

## Ammonites from the Oxfordian-Kimmeridgian boundary and the Lower–Upper Kimmeridgian of Kachchh, western India

Dhirendra K. PANDEY<sup>1</sup>, Matthias ALBERTI<sup>2</sup>, Franz T. FÜRSICH<sup>3</sup>, Ewa GŁOWNIAK<sup>4</sup>, Federico OLÓRIZ<sup>5</sup>

**Key words:** ammonites, Oxfordian-Kimmeridgian, Kachchh, India.

**Abstract.** Several new specimens of ammonites from the Oxfordian and Kimmeridgian of Kachchh, western India, are described and illustrated. The Oxfordian ammonites *?Subdiscosphinctes* Malinowska, *Perisphinctes* Waagen, *Dichotomoceras* Buckman, and *?Larcheria* Tintant, all from Bharodia in the Wagad Uplift, enable tentative biochronostratigraphic correlations with the uppermost Middle Oxfordian up to the lower Upper Oxfordian of the unified Submediterranean zonation, whereas the Kimmeridgian ammonites *Streblites* Hyatt, “*Orthosphinctes*” Schindewolf, *Torquatisphinctes* Spath, *Pachysphinctes* Dietrich, *Katroliceras* Spath, *Aspidoceras* Zittel, and *Schaireria* Checa reconfirm a stratigraphic gap embracing incompletely known parts of the uppermost Oxfordian and the Lower Kimmeridgian as known from the ammonite records of the Kachchh Mainland of the Kachchh Basin.

### INTRODUCTION

Cephalopods of the Kachchh Basin in western India (Fig. 1) have been studied for more than a century beginning with the prominent monographs of Waagen (1873–1875) and Spath (1927–1933). Since then major progress has been achieved in understanding the litho- and biostratigraphy of the area as well as its ammonite taxonomy (*e.g.*, Agrawal, 1956; Deshpande, Merh, 1980; Biswas, 1980, 1991, 1993; Agrawal, Pandey, 1985; Krishna, Westermann, 1987; Krishna *et al.*, 1996a, b, 1998, 2009a, b, c; Fürsich *et al.*, 2001; Mishra, 2009). Nevertheless, three recent field trips to the

Kachchh Basin, which mainly concentrated on the Oxfordian part of the succession, showed that the ammonite record of the area is not yet known comprehensively. During the surveys more than 800 cephalopods were collected with high stratigraphic resolution, and additional specimens collected by the late John H. Callomon in the 1990s were studied at the Oxford University Museum of Natural History. This large collection is the basis of a series of publications enlarging our knowledge on cephalopods and the biostratigraphic framework of the Upper Jurassic of the Kachchh Basin (compare Alberti *et al.*, 2011; Pandey *et al.*, 2012).

<sup>1</sup> Department of Geology, University of Rajasthan, Jaipur 302004, India; e-mail: dhirendrap@hotmail.com

<sup>2</sup> Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Ludewig-Meyn-Straße 10, 24118 Kiel, Germany; e-mail: alberti@gpi.uni-kiel.de

<sup>3</sup> GeoZentrum Nordbayern, Fachgruppe PaläoUmwelt, Friedrich-Alexander-Universität Erlangen-Nürnberg, Loewenichstraße 28, 91054 Erlangen, Germany; e-mail: franz.fuersich@gzn.uni-erlangen.de

<sup>4</sup> Faculty of Geology, University of Warsaw, Żwirki i Wigury 93, PL-02-089 Warszawa, Poland; e-mail: eglownia@uw.edu.pl

<sup>5</sup> Department of Stratigraphy and Paleontology, Faculty of Sciences, University of Granada, Av. Fuentenueva s/n, 18071 Granada, Spain; e-mail: foloriz@ugr.es

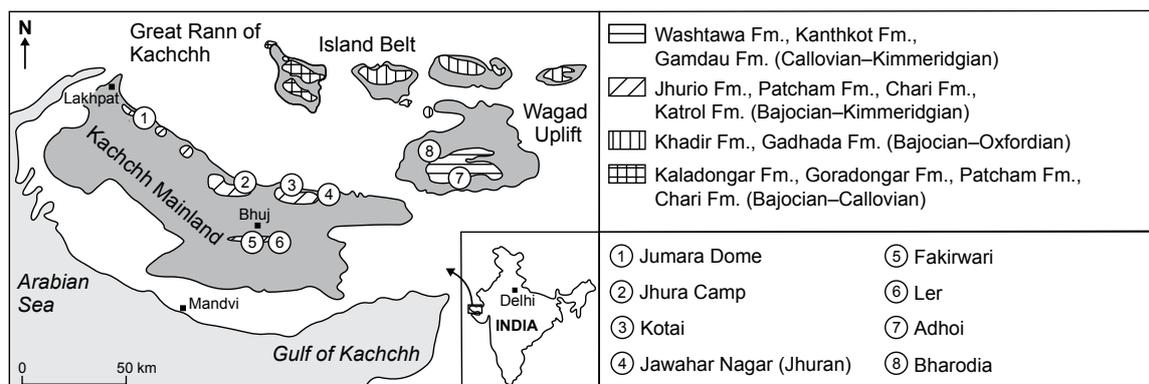


Fig. 1. Geological sketch map of the Kachchh Basin showing the sample localities (modified after Fürsich *et al.*, 2004, 2005)

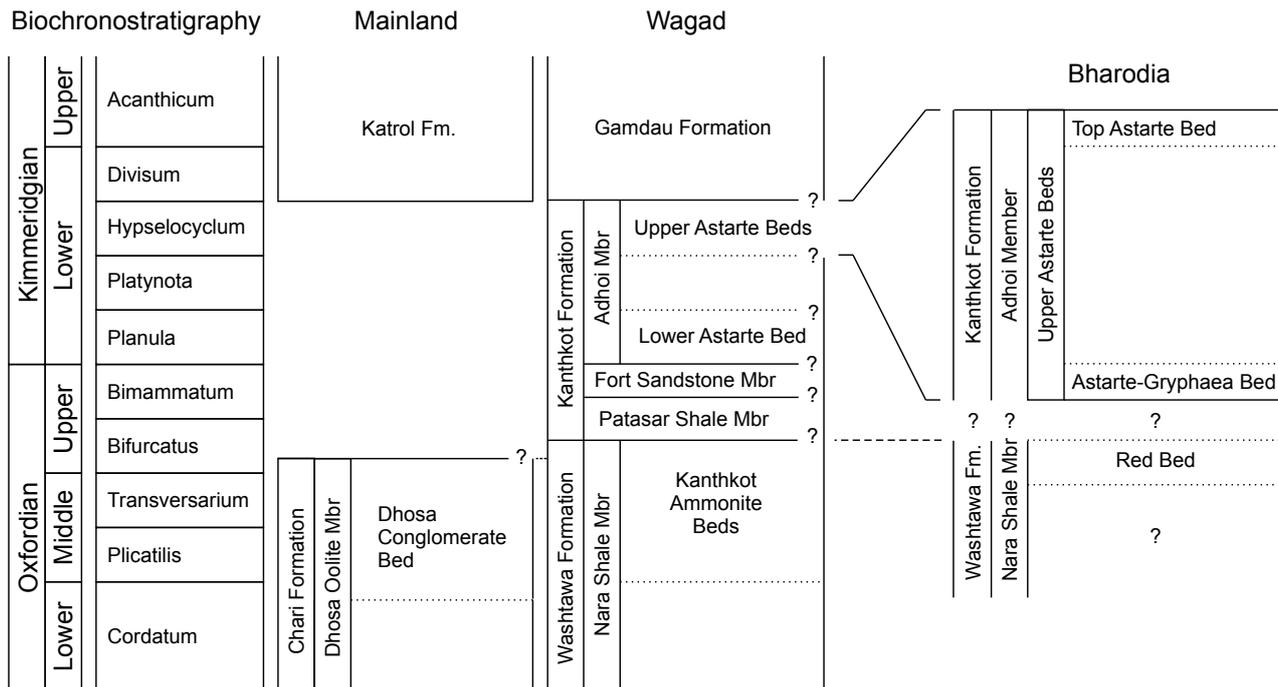
The dark-grey colour refers to the three areas of Kachchh in which Jurassic rocks crop out: Kachchh Mainland, Island Belt, and Wagad Uplift

## GEOLOGICAL SETTING

The Kachchh Basin in western India (Fig. 1) formed during the Late Triassic following rifting between India and Africa (Biswas, 1982, 1991). After an initial phase of terrestrial sedimentation, marine conditions became established during the Middle Jurassic and dominated until the Early Cretaceous (Rajnath, 1932; Singh *et al.*, 1982; Fürsich, 1998; Fürsich, Pandey, 2003). Today, Jurassic outcrops 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 Wagad Uplift near its eastern boundary. The Oxfordian succession of the Kachchh Mainland, which contains most of the well-known sections, is characterized by strong stratigraphic condensation with its thickness commonly being less than 10 m. Taphonomic condensation has been also identified (*e.g.*, Alberti *et al.*, 2013), especially at the top of the Chari Formation (Fig. 2). The upper part of the Chari Formation is the Dhosa Oolite Member. This unit is characterized by the presence of allochthonous, ferruginous ooids in a fine-grained sandstone matrix. The Dhosa Oolite Member is capped by the Dhosa Conglomerate Bed (DCB) which contains abundant, but reworked ammonites of the *Cordatum* to *Transversarium* zones. These ammonites led to the interpretation of an Early to Middle Oxfordian age for the Dhosa Oolite Member, as argued by Alberti *et al.*, 2011; Pandey *et al.*, 2012. Nevertheless, it is worth mentioning that Alberti *et al.* (2012, 2013) suggested an even younger, Late Oxfordian age of the latest phase of deposition in the Dhosa Conglomerate Bed, based on the taphonomic features of some well preserved fossils. This suggestion is justified by the occurrence of some ammonites belonging to *Perisphinctes* sp. having been provisionally compared to *Peris-*

*phinctes* (*Dichotomosphinctes*) *antecedens* Salfeld or to *Perisphinctes* (*Dichotomosphinctes*) *wartae* Bukowski as shown by Pandey *et al.* (2012) (*e.g.* pl. 11: 1–2; pl. 14: 5). Although these specimens are poorly preserved and incomplete, they possess a somewhat younger appearance than the other perisphinctids from DCB, and can be tentatively accommodated in the Wartae Subzone – the lowermost subzone in the three-fold subdivision of the Bifurcatus Zone. Earlier biostratigraphic interpretations envisaging an early Bifurcatus age for the top of the Chari Formation at the Kanthkot area in Wagad (here assigned to the Washtawa Formation, see Fig. 2) were made by Krishna *et al.* (2009a) when interpreting their records of *Larcheria subschilli* (Lee).

The sandstones of the overlying Katrol Formation were deposited only after a long depositional gap comprising inconclusively known parts of the Late Oxfordian and Early Kimmeridgian, which presumably was related to regional tectonics in the Kachchh area (*e.g.*, Krishna *et al.*, 2009a and references therein). The lower sandstones in the Katrol Formation are of shallow marine origin and range in grain size from fine to coarse sandstones exhibiting large-scale cross-stratification, but also bioturbated horizons. The missing time interval is represented by sediments only in the Wagad Uplift, where the presence of the Upper Oxfordian Bifurcatus Zone, with its two lower subzones (Wartae and *Stenocycloides* subzones), has been substantiated in the Kanthkot Ammonite Beds by findings of some guide taxa (*e.g.* *Perisphinctes* (*Dichotomoceras*) *stenocycloides* Siemiradzki, see Pandey *et al.*, 2012) and on the small islet Gangta Bet. We accept the presence of the Upper Oxfordian stratigraphical interval ranging from the upper Bifurcatus Zone (*cf.* Pandey *et al.*, 2014, in press) up to some inconclusive horizons in the Bimammatum Zone. There, in the Wa-



**Fig. 2. Litho- and biostratigraphic framework for the Oxfordian and Kimmeridgian *pro parte* in the Kachchh Basin (modified after Krishna *et al.*, 1996b, 2009a; Alberti *et al.*, 2011; Pandey *et al.*, 2012). The succession of Bharodia differs from that of the remaining Wagad Uplift and is therefore illustrated separately**

Note that the biostratigraphic assignment of a number of lithostratigraphic unit boundaries is uncertain as of now as indicated by question marks. The dotted lines demarcate subunits of the various members. Note within the Bifurcatus Zone (three-fold division) diachronous tops for the Chari Formation, Mainland (?Wartae Subzone, older), and for the Red Bed in Bharodia as well as the Kanthkot Ammonite Beds, Washtawa Fm., Wagad (both in the Stenocycloides Subzone, younger)

gad Uplift, the succession is expanded, comprising several hundred metres in thickness with the occurrence of sandy, in places fossil-rich shallow-water lithosomes providing evidence of sedimentation under the influence of sea-level fluctuations (*e.g.*, Mishra, 2009). Except for the Middle to lower Upper Oxfordian Kanthkot Ammonite Beds (Krishna *et al.*, 2009a, c; Pandey *et al.*, 2012), cephalopod fossils are however very rare in the succession of the Wagad Uplift.

The present study describes ammonites from a series of outcrops in the Kachchh Basin. The basal Katrol Formation of the Kachchh Mainland has yielded ammonites of a late Early to Late Kimmeridgian age at the Jumara Dome, near Jhura Camp of the Jhura Dome, near Kotai of the Habo Dome, near Fakirwari south of Bhuj, and near Ler southeast of Bhuj (Fig. 1). In addition, a section has been measured near Jawahar Nagar (formerly known as Jhuran) in the easternmost Kachchh Mainland (Fig. 1), where the basal Katrol Formation is represented by the so-called Belemnite Marls. In the Wagad Uplift, ammonites have been collected south

of Bharodia and east of Adhoi. The Jurassic succession of Bharodia is particularly interesting as it seems to show a very different development compared with other parts of the Wagad Uplift (Figs 2, 12). The section starts with approximately 4 m of poorly indurate silty fine-grained sandstone which is parallel-laminated and contains a few concretionary, ferruginous levels. On top of this bed follows a characteristic bed, the so-called Red Bed. This Red Bed is a poorly sorted fine- to medium-grained sandstone, which can be followed laterally for several hundred metres, is highly ferruginous, bioturbated, and contains ferruginous ooids. Its fossil content is high and includes ammonites, belemnites, and bivalves. Some ammonites are reworked indicating taphonomic condensation (research in course). These two beds belong to the Washtawa Formation, and the Red Bed corresponds to the top of this formation. After 2.2 m of bioturbated, poorly exposed and poorly indurate, well-sorted fine-grained sandstone, the Upper Astarte Beds begin, overlying discontinuously older beds. In general, the Upper

Astarte Beds are characterised by coarse sandy sediment, common bioturbation (*Thalassinoides*), and repeated shell beds. The first of these shell beds is called the Astarte–Gryphaea Bed (Fürsich, Pandey, 2003) due to abundant specimens of the bivalves *Seebachia* (*Eoseebachia*) and *Gryphaea*. Furthermore, this horizon also contains a large number of fossils of other groups, such as ammonites and belemnites. The uppermost shell bed of the Upper Astarte Beds is called the Top Astarte Bed. The Upper Astarte Beds (as in the rest of the Wagad Uplift) represent the top of the Adhoi Member (Fig. 2). Whereas the ammonites of the Red Bed point to a latest Middle to early Late Oxfordian age, the fossils collected from the Astarte–Gryphaea Bed indicate an Early Kimmeridgian age. Therefore, a considerable depositional gap seems apparent (Fig. 2).

The ammonite collected east of Adhoi is from the Adhoi Member, a few metres below the Upper Astarte Beds. The uppermost part of the Adhoi Member has been erroneously classified as Oxfordian by Mishra (2009), whereas Krishna *et al.* (2009c) assigned the Adhoi Member to the Lower Kimmeridgian (Planula to Hypselocyclum zones). Two figures showing the measured sections, together with the presently recorded ammonite taxa recorded herein, accompany the chapter on biostratigraphy at the end of the article (Figs 11, 12).

Taking into account previous (Krishna *et al.*, 1995, 1996a, b, 2009a–c) and recent contributions (Pandey *et al.*, 2012; Alberti *et al.*, 2011, 2012, 2013) and this paper it seems that the majority of dated tops of Oxfordian deposits in the Kachchh Basin belong to the lower Upper Oxfordian (different parts of the Bifurcatus Zone in the Kachchh Mainland, Khadir and Wagad Uplift, *cf.* Fig. 2), except in the Gangta Bet whose uppermost parts lack conclusive biochronologic data.

It should be remembered that the Kimmeridgian Stage is used in modern sense here, whereas Spath, and other early authors used names Upper Kimmeridgian and even Middle Kimmeridgian for beds now included in the Tithonian. Thus, when older authors are quoted here – such names are given in quotation marks. Furthermore, some modern authors using Kimmeridgian in the current sense insert a “Middle Kimmeridgian” – whereas, formally, the stage is just divided into Lower and Upper parts only.

## SYSTEMATIC PALAEOLOGY

In the present study 38 ammonites assigned to 20 taxa are described. Where specimens of new taxa were well enough preserved, they were measured using Vernier Calipers. The dimensions in the Table 1 are given in millimetres

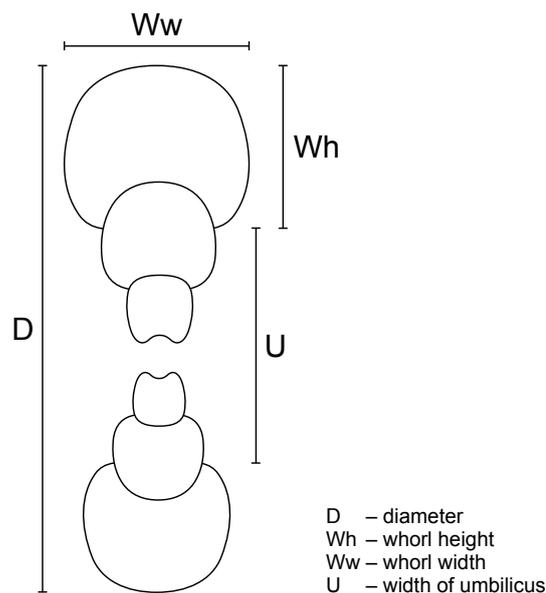


Fig. 3. Measured dimensions of the ammonites and abbreviations used

and the numbers in parentheses are proportional dimensions as a percentage of the diameter. Figure 3 explains the measurements and abbreviations used in this publication. Specimens with the prefix GZN are currently housed in the collections of the GeoZentrum Nordbayern of the Friedrich-Alexander-University Erlangen-Nürnberg, Germany, but are planned ultimately to be stored in the Department of Geology of the University of Rajasthan in Jaipur, India. Material with the prefix OUMNH has been collected by the late John H. Callomon and is kept in the collections of the Oxford University Museum of Natural History, England.

Given the incomplete preservation of the Kimmeridgian material studied (mainly phragmocones and/or juvenile specimens) a direct reference to the nominal morphospecies interpreted by Spath (1927–1933) and other authors working on ammonites collected from the Indo-Malagasy Gulf has been favoured. Thus a merely morphological approach to species previously described is applied to the material under study. Subsequent, more comprehensive interpretations of the ammonite species cannot be evaluated through the analysis of the present material and will not be taken into account for taxonomic/systematic interpretations.

The following morphological parameters were measured: diameter (D), whorl height (Wh), whorl width (Ww), and umbilical width (U). For some taxa the same specimen was measured at different sizes.

Class CEPHALOPODA Cuvier, 1797

Order **Ammonoidea** Zittel, 1884

Suborder **Ammonitina** Hyatt, 1889

Superfamily **Haploceratoidea** Zittel, 1884

Family **Oppeliidae** Douvillé, 1890

Subfamily **Streblitinae** Spath, 1925

Genus *Streblites* Hyatt, 1900

Type species: *Ammonites tenuilobatus* Oppel, 1862.

*Remarks.* – The genus *Streblites* includes ammonite shells of small to moderate size, with small umbilicus and sub-oxyconic to oxyconic whorl section, which can be attenuated throughout the body chamber. Venter crenulated on the phragmocone. The sculpture ranges from subtle to well-marked, radial to sinuous, even falcoid ribs usually weakened across the body chamber. Tuberculation, or rather subtle swelling of rib extremes, and crescent ribs are variably expressed. Suture line complex.

*Biostratigraphic range.* – The genus *Streblites* s.l. (i.e., including the group of *Taramelliceras externodosum* Dorn, 1930 = *Strebliticeras*) is Oxfordian to earliest Tithonian in age in south-European areas (see Höroldt, 1964 for a general overview), but the most typical forms are mainly Kimmeridgian in age. In epicontinental west-Tethyan areas *Streblites* and related taxa of Kimmeridgian age are widely known, but their record is not abundant as indicated by Olóriz (1978) for southern Spain, Sapunov (1979) for Bulgaria, and Pavia *et al.* (1987) and Sarti (1993) for Italy. Northwest-African records from the lowermost Kimmeridgian (current usage of this stage) refer to forms considered homeomorphs by some authors (i.e., *Strebliticeras*) and were reported by Atrops, Benest (1984) and Soussi *et al.* (1991) from Algeria and Tunisia, respectively, whereas more typical Kimmeridgian species were reported from Tunisia by Castany (1951, 1955, quoted in Boughdiri *et al.*, 2005) and Morocco by Benzaggagh, Atrops (1997). In Kachchh *Streblites* was identified by Spath (1927–1933) in his “Middle Kimmeridgian” (Eudoxus–Beckeri? zones) and up to the “Portlandian”. Krishna, Pathak (1991), Pathak (1993), and Krishna *et al.* (1996b) reported *Streblites* from the Upper Kimmeridgian (Intermedius/Acanthicum zones, Acanthicum Subzone, Bathyplocus and lower Katrolensis zones). In neighbouring Madagascar, *Streblites* was placed by Collignon (1959b) in his “Lower and Middle Kimmeridgian” (*Aspidoceras longispinum* and *Torquatisphinctes alterneplicatus* to *Hybonotoceras hybonotum* and *Aspidoceras acanthicum* biozones), through identification mainly of Indo-

Madagascan species and less of European ones. East-African records of *Streblites* are known from the Kimmeridgian of Tanzania (Dietrich, 1925; probably Upper but not uppermost Kimmeridgian, according to Dietrich’s ammonites and micropalaeontologic interpretations provided by Sames, 2008) and Ethiopia (Valduga, 1954; upper Lower/lowermost Upper Kimmeridgian according to ammonite assemblages in Zeiss, 1971); from the Hybonotum Zone in Mombasa, Kenya, by Verma, Westermann (1984), and from the middle Upper or uppermost Kimmeridgian of southern Yemen by Howarth (1998) and Howarth, Morris (1998). Himalayan records of the genus *Streblites* have been known for a long time. This record is obscure as the taxon has not been clearly differentiated from the genus *Uhligites* (e.g., Enay, 2009), but citations with precise identification of fossil assemblages exist pointing to Kimmeridgian rather than Tithonian ages (e.g., Pathak, Krishna, 1993).

*Streblites plicodiscus* (Waagen, 1875)

(Pl. 1: 1a–c; Fig. 4A; Table 1)

1875. *Oppelia plicodiscus* Waagen; p. 56, pl. 10: 5

*Material.* – Three specimens from the Belemnite Marls near Jawahar Nagar (i.e. Jhuran; GZN2010I 031, 033; OUMNH JY.1052).

*Description.* – Corroded inner cast. Shell moderately large, wholly septate, involute, compressed. Whorl section subtriangular with slightly arched flanks and maximum thickness at one-fourth of lateral height. Preserved ornamentation consisting of very fine, dense, peripheral and subtly prorsiradiate ribs. Narrow venter with fine, unicarinate beaded keel. Umbilical wall low but steep with a rounded umbilical edge. The corroded suture line allows recognition of a deep lateral lobe but not a precise analysis.

*Remarks.* – *Oppelia plicodiscus* was erected by Waagen (1875, p. 56, pl. 10: 5) on the basis of a juvenile specimen. Later observations made by Spath (1928a, p. 140–151) offered a more precise interpretation about the morphologic spectrum of this species including size and sculpture, which agrees with the shell parameters obtained from the described phragmocones. *Streblites leptodiscus* Spath (1928a, p. 150, pl. 16: 1) is a closely related species and is difficult to separate except for its slightly narrower whorl section (20% vs. 24% in Spath, 1928a, p. 151). According to Spath (1928a, pl. 8: 1), *Streblites habyensis* seems to be a younger and more coarsely sculptured *Streblites* with a broader shell. Whatever the case under study, information about streblitins from Kachchh is far from complete, the known species are merely morphological proposals and, hence, the information about species-level diversity is very limited.

