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DISTRIBUTION OF CALCAREOUS ALGAE, ONCOLITES AND STROMATOLITES IN WENLOCK-LUDLOW BOUNDARY BEDS IN ESTONIA



GLOBAL
BIOEVENTS

Silurian calcareous algae are known from many localities, including Gotland (Rothpletz, 1913; Riding, 1979), Quebec-Gaspé (Bourque et al., 1981) and Podolia (Ищенко, 1985), the algal assemblages of which are somewhat similar to those of Estonia (Радионова, Эйнасто, 1986; 1988).

The present paper deals with the stratigraphic distribution of calcareous algae in Wenlock-Ludlow boundary beds in the Saaremaa sequence and is based on previously reported data by E. Radionova, R. Einasto and in a minor part on the data (Lahe-taguse, Mõnnuste, Soeginina) by the author. However, to reveal the event-stratigraphic significance of calcareous algae, more thorough studies are needed.

The sequences depicted in Figs. 1 and 2 comprise the shallowest water, i.e. shoal and lagoonal Wenlock and Ludlow deposits of Saaremaa. Although the calcareous algae found in these sections in the interval between the *lundgreni* and *leintwardiensis* zones are mostly long-ranging, their distribution is of a complicated pattern correlative to facies diversity. The latter reflects the general sea level lowering at the end of the Wenlock, as well as local environmental changes like drop of salinity (Эйнасто, 1968). Calcareous algae have been recorded from shoal deposits (skeletal or pelletal grainstones and packstones). They do not occur or have not been preserved in sedimentary dolostones containing instead non-calcified phaeophyte? algae not studied in Estonia but recorded from many other regions (e.g. Podolia).

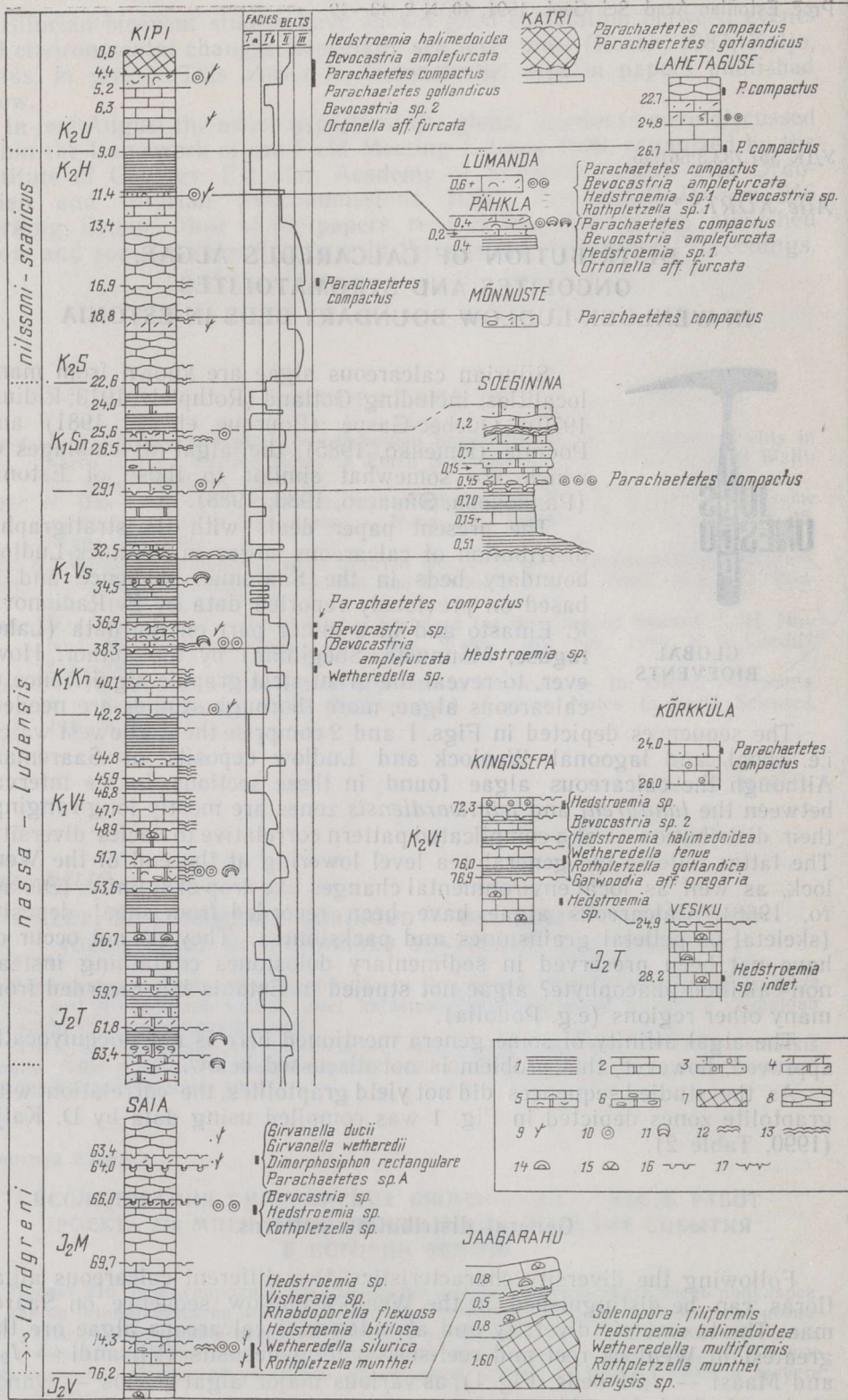
The algal affinity of some genera mentioned here is not unequivocally approved, however, this problem is not discussed below.

