Upper Wenlock to Lower Přídoli (Silurian) conodont biostratigraphy of Saaremaa, Estonia, and a correlation with Britain

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ABSTRACT – The closely related conodonts Ozarkodina bohemica, O. snajdri and O. crispa form a clade that provides useful biostratigraphical indices through the upper Silurian. Collections from boreholes and surface outcrops on Saaremaa and from a borehole at Kolka, Latvia, contain new morphotypes of O. bohemica and O. crispa. A new subspecies, O. snajdri parasnajdri, is also distinguished, occurring above O. crispa in the Kuressaare and lowermost Kaugatuma stages. Evidence from conodonts and other fossils, primarily chitinozoans, ostracods and ichthyoliths, can be used to correlate the upper Silurian succession of Saaremaa with those of the Welsh Borderland and Gotland, although some problems remain to be solved. The microfossil distribution suggests that there may be a major break at the base of the Ludlow Bone Bed Member at Ludlow, equivalent to the Kuressaare Formation on Saaremaa. J. Micropalaeontol. 17(1): 33–50, April 1998.

INTRODUCTION

The study of the Silurian rocks of Estonia dates back to the last century, with the establishment of a Lower Palaeozoic stratigraphical scheme by Schmidt (1858). Details were added in the earlier part of this century, and more recently scientific investigations have been considerably advanced by a group of researchers at the Institute of Geology, Estonian Academy of Sciences, working under the leadership of D. Kaljo. Modern research has been greatly facilitated by the availability of numerous boreholes drilled by the Estonian Geological Survey, and a large number of papers and monographs has been published on Lower Palaeozoic palaeontology, stratigraphy and facies distribution. General summaries of the main results of this work may be found in volumes edited by Kaljo (1970, 1977), Kaljo & Klaamann (1982a,b) and Kaljo & H. Nestor (1990).

The current understanding of the Silurian stratigraphy of Estonia has been summarised by H. Nestor (1993) and the Wenlock–Přídoli correlation chart is shown in Fig. 1. The main stratigraphical units are regional chronostratigraphical stages, within which separate local lithostratigraphical units are distinguished in different parts of the Baltic basin (Bassett et al., 1989). The local units reflect facies differences: Central Estonia and most of Saaremaa (Fig. 2) are dominated by shallow-water facies, whereas in South Estonia and on the Sõrve Peninsula of southern Saaremaa deeper water shelf and outer shelf sediments prevail (H. Nestor & Einasto, 1977; Bassett et al., 1989). Gradual shifts of the facies belts occurred during the evolution of the basin.

The present paper deals with the succession representing the late Wenlock to early Přídoli interval, embracing the Rootsiküla, Paadla, Kuressaare and Kaugatuma stages. In the absence of graptolites, the correlation of these stages and their representative formations with other areas is currently only approximate. The Rootsiküla Formation is considered to correspond to the late Wenlock Klinte Secundo Episode of Jeppsson et al. (1995), when very variable shallow-water sediments were deposited with characteristic cyclic alternation of limestones and primary dolomites. The total thickness is 25–32 m, and the sediments display frequent discontinuity surfaces, mud cracks, ripple marks and trace fossils. Abundant stromatolites and oncolites occur, but the fauna is restricted to eurypterids, thelodonts and conodonts. The Paadla Formation is 26–32 m thick and consists of detrital biomorphous and biothermal stromatoporoid-coral limestones, dolomites and marls. A hiatus beneath the base, established from chitinozoan data, has been reported to eliminate almost all local equivalents of the lower Ludlow Gorstian Stage in parts of the region (Nestor, V., 1982, 1990). The Kuressaare Formation comprises a broadly similar range of lithologies to those found in the Paadla, but there is a rich fauna that includes ostracods and thelodonts, both of which have proved useful in local correlations. Published conodont data are currently limited, with more precision required on the ranges of key taxa (Kaljo, 1990). Indirect correlation suggests that the Kuressaare Stage is at the level of the formosus/balticus standard graptolite biozone (Kaljo, 1990).

In this contribution, we present details of the distribution of key conodont species in exposed sections and borehole cores on the island of Saaremaa, Estonia, and in a borehole from Kolka, Latvia (Fig. 2). The evolving species complex comprising taxa referred to Ozarkodina bohemica (Walliser), O. snajdri (Walliser) and O. crispa (Walliser) is of particular importance, and this group is given especial attention. The conodont data are used in conjunction with information from other fossils to assess the correlations between the Estonian succession and those of Britain and other areas.

BACKGROUND TO CONODONTS

The Ozarkodina bohemica lineage

The oldest reported member of this lineage is O. bohemica subsp. nov. of Aldridge (1985, pl. 3.3, figs 13 a, b), from the lowermost Wenlock of Whiffield, Gloucestershire, England. Above this, there is a gap in records until well into the Homarian Stage (upper Wenlock), where O. bohemica bohemica is widely distributed. Ludlow representatives of the same lineage include O. snajdri, which appears in the upper part of the Gorstian Stage, and O. crispa, of latest Ludlow age; these two were...
considered to be important fossils by Walliser (1964) in his conodont biozonation of the Silurian.

Early views of the relationships of these species varied. Walliser (1964) included \textit{O. bohemica} as a subspecies of \textit{O. sagitta} (Walliser) and commented that \textit{O. snajdri} may be a descendant of \textit{O. excavaata} (Branson & Mehl). Pollock & Rexroad (1973) suggested that \textit{O. snajdri} was ancestral to \textit{O. remsfeldensis eosteinhornensis} (Walliser), or that they shared common ancestry, and Mehrtens & Barnett (1976) also considered \textit{O. snajdri} to be the ancestor of \textit{O. eosteinhornensis}. Helfrich (1975) used morphological characteristics of Pa elements and multielement patterns to identify a 'Spathognathodus sagitta bohemicus Lineage' which incorporated taxa that would now be referred to as \textit{O. bohemica bohemica}, \textit{O. bicornuta} (Helfrich), \textit{O. snajdri}, \textit{O. tillmani} (Helfrich), \textit{O. crispa} and, tentatively, his N. gen. et n. sp. (Helfrich, 1975, pl. 16, figs 1–3, 6). The latter has subsequently been described as \textit{Homeognathodus peniculus} (Denkler & Harris, 1988). Helfrich (1975) recorded that all Pa elements of this lineage possess a basal cavity of similar form which closes before the posterior tip of the blade in stratigraphically older forms but extends further posteriorly relative to the posterior blade in successively younger species. A further characteristic of all the Pa elements, except that of \textit{O. bicornuta}, is a tendency towards fusion of denticles above the basal cavity.

