

AMMONITES FROM THE OXFORDIAN (BIFURCATUS ZONE) STRATA OF GANGTA BET, KACHCHH, WESTERN INDIA

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ABSTRACT

Gangta Bet, an islet situated in the salt marshes of the Great Rann of Kachchh, western India, is composed of Jurassic strata containing a rich fauna of Upper Oxfordian ammonites which are very rare in other parts of the Kachchh Basin. A detailed bed-by-bed collection yielded 148 ammonites belonging to 21 taxa which are briefly described and illustrated. The assemblage is strongly dominated by members of the genus *Perisphinctes* Waagen, 1869, which are excellent guide fossils enabling intrabasinal and intercontinental correlations e.g., with the ammonite zonation of Europe. While the oldest beds on the Gangta Bet did not yield ammonites indicative of a certain biozone, most of the recorded taxa can be assigned to the Bifurcatus Zone (*Stenocycloides* and *Grossouvrei* subzones) of the Upper Oxfordian.

Keywords: Ammonoids, taxonomy, biostratigraphy, Oxfordian, Gangta Bet, Kachchh Basin

INTRODUCTION

Cephalopods of the Jurassic succession of the Kachchh Basin in western India (Fig. 1) have been studied for more than a century, beginning with the monographs of Waagen (1873-1875) and Spath (1927-1933). Since then, much progress has been achieved in ammonite taxonomy and adjacent fields such as litho- and biostratigraphy (e.g., Agrawal, 1956; Deshpande and Merh, 1980; Biswas, 1980, 1982, 1991, 1993; Singh *et al.*, 1982, 1983; Pandey and Agrawal, 1984; Agrawal and Pandey, 1985; Krishna and Westermann, 1987; Pandey and Westermann, 1988; Pandey *et al.*, 1994; Pandey and Callomon, 1995; Jain *et al.*, 1996; Krishna *et al.*, 1996a, b, 1998, 2000, 2009a, b, c; Fürsich *et al.*, 2001). Nevertheless, the fossils of the Kachchh Basin still offer plenty of opportunities for research. During three recent field surveys in the basin, which mainly concentrated on the Oxfordian part of the succession, sections were measured at localities throughout the area and more than 800 ammonites were collected with high stratigraphic resolution. The present study is the third in a series planned to enlarge our knowledge on cephalopods of the Upper Jurassic of the Kachchh Basin (see Alberti *et al.*, 2011; Pandey *et al.*, 2012). It is based on a collection of 148 ammonites from the islet Gangta Bet, which mainly consists of Upper Oxfordian (Bifurcatus Zone) strata, that are otherwise absent in the Kachchh Basin.

GEOLOGICAL OVERVIEW

The Kachchh Basin (Fig. 1) formed in the Late Triassic following rifting between India and Africa (Biswas, 1982, 1991). After a phase of terrestrial sedimentation, marine conditions became established some time in the Bajocian (Singh *et al.*, 1982; Fürsich, 1998; Pandey *et al.*, 2009) and prevailed until the Early Cretaceous. Jurassic outcrops in the basin are traditionally divided into three areas: the Kachchh Mainland occupying the central part of the basin, the Island Belt amidst the salt marshes of the Great Rann of Kachchh, and the proximal Wagad Uplift. While most of the islands display older strata, the majority of the well known Oxfordian outcrops can be found

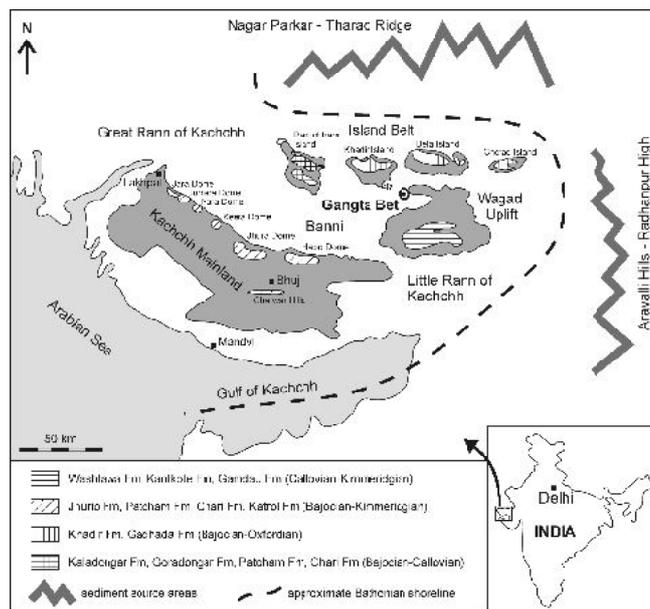


Fig. 1. Geological sketch map of the Kachchh Basin showing the position of the Gangta Bet between the Wagad Uplift and Khadir Island (modified after Fürsich *et al.*, 2004, 2005).

on the Kachchh Mainland as well as the Wagad Uplift. However, the succession on the Kachchh Mainland is characterized by strong condensation, Oxfordian rocks usually comprising only a few metres with parts of the Middle and Upper Oxfordian missing (compare Alberti *et al.*, 2013). In contrast, the succession of the Wagad Uplift is much more expanded comprising several hundred metres without signs of prolonged sedimentary gaps. Nevertheless, rocks around the Oxfordian to Kimmeridgian boundary (upper Bifurcatus to *Hypselocyclum* zones) contain almost no identifiable ammonites here. An abundant ammonite assemblage from the Upper Oxfordian can only be found on the islet of Gangta Bet,

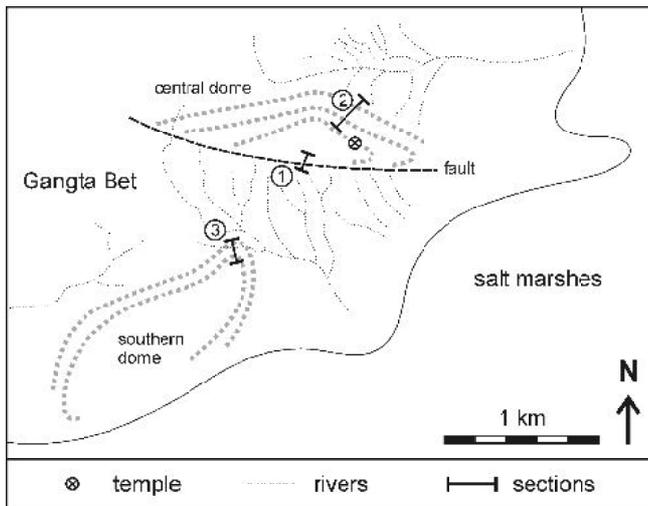


Fig. 2. Schematic map of the southeastern part of Gangta Bet with the position of the three sampled sections and the general geological structures.

northwest of the Wagad Uplift (Fig. 1). Already Waagen (1873-1875) and Spath (1927-1933) described a few specimens from this locality and further scientists visited the Gangta Bet in the following decades (e.g., Biswas, 1980, 1993). Nevertheless, a comprehensive study on its ammonites and their biostratigraphic position has not yet been published.

The islet Gangta Bet, measuring around 5 km across, is situated between Khadir Island and the Wagad Uplift (Fig. 1). Due to its position amidst the salt marshes, it can be accessed only during the dry season. A temple on a ridge in the southeastern part of the islet (N 23°44'04.6" E 070°30'06.0") serves as a useful point of orientation (Fig. 2). The building is close to the centre of a domal structure standing on top of the Brachiopod Bed, an important marker horizon in the lower part of the succession. Lithostratigraphically, the Jurassic rocks exposed on Gangta Bet belong to the Gangta member of the Khadir Formation (compare Biswas, 1980, 1993). Two sections through the flanks of the central dome have been measured and sampled (sections 1 and 2; Fig. 2). However, ammonites only become more abundant in younger strata, which are exposed south of a prominent fault delimiting the central dome and in a second dome near the southern tip of the islet. The majority of the ammonites described in the present publication have been collected from a section measured along the flank of this southern dome (section 3; Fig. 2). A figure with the sections as well as the stratigraphic ranges of the identified ammonite taxa can be found at the end of the article accompanying the biostratigraphic discussion.

SYSTEMATIC PALAEOLOGY

In general, most of the ammonites collected from the Jurassic of Kachchh represent only internal whorls and therefore do not allow to describe all ontogenetic stages of the

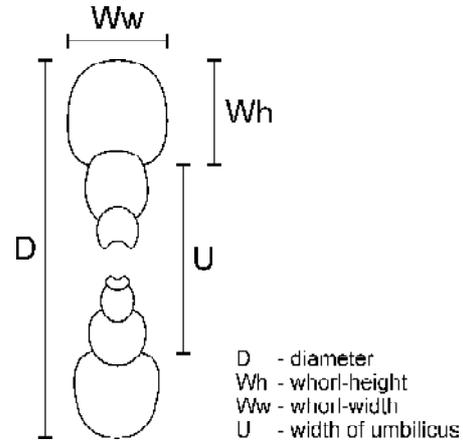


Fig. 3. Measured dimensions of the ammonoids and abbreviations used.

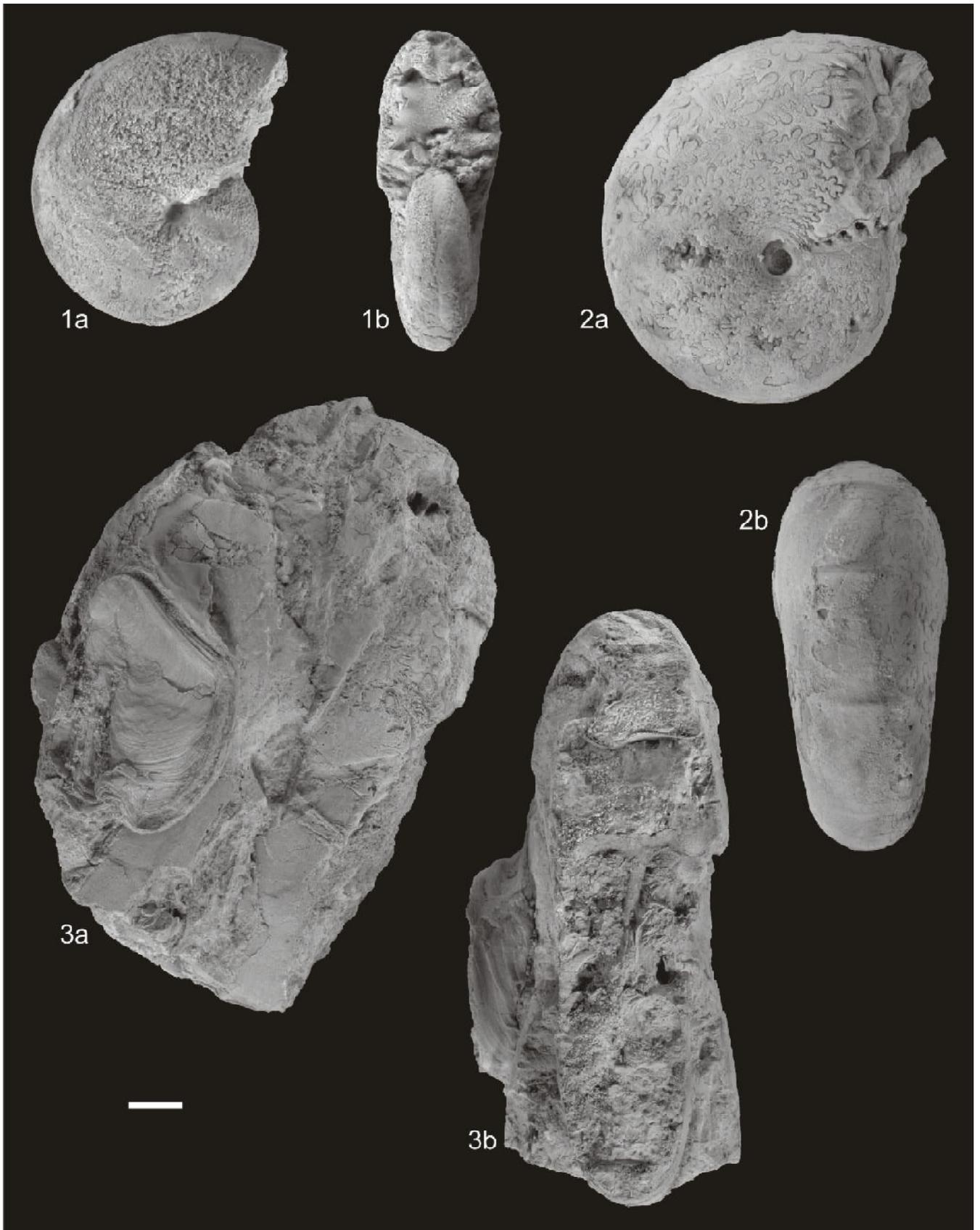
occurring taxa (compare Waagen, 1873-1875; Spath, 1927-1933; Pandey *et al.*, 2012). The present study is based on a thorough collection of the Oxfordian strata of Gangta Bet, yielding more than 300 ammonoids. After exclusion of poorly preserved, unidentifiable specimens, 148 ammonites belonging to 21 taxa as well as one nautiloid remained, which will be described in the following. About half of these specimens are fragments of phragmocones (78 specimens), while more or less complete phragmocones (23 specimens), nuclei (18 specimens), fragments of body chambers (15 specimens), and phragmocones with a part of the body chamber preserved (15 specimens) occur only occasionally. Well preserved specimens have been measured using a Vernier Caliper, and dimensions in the text and tables are given in millimetres (for tables see appendix). Numbers in parentheses are proportional dimensions as percentage of the diameter. The measurements and abbreviations used are explained in Fig. 3. It should also be noted that on several of the plates, the scale bars indicate different sizes for the individual specimens. Fossils numbered with the prefix GZN are currently housed at the GeoZentrum Nordbayern of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, but it is planned to store them ultimately in the collections of the Department of Geology, University of Rajasthan, Jaipur, India.

Since most of the specimens are fragmentary and some of the taxa have been recorded for the first time from the Kachch Basin, they have been identified comparing their proportional dimensions with measurements given by earlier workers (see tables), in addition to further comparisons of morphological characteristics (e.g., ornamentation, whorl section, ontogenetic changes). Depending on the preservation quality, rib curves, whorl sections and ribbing patterns have been drawn. Some of the illustrated specimens showed the last septum of the phragmocone. In such cases, a cross was placed next to the photograph which indicates the start of the body chamber. It should also be noted that a typological approach has been

EXPLANATION OF PLATE I

(note that the scale bar indicates different sizes for the individual specimens)

1. *Phylloceras* sp.; (a) lateral and (b) apertural view of a phragmocone; GZN2011I 157 from the base of bed 8 of section 3 (scale bar = 3 mm).
2. *Ptychophylloceras ptychoicum* (Quenstedt, 1845); (a) lateral and (b) ventral view of a phragmocone; GZN2011I 208 from the central part of bed 8 of section 3 (scale bar = 10 mm).
3. *Holcophylloceras* sp.; (a) lateral view of a phragmocone and (b) transverse cut; GZN2011I 126 from the base of bed 8 of section 3 (scale bar = 10 mm).



used during the taxonomic classification in order to maximize the biostratigraphic resolution.

Class **Cephalopoda** Cuvier, 1797

Order **Ammonoidea** Zittel, 1884

Suborder **Phylloceratina** Arkell, 1950

Superfamily **Phylloceratoidea** Zittel, 1884

Family **Phylloceratidae** Zittel, 1884

Subfamily **Phylloceratinae** Zittel, 1884

Genus **Phylloceras** Suess, 1865

(*Type species*: *Ammonites heterophyllus* Sowerby, 1820)

Phylloceras sp.

(Pl. I, fig. 1; Fig. 4A)

Material: One specimen from the base of bed 8 of section 3 (GZN2011I157).

Remarks: The specimen is very small and represents only the inner whorls of a phragmocone. It is characterised by a compressed and involute shell with a gentle umbilical slope, very small umbilicus, faint, hair-like secondary ribs (lirae) and phylloid suture lines. Due to its small size identification at the species level is not possible. This is the first record of the genus from the Gangta Bet.

Subfamily **Calliphylloceratinae** Spath, 1927

Genus **Holcophylloceras** Spath, 1927

(*Type species*: *Phylloceras mediterraneum* Neumayr, 1871)

Holcophylloceras sp.

(Pl. I, fig. 3)

Material: One specimen from the base of bed 8 of section 3 (GZN2011I126).

Remarks: A moderately large fragment of a phragmocone, highly distorted and partly encrusted by oysters. It is characterised by a compressed and involute shell with a very small umbilicus, deep constrictions, fine ribs on the venter, and phylloid suture lines. Due to its poor preservation no further identification is possible. This is the first record of the genus from the Gangta Bet.

Genus **Ptychophylloceras** Spath, 1927

(*Type species*: *Phylloceras feddeni* Waagen, 1875)

Ptychophylloceras ptychoicum (Quenstedt, 1845)

(Pl. I, fig. 2; Fig. 4B; Table 1)

Ammonites ptychoicus Quenstedt – Quenstedt, 1847, p. 219, pl. 17, fig. 12.

Phylloceras ptychoicum (Quenstedt) – Waagen, 1875a, p. 30, pl. 7, fig. 2a-c.

Ptychophylloceras aff. *ptychoicum* (Quenstedt) – Collignon, 1959c, pl. 98, fig. 371.

Ptychophylloceras (*Semisulcatoceras*) *ptychoicum* (Quenstedt) – Joly, 2000, p. 126, pl. 31, figs 1-3, pl. 39, fig. 6.

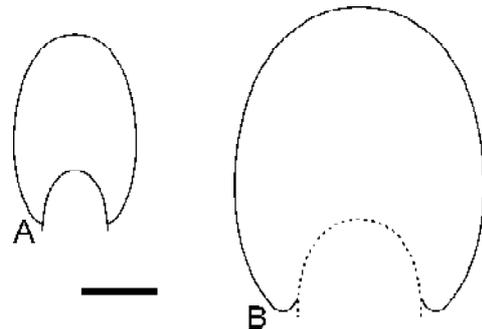


Fig. 4. A. *Phylloceras* sp. Whorl section at ca. 18 mm diameter; GZN2011I 157 (scale bar = 4 mm). B. *Ptychophylloceras ptychoicum* (Quenstedt, 1845). Whorl section at ca. 73 mm diameter; GZN2011I 208 (scale bar = 10 mm).

