CARBONIFEROUS OF CROATIA

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INTRODUCTION

Carboniferous deposits outcrop at several localities in different parts of Croatia (Medvednica Mt., Slavonian Mts., Banovina-Kordun region, Gorski Kotar region, Velebit Mt.), or have been found as pebbles in younger sediments (Gorski Kotar, Hrvatsko Zagorje) (Fig.1).

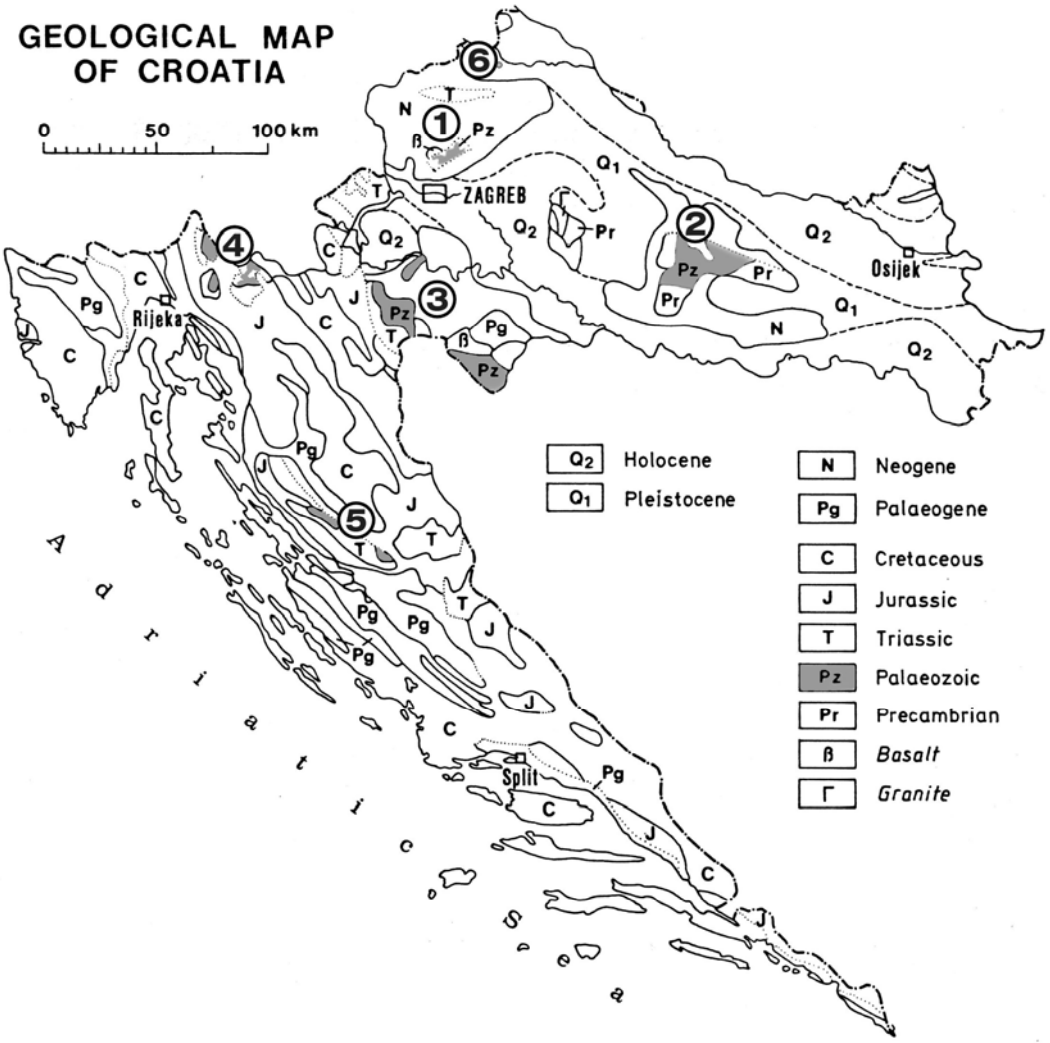

Fig. 1. Schematic geological map of Croatia, with gray coloured Palaeozoic outcrops:

1. Medvednica Mt.
2. Slavonian Mts.
3. Banovina-Kordun
4. Gorski Kotar
5. Velebit Mt.
6. Hrvatsko Zagorje.

MEDVEDNICA MT.

Thick sequence of different rocks, metamorphosed up to the greenschist facies, build up the ridge of the Medvednica Mt. Due to the relic structures observed within the paraschists, it has been presumed that the source rocks have been deposited in different marine environments, from the shore to the open basin (ŠIKIĆ, 1995). Black shales, recrystallized limestones and sandstones, contain scarce, poorly preserved fossils. Stratigraphic range begins with pelagic deposits of the the Lower Silurian (? Uppermost Ordovician) age (SREMAC & MIHAJLOVIĆ-PAVLOVIĆ, 1983).

Carboniferous conodonts have been determined from the limestone intercalations (ĐURĐANOVIĆ, 1973). Mississippian (Viséan cu II - *Anchoralis*-zone) contains the following taxa: *Gnathodus texanus ROUNDY, Hindeodella segaformis* BISCHOF, *Hindeodella* sp., *Neoprionodus* cf. *striatus REXROAD*, *? Polygnathus* sp., *Scaliognathus anchoralis BRANSON & MEHL*,*?Gnathodus* sp., *Siphonodella* sp. (Pl. 3, Figs. 1-4). Visean (cu III) with *Gnathodus* sp.ex gr. *bilineatus (ROUNDY)* and *Gnathodus* sp. is presumed.
Pennsylvanian rocks contain *Idiognathoides* cf. *corrugata HARRIS & HOLLINGSWORTH* and *Idiognathoides* sp (Pl. 3, Figs. 14-15).

