

EARLY MIOCENE LUIDIID ASTEROIDS (ECHINODERMATA, ASTEROIDEA) FROM WINTERSWIJK-MISTE (THE NETHERLANDS)

JOHN W.M. JAGT
Venlo, The Netherlands

Jagt, John W.M. Early Miocene luidiid asteroids (Echinodermata, Asteroidea) from Winterswijk-Miste (The Netherlands). — *Contr. Tert. Quatern. Geol.*, 28(1): 35-43, 3 figs, 1 pl. Leiden, August 1991.

Dissociated ossicles (inferomarginals, ambulacrals and adambulacrals) of luidiid asteroids (Luidiidae) from early Miocene Hemmoorian (Oxlundian) strata at Winterswijk-Miste (province of Gelderland, The Netherlands) are illustrated and briefly described. The material is compared with contemporary *Luidia ciliaris* (Philippi, 1837), but, for the time being, left in open nomenclature. It may represent a new subspecies or forma within the Ciliaris Group (*sensu* Döderlein, 1920) of the genus *Luidia* Forbes, 1839. The present occurrence appears to be stratigraphically older than records of Miocene luidiids from central Poland.

Key words — Echinodermata, Asteroidea, Luidiidae, Miocene, Hemmoorian (Oxlundian), The Netherlands.

J.W.M. Jagt, Tweede Maasveldstraat 47, 5921 JN Venlo, The Netherlands.

CONTENTS

Introduction	p. 35
Systematic description	p. 36
Future studies	p. 39
Acknowledgements	p. 40
References	p. 40

INTRODUCTION

During processing of a rather small sediment sample taken from a temporary outcrop at Winterswijk-Miste (Fig. 1) in 1988, dissociated ossicles of the asteroid genus *Luidia* were recognised amongst the generally diverse echinoderm remains. Asteroids are found in this material as isolated ossicles only and comprise at least nine species. Astropectinids are the commonest asteroids, and include three or four species, some of which appear to be still undescribed. Figure 2 illustrates morphological differences between astropectinids and luidiids. Some of the asteroid ossicles available for study are fairly well preserved, but most are corroded and/or abraded, and often fragmentary. Echinoids comprise cidarids, clypeasteroids and spatangoids. Ophiurid ophiuroids are apparently extremely rare as only

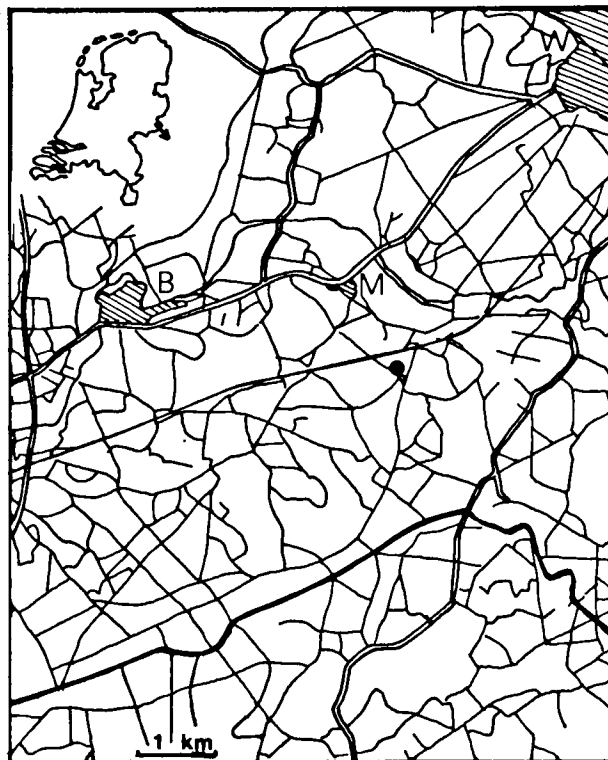


Fig. 1. Locality map showing location of temporary exposure (black dot) at Winterswijk-Miste. Abbreviations: W - Winterswijk, M - Miste, B - Bredevoort (modified after Janssen, 1984).

