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SEDIMENTOLOGY AND FACIES OF A STORM-DOMINATED MIDDLE TRIASSIC CARBONATE RAMP (VYSOKÁ FORMATION, MALÉ KARPATY MTS., WESTERN CARPATHIANS)

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Abstract: The Vysoká Formation is a product of sedimentation on an extensive shallow sea carbonate ramp. The extremely shallow water restrained the activity of tidal currents, but did not impede the destructive activity of violent storms and tidal waves (tsunami). On the basis of detailed sedimentological, microfacial, geochemical, biostratigraphical and paleoecological analyses, the formation was divided into three divisions, in which five facial and fourteen microfacial types may be distinguished. Conodonts, foraminifers, starfish, brachiopods, calcareous sponges, molluscs and one of the richest associations of Anisian bryozoans were found in the formation. Synsedimentary deformation and event structures were identified.

Key words: ramp carbonates, storm beds, littoral flat system, paleogeography, Middle Triassic, Alpine-Carpathian shelf.

Introduction

Vetters (1904) named the formation of dark limestone forming the Vysoká Hill in the Malé Karpaty Mts., "die dunkle Visokakalken". The formation was described by Beck & Vetters (1904), who identified it, according to superposition, underlying the Carpathian Keuper, as Middle Triassic. Andrusov (1959) supposed an equivalence to the Gutenstein limestone, and attributed it to the Anisian age. Maheľ (1961) on the basis of macrofauna identified by Kochanová, proved that the highest deposits belonged to the Upper Ladinian to Lower Carnian. Sedimentological studies of the Vysoká Formation are practically lacking (with the single exception of a short report by Mišík 1983 giving two profiles).

We based our research on a sedimentological field study of 37 profiles (Michalík, Reháková, Masaryk), analysis of microfacies (Masaryk), geochemical lithofacies (Lintnerová), evaluation of conodonts, holothurians (Papšová), foraminifers (Jendrejáková), bryozoans (K. Zágoršek, in prep.) and macrofauna (Michalík). The microfacies were worked out from about 500 thin sections and polished slabs from 9 profiles (Fig. 2: 2, 3, 10, 12, 15-18 and the unillustrated profile from Vysoká - Uhliská). The geochemistry was worked out from three profiles (Fig. 5). CaO, MgO and IR (insoluble residue) were determined by classical chemical analysis, while Sr, Na, Mn, Fe and Zn were determined by atomic absorption analysis. All the elements in the carbonate part were analysed. The mineral composition of the rock was followed by the X-ray diffraction method.

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Regional setting and division

The Vysoká Formation forms the basal part of the Vysoká Nappe (the frontal part of the Krížna Nappe), appearing in a morphologically significant part of the Biele Pohorie Hills between the communities of Kuchyňa and Majdanské. Several superimposed tectonic scales (up to 200 metres thick) originated during the younger Paleogene retro-charriage movements from this formation.

On the basis of our study, we divide the Vysoká Formation as follows: the basal, Geldek Member (new name) formed morphologically by a productive complex of dark grey and dark brown limestones reaching a thickness of 100 to 150 metres. It is well exposed in the higher parts of the range (see Fig. 1). In spite of facial variability, it is possible to divide it into three parts (Figs. 2-3). The lower beds are formed by monotonous thick bedded to massive striped limestones with occasional dolomitized sections. More varied tempestite - biogenic beds, containing shallow sediments and shallow lagoons with storm sediments and filled wash-over channels with fossiliferous limestones - form the middle part of the member. The highest is formed by oolitic and evaporite beds, usually more distinctly dolomitized. The middle member (Ramsau Member) is formed mainly from grey crumbled dolomites with occasional oolitic and breccia intercalations. The determination of its thickness is uncertain (60 - 70 *m*?) because of tectonization and unconnected outcrops. The upper, Parná Member (new name) is formed by oolitic, organodetrital and shelly limestones, with remains of Ladinian to

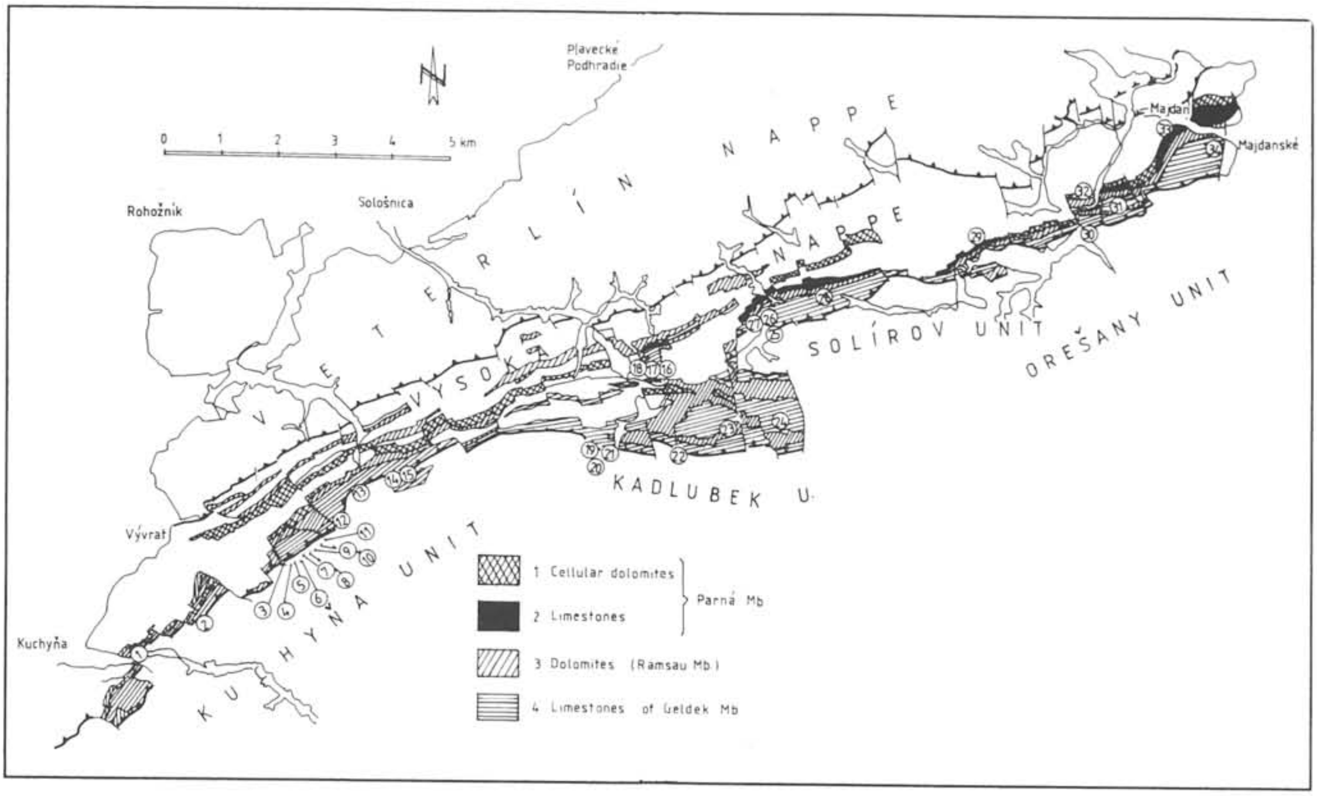


Fig. 1. Distribution of the Vysoká Formation rocks in the Vysoká Nappe of the Malé Karpaty Mts. Studied sections are denoted by Arabic numbers (cf. Figs. 2, 3).

Lower Carnian molluscs bioturbated by infauna and with pseudomorphs of evaporite minerals. The limestones are laterally replaced by bodies of cellular limestone.

Facies

Lithology and geochemistry

The carbonates of the Vysoká Formation are mainly micrites and microsparites (mudstone, wackestone, isolated packstone). Sparite limestones (grainstone, rudstone) are more frequent in the middle and upper parts of the Geldek Member (tempestite - biogenic and oolitic - evaporite beds), and in the highest part (Parná Member). We distinguish five basic facial types (Fig. 4):

Restricted onshore environment (Plate 1)

Well bedded dark grey laminated dolomitized limestones (mudstones) to dolomites containing pseudomorphs of gypsum and anhydrite crystals. Fine-grained dolomites have frequent fenestral porosity. The sequence consists of many upwards shallowing cycles 10 - 150 *cm* thick, ending with stromatolite-loferites (sabkha type). The facies is characteristic of the middle and upper parts of the formation.

The sediments were geochemically analysed in the upper part of the Oberheg profile (Figs. 2, 5; Tab. 1). Besides a high value of Sr, the raised content of Na also indicates the influence of hypersaline solutions (Veizer et al. 1978). Solutions are frequently active in the dolomitization of deposited limestones (Fig. 5). The high content of Na (240 ppm) and the low content of Sr in a single analysed sample of dolomite (Tab. 1) indicates later diagenetic dolomitization. The reduction of Sr content in limestone on dolomitization depends on the structure and porosity of the sediment, and the composition of the dolomitizing solutions. We may observe the difference in degree of dolomitization and Sr content, between the mudstone and oolitic limestones (Pl. 2: 15, 5, Oberheg section; samples 36, 49) We distinguished these microfacies :

MF-1 - Micritic (often microsparitic) and dolomitic limestones, with pseudomorphs of crystallized gypsum and anhydrite (Pl. 1E). The allochem content is low (1 - 3 %, mostly relics of ostracods and pellets). There is significant neomorphism of basic material and partial dolomitization. The pseudomorphs are of several types and sizes, filled with dolosparite, or less frequently with sparite.

MF-2 - Finely laminated microsparitic limestone to dolomite (Pl. 1F) with relics of organisms (isolated ostracods and pellets). Laminated structures recalling loferite are isolated. Alternation of thin (1 - 5 *mm*) laminae divided by darker, more clayey strata is characteristic. Stream orientation and gradation of detritus is lacking, the lamination apparently originated from changes in the sedimentary rate.

