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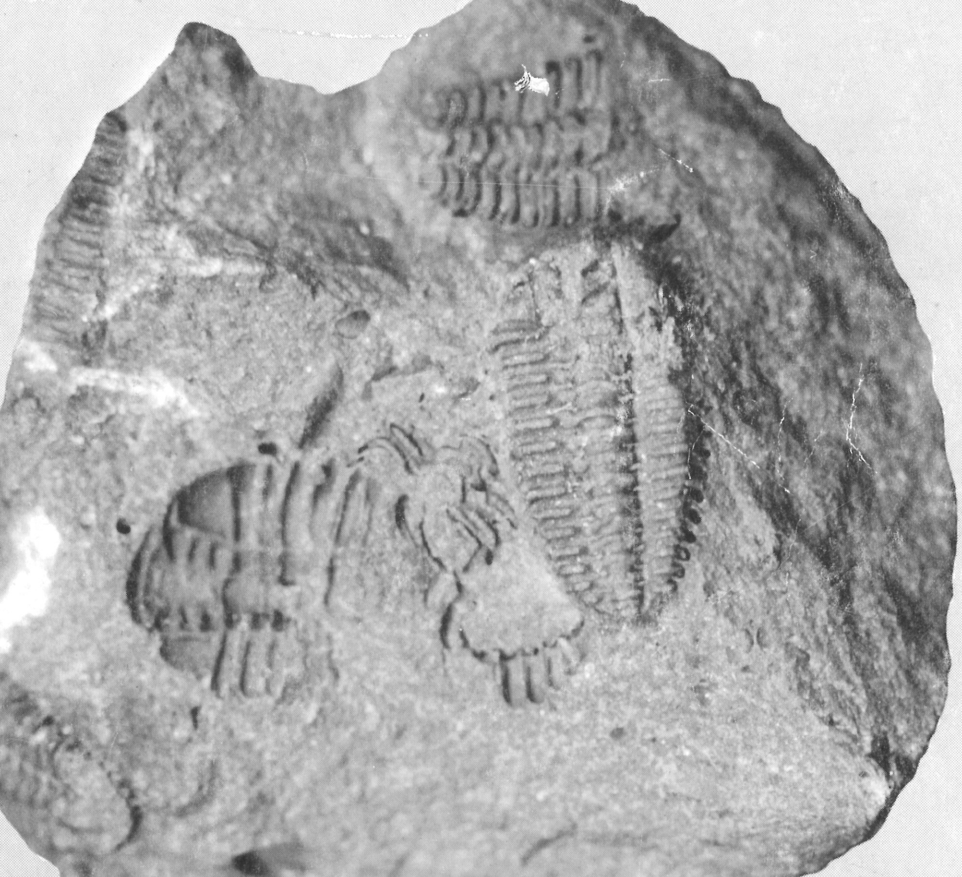

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Quo vadis Ordovician?

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The mid-Caradocian biotic and isotopic event in the Ordovician of the East Baltic

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INTRODUCTION

In recent publications several aspects of the Ordovician biodiversity have beed discussed. This activity has been stimulated by increasing understanding of the general dynamics of biota during the Phanerozoic (Sepkoski 1997) and the importance of the Ordovician period in particular. Highly provincial and rapidly radiating Ordovician faunas had a key position in the formation of Palaeozoic marine faunas (*sensu* Sepkoski). In order to understand better the formation mechanisms of the regional faunal successions and their relationship to the global changes in biodiversity, the local/regional bioevents should be analyzed in the context of global change. An important tool for this purpose is the stable isotope record, which may shed light on the regional or possibly global nature of a particular bioevent in the local record.

Our study deals with aspects of the mid-Caradocian event in the Baltoscandian Palaeobasin. The data on carbon stable isotopic composition allows us to present an enhanced correlation of sections along an onshore-offshore profile. Considering the data from North America, we suggest a possibly global reason of the rearrangement of the mid-Caradocian ecosystem.

