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Ordovician Reefs of the Ural Mountains, Russia: A Review

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KEYWORDS: REEFS – REEF BIOTA – PALEOGEOGRAPHY – URALS – LATE ORDOVICIAN

Summary

The Upper Ordovician reefs of the Urals were formed at a subsiding shelf-margin during an early Late Ashgillian (Sur'ya time interval) regressive phase. Reefs of this age were studied in detail from the western slope of the Northern, the Subpolar and the Polar Urals with respect to lithofacies, biotic composition and paleogeographical patterns. The thickness of the reefs varies between 100 and 500 m. The backreef areas are characterized by lagoons with increased salinity and sabkha development. Microbial associations and a diverse algal flora (Cyanophyta, green and red algae and alga incertae sedis) are the main constituents of reefal boundstones. Tabulate and rugose corals, heliolitids, calcareous sponge-like fossils, bryozoans and problematic hydroids were also part of the reef communities. Each reef exhibits a characteristic framework-building association. Reef development was terminated by a rapid and abrupt sea-level rise at the end of the middle Upper Ashgillian connected with the global Late Ordovician glaciation.

Introduction

Ordovician reefs are known from Northern and Southern America, Europe, Siberia, China and Australia (WEBBY 1984, CECILE 1989, KELLER & FLÜGEL 1995). Russian reefs have been studied for many years but the results are only partly known in the non-Russian-speaking scientific community. Therefore, it is of interest to make a short review of these studies.

The Ordovician organic buildups and reefs of the Urals have been studied since the end of the 1980's with regard to their paleontological, sedimentological and diagenetic criteria. However, the Ashgillian biohermal limestones from the western slope of the Northern Urals were known even earlier in stratigraphic papers (JORDANSKY (1928, KONDIAYN 1967). Biohermal limestones of Arenigian age and reefoid Tremadocian limestones of the Southern Urals were mentioned by VARGANOV et al. (1973). Later, Middle to Upper Ordovician reef carbonates of the eastern slope of the Southern Urals, Lower Caradocian biostromes, and small Caradocian bioherms from the western slope of the Southern and Subpolar Urals were described (SHYSKIY & KLYUZHINA, 1989). Conodont data proved the stratigraphically lower part of the reef-bearing unit of the Subpolar Urals to be Upper Ordovician in age (MELNIKOV, 1986; OPORNYE 1987: Tab. 19) and not Ludlowian as believed up until then. The Ashgillian reefs of the western slope of the Northern, Subpolar and Polar Urals (Fig. 1) have been the subject of current studies (ANTOSHKINA, 1987, 1988, 1992a, b, 1994; ANTOHKINA & ELISEEV, 1988; SHSYSKIY & KLYUZHINA, 1989).

Geologic and paleogeographic setting

The initial stage of the Ordovician history of the Urals was characterized by the opening of the Urals paleo-ocean. A continental slope was formed during the Middle Ordovician in the area of today's western slope in the northern part of the Urals. A shallow-water carbonate platform extended westward from this slope. Before the Upper Ashgillian, this sedimentary basin exhibited a ramp margin with small organic buildups. At the beginning of the Upper Ashgillian the shelf break had been formed and controlled the tectonic as well as paleogeographic position of the Upper Ordovician reefs. A backreef shelf was characterized by lagoons and sabkhas (Fig. 1b). Ashgillian carbonate-evaporite formations of the Pre-Urals fore-deep known only from subsurface data, occur in the Pechora Urals and the Pechora Syneclise. Thicknesses range from 120 to 470 m.

Stratigraphy

The Upper Ashgillian age of the massive light-gray reefal carbonates (corresponding to the Sur'ya unit of the western slope of the Urals, cf. Table 1) is based on conodont

