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Selected Bivalve Fossils from the Maastrichtian, Danian and Eocene of Madagascar*

By

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With Appendix By

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Introduction

Seventy three specimens of bivalve fossils have been forwarded to me for study by Drs. Ikuwo OBATA and Yasumitsu KANIE. I have identified the following fifteen species, which are described in this paper:

Modiolus (*Modiolus*) *incomptaeformis* (COLLIGNON)
Pycnodonte (*Pycnodonte*) *vesicularis* (LAMARCK)
Pycnodonte (*Pycnodonte*) *arrialoorensis* (STOLICZKA)
Exogyra sp.
Gryphaeostrea sp. aff. *G. canaliculata* (SOWERBY)
Crassostrea sp. aff. *C. angusta* (DESHAYES)
Crassostrea sp.
Nicaisolopha? sp.
Atreta chavani (COLLIGNON)
Lucina sp.
Astarte? sp.
Crassatella(?) *protracta* COLLIGNON
Nemocardium? sp.
Tenea? sp.
Pholadomya (*Bucardiomya*) sp. aff. *P. esmarkii* NILLSON

The described specimens were sent back to the Service Géologique, Tananarive, in Madagascar.

Since UJIIÉ, KANIE and OBATA report in detail in the Appendix of this paper about the geographic and stratigraphic positions of fossil localities in this region, they are not repeated here.

Before going further, I would like to express my hearty thanks to Emeritus Professor Tatsuro MATSUMOTO of Kyushu University for his reading the manuscript. I wish also to express my sincere thanks to Dr. Ikuwo OBATA of the National

* Contribution to the Paleontology of Madagascar, IX.

Science Museum of Tokyo and Dr. Yasumitsu KANIE of the Yokosuka City Museum for supplying me with their valuable collection of bivalve fossils in Madagascar for study.

Systematic Description

Order Mytiloida FÉRUSSAC, 1822

Superfamily Mytilacea RAFINESQUE, 1815

Family Mytilidae RAFINESQUE, 1815

Subfamily Modiolinae KEEN, 1958

Genus *Modiolus* LAMARCK, 1799

Modiolus (*Modiolus*) *incomptaeformis* (COLLIGNON)

Pl. 1, figs. 1–3; Fig. 1

Modiola incomptaeformis COLLIGNON, 1951, p. 95, pl. 15 (3), figs. 7, 8.

Material:—Two specimens (NSM.PM 9401–9402) from Loc. Mj 7–1, two specimens (NSM.PM 9403–9404) from Loc. Mj 9–12, three specimens (NSM.PM 9405–9407) from Loc. Mj 13–1 and three specimens (NSM.PM 9408–9410) from Loc. Mj 13–2.

Description:—Shell medium in size; elongate ovate or orbicularly subtriangular in outline, well inflated; umbo subterminal, weakly prominent; anterior dorsal margin short, weakly arched; anterior margin not demarcated clearly from ventral margin; ventral margin elongated, weakly arched to the anterior and nearly straight or weakly concave and forming a shallow sulcus to the posterior; posterior margin obliquely subtruncated, weakly convex or nearly straight; posteroventral margin well rounded; posterior dorsal margin elongated nearly straight or a little arcuated; an obtuse but strong radial carina running from the umbo to the postero-ventral margin, weakly bended to the venter on the central part; surface ornamented with fine, concentric striae.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9403, conj. valv.	42.0	28.0	17.0
NSM.PM 9404, conj. valv.	45.7	27.3	16.9
NSM.PM 9401, conj. valv.	41.3	27.0	16.1
NSM.PM 9402, conj. valv.	37.6	25.5	15.6
NSM.PM 9405, conj. valv.	45.4	48.0	23.9
NSM.PM 9406, conj. valv.	49.0	35.0	22.4
NSM.PM 9407, conj. valv.	40.6	25.0	16.6
NSM.PM 9408, conj. valv.	41.0	22.0	13.5
NSM.PM 9409, conj. valv.	48.0	28.4	19.2
NSM.PM 9410, conj. valv.	42.0	32.2	20.0

Remarks:—The hinge structure is not observable in the available specimen.

Fig. 1. *Modiolus* (*Modiolus*) *incomptaeformis* (COLLIGNON). Showing variation of the shell outline. scale: 10 mm.

This species is very variable in the shell outline as shown in Text-fig. 1, changing from elongated ovate to obtusely subtriangular. The ratio of length to height ranges from 0.54 to 1.06. But the ratio of length to thickness is rather constantly at about 0.24.

Comparison:—This species is similar to *Modiolus typica* (FORBES) (STOLICZKA, 1871; BASSE, 1933), from the Upper Cretaceous Indo-Malgash region, in the strong radial carina on the disk and elongated outline of the shell, but differs from that species in having a bended carina and numerous concentric striae on the surface.

Occurrence:—Mj 9–12; Maastrichtian. Mj 7–1, Mj 13–1 and Mj 13–2; Danian.

Order Pterioida NEWELL, 1965

Suborder Ostreina FÉRSSAC, 1922

Superfamily Ostreacea RAFINESQUE, 1815

Family Gryphaeidae VYALOV, 1936

Subfamily Pycnodonteinae STENZEL, 1959

Genus *Pycnodonte* FISCHER de WALDHEIM, 1835

Pycnodonte (*Pycnodonte*) *vesicularis* (LAMARCK)

Pl. 2, figs. 1–3; Fig. 2

Gryphaea vesicularis; STOLICZKA, 1871, p. 465, pl. 42, figs. 2–4; pl. 43, fig. 1; pl. 45, figs. 7–12.
?Gryphaea vesicularis; MEEK, 1876, p. 20, pl. 6, fig. 2; pl. 16, fig. 8.
?Gryphaea vesicularis; WHITFIELD, 1885, p. 194, pl. 26, figs. 9–10.
?Gryphaea vesicularis? var. *mutabilis* (*Pycnodonta mutabilis* MORTON); WHITFIELD, 1885, p. 38, pl. 4, fig. 3; pl. 5, figs. 1–2.
Gryphaea vesicularis; BOSE, 1910, p. 49, pl. 4, figs. 1–3; pl. 7, fig. 2; pl. 9, fig. 4; pl. 12, fig. 6.
Pycnodonte vesicularis; PERVINQUIÈRE, 1912, p. 195.
Ostrea vesicularis; WOODS, 1913, p. 360, pl. 55, figs. 4–9.
Gryphaea vesicularis; ZITTEL, 1924, p. 427, fig. 785.
Pycnodonta vesicularis; PICARD, 1930, p. 538, pl. 22, figs. 14–15.
Pycnodonta vesicularis; BASSE, 1933, p. 12.
Pycnodonta vesicularis; CHAVAN, 1947, p. 182.
Pycnodonta vesicularis; FRENEIX, 1960, p. 33, pl. 2, figs. 7–8.
Gryphaea vesicularis; NESTLER, 1961, p. 652, pl. 1, fig. 5.
Pycnodonte vesicularis; STENZEL, 1971, N981, fig. J21.
Pycnodonte (*Pycnodonte*) *vesicularis vesicularis*; FRENEIX, 1972, p. 105, pl. 10, figs. 5–7.

