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The Czorsztyn Submarine Ridge (Jurassic–Lower Cretaceous, Pieniny Klippen Belt): An Example of a Pelagic Swell

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Der submarine Czorsztyn-Rücken (Jura–Unterkreide, Pieniny-Klippengürtel): Beispiel einer pelagischen Schwelle

Zusammenfassung

Die submarine Czorsztyn Schwelle erstreckt sich über ungefähr 500 km. Während des Jura und der Unterkreide war sie von einer ausgedünnten pelagischen Karbonatserie mit einigen Hardgrounds bedeckt. Synsedimentäre Tektonik wird durch Störungsbreccien und zahlreiche Gänge belegt. Der Czorsztyn Rücken wurde im Norden durch den Magura-Trog und im Süden durch den Kysuca-Pienninischen Trog begrenzt. Die Sedimente dieser Schwelle unterscheiden sich von den gleichzeitig gebildeten Plattformkarbonaten durch das völlige Fehlen von Algen, Oolithen und Foraminiferen wie z.B. *Protopenerophis* und *Conicospirillina*.

Abstract

The Czorsztyn submarine elevation exhibited a striking extension of about 500 km. During the Jurassic and Early Cretaceous, it was covered by predominantly pelagic condensed carbonate sediments containing hardgrounds. Synsedimentary tectonics are documented by scarp breccias and abundant neptunic dykes. The Czorsztyn ridge was bordered by the Magura trough in the north and by the Kysuca-Pieniny trough in the south. The sediments of this swell differ from those of coeval carbonate platforms by the total lack of algae, oolites and foraminifera such as *Protopenerophis* and *Conicospirillina*.

1. Introduction

Pelagic swells were the characteristic structures sited along passive continental margins during the Mesozoic.

These relatively narrow, several hundred kilometers long elevations ran parallel to the ancient shoreline. They were bordered on both sides by troughs with deep-water sedimentation. Their interpretation is hindered by the lack of recent analogies. A generalized description of such pelagic swells was given by GARCÍA-HERNANDEZ et al. (1988), based on the cases from Peribeticum and Subbeticum in Spain.

According to these authors the characteristic features of pelagic swells are the following:

1) a considerable amount of pelagic sediments but of minor thickness;

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2) a lack of terrigenous clastics;
3) abundant condensed facies of mainly red nodular limestones;
4) hiatuses accompanied by hardgrounds with pelagic stromatolites;
5) synsedimentary tectonics documented by scarp breccias and neptunic dykes; their fillings sometimes document the tilting of blocks.

2. The Czorsztyn Pelagic Swell

2.1. General Characteristics

All the features cited can be observed on the Czorsztyn submarine elevation (ANDRUSOV, 1965; BIRKENMAJER, 1963) that extended over a distance of some 500 kilometres during the Jurassic and Early Cretaceous. It can be traced from West Slovakia, via South Poland to the Carpathian Ukraine (Text-Fig. 1).

The Czorsztyn ridge was bordered on both sides by troughs with deep-water sedimentation (including radiolarites) underlain with oceanic or extremly thinned continental crust. The Magura trough was situated to the north and the Kysuca-Pieniny trough towards the south. The Czorsztyn elevation caused several difficulties during the compilation of paleogeographic maps of the large area between the Alps and the Caucasus (IGCP No. 197, DERCOURT et al., 1990). It was not possible to omit this narrow zone of continental crust not even at the scale 1 : 10,000.000 and put instead of it something like a common Magura-Pieniny ocean.

