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# Campanian *Inoceramus* from the Menabe Area, Southwestern Madagascar* Part II

By

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## Subgenus *Endocostea* WHITFIELD, 1877

### *Inoceramus* (*Endocostea*) *balticus* BÖHM subsp. nov.(?)

Pl. 5, Fig. 4

*Material.*——Two specimens, nos. NSM.PM 9347 and 9348 from loc. Mb 18.

*Description.*——Shell of medium size, equivalve, moderately convex anteroposteriorly and also along the growth axis; umbonal region comparatively thick, anterior part steep to the valve plane, posterior region flattened passing gradually into a broad wing-like area. Outline roughly semicircular, with uniformly rounded margin and somewhat oblique. Hinge-line long (about three fourths of shell length). Umbo terminal, curved moderately inwards and projecting a little beyond the hinge-line.

Surface ornamented by concentric ribs which are low, sharp-topped, regular in strength and separated by somewhat wider and concave interspaces; ribs are moderately crowded, in earlier growth stages, they broaden gradually with growth. Numerous pits are scattered irregularly over the surface of the internal mould.

*Measurements.*——

Table 11A. Measurements of *Inoceramus* (*Endocostea*) *balticus* BÖHM subsp. nov.(?). length in mm.

| NSM. PM | $\alpha$ | h | l | T | HL | rib | l/h | $h_{=60\,mm}/l$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9347 | 126 | 59.0 | 65.7 | | 48.3 | 16 | 1.11 | | 0.90 | | | 0.82 | 0.27 | 42 |
| 9348 | 135 | 42.0 | 52.0 | | 36.7 | 12 | 1.24 | | 0.81 | | | 0.87 | 0.29 | 43H=50mm |

* Contribution to the Paleontology of Madagascar, VII
Part I *Bull. Natn. Sci. Mus., Ser. C*, 4 (1): 11–32, pls. 1–4 (1978)

Table 11B. Numerical characters of *Inoceramus* (*Endocostea*) *balticus* BÖHM. subsp. nov. (?).

| | $\alpha$ | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|
| *N* | 2 | 2 | | 2 | | | 2 | 2 | |
| *m* | 130.5 | 1.175 | | 0.855 | | | 0.845 | 0.280 | |
| *s* | 6.36 | 0.0919 | | 0.6364 | | | 0.0354 | 0.0141 | |
| *V* | 4.87 | 7.8213 | | 7.4433 | | | 4.1893 | 5.0357 | |

For signs see reference of Table 2A and B.
Inmeasurable character (e.g. destroyed, deformed and smaller than standard) is left as a blank.

*Remarks.*——The relative growth of shell height and length and the ontogenetic change of obliquity are shown in Text-figs. 21 and 22. As is demonstrated in Text-fig. 22, the obliquity gradually increases with growth.

The specimens examined closely resemble a variable form of *Inoceramus* (*Endocostea*) *balticus* BÖHM which occurs in the Lower to Upper Campanian of various regions of the world.

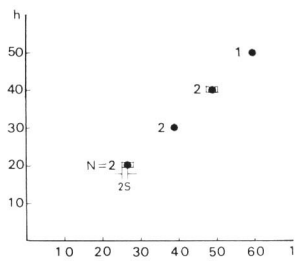


Fig. 21. Relative growth between shell height and length in *Inoceramus* (*Endocostea*) *balticus* BÖHM subsp. nov. (?) N: sample size.

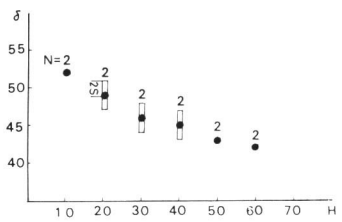


Fig. 22. Ontogenetic change of obliquity in *Inoceramus* (*Endocostea*) *balticus* BÖHM subsp. nov. (?). N: sample size.

When compared with the typical specimen of *I.* (*E.*) *balticus* (COX, 1969, p. 315, 316, fig. C46·4), the present specimens have a more uniformly convex shell which does not show an abrupt bending to venter and the simple ratio h/l is larger in the latters. There are numerous pits on the surface of the internal mould.

The present specimens are somewhat similar to one form of *I.* (*E.*) *balticus kunimiensis* NAGAO et MATSUMOTO from the Campanian of Southwest Japan in shell convexity and marginal outline, but differ in having a longer hinge-line with a terminal umbo, and numerous pits on the surface of the internal mould.