During the Pennsylvanian, shallow marine conditions prevailed. Biostromes with stromatoporids (*Amphipora* sp.) and bryozoans (*Pseudobatostomella* sp. or *Dyscritella* sp.) occur in the southeastern part of the mountain (KOCHANSKY-DEVIDÉ, 1981). Rich fossil assemblage was found in some pebbles, including some ancient taxa (eg. *Palaeospiroplectammina* sp., *Endospiroplectammina venusta (VDOVENKO), Pseudolituotubella tenuissima VDOVENKO, Endothyra prisca RAUZER-ČERNOUSOVA)*, giving the possibility of even earlier uplift in this area (SREMAC, unpublished).

SLAVONIAN MOUNTAINS

Crystalline to low-grade metamorphic rocks from the Slavonian Mountains at least partly belong to the Carboniferous age (Fig. 2). Within the strongly tectonized low-metamorphic “Radlovac” - unit, interpreted as intertidal deposits (RAMOVŠ at al., 1990), Mississipppian (Westfalian) land flora occur. The following taxa were determined: *Asterophyllites equisetiformis (SCHLOTHEIM) BRONGNIART*, *Pecopteris* sp.,*Imparipteris (Neuropteris)* cf. *tenuifolia SCHLOTHEIM, Imparipteris (Neuropteris) attenuata L. & H.* and *Cordaites principalis GERMAR. Calamospora* and *Cordaites* were found in palaeopalinological samples (BRKIĆ, JAMIČIĆ & PANTIĆ, 1974), as well as widely ranged *Cyrtospora* (JERINIĆ et al., 1994).
Freshwater bivalve *Carbonicola* has also been found in these beds.

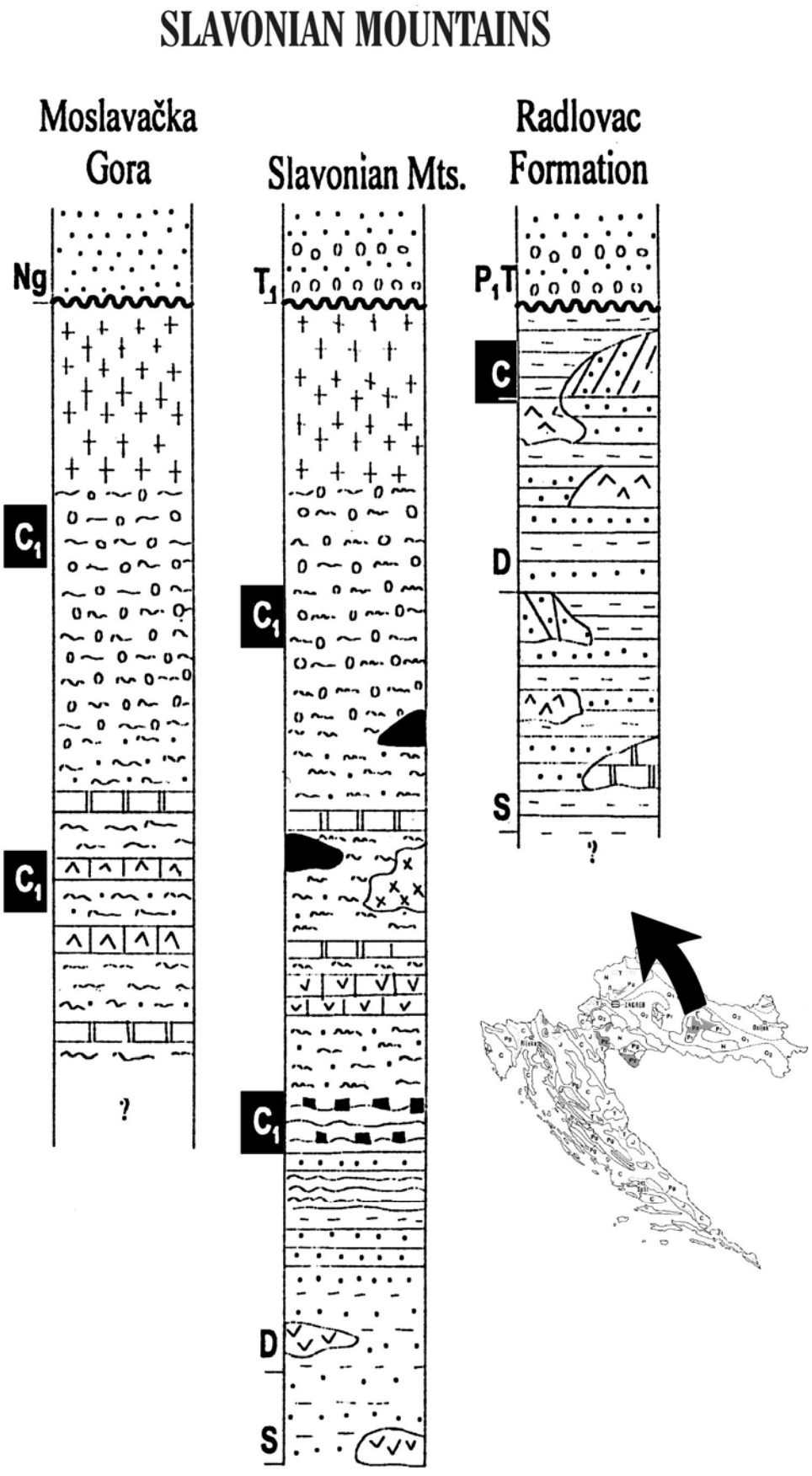

Fig.2. Schematic stratigraphic columns for Slavonian Mts. (after PAMIĆ & JURKOVIĆ).

BANOVINA-KORDUN REGION

Rather thick clastic sequence with fossiliferous carbonate intercalations occur at Trgovska gora Mt. in Banovina district (Fig.3).

