H. WIENBERG RASMUSSEN

LOWER TERTIARY CRINOIDEA, ASTEROIDEA AND OPHIUROIDEA FROM NORTHERN EUROPE AND GREENLAND

Det Kongelige Danske Videnskabernes Selskab
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CONTENTS

Synopsis

Crinoids, asteroids and ophiuroids are common in the Danian but very seldom in the succeeding Paleocene, Eocene and Oligocene sediments. A review of the species found in northern Europe and Greenland is given. The following species are new to science: *Calamocrinus ilimanangei*, *Amphorometra ornata*, *Astropecten granulatus*, *Lophidiaster haunsbergensis*, *Lophidiaster inversus*, *Lophidiaster concavus*, *Ceramaster obtusus*, *Echinaster jacobseni*, *Ophiurae achatae*, *Ophiura furiae*, *Ophiura bognoriensis*, *Ophiura costata*, *Ophiura davisi*, *Ophiura carpelloides*, *Ophiura bartonensis* and *Ophiocoma hessi*.

A redefinition of the genus *Cainocrinus* is given.

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Age and distribution of fauna

The Danian

The Danian originally was established as the uppermost Cretaceous, but is now generally referred to the lowermost Tertiary as a stage, or as a substage of the Paleocene.

The Danian sediments in Denmark, Belgium and the Netherlands contain a rich fauna of crinoids, asteroids and ophiuroids previously described (Rasmussen 1950, 1952, 1961, 1965). There is no new information.

Danian crinoids have been incorrectly recorded from England (Peck 1955). There are however no Danian deposits in England. The specimens belong to *Styracocrinus peracutus* found in the Albian to Cenomanian. They are found in "chalk detritus" near Charing in Kent. The sample is composed of mixed fragments of white and grey chalk redeposited in fluvial gravel of Pleistocene age. No fossil indicating a Danian age of the components has been found (Rasmussen 1961 p. 384).

From borings through the Upper Maastrichtian or Danian of Pulawy in central Poland Maryańska & Popiel-Barczyk (1969) described remains of the following ophiuroids from presumed Danian sediments: *Ophiura hagenowi*, Rasmussen, 1950, *Ophiomusium subcylindricum* (Hagenow, 1840), *Ophiomusium danicum* Nielsen, 1926, and *Asteronyx ornatus* Rasmussen, 1950. They further recorded the remains of *Astropecten* sp., *Chomataster* sp. cfr. *acules* Spencer, 1913, *Teichaster* sp., *Bourgueticrinus* sp. and *Pentacrinus* sp. The ophiuroids described indicate that Danian as well as Upper Maastrichtian may be present in the samples.

In a sample from the presumed Danian at Boryszew in central Poland I have found a few columnals similar to the Lower Eocene *Cainocrinus tintinnabulum* Forbes, 1852, a few columnals of *Bourgueticrinus* sp. or *Democrinus* sp. and marginals of *Astropecten* cfr. *postornatus* (Rasmussen, 1945) and a few badly preserved marginals of *Chomataster?* sp. and *Teichaster?* sp.

From the Danian near Vienna in Austria Kühn (1930 & 1960) described a *Cyathidium* sp. and recorded the presence of *Isselicrinus paucicirrhus* (Nielsen, 1913), *Metopaster* sp. and presumed ophiuroid remains.

Two small samples, each about 300 g, collected by Professor A. Rosenkrantz in the Danian limesand 2 km ESE of Haidhof, north of Vienna in Austria, have been washed and echinoderm remains picked out. The samples contain several brachials and columnals of crinoids, marginals of asteroids, and arm plates and vertebrae of

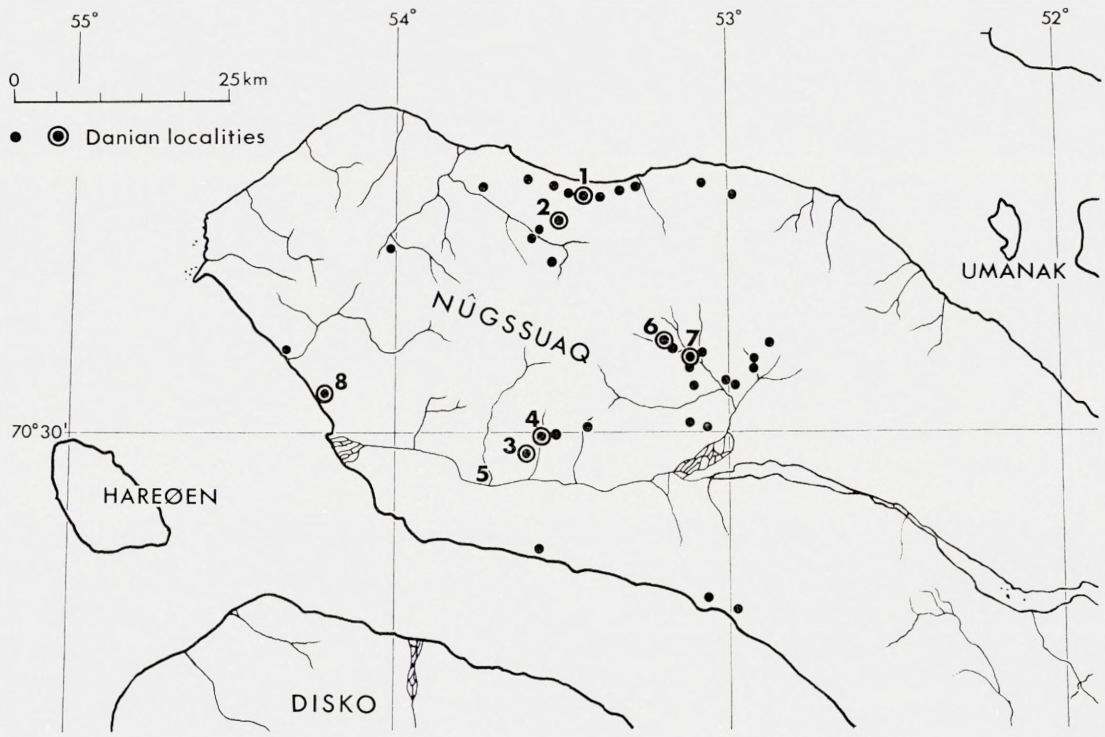

Fig. 1. Nûgssuaq in West Greenland. Danian localities with echinoderms mentioned in the text. Lower Danian Kangilia Formation: 1, Kangilia. 2, Tunorssuaq. 3, Solemyakløft. 4, Ilugigsoq. 5, Auvfarssuaq. 6, Turritellakløft. Upper Danian Agatdal Formation: 6, Turritellakløft. 7, Agatdal. 8, Marrait kitdlît.

ophiuroids. The following species are identified: *Nielsenicrinus fionicus* (Nielsen, 1913), *Bourgueticrinus* cfr. *danicus* Nielsen, 1913, *Lophidiaster punctatus* Nielsen, 1943, *Teichaster retiformis* Spencer, 1913, *Ophiomusium danicum* Nielsen, 1926, *Ophiacantha danica* Rasmussen, 1951, *Ophiura serrata* Roemer, 1840, and *Asteronyx* sp. All these species are known also from the Danian of Denmark.

From the Danian of Nûgssuaq in West Greenland the crinoid *Isselicrinus groenlandicus* was described by Rasmussen (1961) and a preliminary record of the crinoids and asteroids collected during the Nûgssuaq expeditions by Professor Rosenkrantz and his collaborators was given by Rasmussen in Rosenkrantz (1970). A more detailed study of the Danian species from Nûgssuaq has given the following results:

In the Lower Danian Kangilia Formation only *Isselicrinus groenlandicus* is found. In the Upper Danian Agatdal Formation the following crinoids, asteroids and ophiuroids are found: *Isselicrinus* aff. *paucicirrhus* (Nielsen, 1913), *Calamocrinus ilimanangei* n.sp., *Astropecten postornatus* (Rasmussen, 1945), *Teichaster retiformis* Spencer, 1913, *Ceramaster obtusus* n.sp. and *Ophiura achatae* n.sp. The presence of two Upper Danian species in common with Denmark supports the age determination of the Agatdal Formation and is a remarkable faunal resemblance between Denmark and Greenland in the Danian.

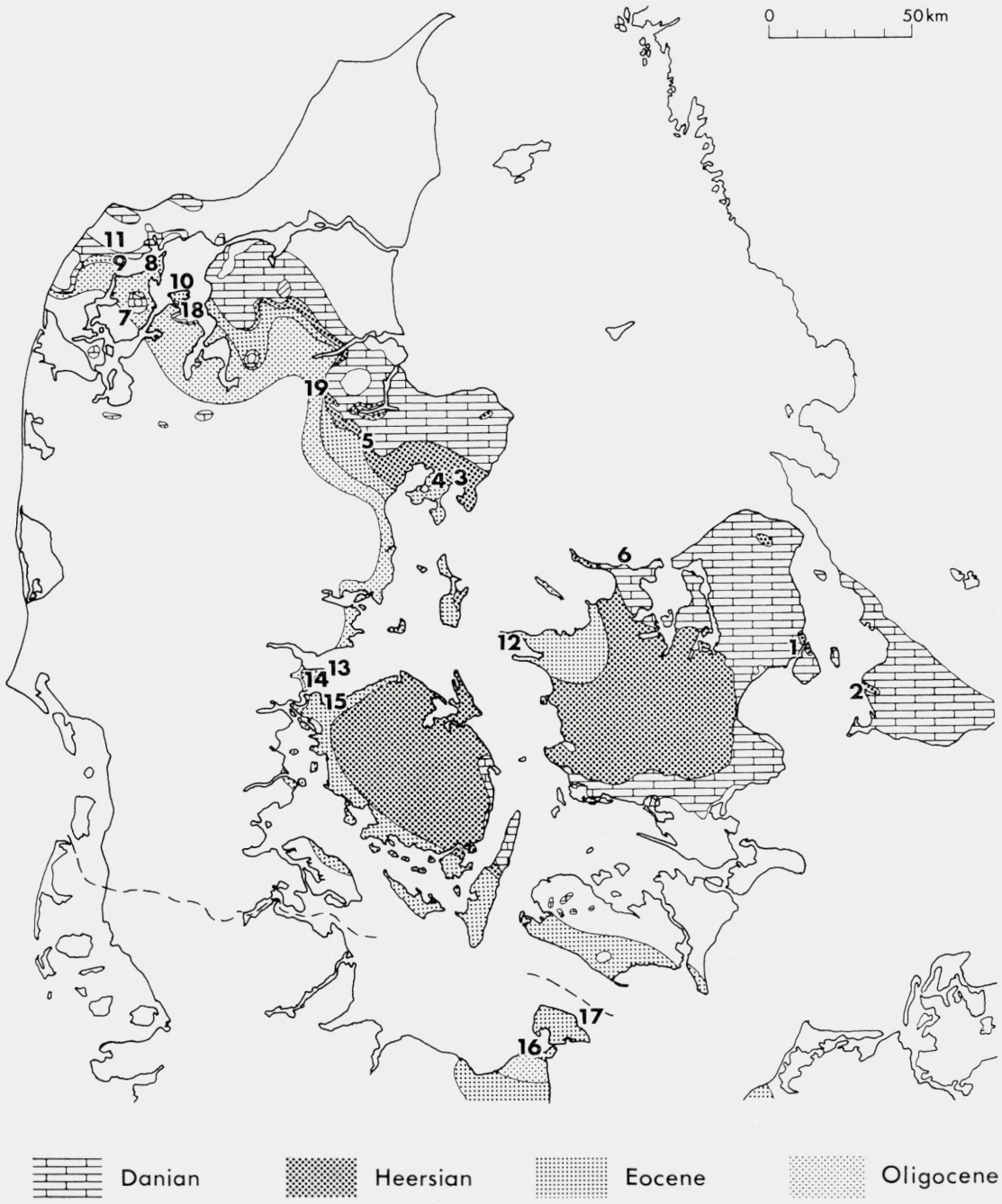

Fig. 2. Lower Tertiary localities in Denmark, South Sweden and northernmost Germany. Heersian: 1, Copenhagen. 2, Klagshamn. 3, Egsmark. 4, Basballe. 5, Hvalløse. 6, Klintebjerg. Ypresian Mo-Clay Formation: 7, Isle of Mors. 8, Skærbæk Cliff. 9, Silstrup Cliff. 10, Isle of Fur. 11, Thy. Ypresian Rösnäs Formation: 12, Ulstrup at Rösnäs. 13, Trelde Næs at Lillebælt. 14, Fredericia. 15, Röjle Cliff. 16, Heiligenhafen. 17, Isle of Fehmern. Middle Oligocene (Rupelian) Branden Clay: 18, Branden. 19, Faarup.

The Paleocene

The Danian may be classified as Lower Paleocene. The remaining Paleocene is represented in Denmark by the Selandian greensand and marl with the Lellinge Formation (Heersian) and the Kerteminde Formation (presumably Landenian).

Crinoids, asteroids and ophiuroids are common in the basal conglomerate at Svanemøllen, Vestre Gasværk and other localities in Copenhagen and at Hvalløse in Jutland, Denmark. They belong to Danian species and have been derived from the Danian together with numerous other Upper Danian fossils. They have previously been described in connection with the Danian.

From the Heersian Lellinge Formation of Egsmark and Basballe near Ebeltoft in Denmark are a few remains of crinoids. In these localities the basal conglomerate is not exposed and there is not observed any derived Danian fossils in the rich fauna of molluscs and foraminifera. It is therefore concluded that the echinoderms found here did survive into the Heersian, in spite of the fact that they belong to the most common species in the Danian. At these localities *Isselicrinus paucicirrhus* (Nielsen, 1913), *Bourgueticrinus danicus* Nielsen, 1913, and *Democrinus maximus* (Nielsen, 1915) are found. A column of the Upper Danian *Nielsenicrinus obsoletus* (Nielsen, 1913) is found in erratics of the Heersian Lellinge Formation at Klintebjerg by Mr. P. Graversen.

No crinoids, asteroids or ophiuroids are found in the Kerteminde Formation.

In South Sweden minor remains of Paleocene sediments are found in Klagshamn and a few other places. The sediments consist of a basal conglomerate over the Danian limestone and a few meters of glauconitic sand and marl belonging to the Heersian. They are rich in derived Danian fossils including crinoids and asteroids previously recorded.

From the true Montian Calcaire grossier de Mons, described by Cornet & Briart (1865) no echinoderms are recorded, and the sediment has not been exposed for many years. In a very small sample from Mons in the Museum of Brussels a few marginals of Teichaster sp. and Astropecten sp. are observed.

From the Paleocene glauconitic marl at Haunsberg north of Salzburg in Austria Traub (1938) has recorded a *Pentacrinus* sp., here referred to *Isselicrinus subbasaltiformis* (Miller, 1821). This specimen may well belong to the Lower Eocene. In samples collected by Professor A. Rosenkrantz at Kroisbach in the same area and belonging to the Upper Paleocene (Landenian) zone with *Globigerina velascoensis*, the following species are found: Columnals of *Bourgueticrinus* sp. or *Democrinus* sp., marginals of *Lophidiaster haunsbergensis*, n. sp., *Lophidiaster inversus* n. sp., *Lophidiaster* aff. *pygmaeus* Spencer, 1913, and *Teichaster lamberti* Valette, 1925, and a lateral arm plate of *Amphiura senonensis* Valette, 1915.

In samples of glauconitic sand from the Sochaczew boring in central Poland referred to the early Paleocene are several columnals of a crinoid similar to *Cainocrinus tintinnabulum* Forbes, 1852. A few columnals of the same species are found in samples from the underlaying bed referred by Pozaryska (1965) to the Danian.

The British Paleocene consists of the marine Thanet Beds and the partly marine Woolwich Beds and Reeding Beds, all correlated with the Landenian. No echinoderms are found.

The Lower Eocene

The Lower Eocene (Ypresian) is represented in Denmark by the Mo-Clay Formation and the Tuff-Clay Formation succeeded by the Rösnäs Formation.

The Mo-Clay Formation is a marine diatomaceous sediment with some clay and about 200 thin beds of volcanic tuff. Its distribution is restricted to the north-western areas of Denmark around the sound of Limfjorden. The Mo-Clay Formation contains several impressions and a few better preserved specimens of *Ophiura furiae* n.sp. and a few impressions of two asteroids, *Coulonia colei* (Forbes, 1852) and *Echinaster jacobseni* n.sp.

The Tuff-Clay Formation found in other areas with Lower Eocene sediments in Denmark is contemporary with the Mo-Clay Formation and contains the same tuff beds in a marine clay with very few fossils. No echinoderms are found.

The Rösnäs Formation is a very fine-grained, sticky clay of illite and montmorillonite, generally deep red in colour. It succeeds the Tuff-Clay Formation without interruption in the sedimentation. The Rösnäs Formation contains several specimens of the crinoid *Isselicrinus subbasaltiformis* in a few places, specially near Fredericia. The fossils are presumably restricted to a zone in the lower part of the formation. Two specimens of an asteroid, *Teichaster stokesii* (Forbes, 1848) are found in the same area. The fossils are generally preserved in pyrite and liable to decomposition. They have all been found on the beach where the clay is exposed.

In North Germany the Lower Eocene Tuff-Clay Formation and Rösnäs Formation are found with similar sediments as in Denmark. They are recorded as Eocene 1 and Eocene 2–3. There is no distinct limit between Eocene 2 and Eocene 3. Several columnals of *Isselicrinus subbasaltiformis* are found in the clay and referred by Gripp (1964) to Eocene 2.

Much new information on British Eocene echinoderms has been obtained by a review of the collections in the British Museum and the Geological Survey, London, and specially by a study of new large collections made by Mr. Bones, Mr. Rundle and Mr. Cooper, and by sorting of old samples collected by Mr. Davis.

The British Lower Eocene consists of the Oldhaven Beds (= Blackheath Beds) succeeded by the London Clay, Claygate Beds, Bagshot Sands and Lower Bracklesham Beds. The London Clay in the London area is subdivided by Wrigley (1924) into Basement Bed and divisions 1–5, and in Bognor Regis by Venables (1963) into Lower, Middle and Upper Clay. The fauna collected along the cliffs on the Island of Sheppey seems, according to Davis (1936), derived from the middle or upper part of the London Clay, corresponding presumably to division 4 of the London Clay or to division 5 in a less sandy facies of stiff clay.

In the Oldhaven Beds are found several well preserved impressions of an ophiuroid here referred to *Ophiura wetherelli* Forbes, 1852.

The London Clay is correlated with the Rösnäs Formation in Denmark and the Eocene 2–3 in North Germany. Volcanic tuff beds probably corresponding to the

Mo-Clay and Tuff Clay Formation in Denmark and the Eocene 1 in North Germany have recently been found by Elliot (1971) 6–7 m above the base of the London Clay at Harwich. The London Clay is locally rich in fossils, including echinoderms described by Forbes (1848, 1849, 1852). The following crinoids, asteroids and ophiuroids are found: *Isselicrinus subbasaltiformis* (Miller, 1821): London area, division 2. *Cainocrinus tintinnabulum* Forbes, 1852: London area, division 2–4, and Bognor Regis, Middle and Upper Clay. *Democrinus londinensis* (Forbes, 1852): London area, division 2–4, and Isle of Sheppey. *Amphorometra ornata* n.sp.: London area, division 2–3. *Lophidiaster concavus* n.sp.: London area, division 2–3. *Coulonia colei* (Forbes, 1852): London area, division 5, and Isle of Sheppey. *Hippasteria tuberculata* (Forbes, 1852): Isle of Sheppey. *Teichaster stokesii* (Forbes, 1848): Isle of Sheppey, and London area, division 2. *Ophiura bognoriensis* n.sp.: Bognor Regis, Lower Clay. *Ophiura wetherelli* Forbes, 1852: London area, Basement Bed and division 2–5, and Bognor Regis, Middle Clay.

From the Lower Bracklesham Beds at Whitecliff Bay in Sussex, the presence of rare and indeterminable asteroid marginals is recorded by Wrigley & Davis (1937).

The Middle Eocene

The Middle Eocene (Lutetian and Auversian) is apparently represented in Denmark by the Lillebælt Formation of clay similar to the Rösnäs Formation but generally greenish grey and non-calcareous. Fossils are extremely rare, and no echinoderms are found.

In North Germany this sequence is recorded as Eocene 4. No echinoderms are recorded.

In England the upper part of Lower Bracklesham Beds is referred to the Lutetian and the Upper Bracklesham Beds to the Auversian. In the Upper Bracklesham Beds are found several ossicles of *Ophiura bartonensis* n.sp. and some well preserved marginals of *Astropecten granulatus* n.sp.

From Belgium the ophiuroid *Stegophiura eocaenus* (Leriche, 1931) was described from a boulder of "Panisélien" sandstone. The stratigraphical age is recorded as uppermost Ypresian or lower part of Lutetian.

The Upper Eocene

The Upper Eocene (Bartonian) is represented in Denmark by the Søvind Marl. The corresponding clay in North Germany is recorded as Eocene 5. No echinoderms are found.

In England the Barton Beds of sandy clay and fine sands at Highcliff in Hampshire contain well preserved marginals of *Astropecten granulatus* n.sp., an ophiuroid previously referred to *Ophiura wetherelli*, but here described as *Ophiura bartonensis* n.sp. and a few arm fragments of *Ophiocoma hessi* n.sp. In a sample from the Middle Barton Beds (horizon E of Burton 1929) are found several remains of *Ophiura bartonensis*,

Fig. 3. British Eocene localities with echinoderms mentioned in the text. 1, Highcliff and Barton Cliff. 2, Bramshaw. 3, Fawley. 4, Whitecliff Bay. 5, Bracklesham Bay. 6, Selsey Bill. 7, Bognor Regis. 8, Herne Bay. 9, Isle of Sheppey and Warden Point. 10, Sheerness. 11, Friendsburg Extra, Upnor. 12, Clacton. 13, Frinton and Walton-on-the-Naze. 14, Harwich. 15, Oxshott. 16, Talworth. 17, Worchester Park. 18, New Malden. 19, Richmond. 20, Beddington. 21, Waddon. 22, Balham. 23, Clapham South. 24. Battersea. 25, Clapham. 26, Stockwell. 27, Brixton. 28, Elmstead. 29, Poyle. 30, Stanwell. 31. Northwood. 32, Brentford. 33, Kenton. 34, Kensington. 35, Cromwell Road. 36, Imperial College. 37, Besborough Gardens. 38, St. James. 39, U. Thames Street. 40, London Wall. 41, The Minories. 42, Trinity. 43, Bond Street. 44, Baker Street. 45, Islington, Caledonian Road and Copenhagen Fields. 46, Kingsbury. 47, Primrose Hill. 48, Chalk Farm. 49, Haverstock Hill. 50, Hendon. 51, Hampstead Heath. 52, Highgate. 53, Hornsey. 54, Finchley. 55, Cockfoster. 56, Seawardstone. 57, Aveley.

	Isselicrinus groenlandicus	I. pauciciirrhus	I. aff. pauciciirrhus	I. subbasaltiformis	Doreckicrinus convexus	D. miliaris	Cainocrinus tintinnabulum	C.? aff. tintinnabulum	Nielseniicrinus fionicus	N. obsoletus	Isocrinus campanularis	I. divergens	I. echinatus	I. longus	Calamocrinus ilimanangei	Bourgueticrinus danicus	B. bruennichimielseni	Bathycrinus windi	Democrinus gisleni	D. maximus	D. londinensis	Monachocrinus regnelli	M. aff. regnelli
Chattian, Germany																							
Ruppelian, Germany																							
–, Denmark																							
Lattorfian																							
Bartonian, England																							
Auversian, England																							
Lutetian, France																					x		
Ypresian-Lutetian, Belgium																							
Ypresian, Sheppey Island																					x		
–, Bognor Regis, M.-U. Clay							x														?		
–, Bognor Regis, L. Clay																							
–, London Clay, div. 5																							
–, London Clay, div. 4							x														x		
–, London Clay, div. 3							x														x		
–, London Clay, div. 2				x			x														x		
–, London Clay, Basement																							
–, Germany, Eocene 2				x																			
–, Denmark, Rösnäs Clay				x																			
–, Denmark, Mo-Clay																							
Landenian, Austria				?																			
–, Vincentown, U.S.A.																	x						
Heersian, Denmark		x								x						x				x			
Heersian?, Poland								x															
Danian?, Poland								x															
Danian, Austria		x							x							?							
U.-, Netherland Belgium										x										x			
M.-, Netherland Belgium																x				x			
L.-, Netherland Belgium																x				x			
U.-, Greenland			x												x								
L.-, Greenland	x																						
U.-, Denmark Sweden		x			x				x	x	x	x	x	x		x	x	x	x	x		x	
M.-, Denmark Sweden		x			x				x			x	x			x				x		x	x
L.-, Denmark Sweden		x			x	x			x		x	x	x			x	x	x		x		x	
Maastrichtian or older																	x		x			x	

(continued)

	Cyathidium holopus	Jaekelometra faxensis	Amphorometra bruennichi	A. semiglobularis	A. ornata	Bruennichometra danica	B. granulata	B. parvicava	Himerometra grippae	Palaeocomaster angelini	Hertha mystica	H. plana	Placometra laticirra	Astropecten postornatus	A. granulatus	A.? beyrichi	Coulonia colei	Lophidiaster punctatus	L. haunsbergensis	L. inversus	L. concavus	L. aff. pygmaeus	Hippasteria tuberculata
Chattian, Germany									x														
Ruppelian, Germany																x							
–, Denmark																							
Lattorfian																							
Bartonian, England															x								
Auversian, England															x								
Lutetian, France																?							
Ypresian-Lutetian, Belgium																							
Ypresian, Sheppey Island																	x						x
–, Bognor Regis, M.-U. Clay																							
–, Bognor Regis, L. Clay																							
–, London Clay, div. 5																	x						
–, London Clay, div. 4																							
–, London Clay, div. 3					x																x		
–, London Clay, div. 2					x																x		
–, London Clay, Basement																							
–, Germany, Eocene 2																							
–, Denmark, Rösnäs Clay																							
–, Denmark, Mo-Clay																	x						
Landenian, Austria																			x	x		x	
–, Vincentown, U.S.A.																							
Heersian, Denmark																							
Heersian?, Poland																							
Danian?, Poland														?									
Danian, Austria	x																	x					
U.-, Netherland Belgium																							
M.-, Netherland Belgium																							
L.-, Netherland Belgium																							
U.-, Greenland														x									
L.-, Greenland																							
U.-, Denmark Sweden			x	x			x			x	x	x	x	x				x					
M.-, Denmark Sweden	x	x	x	x		x	x				x	x						x					
L.-, Denmark Sweden				x				x			x	x	x					x					
Maastrichtian or older	x									x	x	x	x										

(continued)

	Teichaster anchylus	T. retiformis	T. lamberti	T. stokesi	Metopaster kagstrupensis	M. spenceri	M. elevatus	M. planus	M. carinatus	M. maculatus	Ceramaster dividuus	C. granulatus	C. obtusus	C. rabii	C. brandenensis	Recurvaster mammillatus	Stauranderaster miliaris	S. pyramidalis	S. speculum	Valettaster ocellatus	V. granulatus	Pycinaster danicus
Chattian, Germany																						
Ruppelian, Germany														x								
–, Denmark															x							
Lattorfian																						
Bartonian, England																						
Auversian, England																						
Lutetian, France			x																			
Ypresian-Lutetian, Belgium																						
Ypresian, Sheppey Island				x																		
–, Bognor Regis, M.-U. Clay																						
–, Bognor Regis, L. Clay																						
–, London Clay, div. 5																						
–, London Clay, div. 4																						
–, London Clay, div. 3																						
–, London Clay, div. 2				x																		
–, London Clay, Basement																						
–, Germany, Eocene 2																						
–, Denmark, Rösnäs Clay				x																		
–, Denmark, Mo-Clay																						
Landenian, Austria			x																			
–, Vincentown, U.S.A.																x						
Heersian, Denmark																						
Heersian?, Poland																						
Danian?, Poland																						
Danian, Austria		x																				
U.-, Netherland Belgium																						
M.-, Netherland Belgium												x										
L.-, Netherland Belgium					x	x			x								x				x	
U.-, Greenland		x											x									
L.-, Greenland																						
U.-, Denmark Sweden		x						x	x		x					x	x		x	x	x	x
M.-, Denmark Sweden		x					x	x		x		x				x	x	x	x	x	x	x
L.-, Denmark Sweden	x				x	x		x								x	x	x	x	x	x	
Maastrichtian or older																				x		

(continued)

	P. cornutus	P. rosenkrantzi	Chomataster acules	Echinaster jacobseni	Amphiura senonensis	Ophiomusium danicum	O. subcylindricum	Ophiacantha danica	Ophiocoma hessi	Ophiura serrata	O. hagenowi	O. achatae	O. furiae	O. wetherelli	O. bognoriensis	O. bartonensis	O. davisi	O. carpelloides	O. costata	Stegophiura eocaenus	Asteronyx ornatus	A. sp.
Chattian, Germany																						
Ruppelian, Germany																						
–, Denmark																						
Lattorfian																						
Bartonian, England									x							x	x	x	x			
Auversian, England																x						
Lutetian, France																						
Ypresian-Lutetian, Belgium																				x		
Ypresian, Sheppey Island														?								
–, Bognor Regis, M.-U. Clay														x								
–, Bognor Regis, L. Clay															x							
–, London Clay, div. 5														x								
–, London Clay, div. 4														x								
–, London Clay, div. 3																						
–, London Clay, div. 2														x								
–, London Clay, Basement														x								
–, Germany, Eocene 2																						
–, Denmark, Rösnäs Clay																						
–, Denmark, Mo-Clay				x									x									
Landenian, Austria					x																	
–, Vincentown, U.S.A.					x	x																
Heersian, Denmark																						
Heersian?, Poland																						
Danian?, Poland			?			x	x				x										x	
Danian, Austria						x		x		x												x
U.-, Netherland Belgium																						
M.-, Netherland Belgium										x												
L.-, Netherland Belgium			x																			
U.-, Greenland												x										
L.-, Greenland																						
U.-, Denmark Sweden	x	x	x		x	x		x		x												x
M.-, Denmark Sweden			x					x		x												x
L.-, Denmark Sweden			x		x			x		x	x											x
Maastrichtian or older			x		x		x	x		x	x										x	

Ophiura davisi n.sp., *Ophiura carpelloides* n.sp. and a few remains of *Ophiura costata* n.sp. According to Linstow (1912) a specimen of *Astropecten crispatus* from the Bartonian of Barton in Hampshire is preserved in the collection of Berlin.

Isolated marginals of asteroids are recorded by Linstow (1912) from the Eocene of Hammer, Götzreuther and Rollgraben near Traunstein in Bavaria, Germany.

The Oligocene

In Denmark the Lower Oligocene (Lattorfian) is missing. The Middle Oligocene (Rupelian) is represented by the Branden Clay and the Upper Oligocene (Chattian) by the Cilleborg Clay. A single asteroid, *Ceramaster brandenensis* Rasmussen, 1951, is described from the Branden Clay.

In North Germany the Lower Oligocene is very poor in fossils, and no echinoderms are described. From the Middle Oligocene Septarienton at Mark (Westfalen) Linstow (1912) has described two asteroids, *Goniaster (Goniodiscus) rabii*, here referred to *Ceramaster*, and *Astropecten (?Pentaceros) beyrichi*. The comatulid *Himerometra grippae* is described by Anderson (1967) from the Upper Oligocene Grafenberger Sand near Moers in Niederrhein, Germany.

