4927/13

GEOLOGICKÉ PRÁCE

ZPRÁVY 28

GEOFOND, REDAKCIA BRATISLAVA 1963

~~1319~~ x

1319 f
1331/63
20.- Kč

Geologický ústav Dionýza Štúra
Knižnica
20.- Kč

~~1348/1963~~

© Geofond 1963

CONTENTS

1. Roth Zd.: Strukturbeziehungen des Sedimentationsgebietes der Flyschzone der Westkarpaten zum Karpatenvorland und den Zentralkarpaten (Mit einer Abbildung im Text) 5
2. Mahel' M.: Folding Phases and Formations of the West Carpathian Mesozoic . 23
3. Mahel' M.: Several Tectonic Styles the Influence of Rock Properties and Orientation of Overturns in Central Carpathian Mesozoic 39
4. Scheibner E.: Relationship Between Material and Tectonic Style, and Selective Tectonics in the Klippen Belt of West Carpathians 59
5. Biely A.: Beitrag zur Kenntnis des inneren Baues der Choč-Einheit 69
6. Zelman J.: Relation Between the Competency and Incompetency of the Rock of the Epimetamorphosed Mesozoic Series of the Liptovská Teplička District and Fold structures 79
7. Klinec A.: Several Tectonic Structures from the West Carpathian Crystalline Masses and their Interpretation 85
8. Fusán O. — Snopko L.: Bauelemente der Gemeriden 89
9. Rozložník L.: The Relation Between Faults and Foliation in the „Shear Zone" of the Dobšiná Vicinity 103
10. Buday T.: Some Problems of the Origin and Development of the Fault-structures in the Neogene Carpathian Basins 113
11. Buday T.: Comments on the Problems of the Folding Phases in the Neogene of the West Carpathian Mts. 121
12. Seneš J.: Chronological Position of Synsedimentary Tectonics in the Sedimentary Cycle 127
13. Dlabač M. — Mořkovský M.: Einige Bemerkungen zur Tektonik des Neogens der Dyje—Svratka Senke und der Senke von Vyškov 133
14. Vass D.: Tectonic Mobility and its Effect Upon the Miocene Sedimentation of the Ipeľská kotlina Basin 145
15. Jaroš J.: Die Tektonische Entwicklung der Depression von Banská Bystrica während des Tertiärs 151
16. Stránik Z.: Tectonic Structure of the Southern Part of the Ždánice Unit . . 155

17. Marschalko R.: Sedimentary Slump Folds and the Deposition Slope (Flysch of Central Carpathians) 161
18. Snopko L.: Study of Deformation Elements Developed in the Handlová Landslide 169
19. Kuthan M.: Tectonic Deformations of the Central Slovakia Neovulcanic Region and the Relations Between the Volcanism and Tectonics 185

ZDENĚK ROTH

STRUKTURBEZIEHUNGEN DES SEDIMENTATIONSGEBIETES DER FLYSCHZONE DER WESTKARPATEN ZUM KARPATENVORLAND UND DEN ZENTRALKARPATEN

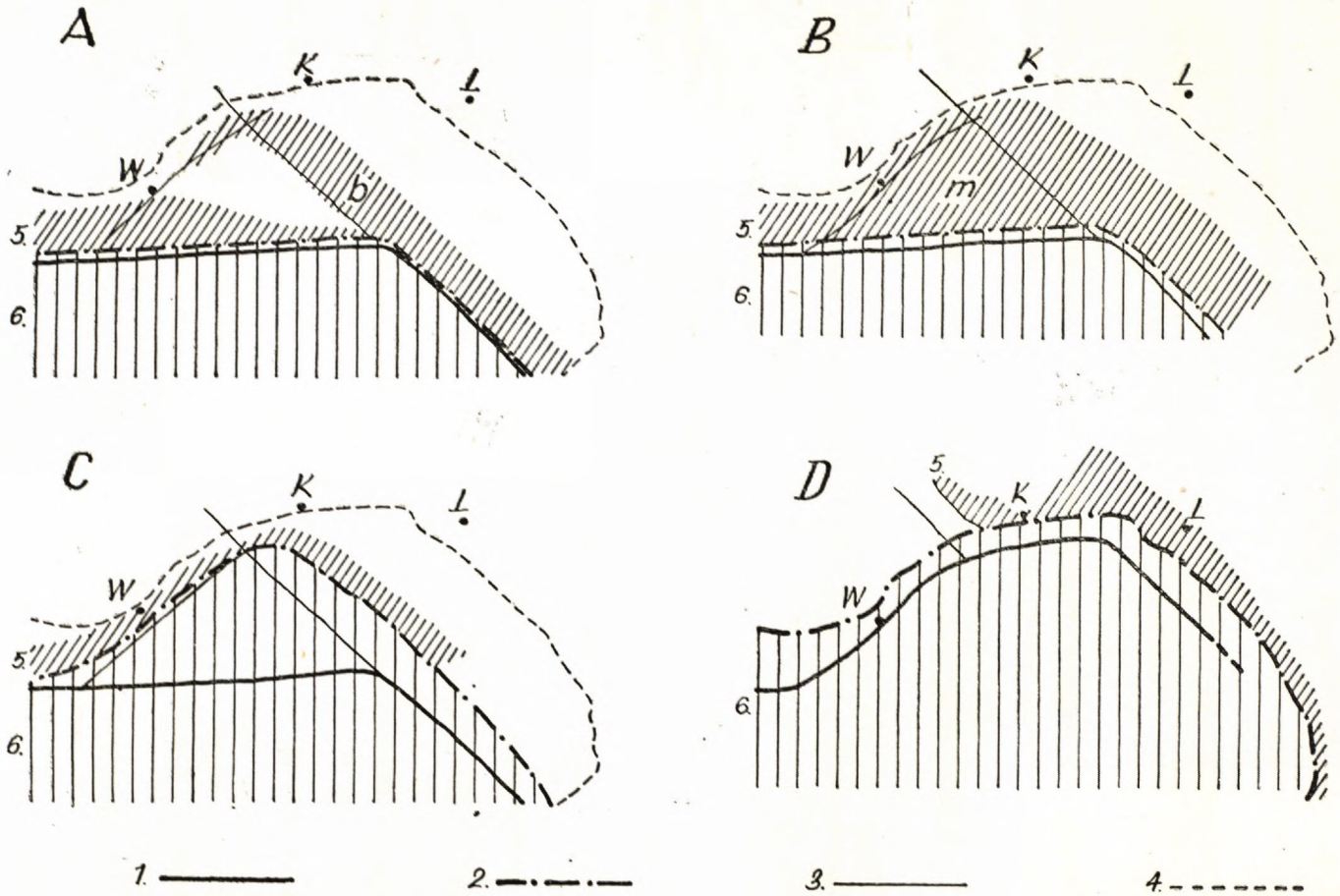
(Mit einer Abbildung im Text)

Bei der Verarbeitung der neuen Gesamterforschung der Flyschzone in der Tschechoslowakei versuchten wir, ihre Beziehung zum Böhmischen Massiv und den Zentralkarpaten neu zu definieren. Am ausführlichsten wurden die Ergebnisse der wichtigsten gedruckten Teilstudien (A. Matějka — Z. Roth 1956; Z. Roth 1957, 1959, 1960, 1961a, 1962b; Z. Roth & cons. 1962a) für den vergangenen Kongreß der Karpato-balkanischen Assoziation zusammengefaßt (Z. Roth 1961a). Vom Gesichtspunkt der strukturellen Stellung der Flyschzone und ihres Sedimentationsgebietes kamen wir zu zwei wichtigen Schlußfolgerungen:

a) Das Sedimentationsgebiet der Flyschzone der Westkarpaten entwickelte sich zunächst innerhalb des Randbereiches der nordeuropäischen Tafel, u. zw. als Graben in der Richtung NW—SO, der im SO in das Gebiet des geosynklinalen Meeres (Tethys) mündete, und wurde erst später (zusammen mit dem SW vom Graben liegenden Teil der Tafel) von der alpidischen Faltenzone annektiert.

b) Die Flyschzone der Westkarpaten ist eine bilaterale Faltenzone von beträchtlicher Selbständigkeit sowohl gegenüber dem Karpatenvorland, als auch gegenüber dem Block der Zentralkarpaten.

Auf Grundlage der von N. S. Schatski (1945—1955, 1961) entwickelten Klassifikation werden wir in dieser Studie versuchen, die Flyschzone der Westkarpaten in einen weiteren Strukturrahmen einzugliedern. N. S. Schatski's Strukturklassifikation (1945—1955), wird hier darum als Richtlinie genommen, weil sie auf einer umfangreichen Vergleichsanalyse begründet ist und auch frühere Klassifikationen (H. Stille, S. v. Bubnoff) kritisch verarbeitet, sowie auch deshalb, weil sie sich direkt in weitem Maße mit der Analyse der Struktur des S-Randes der nordeuropäischen alpidischen Tafel befaßt.


A
K
L
W
b
5.
6.
B
K
L
W
m
5.
6.
C
K
L
W
5.
6.
D
5.
K
L
W
6.
1.
2.
3.
4.

Die Entwicklung des Sedimentationsgebietes der Flyschzone verlief in zwei Etappen, die sich durch die strukturelle Stellung des Gebietes voneinander unterscheiden.

In der *ersten Etappe,* die hauptsächlich Tithon und Kreide umfaßt, lag der Schwerpunkt des Sedimentationsraumes der Flyschzone der Westkarpaten in der innerkontinentalen grabenförmigen Geosynklinale, welche von dem zentralkarpatischen geosynklinalen Faltengürtel durch einen halbinselförmigen Ausläufer der Tafel abgetrennt war. Am Südrand dieses Tafelausläufers, d. h. im pienidischen Sedimentationsgebiet, kann man vor der Oberkreide den nördlichen Rand der neuentwickelten Faltenzone und vor allem die mittelkretazischen Falten der jetzigen inneren Klippenzone der Karpaten verfolgen. Wir bezeichneten die erwähnte grabenförmige innerkontinentale Geosynklinale mit dem Namen *Beskidengraben* (Z. Roth 1962b, S. 460, 472).

In der *zweiten Etappe,* welche vornehmlich dem Paleozän und Eozän zugehört, wurde auch der frühere halbinselförmige Ausläufer der Tafel ein Bestandteil des Sedimentationsraumes der Flyschzone, und sein Innenrand (namentlich im östlichen Teil des westkarpatischen Abschnittes) wurde von einer Zone von laramischen Deformationen (Falten) gebildet.

Wir werden uns jetzt der Reihe nach mit der Stellung des Sedimentationsraumes der Flyschzone in beiden angeführten Etappen und schließlich auch mit der strukturellen Frage seines Untergrundes befassen.

Strukturelle und genetische Stellung des Beskidengrabens (Tithon — Paleozän)

Nach N. S. Schatski (1946a, S. 6) entstand auf der nördlichen Halbkugel nach der Einverleibung der Varisciden des Urals und Westeuropas eine sehr ausgedehnte alpidische Tafel, welche die präkambrisch, kaledonisch und

◁

Abb. 1. **Schema der paläogeographischen Entwicklung des Karpatenbogens sowie des Südrandes der nordeuropäischen Tafel in Laufe der Kreide und des Tertiärs** (nach theoretischen Prinzipien N. S. Schatski's (1945—1948), unter Benützung der Arbeiten von I. Bănciläă (1955), M. Książkiewicz (1957—1960), M. Filipescu (1955), Z. Roth (1960—1962) u. V. Scheffer (1960) zusammengestellt von Z. Roth 1963.

A. Die paläogeographische Situation des Karpatenbogens in der Schlußphase der austrischen Faltung (Ende Cenoman), B. Die Situation in der Schlußetappe der laramischen Bewegungen (Ende Paleozän). C. Die Situation während der Schlußetappe der pyrenäischen Faltung (Oligozän). D. Die Situation zur Zeit der jungsteirischen und jüngeren Faltungen (Obertorton bis Pliozän).

Zeichenerklärung: 1 — Südrand der nordeuropäischen Tafel, 2 — Nordrand der alpinen Faltenzone, 3 — Wichtigste Störungszonen in den Randstrukturen der nordeuropäischen Tafel, 4 — Situation des heutigen Nordrandes der alpinen Faltenzone, 5 — Ungefähre Meerverbreitung auf dem Randgebiet der nordeuropäischen Tafel, 6 — alpine Faltenzone. *b* — Beskidengraben, *m* — der Magura-Sedimentationsraum, *W* — die Lage von Wien, *K* — die Lage von Kraków, *L* — die Lage von Lvov. (Nr 5, 6 nur in den Kartenskizzen.)

variscisch gefalteten Gebiete umfaßte. Der Sedimentationsraum der Flyschzone der Westkarpaten bildete sich im epivariscischen Teil dieser alpiden Tafel aus.

Dies wird auch durch den Charakter des Gerölls und der Blöcke des Kristallins und Paläozoikums belegt (Devon, Karbon, siehe z. B. Z. Roth & cons. 1962a), welche als „Exotika" Bestandteile der Schichten der Flyschzone sind und aus den nördlichen und westlichen Randgebieten der „exotischen" Scholle stammen (die heute nirgends an der Oberfläche hervortritt). Der nördliche, zeitweise zum größten Teil als Rücken emporragende Teil dieser Scholle sonderte den Sedimentationsraum der äußeren (Krosno-) Gruppe der Flyschzone vom Sedimentationsraum der Maguragruppe ab. Die Scholle trat namentlich in der mittleren Kreide und im mittleren Eozän als Quellgebiet des klastischen Materials auf.

Bruchstücke und Geröll des außerkarpatischen Kristallins und der Oberkarbonkohle (D. Andrusov 1931; V. Zoubek 1931, 1958; J. Šilar 1956; V. Havlena 1956; M. Książkiewicz 1957; M. Eliáš 1961; K. Birkenmajer — E. Turnau 1962) können neben zentralkarpatischen Gesteinen auch im Gebiet der inneren Klippenzone als Trümmer der ursprünglichen Unterlage der pienidischen Serien (D. Andrusov — E. Scheibner 1960) im S-Teil der exotischen Scholle vorgefunden werden.

Die exotische Scholle bildete noch in der älteren Kreide ein gemeinsames Ganzes mit der sog. Maleníkscholle* des heutigen westlichen Vorlandes der Flyschzone der tschechoslowakischen Karpaten. Es war die sog. *Maleník-exotische Scholle* (Z. Roth 1961a; Z. Roth & cons. 1962a). Sie begrenzte in der Kreide als erhöhte in der NW—SO Richtung ausgedehnte Schwelle eine ebenso ausgedehnte weiter nördlich liegende Depression, die gegen SO in das Meer der Tethyschen Geosynklinale mündete und nach NW weit in die alpidische Tafel Nordeuropas reichte (siehe z. B. auch D. Andrusov 1959). Diese paläogeographisch bemerkenswerte Depression, auf die im obersten Jura und in der älteren Kreide der Sedimentationsraum der äußeren Gruppe der Flyschzone im großen und ganzen beschränkt war, benannten wir *Beskidengraben* (Z. Roth 1962b).

Es ist vorläufig noch nicht möglich, die Lage ihrer Einmündung in das geosynklinale Gebiet der Tethys genau zu bestimmen. Der mächtige Paläogen der Maguragruppe war auf der Maleník-exotischen Scholle zu jener Zeit abgelagert, während der sie tief herabgedrückt war; da jedoch diese Gruppe auf die Westkarpaten beschränkt blieb, ist es klar, daß der Beskidengraben nicht in das geosynklinale Gebiet der Tethys W der Grenze zwischen dem westkarpatischen und ost-

* Die Bezeichnung „Maleníkscholle" gebrauchte ich bereits früher (Z. Roth 1961a; Z. Roth & cons. 1962a u. A.) einerseits für die NW—SO gestreckte Grenzscholle, welche die Gebirgsgruppe des Maleník umfaßt und den kretazisch gehobenen Teil der Böhmischen Masse in Ostmähren gegen den gesenkten Abschnitt begrenzt (siehe z. B. lc. 1961a, Abb. 1), anderseits wurde darunter in den paläogeographischen Erwägungen der große gehobene SO-Teil der Böhmischen Masse verstanden (lc. 1961a, Abb. 2). In dieser Arbeit wird unter der Bezeichnung „Maleníkscholle" der ganze gehobene SO-Teil der Böhmischen Masse verstanden.

karpatischen Sedimentationsraum der Flyschzone münden konnte. Da anderseits im Marmaroscher kristallinischen Massiv der Ostkarpaten, das durch seine tektonische Lage in mancher Hinsicht an die Maguragruppe erinnert, in bedeutendem Maße Trias, Jura und Unterkreide vorgefunden wird (O. S. Wjalow 1960; D. Patrulius — I. Motas — M. Bleahu 1960), können wir annehmen, daß der Beskidengraben in das alpidische geosynklinale Gebiet weiter westlich mündete.

Der Beskidengraben äußert sich paläogeographisch erst im Tithon (Z. Roth & cons. 1962b) und entstand nicht früher als im Aalen (siehe M. Książkiewicz 1954). Er ist daher bedeutend jünger als das benachbarte alpidische geosynklinale Hauptgebiet, das sich im großen und ganzen ohne Unterbrechung wenigstens vom Perm an entwickelt. Im Vergleich mit der alpidischen Geosynklinale war der Beskidengraben eine Neubildung.

Da die Maleník-exotische Schwelle als herausragender Ausläufer der benachbarten nordeuropäischen Tafel den Beskidengraben von dem geosynklinalen Raum der Tethys im S absonderte, während im SO der Beskidengraben in weitem Maße mit diesem Raum zusammenhing, muß man den Graben als eine kretazische Querstruktur des Südrandes der nordeuropäischen Tafel im Sinne N. S. Schatski's (1945, 1946b) betrachten. Solche Querstrukturen bildeten sich an dem Südrand der nordeuropäischen Tafel bei Faltenbewegungen in der geosynklinalen Zone der Tethys als Neubildungen schon früher aus (Großes Donezbecken — N. S. Schatski 1946b).

Eine der grundlegenden Eigenschaften aller Querstrukturen in Randgebieten der Tafel ist ihr genetischer Zusammenhang mit dem Innenwinkel der Tafel. Besteht auf der Tafel eine randliche Querstruktur (Struktursystem vom Typus einer „innerkontinentalen (Para-) Geosynklinale" im Sinne von H. Stille), so setzt sie immer an dem Innenwinkel der Tafel an (N. S. Schatski 1946b, S. 72, 83). Der Beskidengraben stellte in der Kreide eine solche Para-Geosynklinale dar (Z. Roth, 1961b).

Gehen wir von dieser Feststellung aus und stützen uns auf die Ergebnisse der vergleichenden tektonischen Analyse N. S. Schatski's, die in seinen Studien (1945, 1946a, b, 1947, 1948, 1955, 1961) enthalten ist, so kommen wir durch Extrapolation zu einer Reihe von Schlußfolgerungen, die vom Gesichtspunkt der geologischen Entwicklung der Karpaten von großer Bedeutung sind.

Mit Rücksicht auf die gesetzmäßigen Beziehungen zwischen den randlichen Querstrukturen und den Innenwinkeln der Tafel müssen wir den Innenwinkel der damaligen nordeuropäischen Tafel dort suchen, wo der Beskidengraben in den tethydischen geosynklinalen Raum mündete.

Nach N. S. Schatski (1945, 1946b, 1947) werden die randlichen Querstrukturen der Tafeln durch disjunktive Kräfte hervorgerufen die in den Innenwinkeln als Spannungsresultate der epeirogenetischen und Faltenbewegungen wirken. Die Spannungen wirken senkrecht auf beide Schenkel des Innenwinkels der Tafel in Richtung von Geosynklinale zur Tafel. Wenn dies den zeitlichen Zusammenhang zwischen der Entstehung der randlichen Querstrukturen und den Bewegungen in der Geosynklinale bestimmt, so ist die Entstehung des Beskiden-

grabens zeitlich hauptsächlich mit den *austrischen** *Faltungen* im Zentralkarpatengebiet verbunden. Daraus könnten wir schließen, daß die Mittelkreide—Faltenzone in den Karpaten einen dem heutigen Bogen der westkarpatischen Flyschzone ähnlichen Bogen bildete.

Der Scheitel des Bogens würde an der Innenseite das Sedimentationsgebiet der ostkarpatischen Flyschzone (in ihrer damaligen Lage) berühren. Dies wird bestätigt z. B. durch mächtige Konglomerate, namentlich Apt-Albkonglomerate, im großen Teil der Ostkarpaten (siehe z. B. G. Murgeanu, M. G. Filipescu & cons. 1961). Soweit über den zeitlichen Zusammenhang zwischen der Entstehung des Beskidengrabens und der alpidischen Hauptgeosynklinale.

Der strukturelle Zusammenhang zwischen den randlichen Querstrukturen der Tafel mit der Geosynklinale der Tethys wird durch die Feststellung angedeutet (N. S. Schatski 1946b, S. 83), daß alle randlichen Querstrukturen genetisch mit großen Bruchzonen verbunden sind, die sich zwar nicht immer direkt als Oberflächenrisse äußern, jedoch immer als Fortsetzung der (äußeren) Grenze der Faltenzone (oder eines bedeutsamen Teils hievon) verlaufen, an die sie direkt anknüpfen. Vielfach bilden randliche Querdepressionen eine Fortsetzung der Randsenken in ihrem Streichen (Schatski 1947). Daraus kann geschlossen werden, daß der Beskidengraben durch die Richtung der ihn formenden und nach SW begrenzenden Bruchzone die Gesamtrichtung der Mittelkreidefalten am östlichen Schenkel des Innenwinkels der Tafel andeutet. Das Sedimentationsgebiet des heutigen Südteils der Ostkarpaten, der ehemals gegen SO an den Beskidengraben anknüpfte, hatte tatsächlich den Charakter einer Randsenke der austrischen Faltenzone. Das wird durch die mächtige Entwicklung der Mittelkreide-Konglomerate in einem großen Teil der Ostkarpaten, ihren Charakter und durch Beziehung zu den Ost- und Südkarpaten (siehe G. Murgeanu, M. G. Filipescu & cons. 1961) angedeutet. Der Nordrand der Kreidefalten ging von dem angeführten Winkel der Tafel nach W längs des Südrandes der exotischen Scholle (kretazische Konglomerate der Klippenzone).

Soweit es sich um den lithologischen Zusammenhang der randlichen Querstrukturen der Tafel mit der geosynklinalen Faltungszone handelt, wie sie N. S. Schatski (1946b, S. 84) angibt, so sind ihre lithologischen Formationen größtenteils den Tafelformationen verwandt. Wir machten schon früher (z. B. Z. Roth 1961b, 1962b) auf die engen faziellen Beziehungen zwischen der älteren Kreidefüllung des Beskidengrabens und den ebenso alten Füllungen anderer parallelen Graben innerhalb der Tafel in Norddeutschland aufmerksam.

Da jedoch die randlichen Querstrukturen an das Geosynklinalgebiet münden,

---

* Unter Bezeichnung austrische Bewegungen ist hier auch die subhercynische Unruhe inbegriffen.

sind in der Regel ihre der Geosynklinale nahen Teile durch lithologische Formationen jener Randsenken gekennzeichnet, die oft an die Querstrukturen direkt anknüpfen. Die Fazien der Randsenkenfüllungen reichen jedoch in den randlichen Querstrukturen der Tafel viel weiter ins Innere der Tafel als in den eigentlichen Randsenken (N. S. Schatski l. c.). Dies gilt durchaus für den Beskidengraben. Flysch- und Molasseformationen (Z. Roth 1961b), die nach Schatski (1946a, S. 53) für Randsenken sehr kennzeichnend sind, bildeten einen großen Teil der Füllung des Beskidengrabens.

Nach der paläogeographischen Analyse ging die randliche Querstruktur des Beskidengrabens im Malm und Alb (?) durch das Stadium (Strukturtyp) einer *randlichen Querflexur.* Sie kam wahrscheinlich im Alb in das Stadium eines *einfachen randlichen Quergrabens* (N. S. Schatski 1946b), denn zu jener Zeit war die Strukturdepression nach SW durch einen Bruchabhang der Maleník-exotischen Schwelle begrenzt (Z. Roth 1961b; Z. Roth & cons. 1962a). Gleichzeitig kam es zum Abbruch und einer fortschreitenden Senkung des SE-Teils der Maleník-exotischen Schwelle (der sog. exotischen Scholle — Z. Roth 1961). Diese Senkung ähnelt einer alpidischen Absonderung und Senkung der SO-Forsetzung des Ukrainischen Blocks, der nach S eine ähnliche, jedoch ältere Querstruktur des Südrandes der Tafel, das Donezbecken, begrenzt (N. S. Schatski 1946b).

Grundlage des Abbruchs war wahrscheinlich die Bruchstruktur, die quer über die Maleník-exotische Scholle bis zum Beskidengraben reichte (Z. Roth 1960, 1961b; Z. Roth & cons. 1962a). Nach N. S. Schatski (1946b) kann man diese Tektonik, die die randlichen Querstrukturen der Tafeln kreuzt, oft in engem genetischen Verband mit diesen Strukturen beobachten. Der genetische Zusammenhang der erwähnten Narbe des Querabbruches der exotischen Scholle mit dem Beskidengraben wird auch durch das Kreidealter (Hauterive-Barrem) ihrer ältesten rudimentären Füllung angedeutet (siehe E. Hanzlíková — Z. Roth 1963a).

Beobachtungen zeigen, daß es während der Existenz des Beskidengrabens nicht zu alpinotypen Deformationen seiner sedimentären Füllung kam (Z. Roth 1961b). Es kam jedoch zu weniger intensiven Deformationen der Füllung. Im Baschkagebiet des Beskidengrabens wird die Bewegung durch Sedimentationslücken im Untervalangin und zwischen Cenoman und Untersenon angedeutet. Die jüngere von den zwei Lücken wird von einer geringen Winkeldiskordanz begleitet (A. Matějka — Z. Roth 1949). Auf eine ausgeprägtere Winkeldiskordanz zwischen Cenoman und Senon im Godulagebiet des Beskidengrabens in der Umgebung von Jablunkov hat auch E. Menčík (1960) aufmerksam gemacht. Daraus kann man schließen, daß die Sedimentfüllung des Beskidengrabens im höchsten Tithon bis zum unteren Valangin und noch ausgeprägter im (unteren) Turon (germanotyp) deformiert war. Wie die Umgebung

von Jablunkov zeigt, bildeten sich höchstwahrscheinlich im Gebiet, wo damals die Füllung ihre Maximalmächtigkeit (4000—5000 m) erreichte, Falten von großem Radius, die ungefähr parallel mit der Achse des Beskidengrabens lagen. Der NW-Abschnitt des Grabens wurde hiebei wahrscheinlich für einige Zeit ein Denudationsgebiet. Nach der austrischen Unruhe kann man also die Struktur der Sedimente des Beskidengrabens z. B. mit dem System Wichita in USA vergleichen (sieche N. S. Schatski 1946b) und sie danach zu den höchsten Strukturtypen der randlichen Querstrukturen, d. h. zu den *randlichen Quersystemen* zählen. Ähnliche Bewegungen äußerten sich nicht in der oberkretazischen Sedimentfüllung des Beskidengrabens. Der Beskidengraben kehrt also in der oberen Kreide strukturell zum Typus eines *einfachen randlichen Quergrabens* zurück.

Die weitere strukturelle Entwicklung, die die Sedimentfüllung des Beskidengrabens durchlief, erfolgte erst nach dem Untergang des Beskidengrabens und unter geänderten Bedingungen zwischen dem oberen Eozän und Torton (Z. Roth 1961b) in der pyrenäischen bis steirischen Phase. Die *alpinotype Verfaltung* der Sedimente entstand hauptsächlich während der savischen und steirischen Phase.

Strukturelle und genetische Stellung des Sedimentationsgebiets der Flyschzone der Westkarpaten nach dem Untergang des Beskidengrabens

Der Beskidengraben war zwar mit Tethys in der Oberkreide nicht nur im SO, sondern auch schon im westlichen Teil (durch eine querliegende Meerenge über die Maleník-exotische Schwelle) verbunden; er blieb als ausgeprägte, herabsinkende Senke bis ins Paleozän bestehen. Im Paleozän begann jedoch der durch die Meerenge abgeteilte östliche Teil der Maleník-exotischen Schwelle (die sog. exotische Scholle) rasch zu sinken und wurde zum Sedimentationsgebiet der Maguragruppe. Offenbar nicht allzu intensive *laramische Falten* konnten hiebei nur im Bereich der Kreidefalten, u. zw. ausgeprägter nur im östlichen tschechoslowakischen Abschnitt der inneren Klippenzone, festgestellt werden (D. Andrusov 1938; A. Matějka — Z. Roth 1956; Z. Stráník — Z. Roth 1960; D. Andrusov — E. Scheibner 1960).

Das rasche Sinken des östlichen („exotischen") Teils der ursprünglichen Maleník-exotischen Schwelle kann mit dem Sinken des Stawropol-Plateaus verglichen werden, welches in der variscischen Epoche (durch seinen nördlichen Teil) eine weit nach SO reichende Fortsetzung des Ukrainischen Massivs darstellte, das von dem eigentlichen Massiv durch alpidische Bewegungen abgetrennt wurde und sank. Dieses Plateau begrenzte im Süden den SO-Teil des Großen Donezbeckens und trennte es von dem südlichen geosynklinalen Gebiet (N. S. Schatski 1946a, 1948; N. S. Schatski — A. A. Bogdanoff 1957).

Wie die Eigenschaften der Unterlage und die Entstehung der beskidischen Furche (Tithon — Kreide), sowie des magurischen Sedimentationsraumes (im

Paläogen) zeigen, befand sich der Sedimentationsraum der Flyschzone der Westkarpaten, der beide Teile im Paläogen vereinigte, zur Gänze auf dem Tafelrand. Als Randstruktur der Tafel entstand er im Zusammenhang mit den laramischen Bewegungen in der benachbarten Geosynklinale. Dies wird auch durch den zeitlichen Zusammenhang seiner Entstehung und den lithologischen Charakter der Sedimentfüllung (Flysch und molassoide Sedimente) bewiesen. Da die neugebildete Tafelstruktur als Depression in ihrer ganzen Länge den äußeren Rand der laramischen Falten unmittelbar begrenzt und von ihm durch keinen Wall getrennt ist, gehört sie zu den *typischen Randsenken* (N. S. Schatski 1946a).

Eine ähnliche Randsenke, die bei den mittelkretazischen Falten entstand, war wahrscheinlich schon seit der Kreide das Sedimentationsgebiet der Flyschzone der Ostkarpaten (siehe oben).

Der Charakter des paläogenen Sedimentationsraumes der Flyschzone der Westkarpaten bestätigt N. S. Schatski's Ansicht (lc. 1947), daß die Randsenken eher grabenförmige Gebiete in den Randbereichen der Tafeln als „Restgeosynklinalen" sind, wie H. Stille (1940) einige von ihnen bezeichnet.

Nach Schätzungen von D. Andrusov und E. Scheibner (1960), sowie M. Mahel' (1961, S. 18) kann die Strukturgrenze zwischen der alpidischen Vorlandtafel und dem alpinischen Faltensystem in der Kreide mit der Grenze zwischen dem pienidischen Sedimentationsraum und dem Sedimentationsraum der Maníner Serie zusammenfallen. Dort gab es wahrscheinlich eine sehr tiefe Störungszone, welche bis zum oberen Torton den Tafelrand bildete (N. S. Schatski 1947).

Diese Narbe würde funktionell (keineswegs aber durch ihre Lage) dem „peri-pieninischen Lineament" M. Máška's (in T. Buday & cons. 1960, S. 14) entsprechen.

Zu den Grenzstrukturen der oberflächennäheren Teile dieser Störungszone an der Grenze der Tafel und der Zone der Kreidefalten muß man vielleicht auch die austrischen und laramischen Strukturen der inneren Klippenzone rechnen, die sich sowohl von den gleich alten Strukturen der Zentralkarpaten, als auch von den übrigen Strukturen im Randgebiet der nordeuropäischen Tafel unterscheiden. Dies gilt besonders von den pienidischen Serien, welche sich ursprünglich schon auf einer außerkarpatischen Unterlage absetzten (D. Andrusov — E. Scheibner 1960), jedoch den subherzyn-austrischen alpinotypen Bauplan folgten (siehe z. B. D. Andrusov 1961; Z. Roth & cons. 1962a), wobei sie sich von ihrer ursprünglichen Unterlage vollkommen trennten.

Untergang des Sedimentationsgebiets der Flyschzone der Westkarpaten

Wir haben keine Ursache anzunehmen, daß der Nordrand der laramischen Faltenzone im Gebiet der Westkarpaten die Nordgrenze der geosynklinalen mittelkretazischen Falten nach Norden beträchtlich überschritten hätte. Man kann auch annehmen, daß die laramische Faltung an dem äußeren Umfang des geosynkli-

nalen Gebiets weniger intensiv verblieb als die austrische Faltung. Zum Unterschied von den austrischen Falten bildete sich jedoch im Vorfeld der laramischen Falten eine ausgeprägte Randsenke.

Der exotische Block stellte während der ganzen Kreide einen Ausläufer der Tafel in das geosynklinale Gebiet vor („Außenwinkel" der Tafel) und bildete in Übereinstimmung damit (N. S. Schatski 1947) zur Zeit der subherzynischen und austrischen Bewegungen an dem Rand der Tafel eine erhöhte Struktur, wie z. B. auch der damalige rasche Aufstieg seines NO-Randes über den benachbarten Beskidengraben zeigt (Z. Roth 1961a).

In Übereinstimmung mit dieser erhöhten Struktur wurden damals in diesem Abschnitt des Tafelrandes keine lithologischen Randsenkenformationen des Albs und Turons entwickelt. Die Berührung der mittelkretazischen Faltenzone mit dem Vorland hatte nicht den Charakter einer Randsenke, sondern einer Naht, ähnlich wie z. B. die Aufschiebung der Kaledoniden auf den baltischen Schild in Norwegen oder des S-Teils der Werchojanskzone auf den Aldanschild (N. S. Schatski 1947).

Zum Unterschied von einer Naht im Vorfeld der austrischen Kreidenfalten bildete sich in diesem Abschnitt während der laramischen Bewegungen zu Beginn des Paläogens eine breite Randsenke durch das Absinken der exotischen Scholle. Ähnlich wie bei der randlichen Querstruktur der Tafel des früheren Beskidengrabens war auch diese Randsenke die westliche Fortsetzung der Randsenke in den Ostkarpaten, die auf Kreide zurückging. Der westkarpatische Teil der Randsenke umfaßte im Paläogen neben dem Gebiet des kretazisch-paleozänen Beskidengrabens auch das magurische Sedimentationsgebiet, das auf den gesunkenen ehemaligen „Außenwinkel" der Tafel zurückging. Das Vorhandensein des magurischen Sedimentationsgebietes unterscheidete als spezifische Neubildung im Paläogen das Sedimentationsgebiet der Flyschzone der Westkarpaten von dem Sedimentationsgebiet der Flyschzone der Ostkarpaten. In struktureller Hinsicht waren jedoch im Paläogen beide Gebiete eine einheitliche Randsenke des Faltensystems.

Während der *pyrenäischen Bewegungen* im oberen Eozän ging jedoch das Sedimentationsgebiet der magurischen und silesisch-Těšnovicer Einheit größtenteils unter und bildete sich in ein Denudationsgebiet um (siehe z. B. Z. Roth & cons. 1962b; E. Hanzlíková — Z. Roth 1963a). Da wir in der Schlußphase der Flyschsedimentation des oberen Eozäns beider Einheiten kein Seichterwerden beobachten, müssen wir voraussetzen, daß die Unterbrechung der Sedimentation eher durch eine Faltung der Hülle verursacht wurde als durch epirogenetische Hebung der tief gesunkenen vorpermischen Unterlage. Daraus können wir schließen, daß zufolge der pyrenäischen Faltung der äußere Nordrand der geosynklinalen Faltenzone sich über den ganzen magurischen Sedimentationsraum bis zum mittleren Teil des ehemaligen Beskidengrabens vorschob.

Zum Unterschied von den laramischen Bewegungen bildete sich bei den pyrenäischen Bewegungen (ähnlich wie früher bei den austrischen Bewegungen) ein neuer Bogen der karpatischen Falten an dem Südrand der nordeuropäischen Tafel. Gegenüber dem ähnlichen mittelkretazischen Bogen war der neue Bogen in der Richtung des ehemaligen Beskidengrabens nach NW verschoben. Daraus könnten wir vielleicht schließen, daß der alte Tafelrand mit dem austrisch-laramischen Innenwinkel an der Grenzscheide des Sedimentationsraumes der West- und Ostkarpaten unterging und daß sich weiter gegen NW ein neuer Tafelrand mit einem pyrenäischen Innenwinkel bildete.

Wir werden nun versuchen, diese Änderung des südlichen Tafelrandes auch nach der gesetzmäßigen Entwicklung der Tafelrandstrukturen zu verfolgen, wie sie von Schatski (1945—1948) festgestellt wurde. Bei der Analyse der geologischen Verhältnisse zur Zeit der Neubildung des Bogens der pyrenäischen Falten gelang es uns nicht, eine querlaufende jungeozäne Randstruktur vom Typ des Anadarkobeckens, des Beskidengrabens u. ä. festzustellen. Nach der vergleichenden Studien N. S. Schatski's (1946 b) existieren jedoch auch Innenwinkel der Tafeln ohne randliche Querstrukturen (keineswegs umgekehrt). Nichtsdestoweniger werden wir zu erforschen versuchen, ob an den Bogen der pyrenäischen Falten der Karpaten genetisch nicht eine weniger deutliche Querstruktur gebunden ist, die sich etwa durch Elevationen vom Typ Wichita, Red River u. ä. äußert, oder ob und wann sich eine ähnliche Querstruktur im Laufe der weiteren Entwicklung nachweisen läßt. Dadurch werden wir unsere Schlußfolgerungen über die Entwicklung des Tafelrandes kontrolieren können.

Wir konnten schon in den früheren Studien feststellen, daß die subsilesisch-Ždánicer Serie in ihrem beskidischen Abschnitt durch Menilitschichten abgeschlossen ist, während dieselben in dem Ždánicer Abschnitt in ihrem Hangenden noch mächtige Ždánice—Hustopečer Schichten aufweisen (Z. Roth 1960, 1962a; Z. Roth & cons. 1962a). Da sich im untersten Teil der Ždánice—Hustopečer Schichten bei Kyjov auch Konglomerate mit Gesteinen der silesisch-Těšnovicer Einheit vorfinden (E. Hanzlíková — Z. Roth 1963a), können wir annehmen, daß der Ždánicer Abschnitt der subsilesisch-Ždánicer Einheit eine mit Ždánice—Hustopečer Molasse (Z. Roth 1961) gefüllte Randsenke darstellte, während der benachbarte beskidische Abschnitt eine erhöhte Scholle im Vorland der pyrenäischen Faltenzone war.

Nach Schatski's Analysen (1947) bilden die Randsenken eine Strukturform des Tafelrandes. Auch nach unseren früheren Analysen setzten sich die Sedimente der subsilesisch-Ždánicer Einheit, deren jüngster Teil uns nunmehr als Sedimentfüllung der obereozänen (und jüngeren) Randsenke erscheinen, auf einer Unterlage ab, die einen Bestandteil der Tafel bildete und auch weiterhin bildet (siehe z. B. Z. Roth 1957, 1960; T. Buday 1961). Darum bezeichnet der Beskider Abschnitt der subsilesisch-Ždánicer Serie den damals erhöhten Block auf dem Tafelrand und der Ždánicer Abschnitt zugleich einen gesenkten Block. Man könnte daher vielleicht schließen, daß der erhöhte Block, auf dem sich eine wirkliche Randsenke weder im jüngsten Paläogen noch später

bildete, ein Bestandteil einer pyrenäischen randlichen Querstruktur der Tafel ist, die an einen neu entstandenen pyrenäischen Innenwinkel der Tafel gebunden ist.

Verfolgen wir jedoch die Bewegungen der beiden Abschnitte der subsilesisch-Ždánicer Einheit in die Vergangenheit, so sehen wir, daß der Beskider Abschnitt schon vom Paleozän an stieg, während der Ždánicer Abschnitt gleichzeitig sank. Es handelt sich also um eine viel ältere Bewegung, die eher mit den laramischen als mit den pyrenäischen Bewegungen begann. Nach N. S. Schatski's Forschungen (lc. 1947) entstehen Randsenken in Abschnitten, in denen die gefaltete Unterlage der Tafel schon vorher relativ tiefer lag als in der Nachbarschaft. Es handelte sich also sowohl im Ždánicer als auch im Beskider Abschnitt um eine vormalige epirogenetische radiale Bewegung der Blöcke, welche noch länger vorher eine entgegengesetzte Höhenlage eingenommen hatten (Z. Roth 1960, 1962b). Wir können daher die hohe Lage des Beskider Abschnittes *nicht* als Ergebnis der pyrenäischen Bewegungen und darum als strukturelle Analogie der Aufwölbungen von Wichita, Arbuckle u. Ä. in dem randlichen Quersystem Wichita auf der nordamerikanischen Tafel betrachten (N. S. Schatski 1946b). Es ist daher nicht möglich, in der hohen Lage des Tafelblocks des Vorlandes der pyrenäischen Faltenzone den Beweis einer Querstruktur zu sehen, die genetisch mit dem neuen bogenförmigen Verlauf des äußeren Randes der karpatischen Falten verbunden wäre. Wir haben *keinen Beleg* dafür, daß sich dem neu entstandenen bogenförmigen Verlauf des Außenrandes der Falten gleichzeitig auch der Umriß der Tafel durch Bildung eines neuen Innenwinkels angepaßt hätte.

Obwohl N. S. Schatski nicht untersuchte, unter welchen Bedingungen es in den Innenwinkeln der Tafel nicht zur Bildung randlicher Querstrukturen kommt, können wir in unserem Falle nach älteren Analysen (Z. Roth 1960, 1961a; Z. Roth & cons. 1962a) voraussetzen, daß die Kontur der Tafel hier während der pyrenäischen Bewegungen unverändert blieb. Durch die Faltung wurden nur die Sedimente der paläogenen Randsenke erfaßt. Die sedimentäre Hülle begann sich wahrscheinlich schon damals, auf der inneren karpatischen Seite der Randsenke von der Unterlage abzulösen. Es begann wahrscheinlich auch die Unterschiebung des exotischen Blocks unter den Block der Zentralkarpaten (siehe H. Stille 1953; Z. Roth & cons. 1962a; E. Hanzlíková — Z. Roth 1963b). Wir werden jedoch die Entwicklung in diesem Abschnitt der Westkarpaten weiter verfolgen.

Die *savische Phase* äußert sich hier im interval zwischen Aquitan und Burdigal (siehe T. Buday 1961) als weitere Intensitätssteigerung der pyrenäischen Falten. Die Abscherung der Sedimenthülle von der alten Unterlage drang nach außen bis zum Rand der pyrenäischen Falten. Im äußeren Randteil der pyrenäischen Falten entstand eine Deckenüberschiebung. Mit der Magura-Einheit überschob sich auch die silesisch-Těšnovicer Decke auf die Sedimente der sub-

silesisch-Ždánicer Einheit. Die subsilesisch-Ždánicer Sedimente wurden bei den savischen Bewegungen nur in Falten von großem Radius gewellt, blieben jedoch eine autochthone Hülle der Unterlage (siehe z. B. T. Buday 1961; Z. Roth — E. Hanzlíková — I. Cicha 1963).

Savischen Alters sind vielleicht im wesentlichen die Faltenstrukturen im inneren Teil des beskidischen Abschnitts der silesisch-Těšnovicer Einheit (die Strukturen Zubří — Pindula, Kobylská, Staré Hamry, Predmier in den Mährisch-Schlesischen Beskiden). Diese Strukturen werden zuweilen für jünger als unterer Torton gehalten (E. Menčík 1960 in Z. Roth & cons. 1962 b). Nach einer tektonischen Detailanalyse durch J. Foldyna (1962 mnscr.) handelt es sich jedoch um ältere Strukturen.

Der äußere Rand der karpatischen Falten verschob sich in der savischen Phase bis zur äußeren Grenze des Sedimentationsraumes der subsilesisch-Ždánicer Einheit.

Während der *steirischen Phase* löste sich auch die subsilesisch-Ždánicer Einheit von der alten Unterlage ab und bildete sich zu einer Decke aus. Die äußere Grenze der Falten von großem Radius überschiebt sich breit in das Vorland der Karpaten (siehe Z. Roth 1961b; J. Strnad 1962). Es kommt zu einer Rückverschiebung der Flyschzone auf den zentralkarpatischen Block (Z. Stráník — Z. Roth 1960; Z. Roth 1959, 1961). Strukturstudien führten mich zur Schlußfolgerung, daß sich die subsilesisch-Ždánicer Einheit während der steirischen Faltung wie Schuppen in dem sinkenden Teil des Vorlandes aufhäufte. Dies wird durch die häufigen umgekippten Flügel der liegenden Falten bewiesen (Z. Roth — E. Hanzlíková — I. Cicha 1963).

Die hohe und niedrige Lage der konsolidierten Unterlage des Tafelblocks äußerte sich durch die Entstehung der nachpyrenäischen Randsenke im Ždánicer Abschnitt des westlichen Teils der tschechoslowakischen Flyschzone der Karpaten und die Entstehung einer Struktur von eher Randnahtcharakter während der älteren steirischen Bewegungen im beskidischen Abschnitt desselben Gebiets (siehe schon V. Uhlig 1903). Dieser Charakter blieb bis zum Ende des Karpatiens (Oberhelvet s. l.) erhalten. Während dieses ganzen Intervalls bildete die Störungszone in der Umgebung von Hranice die Grenze zwischen den Abschnitten der Vorsenke und der Naht.

Im oberen Torton beobachten wir, daß sich im Vorfeld des Bogens der karpatischen Falten zwischen Olomouc und Kraków eine Querdepression am Tafelrand von neuem zu bilden beginnt. Es handelt sich um einen einfachen Quergraben, der parallel mit dem Beskidengraben nach NO verschoben ist. Diese Depression wurde durch eine Bucht gefüllt, die in der NW-Fortsetzung der karpatischen Randsenke in Polen lag und in die Umgebung von Opava reichte (I. Cicha — J. Paulík 1960 in Z. Roth & cons. 1962b).

Aus der Bildung dieser nicht sehr großen, jedoch typischen Querstruktur am Rand der Tafel können wir nach den Analysen von N. S. Schatski (1945—

1948) darauf schließen, daß der vorpermische Teil der exotischen Scholle, der sich während der pyrenäischen, savischen und älteren steirischen Bewegungen, wie wir sahen, als Bestandteil der Tafel geltend machte, während der jüngeren steirischen Bewegungen zwischen dem Unter- und Obertorton sichtlich von der Tafel abgesondert wurde. An dem Südrand der nordeuropäischen Tafel entstand dadurch ein neuer Innenwinkel.

Darin sehen wir den Beweis der wesentlichen geologischen Bedeutung der jüngeren steirischen Bewegungen für den Bau dieses Südrandabschnittes der nordeuropäischen Tafel und für den Bau des die Ostalpen und Karpaten umfassenden Faltensystems. Gleichzeitig individualisierte sich die Flyschzone in den Westkarpaten (zum Unterschied von den Ostalpen — siehe M. Mahel', 1960 — und einem Großteil der Ostkarpaten) als bilaterale tektogenetische Zone sowohl gegenüber dem Vorland, als auch dem zentralkarpatischen Hinterland (Z. Roth 1961b). Strukturell schloß sich hier nach Osten an die Flyschzone der Westkarpaten auch das Marmaroschmassiv der Ostkarpaten, das wenigstens teilweise auch nach S übergeschoben wurde (V. Ianovici & cons. 1961).

Bei diesen Bewegungen kam es zu einer beträchtlichen Annäherung zwischen der Vorlandtafel und dem zentralkarpatischen Block. Ziehen wir die Verschiebungen an dem äußeren und inneren Rande und die inneren strukturellen Komplikationen der Flyschzone in Betracht, so muß die Annäherung der der Flyschzone benachbarten Punkte in der eigentlichen steirischen Phase etwa 50 km betragen haben.

Schlußfolgerungen

1. Der Sedimentationsraum der Flyschzone der Westkarpaten entstand und entwickelte sich als alpidische Randstrukturen der nordeuropäischen Tafel.

2. Die strukturelle Entwicklung des Sedimentationsraumes der Flyschzone der Westkarpaten verlief in zwei grundlegengen Etappen, wovon die erste dem höheren Jura und der Kreide entspricht, während die zweite zum Paläogen und dem älteren Neogen gehört.

3. Die erste Etappe ist durch die Existenz des Beskidengrabens gekennzeichnet, der eine fast 400 km lange und etwa 100 km breite Querstruktur (im Sinne N. S. Schatski's 1945—1948) am Rand der Tafel darstellte.

4. Die zweite Etappe der strukturellen Entwicklung umfaßte die Bildung und den Untergang einer typischen Randsenke, die kontinuierlich den Nordrand der alpidischen Faltenzone begrenzte.

5. Der wichtigste Vorgang während der alpidischen Entwicklung des Sedimentationsraumes der Flyschzone der Westkarpaten war der Regenerationsprozeß, bei dem von dem Südrand der Tafel die sog. exotischen Scholle abgelöst wurde.

6. Dieser Prozeß war in allen seinen Phasen die Ursache eines abweichenden

Charakters der Flyschzone der Westkarpaten von der Fortsetzung dieser Zone sowohl in den Ostalpen, wie in den Ostkarpaten (siehe z. B. M. Mahel 1961). Der westkarpatische Abschnitt der Zone unterscheidet sich von dem ostalpinen und ostkarpatischen durch seine Ausdehnung, seinen lithologischen Charakter und seine strukturelle Stellung. Ein spezifisches Glied der Flyschzone der Westkarpaten ist die Maguragruppe und ihren spezifischen strukturellen Charakter (der sich teilweise auch in den Ostkarpaten geltend macht) kennzeichnet die Rückaufschiebung der Zone auf den Block der Zentralkarpaten. Für diesen spezifischen Charakter der Zone in den Westkarpaten wird hier eine genetische Erklärung vorgelegt.

7. Die einzelnen Phasen dieses Prozesses können durch die Gesetzmäßigkeit der strukturellen Entwicklung der Tafelränder begründet werden, wie sie von Schatski (1945—1948) untersucht wurden.

8. Zu einer Individualisierung der exotischen Scholle im Rahmen der Tafel kam es auf Grund der Bildung des jungkimmerisch-austrischen Beskidengrabens, der als einfacher randlicher Quergraben innerhalb der Tafel die exotische Scholle nach NO begrenzte. Eine mit dem Graben genetisch eng verbundene und zum Graben querliegende wenig ausgeprägte Struktur (Z. Roth 1960) sonderte die exotische Scholle von der Tafel ab.

9. Während der laramischen Bewegungen entstand durch Untertauchen der exotischen Scholle eine paläogene Randsenke als neue Form des Sedimentationsgebietes der Flyschzone der Westkarpaten.

10. Der vorpermische Teil der exotischen Scholle verblieb weiterhin ein Bestandteil der Tafel bis zum Ende des Karpatiens, während ihre Sedimenthülle während der austrischen und pyrenäischen Bewegungen schrittweise durch Abscherung zu einem Bestandteil der Karpaten wurde (siehe Z. Roth 1961a, b).

11. Erst während der jüngeren steirischen Bewegungen zu Beginn des Obertortons begann die Bildung einer neuen randlichen Querstruktur der Tafel in Oberschlesien, die auch gleichzeitig zeigte, daß der versunkene exotische Block aufhörte ein Bestandteil der Tafel zu sein.

12. Wenn wir von den Gesetzmäßigkeiten ausgehen, welche N. S. Schatski (1945—1948) durch seine Strukturanalyse an Tafelrändern festgestellt hatte, können wir schließen, daß die entscheidende Rolle in der strukturellen Entwicklung des Sedimentationsraumes der Westkarpaten *der jungkimmerische bis savische Innenwinkel der nordeuropäischen Tafel* spielte, der an der Grenzscheide zwischen den Sedimentationsräumen der West- und Ostkarpaten lag. Erst zu Ende des Karpatiens begann weiter westlich die strukturelle Bildung eines neuen, westlichen Innenwinkels des Tafelrandes.

13. Nach den von N. S. Schatski (1945—1948) gefundenen Gesetzmäßigkeiten und den Ergebnissen unserer früheren Analysen (siehe Z. Roth 1961a, b) können wir die im Jura und Neogen stattgefundenen Änderungen der

Tafelkontur im Abschnitt der Westkarpaten und die von ihnen abhängigen Änderungen des Verlaufs der Nordgrenze der alpinen Falten schrittweise rekonstruieren.

14. Die lithologischen Formationen der karpatischen Flyschzone sind größtenteils Formationen, die in der Randsenke oder im parageosynklinalen randlichen Quergraben der Tafel entstanden.

Geologische Zentralanstalt,
Prag

LITERATUR

[1] Andrusov D., 1931: Étude géologique de la zone des klippes internes des Carpathes occidentales. Rozpravy SGÚ, 6, Praha. — [2] Andrusov D., 1938: Géologie de la Slovaquie. Slovensko a Podkarpatská Rus, sbírka příruček, Praha. — [3] Andrusov D., 1958, 1959: Geológia Československých Karpát I, II, Bratislava. — [4] Andrusov D., 1961: Les grandes nappes de recouvrement des Karpates occidentales. Geol. Práce, Zoš. 60, p. 5—9, Bratislava. — [5] Andrusov D. — Scheibner E., 1960: An Outline of the Present State of Knowledge about the Geology of the Klippenbelt between R. Vlára and T. Tvrdošín. Geol. Sbor. XI/2, Bratislava. — [6] Băncilă I., 1958: Geologia Carpaţilor Orientali. Bucureşti. — [7] Birkenmajer K. — Turnau E., 1962: Carboniferous Microspores as Secondary Deposit in the Aalenian Flysch of the Pieniny Klippen Belt (Carpathians). Bull. Acad. polon. Sci., Sér. Sci. géol. et. géogr. X/2, Warszawa. — [8] Buday T., 1961: Der tektonische Werdegang der Neogenbecken der Westkarpathen und ihr Baustil. Geol. Práce, Zoš. 60, p. 87—106, Bratislava. — [9] Buday T. — Kodym O. sen. — Maheľ M. — Máška M. — Matějka A. — Svoboda J. — Zoubek V., 1960: Tectonic Development of Czechoslovakia. Praha. — Eliáš M., 1961: Comment on petrographic Characteristics of the Inner — Carpathian Flysch in Relation to some Important Source Areas. Geol. Práce, Zoš. 60, 233—243, Bratislava. — [10] Filipescu G. M., 1955: Vederi noi asupra tectonicii flişului Carpaţilor orientali. Revista Univ. „C. I. Parhon" 6—7, Ser. Ştient. Nat., Bucureşti. — [11] Hanzlíková E. — Roth Z., 1963a: Valangin až maastricht flyšového pásma čs. Karpat. Geol. Sbor. XIV/1, Bratislava. — [12] Hanzlíková E. — Roth Z., 1963b: Litofacie, biofacie a sedimentační prostředí křídových vrstev flyšového pásma čs. Karpat. Geol. Sbor. XIV/1, Bratislava. — [13] Havlena V., 1956: Plant Spores of the Carboniferous Cannel Coal Pebbles from the Carpathian Cretaceous. Čas. Mineral. Geol. 1, p. 344—351, Praha. — [14] Ianovici V. — Giuşcă D. — Manilici V. — Gherasi N. — Jude R. — Gheorghiţă J. — Dimitrescu R., 1961: Aperçu général sur la géologie de la région de Baia Mare. Association géologique Carpatobalcanique, Veme Congrès, Bucarest. — [15] Książkiewicz M., 1954: The Jurassic and Cretaceous of Bachowice. Rocz. pol. Tow. geol. XXVI/2—3, Kraków. — [16] Książkiewicz M., 1957: Tectonics and Sedimentation in the Northern Carpathians. Congreso Geologico Internacional, XX^a Sesion, Seccion V (primer tomo) 227—251, Mexiko. — [17] Maheľ M., 1961: Tektonik der zentralen Westkarpaten. Geol. Práce, Zoš. 60, 11—50, Bratislava. — [18] Matějka A., 1960: Основные черты геологического строения флишевой зоны Западныцх Карпат. Материалы Карпато-балканской ассоциации 1, 55—62. Киев. — [19] Matějka A. — Roth Z., 1949: Preliminary Remarks to the Geology of the Moravo-Silesian Bezkydy. Sbor. SGÚ, XVI, 263—328, Praha. — [20] Matějka A. — Roth Z., 1956: The Geology of the Magura Flysch Group in the Northern River Basin of the Váh between Bytča and Trenčín. Rozpr. Ústř. Úst. Geol. XXII, Praha. — [21] Murgeanu

G. — Filipescu M. — Patrulius D. — Alexandrescu Gr. — Tocorjescu M. — Mutihac V. — Contescu L. — Săndulescu M. & J. — Mihalescu N. — Bratu E. — Bombiţa G. — Iliescu G. — Panin N. — Butac A., 1961: Aperçu général sur le crétacé de la courbure des Carpates. Association géol. Carpato-balcanique, Veme Congr., Bucarest. — [22] Patrulius D. — Motaş I. — Bleahu M., 1960: Геологическое строение Румунского Марамуреша. Материалы Карпато-балканской ассоциации, 1, 74—88. Киев. — [23] Roth Z., 1957: L'état actuel de nos connaissances de l'édifice de la zone du Flysch des Carpates Tchécoslovaques. Congreso geol. internacional, XX^a Sesión, Seccion V (primer tomo) 253—265. Mexico. — [24] Roth Z., 1959: Schlussfolgerungen der Erläuterungen zu der geologischen Karte der Tchechoslowakei 1:200 000, Blatt Trstená (NW—Slowakei). Věst. Ústř. Úst. Geol. XXXIV, 379—382. Praha. — [25] Roth Z., 1960: The Relation of the Sedimentation Area of the Czechoslovak West-Carpathians to the Czech Massif (from the Explanation of the map 1:200 000, Sheet Olomouc). Věst. Ústř. Úst. Geol. XXXV, 383—386. Praha. — [26] Roth Z., 1961a: Paleogeographical Features of the Western Part of Czechoslovak Flysch Zone of the Carpathians from the Point of View of the Relations of the Carpathians to the Bohemian Massif. Geol. Práce, Zprávy 21, 181—193, Bratislava. — [27] Roth Z., 1961b: Structure and geological Position of Moravo—Silesian Beskids (ČSSR). Geol. Práce, Zoš. 60, 65—85. Bratislava. — [28] Roth Z., 1962a: Zu Problemen des Flyschgebietes in den tschechoslowakischen Karpaten. Geol. Práce, Zoš. 63, 5—13, Bratislava. — [29] Roth Z., 1962b: Contribution to the Stratigraphy of the Subsilesian Group of Beds in Eastern Moravia. Sbor. Ústř. Úst. Geol., XXVII (1960), odd. geol., 447—473. Praha. — [30] Roth Z. & cons., 1962a: Vysvětlivky k přehledné geol. mapě ČSSR 1:200 000, M-33-XXIV — Olomouc. Praha. — [31] Roth Z. & cons., 1962b: Vysvětlivky k přehledné geol. mapě ČSSR 1:200 000, M-34-XIX. — Ostrava. Praha. — [32] Roth Z. — Hanzlíková E. — Cicha I., 1963: Ein Profil der Kreide- u. Paläogen-Schichten von Tiefbohrungen NP 298, 299 u. 300 (zwischen den Gemeinden Mniší und Lichnov, nördlich bis nordwestlich von Frenštát u. d. Radhošť) geführt. Čas. Mineral. Geol. 8, 49—60. Praha. — [33] Schatski N. S., 1961: Vergleichende Tektonik alter Tafeln. Fortschritte der sowjetichen Geologie 4, Berlin. — [34] Шацкий Н. С., 1945: О сравнительной тектонике Северной Америки и восточной Европы. Известия Акад. Наук СССР, сер. геол. 1945, 4. Москва. — [35] Шацкий Н. С., 1946a: Основные черты строения и развития Восточно-Европейской платформы. Ср. тект. др. платформ. Статья 1. Известия Акад. Наук. СССР, сер. геол. 1946, 1, 5—62. Москва. — [36] Шацкий Н. С., 1946b: Большой Донбасс и система Вичита. Ср. тект. древних платформ. Статья 2. Известия Акад. Наук СССР, сер. геол. 1946, 6. Москва. — [37] Шацкий Н. С., 1947: О структурных связах платформ со складчатыми геосинклинальными областями. Ср. тект. др. платформ. Ст. 3. Известия Акад. Наук СССР, сер. геол. 1947, 5, 37—56. Москва. — [38] Шацкий Н. С., 1948: О глубоких дислокациях, охватывающих и платформы и складчатые области (Поволже и Кавказ). Ср. тект. др. пл., Ст. 4. Известия Акад. Наук СССР, сер. геол. 1948, 5, 39—66. Москва. — [39] Шацкий Н. С., 1955: О произхождении Пачелмского прогиба. Ср. тект. др. платт., Ср. 5. Бюллетен Московского овщества испыт. природы 30, 5, 5—26. Москва. — [40] Schatsky N. — Bogdanoff A., 1957: La carte tectonique de l'USSR. Congreso geol. internacional, XX^a Sesión, Seccion V (primer tomo) 267—287. Mexico. — [41] Scheffer V., 1960: Some Contributions to the Geophysical Knowledge of the Carpathian Basins. Acta technica Acad. Sci. Hungar. XXX/3—4, 423—461, Budapest. — [42] Šilar J., 1956: Vorkommen karbonischer Kohle in senonischen Konglomeraten im Tale der Váh bei Púchov. Čas. Mineral. Geol., 1, 334—343. Praha. — [43] Stille H., 1940: Einführung in den Bau Amerikas. Berlin. — [44] Stille H., 1953: Der geotektonische Werdegang der Karpathen. Beih. zum Geol. Jb. 8. Hannover. — [45] Strániк Z. — Roth Z., 1960: Note préliminaire sur les recherches géologiques dans le Čerhovské pohorie et dans l'Ouest de la partie de Bardejov

de l'Ondavská vrchovina. Zpr. geol. Výzk. 1958, Praha. — [46] Strnad J., 1962: Der Zusammenhang eines Teils des europäischen neogenen Vulkanismus mit dem kimberlitischen Magmatismus. Čas. Mineral. Geol. 7, 434—442, Praha. — [47] Uhlig V., 1903: Bau und Bild der Karpathen. Bau u. Bild Oesterreichs, 649—915. Wien. — [48] Wjalow O. S., 1960: Краткий очерк тектоники Восточных Карпат. Материалы Карпато-балканской ассоциации, 1, 5—30. Киев. — [49] Zoubek V., 1931: Carasteristique de quelques roches cristallophylliennes et éruptives des galets exotiques des conglomérats sénoniens et paléogènes des Carpathes occidentales. Knihovna SGÚ 13A, Praha.

MICHAL MAHEĽ

FOLDING PHASES AND FORMATIONS OF THE WEST CARPATHIAN MESOZOIC

West Carpathians represent a bigenetic mountain chain folded during two orogenic periods — Cretaceous and Neogene (Stille 1953). They form a twin geosyncline — Central Carpathian and the geosyncline of Flysch. The Central Carpathian geosyncline has been folded during the Middle and Upper Cretaceous while the other one — adjacent to the former both in time and space — has been the geosyncline of Cretaceous and Paleogene with a flysch filling and folded in the Lower and Middle Miocene.

The submitted article deals with the pronouncement of the orogenic process of the Mesozoic geosyncline during the rather calm Triassic — Jurassic — Lower Cretaceous period and also with Middle and Upper Cretaceous folding activity. In the analysis included are the fundamental units of Central Carpathians with Gemeridy units and Bükk Mts, further units of Choč, Krížna and Tatridy. Mentioned will be also the Klippen belt and Flysch belt.

Due to the described articulation all the particular expressions of the orogenic phases may be traced both in time and space.

The Carpathian Mesozoic geosyncline in most cases began with the Lower Triassic transgression after the Pfalcian orogenic phase. Its effects are proved in Central Carpathians including the Krížna unit (Zoubek 1930) with an apparent transgressive unconformable bed of lower detritic formation of Lower Triassic resting upon Verrucano or often upon older complexes. The independent distribution of the Lower Triassic quartzites and Verrucano (Biely 1962) as well as the apparent facial change further proves the existence of this orogenic phase in the more northern belts.

The relationship between the Lower Triassic and Permian in the more southern zones became far more complicated the boundaries less pronounced and in the

northern part of Gemeridy the existence of the Pfalcian orogenic phase is already far from certain. Farther southward as for example in the synclinorium of the South Slovakia Carst region a more intense effect of this phase is unlikely because in the Hungarian Bükk Mts the Permian — Lower Triassic boundry is a transitional, gradual one. In this region the transgression passed already in the Upper Permian (B a l o g h 1961). From this point of view very important is also the tectonic relationship of Permian with Mesozoic structures of the southern belts of Carpathians.

Relatively weak pronouncement of another orogenic phase may be observed in the more northern belts between Campillian and Anissian proved by the break of sedimentation, erosion and formation of basal breccias at the bottom of the Vysoké Tatry mantle series Anisian limestone-dolomite complexes (K o t a ń s k i (1961). This new phase resulted in a sudden change of the lower detritic formation in majority of the mantle series as well as in the Krížna unit. The change were expressed in the replacement of detritic by a carbonatic sedimentation same as the agitated Lower Anissian sedimentation with frequent occurence of endostratic breccias and vermicular limestones.

The southern zones have not been apparently effected by this younger phase and also the transition from the Lower Triassic detritic formation into the limestone-dolomitic has been fairly gradual. Both the phases mentioned appear somewhat earlier in the southern zones then in the northern zones of Central Carpathians.

An apparent change in sedimentation came at the beginning of Upper Triassic as a result of L a b i n i a n o r o g e n i c p h a s e effecting the mantle series by the break of sedimentation. Above the Ladinian dolomites appear usually the Carpathian Keuper facies of continental — lagoonal origin with the sedimentation of variegated deposits — sandstones and conglomerates expressing the emerging of areas deeply eroded down to the crystalline basement. The great differences in thickness and composition of frequently neighbouring parts of certain series indicate an articulated relief and acting of faults during the sedimentation. Signs of agitation are observable throughout the Carpathian Keuper of the Mantle Series ranging stratigraphically from Karnian including Norian. The Labinian phase in the Choč belt resulted in the flysch-like sedimentation of the Lower Karnian Lunz beds interrupting the generally quiet character of the limestone-dolomitic formation of the Middle and Upper Triassic.

In the *Krížna unit* distributed partly at the southern margin of the mantle series and perhaps partly also in central depressions the Lunz beds form only a few metres thick layer within dolomites thus demonstrating the weak pronounciation of the Labinian orogenic phase at the Ladinian—Karnian boundary. A far more apparent change in sedimentation may be observed in the Upper Karnian or lowermost Norian, where the limestone-dolomitic sedimentation is

terminated by Carnian dolomites overlain by Carpathian Keuper. Rhytmic alternation of sandstones, shales and dolomites as well as the structures and textures of these sediments show a non-stable environment and the oscillation of the basement. Marine fossil remnants in the dolomites document their marine origin. All the mentioned features show repeated marine transgressions resp. ingressions. Upper Triassic of the mantle and Krížna unit is generally characterized by very agitated environment with a rapid sedimentation change effected by several marine ingressions due to which the dolomite beds appear in between sandy shale sequences of the lagoonal — continental origin.

In the *units extending south of the Choč belt* the Upper Triassic orogenic phase resulted only in the formation of thin intercalations of dark shales with subordinated sandstones appearing in the northernmost parts of Gemeridy unit — i. e. northern Gemeridy syncline. In the zones extending more to the south this orogenic phase is only poorly pronounced.

Extensive changes in the paleogeography of Carpathian geosyncline are related to the Rhaethian orogenic phase (Paleokimmerian). To the Paleokimmerian phase related were the termination of carbonatic-dolomitic sedimentation throughout the West Carpathian geosyncline and the beginning of new formations with different facial types, another more dynamic relief, as well as a different paleogeographic environment. Paleokimmerian phase represents a basic change in the gesynclinal evolution—the boundary of two development stadii. Its effect upon all the belts however has not been synchronous; some series bear evidence of several following phases. In the Vysoké Tatry series (Passendorfer 1961) for example the transgression appears at the beginning of Rhaetian, at some places in later Rhaetian and at the other even at the beginning of Sinemurian (Radwański 1959).

In the *Krížna unit* the change of sedimentation and the beginning of new formation are related to the early Rhaetian transgression. The variability of facies in Rhaetian as well as the sudden horizontal and vertical changes of lithofacies within short distances are due to the rapid changes of sedimentation conditions (mainly bathymetric). No expressive disconformity between both formations are observed in the *Choč unit*. The boundary in some of the structures occur at the beginning of the Liassic basis.

Also in the *northern and southern Gemeridy zones* the Rheatian limestones represent the uppermost member of similar calcareous sedimentation; the new formation beginning most probably only by Lotharingian. The sedimentation break and angular disconformity of Stratenská hornatina mts. (Geráv Hill ridge; Mahel' 1957) indicates an intense effect of the Paleo-kimmerian phase in the Interior Carpathians, accompanied perhaps by folding.

Obviously the effect of *particular folding phases* in particular Carpathian belts during Triassic as to the intensity and timing appears very different. All these

orogenic phases resulted in the change of sedimentation, some of the phases were expressed in an agitated sedimentation for a longer period (mainly during the Upper Triassic). The Paleokimmerian phase represented a very complicated both in time and intensity iregular action within every particular belt. This phase most probably led to folding in the interior Carpathians or Gemeridy units and to the change of sedimentation throughout the entire West Carpathians.

Basing upon the analysis of the tectonic pulse effect during the Triasic two fundamental geotectonic belts may be distinguished. The regions have different sequences of facies in particular development stages i. e. with differing formations and different chronological range as well. They are the Choč-Gemeridy belt in the south and Tatridy-Krížna belt in the north. The boundary is represented by the Veporidy zone the northern portion of which belongs to the northern and the substantial, remaining part to the southern belt.

Initial stage of the Alpine Geosyncline-period of detritic sedimentation in the southern belt ranged from Upper Permian to Middle Campillian characterized by the shale — sandstone formation with products of volcanic activity. Lower Permian facies are usually of lagoonal type. In the northern belt as an equivalent is regarded the Lower Triassic quartzite formation of a very apparent transgressive and disconformable character. Great differences between the two belts arose during the period of carbonatic sedimentation. This period in the southern belt ist represented by the limestone-dolomitic formation ranging from Upper Campillian to Rheatian, while in the northern belt by the dolomitic Keuperian formation within the stratigraphic range of Anissian-Norian. Besides frequent dolomitic facies especially characteristic is the facies of Carpathian Keuperian.

The *new post-Paleokimerian development* possess a different facial arrangement and far more variability as to the number and bathymetric character of facies than the former one. During the Triassic period the shallow-water facies predominated with only a slight difference. The younger stage including Jurassic and Lower Cretaceous besides shallow-water facies (spongolites, crinoid, limestone, oolitic and coquina limestone, reef limestone) contain also many bathyal facies (spotted marlstone, Aptyches limestone, mud limestone of Biancone type, marly concretionary limestone, radiolarian limestone and radiolarites). Scattered occurs also the facies of dark marlstones and silicites characterizing an oxygen poor non — ventilated environment. The lateral changes among facies are very sudden. Apparently the sedimentation area has been differentiated into swells with shalow-water or cordillera type of sedimentation and troughs with predominating bathyal facies.

Paleogeographic change after the Paleokimmerian phase is related also to the change of the geosynclinal axis position from the interior Carpathians to the north into the Krížna and mantle series region with the geosynclinal environment

extending even to the Klippen belt. The interior Carpathian region together with the Choč unit (i. e. the areas with most intense sedimentation and articulation during the Triassic) show a less variegated development. The change of position of geosynclinal axis accompanied by paleogeographic changes due to the Paleokimmerian phase were a logic result of movements of orogenic masses in the subcrustal basement (Kraus 1960).

