ISOS-14 Field Guide
The Ordovician of Estonia

Edited by Olle Hints and Ursula Toom

14th International Symposium on the Ordovician System, Estonia, July 19-21, 2023
Pre-conference Field Excursion: The Ordovician of Estonia, July 15-18, 2023

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About the Ordovician System in Estonia

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The area of continuous distribution of the Ordovician in the Baltic Sea area and east of it extends from the southern part of the Baltic Sea in the west to the vicinity of Moscow in the east and from the Gulf of Finland or northernmost Estonia in the north to Belarus and Poland in the south. In the northern part of this area, in the eastern coastal region of the Baltic Sea, beds are exposed in sections of the Baltic-Ladoga Klint, sometimes with more than 10 m of strata exposed, which attracted the attention of early investigators, together with other coastal and river bank sections, as well as old and new limestone quarries and open cast pits. Well-accessible successions with well-preserved fossils and sedimentary structures attracted the attention of investigators already in the early 19th century and were addressed in the papers by O. M. L. v. Engelhardt (1820), W. T. H. F. Strangways (1821), E. Eichwald (1825), and others. In particular, the characteristic succession of the Cambrian to Middle Ordovician with a number of distinctive rock units (the Cambrian Blue Clay, phosphatic brachiopod coquina, *Dictyonema* argillite, dark green glauconite sandstone and the succession of distinctive limestone units above) was of great interest.

The thorough monographic paper by F. Schmidt from 1858 brought to attention the main features of Ordovician stratigraphy in Estonia for the first time. The general pattern of his very old geologic map in the same volume is already well demonstrating the most characteristic feature of modern bedrock maps of Estonia —latitudinally orientated outcrop belts of the Ordovician and Silurian stages in northern Estonia. The feature is a result of the generally simple geologic structure of the area, with almost horizontal strata dipping southward only 2–5 m/km.

The Lower Ordovician thin succession of siliciclastics comprises sandstones, argillites and clays (Pakerort and Varangu RSs) overlain by the glauconitic sand- and siltstones (Hunneberg and Billingen RSs). Further up, the main part of the Ordovician succession in northern Estonia is heavily dominated by various kinds of limestones but also contains some intercalations of kukersite oil shale concentrated mainly in the Kukruse Regional Stage (RS). The transition from the terrigenous to carbonate rocks in the basal part of the Toila Formation (topmost Lower Ordovician to basal Middle Ordovician) is marked by the fairly sharp appearance of the first limestone/dolomite beds. The appearance of the first representatives of the numerous characteristic Middle Ordovician fossil groups is recorded in the same transition interval or in the overlying Volkhov Stage.

The Ordovician limestone succession in Estonia and adjacent areas begins with carbonates deposited in a sediment-starved shallow marine basin. Upward the sedimentation rates have increased in obvious correlation with the carbonate carbonate production. In the Upper Ordovician, corals make their first appearance, and the first carbonate buildups appear, emphasising a remarkable change in the overall character of the palaeobasin. Informer publications, change in the type of sedimentation and the character of biofacies is ascribed to a gradual climatic change resulting from the northward drift of the Baltica Palaeocontinent from the temperate climatic zone to the (sub)tropical realm (Nestor and Einasto, 1997). This interpretation, however, is not in full accordance with the results of a pilot study on conodont phosphate oxygen isotope palaeotemperature revealing a continuous cooling trend in the palaeobasin throughout the Middle and Later Ordovician (Männik et al. 2022). Independently of that, the Middle and Upper Ordovician changes resulted in an increase of carbonate production and sedimentation rate on the carbonate shelf where the deposition pattern was obviously controlled by accommodation space available.

The problems of the Ordovician geology in the subsurface area in central and southern Estonia were first revealed in the late1950s when the extensive drilling started in the area. Thanks to the high number of drill cores obtained during a comprehensive drilling programme in the 1950s–1980s, the main correlations problems between the stratigraphic successions in the outcrop area and in southern Estonia were mainly resolved. As a result of the comparison of the eastern Baltic and Scandinavian successions, the concepts of the structural-facies zones (by Männil 1966) or confacies belts (by Jaanusson 1976) were introduced for the Ordovician of Baltoscandia (see Fig. 1). As the term “confacies “is unique (being exclusively used for the Ordovician of Baltoscandia only), a different terminology has been introduced by Harris et al. 2004 (see explanation to the Fig. 1). The micropalaeontological and macrofaunal studies of the core sections also revealed the distinctive biogeographic differentiation pattern, characteristic of the Ordovician rocks (Männil 1966; Männil et al. 1968; Meidla 1996, etc.). Although the biofacies pattern is generally described for the eastern Baltic area, the facies zonation of the entire Baltoscandian area is still imperfectly known. The seismic investigations of the Baltic Sea area, performed in the last decades (Tuuling 1998 and references therein), but also detailed (micro)palaeontological investigations (e.g. Tinn 2002) might produce valuable new information in this field.

