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Intergrowth of the Early Cambrian algae *Epiphyton* Bornemann and *Renalcis* Vologdin from SW Sardinia

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ABSTRACT — Early Cambrian archaeocyathid limestones from Seddas Moddizzis near Gonnesa (SW Sardinia) contain three intergrowing algal morphotypes which can be assigned to Epiphyton *Bornemann, 1886,* Renalcis *Vologdin, 1932 and* Chabakovia *Vologdin, 1939. The latter two morphotypes are intergrading shapes of a single taxon which has to be named* Renalcis. *The always very sharp boundary between intergrowing* Renalcis *and* Epiphyton *indicates that the latter morphotype has to be considered as a separate genus. The theory of Pratt (1984) on the origin and the interpretation of* Epiphyton *and* Renalcis *is critically discussed.*

RIASSUNTO — [Alternanza di crescita di *Epiphyton* Bornemann e *Renalcis* Vologdin, alghe del Cambriano inferiore della Sardegna sud-occidentale] — *I calcari ad Archeociatine del Cambriano inferiore di Seddas Moddizzis (Gonnesa, Sardegna sud-occidentale) contengono tre differenti morfotipi algali disposti in posizione alternante, che possono essere attribuiti rispettivamente a* Epiphyton *Bornemann, 1886,* Renalcis *Vologdin, 1932 e* Chabakovia *Vologdin, 1939. Gli ultimi due morfotipi mostrano delle transizioni strutturali e pertanto sono da considerarsi appartenenti a un solo taxon,* Renalcis *Vologdin. Il limite sempre molto netto fra i talli alternanti di* Renalcis *e* Epiphyton *indica che quest'ultimo morfotipo deve essere considerato come un genere a sé stante. La recente teoria di Pratt (1984) sull'origine e interpretazione dei gen.* Epiphyton *e* Renalcis *viene criticamente discussa.*

INTRODUCTION

About hundred years ago, J.G. Bornemann (1886) published the first part of his monograph « Die Versteinerungen des Cambrischen Schichtensystems der Insel Sardinien », in which he erected *Epiphyton flabellatum* n. gen. n. sp., an alga from the Early Cambrian archaeocyathid limestone of Cuccuru Contu near Iglesias (SW Sardinia).

Since this time, *Epiphyton* has been recorded by numerous authors from many parts of the world as a common Paleozoic (Early Cambrian - Early Carboniferous) reef-builder, being particularly frequent in the Cambrian, Early Ordovician and Devonian. Within this time interval, *Epiphyton* is frequently associated and intergrown with the algal genus *Renalcis* Vologdin, 1932. In Early Cambrian, these two genera, which are regarded at present as blue-green algae or red algae, form small mounds and biostromes or they encrust cavities beneath archaeocyathans. They are frequently encased in synsedimentary submarine calcite cement that precipitated in these cavities.

During the preparation of the 19th European Micropaleontological Colloquium (Sardinia, 1985) a series of Early Cambrian samples from Seddas Moddizzis near Gonnesa (SW Sardinia) was studied, being sometimes very rich in *Epiphyton* and *Renalcis*. These studies gave the opportunity to express our opinion on the much discussed problem wether *Epiphyton* and *Renalcis* are intergrading morphotypes of a single organism or two different but frequently intergrowing taxa. A detailed description of *Renalcis-Epiphyton* assemblages from SW Sardinia including a revision of the type-material of *E. flabellatum* is planned.

All thin sections containing the specimens described and figured in this paper are deposited at the Institute of Geology and Paleontology of Frankfurt University (Cherchi-Schroeder collection).