As the studied sequences did not yield graptolites, the correlation with graptolite zones depicted in Fig. 1 was compiled using data by D. Kaljo (1990, Table 2).

General distribution patterns

Following the diversity characteristics, two different calcareous algal floras can be distinguished in the Wenlock-Ludlow sequence on Saaremaa. The taxonomic diversity and abundance of calcareous algae are the greatest in Wenlock reef and reef-surrounding deposits (Vilsandi — J_2V and Maasi — J_2M beds, Fig. 1), as various major algal groups — cyanophytes, rhodophytes, chlorophytes — are represented.

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The algal diversity in the Ludlow reef (Sauvere — K_2S and Uduvere — K_2U beds) and restricted shelf deposits is not so great as in the Wenlock. Ludlow flora is dominated by red algae.

Calcareous algae seem to be extremely rare in the Vesiku Beds (K_1Vs) — only two finds have been recorded. At the same time, the Vesiku Beds are noteworthy for the lateral distribution maximum of oncolites and stromatolites (Fig. 2).

Below some more or less distinct changes in the stratigraphic distribution of algae, oncolites and stromatolites are treated.

Calcareous algae

The algal assemblage of the Vilsandi (J_2V) and Maasi (J_2M) beds is rich and diverse comprising green dasyclad and codiacean (*Rhabdoporella*, *Dimorphosiphon*, *Hedstroemia*), red (*Solenopora*, *Parachaetetes*), blue-green (*Bevocastria*, *Rothpletzella*, *Girvanella*) and somewhat problematic (*Wetheredella*) algae. Both framebuilders and encrusters occur. Some differentiation can be noticed between the fore- and backreef algal content: encrusting *Solenopora filiformis* Nicholson, *Wetheredella silurica* Wood, *W. multiformis* A. Ishchenko and *Rothpletzella munthei* Wood occur in the forereef, while in the backreef bushy forms like *Hedstroemia* are common (Радионова, Эйнасто, 1986).

The lowermost part of the Tagavere Beds (J_2T) should perhaps reveal more algae than shown in Fig. 1, but up to now only two finds of *Hedstroemia* have been recorded: *Hedstroemia halimedoidea* Rothpletz from the Kingissepa and *Hedstroemia* sp. from the Vesiku core.

The lower unit of the Viita Beds (K_1Vt) contains a diverse assemblage resembling in its diversity the underlying Vilsandi and Maasi beds, but in addition some new species — *Wetheredella tenue* Radionova, *Rothpletzella gotlandica* Wood, *Garwoodia* aff. *gregaria* (Nicholson) have been distinguished.

The Kuusnõmme Beds (K_1Kn) have yielded few algae, but there occur *Bevocastria amplefurcata* and *Parachaetetes compactus* (Rothpletz) (Kuusnõmme outcrop; Plate I, 1) which are more characteristic of the overlying part of the Silurian sequence in Estonia. Morphological diversity of *Bevocastria* and *Parachaetetes*, and whether it is due to environmental factors or specific differences, should be studied separately. *Parachaetetes compactus* and *P. gotlandicus* are present in the Vattenfallet section of Gotland already in the Upper Visby Marl and Högklint "C" (Riding, 1979), but they gain predominance in Ludlow assemblages.

In the Vesiku Beds (K_1Vs) algae are very rare. *Parachaetetes compactus* (Plate I, 2) and *Bevocastria* sp. are found in its basal part in the Kipi core.

