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A REVIEW OF THE TITHONIAN AMMONITES FROM THE KACHCHH BASIN, WESTERN INDIA

DHIRENDRA K. PANDEY[1*], MATTHIAS ALBERTI[1,2], FRANZ T. FÜRSICH[3], SNEHA BHAUMIK[1] and WAGIH AYOUB-HANNAA[3]

[1]DEPARTMENT OF GEOLOGY, UNIVERSITY OF RAJASTHAN, JAIPUR 302 004, INDIA
[2]INSTITUT FÜR GEOWISSENSCHAFTEN DER CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL, LUDEWIG-MEYN-STRASSE 10, 24118 KIEL, GERMANY
[3]GEOZENTRUM NORDBAYERN DER FRIEDRICH-ALEXANDER-UNIVERSITÄT ERLANGEN-NÜRNBERG, FG PALÄOUMWELT, LOEWENICHSTRASSE 28, 91054 ERLANGEN, GERMANY
*E-MAIL: dhirendrap@hotmail.com

ABSTRACT

Twenty taxa of ammonites, represented by 53 specimens, are described from three sections of the highly ferruginous Umia Ammonite Beds of western Kachchh, Gujarat. The ammonites are representatives of the families Phylloceratidae, Haploceratidae, Perisphinctidae, Ataxioceratidae, and Berriasellidae and belong to the genera *Ptychophylloceras*, *Holcophylloceras*, *Hildoglochiceras*, *Virgatosphinctes*, *Parapallasiceras*, *Paraulacosphinctes*, *Micracanthoceras*, and *Himalayites*. Four ammonite levels can be distinguished. They are, in stratigraphic order, the *Hildoglochiceras* Horizon, and the Denseplicatus, Microcanthum, and Frequens ammonite zones, and stratigraphically represent the middle Lower to lower Upper Tithonian. The Umia Ammonite Beds are a condensed unit representing the maximum flooding zone of a transgressive-regressive cycle. The degree of condensation varies between the sections: While the four ammonite levels can be differentiated in the Katesar section, they are less clearly developed in the more strongly condensed Lakhapar section.

Keywords: Tithonian, Ammonites, Taxonomy, Biostratigraphy, Kachchh Basin

INTRODUCTION

The Kachchh Basin (Fig. 1) in western India offers a well preserved Jurassic sedimentary succession deposited at the southern margin of the Tethys Sea. Kachchh is a pericratonic basin situated at the western periphery of the Indian subcontinent. The Jurassic rocks of the Kachchh Basin have gained global significance because of their rich fossil assemblages, which range in age from Pliensbachian to Late Tithonian times (Fürsich *et al*., 2013). The outcrops of the marine late Early and Late Tithonian sediments in the Kachchh Basin are mostly confined to the western part of the so-called Kachchh Mainland; the Mundhan Anticline, the areas northeast of Lakhapar Village, west of Soorka Hill, east-southeast of Katesar Temple, and the area near Sahera Village (Fig. 1). Lithostratigraphically, these late Early to Late Tithonian sediments represent the older part of the Umia Formation (Fig. 2).

The Tithonian ammonites described and illustrated in the present paper are the outcome of a systematic, bed-by-bed collection from three outcrops in the Kachchh Basin, viz, 1.5 km ESE of Katesar Temple, 3 km NW of Mundhan Village and 3 km NE of Lakhapar. Sequence stratigraphically the ammonite-bearing beds of these outcrops have been classified as a maximum flooding zone (MFZ; Fig. 3). Lithostratigraphically, these beds are known as the Umia Ammonite Beds (Fig. 2). The horizons consist predominantly of bedded, bioturbated, fossiliferous, ferruginous, glauconitic, often nodular siltstone/fine-grained sandstone with scattered coarse quartz granules. The dominant fossils are bivalves such as *Gryphaea* (occasionally concentrated in small lenses and pockets), *Gervillella*, *Eoseebachia*, *Pterotrigonia*, *Megacucullaea,* ammonites, belemnites, gastropods, and large pieces of wood. The trace fossil *Thalassinoides* is common. The thickness of the Umia Ammonite Beds decreases from ca. 10 m in the Katesar section in the west to about 3 m in the Lakhapar section in the east. Glauconite grains are scattered throughout the MFZ in Lakhapar, whereas in the Katesar section they are confined to certain levels. Both, records of ammonites and the thickness of the entire unit, suggest a more expanded succession in the Katesar area compared with the more strongly condensed succession in the Lakhapar area.