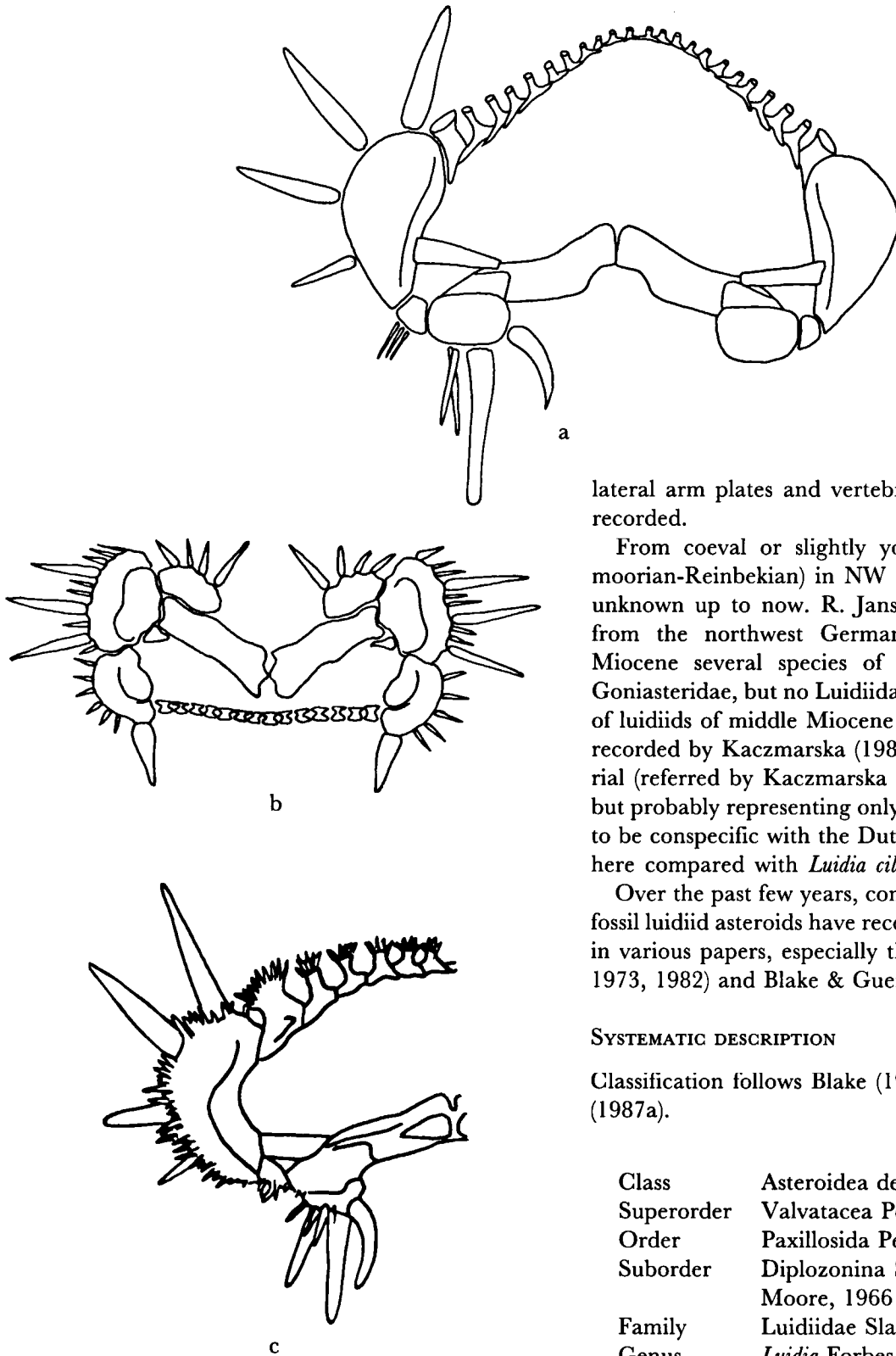


Fig. 2a-c. Cross sections of arms of luidiid (A, C) and astropectinid (B) asteroids to show position of individual ossicles (modified after Clark, 1982, Döderlein, 1920, and Fell, 1963).

lateral arm plates and vertebrae have so far been recorded.

From coeval or slightly younger strata (Hemmoorian-Reinbekian) in NW Europe luidiids were unknown up to now. R. Janssen (1972) described from the northwest German Middle and Late Miocene several species of Astropectinidae and Goniasteridae, but no Luidiidae. Polish occurrences of luidiids of middle Miocene (Badenian) age were recorded by Kaczmarska (1987). The Polish material (referred by Kaczmarska to two modern taxa, but probably representing only one species) appears to be conspecific with the Dutch material, which is here compared with *Luidia ciliaris* (Philippi, 1837).

Over the past few years, contemporary as well as fossil luidiid asteroids have received ample attention in various papers, especially those by Blake (1972, 1973, 1982) and Blake & Guensburg (1989).

SYSTEMATIC DESCRIPTION

Classification follows Blake (1987, 1989) and Gale (1987a).

Class	Astroidea de Blainville, 1830
Superorder	Valvatacea Perrier, 1884
Order	Paxillosida Perrier, 1884
Suborder	Diplozonina Spencer & Wright <i>in</i> Moore, 1966
Family	Luidiidae Sladen, 1889
Genus	<i>Luidia</i> Forbes, 1839

Type species — *Luidia fragilissima* Forbes, 1839 (= *Asterias ciliaris* Philippi, 1837).

Species group — Ciliaris Group (subgenus *Hemicnemis* Müller & Troschel, 1840) *sensu* Döderlein, 1920.

Luidia sp. aff. ciliaris (Philippi, 1837)

Pl. 1

Compare:

- 1837 *Asterias ciliaris* Philippi, p. 194.
- 1920 *Luidia ciliaris* Philippi — Döderlein, pp. 287, 288, pl. 18, fig. 8; pl. 19, fig. 17; pl. 20, fig. 34.
- 1927 *Luidia ciliaris* (Philippi) — Mortensen, p. 70, fig. 39a.
- 1953 *Luidia ciliaris* (Philippi) — Clark, pp. 379, 380.
- 1973 *Luidia ciliaris* (Philippi), 1837 — Blake, p. 40, pl. 10, figs 1-26.
- 1982 *Luidia ciliaris* (Philippi) — Clark, p. 170, fig. 3k (with synonymy).
- 1987 *Luidia ciliaris* (Philippi, 1837) — Kaczmarek, p. 139, pl. 5, figs 6-8.
- 1987 *Luidia alternata* (Say, 1825) — Kaczmarek, p. 139 (? pars), pl. 5, figs 10, 11 (? non 9, 12).

