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STRATOTYPE OF THE PORKUNI STAGE WITH COMMENTS ON THE RÖA MEMBER (UPPERMOST ORDOVICIAN, ESTONIA)

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Abstract. A revised interpretation of the subdivisions within the unit stratotype section of the topmost Ordovician Porkuni Stage is presented together with an improved description of the section. The boundary beds with the underlying Pirgu Stage in the stratotype section are described for the first time. The "Encrinitenlager", a crinoidal limestone (dolomite) bed, established by Schmidt (1858, *Arch. Naturk. Liv-, Ehst- und Kurl., Ser. I*) in the base of his "Borkholmsche Schicht" (Porkuni Stage of current use) is considered to be identical with the Röa Member comprising the lower part of the Ärina Formation. The correlation of the Ärina Formation (including the stratotype of the Porkuni Stage) with the Kuldiga and Saldus formations in South Estonia and Latvia, based on the distribution of chitinozoans and carbon isotope data, shows that the Ärina Formation represents only the lower part of the Porkuni Stage, which in full is correlated with the Hirnantian Stage elsewhere.

Key words: uppermost Ordovician (Hirnantian), unit stratotype, Porkuni Stage, Estonia.

INTRODUCTION

The Porkuni Regional Stage comprises a succession of lithostratigraphical units characterizing the varied topmost Ordovician sequence of the East Baltic and adjacent areas. In the Northern and Central East Baltic the Porkuni Stage is made up of the Ärina, Kuldiga, and Saldus formations. The first formation, consisting mainly of the reef complex, occurs in the Estonian facies belt (Fig. 1), where the stratotype section of the stage is also located. The Kuldiga Formation

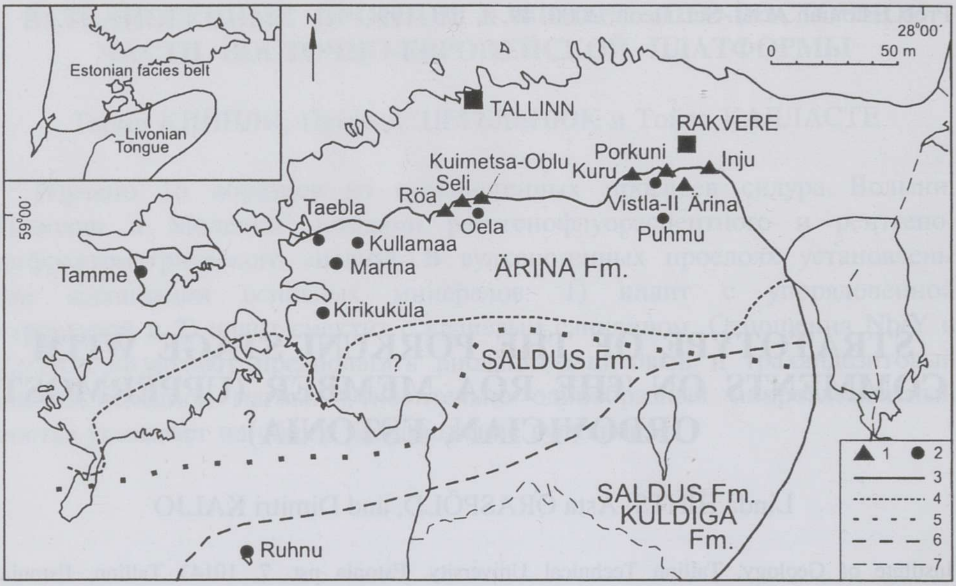
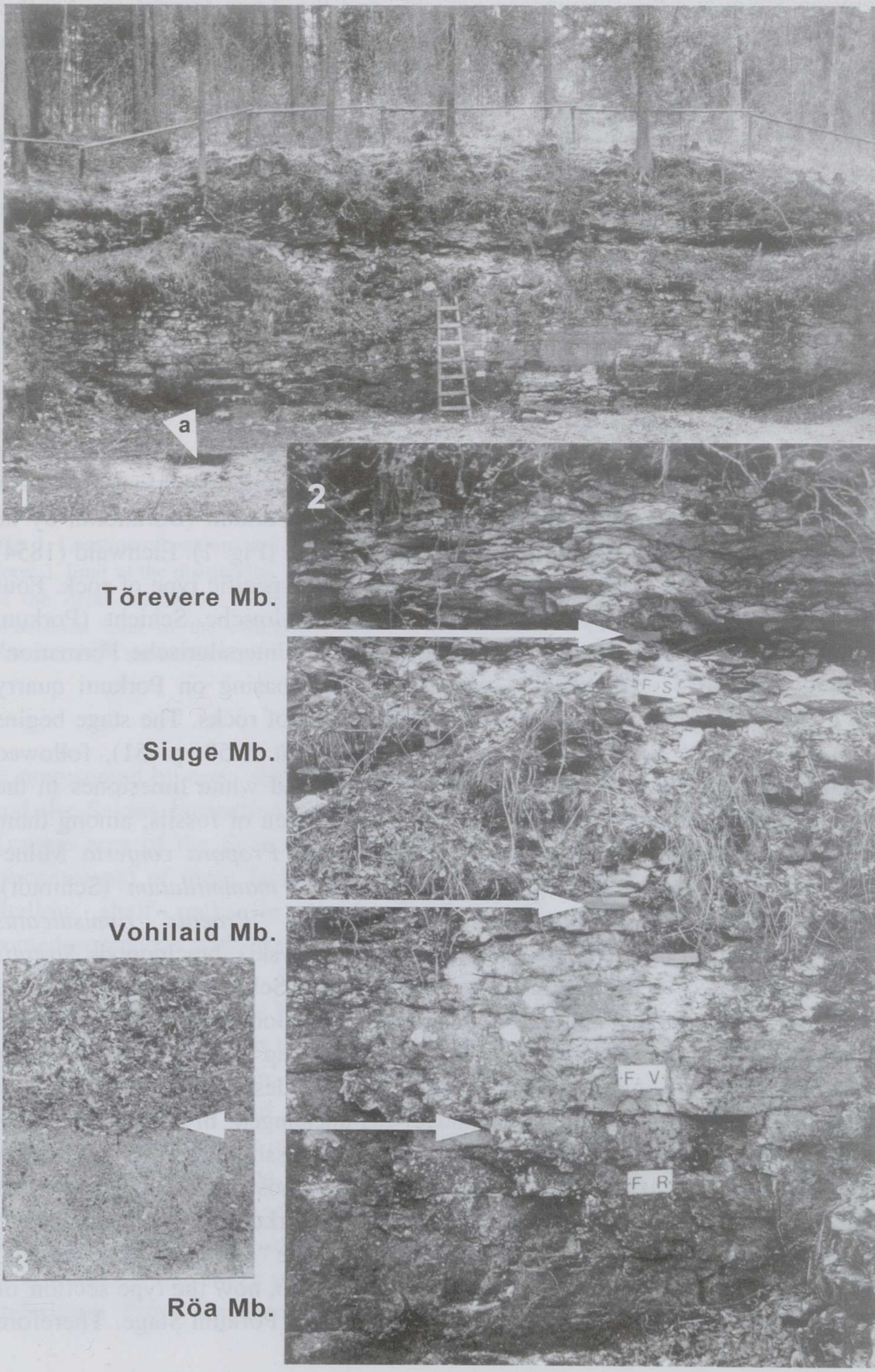


Fig. 1. Location of sections and distribution of formations of the Porkuni Stage. 1, outcrop; 2, drill core; 3, limit of the distribution area of the Porkuni Stage; 4, southern limit of the distribution area of the Ärina Formation; 5, northern limit of the distribution area of the Saldus Formation; 6, northern limit of the distribution area of the Kuldiga Formation (overlain by the Saldus Formation); 7, state boundary.

is represented by open shelf facies, which contain fossils of the *Hirnantia* fauna, and the Saldus Formation terminates the Ordovician sequence in the Livonian Tongue area of the Scandinavian facies belt. Two rather different correlations (successions) of these facies and units have been suggested as follows: 1) the shallow shelf rocks in North Estonia (Ärina Formation) are roughly contemporaneous with deeper facies ones in South Estonia and Latvia (Kuldiga and Saldus formations) (Männil 1966; Ulst et al. 1982), and 2) the Ärina Formation lies below the Kuldiga Formation, representing the whole stage *sensu stricto*. In the latter case the Porkuni Stage is considered pre-Hirnantian in age (Bruton et al. 1997). In recent stratigraphical schemes the Ärina Formation constitutes the lower part of the Porkuni Stage in the Estonian facies belt (the upper part of the stage is missing there) and can be correlated with the lower half of the Kuldiga Formation in the Livonian Tongue area. Due to lithological and faunal differences the exact correlation of the Ärina and Kuldiga formations has been problematic and some additional complications were caused by the assignment of the lower part of the Ärina Formation, the Röa Member, to the underlying Pirgu Regional Stage. The aim of this paper is to discuss the subdivisions of the Porkuni Stage in the type section, to show the relationship between Schmidt's "Borkholmsche Schicht" and the Ärina Formation. Another task is to correlate the stratotype section. The improved descriptions of the stratotype and hypostratotype sections are also presented. The stratigraphical problems concerning the Porkuni Stage and its type section have been topical in context of recent isotope studies relevant to the Hirnantian glaciation. We hope that the discussion in this paper clarifies our understanding of the stratigraphy of the topmost East Baltic Ordovician and enables more precise correlation of the Porkuni Stage with the Hirnantian Stage used in Scandinavia and many other regions of the world.