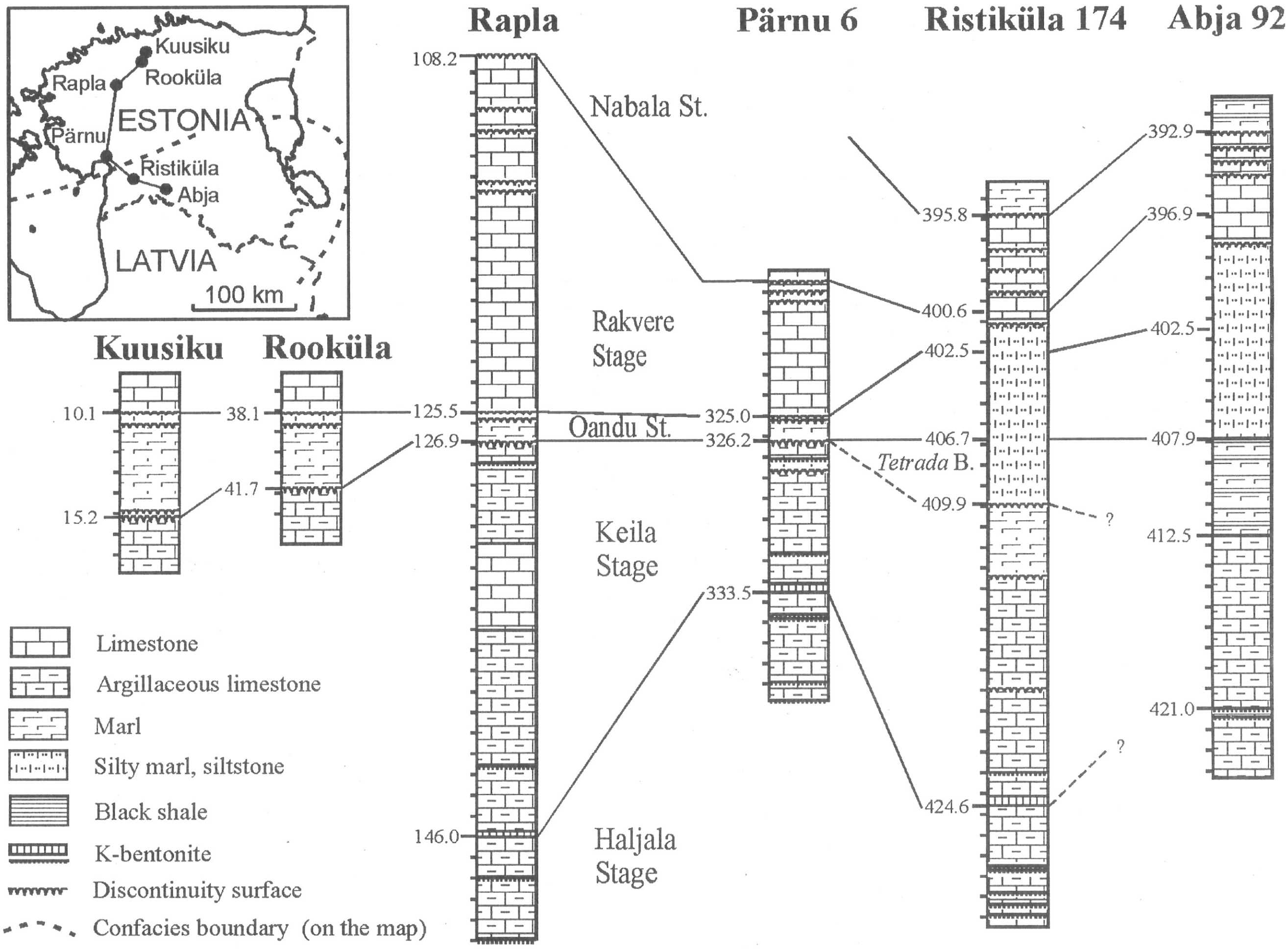

Fig. 1. Correlation of the mid-Caradocian sequence in Estonia along the facies gradient.

GEOLOGICAL SETTING

In the Ordovician, the Baltica Palaeocontinent was covered by an epicontinental sea (the Baltoscandian Palaeobasin) with predominantly carbonate deposition. The post-Tremadocian Ordovician of the East Baltic has a nearly continuous carbonate sequence from Arenig to Ashgill. Minor stratigraphical gaps occur in the sections on the margin of the palaeobasin (northern Estonia, eastern Lithuania) whereas deposition in the depressions (e.g. in western Latvia and central Lithuania) was almost continuous (Nestor and Einasto 1997).

The general distribution of the fauna and lithofacies shows large-scale zonation of the paleobasin, termed confacies belts by Männil (1966) and Jaanusson (1976). The North Estonian Confacies Belt is characterized by limestones formed mainly in open shelf or upper to middle ramp settings, below fair-weather wave base. The Central Baltoscandian Confacies Belt, comprising southern Estonia and western Latvia, is mainly characterized by argillaceous-carbonate sedimentation of lower ramp or deeper. In detail, the confacies belts are thought to be of complicated nature, reflecting the changing balance between terrigenous input and carbonate production in different parts of the basin (Jaanusson, 1982). However, in general they reflect sufficiently well the palaeobathymetry of the Ordovician shelf basin.

