



AMMONITES OF THE GENERA *PELTOCERAS* WAAGEN, 1871, *METAPELTOCERAS* SPATH, 1931, AND *EUASPIDOCERAS* SPATH, 1931 FROM THE UPPER CALLOVIAN AND OXFORDIAN OF KACHCHH, WESTERN INDIA, AND THEIR BIOSTRATIGRAPHIC POTENTIAL

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ABSTRACT

Members of the family Aspidoceratidae Zittel, 1895 dominate the ammonite assemblage of the Upper Callovian of the Kachchh Basin. With the appearance of the genus *Perisphinctes* Waagen, 1869 in the Early Oxfordian they lose their dominance, but still form a relatively diverse group. In the present study, 32 ammonites from the Kachchh Basin in western India have been assigned to 18 taxa belonging to the genera *Peltocheras* Waagen, 1871, *Metapeltocheras* Spath, 1931, and *Euaspidoceras* Spath, 1931. Due to co-occurring ammonites as well as comparisons with European sections, most of these taxa can be attributed to ammonite zones of the Upper Callovian to lower Upper Oxfordian: *Athleta* Zone (*Peltocheras kachhense*, *P.* aff. *kachhense*, *P. ponderosum*, *Metapeltocheras armiger*, *M.* aff. *armiger*, *M.* cf. *kumagunense*, *M. flavum*, *Euaspidoceras acanthodes*), *Mariae-Cordatium* zones (*Euaspidoceras* aff. *babeaunum*), *Cordatium* Zone (*Euaspidoceras waageni*, *E. simile*, *E. badiense*), *Cordatium-Transversarium* zones (*Euaspidoceras sparsispinum*), *Plicatilis-Bifurcatus* zones (*Euaspidoceras wagurensis*), and *Bifurcatus* Zone (*Euaspidoceras varians*, *E.* aff. *jeanneti*).

Keywords: Ammonoids, taxonomy, biostratigraphy, Jurassic, Kachchh Basin, India

INTRODUCTION

The Jurassic succession of the Kachchh Basin in western India (Fig. 1) is well known for its abundant fossil content including a diverse ammonite fauna. Since the first taxonomic studies of Waagen (1873-1875) and Spath (1927-1933), much progress has been achieved especially concerning the litho- and biostratigraphy of the area (e.g., Agrawal, 1956; Deshpande and Merh, 1980; Biswas, 1980, 1982, 1991, 1993; Singh *et al.*, 1982, 1983; Pandey and Agrawal, 1984; Agrawal and Pandey, 1985; Krishna and Westermann, 1987; Pandey and Westermann, 1988; Pandey *et al.*, 1994; Pandey and Callomon, 1995; Jain *et al.*, 1996; Krishna *et al.*, 1996a, b, 1998, 2000, 2009a, b, c; Fürsich *et al.*, 2001, 2013). Nevertheless, three recent field surveys concentrating mainly on the Oxfordian part of the succession showed that despite a considerable number of published taxonomic studies, the ammonite record of the Kachchh Basin has not yet been completely described. During the field work more than 800 specimens were collected with high stratigraphic resolution and additional material collected by the Late John H. Callomon in the 1990s was studied at the Oxford University Museum of Natural History, England. This large collection forms the base for a series of articles planned to enlarge our knowledge on cephalopods from the Oxfordian of the Kachchh Basin (compare Alberti *et al.*, 2011; Pandey *et al.*,

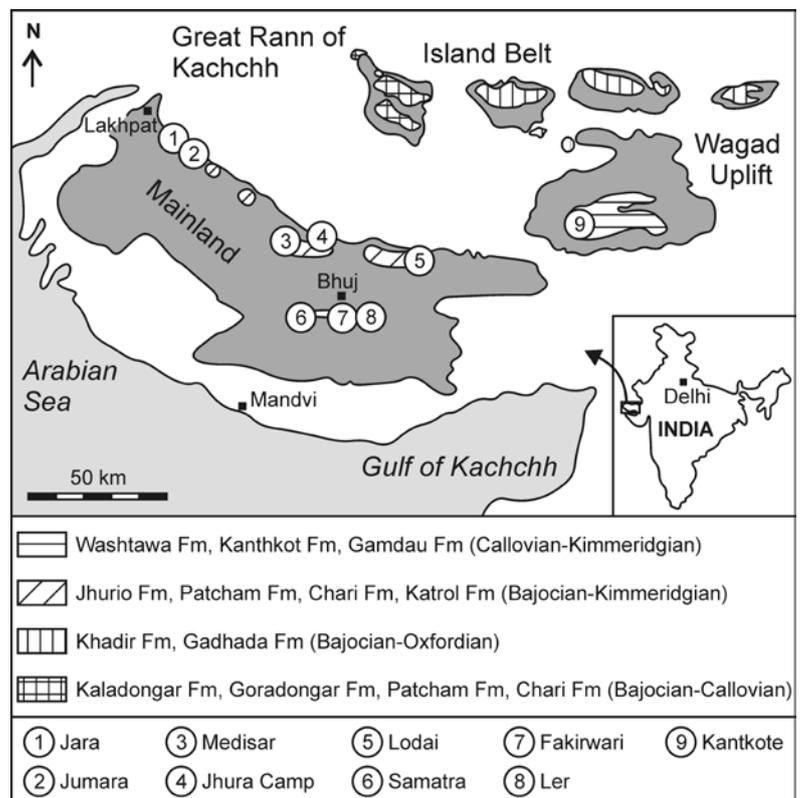


Fig. 1. Geological sketch map of the Kachchh Basin showing the position of the sections yielding ammonites for the present study (modified after Fürsich *et al.*, 2004, 2005).

2012, 2013a, b). The current article presents ammonites of the genera *Peltoceras* Waagen, 1871, *Metapeltoceras* Spath, 1931, and *Euspidoceras* Spath, 1931 which are especially common and diverse around the Middle to Late Jurassic transition.

GEOLOGICAL SETTING

The Kachchh Basin in western India formed in the Late Triassic following rifting between India and Africa (Biswas, 1982, 1991). After an initial phase of terrestrial sedimentation, marine conditions dominated the area from the Bajocian until the Early Cretaceous (Singh *et al.*, 1982; Fürsich, 1998; Pandey *et al.*, 2009). Jurassic outcrops can be found in three areas: the so-called Kachchh Mainland in the central part of the basin, a chain of “islands” amidst the salt marshes of the Great Rann of Kachchh, and the Wagad Uplift.

The oldest ammonites of the family Aspidoceratidae described in the present study have been collected from the upper Gypsiferous Shale member on the Kachchh Mainland which is of Late Callovian age (Athleta Zone; for a bio- and lithostratigraphic overview see Fig. 2). This unit consists of argillaceous silt with abundant secondary gypsum and gradually coarsens into the Dhosa Sandstone member in which ammonites are generally rare. The appearance of allochthonous, ferruginous ooids marks the boundary to the Dhosa Oolite member, which forms the top of the Callovian-Oxfordian Chari Formation on the Kachchh Mainland. Ammonites in the fine-grained sandstone beds of this unit generally point to an Early Oxfordian age (Cordatum Zone; Alberti *et al.*, 2011). Only the uppermost horizon of the Dhosa Oolite member, the Dhosa Conglomerate Bed, contains younger, but reworked ammonites of Early to Middle Oxfordian age (Cordatum, Plicatilis, and Transversarium zones; Pandey *et al.*, 2012). The strongly condensed Dhosa Oolite member and the overlying Katrol Formation are divided by a stratigraphic gap including parts of the Late Oxfordian and Early Kimmeridgian (compare Alberti *et al.*, 2013).

Autochthonous occurrences of Middle and Late Oxfordian ammonites have been found only in the Wagad Uplift and on the small islet Gangta Bet. Both areas have yielded members of the Aspidoceratidae, but since the position of the Gangta Bet is secluded and most of its ammonites can not be found anywhere else in the basin, they have been described separately (Pandey *et al.*, 2013a). The Oxfordian of the Wagad Uplift comprises several hundred metres of rocks which are, however, mostly devoid of identifiable ammonites. Only the Kanthkot Ammonite Beds are well-known for their rich fossil content (Krishna *et al.*, 1996b, 1998, 2009a, b; Pandey *et al.*, 2012) including also few members of the Aspidoceratidae.

SYSTEMATIC PALAEOLOGY

In the following, 32 ammonites are described which have been assigned to 18 taxa. Specimens were measured using a Vernier Caliper, and dimensions in Table 1 are given in millimetres. Numbers in parantheses are proportional dimensions as percentage of the diameter. The measurements and abbreviations used are explained in Fig. 3. In the presence of large tubercles, dimensions were measured at least at two different positions: on and between tubercles. Note that these positions could not always be adjacent to each other.

Most of the specimens were collected during three field surveys to the Kachchh Basin during the years 2008-2011. They have a catalogue number with the prefix GZN and are currently housed at the GeoZentrum Nordbayern of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, but it

is planned to ultimately transfer them to the collections of the Department of Geology, University of Rajasthan, Jaipur, India. Specimens with the prefix OUMNH were collected by the Late John H. Callomon during his research in the Kachchh Basin in the 1990s and were examined at the Oxford University Museum of Natural History, England.

In comparison to many other taxonomic studies, the ammonites of the Kachchh Basin suffer from a series of limitations (compare Pandey *et al.*, 2012). Most taxa are represented only by wholly septate, internal whorls or even fragments thereof. Only very few specimens have been recovered in which parts of the body chamber can be seen. This problem, which was present already in the collection studied by Waagen (1873-1875) and Spath (1927-1933), commonly prohibited the thorough description of the different ontogenetic stages of many species. Similarly, the present material does not allow a complete characterization of the respective species. Nevertheless, based on the measured dimensions, diagnostic whorl section, thickness and position of ribs, as well as density, shape, number, and size of tubercles even several smaller

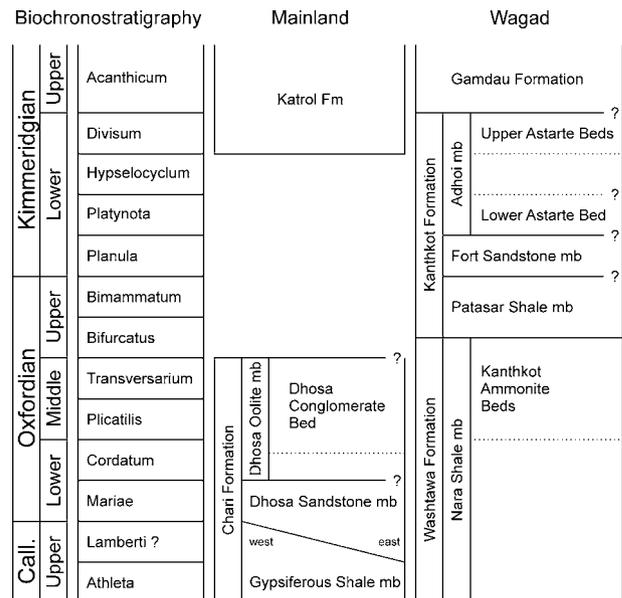


Fig. 2. Litho- and biostratigraphic framework of the Upper Callovian to Kimmeridgian strata of the Kachchh Basin (modified after Krishna *et al.*, 1996b, 2009a; Alberti *et al.*, 2011; Pandey *et al.*, 2012, 2013b). Note the diachronous boundary between the Gypsiferous Shale and Dhosa Sandstone members. The boundary between Dhosa Sandstone and Dhosa Oolite members is based on the arbitrary presence or absence of ferruginous ooids and is also diachronous. Since the stratigraphic units around the Oxfordian to Kimmeridgian boundary in the Wagad Uplift contain only very rare ammonites, their age assignments are still pending.

fragments could be assigned to their appropriate taxa (in some cases only tentatively). The higher stratigraphic resolution while collecting the specimens, compared with older studies, allows more precise biostratigraphic correlations.

- Class **Cephalopoda** Cuvier, 1797
- Order **Ammonoidea** Zittel, 1884
- Suborder **Ammonitina** Hyatt, 1889
- Superfamily **Perisphinctaceae** Steinmann, 1890
- Family **Aspidoceratidae** Zittel, 1895
- Subfamily **Peltoceratinae** Spath, 1924
- Genus **Peltoceras** Waagen, 1871
- Type species: *Ammonites athleta* Phillips, 1829.

Table 1: Dimensions of collected ammonites compared to literature data. Abbreviations are explained in Fig. 3.

taxa	D	Wh	Ww	U	Wh/Ww
<i>Peltoceras kachhense</i> Spath, 1931					
GZN2010I 020 (on tubercles)	-	42.1	43.3	-	0.97
GZN2010I 020 (between tubercles)	-	39.6	33.2	-	1.19
<i>Peltoceras aff. kachhense</i> Spath, 1931					
GZN2010I 018 (on tubercles)	-	38.9	33.5	-	1.16
GZN2010I 018 (between tubercles)	-	38.5	28.4	-	1.36
GZN2010I 004 (on tubercles)	-	31.1	28.8	-	1.08
GZN2010I 004 (between tubercles)	-	28.2	20.7	-	1.36
<i>Peltoceras ponderosum</i> (Waagen, 1875)					
GZN2010I 019 (on tubercles)	-	31.8	~61.0	-	~0.52
GZN2010I 019 (between tubercles)	-	28.3	48.0	-	0.59
<i>Aspidoceras ponderosum</i> Waagen, 1875, p. 95 (on tubercles)	150	59 (39)	103 (69)	65 (43)	0.57
<i>Aspidoceras ponderosum</i> Waagen, 1875, p. 95 (between tubercles)	150	59 (39)	85 (57)	65 (43)	0.69
<i>Metapeltoceras armiger</i> (J. de C. Sowerby, 1840)					
GZN2009II 120 (on tubercles)	-	45.2	45.2	-	1.00
GZN2009II 120 (between tubercles)	-	44.8	38.6	-	1.16
GZN2009II 120 (between tubercles)	71.7	26.1 (36)	~20.3 (28)	29.6 (41)	~1.29
GZN2009II 122 (between tubercles)	45.3	15.9 (35)	13.5 (30)	19.3 (43)	1.18
GZN2009II 122 (on tubercles)	44.3	15.0 (34)	15.6 (35)	19.2 (43)	0.96
<i>Metapeltoceras armiger</i> (J. de C. Sowerby) – Spath, 1931, p. 574	175	60 (34)	51 (29)	70 (40)	1.17
<i>Metapeltoceras aff. armiger</i> (J. de C. Sowerby, 1840)					
GZN2009II 123 (on tubercles)	-	33.3	35.5	-	0.94
GZN2009II 123 (between tubercles)	-	31.4	27.7	-	1.13
GZN2009II 123 (on tubercles)	66.0	19.7 (30)	22.0 (33)	33.3 (50)	0.90
GZN2009II 123 (between tubercles)	66.0	19.3 (29)	18.5 (28)	32.8 (50)	1.04
GZN2009II 123 (on tubercles)	-	13.0	13.8	-	0.94
GZN2009II 123 (between tubercles)	-	12.2	11.6	-	1.05
<i>Metapeltoceras cf. kumagunense</i> (Spath, 1931)					
GZN2009II 126 (between tubercles)	-	36.3	32.8	-	1.11
GZN2009II 126 (on tubercles)	-	36.0	39.0	-	0.92
GZN2009II 127 (between tubercles)	-	35.7	29.7	-	1.20
GZN2009II 127 (on tubercles)	-	33.5	35.3	-	0.95
<i>Peltoceras kumagunense</i> Spath, 1931, p. 566	170	53 (31)	49 (29)	77 (45)	1.07
<i>Metapeltoceras flavum</i> Spath, 1931					
GZN2010I 1009	144.0	46.5 (32)	~35.0 (24)	57.8 (40)	1.33
<i>Metapeltoceras flavum</i> Spath, 1931, p. 577	153	54 (35)	41 (27)	58 (38)	1.30
<i>Euaspidoceras acanthodes</i> Spath, 1931					
GZN2009II 226 (on tubercles)	-	52.4	84.0	-	0.62
GZN2009II 226 (between tubercles)	-	49.2	59.3	-	0.83
GZN2009II 129 (between tubercles)	-	48.2	56.0	-	0.86
GZN2009II 129 (on tubercles)	-	47.7	~76.0	-	0.63
GZN2009II 226 (on tubercles)	-	27.3	~39.0	-	~0.70
GZN2009II 226 (between tubercles)	-	~22.0	25.5	-	~0.86
<i>Euaspidoceras acanthodes</i> Spath, 1931, p. 597	75	27 (36)	32 (43)	30 (40)	0.84
<i>Euaspidoceras badiense</i> Spath, 1931					
GZN2010I 016 (between tubercles)	126.3	44.3 (35)	47.8 (38)	51.7 (41)	0.93
GZN2010I 016 (on tubercles)	121.0	43.2 (36)	60.5 (50)	49.8 (41)	0.71
OUMNH JY.939 (between tubercles)	102.8	36.2 (35)	43.5 (42)	41.2 (40)	0.83
OUMNH JY.939 (on tubercles)	93.5	32.1 (34)	~52.5 (56)	37.8 (40)	~0.61
<i>Euaspidoceras badiense</i> Spath, 1931, p. 609	145	48 (33)	61 (42)	61 (42)	0.79
<i>Euaspidoceras aff. babeanum</i> (d'Orbigny, 1848)					
GZN2009II 124 (on tubercles)	-	40.3	~48.5	-	~0.83

