MICHAL MAHEĽ*

MANIN TECTONIC UNIT; RELATIONS OF THE KLIPPEN BELT AND CENTRAL WEST CARPATHIANS

(Figs. 1–6)

Abstract: The paper offers a new variant of localization of the original sedimentation area of the Manín unit — immediately adjoining the Belá unit. The Manín unit is interpreted as a part of the Krížna nappe, overthrust upon the Klippen Belt, with which it was additionally refolded. Between the boundary of the Klippen Belt (represented by the Klape und Kostelec groups) and between the Manín — Belá ridge, a depression with "black Jurassic" is presumed, which should be running through the whole West Carpathians. The author gives a detailed analysis of the differences between the Manín and High Tatra group, previously considered to be linked together.

Резюме: Статья приносит новый вариант локализации первоначального седиментационного пространства в Манинской единице — в непосредственном соседстве Беланской единицы. Манинская единица интерпретируется в качестве составной части Крижнянского покрова, надвинутой на пояс утесов и дополнительно вместе с ним повторной складчатости. Между границей пояса утесов (представляемой Клапской и Костелецкой сериями) и междуМанинско-беланской возвышенностью предполагается впадина «черной юры», просекающая все Западные Карпаты. Автор дает подробный анализ различий между Манинской в Высокотатранской сериями, которые в прошлом считались тесно связанными.

Perhaps the most discussed and most contradictory tectonic unit in the West Carpathians in the last years is the Manín unit. As a nappe it was defined nearer by D. Andrusov (1938); with indication to facial relationship of its Jurassic — Lower Cretaceous members with the High Tatric unit. In his last syntheses he also considered it as the innermost nappe of the Klippen Belt (D. Andrusov, 1968, 1972) with features typical of the Klippen Belt as the klippen style and mainly the presence of Upper Cretaceous members. An essentially analogous approach to judgment of this unit is also found at several other authors mainly dealing with the study of Cretaceous members of the Klippen Belt. Interesting is the opinion of J. Salaj — O. Samuel (1966), who consider the Manín unit s. l. as one of higher order and besides the Manín group they assign also other groups, known from the inner part of the Klippen Belt, to it — Kostelec, Klape, Streženice groups.

M. Maheľ described an analogous group also at the SW end of the Strážovská hornatina Mts., extending as far as the northern slopes of the Považský Inovec Mts. at a distance not less than 20 km from the Klippen Belt. This has led to the opinion that the Manín group joins the envelope group of the Považský Inovec Mts. (M. Maheľ, 1948). Also a more detailed treatment of stratigraphy and lithology of Jurassic — Lower Cretaceous members of this group (M. Maheľ — A. Kullmanová, 1961) has shown as unfounded to dis-

* Acad. Prof. M. Maheľ, DrSc., Dionýz Štúr Institute of Geology, Mlynská dolina 1, 809 40 Bratislava

tinguish the Manín group of the Klippen Belt from that occurring at the SW end of the Strážovská hornatina Mts., thus in the Central Carpathians. Central Carpathian competence of the Manín unit due to close structural linking of the Manín group with the Krížna nappe is supported by M. Maheľ (1962, 1967)) also basing upon the fact that they form a homogeneous folded system – in which it is difficult to place together the boundary between the Manín and Krížna unit. Consequently, this was also one of the reasons why he considered autochthonity of the Krížna nappe.

M. Rakús (1975, 1977), in tectonic assignment of the Manín unit, was also mainly based upon its Jurassic – Lower Cretaceous members. The younger Upper Cretaceous members folded in amidst this unit he considers as tectonic windows of the innermost Kostelec unit of the Klippen Belt. The layers of polymict conglomerates in the Albian-Cenomanian flysch sequence, however, in accordance with the opinions of D. Andrusov, he genetically puts into connection with the Ultrapieninic cordilera. And this forces him to place the sedimentation area of the Manín nappe between the Klippen Belt and the Inner Carpathians into a particular zone.

In judging the tectonic position of the Manín unit, as visible, the following facts played an important role:

- presence of "exotic" conglomerates in the Albian-Cenomanian flysch sequence (D. Andrusov, 1938, 1972; M. Rakús, 1977);
- lithological-stratigraphic relationship of its Jurassic and Lower Cretaceous members to units of the Inner Carpathians (D. Andrusov, 1938, 1972; M. Maheľ, 1948, 1967);
- structural incorporation in the structure of the Klippen Belt and the klippen style of older members (D. Andrusov, 1938, 1972);
- representation of Upper Cretaceous members including the "couches-rouge" facies of Turonian–Maastrichtian age (D. Andrusov, 1938, 1968; J. Salaj – O. Samuel, 1966);
- representation of the Manín group with its characteristic stratigraphic succession in the Jurassic, Lower Cretaceous and with hiatus in the Albian in the Central Carpathians at the SW end of the Strážovská hornatina Mts. (M. Maheľ, 1967);
- participation of the Manín unit in the homogeneous folded system of Subtatric nappes; the existence of the Albian-Cenomanian flysch sequence as "connecting" member of the Manín and Krížna units. Problematic is there the tectonic boundary of higher order between the Krížna and Manín unit in the Klippen Belt as well as the marginal part of the Central Carpathians in the Strážovská hornatina Mts. (M. Maheľ – A. Kullmanová, 1950, M. Maheľ, 1968).

The different attitude to valuation of the mentioned facts comprehensibly leads to differences, relatively essential, in structural assignment of the Manín unit, mainly in deriving its original sedimentation area. Under such circumstances it is comprehensible that the authors dealing more in detail with the Klippen Belt put its genesis into connection with this zone. The authors tracing more in detail the structure of the Inner Carpathians, on the contrary, see in this unit an Inner Carpathian element, partly incorporated in the structure of the Klippen Belt by later foldings (M. Maheľ, 1967). The endeavour for a compromising attitude (M. Rakús) is understandable in such cases.

Although in judging the position of the Manín unit it is necessary to take into consideration all the mentioned facts, however, in assignment to the system of West Carpathian units as most important I consider clearing up of relation to the analogous unit occurring at the SW end the Strážovská hornatina Mts. in the system of units of the Central Carpathians. This unit reaches with its frontal part the neighbourhood, partly the structure of the Klippen Belt in the