HISTORICAL REVIEW

The quarries used for tens of years for getting building limestone or for production of lime have had an important role in the study of Ordovician rocks. One of the most famous such quarries is located in Porkuni (Borkholm, by its old German name), about 20 km southwest of Rakvere (Fig. 1). Eichwald (1854) was the first to mention the Borkholm dolomite as a specific type of rock. Four years later Schmidt (1858) established the Borkholmsche Schicht (Porkuni Stage of current use), which forms the roof of his "Untersilurische Formation" (= Ordovician). He recognized in this unit, mainly basing on Porkuni quarry (Pl. I, figs. 1, 2), a succession of four different types of rocks. The stage begins with the crinoidal bed ("Encrinitenlager" in Schmidt 1858, p. 51), followed upwards by dolomitic limestones, brownish marls, and white limestones in the upper part (Fig. 2). The rocks contain a rich association of fossils; among them the corals *Palaeophyllum fasciculum* (Kutorga) and *Propora conferta* Milne-Edwards & Haime, stromatoporoid *Clathrodictyon mammillatum* (Schmidt), bryozoan *Phyllopora tenella* (Eichwald), trilobites "*Proetus*" *ramisulcatus* Nieszkowski and *Platylichas margaritifera* (Nieszkowski), brachiopods *Streptis undifera* (Schmidt) and *Geniculina pseudoalternata* (Schmidt) and others were mentioned. The crinoidal bed in the lower part of the Borkholmsche Schicht was mentioned also in the explanation to the geological map published by Grewingk (1879). In 1881, Schmidt published a more detailed description of the Porkuni Stage, but the general concept of the stage was unchanged. In both publications he described four subdivisions of the Schicht, stressing that the uppermost limestone and the lowermost Encrinitenlager are the most stable members of the stage (Schmidt 1858, p. 51). In both papers in the Porkuni quarry section there was mentioned the occurrence of strata belonging to the "Lyckholmsche Schicht" (Pirgu Stage) below the crinoidal bed. The Röa outcrop, now the type section of the Röa Member, was also listed as the locality of the Porkuni Stage. Therefore


1
a
2
Tõrevere Mb.
F S
Siuge Mb.
Vohilaid Mb.
F V
F R
3
Röa Mb.

Schmidt 1858,1881		Wahl 1923		Rõõmusoks 1966, 1983			This paper		
BORKHOLMSCHE SCHICHT	Light grey limestone with corals and brachiopods	BORKHOLMER SCHICHT	Coral limestone, 0.7	PORKUNI STAGE	ÄRINA FORMATION	Tõrevere Mb., 1.2+	PORKUNI STAGE	ÄRINA FORMATION	Tõrevere Mb., 1.5+
	Brownish argillaceous bituminous limestones with layers of marl and siliceous concretions		*Conocardium*-limestone, 1.58			Siuge Mb., 1.2			Siuge Mb., 1.5
	Coarse-grained dolomitic limestone		Bryozoan limestone, 1.14			Vohilaid Mb., 1.37			Vohilaid Mb., 1.0
	Crinoidal bed ("Encrinitenlager")		Crinoidal dolomite, 1.04	F_Ic		Röa Mb., 0.7			Röa Mb., 1.47
Lyckholmsche Schicht		Lyckholmer Schicht			Adila Fm.		F_Ic	Adila Fm., 0.36	

Fig. 2. Subdivisions of the Porkuni Stage with thicknesses (in metres) of units in the Porkuni quarry section. F_Ic, Pirgu Stage.

it is quite clear that Schmidt included the Encrinitenlager in the Borkholmsche Schicht, keeping it separated from the Lyckholmsche Schicht.

Wahl (1923), wishing to draw more attention to the faunal differences of Schmidt's subdivisions of the Porkuni Stage, named them with their characteristic fossils: crinoidal dolomite in the lower part of the stage, which is succeeded upwards by the bryozoan limestone, *Conocardium*-limestone, and the coral limestone (Fig. 2). He repeated also Schmidt's earlier remark about the importance of the lowermost unit for the practical use. It should also be mentioned that the dolomites or dolomitic limestones of the lower part of the Ärina Formation belonging to the Röa Member are used as stone for sculptures and are quarried, for example in Inju quarry (Fig. 1) east of Porkuni (Teedumäe 1987).

Explanation of Plate I

Fig. 1. Porkuni quarry; the white arrow (a) shows the place where the lowermost samples (I–IV) were taken.

Fig. 2. The middle part of the quarry wall described in the paper (the ladder marks the place in fig. 1). The white arrows show the boundary levels between the members. The labels with the indexes F_{II}R, F_{II}V, and F_{II}S fixed on the quarry wall mark the Röa, Vohilaid, and Siuge members.

Fig. 3. The boundary bed between the Röa and Vohilaid members (sample No. 242-8), × 1.

The most complete overview of the Porkuni Stage and descriptions of the outcrops are presented in manuscripts by Sirk (1958) and Rõõmusoks (1966) and in reports compiled during geological mapping (Kõrvel et al. 1970) or specific prospecting work (Lodjak 1982; Saadre et al. 1984). Nestor (1987) described the stage in the Rakvere phosphorite-bearing region and in the stratotype area. Making use of these and some other studies (Martna 1957; Männil et al. 1958), the lithostratigraphical subdivision of the topmost Ordovician in northern Estonia, based on Schmidt's early papers, was formalized and a corresponding nomenclature proposed. The terminal unit of the sequence was named by Rõõmusoks (1983) the Ärina Formation comprising five members: (in ascending order) Röa (Martna 1957), Vohilaid, Siuge, Tõrevere (all by Sirk 1958), and Kamariku (Rõõmusoks 1966). But the lowermost Röa Member was included in the Pirgu Stage and the succeeding members referred to the Porkuni Stage (Männil & Rõõmusoks 1984, p. 59).

The age of the lowermost Röa Member of the Ärina Formation and the stratigraphical position of the boundary between the Pirgu and Porkuni stages have been discussed repeatedly (Jaanusson 1956; Martna 1957; Männil & Rõõmusoks 1984; Rõõmusoks 1966, 1991; Hints & Meidla 1997). Rõõmusoks (1966, 1991) showed on the basis of biostratigraphical data that the Röa Member has more in common with the Pirgu fauna and therefore should be excluded from the Porkuni Stage. This point has been followed in some other papers on the Porkuni Stage (Oraspõld 1975), but the Baltic Stratigraphical Conference considered the better documented earlier concept and so in the so-called official stratigraphical chart (Kaljo 1987) the Röa Member was shown within the framework of the Porkuni Stage with a gap at its lower boundary. This point of view has been followed in a general book on Estonian geology (Raukas & Teedumäe 1997).

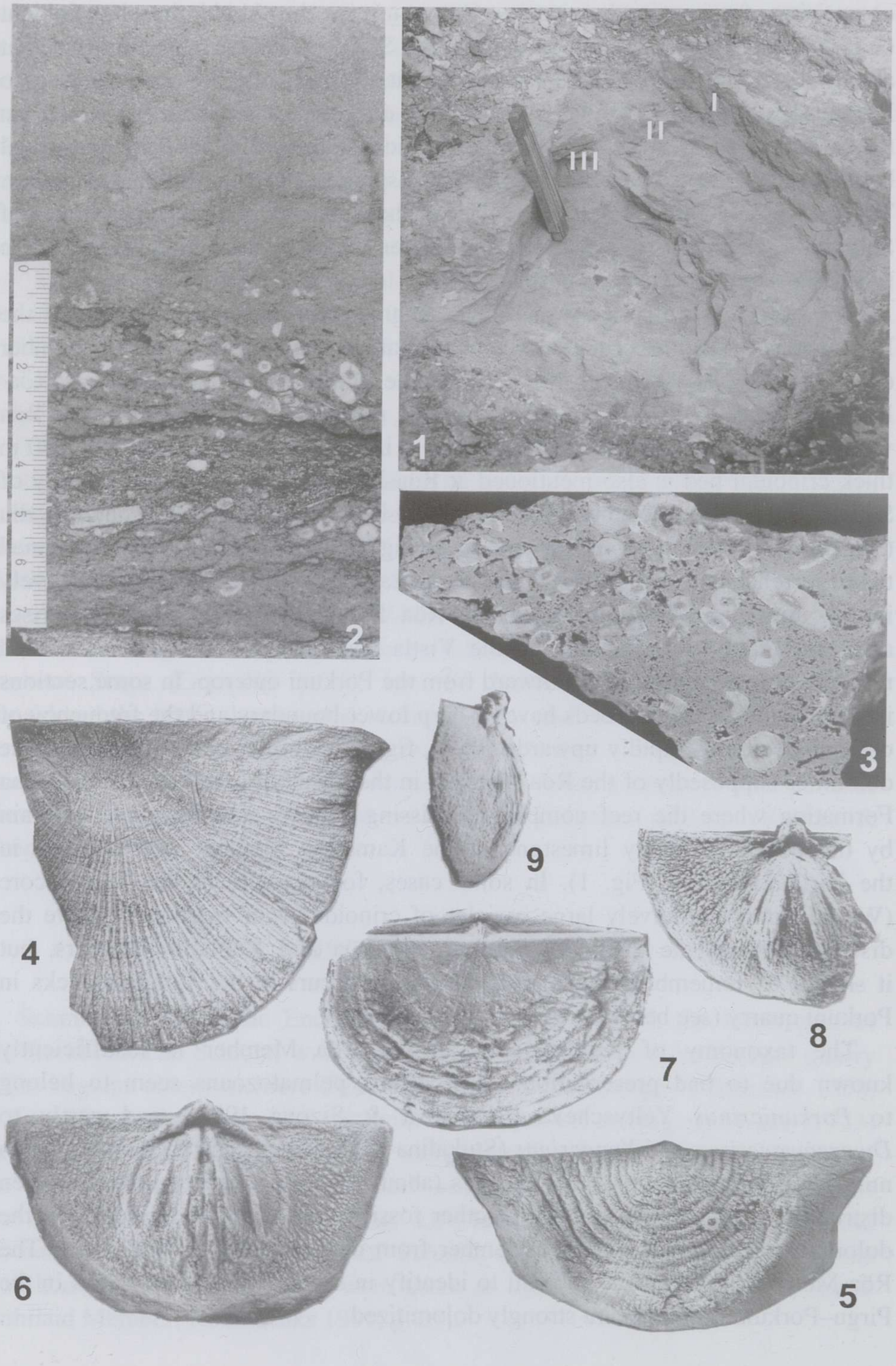
ON SCHMIDT'S CRINOIDAL BED (THE RÖA MEMBER)