Restricted shoreface environment (Plate 2)

Thinly bedded (30 *cm*), dark grey, laminated and often completely dolomitized limestones (micritic and microsparitic), with laminae of organodetritus oriented by currents, with infaunal bioturbation. Convoluted lamination, marly intercalations and evaporite pseudomorphs are isolated.

Only two geochemically analysed samples from the Vysoká II profile (Fig. 5) belong to this facies, similar to samples from fa-

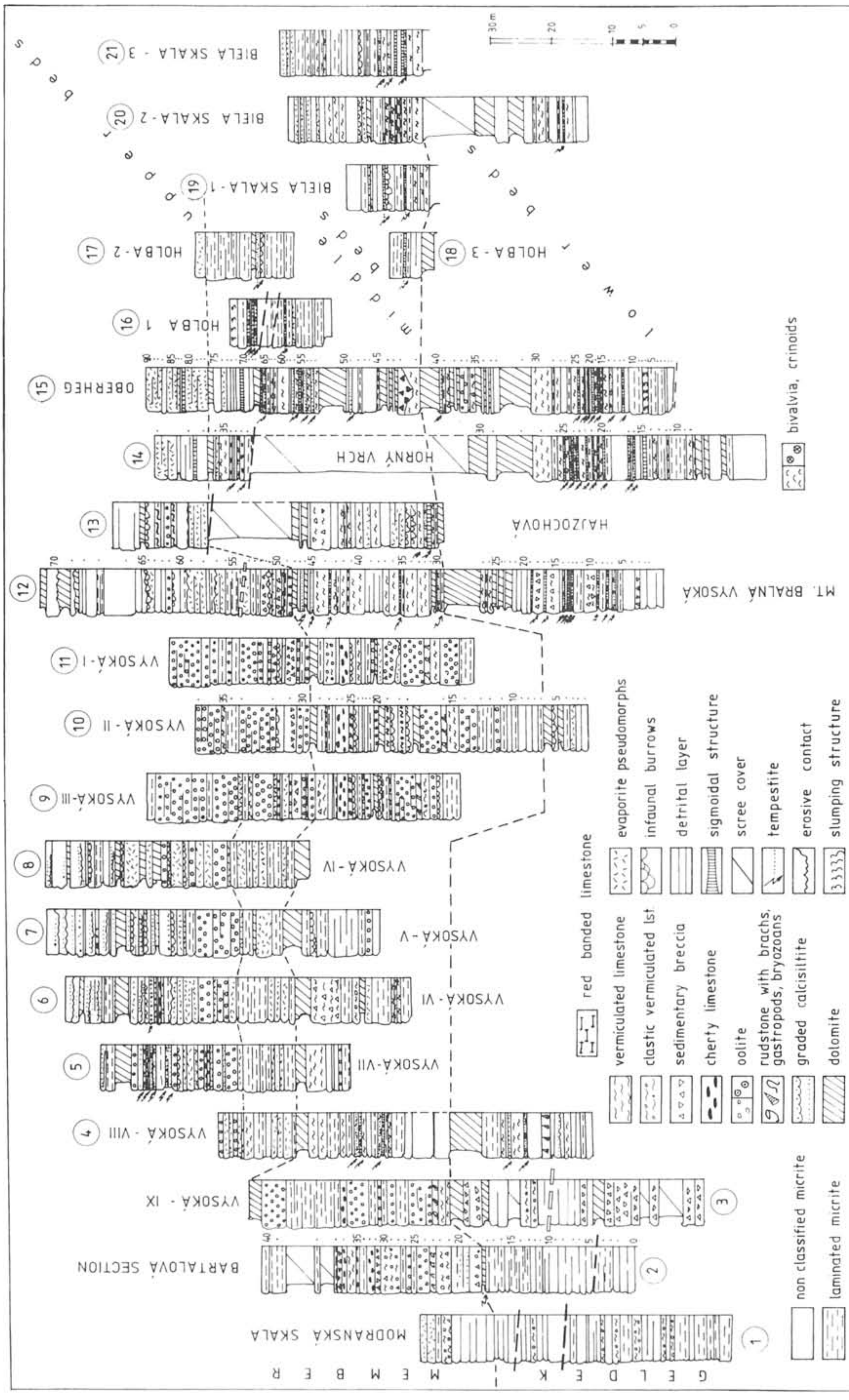


Fig. 2. Lithological and biostratigraphic correlation of the Vysoká Fm. sections (Geldek Mb.) in western part of the Biele hory Hills, Malé Karpaty Mts.

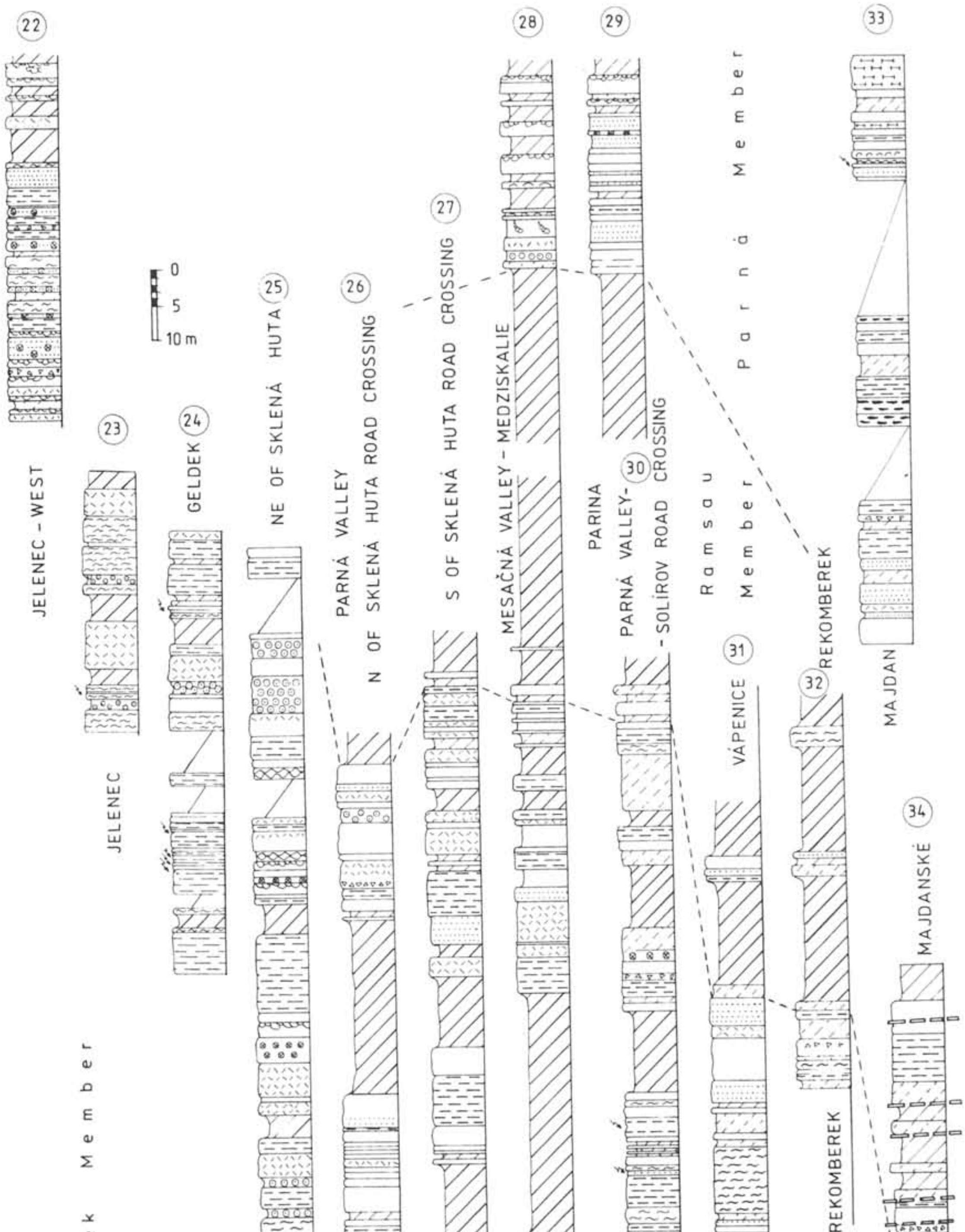


Fig. 3. Lithologic and biostratigraphic correlation of the Vysoká Fm. sections in eastern part of the mountains (Parná Dolina Valley, Malé Karpaty Mts.).

cies C. Differences in the values of Sr (288 and 957 ppm) may be attributed to different degrees of dolomitization (10 and 2 % dolomite, Tab. 1: MgO). The low values of Na indicate normal marine salinity in the whole Vysoká II section (Fig. 5). The raised value of IR (2.85 %) in a sample with a higher value of Sr, does not appear in the Na value, but the sample has a higher content of Fe.