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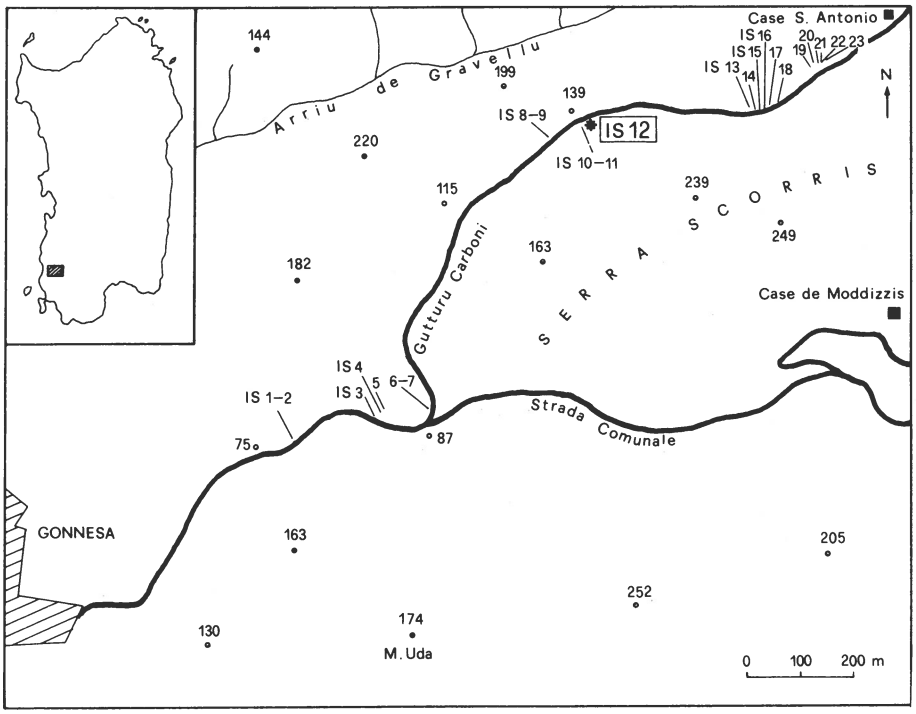


Text-fig. 1 - Geographic position of sample IS-12 containing *Epiphyton* and *Renalcis*. Early Cambrian of Seddas Moddizzis (Gonnesa).

OCCURRENCE OF THE STUDIED MATERIAL

The thin sections described and figured in this paper come from an only archaeocyathid limestone sample (IS-12) which was taken in a small quarry on the southern side of the road between Gonnesa and Case S. Antonio following the Gutturu Carboni valley and situated northwest of Seddas Moddizzis (Serra Scorris) [sheet 233 IV N.W. (Iglesias) of the Carta d'Italia 1:25.000]. For detailed location of the quarry see text-fig. 1.

This archaeocyathid limestone belongs to one of the several lenticular biostromes intercalated in the Matoppa Member, the lower part of the Nebida Formation (Rasetti 1972, p. 9). The Matoppa Member is mainly composed of a monotonous greenish-grey sequence of siltite sandstones, quarzites and argillites. The intercalated biostromes are faunistically characterized by numerous archaeocyathids (see fauna list *in* Debrenne 1964, 1972) and the *Epiphyton-Renalcis* assemblage. A schematic section of the Matoppa Member in the Gonnesa region has been recently published by Pillola & Gross (1982).

The Matoppa Member may be partly Late Aldanian in age (Debrenne 1971), whereas the overlying Punta Manna Member may be of Lenian age (Rozanov & Debrenne 1974, p. 664; Brasier 1976, p. 263).

DESCRIPTION OF THE MATERIAL

Sample IS-12 contains an association of three different algal morphotypes, which can be assigned to the genera *Epiphyton* Bornemann, *Renalcis* Vologdin and *Chabakovia* Vologdin.