THE MID-CARADOCIAN EVENT IN THE ONSHORE SHELF AREA

The development of the post-Tremadocian Ordovician carbonate sedimentation in the Baltoscandian Palaeobasin reflects the gradual shift in southern paleolatitude of Baltica from approximately 50° to 20° south during the Ordovician period (Torsvik *et al.* 1996). Within the continuous trend, the most remarkable change in the general sedimentation pattern was during the mid-Caradoc, (Keila and Oandu stages), which separates two principal epochs of carbonate sedimentation in the palaeobasin. Compared to the first epoch, the second one shows generally greater differentiation in depth as a result of increased tectonic activity, increase in sedimentation rates, decreased but distinctly cyclic influx of terrigenous material into the basin, the appearance of calcilutites and higher gradients of the lithofacies transitions (Põlma 1982; Hints *et al.* 1989). In a profile along the facies gradient (Fig. 1), the onshore (North Estonian) sections (Kuusiku, Rooküla, Rapla and Pärnu) are represented by a predominantly carbonate sequence. Further to the south (Ristiküla, Abja) are highly siliciclastic beds of considerable thickness.

Ainsaar *et al.* (1999b) recently termed the rearrangement of sedimentation and other related changes "the mid-Caradoc event". The event had a relatively short duration, roughly equivalent to the *clingani* graptolite Zone.

In the faunal succession, the specific features of the stratigraphical level under discussion have been known since the 1950s. The first evidence came from the outcrop belt, exposing the limestone sequence of the onshore area of the palaeobasin. The macro- and microfaunal record revealed a diversity drop of brachiopods, ostracodes, echinoderms, gastropods, bryozoans at the boundary of the Keila and Oandu stages (Oraspõld and Rõõmusoks 1956; Männil 1966; Hints *et al.* 1989; Lavrentjeva 1996; Meidla 1996; Isakar 1997; Ainsaar *et al.* 1999a). An episode of rapid diversification in the Oandu Stage changed the taxonomic composition of these groups remarkably; tabulates and stromatoporoids, previously not recorded in the East Baltic area, appeared at the same level (Mõtus 1997; Nestor 1997). The turnover is evident among most shelly fossil groups (Fig. 2). Among brachiopods, trilobites, ostracodes and conodonts, several immigrant taxa appeared (Hints, Rõõmusoks 1997; Rõõmusoks 1997; Meidla 1996; Männik 1992). Some of them were shortlived, for example brachiopods (*Horderleyella*? and *Longvillia*) and the ostracodes (*Baltocyamus*). Of the shelly fossils, trilobites seem to have been less affected, displaying a gradual decrease in diversity, beginning in early Caradoc (Rõõmusoks 1997).Changes in the taxonomic composition of organic-walled microfossils (chitinozoans and scolecodonts) are relatively less distinct, although remarkable in the dynamics of the particular groups (Fig. 2).

CHANGE ALONG THE FACIES GRADIENT

The integration of the data from the Central Baltoscandian Confacies Belt into the diversity database (Fig. 2) is complicated due to biofacies differences and correlation problems. The mid-Caradocian biotic event coincides with a regressive episode (Ainsaar *et al.* 1996, 1999b) which resulted in nonsedimentation and/or erosion in most of northern Estonia. The bio- and chemostratigraphical evidence suggests (Ainsaar *et al.* 1999b) that the sequence is considerably more complete in southern Estonia and elsewhere within the Central Baltoscandian Confacies Belt.

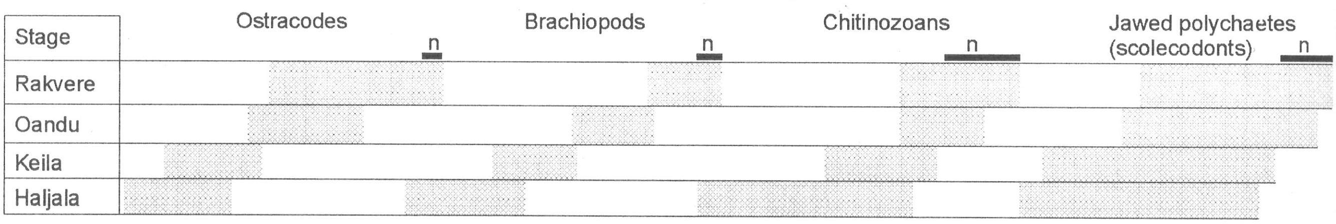

Fig. 2. Number of recorded ostracode, brachiopod, chitinozoan and polychaete taxa in teh stages in North Estonia (data on chitinozoans from the Rapla core only) and the number of transitional taxa at the stage boundaries. Horizontal scale for a group: n=10 species.

