Starfish from the Ordovician of the Oslo Region, Norway

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Two species belonging to the Class Stelleroidea are described from Ordovician rocks of the Oslo Region, Norway. These are the asteroid, *Cnemidactis osloensis* n.sp, from the Elnes Formation (Llanvirn) in the Oslo-Asker area and the cosmopolitan ophiuroid *Stenaster obtusus* (Forbes, 1848) from the Furuberg Formation (Caradoc) of the Hamar district. *C. osloensis* n.sp. is the oldest hitherto described asteroid from Baltoscandia.

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Introduction

Asterozoans have not been described before now from the Lower Palaeozoic rocks of Norway and they are rare in equivalent rocks throughout Baltoscandia (e.g. Rasmussen 1952; Regnéll 1960; Rozhnov 2004). It was therefore of great interest when two amateur collectors, Liv Torgunn Tørud Hagen and Ingebjørg Nilsen from Brumunddal, discovered a rich ophiuroid (brittle star) bed in the Caradocian Furuberget Formation in the Hamar district north of Oslo, Norway (Fig. 1). The specimens occur mainly as decalcified moulds in a fine-grained marlstone. They are scarcely deformed and with the aid of latex casts can be studied in detail. Although we have had access to more than 100 specimens, only one species of the widespread form, *Stenaster obtusus* (Forbes, 1848) has been identified. In addition, during detailed profile logging by one of us (TH) in the uppermost part of the Elnes Formation (Llanvirn) near Slemmestad, Oslo-Asker area, another well-preserved asteroid was found, described herein as *Cnemidactis osloensis* n.sp. This occurrence is of the oldest hitherto described from Baltoscandia, though Sergei Rozhnov (pers. comm. 2004) informs us that undescribed Arenig asteroid material is known from the Leningrad region.

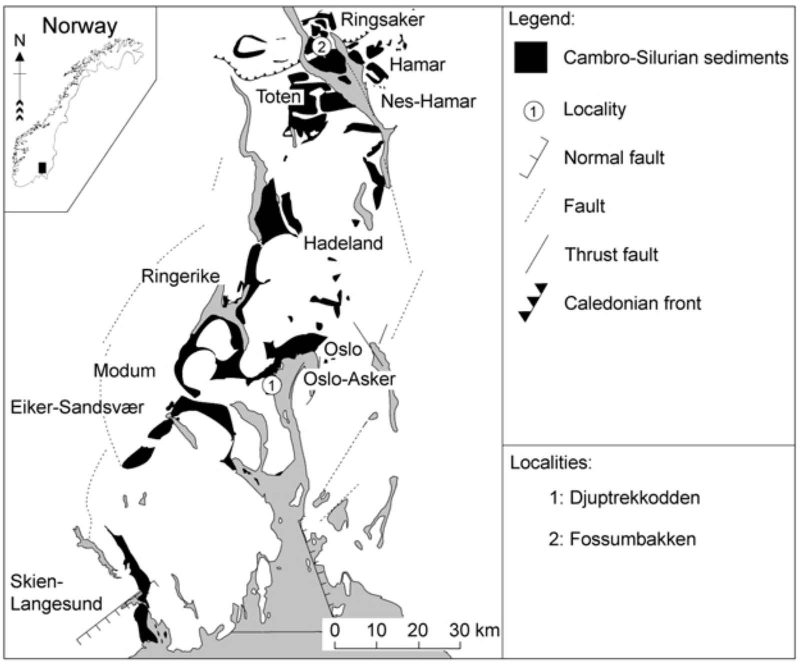

Fig. 1. Map of the Cambro-Silurian rocks of the Oslo Region with the two localities mentioned in the text indicated by numbers in circles. Modified from Ebbestad (1999).