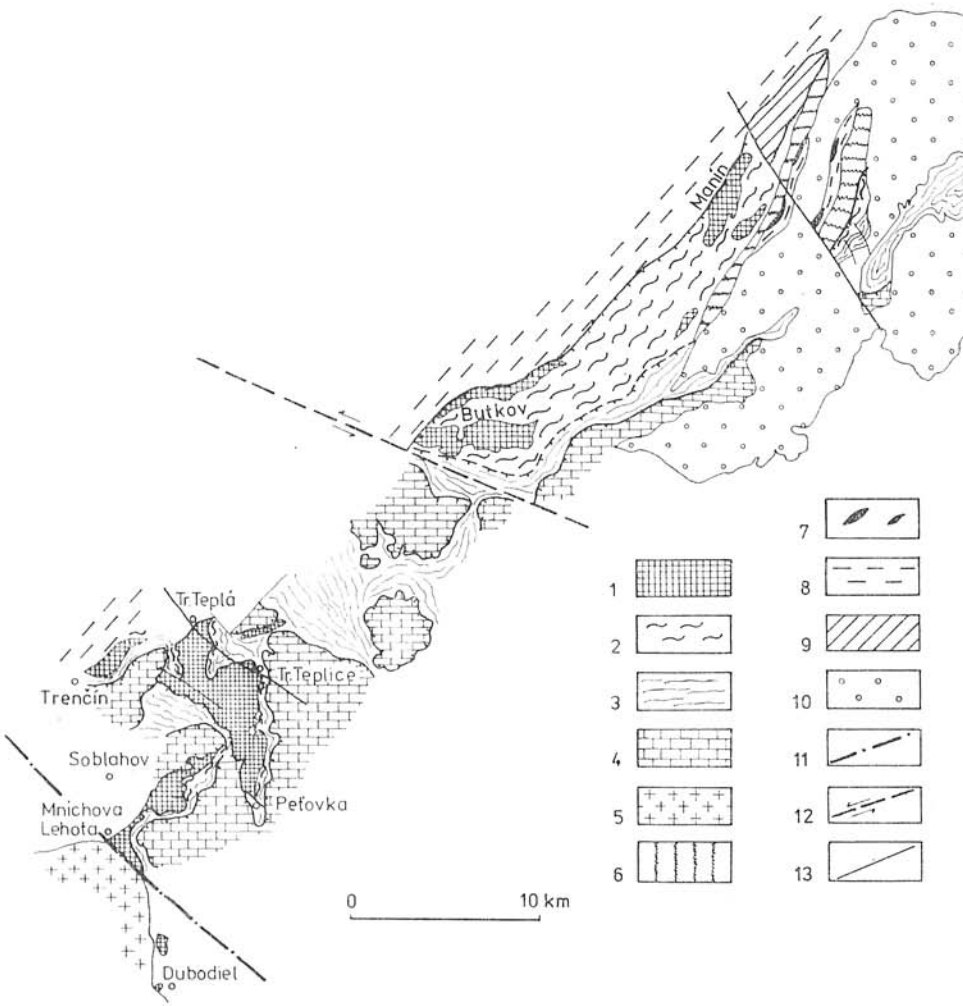


Fig. 1. Sketch-map of extension of the Manín nappe in the Strážovská hornatina mts.

Explanations: 1. Lower members of the Manín nappe up to the Aptian; 2. Albian--Cenomanian of the Manín and Zliechov nappes (thicker complexes); 3. Liassic to Aptian of the Zliechov nappe; 4. Choč nappe; 5. Crystalline core of the Považský Inovec mts.; 6. Albian—Cenomanian-Praznov beds of uncertain tectonic position; 7. Klippen of Kostelec type (Jurassic—Lower Cretaceous); 8—9. Klippen envelope: 8. Albian —Cenomanian, 9. Turonian-Santonian; 10. Paleogene; 11. Deep-seated fault; 12. Strike-slip fault; 13. Faults.

area of Trenčianska Teplá—Trenčín and so with its members comes into a position very close to that of the Manín unit in the Klippen Belt proper. With the evidence of an essentially equal lithological-stratigraphic content of the Manín unit s. s., i. e. in the Klippen Belt and Manín unit s. l. — i. e. in the Central Carpathians, it is hardly logical to range them into two different, genetically unrelated units as suggested by M. Rakús (1977), considering the Central Carpathian part of the unit in question as the Belá unit. Therefore further new knowledge on the lithological-stratigraphic character of the Manín unit, mainly in the Central-Carpathian part and an its tectonic position acquires extraordinary importance. In this regard the last years brought a series of important new data, obtained with compling the geological map 1:10 000 (M. Maheľ, 1970), detailed lithological-sedimentary studies (A. Kullmanová, 1968) and evaluation of borehole SBM-1 sunk in the Manín group near Soblahov at the western end of the Strážovská hornatina Mts. near the crystalline core of the Považský Inovec Mts. at a distance of 10 km from the Klippen Belt (M. Maheľ — A. Kullmanová, 1974); (Fig. 1).

I. Lithological-stratigraphical characterization

The essential part of the Liassic is represented by grey fine-grained sandy-crinoidal limestones, most often thick-banked. They display abundant clastic admixture (in places up to 40 per cent) with little working up of grains and variegated clastic admixture (quartz, feldspars, muscovite, chlorite, garnet, leucoxene, rutile, zircon, tourmaline, magnetite, pyrite, fragments of quartz, cherts, dolomites and limestones). Such a character display sandy-crinoidal limestones at Manín, Butkov (thus in the Klippen Belt), near Trenčianska Teplá (frontal part of the Manín unit s. l., but also near Petrova Lehota, even near Dubodiel) areas at a distance of 15—20 km from the fronts. The rich fauna with abundant brachiopods and lamellibranchiates and more frequent belemnites (mentioned nearer in the works by M. Maheľ et al., 1967; M. Maheľ — A. Kullmanová, 1964) is mainly characterized by a large amount of representatives of the genus Gryphaea, Gryphaea arcuata Lam. and G. cymbium elongata Goldf. in the Lower Liassic, G. obliqua Goldf. in the Upper Liassic. In more southern areas, however, the stratigraphic range of sandy-crinoidal limestones is lesser, bound to the Lower Liassic only. The sandy-crinoidal limestones have a larger portion of chert nodules and chert layers — spongolites in some areas. Besides cherty limestones they contain more often layers of sandy limestones, oolitic limestones, crinoidal and lumachelle limestones, coincidentally in the extent of the whole distinguished Manín unit; concerned is a member formed in littoral or shallow neritic environment.

In some profiles the uppermost parts of the Liassic are represented by pink and brownish-red crinoidal limestones, in some places with higher supply of detrital component (including the intercalations of green sandy shales). For instance, near Tunežice (Butkov stretch of the Klippen Belt) where the Toarcian age is proved by rich ammonite fauna, mainly by Hildoceras bifrons and with belemnites: *Passaloteuthis elongatus* (Miller), *Nannobelus penicilatus Blainville* (M. Rakús, 1977). The uppermost Liassic is represented by pink crinoidal limestones also near Trenčianska Teplá whereas near Soblahov and

Petrova Lehota their stratigraphic range is wider, beginning from the Lotharingian.

In the Dogger more distinct differences are known, even in the bathymetric type of members between Manín and Butkov, thus in the Klippen Belt proper (D. Andrusov, 1938). This is essentially valid also for the Manín unit s. 1. In it, most often equally as at Butkov, the Lower Dogger is represented by a sequence of dark-grey banked cherty limestones, 3—10 m thick, rich in the association of radiolarians but also sponge spicules. The limestones accompanied by layers of dark-grey clayey shales display a tendency to rhythmicity. The Aalenian age is indicated by belemnites *Mesoteuthis beneckei* Schwengler, *M. tripartites* Quenst. In higher layers the sequence described passes into radiolarian limestones and radiolarites.

In the Manín area and near Mníchova Lehota the Dogger is mainly formed by shallow-water red to greenish, partly crinoidal limestones intergrown with cherts and haematite breccias-condensed facies of little thicknesses. The ammonite *Parkinsonia* (Gonolites) *cf. schloenbachi* (Schlipe) points to the Lower Baschiana Colom. A. Kullmanová, 1968).