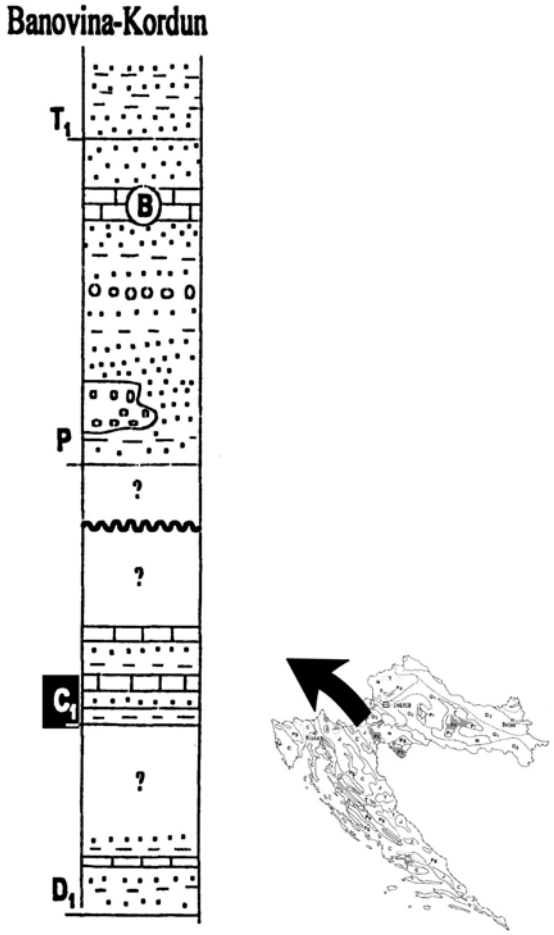

Fig. 3. Schematic stratigraphic column of the Banovina-Kordun region.

Conodonts of Devonian and Carboniferous age have been collected from dark-grey to black clayey limestones, also with recrystallized radiolarians and ostracods. The following Mississippian conodont taxa were determined by ĐURĐANOVIĆ, (1968, 1973): Viséan cu III, *Bilineatus* zone: *Gnathodus bilineatus (ROUNDY), G. commutatus commutatus (BRANSON & MEHL), G. commutatus nodosus BISCHOFF, Hindeodella germana HOLMES, Hindeodella* sp., *Magnilaterella* aff. *robusta (REXROAD & COLLINSON), Neoprionodus singularis (HASS), Ozarkodina roundyi (HASS), Rondya* sp. (Pl. 3, Figs. 5-14).

Fusulinids and calcareous algae from Trgovska gora Mt. were studied by MILANOVIĆ (1982). Microfossils *Tuberitina bulbacea GALLOWAY & HARLTON, Trinodella variolonga KULIK* and *Solenopora sp.* have been found in dark-grey, fine-grained, often mosaic-textured dolomite:

Mississippian corals *Lopholasma* , *Lophophylidium* , *Lophocarinophyllum* (Pl. 4, Fig. 6)*, Thysanophyllum, Geyerophyllum* and *Neokoninckophyllum* were determined by KOSTIĆ-PODGORSKA (1955):

GORSKI KOTAR

The oldest rocks in Gorski Kotar region belong to the Devonian-Early Carboniferous age. After the emersion a continuous marine sedimentation from the Mississippian (Viséan) to the Trogkofel stage in Permian has been documented by fossils (SREMAC & ALJINOVIĆ, 1997) (Fig.4). A continuous deposition to the Uppermost Permian was presumed by some authors.

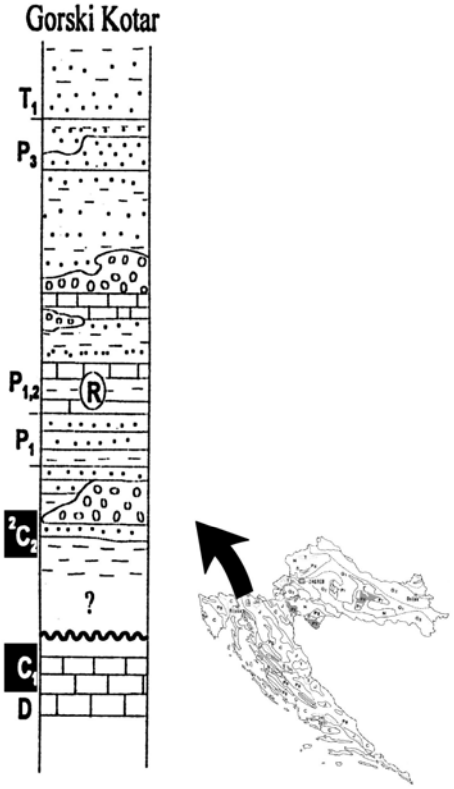

Fig.4. Schematic stratigraphic column from the Gorski Kotar region.

Viséan conodont fauna with the conodont alteration index 5, indicating the presence of the deep-water Viséan, seemingly at a subduction zone has been determined from this region. It has been collected from the upper part of the Roadian deep-water turbidites, as well as in the conglomerates of the overlying shallow-water pebbles of black deep-sea cherts (KOZUR, personal communication).

Dark-grey, hard, quartzite sandstone known as the "Fusulinid sandstone" (or *"Triticites"* sandstone) is the same type of the sediment which occurs in the Velebit Mt. (KOCHANSKY-DEVIDÉ, 1955). It is brown at the weathering surface, with numerous small cavities after the resorption of fusulinids. Parallel orientation of fusulinids or their moulds is typical for this rocks, indicating postmortal transport. Fusulinid taxa were determined by MILANOVIĆ (1982), including *Quasiendothyra, Permodiscus, Schubertella, Fusulinella*, *Pseudostaffella,Triticites* and *Paratriticites* (Pl. 2, Figs. 8-11).

Extremely fossiliferous limestone fragments occur within some postcarboniferous conglomerates (Pl. 2, Figs. 1-4). Several Viséan smaller foraminifers were determined (SREMAC & ALJINOVIĆ, 1997): *Archaediscus , Palaeotextularia* , *Palaeospiroplectammina* ,*Endospiroplectammina, Glomospiranella* and

Endothyra.

