MILAN MIŠÍK*

TRACES OF SUBMARINE SLUMPING AND EVIDENCES OF HYPERSALINE ENVIRONMENT IN THE MIDDLE TRIASSIC OF THE WEST CARPATHIAN CORE MOUNTAINS

(Figs. 1–21)

Abstract: In Middle Triassic carbonate rocks in the „Gutenstein" Limestones of the Low Tatra (locality Donovaly) and the Small Fatra (locality Polom near Žilina) slumping bodies of very similar character have been ascertained. They are made up of blocks and slabs of yellowish, slightly marly, laminated limestones, frequently deformed in hydroplastic state. They are accompanied with fragments of dark-grey dolomites and limestones of various textures, then endostratic breccias and at one of the localities also with neptunian dikes. An important indicator are moulds after salt crystals in yellowish, slightly marly laminated limestones as well as the presence of dolomite pseudomorphs probably after gypsum crystals in limestones. These evidences of very shallow-water and at places of hypersaline conditions throw a new light on the question of possibility of primary origin of a part of dolomite strata of the Middle Triassic in the Carpathians.

Introduction

The Middle Triassic of the Carpathian core mountains was considered as very monotonous and probably that's why lithological and microfacies study of it left backward. Detailed description exist only by J. Kotański (1958, 1959, 1963) of the High Tatra, however microscopic, mineralogical and geochemical investigation also has not been carried out there. I am convinced that also except dasycladaceans Middle Triassic strata offer enough facts suitable for environmental interpretations; I have tried to call attention to some of them in this paper. Numerous detailed studies, however, will be necessary for more complete reconstruction of sedimentation to be available. Correlation of the profiles of the individual core mountains will then enable us to obtain reliable support for tectonic interpretation.

In literature dealing with Czechoslovak Carpathians submarine slumps has been so far described from the Neogene (T. Buday, I. Cícha, P. Čtyroký 1959), from Paleogene of the Flysch-Belt and Central Carpathians (R. Marschalko, J. Volfová 1960, T. Ďurkovič, T. Koráb 1961, R. Marschalko 1963, 1966), from the Cretaceous of the Klippen Belt (V. Scheibnerová, D. Andrusov 1963). From the Triassic it has not been described up to present. I have ascertained slumping at two localities, 0.5 km ESE of Donovaly (Low Tatra) and at the mountain Polom near Žilina (Small Fatra). Their description follows.

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Locality 1. Abandoned quarry 0,5 km ESE of Donovaly, at the road towards Korytnica (fig. 1)

Tectonic ranging of these Middle Triassic strata to the Envelope Series or Krížna Unit is uncertain. J. Jaroš (1966) ranges it in the Envelope (Donovaly) Unit of the Low Tatra. The position shows however that it can be a normal stratigraphical member of the Krížna nappe. This possibility would be attested also by the fact that Middle Triassic limestones of the Envelope Series at elevation point 1055.8 — Bánik, less than one kilometer far from there, are distinctly affected by dynamic metamorphism, not observable at the locality given. The question of tectonic ranging can be solved after detailed lithological study of the Middle Triassic only.

The strata under study were mapped as „Gutenstein Limestone — Anisian". No index fossils however have been found so far which would demonstrate it. Dasycladaceans are missing. In the High Tatra J. Kotański (1958, 1959) employs crinoidal ossicles as criterion of age. Small columnals supposed to belong to the genus Dadocrinus that consequently may indicate Lower Anisian are not found at the mentioned locality, although they are known to occur SW of Sliačany. Index value of calcareous sponges and characteristic Cyanophyceae forming tubular aggregates has not been proved yet. According to relations analogous to the slumping at the locality Polom, stratigraphical range of which was determined as Anisian, I consider this age as the most probable also for this locality.

Rock Types and Accompanying Structures

1. The fundamental type is dark banked „Gutenstein" Limestone (30—50 cm) with white veinlets of secondary calcite which are rarer here than at other

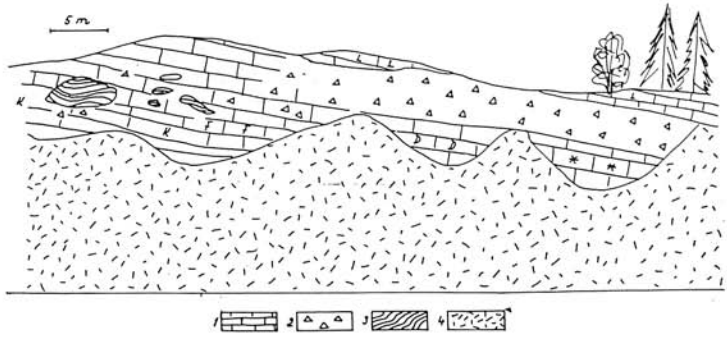

Fig. 1. Abandoned quarry 0,5 km ESE of Donovaly, NW wall with submarine slumping in the Middle Triassic.

Explanations: 1 — Gutenstein Limestone with layers of lightcoloured dolomites, 2 — endostratic breccia wih fragments of limestones and dolomites up to the size of 8 cm, 3 — slabs and block masses of yellowish, slightly marly, laminated limestone, 4 — scree, * — intercalation of organogenic limestone, F — fucoid in limestone L — laminated limestones with alternation of light- and dark-coloured bands, D — epigenetic spong-like dolomitization, K — clastic veins (neptunian dikes).

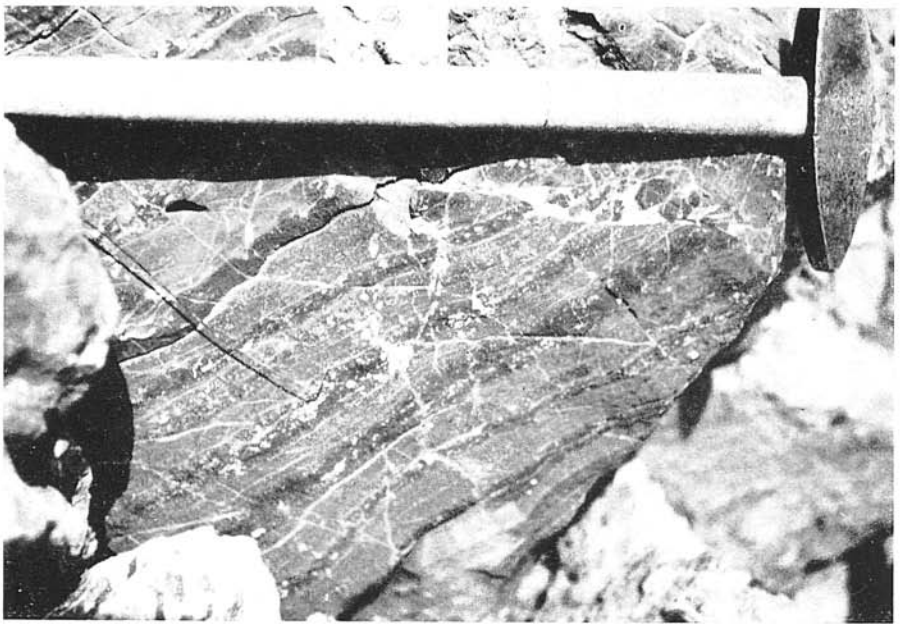

Fig. 2. Rhytmites-banded structure in Middle Triassic limestones. The white spots in dark-coloured bands are dolomite crystals. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by M. Mišík.

localities. It contains layers of ligthcoloured dolomite. Rarely traces of epigenetic sponge-like dolomitization are found.