The late Keilan and Oanduan dolomitic silty beds in South Estonia (Ristiküla) correspond in stratigraphic position to the gap between the Keila and Oandu stages in North Estonia (Fig. 3). The appearance of typical North Estonian

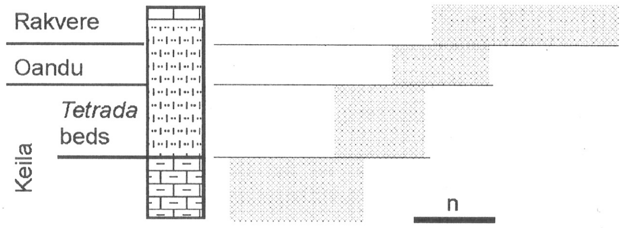

Fig. 3. Number of recorded ostracode species in the stages and distinctive subunits, and number of transitional species at the stage boundaries. Data from the Ristiküla and Tartu sections (Ainsaar *et al.* 1999b). Horizontal scale: n=10 species.

ostracode taxa (*Bichilina, Hesperidella*) in the uppermost Keila Stage in Ristiküla core (Meidla *in* Ainsaar *et al.* 1996) supports a gradual shallowing during late Keila time. The data from the subsurface sections (Fig. 4) displays a turnover in the ostracode composition at a particular level within the silicicalastic interval. The turnover is equally sharp and distinct in this area and in North Estonia, where a sharp faunal boundary may be explained by a gap in the sequence.

The latest studies on stable isotopic composition of carbonate rocks in South Estonian core sections have revealed a significant positive shift in carbon isotopic composition (Ainsaar *et al.* 1999b). The positive $\delta^{13}C$ excursion of a magnitude of +2‰ (Fig. 4) was discovered in the upper part of the Keila Stage, in the sections of southern Estonia (the Central Baltoscandian Confacies Belt). The carbon isotopic excursion in South Estonian sections clearly preceded the faunal change at the Keila-Oandu stage boundary and the turn from carbonate-dominated to siliciclastic-dominated type of sedimentation in the latest Keilan time (Fig. 3; Ainsaar *et al.* 1999b). The new data from North Estonian Kuusiku and Rooküla sections does not display a comparable change in the isotopic record. This is generally in agreement with the proposed regression scenario regression scenarion in which the excursion in the uppermost beds – the Keila Stage are missing in the onshore area (Ainsaar *et al.* 1999b). Together with the biostratigraphical data, isotopic data provides additional evidence for defining the most prominent event horizon in the sections of different facies.

REGIONAL *VERSUS* GLOBAL

The magnitude of the faunal change in the Keila-Oandu transition exceeds considerably the background level of the faunal rearrangement during the middle-late Ordovician. Both the faunal and facies changes in the Keila-Oandu interval have been ascribed, at least in part, to changes in climate which apparently turned more warm and arid (Jaanusson 1973; Webby 1984; Hints *et al.* 1989). Kaljo *et al.* (1996) first suggested the relationship of the mid-Caradoc changes in the Estonian sections to a coeval global drop in the diversity of different invertebrate groups noted by Sepkoski (1995). The palaeontological data from the East Baltic supports the suggestion that the corresponding fluctuation of the global diversity curve may be due to faunal response to real changes of interregional or global scale and not an artifact.

In the East Baltic, the mid-Caradocian faunal changes are associated with one of the most prominent gaps in the Ordovician carbonate sequence. This is particularly evident in the outcrop belt which exposes the sediments of the former onshore area. The gap is mainly ascribed to a regressive event related to tectonic events (Nestor and Einasto 1997). The rapid reestablishment of fairly continuous sedimentation in the former nonsedimentation areas may be related to the global eustatic rise. The same changes are thought to be responsible for nearly coeval patterns in lithologies and faunas in the central United