Schmidt identified the Encrinitenlager (crinoidal bed) in the lower part of the Borkholmsche Schicht, with a thickness of at least 0.6 m in Porkuni quarry ("Sie beginnt einem mehrere Fuss mächtigen Encrinitenlager"; Schmidt 1858, p. 51). The total thickness of the units was about 4.5 m (Fig. 2). Wahl (1923) gave a more exact thickness for the units identified in the quarry section; that for the lowermost unit (Crinoidal Bed) was 1.04 m and the total thickness of the Porkuni Stage was 4.46 m (Fig. 2). Männil (in Männil et al. 1958) and Rõõmusoks (1966) considered that Schmidt's crinoidal bed was part of the Vohilaid Member or the terms were taken as synonyms (encrinal limestone = Vohilaid Member; Rõõmusoks 1991, p. 23).

All three, Schmidt, Wahl, and Rõõmusoks, included the beds below the unit comprising frequent pelmatozoan fragments in the Lyckholmsche Schicht (= Pirgu Stage). The thickness of the Porkuni Stage in the quarry was estimated at about 4.5 m by the two first authors and it reaches only 3.8 m according to Rõõmusoks (1966, 1983) (Fig. 2). These differences in thickness based on the same section by different researchers indicate clearly that Schmidt's crinoidal bed cannot be considered as the unit corresponding to the Vohilaid Member. The assumption that Rõõmusoks enlarged the Vohilaid Member on account of Schmidt's crinoidal bed is also in contradiction with the description given by him for the Porkuni section (Rõõmusoks 1983, p. 144; 1991, p. 30).

The occurrence of ossicles and stem fragments is quite characteristic of the Röa Member. Distinct crinoidal beds occur at several exposures of the member (Pl. II, fig. 3). According to Sirk (1958), the ossicles occur frequently in Röa-Kirsimäe quarry (in Fig. 1 the locality Röa marks several old quarries in Röa village) in the upper half of the Röa Member in a 0.1 m thick bed; a 0.08–0.30 m thick crinoidal bed is also mentioned at Röa-Jakobi, Mäeotsa (in the vicinity of Seli), Kuimetsa-Oblu, Lõiuse-Tammiku (close to the previous section), Veadla (NE from Porkuni), and old Kuru quarries (Fig. 1). Rõõmusoks (1966) mentioned the occurrence of a similar bed in the Martna and Oela core sections, respectively in the upper and lower parts of the Röa Member. The member comprises abundant crinoid ossicles also in the Vistla and Puhmu core sections located respectively westward and southward from the Porkuni outcrop. In some sections in Hiiumaa the crinoidal beds have a sharp lower boundary and the frequency of ossicles decreases rapidly upwards (Pl. II, fig. 2). A crinoidal bed occurs in the dolomites supposedly of the Röa Member in the southern periphery of the Ärina Formation where the reef complex is missing and the dolomites are overlain by the oolitic or sandy limestone of the Kamariku Member (for example in the Kirikuküla core; Fig. 1). In some cases, for example in the Taebla core (West Estonia), relatively large ossicles of crinoids occur frequently above the discontinuity on the boundary between the Röa and Vohilaid members, but it should be remembered that crinoidal debris occurs in the Vohilaid rocks in Porkuni quarry (see below).

The taxonomy of pelmatozoans in the Röa Member is insufficiently known due to bad preservation. Most of the pelmatozoans seem to belong to *Porkunicrinus* Yeltyscheva (Eltysheva & Sizova 1971), and partly to *Dworcowaecrinus* and *Xenocrinus* (Stukalina 1988). The occurrence of beds with numerous, predominantly large ossicles (about 5 mm in diameter), their uneven distribution and relative scarcity of other fossils and their skeletal debris in the dolomites differentiate the Röa Member from under- and overlying strata. The Röa Member is, however, difficult to identify in sections where the rocks in the Pirgu–Porkuni transition are strongly dolomitized.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A detailed record of the shelly fauna in the Röa Member is given by Rõõmusoks (1991, table 1) who stresses its similarity with the fauna of the underlying Adila Formation of the Pirgu Stage. The brachiopods *Aphanomena* sp. n. 1 (= *Pirgumena martnai* in Rõõmusoks 1993), *Eoplectodonta schmidti* (Lindström), *Luhaia vardi* Rõõmusoks, "*Rafinesquina*" *pseudoalternata* (Schmidt) (= *Geniculina pseudoalternata* in Rõõmusoks 1993), gastropod *Maclurites neritoides* (Eichwald), trilobite *Toxochasmops* (= *Valdariops*) *eichwaldi* (Schmidt) and some others are considered by him as taxa indicating a Pirgu age for the Röa Member. The Röa dolomites actually have only a few species in common with the younger reef complex (brachiopods *Thaerodonta nubila* Rõõmusoks, *Platystrophia* cf. *humilis* Oraspõld, gastropods *Ambonychia acutiangulata* Isakar, *Mytilarca porkuniensis* Isakar, *Similodonta wahli* Isakar; according to table 1 in Rõõmusoks 1991). The differences and similarities mentioned are understandable and may be partly due to ecological factors. At the same time it should be mentioned that a great number of genera among brachiopods, gastropods, and trilobites disappear below the Röa Member (in the Pirgu Stage; see Raukas & Teedumäe 1997, pp. 226–238). This disappearance has been attributed to the first wave of the mass extinction of the late Ordovician shallow-water benthic fauna, which in the East Baltic took place before the formation of crinoidal banks and reefs in northern Estonia and before the appearance of the deeper-water *Hirnantia* fauna in southernmost Estonia and Latvia (Kaljo & Hints 1996). Bearing in mind the faunal changes at the Pirgu–Porkuni transition, the primary concept of the Porkuni Stage by Schmidt, and the carbon isotope data (see below), the Röa Member of the Ärina Formation is considered here as a lower part of the Porkuni Regional Stage.

Explanation of Plate II

Fig. 1. Hollow on the floor of Porkuni quarry (see Pl. I); I, II, and III mark the sampled beds (sample IV was taken below sample III).

Fig. 2. Dolomite of the Röa Member with stem fragments of pelmatozoans; sample (No. 242-6) from the Tamme (K-38) drill core (Hiiumaa Island), depth 38.54–38.67 m.

Fig. 3. The crinoidal bed (sample No. 242-7) in old Inju quarry; Röa Member; × 1.

Fig. 4. *Pirgumena martnai* Rõõmusoks, dorsal exterior (No. 242-1); Porkuni quarry, sample II, 0.09–0.12 m below the lower boundary of the Röa Member; Pirgu Stage; × 2.

Fig. 5. *Similoleptaena* sp. n. Rõõmusoks, ventral interior (No. 242-2); sample I, 0.02–0.09 m below the lower boundary of the Röa Member; Pirgu Stage; × 1.5.

Figs. 6, 7. *Thaerodonta nubila* Rõõmusoks. 6. dorsal interior (No. 242-3); sample I. 7. dorsal exterior (No. 242-4); sample II. Both × 3.

Figs. 8, 9. *Thaerodonta* cf. *convexa* Rõõmusoks, dorsal interior and lateral view (No. 242-5); sample II; both × 4.5.

DESCRIPTION OF THE TYPE SECTIONS OF THE PORKUNI STAGE

According to the Stratigraphical Guide (Salvador 1994), Porkuni quarry represents a unit stratotype which together with a hypostratotype section characterizes the Porkuni Stage in Central Estonia; here the stage traditionally consists of the Ärina Formation. There are few descriptions of the Porkuni section published after Wahl (Männil et al. 1958; Nestor 1990), although the section has repeatedly been described in manuscripts. The description presented here reflects the situation in the SW part of the quarry (Pl. I, fig. 1).

