Mitt. Österr. Geol. Ges.	ISSN 0251-7493	**86** (1993)	S. 121–132	Wien, August 1994

Key words
Slovakia
West Carpathians
Tatricum
Lower Austroalpine
Penninicum
Heavy minerals

Heavy Mineral Analyses from "Tatric" Units of the Malé Karpaty Mountains(Slovakia) and their Consequences for Mesozoic Paleogeography and Tectonics

ROMAN AUBRECHT*)

16 Text-Text-Figures, 1 Table

Contents

Schwermineralanalysen aus „Tatrischen" Einheiten der Kleinen Karpaten (Slowakei) und ihre Konsequenzen für die mesozoische Paläogeographie und Tektonik

Zusammenfassung

Schwermineralspektren wurden aus jurassischen Sedimenten der Borinka-, Kuchyňa-, Kadlubek- und Orešany-Einheiten in den Kleinen Karpaten untersucht. Die Borinkaeinheit wurde zunächst als Teil des Penninikums betrachtet, während alle anderen Einheiten dem Tatrikum angehören, das dem Unterostalpin der Ostalpen vergleichbar ist. Dies konnte durch die Schwermineraluntersuchungen nicht erhärtet werden, da in allen Einheiten dieselben Spektren auftreten. In allen Proben konnte eine vorherrschende Vergesellschaftung von Apatit, Turmalin, Zirkon und Rutil erkannt werden, verknüpft mit einem auffallenden Fehlen von Granat. Derartige Schwermineralgesellschaften stehen im klaren Kontrast zu dem zu erwartenden Spektrum aus dem kristallinen Komplex der Zentralen Westkarpaten, in denen Granat vorherrscht und Turmalin nur in geringen Mengen vorhanden ist. Dieser Kontrast kann bis in die Untertrias verfolgt werden.

Die wahrscheinlichste Erklärung dafür ist, daß während des Mesozoikums weiträumig Komplexe von grünschieferfaziellen Metamorphiten (Serizitphylliten und sauren Metavulkaniten) ohne Granat aber mit neugebildetem Turmalin in den Zentralen Westkarpaten aufgeschlossen war. Dieses ursprüngliche Gebiet wurde völlig erodiert und kann nur noch aus den klastischen Beimengungen erkannt werden.

Abstract

Heavy mineral spectra have been examined from the Lower Jurassic sediments of the Borinka, Kuchyňa, Kadlubek and Orešany units of the Malé Karpaty Mountains. The Borinka unit has been recently considered as being a part of the Penninicum, while all the others belong to the Tatricum (this can be correlated with the Lower Austroalpine unit of the Eastern Alps). This was not confirmed by heavy mineral studies in all units. A predominant suite of apatite, tourmaline, zircon and rutile was observed in all the samples, whereas a distinct lack of garnet has been generally noticed. Such heavy mineral assemblages are not supporting an origin from recently known crystalline complexes of the Central West Carpathians, where garnet is predominant and tourmaline occurs only in small amounts. This contrast can be traced down to the Lower Triassic.

*) Author's address: RNDr. ROMAN AUBRECHT, Department of Geology and Paleontology, Faculty of Natural Sciences, Comenius University, Mlynská Dolina, pav. G, SK-84215 Bratislava, Slovakia.

1. Introduction

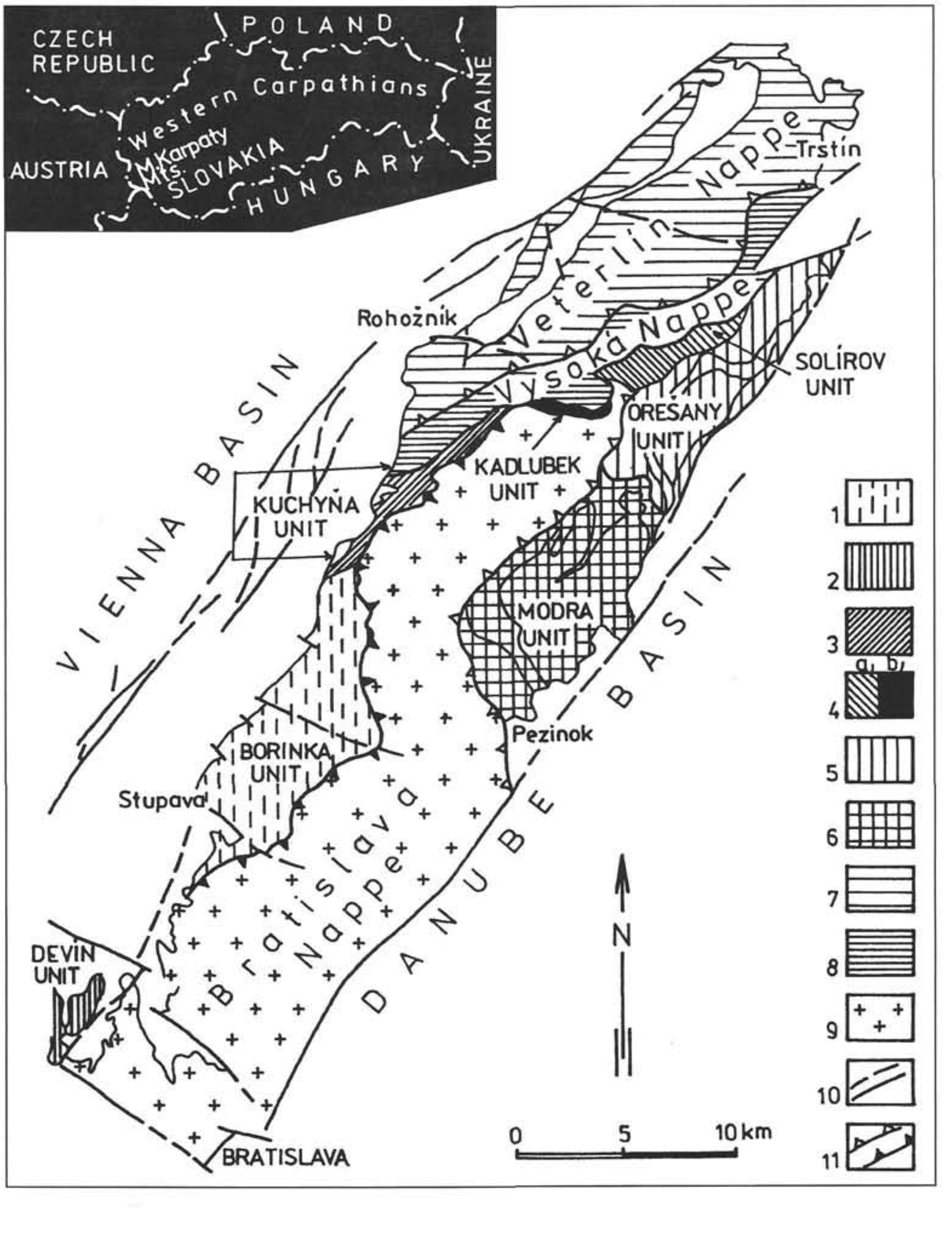
The Malé Karpaty Mts. are the westernmost part of the so-called core mountains in the Central West Carpathians. They formed by several tectonic slices (or nappes) of the Tatric crystalline substratum with their Mesozoic sedimentary cover and by the higher, so called subtatric nappes such as Vysoká Nappe, Vetrlín Nappe etc. (Text-Fig. 1). MAHEL' (1961) distinguished four Mesozoic developments in the Tatricum of the Malé Karpaty Mts. i.e. the Devín, Borinka, Orešany and Kadlubek developments. After the crystalline nappes were distinguished in the Malé Karpaty Mts. (MAHEL', 1980), the Mesozoic sequences were assigned as sedimentary cover to separate tectonic nappes or slices. The Kuchyňa and Solírov units were distinguished in addition (PLAŠIENKA, 1987; PLAŠIENKA et al., 1991). The Borinka unit was formerly considered to be one of the Tatric units (MAHEL' 1961). However, because of its completely different development, it has recently been considered to be part of the subautochthonous South Penninic unit, outcropping beneath the overthrusted Tatric units (PLAŠIENKA et al., 1991). The four formations distinguished in the Borinka unit by PLAŠIENKA, (1987) are as follows(Text-Fig. 2): The Prepadlé Formation consisting mainly of the Borinka Limestone and carbonate breccias; the Korenec Formation – a flyschoid sequence of sandstones and claystones with local olistoliths; the Marianka Formation – a black shale formation with manganolith layers and local intercalations of distal turbidites and the Somár Formation – polymict breccias representing mass flow deposits. The mutualrelations of these formations can be seen in Text-Fig. 2.

Breccias similar to those in the Prepadlé and the Somár Formations were also found in the lowermost Lower Austroalpine of the Eastern Alps e.g. Hochfeind Nappe of Radstädter Tauern Mts. or Hippold Nappe in Tarntaler Mts. (HÄUSLER, 1983, 1988) and also in the Penninic domain (JANOSCHEK & MATURA, 1980; MOSTLER & PAHR, 1981).