A member particularly characteristic of the Upper Dogger and Malm are red nodular limestones 4—6 m thick, maximum up to 10 m. At Butkov they begin already in the Bathonian (*Oppelia aspidoides* /Opp./). The lowermost layers of limestones have nodules of red cherts and represent mainly the filamentous-globochaete, higher up the globochaete-globigerine and highest globochaete-globigerine-saccocoma microfacies (A. Kullmanová, 1974). At Butkov, near Ladce, near Petrova Lehota and Soblahov the upper layers of red nodular limestones contain calpionels (*Calpionella alpina* Colom) and *Crassicolaria;* they reach as high as the Tithonian. In the Soblahovská dolina valley they even reach the Berriasian (*Tintinopsella carpathica* Murgeanu — Fil., *T. cadischiana* Colom. A. Kullmanová, 1968).

The red nodular limestones are passing laterally and vertically into beige to light-grey and pink compact massive limestones, 7—20 m thick; biomicrite with predominating Saccocoma /50—75 per cent/ with abundant Globochaete alpina (15—20 per cent) and only a small amount of radiolarians (up to 5 per cent) and crinoid stems, scarcely foraminifers — *Protoglobigerina* sp. The uppermost layers of these limestones in the Manín group s. 1. (on the slopes of the Opatovská dolina valley near Petrova Lehota), equally as in the Klippen Belt contain calpionels, at the bottom Tithonian, higher up Berriasian. In some profiles the uppermost layers of the Malm are represented by greyish-green, compact limestones with saccocomes and calpionelids in the Manín group s. s. (Manín) and Manín group s. l. (Dubodiel, Mitická dolina valley).

The Upper Tithonian to Hauterivian of the Manín unit are formed by 30—40 m thick grey, marly limestones, mostly platy, with layers of marls, rich in calpionels. In higher layers banked limestones with nodules and small lenticles of black cherts are more frequent; micrite with radiolarians and rock-forming nannocones. In the profile of Manín two alternating microfacies are known: microfacies of organogenic limestones with predominating sponge spicules and radiolarians and microfacies of muddy limestones of globochaete-nannocone microfacies (M. Mišík, 1967). The content of microfossils of the genus *Nannoconus* Camptner indicates distinct deepening of sedimentation conditions,

characteristic of the Neocomian of the Manín unit in the klippen stretch and in the stretch of the Central Carpathians.

The Barremian-Aptian in development of massive grey, dark-grey limestones of organodetrital texture is considered as a characteristic member of the Manín unit. Already in the Manín stretch, however, we know also a different facies, grey banked marly limestones with black spongolites and grey marly limestones and marls-environs of Súľov (M. Rakús, 1977), reaching the Lower Albian. This means that in the area most typical of the Manín unit besides shallow--water bioherm development of the Barremian-Aptian also a more deep-water development is present. Two types of the Barremian–Aptian we know also from the Central-Carpathian part of the Manín unit. Fine-grained compact limestones with chert nodules, with biosparites, massive to coarse-banked with orbitolines, bryozoan fragments with authigene glauconite and echinoderm stems are found in Dobrá; near Soblahov and the Mitická dolina valley dark--grey banked limestones with cherts, calcarenite with glauconite and echinoid spines and echinoderm stems. The finds of foraminifers (*Hedbergella*) in the lower layers near Petrova Lehota, also near Soblahov, show that these limestones already begin in the Hauterivian (A. Kullmanová, 1968).

The Manín unit, s. s. displays a thick flysch development of the Albian–Cenomanian but in places also marls, partly variegated (grey and reddish) of Upper Albian or Lower Cenomanian age, which follow after longer break of sedimentation (Lower-Middle Albian). Another its characteristic is the presence of polymict conglomerates in the sequence of sandstone flysch. Also in the Manín group s. l., besides the Albian-Cenomanian flysch sequence, are known marls and variegated to reddish-grey marly shales, with Lower Cenomanian foraminifers, from Trenčianska Teplá and Dobrá: *Thalmaninella ticinensis* (Gandolfi), *T. apenninica* (Renz.) (M. Maheľ-A. Kullmanová, 1966). In this regard are interesting observations from the borehole near Soblahov where in two horizons was drilled through the sequence of marly to marly--aleuritic shalles with *Thalmaninella ticinensis* and *Th. apenninica* Renz, at a depth 2–10 m and 207–221 m directly in the overlier of organodetrital limestones. In this sequence is not uninteresting the occurrence of fragments of basic rocks, which are more often found in the overlier of Barremian-Aptian limestones or as tuffites at the base of the marlstone sequence.

The presence of polymict conglomerates, mainly in the Cenomanian sequence, is considered as a mark of proximity to the "Ultrapieninic ridge" or of vicinity of the Manín unit to the Klape or Klape-Kostelec sedimentation area, not only in the Manín unit (D. Andrusov, 1972; M Rakús, 1977) but even in the sequences with typical Zliechov succession of Jurassic to Lower Cretaceous members. It serves as the main criterion for distinguishing of a particular periklippen group-the so-called Dúbrava group (D. Andrusov, 1968). The polymict conglomerates are, however, not rare in the Albian-Cenomanian of the envelope groups (High Tatric, Žiar, Malá Magura groups and Krížna nappe) (M. Maheľ, 1967). Therefore in the flysch sequence of the Manín group we do not consider them as a criterion showing linking of this group with the Klippen Belt. Obviously with the onset of flysch sedimentation significant compressional movements took place, the one of consequences of which was also emergence of several "cordillers", not only in the Klippen Belt but also in the Central Carpathian sedimentation area. The so called Manín phase (D.

Andrusov, 1938) is thus of wider reach with hiatuses in several series of the Central Carpathians (M. Maheľ, 1962).

Lithological-stratigraphical characterization of the individual Jurassic and Lower and Middle Cretaceous members of the Manín unit shows accordances in its part located in the Klippen Belt and in the Central Carpathian part (at the NW end of the Strážovská hornatina Mts.) in the stratigraphic succession and lithological-petrographic character of the individual members. This concerns also these members which can be considered as characteristic of this unit (sandy-crinoidal Liassic limestones with grypheas, red nodular limestones of wide stratigraphic range from the Dogger, Barremian-Aptian organodetrital limestones, Middle Cretaceous flysch sequence, most often with hiatus in the Lower to Middle Albian – in some profiles in the whole Albian. It should be stressed here that in both the mentioned areas the most members display variable stratigraphic range. This concerns especially the sandy-crinoidal limestones, red nodular limestones, compact pink limestones but also grey organogenic or organodetrital Lower Cretaceous limestones, Distinct are also the lateral changes of facies of the fundamental members at a relatively little distance. Sandy-crinoidal limestones (mainly their upper layers) pass into crinoidal limestones, red nodular limestones also into deeper-water pink or light-grey limestones in the Malm; organodetrital limestones of the Barremian-Aptian into deeper-water limestones with cherts. Laterally also relation of the Albian-Cenomanian flysch sequence to underlying limestone complexes, changes; in more northern areas with distinct hiatus (in the Albian), in inner areas with transition of the deeper-water facies of the Aptian through marly limestones with cherts of the Lower Albian into the flysch sequence.