Fig. 1. Distribution of calcareous algae in some selected sections of Saaremaa (lithological columns and facies curve by R. Einasto). 1 — lagoonal sedimentary dolostone; 2 — restricted shelf limestone and secondary dolostone; 3 — pelletal and oolite grainstones of shoal; 4 — skeletal grainstones of shoal; 5 — coquinoid rudstone and floatstone; 6 — lithoclastic limestone; 7 — boundstone (reef limestone); 8 — open shelf nodular limestone; 9 — algae; 10 — oncolites; 11 — domal stromatolites; 12 — laminar stromatolites; 13 — continuous layer of laminar stromatolites; 14 — stromatoporoids; 15 — tabulate corals; 16 — discontinuity surface; 17 — mud-cracks. Facies belts: Ia — lagoonal, Ib — restricted shelf, II — shoal, III — open shelf. Beds: J_2V — Vilsandi; J_2M — Maasi; J_2T — Tagavere; K_1Vt — Viita; K_1Kn — Kuusnõmme; K_1Vs — Vesiku; K_1Sn — Soeginina; K_2S — Sauvere; K_2H — Himmiste; K_2U — Uduvere.

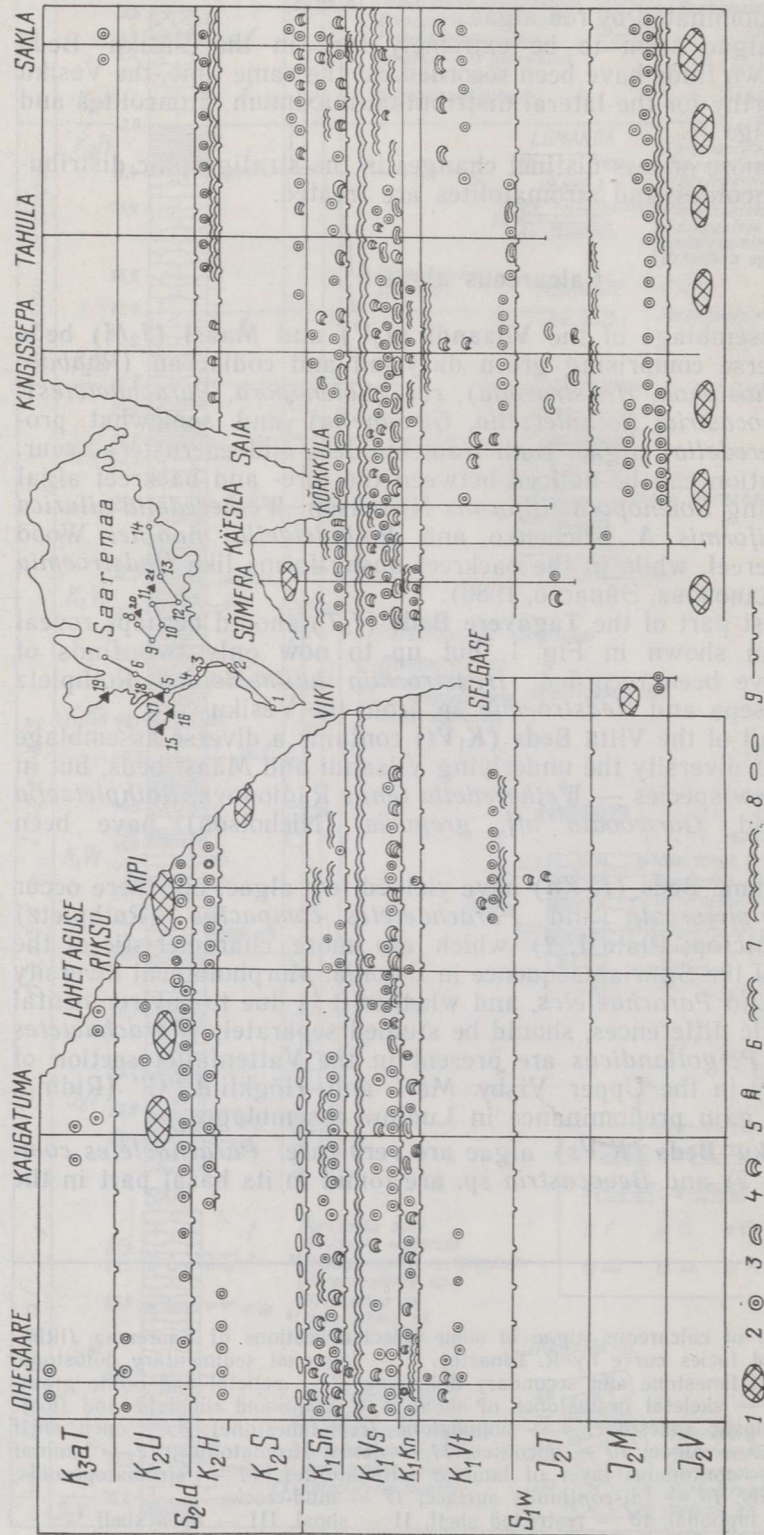


Fig. 2. Distribution of oncolites, stromatolites and reefs in the Wenlock and Ludlow sequences in Saaremaa (data by R. Einasto). 1 — reefs; 2 — oncolites; 3 — oncolites with a pelecypod nucleus; 4 — domal stromatolites; 5 — pebbles; 6 — laminar stromatolites; 7 — a continuous layer of laminar stromatolites; 8 — borings (triangles); 9 — Ohesaare, 2 — Kaugatuma, 3 — Lahetaguse, 4 — Riksu, 5 — Kipi, 6 — Viki, 7 — Selgase, 8 — Sõmera, 9 — Käesla, 10 — Kirkküla, 11 — Saia, 12 — Kingissepa, 13 — Tahula, 14 — Sakla, 15 — Soeginina, 16 — Katri, 17 — Lümanda, 18 — Vesiku 507, 19 — Jaagarahu, 20 — Mõnnuste, 21 — Pähkla.

The red alga *Parachaetetes compactus* becomes abundant in the **Soeginina Beds (K_1Sn)**. It occurs there as nodules or forms the nucleus of an oncolite (Soeginina cliff, Plate I, 3). *Hedstroemia* and *Bevocastria* have been distinguished in this unit in the Riiumäe core.

The **Sauvere Beds (K_2S)** resemble the Soeginina ones as *Parachaetetes compactus* is still the commonest species in skeletal grainstones and boundstones of small reef-bodies. *Parachaetetes* is so abundant in Mõn-nuste backreef grainstones that this limestone could be called "*Parachaetetes* limestone".

Starting with the **Himmiste (K_2H)** and **Uduvere (K_2U)** beds, the algal assemblage becomes diverse again. The Uduvere Beds contain *Hedstroemia halimedoidea*, *Ortonella* aff. *furcata* and *Bevocastria amplefurcata*. *Parachaetetes gotlandicus* is distinguished in the Uduvere Beds in the Saaremaa sequence for the first time. There exists a clear difference between Uduvere reefs and Maasi reefal deposits: the latter comprise green algae while in Uduvere reefs red algae predominate (Plate II, 1, 2, 3).

