 - amphibole-pyroxene diorite (Upper Cretaceous?); 2-7 - Veporicum of the Čierna hora Mts., 2-5 - mantle units: 2 - thin-bedded limestones (Jurassic in general), 3 - dolomites (Middle and Upper Triassic), 4 - quartzose sandstones (Lower Triassic), 5 - shales and graywackes (Permian); 6-7 - the Bujanová crystalline complex: 6 - gneisses (Lower Paleozoic), 7 - biotite granodiorite (Lower Paleozoic); 8-9 - Gemericum: 8 - shales (Permian), 9 - shales, sandstones, basic metavolcanics (Carboniferous); 10 - thrust plane of the Gemericum Nappe; 11 - regionally significant upthrust zones: 12 - BUZ Bujnisko upthrust zone, 13 - Margecany upthrust zone, 14 - faults.

In contrast to muscovite, flakes of clastogenic biotite are very strongly regenerated. The originally brown colour changed into almost black, the flakes lost their pleochroism and they are often changed into isotropic individuals. Similar micas are frequently classified as "hydrobiotite". Electron microanalyses have shown that clastogenic biotites are pseudomorphosed by dark-brown chlorite, this having been confirmed also by diffractography. Analytical data on chlorite can be - after excluding the alkali admixture - recalculated very well to standard chlorite formula consisting of 10 cations of the group Y and Z (Tab. 1).

Anomalous K_2O contents - up to 1.4 % - can be explained either by sporadically preserved relic "packets" of biotite in newly formed chlorite, or by sporadic presence of thin illite layer inclusions (White et al. 1985). According to electron microanalyses of analogous preudomorphs (Veblen & Ferry 1983; Al Dahan & Morad 1986), K-mica relics in chlorite can attain a size of up to 5μ. These sizes are below the distinguishing capability of the used apparatus and thus the analytical results represent average chlorite analyses including layer inclusions of K-micas. The quantity of such inclusions - judging from the K_2O admixture in the analysed micas - changes from flake to flake.

The composition of authigenic micas from the matrix of metaaleurites and metasandstones (Tabs. 1, 2) proved to be unusual. They have low content of phengite and in contrast to muscovites they almost do not contain Ti (Fig. 2). The content of alkalies varies from 0.78 to 0.91 form. units. The Ca deficiency in the group X indicates that authigenic micas belong to illites.

Especially unusual is the exceptionally high ratio Na/Na+K in the authigenic micas (11 – 51 %, Tabs. 1, 2). To check these results, additional determination of alkalies by electron microanalyser has been carried out in authigenic sericite from another thin-section of metaaleurites (Fig. 4). The following results have been obtained:

	1	2	3	4	5
K_2O wt.%	6.21	7.87	7.06	8.75	8.88
Na_2O	2.40	1.52	1.74	0.97	1.02
Na/Na+K %	36.9	22.7	27.2	14.4	15.1

The range of the ratio Na/Na+K corresponds to values obtained by complex microelectron analyses. Since low-temperature illites or muscovites-phengites have very low Na-contents (Guidotti 1984; Frey 1987; Hunziker et al. 1986; Al Dahan & Morad 1986; Korikovsky et al. 1989, 1992), we can assume that the studied micas belong to layer intergrowths of illite and paragonite (Frey 1969). This problem has been studied using diffractometry of

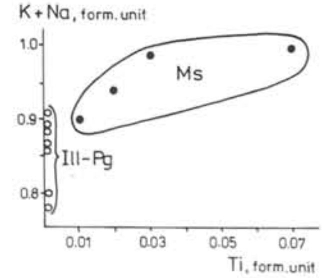

Fig. 2. Ti-contents and the sum of alkalies in authigenic illite-paragonite and clastogenic muscovite micas.

Table 1. Composition of authigenic and clastogene minerals from metaaleurites (see Fig. 4).

