

CARBONATE RAMP ENVIRONMENT OF KELLWASSER TIME-INTERVAL (LESNI LOM, MORAVIA, CZECHOSLOVAKIA)

by Jindrich HLADIL, Zuzana KREJČP, Jiri KALVODA³, Michal GINTER⁴, Arnost GALLE⁵ & Pavel BEROUSEK¹

ABSTRACT

The Frasnian-Famennian limestone sequence of Lesni lom displays a series of significant gaps, especially at a stratigraphical level encompassing the final Late *Pa. rhenana* Zone and the Early *Pa. triangularis* Zone. Mixed nearshore and nektonic/pelagic faunas, as well as mixed allochems derived from a large spectrum of facies belts, point to an inclined outer carbonate ramp depositional environment. The maximum water depth probably exceeded several tens of meters. However, extreme and short-term sea-level falls around the Frasnian-Famennian(F-F) transition might have stripped a substantial part of the sedimentary cover on this ramp. The presence of an increasing amount of unstable siliciclastic grains, followed by the influx of lateritic and ferruginized particles are typical for the Lesni lom F-F sequence. This can be correlated with an oolitic ironstone level, which has been described from an 'inner ramp' sequence at 'V Habesi'. The latter iron-horizon, resembles the Famennian ironstones of Belgium, but it has also good analogues in the F-F sequences of the Russian Platform.

Rebuilt corals and foraminifers seem to indicate different biotic and environmental controls, separately on the outer and/or the inner ramp. Although more than twenty groups of taxa are discussed, only four of them - corals, fish remains, foraminifers and conodonts - have been described in detail.

KEY WORDS

Conodonts, foraminifers, corals, ichthyofauna, biostratigraphy, ecology, sedimentology, carbonate ramps, paleoenvironment, regional geology, Moravia, Upper Devonian, Kellwasser event.

1. INTRODUCTION - BRIEF COMMENTS TO THE CURRENT 'KELLWASSER' INTERPRETATION

J. Hladil

According to the actual state of knowledge, the Frasnian/Famennian Kellwasser Event consists of a series of extinction levels (step-wise extinction) which were apparently associated with anoxic or dysaerobic conditions, at least in a substantial part of the F-F oceans

¹ Geological Survey, Malostranske 19 - CS-118 21 Praha, Czechoslovakia.

² Geological Survey, Leitnerova 22 - CS-658 69 Brno, Czechoslovakia.

³ Department of Geology & Paleontology, Masaryk University, Kotlarska 2a - CS-611 37 Brno, Czechoslovakia.

⁴ Institute of Geology, Warszawa University, Zwirki i Wigury 93 - PL-02 089 Warszawa, Poland.

⁵ Geological Institute, Academy of Sciences, Rozvojova 135 - CS-160 00 Praha-Suchdol, Czechoslovakia.

and outer shelves. This is mainly attributed to climatic changes, especially to ocean water cooling. A typical image of the Kellwasser Event corresponds to open-sea anoxia. However, the problem is more complex, because recent anoxic environments are hardly comparable with the F-F fossil ones (comp. e.g. the overview of Kukal, 1990).

The majority of the described sections corresponds to outer-shelf and/or proto-oceanic ridge environments, including some isolated deep plateaux and moderately domed structures of probable continental margin origin. More than 150 studies have been devoted to this event; the stratigraphical records of the F-F outer facies belts have been precised especially in the Rheinisches Schiefergebirge (e.g. Steinbruch Schmidt in Kellerwald), Harz, Montagne Noire and SE Morocco (Schindler, 1990). Two dark sediment levels are the most conspicuous: Sandberg *et al.* (1988), Walliser *et al.* (1989), and Schindler (1990) ascertained and correlated the lower dark event with the upper part of *Palmatolepis gigas* Zone, and the upper event with the *Palmatolepis linguiformis* Zone. The end of the second anoxia corresponds to the Frasnian-Famennian (F-F) boundary. Schindler (1990) led the event arise in conjunction with several superimposed factors: (a) narrowing of the 'Paleotethys' between Laurussia and 'Gondwana' (but we shall be careful in the definition of those continental groups - comp. Talent *et al.*, 1986), interruption of equatorial circulation (Copper, 1986); (b) beginning of the south-continent glaciation and steeper climatic gradient; (c) overturns in the oceanic-water stratification, unstable regimes or rebuilding of the hypothetical 'El-Nino-like' oceanic megacells. The possibility of simultaneous strong momentary events, like the impacts of bolides (Goodfellow *et al.*, 1988, Playford *et al.*, 1984, McLaren, 1982, Zukalova & Skocek, 1979) and/or unspecified tsunamis in the Lower *Palmatolepis triangularis* Zone (Sandberg *et al.*, 1988) is still under discussion. Contrary to the giant catastrophes, small impulses of 'internal' ecologic nature may provide drastic changes of the biotas (McKinney, 1989). The small 'starting ecological impulses' of M.L. McKinney or other authors are probably more frequent in 'shallow water' than in the 'deeper water column'. Sometimes the causes are questionable and hardly to define even among the recent ex-

inction pulses (e.g. the 1987 and 1990 'whitening', i.e. zooxanthellae-decoupling, and consequent coral mortality of the Caribbean realm; Vanek, 1991). The recent mortalities could be associated with slight warming of the ocean water. Temporal warming episodes as an extinction control may be much more effective than cooling events (Thompson & Newton, 1988), perhaps also in the situation, when the individual warming episodes occur on the background of a larger cooling process.

The significance of shoals for the biotic crises has long been recognized (comp. Johnson & Sandberg, 1988). Shallow-water or epicontinental F-F sections are commonly accessible over the world (Schindler, 1990), along the basinward-shifted ramps underlain by the margins of the Frasnian buildup complexes (comp. Hladil, 1986). As can be well demonstrated in Belgium, the siliciclastic influx increased from the late Frasnian. The carbonate sequences reflect the change from the reef/platform environment of the ramp. Associated disconformities and condensations were described from the section Roc de Rance (Southern margin of the Dinant Synclinorium, Biron *et al.*, 1983): the transition from the Upper *Pa. gigas* reef limestone to reddish and greenish nodular limestone correspond to the end of the Frasnian, while the overlying grey nodular limestone yields the *Pa. triangularis* conodont association. The mudstone facies with limestone and siliciclastic intercalations (Belgian Sinsin and Hony sections) have been assigned to the shelf environment. The siliciclastic layers correspond to the interval between *Pa. linguiformis* and Lower *Pa. triangularis* Zones. A parallel is given here between the shallowing and the extinctions. Surprisingly, the total amount of palynomorphs attains several hundred thousands of specimens per gram of the F-F siliciclastics (Streel & Vanguetaine, 1989). Dusaar (1976) found that many faunas vanish near the F-F boundary, conodonts and rhynchonellid associations display a change in their composition. However, only a weak similarity between the F-F event and the Famennian 'ironstone' events could be found according to the Belgian sequences. The joint control is represented by general regression (Dreesen & Thorez, 1982) and by the fact that the 'ironstone' events became more and more visible since the late *Pa. triangularis* Zone of the lowermost Famennian, continuing into

the Famennian regression (Dreesen, 1982; Dreesen *et al.*, 1988).

Remarkable interruptions, condensations in the thickness and/or disturbances of the sedimentary record are visible in many Euamerican and Asian shelf or slope sections, e.g. Trout River (Northwest Territories, Canada; Goodfellow *et al.*, 1988), Devils Gate (Nevada; Sandberg *et al.*, 1988), Mokra (Moravia; Hladil *et al.*, 1989), Kostomloty (Holy Cross Mts, Central Poland; Racki, 1990) or in the sections referred from China (in three types of the South-China F-F sequences, Hou Hong-fei *et al.*, 1988; or in the well documented section of Baqi Section, Xiangzhou County, Guangxi, Wang & Bai, 1988). The worldwide F-F high energy sedimentation/erosion event (Goodfellow *et al.*, 1988) could be consistent with bolide impacts, but, in our opinion, only few comment on the ultimate bolide causes, especially in the light of the iridium-anomaly revisions (e.g. Hurley & van der Voo, 1990).

Dysaerobic environments may be also recorded in the nearshore environment (Schindler, 1990), but, as mentioned below, not always with the same pattern of sedimentary and biotic records (Playford & Cockbain, 1990, Becker *et al.*, 1990 - Canning Basin; Makhnach *et al.*, 1984 - Bielorrussia; Aristov, 1989 - E of Voronezh, Russian Platform). Especially the latter sections, near Voronezh, are interesting because of the presence of distinct F-F oolitic ironstones. Ironstones and salinity crisis indications are similar to the pattern which has been mentioned from the type Famennian (Dreesen & Thorez, 1982). The anoxic events in the F-F nearshore realm seem to be less frequent than those reported from open-sea environment. Probably, evaporization and currents of sheltered epicontinental basins form different regimes in comparison with the oceanic ones. In this way an anoxic event of regressively separated basins could be of the same age as the oxygenation on the oceanic shelf (e.g. Hladil, 1986). It could be suggested that some scattered epicontinental areas conserved a limited number of Frasnian survivors which took part in the temporaneous post-F-F rebuilding of the benthos, at least up to 'Upper *Pa. crepida* events' of various nature (comp. Johnson *et al.*, 1985, Wang & Bai, 1988, Hladil *et al.*, 1989). The other populations coming into the rebuilding of the shallow-water ecosystems originated probably from

some hypothetical 'deep water benthic colonies', e.g. the scolioporids (corals) of the lower Famennian (Hladil, 1987, 1989). The 'Frasnian-like survivors' among stromatoporoids are mentioned not only from the Famennian strata of Mokra (Hladil *et al.*, 1989), but partly also from Bielorrussia (Makhnach *et al.*, 1984) and from Alberta (Stearn & Halin-Dihardja, 1987).

Data obtained in course of the 'Global Bioevents' IGCP Program speak in favour of complicated step-wise changes of biota (Walliser, 1990). They are documented by the Frasnian brachiopods, trilobites and conodonts (e.g. Farson, 1986, Feist & Clarkson, 1986 and Klapper, 1988) or by the Frasnian to Famennian bryozoans, foraminifers, and corals (e.g. Bigey, 1988, Kalvoda, 1990 and Hladil *et al.*, 1989). The step-wise extinction series are not only typical for the Kellwasser open-sea environment, but, probably much more characteristic of the shallow-water facies. The step-wise extinction event suite may show differences in age between outer and inner shelf and/or between individual areas: complex ecosystems may adapt in different ways to external pressures. Also the original ecosystem composition is not well reflected by the fossil record: perhaps only 2% of the biomass has been preserved in the form of visible fossils. Additionally, shallow-water sections lack substantial parts of the time record, i.e. 50 to 99.99% of the time record could be lost, by erosion, nonsedimentation, and/or dissolution.

The ramp environment of the Lesni lom section is partly comparable to the Belgian ramp development and, also, to the Russian Platform. In the Moravian context, the Lesni lom F-F section represents a different ramp environment in comparison with the Mokra 'shallow and proximal' ramp section.

2. LOCATION OF THE SECTION

J. Hladil

The Lesni lom F-F section is located in the southern tectonic closure of the Moravian Karst, near the city of Brno (300 m SSE of the Vymitalka cross-road and 1500 m NE of the Velka Klajdovka, between 373 and 386 m a.s.l. The section was sampled in the quarry face at the N corner of the Lesni lom

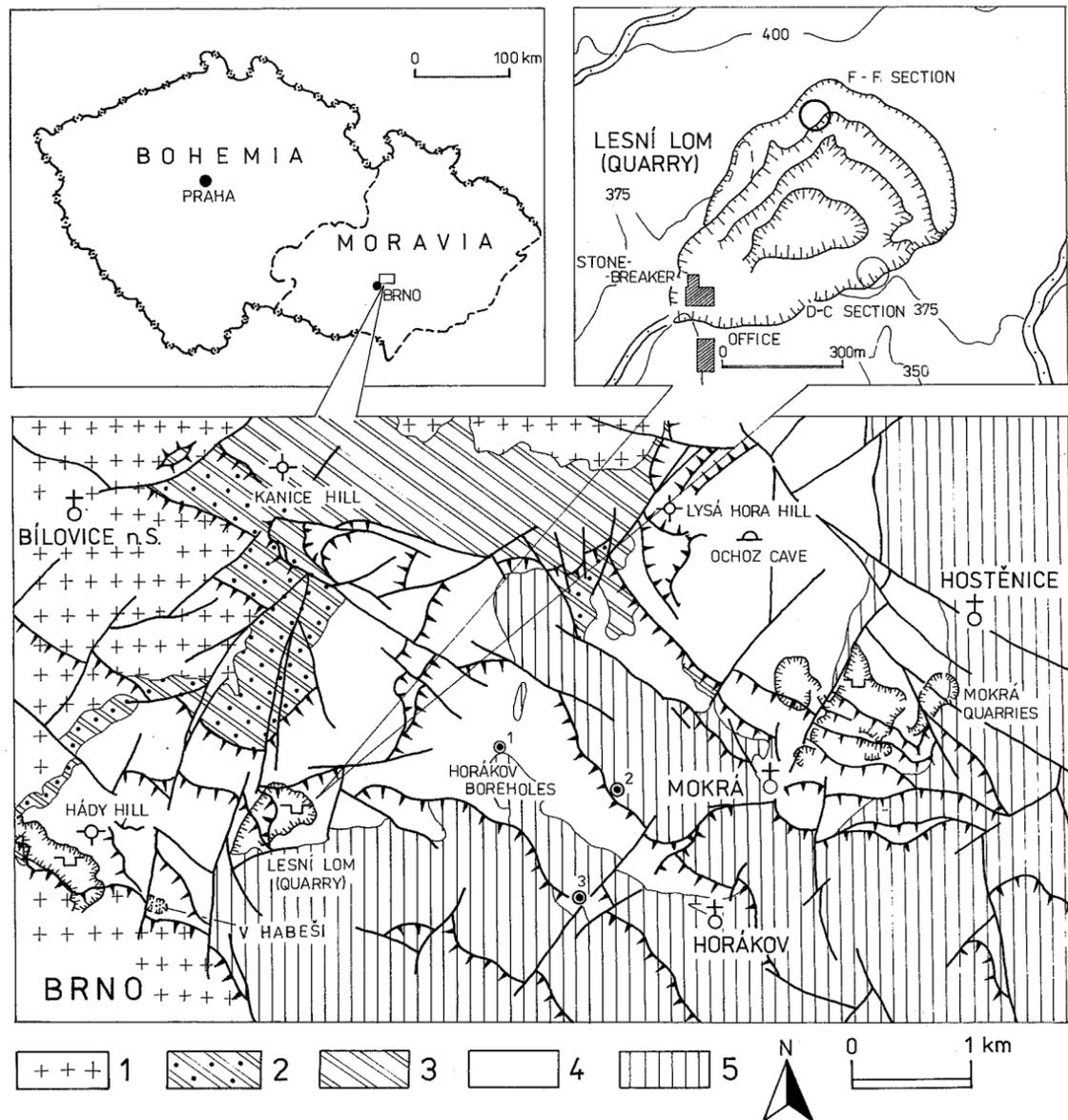


Figure 1 : Location. Lesní lom measured section is situated to the NNE of the city of Brno. Frasnian-Famennian limestones of outer ramp are opened in N-face of the quarry. 'V Habesi' Quarry, completely covered in 1983 (the inner ramp sequence of the Mokra-facies), is located SE of Velka Klajdovka. The structure diagram with thrust faults has been compiled according to geological map-sheet data (Hladil *et al.*, 1987).

Legend :

1. crystalline rocks of the Brno Massif (granodiorite, diorite blocks, various dyke and stock series).
- 2., 3. Devonian siliciclastic rocks : petromict series with acid volcanic tuffs (2) ; quartz sandstone/conglomerate series with only subordinate intercalations of mudstone, greywacke or arkose (3).
4. Devonian and Carboniferous limestones, undistinguished (at the Ochoz Cave and SE of Kanice Hill, Devonian limestones only).
5. Lower Carboniferous Kulm formations (mudstone/siltstone, greywacke/conglomerate).

exploitation plant, on its upper bench (Fig. 1). Here, three tectonically separated blocks occur ; only the middle block was measured and sampled (Fig. 2, Pl. 1). The sequence consists of sediments enclosing allochthems with a 'partial buildup affinity' (uppermost part of the Macocha Formation - up to bed n° 20) and the post-buildup carbonate

sediments (lowermost part of the Lisen Formation). Ten-kilogram samples from twenty nine levels (n° 6, 7, 7A, ... 24, see Fig. 2) constituted the basic material for slabs, thin-sections and dissolutions, but complementary vertical or lateral series of special samples have been added.

The geological setting of the southern end of the Moravian Karst was comprehensively discussed in the explanatory report of the mapsheet Mokra-Horakov (Hladil *et al.*, 1987 ; comp. Fig. 1 of the present paper). Here, J. Kalvoda distinguishes two main Upper Devonian facies patterns : (a) The Mokra Sequence - more micritic, with *Amphipora*-like stromatoporoids surviving up to the early

Famennian, with outlasting *Multiseptida* foraminifers and *Disphyllum-Tabulophyllum-Natalophyllum* coral association ; (b) the Horakov Sequence - more detrital, with significant F-F or earlier extinctions events amongst benthos, including the coral genus *Frechastraea* and the foraminifer genera *Eonodosaria*, *Eogeinitzina*, *Fronilina* and *Nanicella*.

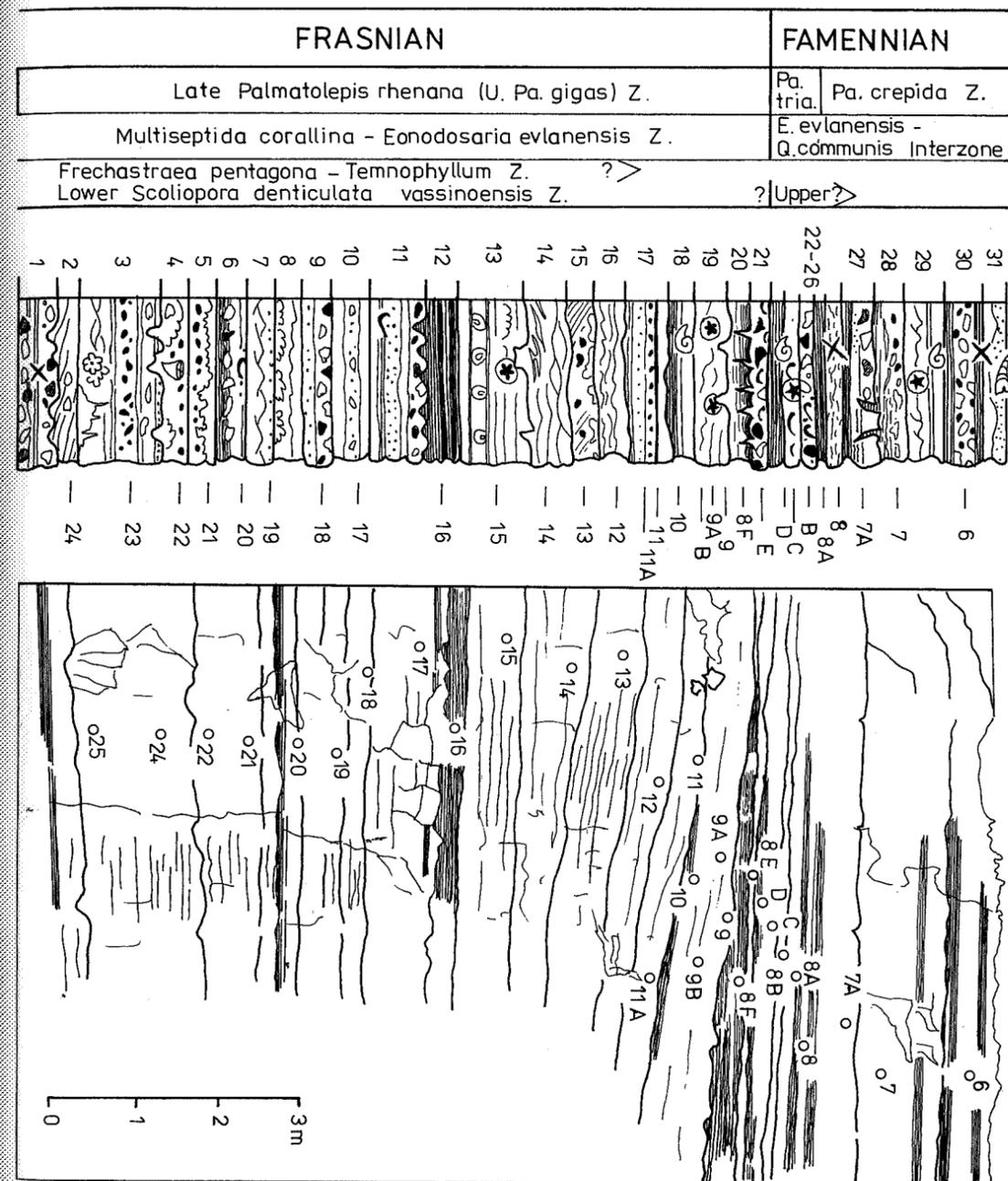


Figure 2 : Correlation of the rock face, stratigraphic column, numbered beds and points, and biozones. Slight syndepositional deformation and unconformities between the beds are visible in the Frasnian-Famennian boundary interval. The measured section was placed into the middle of three blocks which were accessible at the northern corner of the quarry (field work 1989-1990).

All of these facies, as well as other Paleozoic rocks, were traversed in different tectonic situations by several Horakov boreholes (Hladil *et al.*, 1987, 1989). Tectonic segments, which contain the Mokra and/or the Horakov sequences, are elongated parallel to the WNW-ESE trend (Fig. 1 and 6), but they alternate abruptly along the N-S transverses. Among various, mainly variscan tectonic styles, the distinct SSW to NNE thrusting is characteristic of the area investigated (Hladil *et al.*, 1987, Kalvoda, 1989, Schulmann *et al.*, 1991). The Horakov Sequence with its deeper sedimentary environment was thrust over the shallower marine Mokra Sequence (Fig. 6). The root area of the Horakov Sequence is assumed to lie either in the Boskovice Furrow in the SW, or in the probable western prolongation of the Koberice Fault Zone in the South. Reduction of the larger sedimentary area (hypothetic Horakov Bay, Fig. 6) started during the upper Famennian and Tournaisian and created partial ridges and troughs (evidenced by breccia slumps). The thrusting continued during the latest Viséan, even up to the Namurian deformation, as proved by the thrusting of the late Viséan shales and conglomerates. The compression and the thrusting were probably accompanied by a dextral rotation (Fig. 6). The structures were complicated by unhomogenities; moreover, they were deformed by a later extension of probably Permian age, and additionally, by the Mesozoic/Tertiary faults of Alpine foreland.

Besides the tectonic model proposed above, there is another possible explanation: J. Dvorak is in favour of a consistent WNW-ESE compression prior to the subsequent transpression. In his interpretation, the frequent postsedimentary deformation has been minimized in favour of a continuous synsedimentary one. The serial NNE-stacking has been interpreted as gravitational deformation. Small to giant olistoliths were placed into the structure only just before the Upper Viséan Culm sedimentation (J. Dvorak - pers. comm., 1991).