Material:—Ten adult specimens (NSM.PM 9411–9420) and two immature specimens from Loc. Mj 9–12.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9411, left valve	86.3	112.0+	51.1
NSM.PM 9412, left valve	87.2	103.2	58.1
NSM.PM 9413, left valve	88.8	82.3+	49.5
NSM.PM 9414, left valve	97.5	106.1	63.5
NSM.PM 9415, left valve	94.5	85.2	44.5
NSM.PM 9416, left valve	78.8	72.0+	56.8
NSM.PM 9417, left valve	78.9+	87.9+	39.0
NSM.PM 9418, left valve	73.4	66.0	36.5
NSM.PM 9419, left valve	63.0	52.0+	26.6
NSM.PM 9420, right valve	65.3+	68.5	—
immature left valve	12.7	14.0	—
immature left valve	5.4	5.5	—

Remarks:—This species ranges from Coniacian to Danian (BASSE, 1933; PICARD, 1930; FRENEIX, 1972), and is one of well known bivalves as the "big oyster" distributed in Europe, Africa, Palestina, India, Madagascar and ?North America. The present specimens from the Majunga region are closer to an American example, called *Pycnodonta mutabilis* MORTON, which was descriminated from typical examples of *Pycnodonte vesicularis* from the Maastrichtian of Europe (STENZEL, 1971) as a distinct species by STEPHENSON (1941) in having less numerous radial ribs on the right valve. In this paper difference is regarded as a variation within the same species. Two Eocene species, *Pycnodonte gigantica* (SOLANDEA) (STENZEL, 1959, 1971) from England and *P. wollastoni* FINLAY (1927; BOREHAM, 1965) from New Zealand, are similar to this species in the large and thick valve. *Pycnodonte gigantica* is, however, characterized by less prominent umbo and more elongate valve than this species. Also *Pycnodonte*

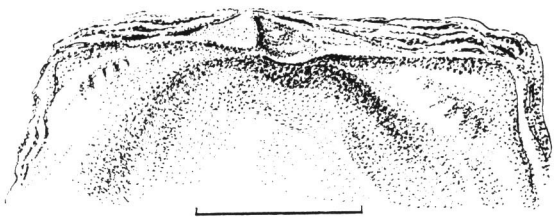

Fig. 2. Younger stage of *Pycnodonte* (*Pycnodonte*) *vesicularis* (LAMARCK). Showing ligamental area of the internal left valve. scale: 10 mm.

wollastoni differs from this species in its more prominent umbo and taller valve. *Pycnodonte* (*Phygrea*) *antique* (SCHWETZOV) (ILJINA and SHMIDT, 1969), from the Upper Paleocene of Mangbishlaka, resembles this species in the subrounded outline of valve, but differs in its nearly smooth surface of the right valve.

Occurrence:—Loc. Mj 9–12. Maastrichtian.

Pycnodonte (*Pycnodonte*) *arrialoorensis* (STOLICZKA)

Pl. 2, figs. 4–5

Gryphaea arrialoorensis STOLICZKA, 1871, p. 464, pl. 42, fig. 9; pl. 45, figs. 13–14.

Material:—Three specimens (NSM.PM 9421–9423) from Loc. Ant 2.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9421, left valve	27.2	26.6	19.0
NSM.PM 9422, left valve	23.5	40.2	21.0
NSM.PM 9423, left valve	19.3	15.7	11.0

Comparison:—This species differs from *Pycnodonte* (*Pycnodonte*) *vesicularis* (LAMARCK) in its much more prominent and opisthogyrate umbo. *Pycnodonte fosseyi* (LEMOINE) (KANIE et al., 1977), from the Cenomanian of Madagascar is easily distinguished from this species in its considerably posterior location of the adductor scar and less prominent umbo.

Occurrence:—Loc. Ant 2. Danian.

Subfamily Exogyrinae VYALOV, 1936

Genus *Exogyra* SAY, 1820

Exogyra sp.

Material:—One specimen (NSM.PM 9424) of left valve from Loc. Tu 2.

Measurements:—Left valve; length: 37.2 mm, height: 42.8 mm, thickness: 19.0mm.

Remarks:—This species may belong to *Exogyra* in view of its strongly opisthogyrate beak, oblique ligament groove and sharply concaved antero-dorsal part. The

surface of the valve is ornamented with poorly defined and flexible radial ribs.

Exogyra olisiponensis var. *ecostata* SEGUENZA (TREVISAN, 1937), from the Cenomanian of Madagascar, is similar to this species in the subtrigonal outline and strong inflation of the valve. The Cenomanian species is, however, characterized by stronger and less numerous ribs on the surface than this species. Since Exogyra prospered in the Cretaceous, this species was probably among the youngest species in *Exogyra*.

Occurrence:—Loc. Tu 2. Upper Eocene.

Genus *Gryphaeostrea* CONRAD, 1865

Gryphaeostrea sp. aff. *G. canaliculata* (SOWERBY)

Pl. 1, fig. 18

?Gryphaeostrea canaliculata; COLLIGNON, 1951, p. 92, pl. 15 (3), figs. 3–4.

Material:—Three specimens (NSM.PM 9425–9427) of left valve from Loc. Ant 1.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9425, left valve	32.0	31.0	15.0
NSM.PM 9426, left valve	34.1	30.0	16.9

Remarks:—This species is probably identical with what COLLIGNON (1951) described as *Gryphaeostrea canaliculata* from Antonibe of Madagascar. It is, however, discriminated from *Gryphaeostrea canaliculata* (SOWERBY) (WOODS, 1913; STOLICZKA, 1871), from the Cretaceous of Europe and India, in having a narrower ligament area and a less prominent umbo.

Occurrence:—Loc. Ant 1. Danian.

Family Ostreidae RAFINESQUE, 1815

Genus *Crassostrea* SACCO, 1897

Crassostrea sp. aff. *C. angusta* (DESHAYES)

Pl. 3, figs. 8–10

Material:—One specimen (NSM.PM 9428) of conjoint valves, two specimens (NSM.PM 9429–9430) of right valve and seven specimens (NSM.PM 9431–9437) of left valve from Loc. Tu 2.

Comparison:—This species is somewhat similar to *Crassostrea angusta* (DESHAYES) (VYALOV, 1936; STENZEL, 1971), from the Lower Eocene of France, but distinguished by its opisthogyrate umbo and concaved posterior margin.

Occurrence:—Loc. Tu 2. Upper Eocene.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9428, conj. valv.	44.4	88.5	39.1
NSM.PM 9429, right valve	36.0	60.8+	11.4
NSM.PM 9430, right valve	30.1	54.0	8.2
NSM.PM 9431, left valve	43.2	77.9	24.5
NSM.PM 9432, left valve	44.0	81.3	30.2
NSM.PM 9433, left valve	22.8	35.0	11.9
NSM.PM 9434, left valve	20.8	51.2	16.2
NSM.PM 9435, left valve	32.3	52.8	18.9
NSM.PM 9436, left valve	32.5	55.8	12.0
NSM.PM 9437, left valve	35.1	50.8+	15.9

Crassostrea sp.

Pl. 3, figs. 6–7

Material:—Two specimens (NSM.PM 9438–9439) of left valve from Loc. Tu 2.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9438, left valve	38.0	95.0	18.1
NSM.PM 9439, left valve	30.3	90.0	16.8

Comparison:—This species resembles *Crassostrea soleniscus* (MEEK) (STEPHENSON, 1952), from the Cenomanian Woodbine Formation of North America, and *Crassostrea* (*Gyrostrea*) *delettrei tarfayensis* FRENEIX (1972), from the Upper Cretaceous of Tarfaya of Morroco (North Africa), in having the longitudinal outline and week radial ribs on the surface. It is, however, difficult to compare precisely this species with them, because the characters of the right valve and immature valve are not well known in the former. This species somewhat resembles the typical living *Crassostrea*, e.g. *C. virginica* (GMELIN) (STENZELL, 1971; ?*Ostrea* (*Gryphaea*) *virginiana*, SHIKAMA, 1964) and *C. gigas* (THUNBERG) (HABE, 1951, 1977; SHIKAMA, 1964), in having the weak radial ribs on the surface and the high ratio of H/L. It is more similar to the living species than the above two Cretaceous species, so far as the features of ligament area are concerned.

Occurrence:—Loc. Tu 2. Upper Eocene.

Subfamily Lophinae VYALOV, 1936

Genus *Nicaisolopha* VYALOV, 1936

Nicaisolopha(?) sp.

Pl. 3, figs. 1–5; Fig. 3

Material:—Three specimens (NSM.PM 9440–9442) of conjoint valves, four

specimens (NSM.PM 9443–9446) of right valve and three specimens (NSM.PM 9447–9449) of left valve from Loc. Tu 2.