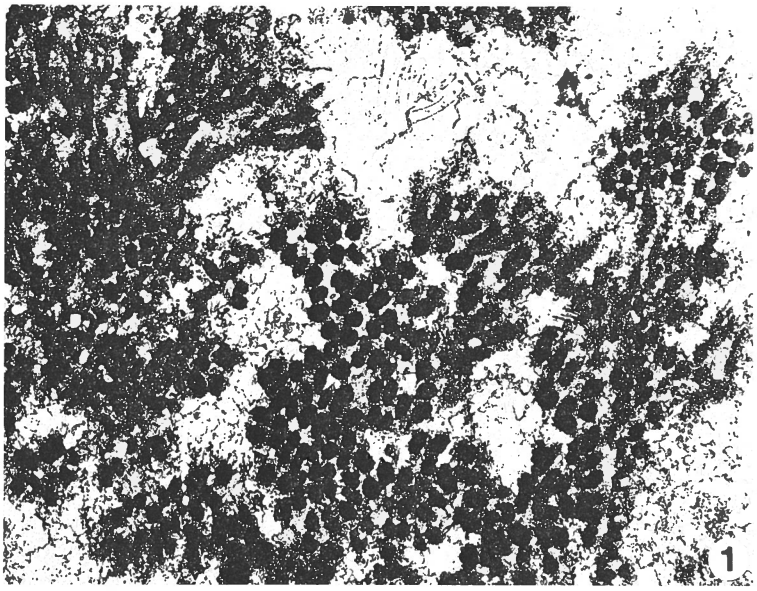
A. *Epiphyton*

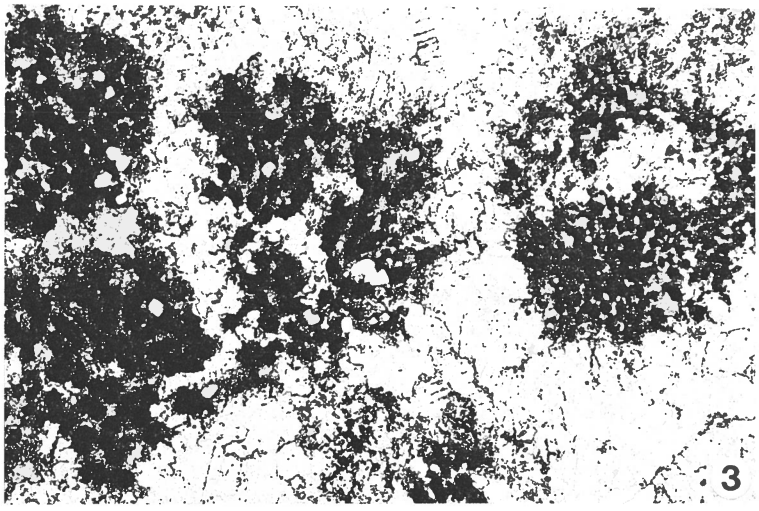
The type material of *Epiphyton flabellatum* published by Bornemann (1886, pl. 1, figs. 9-10) shows bush-like structures consisting of branching rods. Our material from Seddas Moddizzis shows the same mor-