Geological setting

During the Ordovician, the Oslo Region (Størmer 1953; Bruton et al. 1985; Owen et al. 1990) formed a cratonic basin on the western side of the Baltic platform but today its lateral limits are those of a Permo-Carboniferous graben (Dons & Larsen 1978) in which a series of alternating shales (or mudstone) and limestone units (Bjørlykke 1965; 1974) show varying degrees of Caledonian folding and faulting but are generally weakly deformed. Local Permian intrusive bodies suggest that sediments have been subjected to temperatures of 300 degrees centigrade or more, as indicated by the Conodont Colour Alteration Index (CAI) of 4.5-5 (Bergström 1980). In the Oslo area the rocks are parautochthonous while in the Hamar district to the north, the succession has been thrust southwards at least 150 kms (Nystuen 1981; Bockelie & Nystuen 1985) Throughout the Ordovician, Baltica was in the Southern Hemisphere (approximately 30°-45° S). The climate was temperate to subtropical, becoming warmer as the continent approached the equator towards the end of the period. In the Early Llanvirn, faunas were highly endemic but this gradually broke down and by the mid-Caradoc faunal interchange between Avalonia and Baltica had become significant (Christiansen & Stouge 1999; Cocks & Torsvik 2002; Fortey & Cocks 2003).

Stratigraphy

The Elnes Formation

The Early to Middle Llanvirn Elnes Formation (Owen et al. 1990) is dominated by dark siliciclastic graptolite mudstones (Maletz 1997) but towards the top, beds become lighter in colour and consist of tightly packed nodular limestone. The uppermost unit, the Håkavik Member (Fig. 2), is composed of thin alternating silty mudstones, laminated siltstones and calcarenites and small calcareous nodules. This part of the formation was probably laid down in a fairly shallow water environment dominated by storm-induced currents (Bjørlykke 1965, 1974; Owen et al. 1990). Fossils are relatively sparse and occur nearly exclusively in the mudstone and nodules. Only a few echinoderms (crinoid ossicles and the starfish *C. osloensis* n.sp.), graptolites and trilobites have been registered, nearly exclusively at the base of the silt beds.