GZN2009II 124 (between tubercles)	-	40.0	42.2	-	0.95
<i>Aspidoceras babe anum</i> (d'Orbigny) – Waagen, 1875, p. 97 (on tubercles)	180	64 (36)	~120 (67)	80 (44)	~0.53
<i>Aspidoceras babe anum</i> (d'Orbigny) – Waagen, 1875, p. 97 (between tubercles)	180	64 (36)	85 (47)	80 (44)	0.75
<i>Euaspidoceras waageni</i> Spath, 1931					
GZN2009II 131 (on tubercles)	101.8	37.3 (37)	~41.0 (40)	39.4 (39)	~0.91
GZN2009II 131 (between tubercles)	85.4	31.0 (36)	32.2 (38)	32.2 (38)	0.96
GZN2009II 131 (on tubercles)	73.1	27.3 (37)	30.7 (42)	26.8 (37)	0.89
GZN2009II 125 (on tubercles)	40.2	14.8 (37)	14.4 (36)	16.2 (40)	1.03
GZN2009II 125 (between tubercles)	39.1	14.2 (36)	12.3 (31)	15.4 (39)	1.15
OUMNH JY.544 (on tubercles)	38.4	~12.5 (33)	14.0 (36)	~16.4 (43)	~0.89
OUMNH JY.545 (on tubercles)	33.2	12.4 (37)	12.2 (37)	~12.2 (37)	1.01
<i>Aspidoceras perarmatum</i> (non J. Sowerby) – Waagen, 1875, p. 93	200	63 (32)	62 (31)	91 (46)	1.02
<i>Euaspidoceras waageni</i> Spath, 1931, p. 600	180	61 (34)	68 (38)	70 (39)	0.89
<i>Euaspidoceras waageni</i> Spath, 1931, p. 600	160	58 (36)	64 (40)	61 (38)	0.90
<i>Aspidoceras perarmatum</i> (non J. Sowerby) – Waagen, 1875, p. 93	100	38 (38)	42 (42)	42 (42)	0.90
<i>Aspidoceras perarmatum</i> (non J. Sowerby) – Waagen, 1875, p. 93	31	12 (39)	12 (39)	12 (39)	1.00
<i>Euaspidoceras simile</i> Spath, 1931					
GZN2010I 002 (on tubercles)	-	54.7	~65.5	-	~0.84
GZN2010I 002 (between tubercles)	-	51.5	59.9	-	0.86
GZN2010I 1043 (on tubercles)	-	50.5	71.5	-	0.71
OUMNH JY.1138 (on tubercles)	97.0	32.1 (33)	~47.3 (49)	40.7 (42)	~0.68
OUMNH JY.1138 (between tubercles)	95.0	32.0 (34)	37.6 (40)	39.8 (42)	0.85
<i>Euaspidoceras simile</i> Spath, 1931, p. 608	150	51 (34)	60 (40)	62 (41)	0.85
<i>Euaspidoceras sparsispinum</i> (Waagen, 1875)					
GZN2009II 224 (on tubercles)	-	~60.0	~88.0	-	~0.68
GZN2009II 224 (between tubercles)	-	~60.0	~73.5	-	~0.82
<i>Aspidoceras sparsispinum</i> Waagen, 1875, p. 98 (on tubercles)	170	61 (36)	~83 (49)	80 (47)	~0.73
<i>Aspidoceras sparsispinum</i> Waagen, 1875, p. 98 (between tubercles)	170	61 (36)	63 (37)	80 (47)	0.97
<i>Euaspidoceras varians</i> (Spath, 1931)					
GZN2010I 131	71.5	26.7 (37)	~22.0 (31)	28.0 (39)	~1.21
GZN2010I 131	53.3	20.2 (38)	17.3 (32)	20.2 (38)	1.17
<i>Neaspidoceras varians</i> Spath, 1931, p. 615	91	30 (33)	30 (33)	37 (41)	1.00
<i>Neaspidoceras varians</i> Spath, 1931, p. 615	89	34 (38)	29 (33)	34 (38)	1.15
<i>Euaspidoceras waturense</i> (Spath, 1931)					
GZN2010I 101	-	55.3	47.7	-	1.16
GZN2010I 079	-	52.1	43.8	-	1.19
OUMNH JY.1176	157.7	49.0 (31)	45.4 (29)	71.9 (46)	1.08
GZN2010I 107	-	45.3	39.8	-	1.14
GZN2010I 079	-	26.6	25.0	-	1.06
<i>Neaspidoceras waturense</i> Spath, 1931, p. 614	155	50 (32)	47 (30)	76 (49)	1.07
<i>Neaspidoceras waturense</i> Spath, 1931, p. 614	125	40 (32)	35 (28)	58 (46)	1.14
<i>Euaspidoceras aff. jeanneti</i> (Collignon, 1959)					
OUMNH JY.1167	-	24.5	20.4	-	1.20
OUMNH JY.1167	-	31.3	26.0	-	1.20
<i>Arcaspidoceras jeanneti</i> Collignon, 1959, pl. 83, fig. 332	89	32 (36)	30 (34)	37 (42)	1.07
<i>Euaspidoceras</i> sp. A					
GZN2009II 130 (on tubercles)	-	14.6	14.6	-	1.00
GZN2009II 130 (between tubercles)	-	13.6	13.4	-	1.01
<i>Euaspidoceras</i> sp. B					
GZN2009II 244	21.8	8.2 (38)	10.3 (47)	7.8 (36)	0.80
GZN2009II 244	15.3	5.7 (37)	7.7 (50)	5.5 (36)	0.74

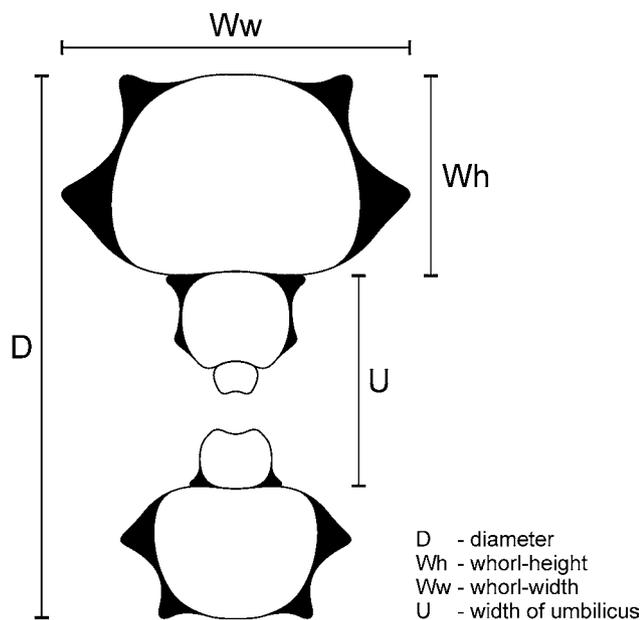


Fig. 3. Measured dimensions of the ammonoids and used abbreviations.

Diagnosis: Evolute, whorls hardly overlapping. Inner whorls with ribs bi- or trifurcating at ventrolateral shoulder. Ribs become thicker during growth, secondaries disappear. Outer whorl with two rows of massive lateral tubercles, outer row developing first. Ventral region nearly flat (compare Arkell *et al.*, 1957).

Peltoceras kachhense Spath, 1931

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

Peltoceras athleta (non Phillips) – Waagen, 1875, p. 81, pl. 17, figs. 2a, b, 3a, b.

Peltoceras kachhense Spath, 1931, p. 561, pl. 107, fig. 1, pl. 108, fig. 3.

Material: Two specimens. One specimen from the Gypsiferous Shale member of the Jumara Dome (GZN2010I 1044) and one specimen from the Gypsiferous Shale member near Samatra, south of Bhuj (GZN2010I 020).

Description: Shell moderately large, evolute, slightly compressed, septate. Whorl section suboval (between tubercles) to subrectangular (at tubercles) with rounded umbilical and ventrolateral shoulders. Venter broad, slightly rounded, crossed by obscure, slightly elevated, broad ridges connecting the tubercles at the ventrolateral shoulder. Maximum thickness of whorl slightly above umbilical shoulder. Ornamentation consists of thick, rounded, straight primary ribs connecting an inner and outer row of tubercles. Inner row slightly above the umbilical shoulder with tubercles elongated parallel to the rib. Outer row at the ventrolateral shoulder with stronger tubercles which are higher, slightly backwards-directed, and moderately elongated perpendicular to the ribs. Umbilical wall high, vertical.

Remarks: The specimens are fragments of phragmocones. The morphology of the tubercles (i.e. smaller, elongated inner tubercles and higher, backwards-directed outer tubercles), the slightly rounded venter with rounded, obscure ridges connecting the ventrolateral tubercles, and the shape of the whorl section of the present specimens match *Peltoceras kachhense* Spath, 1931 which has been described by Spath (1931) from the Gypsiferous Shale member of Samatra, south of Bhuj.

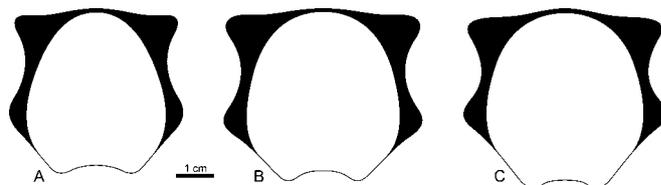


Fig. 4. *Peltoceras kachhense* Spath, 1931. A. Whorl section at unknown diameter; GZN2010I 020. B, C. Whorl sections at unknown diameters; GZN2010I 1044.

Members of the genus *Peltoceras* usually have comparatively densely ribbed inner whorls with secondary ribs on the venter (Arkell *et al.*, 1957). The present specimens represent only fragments of the outer whorls and the ornamentation of the inner whorls is unknown. There are also no imprints of secondary ribs visible on the dorsal side of the fragments. This might support their assignment to the genus *Euaspidoceras*. However, no comparable species of *Euaspidoceras* are known from contemporaneous deposits in the Kachchh Basin. *Euaspidoceras waageni* Spath, 1931 seems to be closely related, but occurs only in the younger Dhosa Oolite member and has somewhat weaker tubercles (see its description below). In addition, Waagen (1875) described specimens later on assigned to *Peltoceras kachhense* by Spath (1931) as showing secondary ribs on the inner whorls thereby justifying its assignment to the genus. It can therefore be assumed that tubercles appear relatively early in *Peltoceras kachhense* connected with a comparatively early disappearance of secondary ribs (compare Bonnot, 1995).

Prasad and Kanjilal (1985) recorded *Peltoceras athleta* (Phillips, 1829) in gypsiferous shales of the Jara Dome on the Kachchh Mainland. Their specimens differ from the present material in having a more depressed shell. Furthermore, the inner tubercles of *Peltoceras athleta* (Phillips, 1829) grow much stronger than the outer ones during ontogeny. This is in contrast to *Peltoceras kachhense* Spath, 1931, whose inner tubercles are always smaller than the outer ones.

Peltoceras aff. *kachhense* Spath, 1931

(Pl. I, fig. 3; Fig. 5; Table 1)

Peltoceras sp. nov. ? aff. *kachhense* Spath, 1931, p. 563, pl. 105, fig. 5, pl. 108, fig. 2a, b, pl. 110, fig. 3, pl. 112, fig. 6, pl. 114, figs. 2, 3, pl. 117, fig. 2.

Material: Two specimens. One specimen from the Gypsiferous Shale member close to Jhura Camp, Jhura Dome (GZN2010I 004), and one specimen from the Gypsiferous Shale member near Samatra, south of Bhuj (GZN2010I 018).

Description: Shell moderately large, evolute, compressed, septate. Whorl section suboval with rounded umbilical and ventrolateral shoulders. Slightly rounded venter crossed by elevated, very broad ridges connecting tubercles at the ventrolateral shoulder. Maximum thickness of whorl slightly above umbilical shoulder. Ornamentation consists of moderately thick, rounded primary ribs connecting an inner and outer row of tubercles. Tubercles are progressively increasing in size during ontogeny. Inner row (slightly above umbilical shoulder) with tubercles elongated along the ribs. Outer row (at the ventrolateral shoulder) with larger tubercles pointing slightly backwards. Umbilical wall high, steep.

Remarks: The specimens are fragments of phragmocones and distinctly more compressed than *Peltoceras kachhense* Spath, 1931 as described above. Although they are broadly similar to this species in terms of ornamentation and whorl

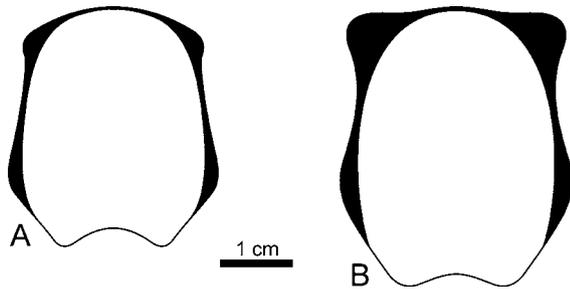


Fig. 5. *Peltoceras* aff. *kachhense* Spath, 1931. A. Whorl section at unknown diameter; GZN2010I 004. B. Whorl section at unknown diameter; GZN2010I 018.

section, the present specimens have smaller tubercles. These differences would support a separation of this taxon from *Peltoceras kachhense* Spath, 1931. Nevertheless, both taxa are closely related as is shown by their occurrence in the same stratigraphic unit and by further transitional forms (Spath, 1931, p. 563). They might therefore reflect intraspecific variability and additional material has to be collected for a definite decision.

Peltoceras ponderosum (Waagen, 1875)

(Pl. II, fig. 1; Fig. 6; Table 1)

Aspidoceras ponderosum Waagen, 1875, p. 94, pl. 20, fig. 1a, b, pl. 21, fig. 2.

Peltoceras ponderosum (Waagen) – Spath, 1931, p. 569, pl. 108, fig. 4a, b, pl. 112, fig. 3.

Material: One specimen from the Gypsiferous Shale member near Samatra, south of Bhuj (GZN2010I 019).