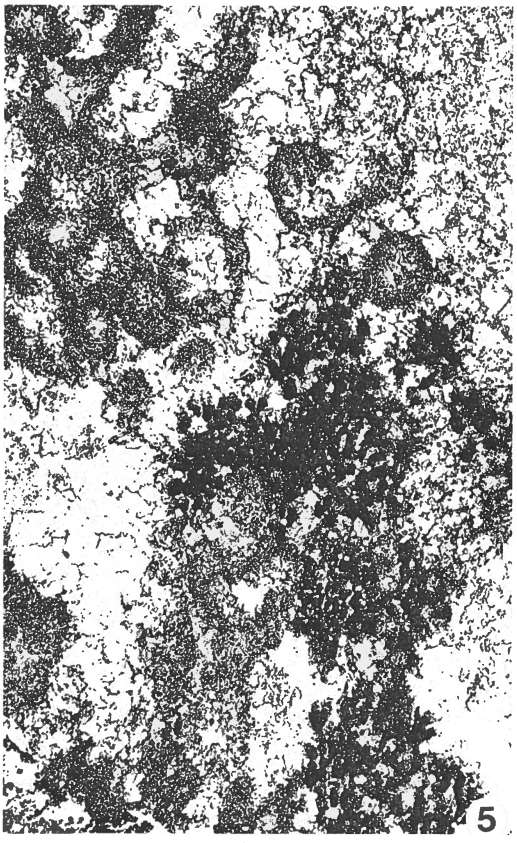
EXPLANATION OF PLATE 1

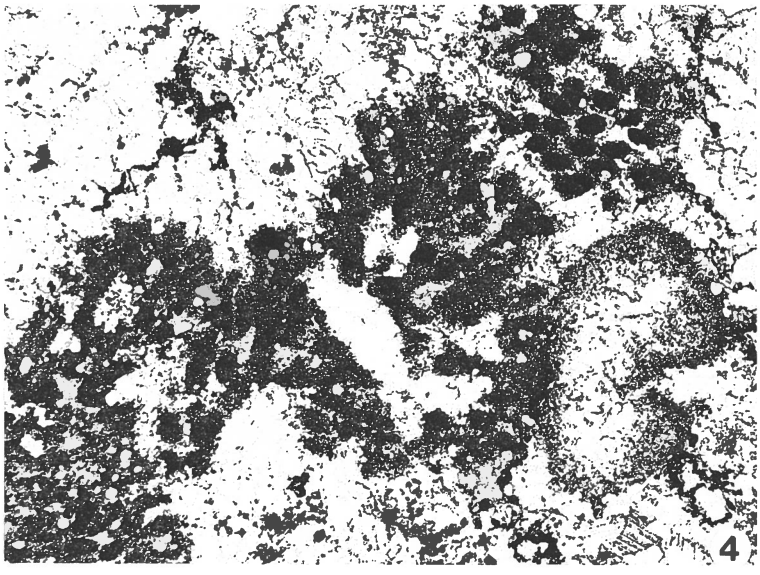
Epiphyton Bornemann and *Renalcis* Vologdin. Seddas Moddizzis near Gonnesa (Iglesiente, Sardinia). Early Cambrian.

Fig. 1 - Radiating branches of *Epiphyton* forming a bush-like thallus. IS 12-7. x 40.
Fig. 2 - Nearly vertically oriented thallus of *Renalcis* showing mostly lunate but also irregularly saccate chambers. IS 12-4. x 40.
Fig. 3 - Oblique sections through two bush-like *Epiphyton* thalli showing different rod diameter. IS 12-7. x 40.
Fig. 4 - A large irregularly saccate chamber of *Renalcis* attached to *Epiphyton* branches. IS 12-7. x 40.
Fig. 5 - *Epiphyton*, partly attached to a tall *Renalcis* thallus (lower part of the figure). The upper half of the figure shows a cluster of *Renalcis* chambers. IS 12-1. x 40.









phology and arrangement. The bushes or tree-like thalli are irregularly dispersed in the sparitic matrix or they are concentrated to form thin layers. The straight or gently curved branches are circular in cross-section and dichotomous (pl. 1, fig. 1; pl. 2, figs. 2-3); the angle between branches is always acute but varying in size within an individual thallus.

There is no considerable variability in the diameter of branches within a single bush (pl. 1, fig. 1). However, the branches of different bushes may have different diameters, as it is shown on pl. 1, fig. 3. The bush on the left side of this figure consists of relatively thick elements (0,040-0,042 mm in diameter); the branches of the right thallus are clearly smaller (0,020-0,025 mm). These dimensions mentioned before represent the extreme values; in the same sample there are numerous thalli showing intermediate branch diameters (e. g. pl. 2, fig. 1).

B. *Renalcis*

A second and very frequent morphotype, being highly variable in size and morphology, is characterized by chambers ranging in shape from very irregularly globular sacs (pl. 1, fig. 5, upper part) to irregularly ramifying tubes (pl. 1, fig. 5, lower part; pl. 2, fig. 1) or elongate sacs (pl. 1, fig. 4; pl. 2, fig. 2). These morphological elements are either isolated (pl. 1, fig. 4) or they are arranged in arborescent or grape-like aggregates (pl. 1, fig. 2; pl. 2, figs. 1, 4). Chambers commonly vary in diameter from 0.15 to 0.7 mm. All these saccate or tubular elements show an outer dark and not well limited layer which is, according to Mamet & Roux (1983, p. 89), the result of an external micritisation of a still enigmatic structure.

