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ALPINE ANCHIMETAMORPHISM OF UPPER CARBONIFEROUS SANDSTONES FROM THE SEDIMENTARY MANTLE OF THE ČIERNA HORA MTS. CRYSTALLINE COMPLEX (WESTERN CARPATHIANS)

(10 Figs., 5 Tabs.)

A b s t r a c t: The discontinuous belt of clastogene sediments near the NE margin of the Čierna hora Mts. has a complicated fold--slice structure and it is markedly dynamometamorphosed. The structure as well as metamorphism are a result of teconometamorphic processes affecting the Bystrá thrust-fault zone. The Bystrá thrust-fault zone is one of the NW-SE thrust-fault zones of the region younger than the thrusting of the West Carpathian Alpine nappes and than the NW-SE fold structure of the crystalline complex and mantle units of the region. The metamorphic paragenesis (Ser $\pm$ $\pm$ Ab $\pm$ Chl + Q) and sericite chemistry of Upper Carboniferous metapsammites indicate the thermal parameter of anchizone (200--300 °C) of this youngest Alpine tectonometamorphic stage in the Čierna hora Mts. region. Analogous chemistry of micas from the basement crystalline complex and from clastogene metapsammites confirmed the autochthonous (i. e. mantle) character of the Upper Carboniferous near the NE margin of the Čierna hora Mts. crystalline complex.

Р е з ю м е: Прерывный пояс кластогенных осадочных пород у СВ окраины г. Черна гора имеет сложную складчато-чешуйчатую структуру и был интенсивно динамометаморфизован. Его структура и метаморфизм являются результатом тектоно-метаморфизма в поясе взбросов Быстра. Пояс Быстра является одним из поясов взбросов СЗ-ЮВ направления находящихся в изученном районе которые моложе движения покровов в Западных Карпатах и СЗ-ЮВ складчатой структуры кристаллиникума и чехла. Метаморфический парагенезис (Ser $\pm$ Ab $\pm$ Chl + Q) и химический состав серицита метапсаммитов верхнего карбона указывают на термальный параметр анхизоны (200—300 °C) этой самой молодой фазы альпийского тектонометаморфизма в районе г. Черна гора. Аналогичный химический состав слюд из кристаллического фундамента и из кластических метапсаммитов подтвердил автохтонный (т зн. чехловой) характер верхнего карбона у СВ окраины кристаллиникума г. Черна гора.

Alpine tectonogenesis in the Čierna hora Mts. crystalline region was accompanied by an increase of thermal gradient, as a results of which the basement and mantle rocks underwent partial recrystallization. These alterations were represented in the rocks of the crystalline complex by mylonitization and diaphtoresis, on the other hand, in the sedimentary rocks of the mantle they had the character of progressive metamorphism. Its intensity can be ascertained

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by a study of the mineralogy of psammites from the mantle complex. For this purpose we have selected Upper Carboniferous sandstones. They are the basal formation of the mantle and they are intensively tectonized, thus it could be expected that their recrystallization reflected the maximal grade of Alpine progressive metamorphism on the territory.

Geologic setting of the Upper Carboniferous formation

The heterogeneous formation of dark-grey clastic rocks exposed along the north-eastern margin of the Čierna hora Mts. crystalline complex according to lithofacial correlations belongs to the Upper Carboniferous forming the mantle of the crystalline complex (Fusán — Záruba — Hromada, 1954; Jacko, 1975, 1979). In the opinon of Vozárová and Vozár (1988) this formation is a constituent of the Nižná Boca Formation (Hronicum).

The most complete section across this formation can be found between the Bystrá Valley and the region Jedľa south-east of Miklušovce. The Upper Carboniferous outcrops attain their maximal width on this area, the rocks have monoclinical dip with an angle of 55—65°. In accordance with the data of Jacko (1975), this formation consists of quartz-sericite phyllites often with increased hematite contents, further metagraywackes and oligomictic metaconglomerates.

The studied metasandstones have been collected on this area. The thickness of the formation decreases considerably south-east of Jedľa, and west of the Ostrý hrb Hill (657.6 m) it thins out between strongly tectonized migmatites of the Miklušovce complex and Permian sediments of the autochthonous mantle of the Čierna hora Mts. crystalline complex.

The most recent results of geological mapping have shown the presence of the Upper Carboniferous also in the western part of the Čierna hora Mts. On the eastern slopes of the Roháčka Hill (west of the Klenovský fault), dark--grey slates, sandstones and graywackes occur in two belts, in one case in the form of a tectonic slice among the Miklušovce Complex migmatites, in the other one above the rocks of the autochthonous mantle of the crystalline complex.

The rocks occurring north-east of Kľuknava — between the Predná and Vysoká Valleys, where they form together with Lower Triassic sandstones a tectonic slice, and in the region of the Francová Valley, at the north-eastern margin of the Sľubica crystalline complex (Zacharov, 1986), where the Upper Carboniferous underlies the rest of the mantle complexes — are of an analogous origin.

Generally, the Upper Carboniferous rocks are intensively tectonized. The dip and strike of the rocks, as well as the type of their tectonic structure coincide with Alpine structures in the adjoining crystalline complex and in the Permian and Mesozoic sediments of the mantle. The differences in their thickness, as well as some important structure elements — such a schistosity, cleavage, intensity of fold compression — reflect on one hand the differences in the competence of the rocks in the formation itself (conglomerates-slates), on the other hand the position of the Upper Carboniferous formation in regional structures, especially in disjunctive ones.

Thus, in the Upper Carboniferous belt on the north-eastern margin of the Čierna hora Mts. crystalline complex, on the immediate basement of the Bystrá thrust-fault zone (having a north-western strike and a dip of 80 ° to SW), wedged-in lenses of the Lower, sometimes Middle Triassic occur very frequently. On the other hand, lenses and slices of Permian matle rocks occur quite frequently among Carboniferous rocks, or on the contact of the Upper Carboniferous with the crystalline complex in the same belt (Fig. 1).