The total thickness of the Ordovician reaches up to 190 m, being maximal in central and eastern Estonia and considerably less in the outcrop area, as well as in the southwestern mainland of Estonia. Several correlation problems still persist in the Ordovician of Estonia due to marked biofacies differences between northern and southern Estonia. In part, they are also discussed in a recent monographic overview of Estonian geology (see

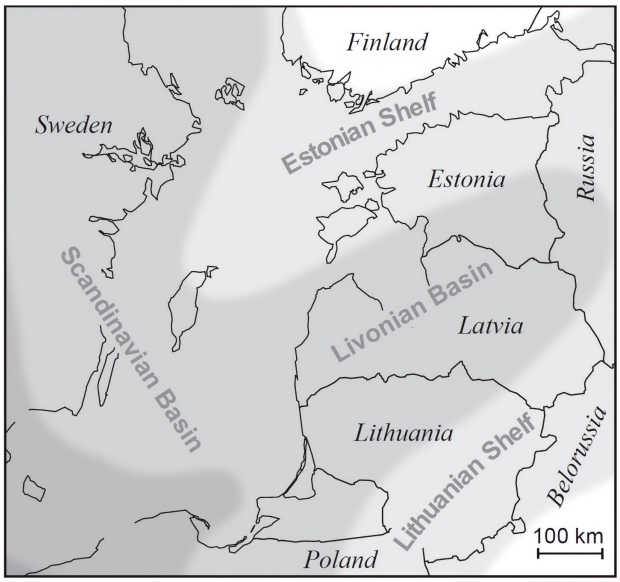

Fig. 2. Post-Tremadocian Ordovician facies zonation according to Harris et al. (2004); from Meidla et al. (2014).

Heinsalu and Viira 1997, Meidla 1997; Hints 1997; Hints and Meidla 1997 in Raukas and Teedumäe, 1997). New prospects in this field have already been opened by stable isotope studies, as the stable carbon isotope curves have demonstrated a good correlation potential (Kaljo et al. 2004, 2007, and references therein; Ainsaar et al. 2004, 2007, 2010).

The development of the stratigraphic classification of the Ordovician strata in Estonia, from the "beds" (*Schichten*) by Schmidt (1858) to the stages in modern meaning, is documented in detail in Männil (1966), Rõõmusoks (1983) and Rõõmusoks et al. (1997). The term "Ordovician" was likely used to describe the Estonian succession for the first time by Bassler (1911) and became widely established in the geological literature of Estonia since Bekker (1921). A number of regional series and subseries for the Ordovician System in Estonia and neighbouring Russia were introduced by Schmidt (1881) and several subsequent authors. Raymond (1916) introduced the traditional American three-fold subdivision of the Ordovician System for this particular area, but this classification was subjected to repeated changes until 1987. Also, the terms "Oeland Series", "Viru Series" and "Harju Series" have been widely used as a basic three-fold classification for the Ordovician System of the area since the 1950s (introduced by Kaljo et al. 1958 and Jaanusson 1960 in a nearly recent meaning). The subseries have been introduced as well (see Männil and Meidla 1994 and Nõlvak et al. 2006 for a summary), but they lost their actuality and are rarely used today.

The modern three-fold classification of the Ordovician System (IUGS 2004) was first used for the Estonian succession by Webby (1998) and is presented here in detail (Fig. 2). In relation to the definition of the GSSP for the base of the Ordovician System in the Green Point section, Newfoundland (Remane, 2003), a revision of the traditional position of the Cambrian-Ordovician boundary at the base of the Pakerort RS in Estonia turned out to be necessary. According to conodont data, the system boundary in the northern Estonian sections lies some metres higher than previously suggested, i.e. in the middle of the Pakerort Stage, within the Kallavere Formation (Puura and Viira 1999). The upper boundary (the lower boundary of the Silurian System) has for a long time been correlated with the major hiatus between the Porkuni and Juuru RSs, corresponding to the maximum regression related to the Hirnantian glaciation, due to the fact that a major faunal overturn is recorded on this level. Recent chemostratigraphic correlations, however, suggest that the falling limb of HICE reaches into the basal part of the Juuru RS (Ainsaar et al. 2010, 2015; Bauert et al. 2014; Meidla et al. 2020, 2023) and the Ordovician–Silurian boundary is located within the beds formerly attributed to the basal Silurian.