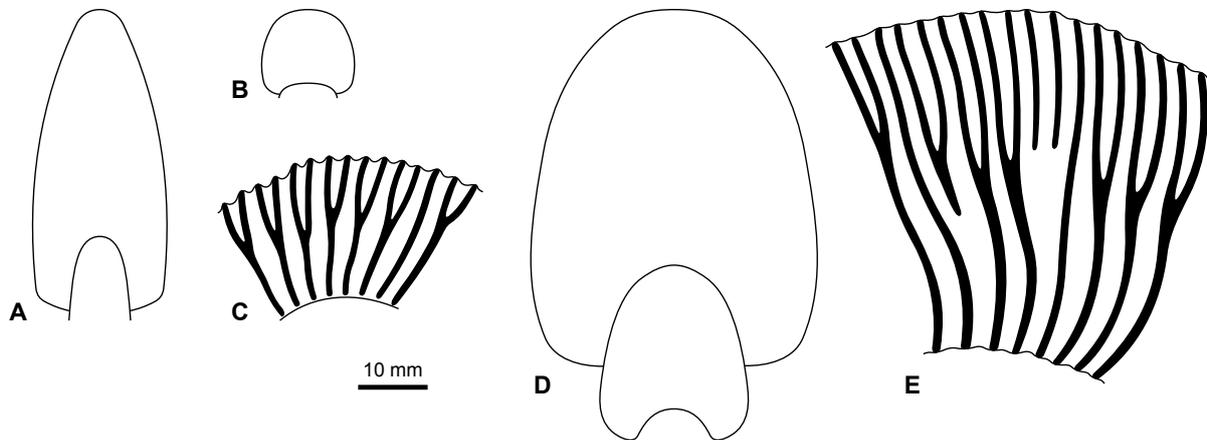
Table 1

## Measurements of the described ammonites (in mm)

	D	Wh	Ww	U	Wh/Ww
<i>Streblites plicodiscus</i> (Waagen, 1875)					
OUMNH JY.1052	73.8	43.7 (59)	19.5 (26)	6.3 (9)	2.24
<i>Perisphinctes</i> ( <i>Dichotomoceras</i> ) aff. <i>bifurcatoides</i> Enay, 1966 (m)					
GZN2010I 046	75.5	23.5 (31)	19.3 (26)	32.7 (43)	1.22
GZN2010I 047	65.3	21.4 (33)	~21.8 (33)	26.4 (40)	~0.98
<i>Perisphinctes</i> ( <i>Dichotomoceras</i> ) cf. <i>duongae</i> Meléndez, 1989, emend. Gygi, 2000a (m)					
OUMNH JY.1131	68.3	21.3 (31)	20.5 (30)	30.2 (44)	1.04
<i>Perisphinctes</i> ( <i>Dichotomoceras</i> ) aff. <i>rotoides</i> Ronchadzé, 1917					
GZN2010I 057	70.7	18.7 (26)	21.2 (30)	34.8 (49)	0.88
? <i>Subdiscosphinctes</i> sp.					
GZN2010I 051	38.4	12.0 (31)	13.9 (36)	15.9 (41)	0.86
GZN2010I 053	21.3	6.4 (30)	8.5 (40)	7.8 (37)	0.75
? <i>Larcheria</i> sp. (M)					
OUMNH JY.1130	140.3	51.6 (37)	~41 (29)	54.3 (39)	~1.26
"Orthosphinctes" sp.					
GZN2010I 059	62.5	19.0 (30)	~13.5 (22)	27.5 (44)	~1.41
	55.8	16.8 (30)	~12.5 (22)	24.3 (44)	~1.34
<i>Torquatisphinctes primus</i> Spath, 1931					
GZN2010I 026	–	24.0	30.4	–	0.79
	49.0	14.2 (29)	18.5 (38)	22.9 (47)	0.77
<i>Torquatisphinctes alterneplicatus</i> (Waagen, 1875)					
GZN2010I 1026	–	29.2	33.7	–	0.87
GZN2010I 028	77.6	23.3 (30)	26.1 (34)	37.5 (48)	0.89
	59.1	17.1 (29)	18.2 (31)	29.3 (50)	0.94
	–	14.1	15.0	–	0.94
	–	7.9	8.0	–	0.99
<i>Torquatisphinctes sparsicostatus</i> (Spath, 1931)					
GZN2010I 1001	126.8	34.6 (27)	–	68.4 (54)	–
	115.3	31.3 (27)	35.2 (31)	55.4 (48)	0.89
<i>Torquatisphinctes</i> sp. gr. <i>intermedius</i> Spath, 1931 – <i>alterneplicatus</i> (Waagen, 1875)					
GZN2010I 041	85.0	25.2 (30)	29.1 (34)	37.4 (44)	0.87
	67.8	20.7 (31)	26.6 (39)	30.0 (44)	0.79
GZN2010I 1035	47.1	16.1 (34)	–	19.9 (42)	–
<i>Torquatisphinctes</i> sp.					
GZN2010I 1028	–	41.2	38.5	–	1.07

	D	Wh	Ww	U	Wh/Ww
<i>?Torquatisphinctes</i> sp.					
GZN2010I 039	~62.0	22.1 (36)	~20.0 (32)	23.2 (37)	~1.11
<i>Pachysphinctes</i> sp. cf. <i>symmetricus</i> Spath, 1931					
GZN2010I 1025	–	27.9	35.5	–	0.79
<i>Katroliceras</i> sp. cf. <i>depressum</i> Spath, 1931					
GZN2010I 1033	69.9	21.0 (30)	~27.3 (39)	35.0 (50)	~0.77
GZN2010I 1031	50.9	14.6 (29)	20.0 (39)	23.0 (45)	0.73
GZN2010I 1008	35.5	9.3 (26)	~16.5 (46)	18.0 (51)	~0.56
GZN2010I 1007	27.1	9.0 (33)	14.5 (54)	11.3 (42)	0.62
<i>Katroliceras</i> sp. cf. <i>sowerbyi</i> Spath, 1931					
GZN2010I 1005	65.6	18.5 (28)	26.0 (40)	32.9 (50)	0.71
Torquatisphinctinae gen. and sp. ind.					
GZN2009II 015	39.5	12.4 (31)	16.3 (41)	15.6 (39)	0.76
<i>Aspidoceras asymmetricum</i> Spath, 1931					
OUMNH JY.1263	112.0	42.8 (38)	52.4 (47)	38.0 (34)	0.82
<i>Schaireria</i> sp. aff. <i>avellanooides</i> (Uhlig, 1910)					
GZN2009II 190	48.2	23.3 (48)	~28.7 (60)	5.3 (11)	~0.81
	38.6	19.2 (50)	25.7 (67)	~5.0 (13)	0.67

Abbreviations are explained in Figure 3, numbers in parentheses refer to proportional dimensions as percentage of the diameter. Note that some specimens have been measured at several diameters



**Fig. 4.** **A.** *Streblites plicodiscus* (Waagen, 1875); whorl section at ca. 74 mm diameter, OUMNH JY.1052. **B.** *?Subdiscosphinctes* sp.; whorl section at ca. 39 mm diameter, GZN2010I 051. **C.** *Perisphinctes* (*Dichotomoceras*) aff. *bifurcatoides* Enay, 1966 (m); ribbing pattern at ca. 65 mm diameter, GZN2010I 047. **D, E.** *?Larcheria* sp. (M); D. Whorl section at ca. 140 mm diameter, OUMNH JY.1130. E. Ribbing pattern at unknown diameter, OUMNH JY.1130

*Biochronostratigraphic range.* – Spath (1928a, p. 148–152) reported *Streblites* species, including *plicodiscus* Waagen, from his “Middle Kimmeridgian” Eudoxus and/or Beckeri Zone identified in the “Katrol Beds” of the easternmost Kachchh Mainland, *i.e.* from the same region as the specimens described here. Later studies showed small biostratigraphic differences in the interpretation of the upper part of the range of *Streblites plicodiscus* (Waagen) in Kachchh. The species was considered to range from the lowermost Upper Kimmeridgian (middle Acanthicum–Intermedius zones) to younger levels in the Upper Kimmeridgian (the Bathyplocus–Katrolensis zonal boundary according to Krishna, Pathak, 1993, or the lowermost Katrolensis Zone according to Krishna *et al.*, 1996b). The related species *Streblites leptodiscus* (Spath) ranges from the middle to upper Acanthicum–Intermedius zones to the lower part of the Bathyplocus Zone (Krishna, Pathak, 1993) or to the Bathyplocus–Katrolensis zonal boundary. Verma, Westermann (1984) interpreted *Streblites habyensis* Spath from the Hybonotum Zone in Kenya as a closely related species, but the specimen illustrated shows a clearly different, less elaborated suture line and a mid-venter depression on the body chamber that is unknown in Spath’s species. Moreover, re-interpretations made by Schweigert *et al.* (1996) of accompanying *Hybonotoceras* from the Kimmeridgian–Tithonian boundary beds in Mombasa studied by Verma, Westermann (1984) could indicate the Beckeri Zone and hence younger horizons within the uppermost Kimmeridgian according to Krishna *et al.* (1996b). *Streblites habyensis* Spath was interpreted as potentially synonymous with *Streblites plicodiscus* (Waagen) by Howarth, Morris (1998), who recorded this species in the middle Upper or uppermost Kimmeridgian of southern Yemen.

The analysed material, collected from the Belemnite Marls near Jawahar Nagar (*i.e.* Jhuran), most probably indicates Kimmeridgian horizons younger than the Lower Kimmeridgian.

Superfamily **Perisphinctoidea**, Steinmann, 1890

Family **Perisphinctidae** Steinmann, 1890

Subfamily **Perisphinctinae** Steinmann, 1890

Genus *Perisphinctes* Waagen, 1869

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

*Perisphinctes* subgen. and sp. ind.

(Pl. 3: 2a, b; Fig. 5G, H; Table 1)

*Material.* – One specimen from the Red Bed near Bharodia, Wagad Uplift (GZN2010I 048).

*Description.* – Incomplete phragmocone of moderately evolute coiling. Whorl section rounded with arched flanks merging smoothly into rounded venter. Ornamentation consisting of moderately spaced, slightly prorsiradiate primary ribs. They bifurcate slightly above mid-lateral height. Occasionally, a zigzag pattern of ribs occurs on the ventral side, ending with an undivided rib on one side. Secondary ribs cross the venter with faint forward-directed sinuosity.

Subgenus *Dichotomoceras* Buckman, 1919

Type species: *Dichotomoceras dichotomum* Buckman, 1919 (m).

*Perisphinctes* (*Dichotomoceras*) aff. *bifurcatoides* Enay, 1966 (m)

(Pl. 1: 2a–c; Pl. 2: 4; Fig. 4C; Table 1)

1966. *Perisphinctes* (*Dichotomoceras*) *bifurcatoides* n. sp. Enay, p. 509, text-figs 155.2, 157, pl. 34: 1a, b, 2 (= holotype), 3, 4.

*Material.* – Two specimens from the Red Bed near Bharodia, Wagad Uplift (GZN2010I 046, 047).

*Description.* – Specimen GZN2010I 046 is wholly septate, with flanks partly obliterated. In specimen GZN2010I 047 the last septum is visible at a diameter of 64 mm, and is followed by the remnants of the body chamber for a distance of one and a quarter whorls. Coiling moderately evolute (GZN2010I 046) to weakly involute (GZN2010I 047). Whorl section suboval with flat flanks. Primary ribs moderately thick, rather densely spaced on the outer phragmocone and bifurcating. Points of division occurring slightly above mid-lateral height. Secondary ribs cross the venter with slight forward-directed sinuosity. Shell constricted.

*Remarks.* – The specimens studied differ from true representatives of *Perisphinctes* (*Dichotomoceras*) *bifurcatoides* Enay (1966, p. 509, text-figs 155.2, 157, pl. 34: 1a, b, 2 (= holotype), 3, 4; Meléndez, 1989, p. 315, text-figs 64, 65, 68, 69, pl. 52: 1–3, pl. 53: 1–3, pl. 54: 1–4; Gygi 2000a, p. 86, text-fig. 48, pl. 9: 2; Głowniak, Wierzbowski, 2007, p. 97, figs 57.1, 58, tab. 32) in their suboval whorl section (which is trapezoidal in *bifurcatoides*), and in their lower rib density on the innermost whorls, which in *bifurcatoides* is much higher. Nevertheless, the coiling of the whorls of the phragmocone, the narrow umbilicus and the large whorl height, the location of the division points of the ribs slightly above mid-lateral height plus the forward inclination of the ribs on the venter are common features indicating the affinity of the described forms with *P. (D.) bifurcatoides*.

*Perisphinctes* (*Dichotomoceras*) *bifurcatus* (Quenstedt, 1847) shows a similar coiling and ornamentation including low division points, but it has a distinctly stronger forward inclination of the ribs on the venter, thinner and sharper ribs,

and is less densely ribbed on the outer whorls, as discussed by Enay, Gygi (2001, p. 458).

**Biochronostratigraphic range.** – *Perisphinctes (Dichotomoceras) bifurcatoides* occurs in the Stenocycloides Subzone of the Bifurcatus Zone (Meléndez, 1989; Gygi, 2000a; Głowniak *et al.*, 2010) assigned to the uppermost Middle Oxfordian (*e.g.*, Enay, Gygi, 2001) or to the unified Submediterranean Upper Oxfordian as discussed by Głowniak (2006).

*Perisphinctes (Dichotomoceras) cf. duongae*

Meléndez, 1989, emend. Gygi, 2000a (m)

(Pl. 1: 4a, b; Fig. 5A, B; Table 1)

1989. *Perisphinctes (Dichotomoceras) duongi* sp. nov. Meléndez, p. 325, pl. 56: 1 (= holotype), figs 2–6; text-figs 67–69.

**Material.** – One specimen from the Red Bed near Bharodia, Wagad Uplift (OUMNH JY.1131).

**Description.** – Specimen septate to 38 mm, with phragmocone whorls strongly weathered. Preserved body chamber extending for nearly one whorl. Whorl section of body chamber suboval, with convex flanks, rounded venter and maximum whorl thickness slightly above the umbilical margin. Ornamentation consisting of moderately thin, prorsiradiate ribs, which bifurcate into secondaries of similar thickness at around two-thirds of lateral height. Occasionally, intercalatory secondary ribs present. Secondary ribs slightly backward directed and crossing the venter with forward-di-

rected sinuosity. Constrictions shallow; on the body chamber associated with two undivided primary ribs.

**Biochronostratigraphic range.** – According to Meléndez (1989, p. 325, pl. 56: 1 (= holotype), figs 2–6; text-figs 67–69) *Perisphinctes (Dichotomoceras) duongae* (see also Gygi, 2000a, p. 86, pl. 9: 4; Głowniak, Wierzbowski, 2007, p. 100, tab. 35) occurs in the Stenocycloides Subzone of the Bifurcatus Zone in the Submediterranean Upper Oxfordian.

*Perisphinctes (Dichotomoceras) aff. rotoides* Ronchadzé, 1917

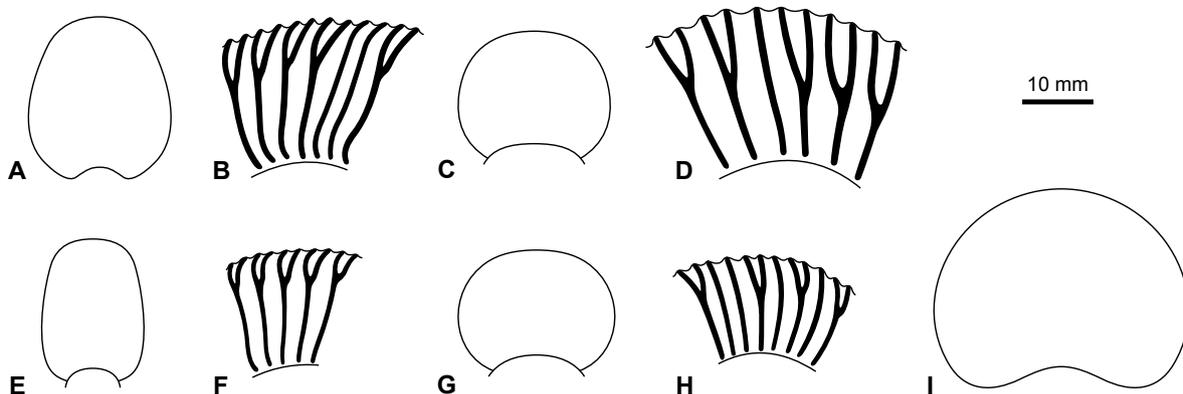
(Pl. 2: 2a, b; Fig. 5C, D; Table 1)

1931a. ?*Biplices* sp. nov. aff. *boehmi* (Steinmann); Spath, p. 425, pl. 69: 2a, b.

**Material.** – One specimen from the Red Bed near Bharodia, Wagad Uplift (GZN2010I 057).

**Description.** – GZN2010I 057 is a wholly septate specimen. Flanks eroded. Coiling moderately evolute. Whorl section subrounded, slightly depressed. Ornamentation consisting of moderately thick, slightly prorsiradiate primary ribs branching into two secondary ribs slightly below the ventrolateral margin. Secondary ribs cross the venter with very slight forward-directed sinuosity. Obscure constrictions occur on the outer whorl.

**Remarks.** – Specimen GZN2010I 057 differs from true representatives of *Perisphinctes (Dichotomoceras) rotoides* Ronchadzé (1917 p. 11, pl. 1: 8; Collignon, 1959a, pl. 64: 287; Enay, 1966, p. 467, figs 138.1–2, pl. 27: 9, 11, non fig. 10; Gygi, 2000a, p. 84, pl. 9: 1; Krishna *et al.*, 2009b, p. 473,



**Fig. 5.** A, B. *Perisphinctes (Dichotomoceras) cf. duongae* Meléndez, 1989 emend. Gygi, 2000a; A. Whorl section at ca. 68 mm diameter, OUMNH JY.1131. B. Ribbing pattern at ca. 66 mm diameter, OUMNH JY.1131. C, D. *Perisphinctes (Dichotomoceras) aff. rotoides* Ronchadzé, 1917; C. Whorl section at ca. 71 mm diameter, GZN2010I 057. D. Ribbing pattern at ca. 70 mm diameter, GZN2010I 057. E, F. "*Orthosphinctes*" sp.; E. Whorl section at ca. 63 mm diameter, GZN2010I 059. F. Ribbing pattern at ca. 56 mm diameter, GZN2010I 059. G, H. *Perisphinctes* subgen. and sp. ind.; G. Whorl section at ca. 60 mm diameter, GZN2010I 048. H. Ribbing pattern at ca. 50 mm diameter, GZN2010I 048. I. *Pachysphinctes* sp. cf. *symmetricus* Spath, 1931; whorl section at unknown diameter, GZN2010I 1025

pl. 1: 2a, b, 4a, b, 5a, b) in its weak forward inclination of ribs on the venter and coarser ribbing. Other characters, such as coiling and rib-thickness, do not differ significantly from this species.

The specimen matches the specimen assigned by Spath (1931a, p. 425, pl. 69: 2a, b) to *?Biplices* sp. nov.? aff. *boehmi* (Steinmann, 1881) from the same locality and horizon.

*Biochronostratigraphic range.* – *Perisphinctes* (*Dichotomoceras*) *rotoides* Ronchadzé, 1917 is diagnostic of the *Rotoides* Subzone, Schilli Zone (Gygi, 2000b) in the upper Middle Oxfordian, but partly correlates with the lower part of the *Bifurcatus* Zone in the unified Submediterranean Upper Oxfordian as discussed by Główniak (2006).

#### Genus *Subdiscosphinctes* Malinowska, 1972

Type species: *Perisphinctes kreutzii* Siemiradzki, 1891 (m).

##### *?Subdiscosphinctes* sp.

(Pl. 1: 3a, b; Pl. 2: 3; Fig. 4B; Table 1)

2001. *Subdiscosphinctes* (*Subdiscosphinctes*) sp.; Enay, Gygi, p. 464, pl. 3: 4, text-fig. 8, tab. 3.

*Material.* – Two specimens from the Red Bed near Bharodia, Wagad Uplift (GZN2010I 051, 053).

*Description.* – Two small, wholly septate specimens. Last preserved whorls covering about one-third of the preceding whorl. Whorl section subrounded or transversely oval. Ornamentation consisting of fine, sharp, closely spaced, prorsiradiate primary ribs. Ribs bifurcate regularly into secondary ribs of same thickness, which cross the venter with slight forward-directed sinuosity. Points of division appearing at two-thirds of whorl-height. Constrictions are oblique.

*Remarks.* – The specimens described resemble those assigned to the species “*jelskii*” (Siemiradzki, 1891) by Spath (1931a, p. 457, pl. 71: 2a, b, pl. 78: 5), which are from the same locality and show a similar coiling, whorl section, and shell ornamentation. Spath’s (1931a) assignation of specimens from Bharodia to “*Lithacoceras jelskii*” was, however, misleading (both in terms of species- and genus-level interpretations), as the original type of *Perisphinctes jelskii* as described by Siemiradzki (1891) is a large macroconchiate species of the genus *Subdiscosphinctes* (cf. the lectotype of *S. jelskii* first illustrated by Główniak, Wierzbowski, 2007, figs. 16–17).

*Biochronostratigraphic range.* – The genus *Subdiscosphinctes* Malinowska (both micro- and macroconchs) first occurs in the uppermost Transversarium Zone in the Middle Oxfordian and ranges higher up into the lower Upper Oxfordian (*Bifurcatus* Zone) (e.g., Enay, Gygi, 2001; Główniak, 2006).

#### Subfamily **Prososphinctinae** Główniak, 2012

Genus *Larcheria* Tintant, 1959

Type species: *Larcheria larcheri* Tintant, 1959 (M)

##### *?Larcheria* sp. (M)

(Pl. 2: 1a, b; Fig. 4D, E; Table 1)

*Material.* – One specimen from the Red Bed near Bharodia, Wagad Uplift (OUMNH JY.1130).

*Description.* – Phragmocone of a macroconch. Ornamentation of the innermost whorls slightly obliterated due to weathering. Coiling changing from moderately evolute on inner whorls to involute on outer whorl. Whorl section oval with slightly arched flanks and fairly narrow, rounded venter. Umbilical wall moderately high, steep. Ornamentation of inner whorls consisting of moderately thick, moderately densely spaced, slightly prorsiradiate ribs. Ribs on the flanks of the outer whorl much more delicate, slightly falcoid to straight. They become blurred at mid-lateral height, where they indistinctly branch, mostly into two secondaries. Intercalatory secondary ribs rare. Occasionally, simple ribs present, or irregular bifurcating ribs arising at mid-flank. Secondary ribs cross the venter with slight forward-directed sinuosity. Constrictions shallow.

*Remarks.* – From well known European macroconchiate species of *Larcheria* described by Tintant (1959, pl. 1: 4: *L. larcheri*; pl. 2: 2–3: *L. latumbilicata*; pl. 2: 4: *L. gignyensis*), specimen OUMNH JY.1130 differs in its bifurcations dominating up to the largest diameters, intercalatory ribs being rare, and thus in having a lower secondary-primary rib ratio per whorl, plus in the occurrence of irregular ribs on the outer phragmocone whorls (bifurcating, but arising at mid-flank or remaining undivided). Other features such as its discoidal shell, blurred primary ribs and high proportion of whorl height to umbilicus width (larger than 1) on the outer phragmocone indicate the affinity of specimen OUMNH JY.1130 to the genus *Larcheria*. The specimen closely resembles *Larcheria latumbilicata* Tintant (1959, pl. 2: 2, 3) due to moderately evolute coiling of its inner whorls and rather thick and fairly densely spaced, and slightly prorsiradiate ribs on the flanks. This specimen, however, has a narrower umbilical width and larger whorl-height ratio of the outer phragmocone as compared to *Larcheria latumbilicata*.

In contrast to any species of *Subdiscosphinctes*, with which specimen OUMNH JY.1130 could be confused, this specimen differs in having a proportion of the whorl height to umbilicus width larger than 1, in the occurrence of irregular branching of ribs on the outer whorl of the phragmocone, and in its thicker and only slightly prorsiradiate primary ribs on the inner whorls.

*Lithacoceras indicum* Spath (1931a, p. 462, pl. 71: 1, pl. 72: 1) has been described from the Kanthkot Sandstone of an unknown locality in the Wagad Uplift of the Kachchh Basin. *Lithacoceras indicum* shows similar ornamentation and coiling, but due to the distorted and compressed preservation of the present phragmocone, a more precise comparison is not possible.