The present specimens are also distinguished from *I.* (*E.*) *balticus toyajoanus* NAGAO et MATSUMOTO, from the Campanian of Southwest Japan in having a more convex shell, terminal umbo and uniformly rounded ventral margin.

A numerous pits on the surface of internal moulds are commonly observed in various species of *Inoceramus* from the area surveyed. The character is interpreted as a pseudosculpture and it is, therefore, of limited value for identification.

In summary, from the above comparisons, the present specimens are not exactly

identical with any known subspecies of *I.* (*E.*) *balticus,* and probably represent a new subspecies, but we defer, at present, the creation of a new name, because of the small size of our sample.

## Subgenus uncertain

### *Inoceramus regularis* D'ORBIGNY
Pl. 2, Fig. 3; Pl. 7, Fig. 1

1962. *Inoceramus regularis* D'ORBIGNY. SORNAY, *Bull. Soc. Geol. France*, vol. 4, p. 120, 121

*Lectotype.*——see SORNAY 1962, p. 120.

*Material.*——Five specimens: NSM.PM 9327 from loc. Mb3, NSM.PM 9343 from loc. Mb9 and NSM.PM 9349, 9350 and 9351 from loc. Mb18.

*Description.*——Shell medium in size, equivalve, gently convex and uniformly inflated antero-posteriorly and also along the growth axis; antero-dorsal part moderately sloping to the valve plane, postero-dorsal part gradually flattening and passing into a wing-like area. Shell outline subcircular with uniformly rounded margin, somewhat longer than high, and somewhat oblique. Hinge-line of moderate length (about a half of shell length), forming an obtuse angle, (145° on average) with the posterior margin. Umbo subterminal, small and inconspicuous.

Surface ornamented by concentric ribs and rings; the ribs low, sharp-topped, regular in strength and separated by wider interspaces which are gradually broadened with growth; numerous concentric rings cover the primary ornament, sometimes crossing the ribs obliquely on the postero-ventral area. A haenleinian depression is not seen.

*Measurements.*——

Table 12A. Measurements of *Inoceramus regularis* D'ORBIGNY. length in mm.

| NSM. PM | $\alpha$ | h | l | T | HL | rib | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9327 | 135 | 47.0 | 51.7 | | 23.4 | 15 | 1.10 | | 0.91 | | | 0.50 | 0.32 | |
| 9343 | 135 | 52.7 | 44.6+ | | 18.0+ | 11 | 0.85+ | | | | | | 0.21 | |
| 9349 | 133 | 73.6 | 81.0 | 39.0 | 46.2 | 13 | 1.10 | 1.11 | 0.91 | 0.90 | 0.53 | 0.63 | 0.18 | 58 |
| 9350 | 133 | 52.2 | 61.0 | 39.5 | 33.6 | 14 | 1.17 | | 0.85 | | 0.76 | 0.64 | 0.27 | 58 |

Table 12B. Numerical characters of *Inoceramus regularis* D'ORBIGNY.

| | $\alpha$ | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\alpha_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|
| *N* | 4 | 3 | | 3 | | 2 | 3 | 4 | 2 |
| *m* | 134.0 | 1.123 | | 0.890 | | 0.645 | 0.590 | 0.245 | 58.0 |
| *s* | 1.15 | 0.0404 | | 0.0346 | | 0.1626 | 0.0781 | 0.0624 | 0 |
| *V* | 0.86 | 3.5975 | | 3.8876 | | 25.2093 | 13.2373 | 25.4694 | 0 |

*Remarks.*——The relative growth of shell height and length and the ontogenetic change of obliquity are shown in Text-figs. 23 and 24. As is demonstrated in Text-fig. 24, the obliquity decreases gradually with growth. With respect to the subcircular outline, gently convex shell, and the ontogenetic change in obliquity, the specimens examined are close to those of the rather variable species *Inoceramus regularis* D'ORBIGNY (SORNAY, 1976, pl. 3, figs. 3, 4).

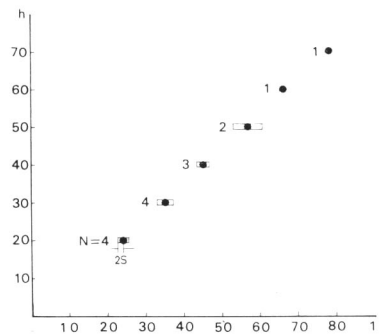


Fig. 23. Relative growth between shell height and length in *Inoceramus regularis* D'ORBIGNY. N: sample size.

