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365 - 371

ANCHIZONAL ALPINE METAMORPHISM OF TATRIC COVER SEDIMENTS IN THE MALÉ KARPATY MTS (WESTERN CARPATHIANS)

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Abstract: Permo-Mesozoic Tatric cover sediments in the Malé Karpaty Mts suffered an early Alpine (Cretaceous) low-T metamorphic imprint mostly at an estimated temperature of 250 - 300 °C (illite-crystallinity, composition of authigenic micas, deformation mechanisms). The source of the metamorphic temperature is tentatively interpreted as an increased heat flow inherited from a previous period of crustal thinning and probable shear heating as well. Synkinematic metamorphic recrystallization is a consequence of basement thrust stacking and thermal equilibration between cold footwall sediments and hot hangingwall basement rocks detached at mid-crustal levels.

Key words: Western Carpathians, Malé Karpaty Mts, Tatricum, Permo-Mesozoic sediments, anchizonal metamorphism, tectonic interpretation.

Introduction

The effects of a slight metamorphic imprint have been often reported from most of the Western Carpathian Mesozoic successions confined to their pre-Alpine crystalline basement, more often from the southern superunits (Meliaticum, Veporicum) and only locally from the Tatricum, which forms an external crustal sheet of the Central Western Carpathians. Very low grade to low grade conditions of the Alpine metamorphism and mostly carbonatic Mesozoic lithologies inhibited a precise definition of the P-T characteristics of metamorphism, however. The units affected by higher metamorphism also show more intense deformation features, such as penetrative foliation and lineation in ductile media, as well as ductile/brittle to brittle structures in more competent rocks. The uneven spatial distribution, but common presence of metamorphic and deformation effects and their linking with high-strain shear zones of different magnitudes made some authors consider the metamorphism to be a purely dynamic process, generated either by the "deep-seated" or "induced" tectonics of composite basement-cover units (e.g. Mahel' 1974), or on the contrary by loading and shearing triggered by overthrusting superficial cover nappes (e.g. Zelman 1982). Nevertheless, the confinement of downwardly increasing metamorphic effects to the lower nappe or subautochthonous units favours the contribution of rising temperature due to a thermal equilibration during and after thrusting (e.g. Plašienka et al. 1989).

The aim of the present paper is to describe the metamorphic conditions in the Tatric cover sediments of the Malé Karpaty Mts, based on illite-crystallinity data, chemical compositions of detrital and authigenic micas in sandstones and on structural data, and to discuss the tectonic background of this metamorphism.

Geological setting

The Malé Karpaty Mts, a small horst of pre-Neogene basement outcropping amidst Tertiary sediments of the Vienna and Danube (Kisalföld) Basins form an important link between the Eastern Alps and Western Carpathians. At the first sight, the grade of the Alpine metamorphism in both mountain ranges differs cardinally: medium to high-grade Cretaceous and Tertiary metamorphism in the central zones of the Alps, but only very low to low grade in the Carpathians. The situation appears different if we compare the corresponding tectonic units. The highest P-T conditions were reached in lowermost crustal superunits of the Alps (Penninic windows) as well as in the rear part of the Middle Austro-Alpine sheet exhumed due to strong Tertiary continental collision and uplift, whilst non-collisional Tertiary convergence in the Carpathians maintained only the upper crustal units at the surface until the present. Consequently, the erosional level of the Central Western Carpathians is generally much higher compared to the Central Alps, which is the primary cause of differences in the surface effects of the early Alpine (eo-Alpine, Cretaceous) metamorphism between the two mountain systems.

The substantial part of the Malé Karpaty Mts is built up by the Tatric basement-cover superunit. Superficial cover nappes (Krížna, Choč and higher ones) overlie the Tatricum only in the northern part of the mountains (Fig. 1). The Tatricum is composed of pre-Alpine crystalline basement and its Permo-Mesozoic sedimentary cover. Several tectonic units have been distinguished in the Malé Karpaty Mts: the subautochthonous Borinka and Orešany Units and allochthonous Modra and Bratislava basement Nappes (for the review of structure of the Malé Karpaty Mts, see Plašienka et al. 1991).