	Metastable Ti-chlorites (pseudomorphs after biotite)			Authigenic illite-paragonite micas from matrix						Clastogene muscovites	
	Ti-Chl			Ill-Pg						Ms	
SiO_2	31.17	28.04	25.88	47.19	49.22	49.00	46.59	50.54	48.90	46.01	47.10
TiO_2	1.52	0.18	1.72	0.07	0.02	0.07	0.07	0.07	0.27	1.32	0.43
Al_2O_3	24.27	22.38	20.07	33.53	36.25	34.02	35.15	36.76	32.24	29.69	32.55
FeO	27.63	27.55	31.71	0.80	0.55	1.04	1.06	0.72	1.04	4.20	0.98
MnO	0.23	0.27	0.28	-	-	-	-	-	-	0.03	-
MgO	6.17	5.36	5.87	0.48	0.33	0.55	0.48	0.41	1.03	0.75	0.36
CaO	0.20	0.15	0.20	-	0.04	0.01	-	-	0.01	-	-
K_2O	1.21	1.43	0.45	8.78	4.87	8.95	8.36	8.16	9.13	10.51	9.47
Na_2Do	0.12	0.20	0.08	0.98	3.79	1.11	0.71	1.00	0.96	0.53	0.82
Total	92.52	85.56	86.26	91.83	95.07	94.75	92.42	97.66	93.58	93.04	91.71
$\frac{Fe}{Fe+Mg}$, %	71.5	74.3	75.2								
Crystallochemic formulae racalculated to 10 (Ti-Chl) and 6 (Ill-Pg and Ms) cations of the group Z + Y											
Z: Si	3.34	3.27	3.00	3.21	3.18	3.24	3.12	3.19	3.28	3.19	3.24
Z: Al_{IV}	0.66	0.73	1.00	0.79	0.82	0.76	0.88	0.81	0.72	0.81	0.76
Al_{VI}	2.41	2.35	1.74	1.90	1.94	1.89	1.89	1.92	1.83	1.61	1.88
Y: Ti	0.12	0.01	0.15	-	-	-	-	-	0.01	0.07	0.02
Y: Fe	3.06	2.68	3.06	0.05	0.03	0.06	0.06	0.04	0.06	0.24	0.06
Y: Mn	0.02	0.03	0.03	-	-	-	-	-	-	-	-
Mg	0.99	0.93	1.02	0.05	0.03	0.05	0.05	0.04	0.10	0.08	0.04
Ca	0.02	0.02	0.02	-	-	-	-	-	-	-	-
X: Na	0.03	0.04	0.02	0.13	0.47	0.14	0.09	0.12	0.12	0.07	0.11
X: K	0.16	0.21	0.06	0.76	0.40	0.75	0.71	0.66	0.78	0.93	0.83
ΣX				0.89	0.87	0.89	0.80	0.78	0.90	1.00	0.94
$\frac{N}{Na+K}$, %				14.6	54.0	15.7	11.2	15.4	13.3	7.0	11.7
$\frac{Fe+Mg+Ti}{\Sigma Y}$, %				5	3	5.5	5.5	4	8.5	19.5	6

Paragenesis: Ill-Pg+Qtz+[Ms+"Bt"±Pl+Qtz] clast

sericites. The fraction under 2μ was separated from samples 1 and 3 and diffractograms of unoriented as well as oriented preparations from original as well as ethylene glycol-saturated samples have been evaluated. We obtained the following results:

1. The value of the Ir index in both samples is lower than 1 (Srodon & Eberl 1984). This means that the studied illites do not contain expandable intralayer "packets" - i.e. they do not belong to the category of hydromicas.

2. Both micas belong to pure polytype modification $2M_1$, from which it follows that the grade of anchimetamorphism of the rocks is considerable.

3. The diffractogram of mica from sample 3 (Fig. 3) shows that it is a mixed-layer illite-paragonite phase (Frey 1969; Kisch 1987; Merriman & Roberts 1985).

At the same time, a two-phase mixture of discretes illite and paragonite flakes has been determined in sample 15; it formed probably by disintegration of a much older mixed-layer mica. The sizes of illite and paragonite individuals are probably smaller than 5 μ and microelectron analyses yield a certain type of average composition.

Clastic plagioclases occur only in metasandstones (Tab. 2), they are partly albitized. Individual grains contain up to 6 % of anorthite component.

