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AGE OF ESTONIAN KUKERSITE OIL SHALE – MIDDLE OR LATE ORDOVICIAN?

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Modern principles of stratigraphy and introduction of a new international time scale for the Ordovician Period have changed the view on regional stratigraphy. Seven global stages and three series allow for a more universal application of the Ordovician time scale, but in some cases the newly defined units differ from their former usage. The regional successions can only be dated by comparing them with global type sections, which for the Upper Ordovician is located in Scania, southern Sweden. Using biostratigraphical methods, we provide some new insights into correlation between the international standard and the Uhaku and Kukruse regional stages in Estonia. The Kukruse Stage and the deposits of kukersite oil shale, which have commonly been treated as middle part of Middle Ordovician, must, in fact, be considered as Upper Ordovician.

Introduction

The kukersite oil shale is composed of the stratigraphically widespread mat-forming cyanobacterium *Gloeocapsomorpha prisca* Zalessky. In Estonia, Ordovician kukersite-bearing strata are assigned to the Kunda to Porkuni regional stages. However, commercially important kukersite beds and the Estonia oil shale deposit belong to the Kukruse Regional Stage.

As a stratigraphic unit, the Kukruse Stage was established already in the late 19th Century: "Kuckerssche Schicht" by F. Schmidt [1] and has been widely used and thoroughly studied since then. The boundary between the Uhaku and Kukruse stages has usually been drawn at the base of the lowest commercially important kukersite bed A in NE Estonia (Fig. 1), as proposed by H. Bekker [2].

The Kukruse Stage belongs to the Viru Regional Series, which represents the middle part of the Ordovician succession in the East Baltic area [3]. Traditionally the Viru Series has been considered to be synonymous with

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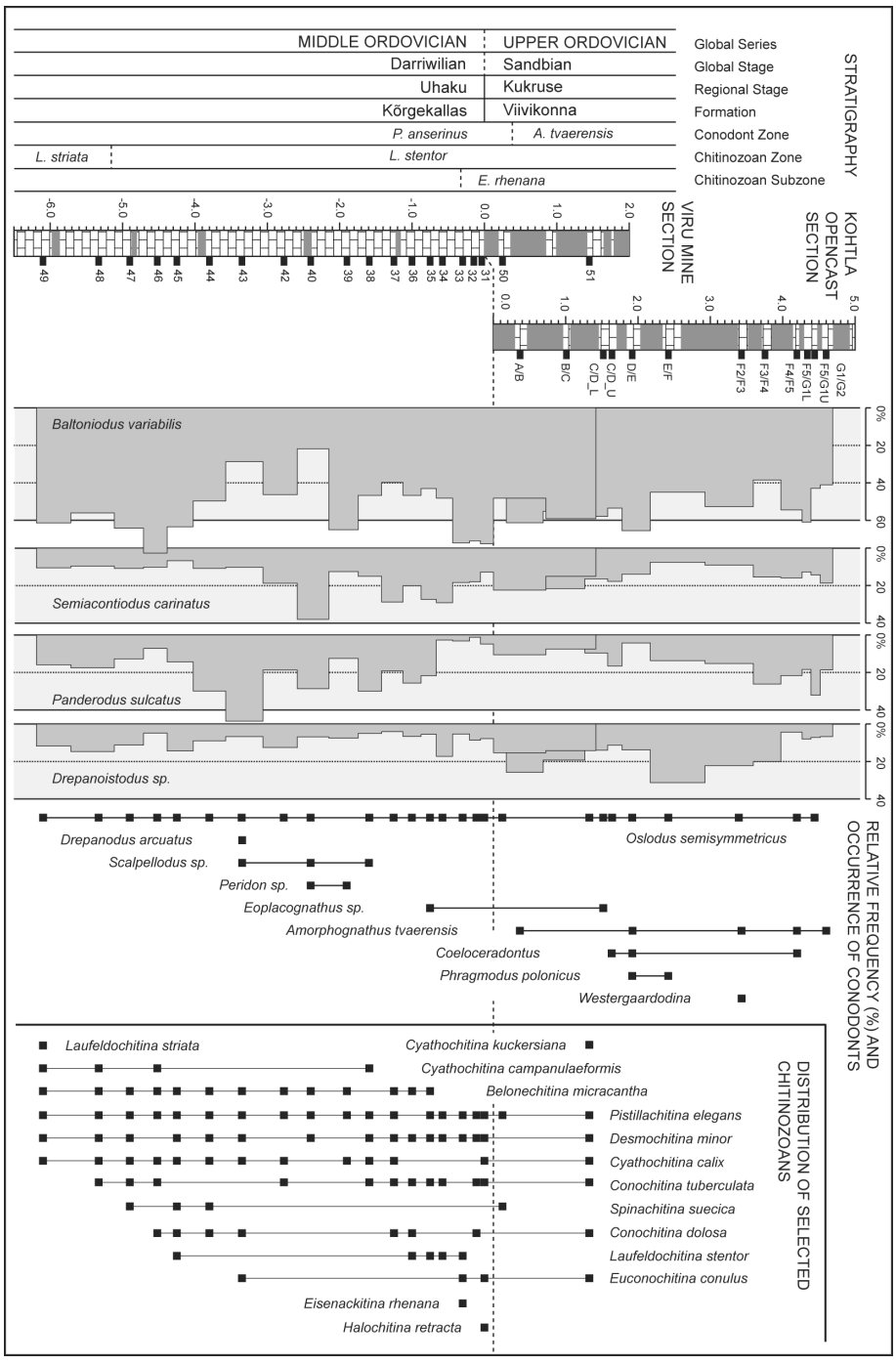