2. Laminated structure (rhytmites) with alternation of lighter and darker beds, sometimes to 1,5 cm thick (fig. 2) is not abundant. With tearing of dark laminae „vermicular limestone" originated (J. Kotański 1955). In darker bands sometimes white „poppy" grains are weathering out; they are dolomite rhombohedrons. This rock may be designated as dolomitic limestone. The limestone has sometimes marked fucoid structure; the fucoids also pass perpendicularly to bedding and rather resemble burrows than structures originated by tearing of variously coloured laminae.

3. Organogenic limestone was found on the right side of the quarry. It forms a bank, about 1 m thick and in higher part of the profile another 10 cm thick intercalation may be found in muddy limestone separated by stylolite suture. It contains blue-green algae, club-shaped echinoid spines, bryozoans, calcareous sponges — *Uvanella irregularis* Ott (fig. 11) and isolated brachiopods.

4. In central part of the quarry coarse-bedded endostratic breccia is markedly represented (fig. 3). The matrix is calcareous, only in lower part formed of coarse-grainded dolomite which also appears in underlying rock. The clastic constituent is represented by angular fragments (up to 8 cm) of dolomite and limestone of

Fig. 3. Sedimentary breccia in the rock surrounding the slumping body. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by M. Mišík.

various tints of light-grey to black colour and with various structures. Maximum size of fragments is 8 cm.

5. Yellowish laminated sligtly marly limestones form block masses and slabs in the slumping body. The largest block mass is of about 5 m diameter. Smaller shreds in semiplastic state were intimately kneaded with fragments of dolomite and limestone („slump balls" — Ph. H. Kuenen 1949) (fig. 4, 5). In these marly limestones up to 25 cm large fragments of dark limestone were found.

6. Neptunian veins (fig. 6) penetrate the dark Gutenstein limestone vertically with regard to bedding. They are up to 4 cm thick, filled up with yellowish marly limestone. At places laminae of coarser material markedly indicate filling of vertical joints from above. Connection of submarine slumping and neptunian dikes was also stated by R. Marschalko (1966); he ascribes the origin of dikes to stress and excess load in the time of slumping.

The phenomena described under 4—6 belong to the group of so called sliding structures (J. C. Crowel 1957). The slumped masses were not washed out any more, what signifies that there was a calm area without currents or the depth under erosion action of waves.

Besides the structures mentioned a mechanoglyph (fig. 7) was found which shows most similarity with so called „frondescent mark" (synonymum of „cabbage leaf"). According to Y. Gubler et all. (1966) it has been found so far in association with turbidites of Flysch only. It originated by sliding of sand

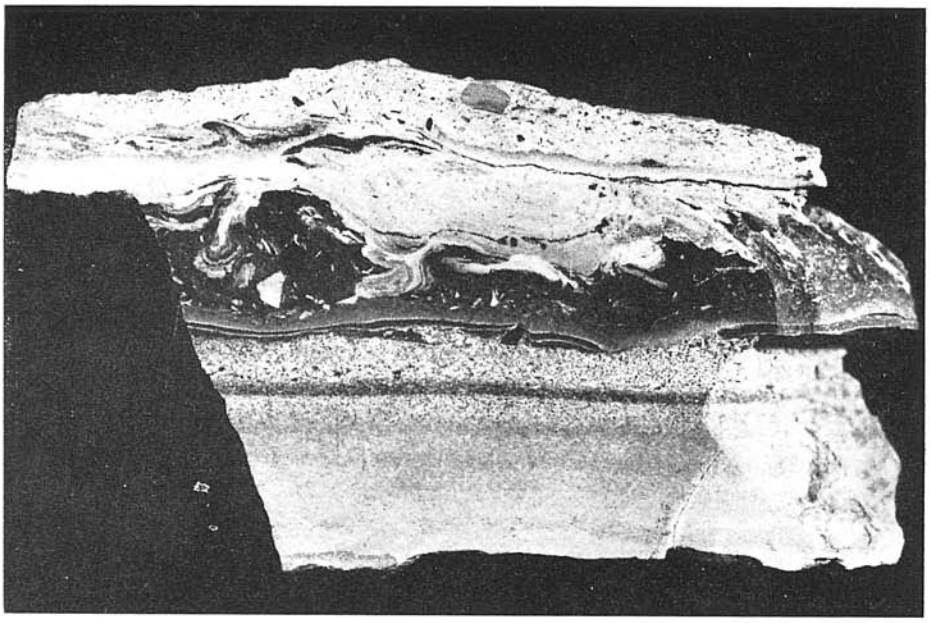

Fig. 4. Structure of synsedimentary sliding and convolution. In the upper part on the eroded surface graded bedding is present (calcisiltite). Yellowish laminated marly limestone, a part of the submarine slump. Polished surface, natural size. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by L. Osvald.

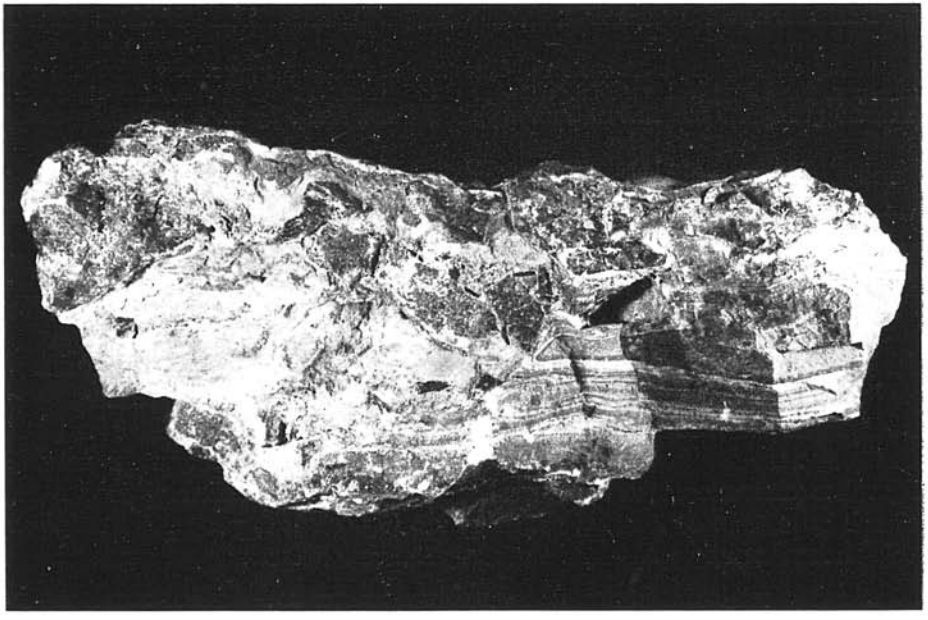

Fig. 5. Breccia with involuted marlstone slabs. Detail of the slumping body. Polished section, reduced 1,5×. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by L. Osvald.