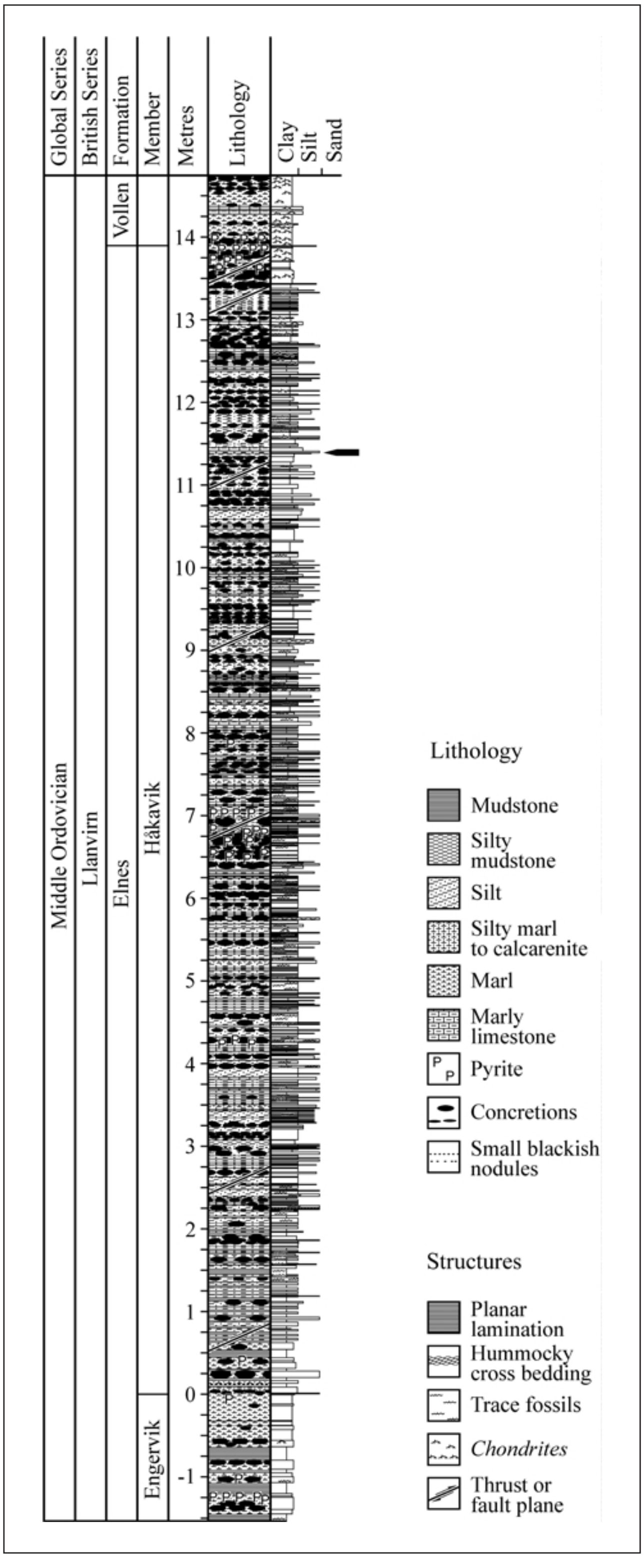

Fig. 2. Sedimentological log for the upper Elnes Formation at Djuptrekodden, Bjerkås. Arrow indicates the silt bed where the Cnemidactis specimen was found.

The Furuberget Formation

The Caradoc Furuberget Formation of the northern Oslo Region is composed of shale with limestones and calcareous siltstones. In the Hamar district the base is characterized by grey to greenish shales with limestones and calcareous siltstones but towards the top, the limestones thicken into horizons of more than 10 cm thickness. The limestones and to a lesser degree the shales contain a diverse shelly fauna of echinoderms, brachiopods, trilobites, bryozoans and calcareous algae by many thought to be allochthonous. However, some siltstone beds contain brachiopods and bryozoans *in* *situ*. Sedimentary structures in the siltstones including cross bedding, suggest that these were deposited in fairly shallow water (Spjeldnæs 1982; Owen et al. 1990).

Material and methods

External moulds of *Stenaster* required very little preparation and have been studied from latex rubber casts. The holotype and only specimen of *Cnemidactis osloensis* n.sp., was found partly exposed in shale with calcium carbonate preserved in parts of the arms (Fig.5A). A rubber cast was made before further treatment. The carbonate was subsequently removed by using a weak solution (5%) of hydrochloric acid leaving an external mould from which a latex cast was made (Fig. 5, C-E). In order to create a uniform photographic appearance, all the latex casts were blackened and then coated with ammonium chloride prior to photographing (by DLB). The terminology used for the description follows Spencer & Wright (1966). All material is deposited in the Geological Museum, University of Oslo and registered using the former Palaeontologisk Museum, Oslo (PMO) numbers.

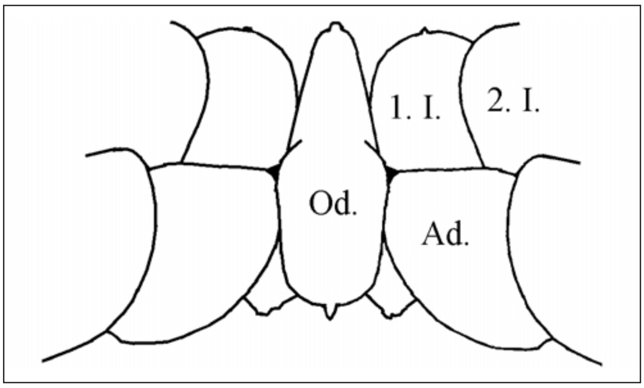

Fig. 3. Plan of ossicles in the interradial angle of Cnemidactis osloensis *n.sp. as seen from the side and slightly below. Ad., adambulacralia; I., inferomarginalia; Od., odontophore.*

Systematic palaeontology

Subphylum Asterozoa Zittel, 1895
Class Stelleroidea Lamarck, 1816
Subclass Asteroidea de Blainville, 1830
Order Forcipulatida Perrier, 1884
Suborder Uractinina Spencer & Wright, 1966
Family Cnemidactinidae Spencer, 1918

Genus *Cnemidactis* Spencer, 1918
Type species. Urasterella girvanensis Schuchert, 1914

Diagnosis. (Emended from Spencer & Wright 1966). Arms relatively steep-sided, with upper column of closely spaced inferomarginals; adambulacrals with broadly convex oral surface; odontophores subrectangular, moderately large; ambulacrals stoutly rectangular, with high L- to T-shaped ridge; aboral surface with rows of small paxillae; oral side with wide mouth in C. girvanensis closed by 5 horizontally orientated tori.