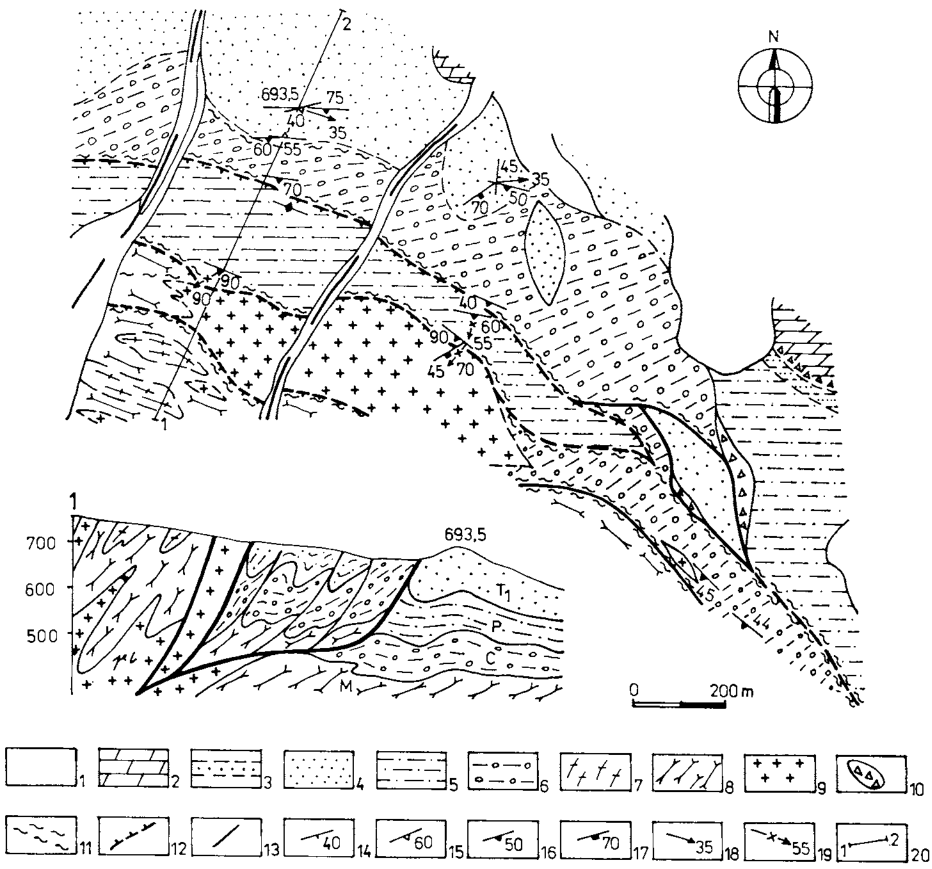

Fig. 1. Structural-geological relations of the crystalline complex, Upper Palaeozoic and Mesozoic near NE margin of the Čierna hora Mts. (0.8 km S of Miklušovce). *Explanations:* 1 — Quarternary sediments; 2-4 — Mesozoic mantle sediments: 2 — Middle Triassic, dolomites, 3 — Lower Triassic, slates, sandstones, 4 — Lower Triassic, quartz sandstones; 5 — Permian mantle sediments, slates, sandstones, graywackes; 6 — Upper Carboniferous mantle sediments, phyllites, metasandstones, metagraywackes, oligomictic metaconglomerates; 7-9 — crystalline complex, Miklušovce Complex: 7 — diaphtorized two-mica gneisses, 8 — diaphtorized stromatite and nebulite migmatites, 9 — aplitic granites; 10 — tectonized dolomites; 11 — tectonites of the crystalline complex; 12 — regional-scale upthrusts; 13 — faults; 14 — bedding; 15 — banding; 16 — schistosity; 17 — cleavage; 18 — fold axes; 19 — axes of slip folds; 20 — section line.

The irregular distribution of the Carboniferous and Permian, in comparison with the crystalline complexes, could have several causes: 1. primary differences in the space distribution of both formations (Carboniferous and Permian), 2. erosion before the beginning of the sedimentation of Permian rocks, 3. tectonic reduction of fold slopes during the folding of a north-western strike, and diagonal truncation of this folding, 4. wedging-in of the relics of fold curves and a reduction of their slopes in the process of the formation of thrust--fault zones of the Margecany type, including the zone of Bystrá near the north-eastern margin of the Čierna hora Mts. crystalline complex.

Petrographic description of metasandstones

The prevailing ones among the Upper Carboniferous sedimentary rocks are mica-quartz and mica-quartz-feldspar metasandstones, arkoses and gravellites, with small intercalations of phyllites (metaaleurites).

The clastogene fraction of the psammites is represented by rounded, rarely angular fragments of quartz, plagioclase, sometimes potassium feldspar, as well as flakes of clastogene (allogenic) muscovite and biotite. The texture is blasto-psammitic (Fig. 2), with signs of schistosity. The cement is represented by very fine-grained sericite and quartz-sericite newly-formed mesostatis.

The grade of fragment regeneration is quite high. Fragmental grains of quartz and feldspars are often broken and substituted on the margin by a fine-grained aggregate of the same composition.

Large flakes of clastogene muscovite are oriented in various angles to the bedding or schistosity. They are usually bent or elastically deformed and from their margins intensively substituted by newly formed sericite aggregate (Fig. 3).

An especially interesting phenomenon are allogenic biotite fragments, frequently regenerated or partly decomposed. The biotites become darker during the regeneration, their pleochroism decreases and, like muscovites, they are corroded by newly formed sericite. At the beginning of the process, the splitting and substitution of biotite occurs only on the margins of the grains (Fig 4a). With progressing decomposition biotites disintegrate along or across cleavage into fine fragments (Fig. 4b), substituted even more intensively by sericite and loosing their pleochroism almost completely.

Except sericite (with an admixture of quartz and albite) and sporadic chlorite flakes, there are no other new minerals in the cement, which indicates a predominantly arkose character of the sandstones. Carbonates, stilpnomelane or metamorphic biotite have not been observed.

Almost all samples show signs of synmetamorphic deformation. Quartz acquires banded or spotted extinction. Feldspars are characterized by brittle--elastic deformation, with simultaneous bending and fine disintegration of twins and their substitution by fine-grained albite aggregate (Fig. 5). Biotite and muscovite fragments were affected by elastic deformations. The flakes were bent under an angle of almost 90° (Fig. 6). A simultaneous process was the formation of schistosity in the sericite mesostasis, sometimes accompanied by fine plication, typical especially for quartz-sericite phyllites (metaaleurites). The

Fig. 2. Structure of arkose metasandstone with quartz fragments. Sample 39a/13, enlarg. 45.

Fig. 3. Resorption of allogenic muscovite by fine-flaked sericite aggregate. Sample 46/31, enlarg. 200.