Fig. 1. Distribution of conodonts and selected chitinozoans in the Viru underground mine and Kohtla opencast sections. Grey areas in lithological columns stand for kukersite beds.

Middle Ordovician [e.g. 4] and hence the oil shale deposits have also been viewed as Middle Ordovician [e.g. 5, 6].

The terms Lower, Middle and Upper Ordovician have been used in very different meanings and contexts worldwide, which makes them difficult to follow and compare [see 7, 8]. Since the mid-1990s, however, the International Commission on Stratigraphy and numerous research groups have been building a more universal and globally usable time scale with carefully selected key events and type sections [see reference 9 and references therein]. The new global Ordovician time scale, which has already received wide acceptance, is now composed of seven formally defined stages and three series, the Lower, Middle and Upper Ordovician.

Apparently the content and geologic time span of the newly defined global series diverge from those of the Baltic regional series. Particularly the global volume of the Upper Ordovician has been expanded compared to its former usage in Estonia. In order to avoid ambiguity of basic terminology, which in turn may easily lead to biased conclusions and generalisations, a clear distinction between the regional and global units must be made. In effect, these two separate sets of stratigraphic units should not be combined, but only compared and correlated to each other. It follows that the terms "Lower", "Middle" and "Upper" should not be used in informal context and regionally the Öland, Viru and Harju series cannot be synonymous with the Lower, Middle and Upper Ordovician, respectively.

Consequently, the principal question about the age of Estonian oil shale depends only on the correlation between the Estonian succession and the new international time scale.

Definition of the Upper Ordovician

In modern chronostratigraphy, series are defined by the lowest stage they contain. Each global stage, on the other hand, is formally defined by its lower boundary as specified by its Global Stratotype Section and Point (GSSP).

The Sandbian Stage, which is the lowermost stage of the Upper Ordovician Series, is established by its GSSP in the Fågelsång section in Scania, southern Sweden, where succession of deep shelf black shales supposedly represents a continuous record of geological time across the Middle and Upper Ordovician boundary. The boundary level itself was chosen to coincide with the level of the first appearance of a globally distributed index fossil — the graptolite *Nemagraptus gracilis* Hall [10].

Middle Ordovician–Upper Ordovician boundary in Estonia

Precise time-correlation in the Ordovician can be achieved by biostratigraphical methods, particularly using graptolite, conodont and chitinozoan

distribution (biozones). Although global geochemical markers can also be found in the Upper Ordovician boundary interval [11], their resolution is currently inferior to that of biostratigraphy. Hence fossils have to be used for correlating the Upper Ordovician boundary worldwide. To improve the correlation of the Upper Ordovician boundary in Estonia, new sections in the Kohtla opencast and Viru underground oil shale mines in northeastern Estonia have been recently studied for microfossils (Fig. 1) and some other collections were re-examined. The results are briefly discussed below.