In addition to the taxonomy of the collected ammonites, the following observations were made in the present study: (1) The ammonites are confined to one package of sediments interpreted as a maximum flooding zone (Fürsich and Pandey, 2003); (2) the ammonites from the Lakhapar section appear to be highly time averaged; (3) the basal part of the Umia Ammonite Beds is marked by concentrations of fossils such as *Megacucullaea* and *Gryphaea*, either in a unit of thin beds (e.g. Lakhapar section) or in several beds (Katesar section); (4) the ammonites closely resemble those recorded by Uhlig (1910) from the Himalayas.

MATERIAL AND METHODS

The 53 specimens described in the present publication were collected from the Umia Ammonite Beds during four field sessions between 1999 to 2015. Most of the specimens underwent preparation with micro-air abrasive and micro-sand abrasive pneumatic tools at the GeoZentrum Nordbayern of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany. The majority of the specimens represent phragmocones. The specimens were photographed by Wagih Ayoub-Hannaa after coating with ammonium chloride.

The specimens are currently housed at the GeoZentrum Nordbayern of the Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany, but planned to be stored ultimately at the Department of Geology, University of Rajasthan, Jaipur, India.

A Vernier Caliper was used for the measurement of the ammonites. The dimensions and abbreviations used in the present description are explained in Fig. 4. Numbers in parantheses are proportional dimensions as percentage of diameter. Whorl-

