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Depositional setting of the Devonian/Carboniferous biohermal Bol'shaya Nadota Carbonate Complex, Subpolar Urals

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ABSTRACT:

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Multi-stage development of carbonate buildups has been recognised in the Bol'shaya Nadota Carbonate Complex, in the vicinity of the town of Inta (Subpolar Urals). The growth of typical stromatoporoid-coral bioherms, characteristic of the Middle-Late Devonian stage, was terminated by the appearance of the shallow water oolitic facies, most probably at the beginning of the Famennian. During the Viséan stage the carbonate platform was reconstructed, but algal-brachiopod-coral bioherms were characterized by relatively small dimensions and an interfingering with organodetrital-oolitic facies. Sporadically, the inter-mound facies is represented by goniatite-bivalve coquinas with two new goniatite species: *Goniatites olysya* sp.nov. and *Lusitanoceras kusinae* sp.nov.
The persistence of biohermal sedimentation in the Bol'shaya Nadota area is most probably caused by the specific position of the region on the boundary of two sedimentary-structural units: Lemva and Elets Zones, which corresponded to a basinal and a tectonically-active elevated part of a platform margin respectively.
The overall biotic composition of the Carboniferous bioherms from Bol'shaya Nadota, situated in the northern periphery of Laurussia, falls generally within the diversity spectrum of Lower Carboniferous mounds described from the southern margin of the continent.

Key words: Devonian, Carboniferous, Carbonate buildups, Subpolar Urals.

INTRODUCTION

In the evolutionary spectrum of carbonate buildups, the Late Viséan forms occupied a transitional position between the Tournaisian/Viséan Waulsortian mounds and the Pennsylvanian algal-foraminiferal frame reefs (*see* SOMERVILLE 2000). This period is characterized by the presence of relatively small biohermal structures with greatly diversified constructor and incruster-guilds, including both micro- and macrobial organisms. The majority of known examples has been described from the southern and south-western margins of Laurussia or the northern margins of Gondwana (BRIDGES & *al.* 1995, BOURQUE & *al.* 1995, SOMERVILLE & *al*. 1996, SOMERVILLE 2000), i.e. from the area located in the Late Viséan between the equator and southern tropics (*see* SCOTESE & MCKERROW 1990). Descriptions of buildups from the region located north of the equator have been limited to some examples from the Western and Northern Canadian Basins (DAVIES *& al*. 1989 and other papers *in* GELDSETZER *& al.* 1989); the Uralian edge of the EEP - East European Platform (see reviews *in* SOKOLOV 1986, ANTOSHKINA 1998, BELAEVA & *al.* 1998); and from south-eastern Poland (BELKA & *al*. 1996, SKOMPSKI 1996, SKOMPSKI & ?YWIECKI 1997). One of the most spectacular examples of such reefs has been described from the carbonate complex exposed on the banks of Bol'shaya Nadota River, near the town of Inta in the Subpolar Urals (Text-fig. 1; VOJNOVSKIJ-KRIGER 1962, ELISEEV 1973, ANTOSHKINA 1998, 1999). According to the palaeogeographical maps of SCOTESE & MCKERROW (1990), both regions of the EEP in the Late Viséan were located almost on the same meridian: Bol'shaya Nadota area on the northern tropic, and the Polish margin of EEP near the equator.

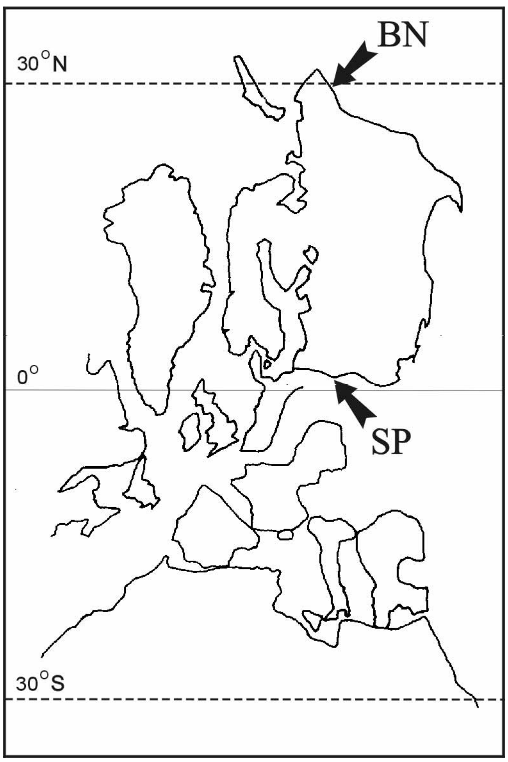

Fig. 1. Palaeogeographical position of Laurussia in the Late Viséan (after SCOTESE & MCKERROW 1990). Arrows indicate regions discussed in the paper: Bol'shaya Nadota section (BN) and Southern Poland (SP)

The main aim of the investigations undertaken in northern Urals was the comparison of reefal complexes from the central and peripheral parts of the area with carbonate sedimentation, as well as a comparison

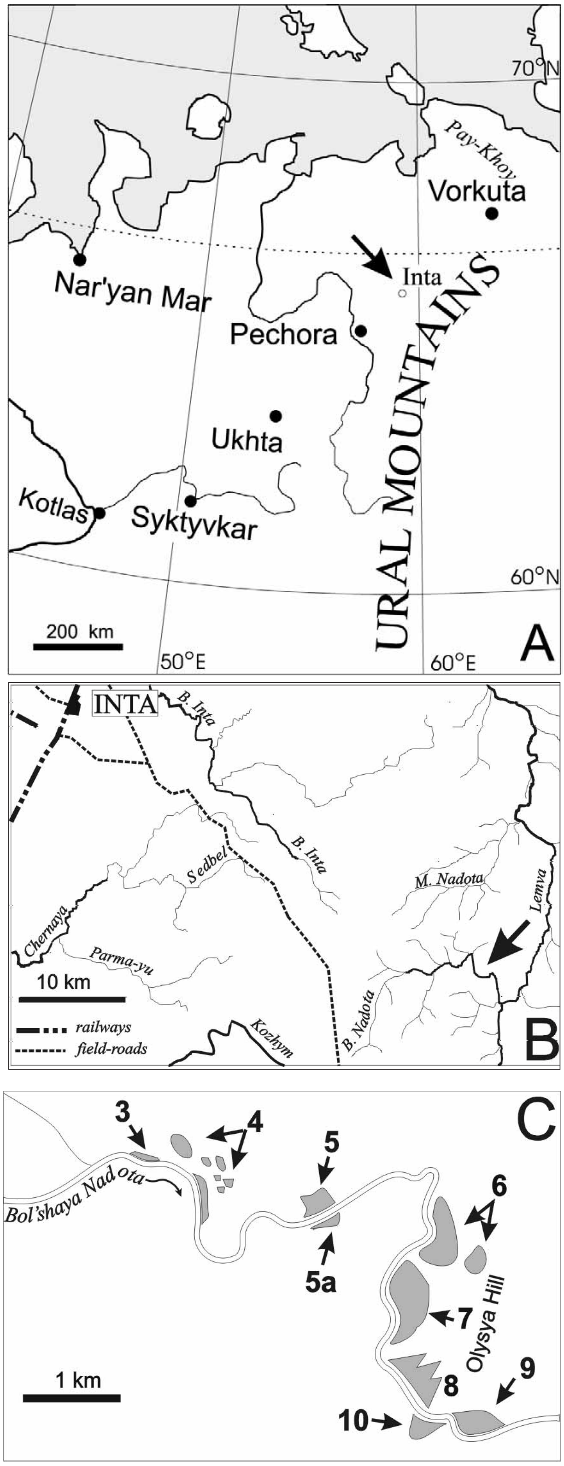

Fig. 2. Location of the Bol'shaya Nadota section (A, B) and outcrops described in text (C)

of reef development on the south-eastern shelves of Laurussia.

GENERAL SETTING OF THE BOL'SHAYA NADOTA CARBONATE COMPLEX (BNCC)

The investigated shallow-water carbonate complex, located on the foothills of the Subpolar Urals, is exposed about 50 km south-east of the town of Inta on the slopes of Olysya Hill, which is encircled by the small River Bol'shaya Nadota (Text-fig. 2). The tectonic contacts with the surrounding, mainly terrigenous units (Ordovician and Lower-Middle Devonian shales, limestones, and sandstones, Permian flysch) has made precise definition of the facies-relationships of the investigated succession to other parts of the Late Paleozoic sequence in this region rather difficult and is thus only approximate. However, several kilometres to the east, along the River Lemva, the stratigraphical equivalents of the BNCC are developed in deep, basinal facies. Consequently, it seems most probable that the BNCC represents a transitional area between two facies domains, described in the Russian literature as the Elets and Lemva Zones. Both of these elements differ not only in facies development but also in structural features and therefore they are known as facies-structural units, characterized by more than 500 km extent (from the springs of Pechora River to Vorkuta, parallel to the fold structures of the Urals) and greater than 100 km in width. In the Elets Zone, which directly bordered the EEP and was generally dominated by shallow-water shelf sedimentation, the transgressive-regressive cycles are distinctly marked and recorded as alternating terrigenous and marine formations. Moreover, within the zone three subunits have been distinguished; the middle one was usually characterized by deeper environments than the marginal subzones. During the Late Viséan the central subzone was dominated by grey, fine-grained calcarenites with flints and cherts, while in more landward located areas the deposition of well-oxygenated limestones with a rich benthic fauna (corals, brachiopods, crinoids, algae, foraminifers) was typical. In this context the external subzone, represented by the BNCC and located on the edge of a broader platform, played the role of a barrier, separating the carbonate shelf from the basin of the Lemva Zone.

The most unusual aspect of this rather simple scheme, proposed by ELISEEV (1973, 1978), is the scarcity of outcrops with biohermal deposits that are typical of the BNCC. Most probably some of them have been covered by Variscan overthrust units; this interpretation is supported by the presence of reefal clasts in out crops of the basinal Lemva succession along the River Lek-Elets (ELISEEV 1978, p. 84).

ELISEEV (1973), and later ANTOSHKINA (1998) interpreted the investigated complex as a complicated reefal system, with reef core and reefal talus on its flanks. Light grey fine-grained limestones (typical of Localities 6-9), are characterized by lack of bedding, numerous laminations and algal incrustations. Small growth cavities were infilled by calcitic or dolomitic cements, which caused a distinctive spotted pattern of the limestone surface. The macrofauna (brachiopods, corals, crinoids, bivalves) is relatively numerous, but is concentrated in pockets, similar to the concentrations of the ooids and lithoclasts. The algal, stromatolitic covers were the most important factors stabilising the sediment. In several outcrops (isolated klippes) located west of the Olysya Hill (Localities 4 and 5) breccias and calcirudites dominate, and this fragment of the BNCC represents marginal reef talus. The foraminifers, goniatites and brachiopods found in the Olysya Hill allowed us to determine the Late Viséan age of the entire complex.

Investigations by two independent groups led in the summer season of 1999 by S. SKOMPSKI (*see* KOKOVIN 1999) and D.B. SOBOLEV (SOBOLEV & *al*. 2000) revealed the Devonian age of the southern part of the BNCC (exposed in the form of high klippes beside the river, Pl. 1, Figs 1-3), which consequently reduced the thickness of the remaining Carboniferous part of the complex. This conclusion clearly indicates that the structure of the BNCC is evidently more complicated than was hitherto known.

SCHEMATIC DESCRIPTION OF OUTCROPS

In this paper only brief descriptions of outcrops are presented. More detailed descriptions have been published by ELISEEV (1973), but his observations are not clearly localized (except for Localities 4 and 5). Although it is difficult to give detailed measurements illustrating the spatial relationships of particular layers (lack of bedding, tectonic contacts, isolated outcrops), the general northward dip of the beds is clear (*see* SOBOLEV & *al*. 2000). This tilting resulted in exposure of the oldest part of the complex in the southern part of the Olysya Hill. Consequently, the description starts from Locality 9 (in the south) and proceeds north in descending numerical order to Locality 4 (Text-fig. 2). This corresponds to the original notation of ELISEEV (1973). The relationships of the isolated beds exposed in Localities 4 and 5 are very approximate and based only on biostratigraphic data.

Locality 9

Devonian and Carboniferous complexes are exposed in the high river cliff (Text-fig. 3, Pl. 1, Fig. 1). Their discordant contact (between units 3 and 5) is poorly visible and is inferred from the observations in Localities 9 and 8 (see discussion of the problem in the next section).

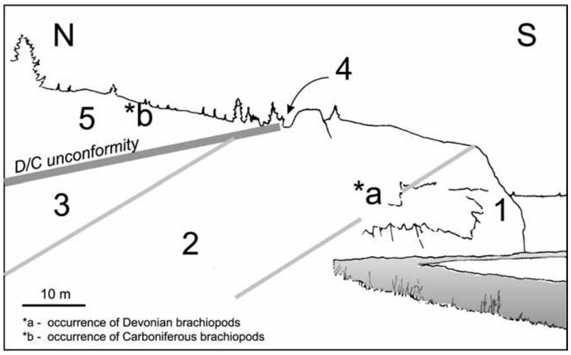

Fig. 3. Schematic location of the main lithological units at Locality 9 (morphology based on Pl. 1, Fig. 1)

*Devonian units (*1 *to* 3*)*

1 – Stromatoporoid-amphiporoid (?) biolithite with numerous corals and cement-filled cavities; partial dolomitization caused spotted grey-yellow pattern of weathered surfaces.

2 – Crinoidal-organodetrital calcarenites with amphiporoid fragments and small intraclasts; partly dolomitized. In some parts, concentrations of poorly preserved brachiopods have been found: *Gypidula* sp., *Hypothyridina* sp. A, *Hypothyridina* sp. B, *Pugnax*? sp., *Desquamatia (Desquamatia) alticoliformis* RZONSNITSKAYA, *Radiatrypa magnitica* (NALIVKIN), *Costatrypa*? *posturalica* (MARKOVSKII), *Cyrtospirifer* sp., *Theodossia*? sp., *Pyramidalia*? sp. The appearance of atrypids *Desquamatia (Desquamatia) alticoliformis*, *Radiatrypa magnitica*, *Costatrypa* ? *posturalica* establishes a Late Frasnian age for the unit *(determination: Dr E. SOKIRAN)*.

3 – Oolitic grainstones with rare, scattered intraclasts; tectonic deformation of the primary ooid form is clearly visible (Pl. 4, Figs 1, 3-4). In a very small sample (less than 200 g) two conodonts have been found: *Polygnathus* sp. and *Palmatolepis minuta minuta* BRANSON & MEHL *(determination: Prof. M. SZULCZEWSKI)*, indicative of the Early-Middle Famennian (late *triangularis* – late *trachytera* Zones)

*Carboniferous units (*4-5*)*

4 – Fine-grained breccia with oolitic and organodetrital clasts (Pl. 6, Fig. 5); the ooids in clasts show the primary spherical form.

5 – Crinoidal-brachiopod-coral calcarenites with rare bryozoans, numerous foraminifers (Appendix, sample BN9/5), abundant brachiopods: *Schuchertella opipara* KALASHNIKOV, *S.* cf. *globosa* TALMATCHOV, *Camarotoechia* cf. *tetraplicata* VOLGIN, *Goniophoria monstrosa* (JANISCHEVSKY), *G. carinata* JANISCHEVSKY, *Striatifera* cf. *angusta* (JANISCHEVSKY), *Schizophoria mesoloba* JANISCHEVSKY, *S.* cf. *infracarbonica* JANISCHEVSKY, *Stenoscisma* cf. *rhomboidea* (PHILLIPS), *S.* cf. *verneuiliana* (GRÜNEWALDT), *Antiquatonia insculpta* (MUIR-WOOD), *Actinoconchus* cf. *transversum* ABRAMOV & GRIGOREVA, *Echinoconchus* cf. *punctatus* (MARTIN); and bivalves: *Myalina* cf. *lamellosa* de KONINCK, *Conocardium inflatum* MCCOY. The micro- and macrofauna indicate a Late Viséan-(?)Early Serpukhovian age.

Westward of this locality, on the slopes of the Olysya Hill, slightly below the tree-line, a few isolated rocks are exposed, which are composed of massive, light grey crinoidal calcarenites or peloidal wackestones with typical clotted structures (Pl. 3, Figs 3-4).