Description: Shell large, evolute, depressed, septate. Whorl section subrounded with rounded flanks merging smoothly into the rounded venter. Ornamentation consists of thick primary ribs with two rows of tubercles in inner and middle whorls. Inner row of tubercles at the region of maximum inflation slightly above the umbilical shoulder. Tubercles of the outer row at the ventrolateral shoulder are slightly weaker. Inner tubercles grow stronger while outer tubercles fade on the outer whorls. Tubercles are conical in shape and circular in outline. Umbilical wall moderately high, umbilical shoulder rounded.

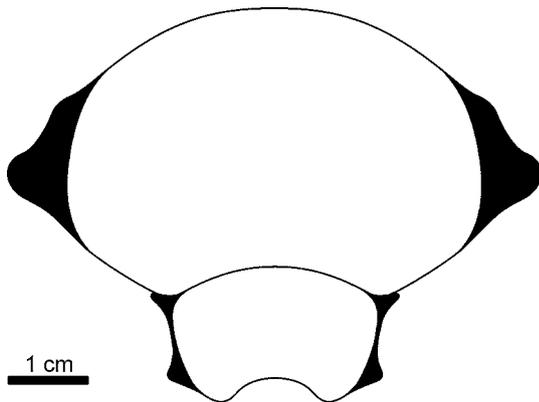


Fig. 6. *Peltoceras ponderosum* (Waagen, 1875). Whorl sections at unknown diameter; GZN2010I 019.

Remarks: The depressed whorl section, the shape of tubercles and the disappearance of the outer row of tubercles on the outer whorl are diagnostic of *Peltoceras ponderosum* (Waagen, 1875), which has been described previously from the Athleta beds of the Kachchh Basin (Waagen, 1875; Spath, 1931). Spath (1931) has assigned *ponderosum* to *Peltoceras* instead *Aspidoceras* by Waagen (1875). The difference between the two genera could be understood only from the ornamentation of inner whorls: parabolic or no-parabolic, however, more features of ornamentation than described above are not preserved in the present specimen therefore no further comment has been done on the specific assignment of this species. The suture-line of this species given by Spath (1931, pl. 112, fig. 3) suggests a *Euaspidoceratinae* (comm. Alain Bonnot)

Genus *Metapeltoceras* Spath, 1931

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

Diagnosis: Evolute, whorls hardly overlapping. Inner whorls with ribs bi- or trifurcating at ventrolateral shoulder. Outer whorls with two rows of lateral tubercles. Inner row developing first but later merging with thick and long primary ribs. Outer row with isolated tubercles up to the body chamber. Venter slightly arched, smooth (compare also Arkell *et al.*, 1957).

Metapeltoceras armiger (J. de C. Sowerby, 1840)

(Pl. II, figs. 2, 3; Fig. 7; Table 1)

Ammonites armiger J. de C. Sowerby, 1840, pl. 23, fig. 13, text-fig. 11.

Metapeltoceras armiger (J. de C. Sowerby) – Spath, 1931, p. 574, pl. 110, figs. 4a, b, 8a, b, pl. 114, fig. 1a, b.

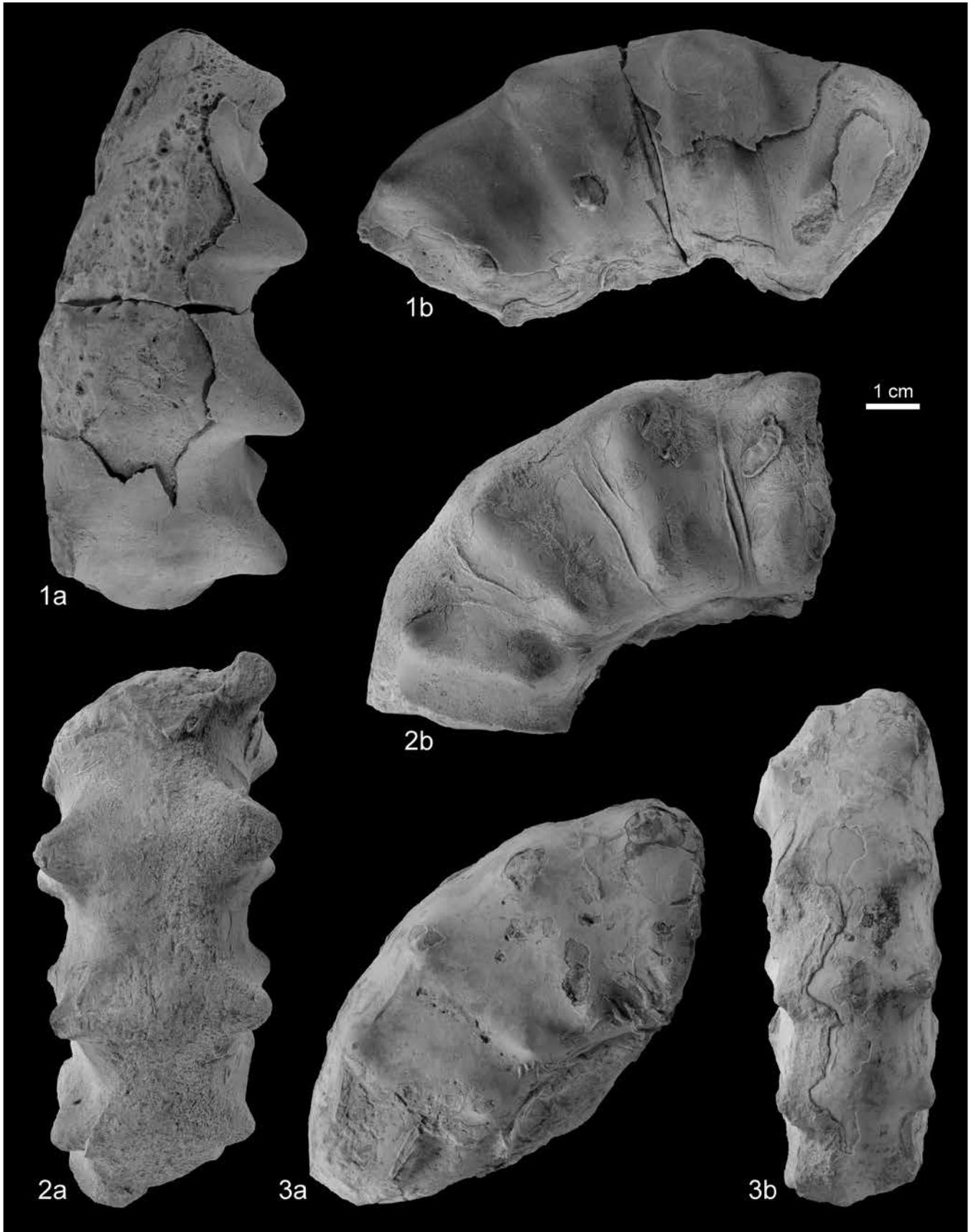
Material: Two specimens from the Gypsiferous Shale member close to Medisar, Jhura Dome (GZN2009II 120, 122).

Description: Shell small to large, evolute, slightly compressed, septate. Whorl section suboval to subrectangular at tubercles with slightly arched flanks merging smoothly into rounded venter. Ornamentation consists of varicostate, prorsiradiate, thick primary ribs with two rows of tubercles on outer whorls. Primary ribs are thickest just above the umbilical shoulder. In inner whorls ribs branch at the middle of the flank into two or three finer secondary ribs with occasionally one or two free secondaries intercalated. Secondary ribs pass the ventrolateral shoulder, but faint before reaching the centre of the venter which is smooth (at least at diameters between 40 and 55 mm). On middle whorls, primary ribs are slightly thicker and show a prominent elevation just above the umbilical shoulder which develops into an inner row of tubercles elongated parallel to the ribs. Eventually secondary ribs disappear and primary ribs become thicker, more distant, and merge with the inner tubercles. The primary ribs diminish slightly short of an outer row of tubercles which develops at the ventrolateral shoulder. Umbilical wall high and steep, umbilical shoulder rounded.

Remarks: The present specimens match *Metapeltoceras armiger* (J. de C. Sowerby, 1840) as described and illustrated by Spath (1931) from the Athleta beds of the Kachchh Basin. This species shows a smooth venter and small tubercles, thereby disagreeing with other members of the *Peltoceratinae*, but

EXPLANATION OF PLATE I

1. *Peltoceras kachhense* Spath, 1931; ventral (a) and lateral (b) view of wholly septate fragment GZN2010I 1044. 2. *Peltoceras kachhense* Spath, 1931; ventral (a) and lateral (b) view of wholly septate fragment GZN2010I 020. 3. *Peltoceras* aff. *kachhense* Spath, 1931; lateral (a) and ventral (b) view of wholly septate fragment GZN2010I 018.



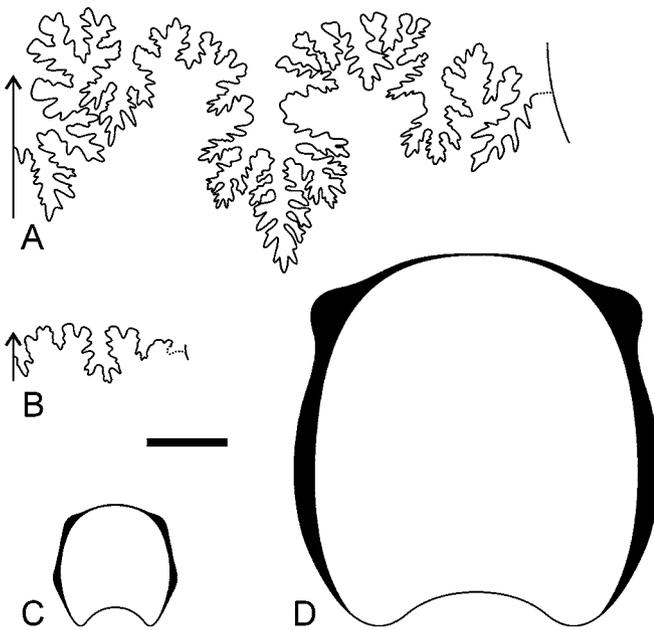


Fig. 7. *Metapeltoceras armiger* (J. de C. Sowerby 1840). A. Suture line at ca. 41 mm whorl height; GZN2009II 120 (scale bar = 7.5 mm). B. Suture line at ca. 31 mm diameter; GZN2009II 122 (scale bar = 7.5 mm). C. Whorl section at ca. 45 mm diameter; GZN2009II 122 (scale bar = 10 mm). D. Whorl section at unknown diameter; GZN2009II 120 (scale bar = 10 mm).

showing an affinity to the contemporary Pseudoperisphinctinae (e.g., *Pseudopeltoceras*). Nevertheless, until more material is collected and a thorough revision of the genus is available, the species and genus are left within the Peltoceratinae.

Metapeltoceras aff. *armiger* (J. de C. Sowerby, 1840)
(Pl. III, fig. 2; Fig. 8; Table 1)

aff. *Ammonites armiger* J. de C. Sowerby, 1840, pl. 23, fig. 13, text-fig. 11.

aff. *Metapeltoceras armiger* (J. de C. Sowerby) – Spath, 1931, p. 574, pl. 110, figs. 4a, b, 8a, b, pl. 114, fig. 1a, b.

Material: One specimen from the Gypsiferous Shale member close to Medisar, Jhura Dome (GZN2009II 123).

Description: Shell moderately large, evolute, slightly compressed, septate. Whorl section subquadrangular with maximum thickness slightly above the umbilical shoulder and slightly rounded venter. On inner whorls ornamentation consists of thick, prorsiradiate, equidistant primary ribs branching into two to three finer secondary ribs at three-fourth of lateral height. Secondary ribs cross straight across the venter. Primary ribs show a prominent elevation just above the umbilical shoulder which develops into a row of tubercles during ontogeny. On outer whorls, ornamentation consists of thick primary ribs originating on the umbilical wall passing through the tubercle just above the umbilical shoulder and terminating in another tubercle at the ventrolateral shoulder. The inner tubercles are elongated parallel to the rib, the outer tubercles are more circular in outline. During ontogeny, inner tubercles develop before the outer ones. Umbilical wall high and steep, umbilical shoulder rounded.

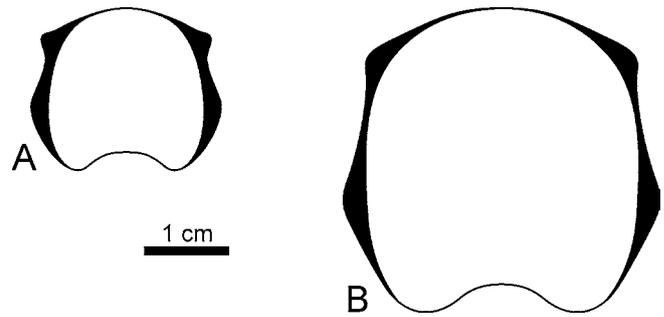


Fig. 8. *Metapeltoceras* aff. *armiger* (J. de C. Sowerby, 1840). A. Whorl section at ca. 66 mm diameter; GZN2009II 123. B. Whorl section at unknown diameter; GZN2009II 123.

Remarks: The specimen greatly resembles *Metapeltoceras armiger* (J. de C. Sowerby, 1840) as described above. However, it differs in having a more depressed whorl section and more prorsiradiate ribs. In the absence of a sufficient number of specimens to evaluate the intraspecific variation, the present specimen has been assigned to *Metapeltoceras armiger* (J. de C. Sowerby, 1840) with qualification only.

Metapeltoceras cf. *kumagunense* (Spath, 1931)
(Pl. IV, fig. 1; Fig. 9; Table 1)

cf. *Peltoceras kumagunense* Spath, 1931, p. 566, pl. 109, figs. 4, 8, pl. 111, fig. 1a, b.

Material: Two specimens from the Gypsiferous Shale member close to Medisar, Jhura Dome (GZN2009II 126, 127).