The Tatric sedimentary cover, the subject of our study, differs to some degree in individual tectonic units as far as its lithostratigraphical content is concerned. The generalized succession con-

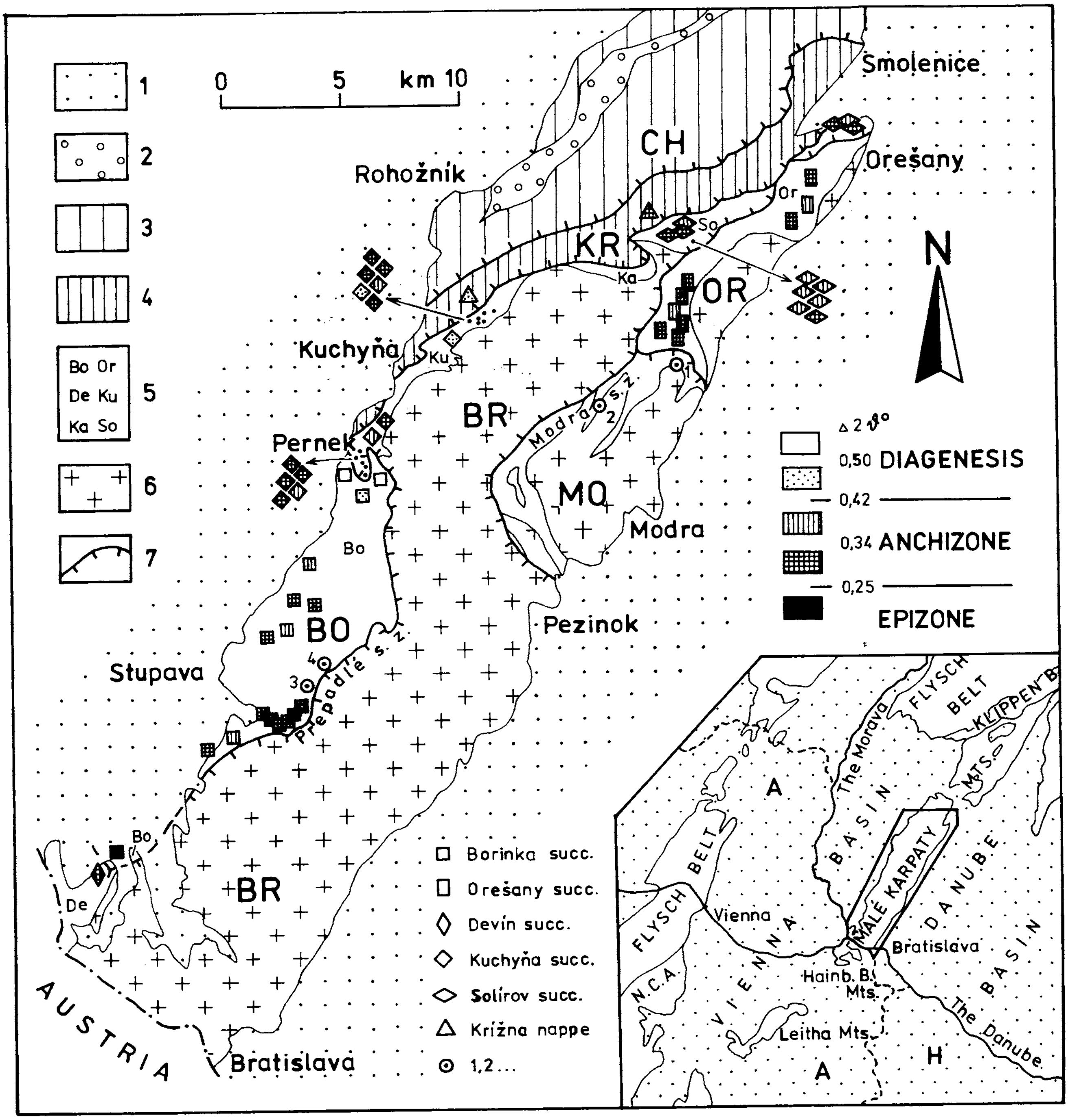

Fig. 1. Geological sketch map of the Malé Karpaty Mts with illite-crystallinity data and sample localities of microprobe analyses.
1 - Neogene sediments; 2 - Paleogene sediments; 3 - Choč and higher cover nappes; 4 - Krížna Nappe; 5 - Permo-Mesozoic Tatric successions: Bo - Borinka, Or - Orešany, De - Devín, Ku - Kuchyňa, Ka - Kadlubek, So - Solírov, 6 - Tatric crystalline basement; 7 - contacts of principal tectonic units: BO - Borinka subautochthonous unit, OR - Orešany subautochthonous unit, MO - Modra Nappe, BR - Bratislava Nappe, KR - Krížna Nappe, CH - Choč and higher nappes. Circles indicate localities of microprobe analyses of metasandstones: 1 - sample No. MKV.441 (Permian metaarcose, Píla village), 2 - sample No. MKV-440 (Permian metaarcose, Piesok), 3 - sample No. MKZ-374 (Triassic metasandstone, Prepadlé Valley), 4 - sample No. MKZ-286 (Jurassic metasandstone, Okopanec hill).