Aldridge & Schönlaub (1989) stated that \textit{O. crispa} was a direct descendant of \textit{O. snajdri}, and that the two occurred in stratigraphical succession. Miller (1995) agreed that \textit{O. crispa} originated in \textit{O. snajdri}, but showed that intermediate forms occurred in the Welsh Borderland at stratigraphically higher levels than the first occurrence of \textit{O. crispa}, so the relationship was not one of simple phyletic transition.

The succession of these conodonts on Saaremaa is comparable with that identified by Helfrich (1975). \textit{Ozarkodina bohemica bohemica}, \textit{O. aff. bicornuta}, \textit{O. snajdri} and \textit{O. crispa} are all recognized, and some specimens of \textit{O. crispa} are transitional to \textit{O. tillmani}. The youngest representatives, above the last occurrence of \textit{O. crispa}, are clearly of \textit{snajdri} affinities and are here referred to as \textit{O. snajdri parasnajdri} subsp. nov.

**Previous records of \textit{O. snajdri} and \textit{O. crispa}**

The holotype of \textit{O. snajdri} is from Muslovka Quarry, Bohemia, a few metres below the base of the \textit{ultimus} graptolite biozone, while that of \textit{O. crispa} is from Santa Creu, Spain (Walliser, 1964). In his conodont biozonation, Walliser (1964) included a 'crispus zone' in the uppermost Ludlow, and a 'snajdri-Horizon' within the upper part of the middle/upper Ludlow siluricus zone; \textit{O. crispa} was represented in samples from his reference section at Cellon in the Carnic Alps, whereas \textit{O. snajdri} was not.

Subsequent records produced some uncertainties about the ranges of \textit{O. snajdri}, \textit{O. crispa} and the index taxon of the zone succeeding the 'crispus zone', \textit{O. r. eosteinhornensis}. Fähraeus (1969) reported the Pa element of \textit{O. crispa} on Gotland in strata above \textit{O. r. eosteinhornensis}, leading Walliser (1971) to question...
whether the 'crispus zone' lay within the 'eosteinhornensis zone' or whether the two overlapped. In fact, the specimen illustrated by Fähraeus (1969, pl. 2, figs 13, 14) may belong to O. snajdri, although subsequent work has resulted in records of O. crispa and representatives of the steinhornensis group in association on Gotland (Jeppsson, 1983; Jeppsson et al., 1994) An association of O. snajdri with specimens referred to as primitive O. r. eosteinhornensis was reported by Rexroad & Craig (1971) in the Bainbridge Formation of Lithium, Missouri, and the two taxa were also recorded together in the Kokomo Limestone Member of the Salina Formation in north-central Indiana by Pollock & Rexroad (1973). The specimens illustrated by Pollock & Rexroad (1973, pl. 1, figs 30–34), however, show several characteristics of the Pa element of O. crispa and the specific assignment is equivocal. An overlap of the ranges of O. crispa and specimens referred to O. r. eosteinhornensis in North America was also found by Helfrich (1975) in the Central Appalachians, while Denkler & Harris (1988) reported that the range of O. snajdri in the same region began below that of O. crispa and terminated above it.

In Australia, De Deckker (1976) found some overlap of the ranges of O. snajdri and O. crispa in the Kildrummie Formation of New South Wales, and was the first to suggest that the range of O. snajdri might be longer than previously thought. He also considered a second possibility that the intraspecific variation of Pa elements of O. crispa may include specimens of similar morphology to O. snajdri. However, his specimens are rather atypical, and resemble those described by Link & Druce (1972, pl. 9, figs 22–28) from the Yass Basin, New South Wales as Spathognathodus cf. S. ranuliformis Walliser, a species that is now assigned to the genus Kockelella.

In Europe, there are records of overlap between O. snajdri and O. r. eosteinhornensis s. l. in sections near Graz, Austria (Ebner, 1976) and in the uppermost Kopianina Formation of Pozarech Quarry, Bohemia (Mehrtens & Barnett, 1976). Feist & Schönlau (1974) found O. crispa, O. r. eosteinhornensis s. l. and Pedavis latilatus (Walliser) together in the Montagne Noire, southern France, and Chlupac et al. (1980) demonstrated the overlap of O. crispa and O. r. eosteinhornensis s. l. in the Muslovka Quarry, Bohemia, leading to a proposal to incorporate a crispa subzone within the lower part of an extended eosteinhornensis zone. Chlupac et al. (1980) also showed an overlap in the ranges of O. snajdri and O. crispa in Kolednik Quarry, Bohemia. In Britain, uppermost Ludlow conodont faunas include O. snajdri, O. r. eosteinhornensis s. l. and O. eosteinhornensis s. l. and O. remshiedensis baccata Miller & Aldridge (Miller, 1995; Miller & Aldridge, 1997). In two sections, at Woolhope and at Tite's Point, Miller (1995) found O. snajdri above O. crispa.

In summary, all possibilities of co-occurrence of O. snajdri, O. crispa and specimens referred to O. r. eosteinhornensis are known; all three may occur together or any pairing. Only in
Bohemia are they represented in clearly succeeding order, in the Muslovka and Kolednik quarries, and even here there is some overlap of the ranges.

**SYSTEMATIC DESCRIPTIONS**

Systematics are given here for members of the *O. bohemica* lineage, based on material from Saaremaa. As noted by Miller & Aldridge (1997), there is some inconsistency regarding the usage of subspecies and morphotype designations in conodont taxonomy. We have followed the principle of retaining subspecies designations for populations that are separated in space and/or time; for morphological variants that occur together in some samples we have used morphotypes. The exceptions are where we subdivide subspecies or existing morphotypes: even if different forms seem to be chronologically exceptions are where we subdivide subspecies or exisisting subspecies designations for populations that are separated in subspecies and morphotype designations in conodont or geographically separated, we have designated them as or morphotype designations for populations that are separated in

**Order Ozarkodinida** Dzik, 1976  
**Family Spathognathodontidae** Hass, 1959  
**Genus Ozarkodina** Branson & Mehl, 1933  
**Ozarkodina bohemica bohemica** (Walliser, 1964)