Moscovian pebbles contain *Tetrataxis, Girvanella,* and dasyclad algae *Gyroporella likana KOCHANSKY-DEVIDÉ and G. constricta KOCHANSKY-DEVIDÉ.*

Kasimovian is represented with schubertelids and triticites (SREMAC & ALJINOVIĆ, 1997).

Foraminifers predominate in Viséan and Kasimovian clasts, and calcareous algae are the most abundant in Moscovian pebbles, as well as in Gzhelian to Asselian clasts. Therefore, a variation of the sea-level can be presumed, with extremely shallow water conditions during the Moscovian and at the Carboniferous/Permian boundary.

VELEBIT MT.

The Upper Palaeozoic tectonic belt of Mt. Velebit and Lika represents the best known and the most completely developed Palaeozoic area in Croatia, showing more or less continuous sedimentation from the Pennsylvanian (Moscovian) to the end of the Permian (Fig.5). Partial anology with Carnic Alps can be observed.

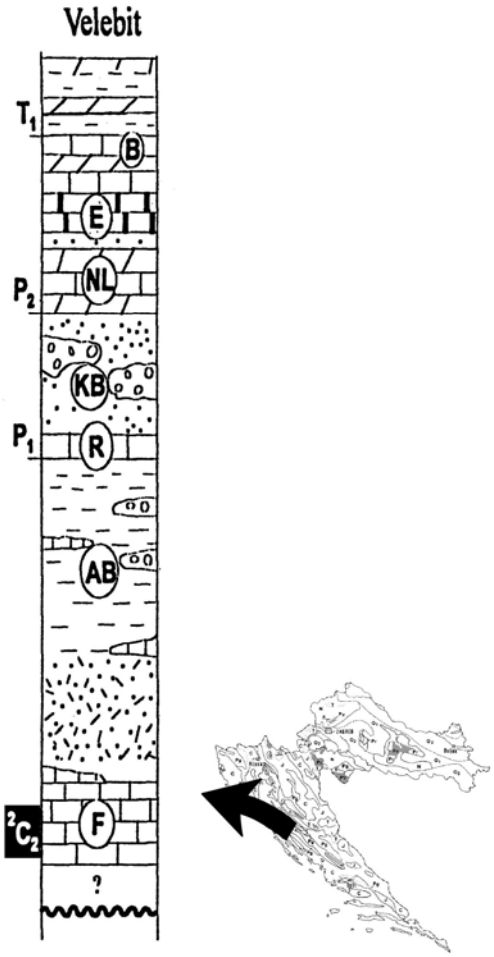

Fig.4. Schematic stratigraphic column from the Velebit Mt. F= Fusulinid Beds, AB= Auernig Beds.

Carboniferous deposits are represented with dark grey, massive limestones, sometimes laterally substituted with dolomites, and/or finely bedded argilaceous slates and graywackes. Their age has been determined on the basis of fusulinids and calcareous algae (Pl. 1, Figs. 1-10; Pl. 2, Figs. 5-7). The lowermost part of the column, determined as Moscovien-Kashirien , contains numerous fossils (KOCHANSKY-DEVIDE, 1955,1970), including *Pseudoendothyra, Schubertella, Fusulinella, Eofusulina, Aljutovella, Tuberitina, Tetrataxis, Globivalvulina, Glomospira, Palaeotextularia, Spiroplectammina, Ammodiscus, Plectogyra, Girvanella, Eugonophyllum, Anchicodium, Anthracoporella, Gyroporella* sp. div., *Connexia* and *Herakella.*
The fossils from the median horizon are: *Pseudoendothyra, Ozawainella*, *Pseudostaffella, Beedina, Hemifusulina, Schubertella, Dvinella* and *Litostroma.* The Uppermost Moscovian sediments outcrop sporadically, and are also reported from the bore-hole. They contain the following microfossils: *Eostaffella, Pseudoendothyra* sp.div., *Schubertella, Fusulinella, Tuberitina* sp.div., *Tetrataxis, Globivalvulina, Cribrostomum, Palaeotextularia, Endothyra, Bradyina, Glyphostomella, Anthracoporella, Beresella, Dvinella, Eugonophyllum* , *Anchicodium*.
Besides the microfossils, gastropods, trilobites, and numerous brachiopods occur within these sediments.
Lower Kasimovian sediments contain the first fusulinid taxa with keriothecal walls, such as *Protriticites.* Some fossils extend from the Moscovian, while some others appear for the first time (*Quasifusulinoides, Velebitella, Tubiphytes*).

Upper Kasimovian sediments cover a much larger area (SIMIĆ, 1935; KOCHANSKY-DEVIDE, 1955; BALAŽ, 1981). Gzhelian beds from this area are often compared with the Auernig beds of the Carnic Alps. Different types of sediments, with numerous remnants of foraminifera, brachiopods, bivalves and trilobites can be distinguished:

1. Argilaceous slates with brachiopods, crinoids, trilobites, bivalves and gastropods (Pl. 4, Figs. 1-4). Among the gastropods, the most abundant are prosobranchs from the families: *Naticopsidae, Bellerophontidae, Subulitidae, Murchisoniidae, Zygopleuridae* and *Pleurotomaridae*.
   Local findings of the land flora (Pl. 4, Figs. 10-11) indicate the vicinity of the shoreline (NĚMEJC, 1936).
2. Fusulinid sandstones with fusulinids, crinoids and small brachiopods.
3. Limestones interbedded with argile-schists, with predominance of *Anthracoporella spectabilis* (Pl. 1, Fig. 3), with crinoids, brachiopods (Pl. 4, Fig. 5), bivalves, corals and foraminifers.
4. Quartz-conglomerates.

Facial differences indicate rhythmic oscillations of the sea level. Marine sediments predominate over sporadic interbeds of continental origin. The same type of sedimentation prolongs into the Permian (Fig. 5).
List of the determined Pennsylvanian macrofossils from this area is rather large (SIMIĆ, 1935; SALOPEK, 1948; RUKAVINA, 1973; BALAŽ, 1981) and includes numerous bivalves, gastropods, brachiopods, echinoderms and land flora.