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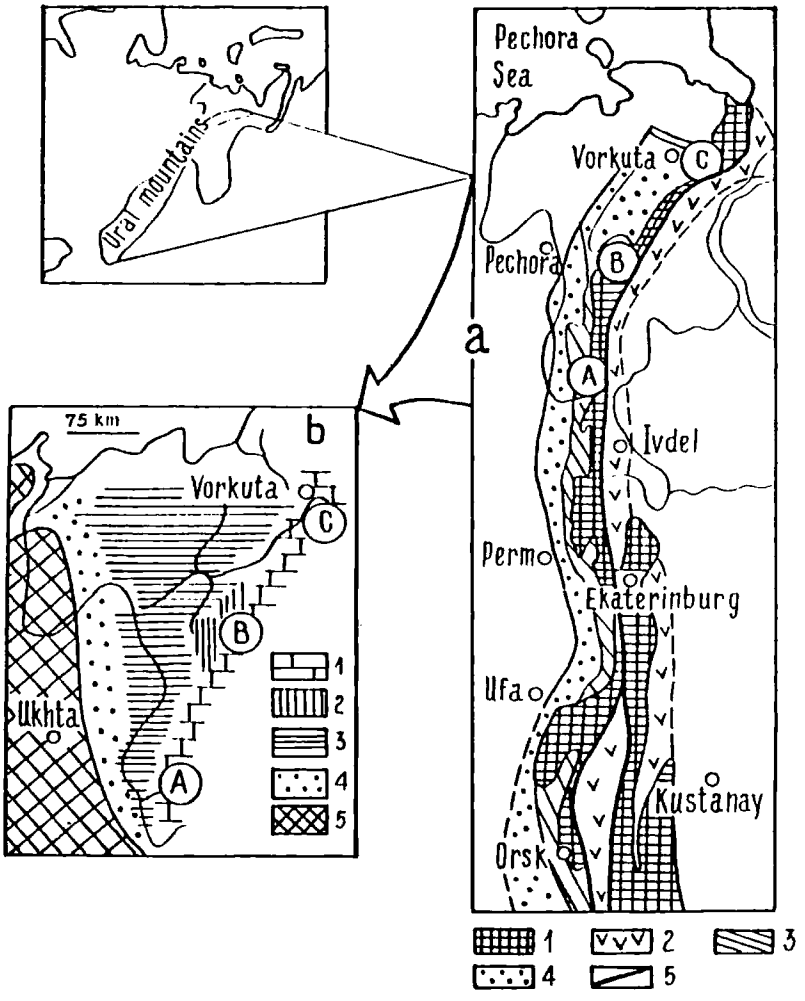


Fig. 1. Map of the area
(a) at reef locations A, B and C and
(b) with the lithology and paleogeography for the time of the reef growth (Late Ashgillian, Sur'ya time).
(a) 1 - outcrops of the Pre-Cambrian and of the large granitoid massives, 2 - Eastern Uralian Volcanic Zone, 3 - Western Uralian Zone, 4 - Pre-Urals Foredeep, 5 - Major Uralian Thrust. A - Ilych River, B - Kozhym River, C - Lek-Elec River.
(b) 1 - carbonate zone with reefs, 2 - lagoonal backreef area (laminated dolomites and mudstones), 3 - hypersaline lagoon, sabkha (micritic dolomites, anhydrite, rarely salt), 4 - coastal plain (sandstones, siltstones, argillites, dolomites and anhydrite), 5 - land.