tains some Permian arcosic sandstones, lower Triassic quartzose sandstones, middle Triassic carbonates, Jurassic to lower Cretaceous limestones, sandstones, breccias, shales, marls and cherts and a middle Cretaceous siliciclastic flysch sequence. The thickness of the Permo-Mesozoic cover considerably varies due to sedimentary basin architecture and tectonic overprint, the maximum primary thickness probably did not exceed two thousand meters. The Tatric units of the Malé Karpaty Mts, from the viewpoint of their lithostratigraphy and structural characteristics, may be best correlated with the lower Austro-Alpine system of the Eastern Alps, especially with the Radstätter Tauern and Semmering areas (cf. Häusler et al. in press).

Table 1: Microprobe analyses of authigenic and detrital white micas from the Permian sandstones.

Sample Nr.		MKV-440			MKV-441			MKV-440	
Analysed minerals		Authigenic Phn						Detrital Ms	
Nr. of analysis		1	2	3	4	5	6	7	8,
SiO_2		49.71	49.24	51.12	51.92	50.63	50.05	48.44	48.26
TiO_2		0.03	0.23	0.33	0.16	0.18	0.44	-	0.83
Al_2O_3		28.18	27.14	28.07	25.59	26.59	28.09	34.59	32.90
FeO		2.55	2.72	2.48	3.84	4.17	3.42	0.75	1.11
MnO		0.03	0.03	-	-	-	-	-	-
MgO		1.96	2.21	2.27	2.37	2.11	1.81	0.46	1.06
CaO		-	0.03	0.04	-	-	-	-	-
Na_2O		0.08	0.08	0.08	0.07	0.09	0.07	1.89	0.77
K_2O		10.76	11.50	10.72	10.23	10.64	11.23	9.06	10.12
Σ		93.30	93.14	95.12	94.18	94.42	95.11	95.55	95.08
Z	Si	3.38	3.37	3.41	3.50	3.42	3.37	3.21	3.22
	Al^{IV}	0.62	0.63	0.59	0.50	0.57	0.63	0.79	0.78
Y	Al^{VI}	1.65	1.60	1.62	1.54	1.55	1.61	1.92	1.80
	Ti	-	0.01	0.02	0.01	0.01	0.02	-	0.04
	Fe	0.15	0.16	0.14	0.21	0.24	0.19	0.04	0.10
	Mg	0.20	0.23	0.22	0.24	0.21	0.18	0.04	0.10
X	Ca	-	-	-	-	-	-	-	-
	Na	0.01	0.01	0.01	0.01	0.01	0.01	0.25	0.10
	K	0.94	1.00	0.91	0.88	0.92	0.97	0.76	0.85
ΣX		0.95	1.01	0.92	0.89	0.93	0.98	1.01	0.95
Mg+Fe/ΣY,%		17.5	19.5	18.0	22.5	22.5	18.5	4.0	8.0
Na/Na+K,%		1.0	1.0	1.1	1.1	1.1	1.0	24.7	10.5

Illite-crystallinity data

The concept of illite-crystallinity (IC) and its application for metamorphic grade determinations was introduced by Weaver (1960) and Kübler (1967, 1968). In spite of some uncertainties in interpretation of the observed IC values, the method seems to be appropriate for the estimation of metamorphic conditions provided that statistically sufficient set of data is available. At least, relative changes in the metamorphic imprint of rocks or units exhibiting no other measurable metamorphic effects can be evaluated.

Sample preparation technique, generally corresponding to the recomendations of Kisch (1990) included jaw crushing, grinding and sieving, the <2μm fraction was obtained by the sedimentation method. Carbonates and organic matter were removed by 0.5 M HCl and H_2O_2. Oriented specimens were analysed in air-dry state and saturated by ethylene glycol. The set of 52 samples of slates, marls and limestones were analyzed on the diffractometer Philips PW 1050/25 under following conditions: CuKα radiation, 40 kV and 20 mA, goniometer scanning rate 2°2Θ/min, chart speed 20 mm/min. The internal quartz standart was used after every 10 measurements. The mineral composition and textures of all samples were also studied from thin sections.