1964 *Spathognathodus sagitta bohemicus* Walliser: 83, pl. 7, fig. 4, pl. 18, figs 23, 24.  
1964 *Ozarkodina editiae* Walliser: 55, pl. 26, figs 12–18.  
1967 *Spathognathodus sagitta bohemicus* Walliser; Austin & Bassett: 278, pl. 14, fig. 19.  
1967 *Spathognathodus cf. sagitta bohemicus* Walliser; Austin & Bassett: 279, pl. 14, fig. 20.  
1967 *Spathognathodus sagitta bohemicus* Walliser; Flajs: pl. 4, fig. 7.  
1969 *Spathognathodus sagitta bohemicus* Walliser; Fähræus: pl. 2, figs 15, 16.  
1975 *Spathognathodus sagitta bohemicus* Walliser; Helfrich: pl. 1, figs 2–4, 8, 12, 17, 20.  
1975a *Ozarkodina sagitta bohemica* (Walliser); Aldridge: 327, pl. 47, fig. 21.  
1975b *Ozarkodina sagitta bohemica* (Walliser); Aldridge: pl. 2, figs 18, 19.  
1976 *Ozarkodina sagitta bohemicus* (Walliser); Barrick & Klapper: 81, pl. 4, figs 1–7, 10, 12.  
1981 *Ozarkodina sagitta bohemicus* (Walliser); Aldridge, Dorning & Siveter: pl. 2.3, figs 1, 3.  
1982a *Spathognathodus sagitta bohemicus* Walliser; Viira: text-fig. 5.4, figs 31, 34.  
1984 *Ozarkodina sagitta bohemicus* (Walliser); Kozur: pl. 2, figs 4, 5.  
1985 *Ozarkodina sagitta bohemicus* (Walliser); Balogh & Kozur: pl. 2, fig. 5.  
1985 *Spathognathodus bohemicus* (Walliser); Aldridge: pl. 3.4, fig. 3.  
1985 *Spathognathodus sagitta bohemicus* Walliser; Yu: 26, pl. 2, figs 1–2, pl. 3, figs 1–3, 6, 11.  
1987 *Ozarkodina sagitta bohemica* (Walliser); An: 200, pl. 32, figs 21, 22.  
1990 *Ozarkodina bohemica* (Walliser); Kleffner: fig. 3, no. 20.  
1990 *Ozarkodina tillmani* (Helfrich); Kleffner: fig. 3, nos 21, 22.  
1993 *Ozarkodina bohemica* (Walliser), Morphotype 1; Schönlaub (*In Kriz et al.*): 829, pl. 1, figs 1, 3, 4.  
1993 *Ozarkodina bohemica* (Walliser), Morphotype 2; Schönlaub (*In Kriz et al.*): 829, pl. 1, fig. 9.  
1993 *Ozarkodina bohemica* (Walliser), Morphotype 3; Schönlaub (*In Kriz et al.*): 829, pl. 1, figs 10–14.  

**Diagnosis.** See Aldridge (1985, p. 88).

**Remarks.** Three morphotypes of *O. b. bohemica* were distinguished by Schönlaub (*In Kriz et al.*, 1993) and numbered 1–3; morphotype 1 has low posterior denticles, similar to *O. sagitta*, whereas morphotype 3 has an abrupt posterior termination and a widely flaring basal cavity. Morphotype 2 is very distinct, with an ornament of ridges of fused denticles on the basal cup. Schönlaub did not mention the specimens originally described by Walliser (1964), with a widely flaring basal cavity extending to the posterior tip, but they appear to be closest to morphotype 3. Because we cannot relate Walliser’s specimens or ours to the Bohemian morphotypes we apply a different notation here. The type specimen and associates represent the α morph. Those from Saaremaa have a less flared cavity which does not extend right to the posterior tip and belong to the β morph.

**Ozarkodina bohemica bohemica β morph**  
(Pl. 1, figs 1–15)

**Description.** Pa element: blade long, with 14–20 denticles that are largest posteriorly. Anterior edge gently convex, posterior edge upright. Basal cavity situated beneath posterior part of blade, terminating short of posterior tip. Small specimens shorter and relatively higher than large specimens. Large specimens usually with fused denticles above basal cavity and a longitudinal ledge in the lower third of the blade. All specimens with white matter, deep above basal cavity and narrowing anteriorly and posteriorly so that extreme denticles may be hyaline.

**Occurrence on Saaremaa.** Rootsiküla Stage: Vesiku borehole

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**Explanation of Plate 1**

Figured specimens on all plates are Pa elements; they are deposited in the Institute of Geology, Estonian Academy of Sciences, Tallinn. figs 1–15.  
**Ozarkodina bohemicus** (Walliser 1964) β morph, Rootsiküla Formation. figs 1, 9, 11, 15; lateral views, Cn 1454–Cn 1457, ×120, ×50, ×80, ×65, Viita Beds, Ohesaare borehole, 145.55 m. figs 2, 3; lateral and aboral views, Cn 1458, ×50, Viita Beds, Ohesaare borehole, 142.25 m. figs 4–6, 10; lateral, lower lateral, aboral and oral views, Cn 1459, ×50, ×135, Cn 1460, ×50, Viita Beds, Kaugatuma borehole, 100.25 m. figs 7, 8; lateral and aboral views, Cn 1461, ×50, ×85, Viita Beds, Ohesaare borehole, 144.05 m. fig. 12, lateral view, Cn 1462, ×55, Viita Beds, Vesiku borehole, 4.95 m. fig. 13; lateral view, Cn 1463, ×55, Viita Beds, Viita outcrop. fig. 14; lateral view, Cn 1464, ×70, Vesiku Beds, Kaugatuma borehole, 81.4 m. figs 16–19.  
**Ozarkodina aff. bicornuta** (Helfrich 1975). figs 16, 17; lateral views, Cn 1465, Cn 1466, ×65, ×75, Soeginnina Beds, Soeginnina cliff, sample 3–87. fig. 18; lateral view, Cn 1467, ×85, lowermost Paadla Formation, Anikaispe outcrop, sample 4–76. fig. 19; lateral view, Cn 1468, ×80, Soeginnina Beds, Soeginnina cliff, sample 2–87. figs 20, 21.  
**Ozarkodina sagitta cf. sagitta** (Walliser 1964). fig. 20; lateral view, Cn 1469, ×80, Torgu Formation, Ohesaare borehole, 113.55 m. fig. 21, lateral view, Cn 1470, ×75, Kuressaare Formation, Kolka borehole, 284.2 m.
Plate 1
Explanation of Plate 2
Figs 1–16, 19, 20. Ozarkodina crispa (Walliser 1964) α3 morph. Figs 1, 2: lateral and oral views, Cn 1471, x70, Sauvere Beds, Kaugatuma borehole, 61.6 m. Figs 3, 7, 8: lateral and aboral views, Cn 1472, Cn 1473, x70, x85, Kudjape Beds, Kolka borehole, 270.8 m. Figs 4, 5: lateral and aboral views, Cn 1474, x85, Sauvere Beds, Riksu borehole, 33.5 m. Fig. 6: lower lateral view, Cn 1475, x75, Himmiste Beds, Kaugatuma borehole, 58.5 m. Figs 9, 10: lateral and aboral views, Cn 1476, x70, x85, Sauvere Beds, Riksu borehole, 35.0 m. Figs 11–16, 19, 20: lateral and aboral views, Cn 1477 – Cn 1480, x65, x85, x70, x90, Himmiste Beds, Karala outcrop. Figs 17, 18, 21, 22. Ozarkodina crispa (Walliser 1964) α3 morph; lateral and aboral views, Cn 1481 – Cn 1483, x85, x70, x85, Himmiste Beds, Karala outcrop.
4.95 m, Sakla borehole 51.86–54.45 m, Kaugatuma borehole 81.4–100.25 m, Ohesaare borehole 142.25–157.2 m, Kolka borehole 362.3 m, Viita outcrop.