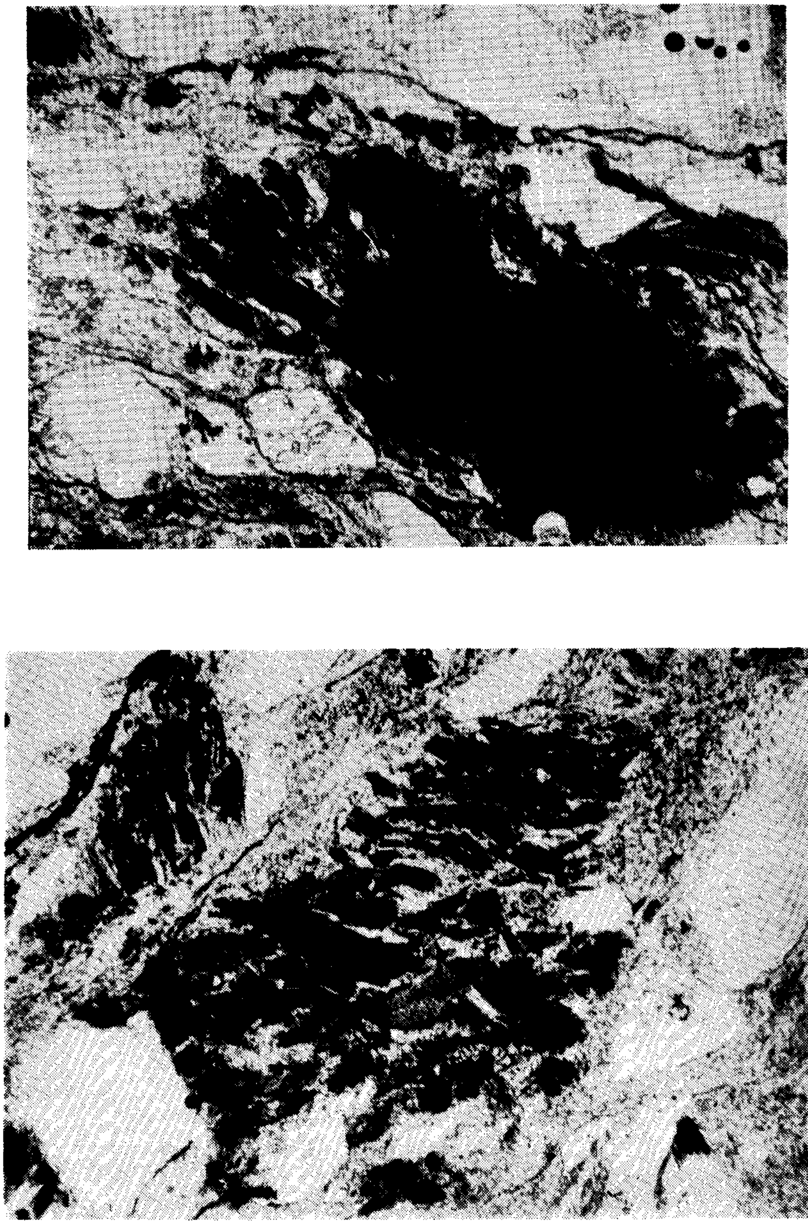

Fig. 4. Decomposition stages in allogenic biotite and its substition by fine-flaked sericite aggregate.
a) beginning — substitution of biotite from the margins, sample 39a/13, enlarg. 40.
b) conclusion — disintegration of biotite into small fragments, sample 41/11, enlarg. 63.

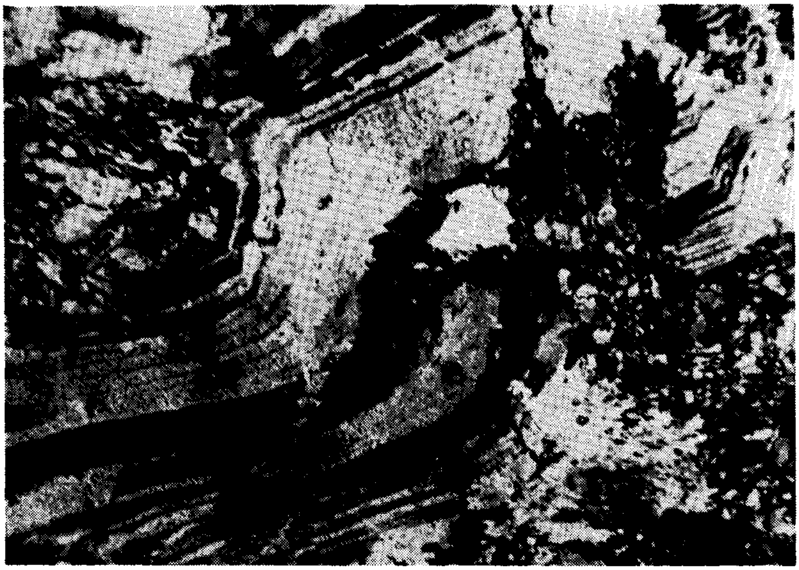

Fig. 5. Brittle-plastic deformation of a clastogene grain of albitized plagioclase with its partial substitution by a fine-grained albite aggregate. Sample 47/362, enlarg. 40.

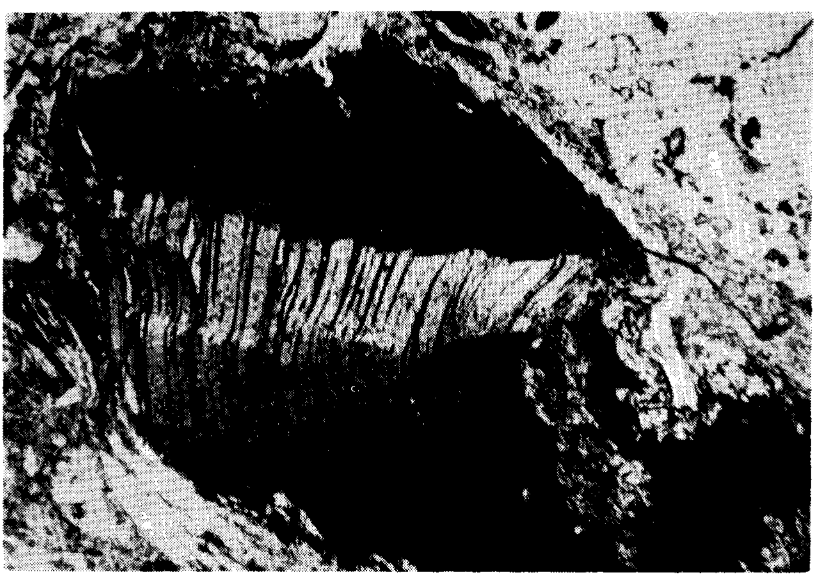

Fig. 6. Elastic deformation of allogenic biotite. Sample 101/16, enlarg. 75.

schist formation involves sometimes also allogenic muscovites and biotites, which acquire thus same orientation as the sericite agregate in which they are dispersed.