*Biochronostratigraphic range.* – *Larcheria* is a taxon of limited geographic distribution in southwestern Europe (Meléndez, Fontana 1993; Głowniak, 2012). It has its acme in the Schilli Subzone in the Gygi's (2000b) Schilli Zone. The unified Middle and Upper Oxfordian substage boundary horizon in the Submediterranean Oxfordian zonation falls within the Schilli Subzone of the Schilli Zone as argued by Głowniak (2006). *Larcheria* has been recorded from Kachchh previously (e.g., Krishna *et al.* 1995, 1996a).

Family Ataxioceratidae Buckman, 1921

Subfamily Ataxioceratinae Buckman, 1921

Genus *Orthosphinctes* Schindewolf, 1925

Type species: *Ammonites tiziani* Opper, 1863.

“*Orthosphinctes*” sp.

(Pl. 3: 1a, b; Fig. 5E, F; Table 1)

*Material.* – One specimen from the upper Adhoi Member east of Adhoi, Wagad Uplift (GZN2010I 059).

*Description.* – Specimen small, wholly septate, evolute, compressed. Whorl-section oval with slightly arched to flatish flanks merging smoothly with the narrowly rounded venter. Ornamentation consisting of fine, closely to moderately spaced, prorsiradiate primary ribs, which branch regularly just below the ventrolateral shoulder into two secondary ribs of the same thickness. Points of bifurcation are hidden by subsequent whorls. Secondary ribs are progressively and subtly longer in the outer whorl preserved. Secondary ribs cross the venter with slight, forward-directed convexity. Adoral secondary ribs bend slightly forward. No parabolic formations occur. Occasionally, a single rib occurs along constrictions where it seems to correspond to its adoral margin. Constrictions are shallow, at least three per whorl, and parallel to ribs. On the outer whorl there is a case in which the bifurcate rib subsequent to the constriction shows a typical, subtle sinuosity, just below the point of bifurcation.

*Remarks.* – The incomplete phragmocone shows a recurrent sculpture among Oxfordian and Kimmeridgian platynota and moderately evolute ammonites – namely, quasi-exclusive bifurcate and blunt rather than sharp ribs with

shallow inter-rib spaces, slight ventral projection, and some shallow constrictions parallel to the ribbing. Among Lower Kimmeridgian taxa, several genera developed conservative sculpture on the inner whorls comparable to those analysed in specimen GZN2010I 059, and more material is necessary before its age can be conclusively assigned.

From the Middle Oxfordian *Dichotomosphinctes* (e.g., *luciaeformis* Enay – *dobrogensis* Simionescu morphological clades) to the Upper but not uppermost Kimmeridgian *Dis-cosphinctoides* (e.g., *roubyanus* Fontannes – *praenuntians* Fontannes – *vandellii* Choffat morphological clade), the sculptural pattern varies between radial and bifurcate ribs with a variable occurrence of simple ribs in the former genus, and more oblique ribbing with the occurrence of scarce intercalatory ribs in the latter. Typical specimens of the genus *Dichotomoceras* Buckman, 1919 show more excavated inter-rib spaces, which is evident in the forward-projecting ventral ribs. Oxfordian–Kimmeridgian ammonites with colubrinoïd appearance (*i.e.*, serpenticone shells with rounded whorl sections and usually well marked constrictions) represent a clearly separate morphological group with variable sculpture (e.g., *Nautilus colubrinus* Reinecke and morphologically related forms).

Concerning the better known European planulate ammonites, the sculpture with its ribs mainly bifurcating in forward-directed secondaries and shallow constrictions parallel to the ribbing could point to the morphologically conservative genera *Orthosphinctes* Schindewolf, 1925 and *Dis-cosphinctoides* Olóriz, 1978, while *Subnebrodites* Spath, 1925 and *Idoceras* Burckhardt, 1906 clearly differ by the type of their sculpture on the flanks and especially the venter. The genus *Orthosphinctes* has been reported from variable levels within the Platynota Zone elsewhere in Europe.

The sculpture in specimen GZN2010I 059 includes at least three shallow constrictions on the outer whorl and could recall morphologically conservative specimens of *Orthosphinctes* cf. *fontannes* (Choffat, 1893) as described by Wierzbowski *et al.* (2010, pl. 11: 2) from the Bimammatum Subzone (see also Olóriz *et al.*, 1999). However, the Polish specimen is larger, developed more constrictions, intercalatory ribs, and more complicated ribbing in shells larger than 100 mm. The inner whorls of *O. (Pseudorthosphinctes) fontannes* (Choffat) in Głowniak, Wierzbowski (2007, fig. 67) could agree with the shell type and sculpture of specimen GZN2010I 059. However, the paratype of *Perisphinctes fontannes* illustrated by Choffat (1893, pl. 9: 2) shows two irregular ribs closely adjacent and preceded by two single ribs (?teratology), longer secondary ribs, and more radial ventral ribs than specimen GZN2010I 059. A lesser forward projection of the secondary ribs and deeper and more oblique constrictions on the inner whorls can be clearly identified on the specimen of *Orthosphinctes fontannes*

(Choffat) illustrated by Atrops, Marques (1988, pl. 2: 1), which was collected from the Bimammatum Zone, Hypselum Subzone, east of the village Pereiro in the Sierra de Monteunto, Portugal. From the same bed 10 at the Cabanas-de-Torres section in the Monteunto Beds, Choffat (1893, pl. 10: 2) illustrated a morphologically closer specimen interpreted as *Perisphinctes* sp. nov. aff. *aeneas* Gemmellaro. The latter specimen shows similar but denser ribbing with rib projection on the venter, rare single and intercalatory ribs. This taxon was also collected from bed 12, together with *Orthosphinctes delgadoi* (Choffat), *O. mogosensis* (Choffat), and *Subnebrodites* cf. *laxevolutum*, indicating a Planula Chron age for the upper range of the ammonites that Choffat (1893) interpreted as *Perisphinctes* sp. nov. aff. *aeneas* Gemmellaro. Ataxioceratina collected from the overlying Abadia Marls range throughout higher horizons in the Platynota Zone and the Lower Kimmeridgian (see also Atrops, Marques, 1986, 1988). Local records of forms belonging to the morphological clade of *O. mogosensis* (Choffat), with slightly tighter coiling and without intercalatories are known from the Bimammatum/Planula zonal boundary in northern Switzerland, but these show more oblique and excavated constrictions – e.g., *Orthosphinctes* (*O.*) cf. *mogosensis* (Choffat) of Gygi (2003, fig. 54). Among *Orthosphinctes* with forward projection of ventral ribs in the lower Platynota Zone, *O. postcolubrinus* (Wegele) shows more evolute shells with stronger ribbing, deeper constrictions, and variable development of intercalatory ribs (Gygi, 2003, fig. 86).

Among European Early Kimmeridgian ataxioceratina related to *Orthosphinctes*, small, conservative specimens of *Lithacosphinctes* Olóriz, 1978 and *Ardescia* Atrops, 1982, as well as inner whorls of their larger representatives with complicated ribbing on the outer whorls, show comparable rib curves and ribbing index (*i.e.*, the number of peripheral ribs per ten primary ribs) according to Atrops (1982) and Moliner (2009). However, *Lithacosphinctes* develops parabolaes on the inner whorls and in the body chamber of small-sized species with low ribbing index (e.g., *L. schaireri* of Moliner, 2009, pl. 3: 3; *Ardescia schaireri* of Atrops, 1982, pl. 4: 4), as well as more excavated, oblique constrictions on the inner whorls. In addition, *Ardescia* shows weaker ribbing in forms with a favourable combination of rib curve and ribbing index (e.g., inner whorls of the *Ardescia enayi* group), and more radial ribbing with the possibility for parabolaes to occur in conservative specimens of *Ardescia* sp. A of Atrops (1982, p. 103 and pl. 45: 2) at the same shell size.

*Discosphinctoides* s. str. was erected by Olóriz (1978) for Upper but not uppermost Kimmeridgian ammonites belonging to the morphologically conservative clade defined by the nominal species *roubyanus* Fontannes – *praenuntians* Fontannes – *vandellii* Choffat, where the coiling is moder-

ately evolute and the ribbing can incorporate intercalatory and polygyrate ribs in adults (well developed in *vandellii* Choffat). The genus *Biplisphinctes* (Olóriz, 1978) is morphologically more distant and first occurs in the middle Upper Kimmeridgian, showing clearly colubrinoid shells with rounded whorl sections, constrictions, bifurcate and some simple ribs, and typically shorter secondaries with variable adoral projection on the venter.

Among the comparatively less known Oxfordian-Kimmeridgian ataxioceratina reported from the Indo-Malagasy Gulf, forms morphologically similar to specimen GZN2010I 059 were reported by Spath (1931a) from India. They were interpreted as *Dichotomosphinctes* from the Dhosa Oolite and the Kanthkot Sandstone, which correlate with the Middle to Upper Oxfordian, Transversarium to Bimammatum zones according to Spath (1933, p. 783–786). However, Enay (2009) interpreted the Dhosa Oolite to include the entire Lower and Middle Oxfordian, while the Kanthkot Sandstone would range from the Bifurcatus Zone to the Planula Zone, which he considered to represent the complete Upper Oxfordian (see also Pandey *et al.*, 2012). Compared with specimen GZN2010I 059, the smaller-sized *Dichotomosphinctes subhelenae* Spath (1931a, pl. 101: 4) from the Dhosa Oolite and the similar-sized *Dichotomosphinctes helenae* (De Riaz) of Spath (1931a, pl. 68: 9) from the Kanthkot Sandstone, vary slightly with respect to projection of the ventral ribs – more projected in the latter which has sharper ribs, less dense ribbing, and constrictions. The *Dichotomosphinctes falculae* (Ronchadzé) of Spath (1931a, pl. 68: 7) from the Kanthkot Sandstone, which is also of equivalent size to specimen GZN2010I 059, has longer secondary ribs and less dense ribbing in the last quarter of the outer whorl preserved.

Some Kimmeridgian “*Lithacoceras*” reported by Spath (1931a) from the Kanthkot Sandstone developed wider shells and ventral regions, tighter coiling, and longer secondary ribs without any relevant projection on the venter (e.g., “*L.*” *jelskii* in pl. 71: 2 and “*L.*” *pseudobangei* in pl. 97: 8). Other ammonites morphologically similar to specimen GZN2010I 059 were reported from the Middle Katrol Group in Kachchh by Spath (1933, pl. 130: 4, 5, 10) and interpreted as *Subplanites* sp. However, these morphologically conservative ammonites also show longer secondary ribs and more inflated shells, and come from uppermost Kimmeridgian to Lower Tithonian horizons according to the present-day biostratigraphy, based on the information given by Spath (1933, p. 791–792 and 864–865).

Some Middle Oxfordian to Lower Kimmeridgian ammonites described by Collignon (1959a, b) from Madagascar can also be morphologically compared with specimen GZN2010I 059. The Middle Oxfordian *Dichotomosphinctes* reported by Collignon (1959a) from his *Dichotomosphinctes*

*wartae* and *Proscaphites anar* biozone are much more evolute with shorter secondary ribs and show variably projecting ventral ribs: less projecting (e.g., *D. stenocycloides* in his pl. 65: 291), similarly projecting (e.g., *D. antecedens* in pl. 56: 271; *D. decari* in pl. 68: 297), and more projecting (e.g., *D. wartae* var. *bedoensis* in pl. 61: 281). *D. falculae* (pl. 75: 314) has stronger ribs.

The Upper Oxfordian (“Rauracian”) *Divisosphinctes* reported by Collignon (1959a) shows similar ribbing in lateral view but the ventral projection of the ribs is more accentuated in the slightly wider shells (e.g., *D. besairei* in his pl. 88: 351). Lower Kimmeridgian ammonites from the *Aspidoceras longispinum* – *Torquatisphinctes alterneplicatus* biozone interpreted by Collignon (1959b) as *Dichotomosphinctes* have more inflated shells and should be interpreted as related to *Torquatisphinctes* (e.g., *D. roubyanus*, as illustrated in his pl. 115: 439). The genus *Torquatisphinctes* has wider shells in the Indo-Madagascan area.

On the western margin of the Indo-Malagasy Gulf, comparable shell morphology and sculpture can be found in eastern Africa among Ethiopian, Somaliland, and Kenyan ammonites. From the Ethiopian Dogou, Harar region, Scott (1943) illustrated *Lithacoceras mombassanum* (Dacqué), a quasi-entirely septate specimen interpreted as indicating uppermost Oxfordian or lowermost Kimmeridgian horizons. The inner whorls of the specimen described by Scott (1943), 122 mm in shell size, resemble specimen GZN2010I 059 except for its slightly more radial ribbing on the flanks and the occurrence of some trifurcations in the outer whorls. In this Ethiopian specimen, adoral projection of the secondary ribs was identified by Scott (1943) but related to the potential effects of crushing. Also from the Harar region, Venzo (1959, pl. 1: 7) reported *Dichotomosphinctes jabolii* n.sp. from the Lower Kimmeridgian showing scarce intercalatory ribs at the end of the preserved outer whorl (up to 160 mm in size), and subtle ventral projection of ribs. This species was later reinterpreted as *Orthosphinctes* by Zeiss (1971, tab. 1), who also mentioned *O. tiziani* Oppel (again a morphologically conservative and evolute form) and referred it to rather imprecise Lower Kimmeridgian horizons. Unfortunately, Zeiss (1971) did not discuss *Orthosphinctes* in his text. *Lithacoceras mombassanum* (Dacqué in Venzo, 1959, pl. 2: 4; pl. 3: 1), interpreted as belonging to the Upper Oxfordian Bimammatum Zone and the Lower Kimmeridgian Tenuilobatus Zone, most probably represents another example of evolute, macroconchiate *Orthosphinctes* and younger recurrent morphologies, or equivalent endemic taxa (Venzo, 1959, p. 93 restricted *L. mombassanum* to the Lower Kimmeridgian). Interestingly, Venzo (1959, p. 92) proposed the morphological correlation of ataxioceratins from his Bimammatum Zone with the Portuguese ammonite assemblages illustrated by Choffat (1893). Younger ammonites

interpreted as *L. (Subplanites) mombassanum* (Dacqué), showing longer secondary ribs and large ventral regions crossed by radial ribs were reported from the Beckeri and Hybonotum zones in Yemen (Howarth, 1998, pl. 19: 1, 2 and pl. 20: 7).

Among Somaliland ammonites, Dacqué (1905) mentioned, without illustration, *Perisphinctes stenocyclus* Fontannes and *P. roubyanus* Fontannes, assuming a Lower Kimmeridgian age by correlation with Crussol (SE France). Accepting his age interpretation, and taking into account the different interpretation of Kimmeridgian substages at the time, the morphologically conservative specimens he analysed most probably were homeomorphs, or else these species would belong to the Upper but not uppermost Kimmeridgian as known in Crussol (SE France) and elsewhere in southern Europe. Hence, the possibility exists that these Ethiopian forms could reveal the occurrence of moderately evolute ammonites with uncomplicated ribbing and variable projection of ventral ribs in the Lower Kimmeridgian.

Spath (1925) reported a loose and poorly preserved specimen from Dar As (Somaliland) lacking the ventral region, and envisaged a potential “Middle Kimmeridgian” age. He interpreted the ammonite as *?Nebroditis* sp. ind. according to the low degree of coiling, and mentioned a close morphologic relationship with *Biplices*. This author made precise allusion to the morphologically conservative species *tiziani* Oppel (evolute *Orthosphinctes* with variable occurrence of intercalatories in present-day interpretations) as being similar but less densely ribbed.

Among Lower Kimmeridgian perisphinctids described and/or illustrated by Spath (1930) from Kenya, forms with uncomplicated ribbing and variable projection of the ventral ribs are common. They were interpreted as *Dichotomosphinctes* (and compared with the so-called *stenocyclus* group), *Prososphinctes* (showing idoceroid-like ribbing with distinct ventral projection), *Lithacoceras (mombassanum* Dacqué, excluding more involute variants, and with specimens referred to the *praenuntians* Fontannes – *roubyanus* Fontannes group), and *Biplices* (with allusion to European species such as *tiziani* Oppel, *mogosensis* Choffat, and *delgadoi* Choffat). Among all the material mentioned, the evolute specimens most probably represent *Orthosphinctes* or a related, endemic genus and species. Their belonging to the Lower Kimmeridgian must be accepted aside from the interpretation of this stage in the English sense by Spath (1930).

Its conservative sculpture, incomplete preservation (only septate whorls preserved) and its isolated record makes any taxonomic and age identification of specimen GZN2010I 059 inconclusive. Hence, the specimen has been envisaged as representing an incomplete microconch of “*Orthosphinc-*

tes” in reference to the morphologically conservative stock of Lower Kimmeridgian ataxioceratin.

*Biochronostratigraphic range.* – Specimen GZN2010I 059 from the Adhoi Member has been collected from fine-grained, poorly cemented sandstone around 4 m below the Upper Astarte Beds. According to Krishna *et al.* (2009c) the oldest deposits identified in the Adhoi Member of their Wagad Formation belong to the Planula Zone and are overlain by Lower Kimmeridgian deposits of the Platynota and Hypselocyclum zones. Krishna *et al.* (2009c, p. 13) reported *Orthosphinctes*, *Subnebrodites*, and *Ataxioceras*, without illustration, and assumed a Bimammatum to Hypselocyclum age for the Adhoi Member, which slightly contrasts with the age proposed in their figure 3. According to these authors, the upper boundary of the Adhoi Member is marked by the top of the Upper Astarte Beds, which implicates an Early Kimmeridgian Hypselocyclum age. Hence, the wholly septate specimen GZN2010I 059 described, and collected 4 m below the Upper Astarte Beds, must be Early Kimmeridgian in age, earlier than the Divisum age. On this basis, any previous taxonomic and biostratigraphic reference to ammonite genera belonging to both the Oxfordian and the Upper Kimmeridgian is excluded.

#### Subfamily Torquatisphinctinae Tavera, 1985

*Remarks.* – Spath (1931a, p. 465) argued for the significance of a “conservative biplicate perisphinctid root-stock, comprising *e.g.*, many so-called *Perisphinctes colubrinus* (Reinecke) and *P. pseudocolubrinus* (Kilian)” when focusing on analysing members of the *Torquatisphinctes-Pachysphinctes-Katrolicer* group occurring in Kachchh. He interpreted this morpho-evolutionary plexus as representing Kimmeridgian species but now it is known that it also includes Lower Tithonian ones (Krishna, Pathak, 1993; Krishna *et al.*, 1996b). Spath (1931a) emphasized both the commonness of morphological transitions in this group and the difficulty of interpreting specimens which are incomplete or poorly preserved. Olóriz (1978, p. 475, 478) considered *P. colubrinus* (Reinecke) and *P. pseudocolubrinus* (Kilian) as representative of a stock of Mediterranean perisphinctoids showing *colubrinus*-like typology that he interpreted as the evolutionary base (“estadiobase”) for distinct, morphologically more differentiated genera. Tavera (1985, p. 52) proposed the new subfamily Torquatisphinctinae (referring to Olóriz and Tavera *in litt.*) for Kimmeridgian and Lower Tithonian ammonites in his study of the Mediterranean Upper Tithonian and Berriasian succession of southern Spain. Among others, he included *Torquatisphinctes*, *Pachysphinctes*, and *Subdichotomoceras* and favoured their evolutionary origin in Ataxioceratinae with *Orthosphinctes*-like nuclei. Also focusing on Tithonian ammonites, Olóriz (*in*

Olóriz, Tintori 1990, p. 474) stated that the subfamily Torquatisphinctinae was proposed “in order to bring together forms which present “colubrinoid” inner whorls, and later bifurcate and polygyrate ribbing with few external intercalatory ribs”.

#### Genus *Torquatisphinctes* Spath, 1924

Type species: *Ammonites torquatus* J. de C. Sowerby, 1840.

*Remarks.* – Medium- to large-sized, evolute ammonite shells with sub-rectangular whorl sections in the outer whorls and relatively straight ribbing. Macro- and microconchs with dominant bifurcating and simple ribs on the phragmocone, together with intercalatory ribs on the body chamber, especially in large specimens. Rare, more complex, pseudo-polygyrate ribbing can occur on the body chamber of the larger specimens. Inner whorls difficult to distinguish from allied taxa.

Incomplete specimens can be indistinguishable from *Pachysphinctes*, except for the less tight coiling, less inflated whorls, and rather longer secondary ribs. Spath (1931a) highlighted the limitations with placing incomplete specimens in the *Torquatisphinctes-Pachysphinctes* morphological plexus that he included in his subfamily Virgatosphinctinae. Olóriz (1978, p. 448) recognized the polyphyletic character of the genus *Torquatisphinctes*, as interpreted at the time, with distinct morphologic plexa respectively related to *Discosphinctoides*-like ataxioceratin and to colubrinoid ones closer to the “Katrol Group”, and related to *Biplisphinctes*, these two taxa being related to the evolutionary basis for the “Katrol Group” (note that Olóriz, 1978 used “Katrol Group” for *Katrolicer* and allies).

*Biochronostratigraphic range.* – The genus *Torquatisphinctes* in Kachchh has been interpreted as an upper Lower (Alterneplacatus Zone) to Upper Kimmeridgian (lower Katrolensis Zone) taxon (*e.g.*, Krishna, Pathak, 1991, 1993; Pathak, 1993; Krishna *et al.*, 1996b; all these authors interpreting the Kimmeridgian as having a two-fold division), but occurrences in the Lower Tithonian of the same region and related areas were previously envisaged by Spath (1927–1933) and Collignon (1959b), at least for the Kimmeridgian-Tithonian boundary and the extreme base of the Tithonian in Madagascar, as now interpreted. A Lower Kimmeridgian to Lower Tithonian range has been assumed for records from western Tethyan areas, the eastern West Gondwanan Block (East African/South Arabian margin), western East Gondwanan Block (Madagascar and western Indian margin), and northeastern Himalayan records, within more or less explicit but diverse reinterpretations of the genus proposed originally by Spath (*e.g.*, Venzo, 1959; Geyer, 1961; Zeiss, 1968, 1971; Enay, Geysant, 1975; Olóriz,

1978; Vigh, 1984; Verma, Westermann, 1984; Cecca *et al.*, 1990; Sarti, 1993; Howarth, 1998; Howarth, Morris, 1998; Boughdiri *et al.*, 2005; Enay, 2009).

*Torquatisphinctes primus* Spath, 1931

(Pl. 4: 3a, b; Fig. 6A–E; Table 1)

1931a. *Torquatisphinctes primus* n. sp. Spath, p. 480, pl. 88: 6a, b, 7a, b.

1931a. *Torquatisphinctes acuticostatus* n. sp. Spath, p. 480, pl. 88: 2, 6a, b, 10a–c.

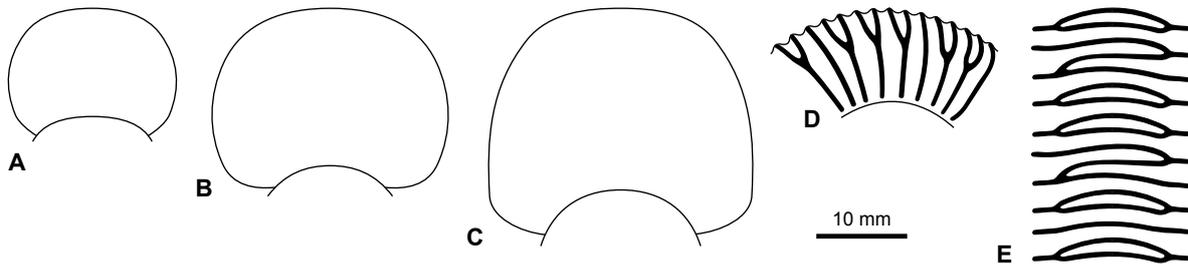
**Material.** – One specimen from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 026).

**Description.** – Shell moderately large to large, evolute, with a part of the body chamber preserved. Inner whorls depressed, outer whorl more compressed. Whorl section in inner whorls subrounded; in outer whorls flanks become flat merging into rounded venter. Ribs originate thin and rursiradiate at the umbilical seam, become thick and sharp at the umbilical shoulder and continue distinctly prorsiradiate on flanks. Primary ribs gradually varicostate (fine with shorter secondaries on the inner whorls and coarser with longer secondaries on the outer whorls). Bifurcating ribs strongly dominate, whereas intercalated simple ribs are scarce. On the outermost whorl primary ribs branch lower, occasionally below the mid-lateral height. Secondary ribs cross the venter with slight forward-directed sinuosity. Occasionally, a zigzag pattern of ribs appears on the ventral side (Fig. 6E). Two constrictions per whorl.