MF-3 - Micrite and microsparite laminated limestones (mudstone - wackestone, Pl. 2E,F) contain ostracods and nodosariid foraminifers, in current directed laminated detritus, as well as

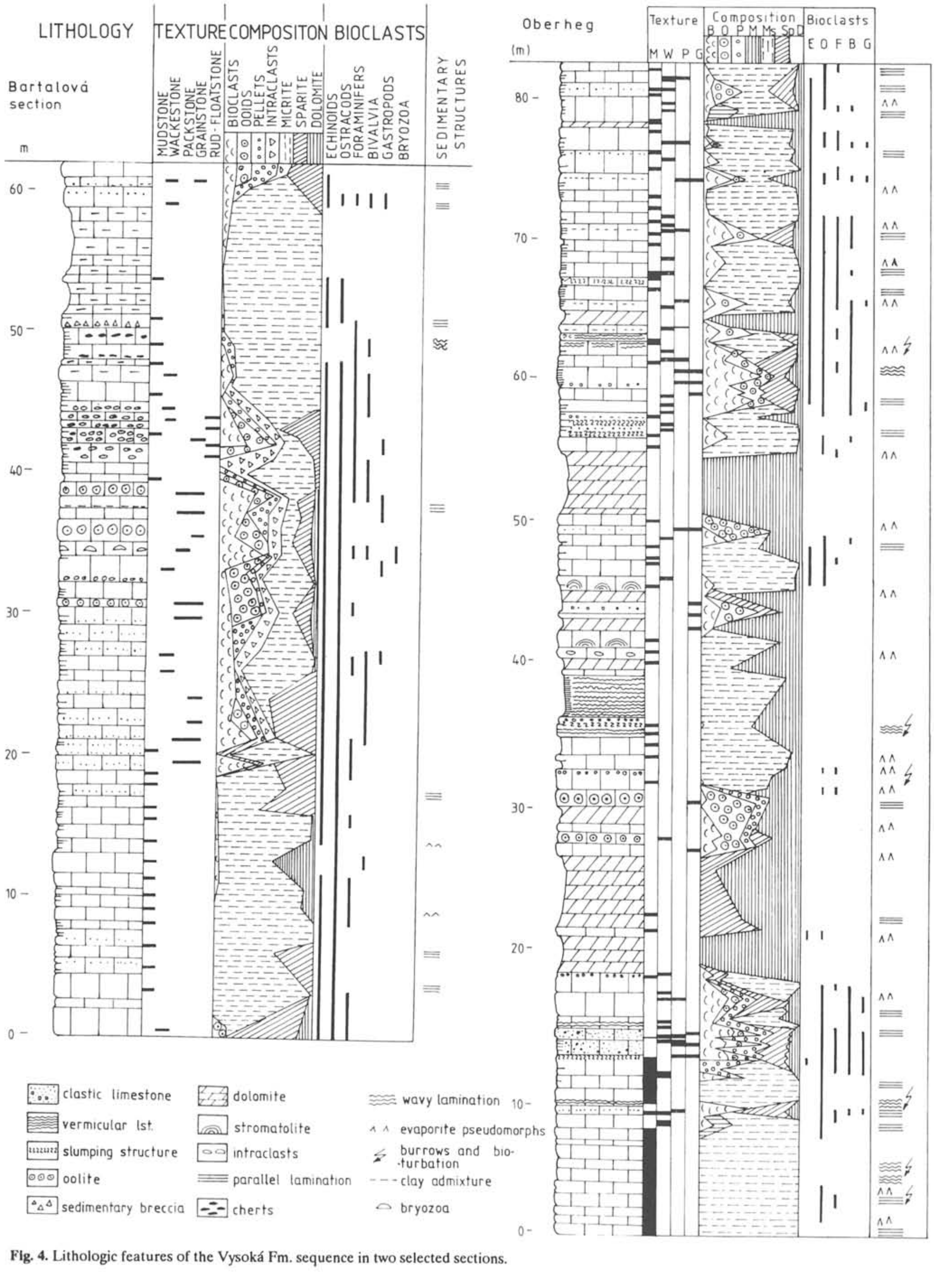


Fig. 4. Lithologic features of the Vysoká Fm. sequence in two selected sections.

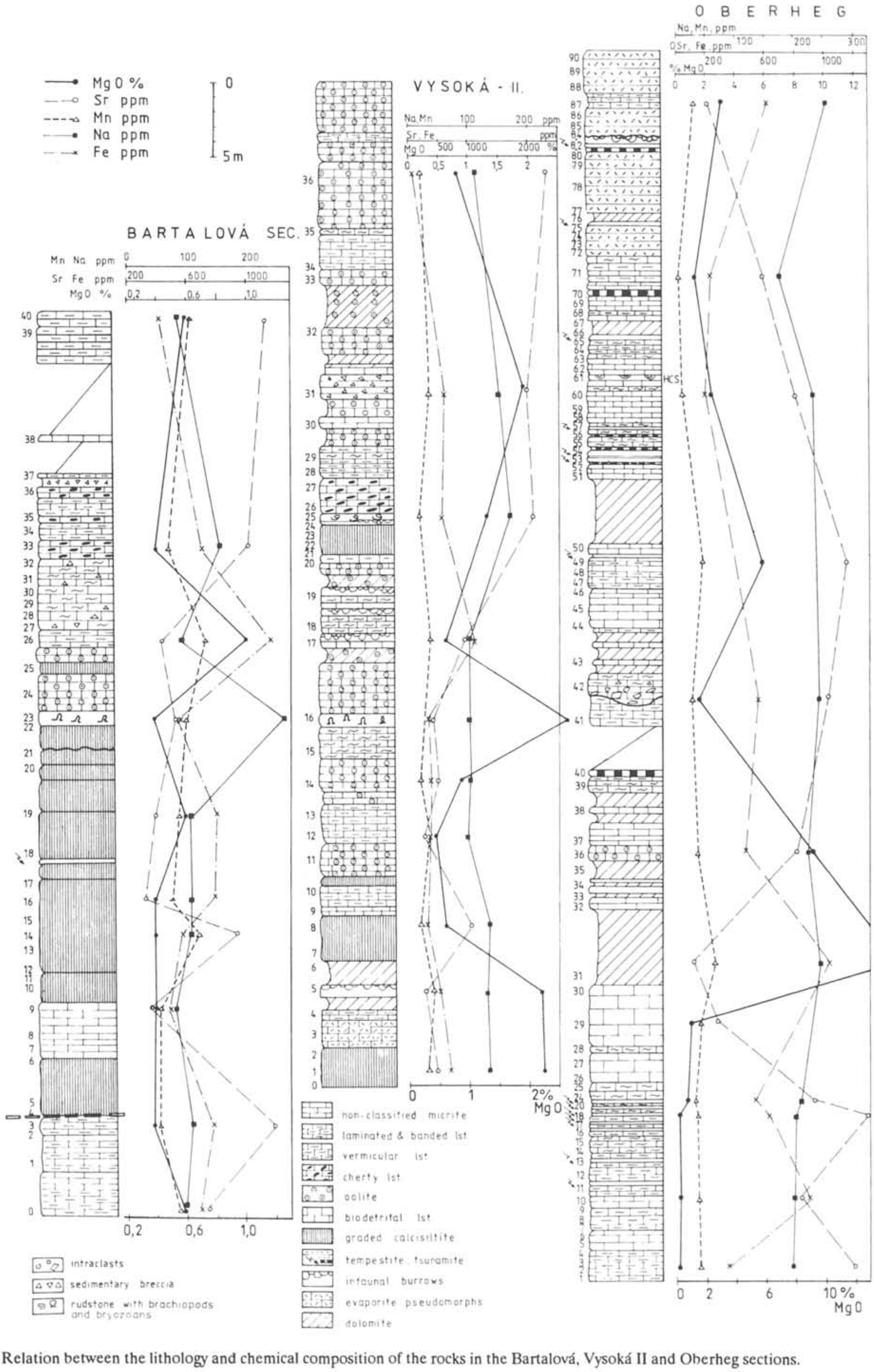


Fig. 5. Relation between the lithology and chemical composition of the rocks in the Bartalová, Vysoká II and Oberheg sections.

Table 1: Chemical composition of the limestone samples from the profiles Oberheg (OH/86), Vysoká II (V/II) and Bartalová (BA/89). Contents of CaO, MgO and IR is in wight %; Sr, Na, Mn, Fe, Zn in ppm; Sr/Ca = 1000 Sr/Ca.

Sample	CaO	MgO	IR	Sr	SrCa	Mn	Na	Zn	Fe
Oh/86/2	55.52	0.10	0.41	1268	3.22	33	190	10	340
Oh/86/10	52.99	0.20	4.33	840	2.23	35	200	12	860
Oh/86/18	55.52	0.30	1.38	1305	3.31	30	200	18	650
Oh/86/22	53.84	0.71	1.22	940	2.46	29	210	17	540
Oh/86/29	52.48	0.92	4.41	269	0.72	44			
Oh/86/31	32.91	19.81	0.84	115	0.49	71	240	23	1020
Oh/86/36	45.14	9.17	0.33	800	2.49	37	220	15	460
Oh/86/42	53.83	1.51	1.23	1020	2.69	27	240	14	550
Oh/86/49	49.55	5.88	1.77	1150	3.26	40			
Oh/86/60	53.56	2.32	0.46	800	2.10	22	230	12	180
Oh/86/71	54.40	1.21	0.34	580	1.50	17	170	9	220
Oh/86/87	52.72	3.05	0.44	240	0.64	35	250	20	600
V/II/1	52.81	2.22	1.09	435	1.16	31	130	4	539
V/II/5	52.71	2.40	0.89	288	0.76	42	120	4	510
V/II/8	54.63	0.66	1.10	1053	2.71	19	130	6	270
V/II/12	55.14	0.44	0.65	293	0.74	26	90	1	260
V/II/14	54.68	0.87	0.57	495	1.27	29	100	3	400
V/II/16	52.53	2.84	0.29	342	0.92	31	100	6	300
V/II/17	53.73	0.59	2.85	957	2.51	35	120	4	1160
V/II/25	53.55	1.27	1.76	2096	5.51	19	170	12	520
V/II/31	52.86	1.96	1.55	1905	5.08	35	150	6	630
V/II/36	54.73	0.87	0.49	2383	6.13	20	110	4	110
BA/89/0	55.79	0.59	0.22	505	1.26	90	95	2	697
BA/89/3	55.51	0.39	0.73	1205	3.04	53	110	5	798
BA/89/9	55.79	0.39	0.82	380	0.95	53	85	4	493
BA/89/14	55.79	0.39	0.52	945	2.37	120	115	3	585
BA/89/16	55.23	0.39	0.67	310	0.78	75	115	3	796
BA/89/19	54.96	0.59	1.89	390	0.99	86	115	3	905
BA/89/23	56.07	0.39	0.18	520	1.29	100	280	4	523
BA/89/26	55.51	0.99	0.67	430	1.08	131	90	3	1150
BA/89/33	54.96	0.39	1.90	1035	2.63	69	155	6	739
BA/89/40	55.79	0.59	0.29	1110	2.78	102	90	2	417

thin walled tests and crinoids. Organic detritus forms 1 - 5 %, in the laminae 10 - 15 % of the rock material. Selective dolomitization of detritus, bioturbation, and burrowing by infauna are significant features.