The differentiation in *two geotectonic belts* were thus valid also in the new development stage. In the southern-less articulated belt the majority of series is supposed to belong to spongolite — marl — limestone facies. In the northern belt marlstones, radiolarian hornsteins, spongolites and crinoidal limestones prevail. This formation is characterized by the presence of two principally different types of facies — one is the trough-type facies (marlstones and radiolarian hornsteins) the other the facies of swells or cordilleras (spongolites and crinoidal limestones). The last type reflected sensitively the tectonic effect expressed in the break of sedimentation, formation of conglomerate beds and strong erosion (Vysoká series — Maheľ 1959). Sudden changes in the shallow water facies within short distances are observed mainly in Doggerian. Obviously also many faults originated during that time or former faults were activized dissecting the sedimentation areas into blocks of different tectonic activity. Similar phenomena in the Vysoké Tatry series as well as the erosion effect and at some places also the transgressive character of Bajocian and Bathonian are connected with the Agazsian orogenic phase (Kotański 1962). Malmian seems to be principally the calmest period when the balancing of facies took place together with the bathyal maximum.

Revival of tectonic processes occured in *Tithonian* when shallowing was observed and in western parts of Vysoké Tatry slight volcanic activity took place characterized by extrusions of limburgites and their tuffs.

The disturbance of sedimentation increased in Neocomian; extensive stratigraphic hiatuses were observed in the cordillera series (the majority of mantle series, Belanská and Czorstyn series) or occasionally pronounced shallowing of environment (Malé Karpaty series — Maheľ 1959; Vysoké Tatry series and Havran series — Passendorfer 1931). In the depressions the shallowing came usually at the end of Neocomian eventually in Aptian, but occasionally also in Upper Hauterivian. The volcanic activity during the Neocomian is expressed in the form of tuff intercalations.

Sediments younger than Intravalangian throughout the southern belt represented by the spongolite—marl—limestone formation are not known. The geosynclinal sedimentation obviously terminated here earlier than in the northern zones. Suggestions of that sort are based not only upon the lack of higher Neocomian and Albian membres but also several other observations as for example Valangian of the Choč unit of Strážovská hornatina Mts. bears evidence of

regression. It is remarkable however, that the northern spur ot the Hungarian Central Hills (Gerecse Mts) shows flysch development already in Valangian (Fülöp 1959). Sedimentation break and the start of the development stage of new formation may be related to the Neokimmerian phase.

An essential change occured also in the development of northern Carpathian belt between Aptian and Albian during the Austrian orogenic phase, terminating the previous stage, represented by the radiolarian sandstone formation with minor share of detritus in the particular lithofacies (with the exception of Liassic lithofacies). In the new formation the flyschoidal facies predominated with a substantially greater share of clastic components. The Flysch facies are accompanied by gray and variegated marls and marly shales characteristic mainly for the Middle Cretaceous of the Klippen belt as well as for the Lower Albian beds of certain Mantle series (Manín, Vysoké Tatry, Malá Fatra, Tribeč, Malá Magura). Tremendous amounts of Albian sediments are found in the Central Carpathian Klippen-near marginal zone (e. g. Manín series). Similar thicknesses of Albian are observed also in the northern marginal sediments of the Krížna unit regarded however as a tectonic accumulation at the nappe front. This fact is in an apparent contrast with the poor development of Albian in the southern zones of this unit as for example in Nízke Tatry Mts. eventualy in the adjacent Veľký Bok series representing the southern marginal rim of the Krížna unit.

Basing upon the facts mentioned drifting of the geosynclinal axis northward may be suggested. Moreover it is necessary to remark that beginning with the Austrian orogenic phase in the so far from the Alpine-inferior Europe (Roth 1962) undifferentiated Flysch belt started the formation of a separate miogeosynclinal sedimentation area.

Similarly in the northern Central Carpathian region the Austrian orogenic phase lacks an angular uncorformity the existence of which would confirm an effective folding. This orogenic phase resulted only in the break of sedimentation accompanied by erosion and formation of carst phenomena on the Aptian limestone surface as well as in the transgressive character of the Middle Albian glauconitic limestones with exotic boulders (Vysoké Tatry series — Passendorfer 1938).

The hiatus in Mantle series were generally longer in some of them ranging from the Lower Neocomian to Upper Albian (Malá Magura series — Maheľ 1961) an in others from Upper Barremian or Lower Aptian to Middle Albian (Malé Karpaty series — Maheľ 1960). In the Manín series the Aptian limestones with eroded surface are overlain in different areas by various members ranging from Lower Albian to Cenomanian. The lack of Neocomian below Albian of Mantle series or its minute thickness are probably due to a weak folding.

The break of sedimentation or even hiatus have been observed in certain cross-

sections of the Krížna unit, sometimes also within the range of Upper Hauterivian—Albian (Cross-section near Zliechov inm Strážovská hornatina Hills; M a h e ľ 1961) at some other places the break comprised the Upper Barremian—Lower Albian (Veľká Fatra Mts near Ružomberok; K a n t o r o v á — M a h e ľ 1960). The effect of Austrian orogenic phase is further proved by A/K absolute age determinations (K a n t o r 1957). Mylonites and diaphtorites of the Račková dolina Valley in Liptovské Tatry Mts show 109 mil years, tectonic deformation of Tribeč series — keuperian 95 mil years. Paleontologically determined glauconitic limestone of Vysoké Tatry series (equall to the Hoplites dentatus horizon (of Middle Albian age showed 88 mil years; K a n t o r 1960). Not less important were also the determination of thick conglomerate beds containing pebbles of older Mesozoic membres and crystalline masses as well. Poor grading and the composition of these conglomerates in the Malá Magura series, Žiar series (M a h e ľ 1961) and Krížna unit of Tribeč Mt. (B i e l y 1962) indicate a cordillera origin. Their formation is related to pressure phenomena. Conglomerates do not belong to the basal transgressive sediments yet they appear in various stratigraphic horizons predominantly in the lower part of Albian flysch sequences. All these facts indicate that the course of Austrian orogenic phase has not been a uniform one.

All the abovementioned facts prove sufficiently the great extent of Austrian phase over the northern belts of Central Carpathians. Its low intensity in the northern belt of Central Carpathians however is indicated by the distribution of Albian and Cenomanian in normal stratigraphic position of the Krížna unit series, in Mantle series and in the Klippen belt (Regardless to the existence of cross — sections showing its position over the Jurassic membres).

For the N e o c o m i a n - A l b i a n o r o g e n i c p h a s e the term Austrian were introduced instead of the previous Pieniny phase (M a t ě j k a — A n d r u s o v 1931) or Manín phase (A n d r u s o v 1960) due to the fact, that the previous terms expressed only its local relations. This phase however is important for the whole Carpathian region representing even one of the most important orogenic phases of the whole Alpine system.

In the conception of the early thirties (M a t ě j k a — A n d r u s o v 1931) and after the later phase at the Aptian — Albian boundary in the Klippen belt. This the s. c. Pieniny orogenic phase at the Aptian — Albion boundary in the Klippen belt. This the s. c. Pieniny orogenic phase was regarded as the cause of formation of the Pieniny and Vysoké Tatry nappes. The Albian—Cenomanian sequences were regarded as a uniform series i. e. the lower klippen mantle covering tectonically accumulated sediments of several Klippen belt series. Upper Cretaceous were regarded as s. c. upper Klippen mantle of transgressive and sometimes disconformable character, originated after a Turonian—Coniacian hiatus. All the above facts and the occurence of variegated pebbles in the s. c. Upohlav conglomerates led to the suggestion on the existence of a separate orogenic phase between Cenomanian and Senonian — the S u b h e r c y n i a n p h a s e. The major effect of this phase upon the Central Carpathian structure were seen in the overthrusting of Subtatric nappes in Malé Karpaty Mts., where the Cretaceous in Gosau facies were of clearly transgressive nature overlying the s. c. higher — Nedzov and Jablonica nappes.

As the main folding phase in Central Carpathians has been regarded the Laramian orogenic phase, supposed to be responsible for thrusting of Subtatric nappes. As a proof of this theory served the transgressive character of Middle Lutetian and the front part of Subtatric nappes thrusted over the Klippen belt mantle formed by Middle and Upper Cretaceous sequences.

All these augestions have been substantially changed in the recent years due to the extensive studies carried out in the Klippen mantle mainly in the lower mantle (Birkenmajer 1957; Andrusov 1960; Andrusov — Scheibner 1960).

Inclusion of the Albian—Cenomanian and sometimes Turonian as the youngest membres of the Jurassic-Lower Cretaceous series led to the abolition of existence of the Lower Klippen mantle uniform for the whole Klippen belt and Manín series. It has been suggested further that the Pieniny nappes (including Manín) have originated during the Subhercynian orogenic phase (Andrusov 1960; Andrusov — Scheibner 1960). This way not only the chronology of thrusting but also the stratigraphic-lithologic range of nappes were substantially changed. The Albian—Cenomanian flysch sequence is now all included in the nappe of Manín i. e. complexes suggested before as lower Klippen mantle. This change of opinions is based upon the change of tectonic inclusion of Albian—Cenomanian flysch — like sequence suggested before as a transgressive member over the thrusted nappes i. e. as a post-tectonic member — i. e. as stratigraphic mantle.

Recently the flysch-like Albian-Cenomanian sequence is regarded as tectonic mantle; being understood as a part of extensive — Manín nappe covering the Klippen belt with a deep-water development of Middle Cretaceous members. The relation of the Albian-Cenomanian flysch-like sequence to the Pienidy nappes however remained further the criterion for the distribution of orogenic phases. Changed is only the interpretation of this relation being now substantially more dynamic because of the inclusion of Middle Cretaceous in the nappes. Due to the facial variability of Middle and Upper Cretaceous this theory is sometimes obscure. Due to this also the effect of *Austrian phase* were reduced only to local activity in the Manín zone or in the inferior cores (Vysoké Tatry) together with introduction of a new term — *Manín phase* (Andrusov 1960) Simultaneously the effect of subhercynian phase upon the whole Central Carpathians and Klippen belts well were emphasized. The discovery of Upper Cretaceous sequence in the Šumiac vicinity, resting unconformably over the Triassic and Liassic membres of the Muraňska plošina plateau Mesozoic, which were regarded as an extensive nappe originated before the sedimentation of this Upper Cretaceous sequence (Bystrický 1959) supported this suggestion. In the previous parts we have emphasized the importance of Austrian phase in Central Carp. Concerning the effect in the Klippen belt suggested before as the main domain of this phase — this problem will be delt with later.

The Subhercynian orogenic phase is recently regarded for the formation of nappes as the most important not only in the Klippen belt but throughout the Central Carpathians (Andrusov — Bystrický 1959; Andrusov 1961) in accordance with Stille (1953) analogically to Eastaern Alps and Eastern Carpathians. This suggestion is supported mainly by the transgressive character of Upper Cretaceous and geochronological measurements (Kantor 1960).

The main role of the Subhercynian phase however is valid only if tectonic phase is regarded as a single action of uniform intensity throughout the mountain chain and if to such an action both the formation of nappes and folded structurs are included. So far however such an idea our observations of tectonics, stratigraphy and sedimentology.

The effects of Subhercynian orogenic phase may be well studied in the southern zones of West Carpathians. The position of Senonian in the northern margin of Muránska plošina plateau (Bystrický 1959) as well as in the Hungarian Bükk Mts is clearly transgressive and unconformable. The geochronological studies of Vepor crystalline diaphtorites (74—84 mil. years) determined the age of the last folding in the area corresponding to Cenomanian — Turonian boundary including the period of Subhercynian phase. Younger orogenic phases in the southern zones were already only of german-type character. This however does not prove that the formation of all tectonic structures is due to the Subhercynian phase in the interior Carpathian belts and the less in the whole Central Carpathians.

The analysis of the tectonics in Muránska plošina plateau Mesozoic series and in the crystalline basement shows evidence of at least two folding phases. To the one of them is related the formation of crystalline basement structures, folding and metamorphosis of the mantle series and to the other one the overthrust of Muránska plošina Pl. Mesozoic and the whole NW portion Gemeridy well. Similarly in the western portion of Stratenská hornatina Hills at least two phases existed. The substantial part of Mesozoic of this region shows tectonic style having the synclines wide open and separated by broken, narrow anticlines, accompanied by upthrowing and thrusting. In the western portion of the region the structures are compressed into a narrow space, deeply folded, wedged and metamorphosed together with the Dobšiná (Foederata) series. After the discovery of mantle Mesozoic wedges of Dobšiná series in the front part of the Vernár zone (Biely 1961) the overthrusting character of Stratenská hornatina Hills is proved sufficiently. The thrusting took part evidently during one phase while folding by compression and inwedging with consequent metamorphosis in the other. The microtectonic elements within both the Mesozoic and its older basement indicate, that after the main phase with consequent compression, thrusting and upthrowing other new movements followed forming oblique and transverse slipping in Mesozoic thus disturbing the overthrust and upthrow planes. As indicated by their B-axes symmetry they are related to fading of the main compressive phase. The effect of on orogenic phase younger than thrusting process were detected also by means of microtectonic study of Gemeridy Carboniferous at the contact with Veporidy unit (Snopko 1963).

The Subhercynian orogenic phase has been the last and the most important one creating the Alpine tectonic style in southern zones of Carpathians. It represented a complicated process, having perhaps a predecessor in an orogenic phase of folding character most probably the Austrian phase. Such a suggestion would be in agreement with the recent results of K/A geochronological studies. Some diaphtorites of Vepor crystalline masses show an absolute age of 106—107 mil. years (Kantor 1960) corresponding approximately to uppermost Neocomian.

Approximately the same (pre-Albian) age 110—115 mil. years were indicated (Kantor 1959) also in Hrončok granite and minor granite intrusions in the northern zone of Vepor crystalline masses. Pre-Middle Cretaceous age is indicated by Gemeridy granites e. g. Betliar type 98 mil. (Kantor 1957).

The existence of orogenic phase in the northern zones of Central Carpathians is based upon the transgressive and disconformable position of Upper Cretaceous over the s. c. higher Subtatric nappes in Myjavská pahorkatina Hills, upon disconformities and hiatuses in the Cretaceous sequences and in the Klippen belt and finally upon the tectonic relation between the frontal segments of Subtatric nappes and Middle to Uper Cretaceous sequences as well as the Central Carpathian Paleogene.

The Upper Cretaceous transgression in Myjavská hornatina Hills over tectonically fabricated Mesozoic structures prove an expressive effect of Subhercynian phase. Upper Cretaceous beginning by Coniacian (Salaj 1960) developed in the Gosau facies show certain relations to the Eastern Alps where the main thrusting phases came before Senonian. This anomaly were further emphasized by its tectonic style regarded as such in times when the Laramian phase were suggested to be the main orogenic agent.

The disconformities of the middle of Cretaceous of the Klippen belt are regarded to be of great importance. Discussing the evolution of opinions on the role of tectonic phases the fundamental importance of changes by the stratigraphic distribution and inclusion of this sequence were emphasized. According to recent investigations (the newest investigations of Salaj 1962) the facial relations are complicated both in distribution and vertical changes. Important for example is the lack of pronounced unconformities between Cenomanian and Santonian and between Maestrichtian and Middle Lutetian quite recently regarded as an effect of Subhercynian and Laramian orogenic phases. Although our present state of knowledge is far from complete the presence of some stratigraphic hiatuses allows to dispute the cyclicity of sedimentation. This consequently makes the tectonic analysis or rather the timing of orogenic phases very difficult, and deserves special approach at the study of tectonic effects upon sedimentation in the geosynclinal evolution and special one in the orokinetic type of formation (Kraus 1960).

A whole series of sedimentary features as fucoids, hieroglyphes and other crawl — prints, occurence of unoxidized organic matter, flow structures convolute bedding indicate an agitated environment during the formation of flysch facies and a considerable differentiation of the sea bottom into swells and troughs.

A remarkable orokinetic facies is represented mainly by variegated conglomerates of Wildflysch character with irregular grading. So far this series were divided into a lower regressive member — Cenomanian Orlov conglomerate and upper transgressive member — Senonian Upohlav conglomerate due to the Subhercy-

nian phase effect. Recent investigations proved the unity of these conglomerates from Middle Albian to Coniacian. The appearance of these conglomerates is thus the result of a cordillera emerged at the interior Klippen belt margin and strongly eroded partly during the Middle and partly at the beginning of the Upper Cretaceous. The distribution of facies and their changes during the Middle Cretaceous indicate the great articulation and mobility of the sedimentation area.

Although the tectonic pulse of Middle and Upper Cretaceous from that of Neogene were certainly different; the tectonic effect of Neogene phases were analogically applied to the tectonic processes in general.

The apparent cyclic sedimentation of the interior Neogene basins are controlled and directed by the effect of orogenic phases. The lack of such a cyclicity in the Middle and Upper Cretaceous sediments however cannot be regarded as a proof of absence of more pronounced folding. The relation of folding phases to the general tectonic pulse during the Cretaceous in Central Carpathians were from that of Neogene substantially different. Therefore any direct application of criteria from the paleogeographic picture of Neogene basins to the far more active tectonic stages is not possible.

Basing upon the recent investigations the Cretaceous-Paleogene relations may be reconstructed as follows. The sedimentation in the Klippen belt during Danian and Paleocene were uniterrupted characterized only by shallowing environment. The angular disconformity generally supposed to exist in connection with Laramian orogenic phase (Andrusov 1959; Andrusov — Scheibner 1961) is pronounced only in the eastern part of the Manín zone, where above the s. c. subtatric nappes fronts the lowermost Ypresian is disconformably developed. Further to the east distant from the Subtatridy and Manín zone contact the transgressive Paleogene conglomerates start in Middle Lutetian. This indicates however that the Laramian phase in the Klippen belt and the western part of Manín zone is not pronounced by a sort of apparent disconformity. The Paleogene transgression from inferior to Central Carpathians passed in several phases and not at once during the Middle Lutetian.

The Middle and Upper Cretaceous sequences of the Klippen belt and Manín zone thus represent an orokinetic formation reflecting an intense tectonic pulse. So far the Upper Cretaceous orokinetic formation does not permitt more exact chronological determination of partial tectonic phases; indicating however the existence of more phases and complexity of tectonic movements.

The relations between the Paleogene sequences and Mesozoic basement indicate that in the Middle and Upper Cretaceous period tectonic structures were formed and overthrusting took part as well. It would be interesting however to know, wheather this process had a long duration or passed in several intervals. The question should be well studied in the Klippen belt where all the Cretaceous and Paleogene membres are present. Unfortunately the tectonics of Klippen belt

is complicated. The whole Klippen belt is practically a tremendous tectonic breccia where after the tectonic selection the effects of younger Savian folding from that of Cretaceous is hard to be distinguished. Still less possible however appears the distinguishing of effects of *individual Cretaceous phases.*

Till recently the Laramian phase were proved by the position of the s. c. frontal portions of Subtatric nappes over the Middle and Upper Cretaceous members of the Klippen mantle series. They were the Neocomian — Cenomanian sequences at the interior margin of Manín zone suggested as a part of Krížna nappe and Jurassic complexes of Klapa and Kostelec development regarded as sheets of a higher Subtatric nappe dredged by later folding into Klippen mantle sequences (Andrusov 1938). The recent investigations indicate however that all these s. c. "Frontal sequences" of the Krížna unit are stratigraphically related and folded together with younger Manín zone members into several structures (Maheľ — Kullmanová 1960; Maheľ 1961; Salaj 1961). The Jurassic sequences of Kostelec represent the interior marginal development of the Manín zone (Maheľ 1961) while that of the Klape type indicate also a locally more expressed cordillera at the internal Klippen belt margin (Maheľ 1961; Began 1962).

All the three basic criteria characterizing the importance and function of particular orogenic phases were now interpreted from a new point of view. Although they indicate the tectonic individuality of Middle and Upper Cretaceous they cannot prove the importance of particular phases; such investigations are supported more by tectonic analysis.

Analyses of tectonic regime in the units of mantle, Krížna and Choč indicate, that the *folding and thrusting could not have resulted from a single tectonic process.* Such an interpretation is opposed by the fact, that Jurassic membres of the Choč unit are frequently folded together with Krížna Neocomian. Similarly one may observe the interfolding of Jurassic and Neocomian membres of Krížna unit into the Choč melaphyre series in Malé Karpaty Mts. Overthrusted limestone-dolomite masses of the Choč nappe are often found resting not upon the youngest member — Krížna unit Albian but upon the Neocomian or occasionally upon folded structures composed of Albian and Neocomian. This fact may be regarded as indication of two subsequent phases — thrusting of the Choč nappe the first and folding the next phase. Such a more-phases process is indicated also by cleavages of Krížna and mantle metamorphic units in Tribeč Mts. (Biely 1962) where the existence of two phases is proved by cleavage folding dissected by diagonal cleavage.

To the effect of Laramian phase belong also the repeating Middle Eocene transgression from the Klippen belt to Central Carpathians. This phase started a new formation apparently of flysch type with a substantially regular rhythm resulting from the epirogenic oscillations and facial stability. The Laramian

orogenic phase initiated the formation of Paleogene megastructures with extensive interior basins.

General evolution of the Carpathian geosyncline with a northward drift of its axis lead to the conclusion that the main orogenic phases of interior Carpathians have to be connected with the *pre- and post-Middle Cretaceous period,* while in the northern Central Carpathian belts they are perhaps connected with the *pre- and post-Upper Cretaceous period.*

SUMMARY

Basing upon the expression of tectonic phases in the West Carpathian Mesozoic several conclusions were drawn concerning the chronological and areal distribution of phases, intensity of their expression in the particular stages and regions of the mountain belt.

1. The main tectonic phases are connected with the formation boundaries separating the individual geosynclinal development stages which are expressed in the changes or leaps in the geosynclinal evolution.

Pfalcian phase (in the Southern geotectonic belt infra-permian) indicates the beginning of Carpathian geosyncline formation followed by the lower detritic formation. The pre-Anissian phase marks the beginning of carbonatic sedimentation with only a slight articulation and variegation of facies. After the Paleokimmerian phase formations of various facies followed characterized by bathyal to shallow water environment. The Austrian phase started the orokinetic formation of flysch-like marlstone character. After the Laramian phase the flysch formations with regular rhytms were deposited and after the Savian phase followed the „Molassa" — like formation of interior basins.

Each such a formation represents a different stage of evolution with a specific dynamics of environment, differing paleogeography but also another distribution of main sedimentation areas.

2. The effect of individual phases appears different in every particular belt of the geosyncline. Some tectonic phases in certain zones have been expressively pronouced (e. g. Labinian phase) while in other often neighbouring zones only slightly pronounced. Time differences between the most intense pronounciations of certain phases in adjacent zones were also observed (Paleokimmerian). Different intensity and different effect of individual tectonic phases upon sedimentation and different chronological position positively effected the general tectonic pulse leading to the formation of four geotectonic belts:

a) Bükk belt (in Hungary); b) Choč-Gemeridy belt, Slovenský kras syncline, Northern Gemeridy syncline, Choč unit, substantial part of Veporidy Mesozoic; c) Tatridy and Krížna belt; d) Region of the Klippen belt and Magura zone of the Flysch Carpathians; e) Inferior Flysch zone.

Each of the geotectonic belts mentioned above is characterized by its individual

tectonic pulse and specific formations with different group of facies as well as a different chronological range.

The southern geotectonic belt or interior Carpathians or also the Choč — Gemeridy region possess the following sequence of formations: a) shale — sandstone with volcanic products of Permian — Lower Campillian age (in the lower of Molassa — resembling character); b) limestone-dolomitic formation — Upper Campillian to Rhaetian; c) Spongolite—marl—limestone formation — Liassic to Valangian.

The more northern Tatridy—Krížna belt or the region of Central Carpathians s. s. are characterized by the following sequence of formations: a) quartzite formation — Lower Triassic; b) Dolomitic-Keuperian formation — Anissian to Norian; c) radiolarian-sandstone formation — Rhaetian to Lower Cretaceous; d) Flysch-like formation — Albian to Cenomanian with flysch-like and flysch facies and marlstone facies es well.

3. In the period of geosynclinal development the northward drift of axis of the main sedimentation area may be observed. In the stage of lower detritic and carbonatic formation i. e. during Triassic the most intense sedimentation took place simultaneously with the most extensive articulation of the sedimentation area in the southern — interior geotectonic belt. The same process took place in the Tatridy — Krížna belt during Jurassic and Lower Cretaceous while in the Klippen belt and neighbouring areas it passed during the orogenic stage of Middle and Upper Cretaceous characterized by the expressive flysch-marlstone formation.

Due to the northward drifting of the main sedimentation area the abovementioned geotectonic belts represent a uniform genetic unit — articulated geosyncline with its jounger Flysch part (twin) extending along the inferior margin.

4. Different paleogeography during particular geosynclinal development stages and their specific dynamics as well led to a differentiated relation of phases and character of sedimentation. Formations of the orokinetic stages indicate that Austrian, Subhercynian and Laramian orogenic phases mark the beginning of several one after the other following phases expressed in the whole formation. This was also perhaps the case of Keuperian Upper Triassic facies of northern geotectonic belt of Central Carpathians (Tatridy — Krížna belt). This indicates however that every particular phase does not express the start or termination of a longer quiet period interrupted in certain regular cyclicity by tectonic processes. Expression of tectonic phases depends upon the stage of evolution of geosyncline in the particular belt.

5. Widely discussed were the question of areal distribution of particular phases. Certain phases mainly those separating the individual formations had greater areal distribution in the whole geosyncline while several tectonic phases (e. g. Labinian, Agassian, Neokimmerian) were pronounced expressively only in certain geosynclinal belts.

Formations and facies characteristic for particular stratigraphic periods resemble each other over extensive areas (e. g. over the substantial part of Central, Western and Southeastern Europe) indicating an affect reaching far beyond the geosyncline). Middle Triassic for example is characterized by a quiet carbonatic sedimentation, for the Jurassic and Lower Cretaceous the marlstone sedimentation is characteristic, for Liassic and Doggerian the crinoidal limestones, sandy limestones and spongolites. The areal distribution of orokinetic formations with flysch facies indicates that the orogenic phases genetically related to these formations are characteristic for geosynclines. In our Alpine geosynclinal system the SE sector with intense volcanism and the other one with scattered volcanic activity are clearly distinguished.

The geosynclinal system is divided into several segments with an individual chronological and areal distribution of facies in the formations depending upon the articulation of geosyncline and intensity of chronological and areal distribution of orogenic phases. The creation of specific structural features — tectonic units is the consequence of differing paleogeography and the process of tectonic movements in the whole segment. The specific features of the West Carpathian segment compared with the easternmost segment of Eastern Alps are the consequence of different intensity, chronological and areal distribution of orogenic phases and greater articulation of the West Carpathian segment. Mostly expressive is here the specific effect of post — Paleogene phases upon the Mesozoic structures originated during the Cretaceous folding.

The Mesozoic units of West Carpathians — did not accomplish any more pronounced northward thrusting during the Paleogene folding. The neighbouring East Alpine tectonic units during the same period accomplished an extensive northward overthrusting upon the Flysch belt. The reasons for this were the different paleogeography and the different tectonic processes practically during the whole Mesozoic (Mahel' 1959) and difference in the relation of the inferior portions of geosyncline with Klippen and Flysch belts to the Central belt.

In the West Carpathian segment as the whole the chronologic distribution of tectonic phases coincides with zonality. The drift of tectonic phases in geological time from the West to the East along individual belts of the segment so far were not observed. Certain segmentation with an individual tectonic regime of partial segments may be observed only in the final stages of geosynclinal evolution (— Neogene; Buday 1961).

Translated by J. Kováčik

REFERENCES

[1] Andrusov D., 1931: Notes sur la géologie des Carpathes du Nord-Ouest. Sborník SGÚ IX, Praha. — [2] Andrusov D., 1938: Étude géol. de la zone des klippes internes des Carpathes occidentales. IIIe partie: Tectonique. Rozpravy SGÚ 9, Praha. — [3] Andru-

sov D., 1938 b: Geologie Slovenska. Sbor. pro výskum Slovenska a Podkarpat. Rusi, Praha. — [4] Andrusov D., 1959: Geológia československých Karpát II. SAV, Bratislava. — [5] Andrusov D. — Bystrický J., 1959: Über die Bedeutung der subhercynischen Faltungsphase im Gebiete der Westkarpaten. Geolog. sborník X/2, Bratislava. — [6] Andrusov D. — Scheibner E., 1960: An outline of the present state of knowledge about the geology of the klippen belt between r. Vlára and t. Tvrdošín. Geolog. sborník XI/2, Bratislava. — [7] Arkell W. J., 1956: Jurassic geology of the World. London. — [8] Began A., 1962: Einige neuen Erkenntnisse aus dem Jura und der Unterkreide in der Klippenzone im Mittleren Waagtal. Geologické práce, Zoš. 62, Bratislava. — [9] Birkenmajer K., 1957: Neue Forschungen über die Stratigraphie der pieninischen Klippenzone in Polen. Geolog. sbor. VIII/1, Bratislava. — [10] Bystrický J., 1959: Beitrag zur Stratigraphie des Muráňer Mesozoikums (Murán+-Plateau). Geologické práce, Zoš. 56, Bratislava. — [11] Buday T. — Kodym O. — Maheľ M. — Máška M. — Matějka Al. — Svoboda J. — Zoubek Vl., 1960: Tectonic Development of Czechoslovakia. ČSAV, Praha. — [12] Colom G., 1957: Sur le caractére des géosynclinaux mésozoiques. Bulletin de la Soc. géol. de France, tom VII, Paris. — [13] Fülöp J., 1959: Die kretazischen Bildungen Ungarns. Verhandlungen der mezosoischen Konferenz, Budapest. — [14] Gamgrelidze P. D., 1960: Mezo-kainozojskije orogeničeskije fazy alpijskoj zony juga SSSR. Meždunarodnyj geolog. kongres XXI, Doklady sov. geologov. — [15] Kantor J., 1957: A^{40}/K^{40} Methode zu absoluten Altersbestimmungen und das Alter des gemeriden Granites von Betliar, Geolog. práce, Zprávy 11, Bratislava. — [16] Kantor J., 1959: Beitrag zur Kenntnis der Granite des Vepor — Gebirges nach der A/K^{40} Methode. Geolog. práce, Zprávy 16, Bratislava. — [17] Kantor J., 1960: Die kretazischen orogenen Prozesse im Lichte der geochronologischen Untersuchungen kristalliner Schiefer der Kohút-Zone (Tatroveporiden). Geolog. práce, Zprávy 19, Bratislava. — [18] Kotański Z., 1961: Tektogeneza i rekonstrukcja paleogeografii pasma wierchowego w Tatrach. Acta Geolog. Polonica, XI/2—3, Warszawa. — [19] Maheľ M., 1959: Eine neue Einheit in den Westkarpaten. Geolog. práce, Zoš. 51, Bratislava. — [20] Maheľ M., 1959b: Neue Gliederung und neuer Blick auf die historisch-geologische Entwicklung des Mesozoikums in den Zentralkarpaten.. Geolog. práce, Zoš. 55, Bratislava. — [21] Maheľ M., 1961: Nouvelles connaissances des certaines „régionclés". Geolog. práce, Zprávy 21, Bratislava. — [22] Maheľ M., 1961: Tektonik der zentralen Westkarpaten. Geolog. práce, Zoš. 60, Bratislava. — [23] Maheľ M., 1961: Geologická stavba Malých Karpát. Sjazdový sprievodca, Bratislava. — [24] Maheľ M. — Kullmanová A., 1961: Beitrag zur Kenntnis der Manín-Serie. Geolog. práce, Zprávy 21, Bratislava. — [25] Matějka Al. — Andrusov D., 1931: Apercu de la géologie des Carpathes occidentales de la Slovaquie centrale et des régions avoisinantes. Knihovna SGÚ 13, Praha. — [26] Matějka Al. — Roth Zd., 1956: The Geology of the Magura Flysch group in the northern river basin of the Váh between Bytča and Trenčín. Rozpravy ÚÚG 22, Praha. — [27] Murgeanu G. — Patrulius, 1960: Les formations mésozoiques des Carpathes roumaines et leur avant-pays. Annales Instituti geolog. publici Hungarici, vol. XLIX/1, Budapest. — [28] Passendorfer E., 1961: Évolution paléogeographique des Tatras. Ann. Soc. géol. Pol. XXX/4, Kraków. — [29] Rakús M. — Siblík M., 1962: Stratigrafia bradiel kosteleckého vývinu. Geolog. práce, Bratislava (in press). — [30] Roth Z., 1962: Vysvětlivky k přehledné geologické mapě ČSSR 1:200 000 list Olomouc M-33-XXIV. NČSAV, Geofond, Praha. — [31] Salaj J., 1962: Zpráva o stratigrafii kriedových sedimentov manínskej série na liste Považská Bystrica. Manuscript; Geofond, Bratislava. — [32] Szentes F., 1959: Mesozoische Krustbewegungen in Ungarn. Verhandlungen der mesozoischen Konferenz, Budapest. — [33] Trümpy R., 1960: Paleotektonic evolution of the Central and Western Alps. Bulletin of the Geolog. Society of America, vol. 71, New York.

Geologické práce, Zprávy 28. Bratislava 1963

MICHAL MAHEĽ

SEVERAL TECTONIC STYLES, THE INFLUENCE OF ROCK PROPERTIES AND ORIENTATION OF OVERTURNS IN CENTRAL CARPATHIAN MESOZOIC

Characterizing the tectonic style of Carpathians the majority of geologists — experts in Carpathian structure including — usually have in mind extensive nappes with minor structures to them properly adapted. The opinion on the nappe tectonic style is closely related also to uniform orientation of tectonic forms or overturn of structures.

Neither the succesive exchange of fold overthrusts by shear thrusting did mean really substantial change in this classical theory. Structural complications of Mesozoic concentrated in the frontal portions of nappes, were explained by the northward plunging folds or digitations. At the surface these forms should have appeared as structures of false character: plunging anticlines as pseudosynclines and vice versa. Partial nappes are frequent mainly in the frontal portions. The outward — mostly northward — overturn is suggested for all the structures including minor forms. Apparently southward overturned structures known already at the time of M. Lugeon and described as back folds are related of tectonic phases of different style. Their origin is believed to be related to post-Paleogene tectonic activity leading in Central Carpathians to southward upthrowing, formation of meganticlines and megasynlines and minor structural forms as well (Andrusov 1959). Autochtonous series (the majority of mantle series) are explained as units with tectonic orientation due to overthrusting more or less tectonically reduced often with wedges at some places cut off and dragged to other by the thrusting nappe masses.

So understood the tectonic style appeared rather monotonous despite several structural cross-sections of geologically complicated regions where the intricacy and complexity of structures were only impressed by drawing of arches and digitatios.

The discovery of a different style of the s. c. Veporidy root Mesozoic involuted as wedges into the crystalline basement ment some revival to this monotony. The structural axes here are dipping steeply to the south and Mesozoic masses are metamorphosed to various extent (Z o u b e k 1930, 1936). Deformations of mesozoic apparently took place in conditions of raised pressure and temperature. This particular tectonic style is being called the i n d u c e d t e c t o n i c s t y l e.

The recent investigations mainly in mantle series Mesozoic indicate considerable distribution of induced tectonic style throughout Central Carpathians. In mantle Mesozoic involuted and jammed in crystalline masses this style appears obviously important.

Besides the metamorphic effects observed such as the formation of new minerals mainly sericite, chlorite, quartz, albite, tourmaline, rutile and biotite further characteristic is the occurence of minor folds with amplitudes ranging to several metres mainly in lower Triassic bedded quartzites (Pl. 1, Fig. 1.) Minor folds of such dimensions are extensively distributed in thin bedded silicite limestones of Neocomian in certain mantle series.

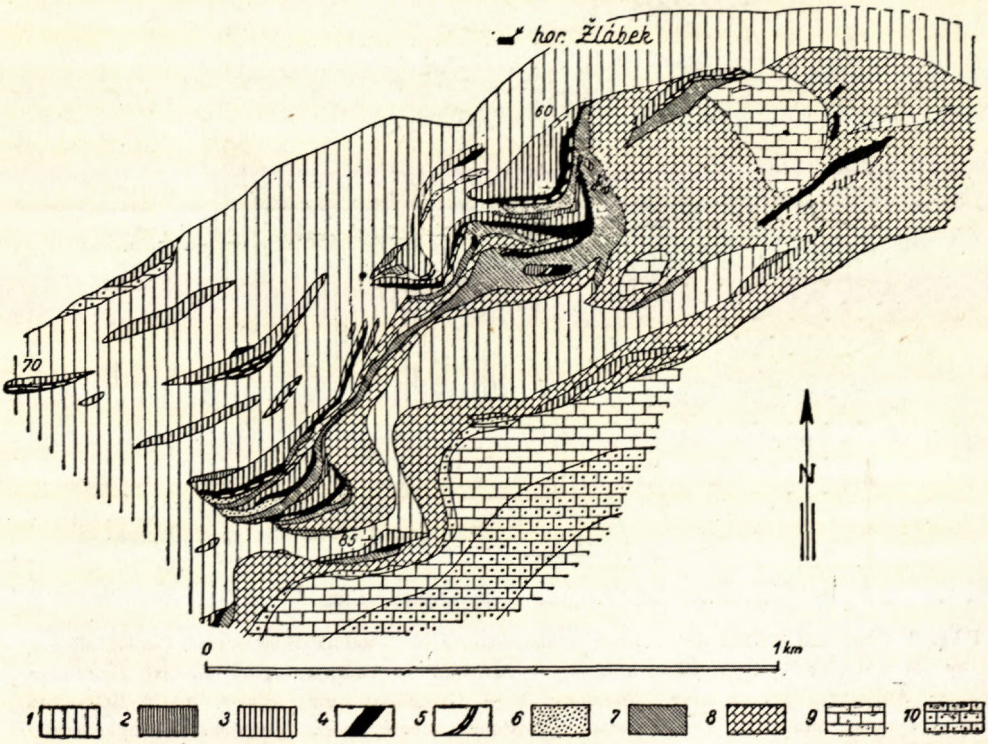
In the Vysoké Tatry series for example in Tomanowa development of Tichá dolina valley the flat folds of Middle Triassic bedded limestones and dolomites of only a few metres amplitude (G o r e k 1956) belong perhaps to this group of structures related with induced process. Clay and clay-marly sequences of mantle series usually bear evidence of well pronounced schistosity even phyllite appearance (Toarcian Marianky beds, Malá Magura Albian series). If locally intercalations of thin limestone beds were present the sequences were intensely folded into minor structures.

Overturn of structures of induced tectonic style shows an apparent northward-outward orientation.

Induced tectonic style is specially characteristic for the stripe of Mesozoic rocks trimming the northern margin of Veporidy belt crystalline masses such as Veľký Bok series and the adjacent series continuing farther to the west at the southern Pohronie synclinorium margin, in the Sklené Teplice Mesozoic, in southern part of Tribeč mountains, as also in the series eastwards within the metamorphosed Mesozoic of Branisko mt. (Hrabkov series) and Čierna hora mt (Kavečany series). The Mesozoic sequence mentioned represent the southern marginal rim of the Krížna unit, by several facial similarities they are related also to the Veľký Bok series. Induced tectonic pronouncement indicate perhaps the autochtonous origin as a consequence of the tectonic position. Relations between the induced tectonic style and autochtonous origin is specially interesting (questionable) in Mesozoic structures of Hron synclinorium southern flank. Deeper structures indicate a higher degree of metamorphosis (mantle structures according to Z o u b e k 1959). The particular members of the upper structure (suggested as Krížna unit) bear evidence of less pronounced metamorphosis in the internal rock structure

while the form of folds in bedded Tithonian-Valangian limestones is rather striking (Pl. I, Fig. 2). Concerning the autochtonous origin very interesting appears the well pronounced metamorphosis of the southernmost imbricated structure of the Krížna unit extending in the Horehronie synclinorium northern sector near Bukovec (M a h e ľ 1955).

Detailed investigations of Mesozoic — initiated by the criticism of nappe conceptions of the early thirties — led recently to the detection of a specific i m b r i c a t e d t e c t o n i c s t y l e related to Mesozoic complexes in majority composed of Jurassic and Lower Cretaceous shallow-water sequences of cordillera type in mantle series and Krížna and Choč units as well. Extensive areas having the character of imbricated structure are found in Krížna unit of Malé Karpaty mts. composed mainly of Vysoká series (M a h e ľ 1959). Existence of two parallel



F i g. 1. Geological map of the area east of Sološnica showing the imbricated tectonic style — Vysoká series (M. M a h e ľ). 1 — Albian: marly shales, calcareous sandstones; 2 — Aptian: dark organogene limestones; 3 — Neocomian: marly cherty limestones; 4 — Malmian: pink limestones; 5 — Upper Doggerian: cherty limestones; 6 — Liassic — Lower Doggerian: crinoidal limestones; 7 — Rhaetian: dark, marly limestones and shales; 8 — Norian: Carpathian Keuper; 9—10 Middle Triassic: 9 — dolomites; 10 — cellular limestones.

„subzones" — structurally different units — is visible directly on the geological map. Interior — lower subzone the one with mantle series in direct contact — is formed by Lower Triassic limestone- dolomite complexes arranged into monoclines of medium (45°—55°) and at some places steep (70°—80°) outward, northwestern dip. The inferior margin represents a stripe of Keuperian and Rhaetian in „Kössen" development i. e. relatively plastic members at some places involuted. Transition of this „subzone" into the more northern one is not pronounced the later consisting in majority of Jurassic, Lower and Middle Cretaceous

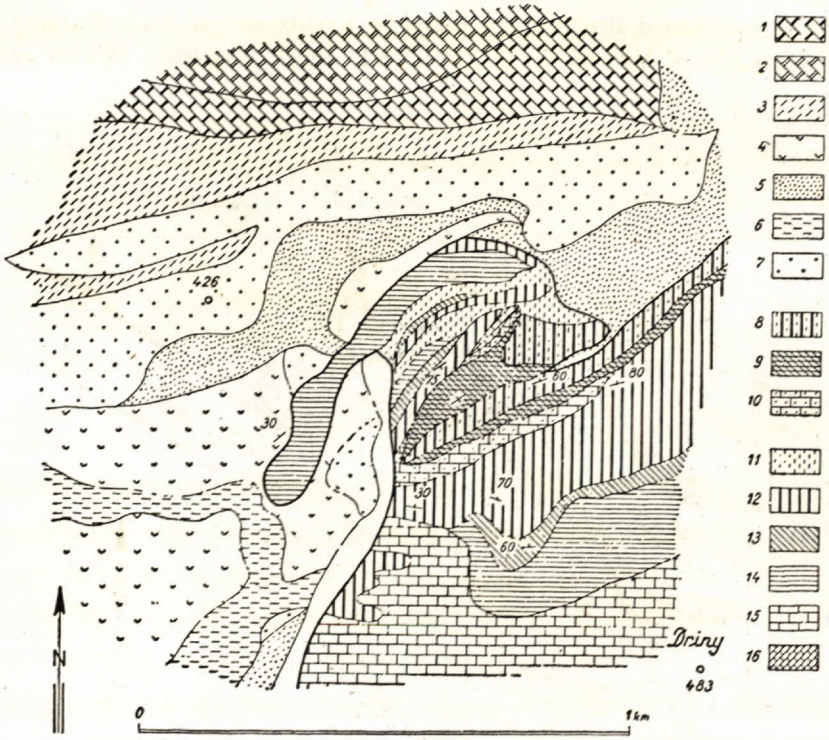


Fig. 2. Choč and Krížna unit contact in the vicinity of Jahodník (Smolenice). Geological map (by M. Mahel). 1—7 Choč unit, 1 — Anissian — Ladinian: gray massive limestones; 2 — Anissian: dark massive limestones; 3 — Campillian: gray shales, marly limestones; 4 — Zeissian quartzites; 5 — Permian: sandstones, subgreywackes, greywackes, conglomerates; 6 — Permian: black shales, conglomerates; 7 — Permian: melaphyres. 8—10 Zliechov series, 8 — Tithonian — Neocomian: light gray Calpionella limestones, gray marls and marly limestones; 9 — Doggerian — Malmian: radiolarites and radiolarite limestones; 10 — Liassic: spotty marls and marly limestones. 11—16 Vysoká series, 11— Albian: marly shales and intercalations of calcareous sandstones; 12 — Neocomian: gray, marly, cherty limestones; 13 — Malmian: pink limestone; 14 — Upper Doggerian: cherty limestones; 15 — Liassic — Lower Doggerian: crinoidal limestones; 16 — Norian: Carpathian Keuper.

sequences. Limestones and dolomites of the Middle Triassic or more frequently Keuperian and Rhaetian occur in these sequences in subordinated amounts. Opposite to the lower „subzone" the particular stratigraphic — lithologic members do not form continuous stripes several km. long. An inclination to such forms were observed only in the northern portion where the several times repeated sequence in a more or less regular stratigraphic development shows a folded structure composed of four anticlines and synclines with axes steeply dipping to the northwest (Dlhý vrch mt. above the western slopes of Bohatá dolina valley). Northwestwards and southeastwards these structures however pass laterally into wedges. Substantial partion of the „subzone" shows variegated structure of a whole series of larger and smaller wedges represented by rigid members of Jurassic or Lower Cretaceous morphologically Klippen-like emerging in between more plastic Albian, Keuperian and Rhaetian sequences, whereas the first one is substantially extended in the inferior and the remaining two members more in the interior portion of the imbricated subzone. Dimensions of wedges are different —

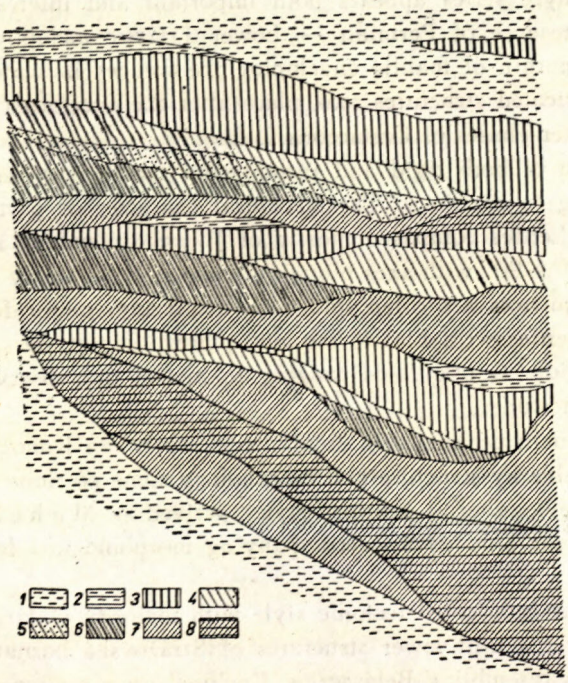


Fig. 3. Sketch of geological situation showing the structural selection in younger members of Krížna unit south of Sološnica in Malé Karpaty Mts. (M. Mahel). 1 — Albian: marly shales and sandstones; 2 — Aptian: dark organogene limestones; 3 — Neocomian; marly cherty limestones and marls; 4 — Malmian: pink limestones; 5 — Upper Doggerian: cherty limestones; 6 — Liassic — Lower Doggerian: crinoidal limestones; 7 — Rhaetian: dark marly limestones and shales; 8 — Norian: Carpathian Keuper — varicolored shales with sandstone intercalations.

from small Klippens to extensive structures several km. long. Larger wedges represent often a set of two or more smaller wedges tectonically brought together by squeezing out of the plastic members, separated during the initial stadii of imbrication. The stratigraphic contents of wedges is rather iregular. Wedges with complete sequence from Lower Liassic to Aptian preserved appear very seldom. More southwards extended wedges frequently contain only members of Liassic, while northwards the wedges are composed rather of Lower Cretaceous accompanyied by Malmian i. e. more competent members. Scattered appear also smaller wedges of Middle Triassic limestones and dolomites. The plastic i. e. mantle members frequently show an interesting side — by side occurence of Keuperian and Rhaetian with Albian.

Huge number of smaller wedges appear at the inferior margin of the unit. They are in majority of Lower Cretaceous members involuted in Albian representing the marginal rim of Krížna unit at the contact with Choč unit melaphyre series. The detection of Lower Cretaceous wedges in the marginal part of the adjacent Choč unit melaphyre series appears both important and interesting. This fact as well as the presence of Permian — Lower Triassic melaphyre series shale sequence in the margin of mantle enveloping the wedges indicate that the final formation of imbricated structures took place after the overthrust of Choč nappe i. e. during the later phases of Cretaceous folding.

The distribution of both rigid and incompetent members reflects the tectonic selection according to plasticity. The structural character of particular lenses is very remarkable. Lenses composed mostly of Jurassic members in majority are steeply dipping 70°—90° with axes plunging towards NW. Marly layers in lenses of Neocomian sequences are often folded in detail into minor folds of various overturn. Larger lenses with Liassic sequences prevailing possess usually rather a low angle position. Gentle folds ranging in metres are observable in Lower Liassic bedded limestones.

Areas with frequent occurence of small lenses (between Rohožník and Sološnica valley) resemble by structure and morphology some portions of the Klippen belt (hence the previous term „Klippen style" derived — M a h e ľ 1959). Klippens however appear only as an accompanying morphological form of smaller wedges.

Generally similar imbricated tectonic style with majority of large wedges may be observed in Krížna unit lower structures of Strážovská hornatina mts. composed of sequences resembling Belá series. Enclosed cross-section exposed at the valley side of a small canyon near Valaská Belá shows the interior complication of the structure depending upon the plasticity of particular members.

Imbricated tectonic style is developed also in cordillera type mantle series possessing the lithological character similar to that of abovementioned Krížna unit series. Due to the similar lithological and structural character many series

belonging to different tectonic units were previously included into one s. c. West Carpathian unit or group (M a h e ľ 1959) Remarkable imbricated structure is that of the younger members of Humenné series. Particular wedges are composed of competent Lower Liassic — Aptian sequence in majority vertically straightened with local northward overturn. Tectonic selection with frequent squeezing — out of incompetent members (Keuperian, Rhaetian, Albian) at one and accumulation at other places but mainly with frequent tectonic substitution of competent members in particular wedges.

Imbricated structure is typical also for Beckov series where in between limestone — dolomitic complexes of mantle series and the Choč unit appear Albian sequences accompanyied by wedges composed of various Jurassic to Lower Neocomian members at some places forming small, morphologically remarkable klippens. Several wedges appear accumulated in the area of the old castle hill.

As wedges may be regarded also the Klippens of Manin series occuring in the Manin and Butkov areas mainly those smaller ones representing the part of the more northern belt. The wedges resulted from the reduction of lower limbs of the westwards overturned anticlines. Morphologically remarkable Klippens are represented by wedges originated due to tectonic selection such as the minor structures of Kostelec and Klapa development of the Manin series. Forms resembling the wedges with an imperfect tectonic selection i. e. uninterrupted stratigraphic sequence were observed also in the Trenčianske Teplice portion of the Manin series.

Also the remaining series of cordillera type Jurassic and Lower Cretaceous possess a more or less pronounced imbricated structure, for example Raztočná series on the southern slopes of Žiar, Tribeč series in Zobor area, mainly in portion between Mechenice and Drážkovce (B i e l y 1962). Detailed investigations of the Červená Magura mts. complex indicate that it is composed of several larger and straightened wedges. The lack of plastic members were reflected in their limited mobility. The tectonic relations between thick — bedded Aptian limestones and shale — sandstone Albian sequence apparently unconformable are remarkable. (M a h e ľ 1961) Errected Aptian sequences with minor folds of several metres show here an overturning tendency over the gently northwards dipping 10° — 15° Albian sequence.

Overturning of the Lower Cretaceous limestone complexes on Albian and involution of Albian into the masses of older more rigid complexes may be well observed in Červené vrchy and Giewont development of the Vysoké Tatry series. The character of folds in Červená Magura (Nízke Tatry) Aptian and specially in the Triassic — Jurassic — Lower Cretaceous limestone complexes of Červené Vrchy mts. is very similar to types related to the induced tectonic style frequently appearing in mantle series. This howerer leads to the suggestion that Červené vrchy and Giewont structures represent a combination of both induced and imbricated tectonic style. Specific role in this process belongs to Albian due to the

plasticity and mobility from those of older member entirely different. Contact planes between Albian and older competent and better movable Lower Cretaceous or Jurassic limestones served as planes of motion and also as lubricants.

Imbricated tectonic style were characteristic for the younger members or rather for the substantial part of those Krížna and mantle unit series which due to cordillera type of the majority of Jurassic and Lower Cretaceous facies were included in the West Carpathian group of series (M a h e ľ 1961). At the beginning of criticism of the former overthrust interpretation of the early thirties this group

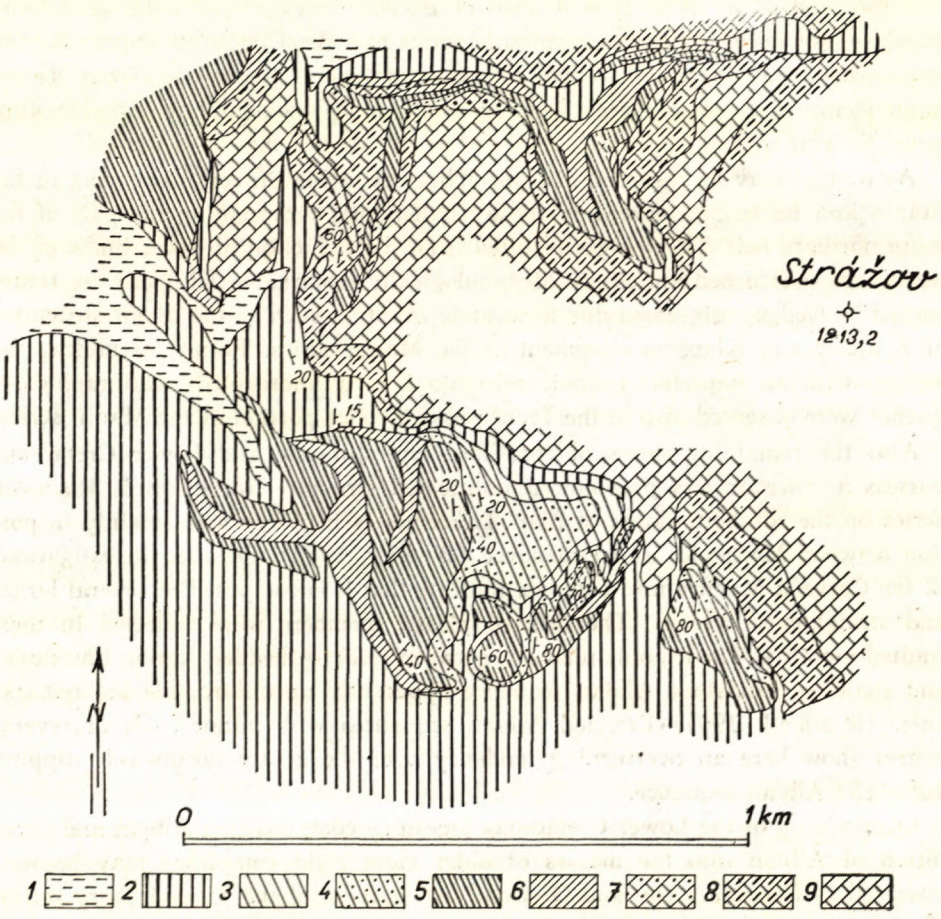


Fig. 4. Geological map of Strážov Mt. slopes showing the complications of structure (imbricated style) (M. M a h e ľ). 1—2: Krížna unit: 1 — Albian: shales and sandstones; 2 — Neocomian: marly limestones and marls; 3 — Malmian: red limestones with radiolorite intercalations; 4 — Doggerian — Malmian: red limestones; 5 — Liassic — Doggerian: crinoidal limestones; 6 — Rhaetian: gray, organogene limestones; 7 — Upper Triassic: platy siliceous limestones; 8 — Middle and Upper Triassic; dolomites; 9 — Middle Triassic: limestones (3—9 Choč unit).

of series were regarded as a separate — West Carpathian unit (M a h e l 1959). This conception however led to a new interpretation of paleogeographic and structural relations among the units of Central Carpathians.

Imbricated structures occur also in the Choč unit in areas composed of Jurassic members facially very similar to the mantle series of Krížna unit with a cordillera Jurassic. Such structures may be observed in Nedzovské pohorie mts., Vysoké Tatry and Nízke Tatry mts. Remarkably appears this structure in Strážovská hornatina where the particular members occur over more extensive areas. Several wedges with transitions to folds may be observed in the Rohatá skala vicinity Imbricated structure is well visible also in the stripe of Mojtínska dolina — Zliechov — Biely potok valley — Veľká Kačka along the contact of two main structures of the Choč unit composed of Triassic limestone — dolomite complexes. As a tectonic "lubricant" may be regarded the shale — marlstone sequence of the Choč unit Valangian and also the Rhaetian sequence if that one is developed in Kössen facies. Best pronounced imbricated structure however is that of Strážov Mt at places where due to the shear overthrust the Jurassic masses of the Choč unit with more foldable Albian or Neocomian of Krížna unit are in direct contact. Mutual folding of two tectonically different units i. e. Jurassic complexes (Valangian including) of Choč nappe and Neocomian — Albian sequences of the underlying Krížna unit prove the existence of folding phase younger than the overthrust. Remarkable straightened wedges may be found in the northern part of Strážov in the vicinity of Neocomian tectonic window. Between the gently folded Neocomian marlstone sequence and flat — lying Triassic limestone — dolomite masses appear wedges consisting of Jurassic. A little more plastic members such as bedded limestone — radiolarian Malmian sequence as well as marly Malmian limestones and Tithonian — Valangian form mantles envelopping large wedges of crinoidal Liassic — Doggerian limestones. Particular members of wedges possess frequently an individual structure. Such phenomenon is exposed at the eastern slope of Strážov. Jurassic members of two straightened adjacent wedges are separated by a thin stripe of platy Tithonian — Valangian marlstones folded in detail. Simultaneously the minor folds were adapted to the straightened position of wedges only in their direct vicinity. The substantial portion of Neocomian however indicate the structure typical for marly sequences minute folds undulating the more or less flatly lying complex. Even the Lower Liassic sequence of bedded silicite — bearing crinoidal limestones possess a specific structure of complicated folds perfectly exposed on a rock precipice of Biely potok valley near the contact with Neocomian tectonic window.

Imbricated tectonic style is evidently related *to facies of cordillera type* in tectonic units of completely different position: in the autochtonous mantle unit (Beckov, Ráztočná, Tribeč, Červená Magura series, Humenné) in the mantle unit regarded as overthrusted (Vysoké Tatry series of Červené vrchy and Giewont

development), in the Krížna unit (regarded by some as overthrusted by others as autochtonous in particular areas) as well as in the Choč unit which doubtlessly represent a true nappe. Similar style may be observed in the series of Klippen belt with facies of similar type the Czorstyn series. Compared with the units of Central Carpathians this series of course differs by the presence of frequent small to minute wedges and remarkable morphological forms of Klippes often with competent masses "floating" or dredged within the plastic mantle. This phenomenon is due to the more advanced tectonic selection caused by greater difference in the plasticity of competent and incompetent sequences (mostly Middle Cretaceous) as also by the more intense compression resulting from different types of movements, which took place during other tectonic phases (post Paleogene). All the abovementioned series of imbricated tectonic style show a clear evidence of relation to younger members of series i. e. to a specific type of facies characterized by certain physical — mechanical properties. Degree of imbrication depends to a great extent upon the relation of rigid and plastic complexes. We are thus dealing with structures controlled by the character of rock material. Older complexes represented mainly by limestone — dolomitic sequence possess a different tectonic style being involed in the formation of wedges only to a small extent. Coincidence of the imbricated tectonic style with cordillera facies is caused partly also by their specific tectonic evolution mainly by the great number of synsedimentary faults. During certain periods (mainly in Doggerian) these faults caused laterally rapid facial changes and great differences in thickness of particular members in short distances. The function of synsedimentary tectonics were reflected in the inhomogenity of rock-material controlling later the formation of wedges. This process is proved by great oscillations in facies and thickness of members of the neighbouring wedges of Krížna unit series (Malé Karpaty Mts.).

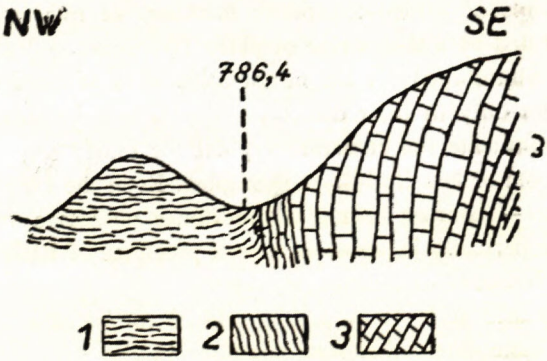


Fig. 5. The tectonic disharmony of the Červená Magura serie. 1 — schist-sandstone sequence of the Albian; 2 — bed-like limestones of the Aptian; 3 — massive limestones of the Jurassic.

The role of incompetent beds of particular series is reflected in the character of imbricated structural style. At places where they were frequent the structures and imbrication were more complicated. Their relation to competent members, mutual grouping of both types, chiefly in the incompetent members, in spite of the wide stratigraphic range — from Keuperian to Albian — all this indicate an important role of the structural selection of rocks (in sense of Galwitz 1959) according to the physical — mechanical properties controlling the formation of imbricated structure. Concerning the size and shape of structural forms besides the competent — easily fluctuable and incompetent — easily foldable rocks it depends also upon thickness of particular types and their grouping. Naturally upon the magnitude of stresses as well. Incompetent masses forming the "envelope" of wedges usually fluctuate into the spaces of lower tectonic strain. In the areas of accumulation of wedges composed of competent members the plastic sequences were tectonically reduced or squeezed out. The examples listed from Central Carpathians indicate that *imbricated structures appear in the geotectonic units — nappes included in certain "subzones" reaching the overthrust plane* (Choč nappe). This fact however proves the validity of structural selection within the frame of the whole tectonic unit resulting in the separation of this unit into "subzones" with differing tectonic style. The imbricated structure thus develops upon the same tectonic style.

Different, not imbricated structure occur in the younger members of substantial part of Krížna unit represented by deep sea Jurassic and Lower Cretaceous (Zliechov series) or sometimes in the mantle series included in the West Slovakian group (Malé Karpaty, Inovec, Malá Magura, Žiar, Malá Fatra, Veľká Fatra series) characterized by prevailing marlstones. In case these sequences occur in minor thicknesses overlying thick Triassic complexes their tectonic style is adapted too; they form more or less steeper *monoclines or flat structures* of great curving radius. The character of structurally simple thin "covers" of overthrust character appear in the Krížna unit of Veľká Fatra mts. overlying the tectonic windows of the Mantle series. In such cases the mantle series and partially some of their members demonstrate the effect of the induced tectonic style previously described.

The structures of mountain chains where younger members of Krížna unit occur as thick complexes covering extensive areas is complicated. Cross — section carried across Krížna unit of Inovec, Malá Fatra, Vysoké Tatry and mainly Strážovská hornatina demonstrate a more time repetition of particular stratigraphic members. In the inferior or s. c. frontal part the youngest members — usually Albian and Neocomian appear at the surface forming higher digitations. In the interior parts nearer to crystalline cores are distributed the older members. Repetitions are regarded as lower digitations, previously suggested as false structures however in the sense of opinion about the nappe plunging northwards and folded

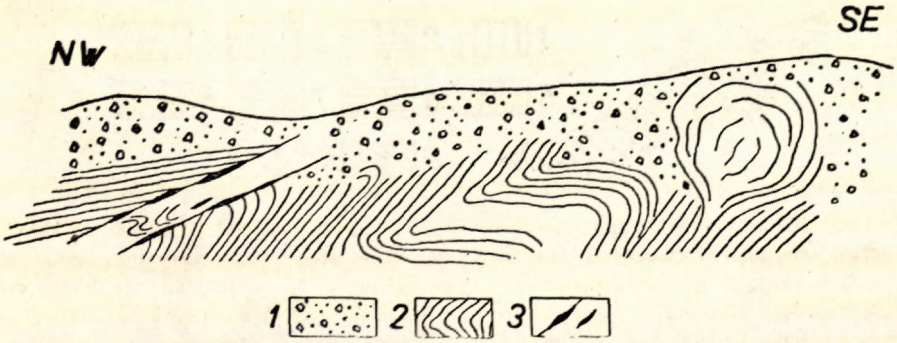
already in the period of overthrusting. In that sense the stripes of older stratigraphic members occuring in between the younger ones are not regarded here as anticlinal cores with overturn depending upon the dip of the axial plane i. e. interior — (southward) overturn but on the contrary they are explained as anticlinal fronts plunging outward from the crystalline core. In the cross — section of course the structures appear as false synclines. Such a conception however is of very hypothetical character based upon scattered observations in Vysoké Tatry mts (Passendorfer 1953) and Malá Fatra mts (Matějka 1931, 1961) which would deserve recently a verification by detailed geological mapping. The examples appear still more doubtfull due to the fact that the relation of two stratigraphically each other substituting elements as dolomites and Keuperian of Krížna unit contain frequently thick beds of dolomites. The determination of the tectonic character is further complicated by the fact that the dolomite masses and beds of shales represent units of entirely different competence. Tectonic forms originated by the involution of plastic shale sequences with rigid dolomite masses, may hardly be generalized as forms characteristic for the whole Krížna unit or even for the younger thick marlstone sequences.

Detailed studies in the heavily digitated region of Strážovská hornatina mts. proved doubtlessly the normal and not the false character of structures. This fact were proved first by detailed geological mapping showing clearly the emerging of older members in cores of anticlines. Similar results were received from observations of character of great folds. Here however by the study of forms and overturns the differences of plasticity of particular members must be taken into consideration. Most reliable results are thus obtained from megastructures consisting of thick competent sequences. The example of Zliechov cross — section prove that the folds of several m thick Tithonian limestones coincide both in shape and overturn with megastructure. The same may be said about the bedded marly limestones occuring frequently everywhere in Tithonian and Upper Liassic forming folds of several m in size (Pl. III, Fig. 6). Thin bedded Doggerian — Malmian radiolarian limestones form minute folds (1 m size) differing from the megastructure — of elongated to nearly isoclinal type with a coinciding overturn (core of the abovementioned megastructure at Zliechov). Marlstones — represented in majority by the Neocomian sequence occuring in greater thickness usually in Krížna unit — are finely folded into minute folds (ranging dm in size) of iregular shape and variable overturn. In majority of cases we may speak about a gentle undulation of flat structures (Pl. IV, f. 7). At the contact the folds show variable orientation (Pl. IV, f. 8). Neocomian sequence similar to that of Rheatian may serve as an example of diversity of structural micro — and mega — forms, all due to the iregular distribution of several rock types differing by physical — mechanical properties and thickness as well (shales, marlstone, limestones). The diversity of relations between competent and incompetent beds is here war-

ranted. The sequence may be divided into a series of larger and smaller units of different competence. The shape of larger folds formed in bedded limestones is controlled to a great deal by the position of incompetent beds within the competent complex. The overturn of these structures coincides with that of the megastructures.

Remarkable partial structures — d i g i t a t i o n s — thus represent structurally independent partial units separated by thrust planes often with apparent differences in the development of certain members. Differences in thickness and facial character of contemporaneous members of neighbouring structures separated by thrust planes led to the opinion that thrust planes initiated at the boundary of abrupt changes of physical — mechanical properties of primarily adjacent complexes and that time relations between the thrust planes and synsedimentary faults which may have caused the differences in thickness and development of facies.

Partial structures (digitations) never extend beyond the limit of a mountain chain in majority they are only of local character. Their distribution incited the consideration of their genetic relation to the basement morphology (Inovec — Maheľ 1951). Occurence of these structures exclusively in the areas of major distribution of Krížna unit in Zliechov series development, their local character, overturn of lower structures inwards and upper — frontal structures outwards prove beyond every doubt that this fan originated in region of their recent extension. If we hawe admitted the overthrust character of Krížna unit (more apparent in Veľká Fatra) than such structures must have originated after the thrusting during a younger phase of folding. Change of opinion on the overturn and origin of described structures deserve as to my concern to abandon the term digitation and for this particular tectonic style characteristic for thick Krížna unit complexes with development of Zliechov series type Jurassic to Lower Cretaceous members (Marlstone-radiolarian type) — introduce the term t e c t o n i c s t y l e o f t h r u s t f o l d s.



F i g. 6. Folding of Krížna unit Rhaetian near Valašská Belá (M. M a h e l). 1 — Debris; 2 — Rhaetian: bedded limestones with shale intercalations: 3 — Red Keuper shales.

Characterizing the described tectonic styles mainly the imbricated one we have mentioned the difference between the tectonic style of Triassic limestone — dolomitic masses which form a more or less structurally continuous rim of the Krížna unit and majority of mantle units. They appear at the crystalline core margin forming at some places steep monoclines with a medium outward overturn. In the areas from the crystalline core margin more distant the structures possess usually a low angle dip and the beds of limestones eventually dolomites show affinity to great radius fold curving. A more complicated structural character of mantle series Triassic masses were usually related to the induced tectonic style with an expressive outward overturn of structures as it were already mentioned above.

Interesting appears also the intense folding of platy dolomites of Malé Karpaty series at the northeastern flank with minor isoclinal folds of dimensions ranging in metres and turned over toward southeast. Platy competent members as we have already seen on radiolarian limestones in areas intensely compressed show an apparent tendency to the formation of isoclinal folds (fig. 9).

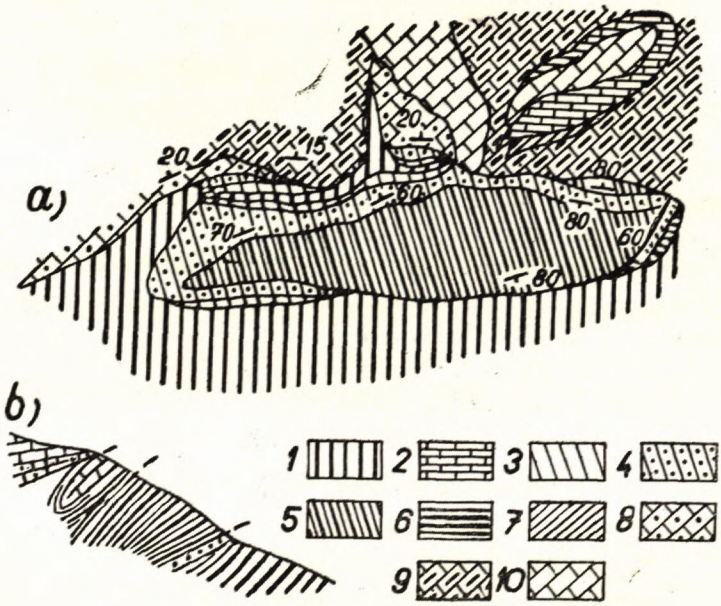


Fig. 7. Lenticular tectonic style at the northern slopes of Strážov Mt. (M. Maheľ) a) Sketch of geological situation; b) Geological cross — section. 1 — Neocomian: marly limestones and marls (Krížna unit); 2 — Tithonian: platy, marly limestones; 3 — Malmian: red limestones with radiolarite intercalations; 4 — Doggerian — Malmian: red limestones; 5 — Liassic — Doggerian: crinoidal limestones; 6 — Lower Liassic: cherty crinoidal limestones; 7 — Rheatian: gray, organogene limestones; 8 — Upper Triassic: platy siliceous limestones; 9 — Middle and Upper Triassic: dolomites; 10 — Middle Triassic: limestones (2—10 Choč unit).