**Remarks.** – The inner whorls of *Torquatisphinctes primus* Spath, 1931 are not preserved in both the specimens described and illustrated by Spath (1931a). Nevertheless, Spath (1931a, p. 480) stated that the inner whorls of *Torquatisphinctes primus* are the same as in *Torquatisphinctes torquatus* (J. de C. Sowerby, 1840) which, however, is less depressed and shows more common simple ribs (Spath, 1931a, pl. 76: 4). The whorl section and ornamentation of

the inner whorls also match those in *Torquatisphinctes alterneplicatus* (Waagen, 1875) var. *neglecta* Spath, 1931, but this taxon shows a finer ribbing and more common single, undivided primary ribs. Among *Torquatisphinctes* species described by Spath (1931a) showing finer, denser ribbing with more abundant simple ribs, *Torquatisphinctes similis* (Spath, 1931a, pl. 78: 3) has a more rounded whorl section, whereas *Torquatisphinctes habyensensis* (Spath, 1931a, pl. 88: 5, 6) has a more quadrate one. *Torquatisphinctes acuticostatus* Spath was considered conspecific to *primus* by Pathak (1993), which results in broadening the intra-specific diversity in terms of number and strength of ribs. Pathak (1993) also envisaged the potential synonymy of *T. primus* Spath and *T. torquatus* (J. de C. Sowerby). However, the type of the Sowerby's species is completely septate (Spath, 1931a, p. 475) and could be either incomplete, or immature (Verma, Westermann, 1984, p. 39).

**Biochronostratigraphic range.** – According to the synonymy list proposed by Pathak (1993) for *Torquatisphinctes torquatus* (J. de C. Sowerby), *Torquatisphinctes primus* was considered as a potential, compressed variant that was not interpreted in biostratigraphic terms. Assuming the biostratigraphic range he proposed for *T. torquatus* (Sowerby), *T. primus* Spath could belong to an indeterminate interval within the Upper Kimmeridgian, from the upper part of the Intermedius–Acanthicum Zone to the lower part of the Katrolensis Zone. *Torquatisphinctes primus* Spath was identified among the ammonite assemblage characterizing the “*Aspidoceras longispinum*–*Torquatisphinctes alterneplicatus*” biozones in Kimmeridgian deposits of Madagascar as interpreted by Collignon (1959b). *Torquatisphinctes cf. primus* Spath has been reported by Enay (2009) from the lower part of the *Parabolerias* Beds in the Spiti Shales of Nepal, which could indicate a late Kimmeridgian age. Outside the Indo-Madagascan area, Zeiss (1971) reported *Torquatisphinctes primus* Spath from his lowermost Tithonian *Subplanites scarsellai* biozone of Ethiopia. Fatmi, Zeiss (1999)



**Fig. 6.** *Torquatisphinctes primus* Spath, 1931; **A.** Whorl section at ca. 49 mm diameter, GZN2010I 026. **B.** Whorl section at ca. 66 mm diameter, GZN2010I 026. **C.** Whorl section at ca. 91 mm diameter, GZN2010I 026. **D.** Ribbing pattern at ca. 31 mm diameter, GZN2010I 026. **E.** Schematic ribbing pattern on the venter at ca. 31 mm diameter, GZN2010I 026

reported *Torquatisphinctes* aff. *primus* from their Middle Ammonite Assemblage in southern Balochistan, Pakistan, without precise reference of the biozone level. Within the epiocenic Tethys, Vigh (1984) reported *Torquatisphinctes* sp. (ex gr. *primus-acuticostatus* Spath) from the Lower Tithonian Verruciferum Zone. Olóriz (1978) reported *Torquatisphinctes* sp. cf. *primus* Spath from the Lower Tithonian of southern Spain and regarded *Subplanitoides* cf. *acuticostatus* (Spath in Enay, Geysant, 1975) from the Semiforme/Verruciferum Zone as a potential synonym.

Specimen GZN2010I 026, collected from the basal Katrol Formation near Ler, southeast of Bhuj, most probably indicates Upper Kimmeridgian horizons within the upper part of the Intermedius–Acanthicum Zone to the lower part of the Katrolensis Zone.

*Torquatisphinctes alterneplicatus* (Waagen, 1875)

(Pl. 4: 2a, b; Fig. 7A–E; Table 1)

1875c. *Perisphinctes alterneplicatus* n. sp. Waagen, p. 199, pl. 50: 2.

1931a. *Torquatisphinctes alterneplicatus* (Waagen); Spath, p. 477, pl. 87: 1a, b.

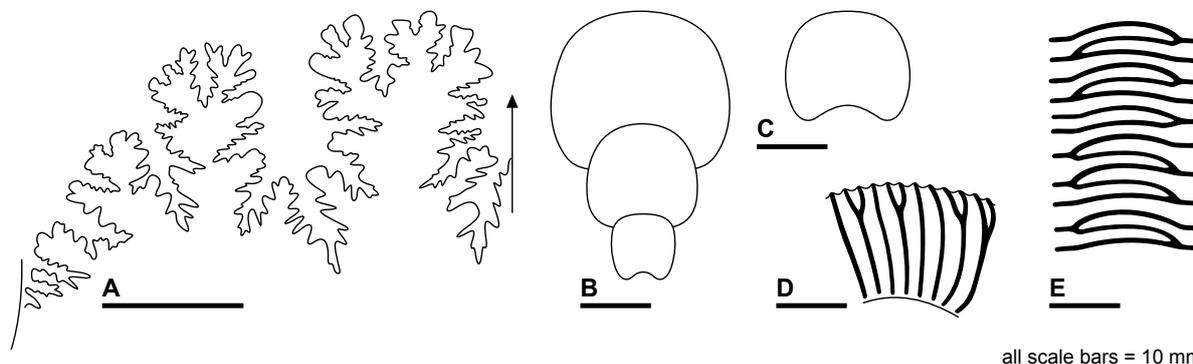
**Material.** – Three specimens. Two specimens from the Belemnite Marls near Jawahar Nagar (*i.e.* Jhuran; GZN 2010I 028, 030) and one specimen from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1026).

**Description.** – Shell moderately large, wholly septate, evolute. Whorl section subrounded to subquadrangular with flat to slightly arched flanks and rounded venter. Ornamentation consisting of fine, sharp, dense, varicostate, prorsiradial primary ribs, which usually bifurcate slightly below the ventrolateral shoulder. Commonly, single, undivided primary ribs on one side create a zigzag pattern of ribs on the ventral side (Fig. 7E). Secondary ribs cross the venter with

slight forward-directed sinuosity. Constrictions present parallel to ribbing and as wide as the space between ribs and accompanied by a single, undivided primary rib. Umbilical shoulder rounded with low, steep umbilical wall.

**Remarks.** – The specimens are fragments of phragmocones broken at different diameters, enabling the study of the whorl section at consecutive whorls but imposing limitations for a conclusive, comparative interpretation. Their ornamentation and whorl section matches *Torquatisphinctes alterneplicatus* (Waagen, 1875). Spath (1931a) differentiated two variants within this species: *Torquatisphinctes alterneplicatus* var. *maculata* and *T. alterneplicatus* var. *neglecta* depending on their dimensions and ribbing density. However, as both variants occur at the same locality and stratigraphic level and exhibit similar whorl height to thickness ratios, these forms should be combined in a single taxon, which only shows minor variations in whorl section and density of ribs (morphotypes). Other *Torquatisphinctes* species described by Spath (1931a) with relatively fine ribbing are *Torquatisphinctes similis* (Spath, 1931a, pl. 78: 3), which is more inflated and has rounded whorl sections, whereas *Torquatisphinctes habyensensis* (Spath, 1931a, pl. 88: 5, 6) has a more quadrate one. *Torquatisphinctes intermedius* (Spath, 1931a, pl. 82: 6) could be a close relative. These three species described by Spath (1931a) have fewer simple ribs but probably belong to the same morphological plexus (?conspecificity).

**Biochronostratigraphic range.** – *Torquatisphinctes alterneplicatus* (Waagen) has been commonly reported from both margins of the Malagasy Gulf and subsequent seaway, with reference to late Early to Late Kimmeridgian ages (*e.g.*, from west to east, Zeiss, 1971 for Ethiopia; Collignon, 1959b for Madagascar; Waagen, 1875, Spath, 1931a, 1933; Krishna, Pathak, 1991; Pathak, 1993; Krishna *et al.*, 1996b, 2002 for Kachchh; and Fatmi, Zeiss, 1999 for Balochistan).



**Fig. 7.** *Torquatisphinctes alterneplicatus* (Waagen, 1875); **A.** Suture line at ca. 88 mm diameter, GZN2010I 028. **B.** Whorl section at ca. 88 mm diameter, GZN2010I 028. **C.** Whorl section at ca. 58 mm diameter, GZN2010I 028. **D.** Ribbing pattern at unknown diameter, GZN2010I 028. **E.** Schematic ribbing pattern on the venter at unknown diameter, GZN2010I 028

*Torquatisphinctes* aff. *alterneplicatus* has been reported by Krishna *et al.* (1982) from the Lower Tithonian *Torquatisphinctes–Aulacosphinctoides* assemblage gathered from the Spiti Shales in the Indian Himalaya.

The three specimens from two sections in the eastern Kachchh Mainland most probably indicate the upper Lower to lower Upper Kimmeridgian *i.e.*, the *Alterneplicatus* Zone to upper but not uppermost *Intermedius–Acanthicum* Zone.

*Torquatisphinctes sparsicostatus* (Spath, 1931)

(Pl. 5: 3a, b; Fig. 8A, B; Table 1)

1931a. *Pachysphinctes bathyplocus* (Waagen) var. *sparsicostata* Spath p. 495, pl. 78: 6.

1931a. *Pachysphinctes bathyplocus* (Waagen) var. *serpentina* Spath p. 495, pl. 88: 1.

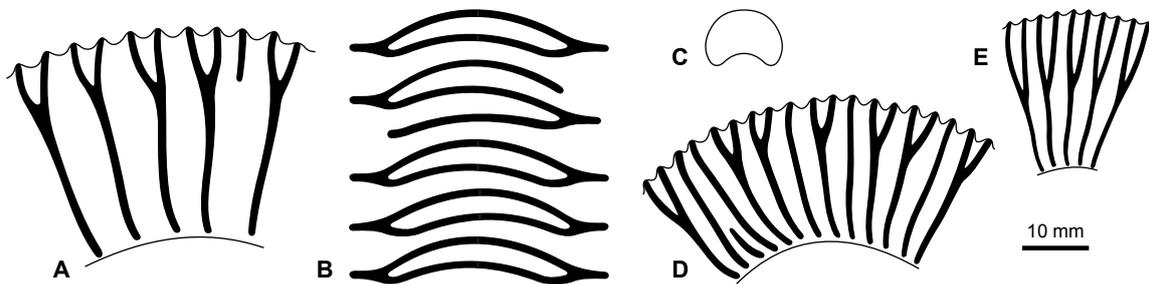
?1996b. *Torquatisphinctes bathyplocus* (Waagen); Krishna *et al.*, p. 200.

**Material.** – One specimen from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1001).

**Description.** – Shell large, evolute, with a part of body chamber. Whorl section subquadrate with slightly arched flanks and venter. Ornamentation consisting of sharp, thick, distant, prorsiradiate, primary ribs with slightly forward-directed concavity just above the umbilical shoulder. Generally, primary ribs bifurcate slightly below the ventrolateral shoulder (branching points are mostly visible in the umbilicus). Occasionally, intercalatory secondary ribs cause a zig-zag pattern of ribs on the ventral side (Fig. 8B). In the outermost part of the shell, primary ribs seem to branch into three secondary, “pseudopolygyrate” ribs since they show an incomplete trend towards a polygyrate pattern linked to enlarged inter-primary-rib spaces (true polygyrates show a longer adoral secondary rib). Secondaries cross the venter with slight forward-directed sinuosity.

**Remarks.** – Numerous morphological transitions exist between *Torquatisphinctes* and *Pachysphinctes*, which were identified, and commented upon, by Spath (1931a), especially when dealing with the species *bathyplocus* (Spath, 1931a, p. 493–496). This author emphasized that the ribbing complexity on the body chamber separated the genera *Torquatisphinctes* and *Pachysphinctes*, the latter commonly showing inflated to depressed whorl sections, and less commonly maintaining subquadrate whorl sections. Given that population level collections are not available and the precise ontogenetic development of *Torquatisphinctinae* from Kachchh is incompletely known, we follow Spath’s guidelines for distinguishing *Torquatisphinctes* from *Pachysphinctes*. Hence, small-sized specimens with conservative ribbing on the body chamber are interpreted as *Torquatisphinctes*. Incomplete specimens are difficult to interpret; *e.g.*, the small specimen illustrated by Waagen (1875c, pl. 50: 1a, b) as *P. bathyplocus* is not a good representative of the species described by this author (Waagen, 1875c, p. 192–193) and could better be referred to *Pachysphinctes* according to his description but not illustration.

The specimen described here is most probably immature due to its small size and conservative ribbing on the body chamber. It matches the illustration of the small-sized *Perisphinctes bathyplocus* Waagen (1875c, pl. 50: 1a, b), which is incomplete with potential for subtle taphonomic compression of the outermost part of the preserved shell. Particularly similar are the illustrations of *Pachysphinctes bathyplocus* (Waagen) var. *sparsicostata* Spath (1931a, p. 495) and *Pachysphinctes bathyplocus* (Waagen) var. *serpentina* Spath (1931a, p. 495). Since the former is an almost complete specimen and in the latter only the posterior part of the body chamber is preserved, these variants of Spath are here interpreted as *Torquatisphinctes sparsicostatus* (Spath). *Torquatisphinctes primus* Spath, 1931 has similar ribbing on the in-



**Fig. 8.** A, B. *Torquatisphinctes sparsicostatus* (Spath, 1931); A. Ribbing pattern at ca. 112 mm diameter, GZN2010I 1001. B. Schematic ribbing pattern on the venter at ca. 112 mm diameter, GZN2010I 1001. C, D. *Torquatisphinctes* sp. gr. *intermedius* Spath, 1931 – *alterneplicatus* (Waagen, 1875); C. Whorl section at unknown diameter, GZN2010I 038. D. Ribbing pattern at ca. 69 mm diameter, GZN2010I 041. E. ?*Torquatisphinctes* sp.; ribbing pattern at ca. 62 mm diameter, GZN2010I 039

ner whorls, but on its outer whorls the ribbing is finer with branching points lower on the flanks, the umbilicus is slightly smaller, and the shell is compressed. *Torquatisphinctes jurunensis* Spath, 1931 has longer and denser primary ribs and common intercalatories on the body chamber. *Torquatisphinctes acuticostatus* Spath, 1931 is more involute with denser ribbing, which also applies to *Torquatisphinctes similis* Spath, 1931.

*Biochronostratigraphic range.* – *Pachysphinctes bathyplocus* (Waagen) var. *sparsicostata* Spath and *P. bathyplocus* (Waagen) var. *serpentina* Spath were erected by Spath (1931a) within the diversity spectrum he envisaged for *Pachysphinctes bathyplocus* (Waagen). The latter species has been interpreted as index fossil for the lower, but not lowermost, Upper Kimmeridgian Bathyplocus Zone in Kachchh (Krishna, Pathak, 1991; Pathak, 1993; Krishna *et al.*, 1996b, 2002). Outside Indo-Madagascan areas, Dietrich (1933) reported *Per. (Pachysphinctes) cf. bathyplocus* from his “Middle Kimmeridgian” Tendaguru Beds, Tanzania. Fatmi, Zeiss (1999) identified *Pachysphinctes cf. bathyplocus* in their middle assemblage from Balochistan, Pakistan, and assumed a middle Upper Kimmeridgian age for Waagen’s species (Fatmi, Zeiss 1999, tab. 2). Enay (2009) reported *Pachysphinctes bathyplocus* from his Kimmeridgian *Parabolicseras* Beds.

Specimen GZN2010I 1001 from the basal Katrol Formation near Ler, southeast of Bhuj, most probably represents lower but not lowermost horizons of the middle Upper Kimmeridgian within the Bathyplocus Zone.

*Torquatisphinctes* sp. gr. *intermedius* Spath,  
1931 – *alterneplicatus* (Waagen, 1875)  
(Pl. 5: 1a, b, 2a, b; Fig. 8C, D; Table 1)

*Material.* – Five specimens. One specimen from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1035) and four specimens from the Astarte-Gryphaea Bed (basal Upper Astarte Beds) near Bharodia, Wagad Uplift (GZN2010I 038, 041, 042, 043).

*Description.* – Shell small to moderately large, evolute, nearly complete with body chamber spanning two-thirds of the last whorl. Whorl section subcircular to slightly depressed with slightly arched flanks merging into the rounded venter. Ornamentation consisting of moderately coarse and well-spaced, sharp, prorsiradiate primary ribs connecting with two secondary ribs of the same thickness between the mid-lateral height and the ventrolateral shoulder. Single, undivided primary ribs are common and cause a zigzag pattern of ribs on the ventral side. Rarely, two single, undivided primary ribs occur next to each other. Secondary ribs cross the venter almost straight on inner whorls and with slight forward-directed sinuosity on the body chamber.

*Remarks.* – A morphological plexus showing coarser to finer ribbing with increasing number of simple ribs is represented by the mainly septate specimens illustrated by Spath (1931a) as “species” *primus* – *torquatus* – *habyensis* – *intermedius* – *alterneplicatus* var. *neglecta* – *alterneplicatus*, in which *primus* and *intermedius* are the only types of Spath that include a partially preserved body chamber. *Torquatisphinctes primus* Spath was analysed above. *Torquatisphinctes torquatus* (J. de C. Sowerby, 1840) has a less depressed shell and finer, more numerous ribs. *Torquatisphinctes intermedius* (Spath, 1931a, p. 482, pl. 81: 3, pl. 82: 6) differs from *alterneplicatus* in its slightly more depressed whorl section. *Torquatisphinctes alterneplicatus* (Waagen, 1875) has a similar umbilical diameter and, in general, finer ornamentation, but the whorl section in the present specimens is more depressed in the inner whorls and later rounded. Nevertheless, one specimen assigned to *Torquatisphinctes alterneplicatus* var. *neglecta* by Spath (1931a: pl. 94: 4a, b) is septate and shows a similar but lower whorl section and slightly finer, dense ribs, and could belong to the intra-species morphological diversity. Spath (1931a) envisaged a large variability in shell type and coarseness of sculpture for his *Torquatisphinctes alterneplicatus* (Spath, 1931a, p. 477, pl. 87: 1a, b), and the intermediate forms with his *Torquatisphinctes intermedius*. ?*Torquatisphinctes lunulaticatus* Spath (1931a, pl. 95: 9a, b) is an entirely septate, morphologically close specimen with slightly higher whorl section and related to the coarse-ribbed forms without simple ribs in the mentioned morphological plexus. *Torquatisphinctes ruber* Spath (1931a, pl. 94: 1a, b) shows shorter secondary ribs and finer, denser ribbing. According to the sculptural trend from coarser to finer ribbing with increasing number of simple ribs, and based on the stratigraphic information in Spath (1933), no clear trend with respect to sculpture and shell type is shown throughout the large stratigraphic interval in which this morphological plexus occurs.

*Torquatisphinctes intermedius* and *alterneplicatus* represent a rather averaged morphology and sculpture within the morphological plexus mentioned above (Spath, 1931a, p. 482 assumed close affinity between these two species), and are the morphologically closest to the specimens described above. Therefore the *Torquatisphinctes intermedius* – *alterneplicatus* group is selected as reference for the morphological plexus mentioned, as the precise identification of species is not possible at present. Hence, even though some particular features have been recognized in the specimens described, the erection of a new species would be inappropriate before a more conclusive interpretation at the species level on the basis of population studies is reached.

*Biochronostratigraphic range.* – The interpretation made above of *Torquatisphinctes* sp. gr. *intermedius* Spath – *alterneplicatus* (Waagen) refers to an average shell morpholo-

gy and sculpture in the morphological plexus mentioned above. Hence no precise age within the stratigraphic interval (upper Lower to Upper but not uppermost Kimmeridgian) of the nominal species erected by Spath (1931a) can be given. Spath (1933) reported *Torquatisphinctes intermedius* from the Lower to ?Middle Katrol Group – *i.e.*, at least lower Upper Kimmeridgian in present interpretations. Following the biochronostratigraphy in Krishna *et al.* (1996b), an age close to the Early/Late Kimmeridgian boundary could be envisaged for the described *Torquatisphinctes* sp. gr. *intermedius*–*alterneplicatus*, (but see below).

Given that the specimens described were collected from separate sections and regions in Kachchh (Ler and Wagad, respectively), it is of interest to consider the reported FADs of the *Torquatisphinctes* “phragmocone-species” illustrated by Spath (1931a, 1933) and included in the morphological plexus mentioned above: *T. primus* was reported by Spath (1933) from the basal Katrol Formation with *Waagenia* (= *Hybonotoceras beckeri*) which could indicate Kimmeridgian horizons up to the uppermost Kimmeridgian. Dubious *T. torquatus* and *Torquatisphinctes* sp. from the Kanthkot Sandstone assigned by Spath (1933) to the middle Upper Oxfordian – the Planula Zone excluded – together with Indian ammonite species referred to *Ataxioceras*, are here reinterpreted as possible *Ardescia*, small *Ardescia* for *Ataxioceras praecox*, less probably ?*Orthosphinctes*, *Ardescia* gr. *desmoides* for *Ataxioceras kachchense*, and early *Ardescia* for those specimens of relatively large size (group of *enayi* Atrops, 1982 as revised by Moliner, 2009) for *Ataxioceras leiocymon*. All these ammonites point to Platynota Zone horizons (*e.g.*, see revision in Moliner, 2009), but Krishna *et al.* (1996b) assumed lowermost Upper Kimmeridgian horizons for their *Ataxioceras kachchense* and *A. leiocymon* within the Katrol Formation. Other ammonites from the ammonite assemblages of the Kanthkot Sandstone illustrated by Spath (1931a) are undoubtedly lower Upper Oxfordian species referable to *Dichotomoceras* and *Subdiscosphinctes*-like forms (*e.g.*, *Torquatisphinctes* sp. in Spath, 1931a, pl. 75: 7), the latter extending to the lowermost Platynota Zone (*e.g.*, Moliner, 2009), as well as other “*Lithacoceras*” species identified by Spath (1931a). *Torquatisphinctes habyensensis* and *T. intermedius* from the Middle Katrol assemblage (1931a, 1933), which is characterized by common *Pachysphinctes* and *Katroliceras*, thus indicate middle Upper to uppermost Kimmeridgian horizons. The *Torquatisphinctes alterneplicatus* var. *neglecta* and *Torquatisphinctes alterneplicatus* from the Belemnite Marls at Jhuran were interpreted by Spath (1933) as Lower Kimmeridgian with *Metahaploceras* below the basal Katrol Bed of southern Kachchh. Accordingly, the potentially oldest stratigraphic horizons for the specimens of *Torquatisphinc-*

*tes* sp. gr. *intermedius* – *alterneplicatus* described most probable range from the Lower Kimmeridgian Platynota Zone to horizons within the Upper Kimmeridgian, with the possibility that the age differs in the two sections studied near Ler and near Bharodia. The possibility for their belonging to older horizons in the Bharodia section seems more likely given the reduced thickness there that separates the record of Oxfordian and Kimmeridgian ammonites (Fig. 12), except for the confirmation of a relatively wide stratigraphic gap, which would be analogous to others reported from Kachchh (*e.g.*, Spath, 1933, p. 783, 789). However, *Torquatisphinctes alterneplicatus* var. *neglecta* and *Torquatisphinctes alterneplicatus* were reported from the Lower Kimmeridgian Belemnite Marls with *Metahaploceras* below the basal Katrol Bed at Joorun (= Jhuran; Spath, 1933, p. 787). It must be emphasized that Mishra (2009) interpreted the Lower and Upper Astarte Beds in Wagad, the latter near Bharodia, as transgressive sequences above highstand deposits (see also Fürsich, Pandey, 2003). Hence, the corresponding sequence boundaries at their bases would have associated stratigraphic gaps, which could explain the erosional basal contacts and the small thickness separating Oxfordian and Kimmeridgian ammonites in the Bharodia section (8 in Figs 1 and 12).

*Torquatisphinctes* sp.

(Pl. 6: 2a, b, 3; Table 1)

*Material.* – Two specimens from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1027, 1028).