Stratigraphical range. Middle to Upper Ordovician

Cnemidactis osloensis n.sp.
Fig. 3, 4, 5A-E

Derivation of name. From Oslo.

Material. Holotype PMO 203.380, from a silt bed 11.41 m above the base of the Håkavik Member of the uppermost Elnes Formation (Zone of *Glyptograptus teretiusculus*), beach section north of Djuptrekodden (MR 843 296; Asker map 1814) Oslofjord (Figs. 1, 2).

Diagnosis. Arms relatively short, tapering; odontophore only reached by proximalmost inferomarginal in side view.

Description. Small without interbrachial arcs; arms moderately long, straight-sided, tapering; arm radius approximately 18 mm; disk radius approximately 4.2 mm; mouth diameter approximately 3.7 mm; central body unknown.

Only the arms are known for the aboral side and these only in part. Arm margin composed of adambulacrals; column of at least 23 inferomarginals inside adambulacrals, separated by broad radial papular area; inferomarginals approximately rectangular in outline, long axis parallel to that of arm, outer granular or spiny side somewhat convex, inner side flat. Proximal 2/3 of arm with about seven inferomarginals for every five adambulacrals; the width and length of each inferomarginal corresponding to 1/6 and 1/5 of arm width respectively, not covering the aboral side of ambulacrals. Radial papular area forming slight depression along mid-arm. The paxillae are only preserved on the middle part of the straight arm (Fig. 5B). Paxillae organized into two sets of diagonal rows superposed on each other; first set strongly obliquely directed inwards from margin towards arm-tip, angle between axis of arm and row 40° - 60°; second diagonal set slightly adorally directed with corresponding angle of about 110°.

Mouth frame of ambulacral type; mouth angle plates small, subtriangular with an inverted sigmoidal ridge along outer flank; small elevated area at distal adradial edge, touching succeeding ambulacral plate; mouth angle plates out of line to succeeding ambulacrals; abradial sides touching adjoining mouth angle plate, odontophore and following adambulacral plate.