Locality 8

A series of several klippes more than 10 m high (Pl. 1, Figs 2-3) is composed of massive calcilutites, with poorly-preserved stromatoporoids and tabulates (*Thamnopora* sp., *Natalophyllum* sp., Pl. 3, Fig. 6; Pl. 9, Fig. 3). In some parts, the limestones are indistinctly bedded (angle of dip about 30^{o}N). The microfacies of the limestones (calcispherid wackestones with rare amphiporoids and renalcids, partially dolomitized, sometimes laminated) corresponds to SMF6 (D11) and SMF19 (D13) according to WILSON's (1975) scheme of Standard Microfacies. The are also relatively numerous conodonts, described by SOBOLEV & *al.* (2000): *Polygnathus varcus, Klapperina ovalis, Mesotaxis falsiovalis, Polygnathus decorosus, P. dubius, P. ljaschenkoi, Ancyrodella* aff. *alata, Icriodus symmetricus* indicate the *varcus* (Givetian) and *falsiovalis* Zones (lower Frasnian).

In the upper part of the "rocky towers", several metres above the place where nearly vertical cliffs pass into the more gentle slope, occur fine-grained peloidal-crinoidal wackestones with Upper Viséan foraminifers (Appendix, sample BN8d/6). Within the wackestones, there is a lenticular bed of monomictic goniatite-bivalve, well-washed mud-free grainstone coquina (Pl. 3, Figs 1-2). Despite the coarse-grained crystalline, grain-supported coquina matrix, the goniatites are well preserved (see: Palaeontological description in the final part of the text) and indicate a Late Viséan age (*determination: Dr D. Korn*).

The goniatites are associated with *Posidonia*-type bivalves: *Grammysia omaliana* (de KONINCK) and ?*Edmondia* sp.; and brachiopods: *Brachythyris* sp. and ?*Antiquatonia* sp., which are generally characteristic of the Viséan.

Slightly above this goniatite-coquina occurs another coquina-type limestone horizon with abundant brachiopods: *Goniophoria monstrosa*, *G. carinata*, *Striatifera* cf. *striata* (FISCHER), *Eomarginifera praecursor* (MUIR-WOOD), *Podtsheremia* cf. *varsanofievae* KALASHNIKOV, *Plicatifera plicatilis katranica* VOLGIN, *Fluctuaria undata* (DEFRANCE), *Schuchertella* sp., *Composita* sp. cf. *C. megala* (TOLMATCHOV), *Cancrinella venevi* SARYTCHEVA, *Antiquatonia* sp., *Davidsonina* cf. *septosa* (PHILLIPS), *Cleiothyridina* sp.; and gastropods: *Rhineoderma* cf. *radula* (de KONINCK), *Straparollus* (*Straparollus*) cf. *dionysii* MONTF., ? *Portlochiella* sp., *Mourlonia* sp. The assemblage is also characteristic of the Late Viséan (*see* GALLAGHER & SOMERVILLE 1997)

Locality 7

Massive, light-grey organodetrital limestones crop out amid the scree on the western slopes of the Olysya Hill. There are sporadic bedded intercalations (Pl. 2, Fig. 1) of coarse-grained, crinoid-foraminiferal-oolitic calcarenites and calcareous breccias. In the uppermost parts of the slope, just below the tree-line, strongly recrystallized grey-yellow “spotted limestone” with corals, brachiopods, bryozoans, gastropods and crinoids appear (Pl. 3, Fig. 7). The spotted pattern on the surface of rocks is caused by different cements, both blocky and fibrous ones. This specific type of rock is very similar to the typical Waulsortian mud-mound facies.

The massive limestones are composed mainly of algal biolithite with abundant brachiopods (sometimes large forms – Pl. 2, Fig. 3) and numerous corals, gastropods, bryozoans and foraminifers (Appendix, samples BN7/1, BN7/2), indicating a Late Viséan-Early Serpukhovian age.

The ‘algal’ assemblage is represented mainly by codiacean or cyanobacterial forms: *Ortonella kershopensis* GARWOOD, *Ortonella* cf. *furcata* GARWOOD, *Garwoodia gregaria* (NICHOLSON), *Mitcheldeania* sp., *Masloviporidium delicata* (BERCHENKO), rare *Calcifolium okense* (SHVETZOV & BIRINA), and the dasycladacean alga *Koninckopora* sp. (Pl. 5, Figs 1-5; Pl. 4, Figs 1-4).

The corals are represented by relatively numerous *Lonsdaleia* cf. *duplicata*, typical of the latest Viséan – Early Serpukhovian, and *Hexaphyllia* sp. The brachiopod assemblage is more diversified: *Striatifera striata* (FISCHER), *Striatifera angusta* (JANISCHEVSKY), *Striatifera* sp., *Davidsonina* cf. *septosa* (PHILLIPS), *Schuchertella* sp., *Podtscheremia varsanofievae* KALASHNIKOV, *Productus pseudoplicatilis* (MUIR-WOOD), *Beecheria khalfini* BESNOSSOVA, *Antiquatonia khimenkovi* (JANISCHEVSKY), *Krotovia spinulosa* (SOWERBY), *Schizophoria mesoloba* JANISCHEVSKY, *Cancrinella* (?) *subtilis* ABRAMOV & GRIGOREVA, *Goniophoria* cf. *monstrosa* (JANISCHEVSKY).

Locality 6

In contrast to Locality 7, the outcrops of Locality 6 in the northern part of the Olysya Hill, on the flat top-surface, reveal the spatial relationships of different lithotypes (Text-fig. 4). The coarse-grained calcarenites and calcirudites (unit 1), lying almost horizontally (angle of dip about 15°N), contain abundant brachiopods (*Cancrinella* (?) *protvensis* KALASHNIKOV, *Gigantoproductus* sp., *Productus pseudoplicatilis* (MUIR-WOOD), *Spirifer* sp., *Camarotoechia* cf. *domgeri* (TSCHERNYCHEV), *Podtscheremia* sp., *Schizophoria mesoloba* (JANISCHEVSKY), bryozoans, solitary as well as colonial corals and large crinoids. Both the macrofauna and the foraminifers (Appendix, sample BN6) indicate the Late Viséan – Serpukhovian age of the youngest beds in the succession (unit 6). Some of the foraminiferal specimens are plastically deformed as an effect of tectonic processes connected with overthrusting.

Description of the main units illustrated in Text-fig. 4

1 – Thick-bedded calcirudites with lithoclasts derived from microbial buildups with clotted structures, early cementation surfaces, truncation surfaces and fibrous cements; matrix organodetrital with abundant brachiopods, solitary

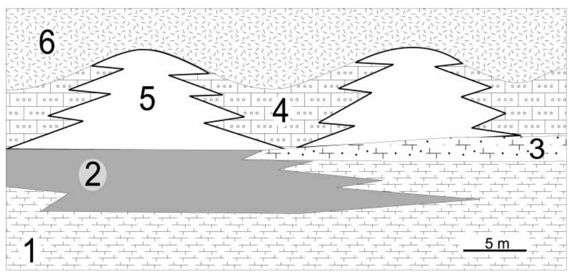

Fig. 4. Schematic relationships of the main lithological units at Locality 6 (description of units in text)

and colonial corals, trilobites, bryozoans and crinoids with relatively long, well-preserved stems.

2 – Thin-bedded calcarenites with flints and cherts; the crushed macrofauna is oriented parallel to the bedding.
3 – Crinoidal calcarenites mixed with rare undeformed ooids.

4 – Oolitic grainstones slightly dolomitized; some ooids are regenerated and coated with single very thin layers (Pl. 4, Fig. 2).

5 – Algal-peloidal biolithite.

6 – Calcarenites with abundant brachiopods and bryozoans.

Locality 5

The group of rocks on the north (5) and south (5A) side of the river (Text-figs 2, 5; Pl. 2, Fig. 2) is cut by faults, one of which has been utilized by the main river-bed. The outcrop is more than 1 km west of the Olysya Hill, and is composed mainly of breccias, with unsorted, sometimes extremely large boulders, several metres in diameter.

The lithological composition of the clasts in the breccia is very diversified. Fragments of stromatoporoid boundstones, goniatite coquinas and numerous oolitic (and even pisolitic) grainstones are distinguishable (Pl. 2, Fig. 4). All of these types are known from localities on Olysya Hill, but the provenance of some of the clasts, especially of black, micritic limestones, is unknown. One distinctive type of clast is algal boundstone with dasycladacean algae and brachiopods. Another distinctive type contains abundant brachiopods, most probably of Tournaisian age (*Cleiothyridina* cf. *tomiensis* Besnossova, *Leptagonia convexa* (Weller), *Eomartiniopsis* sp. and *Fusella* sp.). The matrix of the breccias is oolitic, similar to that of some of the large blocks on the south side of the river.

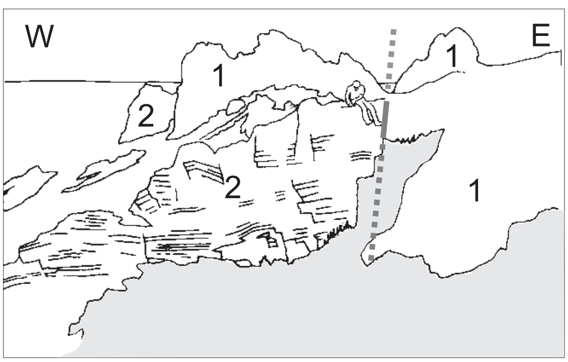

Fig. 5. Schematic relationships of the main lithological units at Locality 5 (comp. Pl. 2, Fig. 2); 1 – breccia, 2 – thin bedded limestones, dashed line = tectonic contact

The thin-bedded succession in northern parts of the section (Locality 5) is unique in the entire BNCC, and is composed of fine-and medium-grained calcarenites with brachiopods. According to the detailed description of this locality by Eliseev (1973), the contact between well-bedded calcarenites and the breccia is sedimentary and illustrates interfingering of facies. On the basis of our observations, we suggest instead a tectonic contact - most probably this section is separated from other parts of the outcrop by a nearly vertical fault. The foraminifers found in the medium-grained calcarenites (Appendix, samples BN5/1, BN5/4) indicate Late Viséan – Serpukhovian age, in agreement with the brachiopods that have been found here (*Davidsonina obtusa* Kalashnikov, *Spirifer* sp., *Cancrinella* cf. *venevi* Sarytcheva, *Antiquatonia* cf. *hindi* (Muir-Wood).

Locality 4

Numerous individual klippes, scattered within the limits of a small hill on the north side of the river, are dominated by conglomerates with clasts of different size but excellent roundness and a crinoidal-oolitic matrix. The clasts represent several different microfacies: mudstones with small numbers of brachiopods, oolitic grainstones and fragments of boundstones mostly composed of 'algae' (*Ortonella*), and containing abundant brachiopods and bryozoans. In relatively numerous clasts, neptunian dykes, filled by lime mud with ostracods (Pl. 7, Figs 1-2) or even ooids, have been observed. In different stages of infilling, the deposit has been penetrated by burrowing organisms.

In the lowermost part of the succession, cropping out in the form of small rocks directly in the river-bed, medium-bedded organodetrital grainstones with sporadic ooids and extremely rich foraminifers occur. The algal forms found here are represented by dasycladacean algae, similar to Palaeoberesellidae.

The abundant foraminifers found in nearly all of the samples taken from Locality 4 indicate a Late Viséan age (zone Cf 6, Appendix, samples BN4/6, BN4/8, BN4h).

RECONSTRUCTION OF THE EVENTS LEADING TO THE DEVELOPMENT OF THE BNCC SUCCESSION

The complicated history of the BNCC succession consists of two stages of growth and decline of carbonate platforms, which developed in the same place, one directly succeeding the other (Text-fig. 6). This rarely observed phenomenon was most probably caused by the constant palaeogeographic position of the discussed area during the Devonian and Early Carboniferous, on the dynamic boundary between two structural zones.

The initiation of the original stromatoporoid bioherm probably took place around the boundary of Middle and Late Devonian, when the world-wide expansion of such type of buildups started. Both the brachiopod data (KOKOVIN 1999 and this paper), and the conodonts (SOBOLEV & *al.* 2000) found in Localities 8 and 9, confirm the Late Givetian and Early – Late Frasnian age of the build-up. The termination of its growth is not precisely dated, but was most probably connected with the Frasnian/Famennian crisis. Shallowing of the sedimentary environment in the beginning of the Famennian led to the development of monotonous oolitic sedimentation. The total thickness (more than several tens of metres) and stratigraphic range of this provisionally dated formation (Locality 9) is unknown, but according to the data from adjacent regions (cf. ELISEEV 1978, SOBOLEV & *al.* 2000), the oolitic sedimentation could also have continued during the Tournaisian. Finally, the subsequent shallowing of the sedimentary environment, recorded in the partial dolomitization of the Devonian complex (Localities 8 and 9), caused the emersion and erosion of the structure. It is not unlikely that this process was completed by the tectonic uplift of some blocks and their erosion, which in consequence created the pre-Viséan unconformity surface. Renewed marine sedimentation commenced in the Late Viséan, when the carbonate platform was reconstructed in a relatively short time, and most probably continued into the Early Serpukhovian.

The crucial problem in this hypothetical reconstruction of the development of the BNCC is the relationship of the Devonian-Tournaisian(?) and Viséan parts of the complex. The postulated unconformity (cf. Text-fig. 3) is not visible in outcrops, but it is suggested by a stratigraphical gap below the Upper Viséan formation, which covers different lithological and stratigraphical members of the Devonian platform (compare sections from the Localities 8 and 9). Direct measurements of bed orientation are either nearly impossible or the beds are tectonically disturbed (cf. SOBOLEV & *al*. 2000), but some general features and a single local observation (i.e. in Locality 8) show that the angle of dip of the Devonian rocks is evidently greater than that of Viséan. Another question is connected with the resolution of the nature of the unconformity, i.e. either acceptance of a simple tectonic (overthrust) model or a more complicated tectono-erosional explanation. SOBOLEV & al. (2000) suggested a tectonic origin of the hiatus (defined by these authors as Upper Frasnian – Lower Viséan). This hypothesis is well supported by the general tectonic style of the area, characterized by the presence of numerous overthrusts; both of the contacts (lower and upper) of the BNCC with adjacent complexes are of this nature. However, in our reconstruction of events, the present authors decided in favour of a tectono-erosional model. The answer to the problem seems to be recorded in the style of deformation of the ooids in the rocks that lie below the unconformity.

Nearly all of the ooid grains are elongated in a particular way: the ellipsoidal shape of ooids expected in the case of normal compaction of deposits, is replaced here by the irregularly elongated shape with a distinctive “snout-like” protrusion on one side of the ooid (Pl. 4, Figs 1, 3-4). In some cases, this protrusion is associated with a similar protrusion in the neighbouring grain, making pairs of chain-like coral beads. On the other hand, the ooid grains are completely devoid of pressure-solution features (pitted ooids), which suggests that deformation has affected the mud-supported deposit. This type of deformation is well known from the so-called “distorted ooids”, described among others by CAROZZI (1961), BACHMANN (1973), RADWAŃSKI & BIRKENMAJER (1977), KETTENBRINK & MANGER (1971) and, more recently, by GIBSON & *al.* (2000). The numerous hypotheses which explain their origin can be generally classified into two groups: (i) processes connected with compaction in early stages of diagenesis or (ii) effects of stress during slip-shearing motion of layers. The discussed type of ooid deformation is not observed in the layer of breccia resting on the unconformity surface (Pl. 6, Fig. 5). If tectonic processes caused the deformation of the ooids, the effects of shearing stress should be recorded in both boundary layers. Therefore, their absence in the breccia favours the other, diagenetical-compactional hypothesis. The explanation proposed by RADWAŃSKI & BIRKENMAJER (1977 suggested “sedimentary boudinage” (MCCROSSAN 1958) as the most probable cause of distortion of the ooids. As a result of increasing compaction pressure, the initially pitted ooids became flattened, with only the area of grain contact remaining relatively uncompacted. Gradually, as the process continued, the grains assumed the form of “snouted ooids”. Overburden by deposits of relatively small thickness could start the deformation, so it is connected with an early stage of diagenesis. RADWAŃSKI & BIRKENMAJER (1977) emphasised that the area of deformation can be limited to isolated places in the oolite bed, according to the distribution of discrete, and unrecognised physical conditions. This would explain why the oolitic grains in oolitic clasts from the overlying breccias are, in some cases, undistorted, as shown in Pl. 6, Fig. 5.

The assumption of the sedimentary-boudinage hypothesis for the origin of deformation in the Famennian oolitic beds makes the tectono-erosional nature of the contact of the two complexes within the BNCC more probable than the interpretation involving overthrusting.

