JÁN VEIZER*

CONTRIBUTION TO TECTOGENESIS AND OROGENESIS OF THE SLOVAK PART OF THE HIGH TATRA MANTLE SERIES

(Figs. 1–9)

Abstract: According to the opinion of the author tectonic structures of the Mantle Series of the High Tatra are conditioned by tangential pressures as consequence of compression of the geosynclinal zone of the West Carpathians. The influence of gravitational sliding on formation of tectonic structure is of a second-order character only.

In the studied region we may distinguish two types of tectonic structures:

1. Lower tectonic structures, formed mainly by carbonate members of Mesozoic succession, characterized by the so called superficial tectonic style;

2. Higher tectonic structures, at which with culmination of compression also were thrust the underlying crystalline and detritic basal Mesozoic members upon the above mentioned structures with the superficial tectonic style. This is the development of the so called induced tectonic style.

The tectonic style of the mentioned region is identical with the tectonic style of miogeosynclinal ridges in the sense of J. Aubouin's classification (1965).

Резюме: По мнению автора тектонические структуры серий плаща Высоких Татр обусловлены тангенциальными давлениями как результат компрессии геосинклинальной зоны Западных Карпат. Влияние гравитационного сдвижения на образование тектонических структур имеет второстепенный характер.

В исследованном районе можно выделить два типа тектонических структур:

1. Нижные тектонические структуры образуемые главным образом карбонатными членами мезозойских слоев, которые отличаются так называемым поверхностным стилем тектоники.

2. Высшие тектонические структуры у которых одновременно с кульминацией компрессии происходит передвижение лежащего в основании кристаллиникума и детритических основных членов мезозоя в направлении к прежде упомянутым структурам с поверхностным стилем тектоники. Тектонический стиль привозимой здесь области согласуется с тектоническим стилем миогеосинклинальных валов в смысле классификации Й. Аубоуина (1965).

INTRODUCTION

The region of the High Tatras has been a subject of intensive study since the beginning of geological investigation of the West Carpathians. This region has served since the beginning for detailed treating of stratigraphy and geology as examining area for interpretation of various theories on the Carpathians. The first significant tectonic synthesis was presented by V. Uhlig (1897, 1900). His map and profiles served to M. Lugeon (1903) to propose the existence of nappes in the Carpathians. In later period an attempt was made to interprete tectonics of this region in the sense of the theory of gravitational sliding (B. Halicki 1955, Z. Kotański 1961) which provoked strong critism on the side of Slovak geologists, especially D. Andrusov (1959) and A. Gorek, J. Veizer (1965).

*RNDr. J. Veizer, C. Sc., Geological Institute of the Slovak Academy of Sciences, Bratislava, Štefánikova ul. 41.

A. Michalik (1955, 1956) supposed non-autochthonous character of almost the whole Mantle Series. The majority of other authors, however, hold the opinion that the Mantle Series of the High Tatra is in its essential part an autochthonous unit resting upon the crystalline of the High Tatra core. In spite of that the question of autochthonous character of the core units as a whole remains an open one.

It is not the aim of this paper to deal with detailed survey of opinions of many older authors. The most important opinions are mentioned in description of the individual areas and treated in detail in the work by Z. Kotański (1961). Stratigraphy and geology of the Mantle Series is treated in detail by Z. Kotański (1961) and J. Veizer (1968).

In spite of intensive geological study of the mentioned region many problems remain still unsolved or only partly solved. One of the most important problems is to solve the character of Alpine tectonics in the crystalline core of the massif of the High Tatra and its reflection in formation of Alpine structures in the sedimentary envelope and complete solution of problems of fine tectonic analysis.

This paper tries to summarize the results reached in the study of the Mantle Series of the High Tatra (fig. 1) until the end of the 1967 year.

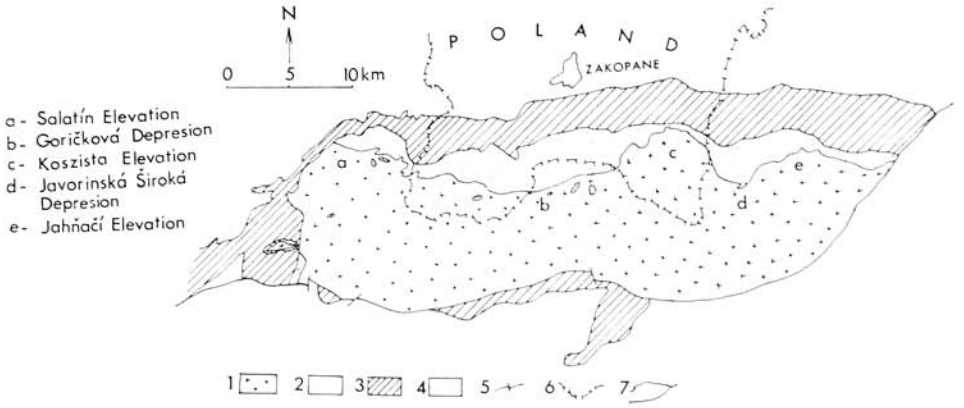

Fig. 1. General Tectonic Map of the High Tatra (topographic Plan — Geological Map of Czechoslovakia 1 : 200 000). Explanations: 1 — Crystalline core of the High Tatra massif, 2 — Mantle Series, 3 — Thrust Subtatric units, 4 — Central Paleogene, 5 — Faults, 6 — State frontier, 7 — Orographic demarcation of the High Tatra.

A. TECTOGENESIS AND OROGENESIS-DESCRIPTIVE PART

1. The Area of Sokol and Mnich

In the mentioned area the group of slices of Malmian—Neocomian (—Urgonian) or also Albian (—Lower Turonian) occurs in normal stratigraphic position. They are directly underlain by the crystalline, on which they were thrust together with the overlying Mesozoic of the Subtatric nappes.

The complex of the Albian-Cenomanian (—Lower Turonian) in the area of Sokol has been known since the time of V. Uhlig (1900), who supposed it to be found in the rock underlying the limestone complex of the Malmian—Urgonian. Since that period the

sequence of strata in the mentioned area has been considered as reversed (cf. also A. Gorek 1953, F. Rabowski 1925, D. Andrusov 1959a, b).

The sequence of the Albian—Cenomanian (—Lower Turonian) found in the complex underlying the Malmian—Urgonian of the complex of Sokol and Mnich is also overlying the Malmian—Urgonian of the complex of the Bobrovec quarry (fig. 2). Both complexes of Malmian—Urgonian show normal stratigraphic sequences, confirmed by mikrofacial study. The Albian—Cenomanian (—Lower Turonian), which on the basis of the above