The material presented was collected from Porkuni quarry (Fig. 3; Pl. I, figs. 1, 2; Pl. II, figs. 1, 4–9) and the Vistla-II core section (Figs. 4–6), which is

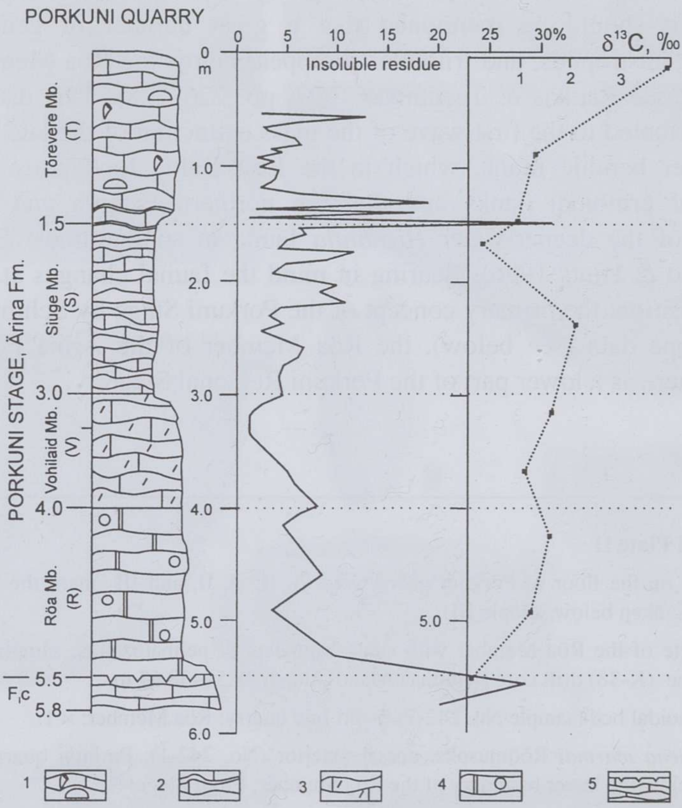

Fig. 3. The Porkuni quarry section, analyses of the insoluble residue and $\delta^{13}C$ composition. Legend (simplified) for the log: 1, reef limestone with corals; 2, biomicritic dolomitic limestone with interlayers of calcitic marl; 3, dolomitic skeletal limestone; 4, dolomite with crinoid ossicles; 5, argillaceous dolomite with discontinuity surface. $F_{I}c$, Pirgu Stage; indexes of the members are given in parentheses.

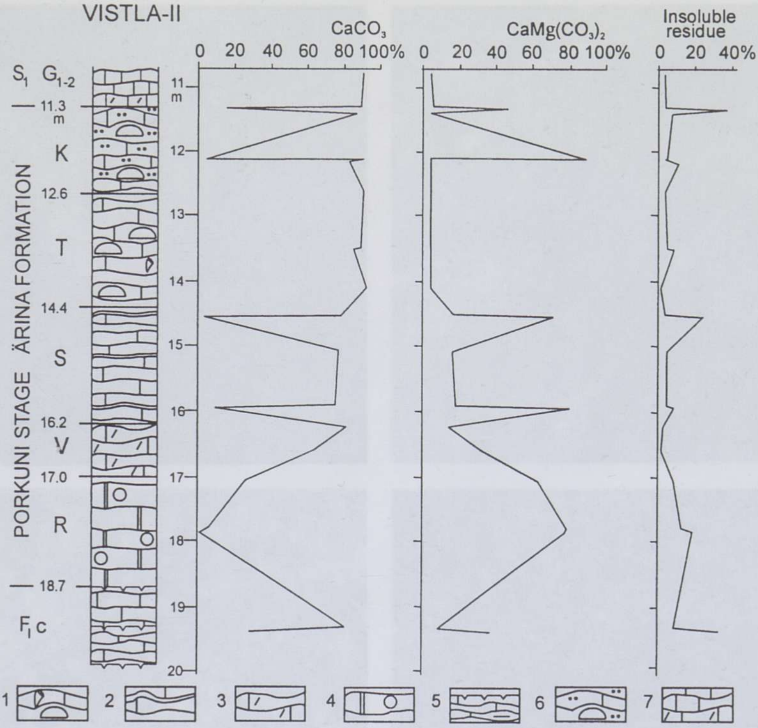

Fig. 4. The Vistla-II core section, chemical composition of rocks, and content of insoluble residue (sampled by L. Põlma). Legend for 1–5 see Fig. 3; 6, sandy reef limestone; 7, micritic limestone with interlayers of rudstone. Indexes of units $F_{I}c$, R, V, S, T see Fig. 3; K, Kamariku Member; S_1, Llandovery; $G_{1\text{-}2}$, Juuru Stage.

located 1130 m SW of the quarry (Fig. 7). The lithological description of the sections is based partly on unpublished data by L. Põlma. The chemical composition of rocks [$CaCO_3$, $CaMg(CO_3)_2$] and insoluble residues were analysed for 81 samples and the structure of the rocks was studied by 63 thin sections (partly from the collection of L. Põlma). Special attention was paid to the four samples from the lowermost part of the section taken in 1999 by digging into the floor of the quarry (Pl. II, fig. 1). The scope of this paper does not enable discussion on the distribution of the rich association of shelly fauna established in the quarry. Some characteristic species for particular subdivisions will be listed.

The polished rock samples, thin sections and fossils are housed at the Institute of Geology at Tallinn Technical University (collection No. 242). The Vistla-II

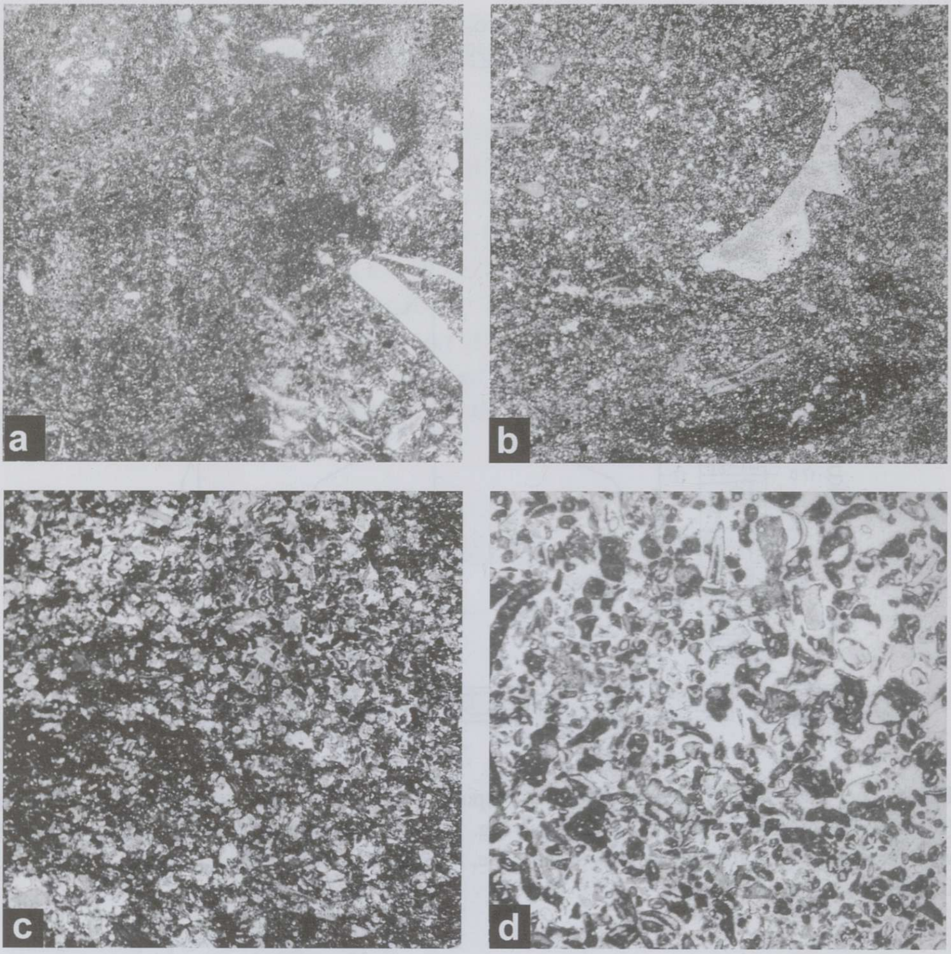

Fig. 5. Thin section photographs of samples from the Vistla-II core section (Pirgu Stage, Adila Formation, and the lower part of the Ärina Formation; coll. of L. Põlma). All × 8. (a) Biomicritic limestone (wackestone); depth 19.38 m; the uppermost part of the Adila Formation, Pirgu Stage. (b) Dolomitic biomicritic limestone; depth 17.09 m; Röa Member, Ärina Formation. (c) Slightly dolomitic fine skeletal limestone; depth 16.59 m; Vohilaid Member, Ärina Formation. (d) Coarse skeletal limestone; depth 16.21 m; Vohilaid Member, Ärina Formation.

core (sampled) together with the duplicate Vistla-I drill core is stored at the Särghaua field station of the institute. The composition of carbon isotopes ($\delta^{13}C$) in bulk rock samples has been discussed earlier (Kaljo et al. 2000); here only four new analyses were included from the Porkuni section.