Asterias propinqua Münster is a nomen nudum introduced by Münster (1835 p. 434) for some undescribed asteroid remains from the Upper Oligocene at Bünde (Westfalen). Philippi (1843) referred marginals from the Upper Oligocene of Freden, Dickholzen and Luithorst (Hannover) to the same species.

Speyer (1864) described asteroid marginals from the Middle Oligocene of Söllingen near Jerxheim (Braunschweig) as *Asterias (Stellaster)* sp. with strongly arched marginals and with irregularly scattered spine pits and slightly concave joint faces.

Several isolated marginals of Tertiary asteroids in German museums are recorded by Linstow (1912) from the Lower Oligocene of Lattorf near Bernburg (Sachsen), Vardeilsen near Einbeck (Hannover), Brandhorst near Bünde (Westfalen), from the Middle Oligocene of Söllingen (Braunschweig), Magdeburg (Sachsen), Kawelwich (Pommern), and from the Upper Oligocene of Astrup near Osnabrück (Hannover), Bünde near Herford (Westfalen), Kassel (Hessen), Krefeld (Nordrhein-Westfalen), Thalsbergsgraben near Siegsdorf and Freden (Hannover). The specimens from the Lower Oligocene of Lattorf are recorded under the name of *Goniaster intistinchus* Semper, a nomen nudum taken from the label of the specimen in the collection.

Hucke and Voigt (1929) recorded the presence of *Ceramaster rabii* in the Middle Oligocene of Steutz (Anhalt) and the remains of *Antedon* and columnals of *Rhizocrinus* in the Middle Oligocene of Joachimsthal (Uckermark, Brandenburg), Germany.

Crinoidea

Isselicrinus groenlandicus Rasmussen, 1961

1961 *Isselicrinus groenlandicus*.—Rasmussen p. 58 pl. 6 fig. 1–5.
1970 *Isselicrinus groenlandicus* Rasmussen.—Rasmussen in Rosenkrantz p. 427.
1970 *Isselicrinus*.—Rasmussen in Rosenkrantz p. 429 (non p. 426, 435).

Isselicrinus from the Maastrichtian and Danian in Greenland

Specimens of *Isselicrinus* are present in the Maastrichtian and Danian of Nûgssuaq in West Greenland, but only specimens from the Lower Danian Kangilia Formation belong to the present species. No other crinoid is found in the Lower Danian of Greenland. Three columns of *Isselicrinus* from the Maastrichtian of Agatdal in Nûgssuaq are referred to *I. buchii* (Roemer, 1840), and columnals from the Upper Danian Agatdal Formation of Nûgssuaq are referred to *Isselicrinus* aff. *paucicirrhus* (Nielsen, 1913).

Material

From the Thyasira Member of the Lower Danian Kangilia Formation at Kangilia are found 26 fragments of columns including the holotype and specimens previously figured.

From the Propeamussium Member of the Lower Danian Kangilia Formation are found 6 fragments of columns at Tunorssuaq, 1 at Solemyakløft, 1 at Ilugigsoq, 1 in a boulder at the southern side of Turritellakløft and 1 in a boulder from Auvfarssuaq near Quvnilik. The specimens are in the collection of the Geological Museum, Copenhagen.

Isselicrinus paucicirrhus (Nielsen, 1913)

1913 *Pentacrinus paucicirrhus*.—Nielsen p. 81 figs. 9, 10, 24, pl. 6 figs. 39–52, pl. 7 figs. 1–26.
1913 *Pentacrinus crassus*.—Nielsen p. 84 fig. 29, pl. 7 figs. 27–53. (non Desor 1845).
1913 *Pentacrinus Rejstrupianus*.—Nielsen p. 94 fig. 21, pl. 9 figs. 32–36.
1913 *Pentacrinus Kagstrupianus*.—Nielsen p. 96 fig. 22, pl. 9 figs. 37–41.
1960 *Balanocrinus paucicirrhus* (Nielsen).—Kuehn p. 163.
1961 *Isselicrinus paucicirrhus* (Nielsen).—Rasmussen p. 61 pl. 5 figs. 1–14.

Previous record

This species has previously been described in details from the Danian. It is a dominant species in the Danian of Denmark and Sweden, and is also recorded from the Danian of Austria.

Material

About 10 columns of *I. paucicirrhus* are found as impressions in the Paleocene (Heersian) glauconitic marl of the Lellinge Formation at Basballe and Egsmark near Ebeltoft in Denmark. At these two localities the basal conglomerate of the Paleocene

is not exposed and there is no indication of derived Danian fossils. It is therefore presumed, that the species did occur in the Heersian fauna. 3 columns are found in erratics of the Lellinge Formation at Klintebjerg near Nykøbing (Sealand) in Denmark. The specimens from the Heersian agree with previous descriptions of the species from the Danian and show no new or uncommon features. The specimens are in the collection of the Geological Museum, Copenhagen.

Isselicrinus aff. **paucicirrhus** (Nielsen, 1913)

Plate 1 fig. 1.

1970 *Isselicrinus*.—Rasmussen in Rosenkrantz p. 435.

The specimens here described from the Upper Danian of Nûgssuaq in West Greenland appear intermediate between *I. paucicirrhus* and *I. subbasaltiformis*.

Material

From the Sonja Member of the Upper Danian Agatdal Formation are fragments of 10 columns at Agatdal in Nûgssuaq. From the Turritellakløft Member of the Agatdal Formation are fragments of 1 column at Turritellakløft in Nûgssuaq. The specimens are in the collection of the Geological Museum, Copenhagen.

Dimensions

	Nr. 1	2	3	4	5	fig.	7	8
Interradius	0.9	1.4	1.5	1.5	2.2	2.2	2.3	2.5
Radius	0.7	1.3	1.4	1.5	1.8	1.9	2.4	2.5
Nodal height	–	–	–	–	–	1.4	–	–
Internodal height	1.0	1.6–1.7	1.1–1.2	1.6–1.8	1.0–1.3	1.0–1.2	1.8	1.4–1.5
Marginal crenellae	6	6	6	10	10	10	10	–

Description

The column is smooth, pentalobate to cylindrical up to 5 mm in diameter. There is a small alternation in height of columnals. The outline is less lobate than in the majority of specimens from Denmark, and there is no alternation in outline or radial furrows on the surface of some columnals as seen in most specimens from Denmark. The height of columnals is as in the Danish specimens or slightly less.

The articular surface shows a gradual transition of crenellae from marginal to adradial position, and the crenellae reach their maximum length near the transition. The number of crenellae along the margin is as in Danish specimens or slightly greater. There is generally a small, smooth radial area outside the crenellae. The suture is slightly crenulate and there is no radial pore.

Isselicrinus subbasaltiformis (Miller, 1821)

Plate 1 figs. 2–5, plate 11 fig. 1.

1821 *Pentacrinus subbasaltiformis.*—Miller p. 142.
1837 *Pentacrinus subbasaltiformis* Miller.—Wetherell p. 136 pl. 8 fig. 3a (non fig. 3b).
1837 *Pentacrinus sowerbii.*—Wetherell p. 136 pl. 8 fig. 4.
1852 *Pentacrinus subbasaltiformis* Miller.—Forbes p. 34 pl. 4 figs. 8–10.
1852 *Pentacrinus sowerbii* Wetherell.—Forbes p. 35 fig. 2.
1852 *Pentacrinus cingulatus* Münster.—Schafhäutl pp. 151, 167.
1863 *Pentacrinus cingulatus* Münster.—Schafhäutl p. 110 pl. 15 fig. 6.
1865 *Pentacrinus subbasaltiformis* Miller.—Gümbel pp. 140, 170.
1900 *Pentacrinus subbasaltiformis* Miller.—Stolley pp. 110, 133.
1902 *Pentacrinus subbasaltiformis* Miller.—Stolley p. 17.
1906 *Pentacrinus subbasaltiformis* Miller.—Gagel pp. 317, 320.
1917 *Balanocrinus subbasaltiformis* (Miller).—Bather pp. 397–404 figs. 6–7.
1924 *Balanocrinus subbasaltiformis* (Miller).—Wrigley pp. 251, 254.
1928 *Balanocrinus subbasaltiformis* (Miller).—Davis pp. 339, 340, 347, 349.
1936 *Balanocrinus subbasaltiformis* (Miller).—Davis p. 333.
1938 *Pentacrinus* sp.—Traub p. 39.
1940 *Balanocrinus subbasaltiformis* (Miller).—Wrigley pp. 235, 240.
1944 *Balanocrinus subbasaltiformis* (Miller).—Sieverts-Doreck pp. 141–152 figs. 1–4.
1945 *Balanocrinus sub-basaltiformis* (Miller).—Wrigley p. 217.
1961 *Isselicrinus subbasaltiformis* (Miller).—Rasmussen p. 46.
1964 *Isselicrinus subbasaltiformis* (Miller).—Gripp pp. 86, 87, 355.

Synonym

P. sowerbii Wetherell, 1837, is the proximal part of a column belonging to the present species.

Type

The columns studied by Miller (1821) and the column figured by Wetherell (1837, pl. 8 fig. 3a) are not identified in the collections. The column nr. 57540 in the collection of the British Museum was therefore selected by Bather (1917) as lectotype. It is from the Lower Eocene (Ypresian) London Clay of Hampstead Heath, London. This specimen is among those on which the description by Wetherell (1837) was based. It has not previously been figured, but is shown here pl. 1 fig. 2.

The type specimen of *Pentacrinus sowerbii* figured by Wetherell (1837) pl. 8 fig. 4 from the London Clay of Hampstead Heath, London, is in the collection of the British Museum (E 5888). It is, as demonstrated by Bather (1917), the proximal part of the column of *I. subbasaltiformis.*

Material

This species is recorded from the London Clay as common and characteristic to division 2, 15–30 m above the basement of the London Clay (Wrigley 1924, 1945, Davis 1928, 1936). Two specimens have been recorded from sediments older than the London Clay, but both must be taken with reservation:

In the collection of München (nr. 1943 II. 33) is a column recorded by Traub (1938 p. 39) as *Pentacrinus* sp. from the Upper Paleocene of the old quarry north-east of St. Pankraz near Salzburg. The column is a typical *I. subbasaltiformis*. It shall be remarked, however, that the profile in the quarry reaches from the Upper Paleocene (Landenian) to the upper part of the Lower Eocene (Upper Ypresian).

In the collection of the Geological Survey, London, is a column (nr. 44807) recorded by Sieverts-Doreck (1944) from the Blackheath Beds (Lower Ypresian or "Sparnacian") of the Elmstead Tunnel near Bromley, Kent. It shall be remarked, however, that the London Clay immediately overlies the Blackheath Beds in the railway cutting, and the preservation in pyrite corresponds to fossils from the London Clay, not from the Blackheath Beds (Mr. Rundle, personal communication).

All other British specimens of which the zone is known are from the lower part of the London Clay (division 2 of Wrigley 1924) or from localities where this zone has been exposed. They are found in the London area, Essex, Middlesex, Surrey and Kent. The species is not found in the cliffs of Sheppey Island or in the Hampshire basin. A large number of columns and columnals are preserved in British collections and recorded by Bather (1917), Sieverts-Doreck (1944) and Wrigley (1940).

The specimen figured by Wetherell (1837) pl. 8 fig. 3b as a cirrus of *P. subbasaltiformis* from the London Clay of Hampstead Heath in London is in the collection of the British Museum (57539). It is, as demonstrated by Bather (1917), the column of *Cainocrinus tintinnabulum*.

In the collection of the British Museum is also a single specimen (E 25023) with theca, arms and a few columnals from the London Clay of Herne Bay, Kent in England. The specimen is described and figured by Sieverts-Doreck (1944).

In North Germany the species is recorded by Gagel (1906), Sieverts-Doreck (1944) and Gripp (1964) from the Lower Eocene clay (Ypresian) of Fehmern, Johannistal near Heiligenhafen and Luisenberg near Kellinghusen in Schleswig-Holstein, from Hemmoor in Hannover and Pisede near Malchin in Mecklenburg. Several specimens from Fehmern and Johannistal are in the collections of Kiel and Copenhagen. The North German specimens are preserved in pyrite. Some are found in erratic boulders, but most specimens are washed out on the coast along cliffs with Eocene clay and referred by Gripp (1964) to the Eocene 2, equivalent to the London Clay.

Columns from the Eocene of Kressenberg in southern Bavaria, Germany, have been referred by Schafhäutl (1852, 1863) to the Jurassic species *Pentacrinus cingulatus*, and by Gümbel (1865) to *P. didactylus* or *P. subbasaltiformis*.

In Denmark several columns preserved in pyrite are found along the coasts of Lillebælt, where the Lower Eocene Rösnäs Formation is exposed. Most of the specimens are found north of Fredericia, but a single column at Røjle Klint. Other columns are found in the Rösnäs Formation near Ulstrup at Rösnäs. A theca with arms and a few proximal columnals preserved in pyrite is found north of Fredericia by Mr. C. Heilmann-Clausen. The Danish specimens are in the collection of the Geological Museum, Copenhagen.

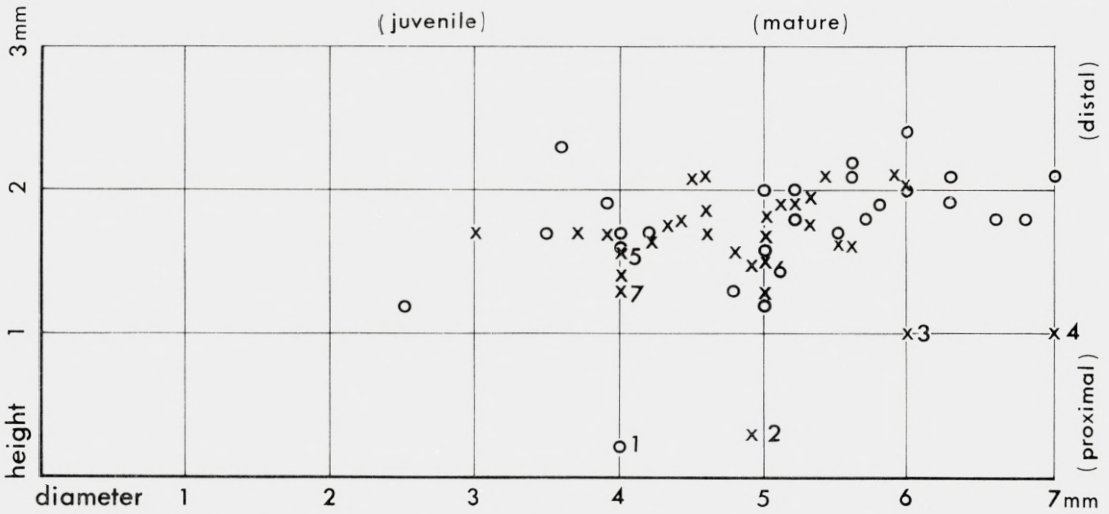

Fig. 4. Columnals of Isselicrinus subbasaltiformis. Mean height and diameter of internodals in the specimens. 1, proximal columnals connected to the theca from Denmark. 2, proximal columnals connected to the theca from England. 3–4, P. sowerbii figured by Forbes. 5–7, P. subbasaltiformis figured by Forbes.

○ columns from Denmark.
× columns from England.

Growth and variation of the column

The most proximal columnals seen in connection with the two thecae are deep pentalobate or stellate with extremely low columnals and alternating height. The majority of columnals, however, are subpentagonal to subcircular in section with a height of 1.5–2.5 mm and a diameter of 3–7 mm. There is a gradual morphologic transition from low stellate columnals with alternating height through pentalobate columnals with alternating height to the dominant type of subpentagonal or cylindric columnals with almost uniform height. These forms represent the change from proximal to distal part of the column known in several genera of Isocrinidae. The height of columnals, the alternation in height and the outline depend only on the position within the column, not on the age or size of the animal.

The diameter of the columnals varies from 3 to 7 mm and is independent of their height and form. This indicates that the diameter has been almost uniform in the entire length of the column, dependent mainly on the age and size of the animal, not on the proximal or distal position of the fragment studied. The height and diameter of columnals are therefore not correlated to a single growth function and do not follow a regression line in bivariate analysis.

A study of the variation in specimens from Denmark, North Germany and England indicates that only one species is represented. The type specimen of *P. sowerbii* is a proximal part of the column in a large individual.

Variation in theca and arms

The theca and arms have been known only in a single specimen from the London Clay described and figured by Sieverts-Doreck (1944) and included by her in the diagnosis of the species. The theca with arms now found in Denmark in a similar preservation differs in several details of the arm ramification and also shows differences between the single arms. Only the features common to the two specimens are therefore maintained in the present diagnosis.

There are 2 primibrachials in each arm. I Br 1–2 and II Br 1–2 are synostosial. It was indicated by Sieverts-Doreck, that also succeeding axillaries have a synostoic articulation with the preceeding brachial, but a control has shown, that this articulation is oblique muscular in the British as well as in the Danish specimen. All the brachial articulations except I Br 1–2 and II Br 1–2 are muscular with a regular alternation in the orientation of the articular ridge. There are no third axillaries in the Danish specimen. The first pinnule is seen on the abaxial side of II Br 2, and pinules are placed on alternating side of all succeeding brachials except the axillaries. The number of brachials within each section of the arm shows considerable variation. The ramification of the arms and the number of brachials in each section is shown in a diagram of the British and the Danish specimen.

Ramification of arms in the British specimen:

I Br 2
- II Br 12
  - III Br 11
    - IV Br 7...
    - IV Br 11..
  - III Br 9...
- II Br 14
  - III Br 2 (+3 reg)
  - III Br 3...

I Br 2
- II Br 7...
- II Br 12
  - III Br 12
    - IV Br 5...
    - IV Br 4 (+12 reg)
  - III Br 10
    - IV Br 7...
    - IV Br 8...

I Br 2
- II Br 13
  - III Br 5 (+10 reg)
    - IV Br ...
    - IV Br 3...
  - III Br 8
    - IV Br 26
    - IV Br 21
- II Br 11
  - III Br 9 (+10 reg)
  - III Br ...

Ramification of arms in the Danish specimen:

I Br 2 { II Br 12 { III Br 3 (+ ca. 15 partly covered)
III Br 16...
II Br 11 { III Br 3...
III Br 3...

I Br 2 { II Br 2...
II Br 3...

I Br 2 { II Br 4...
II Br 3...

I Br 2 { II Br 13 { III Br
III Br 10...
II Br 12 { III Br 2...
III Br 2...

I Br 2 { II Br 10 { III Br 16...
III Br 17...
II Br 8 { III Br 21...
III Br 22...

Description

An *Isselicrinus* of moderate size with a low bowl-shaped theca and a smooth surface. The basals are fairly large but surrounded by the radial ring and only just visible in the interradius around the top of the column. The radials are large, almost horizontal with a slightly arched free surface and an outward sloping, almost vertical articular surface for the brachials. There are 2 primibrachials and 8–14 secundibrachials. The number of tertibrachials is 8 or more, and further isotomous branching may occur. Synostosial articulations are found in I Br 1–2 and II Br 1–2. All other articulations are muscular. Pinnules are found on the abaxial side of II Br 2 and on alternating sides of all succeeding brachials except the axillaries.

The proximal part of the column is pentalobate and the columnals here are low with a tumid surface and with alternating height and tumidity. The distal part of the column is rounded subpentagonal to circular in section with cylindric, almost uniform columnals. The diameter is from 3 to 6 mm and the height from 1.7 to 2.3 mm.

The length of an internode may attain 29 internodals. The nodals are slightly higher than the internodals and have 1–4 small, elliptical cirrus sockets at the lower edge, pointing oblique downwards. In most nodals 2 cirri are found.

The articulation between columnals shows a pattern of five petals surrounded by crenellae. There is generally a gradual transition of crenellae along the periphery and radius, and the crenellae near the periphery form an oblique angle with the radius,

also in specimens with a rather distinct separation of marginal and adradial crenellae. The number of crenellae along the periphery does not exceed 8 in each of the five lobes of the columnal. The suture is generally straight, seldom undulate except in the interradial area of proximal columnals. The articulation between nodal and infranodal shows a similar or slightly less distinct pattern, and the crenellae may fork near the edge.

Affinity

I. subbasaltiformis differs from the Eocene *I. didactylus* (d'Archiac, 1846) from South Europe in the smaller size of columnals. The articular surface of columnals shows in most specimens a more gradual transition of crenellae from marginal to adradial area and a smaller number of crenellae along the margin. Furthermore a granulation of the surface is never found in the columnals.

The species is more similar in size and form of the columnals to *I. buchii* (Roemer, 1840) from the Maastrichtian, and in size and articular surface of the columnals to *I. paucicirrhus* (Nielsen, 1913) from the Danian. Both of these species have almost smooth articulation between nodal and infranodal and a larger number of crenellae along the margin. Furthermore in *I. buchii* the adradial crenellae are small and perpendicular to the radius, and in *I. paucicirrhus* most columnals are pentalobate, often with sharp radial furrows except on the largest internodals, and the suture is often undulating.

Stratigraphy

I. subbasaltiformis seems a useful index fossil to the Middle Ypresian in North Europe. British specimens are common about 15–30 m above the base of the London Clay (Wrigley division 2). German specimens are found close above the tuff-bearing Eocene 1 and are referred by Gripp to Eocene 2. The stratigraphic level of two specimens from a presumed lower level than the London Clay is uncertain.

Cainocrinus tintinnabulum Forbes, 1852.

Plate 2 figs. 1–20.

1837 *Pentacrinus subbasaltiformis* Miller.—Sowerby in Wetherell p. 136 pl. 8 fig. 3.
1852 *Cainocrinus tintinnabulum*.—Forbes p. 33 figs. 1–5.
1852 *Pentacrinus oakeshottianus*.—Forbes p. 35 fig. 3.
1917 *Cainocrinus tintinnabulum* Forbes.—Bather p. 405.
1930 *Cainocrinus? tintinnabulum* Forbes.—Biese p. 716.
1940 *Pentacrinus oakeshottianus* Forbes.—Wrigley pp. 235, 238, 240.
1945 *Isocrinus oakeshottianus* (Forbes).—Wrigley p. 217.
1963 *Cainocrinus tintinnabulum* Forbes.—Venables pp. 253, 255, 258, 263.
1970 *Cainocrinus tintinnabulum* Forbes.—Rundle & Cooper p. 123.

Type

The theca with primibranchials and a proximal part of the column figured by Forbes (1852) p. 33 figs. 1–2 is holotype. It is from the London Clay (Ypresian) of

Hornsey in London and referred to division 3 of the London Clay (Wrigley). The specimen is in the collection of the Geological Survey, London (99793–99794).

The holotype of *Pentacrinus oakeshottianus* is the specimen figured by Forbes (1852) p. 36 fig. 3 from Primrose Hill near Chalk Farm in London. It belongs to division 3 of the London Clay. The specimen is in the collection of the British Museum (57546).

Material

This species has been recorded by Forbes (1852) from the London Clay of Hornsey (division 3) and Copenhagen House (division 2). *P. oakeshottianus* was recorded from near Chalk Farm (division 3). Wrigley (1940, 1945) has recorded *Isocrinus oakeshottianus (= tintinnabulum)* from Stanwell Reservoir and between Stockwell and Clapham South stations (division 2 or 3). Venables (1963) has recorded the species from Bognor Regis in Sussex, where it is found in the Middle Clay (Beetle Bed and Upper Fish Tooth Bed) and more common in the Upper Clay (Pholadomya Bed and Cainocrinus Bed). Rundle & Cooper (1970) have recorded the species from Trans-World Hotel site, Cromwell Road in London (division 2).

In the collection of the British Museum are several specimens from the London Clay: A column (57539) from Hampstead Heath (division 2) including 2 nodals separated by 15 internodals figured by Sowerby (in Wetherell 1837 pl. 8 fig. 3b) as a cirrus of *P. subbasaltiformis*, corrected by Bather (1917 p. 405). A theca with primibrachials in pyrite (E 25992) from the Fish Tooth Bed (Middle Clay) of Bognor Regis. A theca and several fragments of columns from the London Clay (division 3) of Staines (E 50358–66). Isolated fragments of columns from the London Clay (division 3) of Haverstock Hill (E 49830) and near Chalk Farm (57545–6), from the London Clay (division 3 or 4) of Worchester Park (E 25921–41, 50406–17), from the London Clay (division 4 or 5) of Highgate (E 430), and from the Upper Clay, Pholadomya Bed of Bognor Regis (E 50375–405).

In the collection of the Geological Survey are columns from the London Clay (division 3) of Hornsey (Zc 4066–4075).

A very large number of specimens has been washed out of the Middle Clay, Craigweil Bed at Bognor Regis in Sussex by Mr. D. A. Bone, who found recently a horizon very rich in these echinoderms. A part of this collection was given by Mr. Rundle and Mr. Cooper to the Geological Museum in Copenhagen. This collection includes several complete thecae with primibranchials and parts of the column, single thecae, and numerous fragments from all parts of the column, theca and arms as well as single ossicles. Mr. Bone's collection contains 91 thecae and numerous fragments and isolated remains from this horizon. In the collection of Rundle and Cooper are also an incomplete theca and a few other remains of the same species from the London Clay (division 3) of Wraysbury Reservoir at Poyle in Buckinghamshire, England.

Diagnosis

A small crinoid belonging to the Isocrinidae. The column is pentalobate and smooth with rounded interradial edges, often with a tubercle. Interradius of column

generally about 1.2 mm, height of internodals slightly alternating about 0.8 mm. The suture is undulating, and the edge along the suture may be slightly protruding. Length of internodes often 7 internodals. Articulation between nodal and infranodal almost smooth, cryptosymplectial. Other articulations in the column show five petals of crenellae as in *Isocrinus*. Nodals with 5 cirri. The theca is almost hemispheric with smooth surface. The sutures are entrenched in the lower part of theca. The basals form a contiguous ring, somewhat lobate and with short, rostrate median prolongations downward covering the edges of the uppermost columnal. I Br 1–2 is synostosial. I Br 2 axillary. II Br 1–2 synarthrial. II Br 3–4 symmorphial. II Br 4 axillary. III Br 2–3 symmorphial. Other brachial articulations are muscular. First pinnule is on the abaxial side of II Br 2.

Description

The reconstruction and description of the species is based mainly on the large collection from the Craigweil Bed of Bognor Regis. The theca is small, almost hemispherical. Height of theca about 2.8 mm. Height of free surface 2.0 mm. Diameter 3.6 mm. The surface of theca is smooth. There are 5 radials, 5 basals and 5 infrabasals. The small infrabasals are surrounded by the basals, but are seen as a five-rayed star when the radials or the column is removed. Each infrabasal is rod-shaped with a rhombic section.

The basals are seen on the surface of the theca as a complete ring of five-sided plates, slightly wider than high. The basal ring is somewhat lobate in outline with constricted sutures. The lower edge forms a more or less prominent, beak-shaped projection downwards, covering the interradial edges of the uppermost columnal. The joint face against the uppermost columnal is provided with crenellae corresponding to the petaloid pattern of crenellae in the columnals. The surface against the radial ring is roof-shaped, forming two joint faces, and there are two small and narrow faces against the infrabasals. The two nerve canals are seen in the inner end of the basal, running from the radial joint face through the basal to the upper part of the infrabasal joint face. In contrast to other Isocrinidae with infrabasals the nerve canals do not meet and unite inside the basal, although the openings towards the infrabasals almost touch each other. The small surface of infrabasals and basals towards the narrow thecal cavity shows irregular furrows.

The radials are seen on the surface of theca as five-sided plates, almost twice as high and wide as the basals. The outline of the radial ring is almost circular. The articular surface of the radials against primibrachials is outward sloping. It has a deep, concave dorsal ligament fossa and a straight articular ridge. There is a deep median furrow between the ventral muscular fossae. The nerves have formed a ring canal and canals to the basals. There is a narrow radial cavity.

The first primibrachial has a four-sided surface, a little lower than the radial and more curved in the distal than in the proximal end. There is a triangular lateral surface against the neighbouring arm. The proximal articular face is steep, the ventral muscular

fossae almost reaching the distal end of the plate. The distal articular face is flat and smooth corresponding to a synostosial articulation in I Br 1–2. The second primibrachial is axillary. There is a low lateral surface. The two muscular distal articulations meet in an angle of 90°–110°.

II Br 1 is wedge-shaped, higher in the abaxial side. The free surface is slightly curved and there is a flat lateral surface on the abaxial side. Both proximal and distal articular surface are outward sloping and there is no pinnule. The distal articular surface has a prominent median ridge corresponding to a synarthrial articulation in II Br 1–2. II Br 2 has a pinnular socket on the abaxial side. The articulation II Br 2–3 is muscular with the dorsal ligament to the abaxial side. There is no pinnule in II Br 3. The articulation II Br 3–4 is symmorphial with a fairly shallow transverse furrow in the distal face of II Br 3. II Br 4 is axillary. The proximal articular face is symmorphial with a pair of lateral teeth united by a transverse ridge and interlocking with II Br 3. There are often faint crenellae along the dorsal edge. The two distal articulations form an angle of 80°–105°.

III Br 1 is wedge-shaped with a pinnular socket on the abaxial side. The articulation III Br 1–2 is oblique muscular. III Br 2–3 is symmorphial. There is no pinnule on III Br 2, but on the abaxial side of III Br 3. III Br 2 is thus very similar to II Br 3, but is more deep and narrow, and the symmorphial surface is more deeply excavated. The succeeding III Br 4–9 are all wedge-shaped with muscular articulations in both ends and with pinnules alternating adaxial and abaxial. These brachials gradually become more slender, long and rounded.

More distal parts of the arms cannot be correlated to exact number in the succession of brachials, but it is seen that further symmorphy occurs, since there are arm fragments with 4 muscular articulations succeeded by a symmorphy and again 4 muscular articulations or more. Further axillaries are not observed. There are about 125 I Br 2 and a similar number of II Br 4 picked out of the sample. Even considering a collecting failure due to small size, there would be more than 100 third axillaries in the sample if a third arm division occurred. The most distal arm fragments are very slender with long, conical brachials, wider in the distal than in the proximal end. This gives a serrate profile to the distal part of the arms. In these brachials the ventral furrow is very narrow. A single symmorphy was found.

The pinnules consist of long and slender pinnulars. The most proximal pinnular has an almost flat surface, but succeeding pinnulars have a more elliptical section with a rather sharp dorsal edge.

The hour-glass shaped opening of the axial canal in I Br 1–2 and the double opening in II Br 3–4 demonstrate a division of the axial nerve from the base of the first axial plate and before entering the second axial plate. Such features have not been previously observed in any crinoid.

The proximal columnals are low, pentalobate or almost stellate with five concave sides and strongly alternating size. The more distal part of the column is pentalobate with concave sides and rounded interradial edges. The edges often form protruding

nodules in some or all columnals of a specimen. The height of the columnals is half the diameter or less. The edge along the suture may be slightly protruding. The sutures undulate corresponding to the crenellae of the articular face. The nodals have five elliptical cirrus sockets on the radial surface near the lower edge. The articulation between nodal and infranodal is almost smooth or has faint crenellae along the margin. The other articulations of the column show a petaloid ornament of crenellae with 5 elliptic petals and 6–8 crenellae along each, 2–4 of which are adradial and do not reach the margin. The crenellae attain their greatest length at the transition from marginal to adradial position.

