STRATIGRAPHY AND PALEOGEOGRAPHY OF THE ORDOVICIAN IN ESTONIA

By A. RÕÕMUSOKS

Estonia

ABSTRACT

Хроностратиграфическое расчленение ордовика Эстонии осуществлено в результате работ многих исследователей, изучавших, главным образом, выходы ордовика. В послевоенное время в Эстонской ССР проводились обширные буровые работы, причем впервые были получены полные разрезы ордовикских отложений в самой северо-западной, средней и южной частях Эстонии. Нижняя граница ордовика проводится по подошве пакерортского, верхняя же по подошве юуруского горизонта. Ордовик подразделен на 17 горизонтов, которые объединяются в эландскую, вирускую и харьюскую серии (= отделы). В эландской и вируской сериях выделены местные ярусы. Эландская серия в Эстонии представлена в неполном виде: отложения, соответствующие верхам тремадока Английской схемы, здесь отсутствуют

Детальными стратиграфическими исследованиями горизонтов ордовика установлены значительные региональные различия литологического состава пород, а также фауны, которые послужили основанием для выделения в ордовике Эстонии литостратиграфических единиц разного ранга (рис. 2).

Территория Эстонской ССР в ордовикское время представляла северную часть обширного залива, простиравшегося от Швеции в широтном направлении к востоку (рис. 1). В северной части Эстонии существовали относительно прибрежные условия. Осадконакопление в средней части Эстонии было более одообразное и устойчивое, что в известной степени отражалось и на составе фауны. Южная часть Эстонии отличается большей мощностью отложений, что вместе с другими признаками указывает на присутствие здесь более глубоководных условий (центральная часть бассейна).

INTRODUCTION

THE foundation of the chrono-stratigraphic classification of the Ordovician of Estonia was laid in the works of F. Schmidt (1877–1898). This classification was subsequently elaborated by many geologists (Table 1).

Ordovician deposits crop out in the scarp of the North Estonian glint and to the south of the latter in northern Estonia (Fig. 1). The Ordovician rocks dip south at an average angle of 0° 15′.

The lower boundary of the Ordovician was drawn at the base of the Pakerort stage (A_{2-3}) already by Wiman (1902). In NW Estonia (Cape Pakerort) the A_{2-3} has at its base a well-defined basal conglomerate consisting mainly of boulders of the underlying Lower Cambrian Tiskre formation ($A_{I}d$). In the vicinity of Tallinn at the base of A_{2-3} there is a thin conglomerate consisting of phosphatic pebbles. In eastern Estonia there is a brachiopodous conglomerate consisting of the shells of Obolids, small pyritic concretions, phosphatic and Tiskre sandstone pebbles.

The position of the upper boundary of the Estonian Ordovician depends essentially on the determination of the age of the Porkuni stage (F_{II}), hitherto regarded by different authors as belonging either to the Ordovician or the Silurian. In determining

TABLE 1. *The chrono-stratigraphical classification, thickness and correlation of the Ordovician of Estonia.*

Series	Sub-series	Stages	Thickness in meters West- Estonia	East- Estonia	Central Estonia	South- Estonia	British classification
Harjuan (Upper)		Porkuni (F_{II})	3–8	5–12	6–16		Ashgill
		Pirgu ($F_{I}c$)	33–37	39–47	55–57		
		Vormsi ($F_{I}b$)	7–9	7	6–7		
		Nabala ($F_{I}a$)	29–34	34–42	22–30		Caradoc
		Rakvere (E)	12–25	8–15	8–12	?	
Viruan (Middle)	Kurnan	Oandu (D_{III})	0.8–7	0.5–4	0.9	?	
		Keila (D_{II})	16–27	12–14	14	?	
		Jõhvi (D_{I})	4–13	5–11	5	?	
		Idavere (C_{III})	0.4–7	4–11	7	7	
	Purtsean	Kukruse (C_{II})	4–12	11–14	11	12	
		Uhaku ($C_{I}c$)	4–6	11–16	9	16	Llandeilo
		Lasnamägi ($C_{I}b$)	5–9	8–9	6–7	13	
		Aseri ($C_{I}a$)	0.1–2	2–4	3	7	Llanvirn
Oelandian (Lower)	Ontikan	Kunda (B_{III})	0.1–5	7–12	9–10	14	?
		Volkhov (B_{II})	0–2.6	2–3	5	14	Arenig
		Leetse (B_{I})	–04	0.3–3	0.5–0.9	2	
	Iruan	Pakerort ($A_{2\text{-}3}$)	10–21	3–6	15	?	Tremadoc

the upper limit of the Ordovician in Estonia particular importance is attached to its correlation with deposits in other areas, above all in Scandinavia. The Porkuni stage may be fairly well correlated with the *Dalmanitina* stage in Sweden and with the 5b beds of Norway (Keller 1954; Jaanusson 1956; Martna 1957, etc.). In view of the fact that Scandinavian geologists (Henningsmoen 1954; Størmer 1956; Jaanusson 1956; Spjeldnaes 1957; Thorslund 1958a) correlate these deposits with the uppermost Ashgillian of the British classification, the upper boundary of the Ordovician in Estonia should be drawn at the top of the Porkuni stage. This is well borne out by the available data on the character of the boundaries of this stage. It is only the upper boundary that is rather well-defined lithologically (Rosenstein 1943; Sokolov 1951b; Jaanusson 1956). Its lower boundary, however, may be fixed only by means of a complex of discontinuity surfaces—the same rocks are found in the lower part of the Porkuni stage as in the second half of the Pirgu stage ($F_{I}c$) (Fig. 2).