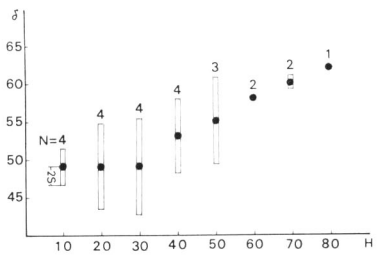


Fig. 24. Ontogenetic change of obliquity in *Inoceramus regularis* D'ORBIGNY. N: sample size.

*I. regularis* closely resembles *I. balticus toyajoanus* NAGAO et MATSUMOTO from the Campanian of Southwest Japan. YABE (1915) compared one of the specimens from Toyajo (Southwest Japan), to *I. regularis*, but the Japanese specimen was distinguished by NAGAO and MATSUMOTO (1940) in more circular and less oblique outline.

*I. regularis* somewhat resemble *I.* (*Cordiceramus*) *pseudoregularis* SORNAY, from the Upper Campanian of Menabe area, in general outline, but *I.* (*C.*) *pseudoregularis* is more elongated antero-posterioly, more oblique as shown in Table 3A and B, and wavy closuer in the posterior margin. There are, however, various intermediates between the two species, which moreover, occur together. It is thus very difficult to separate the two forms specifically at population level.

*Inoceramus* sp. aff. *bererensis* SORNAY
Pl. 1, Fig. 3; Pl. 2, Fig. 4A, 4B.

*Material.*——Three specimens, NSM.PM 9323 and 9325 from loc. Mb3 and NSM. PM 9345 from loc. Mb10.

*Description.*——Shell medium or comparatively large in size, equivalve, inequilateral, relatively oblique, as high as long or scarecely longer than high, moderately inflated antero-posteriorly and along the growth axis. Anterior part thick and steep to the valve plane, posterior half compressed gradually to the margin, without forming a distinct wing. A small anterior wing is developed on specimen NSM.PM 9323.

Antero-dorsal, anterior and ventral margins broadly and uniformly rounded, postero-ventral one narrowly arcuate and passing into straight or slightly convex posterior one; which forms an obtuse angle (127° on average) with the hinge-line. The hinge-line relatively short, less than a half of the shell length. Umbo terminal or subterminal, slightly projecting above the hinge-line, curved inwards and somewhat forwards.

Surface ornamented by a conbination of concentric ribs and rings; the ribs usually low, broad, round-topped, somewhat irregular in size and distance, and frequently bifurcating or inserted. Numerous rings covering the ribs and interspaces. A weak haenleinian depression runs somewhat posteriorly along the growth axis developed on specimens NSM.PM 9323 and 9325, but not on NSM.PM 9345.

*Measurements.*——

Table 13A. Measurements of *Inoceramus* sp. aff. *bererensis* SORNAY. length in mm.

| NSM. PM | $\alpha$ | h | l | T | HL | rib | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9323 | 132 | 61.0 | 67.0 | | 25.5 | 17 | 1.10 | 1.16 | 0.91 | 0.86 | | 0.49 | 0.28 | 57 |
| 9325 | 120 | 66.2 | 74.3 | | 33.8 | 13 | 1.12 | 1.09 | 0.89 | 0.92 | | 0.44 | 0.17 | 53 |
| 9345 | 120 | 91.7 | 85.6 | 58.0 | 44.6 | 18 | 0.93 | 1.08 | 1.08 | 0.93 | 0.61 | 0.47 | 0.19 | 55 |

Table 13B. Numerical characters of *Inoceramus* sp. aff. *bererensis* SORNAY.

| | $\alpha$ | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|
| *N* | 3 | 3 | 3 | 3 | 3 | | 3 | 3 | 3 |
| *m* | 124.0 | 1.050 | 1.110 | 0.950 | 0.903 | | 0.467 | 0.213 | 55.0 |
| *s* | 6.93 | 0.1044 | 0.0436 | 0.1044 | 0.0379 | | 0.0252 | 0.0586 | 2.00 |
| *V* | 5.59 | 9.9429 | 3.9279 | 10.8977 | 4.1971 | | 5.3961 | 27.5117 | 3.64 |

*Remarks.*——The relative growth of shell height and length and the ontogenetic change of obliquity are shown in Text-figs. 25 and 26. As is clear from Text-fig. 26, the obliquity decreases gradually with growth.