HRVATSKO ZAGORJE

Breccias with Carboniferous greyish-brown limestone fragments have been found west from the city of Varaždin in Hrvatsko Zagorje region. Limestone fragments have been determined as foraminiferal-algal biomicrites, built up of the accumulated or partly transported fossils. Foraminifers and algae predominate, but fragments of macrofossils (crinoids, bryozoans, corals and brachiopods) are also present. Fossils are cemented with microcrystalline calcite. Fossils and sediment were later subject to the diagenetic processes and recrystallized. Over 30 species were determined by MILANOVIĆ (1982), including the genera *Ammovertella, Spiroplectammina, Tuberitina, Deckerella, Climacammina, Tetrataxis, Plectogyra, Bradyina, Lasiodiscus, Eolasiodiscus, Ozawainella, Pseudostaffella, Schubertella, Fusulinella, Pseudoendothyra, Eugonophyllum, Anthracoporella, Beresella, Dvinella, Trinodella, Pseudoepimastopora, Gyroporella, Connexia, Herakella* and *Solenopora.*

CONCLUSION

During the long period of the Early Palaeozoic, and the Mississippian, the territory of Croatia was a part of the deep ocean. The dominant uplift took place at the beginning of Pennsylvanian, or somewhat earlier in restricted areas. Pennsylvanian rocks were deposited in shelf conditions, and contain calcareous algae, benthic foraminifers, corals, mollusks, bryozoans, brachiopods and crinoids. Continental deposits with remnants of land flora appear sporadically. Contact with younger rocks is often not clear, but a continuous transition into the shallow water Permian, can be observed at some localities in the Velebit Mt. (SREMAC, 2005).

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PLATES

PLATE I

1 – *Eugonophyllum magnum* (ENDO), 15X, Velebit Mt.

2 – *Dvinella crassitheca* KULIK, 40 X, Velebit Mt.

3 – *Anthracoporella spectabilis* PIA, 15 X, Velebit Mt.

4 – *Gyroporella prisca* KOCHANSKY-DEVIDÉ, holotype, 15 X, Velebit Mt.

5 – *Gyroporella likana* KOCHANSKY-DEVIDÉ, 15 X, Velebit Mt.

6 – *Gyroporella constriata* KOCHANSKY-DEVIDÉ, holotype, 15 X, Velebit Mt.

7 – *Gyroporella intraseptata* KOCHANSKY-DEVIDÉ, 15 X, Velebit Mt.

8 – *Litostroma europaea* KOCHANSKY-DEVIDÉ, holotype, 40 X, Velebit Mt.

9 – *Herakella paradoxa* KOCHANSKY-DEVIDÉ, 15 X, Velebit Mt.

10 – *Connexia fragilis* KOCHANSKY-DEVIDÉ, holotype, 15 X, Velebit Mt.

1-10 Pennsylvanian (Moscovian)

From: Kochansky & Herak (1960)
Kochansky-Devidé (1970)

