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MORPHOLOGY OF FOSSIL ELEMENTARY ORGANOGENOUS BUILDINGS

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Elementary organogenous buildings (less than 0.5-0.8 m in diameter, more rarely amounting to 1.0 m) occur either as independent formations or as component parts of larger and more complex buildings (biostromes, bioherms and their massifs).

V. S. Sayanov (1968) gave the first characteristic of these bodies and named them "small bioherms". Among them he distinguished parallelopipedal, spherical, dome-shaped, bun-shaped, ampullaceous and, lastly, irregular forms. By their external features and the type of lamination he considered them to approximate stromatolithes. The spherical variety of "small bioherms" was described by V. A. Luchinina (1973) as "calyptra"[1]. But among the elementary organogenous buildings, besides those with constantly attached forms (calyptra), there are types, which sometimes move under the action of the ambient water. In literature these formations are called tumours. We proposed to call them akkatiae (the Greek : (α γ Κ α θ ι α).

The calyptrae are built by algae and other organisms growing upon one another beginning from the moment of their attachment to the ground. The tumours are built when algae attach themselves to movable things on the bottom or when some earlier immovable parts are broken off the bottom. Mobility is only characteristic of small elementary organogenous buildings, because, due to their small dimensions (0.01-6.0 cm) they can be easily shifted by the moving water.

As a rule, algae constitute the bulk of elementary organogeneous buildings (Sayanov, 1968 ; Luchinina, 1973, 1975) ; the participation of other organisms is limited.

The calcareous algae in the elementary organogenous buildings are represented by several species or genera, but sometimes they may be represented by single species (colonies or isolated forms). Finally, a large colony (usually of Stromatoporoidea or Tabulata) may play the role of calyptrae too.

CALYPTRAE

According to their dimensions the calyptrae are divided into macrocalyptrae (more than 5-6 cm) and microcalyptrae (from several mm to 5-6 cm).

The external shapes of calyptrae may be thalline, bun-shaped, spherical and columnar. They correspond to the principal shapes of stromatolithes, first established by Pia (1927). A brief characteristic of these types is given below.

Thalline calyptrae are sodlets of algae ; their totality gives the algal layers, called "stratifera", "stromatactis" etc. (Fig. 1). Thalline calyptrae may take part in the building of biostromes. In that case they merge with one another and become indiscernible (Maslov, 1973).

Bun-shaped calyptrae have a flat basis and can retain their outlines in the more complex organogenous buildings, i.e. they are responsible for the so-called reef lamination. The growth of a bun-shaped calyptra begins at once from an algal sodlet of maximal dimensions (for that particular building). Bun-shaped calyptrae resemble monolophoid bioherms (Fig. 2). Similar calyptrae were described earlier by Sayanov (1968) in the Middle Sarmatian beds of Moldavia (Fig. 2a), where calyptrae are built by algae and Nubecularia[2]. Bun-shaped calyptrae very often occur in late Precambrian-early Cambrian ; these calyptrae are built either by algae alone or by algae together with Archaeocyathi (Korolyuk, 1968, Zhuravleva, 1960, 1966) (Fig. 2b, c, d, e). The same kind of calyptrae were also met in Ordovician of Kazakhstan (Nikitin et al., 1974), Fig. 2f, g, in carboni-

[1]"small bioherms" of all shapes and dimensions may be named "calyptra". It is more convenient to use one word.

[2]We know calyptrae that are built by Nubecularia only (Nubecularia Deflandre—subclass of Foraminifera).