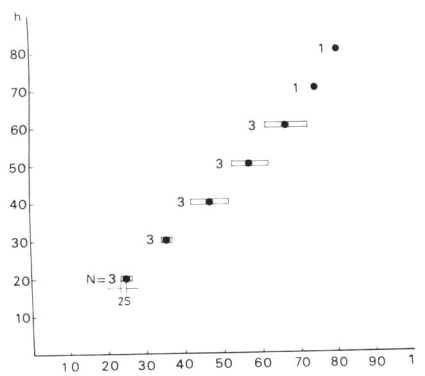


Fig. 25. Relative growth between shell height and length in *Inoceramus* sp. aff. *bererensis* SORNAY. N: sample size.

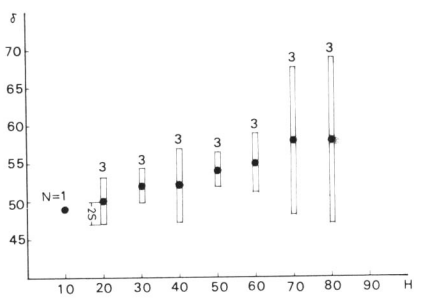


Fig. 26. Ontogenetic change of obliquity in *Inoceramus* sp. aff. *bererensis* SORNAY. N: sample size.

In the specimens examined, the shell convexity, marginal outline, relatively short hinge-line, presence of anterior wing, surface ornamentation of bifurcating ribs and the ontogenetic change of obliquity agree with those of *Inoceramus bererensis* SORNAY, from the Middle Campanian of the Mangoki Basin, southwestern Madagascar. Our specimens differ from SORNAY's specimens in having a somewhat higher outline, i.e. 0.94 against 0.85 on average for the simple ratio h/l. In the specimens at hand, the umbo projects somewhat above the hinge-line but the hinge structure is unknown, whereas in SORNAY's specimens it is less prominent and the hinge-structure is discernible. As the specimens examined are all internal moulds in the umbonal region, the apparent difference may therefore be due to no more than the state of preservation.

According to SORNAY's (1975) original description, the haenleinian depression along the growth axis is invisible in the type specimens of *I. bererensis,* but it is indistinctly visible in our specimens NSM.PM 9325 and 9345. Furthermore, as SORNAY described, the angle between hinge-line and growth axis is about 46° on average, but it is about 55° on average in our specimens and increases gradually with growth (*see* Text-fig. 26).

SORNAY (1975) discussed the relation between *I. bererensis* and *I.* (*Endocostea*) sp. (NAGAO and MATSUMOTO, 1940, pl. 3, fig. 2), but they are clearly distinguishable from each other on the basis of the presence of a small anterior wing and an endocostean groove.

The present species also resembles *I.* (*Cordiceramus*) *mitraikyensis climacoides* SORNAY (1969) from the upper part of the Middle Santonian to the Lower Campanian of Menabe, southwestern Madagascar, in shell convexity, marginal outline and coarser ornament, but differs from the latter in the presence of an anterior wing and a surface ornament without bifurcate ribs.

In summary, it is more reasonable to regard our specimens as akin to *I. bererensis,* on the base of their morphological characters, but we defer to give a new specific name until convincing evidence is obtained.

Subgenus *Trachoceramus* HEINZ, 1932,

*Inoceramus* (*Trachoceramus*) sp. aff. *ianjoanensis* SORNAY
Pl. 6, Fig. 1A, 1B

*Material.*——A single specimen, NSM.PM 9357 from loc. Mb18.

*Description.*——Shell of large size, considerably inflated antero-posteriorly and also dorso-ventrally; anterior part steep, almost perpendicular to the valve plane, flank uniformly convex; postero-dorsal part somewhat flattened without forming a wing-like area. Outline of shell longer than high, very oblique; antero-dorsal border slightly convex, passing gradually to a broadly arched anterior one; ventral margin evenly rounded; postero-ventral extremity circular, continuing the gently curved posterior margin. Hinge-line of moderate length, slightly longer than a half of shell length;

forming an obtuse angle of about 150° with the posterior margin. Umbo subterminal, projecting beyond the hinge-line and slightly curved inwards and forwards.

Surface ornamented by crowded concentric ribs which are round-topped, regular in size and intensity, frequently bifurcated or inserted on the main part of flank and gradually broadening with growth.

*Measurements.*——

Table 14. Measurements of *Inoceramus* (*Trachoceramus*) sp. aff. *ianjonaensis* SORNAY. length in mm.

| NSM. PM | α | h | l | T | HL | rib | l/h | $l/h_{=60\,mm}$ | h/l | $h_{=60\,mm}/l$ | T/h | HL/h | R.D. | $\delta_{H=60\,mm}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9357 | 129 | 100.9 | 109.7 | | 46.0+ | 44 | 1.09 | 1.22 | 0.92 | 0.82 | | 0.46+ | 0.44 | 51 |

*Remarks.*——The relative growth of shell height and length and the ontogenetic change of obliquity are shown in Text-figs. 27 and 28.