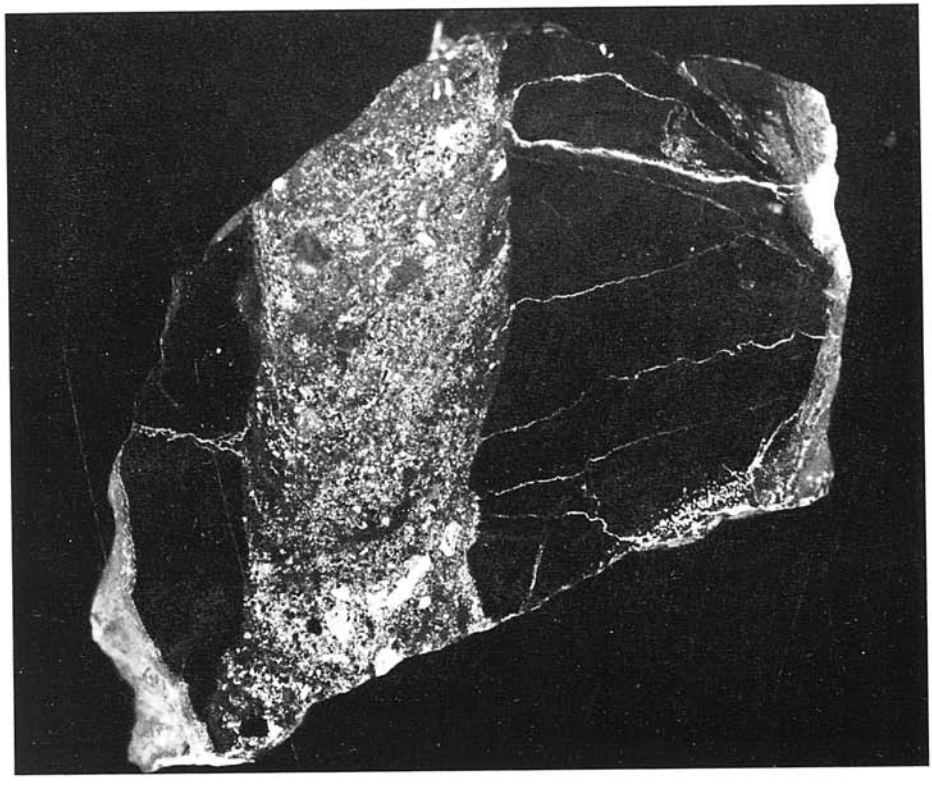

Fig. 6. Neptunian dike in dark-coloured limestone of Gutenstein type. The joint was filled from above, the filling it formed of yellowish marly limestone. Polished section, magn. 2×. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by L. Osvald.

on underlying hydroplastic sediment. It may be typical for frontal parts of turbidites, where it is frequently associated with sedimentary dikes (neptunian veins).

Microscopic Description of Rock Types of Possible Stratigraphical and Genetic Importance

Ad 3. Grey organogenic algal limestone. The most abundant organisms are tubular aggregates of Cyanophyceae, completely identical with those I described from the Triassic of the West Carpathians M. Mišík (1966, pl. VIII, fig. 2a-c). These aggregates are visible also macroscopically as small white tubes (diameter about 0.8 mm); they have a sharply delimited central void bordered by a cluster of undistinct filaments (fig. 8). It is probably *Tubiphytes* sp. Codiaceae, strongly affected by recrystallization are also present. Several recrystallized fragments probably belong to meandriform corals. Some section resemble the problematicum *Cladocoropsis* sp. (fig. 9). Rare are recrystallized gastropods, fragments of bryozoans (fig. 10), echinoderm spines and fragments

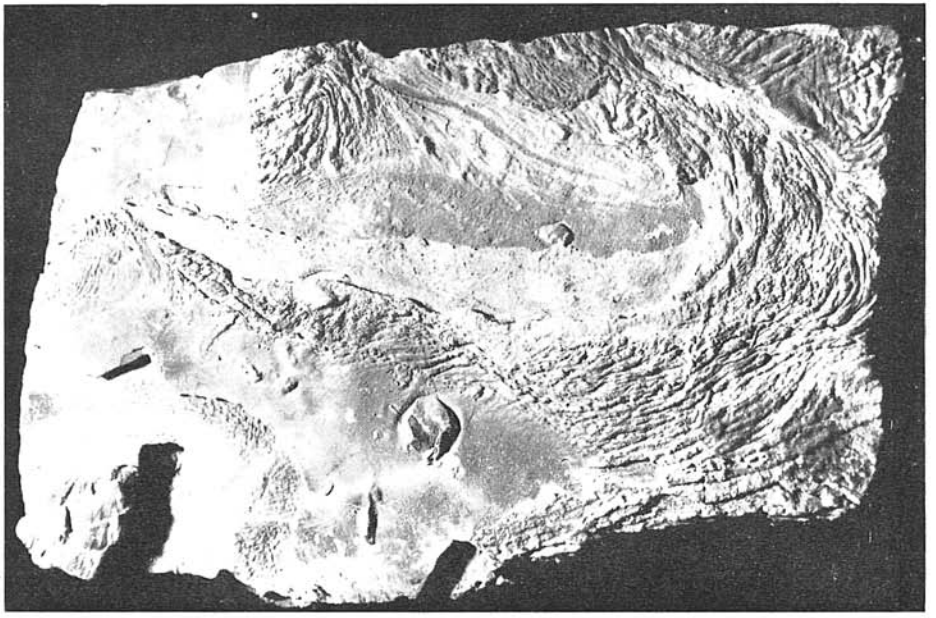

Fig. 7. Mechanoglyph of „frondescent mark" („cabbage leaf") type. Marlstone intercalation, reduced ½×. Abandoned quarry 0,5 km ESE of Donovaly, Low Tatra. Photo by L. Osvald.

of crinoids, further agglutinated foraminifers, ostracods, a recrystallized lamellibranch test, sections of Fissurina sp. and small tubes of 0,05 mm diameter were ascertained (see also M. Mišík 1966, pl. V, fig. 2). Macroscopically and in thin sections calcareous sponges — *Uvanella irregularis* Ott were identified several times (fig. 11).

On weathered bank surface are found projecting fossils, mainly echinoid spines, bryozoans and small brachiopods.

The rock is sometimes of calcarenite (biosparite) character with crustification cement. The calcite crusts are pigmented, whereas the centres of previous pores are formed of pure grains, frequently of twinning-lamellae. The bulk of interstitial mass however was formed of calcareous mud, partly recrystallized with structureless small bodies, granulated small foraminifers and thin tubes mentioned. Crowds of dolomite rhombohedrons up to the size of 0,25 mm originated at the expense of coarse-grained aggregates of cement calcite, recrystallized aggregates („pseudospar") and coral fragments.

Small authigenic idiomorphic quartz is quite seldom. Clastic quartz is absent.

Chemical analyses (anal. by H. Komorová):

CaO	54,45 %	loss by burning	43,74 %
MgO	1,20 %	insoluble residue	0,05 %
FeO	0,07 %		

