Polish Geological Society
Faculty of Geology, University of Warsaw
Institute of Palaeobiology, Polish Academy of Sciences
Polish Geological Institute-National Research Institute

10TH BALTIC STRATIGRAPHIC CONFERENCE

CHĘCINY 12–14 SEPTEMBER 2017

Abstracts and Field Guide

Edited by Anna Żylińska

Faculty of Geology, University of Warsaw
Warszawa 2017

The Guttenberg carbon isotope excursion (GICE; Ordovician) in Estonia

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Over the past 20 years, numerous papers have been published on stable carbon isotopes from Ordovician carbonate rocks. Three prominent and apparently globally distributed positive carbon isotopic excursions ($\delta^{13}C$) have been documented in the Ordovician succession – the Mid-Darriwilian (MDICE), the early Katian Guttenberg (GICE), and the Hirnantian (HICE) excursions. The largest positive excursion is the end-Ordovician HICE, with peak values sometimes exceeding 6‰ in Baltica. The HICE is associated with extensive glaciation on Gondwana, which substantially lowered the global sea-level. At the same time, the causes for MDICE and GICE are less well-known and only a few studies refer to the early Katian cooling with advances of glaciers on Gondwana.

The GICE is extensively studied in Baltoscandia, being well-documented in several outcrops and drillcores from Norway (Eina, Furuberget, Rodeløkke and Fomebu), Sweden (Fjäcka, Smedsby Gård, Borenshult and Solberga 1), and Estonia (e.g., Nurste F-368, Männamaa F-367, Viruküla F-324, Oru D-154, Saku 1098A, Kerguta-565, Ristiküla-174, Viljandi-91, Tartu-453, Mehikoorma-421 and Valga-10). The objective of this overview is to summarise the available information on the GICE $\delta^{13}C_{carb}$ data from Estonia (including the recently analyzed Nurste F-368, Viruküla F-324 and Oru D-154 cores), to examine the GICE $\delta^{13}C_{carb}$ curve shape in relation to the late Sandbian–early Katian facies distribution and basin bathymetry (Fig. 1), as well as to estimate the temporal extent of the GICE, based on high-resolution chitinozoan biostratigraphy.

In the East Baltic, the GICE is recorded in the succession of variably argillaceous carbonate rocks to dolomitic siltstones of the Keila and Oandu regional stages (with the siliciclastic component up to 60–80%, about half of which is silt-sized quartz and K-feldspar in the Ristiküla-174 core). The base of the Keila Stage is marked with the prominent Kinnekulle K-bentonite, often recorded in drillcores of north and central Estonia, and the studied interval is overlain by lime mudstones of Rakvere Age. Detailed chitinozoan biostratigraphic studies have revealed the possibility to track the Kinnekulle K-bentonite level by the *Angochitina multiplex* occurrence event, whereas the base of the Rakvere Stage can be easily and unambiguously recorded by the beginning of the continuous range of *Fungochitina spinifera* in the early Katian succession. The boundary between the Keila and Oandu regional stages is, however, not precisely defined and cannot be easily correlated by chitinozoans at present.

The exact onset of the GICE in all studied sections is rather complicated to identify on a rising limb from the early Sandbian negative carbon excursion (Fig. 1). It seems that the onset of the GICE is preceded by an interval with relatively flat, slightly fluctuating $\delta^{13}C_{carb}$ values. Thus, the beginning of the GICE is drawn at the level where a plateau-like part of the curve ends and a more prominent rise of $\delta^{13}C_{carb}$ values is observed. The GICE $\delta^{13}C_{carb}$ peak values deviate from the baseline by about 1–1.5 ‰. They occur in the transition from argillaceous limestones of the Kahula Formation to silty carbonates of the Variku Formation (e.g., in the Ristiküla section) or to the marls of the Hirmuse Formation (e.g., in the Oru D-154 section). The GICE peak values can be traced rather well by a number of key chitinozoan species: *Desmochitina nodosa* and *Pistillachitina* sp. A disappear at the GICE peak extent interval, whereas *Ancyrochitina bornholmensis* and *Spinachitina* aff. *coronata* appear in this interval in sections from southern Estonia.

The falling limb of GICE shows rather steadily declining $\delta^{13}C_{carb}$ values in most sections studied, except in the Viruküla F-324 and Nurste F-368 cores from NW Estonia, where the GICE is largely missing due to a sedimentary hiatus. A prominently sharp negative shift of $\delta^{13}C_{carb}$ values with an amplitude of up to 3.75‰, is observed in these two sections. This negative excursion, which probably signals the early diagenetic overprint in the limestone unit with a set of well-developed pyritized discontinuity surfaces, is followed by the onset of the Rakvere positive carbon isotope excursion.