*Description and remarks.* – These are fragmentary and partly distorted specimens. Specimen GZN2010I 1027 consists of parts of three whorls, possibly with partial preservation of body chamber. The whorl section changes from depressed and quadrangular in the inner whorls to more compressed in the outermost whorl preserved. The ornamentation consists of mainly biplicate ribbing with secondaries crossing the venter straight; intercalatory and potential polygyrate ribs occur (note a quasi-polygyrate rib preceded by a short intercalatory and bifurcate ribs in Pl. 6: 3). Specimen GZN2010I 1028 shows a wide-rectangular whorl section and a single “pseudopolygyrate” rib (no connection with the anterior, longer intercalatory rib), which is rather bizarre since it shows a rursiradiate course of the primary rib that is uncommon among the ammonites analysed. It is worth mentioning that this does not alter the ribbing style (*e.g.*, producing larger inter-rib spaces), and the ribbing is not affected. Thus, the “pseudopolygyrate” rib most probably results from the intersection of intercalatory, peripheral and interrupted-simple ribs with a transitory peristome, which would indicate a microconchiate individual.

The genus level assignment for these two specimens is doubtful partly due to the limited preservation. The depressed inner whorls, wide sub-rectangular outer whorls, and the moderately thick ribs can be interpreted to fit *Torquatisphinctes* Spath, 1924 more so than *Pachysphinctes* Dietrich, 1925. *Subplanites elegans* as described by Spath (1931a) shows similar ribbing, but the whorl section is rather ovate with maximum width close to the umbilical edge, slightly convex flanks and narrower venter. However, camerate whorls and/or poorly preserved specimens of *Subplanites elegans* Spath were considered by Spath (1931a, p. 501, 503) indistinguishable from those of several species of *Torquatisphinctes*, even of some species of *Pachysphinctes*.

*Biochronostratigraphic range.* – Unknown horizons within the biostratigraphic range reported for the genus *Torquatisphinctes* in Kachchh (*i.e.*, Kimmeridgian up to the Upper Kimmeridgian according to Krishna, Pathak, 1991; Pathak, 1993; Krishna *et al.*, 1996b, among others).

?*Torquatisphinctes* sp.

(Pl. 4: 1a, b; Fig. 8E; Table 1)

1931a. *Torquatisphinctes* sp. nov.? ind. Spath: p. 484, pl. 75: 7.

*Material.* – Two specimens from the Astarte-Gryphaea Bed near Bharodia, Wagad Uplift (GZN2010I 039, 045).

*Description.* – Shell small, wholly septate, evolute, slightly compressed. Whorl section suboval with slightly arched flanks merging smoothly into a rounded venter; maximum inflation at the mid-lateral height. Whorls encompass up to half of precedent ones. Ornamentation consisting of fine, sharp, moderately spaced, prorsiradiate primary ribs with faint forward-directed concavity at the rounded umbilical shoulders. They regularly connect with two secondaries of the same thickness at the mid-lateral height (at the umbilical seam on inner whorls). Secondary ribs cross the venter with slight forward-directed sinuosity.

*Remarks.* – The specimen illustrated resembles *Torquatisphinctes* sp. nov.? ind. Spath (1931a, pl. 75: 7) from the Kanthkot Sandstone north of Wamka in coiling and ribbing, especially by its long, “isocostate” secondaries, but the ribs are slightly more prorsiradiate. The higher whorl section of the specimen of *Torquatisphinctes* sp. nov.? ind. Spath cannot be compared directly with the present specimen since Spath’s specimen is larger in size with its body chamber preserved. Spath (1931a) highlighted its affinity with *T. torquatus* and *T. intermedius*, which belong to the morphological plexus of *T. intermedius* Spath – *alterneplicatus* (Waagen). *Torquatisphinctes acuticostatus* Spath 1931, which was considered to be morphologically close to *T. torquatus* and a potential relative of European species (*cf.* Spath, 1931a) is nowadays interpreted as a crussoliceratin, differing in hav-

ing a slightly wider umbilicus and secondary ribs crossing the venter without forward-directed sinuosity. The prorsiradiate ribs bifurcating at mid-lateral height are also similar to those on specimens described as *Lithacoceras* sp. by Spath (1933: p. 691, pl. 130: 7, 11) from the Katrol Formation southeast of Jadura (Bhuj Taluka). However, the taxon illustrated by Spath (1933) shows occasional simple ribs, which are not seen in the present material. Spath (1933) compared his specimens to *Lithacoceras pseudobangei* Spath (1931a, pl. 97: 5, more involute with denser and more prorsiradiate ribbing) and *Torquatisphinctes habyensis* Spath, 1931a (another member of the morphological plexus mentioned above), but *L. pseudobangei* has also simple ribs and *T. habyensis* is more coarsely ribbed and shows a higher branching of ribs.

Among the ammonites illustrated by Collignon (1959b) from his Lower Kimmeridgian *Aspidoceras longispinum* and *Torquatisphinctes alterneplicatus* biozones of Madagascar, *Discosphinctes* (Collignon, 1959b, pl. 99: 377, 378) and *Lithacoceras* (*ibid.*, pl. 103: 386, 387) show tighter coiling, whereas *Torquatisphinctes alterneplicatus* (*ibid.*, pl. 103: 397) is slightly more evolute with more prorsiradiate ribbing on the outer whorls, and shows more tight coiling of the inner ones. The younger *Discosphinctes ardescicus* var. *constricta* and *Discosphinctes secretanae* (Collignon, 1959b, fig. 441 and 442, respectively) have more discoid, narrower shells with an ovate cross-section. In addition, they are more involute with finer, denser, more prorsiradiate ribbing.

More complete material with precise stratigraphic information is needed for a conclusive identification clarifying the inclusion of these “isocostate” ammonites in either the Early Kimmeridgian *Torquatisphinctinae* or the Late Oxfordian-Early Kimmeridgian *Ataxioceratinae*.

*Biochronostratigraphic range.* – The Upper Astarte Beds were interpreted as being uppermost Oxfordian by Mishra (2009). However, based on the two specimens of ?*Torquatisphinctes* sp., as well as on the four specimens of *Torquatisphinctes* sp. gr. *intermedius* Spath – *alterneplicatus* (Waagen) described above, the Upper Astarte Beds most probably indicate horizons within the Lower Kimmeridgian below the generalized record of the *Alterneplicatus* Zone in the Katrol Formation of the Kachchh Mainland.

#### Genus *Pachysphinctes* Dietrich, 1925

Type species: *Pachysphinctes africanus* Dietrich, 1925.

*Remarks.* – Medium- to large-sized, evolute ammonite shells with depressed whorl sections and relatively coarse ribbing with short secondary ribs. Macro- and microconchs with bifurcating ribs on the inner whorls and polygyrate to diversipartite ribs with intercalatory ribs later on the phrag-

mocone and on the body chamber, especially in large-sized specimens. No true virgatotome ribs are developed. Difficult to distinguish from allied taxa related to *Torquatisphinctes* in absence of complete adults.

*Biochronostratigraphic range.* – The genus *Pachysphinctes* in Kachchh was interpreted by Spath (1927–1933) as belonging to his Middle Katrol Group – *i.e.*, Upper Kimmeridgian to Lower Tithonian (in three-fold division of the Stage). Recent revisions interpreted this genus as an exclusively Upper but not uppermost Kimmeridgian taxon (*e.g.*, Krishna *et al.*, 1996b). Precise biochronostratigraphic interpretations show small differences in the range proposed for its records in Kachchh, where the two-fold division of the Kimmeridgian was favoured by authors – *i.e.*, upper Intermedius/Acanthicum zones to upper but not uppermost Katrolensis Zone (Pathak, 1993); Bathyplocus – Katrolensis zones (Krishna, Pathak, 1991, 1993); and uppermost Intermedius/Acanthicum zones to lower Katrolensis Zone (Krishna *et al.*, 1996b). Himalayan records indicate a late Kimmeridgian age for *Pachysphinctes* in the Spiti Shale Formation of India (Pathak, Krishna, 1993) and an indeterminate Late Kimmeridgian age in central Nepal within the Paraboliceras Beds (Enay, 2009). Outside India, early reports of this genus indicating the “Lower to Middle Kimmeridgian” of East Africa (Dietrich, 1925) agree better with the Late Kimmeridgian age suggested by Dietrich (1933). This interpretation is based on the record of the genus *Pachysphinctes* elsewhere as well as on the assumption of age interpretations made by Sames (2008). The latter considered that the underlying Nerinea Member in Tendaguru, Tanzania, includes Kimmeridgian deposits, whereas the proper Middle Saurian Member would represent the remaining Kimmeridgian and the overlying *Trigonia smeei* Member would be Tithonian in age.

*Pachysphinctes* has been reported from a wider, or younger, stratigraphic interval by Zeiss (1971) who indicated a range from the uppermost Kimmeridgian (*Hybonotoceras kachhense* biozone) to lowermost Tithonian (*Subplanites scarsellai* biozone) in his correlation of the Upper Jurassic ammonite assemblages of Ethiopia and South Germany. Verma, Westermann (1984) indicated a range close to their Kimmeridgian/Tithonian boundary (scarcer in the Beckeri Zone than in the Hybonotum Zone), with the possible occurrence of *Pachysphinctes beyrichi* (Futterer) below the Beckeri Zone in Mombasa, Kenya. The same species was interpreted as “Middle Kimmeridgian” by Venzo (1959) in the highlands of Harar, Ethiopia (*i.e.*, biohorizons today interpreted as including the lowermost Tithonian) and by Collignon (1959b) in Madagascar (*i.e.*, his *Hybonotoceras hybonotum* – *Aspidoceras acanthicum* biozones). At the northern margin of the western to westernmost Tethys, middle Upper to uppermost Kimmeridgian records of *Pachy-*

*sphinctes* were reported from northern Italy by Sarti (1993) and Caracuel *et al.* (1998) among others; an occurrence in the lowermost Tithonian was suggested by Sapunov (1979) in Bulgaria; and an uppermost Kimmeridgian to lowermost Tithonian range was assumed by Olóriz (1978) for southern Spain, with exceptional, rarer potential records in younger, condensed levels of the Lower Tithonian (?homeomorphs). The latter could be the case for reports of *Pachysphinctes* in the Verruciferum Zone of Hungary (Vigh, 1984). In addition, *Pachysphinctes* has been reported from epicontinental Europe, even with reference to species erected by Spath (1931a), from lowermost Tithonian horizons (*e.g.*, Zeiss, 1968).

*Pachysphinctes* sp. cf. *symmetricus* Spath, 1931

(Pl. 3: 3a, b; Fig. 5I; Table 1)

cf. 1931a. *Pachysphinctes symmetricus* n. sp.; Spath, p. 498, pl. 101: 7a, b.

*Material.* – One fragment from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1025).

*Description.* – A fragment of a wholly septate, evolute, and depressed shell. Whorl section with rounded, inflated flanks. Ornamentation consisting of moderately thick, sharp, primary ribs bifurcating at the rounded shoulders. Secondary ribs cross the venter straight. Occasional irregularities in ornamentation are due to simple ribs causing a zigzag pattern of ribs on the ventral side or local incomplete branching on the flanks. In the latter case, rib irregularity relates to alteration in ribbing style through enlarging inter-primary rib spaces. A case of incomplete secondary rib occurs just behind a “pseudopolygyrate” division *i.e.*, incomplete connection of the adapertural secondary rib and the corresponding primary rib. This rib pattern is uncommon, if known at all, from ammonites with regular, true polygyrate ribs, and could indicate another case of irregularity forced by intersection of peripheral ribs with a transitory peristome (microconchiate condition?).

*Remarks.* – The limitations of a conclusive interpretation of phragmocones belonging to the *Torquatisphinctinae* from Kachchh are well known (*e.g.*, Spath, 1924, 1931a, 1933). The depressed whorl section with a biplicate to pseudopolygyrate to quasi-polygyrate ribbing pattern and secondary ribs crossing the venter along a straight line resemble *Pachysphinctes* Dietrich, 1925 (see Arkell *et al.*, 1957) rather than *Torquatisphinctes* Spath, 1924. This preliminary approach is favoured here for the interpretation of the fragmentary specimen described. With regards to ornamentation, *Pachysphinctes symmetricus* Spath, 1931 is the closest ally to specimen GZN2010I 1025 from all members of the genus described by Spath (1931a). Among the *Pachysphinctes*

with conservative sculpture illustrated by Spath (1931a), *Pachysphinctes bathyplocus* (Waagen) var. *serpentina* Spath differs by its quadrate whorl section (Spath, 1931a, pl. 88: 1) and slightly less dense ribbing. The same applies to *Pachysphinctes bathyplocus* (Spath, 1931a, pl. 78: 6), which could include *Pachysphinctes symmetricus* n.sp. as a “variety” (Spath, 1931a, p. 498). *Pachysphinctes major* Spath (1931a, pl. 78: 1; pl. 87: 3) shows a more rounded whorl section and shorter secondaries.

*Biochronostratigraphic range.* – *Pachysphinctes symmetricus* n.sp. was interpreted by Spath (1931a, 1933) as belonging to the Middle Katrol Group, and therefore to his “Middle (or ?Upper) Kimmeridgian”. *Pachysphinctes* or *Torquatisphinctes bathyplocus* (Waagen) initially recorded from the Middle Katrol Group (and assigned to his “Middle Kimmeridgian”) (Spath 1931a: 493–495) has been interpreted as indicating the Upper Kimmeridgian Bathyplocus Zone of Krishna, Pathak (1991); Pathak (1993), and Krishna *et al.* (1996b). According to the trend established by Pathak (1993) for phenotype evolution in the species *bathyplocus* Waagen, *Pachysphinctes symmetricus* could belong to the oldest structural type and thus to the lower part of the Bathyplocus Zone in Kachchh – *i.e.*, Upper but not uppermost Kimmeridgian.

#### Genus *Katrolicer* Spath, 1924

Type species: *Ammonites pottingeri* J. de C. Sowerby, 1840.

*Remarks.* – Medium- to large-sized, moderately evolute ammonite shells with depressed to strongly depressed whorl sections and strong, sharp ribbing. Macro- and microconchs with typical reinforcing of ribs and large inter-ribs space on the outer whorls. Pseudopolygyrate and diversipartite but no true virgatostome ribs are developed on the outer whorl of robust and/or mature specimens. Difficulty may arise distinguishing immature individuals and/or inner whorls from allied taxa in the absence of complete specimens.

*Biochronostratigraphic range.* – The genus *Katrolicer* has been collected in Kachchh mainly from the Middle Katrol Group by Spath (1924, 1927–1933), who interpreted this taxon to be included in his basal or Lower and Middle Katrol ammonite assemblages, thus indicating to him a maximum age range of “Early ? to Middle Kimmeridgian” (the latter including the Steraspis Zone or Gravesia Beds of Europe; Spath, 1933, p. 788–791). Krishna, Pathak (1991), Pathak (1993), and Krishna *et al.* (1996b) identified a more precise range from the uppermost Kimmeridgian, Katrolensis Zone, to the Lower Tithonian, Virgatosphinctoides Zone. Himalayan reports of *Katrolicer* with precise reference to ammonite assemblages or biozones indicate the Lower Tithonian *Torquatisphinctes* – *Aulacosphinctoides* assem-

blage of Krishna *et al.* (1982), the early Lower Tithonian *Aulacosphinctoides* assemblage of Pathak, Krishna (1993) in India, and the Kimmeridgian *Parabolicer* Beds in central Nepal (Enay, 2009). Collignon (1959b) reported *Katrolicer* from his “Middle Kimmeridgian” *Hybonoticer* *hybonotum* and *Aspidoceras acanthicum* biozones. *Katrolicer* from Balochistan, Pakistan, was identified in their Middle assemblage interpreted as Lower Tithonian by Fatmi, Zeiss (1999), and these authors mainly correlated their records with the Hybonotum Zone (Fatmi, Zeiss, 1999, tabs 5, 6 and 8), although they referred to the Kimmeridgian in descriptions of the material collected. East African records of *Katrolicer* referred at the biozone level were reported from Harar, Ethiopia, by Venzo (1959), and interpreted to belong to his Lower Kimmeridgian *Streblites tenuilobatus* Zone below his “Middle Kimmeridgian”, which ranged from the Eudoxus Zone to the Steraspis Zone. Zeiss (1971) interpreted an age corresponding to the Lower Tithonian *Subplanites scarsellai* biozone for specimens collected in northern Ogaden. Verma, Westermann (1984) and Schweigert *et al.* (2012) assumed stratigraphic horizons close to the Kimmeridgian-Tithonian boundary in Mombasa, Kenya.

European records of *Katrolicer* from epicontinental areas are based on the explicit re-interpretation proposed by Geyer (1961), who regarded *Katrolicer* as mainly upper Lower Kimmeridgian ammonites of the Divisum Zone (*i.e.*, crussoliceratins) with scarcer records from the Upper Kimmeridgian Mutabilis Zone in southern Germany. Likewise, *Katrolicer* was applied for ammonites from the Balkan Mountains by Anđelković (1966). However, *Katrolicer* s. str. has been not identified in the epi-oceanic ammonitico rosso facies from the westernmost Tethyan margins in southern Spain and Italy (Olóriz, 1978; Sarti, 1993; Caracuel *et al.*, 1998).

*Katrolicer* sp. cf. *depressum* Spath, 1931

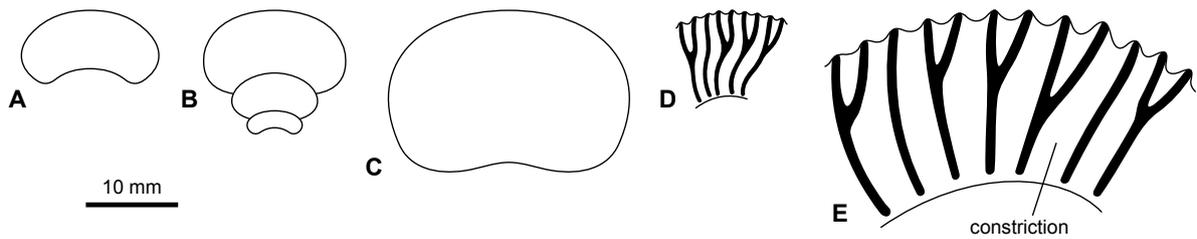
(Pl. 3: 5a, b, 6a, b, 7; Fig. 9A–E; Table 1)

cf. 1931a. *Katrolicer* *depressum* n. sp. Spath, p. 515, pl. 82: 8, pl. 83: 1a, b, pl. 85: 7, pl. 89: 4a, b, 9, pl. 90: 3a, b, pl. 100: 3.

1931a. *Katrolicer* sp. juv.; Spath, p. 513, pl. 89: 8.

*Material.* – Seven specimens. Two specimens from the basal Katrol Formation near Kotai, Habo Dome (GZN2010I 1007, 1008), one specimen from the basal Katrol Formation near Fakirwari, south of Bhuj (GZN2010I 1100), and four specimens from the basal Katrol Formation near Ler, south-east of Bhuj (GZN2010I 1031, 1033, 1037, 1039).

*Description.* – Shell small to moderately large, wholly septate, evolute, depressed. Whorl section sub-rounded to depressed with short, rounded flanks and broadly rounded venter. Ornamentation consisting of fine, sharp, prorsiradi-



**Fig. 9.** *Katroliceras* sp. cf. *depressum* Spath, 1931; **A.** Whorl section at ca. 30 mm diameter, GZN2010I 1033. **B.** Whorl section at ca. 28 mm diameter, GZN2010I 1100. **C.** Whorl section at ca. 70 mm diameter, GZN2010I 1033. **D.** Ribbing pattern at ca. 26 mm diameter, GZN2010I 1007. **E.** Ribbing pattern at unknown diameter, GZN2010I 1033

ate primary ribs branching just below the ventrolateral shoulder and slightly at a lower height on the outer whorls preserved. Secondary ribs cross the venter straight or with a faint forward-directed sinuosity. Occasionally, a single, undivided primary rib on one side joins a bifurcate rib on the other side and causes a zigzag pattern of ribs on the ventral side. Moderately deep constrictions present, oblique to preceding ribs and limited by a simple apertural edge (“simple rib”), which relates to increments of shell growth. Umbilical shoulders rounded, umbilical wall low but steep.

**Remarks.** – The specimens represent only the inner whorls and/or juvenile specimens; hence a conclusive interpretation is difficult with respect to their inclusion into some of the evolute nominal taxa belonging to the Torquatisphinctinae reported from Kachchh. As stated above, we approach the interpretation through reference to the morphologically closest nominal species among those studied and illustrated by Spath (1927–1933).

Specimen GZN2010I 1008 (Pl. 3: 5) does not show any suture line on the outer two-thirds of the last whorl (body chamber or poor preservation?). The ornamentation, particularly a zigzag pattern of ribs on the ventral side, and the depressed whorl section match *Katroliceras depressum* Spath, 1931a. The dimensions of the specimens analysed are close to those of the types illustrated by Spath (1931a), including his var. *pettos* (p. 515, 82, fig. 8). *Katroliceras sowerbyi* Spath, 1931 is slightly less depressed and its secondary ribs on the venter are straight. *Katroliceras* sp. juv. described and illustrated by Spath (1931a) shows a similar whorl section and ornamentation, and is therefore considered synonymous. Specimen GZN2010I 1008 (Pl. 3: 5) resembles *Katroliceras* sp. juv. (transitional between *K. zitteli* and *K. depressum*) depicted in Spath (1931a, pl. 99: 8), and the juvenile of a specimen which was difficult to interpret, *K. sp. juv. aff. arenosum* (Spath, 1931a, pl. 99: 3), as well as to the immature *K. subkatrolense* (Spath, 1931a, pl. 87: 7), but the latter shows more quadrate whorl sections. The phragmocone interpreted as *Katroliceras zitteli* by Spath

(1931a, pl. 87: 6) is comparatively close with respect to ribbing style and whorl section. Specimen GZN2010I 1033 (Pl. 3: 7) represents an evolute form, less dense and coarsely ribbed than *K. zitteli* (Spath, 1931a, pl. 97: 6), but it is similar to coarsely, prosiradiate ribbed morphotypes previously collected from Ler and referred to *K. depressum* (Spath, 1931a, pl. 89: 9), and shows slightly more prorsiradiate ribs than *Katroliceras aff. depressum* (Spath, 1931a, pl. 83: 1).

**Biochronostratigraphic range.** – *Katroliceras depressum* was referred to the Middle Katrol Group by Spath (1931a, 1933), and to the lower Upper Kimmeridgian (two-fold division) lowermost Katrolensis Zone by Krishna *et al.* (1996b). Collignon (1959b) identified *Katroliceras depressum* and *K. aff. depressum* in his *Hybonoticerias hybonotum* – *Aspidoceras acanthicum* biozones of Madagascar. Fatmi, Zeiss (1999) reported *Katroliceras depressum* from the Second Horizon of the Sembar Formation of Balochistan, Pakistan, and suggested a Kimmeridgian age, although they mainly placed *Katroliceras* in the Hybonotum Zone (Fatmi, Zeiss, 1999, tabs. 5, 6, 8). Spath (1933, p. 788, 789) reported *?Katroliceras* spp. juv. from the basal Katrol beds, stated the difficulty of identifying the precise horizon in the Katrol Beds of *Katroliceras* species listed in his Middle Katrol Assemblage (Spath, 1933, p. 791–792), and mentioned abundant juvenile *Katroliceras* difficult to interpret (Spath, 1933, p. 791–792) from horizons in the Lower Katrol Bed (*K. depressum* included) that could belong to his Lower Katrol Assemblage.

The specimens described above tentatively as *Katroliceras* sp. cf. *depressum* Spath, from the basal Katrol Formation of different sections (near Kotai, Habo Dome; near Fakirwari, south of Bhuj; and near Ler, southeast of Bhuj) most probably cover various stratigraphic horizons that are difficult to correlate precisely (Figs 11, 12). Hence no conclusive age interpretation is favoured for any of these possibly diachronous records of juvenile, incomplete specimens, which most probably belong to the Late Kimmeridgian.

*Katrolicerias* sp. cf. *sowerbyi* Spath, 1931  
(Pl. 3: 4a, b; Table 1)

cf. 1931a. *Katrolicerias sowerbyi*; Spath, p. 509, pl. 99: 7.

*Material.* – One specimen from the basal Katrol Formation near Ler, southeast of Bhuj (GZN2010I 1005).