Material: One specimen from the central part of bed 8 of section 3 (GZN2011I208).

Description: Moderately large phragmocone, involute, compressed with oval whorl section. Flanks smooth, labial ridges at regular intervals on the venter. Suture lines well preserved, saddles tetra- to tri- or diphyllic, lobes numbering eight including the ventral lobe.

Remarks: The specimen closely matches *Ptychophylloceras ptychoicum* (Quenstedt) in whorl section, presence of labial ridges, and nature of the suture lines. This species is long-ranging and well known from Tithonian to lower Cretaceous strata of Europe (e.g., Joly, 2000; Lukeneder, 2004, 2005). However, it has also previously been described from Kimmeridgian strata (Krishna and Pathak, 1991) of the Kachchh Basin and its stratigraphic range might therefore very well include the Upper Oxfordian. A closely related species previously recorded from Gangta Bet, *Phylloceras insulare* Waagen (1875a, p. 29, pl. 9, fig. 3a-c), differs from the present specimen by having a larger umbilicus and different suture lines.

Suborder **Ammonitina** Hyatt, 1989

Superfamily **Stephanoceratoidea** Neumayr, 1875

Family **Mayaitidae** Spath, 1928

Genus **Dhosaites** Spath, 1928

(*Type species*: *Dhosaites elephantoides* Spath, 1924)

Dhosaites otoitoides Spath, 1928

(Pl. II, fig. 1; Fig. 5A, B; Table 2)

Dhosaites otoitoides Spath, 1928b, p. 245, pl. 44, fig. 1a, b.

Dhosaites otoitoides Spath – Collignon, 1959a, pl. 39, figs 206, 207.

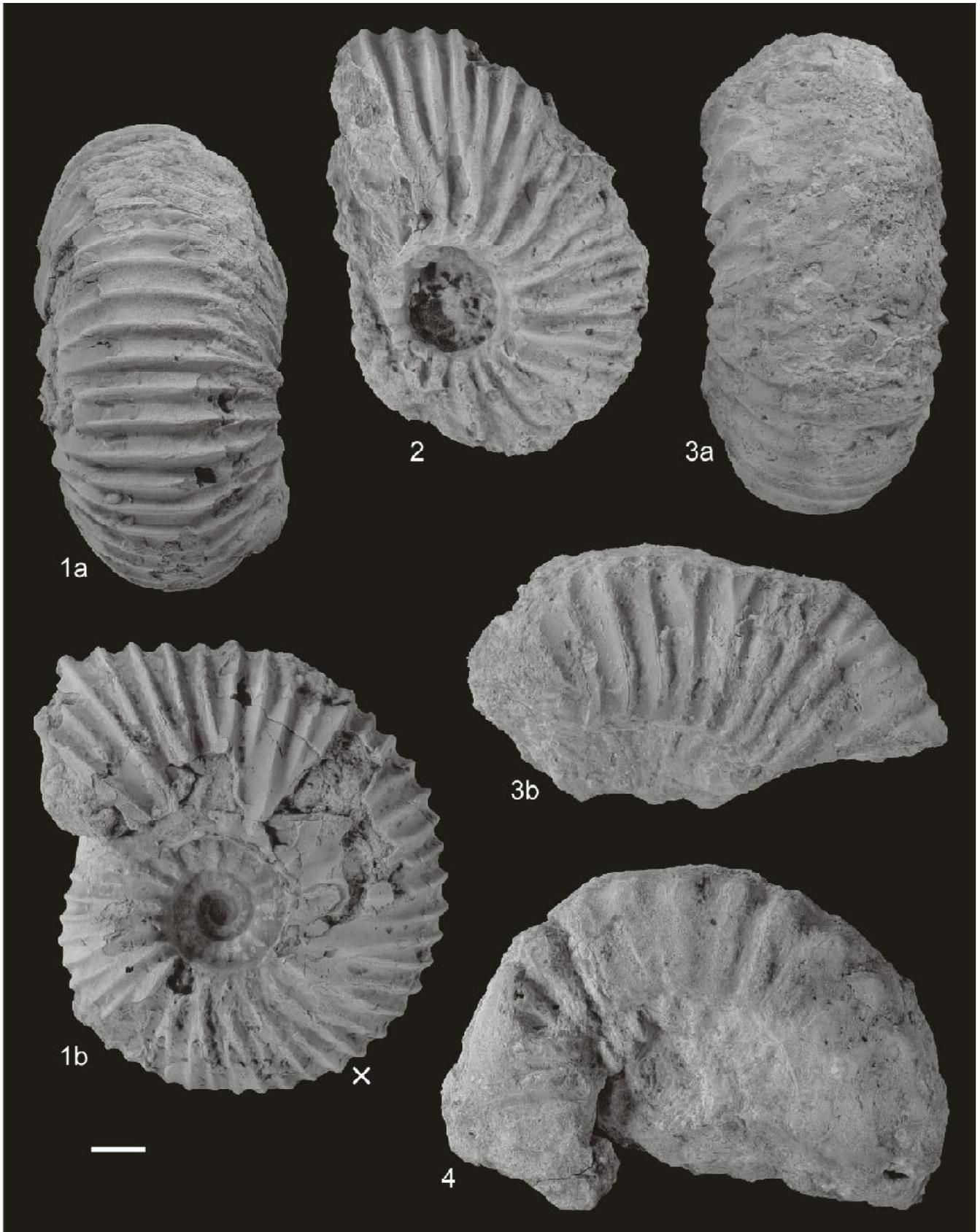
Material: One specimen from bed 10 of section 2 (GZN2011I343).

Description: Phragmocone with parts of the body chamber, involute, depressed with subrounded whorl section. Last suture

EXPLANATION OF PLATE II

(note that the scale bar indicates different sizes for the individual specimens)

1. *Dhosaites otoitoides* Spath, 1928; (a) ventral and (b) lateral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 343 from bed 10 of section 2 (scale bar = 8 mm).
2. *Dhosaites primus* Spath, 1928; lateral view of a phragmocone; GZN2011I 344 from bed 10 of section 2 (scale bar = 5 mm).
3. *Paryphoceras* cf. *crassum* Collignon, 1959; (a) ventral and (b) lateral view of a fragment of a body chamber; GZN2011I 188 from the boundary between beds 7 and 8 of section 3 (scale bar = 8 mm).
4. *Euaspidoceras* sp.; lateral view of a phragmocone; GZN2011I 027 from bed 14 of section 1 (scale bar = 10 mm).



line at a diameter of approximately 50 mm. Ornamentation consists of short, coarse, distant, rectiradiate primary ribs, branching at the region of maximum inflation slightly above the umbilical edge. Secondary ribs bend prorsiradiately and cross the venter with very slight, forward-directed sinuosity. Occasionally, a single rib appears at mid-lateral height.

Remarks: Spath (1928b, p. 245) created this species for members of the genus *Dhosaites* Spath, 1928 with a depressed shell, rounded whorl section, and coarse ribs, which differ from *Dhosaites elephantoides* Spath (1928b, p. 244, pl. 25, fig. 9, pl. 38, fig. 8 a, b) in having a less inflated whorl section as well as a smaller umbilicus. Collignon (1959a) recorded this species from the Upper Oxfordian (Zone of *Peltomorphites eugenii*) of Madagascar. However, the occurrence of *Peltomorphites eugenii* should actually indicate the Lower Oxfordian (Sapunov, 1976; Checa and Sequeiros, 1990).

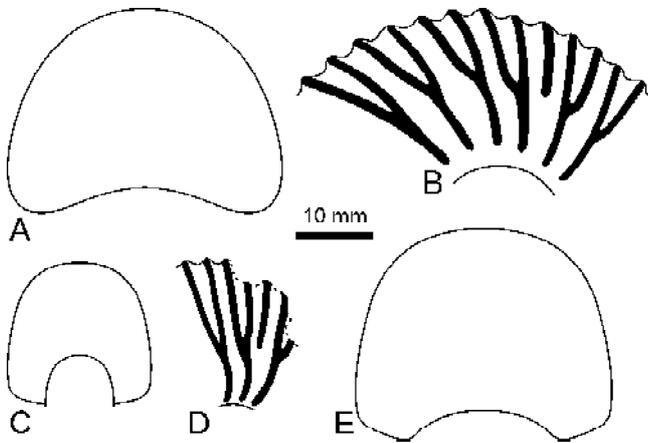


Fig. 5. A, B. *Dhosaites otoioides* Spath, 1928. Whorl section at ca. 73 mm diameter (A) and ribbing pattern at ca. 47 mm diameter (B); GZN20111 343. C, D. *Dhosaites primus* Spath, 1928. Whorl section at ca. 45 mm diameter (C) and ribbing pattern at ca. 45 mm diameter (D); GZN20111 344. E. *Paryphoceras cf. crassum* Collignon, 1959. Whorl section at unknown diameter; GZN20111 188.

Dhosaites primus Spath, 1928
(Pl. II, fig. 2; Fig. 5C, D; Table 3)

Dhosaites primus Spath, 1928b, p. 245, pl. 32, fig. 5, pl. 36, fig. 10a, b, pl. 37, fig. 1a, b, pl. 39, fig. 3, pl. 40, fig. 3, pl. 44, fig. 5a, b, pl. 45, fig. 2a, b, pl. 49, fig. 3a, b, 4, 13.

Material: One specimen from bed 10 of section 2 (GZN20111344).

Description and remarks: This is a small fragment of a phragmocone. The involute, compressed shell with a suboval whorl section and sharp ribs branching around the mid-lateral height closely matches *Dhosaites primus* Spath, which shows a considerable variation in the ratio between height and thickness of the whorl.

Genus *Paryphoceras* Spath, 1928
(Type species: *Paryphoceras badiense* Spath, 1928)

Paryphoceras cf. crassum Collignon, 1959
(Pl. II, fig. 3; Fig. 5E; Table 4)

cf. *Prograyiceras crassum* Collignon, 1959b, pl. 84, fig. 335.

Material: One specimen from the boundary between beds 7 and 8 of section 3 (GZN20111 188).

Description and remarks: The specimen represents only a fragment of the body chamber with a slightly depressed, subrounded to squarish whorl section. Ornamentation consists of long, sharp, coarse, distant, prorsiradiate ribs, which are forwardly concave near the umbilical edge, branch slightly above mid-lateral height, and cross straight across the venter. Occasionally, single primary ribs and shallow constrictions

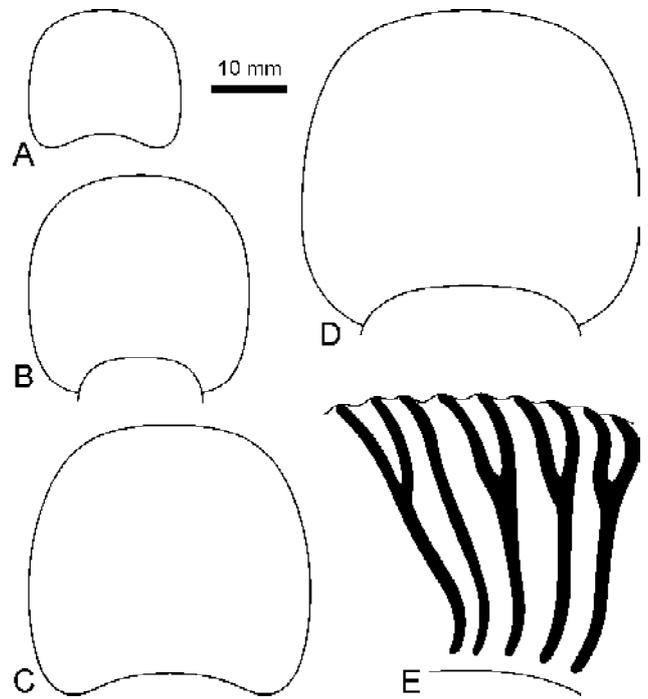


Fig. 6. *Perisphinctes mahabobokensis* (Collignon, 1959). A. Whorl section at ca. 58 mm diameter; GZN20111 088. B. Whorl section at unknown diameter; GZN20111 226. C. Whorl section at unknown diameter; GZN20111 276. D. Whorl section at ca. 142 mm diameter; GZN20111 213. E. Ribbing pattern at ca. 125 mm diameter; GZN20111 213.

can be observed. Umbilicus is large. The shell coiling, whorl section, and ornamentation match the species illustrated by Collignon (1959b). In contrast to the present specimen, *Prograyiceras grayi* Spath (1928b, p. 250; Waagen, 1875c, p. 136, pl. 35, fig. 2) and *Prograyiceras tramaunense* Spath (1928b, p. 251, pl. 28, fig. 7, pl. 50, fig. 5), both from the Kantkote Sandstone of the Wagad Uplift, have secondary ribs which

EXPLANATION OF PLATE III

(note that the scale bar indicates different sizes for the individual specimens)

1. *Perisphinctes mahabobokensis* (Collignon, 1959); (a) lateral and (b) ventral view of a phragmocone; GZN20111 279 from the top of bed 8 of section 3 (scale bar = 12.5 mm).
2. *Perisphinctes mahabobokensis* (Collignon, 1959); ventral view of a phragmocone; GZN20111 226 from the top of bed 8 of section 3 (scale bar = 10 mm).
3. *Perisphinctes mahabobokensis* (Collignon, 1959); (a) lateral and (b) apertural view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN20111 346 from the top of bed 8 of section 3 (scale bar = 20 mm).



cross the venter with a prominent forward-directed sinuosity. Howarth and Morris (1998) placed *Prograyiceras* into the synonymy of *Paryphoceras*, a view which is followed here.

Superfamily **Perisphinctoidea** Steinmann, 1890

Family **Perisphinctidae** Steinmann, 1890

Subfamily **Perisphinctinae** Steinmann, 1890

Genus **Perisphinctes** Waagen, 1869

(Type species: *Ammonites variocostatus* Buckland, 1836)

Perisphinctes mahabobokensis (Collignon, 1959)

(Pl. III, figs 1-3; Pl. IV, figs 1-3; Figs 6, 7; Table 5)

Kranaosphinctes (Pachyplanulites) mahabobokensis Collignon, 1959b, pl. 92, fig. 361, pl. 93, fig. 361a, b.

Material: Thirty-seven specimens. Three specimens from bed 17 of section 1 (GZN2011I 006, 008, 012), one specimen from the base of bed 5 of section 3 (GZN2011I 038), one specimen from the central part of bed 6 of section 3 (GZN2011I 079), four specimens from bed 7 of section 3 (GZN2011I 088, 119, 122, 123), three specimens from the base of bed 8 of section 3 (GZN2011I 128, 161, 169), five specimens from the central part of bed 8 of section 3 (GZN2011I 193, 196, 203, 207, 209), eighteen specimens from the top of bed 8 of section 3 (GZN2011I 212, 213, 218, 220, 226, 228, 231, 237, 242, 262, 264, 265, 276, 279, 282, 287, 292, 346), two specimens from bed 12 of section 3 (GZN2011I 304, 305).

Description: Shells large, septate up to a diameter of 180 mm, evolute, depressed. Whorl section subcircular in inner whorls to subrectangular in outer whorls with short umbilical wall merging into the obtusely rounded umbilical edge. Flanks feebly arched to almost flat merging into venter along a smooth curve. Ornamentation consists of very gradually variocostate, sharp, moderately coarse to thick and distant ribs, which originate from the umbilical wall rursiradiately, bend forward with forward-directed concavity on the umbilical edge, branch into two, very rarely three (GZN2011I 038, 346) secondary ribs slightly below the ventrolateral region, and cross the venter with forward-directed sinuosity (in inner whorls) or straight (in outer whorls). Occasionally, single, undivided primary ribs are followed by a shallow to moderately deep constriction and gallop. Secondary ribs fade at the end of phragmocone, outermost whorl with smooth venter. Primary ribs on the body chamber with tubercles at the ventrolateral shoulder.

Remarks: Several fragmentary specimens give the opportunity to observe the whorl section of inner whorls (Fig. 6). The nature of coiling, whorl shape, ornamentation, and constrictions match *Kranaosphinctes (Pachyplanulites) mahabobokensis* as described by Collignon (1959b). The large size of the species, together with the gradually variocostate, moderately coarse to coarse ribbing, and the presence of constrictions, favours its assignment to the subgenus *Kranaosphinctes*. Nevertheless, the presence of tubercles which can be seen on the body whorl of specimen GZN2011I

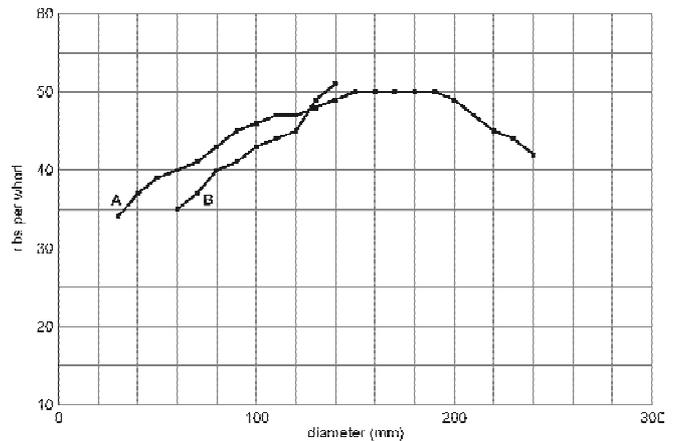


Fig. 7. Rib-density curves for *Perisphinctes mahabobokensis* (Collignon, 1959). A. GZN2011I 346. B. GZN2011I 213.

346 and on the illustrations by Collignon (1959b) is striking. Such tubercles are not known from members of *Kranaosphinctes* (including *Pachysphinctes*; Arkell *et al.*, 1957) or other forms of the Perisphinctinae. Nevertheless, due to the limited number of specimens with the body chamber preserved, the present study refrains from the introduction of a new subgenus. The ornamentation of the inner whorls in the present specimens is also quite similar to that of *Perisphinctes (Dichotomoceras) besairiei* (Collignon, 1959b, pl. 88, fig. 350), a microconch with lappets and a conspicuous terminal constriction. However, the shell of *P. (Dichotomoceras) besairiei* (Collignon) is compressed.