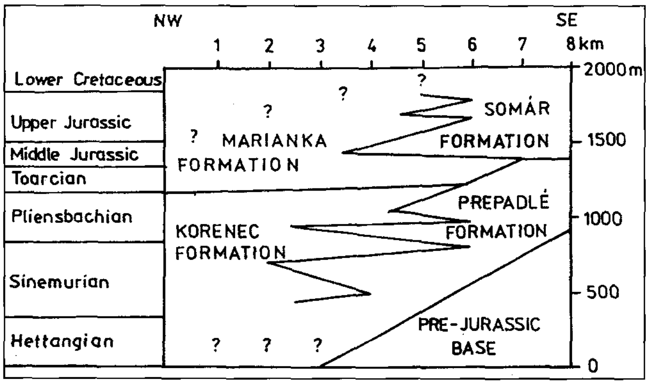
According to PLAŠIENKA et al. (1991), the sedimentation area of the Borinka unit was situated north-westwards from a hypothetic swell, analogous to the Lungau Swell in the Eastern Alps (TOLLMANN, 1977). It separated the Penninic area from the Tatricum, that may be correlated with the Lower Austroalpine unit. However, HÄUSLER (1987) has brought up doubts on the existence of one "Lungau Swell". According to his investigations about three erosional areas existed in the Lower Austroalpine. They represented a system of tectonically tilted blocks that formed due to the opening of the Penninic ocean.

The Tatric units and the Borinka unit are related by having a large hiatus as a common feature. Connecting the extensive erosion of the Triassic sediments affected the crystalline basement, and occurred in these units during the Uppermost Triassic and Lower Liassic.

The Upper Triassic sediments are preserved locally and also occur as pebbles and fragments in the Jurassic sediments. In this way the Lower Jurassic sediments are ge-



Text-Fig. 1.
Tectonic and paleogeographic units of the Malé Karpaty Mts. (after MICHALÍK et al., 1993).
1 = Borinka unit; 2 = Devín unit; 3 = Kuchyňa unit; 4a = Solírov unit; 4b = Kadlubek unit; 5 = Orešany unit; 6 = Modra unit; 7 = Veterlín Nappe; 8 = Vysoká Nappe; 9 = Bratislava Nappe; 10 = faults; 11 = overthrust planes.



Text-Fig. 2.
Facial relations between the formations of the Borinka unit (after PLAŠIENKA, 1987).

nerally transgressive, with an abundance of clastic material. In the Borinka unit, several formations occur containing clasts of psephitic size.

Except for the Prepadlé Formation with abundant carbonatic clasts, the Somár and Korenec formations both contain predominantly clasts of crystalline rocks. PLAŠIENKA (1987) mentioned clasts of phyllites, amphibolites, granites etc.

The clastic material was supposed to have been derived from metamorphic rocks and granitoids of composition similar to the recently outcropping crystalline complexes of the Bratislava and Modra nappes (PLAŠIENKA, 1987: p. 226). Sericite-chlorite phyllites, abundant as clasts, in Somár Breccias but absent in primary outcrops, were considered to be originally metabasites and phyllites, fragments of which were retrogressively metamorphosed in the breccias during the Alpine cycles (PLAŠIENKA, 1987: p. 224).

More probably, their metamorphic state is original and they were derived from the parts of the crystalline complex that are now completely eroded (see chapter 6).

Jurassic strata of the other units lie in a transgressive position on the crystalline basement. Thus the hypothesis was put forward that the Lower Jurassic in all Tatric Mesozoic units of the Malé Karpaty Mts. would contain the same heavy mineral assemblages as the underlying crystalline complexes, or a mixture of these assemblages.

2. Methods of Research

Samples of sandstones and sandy limestones were examined for their heavy mineral content. The clastic admixture was extracted by dissolution in 13 % acetic acid. Some samples (sandstones and quartzites) had to be crushed and pulverised. Then the heavy mineral fraction was separated by bromoform ($CHBr_3$, density 2.9). The fraction 0.09–0.25 mm was studied in transmitted light microscopy. All opaque minerals were omitted. The grains of translucent minerals were counted and their percentages were calculated.

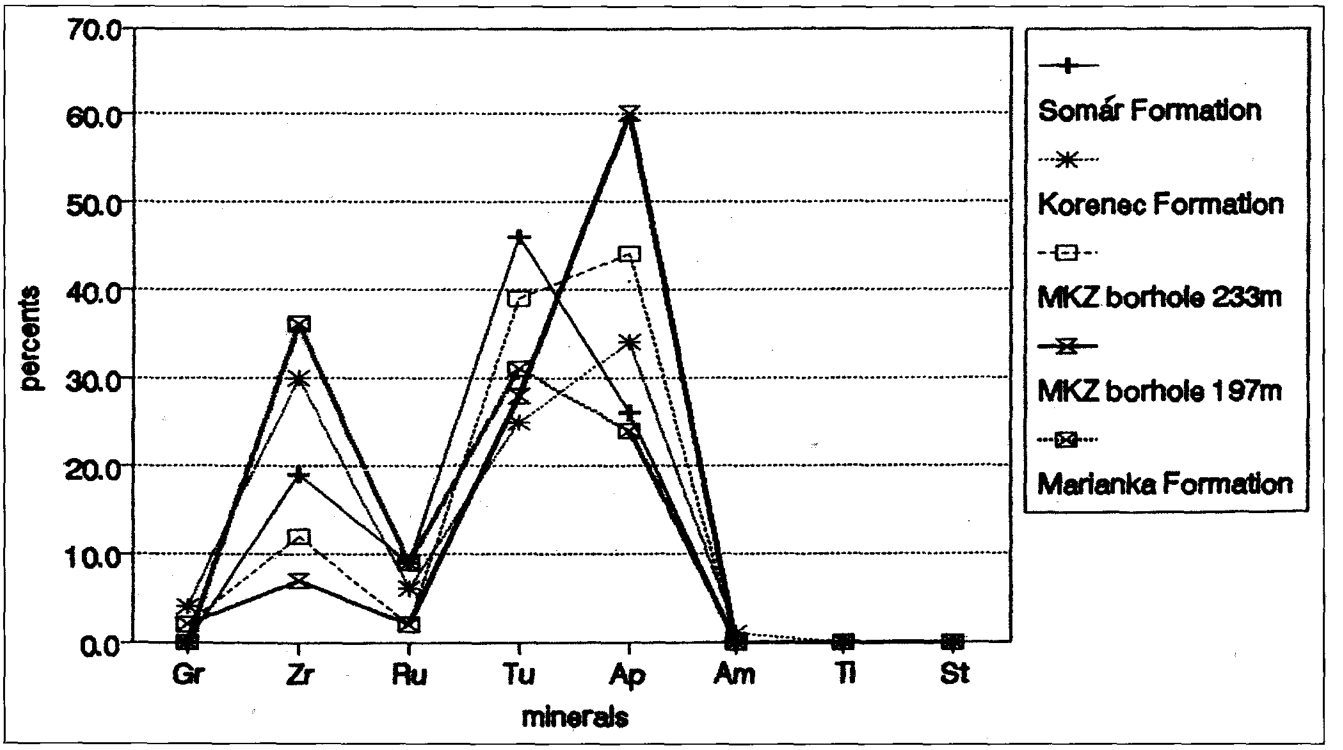
A zircon typology evaluation was made with a JEOL scanning microscope. The percentages of the types were recorded and the mean values were calculated by the methods described by PUPIN & TURCO (1972).

3. Heavy Mineral Assemblages in the Borinka Unit

Five samples were examined from the Borinka unit. They were sampled from almost all the lithostratigraphic formations in this unit, distinguished by PLAŠIENKA (1987) (Text-Fig. 2).

Sample No. 1 represents a sandstone intercalation in the Somár Breccias at Medené Hámre quarry near the village Borinka.

Sample No. 2 was taken from the sandstone of the Korenec Formation, a few hundred meters E of the ruins of Pajštún castle.



Text-Fig. 3.
Graphic evaluation of heavy minerals contents in the Borinka unit (abbreviations see Text-Fig. 16).

Table 1.
Heavy minerals of the Borinka unit and other Tatric units of the Malé Karpaty Mts. [volume %].

Locality	Gr	Zr	Ru	Tu	Ap	Am	Ti	St
Somár Formation	0	19	9	46	26	0	0	0
Korenec Formation	4	30	6	25	34	1	0	0
MKZ borehole 233m	2	12	2	39	44	0	0	0
MKZ borehole 197m	2	7	2	28	60	0	0	0
Marianka Formation	0	36	9	31	24	0	0	0
Borinka Unit-avg.	2	21	6	34	38	0.2	0	0
Kuchyňa Unit	3	22	14	12	47	0	0	0
Orešany Unit	2	31	14	26	27	0	0	0
Kadlubek Unit	0	4	8	44	44	0	0	0
other Tatric units-avg.	2	19	12	27	39	0	0	0

Sample No. 3 represents a sandy intercalation in the shales of Marianka Formation in the outcrop near the village Marianka.