A complete section of the Ordovician deposits is revealed by the Äiamaa and Võhma cores where the thickness of the Ordovician is 176 m. and 168 m. respectively.

THE CHRONO- AND LITHO-STRATIGRAPHIC CLASSIFICATION

Kaljo, Rõõmusoks and Männil (1958) subdivide the Ordovician of the Baltic area into three series: the Oelandian, Viruan and Harjuan, which correspond to the Lower, Middle, and Upper Ordovician respectively. The boundary between the Oelandian and Viruan series is at present drawn according to Raymond (1916) at the top of the Kunda stage (B_{III}, cf. Aaloe et al., 1958 and Table 1). The corresponding boundary in Sweden is that between the *Vaginatum* and *Platyurus* limestones (Jaa-

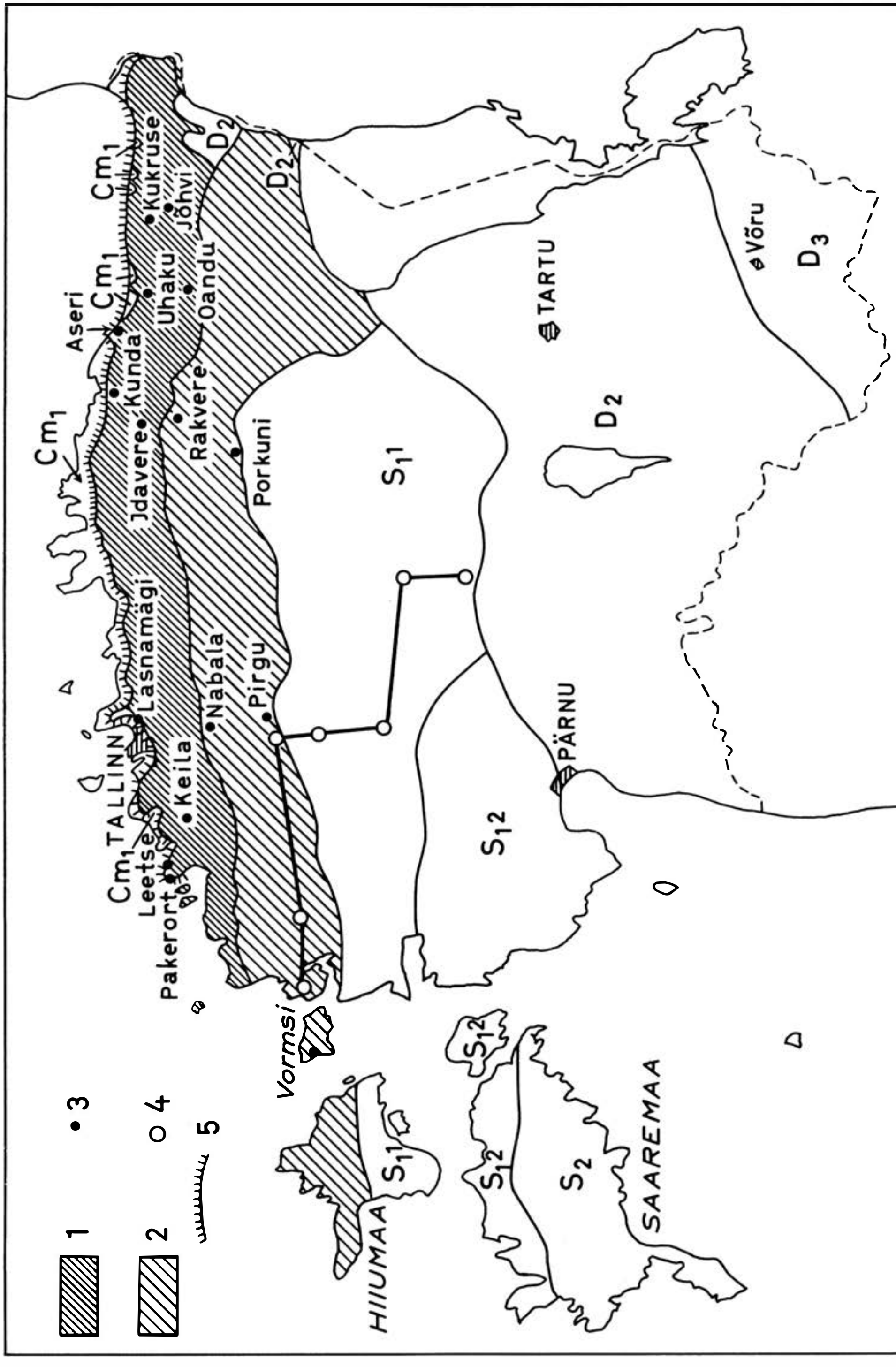

FIG. 1.—*Schematic geological map of the Estonian S.S.R.* 1 – *outcrop of the Viruan series* /O_{1+2}/. 2 – *outcrop of the Harjuan series* /O_3/. 3 – *type locality of the stages.* 4 – *location of borings.* 5 – *North-Estonian glint.* Cm_1 – *outcrop of the Lower Cambrian.* S_1^1 – *outcrop of the Llandoverian.* S_1^2 – *outcrop of the Wenlockian.* S_2 – *outcrop of the Ludlowian.* D – *outcrop of the Middle Devonian.* D_3 – *outcrop of the Upper Devonian. The heavy line represents the section given in fig.* 2.