The recently recognized Devonian portions of the BNCC correspond to the general characteristics of the Devonian in the north-eastern margin of the EEP. ELISEEV (1978) distinguished here a facies-structural unit described as "Patok Gradation" and documented its most typical locality in the eastern part of the Elets Zone. One of the distinctive lithological associations in this unit is composed of Frasnian - Famennian biohermal limestones, fine-grained calcarenites, oolites and dolomites, i.e. all of the lithologies that have been found in the BNCC. ELISEEV (1978) emphasized intercalations of all mentioned lithological types and difficulties in interpretation of their stratigraphic arrangement. The sections presented here distinctly introduce order to this chaotic picture; moreover, they mirror the succession of events typical of growth and decline of the Late Devonian bioherms elsewhere. The obvious analogy seems to be the Upper Devonian succession in the Holy Cross Mts. (Central Poland), on the opposite side of the EEP. The growth of Frasnian stromatoporoid mounds in Kielce (see SZULCZEWSKI 1971, 1973, 1995) was terminated at the end of the Frasnian as a result of tectonic uplift. Shallow water sediments (organodetrital and oolitic material) which covered the upper surface of terminated bioherms were washed out and deposited on their slopes (Kadzielnia mound) or in neptunian dykes (Dalnia region).

The Late Viséan transgression in the Bol'shaya Nadota region is recorded by a thin layer of locally preserved basal breccia or conglomerate, followed by a thick, shallowing-upward carbonate complex. The deposition of this complex was terminated at the end of the Viséan or at the beginning of the Serpukhovian. The exact solution of this stratigraphical question is not possible because of the very imprecise definition of this boundary (cf. discussion of the problem *in* SKOMPSKI & *al.* 1995, SKOMPSKI 1996) and the lack of goniatites, which are the best indices in this boundary interval. In the interpretation presented below, the termination of carbonate platform growth is connected with a relative fall of sea-level. If one assumes that the fall was eustatically controlled, it seems more probable that the emersion of the platform took place in the Early Serpukhovian (end of Steshevian local stage) rather than at the end of the Viséan (cf. POLETAEV & *al.* 1990, ALEKSEEV & *al.* 1996).

The specific feature of Late Viséan sedimentation was the development of small algal or microbial mounds, which is described in more detail in the next section. In the later stages, the mounds tended to merge into larger and more areally extensive forms. The re-activated shallow-water carbonate platform represented probably the type of small isolated forms, surrounded by deeper water environment. This hypothesis is in agreement with the general palaeogeography of the transitional area between the Elets and Lemva Zones, and is also indicated by intercalations of shallow water carbonates with more pelagic cephalopod coquinas. The isolated position of the platform also explains, to some extent, the lack of carbonate facies in the immediate vicinity of the BNCC.

The Carboniferous stage of platform development, like the Devonian one, was terminated in a shallowing of the sedimentary environments. This final period was characterized by the development of a very rich assemblage of benthic fauna and by the appearance of oolitic facies (Locality 6). However, the latter facies was not so homogenous as in the Famennian and sediments belonging to this facies usually contain intercalations of organodetrital material.

The final consequence of the relative fall of sea-level was an emersion of the platform and abrasion of its margins. The breccias and conglomerates observed in Localities 5 and 4 were probably deposited on the abrasional near-shore parts of shelves, where blocks originated in a dynamic cliff area were mixed with the oolitic material from more distant off-shore areas. The roundness level of the pebbles is evidently greater in the conglomerates from Locality 4 than in those from Locality 5, which is only to be expected in such an environment, but the difference could be purely coincidental. The suggested origin of the coarse-grained carbonates is also supported by the composition of the clasts in breccias, which are diverse both lithologically and stratigraphically (*cf.* description in Locality 5). In this context, the hypothesis of ELISEEV (1973), who interpreted most of the breccias as reefal talus, seems to be less probable. The intercalations of allodapic limestones in basinal shaly facies, known from exposures on the banks of River Lemva, several kilometres to the east (*see* ELISEEV 1973), could be interpreted as distal fragments of the submarine fans, fallen from the abraded margin which surrounded the core of the Devonian - Carboniferous complex.

An argument which would be persuasive in relation to the above hypothesis would be evidence of a karstic surface on the top of the emerged platform. Unfortunately this question cannot be solved as the surface in question is completely covered by the overthrust Permian deposits.

The Viséan phase of development of the BNCC has numerous analogies on the opposite side of Laurussia, as well as in other places of the world. While carbonate build-ups in the Early Carboniferous were located in relatively great water depths on the lower parts of ramps, in the later Dinantian, the build-ups were situated in shallower water areas, mostly on the edges of tilted blocks. Independent of the type of organisms which constructed them, relatively fast growth rate of buildups caused their rise up to wave base and the development of shallow water platforms with organodetrital or oolitic sedimentation (*see* review *in* BRIDGES & *al*. 1995, WEBB 1999; an excellent example of repeated growth of build-ups in: BOURQUE & *al*. 1995).

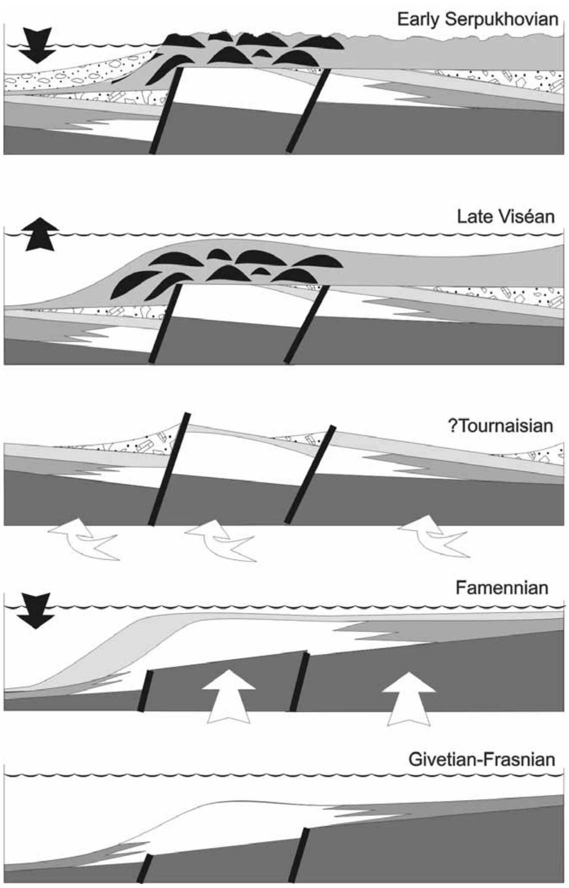

Fig. 6. Scheme of development of the Bol'shaya Nadota Carbonate Complex (description in text)

Moreover, the Carboniferous part of the BNCC quite clearly illustrates the close relationship between sedimentary processes and the eustatic sea-level changes observed on the Laurussia shelf. Transgression and origin of the Viséan part of the BNCC seems to correspond to the transgression observed in the beginning of the Late Viséan in eastern Poland (SKOMPSKI 1996), Belgium (PAPROTH & al. 1983) and Great Britain (GEORGE & *al*. 1976), whereas termination of the platform can be inferred to reflect the regression in the earlier part of the Serpukhovian (approximately Stage E_2).

The particular feature of the BNCC was the renewed building of a biohermal complex at a place which had previously been covered by this type of sediment (in the Late Devonian). To some extent an analogy of this process is known from the Iberg structure in the Harz Mountains (FRANKE 1973), which was rebuilt at least twice, due to the volcanic bed located in the base of carbonate complex. In the case of BNCC, this analogy is only superficial and the structural position of the area is of greater importance, as emphasized by ELISEEV (1971, 1973, 1978).

CLASSIFICATION OF THE CARBONIFEROUS BUILDUPS OF THE BNCC

The Lower Carboniferous part of the BNCC is not sufficiently well exposed to distinguish the biohermal *s. stricto* and interbuildup facies unequivocally, and consequently the precise analysis of a single bioherm morphology and its internal composition is difficult. Nevertheless, the presence of well preserved klippes makes it possible to attempt to classify the buildups, with most being represented by the same type. The most appropriate classification scheme is that proposed by BRIDGES & *al.* (1995) for buildups in the western part of Laurussia.

The relationships of biohermal and interbuildup facies interpreted in Locality 6 (Text-fig. 4) enables estimation of the moderate dimensions of buildups (several metres high and several tens of metres in lateral extent). The most significant organisms responsible for their growth were the calcareous 'algae' classified (according to the classification by MAMET & ROUX 1975) within the group Codiaceae, composed of parallel or interweaved tubes (different species of genera *Ortonella*, *Garwoodia* and *Mitcheldeania*). Sometimes they formed more rigid but irregular constructions, in association with the solenoporacean *Masloviporidium* and undetermined dasycladaceans. Besides taxonomically defined algal forms, the important role in the formation of buildups is played by the microbial organisms, whose activity is confirmed by abundant peloidal structures and stromatolite-like laminations (cf. ELISEEV 1973 - Figs 5-7).

The macrofauna is represented by relatively numerous solitary corals (colonial forms are rare), crinoids and a very diversified and numerous assemblage of brachiopods. In some cases the corallites show algal encrustations (Pl. 7, Fig. 3), or locally they are completely surrounded by ortonellid "scrub". Bryozoans, less abundant in biolithites, were more frequent in the intermound areas, where they were associated with the dasycladacean genus *Koninckopora* and the relatively rare codiacean alga *Calcifolium*, which reached its acme in the Late Viséan. The foraminifers in buildup facies are scarce, only some encrusting tetrataxid forms are more frequent.

The typical feature of buildups is early cementation, indicated by cements in interstitial spaces in algal constructions (Pl. 5, Fig. 1) as well as by the neptunian dykes, infilled by mud with ostracods and penetrated by burrowing organisms. The cavities in algal build-ups are usually irregular, not greater than a few centimetres, and are lined by isopachous fibrous and blocky cements.

The interfingering of biolithite facies with oolitic calcarenites indicate the bathymetrical location of buildups. They represented the group of extremely shallow water forms, which terminated their growth after reaching wave base.

This type of buildup corresponds quite closely to type "4" in the classification of BRIDGES & *al.* (1995). This analogy is confirmed by biotic composition, as well as by bathymetrical position and approximate dimensions. On the other hand, in type "4" buildups, there are more frequent problematic foraminiferal-algal forms similar to *Aphralysia*, but it seems that the ecological requirements of these forms were comparable to those of codiacean (or cyanobacterial according to classification of CHUVASHOV & RIDING 1984, RIDING 1991) ortonellids. According to BRIDGES & *al.* (1995), the discussed types of buildups appeared frequently as "phase D" of typical Waulsortian structures, i.e. at the stage when these giant and deep-water buildups reached the phase of relatively shallow-water development. Similar buildups were also reported by SOMERVILLE & *al.* (1992) from the shallow-water Viséan platform on the northern margin of the Dublin Basin. Those authors emphasized that the microbial communities responsible for growth of these buildups probably 'evolved' from Waulsortian phase D.

COMPARISON OF THE UPPER VISÉAN BUILDUPS FROM THE SOUTHERN AND NORTHERN MARGINS OF THE EEP

According to the palaeogeographical position of the eastern part of Laurussia in the Late Viséan (Text-fig. 1), its southern margin, located directly on the equator, is represented by deposits known from south-eastern Poland. The Upper Viséan carbonates are known from the Lublin Basin, Holy Cross Mts. and Cracow region, but carbonate buildups are recognized only in the first two areas.

In the Lublin Basin, where the Carboniferous deposits are covered by a thick Mesozoic succession, three types of mounds are recognized, known only from the boreholes. The most common are coral reefs, which started to develop in the first phase of transgression on the weakly denuded surface, formed earlier in some places by volcanic processes. The reefs preferred the circum-volcanic areas and an example of such a location is illustrated by SKOMPSKI (1996 - Text-fig. 10). In the next phase of transgression, recorded by Yoredale-type cyclic sedimentation, the reefs became rare and only two examples of such structures have been found. The first bioherm, several metres high, is composed of the phylloid alga *Archaeolithophyllum* (SKOMPSKI 1996 - Pl. 21). The rigid framework of the bioherm is associated with gastropods, encrusting foraminifers, dasycladacean algae and *Aphralysia*-like forms. This buildup, recognized in only one section, is relatively small, but could be treated as one of the oldest ancestors of the Pennsylvanian and Permian phylloid algal buildups.

The second type has been recognized in the central part of the Basin near Lublin (Minkowice buildup, SKOMPSKI & ŻYWIECKI 1997). Its dimensions were radically greater than those of the first type (30-40 metres high, several hundred metres in diameter), and its internal structure corresponded to that of the typical Waulsortian mounds. The growth of the mound was microbially stimulated, and crinoidal material formed the most important macrobial component. The mound was growing in the tectonically active zone, and its development was probably affected by the local increase of the temperature of the bottom water.

In the Holy Cross Mts., the Upper Viséan deposits are represented mainly by deep water radiolarian shales, and the only carbonate deposits are known from several lenses of the coarse-grained calcirudites and breccias, described as the Gałęzice Debrite Member (BELKA & SKOMPSKI 1988, ZDANOWSKI & ŻAKOWA 1995). Most of the clasts, which comprise the basal breccia in this member, have been derived from bioherms built of lithostrotionid corals and auloporid tabulates (*Sinopora polonica*, *Multithecopora* sp.). Other macrofaunal groups – brachiopods, bryozoans, heterocorallia, crinoids) are represented only sporadically, while foraminiferal encrustations (*Tetrataxis* and *Nubecularia*-type forms) are abundant. The matrix is dominated by clotted peloidal structures.

The buildups, reconstructed on the basis of clast lithology, correspond to type "3" of the BRIDGES & *al.* (1995) classification, i.e. relatively small buildups composed of crinoids, brachiopods, corals and bryozoans, which were located on the marginal parts of a shelf or in slightly deeper parts of intrashelf basins. This suggested position fits well to the reconstruction suggested by BELKA & *al.* (1996), which proposed the edge of a small tilted block ("Nida Platform") as the primary location of buildups.

In general, it seems that the buildups from the southern margin of the EEP did not differ qualitatively with those known from the northern margin. The decisive feature is similarity of the algal assemblages described from the Palaeotethys region and from the Northern Urals, as emphasized earlier by BOGUSH & *al*. (1990), IVANOVA & BOGUSH (1992), CHUVASHOV & *al.* (1993). According to MAMET (1992 - Text-fig. 2), the Bol'shaya Nadota section was located in the Late Viséan near the northern boundary of the Palaeotethyan flora, but in fact the differences between the Palaeotethyan and Arctic floras were insignificant. Both of the assemblages were dominated by high numbers of "cosmopolitan" genera, known from the entire shelf of the eastern part of EEP. A lack of distinct provincialism is also observed in other groups of micro- and macrofossils. Thus the types of buildups recognised in the southern margin of the EEP seem to be similar to those of the northern margin. Another significant feature of peri-reefal sedimentation in the Bol'shaya Nadota region is the abundance of oolitic intercalations. Indirectly it confirms previously known conclusions about the location of the northern boundary of carbonate sedimentation in the Late Viséan far to the north of the tropics (MCKERROW & SCOTESE 1990, GOLONKA & *al.* 1994).

DESCRIPTION OF GONIATITES
(by D. KORN)

The Carboniferous ammonoids from the North Urals and the Pay-Khoy are known from a series of monographs written by KUSINA (1971, 1973, 1974, 1980, 1983, 2000), in which she described rich Late Tournaisian (Saourian in the Russian terminology) faunas from localities in the River Kozhim. Late Viséan and Early Namurian faunas are rare in the North Urals, but are well known from numerous outcrops on Novaya Zemlya (LIBROVITCH 1938, 1941; KUSINA 1987; KUSINA & YATSKOV 1988, 1990, 1999; LIBROVITCH *et al*. 1993). The species list provided by KUSINA (2000) demonstrates that the latest Viséan - earliest Namurian faunas are much more diverse than those from the early Viséan, reflecting the general trend in the evolution of the Carboniferous ammonoids.

In the following section, a small goniatite fauna will be described which supplements the knowledge of the ammonoid faunas from the North Urals - Novaya Zemlya region.

Material: The 40 specimens found in the Bol'shaya Nadota section, Locality 8 are slightly distorted, but all of them are suitable for taxonomical study. The original shape of the conchs can be easily reconstructed. Four different species could be recognised, but two of them have to remain in open nomenclature. The specimens are stored in the collection of the GeoInstitute Tübingen under the catalogue numbers GPIT 1874-1to GPIT 1874-40.