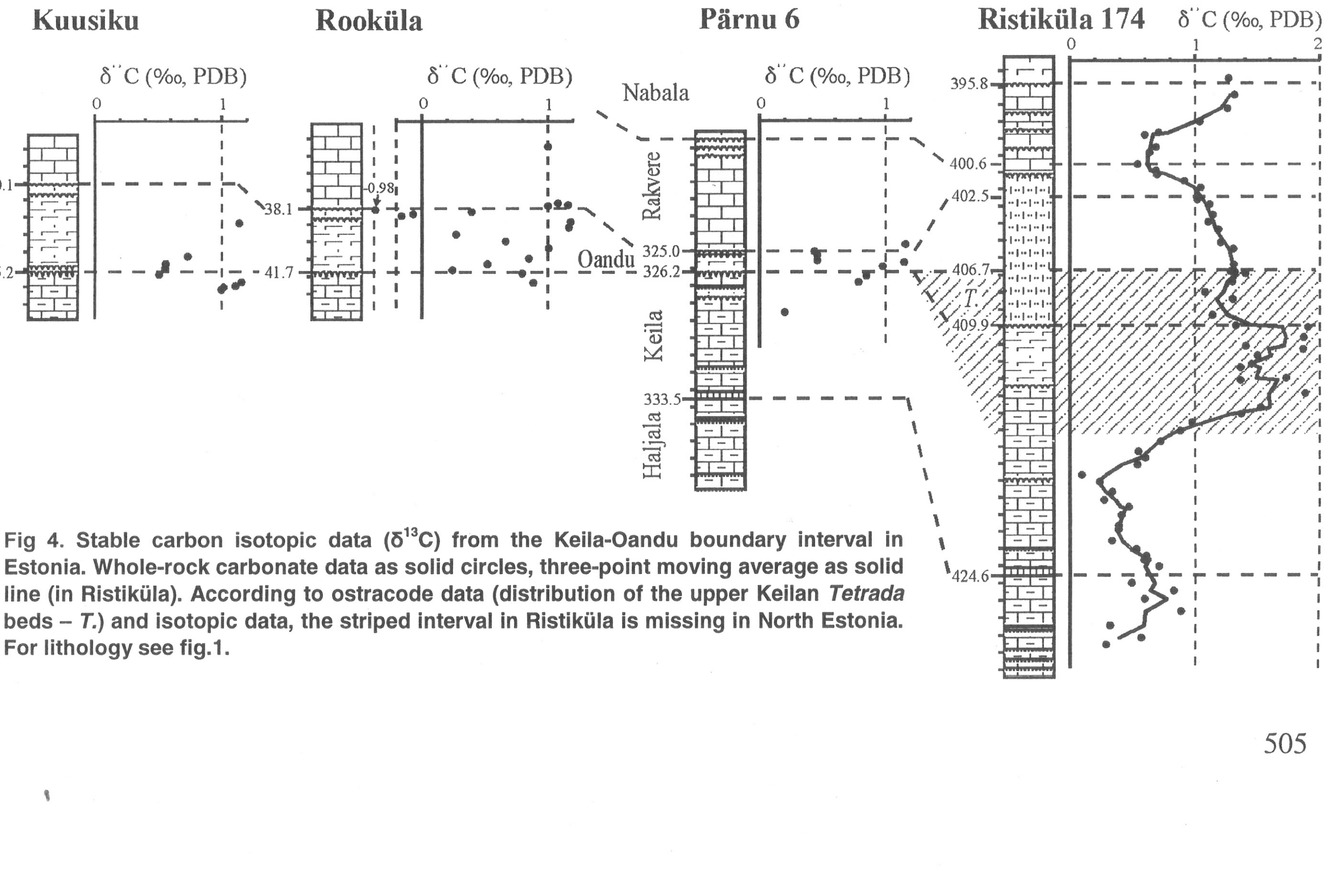

Fig 4. Stable carbon isotopic data ($\delta^{13}C$) from the Keila-Oandu boundary interval in Estonia. Whole-rock carbonate data as solid circles, three-point moving average as solid line (in Ristiküla). According to ostracode data (distribution of the upper Keilan *Tetrada* beds – *T.*) and isotopic data, the striped interval in Ristiküla is missing in North Estonia. For lithology see fig.1.

States area (Patzkowsky and Holland 1993).

The recent discovery of a isotopic shift in late Keila time adds a new aspect to the mid-Caradoc event, emphasizing its complex nature. The isotopic shift, which is supposed to reflect a change in ocean water chemistry, is close to faunal changes and the unconformity in the studied sections. The record of coeval isotopic events of a comparable magnitude in North America (Patzkowsky *et al.* 1997) suggests that changes in the fossil record, basin evolution and stable isotope record may represent different aspects of a global oceanographic and/or climatic event.

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