A part of the Jurassic and Lower Cretaceous members of the Manín group are shallow-water, and so, on the basis of them, one may speak about the ridge or cordillera type of this group. Greater deepening of the Malm–Lower Neocomian (partly also Dogger) is connected with most distinct oceanization of the Alpides). These members are, however, also relatively more shallow-water than in trough sequences. The Manín group as one unit, also in the lithological character and stratigraphic position of most its members, displays a geotectonic character more or less coincident with the groups of the Vysoká type of the Krížna unit (M. Maheľ, 1959, 1967).

As particularly important for determination of the Central Carpathian character of the Jurassic and Lower Cretaceous of the Manín unit I consider observation of A. Kullmanová (1968), testifying to a different lithofacial and microfacial character of the Kostelec klippes, thus klippes of the southernmost subzone of the Klippen Belt, situated in the neighbourhood of the Manín unit. On the contrary to the Manín, the Kostelec klippes display:

- an insignificant share of terrigenous quartz and other material;
- a large amount of glauconite in Liassic crinoidal biosparite;
- a foraminifer microfacies, with essentially higher diversity of species and well-preserved, typical of the Klippen Belt;
- fragments of volcanic rocks secondarily altered in Liassic limestones.

Not of less importance are also latest observations of R. Marschalko and J. Kysela (communications) about differences of the Albian-Cenomanian flysch sequences of the Manín unit from klippen of the Klape and Kostelec Subzone.

II. Tectonic position of the Manín unit

The nappe character of the Manín unit has been unambiguously proved by borehole SBM-1 near Soblahov, abouth 10 km SE of the Klippen Belt (Fig. 2). The borehole located in the upper part of this unit drilled it through already at depth 289 m. From this depth to 936 m it met slices of the Keuper and Rhaetian of envelope type, obviously members of the envelope unit of the Považský Inovec Mts., in allochthonous position. From 936 m to terminal 1801 m the Jurassic-Rhaetian complex of dark-grey limestones, in lower parts also of claystones, sandstones and conglomerates (Lower Liassic-Rhaetian) was drilled. From the character of conglomerates with abundant fragments of the crystalline it may be concluded on the analogy with outcroups of the envelope group of Fatra type not far away near Selce in the Pavažský Inovec Mts. The Manín nappe obviously overlaps in its Central Carpathian part the envelope unit of Fatra type.

The results of the mentioned borehole require to change our older view (M. M a h e ľ, 1948, 1967) of transition of the Manín group into the position of the envelope of the Považský Inovec crystalline core, to which the main occurrence of its continuous sequence led, beginning with Middle Triassic limestones in the area of Mníchova Lehota in neighbourhood of the crystalline core. At present, however, we know (Fig. 1) that there is a tectonic contact connected with one of the most important transversal faults in the Carpathians, the Jastrabie fault.

In the Klippen Belt the Manín unit is considered as nappe, thrust over the inner parts of this zone (D. A n d r u s o v, 1972; M. R a k ú s, 1975).

The nappe character of the Manín unit concerns the Central Carpathian part as well as the part occurring in the Klippen Belt. It is obvious that both parts represent one tectonic unit with different substratum. In its northern part the nappe lies on members of the Klippen Belt, at the SW end of the Strážovská hornatina Mts. on the envelope unit of Fatra type, tectonically sliced. The change of character of the substratum of the Manín nappe is shown in the change of the course of structures of the Manín unit and of the fronts of the Zliechov unit from original direction NNE–SSW to NE–SW into direction W–E (most distinct near Butkov). The different character of the substratum of the Manín nappe is obviously linked with a deeper-anchored transversal fault – strike-slip fault of WNW–ESE direction – we call it the Košeca fault, which divides morphostructurally and in structure different segments of the Klippen Belt – the wide Púchov from the Trenčín segment. South of this fault an overthrust of the Central Carpathians on the Klippen Belt, perhaps also with the upper slices of the crystalline, may be supposed.

More intense refolding of the Manín nappe with its tectonic substratum in the Klippen Belt is comprehensible, as a zone with strong manifestations of the Mesoalpine and Neoalpine (Savian) folding is concerned. A consequence of it is the occurrence of Kostelec klippen and Upper Cretaceous members of the klippen envelope in tectonic contact with structures of the Manín nappe. Resulting from these movements is also tectonic dissection of the Manín unit proper, mainly of its more rigid Jurassic – Lower Cretaceous members. However, it should be stressed that the Manín unit has not true klippen of Pieniny type as in the klippen units. Typical structural forms of the Manín unit are sliced overturned to recumbent frontal folds, often with reduced limbs, parti-

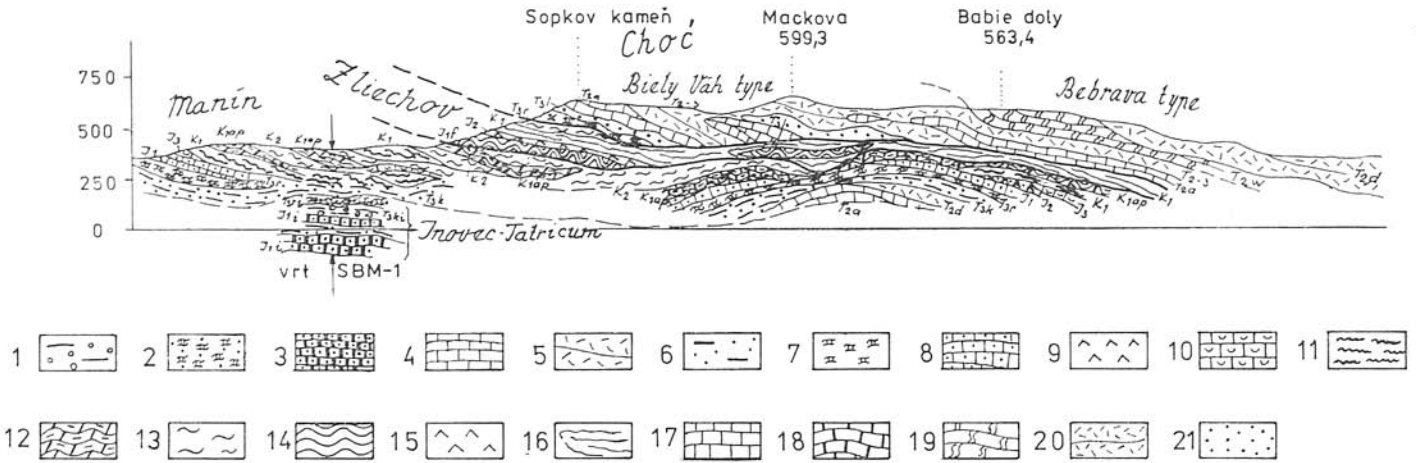


Fig. 2. Geological profile in the area of borehole SBM-1 Soblahov; western end of the Strážovská hornatina mts. *Explantations:* 1—3. Inovec (envelope) group: 1. T_3ki — Carpathian Keuper, 2. T_3ri — Rhaetian, 3. Ji-black limestones, marlstones, siltstones-Jurassic and Upper Rhaetian of the Inovec (envelope) group; 4—13. Manín nappe: 4. T_2a — dark-coloured limestones. 5. T_2d — dolomites, 6. T_3k — Carpathian Keuper, 7. T_3r — Rhaetian, 8. J_1 — Liassic-sandy crinoidal limestones, 9. J_2 — Dogger-silicites, shales, 10. J_3 — Malm-pink; mostly nodular limestones, 11. K_1m — Neocomian-platy limestones with cherts, 12. Kap — Barremian-Aptian: organodetrital limestones, 13. K_2 — Albian-Cenomanian of the Manín and Zliechov nappes: marly shales, flysch; 14—16. Zliechov nappe: 14. J_1 — Upper Liassic-fleckenmergel facies, 15. J_{2-3} — Dogger-Malm radiolarian limestones and radiolarites, 16. K_1 — Neocomian-marly limestones and marlstones; 17—21. Choč nappe: 17. T_2a — Middle Triassic: dark-coloured limestones, 18. T_2r — Middle Triassic-limestones with cherts (Reifling), 19. T_2v — Middle Triassic-light-coloured limestones-Wetterstein, 20. T_{2-3} — Middle-Upper Triassic — dolomites, 21. T_3l — Upper Triassic: Lunz beds.