Description:—Shell inequilateral, inequivalve, higher than long, weakly inflated; subtrapezoidal in outline; shouldered at the anterior dorsal corner; anterior margin subtruncated, nearly straight or slightly concave; anteroventral margin well rounded; ventral margin nearly straight or gently concave; posterior margin obliquely truncated, shorter than the anterior one, weakly concave; postero-ventral part obtusely angular with about 100; anterior dorsal margin subhorizontal, a little convex; posterior dorsal margin concave, shorter than the anterior one; umbo opisthogyrous, inprominent, located at a third or so from the rear of valve; surface of the right valve ornamented with fine and crowded concentric ribs; on the right valve two radial blunt carinae extend from the umbo to the antero-ventral margin and to the postero-ventral corner, with a zone of depression on their outer side in some specimens; surface of left valve sculptured with widely spaced and irregularly waved concentric lines; carinae on the left valve indistinct; ligament area wide and triangular; hinge line as short as about a half length of valve; ligament groove triangular, weakly opisthogyrate; hinge-like chomata absent; inner surface smooth; an oval adductor scar distinctly impressed at a point slightly posterior to the center of the inner surface; pallial line distinct on the left valve in parallel with the shell margin.

Measurements:— (in mm)

Specimen	Length	Height	Thickness
NSM.PM 9440, conj. valv.	37.9	48.3	12.0
NSM.PM 9441, conj. valv.	35.3	49.6	11.5
NSM.PM 9442, conj. valv.	48.3	53.2	26.0
NSM.PM 9443, right valve	41.4	47.3	11.0
NSM.PM 9444, right valve	35.2	51.3	10.0
NSM.PM 9445, right valve	25.0	28.8	8.1
NSM.PM 9446, right valve	41.7	50.2	17.0
NSM.PM 9447, left valve	32.0	51.2	6.0
NSM.PM 9448, left valve	32.0	43.0	6.2
NSM.PM 9449, left valve	32.5	35.3	8.6

Remarks:—The radial carinae are variable in strength. The outline of shell is rather constant for oyster shells. The right valve has a somewhat wider ligament area and stronger and larger ligament groove than the left valve.

The generic assignment of this species to *Nicaisolopha* is uncertain. It could be *Anulostrea* VYALOV, 1936, but this form more similar to typical species of *Nicaisolopha* than that of *Anulostrea* in having the distinct radial carinae. *Cubitostrea* SACCO, (STENZEL, 1971), somewhat resembles this form in the opisthogyrate umbo and the concaved posterior margin, but differs from this form in having its distinct chomata and a crescent adductor scar.

Comparison:—*Nicaisolopha nicasei* (COQUAND) (VYALOV, 1936; STENZEL, 1971),

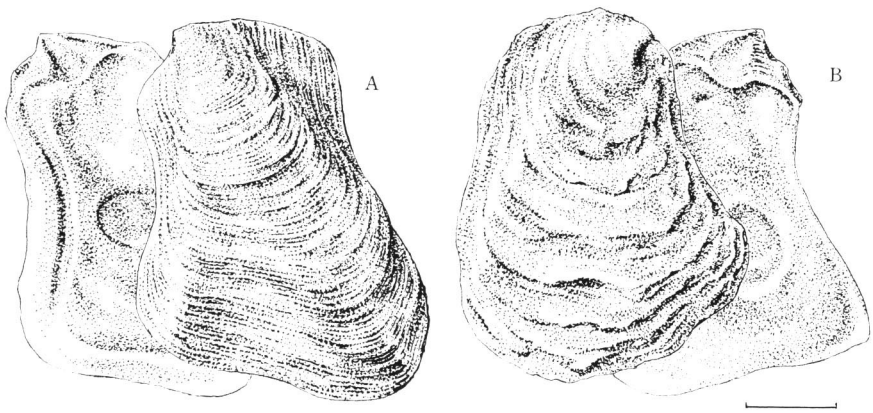

Fig. 3. *Nicaisolopha* sp. A. External view of the right valve and internal view of the left valve; B. External view of the left valve and the internal view of the right valve. scale: 10 mm.

from the Campanian of Algeria differs from this species in having several radial carinae or folds on the disk. *Ostrea cretacea* MORTON (STEPHENSON, 1956), from the Cenomanian of North America, somewhat resembles this species in the concentric ornamentation of surface and the thinness of the left valve, but clearly differs in its less developed radial carina on the right valve and more distinctly orthogyrate umbo.

Occurrence:—Loc. Tu 2. Upper Eocene.

Suborder Pteriina NEWELL 1965

Superfamily Pectinacea RAFINESQUE, 1815

Family Plicatulidae WATSON, 1930

Genus *Atreta* ETALLON, 1862

Atreta chavani (COLLIGNON)

Diploschiza chavani COLLIGNON, 1951, p. 93, pl. 15 (3), figs. 5–6.

Material:—An imperfect specimen of right valve attached to the inner surface of an individual (NSM.PM 9414) of *Pycnodonte* (*Pycnodonte*) *vesicularis* from Loc. Mj 9–12.

Remarks:—This is more similar to *Atreta nilssoni* (HAGENOW) (*Plicatula sigillina* WOODWARD by WOODS, 1901; *Dimyodon nilssoni*, FRENEIX, 1959; NESTLER, 1965; amend. COX, 1964), from the Upper Cretaceous of Europe, than to *Atreta cretacea* (CONRAD) (STEPHENSON, 1934), from North America, and *Atreta intulaevis* TASHIRO (1978), from Japan, in having distinct and numerous striae of inner surface.

Occurrence:—Loc. Mj 9–12. Maastrichtian.

Order Veneroida ADAMS and ADAMS, 1856

Superfamily Lucinacea FLEMING, 1828

Family Lucinidae FLEMING, 1828

Subfamily Lucininae FLEMING, 1828

Genus *Lucina* BRUGUIERE, 1797

Lucina sp.

Pl. 1, fig. 17

Material:—One specimen (NSM.PM 9450) of internal mould of conjoint valves from Loc. Ant 1.

Measurements:—Internal mould of conjoint valves; length: 58.6 mm, height: 58.7 mm, thickness: 27.0 mm.

Description:—The following characters are observable in this specimen: Shell orbicularly subquadrate, moderately inflated; anterior and posterior dorsal margins nearly straight; anterior margin subtruncated, weakly convex and gradually changing into broadly arched ventral margin; posterior margin obliquely truncated, nearly straight; umbo located at a little anterior to the mid-length of the valve; umbonal angle about 120; a strong radial inner ridge extends from the umbo to the postero-ventral margin; posterior adductor scar suboval, distinctly marked; anterior adductor scar oblong, weakly impressed and paralleled with the anterior margin; inner surface sculptured with weak and numerous radial striae.

Remarks:—COLLIGNON (1951) listed *Lucina* (*Dentilucina*) *subnumisumalis* D'ORBIGNY at Antonibe of Madagascar. It is questionable whether this specimen is identified with *L.* (*D.*) *subnumisumalis* of COLLIGNON, because the hinge structure and surface ornamentation are unknown in the available material.

Occurrence:—Loc. Ant 1. Danian.

Superfamily Crassatellacea FERUSSAC, 1822

Family Astartidae D'ORBIGNY, 1844

Subfamily Astartinae D'ORBIGNY, 1844

Genus *Astarte* SOWERBY, 1816

Astarte (?) sp.

Pl. 1, fig. 13

Material:—One specimen (NSM.PM 9451) of conjoint valves from Loc. Mj 7–1.

Measurements:—Conjoint valves; length: 9.9 mm, height: 9.1 mm, thickness: 4.2 mm.

Description:—Shell orbicular in outline; surface ornamented with weak concentric ribs; hinge structure unknown.

Remarks:—The assignment of this species to *Astarte* is tentative, because of insufficiently known characters.

Occurrence:—Loc. Mj 7–1. Danian.

Family Crassatellidae FERUSSAC, 1822

Subfamily Crassatellinae FERUSSAC, 1822

Genus *Crassatella* LAMARCK, 1799

Crassatella (?) *protracta* COLLIGNON

Pl. 1, figs. 7–12; Fig. 4

Crassatella protracta COLLIGNON, 1951, p. 97, pl. 15 (3), fig. 10.
Crassatella protracta var. *inflata* COLLIGNON, 1951, p. 97, pl. 15 (3), fig. 11.