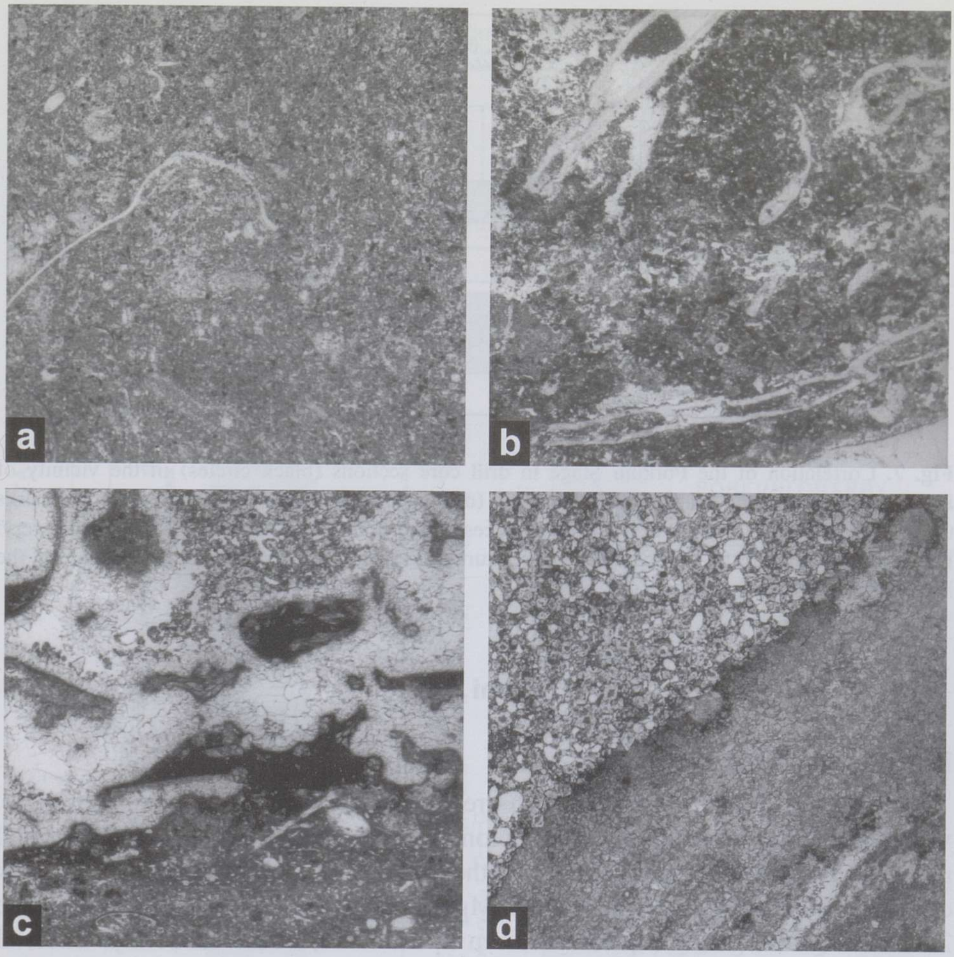

Fig. 6. Thin section photographs of samples from the Vistla-II core section (upper part of the Ärina Formation, coll. of L. Põlma). All × 8. (a) Biomicritic limestone; depth 15.07 m; Siuge Member. (b) Micritic skeletal limestone; depth 13.30 m; Tõrevere Member. (c) The upper boundary of the Tõrevere reef limestone with a pocket of sandy limestone of the Kamariku Member (in the upper middle part); depth 12.60 m. (d) Sandy limestone (quartz grains 0.05–0.50 mm in diameter; in the upper left part) with a large skeletal fragment of a stromatoporoid (in the lower right part); depth 11.38 m; Kamariku Member.

The sections of Porkuni quarry and the Vistla-II drill core will be described in terms of lithostratigraphical units (in ascending order). The depths are measured from top to bottom, the thickness of units is shown in parentheses. For the Vistla-II section, besides the drilling intervals and thickness also the real amount of core extant is given (both in parentheses).

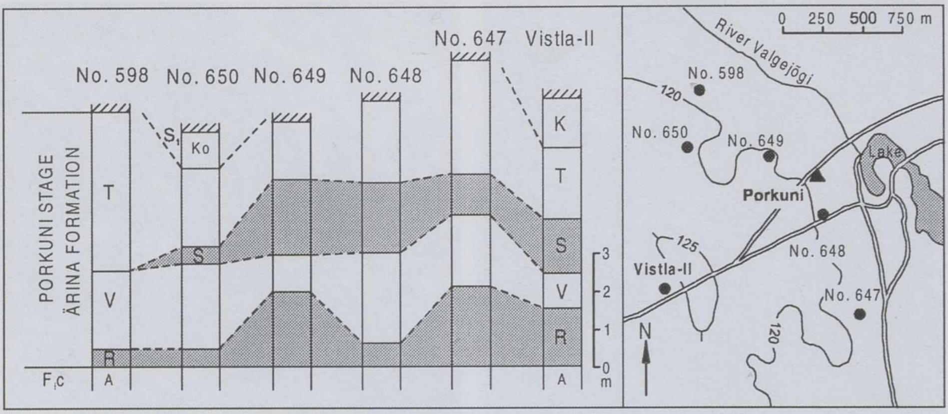

Fig. 7. Correlation of the Porkuni Stage in drill core sections (black circles) in the vicinity of Porkuni, shown on the map on the right side (data by Saadre et al. 1984); the triangle marks the stratotype Porkuni quarry section. For indexes of the units see Figs. 3 and 4; S_1, Llandovery; Ko, Koigi Member of the Varbola Formation, Juuru Stage. The diagonal streaking on the top of the logs marks the Quaternary cover.

Porkuni quarry

Pirgu Stage, Adila Formation

5.5–5.8+ m (0.3+ m) – yellowish-grey to yellow, micro- to fine-crystalline, variably calcitic and argillaceous dolomite with numerous yellow horizontal patterns which may mark the weathered discontinuity surfaces. In rock composition $CaCO_3$ forms 8–31%, $CaMg(CO_3)_2$ 47–85%, and insoluble residue 20–29%. Quartz grains (up to 0.05 mm in diameter) occur randomly. Skeletal debris (bioclastic material) consists of fragments of bryozoans, brachiopods, and echinoderms.

Four succeeding samples (I–IV; Pl. II, fig. 1) from the described interval comprise brachiopods, bryozoans, and rugose corals. *Thaerodonta nubila* Rõõmusoks (Pl. II, figs. 6, 7) occurs in all four samples from the described interval, in the lowermost sample (interval 5.8–5.7 m) the valves and complete shells of these brachiopods are numerous and disposed irregularly in the rock. In the lowermost sample (Fig. 8) this brachiopod is accompanied by the trilobite *Encrinurus moe* Männil (identified by H. Pärnaste) which is considered as a species of Pirgu age (Rõõmusoks 1966). But three similar pygidia from Wahl's collection supposedly are from the younger beds in the same section, because the pieces of the rock with *Encrinurus* are lithologically similar to those of the Vohilaid and Tõrevere members. In sample II one of the specimens of *Thaerodonta* with a high and relatively narrow cardinalia is similar to *T. convexa* known from the Pirgu Stage (Pl. II, figs. 8, 9). *Pirgumena martnai* Rõõmusoks