In the collection of the British Museum a full internode is observed in 2 specimens including 15 and 11 internodals. In the sample from Bognor Regis the number of internodals in a full internode was 9 in 7 specimens, 8 in 10 specimens, 7 in 77 specimens, 6 in 4 specimens and 5 in a proximal fragment of the column. In the most proximal part of the column attached to the theca the number of internodals seen in succeeding internodes was found in one specimen to be 1, 1, 1, 1, 3, 4, and in another specimen 1, 1, 3, 3, 7. The columnals in these specimens are strongly alternating in size.

The cirrals are elliptical in section. They have a transverse articular ridge and a smooth surface. The proximal 6 cirrals are short, width exceeding their length and height. The distal cirrals are long, slender, higher than wide.

Affinity

The present species is remarkable by its small size. No other species of similar size is present in the Eocene except for *P. oakeshottianus*, which seems to be synonymous with the present species. The only other Isocrinidae found in the British Eocene belong to *Isselicrinus*, which differs specially in the form of the nodals. The column of *C. tintinnabulum* is rather similar to the Lower Cretaceous *Isocrinus neocomiensis* (Desor, 1845) but has no sharp interradial edges. The ramification and articulations of the arms differ from other Isocrinidae.

The genus **Cainocrinus** *Forbes*, 1852

Type

Cainocrinus tintinnabulum Forbes, 1852, is type of the genus.

History

The genus *Cainocrinus* was established by Forbes (1852) with *C. tintinnabulum* as type and only species recorded. It was characterised as having a contiguous basal ring.

Loriol (1875) established the genus *Picteticrinus* with the type *P. beaugrandi* Loriol, 1875. In 1877 he stated that the generic name was preoccupied by Étallon and that *Picteticrinus* sensu Loriol is identical with *Cainocrinus* Forbes, having the same diagnostic character of the basal ring.

Carpenter (1884) has demonstrated a considerable variation in the size of basals and the form of the basal ring among recent Isocrinidae and rejected any classificatory value of such characters. For this reason Bather (1898) made *Cainocrinus* a junior synonym of *Isocrinus*.

Biese (1930) in obvious disagreement with the international code of zoological nomenclature transferred the generic name *Cainocrinus* to *P. beaugrandi* Loriol, 1873, making this species type of the genus. *P. beaugrandi* is thus the type of two illegitimate genera, *Picticrinus* Loriol non Étallon and *Cainocrinus* sensu Biese non Forbes. The illegitimate genus "*Cainocrinus*" sensu Biese was characterised by irregular arm divisions and based on the irregularity found in one of the arms in the single specimen referred by Biese to the genus.

Redefinition of the genus Cainocrinus Forbes, 1852

The subdivision of Isocrinidae is based on the pattern of ramification in the arms and articulations in column and arms. The type of *Cainocrinus*, *C. tintinnabulum* Forbes has hitherto been insufficiently known for an adequate definition of the genus comparable with other genera of Isocrinidae, but through the collection and investigation of new material described above, it is now possible to give an exhaustive diagnosis.

Cainocrinus is a genus of Isocrinidae in which the articulations of columnals show 5 petals of distinct crenellae and a gradual transition from marginal to adradial crenellae. The nodals have 5 cirri, circular to elliptical in section. Infrabasals present but not exposed. The articulation I Br 1–2 is flat and smooth, synostosial. I Br 2 is axillary. II Br 1–2 is synarthrial. First pinnule is abaxial on II Br 2. II Br 2–3 is muscular. II Br 3–4 is symmorphial. II Br 4 is axillary. Second pinnule is abaxial on III Br 1. III Br 1–2 is muscular. III Br 2–3 symmorphial. Most succeeding brachials are muscular, but symmorphy does occur. There is no further arm divisions.

Isocrinus (?Cainocrinus) sp. aff. **C. tintinnabulum** Forbes, 1852

Plate 2 figs. 21–22.

Material

Pozaryska (1965) has described a boring at Sochaczew in central Poland 60 km west of Warsaw, passing through beds of glauconitic sand referred to the presumed Montian Pulawy Beds (191–262 m) and the presumed Danian Sochaczew Beds (262–266 m). In washed samples from the Pulawy Beds are found 69 internodals and 10 nodals of this crinoid. In samples of the Sochaczew Beds are found 5 internodals and 2 nodals of the same species. The specimens are in the collection of the geological institute of Warsaw.

Description

The columnals are very similar to the Lower Eocene *Cainocrinus tintinnabulum* in size and form. They are pentalobate to stellate in outline. Height and interradius

about 1 mm or less. The free surface of the columnals have a low and blunt median ridge or elevation and a slightly protruding edge along the undulating suture. The interradial edges may be gently rounded or form blunt longitudinal ridges. Articulation between internodals with 2–3 crenellae along the periphery on each side of the petals and in some columnals a short one to the radius. Articulation between nodal and infranodal is synostosial. Nodals with 5 elliptical cirrus sockets.

Age of samples

The samples are referred by Pozaryska (1965) to the Danian and to the Montian on a basis of Foraminifera, and by Voigt (1964) to the "Dano-Montian" on a basis of Bryozoa. In the absence of the most characteristic Danian and early Paleocene index fossils, the exact age determination should be taken with some reservation.

Nielsenicrinus fionicus (Nielsen, 1913)

1913 *Pentacrinus fionicus*.—Nielsen pp. 76, 90, pl. 8 figs. 41–54, pl. 9 figs. 4–7, textfig. 30.
1961 *Nielsenicrinus fionicus* (Nielsen).—Rasmussen p. 103, pl. 14 figs. 1–11.

Material

Material from the Danian of Denmark and Sweden has previously been described. In two small samples of Danian limesand collected at 2 km ESE of Haidhof, north of Vienna in Austria 10 small internodals and 2 nodals of this species are found. The specimens are in the collection of the Geological Museum, Copenhagen.

Calamocrinus ilimanangei n. sp.

Plate 1 figs. 6–7.

Derivation of name

Ilimanange (Eskimo) the unexpected (or better than expected). Also an Eskimo nickname for Professor A. Rosenkrantz during the expeditions in Greenland.

Holotype

The specimen plate 1 fig. 6 is holotype. It is from the Sonja Member of the Upper Danian Agatdal Formation of Agatdal in Nûgssuaq, West Greenland. The specimen is in the collection of the Geological Museum, Copenhagen (12756).

Material

In the collections of the Geological Museum, Copenhagen are 3 small fragments of columns collected by A. Rosenkrantz among the many thousands of fossils washed out of a loose sandstone ("the Sonja lens") from the type locality. Two of the specimens are slightly curved and their length therefore different in the two sides of the specimens. The area around the axial canal is more or less corroded, specially in the largest specimen, where also the crenellae are rather indistinct.

Dimensions

		holotype	
Number of internodals	6	6	13
Diameter	1.3	2.0	2.6
Height of specimen	1.2–1.6	1.6	3.6–4.4
Number of crenellae	28	36	–

Diagnosis

A crinoid with a slender column, circular in outline, straight or slightly curved. Diameter of column 1.3–2.6 mm. Columnals very low, uniform without nodals or cirri in the preserved specimens. Height of columnals 0.2–0.3 mm. Articular face of columnals with numerous straight, uniform, undivided and evenly spaced radiating crenellae reaching from the margin almost to the axial canal. Central area of articular face slightly concave, wihtout crenellae. Axial canal pentagonal, about 0.3–0.6 mm in diameter. Suture crenulate.

Determination of genus and affinity of Hyocrinidae

The columnals of the present species correspond in form to the much larger columnals found in Millericrinidae but are not similar to small or juvenile columnals of Millericrinidae. The Millericrinidae belong to the Jurassic except for a few specimens found in the Lower Cretaceous. Radiating crenellae are also found in some Cyrtocrinidae, but these have high columnals and few crenellae. No fossil crinoid known is similar to the present species.

Among living crinoids radiating crenellae are found only in the columnals of *Proisocrinus* and among Hyocrinidae, both unknown as fossils.

Proisocrinus was described by Clark (1910) and referred to Apiocrinidae or Pentacrinidae. It was interpreted as a possible intermediate form in the evolution from *Millericrinus* d'Orbigny, 1840, to Pentacrinidae (Isocrinidae). The column of *Proisocrinus* is almost 1 m long and 5–11 mm in diameter. The proximal fourth of the column is pentalobate and has nodals alternating with internodes of increasing length downwards. The median part of the column is cylindrical with uniform columnals, 5 mm in diameter and 1.5 mm high with 15 stout, radiating crenellae on the articular face. There are few nodals. The distal part of the column is similar in form, but the diameter gradually increases to 11 mm and the height of columnals to 4 mm. Even in the median part of the column, which best compares with the present species, the columnals are considerably larger and higher and the crenellae are few and larger. Moreover columnals resembling the proximal and distal part of the column are not found in Greenland. The structure of theca and column in *Proisocrinus* indicates, that this genus should be referred to the Holocrinidae.

Hyocrinidae was established as a family by Carpenter (1884). It is an isolated group of recent crinoids without close relation to other living crinoids except perhaps *Proisocrinus*, but with resemblance to early Mesozoic Millericrinida such as the Tri-

assic *Reocarocrinus* Gislén, 1924, and *Dadocrinus* Meyer, 1847. No fossil Hyocrinidae have been described.

The affinity of Hyocrinidae has been discussed since the first species of *Hyocrinus* was described by W. Thomson (1876) and compared with the recent *Rhizocrinus* Sars, 1864 and with Paleozoic Camarata such as *Platycrinus* Agassiz, 1836, and *Dichocrinus* Münster, 1839. Zittel (1882) placed *Hyocrinus* together with the Jurassic *Plicatocrinus* Münster, 1839, in a family Plicatocrinidae. Carpenter (1884) removed *Hyocrinus* from Plicatocrinidae and established the family Hyocrinidae. Jaekel (1892) considered *Hyocrinus* and *Saccocoma* closely related to Plicatocrinidae and descendants from the Palaeozoic Cyathocrinidae (Inadunata). Agassiz (1890, 1892) described the recent genus *Calamocrinus*, which he considered most closely allied to Mesozoic *Encrinus* and Apiocrinidae including by that time *Millericrinus* and in the conception of Agassiz also *Bourgueticrinus* and *Rhizocrinus*. Bather (1900) and Jaekel (1918) retained *Calamocrinus* closely allied to *Apiocrinus* and *Millericrinus*, but *Hyocrinus*, *Plicatocrinus* and *Saccocoma* were placed by Bather in his Monocyclica Inadunata and by Jaekel in his Costata. Clark (1912) united *Calamocrinus* with *Hyocrinus* and related genera in the Hyocrinidae.

In a review of the Hyocrinidae Gislén (1939) considered this family related to Eudesicrinidae, a Jurassic family of Cyrtocrinida, but not directly descendant from this group.

The Cyrtocrinida including among others the Jurassic *Plicatocrinus* and *Eudesicrinus* and the recent *Holopus*, is a group specially adapted to reef-environments. The Hyocrinidae is a recent group of deep-sea crinoids. These two groups show similartities in the form of the column, the absence of cirri, the reduced or fused basal ring and the large radial cavity. The common ancestor of these groups and perhaps also *Proisocrinus* may be Triassic Millericrinida such as *Reocarocrinus* or *Dadocrinus*.

Among the Hyocrinidae only the type of *Calamocrinus*, *C. diomedae* Agassiz, 1890, is closely similar to the present species in size, form and articular surface of the columnals. It differs from the fossil species in a generally distinct median ridge on the columnals. *Calamocrinus* is the most primitive among recent Hyocrinidae in the structure of the theca with 5 unfused basals. It is living off Galapagos and Panama at a depth of 705–1410 m.

Bourgueticrinus danicus Nielsen, 1913

Plate 1 fig. 8.

1913 *Bourgueticrinus danicus*.—Nielsen p. 53 pl. 2 figs. 49–51, pl. 3 figs. 1–58.
1913 *Bourgueticrinus curvatus*.—Nielsen p. 55 pl. 3 figs. 59–61.
1961 *Bourgueticrinus danicus* Nielsen.—Rasmussen p. 178 pl. 30 figs. 1–8.
1965 *Bourgueticrinus danicus* Nielsen.—Rasmussen p. 34, 35 pl. 8 figs. 10–11.

Previous record

This species has previously been described in detail from the Danian. It has been recorded from the Danian of Denmark, Sweden, Belgium and the Netherlands. It is one of the dominant species in the Danian of Denmark.

Material

One single theca including the proximale has been found in the Paleocene (Heersian) glauconitic marl of the Lellinge Formation at Egsmark near Ebeltoft in Denmark. This is the first and only documented specimen of a *Bourgueticrinus* from post-Danian deposits. The absence of conglomerate and derived fossils in the other faunal elements at the locality indicates that the presence of *Bourgueticrinus* in the Heersian may be reliable.

Columnals of the *Bourgueticrinus-Democrinus* type found in the Danian near Haidhof north of Vienna in Austria most likely belong to this species, but no theca has been found so far.

The specimens are in the collection of the Geological Museum, Copenhagen.

Democrinus maximus (Nielsen, 1915)

1915 *Rhizocrinus maximus*.—Nielsen p. 392 fig. 1
1938 *Democrinus maximus* (Nielsen).—Gislén p. 7 fig. 8.
1961 *Democrinus maximus* (Nielsen).—Rasmussen p. 207 pl. 31 figs. 1–8.
1965 *Democrinus maximus* (Nielsen).—Rasmussen p. 34 pl. 8 fig. 12.

Previous record

This species has previously been described from the Danian and recorded from the Danian of Denmark, Sweden, Belgium and the Netherlands. It is common in the uppermost part of the Danian in Denmark and as derived specimens in the conglomerate at the base of the Heersian in Denmark and Sweden.

Material

A few thecae of this species are found in the Paleocene (Heersian) glauconitic marl of the Lellinge Formation at Egsmark near Ebeltoft in Denmark. The specimens are in the collection of the Geological Museum, Copenhagen.

Democrinus londinensis (Forbes, 1852)

Plate 1 fig. 9.

1852 *Bourgueticrinus londinensis*.—Forbes p. 36 fig. 4.
1884 *Rhizocrinus londinensis* (Forbes).—Carpenter pp. 257, 259.
1928 *Rhizocrinus londinensis* (Forbes).—Davis pp. 347, 349.
1937 *Rhizocrinus londinensis* (Forbes).—Davis p. 79.
1961 *Democrinus londinensis* (Forbes).—Rasmussen p. 208.

Type

The columnals figured by Forbes (1852) p. 36 figs. 4 a–d are syntypes. They are from the Eocene London Clay (Ypresian) of Copenhagen House in London. The specimens are in the collection of the British Museum (E 22093–22094).

Material

This species has been recorded by Davis (1928, 1937) as characteristic to division 2 of the London Clay together with *Isselicrinus subbasaltiformis* at Copenhagen Fields, Beddington, Clapham, London Wall and The Minories and from Warden Point on the Isle of Sheppey. The London Clay of the Isle of Sheppey was correlated by Davis (1936) with the middle part of the London Clay, presumably division 4. Venables (1963) has recorded "*Rhizocrinus* sp. cf. *londinensis*" from the Craigweil Bed (Middle Clay) of Bognor Regis.

In the collection of the British Museum are isolated columnals from the London Clay (division 2) of Copenhagen Fields (E 38688) and from the London Clay (division 4) of Highgate (E 430, 22119, 38716). In a specimen from Highgate (E 38715) the column and theca are found connected in the clay with slightly displaced brachials. A sample from Highgate includes numerous isolated columnals, fragments of columns and 2 thecae (E 22119).

In the collection of the Geological Survey, London, are isolated columnals from the London Clay (division 2) of Clapham (Zc 4066–4075) and The Minories (61650–1, 98808–15).

In the collection of Valette in Dijon, France, are 4 thecae of this species from the Middle Eocene (Lower Lutetian) of Fontcouverte (Aude) in France.

Dimensions

The specimen figured shows the following dimensions: Height of theca 3.8 mm. Height of basals 3.0 mm. Height of radials 1.0 mm. Diameter of theca at top 3.0 mm. Diameter of theca at its base 1.3 mm. Height of distal columnals 3.0 mm.

Diagnosis

A *Democrinus* with rather high, conic theca. The height of the basals is about three times the height of the radials. The columnals are synarthrial with a single articular ridge with different orientation in the two ends of a columnal. The proximal columnals are short and cylindrical. Their height gradually increases through about thirteen columnals until they reach the same height as width. They have a narrow axial canal. The distal columnals have elliptical articular surfaces with greatest diameter in the direction of the articular ridge. They are slightly higher than the greatest diameter. The axial canal is enlarged at the articular surface. There is often a cirrus socket around the suture at the end of the articular ridge.

Remarks on the identification

Columnals similar to the present species occur in species of *Bourgueticrinus* from the Maastrichtian and Danian and in several members of the family Bathycrinidae including *Democrinus*. A safe determination of the genus and species is not possible on the basis of columnals alone. However no theca of *Bourgueticrinus* has ever been found in Eocene or younger sediments. The presence of *Democrinus* in the London Clay is demonstrated by the three thecae recorded. There is no indication of any other Bathycrinidae or of more than one species with such columnals in the British Eocene.

Affinity

The present species differs from *D. maximus* (Nielsen, 1915) in the simple, conic form of the theca and the smaller height of the basals. It differs from *D. gisleni* Rasmussen, 1961, in the much larger size of the theca and height of basals. No other species of *Democrinus* has been recorded from the Tertiary. The recent species of *Democrinus* have a smaller number of short, proximal columnals and more slender distal columnals or a theca of different form.

Columnals of Bathycrinidae

1851 *Apiocrinus ellipticus* (Miller).—Schafhäutl p. 420 pl. 7 fig. 13.
1852 *Bourgueticrinus ellipticus cornutus*.—Schafhäutl p. 151, 167.
1861 *Bourgueticrinus goniaster*.—Gümbel p. 596, 656.
1861 *Bourgueticrinus thorenti* Archiac.—Gümbel p. 596.
1863 *Bourgueticrinus ellipticus* (Miller).—Schafhäutl p. 110 pl. 15 fig. 7.
1863 *Bourgueticrinus cornutus* Schafhäutl.—Schafhäutl p. 111 (non pl. 24a fig. 5).
1930 *Rhizocrinus* sp.—Hucke & Voigt p. 160 pl. 6 fig. 11.
1938 *Rhizocrinus suessi* (Munier-Chalmas).—Traub p. 18.

Several records are given on *Bourgueticrinus* sp. or *Rhizocrinus* sp. from the Paleocene of Denmark and Sweden and from Paleocene erratics in Sweden, Denmark and North Germany. *Rhizocrinus* sp. is also recorded from the Middle Oligocene Septarienton at Joachimstal in North Germany. All these records are based on small, slender columnals of a form found among Maastrichtian and Danian species of *Bourgueticrinus* and in fossil and recent genera of Bathycrinidae.

Similar columnals from the Palaeocene and Eocene near Salzburg in Austria and from southern Bavaria in Germany have been referred to the Cretaceous species *Bourgueticrinus ellipticus* (Miller, 1821) and to the Tertiary south European species *Conocrinus thorenti* (Archiac, 1836) and *Conocrinus suessi* (Munier-Chalmas, 1877).

A few columnals have been picked out of a sample from the *Gryphaea*-bed in the uppermost part of the Paleocene (Landenian) section at Kroisbach north of Salzburg in Austria (collection at Copenhagen).

The species *Bourgueticrinus londinensis* was established by Forbes (1852) on such columnals but can now be connected with the theca described above as *Democrinus londinensis* (Forbes, 1852).

Furthermore the two species *Bourgueticrinus cornutus* Schafhäutl, 1852, and *Bourgueticrinus goniaster* Gümbel, 1861, are established for such indeterminable columnals of Bathycrinidae from the Eocene of southern Bavaria. These species have also been referred to the genera *Conocrinus* and *Rhizocrinus*, but a determination of the genus or species is only possible when also the theca is known. A theca belonging to *Conocrinus* was figured by Schafhäutl (1863) and referred to *B. cornutus*.

The few thecae found in the Tertiary show that *Democrinus* lived in the North European Lower Tertiary, and *Conocrinus* in the South European Lower Tertiary. A few specimens of the recent genera *Bathycrinus* and *Monacocrinus* are found in the Danian of Denmark and Sweden. Only one theca of *Bourgueticrinus* has been found in the Paleocene except for the Danian and derived Danian fossils in the conglomerate at the base of the Heersian in Denmark and Sweden.

Amphorometra ornata n. sp.

Plate 1 figs. 10–15.

1928 *Antedon* n.sp.—Davis pp. 347, 349.

Derivation of name

Ornatum (Latin) ornate, richly decorated. The name is proposed to illustrate the tubercles of the centrodorsal and the thorns of the brachials.

Holotype

The theca with centrodorsal shown plate 1 fig. 10a–c is holotype. It is from the London Clay (division 3) of Wraysbury Reservoir at Poyle in Buckinghamshire, England. The specimen is collected by Mssrs. Macadie, Rundle and Cooper and transferred to the collection of the British Museum (E 53620).

Material

Davis (1928) has recorded a centrodorsal from the London Clay of Clapham (division 2) and 2 centrodorsals from Worchester Park (division 3). These undescribed specimens have not been found in the collections, but they are the only comatulids recorded from the London Clay. In the collection of the Institute of Geological Sciences, London, are several brachials of the present species collected by Davis from the London Clay of Clapham. In the collection of Mssrs. Rundle and Cooper are, apart from the holotype, an incomplete theca, a centrodorsal, 3 axillary I Br 2 with proximal synarthrial articulation, 1 wedge-shaped II Br 1 with distal synarthrial articulation 21 secundibrachials with muscular articulation and pinnular socket, one of them connected to a hyposyzygial, furthermore 4 hyposyzygial and 19 episyzygial secundi-

brachials. All these specimens are from the type locality, but a few brachials in the same collection are from the London Clay (division 2) of Aveley in Essex, England.

Dimensions

Radius of theca 2.5 mm, interradius 2.2 mm, height 3.6 mm not including the top of the radials which is broken off. Height of centrodorsal 2.0 mm. Diameter of centrodorsal cavity 0.8 mm.

Diagnosis

An *Amphorometra* with rather low conical centrodorsal covered by 10 radiating rows of cirrus sockets, generally 3 distinct sockets in each row. The sockets are strongly concave with radiating crenellae along the edge and an articular boss on each side of the axial canal. The edges between the sockets form protruding tubercles where they meet. The dorsal pole is slightly protruding and appears rugose due to tubercles and rudiments of juvenile cirrus sockets. There is no dorsal pit or star. The ventral surface of the centrodorsal is slightly concave with 5 lanceolate furrows for rod-shaped basals. Vaults growing out to form new cirrus sockets occur. There are no radial pits. The centrodorsal cavity occupies about one fifth of the centrodorsal diameter. The outline of the centrodorsal is rather irregular, subpentagonal.

The rod-shaped basals are seen in the interradial corners between the radial plates. The radials cover the entire ventral surface of the centrodorsal. There is a free surface of the radials in continuation of the articular surface as a narrow edge or rim with the same orientation and with a strongly irregular outline forming irregular tubercles and blunt thorns. The radial articular surface forms an angle of about 40° with the axis of the theca. The dorsal ligament fossa is semielliptical and separated from the free surface by a regularly curved faint line. There is a deep ligament pit. The articular ridge is straight with a median canal for the brachial nerve. The interarticular ligament fossae are subtriangular and very deeply excavated. The ventral muscular fossae are narrow, subtriangular with the point downwards near the nerve canal. They are less concave than the interarticular ligament fossae and have a rugose bottom. The right and left muscular fossae are separated by a ridge with a median furrow. The top of the radials is broken off, only one of the muscular fossae appearing almost complete. The articular surface in the upper part of the radial, ventral of the articular ridge, does not reach the interradial suture, and the surface of the radial is here exposed as a narrow band sloping towards the suture. The radial cavity is narrow, but may perhaps be enlarged in the missing top.

The brachials have irregular nodules and blunt thorns along the distal edge. The free surface has scattered tubercles in the larger brachials. The axillary primibrachial, presumably I Br 2, has a synarthrial articulation with the preceeding primibrachial. A strongly wedge-shaped secundibrachial with distal synarthrial articulation, flat lateral sides and a dorsal surface with tubercles is obviously II Br 1. The articula-

tions found in other secundibrachials indicate that about every fourth articulation is syzygial corresponding to a syzygial articulation in every second secundibrachial.

Affinity

No other comatulid is known from North European Eocene. The present species differs from other species of *Amphorometra* by the low conical centrodorsal with tubercles, the crenulate cirrus sockets, and the thorns on the brachials. Together with this species in the London Clay are found remains of *Cainocrinus tintinnabulum*, the brachials of which are smooth.

Asteroidea

Astropectinidae

The name *Astropecten* was introduced as a pre-Linnean name by Linck (1733) and was established as a genus by Gray (1840). Fisher (1908) designated the recent species *Asterias aranciaca* Linne, 1758, as lectotype of the genus. The name *Stellaria* proposed by Nardo (1834) is preoccupied by Müller (1832). The pre-Linnean name *Crenaster* Luidius, 1699, used by d'Orbigny (1850) is in post-Linnean nomenclature a junior synonym.

Pentasteria was established as a genus by Valette (1929) with the type species *P. boisteti* Valette, 1929. It was demonstrated by Hess (1960) that the genus *Archastropecten* Hess, 1955, is a junior synonym of *Pentasteria*. Hess proposed to maintain *Archastropecten* as a subgenus of *Pentasteria*. Considering the close resemblance between this group and *Astropecten*, I prefer to consider *Pentasteria* as a subgenus of *Astropecten*. There is no distinct boundary between the two genera, especially when Tertiary and Recent species are considered.

The genus *Coulonia* was established by Loriol (1873) with the type *C. neocomiensis* Loriol, 1873. Hess (1955) established a genus *Cuneaster* with the type *C. hauteriviensis* Hess, 1955. It was later demonstrated by Hess (1970) that *Cuneaster hauteriviensis* is a junior synonym of *Coulonia neocomiensis*, and *Cuneaster* therefore a synonym of *Coulonia*.

The genus *Lophidiaster* was established by Spencer (1913). The species *L. ornatus* Spencer, 1913, was first mentioned as type of the genus by Valette (1915). The genus was distinguished from *Astropecten* by the absence of dorsal paxillae. Rasmussen (1950) made *Lophidiaster* a synonym of *Astropecten* after the observation of typical paxillae in the type species. Hess (1955) separated again the two genera, using as a new characteristic the large, divided or "horseshoe-shaped" tubercles for spines on the inferomarginals, present in *Astropecten*, but not in *Lophidiaster*. Following this interpretation, however, *L. postornatus* is maintained in the genus *Astropecten*.

Astropecten postornatus (Rasmussen, 1945)

Plate 3 figs. 1–4.

1945 *Lophidiaster postornatus*.—Rasmussen p. 245 pl. 9 fig. 16.
1950 *Astropecten postornatus* (Rasmussen).—Rasmussen p. 91 pl. 10 fig. 21.
1955 *Lophidiaster postornatus* Rasmussen.—Hess p. 66.

Material

This species has been described from the Upper Danian of Denmark including the conglomerate at the base of the Heersian. From the Sonja Member of the Upper Danian Agatdal Formation in Agatdal, Nûgssuaq in West Greenland are 12 superomarginals and 13 inferomarginals of this species. In a sample of the presumed Danian beds (193–207 m) in the boring at Boryszew in Poland are a rather worn superomarginal and inferomarginal probably belonging to this species. The specimens from Denmark and Greenland are in the collection of the Geological Museum, Copenhagen, the specimens from Poland are in the collection of the Geological Institute of Warsaw.

Size of marginals

A study of the marginals, the way in which the wedge-shaped marginals fit into a stellate outline and a comparison with other Astropectinidae show that the orientation of the superomarginal and inferomarginal in the original description is incorrect. The contact between superomarginal and inferomarginal was formed by the surface shown to the right in the figure by Rasmussen (1944 pl. 9 fig. 16c and 1950 pl. 10 fig. 21a). The correct size of the specimens is therefore as follows.

	length	width	height
Denmark (1945 fig.):			
superomarginal	1.7	2.8	4.0
ridge of superomarginal	0.5	0.7	0.5
inferomarginal	1.6	2.8	3.7
ridge of inferomarginal	0.5	0.4	0.3
Greenland (largest specimen):			
superomarginal	1.2	2.0	3.0
ridge of superomarginal	0.8	0.6	0.6
inferomarginal	1.2	2.3	2.5
ridge of inferomarginal	0.7	0.4	0.5

The marginals from Greenland are slightly smaller than the majority of marginals from Denmark. This, however, is expected as a result of differences in sedimentation and sampling. The majority of specimens from Denmark have been washed out of the Paleocene conglomerate succeeding the Upper Danian limestone, and is primarily sorted according to size. The specimens from Greenland were picked out of a very loose sandstone (''the Sonja lens'') and were washed and sorted through a finer mesh than the specimens collected in Denmark.

Description

The superomarginals have a ridge of uniform height. The free surface forms a regular arch. The ornamentation consists of small, uniform, closely placed spine pits, where rudimentary spines or scales were placed. The superomarginals meet in a quarter-elliptical surface.

The inferomarginals are subtriangular in section with a slightly curved free surface. The ridge is almost uniform in height. The ornamentation consists of closely placed granules. Larger granules or tubercles, horseshoe-shaped or incompletely divided by a furrow, form from one to three oblique rows on the ridge of each inferomarginal near the edge against the superomarginal. This, however, is generally obscured by wear of the surface.

Occurrence

This species is found only in the Upper Danian of Denmark and Greenland, but may be present in the presumed Danian of Poland.

Astropecten granulatus n. sp.

Plate 3 figs. 5–8.

? 1937 *Asteroid.*—Wrigley & Davis p. 208.

Derivation of name

Granulum (Latin) grain. Named after the granulated superomarginals and inferomarginals.

Type

The inferomarginal pl. 3 fig. 6 is holotype. It is from the Upper Eocene (Bartonian) Middle Barton Beds (horizon E of Burton 1929) at Barton Cliff in Hampshire, England. The specimen is from a sample in the British Museum collected by Mr. A. G. Davis (E 53627).

Material

Several isolated ossicles have been picked out from the washed sample collected by Mr. Davis. There are 1963 superomarginals, 2395 inferomarginals, 118 ambulacrals including 23 first ambulacral, 15 adambulacrals and 7 terminals. Other isolated marginals from the type locality are also present in the British Museum (E 52170–52210). Further specimens in the British Museum are from the Middle Eocene (Auversian) Upper Bracklesham Beds (Bed XVII of Fisher 1862 and Wrigley & Davis 1937). These specimens are collected in blue clay on the foreshore opposite Medmerry Farm near Selsey Bill in Sussez (E 13789–13826). Indeterminable asteroid marginals are recorded by Wrigley & Davis (1937) from the Lower Eocene (Ypresian) Lower Bracklesham Beds at Whitecliff Bay, Isle of Wight.

Diagnosis

An *Astropecten* with a granulated narrow ridge on the superomarginals and inferomarginals. There is a variable number of larger, divided tubercles for spines forming oblique rows on the inferomarginals and a few scattered tubercles of similar form on most superomarginals.