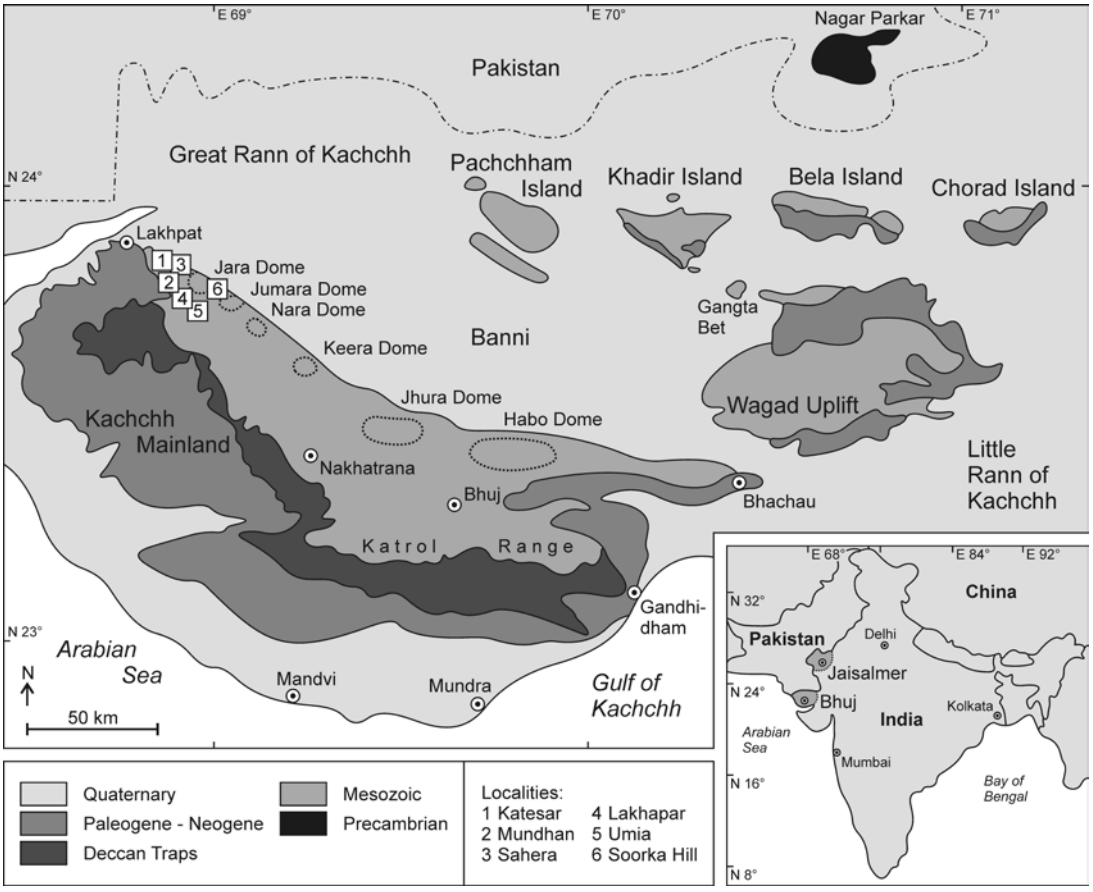


Fig. 1. Geological sketch map of the Kachchh Basin showing the position of the sections and localities yielding Tithonian ammonites discussed in the present study (modified after Fürsich *et al*., 2013).

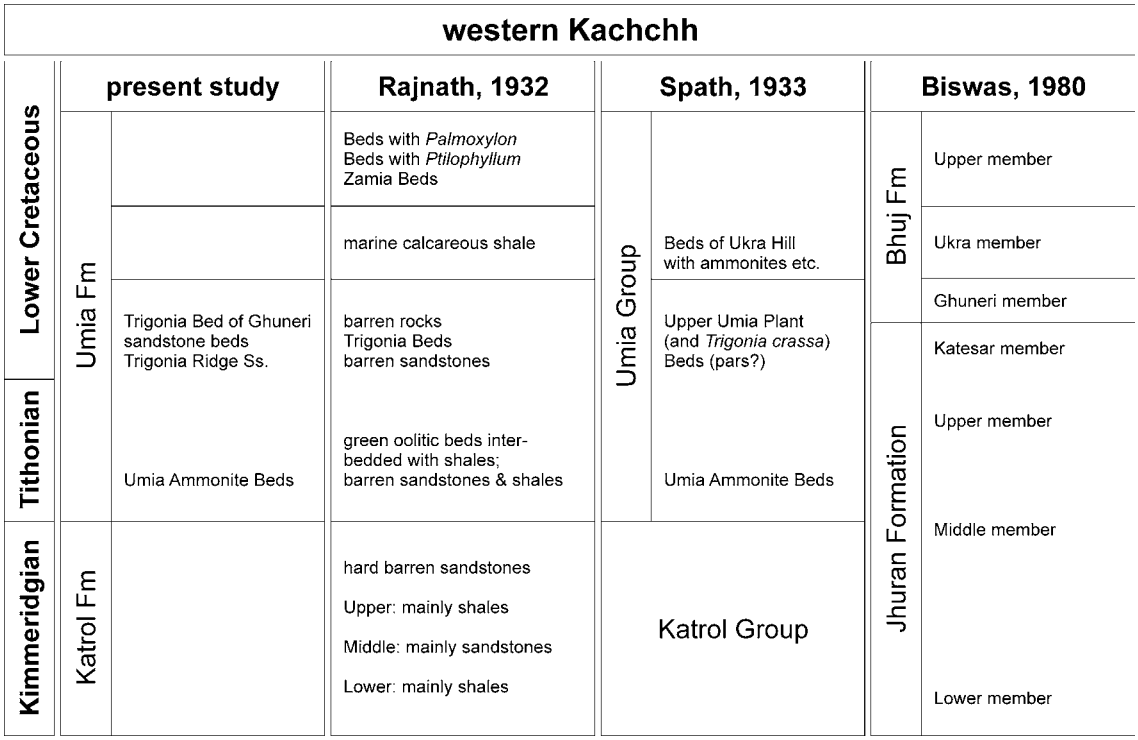


Fig. 2. Lithostratigraphic framework of the Kimmeridgian, Tithonian, and Lower Cretaceous strata of the western Kachchh Basin. Note the two *Trigonia*-bearing horizons above the Umia Ammonites Beds, all grouped into the Umia Formation.