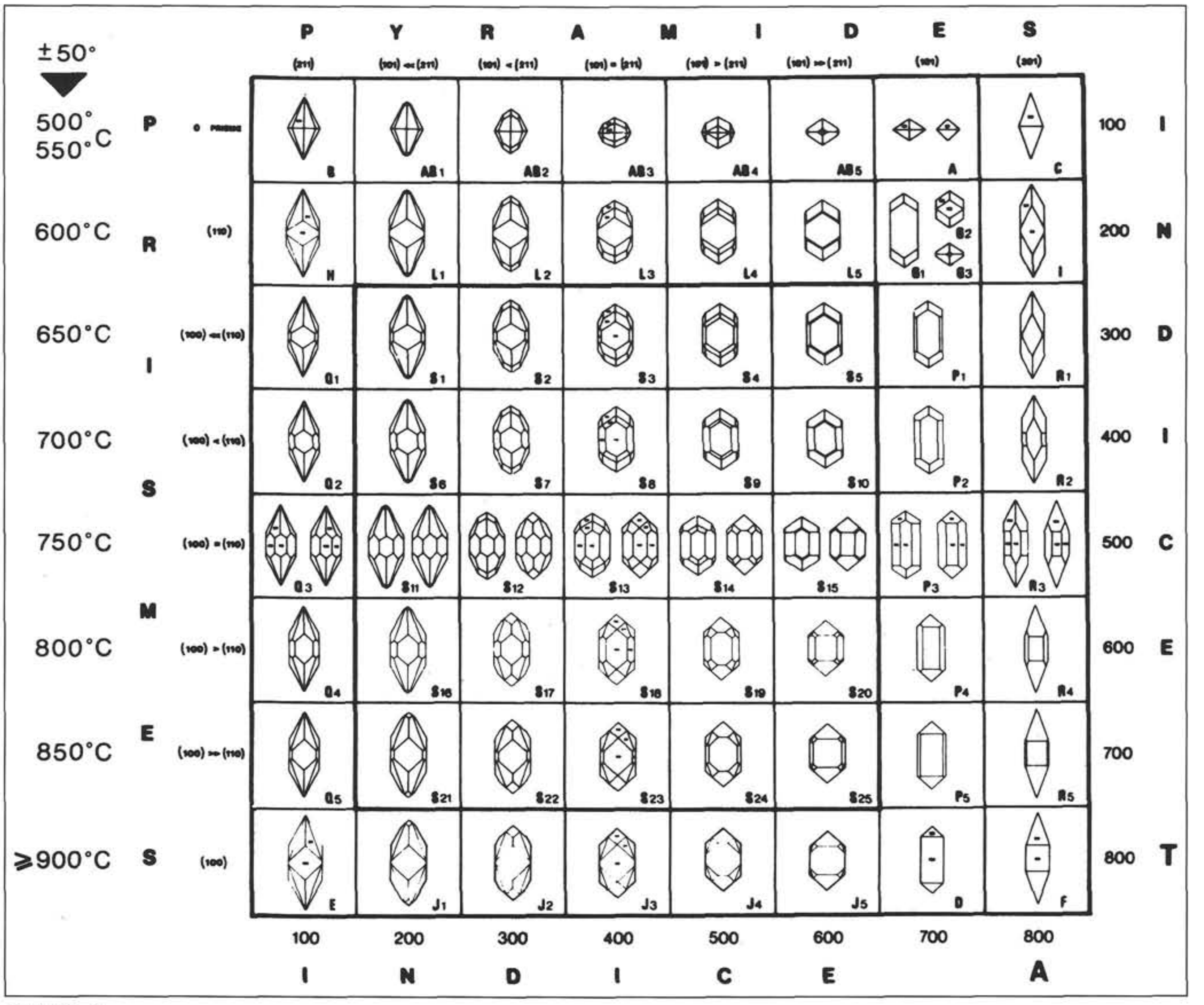
Samples No. 4 and 5 were taken from the Korenec Formation of drill core MKZ1 (197 m and 233 m) situated at Stupava.

There is a considerable similarity in the heavy mineral contents of all samples. They are characterized by the predominance of apatite (min.24 %, max. 60 %, aver. 38 %), tourmaline (min. 25 %, max. 46 %, aver. 34 %) and an increased content of zircon (min. 7 %, max. 36 %, aver. 21 %). Rutile (max. 9 %) and garnet (max. 4 %) are scarce; no staurolite was found (Text-Fig. 3, Tab. 1).

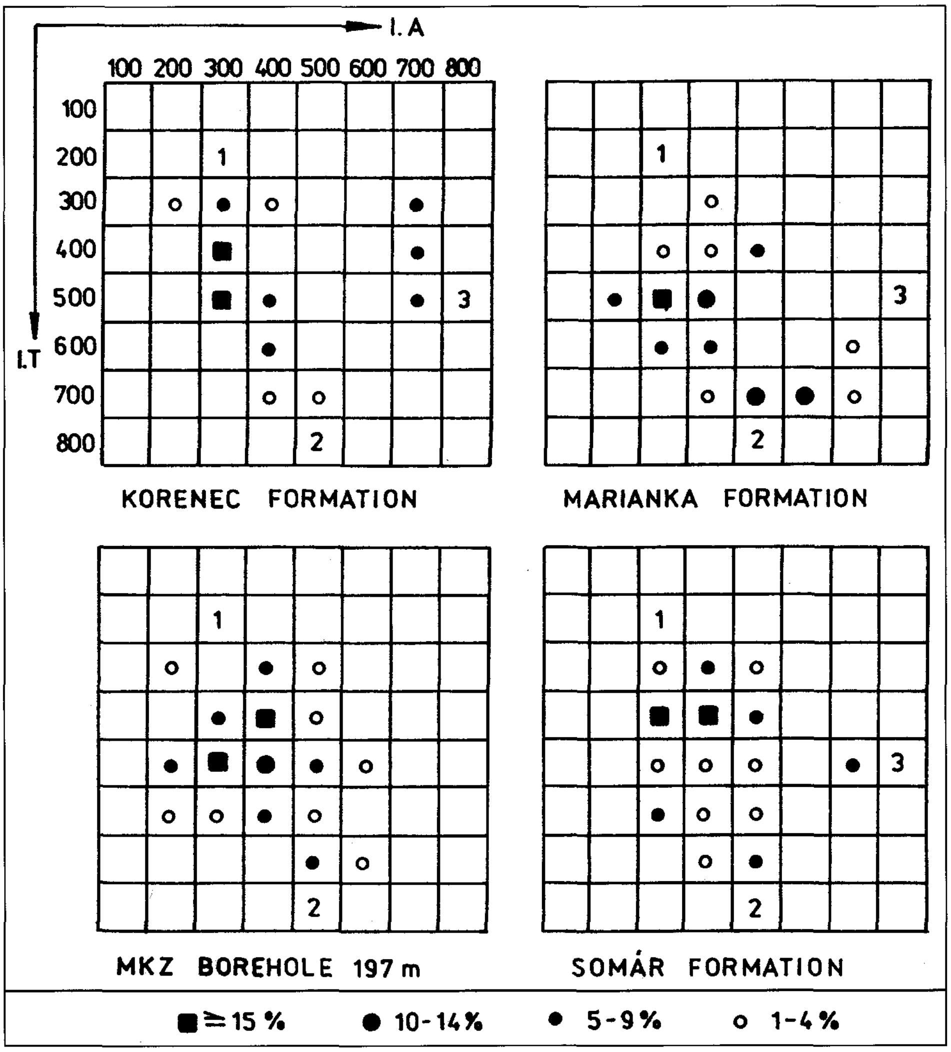
Apatite grains are often clear, without any inclusions. No dusky apatite as described from the granitoids of the Malé Karpaty Mts. (MIŠÍK, 1955) was observed. The grains are always rounded.

Tourmaline is predominantly brown to green, bluish varieties are rare with a strong pleochroism. Zonation was very rarely observed and most of the grains are rounded.

Zircon grains are clear and of reddish colour. Most of the grains are rounded. The ratio between rounded and subhedral zircons ranges from 1 (sample No. 3) to 2.6 (sample No. 2). A zircon typology statistical evaluation according to PUPIN & TURCO (1972) was made on the subhedral grains in samples 1–4. The aim was to determine the source-rocks, the zircons were derived from. About 64 zircon types and subtypes were distinguished (Text-Fig. 4); each of them determined by the agpaicity index (I.A.) and temperature index (I.T.) of the source rock.



Text-Fig. 4.
Zircon types and subtypes distinguished by PUPIN & TURCO (1972).

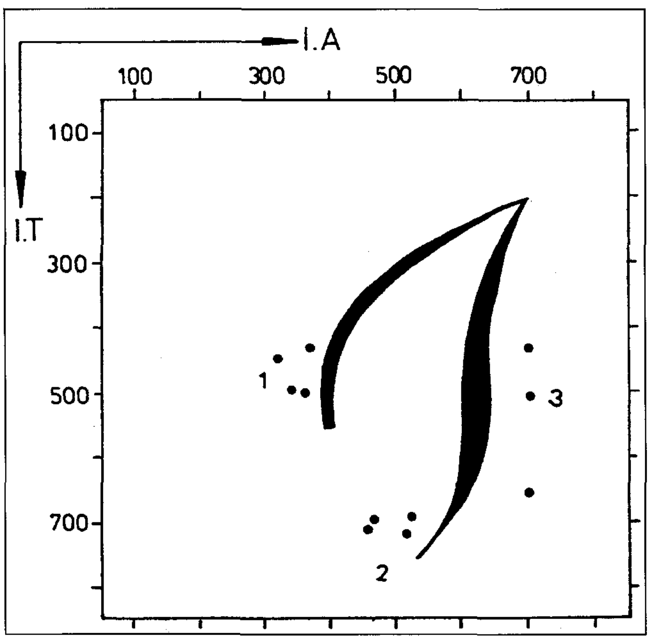


Text-Fig. 5.
Percentages of zircon types from the Borinka unit.
I.A = Agpaicity index, I.T = Temperature index sensu PUPIN & TURCO, 1972; numbers in the diagram sign the three distinguished source-rocks.