Material — Dissociated ossicles including inferomarginals (c. 40), ambulacrals (c. 10) and adambulacrals (c. 10), J.W.M. Jagt Collection, and the speci-

mens illustrated herein (Pl. 1), Nationaal Natuurhistorisch Museum Collections, Leiden, RGM registration numbers 383 547-383 554.

Description — Blake (1973) presented detailed descriptions of the ossicles of various luidiid species (for terminology used see Fig. 3) and indicated the following features to be characteristic of the Ciliaris Group *sensu* Döderlein (1920):

- inferomarginals: outline crescentic, without a distinct inner face step; superambulacrals moderately prominent; distal articulation ridge parallel to ossicle curvature, outline rectangular, very wide and long, with two marginal articulation processes; proximal articulation ridge short and wide.
- ambulacrals: ambulacrals body triangular, asymmetrical; dentition weak, with medial gap; Unt G small; oral apophyse prominent; GG subsymmetrical; aboral ridge low and rounded.

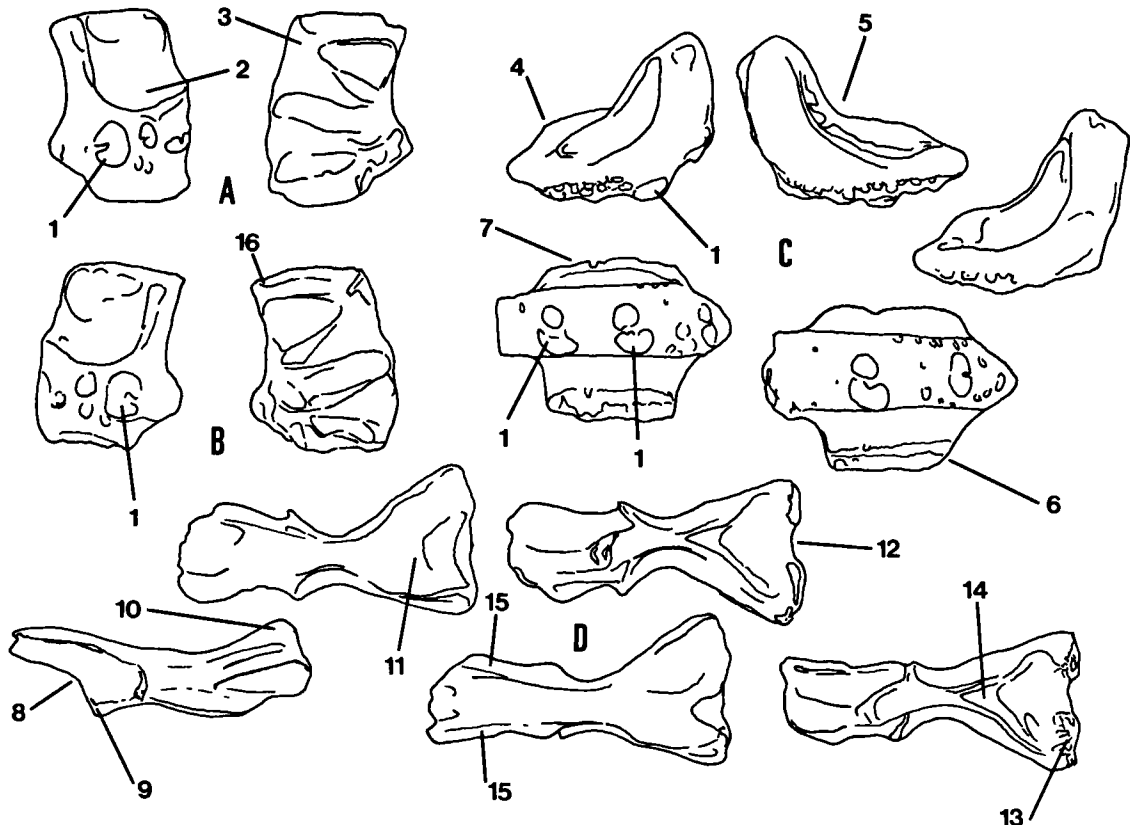


Fig. 3. Diagrammatic representations of various ossicles of a luidiid asteroid (*Luidia neozelanica* Mortensen, 1925; Ciliaris Group) illustrating morphological terms used in the text (modified after Blake, 1973). A - left adambulacrals, B - right adambulacrals, C - inferomarginals, D - ambulacrals; 1 - spine bases, 2 - dml (distal face muscle 1), 3 - psr1 (proximal face surface 1), 4 - superambulacrals boss, 5 - inner face step, 6 - distal articulation ridge, 7 - proximal articulation ridge, 8 - adambulacrals notch, 9 - oral apophyse, 10 - aboral ridge, 11 - ambulacrals body, 12 - medial gap, 13 - dentition, 14 - Unt G ("Grube zur Insertion des unteren Quermuskels"), 15 - GG ("Flügel zur Verbindung mit den Adambulacrals"), 16 - pml (proximal face muscle depression 1). German terminology is after Müller (1953).