MF-4 - Bioturbation micrite - microsparite limestones (mudstones) with dispersed detritus (Pl. 2G). Pellets and ostracods, isolated nodosariid foraminifers and crinoids do not form more than 5 % of the rock.

Restricted offshore environment (Plate 3)

Thickly bedded (100 *cm*) dark grey to black banded, thickly laminated, vermicular and redeposited vermiculated micrite and microsparite (mudstone, wackestone) contain an unevenly distributed clayey admixture. Clayey infiltrations, weak dolomitization, HCS (hummocky cross stratification), slip deformation and black pebbles are typical. Nodular varieties with cherts are isolated. The facies prevails in the lower part of the Geldek Member.

Limestones from the profiles studied (Fig. 5) do not have a higher content of IR (Tab. 1; 0.27 to 1.77 %). Recrystallization and pressure dissolution probably only emphasized an originally laminated and banded structure. The content of micro elements is only partly differentiated in samples from different profiles. The content of Mn is low (17 - 42 ppm), but in the Bartalová section, without obvious facial dependence it reaches 19 to 131 ppm. The Fe content varied more significantly in individual profiles and did not react to movements in Mn values. The Sr content was individually high in samples from the Vysoká II section - 1905 ppm.

MF-5 - Micrites and microsparites (mudstones) with isolated detritus and thick laminated to banded texture (Pl. 3B). The proportion of detritus reaches a maximum of 5 % (pellets, ostracods). The laminated to banded texture is a kind of alternation of laminae with different contents of clayey admixture.

MF-6 - Nonhomogeneous weakly clayey micrite (mudstones) with vermicular structure (Pl. 3D,E). Ostracods prevail in the organic debris (up to 3 %), nodosariid foraminifers, crinoids and gastropods are occasional. The vermiculated limestone in the thin sections shows a content of clayey admixture and secondary pyrite, with a sudden change in granularity, which gives an impression of clastic structure.

MF-7 - Micrite limestones with large intraclasts (black pebbles, Pl. 3C,F) to rounded stones of micrite (floatstone - rudstone). Dark micrite black pebbles reach a size of 1 to 30 *mm*. Subrounded clasts have a lower content of organic matter and secondary pyrite against micrite-microsparite basic material with weakly clayey admixture. The content of allochems and fossils is the same as in *MF-6*.

Restricted offshore environment (Plates 4, 5)

Thick bedded (50 - 200 *cm*) dark grey, grey, often dolomitized oolitic and detritic limestones to dolomites. Some places contain a macrofauna of bryozoans, brachiopods, bivalves and gastropods. Detritic limestones are often paralelly and obliquely laminated, ripple-like stratification and HCS are found occasionally. Oolitic and organodetritic sparite limestones are characteristic of a dynamic environment. Biomicrite limestones with bryozoans, calcareous sponges and brachiopods were sedimented in an environment of wash-over channels. The facies is characteristic of the middle and upper parts of the Geldek Member.

The greater variability of the rock of this facies is also reflected in the movement of diagenetic solutions and in the distribution of analyzed micro elements. The Sr content varies in the wider range of 300 to 2400 ppm (Tab. 1). A closed environment can preserve a high Sr content (aragonite mineralogy). The high Sr content does not exclude the presence of diagenetic celestine, and may be a result of later diagenetic processes. In part of the Vysoká II (beds 25 to 36) they do not have a relation to the structure (Fig. 5). Coarse-grained and partly dolomitized rocks have a lower Sr content. The degree of dolomitization is generally low and in closed diagenetic environments with a source of Mg could actually be high - Mg calcite.

MF-8 - Oosparitic and oobiosparitic limestones (grainstone, Pl. 4D,E,G). The ooids reach a size of 0.3 - 0.5 *mm*, and are often selectively dolomitized and secondarily micritized. The cores and concentric structure of the ooids (bioclasts and pellets) are only preserved occasionally. Bio- and lithoclasts over 0.6 *mm* (bivalves, gastropods, scarce crinoids) remained uncovered.

MF-9 - Oomicritic and intraoomicritic (wackestone - packstone, Pl. 4F). The size and character of the ooid is as in *MF-8*. The content of the ooids varies in the interval 15 - 50%, the content of bioclasts and pellets is up to 10%. Neomorphism of the matrix.

MF-10 - Biomicritic limestones with bryozoans, (wackestone - packstone, Pl. 6M). Organic detritus, the content of which varies from 10 to 60 %, is formed by bryozoans, foraminifers, ostracods, crinoids, ophiuroids, bivalves, gastropods and folded oncoliths. Ooids and intraclasts of biomicrite are isolated. The matrix (microsparite to fine biosparite) is a altered by neomorphism.

MF-11 - Biomicrites and intramicrites with crinoids (wackestone - rudstone, Fig. 6N). The detritus is formed by crinoids, foraminifers, ostracods, bivalves, gastropods and pellets (5 to 30%). Micrite and biomicrite intraclasts are imperfectly rounded (content from 1 to 25 %). There are occasional ooids and folded oncoliths. The matrix is microsparitic.

MF-12 - Shelly biomicrite (wackestone - packstone) with bivalves and gastropods (Pl. 4C). Besides bivalves and gastropods, there are remains of foraminifers, ostracods, pellets and crinoids (10 to 60 %). There is frequent neomorphism of the matrix.

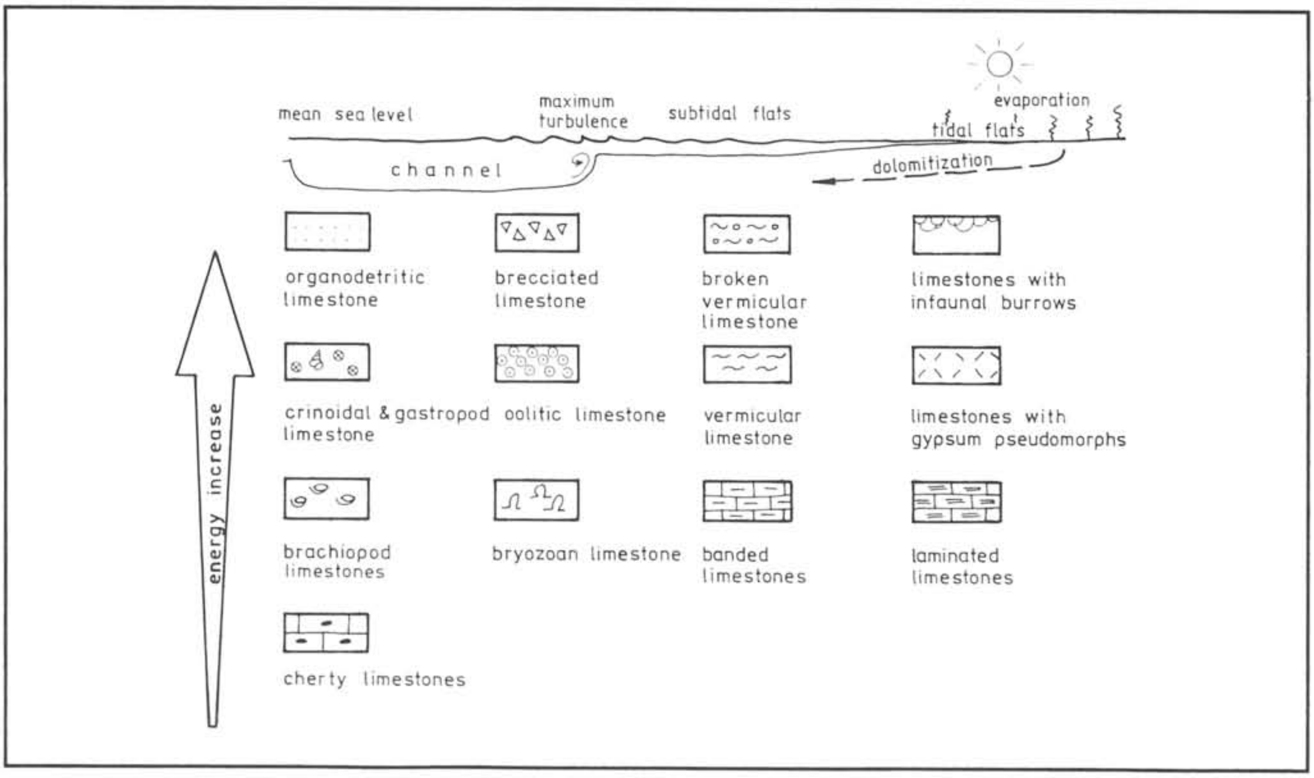


Fig. 6. Distribution of lithofacies in the Vysoká Fm. in an environmental model and their relation to the energy of environment.

Storm environment (Plate 5)

Sharply delimited layers of graded calcarenites (grainstone to rudstone), or intrabiomicrite (wackestone - packstone) in the middle of vermiculated and banded limestones, have variable thickness (1 to 40 *cm*) and character. Event sediments are characteristic of the basal and middle part of the Geldek Member (Figs. 2 - 3, sections 12, 15, 24).

MF-13 - Graded stratified coarse clastic intrabiorudite (floatstone - rudstone). Sparites and microsparites contain coarse detritus with bioclasts and intraclasts up to a size of some *cm*, with remains of bivalves, gastropods and crinoids.