Oncolites and stromatolites

Oncolite accumulations representing the shallow high-energy environment occur in the Wenlock-Ludlow sequence in Saaremaa on 8 levels, the most remarkable of them appearing in the Maasi, Vesiku, Soeginina, and Himmiste beds (Fig. 2). Oncolites are usually distinguished only in the basal unit of the sedimentary cycle formed after a hiatus, but in the Vesiku and Soeginina beds oncolites are widespread also in the middle unit of a sedimentary cycle and absent only in the upper part — in *Eurypterus* dolostones (Раднонова, Эйнасто, 1988). Vesiku oncolites occur on a vast territory, but having been deposited far from the open sea they do not contain algae. On the other hand, Soeginina oncolites have often a solenoporid nucleus or they contain filaments of *Bevocastria* in their outer layers.

The Vesiku Beds are remarkable also as their **laminar stromatolite** bed has the largest distribution area. Usually laminar stromatolites occur as lenses in the Silurian sequence in Estonia. In addition to laminar (in the Maasi, Viita, Soeginina, Himmiste beds) stromatolites, those of columnar and domal form (Plate II, 4) occur in the Vesiku Beds. The first domal stromatolites in the Wenlock-Ludlow sequence have been distinguished in the Maasi Beds, associating with discontinuity surfaces and overlain by grain- or packstones. Domal stromatolites seem to have been formed in high-energy and columnar stromatolites in subtrubulent environment.

Comparison and conclusions

1. The diversity maximum of calcareous algae in the middle Wenlock, analogous with Estonia (Vilsandi, Maasi and lower Viita beds), can be seen in Podolia, the Urals (Чувашов, Шуйский, 1988), Quebec-Gaspé and Sayabec (Heroux et al., 1977). Only, green algae are not so abundant in Saaremaa sections as in Podolia or Quebec, where several species of *Rhabdoporella*, *Dimorphosiphon* and *Ortonella* have been found.

2. The Vesiku Beds contain tidal flat nonskeletal oncolites and widespread laminar stromatolites that might represent the deposits accumulated after the late Wenlock regression maximum, marked also by almost complete disappearance of calcareous algae.