Ambulacrals ordered in two columns of sharply rec-

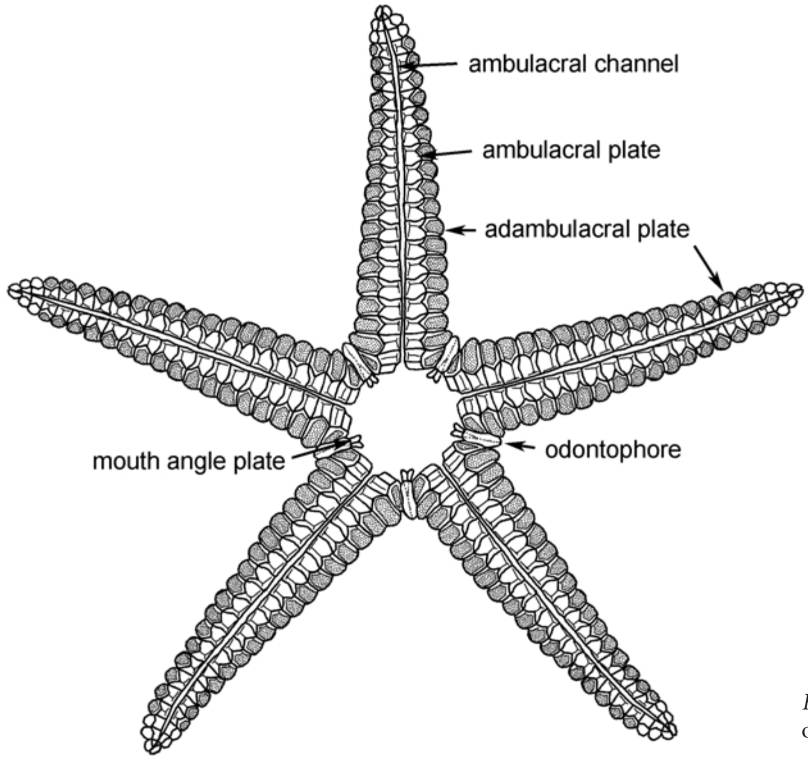

Fig. 4. Reconstruction of oral side of Cnemidactis osloensis *n.sp. Termination of arms unknown.*

tangular to quadrate plates with well-developed T-ridge on central part; size of plates decreasing evenly but slowly towards tip of arm, length relative to the width changing with an L/W-ratio of 0.6 on the 4th ambulacral, 1.0 on the 10th and 1.6 on the 17th ambulacral; proximal ambulacrals very large relative to mouth angle plates, showing a distinct dip towards mouth-cavity; ambulacral groove deep, moderately broad.

Odontophore with free abaxial edge dividing a strong frame of adambulacrals bordering the arms, adaxial edge moved slightly outwards in relation to following adambulacrals; odontophore long, sub-rectangular with a distinct ridge running from distal edge and about 2/3 of the way towards mouth before splitting up in two, diverging evenly to adaxial end. Seen from the side the odontophore reaches from oral side up through adambulacrals and inferomarginals, terminating at aboral side of disk; aboral part only flanked by one inferomarginal on each side (Fig. 3); mesial ridge running unbroken from oral to aboral side; height of plate largely equal to oral length, oral circumference slightly larger than that of the larger of the succeeding adambulacrals.

First adambulacral from odontophore smallish, wedge-shaped in outline, completely enclosed between odontophore and succeeding adambulacral; second adambulacral nearly twice as big, elongated pentagonal to oval in outline, distinct facets present on four inner sides and a sharply convex outer side, L/W ratio approximating $^1/_2$; following adambulacrals becoming gradually narrower, though only slightly shorter, resulting but for a distinct inner edge, in a semispherical outline at tip of arm (Fig. 5A, arm at 2 o'clock). Each side flanked by adjoining adambulacrals marked by smooth furrow delineating central convexly raised and grained area. At least some of the grains or short spines form partly developed V-shaped rows. Raised area on proximal adambulacrals narrower, becoming more like a ridge; each column of adambulacrals containing at least 21 plates.

Discussion

Cnemidactis osloensis n.sp. differs from the British Late Ordovician *C. girvanensis* on the length of the arms, which do not reach more than about four times the disk radius, and by the organization of the odontophore and flanking inferomarginals (cf. Spencer 1918).

Like the Middle Ordovician *C. macroadambulacralatas* Blake & Guensburg, 1993 from North America. *Cnemidactis osloensis* n.sp. has relatively short arms and few adambulacrals relative to inferomarginals. Furthermore the pattern of the paxillae on the radial papular area is nearly identical. *C. osloensis* n.sp. is readily differentiated by the shorter arms with fewer inferomarginals. Additionally the inferomarginals are slightly narrower relative to the arm width. The similarities between *C. osloensis* n.sp., *C. girvanensis* and *C. macroadambulacralatas* remove the uncertainty of assignment of the latter as