Perisphinctes (Arisphinctes) kachchhensis Pandey *et al.* has depressed outer whorls and shows similar ornamentation and coiling, but its inner whorls are compressed and the points of bifurcation of the primary ribs are higher (compare below; Pandey *et al.*, 2012).

Perisphinctes (Dichotomoceras) crassus Enay (1966, p. 507) is a small microconch and has also depressed inner whorls, but the present specimens are more densely ribbed at similar diameters. *Perisphinctes (Dichotomoceras) virguloides* Waagen shows a similar ribbing density on the inner whorls, but a slightly lower branching of primary ribs. In addition the shells are compressed with a less arched flank enabling an easy differentiation between *P. (Dichotomoceras) virguloides* Waagen and the present species (compare description below).

Specimen GZN2011I 282 is a pathological juvenile, being slightly distorted and showing a rapid uncoiling of the last whorl. Identification of smaller specimens can be difficult as the nuclei of *Perisphinctes (Dichotomosphinctes) germaini* (Collignon) and *Perisphinctes (Dichotomoceras) bifurcatoides* Enay are very similar to those of the present species (compare descriptions below). Their separation is based mainly on the measured dimensions.

EXPLANATION OF PLATE IV

(note that the scale bar indicates different sizes for the individual specimens)

1. *Perisphinctes mahabobokensis* (Collignon, 1959); (a) lateral and (b) ventral view of a phragmocone; GZN2011I 242 from the top of bed 8 of section 3 (scale bar = 10 mm).
2. *Perisphinctes mahabobokensis* (Collignon, 1959); (a) lateral and (b) ventral view of a phragmocone; GZN2011I 213 from the top of bed 8 of section 3 (scale bar = 10 mm).
3. *Perisphinctes mahabobokensis* (Collignon, 1959); ventral view of a phragmocone; GZN2011I 264 from the top of bed 8 of section 3 (scale bar = 20 mm).



Perisphinctes sp.
(Pl. VII, fig. 2; Table 6)

Material: One specimen from the boundary between beds 7 and 8 of section 3 (GZN2011I 172).

Description and remarks: The specimen is a fragment of the outer part of a compressed phragmocone. The whorl section is squarish with flat flanks and moderately distinct ventrolateral shoulder and umbilical edge. Ornamentation consists of thick, dense, long, primary ribs originating rursiradiately at the umbilical wall, bending along a broad curve prorsiradiately on the flank with a shallow forward-directed concavity. Primary ribs branch at the ventrolateral shoulder into two faintly visible secondaries with a weak tubercle developed at the point of bifurcation.

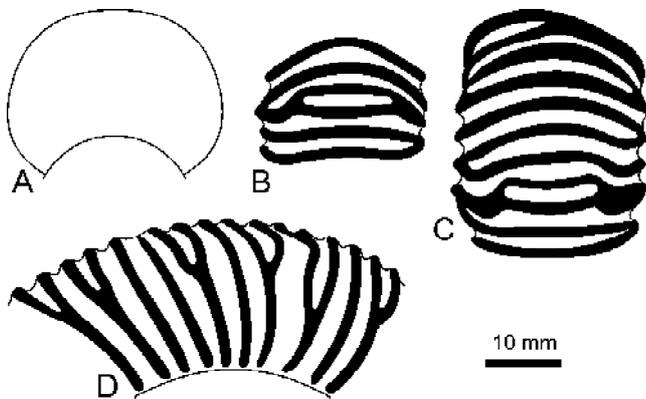


Fig. 8. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931). A. Whorl section at ca. 81 mm diameter; GZN2011I 240. B. Ventral ribbing pattern at ca. 54 mm diameter; GZN2011I 240. C. Ventral ribbing pattern at ca. 75 mm diameter; GZN2011I 240. D. Ribbing pattern at ca. 75 mm diameter; GZN2011I 240.

The ornamentation with thick primary ribs and tubercles is similar to that of *Perisphinctes mahabokensis* Collignon as described above, but the whorl section of the latter is depressed. The poorly preserved specimen does not match any of the specimens in the present collection in the combination of its whorl section, dimensions, as well as ornamentation. However, in anticipation of future, better preserved additional records from the Gangta Bet it has been figured here.

Subgenus *Kranaosphinctes* Buckman, 1921

(*Type species: Perisphinctes (Kranaosphinctes) kranas*
Buckman, 1921)

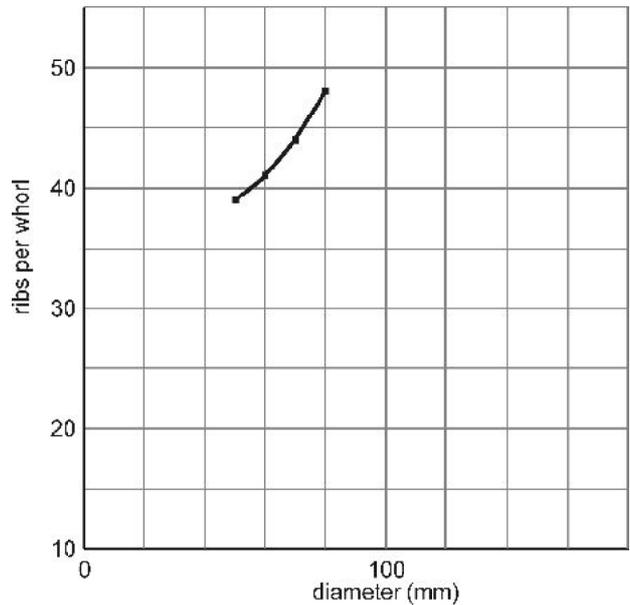


Fig. 9. Rib-density curve for *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); GZN2011I 240.

Perisphinctes (Kranaosphinctes) irregularis (Spath, 1931)
(Pl. V, figs 1-5; Figs 8, 9; Table 7)

Pachyplanulites irregularis Spath, 1931a, p. 433, pl. 95, fig. 8a, b.

Kranaosphinctes (Pachyplanulites) cf. irregularis (Spath) – Collignon, 1959b, pl. 89, fig. 354.

Kranaosphinctes (Pachyplanulites) irregularis (Spath) – Collignon, 1959c, pl. 101, figs 382, 383.

Kranaosphinctes (Pachyplanulites) rabei Collignon, 1959b, pl. 90, fig. 356.

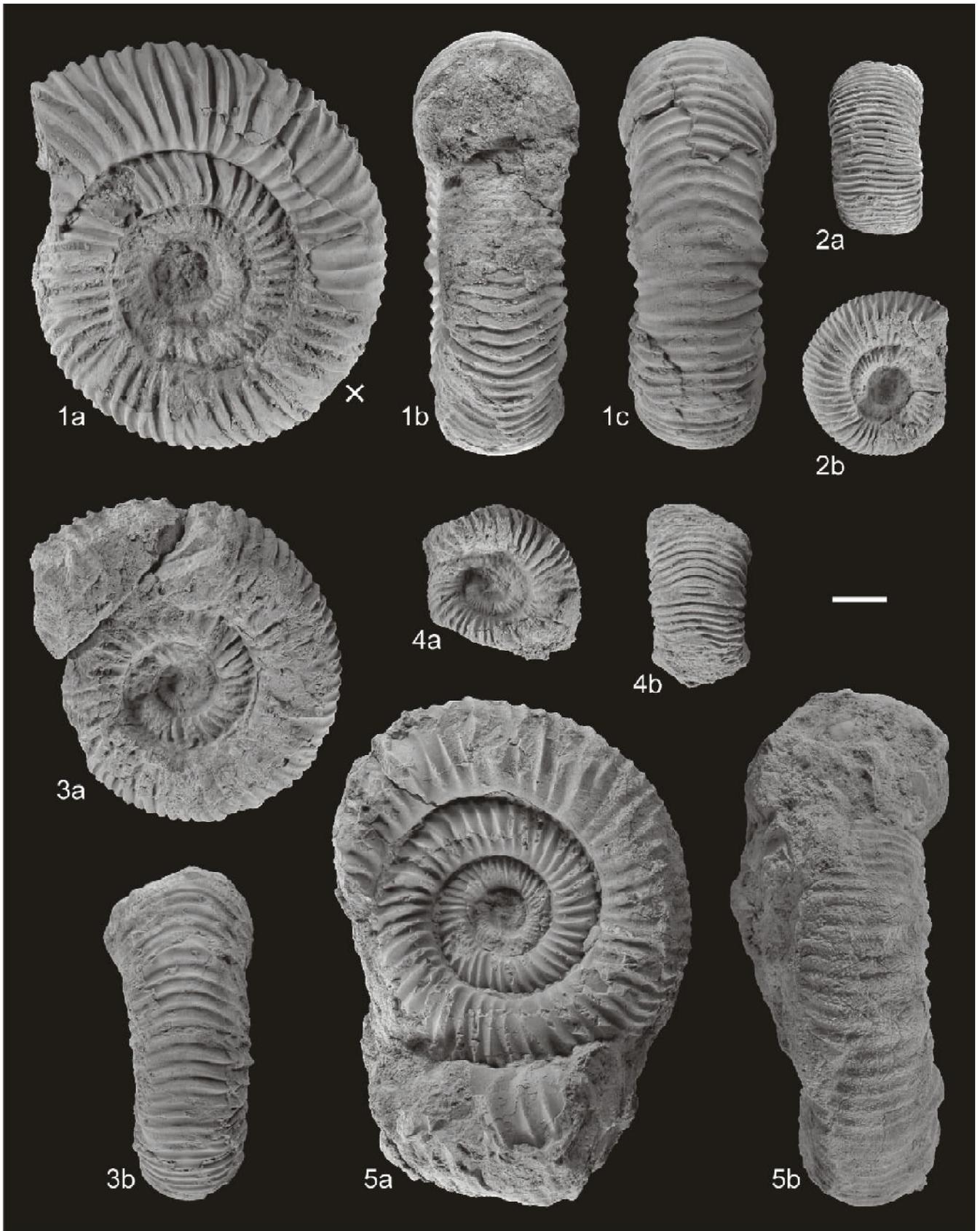
Material: Six specimens. One specimen from bed 17 of section 1 (GZN2011I 011), one specimen from bed 7 of section 3 (GZN2011I 124), two specimens from the central part of bed 8 of section 3 (GZN2011I 204, 205), two specimens from the top of bed 8 of section 3 (GZN2011I 221, 240).

Description: Phragmocones incomplete, depressed, evolute with rounded whorl section, maximum thickness at one-third of lateral height. Ornamentation consists of sharp, moderately coarse primary ribs in inner whorls, originating from the umbilical suture rursiradiately then bending slightly prorsiradiately and branching relatively high at the ventrolateral edge into two secondaries of similar thickness, which cross the venter with slight forward-directed sinuosity. Single primaries and gallops common. Occasionally, one primary rib is bifurcating in the middle of the venter (Fig. 8C). Constrictions

EXPLANATION OF PLATE V

(note that the scale bar indicates different sizes for the individual specimens)

1. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); (a) lateral, (b) apertural, and (c) ventral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 240 from the top of bed 8 of section 3 (scale bar = 10 mm).
2. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); (a) ventral and (b) lateral view of a nucleus; GZN2011I 204 from the central part of bed 8 of section 3 (scale bar = 10 mm).
3. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); (a) lateral and (b) ventral view of a phragmocone; GZN2011I 221 from the top of bed 8 of section 3 (scale bar = 10 mm).
4. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); (a) lateral and (b) ventral view of a nucleus; GZN2011I 011 from bed 17 of section 1 (scale bar = 8 mm).
5. *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931); (a) lateral and (b) apertural view of a large phragmocone; GZN2011I 124 from bed 7 of section 3 (scale bar = 10 mm).



deep, forwardly inclined, three to four per whorl. Primary ribs adjacent to these constrictions show a characteristic branching pattern: They bifurcate near the centre of the flank with the anterior secondary rib then branch again slightly above the ventrolateral shoulder (Fig. 8B-D).

Remarks: Specimen GZN2011I 240 shows a part of a body chamber, but due to its small size, it most likely represents a juvenile. The dimensional proportions, whorl shape, and ornamentation match the species as described by Spath (1931a) and Collignon (1959b, c). Spath (1931a) recorded his specimens from the Lower Katrol Formation (Kimmeridgian) of Fakirwari and Ler on the Kachchh Mainland, whereas Collignon (1959b, c) recorded it from the Rauracien (i.e. Oxfordian) of Madagascar.

Perisphinctes (Kraaosphinctes) pagri Waagen differs from the present specimens in exhibiting finer secondary ribs (compare Spath 1931a, p. 464; Pandey *et al.*, 2012). Collignon's (1959b) species, *Kraaosphinctes (Pachyplanulites) rabei*, shows similar ornamentation, whorl section, and dimensions, and has therefore been merged with this species. Our specimens resemble *Katroliceras zitteli* Spath in all essential respects, but lack the triplicate division of ribs on the body chamber which is one of the diagnostic features of the genus *Katroliceras* Spath, 1924.

Subgenus Arisphinctes Buckman, 1924

(Type species: *Arisphinctes ariprepes* Buckman, 1924)

Remarks: Główniak (2002; also Główniak and Wierzbowski, 2007) placed *Arisphinctes* into synonymy of *Kraaosphinctes*. Nevertheless, until further research has underlined this proposal and due to the low number of specimens with preserved body chambers, the present study follows the traditional view, separating both subgenera mainly by their ribbing density (compare also Enay, 2009; Pandey *et al.*, 2012).

Perisphinctes (Arisphinctes) kachchhensis Pandey, Alberti & Fürsich, 2012

(Pl. VI, fig. 3; Fig. 10; Table 8)

Perisphinctes plicatilis (Sowerby) – Waagen, 1875c, p. 189, pl. 51, fig. 2a, b, 3, pl. 52, fig. 3 (non Sowerby).

Perisphinctes orientalis Siemiradzki – Spath, 1931a, p. 416, pl. 69, fig. 1, pl. 72, fig. 2, pl. 74, fig. 3a, b (non Siemiradzki).

Perisphinctes orientalis Siemiradzki – Spath, 1934, p. 4, pl. 4, fig. 1a, b (non Siemiradzki).

Perisphinctes orientalis Siemiradzki – Collignon, 1959b, pl. 71, fig. 306 (non Siemiradzki).

Perisphinctes (Arisphinctes) kachchhensis Pandey *et al.*, 2012, pl. 11, figs 5, 6; Figs 25, 26 (non Siemiradzki).

Material: Three specimens. One specimen from bed 16 of section 1 (GZN2011I 021), two specimens from bed 7 of section 3 (GZN2011I 120, 125).

Remarks: The specimens match *Perisphinctes (Arisphinctes) kachchhensis* as described by Pandey *et al.* (2012). Although the species was introduced only recently, specimens of this form are known from the Kachchh Basin for

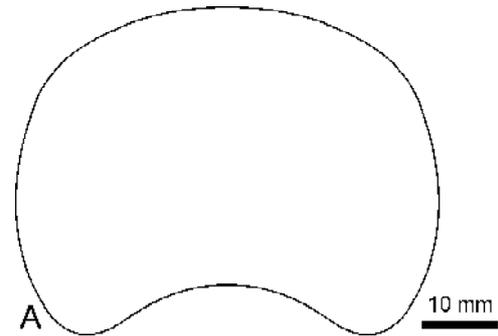


Fig. 10. *Perisphinctes (Arisphinctes) kachchhensis* Pandey *et al.*, 2012; whorl section at unknown diameter; GZN2011I 125.

over a century. Initially, similar material from Gangta Bet was identified by Waagen (1875c) as *Perisphinctes plicatilis* (Sowerby) and later on reassigned by Siemiradzki (1891) to his new species, *Perisphinctes orientalis*. Spath (1931a, p. 416) followed the opinion of Siemiradzki (1891) and described additional specimens from the Kachchh Basin as *Perisphinctes orientalis*. However, this species is based on Polish material (compare Pandey *et al.*, 2012) and already Enay (1966) discussed the differences between the Polish and Kachchh specimens. Therefore, the new species *Perisphinctes (Arisphinctes) kachchhensis* was erected by Pandey *et al.* (2012) to accommodate the Indian specimens described by Waagen (1875c) and Spath (1931a, 1934), as well as further material illustrated by Collignon (1959b) from Madagascar.

Perisphinctes sp. cf. *Perisphinctes (Arisphinctes)*

kantkotensis Pandey, Alberti & Fürsich, 2012

(Pl. VI, fig. 1)

cf. *Perisphinctes (Arisphinctes) kantkotensis* Pandey *et al.*, 2012, p. 500, pl. 8, figs. 6, 7; Figs. 21, 22

Material: One specimen from the top of bed 5 of section 3 (GZN2011I 056).

Description and remarks: This is a small fragment of the body chamber of a large *Perisphinctes*. The specimen shows a steep umbilical slope and thick primary ribs originating at the inner side of the umbilical edge. The ribs soon attain maximum thickness, run prorsiradiately, and flare to branch just below the ventrolateral shoulder. These characteristics along with the density of ribs are very similar to *Perisphinctes (Arisphinctes) kantkotensis* which has been described from the Kantkote Ammonite Beds of the Wagad Uplift (Pandey *et al.*, 2012). As the specimen is fragmentary and poorly preserved, identification is only tentative.

