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Chromian and ferrian spinels from Cretaceous sediments of the West Carpathians

MILAN MIŠÍK, JOZEF JABLONSKÝ, PAVOL FEJDI*, MILAN SÝKORA

Department of Geology and Paleonthology, Faculty of Natural Sciences, Comenius University, Gottwaldovo nám. 19, 886 02 Bratislava
* Department of Mineralogy, as above

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Хромитовые и железистые спинели в осадках Западных Карпат

Галечники известняков баррема-апта и обнажений песчаников альба и сеномана утёсового пояса а также центральных гор (упаковочные серии-татрикум, крижнянский покров-фатрикум) установлены хромспинели и железистые спинели, источником которых являются неизвестные ультраосновные тела пенинской и ультрататридной кордилиеры. Указано, что в краевых зонах Альп и Западных Карпат детритические спинели отсутствуют и наоборот обильные в среднемеловых осадках внутренних поясов.

Chromian and ferrian spinels from Cretaceous sediments of the West Carpathians

Chromian and ferrian spinels are described from pebbles of Barremian-Aptian limestones and from sandstone outcrops of Albian and Cenomanian age from the Pieniny Klippen belt and from core mountains (envelope units of the Tatric and the Krížna nappe of the Fatric). As sources for spinels, unknown ultrabasic bodies served participating on the Pieniny and Ultratatride cordilleras. It is emphasized that detritic spinel lacks in outer belts of the Alps and Western Carpathians but is frequent in Middle Cretaceous sediments of more internal zones.

In the Middle Cretaceous sediments of Pieniny Klippen Belt and Central Western Carpathians (envelope units of the Tatric and the Krížna nappe of the Fatric) a considerable amount of spinels was found in heavy fractions. According to the results of electron microprobe analyses, they belong to chromian and ferrian spinels. As the source of the detrital spinels, only large areas of ultramafic bodies can be taken into consideration. Corresponding ultramafic bodies are unknown at the recent surface of the Western Carpathians. The reconstruction of position, mechanism of penetration and destruction of these ultramafic bodies would be an important contribution to decipher the paleogeography and tectonic history of the Western Carpathians.

The Pieniny Klippen Belt (Pieninic*)

Despite expectations any signs of ultramafic rocks were formerly known from the Pieniny Klippen Belt originated from its ancient trough or lineament (e. g. V. E. C h a i n et al. 1977, fig. 2). Recently, heavy mineral extraction from the limestone pebbles in "Upohlav" Conglomerate (Middle to Upper Cretaceous) confirmed the existence of huge ultramafic bodies on the Pieniny Exotic Ridge (M. M i š í k 1978). Accessory chromite from sandstones of the klippen "mantle" was already mentioned by R. Oberhauser (G. W o l e t z in R. Oberhauser 1968). He supposed the "entry" of the ultramafic bodies during the Cenomanian. Based on numerous occurences with abundant spinel in *Orbitolina*-bearing limestones we may accurate that this "entry" (better said the denudation) of ultramafic bodies started in Barremian-Aptian.

Limestone pebbles containing spinels in thin sections (fig. 1—3) were dissolved in 10 p. c. acetic acid (sandstone pebbles in diluted HCl) and the insoluble residue of 0.25—0.05 mm fraction was sepa-

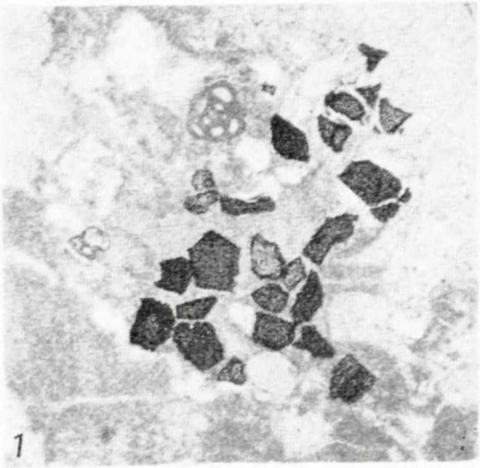

Fig. 1. Accumulation of spinel grains in Barremian — Aptian limestone. Pebble from the Senonian conglomerates, Kysuca-Pieniny unit of Klippen Belt. Locality: Zástranie, playground *a*. Thin section No. 7771. Magn. 136×.
Obr. 1. Zhluk zŕn spinelu vo vápenci barému — aptu. Obliak zo zlepencov senónu kysucko-pieninskej jednotky bradlového pásma. Lok.: Zástranie, ihrisko *a*. Výbrus č. 7771. Zväčš. 136×.

* all names used as Pieninikum, Tatrikum etc. in Slovak and German literature (the editor).

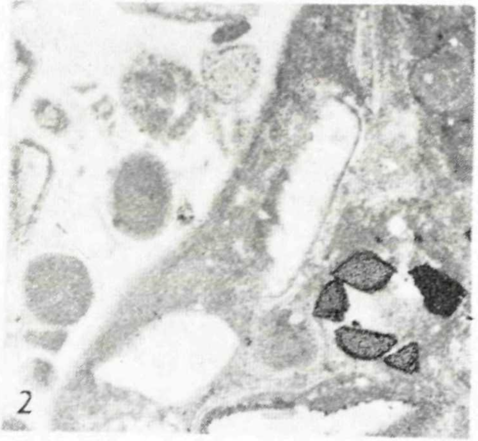

Fig. 2. Spinel grains in an intraclast within oolitic limestone of Barremian — Aptian. As fig. 2. Zástranie *I-n*. Thin section No. 7753. Magn. 43×.

Obr. 2. Zrná spinelov v intraklaste uprostred oolitického vápenca barému — aptu. Ako na obr. 2. Lok.: Zástranie *I-n*. Výbrus č. 7753. Zväčš. 43×.

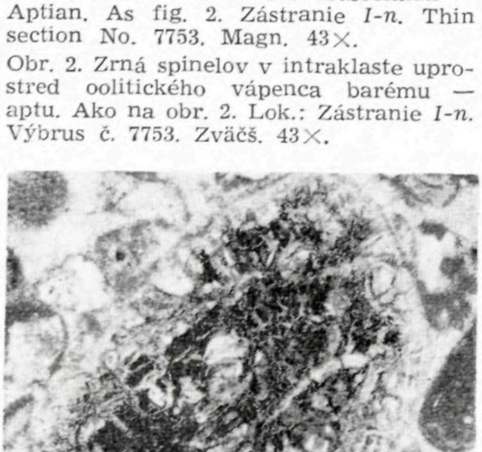

Fig. 3. Small fragment of serpentine with lacy structure in Barremian — Aptian limestone. Pebble from Albian conglomerates, Klape unit of Klippen Belt. Locality: Nosice *I-u*. Thin section No. 8932. Magn. 43×.