Family **Daraelitidae** TCHERNOV, 1907
Praedaraelites SCHINDEWOLF, 1934

Praedaraelites sp.
(Pl. 8, Fig. A)

MATERIAL: 5 specimens with approximately 20 mm conch diameter. They are insufficiently well preserved to enable detailed study of the suture. All of them show a molariform morphology with flattened flanks and moderately wide umbilicus, and specimens GPIT 1874-02 and GPIT 1874-04 display parts of the suture line. As it is a typical feature of the genus, the external lobe is pouched. The first lateral lobe displays weak indications of serration.

Dimensions in mm:

	dm	ww	wh	uw	ww/dm	ww/wh	uw/dm
GPIT 1874-05	20.8	7.5	9.7	0.	36	0.77	
GPIT 1874-01	20.2	6.5	9.4	6.7	0.32	0.69	0.33
GPIT 1874-03	19.2	6.8	9.1	6.7	0.35	0.75	0.35

Family **Girtyoceratidae** WEDEKIND, 1918
Girtyoceras WEDEKIND, 1918

Girtyoceras sp.
(Pl. 8, Fig. B)

MATERIAL: 5 poorly preserved specimens with conch diameter between 16 and 85 mm. The smallest specimen (GPIT 1874-09) shows, at 16 mm diameter, a narrow umbilicate conch with rounded venter. The ornament consists of coarse growth lines and six constrictions on the flanks.

The larger specimens are poorly preserved. Specimen GPIT 1874-06 shows that the venter becomes acute at 20 mm conch diameter. The largest specimen (GPIT 1874-10) has, at 80 mm diameter, the shape of an oxyconic lens.

Family **Goniatitidae** de HAAN, 1825
Goniatites de HAAN, 1825

Goniatites olysya sp. nov.
(Pl. 8, Figs C-H)

DERIVATION OF NAME: After the Olysya Hill, where the described fauna comes from.

HOLOTYPE: Specimen GPIT 1874-11 (Pl. 8, Fig. D)

TYPE LOCALITY AND HORIZON: Subpolar Urals, Bol'shaya Nadota River section, Locality 8 on the slope of Olysya Hill; Late Viséan.

DIAGNOSIS: *Goniatites* with globose to spindle-shaped conch at 15 mm diameter (ww/dm = 0.85 to 1.25) and globose conch at 40 mm diameter (ww/dm = 0.90 to 1.00). Umbilicus moderately wide in juveniles (uw/dm = 0.30) and very narrow (uw/dm = 0.10 to 0.15) at 40 mm diameter. Low aperture, whorl expansion rate between 1.40 and 1.50 in all stages. Suture line with Y-shaped external lobe, moderately high median saddle (0.40 of the tectiform ventrolateral saddle). Weak shell ornament with very fine spiral lines, no constrictions.

MATERIAL: 28 specimens with conch diameter between 15 and 55 mm. Due to deformation of the goniatite coquina, the measurements do not correspond exactly to the original conch geometry. Fragments of the shell ornament are preserved in only one individual, but suture lines can be studied in several specimens.

DESCRIPTION: Similar to other species of *Goniatites* and related genera, the population of *Goniatites olysya* displays a range of conch morphologies. The relative thickness of the conchs varies, between 15 and 20 mm conch diameter, within a range of 0.85 (GPIT 1874-16) and 1.25 (GPIT 1874-14; Pl. 8, Fig. E). In larger specimens, the variability is less striking. Most of the specimens are almost ball-shaped with continuously rounded flanks and venter. All of the specimens have a very low aperture, and hence a whorl expansion rate (WER) of only 1.42 to 1.50. The umbilicus is extremely narrow in juveniles and widens slightly during ontogeny.

The somewhat distorted cross section of the paratype GPIT 1874-17 reveals the ontogenetic development of an average specimen (Text-fig.7). During all stages, the thickness equals the diameter of the conch and only the width of the umbilicus changes. In the juvenile conch, at 2 to 6 mm diameter, the umbilicus is slightly opened with a width of approximately one third of the conch diameter. Stages larger than 6 mm display a continuously closing umbilicus which, at 33 mm conch diameter, is only one-tenth of the conch diameter.

The shell ornament, in the form of fine spiral lines, is visible in the paratype GPIT 1874-13 (Pl. 8, Fig. G) in a limited area around the umbilicus. The spiral lines are arranged in variable distances between 0.15 and 0.4 mm, and become weaker on the flank. Despite the fact that the shell is hardly preserved, it can be assumed that the species had a very weak ornament. None of the specimens has steinkern constrictions. In the paratype, GPIT 1874-12, the suture line can be studied. It is typical of the genus *Goniatites*, with a narrow, Y-shaped external lobe and an acute ventrolateral saddle. Although the suture line is laterally compressed, the ratios of some elements can be estimated as follows: the height of the median saddle is 0.4 of the ventrolateral saddle, and the width of the external lobe is 1.6 of the ventrolateral saddle and 1.15 of the adventive lobe (Text-fig. 8A). In this respect, *Goniatites olysya* resembles other species of the genus.

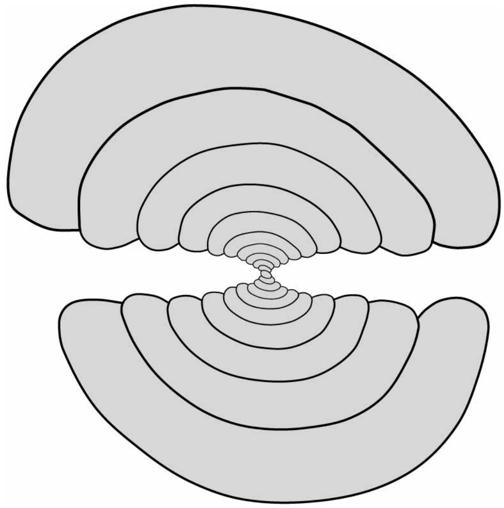

Fig. 7. Cross-section of *Goniatites olysya* sp. n.; paratype GPIT 1874-17; × 2

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
holotype									
GPIT 1874-11	40.3	37.2	19.1	4.8	6.5	1.42	0.92	1.95	0.12
paratype									
GPIT 1874-12	52.5	40.0	28.0	3.3	9.6	1.50	0.76	1.43	0.06
paratype									
GPIT 1874-13	33.8	33.2	16.3	3.6	5.7	1.45	0.98	2.04	0.11
paratype									
GPIT 1874-14	16.6	20.4			2.8	1.44	1.23		
paratype									
GPIT 1874-15	17.6	18.8		2.2			1.07		0.13
paratype									
GPIT 1874-16	19.7	17.0		0.8	3.3	1.44	0.86		0.04
paratype									
GPIT 1874-20	36.8	31.8	18.0	4.9			0.86	1.77	0.13

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
paratype									
GPIT 1874-19	42.0	33.3	21.5	5.7			0.79	1.55	0.14
paratype									
GPIT 1874-18	28.8	24.7	15.1	2.8			0.86	1.64	0.10
paratype									
GPIT 1874-17	32.9	32.4 1	6.0	3.3	5.5	1.44	0.99	2.02	0.10
”	27.4	28.3	13.5	3.23	4.84	1.48	1.03	2.09	0.12
”	18.9	19.6	8.9	2.69	3.17	1.44	1.04	2.19	0.14
”	15.8	16.1	7.3	2.76	2.72	1.46	1.02	2.21	0.18
”	13.0	13.4	5.7	2.78	2.16	1.44	1.02	2.32	0.21
”	10.9	10.7	4.5	2.59	1.81	1.44	0.98	2.35	0.24
”	9.1	8.8	3.7	2.31	1.59	1.47	0.97	2.34	0.25
”	7.5	7.2	3.0	1.97	1.32	1.47	0.96	2.39	0.26
”	6.2	5.8	2.5	1.81	1.06	1.46	0.95	2.34	0.29
”	5.1	5.1	1.85	1.56	0.80	1.41	1.00	2.75	0.31
”	4.3	4.11	1.68	1.28	0.65	1.39	0.96	2.44	0.30
”	3.65	3.38	1.34	1.28	0.63	1.46	0.92	2.52	0.35
”	3.03	2.74	1.04	1.07	0.53	1.47	0.91	2.64	0.35
”	2.49	2.27	0.92	0.78	0.42	1.45	0.91	2.47	0.31
”	2.08	1.83	0.79	0.63	0.47	1.67	0.88	2.30	0.30
”	1.62	1.39	0.66	0.41	0.38	1.70	0.86	2.10	0.26
”	1.23	1.05	0.54	0.21	0.37	2.03	0.85	1.95	0.17
”	0.87	0.85	0.49				0.98	1.72	

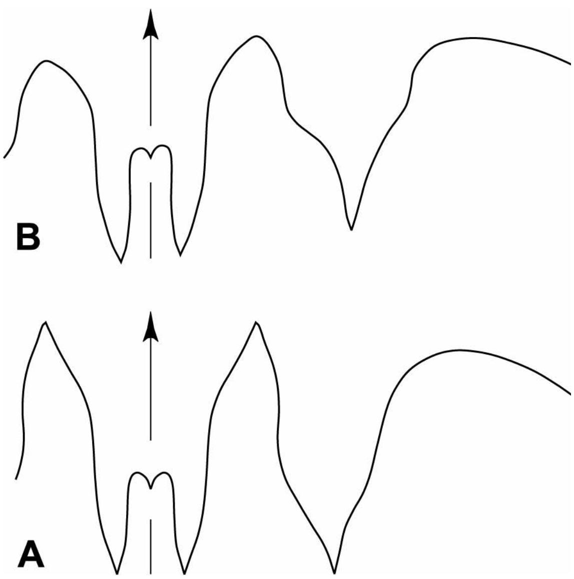

Fig. 8. Suture lines of ammonoids from the Bol'shaya Nadota River section.

A. *Goniatites olysya* sp. n.; paratype GPIT 1874-12; at ww 31.5 mm, × 3.

B. *Lusitanoceras kusinae* sp. n.; holotype GPIT 1874-39; at dm 39 mm, ww 27 mm, × 3

COMPARISONS: *Goniatites olysya* belongs to the species of the genus that display a comparable high median saddle (0.40 of ventrolateral saddle), which clearly separates it from the stratigraphically oldest known species such as *G. hudsoni* BISAT, 1934 (0.30) and *G. crenistria* PHILLIPS, 1836 (0.35). Among the species with a similarly high median saddle, *G. crenifalcatus* BOGOSLOVSKAYA, 1966 differs in rather strong falcate ornament; *G. spirifer* ROEMER, 1850 differs in its more square-shaped cross section and stronger ornament; and *G. fimbriatus* (FOORD & CRICK, 1897) as well as *G. stenumbilicatus* KULLMANN, 1961 differ in the V-shaped external lobe (in contrast to Y-shaped in *Gon. olysya*).

Lusitanoceras PEREIRA DE SOUSA, 1923
Lusitanoceras kusinae sp. nov.
(Pl. 8, Figs I-J)

DERIVATION OF NAME: In honour of Lidya Fedorovna Kusina (Moscow) for her contribution to the knowledge of Early Carboniferous goniatites.

HOLOTYPE: Specimen GPIT 1874-39 (Pl. 8, Fig. 1)

TYPE LOCALITY AND HORIZON: Subpolar Urals, Bol'shaya Nadota River section, Locality 8 on the slope of Olysya Hill; Late Viséan.

DIAGNOSIS: *Lusitanoceras* with pachyconic conch with diameter between 20 and 40 mm (ww/dm = 0.70 to 0.75). Umbilicus almost closed (uw/dm = 0.05) at 20 mm diameter and very narrow (uw/dm = 0.15) at 40 mm diameter. Ornament at 40 mm diameter with 100 coarse and weakly granulated spiral lines which are as wide as their interspaces. Growth lines fine, weakly biconvex. Steinkern with sinuous constrictions. Suture line with moderately high median saddle (half the height as the tectiform ventrolateral saddle) and adventive lobe with strongly sinuous flanks.

MATERIAL: Only two specimens are available, the holotype (GPIT 1874-39) with 39 mm and the paratype (GPIT 1874-40) with 17 mm conch diameter.

DESCRIPTION: The holotype (Pl. 8, Fig. I) is a pachyconic conch with small umbilicus and rounded umbilical margin. It bears the remains of shell ornamented by regularly arranged coarse spiral lines (nearly 100 from umbilicus to umbilicus) 0.5 mm apart. The spiral lines are almost exactly as wide as their interspaces. Growth lines are only barely visible, but they produce a weak granulation when they cross the spiral lines. The steinkern shows three constrictions, which bend backward on the flanks where they are deepest. They are arranged in distances of a little more than 90°.

The suture line displays the typical features of the genus: the external lobe is Y-shaped with a median saddle that is exactly half as high as the tectiform and narrowly rounded ventrolateral saddle. Both flanks of the adventive lobe are strongly sinuous (Text-fig. 8B). In the smaller paratype, the umbilicus is nearly completely closed. It is almost entirely covered by the shell, which displays approximately 110 granulated spirals (Pl. 8, Fig. J). As in the holotype, the constrictions are restricted to the steinkern.

Dimensions in mm:

	dm	ww	wh	uw	ah	WER	ww/dm	ww/wh	uw/dm
holotype									
GPIT 1874-39	39.2	28.2	16.5	5.4	6.3	1.42	0.72	1.71	0.14
paratype									
GPIT 1874-40	16.9	12.2		0.7	3.1	1.50	0.72		0.04

COMPARISONS: *Lusitanoceras kusinae* is similar to *L. orientalis* LIBROVITCH, 1940, but in that species, the umbilicus is much wider (uw/dm = 0.24 in contrast to 0.14 at a comparable diameter). *L. algarviense* PEREIRA DE SOUSA, 1923, and *L. poststriatum* (BRÜNING, 1923), and *L. purum* BOGOSLOVSKAYA, 1988 have similar conchs, but their suture lines do not show an adventive lobe with such a strong sinuosity of the ventral flank as in *L. kusinae*. In this respect, the three *Lusitanoceras* species from Novaya Zemlya, *L. polare* KUSINA, 1987, *L. subtenue* KUSINA, 1999 and *L. berkhense* KUSINA, 1999, resemble the new species, but all differ in their much wider umbilicus, which is almost twice as wide at comparable growth stages.

STRATIGRAPHICAL IMPLICATIONS

The fauna from the Olysya Hill is of Late Viséan age, but the exact assignment is difficult. The most detailed Late Viséan ammonoid successions have been documented from the Rhenish Massif (KORN 1988, 1996), from the British Isles (summarized in RILEY 1993), and from South Portugal (KORN 1997). In these three regions, at least 15 goniatite zones are recognizable (Text-fig. 9). However, a co-occurrence of the genera *Praedaraelites*, *Girtyoceras*, *Goniatites*, and *Lusitanoceras* is not known from the above-mentioned regions of Europe.

Girtyoceras has a distribution throughout the Late Viséan and is thus not indicative. *Praedaraelites* occurs, with the type species *P. culmiensis* (KOBOLD), in a very short interval in the *Neoglyphioceras spirale* Zone (according to the zonation proposed by KORN 1996). In the rich faunas of the South Urals, the genus has a wider distribution around the Viséan - Namurian Boundary (RUZHENCEV & BOGOSLOVSKAYA 1971).

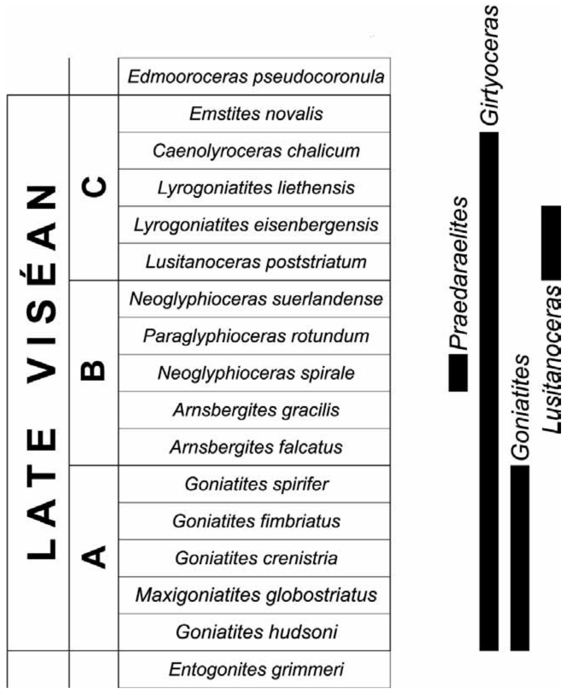

Fig. 9. Ammonoid zonation of the Rhenish Massif (Germany), after KORN (1996) with ranges of the genera which compose the Olysya Hill fauna

Goniatites is known with several succeeding species from numerous sections in the lower part of the Upper Viséan, in which they are zonal index species. In no case, a co-occurrence of the genera *Goniatites* and *Lusitanoceras* is recorded. The latter genus first appears only five or six zones above the highest occurrence of *Goniatites*. Hence three questions arise: Is *Goniatites olysya* an unusual late species of the genus? Is *Lusitanoceras kusinae* an unusual early species of the genus? Does the co-occurrence of the two genera represent an intermediate age?