The low diversity of calcareous algae in Estonia and their absence in Podolia coincide at the level of the Rootsiküla Stage (K_1) and the Ustje Subformation (note the different correlation by A. Ishchenko (Ищенко, 1985, Table 1)). The calcareous algal flora was replaced at the Rootsiküla Age by algal-microbial communities responsible for stromatolite formation. Non-calcified phaeophyte? algae like *Buthotrepis* found a suitable habitat in brackishwater lagoons.

3. The abundant solenoporids found in the Soeginina Beds might refer to the shoal environment with normalizing water circulation.

4. The algal assemblage of inner-shoal patch reefs of the Uduvere time was dominated by red algae *Parachaetetes compactus* and *P. gotlandicus*. The Ludlow assemblages are more diverse in Podolia and Quebec-Gaspé, both rhodo- and various chlorophytes occur there. A more diversified Ludlow assemblage (comparable to the one from Sokol reefs in Podolia) could be found in the East Baltic, perhaps, in the Piltene area, Latvia. The rise of diversity in the Ludlow is not so remarkable in shallow-water succession, but in Podolia the open shelf deposits have yielded a new green alga *Sokolella* and some other dasycladaceans.

A general tendency towards red algal dominance in the Ludlow can be observed in several regions (esp. Gaspé). Red algae seem to have been responsible for most of the calcareous algal biomass at the end of the Ludlow.

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4



1



3



2

1 Specimens of *Parachaetetes compactus* (Rothpletz). $\times 1.2$. Kaarma core, 1.5 m (K_2H , basal).

2 *Parachaetetes compactus* (Rothpletz). $\times 5.6$. Kaarma core, 1.5 m (K_2H , basal).

3 *Parachaetetes compactus* (Rothpletz). $\times 5.6$ Kipi core, 4.7 m (K_2U).

4 Columnar stromatolite. $\times 0.8$. Kaugatuma core, 79.7 m (K_1Vs , basal).

LUBIVETIKATE, ONKOLIITIDE JA STROMATOLIITIDE LEVIK WENLOCKI JA LUDLOW' PIIRIKIHTIDES EESTIS

Artiklis on kokku võetud varem publitseeritud ja mõned uued andmed lubivetikate ja vetikmoodustiste (onkoliitide ja stromatoliitide) leviku kohta madalmerelise päritoluga setendites. Vilsandi ja Maasi kihtides ning Viita kihtide alumises osas esineb mitmekesine lubivetikate assotsiatsioon, mis kaob laguunsete setendite laialdasema ilmumisega läbilõikes (Viita kihtide ülemine osa). Onkoliitide ja stromatoliitide rohkus Vesiku kihtides ning solenoporiidsete punavetikate arvukus Soeginina kihtides viitab nimetatud kihtide transgressiivsele päritolule.

Айле Кыртс

РАСПРОСТРАНЕНИЕ ИЗВЕСТКОВЫХ ВОДОРΟΣЛЕЙ, ОНКОЛИТОВ И СТРОМАТОЛИТОВ В ПОГРАНИЧНЫХ ОТЛОЖЕНИЯХ ВЕНЛОКА И ЛУДЛОВА В ЭСТОНИИ

Обобщены опубликованные и некоторые новые данные по распространению известковых водорослей и водорослевых образований (онколитов и строматолитов) в мелко-водных отложениях. Наиболее разнообразные ассоциации известковых водорослей приурочены к венлокским вильсандским и маазиским слоям, а также к нижней части вийтаских слоев. Обилие онколитов и строматолитов в везикуских и увеличение численности соленопорид в соэгининаских слоях указывают на трансгрессивное происхождение этих отложений.

The presence of the dating of the carbonate sections in Estonia depends on their correlation with the continuous stratigraphic sequence in the central part of the Baltic Sea including West Latvia (see Korts et al. 1977) and the correlation with the Golland sequence in the West. The Wenlock-Ludlow transition is represented by distinct normalizing facies (see V. Nestor, 1982).

Stratigraphic Unit	Stratigraphic Position	Thickness (m)	Color	Texture	Composition	Notes
Maasi	Lower	10-15	Light grey	Massive	Calcareous	Contains small corals
Vilsandi	Upper	5-10	Light grey	Massive	Calcareous	Contains small corals
Viita	Lower	10-15	Light grey	Massive	Calcareous	Contains small corals
Viita	Upper	5-10	Light grey	Massive	Calcareous	Contains small corals
Vesiku	Lower	10-15	Light grey	Massive	Calcareous	Contains small corals
Vesiku	Upper	5-10	Light grey	Massive	Calcareous	Contains small corals
Soeginina	Lower	10-15	Light grey	Massive	Calcareous	Contains small corals
Soeginina	Upper	5-10	Light grey	Massive	Calcareous	Contains small corals

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