**Material.** Pa element: 44 specimens.

**Ozarkodina aff. bicornuta** (Helfrich, 1975)

(Pl. 1, figs 16–19)

aff. 1975 Spathognathodus bicornutus Helfrich: pl. 1, figs 5–7, 11, 13–16, 18, pl. 2, figs 1, 4, 6, 16.

**Description.** Pa element: specimens small; blade rather high, denticles wide, usually 10–11 when not fused. Basal cavity beneath posterior part of blade, circular, not extending to posterior tip. Morphologically close to the smallest specimen illustrated by Helfrich (1975, pl. 1, fig. 5).

**Remarks.** The specimens illustrated by Helfrich (1975) are very variable, but most have a single high denticle at both ends of the blade; between these are 5–10 denticles which show no fusion on any of the figured specimens. The Estonian specimens have an enlarged posteriormost denticle, but the anterior denticle is not markedly different in size from its neighbours; the denticles above the cavity may be fused.

**Occurrence.** Uppermost Rootsiküla Stage: Soeginina samples 1–3, Anikaitse samples 4, 8.

**Material.** Pa element: 9 specimens.

**Ozarkodina crispa** (Walliser, 1964)

1964 Spathognathodus crispus Walliser: 74, pl. 9, fig. 3, pl. 21, figs 7–13.

?1969 Spathognathodus crispus Walliser; Fähraeus: pl. 2, figs 13, 14.

1971 Spathognathodus crispus Walliser; Bultynck & Pelhat: pl. 1, figs 19, 20.

1971 Spathognathodus crispus Walliser; Drygant: 782, figs 1–3.

1974 Spathognathodus crispus Walliser; Feist & Schönlaub: pl. 7, figs 8, 9, 11, 12, 14, 15.

1974 Ozarkodina crispa (Walliser); Klapper & Murphy: 33, pl. 8, fig. 10.

1975 Spathognathodus crispus Walliser; Helfrich: pl. 14, figs 1–4, 9, 14, 19, 21, 24, 27.

1977 Ozarkodina crispa (Walliser); Cooper: 188, pl. 16, figs 16, 17.

1980 Ozarkodina crispa (Walliser); Chlupác et al.: pl. 25, figs 12–15.

1980 Spathognathodus crispus Walliser; Wang: 374, pl. 1, figs 1–3, 14–16, 19–21, 24, 25, text-fig. 4.

1984 Ozarkodina crispa (Walliser); Kozur: pl. 4, fig. 4.

1984 Spathognathodus crispus Walliser; Drygant: 126, pl. 10, figs 12, 13.

1985 Ozarkodina crispa (Walliser); Balogh & Kozur: pl. 3, fig. 3.

1986 Spathognathodus crispus Walliser; Jiang et al.: pl. 4–4, fig. 9.

1987 Spathognathodus crispus Walliser; An: 202, pl. 34, figs 20, 21.

1988 Ozarkodina snajdri crispus (Walliser); Denkler & Harris: pl. 1, figs J, K.

1989 Ozarkodina crispa (Walliser); Walliser & Wang: 114, text-fig. 1, pl. 1, figs 1–16.

1990 Ozarkodina aff. snajdri (Walliser); Männik & Viira: pl. 18, fig. 10.

1990 Ozarkodina crispa (Walliser) \( \beta \) morphtype; van den Boogaard: 11, pl. 6, figs 2–7.

1994 Ozarkodina aff. snajdri crispus (Walliser; Viira: pl. 1, fig. 8.

1994 Ozarkodina snajdri (Walliser; Jeppsson et al.: fig. 4d.

1995 Ozarkodina crispa (Walliser); Miller: pl. 3, figs 1–2, 4–5.

1995 Ozarkodina cf. crispus (Walliser); Miller: pl. 3, figs 3, 6–12

**Remarks.** Pa elements that have been assigned to \( O. crispa \) show considerable variation, and four morphotypes, designated \( \alpha, \beta, \chi, \delta \), were differentiated by Walliser & Wang (1989). The \( \beta, \chi \) and \( \delta \) morphs are all characterized by a furrow on the oral margin of the blade; the \( \alpha \) morph lacks the furrow. The holotype selected by Walliser (1964, pl. 21, fig. 12) lacks a furrow and thus belongs to the \( \alpha \) morph, as do all the specimens from the northern East Baltic. However, there is major variation within this group, and we distinguish \( \alpha_1, \alpha_2 \) and \( \alpha_3 \) morphs, with the holotype belonging to \( \alpha_1 \).

**Ozarkodina crispa \( \alpha_3 \) morph**

(Pl. 2, figs 1–16, 19, 20, Pl. 3, figs 5, 6, 9–11)

**Description.** Pa element: specimens small; blade high, short with fused denticles towards posterior end. Dentine height decreases posteriorly from anterior end to fused portion. Posterior termination of blade concave to vertical. Basal cavity with wide subcircular lips, underlying posterior half of blade and extending to posterior tip. White matter fills denticles, extending down to tip of cavity beneath fused portion of blade.

**Remarks.** These specimens differ from the \( \alpha_1 \) morph in the subcircular, rather than asymmetrical, shape of the basal cavity.

**Occurrence on Saaremaa.** Paadla Stage and lowermost Kuresaaare Stage: Sakla borehole 18.0–33.13 m, Riks boorehole 35.0 m, Kaugatuma borehole 49.7–69.3 m, Ohesaare borehole 99.75–100.8 m, Kolka borehole 270.8–284.2 m; Kärla, Roopa, Paadla and Karala outcrops.