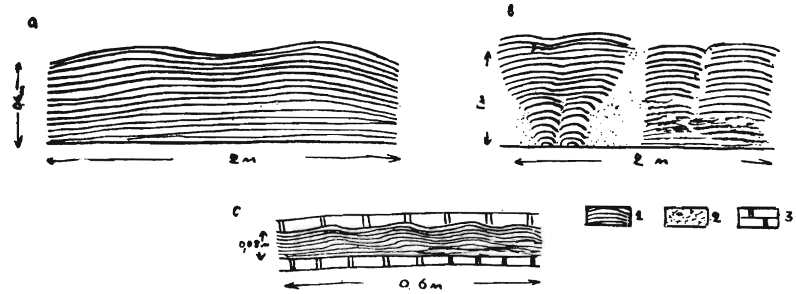


Fig. 1. The thalline calyptrae as the single layer-stratiphera (The laminar stromatolithe).
a—Precambrian of North-West of Siberian platform, Sukharicha suite, Sukharicha river. Outcrop 65, coll of I. T. Zhuravleva, 1966.
b—Precambrian of South-east of Siberian platform, Judomia suite, Aldan river Outcrop 40, coll of I. T. Zhuravleva, 1952.
c—Precambrian of Anabar massiv, Jusmastach suite, Siberian platform, Kotujkan river, the tributary of Kotuj river. Outcrop 6, coll of I. T. Zhuravleva, 1972.
1—algal layers ; 2—the sandstone—detrital material ; 3—dolomite.

ferous of Karachatyr, lower Sarmatian of the Crimea (Fig. 2h), etc.

Spherical calyptrae differ from bun-shaped calyptrae by the character of algae's attachment to the bottom (the development of a calyptra begins from one or several forms of algae). The maximum development was in the middle part of the building. The shape of spherical calyptrae is identical with that of dilophoid bioherms (Zhuravleva, 1968, Fig. 3a-c). Spherical calyptrae may be well discernible in bigger organogenous buildings—biostromes and bioherms (Fig. 3d).

Thus, spherical calyptrae were first described in the lower Cambrian of the Siberian platform. The main framework organisms were algae—Epiphyton and Renalcis ; Archaeocyathi occurring with them were sparse. Abundant spherical calyptrae in bioherms were recorded in the Anderken bioherm range (Nikitin et al., 1974, Fig. 3b, d). But spherical calyptrae may be isolated as well (Zhuravleva, 1960, Fig. 3d).

Columnar calyptrae retain their forms best in columnar stromatolithes and they are discernible in all organogenous buildings. A particular case of columnar macro- and microcalyptrae is represented by the so called branched stromatolithes which are not a colony of algae, but an organogenous building which is split into several separate columns as it grows (Fig. 4a, b ; 5a, b). The splitting is due to mechanical action (accumulation of sand or silt, settling of any other organism, water action etc.) of tendency of algae to preserve the maximal surface of the soldlet.

Columnar microcaliptrae are very abundant in the lower Cambrian deposits of the Lena river, Yacutia (Zhuravleva, 1960). They are also constructed by algae Epiphyton, Renalcis and repeat exactly the form of columnar stromatolithes (Fig. 5a) ; Any of columnar stromatolithes which are abundant in the Precambrian and Phanerozoic of the USSR (Korolyuk, 1968 ; Krylov, 1963, 1975 ; Raaben, Zabrodin, 1972, etc.) and other countries, can serve as an example of columnar calyptrae. The external shape and dimensions of columnar calyptrae built by the same algae, may be quite different in the same biostrome or bioherm depending on the environmental conditions (in the centre of bioherm, on its periphery etc.).

AKKATIAE

The form of akkatia (Table 1) may be spherical or irregular (oncolithi, microphytolithi, tumours). Akkatiae of any dimensions (within the limits characteristic of elementary organogenous buildings) are also built by representatives of several species of algae, and sometimes with the participation of other organisms. Akkatiae larger than microphytolithes are very rare and as a rule are not described by paleontologists. We consider here two cases of building akkatiae whose dimensions are much larger than those of movable organogenous buildings (Fig. 8a, b). The first akkatia has a three-zonal structure (Fig. 8a) while the second, a distinct bizonal one, with a change of frame builders in each zone. This change of structure is due to a cessation of growth and, possibly, even to a temporary cessation of motion of akkatiae (Fig. 8a). In the central part of akkatia there are skeletons of other organisms, a shell of problematical shape in Ordovician of the Siberian platform (Fig. 8a) and Nubecularia in Paleogene of Moldavia (Fig. 8b).