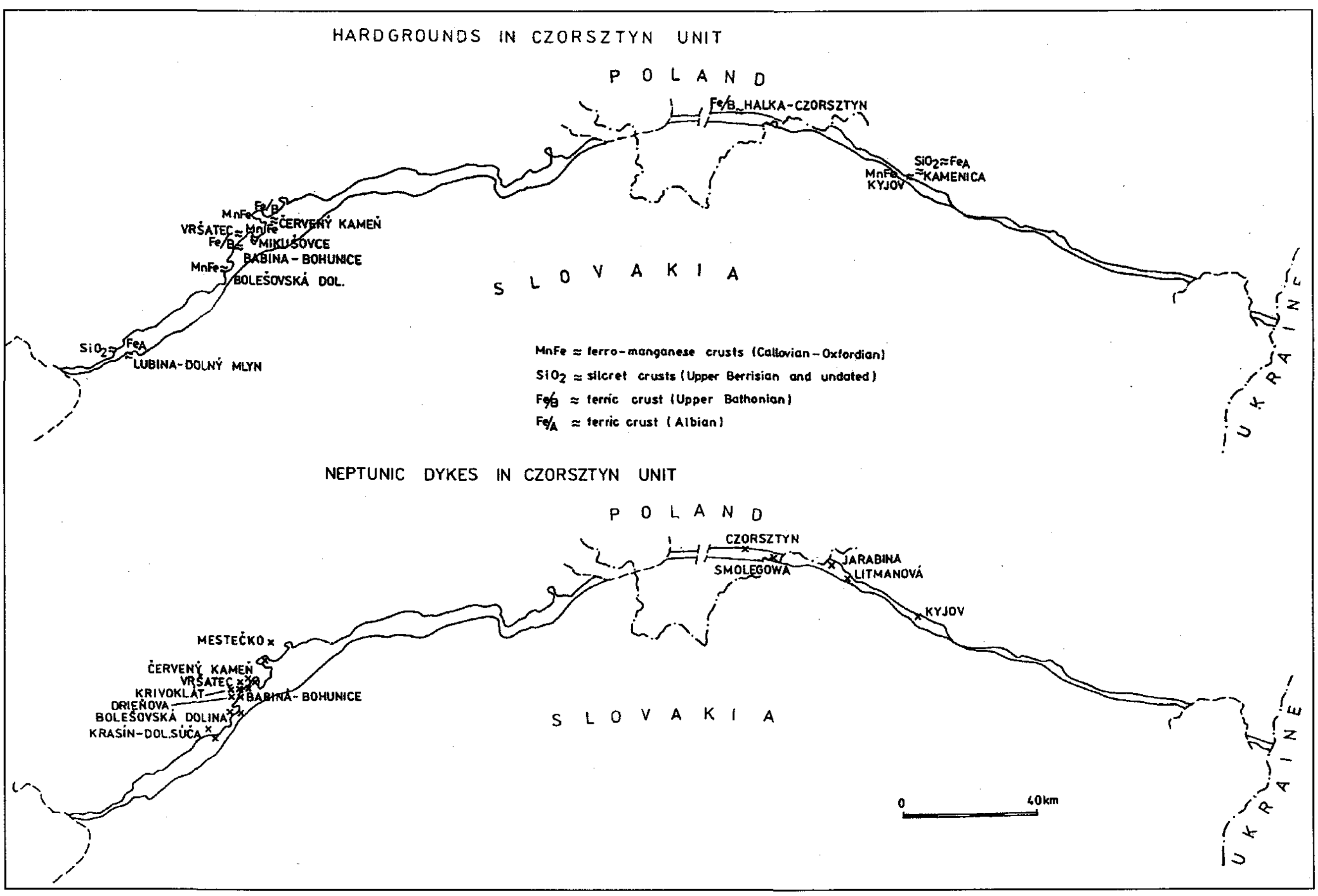
The Czorsztyn sedimentation zone was strongly tectonized forming some hundred tectonic lenses – so-called klippen during the Tertiary.

The pelagic swells of the Tethys represent the separated parts of the fragmented margins of the Triassic carbonate platforms. As for the Czorsztyn elevation, this cannot be directly proved because of the perfect décollement of the crystalline + Paleozoic + Triassic complexes from the Jurassic + Cretaceous strata that took place before the nappe stacking and following boudinage. In spite of the absence of Triassic rocks in the exposed stratigraphic column, the occurrence of small clasts of dolomite in crinoidal limestone of the Dogger supports the idea that the Czorsztyn elevation was a former part of a Triassic carbonate platform.

As in other pelagic swells, siliciclastic sediments are absent in the Czorsztyn succesion, a slight sandy admixture is present only in the Upper Liassic and Dogger limestones. The succession of the Czorsztyn domain consists of crinoidal limestones of Dogger and Berriasian–Hauterivian age, of limestones with dominating pelagic microfauna (Callovian–Oxfordian, Kimmeridgian, Tithonian), of coquina limestones (the so-called Rogóznik coquina of Oxfordian to Tithonian age), of red nodular limestones ranging from Lower Bathonian to Lower Tithonian (RAKÚS, 1990) and exceptionally of bioherm limestones known only from a small area near Vršatec (MIŠÍK, 1979).