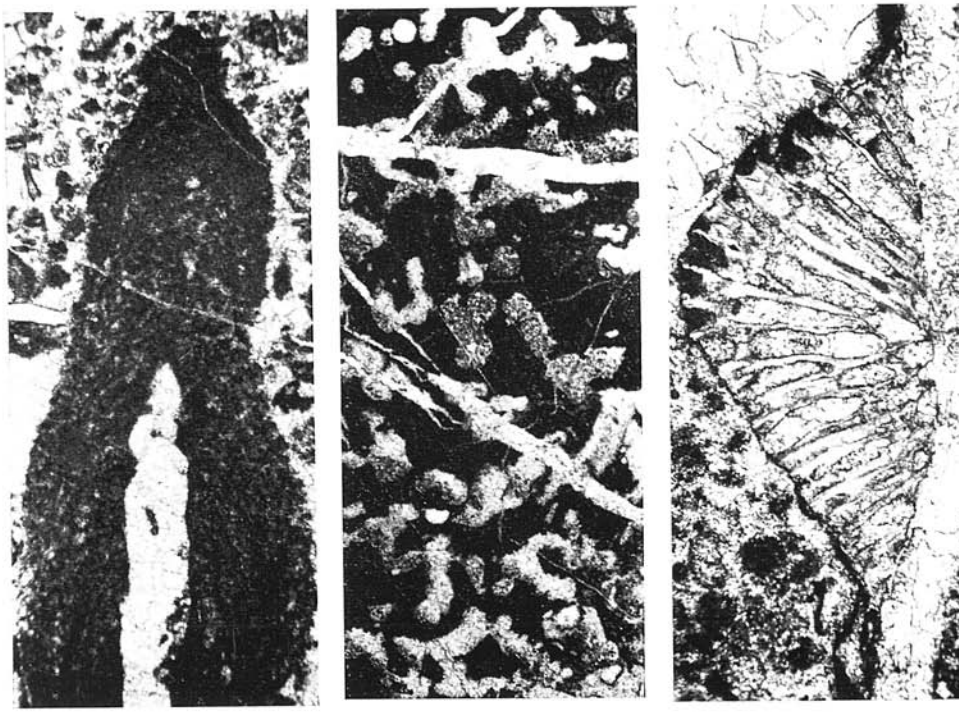

Fig. 8. Longitudinal section of a tubular aggregate of Cyanophyceae with sharply delimited central cavity (*Tubiphytes* sp. ?). Organogenic limestone, Middle Triassic. Abandoned quarry 0,5 km ESE of Donovaly. V-875. Magnif. 22×. Photo by L. Osvald.

Fig. 9. The problematicum *Cladoporopsis* (?) from organogenic limestone. Abandoned quarry 0,5 km ESE of Donovaly. V-709. Magn. 11×. Photo by L. Osvald.

Fig. 10. Bryozoan in Middle Triassic organogenic limestone. Abandoned quarry 0,5 km ESE of Donovaly. Magn. 43×. Photo by L. Osvald.

Ad. 4. Coarsely crystalline dolomite with quartzitic texture. This dark-grey, markedly grained rock is characterized by mosaic texture, with each optical individual containing original pure rhombohedron and a syntaxial rim of irregular shape, pigmented probably by bituminous substances (fig. 12). Pure rhombohedrons contain minute pigment inclusions in central parts only or preferably orientated in diagonal directions. The size of pure rhombohedrons varies within 0.3—0.8 mm (the longer diagonal). The total size of the grains only little exceeds these values. There are almost no twinnigs. Isolated pyrite grains are of irregular shape. At the contact of grains sometimes brown aggregates of clay minerals with refractive index near to that of Canada balsam are found. In one thin section recrystallized remnants of shells are prsent, probably of lamellibranchs.

The rock probably originated by two-phase dolomitization of muddy limestone. In the first phase pure dolomite rhombohedrons crystallized. The smaller part of inclusions was cought in the centre of crystals and preferably in some crystallo-

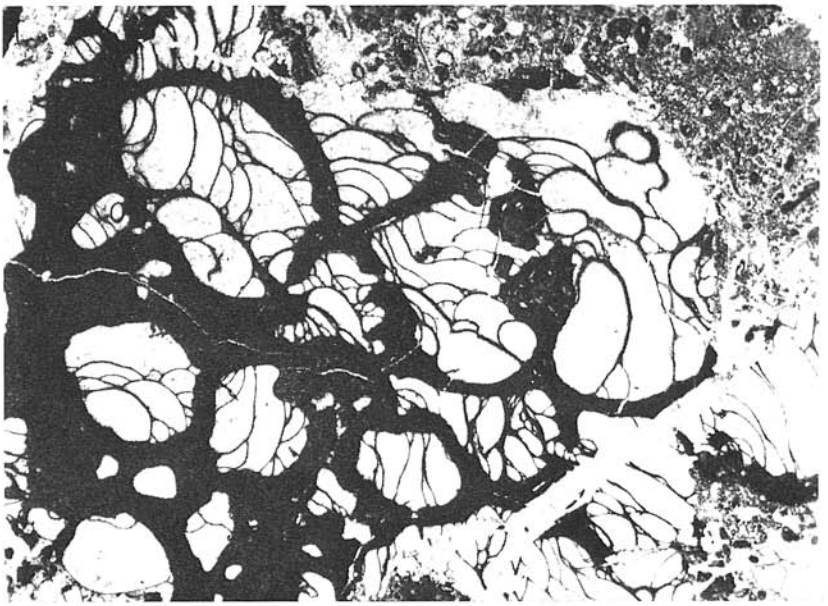

Fig. 11. Calcareous sponge of the group Sphinctozoa — *Uvanella irregularis* Ott in organogenic limestone. Abandoned quarry 0,5 km ESE of Donovaly. V-871. Magn. 11×. Photo by L. Osvald.

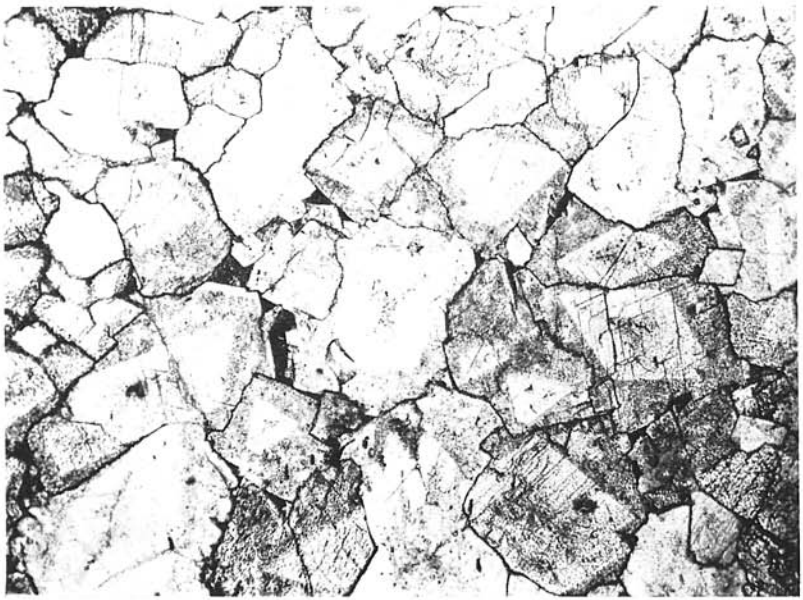

Fig. 12. Dolomite with quartzitic texture. Clear dolomite rhombohedrons with pigmented overgrowths in optical coincidence. Middle Triassic. Abandoned quarry 0,5 km ESE of Donovaly. Magn. 43×. V-720. Photo by L. Osvald.

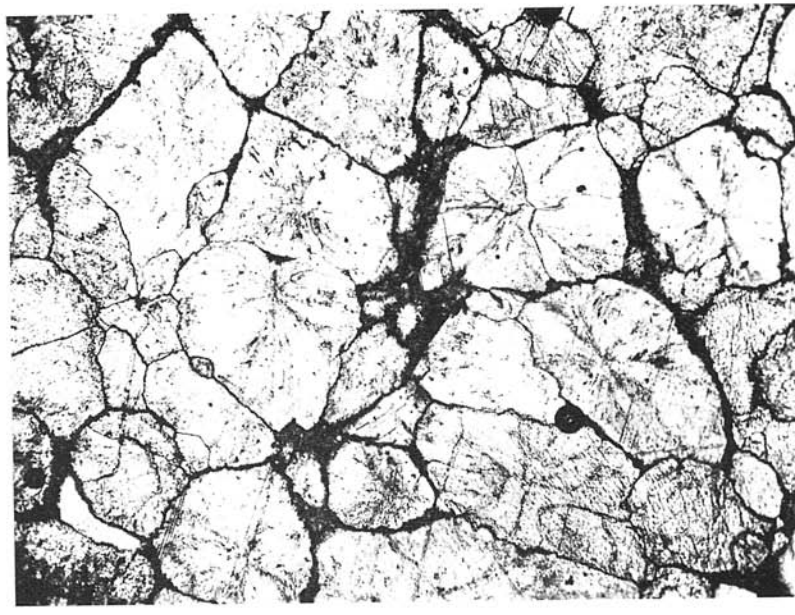

Fig. 13. Coarse-grained dolomite with radially or feather-shaped arranged pigment in dolomite grains. Fragment in sedimentary braccia. Middle Triassic. Abandoned quarry 0.5 km ESE of Donovaly. V-698. Magn. 55×. Photo by L. Osvald.

graphic directions during growth. The most pigment was squeezed out into interstitial mass. In the second phase the rest of interstitial mass was dolomitized and that by corresponding optical growth subsequent to cores — rhombohedrons. The mosaic texture with distinguishable original grains and the overgrowths is analogous to the texture of quartzites and some crinoidal limestones biosparites.