3. MICROFACIES

J. Hladil

The sediments of the measured section show a fining upwards trend, from coarse bioclastic

beds with fragmented 'buildup' bottom-dwellers to fine-grained limestone beds with prevailing open marine neritic/pelagic fauna. Erosional surfaces and hardgrounds are very common at and above the F-F boundary; the beds are also thinner in this interval (Fig. 2, 3).

Relatively large concentrations of coral fragments characterize the sediments between beds 1 and 5. These beds contain locally up to 25-30% of disintegrated coral bioclasts. It is still comparable with a disintegrated fundament of the biologic reef cover (comp. Hubbard *et al.*, 1990). Additionally, relics of the binding algal/stromatoporoid structures are locally preserved. Well washed coral-stromatoporoid rudstone consists of 'in situ debris' as well as of abraded allochems (cortoids, micritized and rounded particles, with microborings or algal envelopes). This 'in situ disintegration' was regularly interrupted by storm-deposits (erosions, intraclasts, cross-bedding, and graded bedding and/or by the lack of coral colonization (bioturbated carbonate sand or mud; bed 1). The southerly dipping foresets at the base of the bed 2 grade into hummocky-stratified sediments. Coated grains, peloids, and intraclasts of micrite are common (beds 3 to 5); diagonal ripples parallel to the WSW-ESE direction occur. *Stachyodes*, *Novitella*, algae, brachiopods, and crinoids dominate among the fragmented bottom dwellers. The presence of *Renalcis*, *Nanicella* and the first *Scoliopora kaisini* in the section should be noticed (bed 3). Cock-crest shaped open structures demonstrate the episodic deposition events and production of early gas from the covered substrate (bed 3, Figs 2 and 3). Coral fragments embedded in the pelbiosparite, algal nodules, echinoid fragments, and bioturbations are relatively common, even in bed 5. Sponge borings penetrated the larger clasts and, additionally, couples of scraping scours (fish teeth?) are occasionally visible on coral surfaces.

The next interval comprises beds n° 6 to 11. The slump breccia at the base of the bed 6 is covered by a wackestone/packstone layer. Fine-grained and sorted grainstones with micritized peloids are rare, but the amount of fossil-free and of iron-rich micrites is significant. Disarticulated brachiopod shells are predominantly in 'convex-down' position. *Cribrosphaeroides* occur in moderately sorted layers (upper part of the bed 6). Strikingly

large numbers of small bioclasts can be related to synchronous and reworked 'coral' debris (Fig. 4). The sedimentation and periodic lamination was disturbed by large-rippled or hummocky stratification (beds 7, 8).

Micrite flakes with internal micro nodular texture probably originated by bacterial activity in the shallow subsurface. Geopetally filled burrows contain ostracodes. Bed 9 represents a poorly washed (slump) breccia with chaotic structure and clasts of variable preburial diagenesis. The first but rare occurrences of ferruginized brown particles and ooids swept down from shoals have been reported from this level. The number of larger, determinable corals rapidly decreases although the total amount of the coral bioclasts is only slightly reduced between beds 6 and 11, in comparison with the previous interval (Fig. 4). Towards bed 11, the coral association becomes more monotonous, while the bryozoans and bivalves are more diversified. Many competitors disappeared, coenitids and/or coenitid-like adaptations (*Alveolites tenuissimus junior*) dominate. However, some rugose coral colonies persisted (fragments with large and flat, vesiculous exotheca). Most of the micrite intercalations contain gastropod and brachiopod shells.

The third interval consists of beds 12 through 17: the relatively dark bed n° 12 was deposited on an eroded hardground floor. Silt-sized micritized grains of higher C organic carbon content are typical for this bed. Wackestone/packstone structures with small intraclasts aligned parallel to the horizontal lamination were affected by a partial substitution by pseudosparite. Fine rubble of coenitids (corals) is common, while gastropods, homoctenids, thin-shelled dactyloconarids, and other bioclasts form a minor component. A complicated sequence can be observed in n° 13: Micritic brachiopod coquina; intraclastic grainstone with *Solenoporacea*; a zebra-banded unit (sedimentation slowdown); bioturbated intrabiomicrite with foraminifers and bryozoan debris; burrows; second 'sedimentation slowdown'; algal laminite; crinoidal packstone; and grainstone with periodically developed algal laminae. The limestone of bed n° 14 shows an increasing grain-size. Several sets inclined to the west, interrupted by drastic erosions were observed (Fig. 3). Semilithified calcarenites were slightly deformed by slumping and bedding

fissures were opened. Rounded plasticlasts of muddy composition, as well as plasticlasts with goniatite fragments, were observed in thin-section. Lens-like relicts of cephalopod micrite can be traced laterally. Episodic strong current flow could account for the increased amount of well-sorted allochems, of numerous erosions or washouts, of intraclasts or plasticlasts, as well for several amputated relicts of larger antidune structures (beds n° 14 through n° 17). The allochems include: pellets, peloids, coated grains, clasts of various, differently timed preburial diagenesis, fragmented thalli of 'moravamminids', ostracodes, foraminifers, *Scoliopora* spp. (corals), tentaculites and dactyloconarids. The poorly washed intraclastic grainstone of n° 16 was bioturbated (Pl. 2/3); the beds n° 13 through n° 17 contain moderately increased micrite contents in comparison with the previous sets (intercalations, mud-supported textures; comp. Figs 3 and 4).

After a gap, the micritic bed n° 18 was deposited (Pl. 2/2). The character of mud-supported and micrite layers is all the more remarkable for the presence of flat bioclasts - broken cephalopod and brachiopod shells. 'Compactite' textures and early half-dissolved micrite bands prevail. Nevertheless, the upper part of the bed was affected by a subsequent, pseudo-microsparite recrystallization (tarnish). It seems paradoxical that 'cephalopod limestone' contains some void and fissure fillings with 'vadose silt'-like textures. Summing these indications, it appears that the ramp might have experienced some drastic events (retreating sea) before or at the F-F boundary.

The crinoidal packstone/grainstones of bed n° 19 consist of numerous crinoid ossicles, tube-like segments of green algae, *Parathuramina*, brachiopods, ostracodes and simple forms of foraminifers. Micritization of bioclasts is still common. Diagenetic quartz (bipyramidal, prismatic, dispersed or aggregated) does not exceed 0.5% of the whole-rock weight.

The wedging laminae of bed n° 20 consist of lime-mudstone/wackestone, rarely of packstone/grainstone. Although the subrounded bioclasts are usually about 200 µm in diameter, larger biomorphs/bioclasts are present as well (such as homoctenids, styliolina, brachiopods, ostracodes, crinoids, and algal remains). The apparently dark bed

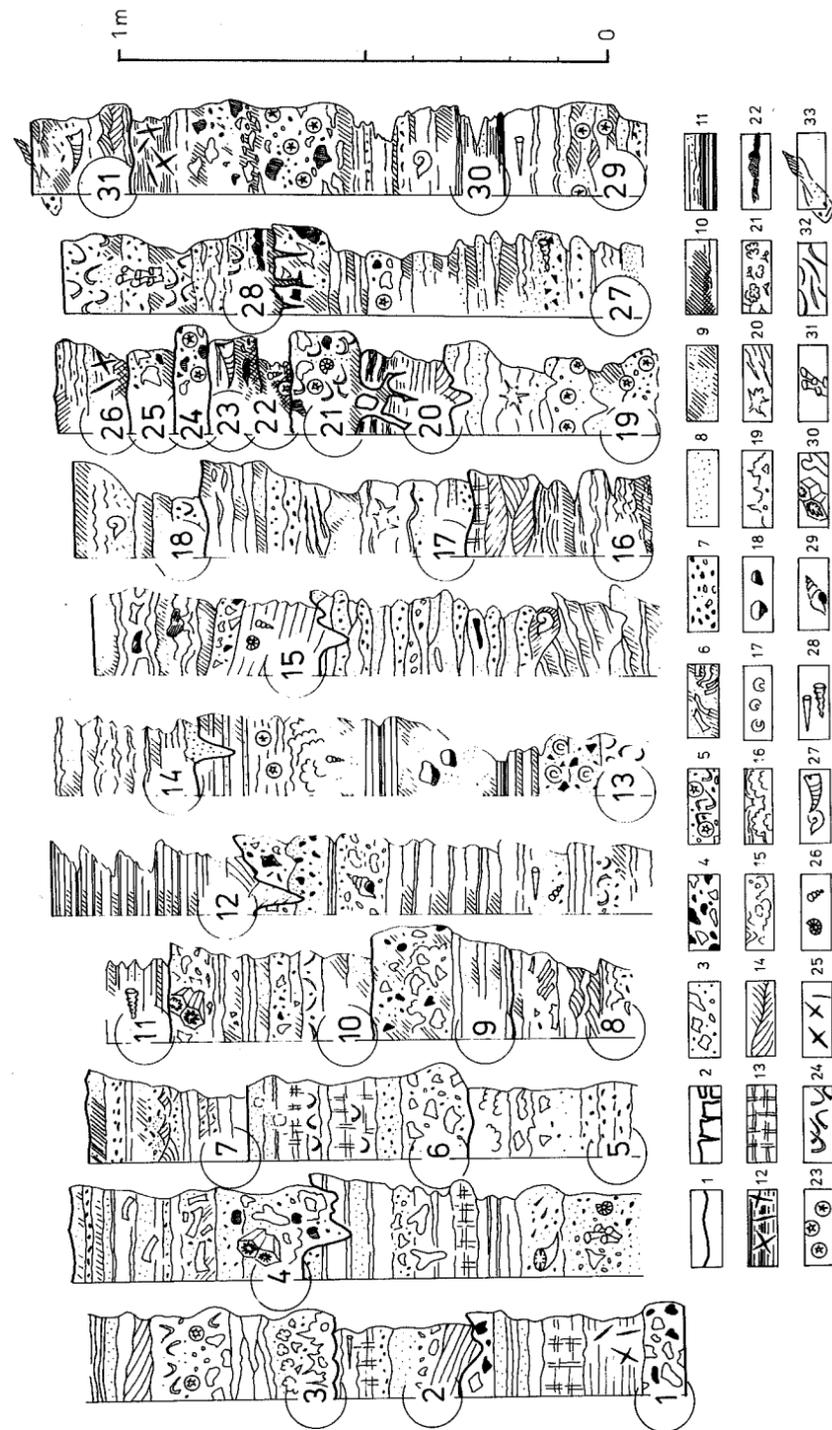


Figure 3 : Sedimentary structures throughout the Lesni lom section.

Legend : (1) bed boundary, (2) eroded hardgrounds, (3) bioclastic breccia, (4) intraclastic breccia, (5) crinoidal-brachiopod grainstone/rudstone, (6) broken algal-stromatoporoid coatings, (7) grainstone/rudstone with pellets, peloids, micritized and coated grains, (8) bioclastic grainstone, (9) packstone/grainstone, (10) packstone/wackestone, (11) muddy algal laminite, (12) spiculite, (13) fine-grained homogenite, (14) rippled and amputated antidune structures, cross-bedding, (15) chaotic depositional structures and associated convolute diagenetic structures, (16) swelled algal coatings to initial spongiostromes, (17) algal nodules, mostly solenoporacean, (18) burrows, (19-20) open structures, (21) *Renalcis*-debris and biocementstone, (22) ferruginized particles and surfaces, muddy admixture, (23) crinoids, (24) brachiopod debris and coquina, (25) sponge spicules, (26) foraminifers, (27) cephalopods, (28) dactyloconarids, (29) gastropods, (30) corals, (31) bryozoans, (32) bivalves, (33) accumulation of fish remains.

(N 2 to N 4 of the Munsell Color Chart) is moderately enriched in iron-oxides below the corroded and fractured upper bedding plane.

Breccia bed n° 21 gradually accumulated. Upper sides of the clasts were coated by micrite 'caps', while the internal space was filled by silt-size calcite debris, fecal pellets, and by ostracode shells. Rare and scattered, moderately ferruginized ooids and other particles are recognizable here. The bed is significant because of the last occurrence of the foraminifer *Nanicella* and the coral *Scoliopora kaisini*. According to the conodont fauna and considering the presence of both the above mentioned benthic indicators, we believe that this bed is the last truly Frasnian bed in the Lesni lom section.

The wackestone/packstone of the bed n° 22 yields an interesting thanatocoenosis : cyrtoconic cephalopod shells dominate over goniatite fragments ; crinoidal debris, thin-shelled brachiopods and dasycladaean algae occur. The sediment displays a higher than average pigmentation (N 3 of the Munsell color chart). Rare brown ooids underwent an abrasion, as their margins are fractured and pitted. These ooids were probably swept down from an hypothetical near-shore area.

The second Famennian bed of the section (n° 23) contains a considerable amount of sponge spicules. Brachiopod, auloporid (coral), crinoid and ostracode clasts are common in addition to more abundant shark and crossopterygid ichthyoliths. In contrast, a

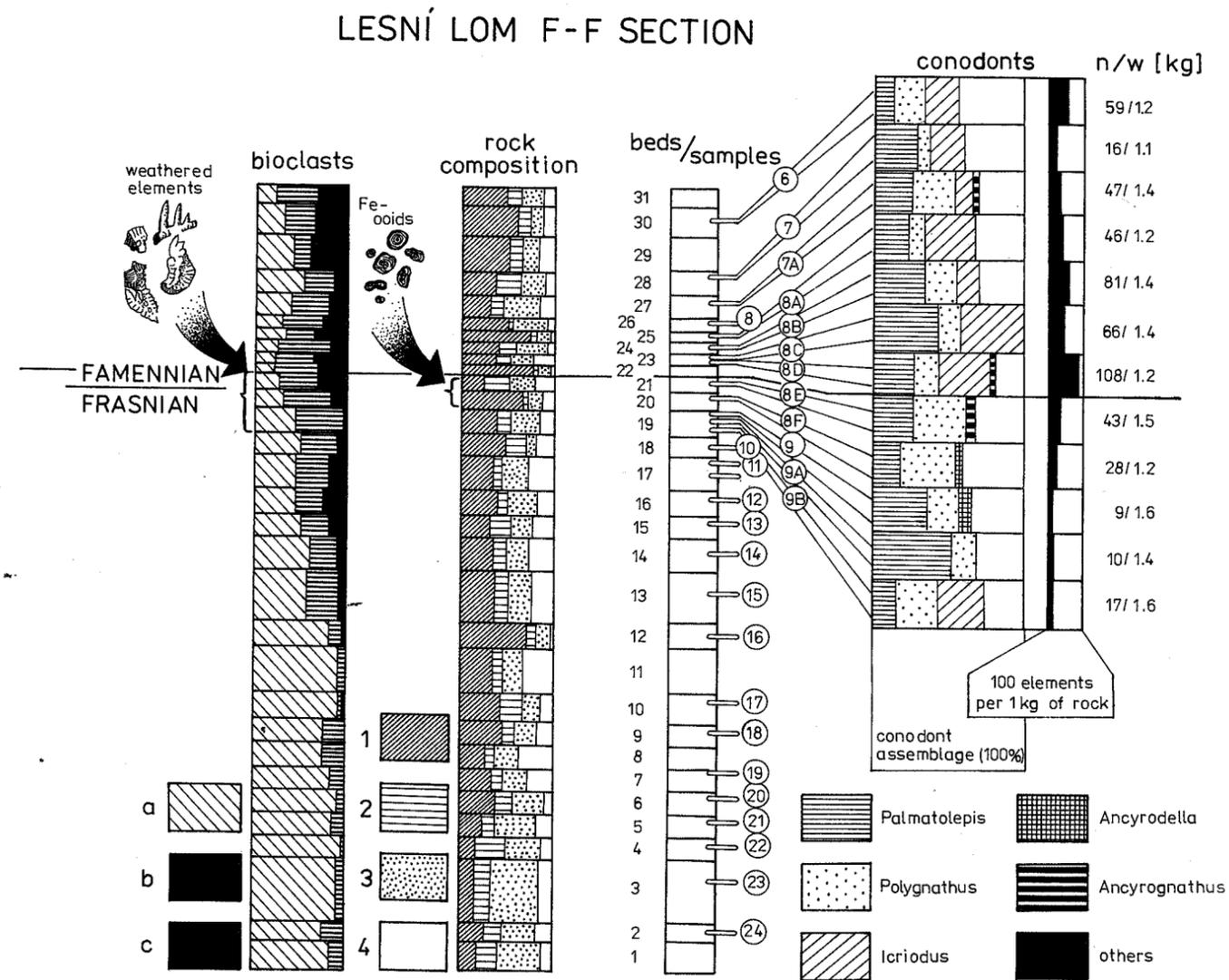


Figure 4 : Percentages of the rock and bioclast compositions : conodont samples around the F-F interval.

Legend : (1) micrite, (2) visible bioclasts, (3) other allochems, (4) cement ; (a) attached bottom dwellers and their skeletal debris, (b) moving and swimming bottom dwellers, (c) nektonic/pelagic organisms.

thin intercalation of winnowed sediment with coated grains and grapestone occurs. Large, micritized and pyritized nuclei are coated by lighter envelopes.

From the chaotic breccia nature of the bed n° 24 it appears that it has been produced by an abrupt sedimentation out of a free water column. The breccia structure is completely different from the previous breccia layers. Lower clasts occasionally show impact deformations (not only solution pits); the less-resistant among them were fractured during the final drop collision rather than during the next compaction. While the amount of the medium-size grains was reduced, the consequent silt-sized deposition of the filling/cover was abundant and uniform, slightly diminishing upwards in grain size. Fish remains, echinoids, sponge spicules, ostracodes, diverse and mixed bioclastic background may be also consistent with the tsunami interpretation (comp. e. g. Sandberg *et al.*, 1988). The breccia was covered by a recrystallized ostracode/sponge wackestone (bed 25).

The succeeding Famennian beds are thicker (Fig. 2; beds 26 and above); they are grey coloured with brownish hue. The packstone layers show a moderate, oscillating package of bioclasts with a contemporaneous shift in favour of the benthic skeletal debris (Fig. 4). Small nodules of *Rectangularina*-like algae and the accumulations of sponge spicules are dispersed in this sediment of the *Pa. crepida* Zone. Nevertheless, homocentrid and styliolina shells still occur in these levels. Sediments of sponges, pelletal, and fish-echinoid microfacies (bed n° 27) include, besides the main components, the following bioclasts: gastropods, bivalves, juvenile rugose and tabulate corals, and unidentified sleeve and bell-shaped infusorians. The top-most part of this bed consists of a parabreccia. The open structures, locally present between the plasticlasts/intraclasts, display pigmented relics of fibrous rim cement, palisade zone and mosaic infill. Wackestone bed n° 28, was especially intercalated by similar parabreccias; the upper limit of the parabreccia layers is grading in a fine-grained rippled unit. *Styliolina*-like shells still occur during this sedimentation.

Each of the last three beds (n° 29-31) shows an upsection tendency to coarser bedding and decreased pigmentation. Wackestones to lime-mudstones were intercalated by repeti-

tive deposits of intraclastic breccia (clasts with disseminated crinoids, cyrtocone and other cephalopods, and fish fragments; Pl. 2/1).

As a conclusion, it is clear that the micrite component of the 'Late *rhenana*' limestones show an oscillating increase towards the F-F boundary (Fig. 4). In the same direction, the dominance of 'clastic' over 'algal' micrite is obvious. Individual maxima of the micrite content can be assigned to the beds 6, 9, 12, 18, 20, etc. (comp. Fig. 4). The lime-mud background of the Famennian sedimentation is more distinct than the Frasnian one. The total bioclastic content apparently is not drastically modified throughout the section (Fig. 4), while the 'attached benthics - vagile benthics - nektonics/pelagics' ratio displays an oscillating left-side shift (Fig. 4). Decrease of the sedimentation rate accompanied by time gaps of various orders of magnitude occur within the larger F-F boundary interval. Brown particles, ooids and their relics are traceable at, but especially below the F-F boundary of the Lesni lom section. Packstones/grainstones with 'mixed allochems of ramp development', are well represented throughout the whole section and they are intercalated by slump, storm, contouring-current, or possibly tsunami deposits. The coral fauna was significantly suppressed, even before the F-F event; nevertheless, an impoverished coral fauna survived during the Lower Famennian. A similar development was observed for the micritization of grains and the brachiopod settlement. Alteration (tarnish) of some beds, voids, 'vadose-silt' fillings, and slightly developed ferruginization suggest the possibilities of episodic, but significant drops of the sea level by several tens of metres.

4. MINERALOGICAL COMPOSITION

J. Hladil

One of the most prominent features associated with the sedimentation in the Lesni lom section is the extremely high calcite content (95 up to more than 99%), while the magnesium content is strikingly low and mostly undetected in energy dispersal spectrometry and electron microprobe analyses. Contrary to it, the phosphate content gradually but markedly increased upsection (conodonts, fishes,

phosphate-bearing brachiopods). The fish and conodont radiations, which could be especially responsible for the increased phosphate content of the ramp sediments, seem to be a common feature for the Moravian and other Laurussian or northern shelf areas in the time-interval from the *Ancyrognathus triangularis* up to the *Palmatolepis crepida* Zone. In the eastern part of Moravia, 'fishes' commonly become more abundant below the F-F boundary, for example in the Lopac section (in a cave, NE of the Macocha karst collapse structure), and in the Usti section (a quarry, E of Hranice n.M.).

The chemical composition of conodont elements, as expected, corresponds to the published data (Lindstroem, 1964, Ziegler & Lindstroem, 1975 and Fahraeus & Fahraeus-van Ree, 1987). However, a more or less impoverished sodium content is typical for the Lesni lom conodont specimens. Microprobe analyses found regular and substantial contents of aluminium, potassium and silicium, which correspond to illite impregnation of uncompact conodont elements.

Moderate surplus of calcium corresponds to the calcite content. The same impregnation was found in the fish teeths, sclerites, and carapaces. Illite fillings were also found in the internal chambers of microfossils ('moravaminid' and prasinophycean algae), as well as in the pseudomorphs after sponge spicules and algae. The conodonts are grey (N3.8 to N4.5). The occasionally white, red and yellow marginal parts are similarly composed, only with negligible shifts in the contents of iron and manganese oxides. The mineralogical reorganizations of these coloured patches seem to be more significant than the shifts in geochemistry.

However, the abraded conodont elements (re-deposited only within the latest interval of the Late *rhenana* Zone) are apparently dark (N2.6 to N3). Their chemical compositions are similar, but silicium partly or totally disappeared. The most probable explanation for this phenomenon is a transformation of illite into boehmite-like aluminium hydroxides. The process differs from the processes known elsewhere in marine environment under burial conditions. We assume that some shallower conodont-bearing rocks were affected by a laterite-bauxite weathering in the vicinity of our section. These alterations were found in the beds 19 and 20. The Al_2O_3/Na_2O ratio of whole insoluble residue is moderately in-

creasing throughout the 'Late *rhenana*' interval of the section (values from 42 up to 56), but the ratio drops down again in the youngest Frasnian bed (value of 37). These values are comparable with the data of Dvorak (1990) who has found an estimated value of 55 for the Frasnian-Famennian transitional interval. The ratio from the whole residue reflected an oscillating balance of two parameters: the rising content of aluminium-rich free oxides, contrary to the rising number of 'fresh' siliciclastic grains. Insoluble residue without these unaltered clasts yields strongly enlarged Al_2O_3/Na_2O ratios (up to values of 100). This means that two processes may have played a role. The first one is the lateritic weathering, and the second one is the fluvial erosion/transport. Both processes point to a humid climatic influence. The increase of the Al_2O_3/Na_2O ratio before the F-F boundary represents a temporary overturn within long-lasting decreasing trend (cf. Dvorak, 1990). The Fe_2O_3/K_2O ratio increases simultaneously up to values of about 10.