2.2. Scarp Breccias

Scarp breccias accompanied by neptunic dykes were evidently caused by synsedimentary faults. At the locality



Text-Fig. 1.
Localities with hardgrounds and neptunic dykes in the Czorsztyn unit, Pieniny Klippen Belt.

Table 1.
Timing of neptunian dykes and pocket fillings in the area of the Czorsztyn submarine swell.

ROCKS CUT BY DYKES	SENONIAN	ALBIAN	NEOCOMIAN	U.TITHONIAN	KIMMERIDGIAN	OXFORDIAN	CALLOVIAN
NEOCOMIAN		DOLNÝ MLYN -VRŠATEC KAMENICA					
U.TITHONIAN	BABINÁ	LITMANOVÁ LEDNICA VRŠATEC	VRŠATEC				
KIMMERIDGIAN							
OXFORDIAN		VRŠATEC					
CALLOVIAN			KRASIN	KYJOV			KRASIN MESTEČKO BABINÁ
BATHONIAN				KYJOV		KYJOV DRIEŇOVÁ	
BAJOCIAN		VRŠATEC		VRŠATEC	BABINÁ	VRŠATEC KRIVOKLÁT VRŠATEC	BOLEŠOV MESTEČKO

Krasin (Text-Fig. 1) the breccias are of Middle Jurassic age and consist of fragments and blocks of various crinoidal limestones up to 1 m. At the locality Kyjov (Text-Fig. 1) the breccias originated in the Upper Jurassic. They are formed by fragments of various limestones of Dogger and Malm. Meter-sized caverns filled with laminated limestone with a pelagic microfauna of Kimmeridgian and Tithonian age give further evidence of the existence of submarine fault scarps. The latest activity of synsedimentary faulting is documented by the youngest neptunic dykes filled with white Berriasian limestones containing *Calpionella alpina* LORENZ.

2.3. Neptunic Dykes

Neptunic dykes and sills are also typical features of the Czorsztyn submarine swell (Fig. 1, Pl. I-A). Part of them could be dated by microfauna (e.g. Tintinnids) and, occasionally, also by Oxfordian brachiopods. A large stratigraphical range of synsedimentary faults, visualized as neptunic dykes, is delineated in Tab. 1. Repeated opening of fractures was proved at Vršatec by double filling: Callovian–Oxfordian + Tithonian, Callovian–Oxfordian + Albian (MIŠÍK, 1979). The filling of neptunic dykes and voids is mostly of red colour. It contains a special association of foraminifers such as small *Trocholina, Turrispirillina, Patellina,* abundant "microforaminifers" (chitinous membranes of juvenile foraminifers, so-called Scytinascias). Nesting organisms and coelobites such as special ornamented ostracods (Pl. I-B, a surprisingly constant microfacies), brachiopods and juvenile ammonites are frequent.

2.4. Hiatuses

Stratigraphic gaps are another characteristic feature of the Czorsztyn ridge. They are mostly of submarine origin. BIRKENMAJER (1958, 1973) considered them all as submarine ones. But, in spite of the lack of direct evidences like weathering crusts, it is necessary to presume an emersion before Albian. In the whole area of the Czorsztyn unit the sediments of the Barremian–Lowermost Albian are absent. The Albian overlays various members, such as Berriasian, Upper Tithonian (Pl. 1-C), furthermore, the Albian sediments penetrated as neptunic dykes and pockets in the Callovian–Oxfordian, Bajocian and Bathonian layers. Such a perfect submarine erosion of all Barremian and Aptian sediments seems improbable. The Albian transgression began with red marls containing pelagic foraminifers. The cause of it could be a sudden collapse of the seashore or an ingression after the break of a neck. Another emersion could be supposed in the area of Oxfordian bioherms at Vršatec. They contain voids enlarged by dissolution (Pl. 1-D) and filled by crystal silt considered as evidence of meteoric diagenesis. A small calcrete fragment was found in a neptunic dyke near Bolešov. The dissolution of aragonitic bivalve shells (Pl. 2-A) was previously considered as meteoric diagenesis. According to SANDBERG (1985) and PALMER et al. (1988) aragonite was dissolved also in shallow-water marine environments, during the Jurassic.