Limestone — dolomitic masses represent a substantial structural element of internal Carpathian — Choč, Northern Gemeridy and Southern Gemeridy units. Except small portions composed of younger members in imbricated tectonic style the limestone — dolomitic complexes impose upon these units a *specific tectonic style.* We may investigate this style first in the Choč unit representing a nappe in its full extension with several partial units. In many of the core — mountains division into several partial structures side by side arranged may be carried out. These partial units of lower order (Malé Karpaty, Strážovská Hornatina Hills, Veľká Fatra, Nízke Tatry, Prosečnianske pohorie) are in majority of cases separated by well pronounced structural lines. Frequently they differ also by another type of Triassic facies i. e. each one is composed of another series. It occupies the lower structure i. e. extends mostly upon the youngest members of Krížna unit. There are however areas where the more southern structure is superposed. This however could be hardly interpreted as individual nappes of more regional importance. Older members represented by the melaphyre series are in majority distributed in the more southern portions of the nappe (Nízke Tatry, Tribeč, southern parts of Strážovská hornatina). Malé Karpaty mts. are an exception having due to the development of all units a special position. In the given case the primary sedimentation area of the Choč unit perhaps were not too distant

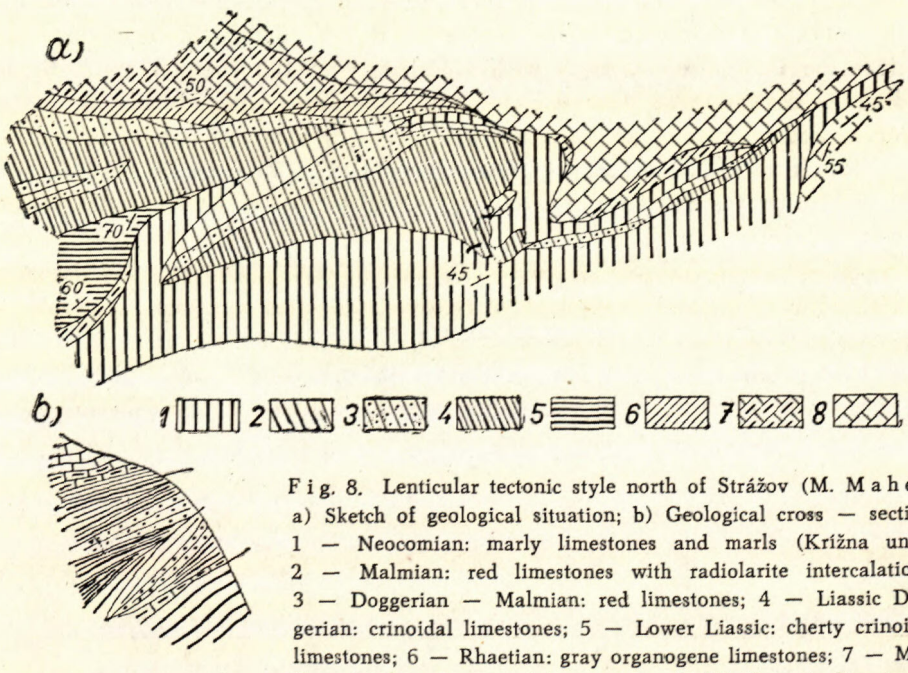


Fig. 8. Lenticular tectonic style north of Strážov (M. Maheľ) a) Sketch of geological situation; b) Geological cross — section. 1 — Neocomian: marly limestones and marls (Krížna unit); 2 — Malmian: red limestones with radiolarite intercalations; 3 — Doggerian — Malmian: red limestones; 4 — Liassic Doggerian: crinoidal limestones; 5 — Lower Liassic: cherty crinoidal limestones; 6 — Rhaetian: gray organogene limestones; 7 — Middle and Upper Triassic: dolomites; 8 — Middle Triassic: limestones.

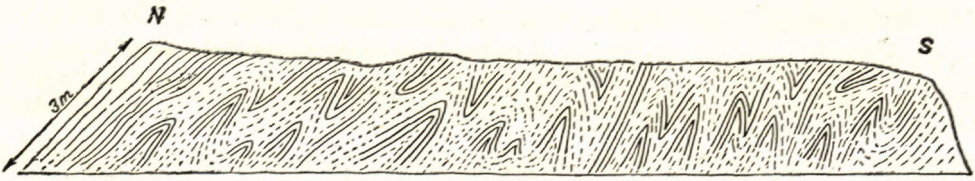
in southeastern direction. The abovementioned facts as well as the distribution of younger mebers in imbricated style occuring in the direct contact with underlying Krížna unit prove beyond any doubt the shear overthrust character of an extensive nappe subsequently divided.

As stress agents in thrusting may be regarded at first the rigid masses of Triassic limestone — dolomitic sequences. In the course of thrusting however distinct areal assortment or *tectonic selection* took place, together with the formation of partial units. Differing physical-mechanical properties and sharp facial boundaries as well as boundaries of different thicknesses caused by the action of synsedimentary agents (faults?) took also a serious part in the thrusting.

The *low- angle position of strata* is related mostly to limestone — dolomitic formation. Morphotectonically two types of structures may be distinguished — flatly lying tectonic blocks and trough -like bent wide synclines with a deep folded bottom. The former appear frequently in the lifted areas situated nearer to the crystaline cores — in the flank portion of post- Paleogene meganticlines. Tectonic blocks of Šíp or Vápec or Veľký Šturec mountains too are all indications of large overthrust of the Choč unit masses. The overthrust character is less apparent in sheets plunging below a younger mostly Paleogene filling of megasynclines (Veľký Choč mt. Kačky complex) and naturally still less at places where the Choč masses take part in the formation of wide megasynclines.

The existence of n a p p e is further proved by tectonic windows appearing at the bottoms of deeply cut valleys frequently due to younger faults (Žihlavník). Besides the undulation of beds with an affinity to flat lying a more distinct folding — digitation of limestone dolomitic complexes were already since long observed and interpreted as digitation with plunging members i. e. as false structure (Poludnica in Nízke Tatry — K e t t n e r 1933). Recent studies of B i e l y (1963) confirm the existence of *extensive fold megastructures* with southern overturn orientation.

Important results on the character of the tectonic style of limestone — dolomitic formation, overturn and chronology of tectonic structures were obtained from the investigations of Stratenská hornatina Hills — a portion of the Northern Gemeridy unit. In the broad northern part of these hills the Middle and Upper Triassic limestone — dolomitic complexes represent the filling of relatively flat, wide



F i g. 9. Isoclinal folds in platy dolomites of M. Karpaty series near Horné Orešany (M. M a h e l).

opened synclines. They stand in sharp contrast with narrower tectonically heavily reduced anticlines composed of underlying, more plastic Werfenian sequence (shale — sandstone — marlstone) dissected by upthrows.

Going westwards simultaneously with the narrowing of the mountain chain and also the individual structures we observe that limestone — dolomitic masses are *straigtened* up passing into narrow, elongated wedges partially opened and *thrusted* southward over the older sequences. Distinct appears the southward overturn orientation of interior structures while the northermost inferior structures show an apparent outward overturn orientation (M a h e ľ 1957).

*

All the abovementioned notions may hardly be exhaustive concerning the rich variability of tectonic styles of such a complicated mountain chain as Central Carpathians. However they certainly did contribute much to the interpretation of previous years. Detection of a *great number of southward oriented overturns* in Mesozoic structures is regarded here as an essential contribution. If such structures were previously mentioned as exceptional cases they were attached to the post — Paleogene movements i. e. to the folding phase with which the formation of megastructures and opening fissures in Central Carpathians were believed to be related.

The southern overturn of tectonic structures is possessed by all the Mesozoic units of Central West Carpathians. We may even say that with the exception of mantle units it is more frequent than the northward overturn. The northward overturn is less apparent also due the Paleogene sequences covering the northern inferior margins of individual structural — geographical units where it is far more frequent. Results obtained from investigation of regions not covered by younger sequences such as Stratenská Hornatina (Vernár stripe including) Juhoslovenský kras, Strážovská hornatina (mainly in its central part) all these prove the existence of a fan arrangement with inward — southern (southeastern) overturn orientation at the broader interior side and outward — northern (northwestern) overturn orientation. The presence of overthrusted masses of the Choč nappe in the fan structure evidently proves that the fan structure and a whole group of partial structures originated after the thrusting during a younger phase but before the Paleogene transgression. To such a younger phase is apparently related also the simultaneous folding involution of Choč and Krížna unit members mentioned previously in the discussion on the characteristics of the imbricated tectonic style Malé Karpaty and mainly Strážovská hornatina Hills. In the same phase of folding resulted also the differential movements of the mobile and rigid Triassic masses of the Choč unit overlying the youngest competent Albian and Neocomian marlstones. Due to these movements the masses of Choč unit

frequently occur over Neocomian representing synchronous anticlinal structures and not above the youngest member i. e. Albian.

Efforts of the last years period characterized by a critical approach toward the nappe conception of West Carpathians of the early thirties contributed to the structural picture by a whole series of essential tectonic conclusions. During the first years of this period several misconceptions were abandoned as for example the interpretation of the huge nappe of Šiprúň series or the nappes of Pajštún and Vysoké Tatry. In the first two cases the correct interpretation were based upon new stratigraphic evaluation of the key sequences previously effected by the nappe conception and related overestimation of the facial stratigraphy.

As a substantial contribution from the tectonic point of view must be regarded the *detection of rich variability of Mesozoic tectonic styles and southward overturned structures* originated during the Cretaceous folding as well as the detection of the fan structure in North Gemeridy, Choč and Krížna units. Intepretation of the new facts however remained within the frame of the old positions firmly established. This concerned first of all the interpretation of the origin of tectonic style and origin of tectonic structures as such believed to be connected and synchronous with the formation of nappes — thrusting of the particular period. Origin of both types of such structures was regarded as an effect of some of the Cretaceous phases. At the beginning it were connected with the Laramian phase (Matějka — Andrusov 1931; Andrusov 1930) and later with Subhercynian phase (Andrusov 1959). This were the influence of the classical tectonics with directly adjusted evolution oriented from paleogeographic units to tectonic ones. It comes only natural that all the new results structural and facial to the old criteria were unadjustable and those mentioned above even in direct contraversy with the former nappe conception. One of the basic obstacles causing contradictions between the new results and former interpretation of nappe origin was the opinion about the uniformity of the overturn orientation of structures formed in a particular period.

Southward overturned structures already previously recognized were regarded by nappists as forms of post-Paleogene age (Schönenberg 1947; Andrusov 1959). For those critically approaching the problem on the contrary these structures represented autochtonous forms similar as were the case of German Alpine geologists. Fan structure with prevailing southward overturn and the presence of imbricated induced tectonic style in Northern Gemeridy Mesozoic of Stratenská hornatina Hills were the major proofs against the nappe interpretation of Northern Gemeridy (Maheľ 1959). Synchronous folding involution of both Choč and Krížna unit members as well as the detection of imbricated tectonic style in Choč unit led to the suggestion that the Choč unit may perhaps have its roots fixed in the northern belts of Central Carpathians although the existence of an extensive Choč nappe overthrusted from the interior parts of Carpathians re-

mained highly probable despite the new synthetic approach (M a h e ľ 1961). Contradictions which arose in the interpretation of structural complications of the Choč unit took an important part in the search for a new general approach.

Detailed analysis of the tectonic pulse of Central Carpathian Mesozoic (see the simultaneously published article: Folding phases and Formations of Central Carpathian Mesozoic) based upon the studies of Formations as well as upon the relations between particular structural elements (both mega — and micro structures) led to the conclusion that *Carpathian Mesozoic structures resulted from several phases of Cretaceous folding.* The nappes of Northern Gemeridy and Choč originated apparently due to an older Cretaceous phase as it is the case of a whole series of fold structures, wedges and thrust folds complicating the general structure causing the diversity of tectonic styles and formation of fan, structures.

The proved fact that southward overturned structures originated during younger phases of Cretaceous orogenic period means a substantial step forward also in the interpretation of certain structural phenomena of the autochtonous units previously connected with the formation of nappes. Such is for example the interpretation of tectonic relations between Krížna and mantle units mainly in areas where Krížna unit occupies a clearly superposed position. Even in the complicated structures of Červené vrchy and Giewont of the Vysoké Tatry series the effect of southward oriented stress might be suggested due to the Krížna unit thrust. Mainly the origin of Lower Triassic wedges and blocks of crystalline should perhaps be logical to connect with such a movement. The northward overturned folds however resulted from some other probably preceding movements related to the induced tectonic style (?).

Translated by J. Kováčik

D. Štúr Institute of Geology,
Bratislava

REFERENCES

[1] A n d r u s o v D., 1959: Stratigraphie und Tektonik der mesozoischen Zone des Massives der Hohen Tatra. Geolog. sborník X, Bratislava. — [2] B i e l y A., 1962: Geológia mezozoika Tribča. Manuscript; Geofond Bratislava. — [3] G a l l w i t z H., 1956: Über tektonische Selektion. Geotekton. Sympos. zu Ehren von Hans Stille. Stuttgart. — [4] G o r e k A., 1958: Geologija massiva Červenego vrchu, Tichoj doliny i Tomanovskoj doliny. Geologický sborník IX/2, Bratislava. — [5] K r a u s E., 1951: Vergleichende Baugeschichte der Gebirge. Berlin. — [6] M a h e ľ M., 1951: Tektonika strednej časti Inovca. Geolog. sborník II, Bratislava. — [7] M a h e ľ M., 1955: Soobraženija o šarjažnoj strukture Zapadnych Karpat. Geolog. práce, Zprávy 3. Bratislava. — [8] M a h e ľ M., 1958: Príspevok k chápaniu tektonického zmyslu makroštruktúr a megaštruktúr križňanskej jednotky v Strážovskej hornatine. Geolog. práce, Zprávy 14. Bratislava. — [9] M a h e ľ M., 1959: Eine neue Einheit in den Westkarpaten. Geolog. práce, Zošit 51. Bratislava. — [10] M a h e ľ M., 1960: Nouvelles connaissances des certaines

„Régions-clés". Geolog. práce, Zprávy 21. Bratislava. — [11] Mahel' M., 1961: Tektonik der zentralen Westkarpaten. Geolog. práce, Zoš. 60. Bratislava. — [12] Passendorfer E., 1953: Regionalna geologia Polski. Tom I — Karpaty. Warszawa. — [13] Schönenberg R., 1948: Geologische Untersuchungen am Nordwestrand des Zips-gömörer Erzgebirges (Karpathen). Ztsch. d. d. geol. Ges. 98, Stuttgart. — (14] Zoubek Vl., 1930: Étude géologique de la zone des racines des nappes subtatriques et des zones voisines au Sud de Podbrezová. Věstník SGÚ VI, Praha. — [15] Zoubek Vl., 1956: Note sur l' exploration géologique de la chaine du Vepor aux environs de Brusno. Zprávy o geol. výzkumech v r. 1956, Praha.

ERVÍN SCHEIBNER

RELATIONSHIP BETWEEN MATERIAL AND TECTONIC STYLE, AND SELECTIVE TECTONICS IN THE KLIPPEN BELT OF WEST CARPATHIANS

Abstract. This paper represents an attempt to generalize dependence of the origin of the tectonic forms on a position in tectonic movements and on material features.

Already M. Neumayr (1871), V. Uhlig (1890), D. Andrusov (1938, 1959), K. Birkenmajer (1958) and others payed an attention to the tectonic forms which occur in the klippen belt. D. Andrusov (1938) and K. Birkenmajer (1958) detaily described the tectonic forms of klippens, klippen mantle and their relationship. They attempted to explain reasons and circumstances of the origin of these forms. In this paper I follow mainly two last authors and I supply their knowledge by new observations and ideas.

Already in the year 1938 D. Andrusov characterized very accurately the klippen belt of West Carpathians (the Pieniny klippen belt) as unusually long, laterally compressed belt with almost vertical position, with chaotic tectonics caused by strong, repeated tectonic movements. It extends in the length of 550 km from western Slovakia (Podbranč—Majeríčky) to Zakarpatská Ukrajina (Neresnica) reaching the breadth of some hundreds m/to a few km. The klippen belt separates the Central West Carpathians from the exterior flysch zone in the north. Differences between these zones are due to the fact that the Central West Carpathians were formed during the pre-Paleogene tectonic movements, while the flysch zone during post-Paleogene ones. The klippen belt was affected by strong tectonic movements forming not only interior, but also exterior zones of the Carpathians and this fact explains the origin of complicated tectonic structure of the klippen belt. In all these zones was described a nappe construction. The tectonic style in details in individual regions is very different. The whole klippen belt is characterized by phenomenon that considerable part of the Triassic, Jurassic and Lower Cretaceous beds defiances to denudation and morphologically

raise above the surrounding, less resistant beds, mainly of Cretaceous and Tertiary age. Morphologically resistant beds produce elevated forms, rocks, reefs or klippens, from which raised the name of the whole klippen belt (klippen belt, Klippen Zone, zone de klippes, bradlové pásmo). The majority of klippens is tectonically separated from surrounding softer suites. These suites may be immediately connected stratigraphically with klippens. Most frequently the plastic suites which mantle klippens are of Middle and Upper Cretaceous age. The plastic suites of the Aalenian frequently have a function of the klippen mantle. G. Stache (1871) pointed out that some klippens are only morphologically raised forms of non-tectonic character and has named them as pseudo-klippens. Such are for instance the Upper Cretaceous exotic conglomerates.

Studying klippens, we see that in details they differ from each other. On a whole, we may distinguish in accordance with other authors (D. Andrusov, 1938; K. Birkenmajer, 1958) some categories. The most frequent forms of klippens are lenses, fragments, vertically or steeply inclined.

In general, here is a rule, that the greater is klippen, the more complete is its stratigraphy. Small fragments are usually composed of rocks of one lithological type, belonging to one stage.

Lenses and fragments composed of plastic suites are usually narrower and more elongated, frequently with detailed folding without evident dependence on the form of lens. Such are the klippens formed by suites of the Lias (marly limestones, marls), Lower Dogger (marls, clays, limestones), Dogger-Malm (radiolarites, Radiolarian limestones and slates), Kimmeridgian (mainly limestones), Neocomian (marly limestones and marls) of the Pieniny series and transitional developments of series (see illustration).

Fragments — klippens formed by rigid, massive rocks of the Dogger and Malm (crinoidal limestones, nodular limestones, massive organodetrital limestones) of the Czorsztyn series are usually shorter and smaller and they resemble blocks, „floes" and „loafs". Such types of klippens are either in horizontal, normal or inverted position, or slightly inclined. These inclined klippens have typical monoclinal structure. Usually we do not see folds, but rather faults. Instances are quoted and illustrated by D. Andrusov (1938): klippen near Lúty Potok in Orava, Kruchý vrch near Vieska in the vicinity of Púchov; klippens with inverted sequence: Mikušovce, klippens near Mestečko in Považie, klippen near Kamionka and others (see illustrations). Some klippens are represented by folds or fragments of folds.

Very instructive example of anticline or of smaller anticlinorium represent the Kysuca series klippens near Turá Lúka (near Myjava) (see Fig. 4). Radiolarites and Radiolarian limestones with siliceous shales are folded into small, erected folds almost isoclinal, locally fan-shaped. Kimmeridgian nodular marly limestones are with cliveage and form smaller lenses. Marly cherty limestones and

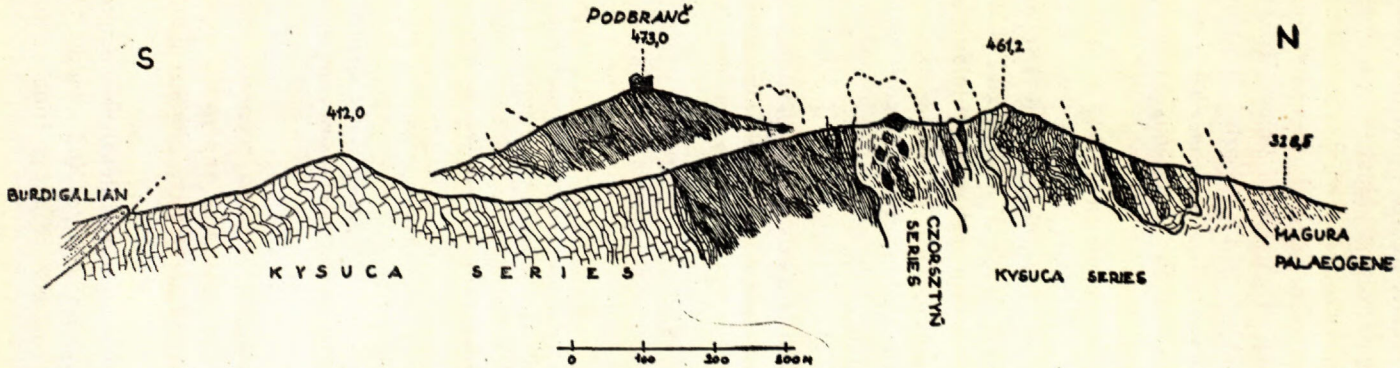


Fig. 1. Geological Section of the Klippen Belt near Podbranč (Western Slowakia). E. Scheibner 1961.

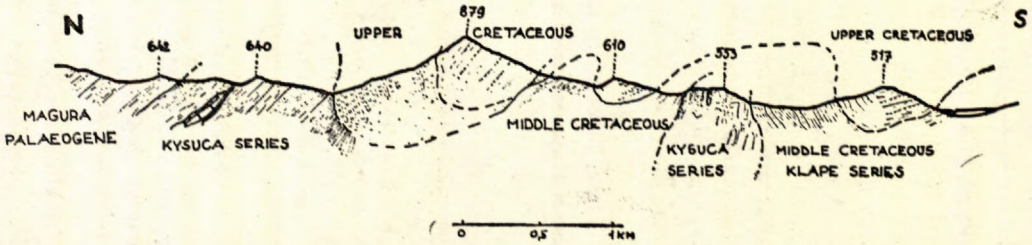


Fig. 2. Geological Section of the Klippen Belt between Varín and Terchová. E. Scheibner 1961.

pink limestones of the Tithonian-Neocomian are slightly folded, rather destructed. This klippen is a good example of different behaviour of individual types of rock-complexes under similar tectonic pressures. The mostly affected are nodular Kimmeridgian limestones. The stratification was also affected, they are compressed into the form of lenses and have cliveage. Radiolarian limestones and radiolarites of the Dogger-Malm are strongly folded. Bedded marly limestones of the Tithonian-Neocomian are less folded and we rather see zones destructed parallely with stratification. Marly shales of the Middle Cretaceous as plastic masses fill up tectonic discontinuities in underlying beds.

We may find in many klippens small folds in the plastic suites, as it was already quoted.

D. Andrusov (1938) described and figured from the Pieniny klippens in Orava detailly folded Neocomian. Here are mostly isoclinal folds. Axial planes of folds are inclined to the north-west. Locally we see disharmonic folding of bedded marly limestones, marly shales, forming the interbeds in limestones.

Regular folded structure have the klippens of the Manín series, known from the Central Považie which occur out of the main klippen belt.

D. Andrusov (1938) described a large Zázrivá klippen which represents a syncline, inverted to the north with immersed frontal part. This klippen belongs to the Kysuca series. In the core of the syncline occurs a mass of detailly folded Neocomian. More recently was found also the flysch Turonian in the core of this fold.

Individual fold structures were described in the Polish part of the klippen belt from the Pieniny series and from transitional developments. From the Czorsztyn series they are not known. (K. Birkenmajer, 1958).

Faults frequently breach klippen suites. Usually they represent less important phenomenon originating due to strong compression, resp. dilatation in invert direction. More important task they have in the Czorsztyn series. Frequently these faults border the „floes" — klippens of the Czorsztyn series accompanied by breccias. Good examples illustrates K. Birkenmajer (1958).

Faults of the regional extent form the southern and locally also northern margin of the klippen belt. These faults in many places have the character of uplifts.

K. Birkenmajer (1958) describes pseudo-tectonic faults originated in the Quaternary by way of breaching of stability of limestone-complexes by erosion. Characteristic are opened fissures without breccias.

The klippen mantle which in tectonic and morphological sense represents more or less plastic suites of the Upper Cretaceous and Paleogene and in the stratigraphical sense the suites of the Upper Cretaceous and Tertiary produce similar forms as are those of the klippens.

Plastic suites of marls, marly shales and marlstones were intensively compressed, frequently originated secondary cliveage. Flysch-like suites and conglomerate complexes, being slightly affected, usually are in monoclinal position or they

form folds. An amplitude of these fold structures is always greater than that of the klippen suites.

In distribution of individual tectonic forms we may locally find some regularities, however, mostly chaotic distribution predominates in details.

Already V. Uhlig (1890) distinguishes two modes of distribution of the Czorsztyn klippens: series and group types.

In series type of the klippens are isolated in series by each other. In the group type small isolated klippens are dispersed in groups, and distances between klippens are lesser than those between the groups. Both the types we know first of all in the Pieniny section of the klippen belt, but they occur also in other sections of the klippen belt for instance near Podbranč in the western part of the klippen belt.

Klippens are made up of the Pieniny series and transitional developments and series and they are arranged in coullises which we may explain partly by lense-like structure.

On a whole, in the distribution of klippens made up of various series we may find certain regularities which are in accordance with results of facial analysis of klippen series. Klippens of the northern geanticlinal Czorsztyn series occur first of all in the northern margin of the klippen belt and klippens of the northern geanticlinal series are restricted in the southern margin in general. Between these klippens there occur klippens of the Pieniny series, transitional developments and series. But in many sections of the klippen belt we see larger belts of klippens occurring north of series, south of which they deposited. North of belts of klippens of the Czorsztyn series occur belts of klippens of the Kysuca, Pieniny series,

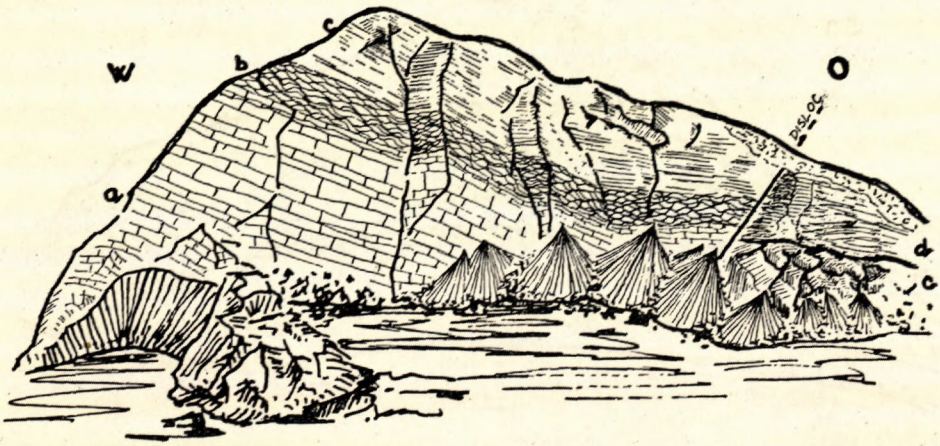


Fig. 3. Czorsztýn Klippen — Quarry Dolný Mlýn. a) crinoidal limestones — Bajocian-Bathonian; b) nodular Czorsztýn limestones — Upper Bathonian-Oxfordian; c) organodetrital limestones — Kimeridgian-Tithonian; d) marly slates — Cenomanian-Turonian.

or transitional developments. The Middle Cretaceous of the Klape series (up to present regarded as belonging to the Manín series) in Považie occurs in whole the breadth of the present klippen belt. These phenomena accordingly to present knowledge we may explain by overthrust of the mentioned rock-complexes in the direction to north in the form of nappes (D. Andrusov, 1938). Locally in the klippen belt occur tectonic windows. From below the Middle Cretaceous of the Klape series in flysch development near Upohlav in Považie the Kysuca series raises with its Middle Cretaceous in deeper development. Similar case is figured on the geological profile between Terchová and Varín.

Already at the beginning we have mentioned that the klippen belt has originated by repeated folding. On the basis of modern stratigraphical investigations was proved that first important tectonic movements in the klippen belt were between the Turonian and Santonian, resp. Lower Coniacian and Upper Santonian (K. Birkenmajer, 1960). The majority of authors (D. Andrusov, 1959; K. Birkenmajer, 1958) mark these movements as subhercynian or pre-Gosau. Due to these movements originated some tectonic units in the region of the klippen belt which were overthrust in the form of nappes. Tectonic reasons which may serve as evidence of this were quoted above. Stratigraphical reasons were described recently (D. Andrusov, E. Scheibner, 1960).

K. Birkenmajer (1958) in accordance with opinions of the Polish authors quotes that the Branisko—Kysuca nappe was thrust over the Czorsztyn one only partially.

K. Birkenmajer (1958) made these conclusion mainly on the basis of the fact that in the region of the Czorsztyn series occur predominantly marly facies of the Upper Cretaceous and in accordance with new investigations of V. Scheibnerová (1962, 1963 in press) also all the Turonian is in marly facies, i. e. the flysch-like development is lacking. Relevance of the flysch-like beds of the Turonian — Lower Coniacian quoted by K. Birkenmajer (1957) needs revision.

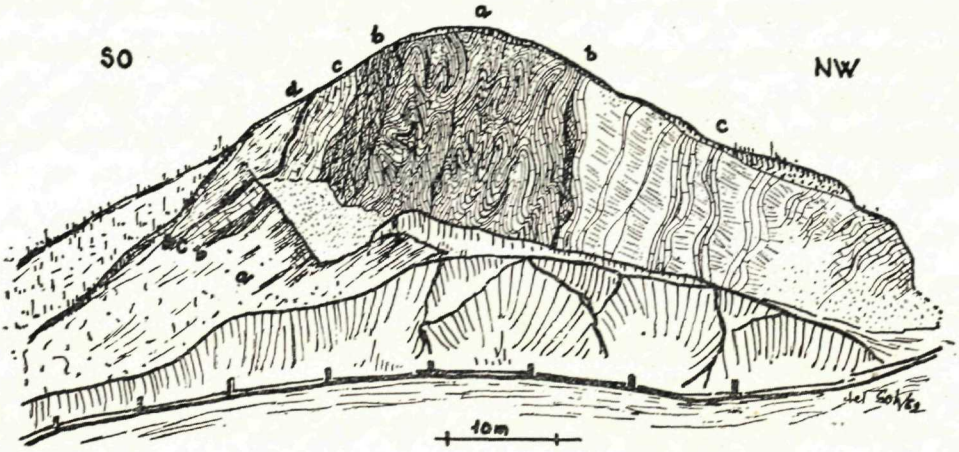


Fig. 4. Intensively folded anticline of the Kysuca Klippen. Quarry near Turá Lúka (Western Slovakia). a) radiolarites, radiolarian limestones, siliceous slates — Dogger-Malm; b) nodular limestones — Kimmeridgian; c) bedded marly and cherty limestones — Tithonian-Neocomian; d) green and reed marly slates — Albian-Cenomanian.

The Czorsztyn series forms klippens normally in the form of prismatic blocks and „floes" of smaller size in comparison with klippens of the Kysuca and locally also Pieniny series. These facts we may explain by gliding of the Kysuca and Pieniny nappe over the Middle Cretaceous of transitional developments. Due to further action of pressure from the south, all the klippen belt was lifted to the north and dilated longitudinally. The rigid substratum of the Pieniny series, also of the Mesozoic mantle representing the pienidy series, was broken up into „floes" and blocks. Upper tectonic units which were lying on the plastic suites of the Cretaceous of lower suites in this time were less affected by dilatation.

The dilatation manifested in these units only in the weakest parts. This might represent the main reason of the origin of such different forms of klippens in particular series.

In the Upper Cretaceous gradually originated new sedimentary district within the area of the folded klippen belt. After the Cretaceous and after deposition of the Lowermost Paleocene took place intensive movements with tendency to the north.

Accordingly to K. Birkenmajer (1958) took place further overthrust of nappes supposed already by older authors. The Upper Cretaceous was folded together with underlying suites. The folding had not such intensity as during the first phases of folding. Again manifested dilatation, because of the pressure of the Central Carpathians, which moved from the south „en block". Accordingly to K. Birkenmajer (1960) in the region of the Czorsztyn series originated diapiric structures. These structures are not identical with true diapires originated

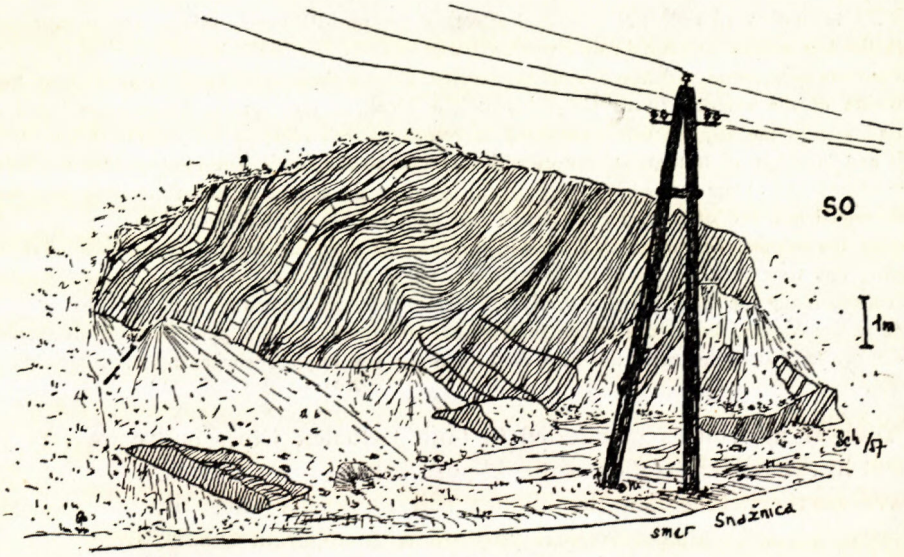


Fig. 5. Slightly folded radiolarites and radiolarian limestones of the Kysuca series near Snežnica.

during the folding of extremely plastic suites. Already D. Andrusov (1938) quoted the diapiric structures, but has not applicated further his opinions. The diapiric structures in our case are of the inverse character. In plastic suites of the Middle and Upper Cretaceous (Globotruncana marls) float rigid complexes which K. Birkenmajer (l. c.) compares with raisins in cake. K. Birkenmajer suggests that due to tectonic pressure the rigid blocks are torn off the substratum and move in plastic masses.

In the year 1947 M. V. Muratov pronounced the opinion that the klippen belt originated by lateral compression and by sliding of suites from elevated regions south of the klippen belt, now probably in the substratum of the Central Carpathian Paleogene. The klippen of Oravský Podzámok, figured by D. Andrusov (1938), quoted as an example of such slide. Essentially, however, this klippen is strongly folded, where suites are variably folded and rolled by their competence. One cannot suppose any slide.

The Czorsztyn klippens may be under certain circumstances interpreted as olistoliths according to M. P. Marchetti (1957). By dilatation of the klippen belt torn off suites of the Czorsztyn series might slide from the elevated northern cordillery in the Turonian marls southwards into the Pieniny sedimentary district of other series which were during this time folded. Olistoliths might be slided to various places which might serve as evidence and explanation of various distribution of klippens of the Czorsztyn series. This interpretation is in contradiction with important fact that up to present have not yet been observed fluidal textures of plastic suites surrounding the Czorsztyn klippens which accompany the origin of olistoliths. Fluidal textures in small size and also olistostromes were observed and described in the Upper Cretaceous Zaskal breccias (E. Scheibner, V. Scheibnerová, 1961).

F. Limanowski (1922) described affects of the post-Paleogene folding and in accordance with the last author D. Andrusov (l. c.) and recently K. Birkenmajer (l. c.). These movements correspond with the Sávian movements. During these movements originated the nappe structure of the exterior flysch Carpathians. The block of the Central Carpathians acted „en block" and in the klippen belt manifested in retrospective folding in the region of the klippen belt and in origin of tectonic structures with direction to the south. The klippen belt was further compressed and across dilated. In longitudinal direction the results of former tectonic movements were wiped out and originated complicated and apparent chaotic tectonics. Almost vertical position of the klippen belt originated (recently proved by deep drilling in Zakarpatská Ukrajina). During this time-period formed the tectonic contact of the klippen belt and Central Carpathian Paleogene along the steep plane. Locally the tectonic contact originated with the Magura Paleogene or the Magura Paleogene occurs in synclinal structures in the klippen belt and in anticlinal structures in Paleogene near the klippen belt occur the klippen elements (D. Andrusov, 1938).

Younger movements manifested in fault tectonics. Cross faults are very frequent in the western section of the klippen belt.

We may conclude that the klippen belt represents unusually laterally compressed belt with almost vertical position with apparent chaotic tectonics originated during intensive and repeated tectonic movements which produced complicated original nappe construction. Of a great importance was a lift of

whole the klippen belt to the north in consequence of which the last was dilated. Due to various position in the folded region of the Pienidy geosyncline originated the main tectonic forms (due to the first tectonic folding movements — Turonian-Lower Santonian). In the southern and central part originated folds (and fold-like formations), in northern part rather faults, breaking up the rigid rock complexes into blocks and floes. The tectonic construction might be complicated by olistoliths, however, their existence up to present was not proved in greater dimensions (see D. Andrusov, V. Scheibnerová, 1963). Folded higher complexes (southern) (Kysuca, Pieniny series) were glided over lower complexes. By further dilatation, in cosequence of stress from the south, higher complexes were less affected. It is interesting that frequently complete suites are more folded than uncomplete ones.

During further movements (Laramic) due to compression of older complexes are folded and impressed into younger ones (Upper Cretaceous) and in consequence of dilatation older complexes were isolated into tectonic individuals, the form of which was produced by former folding.

During the last important folding (Savian phase) due to strong lateral compression are buried the effects of former movements, the rigid complexes are passive; the plastic masses are competent, originate diapiric structures. By further dilatation the tectonic individuality of klippens was made distinct. By retrospective folding originated structures with southern vergency (lenses, uplifts). Also the southern tectonic margin of the klippen belt was produced in this time.

Department of Geology of the Faculty of Natural Sciences
of J. A. Comenius university, Bratislava

REFERENCES

[1] Andrusov D., 1938: Étude géologique de la zone des Klippes internes des Carpathes occidentales. III: Tectonique. Rozpr. SGÚ 9, Praha. — [2] Andrusov D., 1959: Geológia československých Karpát II, Bratislava. — [3] Andrusov D., Scheibner E., 1960: An Outline of the present state of Knowledge of the Geology of the Klippen Belt between R. Vlára and T. Tvrdošín. Geol. sborník SAV XI/2, pp. 239—279, Bratislava. — [4] Andrusov D., Scheibnerová V., 1963: On the origin of redepositions of Foraminifera in the Cretaceous and Paleogene of Carpathians. Geol. sborník SAV XIV/1. — [5] Birkenmajer K., 1957: Neue Forschungen über die Stratigraphie der pieninischen Klippenzone in Polen. Geol. sborník SAV VIII/1, pp. 72—95, Bratislava. — [6] Birkenmajer K., 1958: Przewodnik geologiczny po pieninskim pasie skalkowym. I.—IV. Wyd. geol. Warszawa, p. 350. — [7] Birkenmajer K., 1960: Geology of the Pieniny Klippen Belt of Poland. Jb. Geol. B. A., 103, pp. 1—36, Wien. — [8] Limanowski F., 1921—22: Sur le croisment successif des Maines de l'Europe centrale en Pologne. Spravozd. z bad. geol. I, Warszawa. — [9] Marchetti M. P., 1957: The occurrence of slide and Flowage materials (Olistostromes) in the Tertiary series pf Sicily. Congr. Geol. Inter. 1956, Mexico. Sess. V, Mexico. — [10] Muratov M. V., 1947: Tektonika i osnovnyje etapy rozvitija vostoč. Karpat. Bjul. Mosk. obšč. ispit.

prir. geol. 22/2, pp. 3—48, Moskva. — [11] Neumayr M., 1871: II. Jurastudien, 5. D. Pienninische Klippenzug. Jb. Geol. R. A. 21, 4, pp. 451—536, Wien. — [12] Scheibner E., Scheibnerová V., 1961: On the occurrence of Danian in the klippen belt of W. Carpath. Acta Geol. et Geogr. Univ. Com., Geol. 5, pp. 193—200, Bratislava. — [13] Scheibnerová V., 1962: Biostratigraphy of the Cretaceous and Cretaceous-Tertiary Boundary in the Klippen Belt of West Carpathians in Slovakia. Geol. sborník SAV XIV/1. — [14] Scheibnerová V., 1963: Some interesting profiles from the Klippen Belt of West Carpathians. Geol. sbor. SAV (in press). — [15] Stache G., 1871: Die geologischen Verhältnisse der Umgebung von Unghvár in Ungarn. Jb. Geol. Reichsanst. 21, pp. 379—436, Wien. — [16] Uhlig V., 1890: Ergebnisse geologischer Aufnahme in der westfalizischen Karpathen. II. Der pienninische Klippenzuge. Jb. Geol. Reichanst. 40, 3—4, pp. 559—824, Wien.

ANTON BIELY

BEITRAG ZUR KENNTNIS DES INNEREN BAUES DER CHOČ-EINHEIT

Die Choč-Einheit tritt in mehreren Gebirgen der Westkarpaten in Form von grösseren oder kleineren tektonischen Schollen auf, welche gewöhnlich aus mittlerer Trias gebaut sind. In diesem Falle ist der innere Bau ein einfacher und ist auch richtig interpretiert. Als Beispiel derartiger tektonischer Form sind Schollen im Strážov-Gebirge oder in der Grossen und Kleinen Fatra zu erwähnen. In anderen Gebirgen ist diese Einheit durch mächtige Massen in weitem Raume vertreten und bildet den wesentlichen Anteil des Gebirges, z. B. die nördlichen Abhänge der Niederen Tatra. In diesem Falle ist die tektonische Position der Choč-Einheit zwar auch merkbar, aber ihr innerer Bau ist wesentlich komplizierter. In diesem Beitrage ist die Charakteristik des inneren Baues der Choč-Einheit in der Niederen Tatra kurzgefasst erläutert.

Die nördlichen Abhänge der Niederen Tatra

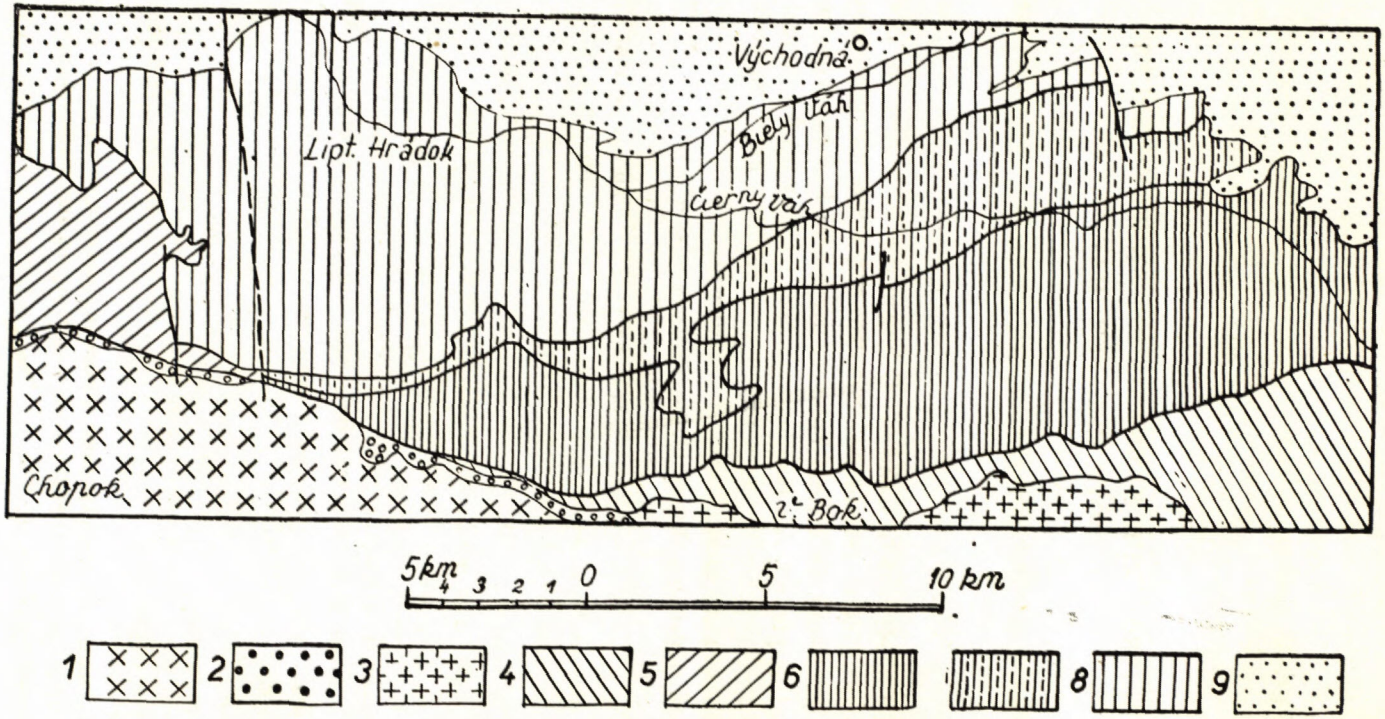
An den nördlichen Abhängen der Niederen Tatra ist die Choč-Einheit durch drei tektonische Teilelemente zweiten Ranges* vertreten. Diese tektonischen Elemente sind durch ihren inneren Bau und lithologisch-stratigraphischen Inhalt gekennzeichnet. Die zwei unteren Elemente sind durch die Melaphyr-Serie** und die als Čiernovážska-Serie bezeichnete Trias vertreten.

* Derartige tektonische Teilelemente werden oft als Teildecken bezeichnet. Diesen Termin werde ich nicht verwenden, da mit ihm auch eine bestimmte genetische Auffassung dieser tektonischen Formen verbunden ist, welche mit unseren Kenntnissen des inneren Baues der Choč — Einheit nicht übereinstimmt.

** Die Sedimente der Melaphyr-Serie wurden in Schichtfolgen gegliedert, deren zwei obere zur unteren Trias, die unter ihnen liegenden zum Perm und zum Karbon angehören. Die Melaphyre sind permischen Alters (Biely 1962).

Tektonische Skizze des östlichen Teiles der Niederen Tatra

Zusammengestellt A. Biely



Erläuterungen: 1. Ďumbier Krystallin, 2. Quarzite-Hülle des Ďumbier Krystallins, 3. Kraklov Krystallin, 4. Serie des Veľký Bok, 5. Ilanová Serie, 6.—8. Teilelemente der Choč-Einheit: 6. unteres, 7. mittleres, 8. oberes, 9. Paleogen

An dem Baue des oberen Teilelementes ist Trias beteiligt, welche als Bielovážska Serie bezeichnet wurde. Im Grunde handelt es sich also um drei übereinander liegende Schichtkomplexe, welche durch sekundäre nördlich abfallende tektonische Flächen zweiten Ranges voneinander abgetrennt sind. Dabei ist merkbar, dass die Vertretung einzelner stratigraphischen Glieder sich vom unteren Schichtkomplexe zum oberen ändert.

Das *untere tektonische Teilelement* tritt an der Oberfläche in Form eines Dreieckes auf, welcher im Svätojánska-Tale beginnt und sich in östlicher Richtung erweitert. Dieses Teilelement ist durch einen monoklinalen Bau gekennzeichnet, welcher durch Karbon und besonders durch Perm gebildet ist. Im Gebiete zwischen dem Svidovský- und Svarínka Bache ist die Trias aussergewöhnlich intensiv reduziert und tritt stellenweise nur in Form von Linsen auf, welche die Aufschiebungsfläche des mittleren Teilelementes begleiten. Die Trias erreicht eine grössere Mächtigkeit östlich vom Bache Svarinka und im Tale des Vyšný Chmelienec treten auch Jura-und Unterkreide-Schuppen auf. Faltungsdeformationen wurden im diesen Komplexe nicht beobachtet.

Das *mittlere tektonische Element* erstreckt sich vom Gebiete des Svidovský-Baches aus nur als einige 10 m mächtiger Streifen, bei Malužina erweitert es sich und setzt sich nach Osten bis Svit fort. An seinem Baue sind an der Oberfläche nur in kleinerer Vertretung vortriassische Glieder beteiligt. Die Hauptmasse ist durch Trias gebildet und im nördlichen Teile tritt auch noch Jura hinzu. Die flache Aufschiebung dieses Teilelementes ist besonders zwischen Malužianka und Svarínka merkbar. In östlicher Richtung fällt diese Aufschiebungsfläche wesentlich steiler nach Norden ab. Was den inneren Bau dieses Elementes anbelangt, beobachten wir im nördlichen Teile nahe der Berührung mit dem oberen Teilelemente eine deutliche Faltung und westlich der Svarínka eine intensive Reduktion der nachuntertriassischen Glieder. Was den Faltencharakter anbetrifft, ist an den SW-Hängen der Sokoly im Reliefe der Sattel einer südvergenten Falte angeschnitten, deren Kern durch Kampil gebildet ist. Die Faltungsdeformation des Dolomitenkomplexes N des Čierny Váh ist auch aus dem Brachysynklinalverschlusse des Lias NÖ der Sokoly und im Hlboká-Tale ersichtlich.

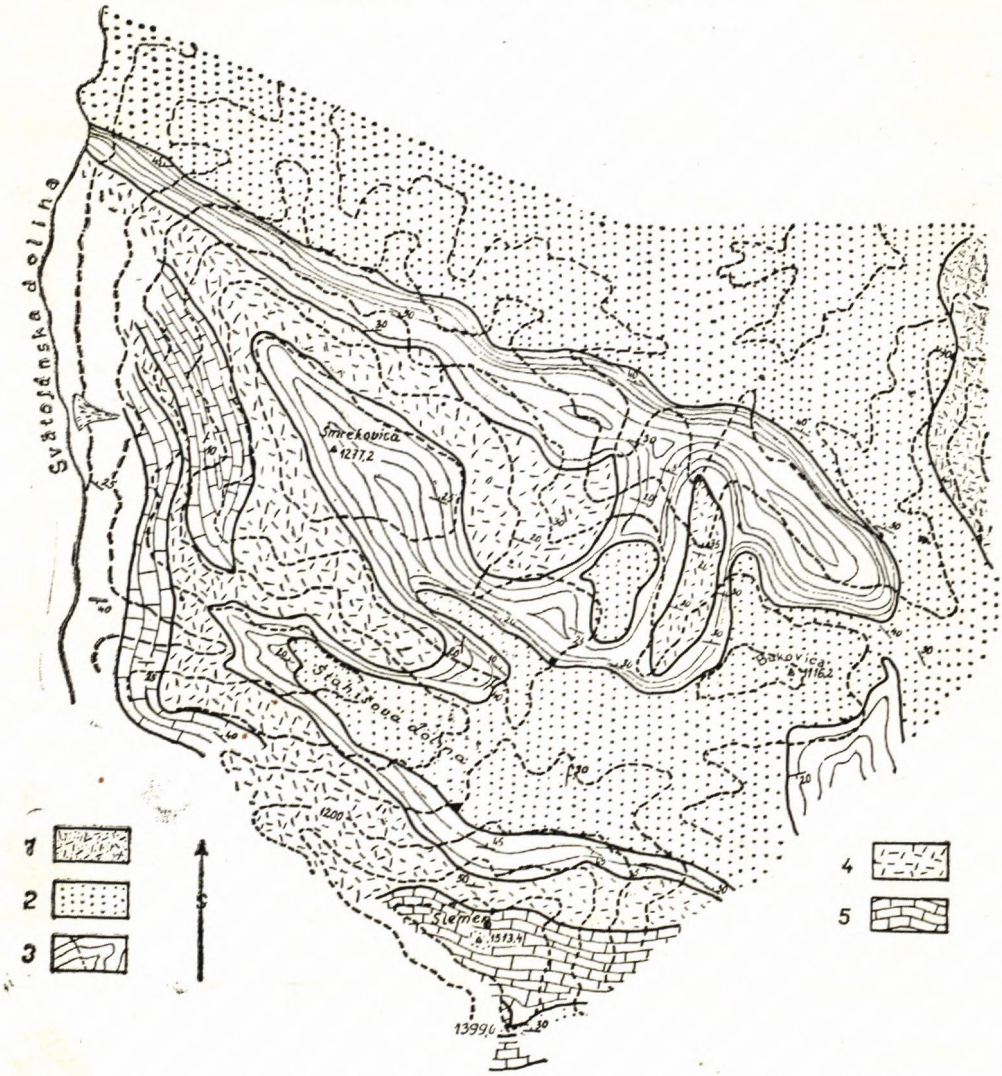
In nördlicher Richtung taucht das untere und mittlere tektonische Element unter das obere. Obwohl es sich um einen etwa 2000 m mächtigen Komplex handelt, ist doch sicher, das er in nördlicher Richtung auskeilt. In den mesozoischen Inseln unter der Hohen Tatra (Liptov-Becken) tritt über dem Neokom der Krížna-Einheit unmittelbar die Bielovážska-Serie auf.

Das *obere tektonische Teilelement* ist im Abschnitte von Demänová-Tale bis Svit durch mittlere bis obere Trias der Bielovážska-Serie gebildet. Westlich des Svätojánska-Tales liegt es über der Ilanovská-Serie, O. dieses Tales über dem mittleren Teilelemente der Choč-Einheit. Die steil nach Norden abfallende Aufschiebungsfläche zwischen dem mittleren und oberen tektonischen Teilelemente

ist S von Východna durch einen Streifen von Linsen mit mittel- und obertriassischen Gesteinen begleitet. Ein einfacherer Bau vom Charakter einer schwach gewellten nach Norden abfallenden Monoklinale ist nur zwischen dem Bocianka- und Čierna-Tale (S von Východná) anwesend. Anderswo befindet sich eine für

Geologische Karte des rechten Abhanges des Svätojanská-Tales zwischen Smrekovica und Slemeň

Zusammengestellt von M. Pulec 1959

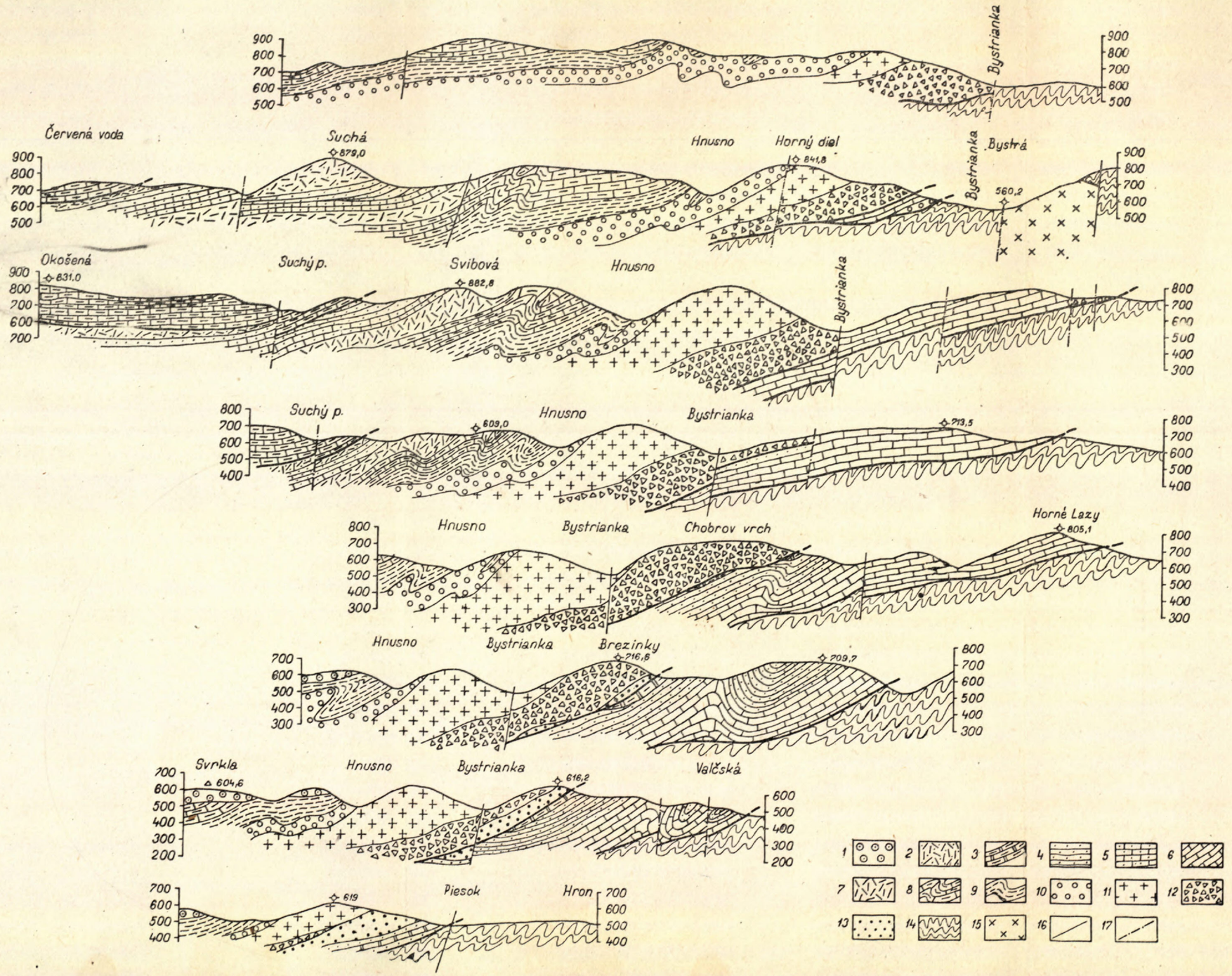


Erläuterungen: 1. Hauptdolomit, 2. Lunzer Schichten, 3. Reinflingkalke, 4. Chočdolomit, 5. Guttensteinkalk

10c

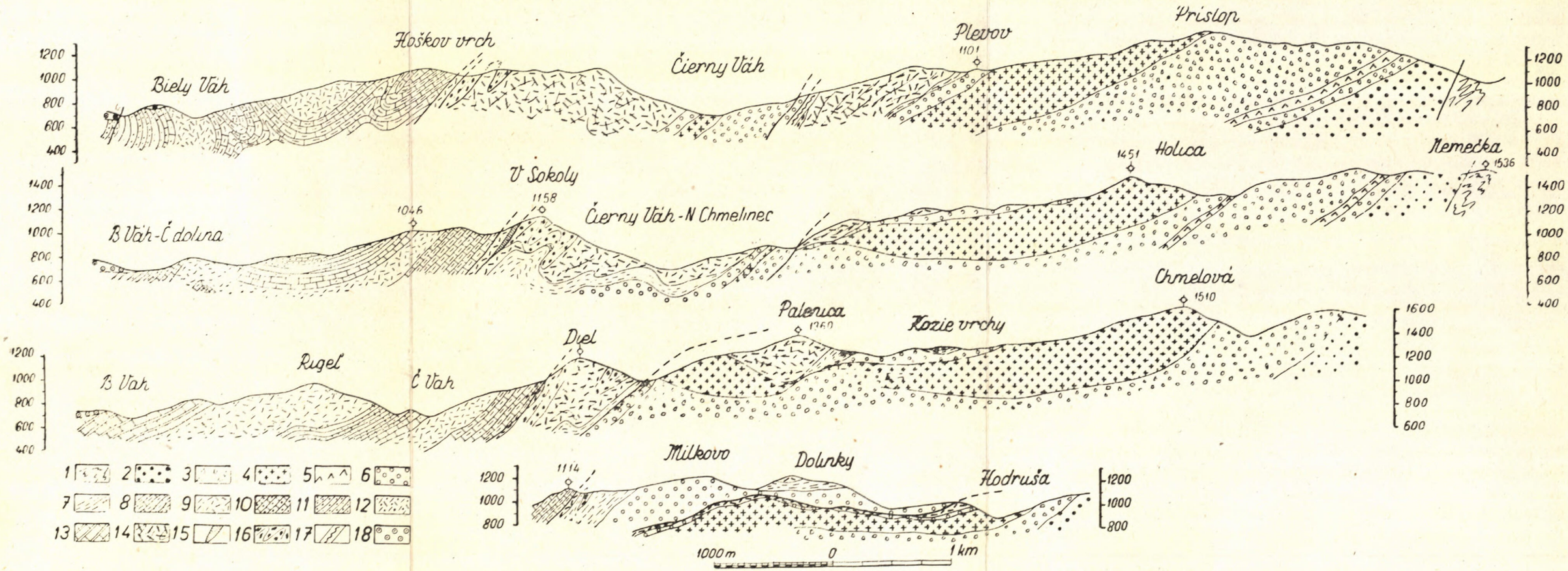
Profile durch die Choč-Einheit zwischen Piesok und Bystrá

A. Biely, 1962



Erläuterungen: 1. Paleogen, 2. Hauptdolomit, 3. helle und dunkle Kalke-obere Trias, 4. Lunzer Schichten, 5. Reiflingkalke, 6. helle und dunkle Kalke, Dolomite und Hornsteinkalke mittlere Trias, 7. Choč-Dolomite, 8. Gutensteinkalke, 12. bunte Schiefer, Sandsteine, Arkosen, Grauwacken, Konglomerate-Perm, 13. dunkle Schiefer, Sandsteine, Arkosen-Karbon, 14. metamorphe Serie vom Typus Veľký Bok, 15. Ľubietová Krystallin

Geologische Profile durch die Choč-Einheit zwischen Malužiná und Východná. (A. Biely 1962)



Erläuterungen: 1. Serie des Veľký Bok, 2.—17. Choč-Einheit: 2. dunkle Schiefer, Sandsteine, Konglomerate-Karbon, 3. bunte Schiefer, Sandsteine, Arkosen, Grauwacken, Konglomerate-Perm, 4. Melaphyre, 5. Augit-Porphyrite, 6. Quarzite und bunte Schiefer-untere Trias, 7. bunte Schiefer und Kalke-Kampil, 8. Guttensteinkalke, 9. Choč-Dolomite, 10. Reiflingkalke, 11. Lunzer Schichten, 12. Hauptdolomit, 13. Dachsteinkalk, 14. helle und dunkle Dolomite an der Basis stellenweise mit dunklen Kalken-mittlere und obere Trias, 15. schwarze Schiefer und Kalke-Rhaet, 16. dunkle Krinoiden- und Hornsteinkalke- Lias, 17. graue mergelige Kalke-Neokom, 18. Paleogen

den inneren Bau charakteristiche intensive Faltungsdeformation. Ein sehr komplizierter Faltenbau befindet sich zwischen dem Čierna-Tale und Važec. Der normale Charakter dieser Falten ist durch brachysynklinale und brachyantiklinale Verschlüsse der Falten im Čierna-Tale bestätigt (Biela A. 1960). Der Südteil dieses Elementes enthält hier einen südvergenten Charakter, der Nordteil dagegen einen nordvergenten. Die Fortsetzung der nordvergenten Falten in westlicher wie auch in östlicher Richtung ist durch Paleogen bedeckt. Es zeigt sich also ein fächerfömiger Bau, welcher in westlicher Richtung in die schon erwähnte wenig deformierte, bis zum Bocianka-Tale reichende Monoklinale übergeht.

Westlich des Bocianka-Tales geht die Monoklinale wieder in einen komplizierten Faltenbau über. Die Vorstellung des inneren Baues der Choč-Einheit ist doch in diesem Gebiete eine wesentlich verschiedene als wie ich es nun östlich des Čierna-Tales beobachtete. Es werden hier komplizierte Teildecken mit nach Norden getauchten Stirnen, also ein typisch nordvergenter Bau beschrieben (R. Kettner 1931, 1958). Es ist doch zu bemerken, dass die Verschliessung der Synklinalen oder der Antiklinalen in den Profilen stets entweder unter dem Relief oder durch Luftsättel dargestellt ist. Nach vielen Orientierungstouren und nach dem Durchstudieren der Karten von M. Pulec (1959) stellen wir fest, dass der innere Bau dieses Gebietes vom Baue des Gebietes von Východná und Važec nicht verschieden ist. Als Beweis dessen dienen die Sättel und Mulden der südvergenten Falten, welche durch den Štiavnica-Bach angeschnitten und am rechten Abhange des Svätojánska Tales aufgeschlossen sind.

Aus dem beschriebenen erfolgt, dass der wesentliche Teil der Falten eine südliche Vergenz aufweist. Daraus geht dann die logische Schlussfolge hervor, dass die Aufschiebungen der einzelnen tektonischen Teilelemente der Choč-Einheit von N nach S folgten. Es sind Erscheinungen, welche zum ersten Blick der Auffassung der Choč-Einheit als weitläufiger von S nach N verschobener Decke grundsätzlich widersprechen. Zur Erklärung dieses Phänomens ist doch nötig aus einer weitgehenderen Analyse der Deformation und der tektonischen Entwicklung der mesozoischen Einheiten auszugehen. Für die nördlichen Abhänge der Niederen Tatra sollte man aus der Analyse der Velký Bok-Serie ausgehen, welche das unmittelbare Liegende der Choč-Einheit bildet. An dieser Serie ist ersichtlich, dass sie vor dem Eozän zweimal deformiert wurde. Die ältere Deformation ist durch eine ältere schichtparallele Kristallisations-Schieferung, die jüngere dagegen durch eine quer zur Schichtung laufende Schieferung dokumentiert. Das heisst, dass das Liegende der Choč-Einheit, d. h. die Veľký Bok-Serie durch zwei voneinender in der Zeit getrennte tektonische Vorgänge betroffen wurde. Wenn wir den inneren Bau der Choč-Einheit an den nördlichen Abhängen der Niederen Tatra von dem Aspekte betrachten, dass im Laufe ihrer Entwicklung sich zwei tektonische Vorgänge äusserten (ähnlich wie auch in ihrem Liegenden), dann steht der südvergente Bau nicht mit der Decken-Position

der Choč-Einheit, sondern mit der bisherigen Erklärungsweise der Genese des inneren Baues im Wiederspruche. Der innere Bau, wie er oben dargelegt ist, scheint uns ein sekundäres Phänomen zu sein, welches jünger als die eigentliche Decken-Aufschiebung ist.

Die südlichen Abhänge der Niederen Tatra

An den südlichen Abhängen der Niederen Tatra haben wir das Gebiet ungefähr zwischen den Bächen Bystrianka und Vajsková durgeforscht. Die Charakteristik des inneren Baues der Choč-Einheit in diesem Gebiete beschrieb R. Kettner (1958). Diese Einheit liegt im SO über der epimetamorphen Serie von Typus Veľký Bok. Nordwestlicher, im Gebiete von Jasenie liegt sie über dem Neokom der Krížna-Einheit. Im Lopej-Kessel ist sie durch eine grobklastiche Formation paläogenen Alters (R. Kettner 1931, 1958) bedeckt.

Die Choč-Einheit erster Ordnung tritt in drei Schichtfolgen-tektonischen Teilelementen zweiter Ordnung auf, welche voneinander durch tektonische Flächen zweiten Ranges abgetrennt sind. Ähnlich wie an den nördlichen Abhängen ist hier in jeder Schichtfolge eine andere stratigraphische Vertretung der Glieder.

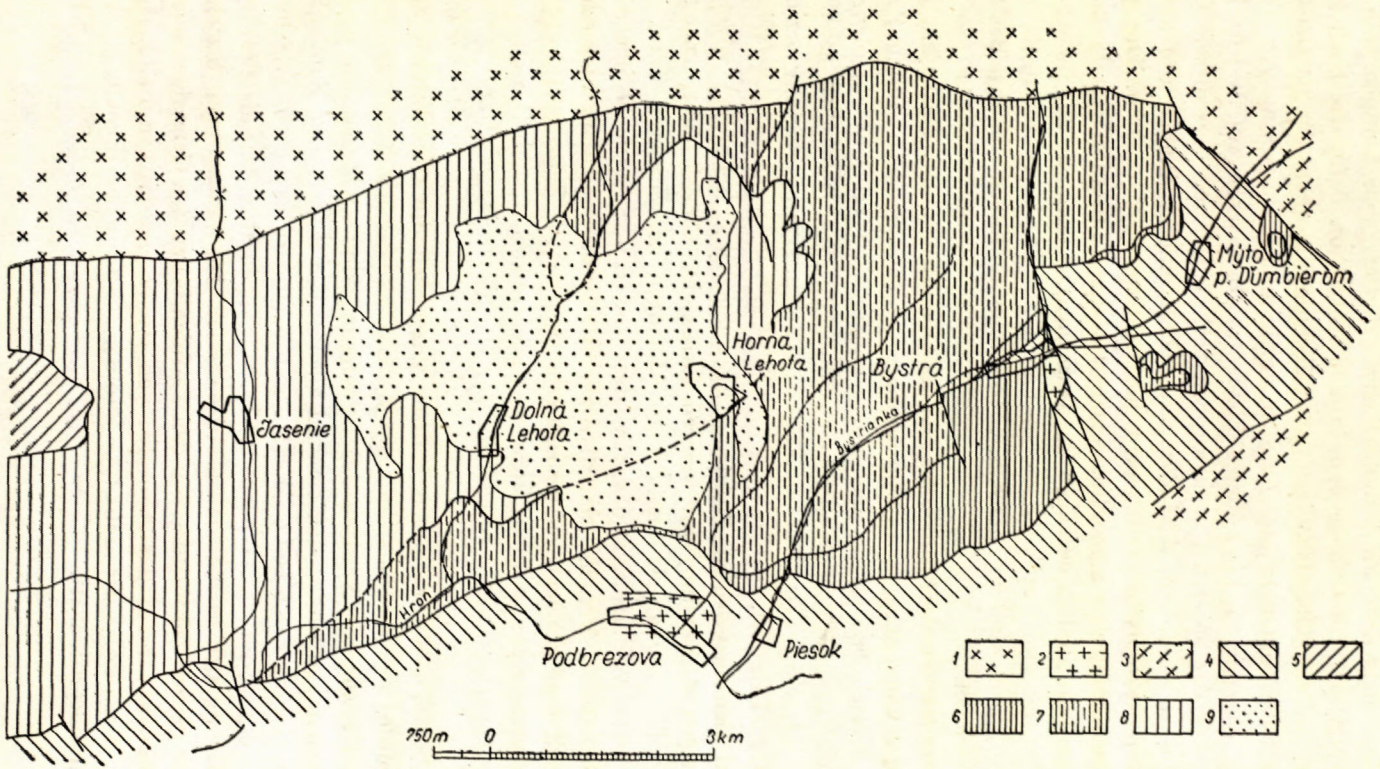
Das *untere Element* hat eine stratigraphische Verbreitung Unter- bis Obertrias. Zu seiner litologisch-stratigraphischen Entwicklung ist zu bemerken, dass gegenüber dem höheren Element in mittlerer und oberer Trias auch weisse Kalke von Wetterstein-Typus anwesend sind. An der Oberfläche hat das untere Teilelement die Form einer in Richtung NO—SW verzerrten Linse. Sie beginnt bei Mýto pod Ďumbierom; in SW-Richtung zwischen Valaská und Bystrá verbreitet sie sich und bei Piesok keilt sie aus. In NW-Richtung neigt sich dieser Linsenkörper unter den Komplex des mittleren Teilelements. Im Gebiete von Jasenie tritt über dem Neokom der Krížna-Einheit untere und mittlere Trias der höheren Teilelemente auf und darum ist es sicher, dass das untere Teilelement in NW-Richtung auskeilt. Morphologisch tritt sie also in der Form einer Linse auf. Was den inneren Bau dieser Linse anbelangt, ist sie im Gebiete von Valaská in Falten mit innerer Vergenz eingefaltet. Die Achsenrichtung ist NO mit einer Neigung zum NO. Der brachyantiklinale Verschluss der Falte ist im Tale N von Valaská aufgeschlossen.

Eine wesentlich grössere laterale und stratigraphische Verbreitung besitzt das *mittlere Teilelement,* welches durch die Melaphyr-Serie und Trias der Bielovážska-Serie vertreten ist. Karbon tritt an der Oberfläche in einer etwa 2 km langen Linse N von Piesok auf. Die Dicke dieser Linse überragt nicht 60—70 m. Wahrscheinlich ist auch die Breite eine kleine und in NW-Richtung keilt sie aus.