*Description.* – Shell small to moderately large, wholly septate, evolute. Whorl section rounded to depressed with relatively low, flattish to slightly convex flanks and broadly rounded, subtly convex venter. Ornamentation consisting of stiff (not sinuous) fine, sharp, prorsiradiate primary ribs branching just below the ventrolateral shoulder on the inner and middle whorls, and slightly below on the outer whorl preserved. Secondary ribs cross the ventral region faintly forward-directed, occasionally exhibiting a zigzag pattern of ribs on the ventral side. Subtle constrictions run slightly oblique to ribbing and are bordered by a simple adapertural edge that resembles a “simple” rib. Umbilical shoulders rounded and descending to the previous whorl through a low but steep umbilical wall.

*Remarks.* – The sculpture and shell features in the septate specimen GZN2010I 1005 (Pl. 3: 4) closely resemble those in *Katrolicerias sowerbyi* (Spath, 1931a, pl. 84: 4, pl. 99: 7). As stated by Spath (1931a, p. 510), *Katrolicerias sowerbyi* differs from *K. depressum* by its more regular, denser ribbing that only changes to the typical *Katrolicerias* style on the body chamber, which begins beyond a diameter of 75 mm. The incomplete specimen shows the camerate shell ornamented with a regular sculpture with higher division points on subtly convex flanks. The latter also can be used as a complementary feature for distinguishing *K. sowerbyi* from *K. depressum*. Spath (1931a, p. 510; 1933) interpreted as *Katrolicerias sowerbyi* var. *difficilis* (specimen illustrated under the name of *Aulacosphinctoides* sp. juv.) a specimen with fine and sinuous ribbing (Spath, 1931a, pl. 88: 3; pl. 89: 3). This latter interpretation is difficult to evaluate since the outer whorls are lacking and the fine ribbing clearly contrasts with the rigid, coarser sculpture on the inner whorls of *K. sowerbyi*. Based on a population study, Pathak (1993) considered *Katrolicerias sowerbyi* Spath to be a younger synonym of *Katrolicerias katrolensis* Spath. Pathak (1993) identified six evolutionary morphotypes according to the start of modified, typical “*Katrolicerias*-ribbing” in mature specimens. In the absence of population data, and given the incomplete nature of the specimen studied, we compare the specimen GZN2010I 1005 to the types described by Spath (1931a) and therefore relate it to *Katrolicerias* cf. *sowerbyi* Spath.

Data from Madagascar (Collignon, 1959b) indicate the occurrence of *Katrolicerias* with regular, progressively changing sculpture in the phragmocone. Accordingly, sever-

al species have been reported, among which *Katrolicerias sowerbyi* was based on a rather poorly preserved specimen (Collignon, 1959b, fig. 454). Outside the Indo-Madagascan Realm, a morphologically close but sculpturally more evolved species is *Katrolicerias somalicum* Valduga (1954), which shows more or less common intercalatory and some polygyrate to diversipartite ribs, and was collected as a loose specimen from Kimmeridgian deposits in Ogaden, Ethiopia. The species was later listed among the Ethiopian ammonites identified by Venzo (1959) from Kimmeridgian deposits northwestwards of Harar, and subsequently by Zeiss (1971) from N-Ogaden. Recently Schweigert *et al.* (2012, pl. 4: 1, 2) illustrated *Katrolicerias somalicum* Valduga and *Katrolicerias katrolensis* (Waagen) from two sites in Freetown, Mombasa area, Kenya and correlated them according to the presence of age-interpreted hybonoticeratins, since no precise horizons of sampling were known. The specimen assigned to *Katrolicerias katrolensis* (Waagen) clearly shows the comparatively less evolved sculpture of *Katrolicerias katrolensis*, which represents a primitive morphotype according to Pathak (1993), and therefore is closer to *Katrolicerias sowerbyi* (Spath) and to the present phragmocone. In accordance with what has been stated above, *Katrolicerias somalicum* Valduga in Schweigert *et al.* (2012, pl. 4: 1) shows more complicated ribbing with common intercalatory, pseudopolygyrate and diversipartite ribs. Its sculpture is thus evolutionarily more specialized.

*Biostratigraphic range.* – *Katrolicerias sowerbyi* was reported from the Lower? and Middle Katrol Group by Spath (1931a), and interpreted as belonging to his “Middle Kimmeridgian”. Spath (1933) included *K. sowerbyi* in his Second Katrol Assemblage of “Middle Kimmeridgian” age. According to the sequence of microevolutionary morphs established by Pathak (1993) for *Katrolicerias katrolensis* (Waagen), those corresponding to *Katrolicerias sowerbyi* Spath would indicate the lower part of the Katrolensis Zone in Kachchh (*e.g.*, Pathak, 1993; Krishna *et al.*, 1996b).

*Katrolicerias sowerbyi* Spath was recognized in the “Middle Kimmeridgian” *Hybonoticerias hybonotum* – *Aspidoceras acanthicum* biozones of Madagascar proposed by Collignon (1959b). Outside the Indo-Madagascan Realm, the morphologically close species *Katrolicerias somalicum* Valduga has been cited from Harar, Ethiopia, by Venzo (1959), but this author did not interpret this species in biostratigraphic terms. Zeiss (1971) interpreted *Katrolicerias somalicum* Valduga as belonging to the *Hybonoticerias kachhense* biozone of the uppermost Kimmeridgian in Ethiopia, which he correlated with the Beckeri Zone of the Submediterranean Tethys. The same biochronostratigraphic interpretation was proposed by Schweigert *et al.* (2012) for *Katrolicerias somalicum* Valduga and *Katrolicerias katrolensis* (Waagen) from the Mombasa area in Kenya.

Specimen GZN2010I 1005 from the basal Katrol Formation near Ler, southeast of Bhuj, and interpreted as *Katrolliceras* sp. cf. *sowerbyi* Spath, most probably indicates some unknown horizon within the lower part of the Katrolensis Zone in Kachchh – i.e., middle Upper? to uppermost Kimmeridgian.

Torquatisphinctinae gen. and sp. ind.

(Pl. 6: 1a, b; Table 1)

*Material.* – One specimen from the basal Katrol Formation near Jhura Camp, Jhura Dome (GZN2009II 015).

*Description.* – Shell small, wholly septate, evolute, with colubrinoid-type inner whorls. Whorl section rounded in the inner whorls and subquadrangular in the outer whorl. Flanks merging smoothly into a moderately arched venter. Umbilical wall low, distinct and steep. Ornamentation consisting of sharp primary ribs originating rursiradiately at the upper part of the umbilical wall, bending prorsiradiately at the umbilical shoulder to cross the flank obliquely towards the aperture. Local irregular trajectory of ribs on the inner whorls has no taxonomic relevance. Regular branching into two secondary ribs occurs above the mid-lateral height. Secondary ribs cross the venter straight. Constrictions distinct, numbering at least four per whorl.

*Remarks.* – The ornamentation and dimensions of specimen GZN2009II 015 are seemingly close to those of the slightly less tightly coiled specimen described as *Aulacosphinctoides* sp. juv. aff. *kachchensis* by Spath (1931a, pl. 86: 6). However, in his figure caption Spath (1931a, pl. 86: 6) was doubtful about the interpretation of the small specimen as it is a distorted juvenile (prorsiradiate ribs), and no particular evidence supports its assignment to *Aulacosphinctoides*. Another similar juvenile showing a comparable coiling degree could be *?Katrolliceras* sp. juv. of Spath (1931a, pl. 89: 5) but the ribbing of specimen GZN2009II 015 is finer with shorter secondaries, whereas *?Katrolliceras* sp. juv. of Spath (1931a, pl. 89: 4) is clearly more evolute and shows a more inflated cross-section with more convex flanks.

The present specimen could belong to the inner whorls of an adult or to a juvenile of the *Torquatisphinctes* – *Pachysphinctes* evolutionary lineage. Given the small size of the entirely septate specimen, its interpretation as the nucleus of a member of the Torquatisphinctinae seems appropriate. Most probably it belongs to *Torquatisphinctes* or *Pachysphinctes* (cf. Spath, 1931a, pl. 92: 6; pl. 93: 4) but even low-specialized *Katrolliceras* (cf. Spath, 1931a, p. 518; pl. 86: 2; pl. 90: 3) might be appropriate, excluding more morphologically specialized ones (cf. Spath, 1931a, pl. 95: 6) and younger taxa such as *Aulacosphinctoides*.

*Biochronostratigraphic range.* – According to the whole material under study, the incomplete specimen from the basal Katrol Formation near Jhura Camp could belong to the upper Lower or the Upper Kimmeridgian.

Family **Aspidoceratidae** Zittel, 1895

Subfamily **Aspidoceratinae** Zittel, 1895

Genus *Aspidoceras* Zittel, 1868

Type species: *Ammonites rogoznicensis* Zeuschner, 1846.

*Remarks.* – Small- to large-sized and more or less evolute ammonite shells. Whorl sections varying from sub-rounded to oval or depressed, leading to variable convexity of flanks and wideness of the ventral region. Sculpture mainly expressed by two rows of tubercles, peri-umbilical and lateral, the latter row being less persistent throughout ontogeny. Rib-like folds can connect peri-umbilical and lateral tubercles, and may also occur on the venter. Dimorphism is debated and no lappets are known, but the occurrence of macro- and microconchs, based just on shell size with no significant differentiation in shell sculpture, is envisaged.

*Biochronostratigraphic range.* – Records of the genus *Aspidoceras* are very common throughout the Upper Jurassic, and it is considered as a long-ranging taxon, from the Upper Oxfordian (Bimammatum Zone) to the Lower Berriasian (Jacobi Zone). In Indo-Madagascan areas bituberculate aspidoceratins dominate the published records (Spath, 1933; Collignon, 1959b). The former author noted the absence of *Aspidoceras* from the Umia Ammonite Bed, interpreted by him as embracing the “Portlandian–Tithonian” boundary. Indian species of *Aspidoceras* were collected from the Belemnite Marls, the Lower Katrol Group, and the Middle Katrol Group as well as from the lowermost Berriasian horizons in Kachchh (e.g., Krishna *et al.*, 1994, who subdivided the Katrol Formation in lower, middle and upper members). Species from Madagascar belong to the *Aspidoceras longispinum* – *Torquatisphinctes alterneplicatus*, as well as to the *Hybonotoceras hybonotum* – *Aspidoceras acanthicum* biozones as proposed by Collignon (1959b). These are mainly bituberculate forms of middle Upper Kimmeridgian to lowermost Tithonian affinity. In the Spiti Shales of central Nepal, Enay (2009) also reported bituberculate forms from his Blanfordiceras Beds.

*Aspidoceras asymmetricum* Spath, 1931

(Pl. 6: 4; Fig. 10A; Table 1)

1931b. *Aspidoceras asymmetricum* n. sp. Spath, p. 629, pl. 103: 2, pl. 118: 3a, b, pl. 119: 3, pl. 123: 3.

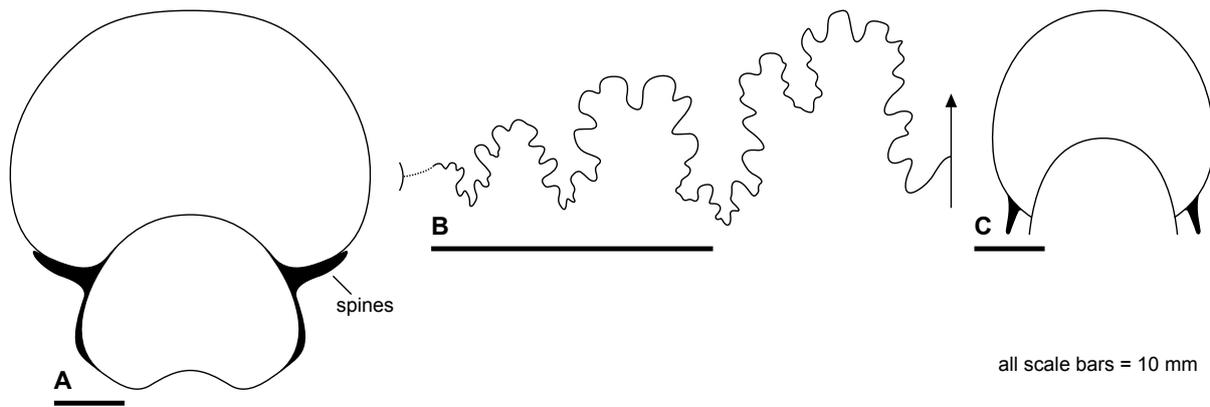


Fig. 10. A. *Aspidoceras asymmetricum* Spath, 1931; whorl section at ca. 111 mm diameter, OUMNH JY.1263. B, C. *Schaireria* sp. aff. *avellanoides* Uhlig, 1910; B. Suture line at unknown diameter, GZN2009II 190. C. Whorl section at ca. 50 mm diameter, GZN2009II 190

*Material.* – One specimen from the Belemnite Marls near Jawahar Nagar (*i.e.* Jhuran; OUMNH JY.1263).

*Description.* – Shell large, wholly septate, evolute. Whorl section rounded to slightly depressed with rounded, but distinct umbilical shoulder, and high and steep umbilical wall. Sculpture consisting of two rows of tubercles that form prominent spines, especially those of the external row when the shell is preserved and the spines are protected by subsequent whorls just below the line of the overlapping whorl. Internal moulds reveal subtle swells (smoothed tubercles) related to the bases of non-preserved spines. On inner whorls the ornamentation consists of two rows of spines on the flank: slightly smaller spines at the umbilical shoulder, and prominent spines near mid-lateral height close to the umbilical seam. The ornamentation seems to fade during ontogeny since the outer whorl only maintains faint, broadly rounded, primary folds which show a slight elevation near the umbilical shoulder, and less numerous equivalent reliefs close to the shell periphery; at least four reliefs can be identified on the outermost quarter of the preserved whorl. The distance between the two rows of tubercles on the outer preserved whorl is close to 41%Wh. Unfortunately there is no information about the body chamber.

*Remarks.* – The sculpture, whorl section, and dimensions of the entirely septate specimen OUMNH JY.1263 match those of *Aspidoceras asymmetricum* Spath, 1931 and relatives in the *binodum* Oppel – *longispinum* Sowerby group or in the *sesquinodosum* Fontannes – *acanthicum* Opper group; *i.e.*, Kimmeridgian morphospecies with either persistent lateral tuberculation or variable trends towards reduction of mid-flank tubercles. Nominal species of these two groups are known from the Indo-Madagascan region. In the former and better represented group in India and Mada-

gascar, more depressed sections with less separation between the two rows of tubercles are more common in *A. binodum* and its allies than in *A. longispinum* and related forms. These two species co-occur within the upper Lower and the lower Upper Kimmeridgian. In cases where the lateral row of tubercles disappears during the later ontogeny (non-preserved), an affinity to the second group exists, which includes also members of the *A. sesquinodosum-deaki* morphological plexus identified by Spath (1930, p. 58; 1931b, p. 624–629). As in the specimens described by Spath (1931b), the spines of the inner row are broken off in the present specimen but, judging from the size of their bases, they might have been of a similar or only slightly smaller size than the outer ones. The combination of depressed whorl section and distance of the two rows of tubercles provides a particularly relevant feature, but the incomplete character of the specimen impedes any conclusion about its belonging to one of the two species groups mentioned above (see also comments in Spath, 1931b, p. 629–630 and Spath, 1933, p. 787–788). For the time being, the specimen is referred to the nominal species erected by Spath (1931b).

*Biochronostratigraphic range.* – *Aspidoceras asymmetricum* was identified by Spath (1931, p. 629–630; 1933, p. 787–788) in his ammonite assemblage of the Belemnite Marls, Lower Katrol Group, at Joorum (= Jhuran), which he regarded as representing most likely a stratigraphic interval in the Lower Kimmeridgian. The specimen was collected from an undetermined horizon within the Belemnite Marls (Katrol Formation) at the Jawahar Nagar section (Jhuran). No complete, age-diagnostic ammonites associated with specimen OUMNH JY.1263 were collected. The specimen is tentatively interpreted as representing some horizon from the upper Lower to lower Upper Kimmeridgian.

Subfamily **Physodoceratinae** Schindewolf, 1925Genus *Schaireria* Checa, 1985

Type species: *Aspidoceras avellanum* Zittel, 1870.

*Remarks.* – Shells of small to medium size, involute to moderately evolute. Whorl sections varying from rounded to oval-subtrapezoidal or highly depressed, displaying high variability in the width of the ventral region. The ornamentation consists of a row of peri-umbilical, oblique tubercles pointing to the centre of the umbilicus. There are shells with less numerous and/or greater tubercles that commonly are less oblique in the outer whorls, as well as cases of smooth shells, which are placed into different species. No lateral tubercles are known in *Schaireria*. Thus, *Schaireria* was envisaged by Checa (1985) to include uni-tuberculate shells (Kimmeridgian to lowermost Berriasian) as well as unsculptured shells, the latter typical of the Lower Tithonian and previously differentiated as a subgenus of *Physodoceras* by Vigh (1984) on a strict morphological basis: *Physodoceras* (*Anaspidoceras*) with “ganz glattem Gehäuse ohne Knotenreihe” (Vigh, 1984, p. 171) in reference to the *neoburgense-cyclotum* plexus. Based on evolutionary analyses, Checa, Olóriz (1984) were the first to differentiate among *Physodoceras*-like ammonites and reported two new taxa at the genus level, namely *Benetticeras* and *Schaireria*. The former evolved from *Physodoceras* and the latter from *Pseudowaagenia* types of shell, in older and younger horizons of the Kimmeridgian (in its present usage), respectively. Hence, *Physodoceras* and *Schaireria* represent one of the better known cases of homeomorphism among Upper Jurassic ammonites *e.g.*, the so-called “inflati” by pioneer authors such as Uhlig (1910, p. 75). In analogy, *Schaireria* with coarser, less oblique tubercles and from stratigraphic horizons close to the Kimmeridgian–Tithonian boundary have been interpreted as *Orthaspidoceras* (*e.g.*, Howarth, 1998, p. 68). On page 63, the latter author suggested that the type species of *Schaireria*, *S. avellanum* Zittel, belongs to *Orthaspidoceras*, including specimens with the occasional development of a lateral row of tubercles, two to four per whorl. Unfortunately, no illustration of these forms was provided. In fact, additional, lateral tubercles neither developed in *Schaireria* nor have been reported from species usually interpreted as *Orthaspidoceras*, and Physodoceratinae with common lateral tubercles are included in the genus *Pseudowaagenia*. Interestingly, lateral tubercles forming a second row occur very rarely in the widely distributed and long-ranging, Lower Kimmeridgian nuclear species of *Physodoceras i.e.*, *cf. Physodoceras wolfi* in Checa (1985). This species was envisaged as potential evidence for the evolutionary derivation of *Pseudowaagenia* (*cf.* Checa, 1985, p. 265–266), a genus

which shows irregular development of additional, lateral tuberculation and persists in horizons that include the Kimmeridgian–Tithonian boundary.

*Biochronostratigraphic range.* – The genus *Physodoceras* in a large sense – *i.e.*, a paraphyletic taxon – has been reported from Upper Oxfordian to Middle Berriasian horizons. It was interpreted in a strict sense by Checa, Olóriz (1984, 1985) and Checa (1985) as restricted to the stratigraphic interval from the uppermost Oxfordian (at present lowermost Kimmeridgian) to the upper but not uppermost Lower Kimmeridgian. Homeomorphs from Kimmeridgian–Tithonian boundary horizons and, more commonly, from the Tithonian interpreted as *Physodoceras* (Collignon, 1959b; Olóriz, 1978 *pars*; Vigh, 1984; Sarti, 1985 from the Mediterranean Tethys; Verma, Westermann, 1984 and Schweigert *et al.*, 2012 from the Kimmeridgian–Tithonian boundary in Mombasa; Enay, 2009 from the Spiti Shales in central Nepal) are interpreted here as *Schaireria* Checa, 1985, an Upper Kimmeridgian – Lower Berriasian genus.

*Schaireria* sp. aff. *avellanoides* (Uhlig, 1910)

(Pl. 6: 5a–c; Fig. 10B, C; Table 1)

aff. 1910. *Aspidoceras avellanoides* Uhlig, p. 75, pl. 3: 1a–e.

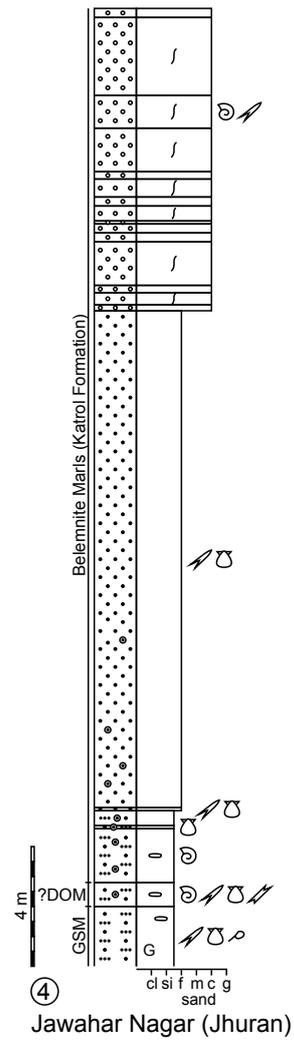
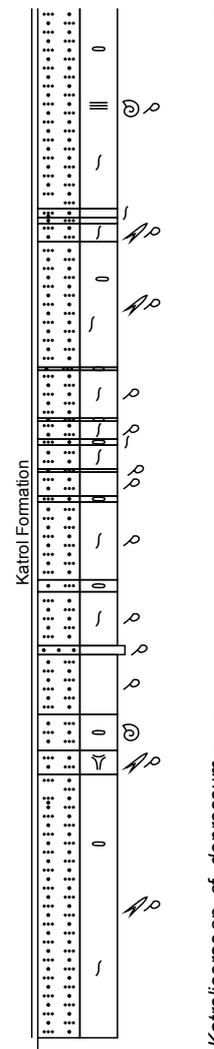
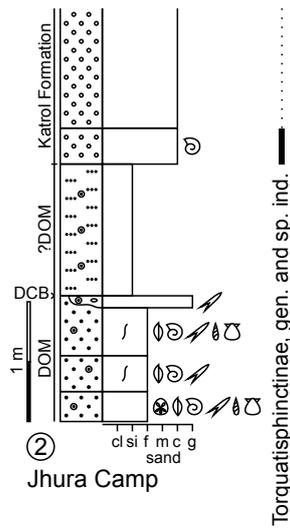
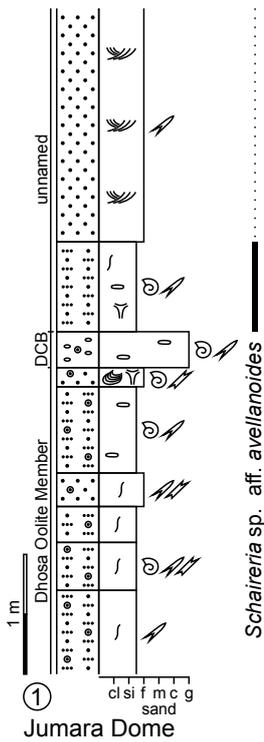
?1931b. ?*Physodoceras* aff. *avellanum* (Zittel); Spath, p. 641, pl. 123: 10.

*Material.* – One specimen from the basal Katrol Formation of the Jumara Dome (GZN2009II 190).

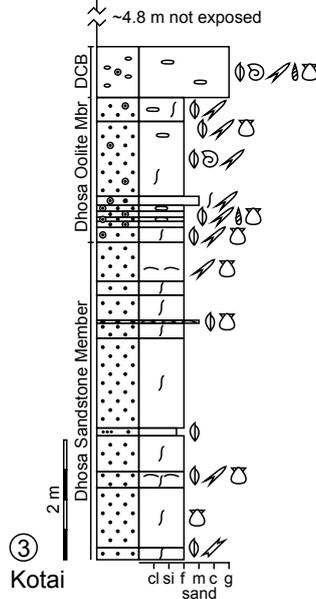
*Description.* – Shell small, wholly septate, involute. Whorl section subcircular. Shell periphery smooth. Oblique spines with relatively large bases defining excavated intertubercular-spaces at the umbilical edge. The suture line shows large but not very deep elements with similar development of the ventral and the lateral lobes.

*Remarks.* – In general terms, *Physodoceras*-like ammonites can be morphologically close to *Schaireria*, and hence to specimen GZN2009II 190, but inter-tubercular spaces are typically less excavated in the peri-umbilical edge and their suture lines are more elaborated.