Obr. 3. Úlomok serpentinitu so slučkovou textúrou vo vápenci barému — aptu. Obliak z albských zlepencov klapskej jednotky bradlového pásma. Lok.: Nosice *I-u*. Výbrus č. 8932. Zväčš. 43×.

rated using bromoform. Grain counting was effected after the mounting of heavy fraction in Canada balsam (minimum number of grains was 108, the maximum 435). The actual share of spinels is a little higher than results show because some of them might be included erroneously to opaque minerals. Pyrite is the most abundant among the latter followed by magnetite and ilmenite. Authigenic pyrite may substantially distort the share of terrigenous components (e. g. in a sample from Malé Hradisko locality glaucophane composes 6.0 p. c. of the heavy fraction but omitting opaque minerals its share rises to 47 p . c.). Therefore the spinel/zircon ratio gives a better expression of the spinel content. Most of micas were bleached by weathering and contain rutile microlites. The proportion of chlorite and chloritoid was checked using immersion medium with a r. i. = 1.66.

Spinels were registered at numerous localities (fig. 4) ranging from the Middle Váh valley to the Orava valley (from Vršatecké Podhradie to Trstená). Their maximum content was 57.8 % of the heavy fraction (see analyses in Tab. 1). Besides limestone pebbles of the Barremian-Aptian, spinels were also found in Albian and Cenomanian sandstone pebbles and in samples from outcrops of Cenomanian sandstones (the Klape unit).

In the limestones with abundant

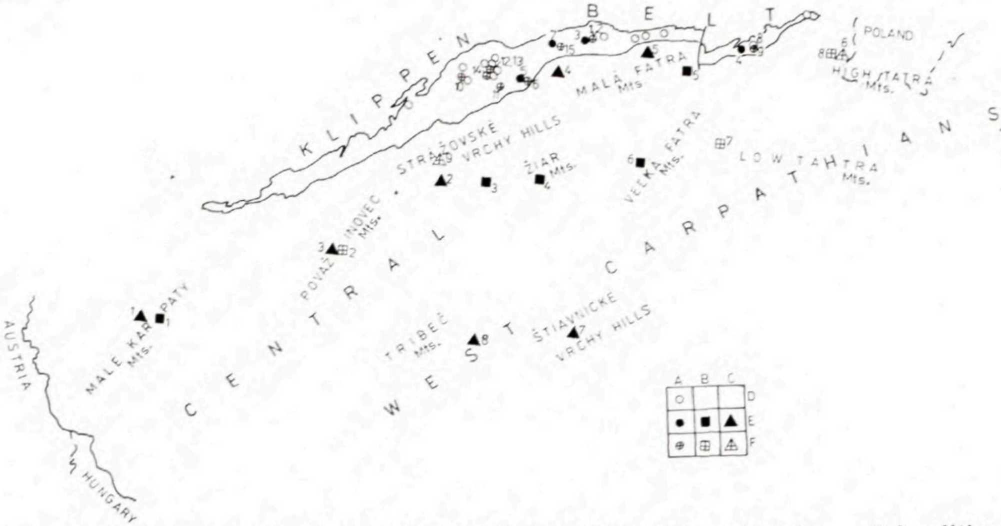

Fig. 4. Occurencies of detrital spinels in West Carpathians (numbers of localities correspond to the analyses in text) A — Klippen Belt, B — Tatrikum, C — Fatrikum (Križná nappe), D — occurence registration only, E — heavy mineral analysis, F — chemical analysis of spinels and heavy mineral analysis

Obr. 4. Výskyty detritických spinelov v Západných Karpatoch (čísla lokalít zodpovedajú analýzam v texte)
A — bradlové pásmo, B — tatrikum, C — fatrikum (krížňanský príkrov), D — len registrácie výskytu, E — rozbor ťažkej frakcie, F — chemické analýzy spinelov

▶

1—3 — Barremian-Aptian limestone pebbles from Senonian conglomerates of the Pieniny Klippen Belt, Kysuca — Pieniny unit. Localities: 1 — Zástranie *I-n*, 2 — Zástranie *I-r*, 3 — Zástranie playground, 4 — Barremian-Aptian limestone pebble from Senonian conglomerates of the Klape unit, Oravský Podzámok locality *I-l*, 5—7 — Barremian-Aptian sandy limestone pebbles from Cenomanian conglomerates of the Manín unit. Localities: 5 — Hradná, Zlatý Diel — *c*, 6 — Hradná JRD — *f*, 7 — Malé Hradisko near Žilina — *b*, 8—10 — Barremian-Aptian limestone pebbles from Cenomanian conglomerates of the Klape unit Localities: 8 — Sedliacka Dubová *I-j*, 9 — Sedliacka Dubová *I-i*, 10 — Nosice *I-u*, 11 — Barremian-Aptian limestone pebble from Cenomanian conglomerate of the Manín unit, Praznov — m locality, 12 — Albian-Cenomanian sandstone pebble from Cenomanian conglomerate of the Klape unit, Považský hrad, quarry *j* locality, 13 — Barremian-Aptian limestone pebble from Cenomanian conglomerate of the Klape unit, Považský hrad, quarry locality. All samples come from the Pieniny Klippen Belt.

1—3 — obliaky barémsko-aptských vápencov zo senónskych zlepencov pieninského bradlového pásma, kysucko-pieninská jednotka. Lokality: 1 — Zástranie *I-n*, 2 — Zástranie *I-r*, 3 — Zástranie — ihrisko, 4 — obliak barémsko-aptského vápenca zo senónskych zlepencov klapskej jednotky, lokalita Oravský Podzámok *I-l*, 5—7 — obliaky barémsko-aptských piesčitých vápencov z cenomanských zlepencov manínskej jednotky. Lokality: 5 — Hradná, Zlatý Diel *c*, 6 — Hradná — JRD *f*, 7 — Malé Hradisko pri Žiline *b*, 8—10 — obliaky barémsko-aptských vápencov z cenomanských zlepencov klapskej jednotky. Lokality: 8 — Sedliacka Dubová *I-j*, 9 — Sedlicka Dubová *I-i*, 10 — Nosice *I-u*, 11 — obliak zarémsko-aptského vápenca z cenomanského zlepenca manínskej jednotky, lokalita Praznov *m*, 12 — obliak albsko-cenomanského pieskovca z cenomanského zlepenca klapskej jednotky, lokality Považský hrad — lom *j*, 13 — obliak barémsko-aptského vápenca z cenomanského zlepenca klapskej jednotky, lokalita Považský hrad — lom. Všetky vzorky pochádzajú z pieninského bradlového pásma.