In Form eines sehr mächtigen Komplexes ist Perm anwesend, seine magmatische wie auch sedimentäre Komponente. Im Norden ist er durch einen Bruch N von Mýto abgegrenzt. In der Form eines mächtigen Streifens zieht er sich von Stupka in Richtung nach SW, bei Bruchačka keilt er aus und in Richtung SW

Tektonische Skizze der Umgebung von Podbrezová

Zusammengestellt A. Biely



Erläuterungen: 1.—3.: Krystallin: 1. Ďumbier-Zone, 2. Ľubietová-Zone, 3. Kraklová-Zone, 4. metamorphe Serien von Typus Veľký Bok, 5. Neokom der Križna-Einheit, 6.—8. Choč-Eeinheit mit tektonischen Teilelementen: 6. unteren, 7 mittlerem, 8. oberem; 9. Paleogen

tritt er schon nicht mehr an der Oberfläche auf. Der ganze Komplex fällt in der Richtung NW ab. Im Gebiete von Jasenie tritt schon Perm wie auch Karbon nicht mehr auf der Oberfläche auf, aber über dem Neokom der Krížna-Einheit liegt unmittelbar untere Trias. Ähnlich treten in der Umgebung von Tály im Liegenden der unteren Trias dieses Elementes Rauwacken auf, welche höchstwahrscheinlich der liegenden metamorphen Serie angehören. Aus diesem Grunde ist es nötig zu vermuten, dass der permische Komplex ähnlich wie auch das ganze untere tektonische Teilelement in Richtung NW auskeilt. Der permokarbonische Komplex ist monoklinal gelagert und von linsenförmiger Form.

Die Trias fällt ähnlich wie auch der Perm in NW-Richtung ab. Zwischen den Bächen Hnusný und Suchý ist sie in Falten mit SO-Vergenz aufgefaltet. Die inneren Vergenzen sind von geschlossenen Falten am linken Abhänge des Suchý-Baches abgeleitet.

Das *obere tektonische Element* tritt an der Oberfläche Ö des Vajskovský-Baches auf. An der Oberfläche ist es von kleiner Ausdehnung, da es durch Paleogen des Lopej-Kessels bedeckt ist. Die untere und mittlere Trias ist auf obere Trias aufgeschoben und fällt in westlicher Richtung ab. Wahrscheinlich gehört auch diesem Elemente die Trias der Choč-Einheit W vom Lopej Kessel an und es setzt sich im Hron-Tale fort.

Der auf den beigelegten Profilen dargestellte tektonische Bau widerspricht der bisherigen Auffassung des inneren Baues der Choč-Einheit (Kettner 1958). Ähnlich wie an den nördlichen Abhängen der Niederen Tatra äussert sich da dieser Widerspruch dadurch, dass die von S nach N überschobene Einheit eine innere Vergenz besitzt. Auch hier befindet sich im Liegenden der Choč-Einheit eine schwach metamorphierte mesozoische Serie vom Veľký Bok-Typus, in welcher zwei Schieferungsrichtungen entwickelt sind. Die ältere Schieferung läuft parallel mit der Schichtung, die jüngere diagonal zur Schichtung. Es handelt sich hier um die Äusserung zweier zeitlich abgetrennter tektonischer Vorgänge, woraus wir vermuten können, dass auch die Choč-Einheit zweimal gefaltet wurde.

Die zwei erwähnten Systeme der Schieferung sind nicht nur für die Veľký Bok-Serie charakteristisch, aber sie sind auch in der Hüllen- und Krížna-Einheit des Tribeč-Gebirges (Biely 1962) und in untertriassischen Schichten der Gemeriden entwickelt (Snopko 1962). Wir sehen also, dass die zwei Systeme der Schieferung sich in regionalem Ausmasse in den mesozoischen Serien praktisch in der ganzen Zentralzone von den Tatriden bis zu den Gemeriden äusserten. Daraus können wir auf das Auftreten von zweier tektonischen Faltungsphasen schliessen, deren Folge der alpinotype Bau der mesozoischen Einheiten, die Choč-Einheit mitinbegriffen, ist.

Zusammenfassung

Die Choč-Einheit besitzt als eine der alpinen tektonischen Haupteinheiten, im östlichen Teile der Niederen Tatra einen komplizierten inneren Bau. Der innere Bau ist dadurch gekennzeichnet, dass die tektonische Einheit erster Ordnung in einige tektonische Teilelemente zweiter Ordnung geteilt ist, welche durch tektonische Flächen zweiter Ordnung und sekundäre tektonische Flächen abgetrennt sind. Die sekundären tektonischen Flächen besitzen den Charakter von Aufschiebungen, welche stellenweise durch linsenförmige Streifen begleitet sind. Die Streifen stellen zerrissene Schichtfolgen von Verbindungsschenkeln zweier Teilelemente dar. Für den inneren Bau der Teilelemente ist zumeist eine Faltendeformation charakteristisch. An den südlichen und nördlichen Abhängen der Niederen Tatra sind die Falten von südvergentem Charakter, nur im Gebiete von Východná besitzt der nördliche Teil des oberen Teilelementes eine Nordvergenz. Die Vorgänge, welche zur Bildung dieses Baues führten, stellen wir uns folgenderweise vor:

Die Choč-Einheit wurde in ihre heutige Lage in der Form einer Scher-Decke in etwa subhorizontaler Lagerung überschoben, wobei der Karbon und Perm eine mindere Ausdehnung als die Trias besitzen. Die jüngeren tektonischen Bewegungen, welche eine Raumverkürzung verursachten, äusserten sich im Baue des Liegenden ausser anderen Erscheinungsformen auch durch Schieferung und in der Choč-Einheit durch Faltung, Enstehung von tektonischen Teilelementen und durch kleinere Aufschiebungen. Im erwähnten Gebiete sind die inneren Flanken der so deformierten Choč-Einheit erhalten geblieben.

Es wurde nicht festgestellt, in welcher Zeitfolge die einzelnen tektonischen Bewegungen-Phasen sich abspielten. Es scheint doch genügend bewiesen zu sein, dass die grossen Deckenüberschiebungen sich während der subherzynischen Phase abspielten (Andrusov — Bystrický 1959). Die Bewegungen, welche die innere Deformation der Choč-Einheit und die Schieferung ihres Liegenden verursachten, waren jünger als die Überschiebungen, aber älter als die Sedimente des Lopej-Kessels (diese lagern diskordant auf ihrem Liegenden und überdeckt die Aufschiebungsflächen der Teilelemente). Wenn das Alter der Sedimente des Kessels Senon ist, (M. Maheľ 1959), so spielten sich beide Bewegungen in der vorgosauischen Phase ab ist et Paleogen (R. Kettner 1950, 1958), dann wären die laramischen Bewegungen in Form von Faltungsbewegungen nicht auszuschliessen. Es ist nicht anzunehmen, dass der südvergente innere Bau der Choč-Einheit Rückfalten von Typus Holica, welche infolge der nachpaleogenen Bewegungen entstanden sind (D. Andrusov 1959) besitzt.

Dionys Štur's Geologisches Institut,
Bratislava

Aus dem Slowakischen übersetzt von J. Pevný.

SCHRIFTTUM

[1] Andrusov D., 1936: Subtatranské přikrovy Západních Karpat. Carpatica, Praha. — [2] Andrusov D., 1959: Prehľad stratigrafie a tektoniky druhohorného pásma masívu Vysokých Tatier na území Slovenska. Geologický sborník X/1, Bratislava. — [3] Andrusov D. — Bystrický J., 1959: O význame subhercynskej fázy vrásnenia v Západných Karpatoch. Geologický sborník X/2, Bratislava. — [4] Biely A., 1960: Chočský príkrov na severných svahoch Nízkych Tatier, Geologické práce, Zprávy 20, Bratislava. — [5] Biely A., 1962: Niekoľko tektonických a stratigraficko-litologických poznatkov z východnej časti Nízkych Tatier a Tribča. Geologické práce, Zoš. 62, Bratislava. — [6] Biela A., 1960: Geologické pomery územia medzi Bielym a Čiernym Váhom. Rukopis, diplomová práca, archív GÚDŠ, Bratislava. — [7] Kettner R., 1931: Geologie du versant nord de la Basse Tatra dans la partie moyenne. Knihovna SGÚ 13 A, Praha. — [8] Kettner R., 1950· O formaci patrně gosauského stáří poblíže stanice Dobšinská ľadová jaskyňa na Slovensku. Věst. Král. čes. spol. nauk Tř. mat.-přír., Praha. — [9] Kettner R. — Šťastný V., 1931: Coup d'oeil sur la géologie de versant sud de la Basse Tatra. Knihovna SGÚ 13 A, Praha. — [10] Kettner R., 1958: Die Tektonik des Gebirges Nízke Tatry (Niedere Tatra). Geologie, Jahrb. 7, Heft 3—6, Berlin. — [11] Maheľ M., 1959: Vysvetlivky ku geologickej generálnej mape — list Banská Bystrica. Manuscript; Archív GÚDŠ, Bratislava. — [12] Pulec M., 1958: Sedimentológia lunzských vrstiev. Manuscript; Geofond, Bratislava.

JULIÁN ZELMAN

RELATION BETWEEN THE COMPETENCY AND INCOMPETENCY OF THE ROCK OF THE EPIMETAMORPHOSED MESOZOIC SERIES OF THE LIPTOVSKÁ TEPLIČKA DISTRICT AND FOLD STRUCTURES*

(1 text figure, Plate V)

General geology

South of Liptovská Teplička has developed the mantle series of Kraklova crystalline called the series of Veľký Bok. It is epimetamorphsed and was regarded as belonging to the Križna series (Kettner 1937; Zoubek 1952; Biely 1956). After Maheľ (1959) it belongs to the „Westcarpathian series" group and there are some signs of the transition to the Križna series. Biely (1961) also dismissed the opinion that it belong to the Križna series, especially as it is lacking in the spotted marls facies in the Lias, which is a very characteristic mark of the Križna series. On the other hand the Lias is developed here in a very shallow facies, which is typical of either the Tatric, or Westcarpathian series.

The stratigraphical succession is the following:

1. Light quarzites, probably the *Lower Triassic.*
2. A complex consisting of the light and dark-grey massive dolomites, probabbly the Middle and Upper Triassic. In the upper part of this complex are interbedded black-grey shales with a small quantity of mica and sandstones with a mica only some metres in thickness — *Lunz Beds.*
3. Shales of various colors interbedded with dolomites and quartzites — *Keuper.*
4. Basal transgressive beds of the *Lias* consist of the breccias and compact limestones.
5. Above this there are beds, the exact stratigraphical succession of which is not known as far as we know. It may be the *Upper Lias* up to the *Dogger.* They consist of light-grey, fine-grained thin-bedded even schistous limestones interbedded with

* From the point of view of small tectonics, which includes macroscopic structural orms from the smallet up to those several tens of metres in size.

thin layers of shales, crinoidal limestones interbedded with cherts, light-grey, relatively fine-grained limestones with relatively few the fragments of crinoids and interbedded with light cherts, schistous, locally rather epimetamorphosed limestones.

6. Cryptocrystallic, locally rather marbled white, pink, violet nodular limestones and the pink, locally rather schistous limestones — the *Malm.*

7. Light-grey, greenish, bedded up to schistous limestones and marly limestones, which are often rather intensively epimetamorphosed — the Neocomian.

All those rocks, except the dolomite complex, are rather expressively epimetamorphosed. We can observe a transition up to the phyllitic slates.

Influence of the competency and incompetency of the rocks upon the development of the fold structures

If we study the rocks mentioned above from this point of view, we observe that they react in various ways on tectonic pressure. This is dependent upon their mechanical properties. Some of them are disposed very well to the folding and we observe the origin of the folds up to the order of a millimetres. On the other hand there are also other rocks where we do not observe the creation of the fold structures, but only the schistosity. At some places we can observe the creation of a second system of schistosity instead of the fold structures.

The *dolomitic complex of the Triassic* consist of massive dolomites only from time to time with slight indication of the stratification. We do not observe the creation of fold structures of the order of a meter here. We can observe expression of tectonic forces here either in the form of rather intensive shattering of the rock, or in the origin the irregular systems of the joints. Preponderant among them are WNW — ESE, NNE — SSW approximately perpendicular to each other and ENE — WSW system.

Lunz Beds are not well uncovered and therefore we cannot exactly know their behaviour under tectonic pressures. They build an interbed in the dolomitic complex only a few metres thick. They consist of black shales and sandstones. We can observe only a rather intensive slaty cleavage of the shales and recrystallization of the sandstones. We do not observe the creation of the fold structures here. These beds as a whole, with respect to the dolomitic complex, are rather incompetent and build lenses of various lengths.

Keuper beds behave against the tectonic forces in this same way. We do not observe the creation of the fold structures here, similarly to Lunz Beds, only rather intensive slaty cleavage of incompetent shales and recrystallization of more competent dolomites, which are alternating with them. It is complex of the beds only some metres in thickness, which is enlarged by tectonics. Keuper beds do not present a continuous interbed on the limit between the dolomitic complex and

the basal breccias of the Lias. These rock suites in relation to the Keuper are much more competent and they had not allowed relatively thin bed complex of the Keuper to create independent structural forms. They create together approximately homocline.

In the *basal breccias of the Lias* we do not observe any tendency to create the fold structures, analogically as in the preceding cases. Sometimes they are either massive, or bedded in the case the cement is preponderant over the fragments.

Above the basal breccias of the Lias are *layers of limestones* either thinly and more thickly, or rather expressionlessly bedded, not seldom thinly-laminated. They show close slaty cleavage. They usually create monoclines and we sometimes observe in them either a break of bedding (Pl. V, fig. 1), respectively of slaty cleavage, because they are identical, or the creation of flexures.

The beds of *the upper part of the Lias, Dogger, Malm and Neocomian stage* behave in an entirely other way against the action of deformative forces. They are very often deformed in fold structures of most various types. They are very often built of bed complexes, which consist of either thinner, or thicker layers of more competent limestones alternating with more incompetent shales. They react to an action of deformative forces in various ways. It is very often expressed in an intensive folding of these bed complexes into folds of the order of centimetres and millimetres (Plate V, fig. 2).

In the lower part of this complex we usually find the suites of rocks belonging perhaps to the upper part of the Lias, which consist of limestones with a close slaty cleavage alternating with small thin layers of shales. The thickness of the limestone layers is about 1—2 millimetres, very often even less. The layers of shales are much thinner. The alternation of the more competent limestone layers and the more incompetent shale ones at such a small thickness was very favourable for the creation of folds of the highest orders. We very often find folds of the order of centimetres, also millimetres here (Plate V, fig. 2). The crinoidal bedded limestones with abundant interbeds of cherts, lying above, behaved as a rather competent rock suite and we do not observe a disposition to the creation of folds there. They create approximately homocline.

We can observe the creation of folds of the most various types in cleaved limestones either of the upper part of the Lias, or of the Dogger, They are light, yellowish, greenish, pinkish limestones, 1—3 millimetres in thickness, alternating with small thin layers of sericit — chlorit. We often observe the creation of folds of the highest orders here. Locally instead of the folds is created the second system of schistosity. The first schistosity is parallel to bedding. The second schistosity creates with the first one a sharp angle and represents a system of approximately parallel planes 2—6 centimetres from each other. We observe a distinct bending of planes of the first schistosity into the S-shape along planes of the second schistosity (Fig. 1).

In the nodular limestones of the Malm the deformative forces are expressed in the rolling out of the nodules. When the Malm is presented by compact thin-bedded limestones, some folds of the order of a metre folded in detail into some folds of a higher order are created there. At some places we observe also the creation of drag folds.

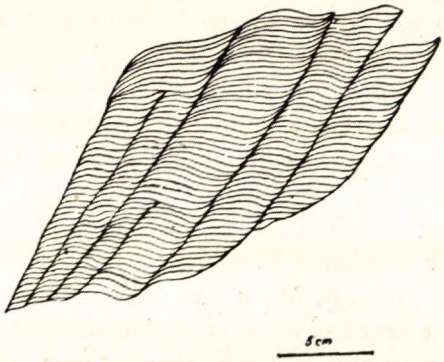


Fig. 1. S-shape bending of the first schistosity along planes of the second one. Schistous limestones of the Lias, respectively of the Dogger.

In the marly limestones of the Neocomian stage we often observe a separation of clay ingredient, so that they represent relatively pure schistous limestones alternating with small thin layers of separated clay ingredient, which are rather metamorphosed. They are often rather intensively folded into the folds of the order of centimetres and millimetres in consequence of alternating thin layers of more competent limestones with more incompetent clay ones. Locally they are very similar to the rock suites of the upper part of the Lias, or of the Dogger described above. Locally we observe the creation of second schistosity causing S-shape bending of the first schistosity, analogically as in rock suites of the upper part of the Lias, or of the Dogger.

Conclusions

When we draw conclusions of the behaviour of each of the above mentioned rock suites against deformative forces, we find out it is dependent namely on the mechanical properties of the rocks and on the form of their appearance (massive, or bedded, thin, or thick-bedded, alternating of competent and incompetent rocks).

The fold structures of a higher order are created in the case of suites of rocks consisting of thin layers of competent rocks alternating with the incompetent ones. If there are competent rocks not alternating with incompetent ones, the fold structures of higher order are not created. Analogically the fold structures of higher order are not created in the case of alternating of thicker-bedded competent an incompetent rocks. The question is not clear about the creation of the fold structures of a higher order in one case and the creation of the second schistosity in rocks of this same type in another one. We can draw some conclusions about the double-action of the deformative processes from relation among the first and the second schistosity and folds. It seems that deformation of the rock suites, described above, took place in twoo periods. During the first one was created the first schistosity, which is parallel to the bedding. During the next one were

created the fold structures and the second schistosity, which is locally created instead of them. We can find that the creation of the first schistosity and the second one were not simultaneous from distinct disturbance of the first schistosity by the second one. It is presented by an S-shape bending the first schistosity along the planes of the second one.

Department of Geology of Komensky's University, Bratislava

REFERENCES

[1] Biely A., 1956: Zpráva o základnom geologickom výskume na SV svahoch Královej Hole. Manuscript; Archív GÚDŠ, Bratislava. — [2] Biely A., 1961: Poznámky ku geológii mezozoika „koreňových zón" Veporíd. Geologické práce, Zprávy 21, Bratislava. — [3] Kettner R., 1937: Geologická stavba severního svahu Královy holy v okolí Liptovské Tepličky (Nízke Tatry). Rozpravy II. Třídy České akadémie, roč. XLVII, č. 7, Praha. — [4] Kettner R., 1937: Geologické poměry okolí Vernáru na Slovensku. Rozpravy II. Třídy České akadémie, roč. XLVII, č. 8, Praha. — [5] Mahel M., 1959: Nové členenie a pohľad na historicko-geologický vývin mezozoika Centrálnych Karpát. Geologické práce, Zoš. 55, Bratislava. — [6] De Sitter L. U., 1956: Structural geology. McGraw — Hill Publishing Company lim., London. — [7] Zoubek V., 1952: II. zpráva o výskumech východní části nízkotatranského jaderného pohoří. Zprávy o geologických výskumech v r. 1952, ÚÚG Praha.

ALBÍN KLINEC

SEVERAL TECTONIC STRUCTURES FROM THE WEST CARPATHIAN CRYSTALLINE MASSES AND THEIR INTERPRETATION

Although the Carpathian geological literature is today a very diverse and rich one only few works so far are dealing with particular structural forms mainly in the crystalline regions. This article aims to discuss several structural forms from the crystalline regions which may also seem important for the studies of ore-bearing formations.

From the previous authors Zoubek suggested the rule about the imposed crystalline tectonics effecting for example the Vepor crystalline mass but without further discussion about the resulting forms. Kubíny studied mostly the great tectonic structures. More detailed work was carried out by Gorek in the crystalline of Liptovské Tatry and Vysoké Tatry Mountains, where the author determined for example the tongue-like form of the granite intrusion.

During the years of 1955—1956 a group of geologists from GÚDŠ in Bratislava carried out some detailed studies in the crystalline of certain core-mountains. In the Malá Magura Mts. minute tectonic forms as for example sigmoidal twisting of layers, fan-structures of bedding cleavage, arching etc. were observed.

Also in the Žiar Mts. several older pre-Triassic anticlines, synclines or transverse depressions and elevations were described. Its crystalline core is represented only by a few types of granitoids while the mantle fragments-biotitic paragneisses and migmatites appear solely at the SE segment of the mountains. The pegmatitic varietes form the upper part of the body sometimes related also to the crystalline schists. One part of these coarse-grained varieties occur as sills. Deeper granitoid horizons are represented by porphyritic bimicaceous granite to granodiorite. Due to the tectonics the whole crystalline mass is slightly folded with axis striking approximately in E—W direction, thus determining the iregular erosion after the upheaval of the region. The Mesozoic resting already upon the various horizons of the lower structure indicate the presence of older tectonics and pre-Triassic erosion as well.

At the SW crystalline-Neogene boundary (Neogene of Prievidza basin) a pronounced relief change is observed the result of a young fault supporting also the above interpretation.

Malá Magura crystalline emerges from below the younger formations Tertiary in the East, Mesozoic in the West as an anticline with a N—S axis. (NE—SW in the northern part). The later raising of the region is related to the post-Paleogene faults although the interior crystalline structure is an old one. Older tectonics is expressed first of all in the formation of crystalline schists.

The structures of the NE part of the territory are interpreted on the enclosures (the cross-sections). In the southern part of the map sheet two fan-like discreeping structures may be observed. The more western one represents the synclinal structure of the schists partly destructed (in the North) due to the lifting of axis farther northward resulting in a granitoid arch. This suggestion is supported also by the direction change of schists forming here a subsided block among granitoids. The block is the floor of a valley while granitoids appear high on the surrounding ridges.

The other fan-like structure extending farther to the East possesses a form very different from a normal syncline. This fact is evident upon the one-direction orientation of dips (in majority to the East). At places where analogically core parts should occur, we find the diorite. (On the enclosure included in granitoids.) This of course is a product younger than the formation of the discussed structure. The orientation of both limbs reflected the eastern strain orientation. Both the fan-like forms are syngenetic, representing primarily two neighbouring parallel synclines with a little anticline inbetween. Practically it is a fold striking N—S with the axis raising toward the north. The eastern segment of this anticline was more intensely compressed so that the primary syncline limbs are now in isoclinal position. The anticlinal fold segment were for the granitoid invasion into the mantle competent.

In the Chvojnica vicinity we find another fan-form structure. The strike is identical however the dips in this part are variable. Three elements took part in the formation of this structure. First is the structural arch SW from Chvojnica. The second a small elevation in the central part between Tužina and Chvojnica the third factor is represented by the later arching of the structure farther to the north. In the Chvojnica vicinity the fold axis shows raising tendency up to the mentioned arching, wherefrom it is sinking in the northern or northeastern direction, interrupted only at the eastern crystalline margin by a small but typical anticline.

Structural elements of the crystalline mass are here of smaller dimensions and change in short intervals. Compared with the Mesozoic complexes the difference in tectonic style is obvious, indicating two separate tectonic processes.

Comparing together both Malá Magura and Žiar crystalline masses substantial differences are apparent, mainly in the composition and structure as well. The

particular crystalline cores bear of course evidence also of many common features, among which the most remarkable is perhaps the existence of mylonites and diaphtorites, distributed over the whole Central Carpathian region except Gemeridy unit. They form narrow zones in the isolated cores but represent an important element in the Vepor crystalline. Character of these elements reflects an intense tectonic process indicating the activity of the region in a particular time interval.

At first the forms of character similar to that of Malá Magura Mts. will be discussed. The Vepor crystalline in the region SW of Červená Skala shows sigmoidal schistosity twisting in gneisses. (Javorina—Muráňska Huta). Unfortunately much less elements occur in these gneisses compared with Muráň granite gneisses. Little folds may be observed throughout the unit building larger structures. Besides the folds fair lineation appear, fissuring and also crossing cleavage systems. In 1961 this somplex of rocks was determined as the deepest element known (Klinec—Vrána). The complex is represented by a narrow belt 2—3 km wide, 12 km long composed of remarkable rocks exposed along a great fault line-the Muráň—Divín fault. This rock complex is in contact with Maráňska plošina plateau Mesozoic at northwestern side and with various crystalline series at the north and east. The whole belt is an arched anticline deformed by faulting. The anticline axis shows opposite dipping in the northern segment to the north, in the southern to southwest. The structure is an old one. Its age is documented by the position of Triassic(?) mantle over the Muráň granitegneiss and migmatite complex representing already a higher crystalline horizon as well.

The combination of old structure with younger ones-anticlinal elevation with young fault is indicated by the fact that the Muráň granite-gneiss series does not appear along the whole segment of the Muráň fault line. The fold axes and lineations of the SW part are farther evidently curved to the west. Unfortunately in this direction the continuation of the structure behind the Muráň fault is covered by higher members of Mesozoic with migmatite complex. (The least representig the higher crystalline horizons.) In the Pohronská Polhora vicinity the Muráň granite-gneiss series again appear in a small, well developed anticline. Summarizing the above facts we came to the conclusion that the granitoids and migmatites of Fabova hoľa Mt. represent not only a higher crystalline element but also indicate the unity of the Kohút and Kráľova hoľa Mts. crystalline masses.

The Vepor crystalline as a whole and Kohút subzone particular provide excellent possibility of structural interpretation. Diaphtorite zones possess an independent imposed tectonics with zones among them suitable for the study of older forms. In the southernmost part of Vepor crystalline in the Kohút subzone young intense epi-to meso-zonal metamorphosis may be observed, characterized by the mass textures and structures frequent by posttectonic granitoids.

Metasomatic processes played here an important role. The effects of younger imposed tectonics prepared the forms for the metasomatosis. Some mantle members

for example due to position and mechanical properties are connected with the lower structure into one unit which in certain parts is changed into a complex nearly similar with the basement by metamorphosis.

Good examples may be found in the synclinal zone of Kyprov vrch (Klinec 1962) extending from Dobšiná creek through Kyprov vrch up to Muráňska Huta, which is an isoclinal syncline appearing in the crystalline mass center complicated by fault tectonics. Intense metasomatic processes were observed also at other places but everywhere there was a suitable substratum combined with a convenient position. The region described is located near the Veporidy-Gemeridy contact line. From the same region the *Markušký vrch* digitation were described by Zoubek — Snopko (1954—55). The Markušovský vrch digitation is composed principally of Kohút crystalline granitoids, phyllites and schists of Hladomorná dolina (Lehotský 1962), sericite-albite schists and quartzites of Foederata series, dark phyllites with conglomerates of Gemeridy Upper Carboniferous. (According to some authors Veporidy.)

Complicated relations between particular members of this unit resulted from the movements of several phases with denudation interruptions. The evolution of this form may be reconstructed as follows: the structure of an anticlinal form with granitoid core and Hladomorná dolina phyllites with Foederata series envelope were compressed into an isoclinal fold. After this tectonic phase raise and consequent denudation of the region followed. Subsequent sinking of the region, folding and thrusting of Gemeridy resulted in wrapping of the teared basal members (Gemeridy Carboniferous) into the syncline which was formed between the old raising and deforming anticline and the crystalline masses. Due to the continued folding the wrapped and imprisoned strange element became an organic member of this complicated structure.

Character of the structure is shown on the geological cross sections carried through the Gemeridy-Veporidy contact. Regardless to the crystalline basement the series developed first during an intense folding which resulted in the formation of folds typical for the Foederata series. Later thrusting superposed the Gemeridy unit over the folded Foederata series.

Excluding the crystalline basement the first folding phase (Foederata series) led to epizonal metamorphosis-schistosity of this series and later metamorphosis till the post-thrusting period resulted in the formation of transverse porphyroblastosis of microcline, albite, biotite, cordierite, disthene and other minerals often automorphly developed in the folded rocks.

*

The study of minor structural forms may lead to certain new results both usefull and interesting. Many great structures as various tectonic zones, lines and faults were known to exist unfortunately their detailed character were studied only to a small extent.

Geologické práce, Zprávy 28. Bratislava 1963

OTO FUSÁN—LAURENC SNOPKO

BAUELEMENTE DER GEMERIDEN

Die Gemeriden als ein Komplex weisen einen sehr komplizierten Bau aus, in dem man schon heute die Ergebnisse einzelner Orogene unterscheiden kann. Dabei gibt es jedoch an einzelnen Stellen bestimmte Unterschiede im Charakter des Baues, die einerseits von der ungleichmässigen Vertretung der paläozoischen und mesozoischen Gebilde, anderseits von der tektonischen Beanspruchung einzelner Teile des Gebietes abhängig sind. Einige Teile, wie z. B. der Zentralteil der Gemeriden, besitzen einen gewissermassen einfachen Bau, was allerdings scheinbar dadurch verursacht sein kann, dass der Zentralteil durch eine Serie — die Gelnica-Serie gebaut ist, die überwiegend eine Flysch-Entwicklung besitzt. In ihr ist es viel schwieriger die jüngeren tektonischen Elemente zeitlich zu bestimmen und zu analysieren. Anderseits weisen die Randabschnitte der Gemeriden, wo sowohl die paläozoischen, als auch die mesozoischen Gebilde vertreten sind, einen viel komplizierteren Bau aus. Jedoch sind dann diese für den Komplex nicht charakteristisch, da in ihnen die Hauptbaueinheit der Gemeriden, die Gelnica-Serie, gewöhnlich nur im begrenzten Masse vertreten ist.

Das einzige Gebiet, wo in bedeutendem Masse die Gelnica-Serie und dazu proportional auch alle Gebilde des Paläozoikums auftreten, und wo auch die Reste des Mesozoikums erhalten sind, ist das Depressionsgebiet zwischen dem Volovec- und Kohút-Massiv, in dessen Fortsetzung nach Norden das Gebirge Stratenská hornatina, gegen Süden die Karstplateaus Plešivecká planina und Koniart liegen. Dieses Gebiet war schon seit langem ein Objekt der geologischen Forschung, da hier grosse Menge der für die Industrie wichtigen Lagerstätten konzentriert ist, wie hauptsächlich Rožňava, Nižná Slaná, Dobšiná. Mlynky, Vlachovo u. a., und auch deshalb, weil sich da klassische Lokalitäten des Jungpaläozoikums befinden (Dobšiná, Ochtiná). In der letzten Zeit kann man dieses Gebiet als klassisch auch für die Gelnica-Serie betrachten.

Der Bau dieses Gebietes, sowie der ganzen Gemeriden, ist das Ergebnis mehrerer orogenetischen Etappen, u. zw. von der jungkaledonischen Etappe bis zum alpidischen Orogen. Die Gebilde des Paläozoikums und der Trias der Gemeriden bieten den Grundbau des Gebietes dar, während die jüngeren Gebilde, die schon durch die tektonischen Prozesse unberührt blieben, wie Pliozän und Quartär, schon eine untergeordnete Rolle spielen und kommen nur in kleineren oder grösseren Terraindepressionen vor, oder am Modellieren der geomorphologischen Formen teilnehmen. Bei dem tektonischen Studium des Gebietes verfolgten wir einerseits die makrostrukturellen Elemente, die nach dem Verlauf der Gebilde auf der geologischen Karte sichtbar sind, anderseits die besonders auf einzelnen Aufschlüssen, oder Profilen studierten feintektonischen Strukturformen, die den inneren Bau einzelner Gebilde charakterisieren.

Das Grundbauelement des Gebietes ist die *Gelnica-Serie* und die *Hnilec-Antiklinale,* die durch die Deformation ihrer Sedimente im jungkaledonischen Orogen entstand und ihre ausgeprägteste mittlere Struktur ist. Den Kern der Antiklinale füllen die Vlachovoer Schichten aus (von den bisher bekannten Schichten die untersten, die in der Umgebung von Vlachovo auftreten), welche von der vulkanisch-detritischen Schichtenfolge der Pačaer Schichten umgeben sind. Die stratigraphische Position, sowie die antiklinale Lagerung der Schichten ist durch die Superposition der feinen lithologischen Flysch-Texturelemente erwiesen.

Die Pačaer Schichten verlaufen in der Hnilec-Antiklinale als nördlicher Flügel aus der südlichen Umgebung der Gemeinde Hnilec bis zur Gemeinde Rejdová. Die Schichten im Abschnitte Hnilec — Dobšinský potok besitzen einen steilen Fallwinkel (70—90°) und verlaufen in der O—NO — W—SW Richtung; westlich von dem Gebiet, zwischen Vyšný Hámor und der Julius-Grube, biegen sich die Schichten gegen Süden und besitzen das NO—SW Streichen. Dieser Verlauf ist nördlich von Vyšná Slaná ausgeprägt, wo sich die Schichten gegen Süden biegen. Westlich von Vyšná Slaná besitzen die Schichten das N—S Streichen. Im ganzen nördlichen Flügel beobachtet man in den Pačaer Schichten an manchen Stellen feine Flysch-Rhythmen, die auf die Superposition der Schichten und auf das Streichen des Liegenden gegen Süden hinweisen.

Südlicher von den *Vlachovoer Schichten* sieht man den Verlauf des südlichen Flügels der Hnilec-Antiklinale, der wiederum durch die von dem Berg Čertova hoľa (K. 1248) über Volovec (K. 1286) gegen Westen in das Tal von Sulovský potok und gegen Gočovo, Kobeliarovo und Brdárka streichenden Pačaer Schichten gebildet ist. Ähnlich, wie im nördlichen Flügel der Hnilec-Antiklinale, besitzen auch im südlichen Flügel die Schichten sehr steiles Fallen und in dem Abschnitt zwischen Volovec und Gampel streichen sie von O nach W. Südlich und westlich von Brdárka biegen sich die Pačaer Schichten im Kobeliarovo gegen NW; in der Umgebung von Široké Pole (westlich von dem Berg Radzim, K. 960) streichen sie von N nach S und vereinigen sich mit dem nördlichen Flügel der Hnilec-Antiklinale.

Diese brachyantiklinale Sperre der Hnilec-Antiklinale versenkt sich allmählich gegen Westen und ist durch die tektonische Aufschiebungslinie der Gemeriden auf die Veporiden in unteren Teilen abgeschert (Scherdecke). In diesen Teilen ist sie auch durch jüngere Prozesse beträchtlich deformiert. Diese Frage werden wir später erörtern.

Die Pačaer Schichten kann man auch in oberen Teilen über dem Kern der Hnilec-Antiklinale verfolgen, wo die ganze Schichtenfolge horizontal liegt. In dieser Lage treten die Pačaer Schichten

über dem Berg Biela Skala und östlich von dem Hägerhaus Súľová, südwestlich von Švedlár auf. Der südliche Flügel der Hnilec-Antiklinale ist im Abschnitte Gočovo—Brdárka mit den jüngeren Gebilden des Karbons, Perms und Mesozoikums oft bedeckt.

Das jüngste Glied der Gelnica-Serie — die Betliarer Schichten treten bloss am linken Flügel der Hnilec-Antiklinale auf. Sie bilden eine schmale Synklinale, die von dem Berg Volovec (K. 1286) über das Súľová—Tal auf Gampel streicht. Weiter westlich setzt der synklinale Streifen von Kobeliarovo über Brdárka bis zu der Gemeinde Rejdová fort. Der synklinale Streifen begrenzt die Hnilec-Antiklinale von der südlichen und westlichen Seite. Auf der nördlichen Seite der Antiklinale tauchen die Betliarer Schichten unter die Sedimente der Rakovec-Serie. Im Abschnitte Rejdová — südliche Umgebung der Gemeinde Hnilec sind nach und nach die ganzen Pačaer Schichten mit den Sedimenten der Rakovec-Serie bedeckt, so dass bei der Gemeinde Hnilec sich die Vlachovoer Schichten mit ihren Sedimenten unmittelbar berühren. Aus der geologischen Position und aus dem Verlauf einzelner Schichtenfolgen ergibt sich die klare Winkeldiskordanz zwischen der Gelnica- und Rakovec-Serie.

Gleichzeitig mit der kaledonischen Faltung wurden die Sedimente der Gelnica-Serie *epizonal metamorphiert.* Die metamorphen Produkte dieser gebirgsbildenden Phase sind besonders in den kompetenten Schichtenfolgen sichtbar, wo sich die Schieferung noch erhalten hat und besonders ausgeprägt war. Die kaledonische Schieferung ist in den Quarzitlagen der Vlachovoer Schichten und in den Quarzitlagen der Pačaer Schichten nördlich von Vyšná Slaná sichtbar. In beiden Fällen stimmt die Schieferung mit der Schichtung überein.

Die südliche Begrenzung der Antiklinale stellt eine Schichtenfolge dar, die in der Gelnica-Serie als jüngste (Silur?) betrachtet und als stark in die synklinale Form mit den senkrecht aufgerichteten Schenkeln im Kern eingefaltet, aufgefasst wird. Da wir diese Tatsache in einem ziemlich ausgedehnten Gebiet beobachten, berechtigt uns dieser Bau zur Vermutung, dass sich die antiklinalen Teile völlig erhielten, während die synklinalen Teile in schmale Streifen ausgezogen wurden.

In der Volovec-Zone beobachtet man mehrere mächtige eingefaltete Synklinalen mit dem im grossen und ganzen O—W Streichen. Es sind die synklinalen Streifen: Nižná Slaná (Manó)—Betliar—Čučma, nördlicher von ihm Nižná Slaná (Gampel)—Volovec. In der westlichen Richtung setzen diese Streifen gegen Kobeliarovo, Hanková und Rejdová fort. Die von Osten nach Westen streichenden synklinalen Streifen besitzen die Tendenz in einem Zentrum zwischen Nižná Slaná und Kobeliarovo zusammenzulaufen. Dieses Zusammenlaufen wurde wahrscheinlich durch die gebirgsbildenden Prozesse, die sich vor der herzynischen Regionalmetamorphose abgespielt haben, verursacht. Woher der Druck wirkte, kann man aus dem bisherigen Studium nicht entscheiden, jedenfalls war er senkrecht auf die entstandenen Antiklinalen und Synklinalen. Von diesem Zentrum an kann man wiederum beobachten, dass die synklinalen Streifen gegen Westen auseinanderlaufen.

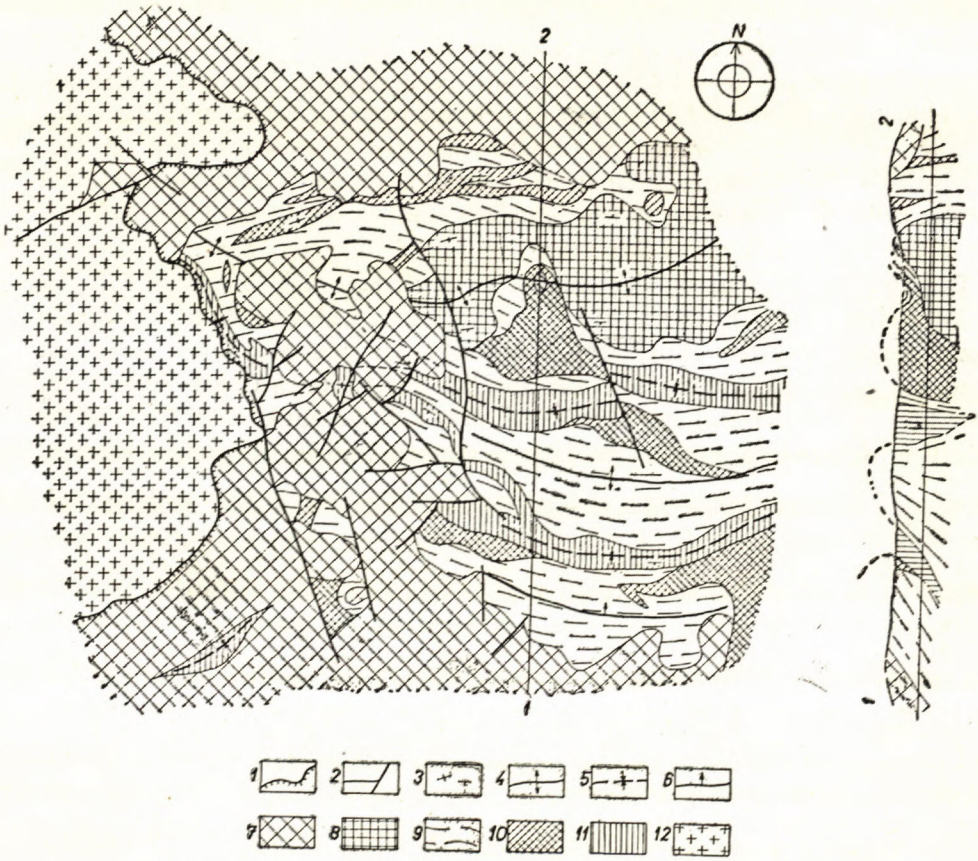
Zwischen den angeführten synklinalen Streifen treten mächtige Massen der Pačaer Schichten auf, die bei der erwähnten stratigraphischen Auffassung weitere antiklinale Zonen darstellen, u. zw. die Lužica- und Turecká-Antiklinale.

Die Synklinale Nižná Slaná (Gampel) — Volovec ist im überwiegenden Teil steil aufgerichtet, stellenweise hat sie auch sehr steiles Fallen gegen Norden (östlich von Gočovo). Der synklinale Streifen Nižná Slaná (Manó)—Betliar—Čučma ist gegen Süden sehr flach aufgelagert. Ihre Lagerungsverhältnisse in der Fortsetzung nach Westen unter das Jungpaläo-

zoikum, sind vorläufig nicht aufgeklärt, jedoch bei Kobeliarovo, wo schon bloss ein Streifen auftritt, ist die Schichtenfolge wiederum nach Süden geneigt, u. zw. mit einem sehr steilen Fallen. Im Abschnitte Hanková—Rejdová kommt es zur Schwenkung des Fallens. Das Fallen ist am Anfang gegen NO bis O und ist schon beträchtlich gemässigt (ca 40°).

Dieser skizzierte Bau der Gelnica-Serie ist hauptsächlich das Ergebnis des kaledonischen Orogens und wurde durch spätere Prozesse noch umgebildet. Für den Bau der Gelnica-Serie im beschriebenen Gebiet ist ein bestimmter tektonischer Stil ausgeprägt, den die mächtigen antiklinalen Zonen, zwischen denen die schmalen synklinalen Streifen eingeklemmt sind, charakterisieren. Zwei-

Schematischer Verlauf der kaledonischen Strukturen in der Gelnica-Serie



Jüngere Strukturen: 1 — Überschiebungslinie; 2 — Dislokationen; kaledonische Strukturen: 3 — Schichtung; 4 — Antiklinalen; 5 — Synklinalen; 6 — Monoklinale; Gemeriden: 7 — jüngere Bauelemente; kaledonisches Bauelement (8—11): 8 — Vlachover Schichten; Pačaer Schichten (9—10) 9 — Sedimente; 10 — sauere Effusivgesteine; 11 — Betliarer Schichten; 12 — Veporiden.

tes Merkmal ist das Zusammenlaufen dieser Strukturen in einen Knoten in der Umgebung von Kobeliarovo. Weiter die Schwenkung der synklinalen Streifen, die östlich von diesem Knoten hauptsächlich gegen Süden, westlich von dem Knoten gegen NO fallen. In dem Knoten sind die Synklinalen steil aufgerichtet.

Das weitere Bauelement der Gemeriden ist die *Rakovec-Serie*, die hauptsächlich im nördlichen Teil ausgebreitet ist. Schon nach den Lagerungsverhältnissen des Jungpaläozoikums, das sich sowohl auf der Gelnica-, als auch auf der Rakovec-Serie ausbreitet, kann man voraussetzen, dass vor ihrer Ablagerung die Rakovec-Serie als eine mächtige monoklinale, mässig wellenförmige Struktur gegen Norden fiel. Auf diese Tatsache deuten sehr ausgeprägt die neuesten stratigraphischen Ergebnisse hin, die die Rakovec-Serie auf drei Grundschichtenfolgen zergliedern.

Die unterste, basale, psammitisch-pelitische Schichtenfolge säumt die mächtige Struktur an ihrem Südrand ein, u. zw. hauptsächlich in dem Abschnitt Rejdová — Hámor bei Dobšiná, sowie im Abschnitte Tešnárka—Hnilec, wo die ganze Struktur auf den älteren liegenden Strukturen der Gelnica-Serie ausgeprägt diskordant liegt.

Die höhere, vulkanogene, hauptsächlich auf das basische, pyroklastische, monotone Material reiche Schichtenfolge bildet den überwiegenden Teil der Ausfüllung der *monoklinalen Struktur*, die im nördlichen Teil des Gebietes mit dem Jungpaläozoikum und Mesozoikum bedeckt ist. In dieser Schichtenfolge ist es sehr schwer eine detailliertere Stratigraphie und so auch den Verlauf der eingehenderen tektonischen Strukturen festzustellen. Die jüngste Schichtenfolge enthält schon karbonatische Einlagen mit der Abwechslung mit den Diabastuffen und Peliten, die in der weiteren Umgebung von Dobšiná zutage treten; gleichfalls der Körper des Quarzdiorits — Amphibols, der sich bisher als das jüngste Glied in der Rakovec-Serie erwies, liegt auf diesem karbonatischen Horizont. Die Erhaltung dieser uns bekannten, jüngsten Schichtenfolge der Rakovec-Serie bedingte hauptsächlich ihre Position. Nämlich in dem Abschnitte Dobšiná—Hámor und Tešnárka ist die Rakovec-Serie längs des mächtigen Bruches gegen die Gelnica-Serie gesunken. Dadurch hat sich in diesem Abschnitt die höchste Schichtenfolge der Rakovec-Serie vor der Erosion in dem voroberkarbonischen Zeitraum erhalten.

Beim detaillierten Studium der monotonen, vulkanogenen Schichtenfolge ist est auf Grund der feinen Texturelemente (Schichtung — Schieferung) gelungen, die *synklinalen und antiklinalen Zonen* festzustellen (Bajaník, 1962). Der Verlauf der inneren Faltenstrukturen in der Rakovec-Serie, in Beziehung auf ihre monoklinale Lagerung, ist im grossen und ganzen übereinstimmend, woraus man urteilen kann, dass die Rakovec-Serie einen gewissen Flügel des mächtigen Synklinoriums bildet, das schon während der herzynischen gebirgsbildenden Hauptprozesse entstanden ist.

Während dieser herzynischen gebirgsbildenden Hauptprozesse wurde nicht nur die Rakovec-Serie als ein herzynisches Bauelement, sondern auch die schon früher gefaltete und metamorphierte, liegende Gelnica-Serie formiert. Die Art ihrer Deformation war jedoch unterschiedlich. Der Unterschied in der Deformation der beiden Serien während der herzynischen gebirgsbildenden Prozesse wurde hauptsächlich durch diese Faktoren beeinflusst.

Die *Gelnica-Serie* stellte einen schon gefalteten und verfestigten, schwach epizonal metamorphierten Komplex dar, der ohne Rücksicht auf den Verlauf ihrer

inneren Strukturen sich schon als ein Komplex benahm und das Liegende der Rakovec-Serie bildete.

Die *Rakovec-Serie* lag auf dem verfestigten Liegenden, wobei sie selbst noch nicht gefaltet und metamorphiert wurde und dazu war sie diagenetisch verfestigt. Ihre Schichtenfolgen hatten im grossen und ganzen eine konstante Mächtigkeit, die proportional zu dem verfestigten Liegenden nur gering war. Deshalb wurde die Rakovec-Serie während der herzynischen Prozesse in ein System der Faltenstrukturen deformiert. Bei der Bewegung wurden die Flächen der ursprünglichen Schichtung ausgenützt, so dass die Schieferung mit der Schichtung auch übereinstimmend ist. Infolge der ziemlich schwachen Metamorphose wandelten sich Sedimente der Rakovec-Serie in verschiedene Typen der Phyllite um.

Ausser den *Schieferungsflächen* beobachtet man in der Rakovec-Serie auch *lineare Elemente,* u. zw. die Gefügeregelung des Serizits, Chlorits und manchmal auch feine Fältelung. Weniger metamorphiert ist nur die basale Schichtenfolge der Quarzite und Schiefer, bei welchen man vereinzelt die Zwischenschichtenschieferung beobachten kann.

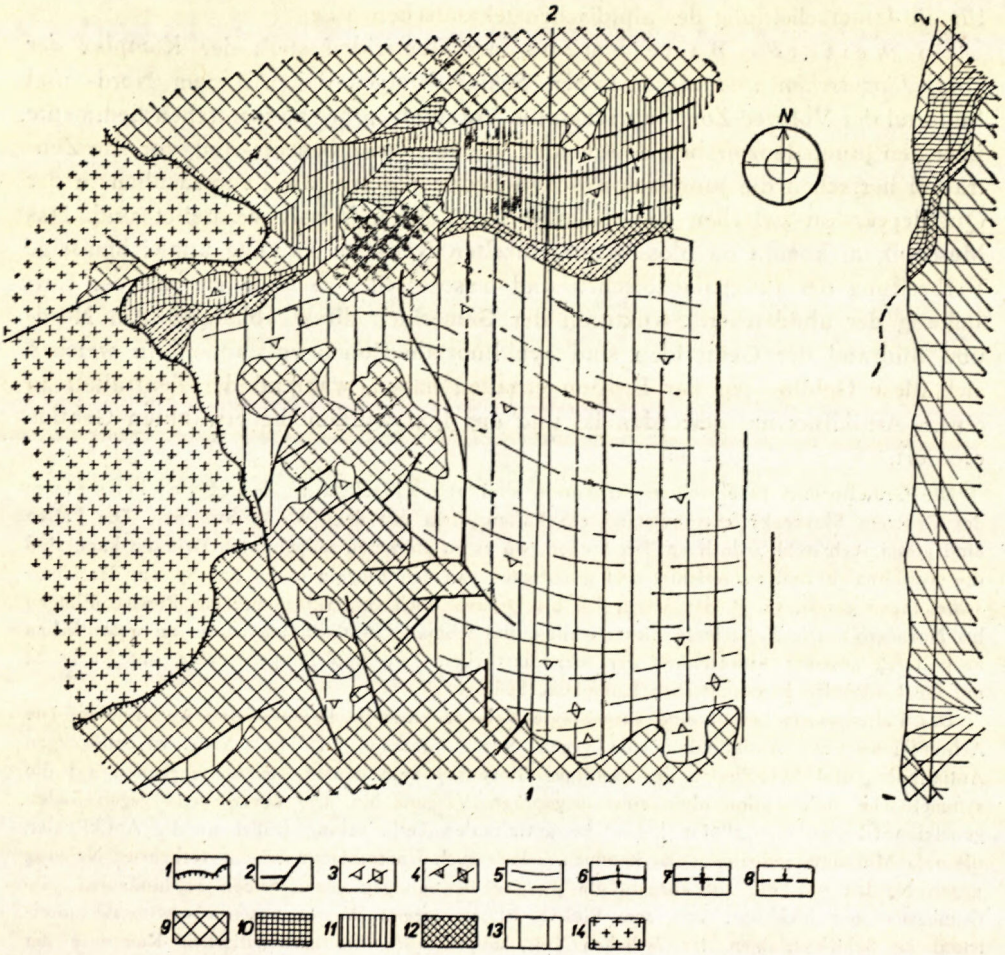
Ganz anders äusserten sich die Wirkungen dieser gebirgsbildenden Phase auf den schon gefalteten Sedimenten der Gelnica-Serie, die gefaltet und schwach epimetamorphiert war. Beim Formieren dieser Serie spielten eine bedeutungsvolle Rolle nicht nur die tangentialen Bewegungen, sondern wahrscheinlich auch der grosse hydrostatische Druck der hangenden Schichten. Unter dem Einfluss dieser Faktoren ergriffen in der Tiefe die ganze Gelnica-Serie die differentialen Teilbewegungen. Die Bewegungen machten sich ohne Rücksicht auf die alten Sedimentkomplexe, resp. auf die Verschiedenartigkeit des Gesteinsmaterials und die alten kaledonischen Faltenstrukturen geltend. Die Schieferung bildete sich regional mit dem O—W Streichen und mit dem ziemlich starken Fallen gegen Süden (35—45°), während in den Sedimentgesteinen, wo man die ursprüngliche Schichtung auf der Rutschfläche beobachten kann, ist die urspüngliche Schichtung durchgeschnitten. Auf Grund dessen kann man die Grösse, Richtung und Art der differentialen Bewegungen feststellen. In meisten Fällen verliefen alle diese Bewegungen längs der fast gleichlaufenden Flächen. Nur in vereinzelten Fällen, wo die Rutschflächen zusammenlaufen, bilden sich Linsen. Bei den monotonen Schichtenfolgen, wie die Tuff- und Tuffitporphyroide sind, kam es zur intensiveren Rekristallisation und Gefügeregelung des gesamten Gesteins.

Im ganzen studierten Gebiete verläuft die Schieferung von O nach W, mit dem Fallen gegen S, ohne Rücksicht auf die alten Faltenstrukturen. Interessant ist jedoch besonders der Bau des Turecká-Massivs, wo sich die fächerförmige Schieferung bildete, deren Fallen so verläuft, dass im ganzen Raum die Schieferungsrichtungen der Tiefe zu zusammenlaufen. Auf den Südhängen des Turecká-Massivs fällt die Schieferung schon gegen Norden (20—30°), wobei die Richtung fast unverändert bleibt. Die Bildung dieser fächerförmigen Struktur ist sichtbar an die regionale Tektonik der bretonischen gebirgsbildenden Phase gebunden, jedoch ihre Beziehung zu den bretonischen Faltenstrukturen ist bisher unaufgeklärt. Die durch diese Phase gebildeten epimetamorphen Produkte sind in diesem Gebiet die intensivsten und ihr Einfluss hat alle ältere tektonische Strukturen verhüllt. Die Gelnica-Serie wurde also gleichzeitig mit der Rakovec-Serie gefaltet und epimetamorphiert.

Daraus sieht man, dass bei den herzynischen gebirgsbildenden Hauptprozessen sich im Paläozoikum der Gemeriden zwei gleichzeitig entstandene Stile ausgeprägt

geltend machten. Die Rakovec-Serie wurde auf ihrer Unterlage in ein Synklinorium mit mässigen Falten gefaltet, die Kristallisationsschieferung ist mit der Schichtung übereinstimmend. Die Gelnica-Serie hatte bei ihrer Faltung zwei Formen: a) die sich immerfort bildende Schieferung gegen Süden zu, die mit Bezug

Schematischer Verlauf der herzynischen Strukturen in der Rakovec- und Gelnica-Serie



Jüngere Strukturen: 1 — Überschiebungslinie; 2 — Dislokationen; herzynische Strukturen: 3 — Querschieferung; 4 — Schichtschieferung; 5 — Verlauf der Schieferung; 6 — Antiklinalen; 7 — Synklinalen; 8 — Monoklinale; Gemeriden: (9—13) 9 — jüngeres Bauelement; herzynisches Bauelement: (10—12) 10 — vulkanogen-karbonatische Schichtenfolge; 11 — vulkanogene Schichtenfolge; 12 — basale Schichtenfolge; 13 — kaledonisches Bauelement; 14 — Veporiden.

auf die Oberfläche ein Fallen von 30—45° besitzt; b) der fächerförmige Bau der Schieferung auf dem Turecká-Massiv mit dem Zusammenlaufen der Schieferung nach unten hin.

Eine sehr passende Bezeichnung für die erwähnten tektonischen Stile ist der *oberflächennahe tektonische Stil,* der sich bei der Rakovec-Serie geltend machte und der *tiefe tektonische Stil* mit unterschiedlichen Faltungsformen bei der Gelnica-Serie. Diese Termini benützte zum ersten Male bei uns M. Mahel (1957) für die Unterscheidung der alpidischen tektonischen Stile.

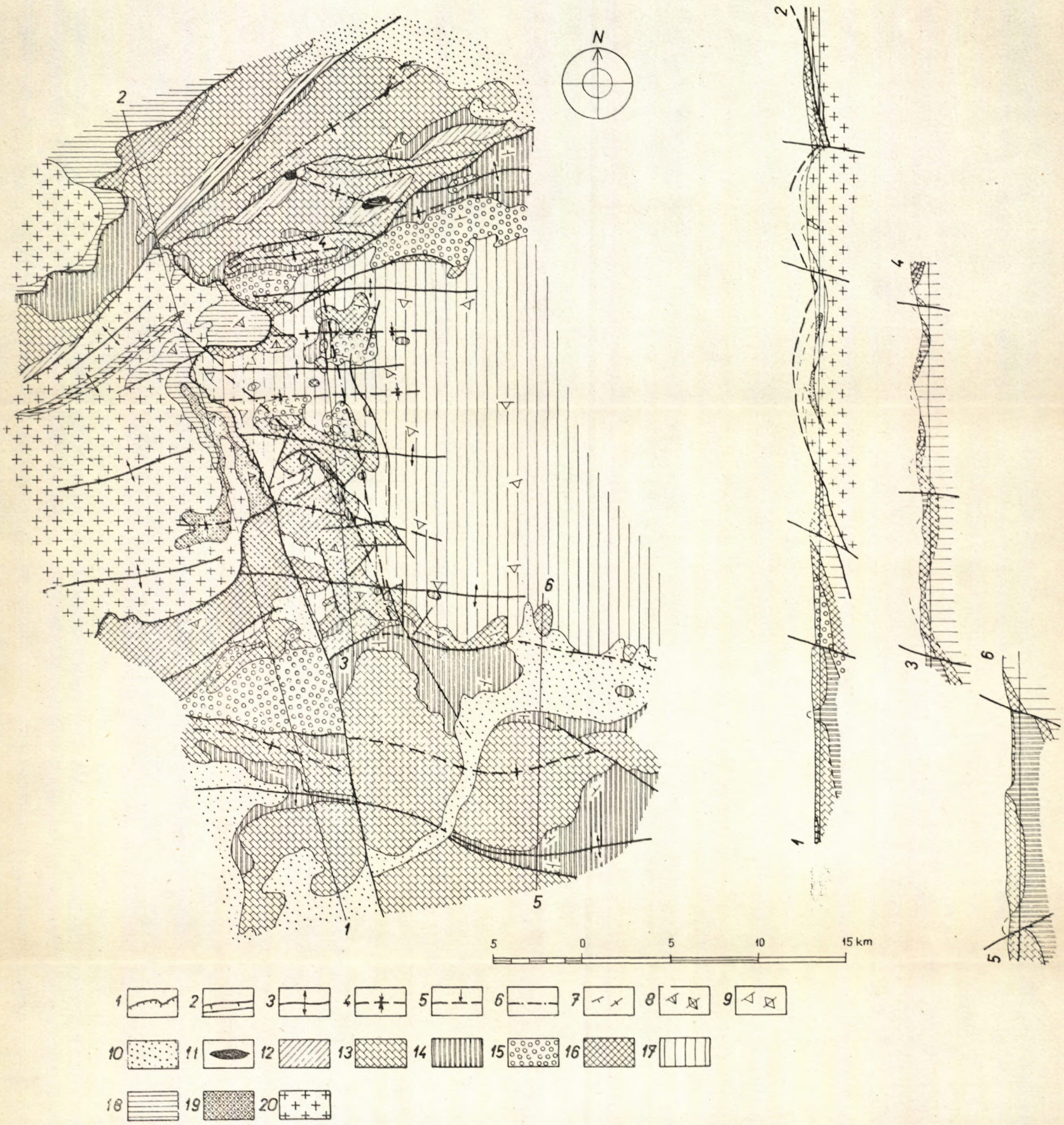
Ein weiteres Bauelement der Gemeriden stellt der *Komplex der jungpaläozoischen und mesozoischen Schichtenfolgen* dar. An dem Nord- und Südrand der Volovec-Zone herrschen die Vorkommen der mesozoischen Sedimente über den jungpaläozoischen Sedimenten, die mit ihnen bedeckt sind, vor. Im Zentralteil herrschen die jungpaläozoischen Sedimente vor, die hauptsächlich in der Querdepression zwischen dem Kohút- und Volovec-Massiv verbreitet sind. Das Mesozoikum kommt da bloss in vereinzelten Relikten vor. Die ungleichmässige Verbreitung der jungpaläozoischen und mesozoischen Gebilde ist von der Entstehung der alpidischen Strukturen der Gemeriden direkt abhängig. Am Nord- und Südrand der Gemeriden sind synklinoriale Zonen entstanden, in welchen sich diese Gebilde vor der Erosion erhalten haben, während der Zentralteil zu einem Antiklinorium geworden ist und aus ihm wurden die erwähnten Gebilde erodiert.

Die Grundformen in einzelnen Strukturen sind unterschiedlich. In dem Synklinorium des Gebirges Slovenský kras entstand ein Faltensystem mit dem W—O Streichen. Die Falten sind gewöhnlich mild, jedoch an den Stellen, wo es zu stärkeren tangentialen Drücken kam, sind die Antiklinalen steil aufgerichtet und grösstenteils an den Flügeln durch das System der Überschiebungen gestört (z. B. das Miglic-Tal bis Drnava, auch von Silica über das Plešivec-Plateau bis Novačany). Die Entstehung dieser steilen und schmalen Antiklinalen wurde im wesentlichen auch durch grössere Anwesenheit der sehr plastischen Ton- und Mergelschiefer, mit Rücksicht auf die hangenden karbonatischen Komplexe, bedingt.

Das Faltensystem besitzt eine ausgeprägte Vergenz bloss in diesen steilen Antiklinalen. Die Achsenflächen der Antiklinalen sind gegen Norden geneigt. In den mässig wellenförmigen Antiklinalen und Synklinalen des Gebirges Slovenský kras deuten die Achsenebenen auf die symmetrische Deformation ohne eine ausgeprägte Vergenz hin. Die überwiegend gegen Süden geneigten Überschiebungslinien heben die antiklinalen Teile hervor, wobei sie die Antiklinalen oft aufs Minimum reduzieren. Es kommen jedoch auch Überschiebungen mit verkehrter Neigung gegen Norden vor, die auf ausgeprägte jüngere Bewegungen gegen Süden zu hindeuten (die Gombasek-Überschiebung). Von dem Plešivec-Plateau gegen Westen treten überwiegend untertriadische Schichtenfolgen, im östlichen Teil hauptsächlich die karbonatischen Komplexe der Mittel- und Obertrias, auf. Diese Tatsache weist darauf hin, dass die Faltenachsen im Raume des Plešivec- und Koniart-Plateaus und im westlichen Teil des Silica-Plateaus sowohl von der westlichen, als auch von der östlichen Seite einsinken, wodurch sie eine ausgeprägte Querdepression bilden (ihre Fortsetzung kann man nach Norden in das paläozoische Gebiet verfolgen).

In dem Antiklinorium der Volovec-Zone kann man am besten die alpidischen Strukturen auf Grund der Ausbreitung der jungpaläozoischen Sedimente und der Relikte des Mesozoikums beobachten.

Schematischer Verlauf der alpidischen Strukturen im Karbon, Perm, Mesozoikum und in ihrem Liegenden



Alpidische Strukturen: 1 — Überschiebungslinie; 2 — Überschiebungen, Dislokationen; 3 — Antiklinalen; 4 — Synklinalen; 5 — Monoklinale; 6 — Quersynklinalen; 7 — Schichtung; 8 — Schichtschieferung; 9 — Querschieferung; Gemeriden: 10 — Das jüngste Bauelement; 11 — Jura; 12 — Obertrias; 13 — Mitteltrias; 14 — Untertrias; 15 — Perm; 16 — Karbon; 17 — ältere gemeride Bauelemente; Veporiden (18—20); *alpidisches Bauelement der Veporiden* (18—19): 18 — Mesozoikum der Hüllenserien; 19 — Karbon, Perm; *ältere Bauelemente der Veporiden:* 20 — Krystalinikum.

In dieser Zone war es möglich drei von Westen nach Osten streichende synklinale Zonen zu begrenzen. Die nördlichste Synklinale verläuft von Dobšiná gegen Fabianka und Nordhänge des Suchý vrch. Den nördlichen Flügel der Synklinale stellt das Karbon nördlich von Dobšiná dar (Masörter, Altenberg, Biengarten u. ä.) und er ist durch die Senkugstektonik, die den Flügel der Synklinale hervorhebt, stark gestört. Den südlichen Flügel stellen die Sedimente des Karbons, Perms und Mesozoikums auf den Nordhängen des Spitzenhügels dar. Die antiklinale Zone verläuft auf dem Gugel-Kamm und trennt die Synklinale von dem Synklinorium des Gebirges Stratenská hornatina. Sowohl die Gugel-Antiklinale, als auch die Dobšiná-Synklinale sind durch das System der von NO nach SW (von Palcmanská Maša gegen Lányiho Huta) quer streichenden Überschiebungen gestört; die jüngeren karbonischen Gebilde sind da erhalten.

Die südliche Synklinale verläuft von Vyšná Slaná gegen Vlachovská Maša. Den nördlichen Flügel bilden die Südhänge des Spitzenhügels mit den Vorkommen des Karbons, Perms und der Trias. Den südlichen Flügel bilden die mesozoischen Trümmer des Berges Radzim, Stožok und die permischen Gebilde auf der rechten Seite des Slaná-Flusses.

Zwischen der von Bučina auf Spúšťadlo streichenden Antiklinale und der südlichsten Antiklinale, die sich von Turecká über Repisko auf Ivánka zieht, ist eine mächtige Synklinale, in der die jungpaläozoischen Sedimente vorherrschen. Die erwähnten Synklinalen in dem Volovec-Antiklinorium sind flachwellig. Es handelt sich im wesentlichen um Brachysynklinalen, die sich von Norden gegen Süden stets vergrössern. Die Achse der Dobšiná-Synklinale hebt sich sowohl in der westlichen, als auch in der östlichen Richtung. Bei den übrigen zwei Synklinalen heben sich die Achsen in der Ostrichtung, während die Synklinalen im Westen durch die Scherdeckenlinie der Gemeriden abgeschnitten sind.

Alle angeführten Synklinalen haben sich in der Querdepression als Relikte erhalten. Sie zeugen von der Hebung der Achsen dieser Längssynklinalen, sowie von der Existenz der Quersynklinalen, die infolge der Entstehung der Depression gebildet wurden. Die Quersynklinalen streichen von NW nach SO. Die westlichere Quersynklinale verläuft von Táflyová über Radzim nach Kobeliarovo und Repisko, die südlichere parallel von Dobšiná über Spitzenhügel gegen Stožok, Gampel und Repisko.

Das charakteristische Formieren des Antiklinoriums der *Volovec-Zone* bestand in der Bildung von mässigen Längsbrachysynklinalen, die sich von Norden gegen Süden zu, was die Breite und Länge betrifft, bei gleicher Amplitude vergrössern; weiter auch in der Tatsache, dass die Antiklinalen gleich gross sind. Die Querdepression, die ihre Fortsetzung nach Süden auch in das Mesozoikum hat, verengert sich in der Richtung nach Norden. Es widerspiegelt sich auf der Verkürzung der Längssynklinalen. Es ist bemerkenswert, dass die Quersynklinalen, die die Depression ausfüllen, eine verkehrte Tendenz besitzen. Sie laufen im Süden (Repisko) zusammen und gegen Norden laufen sie auseinander. An den Stellen, wo die Quersynklinalen die Längssynklinalen kreuzen, haben sich grössere Relikte des Mesozoikums erhalten (Dobšiná, Kobeliarovo). Die Ausprägung der Querdepression verursacht auch das System der unregelmässig konzentrisch angeordneten Brüche in ihrem mittleren Teil.

Im anliegenden Teil der Kohút-Zone beobachtet man unterschiedliche Formen. Es sind mächtige, durch das Kohút-Kristallinikum gebildete antiklinale Zonen, zwischen denen die hauptsächlich durch die Untertrias, bzw. durch das Jungpaläozoikum gebildeten schmalen synklinalen Zonen eingeklemmt und tief eingekeilt sind. (Analoge Formen sieht man auch im nordöstlichen Teil der Gemeriden, im Abschnitt Margecany—Košice, wo das jüngere alpidische tektonische Bauelement — Karbon, Perm, Untertrias — ähnlich eingefaltet ist). Diese Strukturen (Markuška, Stolica, Trešník) ähnlich wie auch die Strukturen in den Gemeriden, sind vor der Aufschiebung der Gemeriden-Decke entstanden. Durch diese Aufschiebung wurde das Antiklinorium der Volovec-Zone in der N—S Richtung abgeschert und hat sich auf das vor ihm liegende Antiklinorium der Kohút-Zone aufgeschoben.

Ganz anders hat es sich nördlich von diesen Antiklinorien abgespielt. Auf das zwischen dem Trešník- und Kráľova hoľa-Massiv liegende Synklinorium, in dem sich die Reste der metamorphierten mesozoischen Hülle befinden, hat sich der obere Teil der *Gemeriden-Decke* (Karbon — Mesozoikum) aufgeschoben und wurde gefaltet. Ein charakteristisches Merkmal dieses Gebietes ist auch das fächerförmige System der Faltenachsen mit der Tendenz in einen Knoten im Abschnitt Vernár—Besník zusammenzulaufen.

In den Berührungszonen der antiklinorialen Volovec-Zone mit den synklinorialen Zonen in den Gebirgen Slovenský kras und Stratenská hornatina besteht ein charakteristischer Überschiebungsbau. Sowohl im Süden, als auch im nördlichen Teil verlaufen da einige mehr oder weniger parallele Überschiebungen, deren Verlauf mit Rücksicht auf die Faltenstrukturen diagonal ist. Typisch sind sie zwischen Dobšiná und Mlynky, im Süden zwischen Železník und Štítnik entwickelt.

Ausser der Entstehung der beschriebenen mittleren Faltenstrukturen in dem alpidischen Bauelement entstanden auch feine Texturelemente. Verhältnismässig einfachste Texturelemente kann man besonders im mittleren Teil des beschriebenen Gebietes verfolgen. Im mittleren Teil kam es in den karbonischen und permischen Sedimenten zur starken, *epizonalen Metamorphose*, gleichzeitig bildete sich in den Sedimenten sekundäre Kristallisationsschieferung, die eine Schichtschieferung darstellt. Am besten entwickelte sie sich bei den petrographisch ungleichartigen Typen der Pelite, Sandschiefer und pyroklastischer Gesteine, wo die Absonderungsflächen sehr gut entwickelt waren. Bei den Gesteinen, wie verschiedene Typen der Konglomerate und Sandsteine sind, entwickelte sich die Schieferung unregelmässig, die Schieferungsflächen sind verhältnismässig uneben, grössere Körner wurden in der Richtung der Schieferung ausgezogen. Die Kalksteine wurden umkristallisiert und an den Stellen, wo man die angedeutete Schichtung beobachten kann, bildeten sich intensive liegende Falten. Ausser den Faltenstrukturen ist es uns gelungen in den karbonaschen und permischen Schichtenfolgen auch andere lineare Elemente festzustellen. Südlich von Kobeliarovo sieht man in den fein geschichteten Kalken und Schiefern die Boudinage, an den Schieferungsflächen bildet sich feine Fältelung, bzw. ist der Serizit und Chlorit linear geregelt. Im allgemeinen herrschen jedoch die Flächenelemente über den linearen vor. Alle Lineationen sind auf der Schieferungsfläche, die mit der Schichtung übereinstimmend ist, entwickelt. Aus dem Studium der Beziehung der Foliationsflächen zu der Lineation folgern wir, dass beide Elemente gleichzeitig, bei demselben Deformationsprozesse entstanden und deshalb je besser die Schieferung entwickelt ist, desto weniger ausgeprägt ist die Lineation. Bei der entwickelten Lineation ist die Foliation undeutlich, bis sie völlig verschwindet. Beim Studium der Klüfte kann man Querklüfte (ac), Längsklüfte (bc) und verschiedene Schrägklüfte unterscheiden. Gegen Norden zu, also südlich von Dobšiná, in den karbonischen und permischen Schichtenfolgen, klingt die Metamor-

phose nach und nach aus. In den Schichtenfolgen der Sandsteine und Schiefer beobachtet man auch Schieferung, die mit der Schichtung übereinstimmend zu sein pflegt, jedoch kommt da ausser der Kristallisations- auch ausgeprägte Kluftschieferung vor. Ähnliche Elemente findet man auch in den Sedimenten der Werfener Schichten südlich von Dobšiná und westlich von Rožňava. An den Stellen, wo im Karbon und im Perm die Faltung und die Metamorphose bloss gering, oder keine war, besonders bei den Schichtenfolgen, wo sich die Schichten mit verschiedener petrographischer Zusammensetzung abwechselten, entwickelte sich die Schieferung an den Schichtgrenzen (clivage).