MF-14 - Fine-grained laminated biointramicrites, intrabiosparites (wackestone, packstone, grainstone, Pl. 5D,E). Often significantly recrystallized and selectively dolomitized graded stratified limestones with remains of bivalves, gastropods, ostracods, crinoids and foraminifers. They contain small intraclasts, pellets and ooids.

Allochems and structures

Tempestite and associated structures

Micrites of the middle beds of the Geldek Member (Figs. 2 - 3 : sections 2, 4 - 6, 12 - 18, 20 - 24). Occasionally they contain 6 - 15 (max. 40) *cm* of coarse detritic insertions. Chudzikiewicz (1975), Džulynski & Kubicz (1975) present similar cases from the Silesian Muschelkalk, Aigner (1977, 1979), Aigner et al. (1978) from the German Muschelkalk and Blendinger (1983) from the south Alpine Middle Triassic Dont Formation, as storm sediments or tempestites. The strata are graded, sharply divided from the overlying and underlying beds, and consist of bioclasts of marine organisms (gastropods, crinoids, brachiopods, bivalves) and clasts of underlying rock (Pl. 5C). The rocks underlying tempestites are usually banded or vermicular limestones, the overlying rocks are vermicular, oolitic or dolomitized limestones. The erosional base is often stylolitized. Parallel, HCS and ripple laminated intervals, indicating a high current regime in the tempestite sequence (Aigner 1982), occur only occasionally. The greater part is equivalent to distal tempestite. Coarse clastic proximal tempestites (rudstone, Pl. 5 E) laterally (often up to several metres) hardly reach a few *cm* of fine-grained calcarenite (grainstone) to fine laminated biomicrite (packstone, Pl. 5D).

Fine detritic limestones with insignificant gradation are another type of storm rock. The beds forming this lithofacies are usually thicker (40 to 100 *cm* and more). Sometimes hummocky cross stratification, and marine microorganisms (conodonts and holothurians at the Bartalová section) occur in them. According to Catenacci (1976) such sediments are deposited in lagoons from the suspension stirred up by a storm. Laterally they probably go to fill wash-over channels, from which water overflowed during storms (Rudowski 1986).

Probable tsunamites

In some cases we found layers of structureless detritic limestones (grainstone - packstone) with large extraclasts. Their character indicates a rapid, single deposition, without subsequent reworking. Among various such detritic inserts in profiles 12 and 24 (Figs. 2 - 3) lies a bed of vermicular limestone with sigmoidally deformed particles (Pl. 5A,B). Nagy (1968) described a similar texture, from deposits of the same age (Misina Fm.) in the Mecsek range, as "zurückgebogene Kreuzschichtung". Kimura et al. (1989) interpreted the origin of sigmoidal deformation ("veins") from recent soft sediments as shears parallel to the stratification, and an accompanying reduction in the amount of pore water. A sudden increase in the pressure of pore water during lateral strain may be the origin of coullise-formed slip surfaces (domino effect). The cause of the sudden pressure event is revealed by the model of the activity of tsunami (Colleman 1968; Catenacci 1976). Perceptible shocks from on-surge movement waves act chiefly on unconsolidated layers of shallow marine sediment. Galli (1990) described imbricated arrangement of bivalve shells underlying the actual tsunamite. The sigmoidally deformed bed in our profiles is evidently the product the same shear stress, which during "on-surge" movement produced slip laminae. Shortening and the origin of lenticular shears occurs along the surface of the affected sediments, in the protected section of bottom. The off-surge phase caused the back movement of the upper part of the lenticular and sigmoidal bending of slip laminae. It is noteworthy, that tsunamite beds are preserved exclusively in environments of vermicular limestones - that is in partly protected lagoons. In areas of elevated bottom, tsunamite is evidently represented by erosional surfaces.

Fossils

Bystrický (1967, 1973) found dasycladal alga *Gyroporella (G.) anisica* Zanin-Burri in the material of M. Peržel from Modranská Skala. Mišík (1983) presented the occurrence of inserts of crinoidal limestones with slightly worn columnals, at various places (Modranská Skala, Vysoká).

By detailed profiling, we succeeded in identifying four association of fossils, which more closely indicate the environmental and age assignment of the formation.

1 - A relatively rich association of holothurian sclerites occur in the Bartalová section (Pl. 6C-E,G). Similar forms to those described by Mostler (1972) from the Alps: *Theelia germanica* Kozur, *Th. mostleri* Kozur, *Achistrum* cf. *triassicum* Frizzel-Exline, *A. pulchrum* Kozur, *Priscopedatus* div. sp. and *ophiuroids,* together with ostracods, micro-problematics, recrystallized foraminifers *Pilamminella* aff. *grandis* (Salaj) (Pl. 6B), and the conodonts *Neospathodus germanicus* Kozur (Pl. 6I-K). The foraminifers identified are also known from the lower part of the profile at Vysoká (3-4, 6, 10, cf. Fig. 2), the species *Meandrospira deformata* Salaj from the Holba section (Pl. 6A). In the tempestite beds (11, 19) of the Oberheg section, a large quantity of small gastropods occur. Conodonts are characteristic of the lower Pelsonian *Germanica Zone*. Bed 23 in the Bartalová section yielded rich finds of bryozoans *Discritella nevadensis* Schaffer et Fois, *D. zardinii* Schaffer et Fois, *Heterotrupidae* gen. nov. (K. Zágoršek, pers. comm., Pl. 6M). This association agrees with the collection, gained from horizon 16 in profiles 9-11 (Fig. 2).

2 - A rich association of macrofauna comes from bed 25 in profile 10 (Fig. 2): *Punctospirella fragilis* (Schloth.), *Coenothyris vulgaris* (Schloth.), *Mentzelia mentzeli* (Dunk.), *Dadocrinus* sp., bivalves, gastropods, microproblematics and spicules of calcareous sponges (Pl. 6N,F). Juvenile conodonts *Gondolella constricta* Mosher et Clark (Pl. 6H,M), indicating Illyrian age were found in this layer. An individual *Pilaminella* ex gr. *densa* Pantič was identified in bed 32, differing from the typical species in its smaller number of coils and wider deuterolocules, that is marks of a developmentally younger species *Pilaminella gemerica* (Salaj). Apart from the species mentioned, there are sporadic fragments of nodosariids and sesile forms. A community with *P. densa* represents a Pelsonian Illyrian acme zone (Salaj et al. 1983, 1988).

3 - Oolitic limestones in the upper part of profiles 9 - 11 (Fig. 2) contain the zoaria of *Dyscritella* sp. n. and *Heterotrypidae* gen. nov. (K. Zágoršek, pers. comm.). Apart from them, small gastropods, bivalves and crinoids occur in the association.

4 - In the upper part of profile 28 (Fig. 3) three shelly beds occur, containing a large quantity of small gastropods and bivalves *Myophoriopsis* (Pseudocorbula) *gregaria* (Münst.), *Placunopsis* cf. *ostracina* Schlotheim, *Pleuromya musculoides elongata* (Goldfuss), *Chlamys* (Praechlamys) *reticulata* (Schloth.), *Lopha monticaprilis* (Klippst.), so the association is identical with the collection of Kochanová (in Mahel' & Buday 1968). The composition indicates the boundary between Cordevolian and Julian.

Discussion on sedimentary and life environment

The Triassic sedimentary sequence of the Alpine-Carpathian nappes were deposited on an extensive (some hundreds to a thousand kilometres wide) shallow marine shelf, along the northern margin of the Tethys Ocean. On the turn of the Spathian and Anisian periods the contribution of terrigenous material ceased, and conditions became suitable for the deposition of carbonates. Monotonous sedimentation over an extensive area, with small and insignificant lateral and vertical changes in facies, was a characteristic feature of the early stage of the formation of the Triassic carbonate platform. From the morphological point of view, this platform may be described as a monoclinal carbonate ramp (Ahr 1973). The dynamic, salinity and oxygene regime of the sedimentation environment of the Vysoká Fm., which occurs in the middle of this ramp, was limited by the climatic conditions and the low column of water, which hindered the free interchange of water with the open sea. Conditions favourable for the development of organisms occurred only episodically, as the few isolated layers with crinoids, ostracods, foraminifers and small gastropods document. The shallow water character of the sedimentation is indicated by the layers of laminite, pseudomorphs of evaporite crystals and flat pebble breccia. The occurrence of tempestite, with thickly detritic (sparitic) sediments, among mainly pure (micritic) and vermicular limestones is characteristic (Fig. 6).

Sedimentological conclusions may also be supported by information about the chemical composition of the carbonates. The increased salinity of the sedimentational environment (distribution of Sr and Na) and the movement of these solutions in post-sedimentational development appears to be the most significant. The distribution of the microelements analyzed indicates a relatively conservative, closed environment with movement of solutions in the pores of the sediment. The differences in the distribution of Sr, and the degree of dolomitization of the limestones, are a result of this. The not very significant differences in the distribution of Mn result more from the mineral composition of the sediment (organic debris, oolites, ooze) since the oxidation environment preserved completely and the accumulation of organic material was not great. The Vysoká limestones are not basically different in chemical composition, from the Middle Triassic limestones of the Gutenstein type. They are pure carbonates with low IR, the values of which could be influenced by silicification, less than by the production of diagenetic sulphides. The source of Si, and also for example Fe could be dispersed clayey minerals, which were in IR (in places accumulated by pressure solution). The increased pH of the saline solutions of the sabkha sediments may help the movement of Si.

Conclusions

1 - The Vysoká Formation is a product of an environment of undifferenciated shallow sea carbonate platform, isolated from tidal currents, but influenced by storm waves.

2 - The sedimentary and living environment of the Vysoká Formation may be divided into four facial zones: restricted onshore, restricted shoreface, restricted offshore, semirestricted offshore.