This morphotype can be assigned to the genus *Renalcis* Vologdin, 1932, whose type-species *R. granosus* has been described from the Cambrian of the Altai Mountains (U.S.S.R.) (see also Mamet & Roux 1983, text-fig. 4/1).

C. *Chabakovia*

The third morphotype is rare in our material and characterized by tubular stacks of relatively flat chambers which are separated by convex-outward micritic septa (pl. 1, fig. 2, arrow). The stacks vary in diameter from 0.15 to 0.2 mm.

Vologdin (1939) has described morphologically comparable septate and branching forms from the Cambrian of Southern Ural (U.S.S.R.) under the name *Chabakovia* (type: *C. ramosa* Vologdin, 1939).

The presence of *Chabakovia* in SW Sardinia was reported for the first time by Debrenne *et al.* (1979, p. 389, text-fig. 13a) from the Early Cambrian Nebida Formation of Rio Cannas (near Carbonia, Sulcis). Pillola & Gross (1982, p. 79) mentioned this genus from the same stratigraphical level (Matoppa Member of the Nebida Formation) of Seddas Moddizzis (Gonnesa).

RELATIONSHIPS BETWEEN THE MORPHOTYPES: INTERGRADING SHAPES OF A SINGLE ORGANISM OR INTERGROWTH OF DIFFERENT TAXA?

The three morphotypes described before have been originally considered as different but sometimes intergrowing genera. Since approx. ten years, however, some authors regarded all these genera, or at least *Renalcis* and *Chabakovia,* as intergrading shapes of a single organism. On the basis of our material the relationships between the different morphotypes will be discussed.

A. *Renalcis - Chabakovia*

Riding & Brasier (1975, p. 208) first supposed that the genera *Renalcis* and *Chabakovia* could be identical. Soltovskaja (1975) came independently to the same conclusion including in this group also the morphologically similar genera *Izhella* Antropov, 1955 (type: *I. nubiformis* Antropov, 1955) and *Shuguria* Antropov, 1950 (type: *S. flabelliformis* Antropov, 1950) from the Devonian of the Russian Platform. Mamet & Roux (1983) have studied a rich and well preserved algal flora from the Visean of Queensland (New South Wales, Australia) containing morphotypes like *Renalcis, Shuguria, Chabakovia* and *Izhella.* They came likewise to the conclusion that all these « genera » are not only intergrowing forms but also intergrading structures of one single organism wich should be named *Renalcis.*