Der Grad der Epimetamorphose und die Art der oberflächennahen Faltung war bei den karbonischen, permischen und Werfener Schichten anders, als bei den Schichtenfolgen des karbonatischen Mesozoikums. Es hat hauptsächlich die petrographische Zusammensetzung der Gesteine und ihre Position verursacht. Bei der Faltung der Kalke und Dolomite kam es nicht zur Epimetamorphose, sondern bloss zur freien Rutschung auf der Schichtung.

Im südlichen Teil der Gemeriden äusserte sich die durch die tektonischen Bewegungen verursachte Schieferung besonders auf den untertriadischen Schichten, u. zw. an den Stellen, wo sie hochbeansprucht wurden, d. h. in den zusammengepressten antiklinalen Zonen. In den höheren Komplexen der Trias äusserte sich die Schieferung vereinzelt und minimal.

Im nördlichen Teil der Gemeriden kam es zu komplizierteren metamorphen Prozessen. Die mesozoischen und älteren Serien, die die Hülle des Kristallinikums der Kohút- und Králova hoľa-Zone bilden, wurden intensiv epizonal metamorphiert (Foederata-Serie, die Serie unter dem Muráň-Plateau, Veľký Bok-Serie, die Serie bei Heľpa). Es bildete sich da mit der Schichtung übereinstimmende, intensive Kristallisationsschieferung. Bei den überschobenen mesozoischen Serien äusserte sich schon bloss die Rutschung auf den Schichtflächen, ohne die metamorphen Wirkungen.

Das alpidische Bauelement (aus den karbonischen, permischen und mesozoischen Gebilden zusammengesetzt) wurde zusammen mit seinem Liegenden, das als ein Komplex auftrat (aus älteren herzynischen, kaledonischen, assyntischen Bauelementen zusammengesetzt) in die Form der mittleren Strukturen verformt. In der Volovec-Zone, wo die Rakovec- und Gelnica-Serie das Liegende des flachwelligen alpidischen Bauelementes bildeten, entwickelte sich gleichzeitig mit den Deformationen die Querschieferung, die ein generelles O—W Streichen mit dem Fallen gegen Süden besitzt. In der Rakovec-Serie ist diese Querschieferung sehr ausgeprägt, während es bei der Gelnica-Serie zur Auflagerung der alpidischen Strukturen auf die älteren herzynischen Strukturen kam und infolgedessen diese grösstenteils unausgeprägt sind.

In dem alpidischen Bauelemente beobachteten wir die Entstehung von *feinen Deformationen* im Einklange mit den Faltenstrukturen, d. h. sie wurden für die Rutschung der Schichtungsfläche ausgenützt. Deshalb bildete sich auch die Schieferung mit anderen Texturelementen, übereinstimmend mit der Schichtung und abhängig von ihr. Diese Art der Deformation bezeichnen wir als *oberflächennaher*

tektonischer Stil der Faltung. In den liegenden Bauelementen bildete sich die Schieferung unabhängig von den älteren Bauelementen und ihren Faltenstrukturen, u. zw. generell gegen Süden fallend, mit dem W—O Streichen. Diese Art der Entstehung der Deformationen bezeichnen wir als *tieftektonischer Stil.*

Sehr oft beobachtet man die Übertragung des oberflächennahen tektonischen Stils in das alpidische Bauelement. So einen Fall treffen wir in der nördlichen Begrenzung der Volovec-Zone, wo in die Komplexe der mächtigen, massiven, permischen Konglomerate die Querschieferung aus dem unteren, liegenden Bauelemente verläuft.

An manchen Stellen kann man auch eine verkehrte Erscheinung beobachten, dass in den eng eingefalteten Synklinalen (in den Veporiden und im nordöstlichen Teil der Gemeriden) sich die Schichtschieferung auch auf das liegende Bauelement überträgt.

An den Stellen, wo der oberflächennahe und tiefe tektonische Stil mit dem alpidischen Bauelement einschliesslich seines Liegenden übereinstimmen, bildeten sich an der Berührung der Komplexe, vorherrschend über den Flächenelementen, die linearen Elemente (in der Form der Halmtextur), die auf intensive Drehbewegungen hindeuten (R-Tektonite). In den Veporiden gibt es schöne Beispiele in den Quarziten der Foederata-Serie, in den Gemeriden in den karbonischen Phylliten der Gelnica-Serie, bei Slavoška und anderswo.

Im nordwestlichen Teil der Gemeriden kam es zu einem anderen, etwas jüngeren Typus der Deformation. Im Liegenden des alpidischen Bauelementes und in ihm selbst bildete sich eine Scherdecke. Die Schieferung bildete sich parallel mit der Überschiebungsfläche, u. zw. intensiver im Liegenden, als im Hangenden. Diese neue, spätere Art der Deformation unterscheidet sich wesentlich von dem vorerwähnten Formieren. Nördlich von der Scherfläche entsteht die Veporiden-Zone, die vordem aus dem Kohút-Antiklinorium gebaut wurde, dessen alpidisches, durch die Hüllengebilde des Karbons, Perms und Mesozoikums gebautes Bauelement — die Foederata-Serie, die Serie unter dem Muráň-Plateau, Heľpa-Mesozoikum — zusammen mit seinem Liegenden (kristalline Gesteine der älteren Bauelemente) durch die aufgeschobenen Massen gänzlich umgebildet wurde. Sie besitzt den *Faltenstil mit der inneren Tektonik* (Zoubek 1935, 1937, 1955), die man auch als liegende Ampferer's Walzzone bezeichnet. Sie ist dadurch charakteristisch, dass durch die geschobenen Massen der Gemeriden die Markuška-Antiklinale in die Form der Digitation des Berges Markušský vrch verformt wurde und ausserdem in ihrem Bauelement, im ganzen Berührungsabschnitt, der Schuppenbau entsteht. Die Zone der Verformung der älteren feinen und mittleren Strukturelemente reicht in bedeutende Tiefe von dem Kontakt der Gemeriden, wobei die Schieferung in den liegenden Serien die Berührungsfläche umrisst.

Dagegen südlich von der Scherfläche hat sich die, gleichfalls aus Antiklinorien und Synklinorien zusammengesetzte Gemeriden-Zone auf die Veporiden-Zone

aufgeschoben. In solchem Fall sprechen wir von einem *Faltenstil der „geschobenen Masse"*. Besonders markant erwies sich dieser Stil nahe dem Abschnitt, wo die Scherfläche über das Liegende des alpidischen tektonischen Elementes, oder direkt in dasselbe überging, bzw. an seiner Grenze vorbeiging. Im Abschnitt Jelšava—Rejdová—Táflyová hat die Scherfläche sowohl die ältere Gelnica- und Rakovec-Serie, als auch das alpidische, aus jungpaläozoischen Sedimenten zusammengesetzte Bauelement durchgeschnitten. Der antiklinale Bau der Volovec-Zone besitzt deshalb im Westen durch die Scherfläche abgeschnittene Achsen der Synklinalen und Antiklinalen, so dass sie gegen Westen nicht mehr fortsetzen. Nördlich von Rejdová schneidet die Scherfläche die älteren Bauelemente durch und läuft direkt in das alpidische Bauelement hinein. Sie verläuft an der Grenze der mechanisch unterschiedlichen Komplexe. So ist besonders die Grenze des Werfens und die höheren kalk-dolomitischen Komplexe (Muráň-Plateau). Oft verläuft sie jedoch auch tiefer, in der Nähe der Grenze mit den unteren Bauelementen, von welchen sich auch die karbonischen Sedimente, d. h. fast das ganze alpidische tektonische Bauelement, abschälen (südliche Seite des Kráľova hoľa-Massivs). Solche geschobene, bloss aus dem alpidischen tektonischen Element zusammengesetzte Massen deformieren sich bei der Schiebung selbständig in verschiedene Faltentypen. Die Schieferung überträgt sich von der Scherfläche auch auf bedeutende Entfernung in die gemeriden Schichtenkomplexe, wobei sie die Überschiebungsfläche umrisst. So kommt es zur Störung, oder völliger Verlöschung der älteren, sowohl sedimentären, als auch tektonischen Texturelemente. In der Nähe der Scherfläche bilden sich oft auch ausgeprägte lineare Halmstrukturen, die von O nach W streichen, unter die Gemeriden tauchen (20—30°) und auf die Bewegungen von S nach N hindeuten.

Ausser den erwähnten alpidischen Deformationen beobachten wir noch eine j ü n g e r e Deformation, u. zw. die *Querschieferung*. Am intensivsten äusserte sie sich an den Rändern des Volovec-Antiklinoriums. Sie verläuft von O nach W. Im Abschnitte Jelšava—Ochtiná—Markuška geht sie über die Berührung der Gemeriden und Veporiden über und fällt gegen Süden. Daraus folgt, dass sie jünger ist, als die Aufschiebung der Gemeriden auf die Veporiden. Davon zeugen auch feine Strukturelemente an der Berührung der Gemeriden mit den Veporiden. In der nördlichen Begrenzung des Veporiden-Antiklinoriums ist sie auch ausgeprägt (auch bei Kráľova hoľa und Heľpa), gleichfalls mit den Fallrichtungen gegen Süden. Da sie schon in den permischen und Werfener Gesteinen, in den Geröllen der eozänen Konglomerate vorkommt, entstand sie noch während der vorpaläogenen alpidischen Faltungsprozesse. Sie stellt den tiefen tektonischen Stil dar.

Als das jüngste alpidische Bauelement in den Gemeriden betrachten wir die *tertiäre Ausfüllung* der kleinen Mulden.

*

Zum Schluss könnten wir zusammenfassen, dass die Faltendeformationen aller Bauelemente (der alpidischen, herzynischen, kaledonischen) im begrenzten Gebiet von Süden gegen Norden aufeinandergelegt wurden und dass sich zwischen den während der Faltung entstandenen Strukturen und den Strukturen, die sich während der Sedimentation einzelner Formationen bildeten, in beträchtlichem Masse die ererbte Tektonik geltend machte.

Aus dem Slowakischen übersetzt von F. Návara.

BIBLIOGRAPHIE

[1] Bajaník Š., 1962: Niekoľko poznámok o stratigrafii, magmatizme a tektonike rakoveckej série medzi Čiernou horou a Hnilcom. Geologické práce, Zošit 61, Bratislava. — [2] Bystrický J., 1962: in Vysvetlivky k prehľadnej geologickej mape ČSSR 1 : 200 000 — Rimavská Sobota (kapitola Mezozoikum, Tektonika). Geofond — Vydavateľstvo, Bratislava. — [3] Fusán O., 1961: Entwicklung des Baues des Gebirges Spišsko-gemerské rudohorie. Geologické práce, Zošit 60, Bratislava. — [4] Maheľ M., 1957: Geológia Stratenskej hornatiny. Geologické práce, Zošit 48, Bratislava. — [5] Snopko L., 1957: Predbežná zpráva o tektonike a metamorfóze kryštalinika Spišského príkrovu v povodí rieky Slanej. Geologické práce, Zprávy 11, Bratislava.

LADISLAV ROZLOŽNÍK

THE RELATION BETWEEN FAULTS AND FOLIATION IN THE „SHEAR ZONE" OF THE DOBŠINÁ VICINITY

Solution of the chronological and space relations between microtectonic and megatectonic elements may significantly aid to the reconstruction of structural development of many regions. The same may be applied to the Spišsko-gemerské rudohorie region where the question concerns the metalogenic problems as well. The author of this article demonstrated by the analysis of the structural — metalogenic elements exposed between Dobšiná and Mlynky (Rozložník 1962a, 1962b) that the study of microstructural elements helped the more accurate dating of the mineralization of the Spišsko-gemerské rudohorie Siderite formation and thus contributed to the understanding of rules of the ore bodies localisation. The article is discussing several peculiarities of the relations between s-planes and faults of the "Shear zone" in the vicinity of Dobšiná in the northwestern part of Spišsko-gemerské rudohorie.

Position of the Shear zone within the framework of the territory

Several structural zones may be distinguished along the cross-section of the studied area differring from each other by the features of the micro and megatectonic elements as well as the degree of metamorphosis.

1. *Upper zone* (Zoubek 1936 — "Overlying building elements"; Mahel' 1957 — "The Surface tectonic style") is formed by rock complexes practically non metamorphosed and relatively poor as for the microtectonic elements. There is only one s-plane developed corresponding genetically to the bedding plane (ss-plane). The ss-planes in general form folds of great amplitude. The small amplitude folds appear only locally. For this reason the B-axes are only slightly pronounced. The fracturing is quite frequent but is rarely typical. The faults of this zone in majority belong to flat overthrusts, shifts and throws.

To the Upper zone a great majority of the Gemeridy Mesozoic and locally also Permian and Middle Carboniferous sequences are included. The zone is separated from its basement — the Shear zone — by disharmonic tectonics. During the tectonic strain action the Upper zone has been separated from the basement and overthrusted to a certain distance.

2. *Shear zone* (Zoubek 1936 — "Lower building elements"; Mahel' 1957 — "The induced tectonic style") in contrast to the Upper zone is far more rich as to the microstructural elements. Several S-planes appear throughout this zone (S_1, S_1, S_2) the s-planes possess usually the metamorphic minerals of the chlorite, sericite and albite facies. Steeply dipping thrust faults are for this zone the most typical. Fracturing is commonly present and characteristic to a great extent.

In the Shear included are the rocks of the Gelnica and Rakovec series further Middle Carboniferous, Permian and in some places also the rocks of Triassic — those having deeper structural roots.

3. *Phyllite zone* is also characterized by the shallow — zone alteration without regional granitization but in contrast to the overlying Shear zone provides only one single s-plane of the metamorphic cleavage (schistosity) lacking the elements of shearing (s_2-planes, thrusts etc.) and is also poor in fractures.

Phyllite zone is formed exclusively by the rocks of the Lower Paleozoic (Gelnica series, event. Rakovec series).

4. *Granitized zone* represents a zone of regional granitization with the planes of crystallization schistosity (— folded) eventually with an isotropic structure (granitoids).

The described structural zoning was developed in three periods, Kaledonian, Hercynian and Alpine. The process of Kaledonian tectogenesis however in the studied area cannot be proved with certainty. (Fusán — Máška — Zoubek 1955; Máška 1960; Snopko 1960; Fusán 1961). From the structural zones mentioned to a great extent exposed over the recent erosive relief only two of them appear: the Upper zone and the Shear zone. The existence of the Phyllite and Granitized zones may only be supposed from the reconstruction of the Hercynian tectogenesis.* The Upper zone resulted exclusively due to Alpine tectogenesis. The Shear zone demonstrates a combined structure — originated by the rearrangement of the upper parts of the Hercynian Phyllite zone in the Alpine period as to the deep horizons of the Hercynian Phyllite zone they seem to be little effected by the Alpine tectonics. The zone however was invaded by the Upper Cretaceous granite intrusions (Gemeridy granite). Concerning the upper parts

* The reconstruction is based partly upon the structural analysis of pre — Midle Carboniferous units partly upon the pebble analysis of Carboniferous and Permian conglomerates. The existence of Hercynian granitization is supported by the occurence of Rakovec series granitized rocks in the vicinity of Dobšiná (Rozložník 1962c).

of the Hercynian granitized zone it has been most probably changed into phyllite zone by the process of diaphtoresis.

The developement of the shear zone has been controlled by the movement regime during the Alpine stress between the folding competent Upper zone and the rigid, during the Hercynian partly consolidated basement zones. The shear zone development is shown on fig. 1 and 2

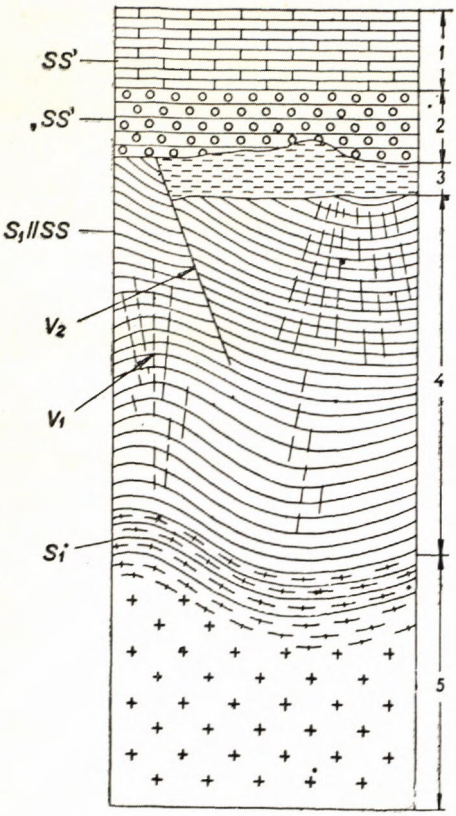
Shear zone s-planes

Three basic regionally widespread kinds of plane elements in the Shear zone were determined: 1. Hercynian S-planes — planes of true bedding schistosity; 2. Alpine S_1-planes — planes of bedding schistosity and bedding (ss-planes); 3. Alpine S_2-planes — planes of oblique schistosity.

1. *Hercynian planes of bedding schistosity* (if eruptive rocks were involved then metamorfic schistosity) originated by the folding metamorphosis of the Hercynian period. In case of the preferred orientation for the new tension arrange ment they were rejuvenated and — refabricated during the Alpine period. The planes possess the preferably oriented metamorphic minerals (sericite, chlorite, quartz) and are folded into folds conformably with the Alpine B-axes. The schistosity in majority of cases is identical with the primary bedding. (S_1), (SS). This type of foliation occurs in the Gelnica and Rakovec series.

2. *Alpine planes of bedding schistosity* eventually exclusively bedding planes (S_1), (S'S and SS') originated during the Alpine process. The planes carry metamorphic minerals only at places of intense refabrication. Elsewhere they only had the character of bedding planes where the reduction of movements took place without any preferred rock minerals orientation. They were folded accordingly with the strike of Alpine structures. The representatives of this foliation type are Middle Carboniferous, Permian and Triassic (the latter only ss'-planes in general).

3. *Planes of oblique schistosity* — fracturing cleavage (s_2-planes) represent a typical microstructural element of the Shear zone. Their strike is nearly constant E—W (eventually NE—SW) dipping to the south. They cros both s_1 and s'_1 planes resulting in shearing and in general not a uniform one — direction shifting. Expression of this process is the fine microfolding. Such a peculiar type of lineation originated as an intersection of s_1 with s_2 planes and may be regarded as *b* — axes symmetrical to the Alpine structural E—W strike of Middle Carboniferous, Permian and Triassic elements. The relation to the Hercynian strike in the complexes of Gelnica and Rakovec series is only locally symmetrical. The formation of s_2-planes in the rocks of Gelnica and Rakovec series is later than crystallization, but the deviation of metamorphic minerals from the s_1-planes into s_2-planes may be observed. For this reason also the s_2-planes are frequently covered by metamorphic minerals. In the younger complexes the s_2-planes often



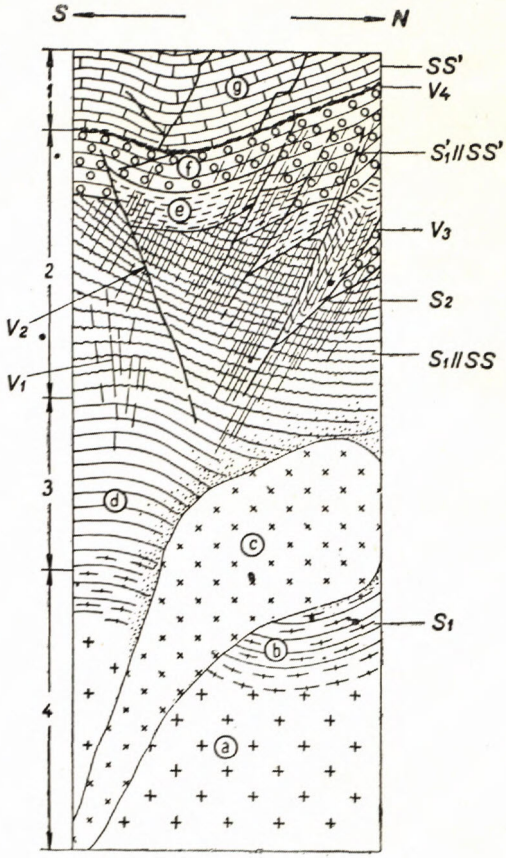


Fig. 1. Assumed structural zonality before the Alpine tectogenesis (Scheme). 1. Triassic, 2. Permian, 3. Middle Carboniferous (1—3) effected only in Germanotype style, 4. Hercynian phyllite zone (Rakovec and Gelnica series — Gemeridy Paleozoic), 5. Granitized Hercynian zone; ss′ — bedding of post — Middle Carboniferous sequences, s_1//ss — Hercynian bedding cleavage of pre — Middle Carboniferous sequences, s_1 — Hercynian crystallization cleavage; v_1 Hercynian embryonal bedding cleavage, v_2 post — Middle Carboniferous — pre — Permian fault.

Fig. 2. Assumed structural zonality after the main Alpine tectogenesis (Scheme). 1. Upper structural zone, 2. Shear zone, 3. Phyllite zone, 4. Granitized zone, a) Hercynian granitoids, b) Hercynian granitized zone, c) Upper Cretaceous Gemeridy granite, d) Gelnica and Rakovec series, e) Middle Carboniferous, f) Permian, g) Triassic, s_1 — Hercynian crystallization cleavage (with Alpine diaphtoresis ?), s_1//ss — Hercynian bedding cleavage of Gelnica and Rakovec series sometimes with Alpine refabrication, s_1//ss′ — Alpine bedding cleavage of Middle Carboniferous and Permian, ss′ — bedding in majority of Triassic, s_2 — Alpine oblique cleavage, v_1 — Hercynian, embryonal axial cleavage, v_2 — Hercynian fault revived in the Alpine period, v_3 — Alpine upthrow, v_4 — Alpine low angle thrust.

appearing in the role of axis cleavage indicate a close relation to the S_1-planes folding. In this case however they are post — crystalline again.

The distribution of s_2-planes is not regular everywhere. S_2-planes with narrow interspacing occur in soft rocks or in places of intense deformation. Elsewhere they possess the character of wide interspacing corresponding rather to fracturing.

Except the plane elements mentioned there are several other types also extended During the Hercynian folding of the S_1-planes an embryonal axes cleavage originated. All such rather exceptional cases are for the solution of given problems only of a limited value.

Faults of the Shear Zone

Little is known about the formation of Kaledonian faults and Hercynian as well. Only two great post — Middle Carboniferous and pre — Permian fault lines* were proved certain in the studied area. Most probably they are faults originated during the late Hercynian dictyogene movements described by Máška 1960 and refabricated to a great extent during the Alpine period.

There genetically different fault groups originated in the Alpine period representing most probably also chronologically different phases of tectonic development: 1. The group of strike — slip** steep upthrows and strike — slip low angle overthrusts; 2. The group of oblique and transverse horizontal movements (event. oblique upthrows); 3. The group of strike — slip (often step — like) and oblique downthrows.

The faults concerned are of various amplitude. Among the minute appear some of greater order e. g. Mlynec upthrow line 600 m, horizontal fault Tešnár 300 m and the downthrow Coburg fault 120—150 m.

The more accurate chronological dating of the particular fault groups appears quite difficult due to the lack of preserved Tertiary deposits. The troubles arise also due to the revival of some of the faults in the course of younger phases often leading to the introduction of reverse directions.

The Relation Between S-planes and Faults

The first group of faults (strike — slip upthrows) performs geometric relations to some of the abovementioned kinds of foliation (s_1, s_1, ss) — in majority to the s_2-planes. In this case not only the strike coincides but also the dip as well.

The conformity of the upthrows with *Hercynian s_1-planes* occured at places

---

* Concerned are the Hnilec fault line (Máška 1960) following the contact of Gelnica and Rakovec series (see S_2 on Fig. 3) and Georgia line (Rozložník 1962b).

** The terms strike — slip, oblique, transverse etc. concern the relation to the Alpine E—W structural strike.

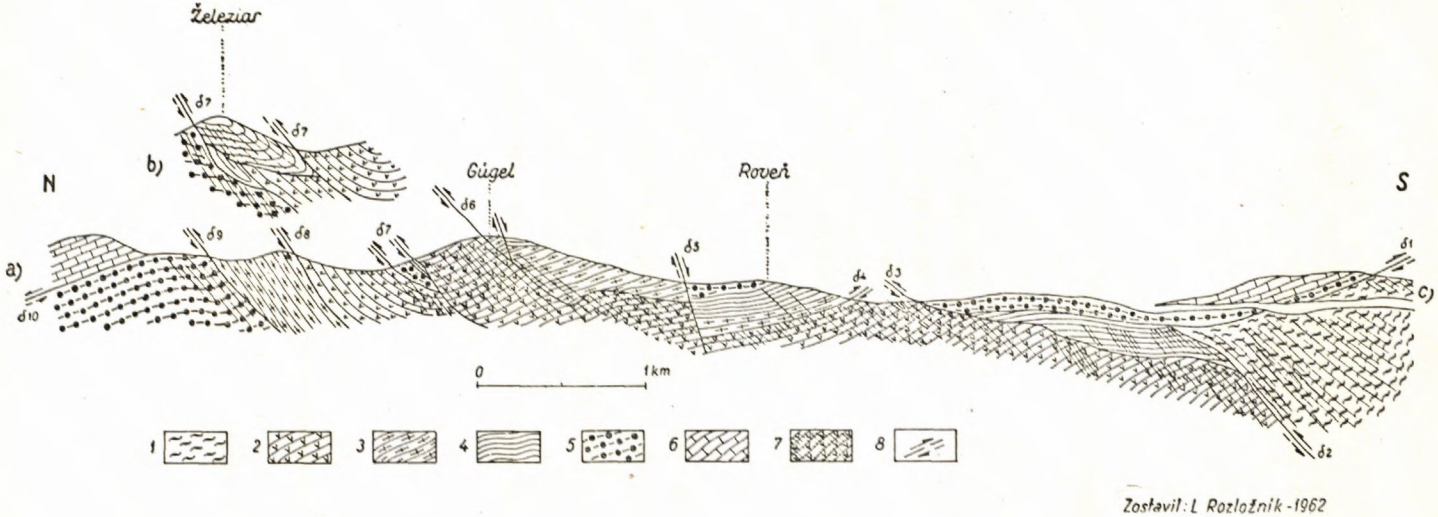


Fig. 3. Geological cross-section of the territory northeast of Dobšiná. 1. Phyllites, quartzites and porphyroids of Gelnica series (Cambrian — Sillurian ?), 2. Phyllites, metadiabases, diabase tuffs and tuffites of Rakovec series (Devonian ?), 3. Amphibolites, hybrid tonalite gneisses, tonalites, granite aplites and pegmatites — granitized rocks of Rakovec series (Upper Devonian — Lower Carboniferous), 4. Conglomerates, bioherm limestones, dark slates and sandstones (Middle Carboniferous of Dobšiná development), 5. Varigated conglomerates, sandstones and slates (Permian), 6. Variegated slates, "rauhwacke" (cellular dolomite), marly shales and limestones (Triassic of northern Gemeridy development), 7. Alpine oblique cleavage, 8. Faults with indicated orientation of movement.

where the strike and dip of the s_1-planes were preferably oriented to the Alpine N—S stress. Such were the situation at the limbs of E—W oriented Hercynian folds in Gelnica and Rakovec series where the s_1-planes represented the preferable orientation and were thus rejuvenated by the slip — movements. By the gradual increase of the folding tension upthrows were initiated in the direction in majority concordant with the strike of s_1-planes. Such upthrows may be observed on the enclosed cross — section (see Fig. 3 — δ_4, δ_8, δ_9 partly δ_7). The upthrows were formed often at the contact of different competency media.

The area studied demonstrated also fair examples of the conformity between the direction of upthrows and that of the *Alpine s_1 or ss-planes.* The example mentioned earlier demonstrated only the termination of the Hercynian folding by the Alpine action of shearing while in the second case a direct one — after — the other continuation of both the actions is concerned i. e. true overthrust folding. Such a development is to be found exclusively in the complexes of Middle Carboniferous and Permian. A fine example may be observed in the Mlynec line (fig. 3, δ_7 fault). Mlynec line is seated in the Hercynian Rakovec series syncline. Into this syncline both Middle Carboniferous and Permian were clammend during the Alpine N—S stress. Later on a strong reduction of the limbs proceeded together with wedge formation to such an extent that in the recent forms in majority of cases only wedges of Carboniferous and Permian clammed in the Rakovec series are observed.

At many places the upthrows shear both s_1 and s_1-planes as well being however *concordant with the planes of oblique schistosity.* In so far a concordant direction of upthrows with the former kinds of foliations is rather local than with the S_2-planes the concordance is of far more regional character and as for the symmetry more accurate. (The dips of both the upthrows as well as s_2-planes are to the south) this is the result of close genetic relations between the origin of oblique schistosity and upthrowing. They were always initiated there where other planes of discontinuity (s_1 and s_1-planes as well as Hercynian faults) were incompetent to reduce sufficiently the tectonic movements. As an example may be taken fault δ_2, δ_6, δ_9 planes (Fig. 3).

The abovementioned relations between s-planes and upthrows concern the upthrows with *steep fault planes.* Upwards these elements die out together with s_2-planes due to the compensation of folding strain by free slip-movements. At the contact of the Shear and Upper zones *low-angle thrust planes occur* often of shear character (e. g. faults δ_1, δ_3, δ_{10} — Fig. 3) accompanied by mylonite zones or fault breccia. Such faults appear at the Triassic basis, in Permian, less in Carboniferous. Low — angle overthrusts were accompanied by the reduction of some of the sequences (e. g. in close vicinity of Dobšiná Permian is reduced to a great extent together with lower horizons of Triassic).

It is apparent in consequence of the mentioned above that the *first group*

of faults (upthrows and overthrusts) demonstrates close relations to elements originated during the intense N — S compression (southern overturn) and so they have to be regarded as elements depending on the main phase of the Alpine movements throughout the West Carpathian territory (by Maheľ 1959; Andrusov — Bystrický 1959 and Kantor 1960 regarded as Subhercynian orogenic phase).

Although in the deeper parts of the Shear zone — due to the partial Hercynian consolidation — the vertical values by the formation of upthrows were more effective (steeply dipping fault planes at the contact of the Shear zone with Upper zone, horizontal one — way slipping originated in connection with the low — angle thrust — planes.

The second group (oblique and transverse movements) represents a younger tectogene phase demonstrating the faulting of the upthrows. Concerning the symmetry of the Alpine B-axes they are supposed to be related to the fading of the main compressive phase thus chronologically being subsequent to the faulting

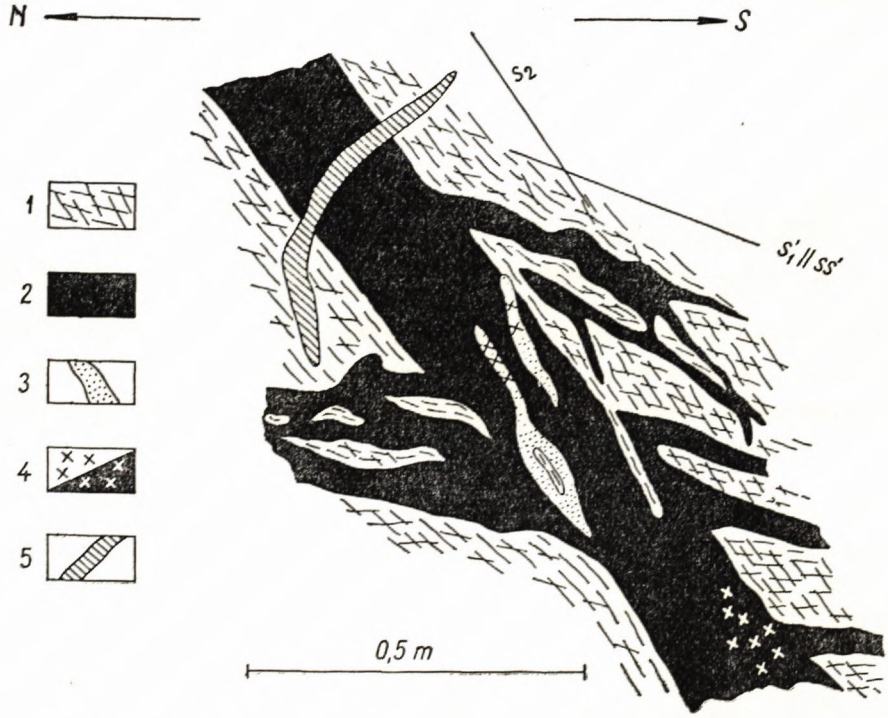


Fig. 4. Detailed skatch of one the hanging-wall veins of Filip vein-zone in Mlynky (stope № F_2). The vein is controlled by the planes of oblique cleavage (s_2) with apophyses following the foliation spaces of bedding cleavage (s'_1 — ss'). 1. Dark hydrothermally altered Middle Carboniferous slates, 2. Siderite, 3. Ankerite, 4. Specularite, 5. Quartz.

of the first group. Besides the dragging and several branching faults all the horizontal movements possess the strike unconformable with all the S-planes.

The third group includes the downthrows. Elements concerned are faults originated after the release of the acting stress. As to the age most probably they are alredy Tertiary. The majority of them represent antithetic downthrows along the strike. The coincidence of the dips with s-planes were not observed. It must be mentioned however that during the formation of third group faults some of the upthrows were repeated as downthrows. That circumstance of course complicates very much the tectonic reconstruction.

The relations between faults and metalogenesis

The analysis demonstrates that the most complicated relations exist between the s-planes and the first group of faults — upthrows. Steeply dipping upthrows and s_2-planes are the characteristic elements of the Shear zone which played an important role also in the mineralization process of the Spišsko-gemerské rudohorie Mts. Siderite formation. In many cases these elements served as channels for the ascent of hydrothermal solutions, and some of them were also filled with precipitated ore minerals. The multilateral relations between the upthrows and surrounding foliation led in the past to the diversity of opinions concerning the position of the ore — veins in the Spišsko-gemerské rudohorie (Ahlburg 1913; Ilavský 1951; Andrusov 1951). The second and third group of faults took part only in the post — mineralization tectonics.

During the Upper Cretaceous ore — mineralization processes from all the abovementioned faults only the Shear zone became ore — bearing. This zone compared with the other ones included a greater number and more competently oriented zones of weakness conditionning great permeability for the hydrothermal solutions to such and extent that the Shear zone acted as a collecting agent for the orebearing solutions. The great mobility of the Shear zone in the course of ore — mineralization (the fading of stress) made easy the circulation of ascending hydrothermal solutions. One must take into consideration the fact that the shear zone also from the thermodynamic viewpoint was fairly competent for deposition of the ore minerals.

Translated by J. Kováčik

LIST OF REFERENCES

[1] Ahlburg J., 1913: Über die Natur und das Alter der Erzlagerstätten des oberungarischen Erzgebirges. Mitteil. aus d. Jahrb. d. Ung. Geol. Reichsanstalt, Budapest. — [2] Andrusov D., 1951: O povahe zoskupenia rudných žíl v severnej časti Spišsko-gemerského rudohoria. Geol. sborník II. Bratislava. — [3] Andrusov D. — Bystrický J., 1959: O význame

subhercynskej fázy vrásnenia v Západných Karpatoch. Geol. sborník X/2, Bratislava. — [4] Fusán O. — Máška M. — Zoubek V., 1955: Niektoré dnešné problémy stratigrafie Spišsko-gemerského paleozoika. Geol. práce, Zprávy 2. Bratislava. — [5] Fusán O., 1961: Entwicklung des Baues des Gebirges Spišsko-gemerské rudohorie. Geol. práce, Zošit 60. Bratislava. — [6] Ilavský J., 1951: Povaha rudných žíl v Spišsko-gemerskom rudohorí. Uhlí a rudy 6. Praha. — [7] Kantor J., 1960: Kriedové a orogenetické procesy vo svetle geochronologického výskumu veporidného kryštalinika. Geol. práce, Zprávy 20. Bratislava. — [8] Maheľ M., 1957: Postavenie Stratenskej hornatiny v severogemeridnej synklinále. Geol. práce, Zošit 46. Bratislava. — [9] Maheľ M., 1959: Nové členenie a pohľad na historicko-geologický vývin mezozoika centrálnych Karpát. Geol. práce, Zošit 55. Bratislava. — [10] Máška M., 1960: The tectonic development of the West-Carpathian System — the Caledonian and Variscian Development; in Tectonic development of Czechoslovakia. Praha. — [11] Rozložník L., 1962a: Problémy metalogenézy okolia Dobšinej. Geol. práce, Zošit 61. Bratislava. — [12] Rozložník L., 1962b: Analýza štruktúrno-metalogenetických prvkov medzi Dobšinou a Mlynkami v severozápadnej časti Spišsko-gemerského rudohoria (in press). — [13] Rozložník L., 1962c: Petrografia granitizovaných hornín rakoveckej série v okolí Dobšinej (in press). — [14] Rozlozsnik P., 1936: Die geologischen Verhältnisse der Gegend von Dobšiná. Geol. Hungarica, Ser. geol. 5. Budapest. — [15] Snopko L., 1960: Stručná zpráva o geologickom mapovaní južne od Dobšinej. Geol. práce, Zprávy 20, Bratislava. — [16] Zoubek V., 1936: Poznámky o krystaliniku západních Karpat. Věstnik Stát. geol. ústavu XII, Praha.

TIBOR BUDAY

SOME PROBLEMS OF THE ORIGIN AND DEVELOPMENT OF THE FAULT-STRUCTURES IN THE NEOGENE CARPATHIAN BASINS

The Neogen basins of the West Carpathians were formed during the late-geosynclinal to post-geosynclinal phase of the development of the mountain range. Their tectogenic development is characterized directly by orogenic movements influenced the alpinotype structural forms only in external basins located in front of the youngest units of the alpinotype structure. But even there the germano-type structures frequently prevail. The basins occurring in the interior and on the inner side of the range were not affected directly by orogenic movements, so that alpino-type structural elements are absent. Their structure results from diktyogenic and epeirogenic movements called forth by the orogenic processes occurring in the marginal units. The structure shows a medio- and germanotype character. The most conspicuous structural elements of these basins are blocks bounded by fault systems which are prevalently to exclusively of normal-fault type. Another widely distributed structural form is represented by the brachy-structures which, for the most part, do not owe their origin to folding (tangential stress), but to the subsidence movements connected or not connected with faults. As is seen, the primary factor in controlling the development of the basins structure are the faults.

An overwhelming majority of faults disturbing the infilling of the Neogene basins are normal faults. The throws vary even at one and the same fault. The vertical displacement on main faults attains several hundreds, occasionally even more than one thousand metres. The main faults are traceable to distances of several tens of kilometres, in places of over hundred kilometres. The analyses of throws have clearly demonstrated that the faults did not break the infilling of the basins postgenetically, but acted syngenetically for a long space of time, frequently during the whole development stage. The abovementioned circumstan-

ces suggest that the origin and location of the main faults are not accidental. The trends of the main faults coincide with the principal tectonic directions of the basement. It has been ascertained that in the Vienna Basin the strikes of the main faults were in different development stages analogous to the directions of tectonic units of the basement which were formed at the pertinent periods. Thus, for instance, the majority of Lower Miocene major faults are parallel with the tectonic units of the Magura Flysch, where as the later Torton-Pliocene faults run parallel with the plane along which the Magura unit was thrust over on the Ždánice unit, and with the structural directions of the latter unit. The spacing, directions and throws of the faults vary accordingly to the nature of the earlier tectonic units building up the basement of the basin. From these few observations it may be concluded that the origin and development of faults depend on the basement of basins. The analysis of the structure of individual basins or of their parts with basements of different characters allows several laws for the origin and development of fault-structures of the basins to be deduced.

It may be stated generally that the location, direction and mobility of the major basin fault-structures are conditioned and controlled by the course of earlier pre-Neogene structural lines of the immediate basement of the basins. The younger and less consolidated the basement, the greater its influence on the Neogene structure, i. e. the more is the structure of the basement reflected in the structure of the Neogene. Most powerful influence is exerted by structural elements which originated or were completed in the Neogene. Thus, for instance the part of the Vienna basin with the Flysch basement has a far more complicated structure than the portion with the Central Carpathian basement. The latter part shows in turn a more complex structure where Central Carpathian basement is built up of younger structural elements formed during the pre-Gosau, Laramide and Savian movements than in portions built up of the pre-Gosau nuclear units. The portions of the Danube basin with a most complicated structure and most persistent mobility are also situated on the basement formed of younger pre-Neogene units as, e. g. NW projections (continuations of Palaeogene or Upper Cretaceous intermontane basins) and the SE part of the basin underlain by the Central Hungarian Palaeogene basin. The attitude of the principal central depression and the course of its boundary faults in the East-Slovakian basin also coincide with the course of the Inner Carpathian Palaeogene depression. The least complex structure is shown by the Danube basin where, except for the above-mentioned parts, there are no structural elements distinguished by extremely marked features and, especially, large throws. This is due to a highly consolidated ancient (mostly crystalline) basement.

The structure and development of the basins are also controlled, event though to a less extent, by the deeper, often pre-Neoidic basement. But while the influence of the immediate basement is direct, as will be shown in the following paragraphs,

the deeper basement does not exert a direct control on the location of the structural units. As was deduced by T. Buday (1961), the influence of deep structural units is manifested first by the control of the location of the basin units in the Carpathians and not by the control of their structures. Nevertheless, even an influence of deep structures is suggested by some examples. Thus, for instance, in the East-Slovakian basin the course of the ancient Hornád line appears to have conditioned the west boundary of the basin and of the N—S structures which are typical for this portion of the basin. The eastern margin of the Danube basin is also affected by ancient N—S lines which can be traced northwards into the Carpathians and to Hungary in the south. The fault-lines (e. g. Kravany fault and others — J. Seneš, 1962) also swing to these directions.

The *basement structures* affect the faults of the Neogene infillings both *directly and indirectly*. The direct control is scarcer; it occurs when on the ancient pre-Neogene fault renewed in the Neogene times the movement continues and breaks the Neogene formations. We do not know yet many examples illustrating this case, owing to relatively few available data. A mere continuation of the Neogene fault into the basement does not yet provide evidence of the pre-Neogene age of the fault. As a basement fault continuing directly into the Neogene may be instanced the Schrattenberg fault in the western part of the Vienna basin, faults limiting the Brezová depression in SE against the Jablonice horst, faults in the Upper-Moravian valley (Z. Roth, 1962) and numerous faults in the area of Ostrava (J. Petránek, 1956; A. Jurková — J. Zeman, 1962). The movements may be of a concordant or reverse sense relative to the basement fault. Thus, for instance, the original "Schrattenberg fault" had been of a reverse-fault type, whereas the rejuvenated Neogene dislocation was of a normal-fault type. In certain cases the sense of movements varies. This was observed particularly at the ancient radial dislocations with a steep to vertical dip. The renewed movements on these faults may lead to "rolling" movements of blocks whose sense in the individual stages of the Neogene development may be varied. Z. Roth records such cases from the area of the upper Morava valley. The sense of the dip of the young rejuvenated fault is usually conformable with the inclination of the original fault (this does not hold for the angle of dip). The faults of a reverse dip may originate only when the basement fault is steeply, almost vertically inclined.

The indirect influence of the basement faults has been ascertained far more frequently. A transitional form between a direct continuation of the basement faults into the Neogene basin fillings and the faults conditioned by the basement faults conditioned by the basement structures is represented by the fault systems. The fault-systems, i. e. systems of most closely spaced, parallel and interconnected faults of a conformable dip chiefly originate at the boundary of two tectonic units of the basement, which are separated from each other by the pre-Neogene faults.

The differing mobility of the two basement units is generally manifested in the first development stages by a fairly strong subsidence of the more mobile part without the formation of a fault, or by an uplift of the basement block, particularly when the pressure phenomena are active in the mountain range. Not until later, when the movements last for a long period or are recurrent, do the faults originate at the boundary of the two units also in the Neogene infilling. In this way, complex fault systems develop above these boundaries which, for the most part, are not a direct continuation of early basement faults, but are conditioned by them. The mechanism of the development and the function of these faults is extremely complicated. A good illustration of their development has been provided by the experiments described by M. Dlabač (1960). The Steinberg and Farský fault systems in the Vienna basin, the Komárno and Hurbanovo fault systems in the Danube basin a. o. are classed with this group of faults. Typical examples of the origin and development of the Neogene faults influenced indirectly by the dislocations in the basement are several transverse and diagonal normal faults and sections of some major longitudinal systems which have an anomalous course. Thus, for instance, in the Vienna basin a concentration of transverse and diagonal faults of irregular courses and longitudinal faults swinging to anomalous (NW to NNW) directions has been observed in the area between Vacenovice and Senica—Jablonica region or between Podivín and Lakšarská Nová Ves. In these places, as seen from the analysis of geophysical data and the structure of the margins of the basin, transverse tectonic lines (of the Sudetic direction) run in the basement, particularly in the deeper portions of the basement, whose mobilization in the Neogene induced the formation of these dislocations. Analogous examples are to be seen in the continuation of this belt in the Danube basin in the area of Trnava and Cífer (Z. Adam, M. Dlabač 1961) or in the vicinity of the water-gap of the Danube near Bratislava.

In the referred cases it is not possible to identify a definite fault in the basement, the less so its direct continuation into the Neogene, nevertheless, the dependence of the origin and of the course of the Neogene faults on the tectonic lines of the basement is unambiguous.

To the above-mentioned conclusions it is necessary to add that, especially in large basins persisting from the beginning of the Neogene to the Late Pliocene, several structural levels may also be generally distinguished in the Neogene basin infillings. D. Andrusov already in 1938 demonstrated that, for instance, in the Vienna basin the Lower Miocene structural level occupies a position of an independent basement unit towards the younger Torton-Panonian infilling. The structural lines of the earlier Neogene basement of the younger basin control apparently the development of the structure of the later Neogene. Their mutual stratigraphic relations are governed by the above-mentioned principles.

The structure of the Neogene, being chiefly controlled by the faults of the basement, is also affected, though to a minor extent, by other structural elements

of the basement. The influence of non-tectonic basement structures till recently has been rather underestimated and erroneously taken for the influence of the basement relief, (e. g. M. Dlabač – Z. Adam, 1956; J. Janoschek 1942, 1943, 1951). We must not forget, however, that even if the influence of morphological elements of the basement (of the relief) is really undeniable if could be exerted on a higher degree only if they were rejuvenated during the sedimentation of the Neogene infilling. Otherwise, they were soon covered by newly deposited sediments and their effect was more pronounced only in the basal layers.

As mentioned above, no earlier pre-Upper Cretaceous structural elements of the basement, neither larger units nor individual folds are generally manifested in the structure of the Neogene. Their influence is apparent only when they were clearly marked in the relief (owing to the selective erosion and denudation), but in this case they belong to the category of buried structures controlled by the relief. In addition to the post-Middle Cretaceous fault- and block structures, megastructures are conspicuous elements in the development of the Neogene structure. Even if their formation was terminated (or in some cases began) in the Neogene, it may be assumed that their foundations had been laid already before the Neogene period, so that they controlled the distribution and development of the Upper Cretaceous and Palaeogene intermontane depressions. This feature was already recognized by A. Matějka and D. Andrusov (1931). If we adopt Mahel's view on a strongly differentiated character of the Mesozoic Carpathian geosyncline, the origin of these structures must be looked for in the first stages of development of the Carpathian system in the Neoidic era. Their most pronounced influence has been ascertained in the Danube basin where, for instance, the Inovec and Tribeč megaanticlinoria continue beneath the Neogene far towards the centre of the basin controlling the most marked block structures of the area. The effects of the megastructures are more pronounced, however, on the margins of the basins than inside them. They often separate the partial basins, too.

We have already mentioned in the introductory paragraph that the faults and blocks bounded by them are the most marked and most widely distributed structural elements of the basins, which account for their tectonic style. The block structure of the basins is generally very complex and has been recognized only thanks to extensive geophysical and boring works. This complexity is due to several factors, the most significant of them are as follows: The basement structure mostly complicated, rejuvenated in different development stages of the basins with different intensity; the strong mobility of the basin areas varying in intensity (rhythmically changing) throughout the period of their development and, finally, the structure developing concomitantly with the sedimentation.

A most enduring and marked influence on the structure of the basin and control over its fundamental structural units is exerted by the basement structure, particularly by the units running parallel with the longitudinal axis of the basin.

The function of other structural elements of the basement is rather of an episodic character, but they do affect not only the formation of transverse or diagonal faults and, consequently, the block units, but frequently also the course of major faults. In every basin one principal direction and corresponding principal block units are well recognizable besides less conspicuous but distinct one or more subordinate directions. These are sometimes manifested by a mere curving (undulation ?) of the axes of the main units, sometimes give rise to independent block units of the second order, either in horizontal or in vertical direction.

A long-termed mobility of basins whose intensity cyclically varied is reflected in the *variability of the function of the main structural elements.* The activity of the faults may in some stages have come to a standstill to be renewed in the subsequent phases. In this way the vertical diversity of the fault systems has developed. The change in the intensity of movements is also influenced by the areal factors. The maximum mobility of individual parts of the basin falls in different periods of time. From this the changes in the significance of the structural elements in different parts of the basin result. The influence of varying mobility is most pronounced at the secondary (transverse or diagonal) faults. They acted more intensely only in stages of an extraordinary tectonic unrest (e. g. at the strong folding when deeper or more consolidated elements of the basement were mobilized). Otherwise they remained at rest for a long period.

The third factor is represented by the *syngenetic development of the fault-structures with the sedimentation.* The significance of the syngenesis, for the Vienna basin in particular, has been emphasized chiefly by J. Janáček (1955). In the periods of intensive, differentiated subsidence the movements took place along a great number of faults differing in strike, simultaneously with the sedimentation. It is apparent that the intensity of subsidence was not the same in all the faults. As deduced already by J. Janáček (1955), as a result of the syngenesis, faults of different strikes acting contemporaneously and not disturbing one another but splitting or coalescing, prevail in the structure of the Neogene basins. In some periods, especially when the mobility was of a lesser intensity, only one system may be in function which disturbs the others post-genetically. The younger faults acting either syngenetically or post-genetically disturb the faults of the preceding cycle postgenetically.

The above-mentioned factors account for the unusually complex and apparently chaotic picture of the fault-structure of the basins. The structure is distinguished first by a certain degree of plasticity, the uneven course of faults and structures bounded by them and the complexity of faults which are mostly arranged in systems of interconnected dislocations of a variable strike (in general, not in detailed direction), dip and amount of throw. This variability can be observed both along the strike and in the vertical direction. Owing to the syngenesis, the main structural units differ also in the thickness and facies of sediments which

change abruptly on the boundary of two units. This rule is valid only as far as a structural unit of one structural level is concerned. The conditions in the lower level may be substantially different. Thus, for instance, in the Lužice-Mikulčice area in the Vienna basin the Tortonian-Pliocene horst of Hodonín—Gbely with a minimum thickness of sediments is underlain by the Lower Miocene depression with a maximum thickness of deposits.

In spite of a considerable complexity of the structure great irregularities in the course, development and significance of the course, development and significance of the structural elements, the *longitudinal direction* is typical and most pronounced in each of the basins. The longitudinal structural elements are most constant horizontally and vertically and, as a rule, serve as a basis for the tectonic differentiation of the basins. Other directions are manifested only occasionally as independent structural units. Their influence is apparent more frequently in the inner differentiation of the longitudinal units, in changes of their distinctness, their course a. s. o. They can be traced over the basins of larger areal extent only occasionally. Their primary importance consists in that typical brachystructures were developed at the crossings with the longitudinal faults. The brachystructures are extremely significant due to the bitumen deposits which accumulated there.

In conclusion we may state that typical structural elements of the Carpathian Neogene basins are the *block structures* bounded by complex and variable (in strike and vertical direction) syngenetic normal faults. These are conditioned to a large extent by the structure of the basement and by the revival of movements along the basement tectonic lines during the Neogene development of the mountain range. This does not mean, of course, that the sediments filling the basins are not disturbed by faults whose origin is not unambiguously connected with the basement structure or that no other structural elements occur in the Neogene filling. The most important and most typical for the Carpathian Neogene basins are however, the above referred structures which control the style of the basin structures.

The genesis and classification of the fault-structures of the Neogene basins provide a field of intricate problems which cannot be exhausted in a short account. The question of these fault structures has not been recently investigated in detail by our geologists, except for several studies by M. Dlabač and Z. Adam (1956), M. Dlabač (1960) and J. Janáček (1955). It will be the task of further studies to elucidate the mutual relations between the earlier and later structural elements, explain in detail the genesis of individual fault types and accomplish the classification of different types of fault- and block structures.

LIST OF REFERENCES

[1] Adam Z. — Dlabač M., 1961: Nové poznatky o tektonice Podunajské nížiny. Věstník Ústř. Úst. Geol. XXXVI/3, Praha. — [2] Andrusov D., 1938: Karpathen Miozän und Wiener Becken. Petroleum. Bd. XXXIV, Nr. 27. Berlin. — [3] Buday T., 1961: Der tektonische Werdegang der Neogenbecken der Westkarpaten und ihr Baustil. Geolog. práce, Zoš. 60, Bratislava. — [4] Dlabač M., 1960: Tektonika (Příspěvek k poznání stavby Podunajské nížiny). Manuscript; VÚ ČND, Brno; Geofond, Praha. — [5] Dlabač M. — Adam Z., 1956: Příspěvek k řešení tektoniky steinberského zlomu v severní části Vídeňské pánve. Sbírka prací výzk. úst. Řada E. Práce VUN, publ. č. 23—25, Praha. — [6] Janáček J., 1955: Nové tektonické a tektogenetické poznatky československé části vnitroalpské pánve. Sborník Ústř. Úst. Geol. XXI/1954 odd. geol., 1. díl; Praha. — [7] Janoschek R., 1951: Das Inneralpine Wiener Becken. in F. X. Schaffer: Geologie von Oesterreich. II. Aufl., Wien. — [8] Jurková A. — Zeman J., 1962: Příspěvek k poznání základní zlomové tektoniky v spodnotortonské čelní hlubině v ostravsko-karvinském revíru. Věstník Ústř. Úst. Geol. XXXVII/1, Praha. — [9] Matějka A. — Andrusov D., 1931: Guide des excursions dans les Carpathes occidentales. Knihovna SGÚ, 13 A, Praha. —[10] Petránek J., 1956: Mladotřetihorní tektonika v ostravsko-karvinském revíru. Sborník Ústř. Úst. Geol. XXII/1955 odd. geol., Praha. — [11] Roth Z. a kol., 1962: Vysvětlivky k přehledné geologické mapě ČSSR 1:200.000 M-33-XXIV Olomouc. Nakl. ČSAV. Vyd. Geofond, Praha. — [12] Seneš J., 1962: Vysvetlivky k prehľadnej geologickej mape ČSSR 1:200.000 L-34-1 Nové Zámky. Geofond, redakcia Bratislava.

TIBOR BUDAY

COMMENTS ON THE PROBLEMS OF THE FOLDING PHASES IN THE NEOGENE OF THE WEST CARPATHIANS

The Neogene period is the second principal stage of folding of the West Carpathians. The centre of the folding process in the Neogene were the outer Carpathians whose fold- and nappe-structure originated and developed at that time. During the Neogene the intensity of the folding movements on our territory gradually decreased and the phases evidenced as occurring during the Upper Miocene and Pliocene in the East Carpathians are no more manifested here by the origin of fold deformations. Every folding phase, however, manifests itself by tectonic movements not only in the zones directly affected by folding (in the centres of folding, i. e. in the Outer Carpathians), but also in other tectonic units of the mountain range. The nature of these movements varies, but for the most part does not have the character of folding. In this brief account a detailed analysis of all problems of the folding phases in the Neogene cannot be presented. Here we shall present only a few comments bearing firstly on the manifestations of folding in different parts of the range and, secondly, on the correlation of the established phases with the orogenic phases defined originally by H. Stille.

We think it necessary to say in advance that we do not use the term "mountain-building (orogenic) phase", as this term does not give a true picture of the processes involved. The mountain-building movements, i. e. the uplift and formation of the mountainous massifs can in the main be of another type, having a character of vertical movements without the co-operation of folding phenomena (see for instance A. A. Bogdanov, 1961). We designate as a folding phase an interval of time during which the pressure phenomena show themselves in the mountain range or in some of its segments by the formation of fold structures (even if their intensity and form differ) or by other structures produced by the pressure phenomena. Thus, we do not consider as a manifestation of folding phases

the interruption of sedimentation, stratigraphic hiatuses or weak unconformities when their association with the folding or other structures called forth by pressure phenomena cannot be evidenced.

The manifestations of the folding phases in the mountain range can be *very diverse.* A detailed analysis of the development of the Neogene basins, their structure, lithology and palaeogeography enabled us to define with a comparative precision the forms of folding manifestations outside the folding centre proper. These relations have been partly solved in a paper in 1961 (T. Buday, 1961). Here we shall give only a short characterization of processes and structural forms originated in connection with the individual phases of folding.

It holds good generally that a phase of folding manifests itself in a segment of the mountain range by the most varied types of processes occurring throughout the segment. Analogously, also the effects of folding phases taking place in adjoining segments can be recognized.

The phase shows itself by folding movements leading to a *complex fold- and, frequently, nappe structure* firstly in the marginal units of the Outer Carpathians, namely in the marginal unit of the Outer Flysch (i. e. in the marginal unit at the respective time interval) and, partly, in the foredeep. Towards the inner side of the mountain range the folding dies out. In the interior units of the Outer Carpathians (including the basins belonging to them) it is expressed by a weaker folding and the origin of thrust-structures (mostly with a retrograde vergency). In the Central Carpathians, the megastructures are formed and emphasized and fault structures are induced or renewed during the phase of folding. The fold structures are completely absent above the median mass i. e. above the innermost units, where only vertical movements take place. In the main, the alpinotype structures pass into medio- to germanotype structures in the direction towards the inner side of the range. But every phase shows itself unconditionally by movements called forth by the pressure phenomena, i. e. by the uplift, cessation of the subsidence of the basins or, in extreme cases, by a maximum retardation of subsidence. It has not been observed anywhere that a strong subsidence would occur simultaneously with the phases of folding, as presumed for instance, by E. Vadász (1954), E. Szádecky – Kardoss (1938) a. o. The formation or rejuvenation of earlier faults in the basement falls generally in the period distinguished by the folding processes. But the main subsidence-movements along these faults take place in the periods which are not characterized in the mountain range by pressure phenomena.

On the basis of the results of investigation of the Carpathian Neogene basins the following sequence of movements may be inferred as occurring in the cycle between two phases of folding: In the periods distinguished in the Outer Carpathians by folding, the subsidence of the basins comes to an end, the whole basin or its higher structural units, at least, are uplifted and the sedimentation is com-

pletely or partially interrupted. In this stage the fault lines mostly develop by the mobilization of the ancient structural lines of the basement. In the phases of strong intensity transverse fault lines are also formed. Along these faults vertical movements (uplifting of blocks) occur chiefly, horizontal displacements take place subordinately, particularly in the vicinity of the folded marginal units. After the dying out of the pressure the whole mountain range begins to sink slowly. The mobile parts are the first to subside and the intensity of the movement increases with time. A new transgression gradually sets in to deposit sedimentary formations of a prevalently monotonous facies throughout the basin. The subsidence movements progressively grade into synsedimentary subsidence movements, which become differentiated after the individual blocks and are accompanied with the sedimentation differentiated in facies and thickness. The arrival of a new folding phase begins with the accentuation of the differences in the intensity of movements of the individual blocks owing to a progressive cessation of the movements of some of the blocks. The subsidence is gradually confined to the most mobile blocks whose movements also slow down. The differentiated sedimentation is substituted by the infilling of the remaining parts of the basins and by the development of lagunar sediments (variegated and often coal-bearing) of a uniform facies in the remaining part of the basin.

This sequence of movements may be reconstructed in all the Carpathian basins. The Middle Miocene of the Vienna Basin may be given as an instance. The so-called Later Styrian folding movements (after H. Stille) leading in the marginal part of Carpathians in Moravia to the shifting of the Ždánice unit on the foredeep are represented in the interior part of Carpathians by the uplift and regression of the sea. The developed megasynclinoria are gradually invaded by the Lower Tortonian sea, which deposited at first very shallow and marginal facies and later the sediments of the monotonous Tegel facies. Towards the end of the Lower Tortonian the monotonous Tegel facies passes into sediments of the upper Lower Tortonian whose facies and thicknesses are strongly differentiated according to individual blocks (brackish and variegated, coal-bearing Lower Tortonian). Towards the end of Lower Tortonian a new folding occurs in the marginal part of the Carpathians in Moravia leading again (especially in the Ostrava area) to the overthrust of frontal nappes on the foredeep. Simultaneously, the sedimentation is interrupted in almost the whole basin, being preserved occasionally in the variegated facies in the remaining depressions. The higher block units yield to heavy denudation. A strong rejuvenation of faults particularly of transverse directions occurs; megaanticlines and the megasyncline of the Vienna Basin (in a stricter sense) are formed. At the onset of the Upper Tortonian (in the zone of the „Agglutinantia") a progressive transgression begins and several hundred metres thick monotonous sediments are deposited. In the upper zones of the Upper Tortonian (in the Bolivino-Bulimina and Rotalia zones) strong spatially differentiated subsidences commence. Towards the end of the Tortonian the sea withdraws again and the sedimentation of the variegated facies is limited to the deepest portions of the basin.

From the above it follows that the folding phases can be ascertained on the basis of the folding movements manifestations in every area of the mountain range. But it is not enough to establish the change of facies (presence of conglomerates a. o.), cessation of sedimentation, minor unconformities etc., since analo-

gous phenomena may also occur, though not on a regional scale, in the period intervening between the folding phases, just when the movements differentiated according to individual blocks are active. Hence, the folding phases may be safely identified only when a regional character of the above-mentioned phenomena or a contemporaneous folding in some mountain unit may be evidenced.

The establishment of folding phases and their correlation are rendered difficult by the fact that the phases *are not contemporaneous in all parts of the mountain range.* Therefore, the connection of ascertained movements with the phases cannot always be unambiguously established. As shown by the writer (T. Buday, 1961), the migration of the Neogene folding phases and the changes of their intensity in different parts of the Carpathian range is quite definite. We do not think it necessary to repeat here the conclusions and examples quoted in the paper referred to. But it must be emphasized that due to this fact, in determining the phase, larger sections, at the best, the whole segment is to be taken into consideration. The circumstance that owing to the migration and different intensities the phases can manifest themselves in different parts of the mountain range differently frequently leads to the denial of the existence of phases and to the views on a persistent unrest or on a continuous folding process. It is evident that in the migration of phases, which proceeds from the west to the east, the typical manifestations of a phase may be in the west recognized already at the time when in the east it still has a typical subsidence regime. In our opinion the question of primary importance is not whether the phases are simultaneous in the whole mountain range or not, but whether the folding phases separated by periods of rest actually exist. In solving this problem we must not omit the factor of space. Taking into consideration an area limited for instance to one segment of the mountain range, the existence of folding phases separated from each other usually by fairly long time intervals without the manifestations of pressure phenomena is undisputable. If we bear in mind, however, for example the whole range of the Alps or even larger units, we can hardly speak justifiably about periods in which the pressure phenomena, i. e. folding, are not shown in the range defined in this way. Therefore, we believe that whatever phase of folding is defined, it is necessary to specify the region considered and correlate the time of folding precisely with the stratighraphic time-table. From this point of view it would be probably more convenient to abandon the long-used terms introduced by H. Stille, or complete them, with an exact specification of the time of folding.

In our opinion the *time oscillations* in the course of the Neogene phases do not affect the validity of the principle of the existence of folding phases in the development history of the Earth. From the point of view of longer intervals of time the Miocene Period, in which the main Neogene phases occur, is comparatively short. The far longer Palaeogene Period was far calmer than the Neogene and did not produce in the range any new structural elements of the first order. As far as the

tectonic significance is concerned, the Neogene may be compared with the Middle Cretaceous when a whole series of folding movements gave rise to new structural units of the Carpathians. We think, therefore, that in discussing whether it is justifiable or not to speak about the existence of folding phases, we must take into account not only larger areal units but also longer periods of time. As a third criterion for the existence of phases in this broader sense we regard the significance of structural changes which they brought about. The action of a series of folding phases concentrated in one geologically relatively short period results in the formation of new structural elements of a higher order. Thus, in the Cretaceous phases the alpinotype folding of the Central Carpathians took place and the Flysch geosyncline developed. In the Neogene phases this geosyncline was folded and Flysch nappes and Neogene basins were formed. Every major period distinguished by the folding of large units is characterized by a series of partial movements. We regard the individual Neogene phases as the partial phases of this very kind. It is conceivable that the determination of partial phases is based on the same criteria as the establishing of the main phases, conformed only to a shorter interval of time, smaller areas and structural changes of a lower order.

From the above-stated it may be concluded that it would be convenient to introduce a classification of phases or folding processes based on the analysis of the effects and the course in time and space of the Neogene phases. It would be possible, for instance, to determine the epochs of folding divided into the groups of folding phases which in turn would be subdivided into the individual phases of folding. In this sense all Neogene phases would constitute the epoch of Neogene folding divided into the: *Lower Miocene group* (Stille's Savian phase) *Middle Miocene group* (Stille's Styrian and Moldavian phases) and *Pliocene group* (Attican and later phases according to Stille). These groups would be subdivided into singular phases actually established in the respective segments of the mountain range and determined on the basis of the abovementioned criteria. An established phase, of the lowest rank ought to be valid for one whole mountain segment, where the differences in time of its manifestations should not justify its affiliation to another phase. This concerns, for example, the relations between the latest Styrian and Moldavian movements according to Stille. Namely, an analysis of the conditions suggests that the Moldavian movements represent in fact a manifestation of the latest Styrian phase, which in W occurs at the Lower Tortonian-Upper Tortonian boundary, whereas in E not until in the upper part of the Tortonian. Analogous relations have also been ascertained between the earliest Styrian and latest Savian movements in the Carpathian foredeep in Austria, Moravia and Poland.

The existence of all significant Neogene phases or groups of phases determined by H. Stille has been in the main corroborated by most recent investigations. Only the time of their occurrence and the effects which they produced in the

structure of the mountain range have been defined with a greater precision. The principal result of recent investigations is a more exact recognition of the complexity of phases and the definiton of structural changes which they brought about. The result have been given in greater detail in the paper by T. Buday (1961) and we do not think it necessary to repeat them here.

LIST OF REFERENCES

[1] Bogdanov A. A., 1961: Problém vztahu kaledonské a variské orogeneze v centrálním Kazachstánu. Knihovna ÚÚG, sv. 36, Praha. — [2] Buday T., 1961: Der tektonische Werdegange der Neogenbecken der Westkarpaten und ihr. Baustil. Geologické práce, Zoš. 60, Bratislava. — [3] Stille H., 1924: Grundfragen der vergleichenden Tektonik. Berlin. — [4] Stille H., 1953: Der geotektonische Werdegang der Karpaten. Beihefte z. Geol. Jahrbuch, H. 8. Hannover.

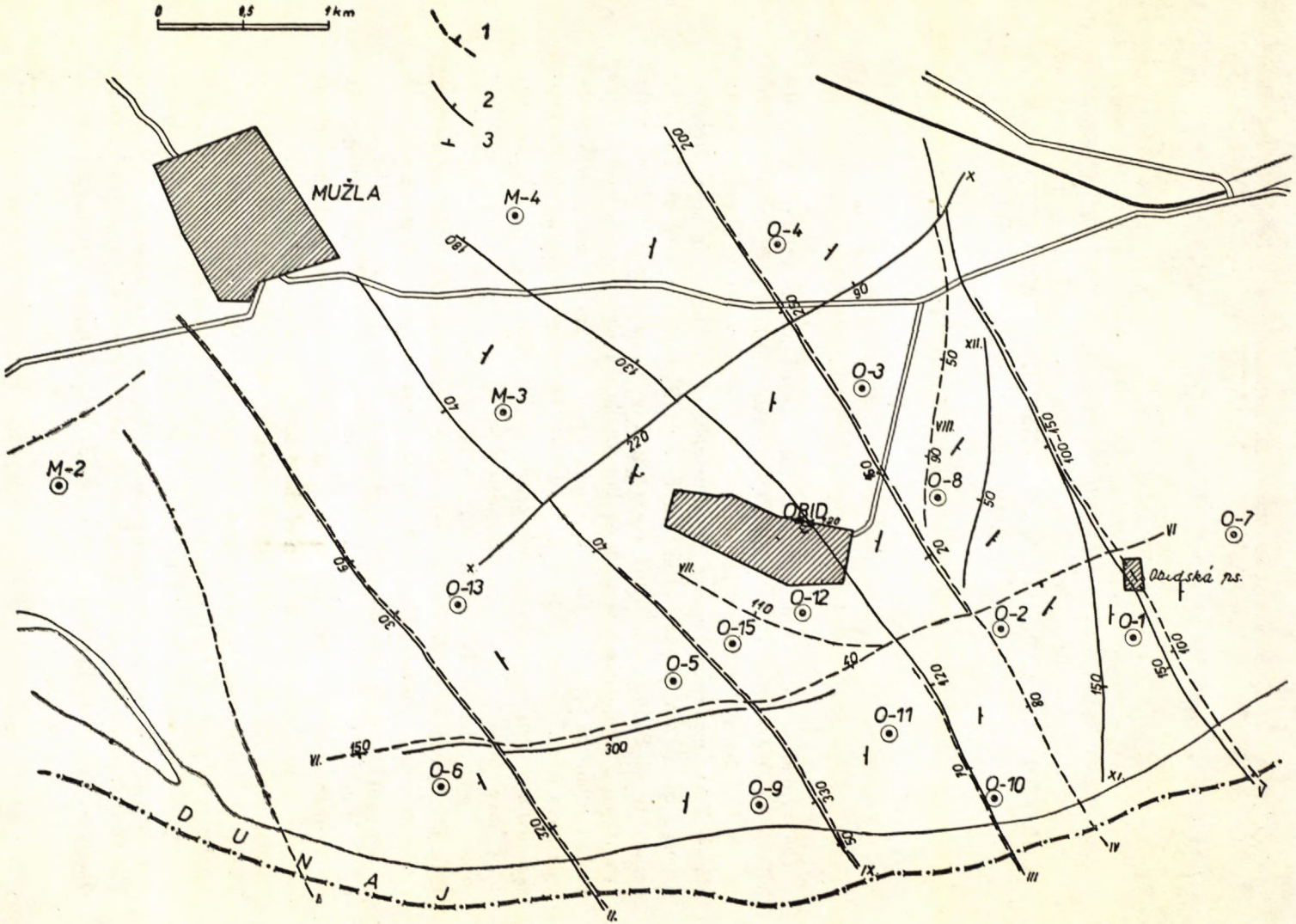
JÁN SENEŠ

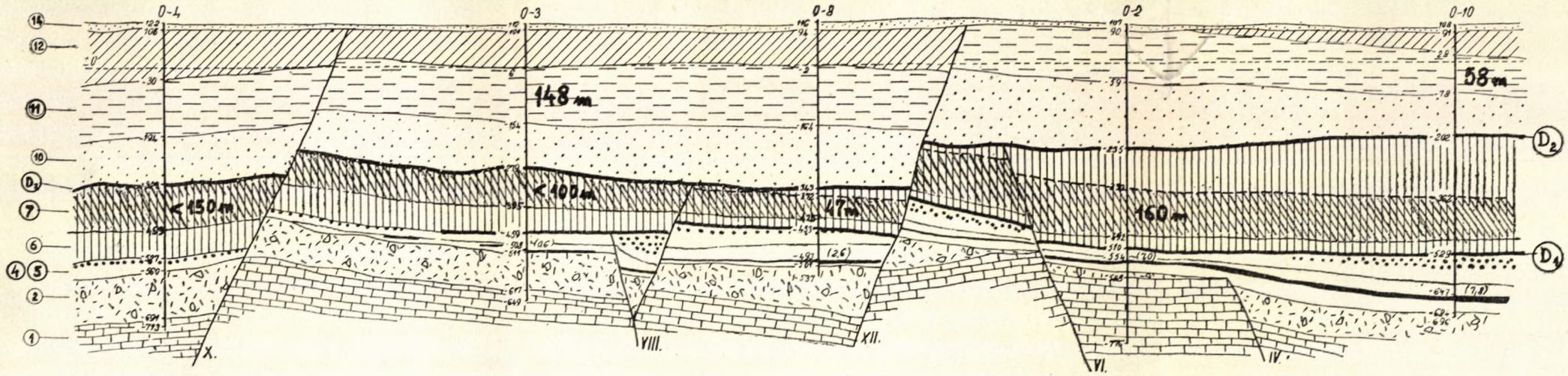
CHRONOLOGICAL POSITION OF SYNSEDIMENTARY TECTONICS IN THE SEDIMENTARY CYCLE

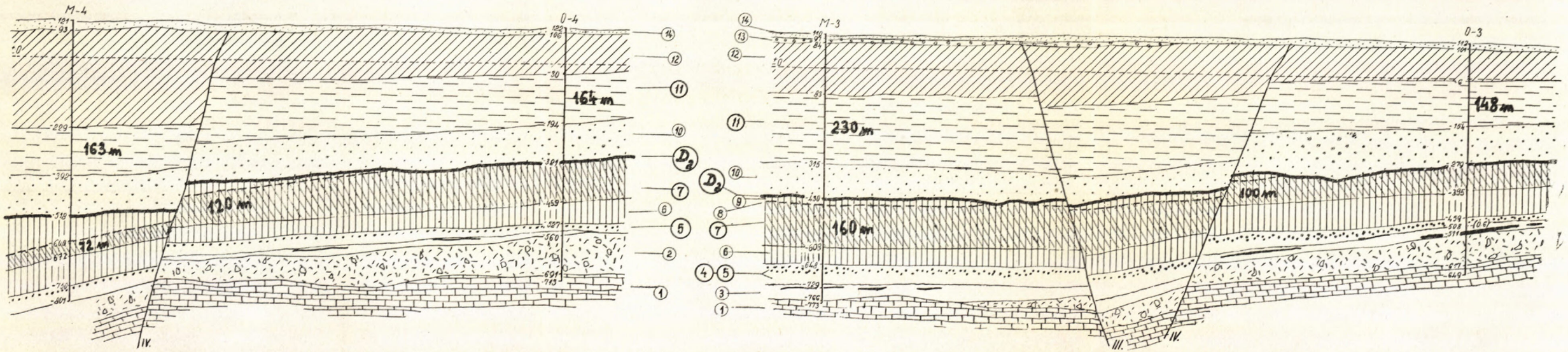
The synsedimentary fault — movements played an important role in the paleogeographic evolution of the West Carpathian Tertiary basins effecting both the thicknesses and facial differences of the sediments of individual tectonic blocks. These movements caused the difference of thicknesses of some Neogene deposits of certain tectonic blocks in Eastern Slovakia as well as the facial variability of Podunajská nížina Eocene and intermittent subsidence with the formation of lignite coal deposits of Podvihorlatská territory. Moreover seems probable that the synsedimentary movements effected also the distribution of the volcanic activity (Seneš 1956, 1957, 1960). The investigation of the Podunajská nížina eastern margin Paleogene contributed also other valuable informations. They have shown a certain, perhaps also a ruled connection between these movements and culmination periods of the sedimentary megacycles.