Coarse-grained dolomite with radially arranged inclusions. A fragment in sedimentary breccia. The fracture surface of this rock is characterized by black, lustrous grains. Dark inclusions, probably bituminous pigment are arranged radially from the centre of individual grains or feather-shaped with regard to the crystallographic directions (fig. 13). The grains are roughly isometric, with irregular delimitation, the outlines are slightly corroded. Their size varies from 0.15 do 0.8 mm. In contrast to the foregoing type the twinning lamellation is frequent. In pores between the grains in places brown aggregates of clay minerals are found. Only at the contact with them are grains of rhombohedral delimitation.

Yellowish slightly marly limestone — a part of the slumping body. Characterized by laminated bedding. The thickness of the laminae varies within 2—5 mm; some laminae are formed of calcisiltite and show graded bedding with sharp lower boundary and gradual transition upwards into marlstone (lutite). Convolute structure is frequent.

Chemical analysis (analysed by H. Komorová):

CaO	50.73 %	los by burning	41.54 %
MgO	2.11 %	insoluble residue	4.64 %
FeO	0.42 %	SiO_2 from insoluble residue	65.89 %
		Al_2O_3 from insol. residue	13.86 %

Locality 2. Big Quarry Polom, 10 km SE of Žilina

On the map by D. Andrusov, M. Kuthan 1 : 25 000 (1943) these strata are marked as Gutenstein Limestone — Anisian of the Krížna nappe; also on the general geological map, map sheet Žilina 1 : 200 000 (1962). The position however does not exclude belonging to the Envelope Unit of the Small Fatra. They show some features identical with Middle Triassic limestone of the envelope of the Small Fatra (e. g. V. Kriváň). On the other hand a conspicuous difference is the marked dynamic metamorphism of Middle Triassic limestones of the Envelope Unit from Kunerad (10 km far from there). The stratigraphic position of these strata was established by the found of *Diplopora hexaster* Pia (determination by Dr. J. Bystrický) in uppermost layers. They consequently belong to Upper Anisian.

Main Rock Types

The fundamental type is dark-grey banked limestone with white veinlets — „Gutenstein" Limestone. In places it is partly dolomitized or contains irregular bodies of dolomites. Sometimes it is of banded structure, rarely contains pseudomorphs after gypsum and anhydrite. Endostratic breccias are frequent. In upper parts of the sequence oolitic, organogenic-detrital limestone are found. Black cherts appear extremly seldom. The slumping body is formed of block masses and smaller slabs of yellowish, laminated, slightly marly limestones, frequently with convolute bedding, rarely with moulds after salt crystals. The Middle Triassic carbonate strata are pierced by a chimney of basic volcanite subsequently torn by tectonic processes. This occurrence in the quarry was found by J. Franzen. It evidently corresponds to basic rocks described by V. Zorkovský (1956) from the near surroundings, where they pierce the Neocomian.

In the next text microscopic description of rock types of possible stratigraphic and genetic importance is presented.

Grey oolitic limestone, partly dolomitized or silicified. It is found in the uppermost part of the quarry near the monument of the Czechoslovak Army Corps.

The oolites are not sorted according to the size; their longer dimension varies within 0.2—0.8 mm. They are greatly recrystallized, mainly in the centre. The presence of many deformed oolites is characteristic, mainly those of collapse, rarer are „S" shaped deformations and linking into chains (fig. 14, 15). The deformations by collapse originated during the compaction of the sediment; the envelopes of the oolites were already partly consolidated then. The intraclasts

Fig. 14. Deformation of oolites arising by the collapse of envelopes during the compaction of the sediment. One of the oolites is almost completely replaced by imperfectly developed dolomite rhombohedron. Upper Anisian. The big quarry Polom near the monument of the Czechoslovak Army Corps, 10 km SE of Žilina, Small Fatra. Magn. 43×. Photo by L. Osvald.

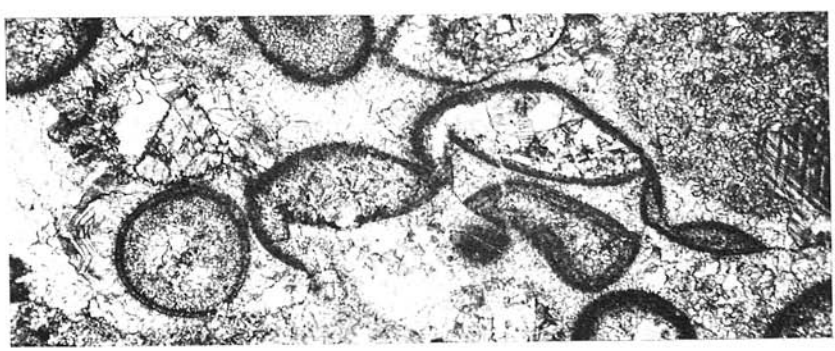

Fig. 15. Deformation of oolites of the type „oolites confluantes". The big quarry Polom, Small Fatra. Magn. 43×. Photo L. Osvald.

are mainly formed of muddy limestones, more seldom they are of oolitic texture.

Organic remnants are very rare. Crinoidal debris, foraminifers and a small gastropods, a fragment of a brachiopod and recrystallized *Dasycladaceae* were rarely found. Only a recrystallized fragments of lamellibranchs are in places

Fig. 16. Corrosion of dolomite rhombohedrons by calcite. The big quarry Polom, Small Fatra. Magn. 55×. Photo by L. Osvald.

abundant forming intercalations of lumachelle limestone. Dr. J. Bystrický determined in thin sections of these limestones *Diplopora hexaster* (Pia) Pia indicating Upper Anisian.

The dolomitization is also visible macroscopically in the form of minute white points. These white „poppy" grains are weathering out. They represent dolomite rhombohedrons up to the size of 0.7 mm with corroded rims. The dolomite rhombohedrons usually grow at the expense of the oolites, in some cases the dolomite crystal represents a pseudomorph of the whole oolite so that it is then of circular delimitation. The corrosion of dolomite rhombohedrons probably was taking place with subsequent recrystallization of calcite groundmass (fig. 16). The distribution of calcite and dolomite in thin section of these as well as of the other mixed rocks has been verified by colouring test with $AgNO_3$.

This rock was rarely affected by silicification in the form of islands of scattered fine-grained chalcedony or of aggregates of quartz with cloudy extinction tending to idiomorphic outlines. The centres of the silicified oolites are overfilled with calcite inclusions and the rim is of purer SiO_2. The zonally arranged inclusions sometimes copy the concentric arrangement of oolite. Authigenic idiomorphic pyrite in pentagonal dodecahedrons is only found in silicified parts. It is younger than chalcedony.