Unfortunately, none of the three possibilities can be favoured at the moment, since the accompanying goniatites do not help in resolving the problem. The morphology of *Goniatites olysya* with its slightly opened umbilicus in the juvenile stage may be regarded as an indication that it is an advanced species of the genus, displaying transitional characters to stratigraphically younger genera such as *Lusitanoceras*. Hence, it might be stratigraphically younger than the Central and North Western European species.

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REFERENCES

ALEKSEEV, A.S., KONONOVA, L.I. & NIKISHIN, A.M. 1996. Devonian and Carboniferous of Moscow Syneclise: stratigraphy and sea-level changes. *Tectonophysics,* **268**, 149-168. Amsterdam.

ANTOSHKINA, A. 1998. Organic buildups and reefs on the Paleozoic carbonate platform margin, Pechora Urals, Russia. *Sedimentary Geology*, **118**, 187-211. Amsterdam.

— 1999. Evolution of the Pechora Urals reefs in the Late Paleozoic. *XIV International Carboniferous and Permian Congress, Calgary 1999, Abstracts*, 3. Calgary.

BACHMANN, G.H. 1973. Die karbonatischen Bestandteile des Oberen Muschelkalkes (Mittlere Trias) in Südwest-Deutschland und ihre Diagenese. *Arbeiten der Institut für Geologie und Paläontologie Universität Stuttgart*, **68**, 1-99. Stuttgart

BELAEVA, N.V., KORZUN, A.L. & PETROVA, L.V. 1998. Model' sedimentacii fransko-turneyskikh otlozhenij na severo-vostoke Evropeyskoy Platformy. Izdatelstvo Nauka, 1-153. Sankt Petersburg.

BELKA, Z. & SKOMPSKI, S. 1988. Mechanizm sedymentacji i pozycja facjalna wapienia węglowego w południowo-zachodniej części Gór Świętokrzyskich. *Przegląd Geologiczny*, **1988** (8), 442-449. Warszawa.

BELKA, Z., SKOMPSKI, S. & SOBOŃ-PODGÓRSKA, J. 1996. Reconstruction of a lost carbonate platform on the shelf of Fennosarmatia: evidence from Viséan polymictic debrites, Holy Cross Mountains, Poland. *In*: STROGEN, P., SOMERVILLE, I.D. & JONES, G. LL. (*Eds*), Recent advances in Lower Carboniferous Geology. *Geological Society Special Publication,* **107**, 315-329. Bath.

BOGUSH, O.I., IVANOVA, R.M. & LUTCHININA, V. A. 1990. Izvestkovye vodorosli famena i nizhnego karbona Urala i Sibiri, 1-160. Izdatelstvo Nauka, Sibirskoe Otdelenie, Novosibirsk.

BOURQUE, P-A., MADI, A. & MAMET, B.L. 1995. Waulsortian-type bioherm development and response to sea-level fluctuations: Upper Viséan of Bechar Basin, western Algeria. *Journal of Sedimentary Research,* **B65** (1), 80-95. Amsterdam.

BRIDGES, P.H., GUTTERIDGE, P. & PICKARD, N.A.H. 1995. The environmental setting of Early Carboniferous mud-mounds. *Special Publication of International Association of Sedimentologists*, **23**, 171-190. Oxford.

CAROZZI, A.V. 1961. Distorted oolites and pseudoolites. *Journal of Sedimentary Petrology*, **31** (2), 262-274. Tulsa.

CHUVASHOV, B.J. & RIDING, R. 1984. Principal floras of Palaeozoic marine calcareous algae. *Palaeontology*, **27**, 487-500. London.

CHUVASHOV, B.J., SHUYSKY, V.P. & IVANOVA, R.M. 1993. Stratigraphical and facies complexes of the Paleozoic calcareous algae of the Urals. *In*: F. BARATTOLO, P. DE CASTRO & M. PARENTE (*Eds*), Studies on Fossil Benthic Algae. *Bollettiono della Societa Paleontologica Italiana,* Spec. Vol. **1**, 93-119. Modena.

DAVIES, G.R., RICHARDS, B.C., BEAUCHAMP, B. & NASSICHUK, W.W. 1989. Carboniferous and Permian reefs in Canada and adjacent areas. *In*: H.J. GELDSETZER, N.P. JAMES & G.E. TEBBUTT (*Eds*), Reefs; Canada and adjacent areas. *Canadian Society of Petroleum Geologists Memoir*, **13**, 565-574. Calgary.

ELISEEV, A.I. 1971. Vizeyskiy rif na zapadnom sklone Pripolarnogo Urala. *Doklady Akadimii Nauk SSSR*, **200** (3), 672-675. Leningrad.

— 1973. Karbon Lemvinskoy zony Severa Urala. Izdat. Nauka, 1-95. Leningrad.

— 1978. Formacji zon ogranitchenija severo-vostoka evropejskoy platformy. Izdat. Nauka, 1-204. Leningrad.

FRANKE, W. 1973. Fazies, Bau und Entwicklungsgeschichte des Iberger Riffes (Mitteldevon und Unterkarbon III, NW-Harz, W-Deutschland). *Geologisches Jahrbuch, Reihe A*, **11**, 1-127. Stuttgart.

GALLAGHER, S.J. & SOMERVILLE, I.D. 1997. Late Dinantian (Lower Carboniferous) platform carbonate stratigraphy of the Buttevant area North Co. Cork, Ireland. *Geological Journal*, **32**, 313-335.

GIBSON, R.L., COURTNAGE, P.M. & CHARLESWORTH, E.G. 2000. Bedding-parallel shearing and related deformation in the lower Transvaal supergroup north of the Johannesburg Dome, South Africa. *South African Journal of Geology*, **102** (2), 99-108. Witwatersrand.

GELDSETZER, H.J., JAMES, N.P. & G.E. TEBBUTT (*Eds*). Reefs;

Canada and adjacent areas. *Canadian Society of Petroleum Geologists Memoir*, **13**, 1-775. Calgary.

GEORGE, T.N. & *al*. 1976. A correlation of the Dinantian rocks in the British Isles. *Special Report of the Geological Society London,* **7**, 1-86. London.

GOLONKA, J., ROSS, M.I. & SCOTESE, C.R. 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps. *In*: A.F. EMBRY, B. BEAUCHAMP & D.J. GLASS (*Eds*), PANGEA: Global Environments and Resources, *Canadian Society of Petroleum Geologists Memoir*, **17**, 1-48. Calgary.

IVANOVA, R.I. & BOGUSH, O.I. 1992. Algae as indicators of a biogeographical zonation in the Early Carboniferous of the Urals, Siberia and northeast Russia. *Facies*, **27**, 235-244. Erlangen.

KETTENBRINK, E.C. & MANGER, W.L. 1971. A deformed marine pisolite from the Plattsburg limestone (upper Pennsylvanian) of southeastern Kansas. *Journal of Sedimentary Petrology*, **41** (2), 435-443. Tulsa.

KOKOVIN, K.A. 1999. Novye dannye o vozraste bolshenadotskogo rifa (Pripolarnyj Ural). Informacionnye materialy 8-oy nautchnoy konferencii Inst. Geologii Komi Nautchnoy Centr, 97. Syktyvkar.

KORN, D. 1988. Die Goniatiten des Kulmplattenkalkes (Cephalopoda, Ammonoidea; Unterkarbon; Rheinisches Schiefergebirge). *Geologie und Paläontologie in Westfalen*, **11,** 1-293. Münster.

— 1996. Revision of the Late Viséan goniatite stratigraphy. *Annales de la Société Géologique de Belgique*, **117** (1), 205-212. Bruxelles.

— 1997. The Palaeozoic ammonoids of the South Portuguese Zone. *Memórias de Instituto Geológico e Mineiro de Portugal*, **33,** 1-132. Lisboa.

KUSINA, L. F. 1971. O nekotorykh novykh i maloizvestnykh ranevizeyskikh (saurskikh) ammonoideyakh. *Paleontologicheskiy Zhurnal*, **1971** (1), 37-48. Moskva.

— 1973. K revizii roda *Muensteroceras*. *Paleontologicheskiy Zhurnal*, **1973** (3), 14-25. Moskva.

— 1974. Saurskiy kompleks ranekamennougol'nykh ammonoidey. *Paleontologicheskiy Zhurnal*, **1974** (4), 18-31. Moskva.

— 1980. Saurskie ammonoidei. *Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR*, **181,** 1-108. Moskva.

— 1983. O nekotorykh novykh rannekamenougol'nykh ammonoideyakh Urala. *Paleontologicheskiy Zhurnal*, **1983** (4), 91-95. Moskva.

— 1987. Viseyskiy kompleks ammonoidei. *Paleontologicheskiy Zhurnal*, **1987** (2), 52-61. Moskva.

— 2000. Ammonoidei iz pogranichnykh Turneyskogo-Vizeyskikh otlozheniy Pay-Khoya i yuzhnogo Urala. *Paleontologicheskiy Zhurnal*, **2000** (5), 16-24. Moskva.

KUSINA, L. F. & YATSKOV, S. V. 1988. Rannekamenougol'nye ammonoidei Novoy Zemli. *Paleontologicheskiy Zhurnal*, **1988** (4), 28-39. Moskva.

— & — 1990. Predstavateli nadsemeystva Neoglyphioceratacea v Dombarskikh (Nizhniy Karbon) otlozheniyakh Novoy Zemli. *Trudy Paleontologicheskogo Instituta Akademiya Nauk SSSR*, **243,** 51-65. Moskva.

— & — 1999. Nizhne- i srednekamenougol'nye ammonoidei Novoy Zemli. *Trudy Paleontologicheskogo Instituta Rossiiyskaya Akademiya Nauk*, **275,** 1-144. Moskva.

LIBROVITCH, L. S. 1938. Kamennougol'nye ammonei c yuzhnogo ostrova Novoy Zemli. *Trudy Arkticheskogo Instituta*, **101,** 47-107. Leningrad.

— 1941. Otryad Ammonoidea. In: Atlas rukovodyashchikh form iskopaemykh faun SSSR, t. IV. Nizhniy otdel kamennougol'noy sistemy. *Gosgeolizdat*, 137-153. Moskva-Leningrad.

LIBROVITCH, L. S., POPOV, A. V. & KUSINA, L. F. 1993. Novye ammonoidei iz Karbona Novoy Zemli. *Paleontologicheskiy Zhurnal*, **1993** (3), 37-48. Moskva.

MCCROSSAN, R.G. 1958. Sedimentary "boudinage" structures in the Upper Devonian Ireton Formation of Alberta. *Journal of Sedimentary Petrology*, **28** (3), 316-320. Tulsa.

MAMET, B. 1992. Paléogéographie des algues calcaires marines carbonifères. *Canadian Journal of Earth Sciences,* **29** (1), 174-194. Ottawa.

MAMET, B. & ROUX, A. 1975. Algues dévoniennes et carboniferes de la Téthys Occidentale. Troisieme partie. *Revue de Micropaléontologie*, **18** (3), 134-187. Paris.

MCKERROW, W.S. & SCOTESE, C.R. 1990. Palaeozoic Biogeography and Paleogeography, *Geological Society of London Memoir*, **12**, 1-435. London.

PAPROTH, E. & *al.* 1983. Bio- and lithostratigraphic subdivisions of the Dinantian in Belgium, a review. *Annales de la Société Géologique de Belgique*, **106**, 185-239. Bruxelles.

POLETAEV, V.I., BRAZHNIKOVA, N.E., VASILYUK, N.P. & VDOVENKO, M.V. 1990. Local zones and major Carboniferous biostratigraphic boundaries of the Donets Basin (Donbass), Ukraine, U.S.S.R. *Courier Forschungsinstitut Senckenberg*, **130**, 47-59. Frankfurt a. Mein.

RADWAŃSKI, A. & BIRKENMAJER, K. 1977. Oolitic/pisolitic dolostones from the Late Precambrian of south Spitsbergen: their sedimentary environment and diagenesis. *Acta Geologica Polonica*, **27** (1), 1-40. Warszawa.

RIDING, R. 1991. Calcified Cyanobacteria. *In*: R. RIDING (*Ed.*) Calcareous Algae and Stromatolites, 55-87. *Springer Verlag*; New York – Heidelberg – Berlin.

RILEY, N. J. 1993. Dinantian (Lower Carboniferous) biostratigraphy and chronostratigraphy in the British Isles. *Journal of the Geological Society, London*, **150**, 427-446. London.

RUZHENCEV, V. E. & BOGOSLOVSKAYA, M. F. 1971. Namyurskiy etap v evolyutsii ammonoidey. Rannenamyurskie ammonoidei. *Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR*, **133,** 1-382. Moskva.

SCOTESE, C.R. & MCKERROW, W.S. 1990. Revised World maps and introduction. *In*: W.S. MCKERROW & C.R.

SCOTESE (*Eds*), Palaeozoic Palaeogeography and Biogeography, *Geological Society London, Memoir*, **12**, 1-21. London.

SKOMPSKI, S. 1996. Stratigraphic position and facies significance of the limestone bands in the subsurface Carboniferous succession of the Lublin Upland. *Acta Geologica Polonica,* **46** (3-4), 171-268. Warszawa.

SKOMPSKI, S., ALEKSEEV, A., MEISCHNER, D., NEMIROVSKAYA, T., PERRET, M-F. & VARKER, W.J. 1995. Conodont distribution across the Viséan and Namurian boundary. *Courier Forschungsinstitut Senckenberg*, **188**, 117-209. Frankfurt a. Mein.

SKOMPSKI, S. & ŻYWIECKI, M. 1997. A Waulsortian-like mound in the Lower Namurian of the Lublin Basin (E. Poland). *18th Inter. Ass. Sediment. Reg. European Meeting, Heidelberg 1997, Abstracts,* p. 316. Heidelberg.

SOBOLEV, D.B., ZHURAVLEV, A.V., KARMANOV, R.S. & GRUZDEV, D.A. 2000. Novye dannye o geologitcheskom stroenii rayona Bolshenadotskogo rifa (Pripolarnyj Ural). *Vestnik Instituta Geologii, Ros. Akad. Nauk, Uralskoe Otdel., Komi Nautchnyj Centr,* **2000** (8), 6-7. Syktyvkar.

SOKOLOV, B.S. (*Ed.*) 1986. Fanerozoyskiye rify i korally SSSR (Trudy V vsesoyuznogo simpoziuma po korallam i rifam, Dushanbe, 1983). 1-232. *Nauka*; Moskva.

SOMERVILLE, I.D. 2000. Review of Irish Lower Carboniferous (Mississippian) mud-mounds: depositional setting, biota, facies and evolution. *Abstracts of SEPM-IAS Research Conference on Permo-Carboniferous Platforms and Reefs*, p. 135, El Paso.

SOMERVILLE, I.D., PICKARD, N.A.H., STROGEN, P. & JONES, G. LL. 1992. Early to mid-Viséan shallow water platform buildups, north Co. Dublin, Ireland. *Geological Journal*, **27**, 151-172. London.

SOMERVILLE, I.D., STROGEN, P., JONES, G. LL. & SOMERVILLE, H.E.A. 1996. Late Viséan buildups at Kingscourt, Ireland: possible precursor for Upper Carboniferous bioherms. *In*: STROGEN, P., SOMERVILLE, I.D. & JONES, G. LL. (*Eds*), Recent Advances in Lower Carboniferous Geology, *Geological Society Special Publications*, **107**, 127-144. London.

SZULCZEWSKI, M. 1971. Upper Devonian conodonts, stratigraphy and facial development in the Holy Cross Mts. *Acta Geologica Polonica,* **21** (1), 1-129. Warszawa.

— 1973. Famennian-Tournaisian neptunian dykes and their conodont fauna from Dalnia in the Holy Cross Mts. *Acta Geologica Polonica*, **23** (1), 15-59. Warszawa.