**Material.** Pa element: more than 100 specimens.

**Ozarkodina crispa \( \alpha_3 \) morph**

(Pl. 2, figs 17, 18, 21, 22, Pl. 3, figs 1–4, 7, 8)

**Description.** Pa element: similar to \( \alpha_2 \) morph but with posterior denticles unfused or only partly fused. Basal cavity variable in position, normally extending to posterior tip. White matter occupies one-third to one-half of blade.

**Remarks.** Specimens in which the basal cavity does not extend beyond the posterior end of the blade are similar to \( O. s. \) snajdri, but differ in the smaller size of the cavity and the shorter blade. The specimens illustrated by Helfrich (1975) encompass the range of variation shown by \( \alpha_2 \) and \( \alpha_3 \) morphs.

**Occurrence on Saaremaa.** Paadla Stage and lowermost Kuresaaare Stage: Sakla borehole 30.15 m, Riks boorehole 33.5–35.0 m, Kuresaaare (Kingisepa) borehole 39.14 m, Ohesaare borehole 100.8 m, Kolka borehole 276.15–284.2 m; Roopa and Karala outcrops.

**Material.** Pa element: 31 specimens.

**Ozarkodina snajdri** (Walliser 1964)

1964 Spathognathodus snajdri Walliser: 84, pl. 9, fig. 2, pl. 21, figs 14–15, pl. 22, figs 1–4.

?1969 Spathognathodus crispus Walliser; Fähraeus: pl. 2, figs 13, 14.

?1969 Spathognathodus cf. snajdri Walliser; Schönlaub: pl. 1, fig. 29.
Explanation of Plate 3

Figs 1–4, 7, 8. *Ozarkodina crispa* (Walliser 1964) α1 morph. figs 1–4; lateral and aboral views, Cn 1484, Cn 1485, ×70, ×85, ×150, Sauvere Beds, Sakla borehole, 30.15 m. fig. 7; lateral view, Cn 1486, ×80, Sauvere Beds, Kērla outcrop. fig. 8; lateral view, Cn 1487, ×85, Himmiste Beds, Roopa cliff.

Figs 5, 6, 9–11. *Ozarkodina crispa* (Walliser 1964) α2 morph. fig. 5; lateral view, Cn 1488, ×85, Sauvere Beds, Sakla borehole, 30.15 m. fig. 6; lateral view, Cn 1489, ×85, Uduvere Beds, Sakla borehole, 18.0 m. figs 9–11; lateral and aboral views, Cn 1490, Cn 1491, ×70, ×150, ×95, Himmiste Beds, Paadla outcrop, sample 3-73.

Figs 12–21. *Ozarkodina snajdri parasnajdri* subsp. nov. figs 12, 13; lateral and aboral views, Cn 1492, ×50, Āigu Beds, Ohesaare borehole, 67.4 m. Figs 14, 16; aboral and lateral views, Cn 1493, Cn 1494, ×120, ×50, Āigu Beds, Ohesaare borehole, 64.65 m. figs 15, 17; lower lateral and oral views, Cn 1495, Cn 1496, ×120, ×45, Āigu Beds, Ohesaare borehole, 61.2 m. figs 18–21, lateral and oral views, oral views of fused denticles and a discrete denticle, Cn 1497, ×50, ×850, Āigu Beds, Ohesaare borehole, 67.4 m.
Conodont biostratigraphy

Explanation of Plate 4

Figs 1–9. *Ozarkodina snajdri parasnajdri* subsp. nov. figs 1, 2; lateral view, Cn 1498, ×50, detail ×2600, Āigu Beds, Kolka borehole, 263.4 m. figs 3, 4; lateral and aboral views, Cn 1499. Āigu Beds, Kolka borehole, 263.4 m. Figs 5, 6, 8; lateral and aboral views, Cn 1500, Cn 1501, ×85, ×95, ×50, Kuressaare Formation, Ilpla outcrop. fig 7; lateral view, Cn 1502, ×50, Āigu Beds, Kolka borehole, 264.4 m. fig. 9; lower lateral view, Cn 1503, ×45, Tahula Beds, Kaugatuma borehole, 45.5 m. Figs 10, 13–17. *Ozarkodina remscheidensis eosteinhornensis* (Walliser 1964) *sensu lato*. fig. 10; lateral view, Cn 1505, ×40, Kaugatuma Formation, Ohesaare borehole, 58.7 m. fig. 13; lateral view, Cn 1506, ×40, Kuressaare Formation, Vaivere outcrop. fig. 14; lateral view, ×50, Kaugatuma Formation, Ohesaare borehole, 64.65 m. figs 15–17, lateral view, Cn 1508, ×40, details of lateral surfaces of denticles ×600, Kaugatuma Formation, Ohesaare borehole, 67.4 m. Figs 11, 12. *Ozarkodina confluens densidentata* (Viira 1983). Lateral view, Cn 1504, ×50, lateral surfaces of two anterior denticles ×650, Viita Beds, Ohesaare borehole, 144.05 m.
1971 *Spathognathodus snajdri* Walliser; Rixroad & Nicoll: pl. 2, figs 4, 5.
1971 *Spathognathodus snajdri* Walliser; Rixroad & Craig: 700, pl. 82, figs 16, 17.
1973 *Spathognathodus snajdri* Walliser; Pollock & Rixroad: 83, pl. 1, figs 30–34.
1975 *Spathognathodus snajdri* Walliser; Helfrich: pl. 2, figs 3,7, 10–15, 17.
1976 *Spathognathodus snajdri* Walliser; Ebner: 20 (292), pl. 4, figs 1, 2.
1976 *Ozarkodina remscheidensis snajdri* Mehrtens & Barnett (sic); Mehrtens & Barnett: 497; pl. 1, figs 19, 22.
1980 *Ozarkodina snajdri* (Walliser); Chlupac et al.: pl. 25, figs 1, 4–11.
1985 *Ozarkodina snajdri* (Walliser); Aldridge: pl. 3.4, fig. 18.
1994 *Ozarkodina snajdri* (Walliser); Jeppsson et al.: fig. 4c.
1995 *Ozarkodina snajdri* Walliser; Miller: pl. 3, figs 14–15, 17–18.
1995 *Ozarkodina cf. snajdri* Walliser; Miller: pl. 3, figs 13, 16.

