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Signs of the Laramian resedimentation and submarine volcanic activity near Zázrivá - Grúne (Orava part of the Pieniny Klippen Belt)

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Abstract

Breccious layers within the greenish Gbelany Marls, grade-bedded turbidites and occurrence of mixed sedimentary- volcanic rocks presumably of Maastrichtian age were found at Zázrivá village (local part Grúne) in the Orava section of the Pieniny Klippen Belt. They represent the third known locality of Laramian resediments in the Orava region; the occurrence of volcanics is unique in this region.

Key words: Upper Cretaceous, Pieniny Klippen Belt, Laramian phase, tectonic resedimentation, submarine volcanism

Introduction

Since the beginning of investigations in the Pieniny Klippen Belt, a multiphase compressional tectonic deformation has been distinguished in its territory. The number of tectonic phases was not clear for a long time. Andrusov (1938) summarized about 5 phases responsible for deformation of the Pieniny Klippen Belt but only 2 of them are recently generally accepted. The first one (Laramian) took place during Late Cretaceous to Paleocene. The transpressional collision between the block of Central Western Carpathians and the ribbon of the Pieninic continental crust resulted in the nappe thrusting and stacking of the Pieninic units together with other units recently forming the Pieniny Klippen Belt. This nappe structure was later destroyed by the second tectonic phase during Early Miocene. It took place as a large sinistral strike-slip movement along the deep-seated peri-Pieninic lineament as a result of the oblique collision between the block of already amalgamated internides and the North European Platform margin. The original Laramian nappe structure was preserved only locally, namely in Pieniny near Jaworki village (dealt in detail by Jurewicz, 1994). Nicely outcropped Laramian discordance is also near Kňažia (Orava), where the steeply inclined Maastrichtian marlstones and Záskalie Breccias are overlain by subhorizontal Paleogene (Middle Lutetian) sediments (see Andrusov, 1959; Tab. LXXXIV, Fig. 2). One of the results of Laramian phase in the Pieniny Klippen Belt was sedimentation of synorogenic Jarmuta Beds (Birkenmajer, 1977, p. 137), represented by sandstones, breccias and conglomerates containing pebbles of all Pieninic units which already reflect their crustal shortening and stacking to the nappe pile. This tectonic event was most likely responsible also for sedimentation of Záskalie Breccias (Maastrichtian) described from Orava territory (Andrusov, 1959; Marschalko et al., 1979). They differ from typical Jarmuta Beds by their high content of very soft and irresistant detrital components i. e. Gbelany Marls (Campanian) which indicates a rapid resedimentation without longer reworking. In newly found occurrence of the Jarmuta Beds at Jelšava near Dolný Kubín (only about 1 km NE from the type locality Záskalie), these resediments bear signs of chaotic sedimentation related to seismic activity (synsedimentary folded marlstones overlain by undisturbed turbiditic layer). Numerous slump structures, turbiditic layers of sandstones, breccias and conglomerates occur in this locality (Jablonský and Halásová, 1994).

This paper deals with another occurrence of the Laramian synorogenic sediments, accompanied by submarine volcanism.

Geographical and geological setting of the examined locality (problems of the geological structure of the area)

The site of interest is represented by a small klippe situated NW from the centre of Zázrivá village in Orava (northern Slovakia), near the Janíkov vrch hill (1003 m) at local part Grúne. Haško and Polák (1978) in their map attributed this locality to the Kysuca Unit, being tectonically surrounded by sequences of the Magura Flysch Zone. However, since this map was published, many new data have been collected from this area, proving its more complex structure. These data deserve some following remarks.

1. At first, the surrounding flysch is not uniform and does not entirely belong to the Paleogene of Magura Zone. Situation is complicated by the fact that, in the surrounding of Zázrivá, at least four different lithostratigraphic units of flysch appearance were distinguished. The ol-

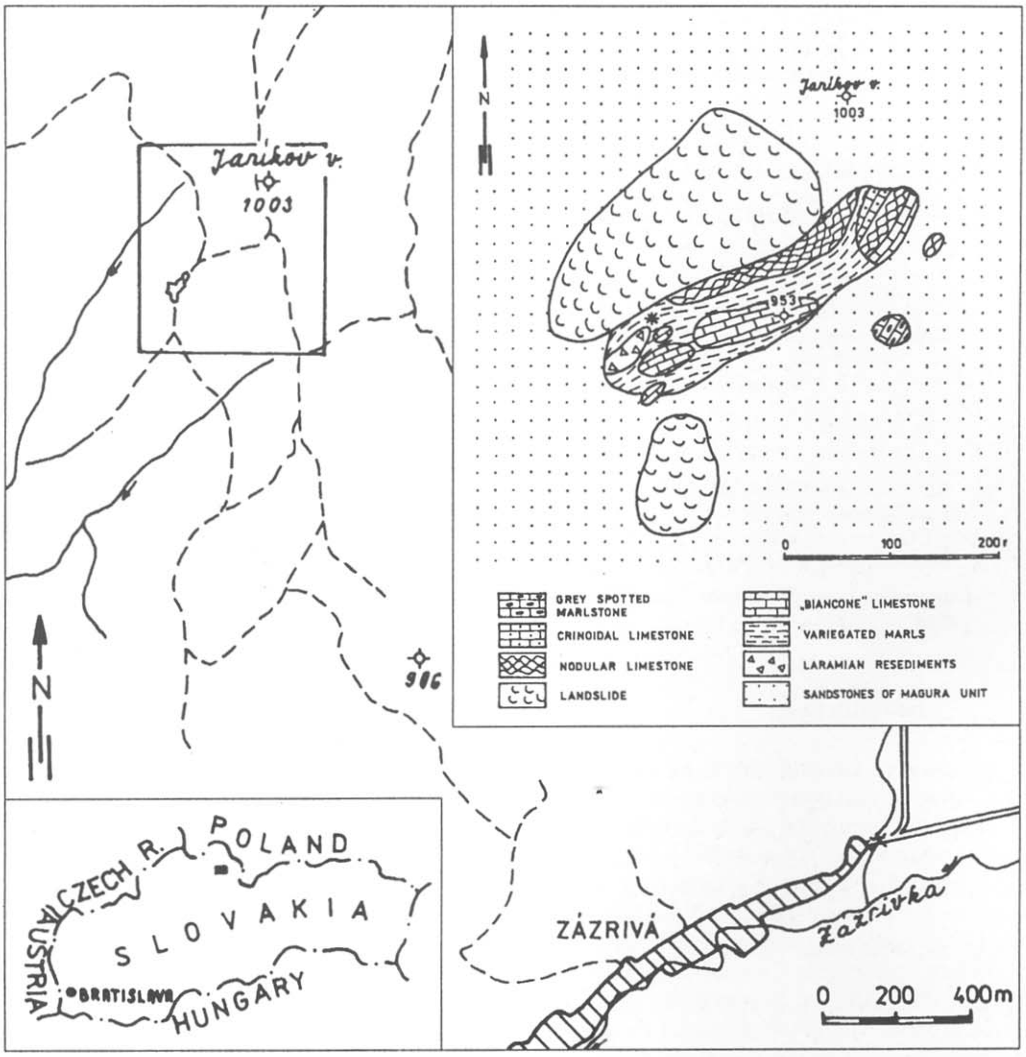


Fig. 1 Geological sketch of the examined locality and its geographical position.