A comparison of Blake's (1973) detailed description of ossicle morphology of *Luidia ciliaris* with the Miste material makes it clear that this should be classed in the Ciliaris Group. It shows the following typical features:

Inferomarginals

- inferomarginal outline crescentic (Pl. 1, Figs 13, 14, 16)
- no distinct inner face step (Pl. 1, Figs 13, 14, 16)
- superambulacral boss moderately prominent (Pl. 1, Fig. 14)
- distal articulation ridge parallel to ossicle curvature (Pl. 1, Figs 10, 14) and outline very angular with distinct marginal notch (Pl. 1, Figs 9, 10, 12)
- three moderate-sized spine bases (Pl. 1, Figs 9-14)
- proximal ridge short and wide (Pl. 1, Figs 9, 12, 15)

Ambulacrals

- ambulacral body triangular and asymmetrical (Pl. 1, Figs 4, 7)
- dentition weak, with medial gap (Pl. 1, Figs 4, 5)
- Unt G small (Pl. 1, Fig. 4)
- oral apophyse prominent (Pl. 1, Figs 5, 6)
- GG subsymmetrical (Pl. 1, Figs 4, 7)
- aboral ridge low and rounded (Pl. 1, Figs 5, 6)

Adambulacrals

- pml moderately wide (Pl. 1, Fig. 3)
- psr1 relatively large (Pl. 1, Fig. 3)
- spine bases weak (Pl. 1, Figs 1, 2)
- dml large (Pl. 1, Figs 1, 2)

In contrast with Blake (1973), who concentrated on descriptive ossicle morphology, Clark (1982) described external features and tabulated the following characteristics for *Luidia ciliaris*:

Arm number 7 or 8; number of consecutive lateral paxillae corresponding to 10 superomarginal ones 15 to 18; paxillar armament consisting of central spinelets distinctly coarser than peripheral ones; shape of superomarginal paxillae more or less elongate; alignment of inferomarginal plates lateral; inferomarginal spines alternating on consecutive plates; number of large erect inferomarginal spines 3 to 5; number of adambulacral spines 2; number of valves on actinal pedicellariae up to 3 when present; oral furrow pedicellariae absent.

Modern *Luidia ciliaris* lives in the NE Atlantic,

from southern Norway, the Skagerrak, Kieler Bucht, Shetland Islands, Faeroe Channel, south to the Canaries and Azores (? Cape Verde Islands), and the Mediterranean at depths between 1-400 metres (Döderlein, 1920; Mortensen, 1927[1977]; Dons, 1937; Blake, 1973; Rodriguez, 1980; Tortonese, 1980; Clark, 1982).

Discussion — The stratigraphically oldest luidiid to have been recorded so far is *Luidia hungarica*, based on a fragmentary specimen from Nagybatony (Hungary) and described by Rakusz (1927). Spencer & Wright (*in* Moore, 1966, p. U 43, fig. 42/3) did not question this generic assignment and it is on this Hungarian material that they based the range of the genus *Luidia* (Miocene-Recent); Dr D.B. Blake (letter of March 28, 1989) tells me that he considers the specimen to be incorrectly identified, with which conclusion I concur. Hess (1955, p. 68) also briefly discussed this record and stated literally, '...*Luidia hungarica* aus dem Miozän dürfte hingegen dieser Gattung angehören.' He remarked that the occurrence of a 'modern' species of luidiid was quite possible, since Mio-Pliocene Italian astropectinid species displayed modern features and were referable to the genus *Astropecten* Gray, 1840. Another fossil asteroid to have previously been referred to the Luidiidae is the Liassic (early Jurassic) *Asterias murichisoni* Williamson, 1836, which Hess (1955, p. 68) referred with a query to *Plumaster* Wright, 1861 (? *Tropidasteridae* Wright, 1880).

The Miste specimens have been collected from the Aalten Member, Miste Bed, *Hiatella arctica* Acme Zone and/or base of *Astarte radiata* Acme Zone (*sensu* van den Bosch *et al.*, 1975) and are of Hemmoorian (Oxlundian) age (A.W. Janssen, 1984; A.W. Janssen & King, 1988; see also Rögl, 1990). This would correspond to the proposed global early Miocene Burdigalian Stage (Cowie & Bassett, 1989; Hinsch, 1990; Jenkins, 1990). The Polish luidiids described by Kaczmarek (1987) are apparently younger and of middle Miocene (Badenian = Langhian/Serravallian in international nomenclature; Haq & van Eysinga, 1987) age. Judging from Kaczmarek's illustrations (pl. 5) the Polish material seems best referred to a single species, instead of to two taxa.