The Precambrian and Early Paleozoic mircophytolithes and oncolithes are now studied very intensively (Z. Zhuravleva, 1964 ; Klinger, 1968 ; Raaben, Zabrodin, 1972 ; Khomentovski et al., 1972, etc.). The microphytolithes of later geological periods are studied less intensively (Radionova, 1973), but even the few data contained in publications show us that there is actually no difference in the form and dimensions of akkatiae of

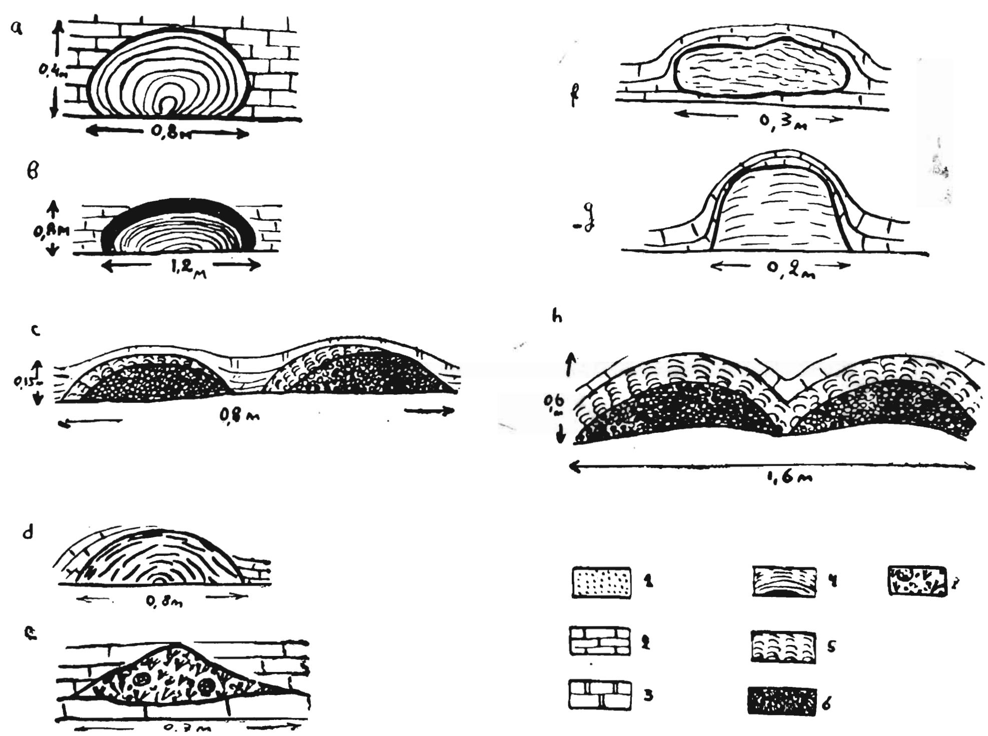


Fig. 2. The bun-shaped caliptrae

a—the single algae—nubecularian caliptra. The middle Sarmat, Moldavia, Dnestr river (V. S. Sajanov, 1968).

b—the single calyptra from the thalline algae (Stromatolithe), The lower Cambrian of the Siberian platform, pestrotzwetnaja suite, Lena river (Koroljuk, 1968).

c—the oncolithian taphoherms passed into the stromatolithian calyptrae. Precambrian of Siberian platform, Nochtujskaja suite, Lena river, near the v. Nochtujskoje (Zhuravleva, 1966).

d—the calyptra from the centre of the bioherm massive. The lower cambrian of Tuva, baincol suite, Bainkol river Zadorozhnaj *et al.*, 1973).