2.5. Hardgrounds

Hardgrounds of several types (Fig. 1) accompanying short submarine hiatuses may be caused by changes of the current regime. The ferro-manganese crust, a few centimeters thick, from the locality Babina contained 14,3 % MnO_2 and 15,3 % Fe_2O_3. The black manganese crust from Mikusovce consists of 50,5 % MnO_2 and 1,6 % Fe_2O_3. Both sites belong together with the locality Bolešovská dolina to the Callovian–Oxfordian deposits associated with planctonic "Protoglobigerina" (Globuligerina) microfacies. The black hardground crust from Vršatec with *Parastomiosphaera malmica* (BORZA) indicating Lower Tithonian age includes mineralized columnar stromatolites (Pl. 2-B) problably of bacterial origin, sessile foraminifers *Bullopora tuberculata* SOLLAS (Pl. 2-C), serpulids (Pl. 2-D) etc. Brown and red ferric crusts are of Bathonian and Albian age. Silica or silcrete crusts (Pl. 2-E, F) are a recently discovered type only some mm thick. They were found at two distant localities. One of them, of Upper Berriasian age was proved by the occurrence of *Calpionellopsis oblonga* (CADISH). These crusts were formed probably during an emersion. The immediately underlying sediment with a thickness of 3–4 mm was also silicified. Phosphatic hardgrounds, frequently observed in the Albian of High Tatric, Manín and Haligovce units, are unknown within the Czorsztyn unit.

3. Differences of Coeval Carbonate Platform Sediments

One of the most peculiar features of the Czorsztyn succession is the total lack of benthic algae. Dasycladacean, e.g. *Clypeina jurassica* FAVRE, very frequent in the carbonate platforms during the Malm, have not been observed. It seems evident that the bottom of the Czorsztyn elevation was situated below the photic zone. Algae are also missing in the extremely shallow-water bioherm facies at Vršatec. Quite surprising is the total absence of foraminifers like *"Conicospirillina" basiliensis* MOHLER, *Protopeneroplis striata* WEYNSCHENK, *Nautiloculina oolitica* MOHLER as well as ooids regularly present in all carbonate platforms like Stramberk limestone (ELIÁŠ & ELIÁŠOVÁ, 1984), in the Upper Malm of Silica nappe (MIŠÍK & SÝKORA, 1980), in the Plassen limestone of the Eastern Alps (FENNINGER & HOLZER, 1972), in the Barmstein limestone-calciturbidites derived from the carbonate platform found in the Čachtické Karpaty Mts. (MIŠÍK & SÝKORA, 1982) and in pebbles from the Pieniny exotic ridge (MIŠÍK & SÝKORA, 1981).

4. Conclusions

The facts mentioned above show that the Czorsztyn elevation cannot be designated as a simple off-shore bank. It is also not possible to use the term aseismic ridge (BIRKENMAJER, 1985, p. 92). The Czorsztyn elevation exhibits remarkable evidences for the seismic activity by the occurrence of neptunic dykes and submarine fault scarps. Thus the term pelagic swell seems to be most suitable. Besides, the similarity of the Czorsztyn pelagic swell with Betic swells, the resemblance to the Dorsal Calcaire of the Tellian Atlas and swells of the Appenins may be stressed.

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Plate 1

Fig. A: **Double filling of a neptunian dyke (in the upper part wackestone, in the lower part packstone with "filaments") cut by a transversal microdyke rimmed with calcite crystal (initial cement) and filled by micrite.**
Callovian-Oxfordian.
Vršatec-8. ×26.

Fig. B: **Ostracods *Pokornyopsis* sp. in the red biomicrite (void filling).**
Callovian-Oxfordian.
Kyjov-XVI. ×26.

Fig. C: **Bivalve boring in the grey Upper Tithonian biomicrite with *Crassicollaria* sp. filled by red Albian biomicrite with *Ticinella roberti* (Gandolfi).**
Lednica. ×43.

Fig. D: **Void enlarged by dissolution in the red crinoidal biomicrite filled by irregularly laminated micrite.**
Callovian.
Vršatec-48, ×4,5.