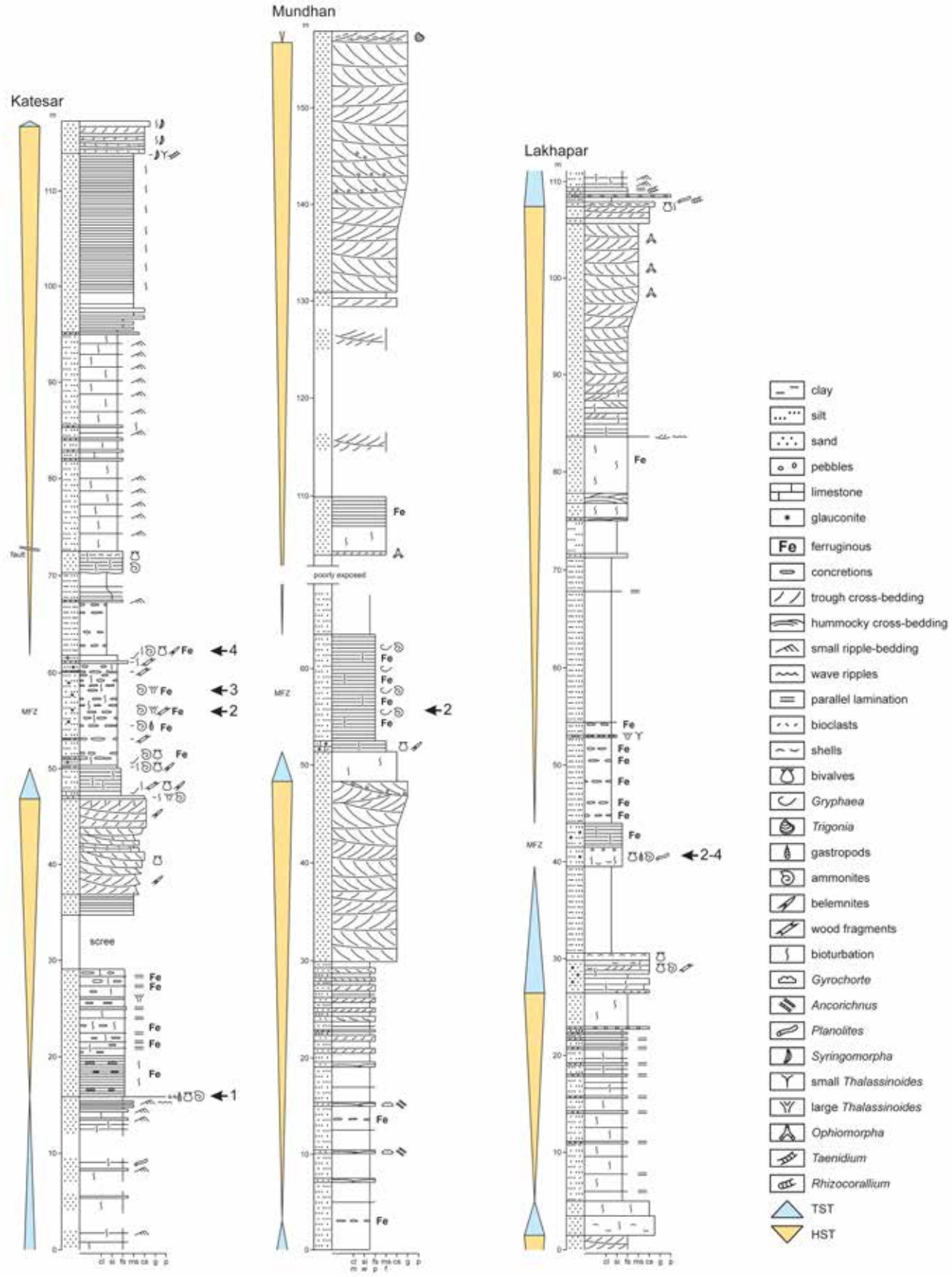


Fig. 3. Lithologs of the localities in the western Kachchh Basin yielding specimens for the present study. The numbers indicate the ammonite-bearing units (1- *Hildoglochiceras* Horizon, 2- Denseplicatus Zone, 3- Microcanthum Zone, 4- Frequens Zone).