e—the single algae-archaeocyathean calyptra. The lower Cambrian of Siberian platform, the pestrotzwetnaja suite, Aldan river, the rocks "Dwortzy" (Zhuravleva, 1960).

f—the single calyptra with the distinct layers of enveloping. The Ordovician of Khazachstan, the valley Kujandysai. Outcrop 36 (Nikitin *et al.*, 1974).

g—the same. The Ordovician of Khazachstan, the valley Anderkenyn-Akchoky. Outcrop 42 (Nikitin *et al.*, 1974).

h—The oncolithian taphoherms (similar with the bun-shaped calyptrae), passed later into the stromatolithian calyptrae. The lower Sarmat of Crimea, V. Demjanovka. Outcrop 11, coll. of I. T. Zhuravleva, 1966.

1—the sandy-detrital materials; 2—limestone; 3—dolomite; 4—the thalline algal; 5—the columnar stromatolithi ; 6—oncolithi ; 7—Epiphyton, Renalcis, the cups of Archaeocyathi.

any geological time (Fig. 9a, b). Their forms and dimensions are only dependent on the duration and intensity of algae growth, the form of akkatia varying from irregular to spherical. In case the water stops moving the organogenous building may be fixed and akkatia is reconstructed into a columnal form, like that of columnal stromatolithe (Fig. 8a). Akkatiae are known to accumulate on one part of the bottom, forming taphostrome or taphoherm and imitating the forms of calyptrae or bioherms. The reason for this local accumulation of akkatiae is not yet known ; a significant part in their accumulation seems to have been played by non-calcarean algae whose slime connected the akkatiae into an aggregate mass. Two examples of development of small oncolithic taphoherms, imitating calyptrae, are shown in Fig. 2c, h.

The columnar micro- and macrocalyptrae (stromatolithes) and akkatiae of the smallest dimensions (oncolithes, microphylithes, catagraphia) are classified at present according to the binary nomenclature depending on the form, dimensions of the elementary organogenous buildings, but very rarely account is taken of the type of algae structure lamination (Z. Zhuravleva, 1964 ; Krylov, 1963, 1973, 1975 ; Korolyuk, 1968 ; Raaben, Zabrodin, 1972, Semikhatov et al., 1970; Semikhatov and Komar, 1965 ; Serebriakov, 1968 ; Shapovalova, 1974 ; Khomentovski et al., 1972, etc.). The artificial systematic cate-

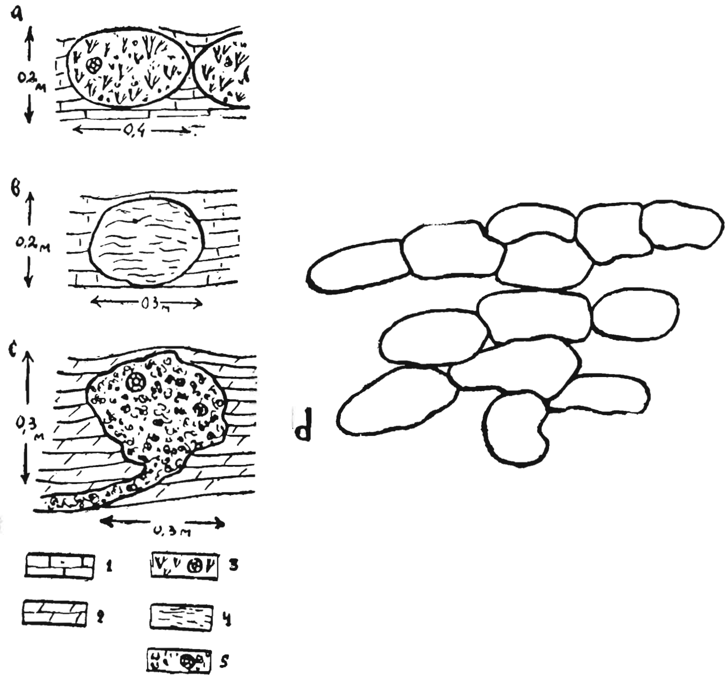


Fig. 3. The spherical macrocalyptrae.