cularly distinct in the folds of Manín and Butkov. The majority of slices — morphological klippen are accompanied by younger upthrusts. With south-vergent upthrusts are also cleared up the occurrences of Kostelec klippen at the contact of the Paleogene and Albian-Cenomanian flysch sequence (M. R a k ú s, 1975).

The Manín unit together with the fronts of the Zliechov nappe forms a homogeneous folded system (M. M a h e ľ, 1967); it represents the lower structures of this system. Thus it is of equal position as the units of Vysoká type. Different is, however, linking with the Zliechov nappe not through Triassic members but through Middle Cretaceous ones and different spatial distribution in the frontal part of the nappe system.

The manifestations of younger foldings are evident in the Manín unit, in its frontal part and in the Central Carpathians. Especially instructive in this regard is the profile near Kolačín (Fig. 3). Above the Lunz beds of the Choč nappe here are directly lying the Albian—Aptian and Neocomian of the Manín unit and above them the Albian and further members of the Krížna unit of the overturned limb of the recumbent fold of the Zliechov unit. Obviously the Manín unit is thrust over the Choč unit here. Nearer tracing of the course and contact of the strip of the Manín and Zliechov units in the area between the brook Teplička and the Opatovská dolina valley justifies us to suppose a younger overthrust of the Manín unit on the Zliechov one, mainly north of Čvirigovec (see profile 4). The Manín unit together with the Krížna and partly also Choč unit are thus affected by later, perhaps Laramide or still later folding. More distinct evidence of later folding processes is indicated by palynological finds, signalizing the presence of the Upper Cretaceous and Paleogene even in the underlier of Manín unit slices (P. S n o p k o v á in M. M a h e ľ — A. K u l l m a n o v á, 1974) in borehole SBM-1.

Between the Manín and Zliechov members is the "connecting" Albian-Cenomanian flysch of uncertain tectonic position. Most often it is assigned to the Krížna nappe because in places folded-in members of the Lower Cretaceous of typical Zliechov development occur in it, e. g. in the Butkov stretch. More often, however, are amidst the Albian-Cenomanian organodetrital limestones of the Aptian, nearer to the Manín unit in development. In the area of Trenčianske Teplice (mount Ivaničkovec) but also in the area of Soblahov (SW of Starý háj) are in this "connecting" Albian-Cenomanian small lenticles, formed by Jurassic-Lower Cretaceous members of "mixed" type. In their character some of them resemble the members of Zliechov type (radiolarites-limestones and radiolarites of the Dogger—Malm, detaily folded marlstone — Tithonian—Neocomian), other ones the members of the Manín unit (red nodular limestones, coarse-banked dark-grey Barremian—Aptian organodetrital limestones densely intergrown with cherts; Fig. 5).

The Central Carpathian part of the Manín unit, its distribution in the underlier of a large recumbent fold of the Zliechov nappe, traceable at length of more than 10 km, makes possible to know its inner structure outside the nappe fronts. In the frontal part equally as in the Klippen Belt an overturned fold with core built up of thick Liassic sequence is apparent (as in the case of Butkov an Manín in the Klippen Belt). Southerly of the frontal part the Manín unit has essentially a two-etage structure. The upper part is with a series of slices built up of younger members.

Recurrence of bed sequences of the youngest members, beginning with the Tithonian, in the mentioned borehole Soblahov, resembles sliced recumbent folds. Smaller slices are located amidst the plastic members of the Keuper and Rhaetian. Between the rigid and plastic members is more often tectonic disharmony. Representation of the individual members in the slices is unequal. Some contain the members from the Liassic to the Albian, others Jurassic or Neocomian only. Obviously tectonic selection (Fig. 4, 5) was evident, so frequent in units of cordiller type. Stressed should be here the more or less flat position of lenticles with dips most often 10–25°. The lower etage is mainly represented by the Rhaetian and Keuper, in places by dolomites and Middle Triassic limestones of little thickness. More often small lenticles of the younger members are just in the upper part of this lower etage.