The significance of authigenic illite-paragonite micas

Analyses of low-temperature illites and muscovites-phengites from various regions show that the Na/Na+K ratio in them is low and varies in the range of 1 – 6 %. It increases - up to the maximal value of 30 – 35 % - only with temperature increase in the garnet or staurolite-chlorite subfacies (Korikovsky 1973; Guidotti 1984).

On the diagram of "phengicity grade" (Fig. 4) the relationships of Fe, Mg+Ti/Y vs. Na/Na+K in authigenic illites-phengites are plotted, the samples coming from some mantle units of the Western Carpathian crystalline complexes, and - for a comparison - also from sediments of the Central Alps (Hunziker et al. 1986) on the example of which the present criteria for anchimetamorphic stages have been defined (Frey 1986). From the diagram it is evident that the predominant majority of illites and phengites from the studied anchimetamorphic rocks the ratio Na/Na+K, i.e. the "natrium" grade, does not exceed 6 – 7 %.

From the above mentioned set (Fig. 4) clearly different are illites-paragonites from Upper Carboniferous metaaleurites of the Gemericum Nappe from the Spálený Hill of the Čierna Hora Mts. (Tab. 1), as well as illites-paragonites from the Central Alps (Hunziker et al. 1986), in which the Na/Na+K ratio attains 54 %. The ratio Na/Na+K in illites-paragonites from anchimetamorphic complexes of other regions varies from 9 to 60 % (Hunziker

Table 2. Composition of authigenic and clastogene fraction from metaarcoses (see Fig. 2).

	Mixture of discrete illite and paragonite flakes			Clastogene minerals		
	Ill + Pg			Ms	Pl	Pl
SiO_2	49.37	49.35	49.13	49.26	66.32	67.25
TiO_2	0.03	0.03	0.07	0.60	-	-
Al_2O_3	35.10	36.29	35.65	33.91	21.05	20.00
FeO	0.82	0.49	0.54	0.82	0.01	-
MnO	0.03	-	-	-	-	-
MgO	0.36	0.23	0.22	0.63	-	-
CaO	0.04	-	-	0.01	1.44	0.08
K_2O	8.29	5.34	6.53	10.23	0.12	0.05
Na_2O	1.78	3.64	2.51	1.04	11.66	11.98
Total	95.82	95.37	94.65	96.50	100.60	99.36
An, %					6.4	0.4

Crystallochemic formulae recalculated to 6 cations of the group Y + Z

Z = 4 { Si	3.22	3.19	3.21	3.24
Z = 4 { Al_{IV}	0.78	0.81	0.79	0.76
Y = 2 { Al_{VI}	1.92	1.95	1.95	1.87
Y = 2 { Ti	-	-	-	0.03
Y = 2 { Fe	0.05	0.03	0.03	0.04
Y = 2 { Mg	0.03	0.02	0.02	0.06
X { Ca	-	-	-	-
X { Na	0.22	0.45	0.32	0.13
X { K	0.69	0.44	0.54	0.86
ΣX	0.91	0.89	0.86	0.99
$\frac{N}{Na+K}$,%	24.2	50.6	37.2	13.1
$\frac{Fe+Mg+Ti}{\Sigma Y}$,%	4	2.5	2.5	6.5

Paragenesis: Ill-Pg+Qtz[Ms+Pl+Qtz] clast

et al. 1966; Merrimann & Roberts 1985; Robinson & Bevins 1986), their stability not exceed the parameters of medium grade of anchizone. In high grades of anchizone mixed-layer illites-paragonites disintegrate into a two-phase mixture of illite and paragonite. The presence of both micas in Upper Carboniferous rocks of the Gemericum Nappe, on the Spálený Hill in the Čierna hora Mts. proves that their metamorphic assemblages correspond to the temperature boundary of medium and high grade of anchizone.

The study of anchimetamorphic zones in various regions (Frey 1969) has shown that illite-paragonite mixed-layer micas and smectites disintegrate with temperature increase already in the conditions of diagenesis and low-grade anchizone. Therefore, the reaction Ill-$Pg_{mixed\ layer} \rightarrow$ Ill+Pg, expressing the stability boundary of mixed-layer micas in general, should not be evaluated from the viewpoint of the real mineralogical boundary of anchi- and epizone. At present, Kübler's crystallinity index is used for the determination of the boundary of these zones; this is less suitable, since it has been demonstrated that there is no simple relationship between this constant and the composition of illite.