dest flysch unit is the Sinemurian sequence of the Jedľovinka klippe consisting of hard, platy quartzose sandstones (almost quartzites) intercalated by thin black shales (Andrusov, 1931). The second one is the Santonian flysch, occurring mainly at Pupov vrch and at Pálenica hill (near the examined locality), attributed by Haško and Polák (1978) to the Manín Unit. The third unit belong to so called Central Carpathian Paleogene and the fourth one to the Magura Flysch zone of the Outer Carpathians. However, some outcrops of conglomerátes to microconglomerates were found, containing exotic pebbles (mostly basic volcanics). They can be attributed either to the Senonian Jarmuta Beds or to the post-tectonic peri-klippen Paleogene. This way it represents a fifth flysch unit in the vicinity of Zázrivá. Nevertheless, some of the flysch units still might remain unrecognized. Two of these mentioned units, occurring in the vicinity of Janíkov vrch, were formerly erroneously attributed to the Magura Unit:

a) Some Sinemurian ammonoids were found at the beginning of the ravine about 450 m S of Janíkov vrch. Upper in the ravine, about 400 m S of Janíkov vrch, a layer of marly limestones with filamentous microfacies (typical for the Lower to Middle Jurassic) was found embedded in the siliciclastic flysch. Also some layers of grey wackestone with numerous sponge spicules (mainly rhaxa) were found. In the roadcut of an old field road about 400 m WNW of Jedľovinka hill (906 m) the siliciclastic flysch contains about 5 cm thick beds of the spotted limestones exhibiting radiolarian microfacies in thin section. All these findings suggest that at least part of the flysch in the maps attributed by Haško and Polák (1978) to the Magura Zone is actually a prolongation of the Lower Jurassic sequences of Jedľovinka klippe.

b) The exotic fine-grained conglomerates, already mentioned as the "fifth flysch unit", were found at two places. First site occurs at the cut of the field road 450 m WNW of Jedľovinka (906 m) and 150 m NE from 808 altitude point WSW of Jedľovinka, the second one at the mentioned beginning of the ravine where also the Sinemurian ammonoids were found. The latter fact together with the extensive soil and grass cover complicate the research in this area and the problem of the flysch has not been fully resolved yet. Therefore in the geological sketch (Fig. 1) the surrounding flysch units are not differentiated.

2. The second problem is the attributing of examined klippe to the Kysuca Unit (Haško and Polák, 1978) since no radiolarites occur in its sequence. On the contrary, the beds of crinoidal limestones were found, allowing us to attribute the klippe to the Czorsztyn Unit, which is very rare case in the Orava part of the Pieniny Klippen belt, where only few klippen of Czorsztyn Unit are known.

The examined klippe itself is dissected, consisting of several small klippen connected by the Senonian marlstones (Fig. 1). The uppermost klippe, just beneath the overthrust Magura Unit, consists of the crinoidal limestone (Krupianka Lst.) (Tab. I, Fig. 1), red and greyish nodular and indistinctly nodular limestone (Czorsztyn Lst.) and the grey thin-bedded biancone limestone (Sobótka Lst.). Czorsztyn and Sobótka limestones occur also in the separate small klippen (see Fig. 1). South of the uppermost klippe occurs an isolated outcrop of the spotty marls of Barremian-Aptian age (Koňhora Beds). The Senonian marls are variegated, mostly with greyish and red colour. At the SW end of the klippe, the breccious and turbiditic layers were found within the Senonian strata, together with a very small outcrop of the mixed volcanic--sedimentary rocks. The latter members are the main aim of this paper. All the mentioned lithostratigraphic units are described in detail in the next chapters.

Pre-senonian rocks in the examined locality

Crinoidal limestone (Krupianka Lst.) represent pink biomicrite (packstone to grainstone) composed mostly of well-preserved crinoidal particles containing frequent twinning lamellae and syntaxial rims (mainly in the sparitic parts). Moreover, the sediment contains also echinoid spines, foraminifers *Lenticulina* sp., *Tetrataxis* sp., *Ophthalmidium* sp., nodosariid and nubeculariid foraminifers, less ostracods, thin-shelled bivalves, punctate brachiopods, rare sponge spicules, gastropods, bryozoans and tubes of serpulid worms. The lithoclasts of recrystallized oolitic limestone and wackestone with ostracods were enregistered in the crinoidal limestone. Quartzose sandy to silty admixture is also present together with rare feldspars. Also some cross-sections of ammonoids were observed macroscopically.

Nodular limestone (Czorsztyn Lst.). Three isolated occurrences of nodular limestone are scattered within the examined locality. Collected samples contain mainly filamentous (Callovian) and *Saccocoma* (Kimmeridgian) microfacies. The microfacies with *Globuligerina* foraminifers (Oxfordian) was not included in the samples for the random sampling (for the microfacial dating see Myczinski and Wierzbowski, 1994, Mišík, 1966).

Biancone limestone (Sobótka Lst.) was not treated in detail. Macroscopically it represents white to light-grey platy micritic limestone often with slightly corrugated bedding planes, sometimes resembling nodular limestones. Their age ranges from Tithonian to Lower Cretaceous.

Spotty marlstone (Koňhora Beds) contain microfacies rich in *Hedbergella infracretacea* (Glaessner) indicating Barremian-Aptian pelagic development. The marlstones contain also the nodosariid foraminifers, detritus of thin-shelled bivalves and ostracodes, rare echinoderm particles and quartzose silty admixture. The micrite consists mostly of *Nannoconus* sp.