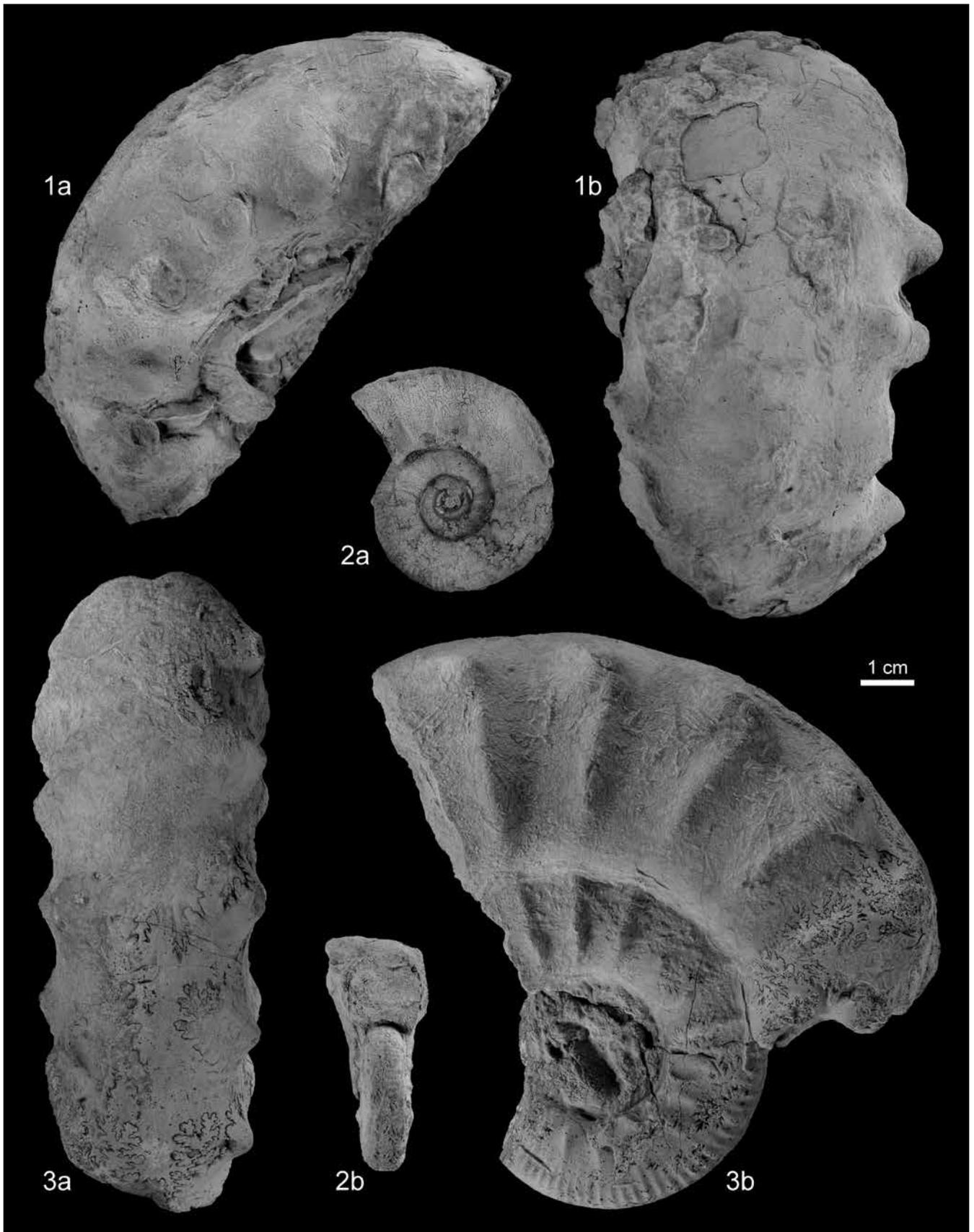
Description: Shell moderately large, evolute, slightly compressed, septate. Whorl section suboval to subquadrangular with maximum thickness slightly above the umbilical shoulder and slightly rounded venter. Ornamentation consists of two rows of tubercles on the outer whorls which are connected by an obscure, broad rib. Inner tubercle slightly above the umbilical shoulder is elongated parallel to the rib, outer tubercle at the ventrolateral shoulder is more circular, pointing slightly backwards. Umbilical wall high and steep, umbilical shoulder rounded.

Remarks: These are fragments of large ammonites with a whorl shape and ornamentation similar to *Metapeltoceras kumagunense* (Spath, 1931). The ornamentation of the inner whorls is not directly observable, but imprints of secondary ribs on the dorsal side of the fragmented specimens are similar to members of the genera *Peltoceras* and *Metapeltoceras*. It has not been described by Spath (1931) and is also not visible in the present specimens whether the outer (as in *Peltoceras*) or the inner (as in *Metapeltoceras*) tubercle develops first during ontogeny. Nevertheless, the species could be assigned to *Metapeltoceras* because of the almost smooth venter of the middle whorls, since *Peltoceras* is commonly characterized by broad, though occasionally weak folds connecting the ventrolateral tubercles across the venter.

Spath (1931) already pointed out the similar ornamentation with respect to the two rows of tubercles compared to *Metapeltoceras armiger* (J. de C. Sowerby, 1840). However, specimens of both taxa can be differentiated by the earlier development of tubercles in *Metapeltoceras kumagunense*

EXPLANATION OF PLATE II

1. *Peltoceras ponderosum* (Waagen, 1875); lateral (a) and ventral (b) view of wholly septate fragment GZN2010I 019. 2. *Metapeltoceras armiger* (J. de C. Sowerby, 1840); lateral (a) and apertural (b) view of wholly septate specimen GZN2009II 122. 3. *Metapeltoceras armiger* (J. de C. Sowerby, 1840); ventral (a) and lateral (b) view of wholly septate fragment GZN2009II 120.



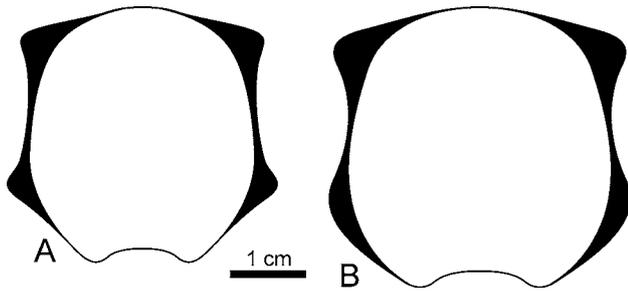


Fig. 9. *Metapeltoceras* cf. *kumagunense* (Spath, 1931). A. Whorl section at unknown diameter; GZN2009II 127. B. Whorl section at unknown diameter; GZN2009II 126.

(Spath, 1931) and the slightly more compressed whorl section of *Metapeltoceras armiger* (J. de C. Sowerby, 1840). Nevertheless, due to the preservation as fragments, the specimens were assigned to this species only tentatively.

Spath (1931, p. 568) described *Metapeltoceras kumagunense* from the Athleta beds as well as the lower Dhosa Oolite member of the Kachchh Basin and tentatively assigned it to the Lamberti Zone of the Upper Callovian. Similarly, the species has been described by Amanniazov (1962) from the Lamberti Zone of Turkmenistan.

Metapeltoceras flavum Spath, 1931
(Pl. IV, fig. 2; Table 1)

Metapeltoceras flavum Spath, 1931, p. 576, pl. 110, fig. 6a, b, pl. 118, fig. 6a, b.

Material: One specimen from the Dhosa Sandstone member south of Lodai, Habo Dome (GZN2010I 1009).

Description: Shell large, evolute, compressed, possibly with parts of the body chamber. Whorl section oval with maximum thickness at one-fourth of lateral height, venter rounded. Ornamentation consists of thick, moderately distant, slightly prorsiradiate primary ribs. Ribs originate at the umbilical shoulder and thicken considerably at one-fourth of lateral height forming a tubercle. At three-fourth of lateral height the rib diminishes only to reappear as a low tubercle at the ventrolateral shoulder. Venter in outer whorls smooth. At least two constrictions visible. Umbilical wall low with rounded umbilical shoulder.

Remarks: The specimen is moderately preserved, its dimensions, whorl section, and ornamentation match *Metapeltoceras flavum* Spath, 1931. This species was previously recorded from the Athleta beds near Jhikadi, Habye (both Habo Dome), and Samatra (south of Bhuj) by Spath (1931). The holotype (figured by Spath 1931, pl. 118, fig. 6) is a fragment and surpassed by the present specimen in preservation quality.

Subfamily *Euspidoceratinae* Spath, 1931

Genus *Euspidoceras* Spath, 1931

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

Diagnosis: Evolute, strongly ribbed, bispinous shells with inner tubercles on early whorls commonly falcoid. Typical is a parabolic ornamentation. Whorl shape commonly (rounded-) quadrate, depressed to compressed. Commonly fine, irregular ribs on inner whorls. The genus includes the taxa *Neuspidoceras*

Spath, 1931 and *Arcaspidoceras* Jeannel, 1951 (compare Arkell *et al.*, 1957; Schlegelmilch, 1994; Bonnot and Gygi, 2001).

Euspidoceras acanthodes Spath, 1931

(Pl. III, fig. 1; Fig. 10; Table 1)

Euspidoceras acanthodes Spath, 1931, p. 597, pl. 109, fig. 13, pl. 115, fig. 8a, b.

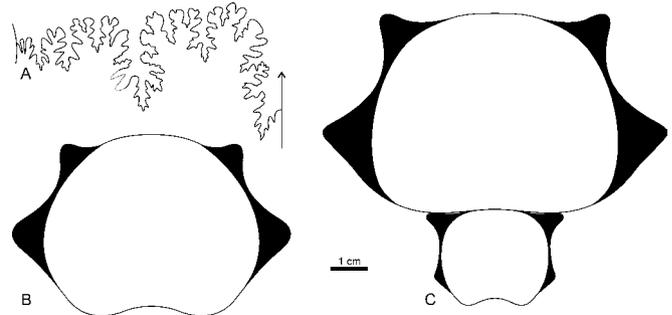


Fig. 10. *Euspidoceras acanthodes* Spath, 1931. A. Suture line at unknown diameter; GZN2009II 129. B. Whorl section at unknown diameter; GZN2009II 129. C. Whorl sections at unknown diameter; GZN2009II 226.

Material: Two specimens from the Gypsiferous Shale member close to Medisar, Jhura Dome (GZN2009II 129, 226).

Description: Shell large, evolute, depressed, septate. Whorl section subrounded with uniformly rounded flanks and venter. Ornamentation consists of thick, rursiradiate, dense (inner whorls) to distant (outer whorls) primary ribs connecting two rows of tubercles. Tubercles significantly increase in size from inner to outer whorls. In inner whorls, the tubercle slightly above the umbilical shoulder is small, elongated parallel to the rib and the tubercle on the ventrolateral shoulder is long, pointing distinctly backwards. In outer whorls, the inner tubercle becomes massive and larger than the outer tubercle. Umbilical wall high, umbilical shoulder rounded.

Remarks: The morphological characters of the specimens match descriptions and illustrations of *Euspidoceras acanthodes* Spath, 1931. The massive tubercles slightly above the umbilical shoulder which can be seen in the outer whorls, together with the strongly depressed whorl section differentiates *Euspidoceras acanthodes* Spath, 1931 from other related forms in the Kachchh Basin. The material shows a strong relationship to *Euspidoceras subbabeantum* as described by Bonnot (1995) from the Lamberti Zone of Europe and might therefore indicate the presence of this zone in the Kachchh Basin.

Euspidoceras badiense Spath, 1931

(Pl. V, figs. 1, 2; Fig. 11; Table 1)

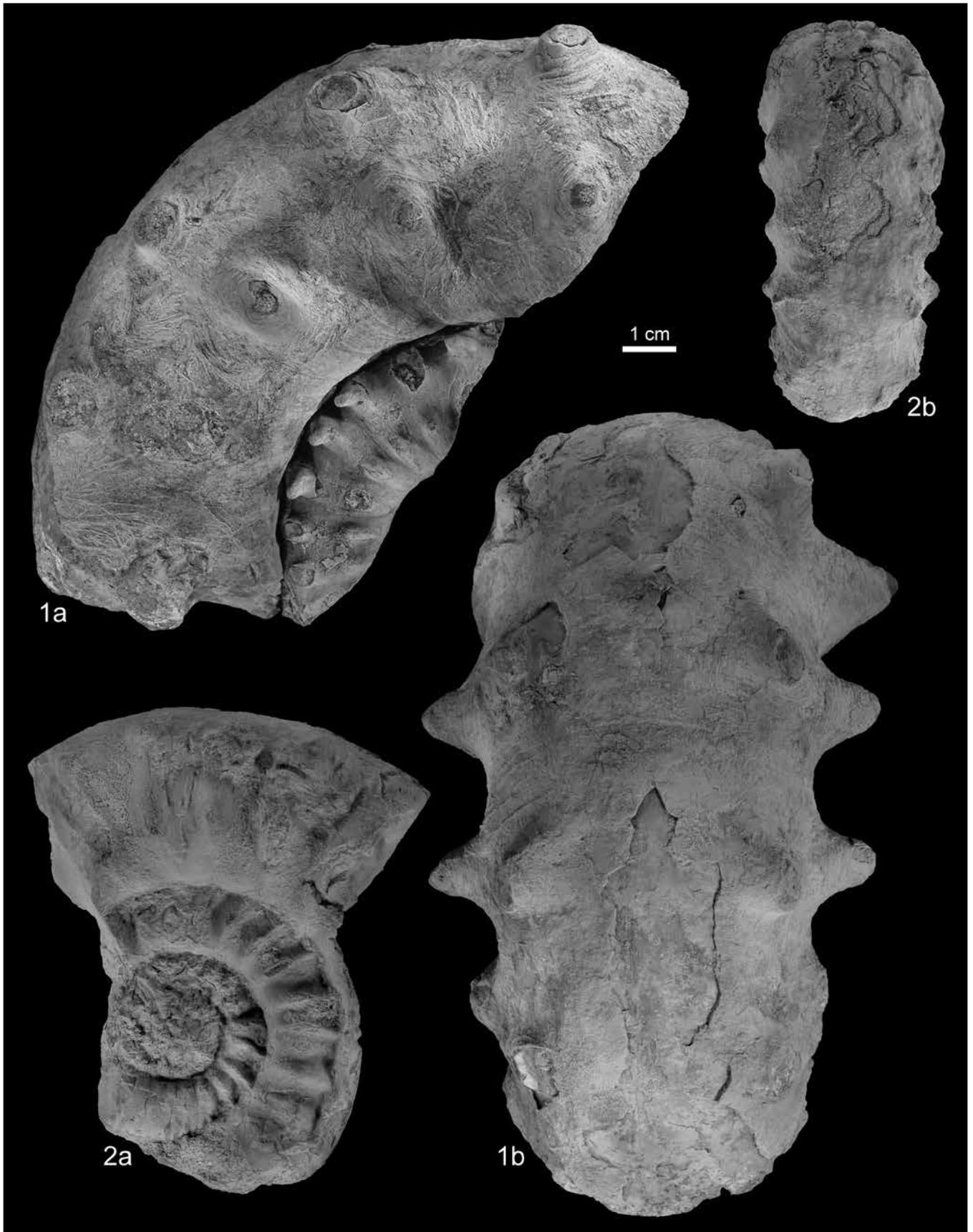
Euspidoceras badiense Spath, 1931, p. 609, pl. 115, fig. 2a, b, pl. 118, fig. 9.

Material: Two specimens. One specimen from the Dhosa Oolite member at Ler, southeast of Bhuj (OUMNH JY.939) and one stray specimen from Samatra, south of Bhuj (GZN2010I 016).

Description: Shell moderately large, evolute, depressed, with parts of the body chamber. Whorl section subrectangular

EXPLANATION OF PLATE III

1. *Euspidoceras acanthodes* Spath, 1931; lateral (a) and ventral (b) view of wholly septate fragment GZN2009II 226. 2. *Metapeltoceras* aff. *armiger* (J. de C. Sowerby, 1840); lateral (a) and ventral (b) view of wholly septate fragment GZN2009II 123.



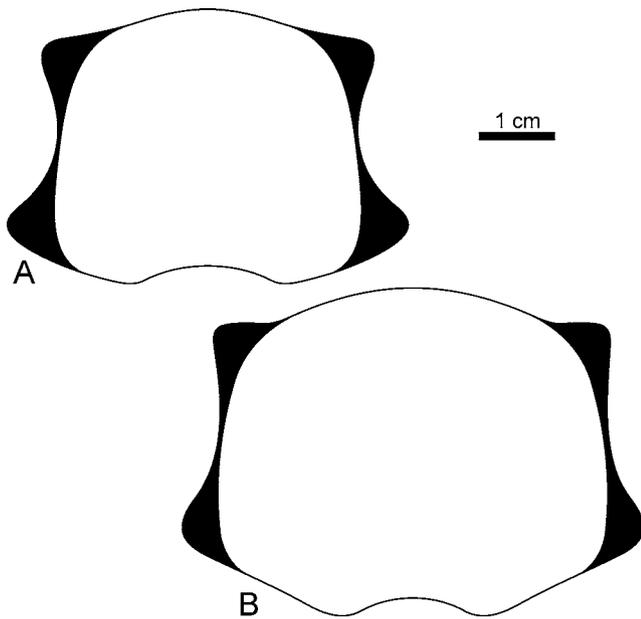


Fig. 11. *Euaspidoceras badiense* Spath, 1931. A. Whorl section at ca. 115 mm diameter; OUMNH JY.939. B. Whorl section at ca. 130 mm diameter; GZN2010I 016.

with broadly curved umbilical and ventrolateral shoulders and arched flanks and venter. Ornamentation consists of varicostate, slightly rursiradiate, straight primary ribs which are moderately thick on inner whorls, becoming thicker, but obscure on outer whorls. Ribs connect two rows of tubercles. Tubercles at the umbilical shoulder are conical in shape, occasionally with their base elongated parallel to ribs. Tubercles at the ventrolateral shoulder are slightly larger and circular to slightly elongated parallel to the periphery of the shell. Outer tubercles appear slightly earlier than inner ones and are situated slightly below the umbilical seam with the succeeding whorl and can therefore be seen well in the umbilicus. Umbilical wall high, steep, rounded, and nearly vertical.