Mineralogy of the metasandstones

Fragmental minerals and sericite from the mesostasis have been investigated by the microprobe CAMECA MS-46 in IGEM, Academy of Sciences of the U.S.S.R.

Allogenic biotites

With the purpose of determining the primary composition of fragmental biotites, we have selected the central parts of flakes with preserved pleochronism and the usual brown colour. Analyses of 12 biotite grains are listed in Tab. 1.

The biotites have an average, moderate ferruginity. From the viewpoint of their primary character, a significant feature is their increased TiO_2 content-up to 3.87 wt. %. Such a high titanium content is usually characteristics of high--temperature magmatic biotites from granitoids; this supports the correctness of their comparison with micas from granitoids of the Čierna hora Mts. crystalline complex (see later).

Allogenic muscovites

The analyses of 7 clastic muscovites are listed in Tab. 2. Their crystallochemical formulas show that the muscovites are poor in the fengite molecule (low Mg and Fe contents), they have a varying and often high Na/Na + K ratio (up to 25 %) and an unusually high content of TiO_2 — up to 1.72 wt. %, i. e. 0.08 form. units of Ti.

These features are characteristic of high-temperature post-magmatic muscovites from granitoid rocks (S p e a r, 1984) formed frequently during the substitution of magmatic biotites. The high titanium content of muscovites, in part inherited from the substituted biotites, is also a sign of such substitutica.

Fine-flaked sericite from newly formed mesostasis of the metasandstones

The analyses of 11 sericites from the mesostatis of psammites are listed in the Tab. 3. This sericite agregate substituted allogenic biotites and muscovites, although it cannot be excluded that a certain part of it originated as a result of recrystallization of primary clayei cement. As it can be seen from the crystallochemical formulas, the sericites are enriched by Mg and Fe, i. e. in the fengite molecule, and they are poor in Ti. At the same time, the relation of Na/Na + K in sericite is not very high and it does not exceed 10 %, usually it is 1.5—4 %. These characteristics are typical of low-temperature micas of the earliest metamorphic stages (K o r i k o v s k y, 1973).

Table 1

Compositions (wt. %) of allogenic biotites from Upper Carboniferous arkose sandstones

Sample No.	41-11			45-10			41-34			39-14		
Analysis No.	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	37.77	37.95	41.09	36.89	36.92	37.20	44.19	38.31	39.04	36.13	36.66	36.73
TiO_2	3.00	3.45	3.02	2.58	2.40	2.20	3.87	3.59	3.59	3.29	3.17	3.44
Al_2O_3	16.41	17.48	17.46	16.35	18.65	17.58	19.01	17.16	16.71	18.37	18.05	18.11
FeO	20.24	19.78	18.34	24.55	24.34	24.57	13.77	15.82	15.42	20.77	20.69	20.13
MnO	0.10	0.10	0.10	0.20	0.23	0.22	0.08	0.08	0.08	0.12	0.10	0.10
MgO	8.26	9.17	7.51	6.33	5.82	6.27	8.26	8.99	8.77	8.02	8.24	7.93
CaO	—	0.08	0.04	0.13	0.04	0.04	0.14	0.08	0.03	—	0.04	0.08
K_2O	10.10	9.53	10.12	9.20	9.34	9.66	9.30	9.16	9.12	9.99	9.39	8.75
Na_2O	—	0.13	0.12	—	0.13	0.13	0.23	—	—	0.13	0.13	—
Total	95.88	97.67	97.80	96.63	97.87	97.87	98.85	93.19	92.81	96.82	96.47	95.27
$\frac{Fe+Mg}{Fe}$, %	57.9	54.7	57.1	68.5	68.7	70.1	48.3	49.7	49.6	59.2	58.5	58.7

Here and in the folowing: samples 39-14, 41-11, 41-34 and 45-19 — medium-grained arkose sandstones with allogenic flakes of muscovite and regenerated biotite, fragments of quartz, feldspars, and newly formed sericite or sericite ± albite-quartz mesostatis.

Table 2

Compositions (wt. %) of large flakes of allogenic muscovites from Carboniferous arkose sandstones

Sample No.		41-11		43			41-34	
Analysis No.		13	14	15	16	17	18	19
SiO_2		49.61	49.48	48.80	49.33	49.14	48.17	48.13
TiO_2		1.72	1.52	0.26	0.17	0.28	1.58	1.28
Al_2O_3		30.44	30.43	36.52	37.02	36.16	28.18	31.24
FeO		1.50	1.72	1.21	1.53	1.27	1.57	1.61
MnO		0.04	0.03	0.18	0.17	0.18	0.03	0.03
MgO		0.90	1.09	0.71	0.52	0.83	0.99	0.86
CaO		—	0.04	—	—	—	—	0.04
K_3O		11.17	11.07	9.03	8.37	9.05	10.81	11.18
Na_2O		0.40	0.49	1.06	1.44	1.24	0.27	0.38
Total		95.78	95.87	97.77	98.55	98.15	91.60	94.75
Crystallochemical formulas calculated to 6 kations of the groups Z + Y								
Z = 4	Si	3.34	3.33	3.11	3.10	3.13	3.39	3.26
	Al_{IV}	0.66	0.67	0.89	0.90	0.87	0.61	0.74
Y = 2	Al_{VI}	1.75	1.75	1.85	1.85	1.83	1.73	1.77
	Ti	0.08	0.04	0.01	0.01	0.01	0.08	0.06
	Fe	0.08	0.10	0.06	0.08	0.07	0.09	0.09
	Mn	—	—	0.01	0.01	0.01	—	—
	Mg	0.09	0.11	0.07	0.05	0.08	0.10	0.08
X	Ca	—	—	—	—	—	—	—
	Na	0.05	0.06	0.13	0.17	0.17	0.04	0.05
	K	0.96	0.95	0.73	0.64	0.73	0.97	0.96
Σ X		1.01	1.01	0.86	0.81	0.90	1.01	1.01

Composition of samples 41-11 and 41-34-see Tab. 1. Sample 43 does not contain biotite.