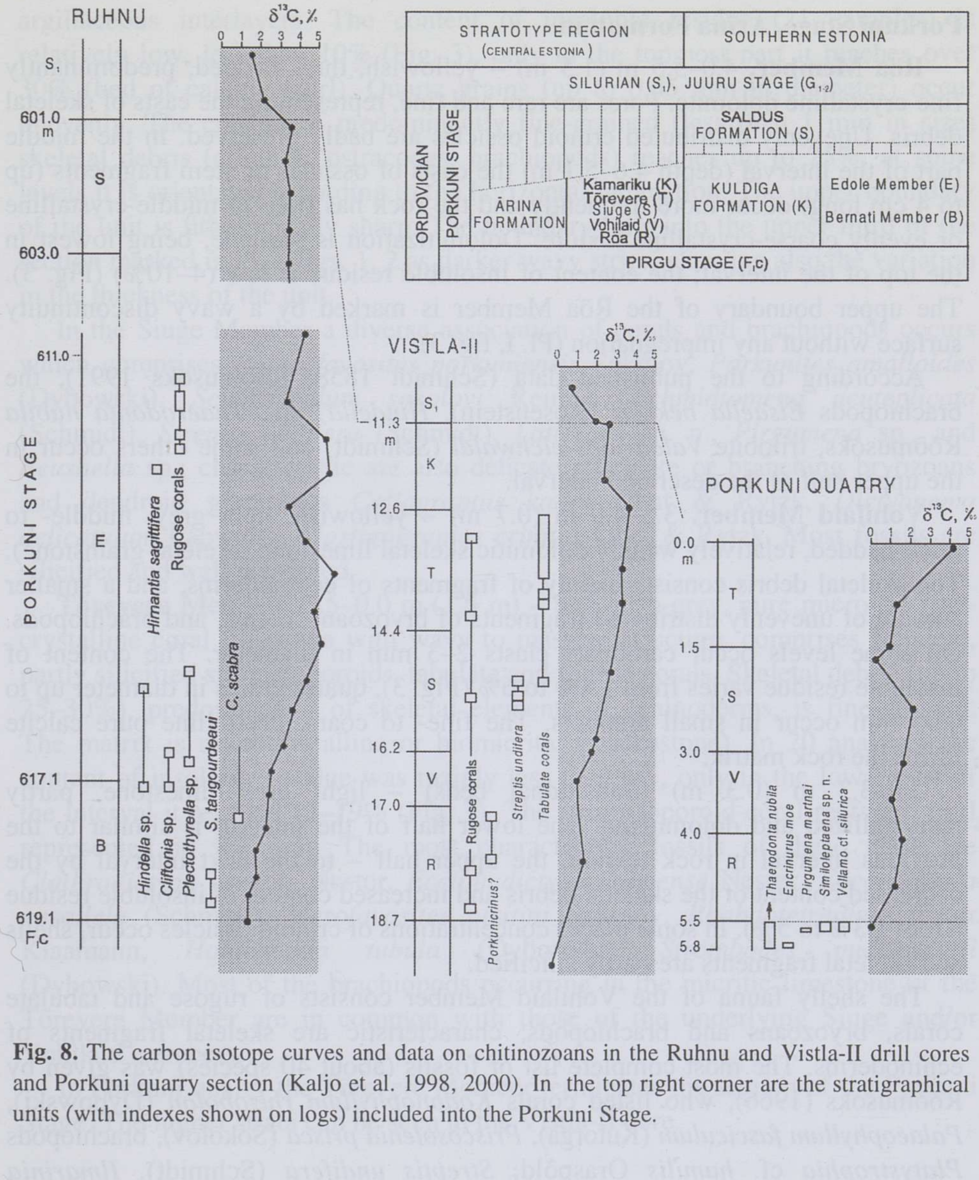

Fig. 8. The carbon isotope curves and data on chitinozoans in the Ruhnu and Vistla-II drill cores and Porkuni quarry section (Kaljo et al. 1998, 2000). In the top right corner are the stratigraphical units (with indexes shown on logs) included into the Porkuni Stage.

(Pl. II, fig. 4) occurs in the same bed. The uppermost sample (interval 5.5–5.6 m) includes *Vellamo* cf. *silurica* Öpik and *Similoleptaena* sp. n. (Rõõmusoks 1991, pl. III, figs. 5–7) (here Pl. II, fig. 5). The first two species indicate a Porkuni age, but *Similoleptaena* sp. n. is known from the Röa Member. For the exact determination of the boundary level between the Pirgu and Porkuni stages additional palaeontological data are needed.

Porkuni Stage, Ärina Formation

Röa Member. 4.0–5.5 m (1.5 m) – yellowish, thick-bedded, predominantly fine-crystalline dolomite. Pores are rare and fine, representing the casts of skeletal debris. Unevenly distributed crinoid ossicles are badly preserved. In the middle part of the interval (depth 4.6–5.1 m) the casts of ossicles or stem fragments (up to 4 cm long) occur more frequently and the rock has fine- to middle-crystalline or evenly coarse-crystalline texture. Dolomitization is variable, being lowest in the top of the interval; the content of insoluble residue is low (4–10%) (Fig. 3). The upper boundary of the Röa Member is marked by a wavy discontinuity surface without any impregnation (Pl. I, fig. 3).

According to the published data (Schmidt 1858; Rõõmusoks 1991), the brachiopods *Elsaella bekkeri* (Rosenstein), *Hindella*? sp., *Thaerodonta nubila* Rõõmusoks, trilobite *Valdariops eichwaldi* (Schmidt) and some others occur in the upper half of the described interval.

Vohilaid Member. 3.3–4.0 m (0.7 m) – yellowish, light grey, middle- to thick-bedded, relatively weakly dolomitic skeletal limestone (skeletal grainstone). The skeletal debris consists mainly of fragments of echinoderms, and a smaller amount of unevenly distributed fragments of bryozoans, corals, and brachiopods. On some levels occur carbonate clasts 2–3 mm in diameter. The content of insoluble residue varies from 1.4% to 6% (Fig. 3), quartz grains in diameter up to 0.05 mm occur in small amounts. The fine- to coarse-crystalline pure calcite forms the rock matrix.

3.0–3.3 m (0.3 m) (transitional beds) – light grey limestone, partly recrystallized and dolomitized. The lower half of the interval is similar to the previous interval in rock texture, the upper half – to the next interval by the decreased content of the skeletal debris and increased content of insoluble residue (from 1.3% to 5%). In some places concentrations of crinoid ossicles occur, shells and skeletal fragments are partly silicified.

The shelly fauna of the Vohilaid Member consists of rugose and tabulate corals, bryozoans and brachiopods; characteristic are skeletal fragments of echinoderms. The most complete list of fossils (about 40 species) was given by Rõõmusoks (1966), who listed corals *Kodonophyllum rhizobolon* (Dybowski), *Palaeophyllum fasciculum* (Kutorga), *Priscosolenia prisca* (Sokolov), brachiopods *Platystrophia* cf. *humilis* Oraspõld, *Streptis undifera* (Schmidt), *Ilmarinia ponderosa* Öpik, *Vellamo silurica* Öpik, *Aphanomena luna* (Lindström), etc. The occurrence of the large tabulate corals (*Mesofavosites dualis* Sokolov) in the southern wall of the quarry shows the beginning of the formation of reefs which was continued into the higher levels.

Siuge Member. 1.5–3.0 m (1.5 m) – yellowish-grey, beige to brownish-grey, micro- to fine-crystalline biomicritic dolomitic limestone (wackestone) and micritic-biodetrital limestone (packstone). Nodular or wavy structure is caused by the wavy or diverging thin interlayers of calcitic marl. Thickness of the beds varies from 2 to 10 cm. Admixture of kerogen is most characteristic of the argillaceous interlayers. The content of insoluble residue (21 samples) is relatively low, less than 10% (Fig. 3), only in the topmost part it reaches over 30% (bed of calcitic marl). Quartz grains (up to 0.05 mm in diameter) occur unevenly. The content of predominantly fine-grained (less than 1 mm in size) skeletal debris (crinoids, ostracodes, brachiopods) reaches up to 25%, at some levels it is orientated according to the horizontal lamination. The upper boundary of the unit is lithologically sharp. The boundary falls into the upper third of the section marked in Pl. I, figs. 1, 2 as darker wavy strips, showing also the variation in the thickness of the unit.

In the Siuge Member a diverse association of corals and brachiopods occurs which comprises *Palaeofavosites porkuniensis* Sokolov, *Porkunites amalloides* (Dybowski), *Sclerophyllum sokolovi* Reiman, *Schmidtomena acuteplicata* (Schmidt), *Streptis undifera* (Schmidt), *Laticrura* sp. n., *Pirgumena* sp., and *Reushella* sp.; characteristic are also delicate reticulate or branching bryozoans and dendroid graptolites *Callograptus kaljoi* Obut & Rytzk, *Dictyonema delicatulum* Lapworth, *Mastigograptus crinitus* Obut & Rytzk. Most fossils are silicified and well preserved.

Tõrevere Member. 1.5–0.0 m (1.5 m) – brownish-grey, pure micro- to fine-crystalline coral limestone with wavy to massive structure, comprises frequent, partly silicified stromatoporoids, tabulate and rugose corals. Skeletal debris (up to 25–30%), predominantly of skeletal elements of echinoderms, is fine-grained. The matrix is microcrystalline or biomicritic (wackestone). In 20 analyses the content of insoluble residue was mainly less than 6%, only in the lower part of the interval it reached 17–19% (Fig. 3). The stromatoporoid-coral reefs are well represented in the unit. The most characteristic fossils of these reefs are *Clathrodictyon gregale* Nestor, *Ecclimadictyon koigiense* Nestor, *Eocatenipora parallela* (Schmidt), *Mesofavosites nikitini* Sokolov, *Rhabdotetradium frutex* Klaamann, *Holacanthia tubula* (Dybowski), *Strombodes middendorfi* (Dybowski). Most of the brachiopods occurring in the micritic limestone of the Tõrevere Member are in common with those of the underlying Siuge and/or Vohilaid members.

In Porkuni quarry the Tõrevere Member terminates the section of the Porkuni Stage. The higher strata can be seen in the Vistla-II core.

Vistla-II core, the hypostratotype

Pirgu Stage, Adila Formation

18.7–20.0 m (1.30/0.65 m) – greenish-grey seminodular argillaceous micritic limestone with fine skeletal debris (wackestone) (Fig. 5a), with interlayers of brownish dolomitic limestone (up to 1 cm thick). Four discontinuity surfaces occur at the depths of 19.9, 19.4, 18.8, and 18.7 m (Fig. 4).

Porkuni Stage, Ärina Formation

Röa Member. 17.0–18.7 m (1.7/1.4 m) – yellowish, white-grey, fine- to microcrystalline, thick-bedded to massive secondary dolomite and dolomitic micritic limestone (Fig. 5b), partly argillaceous and with few quartz grains. Pores (casts of bioclasts) are up to 3 mm in diameter. The content of the insoluble residue varies from 9% to 19% and $CaMg(CO_3)_2$ forms 64–80% in the rock composition (Fig. 4). A primary biomicritic texture for the rocks is probable. The upper boundary is marked by a pyritized discontinuity surface.