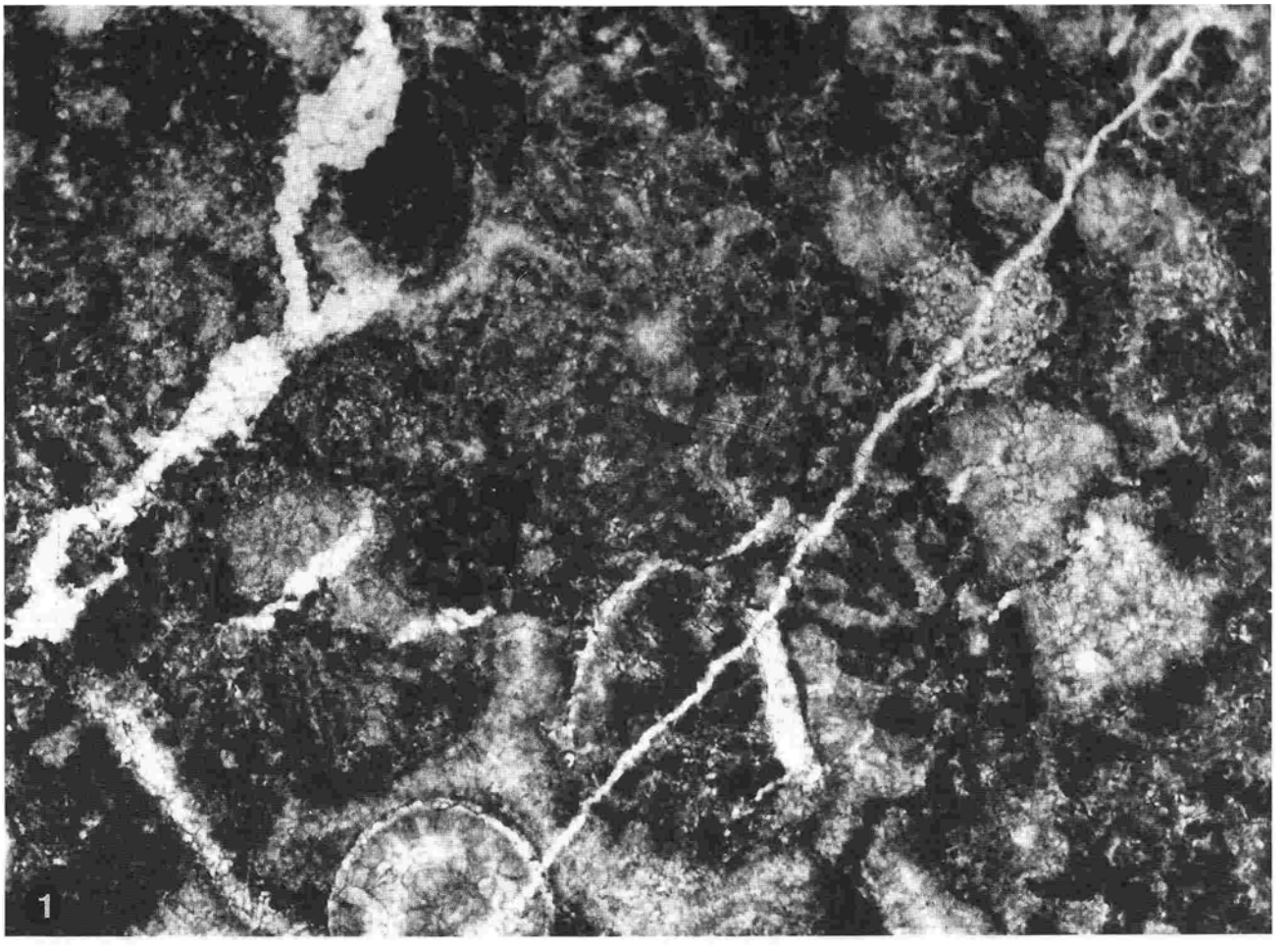
data (*Amorphognathus ordovicicus* BRANSON & MEHL, *Strachonognathus parvus* RHODES, *Phragmodus insculptus* BRANSON & MEHL), tabulate corals (*Palaeofavosites* cf. *alveolaris* (GOLDFUSS), *Grewingkia* cf. *altaica* (TSCHEREPNINA), *Eocatenipora* sp.), heliolitids (*Heliolites* aff. *paopensis* SOKOLOV, *Plasmoporella* sp., *Trochiscolites* sp., *Propora* sp., *Sinopora* sp.) and trilobites. The underlying strata can be correlated with the Poluda Horizon of the Urals (Table 1). They are represented by bedded, bioturbated dark-gray mudstones and wackestones with nodular cherts. Erosional pockets, up to 1.5-2 cm deep, filled with lithoclastic sandstones and conglomerates occur in the upper part of these strata, which also contain crinoids (*Dentiferocrinus dividus* (YELTSIN), *D. subdividus* MILCINA, *Pentagonocrinus* sp.), conodonts (*Aphelognathus shoanensis* SWEET, *Plecodina* sp.) as well as unidentified small brachiopods and bryozoans. The reef carbonates are overlain by dark-gray, in places clayey, bioturbated organogenous limestones and secondary dolomites, yielding a diverse Upper Ashgillian benthic fauna with brachiopods (*Holorynchus* cf. *giganteus* KIAER, *Proconchidium* cf *muensteri* (ST. JOZEPH) and *conodonts* (*Belodina confluens* SWEET). Brachiopod coquinas formed predominantly by broken shells were observed more to the west. These beds correspond to the Kyr'ya horizon of the Urals (Table 1).