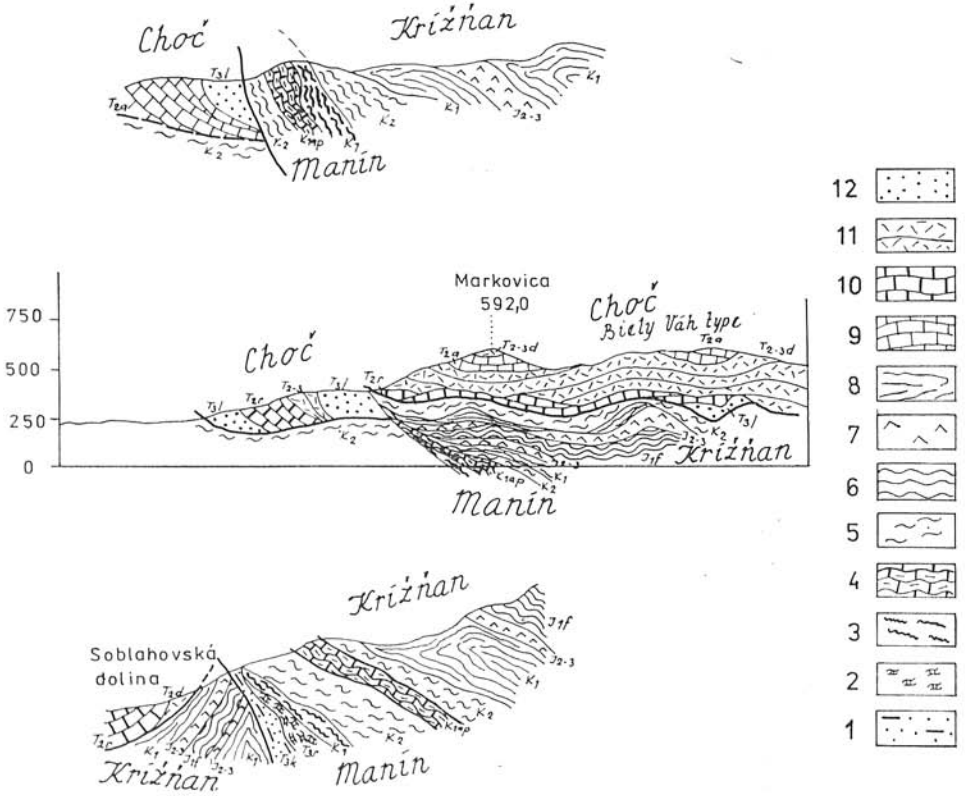


Fig. 3. Profiles showing the younger upthrust of the Manín nappe
Explanations: 1–4. Manín nappe: 1. T_3k – Carpathian Keuper, 2. T_3r – Rhaetian-Carpathian type, 3. K_1m – Lower Neocomian-limestones with cherts, 4. K_2ap – Barremian–Aptian-organodetrital limestones with cherts; 5. K_2 – Albian–Cenomanian-flysch; 6–8. – Zliechov nappe: 6. J_1f – Upper Liassic-fleckenmergel, 7. J_2-$_3$ – Dogger–Malmian radiolarites and radiolarian limestones; 8. K_1 – Neocomian-marls and marly limestones'; 9–12. Choč nappe: 9. T_2a – Anisian–Gutenstein limestones, 10. T_2r – Anisian–Ladinian-Reifing limestones, 11. T_2-$_3d$ – Ladinian–Upper Triassic-dolomites, 12. T_3l – Carnian–Lunz beds.

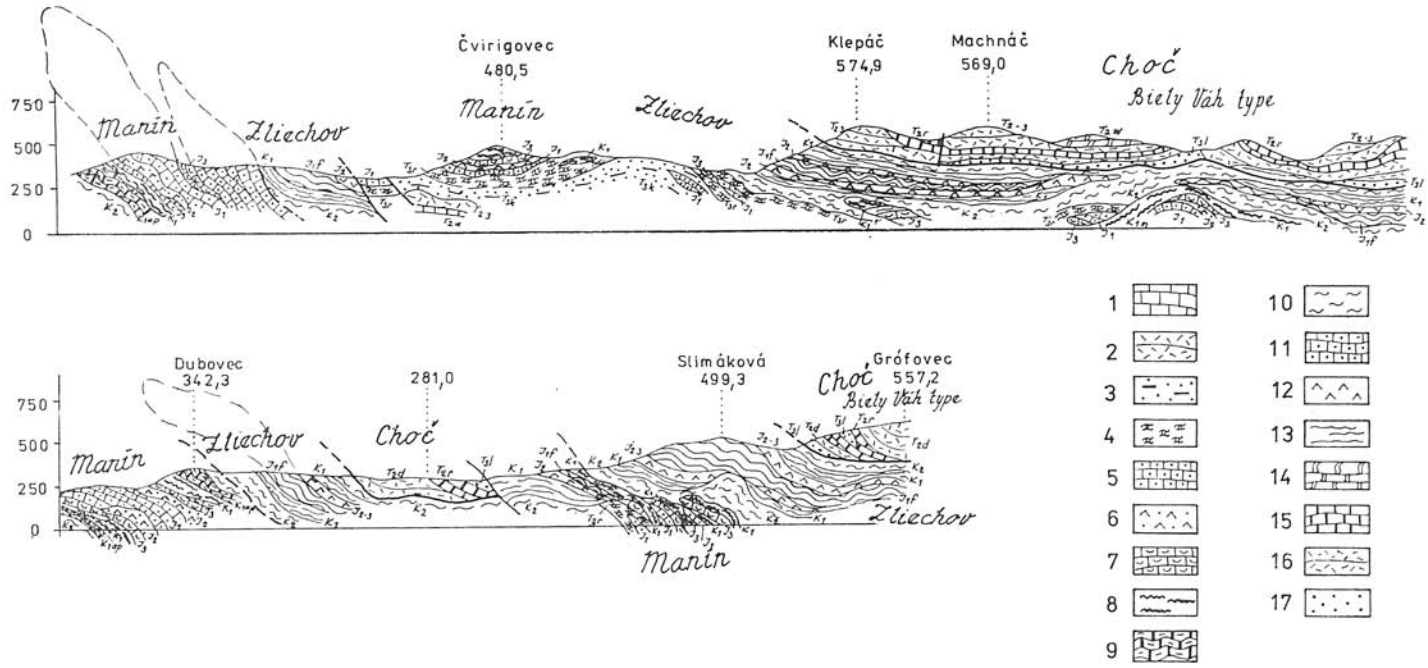


Fig. 4 Geological profiles at the SW end of the Strážovská hornatina mts.

Explantations: 1–9. Manín nappe: 1. T_2a — Middle Triassic-limestones, 2. T_2d — Middle Triassic-dolomites, 3. T_3k — Upper Triassic-Carpathian Keuper, 4. T_3r — Rhaetian-Carpathian Type, 5. J_1 — Liassic sandy crinoidal limestones, 6. J_2 — Dogger--silicites, shales, 7. J_3 — Malm-pink, mostly nodular limestones, 8. K_1m — Neocomian-platy limestones with cherts, 9. Kap — Barremian—Apatian: organodetrital limestones; 10. K_2 — Albian—Cenomanian of the Manin and Zliechov nappes: flysch and marly shales; 11–13. Zliechov nappe: 11. J_1f — Upper Liassic-fleckenmergel facies, 12. J_{2-3} — Dogger—Malm: radiolarian limestones and radiolarites, 13. K_1 — Neocomian — marly limestones and marlstones; 14–17. Choč nappe: 14. T_2r — Middle Triassic-limestones with cherts (Reifling) 15. T_2w — Middle Triassic light — coloured limestones, 16. T_{2-3} — Middle-Upper Triassic-dolomites, 17. T_3l — Upper Triassic: Lunz beds.

In structural sense the Manín nappe represents the frontal lower slices of the Krížna nappe. Thus it is a nappe of second order. The frontal parts of the Manín nappe, north of the Košeca fault, are overthrust directly on units of the Klippen Belt, with which they are refolded – we speak about the Manín nappe s. s. Considerable parts of the Manín nappe, south of the Košeca fault, are covered with members of the Tatra-type envelope unit – we speak about the Manín nappe s. l. These parts of the nappe may be in places connected with the more southerly situated slices in the Ďurčiná or Belá group.