3 - We recognized fourteen microfacial types in the formation (according to the criteria of Dunham 1962), distinguished by sedimentary structure, texture, distribution of allochems, fossils and micro-elements.

4 - The sequence of the Vysoká Formation may be divided into three members (Geldek, Ramsau and Parná Members). The lowest, Geldek Member is composed of lower, massive beds, tempestite - biogenic beds and oolitic - evaporite beds.

5 - On the basis of finds of conodonts, foraminifers and other fossils, two fossiliferous horizons in the middle part of the Geldek Member, can be biostratigraphically dated to the Lower Pelsonian and Pelsonian - Illyrian.

Translated by M.C. Styan

Plate 1: Facies influenced by an arid foreshore sedimentary regime, Horný vrch hill (Oberheg) section.

A - Cycles consisting of slightly dolomitized microsparite (mudstone) with irregular pseudomorphs after evaporite mushes and crusts, terminated by laminite. Bed No. 44.

B - Bed No. 73 of gray slightly dolomitized detritic limestone overfilled by gypsum pseudomorphs. Lower shoreface facies.

C - Polished section of gray slightly dolomitized microsparite to micrite (mudstone) with abundant pseudomorphs after gypsum. Lower shoreface facies. Bar indicates 1 *cm* distance. Bed No. 72.

D - Slightly dolomitized limestone with indistinctly vermiculated texture and numerous tiny pseudomorphs after evaporite minerals. Bed No. 49 (bar = 1 *cm*). Upper offshore facies.

E - Microphoto of a gypsum pseudomorph in slightly dolomitized microsparite (mudstone). Bed No. 66, bar = 10 *m*.

F - Thin section of laminated pelletal wackestone, base of the Bed No. 54. The bar indicates 1 *mm*. Upper shoreface zone.

Plate 2: Restricted shoreface zone.

A - Bedding plane of slightly dolomitized limestone penetrated by infaunal burrows. Horný vrch hill (Oberheg) section, bed No. 83.

B - Polished section of intensively burrowed intertidal laminite. Bralná Vysoká section, bed No. 64. Scale in milimeters.

C - Polished section of slightly dolomitized intertidal laminite. Vysoká VII section.

D - Burrowed bituminous micritic mudstone. Parina section. Bar = 0.1 *cm*.

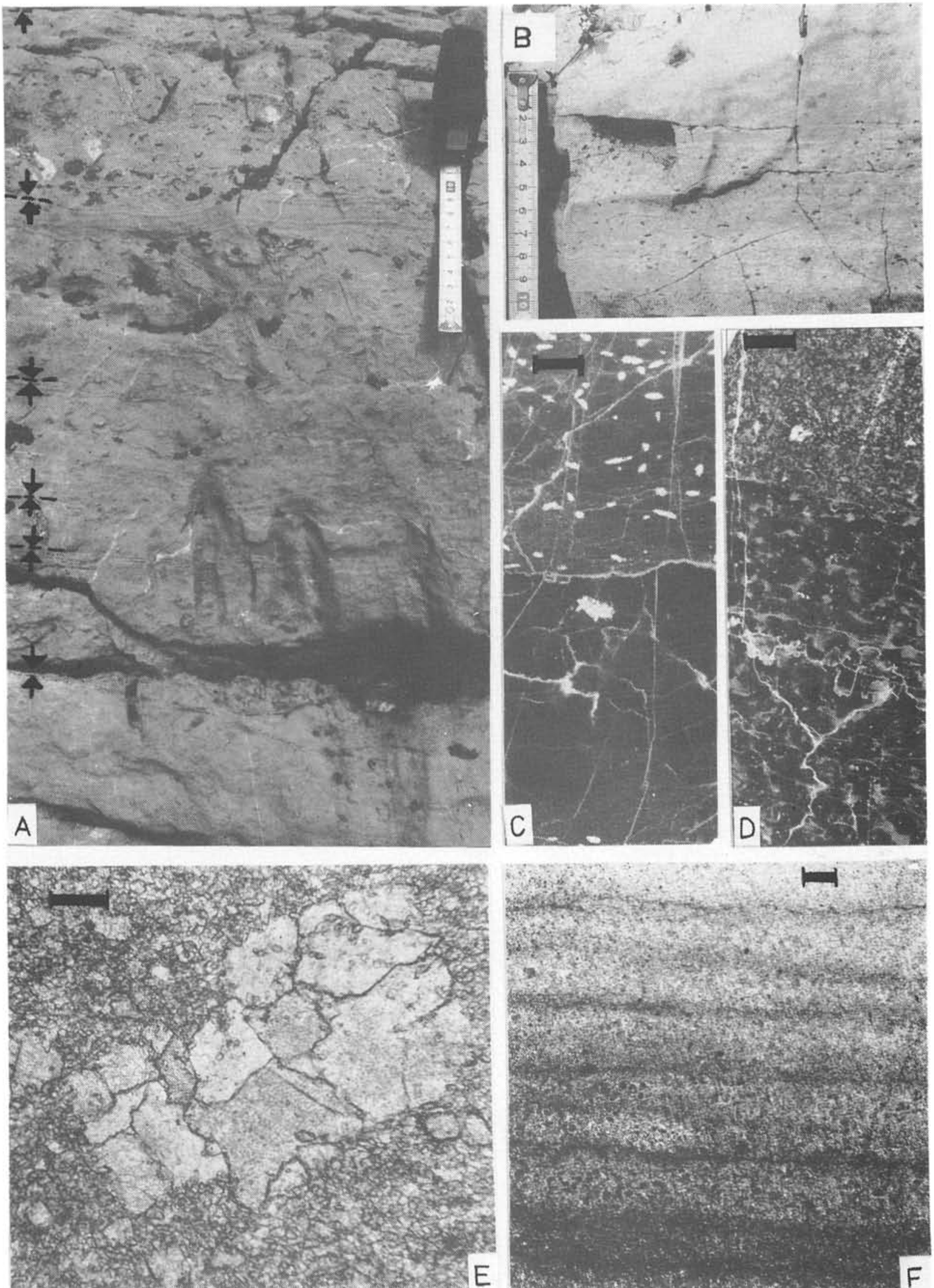
E - Burrowed slightly dolomitized biopelmicrite, Vysoká II section, bed No. 35 (Bar = 1 *mm*).

F - Burrowed slightly dolomitized biomicrite, Oberheg section, bed No. 67.

G - Bioturbated biomicrite, Oberheg section, No. 38.

H - Thin section of laminated pelmicrite. Oberheg section, bed No. 8., bar 0.1 *mm*.

Plate 1



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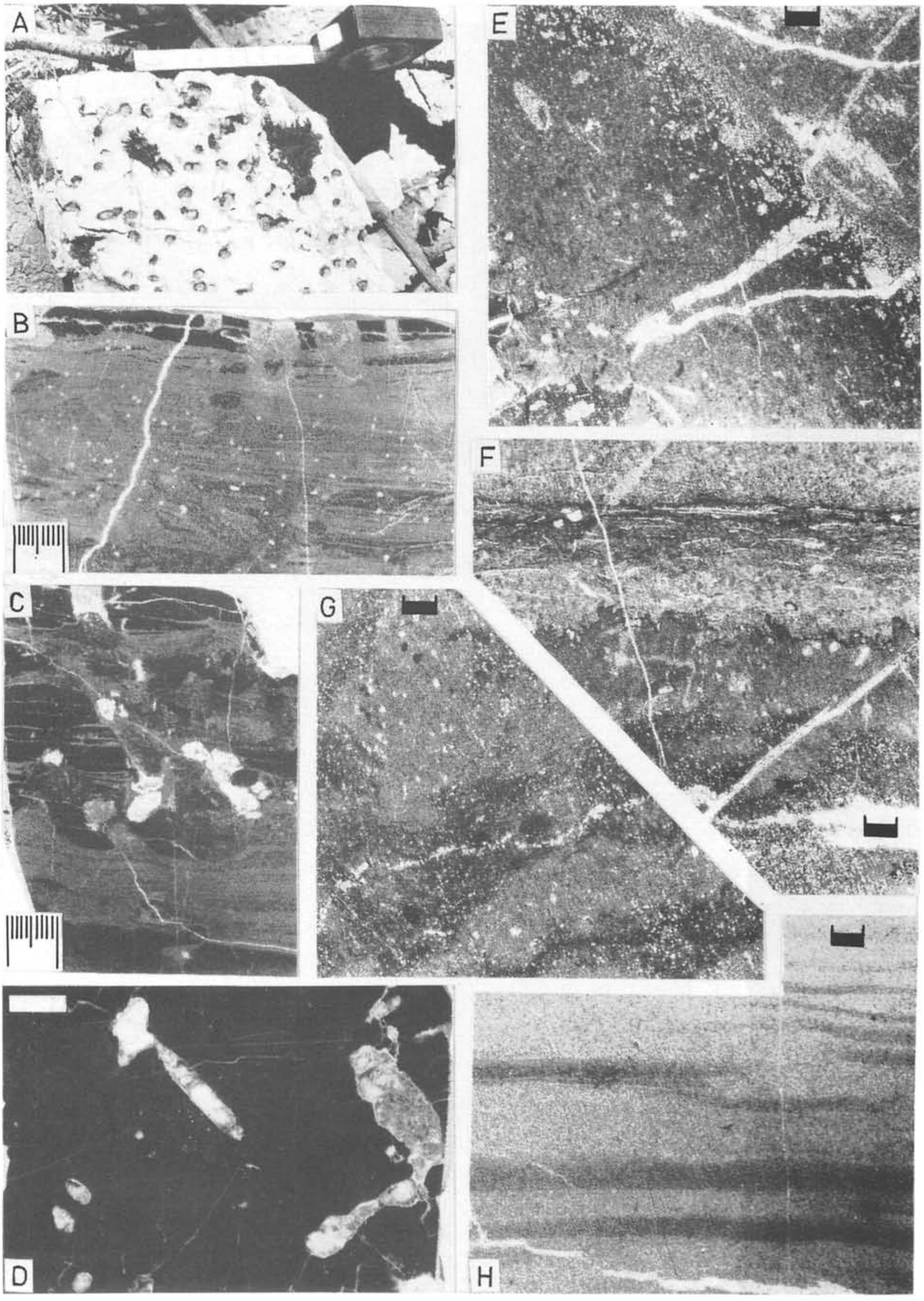