Heavy mineral analyses of pebbles of Middle Cretaceous sedimentary rocks from the Pieniny Klippen Belt

Analýzy ťažkých minerálov z obliakov strednokriedových sedimentárnych hornín pieninského bradlového pásma

Tab. 1

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13
% of insoluble residue	5,90	2,01	—	21,6	5,91	51,5	—	2,41	—	—	—	—	—
% of heavy fraction	0,82	0,44	—	0,10	0,28	0,46	—	0,36	—	—	—	—	—
spinel	24,2	47,1	57,3	24,9	4,2	3,9	0,6	56,3	1,8	11,0	34,3	3,5	1,8
glaucophane	—	—	—	—	1,7	—	6,0	—	—	—	+	2,1	8,8
chloritoid	+	—	—	—	2,9	10,8	5,0	—	—	+	—	3,3	7,5
garnet	0,9	0,9	+	6,4	0,6	2,0	0,2	—	0,4	—	—	1,2	0,3
zircon	1,8	+	2,9	1,6	2,4	4,3	0,5	2,2	10,0	+	1,4	5,9	1,5
rutile	+	+	3,2	1,2	1,3	0,6	0,5	0,8	1,8	+	+	1,4	0,5
turmalin	0,9	1,7	1,1	0,5	2,9	3,6	0,5	1,5	2,7	+	0,6	1,7	0,5
titanite	+	+	0,7	—	—	—	—	—	2,3	—	+	—	—
hypersthene	—	—	+	—	—	—	+	—	—	—	—	—	—
andalusite	—	—	—	—	—	—	—	—	+	—	—	—	—
epidote	—	—	0,7	—	—	—	—	—	—	—	—	—	—
phosphorite	—	—	—	—	—	—	+	—	—	0,9	—	—	—
opaque minerals	40,8	22,7	25,4	21,6	5,4	8,4	64,8	6,6	47,8	4,5	61,0	36,2	27,1
cloudy grains	18,5	+	+	28,7	32,4	47,2	+	27,5	20,5	34,2	—	+	+
white mica	10,2	27,6	8,3	4,6	36,0	10,7	16,6	2,9	10,9	32,8	1,1	33,2	33,4
chlorite	2,7	+	0,7	0,5	10,2	9,3	3,5	2,2	1,8	11,8	—	2,8	13,1
biotite	—	—	—	—	—	—	0,9	—	0,4	1,8	—	—	—
rock fragments (serpentine and others)	+	—	+	—	+	—	—	+	—	+	1,9	8,7	5,5
spinel/zircon ratio	13,4	> 47	19,8	21,8	1,75	0,9	1,2	25,5	0,18	> 11	24,5	0,6	1,2

spinel grains several small fragments (about 1 mm size) of serpentinite with typical mesh structure were found (fig. 3). It is noteworthy that any serpentinite pebbles occur in "Upohlav" conglomerate. Probably, the serpentinite bodies were strongly tectonized in the time when the cordillera (exotic ridge) consisting of tectonic slices has been pushed upwards. During its "intrusion in solid state" the serpentinite rock was triturated to tiny fragments.

Among the accompanying minerals, the glaucophane is the most interesting one from the Barremian-Aptian (M. Mišík 1978, p. 150). Glaucophanite outcrops in the Western Carpathians are known only from the Gemeric (Southern Slovakia). In the Eastern Carpathians, some fragments of glaucophane schists were found at the boundary of the Pieniny Klippen Belt and the Marmarosh zone (G. N. Dolenko — L. G. Danilovich 1976, p. 5).

According to postulations of a plate-tectonic model, the ultramafic massifs may be considered as obducted slices of the oceanic crust and glaucophane-bearing rocks ("blue-schists") are products of a high-pressure metamorphism developed within subducted plate slabs along plate margins. Using this model we may assume that the Pieniny Exotic Ridge was largely formed by subduction mélange what could explain also the extraordinary variety of rock types represented in pebbles of the "Upohlav" Conglomerate (M. Mišík 1978, p. 154, 1979).

The Core Mountains (Tatric and Fatric)

Detrital spinels occur also in the Albian-Cenomanian sandstones of envelope units (Tatric) and of the Krížna nappe (Fatric, formerly Lower Subtatric).

Their share was determined by grain counting of the heavy fractions prepared using the following procedure: crushing of sandstone sample, separation of the fraction 0.1—0.05 mm by sieves, several samples attacking by diluted HCl, bromoform separation and mounting in Canada balsam. Spinels were identified both in polarized (isotropy) and transient light (deep red colour). Several opaque spinels display in incident light a glassy lustre, conchoidal fracture and black colour with a red gleam on fracture edges.

Chromian and ferrian spinels were found in almost all samples (tab. 2 and 3). Their arithmetical mean content in the heavy fraction of samples from envelope units (Tatric) was 5.5 % the maximum content 15 %. The arithmetical mean content in samples from the Krížna nappe (Fatric) was 10.2 % the maximum 58.9 %.

We suppose that there is no possibility to derive all detrital spinels occuring in the Middle Cretaceous beds of the Tatric and Fatric from a common source. It cannot be excluded that the spinels proceeded from the Pieniny Exotic Ridge to more external parts of the Tatric. For the spinels occuring in more internal parts of the Tatric, their provenience from another exotic cordillera (tentatively named as Ultratatric Ridge) situated between the Tatric and Fatric sedimentation areas is suggested (fig. 5). Such deduction follows from several measurements of transport directions and even from the distribution of lithofacies. According to the data from the Červená Magu-

Selected heavy mineral analyses from Middle Cretaceous sandstones, Tatrikum — Central West Carpathians

Vybrané analýzy ťažkých minerálov z pieskovcov strednej kriedy, tatrikum, centrálne Západné Karpaty