The luidiid ossicles here described are provisionally assigned to the contemporary species, *Luidia ciliaris*. Many post-Palaeozoic asteroids are very similar to or indeed inseparable from modern species at the generic level (see discussion in Blake, 1986), and plausibly at the specific level as well,

which seems especially true for Cainozoic species. Yet, in view of the fact that the present material is insufficient to determine this form's range of variation, it is preferred to leave it in open nomenclature. Additional material from Winterswijk-Miste, and preferably from as many coeval occurrences as possible, will certainly show their exact relationship with *L. ciliaris* of which it may well be a precursor distinct at the subspecific or forma level. It belongs without any doubt to the Ciliaris Group of Döderlein (1920) as pointed out above.

Most importantly, this appears to be the stratigraphically oldest record of fossil luidiids for NW Europe. Blake (1973) described five fossil luidiid species from California (U.S.A.): a late Pliocene or early Pleistocene specimen was referred to the modern *L. foliolata* Grube, 1866; two new species, *L. ethegoiensis* Blake, 1973 and *L. sanjoaquinensis* Blake, 1973, of Pliocene and early Pleistocene age, respectively, were erected and three additional species, one of which (*Luidia* sp. A) of Miocene, the remaining of Pliocene age, were left in open nomenclature, but all assigned to the Alternata Group of Döderlein (1920). Blake (1973, p. 55) also pointed out that it might be desirable to treat the Ciliaris Group as a distinct genus, once ossicle morphology of more luidiid species were better known.

Both *Luidia* and *Astropecten* are active predators that hunt during certain periods and then bury themselves to digest prey (Clark, 1968; Lawrence, 1987; Nichols, 1966). They are found on and in unconsolidated sediment, but also on rock and shell bottoms, in shallow, turbulent environments. Amongst the paxillosidans, both *Luidia* and *Astropecten* are offensive specialists (Blake, 1988, 1989, 1990) that feed on molluscs, echinoderms and other invertebrates; the remaining families referred to the Paxillosida being small particle feeders. Deposition of the Miste Bed of the Aalten Member must have taken place in a favourable environment for astropectinids and luidiids, in view of the profuse molluscan assemblages (A.W. Janssen, 1984), and the generally varied echinoderm and other invertebrate faunas. Contemporary *Luidia ciliaris* feeds primarily on other echinoderms and, to a lesser extent, on molluscs (Brun, 1972).

Blake (1989) noted that *Astropecten* and *Luidia* are amongst the most successful of modern genera of asteroids and that their origin and adaptation to shallow, turbulent environments might have been late, considering their comparatively recent (Eocene and Miocene, respectively) first known occurrence.

FUTURE STUDIES

As stated above, the asteroid fauna from Winterswijk-Miste comprises at least nine species. Astropectinids include three or four species, two definitely assignable to *Astropecten* Gray, 1840, and possibly to the Brasiliensis Group of Döderlein, 1917, one reminiscent of *Lophidiaster* sp. aff. *L. pygmaeus* Spencer, 1913 (Rasmussen, 1972, pl. 3, figs 26, 27), and another one strongly resembling representatives of the genus *Coulonia* de Loriol, 1874 (= *Cuneaster* Hess, 1955; *Cuneaster hauteriviensis* Hess, 1955 being a junior synonym of *Coulonia neocomiensis* de Loriol, 1874; see Hess, 1970). This is a genus of astropectinids that ranges from the Early Cretaceous to the Early Eocene (see Rasmussen, 1972). A single terminal in the collection available for study resembles the ossicle referred by Kaczmarek (1987, pl. 3, fig. 2a-b) to *Astropecten granulatus* Rasmussen, 1972, a species first described from British Bartonian (Eocene) strata.

Goniasterids include a possibly new representative of *Ceramaster* Verrill, 1899 or a closely related genus. Rasmussen (1972, see also 1950) recorded three Cainozoic species of this genus, all of which differ in several details from the Miste specimens. Kutscher (1980, 1985) referred with a query dissociated marginals to one of Rasmussen's species of this genus. Another goniasterid species appears to be closely related to *Teichaster* Spencer, 1913, which Gale (1987b) synonymised with *Crateraster* Spencer, 1913. Yet another form displays a superficial resemblance to the Late Cretaceous genus *Caletaster* (Breton, 1979) and to the Late Jurassic-Miocene and Recent *Paragonaster* Sladen, 1889 (see Blake, 1973, pl. 18, figs 14-25). A few aboral ossicles are like those of *Mediaster* Stimpson, 1857, a genus that includes Cretaceous North American (Blake, 1986) and Early Miocene New Zealand representatives. The last goniasterid is characterised by a curious ornament on the marginals, which may, however, be induced by poor preservation.

It is very unfortunate that the Cainozoic strata in the North Sea Basin have not yet yielded any more or less completely preserved asteroids. Finds of remarkably well-preserved specimens of goniasterids and astropectinids as the ones Bałuk & Radwanski (1968) recorded from the early Tortonian of central Poland deserve the closest possible attention. In general, Polish occurrences of Cainozoic starfish are similar to the ones from the North Sea Basin in comprising dissociated ossicles only (see e.g.

