Refinements of carbon isotope stratigraphy in the latest Ordovician of Estonia

D. Kaljo
L. Hints
T. Martma
J. Nõlvak

Institute of Geology, Tallinn Technical University, 7 Estonia Ave., EE0001 Tallinn, Estonia

The main characteristics of a carbon isotope 'event' associated with a glaciation and mass extinctions of biota in the latest Ordovician have been well demonstrated during a few last years (Marshall *et al.*, 1997; etc.). Also Estonian material (brachiopod shells, kerogen) was involved, but due to complications of local geology only a generalized $\delta^{13}C$ curve could be constructed. Below we present the data obtained by analysing bulk carbonate rock samples from drill cores and the stratotype of the Hirnantian Porkuni Stage, with the aim to establish a continuous carbon isotope curve through the uppermost Ordovician of Estonia.

Geological setting

The Porkuni Stage in North Estonian sections is represented by shallow shelf sedimentary rocks (Ärina Formation), micritic limestones, usually more or less argillaceous, at some levels with stromatoporoid-tabulate reefs (Tõrevere Member), in the upper part also with oolitic and sandy limestones (Kamariku Member). In many sections limestones are dolomitized, especially in the lower part (Röa Member). Usually, the top of the Ärina Formation bears clear signs of postsedimentary erosion (palaeokarst, channelling). In South Estonia the Porkuni Stage consists of deeper shelf Kuldiga (argillaceous limestones) and Saldus (oolitic and sandy limestones) formations.

Carbon isotope data

Figure 1 demonstrates a general pattern of carbon isotope excursions in the studied sections. In North Estonia two types of curves occur: (a) Vistla well section and Porkuni quarry show a rather steady rise in $\delta^{13}C$ values from −0.4‰ in the pre-Porkuni rocks until 3.6‰ at Vistla and from 0.2 to 4.1‰ in the stratotype, i.e. the increase is about 4‰. There is only one slight interim set-back in the Vohilaid Member. In the Kamariku Member the curve turns down, the last Ordovician sample shows 1.8‰ $\delta^{13}C$, the first Silurian one 0.6‰. The same pattern is followed at Vodja and Kirikuküla. (b) Two westernmost sections demonstrate reduced curves, The lower rising part of the curve is very similar to the above one, but the upper falling part is missing, evidencing about a gap in the section (e.g. Tamme, a deeper erosional cutting is seen at Kaugatuma).

Two South Estonian sections are two to three times thicker and stratigraphically more complete. The Ruhnu $\delta^{13}C$ curve might be subdivided into three parts: A - a lower rising interval until the first clear peak (6.0‰), B - an extended raised interval with several highs (5.0 to 5.4‰) and lows (3.3 to 3.5‰) and C - upper part of the section with less changing $\delta^{13}C$ values not dropping below the 3‰ level before the Silurian begins.

Discussion

The intervals with increased $\delta^{13}C$ values fall into the limits of the Porkuni Stage. Except the Porkuni and Vistla sections the lowermost beds (Röa and Bernate members, sometimes also higher, Fig.) contain everywhere a good biozonal marker *Spinachitina taugourdeaui* (Eisenack) (Nõlvak and Grahn, 1993). This fossil allows us to conclude that the positive shift of the $\delta^{13}C$ values at the bottom of the Porkuni Stage began in general terms synchronously in all studied sections. In the Ruhnu and Taagepera cores, above the *S. taugourdeaui* Biozone, the highest Ordovician chitinozoan biozone of *Conochitina scabra* occurs (Nõlvak & Grahn, 1993). *C. scabra* is not found in North Estonian sections due to unfavourable conditions for preservation of chitinozoans, but tracing the carbon isotope peak level, we may conclude that the peak falls into the lower part of the zone. Another refinement follows from the correlation of the kerogen $\delta^{13}C$ peak in the top of the *Normalograptus extraordinarius* graptolite Zone of