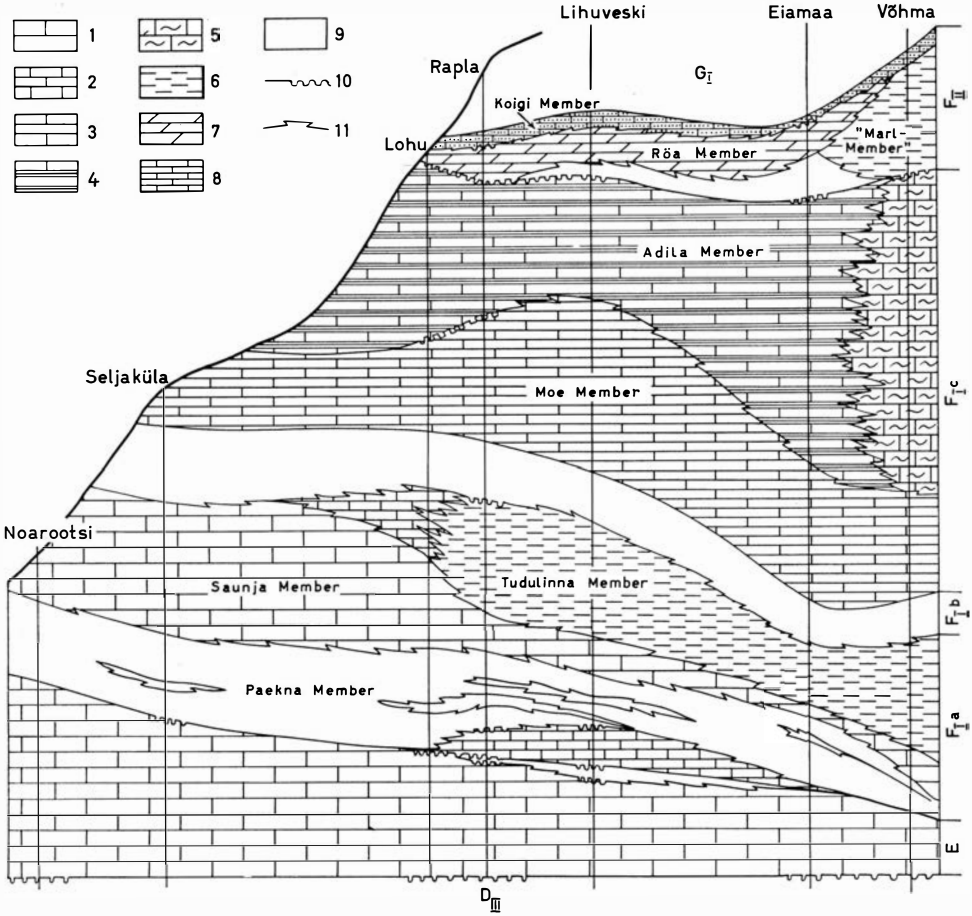

FIG. 2.—*Section of the Harjuan series (data provided by E. Jürgenson, R. Männil, E. Möls and the present writer.* D_{III} – *Oandu stage, E – Rakvere stage,* $F_{I}a$ – *Nabala stage,* $F_{I}b$ – *Vormsi stage,* $F_{I}c$ – *Pirgu stage,* F_{II} – *Porkuni stage,* G_{I} – *Juuru stage (Lower Silurian) ;* 1 – *aphanitic limestone with a shelly fracture.* 2 – *fine-grained limestone (resembling aphanitic with a half-shelly fracture).* 3 – *thick-bedded limestone.* 4 – *thin-bedded limestone.* 5 – *bioherm limestone.* 6 – *marl and marly limestone.* 7 – *dolomitized limestone and dolomite.* 8 – *sandy limestone and calcareous sandstone.* 9 – *thin-bedded marly limestone.* 10 – *synchronous boundaries, with occasional discontinuity surfaces.* 11 – *metachronic boundaries of members. Horizontal scale* 1:600000, *vertical scale* 1:400. *Location of borings and section is shown in fig.* 1.

nusson 1957), and most probably between the graptolite zones of *Didymograptus bifidus* and *D. murchisoni* in the British classification.*

The boundary between the Viruan and Harjuan series is drawn at present at the base of the Rakvere stage (E) (cf. Aaloe et al. 1958 and Table 1 in this paper). Thus the Viruan series includes the Oandu (Vasalemma) stage (D_{III}) which Jaanusson (1945) referred to the Harjuan series because of the marked difference of its fauna

* *D. bifidus* has been found in the Kunda stage and *Gymnograptus linnarssoni* in the Lasnamägi stage, thus indicating a correspondence of the latter stage at least with part of the *D. murchisoni* zone (Obut, 1958).

from that of the Keila stage (D_{II}). More recently, however, Jaanusson (1956) has pointed out that the beds correlated with the D_{III} do not differ faunistically in most areas of Scandinavia from the *Macrourus* or *Extensa* beds which constitute the uppermost Middle Ordovician. This is why he again refers the D_{III} to the uppermost Middle Ordovician (=Viru series, cf. Männil 1958b). In Sweden the boundary corresponding to that between the Viruan and Harjuan series lies between the *Macrourus* and Slandrom limestones in the shelly facies (Jaanusson 1956), and between the graptolite zones of *Dicranograptus clingani* and *Pleurograptus linearis* in the graptolitic facies (Jaanusson and Strachan 1954).

Numerous geologists have attempted to distinguish some subseries within the Ordovician of the Baltic. Fr. Schmidt (1881) subdivides the Lower Silurian (=Ordovician) into five groups of beds (=subseries): B, C, D, E, and F. Sokolov (1951a) Keller (1954), Alichova (1957) and others have since proposed various other divisions. They give their subseries names borrowed from the British classification despite the fact that the boundaries (and consequently the volumes) of the latter differ from those of the Baltic Ordovician.