Dimensions	height	width	length
superomarginal	1.4–1.5	1.2–1.3	0.7–0.9
superomarginal ridge	0.2	0.2–0.3	0.5–0.7
inferomarginal	1.4–1.5	2.7–2.9	0.8
inferomarginal ridge	0.1–0.2	0.6–0.7	0.6–0.7
terminal plate	0.5–0.7	0.8–1.2	0.7–1.0

Description

The marginals and the marginal ridges near the arm base are distinctly wedge-shaped, short near the edge and long near the disc. More distal marginals have almost parallel proximal and distal ends. The inferomarginals are rather high and subtriangular in section. The surface against the superomarginals is very small and forms an obtuse angle with the surface against the body cavity and adambulacrals. The inferomarginals meet in an angular face, intermediate in form between inferomarginals of *Astropecten* and *Coulonia*. A low ridge with interruptions bounds this articular face. The free surface is provided with a ridge, which is very low in the ventral part but continues in a slight curve towards the upper edge, where it gradually increases to a considerable size. The sides of the ridge are covered by a faint but distinct, close granulation. The outer surface of the ridge is covered by large granules or tubercles forming one or more rows depending on the size of the surface. In wedge-shaped inferomarginals from near the arm base, the ridge is so narrow, that no distinct arrangement of the tubercles is seen. The smaller, more rectangular plates from the arm show an arrangement of the large tubercles in oblique rows. A variable number of tubercles in the upper part of the ridge are divided by a furrow (horseshoe-shaped) and often slightly larger than other tubercles, but in some inferomarginals such divided tubercles may cover almost the entire surface of the ridge.

The superomarginals are smaller and more quarter-circular in profile or a little higher than wide. The surface against inferomarginals is distinctly concave. The surface against the body cavity is slightly convex. The free surface is provided with a ridge of almost uniform height. The superomarginals meet in a surface quarter-circular in form or slightly pointed towards the dorsal edge. This articular surface is bound by an unbroken low ridge. The ridge of the free surface is slightly granulated on the sides and provided with tubercles on the outer surface. The tubercles are smaller than on the inferomarginals, but a few tubercles (1–3) in varying position may be enlarged and divided or crater-shaped as on the inferomarginals.

The adambulacrals have a granulated, almost rectangular ventral surface and a point or vertical ridge towards the ambulacral furrow. They meet in strongly sloping proximal and distal faces. The ambulacrals are rather short, almost flat, with a longitudinal micro-ornament on the surface against the body. The terminal plate is closely granulated and almost divided by a median concavity into a semicylindrical right and left part.

Astropecten? beyrichi Linstow, 1912

1912 *Astropecten* (? *Pentaceros*) *Beyrichi*.—Linstow p. 52 pl. 2 fig. 5–7.
1955 *Astropecten* (? *Pentaceros*) *beyrichi* Linstow.—Hess p. 74.

Type

The arm figured by Linstow is holotype and the only specimen known. It is from the Middle Oligocene (Rupelian) Septarienton of Hermsdorf (Mark) in Germany. Collection, according to Linstow, Museum für Naturkunde, Berlin.

Dimensions

Length of arm fragment 21 mm. Width 17 mm at the base and 5 mm at the end of the preserved fragment. Length of marginals 1–1.5 mm. Height of margin 6–7 mm at the base of the arm.

Description

The arm is slender. There are 12 superomarginals and inferomarginals in each side of the preserved fragment. According to the figure, the specimen will fit a stellate form with interradius 1–1.5 cm and radius at least 3 cm. The marginals are short, wide and apparently low, slightly wedge-shaped at the base of the arm. Inferomarginals along the disc are wider than superomarginals. Width of the arm large at the base of the arm, but decreasing towards the distal end. Length of marginals almost uniform. The free surface of the marginals is regularly arched, slightly tumid, apparently without ridge. It is covered by small, closely placed spine pits. There are no ventral covering plates in the narrow arm. A single row of dorsal plates is possibly present between the superomarginals of the arm.

Affinity

The species is referred by Linstow to "*Astropecten* sensu lato". The genus is uncertain but the marginals without ridge show that the species does not belong to Astropectinidae. According to Hess it may perhaps belong to the Goniasteridae. It shows some resemblance to the isolated marginals described by Valette (1925) as *Calliderma atagensis* from the Middle Eocene (Lutetian) of France.

Coulonia colei (Forbes, 1852)

Plate 3 figs. 9–15, plate 11 figs. 2–3, plate 12 figs. 1–2.

? 1811 *Astropecten echinatus minor* Linck.—Parkinson p. 4.
? 1844 *Asteria.*—Ansted p. 66 fig.
? 1848 *Astropecten crispatus.*—Forbes p. 479.
1848 *Astropecten armatus.*—Forbes p. 479 (non Gray 1840, nec Müller & Troschel 1842).
? 1849 *Astropecten crispatus* Forbes.—Forbes Dec. 1 pl. 3 fig. 3.
1849 *Astropecten armatus* Forbes.—Forbes Dec. 1 pl. 3 fig. 4.
? 1852 *Astropecten crispatus* Forbes.—Forbes p. 29 pl. 4 fig. 2.
1852 *Astropecten armatus* Forbes.—Forbes p. 29 pl. 4 fig. 1.
1852 *Astropecten? colei.*—Forbes p. 30 pl. 4 fig. 3.
? 1909 *Astropecten crispatus* Forbes.—Linstow p. 57.
? 1936 *Astropecten crispatus* Forbes.—Davis p. 57.
? 1955 *Archastropecten crispatus* (Forbes).—Hess p. 42.
1955 *Cuneaster armatus* (Forbes).—Hess p. 59.
1955 *Cuneaster colei* (Forbes).—Hess p. 60.
1963 *Archastropecten* sp. cf. *crispatus* (Forbes).—Venables p. 263.

Synonymy

Astropecten echinatus minor Linck, 1733, is a pre-Linnean name for the recent, Mediterranian *Astropecten bispinosus* Otto. The specimen referred by Parkinson (1811) to *Astropecten echinatus minor* is preserved in pyrite from the Isle of Sheppey and probably belongs to *Coulonia colei*, which is rather common on the Isle of Sheppey. *Astropecten crispatus* Forbes, 1848, is a name used for badly preserved, indeterminable specimens covered by pyrite. They come from the same locality and probably belong to the same species. The name *Astropecten armatus* Forbes, 1848, is a homonym of *A. armatus* Gray, 1840 and of *A. armatus* Müller & Troschel, 1842. It is further a synonym of *Astropecten? colei* Forbes, 1852. Hess (1955) referred the species to a new genus of Astropectinidae, *Cuneaster* Hess, 1955. According to Hess (1970) this is a synonym of *Coulonia* Loriol, 1873.

The type of Astropecten crispatus

In the description of *A. crispatus* Forbes (1848) mentioned a specimen communicated by Mr. Stokes to the Geological Survey and a specimen in Mr. Bowerbank's collection. He further referred to the specimen figured by Ansted (1844). The latter specimen is from Bowerbank's collection and now in the collection of the Institute of Geological Sciences (31439) but now completely decomposed, and only two plaster casts and some not identifiable fragments in paraffin are still preserved.

In 1849 Forbes figured a specimen from Bowerbank's collection but not identical with the specimen figured by Ansted. This specimen, pl. 3 fig. 3a, is now in the collection of the British Museum (E 57501) but completely decomposed. He further figured a specimen from Mr. Stokes' collection. This specimen, fig. 3b–c, is now in the Institute of Geological Sciences (49166–49167) but partly decomposed. In 1852 Forbes refigured the specimen previously figured by Ansted. In 1955 Hess selected the speci-

men figured by Forbes 1849 pl. 3 fig. 3 as lectotype without stating which of the two specimens in this figure was meant. According to Hess, the specimen is nr. 31439 in the Geological Survey, which, however, is the specimen figured by Ansted 1844 and Forbes 1852, not by Forbes 1849. There is therefore no unambiguous type of the species.

Identification of Astropecten crispatus

The specimens in the collections referred to this species are from the London Clay of the Isle of Sheppey. All the specimens are more or less completely covered by pyrite and show few or no details. They have in common a stellate form with rapidly tapering arms, very wide near the base, and short, apparently very wide marginals specially in the proximal part of the arm. It is remarkable that no well-preserved specimen shows similar features. The marginals, however, appear double as if divided in an inner and outer part, and in a few specimens it is seen that the outer part is not the marginal but a spine or a group of spines covered by the pyrite. This is seen in the specimen 49166–7 although not indicated in the figure by Forbes, and it corresponds to his indications that a strong spine is attached to each plate in perfect specimens. Interpreted in this way, the actual arm is considerably more narrow in its proximal part, and the specimens may very well belong to *Coulonia colei (= Astropecten armatus)* which is the common species in the London Clay of the Isle of Sheppey.

Other records of Astropecten crispatus

According to Venables (1963) "*Archastropecten* sp. cf. *crispatus*" is found in the Lower Eocene (Ypresian) Upper Fish-tooth Bed (Middle Clay) of Bognor Regis. According to Linstow (1909) two specimens from the Upper Eocene (Bartonian) Barton Clay of Barton in Hampshire, England, are in the collection of Museum für Naturkunde, Berlin.

The type of Astropecten armatus Forbes

The specimen described by Forbes (1848), figured by Forbes (1849) and re-figured as mirror image by Forbes (1852) is holotype and the only specimen recorded. It is from the Lower Eocene (Ypresian) London Clay of Sheppey in Kent, England. It is the best preserved specimen within this group of British Eocene Astropectinidae, but the name must be rejected as a primary homonym. The specimen is in the collection of British Museum (E 57503).

The type of Astropecten? colei

The specimen figured by Forbes (1852) pl. 4 fig. 3 is holotype and the only specimen recorded. It is from the Lower Eocene (Ypresian) London Clay of the Isle of Sheppey, Kent. Although disturbed, the single plates are rather well preserved without pyrite. The specimen is in the collection of the Institute of Geological Sciences, London (49173). The figure given by Forbes is a mirror image of the specimen.

British specimens

Several specimens preserved in pyrite from the London Clay of the Isle of Sheppey in Kent are in the collections of the British Museum (E 34960, 38490, 52331, 57424, 57503, 75909), and in the collection of the Institute of Geological Sciences (49173, 94302–94304, 99789, 100370). There are further in the British Museum one specimen (E 428) from Highgate, London, and one (E 52164) from Oxshott Brickworks, Surrey, both from the London Clay (division 5). These specimens are preserved in clay and E 428, especially, shows several details of the plates. In the specimen E 75909 three of the terminal plates are preserved. An isolated terminal plate of similar form from the London Clay (division 5) of Highgate is in the Institute of Geological Sciences (5807).

Danish specimens

From the Lower Eocene Mo-Clay Formation of Mors and Fur in Denmark are a few asteroids apparently belonging to this species. One of the specimens from the Mo-Clay of Fur is in the collection of the Institute of Paleontology in Uppsala, Sweden

Dimensions

	Highgate	Isle of Sheppey					Fur		
	E. 428	E. 75909	GS. 491	E. 38490	E. 2560	GS. 99789	GS. 94304			
radius	+60	+40	+30	+18	+25	+17	+30	18	25	45
interradius	±10	11	–	±5	±6	8.5	–	3.5	±5	±8
width of arm near base	11	9	±12	±5	±6	8	11	3.5	–	±7
height of paxillae	1–2	–	1–2	–	–	–	1.5	–	–	–
length of marginal spine	2–3	2–3	2–3	.5–1	1	–	–	.7	.8	–
length of adambulacral spine	–	1	–	–	–	–	–	.5	–	–
height of superomarginal	2.5	–	±2.2–2.5	÷1	1.0–1.2	±1	2.2	–	±.8	1.0
width of superomarginal	2.0–3.5	–	±2.5–3.0	.5	±1	±1.5	2.5	–	±.8	–
width of ridge	1.0–2.0	–	±1.5–2.0	–	–	–	1.5	–	±.5	–
height of inferomarginal	3.0	–	2.5–4.2	±1	±1.5	÷1.5–2.0	3.0	–	1.2	1.2
width of inferomarginal	2.0–3.5	±2	3.5–5.5	1.0–1.5	±1.5–2.0	±2.0	3.2	.8	±1.4	1.4
length of inferomarginal	1.5	±1	1.5–2.0	.8	1.0	1.0	1.5	.5	.7	.8
width of marginal ridge	1.0–2.0	–	2.0–4.0	–	–	–	±1.5	–	±1.0	1.0
length of marginal ridge	.4– .6	±.5	.6–1.0	.5	.5	.5	1.0	.3	.4	.6

+, ÷ and ± indicate more than, less than and approximately.

(DM 12). It is preserved as impression in the sediment, showing the dorsal side with distinct paxillae, dorsal and ventral marginals and ambulacrals. Another specimen from Fur is in the collection of Mr. Guldager, Ebeltoft in Denmark. It is preserved as an impression of the dorsal side and embedded dorsal side upwards in the Mo-Clay 35 mm below a 30 mm thick, dark layer of volcanic tuff. The specimen shows the madreporite, ambulacrals, marginals and a few paxillae. In the Geological Museum of Copenhagen is a specimen from the Mo-Clay of Mors, showing the ventral side with distinct ambulacrals, adambulacrals and long adambulacral spines. The inferomarginals are concealed by small spines.

Description

A *Coulonia* with long, narrow arms, almost uniform in width, and meeting in a short interradial arch near the mouth. The marginals are short with a very prominent ridge and small, elevated articulations of almost rectangular outline between the marginals of each row. The surface of the ridge is covered with tubercles where slender spines are attached. The superomarginals are rather small with a high, lateral ridge or wing curved towards the dorsal side and closely covered on the surface by uniform tubercles for small spines and, near the dorsal end of the surface, one or two larger, crater-shaped tubercles for larger spines. The inferomarginals are larger and wider with a narrow, angular articular surface towards joining inferomarginals. There is a very large lateral ridge or wing with tubercles for small spines and two large, horseshoe -shaped or double tubercles for long spines. The adambulacrals are rather large, five-sided with a prominent edge into the ambulacral furrow near the proximal end. The ventral surface of the adambulacral is granulated with at least 3 long spines. The ambulacrals are rather large, and uniform, accomodated to only one row of podia in each side of the ambulacral furrow. The dorsal surface is covered with high paxillae separating the margins as far as the tip of the narrow arm. There is a small ventral area in each interradius covered by flat, ventral plates with a slightly raised, granulated area forming a low ridge radiating towards the inferomarginals. The terminal plate is almost oviform with a deep ambulacral furrow along the ventral side and distal surface, and on each side is a shallow furrow where small distal superomarginals have met the terminal plate. There is a shallow median embayment in the proximal margin of the plate where it has met the dorsal cover of the arm. The free surface of the terminal plate is closely granulated. The length of the plate is 3–4.5 mm. This terminal plate is very similar in form and size to terminal plates described from the Cretaceous and referred to *Asterias* (Nielsen 1943, Rasmussen 1950, Müller 1953).

Lophidiaster punctatus Nielsen, 1943

1943 *Lophidiaster punctatus*.—Nielsen p. 67 pl. 4 fig. 38.
1945 *Lophidiaster punctatus* Nielsen.—Rasmussen p. 423 pl. 9 fig. 15.
1950 *Astropecten punctatus* (Nielsen).—Rasmussen p. 92 pl. 10 fig. 20.
1955 *Lophidiaster punctatus* Nielsen.—Hess p. 66.

Previous records

This species has been recorded only from the Danian of Denmark.

Material

A single superomarginal and inferomarginal of this species is found in the residue of a small washed sample of the Danian limesand from Haidhof north of Vienna in Austria. The specimens are in the collection of the Geological Museum, Copenhagen.

Lophidiaster haunsbergensis n. sp.

Plate 3 figs. 16–17.

Derivation of name

Haunsbergensis (Latin) from Haunsberg, after the type locality.

Type

The superomarginal pl. 3 fig. 16 is holotype. It is from the Upper Paleocene (Landenian) of Kroisbach at Haunsberg north of Salzburg in Austria (locality Kch 2 of Traub 1938). The specimen is from the biozone with *Globigerina velascoensis*. Collection of the Geological Museum, Copenhagen (12779).

Material

In a sample from the type locality collected by Professor A. Rosenkrantz in 1962, 37 superomarginals and 21 inferomarginals including the type have been found. The specimens are in the collection of the Geological Museum, Copenhagen.

Size of marginals

	length	height	width
superomarginals	1.4	1.5	2.1
	1.3	1.3	1.8
	1.2	1.4	2.1
inferomarginals	1.4	1.4	2.6
	1.3	1.5	2.7
	1.2	1.5	2.6

Diagnosis

The superomarginals are short, slightly wedge-shaped. The free surface has a prominent ridge separated from joining superomarginals and from the dorsal surface of the disc by a narrow, depressed rim. The height of the ridge is almost uniform, only slightly larger near the lower edge. The greatest height of the superomarginal is found at the dorsal end of the ridge. The surface of the ridge is curved but not tumid. The edges of the ridge are rather sharp. The surface is covered by spine pits. The surface against the dorsal cover of the disc forms a large, deep concave furrow along the dorsal edge. The surface against the body cavity is of similar size to the surface against the

disc, but is flat. These two surfaces meet in a sharp angle, where the superomarginals reach their greatest width.

The inferomarginals are subtriangular in profile with a prominent ridge on the free surface separated from joining inferomarginals by a depressed rim. The free surface forms a regular curve. The height of the ridge diminishes towards the ventral side. The edges of the ridge are rather sharp, the surface is curved, not tumid. The surface of the ridge is covered by uniform spine pits. The surface against the superomarginals and the surface against the body cavity and ventral cover of the disc are of equal size. They meet at an angle of about 130°. The surface against the ventral cover or adambulacral plates is not distinctly separated from the surface against the body cavity and is not concave or angulate.

Affinity

This species is similar to *L. punctatus* Nielsen, 1943. It differs through the more prominent ridge of the superomarginals, the sharp edges and never tumid surface of the ridge, the more angulate profile of the superomarginals against the disc and the smaller height of the inferomarginals.

Lophidiaster inversus n. sp.

Plate 3 figs. 18–19.

Derivation of name

Inversus (Latin) inverted, referring to the ornament of superomarginals and inferomarginals.

Type

The superomarginal pl. 3 fig. 18 is holotype. It is from the Upper Paleocene (Landenian) of Kroisbach north of Salzburg in Austria (locality Kch 2 of Traub 1938). The specimen is from the biozone with *Globigerina velascoensis*. Collection of the Geological Museum, Copenhagen (12781).

Material

In a sample from the type locality collected by Professor A. Rosenkrantz 1962, 31 superomarginals and 19 inferomarginals of this species have been found. Collection of the Geological Museum, Copenhagen.

Size of marginals

	length	height	width
superomarginals	1.3	1.2	1.6
	1.2	1.1	1.4
	1.1	1.0	1.5
inferomarginals	1.3	1.4	1.9
	1.3	1.3	1.7
	1.2	1.3	1.6

Diagnosis

The superomarginals are small, rather long with a low ridge or elevated area on the free surface limited by a narrow depressed rim along all the edges. Greatest height of superomarginals is at the dorsal end of the elevated area. The surface of the elevated area is curved but not tumid. It is provided with small, rather prominent, scattered granules. The edges of the elevated area are blunt. There are 3–4 small, slightly concave joint faces towards the dorsal cover of the disc and arm. The lower edge of these facets are not very prominent, and there is a blunt angle with the surface towards the body cavity.

The inferomarginals have a slightly more prominent ridge or elevated area than the superomarginals, at least near the edge against the superomarginals. The depressed rim is very narrow along the upper and lower edges. The elevated area forms a regular curve but is not tumid. The surface of the elevated area is covered by uniform spine pits. The surface against the superomarginals is flat or slightly concave. It forms an angle about 125° with a large surface against the disc. The surface against the disc is flat, often with two indistinct impressions presumably corresponding to the adambulacrals. There is apparently no surface against the body cavity.

Lophidiaster concavus n. sp.

Plate 3 figs. 20–25.

Type

The marginal figured plate 3 fig. 22 is holotype. It is from the Eocene (Ypresian) London Clay of Wraysbury Reservoir in Poyle, Buckinghamshire in England (division 3 of Wrigley 1924). The specimen was collected by Mr. Cooper and Mr. Rundle, and transferred to the collection of the British Museum (E 53632).

Material

In the Institute of Geological Sciences, London, are 8 small marginals (61657) collected by A. G. Davis in the London Clay (division 2) of The Minories in London. In the collection of the British Museum are several small marginals (E 13090–13095) from the London Clay of Hampstead Well, and a single marginal (E 49597) from the London Clay of Islington. There are 9 marginals from a sample of London Clay (division 2) collected by Davis at Aveley in Essex. In the collection of Rundle and Cooper are 14 marginals, 2 ambulacrals and 2 dorsal plates picked out of washed samples from the type locality, and at least 10 marginals and 10 terminals from Aveley. The specimens figured are transferred to the collection of the British Museum.

Diagnosis

A Lophidiaster (?) in which the superomarginals and inferomarginals are long with a narrow depressed margin and a low, narrow ridge with concave surface covered by irregular granules and 0–2 larger crater-shaped tubercles.

Description

The marginals are small, high, rather long and narrow with a depressed marginal rim and a low ridge with strongly granulated, concave surface. The ridge is more restricted near the outer edge. The granules are large and protruding, some of them elongated in varying direction. There may be 1–2 protruding, crater-shaped tubercles where spines have been attached. The surface of the presumed superomarginals is somewhat curved. The presumed inferomarginals are thin and almost flat. The surface against the body is smooth and flat or may be divided in two faint impressions presumably meeting ossicles of the ventral side.

The terminal plates show a similar ornament of granules with rounded or elongate outline and in some specimens almost connected into a reticulate pattern. There are prominent facets for the attachment of three distal spines, one median and one on each side of the ventral furrow. The length of the plates and the proximal angle is rather variable.

The dorsal plates are stellate at their base, giving room for papulae. There may be 1 or 2 crater-shaped tubercles on the arched surface of the plates. The ambulacrals are rather stout.

Lophidiaster sp. aff. **pygmaeus** Spencer, 1913

Plate 3 figs. 26–27.

In a sample collected by Professor A. Rosenkrantz in the Upper Paleocene (Landenian) of Kroisbach north of Salzburg in Austria (locality Kch 2 of Traub 1938) are found 9 small marginals of a *Lophidiaster*. The marginals are from the biozone with *Globigerina velascoensis*. They are preserved in the collection of the Geological Museum, Copenhagen.

The marginals are small, higher than wide. Greatest length 1.5 mm, greatest width 1.6 mm, greatest height 1.8 mm. The free surface forms a smooth ridge, which is more narrow and prominent near the outer edge of the margin and becomes low and wide near the disc. Low plates with strongly arched surface may be superomarginals, higher plates with less arched surface and subtriangular profile are presumably inferomarginals. The surface against the body is smooth and flat or may be divided in two faint impressions presumably meeting ossicles of the ventral side.

The marginals are somewhat corroded, but seem to differ from the Upper Senonian *Lophidiaster pygmaeus* in a complete absence of granulation or spine pits. The form of the marginals and marginal ridge shows some resemblance to the Lower Eocene *Lophidiaster concavus*.

Hippasteria tuberculata (Forbes, 1852)

Plate 4 figs. 1–5.

1852 *Goniaster tuberculatus*.—Forbes p. 31 pl. 4 fig. 5.

Type

The specimen figured by Forbes (1852) is holotype. It is from the Lower Eocene (Ypresian) London Clay of Sheppey Island in Kent, England. The specimen is in the collection of the Institute of Geological Sciences, London (not identified).

Material

The presence of additional specimens was recorded by Forbes. Several specimens from the London Clay of Sheppey are in the collection of the British Museum (E 3818a, 33832, 34961, 35521, 36654, 52242, 53295) and the Institut of Geological Sciences (99787). All the specimens are preserved in pyrite and more or less worn on the surface. There is no specimen from any other locality.

Dimensions

No complete specimen is known. As far as can be seen by fitting the incomplete and disturbed specimens into a five rayed star, the interradius has reached 3–4 cm or more. The narrow part of the arm reaches a length of 3 cm and a width about 1 cm in preserved, incomplete fragments. The height of the margin in the interradial area is about 13 mm and decreases to about 7 mm before reaching the narrow arm. The large conical spine of the interradial superomarginals are about 2.2 mm long and 1.8 mm in diameter at the base.

	disc 99787	disc 53295	arm 33832a	arm 52242	arm 33832b
superomarginal:					
height	7.0–3.5	6.5–3.5	3.0–2.5	3.0–2.7	2.2–1.6
width	ab. 4.0	4.5–4.0	3.5–3.0	3.5–3.0	2.0–1.4
length	4.5–5.0	3.0–3.3	4.6–3.1	4.5–4.1	3.5–2.6
inferomarginal:					
height	6.0–4.5	5.5–3.5	3.2–2.9	3.0–2.8	2.2–1.5
width	6.6–5.5	5.0–4.0	4.0–2.8	3.0–2.8	1.5–1.2
length	4.5–5.0	3.0–3.4	4.5–3.4	4.5–3.9	3.5–2.5
adambulacral:					
width	2.5	–	1.5	1.5	1.0–0.8
length	2.5	–	2.0–1.5	2.0	1.9–1.5

Description

A *Hippasteria* with rather large disc and long, very narrow arms. The dorsal surface of the disc is covered by polygonal plates forming a distinct radial row of rather large plates and a dorsolateral pavement of slightly smaller plates together with much smaller plates. The ventral surface of the disc is covered by polygonal plates forming oblique rows from the adambulacrals towards the marginals. The plates along the adambulacrals are rather large and elongate in the direction of the rows with parallel

sides and oblique cut ends. The long and narrow arms have almost parallel sides and a single row of radial dorsal plates with a row of small dorsolateral plates on each side. There are no ventral plates between marginals and adambulacrals in the arm. Small rudimentary spines are placed in spine pits on the surface of dorsal and ventral plates. There is a row of 5–6 spines on the edge of each adambulacral against the ambulacral furrow, and two rows of smaller spines on the ventral surface.

The margin is high and steep along the disc in the interradial area but rapidly diminishes towards the arm. It is formed by closely granulated superomarginals and inferomarginals. A stout conical spine is attached to each superomarginal and at least to some of the inferomarginals. The granulation of the marginals appears to be primary, but may be due to adhering rudimentary spines.

Affinity

The large disc, stout marginals, large marginal spines and differentiation of the dorsal plates are similar to the genus *Hippasteria*, although the arms are more narrow than in recent species of this genus. The only fossil *Hippasteria* described is *H. antiqua* Fell, 1956, from the Senonian of New Zealand, which seems to have broader arms and larger radial dorsal plates than the present species.

Teichaster retiformis Spencer, 1913

Plate 5 figs. 1–2.

1913 *Teichaster favosus* var. *retiformis*.—Spencer p. 122 pl. 12 figs. 17, 19.
1943 *Teichaster retiformis* Spencer.—Nielsen p. 55, pl. 3 figs. 18–19, textfig. 10.
1950 *Teichaster retiformis* Spencer.—Rasmussen p. 71 pl. 10 fig. 5, textfig. 6.

Material

From the Sonja Member of the Upper Danian Agatdal Formation in Agatdal, Nûgssuaq in West Greenland are 8 superomarginals, 5 inferomarginals and 3 marginal fragments. A single small inferomarginal is found in a sample of Danian limesand from Haidhof north of Vienna in Austria. The specimens are in the collection of the Geological Museum, Copenhagen.

Occurrence

This species is known only from the Upper Danian of Denmark, Sweden, Austria and West Greenland.

Teichaster lamberti Valette, 1925

Plate 5 figs. 3–6.

1925 *Teichaster lamberti*.—Valette p. 23 fig. 4.
1966 *Teichaster lamberti* Valette.—Rasmussen p. 11.

Type

The marginals figured by Valette (1925) are syntypes. They are all inferomarginals although some of them are interpreted by Valette as superomarginals. The inferomarginal fig. 4, 1 is here selected as lectotype.

All the marginals figured by Valette are from the Middle Eocene (Lower Lutetian) of Fontcouverte in Aude, France. They are in the collection of Lambert at the Sorbonne in Paris and in the collection of Valette in Dijon. The type has not been identified in the collections.

Material

This species has been known hitherto only from the type locality. There are several marginals in the collections at Paris and Dijon. In a sample of Upper Paleocene (Landenian) dark clay with glauconite and mica collected by Professor A. Rosenkrantz at Kroisbach north of Salzburg in Austria are found 33 superomarginals and 28 inferomarginals of this species. They are smaller than the largest specimens found in France. These marginals may well belong to a single individual. The sample is from the biozone of *Globigerina velascoensis* (locality 2 m east of Kch 1, Traub 1938). The marginals from Kroisbach are in the collection of the Geological Museum, Copenhagen.

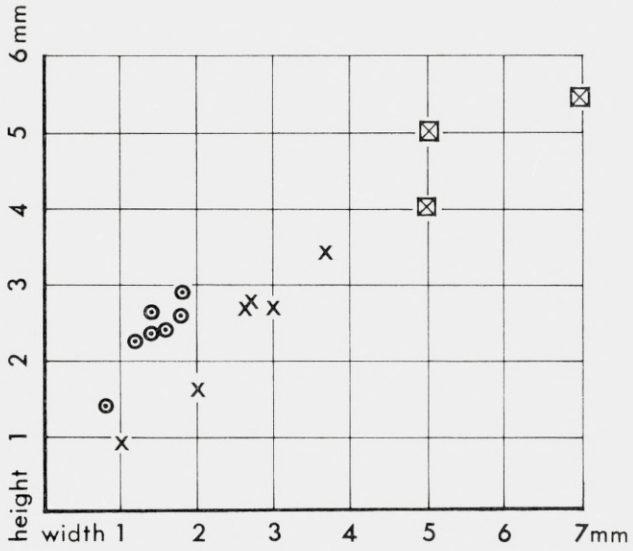

Fig. 5. Teichaster lamberti. Height and width of marginals.

⊙ superomarginals from Austria.
x inferomarginals from Austria.
⊠ inferomarginals figured by Valette.

Description

The marginals washed out of the sample from Austria are smaller than at least some of those from France. Most likely they belong to a single, rather small individual.

There is no other *Teichaster* or similar form in the sample, and it is therefore now possible to combine the inferomarginals with superomarginals not previously identified.

The superomarginals are a little higher than long in the margin along the disc, but lower in the more distal, smaller marginals along the arm. They are always very narrow. The joint face against the inferomarginals is extremely narrow, less than a third of the height of the marginal. The free surface is angulate, divided in an almost flat lateral and dorsolateral area. The lateral area is vertical or slightly outward-leaning and united in a short curve with a dorsolateral area of similar size or slightly smaller. The angle between the two areas is about 110°–130°. The proximal and distal edges are straight and parallel. The edge against the dorsal surface of the disc is curved in the larger plates along the disc but straight in the smaller, more distal marginals along the arm. The facets against the dorsal cover of the disc form a deep furrow along the dorsal margin. The surface against the body cavity is flat or slightly concave and very steep, often almost vertical.