EXPLANATION OF PLATE 2

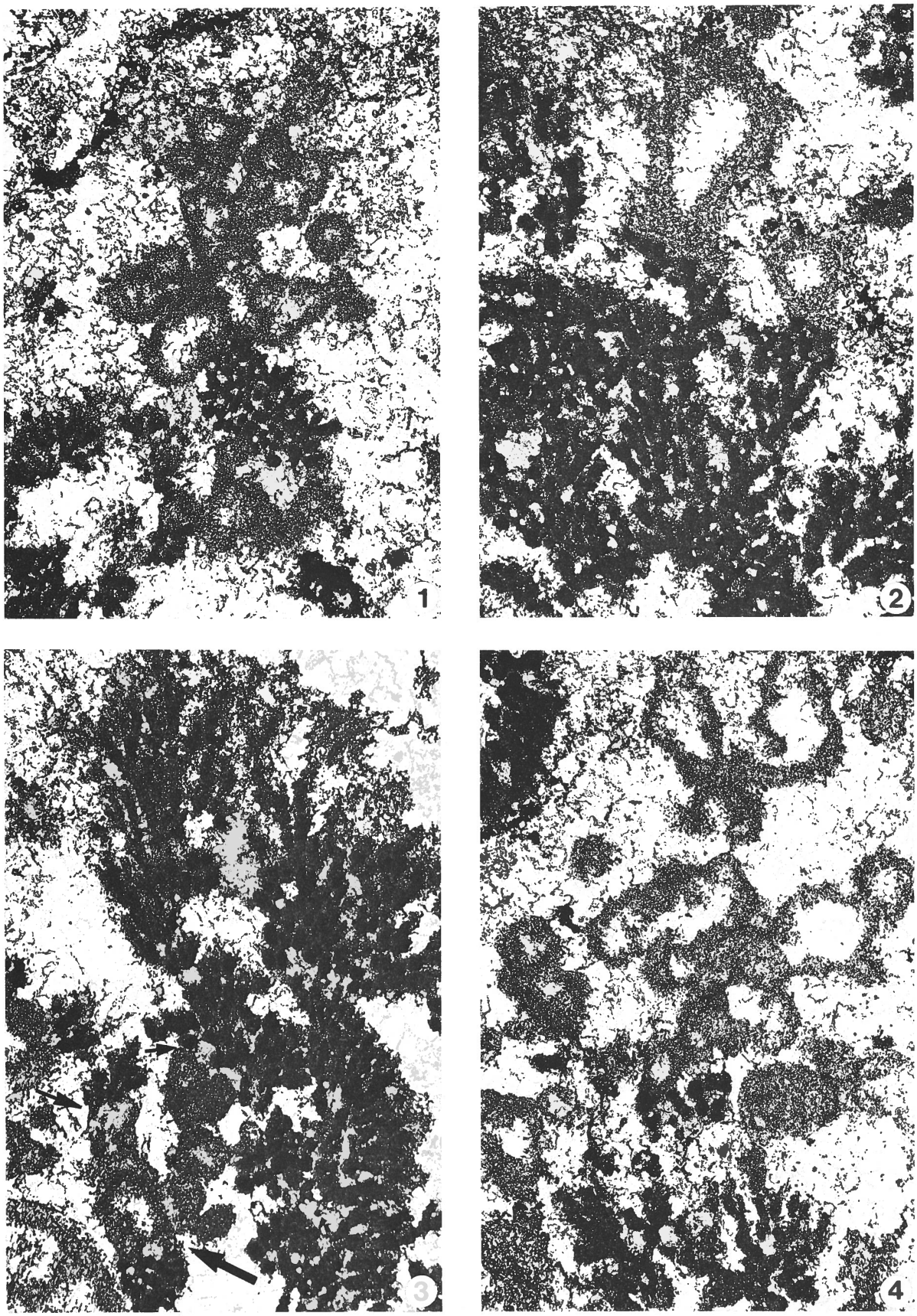
Epiphyton Bornemann and *Renalcis* Vologdin. Seddas Moddizzis near Gonnesa (Iglesiente, Sardinia). Early Cambrian.

Fig. 1 - Intergrowth of *Epiphyton* and *Renalcis*. IS 12-3. x 40.

Fig. 2 - Two large saccate chambers of *Renalcis* (upper half of the figure) attached to the tips of branches of an *Epiphyton* thallus. IS 12-9. x 40.

Fig. 3 - Intergrowth of *Epipyton* and *Renalcis* (lower half of the figure). Note *Epiphyton* attached to *Renalcis* (small arrows) which overgrows itself an *Epiphyton* thallus (large arrow). IS 12-2. x 40.

Fig. 4 - Intergrowth of *Epiphyton* and saccate *Renalcis*. IS 12-6. x 40.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Structures being comparable to *Shuguria* and *Izhella* have not been found in our material. However, we can confirm that an exact separation between *Renalcis* and *Chabakovia* from the Early Cambrian of Seddas Moddizzis is impossible, because there are all transitions between stacks composed of relatively flat chambers (*Chabakovia* morphotype: pl. 1, fig. 2, arrow) and stacks consisting of more globular chambers (*Renalcis* morphotype: pl. 1, fig. 2, upper right quadrant). Structures with mainly circular outline (pl. 1, fig. 5, upper half) could be in part interpreted as transversal sections of flat chambers of the *Chabakovia* morphotype. Therefore, we agree with the cited authors that *Chabakovia* structures grade into *Renalcis* and that the first genus should be considered junior synonym of the second one.