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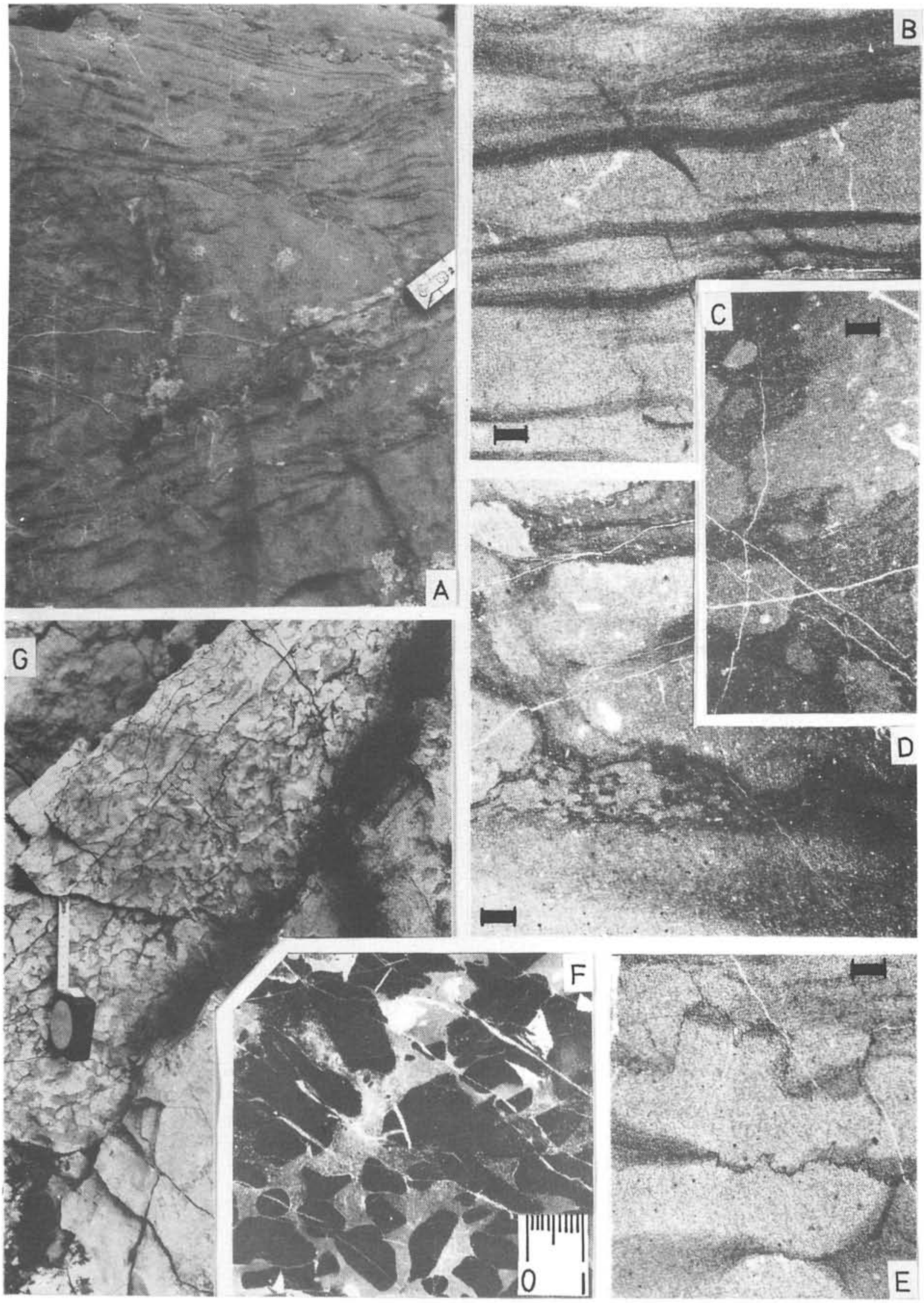

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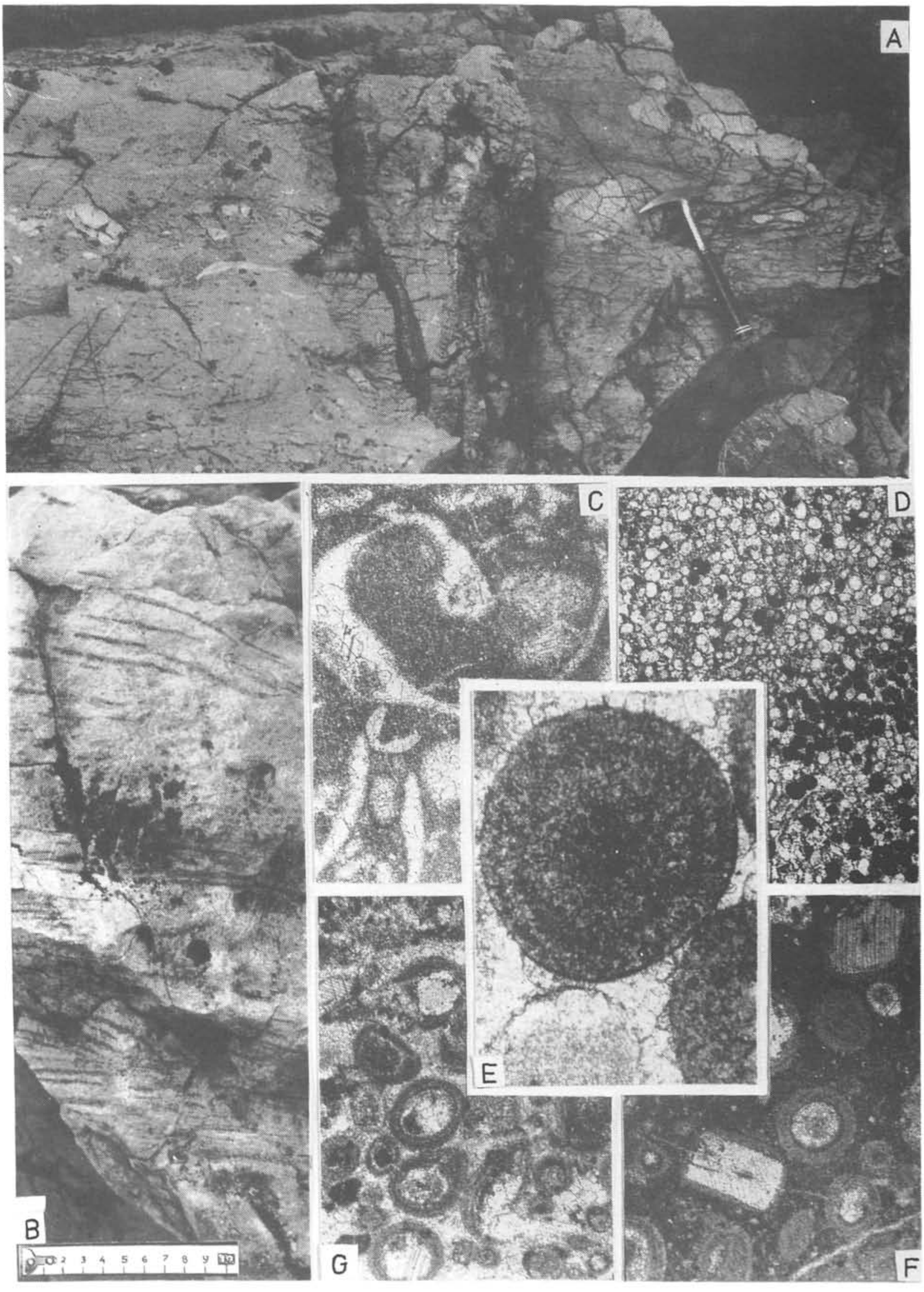