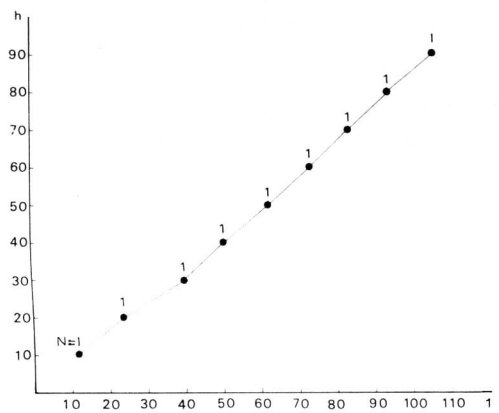


Fig. 27. Relative growth between shell height and length in *Inoceramus* (*Trachoceramus*) sp. aff. *ianjoanensis* SORNAY. N: sample size.

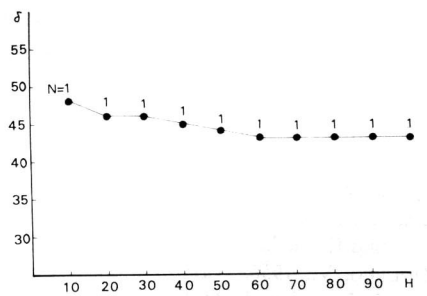


Fig. 28. Ontogenetic change of obliquity in *Inoceramus* (*Trachoceramus*) sp. aff. *ianjoanensis* SORNAY. N: sample size.

In the considerably inflated and uniformly convex shell, oval outline and surface ornamentation the present specimen is compared well with the type of *Inoceramus* (*Trachoceramus*) *ianjoanensis* SORNAY (SORNAY 1973, pl. 3, fig. 5; specimen no. 16–1), from the Lower to Middle Maestrichtian of the Mandembata area, southwestern Madagascar. SORNAY's specimens, however, are commonly characterized by many distinct radial riblets and the concentric ribs of variable size and strength, but specimen no. 16–1, as SORNAY remarked, has regular ribs and reduced radial riblets.

The present specimen is associated with many Campanian *Inoceramus* and ammonite species, whereas SORNAY's ones are from the Lower to Middle Maestrichtian. Thus, the present form may foreshadow the characteristics of the SORNAY's species but the material at hand is insufficient to create a new species.

## Concluding Remarks

13 species of *Inoceramus*, collected from six localities in the Menabe area, southwestern Madagascar, are described. They occurred from three (lower, middle and upper) layers, which are all of the Campanian (probably Lower Campanian) because they are in harmony with the age by cooccurred ammonites such as *Canadoceras hoepeni* and *Hauericeras gardeni*.

Although we tentatively followed SORNAY (1962, 1964, 1968, 1969, 1973 and 1975) in taxonomy, the questions about the definition and scope of the subgenus *Cordiceramus* and also the problem of variation and relationships of the described species remain to be solved in the future.

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## Explanation of Plates

Every specimen illustrated came from the Lower Campanian deposit (Member $C_3a$) in the Menabe area, southwestern Madagascar (Collected by KANIE in 1973: photo by NODA). Pls. 1–4 are in Part I.

### Plate 5

Fig. 1. *Inoceramus* (*Cordiceramus*) *ampambaensis* SORNAY ×0.9
NSM.PM9358 from loc. Mb18. 1A: lateral view of left valve, 1B: posterior view.
Fig. 2. *Inoceramus* (*Selenoceramus*) *flexus* SORNAY ×0.8
MSM.PM9302 from loc. Mb3. anterior view somewhat displaced along the valve plane secondarily.
Fig. 3. *Inoceramus* (*Cordiceramus*) *ampambaensis* SORNAY ×0.9
NSM.PM9330 from loc. Mb3. lateral view of left valve.
Fig. 4. *Inoceramus* (*Endocostea*) *balticus* BÖHM subsp. nov. (?) natural size
NSM.PM9347 from loc. Mb18. lateral view of right valve.