**Remarks.** A new subspecies, *O. s. parasnajdri*, is described here. The holotype and all previously described material belong to the nominate subspecies *O. s. snajdri* (Walliser).

*Ozarkodina snajdri parasnajdri* subsp. nov.

(Pl. 3, figs 12–21, Pl. 4, figs 1–9)

**Holotype.** Specimen Cn 1498, Kolka Borehole 263.4 m; pl. 4, fig. 1, 2.

**Type stratum.** Kaugatuma Formation, Āigū Beds.

**Diagnosis.** Pa element with large subquadrangular basal cavity extending to posterior end of blade; denticles above cavity fused. Other elements unknown.

**Description.** Blade commonly long and low, with small denticles, fused above cavity; anterior end higher, posterior portion arched. Posterior termination of blade vertical or oblique concave. Basal cavity with tip a little posterior of centre of blade; lips commonly quadrangular and extending to posterior tip of blade; cavity extends as a narrow groove to anterior tip. White matter deepest above cavity, rising anteriorly and posteriorly; anterior denticles may lack white matter.

**Remarks.** There is variation in the length of the fused part of the blade and in the position of the basal cavity tip. However, this subspecies differs from *O. s. snajdri* in always possessing fused denticles and in the more central position of the cavity tip. The cavity lips always extend to the posterior tip of the blade.

**Occurrence.** Kuressaare Stage and lowermost Kaugatuma Stage: Kaugatuma borehole 28.9–45.4 m, Ohesaare borehole 61.2–93.4 m, Kolka borehole 253.6–263.4 m; Ilpla and Loode Tammik outcrops.

**Material.** Pa element: 84 specimens.

*Ozarkodina snajdri* cf. *snajdri* (Walliser 1964)

(Pl. 1, figs 20, 21)

**Remarks.** Seven specimens in the Ohesaare and Kolka boreholes are close to *O. s. snajdri*. All have fused denticles above the basal cavity, but on unbroken specimens the cavity can be seen to terminate just short of the posterior end of the blade.

**CONODONT BIOSTRATIGRAPHY OF SAAREMAA**

Samples have been processed for conodont recovery from seven boreholes and nine outcrops (Fig. 2). Spacing of samples in the boreholes was 1–3 m (Fig. 3), with a standard sample weight of 1–1.5 kg, except in the Kuressaare (Kingissepa) borehole where weights were c. 0.5 kg. All samples yielded conodont elements.

The distribution of members of the *O. b. bohemica* lineage is shown in Fig. 4. In addition, samples from the Rootsiküla Stage contain *O. confluent densidentata* (Viira) and *Ctenognathodus murchisoni* (Pander), generally in small numbers. Samples from the Paada Stage contain *O. confluent cornidentata* (Viira), *O. excavata* (Branson and Mehl), *O. roopaensis Viira*, *Oulodus siluricus* (Branson and Mehl), *Panderodus* spp. and, in the upper part, *Coryxognathus dubius* (Rhodes), while those from the Kuressaare Stage have *O. r. eosteinhornensis* s. i., *O. confluent ambigua* (Viira) and *Oulodus elegans* (Walliser) (Viira, 1982 a,b, 1994).

The *O. bohemica* lineage is most completely represented in the Ohesaare borehole (Figs 5 and 6). In the lower part of the Viita Beds *O. b. bohemica* β morph appears at a depth of 157.2 m and is found in seven samples through to 142.25 m. The lineage is not represented in the succeeding 29 m, but rare broken specimens of *O. s. cf. snajdri* are identified at 113.35 m and 106.25 m, in the Torgu Formation of the Paada Stage. At 100.8 m two specimens of *O. crispa* α3 morph occur, and a specimen of *O. crispa* α2 morph is found at 99.75 m. In the interval 93.4–61.2 m, seven samples contain *O. snajdri parasnajdri*. The lowest specimens are small and not well preserved, but have the widely open basal cavity characteristic of this subspecies. The largest specimens occur in the uppermost sample. The lower boundary of the Kuressaare Stage is identified by the occurrence of the thelodont *Theolodus sculpilis* Gross at 95.15 m, just below the first occurrence of *O. r. eosteinhornensis* at 93.40 m.

The next borehole to the north of Ohesaare is at Kaugatuma, where *Ozarkodina b. bohemica* β morph is represented in two samples at depths of 100.25 m (Viita Beds) and 81.4 m (Vesiku Beds). Four samples from the Paada Stage at 49.7–69.3 m contain *O. crispa* α2 morph, with good typical specimens present.
Conodont biostratigraphy

in the uppermost Sauvere Beds and the Himmiste Beds. *Ozarkodina s. parasnajdri* occurs in the interval 28.9–45.4 m of the Kuressaare Stage; as noted in the Ohesaare borehole, small specimens are found in the lowest samples and the biggest specimens are from the upper samples.

In the Riksu borehole further to the north, the highest strata are assigned to the Uduvere Beds. The *O. bohemica* lineage is represented only by *O. crispa* α₂ and α₃ morphs at 33.5–36.0 m in the Sauvere Beds. The most northerly borehole sampled from West Saaremaa is at Vesiku, where *O. b. bohemica* β morph has been recovered from two samples in the Viita and Kuusnomme Beds.

The Sakla borehole is situated in East Saaremaa, where the strata are generally dolomitized. Nevertheless, *O. b. bohemica* β morph has been recovered from the Viita Beds and *O. crispa* α₂ and α₃ morphs occur in the Sauvere Beds and in a single sample from the Uduvere Beds (Fig. 7).

In all the boreholes, including the Kolka borehole in northernmost Latvia, *O. b. bohemica* β morph usually occurs in the Viita Beds and occasionally also in the Kuusnomme and Vesiku Beds of the Rootsiküla Stage. All records of *O. crispa* on Saaremaa are in the Paadla Stage: in the Sauvere Beds of Riksu, the Sauvere and Himmiste beds of Kuagatuma, and the Torgu Formation of Ohesaare. In the Kolka borehole, *O. crispa* occurs with *O. r. eosteinhornensis* s. 1 in the Kuressaare Stage, with the most typical specimens at a depth of 270.8 m. In general, there is a pattern of increasingly high occurrence of *O. crispa* in the lithostratigraphical sequence from north to south, i.e. towards deeper water facies.

The exposure of Himmiste Beds or uppermost Sauvere Beds at Karala has yielded more than 50 specimens of the Pa element of *O. crispa*, with α₂ morphs dominant, but with some α₃ morphs and transitional forms (Fig. 8). A few specimens of the α₂ morph have also been recovered from Kärla (Sauvere Beds) and Paadla (Himmiste Beds). One specimen from Roopa Cliff (Himmiste Beds) is identified as an α₃ morph.