The present writer (1956) has divided the Middle Ordovician of Estonia (=Viruan series) into the Purtse subseries (stages $C_{I}b$–C_{II}) and the Saue subseries (stages C_{III}–D_{II}). Männil (1958b) suggests that the Viruan series should be subdivided into three subseries: Tallinn (stages $C_{I}b$–$C_{I}c$), Ahtme (stages C_{II}–C_{III}) and Kurna (stages D_{I}–D_{III}). Available faunistic data from various groups show, however, that a twofold division of this series is more suitable for the Baltic area and it has been adopted in the present article (Table 1).* Within the Oelandian series Kaljo, Rõõmusoks, and Männil (1958) distinguish the Iruan and Ontikan subseries (Table 1). The boundaries of the subseries of the Harjuan series (Rõõmusoks 1956) still require more accurate definition.

A certain litho-stratigraphic trend in the investigation of the Baltic Ordovician is apparent already in the works of F. Schmidt, who, for instance, distinguished an "untere und obere Linsenschicht". During recent years local litho-stratigraphic subdivisions (members, formations) have been differentiated in all the outcrop areas (Orviku 1958; Müürisepp 1958; cf. also Aaloe *et al.,* 1958) as well as elsewhere (Rõõmusoks 1957; Männil 1958a, b, c). The litho-stratigraphic method has proved to be especially fruitful in the investigation of the stratigraphy of Ordovician deposits in central and southern Estonia where cores differ markedly as regards their lithologic and faunistic characters from similar cores obtained from outcrops (Fig 2). The subdivisions that have been distinguished are not, however, purely litho-stratigraphic in the strict sense of the term. Faunistic data have also been taken into account in almost all cases of the definition of members and formations and their limits.

THE OELANDIAN SERIES

The Iruan subseries. The *Pakerort* (A_{2-3}) in northern Estonia comprises the three members (Müürisepp 1958). The stage consists of fine-grained sandstones and bituminous *Dictyonema* shales. Characteristic fauna includes a number of species of *Acrotreta, Obo-*

* The name "Kurna" proposed by Männil (1958b) is used for the upper subseries instead of the term "Saue" which was infelicitously chosen by the present writer (1956).

lus, Keyserlingia, Schmidtites and *Dictyonema sociale* Salter, *D. graptolithinum* Kjerulf and *D. flabelliforme* (Eichw.).

On the basis of its graptolite fauna the A_{2-3} is correlated only with the lower part of the Tremadocian (the beds containing *Dictyonema*). According to Lamansky (1905), Raymond (1916), and Keller (1954) the beds corresponding to the upper part of the latter (*Ceratopyge* beds; 3a in Norway) do not occur in the Baltic area. A number of the other writers regard the overlying Leetse stage (B_I) as an equivalent of the Ceratopyge beds (Öpik 1930; Alichova 1956 and others). The present writer supports the view of Lamansky because of the following considerations. In many localities the B_I rests on the weathered surface of A_{2-3} (sometimes on the Lower and Middle(?) Cambrian rocks (Mahnatch 1958, Paskevicius 1958). Considering that no traces can be observed within the B_I of any break in sedimentation and that Tjernvik (1956) has reliably correlated substage $B_I\beta$ on the basis of its fauna with the Billingen group (=zone of *Phyllograptus densus;* 3b in Norway), the substage $B_I\alpha$ must be correlated either with the lower part of this stage or with the Hunneberg group. Thus the break between the A_{2-3} and B_I corresponds to an age when *Ceratopyge* beds were being deposited in different parts of Scandinavia and the transgression at the beginning of the Ontika epoch may consequently coincide only with that at the beginning of the Hunneberg age, i.e. with the beginning of the Arenigian (cf. Tjernvik 1956 and Table 1 in this paper).

The Ontikan subseries. The *Leetse stage* (B_I) is divided by Lamansky (1905) into two substages ($B_I\alpha$ and $B_I\beta$). The stage is made up of green fine-grained sandstones and calcareous sandstones containing numerous grains of glauconite. The characteristic fauna of $B_I\alpha$ includes: *Thysanotos siluricus* (Eichw.), *Leptembolon lingulaeformis* (Mickw.), and conodonts. The fauna of $B_I\alpha$ includes the first Ordovician trilobites and articulated brachiopods of Estonia: *Megalaspides* (*Megalaspides*), *Pliomeroides, Krattaspis, Angusticardinia, Antigonambonites* etc.

The *Volkhov stage* (B_{II}) is subdivided by Lamansky (1905) into three substages ($B_{II}\alpha$, $B_{II}\beta$ and $B_{II}\gamma$). Orviku (1958) distinguishes a number of members in the outcrop area of this stage. The stage is characterized by greenish-grey limestones, partly by many layers of marl, containing numerous grains of glauconite. In southern Estonia this stage is represented mainly by brown and greyish-brown limestones containing grains of glauconite. Its fauna includes species of the genera *Ampyx, Asaphus* (*Asaphus*), *Megistaspis* (*Megistaspis*), *Niobe, Ingria, Paurorthis, Productorthis,* etc.

The *Kunda stage* (B_{III}) was subdivided by Lamansky (1905) into three substages ($B_{III}\alpha$, $B_{III}\beta$ and $B_{III}\gamma$). Only the two upper substages occur in Estonia. Orviku (1958) distinguished a number of members of this stage in the outcrop area. In the eastern part of the outcrop area the stage is represented by marly limestones containing numerous fine brownish-grey ferruginous oölites and thick-bedded limestones containing fine grains of glauconite. In the western part of the outcrop the rocks of B_{III} are represented by fine-grained calcareous sandstones. In southern Estonia B_{III} consists of greyish-brown to dark brown and bluish-grey marly limestones. The stage is characterized by *Asaphus* (*Asaphus*) *raniceps* (Ang.), *Pseudoasaphus globifrons* (Eichw.), *Pliomera fischeri* (Eichw.), *Ahtiella baltica* Öpik, *Clitambonites adscendens* (Pand.), and numerous nautiloids.