The inferomarginals are lower and wider than the superomarginals. The free surface is divided in a lateral and a ventral area meeting in a gentle curve. The lateral area is slightly concave and vertical or leans generally slightly outwards. The ventral area is slightly curved and tumid, more or less horizontal. The surface against the superomarginals is very narrow. The surface against the ventral covering plates is of similar size and often divided in 2–3 joint faces, which have met the covering plates or the adambulacrals. There is a distinctly concave surface against the body cavity even in the small distal inferomarginals.

The free surface of superomarginals and inferomarginals is covered with rather large and shallow, closely spaced, uniform spine pits.

Teichaster stokesii (Forbes, 1848)

Plate 5 figs. 7–10.

1848 *Goniaster* (*Astrogonium*) *stokesii*.—Forbes p. 475.
1848 *Goniaster* (*Astrogonium*) *marginatus*.—Forbes p. 475.
1849 *Goniaster stokesii* Forbes.—Forbes decade I pl. 3 p. 1 fig. 1.
1849 *Goniaster marginatus* Forbes.—Forbes decade I pl. 3 p. 2 fig. 2.
1852 *Goniaster stokesii* Forbes.—Forbes p. 30 pl. 4 fig. 6.
1852 *Goniaster marginatus* Forbes.—Forbes p. 31 pl. 4 fig. 4.
1928 *Goniaster stokesii* Forbes.—Davis p. 349.
1928 *Goniaster marginatus* Forbes.—Davis p. 349.
1936 *Astropecten stokesii* (Forbes).—Davis p. 340.
1940 *Goniaster stokesi* Forbes.—Wrigley p. 235.
1963 *Goniaster* sp. cfr. *stokesi* Forbes.—Venables p. 263.

Type

The specimens described by Forbes 1848, and redescribed and figured 1849 are syntypes. The specimen shown from the dorsal side pl. 3 fig. 1 d is here selected as lectotype. The specimens were collected by Mr. Stokes in the Lower Eocene (Ypresian)

London Clay of the Isle of Sheppey (Kent) in England. The lectotype is in the collection of the Institute of Geological Sciences, London (49170). The holotype of *Goniaster marginatus* is the specimen figured by Forbes. It is from the same locality. The specimen is in the Institute of Geological Sciences (49165) but is completely decomposed.

Material

Several specimens are recorded by Forbes from the London Clay of the Isle of Sheppey, England. Further specimens are recorded by Davis (1928) from the London Clay (division 2–3) of South London and (1936) of Sheppey, and by Wrigley (1940) from Stockwell. *Goniaster* sp. cf. *stokesi* is recorded by Venables (1963) from the Middle Clay (Beetle Bed and Upper Fish Tooth Bed) of Bognor Regis.

In the collection of the British Museum are 20 specimens (E 3811, 4332a–b, 24625, 28404, 33844, 34486, 38488, 38489a–c, 38587, 38681, 52239 = 1852 fig. 6a, 52240, 52241, 52350, 75842, 75910), and in the Institute of Geological Sciences are 3 specimens (49169 = 1849 fig. 1a, 49170 = 1849 fig. 1d, 49171 = 1849 fig. 1c). All the specimens are from the Isle of Sheppey, and are preserved in pyrite.

In the collection of Mr. Rundle are at least 10 marginals from the London Clay (division 2) of Avely in Essex, England.

In the collection of Copenhagen are 2 specimens (12791, 12792) preserved in pyrite. They were found on the coast north of Fredericia in Denmark, washed out of the Lower Eocene Rösnäs Formation. The Danish specimens show the margin along the disc and a part of the ventral side with covering plates and adambulacrals. A few paxillae from the dorsal side are preserved.

Dimensions

Forbes (1849) indicated a radius from the center of the disc, to the tip of an arm greater than 11 cm and an interradius about 5 cm. A single specimen (E 75910) showing the ventral side is about this size, but the determination of the species is not certain. A reconstruction based on other preserved specimens fit a five-rayed star with a radius about 8 cm and an interradius about 3 cm. There have been 4–5 superomarginals and inferomarginals from the interradius to the base of the arm succeeded by 10–13 superomarginals and inferomarginals in each side of the narrow arm. The length of the marginals along the disc is 3–4 mm. Width of margin along the disc 4–6 mm. Height of margin 6–11 mm.

Description

A rather large *Teichaster* with flat, pentalobate disc and long, narrow arms. The disc is bordered by at least 8 superomarginals and 8 inferomarginals in each side forming a regular curve. The margin is of moderate hight and not very steep. The marginals along the disc are slightly wedge-shaped, almost rectangular with rounded edge against the dorsal and ventral covering plates. The height of the marginals is almost uniform along the disc and arms. The surface is curved and may be slightly

tumid, especially in the superomarginals. It is covered by closely placed, uniform spine pits for rudimentary spines, often preserved on the inferomarginals and giving the surface a granulated appearance. From the base of the arm, the superomarginals meet on the dorsal side, and the inferomarginals are separated only by the adambulacral and ambulacral plates. The inferomarginals are narrower than the superomarginals. The arms are almost parallel-sided and the marginals diminish only slightly up to the obtuse point of the arm, where two smaller superomarginals meet a small, semicircular terminal plate. There are about 10–13 superomarginals and inferomarginals in each side of the narrow arm. The distal superomarginals in the arm are often rather high and the tip of the arm may be recurved. The dorsal surface of the disc is covered by stout, pentagonal, uniform paxillae, the ventral side by flat, polygonal, uniform plates with spine pits. The adambulacrals are almost rectangular with a ridge towards the ambulacral furrow near the proximal end. There is a row of 5–7 small spines on the edge of each adambulacral and two rows of smaller spines on the ventral surface.

"*Goniaster marginatus*"

The type and only specimen referred by Forbes to *Goniaster marginatus* is a specimen from the London Clay of Sheppey, where *T. stokesii* is common. It consists of 5 superomarginals and 5 inferomarginals preserved in pyrite together with parts of the disc. A row of small plates in the other side of the specimen is the adambulacrals. The marginals preserved are nr. 1–4 from the interradius. The surface is covered by closely placed spine pits.

The specimen is now completely decomposed, but according to the figure it differs from *T. stokesii* only in the elevated rim along the edge of some marginals. This was taken by Forbes as a distinctive character of the species, but is obviously a result of the preservation. The central area of these marginals is depressed and partly exfoliated, leaving the protruding rim along some of the edges. The exfoliation along previous surfaces covered during growth is not uncommon in fossil asteroids and does not change the surface ornament. A similar preservation is seen in 4 of the superomarginals in one of the Danish specimens.

Affinity

The present species may be confused with *Hippasteria tuberculata* from the same locality, but seems to differ in the closely placed spine pits of the marginals. It is, however, very difficult to distinguish a granulation from rudimentary spines preserved in their spine pits on the pyrite fossils. *T. stokesii* further differs in the less steep margin, the absence of large marginal spines and the superomarginals meeting on the dorsal side of the arm.

Ceramaster obtusus n. sp.

Plate 5 figs. 11–13.

Derivation of name

Obtusus (Latin) blunted.

Type

The terminal inferomarginal pl. 5 fig. 12 is holotype. It is from the Sonja Member of sandstone from the Upper Danian Agatdal Formation in Agatdal, Nûgssuaq in West Greenland. The specimen is in the collection of the Geological Museum, Copenhagen (12794).

Material

From the type locality are 23 marginals including a terminal superomarginal and inferomarginal, and from Marrait kitdlît are a terminal superomarginal and inferomarginal and a median marginal found in calcareous and volcanic tuff from the Agatdal Formation. The preservation of the specimens is rather poor, and most of the marginals are exfoliated along growth surfaces, which however does not destroy the form or ornament.

Dimensions

	terminal superomarginal	terminal inferomarginal	median superomarginals		
length (along margin)	2.4	3.4	2.8	2.8	4.4
width (perpendicular to margin)	2.4	2.9	3.0	4.0	5.6
height	2.5	2.8	3.1	2.9	4.5

The width of the terminal superomarginal shows, that it belongs to a smaller individual than the terminal inferomarginal.

Diagnosis

A *Ceramaster* with equal number of superomarginals and inferomarginals. The marginals have scattered spine pits on the free surface and a depressed border with closely placed, small and shallow spine pits where small, rudimentary spines have been attached. The median superomarginals are evenly arched and a little tumid. The terminal superomarginal is rather large and compact, subtriangular with a rounded free surface indicating an obtuse arm-point. The terminal superomarginal meets the corresponding plate in its entire height along the midline of the arm, leaving no surface against the body cavity. The length of the plate is a little greater than its height and width. The inferior surface of the terminal superomarginal is a single joint face for the inferomarginal. The inferomarginals are less arched and not tumid. The terminal inferomarginal is almost identical in form and size with the terminal superomarginal but less tumid, and it shows faint impressions of adambulacral plates on the otherwise plane surface against the ambulacral system.

Ceramaster rabii (Linstow, 1912)

1912 *Goniaster* (*Goniodiscus*) *rabii*.—Linstow p. 47 pl. 2 figs. 1–4.
1929 *Goniodiscus rabii* Linstow.—Hucke & Voigt p. 160.

Type

The specimen described and figured by Linstow (1912) pl. 2 figs. 1–3 is here selected as lectotype. It is from the Middle Oligocene (Rupelian) Septarienton of Freienwalde near Mark (Westfalen) in Germany. According to Linstow the specimen is in the collection of Preussische geologische Landesanstalt, Berlin.

Material

The type specimen consists of 4 superomarginals and 4 inferomarginals in natural position corresponding to two incomplete sides of the disc. Another specimen with 3 superomarginals and 3 inferomarginals is described by Linstow from the same locality. Both specimens are preserved in pyrite. The species has further been recorded by Hucke & Voigt (1929) from the Middle Oligocene of Steutz (Anhalt) in Germany.

Dimensions

Length of marginals from 3.5 mm along the margin to 4 mm along the disc. Width of margin 7 mm. Height of marginals estimated about 3.5–4 mm.

Description

The marginals are slightly wedge-shaped, almost rectangular. Superomarginals are placed immediately above inferomarginals. The angle between the two margins of the disc partly preserved in the type indicates that the outline has been slightly stellate, almost pentagonal, and the marginals preserved in the specimen are presumably nr. 1–2 or 2–3 from the interradius. The tip of the arm is not preserved, but the almost uniform marginals indicate a structure as in *Ceramaster* with equal number of superomarginals and inferomarginals. This is also supported by the resemblance to *C. brandenensis*. It may be expected, that if the species was a *Metopaster*, the large and robust ultimate superomarginal would be preserved. The length of the marginals is considerably smaller than their width. This is seen from the dimensions and from fig. 3 in Linstow, but not from figs. 1–2 of the same specimen. The contact between superomarginals and inferomarginals in fig. 1 shows that figs. 1 and 2 are not perpendicular to the disc. The joint faces between marginals are smooth and flat. The free surface is arched but apparently not tumid. The surface is covered with large, scattered spine pits and a rather narrow, slightly irregular margin of considerably smaller, closely placed spine pits.

The species differs from *C. brandenensis* in the shorter marginals, the larger spine pits on the central area, the more restricted marginal ornament and the similar ornamentation of the inferomarginals. It differs from *Teichaster stokesii* in the smaller size, pentagonal form, the few and uniform marginals and the larger spine pits.

Ceramaster brandenensis Rasmussen, 1951

1951 *Ceramaster brandenensis*.—Rasmussen p. 588 fig. 1.

This species has previously been described and figured. It is found in the Middle Oligocene (Rupelian) Branden Clay at Branden and Faarup in Denmark. It differs from other species of *Ceramaster* in the almost squarish median superomarginals, the restricted median ornament of scattered spine pits on the median superomarginals and the absence of a similar ornament on the inferomarginals. There is no new information. The type is in the collection of the Geological Museum, Copenhagen (7639).

Echinaster jacobseni n. sp.

Plate 5 fig. 14, plate 12 fig. 7.

Derivation of name

The species is named in honour of the collector of the type specimen, the Danish writer and botanist J. P. Jacobsen (1847–1885). J. P. Jacobsen is also known as the naturalist who translated the works of Darwin and introduced the theory of evolution to the layman in Denmark.

Type

The specimen figured is holotype. It is from the Lower Eocene (Ypresian) Mo-Clay Formation of diatomaceous clay with volcanic ash layers at Silstrup Cliff near Tisted in Denmark. The specimen is in the collection of the Geological Museum, Copenhagen (12769).

Material

The type specimen is an impression of the ventral side showing a part of the small disc and proximal parts of 3 arms. In the local museum of Fur in Denmark is the impression of the dorsal and ventral side of an asteroid together with some specimens of *Ophiura furiae* from the diatomaceous clay of Fur. The asteroid shows the undisturbed ambulacrals, adambulacrals and adambulacral spines but no covering plates from the disc. There is no indication of marginals, and the asteroid presumably belongs to the present species. In the Geological Museum of Copenhagen are 5 rather poorly preserved asteroids in a calcareous layer (cement-stone) from the Mo-Clay of Skærbæk Cliff on Mors. They show the outline and some of the ambulacrals, but no indication of marginals, and may well belong to the present species.

Dimensions

The length of the arms is unknown in the holotype. They are preserved in a length of 15 mm from the mouth frame without distinctly tapering. Width of the ambulacral furrow is 3.5 mm. The specimen from Fur has arms 11 mm long and tapering through the distal half. The width of the ambulacral furrow is 3 mm. The specimens from Skærbæk Cliff are of similar size.

Diagnosis

An *Echinaster* with rather large, triangular mouth-angle plates with 3 spines along the radial edge, not terminal. Adambulacrals with a transverse row of 2–3 ventral spines and apparently a spine into the furrow. Ventral covering plates rather irregular and with 1 or 2 spines attached to nodules or tubercles on most of the plates. No ventral papulae.

Description

The ambulacrals on each side of the ambulacral furrow are uniform and evenly spaced, not two and two forming symmetrical pairs as in *Asterias*. The adambulacrals are slightly oblique, almost cube-formed with an arched surface and no sharp angle between ventral and adradial area. The proximal and distal edges are sharp and somewhat protruding. The arched median area is provided with 2 tubercles for large spines. A smaller tubercle may be indicated on the adradial side. Spines connected with the large tubercles are slender and reach a length of 1 mm.

The mouth-angle plates are rather large and meet in a sharp edge along the interradius. Their surface is evenly arched and apparently smooth. They are not obtuse, but form a point into the mouth. In 3 of the plates is seen a row of 3 spines decreasing in size towards the mouth, and apparently attached along the rounded edge between ventral and adradial area.

Outside the adambulacral plates there seems to be a row of smaller rounded plates more or less imbricate or raised on edge. In the interradial area between the arm bases are further seen a pavement of rather flat plates with more or less elliptical to rounded subtriangular outline, and some of them with one or two nodules or tubercles where spines have been attached. There is no space for papulae between the plates on the ventral side. The dorsal side is unknown.

Determination of the genus

The Echinasteridae have not previously been recorded as fossil except for a single specimen possibly belonging to *Henricia* according to Durham & Roberts (1948) and the Neocomian *Rhopia prisca* Loriol, 1873, which is now type of the genus *Protothyraster* Hess, 1970.

The absence of marginals shows that the species belongs to the group "Cryptozonia". The form of the ambulacrals shows that there have been two rows of podia in the ambulacral furrow opposite Asteriidae, who have four rows of podia and the ambulacrals in each side of the furrow forming symmetrical pairs. The absence of papulae on the ventral side of the disc excludes *Henricia*. The form of mouth-angle plates, the single transverse row of spines on the adambulacrals and the form of ventral plates in the interradial area correspond to the recent genus *Echinaster*. The great similarity was confirmed by a study of the recent *Echinaster sepositus* Retzius after removal of the organic tissue.

Ophiuroidea

Amphiura? senonensis Valette, 1915

Plate 6 fig. 1.

1915 *Amphiura senonensis.*—Valette p. 16 fig. 6.
1950 *Amphiura? senonensis* Valette.—Rasmussen p. 118 pl. 15 figs. 6–10.
1951 *Amphiura? senonensis* Valette.—Rasmussen p. 50 fig. 4.

Previous records

This species has previously been recorded from the Upper Senonian of France, England, Spain, Germany and Denmark, from the Danian of Denmark and South Sweden, and from the Upper Paleocene Vincentown Limesand of New Jersey, U.S.A.

Material

A single but well preserved lateral arm plate of this very characteristic species is found in the Upper Paleocene (Landenian) glauconitic marl of Kroisbach north of Salzburg in Austria. The sample belongs to the biozone with *Globigerina velascoensis* as does the Vincentown Limesand. The specimen is in the collection of the Geological Museum, Copenhagen (12797).

Remark

As mentioned by Rasmussen (1950 p. 119) this species should hardly be referred to *Amphiura*.

Ophiomusium danicum Nielsen, 1926

1926 *Ophiomusium danicum.*—Nielsen p. 11 figs. 2–4.
1950 *Ophiomusium danicum* Nielsen.—Rasmussen p. 102 pl. 12 figs. 1–6.
1951 *Ophiomusium danicum* Nielsen.—Rasmussen p. 56.
1969 *Ophiomusium danicum* Nielsen.—Maryanska & Popiel-Barczyk p. 135 pl. 2 fig. 2.

Previous records

This species has been recorded by Rasmussen (1950, 1951) from the Upper Danian of Denmark and South Sweden, and by Maryanska & Popiel-Barczyk (1969) from the uppermost Maastrichtian or the Danian of Nasilow near Pulawy in Poland.

Material

5 lateral arm plates of this species were found in the residue after washing a small sample of Danian limesand from Haidhof north of Vienna in Austria. The specimens are in the collection of the Geological Museum, Copenhagen.

Affinity

The species is very similar to *Ophiomusium stephensoni* Berry, 1942, from the Upper Paleocene (Landenian) Vincentown Limesand of New Jersey, U.S.A.

Ophiomusium subcylindricum (Hagenow, 1840)

1840 *Ophiura* (*Aspidura*) *subcylindrica*.—Hagenow p. 661 pl. 9 fig. 7.
1950 *Ophiomusium subcylindricum* (Hagenow).—Rasmussen p. 108 pl. 14 figs. 4–6.
1951 *Ophiomusium subcylindricum* (Hagenow).—Rasmussen p. 50.
1965 *Ophiomusium subcylindricum* (Hagenow).—Rasmussen p. 37.
1969 *Ophiomusium subcylindricum* (Hagenow).—Maryanska & Popiel-Barczyk p. 135 pl. 2 fig. 3.

Previous records

This species has been recorded by Rasmussen (1950, 1951, 1965) from the Maastrichtian of Denmark, Germany and Limbourg (Netherland-Belgium). It has further been recorded by Maryanska & Popiel-Barczyk (1969) from Upper Maastrichtian and presumed Danian deposits at Nasilow near Pulawy in Poland.

Ophiacantha? danica Rasmussen, 1951

Plate 6 fig. 2.

1950 *Ophiacantha?* sp.—Rasmussen p. 120 pl. 18 fig. 10.
1951 *Ophicantha? danica*.—Rasmussen p. 52 fig. 6.

Previous records

This species has been recorded from the Maastrichtian of Denmark and Germany and from the Danian of Denmark and Sweden.

Material

2 lateral arm plates of this species were found in the residue of a small washed sample of the Danian limesand from Haidhof north of Vienna in Austria. The specimens are in the collection of the Geological Museum, Copenhagen (12798).

Ophiura serrata Roemer, 1840

1840 *Ophiura serrata*.—Roemer p. 28 pl. 6 fig. 23.
1907 *Ophiura serrata* Roemer.—Spencer p. 102 pl. 27 fig. 3.
1907 *Ophiura parvisentis*.—Spencer p. 103, 134 pl. 27 fig. 4.
1915 *Ophioglypha parvisentis* (Spencer).—Valette p. 7 fig. 2.
1950 *Ophiura serrata* Roemer.—Rasmussen p. 111 pl. 16 figs. 1–8.
1951 *Ophiura serrata* Roemer.—Rasmussen p. 50, 56.

Previous records

This species has been recorded from the Cenomanian—Lower Senonian of England, the Senonian of France, Spain, Germany and Denmark, from the Danian of Denmark and Sweden, and possibly from the Upper Paleocene (Landenian) Vincentown Limesand of New Jersey, U.S.A.

Material

A lateral arm plate from the Danian limesand of Haidhof north of Vienna in Austria is referred to this species. Collection of the Geological Museum, Copenhagen.

Ophiura? hagenowi Rasmussen, 1950

1950 *Ophiura? hagenowi.*—Rasmussen p. 114 pl. 17 figs. 1–5.
1951 *Ophiura? hagenowi* Rasmussen.—Rasmussen p. 51.
1969 *Ophiura? hagenowi* Rasmussen.—Maryanska & Popiel-Barczyk p. 133.

Previous records

This species has been recorded by Rasmussen (1950, 1951) from the Upper Senonian of England, Germany, Spain and Denmark, and from the Lower Danian of Denmark. It has further been recorded by Maryanska & Popiel-Barczyk (1969) from the Upper Maastrichtian and from presumed Danian samples at Nasilow near Pulawy in Poland.

Ophiura achatae n. sp.

Plate 6 fig. 3.

Derivation of name

Achates (Latin) agate. The species is named after the type locality Agatdal (Agate-valley).

Type

The fragment of an arm figured is holotype and the only specimen known. It is from the Sonja Member of sandstone belonging to the Upper Danian Agatdal Formation in Agatdal, Nûgssuaq in West Greenland. The specimen is in the collection of the Geological Museum, Copenhagen (12799).

Dimensions

The arm fragment consists of 6 joints. Length of the fragment is 3.6 mm. Width tapering from 1.8 to 1.6 mm, height from 1.7 to 1.5 mm, width of dorsal arm plates from 1.4 to 1.2 mm and width of ventral arm plates from 1.2 to 0.8 mm. Length of uppermost lateral spine 0.7 mm.

Diagnosis

An ophiuroid in which the arm is about as high as wide with flattened ventral side and steep lateral sides. Dorsal side evenly arched without ridge. Lateral arm plates thick, short and high with a spine attached near the upper edge, a second below the middle of the frontal edge and a third just above the podial pore. There are no prominent tubercles or pits for the articulation of the spines. The spines are adpressed, the upper one long. Dorsal arm plates imbricate. They are short, wide, evenly arched with regular frontal edge. The ventral arm plates are just in contact along the median line. They are short and wide with a bilobed frontal edge. The surface of the lateral arm plates has an ornament of delicate vertical ridges and furrows. Other plates are smooth. Vertebrae zygospondylous.

Description

The distinctly tapering width of the arm and of the dorsal and ventral arm plates shows that the fragment belongs to the proximal part of an arm. The height of the arm is almost equal to the width. In section the arm is almost subquadrate with flattened ventral side, steep, slightly arched lateral sides and evenly arched dorsal side without median ridge. The joint are short.

The lateral arm plates are thick, high and short with a thick and rounded frontal edge. The surface is covered with delicate ridges and furrows forming a vertical pattern.

At the frontal margin of the lateral arm plate, near the rounded upper end, is a slight elevation to which a long spine is attached. A second, slightly smaller spine is attached to an elevation well below the middle of the frontal edge, and apparently a third has been attached immediately above the podial pore. There are a few papillae on the edge of the podial pore.

The dorsal arm plates are short and wide, evenly arched and with a regular curved frontal edge. There is a short, depressed posterior rim covered by the preceeding plate. The surface is smooth.

The ventral arm plates are rather large, wide and five-sided. They just touch each other along the mid-line of the arm between the lateral arm plates. The frontal margin is slightly bilobate. The surface is smooth.

The vertebral ossicles are large. The proximal end shows a pair of large articular faces for the upper pair of muscles. They form together a little more than half a circle with a shallow embayment for the dorsal furrow. The marginal furrow is distinct and rather deep. There is a zygospondylous articulation.

Affinity

The present species has some resemblance to *Stegophiura eocaenus* (Leriche, 1931), but differs by the short joints and plates of the arm and by the form of the dorsal arm plates. It is distinctly different from other Cretaceous and Tertiary species described.

Ophiura furiae n. sp.

Plate 6 figs. 4–5, plate 13 fig. 1.

Derivation of name

The species is named after the island of Fur in Denmark.

Type

The individual showing the ventral surface in the specimen figured plate 13 fig. 1 (lower part) and plate 6 fig. 4 is holotype. It is from the Lower Eocene (Ypresian) Mo-Clay Formation of diatomaceous clay with tuffit and is preserved in the weathered surface of a calcareous concretion (cement stone) collected by the late schoolmaster

J. P. Andersen in 1948 among removed material from the lower part of the formation in the clay-pit of Fur Molercompany on the Island of Fur in Denmark. The specimen is in the collection of the Geological Museum, Copenhagen (12800).

Material

Together with the holotype in the same concretion are three other individuals, two showing the ventral side and one the dorsal side. The specimen further contains numerous tiny shells of the gastropod *Spiratella mercinensis*.

Several specimens in the collection of the Geological Museum of Copenhagen are found as impressions in the diatomaceous clay from Fur, Mors and Thy in Denmark, but their ossicles are dissolved and very few details are seen. In the local Museum of Fur are a few individuals in a concretion and several specimens as impressions in the diatomaceous clay from Fur. In the collection of Mr. Groes are specimens from cementstone in the diatomaceous clay of Ejerslev.

Dimensions

The diameter of the disc varies from 5 to 8 mm. The preserved parts of the free arms reach a length of 25 mm. The width of the arm basis is in the holotype 1.3 mm.

Diagnosis

An *Ophiura* with pentagonal disc and large, subtriangular radial shields, apparently separated in the proximal part by a single row of plates. A dorsal arm plate is seen in the small radial embayment of the disc. The oral shields are large, five-sided, the adoral plates are straight. The arms are slender, subtriangular in section, higher than wide. The dorsal arm plates are narrow. They are in contact through about seven proximal arm joints. The ventral arm plates are small, five-sided and separated. The lateral arm plates are thin, adpressed and smooth with short, adpressed spines on the distal edge.

Description

The disc is pentagonal with straight or slightly concave sides. Sutures in the dorsal side of the disc are indistinct in most specimens. The radial shields are rather large and subtriangular, slightly more than half the radius of the disc. Near the margin they meet in the radius, more proximally they seem to be separated by a single row of plates. The rest of the dorsal surface shows no larger plates, but small scales are seen in some of the specimens. In an impression of the dorsal side in the diatomaceous clay the large radial shields are seen, and the rest of the dorsal surface is sunken down, so that only the area of the jaws stands up covered by small scales. There is a small embayment over the arms between the radial shields where a dorsal arm plate is seen.

The ventral side of the disc shows large five-sided oral shields with a convex outer edge evenly connected with concave lateral sides. The adoral plates are straight with no distal curve along the radius. The oral plates are slightly curved and protruding where they meet the jaw plate (torus angularis). There is a single row of teeth and

apparently a row of oral papillae along the moth frame. Outside the oral shields the disc is covered by small uniform scales. On each side of the arm is a narrow genital plate. The oral second ventral arm plate at the edge of the mouth is triangular. The five succeeding arm joints are included in the disc and have five-sided, almost rectangular ventral arm plates of similar size or slightly more narrow. The length of these ventral arm plates in the disc is about half the width. Their distal edge is almost straight. They are small and separated by the lateral arm plates. The first tentacle pore seen on the ventral surface of the disc is placed between the first ventral arm plate and the jaw, proximal to the first lateral arm plate and corresponds to the second podia.

The free arms reach a length of twice the diameter of the disc or more. They are subtriangular in section with a rounded dorsal ridge and a flattened ventral side. The dorsal plates in the proximal two free arm joints are slightly wider than long. In the succeeding joints they are narrow and wedge-shaped with strongly curved distal edge. They are in contact with each other in the proximal part of the arm for about 7 joints but separated in the distal part of the arm. The ventral arm plates are small, five-sided with almost straight distal edge. They are completely separated. The lateral arm plates are subcylindrical, thin and adpressed or with slightly protruding distal edge in the proximal part of the arm. The surface is smooth without any ridges or furrows. The distal margin is provided with a row of adpressed spines in a number of three or possibly more. The spines vary in length from one third to two thirds the length of the lateral arm plate.

Affinity

The present species differs from *O. wetherelli* in the smooth lateral arm plates, the five-sided ventral arm plates and the greater number of arm joints included in the disc.

It differs from *O. bognoriensis* in the smaller radial embayment of the disc, the more slender arms and arm joints and the more narrow dorsal arm plates. From *O. bartonensis* it differs in the section of the arms and the smaller dorsal arm plates, and from *Stegophiura eocaenus* in the small dorsal and ventral arm plates.

Ophiura wetherelli Forbes, 1852

Plate 7 figs. 1–5, plate 13 figs. 2–3.

1834 *Ophiura* sp.—Wetherell p. 417.
1852 *Ophiura wetherelli*.—Forbes p. 32 pl. 4 fig. 7.
1866 *Ophiura wetherelli* Forbes.—Busk pl. 12 fig. 4.
1923 *Ophioglypha wetherelli* (Forbes).—Davis p. 113 pl. 3.
1928 *Ophioglypha* sp.—Davis p. 349.
1970 *Ophioglypha wetherelli* (Forbes).—Rundle & Cooper pp. 114, 116, 118, 120.

Type

The specimens figured by Forbes (1852) are syntypes. They are from the Lower Eocene (Ypresian) London Clay of Highgate, London, referred by Wrigley (1924)

to division 5 of the London Clay. The specimens 99786 in the Institute of Geological Sciences and E 2680 in the British Museum are indicated on the labels as types of the figures. The specimen 99786 corresponds to fig. 7 b and is here selected as lectotype. The specimen E 2670 is also figured by Sowerby in Busk (1866).

Material

This species seems to occur from the Oldhaven Beds and Basement Beds below the London Clay at Herne Bay and Lower Upnor near Friendsburg Extra in Kent and Northwood in Middlesex through the London Clay division 2 at Copenhagen Fields, Clapham and Brixton (Victoria Line shaft) in London, division 4 at New Malden in Surrey and division 5 at Oxshott and Talworth in Surrey and at Finchley and Highgate in London. At Bognor Regis the species is found in the Middle Clay (Aldwick Beds). The species is recorded by Forbes (1852) from Hampstead and Highgate in London and Highcliff at Barton, by Davis (1923) from New Malden, Finchley and Copenhagen Fields in London and from the Isle of Sheppey, by Rundle & Cooper (1970) from Bessborough Gardens, Brentford, Brixton and Imperial College in London.

In the Institute of Geological Sciences, London are specimens from Northwood (51231), Talworth (61662, 62106) and Highgate (99786). In the collection of the British Museum are specimens from Herne Bay (E 52343–4, 52358–9), Lower Upnor (E 53229–31, 53233–43), Copenhagen Fields (E 429), New Malden (E 13702), Oxshott (E 52154, 52161–3), Talworth (E 13755, 20639–41, 52155–6, 52167, 52216, 53215–9), Finchley (E 54552), Highgate (E 2650–1, 2670, 13679, 50227) and Bognor Regis (E 20636). In the collection of Mr. Rundle are isolated arm fragments from Brixton (Victoria Line shaft).

The specimens previously recorded from the Isle of Sheppey by Davis (1923, 1936) are covered by pyrite and indeterminable (E 28697). Specimens from the Lower Clay of Bognor Regis referred by Venables (1963) to *Ophiura (Ophioglypha)* aff. *wetherelli* are here referred to *Ophiura forbesi* n.sp. The specimens (E 13702) previously figured by Davis (1923) show the dorsal side of two individuals and the ventral side of three individuals, but the plates of the disc are not distinct. Only the rather small specimens preserved as impressions in clay from Lower Upnor show details of the dorsal surface of the disc. Although in a different preservation and from a deeper level of the clay series than the type, they are referred to the present species and show the same structure, section and ornament of the arms. The present description is based mainly on these specimens.