The term "(Regional) Stage", first applied by Bekker (1921), has become the principal category in the chronostratigraphic classification of the Ordovician System in Estonia.

The main features of the chronostratigraphic classification of the Ordovician System were established already by Männil (1966). Only minor changes were introduced in the later decades: the Ceratopyge RS was renamed the Varangu RS (Männil, 1990), the Latorp RS was replaced by the Hunneberg and Billingen RSs (Hints et al., 1993) and a new unit, the Haljala RS, is used instead of the Idavere and Jõhvi RSs (following Jaanusson, 1995 and Nõlvak, 1997). Hints and Nõlvak (1999) brought the concept of boundary stratotypes ("golden spike") into the Estonian stratigraphy, proposing a stratotype — the Pääsküla outcrop — for the lower boundary of the Keila RS. However, as stratigraphic hiatuses on the stage boundaries are very common in northern Estonia (remarkable faunal changes are usually related to hiatuses), wide usage of this concept for the stage boundaries in this area looks rather complicated.

The lithostratigraphic classification of the Ordovician rocks was introduced by Orviku (1940) for the upper Middle Ordovician. This approach was widely accepted by subsequent authors and led to the compilation of a series of detailed correlation charts approved by the Interdepartmental Stratigraphic Committee of the former USSR (Resheniya... 1965, 1978, 1987 and a related paper by Männil and Rõõmusoks, 1984). The last version of such a formal correlation chart (the edition of 1987) was, in a slightly emended form, published also in English in the series of the IUGS publications (Männil and Meidla, 1994).

The correlation chart in Fig. 2 contains some recent improvements compared to this publication, the most recent ones being introduced by Ainsaar and Meidla (2001), Nõlvak et al. (2006), Meidla et al. (2020 and references therein) and Paiste et al. (2022, 2023). Some more versions of the Ordovician correlation charts for Estonia have also been published by Hints et al. (1993), Nõlvak (1997) and Meidla et al. (2014).