Bałuk, 1970; Bałuk & Radwanski, 1977; Gutowski, 1984).

Future studies will hopefully comprise additional material of luidiids, in addition to extensive discussions of the species mentioned above.

ACKNOWLEDGEMENTS

I wish to extend my best thanks to Dr B.D. Blake (University of Illinois, Urbana, U.S.A.) for items of literature, for critical reading of the manuscript and for expressing his views on the material described in this paper and to Dr U. Radwanska (Uniwersytet Warszawski, Instytut Geologii Podstawowej, Warszawa) for supplying an offprint of a Polish paper. The SEM micrographs were taken by Dr M. van den Boogaard with the JEOL JSM-840A unit of Leiden University and Mrs C. Pepermans (Leiden University library) provided an item of literature; their assistance is gratefully acknowledged. Fellow members of the Werkgroep voor Tertiaire en Kwartaire Geologie (Cor Karnekamp, Nico Dekker, Wim Groeneveld, Jac Parren, André Jansen, Wim in 't Hout, Jan Boes, Bert Kokmeijer and Freek Rhebergen) are thanked for making available echinoderm material from Winterswijk-Miste. Dr P.A.M. Gacmers (Leiden) is thanked for drawing my attention to a Polish paper.

REFERENCES

- Bałuk, W., 1970. Dolny torton Niskowej kolo Nowego Sacza. — *Acta geologica polonica*, 20(1): 101-157.
- Bałuk, W., & A. Radwanski, 1968. Dolnotortonnskie piaski w Nawodzicach kolo Klimontowa, ich fauna i wykształcenie facjalne. — *Acta geologica polonica*, 18(2): 447-471.
- Bałuk, W., & A. Radwanski, 1977. Organic communities and facies development of the Korytnica basin (Middle Miocene; Holy Cross Mountains, Central Poland). — *Acta geologica polonica*, 27(2): 85-123, 6 figs, 12 pls.
- Blake, D.B., 1972. Sea star *Platasterias*: ossicle morphology and taxonomic position. — *Science*, 176: 306, 307, 2 figs.
- Blake, D.B., 1973. Ossicle morphology of some Recent asteroids and description of some West American fossil asteroids. — *University of California Publications in Geological Sciences*, 104: 1-59, 3 figs, 19 pls.
- Blake, D.B., 1982. Somasteroidea, Asteroidea, and the affinities of *Luidia* (*Platasterias*) *latiradiata*. — *Palaeontology*, 25(1): 167-191, 3 figs, 2 tabs, pls 20-22.
- Blake, D.B., 1983. Some biological controls on the distribution of shallow water sea stars (Asteroidea; Echinodermata). — *Bulletin of Marine Science*, 33(3): 703-712, 3 figs, 1 tab.
- Blake, D.B., 1986. Some new post-Paleozoic sea stars (Asteroidea: Echinodermata) and comments on taxon endurance. — *Journal of Paleontology*, 60(5): 1103-1119, 3 figs.
- Blake, D.B., 1987. A classification and phylogeny of post-Paleozoic sea stars (Asteroidea: Echinodermata). — *Journal of Natural History, London*, 21: 481-528, 13 figs.
- Blake, D.B., 1988. Paxillosidans are not primitive asteroids: A hypothesis based on functional considerations. *In*: R.D. Burke, P.V. Mladenov, P. Lambert & R.L. Parsley (eds). *Echinoderm Biology. Proceedings of the sixth international echinoderm conference, Victoria/23-28 August 1987. Rotterdam & Brookfield (A.A. Balkema): 309-314, 4 figs.*
- Blake, D.B., 1989. Asteroidea: Functional morphology, classification and phylogeny. *In*: M. Jangoux & J.M. Lawrence (eds). *Echinoderm Studies 3. Rotterdam & Brookfield (A.A. Balkema): 179-223, 3 figs, 3 tabs, pls 1-3.*
- Blake, D.B., 1990. Adaptive zones of the class Asteroidea (Echinodermata). — *Bulletin of Marine Science*, 46(3): 701-718, 3 figs, 5 tabs.
- Blake, D.B., & T.E. Guensburg, 1989. *Illusioluidia teneryi* n. gen. and sp. (Asteroidea: Echinodermata) from the Pennsylvanian of Texas, and its homeomorphy with the extant genus *Luidia* Forbes. — *Journal of Paleontology*, 63(5): 662-668, 4 figs.
- Bosch, M. van den, M.C. Cadée & A.W. Janssen, 1975. Lithostratigraphical and biostratigraphical subdivision of Tertiary deposits (Oligocene-Pliocene) in the Winterswijk-Almelo region (eastern part of the Netherlands). — *Scripta Geologica*, 29: 1-167, 37 figs, 10 tabs, 2 encl., 23 pls.
- Breton, G., 1979. Les astéries du Crétacé de Normandie. — *Bulletin de la Société géologique de Normandie et des Amis du Muséum du Havre*, 65(4)(1978): 5-87, 32 figs, pls 1-8.
- Brun, E., 1972. Food and feeding habits of *Luidia ciliaris* Echinodermata: Asteroidea. — *Journal of the Marine Biological Association of the United Kingdom*, 52: 225-236, 5 figs, pl. 1.
- Clark, A.M., 1953. Notes on asteroids in the British Museum (Natural History). III. *Luidia*. — *Bulletin of the British Museum (Natural History), Zoology*, 1: 379-396, 12 figs, pls 39-41.
- Clark, A.M., 1968. *Starfishes and their relations* (2nd edition). London (Trustees of the British Museum (Natural History), 119 pp., 30 figs.
- Clark, A.M., 1982. Notes on Atlantic Asteroidea. 2. *Luidiidae*. — *Bulletin of the British Museum (Natural History), Zoology*, 42(3): 157-184, 6 figs, 1 tab.
- Cowie, J.W., & M.G. Bassett, 1989. IUGS 1989 global stratigraphic chart. — *Episodes*, 12(2): 1 pp. (supplement).
- Döderlein, L., 1917. Die Asteriden der Siboga-Expedition. I. Die Gattung *Astropecten* und ihre Stammesgeschichte. *In*: M. Weber (ed.). *Siboga-Expedition - Uitkomsten op zoologisch, botanisch, oceanographisch en geologisch gebied verzameld in Nederlandsch Oost-Indië 1899-1900 aan boord H.M. Siboga onder commando van Luitenant ter zee 1e kl. G.F. Tydeman*, 46a: 1-192, 20 figs (A-U), pls 1-17. Leiden (E.J. Brill).
- Döderlein, L., 1920. Die Asteriden der Siboga-Expedition. II. Die Gattung *Luidia* und ihre Stammesgeschichte. *In*: M. Weber (ed.). *Siboga-Expedition - Uitkomsten op zoologisch, botanisch, oceanographisch en geologisch gebied verzameld in Nederlandsch Oost-Indië 1899-1900 aan boord H.M. Siboga onder commando van Luitenant ter zee 1e kl. G.F. Tydeman*, 46b: 193-293, 5 figs, pls 18-20. Leiden (E.J. Brill).
- Dons, C., 1937. Die Verbreitung von *Luidia ciliaris*. — *Kongelige Norske Videnskabers Selskabs Forhandling*, 9: 149-152.
- Fell, H.B., 1963. The evolution of the echinoderms. — *Annual Report of the Board of Regents of the Smithsonian Institution, Publication 4518 (1962): 457-490, 18 figs, pls 1-3.*
- Gale, A.S., 1987a. Phylogeny and classification of the Asteroidea (Echinodermata). — *Zoological Journal of the Linnean Society, London*, 89: 107-132, 10 figs, 1 tab.