Tab. 2

Sample	1	2	3	4	5	6	7	8
pyrite + limonite	16,9	16,3	47,9	22,6	12,0	30,4	11,7	19,0
spinel	6,9	8,7	1,5	0,9	2,9	2,1	3,2	4,0
leucoxene	19,7	17,7	7,1	19,9	37,3	30,1	30,9	20,6
other opaque m.	4,9	8,8	2,1	17,3	2,2	2,4	7,3	4,2
chlorite	0,7	3,9	0,2	1,3	4,9	2,1	0,2	4,7
mica	14,1	8,0	4,6	1,5	3,7	2,9	6,8	2,7
apatite	0,3	0,6	—	7,2	0,5	4,7	4,6	4,0
zircon	32,0	5,5	6,4	10,0	4,6	9,2	14,3	9,9
rutile	1,3	1,1	0,5	2,4	2,0	3,4	4,1	3,0
tourmalin	0,3	—	0,3	2,8	2,2	1,3	1,7	0,5
titanite	1,6	—	0,3	0,4	0,2	—	—	0,5
hypersthene	—	0,8	—	0,6	0,2	—	—	0,3
pyroxene	0,7	0,8	—	1,1	0,5	0,3	0,2	—
amphibole	—	0,3	—	—	—	—	—	—
sillimanite + staurolite + + disthene + andalusite	—	—	—	0,2	4,6	0,3	0,2	3,7
garnet	—	—	0,2	0,4	—	0,2	0,4	+
cloudy grains	0,3	—	10,9	11,4	21,7	10,2	14,2	5,2
others	0,3	26,4	18,0	—	0,5	0,4	0,2	17,7
spinel/zircon ratio	0,22	1,55	0,23	0,09	0,63	0,23	0,22	0,4

1 — Sklená Huta 150, Malé Karpáty Mts.; 2 — Nová Lehota 117, Považský Inovec Mts.; 3 — Čavoj (Obšiar) 73a, Strážovské vrchy Mts.; 4 — Vyšehradné — sedlo 136a, Žiar Mts.; 5 — Párnica 54b, Malá Fatra Mts.; 6 — Necpaly valley 131, Veľká Fatra Mts.; 7 — Ludrová valley 125a, Nízke Tatry Mts.; 8 — Oravice — Suchá dolina 82/2b, High Tatra Mts.

ra Mts. (envelope units of the Nízke Tatry Mts.), the transport direction in proximal facies was from the south and currents were coming from the neighbourhood of the Krížna sedimentary area. In the Krížna nappe (Fatric) of the Strážovské vrchy Mts., in its proximal facies, the transport directions are oriented from WSW (J. Jablonský 1978), thus from the neighbourhood of the Tatric sedimentation area (fig. 5).

However, in the Albian sandstone of the Krížna nappe (Fatric) of the Malá Fatra Mts. and of the High

Selected heavy mineral analyses from Middle Cretaceous sandstones, Fatrikum — Central West Carpathians

Vybrané analýzy ťažkých minerálov z pieskovcov strednej kriedy, fatrikum, centrálne Západné Karpaty

Tab. 3

Sample	1	2	3	4	5	6	7	8
pyrite + limonite	38,2	54,0	12,4	42,4	15,6	6,5	49,6	25,7
spinel	10,4	2,3	6,2	8,4	7,8	55,2	2,1	8,4
leucoxene	12,4	13,0	51,4	13,8	32,2	17,9	22,3	24,5
other opaque m.	2,3	1,1	3,7	2,7	1,4	7,5	5,1	5,0
chlorite	1,9	1,6	4,5	5,2	5,9	1,8	—	4,9
mica	5,8	2,4	3,1	4,8	1,5	0,2	3,1	4,5
apatite	2,3	1,1	0,8	2,5	—	0,5	1,0	2,5
zircon	15,1	9,5	5,6	6,8	21,8	6,2	3,8	11,4
rutile	0,8	1,7	0,8	2,0	5,4	1,3	1,0	2,7
tourmaline	1,2	1,0	0,8	0,7	4,3	0,3	1,0	1,2
titanite	—	0,1	0,6	0,5	—	0,2	—	0,2
hypersthene	—	—	0,8	—	0,4	—	—	0,2
pyroxene	—	0,2	0,3	—	0,4	0,2	—	0,2
amphibole	—	—	—	—	—	—	1,0	—
sillimanite + staurolite + + disthene + andalusite	—	—	0,6	0,2	0,3	0,1	—	0,2
garnet	0,8	0,1	0,3	—	0,1	0,2	—	—
cloudy greins	3,5	1,6	5,1	5,0	0,3	1,9	8,6	5,2
others	0,7	10,2	3,0	5,0	—	—	1,4	3,2
spinel/zircon ratio	0,34	0,24	1,1	1,23	0,36	8,3	0,55	0,73

1 — Sološnica valley 152, Malé Karpáty Mts. (Vysoká subunit); 2 — Čierna Lehota 155, Strážovské vrchy Mts. (Belá subunit); 3 — Stará Lehota 119, Považský Inovec Mts.; 4 — Lietava 132, Strážovské vrchy Mts. (other analyses are published in J. Jablonský, 1978, p. 180); 5 — Vrátna valley Pl/b, Malá Fatra Mts.; 6 — Juráňova valley 78, High Tatra Mts.; 7 — Sklené Teplice 109, Štiavnické vrchy Mts.; 8 — Jedľové Kostoľany 111, Tribeč Mts.

Tatra Mts. the transport directions are oriented from E and SE to W and NW whereby the maximum spinel content (58.9 %) was found in the High Tatra Mts. These transport directions can hardly be derived from the supposed Ultratatric Ridge even if we admit that currents twisted towards the basinal axis. An alternative solution might be the existence of another elevation (the Ultra-Krížna source area) near to the internal boundary of the Krížna sedimentation area or southernly from it (fig. 5).

The problem concerning the position of the Krížna nappe (Fatric) sedimentation area was not yet definitively solved. Some years ago there was generally admitted that the Krížna nappe proceeded from the Čertovica suture representing the boundary between the Tatric and Veporic (A. Biely — O. Fusán 1967). Recently, the opinion about the Veporic as the Krížna nappe homeland seems to be more plausible and then the Veľký Bok Group may be considered as a Krížna nappe Mesozoic in "envelope"

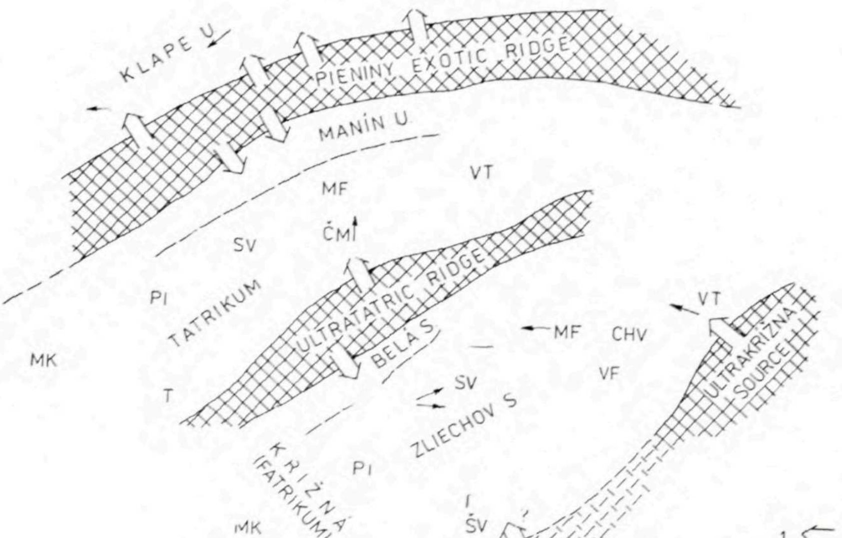

Fig. 5. Palinspastic scheme of the West Carpathians studied area for Albian — Cenomanian
1 — supposed area of clastic material entry into the basin, 2 — measured paleocurrents directions, 3 — position of mountain ranges with analysed outcrops of Middle Cretaceous sediments