The results are depicted in the Fig. 1. Almost all the measured IC values correspond to the field of anchizone. X-ray analysis proving the presence of chlorite in some samples, while montmorillonite and kaolinite were not detected.

The **Borinka Unit**, the lowermost subautochthonous Tatric unit of the Malé Karpaty Mts, displays an average IC value of 0.34° Δ 2Θ (17 measurements), the highest measured crystallinity being 0.21° and the lowest one 0.53° (standart deviation 0.07). Slates, marlstones and limestones of mostly Lower Jurassic age were analysed. Regionally, there is a considerable increase of IC from N to S, the highest being confined to the neighbourhood of the ductile shear zone in the Prepadlé Valley, along which the Bratislava basement Nappe overthrusted the Borinka Unit (Plašienka 1990; Putiš 1991).

The **Orešany Unit**, another subautochthonous Tatric element, provided an average value of 0.31° Δ 2Θ (9 measurements) in the span 0.27 - 0.35°, standart deviation 0.03. Analysed were Jurassic and Cretaceous marly shales.

The Permo-Mesozoic cover of the allochthonous **Bratislava Unit** is divided on the basis of its lithostratigraphical content, into several successions. These successions outcrop in different areas (see Fig. 1). From the Devín Succession only one datum is available (0.27°). The Kuchyňa Succession yielded a dispersion of data between 0.28 and 0.46° Δ 2Θ, with an average of 0.34° (14 measurements, standart deviation 0.04), the Solírov Succession is similar with the span 0.26 - 0.4° Δ 2Θ and the average 0.34° (12 data, standart deviation 0.05). All samples came from Jurassic to Cretaceous marly shales and limestones.

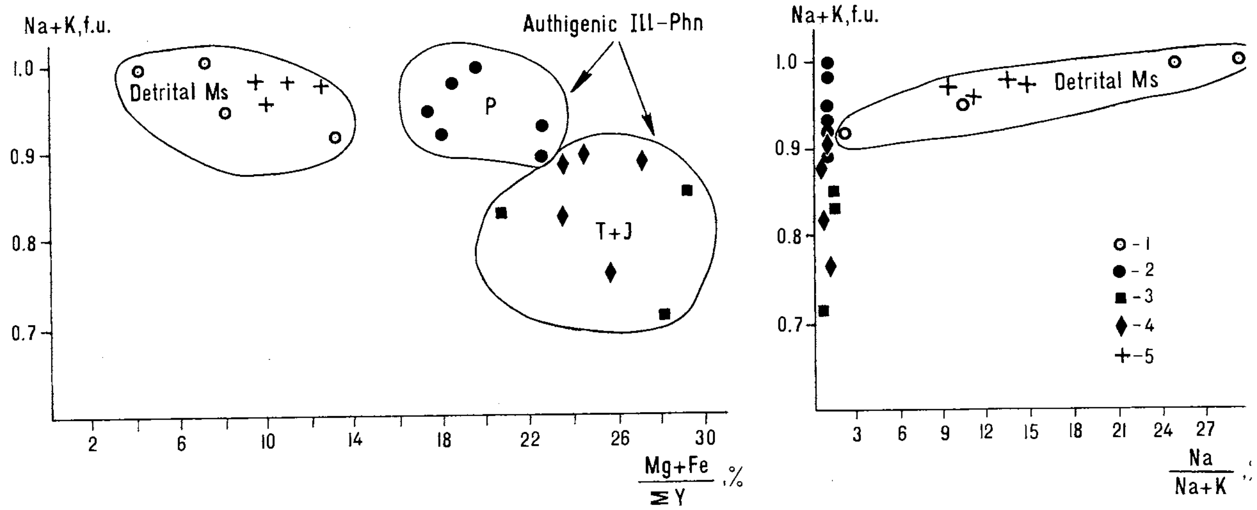

Fig. 2. Compositions of authigenic and detrital white K-micas from the Tatric cover of the Malé Karpaty Mts on the plots of Na + K - (Mg + Fe)/ΣY and Na + K - Na/(Na + K).
1 - detrital muscovites from Permian and Triassic metasediments; 2-4 - authigenic micas from Permian (2), Triassic (3) and Jurassic (4) metasediments; 5 - postmagmatic muscovites from the Bratislava Granitoid Massif (taken from Petrík 1985). Every point represents an average of 2 - 3 measurements.