PLATE I

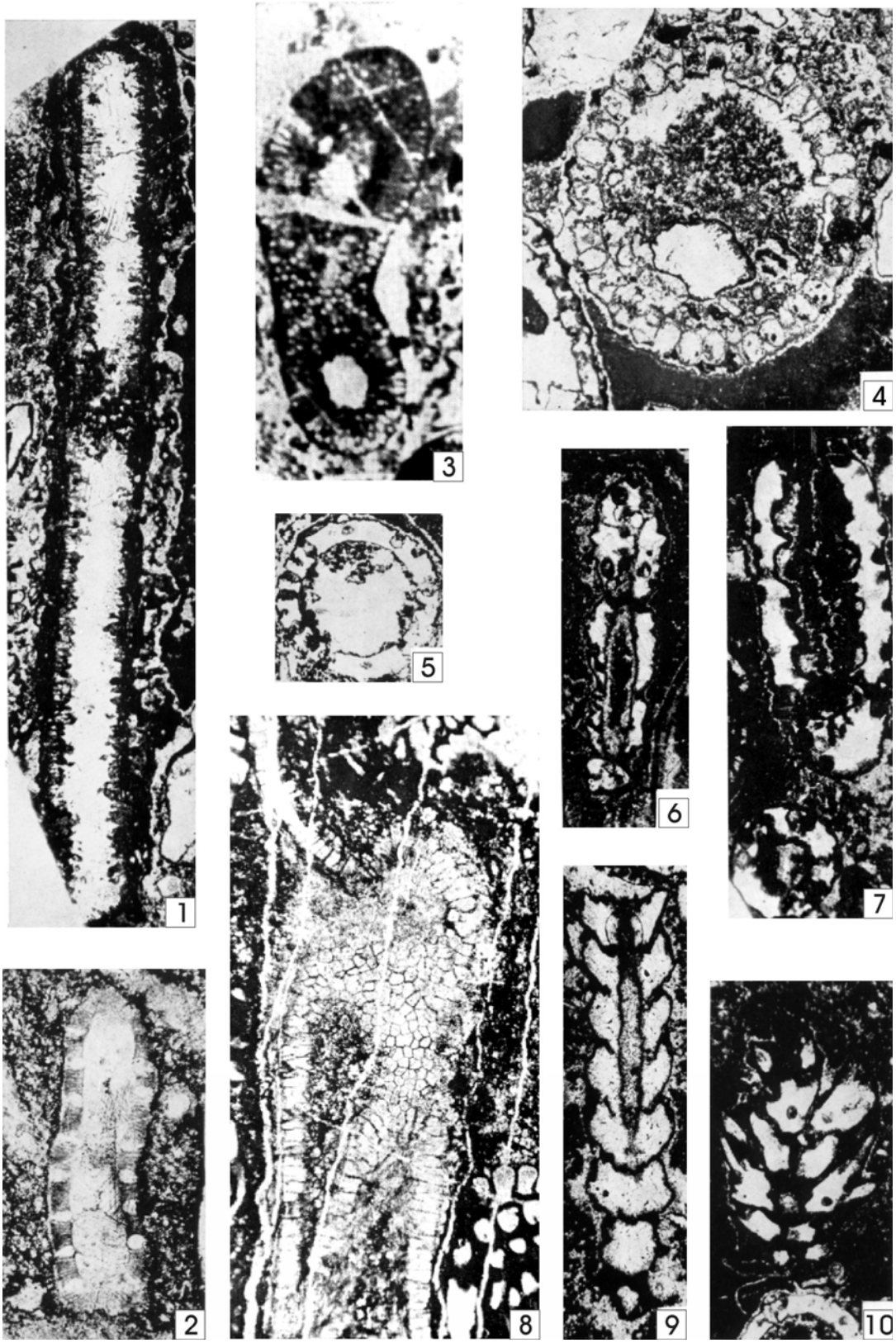


PLATE II

1 – *Tolypammina glomospiroides* BOGUS & JUFEREV, 50 X, Gorski Kotar (from pebbles)

2 – *Palaeospiroplectammina* sp., 50 X, Gorski Kotar (from pebbles)

3 – *Archaediscus reditus* CONIL & LYS, 50 X, Gorski Kotar (from pebbles)

4 – *Planoendothyra spirilliniformis* BRAZNIKOVA & POTIEVSKAYA, 40 X, Gorski Kotar (from pebbles)

5 – *Pseudostaffella sphaeroidea* MÖLLER, 50 X, Velebit Mt.

6 – *Boultonia willsi* LEE, 75 X, Velebit Mt.

7 – *Ozawainella angulata* COLANI, 50 X, Velebit Mt.

8 – *Paratriticites croaticus* MILANOVIĆ, 50 X, Gorski Kotar

9 – *Triticites kochanskae* MILANOVIĆ, 60 X, Gorski Kotar

10 – *Triticites* cf. *salopeki* (KOCHANSKY-DEVIDÉ), 50 X, Gorski Kotar

11 – *Fusulinella heraki* MILANOVIĆ, 70 X, Gorski Kotar

1-11 Pennsylvanian (Kasimovian)

1-4 From: Sremac & Aljinović (1997)
5-7 From: Kochansky-Devidé (1955)
8-11 From Milanović (1981)

PLATE II

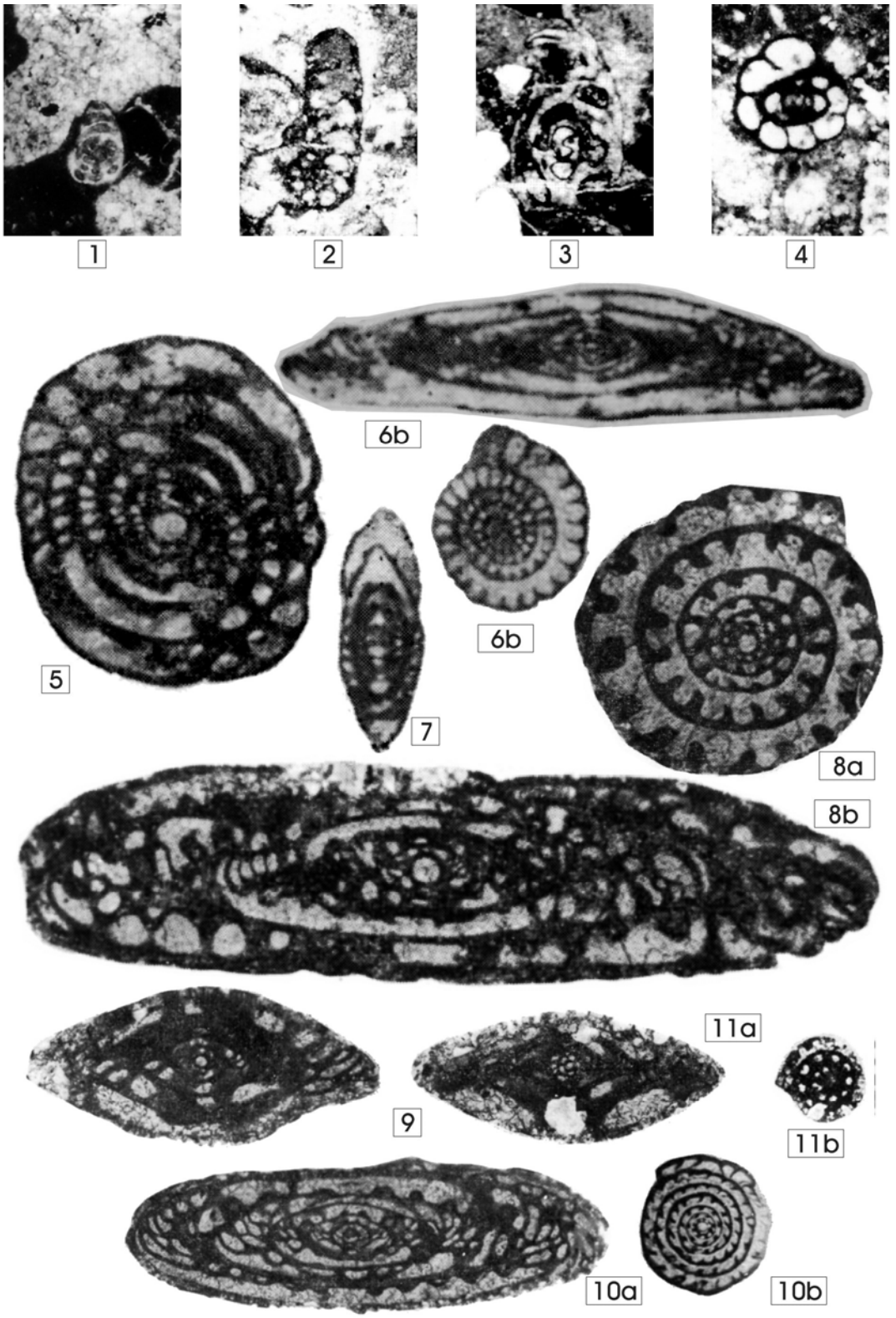


PLATE III

1 a, b; 2 – *Gnathodus texanus* ROUNDY (mladi primjerci), 52 X, Medvednica Mt.