?*Physodoceras* aff. *avellanum* (Zittel, 1870) described by Spath (1931b) from the Kachchh Basin is a smaller, slightly less depressed nucleus that certainly does not belong to Zittel’s species as recognized in Europe, and could be close to *Schaireria avellanoides* (Uhlig). Uhlig (1910, p. 76) interpreted *Aspidoceras avellanoides* as almost identical to *Aspidoceras avellanum* Zittel, the latter differing in having shorter, stouter accessory lobes or lobules (a preservational bias?). This author also compared *Aspidoceras avellanoides* with nominal species of *Physodoceras* today interpreted as belonging to the *wolfi-altenense* morphological plexus, but all these forms are Lower Kimmeridgian



- |  |                       |  |                       |
|--|-----------------------|--|-----------------------|
|  | conglomerate          |  | parallel bedding      |
|  | coarse sand           |  | plant debris          |
|  | medium – coarse sand  |  | wood fragments        |
|  | medium sand           |  | echinoids             |
|  | fine – medium sand    |  | brachiopods           |
|  | fine sand             |  | ammonites             |
|  | silty fine sand       |  | belemnites            |
|  | silt                  |  | gastropods            |
|  | silty clay            |  | bivalves              |
|  | shell bed             |  | bioturbation          |
|  | ferruginous ooids     |  | <i>Chondrites</i>     |
|  | concretions           |  | <i>Planolites</i>     |
|  | secondary gypsum      |  | <i>Thalassinoides</i> |
|  | through cross-bedding |  | <i>Zoophycus</i>      |



ammonites (*i.e.*, indicating morphological convergence). The specimen close to the type of *Aspidoceras avellanoides* Uhlig was collected from southern Turkey by Enay *et al.* (1968, p. 406, 408) and considered close to *P. avellanum* Zittel. Among aspidoceratids from Madagascar, *Physodoceras cf. periacense* (Fontannes) from the *Hybonotoceras hybonotum* – *Aspidoceras acanthicum* biozones (Collignon, 1959b, fig. 481) shows a very similar but slightly narrower whorl section and a larger umbilicus than *Schaireria avellanoides* (Uhlig), and could represent a form close to *Schaireria cf. neumayri* Checa. *Physodoceras cf. circumspinosum* (Oppel) in Collignon (1959b, fig. 407) does not show tubercles, was collected from his *Aspidoceras longispinum* – *Torquatisphinctes alterneplicatus* biozones, and must belong to *Schaireria neoburgense* (Oppel). Among other Mediterranean species of *Schaireria*, the Lower Tithonian *S. pipini* Oppel is more evolute and has stronger tubercles, while *Schaireria longaeva* (Leanza) is clearly younger (Lower Berriasian). Non-tuberculated, Lower Tithonian species of *Schaireria* (*e.g.*, Oppel's species *neoburgensis* and *episa*) are easily identified.

Since slight uncoiling can occur at the mature ontogenetic stage in species of the genus *Schaireria*, the more conclusive identification of the phragmocone described, interpreted as being close to *Schaireria avellanoides* (Uhlig), requires more complete specimens from the same level to provide insight into intra-specific diversity in the Kachchh Basin. Noting only minor differences (intra-species diversity?) between the shell parameters of *Schaireria avellanoides* (Uhlig) and *S. avellana* (Zittel), these two nominal species were merged in *Schaireria avellana* (Zittel) by Checa (1985). Shell parameters shown in the measurements given above fall within the range of intra-specific variability of *Schaireria avellana* (Zittel), including size-related deviations (*cf.* Checa, 1985). Therefore, the use of *Schaireria avellanoides* (Uhlig) and *S. avellana* (Zittel) as a separate species is only tentative, and relates to the very limited information about the morphological diversity of the Indo-Madagascan and East-African material and the possibility for its potential, biogeographic significance (at the metapopulation or subspecies levels?).

*Biochronostratigraphic range.* – *Schaireria avellana* (Zittel) is Lower Tithonian (in three-fold division of the Stage). *?Physodoceras aff. avellanum* (Zittel) was inter-

preted as belonging to the K2 faunal assemblage of the “Middle or Upper Kimmeridgian” by Spath (1931b, p. 642) from the Middle Katrol Group by Spath (1933, p. 734–735, tab. 4), who interpreted his “Middle Kimmeridgian” as embracing stratigraphic intervals from the *compsum-holbeini* group up to the Beckeri–Steraspis or Gravesia zones (Spath, 1933, p. 788–792). He defined his stratigraphic interval as mainly characterized by *Pachysphinctes* followed in species abundance by *Katroliceras*, together with persistent bituberculate aspidoceratids, streblitids, and two species of *Waagenia* (= *Hybonotoceras*), today interpreted as uppermost Kimmeridgian. *Schaireria avellanoides* (Uhlig) co-occurred with *Hybonotoceras hybonotum* at the D367 site in Degirmenlik, southern Turkey, together with other ammonite species indicating Lower Tithonian or even uppermost Kimmeridgian horizons (Enay *et al.*, 1968, p. 409).

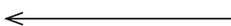
The septate specimen GZN2009II 190 was collected from the basal Katrol Formation at the Jumara Dome in the northwestern Kachchh Mainland and most probably indicates a stratigraphic horizon close to the Kimmeridgian–Tithonian boundary.

## BIOCHRONOSTRATIGRAPHY AND CORRELATION POTENTIAL

The ammonites described above are mainly phragmocones with variable preservation. They mainly represent relatively long-ranging, more or less endemic Kimmeridgian taxa from the Kachchh Basin, and variable occurrences in other areas of the Indo-Malagasy Gulf. Some Oxfordian ammonites from the Wagad Uplift providing precise biostratigraphic resolution down to the subzonal level are also described.

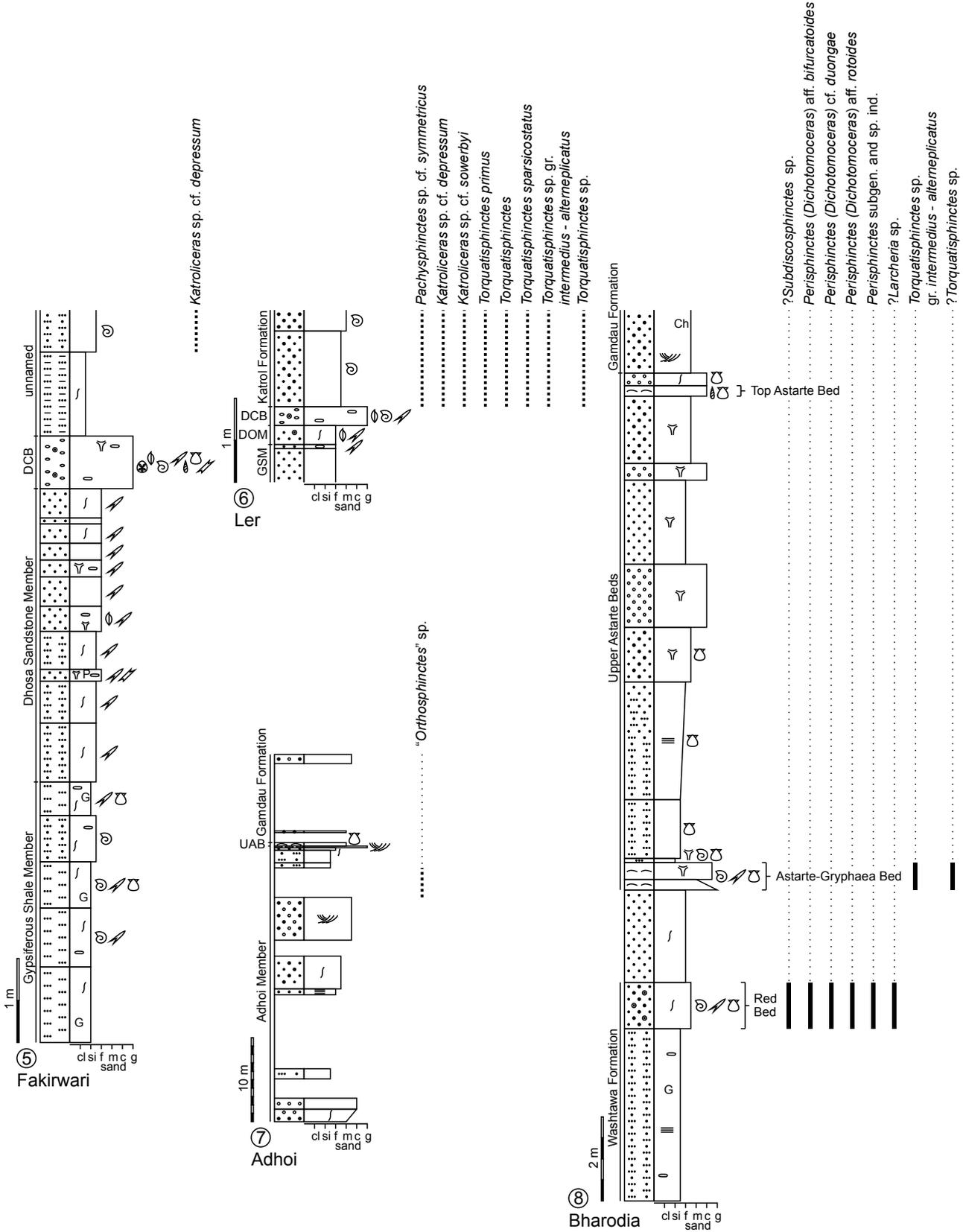
In the Wagad Uplift, special attention was paid to the ammonites from a section near Bharodia, collected from the so-called Red Bed (Fig. 12). The fine-grained sandstones of the Red Bed yielded some ammonites with Oxfordian affinities, *i.e.*, the genera *?Subdiscosphinctes* Malinowska, *?Larcheria* Tintant, and *Perisphinctes* Waagen. The latter genus comprises some specimens classified herein in open nomenclature as *P. (Dichotomoceras) aff. rotoides* Ronchadzé, 1917, *P. (Dichotomoceras) cf. duongae* Meléndez, 1989, emend. Gygi, 2000a, *Perisphinctes (Dichotomoceras) aff. bifurcatoides* Enay, and *Perisphinctes* subgen. and sp. ind. In this group *P. (D.) aff. rotoides* is interpreted as a reworked specimen, indicating the taphonomical condensation of its parent horizon.

The European reference taxa recognised in the Red Bed occupy well established biochronostratigraphic positions in the regional Submediterranean Middle to Upper Oxfordian zonation of south-western Europe (*e.g.* Atrops, Meléndez,



**Fig. 11. Sections in the western and northern Kachchh Mainland yielding ammonites for the present study and the stratigraphic ranges of the recorded taxa**

The bold dotted lines demarcate stratigraphic horizons in which a particular taxon occurs, but whose precise position is not known



1993; Gygi, 2000b; Enay, Gygi, 2001), and their vertical ranges have been precisely correlated with the Oxfordian zonal schemes based on perisphinctid ammonites in central Europe, where *e.g.* *P. rotooides*, *P. duongae*, and *Larcheria* are rare or virtually absent for palaeobiogeographic reasons (Główniak, 2006, 2012). Consequently, ammonites collected from the Red Bed in the Bharodia section (8 in Fig. 12) point to a time span of its deposition from as early as latest Middle Oxfordian and to early Late Oxfordian (following unified boundary horizons of the substages in the Submediterranean areas as argued by Główniak, 2006). The oldest ammonites found in the Red Bed are ?*Larcheria* sp. and *P. (Dichotomoceras)* aff. *rotooides* (a reworked specimen), taxa which never co-occur in the Oxfordian ammonite successions with expanded sedimentation in south-western Europe where they are diagnostic of two successive subzones (Schilli and Rotoides) in the Schilli Zone following Gygi (2000b). The latter zone correlates with the latest Middle Oxfordian Transversarium Zone (but only its topmost part) and the early Late Oxfordian Bifurcatus Zone (but only with the lower Wartae Subzone, the lowest subzone) in central Europe (note the three-fold subdivision of the Substage, with the Wartae Subzone re-introduced at the base of the Bifurcatus Zone, as discussed by Główniak, 2006). A somewhat younger age of upper horizons included in the Red Bed is substantiated by *Perisphinctes (Dichotomoceras)* aff. *bifurcatoides* Enay. In fact, the Submediterranean species *P. bifurcatoides* occurs exclusively in the middle part of the Bifurcatus Zone (Stenocycloides Subzone), indicating the age when the Red Bed seems to have eventually formed. The stratigraphic range of ?*Subdiscosphinctes* sp. overlaps with that of the taxa previously mentioned, thus providing no more precise information about the age of the Red Bed.

It is worth noting that the occurrence of the genus *Larcheria* in the Kachchh Basin was first reported (and illustrated) by Krishna *et al.* (1995, 1996a), based on some ammonites collected from red calcareous sandstones with intercalated shales *i.e.*, the Kanthkot Ammonite Beds, from the topmost Washtawa Formation in the Wagad Uplift. Krishna *et al.* (1996a) identified there the Schilli Subzone, which should be interpreted as indicating an early Bifurcatus Zone age in terms of the unified boundary horizons of the Oxfordian substages in the Submediterranean areas as argued by Główniak (2006). A subsequent contribution by

Pandey *et al.* (2012) provided new data on the occurrence of somewhat younger ammonite taxa in the Kanthkot Ammonite Beds, diagnostic of the Wartae and also of the overlying Stenocycloides subzones of the early Late Oxfordian Bifurcatus Zone. The list of ammonite taxa of Pandey *et al.* (2012) contains *e.g.* *Perisphinctes (Dichotomosphinctes)* aff. *wartae* indicating the Wartae Subzone; *Perisphinctes* sp. cf. *P. (Dichotomoceras) bifurcatoides*, and *Perisphinctes (Dichotomoceras) stenocycloides* diagnostic of the Stenocycloides Subzone. Other taxonomic assignments at species-level of some other ammonites described by Pandey *et al.* (2012), namely *Perisphinctes (Dichotomoceras)* cf. *bifurcatus* and *P. (D.)* gr. *crassus*, which apparently indicate the uppermost, Grossuvrei Subzone of the Bifurcatus Zone, have to be carefully re-considered, before coming to a definite conclusion on the occurrence of this subzone in the Red Bed in the Wagad Uplift. All the above biostratigraphic data indicate that the top of the Washtawa Formation in the Wagad Uplift is early Late Oxfordian in age. Apparently, the top of the Kanthkot Ammonite Beds in Adhoi and of the Red Bed at Bharodia (*cf.* 8 in Fig. 12) are approximately isochronous, correlating in these two areas with the middle, Stenocycloides Subzone in the Bifurcatus Zone (Fig. 2). As the overlying Upper Astarte Beds of Bharodia contain ammonites of the Early to Late (but not latest) Kimmeridgian age (see below), a major depositional gap must be assumed between the Red Bed and the Astarte–Gryphaea Bed of the Upper Astarte Beds (compare Fig. 2). More than 200 m of sediment represented by the Patasar Shale, Fort Sandstone, and Adhoi members of the Kanthkot Formation, present less than 30 km away at Kanthkot, are missing at Bharodia.

Kimmeridgian ammonites were collected from deposits directly overlying the Dhosa Conglomerate Bed (DCB in Figs 11 and 12) on the Kachchh Mainland, or from identified stratigraphic intervals above with some local degree of uncertainty about their precise horizons. The lower part of the Kimmeridgian succession in the Kachchh Basin is mainly composed of fine- to medium-sandy deposits followed by coarser sandstones, with or without cross-bedding, that belong to the Katrol Formation and lateral equivalents.

Ammonites from the lower, fine-sandy deposits are *Schaireria* sp. aff. *avellanoides* (Uhlig) and *Torquatisphinctes alterneplicatus* (Waagen), collected from different sections. Also potentially recovered from horizons below the coarser-grained sandstones are *Katrolliceras* sp. cf. *depressum* Spath, *Streblites plicodiscus* (Waagen), and *Aspidoceras asymmetricum* Spath, but these three species can also be found in the overlying coarser-grained sandstones. In the Wagad area, where the Dhosa Conglomerate Bed does not occur, conservative *Torquatisphinctinae* (or ?*Ataxioceratinae*) are quite common and are interpreted as belonging to the morphological plexus *Torquatisphinctes* sp. gr. *interme-*



**Fig. 12. Sections in the southern Kachchh Mainland and Wagad Uplift yielding ammonites for the present study and the stratigraphic ranges of the recorded taxa (for explanations see Figure 11)**

The bold dotted lines demarcate stratigraphic horizons in which a particular taxon occurs, but whose precise position is not known

*dius* Spath – *alterneplicatus* (Waagen), which corresponds to several species erected by Spath (1931a). A single record from the neighbourhood of Adhoi, collected from the Adhoi Member (7 in Fig. 12) and referable to the inner whorls of conservative ataxioceratins, is interpreted preliminarily as “*Orthosphinctes*” sp.

Ammonite assemblages from the overlying coarser sandstones do not differ significantly and are composed of indeterminate *Torquatisphinctinae* and more or less local records of *Katrolicerias* sp. cf. *depressum* Spath, *K.* sp. cf. *sowerbyi* Spath, *Pachysphinctes symmetricus* Spath, *Torquatisphinctes primus* Spath, *T. alterneplicatus* (Waagen), *T. sparsicostatum* (Spath), *T.* sp. gr. *intermedius* Spath – *alterneplicatus* (Waagen), and *Torquatisphinctes* sp. As mentioned above, *Streblites plicodiscus* (Waagen) and *Aspidoceras asymmetricum* Spath may also locally occur in the assemblages of the overlying coarser sandstones.

According to the species identified and the most detailed published biostratigraphic interpretation of the Kimmeridgian deposits in Kachchh (*e.g.*, Krishna *et al.*, 1996b, 2002), it seems that the lithological change from silty fine-grained sandstones to coarser-grained sandstones does not strictly correspond to any relevant change in the occurrence of ammonite species nor to any potential turnover in ammonite assemblages. Moreover, local occurrences of ammonite species such as that of *Schaireria* sp. aff. *avellanooides* (Uhlrig) indicate that the lithological change to coarser-grained deposits above the Dhosa Conglomerate Bed was not isochronous across the Kachchh Basin (*i.e.*, on the Kachchh Mainland it occurred later towards the west; section 1 in Fig. 1). In general, lowermost Upper and locally uppermost Kimmeridgian horizons were well recorded eastwards on the Kachchh Mainland (sections 3, 4, and perhaps 5 in Fig. 1), and the older Kimmeridgian horizons, inconclusively known but most probably belonging to the Lower Kimmeridgian below the *Alterneplicatus* Zone of Krishna *et al.* (1996b, 2002), are represented in the Wagad area of eastern Kachchh (Bharodia section, 8 in Fig. 1). Thus, the major traits in the ammonite biostratigraphy agree with the general stratigraphic framework provided by the previous studies of Krishna *et al.* (2009c) and Mishra (2009), but interpretations based on the present record show different biostratigraphic boundaries concerning the Wagad succession. In addition, the local, precise biostratigraphic data obtained here reveal some differences with respect to previous work. For example, the lowermost ammonite record obtained from above the Dhosa Conglomerate Bed at the Jumara Dome section (1 in Fig. 1) is younger than those recorded eastwards, and the 2-m-thick stratigraphic interval accommodating the Lower Kimmeridgian below the level with recorded ammonites (*Astarte*–*Gryphaea* Bed) in the Bharodia section (8 in Fig. 1) deserves more research in the near future (to compare it with

interpretations in Krishna *et al.*, 2009c and Mishra, 2009; among others).

On the basis of the composition of the ammonite assemblages, plus the ammonite biostratigraphy in Krishna, Pathak (1993) and Krishna *et al.* (1996b, and references therein), and the biozonation proposed by Krishna *et al.* (1996b, 2002), we conclude that their upper Lower and particularly their lower Upper Kimmeridgian is well represented through the combined records of *Torquatisphinctes alterneplicatus* (Waagen), *Streblites plicodiscus* (Waagen), and *Aspidoceras asymmetricum* Spath, together with common primitive, morphologically little – specialized *Torquatisphinctinae* (dominated by *Torquatisphinctes*). All these data could indicate partial records of the *Alterneplicatus* and *Intermedius*–*Acanthicum* Zone, except, perhaps, the uppermost part of the *Intermedius*–*Acanthicum* Zone. The species *plicodiscus* and *asymmetricum*, are, respectively, regional members of the Tethyan genera *Streblites* and *Aspidoceras* of the *binodosum*–*longispinum* and/or, less probably, of the *sesquinosum*–*acanthicum* evolutionary lineages (also identified in Kachchh by Spath, 1930, 1931b). Younger stratigraphic levels within the Kimmeridgian are documented by the record of *Katrolicerias* sp. cf. *depressum* Spath, *Torquatisphinctes alterneplicatus* (Waagen), and *Torquatisphinctes primus* Spath, followed by those of *Torquatisphinctes sparsicostatus* Spath and *Pachysphinctes* sp. cf. *symmetricus* Spath, and finally by *Katrolicerias* sp. cf. *sowerbyi* Spath. These ammonites indicate successive horizons within the Upper Kimmeridgian, from the *Intermedius*–*Acanthicum* Zone to the lower *Bathyplocus* Zone, and then of the lower *Katrolensis* Zone. The local occurrence of *Schaireria* sp. aff. *avellanooides* (Uhlrig) might indicate horizons close to the Kimmeridgian–Tithonian boundary (*i.e.*, close to the *Katrolensis*–*Pottingeri* zonal boundary or lower horizons in the *Katrolensis* Zone).

Concerning the potential correlation with the ammonite biostratigraphic standard scale for the Kimmeridgian in the Tethyan Realm, Mediterranean and Submediterranean areas (Hantzpergue *et al.*, 1997 and references therein), the interpretation of the data corresponds with partial records of the *Divisum*–*Compsum* zones in Mediterranean or epioceanic areas (Olóriz, 1978) and of the *Divisum* – *Acanthicum* zones in Submediterranean, epicontinental areas (Hantzpergue *et al.*, 1997). Less clear is the correlation with Lower Kimmeridgian horizons below the *Divisum* Zone, as assumed for “*Orthosphinctes*” sp. Locally, correlation is possible with horizons close to the Kimmeridgian – Tithonian boundary (*i.e.*, not clearly defined horizons of the *Beckeri* and/or, perhaps, the lower *Hybonotum* zones). More precise correlation at the subzonal and/or biohorizon level is not available on the basis of the new data, and the general proposals provided by Krishna *et al.* (1996b, 2002) apply at

the ammonite biochronozone level, at least for the Kimmeridgian. The so-called *Ataxioceras*, identified among the Kachchh faunas (e.g., from Spath, 1931a to Krishna *et al.*, 1996b), must be assigned to other ataxioceratin genera according to their respective stratigraphic intervals. This point will also deserve closer attention in the future.

Given the relatively scarce material and its limited preservation, the biochronostratigraphic interpretation just discussed must be considered as a first, preliminary step to be improved by future research based on more abundant, better preserved material collected under strict biostratigraphic control.