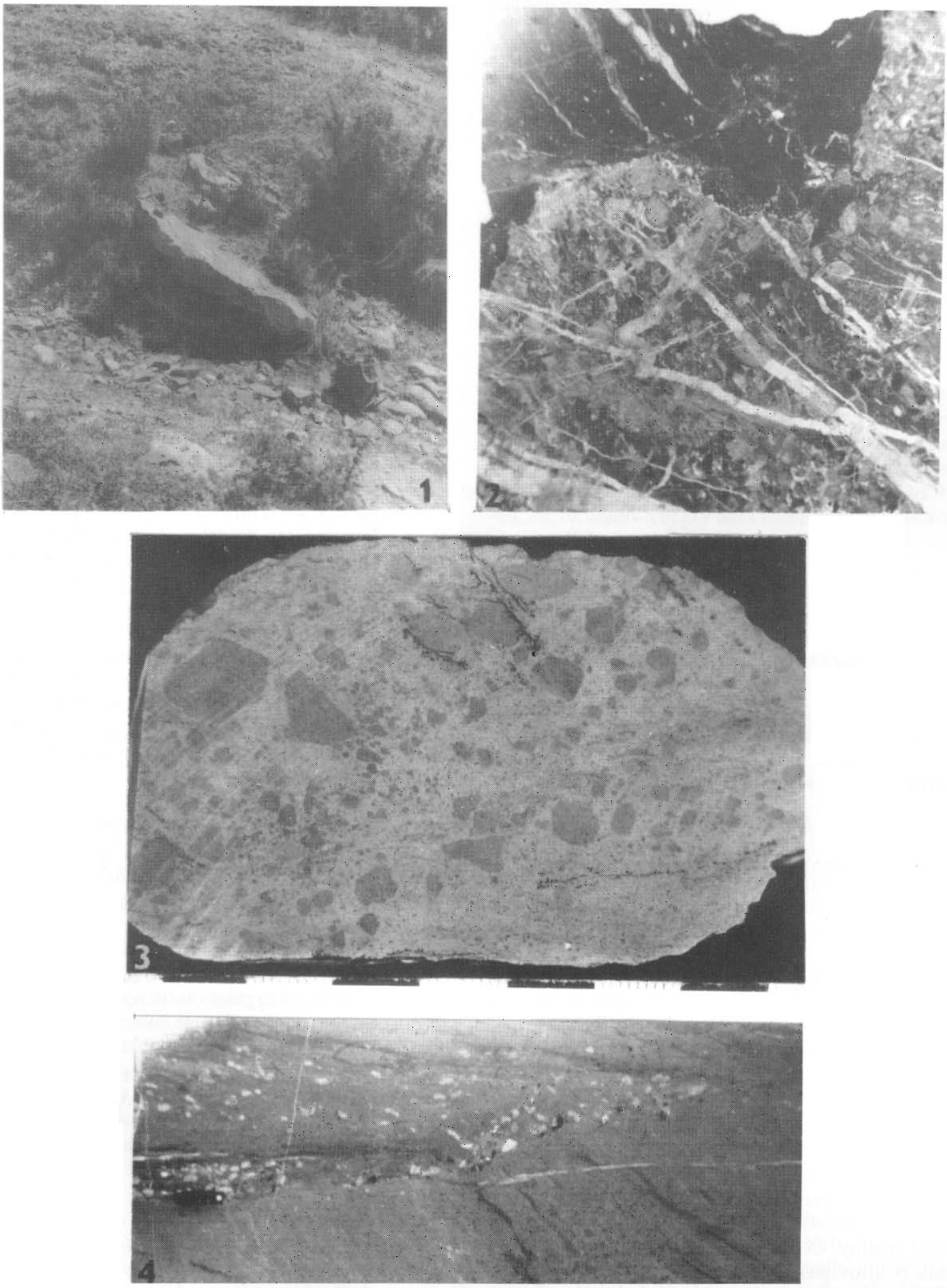
Senonian rocks in the examined locality

Undisturbed variegated marls and marlstones (Gbelany Marls, ≈Malinowa Formation, ≈Púchov Marls) connect the pre-Senonian klippen forming their soft cover. However, the contact with the klippen is not tectonic since the marlstones were found also as the filling of small depressions in the crinoidal limestone mentioned before (Tab. I, Fig. 2). Therefore, the contact is either transgressive or the klippen represent an olistostrome embedded in them. However, the marlstones in the surrounding parts of the klippen bear no signs of resedimentation which makes the latter possibility unlikely.