Moderate illite impregnations are responsible for the higher resistance of crinoid ossicles against the artificial acid-corrosion, while the silica or dolomite contents are low.

Additionally, kerogene and pyrite dispersed in the ossicle elements represent chemical barriers that influence negatively the dissolution rate. Illite clasts, aggregated flakes and impregnations dominate among the clay minerals throughout the whole F-F section, whereas less common kaolinite and glauconite flakes were detected, especially below bed n° 12.

Clastic muscovite and corroded grains of sphene were observed in bed n° 17, while biotite associated with partly altered pyroxene and hornblende is common in bed n° 22 (grains up to 350 μm in diameter). Rounded and elongated clasts of 'green-schist', fine grained-crystalline rocks (up to 450 μm in length, beds 23 to 27) were found higher in this section. Spherical, yellowish-pale, rose, and transparent quartz grains (part of them probably aeolian) dominate in the lower part of the section, while the milky-white, fine-crystalline quartz variety with fractures filled by purple oxides, was noted above bed 23.

Examined insoluble residues of styloliths display a moderately increased amount of barium in the Frasnian strata, and titanium nearly

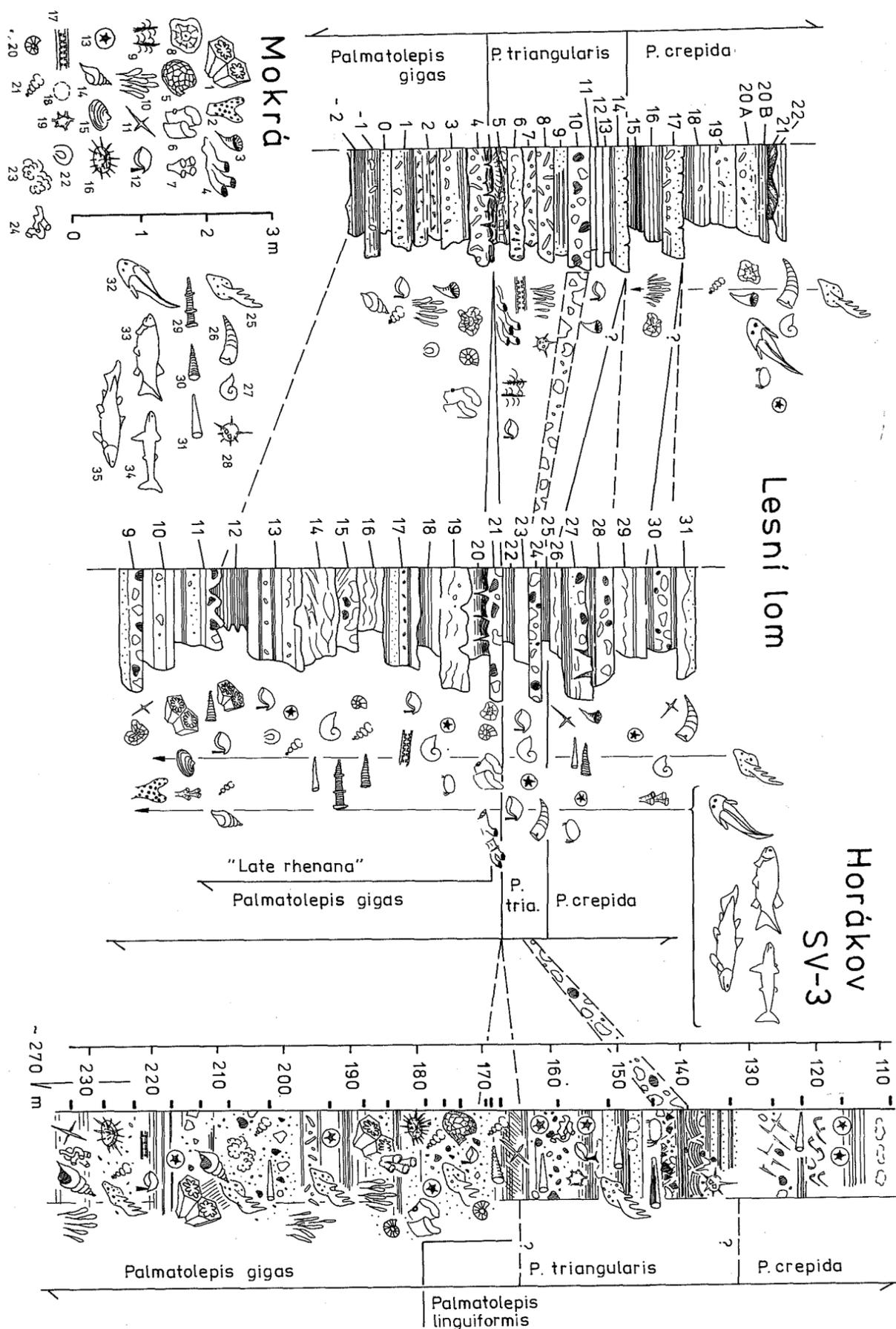


Figure 5 : Correlation of three significant sections in the southern tectonic closure of the Moravian Karst : Mokra (inner ramp), Lesni lom (outer ramp), and Horákov SV-3 (trough). Legend : (1) colonies of Rugosa, (2) *Thamnopora*, Tabulata, (3) solitary Rugosa, (4) *Aulostegites* and syringoporids, Tabulata, (5) alveolitids, Tabulata, (6) *Scoliopora kaisini*, Tabulata, (7) Bryozoa, (8) actinostromatid, clathrodictyid, and stromatoporidae colonies, (9) labechiids, Stromatoporoidea, (10) *Amphipora*, *Stellopora Novitella*, Stromatoporoidea, (11) Porifera, (12) Brachiopoda, (13) Crinoidea, (14) Gastropoda, (15) Bivalvia, (16) Echinoidea, (17) *Moravammina*, Algae, (18) *Cribrosphaeroides*, (19) *Parathuramina*, Foraminifera, (20) *Nanicella*, Foraminifera, (21) uniserial shells of benthic Foraminifera, (22) Solenoporaceae, Algae, (23) *Renalcis*, (24) *Girvanella*, Algae, (25) Conodonta, (26) cyrtoceracone shells, Cephalopoda, (27) goniatites, Cephalopoda, (28) Radiolaria, (29) *Tentaculites*, (30-31) Dacryoconarida, (32) benthic fishes, Placodermi, (33) neritic and open-sea fishes, (34) sharks, (35) Crossopterygii.

throughout the whole section. Manganese contents are high in beds 17 and 18. However, the contents do not exceed tens to hundreds of ppm in the whole rock samples.

5. BIOTA

5.1. CONODONTS

Z. Krejci

5.1.1. Samples, diversity and abundance of conodonts

A total of 28 conodont samples (n° 6 to 23, cf. Fig. 2) from the Lesni lom F-F section have been dissolved in fifteen % acetic acid. The weight of the dissolved rock ranges from 1.1 to 2.4 kilograms (cf. partly Fig. 4). The evaluation of the conodont assemblages is based on the standard conodont zonation for the Upper Devonian, including its most recent revision by Ziegler & Sandberg (1990).

The subspecies *Palmatolepis gigas extensa* Ziegler & Sandberg, species *Palmatolepis prorhomboidea* Sandberg & Ziegler, and a specific form assigned to the genus *Palmatolepis* (*Palmatolepis* sp., Pl. 13/8) appear for the first time in the Moravian Devonian.

Generally, the late Frasnian conodont assemblages (*Pa. rhenana* - *Pa. linguiformis* Zones) are poor in specimens, and not diversified. This situation is common in the F-F sections of the Moravian Karst (e.g. Balcarova skala, Jedovnice quarry ; Krejci, 1991). Contrary to it, apparently more diversified and richer assemblages are typical for the base of the Famennian sequence (*Pa. triangularis* Zone). The lower Famennian diversity and abundance 'boom' differs the Lesni lom section from many other sections, where both the Frasnian and the Famennian

parameters do not show drastic changes (e.g. Sluchowice, Poland ; Steinbruch Schmidt, Kellerwald, Germany ; Hony Railroad Cut, Belgium ; Devils Gate, Nevada - cf. Szulczewski, 1971, Mouravieff, 1970, Bouckaert *et al.*, 1972 and Sandberg *et al.*, 1988). We assume that the above mentioned sections represent various types of outer shelf, slope and off shore environments. They were probably affected by the oceanic control of diversity, while the Lesni lom section might represent a transition to a sheltered environment with a different diversity control. Additionally, 'tilting' (cf. chapter 6.2) of the lower Famennian ramps occurs in the Moravian Karst so that the underlying Frasnian shallow-water sediments are only poor in conodonts.

5.1.2. Conodont assemblages

Samples 23 to 17 : among the key species, *Palmatolepis gigas*, *Ancyrodella curvata*, and *Polygnathus normalis* occur. *Palmatolepis subrecta* (sensu stricto, cf. Ziegler & Sandberg, 1990) has not yet been recorded. Considering the poor conodont assemblages, as well as the 'very late Frasnian image' of foraminifers and corals, we assume that this absence is not sufficiently significant for the identification of 'the Early *rhenana* Zone'. We presume, that the samples may be likely 'transitional or Late *rhenana*' in age.

Samples 17 to 8F : *Palmatolepis subrecta* is characteristic. The associated conodont fauna is roughly the same (cf. Tab. 1). *Polygnathus brevis*, which would not exceed the top of the Late *Pa. rhenana* Zone, is well documented in sample 8F (Pl. 14/9, 10). According to these facts, we interpret this set of samples as 'Late *rhenana*' in age.

Sample 8E : the latest Frasnian sample may be assigned to the stratigraphic interval of the 'Late *rhenana* to *linguiformis* Zones'. The

accuracy of the determination is rather weak, because of the total lack of diagnostic species of the *Pa. linguiformis* Zone.

The Frasnian assemblages are rich in *Polygnathus* specimens, which moderately prevail over *Palmatolepis*. As substantial *Icriodus*-component appears only in sample 9B (Fig. 4). The ratio of the Frasnian platform conodont genera resembles the biofacies analyses from the SE border of the Dinant Basin, for example in the Hamoir-Xhignesse, and Noiseux sections (Dusar, 1976), or in the Havelange borehole (Dreesen, 1984). The biofacies corresponds to a Polygnathid-Palmatolepid Biofacies of the less profound subtidal shelf environment. The assemblage of sample 9B could be assigned to a mixed Polygnathid-Palmatolepid-Icriodid Biofacies, which is also common within the shallower of the Belgian Famennian environments (cf. Sandberg *et al.*, 1988).

Sample 8D : the first Famennian sample yields numerous and diversified conodonts (108 specimens per 1.2 kg of rock). The '*Icriodus*-boom' is visible (*I. alternatus*, *I. alternatus helmsi*, and *I. iowaensis*, cf. Tab. 1). This '*Icriodus*-boom' seems to be a typical feature for the beginning of the Famennian (Dusar, 1976 ; Ziegler & Sandberg, 1990). *Palmatolepis triangularis*, *Pa. triangularis* with transitional features to *Pa. clarki*, *Pa. delicatula delicatula*, *Po. brevilaminus* are the next diagnostic species significant for the upper part of the Lower *Pa. triangularis* Zone.

Sample 8C : the first occurrence of *Pa. protorhomboides* and the last occurrence of *Pa. delicatula delicatula* are here recorded. The other components of the assemblage are comparable with the previous sample. Estimated age is Middle *Pa. triangularis* Zone.

Sample 8B : contains the first occurrence of *Palmatolepis clarki*, and *Pa. minuta minuta*. This assemblage has been assigned to the '*Late triangularis* Zone'.

Samples 8A and 8 : The fauna shows a lack of diagnostic species (cf. Tab. 1). The proposed stratigraphic range here is larger : '*Late triangularis*' to '*Early crepida*' Zone.

Samples 7A, 7 and 6 : *Palmatolepis minuta loba* (first appearance), *Pa. termini*, whose extinction coincides with the top of the '*crepida*' Zone is still present. A '*Late*

crepida' age is suggested for these assemblages (cf. Tab. 1).

The mixed Palmatolepid-Icriodid Biofacies is typical for all of the lower Famennian assemblages of the Lesni lom section. This biofacies composition is well-defined especially in Belgium, e.g. in the Vesdre Massif (in VRD-27, VRD-28, and VRG-28 boreholes ; Dreesen, 1984). This conodont biofacies may indicate a shallower subtidal environment (sensu Dreesen & Thorez, 1980) and corresponds to a mixed sedimentation on an inclined carbonate ramp (see 6.2).

5.2. TABULATE CORALS

J. Hladil & J. Berousek

The prospection for tabulate corals was based on cutting and etching of limestone. Low contrast in pigmentation, absence of marginal muddy residue, as well as the fresh quarry face complicated the extraction. Frequencies were estimated in relevance to ten-kilogram volumes of rock (Tab. 2). Colonies were registered and the selected fields were thin-sectioned.

Relatively abundant and diversified corals are traceable up to bed n° 17 (Tab. 2, cf. Figs 3 and 4). The relatively poor associations which occur higher on predominantly consist of coenitids. The last occurrence of *Scoliopora kaisini* (Lecompte, 1936) corresponds to the last Frasnian bed.

In the Famennian part of the section, only *Scoliopora denticulata rachitiforma* Hladil 1987 occurs in the '*Late triangularis*' 'tsunami' breccia ; undeterminable young colonies and fragments of coenitids and auloporids (probably also syringoporids) are traceable up to the '*crepida*' Zone. Lack of lower Famennian corals differentiates the Lesni lom section from the Mokra Sequence (Fig. 5).

The assemblage of tabulate corals represents unusual communities, which, in fact, were not known until now. A probable explanation for this might be the age of the youngest Frasnian beds. Neither from Belgium, nor from the Russian Platform, tabulate-coral assemblages of satisfying synchronicity are known. Nevertheless, some corals are related to the Belgian taxa of the '*Upper asymmetricus/Ancyrognathus triangularis*' stratigraphic levels, as is also expressed in the

SAMPLES TAXA	6	7A	8A	8C	8E	9	9B	11	12	14	16	18	20	22				
	7	8	8B	8D	8F	9A	10	11A	13	15	17	19	21	23				
<i>An. curvata</i>						1		2		2	2	1	1	1				
<i>An. sp.</i>					1													
<i>Anc. asymmetricus</i>					2		1											
<i>Anc. sinelaminus</i>		1																
<i>Anc. sp.</i>				1														
<i>Bryanthodus sp.</i>							1											
<i>Diplodella aurita</i>		3																
<i>Diplodella sp.</i>	7						2											
<i>Euprionodina prona</i>				6		2	4											
<i>Hindeodella germana</i> L. sp.	3	1	6	12	15	4	3	13	6	5								
<i>I. alternatus alternatus</i>	15	4	6	3	5	12	14	23										
<i>I. alternatus helmsi</i>			11	9	12													
<i>I. iowaensis</i>				3	1													
<i>Ligonodina falciformis</i>	3							1										
<i>Ligonodina sp.</i>											1							
<i>Nöthognathella abnormis</i>				1	6	2	1	1		1								
<i>Ozarcodina homoarctuata</i>	11																	
<i>Oz. regularis</i>	2	8	3	4	3			3	5	4	1	4	4	2				
<i>Palmatodella delicatula</i>			4	3							1							
<i>Palmatolepis clarki</i>				1														
<i>Pa. crepida</i>	2																	
<i>Pa. delicatula delicatula</i>				6	5													
<i>Pa. delic. protorhomboides</i>				1														
<i>Pa. gigas extensa</i>										1								
<i>Pa. gigas gigas</i>								1			2							
<i>Pa. gigas</i>												1	1					
<i>Pa. minuta loba</i>		5																
<i>Pa. minuta minuta</i>			6	14														
<i>Pa. perlobata perlobata</i>	2																	
<i>Pa. quadrantinodosalobata</i>	3	2																
<i>Pa. rhenana nasuta</i>					1					2								
<i>Pa. rhenana rhenana</i>					2	1												
<i>Pa. subperlobata</i>	3			2	4													
<i>Pa. subrecta</i>				2	12	4	3	4	3	16	6	5	1	4	3	2		
<i>Pa. tenuipunctata</i>	4	7																
<i>Pa. triangularis</i>			7	7	19	19												
<i>Pa. triangularis / Pa. clarki</i>				2														
<i>Pa. triangularis / Pa. quadrantinodosalobata</i>				3														
<i>Palmatolepis sp.</i>			1															
<i>Polygnathus brevilaminus</i>	1	3		9	11	13												
<i>Po. brevis</i>						7												
<i>Po. decorosus</i>		12	4	10	9		5		2	2		1		2	3			
<i>Po. foliatus</i>								1										
<i>Po. nodocostatus</i>	9																	
<i>Po. normalis</i>	6				19	6	2	2	15	12	9	1	6	8	2	1	1	12
<i>Scutulla bipennata</i>				2														
<i>Sc. venusta</i>										1								

LESNI LOM - DISTRIBUTION OF CONODONTS

FAMENNIAN

FRASNIAN

Table 1 : Conodont occurrences throughout the extended Frasnian-Famennian boundary interval of Lesni lom. Number of specimens which have been assigned to the taxa is included. For frequencies of determinable conodont specimens see Fig. 4. Conodonts, as well as other phosphate-bearing faunas are common, especially in the Famennian beds.

formal way (*Scoliopora kaisini*, *Thamnopora gosseleti*, and *Alveolites tenuissimus*). Some 'Eifelian' morphotypes (*Scoliopora tetralobata*, *Sc. relict*) experienced a remarkable 'come-back'. Two explanations can be forwarded : (a) functionally forced morphological imitations, or, (b) 'come-back' of old groups, which were suppressed and/or hidden during the Givetian/Frasnian carbonate-platform expansion.

5.2.1. Diagnoses of new taxa

Class ANTHOZOA

Order Favositida

Family Alveolitidae Duncan 1972

Subfamily Natalophyllinae Sokolov 1952

Genus *Scoliopora* Lang, Smith & Thomas 1940

Scoliopora tetralobata Hladil et Berousek sp. n. (Pl. 3)

Derivation of name : tetralobata, i.e. having four lobes, latinized, from Greek

Type section : 3/358/LHNp/5e, bed n° 5, 'Late rhenana' Zone, Lesni lom. Pl. 3/3.

Diagnosis : polygonal to elliptic corallites of axial zone transformed into the scolioporan shape with the septal ridge on the lower wall ('upper' with respect to the arrangement in branch - Pl. 3/1). New corallites separated in lateral budding and dividing were distributed in a diagonally rectangular net. Tetralobate shape of corallites was incidental to intensive pore communications which were diagonally arranged. Diploid to slightly meandroid final forms of corallites indicate uncomplete dividing. Diameter of densely spaced spores is 120 µm.

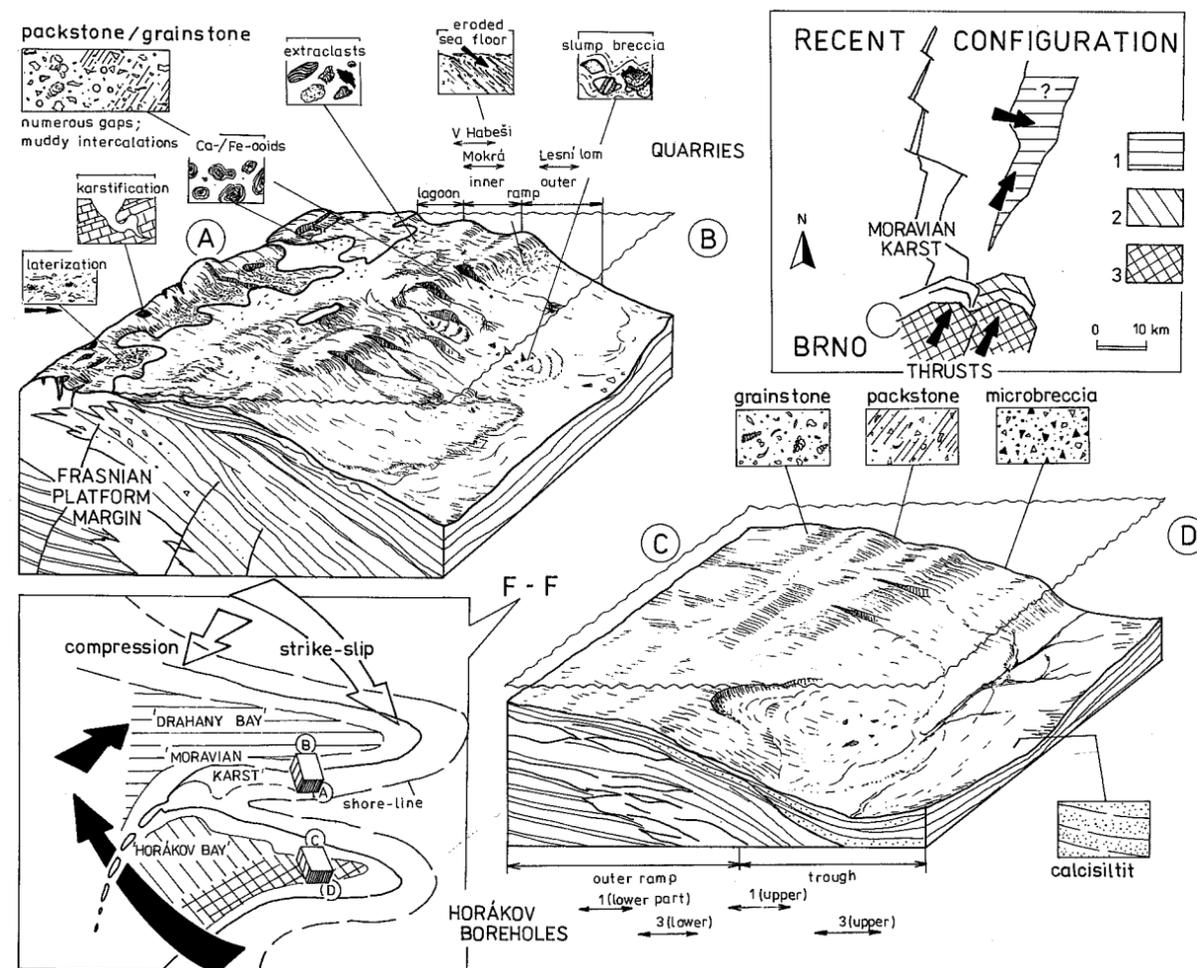


Figure 6 : Tentative model of the Frasnian-Famennian and recent configurations. Arrangement of facies segments and the deformation itself indicate dextral strike-slip, strong compression and also thrusting towards the N. Two blockdiagrams illustrate the ramp environment and the subsurface configuration during the beginning Famennian. Oscillating sea level drops were probably significant in the F-F boundary interval.