Obr. 5. Plinspastická schéma študovanej časti Západných Karpát pre alb — cenoman
1 — predpokladané oblasti vstupu klastík do panvy, 2 — namerané paleoprúdové smery, 3 — lokalizácia dnešných pohorí, v ktorých sú odkryté súvrstvia strednej kriedy príslušnej jednotky

position above the Kráľova hoľa crystalline. If we agree that the Kráľova hoľa complex lies in nappe position above the Hron complex (A. Klinec 1976, A. Biely 1978) then the "roots" of the Krížna nappe would have been in the southermost part of the Veporic and the Ultra-Krížna Ridge at its southern limit. These exotic ridges together with joined proximal facies of the Albian-Cenomanian flysch disappeared during orogenetic movements.

There is no possibility to locate the ultramafic source of spinels immediately into the Tatric and Fatric (Krížna) sedimentation area. Only three small occurences of ultramafic rocks are recently known within the Tatric area (Veľká Lúka in the Malá Fatra Mts., Lúžna in the Nízke Tatry Mts. and Sedlice in Eastern Slovakia) but these bodies were certainly covered by Mesozoic strata during the Middle Cretaceous. Moreover, the composition of their spinels differs from the detrital ones (fig. 7).

Only small occurences of serpentinite are known to occur within the Veporic considered as the homeland of the Krížna nappe. Small bodies occur there in the Kohút zone (localities see in D. Hovorka 1965). These could not be an adequate source for detrital spinels in sandstones of Cretaceous age and also the denudation of this crystalline with ultramafic bodies is improbable during the Barremian-Aptian nor Albian time. Moreover, the supposed serpentinite bodies of source areas were probably associated with carbonate rocks and not with crystalline ones because large amounts of detrital carbonate grains occur together with the maximum concentration of spinel grains in the Middle Cretaceous sandstones of the Krížna nappe from the High Tatra Mts.

It is noteworthy that spinels were found also in two thin sections of Barremian-Aptian limestone pebbles with *Palorbitolina lenticularis* and *Dasycladacea* sampled from Albian conglomerate near Čavoj (Tatric, envelope unit of the Suchý Mts.). The spinel/zircon ratio is unusually high and achieves the value 75 in the heavy fraction separated from the pebble. Thus there is a close analogy with the spinel-bearing *Orbitolina* limestone pebbles of the Pieniny Klippen Belt and the time of the first spinel "entry" into the Pieninic and Tatric sedimentation areas was the same. The spinel concentration in the Barremian-Aptian rocks is the highest one in comparison with sediments of Middle and Upper Cretaceous or even of Paleogene age.

The supposed cordilleras (the Ultratatric ridge and the Ultra-Krížna sedimentation area) yielded, besides the chromian and ferrian spinels, also some exotic rock pebbles such as acid and intermediary volcanics and carbonate in facies unknown from the Core Mountains. These will be described elsewhere.

The possible continuation of West Carpathian spinel-bearing zones into the Eastern Carpathians and Alps

The Eastern Carpathians

Spinel occurences continue probably into the East Slovakian part of the Klippen Belt where M. Starobová (1962) mentioned chromite composing one third of the heavy fraction of an isolated sample from the Paleogene of the Klippen Belt. Chromite points to the presence of ultramafic bodies in the Neopieninic cordillera (R. Marschalko et al. 1976) emerged during the Lower Paleogene. We suppose a rich spinel content also for the Central Carpathian Paleogene in the southern neighbourhood of the Klippen Belt on Slovakian territory because S. S. Kruglov (1974, p. 208) quoted extraordinary abundant spinel content in heavy fractions of Eocene sandstones accompanied by small serpentinite fragments from boreholes on the USSR territory. He supposed them to derive from ultrabasic bodies protruded by tectonic movements along the boundary of the Klippen Belt and the Transcarpathian basin.

Ultramafic bodies of the Marmarosh ophiolite suture according to M. G. Lomize (1976, p. 1411) appeared at the eroded surface during the Middle Cretaceous what gives a remarkable coincidence in time with data from the Klippen Belt. The Marmarosh ultramafic bodies served as the probable source of chromite grains figured out by M. G. Diadchenko — A. G. Kudykin (in E. K. Lazarenko et al. 1963, pp. 236—237) from alluvial deposits of the Terebla river.

Northern Hungary

Chromite as the most abundant heavy mineral (except of authigenic pyrite) is quoted by K. Vaskó-David (in J. Fülöp 1976, pp. 109—113) from Lower Albian siltstones near Tata. The denudation of unknown ultramafic bodies took place evidently in the same time as it is evidenced for our detrital spinels from the Western Carpathians.

Western Alps

Important informations from Switzerland were gathered by U. Gasser (1967). In the flysch sediments of more external zones (Ultrahelvetic and North Penninic), spinels are lacking. In the nappes of the Préalpes derived from the central and southern parts of the Penninic area, i. e. from the innermost zones, spinel is abundant. In the younger and most external sediments of the North Helvetic and of the Subalpine molasse, spinels are present in lower quantities and their retransportation from higher nappes of the Préalpes was proved there. Spinels are absent in all Ultrahelvetic and North Penninic flysch subunits studied (the Habkern, Gurnigel, Schlieren, Niesen, Wäggital, Voralberg and Vaduz Flysch). Considerable amounts of spinels occur in flysch sequences of the Klippe nappe derived from the Central Penninic, the Breccia (Brèche) nappe of the South Penninic and also in the Cenomanian of the Simme nappe with its home area at the boundary of the South Penninic and Austroalpine domain. From these occurences, the redeposition of spinels occured into the Aldorf Sandstone of Oligocene age (North Helvetic), the d'Anot Sandstone of the same age (Peïra-Cava Flysch in France, A. H. Bouma 1959) and also into the Subalpine molasse.