Chemical analysis of oolitic limestones (analysed by H. Komorová):

CaO	54,93 %	loss by burning	43,66 %
MgO	0,85 %	insoluble residue	0,06 %
FeO	0,05 %		

I dont know any deformation of oolites of the described type (collapse of oolites) from oolitic rocks of the Carpathians, only except for the Middle Triassic of the Malé Karpaty Mts., the Monrepos castle (locality of M. Peržel). It is probably the same stratigraphic horizon.

Endostratic breccias. They are formed of limestone and dolomite fragments of various textures. Their size usually does not exceed 5 cm. The fragments are of grey colour in various tints, rarely also black fragments of

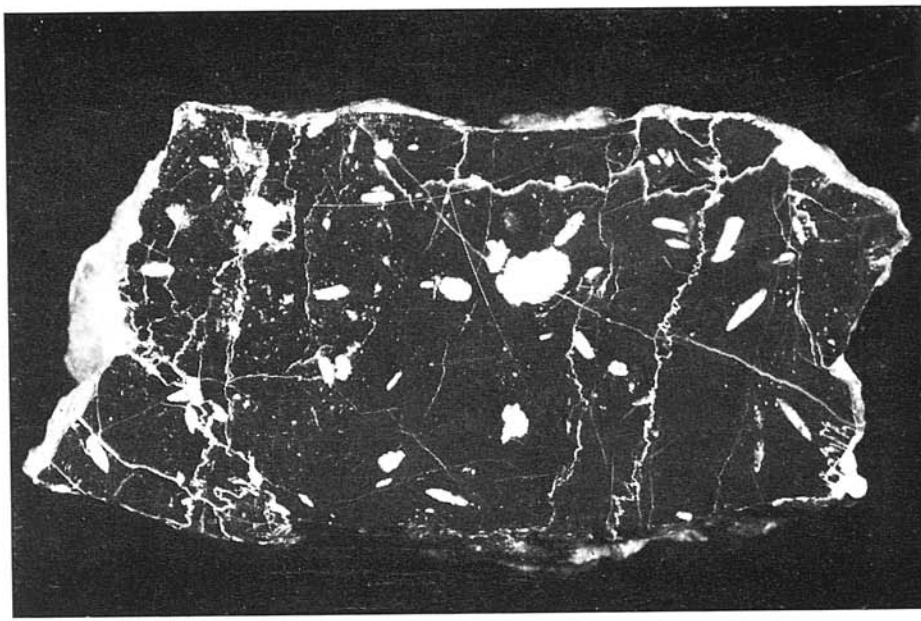

Fig. 17. Dolomite pseudomorphs after crystals of gypsum or anhydrite in Middle Triassic (Anisian) limestone. The big quarry Polom near Žilina, Small Fatra. Polished section, slightly magnified 1.2×. Photo by L. Osvald.

limestone and pinkish fragments of dolomites are present. The matrix is formed of inequigranular dolomitized limestone and is pigmented with hydrated oxides of Fe.

Dark-grey limestones with white laths — dolomite pseudomorphs after gypsum and anhydrite (fig. 17, 18). The „laths" are 3—7 mm long, up to 2 mm thick. They also form interpenetration twins and accidental compound crystals of various shape. There is no doubt about their inorganic nature. They are dolomite pseudomorphs after crystals, most probably of gypsum (wedge-like ending) or of anhydrite rods with marked rectangular ending. Under the microscope their boundaries are not very sharp due to the recrystallization. There is a differenciated aggregate of grains in almost each individual, finer-grained (about 0.04 mm) on one side and coarser-grained (about 0.2 mm) in the rest. In one thin section the distribution of this different grain size in the set of pseudomorphs shows a quite distinct „top-and-bottom" structure. As the sample comes from blast material this phenomenon cannot be evaluated for the present.

The groundmass is inequigranular, among a very fine-grained aggregate of calcite grains (0.008 mm on an average) larger grains of irregular delimitation (about 0.06 mm) are scattered. From organic remnants „filaments" were seldom found. The rock including pseudomorphs is penetrated with calcite veins with characteristic granulated borders.

Chemical analysis (analysed by H. Komorová):

CaO	51.59 %	loss by burning	43.77 %
MgO	3.51 %	insoluble residue	0.60 %
FeO	0.10 %		

Similar dolomite pseudomorphs after Ca sulphates I know from the Middle Triassic of the Belanské Tatry Mts. — from the Bujačí Mount, from the Western Tatra — Kopa Kondratská and from the Vysoká subunit of the Malé Karpaty Mts., locality Sklenné Huty. They evidently are not rare in the Middle Triassic of the core mountains, only have not been within the reach of attention till now.

Black cherts in dark-grey muddy limestone. The limestone contains seldom fossil remains such as calcified monaxon sponge spicules, scarce „filaments" and ostracods. The chert is impure, with abundant limestone inclusions and scattered calcite rhombohedrons (muddy calcite recrystallized under the influence of colloidal SiO_2). The chert mass is formed of fine-grained chalcedony. On its border microstylolites are developed. The source of silica were probably sponge spicules.

In the Polom quarry cherts have been found in one bank only in the uppermost level on the right side.

Banded dolomitic limestone found at several places in the lower part on the left side. The light-coloured bands usually are about 1 cm thick.

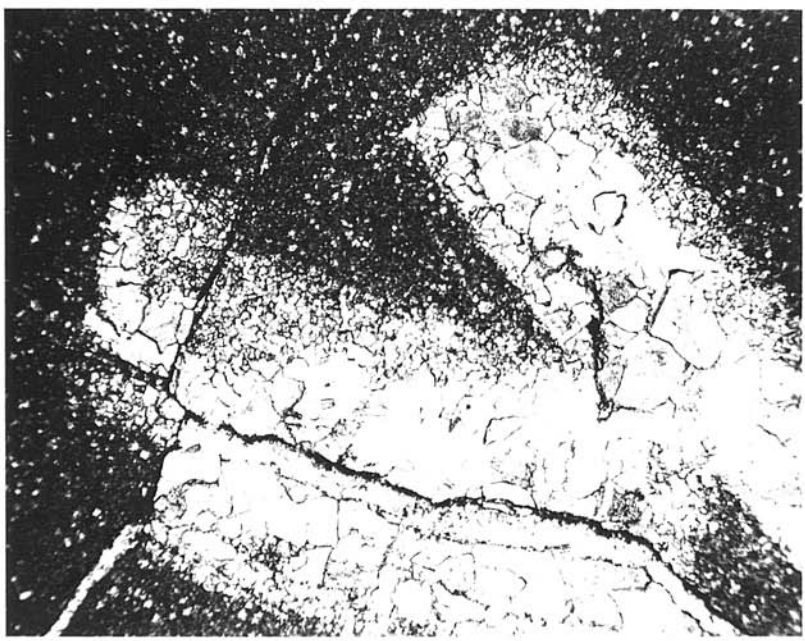

Fig. 18. Dolomite pseudomorphs after crystals, probably of anhydrite, in Middle Triassic limestone. The big quarry Polom near Žilina, Small Fatra. Thin section, magn. 22×. Photo by L. Osvald.