- Gale, A.S., 1987b. Goniasteridae (Asteroidea, Echinodermata) from the Late Cretaceous of north-west Europe. 2. The genera *Calliderma*, *Crateraster*, *Nymphaster* and *Chomataster*. — *Mesozoic Research*, 1(4): 151-186, 6 figs, 7 pls.
- Gutowski, J., 1984. Sedimentary environment and synecology of macrobenthic assemblages of the marly sands and red-algal limestones in the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). — *Acta geologica polonica*, 34(3-4): 329-339.
- Haq, B.U., & F.W.B. van Eysinga, 1987. Geological time table. Amsterdam (Elsevier Science Publishers), 1 pp.
- Hess, H., 1955. Die fossilen Astropectiniden (Asteroidea). Neue Beobachtungen und Übersicht über die bekannten Arten. — *Schweizerische Paläontologische Abhandlungen*, 71: 1-113, 62 figs, 4 pls.
- Hess, H., 1970. Schlangensterne und Seesterne aus dem oberen Hauterivien "Pierre jaune" von St-Blaise bei Neuchâtel. — *Eclogae geologicae Helvetiae*, 63(3): 1069-1091, 16 figs, pls 1-4.
- Hinsch, W., 1990. Subdivision and palaeogeography of the Gramian and Syltian stages (Late Miocene) in Schleswig-Holstein and Wursten (NW Germany). In: J.J. Hooker (ed.). Correlation in the North Sea Basin Tertiary. RNCPS/RCNNS Thematic Issue. — *Tertiary Research*, 11(2-4): 159-177, 6 figs, 1 tab.
- Janssen, A.W., 1984. Mollusken uit het Mioceen van Winterswijk-Miste. Een inventarisatie, met beschrijvingen en afbeeldingen van alle aangetroffen soorten. Amsterdam (K.N.N.V., N.G.V., R.G.M.), 451 pp., 7 figs, 82 pls.
- Janssen, A.W., & C. King, 1988. Planktonic molluscs (Pteropods). In: R. Vinken *et al.* (eds). The Northwest European Tertiary Basin. Results of the International Geological Correlation Programme Project no. 124. — *Geologisches Jahrbuch*, (A) 100: 356-368, figs 188-207.
- Janssen, R., 1972. Beiträge zur Kenntnis der Bryozoa, Vermes, Crustacea und Echinodermata aus dem nordwestdeutschen Mittel- und Obermiozän — Veröffentlichungen aus dem Überseemuseum Bremen, (A)4(11): 71-108, 56 figs, 1 tab.
- Jenkins, D.G., 1990. Neogene stages. Letter of 18th August 1989, published in: RCNNS-RCNPS Newsletter, 4: 8.
- Kaczmarek, G., 1987. Asteroids from the Korytnica Basin (Middle Miocene; Holy Cross Mountains, Central Poland). — *Acta geologica polonica*, 37(3-4): 131-144, 3 figs, pls 1-8.
- Kutscher, M., 1980. Die Echinodermen des Oberoligozän von Sternberg. — *Zeitschrift der geologischen Wissenschaften*, 8(10): 221-239, 1 fig., 4 pls.
- Kutscher, M., 1985. Die Echinodermen des Magdeburger Grünsandes (Mittel-Oligozän). — *Abhandlungen und Berichte zur Naturkunde und Vorgeschichte (Magdeburg)*, 12(6): 3-14, 3 pls.
- Lawrence, J., 1987. A functional biology of echinoderms. London and Sydney (Croom Helm), 340 pp., figs.
- Mortensen, T., 1927[1977]. Handbook of the echinoderms of the British Isles (reprint). Rotterdam (W. Backhuys), ix + 471 pp., 269 figs.
- Müller, A.H., 1953. Die isolierten Skelettelemente der Asteroidea (Asterozoa) aus der obersten Schreibungkreide von Rügen. — *Geologie, Beiheft* 8: 1-66, 9 figs, 8 tabs, 10 pls.
- Nichols, D., 1966. Echinoderms. London (Hutchinson University Library), 200 pp., 26 figs.
- Philippi, R.A., 1837. Ueber die mit *Asterias aurantiaca* verwandten und verwechselten Asterien der Sicilianischen Küste. — *Archiv der Natur*, 3(1): 193, 194.
- Rakusz, J., 1927. Asteroiden der älteren Mediterran-Stufe aus der Umgebung von Salgótarján. — *Földtani Közlöny*, 56: 191-195, 1 pl.
- Rasmussen, H.W., 1950. An Oligocene asteroid from Denmark. — *Meddelelser fra danske geologiske Forening*, 11(5): 588, 589, 1 fig.
- Rasmussen, H.W., 1972. Lower Tertiary Crinoidea, Asteroidea, and Ophiuroidea from northern Europe and Greenland. — *Det Kongelige Danske Videnskabernes Selskab, Biologiske Skrifter*, 19(7): 1-83, 3 figs, 14 pls.
- Rodriguez, J., 1980. Echinoderms (except Holothuroidea) of the Southern Mediterranean coast of Spain. In: M. Jangoux (ed.). Echinoderms: Present and Past. Proceedings of the European Colloquium on Echinoderms, Brussels/3-8 September 1979: 127-131, 1 fig. Rotterdam (A.A. Balkema).
- Rögl, F., 1990. Das nordwesteuropäische Tertiär - zum erfolgreichen Abschluss des IGCP Projektes No. 124. — *Geologicky Zbornik-Geologica Carpathica*, 41(5): 575-584, 7 tabs.
- Spencer, W.K., & C.W. Wright, 1966. Asterozoans. In: R.C. Moore (ed.). Treatise on Invertebrate Paleontology, Part U, Echinodermata 3(1): U 4-U 107, figs 1-89. Boulder and Lawrence (The Geological Society of America and University of Kansas Press).
- Tortonese, E., 1980. Review of present status of knowledge of the Mediterranean Echinoderms. In: M. Jangoux (ed.). Echinoderms: Present and Past. Proceedings of the European Colloquium on Echinoderms, Brussels/3-8 September 1979: 141-149. Rotterdam (A.A. Balkema).