Illite-paragonite mixed-layer micas have been only very rarely described since their identification (Frey 1969). This has been caused by the fact that among the conditions of their formation is not only low temperature, but also specific rock composition. The diagram "adularia-albite-pyrophyllite" (Fig. 5) shows the principially possible equilibria of white micas and feldspars in medium (Fig. 5-1) and high (Fig. 5-2) grade of anchizone. From the figures it is evident that paragonite is stable only in rocks relatively rich in Al, with a high Al/Na ratio. The most frequent paragenesis of the majority of clastogenic rocks, Ill+Ab (1) corresponds to a low value of the ratio Al/Na, the paragenesis Ill-Pg/or Ill+Pg/+AB to medium-high value of the ratio and the stability of mixed-layer illites-paragonites (or of the bimineral mixture Ill+Pg) without albite corresponds to maximal ratio of Al/Na. By the way, high Al-contents in the rocks (Fig. 5) explain also the unusually high Al content and at the same time low Mg and Fe contents in illite paragonite micas.

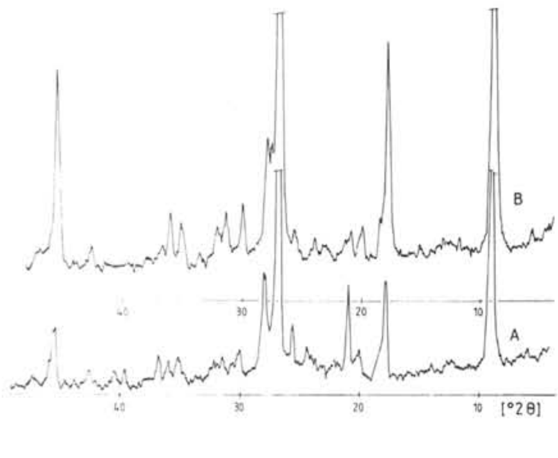

Fig. 3. X-ray diffraction records of oriented preparations of authigenic micas from Upper Carboniferous metasediments of the Gemericum Nappe on the Spálený Hill, Čierna hora Mts. - fraction under 2 μ (Figs. 2, 4).
B - sample with reflexes typical for mixed-layer muscovites paragonites (according to Frey 1987); A - without reflexes of Mu/Pa.

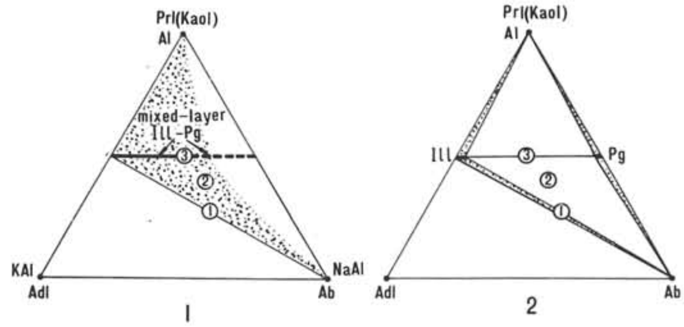

Fig. 5. Principal equilibrium of white micas and feldspars in the anchizone.
Medium grade (1) - stable mixed-layer illites paragonites with the value of Na/Na+K of up to 60 % and higher. High grade (2) - disintegration of mixed-layer micas into a two-phase mixture: low-sodium illite + low-potassium paragonite.