Remarks: The depressed whorl section and the ornamentation with two rows of relatively high tubercles which are very close to each other due to the small whorl height are diagnostic of *Euaspidoceras badiense* Spath, 1931.

Euaspidoceras aff. *babe anum* (d'Orbigny, 1848)

(Pl. V, fig. 3; Fig. 12A; Table 1)

aff. *Ammonites babe anus* d'Orbigny, 1848, p. 491, pl. 181.

aff. *Aspidoceras babe anum* (d'Orbigny) – Waagen, 1875, p. 96, pl. 19.

aff. *Aspidoceras* (*Euaspidoceras*) *babe anum* (d'Orbigny) – Arkell, 1944, p. 286, pl. 62, fig. 4.

aff. *Euaspidoceras babe anum* (d'Orbigny) – Fischer *et al.*, 1994, p. 159, pl. 69, figs 3a, b, 4a, b.

aff. *Euaspidoceras babe anum* (d'Orbigny) – Schlegelmilch, 1994, p. 120, pl. 63, fig. 3.

Material: One specimen from the Dhosa Oolite member of the Jara Dome (GZN2009II 124).

Description: Shell moderately large, evolute, depressed, septate. Whorl section subrectangular with broad, slightly

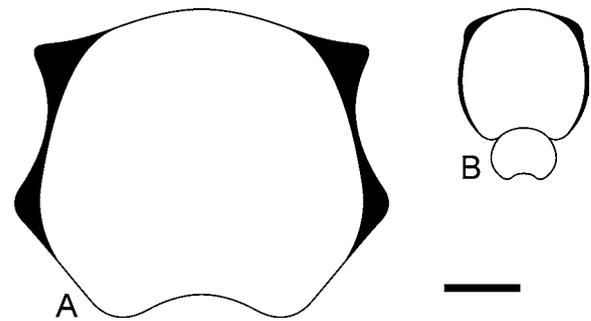


Fig. 12. A. *Euaspidoceras* aff. *babe anum* (d'Orbigny, 1848); whorl section at unknown diameter; GZN2009II 124 (scale bar = 10 mm). B. *Euaspidoceras* sp. A; whorl sections at unknown diameter; GZN2009II 130 (scale bar = 7.5 mm).

rounded venter and two rows of tubercles connected by a very obscure rib. The inner tubercle slightly above the umbilical shoulder is comparatively small and elongated parallel to the rib. The outer tubercle at the ventrolateral shoulder is more prominent, rather conical, showing a forward-directed inclination. The tubercles are comparatively sharp and pointed. Umbilical wall low and rounded.

Remarks: The specimen is a small fragment of a phragmocone which matches *Euaspidoceras babe anum* (d'Orbigny, 1848) with respect to the shape of the whorl section and ornamentation. Nevertheless, due to its fragmentary state of preservation, it has been assigned to this species only tentatively. The specimen can be differentiated from *Euaspidoceras waageni* Spath, 1931 by its more depressed whorl section and the sharper, spiky tubercles. *Euaspidoceras simile* Spath, 1931 has a similar whorl section, but much thicker and larger tubercles.

Euaspidoceras waageni Spath, 1931

(Pl. VI, figs. 1, 2; Fig. 13; Table 1)

Aspidoceras perarmatum (non J. Sowerby) – Waagen, 1875, p. 91, pl. 16, figs. 4a, b, 5, 6 (after Spath, 1931).

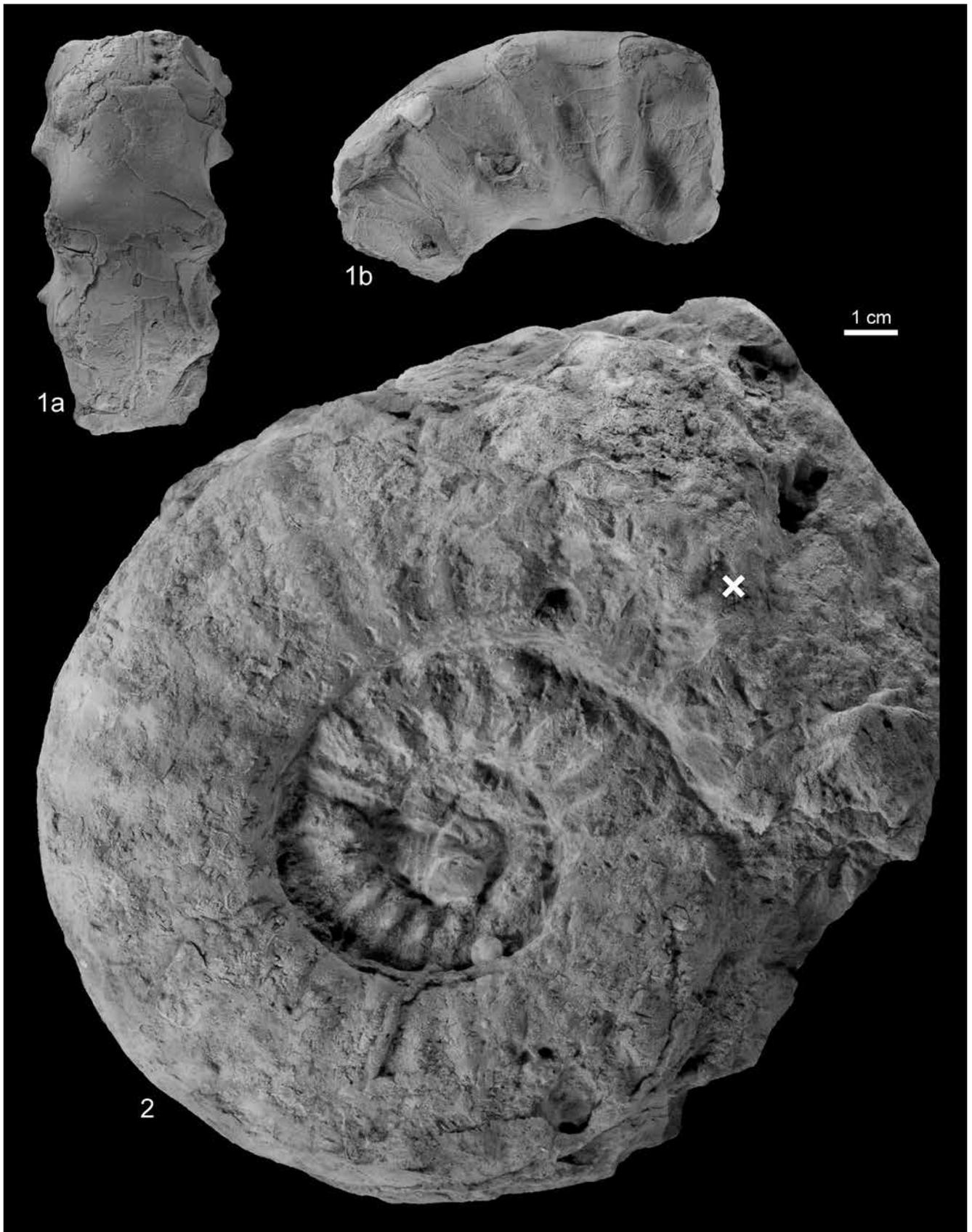
Euaspidoceras waageni Spath, 1931, p. 599, pl. 112, fig. 1a, b, pl. 113, fig. 2a, b, pl. 115, figs. 3, 6a, b, 7a, b, pl. 124, fig. 1.

Material: Four specimens. Two specimens from the Dhosa Oolite member (GZN2009II 125, 131) and two specimens from the matrix of the Dhosa Conglomerate Bed (OUMNH JY.544, OUMNH JY.545) of the Jara Dome.

Description: Shell small to moderately large, evolute, septate. Whorl section subquadrangular with faintly arched venter and distinct umbilical and ventrolateral shoulders. Inner whorls ornamented with thin, rectiradiate ribs, outer whorls characterized by thicker, rounded, slightly rursiradiate ribs. In inner whorls very fine striae are visible between the thicker ribs. Two rows of tubercles connected by the primary ribs develop comparatively early in ontogeny. Tubercles at the umbilical shoulder are comparatively small, subcircular, irregular, and occasionally slightly elongated along the rib. Tubercles at the ventrolateral shoulder are larger, elongated parallel to the periphery, and develop slightly earlier than inner tubercles. Commonly, the distances between ribs are irregular. Rarely, an inner tubercle is developed with no corresponding outer tubercle. Umbilical wall high, steep, and almost vertical.

EXPLANATION OF PLATE IV

1. *Metapeltoceras* cf. *kumagunense* (Spath, 1931); ventral (a) and lateral (b) view of wholly septate fragment GZN2009II 127. 2. *Metapeltoceras flavum* Spath, 1931; lateral view of specimen GZN2010I 1009 with the last visible septum indicated by a cross.



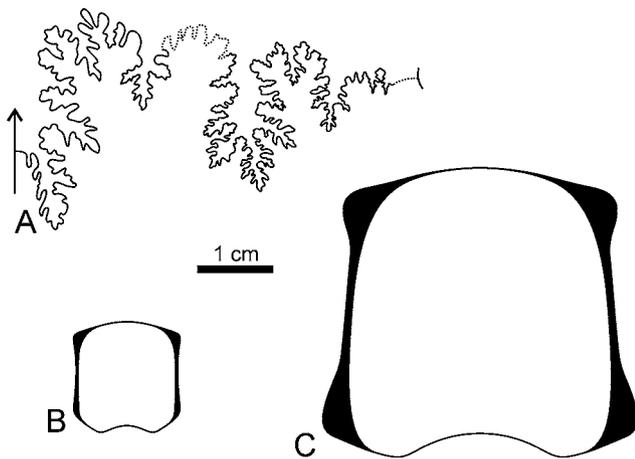


Fig. 13. *Euaspidoceras waageni* Spath, 1931. A. Suture line at ca. 100 mm diameter; GZN2009II 131. B. Whorl section at ca. 40 mm diameter; GZN2009II 125. C. Whorl section at ca. 102 mm diameter; GZN2009II 131.

Remarks: The present specimens match *Euaspidoceras waageni* Spath, 1931 in ornamentation, whorl section, and dimensions. The species shows a transition from inner compressed to outer depressed whorls, but the diameter at which this change occurs can vary considerably (Spath, 1931). The irregular shape and position of tubercles, together with the almost quadrangular whorl section, differentiates the species from other members of *Euaspidoceras* in the Kachchh Basin. The slightly younger *Euaspidoceras perarmatum* (J. Sowerby, 1822) has stronger ribs, which are also seen on the venter (Arkell, 1940, p. 193, pl. 41, figs. 1-5; Schlegelmilch, 1994).

Euaspidoceras simile Spath, 1931

(Pl. VI, fig. 3; Pl. VII, fig. 1; Fig. 14; Table 1)

Euaspidoceras simile Spath, 1931, p. 608, pl. 117, fig. 6a, b.

Material: Three specimens. One specimen from the matrix of the Dhosa Conglomerate Bed of the Jumara Dome (GZN2010I 1043), one specimen from the Dhosa Oolite member near Samatra, south of Bhuj (OUMNH JY.1138), and one specimen from the matrix of the Dhosa Conglomerate Bed near Fakirwari, south of Bhuj (GZN2010I 002).

Description: Shell large, evolute, depressed, septate. Whorl section subquadrangular (inner whorls) to subrounded (outer whorls) with broadly rounded umbilical and ventrolateral shoulders and moderately rounded venter. Maximum thickness near the umbilical shoulder. Ornamentation consists of varicostate, moderately thin (inner whorls) to thick (outer whorls) ribs connecting an inner and outer row of tubercles, which are irregular in size and broadly conical in shape with a subcircular base. At irregular intervals, an additional outer tubercle is intercalated between ribs without a corresponding inner tubercle. Umbilical wall high and steep, almost vertical.

Remarks: The specimens match *Euaspidoceras simile* Spath, 1931 in ornamentation, whorl section, and dimensions. Its more rounded whorl section, irregularly placed tubercles with an occasional, intercalated outer tubercle differentiate this

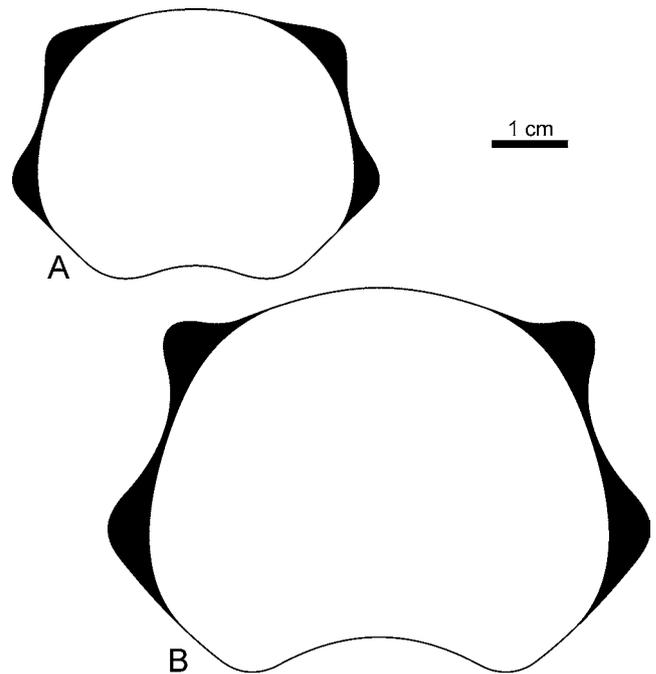


Fig. 14. *Euaspidoceras simile* Spath, 1931. A. Whorl section at ca. 110 mm diameter; OUMNH JY.1138. B. Whorl section at unknown diameter; GZN2010I 1043.

species from *Euaspidoceras badiense* Spath, 1931, as described above.

Euaspidoceras sparsispinum (Waagen, 1875)

(Pl. VII, fig. 3; Fig. 15; Table 1)

Aspidoceras sparsispinum Waagen, 1875, p. 98, pl. 18, fig. 1a, b.

Euaspidoceras sparsispinum (Waagen) – Spath, 1931, p. 603.

Material: One specimen from the matrix of the Dhosa Conglomerate Bed close to Medisar, Jhura Dome (GZN2009II 224).