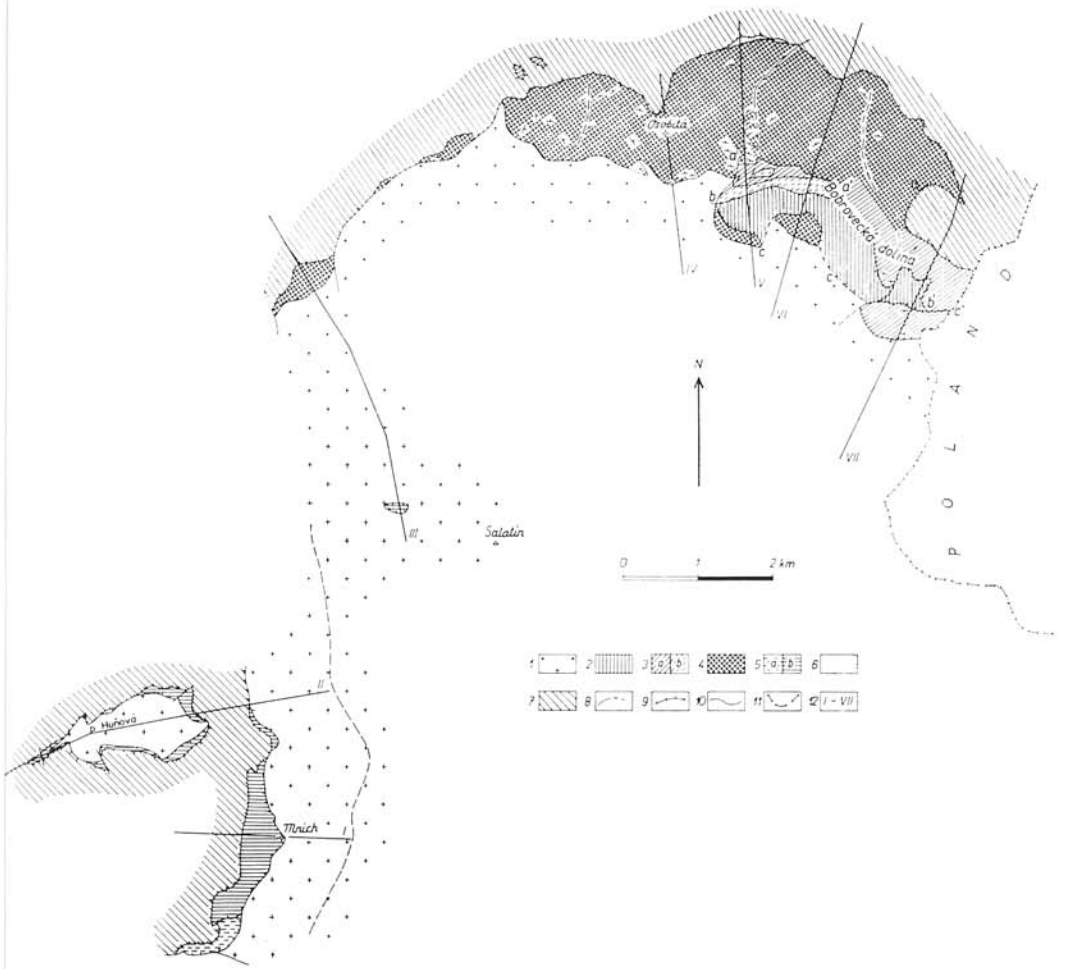

Fig. 2. Tectonic Map of the Western Part of the Mantle Series of the High Tatra. Explanations: 1 — Crystalline core of the High Tatra massif, 2 — Southern tectonic slice of the crystalline, 3a — Northern tectonic slice — crystalline, 3b — Northern tectonic slice — Lower Triassic, 4 — Mantle Series in autochthonous position, 5a — Tectonic slice of the Bobrovec Fault, 5b — Tectonic slices of Sokol-Mnich, the Huňová Brook and Salatín, 6 — Tectonic slice of Mihuľčí, 7 — Thrust Subtatric units or central Paleogene), 8 — Faults, 9 — Thrust lines, 10 — Boundaries of tectonic units, 11 — State frontier, 12 — Profile lines.

interpretation should underlie both Malmian-Urgonian complexes, was not encountered in boreholes below the lower (Bobrovec Quarry) comple (V. Kráľ 1961).

For these reasons it seems probable that there are two tectonic slices in normal stratigraphic sequences thrust on one another.

2. *The Area of the Huňová Brook*

This area was treated first by A. Gorek (1950) and Z. Ševček (1961). Its interpretation was similar as that of the above mentioned area.

There is again a tectonic slice formed by the Malmian—Neocomian (—Urgonian) and Albian—Cenomanian (—Lower Turonian). The boundary between these complexes is of tectonic character along a fault line dipping 45° WSW (cf. also Z. Ševček 1961). Along this fault line the Albian—Cenomanian (—Lower Turonian) complex is thrust at a short distance over the Malmian—Neocomian (—Urgonian) as it is to been seen in figs. 2 and 5. Also in this case there is probably a normal and not reversed sequence.

3. *Salatín Tectonic Slice*

It is a tectonic slice of the Malmian, of a character similar to that in the above described areas, already known to W. Kuzniar (in B. Swiderski 1922), A. Gorek (1953) a Š. Kahan (1961) — fig. 2 and 5.

The tectonic style of these areas may be generally characterized as tectonic slices with normal stratigraphic sequence thrust on the crystalline together with the overlying Subtatric nappes (Krížna—nappe).

The Jalovec Valley is probably founded on a zone predisposed tectonically (fault) of nearly N—S direction (similar opinion is also held by Š. Kahan — personal communication), a consequence of what is also various altitude of the base of the Mesozoic on the Salatín (1850 m) and in the group of Mních (1500 m).

4. *Area of Osobitá and the Bobrovec Valley*

This area has been subject of study by several authors. V. Uhlig (1897) and S. Kreutz (1913) accepted in essentials the opinion of the monoclinal structure of the Mantle Series. F. Rabowski (1930) supposed the complex overlying the limburgites to be a part of the thrust units. After the works by D. Andrusov (1931 and 1932) have been published however. F. Rabowski (1933) came back to original interpretation, already presented by V. Uhlig (1897). A. Michalík (1955) expressed the opinion that in the area of the valley of Látaná dolina Lower Triassic quartzites are plunging below the crystalline (correct observation) and concluded thrusting of the whole Mantle Series of this area on a lower unit. Z. Kotański (1961) came back to monoclinal autochthonous interpretation of the Mesozoic of the Mantle Series.

In this area strata show prevailingly northerly monoclinal dipping (NW—NE). Tectonic complications are in the area southerly of the Bobrovec Valley and Osobitá, where the crystalline together with Lower Triassic complexes is forming several wedges (fig. 2 and 6). Along the line a—á the crystalline is probably thrust on Lower Triassic quartzites and quartzitic sandstones to the north at a shorth distance, as plunging of quartzites to the south below the crystalline would indicate (fig. 6). For similar reason further thrusting of the crystalline along the line b-b′ and also backward thrusting of

the crystalline on quartzites, quartzitic. In the case of the line c—c' we have essentially a line along which, A. Michalik (1955) supposed thrusting of larger part of the Mantle Series on lower tectonic unit. Tectonic complications of this area have been so far interpreted as a steed infolded synclines (D. Andrusov 1959b, Z. Kotański 1961), however, on the basis of a very undetailed geological map. More complicated character of the tectonic structure than that presented here cannot be excluded and more marked progress can be reached with detailed mapping and application of other geological investigation methods only. The mentioned tectonic complications can reflect deep-seated tectonic style and represent western continuation of the line of Javorinská Široká—Stoly—Kominy Tylkowe (A. Gorek, J. Veizer 1965).

Northeasterly of the Osobitá (Mihulčie) a tectonic slice of the Liassic—Doggerian—Malmian with reversed sequence of strata occurs in the rocks underlying the Subtatric nappes, already known to D. Andrusov (1959b) — cf. figures 2 and 6.

The slices of the „Urgonian" NW of the Osobitá, mapped by A. Medvecký (1962) in rocks overlying the Albian—Cenomanian (—Lower Turonian) of the Mantle Series and underlying dolomites of the Choč nappe are probably equivalent to the Reifling Limestone and form a part of stratigraphic sequence of the Choč nappe. They are light-coloured, slightly marly limestones with marly nodules while the Urgonian of the Mantle Series is present in the form of fine-grained, frequently crinoidal limestones with proper cherts in this area. The dolomites of the Choč nappe in the area of Osobitá would then correspond to the „Choč" Dolomites only.

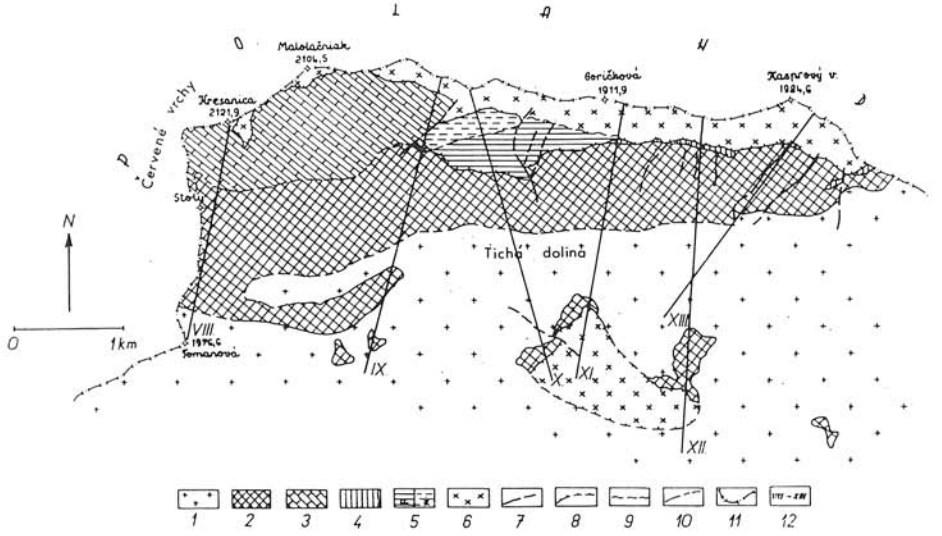

Fig. 3. Tectonic Map of the Central Part of the Mantle Series of the High Tatra. Explanations: 1 — Crystalline core of the High Tatra massif, 2 — Mantle Series in autochthonous position, 3 — Overturned limb of the fold of Stoly, 4 — Zdziary unit, 5a — Tectonic slice of Javor — crystalline, 5b — Tectonic slice of Javor — Lower Triassic, 6 — Crystalline of Giewont unit, 7 — Faults, 8 — Thrust lines, 9 — Mylonite zones, 10 — Boundaries of tectonic units, 11 — State frontier, 12 — Lines of tectonic profiles.