Several sources of clastic zircons can be distinguished (Text-Fig. 5 and 6). Sources 1 and 2 are closely connected, maybe due to their comagmatic origin. The approximate boundary dividing the sources can be drawn between S23, S24 and S18, S19 types. Source 3 represented by the P-types of zircons is clearly different.

Source No. 1 is represented mainly by S7, S8, S12 and S13 types (Text-Fig. 7) indicating granitoids mainly of crustal origin as a source-rock sensu PUPIN (1980). They are widespread in the Hercynian granitoids of the Central West Carpathians (BROSKA & UHER, 1991).

Source No. 2 is less characteristic. It is represented by S23,S24 and S25 types (Text-Fig. 8). These types are unknown from the primary sources, but are predominant in the Lower Miocene sediments in the northern part of the Malé Karpaty Mts. (KOVÁČ et al., 1991). The mean values of this source lie in the field reserved for charnockites or trachyandesites (PUPIN, 1980).



Text-Fig. 6.
The mean values of the sources of clastic zircon from the Borinka unit. The thick line separates the fields of the rocks of crustal origin (left), hybrid rocks (middle) and rocks of mantle origin (right).

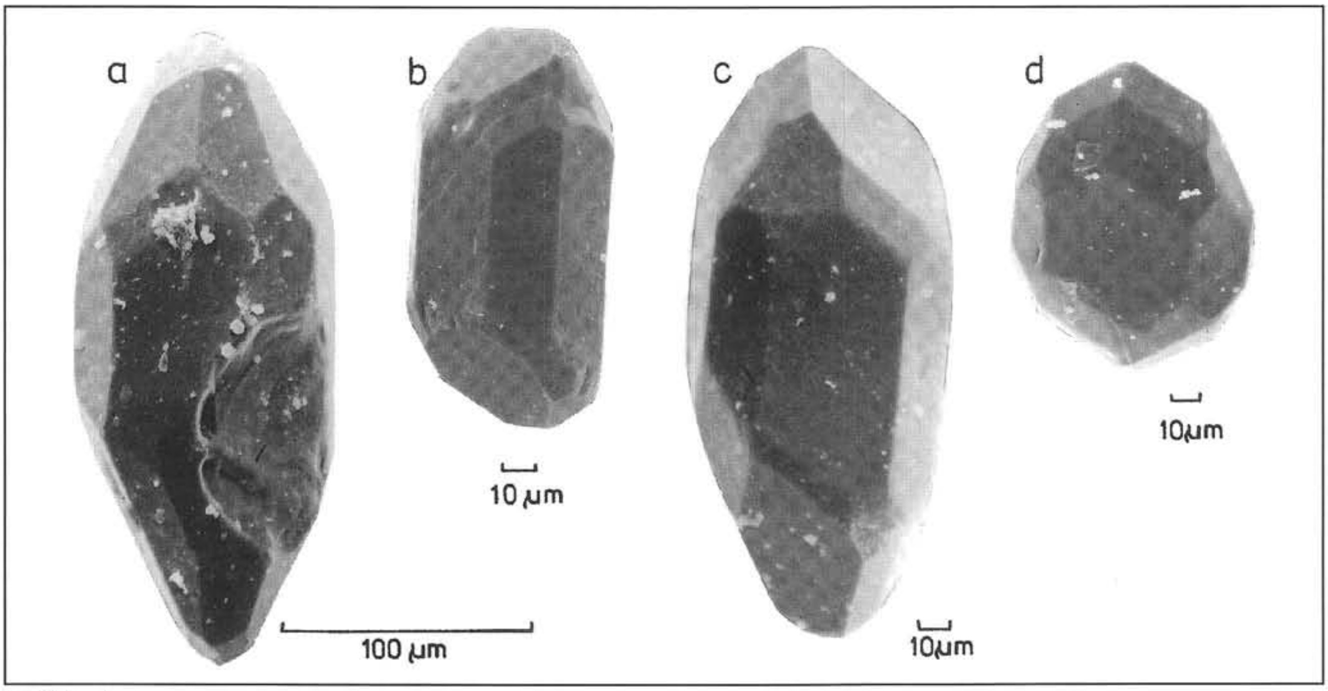
Source No. 3 occurs only locally. The zircon types exhibit a rather wide dispersion of T indices. The source is represented mainly by P3, P2 and P1 types (Text-Fig. 9) that indicate a granitoid source of mantle origin or alkaline rhyolites and basalts (PUPIN, 1980).

P-type zircons were described only from local primary sources in the West Carpathians i.e. Permian rhyolites, Rochovce and Hrončok granites (UHER & MARSCHALKO, 1993), leptinites in the Veporic zone (KRIST et al., 1986), granitoids of the Velence Mts. (GBELSKÝ & HATÁR, 1982) etc. Permian rhyolites should provide the best possible source of zircons because of their relative abundance in the West Carpathians.

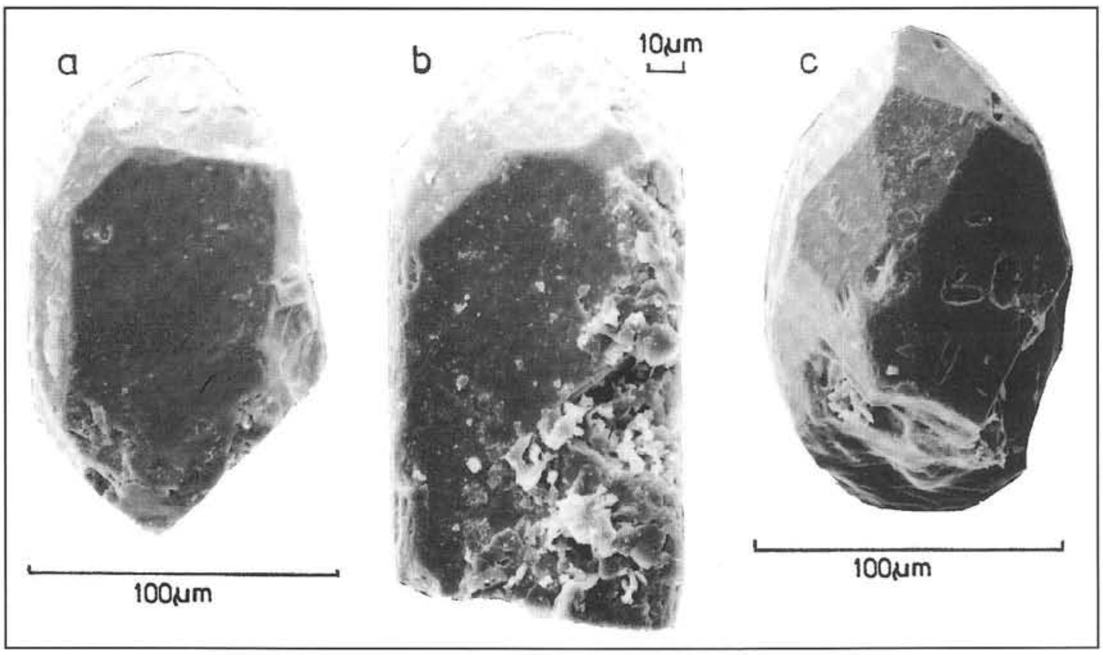
The P-type zircons from these rocks differ from those found in the Borinka unit by relatively higher temperature indices. Zircons preserved in metamorphics have not yet been studied systematically.

The zircon types of sources 2 and 3 are relatively rare in the West Carpathians and have not been found in the Malé Karpaty Mts. yet. The analyses of DEMÉNY (1988) from the Penninicum of Köszeg Hills (Velem Calcareous Phyllite Formation) show completely different results.

The dominant types are G1, P, D and J5, from which only P-types are present in the Borinka unit. Rutile is red, brownish to orange in colour and the grains are often rounded.



Text-Fig. 7.
Zircon types of the source No. 1 found in the Borinka unit.
a = S7 type – Somár Fm.; b = S8 type – MKZ borehole; c = S7/S8 type – Somár Fm.; d = S13 type – MKZ borehole.



Text-Fig. 8.
Zircon types of the source No. 2 found in the Borinka unit.
a = S24 type – Somár Fm.; b = S24 type – Somár Fm.; c = S23 type – Marianka Fm.

4. Heavy Minerals of Other Tatric Units in the Malé Karpaty Mountains

Three samples of the Lower Jurassic rocks were studied from the Kuchyňa, Orešany and Kadlubek units and compared to those of the Borinka unit.

Sample No. 6 comes from the Lower Jurassic organodetrital limestone directly overlying the Lower Triassic quartzites (Lúžna Formation) on the Ostrý vrch hill ridge (Kuchyňa unit).