Eastern Alps

Data on heavy mineral distribution may be found in the following papers: G. Woletz (1963, 1967), K. Müller (1973), P. Faupl (1975), V. J. Dietrich (1976) and V. J. Dietrich — U. Franz (1976). The lack of spinels (chromite) in the northern (external) sedimentary zones and their abundance in the more southern ones was confirmed in the Eastern Alps, too. Spinels are practically absent in the Helvetic, Ultrahelvetic ("Buntmergelserie") and North Penninic units (Rhenodanubian flysch) with an exception for the Kaumberg Beds of the Senonian containing only an amount of 1.5 % as average in positive samples (P. Faupl 1975). In the southern part of the Wienerwald, a small chromite content was found in Aptian sandstones and in the Cenomanian Reiselberg Sandstone near Ybbsitz and Satzberg (G. Woletz 1963). Chromite is characteristic for the Cenomanian of the Arosa scale zone and for the Pieniny Klippen Belt near St. Veit (till to a 50 % of the heavy fraction, G. Woletz 1963).

In the Austroalpine (Oberostalpine) of the Alps, the Neocomian Rossfeld Beds (Tirolikum according to P. Faupl — A. Tollmann 1979 and A. Tollmann 1978, p. 317) disclose a typical chromian spinel assemblage (up to 56 % content: G. Woletz 1963). The "Randcenoman" Sandstone (Bajuvarikum) contains abundant chromian spinels as well (6—71 % according to K. Müller 1973). The Gosau Formation contains chromian spinels in Upper Santonian to Lower Campanian beds up to 93 % of the heavy fraction (G. Woletz l. c.). The source for all these detrital chromian spinels is sought in the Ultrapieninic Ridge. Higher levels of the Gossau Formation commencing from the Upper Campanian are devoided of chromian spinels. According to R. Oberhauser (1968), advancing Upper Austroalpine nappes covered at that time the source area the Ultrapieninic Ridge.

There is a slight divergence in views as to the position of the Ultrapieninic Ridge. A. Tollmann (1977, p. 5) situated it at the southern edge of the Helvetic area or along the Helvetic — Penninic boundary. R. Oberhauser (1968) claimed for its position within the Penninic domain at the boundary of the Briançon and Piemont zones. V. J. Dietrich (1976) did not use the term "exotic ridge" (cordillera) but he supposed the source area to have been originated as a flysch wedge by accumulation of tectonic scales representing remnants of an oceanic crust (rocks of the ophiolite suite, radiolarite, pelagic limestone and older flysch deposits). This flysch wedge became puhsed out during the subduction of the oceanic margin according to the model proposed by D. E. Karig — G. H. Sharman (1975). The ophiolitic detritus described thoroughly by V. J. Dietrich — U. Franz (1976) includes chromian spinel grains, small fragments of mafic and ultramafic rocks and also a 15 m thick layer of consolidated serpentinite sand in the middle part of the Gosau Formation.

Besides the Ultrapieninic Ridge considered generally to represent the continuation of the Pieniny Ridge from the Western Carpathians, other source areas are supposed as well for the Cretaceous of the Eastern Alps. P. Faupl — A. Tollmann (1979, in A. Tollmann 1978, p. 317) pointed out that detrital chromite and brown hornblende of the Rossfeld Beds (Lower Cretaceous) were transported from the south and therefore they were derived from another cordillera. There is an interesting analogy with our West Carpathian territory for which we suppose at least one other and more southern source within the Central Carpathian area, the Ultratatric Ridge, yielding spinels into the Middle Cretaceous deposits besides the Pieniny Ridge.

In the Eastern Alps, another less important parallel elevation existed northernly from the Ultrapieninic Ridge during the Senonian. This Kaumberg Ridge yielded a small amount of chromite into the Kaumberg Trough (P. Faupl 1975).

The West Carpathian Flysch Zone

Similarly to the Alps, spinel (chromite) also lacks in the external (northern) zones of the Western Carpathians. There is any mention of spinels in heavy mineral analyses by H. Peslová (1971) and F. Pícha (1973). I. Krystek (1973) registered a very small amount of picotite from the Godula Beds of Cenomanian — Lower Senonian age (Moravian-Silesian Beskydes).

The problem of chromian spinel grains redeposition

It was already indicated that chromian spinel occurences in Oligocene beds of the most external zones of the Western Alps are explained by redeposition (occurences on the third place). As spinel is a resistent mineral, its redeposition is not surprising. Naturally, this evokes a question wherther is correct our paleogeographical conception concerning the position of ultramafic bodies. It is impossible assume an "omnipresence" of spinels and therefore their higher concentrations must be surely caused by a transport from the primary source. For the large part of the Tethyan realm, the appearance of detrital chromian spinels is typical for the Middle Cretaceous time and for certain zones.

However, it is necessary to search for detrital spinels also in older sediments in the same territory with the aim to verify the hypothesis about the "entry" of ultramafic bodies into the erosion area during the Middle Cretaceous. Minor ultramafic bodies are supposed to accompany the Variscan or older orogenies in the Western Carpathians. From the Upper Triassic Lunz Beds of the Eastern Alps, M. Behrens (1972, p. 62, pl. 1, fig. 4) quoted a minor amount of "spinels (chromites) of honey yellow and dark red colours" up to 10 % of the heavy fraction (opaque grains omitted). Spinel was not found in the Aalenian flysch sediments of the Pieniny Klippen Belt (J. Loziński 1956). From our preliminary results, we may ascertain the lack of spinels in Liassic and Doggerian sandy limestones of the Czorsztyn and Klape units of the Pieniny Klippen Belt. Heavy mineral analyses of Liassic sediments from all West Carpathian units will be carried out in the next future.

Chemical composition of studied spinels

No data on the chemical composition of detrital spinels were published till now from the Alps and Carpathians. There are even discrepancies concerning the name of spinel varieties. For example, G. Woletz (1967) wrote about chromite, U. Gasser (1967) designated the same mineral as spinel and V. J. Dietrich — U. Franz (1976) as chromian spinel.

Analyses of spinels have been carried out using the JEOL manual operating JXA-5A electron microprobe analyser. The instrumental setting included a maximum focused electron beam (diameter 4 μ), an accelerating potential of 25 kV and sample current of 20 nA. Pure element standards served for calibration (a special attention has been paid for wavelenght shift correction). Raw measurement data were corrected for drift, background, generation factor and to the absorption and characteristic fluorescence using the computer program EMPADR VII (J. Rucklidge — E. L. Gasparini 1969). In all samples the homogeneity of distribution of any element has been verified with the aid of X-ray images. Spinel analyses were recalculated into cell formulae assuming a stoichiometric relationship $R^{2+}R_2^{3+}O_4$ to establish proportions of FeO and Fe_2O_3. Analytical results are given in tab. 4 and 5.