The correlation of the Ontika subseries with the British classification presents certain difficulties. The lower limit of this subseries is correlated with that of the Arenigian (cf. p. 6). Obut (1958) has recorded *Didymograptus bifidus* (Hall) from B_{III}, thus making it possible to correlate these subseries with the lowermost part of the Llanvirnian. But since the position of $B_{III}\,\alpha$ (=*Expansus* limestone) is uncertain, the lower boundary of the Llanvirnian is drawn tentatively at the top of $B_{III}\,\alpha$ (Table 1).

THE VIRUAN SERIES

The Purtse subseries. The *Aseri stage* ($C_{I}a$) is according to Orviku (cf. Aaloe *et al.* 1958) subdivided into three members. In the eastern part of the outcrop it is mainly represented by grey limestones containing fine brown ferruginos oölites. In the western part of the outcrop the stage is characterized by sandy limestones. In southern Estonia the $C_{I}a$ consists of bluish-grey and reddish-brown marly limestones. The fauna of the stage includes many species of the genera *Asaphus* (*Neoasaphus*) and *Illaenus*. In addition, the species of the genera *Echinosphaerites, Hemipronites, Inversella, Ladogiella, Leptelloidea, Leptestia, Platystrophia,* etc., are often met with.

The *Lasnamägi stage* ($C_{I}b$) is represented by light-grey partly thin-bedded marly limestones. In southern Estonia the $C_{I}b$ is made up of reddish-brown limestones with bluish-grey spots. The typical fauna includes: *Heliocrinites araneus* (Schloth.), *Christiania* cf. *oblonga* (Pand.), *Sowerbyella* (*Viruella*?) *orvikui* Rõõm., *Illaenus schroeteri* (Schloth.), *Xenasaphus devexus* (Eichw.), etc.

The *Uhaku stage* ($C_{I}c$) is by the author (1956) subdivided into two substages: $C_{I}c\,\alpha$ (=Uhaku-Stufe, Orviku 1940) and $C_{I}c\,\beta$. The stage is represented by bluish-grey up to greenish-grey thin-bedded marly limestones. In the $C_{I}c\,\beta$ of NE Estonia there occur many beds and layers of oil-shale. The characteristic fauna includes: *Heliocrinites balticus* (Eichw.), *Platystrophia biforata* (Schloth.), *Sowerbyella* (*Viruella*) *uhakuana* Rõõm., *Palaeostrophomena concava* (Schm.), *Illaenus intermedius* Holm, *Atractopyge xipheres* (Öpik), etc.

The *Kukruse stage* (C_{II}) is subdivided by the author (1957) into the substages $C_{II}\,\alpha$ and $C_{II}\,\beta$. He distinguishes four members within the stage. The stage in northern and central Estonia is composed of bluish-grey up to brownish-grey thin-bedded limestones with thicker or thinner layers of light-brown oil-shale. In southern Estonia it is represented by grey to bluish-grey marly limestones: oil-shale is lacking. The fauna of the stage is exceptionally rich (about 350 species). Its typical representatives include: *Hoplocrinus grewingki* Öpik, *Phylloporina furcata* (Eichw.), *Pseudohornera bifida* (Eichw.), *Bilobia musca* (Öpik), *Cyrtonotella kuckersiana kuckersiana* (Wys.), *Glossorthis tacens* Öpik, *Sowerbyella* (*Viruella*) *lilliifera* Öpik, *Paraceraurus aculeatus* (Eichw.), *Lichas kuckersianus* Schm., *Reraspis plautini* (Schm.), etc.

The Purtse subseries is correlated with the upper part of the Llanvirnian (the zone of *Didymograptus murchisoni*), the Llandeilian and the lowermost part of the Caradocian (the zone of *Nemagraptus gracilis*) of the British classification (cf. also Obut 1958 and Table I in this paper).

The Kurna subseries. The *Idavere stage* (C_{III}) is by Männil (unpublished data from 1948) subdivided into two substages: $C_{III}\,\alpha$ (=Itfersche Schicht, Schmidt 1881) and $C_{III}\,\beta$. The stage is composed of grey more or less marly limestones interstratified with beds of marl. In the upper part of $C_{III}\beta$ two or three thin beds of metabentonite are met with on the whole territory of Estonia. C_{III} α peters out in NW Estonia. The typical fauna includes: *Clitambonites schmidti epigonus* Öpik, *Platystrophia lynx lynx* (Eichw.), *Chasmops wrangeli* (Schm.), *Ch. marginatus* (Schm.), *Echinosphaerites,* etc.

The *Jõhvi* stage (D_I) is represented by relatively homogenous bluish-grey marly limestones rhytmically interstratified with layers of marl. In the middle part of the stage in central Estonia one can observe, in places, a thin bed of metabentonite. In southern Estonia the D_I is represented by dark-grey marls. The characteristic fauna includes *Clinambon anomalus* (Schloth.), *Apatordlus tenuicosta* (Eichw.), *Estlandia pyron silicificata* Öpik, *Chasmops wenjukowi* (Schm.), *Hemicosmites extraneus* (Eichw.), etc.