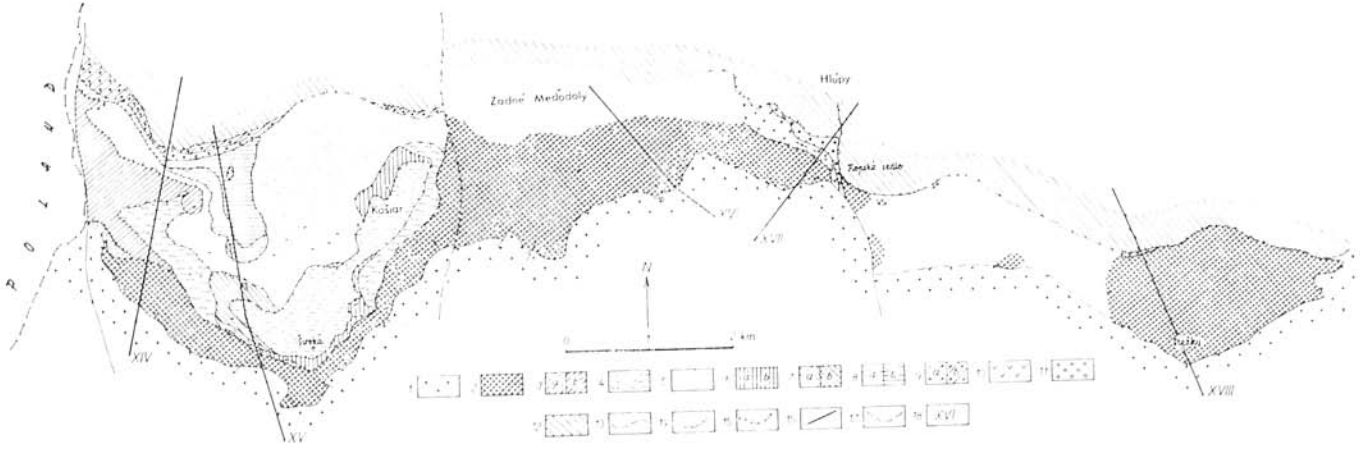

Fig. 4. Tectonic Map of the Eastern Part of the Mantle Series of the High Tatra. Explanations: 1 — Crystalline core of the High Tatra massif, 2 — Tectonic unit I (autochthonous) in the group of Javorinská Široká, 3 — Tectonic unit Ia (thrust backward) in the massif of Javorinská Široká, a — crystalline, b — Mesozoic, 4 — Tectonic unit II in the massif of Javorinská Široká, 5 — Tectonic unit III in the massif of Javorinská Široká, 6 — Tectonic unit IV in the massif of Javorinská Široká, a — crystalline, b — Lower Triassic, 8 — Tectonic unit VI in the massif of Javorinská Široká, a — crystalline, b — Lower Triassic, 7 — Tectonic unit V in the massif of Javorinská Široká, a — crystalline, b — Lower Triassic, 9 — Tectonic unit VII in the massif of Javorinská Široká, a — crystalline, b — Lower Triassic, 10 — Lower tectonic slice on the saddle of Kopské sedlo, 11 — Higher tectonic slice on the saddle of Kopské sedlo and N of Stežky, 12 — Thrust Subtatric units, 13 — Faults, 14 — Thrust lines, 15 — State frontier, 16 — Boundaries of tectonic units, 17 — Diaphtorites, 18 — Lines of tectonic profiles.

5. *Area of Červené vrchy and Tichá dolina Valley*

This area was studied first more in detail by V. Uhlig (1897 and 1900), who also compiled the first geological map of it. On the basis of this map and profiles M. Lugeon (1903) compiled profiles, in which he applied knowledge of the theory of nappes, first time in the West Carpathians. In the next period they were the works by M. Limanowski (1911) and mainly by F. Rabowski (1925, 1938, 1959), in which opinions of the tectonic structure of this area were developed. Tectonic structures of this part were explained as recumbent folds (the fold of the Červené vrchy and Giewont). Among later works it is that by A. Michalik (1955), in which this author supposed two tectonic structures of the Mantle Series in the area of the saddle of Ľaliové sedlo. A. Gorek (1958) interpreted the tectonic structure in the sense of F. Rabowski. New information, partly leading to modification of the opinions of the tectonic structure of this area, was mainly provided from the works by Z. Kotański (1961, 1963), discussed nearer in the next part. Substantiation of this division see e. g. in Z. Kotański (1961, 1963).

On the Slovak territory only apical parts of the tectonic structures are found, with

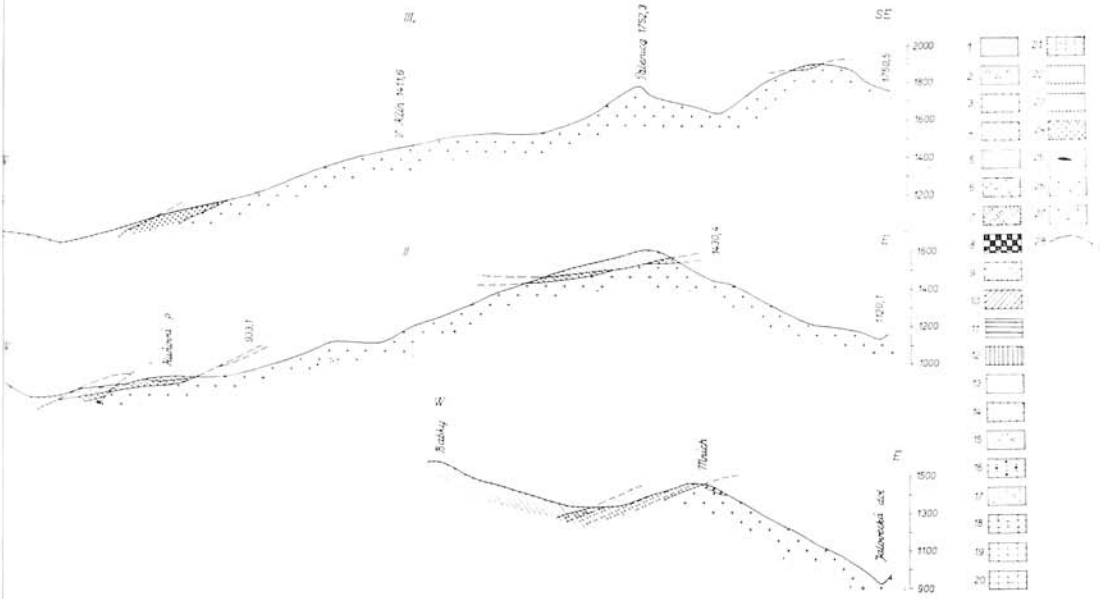

Fig. 5. Tectonic Profiles through the Western Part of the Mantle Series of the High Tatra. Explanations (for figs. 5—9): 1 — Quarternary, 2 — Quarternary — Rock Block Fields, 3 — Paleogene, 4 — Subtatric nappes, 5 — Albian-Lower Turonian, 6 — Barremian-Aptian (=Urgonian), 7 — (Neocomian)—Barremian—Aptian, 8 — Limburgites, 9 — Malm—Neocomian or Malmian in the Osobitá and Bobrovecká Valley Regions, 10 — Basal Malmian?, 11 — Bathonian, 12 — Bajocian, 13 — Liassic, 14 — Upper Rhaetian—Hettangian, 15 — Rhaetian (Tomanová Beds), 16 — Lower Anisian or Carnian—Norian in the Javorinská Široká Region, 17 — Carnian-Norian, 18 — Ladinian, 19 — Anisian, 20 — „Myophoria" Beds and Lower Anisian in the Javorinská Široká Region, 21 — „Myophoria" Beds, 22 — Cavernous „Dolomites", 23 — Werfenian „Shales", 24 — Lower Triassic „Quartzites", 25 — Permian, 26 — Allochthonous Crystalline, 27 — Autochthonous Crystalline, 28 — Faults.