The most conspicuous features revealed by the analyses are the homogeneity and relative chemical uniformity of spinels without any dependence on the regional setting. All spinels analysed are relatively rich in MgO and Al_2O_3 and poor in Cr_2O_3 content. According to the classification of H. W. Haslam

Chemical composition of detrital spinels from the Barremian — Aptian limestone pebble; Cretaceous conglomerates of Pieniny Klippen Belt

Chemické zloženie detritických spinelov z obliaka barémsko-aptského vápenca, kriedové zlepence pieninského bradlového pásma

Tab. 4

	10	9	12	1	6	11
FeO	5,62	8,15	0,69	0,15	5,93	9,33
Fe_2O_3	11,85	6,37	16,08	13,32	12,12	8,06
MgO	21,29	21,53	24,46	24,89	21,16	18,57
Al_2O_3	49,30	58,48	46,82	50,89	48,81	49,16
Cr_2O_3	7,42	5,28	8,65	5,70	8,07	8,86
Σ	95,48	99,81	96,70	94,95	96,09	93,98
Unit cell (on 32 oxygen atoms)						
Fe^{2+}	1,031	1,399	0,125	0,023	1,086	1,757
Mg	6,968	6,955	7,870	7,969	6,908	6,237
Σ	7,999	7,994	7,995	7,992	7,994	7,994
Fe^{3+}	1,956	0,983	2,610	2,151	1,996	1,364
Al	12,753	14,151	11,906	12,876	12,592	13,047
Cr	1,289	0,857	1,477	0,968	1,397	1,577
Σ	15,998	15,991	15,993	16,015	15,985	15,988
Σtotal	23,997	23,985	23,988	24,007	23,979	23,982
$Al/\Sigma R^{3+}$	0,797	0,885	0,744	0,804	0,788	0,816
$Cr/\Sigma R^{3+}$	0,081	0,054	0,092	0,060	0,087	0,099
$Fe^{3+}/\Sigma R^{3+}$	0,122	0,061	0,163	0,143	0,125	0,085

* Fe_2O_3 content calculated from total iron supposing stoichiometry of $R^{2+}R_2^{3+}O_4$
10 — Nosice I-u, Klape unit, 9 — Sedliacka Dubová I-i, Klape unit, 12 — Považský Hrad lom-j, Klape unit, 1 — Zástranie I-n, Kysuca — Pieniny unit, 6 — Hradná JRD (f) 7117, Manín unit, 11 — Praznov m, Manín unit.

Chemical composition of detrital spinels from Middle Cretaceous sandstones
Chemické zloženie detritických spinelov zo strednokriedových pieskovcov

Tab. 5

	15	14	8	2	7	6	9
FeO	4,12	4,25	5,98	4,67	6,85	7,76	11,26
Fe_2O_3*	12,78	11,89	10,52	12,34	12,20	11,20	5,34
MgO	22,37	22,02	20,41	22,66	21,75	21,07	17,48
Al_2O_3	48,71	48,67	47,19	49,88	50,71	51,80	51,20
Cr_2O_3	8,33	8,20	9,33	9,3	8,35	8,04	8,36
Σ	96,31	95,03	93,43	98,85	99,86	99,87	93,64
Unit cell (on 32 oxygen atoms)							
Fe^{2+}	0,748	0,780	1,129	0,828	1,209	1,369	2,122
Mg	7,246	7,212	6,866	7,165	6,850	6,629	5,872
Σ	7,994	7,992	7,995	7,993	8,059	7,998	7,994
Fe^{3+}	2,087	1,964	1,784	1,966	1,938	1,777	0,904
Al	12,468	12,597	12,545	12,460	12,618	12,878	13,596
Cr	1,431	1,424	1,663	1,558	1,393	1,341	1,490
Σ	15,986	15,985	15,992	15,984	15,949	15,996	15,990
Σtotal	23,980	23,977	23,987	23,977	24,008	23,994	23,984
$Al/\Sigma R^{3+}$	0,780	0,788	0,784	0,779	0,791	0,805	0,850
$Cr/\Sigma R^{3+}$	0,090	0,089	0,104	0,097	0,087	0,084	0,093
$Fe^{3+}/\Sigma R^{3+}$	0,131	0,123	0,112	0,123	0,122	0,111	0,057

* Fe_2O_3 content calculated from total iron supposing stoichiometry of $R^{2+}R_2^{3+}O_4$
14, 15 — Klippen Belt; 2, 7, 8 — mantle series (Tatrikum); 6, 9 — Krížna unit (Fatrikum), 15 — Strážov 304 a, Klape unit, 14 — Považská Bystrica, Klape unit, 8 — Oravice 82/2 b, High Tatra Mts., 2 — Nová Lehota 117, Považský Inovec Mts., 7 — Ludrovská dolina 125, Low Tatra Mts., 6 — Juráňova dolina 78, High Tatra Mts., 9 — Homôlka 66 a, Strážovské vrchy Hills.

et al. (1976), the studied spinels belong to the chromian and ferrian spinel group (fig. 6).

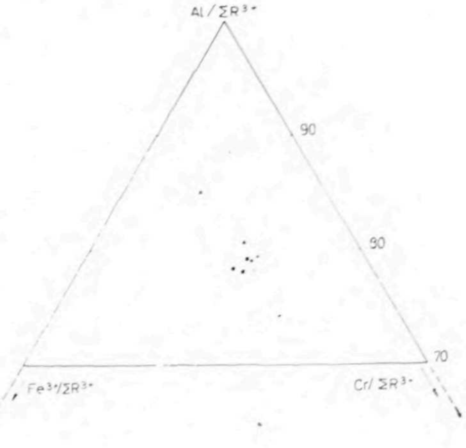

Fig. 6. Compositional plot of analysed spinels.
Solid circles — Klippen Belt pebble; open circles — Klippen Belt sandstones; squares — Tatrikum; triangles — Fatrikum (Krížna nappe)
Obr. 6. Súhrnný diagram analýz spinelov. Plné krúžky — obliaky z bradlového pásma; prázdne krúžky — pieskovce bradlového pásma; štvorce — tatrikum; trojuholníčky — fatrikum (krížňanský príkrov)

Spinels discussed above have no relationship to other chromites of the recently known West Carpattian serpentinite bodies the analyses of which have been published by J. Hurný et al. (1978) and I. Rojkovič et al. (1978, see fig. 7). On the other hand, spinels with similar chemical composition have been found in lherzolite xenoliths enclosed in Late Cenozoic alkali basalts of Southern Slovakia (D. Hovorka — P. Fejdi 1979).