The *Keila stage* (D_{II}) is subdivided by Männil (1958b) into two substages (D_{II} α and $D_{II}\beta$). He also distinguishes four members within the stage (cf. Jaanusson 1945). The stage is represented by marly limestones interstratified with layers of marl and fine-grained compact limestones with a conchoidal or sub-conchoidal fracture. The uppermost part of D_{II} β over a small piece of ground in the neighbourhood of the settlement of Vasalemma (about 30 km to the SW of Tallinn) is formed as a coarse-grained cystoid limestone which passes over into the overlying Oandu stage (D_{III}). At the base of both D_{II} α and $D_{II}\beta$ there is a bed of metabentonite. In southern Estonia dark-grey and greenish-grey marls belong to the D_{II}. The fauna of the stage includes: *Kjerulfina asmusi* (Vern.), *Platystrophia crassoplicata* Alich., *Sowerbyella* (*Sowerbyella*) *forumi* Rõõm., *Vellamo magna* Öpik, *Conolichas deflexus* (Ang.), *Leiolichas illaenoides* (Nieszk.), etc.

The *Oandu* (Vasalemma) *stage* (D_{III}) is subdivided by Männil (1958c) into four members. The stage is represented by different rocks (marly limestones, clays, cross-bedded calcareous siltstones and dolomitized limestones). In the settlement of Vasalemma there extend coarse-detritic cystoid (hemicosmite) limestones containing bryozoan-algal bioherms. The characteristic fauna includes: *Liopora grandis* Sok., *Brachyelasma cylindricum* (Troedsson), *Ilmarinia dimorpha* Öpik, *Dalmanella wesenbergensis* (Wys.), *Rhynchotrema nobilis* Oraspõld, *Sowerbyella* (*Sowerbyella*) *tenera* Rõõm., *Chasmops extensus* (Boeck), *Bythopora subgracilis* (Ulrich), *Hemicosmites rudis* Jaekel, etc.

In the British classification the Kurna subseries correspond to the lower part of the Caradocian (apparently from the zone of *Diplograptus multidens* up to the zone with *Dicranograptus clingani* cf. Table 1).

THE HARJUAN SERIES

The *Rakvere stage* (E) is represented by light-grey up to yellowish grey aphantic limestones with a conchoidal fracture (Fig. 2). The typical fauna of the stage includes: *Dalmanella wesenbergensis* (Wys.), *Rafinesquina inaequiclina* Alich., *Sowerbyella* (*Sowerbyella*) *raegaverensis* Rõõm., *Encrinuroides seebachi* (Schm.), *Isotelus remigium* (Eichw.), etc.

The *Nabala* (Saunja) *stage* (F_Ia) is subdivided by Männil (1958a) into two substages (F_Ia α and F_Ia β). He also distinguishes three members within the stage (Fig. 2). The stage is composed of grey marly thin-bedded limestones (in places interstratified with aphanitic limestones with a conchoidal fracture), aphanitic limestones and marls. The characteristic fauna of the stage includes: *Streptelasma* (*Kenophyllum*) *canaliferum* (Reiman), *Strophomena* sp. n., *Leptaena schmidti* (Gagel), *Pharostoma pediloba* (Roemer), *Subulites enormis* Koken, etc.

The *Vormsi stage* (F_Ib) is faunistically subdivided in its outcrop area by Jaanusson (1944) into two substages (F_Ib α and F_Ib β). The stage is composed of bluish-grey thin-bedded limestones containing beds of marl. The characteristic fauna includes: *Brachyelasma diversa* Kaljo, *Grewingkia anthelion* Dyb., *Boreadorthis crassa* Öpik, *Sampo hiiuensis* Öpik, "*Sowerbyella*" *schmidti* (Lindstr.), *Triplesia insularis* (Eichw.), *Subulites gigas* Eichw., *Encrinurus moe* Männil, etc.

The *Pirgu stage* ($F_{I}c$) is in its outcrop area faunistically subdivided by Jaanusson (1944) into three substages ($F_{I}c\,\alpha$, $F_{I}c\,\beta$, and $F_{I}c\gamma$). Within the stage the present author distinguishes four members (Fig. 2). The stage is mainly represented by grey thick- and thin-bedded limestones and marls. In the western part of the outcrop area there occur bioherms (Huitberg, Nyby). In the central part of Estonia (the Võhma core) the middle and upper parts of $F_{I}c$ are represented by light and pink limestones of the bioherm type. The typical fauna includes: *Kiaerophyllum europaeum* (Roemer), *Sarcinula organum* (L), *Barbarorthis foraminifera* Öpik, *Plectatrypa sulevi* Jaan., *Luhaia vardi* Rõõm., *Maclurites neritoides* Eichw., *Eobronteus laticauda* (Wahlenb.), *Stenopareia linnarssoni* (Holm), etc.

The *Porkuni stage* (F_{II}) is subdivided by the author into four members (Fig. 2). The Adila member may be traced in the lowermost part of the stage in Eastern Estonia. The Röa member (=Röa beds, Martna 1957) is lithologically varied and includes dolomites, dolomitized limestones, lenses of poorly bituminous limestones, etc. The Koigi member in its outcrop area consists partly of bioherm limestones containing sandy layers. To the south of the outcrop area the lower part of this member is represented by sandy limestones or by calcareous sandstones (Rosenstein 1943; Martna 1957). The typical fauna includes: *Codonophyllum rhizobolon* (Dyb.), *Propora magna* Sok., *Fenestella striolata* Eichw., *Leptaena acuteplicata* Öpik, *Streptis undifera* (Schm.), *Platylichas margaritifer* (Nieszk.), etc.

The Harjuan series corresponds to the upper part of the Caradocian and to the Ashgillian (the zones of *Pleurograptus linearis* to that of *Dicellograptus anceps*) of the British classification (Table I).