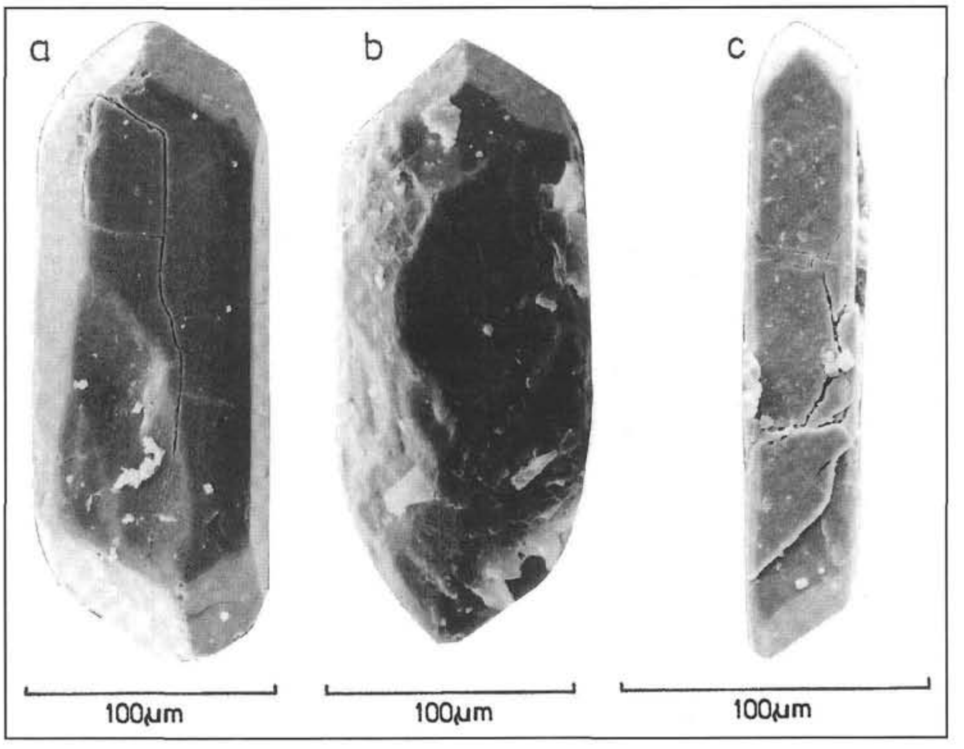
Sample No. 7 represents the red crinoidal limestone with a siliciclastic admixture found on Kadlubek hill (Kadlubek unit).

Sample No. 8 represents cherty limestone with a rich sandy admixture taken S of Zabité and Zrkadlisko hill near the village Dol'any (Orešany unit).

The heavy mineral associations are very similar to those from the Borinka unit. They contain predominantly apatite, tourmaline and less zircon (Text-Fig. 10, Tab. 1). The amount of rutile is slightly increased if compared with the Borinka unit and also rare garnet and staurolite are occurring in these units.

5. Origin of the Clastic Material

The clastic material was undoubtedly derived from the pre-Liassic rocks, from which only crystalline complexes



Text-Fig. 9.
Zircon types of the source No. 3 found in the Borinka unit.
a = P2 type – Korenec Fm., b = P3 type – Somár Fm., c = P1 type – Korenec Fm.

and Lower Triassic quartzites are recognisable in the Malé Karpaty Mts. The comparison of the possible sources of the Lower Jurassic rocks and the problems connected with their comparison are discussed in this chapter.

5.1. Heavy Minerals of the Metamorphosed and Granitoid Rocks in the Malé Karpaty Mountains

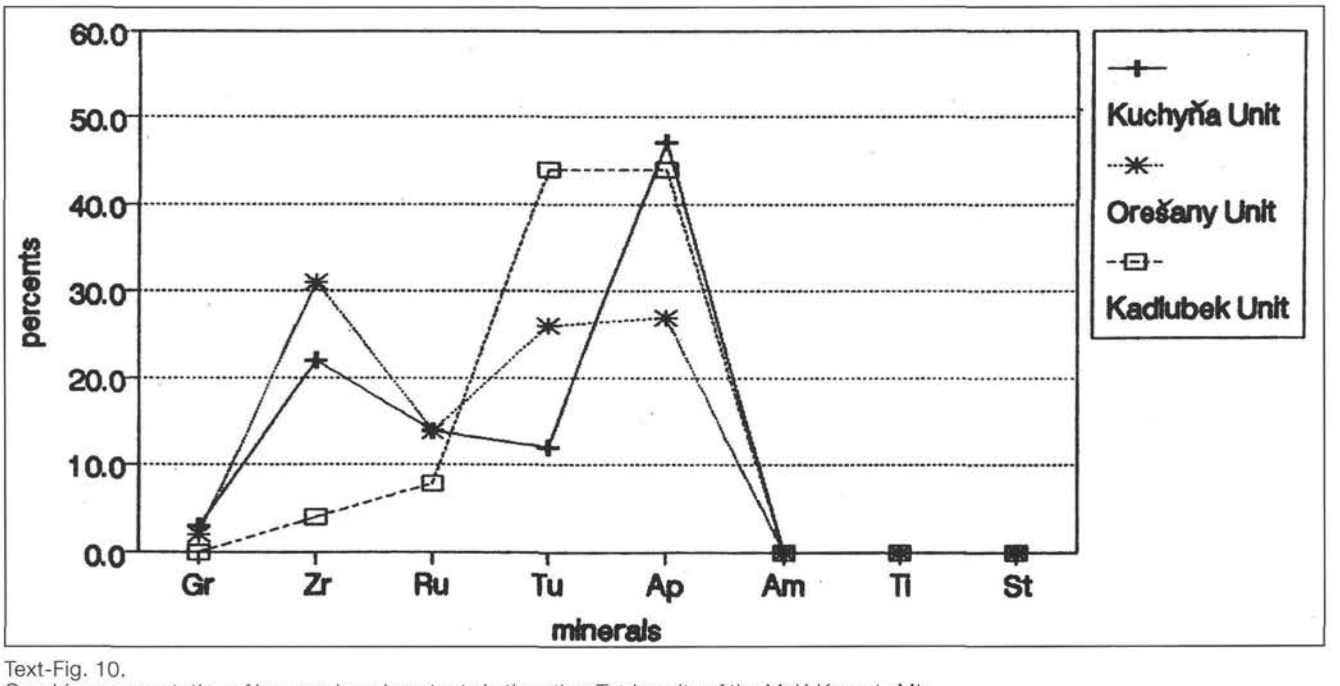
The first analyses of heavy minerals in the Malé Karpaty Mts. were made by MIŠÍK (1955) from the granitoids of the Bratislava Massif (recently Bratislava Nappe).

This author found a predominance of apatite and garnet, less epidote, amphibole and zircon (Text-Fig. 11).

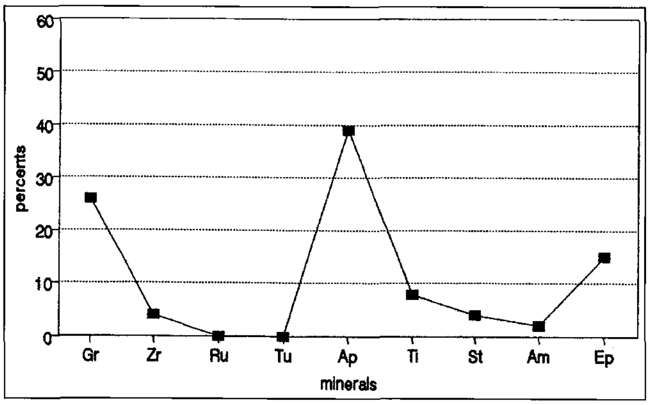
There is a very striking lack of tourmaline (less than 1 %), which is very important for comparing the heavy minerals of the Lower Jurassic sediments, which contain plenty of tourmaline but no garnet.

Later also VESELSKÝ & KOVALSKÁ (1981) analysed the accessory minerals of the metamorphic rocks in the whole area of the Malé Karpaty Mts (Text-Fig. 12). They discovered a high proportion of garnet, apatite, zircon and amphibole. The content of tourmaline was relatively low; it reached values locally up to 21 % (in phyllites at Devín castle), but always with a predominance of garnet. BROSKA & JANÁK (1985) examined heavy mineral assemblages from a profile in metamorphics near Záhorská Bystrica. Their results were the same as previously mentioned.

There is also a strong difference when compared with the Lower Jurassic sediments. The very low ratios of garnet to tourmaline indicate an exotic character of the clastics.



Text-Fig. 10.
Graphic representation of heavy mineral contents in the other Tatric units of the Malé Karpaty Mts.
Abbreviations see Text-Fig. 16.



Text-Fig. 11.
Graphic representation of an average heavy mineral content in the granitoids of the Malé Karpaty Mts.
After MIŠÍK (1955); abbreviations see Text-Fig. 16.