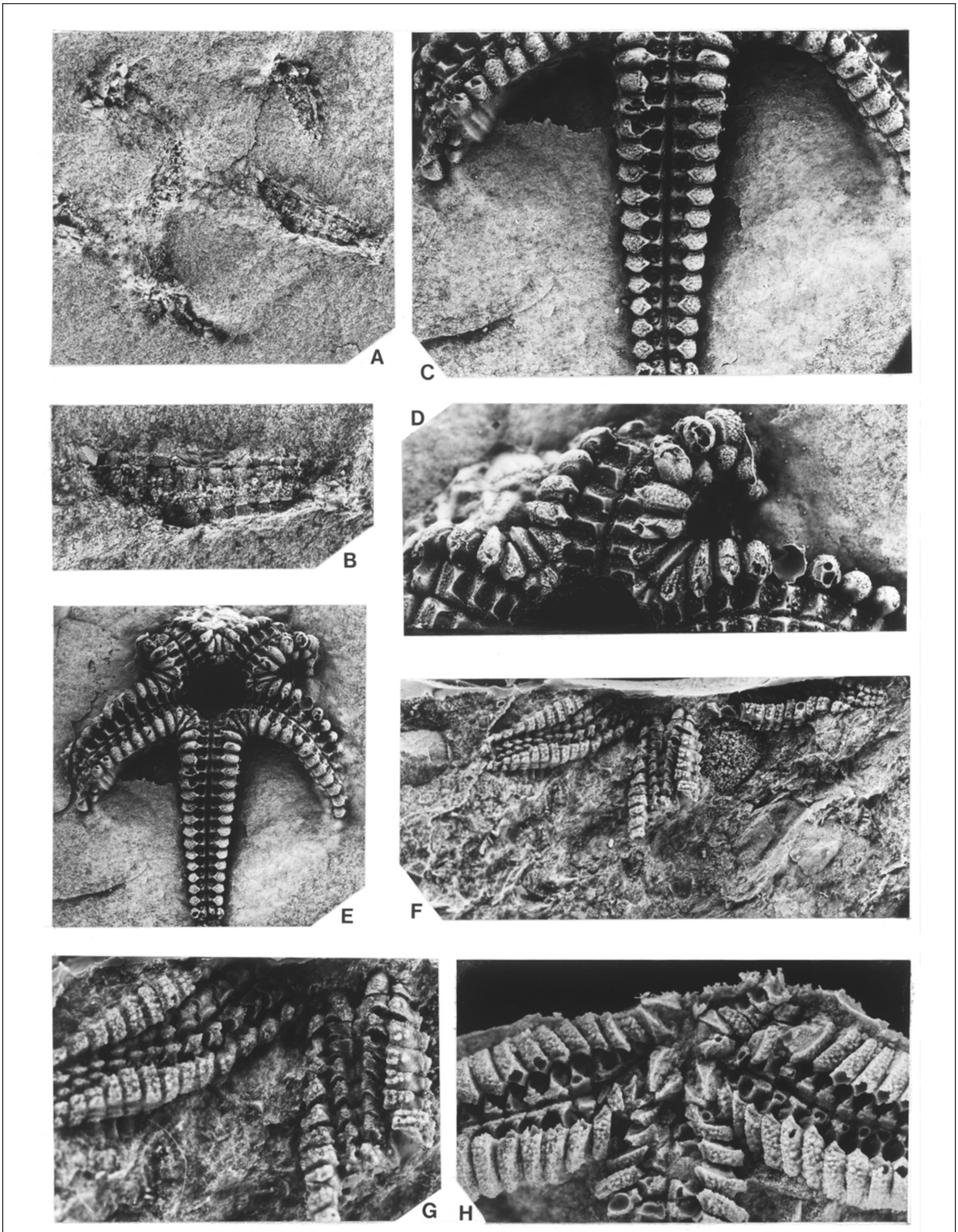

Fig. 5. A-E. Cnemidactis osloensis *n.sp., Holotype PMO 203.380. A. Aboral side before removal of skeleton with acid, X3.1. B. Aboral side of arm, X6.2. C. Rubber cast of oral side of arm. The central arm is the one pointing towards 4 o'clock in figure A, X5.5. D. Mouth region, X7. E. Oral side, X3. F-H.* Stenaster obtusus *(Forbes, 1848). F, G. Rubber cast of aboral side, PMO 203.398, X3 and X5.5. H. Rubber cast of mouth region, PMO 203.396, X6.*

expressed by Blake & Guensburg (1993).
The occurrence of *Cnemidactis* in Norway as early as the Llanvirn, indicates the exchange of asteroid taxa between Laurentia and Baltica at a time when faunal exchange was low and only a few deep water or pelagic animals seem to have made it across Iapetus (cf. Cocks 2000; Fortey & Cocks 2003).