— 1995. Depositional evolution of the Holy Cross Mts. (Poland) in the Devonian and Carboniferous – a review. *Geological Quarterly*, **39** (4), 471-488. Warszawa.

VOJNOVSKIJ-KRIGER, K.G. 1962. Devonskie otlozhenija lemvinskoy facjalno-strukturnoy zony i prilegayustchikh rajonow (zapadnyj sklon polyarnogo Urala). *Biuleten Moskovskogo Obstchestva Ispytateley Prirody,* **37** (2), 103-123. Moskva.

WEBB, G.E. 1999. Youngest early Carboniferous (late Viséan) shallow-water patch reefs in eastern Australia (Rockhampton Group, Queensland): combining quantitative micro- and macro-scale data. *Facies*, **41**, 111-139. Erlangen.

WILSON, J.L. 1975. Carbonate facies in geologic history. 1-471. *Springer*; New York – Heidelberg – Berlin.

ZDANOWSKI, A. & ŻAKOWA, H. (*Eds*) 1995. The Carboniferous system in Poland. *Prace Państwowego Instytutu Geologicznego*, **148**, 1-215. Warszawa.

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Appendix - Occurrences of foraminifers in BNCC

sample	BN 8d/6		BN4/6	BN4/8	BN4h	BN5/1	BN5/4	BN6/3	BN7/1	BN7/2
zone	Cf6									
Vicinesphaera sp.		+				+			+	
Parathurammina sp.		+	+							
Caligella sp.				+						
Eotuberitina sp.		+		+		+	+		+	+
Pseudoglomospira sp.		+			+					
Brunsia sp.					+					
Koskinotextularia sp.	+			+	+		+			+
Plectogyranopsis exelicta (Con. et Lys)	+					+				+
Plectogyranopsis sp.		cf.	+							
Pseudoammodiscus volgensis (Rauz.-Chern.)		+								+
Latiendothyranopsis sp.		+								
Endothyranopsinae								+		
Cribrospira sp.				+						
Priscella prisca (Rauz.-Chern. et Reitl.)	+		+				+			+
Pseudolituotuba sp.	+				+	+		+		
Vissariotaxis exilis (Viss.)	+									
Lituotubellinae		+			+	+			+	
Archaediscidae					+	+				+
Archaediscus convexus Gr.et Leb. v. *declinata* Con. et Lys.		+								
Tetrataxis sp.					+			+		+
Scalebrina sp.			+							
Neoarchaediscus sp.		+					+	cf.		?
Neoarchaediscus incertys (Gro. et Leb.)			+	+						
Plectogyra uva Con. et Lys		cf.							+	
Endothyra sp.		+		+			+	+		
Endothyra baschkirica Pot.			cf.							
Endothyra ex gr. *excellens* (Zell.)			+							
Endothyra ex gr.*spira* (Con. et Lys)					+					
Planoendothyra spirilliniformis (Brazhn. et Pot.)			+							
Planoendothyra ex gr. *aljutovica* Reitl.					+					
Planoendothyra sp.								+		
Vissariotaxis compressa (Brazhn.)		+								
Bisphaera sp.							+			
Eostaffella proikensis Rauz.						+				+
Eostaffella parastruvei Rauz.-Chern.						+				+
Mediocris mediocris Viss.			+					+		
Omphalotis minima (Rauz.-Chern. et Reitl.)						+	+		+	+
Forschia subangulata (Moell.)						+				+
Forschiinae						+			+	
Tetrataxis paraminimus Viss.						+				+
Endothyra bradyi Mikh.						+		+	+	+
Endothyra obsoleta Rauz.-Chern.			+			+			+	+
Bradyina rotula (Eichw.)					+				+	+
Janischewskina operculata (Rauz. et Reitl.)					+					
Endostaffella parva (Moell.)						+	+		+	
Palaeotextularia consobrina					+					
Palaeotextularia longiseptata Lip.					+					
Koskinobigenerina sp.					+					
Palaeotextularidae								+		
Archaediscus krestovnikovi Rauz.-Chern.			+		+		+	+		+
Archaediscus mellitus Schlyk.			+							
Archaediscus pauxillus Schlyk.				+				+		

Archaediscus ex gr.karreri Brady								+		
Planoarchaediscus spirillinoides (Rauz.-Chern.)			+							
Asteroarchaediscus sp.		cf.	cf.		+		+	cf.	+	
Neoarchaediscus probatus (Reitl.)							+	+		
Eosigmoilina sp.			cf.	cf.						
Millerella sp.				+					+	
Eostaffella sp.					+		+	+	+	+
Eostaffella pseudostruvei (Rauz.)				+						
Pseudoendothyra sp.							+		+	
Endothyranopsis crassa (Brady)					+		+		+	+
Eolasiodiscus sp.							+			
Howchinia bradyana (How.)							+			
Howchinia gibba (Moell.)							+			
Howchinia sp.							+			
Tetrataxis gradi Con. et Lys							+			
Earlandia sp.			+	+			+		+	
Saccamminopsis sp.							+			
Climacammina sp.			+		+				+	
Eostaffella mosquensis Viss.									+	+
Haplophragmella sp.									+	+
Palaeotextularia lipinae Con. et Lys									+	
Earlandia vulgaris (Rauz.-Chern.et Reitl.)										+
Climacammina prisca Lip.										+
Palaeotextularia gibbosa d`Orb.v .*minima* Lip										+
Globoendothyra globulus (Eichw.)								+		+
Globoendothyra sp.					+					
Bradyina sp.					cf.				+	+
Permodicus vetustus Dutk.										+.
Asteroarchaediscus rugosus (Rauz.-Chern.)										+
Pseudoendothyra sublimis (Schlyk.)								+		+

PLATE 1

1 – Bol'shaya Nadota section, Locality 9 – view from NW; arrows indicate horizons with Devonian (black arrow) and Carboniferous brachiopods (white arrow); cf. the schematic diagram (Text-fig. 3) identifying lithological units 1-5; approximate height of cliff face = 20 m.

2 – Bol'shaya Nadota section, klippes in Locality 8, composed mainly of Givetian/Frasnian stromatoporoid limestone – the view from W; a red tent on the left-hand side of photo as a scale; the upper part of the Olysya Hill (above the klippes) is composed of Carboniferous sediments (arrowed).

3 – Bol'shaya Nadota section, klippes in Locality 8 – view from N, the uppermost part of the rocky walls is composed of Carboniferous sediments (arrowed); approximate height of cliff face = 40 m.

PLATE 2

1 – Bol'shaya Nadota section, Locality 7 – view from S; Upper Viséan oolitic-organodetrital packstones intercalated with brecciated parts; the geologist is 1.8 m high.

2 – Bol'shaya Nadota section, Locality 5 – view from S; tectonic contact of well-bedded Upper Viséan organodetrital limestones with breccias, cf. scheme in Text-fig. 5; the geologist is 1.8 m high.

3 – Upper Viséan organodetrital limestones with productid coquina – Bol'shaya Nadota section, Locality 7, scale bar = 5 cm.

4 – fragment of breccia with pisolitic clasts – Bol'shaya Nadota section, Locality 5; scale bar = 5 cm.


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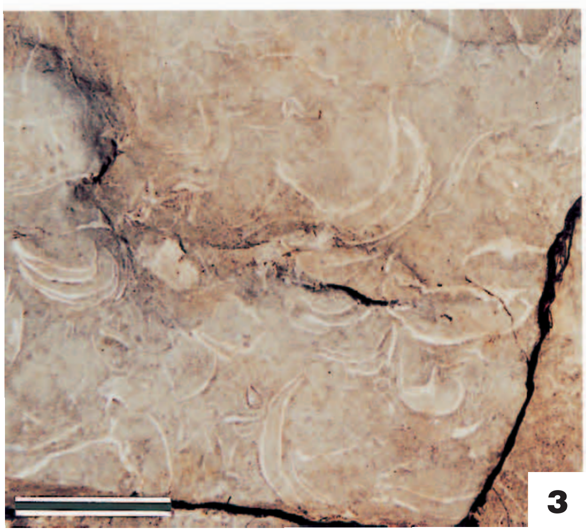
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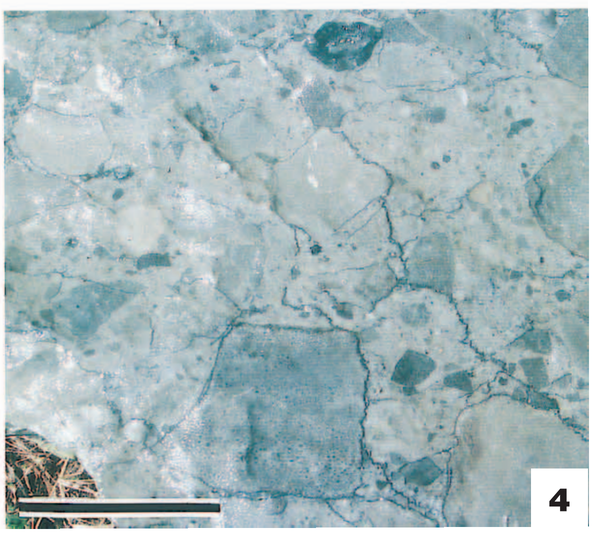
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PLATE 3

Scale bar = 3 cm

1-2 – Upper Viséan cephalopod-bivalve coquina; polished slabs, Locality 8.

3-4 – Biolithite, strongly cemented and partly dolomitized fragments from the single klippes within the Upper Viséan complex; polished slab, Locality 9.

5 – Upper Viséan brachiopod-algal biolithite; polished slab of a clast in the breccia (Locality 5).

6 – Givetian/Frasnian stromatoporoid biolithite; polished slab, Locality 8.

7 – Upper Viséan strongly cemented and dolomitized coral biolithite; polished slab, Locality 7.

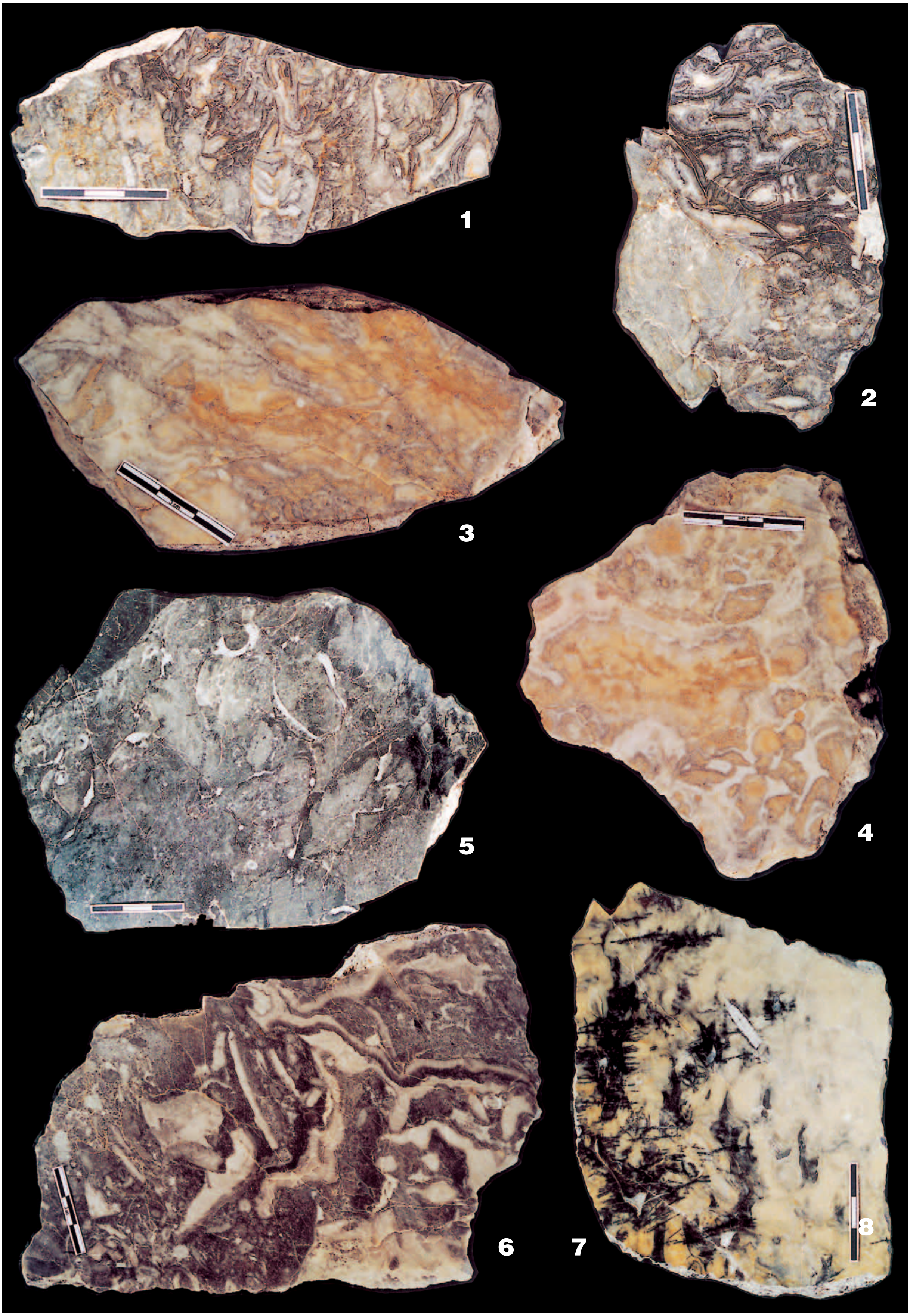
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PLATE 4

1, 3-4 – Famennian - ?Tournaisian distorted ooids; as a result of “sedimentary-boudinage” some of the ooids developed the “snouted” form (arrowed on Figs 3 and 4); Locality 9, layer no. 3 on Text-fig. 3; scale bar = 1 mm.

2 – fragment of breccia with undeformed oolitic clasts and dolomitized matrix; Locality 6, sample 6g; scale bar = 1 mm.

5-6 – Frasnian calcispherid-crinoidal wackestone, typical of the cover of stromatoporoid bioherms; sometimes strongly dolomitized; Locality 8, scale bar = 1 mm.