Subgenus Dichotomosphinctes Buckman, 1926

(Type species: *Perisphinctes antecedens* Salfeld, 1914)

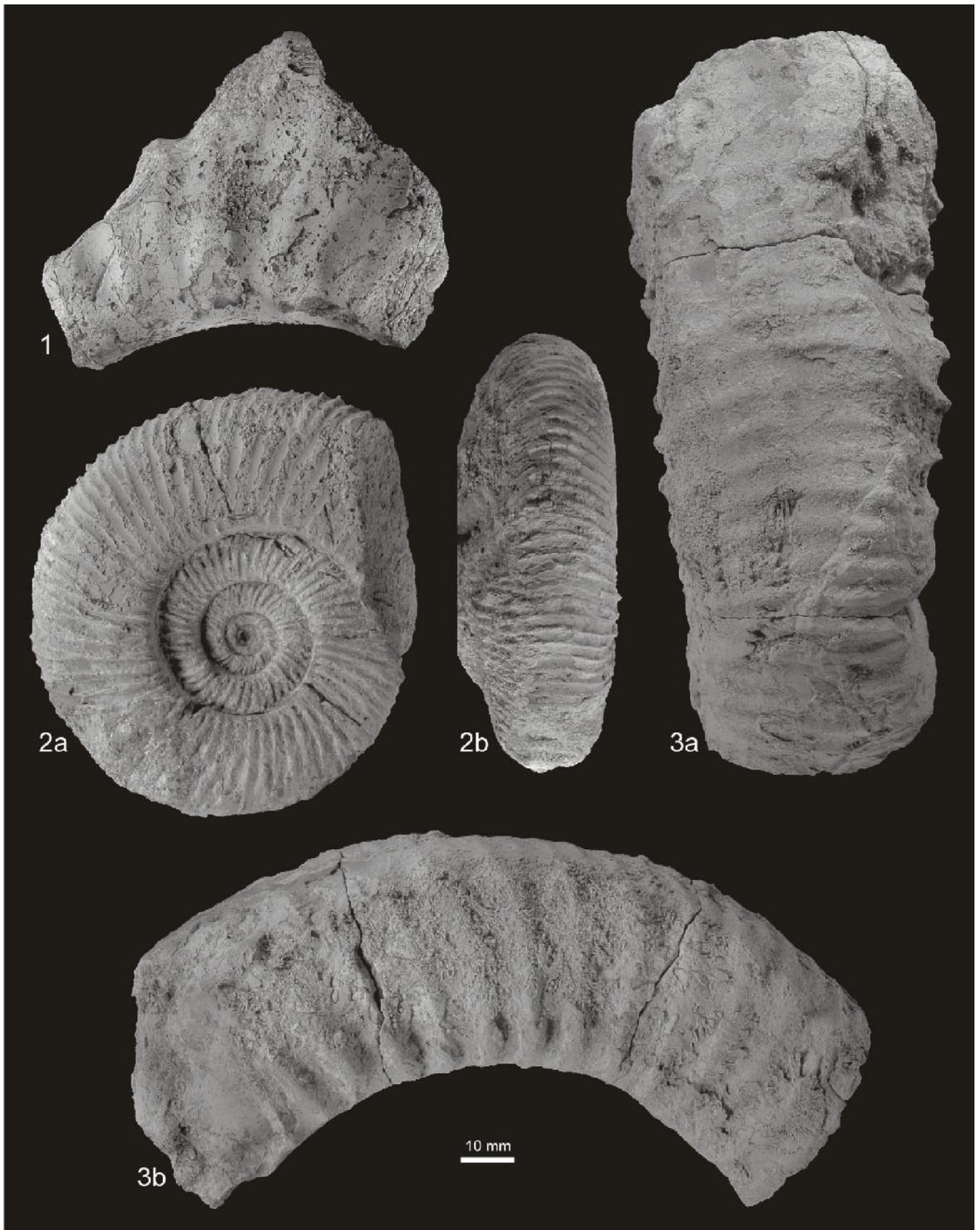
Perisphinctes (Dichotomosphinctes) cf. germaini

(Collignon, 1959)

(Pl. VI, fig. 2; Figs 11A, 12A; Table 9)

EXPLANATION OF PLATE VI

1. *Perisphinctes* sp. cf. *Perisphinctes (Arisphinctes) kantkotensis* Pandey *et al.*, 2012; lateral view of a small fragment of a body chamber; GZN2011I 056 from the top of bed 5 of section 3.
2. *Perisphinctes (Dichotomosphinctes) cf. germaini* (Collignon 1959); (a) lateral and (b) ventral view of a specimen with no suture lines visible in the outer whorl; GZN2011I 040 from the base of bed 5 of section 3.
3. *Perisphinctes (Arisphinctes) kachchhensis* Pandey *et al.*, 2012; (a) ventral and (b) lateral view of a fragment of a phragmocone; GZN2011I 125 from bed 7 of section 3.



cf. *Dichotomosphinctes germani* Collignon, 1959b, pl. 91, fig. 360.

Material: One specimen from the base of bed 5 of section 3 (GZN20111040).

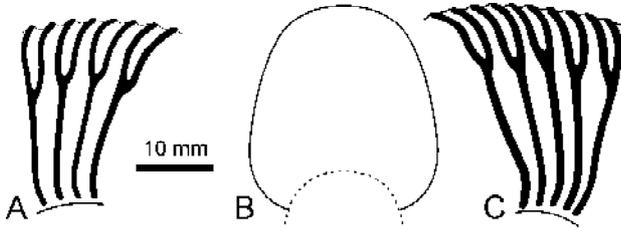


Fig. 11. A. *Perisphinctes (Dichotomosphinctes)* cf. *germani* (Collignon, 1959); ribbing pattern at ca. 75 mm diameter; GZN20111 040. B, C. *Perisphinctes (Dichotomosphinctes)* aff. *germani* (Collignon, 1959). B. Whorl section at ca. 77 mm diameter; GZN20111 302. C. Ribbing pattern at ca. 70 mm diameter; GZN20111 302.

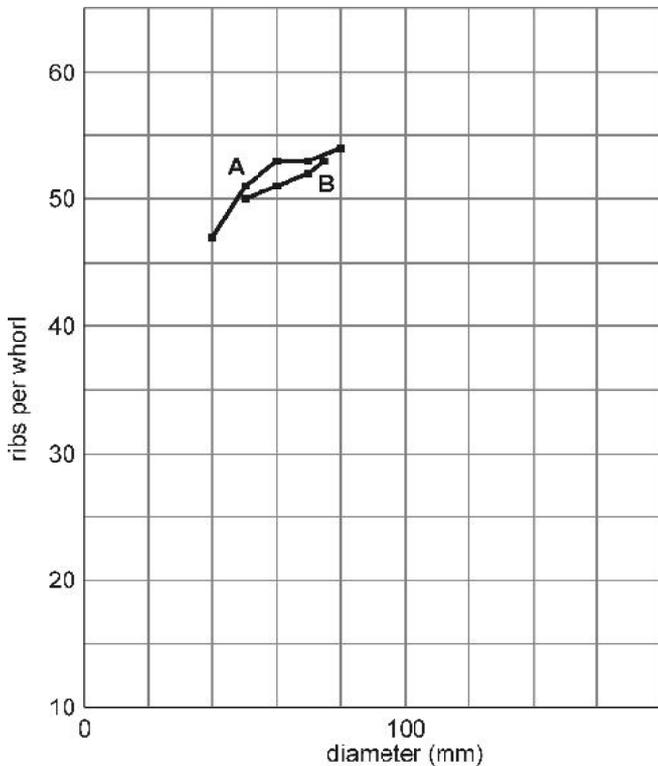


Fig. 12. A. Rib-density curve for *Perisphinctes (Dichotomosphinctes)* cf. *germani* (Collignon, 1959); GZN20111 040. B. Rib-density curve for *Perisphinctes (Dichotomosphinctes)* aff. *germani* (Collignon, 1959); GZN20111 302.

Description: Shell incomplete, evolute, and compressed. Whorl section oval. Ornamentation consists of fine, dense, prorsiradiate primary ribs crossing the flank with very slight, forward-directed concavity, branching into two secondaries

just below the ventrolateral shoulder. Occasionally single primary ribs present.

Remarks: The specimen is poorly preserved, suture lines are not visible. The nature of coiling, dimensions, and ornamentation (including the prorsiradiate primary ribs with the uniform, forward-directed concavity) match *Perisphinctes (Dichotomosphinctes) germani* (Collignon). Owing to its poor state of preservation the specimen has been assigned to this species only tentatively.

Perisphinctes (Dichotomosphinctes) aff. *germani* (Collignon, 1959)

(Pl. VII, fig. 1; Figs 11B, C, 12B; Table 10)

aff. *Dichotomosphinctes germani* Collignon, 1959b, pl. 91, fig. 360.

Material: One specimen from bed 12 of section 3 (GZN20111302).

Description and remarks: The compressed phragmocone with its suboval whorl section, the dense, fine, prorsiradiate primary ribs with their low and regular bifurcation at the umbilical suture of the succeeding whorl, and the very faint constrictions match the inner whorls of *Perisphinctes (Dichotomosphinctes) germani* (Collignon). However, the present specimen has a smaller umbilicus and the forward-directed sinuosity of the secondary ribs on the venter is less conspicuous than in the illustration of Collignon (1959b) as well as in *P. (D.)* cf. *germani* as described above. Because of these differences, the specimen has only been placed in the affinity of the species.

Subgenus *Dichotomoceras* Buckman, 1919

(Type species: *Dichotomoceras dichotomum* Buckman, 1920)

Perisphinctes (Dichotomoceras) sp.

(Pl. VIII, fig. 1; Fig. 13; Table 11)

Material: Seven specimens. One specimen from bed 7 of section 3 (GZN20111 113), two specimens from the central part of bed 8 of section 3 (GZN20111 191, 206), three specimens from the top of bed 8 of section 3 (GZN20111 233, 238, 263), one specimen from bed 12 of section 3 (GZN20111 301).

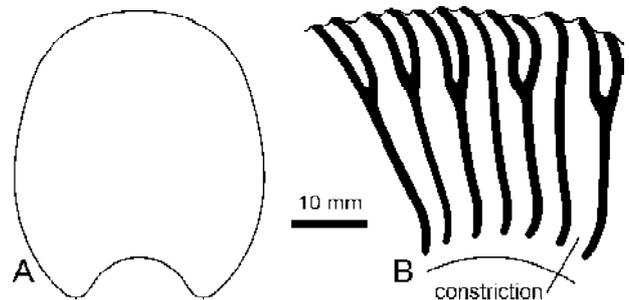


Fig. 13. *Perisphinctes (Dichotomoceras)* sp. A. Whorl section at unknown diameter; GZN20111 301. B. Ribbing pattern at ca. 115 mm diameter; GZN20111 263.

EXPLANATION OF PLATE VII

(note that the scale bar indicates different sizes for the individual specimens)

- Perisphinctes (Dichotomosphinctes)* aff. *germani* (Collignon, 1959); (a) ventral and (b) lateral view of a phragmocone; GZN20111 302 from bed 12 of section 3 (scale bar = 10 mm).
- Perisphinctes* sp.; lateral view of a fragment of a phragmocone; GZN20111 172 from the boundary between beds 7 and 8 of section 3 (scale bar = 12.5 mm).
- Perisphinctes (Dichotomoceras)* cf. *predivisum* (Spath, 1931); (a) lateral and (b) ventral view of a fragment of a body chamber; GZN20111 243 from the top of bed 8 of section 3 (scale bar = 10 mm).



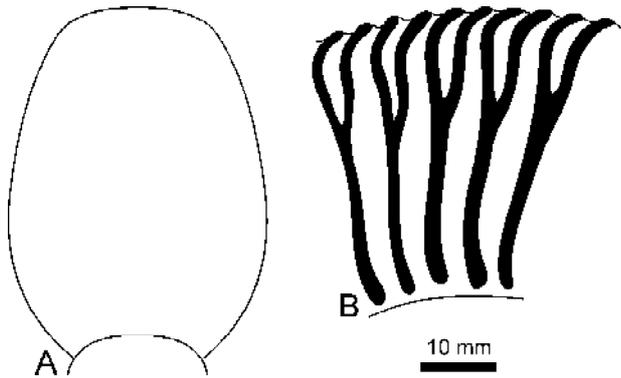


Fig. 14. *Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966. A. Whorl section at ca. 154 mm diameter; GZN2011I 171. B. Ribbing pattern at unknown diameter; GZN2011I 171.

Description: Shells mostly phragmocones (only specimen GZN2011I 263 has part of the body chamber), evolute, and compressed. Whorl section suboval with low umbilical wall, slightly arched flanks, and rounded venter. Ornamentation consists of moderately thick primary ribs, originating rectiradiately on umbilical wall, bending slightly prorsiradiately on flanks and branching into two at two-thirds of lateral height. Secondary ribs more or less of the same thickness as primary ribs, crossing the venter with slight forward-directed sinuosity. One prorsiradiate constriction and at least two shallow wider inter-rib spaces associated with a single primary rib on outer whorls.

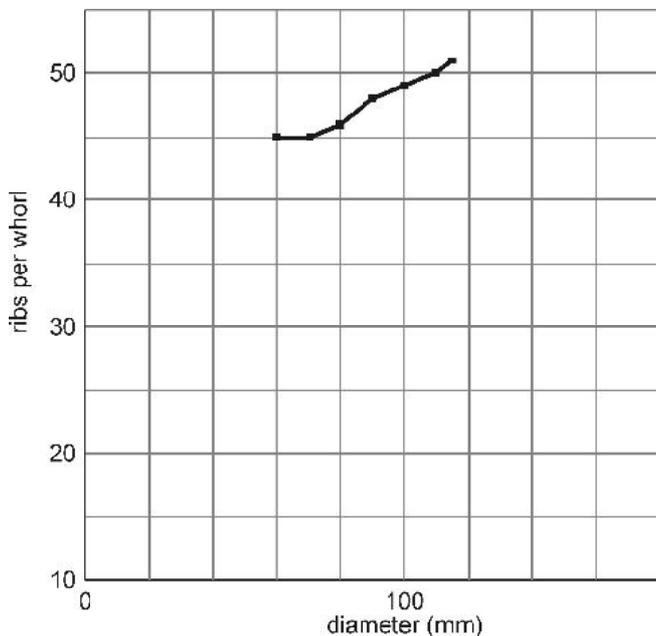


Fig. 15. Rib-density curve for *Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; GZN2011I 190.

Remarks: The coiling, whorl section, and constrictions match *Orthosphinctes tiziani* (Oppel) (Choffat, 1893, p. 32, pl. 5, fig. 8; Arkell, 1935, p. xxxiii, pl. C, fig. 1a, b; Alavi-Naini, 1972; Matyja and Wierzbowski, 1997; Schweigert and Callomon, 1997), but the point of bifurcation of the ribs is slightly lower in the present specimens. Their dimensions and ornamentation are comparable to *Perisphinctes virguloides* Waagen (1875c, p. 203, pl. 49, fig. 1a, b; Collignon, 1959b, pl. 88, fig. 351). However, this species shows no constrictions on the body chamber (see below).

Perisphinctes (Dichotomoceras) bifurcatoides Enay, 1966 (Pl. IX, figs 1-3; Pl. X, figs 1, 2; Figs 14, 15; Table 12)

Perisphinctes (Dichotomoceras) bifurcatoides Enay, 1966, p. 509, pl. 34, figs 1-4, figs 155.2, 157.

Perisphinctes (Dichotomoceras) bifurcatoides Enay – Schairer, 1988, p. 41, fig. 1.

Perisphinctes (Dichotomoceras) bifurcatoides Enay – Schairer, 1989, p. 117, pl. 3, fig. 5.

Perisphinctes (Dichotomoceras) bifurcatoides Enay – Schlegelmilch, 1994, p. 197, pl. 20, fig. 5.

Dichotomoceras cf. *bifurcatoides* Enay – Branger *et al.*, 1995, p. 124, pl. 21, fig. 2.

Perisphinctes (Dichotomoceras) cf. *bifurcatoides* Enay – Majidifard, 2003, p. 149, pl. 15, pl. 8.

Dichotomoceras bifurcatoides Enay – Seyed-Emami and Schairer, 2011, p. 17, fig. 5g.

Material: Nineteen specimens. One specimen from the base of bed 5 of section 3 (GZN2011I 047), one specimen from the central part of bed 5 of section 3 (GZN2011I 054), one specimen from the top of bed 5 of section 3 (GZN2011I 065), two specimens from bed 7 of section 3 (GZN2011I 100, 111), three specimens from the boundary between beds 7 and 8 of section 3 (GZN2011I 148, 171, 185), one specimen from the base of bed 8 of section 3 (GZN2011I 137), two specimens from the central part of bed 8 of section 3 (GZN2011I 190, 202), eight specimens from the top of bed 8 of section 3 (GZN2011I 219, 222, 245, 267, 269, 271, 275, 298).

Description: Shells moderately large, evolute, inner whorls depressed and rounded in cross-section, outer whorls compressed and oval in cross-section with broad umbilical edge and maximum thickness at one-fifth to one-third of whorl height. Ornamentation consists of prorsiradiate, thin (inner whorls) to thick (outer whorls) and long primary ribs, which originate at the umbilical suture, run rursiradiately on the short, umbilical wall, turn prorsiradiately and pass wavy across the flank. Primary ribs branch regularly into two secondaries slightly below the ventrolateral edge. Secondaries cross the venter with forward-directed sinuosity.

Remarks: The specimen GZN2011I 171 shows a part of the body chamber. The largest phragmocone in the present specimens is about 110 mm in diameter in comparison to ca. 90 mm in the holotype of Enay (1966, p. 509). The dimensions, whorl outline, and ornamentation of the present specimens

EXPLANATION OF PLATE VIII

(note that the scale bars indicates different sizes for the individual specimens)

- Perisphinctes (Dichotomoceras)* sp.; (a) lateral and (b) ventral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 263 from the top of bed 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras)* cf. *dichotomus* (Buckman, 1919); (a) ventral and (b) lateral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 189 from the central part of bed 8 of section 3 (scale bar = 12.5 mm).



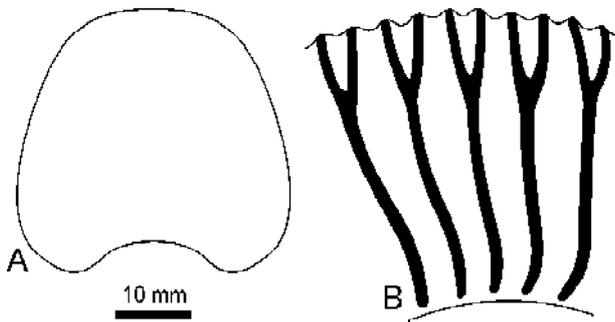


Fig. 16. *Perisphinctes (Dichotomoceras) cf. dichotomus* (Buckman, 1919). A. Whorl section at unknown diameter; GZN2011I 133. B. Ribbing pattern at ca. 129 mm diameter; GZN2011I 189.

match this species, except that secondary ribs are rarely visible in the umbilicus.