Plate 1 Ordovician reef carbonates and biota from the Northern and Polar Urals. Upper Ashgillian, Sur'ya Horizon. Thin-sections

Fig. 1. Dolomitized algal boundstone with *Girvanella* (right), *Hedstroemia* (left) *Garwoodia?* (center right) and unidentified microbes. Polar Urals, Lek Elec River. Sample 17/286. x 24

Fig. 2. Coral-algal boundstone with *Sinopora* sp. (white)) encrusted by *Renalcis* and other calcified microbes. Northern Urals, Ilych River. Sample 9/442. x 15

Fig. 3. *Propora* sp. covered by crusts of unidentified microbial material. Northern Urals, Ilych River. Sample 9/439. x 8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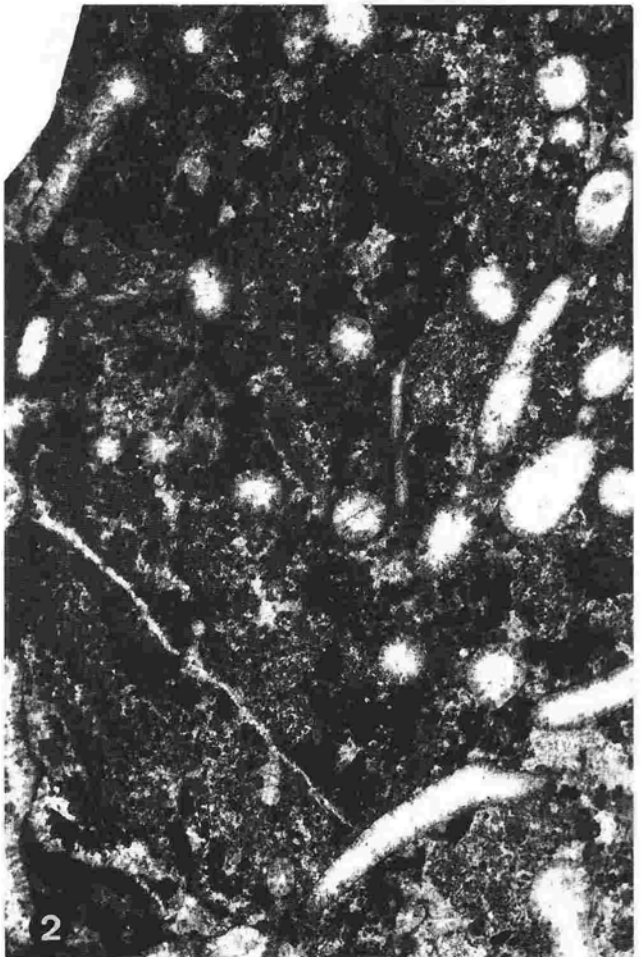
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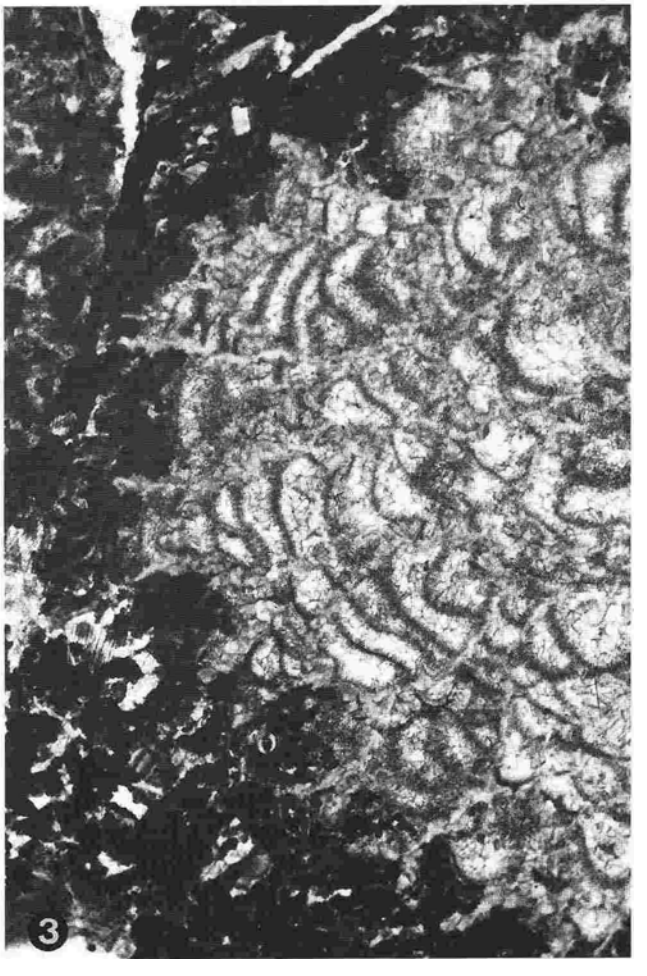
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	Stratigraphy of the western slope of the Urals	Local subdivision	Environments
	Horizon	Suite	
438 ma ORDOVICIAN Ashgillian	Kyr'ya	Japtikshor	shallow water, low energy erosional and transgressive surfaces
	Sur'ya	Malaya Tavrota	reef / backreef lagoonal deposits
	Poluda		shallow-water, high-energy shallow-water, low energy
448 ma	Rassokha	Ust'zyb	deep-water low energy