In Estonia, the Kukruse Regional Stage has been considered roughly coeval with the *Nemagraptus gracilis* Biozone [12]. This would mean that the oil shale deposit belongs entirely to the Upper Ordovician. In details the problem is more complicated, since graptolites, including *N. gracilis* are very rare in shallow shelf carbonate successions like that of Estonia. Recent taxonomical studies have shown that the first reliable finds of *N. gracilis* in Estonia come from the middle part of the Kukruse Stage [13]. In the outcrop area, attempts to find *N. gracilis* have been unsuccessful, possibly due to a stratigraphic hiatus in the upper part of the Kukruse Stage in northern Estonia [14, 15]. On the other hand, studies from the global stratotype show that in the lower part of its range, below the "Fågelsång Phosphorite", finds of *N. gracilis* are very rare [10]. Thus it is also possible that the early specimens of this graptolite species were not distributed into carbonate facies, or they have hitherto remained undiscovered there due to low frequency.

However, based solely on actual finds *N. gracilis*, the Estonia oil shale deposit (kukersite beds A–F_1) falls in the topmost part of the Middle Ordovician, whereas the stratigraphically younger Tapa occurrence (bed III) and the overlying beds [6, 14] belong to the Upper Ordovician (see Fig. 2).

Conodont studies from the Fågelsång stratotype [10] show that the boundary between the *Pygodus anserinus* and *Amorphognathus tvaerensis* biozones lies well above the appearance level of *N. gracilis*, that is, above the global Upper Ordovician boundary. New finds of conodonts in northern Estonia (Kohtla opencast, Fig. 1) indicate that the *A. tvaerensis* Biozone starts very close to the base of the Kukruse Stage (bed A) [16]. Accordingly, the *P. anserinus–A. tvaerensis* biozone boundary lies in the upper part of the Uhaku Stage and thus the Upper Ordovician boundary could be drawn within the upper part of the Uhaku Stage [16], which in turn would mean that the Estonia oil shale deposit and Tapa oil shale occurrence are Upper Ordovician. However, based on conodont data from two boreholes, the biozone boundary could be traced within the lower part of the Kukruse Stage [17, 18].

Chitinozoans, particularly the *Eisenackitina rhenana* Sub-biozone, have proved very useful for correlation of the base of the Kukruse Stage in southern and western Estonia, where kukersite-rich beds are missing or cannot be confidently identified. New finds of *E. rhenana* very close to the base of kukersite bed A in the Viru mine section (Fig. 1) further emphasize the utility of this species. In the Fågelsång stratotype section, *E. rhenana*