Material:—Four specimens (NSM.PM 9452–9455) from Loc. Mj 7–1, four specimens (NSM.PM 9456–9459) from Loc. Mj 13–1 and two specimens (NSM.PM 9460–9461) from Loc. Mj 13–2. All specimens are conjoint valves.

Description:—Shell trigonal ovate, longer than high, well inflated; umbo orthogyrous, weakly prominent, located at about one third from the anterior end of valve; anterior dorsal margin short, weakly concave; anterior margin well rounded; ventral margin broadly arched in the anterior half and nearly straight and horizontal or slightly sinuated in the posterior; postero-ventral part angulated with about 75°; posterior margin straight obliquely truncated, nearly as long as a half of valve height; posterior dorsal margin nearly straight; lunule narrow, well depressed; escutcheon elongated, nearly smooth except for fine growth lines; posterior carina bluntly angulated, extending straight from the umbo to the postero-ventral corner; surface densely ornamented with numerous concentric ribs, which are wider than their interspaces, closely crowded on the umbonal part but less so on the ventral part; fine numerous radial striae discernible on the subinternal surface which are particularly distinct near the umbo; anterior and posterior adductor scars distinct; pallial line indistinct; hinge unknown.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9452, int. mol. conj. valv.	31.6	24.5	17.9
NSM.PM 9453, conj. valv.	19.0	19.8	10.6
NSM.PM 9454, conj. valv.	22.1	18.0	17.0
NSM.PM 9455, conj. valv.	25.5	20.4	18.8
NSM.PM 9456, int. mol. conj. valv.	37.3	29.0	21.0
NSM.PM 9457, int. mol. conj. valv.	33.0	25.2	17.8
NSM.PM 9458, int. mol. conj. valv.	31.8	25.2	18.1
NSM.PM 9459, int. mol. conj. valv.	33.2	24.9	18.3
NSM.PM 9460, int. mol. conj. valv.	28.0	21.3	15.3
NSM.PM 9461, int. mol. conj. valv.	28.2	23.2	19.2

Remarks:—The species represented by the above specimens is identical with *Crassatella protracta* COLLIGNON (1951). COLLIGNON discriminated *Crassatella protracta* var. *inflata* COLLIGNON from *C. protracta* s. str. as a variety because of the difference in the thickness of valve between these forms. The intermediate forms are, however, commonly present. Since they occur in the same bed, these two nominal

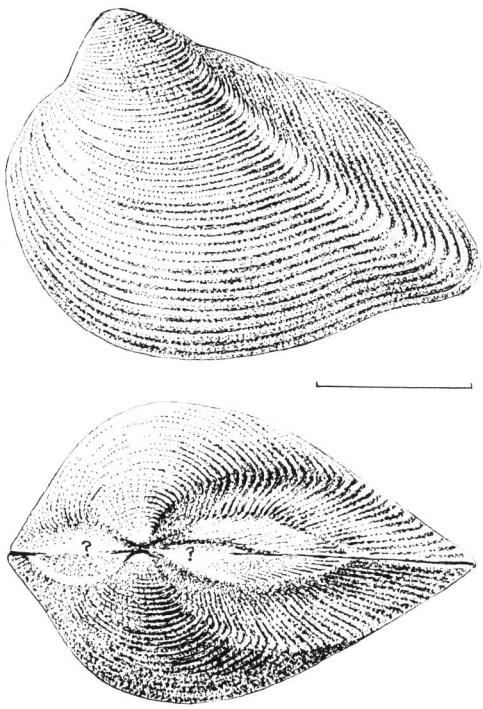

Fig. 4. *Crassatella*? *protracta* COLLIGNON. scale: 10 mm.

taxa cannot be distinguished subspecifically.

As the hinge structure of this species is unknown, the generic position of this species is not clear. A shallow concavity seems to be an external ligament nymph is observable on an individual (NSM.PM 9454. see Text-fig. 4). This species rather resembles some species of *Cryptonema* JUKES-BROWNE (HABE 1951, 1977), from Recent or *Mesochione* TASHIRO (1976) from the Maastrichtian of Japan, in having radial subinternal striae and concentric ribs and subtriangular outline of the valve.

Comparison:—This species differs from *Crassatella wanneri*, BASSE, 1933 (non. PERVINQUIÈRE, 1912) from the Senonian of Mitsinjo in Madagascar, in its much crowded concentric ribs. *Crassattela rothi* FRAAS (PICARD, 1930; CHAVAN, 1947), from the Campanian of North Africa clearly differs from this species in its widely spaced concentric ribs and much rounded outline of the valve.

Occurrence:—Loc. Mj 7–1, Mj 13–1 and Mj 13–2. Danian.

Superfamily Cardiacea LAMARCK, 1809

Family Cardiidae LAMARCK, 1809

Subfamily Protocardiinae KEEN, 1951

Genus *Nemocardium* MEEK, 1876

Nemocardium (?) sp.

Pl. 1, figs. 14–16

Material:—Four specimens (NSM.PM 9462–9465) of conjoint valves from Loc. Mj 7–1.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9462, int. mol. conj. valv.	13.6	13.8	7.4
NSM.PM 9463, int. mol. conj. valv.	12.5	18.1	7.8
NSM.PM 9464, int. mol. conj. valv.	12.0	10.4	7.3
NSM.PM 9465, int. mol. conj. valv.	9.9	8.9	6.0

Description:—Shell small, orbicularly subtrapezoidal in outline; umbo prominent, located at about the mid-length of valve; anterior and posterior margins truncated, nearly vertically in the former and obliquely in the latter; ventral margin moderately arched; an obtuse carina running straight from the umbo to the postero-ventral end; numerous, very fine radial striae discernible near the carina on the inner surface; hinge unknown.

Remarks:—This species resembles *Cardium* aff. *marquarti* MULLER (BASSE, 1933), from the Senonian of Mitsinjo in Madagascar, in having the subtrapezoidal outline, but differs in its small size and more numerous radial striae. As the hinge is unknown, the generic assignment is tentative.

Occurrence:—Loc. Mj 7–1. Danian.

Superfamily Arcticaceae NEWTON, 1891

Family Arcticidae NEWTON, 1891

Genus *Tenea* CONRAD, 1870

Tenea (?) sp.

Pl. 3, fig. 7

Material:—One specimen (NSM.PM 9466) of internal mould of conjoint valve from Loc. Mj 10–3.

Measurements:—Internal mould of conjoint valves; length: 19.7 mm, height: 21.3 mm, thickness: 12.0 mm.

Remarks:—This is probably assigned to the genus *Tenea* on account of the well inflated and rounded valve.

Occurrence:—Loc. Mj 10–3. Danian.

Order Pholadomyoida NEWELL, 1965

Superfamily Pholadomyacea GRAY, 1847

Family Pholadomyidae GRAY, 1847

Genus *Pholadomya* SOWERBY, 1823

Subgenus *Bucardiomya* ROLLIER in COSSMANN, 1912

Pholadomya (*Bucardiomya*) sp. aff. *P. esmarkii* NILLSON

Pl. 1, figs. 4–6; Fig. 5

Pholadomya esmarkii; COLLIGNON, 1951, p. 99, pl. 15 (3), figs. 12, 13.
Pholadomya (*Flabellomya*) *desussata*; COLLIGNON, 1951, p. 100, pl. 15 (3), fig. 14.

Material:—Four specimens (NSM.PM 9467–9470) from Loc. Mj 7–1, four specimens (NSM.PM 9471–9474) from Loc. Mj 13–2 and two specimens (NSM.PM 9475–9476) from Loc. Mj 13–1. All specimens are internal moulds of conjoint valves.

Description:—Outline of shell asymmetrically subtrigonal, but considerably variable, as shown in Text-fig. 5; radial ribs, as far as observed on internal moulds, also variable in strength and number; concentric ribs irregularly spaced; umbo subterminal on most specimens; escutcheon not clearly demarcated from the disk.