In the Paleogene of the recent Podunajská nížina lowland three sedimentary cycles were distinguished. They began by the fluviolimnic and brackish sedimentation, culminated by the formation of neritic or bathyal deposits and terminated by the gradual filling of the sedimentation area, or instead by the sudden break of the marine environment due to some active alpine-type orogenic movements reflected also in this marginal area of the epicontinental zone.

Concerning the structure of the disscussed area it is exclusively of *fault-type*. The area is dissected by faults into rectangles with the NW orientation. The amplitude of some faults reaches up to 300 m; amplitude of the regional fault separating the Eocene from Pliocene and forming probably also the western boundary of the Gerecse Mts. (Kravany—Hron fault line) reaches 1000 m. The fault tectonics in some periods had synsedimentary in other postsedimentary character. The synsedimentary movements effected mainly the facial development


0
0,5
1 km
1
2
3
MUŽLA
M-4
O-4
M-3
O-3
M-2
O-8
ORID
O-7
Ovčarská ps.
O-13
O-12
O-15
O-2
O-1
O-5
O-11
O-6
O-9
O-10
D U N A J
VI.
VII.
VIII.
XII.
XI.
IV
III
II.
I.
V
IX.
X





Cross — sections through the eastern part of the Podunajská nížina Paleogene — (crossing the "O" and "M" drill-holes) showing the change of sediments thickness during the culmination of transgressions within particular sedimentatry cycles as well as the facial changes due to the synsedimentary effect of faults. 1. Mesozoic basement (Dachstein limestone, Hauptdolomit, Liassis Ammonites limestone and Cretaceous sandstone); 2. Cretaceous or Paleocene continental detritic sequence; 3. Ypressian (Lower Lutetrian ?) coal — bearing sequence; 4. Lower Lutetian (Upper Ypressian ?) marine Turitella clays; 5. Lower Lutetian (Upper Ypressian ?) marine Turitella clays and coral sandstones partly substituting the Turitella clays, (Sequences 4 and 5 originated during the synsedimentary fault activity); 6. Upper Lutetian variegated, fluviolimnic, brackish and marine sediments; 7. Upper Lutetian, organogene limestones, sandstones and marls; 8. Upper Lutetian — Priabonian biotite horizon; 9. Priabonian organogene limestones and marls, (Sequences 7, 8, 9 originated during the synsedimentary fault activity. Due to the denuded Priabonian the changes in thickness on given cross-section are visible only at the N° 7 sequence); 10. Lower Rupelian, brackish and marine coal — bearing sediments; 11. Rupelian, Foraminifera clays (s. c. Kiscell clays) neritic to bathyal; 12. Aquitanian, marine, sandy clays, and regressive brackish sequences, (Sequences 11 and perhaps also 13 originated during the synsedimentary fault activity. Due to the post — Aquitanian denudation period thickness changes are reconstructable only in the N° 11 sequence); 13. Pliocene gravels and clays (Pontian); 14. Quaternary. D_1 Post — Lover Lutetian denudation surface appearing only locally on the formerly raised blocks; D_2 Post — Priabonian denudation period. Faults marked with roman numbers coincide with marking of faults in the tectonic map.

and the thickness of sediments while the postsedimentary movements caused the division of the area into distinctly lifted and thrown blocks. Consequently during the periods of denudation the movements effected the preservation and retransportation of sediments. In the abovementioned area the following faults may be further distinguished: the faults of one single synsedimentary or post-sedimentary movement, faults with heritable repetition of movements and finally the faults which were active in one part earlier in the other later.

Basing upon the detailed correlation of particular Paleogene horizons of this district (according to drill-core material; Seneš 1960) not only the detailed tectonics but also its age, periods of recess, periods of revival as well as the inverse movements of the individual fault lines have been determined. The cross-sections have shown a great variability of the thicknesses and in same places also of the facial development of contemporaneous sediments located in particular often neighbouring tectonic blocks. Consequently we were able to collect the detailed data about the geotectonic development of this district in Paleogene and then demonstrate certain rules existing between the movements of different character on one and the phases of sedimentary cycles on the other hand.

Qualitatively different fault-movements demonstrate the *periodical repetition of mobility* within the frame of particular sedimentary cycles-the fact stated should seem rather natural while every transgression and regression especially their cyclicity is the consequence of the cyclicity of tectonic movements. It was not natural however or little was known about the fact that the particular types of movements appear always in connection with particular phases of the sedimentary cycle. It has been learned that during the Neogene three phases of new fault movements have existed. Their effect has been synsedimentary and post-sedimentary, the former ones remained acting as herited fault-lines with repeated movements along identical directions. The main periods of fault formation appear always at the beginnig of the sedimentary cycle i. e. at the basis of Ypresian — Lower Lutetian, Upper Lutetian — Priabonian and Oligocene — Aquitanian cycles.

The movements had the following features:

I cycle: a) Still before the deposition of basal fresh-water Eocene sequence (Ypresian — Lower Lutetian) probably during Paleocene certain parts of the basement Mesozoic and continental sequence were lifted, faulted. The beds with greatest thicknesses of basal continental detritus were preserved or rather accumulated in the deeply thrown blocks.

◁

Tectonic map of the Obid-Mužla Sector of the Podunajská nížina eastern part. 1 — Post-Priabonian faults; 2 — Post-Aquitanian faults; 3 — The dip orientation of particular blocks. Roman numbers (order of faults) correspond with the numbers in cross-section. At the side of each faults their amplitude is marced in arabic numbers.

b) During the formation of coal-bearing and brackish deposits the subsidence along the marginal faults started — the transgression involved the undivided-uniform depression. There was a uniform development of sediments.

c) At the period of the transgression culmination (the deposition of Turitella marls and coral sands) the activity of the internal basin faults was rejuvenated and led to the formation of sediments with facial differences and variable thicknesses in the respective blocks.

II cycle: a) Swift revival of the Ist cycle faults and the upheaval of nearly the whole territory especially of the marginal areas at the Upper and Lower Lutetian boundary. The creation of new faults.

b) Undifferentiated, uniform epeirogenic subsidence of the whole territory. The sedimentation of fresh-water, brackish in some places also coal — bearing deposits.

c) Differentiated subsidence and synsedimentary movements along the internal fault — lines at the end of Upper Lutetian and mainly Priabonian, sedimentation of organogene limestones and sandstones but Bryozoa marls during the culmination of the transgression.

III cycle: a) The revival of the old faults and the formation of new fault-lines after the upheaval in the period between Priabonian and Oligocene, denudation and peneplainization of the relief, according to which e. g. the eastern part of the Obid depression the complete Priabonian was denuded.

b) In general undifferentiated gradual subsidence, the formation of brackish and coal — bearing sediments at the Oligocene basis.

c) Synsedimentary movements along the existing faults, differentiation of the speed of subsidence at individual blocks separated by faults, sedimentation of bathyal Foraminifera clays (s. c. Kiscel clays) of variable thickness at the particular blocks.

Analyzing the disscussed faulting activity the following may be concluded: *differentiated synsedimentary fault — movements are dependably related to the culmination of transgressions.* This fact is evident at the first Eocene sedimentary cycle of the Lower Lutetian at the second cycle of Priabonian and at the Oligocene cycle by the Kiscel clays deposition. *The beginning of the transgression happened in contrast to the former always in close connection with the general epeirogenic and thus undifferentiated negative movements with no synsedimentary activity of the faults.* (E. g. fresh-water Ypresian-Lower Lutetian sediments, basal Upper Lutetian deposits, Oligocene coal-bearing and sandstone complex.)

The question is however wheather that fact may be regarded as a law of tectonic mobility in connection with the sedimentation areas development and in relation to the particular transgressional phases. The further question is whether the facts stated are characteristic only for the marginal epicontinental areas or wheather they involve the geosynclinal areas too; then what is the reason

Relations of Synsedimentary Fault Movements to the Culmination of Transgressions of the Podunajská nížina Paleogene

J. Seneš 1962

Age	Character of sediments	Cycle	Sedimentary cycle	Character of tectonic movements		Orogenic phase
Aquitanian	Marine and brakish	III	Filling — in of the sedimentation area	C	Differentiated subsidence, synsedimentary fault movements	
	Marine — neritic to bathyal		Transgressional culmination			
Oligocene	Brackish to marine coal-bearing		Beginning of the transgression	B	Undifferentiated general subsidence	
	—		Peneplaination	A	Formation of new faults	Pyrenean
Priabonian	Marine- sublittoral to neritic	II	Transgressional culmination	C	Differentiated subsidence, synsedimentary fault movements	
Upper Lutetian	Brackish to marine sublittoral		Beginning of the transgression	B	Undifferentiated general subsidence	
	Fluviolimnic		Peneplaination in some places	A	Formation of new faults	Illirian
Lower Lutetian — Ypresian	Marine neritic	I	Regression transgressional culmination	C	Differentiated subsidence, synsedimentary fault movements	
	coal-bearing fluviolimnic and brackish		Beginning of the transgression	B	Undifferentiated general subsidence	
	Detritic continental		Peneplaination	A	Formation of new faults	Post-laramian

of differentiated movements of the sedimentary bottom areas just at the period of transgressional culmination. Whether this fact is the result of the loading of sediments or that it rather depends exclusively upon the geomechanic agents in connection with the cyclicity of the movements during the basin development.

It should be the aim of the further investigations to verify or overrule the general validity of the relations between the synsedimentary fault — movements and the periods of transgressional culminations.

Translated by J. Kováčik

D. Štúr Institute of Geology, Bratislava

LIST OF REFERENCES

[1] Seneš J., 1956: Poznámky ku geotektonickému a paleogeografickému vývoju neogénu východného Slovenska. Geol. práce, Zprávy 7, Bratislava. — [2] Seneš J., 1956: K otázke vzniku uhoľných a pelosideritových slojov v Podvihorlatskej panve. Geol. sborník VII/1, Bratislava. — [3] Seneš J., 1957: Vzťahy neogénneho vulkanizmu ku geotektonickej stavbe východného Slovenska. Geolog. Sborník VIII/2, Bratislava. — [4] Seneš J., 1960: Základné črty paleogénu Podunajskej nížiny. Geol. práce, Zošit 59, Bratislava.

MIKULÁŠ DLABAČ—MILAN MOŘKOVSKÝ

EINIGE BEMERKUNGEN ZUR TEKTONIK DES NEOGENS DER DYJE—SVRATKA SENKE UND DER SENKE VON VYŠKOV

Einleitung

Im südlichen Teil der Karpatenvortiefe wurde in den letzten Jahren im Rahmen der Aufsuchung von Erdöl- und Erdgaslagerstätten ein ausgedehntes bohr- und geophysikales Messprogramm durchgeführt, welches unter anderen ermöglichte auch einige tektonische Beziehungen und Schlüsse weiteren Wirkungsbereiches zu ziehen. Im besprochenen Gebiet wurde ein Netz von Flachbohrungen (Cf) bis zu einer Tiefe von 300 m und 18 Strukturbohrungen 600 m durchgeführt, welche den Bau des Neogens verfolgten und die Konstruktion einer Strukturkarte der Basis des Oberhelvetes ermöglichten. Eine Reihe neuer Tiefbohrungen, wie: Hrušovany, Novosedly, Pouzdřany, und von den älteren Pasohlávky, Vranovice u. a., trugen zur Klärung des vortertiären Reliefes und der Lösung der Beziehungen zwischen Relief und neogener Tektonik bei. Von geophysikalischen Arbeiten wurden im beschriebenen Gebiet Messungen fast aller bekannten Disciplinen durchgeführt, welche durchwegs geologisch gut interpretierte Unterlagen lieferten. Zur Bestimmung des vortertiären Reliefes wurden reflektions-seismische Fächermessungen, Gravimetrie und geoelektrische Messungen benützt. Schliesslich wurde der neogene Bauplan und der Verlauf der Neogen—Mesozoikum, resp. Neogen—Kristallin-Grenze durch zahlreiche reflexions-seismische Profile ergänzt.

Tektonische Gliederung

Eine detailierte Gliederung der neogenen Vortiefe kann in erster Linie vom vortertiären Relief (sieh Abb. No. 1) abgeleitet werden, von welchem der eigentliche Bau des Neogens direkt abhängig ist. In diesem Sinne haben M. Dlabač (1946), E. Veit (1953) u. a. ein Oberhelvet- und ein

Torton-Becken ausgeschieden, welche in der Senke von Vyškov durch einen begrabenen Rücken (Židlochovice—Dražovice Rücken, V. Homola, 1961; Slavkov—Těšín Rücken, M. Dlabač, 1962) voneinander getrennt sind. In der Querrichtung ist der südliche Teil des Beckens durch die *Gräben von Vranovice, Nesvačilka* und *Bučovice-Rousínov* (V. Homola, 1961) geteilt. Die quergerichteten Elevationszüge sind weniger markant und machen sich eher als breite Schollen bemerkbar. Auf die Existenz von Querelevationen hat als erster T. Buday (1960) aufmerksam gemacht. M. Dlabač (1962) unterschied im südlichen Beckenteil den Hodonicer Rücken, die Miroslav-Mušover Querelevation, sowohl wie die Želešice—Měnín Querelevation.

In der Vyškover Senke hat der begrabene Längsrücken einen parallelen Verlauf mit dem heutigen Rand der Böhmischen Masse, an welche sich hier das Tortonbecken angliedert. In der Dyje—Svratka Senke, südlich des Nesvačilka-Grabens und noch ausgeprägter südlich des Vranovice-Grabens, weicht der Slavkov—Těšíner Rücken vom Rande der Böhmischen Masse ab und nimmt schliesslich bei der oesterreichischen Grenze eine N—S Richtung an. Es ist bemerkenswert, dass die eigentliche *tortonische Vortiefe* mit der mächtigeren Ausfüllung des Tegels dabei in groben Zügen die gleiche Breite wie in der Senke von Vyškov bewahrt. Südlich des Nesvačilka-Grabens reicht über den Rücken noch Oberhelvet (karpatische Formation, Laaer Schichten), Helvet s. s., resp. Burdigal bis zum Rande der Böhmischen Masse hinweg. NO von Znojmo bildet das tiefere Miozän ein *Teilbecken von Mackovice.*

Den Slavkov—Těšíner Rücken kann man bis zur österreichischen Grenze verfolgen. Von S nach N kann man auf dem beschriebenen Gebiet die *Teil-Elevationen von Novosedly, Mušov, Měnín, Křenovice, Slavkov und Dražovice* unterscheiden. Diese Teil-Elevationen haben im Neogen meist die Form von unregelmässigen Kuppeln über begrabenen Bergen. Längs des Westrandes des Längsrückens lässt sich in der Dyje—Svratka Senke der *Dyje-Bruch* mit einem westlichen Einfallen verfolgen. Die tortonische Vortiefe ist hier an der gegenüberliegenden Seite zum Teil durch den östlichen *Mailberger Bruch* begrenzt. Zusammen mit dem Dyje-Bruch bildet er den tektonischen *Graben von Drnholec* (Abb. No. 2.). Der parallelverlaufende und gleichgesinnte westliche Mailberger Bruch verliert auf unserem Gebiet an Sprunghöhe und klingt bald aus. Von Teilbecken der Tortonmulde kann man ausser des erwähnten Grabens von Drnholec auch in der Senke von Vyškov die *Depression von Holubice und Vyškov* erwähnen. Schliesslich verdient noch der *antitetische Pravicer Bruch* erwähnt zu werden, welcher gegen Osten das Mackovicer Teiltief begrenzt. Das Anzeichen eines Horstes zwischen den Mailberger Brüchen und dem Pravicer Bruch kann man mit einem äusseren Wall parallelisieren, der gegen Westen die Tortonvortiefe in der Senke von Vyškov begrenzt und sich weiter nördlich auch durch einen von Torton begrenzten Inselzug von Unterkarbonaufschlüssen bemerkbar macht.

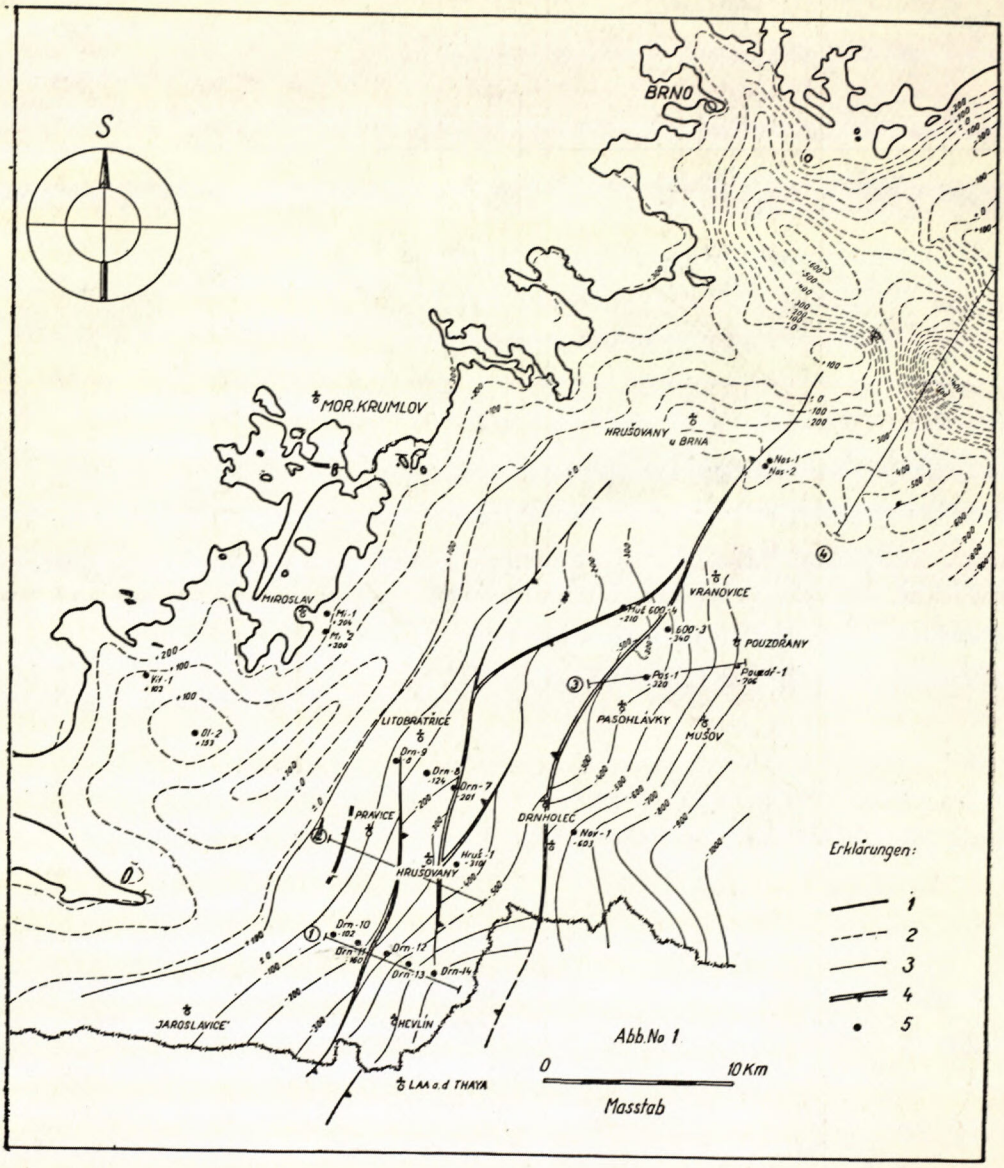


Abb. 1 — Tektonisches Schema der Dyje—Svratka Senke. *Erklärungen:* 1. Linie des heutigen Beckenrandes; 2. Strukturlinien der Tertiär-Basis; 3. Strukturlinien der Basis des Oberhelvets; 4. Bruchlinien; 5. Bohrungen.

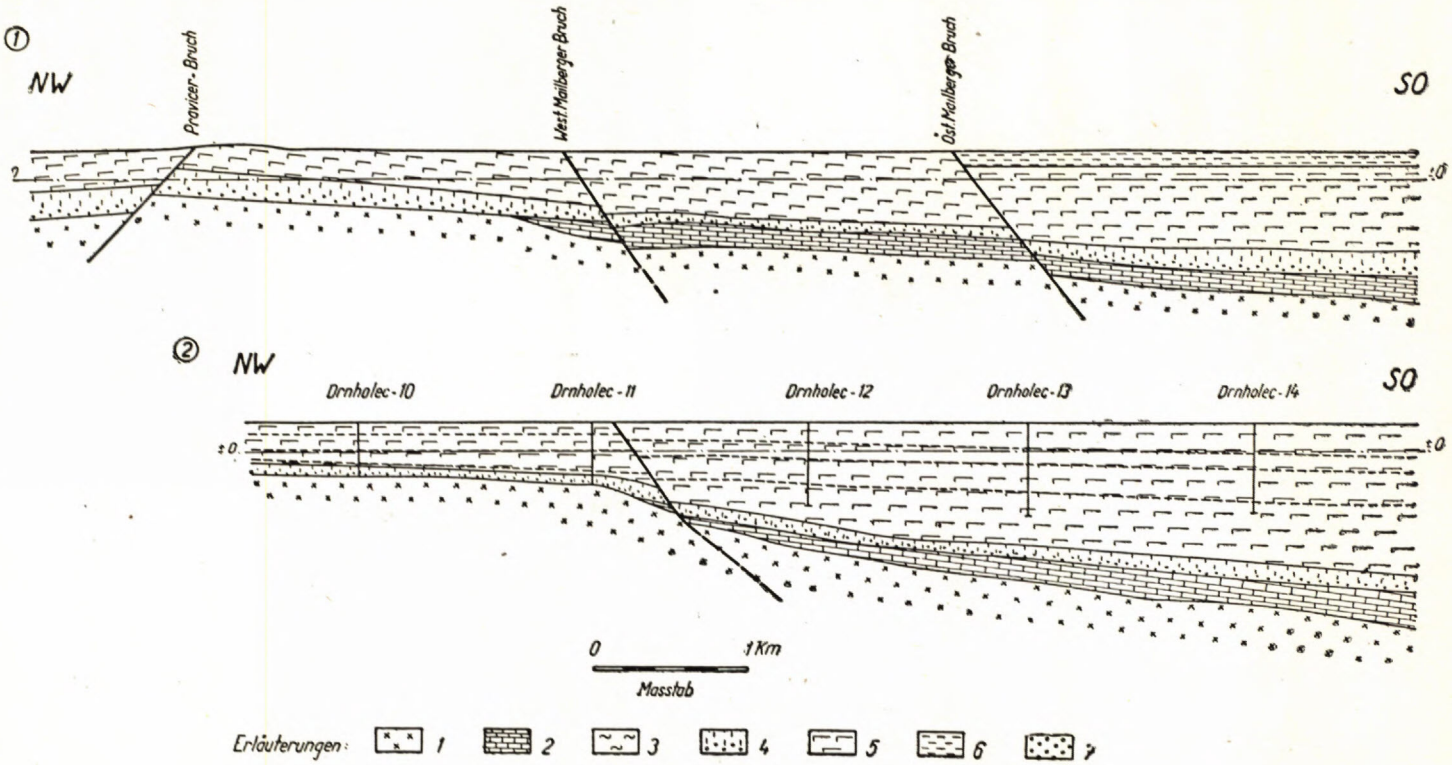


Abb. 2 — Geologische Profile (No. 1 u. 2) im Raume des südlichen Endes des Drnholec-Grabens. *Erklärungen:* 1. Kristallin der Böhmischen Masse; 2. Jura (Malm); 3. Autochtones Oligozän; 4. Untermiozän (Pelitte, klastische Sedimente); 5. Oberhelvet; 6. Untertorton-Tegel; 7. Untertorton — Schotter u. Sande.

Längsbrüche

Einen Bruch, der Torton vom Helvet abgrenzt, erwähnt in der Vyškover Senke zuerst A. Šob (1940). In der darauffolgenden Arbeit zeichnet derselbe Autor (1941) diesen Bruch in der Karte und verlängert ihn gegen Süden bis Židlochovice. Durch Bohrarbeiten wurde später ein bruchloser SÖ Rand der Tortonvortiefe bei Dražovice (M. Dlabač, 1946) und bei Slavkov (M. Mořkovský, 1962a) bewiesen. Südlich von Telnice bis Pasohlávky konnte hingegen ein Bruch durch zahlreiche Strukturbohrungen verfolgt werden (M. Mořkovský, 1962). Auf Grund neuester Bohrungen und geophysikalischer Messungen gelang es schliesslich denselben Bruch bis zu der österreichischen Grenze zu verfolgen und hier an den von E. Veit (1953) angeführten Bruch anzuschliessen. Den Namen *Dyje-Bruch,* den zuerst M. Vašíček (1951) anführt, wollen wir auch weiterhin für diese bedeutungsvolle Störung beibehalten. Der Bruch hat eine karpatische, d. h. NNO—SSW Richtung mit westlichem Einfallen. Die Sprunghöhe ist veränderlich, im südlichen Teil bei Pasohlávky 100—120 m und verringert sich gegen Norden in der Umgebung von Měnín auf 40 m, um schliesslich im Gebiet des Nesvačilka-Grabens völlig auszuklingen. In der Sprunghöhe lässt sich ein gewisser Zusammenhang mit der Mächtigkeit der tortonischen, resp. untermiozänen Beckenfülle feststellen. Der Bruch grenzt durchwegs Pelitte des Untertortons in der Tiefscholle von basalen Tortonschottern, resp. Sedimenten des Oberhelvets der Hochscholle ab.

Auf Grund der mässig zunehmenden Mächtigkeit der basalen Schotter in der Tiefscholle, setzen wir eine synsedimentäre Funktion des Bruches zu Beginn des Untertortons voraus. Auf ein untertortonisches Alter weist auch die erhaltene bedeutende Mächtigkeit des Tegels bloss in der Tiefscholle hin. Schliesslich kann auch der Umstand, dass der Bruch auf eine Entfernung von 35 Km das eigentliche Tortonbecken begrenzt, gewissermassen als Beweis seines tortonischen Ursprungs angesehen werden. Die Bohrergebnisse, sowohl wie die geophysikalischen Messungen, zeugen dafür, dass der Bruch auch das Liegende des Neogens, d. h. das Mesozoikum, und zum Teil im Bereich des Vranovicer Grabens auch das Oligozän, versetzt.

Der Dyje-Bruch hat meist eine geradlinige Richtung. Bloss im Bereich der Elevation von Novosedly und Mušov macht sich eine Ausbuchtung nach Westen bemerkbar. Diese Ausbuchtung, sowohl wie die Abhängigkeit der Sprunghöhe von der Mächtigkeit der tortonischen Beckenfülle, zeugt auf eine tektonische Sukcession des Bruches in Beziehung zu den begrabenen Rücken.

Die für den Bau des Gebietes wichtigen *Mailberger Brüche* setzen aus dem Raum westlich Hevlín auf tschechoslowakisches Gebiet fort. Dieser Doppelbruch hat einen syntetischen Charakter, d. h. ein östliches Einfallen. Seine Sprunghöhe verringert sich von cca 700 m auf dem Gebiet von Oesterreich auf 250—100 m in der ČSSR.

Den Mailberger Bruch stellt (laut E. Veit, 1951) auf oesterreichischem Gebiet zuerst auf Grund von Gravimetrie B. Kunz (1943) fest. Er trennt hier die Sitzendorfer Hochscholle

mit einer Neogenmächtigkeit bis 400 m und Kulm im Liegenden von der eigentlichen Tiefscholle mit über 1000 m mächtigem Neogen. Der Bruch verläuft im Süden fast geradlinig und ist verlässlich durch Reflexionsseismik und an einigen Stellen auch durch Bohrungen festgelegt (Abb. No. 1).

Sowohl in Oesterreich wie auch auf dem Gebiet der ČSSR gliedert sich der Bruch in einen östlichen und einen westlichen Zweig. Der östliche Mailberger Bruch verliert schon auf dem oesterreichischen Gebiet an Sprunghöhe, klingt an der Staatsgrenze völlig aus und setzt erst südlich von Hrušovany n/Jev. wieder an. Hier begrenzt er abgesunkenes Untertorton vom Oberhelvet der Hochscholle. Nördlich von Hrušovany nähern sich beide Äste, wobei die gemeinsame Sprunghöhe cca 200 m ausmacht. Weiter nördlich macht sich eine deutliche Abzweigung bemerkbar und der östliche Ast nimmt eine NÖ Richtung an. In weiterem Verlauf wächst die Sprunghöhe dieses abgezweigten Bruches auf minimal 230 m an, was die Mächtigkeit des Untertortons auf der abgesunkenen Scholle in der Bohrung Cf Mušov No. 4 ausmacht (M. Mořkovský, 1962), worauf sich der Bruch dem Dyje-Bruch nähert, um an ihm voraussichtlich zu enden.

Auch bei diesem Bruche setzen wir auf Grund von reflexionsseismischen Messungen und Gravimetrie eine Fortsetzung in das mesozoische Beckenliegende voraus.

Bezugs des Alters des östlichen Mailberger Bruches können wir bloss feststellen, dass er untertortonischen Tegel versetzt.

Wie wir schon angeführt haben, bildet der östliche Mailberger Bruch in südlichem Teil der Dyje—Svratka Senke den eigentlichen Randbruch der tortonischen Vortiefe. Dies ist auch die einzige Strecke, wo durch Bohrungen bewiesen ist, dass Torton gegen Westen durch einen Bruch begrenzt wird. Im Bezug zu der gleichbleibenden Breite des Untertorton-Tegelbeckens im Graben von Drnholec und in der Vyškover Senke, könnte man hypotetisch annehmen, dass der Bruch bloss in dem Abschnitt zwischen dem Vranovicer und Nesvačilka- Graben verschwindet, um nordöstlich von Brno als Randbruch den geradlinigen und morphologisch ausgeprägten westlichen Beckenrand zu bilden. Eine ähnliche Konzeption nimmt T. Buday (1960) in der tektonischen Karte der ČSSR an. Zu dieser Auffassung muss man noch hinzufügen, dass der Randbruch in der Vyškover Senke bisher weder durch Geophysik, noch durch Bohrarbeiten bewiesen wurde. Die Grundlage des Baues ist auf Grund der Refraktionsseismik (Fächermessungen) und der Gravimetrie im Gegenteil eine regelmässige Mulde, wobei für einen Randbruch kaum mehr als einige wenige zehn Meter Sprunghöhe gerechnet werden könnten.

Der westliche Mailberger Bruch behält von der oesterreichischen Grenze seine NNÖ Richtung bei, um sich nördlich von Litobratřice gegen NO zu wenden. Nach unserer Meinung hat dieser Bruch bloss für den tieferen Bau der Vortiefe einen grösseren Einfluss.

Das Liegende des Neogens wird auf der Sitzendorfer Scholle im Raum zwischen Hevlín und Litobratřice vorherrschend von Kristallin der Böhmischen Masse, von Graniten und Granodioriten der Thaya-Kuppel gebildet. An einer Stelle bei Litobratřice wurden im Liegenden typischen Neogens rote Sandsteine erbohrt, wobei es sich um umgelagerten Perm handeln könnte.

Einige Bohrungen erbohrten auch auf der Hochscholle des westlichen Mailberger Bruches Mesozoikum. Es sind dolomitische Kalksteine und Kalksteine voraussichtlich jurasischen Alters, die auf dem Krystallin in Form von Denudationsresten einer früher ausgedehnteren Bedeckung aufliegen. Ihre Mächtigkeit ist bloss 100—200 m. Ein zusammenhängendes, mächtigeres Mesozoikum ist heute bloss auf der Tiefscholle erhalten.

Auf das Kristallin transgrediert weiter westlich in der Richtung des heutigen Randes der Böhmischen Masse direkt Untermiozän. Der heutige Beckenrand ist in der Dyje—Svratka Senke nirgends bruchförmig, wie man eindeutig aus seiner ausgeprägten Gliederung, mit zahlreichen Ausläufern und Buchten (Abb. No. 1) schliessen kann. Aus dem Verlauf der Neogen—Kristallin-Grenze in Ausbissen am Beckenrand, bzw. aus den Strukturlinien die auf Grund dieser Ausbisse konstruiert wurden, kann man hier ein Einfallen der Neogenbasis von 6° ableiten.

Die Funktion eines Randbruches übernimmt hier gewissermassen der westliche Mailberger Bruch. Der Umstand, dass er bis in die oberen Partien des Kristallins verfolgt werden kann, zeugt von seiner Persistenz. Weiter bedingt er auch eine syntektonische Zunahme der Mächtigkeit des Oberhelvets, welche im südlichen Teil des Beckens festgestellt wurde. Hingegen beeinträchtigt er nicht die Mächtigkeit des Untermiozäns. In diesem Zusammenhange möchten wir nochmals betonen, dass die zusammenhängende Bedeckung des Mesozoikums an die Tiefscholle dieses Bruches gebunden ist, wogegen auf der Hochscholle bloss seine Denudationsreste erbohrt wurden. Da können wir also voraussetzen, dass dieser Bruch vor der Sedimentation des Neogens zu wirken begann und die intensivere Erosion der Hochscholle bedingte.

Der antitetische und somit westlich einfallende *Pravicer Bruch* verläuft in NNO—SSW Richtung. Bisher wurde er bloss durch reflexionsseismische Messungen (Abb. 2, Profil 2) mit einer vorausgesetzten Sprunghöhe von 130 m festgestellt. Mit der Funktion dieses Bruches scheint die Entstehung der Mackovicer Mulde zusammenzuhängen.

Elemente der Quertektonik:

Den *Graben von Nesvačilka* interpretiert V. Homola (1961) bloss tektonisch und begrenzt ihn beiderseits durch Brüche. Bei der geologischen Interpretation einiger reflexionsseismischer Profile gelangten wir zu dem Schluss, dass es sich hier um einen einseitigen Graben handelt, der bloss an der SW Seite durch Brüche begrenzt ist (Abb. No. 4). Zwei parallele Brüche kann man im Paläozoikum aus dem veränderten Einfallen der Reflexionsflächen gut ablesen. Ihre Sprunghöhe schätzen wir auf Grund der Seismik im Paläozoikum auf cca 500 m. Der NÖ Hang zeigt ein fast paralleles Einfallen der Neogenbasis mit dem Paläozoikum. Erst in der jüngeren tertiären Grabenfüllung sind die Schichten flachgelagert. Schliesslich können wir aus den erwähnten seismischen Messungen auf eine voroligozäne erosive Modelation des Grabens schliessen. In den paläozoischen und jurasischen Kalken beobachten wir häufig eine kanionartige Form des Grabens, oder bloss steil einfallende Hänge, was ja dem Charakter der Gesteine auch

völlig entspricht. Es sei hier bloss erwähnt, dass ein erneutes Aufleben der Karstphenomene mit Kanionbildung sich sowohl vor dem Untermiozän, wie auch vor der Sedimentation des Untertortons wiederholt.

Im Laufe der Sedimentation des Oligozäns bildete der Graben eine gleichzeitig mit dem Becken absinkende Bucht, wie man aus dem lithologischen Charakter der oligozänen Schichten schliessen kann.

Der *Vranovicer Graben* wurde auf Grund von refraktionsseismischen und gravimetrischen Messungen gedeutet (V. Homola, 1961). Neuestens konnte man die Existenz des Grabens auch durch Bohrergebnisse der Tiefbohrung Pouzdřany 1 bestätigen, welche von 987 m bis 1200 in Oligozän bohrte, ohne bis zur Endtiefe das hier vorausgesetzte jurasische Beckenliegende erbohrt zu haben (Abb. No. 3). Die Genesis des Vranovicer Grabens deuten wir identisch mit der des Grabens von Nesvačilka, wie oben dargelegt wurde. Auf Grund der Geophysik kann man auch hier einen asymmetrischen Grabenbau mit einer südlichen Bruchbegrenzung voraussetzen.

Die *Querrücken* sind weniger ausgeprägt als die Gräben. Trotz zahlreichen Bohrungen und geophysikalischen Messungen konnte im beschriebenen Gebiet keine Begrenzung durch Brüche bewiesen werden. Hingegen kann man bei den Rücken eine gewisse Persistenz eines asymmetrischen Baues beobachten, der sich durch ein Emporheben der dem Graben im Süden anliegenden Schollen in den jüngeren Formationen bemerkbar macht. So eine Bewegung ist am auffälligsten im Torton, wo die höchstliegenden Elevationen des Slavkov—Těšíner Rückens stets der Südseite der Gräben anliegen. In diesem Zusammenhange ist auch auffälig, dass einerseits die Längsbrüche bei den Gräben ausklingen, wie zum Beispiel der Dyje-Bruch beim Nesvačilka-Graben, oder der östliche Ast des östlichen Mailberger Bruches beim Vranovicer Graben. Auch endet am Vranovicer Graben der Längsgraben von Drnholec, welche Erscheinung ebenfalls durch ein Emporheben der dem Quergraben südlich anliegenden Schollen, resp. durch eine Schrägstellung dieser Schollen mit südlicher Vergenz gedeutet werden kann. Eine solche Lage der Schollen im tieferen Miozän beweist ebenfalls die grössere Breite des südlichen Beckenteiles, sowohl wie eine vorausgesetzte Grenze des Oberhelvets im Bereiche des Nesvačilka-Grabens.

Einige Bemerkungen zur tektonischen Entwicklung

Wir haben schon erwähnt, dass die westliche Begrenzung des Untertortons gegenüber dem Oberhelvet im südlichen Teil der Dyje—Svratka Senke vorherrschend tektonisch ist. Im Laufe der Bohrarbeiten im Raum zwischen Hrušovany n/Jev. und Hevlín, wo der Mailberger Bruch ausklingt, ist das Torton durch die Linie seines Ausstreichens an die Oberfläche begrenzt. Durch eine normale Ausbiss-Grenze ist der untertortonische Tegel auch gegen Süden begrenzt. Der in früheren Arbeiten (I. Cicha — J. Paulík, 1961) hier vorausgesetzte NW—

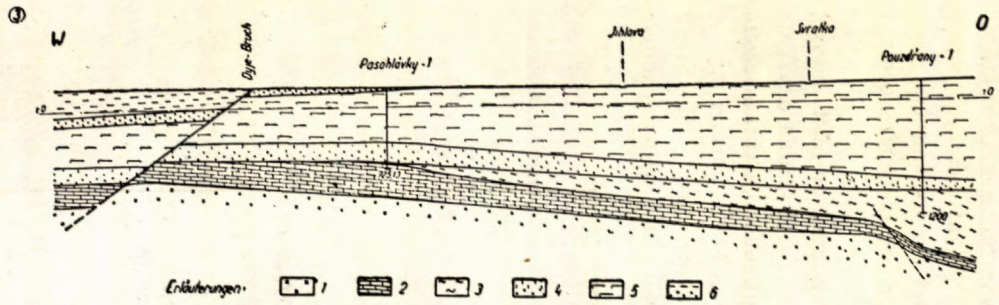


Abb. 3 — Geologisches Profil (No. 3) über die Bohrung Pasohlávky 1 und Pouzdřany 1. Erklärungen sieh Abb. No. 2.

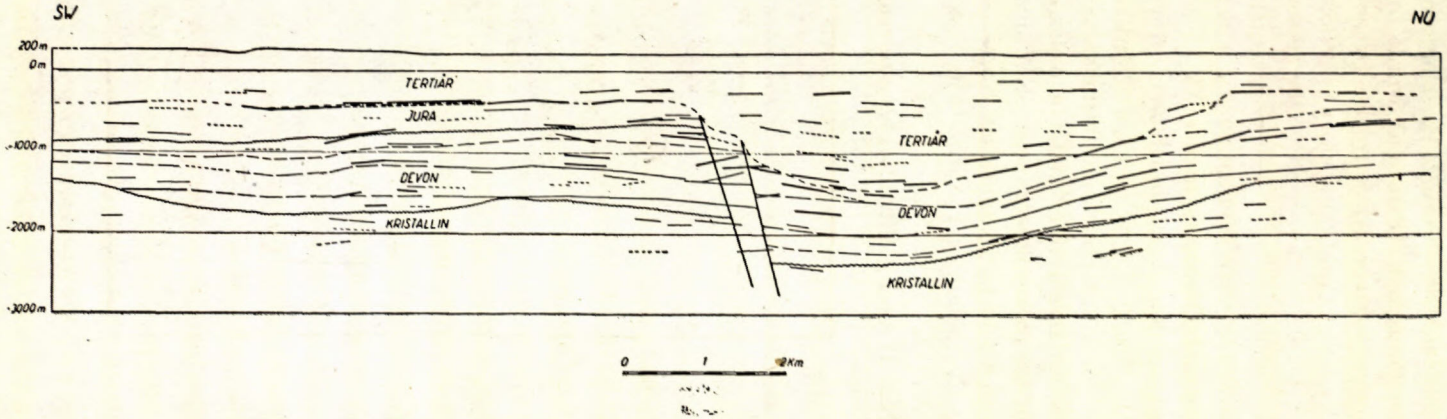


Abb. 4 — Seismogeologisches Profil (No. 4) durch den Graben von Nesvačilka. *Erklärungen:* 1. Seismische Reflexionsflächen; 2. Geologische Grenzen und Korelationshorizonte; 3. Diskordanz.

SO Bruch wurde durch neuere Forschungen nicht bestätigt. In der weiteren Umgebung von Pouzdřany (Pausram) wurde in zahlreichen Strukturbohrungen Oberhelvet unter und vor der Stirn der Decke der äusseren Flyschgruppe (Ždánicer Einheit) erbohrt. Auf Grund einer ungestörten Lagerung verlässlicher Korelationshorizonte wurde bewiesen, dass Oberhelvet direkt an der Deckenstirn und unter der Überschiebungsfläche flach gelagert ist.

Neue Erkenntnisse konnten auch aus der Umgebung von Slavkov (Austerlitz) bei Brno und Dražovice in der Vyškover Senke bei Erdölaufsuchungsarbeiten gewonnen werden. Einen bruchlosen östlichen Beckenrand der tortonischen Vortiefe (Abb. No. 5, 6), welcher durch vertikale Bewegungen des Liegenden bedingt ist, bilden hier vorherrschend tournaisische Kalke.

Oberhelvet transgrediert auf ein meist flaches, nördlich Slavkov auch mässig aufgewölbtes paläozoisches, gegen NW ansteigendes Relief. Auf Grund des Verlaufes von mikrostratigraphischen Korrelationshorizonten kann man voraussetzen, dass die Überhöhung der Aufwölbung maximal einige zehn Meter ausmacht.

Die westliche Strandlinie verlief in der Nähe der Strukturbohrung Cf—Sl—5 (Abb. No. 5) und greift infolgedessen mässig in den Raum der späteren unter-

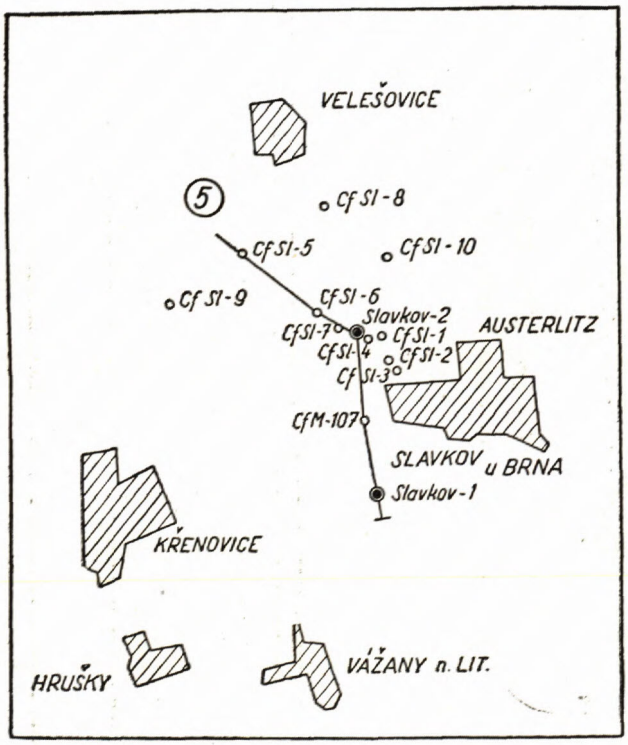


Abb. 5 — Situationskizze des Gebietes von Slavkov (Austerlitz).

tortonischen Überschwemmung über. Am Ende des Unterhelvets und kurz vor der Ablagerung des Untertortons kommt es zu der flachen Aufschiebung des äusseren Flysches auf die miozänen Vortiefen. Vertikale Bewegungen bedingen, dass das neogene Gebiet SW von Slavkov absinkt und die Denudation des Oberhelvets weniger intensiv ist. In diesem Zusammenhange muss man auf den vererbten Charakter der Senkungsbewegungen, besonders des südlichen Teiles, der Dyje—Svratka Senke hinweisen. Von solchen Bewegungen spricht schon die Ausbreitung des Jura, sowohl wie des Burdigals und Unterhelvets.

Direkt vor der Transgression des Untertortons kann man Anzeichen einer Inversion dieser Bewegungen beobachten, wobei sich der nördlicher gelegene Raum von Dražovice im Bezug zu Slavkov mässig emporhebt. Auf eine solche Bewegung kann man auf Grund des lithologischen Charakters der basalen tortonischen Sedimente schliessen. Auch transgrediert Untertorton weit über die Decke der Ždánicer Einheit, worauf Funde von basalen Schottern (F. Chmelík, 1960) hinweisen. Nach der Ablagerung der basalen klastischen Sedimente können wir bei Slavkov ein Emporheben des Slavkov—Těšíner Rückens beobachten, welches sich bis in die Zeit der Ablagerung des Montmorillonit-Horizontes abspielte. Die Intensität der Bewegung ist gut an der Mächtigkeitszunahme des Untertortons sichtbar (Profil 5, Abb. No. 6). Die heutige Gestalt der Kordiliere entsteht also zu Beginn des Untertortons, und ist während der weiteren Sedimentation des Tortons nicht bedeutsam erneuert. Nach der Sedimentation des Montmorillonit-Horizontes folgt eine allmähliche Subsidenz des Tortonbeckens, wobei die Mächtigkeit und Entwicklung der einzelnen Schichtglieder ganz regelmässig ist.

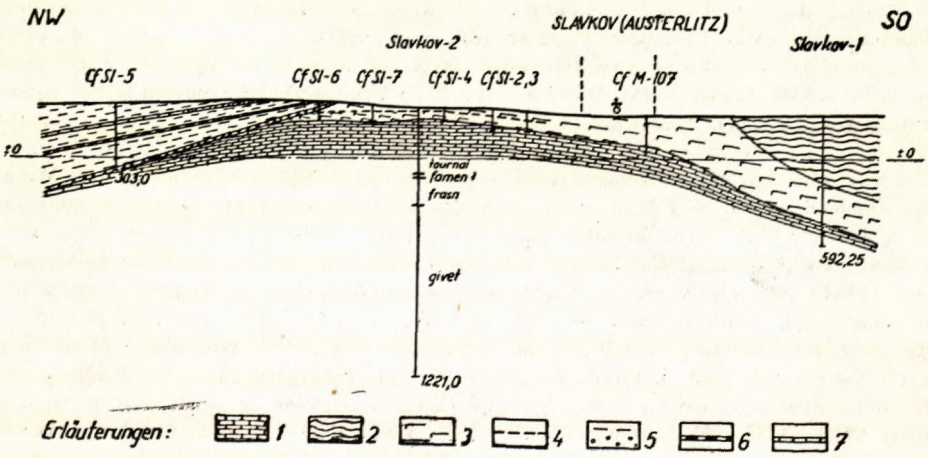


Abb. 6 — Geologisches Profil (No. 5) über die Elevation von Slavkov. *Erklärungen:* 1. Paläozoikum; 2. überschobener äusserer Flysch; 3. Oberhelvet; 4. Hilfskorelations-Horizont im Oberhelvet; 5. Untertorton, Schotter, Tegel; 6. Tortonischer Montmorillonithorizont; 7. Lithothamnienkalk.

In diesem Zusammenhange wollen wir noch auf eine auffällige Übereinstimmung in der Lage des Hügelzuges zwischen Židlochovice und Kojetín mit der Lage des Slavkov—Těšíner Rückens hinweisen. Wenngleich die Hügel stellenweise zweifellos durch geringere Denudation der widerstandsfähigeren basalen tortonischen Schotter gebildet sind, kann doch im gesammten Verlauf ein neotektonischer Einfluss auch beobachtet werden.

Abschluss

Der neogene Bau der Vyškover und der Dyje—Svratka Senke erscheint als Abbild des vortertiären Reliefs des SÖ Hanges der Böhmischen Masse. Das monoklinale Einfallen des Hanges wird hauptsächlich durch voroligozäne Quergräben und den tortonischen Rücken kompliziert. Beide Elemente werden durch syntetische und antitetische Verwerfungen gestört. Die Brüche sind im Beckenliegenden fundamentiert und versetzen auch vortertiäre Einheiten. Auf Grund der Persistenz älterer Bewegungen erscheint der neogene Bauplan als Folgeerscheinung vertikaler Schaukelbewegungen, welche in verschiedenen Phasen der geologischen Entwicklung durch Hebungen der Längs- oder Querschollen bedingt sind.

Československé naftové doly, n. p.,
Institut für Erdölforschung, Brno

LITERATURVERZEICHNIS

[1] Buday T., 1960: Souhrnná zpráva o ocenění prognosních zásob nafty a plynu na území ČSSR a směry geologicko-vyhledávacích a průzkumných prací. Manuscript; Geofond, Praha. — [2] Buday T. u a., 1960: Tektonická mapa ČSSR. — [3] Cicha I. — Paulík J., 1961: Tektonika čelní hlubiny. Vysvětlivky ke gener. geol. mapě 1:200.000. — [4] Dlabač M., 1946: Geologické výsledky vrtních prací ve Vyškovském úvalu mezi Slavkovem a Vyškovem v roce 1943. Sborník SGÚ XIII, Praha. — [5] Dlabač M., 1962: Výzkum vzniku naftových ložisek oblasti vněkarpatského neogénu. Manuscript; Geofond, Praha. — [6] Homola V., 1961: Opěrná vrtba Nesvačilka 1 v jihozápadní části vněkarpatské pánve na Moravě. Práce VÚN, Brno. — [7] Chmelík Fr., 1960: Geologie ždánické jednotky mezi Dyjí, Slavkovem a Čejčí. Manuscript; Geofond, Praha. — [8] Mořkovský M., 1962: Poznámky ke geologickým poměrům okolí Vranovic v jižní části vněkarpatské pánve. Časopis pro mineralogii a geologii č. 1, Praha. — [9] Mořkovský M., 1962a: Závěrečná zpráva o mělkém strukturním průzkumu provedeném v okolí hořících plynových výronů ve střední části karpatské čelní hlubiny (Slavkov u Brna) v roce 1961. Manuscript; Geofond, Praha. — [10] Šob A., 1940: Geologické poměry v jihozápadní části Vyškovského úvalu. Věst. SGÚ, Praha. — [11] Šob A., 1941: Geologische Entwicklung der Vischauer Senke. Verh. d. naturf. Ver., Brno. — [12] Vašíček M., 1951: Současný stav mikrostratigrafického výzkumu miocénních sedimentů ve vněkarpatské neogénní pánvi na Moravě. Sborník ÚÚG XVIII, odd. paleont., Praha. — [13] Veit E., 1953: Molasse und alpin-karpatischer Überschiebungsgrand in Niederösterreich und Südmähren. Neues Jb. f. Geol. u. Paläontol., Abh. 97, Stuttgart.

DIONÝZ VASS

TECTONIC MOBILITY AND ITS EFFECT UPON THE MIOCENE SEDIMENTATION OF THE IPEĽSKÁ KOTLINA BASIN

The Hungarian Central Hills mobile belt (term introduced by Buday 1961 for the regional tectonic unit at the Hungarian—Slovakian border) and its part Ipeľská kotlina basin are dissected in the eastern portion by a system of faults striking generally in the NW—SE direction. The general strike of these faults has been noted already by many previous authors in majority however basing only upon surface geological mapping. The mentioned faults formed faults structure which was developed during the Lower Tortonian. In the same period the Hungarian Central Hills belt lost the mobility and was stabilized in such a way that the alternating vertical movements were substituted by only uplifting movements. The Upper Tortonian sea had no more possibility of communication across the lifted Hungarian Central Hills belt despite of the several 100 m. thick sediments deposited in the adjacent parts of the Pannonian basin as for example in the NE part of the Podunajská nížina. (Borehole by Lontov — Ivan 1960; boreholes in the Štúrovo environment — Seneš 1962.) Vaste resources of the volcanic products in the Upper Tortonian led to the sedimentation in the area of the uplifted zone. The sedimentation was further controlled by the differentiation of the lifted area by the developing fault system into troughs — the future fault troughs — and uplifted blocks. The acting faults caused the formation of a structure with facial differences of continental deposits existing among the troughs and uplifted blocks.

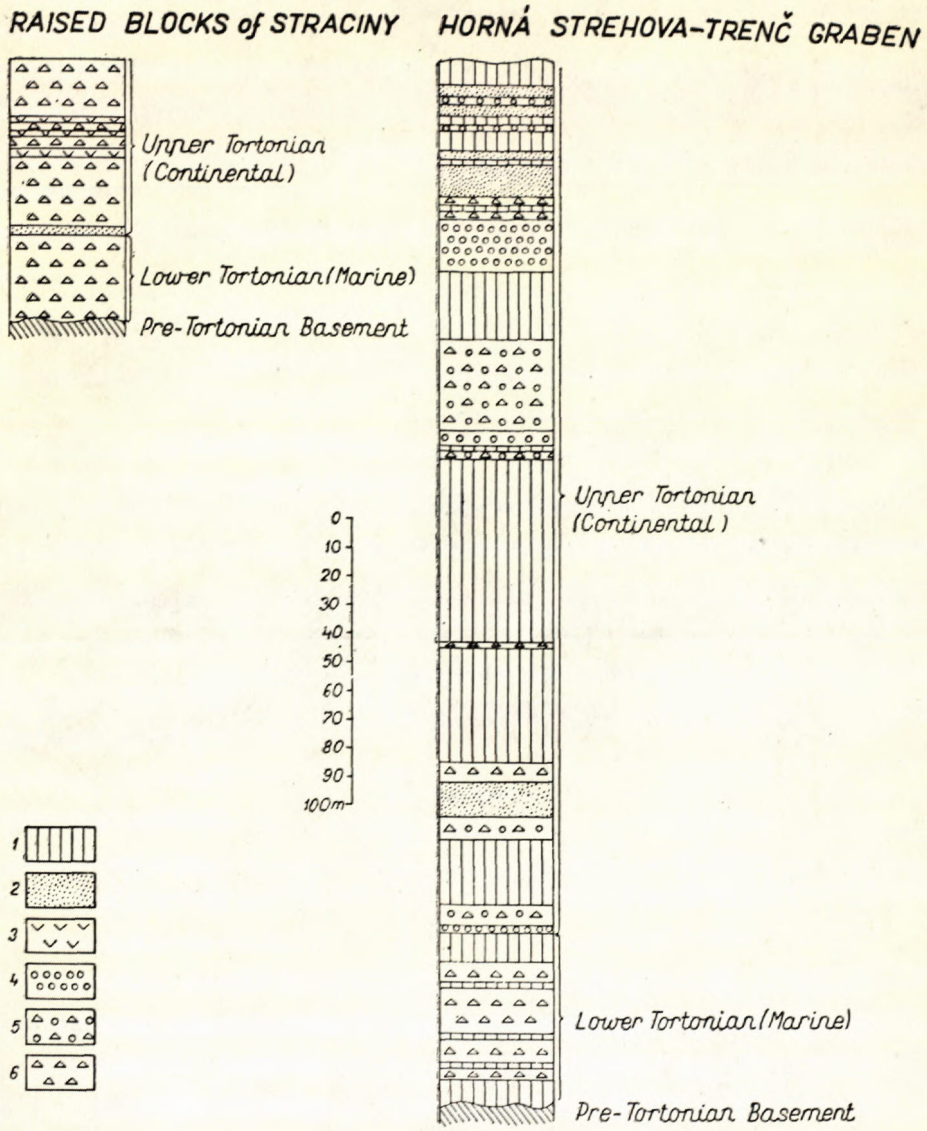
Resting upon the uplifted blocks of the Ipeľská kotlina eastern district (the s. c. Straciny high uplifts) is the Upper Tortonian with tuffite sandstones developed at the basis, overlain by tuff agglomerates and block — tuffs in majority of continental origin. In the eastward neighbouring Horné Strháre—Trenč trough the Upper Tortonian appears more variable. The tuff agglomerates are less fre-

quent or they are missing. They are replaced by the lithofacies of agglomerate tuffites (subaqueous sediments with partially clastic material in the form of rounded pebbles) and conglomerate lithofacies. Iregularly alternating tuffite sandstones and tuffite pellites prevail in the sequence. Subaqeous mainly limnic sedimentation within the trough is demonstrated by the bedding of deposits, grading of fragments, roundness of clastics and to a large extent also by the frequent occurence of well preserved leaf — casts in pellitic tuffites as well as the sporadic occurence of fresh — water fauna.

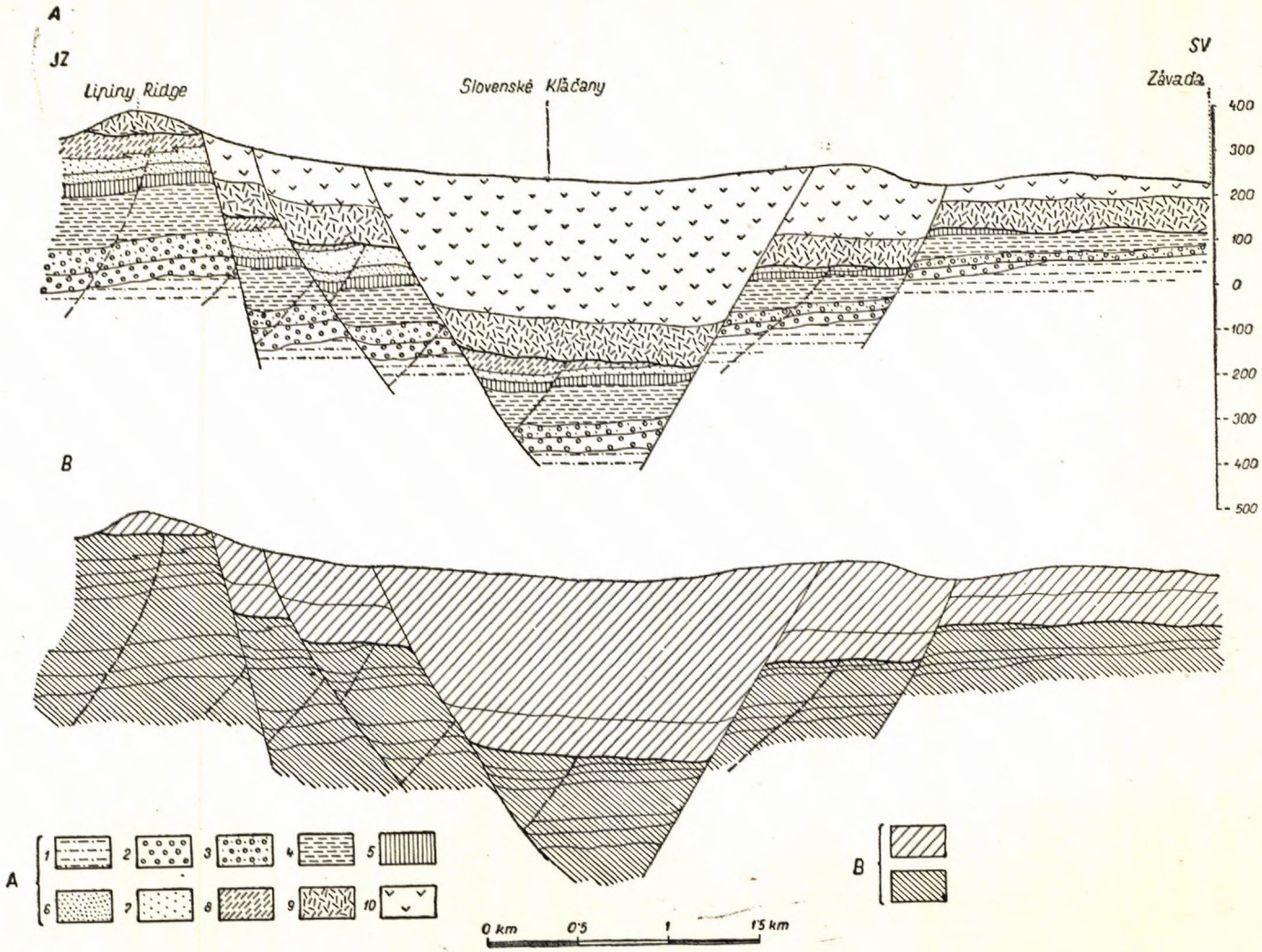
The depth exploration of the Horné Strháre—Trenč trough (carried out with respect to the coal reserves enlargement in the Modrý Kameň Coal basin) yielded interesting informations. Stratigraphically deeper pre — Tortonian deposits do not possess any evidence of the graben structure, on the contrary they belong to *another older fault structure* which in the central part of the post — Lower Tortonian graben formed *high uplifted blocks.* The evidence of such a structure appear already in the lowermost Helvetian sediments — s. c. productive beds the whole thickness of which diminishes eastward together with the thicknesses of individual coal beds. The thicknesses of the three main coal beds reaching the maximum Values of 2,10—3,30—5,10 m apear reduced in the graben SW of Dolná Strhová to 0,20—1,20 m, farther eastward to one single coal bed 0,20 m thick. The decrease in thickness included also the overlying clays, which in the Straciny lifted blocks reached 200 m of thickness decreasing to a maximum of 100—120 m in the graben territory. Analogous relations are found also westward of the blocks of Straciny. They appear again in the eastern part of the Pribel—Plachtince lifted blocks over a small area around Stredné Plachtince.

The existence of an older structure is supported also by *facial differences* of the Carpathian "Schlier beds" — fine marly siltstones (in previous works referred to as Upper Helvetian — Čechovič 1952). "Schlier beds" well exposed in the Potor viscinity and further in several bore holes pass on the western graben margin into more arenaceous to very sandy sediments. The shallowing of the environment in relation to the contemporaneous beds of the Straciny lifted blocks is proved by the fauna ecology (Seneš 1951). The existence of an elevated area in the vicinity of Slovenské Kľačany prior to Lower Tortonian is further inevitably proved by reduction of the "Schlier beds" or the s. c. "manganese — bearing sandstones". Sporadically these Carpathian deposits are completely reduced and the Lower Tortonian rests directely upon the overlying Helvetian clays.

Two tectonic structures may be thus distinguished in the eastern part of the Ipeľská kotlina basin. The general strike of the younger one was well known while that of the older one remained undetermined so far. It is suggested that its direction is diagonal or rather slightly diagonal to the strike of the post — Lower Tortonian structure (several important faults striking NE—SW were determined in beds older than Tortonian).



Effects of synsedimentary tectonics in the Ipeľská kotlina basin: Differences in the Upper Tortonian lithofacies on the raised blocks and on the blocks subsided (according to drilling results). 1. Pellitic tuffites; 2. Sands tuffites; 3. Ash tuffites; 4. Andesite conglomerates; 5. Cartaminated agglomerate — conglomerate tuffites; 6. Agglomerate tuffs and tuffites.


A
JZ
SV
Lininy Ridge
Slovenské Kľačany
Závada
400
300
200
100
0
-100
-200
-300
-400
-500
B
A
1
2
3
4
5
6
7
8
9
10
B
0 km
0·5
1
1·5 km

The crossing of fault throws of the reversed character and different age were described by W. K l ü p f e l (1955) from the Upper Hessen territory (Büdinger Wald Mts) introducing the term "Kreuzsprungzone". The eastern part of the Ipeľská kotlina basin represents also such a belt of crossing fault throws.

From the view point of the proof-material so far existing the explanation of the reasons controlling the tectonic regime of Miocene period which resulted in the creation of two in both the direction of movements and age differring structures is very difficult. We suppose that the reasons may be found in the reaction of the old basement to the tectonic strain to which during the Miocene the West Carpathian area hac been exposed. From the very scattered informations about the basement of the discussed area it may be suggested that westwards from Lučenec the contact between the Gemeridy and Veporidy tectonic units (the Margecany—Ľubeník line) abruptly changes the direction to the south (F u s á n 1961). The boreholes at Lučenec and Podrečany penetrated Gemeridy Carboniferous, the borehole at Bušince and several other westward penetrated the Veporidy crystalline complex.) It is quite possible that the southward curved contact line extends just below the Horné Strháre—Trenč graben. During the folding of the external parts of West Carpathians in Lower Miocene the movements may have started also along important tectonic lines of Central Carpathians resulting in the elevation and dissection of the Miocene resting horizontally above the said lines e. g. the Margecany—Ľubeník tectonic line in the area west from Lučenec. This way the origin of the older structure could be explained.

Concerning the origin of the younger structure the suggestions were already given earlier. (V a s s & T o m á š e k 1963). We suppose that the strike of this structure — in the western part of the West Carpathians for Upper Neogene quite peculiar — has its origin in the old fault lines of the crystalline basement. This strike were also parallel with the important lines of the Sudetian direction which became well pronounced during the formation of the main West Carpathian Neogene basins (B u d a y 1961). The rejuvenation of the old faults in the post-Lower Tortonian period may be understood as a result of the tangential strain release in the West Carpathians due to the shifting of the maximum orogenic activity to East Carpatians in this period.

◁

Cross-section through the Horné Strháre—Trenč graben showing the crossing of two fault structures differring both in the orientation of movements and age as well.

A. Stratigraphical interpretation of the geologic cross-section.

1. Sands with sandstone intercalations (Aquitanian); 2. Gravels, sands, variegated clays and rhyodacite tuffites (Upper Burdigalian); 3. Sands with brown — coal beds; 4. Clays; 5. Sands with Rzehakia (3—5 Helvetian); 6. Sands; 7. Marly sands; 8. Marly clays (Schlier) (6—8 Karpatian — Upper Helvetian); 9. Andesite agglomerate tuffites, sands and pellitic tuffites (Lower Tortonian); 10. Andesite agglomerate tuffs (Upper Tortonian).

B. Structural interpretation of the geologic cross-section.

1. Pre — Lower Tortonian fault structure; 2. Post — Lower Tortonian fault structure.

Conclusion of the main points:

1. The post — Lower Tortonian fault structure of the Ipeľská kotlina basin which originated during the uplift of the whole Hungarian Central Hills belt (sedimentation area of Northern Hungary and Southern Slovakia) due to the plenty of pyroclastic material were developed as a sysedimentary structure, the fact reflected in the facial differences of the continental deposits on the high lifted blocks and in the troughs.

2. The eastern part for the Ipeľská kotlina basin represents a structurally very active territory — the zone of crossing fault throws — where two Miocene structures can be distinguished differring from each other both by the direction of movements and the period of action.

3. The reasons for the character of the Miocene tectonic activity are to be sought in the basement; in the Lower Miocene mobility of the tectonic contact of Gemeridy and Veporidy units west of Lučenec and in the rejuvenation of the older faults in Upper Miocene.

Translated by J. Kováčik

D. Štúr Institute of Geology,
Bratislava

LIST OF REFERENCES

[1] Buday T., 1961: Der tektonische Werdegang der Neogenbecken usw. Geol. práce, Zoš. 60, Bratislava. — [2] Čechovič V., 1952: Geologia juhoslovenskej panvy. Geol. práce, Zoš. 33, Bratislava. — [3] Fusán O., 1961: Entwicklung des Baues des Gebirges Spišsko-gemerské rudohorie. Geol. práce, Zoš. 60, Bratislava. — [4] Ivan L., 1960: Poznámky k vývoju sarmatu s horninami diatomitového typu v Ipeľskej tabuli. Geol. práce, Zprávy 19, Bratislava. — [5] Klüpfel W., 1957: Kolebatelnye dviženija i proischodenie „krestových" sbrosov. Živaja tektonika. Izd. inostr. literatury. Moskva. — [6] Seneš J., 1951: Nový nález helvétskej fauny pri Pôtore. Geol. sbor. II., Bratislava. — [7] Seneš J., 1962: Vysvetlivky k prehľadnej geol. mape ČSSR 1:200 000 L-34-I. Nové Zámky. Geofond — Vydavateľstvo, Bratislava. — [8] Vass D. — Tomášek B., 1963: Elevácia predterciérneho podložia pri Šahách. Geol. práce, Zprávy 27.

JOSEF JAROŠ

DIE TEKTONISCHE ENTWICKLUNG DER DEPRESSION VON BANSKÁ BYSTRICA WÄHREND DES TERTIÄRS

Die Depression von Banská Bystrica ist ein Bestandteil des Systems der im Gebirgsbogen der Zentralkarpathen liegenden Tertiär-Becken. Sie ist im Norden von den morphologisch-tektonischen Elevationen Nízké Tatry und Veľká Fatra, im Süden von der Vepor- (Ľubietová-) Zone eingeschlossen, die gegen Osten zusammenlaufen; im Westen ist sie von der Kette des vulkanischen Gebirges von Kremnica begrenzt und nach SW in den grösseren Zvolen- und Slatina-Becken geöffnet.