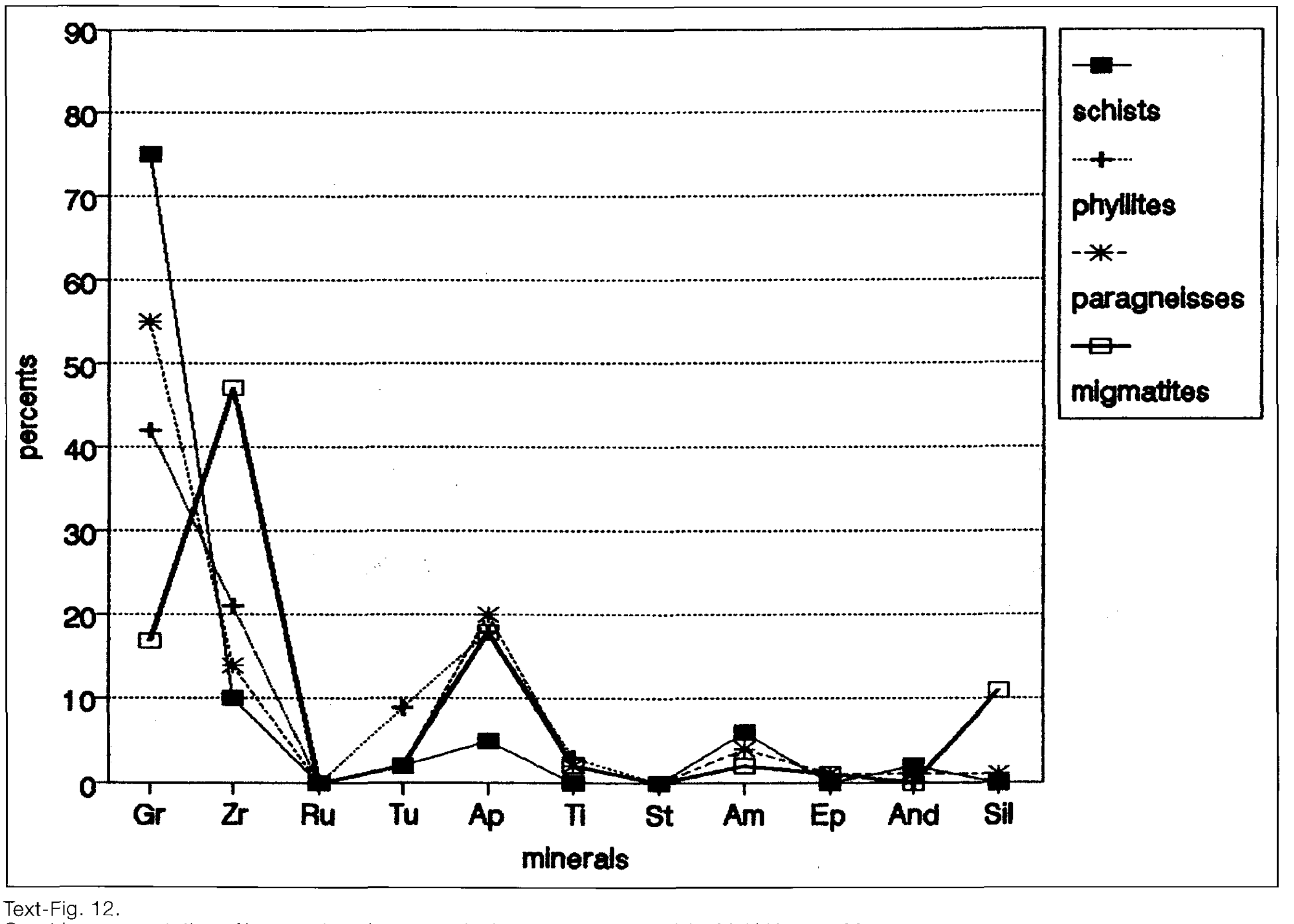
5.2. Heavy Minerals of Lower Triassic Quartzites (Lúžna Formation)

The Lower Triassic quartzites are most similar in their heavy minerals with those of the Lower Jurassic of the Malé Karpaty Mts. MIŠÍK & JABLONSKÝ (1978) describe three heavy mineral analyses in this formation from the Malé Karpaty Mts. and from the Nízke Tatry Mts. These results were complemented with some new analyses from the quartzites of Braunsberg hill in Austria – the geological continuation of the Malé Karpaty Mts. to the West and in the Malá Fatra Mts. between the locations Párnica and Kral'ovany (made by elimination of the opaque minerals in order to compare data, and baryte (Donovaly loc.), because of its authigene origin, a predominance of zircon and tourmaline with less rutile became evident (Text-Fig. 13)). Garnet is rare, as are apatite, titanite and staurolite. This can be explained by the perfect mineralogical maturity of the sediments. Significant differences between the samples from all localities were not found.

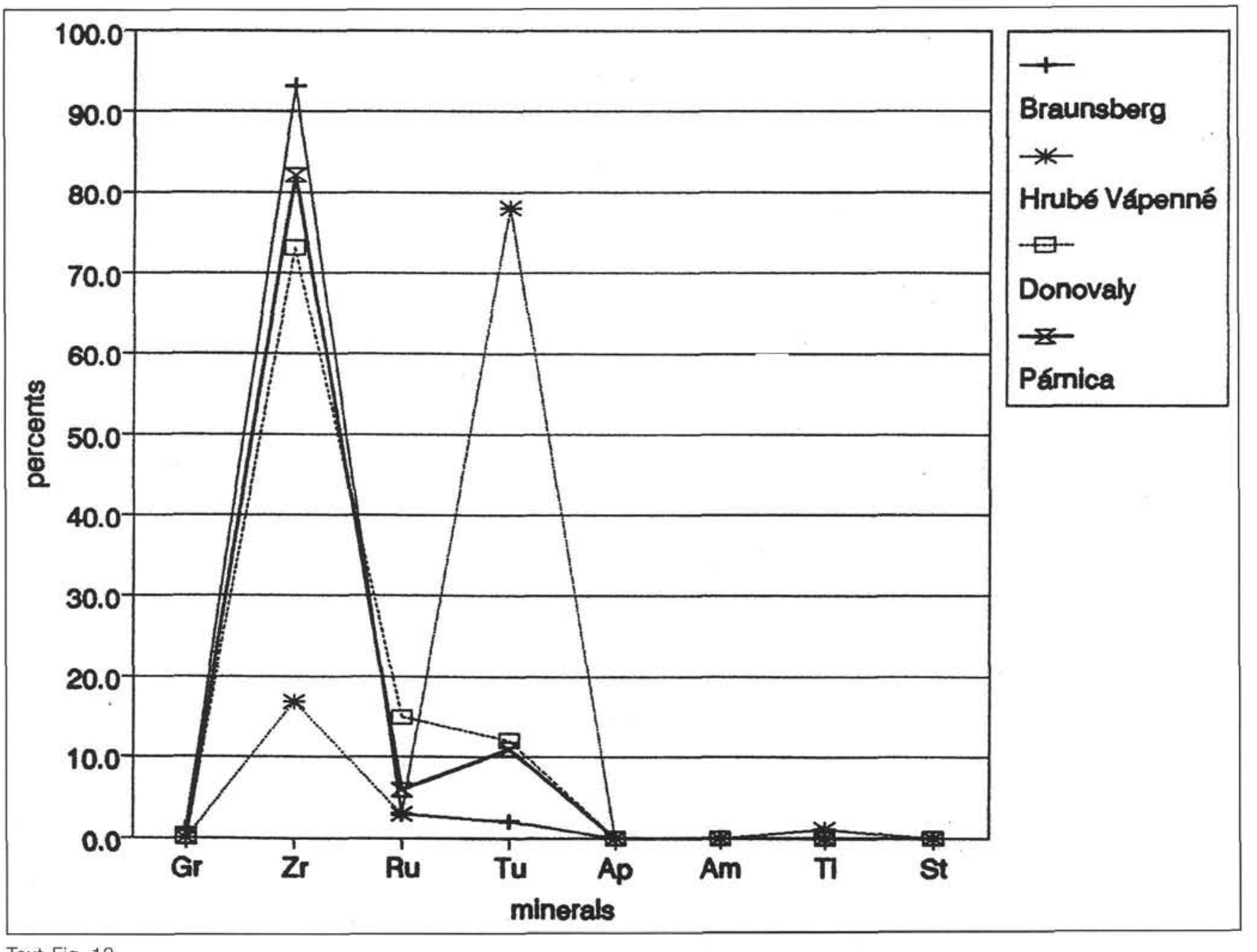
The tourmaline found in the Lower Jurassic of the Malé Karpaty Mts. most probably comes from the same source as in the Lúžna Formation. The possibility that they were only redeposited from this formation can be eliminated since the quartzites contain abundant perfectly rounded zircons of oval shape (Text-Fig. 14) rounded by aeolian processes (see MIŠÍK & JABLONSKÝ, 1978). Such zircons are almost absent in the Lower Jurassic.

5.3. The Problem of Tourmaline-Bearing Clastics

Tourmaline bearing rocks (turmalinised greywackes, phyllites and quartzites) are frequently found as clasts in conglomerate and breccia intercalations in the Lower Triassic quartzites (MIŠÍK & JABLONSKÝ, l.c.). However, their source is exotic and unknown in the crystalline core areas of the West Carpathians. The transport directions measured in this formation show transport from W and NW, i.e. from the Outer

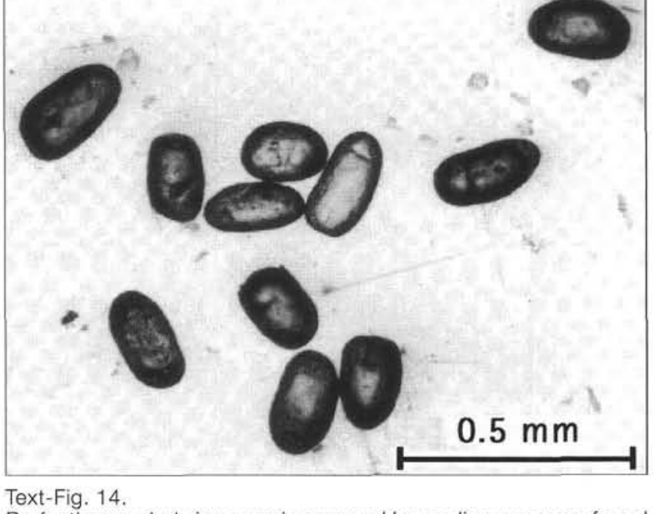


Text-Fig. 12.
Graphic representation of heavy mineral contents in the metamorphics of the Malé Karpaty Mts.
After VESELSKÝ & KOVALSKÁ (1981); abbreviations see Text-Fig. 16.