### Plate 6

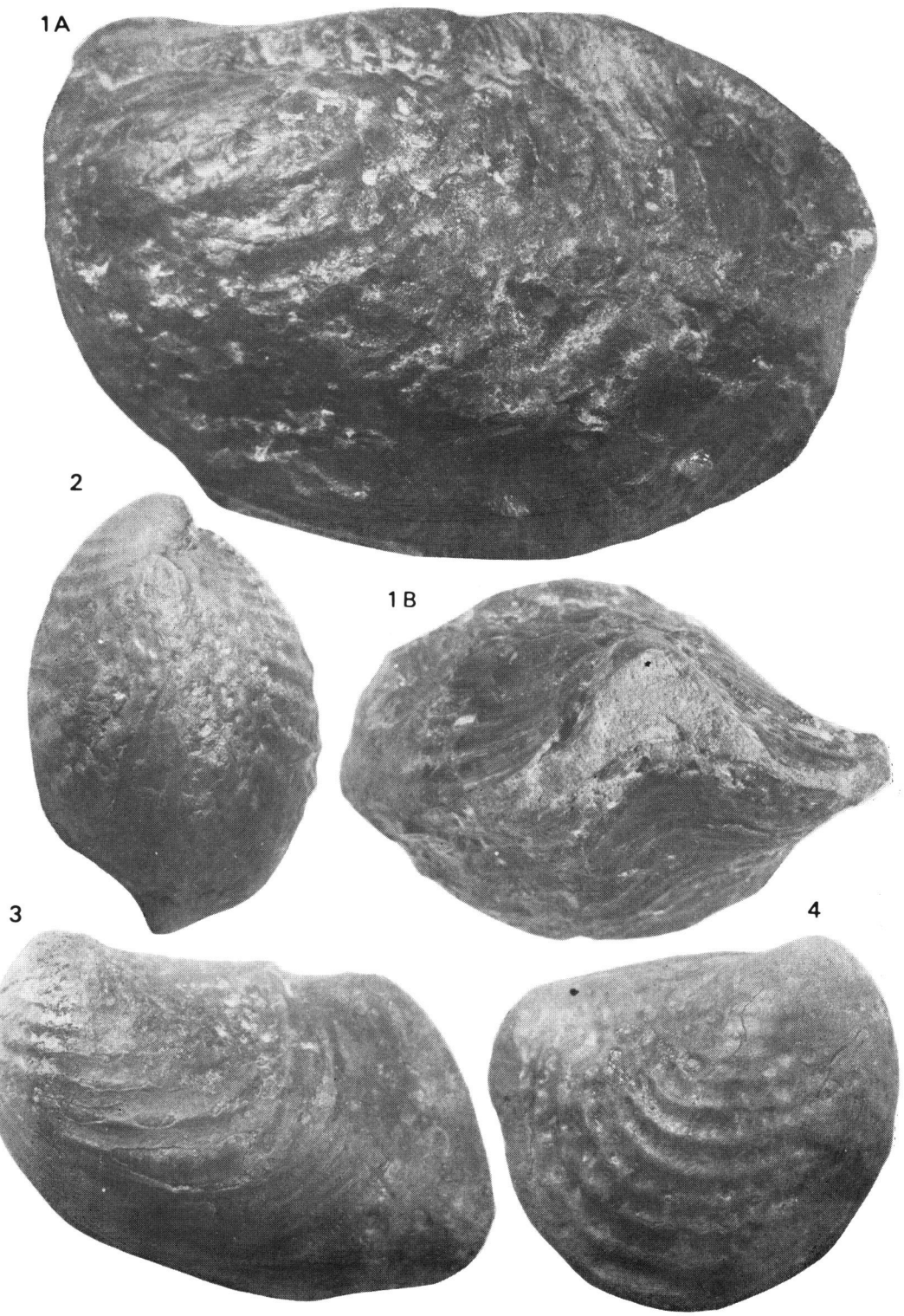
Fig. 1. *Inoceramus* (*Trachoceramus*) sp. aff. *ianjianensis* SORNAY natural size
NSM.PM9357 from loc. Mb18. 1A: lateral view of right valve 1B: dorsal view.
Fig. 2. *Inoceramus* (*Cordiceramus*) sp. $\alpha$ aff. *pseudoregularis* SORNAY natural size
NSM.PM9326 from loc. Mb3. 2A: lateral view of left valve, 2B: dorsal view, 2C: anterior view.