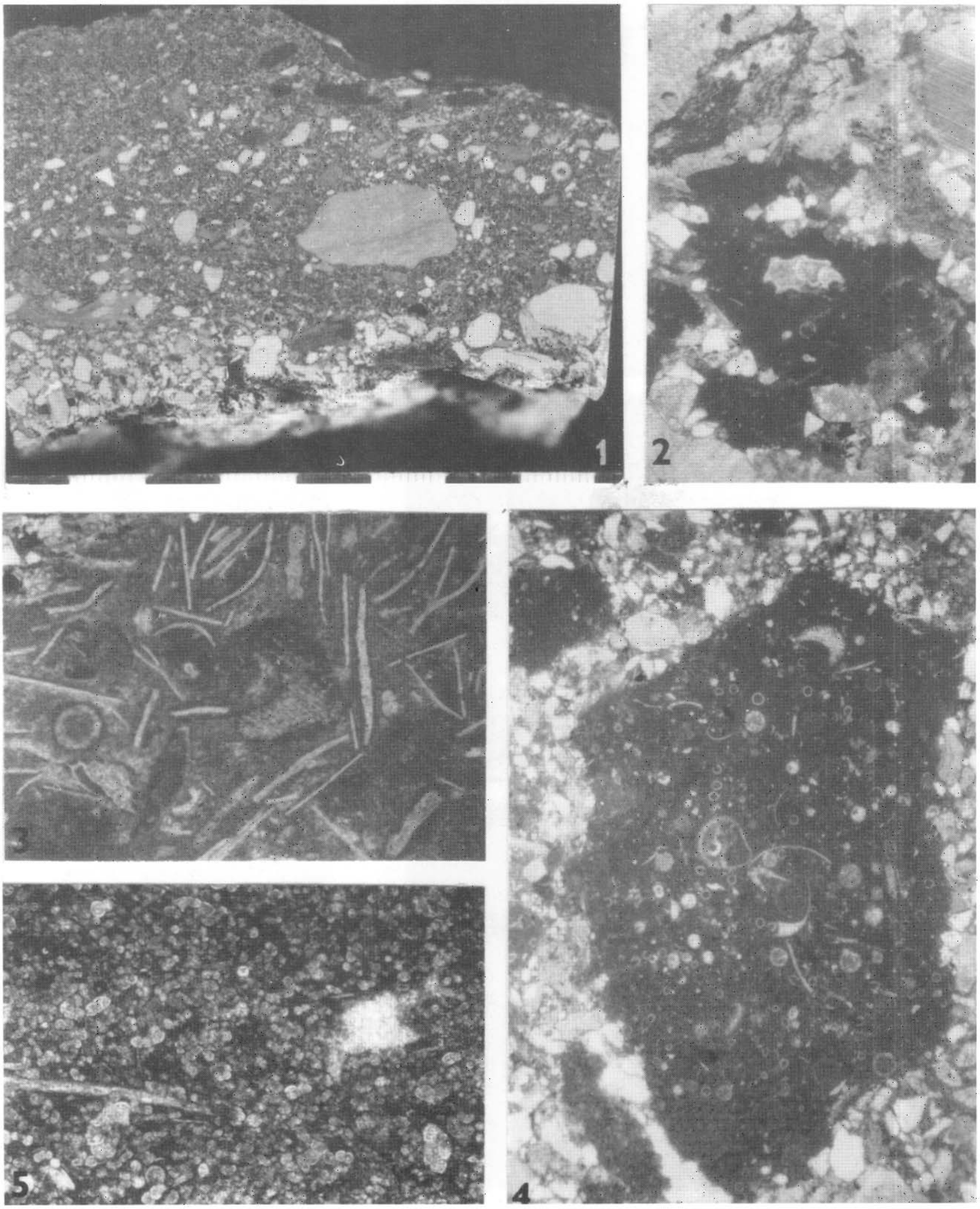
The marls and marlstones possess red to greyish colour and contain rich fauna of planktonic foraminifers. Following taxa were determined in thin section: *Marginotruncana pseudolinneiana* (Pessagno), *Globotruncana linneiana* (D'Orbigny), G. *(Rosita) fornicata* Plummer, *G. stuarti* and *Heterohelix globulosa* (Ehrenberg). The maximum time overlap of the taxa was in the Campanian which indicates also the age of the formation.

In the SW part of the examined locality (Fig. 1), in an old roadcut (largely covered without better outcrops) above the isolated settlement, a detrital sequence was found. It is composed of synsedimentary brecciated marlstones and coarse-grained turbidites apparently connected with the Laramian orogenic collisional event.

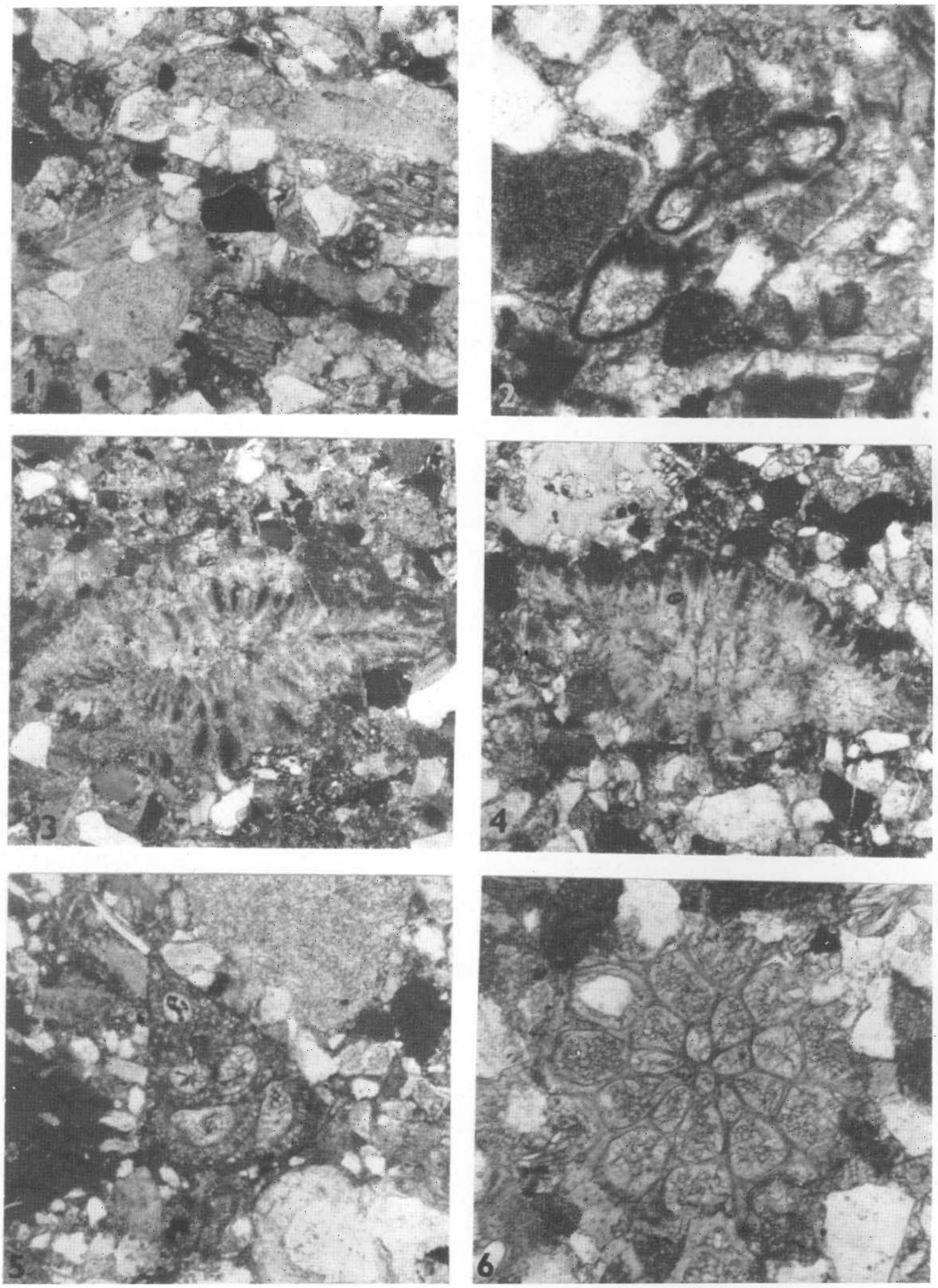
Synsedimentary brecciated marlstones (Záskalie Breccias). The intraformational breccia (Tab. I, Fig. 3) consists of the angular to subangular clasts up to 3 cm in size, embedded in the matrix of same lithology, hence the clasts are not always well distinguishable from matrix (Tab. I, Fig. 4). The best possibility of distinguishing is on the weathered surfaces or in slabs. In thin sections the clast margins are either visible forming only very thin stylolitic rim or invisible at all. It is caused by very similar colour and lithological character of both components. It suggests a very short transport of the detritus. Also the fauna of planktonic foraminifers seems to be the same in the clasts and in the matrix, indicating short time span between their sedimentation. Following foraminifers were determined in thin sections: *Marginotruncana pseudolinneiana* (Pessagno), *Globotruncana (Rosita)* cf. *fornicata* Plummer, *G. elevata* (Brotzen), *G. arca* (Cushman), *G. aff. calcarata* Cushman, *Hedbergella sp.* and *Heterohelix globulosa* (Ehrenberg). The most probable age of this assemblage is Upper Campanian. This lithotype probably