It is possible that the host rock of described spinels was a peridotite belonging to M. J. O'Hara's (1965) spinel peridotite facies. Due to the absence of any coexisting mineral from these supposed spinel peridotites (olivine and pyroxenes) caused by their chemical instability, we are unable to confirm this hypothesis.

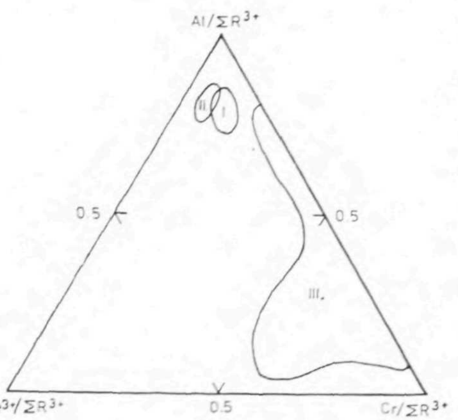

Fig. 7. Compositional plot of West Carpathian spinels
I — presend study, II — spinels from lherzolite xenoliths (D. Hovorka — P. Fejdi 1979), III — spinels from Mesozoic serpentinite bodies (I. Rojkovič et al. 1978)

Obr. 7. Porovnávací diagram zloženia spinelov zo Západných Karpát
I — predkladaná práca, II — spinely z lherzolitových xenolitov (D. Hovorka — P. Fejdi 1979), III — spinely z mezozoických serpentinitov (I. Rojkovič et al. 1978)

Conclusions

Detrital spinels from Barremian-Aptian limestone pebbles and from Albian-Cenomanian sandstones of the Pieniny Klippen Belt and Core Mountains (envelope units of the Tatric and the Krížna nappe of the Fatric) are described. No adequate source rock can be found to outcrop in the Western Carpathians. Supposed sources of ultramafic rock bodies were situated on cordilleras (the Pieninic Exotic Ridge, the Ultratatric Ridge and, possibly, also the Ultra-Krížna sources area) disappeared during tectonic movements.

Data on detrital spinels from neighbouring countries are discussed. The following regularity in the detrital spinel distribution has been ascertained: spinels lack in the outer belts of the Alps and Carpathians (Helvetic, North Penninic, Rhenodanubian Flysch, the West Carpathian Flysch Belt) whereas they are abundant in the inner zones (Central and South Penninic and Austroalpine: Tirolikum, Bajuvarikum, the Gosau Formation, Ultrapieninic Ridge, southern part of the Pieniny Klippen Belt, Tatric, Fatric or Krížna nappe of the Central Carpathian Core Mountains). Abundant detrital spinel appears everywhere beginning from the Middle Cretaceous. In both West Carpathian studied areas, the first "entry" of spinels was precisely during the Barremian-Aptian signifying that supposed ultramafic bodies have been exposed already at that time.

Exact data are available on the, chemical composition of detrital spinels from the Alps. Results of electron microprobe analyses show that both the Pieniny Klippen Belt and the Core Mountains contain chromian and ferrian spinels.

Preložil autor
Odporučil D. Hovorka

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Chrómové a železité spinely z kriedových sedimentov Západných Karpát

MILAN MIŠÍK, JOZEF JABLONSKÝ, PAVOL FEJDI, MILAN SÝKORA

Zrná klastických spinelov sa vyskytujú vo vápencoch barému — aptu a pieskovcoch albu — cenomana bradlového pásma, ako aj obalových sérií (tatrikum) a krížňanského príkrovu (fatrikum). V Západných Karpatoch nie je známy nijaký primeraný povrchový zdroj detritických spinelov z kriedových sedimentov. Predpokladané zdrojové telesá ultrabázik museli vystupovať na kordilérach (v bradlovom pásme pieninská kordiléra, v centrálnokarpatskej oblasti podľa merania transportných smerov ultratatridná kordiléra a pravdepodobne aj ultrakrížňanský zdroj). Tieto kordiléry, ktoré možno charakterizovať aj viacerými typmi rozmanitých exotických hornín, zmizli v priebehu tektonických procesov.

Z porovnania údajov z literatúry o detritických spineloch z okolných krajín vychodí nasledujúce pravidlo: Detritické spinely chýbajú vo vonkajších zónach Álp a Západných Karpát (helvetikum, ultrahelvetikum, severné penninikum, rýnsko-dunajský flyš, flyšové pásmo Západných Karpát); naopak hojné sú vo vnútorných zónach (stredné a južné penninikum, ostalpin, tirolikum, bajuvarikum, v gosauskej formácii — pochádzajúce z ultrapieninského chrbta, v bradlovom pásme — pochádzajúce z pieninskej kordiléry, obalové série, krížňanský príkrov). Vo všetkých týchto oblastiach je detritický spinel hojný od strednej kriedy. V pieninskom bradlovom pásme, ako aj v jadrových pohoriach bol prvý „vstup" spinelov do sedimentačného priestoru v bareme — apte, keď sa predpokladané ultrabázické telesá začali obnažovať. Z Álp doteraz údaje o chemickom zložení detritických spinelov nie sú. Analýzy pomocou elektrónovej mikrosondy ukázali, že v bradlovom pásme aj v jadrových pohoriach ich možno presnejšie charakterizovať ako chrómové a železité spinely.

ZO ŽIVOTA SPOLOČNOSTI

R. Mock: **Gemerikum — definícia a ohraničenie** (Bratislava 31. 1. 1980)

Gemerikum a bükkikum tvoria vnútorné Západné Karpaty (v zmysle R. Mocka 1978). Ich geologický a tektonický vývoj v paleozoiku, ako aj v mezozoiku sa od vývoja v centrálnych Západných Karpatoch veľmi odlišuje (pozri aj M. Maheľ 1979 a H. Kozur — R. Mock 1979), a preto ich treba pokladať za dve osobitné geotektonické jednotky.

Gemerikum je budované epimetamorfným paleozoikom a mezozoikom. Silicikum, ktorého paleozoické podložie nepoznáme a ktoré pochádza z gemerskej jazvy, nie je súčasťou gemerika; pokladáme ho za najjužnejšiu zónu centrálnych Západných Karpát. Ich severnejšími zónami sú hronikum, veporikum, fatrikum a tatrikum. Severné ohraničenie gemerika je jasné: je to výrazne tektonický styk s veporikom, známy ako gemerská jazva alebo margeciansko-lubenícka línia. Hranica medzi gemerikom a bükkikom je t. č. nejasná, lebo na J od rožňavskej línie a na S od pohoria Szendrö paleozoické podložie meliatskej série nie je známe. Jeho poznanie bude v tejto otázke rozhodujúce.