3 a, b – *Hindeodella segaformis* BISCHOFF, 52 X, Medvednica Mt.

4 – *Neoprioniodus* cf. *striatus* REXROAD, 52 X, Medvednica Mt.

5 a, b; 6; 7 – *Gnathodus bilineatus* (ROUNDY), 52X, Banovina

8 a, b; 9 – *Gnathodus commutatus commutatus* (BRANSON & MEHL), 52 X, Banovina

10 a, b, c – *Gnathodus commutatus nodosus* BISCHOFF, 52 X, Banovina

11; 12 – *Neoprioniodus singularis* (HASS), 52 X, Banovina

13 – *Hindeodella germana* HOLMES, 52 X, Banovina

14 – *Ozarkodina* sp., 52 X, Banovina

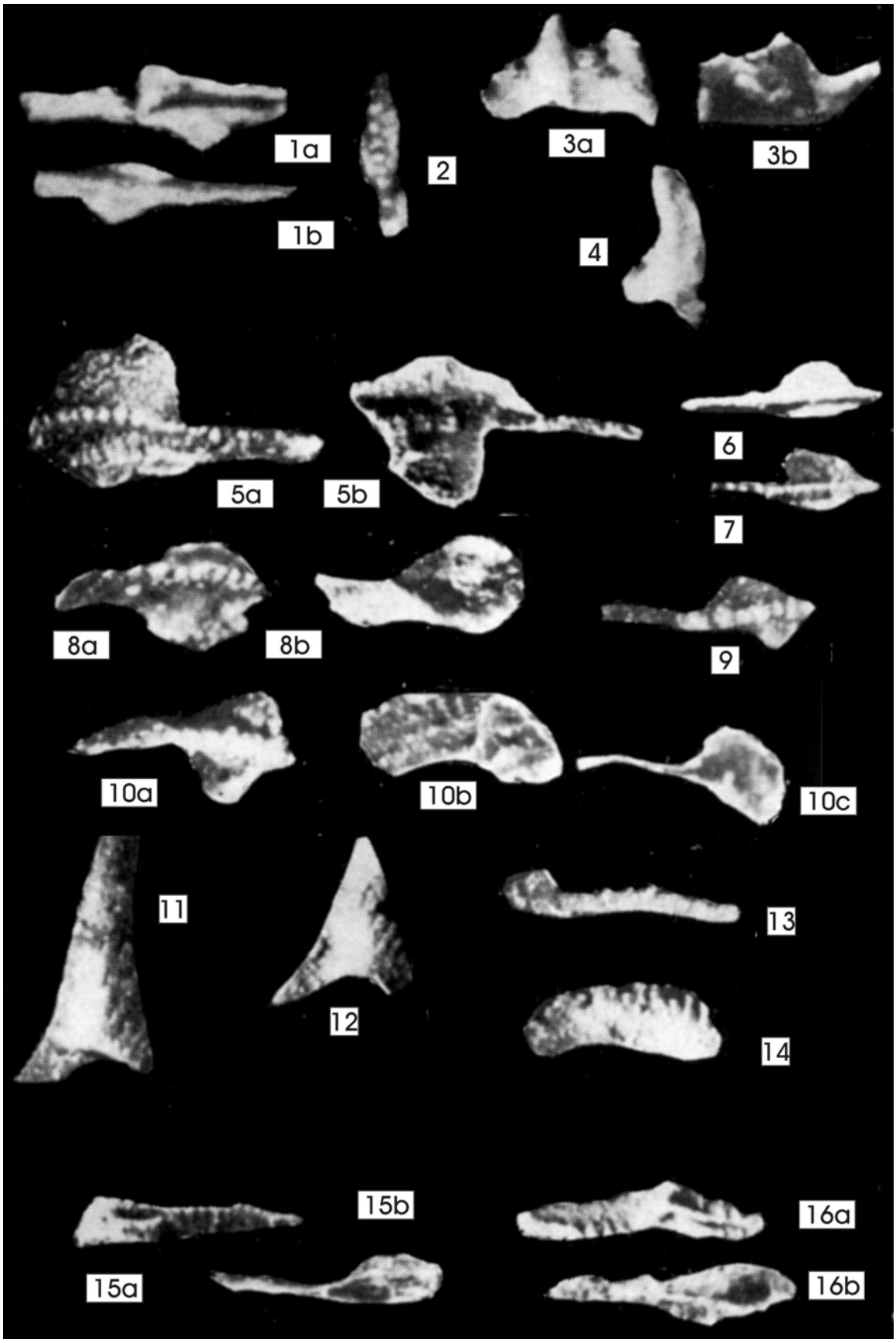
15 a, b – *Idiognathoides corrugata* (HARRIS & HOLLINGSWORTH), 52 X, Medvednica Mt.

16 a, b – *Idiognathoides* cf. *corrugata* (HARRIS & HOLLINGSWORTH), 52 X, Medvednica Mt.

1-14 Mississippian (Viséan)
15-16 Pennsylvanian

From: Đurđanović (1973)

PLATE III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16b

PLATE IV

1 – *Bellerophon khairliensis* REED, 1 X, Velebit Mt.

2 – *Naticopsis (Jedria) meeki* (KNIGHT), 2 X, Velebit Mt.

3 – *Zygopleura rugosa* MEEK & WORTHEN, 4 X, Velebit Mt.

4 – *Aclisina striatula* KONINCK, 4 X, Velebit Mt.

5 – Productoid brachiopods (internal moulds), 0,5 X, Velebit Mt.

6 – *Lophocarinophyllum acanthiseptum* GRABAU, 2 X, Velebit Mt.

7 – *Pinna triquetra* GEMMELARO, 1 X, Velebit Mt.