sections, ribbing patterns, and suture lines are illustrated by drawings, particularly if the specimens were not well preserved and it was not possible to show these morphological features through photographs. Additionally, primary and secondary ribs have been counted per half-whorl at different diameters in order to document changes in ornamentation during the ontogeny of the species. The synonymy lists are restricted to first descriptions and the most important references relevant to the region.

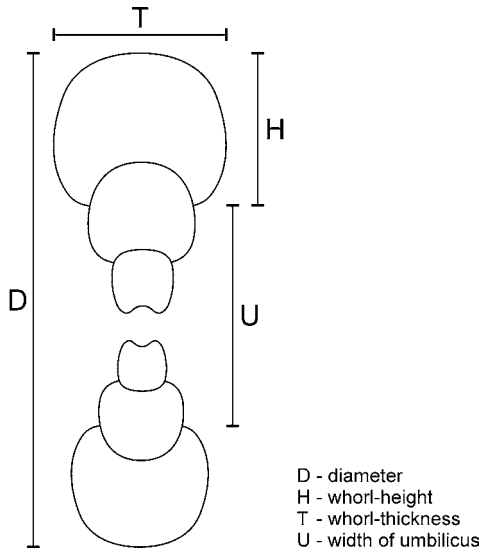


Fig. 4. Measured dimensions and used abbreviations of the ammonoids.

In the taxonomic descriptions the term "closely spaced ribs" has been used if inter-ribs width is either equal to or less than the thickness of ribs, whereas "moderately spaced ribs" refer to an inter-ribs width that is greater than the thickness of ribs.

SYSTEMATIC PALAEONTOLOGY

Class **Cephalopoda** Cuvier, 1797
Order **Ammonoidea** Zittel, 1884
Suborder **Phylloceratina** Arkell, 1950
Superfamily **Phylloceratoidea** Zittel, 1884
Family **Phylloceratidae** Zittel, 1884
Subfamily **Phylloceratinae** Zittel, 1884
Genus ***Ptychophylloceras*** Spath, 1927

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

Ptychophylloceras ptychoicum (Quenstedt, 1845)
(Pl. I, fig. 3; Fig. 5A)

Ammonites ptychoicus sp. nov.–Quenstedt, 1845, p. 219, pl. 17, fig. 12.
Phylloceras ptychoicum (Quenstedt) – Waagen, 1875, p. 30, pl. 7, fig. 2a-c.
Ptychophylloceras ptychoicum (Quenstedt) – Pandey *et al*., 2013b, p. 142, pl. 1, fig. 2; Fig. 4B.

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 15).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 15	51.5	29.0 (56)	-	5.5 (11)	
	at 38.0	21.5 (57)	17.8 (47)	4.5 (12)	1.21

Description: Shell incomplete, only inner part of phragmocone, involute; whorl section oval, compressed with broad ventral region and maximum inflation slightly above mid-lateral height (Fig. 5A). External surface smooth, labial ridge present. Suture lines well preserved.

Remarks: The specimen closely resembles *Ptychophylloceras ptychoicum* (Quenstedt, 1845) in whorl section, smoothness of external surface, and presence of a labial ridge. Although this is a long-ranging species (Pandey *et al*., 2013b), the occurrence of this species together with characteristic Tithonian ammonites is of interest as already Oppel (1865a, p. 551) and Waagen (1875, p. 31-32) described it as a typical species of Tithonian assemblages in Europe.