Measurements:—(in mm)

Specimen	Length	Height	Thickness
NSM.PM 9467, int. mol. conj. valv.	36.0	32.0	19.3
NSM.PM 9468, int. mol. conj. valv.	28.5	27.8	17.8
NSM.PM 9469, int. mol. conj. valv.	33.9	28.2	18.0
NSM.PM 9470, int. mol. conj. valv.	33.3	28.6	18.9
NSM.PM 9471, int. mol. conj. valv.	19.4	19.2	10.6
NSM.PM 9472, int. mol. conj. valv.	31.0	30.0	16.7
NSM.PM 9473, int. mol. conj. valv.	28.9	34.3	19.5
NSM.PM 9474, int. mol. conj. valv.	29.0	25.3	16.4
NSM.PM 9475, int. mol. conj. valv.	33.0	25.2	18.0
NSM.PM 9476, int. mol. conj. valv.	36.5	36.0	25.8

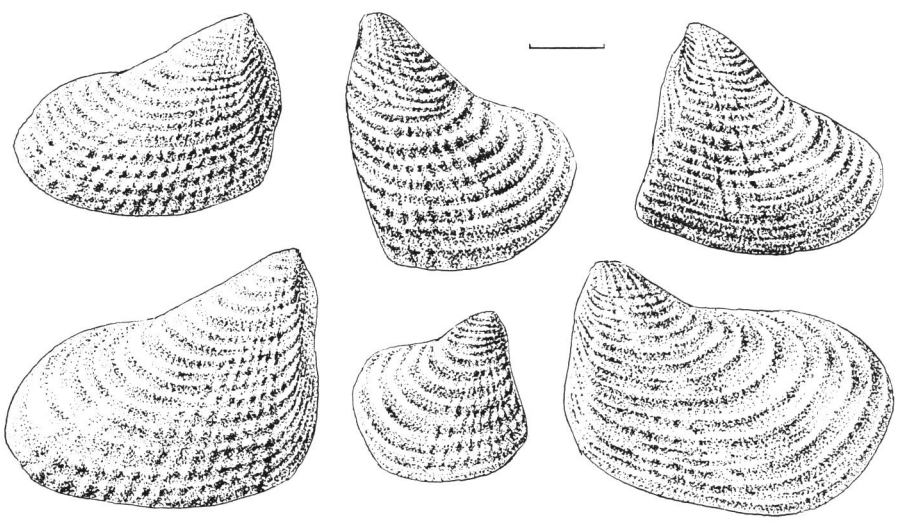

Fig. 5. *Pholadomya* (*Bucardiomya*) sp. aff. *P. esmarkii* NILLSON. Showing variation of the outline and the external sculpture. scale: 10 mm.

Remarks:—This species resembles several Eocene and Paleocene species, *e.g.*, *Pholadomya* (*Bucardiomya*) *margaritacea* (SOWERBY) (COX, 1969; including *P. margaritacea,* YOKOYAMA, 1911; NAGAO, 1928), *P.* (*B.*) *peishankuensis* KANNO and CHUNG (1973, 1975) and *P.* sp. (GIVENS, 1974), in having the subterminal umbo and triangular outline of the valve.

Occurrence:—Loc. Mj 7–1, Mj 13–1, Mj 13–2. Danian.

Concluding Remarks

The bivalve fauna of the "Danian" in the Majunga region of northwestern Madagascar is characterized by *Pholadomya* (*Bucardiomya*) sp., *Modiolus* (*Modiolus*) *incomptaeformis, Crassatella* (?) *protracta, Pycnodonte* (*Pycnodonte*) *vesicularis* and *P.* (*P.*) *arrialoorensis.*

According to COLLIGNON (1951, 1961) and OBATA and KANIE (1978), *Hercoglossa* indicating the Paleocene and Eocene, had been reported as the product from the "Danian" at Antonibe and Majunga in Madagascar. In this Majunga region, it is, however, impossible to discriminate the bivalve fauna of the "Danian" clearly from that of the "Maastrichtian". As far as I can see, the bivalves from the "Danian" of Majunga are much concerned with those from the Upper Cretaceous. The reason is as follows.

Crassatella (?) *protoracta* may closely be related to *Crassatella wanneri* (BASSE, 1933), from the Senonian in Madagascar, and *Modiolus* (s. str.) *incomptaeformis* is probably concerned with *Modiolus typica* from the Maastrichtian in Madagascar and India (BASSE, 1933; STOLICZKA, 1871). While, *Pycnodonte* (s. str.) *vesicularis* is a well known "big oyster" from the Upper Cretaceous. *Pycnodonte* (s. str.) *arrialoorensis* is also known from the Maastrichtian of India, (STOLICZKA, 1871). And *Tenea*, which is one of the cosmopolitan genera, is distributed in the Upper Cretaceous.

On the other hand, the Maastrichtian faunas in Japan are provided with more numerous bivalve genera, *e.g.*, *Acila, Microtrigonia, Corbula, Nanonavis, Leptosolen, Mesochione* etc. And the "big oyster" in Japan is *Crassostrea* (TASHIRO, 1976). The common genera of Maastrichtian faunas between Majunga and Japan are few, *e.g.*, *Tenea.* Therefore bivalve fauna of the Maastrichtian of Majunga have a little in common with those in Japan. If *Crassatella* (?) *protracta* is related to Japanese Maastrichtian genus *Mesochione* as mentioned in the description, it would probably become one of the interesting elements in considering about the relationship of faunas between Madagascar and Japan.

Exogyra sp. and *Nicaisolopha* sp. from the so-called Upper Eocene of Majunga should be noted in view of the fact that the two genera are more abundantly known in the Late Cretaceous time.

Appendix

Notes on Localities of the Cretaceous-Tertiary Pelecypods described from Madagascar

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The described specimens were collected on the occasions of the paleontological reconnaisance survey of the Antonibe area by UJIIÉ and KANIE in 1973, the Majunga area by UJIIÉ and KANIE in 1973, OBATA and KANIE in 1975, and the Tuléar area by UJIIÉ in 1973 (Fig. 1). The following is the record of the localities where the pelecy-

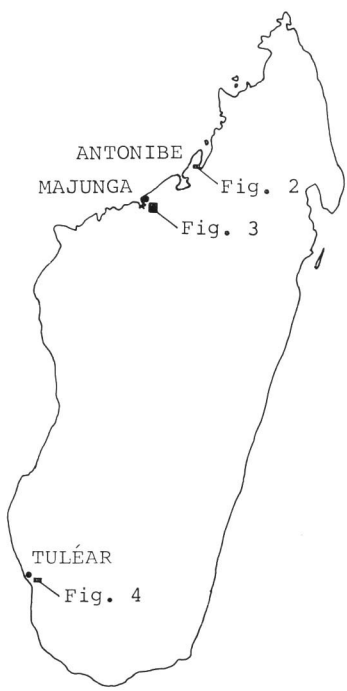

Fig. 1. Map for showing the area described in the text-figures 2–4.

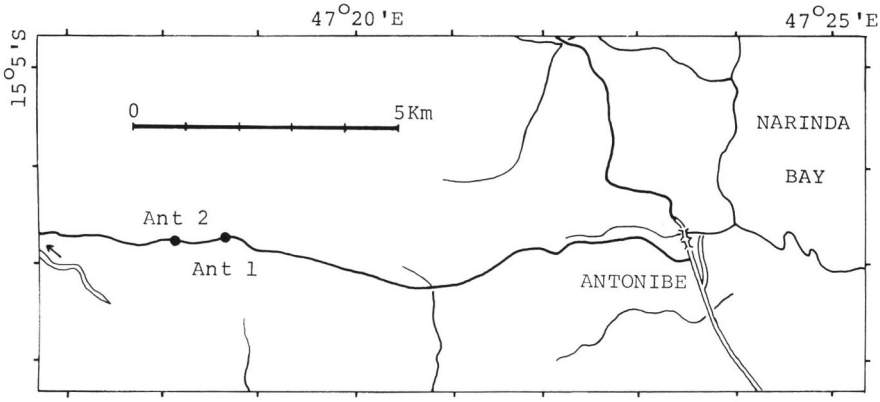

Fig. 2. Localities of the pelecypods described from Antonibe, northwestern Madagascar.

pod specimens of this report were obtained. Their locations are indicated in Text-figures 2–4. The invertebrates associated with the described pelecypods are also listed.