ON THE PALEOGEOGRAPHY OF THE ORDOVICIAN

Sedimentation and facial conditions of the basin extending over the north-western part of the Russian platform in the Ordovician period as well as in the previous epochs were determined by the development of the structures of the Precambrian basement. The unequal sinking of the latter makes it possible to distinguish two principal structural regions on the territory of Estonia. Northern and central Estonia belong to the southern slope of the Baltic shield, southern Estonia, on the other hand, being included in the north-western part of the Moscow depression.

In the second half of the Cambrian period there occurred a rising of the southern slope of the shield, which brought about a considerable regression in the Baltic area. A new period of sedimentation began on the territory of Estonia only at the very outset of the Ordovician period, i.e. in the Pakerort age. The end of the Tremadocian age was marked by another, though brief rising, as the upper part of the Tremadocian is lacking in Estonia (cf. p. 6).

The beginning of the Ontikan subepoch is characterized by a new sinking which caused another transgression and sedimentation of sandy rocks enriched with glauconite. The zone of the maximum sinking was in north-western Estonia. In the middle of the Ontikan age the northern coastline of the Baltoscandian basin apparently was to some extent dislocated toward the north and in Estonia there were deposited chiefly limestones containing grains of glauconite and many ferruginous compounds. In the most north-western part of Estonia there are indications of relatively littoral conditions (the petering out of the Volkhov stage or of its separate substages, lack of sediments in the lowermost part of the Kunda stage, sedimentation of sandy limestones, small thickness of rocks, etc.). These indications point to an intense development of the so-called Central Baltic uplift existing already from the beginning of the Middle Cambrian in the district of the island of Gotland. In southern Estonia the sinking continued in connection with the development of the Moscow depression.

The Purtse subepoch is characterized by an almost uninterrupted sinking, which was most intense in central Estonia. The thickness of the sediments in northern Estonia is larger than in the previous epochs, which together with other indications is evidence of a continuing movement of the northern coastline of the Baltoscandian basin toward the north.

At the start of the Kurna subepoch in north-western Estonia one can again observe a certain tendency to rising, which finds its expression in the petering out of $C_{III}\ \alpha$. Beginning with the second half of the Idavere age metabentonites were repeatedly deposited on the territory of Estonia, indicating a lively volcanic activity in Scandinavia. The Kurna subepoch is characterized by a change in the distribution of the thickness of rocks, which was most probably caused by a certain rising of the central part of Estonia. It is during this age that large thicknesses of sediments begin to accumulate in northern Estonia (deposits of relatively insignificant thickness having accumulated here before the Jõhvi age). An active rising of the Central Baltic region, which in the islands of Gotland and Gotska Sandön called forth sedimentation of calcareous sandstones of small thickness (Thorslund 1958b) was not reflected in the territory of Estonia, unless, one connects with this process an obvious shallowing of the sea in the Oandu age in the NW and N parts of Estonia (development of bioherms and of coarse detrital limestones).

The beginning of the Harjuan epoch is marked by a sudden change in the character of the sediments: in Estonia, as in the adjacent regions, aphanitic limestones began to be deposited. The thickness of the sediments in northern Estonia is still fairly large as before. A certain change in the distribution of the thickness of the sediments on the territory of Estonia occurred at the beginning of the Pirgu age when sediments of larger thickness than in the previous epochs began to be deposited in central Estonia. This was probably connected with the extension of the Moscow depression in the north-western direction. In NW Estonia bioherms began to develop in the first half of the Pirgu age, whereas in the central part of Estonia (the Võhma core) one observes the development of limestones of the bioherm type during the second half of the Pirgu age. The end of the Ordovician period has a clearly expressed regressive character in Estonia (calcareous sandstones, bioherms, etc. of the Porkuni stage).

LITERATURE

Aaloe, A., Mark, E., Männil, R., Müürisepp, K., Orviku, K. (1958):
Обзор стратиграфии палеозойских и четвертичных отложений Эстонской ССР. Акад. Наук Эст. ССР, Инст. геол. Таллин.

Alichova, T. N. (1956):
О границе между кембрием и ордовиком в Европейской биогеографической провинции. Информационный сборник ВСЕГЕИ No. 4. Ленинград.

ALICHOVA, T. N. (1957):
К вопросу о расчленении ордовикской системы. Советская геология. No. 55.

HENNINGSMOEN, G. (1954): Upper Ordovician Ostracods from the Oslo Region, Norway, *Norsk Geol. Tidsskrift*, Bd. 33. Oslo.

JAANUSSON, V. (1944): Übersicht der Stratigraphie der Lyckholm-Komplexstufe. *Bull. Comm. Geol. Finlande*, 132. Helsinki.

JAANUSSON, V. (1945): Über die Stratigraphie der Viru- resp. Chasmops-Serie in Estland. *Geol. Fören. Förhandl.,* Bd. 67, H. 2. Stockholm.

JAANUSSON, V. (1956): Untersuchungen über den oberordovizischen Lyckholm-Stufenkomplex in Estland. *Publ. Palaeont. Inst. Univ. Uppsala,* Nr. 12. Uppsala.

JAANUSSON, V. (1957): Unterordovizische Illaeniden aus Skandinavien. Mit Bemerkungen über die Korrelation des Unterordoviziums. *Publ. Palaeont. Inst. Univ. Uppsala.* Nr. 15. Uppsala.

JAANUSSON, V., and STRACHAN, I. (1954): Correlation of the Scandinavian Middle Ordovician with the graptolite succession. *Geol. Fören. Förhandl.,* Bd. 76, H. 4. Stockholm.

KALJO, D., RÕÕMUSOKS, A., MÄNNIL, R. (1958):
О сериях прибалтийского ордовика и их значении.
Eesti NSV Tead. Akad. Toim. VII köide. Tehn. ja füüs.-mat. tead. seeria, Nr. 1. Tallinn.