Table 3

Compositions (wt. %) of fine-flaked newly formed sericites from Upper Carboniferous arkose sandstones

Sample No.		41-11			45-10		43		41-34		39-14	
Analysis No.		20	21	22	23	24	25	26	27	28	29	30
SiO_2		49.41	53.65	50.95	49.41	50.52	49.93	51.38	52.04	49.18	53.04	49.74
TiO_2		0.27	0.08	0.62	0.27	0.22	0.47	0.28	0.68	0.22	0.38	0.22
Al_2O_3		25.00	26.23	25.14	26.93	25.55	33.99	33.85	25.38	24.55	26.40	26.79
FeO		4.30	4.54	5.09	5.26	5.12	1.70	1.78	6.42	5.91	5.05	4.37
MnO		0.04	0.08	0.04	0.04	0.04	0.22	0.19	0.03	0.03	0.01	0.04
MgO		2.55	2.84	2.75	1.56	1.62	1.02	0.91	3.23	2.37	2.70	2.52
CaO		0.04	0.04	—	0.04	—	—	—	0.04	—	0.04	—
K_2O		11.42	11.13	11.34	10.36	8.87	10.73	9.50	10.93	10.85	10.55	11.27
Na_2O		0.09	0.09	0.10	0.09	0.09	0.16	0.69	0.00	0.09	0.21	0.21
Total		93.12	98.63	96.03	93.96	92.03	98.22	98.58	98.84	93.20	98.38	95.16
Crystallochemical formulas calculated to 6 kations of the groups Z + Y												
Z = 4	Si	3.44	3.49	3.42	3.37	3.47	3.21	3.27	3.37	3.41	3.44	3.36
	Al_{IV}	0.56	0.51	0.58	0.63	0.53	0.79	0.73	0.63	0.59	0.56	0.64
Y = 2	Al_{VI}	1.48	1.49	1.41	1.53	1.54	1.78	1.80	1.31	1.41	1.45	1.49
	Ti	0.01	—	0.03	0.01	0.01	0.02	0.01	0.03	0.01	0.02	0.01
	Fe	0.25	0.24	0.29	0.30	0.29	0.09	0.09	0.35	0.34	0.27	0.25
	Mn	—	—	—	—	—	0.01	0.01	—	—	—	—
	Mg	0.26	0.27	0.27	0.16	0.16	0.10	0.09	0.31	0.24	0.26	0.25
X	Ca	—	—	—	—	—	—	—	—	—	—	—
	Na	0.01	0.01	0.01	0.01	0.01	0.02	0.08	0.01	0.01	0.03	0.03
	K	1.00	0.92	0.97	0.90	0.77	0.88	0.77	0.96	0.96	0.87	0.97
ΣX		1.01	0.93	0.98	0.91	0.78	0.90	0.85	0.91	0.97	0.90	1.00

Some of the chemical constants of allogenic muscovites and newly formed sericites are plotted on Fig. 7, with the aim to show the differences in their composition. We can see very clearly that micas form several fields; sericites appear to be generally richer in fengite, poorer in sodium and titanium than allogenic muscovites. However, both minerals sometimes show a marked deficit of alkalies, the sum of which decreases down to 0.78—0.8 form. units.

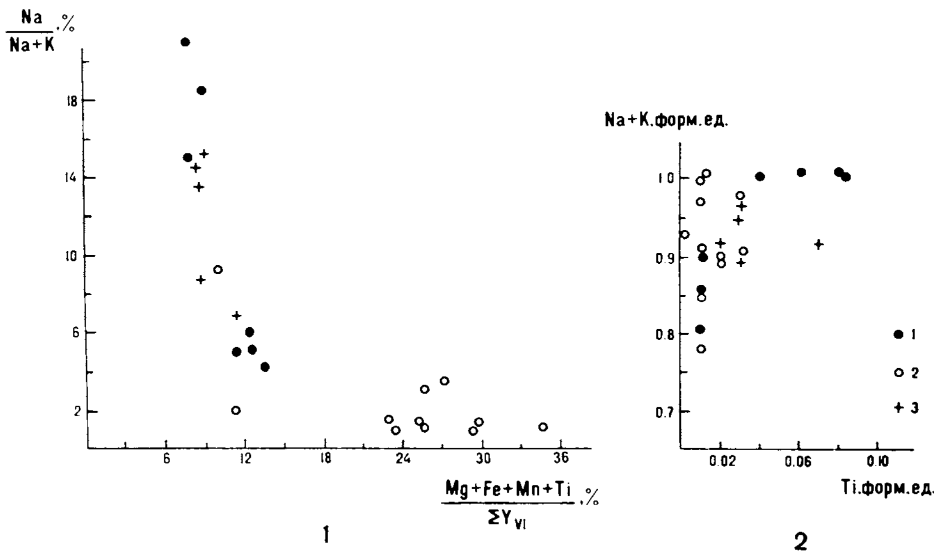

Fig. 7. Diagrams Na/Na + K-Mg + Fe + Mn + Ti) Y_{VI} (1) and (Na + K)-Ti (2) for white micas from metasandstones (Tabs. 1, 2 and 5).
Explanations: 1 — plagioclases, 2 — potassium feldspars.
3 — muscovites from two-mica migmatites of the Miklušovce Complex.

Fragmental feldspar

The analyses of 4 plagioclases and 3 potassium feldspar are displayed in Tab. 4.

The plagioclases belong to almost pure albites containing not more than 1.3 % of anorthite and 1.2 % of orthoclase molecule. Apparently this is a result of a low-temperature recrystallization of clastogene plagioclase which primarily had a more basic composition.

The potassium feldspars contain up to 8.5 % of the albite molecule. This relatively high content of albite indicates an incomplete recrystallization of K-feldspar which should have been, as it is characteristic of such low-temperature conditions, transformed into pure potassium adulars. A significant Ba content (celsian molecule) indicates primary magmatic character of the potassium feldspars.

Table 4

Compositions (wt. %) of clastic plagioclases and K-feldspars from Carboniferous arkose sandstones

Sample No.	45-10		39-14			45-10	39-14	
Mineral	plagioclases				potassium feldspars			
Analysis No.	31	32	33	34		35	36	37
SiO_2	68.47	68.08	66.46	69.11		64.24	62.98	62.54
Al_2O_3	19.33	19.16	19.24	19.11		18.18	18.48	18.96
CaO	0.29	0.29	—	0.04		0.10	0.06	0.10
K_2O	0.08	0.12	0.23	0.25		16.19	15.98	16.14
Na_2O	12.11	11.78	12.32	12.37		0.99	0.70	0.70
BaO	—	—	—	—		—	0.79	0.53
Total	100.28	99.43	98.25	100.88		99.70	98.99	98.97
Ab	98.3	98.2	98.8	98.5	Ort	91.5	92.5	93.2
An	1.3	1.2	—	0.3	Ab	8.5	6.1	6.0
Ort	0.4	0.6	1.2	1.2	Cs	—	1.4	0.8

The composition of feldspars is demonstrated on component diagrams (Fig. 8).