main developments northerly of the boundary ridge in the Polish part of the Tatra. The following tectonic structures (units) may be generally distinguished there — figs. 3, 7 and 8.

a) Autochthonous series with prevailingly monoclinal dip to the north. Southerly of the mount of Kasprový vrch and the saddle of Łaliové sedlo this series is refolded together with the Mesozoic of the Červené vrchy—Zdziary unit (P. Reichwalder 1964).

b) Westerly in the group of Červené vrchy autochthonous Mesozoics is upright and forms a folded structure, considered as synclinal closure of the fold of Červené vrchy in its original conception by older authors (F. Rabowski 1959, A. Gorek 1958, D. Andrusov 1959b and others). In more recent literature this tectonic structure is termed as the fold of Stoły (Z. Kotański 1961, 1963, J. Veizer 1964, A. Gorek, J. Veizer 1965).

c) In the central part a slice of the crystalline and the Lower Triassic is found in normal stratigraphic position, wedged in between the Mesozoics of the autochthonous series and the crystalline of the Giewont unit. In older interpretations it was considered as the crystalline core of the fold of Červené vrchy (F. Rabowski 1925, 1959, A. Gorek 1958, D. Andrusov 1959b and others). According to present conception

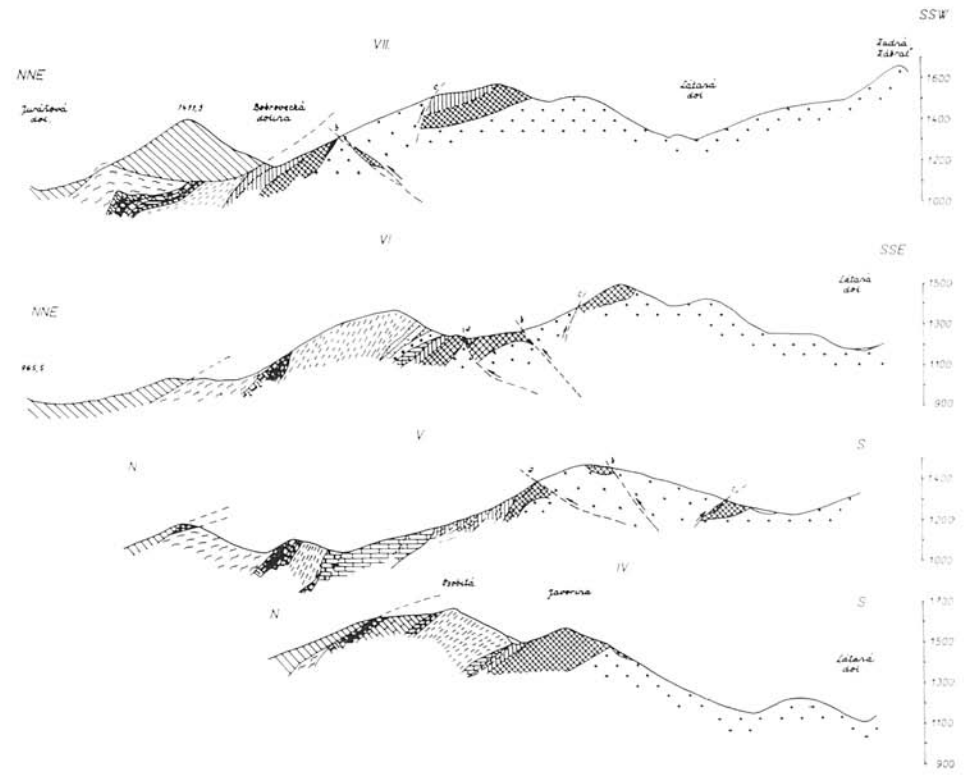

Fig. 6. Tectonic Profiles through the NW Part of the Mantle Series of the High Tatra. Explanations — see fig. 5.

it forms an independent tectonic structure termed as the slice of Javor (J. Veizer 1964).

d) Slices of the Middle Triassic and sporadically of the Urgonian in normal strati-

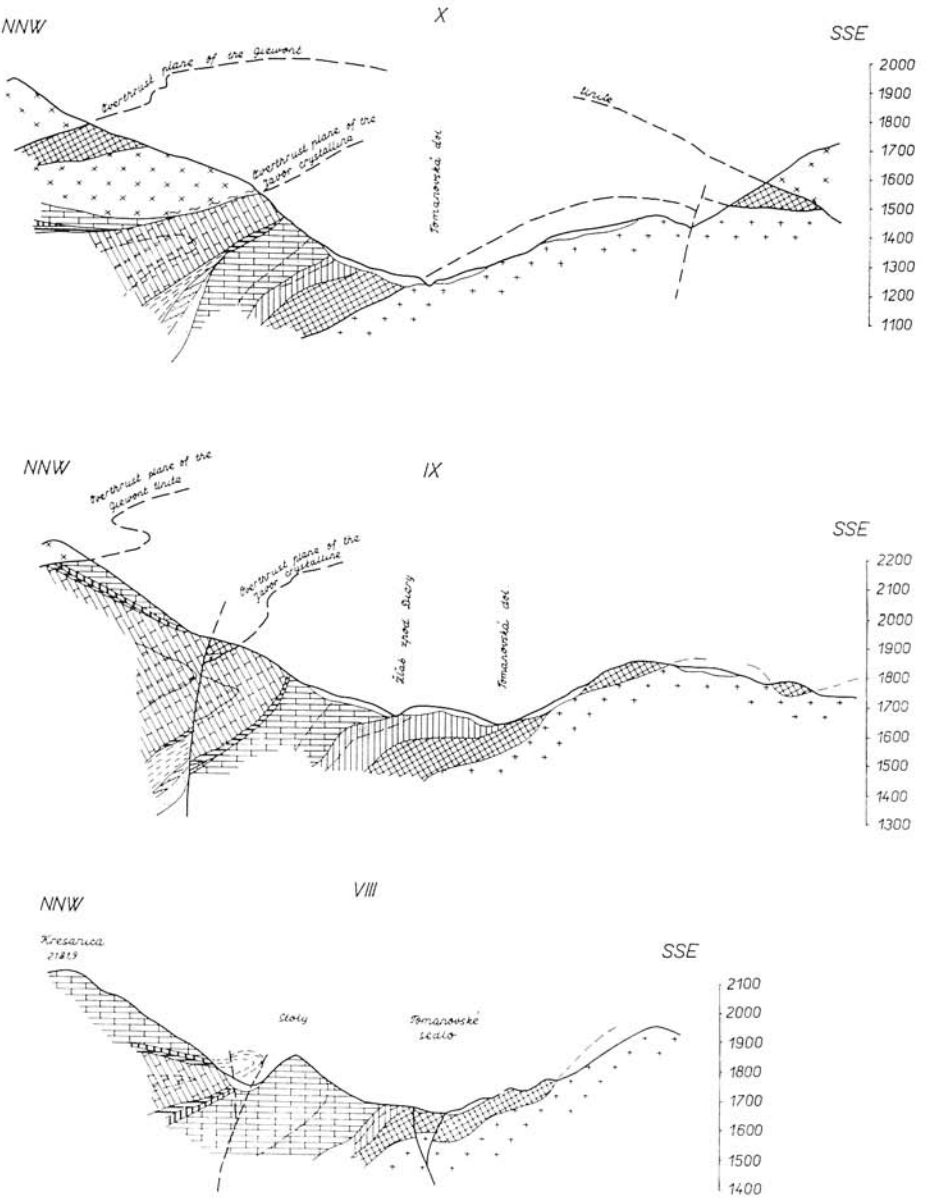

Fig. 7. Tectonic Profiles through the Area of Červené vrchy. Explanations: as fig. 5, in profile X the SSE part is interpreted according to P. Reichwalder (1964).

graphic sequence wedged in between the autochthonous Mesozoic and the crystalline of the Giewont unit on the northern slope of the Tichá dolina Valley. They were considered as the middle dragged out limb of the of Červené vrchy (F. Rabowski l. c., A. Gorecki l. c., D. Andrusov l. c. etc.). In present interpretation they are termed as the Mesozoic of the Zdziary unit (Z. Kotański 1961, 1963).

c) Crystalline of the Giewont unit. This crystalline forms the ridge on the Polish