PLATE 1

Dissociated ossicles of *Luidia* sp. aff. *ciliaris* (Philippi, 1837) from temporary exposure at Winterswijk-Miste. Early Miocene (Hemmoorian, Pteropod Zone 18 of Janssen & King, 1988), Breda Formation, Aalten Member, Miste Bed (van den Bosch *et al.*, 1975). All specimens illustrated have been deposited in the collections of the Nationaal Natuurhistorisch Museum at Leiden (formerly: Rijksmuseum van Geologie en Mineralogie), RGM registration numbers (leg. J.W.M. Jagt):

- Figs 1, 2. right adambulacral, oblique distal and oblique lateral views, respectively, RGM 383 547, x 22 and x 26, respectively.
- Fig. 3. left adambulacral, oblique proximal view, RGM 383 548, x 21.
- Figs 4-6. right ambulacral, oral, and two lateral views, respectively, RGM 383 549, x 18.
- Figs 7, 8. left ambulacral, aboral and oblique lateral view, respectively, RGM 383 550, x 26.
- Figs 9-11. right inferomarginal, oral, oblique distal view and detail of spine base, respectively, RGM 383 551, x 23 and *c.* 50, respectively.
- Figs 12, 13. right inferomarginal, oral and proximal view, respectively, RGM 383 552, x 18.
- Fig. 14. left inferomarginal, distal view, RGM 383 553, x 16.
- Figs 15, 16. right inferomarginal, oral and proximal view, respectively, RGM 383 554, x 16.

PLATE 1