Subclass Ophiuroidea Gray, 1840
Order Stenurida Spencer, 1951
Family Stenasteridae Schuchert, 1914

Genus *Stenaster* Billings, 1858
Type species.- *Uranaster obtusus* Forbes, 1848

Stratigraphical range. Middle Ordovician to Silurian (Llandovery); see Jell & Baillie (1984); Spencer & Wright (1966).

Stenaster obtusus (Forbes, 1848). Fig. 5F-H, 6A-D

Synonymy.
A more complete list has been given by Spencer (1927).
1927 Stenaster obtusus (Forbes) (sic); Spencer, pp. 356-359, pl. 23, textfig. 221-231 (description, occurrence, figures, discussion).
1960 Starfish (undescribed); Regnell, p. 174 (mentioned).
1984 *Stenaster obtusus* (Forbes, 1848); Jell & Baillie, pp. 272-274, fig. 1 (diagnostic description, occurrence and figures).
1999 *Stenaster obtusus* (Forbes, 1848); Dean, pp. 225-250, figs 1-7, table 1-3 (description, occurrence and figures, discussion, biology).

Material. More than 100 specimens of which the following are figured: PMO 203.396, PMO 203.397 (four specimens) and PMO 203.398. Collected by Liv Torgunn Tørud Hagen and Ingebjørg Nilsen from the Furuberget Formation at Fossumbakken (MR 019 485; Hamar map 1916 IV) Hamar district, Oslo Region, Norway (Fig. 1).

Diagnosis. Arms broad, petaloid; disk small, podial basins shared.

Description. Arms five, wide, petaloid; disk small. Arms radii 12.3-14.1 mm. Widest part of arm located about halfway between disk centre and distal arm tip, 4.3-5.4 mm wide corresponding to slightly more than 1/3 of arm radius; disk radius 2.1-2.6 mm, slightly more than 1/6 of arm radius; aboral surface showing two columns of ambulacrals and flanking adambulacrals; ambulacrals lying in deep groove shaped by adambulacrals; proximal part of arm characterized by Y-shaped, transversely rounded ridge.

Interradial mouth angle plates abutting proximal adambulacral; mouth angle plate distinctly facetted, sub-triangular in outline.

Oral side of arms composed of two ambulacral columns lying in deep ambulacral groove, each column containing at least 20 to 21 ambulacrals, each ambulacral paired with ambulacral of opposite column and adjacent adambulacrals, forming straight transverse rows. T-ridge on ventral surface well developed; adambulacrals and T-ridges enclosing smooth hemispherical podial basins.

Adambulacrals orally wide, short, adradially with straight sides and short edge abutting T-ridge on ambulacrals, width on widest part of arm corresponding to about 35% of total arm width, decreasing significantly near distal and proximal end of arm. Length of adambulacrals on mid-arm approximating 40% of width, increasing to about 100% at tip of arm. Oral side of plates covered by dense, moderately fine granulation. Aboral side with varying number of pustules from as few as two to three on proximal parts of arm to a larger number on mid arm plates, decreasing again on distal part of arm.

Discussion. Based of the descriptions given by Spencer (1927) and a thorough redescription by Dean (1999) the Norwegian material seems to lie well within the variation observed for *Stenaster obtusus* (Forbes, 1848). This species has an extremely wide distribution having been recorded from Middle to Upper Ordovician rocks in Great Britain, Kazakhstan, North America and from Llandovery rocks in Australia (Dean 1999; Jell & Baillie 1984). Dean (1999, p. 246) suggested that because of the relatively inflexible arms of *Stenaster*, adult specimens had limited mobility. Thus this could have restricted them to the area in which they grew up. The wide geographical distribution of *S. obtusus* might therefore indicate that the species had a relatively long planktonic larval stage.