Dimensions

Diameter of disc 3.5–9 mm. Length of arms more than twice the diameter of the disc. Width of arm near the disc 1.0–1.5 mm.

Description

The disc is flat, pentagonal in outline. The radial shields are subtriangular, about half the radius of the disc, and separated by two smaller plates along the radius suc-

ceeded by two dorsal arm-plates in the radial embayment limited by the radial shields and genital plates. Between the proximal end of the radial shields are two adradial plates or, in some specimens, possibly a single plate. The interradial areas seen in the specimens from Friendsburg Extra are covered by two interradial plates separated by an interradial pair of plates. Smaller plates may be seen along the radial shields. The central area of the disc is covered by a central plate and alternating circles of interradial and radial plates. There is a thin marginal interradial plate at the edge of the disc of similar size as the dorsal scales or smaller.

The ventral surface of the disc is seen in E 13702. There is in each interradius a rather large, five-sided oral shield with a convex outer edge and concave sides. The adoral plates are straight. There is a single row of teeth on torus angularis. Outside the oral shields are smaller scales, a large interradial marginal plate and along each arm a genital plate. The oral second ventral arm plate at the edge of the mouth is rather large, triangular. The three succeeding arm joints are also included in the disc and have five-sided ventral plates of decreasing size. They are separated by the lateral arm plates. The first tentacle pore visible on the ventral surface is placed between the oral plate and the ventral arm plate proximal to the first lateral arm plate, thus corresponding to the second podium.

The free arms outside the disc are slender and reach a length of at least 2.5 times the diameter of the disc. They are subtriangular to semicircular in section, slightly wider than high, with a flat ventral side. The arm plates are thin. The dorsal arm plates are fairly long and narrow with a slightly trilobate distal edge. In the proximal part of the arm they are in contact with each other, but from about number ten of the free joints they are separated. The ventral arm plates are small, triangular or five-sided, short and wide, and completely separated. The lateral arm plates are thin, adpressed, and have a distinct ornament of delicate, slightly irregular vertical ridges and furrows. Close behind the distal edge and above the podial pore are three closely placed, small, adpressed spines, a little shorter than the lateral plates. On the inner side of the lateral arm plate is an oblique ridge from the proximal part of the dorsal edge to the distal part of the ventral edge. The vertebral ossicles are similar to other species of *Ophiura*.

Affinity

O. wetherelli differs from *O. bognoriensis* in the ornament of the lateral arm plates and the arrangement of their spines, and in the more narrow dorsal arm plates.

Ophiura bognoriensis n. sp.

Plate 8 figs. 1–10, plate 14 fig. 1.

1959 *Ophiura wetherelli* Forbes.—British Caenozoic Fossils pl. 4 fig. 7.
1963 *Ophiura* (*Ophioglypha*) aff. *wetherelli* Forbes.—Venables p. 248, 264.

Derivation of name

The species is named after the type locality Bognor Regis in Sussex, England.

Type

The specimen figured 1959 in a publication from the British Museum under the title of British Caenozoic Fossils and refigured in the present publication is holotype. It is from the Lower Eocene (Ypresian), Starfish Bed (Lower Clay), London Clay of Bognor Regis in Sussex, England. The specimen is in the collection of the British Museum (E 13761).

Material

This is the only species of Ophiuroidea identified from the Astarte Bed and Starfish Bed (Lower Clay) of Bognor Regis. The holotype is unusually well preserved, but only the arms and the dorsal side of the disc are seen. In the same collection are the remains of three specimens (E 13764–6), an arm (E 13718) and a few isolated arm plates (E 13767–76, 52168) all from the Starfish Bed of Bognor Regis. In the collections of Mr. Rundle, London, and Mr. Gale, Canterbury, are several fragments from the Astarte Bed and Starfish Bed of Bognor Regis.

Dimensions

Diameter of disc 12 mm. Length of arm more than 20 mm. Proximal part of arm about 3.5 mm high and wide. Length of proximal arm joints about 0.8 mm. Width of proximal dorsal arm plate 2.2 mm. Vertebra from proximal part of arm about 1.9 mm high, 1.8 mm wide and 0.7 mm long.

Diagnosis

An *Ophiura* with flat, subpentagonal disc. Radial shields large, subtriangular, about two thirds of the radius of the disc. The proximal part of the radial shields are separated by a single row of three plates increasing in size towards the center of the disc. On each side of the arm base is seen a genital plate. The embayment over the arm shows four dorsal arm plates, two larger between the genital plates and two smaller between the radial shields. Along the genital plates is an arm-comb with distinct papillae, which do not meet over the arm. The central part of the disc and the narrow interradial areas are covered by smaller scales. There is no large marginal interradial plate. A large, shield-shaped oral shield is found together with other remains in the Starfish Bed.

The arms are subtriangular in section with almost equal height and width. The arm plates are smooth. The dorsal arm plates are very wide in the proximal part of the arm, the exposed part of the imbricating plates about four times as wide as long. The distal margin is regularly curved, not lobate. The dorsal arm plates are in contact with each other in all preserved parts of the arms, including more than 20 joints. The most distal arm plates preserved are about as long as wide. The ventral arm plates are seen in the proximal part of one of the arms and in the distal part of another. They are short, five-sided and completely separated. The thick and stout lateral arm plates are high and short, adpressed and imbricating with a depressed proximal border. There is a very prominent ridge on the inner side of the lateral arm plates. The distal

edge shows three small indentations for three spines, the lower one of which is very small. The upper spine is distinctly separated from the two lower. The spines are adpressed, and the two larger reach a maximal length of two thirds of the joint. The vertebral ossicles are rather short, higher than wide, elliptical with almost parallel sides.

Affinity

The present species differs from *O. wetherelli* by the stout, smooth arm plates, the much wider dorsal arm plates and the arrangement of secondary plates in the dorsal side of the disc. It differs from *Stegophiura eocaenus* in the smaller ventral arm plates.

Ophiura bartonensis n. sp.

Plate 9 figs. 1–9, plate 14 figs. 2–4.

1933 *Ophioglypha* sp.—Burton p. 152.

Derivation of name

The species is named after the locality Barton in Hampshire, England.

Type

The specimen plate 9 fig. 2 and plate 14 fig. 2 is holotype. It is from the Upper Eocene (Bartonian) Barton Beds of Highcliff, Barton in Hampshire, England. The specimen is in the collection of the British Museum (E 52158).

Material

Several specimens in slightly cemented grey sand are found in the Highcliff Sands (Lower Barton Beds A-3) and in unspecified levels of the Lower Barton Beds at Highcliff. The specimens are in the collection of the British Museum (E 33394, 35263, 49813, 52157–8, 52211–4). There is a small arm fragment from the Middle Eocene (Auversian) Upper Bracklesham Beds at Medmerry Farm, Selsey Bill in Sussex (E 13827–8). Several isolated plates are picked out of samples from the Middle Barton Beds (horizon E) at Barton collected by Mr. Davis (see also p. 71–72). In the collection of Mssrs. Rundle and Cooper are a few fragments from the Lower Bracklesham Beds (Prestwickianus Bed) and the Upper Bracklesham Beds (Brook Beds) of the stream section near Bramshaw in Hampshire, and a large number of specimens from the Highcliff Sands. A single specimen from the Upper Bracklesham Beds (Brook Bed) of Fawley Transmission Tunnel south of Southampton in Hamshire is in the collection of Mr. Stinton. This specimen was taken in Bed L of the profile described by Curry & West (1968). Details of the surface are in most specimens obscured by a thin cover of pyrite, especially along the sutures between the plates and thus no doubt a result of decay in the soft tissue of the dead animal.

Dimensions

The diameter of the disc varies from 7 to 20 mm. In a specimen 9 mm in diameter of the disc, the proximal arm joints are 0.8 mm long, 1.5 mm high and 2.4 mm wide.

Description

An *Ophiura* with a flat disc, almost circular in outline and covered by a regular pattern of plates. The radial shields are thin, rather large, subtriangular. They cover about half of the radius of the disc and almost touch over the arm base. On the inner side of the radial shield is seen the slightly protruding distal area meeting the genital rod, and a deep pit near the distal end. There is a sloping face meeting the dorsal arm plate in the radial embayment. Outside each radial plate is a genital plate with a few papillae of the arm-comb preserved and not meeting over the arm. The genital plate is subtriangular, strongly curved and smooth. There is only a small radial embayment in the disc with 2 dorsal arm plates and in some specimens a very small proximal third arm plate separating the genital plates and the distal end of the radial shields. The proximal end of the radial shields are separated by 3 plates increasing in size towards the centre of the disc. A few small lateral scales may be intercalated. The central area is covered by a central plate, primary radial and interradial plates and a few secondary scales. The interradial area is covered by a proximal and a distal interradial plate, a median pair of lateral plates and a few smaller scales. There is a very large and stout marginal plate in each interradius. It is elliptical with a lateral and a small ventral area. It covers the entire margin between the genital plates and is seen from the ventral as well as from the dorsal side of the disc. The interradial area of the ventral side is covered by a large oral shield separated by a few scales from the marginal plate. The adoral shields are straight and rod-shaped without distal flap. They meet the first lateral arm plate. There is a single vertical row of teeth on torus angularis. Oral papillae are not preserved. The second podial pore is seen from the ventral side at the edge of the mouth slit.

The arms are slender, elliptical in section, wider than high, with a flattened ventral side. The arm plates are thin. The dorsal arm plates are fairly wide in the proximal part of the arm, somewhat wider than long, but rapidly diminishing in width. Their distal edge is angular. They are in contact with each other in the proximal part of the arm, at least in 10 free joints, but separated in the distal joints. The ventral arm plates are short, rather wide, triangular with an almost straight distal edge. They are separated in the free part of the arm. The two most proximal ventral arm plates in the disc have a pattern of transverse furrows. The lateral arm plates are thin, adpressed with 3 adpressed spines on the distal edge. The median spine is a little shorter than the arm joint, the upper and lower spines are smaller. There is a small separation between the upper and the lower spines. The surface of the lateral arm plates has a pattern of delicate vertical furrows on the lateral part of the surface succeeded by a delicate and irregular granulation along the dorsal, ventral and distal edges.

Affinity

The very large interradial marginal plate and the rather few covering plates of the disc are unusual characteristics except in juvenile specimens of ophiuroids. The present species differs from *O. wetherelli* by the large interradial marginal plate, the low and wide section of the arms and the restriction of the ornament of furrows on the lateral arm plates. It differs from *O. bognoriensis* in the section of the arms, the form and size of arm plates and the ornament of the lateral arm plates. It differs from *Stegophiura eocaenus* in the dorsal side of the disc and the small, separated ventral arm plates.

Ophiura costata n. sp.

Plate 6 figs. 8–9.

Derivation of name

Costatus (Lat.) costate, ribbed. The name refers to the ornament of the lateral arm plates.

Type

The lateral arm plate pl. 6 fig. 8 is holotype. It is from the Upper Eocene (Bartonian) Middle Barton Beds, horizon E of Barton Cliff in Hampshire, England. The specimen is in the collection of the British Museum (E 53637).

Material

29 lateral arm plates are found among the echinoderm remains in a washed sample from the type locality. This sample, collected by Mr. A. G. Davis, also contains numerous remains of other echinoderms recorded on p. 72. 15 vertebra do not belong to other ophiuroids present in this sample and are therefore referred to the present species.

Dimensions

Lateral arm plates: Height 1.6–1.7. Width 0.4–0.6. Length 1.2–1.7. Vertebrae: Height 0.9–1.3. Width 1.0–1.5. Length 0.6–0.9.

Description

An ophiuroid with rather thin, slightly curved almost flat lateral arm plates. The distal edge is provided with a row of 8 rounded tubercles of increasing size towards the ventral edge. There is a row of similar tubercles on the lateral surface close behind the edge. There is no pit or depression on the tubercles and no indication of lateral spines attached to the plates. In the upper part the two rows of tubercles are almost fused, but in the lower part the 4 lateral tubercles are separated by a narrow smooth area from the marginal row. A low ridge divides the lateral surface in a distal and a proximal area, and a high and prominent ridge divides the proximal area in a dorsal

and a ventral part. The ventral part is cut by a very deep incision for the podium and a small embayment near the proximal ventral angle. The inner surface of the lateral arm plate is almost flat, sloping towards the proximal and distal edges. The dorsal and distal edges meet in a gentle curve where a group of 5 radiating crenellae reach the margin. The flat area along the ventral margin is cut by the deep and narrow podial incision, in front of which an irregular crenulation is seen. A slight depression runs towards the ventral proximal angle.

Other remains referred to O. costata

The sample collected by Davis includes 15 vertebrae distinctly different from other species present in the sample. The low number of these vertebrae agrees with the frequency of lateral arm plates and supports the determination. The vertebrae are zygospondylous, short and disc-shaped, slightly wider than high, almost elliptical with a broad, rounded dorsal edge and a low dorsal furrow. The hinge in the adoral surface is placed in a large, concave, subcircular area with a raised margin, and the dorsal nose is almost divided in two lateral knobs. The lateral surface forms a concave furrow of uniform width along the dorsal muscular faces. The aboral surface has a hinge of two stout knobs and a ventral nose divided by a median furrow.

Ophiura carpelloides n. sp.

Plate 10 figs. 1–9.

Derivation of name

Carpellum (Lat.) a carpel. The species is named after the form of the lateral arm plates, resembling the carpels of an orange.

Type

The lateral arm plate pl. 10 fig. 1 is holotype. It is from the Upper Eocene (Bartonian) Middle Barton Beds (horizon E of Burton 1929) at Barton in Hampshire, England. The specimen is in the collection of the British Museum (E 53658).

Material

In washed samples from the type locality collected by Mr. A. G. Davis are a large number of plates referred to this species together with plates referred to *O. davisi*, *O. bartonensis* and *O. costata*. The specimens are in the collection of the British Museum.

The Middle Barton Bed sample

A large sample of fossils have been washed out of the Middle Barton Clay (horizon E) at Barton by Mr. Davis. Numerous remains of 1 new species of asteroids and 4 new species of ophiuroids have been picked out of the sample. The combination of single ossicles was possible only because one species, *O. costata* is so characteristic in form and ornament of the lateral arm plates, that it cannot be confused with any other

ophiuroid known and also so seldom, that no common remains of the species can be expected in the sample. Furthermore one species, *O. bartonensis*, is found as complete specimens at other localities, so that all types of ossicles belonging to this species can be sorted out from the sample. After comparing size, form and ornament of the common plates, and after several attempts at reconstructing parts of the animals, at least some of the plates have been referred to species.

Astropecten granulatus		
superomarginals	1963	
inferomarginals	2395	
ambulacrals	118	(including 23 first amb.)
adambulacrals	15	
terminals	7	
Ophiura carpelloides		
lateral arm plates	193	(96 right, 97 left)
ventral arm plates	10	
dorsal arm plates	15	
radial shields	204	
oral shields	87	
genital plates	96	
jaws	43	
vertebrae	106	(including 21 first vertebra)
Ophiura davisi		
lateral arm plates	347	(172 right, 175 left)
ventral arm plates	6	
oral shields	45	
vertebrae	247	(no first vertebra)
Ophiura bartonensis		
lateral arm plates	300	(142 right, 158 left)
dorsal arm plates	2	
radial shields	45	
interradial marginal plates	48	
genital plates	32	
vertebrae	35	
Ophiura costata		
lateral arm plates	29	
vertebrae	15	
Not identified ophiuroids, mainly disc plates	58	
Crinoid brachials	4	

Among the ophiuroid plates remaining after removal of *O. bartonensis* and lateral arm plates of *O. costata* are two kinds of lateral arm plates from which the types of *O. carpelloides* and *O. davisi* are selected. An uncommon type of vertebrae is referred to *O. costata*. There are two kinds of common vertebral ossicles not belonging to *O. bartonensis*. One is very high and narrow with a lateral bead. It fits well between the lateral arm plates of *O. davisi*. The other is more broad and triangular with a lateral furrow and may fit between the lateral arm plates of *O. carpelloides*. A few small and very thick dorsal and ventral arm plates are referred to *O. carpelloides* and may fit the reconstruction of the arm. Thin ventral arm plates with a large podial embayment fit the reconstructed arm of *O. davisi*. There are several first vertebra of the triangular kind with no lateral bead, indicating a dominans of remains from the disc. The arms of *O. carpelloides* may therefore have been short and rapidly tapering. There are also two kinds of oral shields not belonging to *O. bartonensis*. One of them is unusally large and stout, almost hemispheric. It is therefore combined with the unusally large and stout arm plates of *O. carpelloides*. The other is rather thin and flat, and is referred to *O. davisi*. The large number of oral shields from *O. carpelloides* compared with *O. davisi* is explained by the robustness of the plates and the dominance of remains from the disc in *O. carpelloides*. There are two kinds of radial shields in the sample, but one of them agrees with the radial shield of *O. bartonensis*. The other must therefore belong to *O. carpelloides* or *O. davisi* or both. They are large, subtriangular, very thick with a broad bevelled edge and a short furrow in the distal edge. Since they cannot be subdivided on a morphologic basis, it is concluded, that large, subtriangular radial shields are present only in one of the species. I have referred these thick radial shields to *O. carpelloides*. The number of radial shields to oral shields in the animal is 2 to 1, but there is a small overweight of radial shields in the sample. There are also two kinds of genital plates in the sample, one of them corresponding to *O. bartonensis*. The other is here referred to *O. carpelloides*. The few unidentified plates are mainly asymmetric plates from the disc. Most of them are rather thick and may well belong to *O. carpelloides*.

Dimensions	length	width	height
lateral arm plates	0.72–1.40	0.94–1.57	2.11–3.72
ventral arm plates	0.58–0.66	1.37–1.41	ab. 0.8
radial shields	2.27–3.76	1.88–2.82	0.78–1.10
oral shields	1.56–2.04	1.61–2.23	0.78–1.25
genital plates	2.35–2.86	0.94–1.06	0.63–0.70
jaws	1.25–1.84	0.63–0.70	1.14–1.49
vertebrae	0.74–0.86	1.33–1.69	1.21–1.49
reconstructed arm joint	1.37	3.72	3.84

Diagnosis

An ophiuroid with arms covered by very high and stout but short lateral arm plates. The lateral arm plates are cresentic, slightly more curved towards the ventral

side. The outer surface is completely smooth and tapers to a dorsal point. The distal edge is sharp and there is no trace of spines. There is no incision for a podial pore. The proximal margin is somewhat restricted and shows irregular bosses meeting the overlapping plate from the preceeding joint. The plates are triangular in section with proximal and distal sides of similar size as the outer surface. The proximal side is smooth and concave, the distal side is flat or slightly concave with a radiating micro-ornament. The proximal and distal surfaces meet in the upper part of the plate under an angle of 30°–40°, but are separated in the lower part of the plate by a small, concave inner surface against the vertebra restricting the width of the distal and specially the proximal side in the lower part of the plate.

Description of other plates referred to O. carpelloides

Among the two kinds of ophiuroid vertebrae common in the sample, those with a subtriangular outline may fit between the lateral arm plates. The vertebrae are zygospondylous, short, disc-shaped, with a narrow lateral furrow along the large dorsal muscular fossae. The dorsal furrow is short and narrow. The adoral hinge is formed by two angular ridges. The dorsal nose is heart-shaped. The aboral hinge is formed by two lateral bosses and there is a prominent ventral nose. The first vertebra differs in having four lateral articular bosses in the proximal surface, and the lateral furrow is restricted to the dorsal end. The lateral arm plates may have met above the vertebra, but are separated by a ventral arm plate below the vertebra. The dorsal arm plate is small, very thick with a sharp distal edge. The distal edge is curved, the sides converge towards the proximal end. Dorsal arm plates from the arm base have a pair of dorsolateral ridges where they meet the radial shields or genital plates. The ventral arm plate is very thick in the proximal part. The distal edge is almost straight and rather sharp. The sides are almost parallel. The ventral surface is four-sided, short and rather wide, and slightly arched. It forms an obtuse angle with the large proximal side of the plate. The inner surface of the plate is divided in a proximal part towards the vertebra and a distal part meeting and slightly overlapping the succeeding plate. The radial shields referred to this species are large, rounded subtriangular in outline, and very thick. There is a broad, gently sloping bevelled margin along the adradial and abradial sides. The rounded distal edge is more steep with a curved, almost horizontal furrow near the underside from the middle of the distal edge towards the presumed adradial side. This furrow may be the joint face towards a disc plate, presumably the genital plate. The underside of the radial shield is slightly concave with a slightly elevated area where it meets the inner genital bar. There is no pit in the underside of the radial shield. The oral shields are large, very thick and tumid, almost circular in outline with curved, sharp lateral edges and in most specimens a short, straight distal edge. The underside shows a steep distal edge and sloping lateral margins forming 3 more or less distinct bosses separated by 2 furrows in each side, and 2 large, flat or concave faces meeting in the proximal point under an angle of 100°–150°. The thick central part of the underside is concave. The genital plates are

axe-shaped and curved. There is a pair of furrows on the side of the handle, where papillae may have been attached, and one or two ridges separated by furrows on the head. The jaws show the first and second podial pore just above each other. The second pore has opened on the ventral surface behind four small pits where mouth papillae were attached.

Ophiura davisi n. sp.

Plate 10 figs. 10–15.

Derivation of name

The species is named after the British geologist Mr. A. G. Davis, collector of the specimens and of many other fossils from the British Eocene.

Type

The lateral arm plate pl. 10 fig. 11 is holotype. It is from the Upper Eocene (Bartonian) Middle Barton Beds (horizon E of Burton 1929) at Barton in Hampshire, England. The specimen is in the collection of the British Museum (E 53668).

Material

In a washed sample from the type locality are found 347 lateral arm plates together with 247 vertebrae, 6 ventral arm plates and 45 oral shields referred to this species. Remains of other species from the Middle Barton Bed sample are recorded p. 72.

Dimensions	length	width	height
lateral arm plates	0.94–1.18	0.58–0.78	1.45–2.31
oral shields	1.76–1.96	1.25–1.61	0.47–0.58
vertebrae	0.78–0.91	0.91–1.61	1.25–1.71

Diagnosis

The lateral arm plates are rather large and thick, almost cresentic, slightly arched. The lateral surface is divided in a proximal part with 5–8 large crenellae meeting the overlapping preceeding plate, and a slightly tumid, smooth distal part. The distal edge is sharp with faint traces of pits for the attachment of 4–6 well separated lateral spines increasing in size towards the ventral side. There is a large ventral notch for the podium. The dorsal end of the plate is rounded in the small plates and has a small, inwards sloping median facet above the vertebra, but in most of the larger arm plates is a flat or slightly concave, smooth, outwards sloping dorsolateral facet of variable size. These lateral arm plates may have been included in the disc, the oblique facet meeting the genital bar. The proximal end of the lateral arm plate is rather thick with a high and narrow, concave inner surface towards the vertebra. The distal part of the inner surface is concave, sloping towards the anterior margin, and there are 5–8 crenellae meeting the succeeding plate. There is a large furrow for the podium.

Description of other plates referred to O. davisi

The form of the lateral plates indicates a very narrow vertebra. About 247 vertebrae of this form are found in the sample and referred to this species. The vertebrae are zygospondylous, very narrow, height more than twice their width and very short, disc-shaped. They have always a prominent lateral bead filling out the lateral furrow except in the dorsal end of the vertebra. The dorsal furrow is short and narrow. The edges of the dorsal adoral muscle face form a double median ridge from the dorsal furrow to the V-shaped dorsal nose. The hinge is not very prominent, but there is a distinct ventral nose in the aboral surface. Some of the vertebrae are wider, more triangular in outline and have a restricted lateral bead. They resemble the vertebrae referred to *O. carpelloides*, but may be proximal vertebrae of the present species. Among the numerous plates in the sample are some presumed oral shields referred to this species. They are rather thin, linguiform, pointed towards the proximal end with a rounded central area and a sloping margin towards the straight or curved, sharp distal edge. The inner side of the oral shield is flat or slightly concave with two narrow facets meeting in the proximal point and forming an angle of about 60°.

There are 6 small ventral arm plates obviously belonging to this species as indicated by the size and the podial pore. They are shield-shaped with a wide, bilobate distal edge. Close behind the distal edge is a large lateral embayment corresponding to the podial pore and occupying most of the lateral edge. The ventral surface is flat with a rather wide, bevelled proximal margin divided by a median ridge. The proximal edge is sharp and slightly bilobate. On the inner side the distal margin of the ventral arm plate is bevelled corresponding to the overlap of the plates. When the lateral points of the thin distal edge are broken away, this very small plate will hardly be recognized as an ophiuroid remain, and moreover most of the plates may be lost by washing and sieving of the sample.

Ophiocoma hessi n. sp.

Plate 6 figs. 6–7.

Derivation of name

The species is named after Dr. H. Hess (Basel), student of fossil asteroids and ophiuroids.

Type

The fragment of an arm shown pl. 6 fig. 6 is holotype. It is from the Upper Eocene (Bartonian) Highcliff Sands (Lower Bartonian Beds A-3) at Highcliff in Hampshire. The specimen is transferred from the collection of Mr. Rundle to the collection of the British Museum (E 53635).

Material

There are 6 fragments of arms from the type locality, including the holotype, in the collection of Mr. Rundle.

Dimensions

Specimen:	1.	2.	3.	4.	5.	Type
number of joints preserved	8	6	4	3	6	6
length of joint	0.33	0.43	0.50	0.50	0.54	0.58
width of joint	0.90	1.40	1.64	1.44	1.48	1.55
height of joint	ab. 0.49	1.05	0.94	0.94	0.82	1.02
length of ventral plate	–	0.46	0.50	0.50	0.58	0.58
width of ventral plate	–	0.54	0.69	0.66	0.66	0.62
length of dorsal arm plate	0.39	0.46	–	–	0.58	0.54
width of dorsal arm plate	0.70	1.00	–	–	1.16	1.16

Description

An *Ophiocoma* in which the arms are low and wide, almost elliptical in section with a flat ventral side. The height of the arm is a little more than the width. The lateral arm plates are short and cresentic, tapering to a narrow dorsal point and forming a more obtuse ventral projection giving plenty of room for the podium without surrounding a distinct podial pore. They are rather thick with somewhat outwards projecting distal edge. There are four well separated, horseshoe-shaped, prominent tubercles immediately behind the edge for the attachment of lateral spines. The lowermost tubercle is above the podial embayment, the uppermost is near the lateral point of the dorsal arm plate. The tubercles are similar in size or the second from the ventral side may be slightly larger. The surface of the lateral arm plates is smooth except for the four tubercles. The ventral arm plates are rather large, flat and smooth, slightly wider than long, almost square with an angular proximal side and a slightly concave distal side. They meet in the midline between the lateral plates. The dorsal arm plates are large, thin, smooth very wide and slightly arched. The proximal edges meet in an obtuse angle. The distal edge forms a gentle curve connected by a short lateral round to the proximal edge. They meet and overlap along the midline at least in the proximal part of the arms. The vertebrae are zygospondylous with thin lateral wings corresponding to the section of the wide and low arm, and with a narrow lateral furrow.

Affinity

The species is similar to *Ophiocoma rasmusseni* Hess, 1960 in the arm section and in the form of lateral arm plates and vertebrae, but differs in the short arm joints and plates.

Stegophiura eocaenus (Leriche, 1931)

1931 *Ophiurites eocaenus*.—Leriche p. 109 figs. 1–4 pl. 6 figs. 1–3.

Type

The specimen A among the individuals figured by Leriche is here selected as lectotype. It is from a boulder of sandstone collected at the base of the mole in the

harbour of Zeebrugge in Belgium. The boulder contains 4 individuals and some fragments of the present species. The sandstone is referred to the Eocene ("Paniselian"), corresponding presumably to the uppermost Ypresian or lower part of the Lutetian. The specimen is in the collection of the museum in Brussels.

Dimensions

Diameter of disc 11–13 mm. Length of free arm more than 35 mm. Width of arm near disc 1 mm.

Description

The disc is almost circular. Dorsal plates of disc rather large. The radial shields are rounded subtriangular and reach about half the radius of the disc. They are separated by a single row of 6 radial plates including dorsal arm plates and increasing towards both ends. The interradial area between the radial shields is covered by two marginal and two interradial plates. At the proximal end of each radial shield is a plate separating the interradial plate from the large plate at the end of the radial row. The central area of the disc is not preserved. The ventral side of the disc shows no details except in connection with the arm. There are 5 brachial joints included in the disc.

The dorsal arm plates are rather large, and contiguous through more than 25 joints. They are wider than long for about 20 free joints. In the distal part of the arm they are longer than wide. The distal edge of the dorsal arm plates is divided in a straight median part, which forms an angle with shorter lateral parts. The ventral arm plates are large, almost square with concave sides against the large podial pores. They are contiguous in the entire length of the arm preserved, including more than 30 free joints. The lateral arm plates are adpressed. No spines are seen

Affinity

The present species was placed by Leriche (1931) under the provisional generic name *Ophiurites*. The very large arm plates are similar to the arm plates of *Stegophiura*. Unfortunately arm spines are not preserved. The species is distinguished from other Tertiary ophiuroids specially by the large ventral arm plates.

Asteronyx? ornatus Rasmussen, 1950

1950 *Asteronyx? ornatus*.—Rasmussen p. 121 pl. 18 fig. 11.
1950 *Asteronyx granulosus*.—Müller p. 33 pl. 2 figs. H, 1–5.
1951 *Asteronyx? ornatus* Rasmussen.—Rasmussen p. 52.
1969 *Asteronyx? ornatus* Rasmussen.—Maryanska & Popiel-Barczyk p. 136 pl. 1 fig. 4.

Previous records

This species has been recorded by Rasmussen (1950, 1951) from the Maastrichtian of Denmark and Germany, and by Maryanska & Popiel-Barzcyk (1969) from the Upper Maastrichtian and presumed Danian at Nasilow near Pulawy in Poland.

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Indleveret til Selskabet den 4. maj 1972.
Færdig fra trykkeriet den 28. december 1972.

PLATES

Plate 1

Fig. 1. Isselicrinus aff. paucicirrhus (Nielsen, 1913), p. 16. Upper Danian sandstone ("Sonja lens"), Sonja Member of the Agatdal Formation. Agatdal in Nûgssûaq, West Greenland. Collection Geological Museum, Copenhagen (12752). Column, × 5; a, lateral; b, articular surface.

Figs. 2–5. Isselicrinus subbasaltiformis (Miller, 1821), p. 17. Ypresian.
Fig. 2. London Clay (division 2). Hampstead Heath, London. British Museum (57540). Column, lectotype × 1.4; lateral view.
Fig. 3. Rösnäs Clay. Røsnæs in Denmark. Geological Museum, Copenhagen (12753). Column, × 5; a, lateral; b, articular surface of nodal.
Fig. 4. Rösnäs Clay. Røsnæs in Denmark. Geological Museum, Copenhagen (12754). Articular surface of internodal, × 5.
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Figs. 6–7. Calamocrinus ilimanangei n. sp., p. 28; × 8.2. Upper Danian sandstone ("Sonja lens"), Sonja Member of the Agatdal Formation. Agatdal in Nûgssuaq, West Greenland.
Fig. 6. Geological Museum, Copenhagen (12756). Holotype, column; a, lateral; b, articular surface.
Fig. 7. Geological Museum, Copenhagen (12757). Column.