We express our sincere gratitude to Dr. Keisaku TANAKA of the Geological Survey of Japan for identification of echinoids. The field work was carried out with the facilities afforded by the Geological Survey, Department of Mines and Energy of the Malagasy Republic. The study was supported by a Grant in Aid for Overseas Scientific Survey defrayed from the Ministry of Education, Science and Culture of Japan.

1. Antonibe area (Fig. 2)

According to the geological map of the Service Géologicque de Madagascar "Antonibe-Baie de Narinda" (1: 100,000) published in 1960, Loc. Ant. 1 may be included in the Formation C^8 (Campanian; grés continentaux et argiles) and Loc. Ant. 2 in the Formation C^9 (Maastrichtian; marnes à *Pycnodonte vesicularis* et *Alectryonia ungulata*), though following occurrences of the fossils suggest that the two localities are assigned to the Danian in age.

Loc. Ant 1. (grey mudstone). Cephalopoda gen. et sp. indet., *Brissopneustes dacaryi* LAMBERT, *Linthia* (*Linthia*) cf. *inconstans* (LAMBERT) and *L.* (*Linthia*)? spp.

Loc. Ant 2. (grey mudstone). Cephalopoda gen. et sp. indet.

2. Majunga area (Fig. 3).

The Danian stratigraphy of this area was outlined on the occasion of descriptive work of a *Hercoglossa* (OBATA and KANIE, 1978).

Loc. Mj 7–1 (Upper to middle part of Formation C^{10}, Danian). At an exposure about 50 m southwards apart from the national road around Ambohizavavy abundant megafossils were obtained from chalk. The associated fossils with pelecypods are *Linthia* (*Linthia*) *inconstans* (LAMBERT) and *Hemiaster* (*Bolbaster*) *hawkinsi* LAMBERT.

Loc. Mj 7–2 (Upper to middle part of Formation C^{10}, Danian). At an exposure about 200 m northwards apart from the national road around Ambohizavavy abundant megafossils were obtained from chalk. Decapoda gen. et sp. indet. and Bryozoa gen.

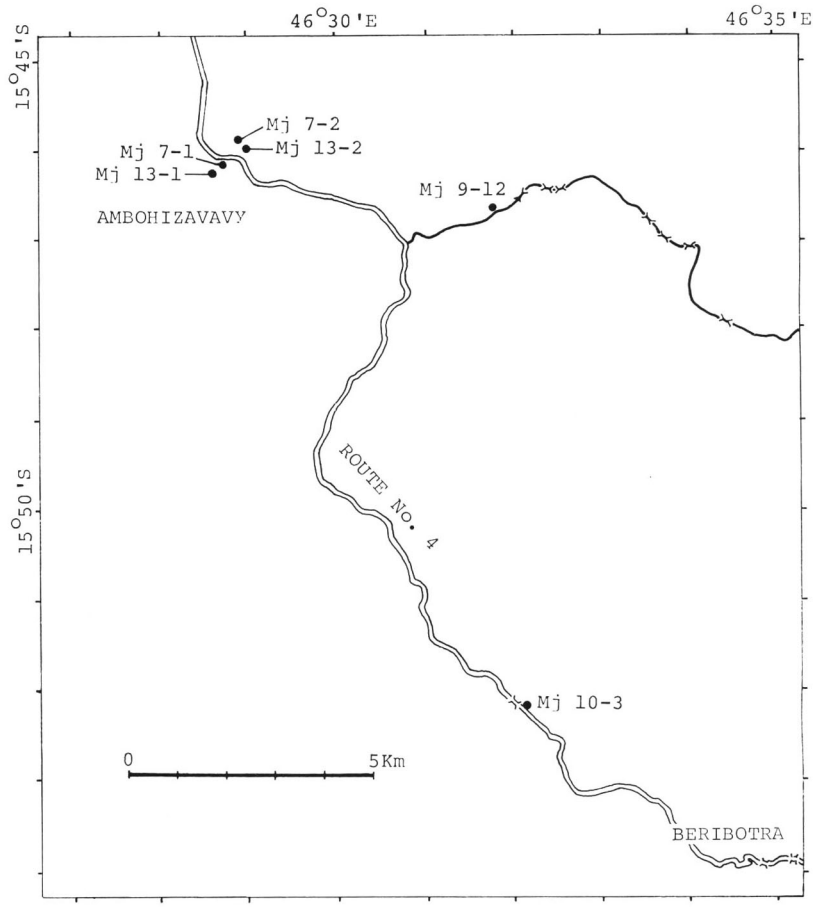

Fig. 3. Localities of the pelecypods described from Majunga, northwestern Madagascar.

et sp. indet. were discovered from the same rock.

Loc. Mj 9–12 (Formation C^9, Maastrichtian). At an exposure about 2 km eastwards from the crossroads of Ambohizavavy numerous bivalve specimens of *Pycnodonte vesicularis* occur from calcareous mudstone. Small gastropods and corals are rarely found.

Loc. Mj 10–3 (Formation C^{10}, Danian). At a roadside cutting about 5.5 km northwest of Berivotra village numerous trace fossils of Polychaeta were found from the chalk. *Linthia* sp., *Turritella*? sp. and *Eriphyla* sp. occur from the same rock with commonly found pelecypods.

Loc. Mj 13–1 (Middle to upper part of Formation C^{10}, Danian). At an exposure about 200 m southwest of Loc. Mj 7–1 the megafossils were frequently obtained from chalk. The invertebrates associated with pelecypods are "*Cidaris*" *majungensis* (LAMBERT), *Gauthieria menuthiae* LAMBERT et SAVIN, *Hemiaster* (*Bolbaster*) *hawkinsi* LAMBERT,

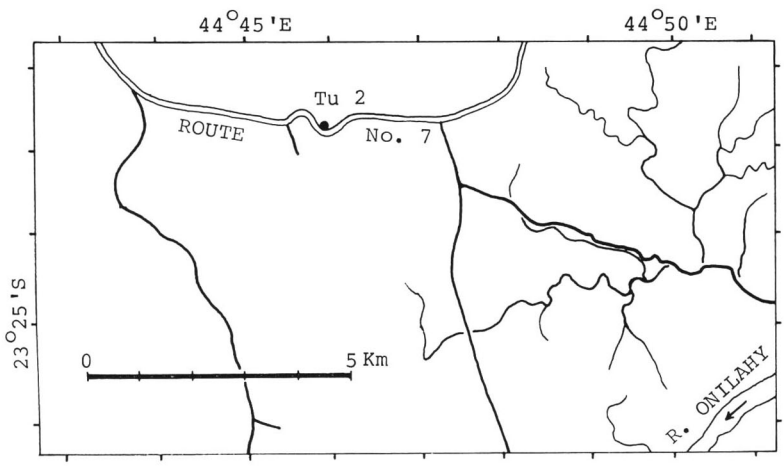

Fig. 4. Locality of the pelecypods described from Tuléar, southwestern Madagascar.

H. (*Mecaster*) *boulei* COTTREAU, *H.* (*Mecaster*) sp., *Linthia* (*Linthia*) cf. *inconstans* (LAMBERT) and *Natica* sp.

Loc. Mj 13–2 (Upper to middle part of Formation C^{10}, Danian). At an exposure about 50 m northeast along the national road around Ambohizavavy megafossils are abundantly yielded from chalk. The invertebrates associated with pelecypods are *Hemiaster* (*Bolbaster*) *hawkinsi* LAMBERT, *Abatus* ? sp., *Linthia* (*Linthia*) *inconstans* (LAMBERT), *Turritella*? sp., *Natica*? sp., Decapada gen. et sp. indet. and Bryozoa gen. et sp. indet.

3. Tuléar area (Fig. 4)

Ostreid bearing mudstone. According to the geological map published in 1957 by the Service Géologique de Madagascar, Formation e^3 (Upper Eocene) is distributed there. A hill 159 m high in altitude at road-side about 13 km southeast of Tuléar is composed of the Formation e^3 (Upper Eocene; calcaire et marnes à huîtres) according to the geological map "Ambohimahavelona-Tongobory" (1: 100,000) published in 1957 by the Service Géologique de Madagascar. Beneath a oolitic limestone bed covered the hill-top rather loosely compacted mudstone is developed in containing abundant ostreids which are described in this paper.