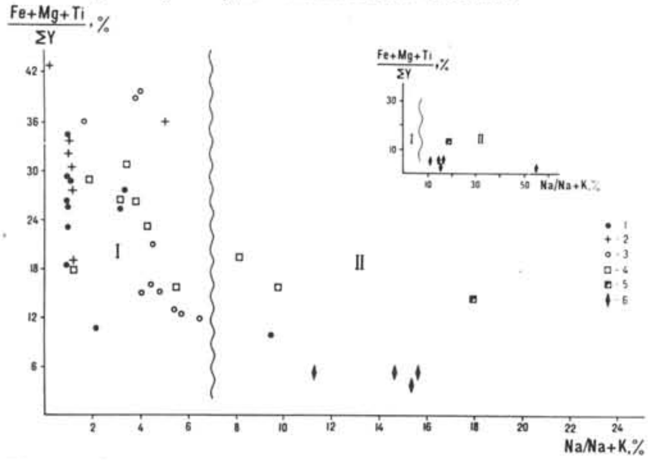

Fig. 4. Phengicity grade (Fe+Mg+Ti/Y) and the value of Na/Na+K in authigenic sericites from anchimetamorphosed rocks.
1 - mantle Carboniferous of the crystalline complex on the NE margin of the Čierna hora Mts. - upthrust zone of Bystrá (Korikovsky 1989); 2 - Veľký Bok Formation, Kráľova hoľa Hill (Korikovsky et al. 1992); 3 - the mantle of Tribeč Mts.; 4-5 - illites from phyllites of the Central Alps (Hunziker et al. 1986); 4 - K-illites, 5 - mixed-layer illites-paragonites; 6 - mixed-layer illites-paragonites from Upper Carboniferous metaaleurites of the Spálený Hill, Čierna hora Mts. (Tab. 1).

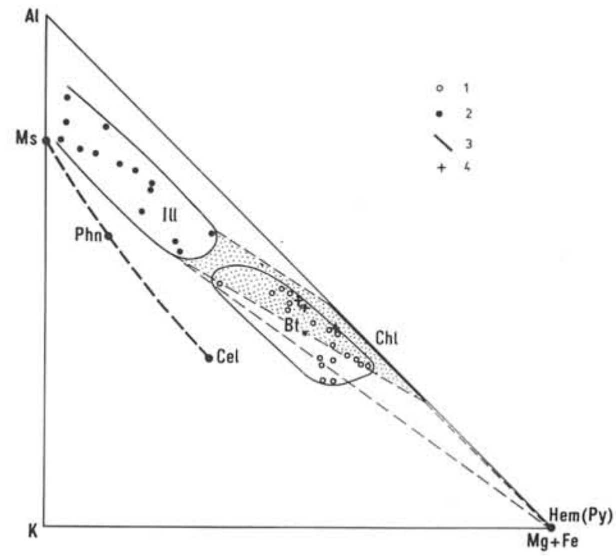

Fig. 6. Composition of diagenetically altered clastogenic biotites (1) and their anchimetamorphic products - illites (2) and chlorites (3) from metasandstones of the Visingsju series, Sweden (Al Dahan & Morad 1986). (4) - composition of Ti-chlorites replacing clastogenic biotites in metaaleurites of the Upper Carboniferous in Gemericum of the Spálený Hill - Čierna hora Mts. (Tab. 1). Thick dashed line - theoretical trend of the composition of muscovite-phengite-seladonite series.

Authigenic sericites in common metapsammites with low Al-contents are usually represented by typical phengites.

Authigenic chloritization of biotites in metapsammites

Chloritization of biotite is one of typical anchimetamorphic processes. From the study of the chemistry of reactions it follows that there are two variants of this process. In the first case, newly-formed chlorite (often intergrown with illite) has common composition and negligible contents of Ti (Al Dahan & Morad 1988), which is usually extracted along with K, or it is individualized in leucoxene (Veblen & Frey 1981), or in sagenite. This process approaches equilibrium.

In the second case, biotite changes into brown, optically anomalous Ti-chlorite with high birefrigence, containing 4 – 4.5 wt.% TiO_2. Such chlorites with unusually high Ti-contents formed due to replacement of biotites are considered to be transitional, metastable phases (McDowell & Elders 1983), originating during anchimetamorphic processes. They have been lately described also in mantle units of the Western Carpathian crystalline complexes.

In the studied rocks, for example, which belong to the Gemericum Nappe, the TiO_2 content in one of the flakes of almost totally chloritized biotite (Tab. 1), with K_2O content of 0.45 wt.%, remains relatively high (1.72 wt.%). The determination of the replacing phase - chlorite - on Fig. 2 has been confirmed diphractographically. At the same time, it is noteworthy that chlorite has been determined in the fraction $>50\mu$ but it is missing in the fraction $<2\mu$. This means that authigenic chlorite does not form in the matrix of metaaleurites, but only in pseudomorphs after relatively large flakes of clastogenic biotites.