Description and remarks: Specimen GZN2009II 224 is a fragment of a large, evolute, depressed phragmocone. Its whorl section is rounded with the maximum thickness at the middle of the flank. Its ornamentation consists of thick, distant primary folds, which are less distinct at the middle of the flank, and

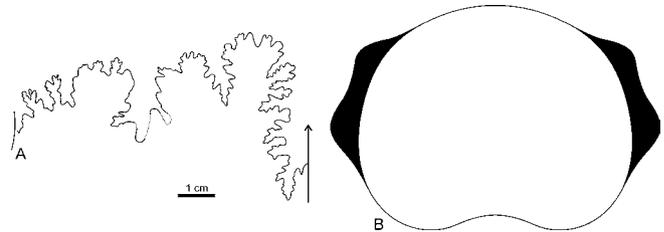
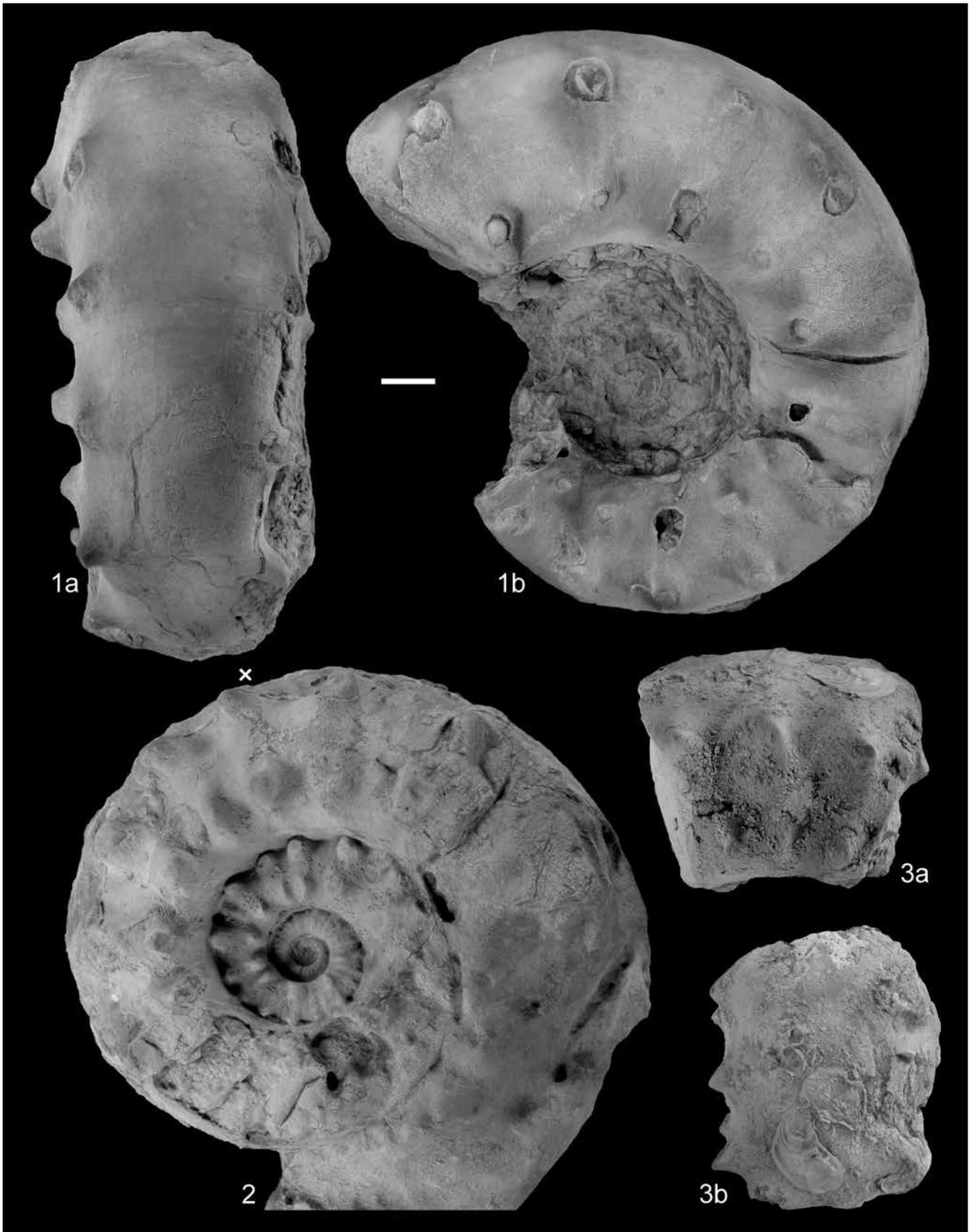


Fig. 15. *Euaspidoceras sparsispinum* (Waagen, 1875). A. Suture line at unknown diameter; GZN2009II 224. B. Whorl section at unknown diameter; GZN2009II 224.

EXPLANATION OF PLATE V

1. *Euaspidoceras badiense* Spath, 1931; ventral (a) and lateral (b) view of specimen GZN2010I 016 with the last septum covered by shell (scale bar = 11 mm).
2. *Euaspidoceras badiense* Spath, 1931; lateral view of specimen OUMNH JY.939 with the last visible septum indicated by a cross (scale bar = 11 mm).
3. *Euaspidoceras* aff. *babe anum* (d'Orbigny, 1848); lateral (a) and ventral (b) view of wholly septate fragment GZN2009II 124 (scale bar = 10 mm).



two rows of thick tubercles, one at the umbilical and one at the ventrolateral shoulder. The specimen matches *Euspidoceras sparsispinum* (Waagen, 1875) as illustrated and described by Waagen (1875) and Spath (1931). *Euspidoceras babe anum* (d'Orbigny, 1848) occurs together with *Euspidoceras sparsispinum* (Waagen, 1875) but is distinctly more compressed (see above).

Euspidoceras varians (Spath, 1931)

(Pl. VIII, fig. 1; Table 1)

Neaspidoceras varians Spath, 1931, p. 615, pl. 105, fig. 7a, b, pl. 110, fig. 1a, b.

Material: One specimen from the Kanthkot Ammonite Beds southwest of Kantkote Village, Wagad Uplift (GZN2010I 131).

Description: Shell small, evolute, compressed, septate. Whorl section subrectangular with flat flanks and moderately rounded venter. Inner whorls ornamented with very fine ribs originating rursiradiately on the umbilical wall, turning prorsiradiately at the umbilical shoulder where they attain their maximum thickness. Most ribs bifurcate into thinner secondary ribs slightly above the umbilical shoulder. Ribs become gradually more distant, slightly thicker, and do not branch anymore. A row of small tubercles at the ventrolateral shoulder develops comparatively early in ontogeny, a second row of tubercles at the umbilical shoulder appears slightly later. Ribs become weak until they are only visible as very faint ridges connecting both rows of tubercles. Inner tubercles are small and almost circular in outline. Outer tubercles are slightly stronger, relatively long, and spiky. Umbilical wall gradually becoming high and steep.

Remarks: The specimen matches *Neaspidoceras varians* as described by Spath (1931) in ornamentation, whorl shape, and dimensions. The status of the genus *Neaspidoceras* has not been completely resolved yet. The taxon has been included into the genera *Euspidoceras* (e.g., Marques *et al.*, 1992; Schlegelmilch, 1994) or *Clambites* (e.g., Enay and Gygi, 2001), but some authors also treat it as a separate genus (e.g., Wierzbowski and Matyja, 2014). As the present material is not suited to solve this problem, a traditional approach has been chosen by following Arkell *et al.* (1957) who favoured to include members of *Neaspidoceras* into *Euspidoceras*. *Euspidoceras wagurens*e (Spath, 1931) has a distinctly wider umbilicus and different whorl section (see below; compare Spath, 1931, pl. 120, fig. 7b). *Euspidoceras tenuispinatum* (Waagen, 1875) has a more rectangular and depressed whorl section.

*Euspidoceras wagurens*e (Spath, 1931)

(Pl. VIII, fig. 2; Pl. IX, figs. 1, 2; Fig. 16; Table 1)

*Neaspidoceras wagurens*e Spath, 1931, p. 614, pl. 120, fig. 7a-d.

Material: Four specimens from the Kanthkot Ammonite Beds southwest of Kantkote Village, Wagad Uplift (GZN2010I 079, 101, 107, OUMNH JY.1176).

Description: Shell moderately large to large, evolute, compressed, septate. Whorl section suboval with moderately arched flanks and moderately rounded venter. Ornamentation consists of thick, rounded, weak, slightly rursiradiate, straight primary ribs connecting two rows of tubercles. The inner

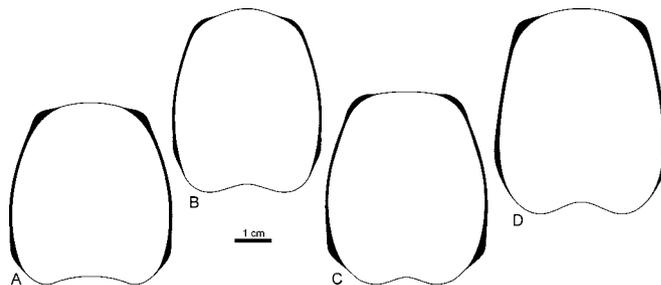


Fig. 16. *Euspidoceras wagurens* (Spath, 1931). A. Whorl section at ca. 158 mm diameter; OUMNH JY.1176. B. Whorl section at unknown diameter; GZN2010I 107. C. Whorl section at unknown diameter; GZN2010I 079. D. Whorl section at unknown diameter; GZN2010I 101.

tubercles at the umbilical shoulder are relatively small and circular to oval in shape. The outer tubercles at the ventrolateral shoulder are larger, oval in shape, and pointed slightly forward. Umbilical shoulder broadly rounded, umbilical wall low and steep.

Remarks: The specimens match *Neaspidoceras wagurens* as described by Spath (1931) in ornamentation, whorl section, and dimensions. This species has been included into *Euspidoceras* as the status of *Neaspidoceras* has not been completely resolved (see discussion above). *Euspidoceras jeanneti* (Collignon, 1959) has a slightly smaller umbilicus and a more rectangular whorl section (flat flanks).

Euspidoceras aff. *jeanneti* (Collignon, 1959)

(Pl. IX, fig. 3; Fig. 17; Table 1)

aff. *Arcaspidoceras jeanneti* Collignon, 1959, pl. 83, figs. 332, 333.

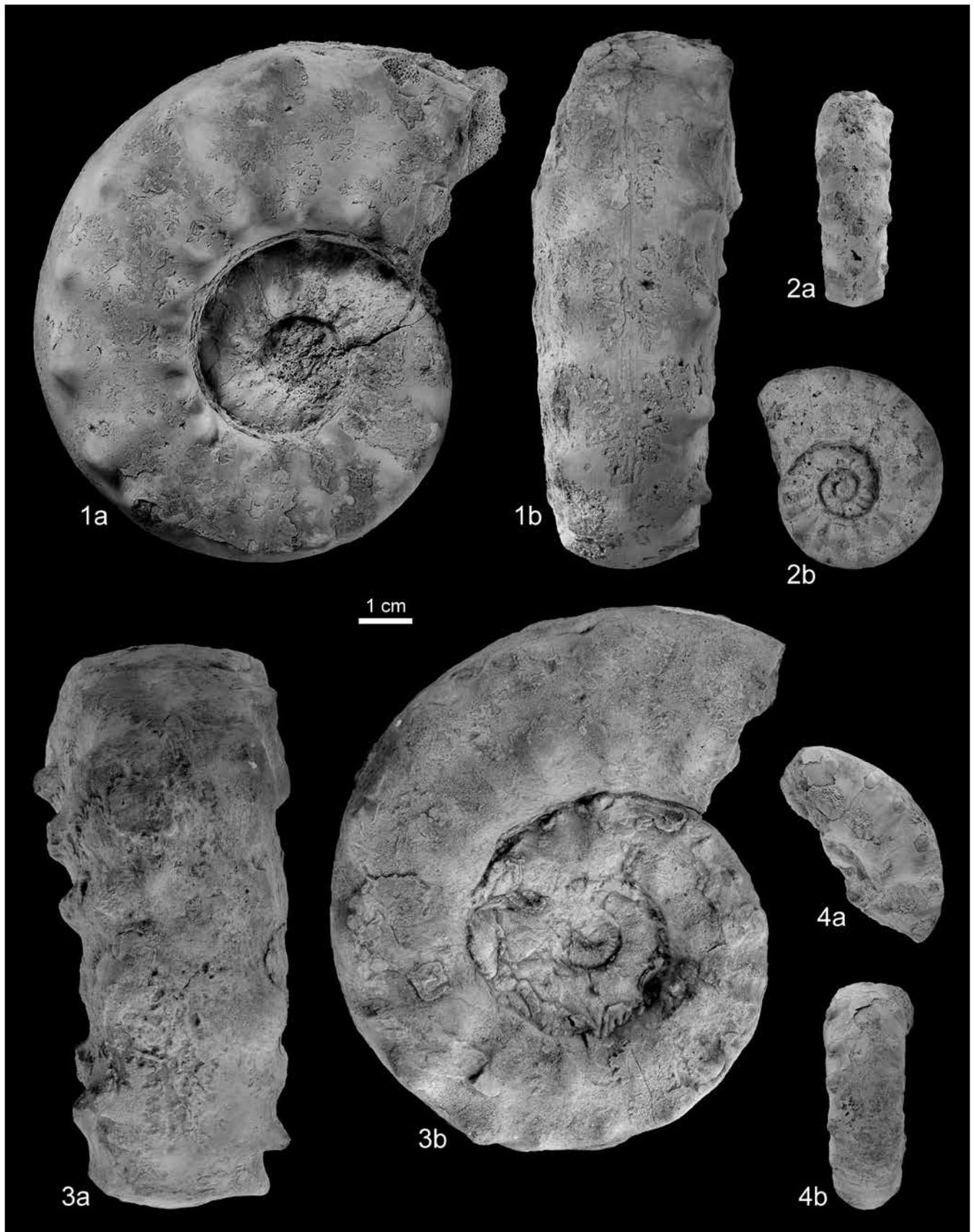
Material: One specimen from the Kanthkot Ammonite Beds southwest of Kantkote Village, Wagad Uplift (OUMNH JY.1167).

Description: Shell small, evolute, compressed, septate. Whorl section subrectangular with comparatively flat flanks and a moderately rounded venter. Ornamentation consists of two rows of tubercles connected by a weak, rounded rib. Inner bullae small and circular, outer tubercles larger and pointing forward. The umbilical wall and flank is covered by very fine and dense striae. Umbilical shoulder distinct, umbilical wall steep.

Remarks: The specimen matches *Arcaspidoceras jeanneti* as illustrated by Collignon (1959) with respect to ornamentation, whorl section, and dimensions. The genus *Arcaspidoceras* has been included into *Euspidoceras* by Arkell *et al.* (1957) and subsequent authors. The present material does not allow to evaluate the status of the genus and therefore the proposal of Arkell *et al.* (1957) is followed (compare Schlegelmilch, 1994). Since only a fragment of the shell is preserved, it has been placed only into the affinity of the species. Furthermore, the outer tubercles of *Euspidoceras jeanneti* point backwards, while in the present specimen they seem to point forwards. *Euspidoceras wagurens* (Spath, 1931) is a closely related species, but differs in having a more oval whorl section and a slightly larger umbilicus.

EXPLANATION OF PLATE VI

1. *Euspidoceras waageni* Spath, 1931; lateral (a) and ventral (b) view of wholly septate specimen GZN2009II 131. 2. *Euspidoceras waageni* Spath, 1931; ventral (a) and lateral (b) view of wholly septate specimen GZN2009II 125. 3. *Euspidoceras simile* Spath, 1931; ventral (a) and lateral (b) view of wholly septate specimen OUMNH JY.1138. 4. *Euspidoceras* sp. A; lateral (a) and ventral (b) view of wholly septate fragment GZN2009II 130.



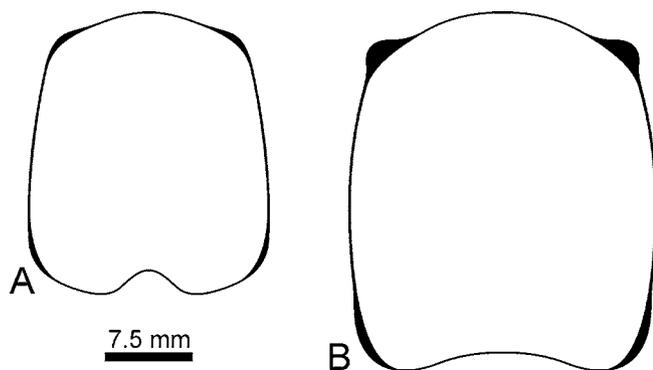


Fig. 17. *Euaspidoceras* aff. *jeanneti* (Collignon, 1959). A. Whorl section at unknown diameter; OUMNH JY.1167. B. Whorl section at unknown diameter; OUMNH JY.1167.