Text-Fig. 13.
Graphic representation of heavy minerals contents in Early Triassic quartzites (Lúžna Fm) of the West Carpathians.
Abbreviations see Text-Fig. 16.

Carpathian zones to the Central West Carpathians. Clastic tourmaline-bearing rocks were found also in the analogous Lower Triassic Semmering quartzite near Trattenbach in the Eastern Alps (Lower Austroalpine unit) (FAUPL, 1970) (Text-Fig. 15). RADWANSKI (1959) mentioned quartz-tourmaline bearing clasts in the Upper Liassic in the High Tatra Mts.



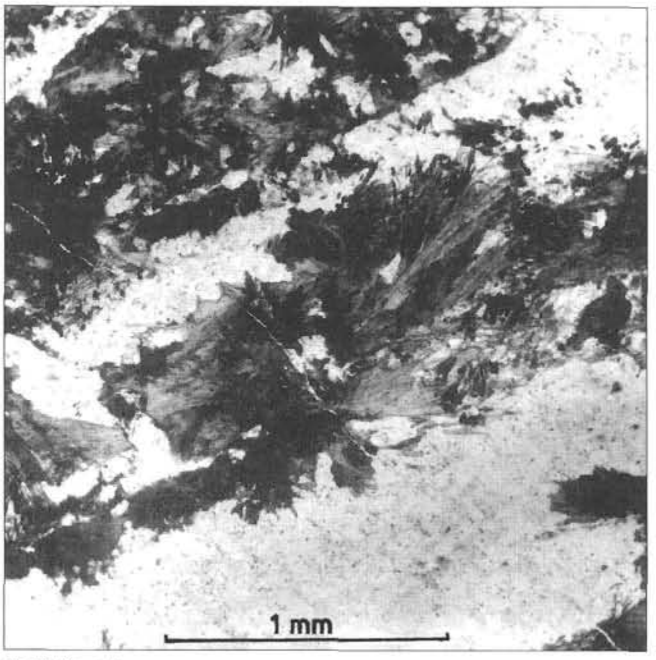
Text-Fig. 14.
Perfectly rounded zircon grains caused by aeolic processes found in the Early Triassic quartzites at Braunsberg Hill (Austria).

TURNAU-MORAWSKA (1953) described similar clast from the High Tatra Keuper. Some pebbles of tourmaline-bearing rock were also found in the Upohlav conglomerates of the Pieniny Klippen Belt (MIŠÍK & JABLONSKÝ, l.c.).

From the more inner zones of the West Carpathians, tourmaline-bearing rocks were mentioned also as clasts in the Permian of the north Veporic zone (VOZÁROVÁ, 1966). Their possible primary source was described by MIKO & HOVORKA (1978), who found tourmaline-bearing rocks in several occurrences of metamorphosed volcanoclastics in the Veporic crystalline complexes of the Nízke Tatry Mts. This tourmaline is most likely of metamorphic origin. It is always very fine-grained and often cannot be determined under the microscope. This difference is considerable if compared with clastic tourmaline from the above mentioned Mesozoic formations. REICHWALDER (1973) described tourmaline of metamorphic origin from the Upper Paleozoic quartzitic phyllites in Buâina Formation in the Gemeric zone. It is also connected with acid metavolcanic rocks.

5.4. The Lack of Garnet

Garnet is one of the most frequent accessory minerals in presently known crystalline complexes of the West Carpathians, e.g. from granitoids and metamorphics (MIŠÍK, 1955; VESELSKÝ & KOVALSKÁ, 1981). A predominance of garnet is also existing in the heavy mineral spectra of recent



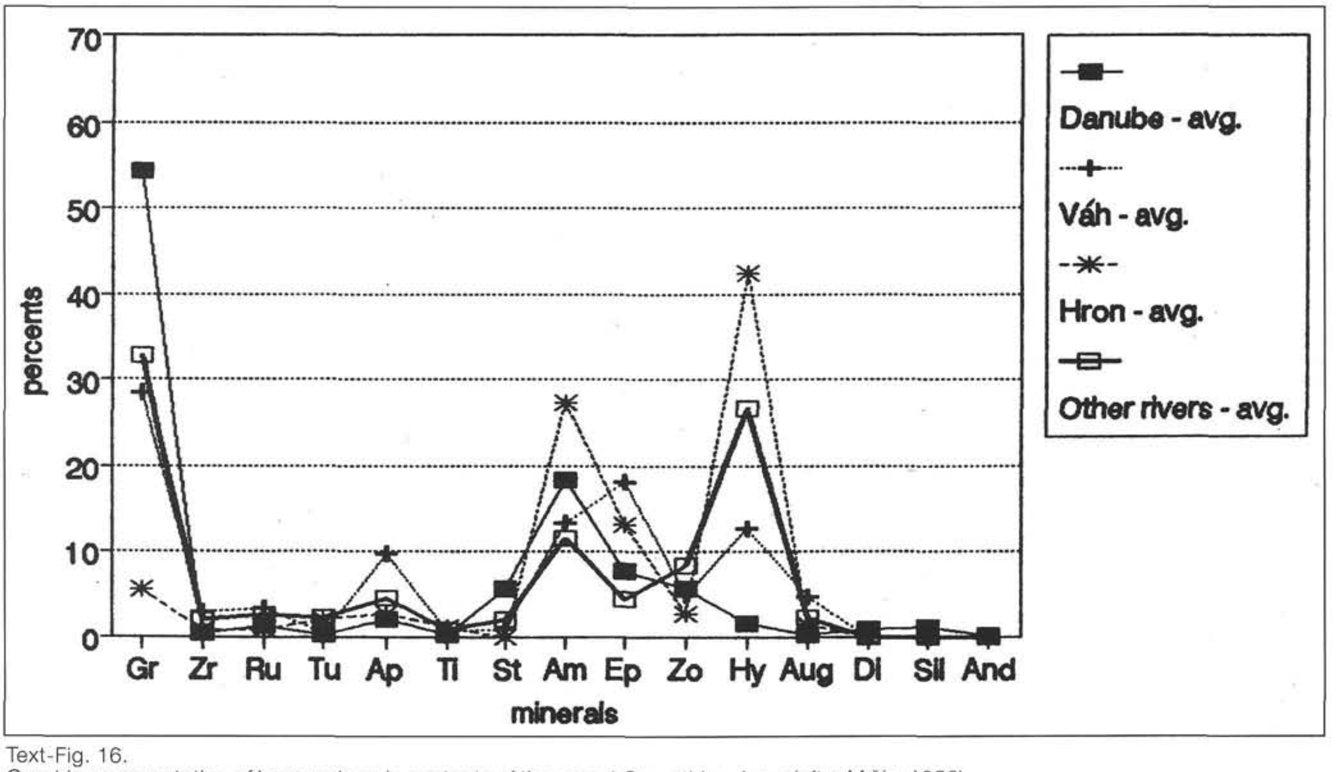
Text-Fig. 15.
Clast of tourmaline-bearing rock found in the Semmering Quartzite near Trattenbach (Austria).

fluvial sediments of Carpathian rivers (MIŠÍK, 1956). They reflect average sampling from the presently outcropping territory of the West Carpathians (Text-Fig. 16).

The above mentioned analysed Mesozoic clastics contain very small amounts of garnet, together with a high quantity of tourmaline. This is the main difference between the presently outcropping source areas and those of Triassic and Lower Jurassic age. The Middle Triassic carbonates contain no siliciclastics, while younger clastic formations (in the Central West Carpathians), represented by Carpathian Keuper, contain zircon, tourmaline and rutile, with only local input of garnet (AL-JOUBOURRY, 1992). The general lack of garnet continues locally up to the Middle Jurassic in the Malé Karpaty Mts.

6. Conclusions

1. Differences supposed between the Borinka unit and other Tatric Mesozoic units in the Malé Karpaty Mts. are not reflected in the heavy mineral content. The clastic material probably came from the same source area.
2. The source area was of a different composition to the crystalline-core complexes of the West Carpathians outcropping today. The heavy mineral association (apatite, tourmaline, zircon, rutile) in the examined formations is exotic.
3. The lack of garnet and the presence of the ultrastable association tourmaline + zircon + rutile suggests possible resedimentation from the well-matured sediments (e.g. Lower Triassic or Keuper quartzites). However, the predominance of relatively unstable apatite does not fit to this theory.
4. The source was probably represented by low-grade metamorphosed rocks, most likely sericitic phyllites containing tourmaline of metamorphic origin, without garnet. Tourmaline could be formed by the metamorphism of volcanoclastic intercalations, or directly by the conversion of illite to sericite (REYNOLDS, 1965). However, *this theory is only speculative. In order to prove it, some* chemical analyses have already been undertaken; the results will be published elsewhere. There is one fact not supporting this theory: Tourmaline of the metamorphic origin tends to be very fine-grained, while the clastic tourmaline grains found in the examined samples are of a



Text-Fig. 16.
Graphic representation of heavy minerals contents of the recent Carpathian rivers (after MIŠÍK, 1956).
Gr = garnet, Zr = zircon, Ru = rutile, Tu = tourmaline, Ap = apatite, Ti = sphene, St = staurolite, Am = amphibole, Ep = epidote, Zo = zoisite, Hy = hypersthene, Aug = augite, Di = kyanite, Sil = silimanite, And = andalusite.

larger size. On the other hand, exotic tourmaline-bearing rocks found especially in Lower Triassic quartzites are composed of fine-grained tourmaline. Finally, sericitic rocks are very unstable against weathering and transport, thus a large area covered by these rocks could be completely eroded, without any clastic remnants, except the resistant minerals.