Another type of processes - replacement of biotite by authigenic phengite according to the reaction Bt_{clast} + Ms_{clast} Phn_{auth} (Korikovsky et al. 1992) is together with chloritization of clastogenic biotites very frequently seen in the mantle units of the Western Carpathians. The reaction has isochemic character in relation to the participating phases. The problem of controls on this or other types of replacement cannot be so far objectively explained, since e.g. K-depletion cannot be demonstrated in thin sections by an adequate type of metasomatism.

More probable is another explanation - that only those biotites are chloritized which were affected by dealkalization during sedimentogenesis or early diagenesis. It is a well-known lithological process, during which biotites until the beginning of anchimetamorphism loose a considerable quantity of K (Mitchel & Taka 1979; Gilkes 1973; Gilkes & Suddhiprakarn 1979). Fig. 6 shows the composition of diagenetically altered biotites from the Visingsju series in Sweden (Al Dahan & Morad 1986) and the composition of Ti-chlorites from the studied metaaleurites of the Splálený Hill. Biotites of both groups occupy very near positions. Such biotites can be replaced by Ti-chlorites as a result of simple isochemical recrystallization.

It is probable that a part of clastogenic biotites from Upper Carboniferous metaaleurites of the Gemericum Nappe fragment on the Spálený Hill underwent the process of sedimentogenic or diagenetic dealkalization leading to their replacement by Ti-chlorite and not phengite.

We would like to point out that the fact of replacement of a part of biotites by metastable Ti-chlorite and Ti-phengites by itself documents the conditions of anchimetamorphism. The participating phases acquire with the transition to the chlorite-sericite subfacies of regional metamorphism an equilibrium state and Ti-chlorites and Ti-phengites are replaced by common low-Ti chlorites and phengites, with individualized leucoxene or sphene phases.

Conclusions

1. The matrix of Upper Carboniferous metapsammites of the Gemericum Nappe thrusted onto Jurassic sequence of the Veporicum crystalline complex mantle in the Čierna hora Mts. contains stable mixed-layer illite-paragonite micas or their disintegration products - a discrete mixture of illite and paragonite flakes.

2. Authigenic micas display an alkali deficiency in the group X - 0.78 – 0.91 form. units, and thus sthey belong to illites. Clastogenic muscovites have the sum of Na+K of 0.8 - 1.0 form. units, thus they belong to common muscovites typical for medium-temperature gneisses. The differences in the composition of authigenic and clastogenic white micas indicate incomplete equilibrium in the rock.

3. Clastogenic biotites are not replaced by common chlorites, but by optically anomalous metastable Ti-chlorites.

4. These facts indicate that recrystallization of the Upper Carboniferous sequence of the Gemericum Nappe in the SW part of the Čierna hora Mts. corresponds to the conditions of medium-grade anchizone, which corresponds to temperatures of up to 250 °C (McDowell & Elders 1983). Analogous temperature values (200 - 250 °C) have been obtained from the Permian and Upper Carboniferous of the E part of Gemericum (Šucha et al. 1990).

5. Metamorphic grade on the basement of the Gemericum Nappe in the SE region of the Čierna hora Mts. is thus recognizably lower that the grade of the relatively younger Alpine metamorphism (200 - 300 °C) in the mantle Carboniferous (in the upthrust zone of Bystrá) near the NE margin of Veporicum in the Čierna hora Mts. (Korikovsky et al. 1989). The obtained results are consistent with the intensity of tectonic reworking of the studied Carboniferous rocks from Gemericum and mantle Carboniferous rocks of the Čierna hora Mts. They indicate the necessity of systematic profile studies to the nappe-approached units. Data from profiles situated perpendicularly to the direction of regional upthrust zones will help to separate the parameters of Alpine metamorphism related to the thrusting of paleo-Alpine nappes from the intensity of metamorphism in relatively younger upthrust zones.

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