Discussion : a comparable coral from Eifelian of the Urals, *Cladopora ? cruciformis* Yanet 1959 may be considered as a similarly shaped *Scoliopora*. However, the corallum is smaller and the connecting pores are narrower (about 50 µm) in Yanet's species.

Occurrence : Lesni lom, Late Pa. rhenana Zone.

Scoliopora relict Hladil & Berousek sp. n. (Pl. 4/5).

Derivation of name : relict, as relict, from Latin.

Type section : 2/8051/LHTi/17r, bed n° 7, 'Late rhenana' Zone, Lesni lom. Pl. 4/5.

Diagnosis : delicate branches. Corallites swelled very early. Septal ridge was transformed into a broad elevation of lower wall. Intracalicular budding coming from upper right lobe prevailed. Filial corallites rotate up to irregular opposition (an upper wall to another upper wall). Moderately distorted pore canals connected the lower lobes of the corallites. Mode of budding and connection evoked a distorted picture in sections.

Discussion : similar construction of corallum is visible in *Scoliopora serpentina* Yanet 1972 from the Givetian in the East Ural, but with an apparently larger axial zone and plausible serial building in lateral rows.

Occurrence : Lesni lom, Late Pa. rhenana Zone.

Subfamily Coenitinae Sardeson 1896
Genus *Coenites* Eichwald 1829

Coenites otavai Hladil & Berousek sp. n. (Pl. 5)

Derivation of name : otavai, as Otava's ; in honour of the Moravian geologist and sedimentologist Mr Jiri Otava.

Type section : 1/348/LHNp/5a/bed n° 5, 'Late rhenana' Zone, Lesni lom.

Diagnosis : mainly branched, but also coating, nodular and platy colonies. Small and low-arched initial corallite grew horizontally.

Walls swelled early. Axial zone consists of polygonal to oval corallites. Calices of mature colony are slot-shaped. Their upper walls (in branch turned down) are flat, while the lower walls are ornamented with disarranged elevations and low and broad spines. On the surface of colony, the calices were stacked into oblique and parallel rows. Connecting pores developed irregularly, but occasionally gained a remarkable density and diameter (650, and 105 µ).

Occurrence : Lesni lom, Late Pa. rhenana Zone.

Subfamily Alveolitinae Duncan 1872
Alveolites Lamarck 1801

Alveolites tenuissimus junior Hladil & Berousek subsp. n. (Pl. 6).

Derivation of name : junior, as younger, from Latin.

Type of section : 1/351/LHNp/5b, bed n° 5, 'Late rhenana' Zone, Lesni lom. Pl. 6/1.

Diagnosis : cake-like shapes dominate over the branched ones. Initial corallites are conspicuously large, domed to tetragonal. Mature colony structures were functionally modified into a coenites style, but the wall was built by dense sclerenchyme of alveolitid type, with radial recrystallization. In the same bed with corresponding diagenesis, the relic microstructure is well distinguishable from the *Scoliopora* one (with concentric zones) and from the *Coenites* one (with milky cryptocrystalline mass). Pores were reduced. Ten percent of the pores remained open, while the others were blind. Pore diameter is 110 µ m, rudimentary pores are spaced in 250 µm intervals.

Discussion : differences from *Alveolites tenuissimus* Lecompte 1933 : Lesser dimensions of corallites (Pl. 6), lack of septal apparatus. Coenitid affinity is refused considering the big initial corallites, dense alveolitid sclerenchyme and numerous rudimental pores. These are, in our opinion, distinctive features in comparison with *Coenites medius* Lecompte 1939 and other representatives of *Coenites* Eichwald 1829. Big initial corallites and numerous alveolitid pores (not the microstructure) separate the

described coral from *Levisicoenites* Hladil 1989.

Occurrence : Lesni lom, Late Pa. *rhenana* Zone. All the tabulate colonies of the new taxa only originate from the Lesni lom section. For distribution in the section see Tab. 2.

5.2.2. Conception of *Coenites*-like corals

In the authors opinion, Eichwald (1861, p. 100, fide Dubatolov & Ivanovskiy, 1977, p. 25) sufficiently defined the branching, coating and foliate *Coenites* colonies with typical sickle-shaped calices. We do not find systematical use of the reestablishment of Davies 1877 *Platayaxum* and Spriesterbach's 1935 *Roseoporella* (see Byra, 1983), as their diagnoses are poor in data, and, additionally, the branching, foliate or coating shapes of colonies appear to be partly environment-controlled.

Roseoporella is well and more exactly known as *Alveolites taenioformis* Schluter 1889. Sclerenchyme dense, originally pigmented ; walls stabilized in thickness ; corallites very long in longitudinal section, oval and arched in transversal section ; pores more regular : all these features are indicative open for the 'Alveolites' than for the 'Coenites' interpretation. *Alv. taenioformis* and *Coenites medius* Lecompte, 1939 are identical only in small bilateral corallites and coating colonies, i.e. in rather undistinguishing and environmental features. Shape of initial corallite, inherent pattern of connecting system and septal apparatus, pattern of general internal architecture, and type of sclerenchyme may serve for distinguishing *Alveolites*, *Coenites* and lower groups, although importance of the features fluctuates with the time and throughout the populations and taxa. Ostensible simplicity of these corals complicate the systematic evaluation.

5.3. ICHTHYOLITHS AND FISH-FAUNA

M. Ginter

Ichthyolith frequencies range between 2 and 20 specimens per kilogram within the Frasnian limestone samples. More abundant ichthyoliths originate from the Famennian part of the section, where their number increases up to 80 fragments per kg of rock

(bed 31). Placoderm, shark, and crossopterygiid remains dominate.

5.3.1. Description of significant species - teeth

Class CHONDRICHTHYES
Order Euselachii

Superfamily Ctenacanthoidea Zangerl 1981
Family Phoebodontidae Williams 1985

Phoebodus sp n. Ginter, temporarily unnamed (Pl. 8/1₁, 1₂, and 2).

Material : one almost complete tooth (Pl. 8/1) from sample 16 and tooth without one lateral cusp (Pl. 8/2) from sample 21 (comp. Fig. 2).

Diagnosis : the crown consists of three main cusps, rather strongly inclined linguad, and two additional, intermediate ones which are short, and fused to the major cusps by their lower parts. The labial face of the cusps is covered by strong, subparallel, slightly curved ridges, almost from tip to base. The most characteristic feature is the base : thick, advanced far linguad and curved, forming an almost semicylindrical tunnel. The angles of the base may be expanded linguad further than its median part. The underside is perforated by two large and many minute canals. On the upper side a low but broad button occurs.

Remarks : *Phoebodus* sp. n. was found also in Poland (Holy Cross Mountains, Mt. Karczowka) and Bashkiria. The Upper Frasnian or Frasnian/Famennian age was confirmed in all the localities. Most of the specimens from Karczowka are two or even three times larger than those from Lesni lom, and possess stronger and more evidently curved sculpture of the cusps. The other features are identical. Very close morphological relations exist between *Phoebodus* sp. n. and the teeth of a recent shark *Chlamydoselachus anguineus* Garman 1884 (Squalomorphii, Hexanchiformes ; see Cappetta, 1987, Fig. 46 A-D). The cusps of the latter species are more gently ornamented, but their shape, the outline of the base and perforation of the underside is very similar. This might confirm the relationship between Paleozoic Ctenacanthoidea and neoselachian

Hexanchiformes, proposed by Compagno (1977 ; fide Cappetta, 1987, fig. 45).

Phoebodoides zuzanae Ginter gen. et sp. n. (Pl. 8/3)

Derivation of name : zuzanae, as Zuzana's ; in honour of Moravian paleontologist Mrs. Zuzana Krejci.

Holotype : the specimen from sample 8e (last Frasnian bed), figured herein (Pl. 8/3).

Material : holotype only.

Diagnosis : three slender cups in the crown, equal in size, gently ornamented associated with two pairs of small cusplets : intermediate and lateral ones. The base is thin and elliptical.

Remarks : *Phoebodoides zuzanae* is very similar to the teeth of *Phoebodus*, especially to *Phoebodus limpidus* Ginter 1990, but its diagnostic feature is the second, outer lateral pair of cusplets.

Superfamily Protacrodontoidea Zangerl 1981

Protacrodus cf. *vetustus* Jaekel 1921 (Pl. 8/5).

Material : one broken specimen from comparative sample 90/5, Pa. *rhenana* Zone of the NE block of the measured section.

Description : thick and low median cusp of the crown and probably three pairs of smaller lateral cusps, similar in shape. All the cusps are ornamented with ridges. The base is thick, long and narrow, with many foramina along its wall.

Remarks : the tooth is very similar to the specimens of *Protacrodus vetustus* Jaekel 1921, illustrated in Gross (1938 ; fide Zangerl, 1981, Fig. 62). However, the state of preservation is very poor, so it can be assigned to that species only tentatively.

Order Symmoriida Zangerl 1981
Family Stethacanthidae Lund 1974

Stethacanthus sp. (Pl. 8/4, Pl. 9/2, and 3)

Material : three partially broken teeth : one from sample 7A (Pl. 8/2), and two from comparative sample 90/39, Pa. *triangularis* Zone of the NE block (Pl. 8/4 and Pl. 9/3).

Description : typical cladodont tooth with five cusps in the crown. The median cusp is higher and thicker than the lateral cusps, the outer pair of which is higher than the intermediate one. The angle between the outer lateral cusps is large, almost 90°. All cusps are ornamented with ridges on their labial face ; the specimen from sample 7A (Pl. 8/2) has a similar sculpture also on its lingual face. The base is broader than the crown. It possesses a very characteristic double 'button' (articular boss) close to its lingual rim. Two major nutritive foramina perforate the vicinity of the 'button' - one from above and another from the lingual side (see Pl. 9/3). Many other openings are irregularly placed all over the base.

Remarks : very similar teeth, especially closely related to the specimen from sample 7A, were found in Holy Cross Mts (Mt. Miedzianka) in the 'Upper Pa. *triangularis*' Zone.

Order and family indet.

'Cladodus' spp.

Several different teeth possessing high median cusps and two or more pairs of smaller lateral cusps are assigned to this artificial genus. Those are three specimens from sample 10 (Late Pa. *rhenana* Zone, e.g. Pl. 9/1, and 6), one from sample 8E (last Frasnian bed), one from sample 90/29 (Upper Pa. *rhenana* Zone of the NE block), and two from sample 90/39 (Pa. *triangularis* Zone of the NE block, Pl. 9/4, 5).

Class OSTECHTHYES
Order Crossopterygii

Family Onychodontidae Woodward 1891

Genus *Strunius* Jessen, 1966

Type species : *Strunius rolandi* (Gross, 1956)

Strunius rolandi (Gross, 1936) (Pl. 10/3)

SAMPLES TAXA	6	7A	8B	8D	9	11	13	15	17	19	21	24
	7	8A	8C	8E	10	12	14	16	18	20	23	
ALGAE												
Solenoporaceae indet.												
Renalcis sp.												
Calcisphaera sp.												
Girvanella sp.												
Moravamminidae sp.												
Tuborecta sp.												
FORAMINIFERS												
Bisphaera sp.												
Irregularina sp.												
Parathuramina sp.												
Caligella sp.												
Nanicella sp.												
Tikhinella multiformis (Lipina)												
Eogeinitzina sp.												
Nanicella evoluta Reitlinger												
Eonod. cf. insignis Konoplina												
Eonodosaria sp.												
Tikhinella sp.												
Nanicella porrecta Bykova												
Nanicella cf. evoluta Reitl.												
Eogeinitzina devonica Lipina												
Nanicella uralica T chuvashov												
Nanicella tchernyshevae Lip.												
Tikhinella fringa Bykova												
Tikh. aequalis Konoplina												
Frondilina sp.												
Eonodosaria micra (Bykova)												
Eonod. evlanensis Lipina												
? Septabrunsiina sp.												

FAMENNIAN **FRASNIAN**
LESNI LOM - FORAMINIFERS and associated ALGAE

Table 3 : Foraminiferal fauna with some data on algae. Relatively continuous occurrences of *Nanicella*, *Eonodosaria* and *Eogeinitzina* were interrupted near the Frasnian/Famennian boundary. In the early Famennian, unilocular forms dominated. Contrary to inner ramps, no *Multiseptida* foraminifers inhabited the Lower Famennian sea floor.

known were only from the Frasnian of Poland.

A typical and relatively diverse fauna of the *F. pentagona - Temnophyllum* Biozone may be correlated with earlier *Pa. gigas* levels (Sumbera, Cebin and Brezina), while a decrease both in diversity and in specimens number is visible in 'Late *rhenana*' strata of the Horakov Sequence (Tab. 4).

5.5.3. Description of the new species

Family Phillipsastraeidae Hill 1954
Phillipsastraea d'Orbigny 1849

Phillipsastraea zerda Galle, sp. n. (Pl. 12/1, 2).

Derivation of name : zerda, as Zerda, the dog-friend of paleontologist Arnost Galle.

Holotype : specimen AG 1201 A, B, transverse and longitudinal sections figured herein ; borehole Horakov SV-1, E of Brno, depth 142.6 m ; limestones of the Horakov Sequence, *Palmatolepis gigas* Zone. No other material and paratypes.

Description : corallum cerioid, its shape and size are unknown. Both major and minor septa are long, majors reaching the tabularium, minors of nearly the same length. They are built of rhipidacanth in narrow asymmetrical fans, steep towards the tabularium, less steep to almost flat towards the periphery. Discontinuous row of horseshoe dissepiments is present in the axis of trabecular fan. Horseshoes are separated from the tabularium with two or three rows of small steeply inclined globose dissepiments. Nearly horizontal dissepimental floor is developed among the horseshoes and corallite periphery ; its dissepiments are relatively larger, globose to elongate. Tabularium is built of numerous densely spaced mesa-shaped tabularial floors. Periaxial tabellae are steeply turned down and sigmoidally bent on some places. Axial series of tabellae complete and incomplete, horizontal or slightly convex.

Dimensions (holotype, two measurements) :

	d	dt	NI+II	tabulae per 5 mm
OR	5.29-6.18	2.65-2.82	23-25	107
mean value	5.735	2.735	24	

Remark : the species discussed resembles *Phillipsastraea* cf. *ananas ananas* (Goldfuss, 1826) figured by Coen-Aubert (1974) on Pl. IV, figs. 1, 2. However, the Moravian species differs in more densely spaced tabulae and dissepiments.

5.6. STROMATOPOROIDS

J. Hladil

Actinostroma spp. are traceable up to bed n° 10. Recrystallized *Stromatopora*-like coenostea are less abundant in comparison with *Clathrodictyidae*, especially *Clathrocoilon* spp. The frequency of *Stachyodes* branches decreases towards the Frasnian/Famennian boundary, where a temporal absence can be traced. However, some scattered branches are present also in beds 24 and 28. In the Krtiny HV-105 borehole or in the Mokra section, the latter cf. Fig. 5, *Stachyodes* occur together with *Pa. crepida* conodonts. While *Stellopora* disappears in bed n° 5, *Amphipora* and *Novitella* stems are recognizable up to bed n° 11. Generally, the Lesni lom section is poor in *Amphipora*-like stromatoporoids. Except for rare stachyods, no other stromatoporoids were found in the early Famennian limestones of the Lesni lom section. This is apparently different from the nearest stromatoporoid colonizations at Mokra Quarry (Fig. 5), and probably, also of the former V Habesi Quarry, SE of Velka Klajdovka.

5.7. BRACHIOPODS

J. Hladil

In the 'Late *Pa. rhenana*' beds, small brachiopods correlatable with *Trigonirhynchidae* occur (*Eoparaphorhynchus* ?), in association with broken punctate shells of larger brachiopods. The abundance of brachiopods is typical for the F-F boundary interval, where brachiopod layers and coquinas of their shells developed (Lesni lom, Sumbera, but also Mokra). Representatives

LOCALITY	Localities with typical F. pentagona - Temnophyllum Biozone : SUMBERA, CEBIN and BREZINA	HORAKOV SV-1 borehole (Pa. gigas Zone)	LESNI LOM (Pa. gigas, Late rhenana Zone)	MOKRA W-Quarry (Pa. crepida Zone)
Mendelastraea zerda gen. et sp.n.		1		
Piceaphyllum sp.		1		
Frechastraea pentagona	tens	1	1	
Hexagonaria ? sp.			1	
Neaxon ? sp.			1	
Alaiophyllum ? sp.			1	
Alaiophyllum cf. jana	5			
Alaiophyllum jana				2
Tabulophyllum maria				2
Tabulophyllum mcconnelli	1			
Charactophyllum cf. lotzei	2			
Temnophyllum isetense	7			
Truncicarinulum sp.	3			
Haplothecia filata	1			
Thamnophyllum spp.	8			
Smithicyathus sp.	7			

RUGOSE CORALS

FRASNIAN

FAMENNIAN

Table 4 : Rugose coral occurrences in the Late Frasnian, and a comparison with the Mokra W-Quarry (Lower Famennian). Sumbera outcrops are the most significant among the typical localities with the *F. pentagona* - *Temnophyllum* fauna. After an increase of diversity (about the Lower *Pa. gigas* Zone), the inner, but especially the outer ramp rugosans experienced an impoverishment which began during the Upper *Pa. gigas* Zone.

of Yunnanellidae (*Ladogia* ?) are common in the boundary interval. Similar accumulations were described also from other shoal and ramp sections (e.g. Aristov, 1989, Jia Hui-chen *et al.*, 1988). Controversally, the brachiopods of the family Wellerellidae dominate in the Lower Famennian breccias (pers. comm. M. Mergl & V. Havlicek, 1990). Insoluble residues from '*triangularis* to *crepida*' limestones contain small phosphatic, linguloid shells.

5.8. BIVALVES

J. Hladil

Simple and unornamented valves of late Frasnian age are comparable with *Eolucina* bivalves. Larger valves, with a roof-like cross-section are similar to *Beichuania* ? (Palaeotaxodonta). In southern Moravia, the larger bivalves occur rather in Famennian than in the Frasnian limestones. *Megalodon* spp. occurring between the 'Upper *gigas* and

marginifera' Zones at Mokra (J. Dvorak's blocks B, and D) were not found in the Lesni lom section.

5.9. GASTROPODS

J. Hladil

Shells evolved within the right apex-angle, up to 1.5 cm broad, are abundant in bed 11. Thick shells only ornamented by five thick, low and sharp longitudinal ribs may be of Archaeogastropod affinity. Two other types are traceable in Famennian part of the Lesni lom section ; (a) a two-whorl, *Strophostylus*-like type, and (b) thinner shells of advanced morphology with umbilicus.

5.10. DACRYOCONARIDS AND TENTACULITES

J. Hladil & J. Kalvoda

Tentaculites were cut and extracted in beds 14 and 15. At approximately the same stratigraphical position, they were also found in oil-wells to the south of the Ostrava industrial agglomeration (collections of V. Zupalova). Homoctenids and *Styliolina*-like dacryoconarids were found in thin-sections and insoluble residues of Frasnian age (Lesni lom), but surprisingly, they continue up to '*crepida*' beds of the section (Fig. 5). The Famennian shells are not so common in comparison with the Frasnian ones, but we are quite sure that they are not reworked and that their last stratigraphic occurrences are younger than commonly thought. Dacryonarids accompanied by '*crepida*' to '*marginifera*' conodonts were also found at Horni Benesov (collections of J. Dvorak and O. Friakova), as well as in the Potstat-1 pioneer well and in the boreholes near Horakov (collections of J. Hladil and J. Kalvoda, Fig. 5).

5.11. CEPHALOPODS

J. Hladil

Thin shells of cephalopods are nearly unextractable from pure limestone and their sections are nearly undeterminable. The cephalopod frequency increases from the Frasnian to the Famennian. Convolute shells may be related to goniatites. The cyrtoceranconic shells occur from the bed 23

onwards. They are usually 15 cm long, but some larger fragments are scattered within the '*crepida*' breccias.

5.12. BRYOZOA

J. Hladil

Bryozoan fragments are dispersed in different levels of the section (Fig. 3), especially in beds 3, 11, 28 and 30. Cystoporida (Fistuliporidae), and Cryptostomida (Fenestellidae) occur only in the Frasnian, while the Trepostomida continued up to Famennian strata. A similar distribution of bryozoans was found in the Sumbera section (pers. comm. F. Hladilova, 1991).

5.13. CRINOIDS

J. Hladil

Disarticulated columnals dominate. *Cupressocrinites* ossicles (tetragonal, with narrow secondary lumens which reach nearly the ossicle margins) are common within the late Frasnian strata. *Hexacrinites* occur in the F-F interval, while *Preptopremnum* and *Anthinocrinus*-like columnals are mostly present in the overlying Famennian beds. Columnals of an artificial genus '*Cyclocyclicus*' are common throughout the whole section.

5.14. TRILOBITES

J. Hladil & J. Kalvoda

Trilobite microremains were observed in thin sections. Frasnian cuts show a duplicature ; they may be compared to some proetids. The larger fragments of trilobites may correspond to phacopids. The presence of *Scutellum*, sampled by J. Oppenheimer at the beginning of this century (SW slope of the Hady Hill), has not been newly confirmed in the late Frasnian - early Famennian beds. No data exist on trilobites of the '*crepida*' Zone.

5.15. OSTRACODES

J. Hladil

Short and oval, thick-shelled ostracodes are common in the Frasnian packstone/grainstone layers. Entomozocean ostracodes became more frequent from bed 5 onwards, but especially in the beds 17 and 28.

Their extraction is difficult but possible. The *Entomoprimitia*-like ostracodes occur closely above the F-F boundary.

5.16. SPONGE SPICULES

J. Hladil

Sponge spicules are more or less represented in many micrite beds, but spicule layers are developed only in beds 1,6, 12, 18, 26 and 30. Larger *Oxea* types are common in the lower part of the section, while the tetrapod and triactine types occur only above the F-F boundary. Corals from bed 5 were opened by large sponge borings (spheric cavities with radial canals).

5.17. SCOLECODONTS

J. Hladil

The material consists of polychaetid jaws which were partly substituted by illite. Typical first (1.3 mm), and fourth maxillae (0.35 mm) are present in the insoluble residue of bed 12. Maxillae are unusually broad, with lateral and medial rows of cusplets. Larger lateral cusps are convex. Mechanically damaged remains occur in the Famennian wackestone/packestone.

5.18. ECHINOIDS

J. Hladil

Echinoid spines are common, mostly within the moderately winnowed grainstone layers of late Frasnian age. Conical shape of spines dominates, but some swelled spines were found, too. Length of spines ranges from 3 to 15 mm, and the diameter of the base from 0.5 to 2 mm.

5.19. ALGAE

J. Kalvoda & J. Hladil

The *Renalcis* occurrences are summarized in table 3. Considering the microfacies studies we can say that *Renalcis* is significant up to bed 11, while in overlying beds the solenoporacean algae are more common (e.g. bed 13). Tubular segments of '*Acetabularia*-like' thalli dominate in the Frasnian, while some dasycladacean algae of more complicated structure occur in the Famennian. *Girvanella*, *Rectangularina* and

'moravaminid' algae are more restricted to the micritic layers of the section.