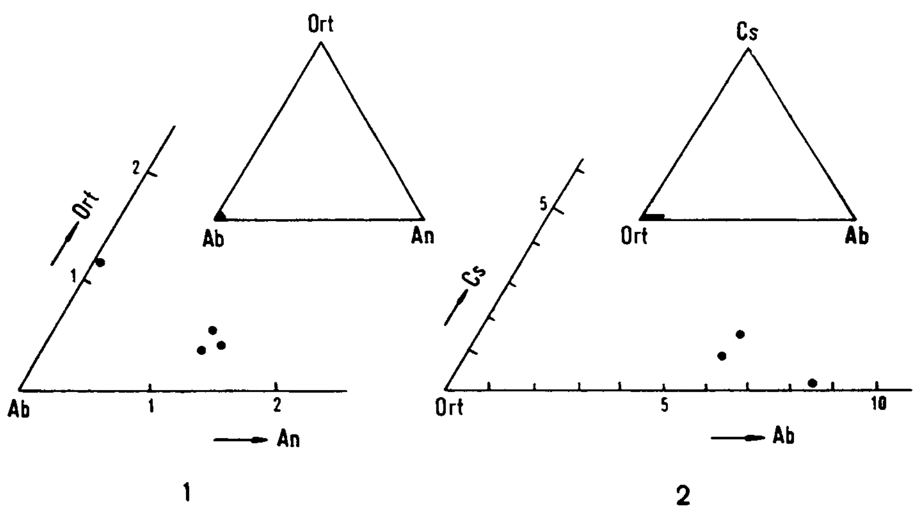

Fig. 8. Compositions of clastogene feldspars (Tab. 4).
Explanations: 1 — plagioclases, 2 — potassium feldspars.

Possible source of allogenic muscovites and biotites from Upper Carboniferous sandstones

The determination of the possible source of clastogene matter in the Upper Carboniferous sedimentation has been attempted with the help of a comparison of the compositions of allogenic minerals from psammites with minerals of the principal rock varieties of the Čierna hora Mts. crystalline complex. The most convenient method is the study of micas, since the composition of clastogene muscovites and biotites from metasandstones, in contrast to feldspars, proved to be least recrystallized by Alpine metamorphism.

The list of mineral analyses to be compared encompasses 3 analyses of biotites from the Čierna hora Mts. granitoids (J a c k o — P e t r í k, 1987), 4 bioti-

Table 5

Compositions (wt. %) of muscovites and biotites from two-mica migmatites of the Miklušovce Complex

Sample No.	15	11				12		CH-165/8a
Mineral	Mu	Bi		Mu		Bi	Mu	Mu
Analysis No.	38	39	40	41	42	43	44	45
SiO_2	50.50	36.38	36.38	48.56	48.85	36.29	48.92	49.65
TiO_2	1.37	2.56	2.74	0.55	0.53	2.29	0.67	0.45
Al_2O_3	33.45	17.94	18.16	34.25	34.39	18.66	34.51	34.04
FeO	1.67	23.10	24.11	1.25	1.21	22.05	1.25	1.74
MnO	0.03	0.26	0.36	0.01	0.01	0.22	—	0.01
MgO	0.75	7.48	7.23	0.71	0.62	7.61	0.68	0.61
CaO	—	0.04	0.04	0.01	0.01	0.12	—	0.01
K_2O	10.44	9.28	9.56	9.04	9.92	9.03	9.65	9.88
Na_2O	0.49	0.13	0.13	0.94	1.09	0.26	1.11	0.63
Total	98.70	97.16	98.71	95.32	96.63	96.53	96.79	97.02
Fe/Fe + Mg, %		63.4	65.1			61.9		
Crystallochemical formulas								
Z = 4 Si	3.24	2.75	2.73	3.18	3.19	2.75	3.18	3.23
Z = 4 Al_{IV}	0.76	1.25	1.27	0.82	0.81	1.25	0.82	0.77
Y = 2 Al_{VI}	1.77	0.35	0.34	1.83	1.84	0.41	1.83	1.83
Y = 2 Ti	0.07	0.14	0.15	0.03	0.03	0.13	0.03	0.02
Y = 2 Fe	0.09	1.46	1.51	0.07	0.07	1.39	0.07	0.09
Y = 2 Mn	—	0.01	0.02	—	—	0.01	—	—
Y = 2 Mg	0.07	0.84	0.81	0.07	0.06	0.86	0.07	0.06
X Ca	—	0.00	0.00	—	—	0.01	—	—
X Na	0.06	0.02	0.02	0.12	0.14	0.03	0.14	0.08
X K	0.85	0.89	0.91	0.77	0.82	0.87	0.80	0.82
Σ X	0.91	0.91	0.93	0.89	0.96	0.90	0.94	0.90

tes from biotite-hornblende and garnet-biotite gneisses of the Bujanová Complex (data of the authors, in press), as well as 2 biotites and 5 muscovites from two-mica migmatites and gneisses from the Miklušovce Complex (Tab. 5).

As far as the size and form of the grains are concerned, large allogenic muscovites from the metasandstones correspond to the muscovites from the Miklušovce migmatites. Their compositions proved to be very similar too (compare the data from Tabs. 2 and 5). Diagrams on the Fig. 7 show that muscovites from both rock types contain the same low admixture of the fengite molecule, they have a variable, but generally increased relation of Na/Na + K and a high limit of TiO_2 contents (up to 1.37 wt. % in muscovites of the Miklušovce migmatites and up to 1.72 wt. % in allogenic micas). Thus, the mica-rich migmatites and granites of the Miklušovce Complex are the most probable source of clastogene muscovite.