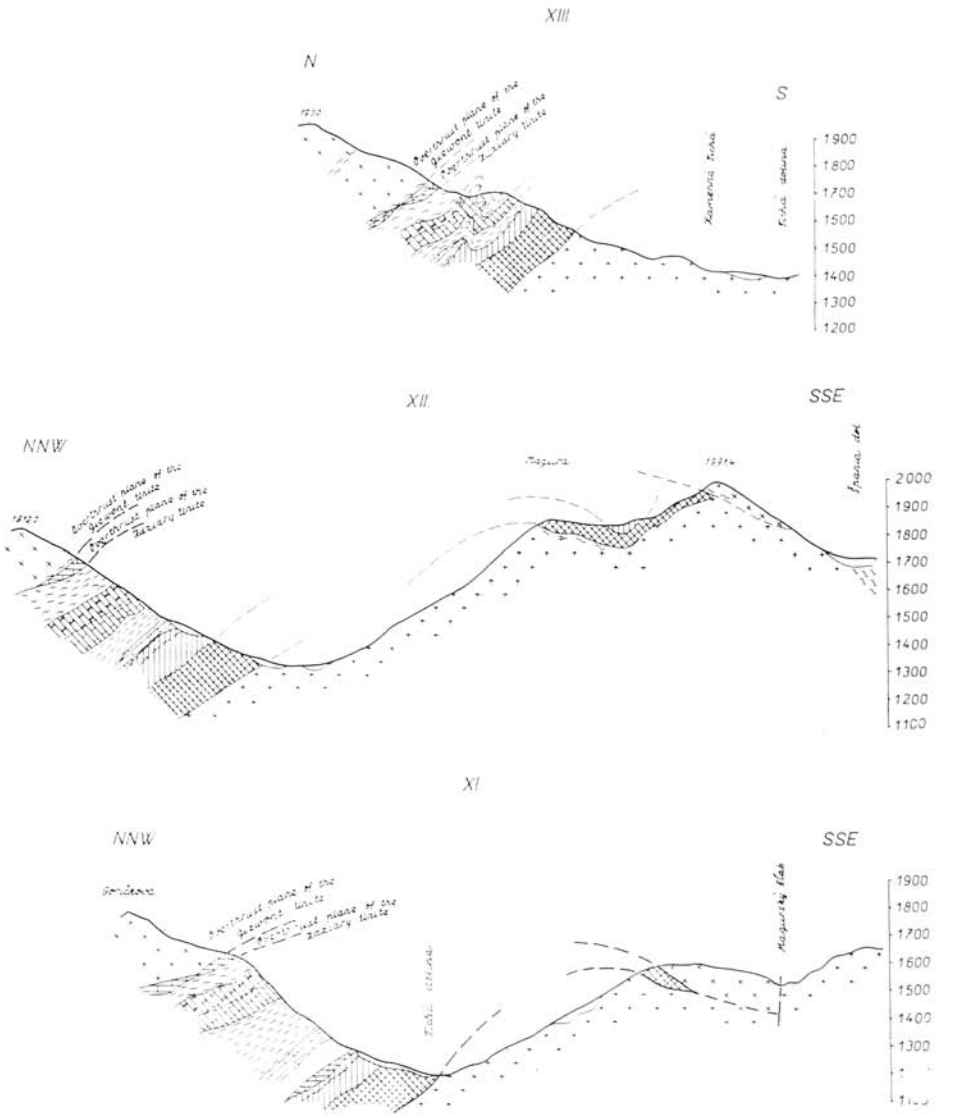

Fig. 8. Tectonic Profiles through the Area of Tichá dolina Valley. Explanations: as fig. 5. The SSE part of profiles XI and XII and the whole profile XIII are interpreted according to P. Reichwalder (1964).

boundary and the slice in the group of Veľká Kopa, where it is thrust on the Lower Triassic (Z. Kotański 1961, F. Reichwalder 1964).

Since this is a classical area, terms of which are used very frequently, certain clarification and parallelization of older and newer terms is necessary.

In the new conception these tectonic structures may be distinguished according to their superposition:

a) Autochthonous series

b) Zdziary unit (= anticlinal part of the fold of Červené vrchy).

c) Fold of Stoly (= synclinal part of the fold of Červené vrchy).

d) Tectonic slice of Javor (= crystalline core and quartzites of the Lower Triassic ranged to the upper limb of the anticlinal part of the fold of Červené vrchy).

e) Crystalline unit of the Giewont (= core of the fold of Giewont).

Changes in teminology are mainly concerning the previous fold of Červené vrchy s. l. which was considered as the fold with reduced middle limb (mainly by F. Rabowski 1925, 1959, M. Limanowski 1911, A. Gorek 1958, D. Andrusov 1959b and others). According to the new conception these are independent tectonic structures of the type of thrusts of the Mesozoics together with the underlying crystalline on a shorter distance (A. Gorek, J. Veizer 1965), with the Mesozoics being folded into frontal parts of such structures.

6. *Area of Javorinská Široká*

This area was already treated by V. Uhlig (1900), S. Sokołowski (in J. Nowak 1929), F. Rabowski (1939), D. Andrusov (1950) and Z. Kotański (1961). All up to present authors, with partial exception of the latter, considered tectonics of this area as typical example of folded structures. The most complete and profound study about the tectonic structure of this area is the work by D. Andrusov (1950). The fundamental division presented by D. Andrusov is to a considerable degree also kept in this paper.

Some facts, however rather suggest thrusts of small extent (several km) and not to folded structures. To a certain degree there is an analogy to the tectonic structure of the area of the Červené vrchy. Such an interpretation is substantiated by systematic „dragging out" of the overturned limbs of folds with the exception of unit III (cf. following paragraph), the great portion of the crystalline mainly in the structure of higher units and the existence of a large mumber of tectonic slices.

In this area following tectonic units were distinguished (fig. 4 and 9):

Unit I (autochthonous): forms the lowest tectonic structure, composed of Lower and Middle Triassic strata or also Malmian in normal sequence with monoclinal dip to the north, (NW—NE). Below the Zámky the Middle Triassic strata are upright and form a small synclinal closure (photograph in D. Andrusov 1950).

Unit Ia (subautochthonous): the continuation of the autochthonous unit to the north but thrust backward on it. This phenomenon in the valley of Biela voda was already observed by D. Andrusov (1950). This backward thrusting is within the order of 100 m only. The unit includes more complete stratigraphic sequence with the Liassic and reduced Middle Triassic. This tectonic structure was probably predisposed by a zone of tectonic weakness, which already during the Late Triassic and Liassic periods dissected the sedimentary basin and caused the diversification of the facial development (J. Veizer 1968).

Unit II: formed by Middle Triassic—Urgonian complex in normal sequence of strata,