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Explanation of Plates

Plate 1

Modiolus (*Modiolus*) *incomptaeformis* (COLLIGNON)

Fig. 1. NSM.PM 9405, ×1, Loc. Mj 13–1.
Fig. 2. NSM.PM 9407, ×1, Loc. Mj 13–1.
Fig. 3a. NSM.PM 9404, ×1, Loc. Mj 9–12.
Fig. 3b. dorsal view of same specimen.

Pholadomya (*Bucardiomya*) sp. aff. *P. esmarkii* NILLSON

Fig. 4. NSM.PM 9475, ×1, Loc. Mj 13–1.
Fig. 5. NSM.PM 9469, ×1, Loc. Mj 7–1.
Fig. 6a. NSM.PM 9470, ×1, Loc. Mj 7–1.
Fig. 6b. dorsal view of same specimen.

Crassatella (?) *protracta* COLLIGNON

Fig. 7. NSM.PM 9456, ×1, Loc. Mj 13–1.
Fig. 8. NSM.PM 9458, ×1, Loc. Mj 13–1.
Fig. 9. NSM.PM 9459, ×1, Loc. Mj 13–1.
Fig. 10. NSM.PM 9454, ×1.5, Loc. Mj 7–1.

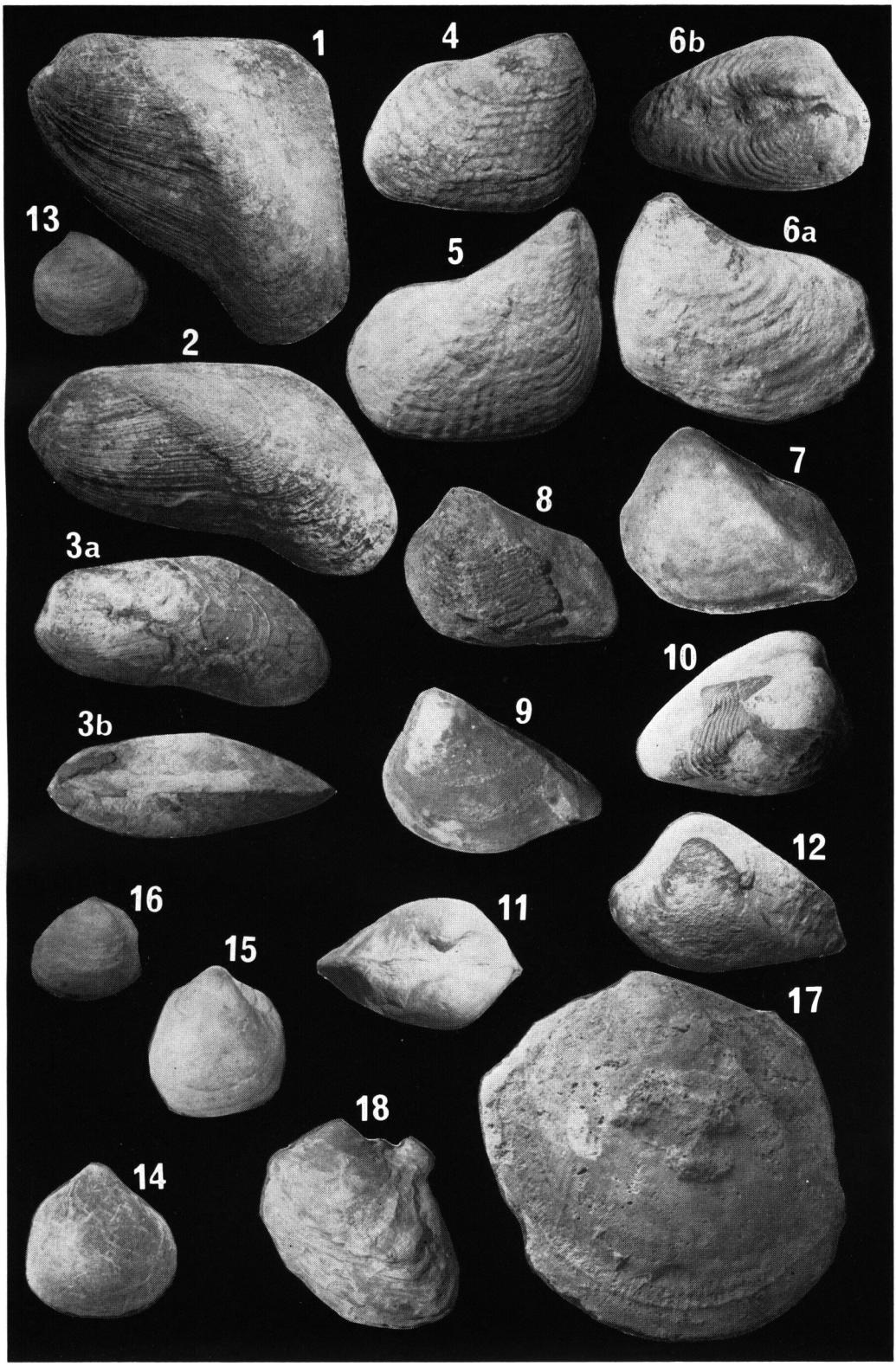
Fig. 11. NSM.PM 9455, ×1.2, Loc. Mj 7–1.
Fig. 12. NSM.PM 9457, ×1, Loc. Mj 13–1.
Astarte? sp.
Fig. 13. NSM.PM 9451, ×2, Loc. Mj 7–1.
Nemocardium? sp.
Fig. 14. NSM.PM 9465, ×2, Loc. Mj 7–1.
Fig. 15. NSM.PM 9463, ×1.5, Loc. Mj 7–1.
Fig. 16. NSM.PM 9462, ×1.5, Loc. Mj 7–1.
Lucina sp.
Fig. 17. NSM.PM 9450, ×1, Loc. Ant 1.
Gryphaeostrea sp. aff. *canaliculata* (SOWERBY)
Fig. 18. NSM.PM 9425, ×1, Loc. Ant 1.

Plate 2

Pycnodonte (*Pycnodonte*) *vesicularis* (LAMARCK)
Fig. 1. left valve, NSM.PM 9412, ×1, Loc. Mj 9–12.
Fig. 2a. internal view of right valve, NSM.PM 9420, ×1, Loc. Mj 9–12.
Fig. 2b. external view of same specimen.
Fig. 3. left valve, NSM.PM 9413, ×1, Loc. Mj 9–12.
Pycnodonte (*Pycnodonte*) *arrialoorensis* (STOLICZKA)
Fig. 4. left valve, NSM.PM 9421, ×1.2, Loc. Ant 1.
Fig. 5. left valve, NSM.PM 9422, ×1.2, Loc. Ant 1.
Exogyra sp.
Fig. 6. left valve, NSM.PM 9424, ×1, Loc. Tu 2.
Tenea? sp.
Fig. 7a. NSM.PM 9466, ×1, Loc. Mj 10–3.
Fig. 7b. dorsal view of same specimen.

Plate 3

Nicaisolopha? sp.
Fig. 1. left valve, NSM.PM 9448, ×0.9, Loc. Tu 2.
Fig. 2. right valve, NSM.PM 9444, ×0.9, Loc. Tu 2.
Fig. 3. right external view of conjoint valves, NSM.PM 9440, ×0.9, Loc. Tu 2.
Fig. 4. internal view of left valve, NSM.PM 9447, ×0.9, Loc. Tu 2.
Fig. 5. internal view of right valve, NSM.PM 9446, ×0.9, Loc. Tu 2.
Crassostrea sp.
Fig. 6. left valve, NSM.PM 9438, ×0.9, Loc. Tu 2.
Fig. 7. internal view of left valve, NSM.PM 9439, ×0.9, Loc. Tu 2.
Crassostrea sp. aff. *angusta* (DESHAYES)
Fig. 8a. right external view of conjoint valves, NSM.PM 9428, ×0.9, Loc. Tu 2.
Fig. 8b. posterior lateral view of same specimen.
Fig. 9. internal view of left valve, NSM.PM 9431, ×0.9, Loc. Tu 2.
Fig. 10. left valve, NSM.PM 9532, ×0.9, Loc. Tu 2.