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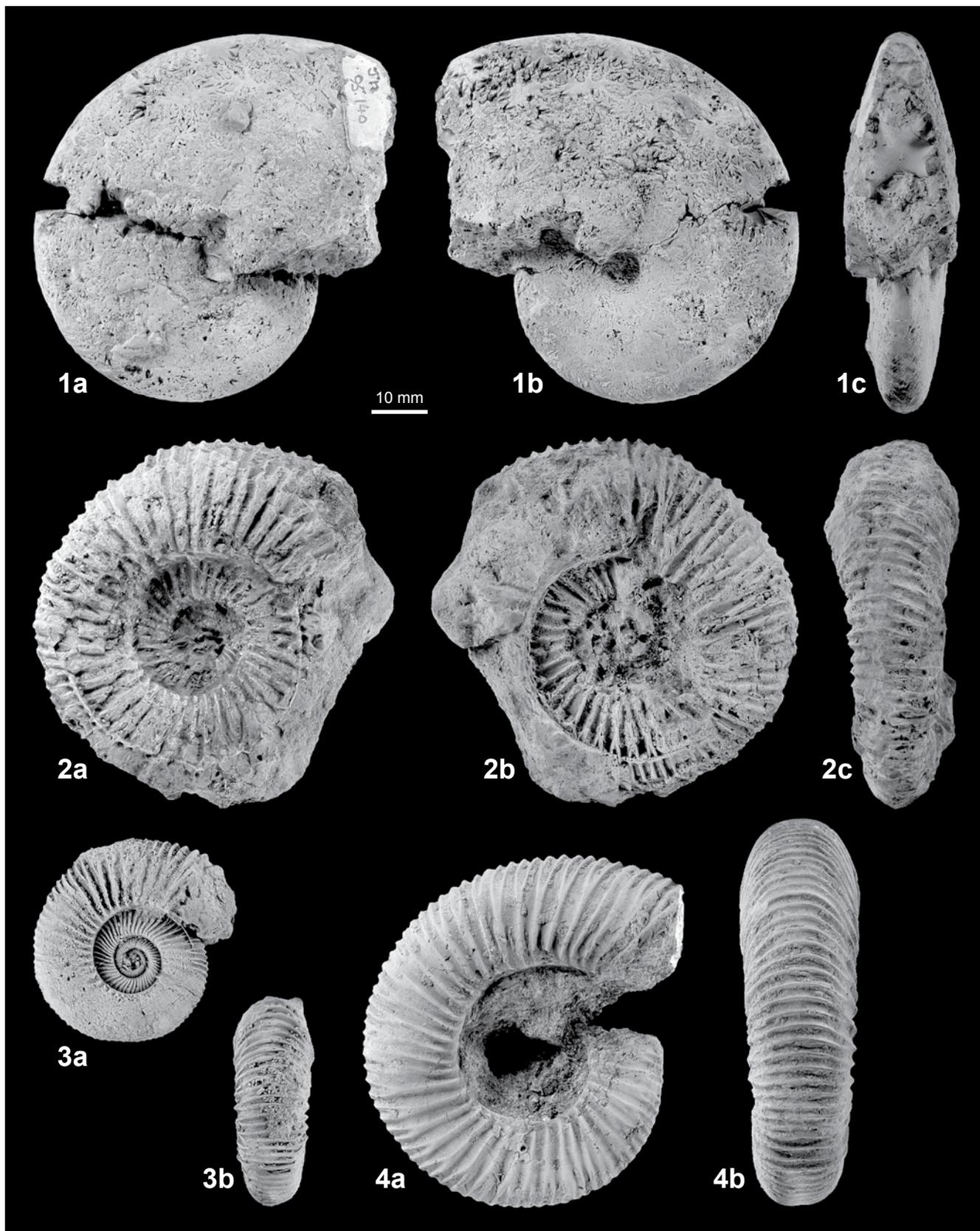
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## PLATE 1

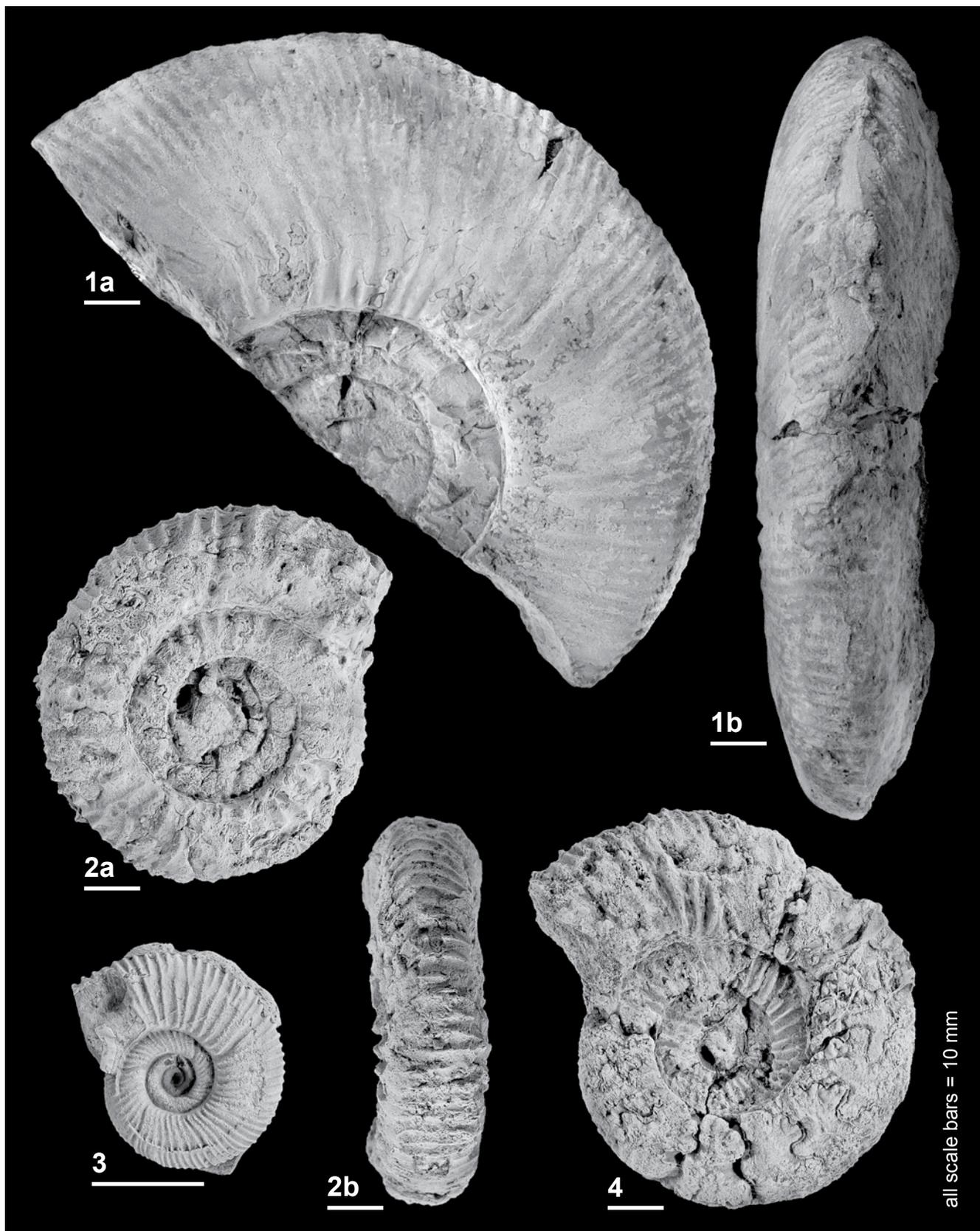
- Fig. 1. *Streblites plicodiscus* (Waagen, 1875); lateral (a, b) and apertural (c) views of OUMNH JY.1052
- Fig. 2. *Perisphinctes* (*Dichotomoceras*) aff. *bifurcatoides* Enay, 1966 (m); lateral (a, b) and ventral (c) views of GZN2010I 047
- Fig. 3. ?*Subdiscosphinctes* sp.; lateral (a) and ventral (b) views of GZN2010I 051
- Fig. 4. *Perisphinctes* (*Dichotomoceras*) cf. *duongae* Meléndez, 1989, *emend.* Gygi, 2000a (m); lateral (a) and ventral (b) views of OUMNH JY.1131



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## PLATE 2

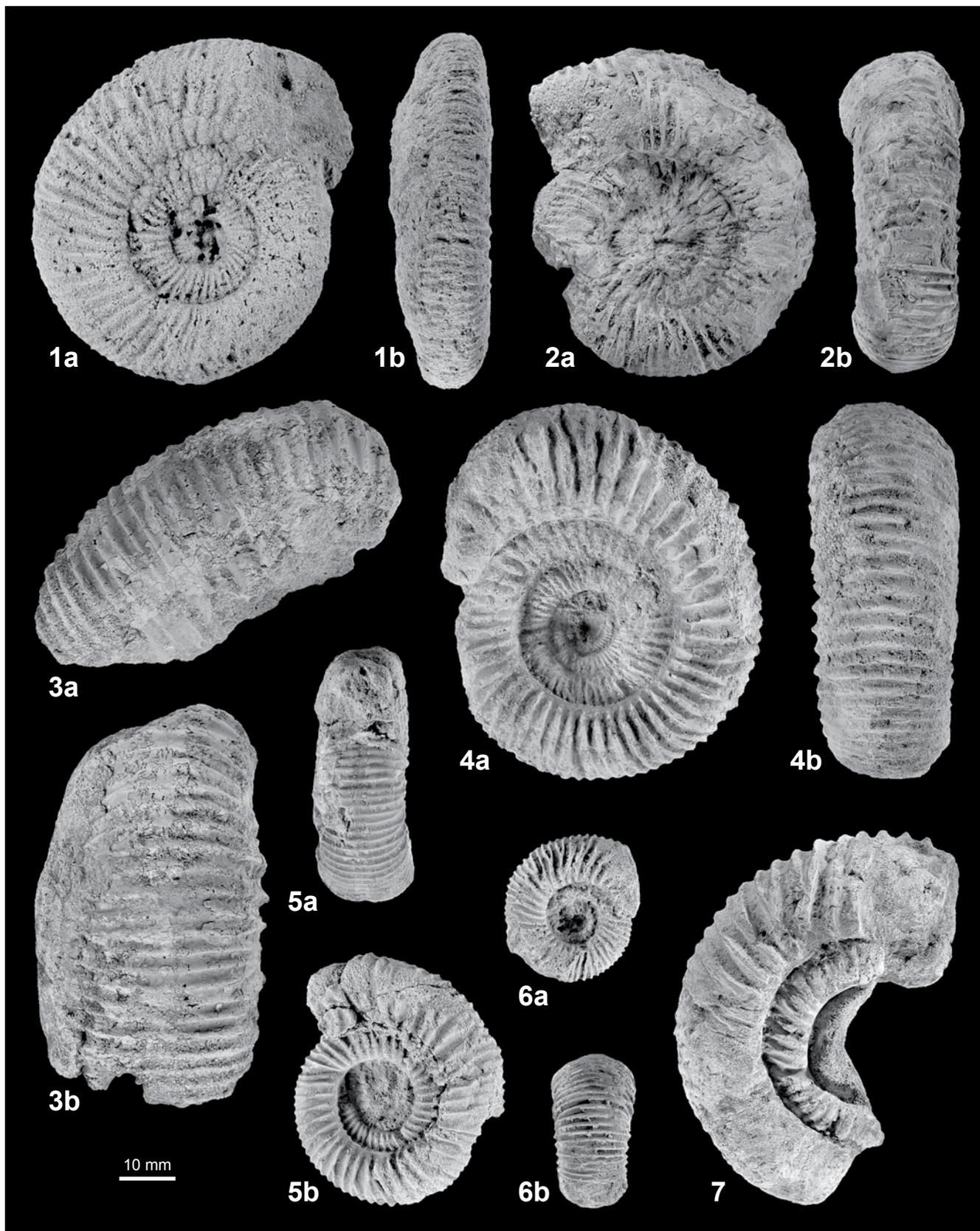
- Fig. 1. ?*Larcheria* sp. (M); lateral (a) and ventral (b) views of OUMNH JY.1130
- Fig. 2. *Perisphinctes* (*Dichotomoceras*) aff. *rotoides* Ronchadzé, 1917; lateral (a) and ventral (b) views of GZN2010I 057
- Fig. 3. ?*Subdiscosphinctes* sp.; lateral view of GZN2010I 053
- Fig. 4. *Perisphinctes* (*Dichotomoceras*) aff. *bifurcatoides* Enay, 1966 (m); lateral view of GZN2010I 046



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### PLATE 3

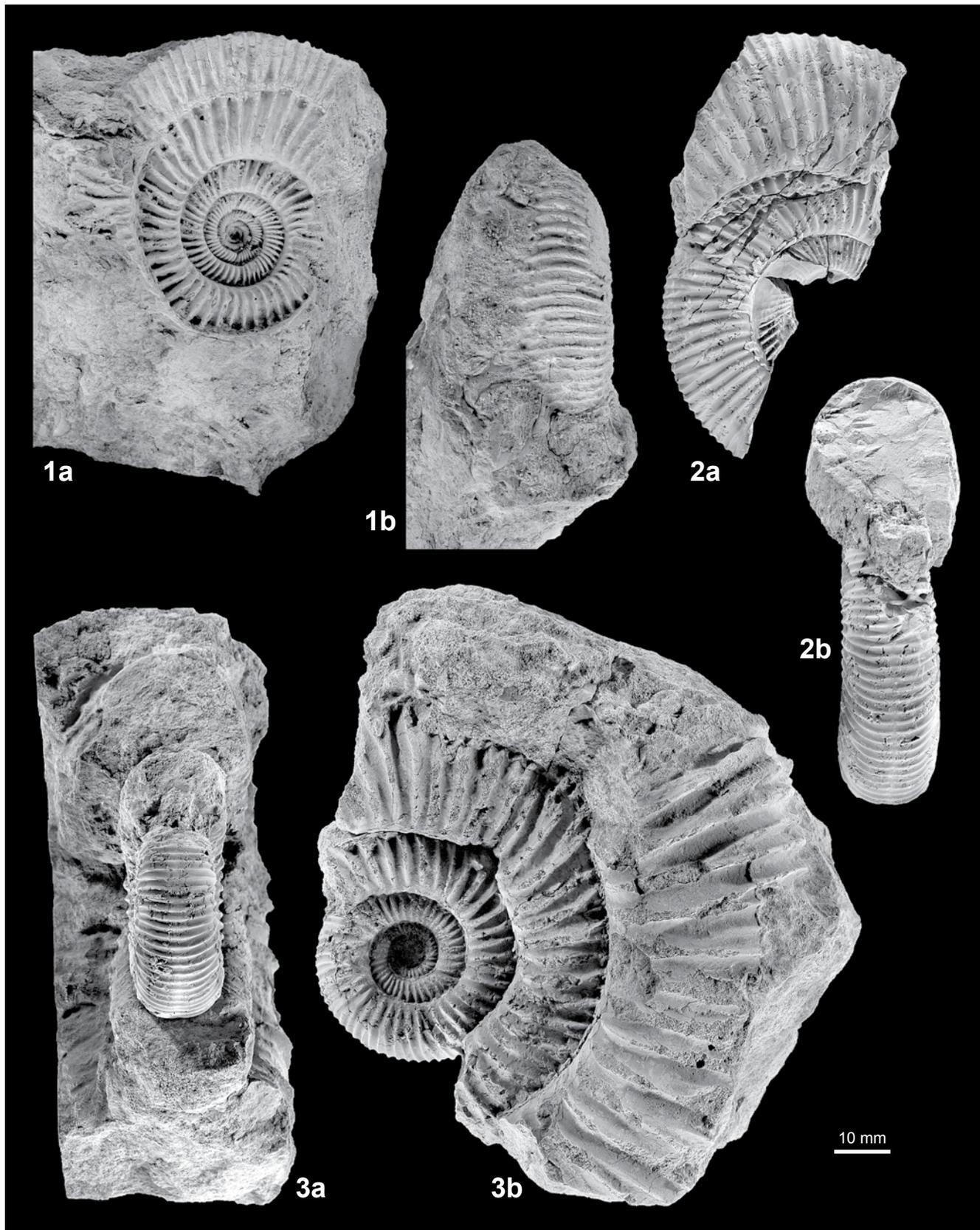
- Fig. 1. "*Orthosphinctes*" sp.; lateral (a) and ventral (b) views of GZN2010I 059
- Fig. 2. *Perisphinctes* subgen. and sp. ind.; lateral (a) and ventral (b) views of GZN2010I 048
- Fig. 3. *Pachysphinctes* sp. cf. *symmetricus* Spath, 1931; lateral (a) and ventral (b) views of GZN2010I 1025
- Fig. 4. *Katroliceras* sp. cf. *sowerbyi* Spath, 1931; lateral (a) and ventral (b) views of GZN2010I 1005
- Fig. 5. *Katroliceras* sp. cf. *depressum* Spath, 1931; apertural (a) and lateral (b) views of GZN2010I 1008
- Fig. 6. *Katroliceras* sp. cf. *depressum* Spath, 1931; lateral (a) and ventral (b) views of GZN2010I 1007
- Fig. 7. *Katroliceras* sp. cf. *depressum* Spath, 1931; lateral view of GZN2010I 1033



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## PLATE 4

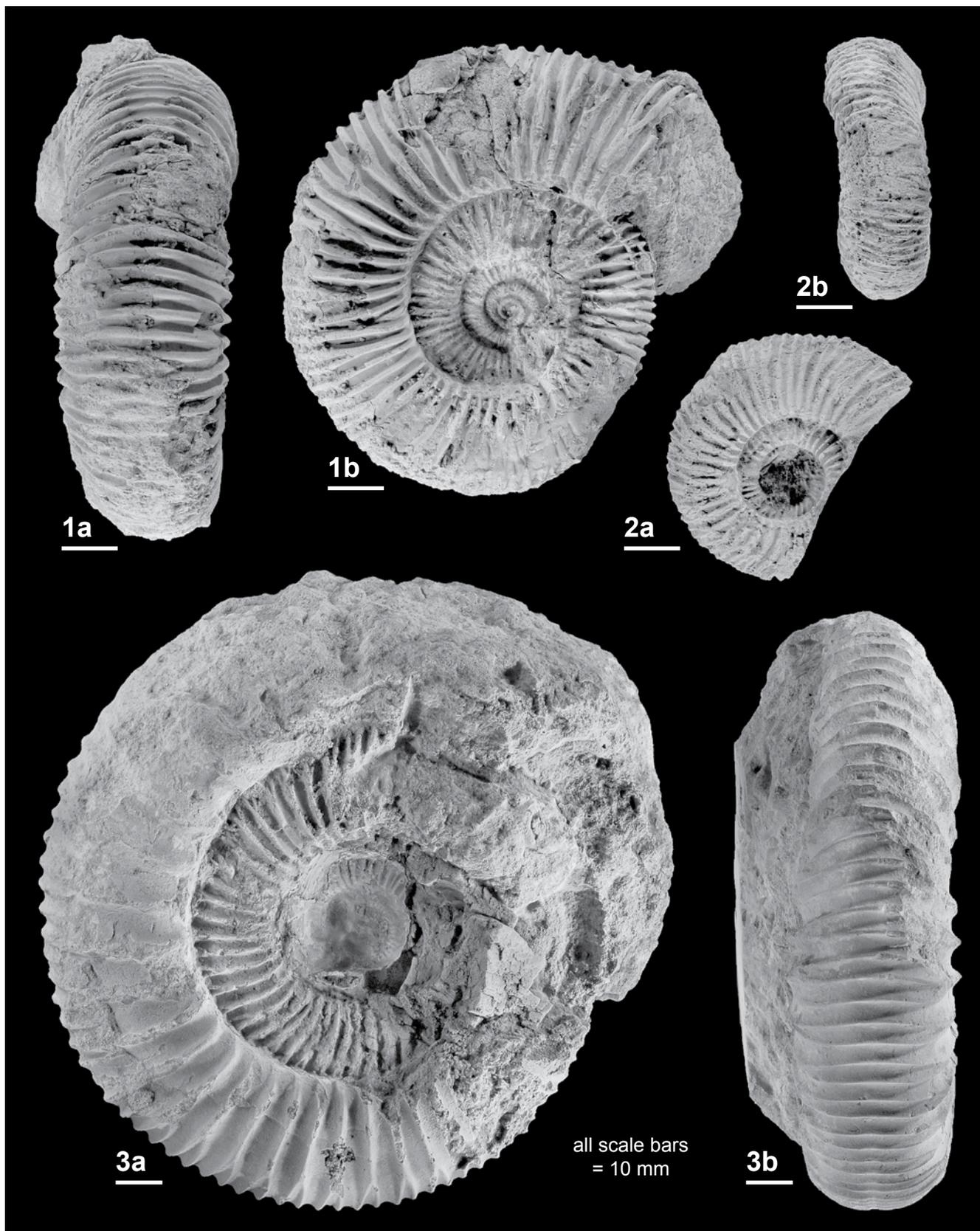
- Fig. 1. *?Torquatisphinctes* sp.; lateral (a) and ventral (b) views of GZN2010I 039
- Fig. 2. *Torquatisphinctes alterneplicatus* (Waagen, 1875); lateral (a) and apertural (b) views of GZN2010I 028
- Fig. 3. *Torquatisphinctes primus* Spath, 1931; apertural (a) and lateral (b) views of GZN2010I 026



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## PLATE 5

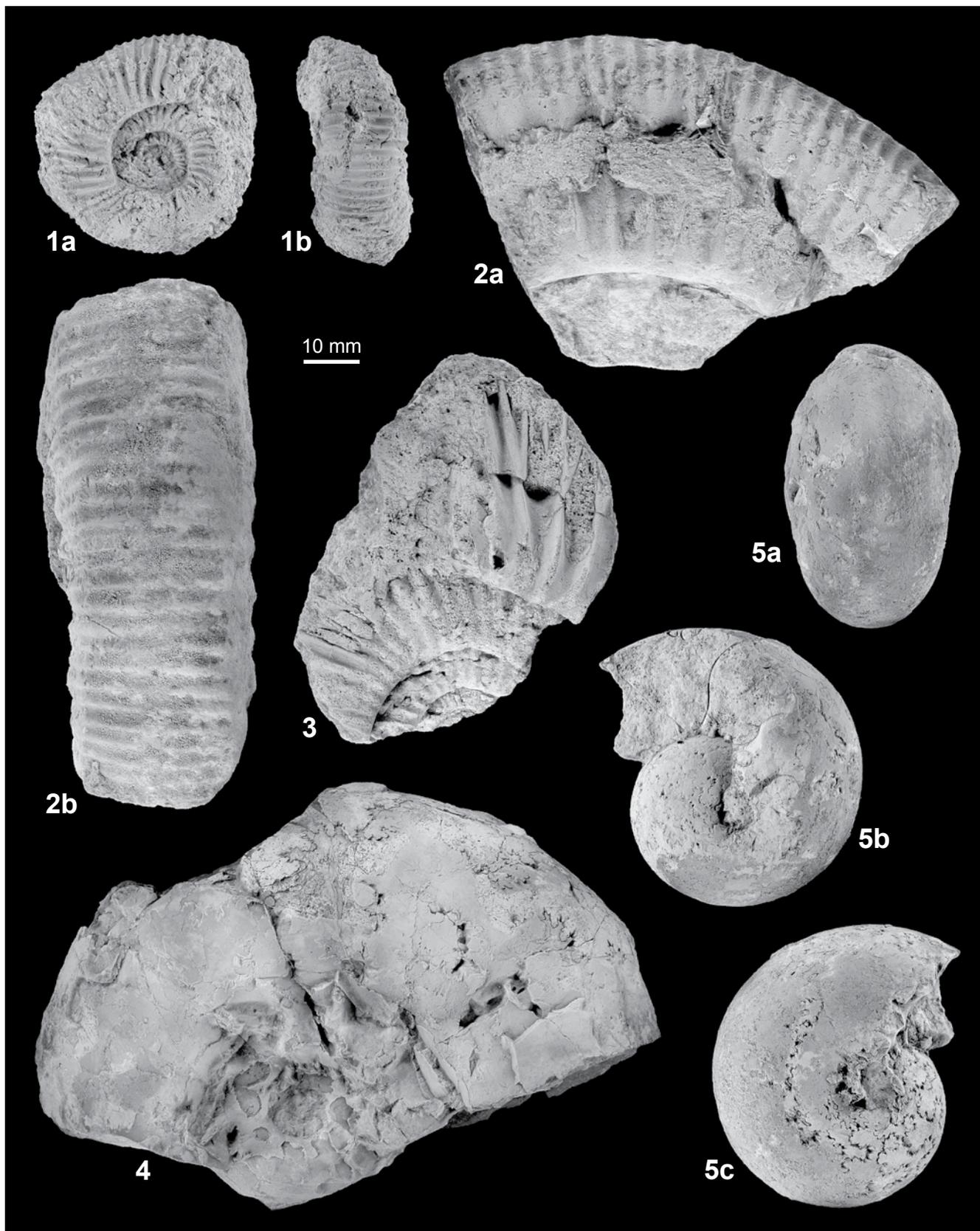
- Fig. 1. *Torquatisphinctes* sp. gr. *intermedius* Spath, 1931 – *alterneplicatus* (Waagen, 1875); ventral (a) and lateral (b) views of GZN2010I 041
- Fig. 2. *Torquatisphinctes* sp. gr. *intermedius* Spath, 1931 – *alterneplicatus* (Waagen, 1875); lateral (a) and ventral (b) views of GZN2010I 1035
- Fig. 3. *Torquatisphinctes sparsicostatus* (Spath), 1931; lateral (a) and ventral (b) views of GZN2010I 1001



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## PLATE 6

- Fig. 1. *Torquatisphinctinae*, gen. and sp. ind.; lateral (a) and ventral (b) views of GZN2009II 015
- Fig. 2. *Torquatisphinctes* sp.; lateral (a) and ventral (b) views of GZN2010I 1028
- Fig. 3. *Torquatisphinctes* sp.; lateral view of GZN2010I 1027
- Fig. 4. *Aspidoceras asymmetricum* Spath, 1931; lateral view of OUMNH JY.1263
- Fig. 5. *Schaireria* sp. aff. *avellanooides* (Uhlig, 1910); ventral (a) and lateral (b, c) views of GZN2009II 190



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