Table 1. Simplified lithostratigraphy for the Upper Ordovician succession of the Urals.

Description of the reefs

Three reef complexes were studied in detail (Fig. 1, Table 2):

(1) The **reef complex at the Bol'shaya Kos'yu River** (a tributary of the **Ilych River** in the Northern Urals) is 110 m thick. The reef is in tectonic contact with clay shales, argillaceous limestones of Middle Ordovician age (*Passerinus* Zone). The reef boundstones were formed by various calcareous algae and microbes together with heliolitids, tabulate and rugose corals, and sponge-like organisms. The main reef-builders are listed in Table 2. Corals and heliolitids are commonly coated with thin microbial crusts (Pl. 1/2-3). Microbial bindstones with an irregular laminoid fenestral fabric are common constituents of the reef. Reefal rudstones containing bioclasts as well as carbonate and sandstone lithoclasts are abundant. Most bioclasts are crinoids, corals and algae. The upper surface of the reef exhibits large-scale erosional pockets filled with fragments of reef-building organisms, reef-debris and reef rocks as well as fragments from the overlying beds.

(2) The **reef complex at the Kozhym River** in the Subpolar Urals is 260 m thick. Many rocks are dolomitized. The reef boundstones are characterized by bioclasts that are encrusted by microbes and various calcareous algae (Pl. 2/1-2). Biohermal rocks formed by red and green algae as well as by algae of uncertain systematic position are widespread (Table 2, Pl. 2/3-4). The skeletal grains are

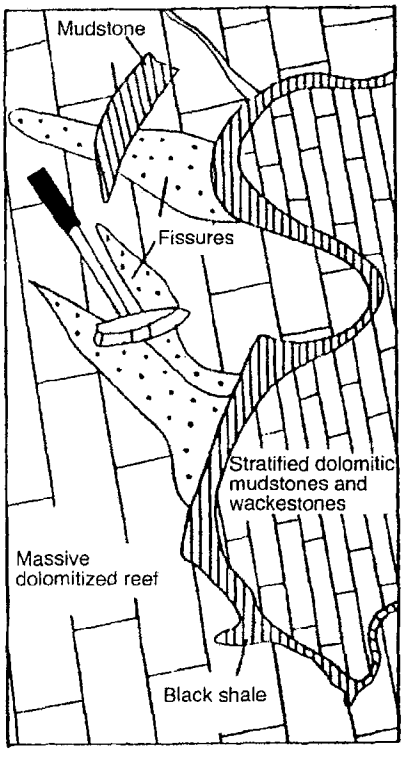


Fig. 2. Erosional contact of the massive, dolomitic Sur'ya reef and the stratified dolomitic Kyr'ya mudstone and wackestones observed in the outcrop at the Kozhym River, left bank opposite the mouth of the Bad'yashor creek. The massive dolomitized reef belongs to the O_3mt, the stratified dolomitic mudstones and wackestones to the O_3jspl of the Upper Ashgillian. Drawn after a photo.