Ordovician stratigraphy in Estonia, 2023

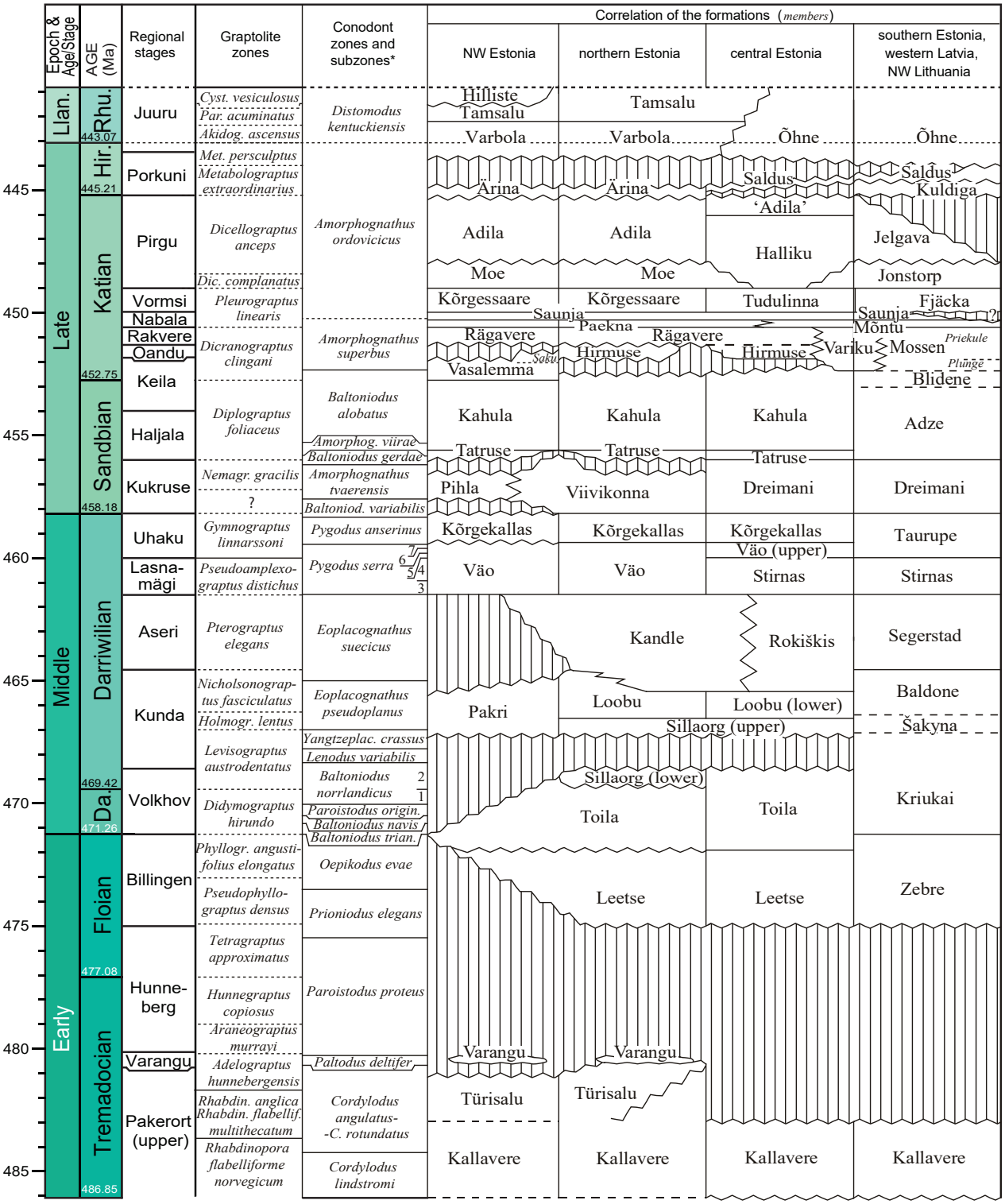

Fig. 3. Ordovician stratigraphy of Estonia. Graptolite zonation according to Kaljo & Vingissaar, 1969, Kaljo et al., 1986, Männil, 1976, Resheniya..., 1987, Männil & Meidla, 1994, Nõlvak et al., 2006, conodont zones according to Männik in Nõlvak et al. 2006, Paiste et al. 2020, 2022 and Meidla et al. 2023. Numbers in the column of the conodont zonation correspond to the conodont subzones as follows: subzones of the *Baltoniodus norrlandicus* Zone: 1 – *Trapezognathus quadrangulum* Subzone, 2 – *Lenodus antivariabilis* Subzone; subzones of the *Pygodus serra* Zone: 3 - *Eoplacognathus foliaceous* Subzone, 4 - *Eoplacognathus reclinatus* Subzone, 5 - *Eoplacognathus robustus* Subzone, 6 - *Eoplacognathus protoamosus* Subzone, 7 - *Eoplacognathus lindstroemi* Subzone. Abbreviations: Llan., Llandovery; Da.,Darriwilian; Hir., Hirnantian; Rhu., Rhuddanian; *Cyst.*, *Cystograptus; Par.*, *Parakidograptus; Met.*, *Metabolograptus*; *Dic.*, *Dicellograptus*; *Nemagr.*, *Nemagraptus*; *Holmogr.*, *Holmograptus*; *Phyllogr.*, *Phyllograptus*; *Rhabdin*, *Rhabdinopora*; *flabellif.*, *flabelliforme*; *Amorphog.*, *Amorphognathus*; *Baltoniod.*, *Baltoniodus*; *Yangtzeplac.*, *Yangtzeplacognathus*; *origin.*, *originalis*; *trian.*, *triangularis*.

The composition and textures of the Ordovician carbonate rocks and the principal differences between the confacies belts were summarised by Põlma (1982 and references therein).

The monographic studies on Ordovician palaeontology started already in the 19th century. After the comprehensive review of the Ordovician and Silurian strata (in modern meaning) by Schmidt (1858 and several subsequent monographic papers), a number of important monographic papers were published by F. B. Rosen, W. Dybowski, A. Pahlen, G. Holm, A. Mickwitz, O. Jaeckel, J. H. Bonnema and R. F. Bassler. The tradition of palaeontological investigations on the Ordovician material of Estonia was continued by A. Öpik (1930, 1934 and others) and, later on, by the recent generation of palaeontologists. Monographs and extensive monographic papers were published on the Ordovician brachiopods, corals, stromatoporoids, chitinozoans, scolecodonts, ostracods, conodonts, etc. Summaries on the palaeontological investigations on virtually all fossil groups recorded from the Ordovician of Estonia are published in the recent monograph "Geology and mineral resources of Estonia" (Raukas and Teedumäe 1997).

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