The inner whorls of this species are similar to the nuclei of the macroconchs of *Perisphinctes (Dichotomoceras) virguloides* Waagen as described below (compare also Enay, 1966, pl. 34, fig. 2). However, the present specimens differ from this species by having more depressed inner and more compressed outer whorls, and a wider umbilicus. *Perisphinctes (Dichotomoceras) bifurcatus* (Quenstedt) described by Enay (1966, p. 504) is another close form in showing a similar rib density at comparative diameters, but in *P. (Dichotomoceras) bifurcatus* (Quenstedt) the phragmocone diameter reaches only 50 mm, the whorl is more depressed, and the umbilical diameter is smaller. *Perisphinctes subwartaeformis* Arkell (1947, p. 367, text-fig. 129) has a similar whorl section, the maximum thickness of the whorls is in both species at the same lateral height, but the point of bifurcation of primary ribs in *P. subwartaeformis* Arkell is higher (at the ventrolateral edge). *Perisphinctes (Perisphinctes) variocostatus* (Buckland) as described by Arkell (1947, p. 363, pl. 76, figs 1-4) has a very large phragmocone (diameter larger than 250 mm) and the rib density is less. Specimen GZN2011I 219 is an inner whorl and shows intermediate characters between *Perisphinctes (Dichotomoceras) virguloides* Waagen and *Perisphinctes (Dichotomoceras) bifurcatoides* Enay in terms of whorl thickness and diameter of umbilicus.

Perisphinctes (Dichotomoceras) cf. dichotomus
(Buckman, 1919)
(Pl. VIII, fig. 2; Fig. 16; Table 13)

cf. *Dichotomoceras dichotomum* Buckman, 1919, p. 27, pl. 139, fig. A.

cf. *Perisphinctes (Biplices) dichotomus* (Buckman) – Arkell, 1947, p. 358, pl. 75, fig. 1.

cf. *Perisphinctes (Dichotomoceras) dichotomus* (Buckman) – Arkell et al., 1957, p. 322, fig. 411.

Material: Three specimens. One specimen from the top of bed 5 of section 3 (GZN2011I 058), one specimen from the

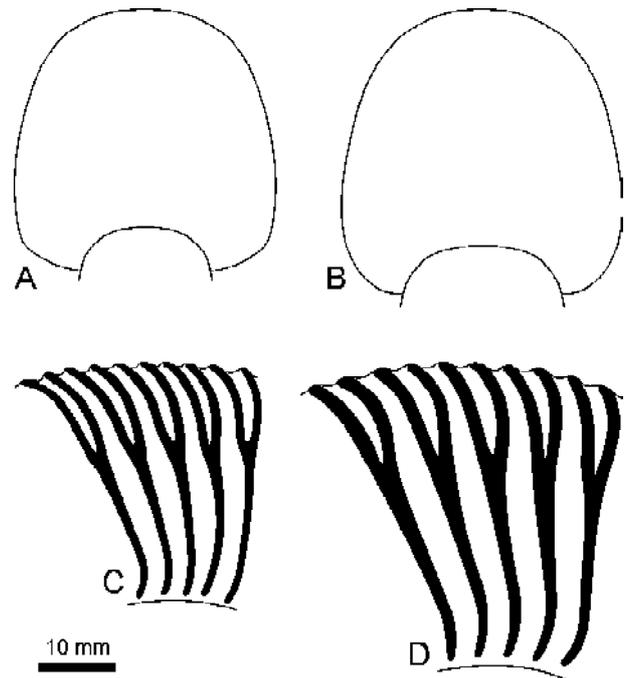


Fig. 17. *Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875. A. Whorl section at ca. 119 mm diameter; GZN2011I 149. B. Whorl section at ca. 129 mm diameter; GZN2011I 235. C. Ribbing pattern at ca. 94 mm diameter; GZN2011I 198. D. Ribbing pattern at ca. 123 mm diameter; GZN2011I 235.

boundary between beds 7 and 8 of section 3 (GZN2011I 133), one specimen from the central part of bed 8 of section 3 (GZN2011I 189).

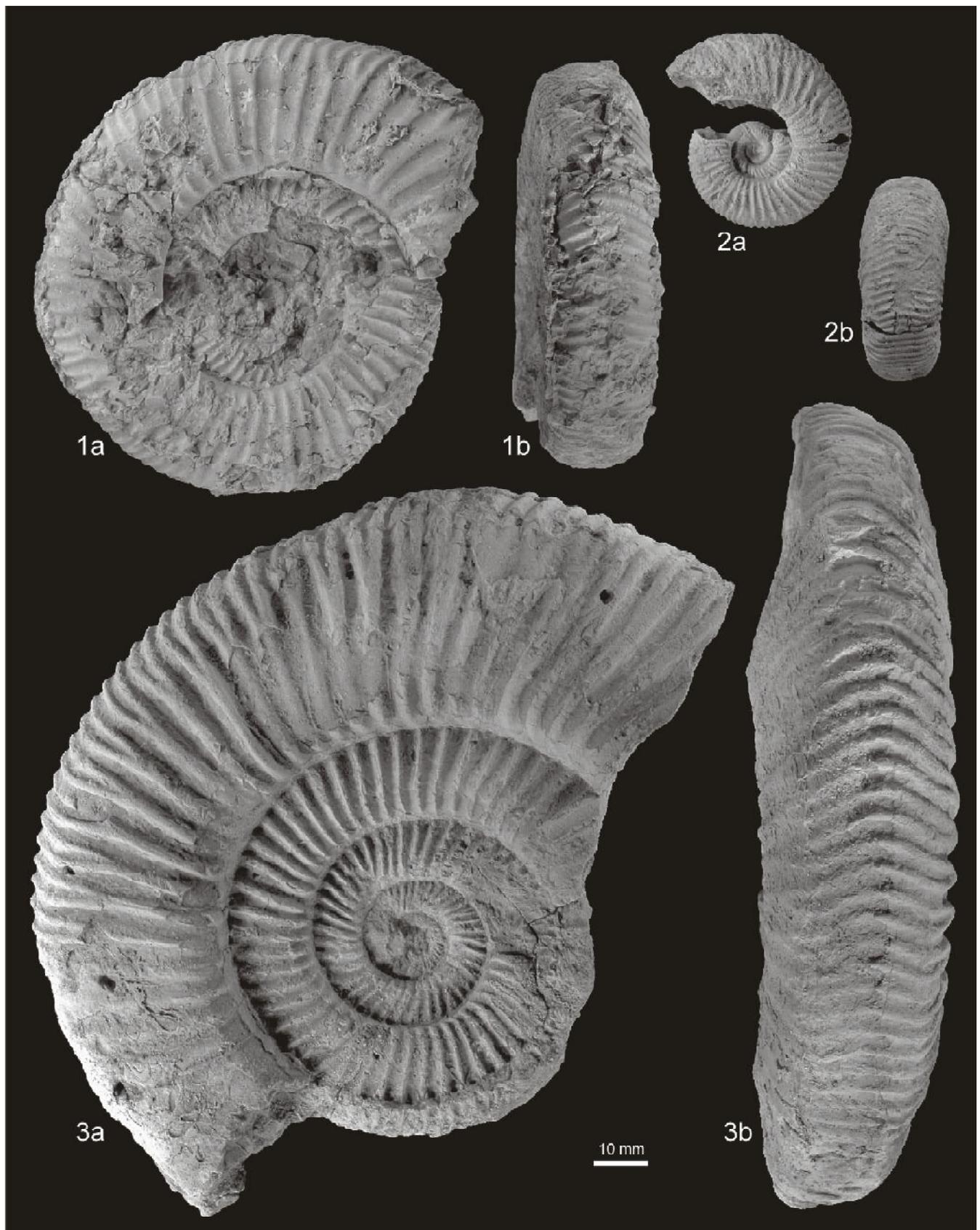
Description: Shells moderately large, evolute, compressed, whorl section subrectangular in inner whorls changing to suboval in outer whorls with arched sides merging smoothly into rounded venter. Umbilical wall distinct, steeply inclined with obtusely rounded umbilical edge. Ornamentation consists of moderately coarse, sparse, slightly prorsiradial primary ribs, which branch into two secondaries slightly below the ventrolateral edge. Occasionally, secondary ribs are visible in the umbilicus. Secondaries cross the venter with a slight forward-directed sinuosity on inner whorls, but are straight on outer whorls. Occasionally, single ribs and gallops are present.

Remarks: The shells are moderately well preserved. The inner whorls of specimen GZN2011I 189 are distorted, its outer whorl shows no trace of suture lines and therefore is thought to represent part of the body chamber (septate until a diameter of about 85 mm).

Perisphinctes (Biplices) dichotomoides Arkell (1947, p. 359, pl. 75, fig. 2) is a comparable species to *Perisphinctes (Dichotomoceras) dichotomus* (Buckman), but members of this species have more depressed whorls and are more evolute. *Perisphinctes (Perisphinctes) variocostatus* (Buckland) as

EXPLANATION OF PLATE IX

- Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; (a) lateral and (b) ventral view of a phragmocone; GZN2011I 219 from the top of bed 8 of section 3.
- Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; (a) lateral and (b) ventral view of a nucleus; GZN2011I 137 from the base of bed 8 of section 3.
- Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; (a) lateral and (b) ventral view of a specimen with a part of the body chamber (no suture lines visible in the outer whorl); GZN2011I 171 from the boundary between beds 7 and 8 of section 3.



described by Arkell (1947, p. 363, pl. 76, fig. 4) is very similar with respect to the number and thickness of ribs, but it has a depressed, less evolute shell. *Perisphinctes (Dichotomoceras) bifurcatoides* Enay (1966, p. 509) is more compressed and evolute. The ratio between whorl height and thickness of the present specimens is intermediate between the two last mentioned species. However, the secondary ribs on the outer whorls of the present specimens cross the venter along a characteristic straight line lacking the forward-directed sinuosity typical of other closely related taxa.

Perisphinctes (Dichotomoceras) virguloides Waagen, 1875 (Pl. XI, figs 1-3; Pl. XII, figs 1-4; Figs 17, 18; Table 14)

Perisphinctes virguloides Waagen, 1875c, p. 203, pl. 49, fig. 1a, b (non pl. 47, fig. 4a, b; compare Spath, 1931a, p. 451).

Prososphinctes virguloides (Waagen) – Spath, 1931a, p. 441, pl. 70, fig. 3, pl. 90, fig. 4.

Perisphinctes virguloides (Waagen) – Collignon, 1959b, pl. 88, fig. 351.

Material: Twenty-two specimens. One specimen from bed 1 of section 3 (GZN2011I 028), one specimen from bed 2 of section 3 (GZN2011I 029), one specimen from bed 3 of section 3 (GZN2011I 030), one specimen from the top of bed 5 of section 3 (GZN2011I 059), one specimen from the central part of bed 6 of section 3 (GZN2011I 083), one specimen from the top of bed 6 of section 3 (GZN2011I 086), two specimens from bed 7 of section 3 (GZN2011I 103, 121), three specimens from the boundary between beds 7 and 8 of section 3 (GZN2011I 149, 177, 182), three specimens from the base of bed 8 of section 3 (GZN2011I 159, 162, 168), two specimens from the central part of bed 8 of section 3 (GZN2011I 194, 198), six specimens from the top of bed 8 of section 3 (GZN2011I 223, 235, 236, 241, 261, 291).

Description: Shells incomplete, evolute. Whorl sections initially depressed, gradually becoming compressed, oval with maximum thickness at inner-fifth of whorl height. Flanks slightly arched, and ventrolateral shoulder broadly rounded in inner whorls, moderately distinct with a narrowly rounded venter in outer whorls. Umbilical edge moderately distinct. Ornamentation consists of gradually varicostate, slightly prorsiradiate, sharp, very thin, dense (inner whorls) to sharp, distant, moderately coarse (outer whorls) long primary ribs, originating at the umbilical suture, crossing the umbilical edge with a backward slope, then turning prorsiradiate on the flank, branching into two secondaries slightly below the ventrolateral edge. Single, undivided primary ribs are common on inner whorls. Secondaries slightly thinner, crossing the venter with slight forward-directed sinuosity and gallop. Posterior secondary rib of each primary rib slightly rursiradiate. At least three distinct, forwardly inclined constrictions present in the inner whorls.

Remarks: The large number of fragmentary specimens collected from the same horizon provides an excellent opportunity to study both inner and middle whorls. Specimen GZN2011I 059 (diameter up to 140 mm) and GZN2011I 198 show

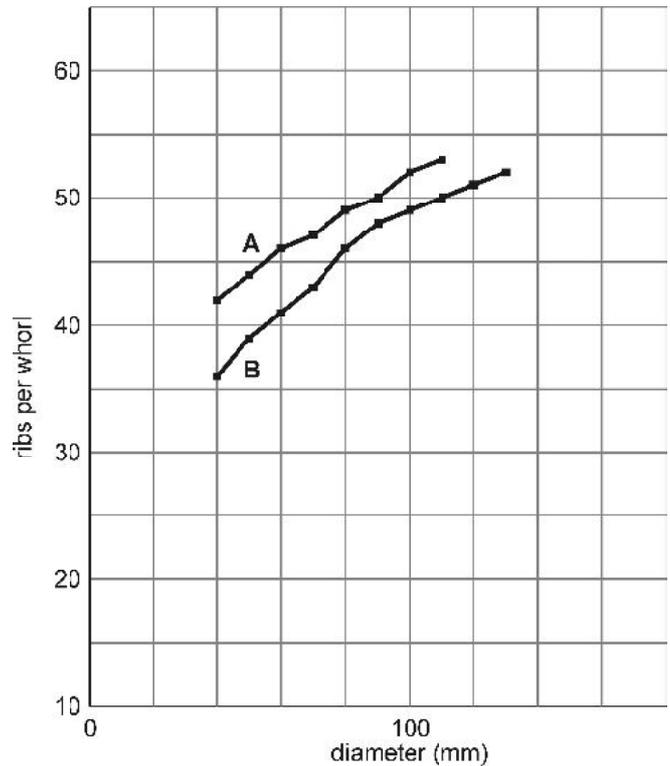


Fig. 18. Rib-density curves for *Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875. A. GZN2011I 236. B. GZN2011I 235.

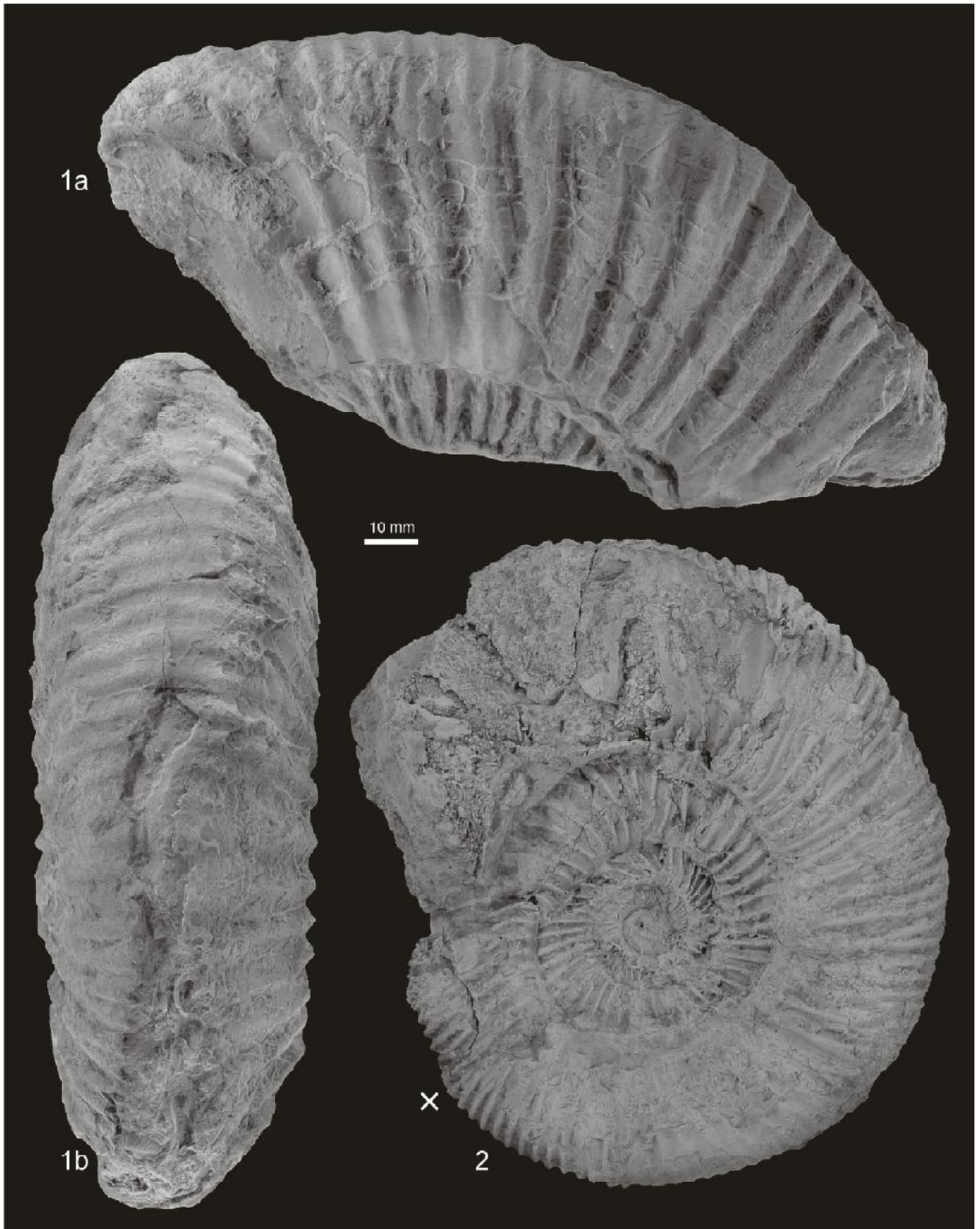
a part of the body chamber without interruption in the biplicate ornamentation. The rest of the specimens are phragmocones only (maximum diameters up to 130 mm). The maximum size of the species as recorded by Waagen (1875c) and Spath (1931a) is 125 mm. Waagen (1875c, p. 203) mentioned “full grown” specimens, i.e. specimens with at least a part of the body chamber preserved. The possibility of a dimorphic pair in this species can not be ruled out and could be investigated by collecting a larger number of adult specimens.