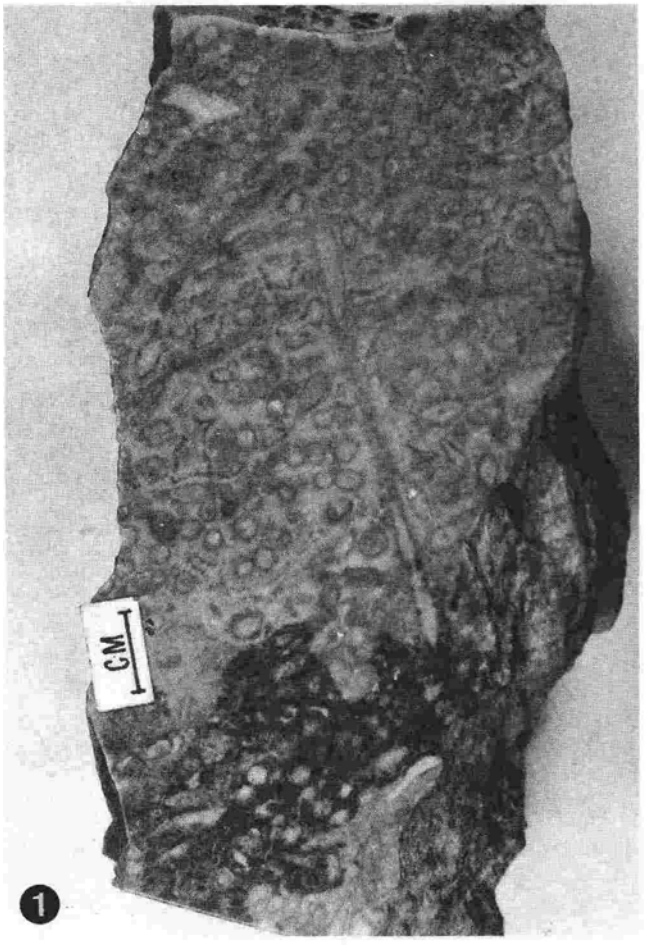
Plate 2 Ordovician algae from the Bad'ya reef, Subpolar Urals, Kozhym River (opposite the mouth of Bad'yashor creek).Upper Ashgillian (Sur'ya Horizon)

Fig. 1. Dolomitized algal talli of the chlorophyte *Dimorphosiphon* sp.. Polished sample 77/38. Scale is 1 cm.

Fig. 2. Mottled appearance of dolomitized bioclastic algal debris and spar-filled cavities. Polished sample. Scale is 1 cm.