Die tertiäre Füllung der Depression bilden die Einlagerungen *von fünf sedimentären und einem vulkanischen Zyklus* in folgender stratigraphischen Einreihung: 1. *der marine Sedimentationszyklus Lutet—Priabon;* 2. *der marine Sedimentationszyklus Chatt—Aquitan;* 3. *der limnische Sedimentationszyklus Untertorton (bezw. Oberhelvet)* (die Formation von Kordíky; D. Andrusov, 1954); 4. *der vulkanische Zyklus Obertorton—Sarmat—Unterpliozän;* 5. *der limnische Sedimentationszyklus Sarmat—Pannon (synvulkanisch);* 6. *der fluviatil-limnische sedimentare Zyklus Oberpliozän* (die Formation von Banská Bystrica — D. Andrusov, 1954; die Hronformation, A. Nemčok, 1957).

Der tektonische Bau der Tertiärsedimente der Depression von Banská Bystrica — angesichts des subhercynischen Baues des Mesozoikums und seines Liegenden posthum — ist durchwegs ein Schollenbau. Die Radialstörungen sind *teils parallel, teils quer in Richtung des Karpathenbogens orientiert,* nur selten setzen sich die Störungen der OW und NS-Richtung durch. Nachdem die Umgebung von Banská Bystrica *ein Gebiet der Karpathenbogenbiegung ist,* ändern ihre Richtung sowohl die Längsstörungen (von OSO—WSW im Osten gegen NO—SW im Westen) als auch die Querstörungen (von NNO—SSW im Osten gegen NW—SO im Westen).

Der Strukturplan der Depression von Banská Bystrica machte im Tertiär *zwei Entwicklungsperioden* durch: in dem Strukturplan der älteren Etappe herrschten die gegen den Karpathenbogen parallel orientierten Bruchstrukturen vor, im Strukturplan der jüngeren Periode dagegen die quer gegen den Karpathenbogen orientierten Störungsstrukturen.

Der Strukturplan der älteren Etappe setzte sich im Paläogen und im untersten Miozän durch. Er beeinflusste die paläogeographische Regelung der Sedimentationsräume der beiden älteren (marinen) Sedimentationszyklen. Die Sedimente dieser Zyklen blieben in dem komplizierten, die Biegung des Karpathenbogens parallel durchlaufenden Hrongraben erhalten. Der Graben ist im Norden von einer breiteren Bruchzone, im Süden dann von dem fast einheitlichen Hronbruche begrenzt und sowohl im Längs- als auch im Querprofil in Teilgräben und Teilhorste eingeteilt.

Der Strukturplan der jüngeren Etappe setzte sich im Laufe des mittleren und des oberen Neogens und im Pliozän durch. Er beeinflusste die paläogeographische Regelung der Sedimentationsräume und zum Teil auch der vulkanischen Felder der drei jüngeren (Süsswasser-) Sedimentationszyklen und des vulkanischen Zyklus. Die Sedimente und Produkte der vulkanischen Tätigkeit blieben (nördlich der Ľubietová-Elevation) in den Quergräben erhalten, die ihre Richtung in Abhängigkeit von der Karpathenbogenbiegung (von Osten nach Westen) ändern: in den *Gräben von Moštenice—Ľubietová, Medzibrod, Poniky, Mičina und Kordíky.* Die oberpliozänen Sedimente sind in ihrer Verbreitung an das heutige Hrontal und seine nächste Umgebung (sie verlaufen auch in den Becken von Poniky) gebunden, werden jedoch durch die Brüche der Quergräben gestört, während sie auf dem Längsbruche des Hron ohne bedeutendere Störungen liegen. Besonders an die markanteren Störungslinien (Hronbuch, nordöstliche Randbruchzone des Kordíky-Grabens und die Brüche der Moštenice—Ľubietová-Gräben) und ihre gegenseitige Kreuzung sind deutlich an die historischen Erdbeben gebunden.

Während des Tertiärs verliefen in der Depression von Banská Bystrica tektonische Bewegungen zweierlei Charakters. Erstens *epeirogenetische Bewegungen* als nicht differenzierte Bewegungen der ganzen Zentralkarpathenscholle, die im Tertiär eine generelle Hebungstendenz hatten (das Vertauschen der alttertiären marinen Sedimentationszyklen durch die jungtertiären limnischen Sedimentationszyklen und zuletzt durch den fluviatil-limnischen Zyklus im jüngsten Tertiär und den fluviatilen Zyklus im Quartär). Die Bewegungen hatten wahrscheinlich einen ungleichmässigen Verlauf auch in Abhängigkeit von den begleitenden differenzierten Bewegungen der grösseren Schollen (megastrukturellen Elevationen und Depressionen), wobei bei der generellen Hebung des Gebietes sich die Elevationen relativ intensiver hoben und bei der generellen Senkung des Gebietes die Depressionen intensiver sanken.

Die Intensität der *orogenetischen Bewegungen* wurde im Laufe des Tertiärs

schwächer: während die älteren Bewegungen in der Zeit der Pressungsanlage auch die Entstehung der grossamplituden Faltungserscheinungen hervorriefen, entwickelten sich in der Zeit der ausklingenden jüngeren Bewegungen — in der sich die Zerrungskräfte durchsetzten — nur noch die ausgesprochen radialen Störungen. Die Sprunghöhen dieser Dislokationen von den älteren zu den jüngeren Bewegungen werden immer niedriger.

Die orogenetischen Bewegungen an den Dislokationen, überwiegend Absenkungen bei Lockerung der Erddrucke, verliefen wahrscheinlich periodisch und in verschiedener Intensität vor Beginn der einzelnen Zyklen (Abgrenzung der Sedimentationsräume), während der Sedimentation (eine synsedimentäre Senkung des Muldenbodens und Hebung der Abtragungsgebiete) und nach Beendigung der Sedimentation (das Einschlingen in die Gräben). Besonders intensiv verstärkte orogenetische Bewegungen verliefen offensichtlich in der Periode der Hiaten zwischen den einzelnen Sedimentationszyklen und lassen sich mit (für die Zentralkarpathen angeführten) den *orogenetischen Phasen* H. Stille's (1953) und T. Buday's (1961) parallelisieren. Im Gebiete der Depression von Banská Bystrica sind dies: *die ältere savische Phase* zwischen Lutet-Priabon und dem Chatt-Aquitanzyklus (wahrscheinlich vor Ende des Oligozäns), *die jüngere savische Phase* in dem unteren Teile des Burdigal — Oberhelvet ?-Hiats (ungefähr an der Grenze Burdigal-Helvet), *die ältere steirische Phase* in dem oberen Teile des Burdigal — ?Oberhelvet-Hiats (entweder an der Wende des unteren und des oberen Helvets oder zwischen Helvet und Torton in Abhängigkeit von dem bisher nicht biostratigraphisch fixierten Alter der Kordíky-Serie), *die jüngere steirische Phase* nach Beendigung des untertortonischen (bezw. oberhelvetischen) und vor Beginn des vulkanischen Zyklus (wahrscheinlich an der Wende des unteren und des oberen Tortons), *die rhodanische Phase* zwischen dem unteren und dem oberen Pliozän und *die walachische Phase* zwischen dem Pliozän und Pleistozän. Beweise für verstärkte orogenetische Bewegungen in der Zeit der moldavischen und attischen Phase wurden in der Depression von Banská Bystrica nicht gefunden.

Mit Rücksicht darauf, dass einzelne orogenetische Phasen nicht durch eine Aenderung des Strukturplanes des Gebietes voneinander abweichen und dass der tektonische Bau der tertiären Gesteine ein Ergebnis nicht nur der verstärkten Bewegungen zwischen den einzelnen sedimentaren und vulkanischen Zyklen, sondern auch der synsedimentaren Dislokationsbewegungen ist, kann man im Tertiär der Depression von Banská Bystrica *zwei tektonische Phasen im Sinne* N. S. Šatski's (1951) feststellen: eine *ältere tektonische Phase (Alttertiär)*, die den Strukturplan der älteren Periode mit den vorherrschenden Längsstrukturen formierte und zu der die ältere und jüngere savische Phase gehören und eine *jüngere tektonische Phase (Jungtertiär)*, die den Strukturplan der jüngeren Periode, mit den vorherrschenden Querstrukturen formiert und zu der die ältere und die jüngere steierische Phase, die rhodanische und wallachische Phase gehören.

LITERATUR

[1] Andrusov D., 1954: O veku výplne Turčianskej kotliny a o vývine pliocénu na strednom Slovensku. Geol. sborník V, Bratislava. — [2] Buday T., 1961: Der tektonische Werdegang der Neogenbecken der Westkarpaten und ihr Baustil. Geol. práce, Zoš. 60, Bratislava. — [3] Nemčok A., 1957: Vplyv geologických štruktúr na morfologický vývoj údolia Hrona. Geol. sborník VIII/1, Bratislava. — [4] Stille H., 1953: Der tektonische Werdegang der Westkarpaten. Hannover. — [5] Šatskij N. S., 1951: O dlitelnosti skladboobrazovanija i o fazach skladčatosti. Izv. AN SSSR, ser. geol., No 1. Moskva—Leningrad.

ZDENĚK STRÁNÍK

TECTONIC STRUCTURE OF THE SOUTHERN PART OF THE ŽDÁNICE UNIT

A detailed survey carried out from 1960 to 1962 in the southern part of the Ždánice unit (Hustopeče and Pavlov Hills*) has confirmed and completed the results of the general survey for a map of the Brno area on a scale 1 : 200 000 (F. Chmelík 1960; A. Matějka 1960). The investigated part of the Ždánice unit is biult up of the Čejč—Zaječí anticlinorial zone, the Ždánice unit proper and the Pouzdřany thrust-sheet.

The *Čejč—Zaječí anticlinorial zone* (F. Chmelík 1960; A. Matějka 1960) is thrust to the north-west on the Ždánice unit proper. In the south-east it is limited by the post-Panonian longitudinal faults against the Vienna basin. Towards the north-east and south-west the minutely folded pelitic Upper Cretaceous to Upper Miocene strata merge beneath the Ždánice—Hustopeče formation. The tectonic remnants of the Magura nappe which were preserved on the anticlinorial zone composed of strata of different age attest to an advanced denudation preceding the Magura overthrust (A. Matějka — F. Chmelík 1955).

The *Ždánice unit* proper is overthrust to the north-west on the Bourdigalian-Carpathian of the foredeep. Only north of the river Dyje (between Pouzdřany and Rychmanov) the Pouzdřany thrust sheet emerges in front of its head. In the area of the Hustopeče hilly country the unit is characterized by the Hustopeče synclinorium which continues southwards into the region laying east of the Pavlov Hills.

The anticlinorial zones are continuous only along the outer margin of the unit

* The results of the investigations are summarized in the papers by A. Matějka — Z. Stráník (1916a, b), E. Benešová — I. Cicha — F. Pícha — Z. Řeháková — Z. Stráník (1962), Z. Stráník — E. Hanzlíková — M. Eliáš (1962), F. Pícha — Z. Stráník (in press).

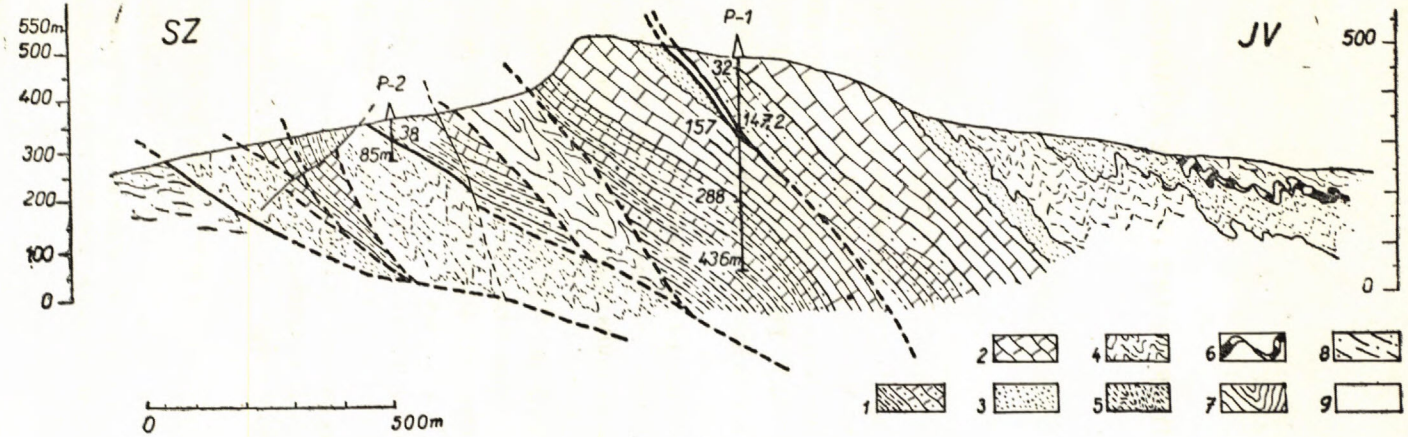

SZ
JV
P-1
P-2
550m
500
400
300
200
100
0
32
157
14,72
288
436m
38
85m
0
500m
1
2
3
4
5
6
7
8
9

Fig. 1.

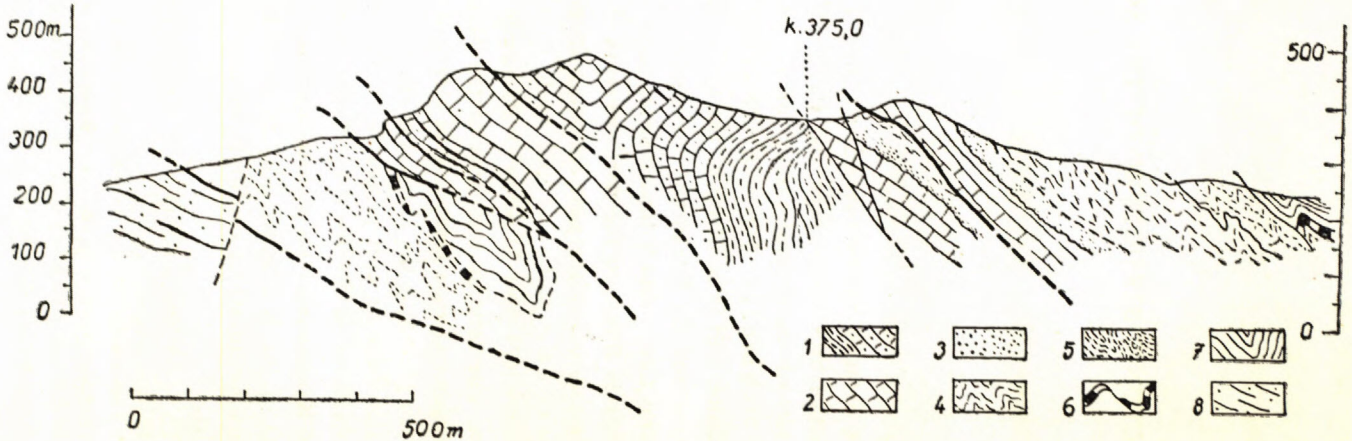

500m
400
300
200
100
0
k.375,0
500
0
0
500m
1
2
3
4
5
6
7
8

Fig. 2.

(the anticlinal zone of Němčice and of the Pavlov Hills). Inside the unit they intersect the Ždánice—Hustopeče formation in the form of discontinuous narrow slices. The pelitic beds of the anticlinal zones are minutely folded (menilite beds) and locally drawn out (unevidenced Paleocene in the anticlinal zone of the Pavlov Hills). The Hustopeče synclinorium and the synclinal zones are formed by the Ždánice—Hustopeče formation of sandstone-claystone beds which is folded prevalently into broad flat synclines. The different intensity of folding results from differing plasticity of rocks.

In the anticlinal zone of the Pavlov Hills (A. Matějka — Z. Stráník 1961a, b) the Jurassic tectonic remnants with the Middle Cretaceous envelope are forced through the Upper Cretaceous-Aquitanian strata to appear in the form of klippes (W. Petraschek 1920). In the north the zone plunges into the Dyje valley and continues southwards into the *Waschberg zone*. In the area of the Pavlov Hills the Jurassic klippes occur in two tectonic slices separated by the discontinuous synclinal Zone of the Ždánice—Hustopeče formation (A. Matějka — Z. Stráník 1961a, b). The klippes in the western slice are smaller. South of Bavory only the Eocene strata are exposed. The eastern tectonic slice is distinguished by conspicuous large klippes, such as, Devín, Palava (= Kotel), Stolová (= Tabulová) hora, Turold, Sv. Kopeček atc. The klippes are built up of rigid carbonate rocks which exert an influence both on their tectonic structure and their tectonic relation to the Upper Cretaceous — Aquitanian strata (Palava — Fig. 2). The structure of the klippes is prevalently monoclinal and imbricate (Děvín, Sv. Kopeček). Only the Palava klippe exhibits strata folded into a minor syncline in the central slice. The imbricate structure of the Děvín klippe (O. Abel 1899; H. Schön 1925; K. Jüttner 1923, 1933) has been proved by the boring Palava — 1 which at the depth of 147,2 to 153,0 m traversed the fault plane dipping 47 to 50° to SW (Fig. 1). The date of the formation of the imbricate structure (cf. K. Jüttner 1933) is suggested by the fragments of Palaeogene and probably also Miocene beds encountered in the fault zone (at the depth of 147,2—153,0 m) by the boring Palava — 1. They were dragged into the Upper Cretaceous beds together with fragments of the Ernstbrun limestones and Klentnice beds. The Miocene elements have also been determined in the microfauna of the Campanian-Maastrichtian strata established in the vicinity of

◁

Fig. 1. Section through the Děvín klippe: 1 — Klentnice Beds., 2 — Ernstbrun limestone, 3 — Klement Beds (Upper Turonian), 4 — Upper Cretaceous, 5 — Eocene, 6 — Menilite Beds, 7 — Ždánice Hustopeče formation, 8 — Bourdigalian—Carpathian, 9 — Upper Cretaceous-Miocene.

Fig. 2. Profile of the south-eastern part of the Děvín klippe and of the klippe Palava: 1 — Klentnice Beds, 2 — Ernstbrun limestone 3 — Klement Beds (Upper Turoinan), 4 — Upper—Creataceous. 5 — Eocene, 6 — Menilitic Beds, 7 — Ždánice—Hustopeče formation, 8 — Bourdigalian—Carpathian.

the overthrust close to the south-western termination of the Děvín klippe (E. Benešová). On the evidence of these new data we may infer that the imbricate structure is later than the Palaeogene (dating obviously from the Miocene), that means, it occurred simultaneously with the folding and overthrusting of the Ždánice unit. So far evidence for the earlier folding is lacking. During the late-Kimmerian movements, towards the end of the Tithonian, only the *geanticlinal zone of Pavlov* had been uplifted (D. Andrusov 1959), which prior to the Upper Turonian underwent a partial denudation. This is indicated by the transgressive Klement Beds deposited almost concordantly on the uneven surface of the Ernstbrun limestones (Turold — K. Jüttner 1933). The presumed hiatus in the lower Upper Cretaceous (Coniacian-Santonian) cannot be regarded as substantial evidence for the folding movements (M. Glaessner 1931; A. Matějka — Z. Stráník 1961a, b). During the post-Paleogene folding of the Ždánice unit the Jurassic klippes became detached from the pre-Upper Cretaceous basement and were incorporated tectonically in the Ždánice unit. The detachment occurred in an elevated area which extended most probably at the place of the present seismically evidenced elevation near Milovice, 4 km east of the Pavlov Hills.

The *Pouzdřany thrust sheet* represents a fragment of the autochthonous envelope of the Bohemian Massif which had been torn off and brought to the surface at the overthrusting of the Ždánice nappe (F. Chmelík 1960). It is probably locally thrusted with the Miocene beds of the foredeep (Fig. 2).

In the depression located between Velké Pavlovice, Starovičky and Šakvice the strata of the *upper Lower Miocene Carpathian* lie obviously unconformably on the Ždánice unit proper and Čejč—Zaječí anticlinorial zone. Along the thrust plane, of which the Čejč—Zaječí zone was moved forward on the Ždánice unit proper the variegated clays analogous to the Middle Eocene beds of the Čejč—Zaječí anticlinoril zone were dragged out into the Carpathian strata (cf. E. Benešová—I. Cicha—F. Pícha—Z. Řeháková—Z. Stráník 1963). They point to the contemporaneity of this overthrust with the thrusting of the Ždánice nappe over the Carpathian of the foredeep.

The structure of the Ždánice unit is disturbed by the *system of transverse dislocations* striking NW—SE to W—E. They bound the upper Lower Miocene and Carpathian on the Ždánice unit near Velké Pavlovice and Šakvice (F. Pícha — Z. Stráník, in press). In the Pavlov Hills radial and horizontal movements occurred on these faults which gave rise to transversal blocks (cf. A. Matějka 1960). Strong disturbances of the longitudinal structures, the front of the nappe included, and the limitation of the Carpathian demonstrate that they were formed after the overthrusting, i. e. later than the Helvetian period. According to some faults the movements also took place after the Lower Tortonian (south of Mikulov). The fault near Šakvice which controlled evidently the marked bending of the front of the Ždánice nappe near Strachotín, as well as the dislocation which

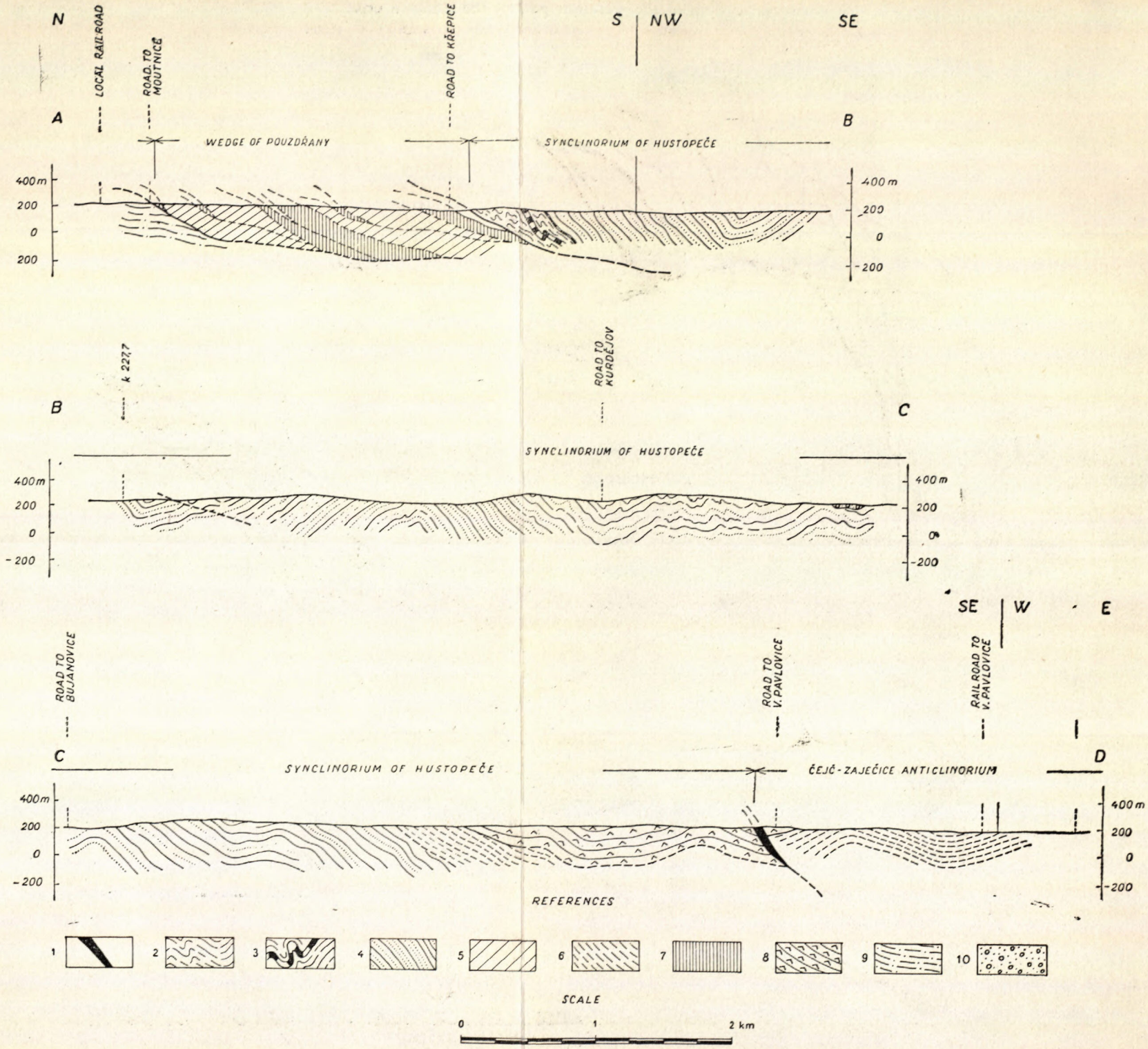
makes the northern termination of the anticlinal zone of the Pavlov Hill more pronounced (J. V. Novák 1924; K. Zapletal 1930, 1932; J. Krejčí 1931; J. Stejskal 1935) and the southern termination of the Čejč—Zaječí anticlinorial zone are apparently associated with *the ancient suture* in the basement of the Ždánice unit which was active as late as the Miocene. Its possibles influence on the distribution of the autochthonous Eocene-Oligocene of the Pouzdřany formation cannot be excluded either.

The thrusting of the Ždánice nappe over the Carpathian of the foredeep occurred on the fault-plane of a very low angle, particularly north of the Dyje river, as evidenced by a small thickness of the nappe ascertained in the boring Nesvačilka — 1 (V. Homola 1961) and by the course of its front line. The boring has shown that the nappe moved forward to a distance of 3 to 4 km (F. Chmelík 1960).

LIST OF REFERENCES

[1] Abel O., 1899: Die Beziehungen des Klippengebietes zwischen Donau u. Thaya zum alpin-karpatischen Gebirgssysteme. Verhandl. d. geol. A. A., Wien. — [2] Andrusov D., 1959: Geológia československých Karpát II, Bratislava. — [3] Benešová E. — Cicha I. — Pícha F. — Řeháková Z. — Stráník Z., 1963: Profil ždánickou jednotkou mezi Velkými Pavlovicemi a Nosislaví. Manuscript; Geofond, Praha. — [4] Homola Vl., 1961: Opěrná vrtka Nesvačilka—1. Časopis Ústavu pro naftový výzkum, Brno. — [5] Chmelík F., 1960: Geologie ždánické jednotky mezi Dyjí, Slavkovem a Čejčí (of gener. map for Brno) Manuscript; Archiv ÚÚG, Praha. — [6] Jüttner K., 1922: Enstehung und Bau der Pollauer Berge. Nikolsburg. — [7] Jüttner K., 1933: Zur Stratigraphie und Tektonik des Mesozoikums der Pollauer Berge. Verhandl. d. Naturf. Verein. 64, Brünn. — [8] Jüttner K., 1938: Das Südende des mährischen Flysches. Verhandl. d. Naturf. Verein. 64, Brünn. — [9] Jüttner K., 1940: Erläuterungen zur geologischen Karte des unteren Thaylandes. Mitteil. der Reichsstelle f. Bodenforsch. B. 1, H. 1, Wien. — [10] Kettner R., 1927: Geologické poměry flyšového území mezi Čejčí a Klobouky. Časopis Vlast. spol. mus., r. XXXIX, Olomouc. — [11] Krejčí J., 1931: Příspěvek k otázce abrasních teras ve Ždánském lese. Spisy přírod. fak. MU v Brně č. 139, Brno. — [12] Matějka A., 1960: Flyšové pásmo jižně od řeky Dyje. Manuscript; Geofond, Praha. — [13] Matějka A. — Chmelík F., 1955: Zpráva o geologickém výzkumu a mapování v terénu Čejč—Zaječí. Manuscript; Archiv ÚÚG, Praha. — [14] Matějka A. — Chmelík F., 1956: Zpráva o geologickém výzkumu terénu Čejč—Zaječí. Zprávy o geol. výzkumech za r. 1955, Praha. — [15] Matějka A. — Stráník Z., 1961a: Geologie Pavlovských vrchů. Zprávy o geol. výzkumech za r. 1960, Praha. — [16] Matějka A. — Stráník Z., 1961b: Zpráva o geologickém výzkumu Pavlovských vrchů. Čás I. Manuscript; Archiv ÚÚG, Praha. — [17] Novák J. Vl., 1924: Morfologický vývoj neogenních sníženin na Moravě. Věstník Král. čs. spol. nauk, Praha. — [18] Petrascheck W., 1920: Tektonische Untersuchungen am Alpen und Karpathenrande. Jahrb. d. geol. R. A., Wien. — [19] Pícha F. — Stráník Z., 1962: Geologie ždánické jednotky. Manuscript; Geofond, Praha. — [20] Pokorný Vl., 1959: Příspěvek mikropaleontolgie k řešení tektoniky Pavlovských kopců. Časopis pro miner. a geol., Praha. — [21] Pokorný Vl., 1961: K mikrostratigrafickému členění hustopečských slínů v okolí Trkmance a Zaječí (ždánická jednotka, jižní Morava). Čas. pro miner. a geol., roč. VI/3, Praha. — [22] Pokorný Vl., 1962: K charak-

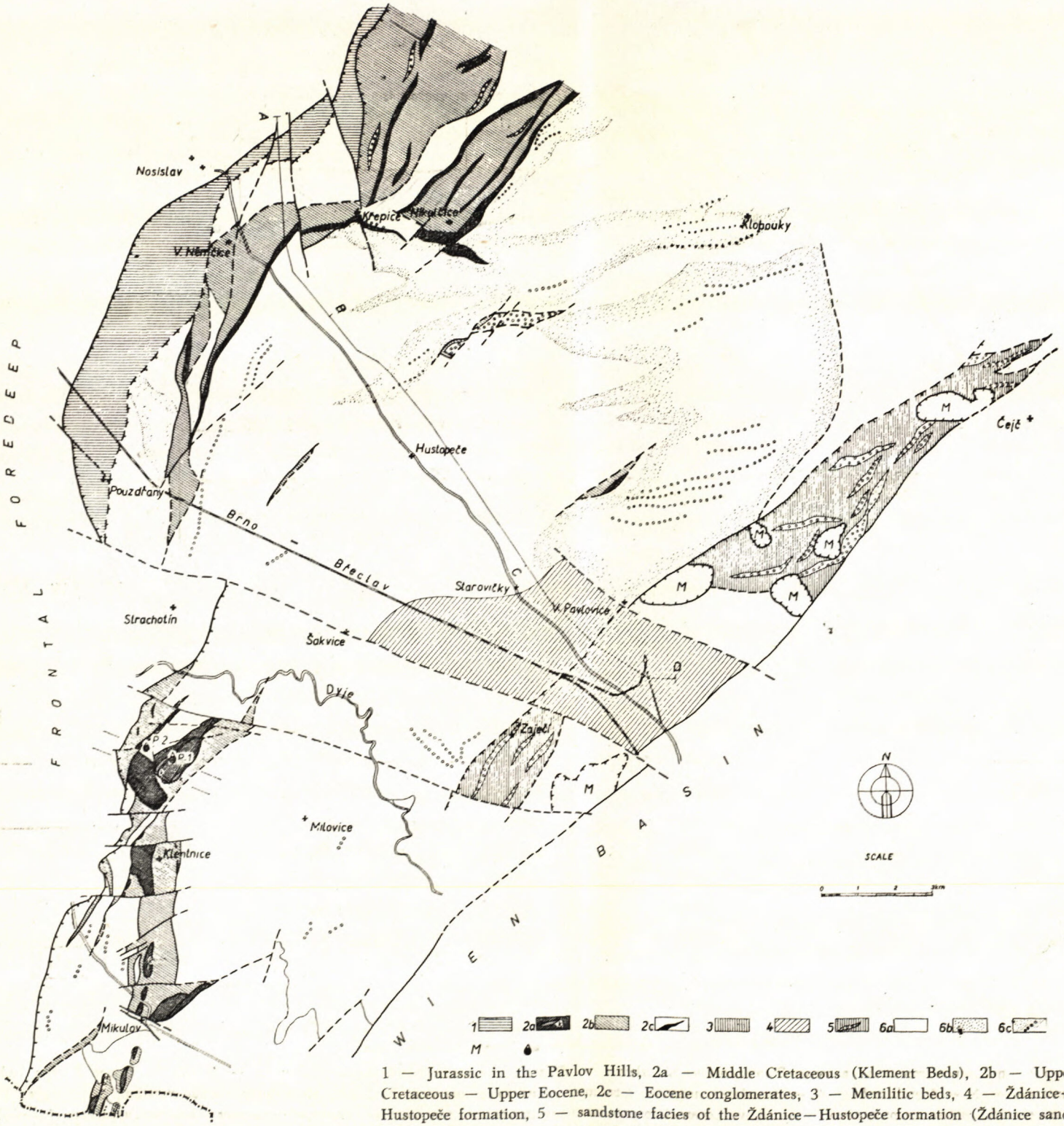
teristice oligomiocenních vrstev okrajového pruhu Ždánického lesa. Čas. pro min. a geol. r. VII/3, Praha. — [23] Rzehak A., 1918: Moravské třetihory. Knihovna SGÚ Praha. — [24] Schön H., 1925: Zur Tektonik der Pollauer Berge. Verhandl. d. naturforsch. Verein. in Brünn LX, Brno. — [25] Stejskal J., 1935: Geologická stavba Pavlovských vrchů na již. Moravě; I. stratigrafie. Věstník SÚG X, Praha; II. část: Věstník SÚG XI, Praha. — [26] Stráník Z. — Hanzlíková E. — Eliáš M., 1962: Zpráva o geologickém výzkumu Pavlovských vrchů. Část II. Manuscript; Archiv ÚÚG, Praha. — [27] Veit E., 1953: Mollase u. alpin-karpatischer Überschiebungsrand in Niederösterreich und Südmähren. Neues Jahrb. f. geol. und Pal., Abhandlungen Bd. 97, Stuttgart. — [28] Zapletal K., 1932: Geologie a petrografie země Moravskoslezské. Brno — [29] Zapletal K, 1930: Die mährische Flyschzone und die miozäne Vortiefe mit Rücksicht auf die Ölführung Petroleum 26, Berlin—Wien.



Profile through the Ždánice unit between Velké Pavlovice and Nosislav. 1 — Beds of the Čejč—Zaječí anticlinorium, 2 — Middle to Upper Eocene beds of the Ždánice unit proper, 3 — Menilitic beds, 4 — Ždánice—Hustopeče formation — a) lower division, b) middle division, c) upper division, 5 — Upper Eocene — Oligocene of the Pouzdřany tectonic slice, 6 — upper Lower Miocene (Bourdigalian?) on the Ždánice unit, 7 — Lower Miocene-Carpathian infolded in the Pouzdřany slice, 8 — Carpathian on the Ždánice unit, 9 — Carpathian of the foredeep, 10 — Tortonian.

Geological map of the southern part of the Ždánice unit.

Made use of the investigations of I. Cicha, F. Chmelík, A. Matějka, F. Pícha



1 — Jurassic in the Pavlov Hills, 2a — Middle Cretaceous (Klement Beds), 2b — Upper Cretaceous — Upper Eocene, 2c — Eocene conglomerates, 3 — Menilitic beds, 4 — Ždánice—Hustopeče formation, 5 — sandstone facies of the Ždánice—Hustopeče formation (Ždánice sandstones), 6a — conglomerates of the Ždánice—Hustopeče formation, 6b — Pouzdřany series, 6c — upper Lower Miocene — Carpathian on the Ždánice unit, M — remnants of the Magura nappe, . — borings.

ROBERT MARSCHALKO

SEDIMENTARY SLUMP FOLDS AND THE DEPOSITIONAL SLOPE

(Flysch of Central Carpathians)

Central Carpathian Flysch represents one of those rare basins which after the extinction have not been disturbed by folding tectonics. The sequences lic mostly in subhorizontal position and the reconstruction of preconsolidation structures is rather easy. Slump structures of fold type were identified at many places. The slump movements were studied in relation to the primary depositional slopes. We found out that on steep primary depositional slopes directly adjacent to the source areas the longitudinal axes of sedimentary folds were oriented mostly oblique and perpendicular to the orientation of deposition maximum whereas in the segments farther from the source areas the orientation was parallel. The systematic study of slump structures of great extension will help the interpretation of boundary between the sedimentary slump structures and tectonic gliding.

Some General Remarks and Differentiation of Slump Structures

Slumping of more layers together were observed mainly in rhythmic series of many geosynclines. To great details these phenomena were studied by A. Heim (1908), A. D. Archangelskij (1930), O. T. Jones (1937), R. W. Fairbridge (1946) the latest of whom presented a classification of submarine slumping based upon the degree of deformation. It was generally admitted, that the main reason of downslope layer sliding was the gravitation, with the angle of slope experimentally determined by A. D. Archangelskij to 1°—3°.

Importance of slumping structures was admitted mainly after P. H. Kuenen and C. I. Migliorini (1950) began explaining the formation of rhythmic sequences (Flysch, Macigno) by the process of turbidity currents in

deep-water environment. According to this opinion the zone of clastic deposition in the flysch basin extended from the edge of shore terraces into considerable depths including different angles of primary depositional slopes and various intensity of slump structures developement.

Slump structures in the Flysch of Carpathians were studied by many sedimentologists. M. Książkiewicz (1958) divided the slump structures in two groups. First is the slumping of more than two beds which however is very rare. Slumping of one or at most two beds belongs to the second widely distributed group. Directly from the Central Carpathian Flysch submarine slumps were described by J. Golab (1954) on the Polish territory as well as by A. Radomski (1958) who studied them from the view point of sedimentology.

Slump structures described in this article belong to the first group of M. Książkiewicz due to the fact, that irregularities, curving and deformations involved at least three turbidite beds. These structures may be placed also into the group of s. c. flow rolls of J. F. Pepper, W. J. de Witt, Jr. Wallace and D. F. Demarest (1954) or between the inter-formational folds situated among the parallel, undisturbed beds (R. W. Fairbridge 1946).

Shape and Features of Slump Structures in the Central Carpathian Flysch

Slump structures were studied, in the localities Radiša in Bánovská kotlina basin appearing in turbidity sequences (Pl. VI, Photo 1) with extensive fluxoturbidity conglomerates, locality Poronin (Pl. VII, Ph. 2, 3) in the Polish territory studied by A. Radomski (1958), further in the typical turbidity and fluxoturbidity sequences of Levočské Hory Mts at Holumnica (Pl. VIII, Photo 4). Such structures were also studied in Šarišské Hory Mts — locality Ovčie (Pl. VIII, Photo 5) north from Čierna Hora — Gemer source area in Wildflysch and Conglomerate flysch sequences (R. Marschalko 1961, 1963).

The majority of slump structures were characterized by the arrangement of beds into remarkable more or less symmetrical and flattened folds resting side by side. (Pl. VI, Ph. 1) Basement sandstone and claystone layers (excluding Radiša slump) by the slump movement were only slightly curved (Pl. VII, Photo 2, Fig. 1) without being destroyed. The slump body rested usually upon claystone beds often of minute thickness supposed to have served as a lubricant in the course of movement. Among the folds front often curved an infolded basement claystones and sandstones were observed which were dragged into the slumping movement (Pl. VI, VII, Photo 1, 2). At other places thick layers were pressed underneath the fold fronts and consequently deformed (Pl. VI, Photo 1). The extinction of slump structures and lateral transitions into normal stratification generally could not be determined. The width of the partly exposed Radiša slump body exceeded 100 m.

In all the cases studied the slump folds were abruptly cut off by erosion and covered by a new bed indicating that the slumps were formed before the deposition of the said layer. In the case the deformations effected also the overlying bed (Kuenen 1956). Plasticity of beds sliding down the slopes was rather high. It seems quite probable, that flattened, compressed sedimentary folds were formed after the gliding folds without a stop passed by. This may be proved by the position of erosional level corresponding with the surface of the sedimentary fold. The deformation therefore must have occured before the erosion of the particular layer thus being younger than the consolidation.

If the curving of beds and formation of sedimentary folds reflected the reduction of space more extensive movements had to be supposed. In all the cases mentioned the maximum angle range of the longitudinal fold axes in one slump body did not exceed 35°, ranging around 20°. This fact led to the conclusion that the sedimentary folds were formed on a plane bottom. The wrapping and curving of beds into independent folds may have resulted only after the break of continuity and fragmentation of bed into narrow, oblong rectangles. The sense of curving may differ and thus must be identified from case to case. The position of flute-casts preserved at the bottom of layer or lamination at the top of the layer supports usually the determination of the sense of bed curving. The position of lamination at the bottom of the slumped beds in the fold (Pl. VI, Photo 1) for example we suggest that the moving bed were curved downwards. Upward curving may be observed on the slump folds of Poronin (Pl. VII, Photo 3) and Holumnica (Pl. VIII, Photo 4).

Except the types of slump folds just described other structures with flexure-like shape of the whole sequence have been observed north from Čierna Hora Mt. in the marginal wildflysch lithofacies (Pl. VIII, Photo 5). We observed that the deformed beds were suddenly broken within a short distance floating in the form of elongated lenses surrounded by the coarse-grained clastics (microconglomerates). According to the authors's suggestion these forms may be regarded as pull-apart structures (M. L. Natland, P. H. Kuenen 1951) which may include all the stages of pulling, breaking and deformation of beds.

Orientation of Slump Folds and Primary Depositional Slope

Direction of slump folds movement cannot be deduced solely from their shape although logically the orientation of the longitudinal fold axis is perpendicular to the movement direction with the fold front dipping downslopes (R. R. Shrock 1948).

Turbidity sequences in which the slumps occured were deposited by turbidity currents provided the presence of convenient slope. Due to this fact the uniform orientation of currents measured in turbidity sequences deposited during a con-

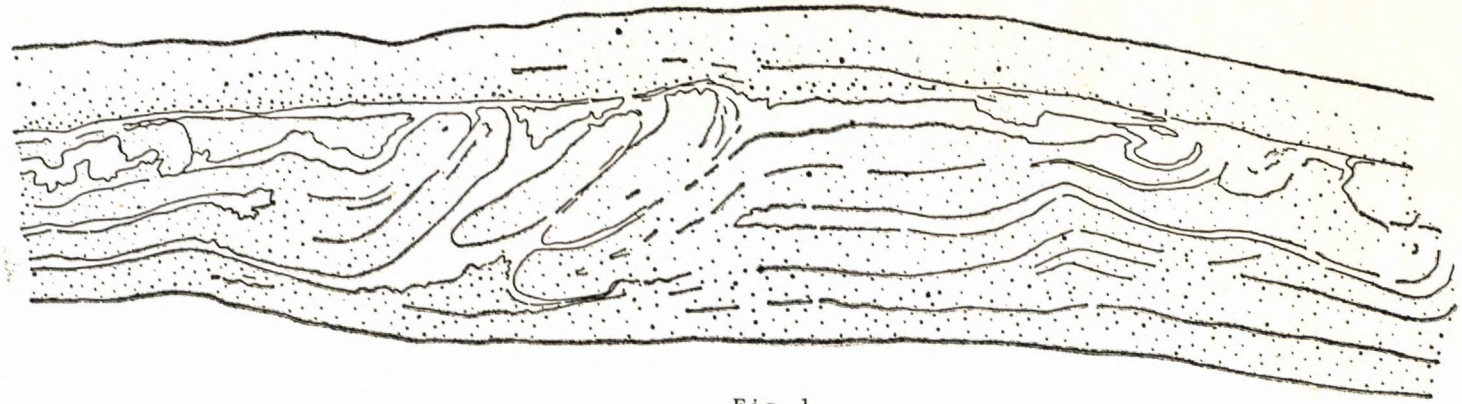


Fig. 1.

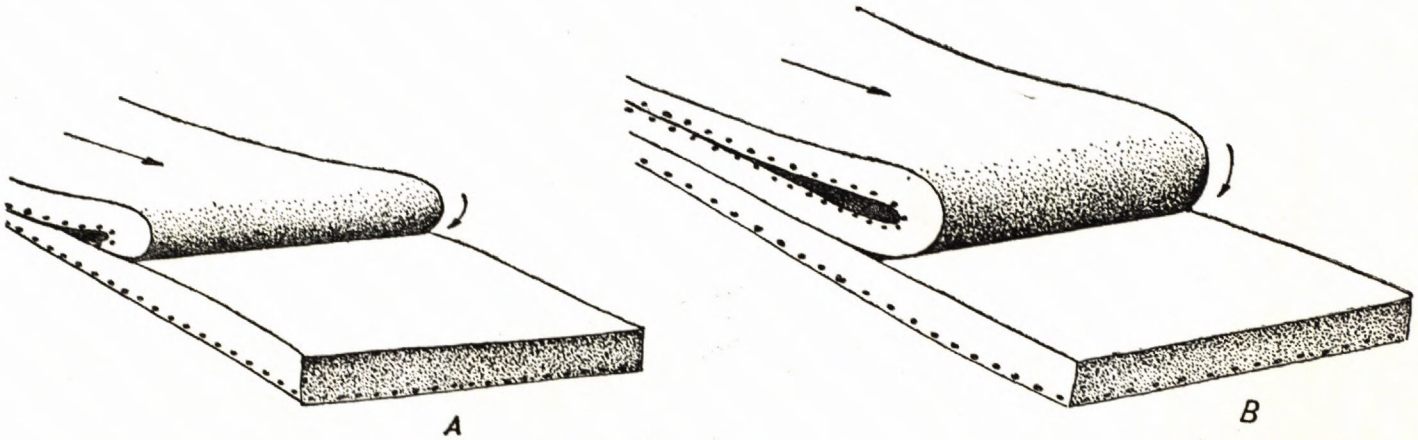


Fig. 2.

siderable period of time indicates also the dip of slope in the turbidity current direction (E. Teen Haaf 1959). Also the load casts of conformable orientation with the prevailing direction of flow proved the suggestion that the filling by clastics was the first and most important agent controlling the primary depositional slope. The relations between the direction of turbidity deposition and orientation of slump folds occuring locally and from time to time during the process of deposition were observed by the author of this article. In turbidity sequences in which slumping took place the linear features indicating the transport direction such as flute casts, impact casts, grains lineation were measured and compared with the orientation of longitudinal slump fold axes (Fig. 3 A, B, C). The values measured were arranged in radial diagrams.

Diagram Radiša (Fig. 3A) indicates for example that the direction of slumping was similar to that of the current advancement i. e. downslopes of the primary, rapidly accumulated and unstable submarine fan of the clastic filling. This relation determines also the direction of slump folds movement and their mode of origin as well. They represent a simplified thrusting (Fig 2) with the fold limb formed by the pulling tension. By increased intensity of downslope movement started the downward wrapping of the layer resulting in a reversed layer sequence. This process in particular fragments of beds passed separately and perpendicular to the movement direction.

Similar relation was observed in Wildflysch sequences of the Čierna Hora Mts. marginal lithofacies (Fig. 3B). Direction of slump folds were oblique to the maximum transport direction proceeding from SE, Some of the slump folds in diagram not included show a similar orientation perpendicular to the transport direction with front striking down the primary depositional slope.

According to our opinion the slumps and pull — apart structures in the Wildflysch marginal lithofacies north from Čierna Hora Mt. and in Bánovská kotlina basin represent cases, where the primary depositional slope raised due to rapid clastic filling from vigorously lifted source areas to such a degree that it became unstable causing movement of the youngest layers, formation of pull- apart structures and slump folds.

Slump near Holumnica is regarded as entirely different, with longitudinal fold axis striking parallel with prevailing transport direction (Fig 3C). In majority finegrained and thin — bedded turbidites regularly alternating with claystones indicate the origin from distant and fading turbidity currents thus marking

◁

Fig. 1. Submarine slump with development of a flat sedimentary fold. The slump body pressing upon the basement layer by loading. Graded bedded layer leveling the surface of the slump body.

Fig. 2. Sedimentary fold blockdiagram. In the first stage the layer is torn and curved downslopes. B. Wrapping — involute and downslope movement.

a low-angle primary depositional slope. Remains a question whether under such circumstances formation of slump folds was ever possible moreover with an orientation parallel to the transport direction. According to observations however best conditions for slumping resulted mainly in the front of the unstable depositional slope at places where the submarine filling fan was connected with steep slopes of the shore terraces (R. Marschalko 1963).

It seems more appropriate however that the slumping were controled by isostatic tectonics — slight upheaval of beds already deposited by the tectonic revival of the ancient source zone parallel with the maximum transport direction (ESE—WNW) emerged south from the Klippen belt (R. Marschalko — A. Radomski 1960). Tectonics of this belt and slight subsidence of the deposition area controlled

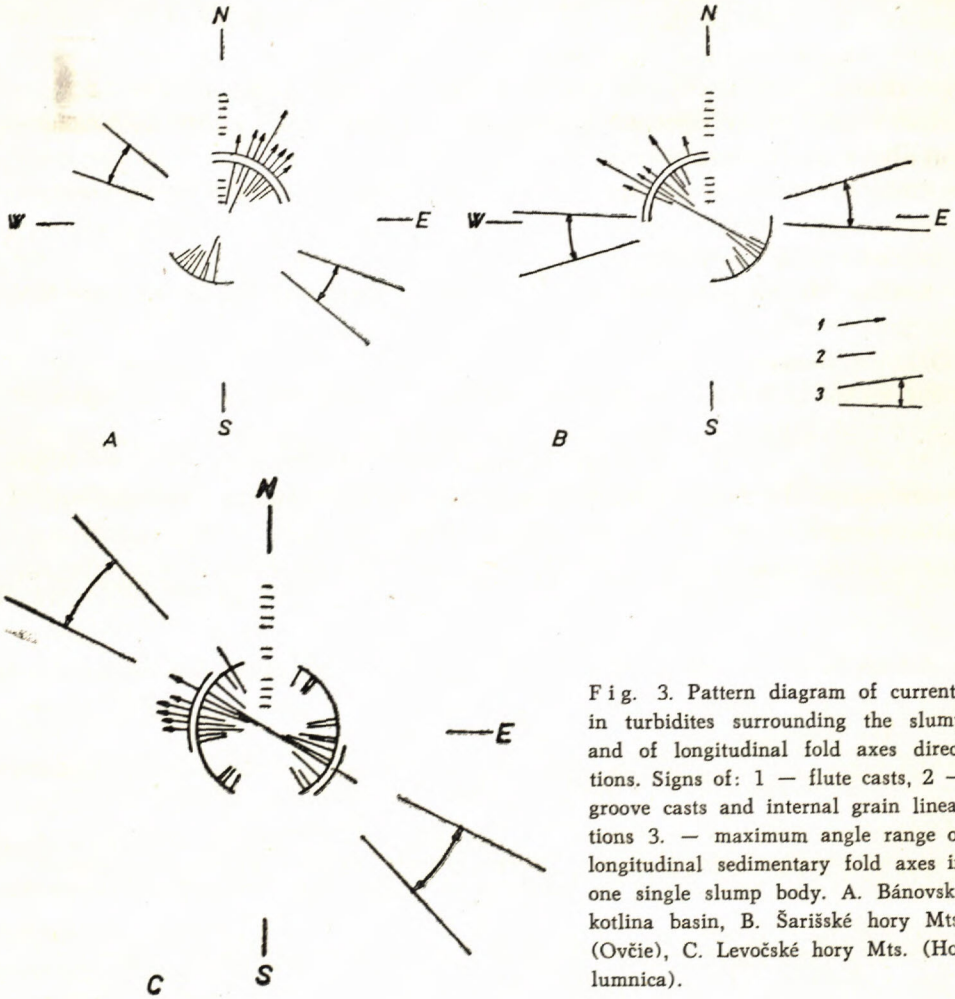


Fig. 3. Pattern diagram of currents in turbidites surrounding the slump and of longitudinal fold axes directions. Signs of: 1 — flute casts, 2 — groove casts and internal grain lineations 3. — maximum angle range of longitudinal sedimentary fold axes in one single slump body. A. Bánovská kotlina basin, B. Šarišské hory Mts. (Ovčie), C. Levočské hory Mts. (Holumnica).

the slope angle suitable for slump — down of sedimentary folds from north to south. This possibility is supported also by current directions advancing from the north observed in several cases. The same explanation may be preliminarily admitted also for the origin of extensive sedimentary folds exposed near Poronin in Polish Podhalie. After A. Radomski the transport direction proceeded from the west to the east and slumping from north to the south while wrapping of folds had an upward orientation (Photo 3, 4).

Summary

Investigation of slump folds in the marginal Flysch lithofacies indicated a preferable longitudinal axis orientation perpendicular or oblique to the prevailing deposition of clastics. The folds are of slump synsedimentary origin formed at the primary depositional slope. The folds fronts were dipping downslopes as well as curving and wrapping of beds.

In turbidity sequences representing a distant filling of fading turbidity currents with the transport direction striking parallel to the first order structural line the fold axes also parallel to this line were observed. The bed sequences were normal with upward fold wrapping.

Direction of the slumping down the primary slope from the sedimentary fold fronts and overturns can hardly be determined. Maximum angle-range of the longitudinal axes belonging to sedimentary folds in one slump body did not exceed 35° having been 20° in average. Longitudinal axes orientation may be used in slump folds for the determination of downslope slump direction.

Minor slumps did not change into slump avalanches and the transition of such slumping into turbidity currents also was not observed. The slumping beds moved downward due to their deposition on slope or under the influence of isostatic tectonic balancing of the basin bottom. Such slumps originated during the plastic stage of layers rendering their pliability and variability of forms.

Translated by J. Kováčik

D. Štúr Institute of Geology,
Bratislava

REFERENCES

[1] Archangelskij A. D., 1930: Opolzanije osadkov na dne Černogo Morja i geologičeskoje značenije etogo javlenija. BMOIP. VIII, Vyp. 1—2. — [2] Fairbridge R. W., 1946: Submarine slumping and location of oil bodies Bull. Amer. Assoc. Petrol. Geol. 3o, No 1. New York. — [3] Golab J., 1954: Rockslides and flows and their meaning for the tectonic of the Flysch of Podhale. Bull. Soc. Sci. Letr., Lodž. — [4] Heim A., 1908: Über rezente und fossile subaquatische Rutschungen und deren lithologische Bedeutung. N. Jb. Mineral. Geol. etc. 2, Stuttgart. — [5] Jones O. W., 1937: On the Sliding and Slumping of Submarine

Sediments in Denbighshire, North Wales, during the Ludlow Period. Quart. J. Geol. Soc. London, 93. — [6] Książkiwicz M., 1958: Submarine slumping in the Carpathian Flysch. Ann. Soc. Géol. Pol., Vol XXVIII, fas. 2, Warszawa. — [7] Kuenen Ph. H., 1956: The difference between sliding and turbidity flow. Deep Sea Research, Vol. 3, London. — [8] Kuenen Ph. H., Migliorini C. I., 1950: Turbidity currents as cause of graded bedding J. Geol., Vol. 58, Chicago. — [9] Marschalko R., Radomski A., 1960: Preliminary results of investigations of current direction in flysch basin of the Central Carpathians. Ann. Soc. Géol. Pologne 30, Kraków. — [10] Marschalko R., 1961: Sedimentologic investigations of the marginal lithofacies of the Central Carpathian Flysch. Geol. Práce, Zoš. 60, Bratislava. — [11] Marschalko R., 1963: Sedimentary structures and Paleocurrents in the marginal lithofacies of the Central Carpathians Flysch (in press). — [12] Natland M. L., Kuenen Ph. H., 1951: Sedimentary history of the Ventura Basin, California, and the action of turbidity currents. So. Econ. Pal. Min. Sp. Publ. 2, London. — [13] Pepper J. F., De Witt, W. Jr., Wallace Jr. and Demarest D. F., 1954: Geology of the Bedford shale and Berea Sandstones in the Appalachian basin. U. S. Geol. Survey. Prof. Paper 259, New York. — [14] Radomski A., 1958: The Sedimentological character of the Podhale Flysch. Acta Geol. Pol. Vol. VIII, Warszawa. — [15] Shrock R. R., 1948: Sequences in layered rocks. New York. — [16] Ten E. Haaf, 1959: Graded beds of the Northern Apennines. Thesis Groningen.

LAURENC SNOPKO

STUDY OF DEFORMATION ELEMENTS DEVELOPED IN THE HANDLOVÁ LANDSLIDE

In the last days of December 1960 tremendous masses of land started sliding down the NW slopes of Kozie chrbty Hills SE from Handlová. After the detailed mapping of surface sliding deformations in 1 : 5000 scalle studies were carried out on the chronological development of landslide in its individual segments. In the area of sliding three current slides were distinguished, two of them independent and the third one as the result of the strain caused by the main slide (Far northward from Handlová still another small landslide were formed.) At the main landslide all the particular elements the separation area, landslide track, landslide front and the landslide forland were developed. All of them developed separately with the specific features respecting the general chronology.

Formation of various types of surface deformations was the result of two factors. The first one-gravitation caused the movements in the direction of current (sometimes also to the marginal parts of the landslide). In this case compression of the main mass (or sometimes marginal) occured. In the upper parts of the landslide and the sliding track on the contrary strain release may be observed with the formation of other types of deformations. The second factor was the composition of soils where several types were distinguished: the uppermost part reinforced by vegetation roots and frost. The thickness of this bed ranged between 15—30 cm. The second bed were represented by weathered clays, marly and sandy clays of weak coherance-ranging up to 1,5 m in thickness. The remaining part of the sliding mass were formed by sedimentary rocks such as clays, marly clays, tuffites, tuffite sandstones and exceptional conglomerates. They were transported alredy as fossil landslides into the lower areas readily plastic, according to the amount of soaked water.

The differring mechanical properties of the rocks concerned were expressed in various surface deformations.

Typical deformation elements as the result of compression were different sorts of *fold resembling mounds.* Such were mainly the marginal mounds. Their formation is very similar to that of the fold. First several assymetric, minute tongue-like folds 10—30 cm high were developed in a concentric arrangement. Due to the side strain the synclinal part of the fold began to close, roll-in resulting in a flat lying fold. By the further movement the fold grew bigger until the lower syncline limb was broken with the anticlinal part thrusting over the synclinal one. The folding was observed only in the uppermost soil bed while the lower clay-sandy mass was developed by another way. Here a low angle shear plane (20°—30°) with the dip opposite to sliding were first developed upon which than the movement proceed. This process was reflected by the formation of marginal mounds on the surface. Simultaneously with raise of anticline the lifting of the whole adjacent area were observed ranging up to 2—3 m in the main landslide front and 0,5—1 m in the foreland. By the further process the front part of the sliding mass (crest of anticline at the beginning) were slowly rolled under the main mass. Always new marginal mounds originated concentrically at the front of the landslide. The strain distribution showed typical features mainly at the accumulation areas, sliding front and the foreland.

Another type of deformation were the *opposite overturned mounds (folds),* originating chiefly at places of mass accumulation in the sliding track. At the surface thy were reflected by minute folds sometimes overtuned. Folding involved mainly the frozen turf which was first separated from the clay basement. There were no deformations observed in the clay basement except plastic compression. The overturn of folds was oriented against the sense of movement. The fold axes were oriented perpendicular to the strain. All these facts indicate clearly that the movements were faster in the basement than on the surface.

Similar types of mounds were observed in the slide track below the area of separation. Mounds in the shape of vertical folds were formed due to the compression in the narrow gorge of the slide track and hence their axes were parallel to that of the sliding.

Larger deformations were represented by *synclinal and anticlinal features* originating in the landslide forland. The amplitude ranged within 15—30 m, length 150—200 m, height 1,5 m. Along the fold axes minute vertical folds were formed at the beginning, later also at the limbs of synclines. As counterbalance to the syncline, reverse to the movement an anticline of approximately same dimensions was formed. The axis of anticline was accompanied by cracks and widening fissures in parallel arrangement. Not so characteristic were two other smaller synclines originated opposite to the movement direction. One of them were filled by a small pool the ice cover of which were also folded into a vertical fold. These

forms originated due to the compression of the plastic basemement below the more rigid turf in the landslide forland. Similar observations were made also at the forland side margins but with axes orientation parallel with the sliding.

The last sort of deformations related to compression were *blocks* formed by the split of the slide-plane in two or more segments thus producing wedges deformed by compression into assymetric folds. At places of intense compression pinnacles originated lifted 1,5—2 m above the surrounding level. Three remarkable pinnacles were formed in the central part of the main landslide below the area of accumulation, indicating (as the opposite minor folding) faster movement and intense strain of the basement.

Release of the strain led to the *sinking of blocks* in the separation area along concave planes-gravitational cracks of crescent shape. The dip of cracks ranges 80°—90° flattening in the sense of mevement. The sliding blocks were arranged gradually step-like with surfaces dipping backwards. Length of slipplanes ranged between 10—50 m. Directy observable depth 5—12 m indicates a substantial penetration. The shape of the fissure in the upper bed was uneven and iregular, white in the basement clays the plane was smooth with tectonic striation — lineation along the "a" axis of the strain ellipsoid.

The process was started by creation of separated cracks which were further united thus forming the *individual step-like arranged blocks.* Blocks sliding along the track margin were rotated. In case of faster basement movements the blocks incline backwards while in the opposite case forwards with frequent overlap. Separation were observed also along the track side in cases where the landslide levels was below the surrounding terrain. The separated blocks were asymmetric in the contrary to the symmetric blocks of main separation area. The blocks floating over the plastic basement were separated on considerable distances thus indicating the release of tension in the basement.

Detailed studies were made on the evolution of *sliding planes.* The planes were developed either backwards by the concave sliding planes in the separation area or more frequently forwards during the formation of sliding track and limitation of the landslide front.

The birth of a fissure started by the formation of minute tension cracks in diagonal orientation 30—45° the prospective fissure. The cracks were observable only in the upper — hard frozen crust, which by further continuation of process were widely opened (S-form) up to 10 cm. In that stage the lower — plastic basement was broken starting the sliding movement. If the distance of movement exceeded 0.5 m the turf bed were deformed, fractured by diagonal cracks into small blocks — due to the sidle fixation and simultaneously rotating. Shortening of the surface led to the formation of specific minute folds turned over opposite to movement. Their lenght 0.5—1 m, height 0.3 m, amplitude 0.5—0.7 m. Nearly all the diagonal blocks were deformed in the same way.

After the total separation and isolation of the block by further movement complete sliding planes resulted. The margins show slightly undulated planes from the previous connection with the above folds.

Different deformations resulted from the side pressure of the sliding mass. On the interior track margin side undulation occured 5—8 m wide, 10—15 m long and 0.7—1 m high with axes dipping 65° to the slip — plane. This phenomenon were observed if the levels of both the frack and landslide margins were in the same level. by lower track margin. This were overlapped by the sliding mass, white in the opposite case the track margin were broken and overlapping the landslide.

Similar undulations appear also at the inferior sliding plane. Further type of deformations are the cracks in feather arrangement 2—3 m long and 1—1.5 m distant. After such a crack system were born the original sliding plane stopped acting and in stead a new formation started at the end of crack systems. (The right side of the landslide II.)

Along the track-side marginal separation areas were developed. First the cracks opened and the fissures were prolongated up to 20—50 m. The resulted blocks sank forming miniature grabens. Such phenomena were observed at the right side of landslide II, and the left side of main landslide.

The sliding-planes were desintegrated either due to the formation of marginal separation areas after the outflow of the mass from sliding track or by deformation at the landslide front in reversed strain conditions. The sliding planes in the lower parts continuously arose, in the central parts were in full activity and in the upper parts of the landslide were dying out.

Very little is however known about the nature of the main sliding plane below the whole landslide. Most probably it were formed by the connection of partial concave slip-planes of individual blocks. Within the sliding track this plane was most probably of channel form. Its regular shape in central part of the landslide may be deduced from the rotation of sliding mass along a rounded plane. The surface of landslide were dipping to the right side thus the right margin were below the surrounding level. More complicated conditions developed at places of branchings of the main sliding plane. The existence of sliding plane below the landslide front besement is doubtful. As compensation concave forms originated below the marginal moulds where the individual blocks were thrusted one upon the other.

Characteristic deformations:

A. *Area of separation*

1. Concave planes with step-like symmêtric blocks.
2. Backward forming slip-planes with rotation of blocks.

B. *Landslide track*

1. Well pronounced sliding planes in all stages of development.
2. Marginal asymmetric separation areas.
3. Dragging of side-walls with the formation of symmetric block grabens.
4. Branching of sliding planes and a formation of block — wedges.
5. Formation of vertical moulds parallel with sliding axis in the upper part of track as the result of transportation.

6. Separation of the landslide into a great number of iregular blocks.
7. Formation of opposite overturned minute folds in the area of accumulation.
8. Exceptional formation of pinnacles pushed upwards from the basement parts.

C. *Landslide front*

1. Rolling folds in concentric arrangement.
2. Bowl-form shear zones dissecting the lower fold limbs.

D. *Landslide forland*

1. Opening fissures in radial fan-arrangement.
2. Flat transverse and longitudinal synclines and anticlines.
3. Partial slides and rolling folds at the forland margin.

The main landslide was observed in December 1960 already well developed. The start of a current landslide was watched mostly on the formation of landslide II.

The process started in a small shallow valley with water soaked soil by formation of crescent shaped cracks, along which the separated segments sank for some 20—30 cm. The sinking wese too slow to be observed. The cracks gradually widened forming fissures while other new ones arose over the former. The resulting blocks so far were not completely separated. The fissures were dipping perpendicular to the surface.

Due to the pressure of the sliding blocks systems of diagonal cracks with 30—45° orientation against the direction of flow were created along both sides of the separation area. By the further movements these cracks were twisted, wide opened and finally united into one great fissure along both sides of the future landslide at a daily rate of 100—150 m. So far no deformations appeared on the surface. While in the upper parts the sliding proceeded at a rate of 2—3 m per day (later increasing to 5—10 m) in the lower part the sliding plane were still not completed.

The limitation of the landslide area was finished within a relatively very short time. The further evolution was marked by the action of side tensions, leading to theg formation of cracks in feather arrangement converted later into concave slip-planes along which the blocks started toslide either irregular or in step-like grabens. On the left side marginal separation areas were created. In the main separation area new cracks and fissures were opened the way backwards resulting in sliding of always new blocks joining the main sliding mass. This process may be alredy regarded as the second stage with predominating disjunctive tensions.

The third stage were characterized by the surface deformations in the upper part of the landslide while in the lower the limitation of landslide along the sliding plane still proceeded. The lower segment of the sliding plane were formed some 250 m ahead of the surface deformations. At the beginning of this stage the original length of the sliding area were shortened for about 10—15 m without observable deformation. From now on mould arose at planes where the morphology was preferable. The moulds in the uppor part of the landslide took the shape of vertical folds by the separation of frozen turf from the plastic basement. The lower part of such a fold were compressed to an adequate length without any specific deformation. Those folds arose adjacent to the first one both in the front and rear. The mounds were oriented perpendicular to the direction of stress with a straight axis. At steeper slopes the deformations were

entirely different. The moulds took the shape of flat bying folds with the lower limb always reduced. The folds here were concentrically arranged with bowing axes. The moulds height ranged within 0.5—1 m. The front of the landslide II were similarly deformed.

The landslide II remained in the position just described. Tre breaks in development were caused by the low slope angle and the great width of landslide leading to the release of strain and its distribution over an extenisine area.

,Formation of the No I main landslide were from the very beginning far more complicated. The separation area were divided into four individual segments separated by independent sliding planes. (Exlosure No 1.) The left part of the landslide represented in fact an individual landslide originated from highly soaked soils separated from the less soaked basement by a single act and practically directly flown out in such a manner that in the small valley only an empty landslide track channel remained. The track channel were later filled by individual blocks separated from the steep margin scarps and slid into the depression. The whole floating mass was torn into a great number of small irregular blocks arranged in the direction of current. The fastest movement resulted in the central part while. The margins flowed slowlier cansing the rotation of blocks around their vertical axis. The faster movements of deeper horizons were reflected in the backward inclined blocks while in the opposite case the blocks were forward overlapped. (Enclosure No 1a)

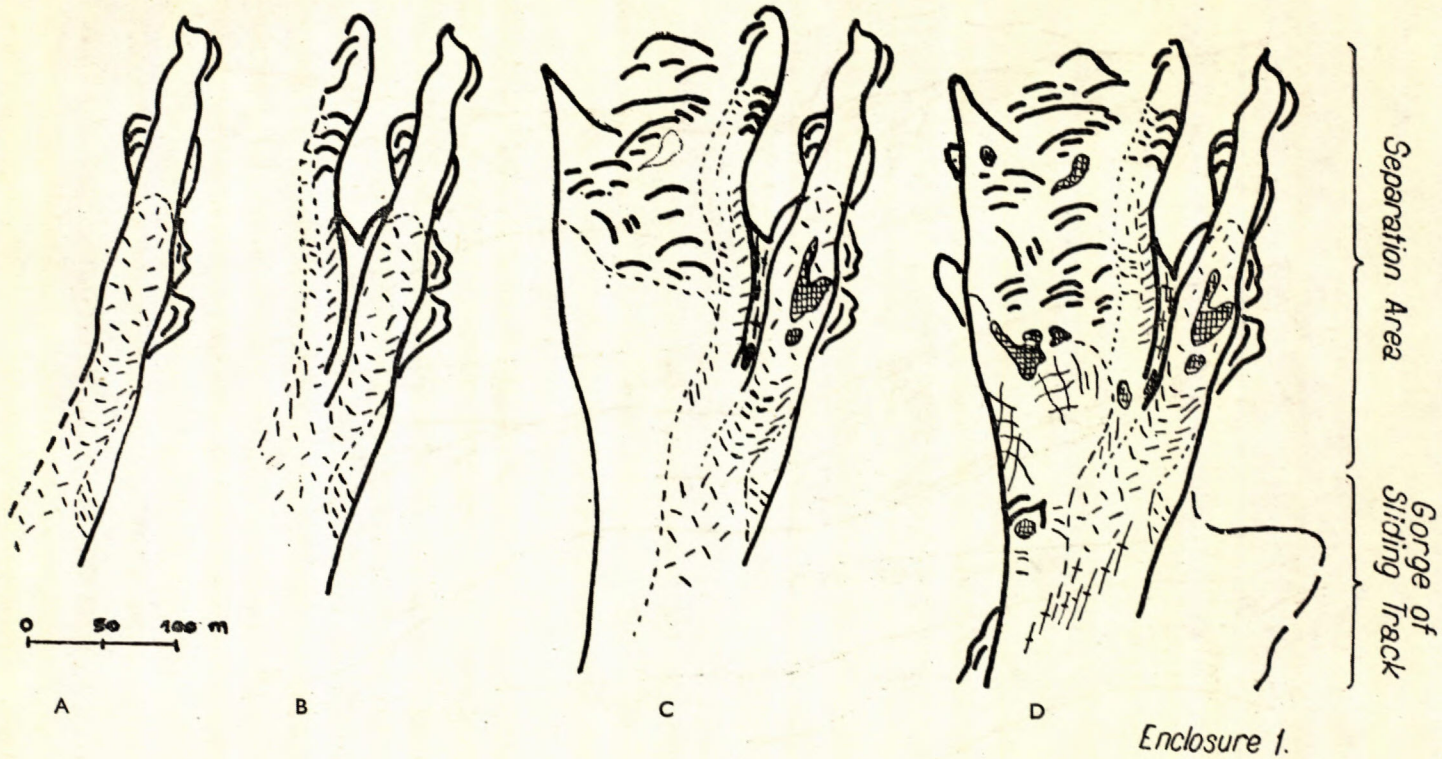
Due to the lower level of landslide surface marginal separation areas were formed at the right side. By their further continuous division by the retrograde erosion new small landslide were originated along the concave sliding planes as the only example of the retrograde formation of sliding planes from concave partial members. By this process the central part of the landslide were formed. The movement and the separation of individual blocks (Enclosure No 1b) were at this stage still fairly observable. Between both the landslides a tongue-like apophlysis remained undisturbed. Both small landslides caused the separation of a giant block which remained untouched untill the stabilisation of the main landslide except several fissures resulting from the effect of uneven basement. Above this block naturally further new separation areas were developed. (Enclosure No 1c)

All the transported blocks were concentrated in the valley into the track-channel gorge where their rocks were clammed and compressed. (Formation of vertical folds with axes parallel to the flow direction. Although the process of landslide evolution was perhaps succesfully interpreted only at the left side while in the central part the development proceeded nearly simultaneously within a short time. (Enlosure No 1d).