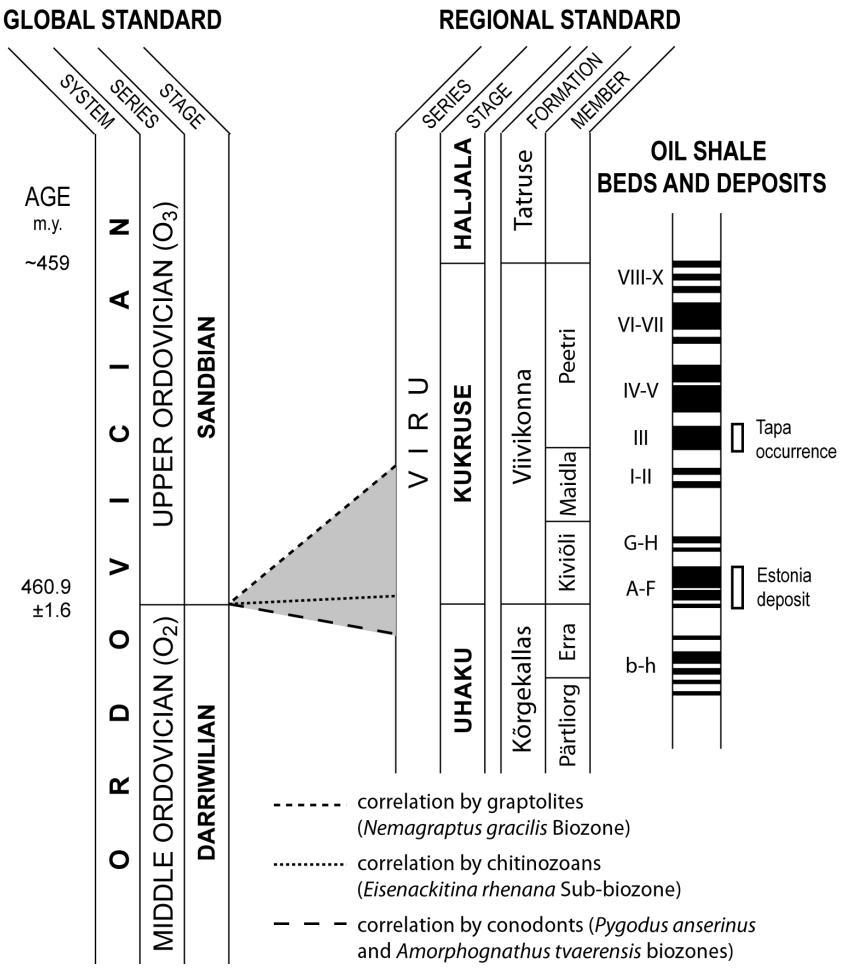

Fig. 2. Stratigraphic chart of the Kukruse Stage, showing correlation between global and regional time scales. Main kukersite oil shale beds given after Bauert and Kattai [5]. Absolute ages after Cooper and Sadler [11].

appears slightly below *N. gracilis* and has been proposed as a good approximation of the lower boundary of Upper Ordovician [19]. Thus, according to chitinozoans, the global Middle–Upper Ordovician boundary lies probably within the Kukruse Stage, very close to its lower boundary.

Age of the oil shale

It is not uncommon that different fossil groups may lead to slightly different stratigraphic conclusions, especially if studied at fine temporal scale as in the present case (Fig. 2).

There is a potential to solve this biostratigraphical ambiguity by obtaining more fossil material from the stratotype section in Sweden. In this respect, two successive chitinozoans are especially promising. *Conochitina* "*savalaensis*" and *C.* "*viruana*" [20] (corresponding to *Conochitina* sp. 1 and *C.* sp. 2 of Nõlvak [21]) occur in many East Baltic successions (including Sirgala opencast mine and Savala drill core, northwestern Estonia), but have hitherto not been recovered in the Fågelsång stratotype section. Moreover, further taxonomical work on conodonts and chitinozoans, both in Estonia and Sweden, might help to resolve different opinions.

Based on currently available biostratigraphical data, however, the global Upper Ordovician boundary in Estonia could be drawn at the lower boundary of the Kukruse Stage. The kukersite oil shale deposits of Estonia are therefore of Late Ordovician rather than Middle Ordovician age. In regional stratigraphy, however, main kukersite oil shale belongs to the Viru Regional Series and can be classified as of Viruan age.

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REFERENCES

1. *Schmidt, F. B.* View to our newest knowledge about Silurian system in St. Petersburgian and Estonian areas and Ösel Island) // Tr. S.-Peterb. Obshch. Estestv. 1879. Vol. 10. P. 42–48 [in Russian].
2. *Bekker, H.* Some new data on the stratigraphy and fauna of the Kukruse Stage // Acta et comm. Univ. Tartuensis, A. 1924. Vol. 4. P. 1–20 [in Estonian].
3. *Nõlvak, J., Hints, O., Männik, P.* Ordovician timescale in Estonia: recent developments // Proc. Estonian Acad. Sci. Geol. 2006. Vol. 55, No. 2. P. 95–108.
4. *Männil, R.* The Ordovician of Estonia // Field Meeting Estonia. An Excursion Guidebook / D. Kaljo, H. Nestor (eds.). – Tallinn: Estonian Academy of Sciences, 1990. P. 11–20.
5. *Bauert, H., Kattai, V.* Kukersite oil shale // Geology and Mineral Resources of Estonia / A. Raukas, A. Teedumäe (eds.). – Tallinn: Estonian Academy Publishers, 1997. P. 313–327.
6. *Kattai, V., Saadre, T., Savitski, L.* Estonian Oil Shale. – Tallinn: Geological Survey of Estonia, 2000 [in Estonian with English and Russian summaries].
7. *Jaanusson, V.* On the Series of the Ordovician System // Publ. Paleontol. Inst. Univ. Uppsala. 1960. Vol. 32. P. 70–81.