a—the single algal calyptra in the biostrome. The lower cambrian of Siberian platform, pestrotzwetnaja suite, Lena river near the v. Oimuran (Lutchinina, 1973, the figure is made according the photo; fig. 2, pl. VIII).

b—the single calyptra in bioherm, composed from the thalline algae. The Ordovician of Khazachstan, the valley Anderkenyn- Akchoku (Nikitin *et al.*, 1974, the detail of Fig. 9).

c—the single algae—archaeocyathean calyptra near the bioherm massive. The lower Cambrian of Siberian platform, the pestrotzwetnaja suite, Lena river, opposite Jura river (Zhuravleva, 1960).

d—the bioherm, composed from the disunited calyptrae. The Ordovician of Khazachstan, the valley Anderkenyn-Akchoku. Outcrop 42 (Nikitin *et al.*, 1974).

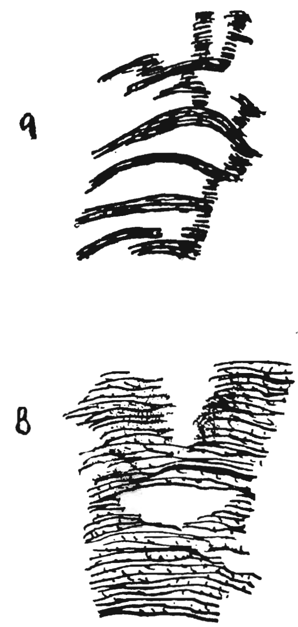
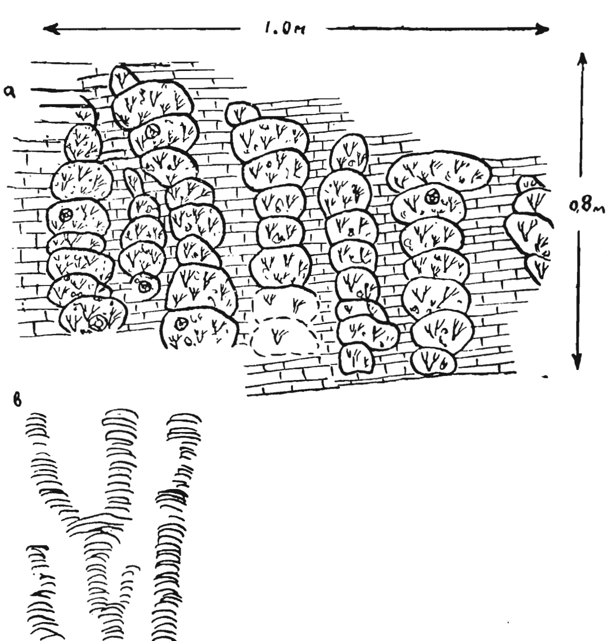


Fig. 4. The types of branching of tne columnar stromatolithi ("branching" according A. G. Vologdin *et al.*) The upper Precambrian of Siberian Platform, Angara river (Vologdin, 1962, the detail of Fig. 4a, b, ×1).



← Fig. 5. The columnar macro- and microcalyptrae.

a—the algal columnar macrocalyptrae, composed from Epiphyton and Renalcis. There are rare archaeocyathi. The lower Cambrian of Siberian Platform, pestrotzwetnaja suite, Lena river near v. Judjai (Zhuravleva, 1960).

b—the longitudinal section of columnar microcalyptrae (Stromatolithi). The upper Precambrian of East Baikal region, Ulunthuj suite (Vologdin, 1962 ; the figure is made according fig. 2, pl. III, × 1/4). See the legende of the fig. 2.