Fig. 8. Bourgueticrinus danicus Nielsen, 1913, p. 30; × 5. Heersian glauconitic marl, Lellinge Formation. Egsmark in Denmark. Geological Museum, Copenhagen (12758).

Fig. 9. Democrinus londinensis (Forbes, 1852), p. 31; × 3.3. Ypresian, London Clay. Highgate in London. British Museum (E 38715).

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Fig. 11. Centrodorsal (E 53621), ventral side.
Fig. 12. Primibrachial I Br 2 (E 53622); a, proximal; b, dorsal; c, distal.
Fig. 13. Secundibrachial II Br 1 (E 53623); a, proximal; b, dorsal; c, distal.
Fig. 14. Muscular secundibrachial (E 53624); a, dorsal; b, distal.
Fig. 15. Syzygial secundibrachial (E 53625); a, proximal; b, dorsal; c, distal.

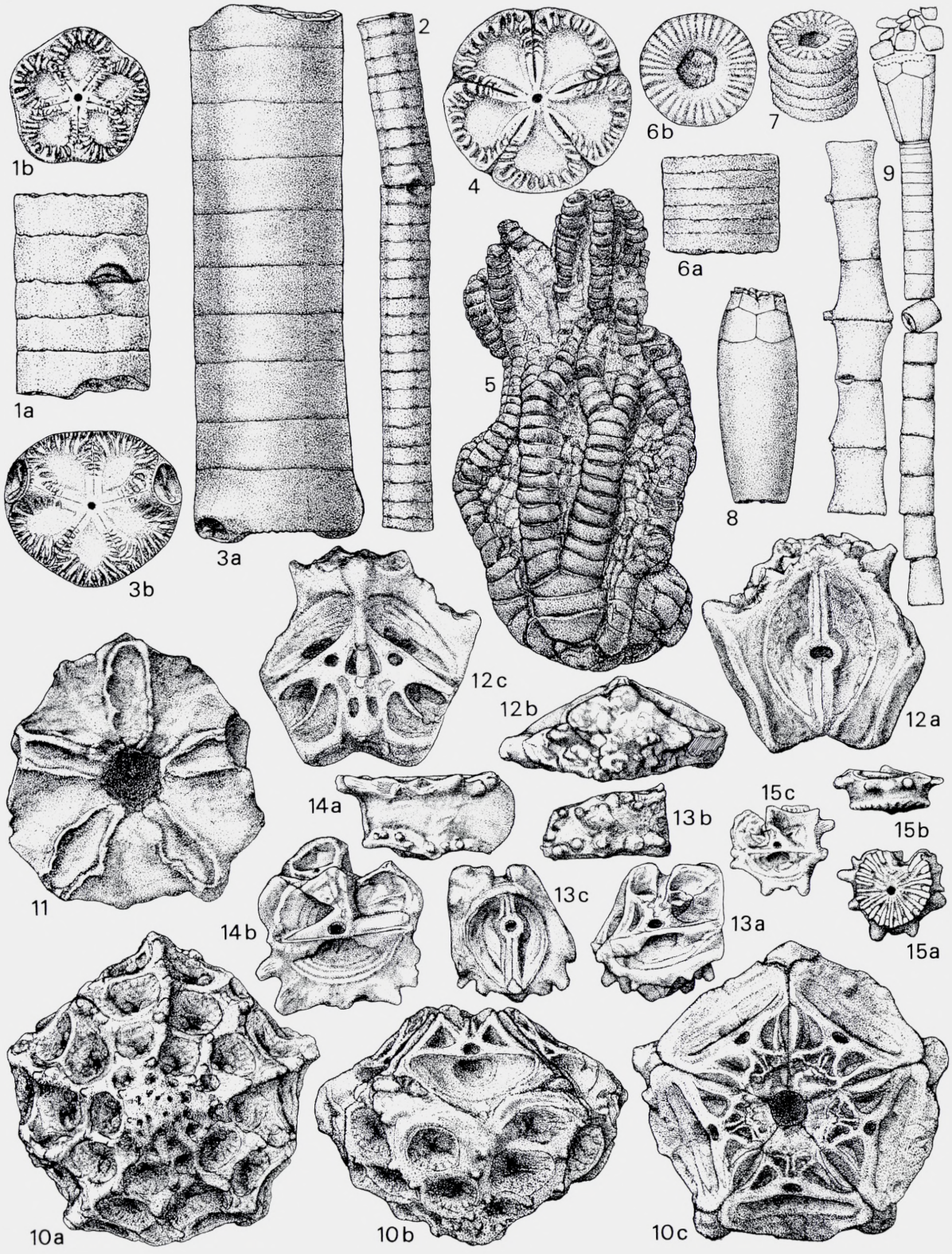
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Plate 2

Figs. 1–20. Cainocrinus tintinnabulum Forbes, 1852, p. 22. Ypresian, Middle Clay (Craigweil Bed). Bognor Regis, England. Collection Geological Museum, Copenhagen.

Fig. 1. Reconstruction, × 4.
Fig. 2. Diagram of arm.
Fig. 3. Theca with column and first primibrachial, × 11. (12759).
Fig. 4. Column, × 8. (12760). a, lateral; b, articular surface.
Fig. 5. Column, × 7.5. (12761).
Fig. 6. Cirrus with first 6 cirrals, × 10. (12762).
Fig. 7. Basals, infrabasals and proximal columnals, × 10. (12763). a, lateral; b, surface against radial ring.
Fig. 8. Basal showing joint face for infrabasals and column, × 10. (12764).
Fig. 9. Radial, × 10. (12765). a, dorsal side and brachial articulation; b, lateral.
Fig. 10. Primibrachial I Br 1, × 10. (12766). a, proximal; b, dorsal surface and distal articulation.
Fig. 11. Primibrachial I Br 2, × 10. (12767). a, proximal; b, dorsal; c, distal.
Fig. 12. Recombined fragment of arm with I Br 1 to III Br 5, × 5. (12768).
Fig. 13. Secundibrachial II Br 1, × 10. (12769). a, proximal; b, dorsal surface and distal articulation.
Fig. 14. Secundibrachial II Br 2, × 10. (12770). a, proximal; b, dorsal; c, distal articulation with pinnular articulation in left side.
Fig. 15. Secundibrachial II Br 3, × 10. (12771). a, dorsal; b, lateral; c, distal.
Fig. 16. Secundibrachial II Br 4, × 10. (12772). a, proximal; b, dorsal; c, lateral; d, distal.
Fig. 17. Tertibrachial III Br 1, × 10. (12773). a, dorsal; b, distal.
Fig. 18. Tertibrachial III Br 2, × 10. (12774). a, dorsal; b, lateral; c, distal.
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Fig. 20. Distal fragment of arm, × 10. (12776). a, dorsal; b, lateral; c, ventral.

Figs. 21–22. Isocrinus (?Cainocrinus) sp. aff. C. tintinnabulum Forbes, 1852, p. 27. Paleocene, Pulaway Beds in the Sochaczew boring 260–262 m, Poland. Collection Geological Institute, Warsaw. Columnal, × 10. a, lateral; b, articular surface.

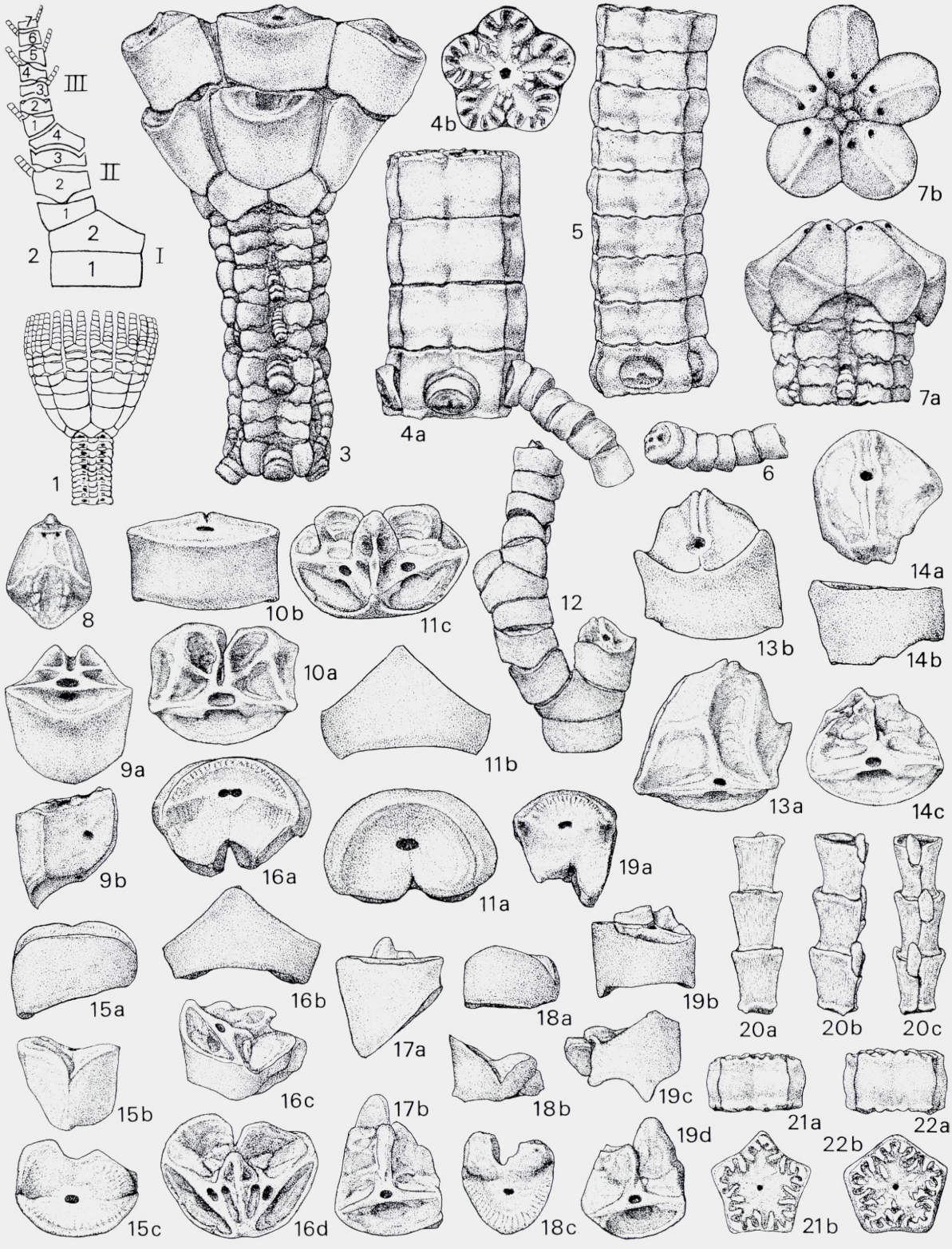
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Plate 3

Figs. 1–4. Astropecten postornatus (Rasmussen, 1945), p. 37. Upper Danian. Geological Museum, Copenhagen.
Fig. 1. Superomarginal (5184a), × 5. Conglomerate at base of Lellinge Formation. Svanemøllen in Copenhagen, Denmark.
Fig. 2. Inferomarginal, lectotype (5184b), × 5. Conglomerate at base of Lellinge Formation. Svanemøllen in Copenhagen, Denmark.
Fig. 3. Superomarginal (12777), × 10. Sandstone ("Sonja Lens"), Sonja Member of Agatdal Formation. Agatdalen, Nûgssuaq, West Greenland.
Fig. 4. Inferomarginal (12778), × 10. Sandstone ("Sonja Lens"), Sonja Member of Agatdalen Formation, Agatdalen, Nûgssuaq, West Greenland.

Figs. 5–8. Astropecten granulatus n. sp., p. 38. Bartonian, Middle Barton Bed, (Horizon E). Barton Cliff, England. British Museum.
Fig. 5. Superomarginal (E 53626), × 10.
Fig. 6. Inferomarginal, holotype (E 53627), × 10.
Fig. 7. Terminal plate (E 53628), × 20.
Fig. 8. Ambulacral (E 53629), × 10.

Figs. 9–15. Coulonia colei (Forbes, 1852), p. 41. Ypresian.
Fig. 9. London Clay (division 5), Highgate in London. British Museum (E 428). Dorsal side of arm, × 5.
Fig. 10. Same specimen, superomarginal, × 5.
Fig. 11. Same specimen, inferomarginal, × 5.
Fig. 12. Same specimen, two paxillae, × 5.
Fig. 13. Same specimen, two marginal spines, × 5.
Fig. 14. London Clay, Isle of Sheppey, England. British Museum (E 38490). Dorsal side of arm, × 3.5.
Fig. 15. London Clay (division 5), Highgate in London. Geological Survey, London (5807). Terminal plate, × 6.

Figs. 16–17. Lophidiaster haunsbergensis n. sp., p. 45; × 12. Landenian. Kroisbach near Haunsberg, Austria. Geological Museum, Copenhagen.
Fig. 16. Superomarginal, holotype (12779).
Fig. 17. Inferomarginal, (12780).

Figs. 18–19. Lophidiaster inversus n. sp., p. 46; × 10. Landenian. Kroisbach near Haunsberg, Austria. Geological Museum, Copenhagen.
Fig. 18. Superomarginal, holotype (12781).
Fig. 19. Inferomarginal, (12782).

Figs. 20–25. Lophidiaster concavus n. sp., p. 47. Ypresian, London Clay. British Museum.
Fig. 20. Lateral view of reconstructed arm (E 53630), × 5. London Clay (division 3) Wraysbury Reservoir at Poyle, England.
Fig. 21. Superomarginal, (E 53631), × 10. Same locality.
Fig. 22. Inferomarginal, holotype (E 53632), × 10. Same locality.
Fig. 23. Dorsal plate (E 53633), × 10. Same locality.
Fig. 24. Ambulacral (E 53634), × 10. Same locality.
Fig. 25. Terminal plate (E 53675), × 10. London Clay (division 2). Aveley, England.

Figs. 26–27. Lophidiaster sp. aff. L. pygmaeus Spencer, 1913, p. 48; × 10. Landenian. Kroisbach near Haunsberg, Austria. Geological Museum, Copenhagen.
Fig. 26. Superomarginal (12783).
Fig. 27. Inferomarginal (12784).

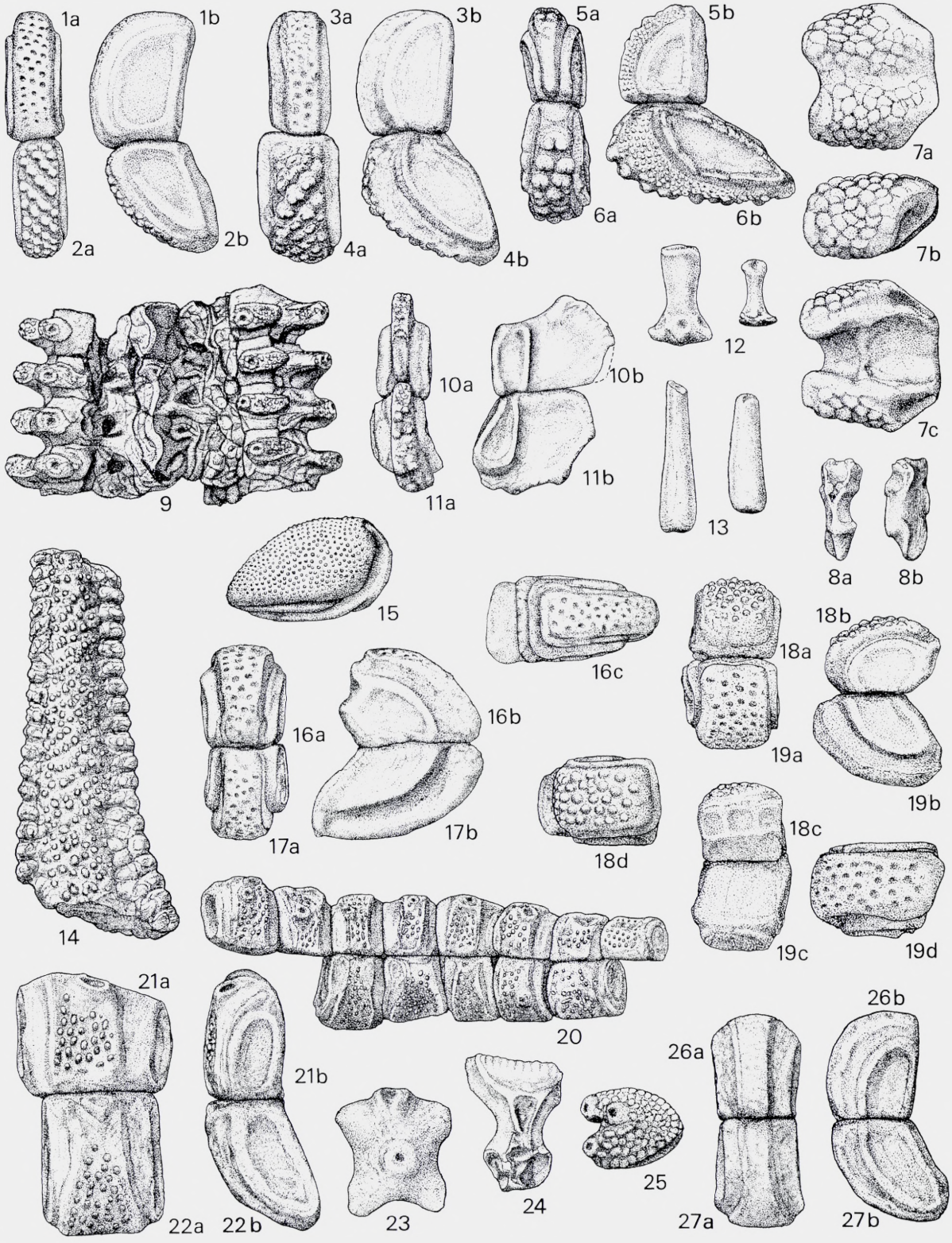
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PLATE 4

Figs. 1–5. Hippasteria tuberculata (Forbes, 1852), p. 48. Ypresian, London Clay, Isle of Sheppey, England.

Fig. 1. Part of disc and arm, × 1.6. Geological Survey, London (99787). a, dorsal; b, ventral.

Fig. 2. Part of disc with base of arm, × 1.6. British Museum (E 53295). a, ventral side (covered by pyrite) and margin; b, profile of margin.

Fig. 3. Distal part of arm, × 1.6. British Museum (E 33832a). a, dorsal; b, lateral; c, ventral; d, proximal section.

Fig. 4. Distal part of arm, × 3.2. British Museum (E 33832b). a, dorsal; b, lateral; c, ventral; d, proximal section.

Fig. 5. Arm, × 2.5. British Museum (E 52242). a, dorsal; b, ventral.

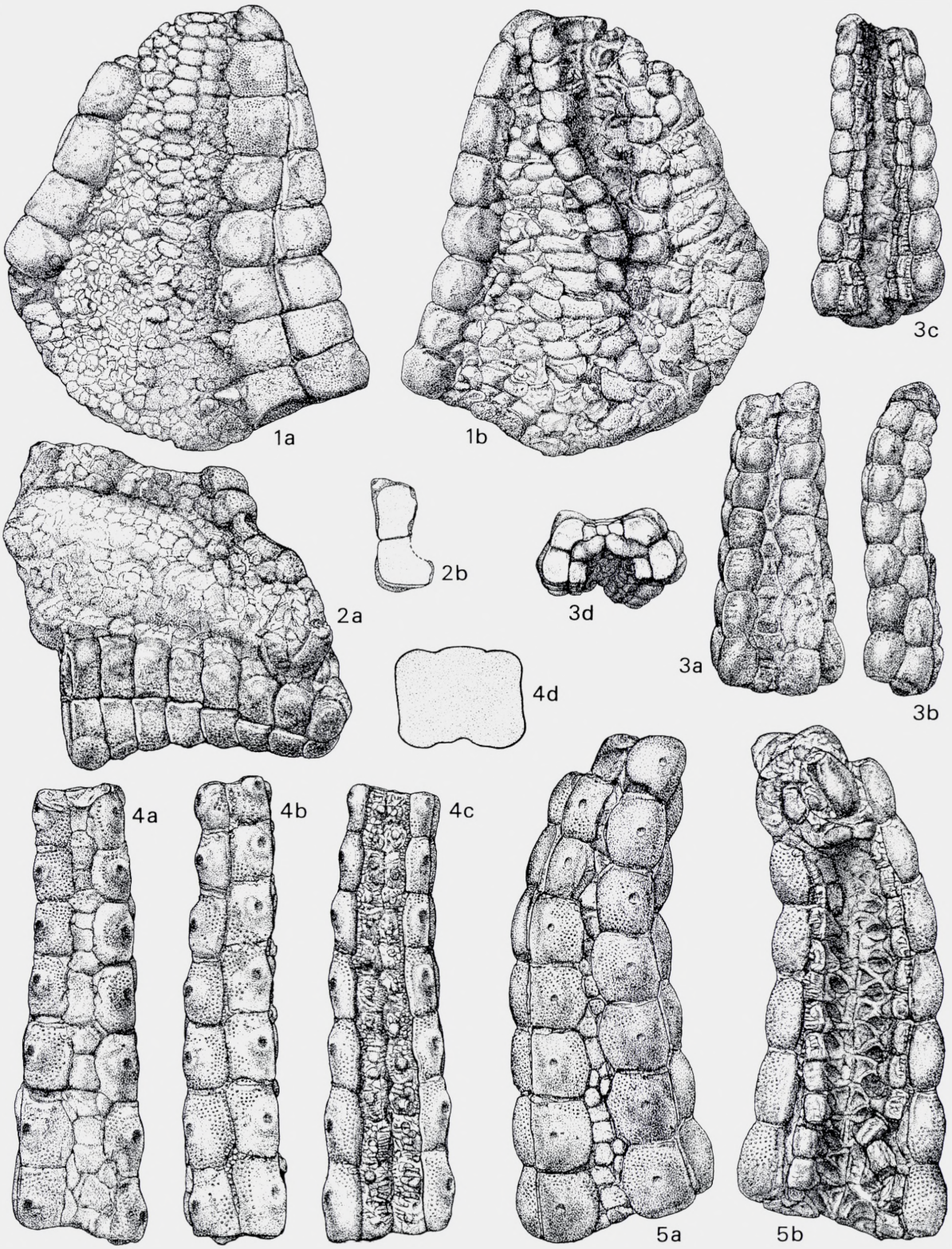
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Plate 5

Figs. 1–2. Teichaster retiformis Spencer, 1913, p. 50. Marginals, × 5. Upper Danian sandstone ("Sonja lens"), Sonja Member of Agatdal Formation. Nûgssuaq in West Greenland. Geological Museum, Copenhagen.
Fig. 1. Superomarginal (12785).
Fig. 2. Inferomarginal (12786).

Figs. 3–6. Teichaster lamberti Valette, 1925, p. 50. Marginals, × 5. Landenian, glauconitic clay. Kroisbach near Haunsberg, Austria. Geological Museum, Copenhagen.
Fig. 3. Superomarginal (12787).
Fig. 4. Inferomarginal (12788).
Fig. 5. Superomarginal (12789).
Fig. 6. Inferomarginal (12790).

Figs. 7–10. Teichaster stokesii (Forbes, 1848), p. 52. Ypresian.
Fig. 7. London Clay. Isle of Sheppey, England. British Museum (E 38587). Arm and part of disc, × 1.6; a, dorsal; b, ventral; c, profile of margin of disc.
Fig. 8. London Clay. Isle of Sheppey, England. British Museum (E 38489). Distal part of arm, × 1.6; a, dorsal; b, lateral.

Fig. 9. Rösnäs Clay. Trelde Næs north of Fredericia, Denmark. Geological Museum, Copenhagen (12791). Part of disc and base of arm, × 1.2; a, dorsal; b, lateral; c, ventral.
Fig. 10. Rösnäs Clay. Trelde Næs north of Fredericia, Denmark. Geological Museum, Copenhagen (12792). Part of disc, × 1.2; a, dorsal side and margin; b, ventral.

Figs. 11–13. Ceramaster obtusus n.sp., p. 54; × 5. Upper Danian sandstone ("Sonja lens"), Sonja Member of Agatdal Formation. Agatdal in Nûgssuaq, West Greenland. Geological Museum, Copenhagen.
Fig. 11. Terminal superomarginal, (12793); a, lateral; b, profile; c, adradial.
Fig. 12. Holotype, terminal inferomarginal, (12794); a, lateral; b, profile; c, adradial; d, ventral.
Fig. 13. Median superomarginal, exfoliated, (12795); a, dorsal; b, profile.

Fig. 14. Echinaster jacobseni n.sp., p. 57. Holotype, × 4. Ypresian, diatomaceous clay, Mo-Clay Formation. Silstrup Cliff south of Tisted, Denmark. Geological Museum, Copenhagen (12796). Ventral side of disc and arms.

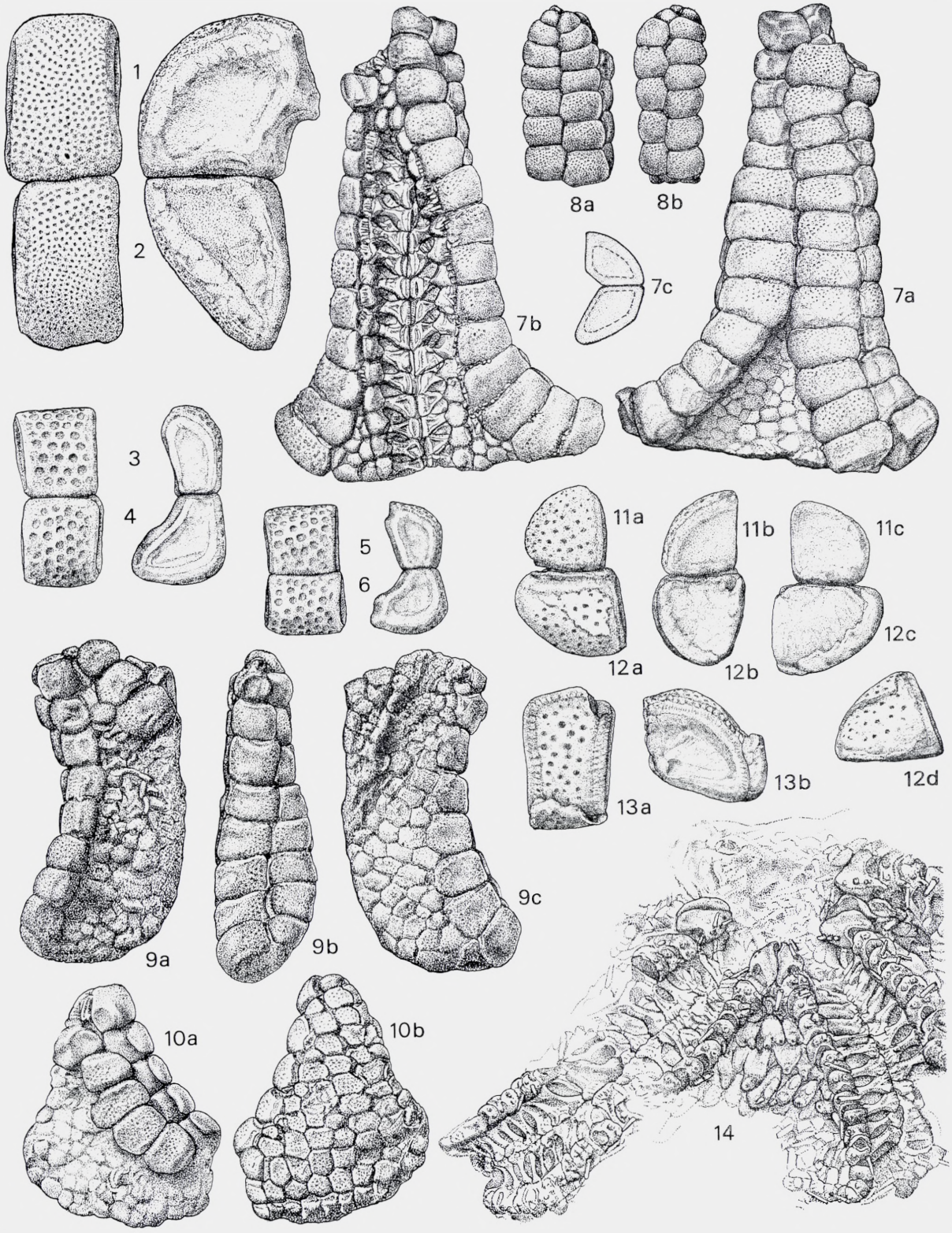
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Plate 6

Fig. 1. Amphiura senonensis Valette, 1915, p. 59. Lateral arm plate, × 10. Landenian, glauconitic marl. Kroisbach at Haunsberg, Austria. Geological Museum, Copenhagen (12797).

Fig. 2. Ophiacantha danica Rasmussen, 1951, p. 60. Lateral arm plate, × 10. Danian limesand. Haidhof near Vienna, Austria. Geological Museum, Copenhagen (12798).

Fig. 3. Ophiura achatae n.sp., p. 61. Fragment of arm, × 16. Upper Danian, sandstone ("Sonja lens"), Sonja Member of Agatdal Formation. Agatdal in Nûgssuaq, West Greenland. Geological Museum, Copenhagen (12799). a, ventral; b, lateral; c, dorsal; d, proximal end.

Figs. 4–5. Ophiura furiae n.sp., p. 62. Ypresian. Calcareous concretion (cement stone) in diatomaceous clay. Mo-Clay Formation. Fur in Denmark. Geological Museum, Copenhagen.
Fig. 4. Holotype (12800), × 5; a, ventral side; b, section of arm near base.
Fig. 5. Dorsal side of other specimen in the same sample (12801).

Figs. 6–7. Ophiocoma hessi n.sp., p. 76. Fragments of arm, × 20. Bartonian Highcliff Sands (Lower Barton Beds, A-3). Highcliff, England. British Museum.
Fig. 6. Holotype (E 53635); a, ventral; b, lateral; c, dorsal.
Fig. 7. Distal end of other fragment (E 53636).

Fig. 8. Ophiura costata n.sp., p. 70. Holotype, lateral arm plate, × 10. Bartonian, Middle Barton Beds. Horizon E of Barton Cliff, England. British Museum (E 53637). a, lateral; b, distal edge; c, inner surface.

Fig. 9. Ophiura cfr. costata n.sp. Vertebra, × 17. Bartonian, Middle Barton Beds. Horizon E of Barton Cliff, England. British Museum (E 53638). a, proximal end; b, lateral; c, distal end.