5.20. SPORES AND OTHER PALYNOMORPHS

J. Hladil

Organic matter was conspicuously damaged in the course of oxidation, bacterial decay, resedimentation and thermal degradation. Generally, the Famennian remains and especially the ones of the SW block are somewhat better preserved. Trilete spores are traceable in the Frasnian samples from beds 19-21, but their preservation is unsatisfactory. In the '*crepida*' Zone, the number of oval and/or bean-shaped spores increased. Undeterminable debris of terrestrial plants is scattered within beds 20 and 29. No chitinozans were found in complex samples; the presence of acritarchs is questionable (pers. comm. P. Dufka, M. Vavrdova, 1991).

5.21 TRACE FOSSILS

J. Hladil

Corals from bed 10 probably underwent scraping by fishes (double-teeth traces). *Lumbricaria* (fish excrements) are visible in several grainstone beds of Frasnian age. Irregular burrows opened with one tube to the sea floor, occur in bed 13.

6. CONCLUSIONS

6.1. BIOSTRATIGRAPHY

Z. Krejci, J. Hladil, J. Kalvoda & A. Galle

The evaluation of the Lesni lom section confirmed that the last occurrences of *Nanicella*, *Eogeinitzina* and *Eonodosaria* spp. (foraminifers) and *Scoliopora kaisini* (tabulate coral) are approximately correlatable with the Frasnian/Famennian boundary. Conodont sequences indicate that larger gaps developed at least between the upper part of the *Pa. linguiformis* and the lower part of the *Pa. triangularis* Zone. Dacryoconarids did not become extinct at the F-F transition, as previously assumed, but they continued higher up to the *Pa. crepida* Zone (bed 27). Considering the previous data from Horni benesov, Potstat and Horakov, we assume that their final extinction might correspond to the

early '*marginifera*' levels. Alveolitinae (tabulate corals) became extinct before or at the F-F boundary, while Coenitidae and Auloporidae continued up to the '*crepida*' levels. The Alveolitinae-corals of the Lesni lom section experienced some 'Coenitid-like' functional modifications even before the Kellwasser event (cf. chapter 5.2).

6.2. ENVIRONMENT

J. Hladil, J. Kalvoda & A. Galle

Eroded hardgrounds with 'recrystallized and tarnished' crusts, as well as the presence of locally preserved voids and 'vadose-silt' fillings (beds 18, 20) reflect the response of Lesni lom F-F depositional environments to an overall sea-level fall. The numerous gaps, the condensation of the total thickness, sedimentation quiet in contrast with slumps and storm deposits, were common during the Famennian, as well as during the F-F boundary time interval, not only in the Lesni lom section but also on a global scale (Dreesen & Thorez, 1982; Johnson & Sandberg, 1988, Goodfellow *et al.*, 1988).

Quartz grains, often of aeolian character, which were abundant at the start of the Late *rhenana* interval were gradually substituted by less stable mineral grains and by elongated grains of greenschist metamorphic rocks in the Famennian beds of the Lesni lom section. The clay mineral content increased slightly but evidently throughout the section. These features reflect an increasing trend of climatic humidity, which has been evidenced, in our opinion, also by the presence of plant-bearing siltstones and mudstones of the Famennian sequences in Belgium and France (e.g. Feist, 1990).

Weathered and abraded conodont elements which have been found in the Lesni lom F-F interval most probably have been affected by lateritic weathering. Clay admixture with an excess of aluminium (cf. chapter 4) became significant even before the boundary event. Both of the above mentioned signals correlate with the suggested lateritic weathering on the surrounding land. The washed lateritic products embedded in the F-F and Famennian sequences of Moravia, recognizable by brown/red/violet colour and their mineral and chemical composition, have been studied earlier (Dvorak, 1980, 1990). The plausible lateritic weathering corresponds well to the

reconstructed paleokarst features. Corroded fissures and caves of Frasnian-Famennian age have been documented, for example, in the SW-blocks of the Middle Mokra Quarry. Reviewing these observations, it is suggested that the general cooling of the climate (i.e. based on the eustatic fall of the sea level, scattered isotope evidences, e.g. C.A. Sandberg's data, in Goodfellow *et al.*, 1988) did not surpass the lower limits of the lateritic weathering and karst development in East Moravia.

Rare indications of ferruginized particles and iron-rich ooids were found near and above the F-F boundary (Fig. 4). Thus the investigation of Lesni lom confirmed the previous data (Skacel, 1953) on oolitic ironstone from the former V Habesi Quarry (Fig. 1). Skacel (1953) noticed: 'oolitic ironstone and clay intercalations with reworked amphipora and stromatoporoid fauna occur within the beds of upper coral limestones'. Coherency between the Habes and the W-Mokra Quarry Frasnian/Famennian sequence is conspicuous, except of less significant ferruginization, at the F-F gap, within the second of the mentioned sections. The iron ooids were dispersed by storms and slumps along the ramps. The F-F level of iron ooids was found not only in Moravia; conspicuous oolitic ironstones associated with gaps and siliciclastic intercalations have been described also from the Russian Platform (Voronezh district, Aristov, 1989). Although the F-F level of iron oolites does not seem to be well developed in comparison with the iron-bearing beds of the type Famennian (Belgium, Dreesen, 1982), a similarity could be suggested. The iron ooids probably originated in schizohaline estuaries during the locally decelerated carbonate and siliciclastic deposition, but also other origins are possible (Dreesen, 1982, Nahon *et al.*, 1980).

The emergence of nearshore settings, however, was connected with subsiding offshore settings. These controversial trends may be derived from occurrences of open-sea fauna which was mixed with the shallow-bottom dwellers nearshore. An increase of phosphatized organisms, which may correspond in its original cause to the upwelling of deeper oceanic waters, can be traced from the *Pa. gigas* Zone towards the Famennian. During the latest Frasnian, the relief consisting of a 'platform with reefbuilders, slope, and off-reef' was substituted by inclined ramps.

These ramps with dominant packstone/grainstone and mixed allochems resembles only few recent examples (partly the ramps of the Persian Gulf in the foredeep of the Zagros Mts, which continue down to a depth of several tens of meters; Wilson & Jordan, 1983, p. 310).

Increased inclination of the ramps was confirmed by gradually rising slump deformations. All of the mentioned features speak not only for a climatic change of the sedimentation and relief, but also in favour of the tectonic 'tilting hypothesis'. Emergence of shore and islands associated with rapid but continuous transitions to the deeper facies (an evidence for tilting) was described in the middle part of the Moravian Karst (Dvorak *et al.*, 1976). Tilting of former platforms has been interpreted as a synchronous phenomenon to the larger F-F interval in many other areas (e.g. Cantabrian Mts., Garcia-Alcade, 1990; Great Xingan ranges - Mongolia / China, Guo Shengzhe, 1990). Erosion, beginning on the uplifted segments during 'Late rhenana' times, and the succession of opened fissures, karst and neptunic fillings, as well as the narrowing of the facies belts in the Famennian, also speak in favour of the 'tilting' mechanism (cf. Fuchs, 1987). Approximate synchronicity of this event with compressive deformations seems to be evident at least in some territories, like in the Moravia.

Interesting were the relations between the shallow-water and the open-sea faunas during the Kellwasser crisis. The open-sea fauna (conodonts, goniatites and trilobites) was essentially rebuilt (comp. Schindler, 1990). Also the hemipelagic palmatolepids were more stressed in comparison with the shallow-water conodonts (*Icriodus*). Similarly, among the fish fauna, sharks and placodermi were less affected by the extinctions than the open-sea fishes (McGhee, 1982). Typical foraminifers of open ramp became extinct, while those of the sheltered ramps survived. This ecologic selectivity could support a hypothesis on the significance of oceanic changes (like overturns, cold oceans and interruption of the equatorial circulation). However, also the role of the shallow-water biota is commonly considered as very significant in the extinctions. Johnson & Sandberg (1988) noticed: 'The eustatic fall produced the late Frasnian global mass extinction' (comp. pp. 175/176). Substantially reduced shoals with rebuilt ecosystems pro-

vided restricted possibilities for pasture and reproduction of many organisms. Additionally, some typical reef-dwellers, like *Alveolites*-corals, became extinct, while the deeper and euryfacial *Scoliopora* survived (Hladil, 1989). Summing the observable data, we suggest at least two tendencies in the biologic crisis: one coming from the ocean and the second coming from the shoals. In our opinion, the ultimate causes on the rather net of the fossil data are hardly to define now. We believe provisionally, that climatic and tectonic changes (humidity, cooling in the global sense, collisions of plates) may represent a significant background for the process of mass extinction, while the local warming episodes and various 'seemingly negligible, small but important ecological starting impulses' may be responsible for the step-wise extinctions and rebuildings. No direct evidence (like tektites etc.) was found for a hypothetical F-F bolide bombarding (cf. for example Goodfellow *et al.*, 1988, *versus* Hurley & van der Voo, 1990).

ACKNOWLEDGEMENTS

The authors are indebted for consultations and cooperation to Ings. V. Sixta and Ananda Gabasova, Drs. Ivo Chlupac, Petr Cejchan, Pavel Dufka, Milada Vavrdova, Rudolf Prokop, Pavel Lukes, Michal Mergl, Vladimir Havlicek, Zdenek Kukal and Zdenek Taborsky. Discussion and criticism by Jaroslav Dvorak were important. We appreciated the valuable alpinistic assistance of Drs. Jiri Otava and Oldrich Krejci, as well as the kind cooperation of the quarry staff (Mokra-Cement-Works co.). At last but not least, the authors appreciated the significant suggestions and justifications from Drs. Michiel Dusar, Roland Dreesen, Pierre Bultynck and Francis Tourneur.

REFERENCES

- ARISTOV, V.A., 1989 - Devonskie konodonty Central' nogo devonskogo polia (Russkaia platforma). *Izd. Nauka*, 119 p., Moskva.
- BECKER, R.T., HOUSE, M.R. & KIRCHGASSER, W.T., 1990 - Bioevents at the Frasnian/Famennian boundary in northwestern Australia. *Abstr. conf. Global Bioevents, Oxford 1990, University*. Unpagged, Oxford.

- BIGEY, F.P., 1988 - Devonian Bryozoa and global events: the Frasnian/Famennian extinction. *In: Devonian of the World, III, C.S.P.G. Mem.*, 14: 53-62, Calgary.
- BIRENHEIDE, R., 1978 - Rugose Korallen des Devon. *In: Krommelbein, K. (Ed.), Leitfossilien... Begrundet von Georg Gürlich*, 2: 1-265, Berlin-Stuttgart.
- BIRON, J.P., COEN-AUBERT, DREESEN, R., DUCARME, B., GROESSENS, E. & TOURNEUR, F., 1983 - Le trou de Versailles ou carrière à Roc de Rance. *Bull. Soc. belge Géol.*, 92/4: 317-336.
- BOUCKAERT, J., MOURAVIEFF, A.N., STREEL, M., THOREZ, J. & ZIEGLER, W., 1972 - The Frasnian-Famennian boundary in Belgium. *Geologica et Paleontologica*, 6: 87-92.
- BYRA, H., 1983 - Revision der von Cl. Schlüter (1880-1889) beschriebenen Chaetetida und Tabulata aus dem Rheinischen Devon. *Cour. Forsch.-Inst. Senckenberg*, 59: 1-127, Frankfurt a.M.
- CAPPETTA, H., 1987 - Chondrichthyes II. Mesozoic and Cenozoic Elasmobranchii. *Handbook Paleichthyology*, 3A, Stuttgart-New-York.
- COEN-AUBERT, M., 1974 - Représentants des genres *Phillipsastraea* d'Orbigny, A., 1894, *Billingsastraea* Grabau, A.W., 1917 et *Iowaphyllum* Stumm, E.C., 1949 du Frasnien du Massif de la Vesdre et de la bordure orientale du Bassin de Dinant. *Bull. Inst. r. Sci. nat. Belg., Sci. Terre*, 49/8: 1-38, Bruxelles.
- COPPER, P., 1986 - Frasnian/Famennian mass extinction and cold-water oceans. *Geology*, 14: 835-839.
- DREESEN, R., 1982 - Storm-generated oolitic ironstones of the Famennian (Fa1b-Fa2a) in the Vesdre and Dinant synclinoria (Upper Devonian, Belgium). *Ann. Soc. Géol. Belg.*, 105: 105-129.
- DREESEN, R., 1984 - Stratigraphic correlation of Famennian ironstones in the Havelange (Dinant Basin) and Verviers boreholes (Vesdre Massif) (Upper Devonian, Belgium). *Bull. Soc. belge Géol.*, 93: 179-211.

- DREESEN, R., 1989 - The 'Cheiloceras limestone', a Famennian (Upper Devonian) event-stratigraphical marker in Hercynian Europe and northwestern Africa? *Bull. Soc. Géol. Belg.*, 98/2: 127-133.
- DREESEN, R., PAPROTH, E. & THOREZ, J., 1988 - Events documented in Famennian Sediments (Ardenno-Rhenish Massif, Late Devonian, NW Europe). *In: Devonian of the World, II, C.S.P.G. Mem.*, 14: 295-308, Calgary.
- DREESEN, R. & THOREZ, J., 1980 - Sedimentary environments, conodont Biofaces and paleoecology of the Belgian Famennian (Upper Devonian) - an approach. *Ann. Soc. Géol. Belg.*, 103: 97-110.
- DREESEN, R. & THOREZ, J., 1982 - Upper Devonian sediments in the Ardenno-Rhenish area; sedimentology and geochemistry. *Public. Natuurhist. Gen. Limburg*, 32/1-4: 8-15.
- DUBATOLOV, V.N. & IVANOVSKIY, A.B., 1977 - Ukazatel rodov tabulyat. *Trudy Akad. Nauk SSSR, Sibir. Otd., Geol. Geofiz.*, 336: 3-155, Moskva.
- DUSAR, M., 1976 - The Lower Famennian at the southeastern border of the Dinant Basin. *Ann. Soc. Géol. Belg.*, 99: 565-570.
- DVORAK, J., 1980 - Geotectonic conditions of the forming and extinction of the reef complex, notably in the Devonian of Moravia. *Vest. Ustr. Ust. Geol.*, 55/4: 203-208, Praha.
- DVORAK, J., 1990 - Paleofacial and paleoclimatic aspects of the Devonian and Carboniferous sedimentation in the Rhenohercynicum and Moravia. *Vest. Ustr. Ust. Geol.*, 65/2: 65-74, Praha.
- DVORAK, J., FRIAKOVA, O. & LANG, L., 1976 - Block structure of the old basement as indicated by the facies development of the Devonian and the Carboniferous in the Moravian Karst (Sudeticum, Moravia). *Geologica et Palaeontologica*, 10: 153-160.

- FAHRAEUS, L.E. & FAHRAEUS-van REE, G.E., 1987 - Soft tissue matrix of decalcified pectiniform elements *Hindeodella* confluences (Conodonta, Silurian). In: Aldridge, R.J. (Ed.), *Palaebiology of conodonts*, 105-110, Harwood, Chichester.
- FARSAN, N.M., 1986 - Frasnian mass extinction - a single catastrophic event or cumulative? *Lecture Notes Earth Sci.*, 8: 189-197.
- FEIST, R., Ed., 1990 - The Frasnian-Famennian boundary and adjacent strata of the eastern Montagne Noire, France. *Guidebook Meet. Internat. Subcomm. Devon. Stratigr. Montagne Noire*.
- FEIST, R. & CLARKSON, E.N., 1986 - Evolution of the Tropicorophinae (Trilobita) during the Frasnian. *Lecture Notes Earth Sci.*, 8: 199-201.
- FRIAKOVA, O., GALLE, A., HLADIL, J. & KALVODA, J., 1985 - A Lower Famennian fauna from the top of the reefoid limestones at Mokra (Moravia, Czechoslovakia). *Newsl. Stratigr.*, 15: 43-56.
- FUCHS, A., 1987 - Conodont biostratigraphy of the Elbingerode Reef Complex, Harz Mountains. *Acta geol. Polonica*, 37/1-2: 33-50.
- GALLE, A., 1985 - Biostratigraphy and rugose corals of Moravian Devonian (Czechoslovakia). *Newsl. Stratigr.*, 14/1: 48-68.
- GALLE, A., 1987 - Rugose corals from the Mokra Cement Works quarry (Famennian, *Palmatolepis crepida* Zone). *Vest. Ustr. Ust. Geol.*, 62/1: 35-40, Praha.
- GALLE, A., FRIAKOVA, O., HLADIL, J., KALVODA, J., KREJCI, Z. & ZUKALOVA, V., 1988 - Biostratigraphy of the Middle and Upper Devonian carbonates of Moravia, Czechoslovakia. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 633-645, Calgary.
- GARCIA-ALCADE, J.L., 1990 - Preliminary report on the Frasnian-Famennian boundary in the Cantabrian Mountains (NW Spain). *Doc. Subcomm. Devon. Stratigr.*, Frankfurt.
- GINTER, M., 1990 - Late Famennian shark teeth from the Holy Cross Mts., Central Poland. *Acta Geol. Polonica*, 40/1-2, Warszawa.
- GOODFELLOW, W.D., GELDSETZER, H.H.J., McLAREN, D.J., ORCHARD, M. J. & KLAPPER, G., 1988 - The Frasnian/Famennian extinction: Current results and possible causes. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 9-22, Calgary.
- GROSS, W., 1936 - Über Crossopterygier und Dipnoer aus dem baltischen Oberdevon im Zusammenhang einer vergleichenden Untersuchung des Porenkanalsystems paläozoischer Agnathen und Fische. *Kungl. Svenska Vetenskapsakad. Handl.*, 5/6.
- GUO SHENG-ZHE, 1990 - Frasnian-Famennian extinction and late Devonian rugose corals from Great Xing'an ranges, NE China. *Acta palaeont. sin.*, 29/4: 427-446.
- HLADIL, J., 1986 - Trends in the Development and Cyclic Patterns of Middle and Upper Devonian Buildups. *Facies*, 15: 1-34.
- HLADIL, J., 1989 - Function morphology of Alveolitinae and its dependence on the Kellwasser and other events (Tabulata, M. to U. Devonian, Moravia, CSSR). *Newsl. Stratigr.*, 21/1: 25-37.
- HLADIL, J., 1989 (1. cit. 2) - Branched tabulate corals from the Koneprusy reef (Pragian, Lower Devonian, Barrandian). *Vest. Ustr. Ust. Geol.*, 64/4: 221-230, Praha.
- HLADIL, J., KALVODA, J., FRIAKOVA, O., GALLE, A. & KREJCI, Z., 1989 - Fauna from the limestones of the Frasnian/Famennian boundary at Mokra (Devonian, Moravia, Czechoslovakia). *Sbor. Geol. Ved, R. Paleont.*, 30: 61-84, Praha.
- HLADIL, J., DVORAK, J., OTAVA, J., PRICHYSTAL, A., REJL, L., ELIAS, M., BRZOBOHATY, R. & HAVLICEK, P., 1987 - Vysvetlivky k základni geologicke mape 1:25000, 24 413 Mokra-Horakov. *Map sheets and reports, manuscript, Ustr. Ust. Geol.*, 130 pp., Praha.
- HOU HONG-FEI, JI QUIANG & WANG JINXING, 1988 - Preliminary report on Frasnian-Famennian events in South China. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 63-69, Calgary.
- HUBBARD, D.K., MILLER, A.I. & SCATURO, D., 1990 - Production and cycling of calcium carbonate in a shelf-edge reef system (St. Croix, U.S. Virgin Islands): applications to the nature of reef systems in the fossil record. *J. Sed. Petrol.*, 60/3: 335-360.
- HURLEY, N.F. & van der VOO, R., 1990 - Magnetostratigraphy, Late Devonian iridium anomaly, and impact hypotheses. *Geology*, 18: 291-294.
- JESSEN, H., 1966 - Die Crossopterygier des Oberen Plattenkalkes (Devon) der Bergisch-Gladbach-Paffrather Mulde (Rheinisches Schiefergebirge) unter Berücksichtigung von amerikanischem und europäischem *Onychodus*-Material. *Archiv für Zoologie, Serie 2*, 18/14
- JIA HUI-CHEN, XIANG SI-YOU, YANG DE-LI, ZHOU HUAI-LIN, HAN YING-JIAN, CHEN ZHEN-HUAN, WANG JIN-XING, WANG RUI-GANG, WANG SHI-TAO, ZHANG ZHEN-XIAN & WEI MING, 1988 - An Ideal Frasnian/Famennian boundary in Ma-Anshan, Zhongping, Xiangzhou, Guangxi, South-China. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 79-91, Calgary.
- JOHNSON, J.G. & SANDBERG, C. A., 1988 - Devonian eustatic events in the Western United States and their biostratigraphic responses. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 171-178, Calgary.
- KALVODA, J., 1989 - Foraminiferova zonace svrchniho devonu a spodniho karbonu moravskoslezskeho paleozoika. *PhD (CSc) thesis, Ustr. Ust. Geol., manuscript*, Praha, Brno.
- KALVODA, J., 1990 - Foraminiferal zonation of the Upper Devonian and Lower Carboniferous in Moravia (Czechoslovakia). *Acta Mus. Moraviae, Sci. Natur.*, 75: 71-93, Brno.
- KLAPPER, G., 1988 - The Montagne Noire Frasnian (Upper Devonian) conodont succession. In: Devonian of the World, III, *C.S.P.G. Mem.*, 14: 449-468, Calgary.
- KREJCI, Z., 1991 - Konodontova spolecenstva svrchniho devonu na Morave (Conodont assemblages of Upper Devonian in Moravia). *PhD Thesis, Geological Survey*, Brno.
- KUKAL, Z., 1990 - Recent and ancient marine anoxic environments. *Cas. Mineral. Geol.*, 35/3: 287-300, Praha.
- LECOMPTE, M., 1939 - Les Tabulés du Dévonien moyen et supérieur du bord sud du bassin de Dinant. *Mém. Mus. r. Hist. natur. Belg.*, 90: 1-229, Bruxelles.
- LINDSTROEM, M., 1964 - Conodonts. *Elsevier*, Amsterdam, 196 p.
- MAKHNACH, A.S., MOSKVICH, V.A., KRUCHEK, S.A. & UR EV, I.I., 1984 - Organenogennye postroiki devona Belorussii. *I.G.C.P. 86, E-Europ. Platf., Izd. Nauka i Tech.*, 234 p., Minsk.
- McGHEE, G.R., 1982 - The Frasnian/Famennian extinction event: A preliminary analysis of Appalachian marine ecosystems. *Geol. Soc. Am. Spec. Pap.*, 190: 477-484.
- McKINNEY, M.L., 1989 - Periodic mass extinctions: product of biosphere growth dynamics? *Historical Biology*, 2: 273-287, London.
- McLAREN, D.J., 1982 - Frasnian/Famennian extinctions. *Geol. Soc. Am. Spec. Pap.*, 190: 491-500
- MOURAVIEFF, A.N., 1970 - Biostratigraphie par conodontes du Frasnien Moyen et Supérieur de la Belgique. *Thesis, Univ. Louvain*.
- NAHON, D., CARROZZI, A. & PARON, C., 1980 - Lateritic weathering as a mechanism for the generation of ferruginous ooids. *J. Sed. Petrol.*, 50: 1287-1298.