The composition of micas in metasandstones

Slightly metamorphosed sandstones containing clastic micas and newly-formed, authigenic sheet silicates seem to be a convenient material for the study of phase equilibria between clastogenic and authigenic micas by means of microprobe chemical analyses. Phase equilibria, or rather disequilibria generated by low temperature recrystallization and ion diffusion can give valuable information about the estimated metamorphic temperature (Hunziker et al. 1986; McDowell & Elders 1980, 1983). A similar methodological approach has been applied in the Western Carpathians by Korikovsky et al. (1989, 1992).

The clastic fraction of the analysed sandstones is composed of angular quartz, albitized plagioclase, K-feldspar, tourmaline, muscovite and semidecomposed biotite. Illite-phengite, fine-grained secondary quartz and albite dominate among authigenic minerals, chlorite is rare.

The authigenic white micas in Permian arcosic metasandstones (Modra Nappe, Fig. 1) are rich in Mg and Fe, with a high content of K (0.85 - 1.0 form. units - Tab. 1). This composition refers to normal phengites typical for the epizone (Hunziker et al. 1986; Korikovsky et al. 1991). Detrital muscovites are fairly poor in Mg and Fe, but have much higher content of Na.

Authigenic white micas from Lower Triassic quartzose sandstones (olistolites in Jurassic scarp breccias) and Jurassic flysch metasandstones exhibit different composition (Tabs. 2 and 3). They are rich in Mg and Fe, as are Permian metapsammites, but contain less K (0.71 - 0.9 form. units). This indicates illite-phengites, micas typical for anchizone. The composition of detrital muscovites is identical to that in Permian rocks.

The results obtained are summarized in Fig. 2. The (Na + K)-(Mg + Fe)/ΣY diagram clearly shows the difference between authigenic and clastic micas. Composition of detrital muscovites is analogous to postmagmatic muscovites from the Bratislava Granite Massif (Petrík 1985) characterized by a low Mg and Fe content and high Na/(Na + K) ratio. The compositions of authigenic K-micas indicate generally low temperature metamorphic conditions, according to the extremely low Na/(Na + K) ratio (0 - 1.3, Tab. 1 - 3; Fig. 2). Somewhat higher temperatures were reached in Permian metapsamites of the Modra Unit.

Unfortunately, clastic biotites or pseudomorphoses of Ti-chlorites or Ti-phengites after them are almost missing in the analysed samples, so the correlation with other anchimetamorphic Western Carpathian complexes is obliterated in this aspect (Korikovsky et al. 1989, 1992). Nevertheless, the sharp difference in compositions of authigenic and detrital white micas is identical. This gives evidence for both incomplete phase equilibria and anchi- to epizonal metamorphic conditions (250 - 300 °C). In the chlorite-sericite subfacies of low grade metamorphism (with temperatures higher than 300 °C) compositions of authigenic and detrital micas should equilibrate.

Structural data

The metamorphic recrystallization of the Tatric cover rocks in the Malé Karpaty Mts is accompanied by deformational structural elements grouped into the first Alpine deformational stage AD_1. The structural paragenesis of AD_1 comprises foliation S_1 mostly parallel to bedding, which is penetrative in zones with localized ductile deformation, i.e. shear zones surrounding overthrust planes of the Tatric basement nappes. Stretching lineation, small-scale asymmetric structures, S-C mylonitic fabric and quartz microstructure point to the top-to-NW translation of the allochthonous body (Plašienka 1990; Putiš 1987, 1991).

The varied lithologies of the complexes involved in shear zones influenced their metamorphic fabrics and deformational mechanisms. Pure fine-grained limestones show dynamic recrystallization and flattening, coarse-grained twinning and deformation lamellae. Impure marly limestones are deformed mostly by pressure solution processes, the insoluble residuum being formed by fine-grained white micas (sericite) and opaque pigment. Slates show less penetrative fabric with tiny flakes of authigenic micas and very fine-grained quartz aggregates. Sandstones exhibit only scarse features of pressure solution, their matrix recrystallized into fine-grained sericite-quartz aggregates. Quartzose sandstones show very little dynamic recrystallization, except areas around the Modra overthrust shear zone (in the neighbourhood of our

Table 2: Microprobe analyses of authigenic and detrital white micas from the Triassic metasandstones (sample MKZ-374).