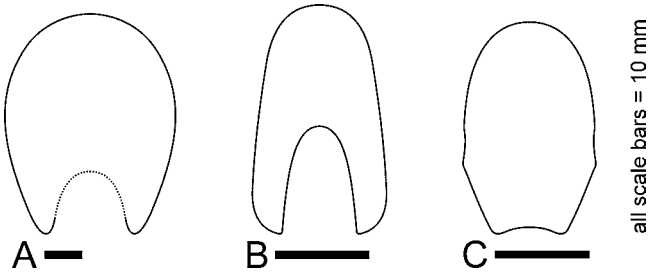


Fig. 5. A. *Ptychophylloceras ptychoicum* (Quenstedt, 1845). Whorl section at ca. 52 mm diameter; GZN2015I 15. B. *Holcophylloceras* sp. Whorl section at ca. 20 mm diameter; GZN2015I 01. C. *Hildoglochiceras latistrigatum* (Uhlig, 1903). Whorl section at ca. 34 mm diameter; GZN2015I 17.

Subfamily **Calliphylloceratinae** Spath, 1927
Genus ***Holcophylloceras*** Spath, 1927
(Type species: *Phylloceras mediterraneum* Neumayr, 1871)

Holcophylloceras sp.
(Pl. I, fig. 1; Fig. 5B)

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 01).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 01	20.0	9.5 (48)	6.5 (33)	4.0 (20)	1.46