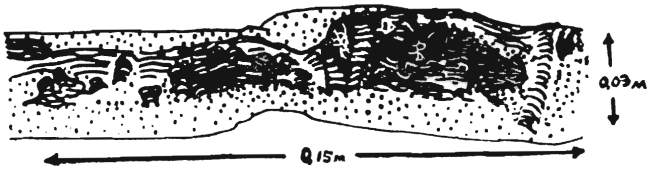


Fig. 6. The longitudinal section of columnar microcalyptrae (Stromatolithi). The Silurian of Siberian Platform, Venlock, Moiero river. Outcrop 46, coll. E. I. Miagkova, 1968. See the legende of the fig. 2.

Fig. 7. The different types of columnar microcalyptrae (Stromatolithi), developed on the little place. The lower Cambrian of Tuva, bainkol suite, Bainkol river (Zadorozhnaja *et al.*, 1973).

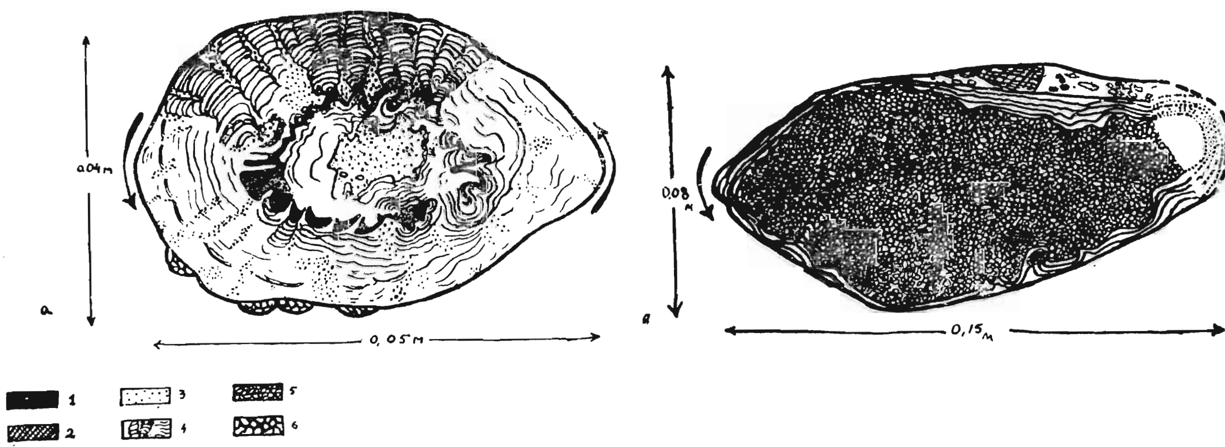


Fig. 8. Akkatiae.

a—akkatia, composed from three zones—central (microphytolithi, thalline algae, large shell) intervening (columnar stromatolithi) and interrupted peripherical (algae). The middle Ordovician of Siberian platform. Krivolutzki stage, Moiero river. Outcrop 71, coll. of E. I. Miagkova, 1968.

b—akkatia, composed from two different zones—a large central (Nubecularia) and weakly developed peripherical (thalline algae). The middle Sarmat, Moldavia. Coll. of I. T. Zhuravleva and E. I. Miagkova, 1966.

1—rests of invertebrate fossils ; 2—mineral inclusions ; 3—sandy—argillaceous material ; 4—columnar stromatolithi ; 5—Nubecularia ; 6—Algae.