Analysed minerals		Authigenic Ill-Phn			Detrital Ms	
Nr. of analysis		9	10	11	12	13
SiO_2		50.23	51.61	51.23	49.71	48.36
TiO_2		0.38	1.07	0.29	0.27	1.90
Al_2O_3		25.83	23.61	26.86	33.72	30.58
FeO		25.83	23.61	26.86	33.72	30.58
MnO		-	-	-	-	-
MgO		1.99	2.54	2.09	0.78	1.26
CaO		-	0.13	0.10	-	-
Na_2O		-	0.05	0.07	2.45	0.20
K_2O		8.31	9.56	9.60	8.74	10.58
Σ		93.20	94.22	93.84	96.72	95.36
Z	Si	3.38	3.49	3.44	3.25	3.23
	Al^{IV}	0.62	0.51	0.56	0.75	0.77
Y	Al^{VI}	1.42	1.37	1.57	1.85	1.64
	Ti	0.02	0.05	0.02	0.01	0.10
	Fe	0.36	0.32	0.20	0.06	0.14
	Mg	0.20	0.26	0.21	0.08	0.12
X	Ca	-	0.01	-	-	-
	Na	-	0.01	0.01	0.30	0.02
	K	0.71	0.83	0.82	0.73	0.90
ΣX		0.71	0.85	0.83	1.03	0.92
Mg+Fe/ΣY,%		28	29	20.5	7	13
Na/Na^+K, %		-	1.2	1.2	29.1	2.2

Table 3: Microprobe analyses of authigenic white micas from the Jurassic quartz metasandstones (sample MKZ-286).

Analysed minerals		Authigenic Ill-Phn				
Nr. of analysis		14	15	16	17	18
SiO_2		51.62	51.78	51.37	52.47	53.42
TiO_2		0.21	0.19	0.24	0.19	0.20
Al_2O_3		25.45	26.50	25.04	25.40	24.51
FeO		2.21	2.18	2.21	2.00	2.12
MnO		-	0.03	-	-	-
MgO		3.61	3.68	4.05	3.54	3.48
CaO		0.04	0.06	0.03	0.08	0.06
Na_2O		0.05	0.04	-	0.03	0.03
K_2O		10.41	9.03	10.47	9.58	10.36
Σ		93.60	93.69	93.41	93.29	93.18
Z	Si	3.48	3.42	3.46	3.52	3.56
	Al^{IV}	0.52	0.58	0.54	0.48	0.44
Y	Al^{VI}	1.50	1.48	1.45	1.52	1.52
	Ti	0.01	0.01	0.01	0.01	0.01
	Fe	0.13	0.12	0.13	0.11	0.12
	Mg	0.36	0.39	0.41	0.36	0.35
X	Ca	-	-	-	-	-
	Na	0.01	0.01	-	-	-
	K	0.89	0.75	0.89	0.82	0.89
ΣX		0.90	0.76	0.89	0.82	0.89
Mg+Fe/ΣY,%		24.5	25.5	27.0	23.5	23.5
Na/Na^+K,%		1.1	1.3	0.0	0.0	0.0

sample localities for microprobe analyses depicted in Fig. 1), where the ductile fabric is sometimes obvious. Allochthonous granites bear features of ductile-brittle shearing, as mylonitization, occasionally with S-C fabric and cataclastic flow restricted directly to overthrust planes (Putiš 1991). Rocks outside overthrust shear zones are free of penetrative deformations, only spaced anastomosing foliation S_1 is widespread in limestone rocks. Nevertheless, low-temperature metamorphic imprint is recorded microstructurally by frequent annealing of calcite rocks, bluring of microfossils, flattening and pressure solution surfaces bearing very fine-grained phyllosilicates. Larger calcite crystals are sometimes heavily twinned. All observed deformational mechanisms point to the low-temperature conditions (e.g. Schmid 1982), most probably below and around 300 °C.

Discussion

There is a clearly visible lateral increase of metamorphic imprint from N to S in the Borinka Unit (Fig. 1). The erosional level also deepens in this direction, i.e. lowermost structural stages appear in the Prepadlé Valley, where the lowest IC values were also obtained. Moreover, this locality corresponds to the ductile to ductile-brittle overthrust shear zone of the Bratislava Nappe. Seemingly, the dynamic factor improving the metamorphic recrystallization and/or some contribution of shear heating were probably operating in this zone.