Fig. 3. *Kozhymella dembovskii* Shuyskiy. Thin-section, sample 77/36. x 6

Fig. 4. Bioclastic algal dolomite or limestone, encrusted by various algae and unidentified microbial organisms. Lower right: *Vermiporelloides kozhymicus* Shuyskiy. Thin-section, sample 77/37. x 6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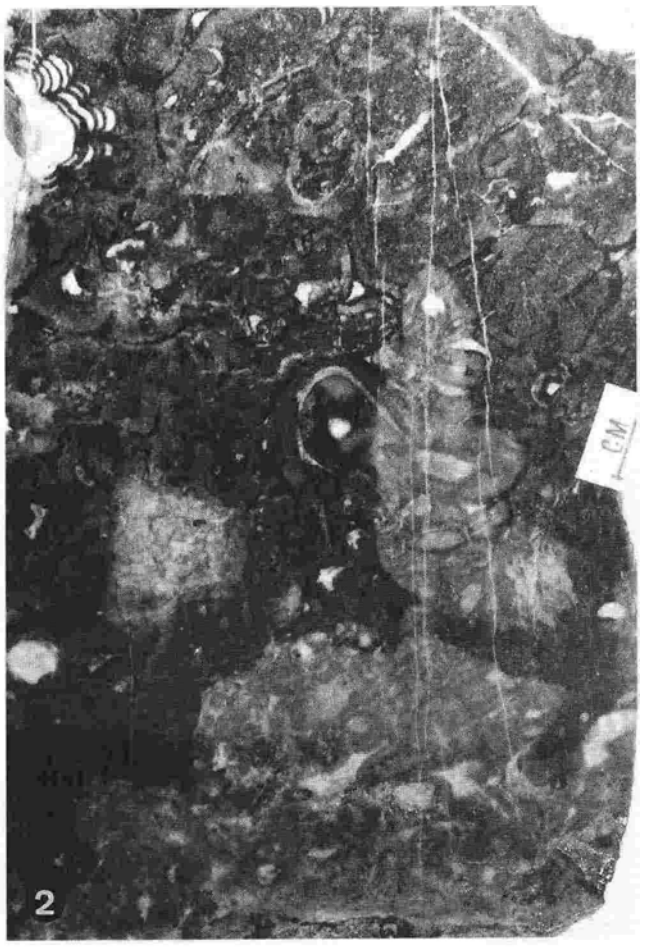
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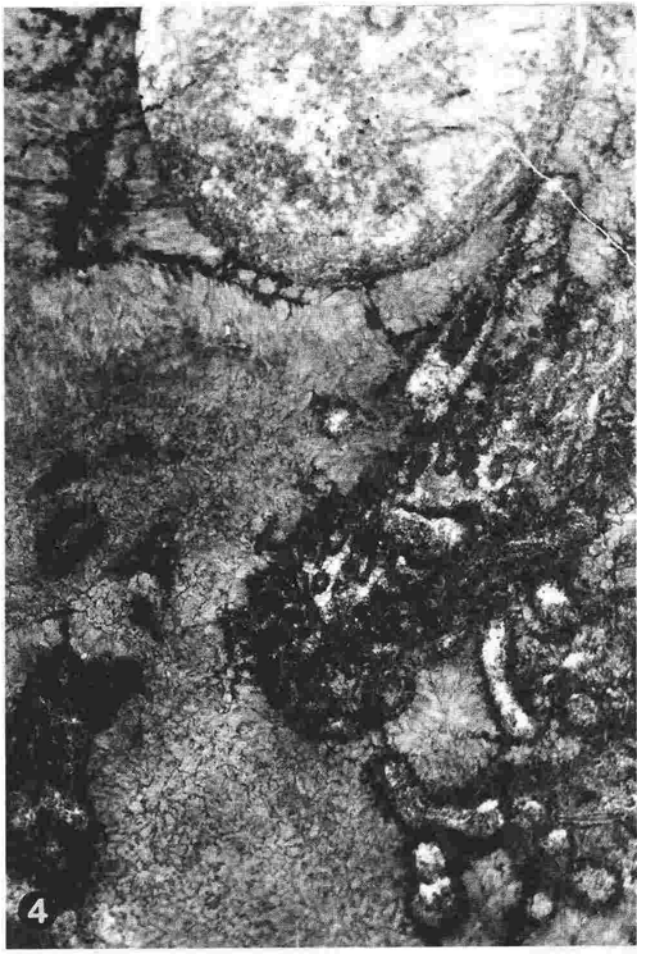
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Reef-builders \ Reefs	Ilych	Kozhym	Lek-Elec
Unidentified microbes	+	+	+
Cyanophyta			
Girvanella	+	B	B
Renalcis	B	B	B
Rothpletzella	+	B	B
Ortonella	B	0	?
Hedstroemia	?	0	B
Garwoodia	?	0	B
Chlorophyta			
Dimorphosiphon	0	+	0
Dasycladacea	+	+	B
Rhodophyta			
Solenopora	B	B	+
Incertae sedis			
Nuia	B	B	B
*) *Kozhymella*	0	+	0
*) *Vermiporelloides*	0	+	0
Tabulata	B	B	x
Rugosa	+	B	B
Heliolitida	+	B	0
Calcareous sponge-like organism	x	?	?
Bryozoa	B	B	x
Hydrozoa (problematic)			
Fistullella	B	?	?

Table 2. Occurrence of the main Upper Ordovician reef-builders. + - frequent, x - often in accumulations, B - present, ? - questionable occurrence, *) unestablished taxa of problematic red and green algae described by SHUYSKIY & KLYUZHINA (1989).

overgrown by column-shaped microbial crusts exhibiting a peloidal spongiostromate fabric which stabilized the bioclastic and lithoclastic sediment.