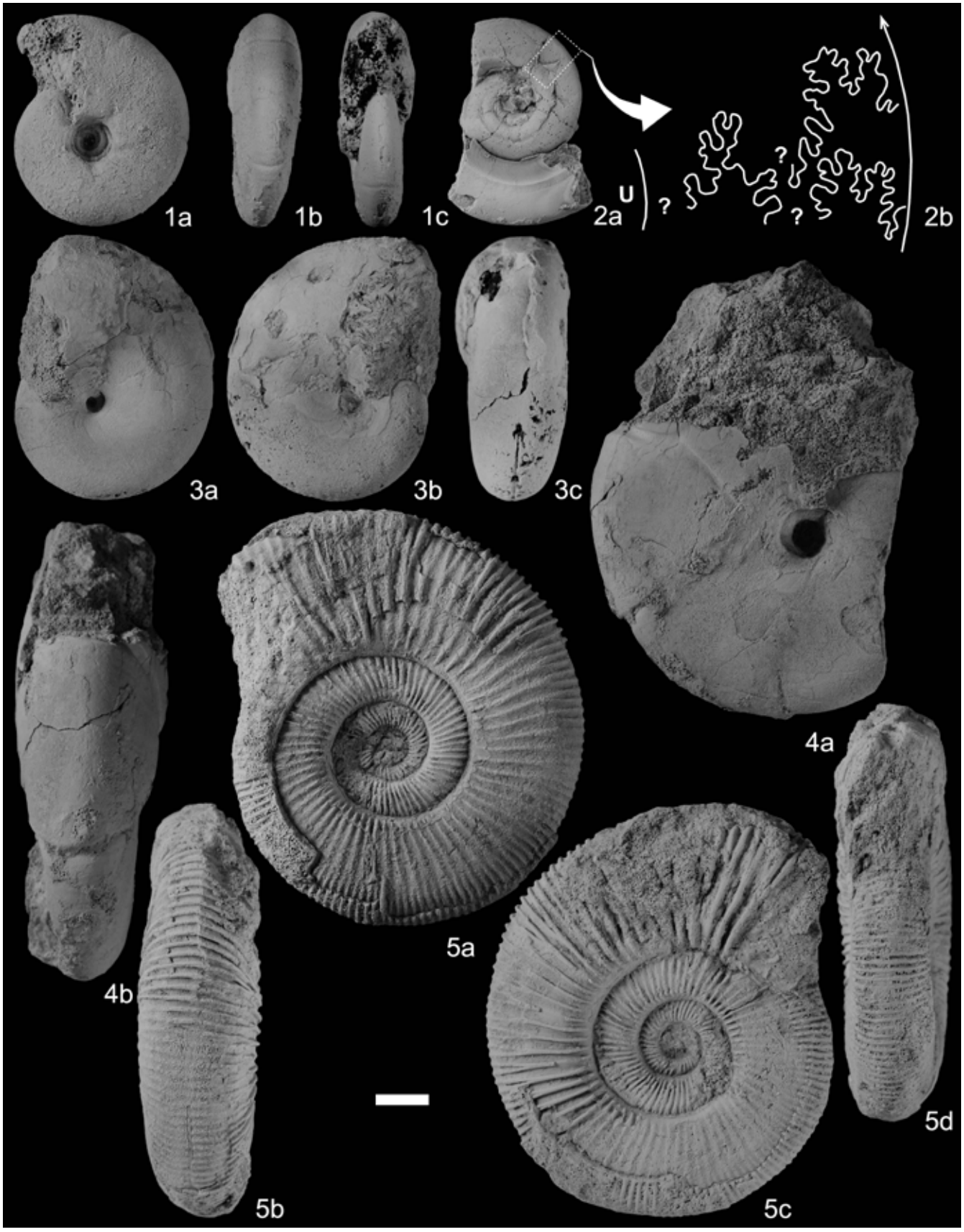
EXPLANATION OF PLATE I

(specimens in natural size except fig. 1a-c)

1. ***Holcophylloceras*** sp.; (a) lateral view, (b) ventral view showing the well developed sigmoidal constrictions across the venter, and (c) apertural view; GZN2015I 01 (scale bar = 6.7 mm). 2. ***Hildoglochiceras latistrigatum*** (Uhlig, 1903); (a) incomplete lateral view, (b) incomplete suture; GZN2015I 17 (scale bar = 10 mm). 3. ***Ptychophylloceras ptychoicum*** (Quenstedt, 1845); (a, b) lateral views and (c) ventral view showing an incomplete suture; GZN2015I 15 (scale bar = 10 mm). 4. ***Holcophylloceras*** sp. indet.; (a) lateral view and (b) ventral view showing the deep constrictions across the ventral area; GZN2015I 16 (scale bar = 10 mm). 5. ***Virgatosphinctes denseplicatus*** (Waagen, 1875); (a, c) lateral views showing the regularly biplicate to rectiradiate primary ribs, (b) ventral view, and (d) apertural view; GZN2015I 07 (scale bar = 10 mm).

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate I



Description: Shell small, incomplete, only inner part of phragmocone, involute; whorl section oval, compressed with acutely rounded ventral region and maximum inflation slightly above umbilical shoulder (Fig. 5B). External lateral surface smooth with at least four acutely sigmoidal constrictions crossing the smooth ventral region with pronounced forward-directed concavity. Suture lines well preserved.

Remarks: This specimen bears all characters typical of the genus *Holcophylloceras* Spath, 1927 (see Arkell *et al*., 1957, p. L189). The size of the specimen is too small for any specific identification, hence it is kept in open nomenclature. Its whorl section matches that of a specimen collected by Raj Nath from the Tithonian Umia Ammonite Beds 3 km northeast of Lakhapar and illustrated by Spath (1931, pl. 101, fig. 5a, b) as *Holcophylloceras silesiacum* (Oppel, 1865).

Holcophylloceras sp. indet.
(Pl. I, fig. 4)

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 16).

Description: Shell moderately large, incomplete, consisting only of part of phragmocone, involute; whorl section oval, compressed , with moderately rounded ventral region and maximum inflation slightly below mid-lateral height. Ornamentation consisting of fine, closely spaced ribs and acutely sigmoidal, deep constrictions crossing the smooth ventral region with forward-directed concavity. Umbilical shoulder moderately distinct, wall moderately deep and convex. Suture lines well preserved.