In the northern part of the Borinka Unit near the village Pernek (Fig. 1), there is a considerable difference in IC values between the underlying Borinka rocks (0.5 - 0.53° Δ 2Θ) and allochthonous Kuchyňa Succession (0.28 - 0.34°), which implies that the metamorphic imprint preceded thrusting. Nevertheless, in areas where the Bratislava-Modra allochthon has thick crystalline complexes at the base, there are no differences between the footwall and hangingwall IC values in Mesozoic rocks (Orešany vs. Solírov Successions - Fig. 1). In this case the equalized temperature conditions were probably reached by conductive heating of the footwall by the hot overriding units.

Inverted metamorphic zonation has been described from many overthrusting terrains. Discontinuous zonation reveals post-metamorphic thrusting (Frey 1988; Spring et al. 1993), a continuous reverse zonation in very low grade conditions was explained by shear heating by Aprahamian & Pairis (1981). In higher grade terrains, however, the thermal source for an inverted metamorphism is almost unambiguously prescribed to conductive heating from above by a hot overriding thrust sheet with some contribution of shear heating (e.g. LeFort 1975; Frank et al. 1973; Arita 1983).

The difference in metamorphic temperatures observed by microprobe study of authigenic micas of Permian (up to 300 °C) and younger sandstones (about 250 °C) may be explained in two ways: either by a late Permian thermal event (volcanism), or more probably by the different tectonic position of the samples studied, because the Permian rocks were taken from the lower, strongly sheared allochthonous Modra Unit overlain by the 5 - 7 km thick Bratislava basement sheet, whilst younger Triassic and Jurassic sandstones come from the footwall of the frontal parts of the Bratislava Nappe, where the tectonic burial probably did not exceed 3 - 5 km.

On the basis of the observed data and taking into account the current views on the structural evolution of the Tatric units in the Malé Karpaty Mts, we propose the following tectonic scenario:

1 - A long-term extensional tectonic regime (Lower Jurassic to Middle Cretaceous, approx. 100 Ma) created the dissected basin architecture of the Tatric Mesozoic successions and led to the considerable thinning of the epi-Variscan continental crust underlying individual basins, which may be mostly regarded as half-grabens over tilted upper-crustal blocks (Plašienka et al. 1991; Plašienka 1991). Lithospheric thinning (evidenced by small portions of lower Cretaceous hyalobasanites and by thermal subsidence period) brought about a rise in temperature at the base of attenuated crust and diastathermal heating of the crust and cover sediments (cf. Robinson & Bevins 1989). The temperatures in mid-crustal levels, where listric extensional detachment faults flattened (probably not more than 5 - 7 km according to the corresponding thicknesses of the later basement thrust sheets) exceeded 300 °C, i.e. thermal gradient of 50 - 60 $°C.km^{-1}$ occured. However, a relatively thin sedimentary cover allowed only moderate temperatures at its base (not more than 100 °C - Fig. 3a).

2 - Late Cretaceous (Turonian) compression inverted the extensional crustal structures into an imbricated thrust stack with ramp-flat geometry (Fig. 3b). Thrust sheets detached at middle to upper crustal levels ($\approx$300 °C) overrode cold cover sediments and their conductive heating from above caused very low to low-grade dynamothermal metamorphism in allochthonous units (Bratislava and Modra Nappes). Basement mylonites lost radiogenic Ar during shearing and thrusting, which is evidenced by K-Ar dating of sericite from mylonitized granitoids of the Prepadlé (Borinka) and Modra shear zones (77 and 74 Ma, respectively - ex Putiš 1991). Final thrusting over the foreland Borinka Unit (behind the frontal ramp) brought thermally balanced cooling allochthonous masses over cold sediments, hence their decreasing thermal capacity allowed only restricted footwall heating in the rear parts of the overthrust (Prepadlé shear zone), while in the more external zones slightly metamorphosed cover successions overrode unmetamorphosed Borinka sediments (Fig. 3c).