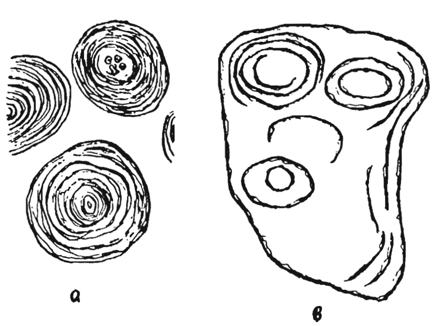


Fig. 9. Akkatiae (oncolithi).

a—"Osagia grandis" Z. Zhur. The upper Rifean of Patom Upland, Chenchian suite, Zhuja river (Knomentovski *et al.*, 1972 ; the figure is made according the fig. 4, pl. IV, ×15.)

b—"Osagia decimana" Jakshin. The upper Rifean of Patom upland, calanchevaskaja suite, Lena river (ibid ; the figure is made according the fig. 2, pl. II, ×15).

gories (in the rank of a group or a form), thus singled out, are ascribed to a very distinct biostratigraphical position[1]. But the form and dimensions of calyptrae are determined, just as those of all organogenous buildings, not by algae species or genera, but are derivates of the duration and speed of algae growth, and for the akkatiae they are derivatives of the duration and intensity of motion.

Hence the application to these formations of binary nomenclature based on the form and dimensions of organogenous buildings is inadmissible. As for the lamination types of combined forms of algae (microlayers, according to V. Yu. Shenfil ; Khomentovski et al., 1972) making up one another type of elementary organogenous buildings, they really reflect the primary algal

[1]It is characteristic that biostratigraphical schemes are given only for Precambrian and Early Cambrian.

nature (Maslov, 1950, 1960, 1973 ; Sonin, 1965 ; Pjanovskaja, 1974 ; Pospelov, 1974, etc.) and should be used for the classification. As a matter of fact, V. P. Maslov's point of view (1973) which he has expressed more than once is confirmed here.

Elementary organogenous buildings on a limited territory just as all the other organogenous structures may possess common specific structural features expressed in their shapes and dimensions. This may be used to correlate deposits according to the morphology of micro- and macrocalyptrae (including stromatolithes, oncolithes, microphytolithes) but only on a limited territory (within one region).

The understanding of the structure of elementary organogenous buildings and the mechanism of their formation permits to trace the entire process of their construction from the dispersal of isolated algae to the appearance of large organogenous buildings (biostromes, bioherms). Thus the initial dispersal of algae inevitably leads to the accumulation of organic detritic or terrigenous material. If the conditions are favourable, the algae continue to grow and cover larger territories. As a rule this leads to the formation of sods of thalline or bun-shaped calyptrae, and to the simultaneous dispersal of various groups of benthonic organisms (in the Cambrian-archaeocyathi, brachiopoda, hyolitha, trilobita ; in the Ordovician-Devonian—stromatoporoidea, soanitidae, brachiopoda, crinoidea, anthozoa, trilobita and other groups, (Fig. 10a, b, c, d) etc. This activization of benthonic fauna seems to be connected with the optimal environmental life on these sites and, necessarily, with the temporary cessation of sedimentation. After this the elementary organogenous building often stops developing and, as a result, is very quickly covered by terrigenous or chemogenous deposits. Not infrequently a situation arises when an organogenous building can revive ; if that is the case, and if algae and other frame-building organisms disperse intensively, the building passes very quickly into a biostrome or bioherm, to the extent of a biostromal or biohermal massif. These transitional layers from non-organogenous rocks to organogenous buildings, are a realizable criterion for determining the syngenetic