8 – *Aviculopecten (Acanthopecten) carboniferous* STEVENS, 1 X, Velebit Mt.

9 – *Lima duplicostata* STUCKENBERG, 2 X, Velebit Mt.

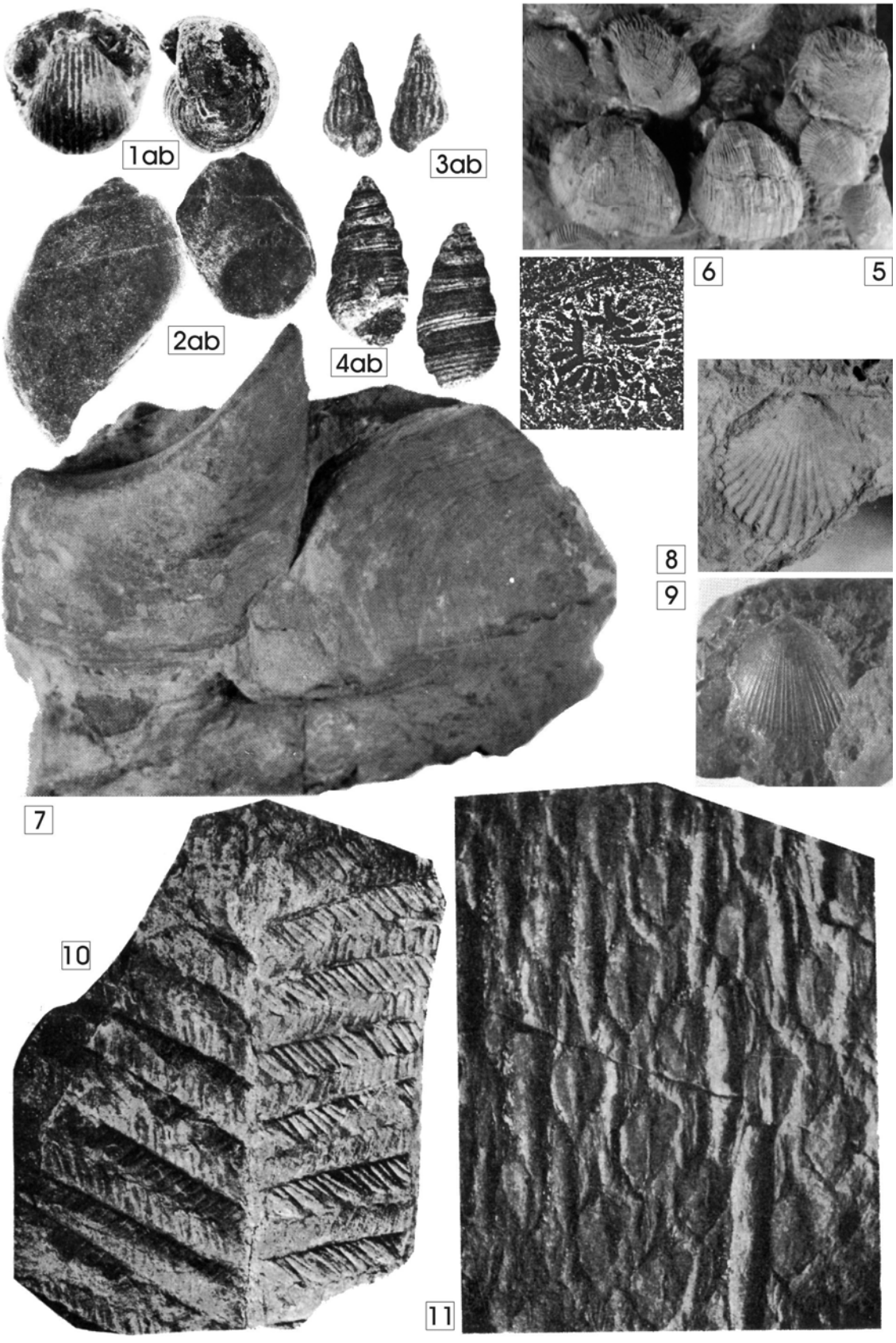
10 – *Acytheca polymorpha* BRONGNIART, 1 X, Velebit Mt.

11 – *Lepidodendron* sp., 1 X, Velebit Mt.

1-11 Pennsylvanian

1-4 From: Balaž (1981)
6 From: Kostić-Podgorska (1955)
7-9 From: Rukavina (1973)
10-11 From: Němejc (1936)

PLATE IV



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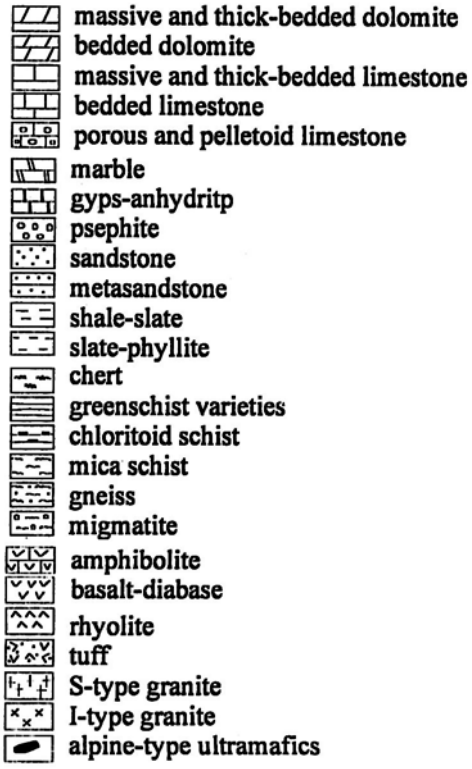
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bedded dolomite
massive and thick-bedded limestone
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marble
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shale-slate
slate-phyllite
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chloritoid schist
mica schist
gneiss
migmatite
amphibolite
basalt-diabase
rhyolite
tuff
S-type granite
I-type granite
alpine-type ultramafics

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