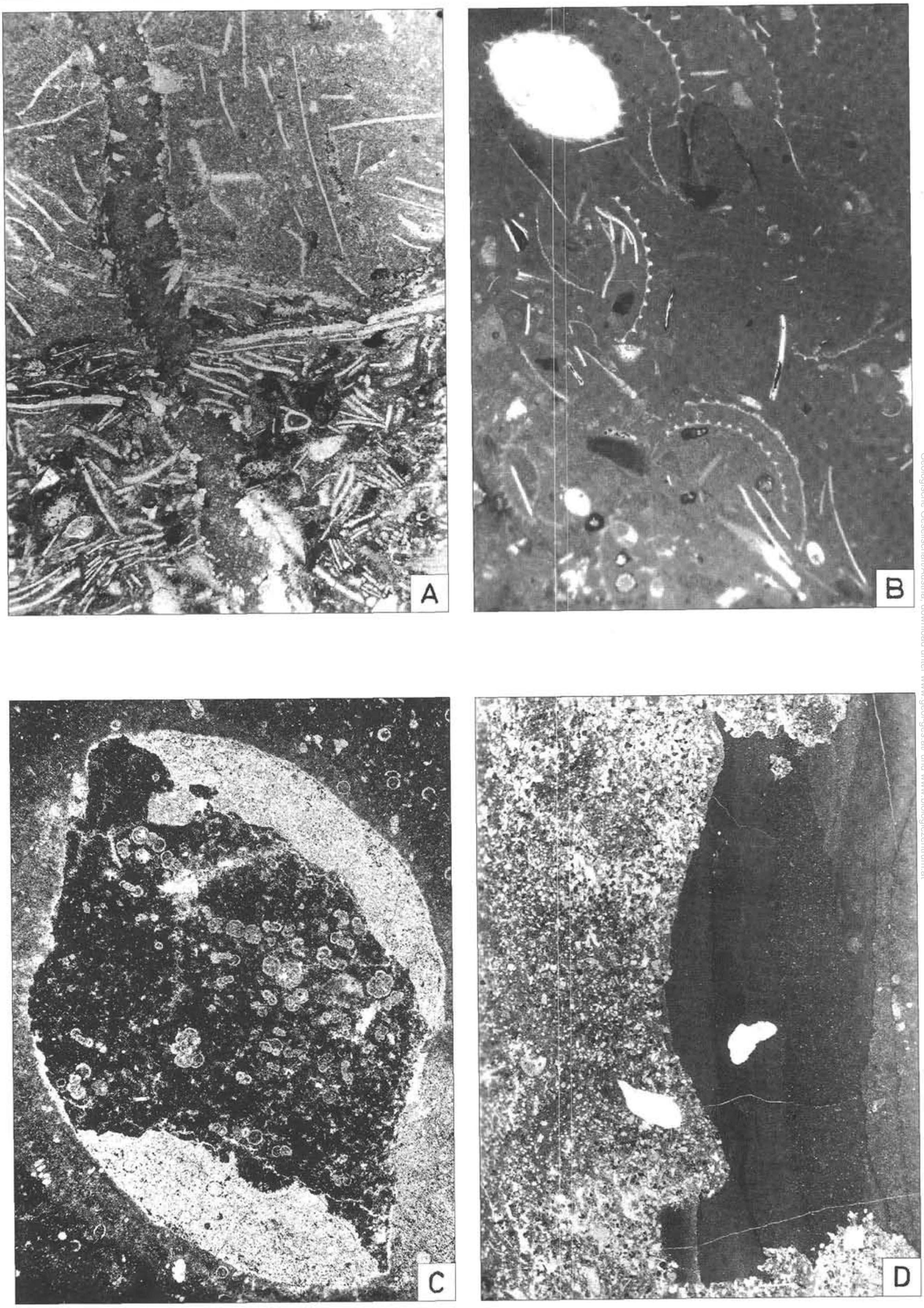

A
B
C
D

Plate 2

Fig. A: **Fragments of dissolved aragonitic bivalve shells visible as "ghosts" due to their Fe-Mn coatings.**
Lower Tithonian filling of a pocket in the submarine scarp within Oxfordian limestone.
Kyjov-II. ×30.