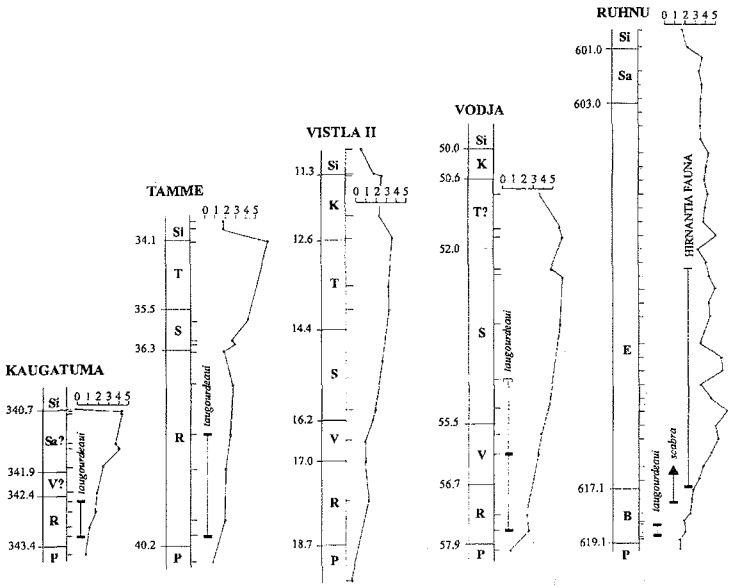

FIG. 1. $\delta^{13}C$ curves and the distribution of zonal chitinozoans. P: Pirgu Stage. Subdivisions of the Porkuni Stage, Ärina Formation with R: Röa, V: Vohilaid, S: Siuge, T: Tõrevere and K: Kamariku members: Kuldiga Formation with B: Bernate and E: Edole members; Sa: Saldus Formation. Si: lowermost Silurian.

the Dob's Linn section, where the area with the rising carbonate $\delta^{13}C$ curve corresponds to the Laframboise Member and the basal Oncolite Platform Beds of Western Anticosti Island (Underwood *et al.*, 1997). The raised area is also at some distance above the *S. taugourdeaui* Biozone. The Dob's Linn section is a highly condensed section (for whole Hirnantian less than 4 m). The Western Anticosti and South Estonian sections are several times thicker and therefore the raised areas of $\delta^{13}C$ are very similar in both regions. Thus, in the same way as done by Underwood *et al.* (1993) we correlate the interval B in the Ruhnu core with the peak level at Dob's Linn. Our conclusion is partly supported by kerogen $\delta^{13}C$ data from boreholes on Hiiumaa Island (Marshall *et al.*, 1997), among them also the Tamme core (K-38) studied by us. Our data confirm coincidence of kerogen and carbonate $\delta^{13}C$ excursions and therefore correlation of the carbon isotope peak in the Porkuni Stage with the mid-Hirnantian peak at Dob's Linn seems well grounded. In South Estonia, below the peak level, typical representatives of the Hirnantian brachiopod-dominated association occur. According to this correlation, the upper Hirnantian part of the carbon isotope curve is represented in the uppermost Kuldiga and Saldus formations. The drop of the curve in the *N. persculptus* Biozone is much less drastic (2–3‰) in Baltic than at Dob's Linn (4–5‰), which may largely be due to differences in the sedimentary environments.

Conclusions

The carbon isotope curve measured in whole-rock samples from the Porkuni Stage of Estonia shows a strong positive excursion in the middle of the Hirnantian and a slow decrease in values until the end of the Ordovician. In general, the Estonian curve is similar to that of Dob's Linn, but much smoother because of differences in sedimentary environments.

This is a contribution to IGCP projects 386 and 410.

References

Marshall, J.D., Brenchley, P.J., Mason, P., Wolff, G.A., Austini, R.A., Hints, L. and Meidla, T. (1997) *Palaeo, Palaeo, Palaeo.*, **132**, 195–210.

Nõlvak, J. and Grahn, Y. (1993) *Rev. Palaeobot. Palynol.*, **79**, 245–69.

Underwood, C.J., Crowley, S.F., Marshall, J.D. and Brenchley, P.J. (1997) *J. Geol. Soc. Lond.*, **154**, 709–18.