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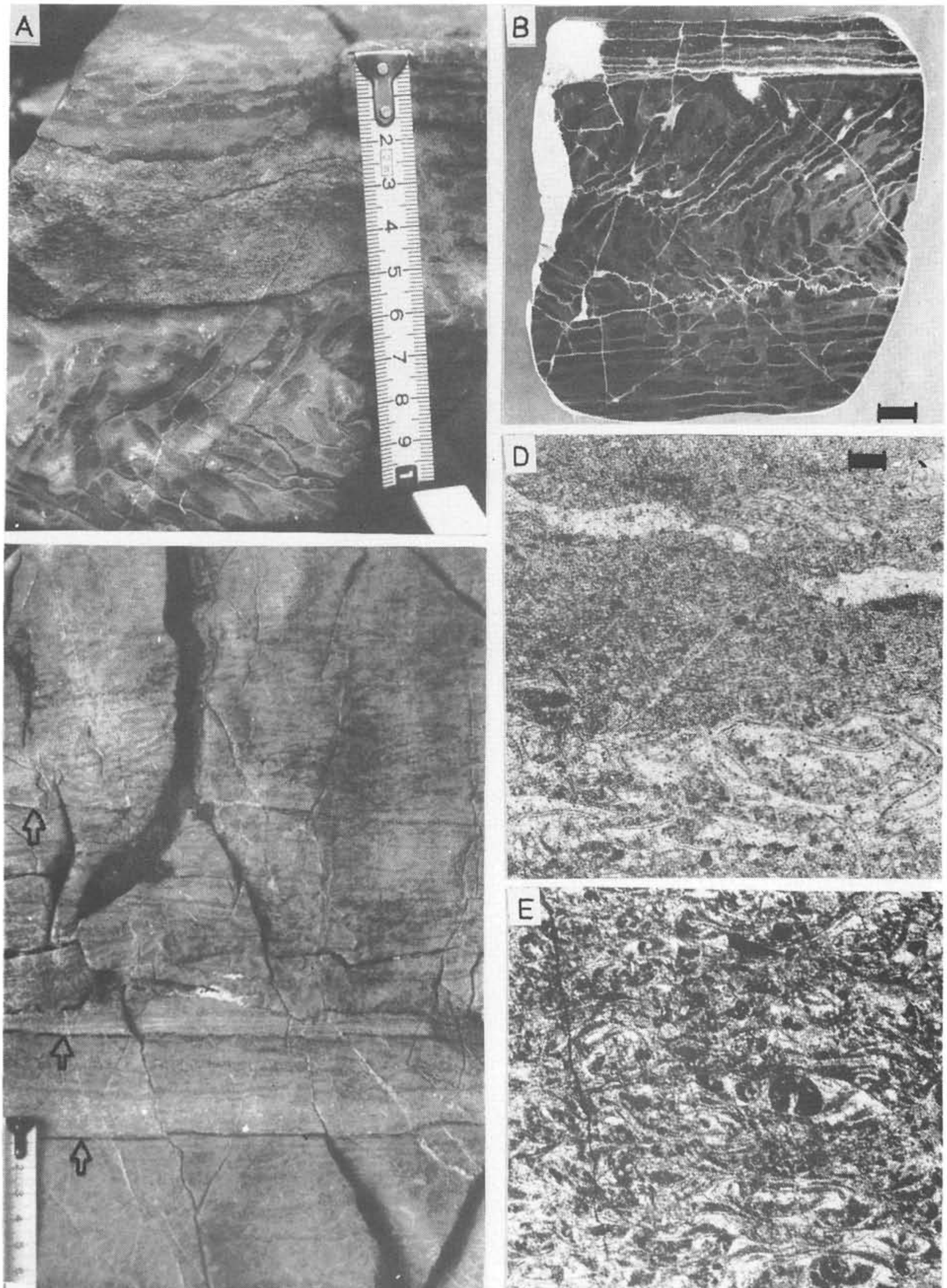

Plate 6

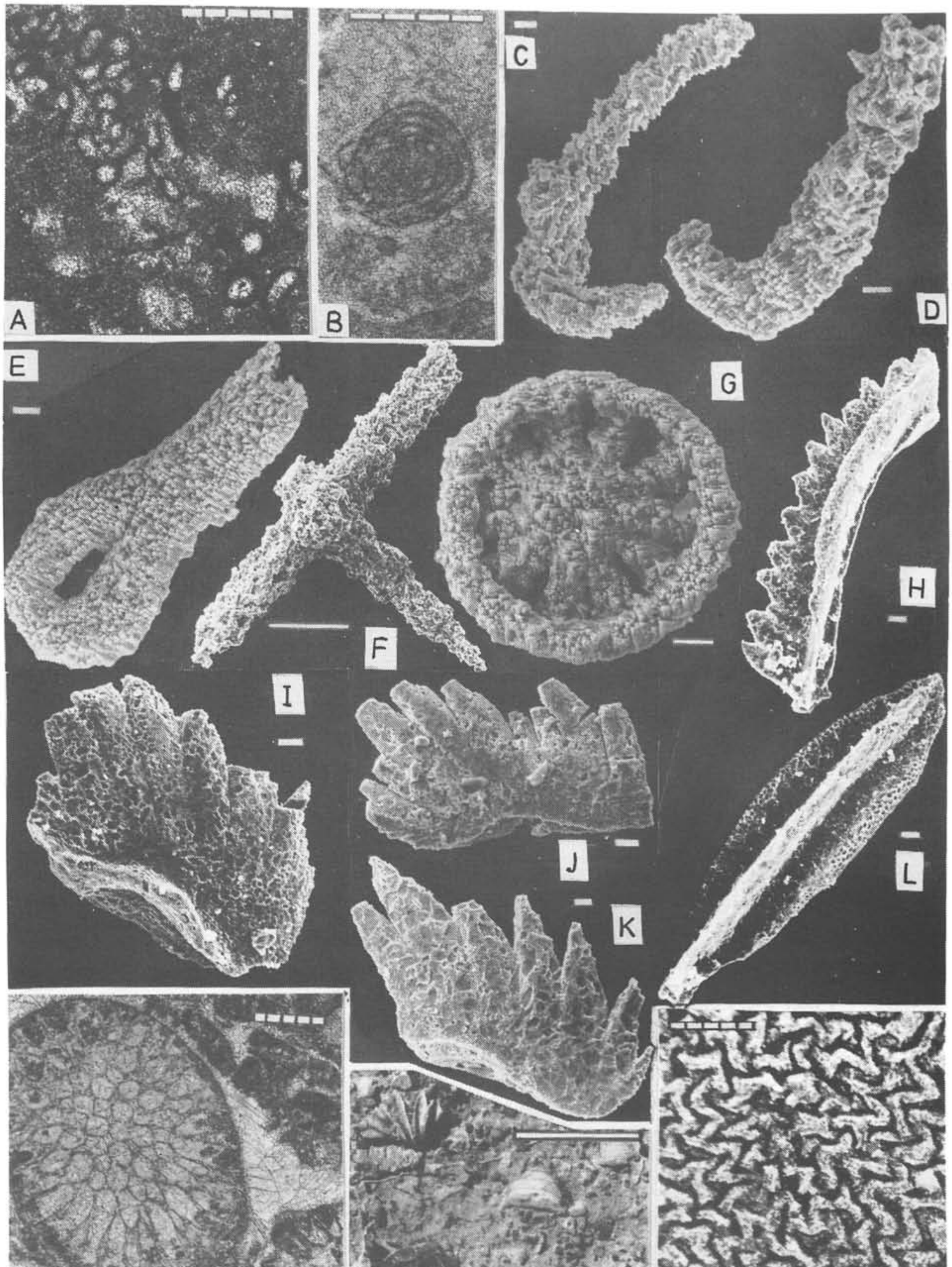

Plate 3: Facies of restricted nearshore flats and lagoons.
A - Banded (indistinctly vermiculated) micritic limestone with slumping texture. Oberheg section, bed No. 25.
B - Thin section of thick laminated (banded) micritic limestone. Oberheg section, bed No. 14 (bar = 1 *mm*).
C - Thin section of micritic limestone with abundant intraclasts. Vysoká IX section, bed No. 20.
D - Thin section of thick laminated limestone with arising vermiculated texture. Bralná Vysoká section, bed 55.
E - Thin section of vermiculated limestone with expressive stylolitization.
F - Fine brecciated limestone (to gravellite) arisen from vermiculated limestone (scale in milimeters). Vysoká II section, bed No. 31.
G - Bed No. 31 (Vysoká I section) consisting of brecciated vermicular limestone.

Plate 4: Semirestricted facies of wash-over channels.
A - Washover channel filled with fine-grained (to micrite) limestone with abundant limestone clasts. Oberheg section, bed No. 42.
B - Cross bedded slightly dolomitized oolitic limestone. Oberheg section, bed No. 33., scale in centimeters.
C - Biodetrital limestone with abundant gastropods and bivalve shell fragments. Bartalová section, bed No. 12 (bar = 1 *mm*).
D - Slightly dolomitized oolitic limestone. Oberheg section, bed No. 36.
E - Thin section of limestone ooid, showing recrystallization of calcitic coatings. Oberheg section, bed No. 36.
F - Thin section of oolitic limestone with crinoid columnalia. Bartalová section, bed No. 21.
G - Thin section of oolitic limestone with superficial ooids. Bartalová section, bed No. 23.

Plate 5: Organoclastic facies with tempestites and tsunamites. Horný vrch hill (Oberheg) section.
A - Tsunamite layer in vermiculated limestone. Note sigmoidal deformed bed in its direct underlie. Bed No. 24.
B - Polished section of sigmoidal deformed layer followed by thin (off-surge) detrital layer. Bed No. 16 (bar = 1 *cm*).
C - Layer of vermiculated limestone containing three tempestite horizons (see the arrows). Bed No. 18.
D - Thin section of biodetrital microsparite of tempestite origin. Bed No. 58 (bar = 1 *mm*).
E - *B* - Thin section of rough intrabiosparite of tempestite origin. Bed No. 13 (bar = 1 *mm*).

Plate 6: Organisms of the Vysoká Formation.
A - *Meandrospira deformata* Salaj, scree below the section 18, bar = 0.5 *mm*. *B* - *Pilamminella* aff. *grandis* (Salaj), Bartalová 23, bar = 0.4 *mm*. *C* - *Holothurian* spicule, Bartalová 10, 2879, bar = 10 *μm*. *D* - dtto, Bartalová 15, 2863, bar = 10 *μm*. *E* - dtto, Bartalová 15, 2866, bar = 10 *μm*. *F* - Sponge spicule, Vysoká III/25, 2907, bar = 100 *μm*. *G* - *Theelia* sp., Bartalová 10, 2881, bar = 10 *μm*. *H* - *Gondolella constricta*, Vysoká II/25, 2894, bar= 10 *μm*. *I* - *Neospathodus germanicus* Koz., Bartalová 15, 2870, bar=10 *μm*. *J* - dtto, Bartalová 20, 2868, bar = 10 *μm*. *K* - dtto, Bartalová 10-top, 2884, bar = 10 *μm*. *L* - *Gondolella constricta*, Vysoká II/25, 2893, bar = 10 *μm*. *M* - bryozoans, Bartalová 23, bar = 0.5 *mm*. *N* - *Punctospirella fragilis*, Vysoká II/25, bar = 10 *mm*. *O* - siliceous sponge (?), Oberheg 15 top, bar = 0.5 *mm*.

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