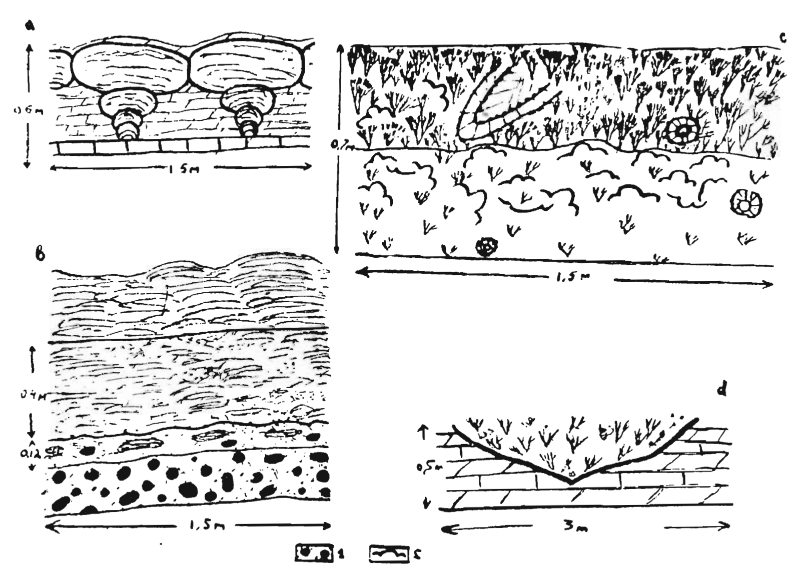


Fig. 10. The young stages of development of biostromes and bioherms.

a—the moment of establishment of biostrome. The calyptrae in the base layer are rare, their diameter is less than 0, 1m. At the top of the biostrome the calyptrae are connected their diameter reaches to 0. 7 m. The lower cambrian of Siberian platform, pestrotzwetnaja suite, Lena river, the middle part, the canyon Bachyk. (Zhuravleva, 1972).

b—the moment of establishment of bioherm massive—from the first settlement of rare algae thalli on the sandy ground to the entire development of algae-reefbuilders at the top of beds. The lower Cambrian of Tuva, bainkol suite, Bainkol river (Zadorozhnaja *et al*, 1973).

c—the moment of establishment of the thalline biostrome. There are the rare bushlets of Epiphyton, the numerous trilobita sheets, archaeocyathean cups at the base. At the top—the same algae as the reefbuilders ; trilobita disappeared. The lower cambrian of Bateny ridge, obrutchev horizon, the mount Dolgy mys. Outcrop 13, coll. of I. T. Zhuravleva, 1956.

d—the establishment of dilophoid bioherme, without the intervening layers. The lower cambrian of Siberian platform, Lena river, the middle part (Zhuravleva, 1972).

1—the conglomerates ; 2—the sections of sheets of Trilobita. See also the explanations to the fig. 2 and 8.

position of the organogenous building and the containing rocks. There may be cases, however, when organogenous buildings appear without the transitional stage of the development of isolated macro- and microcalyptrae (Fig. 10d).

In conclusion it should be noted that in Precambrian blue-green algae were the only builders of organogenous buildings with the possible participation of bacteria (Rutten, 1971), while from the Early Cambrian up to the present time most diverse groups of organisms, alongside with algae, have been taking part in the formation of organogenous buildings (archaeocyathi, porifera, bryozoa, anthozoa, etc.). But their part in that process has been subordinate. Middle Paleozoic Stromatoporoidea, Paleozoic and Mesozoic bryozoa and modern madreporoid corals are an exception. In spite of the leading role of algae in the formation of organogenous buildings in the Phanerozoic, they practically have not been studied in that aspect.

To sum up : 1. Elementary organogenous buildings may be either independent formations or they may constitute the principal part of biostromes and bioherms (the block principle, Zamarski, 1967).

2. Among the elementary organogenous buildings one can distinguish, according to their manner of attachment to the ground, calyptrae and akkatiae. The akkatiae are constructed with the ambient water masses moving actively.

3. The forms of elementary organogenous buildings, i.e. micro- and macrocalyptrae vary from thalline to spherical and columnar.

4. The thalline and bun-shaped calyptrae may serve as the bases to biostromes and bioherms massifs in which case they may serve as a site of mass dispersal of other groups of organisms.

5. Stromatolithes, microphytolithes, oncolithes, as elementary organogenous buildings, cannot be classified according to the binary nomenclature, as is the case with living organisms. The classification of algae, forming them must be based on the morphology of the remains of algae proper (thallomes, sodlets, microlayers, threads, etc., Schopf, Fairchild, 1973).

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