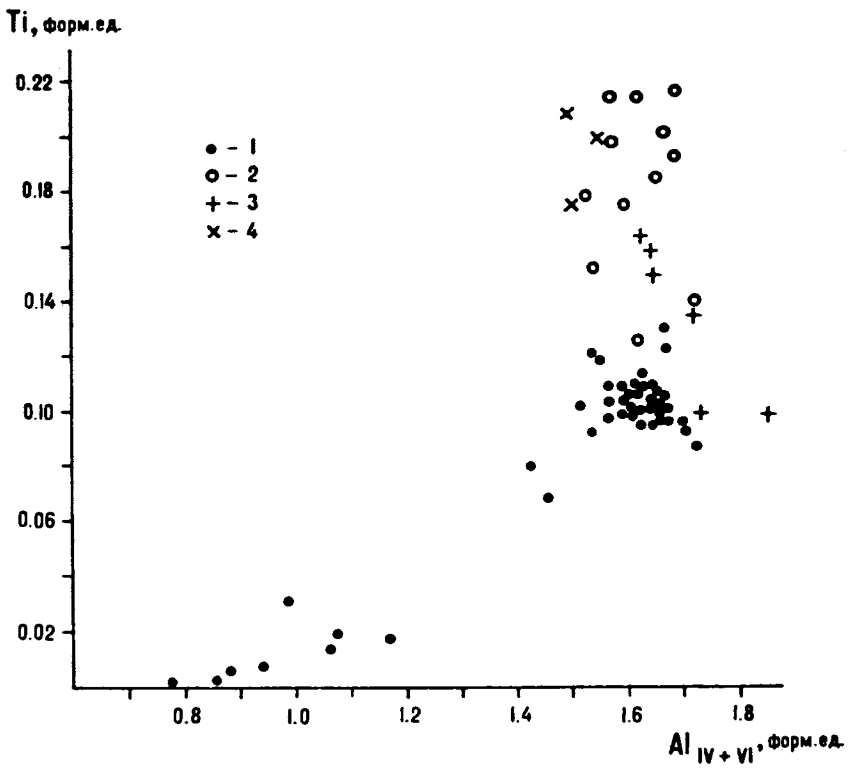

Fig. 9. Titanium and alumina contents of biotites from rocks of the Čierna hora Mts. crystalline complex and from rocks of the biotite subfacies from various regions. *Explanations:* 1 — metamorphogenic biotites from metasandstones of the biotite subfacies (G r a w f o r d, 1966; R a m s a y, 1973; W a n g — B a n n o, 1987; B r o w n, 1967; M a t h e r, 1970; M c D o w e l l — E l d e r s, 1980); 2 — allogenic biotites from metasandstones of the Upper Carboniferous (Tab. 1); 3 — biotites from the Miklušovce migmatites (Tab. 5) and gneisses of the Bujanová Complex (data of the authors, in press); 4 — biotites from granitoids of the Čierna hora Mts. (J a c k o — P e t r í k, 1987).

The biotite compositions agree very well, too. Thus, the ratio Fe/Fe + Mg is for allogenic biotites from metasandstones 48—70 % (Tab. 1), for biotites from granites, migmatites and gneisses of the Čierna hora Mts. crystalline complex 44—65 %. The overall content of Ti and summary alumina (Fig. 9) of these micas are also very similar. However, certain differences can be observed: allogenic biotites are almost totally identical with micas of the Čierna hora Mts. granitoid complex (Jacko — Petrík, 1987), but the content of Ti in biotites from the Miklušovce migmatites and Bujanová gneisses is a little lower than in allogenic micas. Although the differences are not very significant, it is more probable that eroded granitoids of the Čierna hora Mts. are the principal source of biotite.

Very interesting is also the comparison of allogenic biotites from Upper Carboniferous metasandstones of the Čierna hora Mts. with the composition of low-temperature metamorphogenic biotites from the biotite zone of metamorphism. For this purpose, analyses of newly formed biotites from analogous — as far as their val composition is concerned — arkoses and polymictic sandstones of the biotite subfacies from various regions of the world have been plotted on Fig. 9 (Ramsay, 1973; Wang — Banno, 1987; Brown, 1967; Mather, 1970; McDowell — Elders, 1980).

These biotites appear to have nothing in common. The contents of Ti in metamorphic biotites from the biotite zone are much lower than in allogenic micas from the Čierna hora Mts. metasandstones.

It follows that there is no doubt that biotites from arkose sandstones of the Čierna hora Mts. Upper Carboniferous are not metamorphic but they formed as a result of erosion and redeposition of granitoids and migmatites of the Variscan crystalline basement.

Parameters of anchimetamorphism of the metasandstones

The studied parageneses of the metasandstones, the composition of allogenic and newly formed minerals in them allow a fairly precise estimation of the facial conditions of progressive Alpine metamorphism in the region of the Čierna hora Mts. crystalline complex.

Summing up the characteristics of the metasandstones, the most important ones appear to be the following: They contain incompletely regenerated allogenic minerals — the products of erosion and redeposition of high-temperature rocks of the crystalline complex. The most completely recrystallized (albitized) are plagioclases, less completely potassium feldspars. The grade of substitution of allogenic biotites and muscovites by newly formed sericite is very variable — from well-preserved flakes (Figs. 3 and 6) to almost completely decomposed ones (Fig. 4b).

The newly formed paragenesis in the cement of the metasandstones is Ser ± ± Ab ± Chl + Q[1].

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[1] The abbreviations of minerals on diagrams and in the text are: Ab — albite, An — anorthite, Bi — biotite, Chl — chlorite, Cs — celsian, Mu — muscovite, Ort — orthoclase, Phn — phengite, Ser — sericite. Q — quartz, Sld — seladonite.

Thus, the grade of metamorphism of Upper Carboniferous metasandstones of the Čierna hora Mts. region corresponds either to the chlorite-sericite subfacies of the greenschist facies, or to the conditions of anchimetamorphism.

In correspondence to the latest classification elaborated on the example of Central Alps (Kübler, 1967; Frey, 1986; Hunziker et al., 1986), anchimetamorphic alterations are divided further into the zone of diagenesis, anchizone and epizone. The qualitative criterion of the division is the "index of crystallinity" (Kübler, 1967), increasing towards the epizone where illite changes into common muscovite. The increase of the crystallinity is accompanied by quantitative changes in the composition of micas: an increase of the sum of alkalies ($K_2 + Na_2O$) in illite-muscovites from 6—8 wt. % in the zone of diagenesis (0.6—0.7 form. units) to 8.5—10 % in the anchizone (0.7—0.9 form. units) and 10—11.5 % in the epizone (0.9—1.0 form. units) (Hunziker et al., 1986).