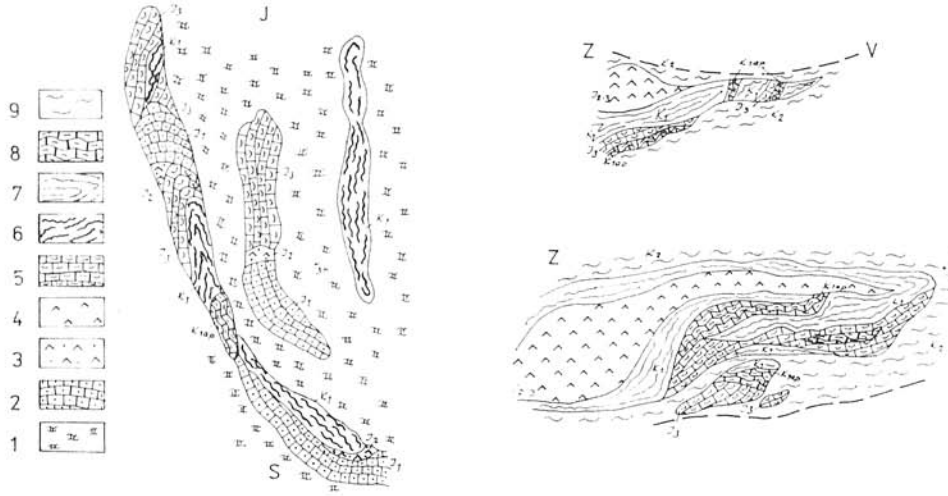


Fig. 5 Sketch-map of the Manín nappe slices near Trenčianske Teplice
a) Slices of rigid members (Liassic–Aptian) amidst a plastic Rhaetian
b) Slices of "mixed" facies of the Jurassic and Lower Cretaceous amidst the Albian–Cenomanian, connecting the Manín and Zliechov nappes
Explanations: 1. T_3r – Rhaetian–Carpathian type, 2. J_1 – Liassic-sandy crinoidal limestones, 3. J_2 – Silicites, shales, 4. J_{2-3} – Radiolarian limestones and radiolarites, 5. J_3 – Malm-pink, mostly nodular limestones, 6. K_1 – Lower Neocomian-limestones with cherts, 7. K_1 – Neocomian-marls and marly limestones with cherts, 8. K_1ap – Barremian–Aptian organodetrital limestones, 9. K – Albian–Cenomanian-flysch.

III. Genetic relations of the Manín units to units of the Inner Carpathians

In the past facial relations of the Manín unit to the High Tatric unit were studied (D. Andrusov, 1938, 1968). This investigation set out mainly from the high portion of detrital component in the Liassic, especially represented by sandy-crinoidal limestones and Urgon-type limestones in the Manín unit. It should be added that in the Liassic of the High Tatric unit not only sandy limestones as in the Manín unit but also sandstones, more often also conglomerates with ferric–quartzy and calcareous cement, the so called Pisana quartzites, occur. Especially different are layers of conglomerates with blocks and large boulders (up to fist-size) of Triassic limestones and dolomites, quartzites and granite. Characteristic of the High Tatric group is a break of sedimentation at the boundary of the Liassic and Dogger and the transgression begins only with

the Callovian in some profiles. In the Manín unit, on the contrary, to the end of the Liassic deepening, onset of the radiolarian facies occurred. The Malm in the High Tatric group indicates proximity of the facies to the Manín ones with grey, pink limestones of globochaete and saccocoma microfacies. Its particularity are layers of dark-grey dolomitic limestones. The Tithonian to Lower Neocomian of both groups are also different. In the High Tatric group are no deeper-water facies, but predominantly oolitic or pseudoolitic limestones, thus shallow-water facies, reaching the Aptian. In the Barremian—Aptian of the High Tatric group there are more distinct reef breccias.

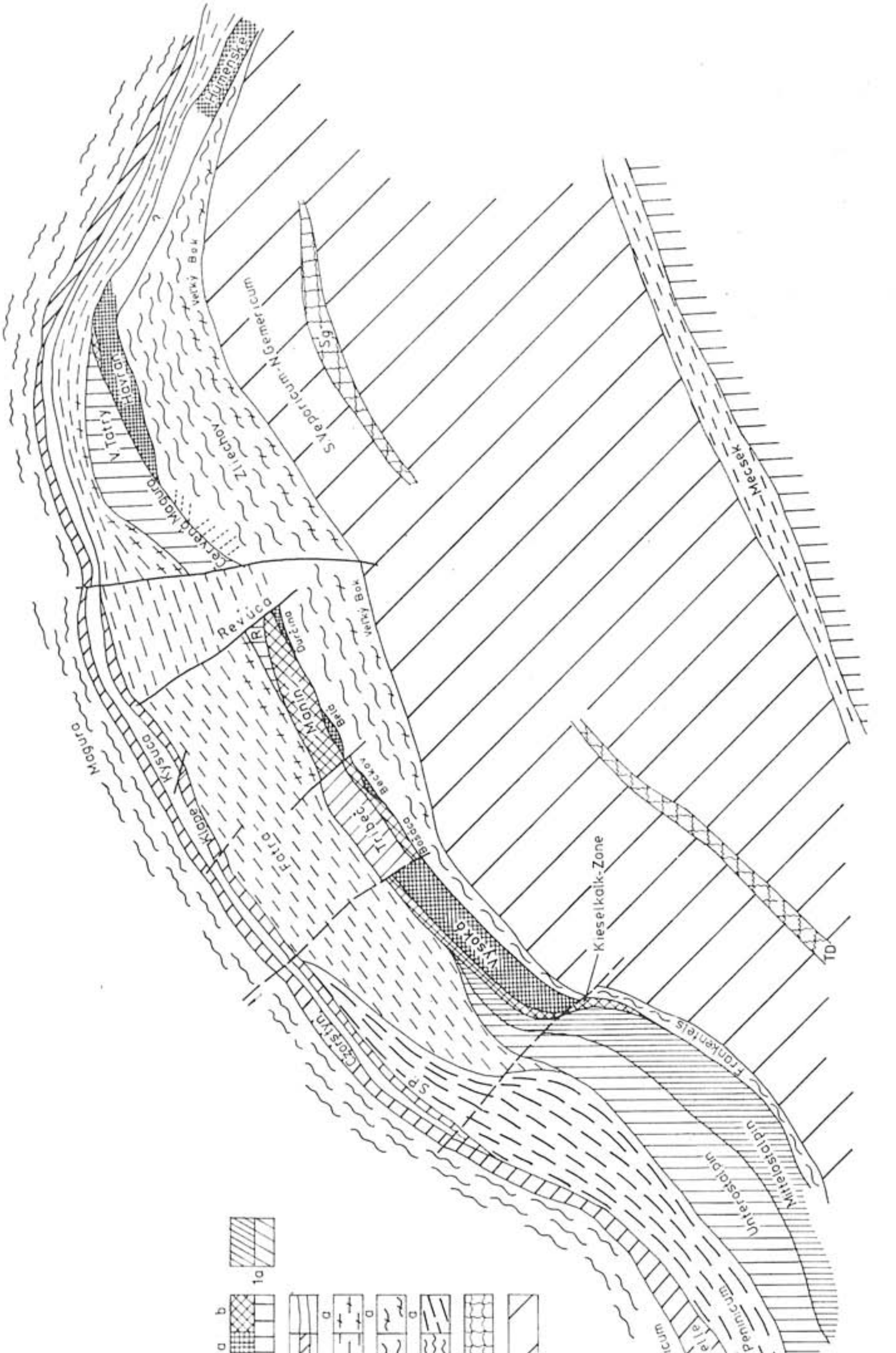
On the whole it may be said that in the Jurassic and Lower Cretaceous the High Tatric group is of distinctly more shallow — water character, without the presence of deeper-water facies, which occur partly in the Dogger, partly in the Malm and Lower Neocomian in the Manín unit. The High Tatric group displays a different relation to the Rhaetian, characterized by terrestrial-lagoonar argillites and sandstones to quartzites. On the contrary, the Manín Liassic develops from the Rhaetian, marked by organogenic lumachelle limestones with association of fauna typical of the Krížna unit with Rhaetina gregaria, Avicula contorta, Placunopsis alpina, Lopha haidingeriana etc.