- PLAYFORD, P.E., McLAREN, D.J., ORTH, C.J., GILMORE, J.S. & GOODFELLOW, W.D., 1984 - Iridium anomaly in the Upper Devonian of the Canning Basin, Western Australia. *Science*, **226**: 437-439.
- RACKI, G., 1990 - Frasnian/Famennian event in the Holy Cross Mts, Central Poland: stratigraphic and ecologic aspects. In: Kauffman, E.G. & Walliser, O.H. (Eds). *Extinction events in Earth History, Lecture Notes Earth Sci.*, **30**: 169-182.
- ROZKOWSKA, M., 1953 - Pachyphyllinae et Phillipsastraea du Frasnien de Pologne. *Palaeontol. Polon.*, **5**: 1-89, Warszawa.
- ROZKOWSKA, M., 1979 - Contribution to the Frasnian tetracorals from Poland. *Palaeontol. Polon.*, **40**: 1-56, Warszawa.
- SANDBERG, C. A., ZIEGLER, W., DREESEN, R. & BUTLER, J.L., 1988 - Late Frasnian mass extinction: conodont event stratigraphy, global changes, and possible causes. *Cour. Forsch.-Inst. Senckenberg*, **102**: 263-307, Frankfurt.
- SCHINDLER, E., 1990 - Die Kellwasser-Krise (hohe Frasnien-Stufe, Ober-Devon). *Göttinger Arb. Geol. Palaeont.*, **46**, 115 p., Göttingen.
- SCHULMANN, K., LEDRU, P., AUTRAN, A., MELKA, R., URBAN, M., LARDEUX, J.M. & LOBKOWICZ, M., 1991 - Evolution of nappes in the eastern margin of the Bohemian Massif: a kinematic interpretation. *Geol. Rdsch.*, **80/1**: 73-92.
- SKACEL, J., 1953 - Oolitické železné rudy v devonu Moravského krasu u Brna. *Prirodoved. Sbor. Ostrav. Kraje*, **14/1-2**: 20-31, Opava.
- STEARNS, C.W. & HALIN-DIHARDJA, M.K., 1987 - An oil-producing stromatoporoid patch-reef in the Famennian (Devonian) Wabamun Formation, Normandville Field, Alberta. *Palaios*, **2**: 560-570.
- STREEL, M. & VANGUESTAINE, M., 1989 - Palynomorph distribution in a siliciclastic layer near the Frasnian/Famennian boundary at two shelf facies localities in Belgium. *Bull. Soc. belg. Géol.*, **98/2**: 109-114.
- SZULCZEWSKI, M., 1971 - Upper Devonian conodont stratigraphy and facial development in the Holy Cross Mts. *Acta geol. polonica*, **21**: 1-128.
- TALENT, J.A., GRATSIANOVA, R.T. & YOLKIN, E.A., 1986 - Prototethys: Fact or phantom? Palaeobiogeography in relation to the crustal mosaic for the Asia-Australia hemisphere in Devonian - early Carboniferous time. *Internat. Symp. Shallow Tethys/Wagga Wagga*, 87-111.
- THOMPSON, J.B. & NEWTON, C.R., 1988 - Late Devonian mass extinction: episodic climatic cooling or warming. In: Devonian of the World, III, *C.S.P.G. Mem.*, **14**: 29-34, Calgary.
- VANEK, S., 1991 - Teple vody: blednoucí korali. *Vesmir*, **1991/6**: 313, Praha.
- WALLISER, O.H., GROSS-UFFENORDE, H., SCHINDLER, E. & ZIEGLER, W., 1989 - On the Upper Kellwasser horizon (boundary Frasnian/Famennian). *Cour. Forsch.-Inst. Senckenberg*, **110**: 247-255, Frankfurt.
- WALLISER, O.H., 1990 - Annual Report 1989, I.G.C.P. 216, Global Bioevents. *Manuscript*, Göttingen.
- WANG, K. & BAI, S., 1988 - Faunal changes and events near the Frasnian/Famennian boundary of South China. In: Devonian of the World, III, *C.S.P.G. Mem.*, **14**: 71-78, Calgary.
- WELLS, J.W., 1944 - Fish remains from the Middle Devonian bone beds of the Cincinnati Arch Region. *Palaeontogr. Americana*, **3/16**, New York.
- WILSON, J.L. & JORDAN, C., 1983 - Middle Shelf Environment. In: Scholle, P.A., Bebout, D.G. & Moore, C.H. (Eds.), *Carbonate Depositional Environment. Amer. Assoc. Petrol. Geol. Mem.*, **33**: 278-343.
- YANET, F.E., 1972 - Podklass Tabulata. In: Breivel, M.G. et al., *Kishechnopolostye*

i brachiopody zhivestshikh otlozh. vost. Urala, Izd. Nedra, 48-98, Moskva.

ZANGERL, R., 1981 - Chondrichthyes I, Paleozoic Elasmobranchii. *Handbook of Paleoichthyology*, **3A**, Stuttgart.

ZIEGLER, W. & LINDSTROEM, M., 1975 - Fortschrittsbericht Conodonten. *Palaeont. Z.*, **49/4**: 565-598.

ZIEGLER, W. & SANDBERG, C. A., 1990 - The Late Devonian standard conodont

zonation. *Cour. Forsch.-Inst. Senckenberg*, **121**: 1-115, Frankfurt.

ZUKALOVA, V. & SKOCEK, V., 1979 - Mass extinction of organisms and lithologic boundaries in the Paleozoic sediments in Moravia, Czechoslovakia. *Vest. Ustr. Ust. Geol.*, **54/3**: 129-142, Praha.

Manuscript received on 19 February 1991 and accepted for publication on 28 August 1991.

PLATE 1

General view to the quarry face : the Lesni lom measured section.

Positions of large volume 'complex' samples have been marked by the numbered white squares. The view is oriented to the NW. The quarry face is relatively steep, therefore it was described and sampled in alpinistic way. Nevertheless, a substantial part of the section is accessible from the scree which surrounds the middle block. October 1989, the same state until present.

Plate 1

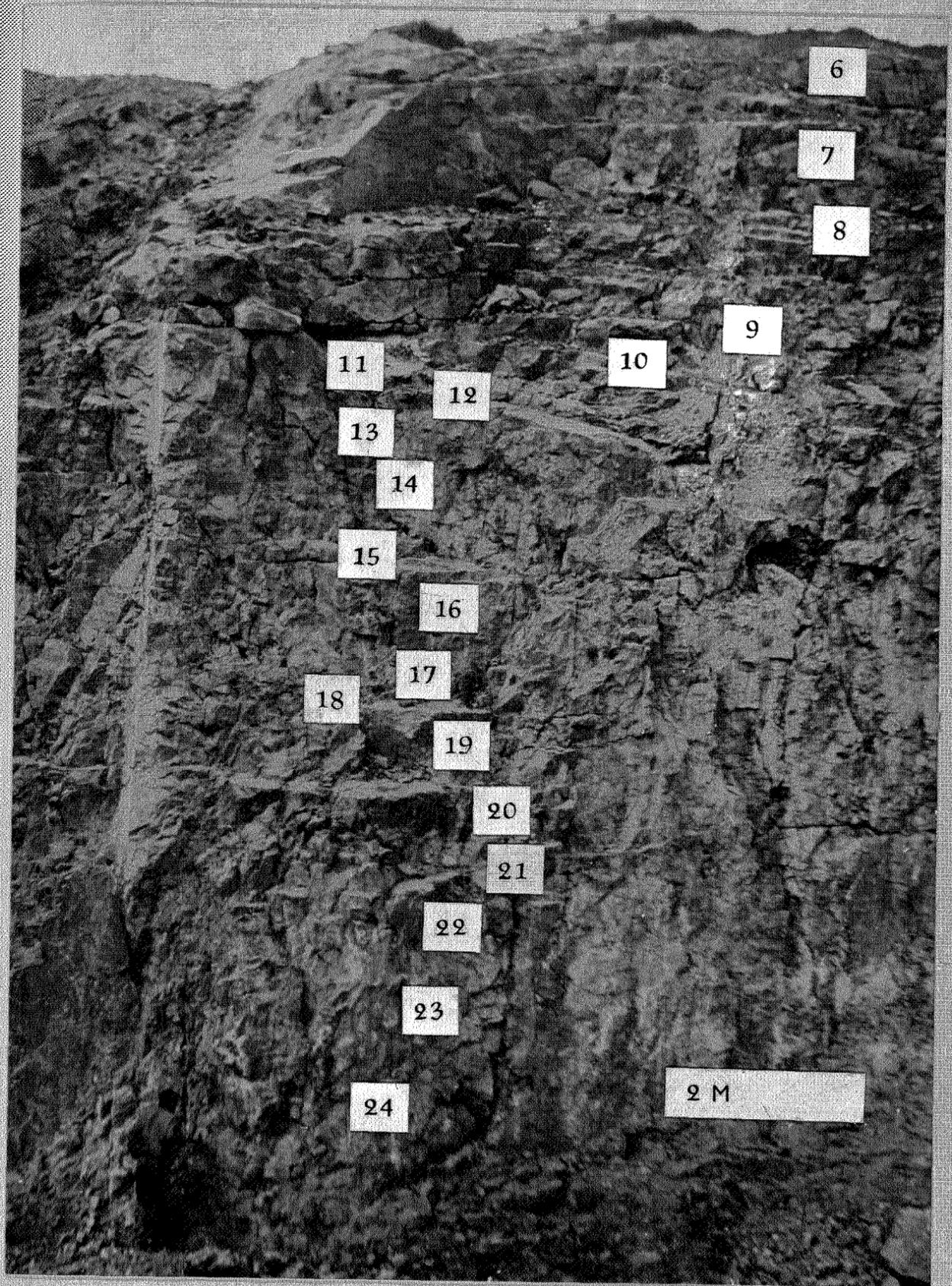


PLATE 2

Examples of microfacies

Figure 1 : Breccia with open spaces and micrite caps on the clasts. Intraclasts contain numerous fish remains, fragments of crinoids and cephalopods. The internal sediment was horizontally laminated and covered wackestones of poor breccia supporting structure (right, below). Bed n° 30, sample 6.

Figure 2 : Packstone intercalated by intraclastic packstone/grainstone. Peloids, micritized grains and bacterial flakes take part in the structure. Small burrows have geopetal fillings. Part of the structure is weakly nebular due to the recrystallization. Bed n° 18, sample 10.

Figure 3 : Laminated intraclastic packstone/grainstone (an intercalation in the more micritic band). The laminae of lime-mud-supported carbonate sand were covered by thin muddy films, rich in iron-oxides. Marginal section of a vertical burrow is visible. Bed n° 12, sample 16. Bar scale (1 cm) for all the photographs.

Material is deposited in the collection of J. Hladil, Geological Survey, Malostranske 19 - CS-118 21 Praha.

Plate 2

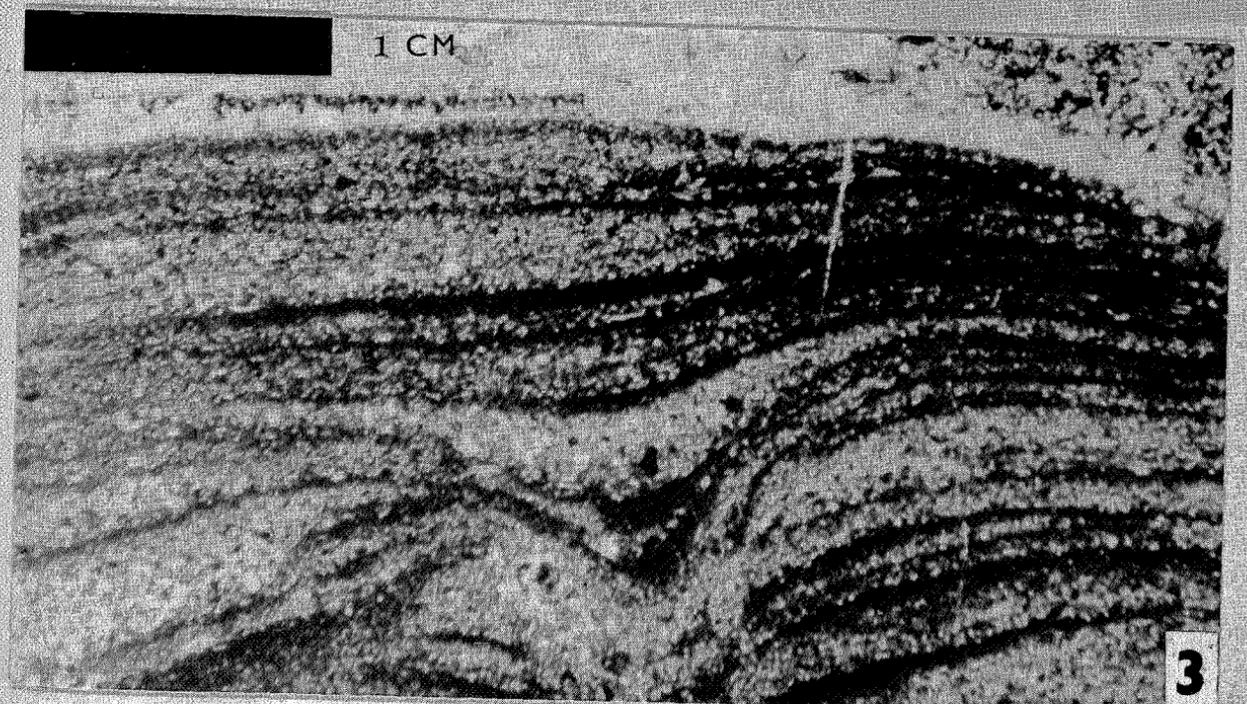


PLATE 3

Scoliopora tetralobata Hladil & Berousek, sp. n.

Bar scale (1 mm) has been used in the illustration of tabulate corals (Pl. 3-7). Sample number (comp. Fig. 2 in text) is on the right side of the figure-number. Tetralobate shape of corallites, incomplete dividing, and transitions from branched to the coating shapes are visible. Lesni lom section, bed n° 5.

Figure 1 : 1/349/II/LHNp/5a.

Figure 2 : 2/348/LHNp/5a.

Figure 4 : 4/351/II/LHNp/5b.

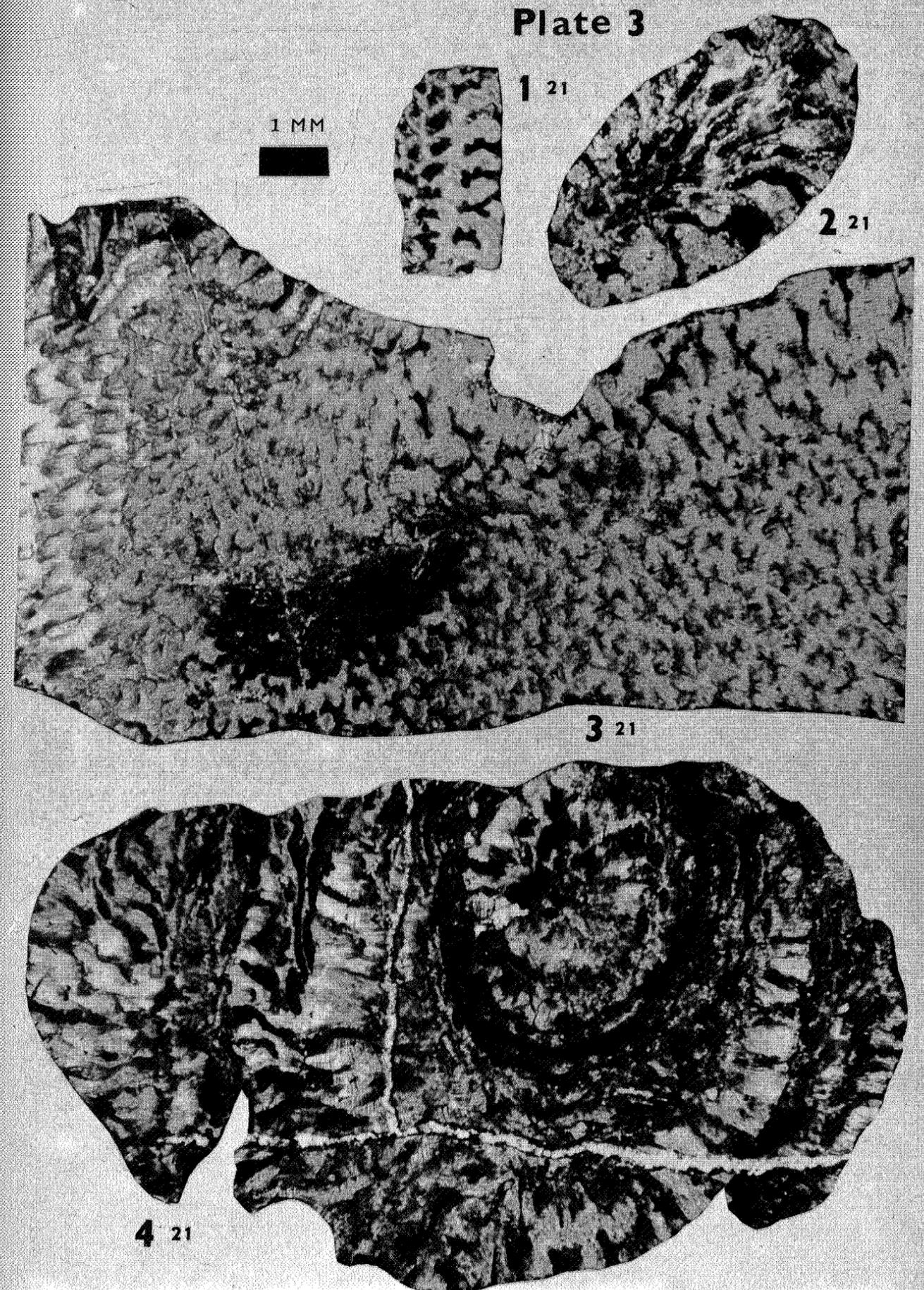


PLATE 4

Different tabulate corals from the 'Late *rhenana*' Zone of the Lesni lom section.

Figure 1 : *Thamnopora gosseleti* Lecompte 1939. Fragmented coralla indicate branched, flattened shapes arranged in loaf-like series. 1/8054/III, bed n° 10 (left), 1/352/LHNp/5c, bed n° 5 (right).

Figure 2 : *Aulostegites* sp., 2/8054/III, bed n° 10 (left), 2/349/LHNp/5a, bed n° 5 (right).

Figure 3 : *Scoliopora kaisini* Lecompte 1936, 3/8054/III, bed n° 10.

Figure 4 : *Scoliopora denticulata rachitiforma* Hladil 1987, 4/8055/III, bed n° 9.

Figure 5 : *Scoliopora relicta* Hladil & Berousek, sp. n., type section, bed n° 7. Slim branches with distorted internal structure are well distinguishable among the other branched corals.

Figure 6 : Three different section through fragmented, branched and anastomosed corallum of *Coenites (Egosiella) gracile* (Lecompte 1939). GL/8012/II, bed n° 10.

Plate 4

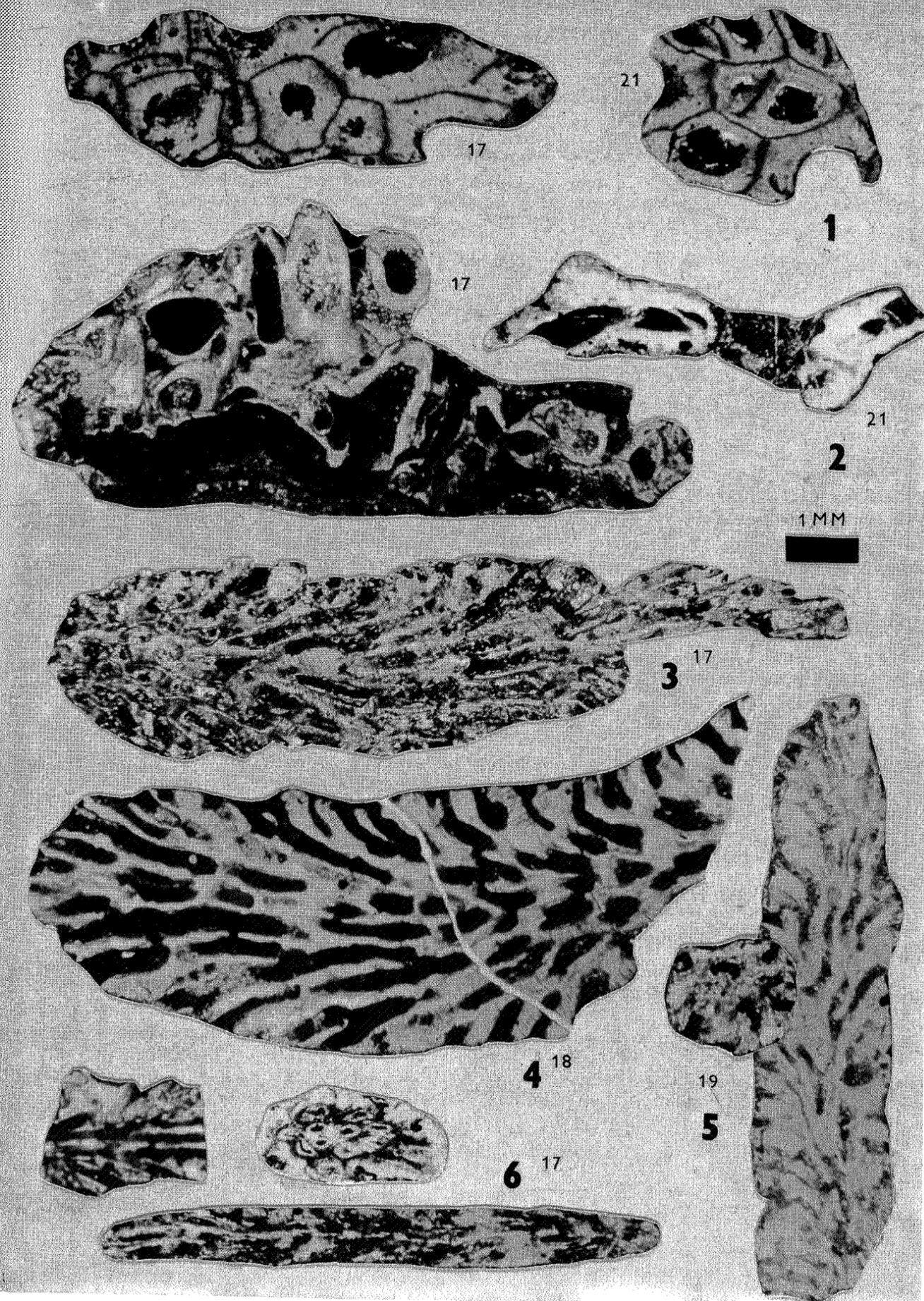


PLATE 5

Coenites otavai Hladil & Berousek, sp. n., coral bed n° 5. Branched corallum irregularly diverged and swelled with transitions to coating digitations. Colony and corallite shapes are more fluctuating.

Figure 1 : type section.

Figure 2 : 2/348/II/LHNp/5a.

Figure 3 : 3/349/II/LHNp/5a.