In the analyzed sericites and allogenic muscovites from the Upper Carboniferous sandstones of the Čierna hora Mts., the sum of alkalies (K + Na) in the group X varies between 0.78 and 1.00 form. units. This means that the conditions of their crystallization corresponded to anchimetamorphism, either in the conditions of anchizone or they were inconstant and varied between anchi- and epizone. The second supposition appears to be more probable. Analogously with other regions, the temperature of anchimetamorphism of the given grade should correspond to the range 200—300 °C (McDowell—Elders, 1980; Frey, 1986).

Except the composition of muscovite-illite micas, there is a second important criterion indicating that the metamorphic grade of the metasediments did not reach the chlorite-sericite subfacies. In the chlorite-sericite subfacies (Turner, 1968; Brown, 1967; Frey et al., 1988) the newly formed minerals are in complete equilibrium, allogenic biotites are fully decomposed and allogenic muscovites are either also totally decomposed or they are recrystallized and their composition is adjusted to the composition of the newly formed sericite in mesostasis.

In the Upper Carboniferous metasandstones from the Čierna hora Mts., the situation is quite different. Here, phases clearly instabile in the conditions of low temperatures are preserved as well as relic titanium-rich biotites of primary-magmatic genesis, allogenic muscovites are slightly recrystallized and according to their composition they differ from newly formed sericites from the mesostasis; clastogene potassium feldspars are not fully recrystallized into low-natrium adulars. Such incomplete regeneration is possible only in the conditions of anchimetamorphism, but not in proper regional metamorphism.

Anchimetamorphic reactions in the metasandstones

The metasandstones display well-visible reactions of a substitution of allogenic muscovite and biotite by newly formed fengite-sericite. Since no signs of metasomatic transfer of matter could be observed in the rock, it is most probable that the anchimetamorphism was essentially of isochemical character.

A model of these reactions can be deduced from the diagrams Al-(K, Na)-(Mg, Fe, Ti), where the actual composition of micas in each studied sample

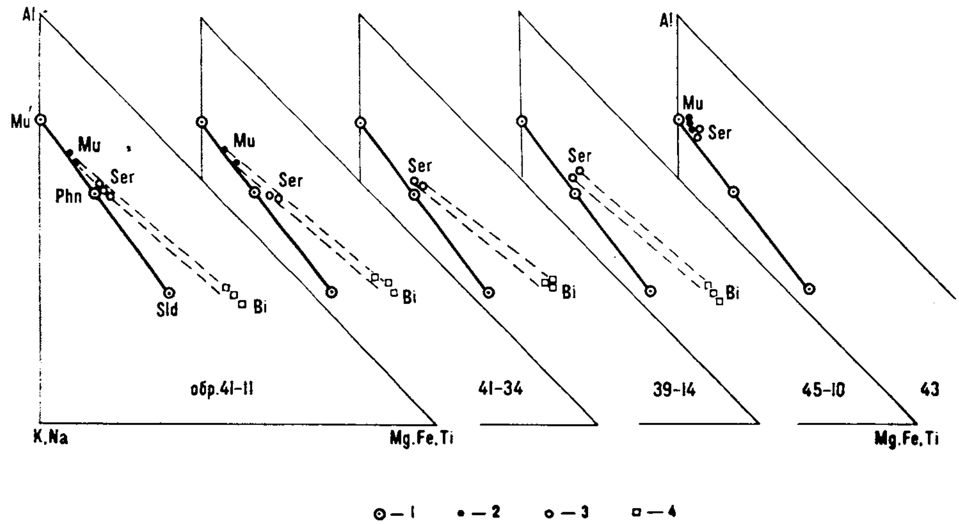

Fig. 10. Compositions of micas from Upper Carboniferous metasandstones (Tabs. 1-3) on the diagrams Al-(K, Na)-(Mg, Fe, Ti).
Explanations: 1 — micas of the theoretical succession muscovite-fengite-seladonite; 2 — allogenic muscovites; 3 — newly formed sericites in mesostasis; 4 — allogenic biotites.

is plotted (Fig. 10) according to data from Tabs. 1—3. As we can see on the diagrams, newly formed sericites in the samples 41-11, 41-34, 39-14, 45-10 have fengite composition and they lie on the connode connecting the compositions of allogenic muscovites and biotites occurring in these rocks. Thus, the formation of fengite sericites can be due to an isochemical reaction between allogenic muscovites and biotites, resulting in the substitution of both micas by a fine-grained fengite aggregate:

$$Bi_{allog} + Mu_{allog} \rightarrow Ser_{Phn}$$

However, the sample 43 lacks allogenic biotite and the fragments are represented only by muscovite. It turned out that in this case newly formed sericites have a different composition similar to the substituted muscovite (Fig. 10). Thus, in this rock the reaction is

$$Mu_{allog} \rightarrow Ser_{Al}$$

The completion of anchimetamorphic reactions would have led to a full decomposition and disappearance of allogenic micas. However, even in highly tectonized Upper Carboniferous metasandstones this was not the case.

Thermal values of Alpine metamorphism in the Bystrá thrust-fault zone near the NE margin of the Čierna hora Mts. thus do not exceed the conditions of medium and high grades of anchimetamorphism. We would like to stress that the determined temperature range refers to the youngest stage of Alpine dynamometamorphism in the most externally situated thrust-fault zone on this territory. Its more general application will be necessary to test on other thrust-fault zones of the Margecany type, especially in those which are developed in deeper levels of the crystalline complex. At the same time, the temperature range cannot be applied directly (withouth more studies) on relatively older stages of Alpine metamorphism, namely on the stage connected with the regional NW-SE fold structure of the territory and on the stage of nappe thrusting.

Conclusions

1. The composition of newly formed illite-muscovite micas in the cement of Upper Carboniferous metasandstones, the relative preservation of allogenic minerals, especially biotites and muscovites prove that Alpine recrystallization of the rocks in the mantle of the Čierna hora Mts. crystalline complex did not exceed the upper grades of anchimetamorphism, corresponding to temperatures not over 250—300 °C.

2. The comparison of the compositions of allogenic muscovites and biotites from the metasandstones with the composition of micas from high-temperature rocks of the crystalline complex — migmatites and gneisses of the Miklušovce Complex and granitoids of the Bujanová Complex — has shown that allogenic material of the sandstones was formed as a result of erosion of the crystalline rocks. This proves that the Upper Carboniferous formation is not in a nappe position, but that it forms a part of the whole mantle complex on the Čierna hora Mts. crystalline rocks.

Translated by K. Janáková

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