Euaspidoceras sp. A

(Pl. VI, fig. 4; Fig. 12B; Table 1)

Material: One specimen from the matrix of the Dhosa Conglomerate Bed close to Medisar, Jhura Dome (GZN2009II 130).

Description: Specimen GZN2009II 130 is a small fragment of the inner whorl of a phragmocone. Its whorl section is subrounded with thickness almost equal to height. Slightly rounded flanks merge smoothly into a comparatively broad venter. Ornamentation consists of broad primary ribs originating obscurely on the umbilical wall and terminating at the ventrolateral shoulder where a tubercle is developed. These tubercles have a circular base and occur in irregular distances from each other. Umbilical wall low, umbilical shoulder indistinct without tubercles at this diameter.

Remarks: The specimen resembles co-occurring forms such as *Euaspidoceras varians* (Spath, 1931), *Euaspidoceras wagurensis* (Spath, 1931), and *Euaspidoceras* aff. *jeanneti* (Collignon, 1959), but these taxa are more compressed and commonly have an inner row of tubercles developed at similar diameters. Since only a small fragment of the phragmocone is preserved, it has been left in open nomenclature.

Euaspidoceras sp. B

(Pl. VII, fig. 2; Table 1)

Material: One specimen from the Dhosa Oolite member at Ler, southeast of Bhuj (GZN2009II 244).

Description: Shell very small, evolute, depressed, septate. Whorl section subquadrangular with rounded venter. Ornamentation consists of moderately thick, prorsiradiate, slightly falcoid primary ribs and a row of tubercles at the ventrolateral shoulder. Umbilical wall low and rounded.

Remarks: This is a nucleus of *Euaspidoceras* with the inner tubercles not yet developed. Occasionally, primary ribs show an elevation just above the umbilical shoulder from which the formation of tubercles can be expected. Outer tubercles can be seen from a diameter of 15 mm onwards. Due to the small size of the specimen, it cannot be reliably assigned to a species.

PALAEONTOLOGICAL CONCLUSION

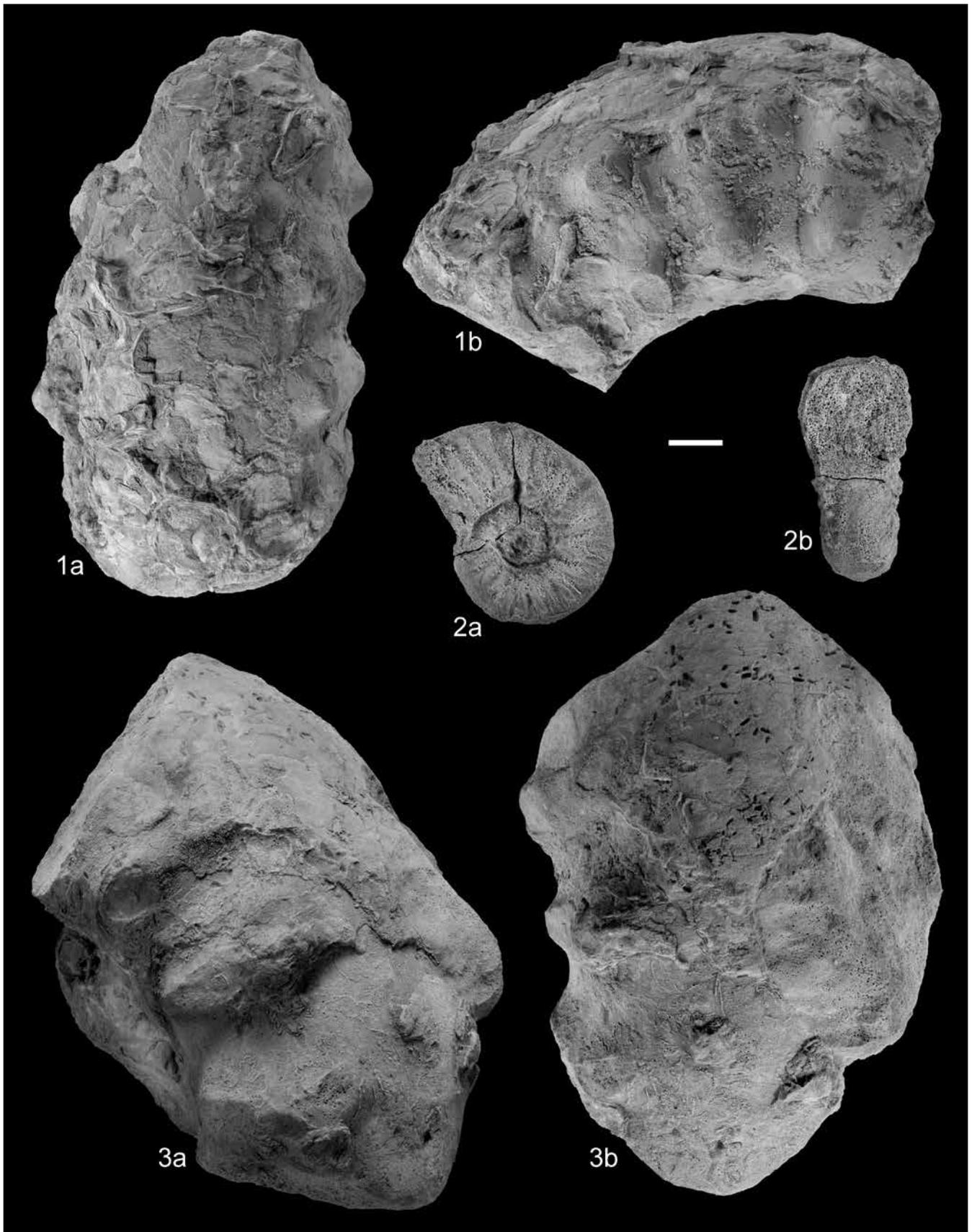
Aspidoceratids are an important ammonite group in the Upper Callovian to Oxfordian rocks of the Kachchh Basin in western India. The group dominates the ammonite assemblage of the Upper Callovian, but loses this dominance in diversity to *Perisphinctes* Waagen within the Lower Oxfordian. Most of the described taxa are represented by fragments of the phragmocone and only few specimens have a part of the body chamber preserved. In most of the specimens the inner whorls and suture lines are not preserved, thus complicating the separation of the subfamily Peltoceratinae from the Aspidoceratinae or Euaspidoceratinae. For the same reason a differentiation between *Peltoceras* and *Metapeltoceras* was not easy. Nevertheless, an identification of most of these fragmentary specimens was possible because their morphological characteristics, such as the proportional dimensions, the shape of the whorl-section, their ornamentation (particularly the thickness and branching of primary ribs, the smoothing of the ventral region, the appearance/disappearance, position, density, size, shape, number, and direction of tubercles, as well as the morphology of the ridge connecting tubercles of separate rows) were found very similar to specimens, representing more or less similar ontogenetic stages, of the corresponding species described and illustrated by Waagen (1873-1875) and Spath (1927-1933) from the Kachchh Basin. Although the present material does not allow a complete characterisation of the respective species, it enables an overview on the development of the group as well as furthers the knowledge on the lateral and vertical distribution of its members in the basin.

The oldest taxa of the family Aspidoceratidae described in the present article belong to the subfamilies Peltoceratinae and Euaspidoceratinae. These come from the upper Gypsiferous Shale member of a Late Callovian age, exposed in the Kachchh Mainland (Fig. 2). The youngest occurrence, recovered from the top part of the Kanthkot Ammonite Beds with a Late Oxfordian age, in the Wagad Uplift (Fig. 2), is represented exclusively by the members of the subfamily Euaspidoceratinae. Out of the 18 taxa described in the present study, three belong to the genus *Peltoceras* Waagen, four to *Metapeltoceras* Spath, and eleven to *Euaspidoceras* Spath. These three genera can be differentiated in the Kachchh Basin as follows:

The genus *Peltoceras* is characterised by hardly overlapping, slightly compressed whorls with usually comparatively dense primary ribs on inner whorls which bi- or trifurcate at the ventrolateral shoulder. The secondary ribs pass the nearly flat venter. The ribs become thicker with ontogenetic growth and the secondary ribs gradually disappear. Tubercles may appear relatively early, first a row develops along the ventrolateral shoulder and later on a second row of tubercles forms on the flank or near the umbilical shoulder. On the outer whorl ornamentation consists of two rows of tubercles only. In fragmentary specimens, imprints of secondary ribs of inner whorls can commonly be seen on the dorsal side. The occasional absence of such imprints points to an early appearance of tubercles connected with an early disappearance of secondary ribs (compare Bonnot, 1995).

EXPLANATION OF PLATE VII

1. *Euaspidoceras simile* Spath, 1931; ventral (a) and lateral (b) view of wholly septate fragment GZN2010I 1043 (scale bar = 11 mm). 2. *Euaspidoceras* sp. B; lateral (a) and apertural (b) view of wholly septate specimen GZN2009II 244 (scale bar = 5 mm). 3. *Euaspidoceras sparsispinum* (Waagen, 1875); lateral (a) and ventral (b) view of wholly septate fragment GZN2009II 224 (scale bar = 11 mm).



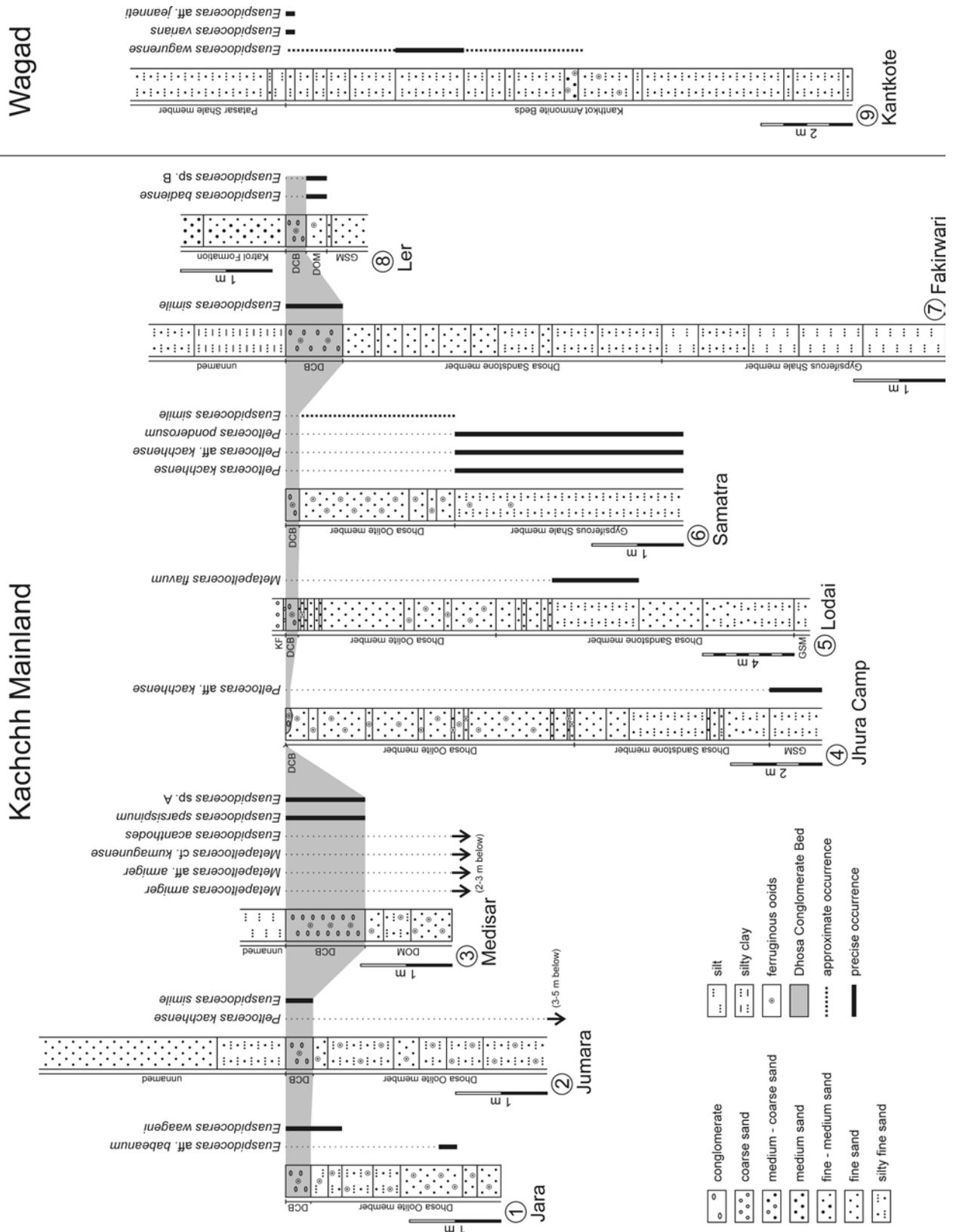
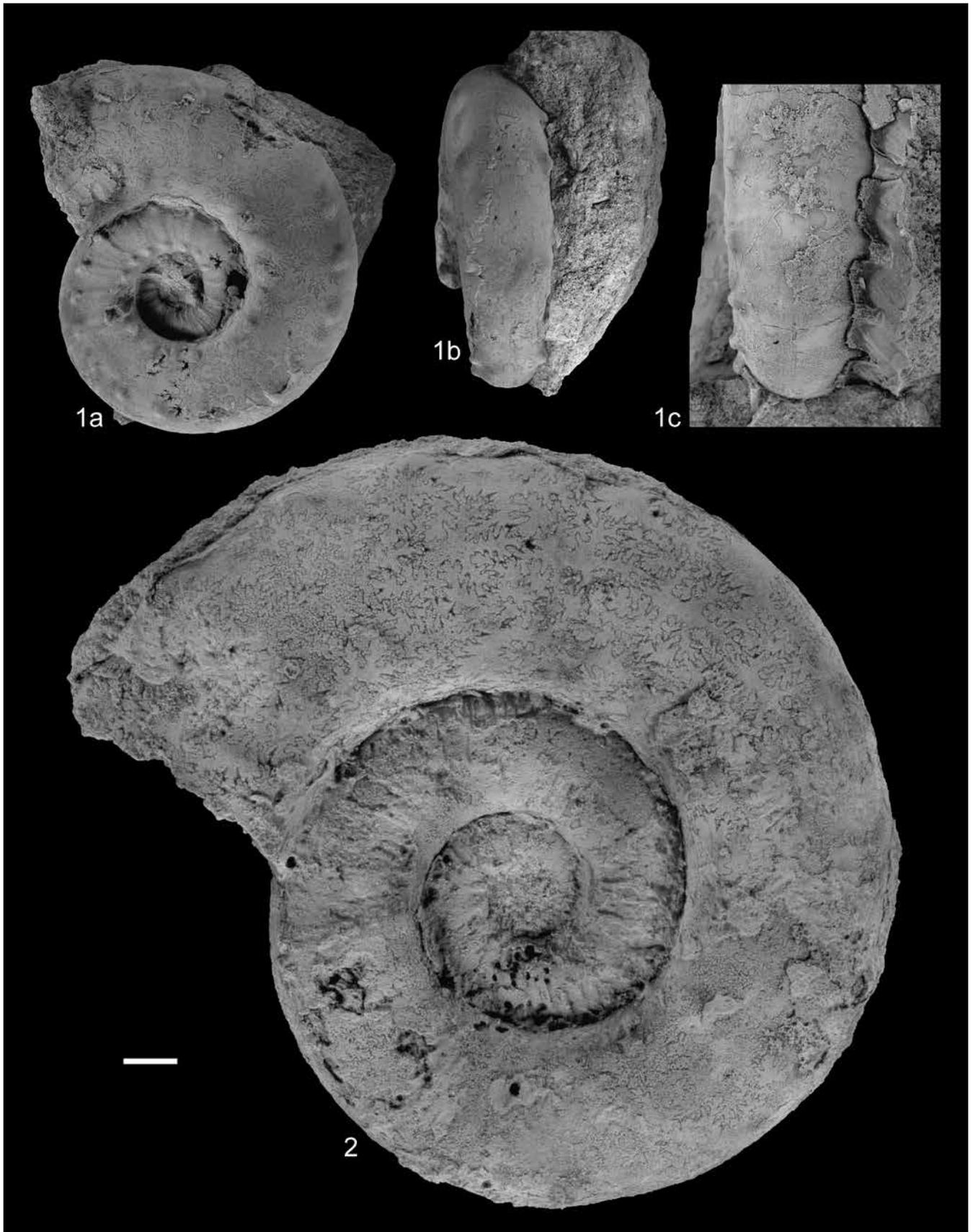


Fig. 18. Schematic lithologies of the localities in the Kachchh Basin yielding specimens for the present study with the stratigraphic ranges of the taxa. Note the different scales (DCB – Dhosa Conglomerate Bed; DOM – Dhosa Oolite member; GSM – Gypsiferous Shale member; KF – Katrol Formation).