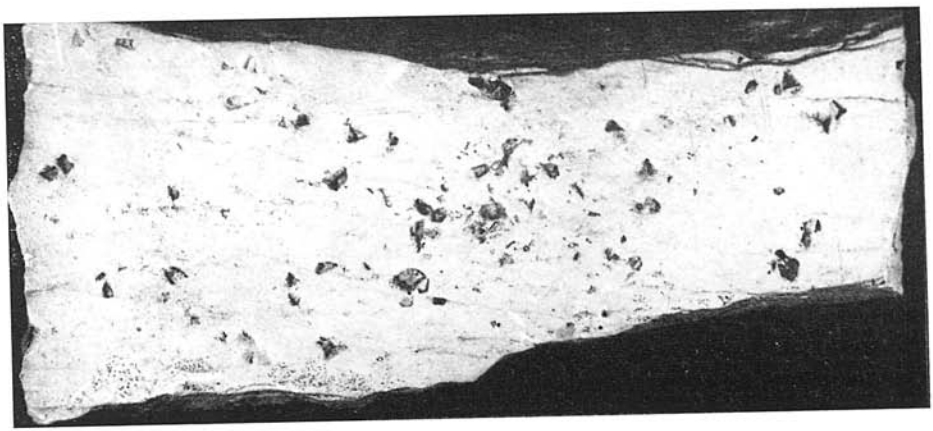

Fig. 19. Moulds after salt crystals in yellowish laminated marlstones forming the slumping body. Anisian. The big quarry Polom near Žilina. Slightly reduced 1,4×. Photo by L. Osvald.

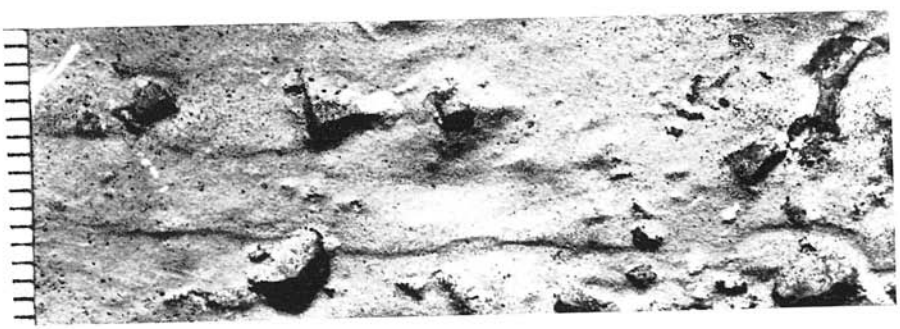

Fig. 20. Moulds after salt crystals. Detail magn. 2,5×. The big quarry Polom near Žilina, Small Fatra. Photo by L. Osvald.

the dark ones about 0.5 cm thick. The light-coloured bands contain frequent dolomite rhombohedrons visible in the rock as white „poppy" grains. They are greatly corroded. In places the rhombohedrons are touching mutually and also merging into irregular aggregates. Darker bands contain almost no dolomite rhombohedrons. They are formed of fine-grained slightly recrystallized calcite. Authigenic quartz forming idiomorphic rods up to 0,12 mm long is frequent in them. In less recrystallized rock the dark bands are formed of limestone with marked pellets (probably coprolites) of oval shape and roughly equal size of about 0,4 mm.

An almost identical rock, the dark bands of which contain abundant coprolites, I know from the Choč Unit of the Low Tatra, locality Svarínka. The cause of rhythmical alternation of the bands is unknown.

In the uppermost level of the quarry also almost typical „vermicular" lime-

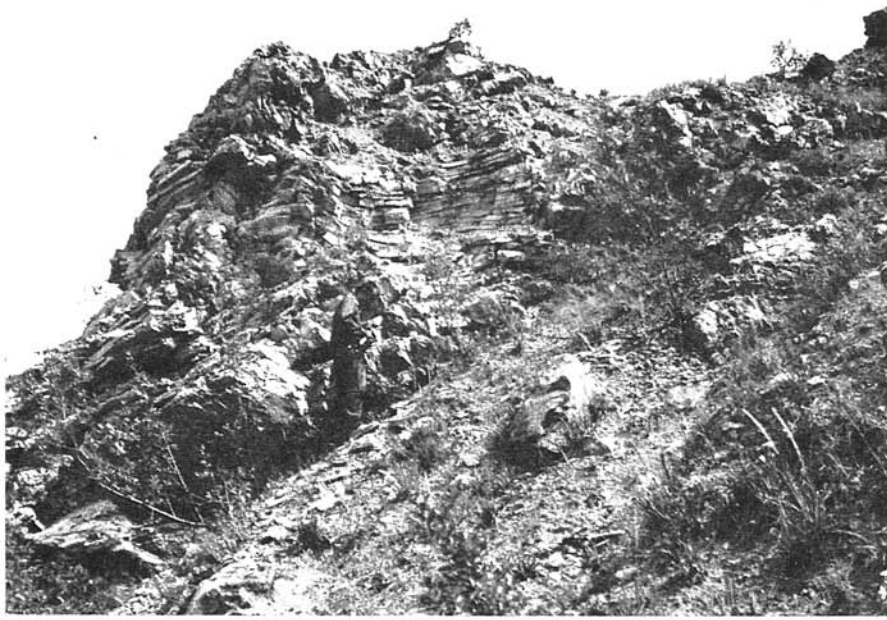

Fig. 21. Blockmass of yellowish marly laminated dolomites forming the core of the slumping body. The general dip of the beds surrounding the slumping body can be seen close to the standing figure. The big quarry Polom near Žilina, Small Fatra. Photo by M. Mišík.

stones are found, which according to J. Z. Kotański (1955) originated by tearing of laminae with sliding of the sediment still in plastic state.

Light-grey crumbly dolomite with white round spots. The dolomite is fine-grained, equigranular (average grain size of 0.04 mm). The spots are most frequently of a diameter of half a centimeter. In the most cases there is only the partial filling formed of calcite crystals (geode) and the rest of the original void remains not filled up in the centre. The void was mostly completely filled up with coarse-grained aggregate of calcite, the grains of the size of 0,3—1.0 mm are partly idiomorphic with zonally arranged dust inclusions.

Chemical analyses (analysed by H. Komorová):

CaO	36.50 %	los by burning	46.27 %
MgO	16.26 %	insoluble residue	0,41 %
FeO	0,16 %		

Similar structures are designated as „bird's-eye" or „vugs" and explained in various way (e. g. as voids after escape of gas). Their origin in the case described is not clear for the present.

An identical rock occurs in the Envelope Unit of the Small Fatra on the Veľký Kriváň, where these dolomites are more crumbly so that white spheroidal bodies

are weathering out from them. In the centre of the geodes also authigenic quartz may be found there.

Yellowish slightly marly laminated limestone. It is characterized by laminated and rarely also by convolute bedding. It forms a proper slumping body (fig. 21). In one layer moulds after salt crystals corners and edges of the size of 3—4 mm were found. Some mould voids are completely preserved, other show slight deformation due to the compaction of the sediment that evidently has not been wholly consolidated yet (fig. 19, 20).

Chemical analysis (analysed by H. Komorová):

CaO	53,23 %	loss by burning	41,54 %
MgO	0,85 %	insoluble residue	4,64 %
		SiO_2 from insol. residue	59,98 %
		Al_2O_3 from insol. residue	14,49 %

Interpretation

In both cases there are slumping bodies with the dimensions of the detached block masses showing not very far transportation. The rocks surrounding the slumping elements also indicate shallow water environment.