Plate 5

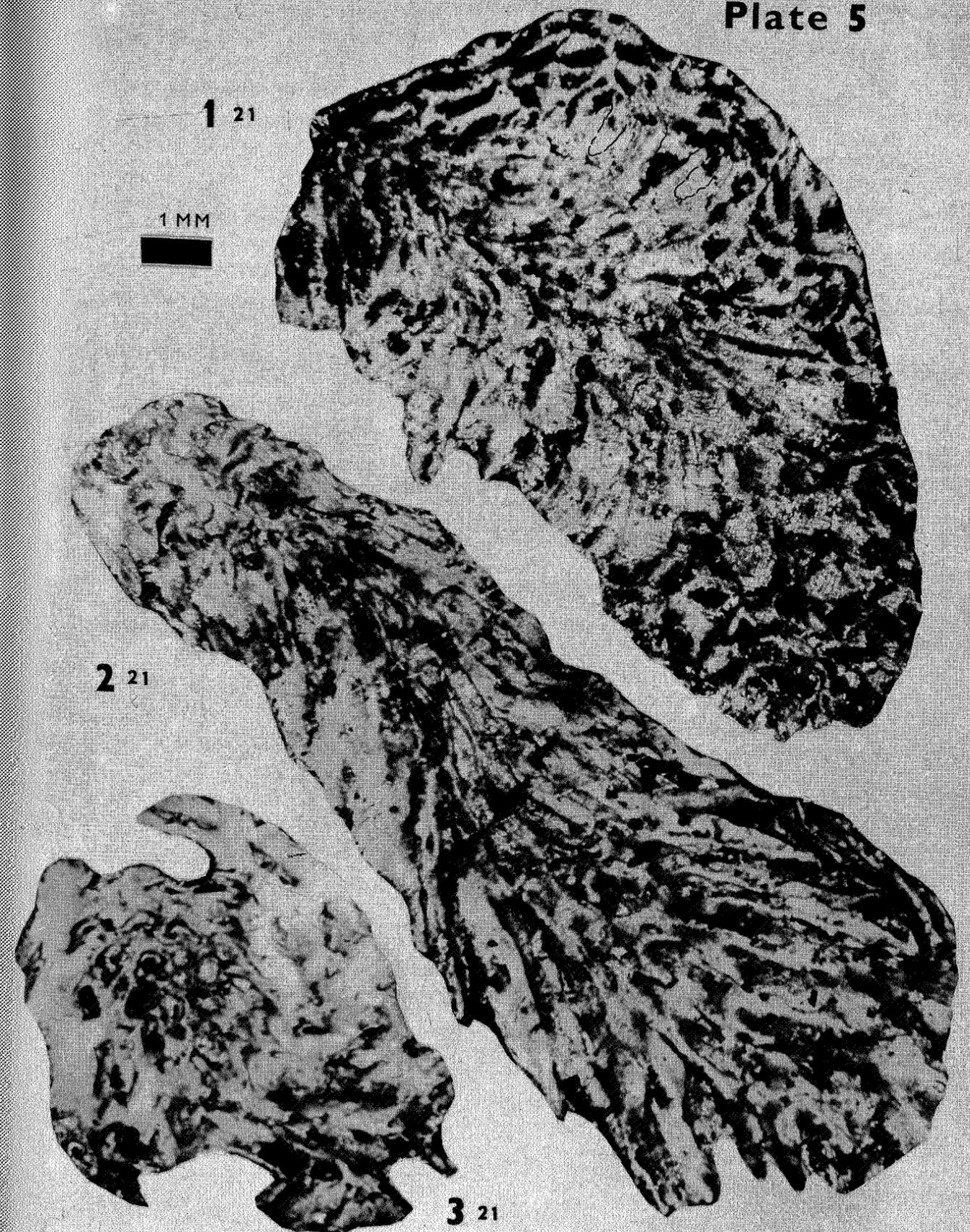


PLATE 6

Alveolites tenuissimus junior Hladil & Berousek, subsp. n., bed n° 5. Parts of multiple-benched tower-like coralla.

Figure 1 : type section. A part of larger sponge boring (radial canal, above), and unsalved wounds caused by plausible fish-scrapers, colonized with algae and stromatoporoids (below), are visible.

Figure 2 : 2/350/II/LHNp/5b. A boring with small, densely arranged fecal pellets disturbed the corallum in divergent zone.

Plate 6



1 MM

1 21

2 21

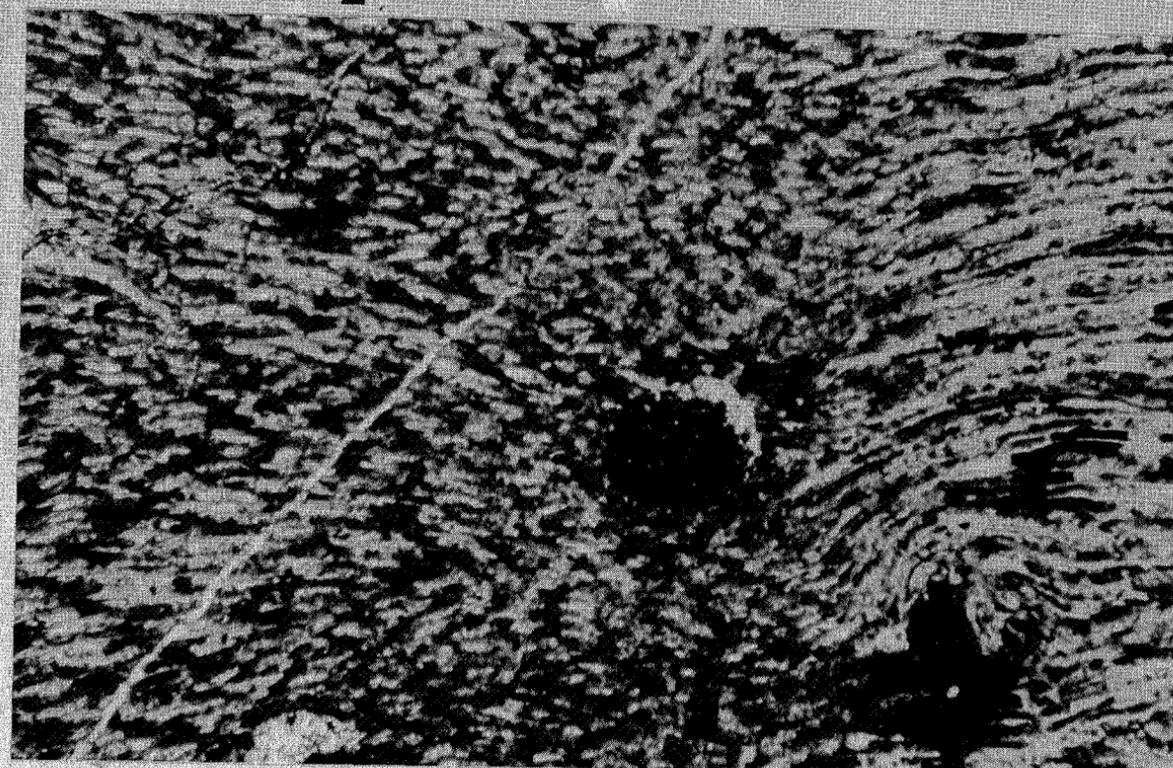


PLATE 7

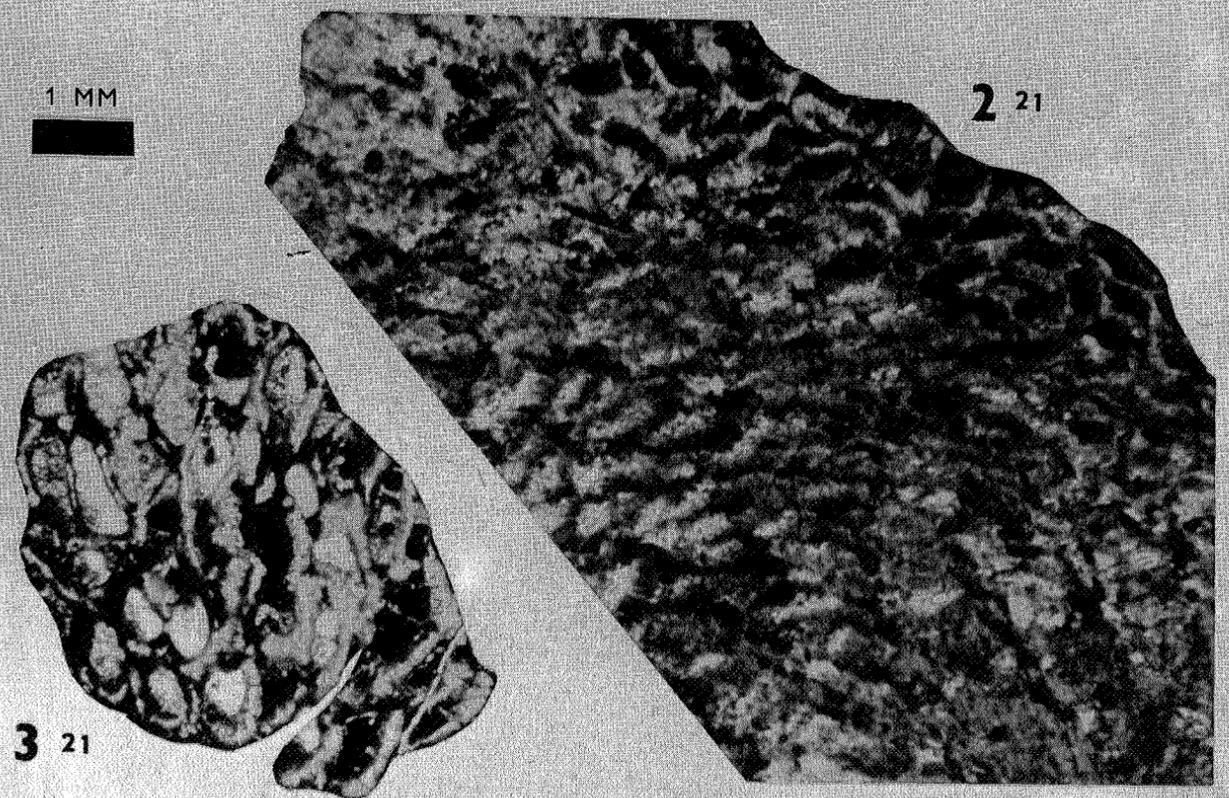
Different sections of *Alveolitella* sp. Gradual transitions among different growth shapes are traceable in different populations, but also in one corallum. Plasticity of corallite and colony shapes are remarkable. Coral bed n° 5.

Figure 1 : 4/352/III/LHNp/5a.

Figures 2, 3 : 3/347/III/LHNp/5c. Branching digitations developed above lithified surface ; coating in originally soft micritic layer.

Material is deposited in the collection of J. Hladil, Geological Survey, Malostranske 19 - CS-118 21 Praha.

Plate 7



Shark teeth from Frasnian-Famennian transitional interval, Lesni lom.

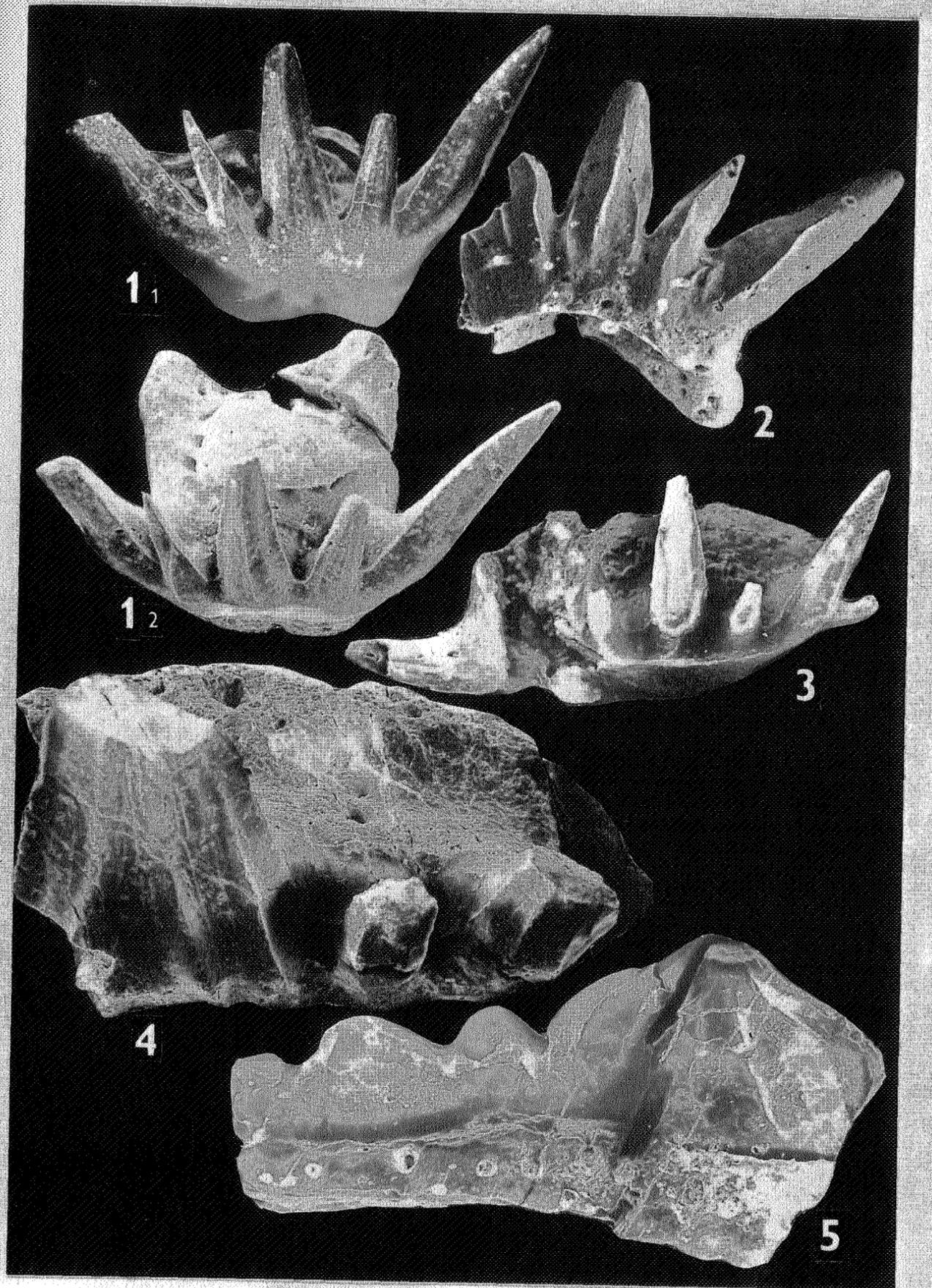
Figure 1 : *Phoebodus* sp., 1₁ and 1₂ : the same tooth in different views (3053/3143). Bed n° 12, sample 16, X 90.

Figure 2 : *Phoebodus* sp., broken tooth (3055/3132). Coral bed n° 5, sample 21, X 90.

Figure 3 : *Phoebodoides zuzanae* Ginter, sp. n., tooth from the last Frasnian bed n° 21, sample 8E. Holotype (3130), X 90.

Figure 4 : *Stethacanthus* sp., broken tooth (3041). Sample 90/39 from '*Pa. triangularis*' Zone of the NE block, X 90.

Figure 5 : *Protacrodus* cf. *vetustus* Jaekel 1921, broken tooth (3045), sample 90/5 '*Pa. rhenana*' Zone of the NE block, X 90.



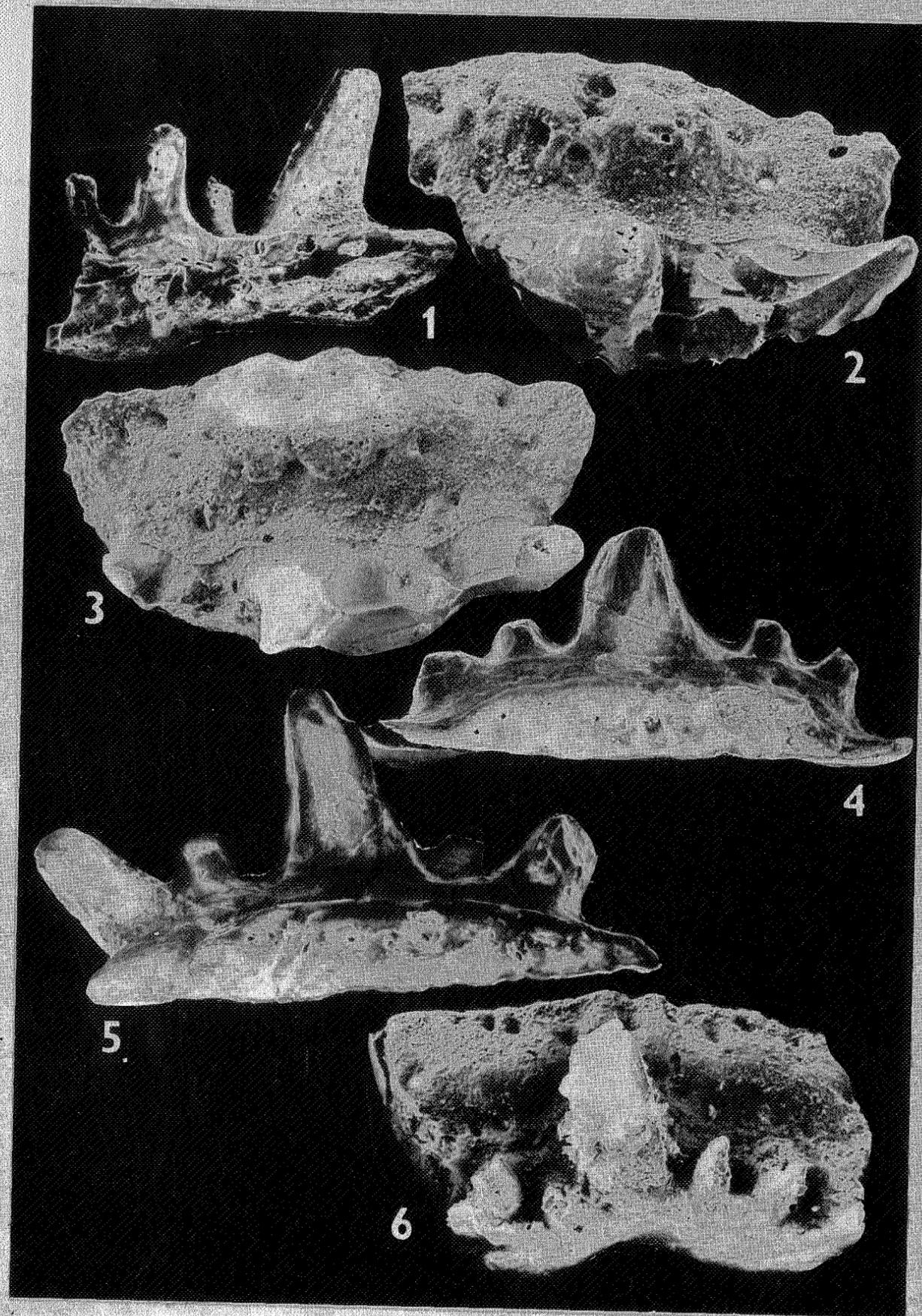
Shark teeth (especially of artificial genus *Cladodus*) from Lesni lom sections.

Figure 1 : '*Cladodus*' sp., (3138), bed n° 18, sample 10, X 120.

Figures 2, 3 : *Stethacanthus* sp., 2 - (3131), X 90, from bed n° 27 of the measured section, 'Upper *Pa. triangularis* to *crepida*' age ; 3 - (3038), X 70, from sample 90/39 of '*triangularis*' Zone, in NE block.

Figures 4, 5 : '*Cladodus*' spp., two teeth (3044 and 3042) from the Famennian comparative sample 90/39, '*triangularis*' Zone, the NE block, X 90.

Figure 6 : '*Cladodus*' sp., (3057), a typical tooth for bed n° 18, sample 10, X 120.



Other fish microremains ; Frasnian to Famennian of Lesni lom.

Figure 1 : a narrow shark scale with imbricated denticles on its posterior end (3054), coral bed n° 5, sample 21, X 120.

Figure 2 : fragment of plausible palatinal tooth of *Strunius rolandi* (Gross, 1956) sp., Crossopterygii, from comparative Famennian sample 90/39, NE block.

Figure 3 : *Strunius rolandi* (Gross, 1956), Crossopterygii. The simple teeth, or complemented with two small cusplets, are common throughout the section. Depicted tooth : (3049), bed n° 15, sample 13, X 50.

Figure 4 : simple tooth, with large base (3136), from the Frasnian bed n° 18, sample 10, X 200.

Figure 5 : another shark tooth of 'Upper *gigas* age, (3035), sample 90/29 of the NE block, X 110. Associations of shark teeth are abundant even below the Kellwasser event, but especially in the Famennian.

Material is deposited in the collection of M. Ginter, Institute of Geology, Warszawa University, Zwirki i Wigury 93 - PL-02 089 Warszawa.

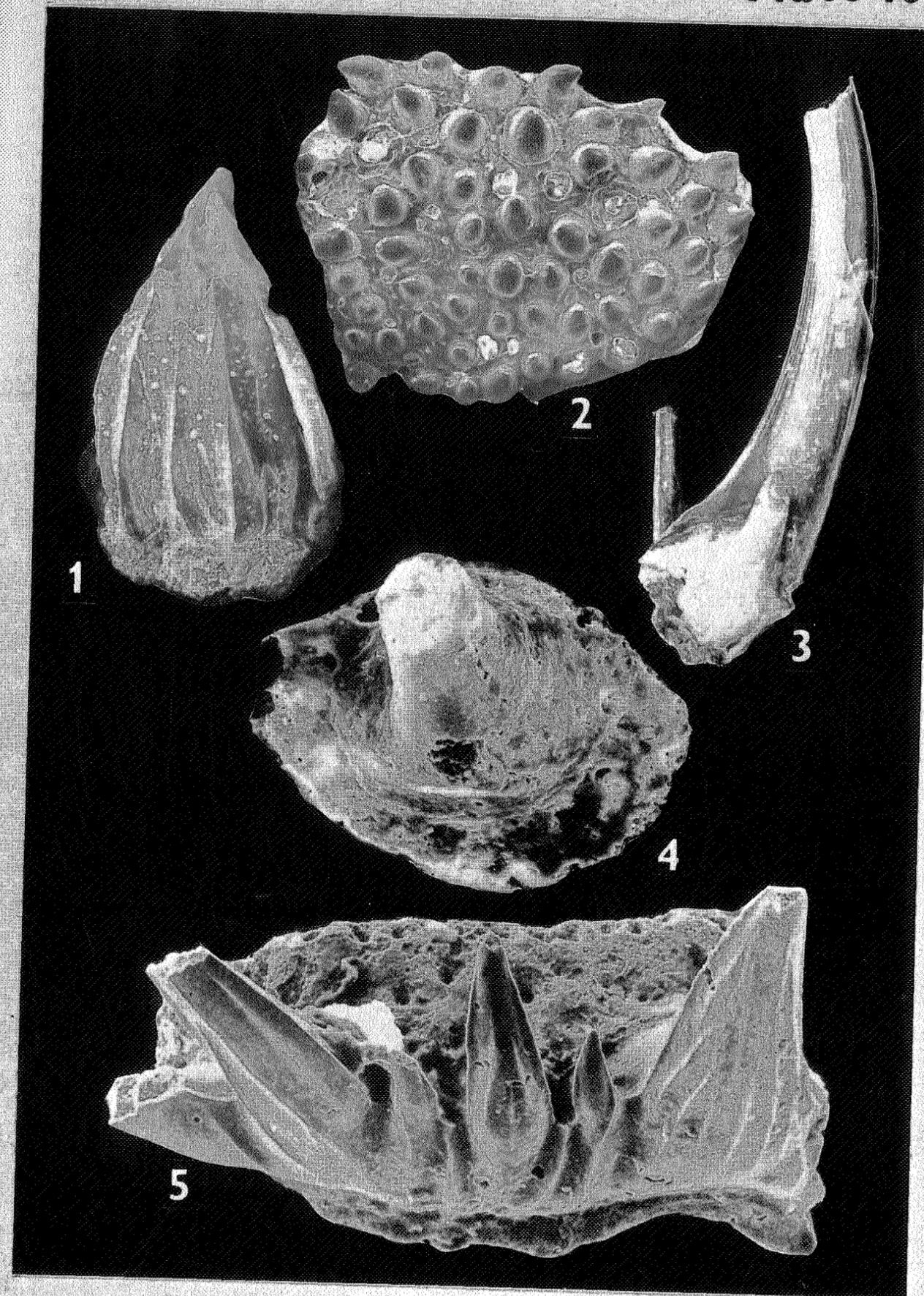


PLATE 11

Foraminifers from the Lesni lom section. Dark bar scale (below) is 0.5 mm.