The biplicate ribs branching below the ventrolateral region but considerably above the centre of the flank, together with the compressed whorl section at comparable diameters, match the Madagascan taxon *Perisphinctes (Dichotomoceras) besairiei* (Collignon, 1959b, pl. 88, fig. 350). However, the present specimens have a higher rib density and are larger (still septate at diameters up to 130 mm), while *P. (Dichotomoceras) besairiei* (Collignon) is a microconch having a smaller shell and lappets (Collignon, 1959b, pl. 88, fig. 350). In the present specimens single ribs are relatively common in the inner whorls, thereby causing gallop. In the outer whorls regularly bifurcating ribs dominate. The occurrence of gallops on the outer whorls depends therefore on whether the last single rib has created or terminated the gallop.

The present specimens match *P. (Dichotomoceras) virguloides* Waagen except for their slightly larger size (diameter 140 mm, instead of 125 mm of the specimens described by

EXPLANATION OF PLATE X

1. *Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; (a) lateral and (b) ventral view of a fragment of a body chamber; GZN2011I 202 from the central part of bed 8 of section 3.
2. *Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966; lateral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 190 from the central part of bed 8 of section 3.



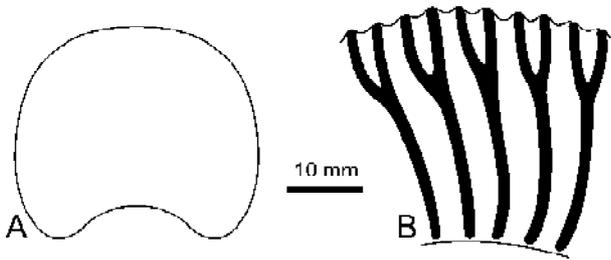


Fig. 19. *Perisphinctes (Dichotomoceras) cf. predivisum* (Spath, 1931). A. Whorl section at unknown diameter; GZN20111 313. B. Ribbing pattern at ca. 97 mm diameter; GZN20111 243.

Waagen, 1875c). The inner whorls of the present specimens also show a depressed or squarish whorl section as mentioned by Waagen (1875c, p. 203). The inner whorls of the present specimens are also similar to *Perisphinctes (Dichotomoceras) bifurcatoides* Enay (1966; described above), but the outer whorls in *bifurcatoides* are more compressed, more evolute and have a less distinct umbilical edge. *Perisphinctes (Arisphinctes) colei* Spath (1931a, p. 421, pl. 80, fig. 2a, b) is comparable in ornamentation, but has a depressed and more evolute shell.

The proportional dimensions as well as the orientation, thickness, and density of ribs are also similar to those of specimens described as *Perisphinctes (Arisphinctes) helena* (de Riaz) by earlier workers (e.g., Enay, 1966, p. 413, pl. 20, figs 1-4, textfigs 118, 119), but the points of bifurcation of the ribs are slightly lower in the present specimens. Similarly, the morphological characters are very close to *Perisphinctes (Perisphinctes) chloroolithicus* (Gümbel) (e.g., Gygi, 2001, p. 60, figs 89-91), but the whorl sections of the present specimens are thicker and the flanks are more rounded.

The gradual varicostate ornamentation of the present species does not justify its earlier assignment to *Prosophinctes* Schindewolf, 1925 (see Spath, 1931a, p. 441). *Prosophinctes* is a finely ribbed genus (Arkell *et al.*, 1957, p. 321), whereas members of the present taxon are moderately coarse-ribbed (compare Waagen, 1875c, p. 203). The comparatively small size, gradual varicostate, fine to moderately coarse ornamentation, together with the typical ribbing pattern in the moderate-sized specimens, justify their subgeneric assignment to *Dichotomoceras* Buckman, 1919.

Perisphinctes (Dichotomoceras) cf. predivisum
(Spath, 1931)
(Pl. VII, fig. 3; Fig. 19; Table 15)

cf. *Dichotomoceras predivisum* Spath, 1931a, p. 422, pl. 88, fig. 4a, b, pl. 97, fig. 2, pl. 98, fig. 2, pl. 100, fig. 4.

Material: Three specimens. One specimen from the base of bed 8 of section 3 (GZN20111 165), one specimen from the top of bed 8 of section 3 (GZN20111 243), one specimen from bed 12 of section 3 (GZN20111 313).

Description: Shells incomplete, evolute, depressed, whorl section subrounded with faintly arched flanks and rounded venter. Ornamentation consists of moderately coarse and distant, prorsiradiate ribs. Primaries originate rursiradiately on the umbilical wall, bend prorsiradiately with forward-directed concavity at the umbilical edge, and branch slightly above mid-lateral height. Rarely, a single primary rib on one side becomes secondary on the other side (gallop). Secondary ribs cross the venter with slight forward-directed sinuosity. Constrictions present.

Remarks: The early part of specimen GZN20111 243 shows traces of suture lines, whereas the later part belongs to the body chamber. Nevertheless, the exact point where the septation ceases cannot be examined. The dimensions, ornamentation, and whorl section correspond to those of *Perisphinctes (Dichotomoceras) predivisum* (Spath), but owing to the poor preservation and fragmentary nature only an assignment with qualification is possible.

Perisphinctes (Dichotomoceras) antrobikensis
(Collignon, 1959)
(Pl. XIV, fig. 1; Fig. 20; Table 16)

Lithacoceras mombassanum (Dacqué, 1910) var. *antrobikensis* Collignon, 1959b, pl. 90, fig. 359.

Holotype: The specimen from the Upper Oxfordian of Antrobika (Madagascar) designated as a variety of the East African Upper Kimmeridgian species *Lithacoceras*

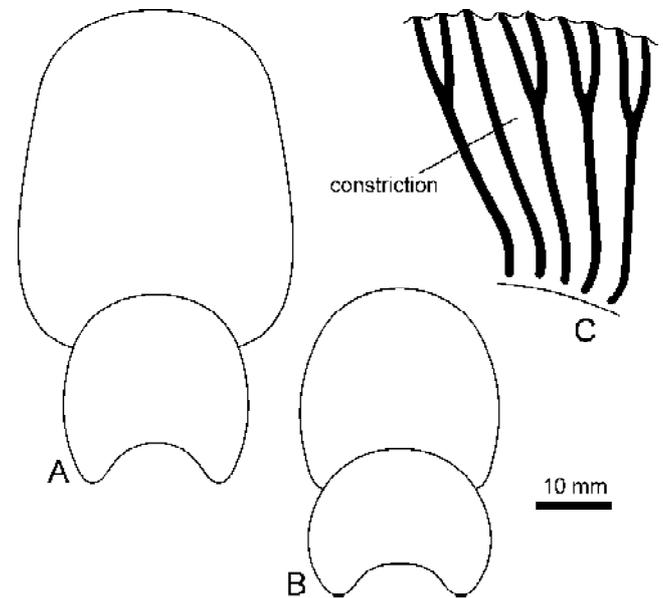


Fig. 20. *Perisphinctes (Dichotomoceras) antrobikensis* (Collignon, 1959). A. Whorl section at ca. 130 mm diameter; GZN20111 134. B. Whorl section at ca. 94 mm diameter; GZN20111 134. C. Ribbing pattern at unknown diameter; GZN20111 134.

EXPLANATION OF PLATE XI

(note that the scale bar indicates different sizes for the individual specimens)

- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; lateral view of a phragmocone; GZN20111 149 from the boundary between beds 7 and 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; (a) lateral and (b) ventral view of a nucleus; GZN20111 159 from the base of bed 8 of section 3 (scale bar = 8 mm).
- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; (a) lateral and (b) ventral view of a large phragmocone; GZN20111 235 from the top of bed 8 of section 3 (scale bar = 8 mm).



mombassanum (Dacqué, 1910) by Collignon (1959b, pl. 90, fig. 359).

Material: Two specimens from the boundary between beds 7 and 8 of section 3 (GZN2011I 134, 176).

Diagnosis: Shell moderately large, whorl section squarish to suboval, venter rounded. Ornamentation of long, prorsiradiate, straight primary ribs, branching at around two-thirds lateral height. Occasionally, with a single primary or secondary rib. Constrictions rare, shallow, on outer whorl.

Description: Shell incomplete with only parts of phragmocone and body chamber preserved (septation ceases between diameters of 65 to 85 mm), evolute, compressed. Whorl section squarish to suboval with low umbilical wall, moderately distinct umbilical edge, and slightly arched flanks merging smoothly into rounded venter. Ornamentation consists of long, prorsiradiate, straight primary ribs, originating rursiradiately at the umbilical suture and branching low, at around two-thirds of flank height. Occasionally, a single primary or free secondary rib crosses the venter and continues into a secondary rib on the other side of the shell. Generally, secondary ribs cross the venter with smooth forward-directed sinuosity. Constrictions rare, shallow, on outer whorl.

Remarks: The morphological characters match *Lithacoceras mombassanum* (Dacqué) var. *antrobikensis* as described by Collignon (1959b) from the Upper Oxfordian of Madagascar. *Lithacoceras (Subplanites) mombassanum* (Dacqué) from the Upper Kimmeridgian of Yemen as illustrated by Howarth and Morris (1998, p. 87, pl. 19, figs 1, 2, pl. 20, fig. 7; compare also Dacqué, 1910, p. 15, pl. 3, fig. 4, pl. 4, fig. 1; Spath, 1930, p. 48, pl. 4, fig. 1) shows a slightly lower ribbing density than the form from Madagascar.

Lithacoceras Hyatt, 1900 is characterised by a large, involute, compressed, constricted, and densely ribbed shell (Arkell *et al.*, 1957, p. 323). The ribs are biplicate and triplicate on inner and middle whorls, but become distant and fasciculate on the outer whorl, with up to eight secondaries per primary and a tendency to become virgatotome. This taxon is a late Kimmeridgian-Tithonian genus which was formerly misunderstood due to the incomplete state of the lectotype of the type species *L. ulmense* (Oppel) (Schweigert and Zeiss, 1999). Consequently, ammonites formerly assigned to *Lithacoceras* from Oxfordian/Lower Kimmeridgian beds have been placed in different genera, e.g. some of them in *Lithacosphinctes* Olóriz. The ammonites from Madagascar and Kachchh originally described as *Lithacoceras*, however, neither belong to *Lithacoceras* nor to *Lithacosphinctes* (personal communication, G. Schweigert, 2012).

Among the Kachchh species, *Perisphinctes (Dichotomoceras) virguloides* Waagen (as described above) is the closest comparable relative. However, this species has more curved primary ribs in comparison with the straight ribs of the present specimens.

In *Lithacoceras mombassanum* (Dacqué) var. *antrobikensis* as illustrated by Collignon (1959b) constrictions are not common and can only be seen at the end of the last whorl, there is no triplication, and the ribs are only moderately dense. The moderate size of the shell and its style of ornamentation favours its assignment to the subgenus *Dichotomoceras* Buckman, 1919.

Perisphinctes (Dichotomoceras) grossouvrei
Siemiradzki, 1898

(Pl. XIII, figs 1-3; Figs 21, 22; Table 17)

Perisphinctes grossouvrei Siemiradzki, 1898, p. 193, pl. 27, figs 54, 55.

Material: Thirty-five specimens. One specimen from the base of bed 5 of section 3 (GZN2011I 037), one specimen from the central part of bed 5 of section 3 (GZN2011I 052), eight specimens from the top of bed 5 of section 3 (GZN2011I 055, 057, 063, 067, 068, 069, 071, 072), two specimens from the boundary between beds 7 and 8 of section 3 (GZN2011I 175, 183), six specimens from the base of bed 8 of section 3 (GZN2011I 132, 144, 146, 151, 158, 167), five specimens from the central part of bed 8 of section 3 (GZN2011I 192, 195, 199, 200, 211), eight specimens from the top of bed 8 of section 3 (GZN2011I 214, 274, 281, 285, 289, 293, 294, 297), four specimens from bed 12 of section 3 (GZN2011I 300, 306, 312, 317).

Description: Shells moderately evolute, compressed. Whorl section subrectangular with acutely rounded venter. Ornamentation consists of thin, moderately spaced, prorsiradiate, slightly flexuous ribs (numbering around 40 in inner whorls and 50 in outer whorls), branching slightly below

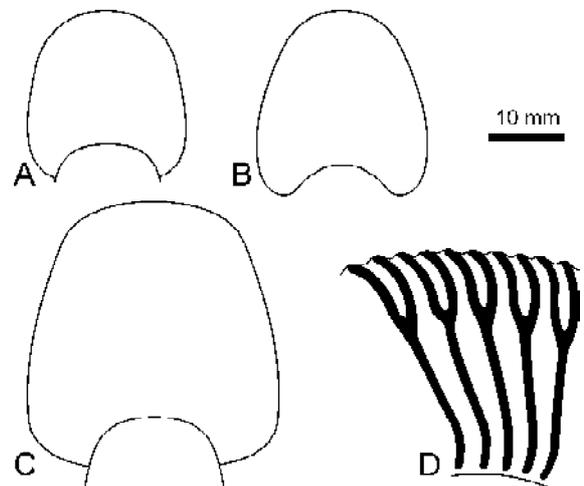


Fig. 21. *Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898. A. Whorl section at unknown diameter; GZN2011I 297. B. Whorl section at unknown diameter; GZN2011I 306. C. Whorl section at ca. 105 mm diameter; GZN2011I 132. D. Ribbing pattern at ca. 93 mm diameter; GZN2011I 132.

EXPLANATION OF PLATE XII

(note that the scale bar indicates different sizes for the individual specimens)

- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; (a) lateral and (b) ventral view of a specimen with a small part of the body chamber (the cross indicates the last visible septum); GZN2011I 198 from the central part of bed 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; lateral view of a nucleus; GZN2011I 103 from bed 7 of section 3 (scale bar = 8 mm).
- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; (a) lateral and (b) ventral view of a phragmocone; GZN2011I 241 from the top of bed 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875; lateral view of a phragmocone; GZN2011I 236 from the top of bed 8 of section 3 (scale bar = 10 mm).



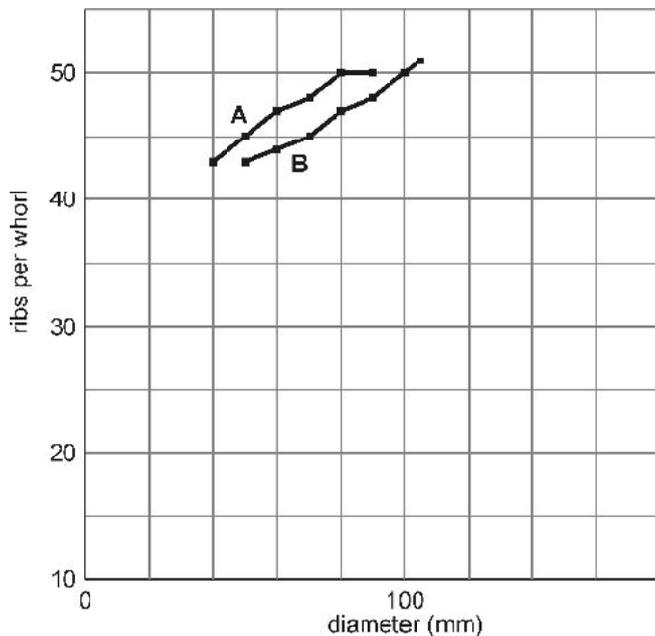


Fig. 22. Rib-density curves for *Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898. A. GZN2011I 192. B. GZN2011I 132.

the ventrolateral region. Secondary ribs cross the venter with a pronounced forward-directed sinuosity. Occasionally, undivided primary ribs occur. Constrictions are present on inner whorls.

Remarks: The specimens match *Perisphinctes grossouvrei* as described by Siemiradzki (1898). The body chamber in this species begins already at a diameter of around 40 mm. Specimen GZN2011I 132 is an almost complete adult which shows decreasing distances between the last few septae of the phragmocone. In contrast, specimen GZN2011I 312 is a small juvenile form with parts of the body chamber.

Perisphinctes (Dichotomoceras) virguloides Waagen is very similar with respect to rib density (see above), but in the present specimens, the umbilicus is larger and the primary ribs show a pronounced concavity at the umbilical edge.

Siemiradzki (1898, p. 193) differentiated his species from *Perisphinctes bifurcatus* (Quenstedt) by a narrower umbilicus and more pronounced S-shaped, forwardly inclined ribs on the inner whorls. Specimen GZN2011I 302, described above as *Perisphinctes (Dichotomosphinctes) cf. germani* (Collignon), is quite close to this species in dimensions, but differs in having a slightly denser ribbing.

Family **Aspidoceratidae** Zittel, 1895

Subfamily **Euaspidoceratinae** Spath, 1931

Genus **Euaspidoceras** Spath, 1931

(Type species: *Ammonites perarmatus* J. Sowerby, 1822)

Euaspidoceras sp.
(Pl. II, fig. 4)

Material: One specimen from bed 14 of section 1 (GZN2011I027).

Description: The shell is part of an incomplete phragmocone, evolute, and compressed. Its whorl section is subrectangular with a distinct ventrolateral edge and slightly arched venter. The ornamentation consists of two rows of tubercles, one near the umbilical edge and a slightly stronger one at the ventrolateral edge. Tubercles are connected by moderately thick, rectiradiate, regularly spaced (thickness of ribs equal to inter-rib space) ribs, which very faintly cross the venter. Suture lines well preserved, almost touching each other at the outermost part of whorl.

Remarks: The specimen represents half the whorl of a phragmocone with a diameter of around 90 mm. The whorl section and the ornamentation can be compared with *Euaspidoceras* sp. figured by Seyed-Emami and Schairer (2011, p. 17, fig. 5b) from the Upper Oxfordian (Bifurcatus and Bimammatum zones) of Iran. Seyed-Emami and Schairer (2011) compared their specimen with *Euaspidoceras rotari* (Oppel), which has been figured by Schlegelmilch (1994, p. 122, pl. 66, fig. 1) and stems from the Middle Oxfordian Transversarium Zone. Although the latter specimen has a much smaller diameter, it shows the essential characteristics found in specimen GZN2011I 027. *Euaspidoceras perarmatum* (J. Sowerby) figured by Schlegelmilch (1994, p. 119, pl. 62, fig. 4) has a more quadrangular whorl section and distant ribs. Due to the poor preservation of specimen GZN2011I 027, it cannot be identified at the species level.