The highly wiggling nature of the $\delta^{13}C_{carb}$ curve in NW Estonia (Nurste F-368, Männamaa F-367) and somewhat less fluctuating nature in the Viruküla F-324 sections most probably reflects the influence of meteoric water run-off to the shallow shelf areas as implied by the presence of the Vasalemma shallow water reefs in NW Estonia.

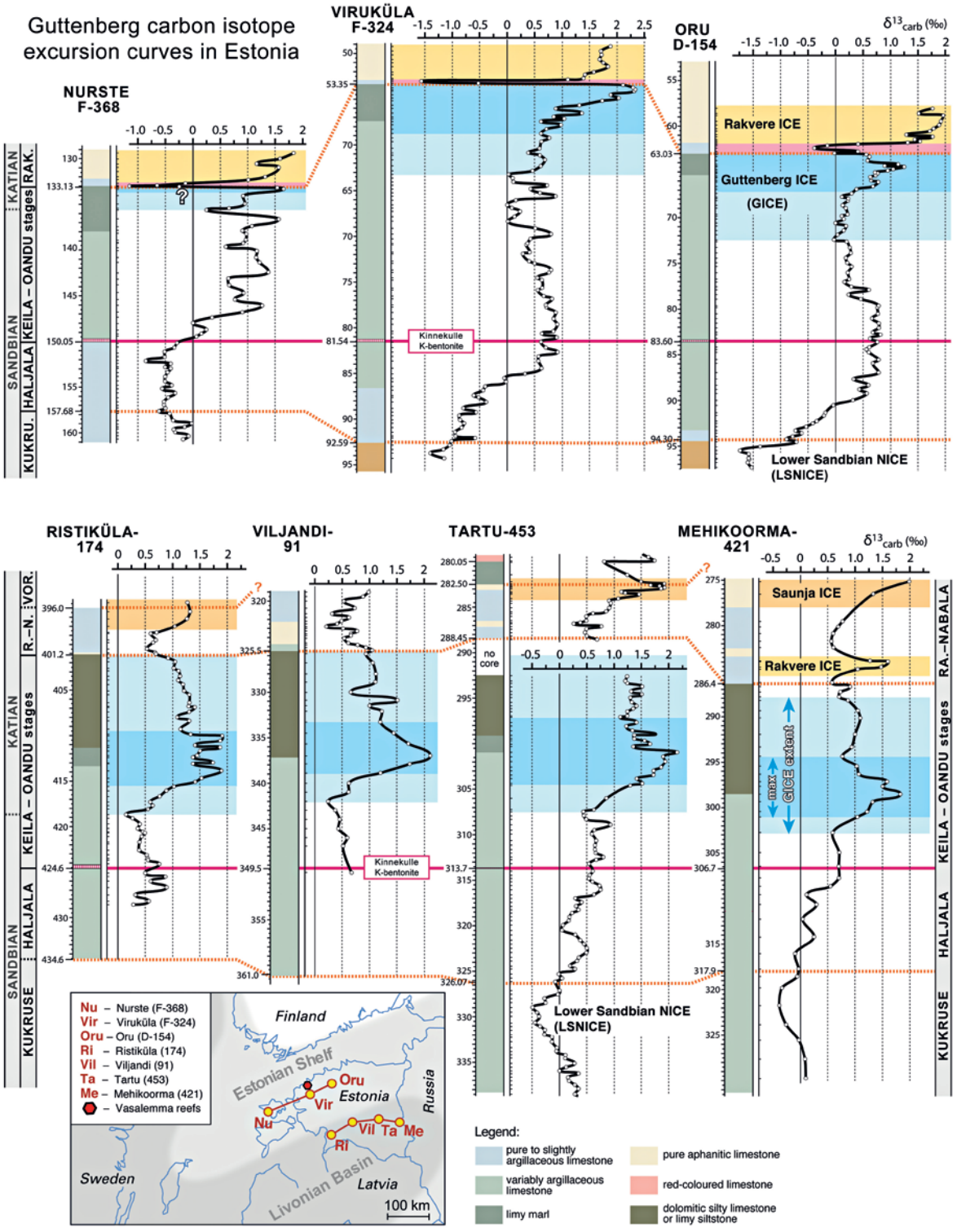

Fig. 1. Sandbian to early Katian carbon isotopic excursions with temporal range of the GICE (temporal extent of the GICE – light blue colour, maximum carbon isotopic values – dark blue colour). The Nurste F-368, Viruküla F-324 and Oru D-154 cores were recently analysed for $\delta^{13}C_{carb}$ values. Other $\delta^{13}C_{carb}$ data are from previously published sources: Ristiküla-174, Viljandi-91, Tartu-453 and Mehikoorma-421 cores. Inset: Ordovician Palaeobaltic basin (darker colour denotes deeper facies) with locations of studied drillcores and showing the shallow-water Vasalemma reef area.