5. Zircon typology from the clastics of the Borinka unit indicates one source from Hercynian granitoids of crustal origin (Bratislava nappe) and two possible exotic sources of zircons. The first one probably represents charnockites or trachyandesites unknown in the Paleozoic and Mesozoic of the West Carpathians. The second one came perhaps from Permian rhyolites or alkaline granitoids. At the present time, from all the possible zircon-bearing complexes, only the Hercynian granitoids were examined systematically. The analyses in this paper provide the material for future comparisons with possible sources. If compared with the Penninic unit of the Köszeg-Rechnitz window, the results of zircon typology analyses show considerable differences (see DEMÉNY, 1988).

Acknowledgements

My thanks belong to Prof. MIŠÍK, (Comenius University, Bratislava), Dr. PLAŠIENKA and Dr. UHER (both Slovak Academy of Sciences) for useful advice during the preparation of this paper. Financial support was provided by a GGC grant from the Ministry of Education and Youth of the Slovak Republic.

References

AL-JUBOURRY, A.I., 1992: Sedimentary-petrographic research of Upper Triassic (Keuper) rocks in the West Carpathians of Czecho-Slovakia. – Ph.D. dissertation, unpublished – Faculty of Nat. Sci. Univ. Com. Bratislava, 122 S.

BROSKA, I. & JANÁK, M., 1985: Accessory minerals of metapelites and their relation to metamorphism in area of Záhorská Bystrica (Malé Karpaty Mts.). – In Slovak with English summary – Akcesorické minerály, Bratislava (GÚDŠ), 101–106.

BROSKA, I. & UHER, P., 1991: Regional typology of zircon and its relationship to allanite/monazite antagonism (on an example of hercynian granitoids of Western Carpathians). – Geologica Carpathica, Bratislava, **42**/5, 271–277.

DEMÉNY, A., 1988: Determination of ancient erosion by zircon morphology and investigations on zoned tourmaline in Köszeg-Rechnitz window (Western Hungary). – Acta Miner.-Petr., Szeged, **29**, 13–26.

FAUPL, P., 1970: Zur Geologie des NW-Abschnittes des Wechselgebietes zwischen Trattenbach (N.Ö.) und Fröschnitz (Steiermark) – Österreich. – Mitt. Ges. Geol. Bergbaustud. Wien, **19**, 27–70.

GBELSKÝ, J. & HATÁR, J., 1982: Zircon of some granitoid rocks of the Velence and Mecsek Mts. – Geologica Carpathica, Bratislava, **33**, 3, 343–362.

HÄUSLER, H., 1983: Beobachtungen und Interpretationsversuche an nachtriadischen Breccien der Radstädter Tauern und Tarntaler Berge (Unterostalpin, Salzburg-Tirol). – Jber. 1982, Hochschulschwerpkt. S. 15, 163–167.

HÄUSLER, H., 1987: The northern Austroalpine margin during the Jurassic: Breccias from the Radstädter Tauern and Tarntaler Berge. – In: FLÜGEL & FAUPL (eds.): Geodynamics of the Eastern Alps, Wien (Deuticke), 103–111.

HÄUSLER, H., 1988: Unterostalpine Jurabreccien in Österreich. Versuch einer sedimentologischen und paläogeographischen Analyse nachtriadischer Breccienserien im unterostalpinen Rahmen des Tauernfensters (Salzburg-Tirol). – Jb. Geol. B.-A., Wien, **131**, 21–125.

JANOSCHEK, W.R. & MATURA, A., 1980: Outline of the Geology of Austria. – Abh. Geol. B.-A., Wien, **34**, 7–98.

KOVÁČ, M., BARÁTH, I., ŠUTOVSKÁ, K. & UHER, P., 1991: Lower Miocene events in the sedimentary record of the Dobrá Voda Depression. – In Slovak with English summary – Mineralia slovaca, Košice, **23**/3, 201–213.

KRIST, E., HATÁR, J., GREGUŠ, J. & VÍDENSKÝ, J., 1986: Petrogenesis and accessory leptinite minerals of the Čierny Balog Group (Král'ova hol'a zone of the Veporide Crystalline complex). – Acta geol. et geogr. Univ. Com., Geologica, Bratislava, **41**, 49–65.

MAHEL', M., 1961: Tektonik der Zentralen Westkarpaten. – Geol. Práce, Bratislava, Zoš., **60**, 11–50.

MAHEL', M., 1980: Represent the granitoids of the Malé Karpaty Mts. Nappes? – in Slovak with English abstract – Mineralia slovaca, Košice, **12**/2, 185–187.

MICHALÍK, J., REHÁKOVÁ, D. & ŽÍTT, J., 1993: Upper Jurassic and Lower Cretaceous facies, microplankton and crinoids in the Kuchyňa unit, Malé Karpaty Mts. – Geologica Carpathica, Bratislava, **44**/3, 161–176.

MIKO, O. & HOVORKA, D., 1978: Quartz-tourmalinic rocks of the Veporide crystalline complex in the Nízke Tatry Mts. – In Slovak with English summary – Záp. Karpaty, Bratislava, Sér. min., petr., geoch., matalog., **5**, 7–28.

MIŠÍK, M., 1955: Die akzessorischen Minerale der Kleinkarpatischen Granitmassive. – In Slovak with German summary – Geol. Sbor. SAV, Bratislava, **6**/3–4, 161–176.

MIŠÍK, M., 1956: Anwendung der Schwerminerale in der paläogeographischen und stratigraphischen Forschung in Bezug auf das Neogen und Quartär der Slowakei. – in Slovak with German summary – Geol. Práce, Bratislava, Zoš. 743, 59–139.

MIŠÍK, M. & JABLONSKÝ, J., 1978: Untertriassische Quartzite und Konglomerate der Kleinen Karpaten (Gerölanalyse, Transportrichtungen, Genese) – in Slovak with German summary – Acta geol. et geogr. Univ. Com., Geologica, Bratislava, **33**, 5–36.

MOSTLER, H. & PAHR, A., 1981: Triasfossilien im Čáker Konglomerat" von Goberling. – Verh. Geol. B.-A., Wien, 83–91.

PLAŠIENKA, D., 1987: Lithological, sedimentological and paleotectonic pattern of the Borinka unit in the Little Carpathians. – in Slovak with English abstract – Mineralia slovaca, Košice, **19**/3, 217–230.

PLAŠIENKA, D., MICHALÍK, J., KOVÁČ, M., GROSS, P. & PUTIŠ, M., 1991: Paleotectonic evolution of the Malé Karpaty Mts. – an overview. – Geologica Carpathica, Bratislava, **42**/4, 195–208.

PUPIN, J.P. & TURCO, M.J., 1972: Une typologie originale du zircon accessoire. – Bull. Soc. Franc. Minéral. Cristallogr., Paris, **95**, 348–359.

PUPIN, J.P., 1980: Zircon and Granite Petrology. – Contrib. Mineral. Petrol., Berlin – Heidelberg – New York, **73**, 207–220.

RADWANSKI, A., 1959: On the research of Upper Liassic petrography. – In Polish – Przegl.geol., Warszawa, **8**, 359–362.

REICHWALDER, P., 1973: Geologische Verhältnisse des jüngeren Paläozoikums im SO-Teil des Zips-Gemerer Erzgebirges. – In Slovak with English abstract and German summary – Záp. Karpaty, Bratislava, Sér. ZK, **18**, 99–139.

REYNOLDS, R.C.Jr., 1965: Geochemical behaviour of boron during the metamorphism of carbonate rocks. – Geochim. et Cosmochim. Acta, London, **29**, 1101–1114.

TOLLMANN, A., 1977: Geologie von Österreich., Bd 1., Wien (Deuticke), 766 S.

TURNAU-MORAWSKA, M., 1953: Tatra Keuper, its petrography and sedimentology. – in Polish with English summary – Acta Geol. Pol., Warszawa, **3**, 33–102.

UHER, P. & MARSCHALKO, R., 1993: Typology, zoning and chemistry of zircon from main types of granitic and rhyolitic pebbles in conglomerates of the Pieniny Klippen Belt Cretaceous flysch (Western Slovak Segment, Western Carpathians). – Geologica Carpathica, Bratislava, **44**/2, 113–121.

VESELSKÝ, J. & KOVALSKÁ, V., 1981: Accessory minerals of schistose crystalline rocks of Malé Karpaty Mts. – in Slovak with English summary – Acta geol. et geogr. Univ. Com., Geologica, Bratislava, **37**, 121–135.

VOZÁROVÁ, A., 1966: On the found of tourmalinic rock pebbles in the Permian of L'ubietová. – in Slovak – Geol. Práce, Zprávy, Bratislava, **40**, 165–167.

Manuscript received: 27. 10. 1992
Revised version received: 02. 07. 1993
Manuscript accepted: 27. 10. 1993