1
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3a
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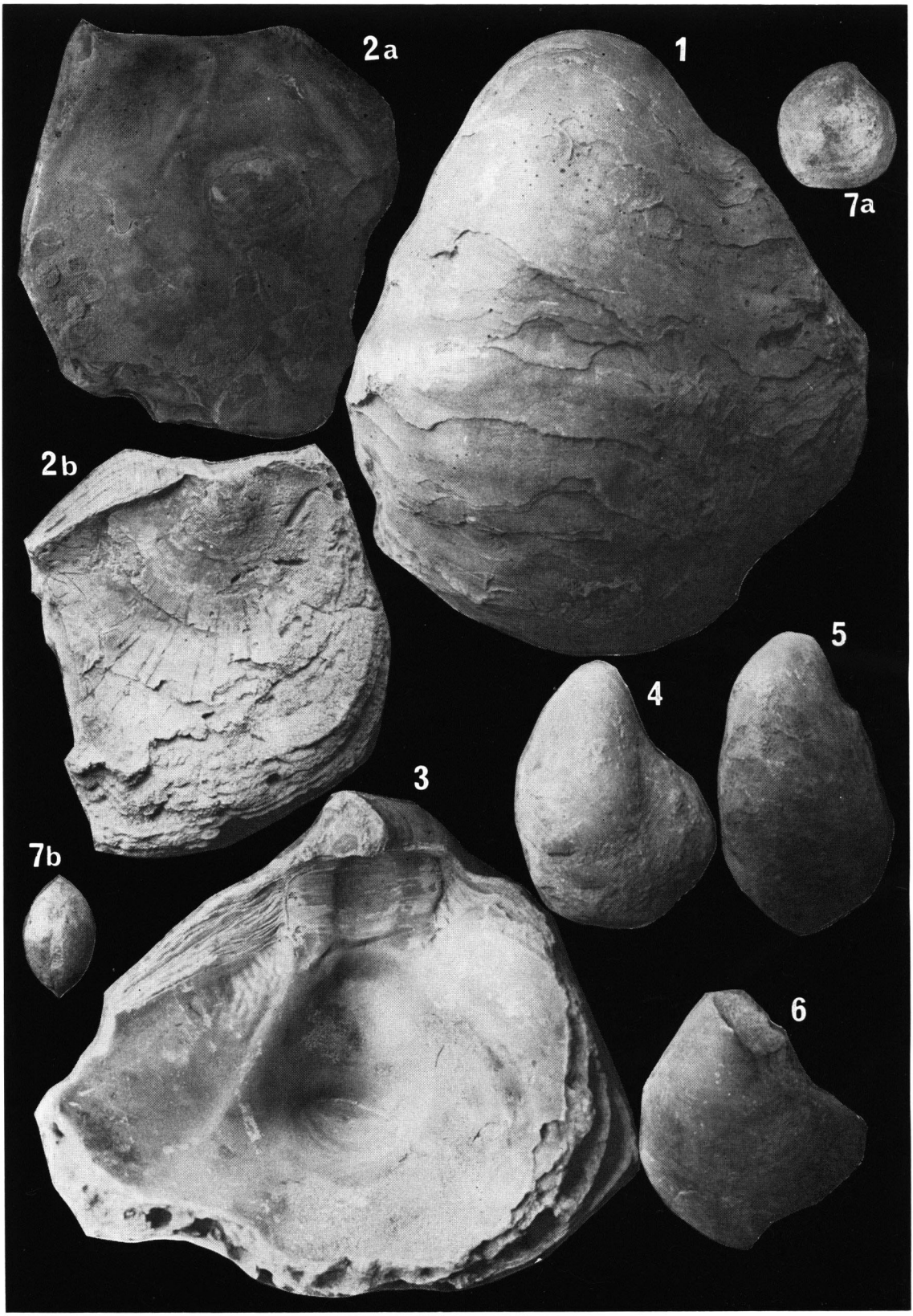
2a
1
7a
2b
5
4
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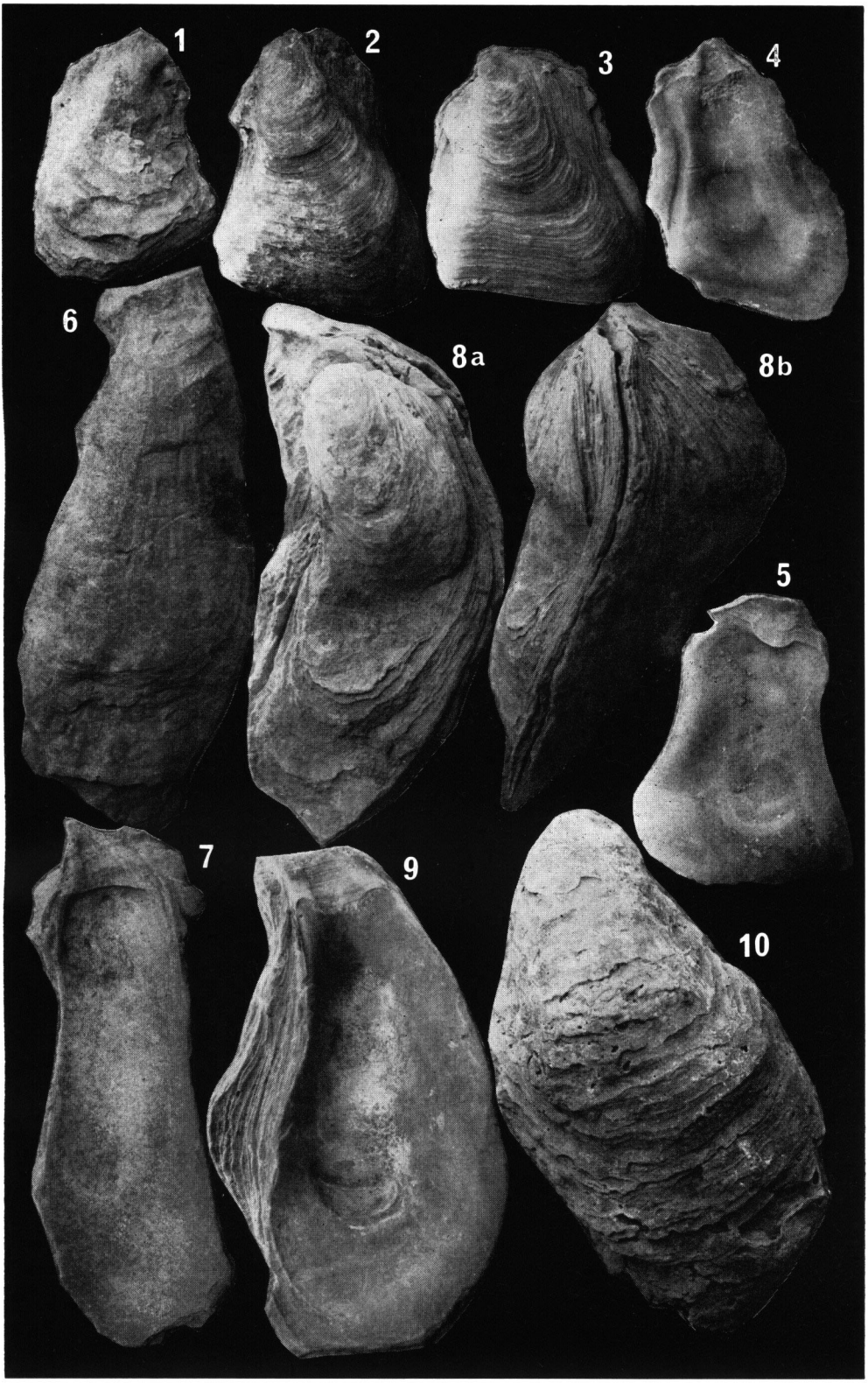
7b
6


1
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3
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6
8a
8b
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