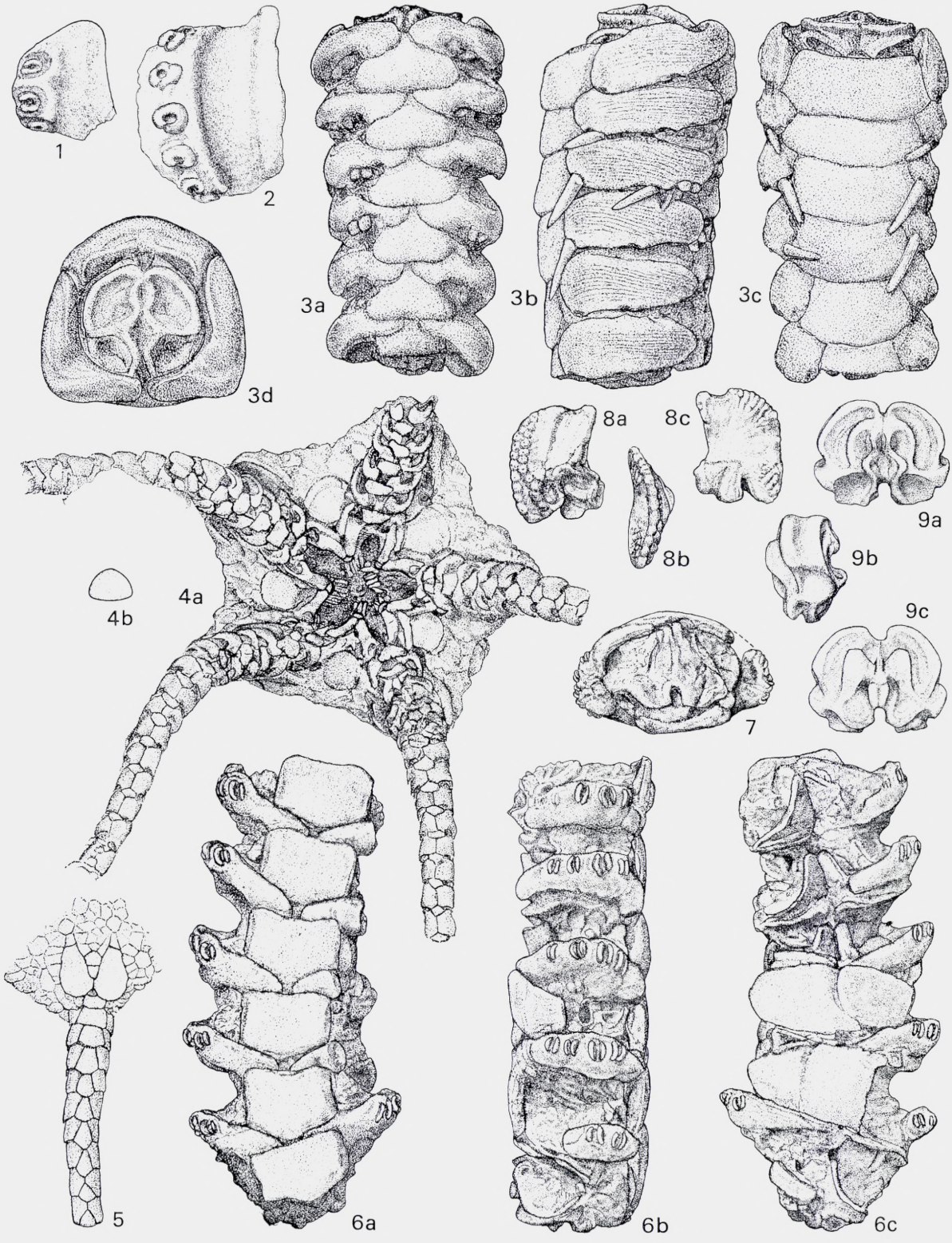
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Plate 7

Figs. 1–5. Ophiura wetherelli Forbes, 1852, p. 64. Ypresian. British Museum.

Fig. 1. Oldhaven Beds. Lower Upnor near Friendsburg Extra, England. (E 53243), × 9; a, dorsal side; b, reconstruction of dorsal side; c, section of arm.

Fig. 2. London Clay (division 4). New Malden, England. (E 13702), × 6; a, ventral side; b, reconstruction of ventral side.

Fig. 3. Fragment of arm, × 20. London Clay (division 2). Victoria Line shaft at Brixton, London. (E 53639); a, dorsal; b, lateral; c, ventral; d, distal end.

Fig. 4. Lateral arm plate, × 20, inner side. London Clay (division 2). Victoria Line shaft at Brixton, London. (E 53640).

Fig. 5. Vertebra, × 20. London Clay (division 2). Victoria Line shaft at Brixton, London. (E 53641); a, lateral; b, proximal end.

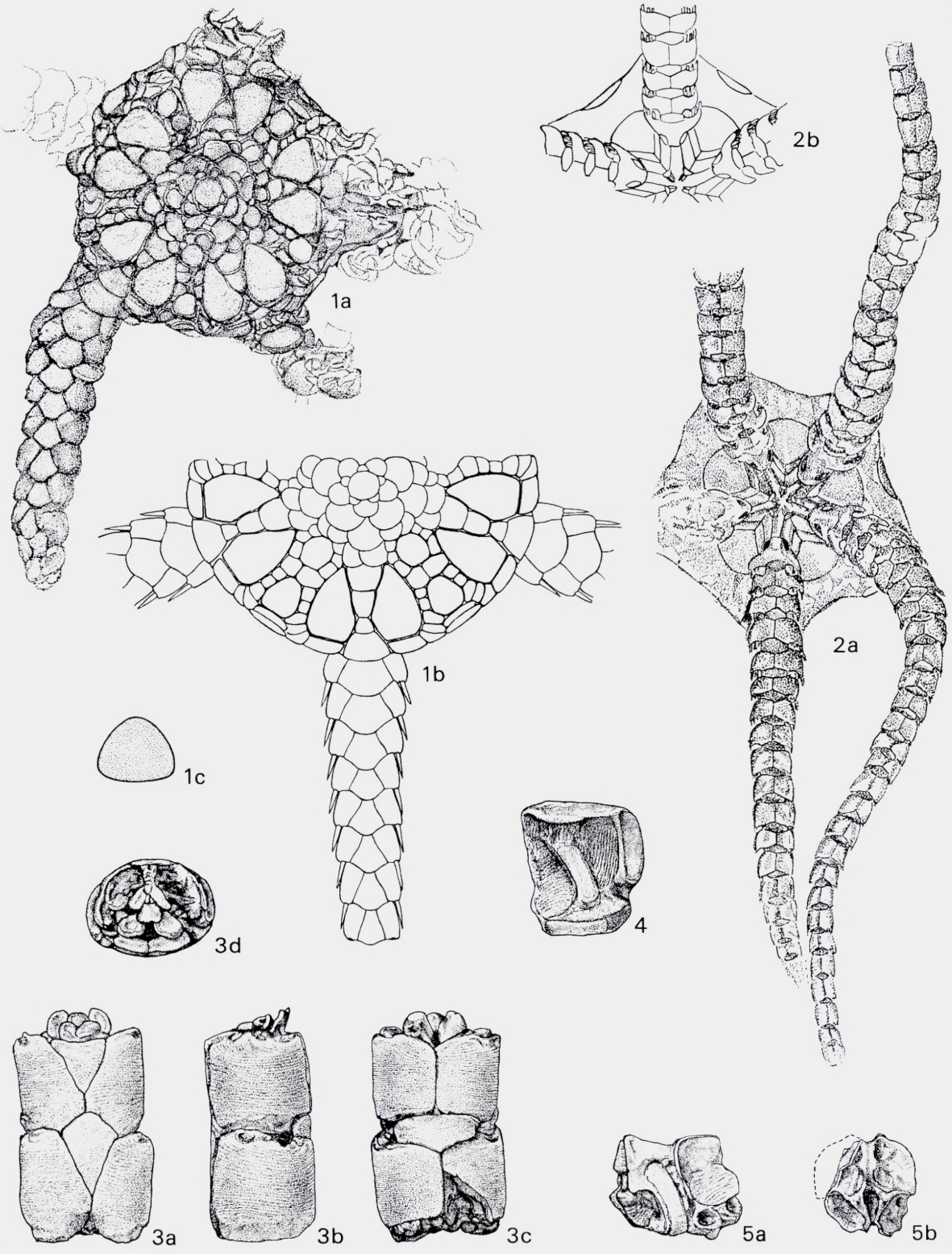
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Plate 8

Figs. 1–10. Ophiura bognoriensis n.sp., p. 66. Ypresian. London Clay (Lower Clay) of Bognor Regis, England. Collection of the British Museum.

Fig. 1. Holotype (E 13761). Starfish Bed, × 2.7; a, dorsal side; b, reconstruction of dorsal side.

Fig. 2. Proximal arm fragment (E 53642). Astarte Bed, × 10; a, ventral; b, left side; c, dorsal.

Fig. 3. Distal arm fragment (E 53643). Astarte Bed, × 10; a, ventral; b, right side; c, dorsal; d, distal end.

Fig. 4. Dorsal arm plate (E 53644). Astarte Bed, × 10.

Fig. 5. Inner side of lateral arm plate (E 53645). Astarte Bed, × 10.

Fig. 6. Lateral view of proximal vertebra (E 53646). Astarte Bed, × 10.

Fig. 7. Jaw plate (E 53647). Starfish Bed, × 10; a, adradial; b, interradial; c, ventral surface.

Fig. 8. Radial shield (E 53648). Starfish Bed, × 10; a, dorsal; b, inner side.

Fig. 9. Oral shield (E 53649). Starfish Bed, × 10; a, ventral surface; b, inner side.

Fig. 10. Genital plate (E 53650). Starfish Bed, × 10; a, surface; b, adradial side; c, interradial side.

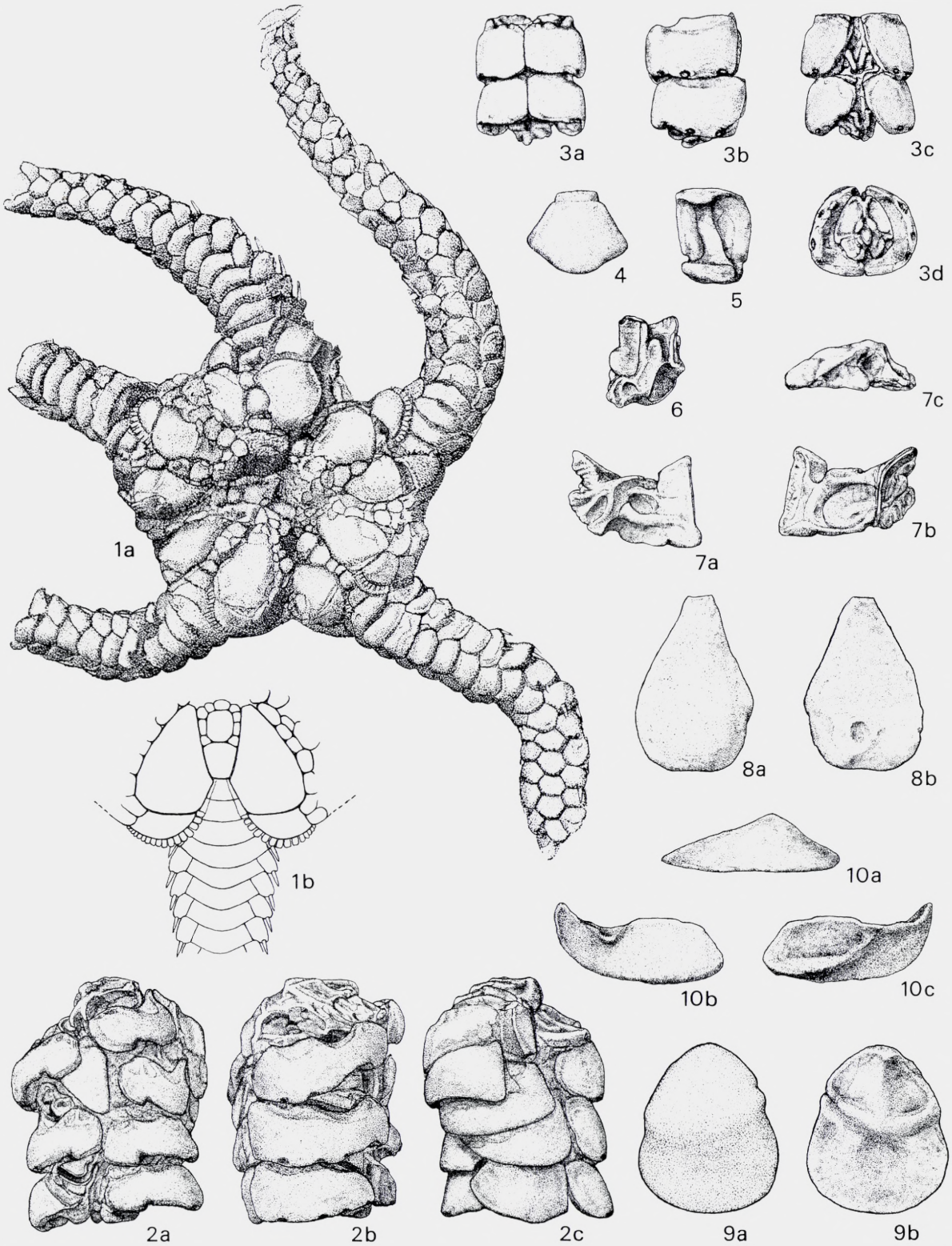
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Plate 9

Figs. 1–9. Ophiura bartonensis n. sp., p. 68. Bartonian, near Barton in England. Collection of the British Museum.

Fig. 1. Dorsal side, reconstructed.

Fig. 2. Dorsal side of holotype (E 52158), × 5. Bartonian, Highcliff Sands. Highcliff near Barton.

Fig. 3. Fragment of arm (E 53651), × 10. Lower Barton Beds (horizon A 3). Highcliff near Barton. a, dorsal; b, right side; c, ventral; d, distal end.

Fig. 4. Interradial edge of disc (E 53652), × 10. Lower Barton Beds (horizon A 3). Highcliff near Barton.

Fig. 5. Surface of lateral arm plate (E 53653), × 20. Middle Barton Bed (horizon E) at Barton.

Fig. 6. Interradial marginal plate (E 53654), × 10. Middle Barton Bed (horizon E), Barton. a, surface; b, edge; c, inner side.

Fig. 7. Radial shield (E 53655), × 10. Middle Barton Bed (horizon E), Barton. a, dorsal surface; b, inner side.

Fig. 8. Genital plate (E 53656), × 10. Middle Barton Bed (horizon E), Barton. a, surface; b, inner side.

Fig. 9. Vertebra (E 53657), × 20. Middle Barton Bed (horizon E), Barton. a, proximal; b, lateral; c, distal.

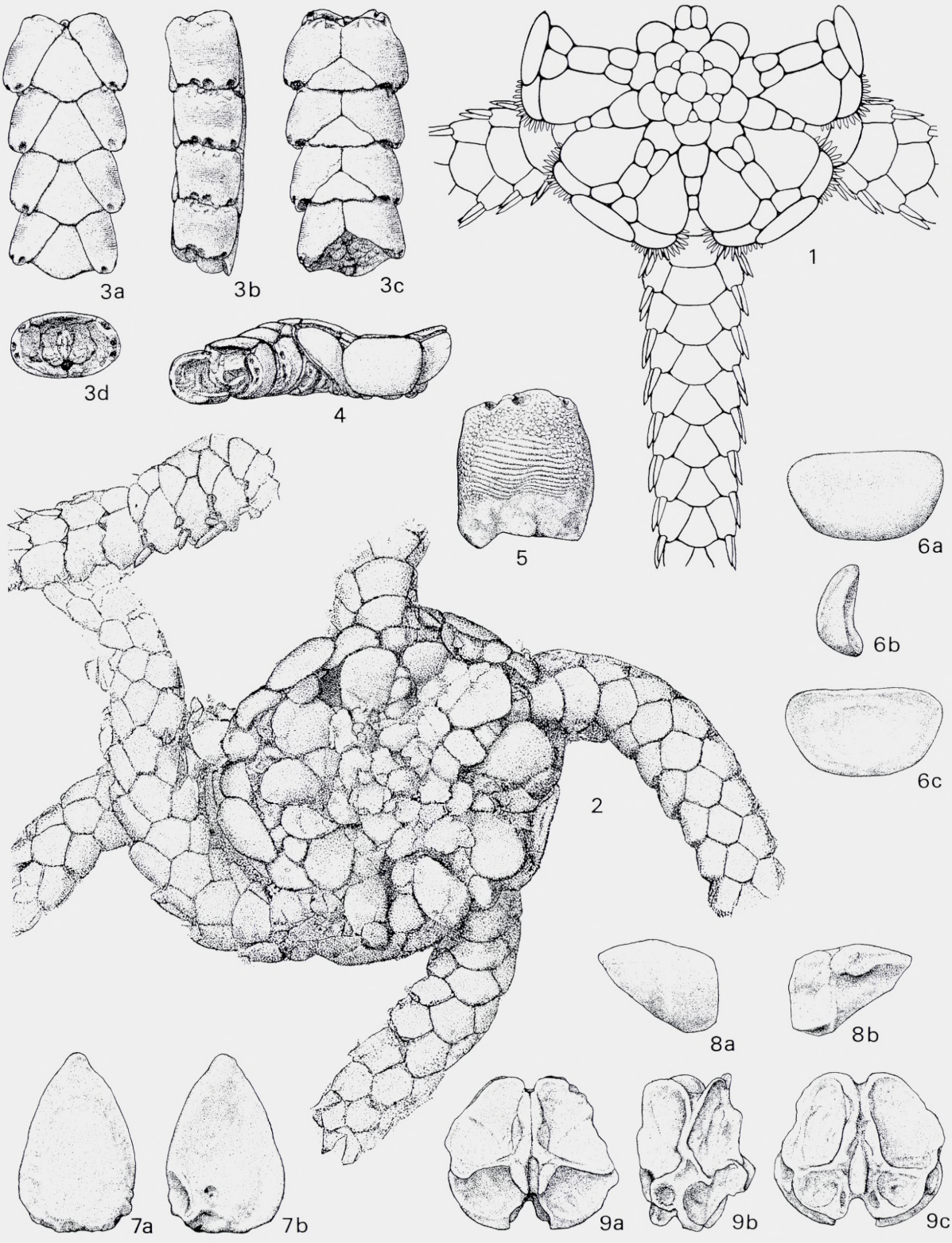
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Plate 10

Figs. 1–9. Ophiura carpelloides n.sp., p. 71. Bartonian, Middle Barton Beds (horizon E). Barton in England. × 10. Collection of the British Museum.

Fig. 1. Holotype, lateral arm plate (E 53658); a, proximal; b, inner side; c, anterior; d, lateral.
Fig. 2. Arm joint, recombined (E 53659); a, proximal; b, dorsal.
Fig. 3. Radial shield (E 53660); a, dorsal; b, inner side; c, distal edge.
Fig. 4. Vertebra (E 53661); a, distal; b, lateral.
Fig. 5. Proximal end of first vertebra (E 53662).
Fig. 6. Ventral arm plate (E 53663); a, proximal and ventral surface; b, inner side.
Fig. 7. Genital plate (E 53664); a, surface; b, inner side.
Fig. 8. Oral shield (E 53665); a, surface; b, inner side.
Fig. 9. Jaw (E 53666); a, adradial; b, ventral; c, interradial.

Figs. 10–15. Ophiura davisi n.sp., p. 75. Bartonian, Middle Barton Beds (horizon E). Barton in England. × 10. Collection of the British Museum.

Fig. 10. Lateral arm plate (E 53667); a, lateral; b, distal; c, inner side.
Fig. 11. Holotype, lateral arm plate from the disc (E 53668); a, lateral; b, distal; c, inner side.
Fig. 12. Lateral arm plate from the disc (E 53669); a, lateral; b, distal; c, inner side.
Fig. 13. Arm joint and lateral arm plate, recombined (E 53670); a, proximal; b, ventral.
Fig. 14. Vertebra (E 53671); a, distal end; b, lateral.
Fig. 15. Oral shield (E 53672); a, ventral surface; b, inner side.

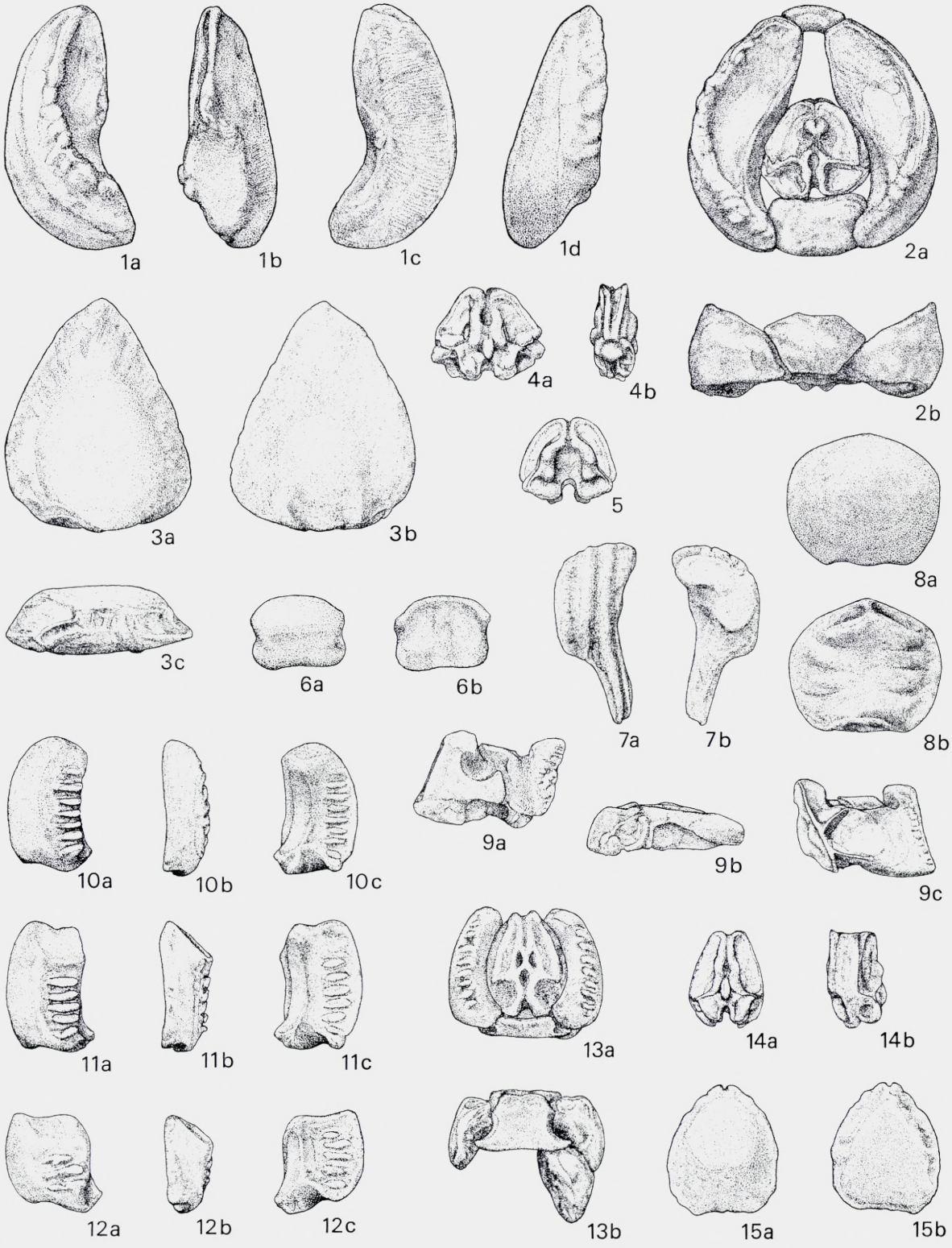
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PLATE 11

Fig. 1. Isselicrinus subbasaltiformis (Miller, 1821), p. 17. Theca and arms, × 1.9. Ypresian, Rösnäs Clay. Trelde Næs in Denmark. Geological Museum, Copenhagen (12755). Also plate 1 fig. 5.

Fig. 2. Coulonia colei (Forbes, 1852), p. 41. Cast from impression of ventral side in diatomaceous clay; × 4.5. Ypressian, Mo-Clay Formation. Mors in Denmark. Geological Museum, Copenhagen (12802).

Fig. 3. Coulonia colei (Forbes, 1852). Cast from impression of dorsal side in diatomaceous clay; × 3.4. Ypresian, Mo-Clay Formation. Fur in Denmark. Palaeontologic Institute, Uppsala (DM 12). Cast in Geological Museum, Copenhagen (12803).

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Plate 12

Fig. 1. Coulonia colei (Forbes, 1852), p. 41. Dorsal side, × 1.2. Ypresian, London Clay. Highgate in London. British Museum (E 428). Also plate 3 figs. 9–13.

Fig. 2. Coulonia colei (Forbes, 1852). Holotype, × 1.37. Ypresian, London Clay. Isle of Sheppey, England. Geological Survey, London (49173). Also Forbes (1852) plate 4 fig. 3.

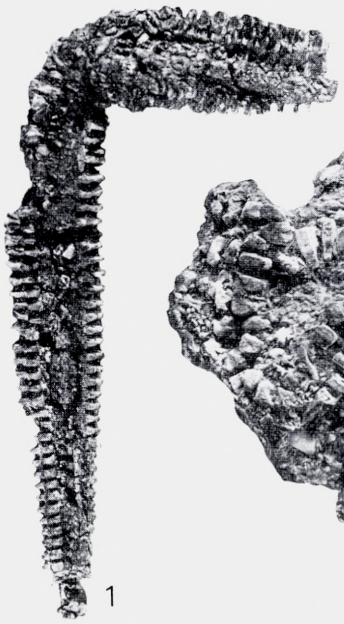
Fig. 3. Hippasteria tuberculata (Forbes, 1852), p. 48. Dorsal side of arm, × 1.33. Ypresian, London Clay. Isle of Sheppey, England. British Museum (E 52242). Also plate 4 fig. 5.

Fig. 4. Hippasteria tuberculata (Forbes, 1852). Dorsal side, × 1.6. Ypresian, London Clay. Isle of Sheppey, England. Geological Survey, London (99787). Also plate 4 fig. 1.

Fig. 5. Teichaster stokesii (Forbes, 1848), p. 52. Dorsal side, × 1.4. Ypresian, London Clay. Isle of Sheppey, England. British Museum (E 38587). Also plate 5 fig. 7.

Fig. 6. Coulonia colei (Forbes, 1852). × 0.97. Ypresian, London Clay. Isle of Sheppey, England. British Museum (E 75909).

Fig. 7. Echinaster jacobseni n.sp., p. 57. Holotype. Cast from impression of ventral side in diatomaceous clay, × 4.5. Ypresian, Mo-Clay Formation. Silstrup Cliff, Denmark. Geological Museum, Copenhagen (12769). Also plate 5 fig. 14.



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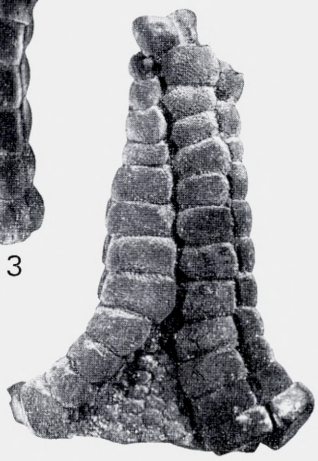

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PLATE 13

Fig. 1. Ophiura furiae n.sp., p. 62. Ventral side of holotype (below), and remains of three other specimens in the weathered surface of a calcareous concretion from diatomaceous clay. × 4.25. Mo-Clay Formation, Fur in Denmark. Geological Museum. Copenhagen (12800–12801). Also plate 6 figs. 4–5.

Fig. 2. Ophiura wetherelli Forbes, 1852, p. 64. Dorsal side of decalcified specimen in Oldhaven Beds. Lower Upnor, Kent in England; × 7.5. British Museum (E 53243). Also plate 7 fig. 1.

Fig. 3. Ophiura wetherelli Forbes, 1852. Specimens figured by Davis (1923) from the London Clay of New Malden, England; × 3.75. British Museum (E 13702).


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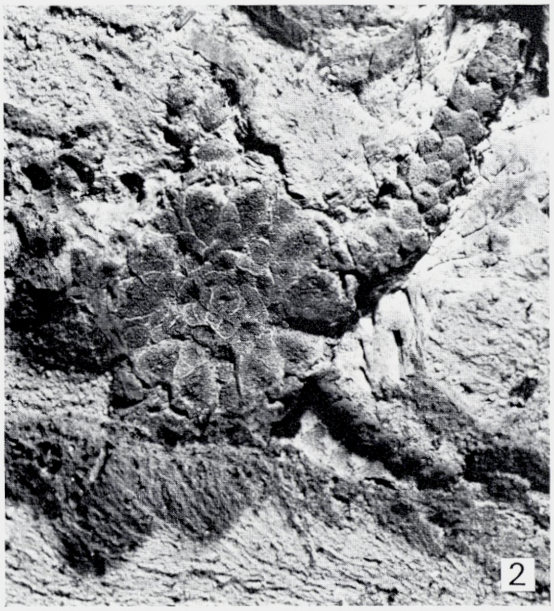
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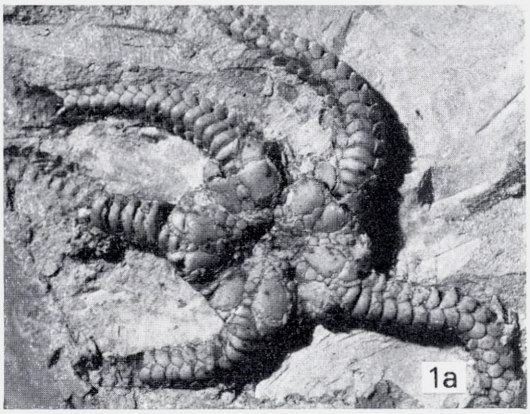
PLATE 14

Fig. 1. Ophiura bognoriensis n. sp., p. 66. Holotype. Ypresian, Lower Clay (Starfish Bed) of Bognor Regis, England. British Museum (E 13761). Also plate 8 fig. 1. a, dorsal side, × 2; b, ventral side of arm, × 5.

Fig. 2. Ophiura bartonensis n. sp., p. 68. Holotype. Bartonian, Highcliff Sands of Highcliff near Barton. Dorsal side, × 5. British Museum (E 52158). Also plate 9 fig. 2.

Fig. 3. Ophiura bartonensis n. sp. Ventral side, × 9. Bartonian, Lower Barton Beds (horizon A 3) of Highcliff. British Museum (E 53673).

Fig. 4. Ophiura bartonensis n. sp. Several specimens in Highcliff Sands; × 1.6. Bartonian, Lower Barton Beds (horizon A 3) of Highcliff. British Museum (E 53674).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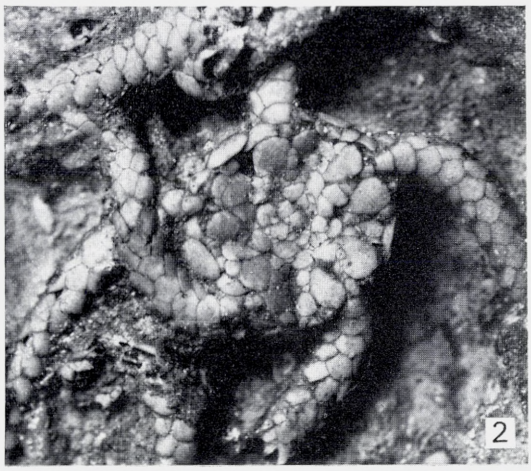
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