8. *Webby, B. D.* Steps toward a global standard for Ordovician stratigraphy // Newsl. Stratigraphy. 1998. Vol. 36, No. 1. P. 1–33.
9. *Finney, S.* Global Series and Stages for the Ordovician System: A Progress Report // Geol. Acta. 2005. Vol. 3, No. 4. P. 309–316.
10. *Bergström, S. M., Finney, S. C., Xu, C., Pålsson, C., Zhi-hao, W., Grahn, Y.* A proposed global boundary stratotype for the base of the Upper Series of Ordovician System: The Fågelsång section, Scania, southern Sweden // Episodes. 2000. Vol. 23, No. 2. P. 102–109.
11. *Cooper, R. A., Sadler, P. M.* The Ordovician Period // A Geologic Time Scale 2004 / F. M. Gradstein, J. G. Ogg, A. G. Smith, F. P. Agterberg, W. Bleeker et al. (eds.). Cambridge University Press, 2004. P. 165-187.
12. *Männil, R.* Distribution of graptoloids in the Ordovician carbonate rocks of the East Baltic area // Graptolites and Stratigraphy / D. Kaljo, T. Koren (eds.). Tallinn: Academy of Sciences of Estonian SSR, Institute of Geology, 1976. P. 105–118 [in Russian with English summary].
13. *Nõlvak, J., Goldman, D.* Biostratigraphy and taxonomy of three-dimentionally preserved Nemagraptids from the Middle and Upper Ordovician of Balto-scandia // J. Paleont. 2007. Vol. 81, No. 2. P. 254–260.
14. *Männil, R.* On the stratigraphic subdivision of the Kukruse Stage in the stratotype area // Proc. Acad. Sci. Est. SSR. Geol. 1984. Vol. 33. P. 46–54 [in Russian with English summary].
15. *Nõlvak, J.* A characterization of the boundary beds of the Kukruse and Idavere stages in the Lipu boring. – Tallinn: Valgus Publishers, 1972. P. 39–59 [in Estonian with English summary].
16. *Viira, V., Aldridge, R. J., Curtis, S.* Conodonts of the Kiviõli Member, Viivikonna Formation (Upper Ordovician) in the Kohtla section, Estonia // Proc. Estonian Acad. Sci. Geol. 2006. Vol. 55, No. 3. P. 213–240.
17. *Männik, P.* Distribution of conodonts // Estonian Geological Sections. Bulletin 5. Ruhnu (500) drill core / A. Põldvere (ed.). – Tallinn: Geological Survey of Estonia, 2003. P. 17–23.
18. *Männik, P., Viira, V.* Distribution of conodonts // Estonian Geological Sections. Bulletin 6. Mehikoorma (421) drill core / A. Põldvere (ed.). – Tallinn: Geological Survey of Estonia, 2005. P. 16–20.
19. *Vandenbroucke, T.* Chitinozoan biostratigraphy of the Upper Ordovician Fågelsång GSSP, Scania, southern Sweden // Rev. Palaeobot. Palynol. 2004. Vol. 130. P. 217–239.
20. *Männil, R.* Stratigraphy of kukersite-bearing deposits (C_Ib-C_{III}) // Geology of the kukersite-bearing beds of the Baltic oil shale basin / V. Puura (ed.). – Tallinn: Valgus Publishers, 1986. P. 12–24 [in Russian with English summary].
21. *Nõlvak, J., Bauert, G.* Distribution of Ordovician chitinozoans // Estonian Geological Sections. Bulletin 7. Kerguta (565) drill core / A. Põldvere (ed.). – Tallinn: Geological Survey of Estonia, 2006. P. 9–11.

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