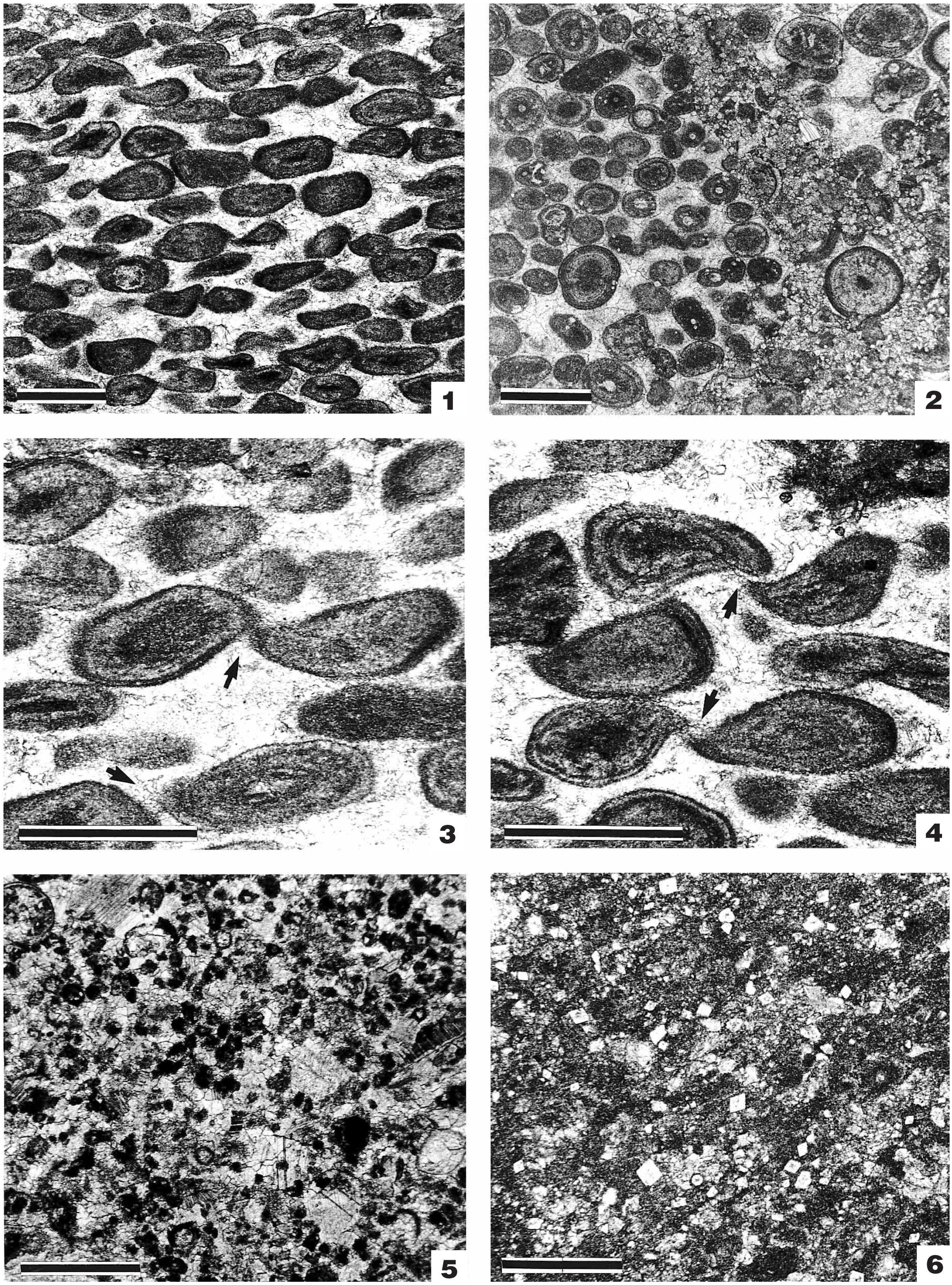
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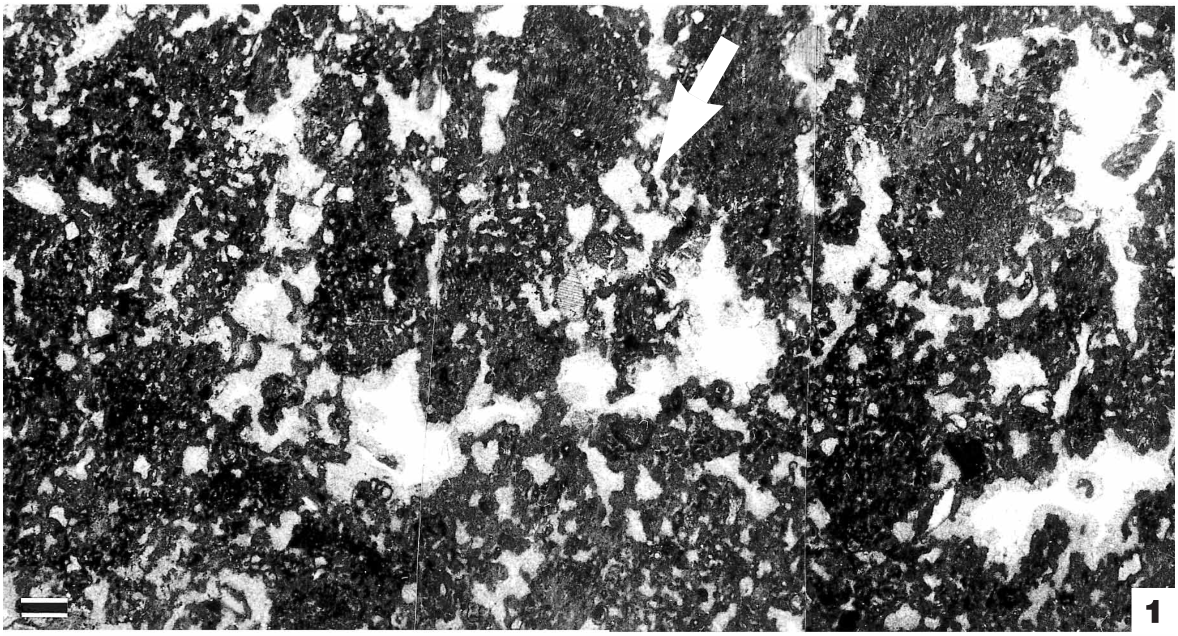
PLATE 5

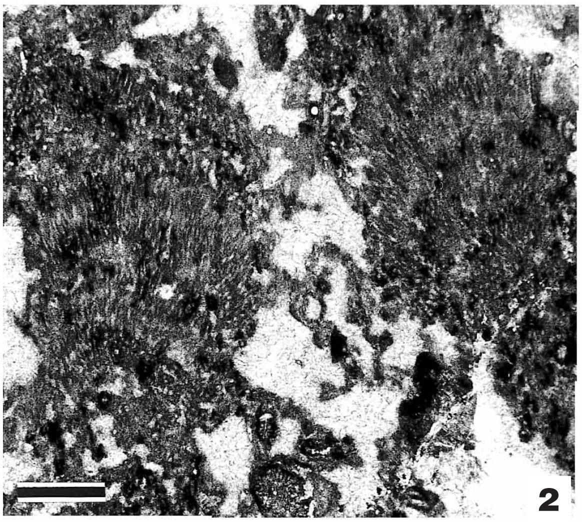
1 – Fragment of small ortonellid buildup with ‘algal’ columnals in growth position and multistage cementation in cavities; Locality 7, sample 7g; arrow indicates the part enlarged on Fig. 2; scale bar = 1 mm.

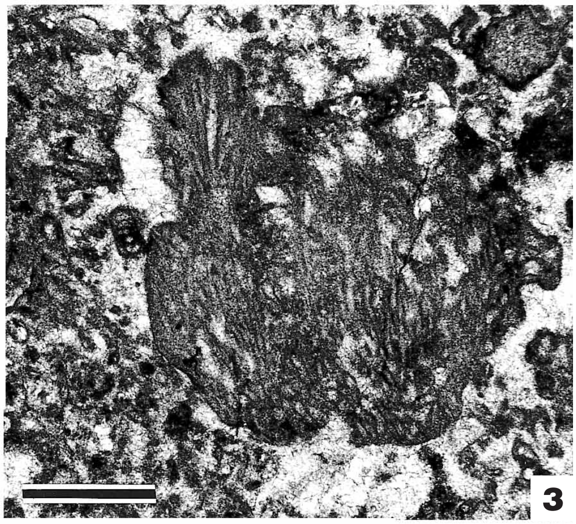
2 – *Ortonella kershopensis* GARWOOD (enlarged part of Fig. 1).

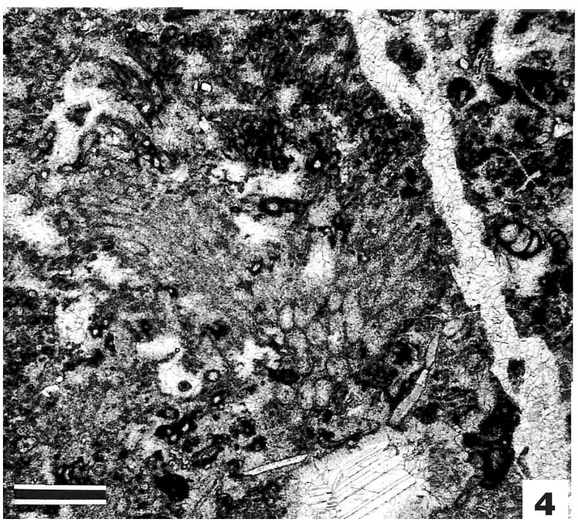
3 – *Ortonella* cf. *kershopensis* GARWOOD; Locality 7, sample 7c; scale bar = 1 mm.

4-5 – *Ortonella furcata* GARWOOD; Locality 7, sample 7b (Fig. 4), sample 7j (Fig. 5); scale bar = 1 mm.









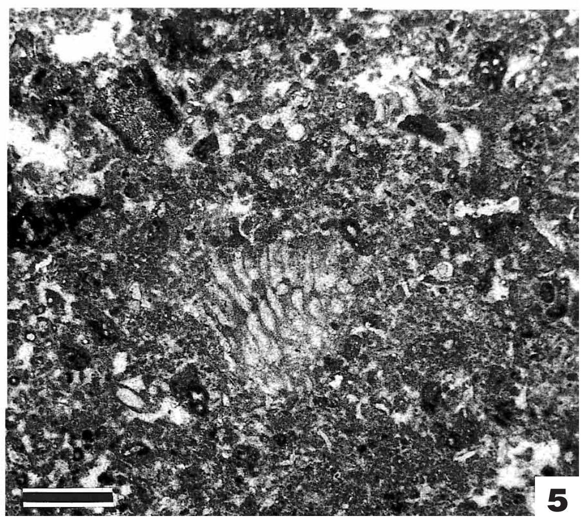


PLATE 6

1 – *Ortonella* sp. and *Masloviporidium delicata* (BERCHENKO); Locality 7, sample 7c; scale bar = 2 mm.

2 – *Garwoodia gregaria* (NICHOLSON); Locality 7, sample 7i, scale bar = 1 mm.

3-4 – *Koninckopora* sp. in organodetrital-oolitic packstones; Locality 7, samples 7e, 7c; scale bar = 1 mm.

5 – Upper Viséan basal breccia with undeformed oolitic clasts; Locality 9, layer 4 (comp. Text-fig. 3; scale bar = 1 mm.

6 – Recrystallized and partly dolomitized Devonian amphiporoid floatstones; Locality 8, sample 8/2; scale bar = 1 mm.

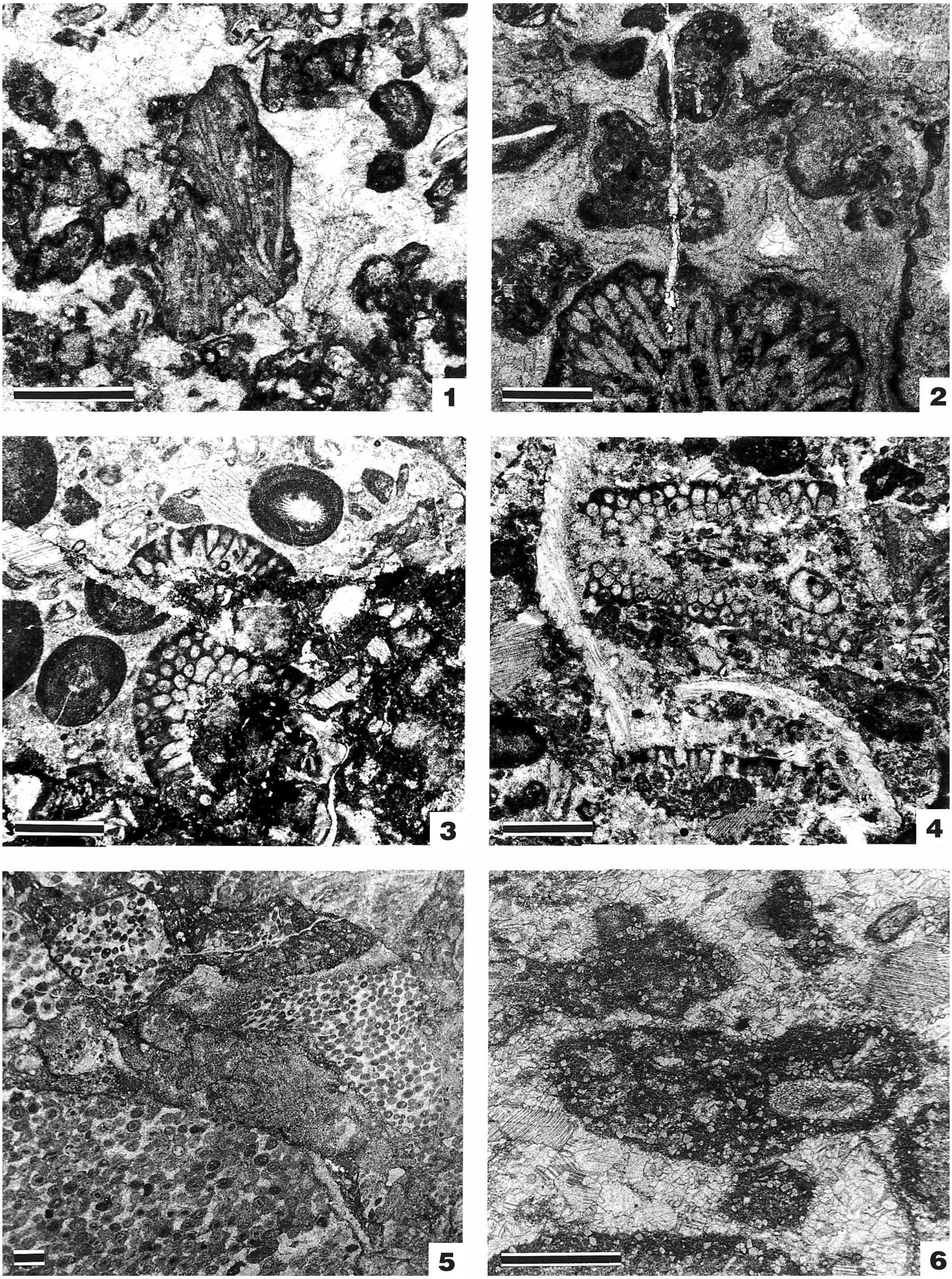


PLATE 7

1-2 – Infilling of neptunian dyke with ostracods and juvenile goniatites penetrated by *Trypanites*-like borings infilled with oolitic material; clast from breccia; Locality 4, sample 4a/1; scale bar = 1 mm.

3 – Algal incrustation on the surface of solitary coral; Locality 7, sample 7/2c, scale bar = 1 mm.

4 – Renalcid forms; Upper Viséan; Locality 6, sample 6g, scale bar = 1 mm.

5 – Algal-foraminiferal-crinoid grainstone typical of the Upper Viséan microfacies; Locality 7; scale bar = 1 mm.

6 – *Eovelebitella* sp.; clast from breccia, Locality 4, sample 4h, scale bar = 1 mm.

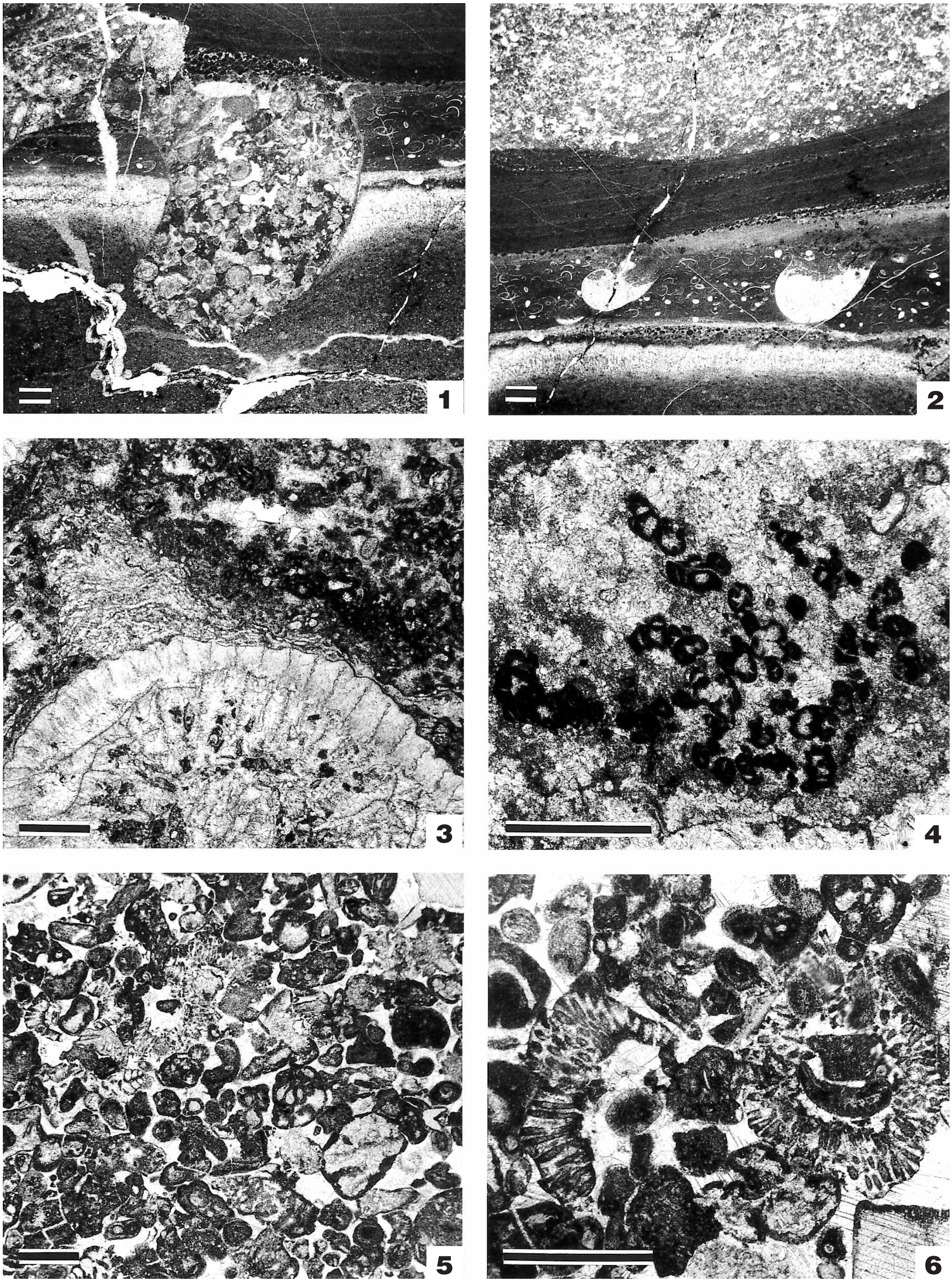

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PLATE 8

Late Viséan ammonoids from the Bol’shaya Nadota section, Locality 8 on the slope of Olysya Hill (Subpolar Urals)

A – *Praedaraelites* sp.; GPIT 1874-01; × 1.5.
B – *Girtyoceras* sp.; GPIT 1874-09; × 2.
C – *Goniatites olysya* sp. nov.; dorsal view of paratype GPIT 1874-12; , × 1.
D – *Goniatites olysya* sp. nov.; holotype GPIT 1874-11; × 1.
E – *Goniatites olysya* sp. nov.; dorsal view of the spindle-shaped paratype GPIT 1874-14; × 1.75.
F – *Goniatites olysya* sp. nov.; dorsal view of the globular paratype paratype GPIT 1874-15; × 1.75.
G – *Goniatites olysya* sp. nov.; paratype GPIT 1874-13; × 1.
H – *Goniatites olysya* sp. nov.; paratype GPIT 1874-18; × 1.5.
I – *Lusitanoceras kusinae* sp. nov.; holotype GPIT 1874-39; × 1.25.
J – *Lusitanoceras kusinae* sp. nov.; paratype GPIT 1874-40; × 2.