Vohilaid Member. 16.2–17.0 m (0.8/0.65 m) – light grey, thick-bedded to massive, unevenly dolomitized grainstone. The lower part (16.55–17.00 m) is represented by fine skeletal grainstone (Fig. 5c), the upper one by coarse skeletal grainstone (Fig. 5d). Skeletal debris is sorted, fragments of pelmatozoans dominate over bryozoans and brachiopods. The content of $CaMg(CO_3)_2$ varies from 15% to 80% and the content of insoluble residue increases upward (Fig. 4). The upper boundary is lithologically sharp.

Siuge Member. 14.4–16.2 m (1.8/1.35 m) – yellowish to brownish-grey, medium- to thick-bedded, variably argillaceous biomicritic limestone (wackestone) or micritic skeletal limestone (packstone), with 1–5 cm thick interlayers of calcitic marl or argillaceous limestone (Fig. 6a). The content of kerogen has caused the brownish colour of rocks. The composition of skeletal debris is variable, in some parts of the interval fragments of algae, in other parts pelmatozoans are dominant. The lower, argillaceous part, comprising also quartz grains (up to 0.05 mm), is more strongly dolomitized than the upper one. The most argillaceous bed (content of insoluble residue up to 24%) occurs similarly to the Porkuni quarry section in the top of the interval. The upper boundary of the Siuge Member is lithologically transitional.

Tõrevere Member. 12.6–14.4 m (1.8/1.7 m) – reef limestone with corals and stromatoporoids (Fig. 6b) which form more than 20% of the composition of rock. Matrix of the limestone is biomicritic, stylolite surfaces mark the bedding planes. Dolomitization is weak and uneven. The skeletal debris consists mainly of fragments of bryozoans, echinoderms, trilobites, brachiopods, and ostracodes. The upper boundary of the interval is marked by a wavy discontinuity surface with pockets (Fig. 6c).

Kamariku Member (?). 12.6–11.3 m (1.3/1.1 m) – sandy limestone with frequent stromatoporoids. The carbonate clasts and fine sand (grains over 0.05 mm in diameter) fill the cavities and holes between the stromatoporoids and corals (Fig. 6d). The content and grain size of the quartz is variable in different beds. At the lower boundary (12.6 m) the quartz grains are relatively large, up to 0.1–0.2 mm in diameter, at a depth of 12.2 m – 0.05–0.3 mm, and in the sandy stromatoporoid limestone at a depth of 11.38 m up to 0.4–0.5 mm in diameter. In four samples the content of insoluble residue varied from 4% to 8%, which is similar to the Tõrevere Member, but in two samples (depths 12.17 and 11.35 m) it was higher (11% and 37%, respectively). The admixture of sandy material in the composition of the reef complex indicates some relation with the sandstone and sandy limestone of the Kamariku Member developed southwards from Porkuni.

The top of the last piece of core from the described interval is marked by a discontinuity surface, but it differs from the typical upper boundary of the Porkuni Stage and therefore we think that the actual topmost piece of core is missing. The Kamariku Member is overlain by a 8 cm thick bed of rudstone belonging to the lower part of the Koigi Member (Varbola Formation) of the lowermost Silurian.

CORRELATION OF THE STRATOTYPE SECTION

The four lithostratigraphic units, the Röa, Vohilaid, Siuge, and Tõrevere members established in the Porkuni stratotype section, comprise together with the Kamariku Member the Ärina Formation representing the Porkuni Stage in the Estonian facies belt (Hints & Meidla 1997, fig. 61). Due to the distinctiveness of these units, subdivision of sections and correlation with the stratotype are usually possible (Oraspõld 1975). However, the thickness and succession of the units might be variable even over short distances (Fig. 7), especially in the reef complex (Vohilaid, Siuge, and Tõrevere members together), where the position of the Siuge Member is most variable. The topmost Kamariku Member with its abundant sandy matrix is usually a clear lithological entity which overlies the reef complex in many drill core sections. Only in the Vistla-II core section, as described above, it consists of reef limestone with sand admixture and this lithology is rather different from the usual facies pattern.

In South Estonia (the Livonian Tongue area) the Porkuni Stage is represented by the Kuldiga and Saldus formations (Fig. 1). Due to facies differences and missing of the sections transitional from the Ärina to Kuldiga formations there are only sparse biostratigraphical data available for correlation with the stratotype. Up to now the distribution of chitinozoans (Nõlvak & Grahn 1993; Nõlvak 1999) and data on the isotope composition (Marshall et al. 1997; Kaljo et al. 1999; Kaljo et al. 2000) have been used successfully for the correlation of sections across the region. Unfortunately, in the stratotype Porkuni section zonal chitinozoans have not been found during preliminary micropalaeontological studies (Nõlvak, pers. comm.). The total range of *Spinachitina taugourdeaui* comprises the interval from the topmost Pirgu Stage to the lower half of the Porkuni Stage (Nõlvak & Grahn 1993), but the continual distribution of this taxon falls into the lowermost part of the latter (Nõlvak 1999). In the stratotype area the zonal chitinozoan *S. taugourdeaui* has been identified in the core sections in the lower half of the Ärina Formation up to the Siuge Member (Nõlvak 1986). The Vohilaid and Tõrevere members of the reef complex seemingly represent an unsuitable facies for the occurrence or preservation of chitinozoans. The topmost Ordovician *Conochitina scabra* chitinozoan Zone is established in the Kuldiga

Formation above the *S. taugourdeaui* Zone. Based on the distribution of zonal chitinozoans, the Ärina Formation of the stratotype area has been correlated with the lowermost part of the Kuldiga Formation (Bernati Member) (Nõlvak & Grahn 1993).

The isotopic composition of the topmost Ordovician rocks in the East Baltic is discussed in several publications (e.g. Brenchley et al. 1994; Marshall et al. 1997; Kaljo et al. 1999). The Pirgu rocks, including the strata with *Holorhynchus* (Brenchley et al. 1997), are characterized by low values of $\delta^{13}C$. A more or less continuous rise of values begins in North Estonia from the Röa Member of the Porkuni Stage (Kaljo et al. 1999). The shift back towards the low values of $\delta^{13}C$ is observed in the topmost Porkuni or in the lowermost Silurian (Fig. 8). The same trend of changes of the isotopic composition was established also in the Porkuni stratotype and in the Vistla-II sections (Kaljo et al. 2000). In South Estonia the corresponding $\delta^{13}C$ curve can be correlated with that of the Ruhnu section (Fig. 8), where the rise of values begins in the Bernati Member of the Kuldiga Formation, and the Saldus Formation shows some decline in values. The highest values fall into the top of the Tõrevere Member (top of the reef complex) and into the lower half of the Edole Member (Kuldiga Formation), where brachiopods of the *Hirnantia* fauna and chitinozoans of the *Conochitina scabra* Zone occur.

Data on the distribution of chitinozoans and the isotopic composition of rocks of the Porkuni Stage allow us to conclude that the stratotype section of the Porkuni Stage comprises strata of early Porkuni age, including the time of the appearance of the *Hirnantia* fauna in the East Baltic. This does not support the opinion that the Porkuni Stage is older than the Hirnantian Stage. Vice versa, comparison of carbon isotope trends in the East Baltic and at Dob's Linn, Scotland (Underwood et al. 1997), shows that the Ärina Formation and main part of the Kuldiga Formation can be correlated with the *Normalograptus extraordinarius* graptolite Biozone; the Saldus Formation is most probably an equivalent of the *N. persculptus* Biozone (Kaljo et al. 2000).

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REFERENCES

Brenchley, P. J., Marshall, J. D., Carden, G. A. F., Robertson, D. B. R., Long, D. F. G., Meidla, T., Hints, L. & Anderson, T. E. 1994. Bathymetric and isotopic evidence for a short-lived Late Ordovician glaciation in a greenhouse period. *Geology*, **22**, 295–298.

Brenchley, P. J., Marshall, J. D., Hints, L. & Nõlvak, J. 1997. New isotopic data solving an old biostratigraphic problem: the age of the upper Ordovician brachiopod *Holorhynchus giganteus*. *J. Geol. Soc. London*, **154**, 335–342.

Bruton, D. L., Hoel, O. A., Beyene, L. T. & Ivantsov, A. Yu. 1997. Catalogue of the trilobites figured in Friedrich Schmidt's "Revision der ostbaltischen silurischen Trilobiten" (1881–1907). *Contrib. Palaeontol. Mus. Univ. Oslo*, **403**.

Eichwald, E. 1854. Die Grauwackenschichten von Liv- und Estland. *Bull. Soc. Nat. Moscou*, **27**.

Eltysheva, R. S. & Sizova, E. N. 1971. Ontogenetic changes of columnals of some Palaeozoic crinoids. *Vopr. paleont.*, **VI**, 33–40 (in Russian).

Grewingk, G. 1879. Erläuterungen zur zweiten Ausgabe der geognostischen Karte Liv-, Est- und Kurlands. *Arch. Naturk. Liv-, Ehst- und Kurl., Ser. I*, **VIII**, 343-466.

Hints, L. & Meidla, T. 1997. Porkuni Stage. In *Geology and Mineral Resources of Estonia* (Raukas, A. & Teedumäe, A., eds.), pp. 85–89. Estonian Acad. Publ., Tallinn.

Jaanusson, V. 1956. Untersuchungen über den oberordovizischen Lyckholm-Stufenkomplex in Estland. *Bull. Geol. Inst. Univ. Upsala,* **36**, 369–400.