B. *Renalcis - Epiphyton*

Intergrowth between *Renalcis* and *Epiphyton* morphotype is very frequent in the studied thin sections. A characteristic example is figured on pl. 2, fig. 3: a small thallus of *Epiphyton* (lower margin of the figure) is overgrown by branching *Renalcis* structures (large arrow) which latter are again overgrown by *Epiphyton* (small arrows). Large and irregularly saccate chambers of *Renalcis* are sometimes attached to the surface of *Epiphyton* bushes (pl. 1, fig. 4).

In contrast to the *Renalcis-Chabakovia* intergrowth described before, the boundaries between *Epiphyton* and *Renalcis* are very sharp. We have never observed intergrading structures between these two morphotypes. This statement refers to not only thalli lying one upon the other (pl. 2. fig. 3) but also laterally joined structures. A good example for this latter case is the somewhat oblique section of an *Epiphyton* thallus situated in the center of pl. 2, fig. 1, which is in part laterally surrounded by attached *Renalcis* structures.

The complete absence of intergrading structures between *Renalcis* and *Epiphyton,* resp. the very sharp boundaries between the two structures lead us to the conclusion that these two morphotypes have to be considered as different algal organisms.

REMARKS ON THE THEORY OF PRATT (1984) CONCERNING THE RELATIONS BETWEEN *EPIPHYTON* AND *RENALCIS*

The discussion on the relations between *Epiphyton, Renalcis* and morphologically similar genera was revived by a recent paper of Pratt (1984), in which he proposed a new theory on the origin of these forms.

According to Pratt, this group can be subdivided into five morphotypes: dendritic (e. g. *Epiphyton*), septate (e. g. *Chabakovia, Gordonophyton*), chambered (e. g. *Renalcis*), saccate (e. g. *Izhella, Renalcis*), and clotted (e. g. *Renalcis*). All these morphotypes are joined by intermediate forms, except *Epiphyton* and *Renalcis*, which « do not intergrade directly » (1984, p. 953).

Pratt supposes that these different morphotypes formed by synsedimentary precipitation of calcite crystals within thick mucilaginous sheaths surrounding colonies of coccoid blue-green algal cells. Calcification of entire colonies resulted in solid clots, whereas calcification of only their margins resulted in chambers. According to this theory, dendritic *Epiphyton* formed by successive growth and complete calcification of colonies living on branch tips. However, chambered *Renalcis* formed by intermittent growth and sheath calcification of colonies successively encrusting older, calcified sheath.

Colony size and relative intermittence of calcification « argue for a possible general relation of these characteristics to environmental factors », mainly currents, which also may have promoted submarine cement precipitation. Pratt supposes that the uniform branch diameters of *Epiphyton* are maintained by constant turbulence; the dichotomous braching of this morphotype is explained by the constraint of splitting of the expanding colonies. On the other hand, the intermittence of calcification of *Renalcis* colonies may be influenced by inconstant current strength. Consequently, intergrowths of the main morphotypes «might suggest, therefore, overall fluctuations in the degree of control of currents, probably a combination of those both affecting the entire reef and modified in the specific micro-environment in which the thalli were accreting » (Pratt 1984, p. 966).

In our opinion, the shape of the intergrading morphotypes *Renalcis, Chabakovia, Izhella* and *Shuguria* may be indeed influenced by environmental factors. However, it seems to be highly speculative to explain the morphological differences between *Renalcis* and *Epiphyton* as controlled by factors like constant or inconstant turbulence. Following the theory of Pratt, the always very sharp boundary between intergrowing *Epiphyton* and *Renalcis* should also imply an always sharp current change. The question arises, however, why no intermediate morphological forms have been found indicating a gradual transition between constant and inconstant turbulence or between the extremes of other ecological factors.

We believe, therefore, that the morphological difference between *Epiphyton* and *Renalcis* expresses much more than a simple reply to environmental factors. These two intergrowing but never intergrading morphotypes represent, in our opinion, two taxonomically different algal organisms, whose organisation and exact systematic position is still largely enigmatic.

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