In general, however, the High Tatric and Manín groups belong to the group of series with several shallow-sea facies of the Jurassic and Lower Cretaceous, ranged by M. M a h e ľ (1959) to the series formed on the intraoceanic ridge, to the so called West Carpathian group of series. From the envelope series belong here the Tríbeč group, Raztočná group in the Žiar Mts., of Červená Magura (including the Donovaly group) in the Low Tatra. It is remarkable that just with these series the Manín group has most analogous facies, equally as with the northern development of the Vysoká group in the Malé Karpaty Mts. To this "relationship" also belong other Vysoká-type series of the Krížna nappe: the Beckov group in the Považský Inovec Mts., Belá group in the Strážovská hornatina Mts., Ďurčiná group in the Malá Fatra, the subordinate nappe of Havran in the Belanské Tatry (including the Ružbachy island) and the Humenné group. In the attached table (Tab. 1) we tried to show the accordances and differences in development of the individual Jurassic and Lower Cretaceous members of the Manín and all the named groups.

For solving genetic relation of the Manín unit, comparison with geotectonically analogous series occurring as lower structural elements of the Krížna nappe, mainly at not great distance from the Manín unit, is of particular importance. This concerns mainly the Belá, Ďurčina, Beckov but also the Vysoká group (mainly because in some regards a type series is concerned).

Fig. 6 Paleogeographical sketch-map of the Inner West Carpathians in the Jurassic and Lower Cretaceous and linking to the Eastern Alps

Explantation: 1. West-Carpathian ridge, later tectonically re-formed: A. into nappes: a) of Vysoká group, b) Manín nappe, B. into Tatride units, mostly parautochthonous; la. Western continuation of the West-Carpathian ridge into the Eastern Alps: A Mittelostalpin, B. Unterostalpin; 2. Cordillers of the Klippen Belt island zone: a) accompanying trench; 3. Troughs with thick continental crust: a) its marginal near—ridge part; 4. Trough with thinner continental (suboceanic) crust: a) its near—margin part; 5. Trough with oceanic crust, a) with thin suboceanic to oceanic crust; 6. Depressions on the intreaoceanic margin: SG — South-Gemeride, TD — Transdanubian; 7. Intraoceanic margins.


Humenské
V. Tatry
Havran
Červená Magura
Zliechov
Veľký Bok
S.Veporicum-N.Gemericum
Sg
Mecsek
Revúca
R
Ďurčina
Manín
Biela
Magura
Kysuca
Klape
Fatra
Tribeč
Beckov
Bošáca
Vysoká
Kieselkalk-Zone
TD
Frankenfels
Czorsztyn
S.P.
Unterostalpin
Mittelostalpin
N Peninicum
Penin.-Swelle
S. Peninicum
1 A B a b 1a
2 a
3 a
4 a
5 a
6
7

In all the series the Liassic develops gradually from marine Rhaetian facies; it is shallow-water with a relatively high portion of clastic admixture, unequally distributed. Most clastic admixture displays the Manín unit where sandy crinoidal limestones are the fundamental component. A case similar to it is the northern area of the Vysoká unit. This group displays greatest variations of clastic admixtures in the Liassic. In all the series clastic admixture is relatively variegated with prevalence of weaker worked up quartz grains and fragments of older limestones. The predominating Liassic microfacies are the crinoidal and sponge ones, abundant are lumachelles of lamellibranchs and brachiopods; gryphea lumachelles are, however, typical of the Manín group only. Characteristic of the Dogger are facies of radiolarian limestones, red nodular limestones but rare are also crinoidal biosparites. All the facies of different bathymetry are represented in the Manín and Vysoká groups; in the Ďurčina and Belá groups the shallow-water facies of crinoidal limestones is known only. A contrastness of facies is characteristic of the Vysoká and partly of the Manín unit also in the Malm represented by radiolarian limestones, pink or light-coloured limestones of globochaete–sacocoma microfacies. Representation of a relatively more shallow-water facies display mainly the Beckov, Belá and Ďurčina groups. In the most series the Tithonian and Lower Neocomian display a more deep-water character of Biancone type with calpionels, more marly cherty limestones with nannocones in the upper layers. A more shallow-water character display the Beckov and Belá groups. Characteristic of the Barremian–Aptian are organodetrital limestones, especially typical of the Manín and Belá units. In the Ďurčiná group this member is unknown, in the Vysoká group it displays a less shallow-water facies. The Albian-Cenomanian is characterized by flysch development, getting more variegated in the Manín unit due to the facies of variegated marls following after a hiatus in the Albian. Remarkable is the presence of organodetrital limestones in the Albian of the Manín, Belá and Vysoká groups.

When comparing the Jurassic and Lower-to Middle Cretaceous members of the Manín unit with the High Tatric, Vysoká, Belá and Ďurčiná but also with further previously mentioned groups with several Jurassic and Lower Cretaceous shallow-water facies, we come to the conclusion that though each of them has a series of particularities in development of some members, however, there are many accordances between them, indicating a nearly equal geotectonic character – of dissected intraoceanic ridge. They represent one group different in the stratigraphic succession from the deep-water Zliechov type, also from the Fatra type. In a series of facies more deep-water as radiolarian limestones, Biancone-type limestones, nannocone marly limestones, Albian-Cenomanian flysch sequence, they are nearer to these sequences. They have obviously formed in vicinity to troughs, on slopes of the ridge where bathymetric conditions changed distinctly in the Jurassic and Lower Cretaceous.

The palinspastic conception of the Carpathian geosyncline, based upon present-day distribution of the mentioned "cordiller" series and upon their relations leads us to the idea of the existence of a wide ridge in the Jurassic and Lower Cretaceous situated between the northern Fatra basin and southern Zliechov trough (see Fig. 6).

Lacking series of cordiller type in the Veľká Fatra and Malá Fatra (with exception of the westernmost end of the Ďurčiná group) and close facial relationship of the Malá Fatra and Veľká Fatra groups to the Zliechov group on the other

hand lead to the conception of interruption of the ridge by a transversal depression. I designate it as the Revúca depression-dividing it into the western or Zobor (new name) and eastern Tatra part.

In ridge-type series characteristic is not only the variety of content of series but also diversity of the structural position of tectonic units formed from this ridge by Paleoalpine folding. The essential part of the ridge was tectonically incorporated as part of the Krížna nappe as follows:

a) its frontal slices: the Manín unit in the Klippen Belt

b) lower slices moved near to the nappe fronts: the Ďurčiná group, essential part of the Central-Carpathian part of the Manín unit

c) lower subordinate nappe of the Krížna unit (Havran nappe)

d) lower subordinate slices, partly lower digitations of the Krížna nappe, distributed on the Mesozoic envelope of the near crystalline core: Beckov and mainly Belá groups

e) essential parts of the Krížna nappe — Vysoká, Humenné groups.

A part of the ridge, mainly some of its segments remained in the position of more or less autochthonous envelope units:

a) as parautochthonous slices; the essential part of the Tríbeč, Ráztočna (?), Červená Magura, the essential part of the High Tatric unit (mainly the folds of Giewont and Červené vrchy but also other slices); b) relatively autochthonous units: part of the High Tatric and part of the Tríbeč unit.

Translated by J. Pevný

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Review by M. Mišík Manuscript received March 17, 1978