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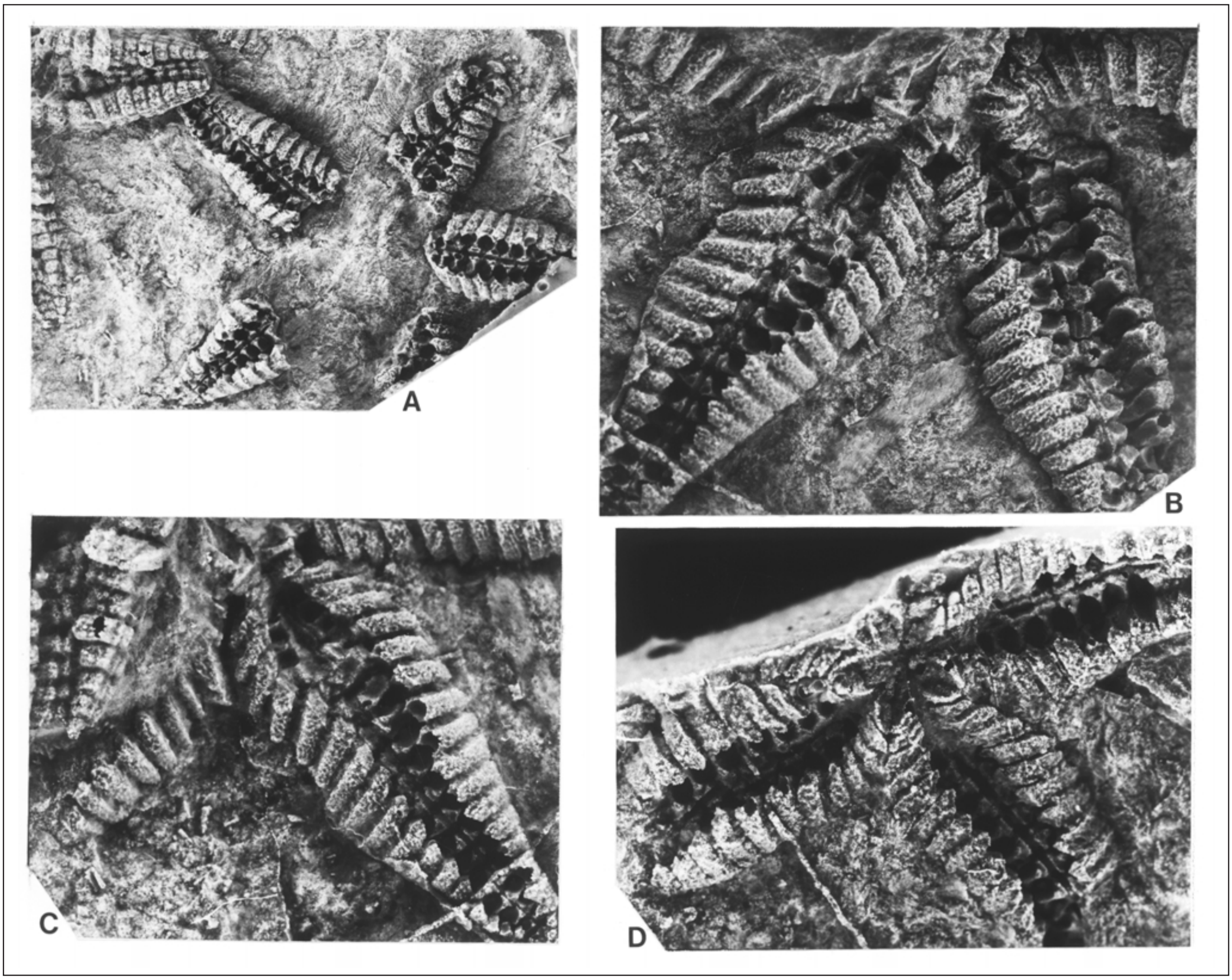

Fig. 6. A-D. Stenaster obtusus *(Forbes, 1848). A. Rubber cast of oral side, PMO 203.397/1, X3.2. B, C. Rubber cast of mouth region and arms, PMO 203.397/2, X5.5. D. Rubber cast of mouth region, PMO 203.397/3, X6.*

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