### Plate 7

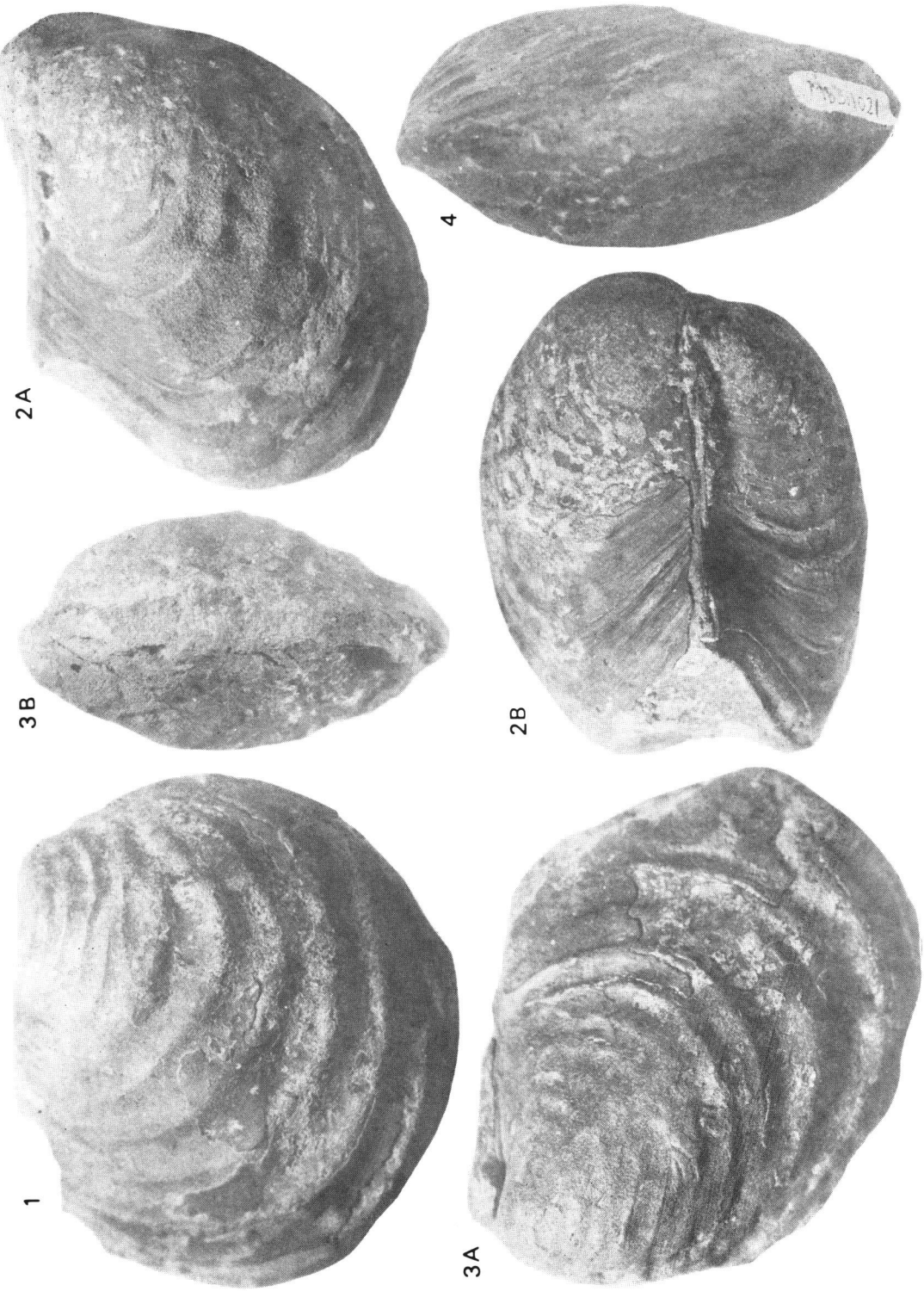
Fig. 1. *Inoceramus regularis* D'ORBIGNY natural size
NSM.PM9349 from loc. Mb18. lateral view of right valve.
Fig. 2. *Inoceramus* (*Condiceramus*) sp. $\beta$ aff. *pseudoregularis* SORNAY ×0.9
NSM.PM9353 from loc. Mb18. 2A: lateral view of right valve, 2B: dorsal view.
Fig. 3. *Inoceramus* (*Cordiceramus*) *pseudoregularis* SORNAY ×0.8
NSM.PM9322 from loc. Mb3. 3A: lateral view of left valve, 3B: anterior view somewhat displaced along the valve plane secondarily.
Fig. 4. *Inoceramus* (*Cordiceramus*) sp. cf. *heberti* FALLOT ×0.9
MSM.PM9321 from loc. Mb3. posterior view somewhat displaced along the valve plane secondarily.