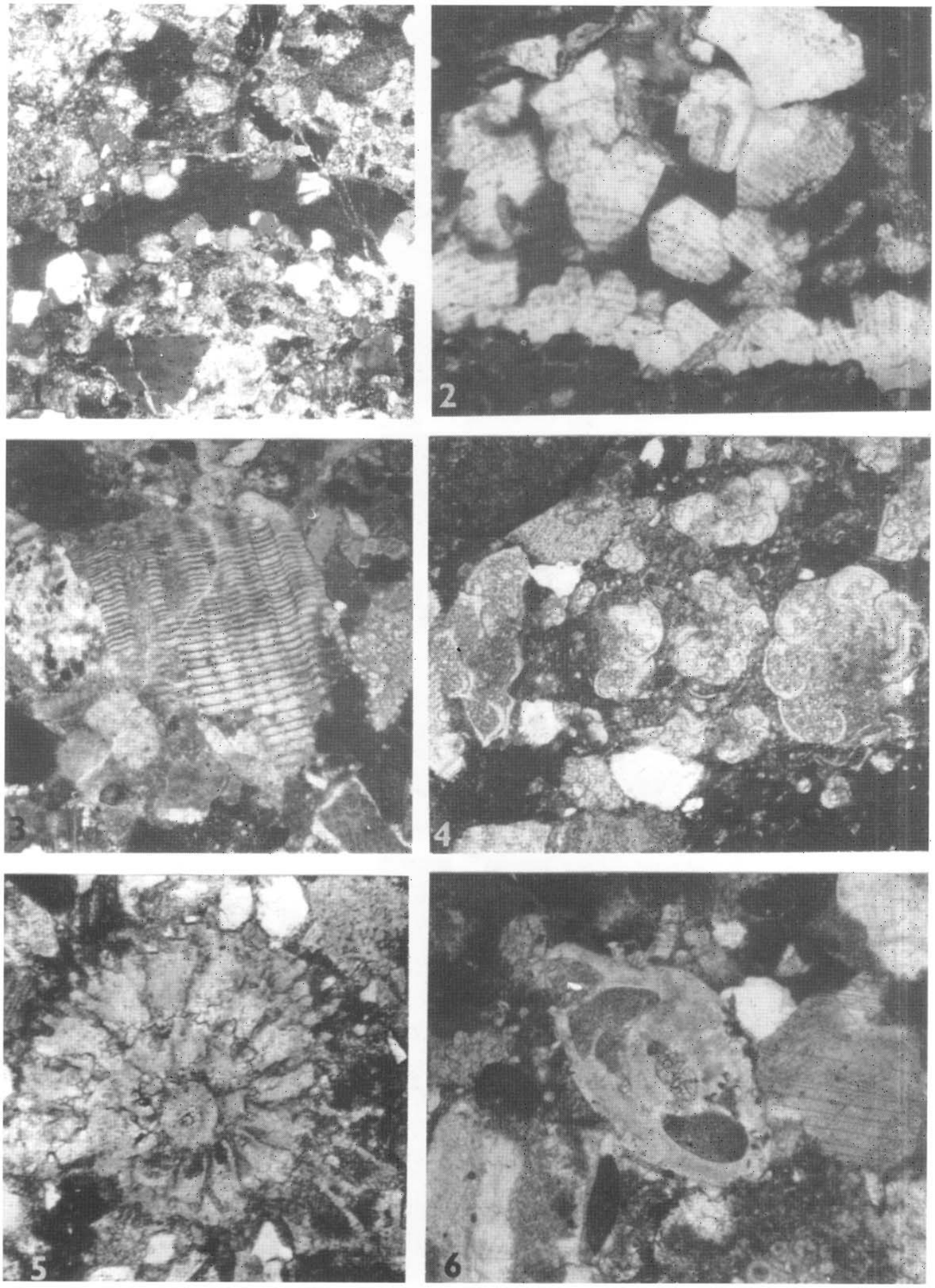
Pl. I. 1 - Oucrop of the bedded crinoidal limestone in the topmost part of the klippe near Janíkov vrch at Zázrivá. 2 - Contact between crinoidal limestone (bottom) and Senonian marlstone (dark, top). Note that only some calcite veinlets continue from the limestone to the marlstone which is caused by different physical properties of the rocks. Magn. 3.5x, thin section No. 23 496., neg. No. 90 783. (all photos except the first one were made by L. Osvald). 3 - Slab of the intraformational breccia in Senonian marlstones (Záskalie Breccia) indicating the beginning of the resedimentation event. Neg. No. 90 744. 4 - Angular contact between the marlstone clast and younger marlstone with planctonic foraminifers concentrated on the top of the clast. Magn. 3.5x, thin section No. 21 430, neg. No. 90 743.