Order **Nautilida** Agassiz, 1847

Superfamily **Nautiloidea** de Blainville, 1825

Family **Paracnoceratidae** Spath, 1927

Genus **Paracnoceras** Spath, 1927

(Type species: *Nautilus hexagonus* J. de C. Sowerby, 1826)

Paracnoceras sp.
(Pl. XIV, fig. 2)

Material: One specimen from the base of bed 8 of section 3 (GZN2011I 131).

Description and remarks: The shell is partly abraded and distorted, therefore the exact shape is not easy to determine. Nevertheless, the specimen has clearly a rapidly expanding, very involute shell. While the inner whorls are more rounded, the outer whorl acquires a subtrapezoidal outline with flat flanks and flat venter. The suture lines are only slightly sinuous, consisting of broad, shallow, ventral and lateral lobes and narrow saddles at the ventrolateral shoulder and umbilical edge. The specimen matches the characteristics of *Paracnoceras* (compare Kummel, 1956, p. 402; 1964, p. 451), but due to its poor preservation, a specific assignment is not possible. The

EXPLANATION OF PLATE XIII

(note that the scale bar indicates different sizes for the individual specimens)

- Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898; (a) lateral and (b) ventral view of a specimen with no suture lines visible; GZN2011I 192 from the central part of bed 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898; (a) lateral and (b) ventral view of a specimen with a part of the body chamber (the cross indicates the last visible septum); GZN2011I 132 from the base of bed 8 of section 3 (scale bar = 10 mm).
- Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898; (a) lateral and (b) ventral view of a specimen with no suture lines visible; GZN2011I 312 from bed 12 of section 3 (scale bar = 8 mm).



genus has previously been recorded from Oxfordian rocks of the Kachchh Basin (Spath, 1927; Halder, 2000). Spath (1927, pl. 4, fig. 3) illustrated a nautiloid identified as *Paracnoceras* cf. *kumagunense* (Waagen) from the Gangta Bet, but the present specimen is much thicker.

BIOSTRATIGRAPHY

Based on the collected ammonites, the studied Upper Jurassic succession on the Gangta Bet can be divided into three parts. Figure 23 shows the three measured sections as well as the stratigraphic ranges of the recorded ammonite taxa. The lower half of section 1 (beds 1-15) as well as the entire section 2 yielded only three taxa: *Dhosaites otoitoides*, *Dhosaites primus*, and *Euaspidoceras* sp. Unfortunately, an exact age assignment based on these specimens is not possible. *Dhosaites* is a common genus of Early to Middle Oxfordian sediments of the Kachchh Mainland and the Wagad Uplift, and its members are relatively long-ranging, not confined to a single ammonite zone, and can be found from the Cordatum to the Transversarium Zone. So far, they are not known from any higher horizon. The specimen of *Euaspidoceras* sp. shows similarities with species previously described from the Middle Oxfordian (Transversarium Zone), but due to its poor preservation, a specific identification is not possible. Still, it seems therefore likely that the rocks of the lower part of the succession belong to the Middle Oxfordian (Transversarium Zone), as of now this cannot be proven beyond any doubt.

The following part of the succession can be best studied in section 3 which has yielded the majority of identifiable ammonites. The first species appearing in the lower part of section 3 (beds 1-3) is *Perisphinctes (Dichotomoceras) virguloides*. This species is endemic to the Indo-East-African faunal province and not known from any other neighbouring faunal provinces. In the Kachchh Basin it has previously been recorded from the Lower Bifurcatus Zone (Stenocycloides Subzone) of the Wagad Uplift (Pandey *et al.*, 2012). Fossils are still comparatively rare in these beds and no other taxa typical of this ammonite zone and known to co-occur with *Perisphinctes (Dichotomoceras) virguloides* in the Wagad Uplift have been found in the Gangta Bet. In addition, *Perisphinctes (Dichotomoceras) virguloides* is a rather long-ranging taxon which has been found also in higher and younger beds. A definite age assignment of beds 1 to 3 of section 3 is therefore difficult and is largely based on the absence of younger species typical of the Upper Bifurcatus Zone (Melendez, 1989). Further research on the Gangta Bet might potentially lower the boundary between the Lower and Upper Bifurcatus Zone, if more specimens and taxa are collected.

Beds 5 and 6 of section 3 contain abundant ammonites and mark the first appearance of several taxa including *Perisphinctes mahabobokensis*, *P. (Dichotomosphinctes) cf. germani*, *P. (Dichotomoceras) bifurcatoides*, and *P. (Dichotomoceras) grossouvrei*. Based on the first appearance of *P. (Dichotomoceras) grossouvrei*, this interval can be safely assigned to the Upper Bifurcatus Zone (Grossouvrei Subzone;

Melendez, 1989). *P. (D.) bifurcatoides* is known from the Bifurcatus Zone (Sapunov, 1976; Caracuel *et al.*, 2006; Pandey *et al.*, 2012) and its first appearance generally marks the lower boundary of the Stenocycloides Subzone (Głowniak *et al.*, 2010). Nevertheless, due to its co-occurrence with *P. (D.) grossouvrei*, the species seems to continue also into the Upper Bifurcatus Zone (at least in the Kachchh Basin).

Several ammonite species continue from beds 5 and 6 of section 3 into higher horizons, i.e., *Perisphinctes mahabobokensis*, *P. (Dichotomoceras) bifurcatoides*, *P. (D.) grossouvrei*, *P. (D.) virguloides* and *P. (D.) cf. dichotomus*. In addition, a series of new taxa are recorded in beds 7 to 12, which have yielded the majority of the collected ammonites (nearly 60% of all specimens are from bed 8), e.g., *Perisphinctes (Kranaosphinctes) irregularis*, *P. (Dichotomoceras) antrobikensis*, *P. (D.) cf. predivisum*, and the cosmopolitan phylloceratids. Considering the first appearance of these ammonite taxa, the assignment of beds 7 to 12 to a new ammonite horizon might be tempting. Nevertheless, due to the presence of the index ammonite *P. (D.) grossouvrei* up to bed 12 of section 3, these levels can still be assigned to the Grossouvrei Subzone, while the higher number of recorded taxa is most probably caused by the larger amount of collected fossil material.

At this point, it should be noted that *Perisphinctes (Arisphinctes) kachchhensis*, present in bed 7 of section 3 and bed 16 of section 1, has also been recorded from the Lower Bifurcatus Zone (Stenocycloides Subzone) of the Wagad Uplift (Pandey *et al.*, 2012) and therefore cannot help in separating both subzones. Nevertheless, it can be considered as indicative of the Bifurcatus Zone. This explains why bed 16 of section 1 is only broadly assigned to the Bifurcatus Zone based on the presence of one specimen of *Perisphinctes (Arisphinctes) kachchhensis*. Although *Perisphinctes mahabobokensis* and *P. (Kranaosphinctes) irregularis* recorded from the following bed 17 of section 1 point to a younger ammonite horizon, the exact boundary between the Lower and Upper Bifurcatus Zone cannot be ascertained.

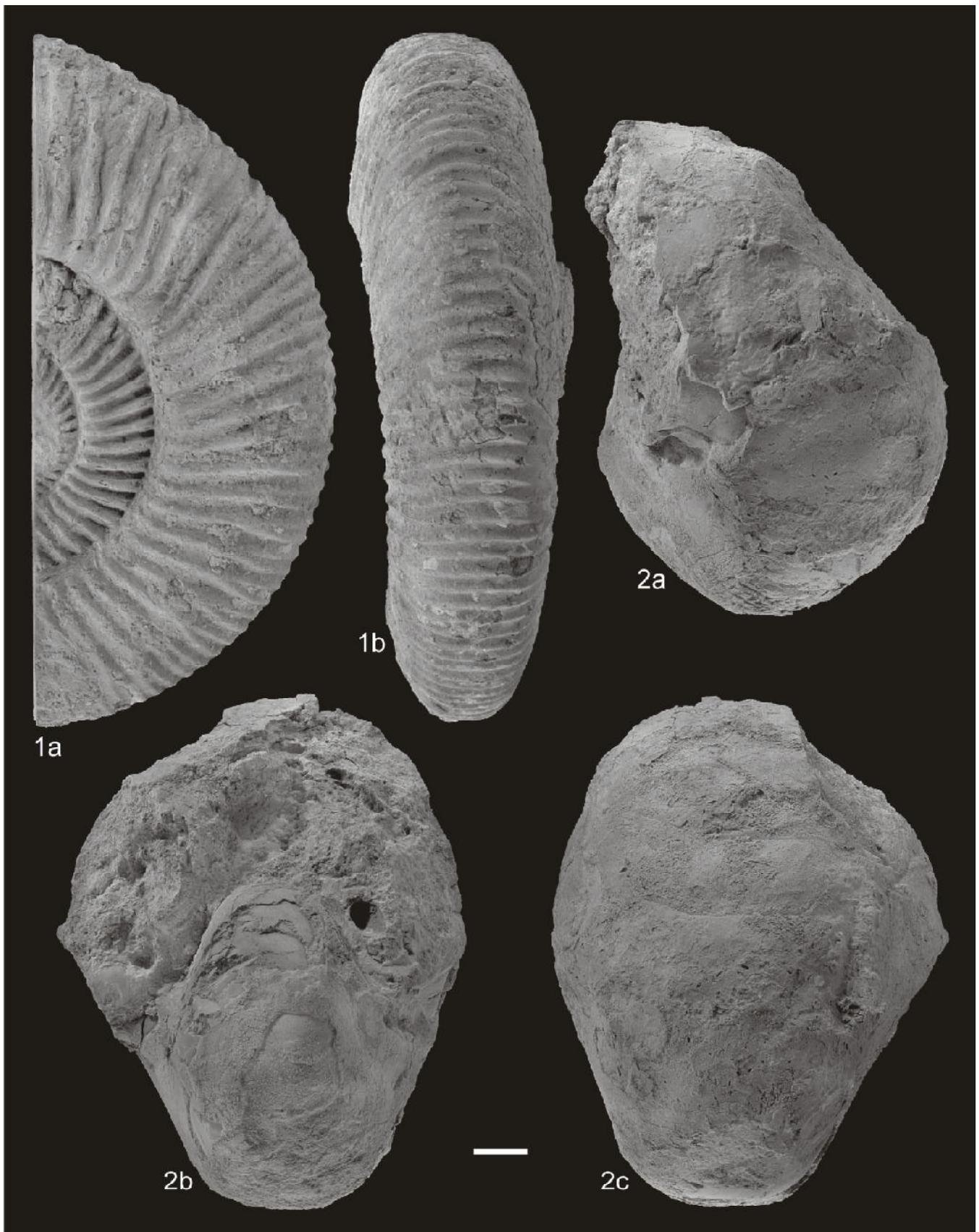
It is the general opinion that the genus *Orthosphinctes* Schindewolf and indeed the whole subfamily Ataxioceratinae appeared in the Hypselum Subzone of the Bimammatum Zone (e.g., Enay, 1966; Conze *et al.*, 1984; Atrops and Meléndez, 1993), but Parent *et al.* (2012) recorded the first members of this genus already in the Grossouvrei Subzone in Iran. Similarly, specimen GZN2011I 263 from Gangta Bet presently described as *Perisphinctes (Dichotomoceras) sp.*, shows already characteristics of *Orthosphinctes* and might therefore represent an early form closely related to this genus.

A series of ammonites recorded from the uppermost beds of section 3 have previously been described from the Rauracien of Madagascar (Collignon, 1959b), such as *P. (Dichotomoceras) antrobikensis*, *P. (Dichotomosphinctes) cf. germani*, and *Perisphinctes (Kranaosphinctes) irregularis*. Spath (1933, p. 872) considered the Rauracien to be equivalent to the Bimammatum Zone. Geiger and Schweigert (2006)

EXPLANATION OF PLATE XIV

(note that the scale bar indicates different sizes for the individual specimens)

1. *Perisphinctes (Dichotomoceras) antrobikensis* (Collignon, 1959); (a) lateral and (b) ventral view of a specimen with a part of the body chamber (no suture lines visible in the outer whorl); GZN2011I 134 from the boundary between beds 7 and 8 of section 3 (scale bar = 10 mm).
2. *Paracnoceras* sp.; (a) lateral, (b) apertural, and (c) ventral view; GZN2011I 131 from the base of bed 8 of section 3 (scale bar = 12.5 mm).



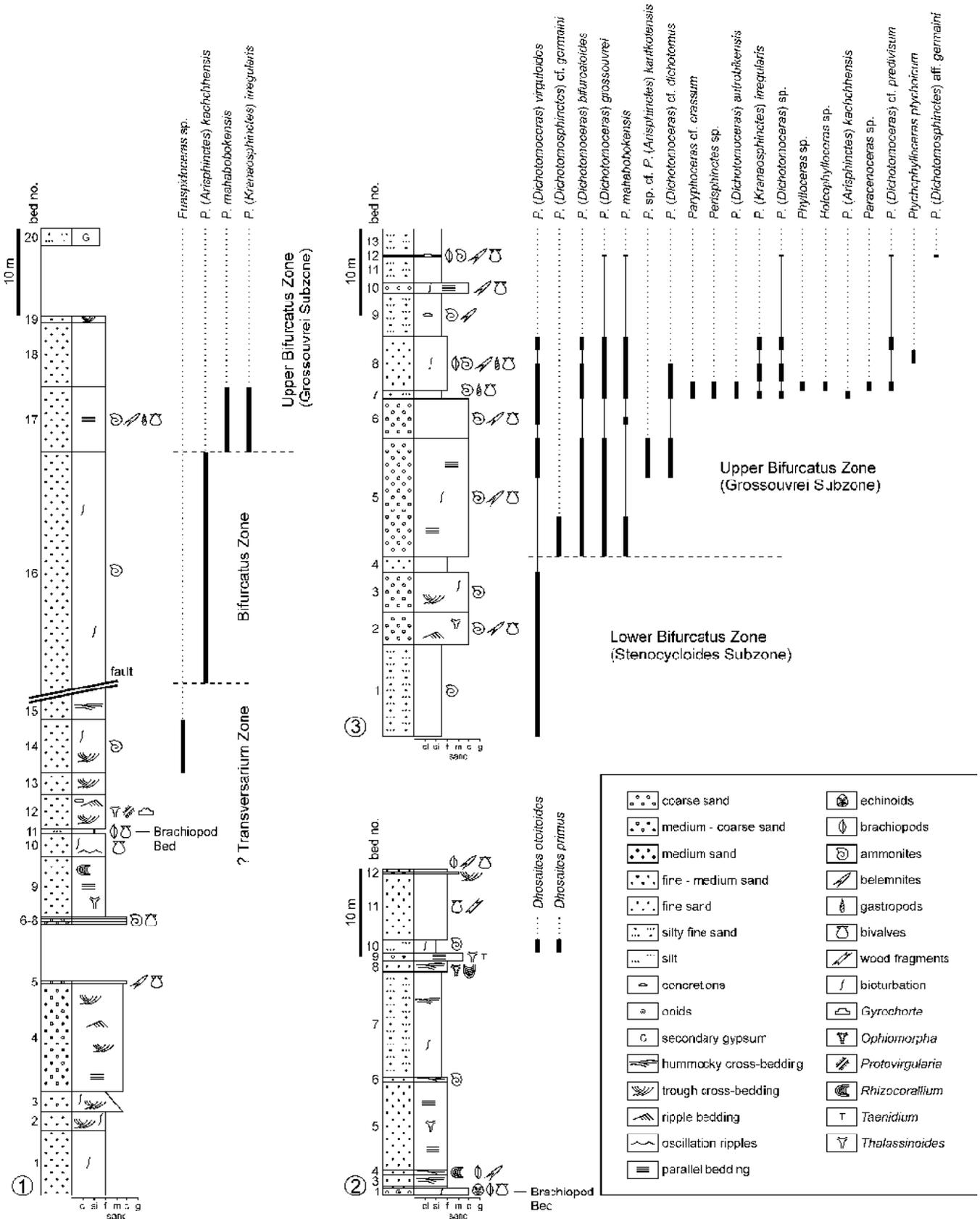


Fig. 23. The three investigated sections on the Gangta Bet with the stratigraphic ranges of the recorded taxa and the assigned ammonite zones.

considered the Rauracien sensu Collignon (1959b) to represent uppermost Oxfordian to Lower Kimmeridgian, but other authors (e.g. Hoffmann and Keupp, 2008, p. 54) assigned it to the upper Middle Oxfordian. Nevertheless, in the absence of any true index form of the Bimammatum Zone and due to the occurrence of *P. (D.) grossouvrei*, it seems the most reliable to assign beds 7 to 12 to the Grossouvrei Subzone.

Ammonites indicative of a Kimmeridgian age have not been recorded during the field survey, but only a part of the Gangta Bet has been thoroughly investigated so far and there is still potential for further research on the ammonite record of this islet amidst the salt marshes of the Great Rann of Kachchh. It is significant to note here that Spath (1931a) recorded *Perisphinctes (Kranaosphinctes) irregularis*, which in the present study has been recorded from the Upper Bifurcatus zone (Grossouvrei Subzone) of Gangta Bet, from the Lower Katrol Formation (Kimmeridgian) of Fakirwari and Ler on the Kachchh Mainland.