Kaljo, D. L. (ed.). 1987. *Resheniya mezhvedomstvennogo soveshchaniya po ordoviku i siluru Vostochno-Evropejskoj platformy 1984 g. s regional'nymi stratigraficheskimi skhemami.* VSEGEI, Leningrad (in Russian).

Kaljo, D. & Hints, L. 1996. Late Ordovician–Early Silurian succession of palaeoecosystems in Estonia. *Paleont. J.*, **30**, 693–700.

Kaljo, D., Hints, L., Martma, T. & Nõlvak, J. 1998. Refinements of carbon isotope stratigraphy in the latest Ordovician of Estonia. *Mineral. Mag.*, **62A**, 740–741.

Kaljo, D., Hints, L., Hints, O., Martma, T. & Nõlvak, J. 1999. Carbon isotope excursion and coeval environmental and biotic changes in the late Caradoc and Ashgill of Estonia. *Acta Univ. Carolinae Geol.,* **43**, 507–510.

Kaljo, D., Hints, L., Martma, T. & Nõlvak, J. 2000. Carbon isotope stratigraphy in the latest Ordovician of Estonia. *Chem. Geol.* (in press).

Kõrvel, V. E, Kõrvel, N. S. & Rohtlaan, A. A. 1970. *Geologicheskaya karta SSSR masshtaba 1 : 200 000: Seriya Pribaltijskaya, List 0-35-IX, ob"yasnitel'naya zapiska*. Min. geol. SSSR, Uprav. geol. Sov. Min. Ést. SSR, Moskva (in Russian).

Lodjak, T. 1982. *Linnusöödaks kõlblike lubjakivide otsingutööde aruanne, I.* NSVL Geol. Min., ENSV Geol. Valitsus, Keila Geoloogiaekspeditsioon. Keila (manuscript).

Männil, R. 1966. *Istoriya razvitiya Baltijskogo bassejna v ordovike.* Valgus, Tallinn.

Männil, R. & Rõõmusoks, A. 1984. A revision of the lithostratigraphic subdivision of the Ordovician of North Estonia. In *Stratigrafiya drevnepaleozojskikh otlozhenij Pribaltiki* (Männil, R. & Mens, K., eds.), pp. 52–62. Inst. Geol., Tallinn (in Russian).

Männil, R. M., Orviku, K. K. & Rähni, E. E. 1958. *Putevoditel' geologicheskoj ékskursii nauchnoj sessii, posvyashchennoj 50-j godovshchine so dnya smerti akad. F. B. Schmidta*. Inst. geol. AN ÉSSR, Tallinn (in Russian).

Marshall, J. D., Brenchley, P. J., Mason, P., Wolff, G. A., Astin, R. A., Hints, L. & Meidla, T. 1997. Global carbon isotopic events associated with mass extinction and glaciation in the late Ordovician. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **132**, 195–210.

Martna, J. 1957. Notes on the Upper Ordovician and Lower Silurian of the Tapa district: Estonia. *Geol. Fören. Stockh. Förh.*, **36**, 369–400.

Nestor, H. 1987. Porkuni Stage. In *Geology and Mineral Resources of the Rakvere Phosphorite-Bearing Area* (Puura, V., ed.), pp. 69–71. Valgus, Tallinn (in Russian).

Nestor, H. 1990. Locality 4:3 Porkuni quarry. In *Field Meeting Estonia 1990: An Excursion Guidebook* (Kaljo, D. & Nestor, H., eds.), pp. 153–155. Estonian Acad. Sci., Tallinn.

Nõlvak, J. 1986. *Rasprostranenie khitinozoj v razrezakh verkhnego ordovika Éstonii.* Inst. geol. AN ÉSSR, Tallinn. VINITI N. 8526–B86 (in Russian).

Nõlvak, J. 1999. Ordovician chitinozoan biozonation of Baltoscandia. *Acta Univ. Carolinae Geol.*, **43**, 287–290.

Nõlvak, J. & Grahn, Y. 1993. Ordovician chitinozoan zones from Baltoscandia. *Rev. Palaeobiol. Palynol.*, **79**, 245–269.

Oraspõld, A. 1975. On the lithology of the Porkuni Stage in Estonia. In *Töid geoloogia alalt VII. Acta Comment. Univ. Tartuensis*, 359, 33–75 (in Russian).

Raukas, A. & Teedumäe, A. (eds.). 1997. *Geology and Mineral Resources of Estonia.* Estonian Acad. Publ., Tallinn.

Rõõmusoks, A. 1966. *Stratigrafiya Viruskoj i Khar′yuskoj serii (ordovik) Severnoj Estonii.* DSc thesis (manuscript at the University of Tartu) (in Russian).

Rõõmusoks, A. 1983. *Eesti aluspõhja geoloogia.* Valgus, Tallinn.

Rõõmusoks, A. 1991. On the stratigraphy and fauna of the boundary beds between the Pirgu and Porkuni stages of North Estonia. In *Töid geoloogia alalt XII. Acta Comment. Univ. Tartuensis*, 934, 23–42 (in Russian).

Rõõmusoks, A. 1993. A review of Estonian Ordovician Rafinesquinids (Brachiopoda, Strophomenacea). *Proc. Estonian Acad. Sci. Geol.*, **42**, 160–166.

Saadre, T., Mardim, T., Morgen, E., Põldvere, A., Vaher, R., Suuroja, K. & Saaremets, V. 1984. *Otchet o kompleksnoj gruppovoj geologo-gidrogeologicheskoj s″emke m-ba 1 : 50 000 i doizuchenii ranee zanyatykh ploshchadej Rakvereskogo fosforitonosnogo rajona (v 5-i tomakh).* Keila (in Russian).

Salvador, A. (ed.). 1994. *International Stratigraphic Guide: A Guide to Stratigraphic Classification, Terminology, and Procedure.* Second Edition. The Geol. Soc. of America.

Schmidt, F. 1858. Untersuchungen über die silurische Formation von Ehstland, Nord-Livland und Oesel. *Arch. Naturk. Liv-, Ehst- und Kurl., Ser. I*, **2**.

Schmidt, F. 1881. Revision der ostbaltischen silurischen Trilobiten nebst geognostischer Übersicht des ostbaltischen Silurgebiets. Abt. I: Phacopiden, Cheiruriden und Encrinuriden. *Mém. Acad. Sci. St.-Pétersb., sér. VII*, **30**, 1.

Sirk, Ü. 1958. *Porkuni lademe geoloogiast.* Diploma thesis. TRÜ geol. kateeder, Tartu (manuscript at the University of Tartu).

Stukalina, G. A. 1988. Studies in Paleozoic crinoid-columnals and -stems. *Palaeontographica, Pal. A*, **204**.

Teedumäe, A. 1987. Carbonate rocks. In *Geology and Mineral Resources of the Rakvere Phosphorite-Bearing Area* (Puura, V., ed.), pp. 167–173. Valgus, Tallinn (in Russian).

Ulst, R. Z., Gailite, L. K. & Yakovleva, V. I. 1982. *Ordovik Latvii.* Zinatne, Riga (in Russian).

Underwood, C. J., Crowley, S. F., Marshall, J. D. & Brenchley, P. J. 1997. High-resolution carbon isotope stratigraphy of the basal Silurian Stratotype (Dob's Linn, Scotland) and its global correlation. *J. Geol. Soc. London*, **154**, 701–718.

Wahl, A. von. 1923. Mitteilungen über die Geologie von Borkholm und seine Umgebung. *Loodusuurijate Seltsi aruanded*, 29, 23–29.

PORKUNI LADEME STRATOTÜÜP JA KOMMENTAAR RÖA KIHISTIKU KOHTA (ÜLEMORDOVIITSIUM, EESTI)

Linda HINTS, Asta ORASPÕLD ja Dimitri KALJO

On esitatud Porkuni lademe stratotüüpses (Porkuni vana murd) ja hüpostratotüüpses (Vistla-II puursüdamik) läbilõikes eraldatud kihistike täiustatud kirjeldused. On selgitatud Fr. Schmidti (1858) poolt eraldatud "krinoiidide kihi" (*Encrinitenlager*) vastavust Röa kihistikule, mis moodustab Ärina kihistu alumise osa. On põhjendatud Röa kihistiku kuulumist Porkuni lademesse ja lademe stratotüüpse läbilõike vara-Porkuni vanust. On esile toodud tsonaalsete kitinosoade leviku ja kivimite isotoopse koosseisu muutuste olulisus läbilõigete korreleerimisel ja stratotüübi vanuse hindamisel.

СТРАТОТИП ПОРКУНИСКОГО ГОРИЗОНТА И КОММЕНТАРИЙ К РЁАСКОЙ ПАЧКЕ (ВЕРХИ ОРДОВИКА, ЭСТОНИЯ)

Линда ХИНТС, Аста ОРАСПЫЛЬД и Димитри КАЛЬО

Приведены дополненные описания пачек, выделенных в стратотипическом разрезе поркуниского горизонта (в старой каменоломне в Поркуни) и в близлежащей скважине Вистла-II. Обсуждено соответствие выделенного Ф. Шмидтом (1858) "экринитового слоя" рёаской пачке, в современных стратиграфических схемах относимой к эринаской свите. Обоснована принадлежность рёаской пачки к поркунискому горизонту. Подчеркнута важность зональных хитинозой и состава изотопов углерода в породах для корреляции разрезов и для оценки возраста стратотипа.