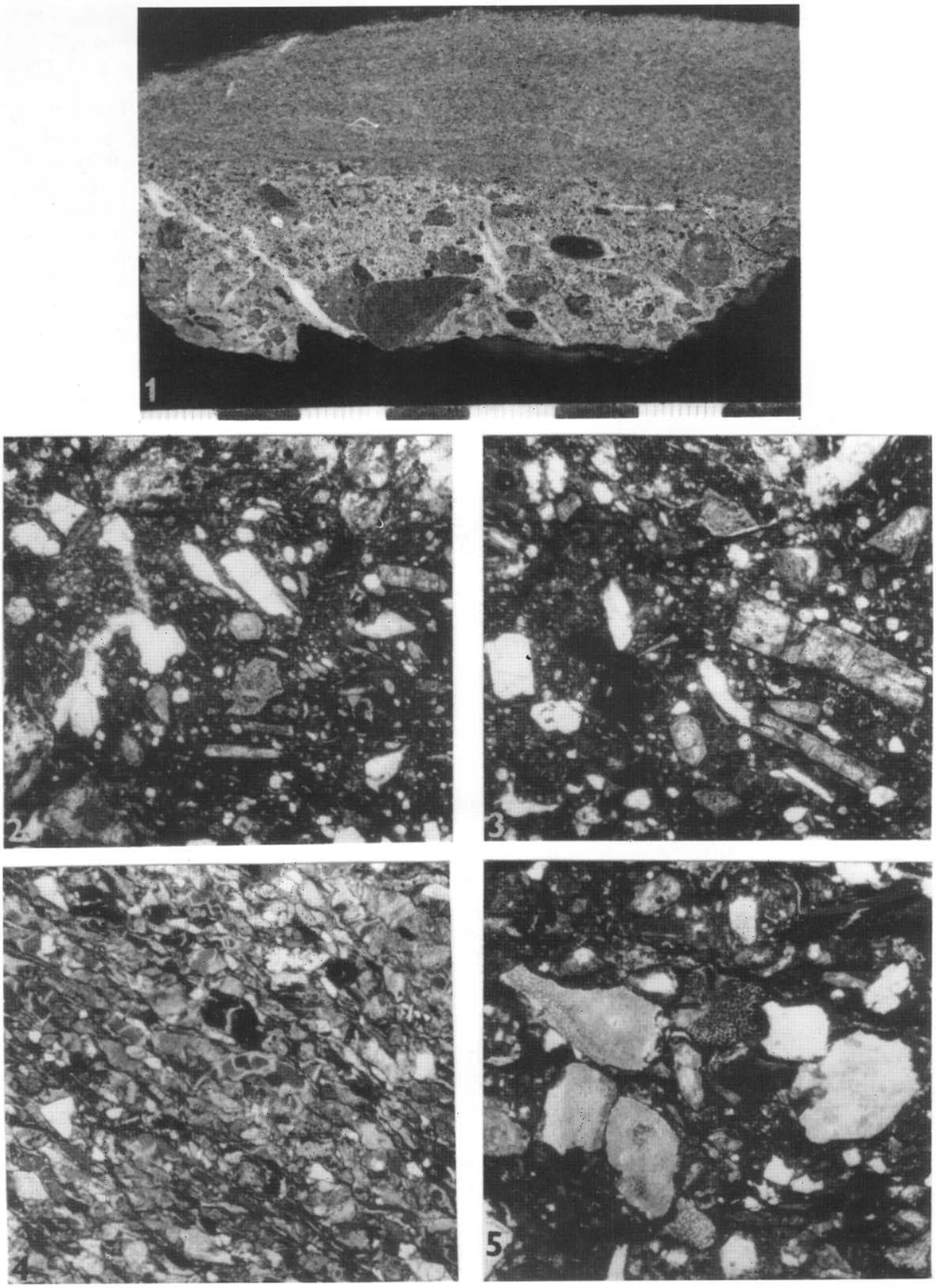
Pl. II. 1 - Slab of the polymictic grade-bedded Senonian turbidite indicating the progress of nappe stacking and erosion during Laramian folding. Neg. No. 88 889. 2 - Small clast of the Senonian Globotruncana marlstone in the polymictic turbidite. Magn. 27x, thin section No. 20 587, neg. No. 90 734. 3 - Clast with filamentous microfacies (Lower to Middle Jurassic). Magn. 45x, thin section No. 20 516, neg. No. 84 518. 4 - Limestone clast with *Calpionella alpina* Lorenz (Berriasian). Magn. 27x, thin section No. 20 515, neg. No. 90 735. 5 - Clast with *Ticinella roberti* (Gandolfi) and *Thalmanninella ticinensis* (Gandolfi) (Albian-Cenomanian). Magn. 27x, thin section No. 20 515, neg. No. 84 519.



Pl. III. 1 - Large chrome-spinel grain (in the middle) in the polymictic Senonian turbidite. Magn. 45x, thin section No. 20 586, neg. No. 84 527. 2 - *Anomalina* sp. in the polymictic turbidite. Magn. 86x, thin section No. 20 510, neg. No. 84 530. 3 - *Pseudosiderolites vidali* (Douvillé) in the polymictic turbidite. Crossed polars. Magn. 45x, thin section No. 20 588, neg. No. 84 521. 4 - As in the previous picture. Plain polarized light. Magn. 45x, thin section No. 20 586, neg. No. 84 529. 5 - *Gaudryina rugosa* D'Orbigny in the polymictic turbidite. Magn. 45x, thin section No. 20 274, neg. No. 84 523. 6 - Cyclostome bryozoan zoarium - perpendicular cross-section. Magn. 86x, thin section No. 20 586, neg. No. 84 528.



Pl. IV. 1 - Coralline alga partially replaced by authigenic quartz. Crossed polars. Magn. 45x, thin section No. 20 587, neg. No. 84 526. 2 - Coralline alga with authigenic quartz containing preserved relics of the original structure. Plain light. Magn. 86x, thin section No. 23 463, neg. No. 90 739. 3 - Fragment of rudist - one of the shallow water elements in the polymictic Senonian turbidites. Magn. 27x, thin section No. 23 464, neg. No. 90 741. 4 - *Globotruncana orientalis* El Naggar (left) and *G.* cf. *elevata* (Brotzen) (right) in the matrix of the polymictic turbidites. The first species indicates Maastrichtian age. Magn. 45x, thin section No. 20 274, neg. No. 84 522. 5 - Rotaliid foraminifera (Paleocene ?) in the polymictic turbidite. Magn. 86x, thin section No. 20 510, neg. No. 84 531. 6 - Rotaliid foraminifera - transversal view. Magn. 45x, thin section No. 23 464, neg. No. 90 742.