Material is deposited in collection of J. Hladil, Geological Survey, Malostranske 19 - CS-118 21 Praha.

Figure 1 : *Nanicella porrecta* Bykova, 8057, bed n° 9, sample 18.

Figure 2 : *Nanicella* sp., 9571, bed n° 21, sample 8E.

Figure 3 : *Nanicella* cf. *porrecta* Bykova, 329, bed n° 4, sample 22.

Figure 4 : *Tikhinella aequalis* Konoplina, 8042, bed n° 15, sample 13.

Figure 5 : *Eonodosaria* sp., 9571, bed n° 21, sample 8E.

Figure 6 : *Eonodosaria* cf. *evlanensis* Lipina, 9571, the same bed.

Figure 7 : *Tikhinella* sp., 9571, the same bed.

Figures 8-10 : *Tikhinella multiformis* (Lipina) ; 8 - 8046, bed n° 13 (sample 15) ; 9 - 345, bed n° 11 ; and 10 - 355, bed n° 5 (sample 21).

Figures 11, 12 : *Eogeinitzina devonica* Lipina, 9571, bed n° 21 (sample 8E).

Figure 13 : *Nanicella tchernyshevae* Lipina, 9571, the same bed.

Figure 14 : *Nanicella porrecta* Bykova from the coral bed n° 5 (sample 21). Correlable sections are common in Sumbera coral layers of *Palmatolepis gigas* Zone. A typical diagenetical look for the Horakov facies.

Plate 11

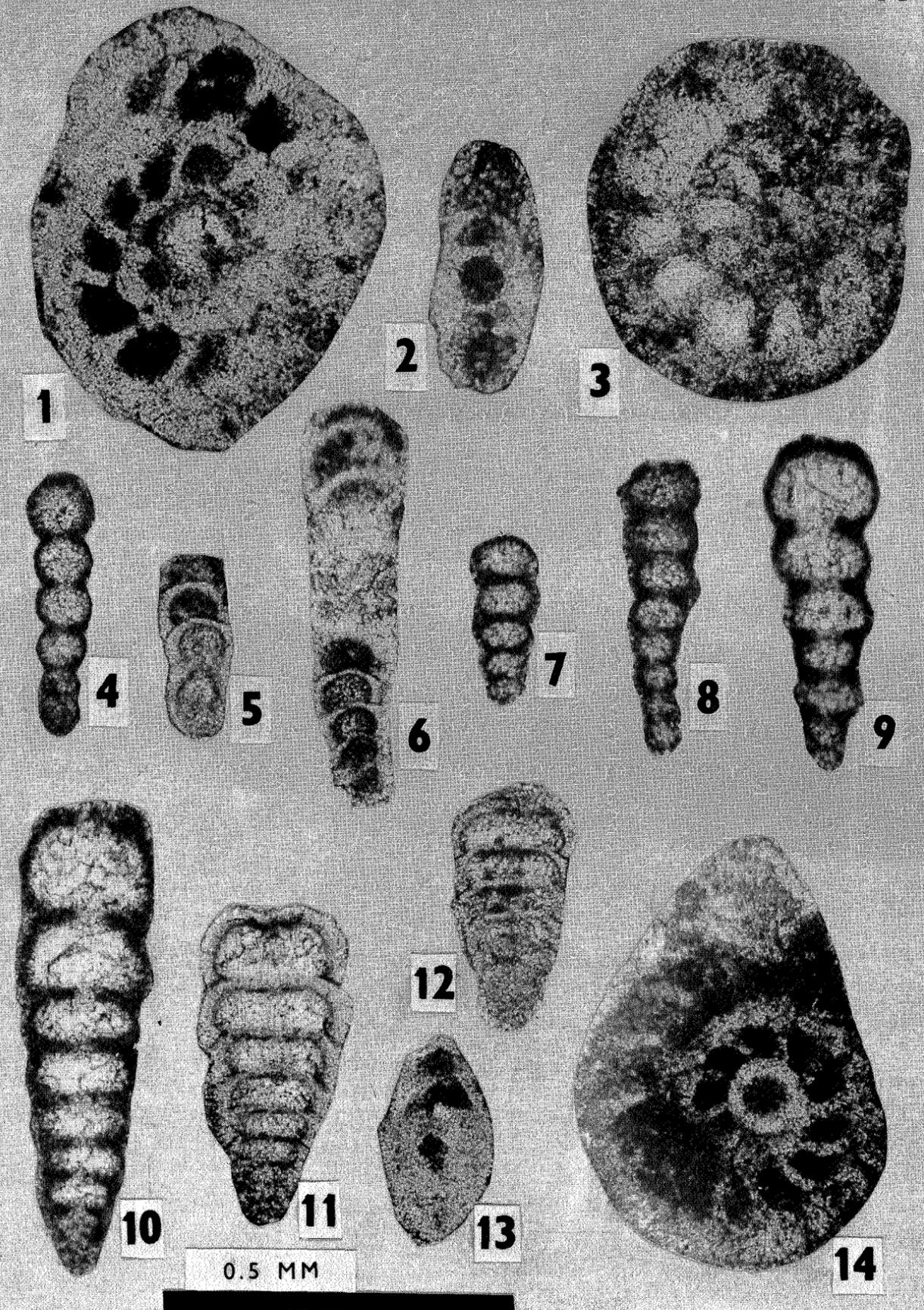


PLATE 12

Late Frasnian rugose corals from Lesni lom and Horakov.

Figures 1, 2 : *Phillipsastraea zerda* Galle, sp. n. Holotype, specimen AG 1021, borehole Horakov SV-1, 142.6 m, (1) transverse section, (2) longitudinal section, X 4.5.

Figure 3 : *Hexagonaria* ? sp. Specimen V/22 from bed n° 4, Lesni lom, oblique transverse section, X 5.

Figure 4 : *Alaiophyllum* ? sp. Specimen V/16 from bed n° 12, Lesni lom, longitudinal section, X 5.

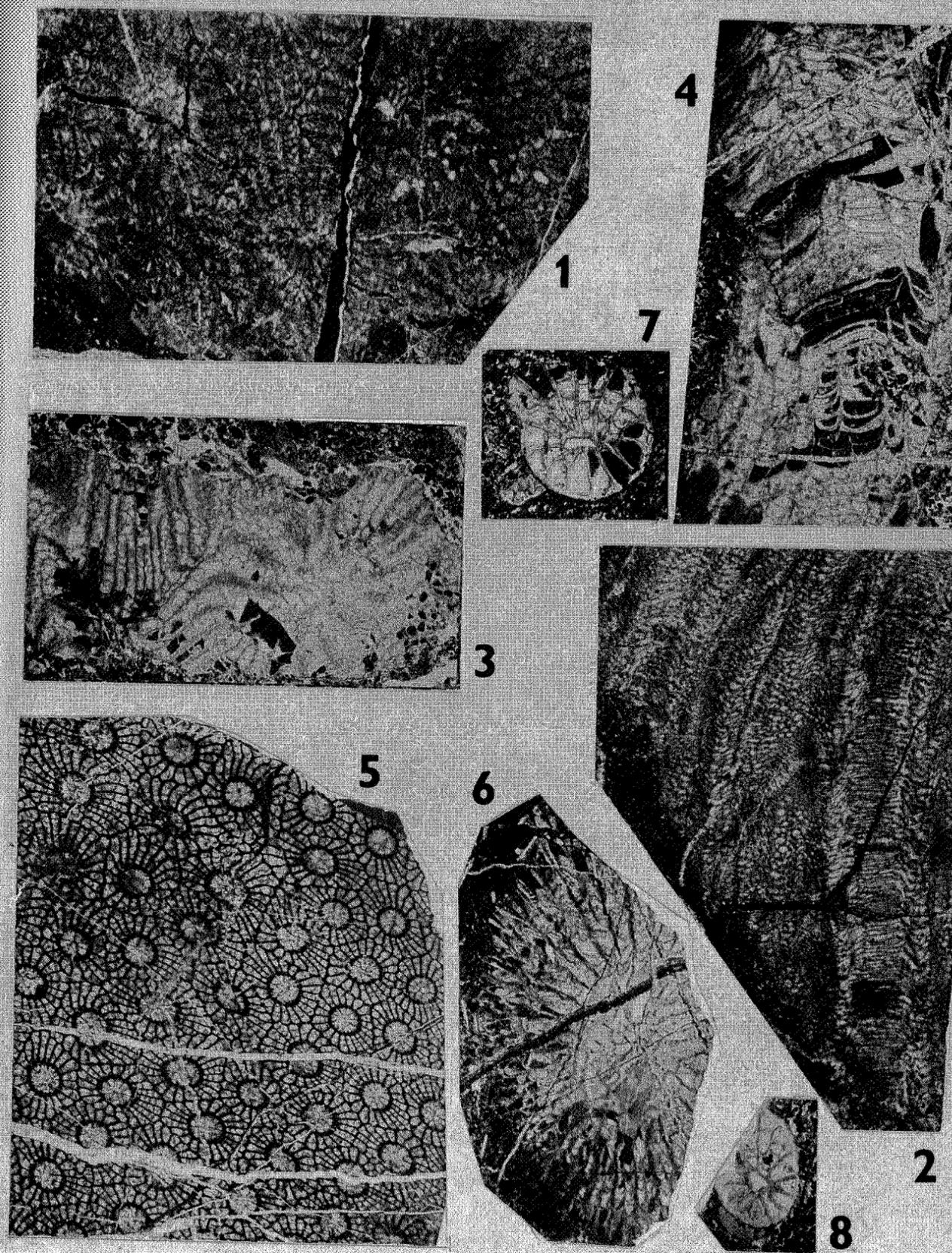
Figure 5 : *Frechastraea pentagona* (Goldfuss 1826). Specimen AG 1022, borehole Horakov SV-1, 143.7 m, transverse section, X 4.5.

Figure 6 : *Piceaphyllum* sp. Specimen AG 1024, borehole Horakov SV-1, 153.9 m, transverse section, X 4.5.

Figures 7, 8 : *Neaxon* ? sp. Specimen V/23 from bed n° 3, Lesni lom, transverse sections, X 5.

Material labelled with numbers starting with AG is deposited in the collection of A. Galle (Geological Institute, Academy of Sciences, Rozvojova 135 - CS-160 00 Praha-Suchdol) ; material with numbers starting with V is deposited in the collection of J. Hladil (Geological Survey, Malostranske 19 - CS-118 21 Praha).

Plate 12



Lower Famennian conodonts from the Lesni lom section.

Figure 1 : *Palmatolepis delicatula delicatula* Branson & Mehl. Sample 8D, upper view, a typical element with massive platform and a distinct trianguloid internal lobe, X 112.

Figure 2 : *Palmatolepis delicatula delicatula* Branson & Mehl. Sample 8C, upper view, a massive specimen, X 107.

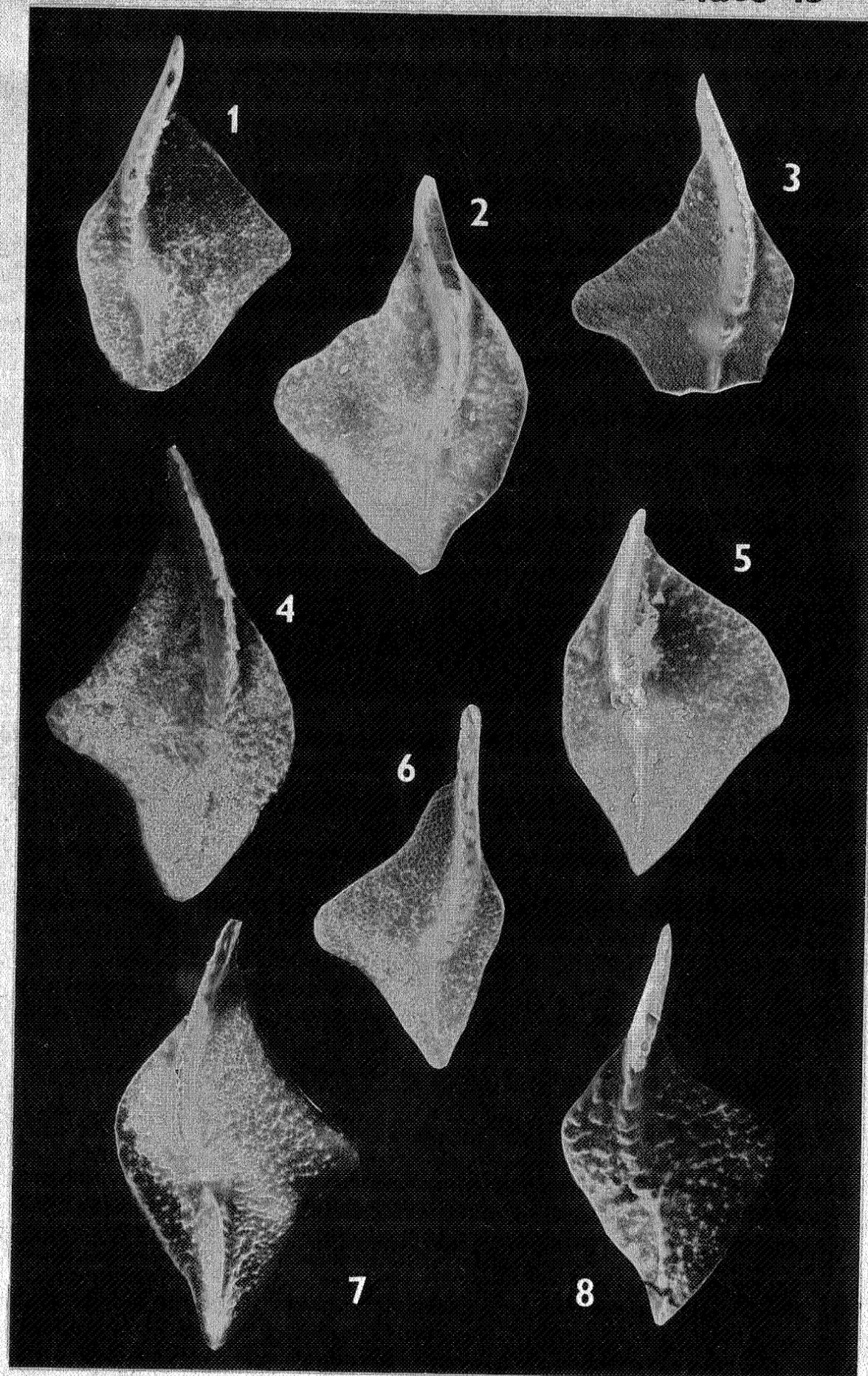
Figure 3 : *Palmatolepis clarki* Ziegler. An upper view, specimen with broken posterior part of the platform. Sample 7, X 92.

Figure 4 : *Palmatolepis triangularis* > *Palmatolepis clarki*. Outline of the platform corresponds to *Pa. triangularis*, but the anterior is similar to *Pa. clarki*. Sample 8D, X 94.

Figure 5 : *Palmatolepis prorhomboides* Sandberg & Ziegler. Upper view of specimen with a typical shape of the platform and grooves in the anterior part. Sample 8C, X 112.

Figure 6 : *Palmatolepis minuta loba* Helms. Well developed lateral lobe, upper view. Sample 7A, X 106.

Figure 7 : *Palmatolepis* sp. Rhomboidal platform covered by nodes. The posterior edge is turned up. Sample 7A, X 106.



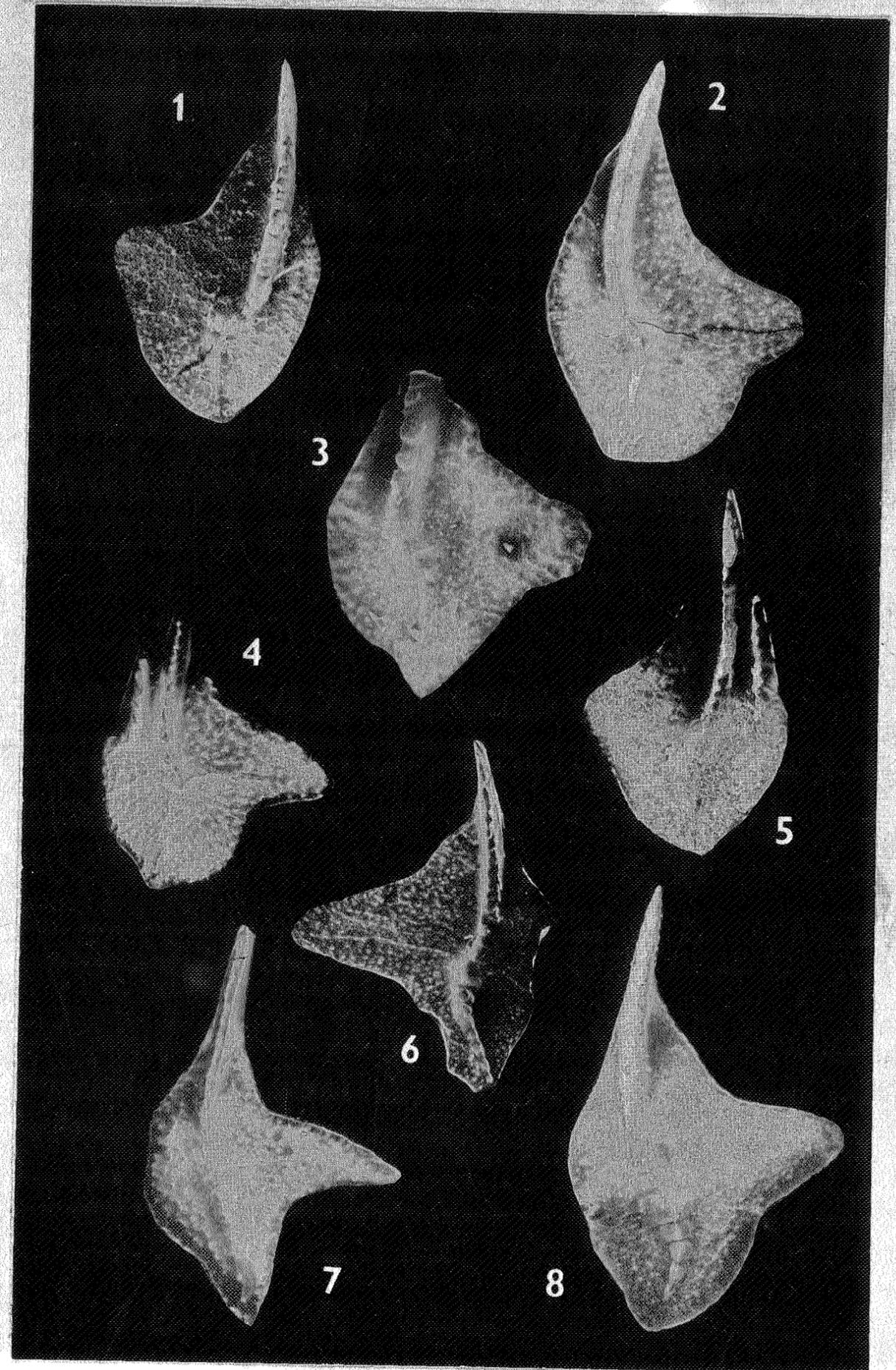
Frasnian conodonts from the Lesni lom section.

Figures 1, 2 : Palmatolepis subrecta Miller & Youngquist. Upper view of two typical specimens. (1) Sample 14, X 107, (2) Sample 12, X 93.

Figures 3-5 : Palmatolepis gigas gigas Miller & Youngquist. Lateral lobes are more or less intensively developed. The platform surfaces possess deeper reliefs, with a distinct ridge in the outer anterior parts of the platform. (3) Sample 11, X 66, (4) Sample 11, X 53, (5) Sample 16, X 57.

Figures 6-7 : Palmatolepis rhenana rhenana Bischoff. Upper views of specimens from the sample (6) 8F, X 53, and (7) 9A, X 47.

Figure 8 : Palmatolepis rhenana nasuta Mueller. Smooth surface of platform. Sample 8E (the last Frasnian bed), X 77.



Frasnian and Famennian conodonts from the Lesni lom sections.

Figure 1 : *Ancyrodella curvata* (Branson & Mehl). Sample 17, an upper view, X 69.

Figure 2 : *Ancyrognathus sinelaminus* (Branson & Mehl). Uncomplete specimen with broken anterior tip. Sample 7A, X 93.

Figure 3 : *Ancyrognathus* sp. Upper view of a robust element from the sample 8D. On the lower side of the platform, the main and three adjacent carinae are developed, X 73.

Figure 4 : *Icriodus alternatus alternatus* (Branson & Mehl). Sample 8D, X 107.

Figure 5 : *Icriodus iowanensis* Youngquist & Peterson. Upper view of the specimen from the sample 8C, X 80.

Figure 6 : *Nothognathella abnormis* Branson & Mehl. Lateral view of an element from the sample 10, X 100.

Figure 7 : *Polygnathus brevilaminus* Branson & Mehl. An oblique upper view. As visible here, the platform is not connected with the posterior tip of the blade. Sample 8C, X 67.

Figure 8 : *Polygnathus normalis* Miller & Youngquist. Sample 10, X 75.

Figures 9, 10 : *Polygnathus brevis* Miller & Youngquist. Two broken elements from the sample 8F. (9) Distorted free blade, X 67, (10) posterior of the platform, X 53.

Figure 11 : *Scutella bipennata* Sannemann. Sample 7, X 75.

Conodont specimens are deposited in the collection of Z. Krejci, Geological Survey, Branch Brno, Leitnerova 22 - CS-658 69 Brno.