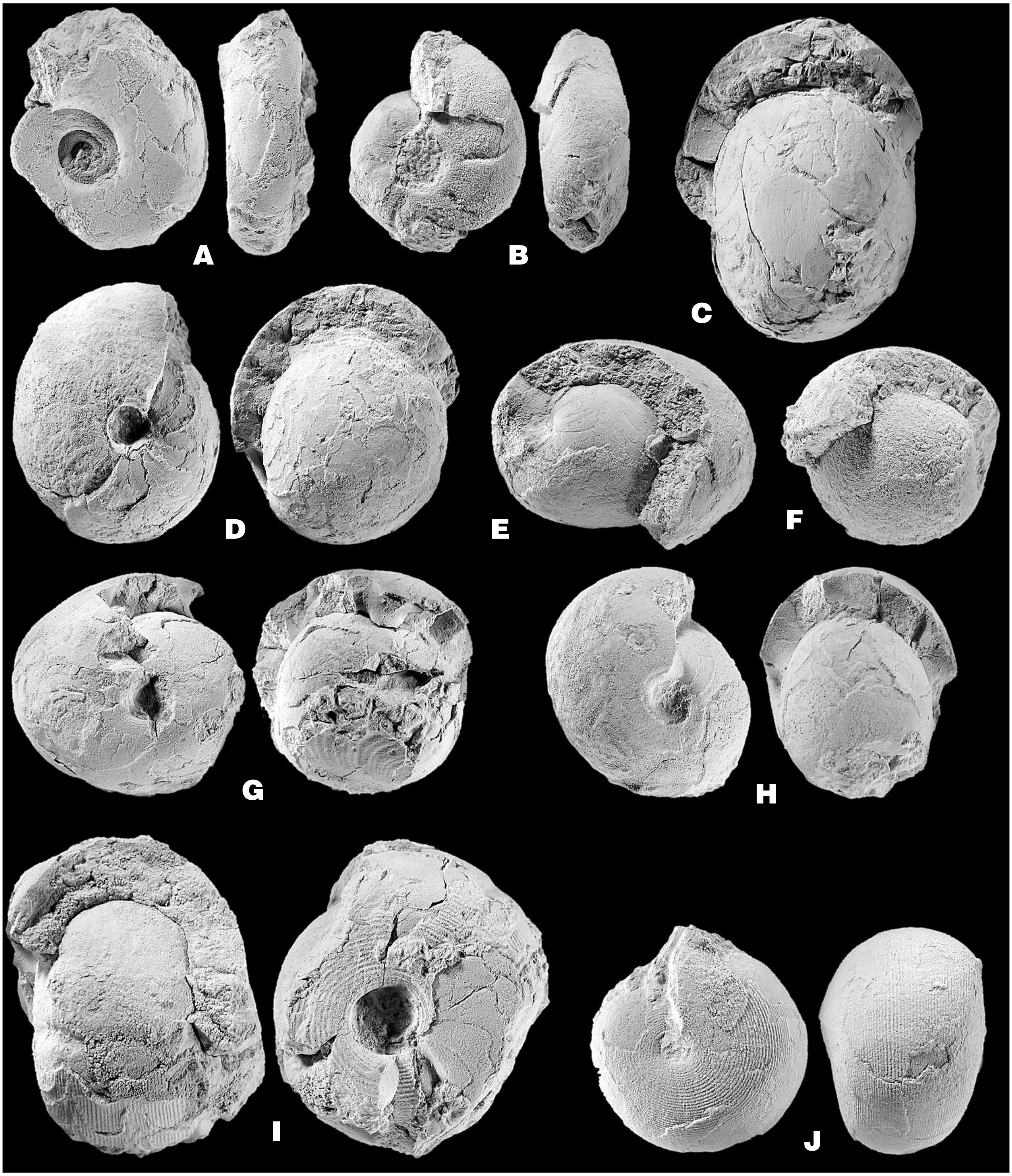


PLATE 9

Devonian (Figs 1-3) and Carboniferous (4-6) corals from Bol'shaya Nadota section, Subpolar Urals

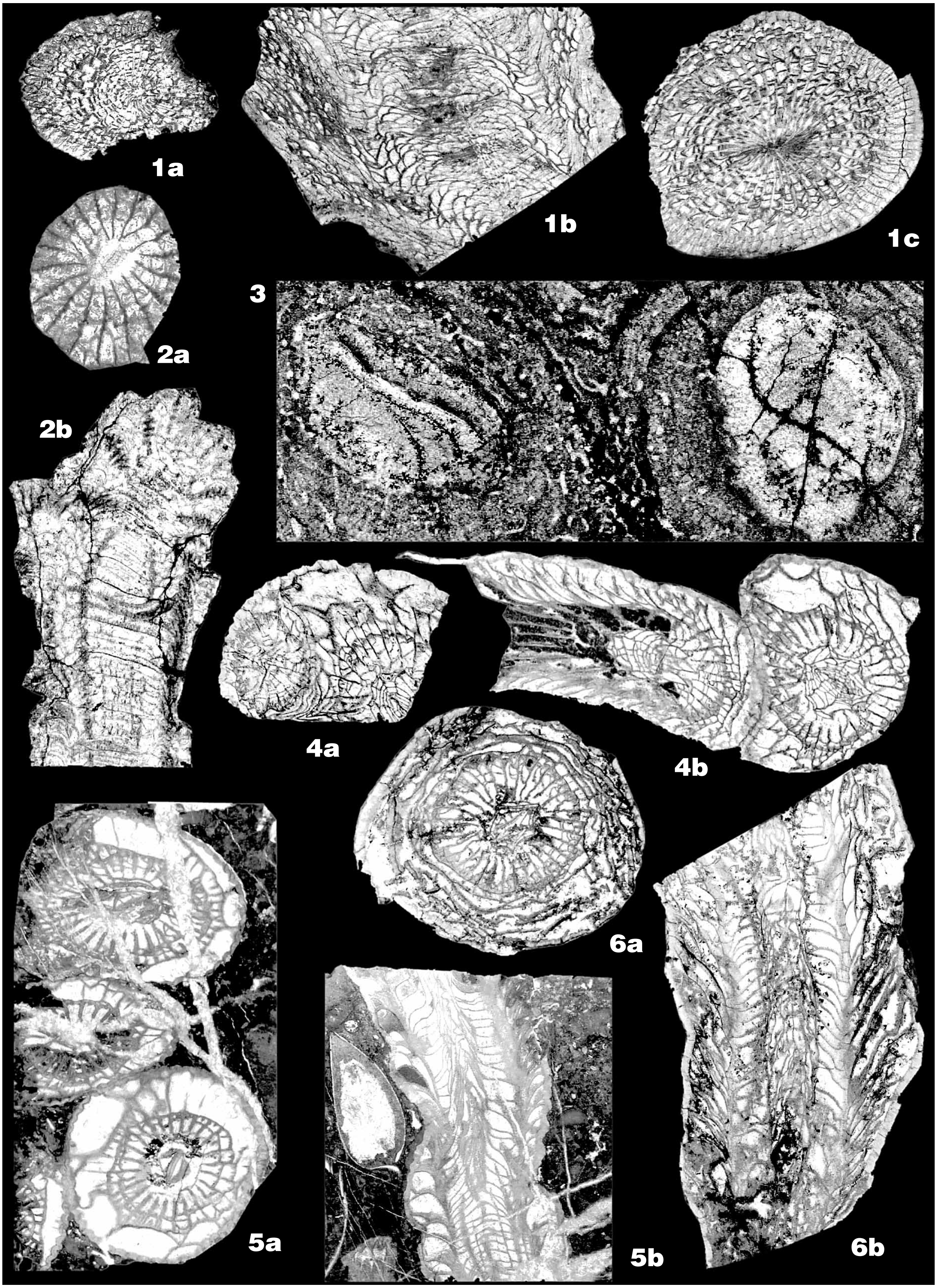
1 – *Temnophyllum*? sp., Middle/?Upper Devonian, specimen BNA07H, magnified × 3: 1a – proximal transverse section; 1b – longitudinal section; 1c – distal transverse section.

2 – *Peneckiella* sp., ?Frasnian, specimen BNA11, magnified × 5: a – transverse; 2b – longitudinal section.

3 – *Natalophyllum* sp., Middle/?Devonian – branches of tabulate colonies overgrown by massive stromatoporoid, magnified × 5.

4-5 – *Lonsdaleia* cf. *duplicata*, uppermost Viséan or Lowermost Namurian (Brigantian – Serpukhovian), magnified × 3; Fig. 4 - specimen BNA07C: 4a – proximal, 4b – distal section through branching corallite, the latter with oblique-longitudinal section of an offset; Fig. 5 – specimen BNA06-0: 5a – transverse, 5b – longitudinal section.

6 – *Axophyllum* sp., uppermost Viséan or Lowermost Namurian (Brigantian – Serpukhovian), specimen BNA08', magnified × 3: 6a – transverse, 6b – longitudinal section.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1c
2a
2b
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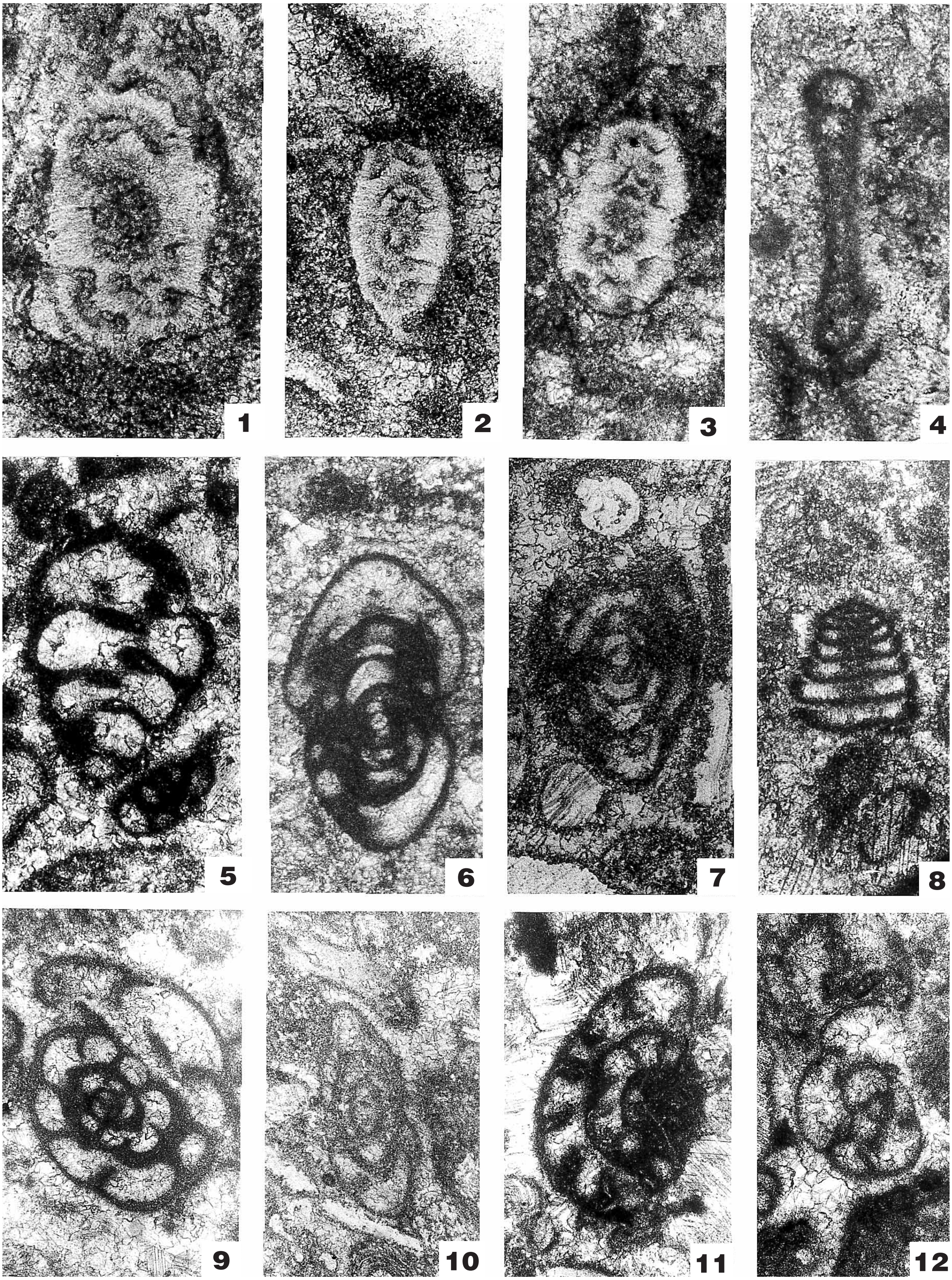
4a
4b
5a
5b
6a
6b

PLATE 10

Upper Viséan foraminifers from the Bol'shaya Nadota section, Subpolar Urals

1 – *Neoarchaediscus probatus* (REITLINGER); Locality 5, sample 5/4, × 190.
2 – *Permodiscus vetustus* DURKINA; Locality 7, sample 7/2, × 190.
3 – *Asteroarchaediscus rugosus* (RAUSER-CHERNOUSSOVA); Locality 7, sample 7/2, × 190.
4 – *Eolasiodiscus* sp.; Locality 5, sample 5/4, × 190.
5 – *Palaeotextularia gibbosa* D'ORBIGNY var. *minima* LIPINA.; Locality 7, sample 7/2, × 95.
6 – *Eostaffella parastruvei* RAUSER-CHERNOUSSOVA, Locality 7; sample 7/2, × 95.
7 – *Eostaffella proikensis* RAUSER-CHERNOUSSOVA; Locality 7, sample 7/2, × 95.
8 – *Howchinia bradyana* (HOWCHIN); Locality 5; sample 5/4, × 95.
9 – *Omphalotis minima* (RAUSER-CHERNOUSSOVA & REITLINGER); Locality 7; sample 7/1, × 50.
10 – *Pseudoendothyra sublimis* (SCHLYKOVA); Locality 7, sample 7/2, × 50.
11 – *Endothyranopsis crassa* (BRADY); Locality 7; sample 7/2, × 50.
12 – *Plectogyra uva* CONIL & LYS, Locality 7, sample 7/1, × 50.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