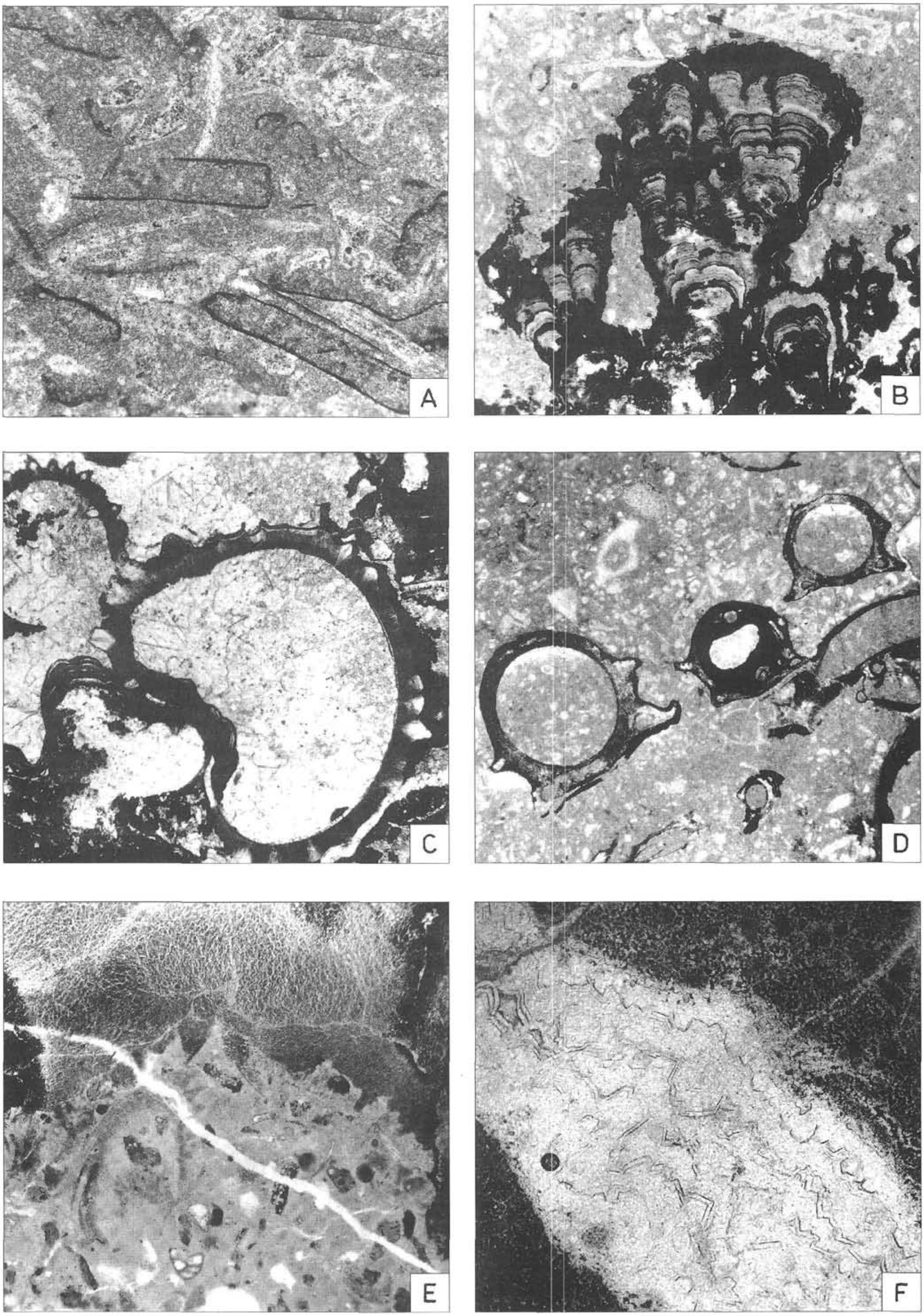
Fig. B: **Mn-impregnated stromatolites at the hardground crust.**
Lower Tithonian with *Parastomiosphaera malmica* (Borza).
Vrsatec-47. ×95.

Fig. C: **Sessile foraminifer *Bullopora tuberculata* (Sollas) fixed at the same hardground as B.**
×95.

Fig. D: **Serpulids impregnated by Mn-oxides.**
The same as B. ×30.

Fig. E: **Silcret with a dense network of thin syngenetic cracks on the Lower Neocomian limestone (partly silicified under the silcret *hardground*).**
Kamenica-12. ×30.

Fig. F: **Silcret with a void filled by quartz aggregate (Lower Neocomian?).**
Lubina, U Vajíčkov. ×40.


A
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