Small specimens with short blades and large posterior and anterior denticles have been recovered from the Soeginina cliff section (uppermost Rootsiküla Stage) of West Saaremaa and from the outcrop at Anikaitse in East Saaremaa. They are identified as *O. aff. bicornuta*. *O. bicornuta* was placed in the *bohemica* lineage between *O. b. bohemica* and *O. snajdri* by Helfrich (1975).

The relative completeness of the *O. bohemica* lineage in the Ohesaare borehole is complemented by evidence that *Coryssognathus dubius* has its longest range in this section. A more
Fig. 5. Distribution of conodonts, ichthyoliths (Märs, 1986), chitinozoans (Nestor, 1982) and ostracods (Sarv, 1971) in the Ohesaare borehole. J2Jg – Jaagarahu Formation, K1Vt – Viita Beds, K1Kn – Kuusnõmme Beds, K1Vs – Vesiku Beds, K1Sn – Soeginina Beds, K2T – Torgu Formation, K3aT – Tahula Beds, K3bA – Kudjape Beds, K3bA – Aigu Beds. Lithological column and stratigraphical divisions after Kaljo & Nestor (1990).

The distribution of conodonts in the Paadla Formation, in particular, suggests the presence of gaps in the Saaremaa succession. V. Nestor (1982) has previously suggested on the basis of chitinozoan data that there is a gap between the Rootsiküla and Paadla stages, and an increase in the scale of this gap northwards has been recognized (Nestor, V., 1990; Nestor, H., 1993). Conodont correlations with Gotland confirm a hiatus at this level (Jeppsson et al., 1994), and the absence of O. s. snajdri in all studied sections except Ohesaare provides consistent evidence. A break between the Paadla and Kuressaare stages was also postulated by Einasto (1991) and Märs (1992), and is corroborated by the fact that overlap between O. crispa and O. r. eostiinhornensis s. l. is apparent in the Kolkka section, but has not been found anywhere on Saaremaa. Alternatively, the restricted nearshore facies represented by the Uduvere Beds

| Dolomites | General | Argillaceous | Bioturbated argillaceous | Eurypterus - dolomite | Crypto laminated argillaceous |
|-----------|---------|--------------|--------------------------|-----------------------|----------------------------|
| Limestones | General | Argillaceous | Bio calcareous | Rare skeletal packstone | Pellet grainstone & packstone |
|           |         |              | Light skeletal grainstone | Coquid rudstone & floatstone | Limestone/marlstone interbedding |

complete section in this borehole than in others is also confirmed by occurrences of ichthyoliths and ostracods (Märs, 1986, 1990; Sarv, 1971).
Conodont biostratigraphy

| Depth (m) | Specimens |
|-----------|-----------|
| 61.2-61.4 | 3 specimens |
| 64.65-65.0 | 12 specimens |
| 67.4-67.7 | 14 specimens |
| 69.9-70.05 | 4 specimens |
| 73.5-73.7 | 4 specimens |
| 76.7-76.9 | 1 specimen |
| 93.4-93.7 | 2 specimens |
| 95.95-96.2 | 1 specimen |
| 99.75-99.9 | 1 specimen |
| 100.8-101.05 | 2 specimens |
| 106.25-106.55 | 1 specimen |

Fig. 6. Specimens of *Ozarkodina snajdri* cf. *snajdri* O. *crispa* $\alpha_2$ and $\alpha_3$ morphs and *O. s. parasnajdri* in the Ohesaare borehole.

may be a factor in producing the differences in the observed stratigraphical distributions of the conodonts.

**OTHER FOSSIL DATA**

**Chitinozoans**

Chitinozoans are very poorly represented in the Rootsiküla Stage, but a biozonal scheme has been developed for the Paadla and Kuressaare stages (Nestor, V., 1982, 1990). All biozonal species occur in the Ohesaare borehole (Fig. 5). *Conochitina latifrons* Eisenack and *Angochitina elongata* Eisenack appear in the lowermost Paadla Formation, and by correlation with the Ventspils borehole, Latvia, Nestor, V. (1982) deduced that strata representing the *nilssoni* and *scanicus* graptolite biozones were absent. In the Ohesaare borehole, *Eisenackitina lagenomorpha* (Eisenack) and *E. philipi* Laufeld range from the uppermost Paadla Stage into the Kuressaare Stage, with *E. lagenomorpha* extending much further upwards. The succeeding biozones of the Kuressaare Stage have as index species *Conochitina granosa*
Ostracods
The distribution of ostracods in the Ohesaare borehole has been documented by Sarv (1971), and the ranges of key species are shown in Fig. 5. Ostracods are rare in the Rootsiküla Stage and absent from the lowermost Paadla Stage, but in the Paadla Stage above a depth of 115 m, rich assemblages occur. Sarv (1971) reported that five species, including Neoheyrichius nutans Martinsson, had not been found in the northern East Baltic other than in the Ohesaare borehole, but included a N. nutans biozone in the upper Paadla Stage of Saaremaa (Sarv, 1982). In Britain, N. nutans occurs in the Lower Leintwardine Formation (Siveter, 1989), but other species recorded in the Ohesaare borehole are not represented.

Ichthyoliths
A microvertebrate biozonation for the Silurian of the northern East Baltic has been established by Märs (1982, 1990), and all the zonal species for the Rootsiküla, Paadla and Kuressaare stages are represented in the Ohesaare borehole (Märs, 1986; see Fig. 5). Logania martinssonii (Gross) occurs in the Rootsiküla and lowermost Paadla stages, and has also been found in the Halla, Mulde, Klinteberg and Hemse beds of Gotland (Fred-
**Conodont biostratigraphy**

|          | Specimens | Weight  |
|----------|-----------|---------|
| **KARALA** | >50       | 13650g  |
| **ROOPA**  | 1         | 4680g   |
| **KÄRLA**  | 1         | 1050g   |
| **PAADLA** | 3         | 1500g   |

Fig. 8. Specimens of *Ozarkodina crispa* $\alpha_2$ and $\alpha_3$ morphs in the Karala, Roopa, Kärla and Paadla outcrops.