In calcareous sediments we can see some analogy with clastic sediments, from which a whole series of transitions from submarine slides to fluxoturbidites as far as turbidites has been described. The proper turbidites are supposed to have undergone a long transportation, up to hundreds of km and deposition in deeper parts of the basin. It would be reasonable then to seek for their traces in deep water limestone. Under such circumstances they were described by A. Carozzi (1955) and K. D. Meischner (1964) quote them as „allodaphische Kalke". In the West Carpathians I know one occurrence only, in the Tithonian of the Kurovice klippe (Magura Zone of the Flysch Belt). In deep water limestones of the „biancone" type with radiolarian-stomiosphaera microfacies 5—10 cm thick intercalations of „aptychus lumachelles", calcarenites to calcirudites (maximum size of limestone fragments 1 cm) with graded bedding and sharp lower boundary are found there. An evidence of shallow water origin of a part of the calcarenites are benthonic foraminifers, echinoderm ossicles and scarce oolites.

The fact is not to be excluded that also with the origin of the described submarine slumpings suspensional eddying of calcareous mud did not take place. The short transportation and the shallow basin however did not render possible complete development of this phenomenon. If we consider corrections as to the difference in original material, these resultant products seem to be comparable with proximal parts of the fluxoturbidites („eddying flow" according to P. H. Stauffer 1967).

Yellowish, slightly marly laminated limestones in all probability are almost of the same age (a little older) as the surrounding limestones and the dolomites, they show evidences of incomplete lithification in the time of slumping. Both

submariene slumps mentioned above are roughly of the same age. One of the possible causes of their formation is the underwashing of the shore made up of rigid rocks or the erosion effect of the storm waves on not emerged sediment. As a more plausible explantion I consider the seismic forces. Some authors draw from similar phenomena conclusions on manifestations of tectonic phases. The increase in intensity of seismic activity is directly connected with the increase in tectonic activity. It is questionable, however, whether such pulses can be laid on a level with the tectonic phases inducing folding, emersion of extensive areas, regroupping of masses (in the case mentioned it would be the „Montenegrian phase").

The sedimentation of the Alpine-Carpathian Middle Triassic was taking place on shallows comparable with limey sedimentation in the region of the Bahama Islands and Florida. Those extensive shallows of the Middle Triassic in spite of their monotony displayed some second-rate relief oscillations, depressions and elevations in the form of islands. On these shallowest parts, from time to time emerged, sediments have been deposited, from which yellowish, laminated, slightly marly limestones, in places also dark muddy limestones originated. From the mud cracked by desiccation a part of fragments of endostratic breccias formed. At these places partial detachment and concentration of the salt content also was taking place, however not exceeding the stage of precipitation of individual crystals of halite (found in yellowish marlstones and gypsum pseudomorphs in dark-grey limestone). Increased salinity is also attested by the scarcity of fauna, the absence of ammonites, etc. These evidences of hypersaline environment show that a part of Middle Triassic dolomites may be primary, formed according to the idea of M. S. Strachov (1956).

According to present-day ideas the overwhelming part of the dolomites originated due to hypersaline conditions (G. M. Friedman, J. E. Sanders in G. V. Chilingar, H. J. Bissel, R. W. Fairbridge 1967). Concentration of the solution can be reached not only by evaporitation in a separated bay but also by capillary rise in arid regions or by concentration of the salt content of subsurface water (connate water). Generally spoken the concentration of the solution on the bottom of a separated bay corresponds to current idea of the origin of primary dolomites. Percolation („seepage") of concentrated solutions from the bottom of a separated bay or shallows into the beds underlying the sediment (reflux) corresponds to early diagenetic dolomitization. Concentrated connate waters couse epigenetic (late diagenetic) dolomitization, mainly near the faults. According to the authors mentioned a considerable increase in the share of Mg/Ca in contrast to its share in sea-water is necessary for the dolomitization to be reached. It is supposed that a part of calcium is removed from the brain to form gypsum. This, however, could have been almost never proved because as gypsum is believed to dissolve again in deeper parts or to be reduced to H_2S by the bacteria. That is why the described pseudomorphs of dolomite after Ca sulphates as well as the salt crystals casts are interesting. They show that hypersaline environment necessary for the origin of

primary dolomites could exist in the Middle Triassic of the Western Carpathians although occurrences of evaporite rocks have not been found there.

Translated by J. Pevný.

REFERENCES

Andrusov D., Scheibnerová V., 1963: On the origin of redeposition of foraminifera in the Cretaceous and Paleogene of Carpathians. Geol. sborn. Slov. akad. vied 14, 1. Bratislava. — Carozzi A., 1955: Nouvelles observations microscopiques sur les depôts de courants de turbidité du Malm de la nappe de Morcles en Haute-Savoie. Bull. Inst. Nat. Genevois 57. — Crowell J. C., 1957: Origin of pebbly mudstones. Bull. Geol. Soc. Amer. 68. — Durkovič T., Koráb T., 1961: Podmorský zosuv južne od Lopúchova (Magurský flyš východného Slovenska). Geol. práce, Zprávy 23, Bratislava. — Chilingar C. V., Bissel H. J., Fairbridge R. W., 1967: Carbonate rocks. Origin, Occurrence and Classification Developments in Sedimentology 9 A, Amsterdam. — Gubler Y. et all., 1966: Essai de nomenclature et caractérisation des principales structures sédimentaires. Technip, Paris. — Jaroš J., 1966: Structure tectonique du bord ouest du noyau cristallin des Basses Tatras. Geol. sborn. Slov. akad. vied 17, 2, Bratislava. — Kotański J. Z., 1955: Wapienie robaczkowe środkowego triasu serii wierchowej Tatr. Acta geol. pol. 5, 3 (pars geologica), Warszawa. — Kotański Z., 1958: Stratigraphical and paleogeographical position of the subtatric Triassic in the Bielskie Tatry Mts. Bull. Acad. Pol. Sci. 8, 8, Warszawa. — Kotański Z., 1959: Stratigraphy, sedimentology and paleogeography of the high-tatric Triassic in the Tatra Mts. Acta Geol. Pol. 9, 2, Warszawa. — Kotański Z., 1963: Stratygrafia i litologia triasu regli zakopiańskich. Acta geol. pol. 13, 3—4, Warszawa. — Kuenen Ph. H., 1950: Marine Geology. New York. — Marschalko R., Volfová J., 1960: Podmorský zosuv a jeho makrofauna v paleogéne Centrálnych Karpát. Geol. práce, Zprávy 19, Bratislava. — Marschalko R., 1963: Sedimentary slump folds and the depositional slope (Flysch of central Carpathians). Geol. práce, Zprávy 27, Bratislava. — Meischner K. D., 1964: Allodaphische Kalke, Turbidite in Riff-nahen Sedimentations-Becken. Developments in Sedimentology 3 — Turbidites (ed. A. H. Bouma, A. Brower). Amsterdam-London-New York. — Mišík M., 1966: Microfacies of the Mesozoic and Tertiary Limestones of the West Carpathians. SAV, Bratislava. — Ott E., 1967: Segmentierte Kalkschwämme Sphinctozoa aus der alpinen Mitteltrias und ihre Bedeutung als Riffbilder im Wettersteinkalk. Bayerische Akad. Wiss. math. nat. Kl. Abh., Neue Folge, H. 131. — Stauffer P. H., 1967: Mass-flow deposits in flysch sequences. VI^th. Sedimentological Congress Reading-Edinburg (preprints). — Strachov M. S., 1956: O tipach i genezise dolomitovych porod (Sostojanie znanij). Trudy geol. inst. AN SSSR 4, Moskva. — Zorkovský V., 1956: Výskyt tufitickej brekcie v neokóme Malej Fatry, juhovýchodne od obce Varín. Geol. práce, Zprávy 8, Bratislava.

Review by K. Borza.