Corals , problematic hydroids and calcareous sponge-like organisms occur in places in small concentrations. The base of the complex is a rudstone containing reworked material from the underlying beds. The reef itself is composed of grainstones with lithoclasts and crinoidal debris. Erosion fissures up to 3 m deep extend from the upper surface of the reef downwards. The reef surface is marked by a thin layer of black shale (Fig. 2).

(3) The **reef complex at the Lek-Elec River** in the Polar Urals is up to 500 m thick. The rocks are partially dolomitized and characterized by strong cavern porosity. The reef boundstones were formed by laminar crusts and ribbon-like microproblematica, calcareous algae, microbially encrusted concentrations of bioclasts, tabulates and of calcareous sponges (Fig. 3, Pl. 1/1). Red and green algae are also present (cf. Table 2). Large parts of the reef are occupied by microbial-peloidal crusts with only rare additional fossils. The upper beds of the reef complex are characterized by the occurrence of lithoclasts, fenestral fabrics and ooids. In this part packstones and micritic rudstones are more frequent than wackestones and floatstones. The uppermost part of the reef exhibit thin beds of a laminar clayely dolomite showing indications of the slumping and brecciation. The flat and smooth top surface of these beds exhibits mud cracks and pyrite impregnations. These beds are overlain by lense-like dark gray wackestone sometimes exhibiting cross-bedding.

Conclusion

(1) All the reef complexes of the Urals are of Ashgillian age.

(2) The reefs were established at the western slope of the Pechora Urals and occur only in a shelf-margin position.

(3) Reef development was strongly controlled by regional differences in subsidence near the shelf-margin and by the Upper Ashgillian regression.

(4) Sea-level fluctuations and differential subsidence are reflected by the differences between the Subpolar and Polar reefs and the reefs in the Northern Urals. The development of the latter reefs was strongly disturbed by syndepositional erosion (indicated by abundant lithoclasts and interruptions of the growth of tabulate and heliolitid colonies observed in the Ilych reef complex). A sea-level drop during the middle part of the Upper Ashgillian is reflected in a varying degree of erosion of the upper part of the reefs. The open-marine shelf sediments overlying the

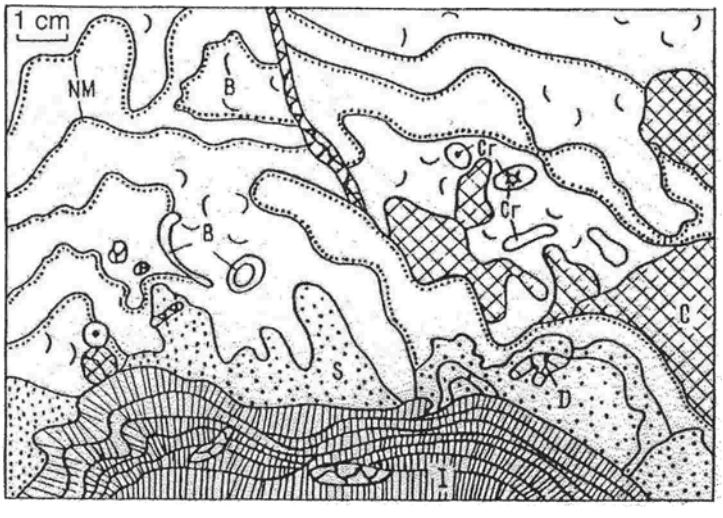

Fig. 3. Coral(?)-algal boundstone. Lek-Elec River, outcrop 17, sample 282. 1 - dolomite growing on calcitic incrustations, S - stromatolitic crust of a spongiostromate algae, NM - unidentified dolomitized microbes, C - tabulate coral (?), Cr - crinoids, B - various bioclasts, D - dolomite. Drawn after a polished sample.

reef top indicate an abrupt sea-level rise at the end of the Upper Ashgillian, causing the termination of reef growth. These sea-level fluctuations must be seen in context with the pulsation of the continental glaciation of the Southern hemisphere.

(5) The significant differences in the thickness of the reef complexes and the backreef carbonate-evaporitic deposits are the results of differences in the movements of isolated blocks of the basement of the Pechora plate connected with the subsidence of the margin of the Russian platform margin at the Ordovician-Silurian boundary.

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