According to this conception, the primary source of the rising metamorphic temperature was diastathermal heating, which was tectonically transported from the middle to upper crustal levels to be able to generate metamorphic recrystallization of the relatively thin blanket of Tatric Mesozoic cover sediments. The Western Carpathian Tatricum laterally passes SW-ward to the lower Austro-Alpine units of the Eastern Alps, where corresponding IC values are summarized by Kralik et al. (1987) from

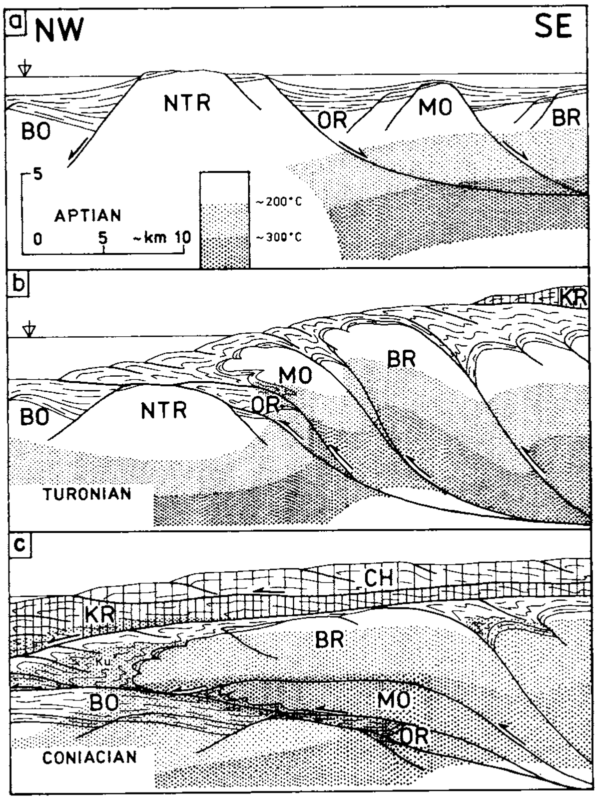

Fig. 3. Interpretative tectonic model for the evolution of Alpine metamorphism in the Tatricum of the Malé Karpaty Mts. **a** - Aptian period of maximum extension and increased heat flow from the mantle due to lithospheric stretching; **b** - incipient Turonian shortening, reactivation of extensional normal faults to thrust faults, perturbation of the thermal field; **c** - termination of thrusting, slow equilibration of temperatures and general cooling.
Dotted areas represent inferred temperature fields, vertical ruling - Permo-Mesozoic sediments of cover nappes, Tatric cover is faintly hatched and crystalline basement is unornamented. Tectonic units as in Fig. 1, NTR - North Tatric Ridge.

Triassic limestones of the Hainburger Berge Mts (prolongation of the Malé Karpaty Mts on Austrian side) and Leitha Gebirge Mts. The interpretation of sources of this early Alpine metamorphism closely approaches our view.

Similar processes were probably also responsible for the low grade Alpine metamorphism in other Western Carpathian Mesozoic units, as it was proposed e.g. by Plašienka et al. (1989) and Plašienka (1991) for the northern Veporicum. The superficial cover nappes (Krížna, Choč and higher ones) are too thin to produce sufficient burial (together not more than 3 - 4 km in the Tatric realm) and the structures of their sole point to brittle emplacement mechanisms by gliding along a thin overpressure cataclastic horizon (Jaroszewski 1982) with little influence on the footwall structures. The occasionally detected anchimetamorphic overprint at their soles is probably inherited from the diastathermal period as well.

Conclusions

The temperature conditions of a slight metamorphism of Permo-Mesozoic Tatric cover sediments in the Malé Karpaty Mts were studied by means of illite crystallinity determinations, compositions of authigenic micas in metasandstones and observations on deformation mechanisms. Most of the data point to the very low to low grade (anchizonal) conditions, approximately between 250 and 300 °C. Since the primary thickness of the Permo-Mesozoic cover is insufficient to produce necessary burial and metamorphism is accompanied by a dynamic recrystallization, as well as metamorphic imprint is regionally distributed and probably only locally increased by some shear heating, the interpretative tectonic model considers first the necessary crustal temperature rise due to diastathermal heating generated by lithospheric stretching and secondly tectonic transportation of hot mid-crustal rocks over cold cover sediments and their metamorphism through conductive thermal equilibration and hot fluids migration during and after the thrusting. As these processes occured at upper crustal levels, the temperature loss should have been quite rapid, so some differences in metamorphic grade observed in frontal parts of the thrust stack (metamorphosed rocks over unmetamorphosed) were recorded.

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