**Correlation**

The evidence given by conodonts, chitinozoans and ichthyoliths for correlations is not always consistent. An attempt to provide the most parsimonious correlation between the succession on Saaremaa and those of the Ludlow type area and of Gotland is shown in Fig. 9. The correlation with Gotland is based on the recent conodont work by Jepsson *et al.* (1994), who confirmed the presence of gaps in the exposed Saaremaa sequence. One of these gaps is between the Jaagarahu and Rootsiküla stages, embracing strata referred to the upper Slite Beds, Mulde Beds and Halla Beds on Gotland. This results in only part of the *O. b. bohemica* Biozone being recognized on Saaremaa, here characterized by the $\beta$ morph.

The gap between the Rootsiküla and Paadla stages on Saaremaa corresponds to the uppermost Klinteberg Beds and lower Hemse Beds of Gotland (Jepsson *et al.*, 1994). Chitinozoan evidence, particularly the presence of *C. latifrons* in the Ohesaare borehole, indicates that at least the upper part of the Gorstian Stage is represented on Saaremaa; the occurrence of *Phlebolepis ornata* is consistent with this. The hiatus is probably of greater significance in shallower facies away from Ohesaare, where *P. ornata* has not been found, and Kaljo (1990, p. 26) has suggested that the entire Gorstian may be lacking in the shoreward region. The conodont *O. s. cf. snajdri* and the ostracod *N. mutans* have also been found only in the Ohesaare borehole.

Jepsson *et al.* (1994) also determined the presence of a gap between the Paadla and Kuressaare stages, equivalent to the upper Hemse and Eke beds of Gotland. Part of the evidence for
characterized by C. documented in detail by Miller (1995). He noted that the top faunas from the Welsh Borderland have recently been Kuressaare boundary on Saaremaa, with C. and O. eosteinhornensis, s. and O. crispa. The absence of O. eosteinhornensis, s. and O. crispa, with less common O. cf. O. crispa, with O. cf. O. crispa, O. confluens, Oulodus elegans and Polygnathoides siluricus (Walliser). The base of the Přídolí Series is commonly identified by the appearance of the ostracod Frostiella groenvalliana Martinsson (Hansch & Siveter, 1994), which occurs in the basal Downton Castle Sandstone Formation of Ludlow (Bassett et al., 1982; Miller, 1995) and in the lower part of the Kaugatuma Stage on Saaremaa (Sarv, 1982). However, the conodont fauna of the Kuressaare Stage suggests a Přídolí age, or at least an age post-dating the highest Upper Whitcliffe Formation at Ludlow. One explanation that fits all the fossil data would be the existence of a gap in the succession at Ludlow at the top of the Upper Whitcliffe Formation, as intimated by Jeppsson (1983, p. 137), equivalent to the Kuressaare Stage of Estonia and encompassing the highest part of the Ludlow Series. Bassett et al. (1982, p. 6), however, while noting that the basal contact of the Downton Castle Sandstone Formation is sharp and scoured, considered there to be no indication of a major break in sedimentation at this level.

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**APPENDIX: Locality information**

Ohesaare borehole – situated in the southern part of the Ohesaare cliff, on the west coast of the Sõrve Peninsula.

Kaugatuma borehole – situated near Kaugatuma cliff on the west coast of the Sõrve Peninsula.

Ríksu borehole – situated near Ríksu lake, Ríksu village, southwest Saaremaa.

Vesiku borehole – situated near the mouth of Vesiku brook, westernmost Saaremaa.

Kuressaare (Kingissepa) borehole – situated in the centre of Kuressaare (in the yard of the restaurant ‘Tuulik’).

Sakla borehole – situated on the south side of Sakla village,

| SERIES & STAGES | WENLOCK & LUDLOW AREA | SAAREMAA (SOUTHERN) | GOTLAND |
|-----------------|------------------------|---------------------|--------|
| **PŘIDOLÍ** (part) | Downton Castle Sandstone Fm. | Kaugatuma Formation | Sundre Beds |
| **LUDLOW** | Upper Whitcliffe Formation | Kuressaare Formation | Hamra Beds |
| | Lower Whitcliffe Formation | ? | Burgsvik Beds |
| | U. Leintwardine Fm. | ? | Eke Beds |
| | L. Leintwardine Fm. | Torgu Formation | |
| | U. Bringwood Fm. | | Hemse Beds |
| | L. Bringwood Fm. | | |
| | U. Elton Fm. | | |
| | M. Elton Fm. | | |
| | L. Elton Fm. | | |
| **GORIATAN** | Much Wenlock Limestone Fm. | Rootsiküla Formation | Klinteborg Beds |
| | Coalbrookdale Fm. (upper part) | | |

**Fig. 9.** Correlation of the upper Wenlock to lower Přidolí sequences of Britain (Wenlock Edge and Ludlow area), Estonia (southern Saaremaa) and Gotland.

this is the absence of Polygnathoides siluricus Walliser on Saaremaa, although this species is rare in most facies and its distribution may have been environmentally controlled. However, there is a marked change in conodonts at the Paadla/ Kuressaare boundary on Saaremaa, with C. dubius, O. excavata and O. crispa disappearing, and a fauna characterized by O. r. eosteinhornensis, s. l., O. confluens, Oulodus elegans (Walliser) and O. snajdri parasnajdri appearing.

Uprmost Ludlow and lowermost Downton conodont faunas from the Welsh Borderland have recently been documented in detail by Miller (1995). He noted that the top of the Upper Whitcliffe Formation in the Ludlow area is characterized by C. dubius and O. s. snajdri, with less common O. r. eosteinhornensis and O. cf. crispa. At Ludlow itself, O. cf. crispa ranges 30–15 cm below the top of the formation; the specimens compare with the α₂ morph described in this paper and found in the upper Paadla Stage on Saaremaa. Miller (1995), however, also recovered O. crispa from the lower part of the Whitcliffe Formation at Tite’s Point, Gloucestershire, and from the lower part of the Upper Perton Beds at Woolhope; these specimens have a narrow furrow on the upper surface and are similar to the β morph of Walliser & Wang (1989).
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Kärä – outcrop in Kärä brook, central Kärä village, westernmost Saaremaa.

Loode Tammik – small old quarry (1.2 m) in Loode Oak Wood (Tammik), 2 km west of Kuressaare, south Saaremaa.

Paadla – old quarry (1.8 m) in Paadla village, 50 m south of the Kuressaare–Kihelkonna road, central Saaremaa.

Roopa – small cliff (1.5 m) on the southernmost cape of the Atla Peninsula, western coast of Saaremaa.

Soegíina – cliff (4.2 m) on the south-west shore of the Atla Peninsula, westernmost Saaremaa.

Viita – old trench on the shore at Rootsküla village, 2 km southwest of Kihelkonna, westernmost Saaremaa.

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