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APPENDIX

Table 1: Measurement of *Ptychophylloceras ptychoicum* (Quenstedt, 1845).

specimen	D	Wh	Ww	U	Wh/ Ww
GZN2011I 208 (Pl. I, fig. 2)	70.9	41.5 (59)	32.5 (46)	6.6 (9)	1.28
<i>Phylloceras ptychoicum</i> (Quenstedt) – Waagen, 1875a, p. 30	90	53 (59)	39 (43)	7 (8)	1.36
<i>Ptychophylloceras (Semisulcatoceras) ptychoicum</i> (Quenstedt) – Joly, 2000, p. 126	62.0	36.0 (58)	28.6 (46)	6.0 (10)	1.26
<i>Ptychophylloceras</i> aff. <i>ptychoicum</i> (Quenstedt) – Collignon, 1959c, pl. 98, fig. 371	57	32 (56)	28 (49)	-	1.14
<i>Ptychophylloceras (Semisulcatoceras) ptychoicum</i> (Quenstedt) – Joly, 2000, p. 126	47.2	28.4 (60)	23.2 (49)	5.0 (11)	1.22
<i>Phylloceras insulare</i> Waagen, 1875a, p. 29	46	25 (54)	20 (43)	7 (15)	1.25

Table 2: Measurement of *Dhosaites otoitoides* Spath, 1928.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 343 (Pl. II, fig. 1)	64.7	28.0 (43)	34.0 (53)	17.4 (27)	0.82
<i>Dhosaites otoitoides</i> Spath, 1928b, p. 245	67	29 (43)	31 (46)	20 (30)	0.93
<i>Dhosaites otoitoides</i> Spath – Collignon, 1959a, pl. 39, fig. 207	62	30 (48)	35 (56)	17 (27)	0.86
<i>Dhosaites otoitoides</i> Spath – Collignon, 1959a, pl. 39, fig. 206	55	25 (45)	31 (56)	15 (27)	0.81
<i>Dhosaites elephantoides</i> Spath, 1928b, p. 244	108	42 (39)	63 (58)	42 (39)	0.67

Table 3: Measurement of *Dhosaites primus* Spath, 1928.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 344 (Pl. II, fig. 2)	43	21.0 (49)	19.0 (44.1)	11.5 (26)	1.11
<i>Dhosaites primus</i> Spath, 1928b, p. 245	78	33 (42)	32 (41)	24 (31)	1.02
<i>Dhosaites primus</i> Spath, 1928b, p. 246	45	20 (44)	24 (53)	14 (31)	0.83

Table 4: Measurement of *Paryphoceras* cf. *crassum* Collignon, 1959.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 188 (Pl. II, fig. 3)	-	31.0	34.4	-	0.90
<i>Prograyiceras crassum</i> Collignon, 1959b, pl. 84, fig. 335	~104	37 (36)	46 (44)	32 (31)	0.80

Table 5: Measurement of *Perisphinctes mahabobokensis* (Collignon, 1959).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 346 (Pl. III, fig. 3)	225.0	60.0 (27)	67.0 (30)	113.0 (50)	0.90
GZN2011I 128	-	52.8	56.4	-	0.94
GZN2011I 265	-	49.0	50.5	-	0.97
GZN2011I 213 (Pl. IV, fig. 2)	138.0	42.0 (30)	42.5 (31)	60.0 (43)	0.99
GZN2011I 276	-	36.0	39.3	-	0.92
GZN2011I 079	-	29.5	31.6	-	0.93
GZN2011I 088	100.0	29.0 (29)	30.0 (30)	50.0 (50)	0.97
GZN2011I 226 (Pl. III, fig. 2)	-	28.5	29.2	-	0.98
GZN2011I 226 (Pl. III, fig. 2)	-	26.0	27.0	-	0.96
GZN2011I 242 (Pl. IV, fig. 1)	83.0	25.0 (30)	26.0 (31)	~37.0 (45)	0.96
GZN2011I 161	73.8	24.5 (33)	27.0 (37)	33.0 (45)	0.91
GZN2011I 265	-	20.5	21.5	-	0.95
GZN2011I 304	-	20.0	25.0	-	0.80
GZN2011I 161	-	19.0	21.0	-	0.90
GZN2011I 228	-	16.5	20.0	-	0.83
GZN2011I 226 (Pl. III, fig. 2)	-	16.0	18.8	-	0.85
GZN2011I 228	-	14.0	17.5	-	0.80
GZN2011I 169	-	14.0	15.0	-	0.93
GZN2011I 282	33.2	11.0 (31)	11.4 (34)	12.5 (38)	0.96
GZN2011I 228	-	8.5	12.5	-	0.68
<i>Kranaosphinctes (Pachyplanulites) mahabobokensis</i> Collignon, 1959b, pl. 92, fig. 361	200	57 (28)	68 (34)	100 (50)	0.84
<i>Kranaosphinctes (Pachyplanulites) mahabobokensis</i> Collignon, 1959b, pl. 92, fig. 361	162	47 (29)	55 (34)	78 (48)	0.85
<i>Perisphinctes (Dichotomoceras) crassus</i> Enay, 1966, p. 507	90	27 (30)	29 (32)	43 (48)	0.93
<i>Perisphinctes (Dichotomoceras) crassus</i> Enay, 1966, p. 507	65	20 (31)	25 (38)	31 (48)	0.80

Table 6: Measurement of *Perisphinctes* sp.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 172 (Pl. VII, fig. 2)	-	63.0	~50.0	-	1.26

Table 7: Measurement of *Perisphinctes (Kranaosphinctes) irregularis* (Spath, 1931).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 124 (Pl. V, fig. 5)	92.5	23.0 (25)	33.0 (36)	50.0 (54)	0.70
GZN2011I 240 (Pl. V, fig. 1)	79.0	20.0 (25)	27.0 (34)	~40.5 (51)	0.74
GZN2011I 240 (Pl. V, fig. 1)	65.0	16.2 (25)	22.0 (34)	~37.0 (57)	0.74
GZN2011I 240 (Pl. V, fig. 1)	63.0	17.0 (27)	23.0 (37)	32.0 (51)	0.74
GZN2011I 221 (Pl. V, fig. 3)	58.0	17.0 (29)	~22.0 (38)	~27.0 (46)	0.77
GZN2011I 204 (Pl. V, fig. 2)	32.3	9.0 (28)	17.0 (53)	15.0 (46)	0.53
GZN2011I 011 (Pl. V, fig. 4)	23.0	7.0 (30)	13.0 (57)	10.0 (43)	0.54
<i>Kranaosphinctes (Pachyplanulites) irregularis</i> (Spath) – Collignon, 1959c, pl. 101, fig. 383	138	42 (30)	48 (35)	72 (52)	0.88
<i>Kranaosphinctes (Pachyplanulites) irregularis</i> (Spath) – Collignon, 1959c, pl. 101, fig. 382	79	27 (34)	34 (43)	37 (47)	0.79
<i>Pachyplanulites irregularis</i> Spath, 1931a, p. 433	78	22 (28)	31 (40)	39 (50)	0.70
<i>Kranaosphinctes (Pachyplanulites) cf. irregularis</i> (Spath) – Collignon, 1959b, pl. 89, fig. 354	72	20 (28)	28 (39)	37 (51)	0.71
<i>Kranaosphinctes (Pachyplanulites) rabei</i> Collignon, 1959b, pl. 90, fig. 356	68	21 (31)	29 (43)	36 (53)	0.72
<i>Kranaosphinctes (Pachyplanulites) rabei</i> Collignon, 1959b, pl. 90, fig. 356	40	14 (35)	22 (55)	20 (50)	0.64
<i>Katroliceras zitteli</i> Spath, 1931a, p. 513	84	25 (30)	33 (39)	42 (50)	0.77
<i>Katroliceras zitteli</i> Spath – Collignon, 1959c, pl. 120, fig. 454	62	16 (26)	23 (37)	31 (50)	0.70

Table 8: Measurement of *Perisphinctes (Arisphinctes) kachchensis* Pandey et al., 2012.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 125 (Pl. VI, fig. 3)	-	41.3	53.2	-	0.78
GZN2011I 120	-	37.9	~44.5	-	~0.85
<i>Perisphinctes orientalis</i> non Siemiradzki – Spath, 1931a, p. 417	235	56 (24)	63 (27)	129 (55)	0.89
<i>Perisphinctes orientalis</i> non Siemiradzki – Spath, 1931a, p. 417	210	48 (23)	53 (25)	103 (49)	0.92
<i>Perisphinctes (Arisphinctes) kachchensis</i> Pandey et al., 2012	200.0	50.0 (25)	56.9 (28)	109.7 (55)	0.88
<i>Perisphinctes plicatilis</i> (non Sowerby) – Waagen, 1875c, p. 190; syn. after Spath, 1931a	77	23 (30)	18 (23)	38 (49)	1.28

Table 9: Measurements of *Perisphinctes (Dichotomosphinctes)* cf. *germaini* (Collignon 1959).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 040 (Pl. VI, fig. 2)	82.0	27.0 (33)	26.2 (32)	34.5 (42)	1.03
<i>Dichotomosphinctes germaini</i> Collignon, 1959b, pl. 91, fig. 360	136	42 (31)	40 (29)	64 (47)	1.05

Table 10: Measurements of *Perisphinctes (Dichotomosphinctes)* aff. *germaini* (Collignon, 1959).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 302 (Pl. VII, fig. 1)	65.0	27.0 (42)	26.0 (40)	26.0 (40)	1.04
<i>Dichotomosphinctes germaini</i> Collignon, 1959b, pl. 91, fig. 360	136	42 (31)	40 (29)	64 (47)	1.05

Table 11: Measurements of *Perisphinctes (Dichotomoceras)* sp.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 263 (Pl. VIII, fig. 1)	120.0	36.0 (30)	33.0 (28)	53.0 (44)	1.09
GZN2011I 263 (Pl. VIII, fig. 1)	112.0	32.0 (29)	28.0 (25)	52.0 (46)	1.14

Table 12: Measurement of *Perisphinctes (Dichotomoceras) bifurcatoides* Enay, 1966.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 171 (Pl. IX, fig. 3)	154.0	46.0 (30)	~36.0 (23)	75.5 (49)	1.28
GZN2011I 190 (Pl. X, fig. 2)	112.0	37.0 (33)	30.0 (27)	50.0 (44)	1.23
GZN2011I 219 (Pl. IX, fig. 1)	90.0	25.0 (28)	23.5 (26)	42.5 (47)	1.06
GZN2011I 219 (Pl. IX, fig. 1)	78.0	23.5 (30)	22.4 (29)	36.5 (47)	1.05
GZN2011I 269	35.5	11.5 (32)	14.2 (40)	15.5 (44)	0.81
GZN2011I 137 (Pl. IX, fig. 2)	34.8	12.0 (34)	15.0 (43)	13.5 (39)	0.80
GZN2011I 137 (Pl. IX, fig. 2)	29.5	11.5 (39)	14.3 (48)	11.5 (39)	0.80
<i>Perisphinctes (Dichotomoceras) bifurcatoides</i> Enay, 1966, p. 509	139	41 (29)	-	68 (48)	-
<i>Perisphinctes (Dichotomoceras) bifurcatoides</i> Enay, 1966, p. 509	117	34 (29)	25 (21)	54 (46)	1.36
<i>Perisphinctes (Dichotomoceras) bifurcatoides</i> Enay, 1966, p. 509	110	33.5 (30)	21.5 (19)	51.5 (46)	1.56
<i>Divisosphinctes besairiei</i> Collignon, 1959b, pl. 88, fig. 350	102	35 (34)	31 (30)	45 (44)	1.13

Table 13: Measurement of *Perisphinctes (Dichotomoceras)* cf. *dichotomus* (Buckman, 1919).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 189 (Pl. VIII, fig. 2)	129.0	40.0 (31)	34.3 (27)	53.5 (41)	1.17
<i>Dichotomoceras dichotomum</i> Buckman, 1919, pl. 139, fig. D	173	52 (30)	43 (25)	83 (48)	1.21
<i>Dichotomoceras dichotomum</i> Buckman, 1919, pl. 139, fig. D	150	47 (31)	38 (25)	71 (47)	1.24
<i>Dichotomoceras dichotomum</i> Buckman, 1919, pl. 139, fig. A	146	47 (32)	41 (28)	70 (48)	1.14
<i>Dichotomoceras dichotomum</i> Buckman, 1919, pl. 139, fig. D	97	28 (29)	25 (26)	43 (44)	1.12
<i>Dichotomoceras dichotomum</i> Buckman, 1919, pl. 139, fig. A	90	29 (32)	27 (30)	37 (41)	1.07
<i>Perisphinctes (Perisphinctes) variocostatus</i> (Buckland) – Arkell, 1947, p. 363	150	47 (31.5)	47 (31.5)	71 (47.5)	1.00
<i>Perisphinctes (Perisphinctes) variocostatus</i> (Buckland) – Arkell, 1947, p. 363	100	34 (34)	33 (33)	45 (45)	1.03
<i>Perisphinctes (Biplices) dichotomoides</i> Arkell, 1947, p. 359	100	32 (32)	32 (32)	46 (46)	1.00
<i>Perisphinctes (Biplices) dichotomoides</i> Arkell, 1947, p. 359	75	24 (32)	25 (33)	35 (47)	0.96

Table 14: Measurements of *Perisphinctes (Dichotomoceras) virguloides* Waagen, 1875.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 241 (Pl. XII, fig. 3)	-	41.0	37.0	-	1.11
GZN2011I 235 (Pl. XI, fig. 3)	125.0	40.0 (32)	36.0 (29)	57.0 (46)	1.11
GZN2011I 083	122.0	40.0 (33)	37.5 (31)	58.0 (48)	1.07
GZN2011I 261	-	36.0	33.0	-	1.09
GZN2011I 235 (Pl. XI, fig. 3)	112.5	33.0 (29)	29.0 (26)	44.6 (40)	1.14
GZN2011I 236 (Pl. XII, fig. 4)	99.3	33.0 (33)	29.5 (30)	42.0 (42)	1.12
GZN2011I 198 (Pl. XII, fig. 1)	97.0	31.0 (32)	24.0 (25)	38.0 (39)	1.29
GZN2011I 162	38.6	13.5 (35)	14.5 (38)	-	0.93
GZN2011I 159 (Pl. XI, fig. 2)	36.5	13.0 (36)	16.5 (45)	13.2 (36)	0.79
GZN2011I 103 (Pl. XII, fig. 2)	25.7	9.0 (35)	11.0 (43)	10.6 (41)	0.82
GZN2011I 168	17.3	6.0 (35)	8.0 (46)	6.8 (39)	0.75
GZN2011I 168	15.2	4.5 (30)	5.6 (37)	5.5 (36)	0.80
<i>Prososphinctes virguloides</i> (Waagen) – Spath, 1931a, p. 441	125	40 (32)	35 (28)	59 (47)	1.14
<i>Perisphinctes virguloides</i> Waagen, 1875c, p. 203	118	34 (29)	28 (24)	49 (42)	1.21
<i>Prososphinctes virguloides</i> (Waagen) – Collignon, 1959b, pl. 88, fig. 351	89	29 (33)	24 (27)	40 (42)	1.21
<i>Perisphinctes virguloides</i> Waagen, 1875c, p. 204	42	14 (33)	14 (33)	17 (40)	1.00
<i>Divisosphinctes besairiei</i> Collignon, 1959b, pl. 88, fig. 350	102	35 (34)	31 (30)	45 (44)	1.13
<i>Perisphinctes martelli</i> Oppel – Waagen, 1875c, p. 191	88	30 (34)	28 (32)	37 (42)	1.07
<i>Perisphinctes colei</i> Spath, 1931a, p. 421, pl. 80, fig. 2a, b	100	25 (25)	27 (27)	53 (53)	0.93

Table 15: Measurements of *Perisphinctes (Dichotomoceras) cf. predivisum* (Spath, 1931).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 243 (Pl. VII, fig. 3)	120.0	35.5 (30)	37.5 (31)	59.0 (49)	0.95
GZN2011I 313	-	28.5	33.5	-	0.85
GZN2011I 165	39.0	15.0 (38)	16.8 (43)	~14.2 (36)	0.89
<i>Dichotomoceras predivisum</i> Spath, 1931a, p. 422	98	29 (30)	31 (32)	47 (48)	0.94

Table 16: Measurements of *Perisphinctes (Dichotomoceras) antrobikensis* (Collignon, 1959).

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 134 (Pl. XIV, fig. 1)	129.5	42.1 (33)	~35.8 (28)	58.2 (45)	~1.18
GZN2011I 134 (Pl. XIV, fig. 1)	95.0	28.1 (30)	26.8 (28)	44.6 (47)	1.05
GZN2011I 134 (Pl. XIV, fig. 1)	72.8	23.9 (33)	22.5 (31)	29.3 (40)	1.06
<i>Lithacoceras mombassanum</i> (Dacqué) var. <i>antrobikensis</i> Collignon, 1959b, pl. 90, fig. 359	87	30 (34)	26 (30)	37 (43)	1.15
<i>Lithacoceras (Subplanites) mombassanum</i> (Dacqué) – Howarth and Morris, 1998, p. 87	190.0	56.0 (29)	48.2 (25)	90.0 (47)	1.16
<i>Lithacoceras (Subplanites) mombassanum</i> (Dacqué) – Howarth and Morris, 1998, p. 87	134.5	41.2 (31)	34.3 (25)	62.0 (46)	1.20
<i>Lithacoceras (Subplanites) mombassanum</i> (Dacqué) – Howarth and Morris, 1998, p. 87	101.0	31.0 (31)	-	45.0 (45)	-

Table 17: Measurements of *Perisphinctes (Dichotomoceras) grossouvrei* Siemiradzki, 1898.

specimen	D	Wh	Ww	U	Wh/Ww
GZN2011I 132 (Pl. XIII, fig. 2)	112.0	34.0 (30)	31.0 (28)	45.0 (40)	1.10
GZN2011I 192 (Pl. XIII, fig. 1)	94.3	32.0 (34)	29.0 (31)	38.8 (41)	1.10
GZN2011I 199	85.5	29.0 (34)	26.3 (31)	35.0 (41)	1.10
GZN2011I 200	66.0	24.5 (37)	24.0 (36)	25.8 (39)	1.02
GZN2011I 312 (Pl. XIII, fig. 3)	48.0	16.5 (34)	16.0 (33)	19.0 (40)	1.03
GZN2011I 132 (Pl. XIII, fig. 2)	-	15.0	18.5	-	0.81
GZN2011I 132 (Pl. XIII, fig. 2)	-	12.0	14.0	-	0.86
GZN2011I 167	28.5	12.2 (43)	13.4 (47)	8.5 (30)	0.91
GZN2011I 167	26.9	10.8 (40)	11.8 (44)	8.7 (32)	0.92
GZN2011I 144	22.5	11.0 (49)	12.5 (56)	6.5 (29)	0.88
<i>Perisphinctes grossouvrei</i> Siemiradzki, 1898, p. 193	53	19 (36)	19 (36)	21 (40)	1.00
<i>Perisphinctes grossouvrei</i> Siemiradzki, 1898, p. 193	50	18 (36)	18 (36)	20 (40)	1.00
<i>Perisphinctes grossouvrei</i> Siemiradzki, 1898, p. 193	25	10 (40)	12 (48)	8 (33)	0.83