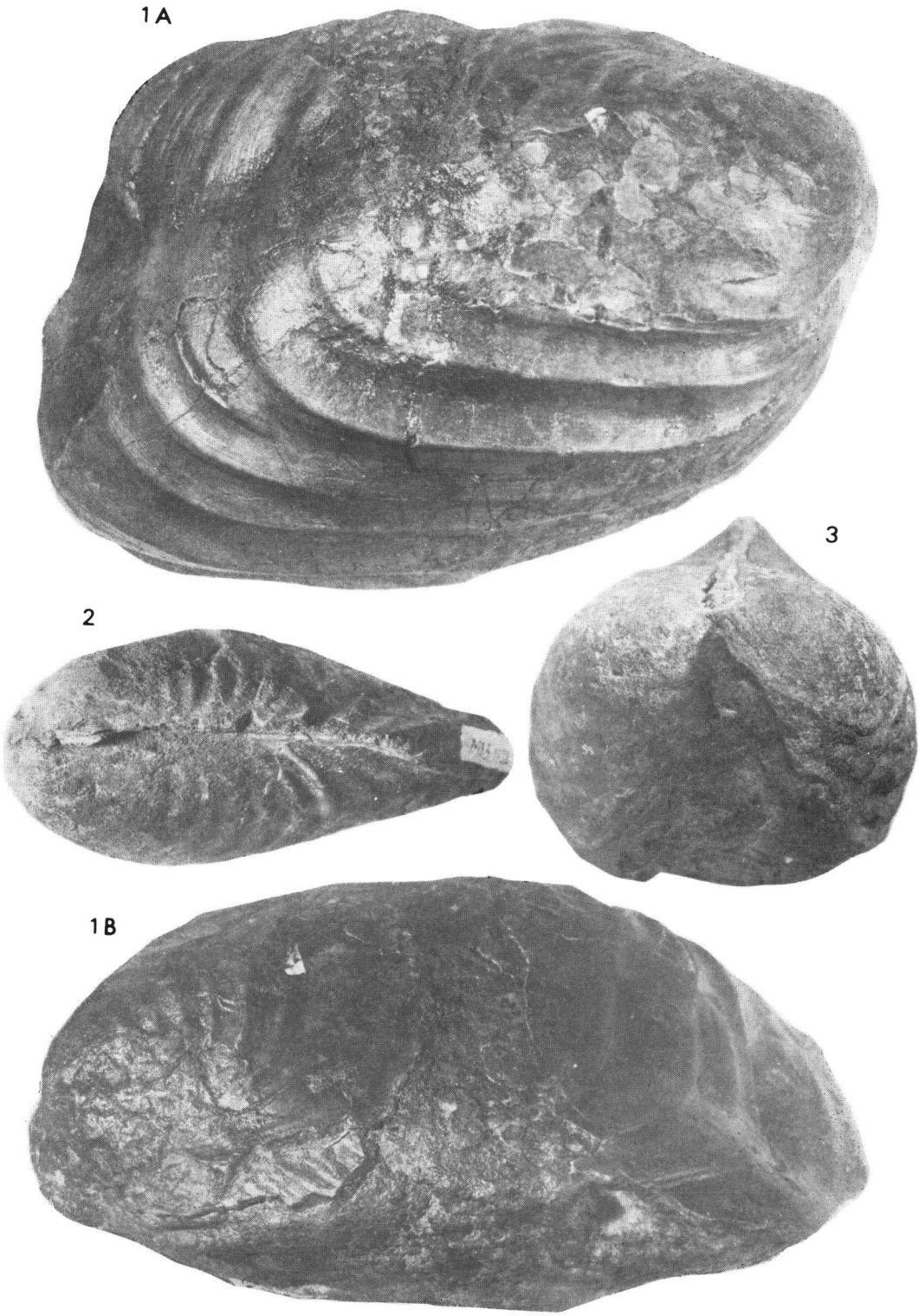
### Plate 8

Fig. 1. *Inoceramus* (*Cordiceramus*) sp. aff. *arculiferus* SORNAY ×0.7
MSM.PM9342 from loc. Mb7. 1A: lateral view of right valve, 1B: dorsal view.
Fig. 2. *Inoceramus* (*Cordiceramus*) *pseudoregularis* SORNAY ×0.8
MSM.PM9322 from loc. Mb3. dorsal view.
Fig. 3. *Inoceramus* (*Cordiceramus*) sp. $\beta$ aff. *pseudoregularis* SORNAY ×0.9
NSM.PM9353 from loc. Mb18. anterior view.


1A
2
1B
3
4


2A
2C
2B
1A
1B


1
2A
2B
3A
3B
4


1A
3
2
1B