EXPLANATION OF PLATE VIII

1. *Euspidoceras varians* (Spath, 1931); lateral (a) and ventral (b) view and detail of spines (c) of wholly septate specimen GZN2010I 131 (a, b: scale bar = 10 mm; c: scale bar = 5 mm). 2. *Euspidoceras wagurensis* (Spath, 1931); lateral view of wholly septate specimen OUMNH JY.1176 (scale bar = 10 mm).



In the genus *Metapeltoceras*, the inner row of tubercles develops first merging with thick and long primary ribs. The outer row of isolated tubercles develops later, but also continues up to the body chamber. The ventral region is slightly arched, and commonly appears smooth.

In contrast, the genus *Euaspidoceras* is characterised by rursiradiate, fine, dense, as well as irregular ribs on the inner whorls and distant, but strong ribs on the outer whorls. In some cases, the ribs of early ontogenetic stages bifurcate into thinner secondary ribs slightly above the umbilical shoulder. No tubercles are present on the innermost whorls. A row of small tubercles at the ventrolateral shoulder (the outer row) develops comparatively early and a second row of tubercles at the umbilical shoulder (the inner row) appears slightly later. Commonly, the inner row of tubercles on the inner whorls are falcoid and primary ribs connect both rows of tubercles. Rarely, an inner tubercle is developed without any corresponding outer tubercle. Tubercles also significantly increase in size from inner to outer whorls. Typical is a parabolic ornamentation.

BIOSTRATIGRAPHY

The described specimens of the family Aspidoceratidae Zittel, 1895 have been collected bed-by-bed from sections through the Upper Callovian to Oxfordian of the Kachchh Basin (Fig. 18). Since most of them occur together with other time-diagnostic ammonites, they could be assigned to certain biozones (Fig. 19).

Most of the described taxa have previously been recorded from the area by Waagen (1873-1875) and Spath (1927-1933), but the lithostratigraphic understanding of these authors was limited and they did not figure individual sections for their sample localities. The thorough collection of ammonites by the present authors, especially from Oxfordian strata, now allows the study of the Aspidoceratidae with a much greater stratigraphic precision. The most abundant member of the family is the genus *Peltoceras* Spath, 1924, which is restricted to the Cordatum Zone of the Lower Oxfordian and has already been described by Alberti *et al.* (2011). Even though other representatives of the family are less numerous, they show a high diversity with 18 taxa described in the present study.

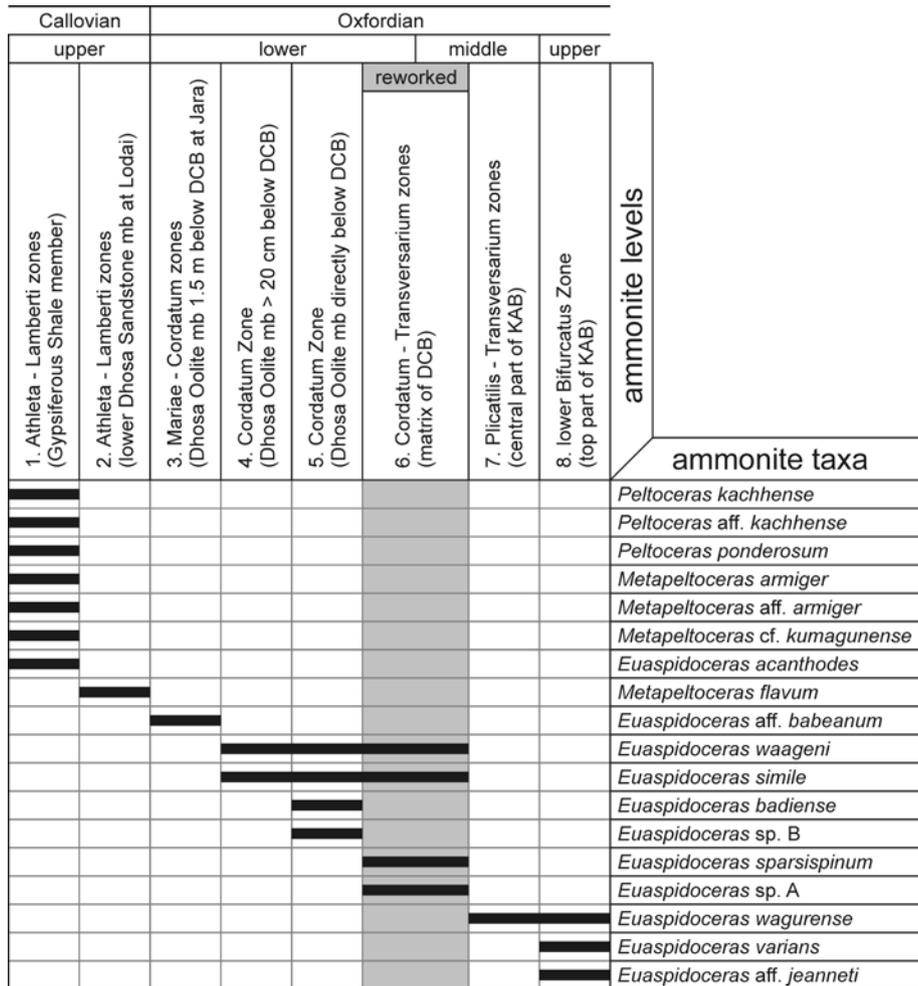
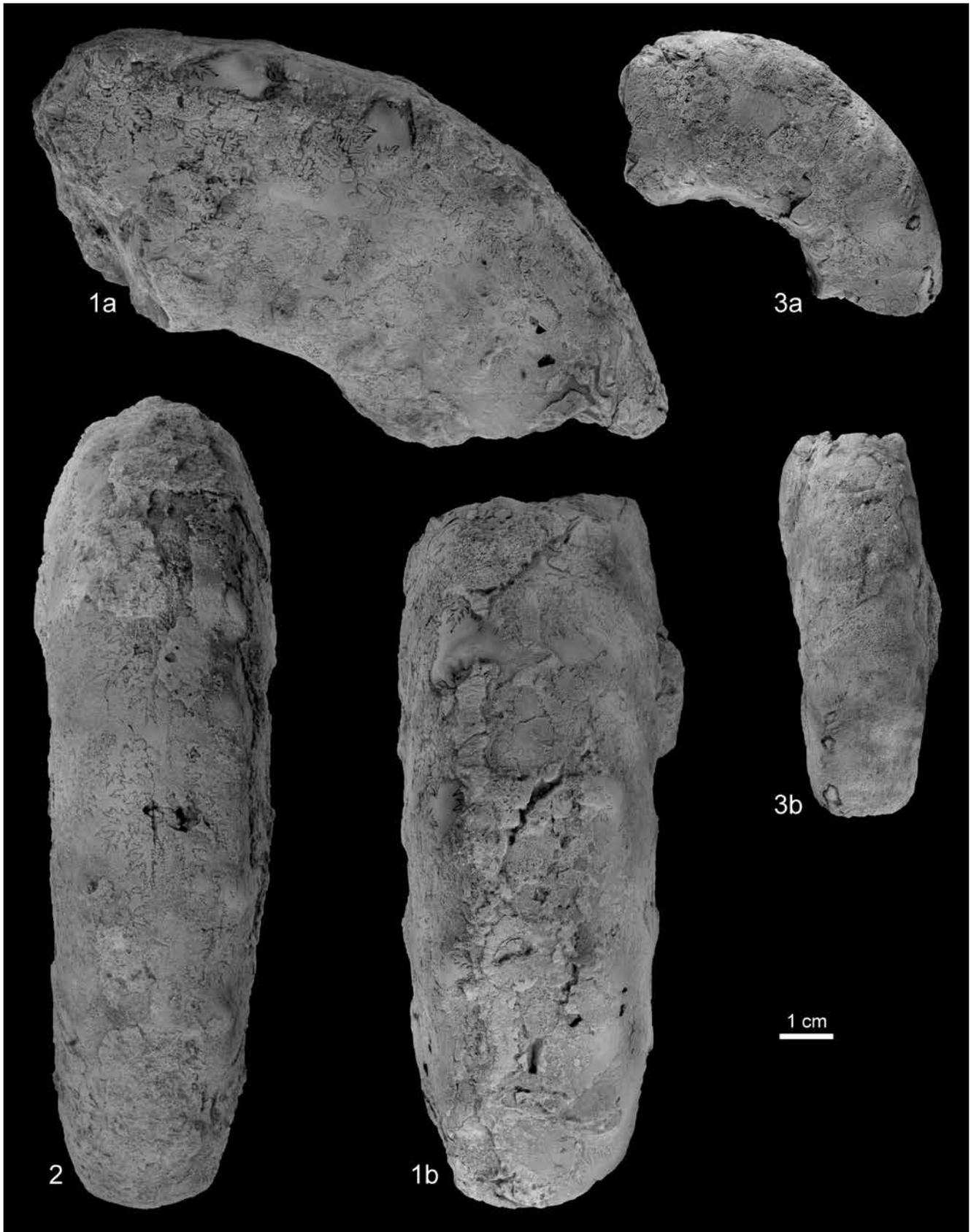


Fig. 19. Stratigraphic occurrence of ammonites of the genera *Peltoceras*, *Metapeltoceras*, and *Euaspidoceras* collected from the Upper Callovian and Oxfordian strata of the Kachchh Basin. The Dhosa Conglomerate Bed is shaded in grey to highlight the reworked nature of the ammonites in this horizon (DCB – Dhosa Conglomerate Bed; KAB – Kanthkot Ammonite Beds).

EXPLANATION OF PLATE IX

1. *Euaspidoceras wagurense* (Spath, 1931); lateral (a) and ventral (b) view of wholly septate fragment GZN20101 101.
2. *Euaspidoceras wagurense* (Spath, 1931); ventral view of wholly septate specimen OUMNH JY.1176.
3. *Euaspidoceras* aff. *jeanneti* (Collignon, 1959); lateral (a) and ventral (b) view of wholly septate fragment OUMNH JY.1167.



The oldest specimens were collected from argillaceous silt of the Gypsiferous Shale member of the Kachchh Mainland (Fig. 2). This unit contains a highly diverse ammonite fauna dominated by the Aspidoceratidae with seven taxa described in the present study: *Peltoceras kachhense*, *P. aff. kachhense*, *P. ponderosum*, *Metapeltoceras armiger*, *M. aff. armiger*, *M. cf. kumagunense*, and *Euaspidoceras acanthodes*. These rocks had previously been assigned to the Athleta Zone of the Upper Callovian (e.g., Spath, 1927-1933). Spath (1931) speculated that *Metapeltoceras kumagunense* and *Euaspidoceras acanthodes* might be indicative of the Lamberti Zone of the uppermost Callovian. However, in the present study it has not been possible to determine whether these species regularly occur in higher parts of the Gypsiferous Shale member than the other taxa.

The following lithostratigraphic unit, the Dhosa Sandstone member, is generally less fossiliferous. In the western Kachchh Mainland, these rocks are relatively thin and contain few ammonites indicative of an Oxfordian age. In contrast, the Dhosa Sandstone member at the more proximal locality Lodai, near the eastern boundary of the Kachchh Mainland, is much thicker (Fig. 18) and yielded a specimen of *Metapeltoceras flavum* indicative of the Upper Callovian (Spath, 1931). It seems therefore plausible, that the lower boundary of the Dhosa Sandstone member is diachronous, with sedimentation of the coarser siliciclastics starting already in the Late Callovian near the proximal, eastern margin of the Kachchh Mainland, but not before the Early Oxfordian in its central and western part.

While the genera *Peltoceras* Waagen, 1871 and *Metapeltoceras* Spath, 1931 have been found only in the Callovian, *Euaspidoceras* Spath, 1931 reaches its highest diversity in the Oxfordian part of the succession. The fossiliferous Dhosa Oolite member consists of partly cross-bedded sandstone beds with ferruginous ooids. Its top is formed by an important marker horizon, the Dhosa Conglomerate Bed, traceable throughout Kachchh Mainland (Alberti *et al.*, 2013). *Euaspidoceras aff. babe anum* has been found approximately 1.5 m below this horizon and is therefore stratigraphically the oldest taxon in the Dhosa Oolite member (Fig. 19). *Euaspidoceras babe anum* is a species commonly known from the Mariae Zone (Lower Oxfordian) of Europe (Arkell, 1944, p. 287), though Schlegelmilch (1994, p. 120) reported further, but doubtful specimens from higher horizons. Additional specimens of *Euaspidoceras* Spath, 1931 assigned to *E. waageni*, *E. simile*, *E. badiense*, and *E. sp. B* were collected from horizons below the Dhosa Conglomerate Bed together with members of *Peltoceratoides* Spath, 1924 and can therefore be placed into the Cordatum Zone (Alberti *et al.*, 2011). The Dhosa Conglomerate Bed itself is the most fossiliferous unit in the Oxfordian of the Kachchh Basin and known for its reworked ammonites from several biozones (Cordatum to Transversarium zones; Pandey *et al.*, 2012). Taxa of *Euaspidoceras* Spath, 1931 collected from this unit include *Euaspidoceras waageni*, *E. simile*, *E. sparsispinum*, and *E. sp. A*.

While most parts of the Upper Oxfordian and Lower Kimmeridgian are missing on the Kachchh Mainland (compare Alberti *et al.*, 2013), these strata are well exposed in the more proximal Wagad Uplift. Especially the Kanthkot Ammonite Beds near Kantkote Village are known for their abundant fossil content of Middle and Late Oxfordian age (Plicatilis to Bifurcatus zones; Pandey *et al.*, 2012). Members of the genus *Perisphinctes* Waagen, 1869 dominate the assemblage and allow comparatively precise age assignments. Pandey *et al.*

(2012) recorded *Perisphinctes (Liosphinctes) plicatilis*, *P. (Perisphinctes) martelli*, and *P. (Arisphinctes) chloroolithicus* from the Plicatilis to Transversarium zones of the Kanthkot Ammonite Beds. Indicative perisphinctids of the lower Bifurcatus Zone are *Perisphinctes (Dichotomoceras) stenocycloides* and *P. (Dichotomosphinctes) elisabethae* (Pandey *et al.*, 2012). Along these sections, only six specimens of the Aspidoceratidae have been found. *Euaspidoceras wagunense* occurs in beds of the Plicatilis and Transversarium zones, but might even appear in the lower Bifurcatus Zone. *Euaspidoceras varians* and *Euaspidoceras aff. jeanneti* are represented by only one specimen each from the lower Bifurcatus Zone.

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