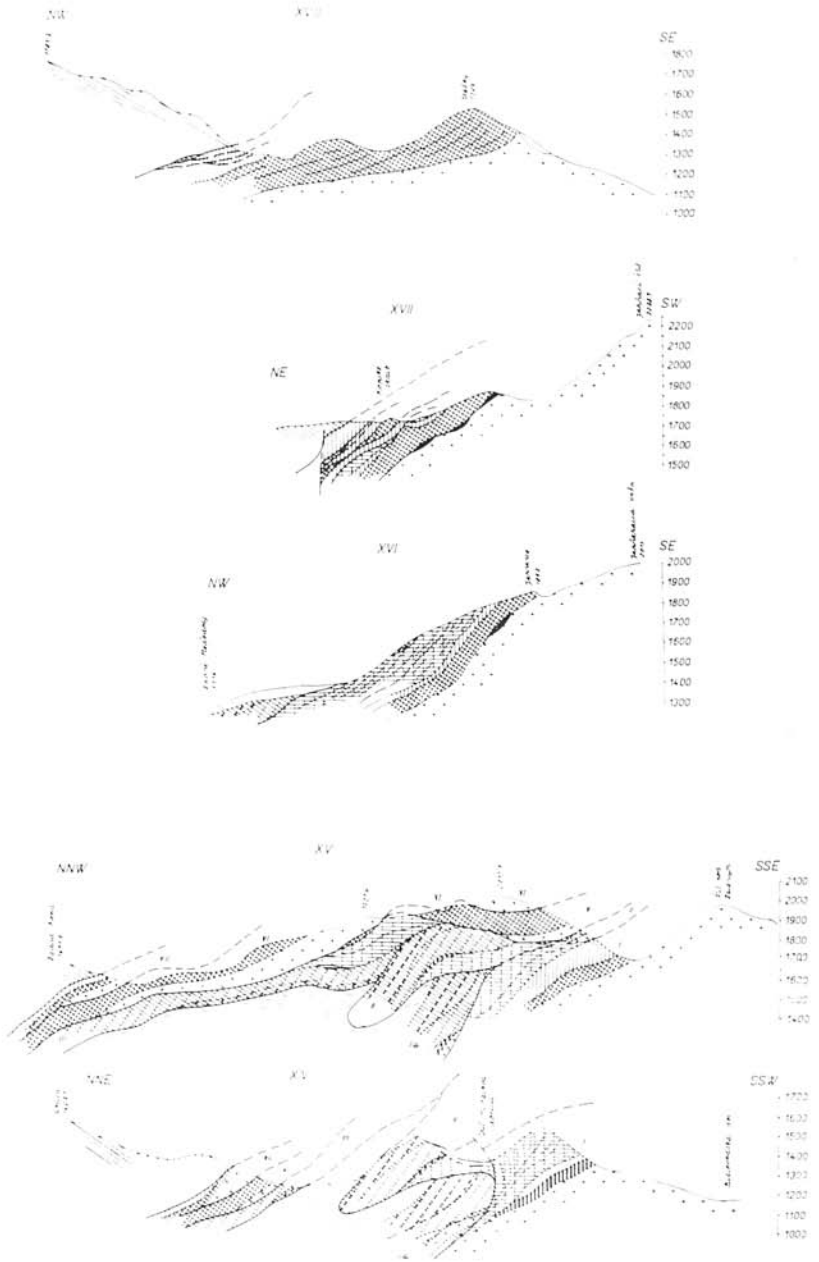

Fig. 9. Tectonic Profiles through the Eastern Part of the Mantle Series of the High Tatra. Explanations: as fig. 5.

Unit III: formed by Campilian to Urgonian complex in reversed sequence.

Unit IV: prevailingly formed by Lower Triassic quartzites with crystalline slice at the base.

Unit V: ditto.

Unit VI: forms the most distinct tectonic structure in the mentioned area. It is built up of the crystalline and Lower Triassic quartzites.

Unit VII: formed by slices of the crystalline, quartzites and Werfenian Shales or also Middle Triassic limestones. This unit forms the highest tectonic structure in the area of Javorinská Široká, directly underlying tectonically the Krížna nappe.

Units III—IV or II—VI mostly correspond to the fold of Červené vrchy and unit VII to the fold of Giewont according to older conception (cf. e. g. D. A n d r u s o v 1950).

In this area certain tectonic complications are evident in linking up and interpretation of the profiles through Zámky and the peak of Chorvátsky Štít with profiles from the Javorinská Široká and Košiar (fig. 9). In the latter case we may consider the Middle Triassic to Malmian—Urgonian above the valley of Javorová dolina also as autochthonous development. In this case however, difficulties appear in linking up this profile with the profiles westerly of the line Javorinská Široká—Košiar (cf. also Z. K o t a ň s k i 1961). For that reason interpretation mentioned in fig. 3 was chosen however, this question remains open, and more attention has to be paid to it in future.

7. Area of Zadná Medodolská dolina Valley as far as Stežky

The tectonic structure of this area was partly treated by V. U h l i g (1900) and more in essentials by S. S o k o l o w s k i (1948), D. A n d r u s o v 1959a, b) and Z. K o t a ň s k i (1961). The tectonic structure of the saddle of Kopské sedlo was mainly discussed in connection with randing of a part of the Werfenian complex to overthrust Subtatric units. All the above mentioned authors consider the main part of the Mantle Series of the High Tatra as autochthonous. A. M i c h a l i k (1956) held different opinion, considering the Medodol Beds as tectonites originated as a consequence of thrusting of the Mantle Series and thus he considered the Mantle Series as non-autochthonous unit. This opinion has not been confirmed by later works and the reasons of considering the Medodol Beds as cataclastites were mostly disproved convincingly by E. P a s s e n d o r f e r (1957) and M. T u r n a u - M o r a w s k a (1957).

The Mesozoic of the Mantle Series is in monoclinal position, dipping to the north, without greater tectonic complications (fig. 9). In the western area it is of indistinct basin-like structure. In the area of the saddle of Kopské sedlo two small tectonic slices with normal stratigraphic sequence are found in the part overlying tectonically the autochthonous series. The range of the lower slice is from basal „quartzites" up to Werfenian Myophoria Beds while the higher slice is formed by Werfenian variegated shales and cellular dolomites. It is possible that the higher slice already forms the base of the Havran partial nappe.

A slice of the Werfenian of similar character as the higher slice in the saddle Kopské sedlo is also found XXW od the Stežky. In this case it is also possible that this slice already belongs to the basal part of the Bujači partial nappe.

In evaluation of the tectonics and its character it is necessary mainly to notice plasticity and rigidity of the individual members of the stratigraphic sequence and to evaluate their importance for development of the tectonic style.

The most significant discontinuity plane is the boundary between the Werfenian Shales and carbonate complexes of the uppermost Campilian and Middle Triassic.

Although it is a very favourable detachment plane, it was manifested distinctly in the units of Zdziary and Organy (in the sense of Z. K o t a ń s k i 1961, 1963) and units II and III in the group of Javorinská Široká only. There is a conspicous big portion of the crystalline in the structure of many tectonic units, mainly higher ones, on the contrary. This leads to the conclusion of the double character of tectonics of thrust units in the Mantle Series.

a) In lower tectonic units (Organy, Zdziary unit in the area of Červené vrchy and unit II and III in the area of Javorinská Široká) detachment was taking place along the detachment plane at the boundary Werfenian Shales-Myophoria Beds.

b) In higher units (Giewont unit and Javor tectonic slice in the area of Červené vrchy, units IV, V, VI and VII in the area of Javorinská Široká and also probably tectonic complications S of the Osobitá and the valley of Bobrovecká dolina) the portion of crystalline has been playing a great rôle. There is, however, an essential difference between the Giewont unit with complete Mesozoic sequence and the other ones reaching up to the Lower od Middle Triassic only. The latter ones probably represent the „tegument" (M. G i g n o u x 1949) only, which may be a remnant after thrusting away of lower tectonic units, mentioned in case „a". In case „b" there is marked influence of basement tectonis as to formation of tectoinc style of Mesozoic sedimentary series.

Such an interpretation is also evidenced by the fact that the units of type „a" originally formed more external zones while tectonic units of type „b" with complete development of the Mesozoics (Giewont unit) formed more internal zones of the original area of sedimentation.

Conclusions

The underlying crystalline shows so called „compressional basement style" (J. A u b o u i n 1965) having manifested in a double way in the overlying sedimentary series (upper structure) at the time of compression of the area of the geosyncline:

a) In the initial period the sedimentary envelope of the external zone was defached and accumulated in the fore-land in the form of so called superficial „folds". This is so called „s u p e r f i c i a l s t y l e" (J. A u b o u i n 1965). There is free tectonic, without overloading from above, the „folds" are understood as platy bodies, folding of which was only proceeding in the frontal part of this „plate" in that period.

b) With higher intensity of compression in the time of termination of tectonogenic processes, thrusts, wedges or also fault-folds (units of type „b") originated or there was direct reflection of basement tectonics, i. e. origin of i n d u c e d s t y l e (J. A u b o u i n 1965). In that period probably fault lines played an important rôle in basement crystalline, as the detachment planes. This type of tectonics, mainly in its culminating stage, may be termed overloading tectonics.

In the fore-land in autochthonous and also thrust units of the Mesozoic of type „a" d i f f e r e n t i a l d e t a c h m e n t planes were forming at the boundary between complexes of various plasticity and mutual thrusting of the order of 10 metres and also of greater order was proceeding along these planes during this phase. Shifting is more distinct in units thrust than in autochthonous ones. Such planes are, for instance, the boundary of the Liassic and Malmian—Urgonian in the valley of Tichá dolina (fig. 8), the Middle Triassic and Doggerian—Urgonian in unit II on the Javorinská Široká (fig. 9), the Liassic and underlying stratigraphic horizons in the tectonic slice of Mihuľčí (or also Swierkuły) and others. Besides, the folding, mainly of the frontal parts of the previously overthrust units, continued.

A completely independent style is evident in the plastic Albian—Cenomanian (Lower

Turonian) complex, which forms a system of slices thrust repeatedly on each other, as it is the case in the area of the valley of Tichá doline or is crenulated and forms cores of synclines and filling of „deaf" positions in refolded more rigid members, mainly in their frontal part (cf. fig. 9).