KELLER, B. M. (1954):
Типовые разрезы ордовика. Труды Геол. инст. АН СССР, вып. 154, серия геол. (No. 65). Москва.

LAMANSKY, V. V. (1905):
Древнейшие слои силурийских отложений России. Труды Геол. Ком., новая серия, вып. 20. С.-Петербург.

MAHNATCH, A. S. (1958):
Древнепалеозойские отложения Белоруссии. Инст. геол. наук АН БССР. Минск.

MARTNA, J. (1957): Notes on the Upper Ordovician and Lower Silurian of the Tapa district, Estonia. *Geol. Fören. Förhandl.,* Bd. 79, Stockholm.

MÄNNIL, R. (1958a):
К стратиграфии набалаского горизонта ($F_{I}a$) верхнего ордовика Эстонской ССР.
Eesti NSV Tead. Akad. Geol. Inst. Uurim. II. Tallinn.

MÄNNIL, R. (1958b):
Основные черты стратиграфии кейлаского горизонта (D_{II}, ордовик) в Эстонии.
Eesti NSV Tead. Akad. Toim., VII köide. Tehn. ja füüs.-mat. tead. seeria, Nr. 3. Tallinn.

MÄNNIL, R. (1958c):
Стратиграфия и палеогеография оандуского горизонта (D_{III}) в Эстонии. Тезисы докладов Акад. наук Эст. ССР. Инст. геол. Таллин.

MÜÜRISEPP, K. (1958b):
Характеристика нижней границы пакерортского горизонта от мыса Пакерорт до реки Сясь.
Eesti NSV Tead. Akad. Geol. Inst. Uurim. III. Tallinn.

OBUT, A. M. (1958):
Корреляция некоторых частей разреза ордовикских и силурийских отложений Эстонской ССР по граптолитам. Тезисы докладов Акад. наук Эст. ССР. Инст. геол. Таллин.

ORVIKU, K. (1940): Lithologie der Tallinna-Serie (Ordovizium, Estland) I. *Acta et Comm. Univ. Tartuensis* A XXXVI, 1. Tartu.

ORVIKU, K. (1958):
О литостратиграфии кейлаского и кундаского горизонтов в Эстонии. Тезисы докладов Акад. наук Эст. ССР. Инст. геол. Таллин.

ÖPIK, A. (1930): Brachipoda Protremata der estländischen ordovizischen Kukruse-Stufe. *Acta et Comm. Univ. Tartuensis* A XVII, 1. Tartu.

PASKEVICIUS, J. (1958):
Стратиграфия и фауна ордовикских и силурийских отложений Южной Прибалтики. Вильнюсский гос. университет им. Капсукаса. Вильнюс.

RAYMOND, P. E. (1916): Expedition to the Baltic Provinces of Russia and Scandinavia, 1914. Part 1. – The Correlation of the Ordovician strata of the Baltic basin with those of Eastern North America. *Bull. Mus. Comp. Zool. at Harvard College.* Vol. LVI, Nr. 3. Cambridge, Mass.

ROSENSTEIN, E. (1943): Unregelmässigkeiten in Einfallen der Untersilurischen Schichten Estlands im westlichen Teil der Pandiver'schen Erhebung. Tartu Ülik. Lood. Seltsi Aruanded 47^{3-4}; *Publ. Geol. Inst. Univ. Tartu,* Nr. 65. Tartu.

RÕÕMUSOKS, A. (1956):
Биостратиграфическое расчленение ордовика Эстонской ССР.
Eesti NSV Tead. Akad. Geol. Inst. Uurim. I. Tallinn.

RÕÕMUSOKS, A. (1957):
Стратиграфия кукрусеского горизонта (C_{II}) Эстонской ССР.
Tartu Riikl. Ülik. Toim., vihik 46. Tallinn.

SCHMIDT, FR. (1881): Revision der ostbaltischen silurischen Trilobiten nebst geognostischer Übersicht des ostbaltischen Silurgebiets. Abt. I. *Mém. de l'Acad. Imp. des Sciences de St.-Pétersbourg,* VII^e Ser., T. XXX, Nr. 1. – St.-Pétersb.

SOKOLOV, B. S. (1951a):
Табуляты палеозоя Европейской части СССР, ч. I. Труды ВНИГРИ, новая серия, вып. 48. Ленинград-Москва.

SOKOLOV, B. S. (1951b):
Табуляты палеозоя Европейской части СССР, ч. II. Труды ВНИГРИ, новая серия, вып. 52. Ленинград-Москва.

SPJELDNAES, N. (1957): The Silurian/Ordovician border in the Oslo district. *Norsk Geol. Tidsskrift,* Bd. 37. Bergen.

STØRMER, L. (1956): Dalmanitina Series. *Lexique Stratigraphique International,* Vol. 1, Fasc. 2a. Paris.

THORSLUND, P. (1958a): Dalmanitina beds. *Lexique Stratigraphique International,* Vol. 1, Fasc. 2c. Paris.

THORSLUND, P. (1958b): Djupborrningen på Gotska Sandön. Abstract: A preliminary report on a boring at Hamnudden on the island of Gotska Sandön. *Geol. Fören. Förhandl.,* Bd. 80. Stockholm.

TJERNVIK, T. E. (1956): On the Early Ordovician of Sweden. Stratigraphy and Fauna. *Publ. Palaeont. Inst. Univ. Uppsala,* Nr. 9. Uppsala.

WIMAN, C. (1902): Studien über das Nordbaltische Silurgebiet I. *Bull. Geol. Inst. Upsala,* Vol. VI, Nr. 2. Upsala.

[*Manuscript received October* 13*th,* 1959]