Pl. V. 1 - Slab of the Senonian altered grade-bedded sediment mixed with disintegrated volcanic rock (palagonite). Neg. No. 88 890. 2 - Altered volcanic rock with remnants of apatite, quartz and plagioclase phenocrysts (with organic detritus also present). Magn. 27x, thin section No. 23 458, neg. No. 90 737. 3 - As in the previous picture. Magn. 27x, thin section No. 23 458, neg. No. 90 736. 4 - Altered detritus of the globotruncanas filled by greeish- brown clay minerals. Magn. 27x, thin section No. 21 436, neg. No. 90 740. 5 - Crinoidal particles in the volcano-sedimentary mixture (atypical for Senonian). Magn. 27x, thin section No. 23 458, neg. No. 90 738.

indicates the starting of the synorogenic resedimentation in this sedimentary area. The resedimentation was not fully developed yet but the breccia already locally contains a quartz-dominated sandy admixture; also some feldspar grains, mica scales and zircon grains were found in thin sections. Nevertheless, most of the samples were still free of this admixture.

Synorogenic turbidites. The turbidites represent mostly grade-bedded sandy turbiditic breccias with clasts up to 3 cm in diameter (Tab. II, Fig. 1). The most frequent are clasts of Gbelany Marls with globotruncanas (Tab. II, Fig. 2) (Senonian), less frequent are other rocks typical for Pieninic units of the Klippen Belt: spongolites (Lower to Middle Jurassic), micritic limestones with filamentous microfacies (Tab. II, Fig. 3) (Lower to Middle Jurassic), crinoidal limestones (Middle Jurassic), radiolarites (Middle to Upper Jurassic), biancone limestones with *Calpionella* (Berriassian) (Tab. II, Fig. 4), Nannoconus limestones (Hauterivian), marlstones with *Pithonella ovalis* Kaufmann (Albian), marlstones with *Ticinella roberti* (Gandolfi) and *Thalmanninella ticinensis* (Gandolfi) (Albian-Cenomanian) (Tab. II, Fig. 5). Clasts of unknown origin were also found in the turbidites. Among them sandstones, recalcified dolomites (probably Triassic), known also as a clastic admixture in the Middle Jurassic crinoidal limestones of the Czorsztyn Unit. Tiny rounded clasts of basic volcanics and frequent chrome-spinel grains (Tab. III, Fig. 1) which might come from the exotic cordillera (Andrusov Ridge), were found also. This indicates the considerable tectonic shortening of the area between Pieninic units and the exotic ridge in this time.

Organic detritus present in the turbidites is represented mainly by echinoderm plates (mainly crinoids, abundance of which is not typical for this stratigraphic stage), foraminifers *Lenticulina* sp., *Anomalina* sp. (Tab. III, Fig. 2), *Spiroplectamina* sp., large benthic foraminifers *Pseudosiderolites* aff. *vidali* (Douvillé) (Tab. III, Fig. 3, 4), various agglutinated foraminifers, among them *Gaudryina rugosa* D'Orbigny (Tab. III, Fig. 5), cyclostome bryozoans (Tab. III, Fig. 6), frequent coralline algae (often partially replaced by authigenic quartz; Tab. IV, Fig. 1, 2), gastropods and bivalves (rudists - Tab. IV, Fig. 3 - inocerams and oysters), rare echinoid spines. Planktonic Late Cretaceous foraminifers occur both, in the marlstone clasts and in the matrix, hence they might be partially resedimented. They are as follows: *Globotruncana arca* (Cushman), *G. elevata* (Brotzen) (Tab. IV, Fig. 4), *Marginotruncana pseudolinneiana* (Pessagno), *Stensioina* sp., *Cibicides* sp., *Gavelinella* sp., *Gyroidina* sp., *Heterohelix globulosa* (Ehrenberg), *Globigerinelloides* sp., *Globotruncana gansseri* Bolli, *G. orientalis* El Naggar (Tab. IV, Fig. 4), *G. falsostuarti* Sigal. Mentioned foraminifers indicate mostly the Campanian age but latter three taxa belong to the Maastrichtian. Also rotaliid foraminifers (Tab. IV, Fig. 5) were found, with stratigraphic span reaching up to Paleogene. As in many cases in the Western Carpathians, the age appointment of the Cretaceous-Paleogene boundary strata has to be made with care because of the extensive resedimentation of the Cretaceous foraminifers into younger formations for example in the Paleogene of Myjava Group (Salaj - pers comm.). Respecting this, the age determination of the turbidites is Maastrichtian to Paleocene (?).

Synorogenic submarine volcanism. About 50 m N of the above described occurrence, a very small outcrop (cca 0.5 m^2) occurs, formed by greenish palagonite-like rock, mixed with greenish marlstones and some lithoclasts. As apparent in the slabs, this mixture sometimes possess graded-bedding (Tab. V, Fig. 1). Also the euhedral crystals of quartz, apatite and biotite are frequently found (Tab. V, Fig. 2, 3), visible even macroscopically (biotite being up to 4 mm in diameter, apatite grains up to 1 mm in length). Their shape suggests the autochthonous origin either in the volcanic rock itself or due to thermal effect on the sediment.

Observations in thin sections show that the rock is composed mainly of the altered Globotruncana marls (Tab. V, Fig. 4) mixed with volcanic remnants, lithoclasts (mainly phyllites) and sandy siliciclastic admixture. Skeletal detritus is represented by frequent planctonic foraminifers (summarized further), echinoderm particles (Tab. V, Fig. 5), bryozoans, some oyster shells and rare gastropods. The rock was largely affected by hydrothermal alteration. The interiors of foraminiferal tests are filled by greenish mineral resembling chlorite, but its isotropic behaviour indicates rather some greenish fine-grained clay mineral. The green colour is ubiquitous in the whole rock, even the volcanic remnants are completely altered. The carbonatization and hematitization is also frequent, the latter affecting mainly echinoderm particles. Moreover, some foraminifers in the marlstone clasts are silicified. This entire alteration probably caused that the washed samples contained no preserved foraminifers, though they are perfectly visible in thin section. Alteration of volcanic remnants made the determination of the type of volcanism difficult; only former euhedral plagioclase phenocrysts are distinguishable. The presence of euhedral biotite would suggest rather acid or intermediate volcanism; however, the mica scales could also crystallize at the expense of clay minerals in the sediment and they were not necessarily related to the volcanic rock. Its palagonitic character and relics of plagioclase phenocrysts rather suggest a basaltic origin.