Briefly summarizing the character of tectonics of the Mantle Series in the High Tatra, we may designate it as combination of superficial and induced style, conditioned by compressional basement style. The character of tectonics also confirms designation of the area of sedimentation of the Mantle Series as geosynclinal ridge of Brianconnais type (cf. J. Aubouin 1965).

B. GENETIC INTERPRETATION OF TECTONIC STRUCTURES

The opinions of the origin of the tectonic style of the Mantle Series in the High Tatra as also of the most of mountain ranges of Alpine type are varying between two theories of the origin of the above mentioned structures.

a) Theory of tangential compression initiated already by M. Lugeon (1903) and V. Uhlig (1907) and corroborated for the West Carpathians mainly by A. Matějka, D. Andrusov (1931) and D. Andrusov (1959a, b).

b) Theory of gravitational sliding, recently held by mainly B. Halicki (1955), Z. Kotański (1961) and H. Grabowska-Hakenberg (1962).

The last-mentioned theory can be relatively unambigously excluded in explanation of the origin of essential tectonic structures not only of the West Carpathians as a whole (e. g. D. Andrusov 1959b, M. Mišík 1966) but for several reasons (A. Gorek, J. Veizer 1965) also of the High Tatra alone. As the most important argument I consider the that gravitational sliding theory is not solving the problem of lower structure reduction but only supposes its vertical "undulation" in the form of geotumors and their migration from the internides towards the externides. With such an explanation we cannot expect greater rôle of the lower structure (crystalline) in formation of tectonic structures because of lacking detachment planes in this lower structure. In the High Tatra however, the contrary may be observed. Besides that in many mountain ranges of Alpine type with strong reduction of the lower structure, existing sedimentary series although reduced would largely exceed the extent of lower structure after unfolding. This does not exclude the possibility of gravitational sliding also in the High Tatra region but gravitational sliding is only considered as secondary factor while tangential pressure as primary factor.

The character of tectonic style, as mentioned above, unambigously indicates tangential forces as the decisive moment in its formation. An attempt of explanation of the origin of tectonic structures is presented as follows (mostly according to A. Gorek, J. Veizer 1965):

As a consequence of strong tangential pressures on the slightly elevated geanticlinal zone of the High Tatra, formation of new or re-activation of older tectonic lines of longitudinal (E—W) and transverse (N—S) direction was taking place. This way the Tatride zone was divided into a system of blocks thrust to the north, uplifted and shifted against each other, whereby a system of elevations and depressions was formed, mainly distinct in transverse direction. At the tectonic lines of longitudinal direction the southern blocks were thrust on the northern ones together with the overlying Mesozoics (Giewont unit) or in their fore-land the Mesozoics was detached, along the detachmant plane of the Myophoria Beds, and was thrust (also possible gravitationaly sliding) into the external zones in the form of fold — nappe structures of small amplitude. This is so called superficial style of tectonic units, mentioned above. The

result of it was accumulation of sedimentary series on depressed blocks while on elevation blocks their reduction was proceeding. This way phenomena of compensation are explained, considered as evidence of gravitational sliding (Z. Kotański 1961) because thrusting was proceeding diagonally to the axes of forming depression. With termination of tectonic processes, reaching more and more external zones, not only futher thrusting of southern tectonic structures was taking place but during this phase also the "tegument" of the Werfenian in the fore-land was affected to a considerable degree, thrust together with the underlying crystalline in the form of slices (Javor. units IV—VII in the area of Javorinská Široká) on Mesozoic units thrust formerly. Thus there is induced tectonic style, described above. Simultaneously also the elevation and depression character of the individual blocks was getting more distinct along transverse tectonic lines. Mesozoic tectonic units, which already formerly had formed superficial "folds" in the fore-land, were more finely refolded and differential planes of detachment formed in them in that period. In the apical part of these units strata were getting into vertical position and formed synclinal turns (Stoly, Zámky etc.). Mesozoic slices were detached, refolded and thrust to the north (slice of Mikulčie, Swierkule), units thrust initially (unit of Červené vrchy s. l. and units II, III in the group of Javorinská Široká) were divided into „partial units" and finally the southern "partial units" were thrust on the northern ones (the Zdziary unit on the Organy unit). This stage culminated during the time, when the early thrusting of the subtatric nappes caused not only the phenomena already described, but also the infolding of the frontal part of the Giewont unit with the Krížna nappe (F. Rabowski 1959). This character of tectonic structural development also explains well accumulation of the plastic Albian—Cenomanian—Lower Turonian complex in frontal parts of the tectonic structures as it is to be seen well in the area of Javorinská Široká.

It is obvious from the description, that the tectonics involved is mainly of the „tectonics with overload" type, whereas the „free tectonics" was of any importance only during the initial period.

The termination of maximal tectonic space reduction, after the time of Subhercynian or Laramide tectonic phase (D. Andrusov 1959a, b, V. Cúlová, D. Andrusov 1964), caused release of pressures and backward thrusting in the Osobitá and Javorinská Široká areas. This is a tectonic development analoguous to that one described in the Strážovská hornatina highlands (M. Maheľ et al. 1967). The backward thrusting was a manifestation of the deep seated tectonic line, which already during the sedimentation of the Mesozoics as well as during the formation of tectonic structures (thrusting of the Zdziary „partial unit" on the Organy „partial unit", development of the fold structures of Stoly, Kominy Tylkowe, Javorinská Široká etc.) played an important rôle.

Post-Eocene (Savian? — K. Birkenmajer 1960, D. Andrusov 1959a, b) movements were mainly of vertical character, resulting in uplifting of the High Tatra megantlicline as well as in dictinct division of blocks into transverse elevations and depressions with re-activation of many older tectonic lines of N—S and E—W direction levels probably represents various tectonic blocks delimited to each other by tectonic lines being of fault character in the basement crystalline while in the overlying Mesozoic they are usually of flexure character (S. Sokołowski 1961, A. Gorek, J. Veizer 1965). During this period the line Kominy Tylkowe, Stoly, Javorinská Široká and possibly the tectonic complications to the south of Osobitá and Bobrovecká dolina valley manifested itself for the last time. The line represents more or less the southern boundary of the present outcropping of the Mesozoics.

The consequence of these processes is present geological and tectonic structure of the Mantle Series of the High Tatra.

SUMMARY

According to author's opinion tectonic structures of the Mantle Series of the High Tatra are mainly conditioned by tangential pressures as a consequence of compression of the West Carpathian geosynclinal zone. The influence of gravitational sliding on formation of tectonic structures is supposed to be of second-rate importance only. In the Mantle Series of the High Tatra two types of tectonic structures may be distinguished:

a) Lower tectonic structures prevailingly formed by carbonate members of the Mesozoic sequence, characterized by so called superficial tectonic style.

b) Higher tectonic structures with considerable portion of crystalline and detritial basal Mesozoic members with development of so called induced tectonic style.

Translated by J. Pevný.