The initial impulse was given by the rapid downslide of the small valeys at the left side just previously described. The second stage was mainly the delimitation of the whole landslide area from the track gorge downwards. (Enclosure No 2a) We may deduce however that even a very small sliding impulse is sufficient to evoke the delimitation of a large area by separation planes, although this will remain untouched by surface deformations. The deformations were observable only later after the limit of elasticity were exceeded thus marking the beginning of the third stage of evolution.

During the process of backward separation in the lower part the delimitation of erosion track proceeded. Due to the narrow valley the sliding track could not be widened enough thus leading to the concentration of strain within the main sliding mass. The sliding plane on the left side branched in two segments resembling the horse tail tectonic structure (Enclosure No 2a)

Below the track gorge a great number of little blocks were observed slid from the separation area. The sliding mass composed of clays, marly clays, tuffites etc. were at this place pressed closely together although its level were remarkably below the neighbouring area (4—6 m) indicating the extension by plastic flow. (Enclosure No 2b) Few metres below a mass accumulation was observed with the level 1—3 m pushed above the terrain, confirmed further by the



Enclosure 1. Formation of Separation Area of Current Landslide. a) single initial; b) formed backwards; c) separation of sliding block and backward enlargement of separation area; d) sliding into the sliding track gorge, compression and formation of straightened folds.

Enclosure 2. Compiled from aerial Photographs and Geological Maping of Surface structures.

style of surface deformation. Due to the faster flow of the deeper masses the moulds were overturned as folds towards the rear of landslide.

At the left side due to the branching of separation plane an independent block arose with the peak and one side touching the landslide margin and the basis supported by the so far undeformed rocks and soils. Sliding of the mass were prevented from the right side in a sort od wedging, causing the formation of craks oriented 30—45° oblique to the sliding axis. The triangle blocks were arched upwards into a sort of brachyanticline with axis running from the triangle peak perpendicular to the basis. The segment between the axis and inerrior of landslide was deformed by minute overturned folds, while the triangle peak by longitudinal fissures. (Enclosure No 2b)

In the period of surface deformation of the upper part and first stage process in the segment from track gorge to accumulation area the formation of the lower part of track channel proceeded, repeating the process already described. The area involved were larger because of greater width of the valley and the termination of sliding planes more complicated. On the left side the sliding plane was divided into fine branches curving towards the centre of the future track channel, giving birth to four block triangles connected together by their peaks at the left side of the landslide. (Enclosure No 2b, c) The other sliding plane (Right) were decided somewhat below in two branches curved also towards the center with the delimination of a triangle block. Toether with the delimination of the lower landslide part started the surface formation of the other part of sliding track (Enclosure No 2c). The greatest stress originated probably below the accumulation area in the upper part of sliding track. At the left side of landslide the desintegration of the pushed mass into a great number of irregular blocks was observed. Among the blocks several forms resembling the pinnacles occured. These forms were pushed upwards from among the moving blocks. After this impulse independen sliding started in the lower part of landslide, faster than in the upper part. The speed was indicated by an extensive separation area within the track channel as widening along concave planes as well as sinking of the whole surface 1—1.5 m below the margin level.

The lower accumulation area was formed similarly to the upper area with triangle blocks compressed and deformed in the same manner (fissures and minute overturned folds) (Enclosure No 2c)

The evolution of the sliding track passed generally in *two phases*. They were the *branching of sliding planes and formation of block triangles*, deformation of the accumulation area with the shortening and simultaneous lifting of slided mass above the level of neighbouring terrain. In the upper part it was the division of the mass into individual blocks, plastic flow as well as the subsidence of surface below the neighbouring terrain.

The two phases were controlled by two factors:

1. Internal-expressed inside of the moving mass-depending upon the viscosity:

a) Development of sliding plane only to certain distance and subsequent branching. The delimitation were possible up to the moment of excess of the elasticity. In such a case landslide moved downward as a complete block. In case of exceeding the rock elasticity the delimitation were stopped and replaced by deformation.

b) Branching led to the creation of block triangles wedging and preventing the mass movement. The triangle blocks were exposed to intense compressive deformation expressed by the creation of oblique ckracks with 30—45° orientation toward the direction of stress parallel with the flow axis.

2. Morphology of the sliding track basement which was probably nearly similar to that of the

surface. The accumulation areas in both cases were not dipping so steeply as the areas where intense sliding and plastic flow were observed.

The character of landslide basement was expressed by several phenomena.

a) Small pools were formed above the upper accumulation area at places, where the branching of sliding plane occured. Although the whole surrounding mass slided downwards, the pool did not change its absolute position; the ice covers freezing on the surface were moving downwards together with remaining sliding mass. This observation led to the conclusion that below the pool a depression must exist, related exclusively to the basement.

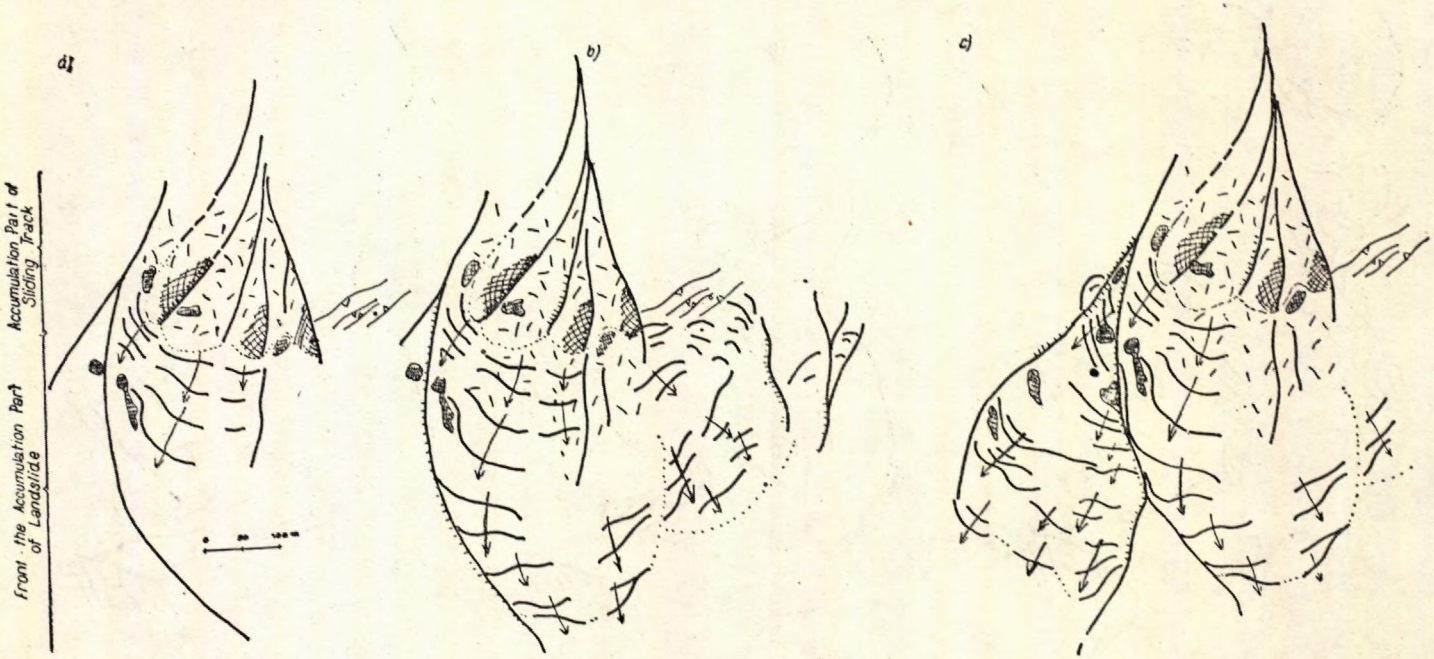
b) An intense subsidence of blocks was observed below the upper accumulation area along concave slip-planes. This phenomenon indicated the existence of a sort of step in the basement.

The differences between both the areas are as follows: The upper part of sliding track is far more deformed, the accumulation area greater and the outflow of sliding mass rather complete on the contrary the lower segment is greater with a large and complicated accumulation area, smaller area of separation and far less intense surface deformation. At the end of sliding track evolution both segments were sliding down as one unit (Enclosure No 2c).

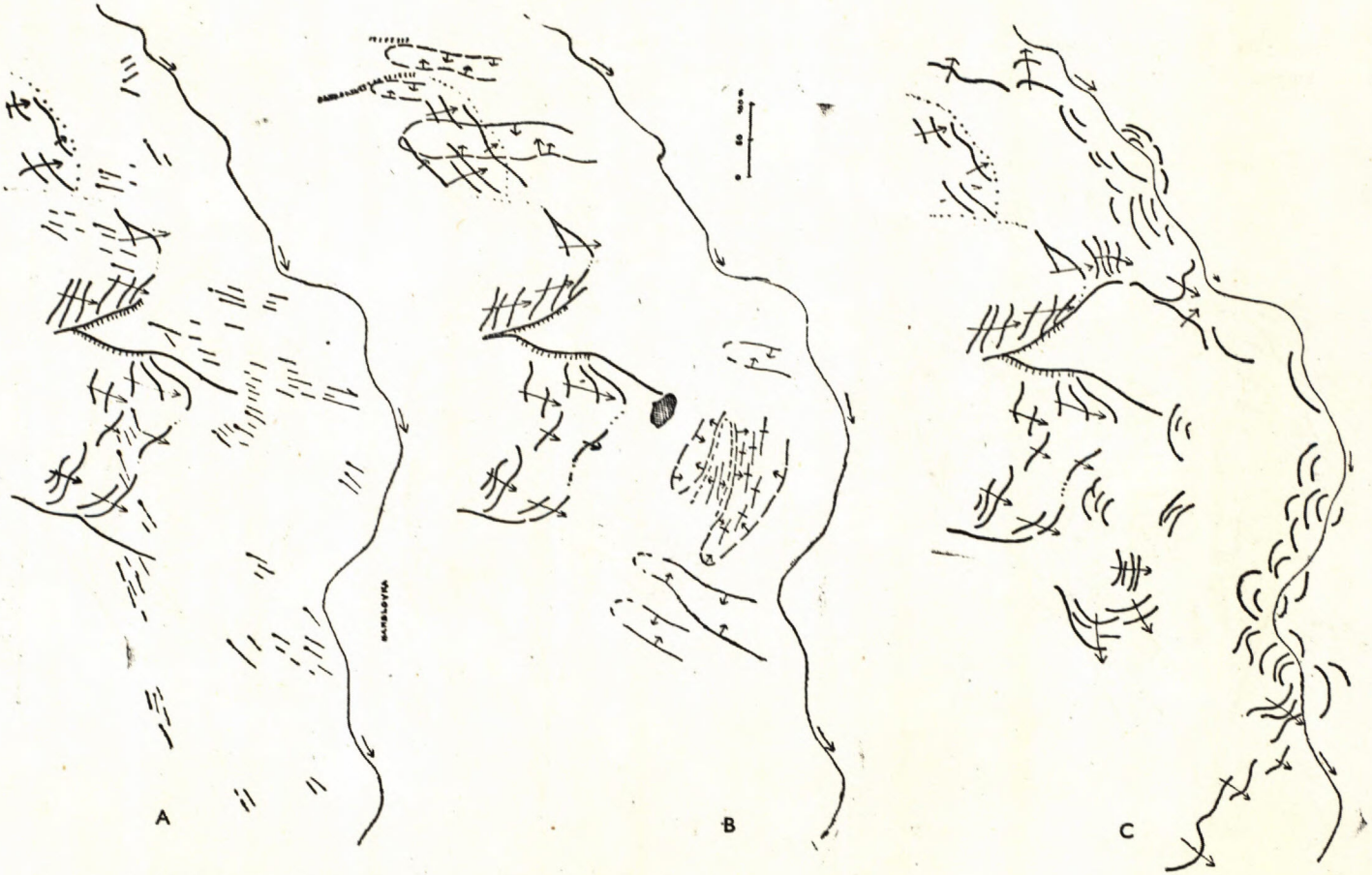
The landslide front were created alredy in the period of lower accumulation area formation. Due to the maximum stress acting along the hight margin of landslide the sliding plane prolongated in the same direction (Encl. 3a) At this place also the maximum speed of sliding were observed ranging to 1 cm per min. Simultaneously with the formation of sliding plane the individual block triangles were pushed into the landslide front by the acting stress in such a way that the blocks slided one upon the other thus closing the lower segment of sliding track channel pushing the rock and soil mass forward in the front of their bases. Although the triangle blocks were deformed into longitudinal (in sense of sliding) asymmetric folds the greatest value of strain acted at their bases. In the newly created front of the landslide new forms and shapes resulted which so far were not observed in the evolution scheme. Resulting forms had the shape of peripheral (circumferent) moulds (Enc. 3a) The shear zone cutting off the lower limb of the fold pentrated into considerable depth. With upheaval of anticline a wide back land area rose also. The resulting blocks and folds thrusted one upon the other were further fractured by longitudinal and transverse cracks. The peripheral moulds concentrated in the landslide front in tongue-like shapes of the movement were directly reflected in the formation of rolling moulds which were the largest at the right landslide margin with fastest movement. Towards the center and the left side the moulds were smaller and gradually diminished in relation to the shortening of sliding distance. The centre of rotation was located at the left side near the sliding track terminus. The formation of the landslide front caused the release of left side slope balance, and consequently the formation of new, extensive area of separation (Encl. 3b)

A small landslide III originated by the process just described preventing the farther sliding of the main mass at the left side. Due to the continuation of mass movement the flows were changed into opposite direction. (Encl. 3c) forming a new landslide front at the right side below the track channel. The sliding plane at the right side were prolongated, peripheral moulds arose and the mass were pushed over the centre of the front. (Encl. 3)

While inside of the sliding track the increase of moving material with the tendency for deep erosion and faster movement of lower layers were the characteristic features, at the landslide



Enclosure 3. Compiled from aerial Photographs and upon the Results of Geological Mapping of Surface Structures. a) sliding plane and landslide front; b) partial landslide III. at the front of the main landslide; c) widening of the landslide front to the right side.



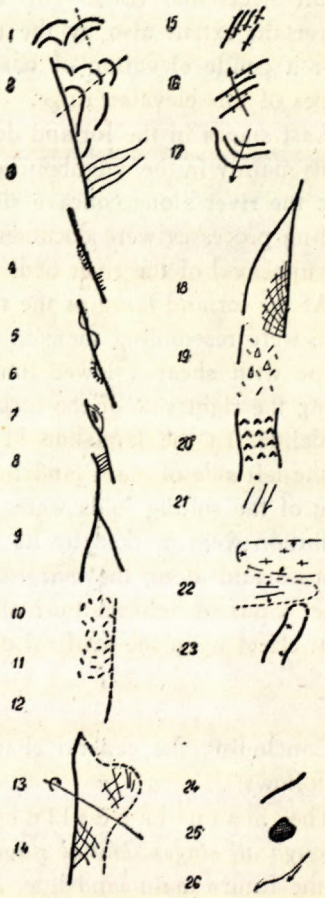
Enclosure 4. Compiled from Geological Mapping. a) Fan arrangement of cracks and fissures; b) Longitudinal and transverse synclines and anticlines; c) Peripheral Mounds and partial landslides in the foreland.

front the features are just the opposite. The strain and movements had the tendency for wide dispersion, slow-down of lower layers movement and the vertical accumulation of masses. This stage indicates the termination of sliding process.

On the Handlová landslide we have observed that the forland of the main landslide covered an area 4 times greater than the frontal part. The first movements pronounced in the forland effected mainly artificial objects as buildings, roads, protective wall etc. Hard and resistant material of these objects were cracked passing later into fissures. After some time the formation of cracks were observed also in the frozen turf. On the contrary to the features related to sliding planes there were no horizontal movements along the fissures. The tension effected the further widening of the fissures. The fissures were fan-like, radially arranged from the margin to the periphery and later due to the stress orientation change mainly to the right side (Encl. 4a).

References to the Encl.

1. area of separation; 2. side separation area; 3. symmetrical subsidence of blocks (style of Graben); 4. sliding plane. Landslide above the adjacent level. Landslide below. 5. side undulation; 6. overturning (overflow) of sliding mass; 7. backward overturn; 8. feather-like fissures; 9. branching of sliding plane (Triangular wedge); 10. irregular arrangement of blocks; 11. blocks oriented in the direction of flow; 12. suggested sliding plane; 13. massive sliding block dissected by fissures; 14. Axis of block bending; 15. errected mounds (folds); 16. mounds with opposite overturn (folds); 17. peripheral mounds (lowangle foldes); 18. deformations of triangular block (inversely overturned mouds opened fissures) at the sliding plane; 19. pinnacles pushed upwards among the blocks; 20. separation area (area of released tension) within the sliding track; 21. open fissures in fan arrangement (dislocation observable) lowangle; 22. transverse depressions (synclines with straightened mounds). Transverse elevations (flat anticlines with longitudinal, open fissures); 23. longitudinal depressions (Low angle synclines); 24. main road; 25. newly formed; 26. Handlovka river.



Further stage was one of the most interesting. Exactly below the landslide front wavy deformations of amplitude were gradually formed. First were the lowest, large, *transverse synclines* and afterwards continuing *backwards* (upward) *anticlines* and synclines follwed gradually of smaller dimensions. Somewhat later longitudinal flat folds were formed along both sides of the forland. Due to the effect of the acting stress the same folds resulted in the masses of landslide III already in stillstand. The formation of longitudinal folds were caused by the effect of mass compression below the landslide front and thus shortening of space. In the center of synclines minute vertical anticlines indicating also the shortening of interior space. The minute anticlines were arranged in several parallel rows up to 5 in number. Their formation was most probably related rather to the escape of matter from below the frozen turf than to the surface deformation of turf due to pressure. The longitudinal marginal fold deformations were the result of side pressure. The forland as a whole thus were compressed and reacted to the strain in all directions. (Encl. 4b) The formation of forland features were influenced to certain extent also by the basement morphology. Transverse folds originated over a gentle elevation of basement while the longitudinal forms over the side slopes of this elevated ridge.

Last stages in the forland development were represented by marginal deformations mainly in the neighbourhood of Handlovka river. Rock and soil blocks slided into the river along concave slip planes. The relations of these phenomena to the sliding processes were documented by the formation of gravitational fissures and the upheaval of the river bed. (Encl. 4c)

At the forland margins the river slopes were far more gentle. The deformations here were resembling these in the landslide front, i. e. peripheral moulds of fold shape with sheared lower limb. These forms were most remarkably developed along the right side of the forland and partly also along the left side of the main landslide. In the landslide II they were formed on both sides. At the contact of the left side of main landslide forland with the right side of landslide III crossing of the rolling folds were observed. (Encl. 4c) The end of landslide forland evolution were marked by its partial "refabrication". In the centre gravitational fissures and along the margins peripheral moulds were formed. Compared with other kinds of deformations all these were rather gentle, though with a catastrophal effect upon the artifical objects.

*

Concluding the general character of Handlová landslide may be summarized as follows:

The main landslide (I) of Handlová developed in a classical form *through all stages. Initial stage* began by a small single landslide at the left side of the future main landslide. 2nd and 3th stage of sliding track delimitation and

the surface deformation were closely related together. The sliding track developed in two stages similarly in the upper and lower segments.

In the *first substage* passed the delimitation of upper segment with the backward development of separation area. In the *second substage* the lower segment of sliding track were formed while the deformation of the upper segment proceeded.

The *landslide front development* passed also in two stages. In the first its left side were formed giving the impulse for movement of landslide III. Simultaneously the surface of lower track segment were deformed. In the second the right side of the landslide front were developed and the whole movement were transfered to the right side.

The *terminal stage* were marked by the stress of the landslide front upon the forland. At the beginning the radial fissures were created later flat transverse and longitudinal synlines were formed below the landslide front. In the Handlovka river valley the dragging of river bed and formation of concave slip planes were observed. Minor peripheral moulds around the margins appeared marking the whole sliding territory. At this stage the landslide may be regarded as a fully developed complicated current landslide with all the evolution stages and seceral substages. (Encl. 6.)

The landslide II was similarly developed. Initrial stage started by sudden subsidence along concave slip planes. 2nd and 3rd stage of the sliding track delimitation were closely related but while the first substage were completed, the second one only began and were not further developed. Formation of landslide front were only poorly pronounced. This type of current landslide may be regarded as partly developed simple current landslide, with several stages and substages not developed.

The landslide III was regarded as undeveloped simple current landslide. Initial stage were started by the direct impulse of the main landslide. 2nd and 3rd stage of the sliding track delimitation passed only along the left side. The surface deformation resulted due to the main landslide effect. The formation of landslide front passed within a short distance from the separation area and sliding track as well.

Landslide IV represents only a small, shallow landslide 2,5 km north of Handlová.

MIROSLAV KUTHAN

TECTONIC DEFORMATIONS OF THE CENTRAL SLOVAKIA NEOVOLCANIC REGION AND THE RELATIONS BETWEEN THE VOLCANISM AND TECTONICS

Analyzing the geological maps of Carpathian neovolcanic regions one basic defect became obvious — the lack of tectonic interpretation. Two main reasons may be considered. The first were the insufficient emphasis upon the volcanologic aspect of the matter, the second an insufficient methodical exploration standard with the lack of criteria for the evaluation of deformations and destructions by the tectonic agents. The problem is further complicated by the variability of the volcanic activity both in time and space controlling the many forms of volcanic products. Adjacent there is still the presence of synvolcanic and postvolcanic tectonics and nearly synchronous destruction of the surface forms due to different reasons. Great majority of the previous geological maps were made by petrographically oriented investigators — the petrography being than the only key to the solution of volcanic problems; this way of study apparently were reflected in the maps by the simple contouring of the rock types without any stress laid upon the geological position or mutual relations between the different volcanic units. Volcanologic aspects were introducted first by Kettner (1928), later by Fiala (1913) and widely applied by Kuthan (1943). Such a qualitative change of methods made possible the solution of the basic structural character of extensive neovolcanic regions together with the principal features and the development of the volcanic activity.

The aim of learning more about the internal structure of the particular volcanic relicts led to the study of the s. c. small forms (after Bernauer 1936, 1939) originated in the course of the volcanic activity or formed and modified later by different processes (hydrothermal, supergene, tectonic etc.). The results of small forms studies (Bernauer 1939; Philipp 1936; Karolus 1958; Kuthan 1958) as well as of the rock matrix in relation to the geologic position of the eruptive body (Mihaliková 1958, 1959) opened the gate for the solution of certain tectonic problems.

The effect of tectonics in the neovolcanic complexes is characterized by several specific features.

Very frequent is the *formation of crushed zones* which may be traced for several 1000 m distances. Such zones are composed of a set of partial parallel stripes where crushing takes place. These partial stripes are usually very thin (from 20 cm up) separated by stripes of the same thickness not effected by the tectonics. The crushing has the form of a dense net of parallel fractures arranged in distances of 1—7 cm resulting in a platy cleavage. The dip of the crushed zones is vertical or nearly vertical. These crushed zones originated in majority in a single tectonic act. The morphological expression of the crushed zones is characterized by the formation of parallel channels and valleys separated by narrow rock ridges. Into such a disturbed zones the erozion was concentrated to such an extent, that the main tectonic orientation ruled also the orientation of the river network (Kuthan — Dublan 1960). Besides the effects of the hypergene process postvolcanic decomposition of rocks is often observable (Forgáč 1958, 1961) demonstrating a relatively great penetration of the crushed zones.

In spite of the very strongly pronounced tectonic effect no slipping either vertical or horizontal was observed. The position of separated blocks remained unchanged. The tectonic lines of this kind dissect the geological formations but they do not form their boundaries (Žarnov in Vtáčnik, Pasenov grúň N of Ban. Štiavnica etc.).

Characteristic sort of tectonic deformations is a *gradual partial slipping of segments*. Within a width of several 100 m the geological unit is teared into a great number of narrow segments (fairly observable on lava-flows) each of them slipped away only for a small distance even a few cm. The total of the partial slip-distances of the marginal segments may go up to several 100 m. The contact planes of the segments are smoothed to a great extent. The fissures between partial segments may be characterised by presence of tectonic breccia, with crushing and displacement of fragments, sometimes rounding of particles and forming of tectonic argillaceous matrix. The dip of these faults ranges between 30°—60°.

The strike-extension of such gradual, partial slip faults so far was not determined due to the conceal of the volcanic. fields. When interpreted on a map this sort of structure is observed as a horizontally or vertically curved body resembling the mega-flexure. In the concealed places such a secondary form may be easily misinterpreted for a primary one originated e. g. by the lava-flow basement with the depressions filled and elevations avoided.

Characteristic tectonic deformations are the *upthrows and downthrows of blocks*. Although they have a different source of origin they appear often in one geologic structure. Tangential forces responsible for tangential deformations mainly of upthrowing character separated the geological units into large blocks several 100 m wide which were dragged in the direction of the acting stress. The release

following as a counter-act of the tangential stress was distributed over the same tectonic lines only with inverse orientation. The block upthrows were replaced by the downthrowing blocks. The fault planes dip ranges in both cases around 30°—60°. By direction change very often the same blocks were revived which originated during the previous tectonic acts but with the character of accompanying subsequent faults. Beside the ordinary release also radial forces became active due to the tendency of compensating the differences of the gravity field. The differences of the gravity distribution originated in the period of tangential stress at some places concentrating enormous amounts of rock masses. These differences were further increased by the magmatic differentiation activized after fading of tangential stress. The radial deformations released substantially the stress in fissures eventually they opened them. Due to the great depth persistence the ways were opened not only for volatile magmatic residues but also for the ascent of eruptive rocks. Radial tectonic deformations are the main structures to which the systems of dyke rocks as well as the ore vein deposits are related. The relations are sometimes so close that the ore veins follow the strike and the dip of dykes and vice versa (Lipold 1869).

Fault lines were several times *revived*. Not only that the release and subsequent widening of fissures occured during several periods but also they were often interrupted by strong compression. Widening of fissures leading eventually to the subsequent filling by precipitated minerals may have been replaced by compression resulting in the deformation and crushing of the filling mainly near the walls of veins and dykes. The repetitions of these acts may be regarded as one reason of pulsating character of the existing ore veins (Koděra 1956, 1960).

Structurally important deformations effecting the neovolcanic regions are the *mega-elevations and mega-depressions* in connection with the latest Carpathian formation process. During the Upper Pannonian the recent mountain regions were lifted with simultaneous subsidence of certain areas filled by terrigene material deposited in a fresh water environment (Buday 1961). The geological reasons for these young movements were expressed recently by Buday (1961) although they were long before suggsted theoretically from the geomorphology.

In the neovolcanic regions the existence of the said structures has been supposed due to the position of relative altitude of the basal volcanic sequence (Kuthan 1961). The basal sequence were deposited in a fluvio-lacustrine environment or even fluvio-lagoonal conditions. The sedimentary character of the complex (Karolusová 1958) together with a uniform petrographic and facial development all over the Southern and Central Slovakia prove the suggestion of a uniform and genetically common origin. This basal complex regarded as pyroclastics of pyroxene andesites in a tuffite facies originated by a synvolcanic destruction of the surface volcanic bodies and by the deposition of the resulted material throughout the area between the Považský Inovec Mts. and Juhoslovenský Kras

carst region. The northern limit of this area was situated in the recent southern slopes of Nízke Tatry Mts.

Basing upon the existence of a uniform basal sequence a gradual uplift of the Kremnické hory Mts may be observed from approx. + 500 m level (near Králiky) to the 900 m level. Similarly the northern margin of the Poľana Mt. is raised from approx. + 400 m level at Hriňová to + 1040 m level in the northern saddle of Ľubietovský Vepor Mt. The dimensions of these large structures are characterized by the parameters $\lambda/2 \doteq 10-20$ km, $v \doteq 400-600$ m. Together with such large deformations analogic structures appear of smaller dimensions $\lambda/2 = 1-5$ km, $v \doteq 60-180$ m. The structures are often accompanied by fractures or gradual block shifting, modifying the primary form of the deformation. The resulting form of the elevation is that apparently asymmetric. One segment (usually the southern) e. g. may be 1—5 km long while the other one (the northern) 0,5—1 km.

The tectonic deformations described may be divided into following groups:

1. Deformations resulting directly from the effect of tangential forces-crushed zones and upthrows,
2. Deformations resulting from the release of tangential stress accompanied by radial forces — downthrows
3. Deformations resulting from the isostatic epeirogene effect upon the blocks of different load — mega elevations and gradual block slipping.

In the tectonic development of Central Slovakia neovolcanics the deformations took place in certain chronologic and space relations in various combinations. The timing of the tectonic activity is based mainly upon the relations of the main tectonic strike orientation and partly also the relations to the eruptive formations. Paleontological-stratigraphical proofs may be found only in regions with contaminated synsedimentary and volcanic formations.

The areal distribution of tectonic orientation is not uniform.

The following chronology of tectonic phases is considered by Kuthan (1948, 1961):

Strike Orientation	Age	Volcanic Phase
W—E (Approx. along the Parallel)	Pontian	Terminal basalt volcanism of Southern Slovakia
NE—SW (Revived Carpathian orientation)	Sarmatian	Final phase of the subsequent volcanism
N—S (Banská Štiavnica or approx. along Meridian)	Sarmatian Middle Tortonian	IIIrd rhyolite phase IIIrd andesite phase IInd andesite phase (partially)
NW—SE (South Slovakia or Sudetian)	Middle Tortonian Lower Tortonian	IInd andesite phase (partially) Ist andesite phase?

The NW—SE orientation is characteristic for the eastern (southeastern) regions e. g. Cserhát Mts in Hungary. Toward the central part this orientation is only very slightly pronounced, while in the northwestern and western parts it appears mainly in the pre-volcanic formations and within the volcanics along the rejuvenated tectonic lines. The relation of the Ist phase volcanics to the discussed tectonic orientation is not so clear as e. g. that of the IInd phase in the south-eastern periphery of the Central Slovakia neovolcanics or even in Cserhát Mts where andesite dykes several kilometers long strike along this direction.

N—S orientation is concentrated in the centre of the region with the axis running along the line connecting the towns of Kremnica and Banská Štiavnica. N—S faults range within N 5 E—N 30 E, rather rarely N 5 W—N 30 W. In this direction the tectonic activity nas been several times repeated, and the fissures served as ascent channels for a great number of eruptive masses. (E. g. part of the IInd andesite phase, IIIrd andesite phase and also the IIIrd rhyolite phase.) To the same fissures was related also the escape of magmatic residual volatiles, leading to ore-formation. (Polymetalic mineralization of Banská Štiavnica type and gold-silver mineralization of Kremnica type. Volatiles led also to certain concentration of Si O_2 on the surface in the form of geysirites.

NE—SW direction is a herited structure of the Carpathian basement, which may be traced diagonally across nearly the whole neovolcanic region of Central Slovakia. Several main tectonic lines (e. g. Šahy—Ábelová—Tuhár, Tekovské Trsťany—Sebechleby, Levice—Anton—Breziny) separating in general certain geological units, appear morphologically as very distinct steps and gravimetrically manifested by an extraordinary concentration of isolines into a narrow zone. Eruptions of the terminal phase of subsequent volcanism with this tectonic activity are believed to be in close connection.

W—E oriented tectonics effected the whole area of Central Slovakia neovolcanics; the effect is mostly pronounced in the central and eastern parts where the volcanics form a uniform mass. In the western part where the volcanics occur more or less as isolated relicts or apophyses the relations between the elevation axes are not so clearly pronounced. The W—E oriented tectonics effected the river network to a great extent mainly in the central part. After the termination of the volcanic activity especially of the IInd andesite phase the rivers were flowing more or less directly down to the Hungarian lowland. Relicts of the river deposits are preserved at many places of the Krupinská vrchovina Hills. Wavy arching of this territory closely related to the fold fractures prevented the direct southward flow of the rivers. The N—S river network orientation has been replaced over a wide area by the W—E orientation. (E. g. Hron river bow from Zvolen to Žiarska Kotlina depression the s. c. Zvolen—Kriváň swell, etc.) The extrusions of the terminal basalts are believed to be also related to this strutural orientation mainly to the crossings with the NW—SE system.

The iregular distribution of the main structural orientations is regarded to be in close connection with the relations between the localisation of individual neovolcanic territories of Central Slovakia and Alpine and pre Alpine basement structures. Great importance is attached to the fault zone of Central Carpathians (Kubíny 1962a, b). The fault zone dissects the Carpathians approximately in the N—S direction extending from the western sigmoidal deformation of the Klippen belt (Andrusov 1926) across the central part of the Central Slovakia neovolcanics farther southward into the fault system of Budapest in Hungary. This fault zone probably of pre-Alpine origin and several times rejuvenated has been intensely revived in Neogene during the period of subsequent volcanism (Kubíny 1962).

The Central Carpathian fault zone is composed of parallel fractures with horizontal strike-slip movements. The accompanying deformations were expressed in the opening of fissures specially at the zone margin or even outside of the fault zone at places where the tangential forces resulted only in the disturbing of geologic units. Fissures belonging to this system opened the way for the extrusion of products of certain volcanic phases. Intensity of movements together with the long duration and several times repeated activity of this fault zone subtantiall diminished the effect of other tectonic directions.

In conclusion the acting tectonic lines of the Central Slovakia Neovolcanics may be genetically distributed into following groups:

a) NW—SE, N—S, NE—SW tectonic directions have the common source in the tangential (and antithetic) forces and therefore are characterized by uniform deformations, crushed zones, upthrows and downthrows.

b) The W—E tectonic orientation is related mainly to the isostatic compensation of the gravity differences of particular geotectonic units characterized by the large scale elevations accompanied by partial undulations and locally modified by the gradual slipping of segments.

Relationship between the volcanism and tectonics

The question of relationship between the volcanism and tectonics includes two basic problems — the relations of the surface volcanism and the relations of subsurface volcanism to tectonics. The problem may be demonstrated on the relations of eruptive rhyolite — andesite formation to the tectonic deformations caused by the tangential and antithetic forces, as well as the relations between plateau basalts and consolidated — cratogene areas effected only by epirogene movements accompanied at inverse sectors by the deep fracturing of the earth crust with opening of the vent fissures for the respective extrusions.

The basic relations of plutonism — with orogene volcanic members rhyolite, andesite — to the tectonics must be searched already in the syntectonic phase of orogeny i. e. in the main Alpine folding period, when the maximum concentration and orientation of kinetic energy took place. Its effect activized the mobilization of granitoid masses. Extensive migmatizing and migmatite fronts originated with a granitic nucleus pressed as a diapiric form into the mantle or intruded after gas enrichment. The passiveness or activity of the granitic masses depended upon the energetic tension. Geotectonic position of the granitic mass and the orientation of the migmatizing front were determined by the resulting vector of the kinetic energy. The homogenity of granitic masses in a single tectonic unit as well as in one orogenic system is based upon the abovementioned genetic relationship.

Representatives of these young formations are the *Gemeridy granites*. There are no equivalents of such rocks proved to exist in other belts of West Carpathians.

The granitization effects in the Kohút zone were explained by the activity of the far reaching migmatite front, originated in the main Alpine period.

The activity of granitic masses mobilized during the syntectonic stage and consolidated in situ or in the form of mantle intrusions were terminated. This act caused the strict separation of synorogene volcanism from the further volcanic stage i. e. late orogenic accompanied by the subsequent volcanism.

The evolution of granitic masses which during the syntectonic phase remained unconsolidated or were not fixed in the mantle proceeded further howerer under changed conditions. The frontal migration of migma proceeding along the direction of acting stress slowed down and granitization process died out. During the late orogenic stage the oriented stress was fading and replaced by hydrostatic pressure. In such conditions differentiation replaced the granitization process modified locally by assimilation. Palingenic, granitic magma originated during the syntectonic phase of the orogeny was further developed during the late orogenic stage unless it was not as a consolidated element involved in the mountain building. The scheme of this evolution was the following: *granite, granodiorite quartz diorite, granogabbro, quartz gabbro.*

Geotectonic position of these differentiates is controlled by the most favourable genetic conditions with regard to the orogenic back-land, which is characterized by the prior fading of tangential forces and a quiet differentiation of the palingenic granitic magma under conditions of purely hydrostatic pressure. The *acidic rock differentiates* beside the apparent intrusive forms demonstrate in some cases also slight granitic-metasomatosis while the basic differentiates have an apparent strictly intrusive position.

The differentiation scheme of *abyssal bodies* ruled also the conditions of the subsequent volcanism extrusives: *rhyolite — andesite — basalt.*

A very close petrochemical relations between the abyssal rocks and extrusives is reflected in the relation of acidic to the basic rocks. The differentiation of the palingenic granitic magma is characterized by reduction of mass of every younger differentiation member to a half rate of the preceding member. The final basic members of the differentiation thus form only a small fragment of the whole magmatic mass. The same is of course applied to the extrusive equivalents, which may be often missing or replaced by compound rocks of andesitic character with intratelluric minerals being already extremely basic (plagioclases).

Such close petrochemical relations between the abyssal and extrusive rocks concerning the differentiation scheme as well as the ratio of abyssal rock differentiates to the succesion of extrusives led in the past many authors to the conclusion that the effusive rocks were considered as direct equivalents of deep seated masses (e. g. andesites-diorites, Judd, Szabó). The latest investigations in the Hodruša—Vyhne vicinity show however that although the extrusive rocks of the subsequent volcanism represent a petrochemical equivalent of abyssal bodies (andesite-diorite) they may be the product of younger-geotectonic, magmatic stage (Rozložník 1961). The conditions for such a process have remained uncertain while it has been learned

however that the structural and textural development as well as the relation of mineral components characteristic for effusive rocks has been definitely proved also for the subvolcanic forms. (Atanasiu, Dimitrescu, Semeka 1953; Mihaliková Á 1958).

The territorial distribution of the surface volcanism reflected the geotectonic position of the abyssal differentiates of palingenic, granitic magma. The rich representation of subsequent volcanism in the Carpathian back-land indicate the favourable conditions of this area also as of an orogenic back-land. The assymetric structure of Carpathians as the result of orientation of tangential forces is apparently reflected by the asymmetric development of subsequent volcanism concentrated to the southern internal margin while in the northern — external margin only scarce rudiments of volcanic activity are observed.

The relationship of the *surface volcanic vents to the structural lines* in the Central Slovakia neovolcanic region has been discussed in the scheme of tectonic activity, indicating a close connection between the volcanic vents of certain volcanic phases and the tectonic lines. These lines were essential for the extrusions of fissure character observable e. g. on the relicts of the IIIrd andesite and IIIrd rhyolite phase as well as the formation of andesite dykes several km long in the Hungarian Cserhát Mts.

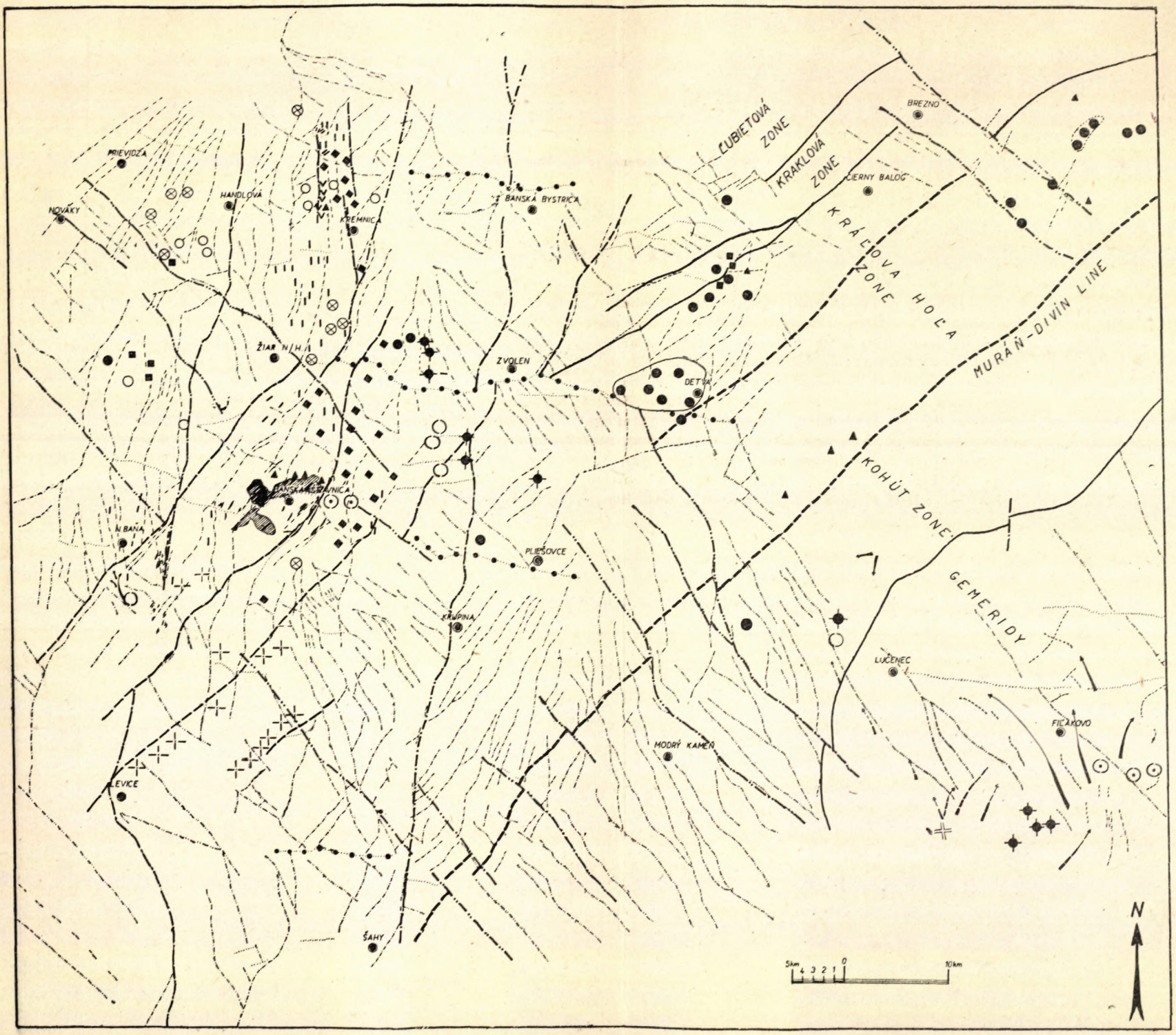
Beside such an apparent relation there is a great number of iregular concentration of volcanic vents in certain areas. The form of these necks and the character of the concentration have been exposed by the erosion at places where it has reached the pre-volcanic basement (Fabova hoľa Mt., Muránska plošina plateau). The neck-section is circular or elliptical, the dimensions rarely exceeding 20 × 20 m often reduced to 1 × 2 m. The exact number of these volcanic vents per 1 sqkm. is difficult to determine due to the extensive recent cover. It is estimated however to 4—6 vents per sqkm.

Such an arrangement of volcanic vents created for the subsequent volcanism a specific form — group volcano where instead of concentration of activity and formation of a single stratovolcano the eruptive centres alternated thus leading to the formation of an extensive volcanic block composed of a great number of partial volcanos in various stages of evolution and dimensions.

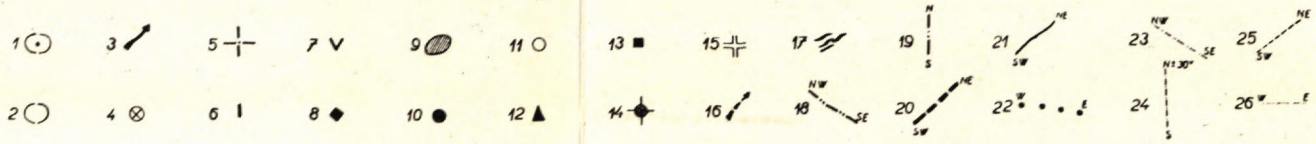
Conditions for the formation of such a volcanic apparatus must be seen in the palingenic origin of the abyssal equivalents of subsequent volcanism as well as in the position of the deep seated body in relation to the tectonic structures.

The character of the *subsequent volcanic activity* is the result of the palingenic origin of the eruptive rocks. Due to its origin the magma rich in volatiles vigorously exploded after reaching the surface predominantly in the Katmai, Mont Peleé style, less in the Stromboli style. The eruptive explosivity is reflected in the predomination of pyroclastics over effusive rocks the ratio being approx. 9:1. From among the pyrolastics predominating are chaotic block tuffs deposited from the glowing clouds, ladus or lahar, event. by the explosion dispersed eruptive

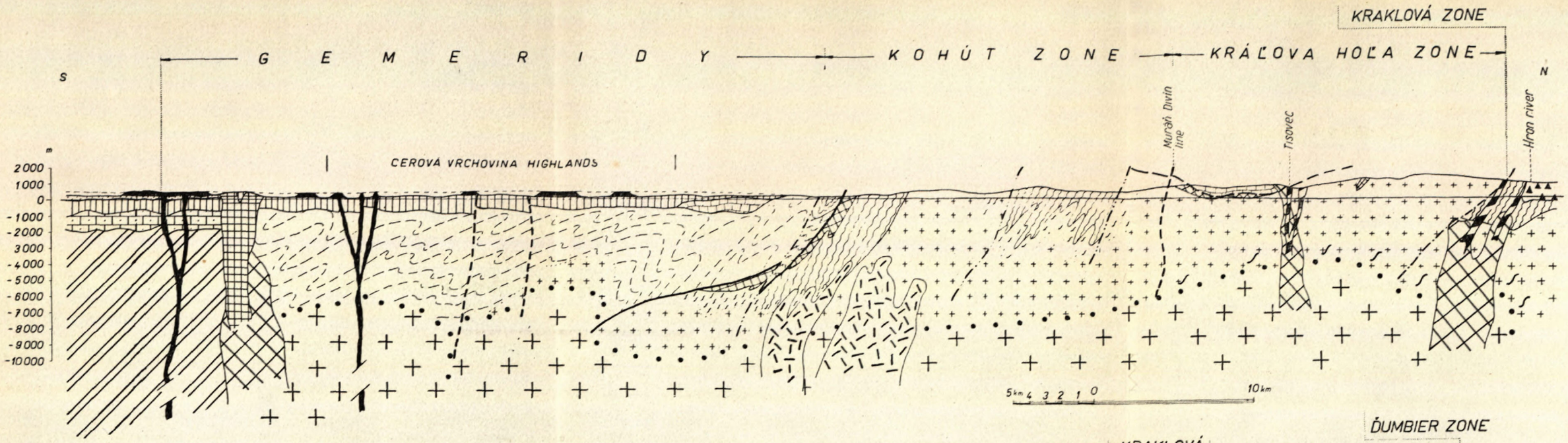
The Map-scheme of Volcano-Tectonic Structures in the Central Slovakia Neovolcanic Region

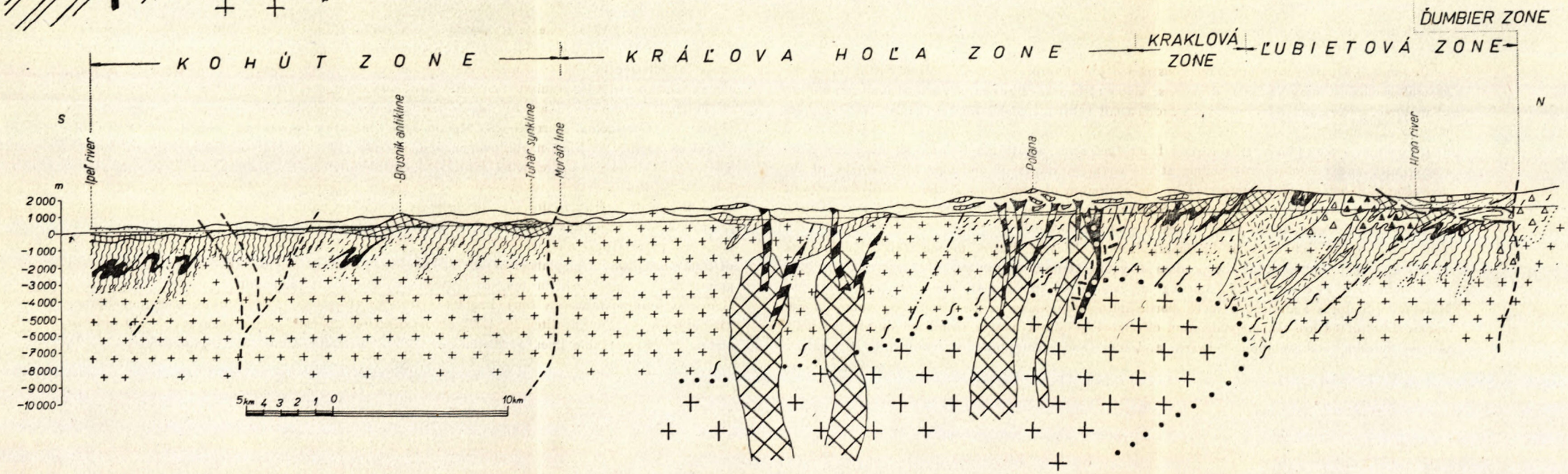


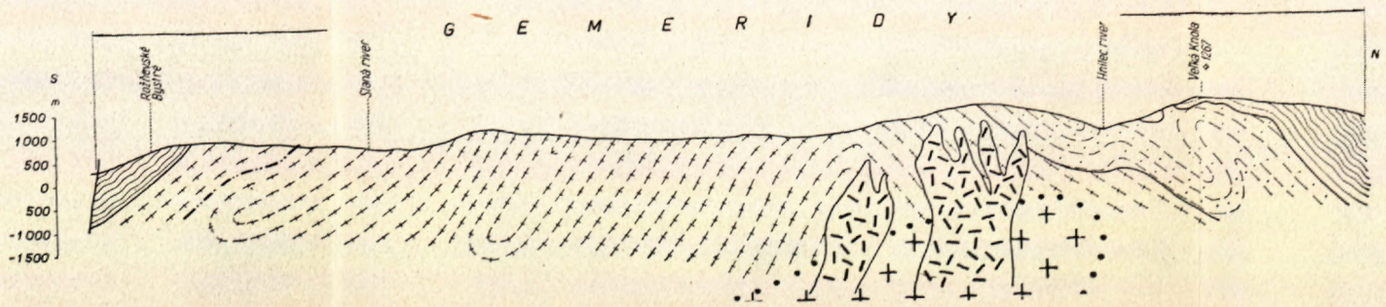
Reference to the Map-scheme

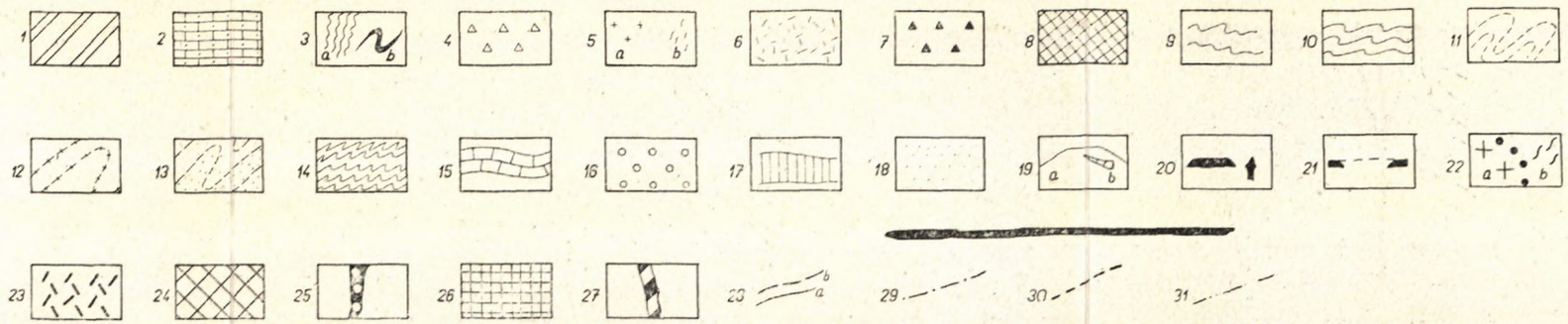


Final volcanism: Final basalt centers localised (1) supposed (2) orientation of basalt flows (3). Preparatory phase basaltoid andesite (4). Subsequent volcanism: Terminal phase, supposed areas of volcanic activity (5), IIIrd rhyolitic phase (6) — orientation of signs indicate the axis of eruptive area young granitoid mass (supposed by Böhmer in Kremnica) (7), IIIrd andezitic phase (8), dacite dykes area (9), IInd andesitic phase, area of eruptive activity (10), localized, (11) supposed; diorites and granodiorites (12); IInd rhyolitic phase (13); Ist andesitic phase (14); Ist rhyolitic phase — areas of eruptive activity supposed to be in Hungarian territory (15), directions of their material transportation (16). Ore veins (17). Regional tectonic structures: Sudetian (18) or Skýcov line (Biely), South Slovakian (Čechovič) Lines of Meridional direction (19) or Central Carpathian fault zone (Andrusov and Kubíny), revived lines of Carpathian direction (20a), Muráň — Divín line and overthrust planes between the belts (20b), Parallel orientation (21) — Zvolen — Kriváň fault. *Adjacent tectonic lines of minor extension and little amplitude:* Sudetian (22), Meridional or Banská Štiavnica direction (23), revived Carpathian (24), Parallel direction (25).


KRAKLOVÁ ZONE
G E M E R I D Y
KOHÚT ZONE
KRÁĽOVA HOĽA ZONE
S
N
m
2000
1000
0
-1000
-2000
3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
CEROVÁ VRCHOVINA HIGHLANDS
Muráň Divín line
Tisovec
Hron river
5km 4 3 2 1 0
10km


ĎUMBIER ZONE
KOHÚT ZONE
KRÁĽOVA HOĽA ZONE
KRAKLOVÁ ZONE
ĽUBIETOVÁ ZONE
S
N
Ipeľ river
Brusník anticline
Tuhár synkline
Muráň line
Poľana
Hron river
m
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
-10000
5km 4 3 2 1 0
10km


G E M E R I D Y
S
N
m
1500
1000
500
0
500
-1000
-1500
Rožňavské Bystré
Štiavnica river
Hnilec river
Veľká Kopa



References to Cross — Sections

Geological Cross — sections were constructed and interpreted by O. Fusán basing upon the general geological maps 1:200 000 (sheets: Zvolen, Banská Bystrica, Vysoké Tatry). Evolution of plutonic masses and relations to the products of subsequent and final volcanism were supplemented by author.

Cross — Section I is carried from Ipeľ river across the Poľana Mt. into the Hron river valley (near Podbrezová) ending at the southern slopes of Ďumbier Mt. Geology of the neovolcanic basement were interpreted by the projection of conditions at the eastern neovolcanic margin into the cross — section plane. Section indicates the relations between young granites, rhyolites and andesites to the deep — seated plutonic rocks.

Cross — Sections II is runnig from Rožňavské Bystré to the Veľká Kuola peak (1.267 m a. s. l.), interpreting the position of young Gemeridy granites.

Cross — section III Starting at Salgótárján in Hungary the line is crossing the Karanč — Siatoroš andesites, Tisovec diorite intrusions ending in the Hron river valley at Závadka. Interpreted are the migmatization effects of granitoid masses mobilized during the main Alpine folding and relation between andesites and geotectonic structures. 1. Crystalline and Paleozoic of Alföld shield. 2. Mesozoic of Central Hungarian Hils (Magyar középhegység). 3. Algonkian (?) to Lower Paleozoic (?) sedimentary complex (a) with intercalations of basic rocks (b) effected by epi — to mesozonal metamorphosis. 4. Orthogneiss (Proterozoic ?). 5. Hercynian and older (?) granites (a) with adjacent migmatites (b). 6. Hypoabyssal intrusions of Permian volcanics — granite porphiries, granites, granodiorites. *Crystalline Core Mantle* (7—8): 7. Continental Permian. 8. Metamorphic Mesozoic sometimes with Upper Paleozoic. 9. Krížna nappe, 10. Choč nappe. *Nappe of Gemeridy* (11—14): 11: Gemeridy Paleozoic in the basement of Fiľakovská Vrchovina Hills — undifferentiated. 12. Gelnica series (Cambrian — Silurian ?) Rakovec series (Devonian ?) 14. Upper Paleozoic 15. Mesozoic. 16. Upper Cretaceous filling of interior basins. 17. Sedimentary complex Chattian—Aquitanian. 18. Sedimentary complex Lower and Middle Miocene. 19. Relict of subsequent volcanism (redeposited and autochtonous pyroclastics) (a) with effusive (b), in majority of IInd andesitic phase. 20. Relicts of final volcanism — plaplateau basalt. 21. Suggested extension of plateau basalts. 22. Suggested granitoids (a) mobilized in the main Alpine folding with migmatite front (b). 23. Young Gemeridy granite intrusions (including the granite of Hrončok ?). 24. Diorites and granodiorites (Banatites s. l.) 25. Rhyolites 26. IIIrd phase andesites. 27. IInd phase andesites. 28. Overthrust planes. 29. Remarkable lines od disjunction. 30. Remarkable faults. 31. Upthrows.

material welded into ignimbrites or the form of thick layers of fine-grain tuffs covering tremendous areas. For example the lower rhyolite tuff is distributed over Northern Hungary, Southern Slovakia, southern part of the Carpathian Ukraine and even Roumania, where it is called the „Dej tuff."

The relicts of group volcanos are related to the areas around tectonic lines of upthrowing character, accompanied by adjacent lines where the fissures after the release of tension or retreat movement did not open. The tectonic agitation around the structures disturbed the balance of hydrostatic pressure leading to the release of volatiles at the areas of decreased loading and consequently the penetration of vents near the surface in an explosive manner. An example of such a volcano may serve the Poľana Mt. situated at the contact of two tectonic units — the zone of Kráľova hoľa Mt. and the zone of Krakľová (Húsenica J., 1959; Kubíny D. 1958). Another example is the area of andesitic necks and dioritic bodies in the Tisovec—Fabova hoľa vicinity, where the same upthrow contact of both the tectonic zones is crossed by a young NW—SE structural line (Extending north from Tisovec toward the Michalová—Brezno n/Hr depression).

The role of tectonis has not been limited only to the arrangement and orientation of the volcanic vents and thus the formation of the particular volcanic apparatus. The tectonic played a basic role in the formation of the type of volcanism. Terminated differentiation of palingenic granitic magma has been expressed at the surface by the extrusion of basic rocks resulted in the consolidation of mobile zones. The herited gravitational irregularities were balanced by the epirogenic movements while in the conditions of inversion by faulting which penetrated deep into the earth crust.

The subsequent volcanism characteristic for the late orogenic stage is replaced by the *terminal volcanism,* with the production of *flood basalts.* The basalts have formed large plateaus extending from southern slopes of Carpathians through the Lučenec—Fiľakovo area down to the Northern Hungary. The character of final volcanism eruptions is from that of subsequent entirely different. The pyroclastics represent only a small amount of the total extrusive masses. The eruptions had the character of quiet effusions forming small slag-craters (Remnants at Ragač).

The *plateau basalts* are further characterized by the formation of only a minute amount of differentiates. The ratio of acidic differentiates in the flood basalt areas reached less than 1 % of the whole extrusive mass. The low explosiveness and the petrochemical character of plateau basalts according to v. Bemmelen (1950) is due to the low content of resurgent gases. Plateau basalts are believed to be derived from the juvenile alkaline-basaltic magma which in the upper parts has been contaminated by the assimilation of dry sialic rock masses of the surface crust.

The change of the tectonic style from the Alpine-type to a germano-type has been

characterized by the transition of the synorogene plutonism through subsequent volcanism and terminated by the final volcanism. Beside such a substantial change in the style of volcanism the geological evolution of Central Slovakia neovolcanics bears evidence of the synvolcanic tectonics playing also a definite part in the succesion and character of eruptive rocks.

The succesive order of eruptive phases and their products is indicated by the following scheme (Kuthan 1962):

Formation	Age	Phase	
Plateau basalts	Recent — Uppermost Tertiary	Main	Final volcanism
Basaltoid andesites Andesitoidal basalts	Uppermost Tertiary	Preparative	
Vitrofyric andesites Rhyolites, rhyodacites	Sarmatian	Terminal IIIrd rhyolitic	Subsequent volcanism
Coarse porfyritic andesites, biotite-hornblende andesites dacites and dacitoid andesites of the same mineralogic composition	Sarmatian	IIIrd andesitic	
Pyroxene, andesite (± hornblende, biolite, olivine)	Sarmatian Upper Tortonian	IInd andesitic	
Rhyolites, rhyodacites, dacites	Middle Tortonian	IInd rhyolitic	
Pyroxene-hornblende andesites partly autometamorphosed	Lower Tortonian	Ist andesitic	
Rhyolites, rhyodacites	Burdigalian	Ist rhyolitic	

If this succesion scheme is compared with the Neogene tectonic scheme of Seneš (1961) the following relations are apparent:

Stage of tectonic phase	Age of stage of tectonic phase	Eruptive phase
I Rhodanian	Pannonian / Sarmatian	Terminal phase of subsequent volcanism
I Attican	Sarmatian / Upper Tortonian	IIIrd rhyolitic IIIrd andesitic IInd andesitic
IV Late Steyrian	Upper Tortonian / Lower Tortonian	IInd andesitic IInd rhyolitic
III Late Styrian	Lower Tortonian / Carpathian	Ist andesitic
II Early Steyrian	Carpathian / Helvetian	In the Central Slovakia neovolcanic region volcanic activity so far not determined
I Early Steyrian	Helvetian / Upper Burdigalian	
III Savian	Upper Burdigalian / Lower Burdigalian	Ist rhyolitic

According to Buday (1959, 1960) and Seneš (1959a, b, 1961) the upheaval and formation of the West Carpathian central units passed in three stages:

1. In the Upper Burdigalian the substantial paleogeographic inversion of the Carpathian region took place.

2. Between Carpathian and Lower Tortonian the barrier of Southern Slovakia was raised and the internal basins initiated.

3. Beginning from the middle Tortonian the inversion proceeded with the culmination in Pontian. In this stage the orographic units of West Carpathians were formed.

The *eruptive activity* of subsequent volcanism reflected in the Carpathian evolution (ommitting the products transported from adjacent territories) indicate, that the rhyolite volcanism is directly connected with the movements of lifting character or that the volcanism directly follows them. On the contrary the andesite volcanism is related to the subsidence and after Seneš (1958) its products are predominantly of synsedimentary character.

The change in chemical composition of effusive rocks reflects the abovementioned differentiation scheme. The relation of the rhyolite volcanism to the lifting tectonics and of the andesite volcanism to the subsidence led to the conclusion that all these movements disturbed the conditions of differentiation and the process of differentiation as well. The changes in the pressure due to the upheaval resulted in a spontaneous separation of volatiles of granitic nature thus giving the basis for the rhyolite volcanism. During the subsidence movements however the extruding magma had the petrochemical character of that very stage. Such a suggestion is further supported by the fact that the ryolite volcanism is keeping steady petrochemical character while the volcanism of andesites shows the tendency of increasing its basicity coresponding to the general trend of differrentiation. Deviations from this general scheme are due either to the processes of assimilation (occurences of relicts of enalogene enclosures — Fiala 1953) or tectonic agitation of some areas during a long period. Such a very distinctive anomaly is the relation of the IIIrd andesite phase to the IIIrd rhyolite phase. The products of the IIIrd andesite phase are distributed mainly in the areas of the Central Carpathian Fault zone, characterized by a long-duration and several times repeated tectonic activity.

It may be finally concluded that the relations between the volcanism and tectonics are not limited only to the localization of volcanic vents and the formation of a certain volcanic apparatus. The tectonics determines also the type of volcanism (subsequent and final) and even the petrochemical character of volcanic products determining thus the character of eruptions.

Translated by J. Kováčik

D. Štúr Institute of Geology, Bratislava

REFERENCES

[1] Bemmelen R. W., 1950: On the origin of the igneous rocks in Indonesia Geologie en Mijubouw 12. — [2] Bernauer F., 1936: Bewegungs- und Schwundformen von Laven.

Zeitschrift für Vulkanologie XVII, Berlin. — [3] Bernauer F., 1939: Die Italienreise der Deutschen Geol. Gesellschaft und dabei behandelte Fragen. Zeitschrift d. d. Geol. Gesellschaft 91, Berlin. — [4] Buday T., 1959: Vývoj neogénu v západních Karpatech. Časopis min. geol. 4, Praha. — [5] Buday T., 1960: Tektogeneze neogenních pánví západních Karpat a jejich stavební styl. Geologické práce, Zoš. 60, Bratislava. — [6] Fiala F., 1931: Coupe des stratovolcan d'andésite á pyroxene au Sud de la station Horná Štubňa. Quide des excursions dans les Carpathes occidentales. Knihovna SGÚ 13, Praha. — [7] Fiala F., 1955: Některé uzavřeniny z andezitů Slovenského Středohoří. Sborník ÚÚG XXI, Praha. — [8] Fiala F., 1955: Some xenoliths from the andesites of the Slovenské Stredohorie. Sborník ÚÚG XXI, Praha. — [9] Forgáč J., 1958: Beitrag zur Kenntnis der Umwandlungen Slowakischer Neovulkanite. Geologické práce, Zoš. 49, Bratislava. — [10] Forgáč J., 1961: Studium der Veränderungen der Neovulkanite in der Slowakei. Geologické práce — Zprávy 23, Bratislava. — [11] Húsenica J., 1956: Die geologischen Verhältnisse der Kyslinky im Gebiete der Poľana. Lesnícky časopis II, Zvolen. — [12] Húsenica J., 1958: Beitrag zum geologischen Bau des polygenen Vulkans der Poľana. Geologické práce, Zoš. 49, Bratislava. — [13] Karolusová — Kočiščáková E., 1958: Beitrag zur Problematik der pyroklastischen Gesteine. Geologické práce, Zoš. 49, Bratislava. — [17] Karolus K., 1958: Beitrag zu den makrotexturellen Merkmalen der Intrusiv- und Effusivgesteine. Geologické práce, Zoš. 49, Bratislava. — [15] Karolus K., 1958: Príspevok k makrotexturálnym znakom intruzív a efuzív. Geologické práce, Zoš. 49, Bratislava. — [16] Klinec A., 1960: Niekoľko poznámok k územiu styku gemeríd s veporidami. Geologické práce, Zprávy 20; Bratislava. — [17] Koděra M., 1956: Paragenese und Chemizmus des Theresia-Ganges in Banská Štiavnica. Geologické práce, Zoš. 42, Bratislava. — [18] Kubíny D., 1958: Poznámky o geológii, tektonike a metamorfizme veporíd južne od Hrona. Geologické práce, Zprávy 12, Bratislava. — [19] Kubíny D., 1962. Geologická pozícia Starohorského kryštalinika. Geologické práce, Zošit 62; Bratislava. — [20] Kuthan M., 1943: Geologische Karte der Slowakei. Blatt Zlatá Baňa (4467/L). Štátny geologický ústav, Bratislava. — [21] Kuthan M., 1948: The undation volcanism of the Carpathian orogene and volcanological survey of the northern part of the Prešov Mountains. Práce ŠGÚ 17, Bratislava. — [22] Kuthan M., 1958: Probleme des jungtertiären Vulkanismus der Slowakischen Karpaten. Geologické práce, Zoš. 49; Bratislava. — [23] Kuthan M., 1959: The young tertiary volcanism in the north-eastern part of central Slowakia. Sborník k osemdesátinám akademika F. Slávika, Praha. — [24] Kuthan M. — Dublan L., 1960: Mapa riečnej siete v Štiavnickom pohorí. Ročná zpráva za rok 1960. Manuscript; Archív Geofondu, Bratislava. — [25] Kuthan M., 1961: Hlavné geotektonické prvky stredoslovenských neovulkanitov. Referát sekcie neovulkanitov prednesený na II. celoslovenskej geologickej konferencii. Manuscript. — [26] Lipold V. M., 1867: Der Bergbau von Schemnic in Ungarn. Jahrbuch d. k. k. geol. Reichsanstalt, Wien. — [27] Mihaliková A., 1958: Verfolgung der Entwickelung der Grundmasse einiger Slowakischer Neovulkanite. Geologické práce, Zoš. 49, Bratislava. — [28] Mihaliková A., 1959: Verfolgung der Entwicklung der Grundmassenstruktur einiger Basalte aus der Umgebung von Fiľakovo. Geologické práce, Zoš. 54, Bratislava. — [29] Philipp H., 1936: Bewegungen und Textur in magmatischen Schmelzflüssen. Geologische Rundschau 27, Stuttgart. — [30] Rozložník L., 1961: Ročná zpráva o geologicko-výskumných prácach prevedených v r. 1961 na probléme „Výskum hornín Štiavnického ostrova" — stať o geotektonike. Katedra geológie a mineralógie VŠT Košice — Manuscript. — [31] Seneš J., 1959: Súčasné znalosti o paleogeografii centrálnej Paratethydy. Geologické práce, Zoš. 55; Bratislava. — [32] Seneš J., 1959: Entwicklungsphasen der Paratethys. Congr. Néog. Méditerran, Wien. — [33] Seneš J., 1961: Paleogeographie des westkarpatischen Raumes in Beziehung zur übrigen Paratethys im Miozän. Geologické práce, Zoš. 60, Bratislava.

GEOLOGICKÉ PRÁCE, ZPRÁVY 28

Vydal Geofond, redakcia Bratislava roku 1963
vo Vydavateľstve Slovenskej akadémie vied v Bratislave

Hlavný redaktor člen-korešpondent ČSAV D. Sc. Michal Maheľ

301-03. Daň 5 %. 52137/62-VO. Papier 5154-01, 70 × 100, 80 g.
AH 16,76, VH 17,22. Vytlačila Pravda, vydavateľstvo ÚV KSS
v Bratislave písmom garmond Kolektív. K-03*31248

Cena brož. Kčs 20,—
56/III-3

Fig. 1. Northoward overturn (induced tectonic style) of lower triassic quartzites near Lipt. Lužná.

Fig 2. Folding of slightly metamorphosed neocomian marlstone sequence (series equivalent to that of Veľký Bok). Ľubietovská dolina.

Fig. 3. Folded beds of Ľubietovská dolina valley.

Fig. 4. Folding of bedded spongolite — crinoidal limestones of Vysoká series — Lower Liassis. Sološnická dolina valley.

Fig. 5. Minute folding of lower liassic bedded spongolite — crinoidal limestones. Choč Unit — Biely Potok valley. Strážovská hornatina.

Fig. 6. Minor folds (dimensions ranging in metres) in tithonian bedded limestones of Krížna Unit. Zázrivská dolina valley.

Fig. 7. Minute folding of neocomian marlstones. Krížna unit north of Valaská Belá, Strážovská hornatina Mts.

Fig. 8. Straightened folds of Krížna Unit — neocomian marlstones near the tectonic line of Klačno.

Fig. 1. Break of the bedding in the thin-bedded laminated limestone of the Lower Lias. Liptovská Teplička.

Fig. 2. Small folds in the thin-bedded limestone of the upper part of Lias. Liptovská Teplička.

Photo 1. Flat sedimentary folds resting in normal supperposition. Reversed bed sequence with the bottom lamination. The slump body does not deform the underlying bed. Movement from left to right. Bánovská kotlina basin, Radiša.

Photo 2. Bending of underlying beds under the load of sedimentary folds, compression, rolling and tensile. Poronin, Poland.

Photo 3. Detail of fold with flute casts well preserved. Longitudinal fold axis parallel to the flute cast axis. Poronin, Poland.

Photo 4. Complicated development in the right flank of the slumping body. The movement acquired an iregular character with loss of layer continuity. Holumnica.

Photo 5. Pull — apart structure. Flexure — like bend leyered sequence freely floating surrounded by clastics of coarse grain. Šarišské hory mts. Ovčie.