Another question was the age of the rock. Attempts to make the fission-track dating from apatite grains were not successfull, as the length of fission-tracks was shortened by later re-heating. It reduced the density of the tracks at least of 30 %. However, the foraminifers determined from thin sections provided some stratigraphical data. Following taxa were determined: *Globotruncana coronata* Bolli, *G.* aff. *bulloides* Vögler, *G. arca* (Cushman), *G. stephensoni* Pessagno, *Radotruncana* cf. *calcarata* (Cushman) and *Praebulimina laevis* Hoffker. The foraminifers are representatives of wider time scale from Coniacian to Campanian, but the latter one indicates Maastrichtian age, which is probably the resulting age of the sediment. Large resedimentation of individual foraminifer specimens was related to the resedimentation of marls. Marlstone clasts in the described rock even contain similar, slightly older clasts. All these facts demonstrate that the processes of resedimentation and submarine volcanism were coeval. The extrusion of lava flow probably resulted in slump and turbiditic movement on the slope, where the disintegrated lava (palagonite) was mixed with unconsolidated sediment causing its thermal alteration with newly formed secondary clay minerals. The crystallization of the biotite and apatite took place still in the disintegrating lava. The newly formed minerals are too large to be produced by a short-time thermal event, but some part of them might also crystallize at the expense of surrounding sediments. Microscopical study did not provide any satisfactory response to this question because of the indistinct boundaries between the altered volcanic rock and surrounding sediment.

Discussion

Our results, mainly the composition of detrital material, showed that the Laramian resedimentation affected all the Pieninic units together with the "exotic" (Klape) unit which were already mutually very close, most probably just being stacked into nappe pile. The presence of an elevation in that area is documented by the shallow-water Senonian fauna e. g. rudists, coralline algae, large benthic foraminifers *Pseudosiderolites vidali* (Douvillé) etc.

Our occurrence can be linked with two hitherto known sites of rapid Laramian synorogenic resedimentation in Orava part of the Pieniny Klippen Belt - Záskalie and Jelšava. The similarity in the sediments and sedimentary structures is obvious. Unlike these large outcrops, our locality is of very small size and does not provide any possibility of large-scale detailed sedimentological study. There are also some other differences concerning the exclusively greenish colour of the marlstones and their clasts and the absence of large exotic pebbles in our locality. Nevertheless, it provided the first evidence of synorogenic submarine volcanism, which is relatively atypical in the collisional tectonic regime. Gradual development of sedimentation reflects the collisional progress. In the undisturbed Gbelany Marls are the foraminifers of Campanian age, the Upper Campanian intraformational breccias contain only the clasts of the same lithology, while the youngest fauna in the polymictic turbidites and submarine volcanics indicates Maastrichtian age. The evidence of Senonian volcanism is itself a rarity in the Pieniny Klippen Belt. Several occurrences were already summarized by Birkenmajer and Wieser (1956) and Mišík (1992, see also literature quoted therein). They represent mainly Campanian and Maastrichtian tuffites either within the Jarmuta Formation or in the variegated shales (the first two authors consider their occurrence to be of Danian age). The Maastrichtian one was also radiometrically dated (Wieser, 1985).

Conclusions

1. The Laramian resediments, together with atypical submarine volcanics found near the Zázrivá-Grúne, can be linked with so far known sites of Laramian resedimentation in Orava territory.

2. Their succession and detrital content reflects the continuous collisional deformation of the Pieninic units.

3. Following evolution has been reconstructed: The deposition of Campanian marls was disrupted during the Late Campanian by shallow erosion and rapid resedimentation of the marls. It resulted from the imbrication and gradual collision between the Central Western Carpathians and the ribbon of the Pieninic units in the Late Cretaceous. During Maastrichtian, the polymictic material, together with the volcanic effusions reflect the progress in the collisional process and erosion level.

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Znaky laramskej resedimentácie a submarinného vulkanizmu pri Zázrivej - časť Grúne (oravská časť bradlového pásma)

Neďaleko bradla pod Janíkovým vrchom (1003 m) pri Zázrivej (časť Grúne) sa zistili senónske sedimenty so znakmi laramskej resedimentácie a submarinného vulkanizmu.

Bradlo sa člení na niekoľko bradielok spojených senónskymi sedimentmi, prevažne zelenkastými, zriedka aj červenkastými púchovskými slieňmi. Keďže sa v najsevernejšom bradielku našli dogerské krinoidové vápence, ale chýbajú v ňom rádiolarity, je začlenenie bradielka do kysuckej jednotky na mape Haška a Poláka (1978) zrejme chybné. Z predsenónskych hornín sa okrem už spomenutých krinoidových vápencov (krupianskych) v bradielkach vyskytujú aj červené a sivasté czorsztynské hľuznaté vápence kelovejského až kimeridžského veku, ďalej sivé až biele doskovité kalové vápence (sobótske) titónu až neokómu a sivé škvrnité sliene (koňhorské vrstvy) barému až aptu. Zo senónskych hornín sa v bradle vyskytujú nasledujúce typy hornín:

1. Gbelianske sliene (kampán).
2. Polohy monomiktných intraformačných brekcií v rámci zelenkastých púchovských slieňov (vrchný kampán).
3. Polohy polymiktných brekcií a turbiditov s klastmi pochádzajúcimi z rozličných jednotiek bradlového pásma (mástricht).
4. Malý odkryv horniny, ktorá predstavuje zmes rozrušeného podmorského vulkanitu (palagonitu) s vtedy ešte nespevnenými globotrunkánovými slieňmi a s rozličnými litoklastmi (mástricht).

Posledné tri členy vznikli v laramskej orogénnej fáze, ktorá sa odohrala v bradlovom pásme počas senónu až paleocénu. Vek senónskych členov odráža vývoj synorogénnej sedimentácie s postupne sa zväčšujúcim eróznym zrezom a s netypickými prejavmi vulkanizmu pri kulminácii kolízie. Klastická prímes v polymiktných sedimentoch predstavuje veľmi pestrú škálu hornín zo všetkých jednotiek bradlového pásma, čo už svedčí o tektonickom zblížení týchto jednotiek. Opísané sedimenty charakterom zodpovedajú záskalským brekciám opísaným napr. v práci Marschalka et al. (1979) a Jablonského a Halásovej (1994) a sú vekovým ekvivalentom (alebo priamo súčasťou) jarmutských vrstiev (Birkenmajer, 1977, s. 137). Ide o tretí zistený výskyt takýchto hornín v oravskom úseku bradlového pásma, ale nález vulkanitu je v rámci oravskej časti bradlového pásma z tohto obdobia zatiaľ jediný.