REFERENCES

Andrusov D. 1931: Zpráva o geologických výskumoch v masívu Vysokých Tatier v létě roku 1931. Věst. St. úst. geol. ČSR 7, 6, Praha. — Andrusov D., 1932: O pokračovaní ležaté vrásy Czerwonych Wierchů ve skupině Osobité a o postavení tatranských limburgitů. Věst. St. geol. úst. ČSR 8, Praha. — Andrusov D., 1950: Tektonická stavba masívu Širokej. Geol. sborn. Slov. akad. vied 1, Bratislava. — Andrusov D., 1959a: Geológia československých Karpát II. Vydavateľstvo SAV, Bratislava. — Andrusov D., 1959b: Prehľad stratigrafie a tektoniky druhohorného pásma masívu Vysokých Tatier na území Slovenska. Geol. sborn. Slov. akad. vied 10, 1, Bratislava. — Andrusov D., 1965: Aperçu général sur la géologie des Carpathes occidentales. Bull. Soc. géol. France 7, 1967, Paris. — Aubouin J., 1965: Geosynclines. Elsevier Publ. Comp. — Birkenmajer K., 1960: Geology of the Pieniny Klippen Belt. Jb. Geol. Reichsanst. 103, Wien. — Cúlová V., Andrusov D., 1964: Précision de l'âge de la formation des nappes recouvrement des Karpates occidentales centrales. Geol. sborn. Slov. akad. vied 15, 2, Bratislava. — Debelmas J., 1960: Comparaison du Trias hauttatrique avec celui des Alpes occidentales — Zone intra-alpine. Acta geol. Polonica 10, 2, Warszawa. — Fallot P., 1955: Les dilemnes tectoniques des Alpes orientales. Ann. Soc. géol. Belg. Bull. 77, Bruxelles. — Gignoux M., 1949: Méditations sur la tectonique d'écoulement par gravité. Trav. Lab. Géol. Fac. Sci. Univ. Grenoble 27, Grenoble. — Gorek A., 1950: Tektonické okná na západnom ukončení Vysokých Tatier. Geol. sborn. Slov. akad. vied 1, 1, Bratislava. — Gorek A., 1953: Geologické štúdiá na JZ svahu Vysokých Tatier. Geol. sborn. Slov. akad. vied 4, 2, Bratislava. — Gorek A., 1958: Geologické pomery skupiny Červených vrchov, Tomanovej a Tichej doliny. Geol. sborn. Slov. akad. vied 9, 2, Bratislava. — Gorek A., 1966: Diskusia o povahe porúchových pásiem v kryštaliniku Vysokých Tatier a ich odraz v tektonickom vývoji mezozoických sérií. Unpublished. Záverečná správa „Základné geologické mapy, listy Nižná a Bystrá" 1 : 50 000. Geofond, Bratislava. — Gorek A., Veizer J., 1965: Der Charakter der alpinen Tektonik in der Hohen Tatra. Geol. sborn. Slov. akad. vied 16,2, Bratislava. — Grabowska-Hakenberg H., 1962: Tectonogenesis of the French Alps in the Light of the Theory of Gravity Flowage and Attemp of Applying this Theory in the Tectonogenesis of the Central Carpathians. Kwartalnik geol. 6, 4, Warszawa. — Halicki B., 1955: O przebiegu jednostek reglowych w dorzeczu Suchej Wody w Tatrách. Acta geol. Pol. 5, 1, Warszawa. — Kahan Š., 1961: Geologicko-petrografické pomery na JZ svahoch Záp. Tatier v oblasti Žiarskej a Jaloveckej doliny. Unpublished. Katedra geológie UK, Bratislava. — Kotański Z., 1959a: Stratigraphy, sedimentology and paleogeography of the high-tatric Triassic in the Tatra Mts. Acta geol. Pol. 9, 2, Warszawa. — Kotański Z., 1959b: Trias wierchowy. Biul. Inst. Geol. 149, Warszawa. — Kotański Z., 1961: Tektonogeneza i rekonstrukcija

paleografii pasma wierchowego w Tatrach. Acta geol. Pol. 11, 2—3, Warszawa. — Kotański Z., 1963: Nowe elementy budowy masywu CzerNonych Wierchow. Acta geol. Pol. 12, 1, Warszawa. — Kotański Z., 1964: Quelques observations sur la stratigraphie du Trias briançonnais dans les Alpes Françaises. Bul. Acad. Pol. 14, Warszawa. — Kotański Z., 1965: Analogie litologiczne triasu tatrzańskiego z triasem wschodnioalpejskim. Roczn. Pol. Tow. Geol. 35, 2, Kraków. — Král V., 1960: Záverečná zpráva — problém 54300091. Unpublished. Geofond, Bratislava. — Kreutz S., 1913: O limburgicie w Tatrach. Bul. Int. Akad. Pol. Sci., Cl. math.-nat. 7, Kraków. — Limanowski M., 1911: Geologiczne przekroje przez wielki fald Czerwionych wierchow miedzy dolina Suchej Wody a Chocholowska w Tatrach. Rozpr. Pol. Akad. Um. 51, 2, Kraków. — Lugeon M., 1903: Les nappes de recouvrement de la Tatra et l'origine des Klippes des Carpathes. Bul. Soc. vaudoise Sci. nat. 39, Lausane. — Maheľ M. et al., 1967: Reigonální geologie ČSSR I. Západní Karpaty I. Nakl. ČSAV, Praha. — Matějka A., Andrusov D., 1931: Aperçu de la géologie des Carpathes occidentales de la Slovaquie centrale et de régions avoisinantes. Guide dans les Carpathes occidentales. Knih. St. geol. úst. ČSR 13A, Praha. — Medvecký A., 1962: Geologické pomery masívu Osobitej. Unpublished. Archív Katedry geológie UK, Bratislava. — Michalik A., 1955: Tektonika serii wierchowej na obszare Liliowego i Malej Koszystej. Biul. Inst. Geol. 96, Warszawa. — Michalik A., 1956: W sprawie genezy „zlepieńca kopersadzskiego" w Tatrach. Biul. Inst. Geol. 109, Warszawa. — Mišík M., 1966: Mikrofacies of the Mesozoic and Tertiary Limestones of the West Carpathians. Vydav. SAV, Bratislava. — Nowak J., 1929: Zarys tektoniki Polski. Pam. II-Zj. Slow. Geogr. i Etnogr., Kraków. — Passendorfer E., 1938: Uwaga w dyskusji na zebraniu Francuskiego Towarystwa Geologicznego w dniu 15 września 1938 r. w Briançon. C. R. Soc. Géol. France 5, Paris. — Passendorfer E., 1957: Zlepience koperszadzki, jego geneza i wiek. Acta geol. Pol. 7, 2, Warszawa. — Rabowski F., 1921: O triase wierchowym w Tatrach. Spraw. P. I. G. 1, 2—3, Warszawa. — Rabowski F., 1925: Budowa pasma wierchowego. Spraw. P. I. G. 3, 1, 2, Warszawa. — Rabowski F., 1930: O pochodzeniu limburgitow tatrzańskich i o stosunku vzajemnym płaszczowin wyobrebnionych miedzy pasmem Skalek a gorami Veporu. Spraw. P. I. G. 4, Warszawa. — Rabowski F., 1933: Spostrzezenia geologiczne w grupie Osobitej. Pos. nauk. P. I. G. 35, Warszawa. — Rabowski F., 1938: Uwagi tyczace sie tektoniki trzonu krystalicznego Tatr. Biul. P. I. G. 4, Warszawa. — Rabowski F., 1939: Jaworzyna i jej zagadnenia geologiczne w nauce Polskiej. Wiad. Mus. Ziemi 1, 2, Warszawa. — Rabowski F., 1959: Serie wierchowe w Tatrach Zachodnich. Prace P. I. G. 27, Warszawa. — Reichwalder P., 1964: Geologicko-petrografické pomery medzi Tichou a Kôprovou dolinou v Záp. Tatrách. Unpublished. Katedra geológie UK, Bratislava. — Sokołowski S., 1948: Tatry Bielskie. Geologia zboczy południowych. Prace P. I. G. 4, Warszawa. — Sokołowski S., 1961: Uwagi o wynikach nowych badań nad tektonika Tatr. Roczn. Pol. Tow. Geol. 31, Kraków. — Ševčík Z., 1961: Geologické pomery JZ svahu Záp. Tatier severne od Liptovského Mikuláša. Unpublished. Archív Katedry geológie UK, Bratislava. — Swiderski B., 1922: Korzenie lezacego faldu Czerwionych Wierchow oraz nowe elementy budowy trzonu Tatr. Rozpr. P. I. U. A 61, Warszawa. — Tollmann A., 1964: Gehören die Tatriden zum Unterstalpin oder Penin? Geol. sborn. akad. vied 16, 2, Bratislava. — Trümpy R., 1960: Paleotectonic evolution of the central and western Alps. Bul. Geol. Soc. Amer. 71, 6. — Turnau-Morawska M., 1957: Petrografia i geneza zlepienca kopersadzkiego. Acta geol. Pol. 7, 2, Warszawa. — Uhlig V., 1897: Geologie des Tatragebirges I. Einleitung und stratigraphischer Teil. Denkschr. Akad. Wiss., Kl. Math.-Nat. 64, 67, Wien. — Uhlig V., 1900: Die Geologie des Tatragebirges II—IV. Anz. Akad. Wiss. Kl. Math.-Nat. 68, Wien. — Uhlig V., 1907: Über die Tektonik der Karpathen. S-B. Akad. Wiss. Kl. Math.-Nat. Abt. 1, 116, Wien. — Veizer J., 1964: Geologicko-petrografické pomery územia medzi Kamenistou a Tichou dolinou (Západné Tatry). Unpublished. Archív Katedry geológie UK, Bratislava. — Veizer J., 1968: Obalová séria Vysokých Tatier — slovenská časť. Unpublished. Geologický ústav SAV, Bratislava.

Review by M. Maheľ and A. Gorek.