Remarks: This fragmentary specimen is more than 83 mm in diameter. Its ornamentation is very faintly seen near the last preserved constriction. It closely resembles *Phylloceras mediterraneum* Neumayr, 1871 as illustrated by Waagen (1875, p. 34, pl. 5, fig. 1) from the Early Callovian (Macrocephalus Beds) of Jara Dome and by Spath (1927, p. 58, pl. 5, fig. 1) from the Middle Callovian Anceps Zone of Kheera Dome. It also resembles *Holcophylloceras* aff. *polyolcum* (Benecke, 1865) (Spath, 1927, p. 60, pl. 6, figs 1, 2) from the Katrol Beds (Kimmeridgian) of Fakirwari and the Tithonian? 'Moondan Group' of West Soorka. [From the description of Spath (1933, p. 756, 792) it appears that the 'Moondan Group' is a group of beds comparable to the Trigonia Ridge sandstone northwest of Mundhan Village]. Spath (1927, p. 58) mentioned several transitional forms between *Holcophylloceras mediterraneum* and *H. polyolcum*. Both species have long temporal ranges, but can be distinguished by the number of constrictions per whorl. In this respect the present specimen is closer to *H. polyolcum*. However, due to the fragmentary nature of our specimen no specific identification is possible.

Superfamily **Haploceratacea** Zittel, 1884
Family **Haploceratidae** Zittel, 1884, *sensu* Zigler, 1947
Subfamily **Haploceratinae** Zittel, 1884, *sensu* Zigler, 1947
Genus ***Hildoglochiceras*** Spath, 1924

(Type species: *Hecticoceras latistrigatum* Uhlig, 1903.)

Remarks: According to Myczynski (1989, p. 85), the ammonites of the genus *Hildoglochiceras* described by Imlay (1939, 1940, 1980) from the Tithonian strata of Mexico and Cuba show some resemblance to the Indian (Spath, 1924) and Madagascan (Collignon, 1960) species, but owing to the comparatively involute nature of their shells, Myczynski (1989) described these species from western Cuba within the subgenus *Salinites*. The specimen described here, however, shows an evolute nature of the shell.

Hildoglochiceras latistrigatum (Uhlig, 1903)
(Pl. I, fig. 2; Fig. 5C)

Hecticoceras latistrigatum sp. nov. – Uhlig, 1903, p. 27, pl. 2, fig. 4; pl. 3, fig. 5.

Material: One specimen from a horizon approximately 34 m below the Umia Ammonite Beds 1.5 km ESE of Katesar Temple (GZN2015I 17).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 17	38.0	11.5 (30)	8.2 (22)	17.0 (45)	1.40
Hildoglochiceras latistrigatum (Uhlig) – Uhlig, 1903, p. 27	64	20.8 (33)	13.2 (21)	27 (42)	1.58

Description and remarks: Shell small, incomplete and evolute, consisting of three-fourth of the phragmocone and a small part of the body chamber. Whorl section oval, compressed (Fig. 5C). Lateral surface flat and mostly smooth except for a moderately distinct sickle-shaped rib. A shallow spiral groove runs along the middle of the lateral surface of the phragmocone. Its lower boundary is sharp and coincides with the maximum thickness of the body chamber. Inner third of body chamber, i.e. area below spiral groove, converging towards umbilical seam. Suture lines preserved. Inner whorls a bit crushed, so that the beginning of the spiral groove cannot be pinpointed with confidence. However, on the basis of the morphological characters the present specimen can be safely assigned to *Hildoglochiceras latistrigatum* (Uhlig, 1903). The sickle-shaped rib appears at a diameter of about 39 mm, which is very similar to the situation in the specimens of Uhlig (1903).

Previous records: Uhlig (1903, 1910) described the species from the Spiti Shales of Chidamu in the Himalayas of northern India. According to Spath (1933, p. 673), this species from Spiti may be associated with the *Aulacosphinctoides* fauna, which had almost disappeared when *Virgatosphinctes* became dominant in the Early Tithonian.

Suborder **Ammonitina** Hyatt, 1989
Superfamily **Perisphinctoidea** Steinmann, 1890
Family **Perisphinctidae** Steinmann, 1890
Subfamily **Virgatosphinctinae** Spath, 1923
Genus ***Virgatosphinctes*** Uhlig, 1910

(Type species: *Virgatosphinctes broilii* Uhlig, 1910)

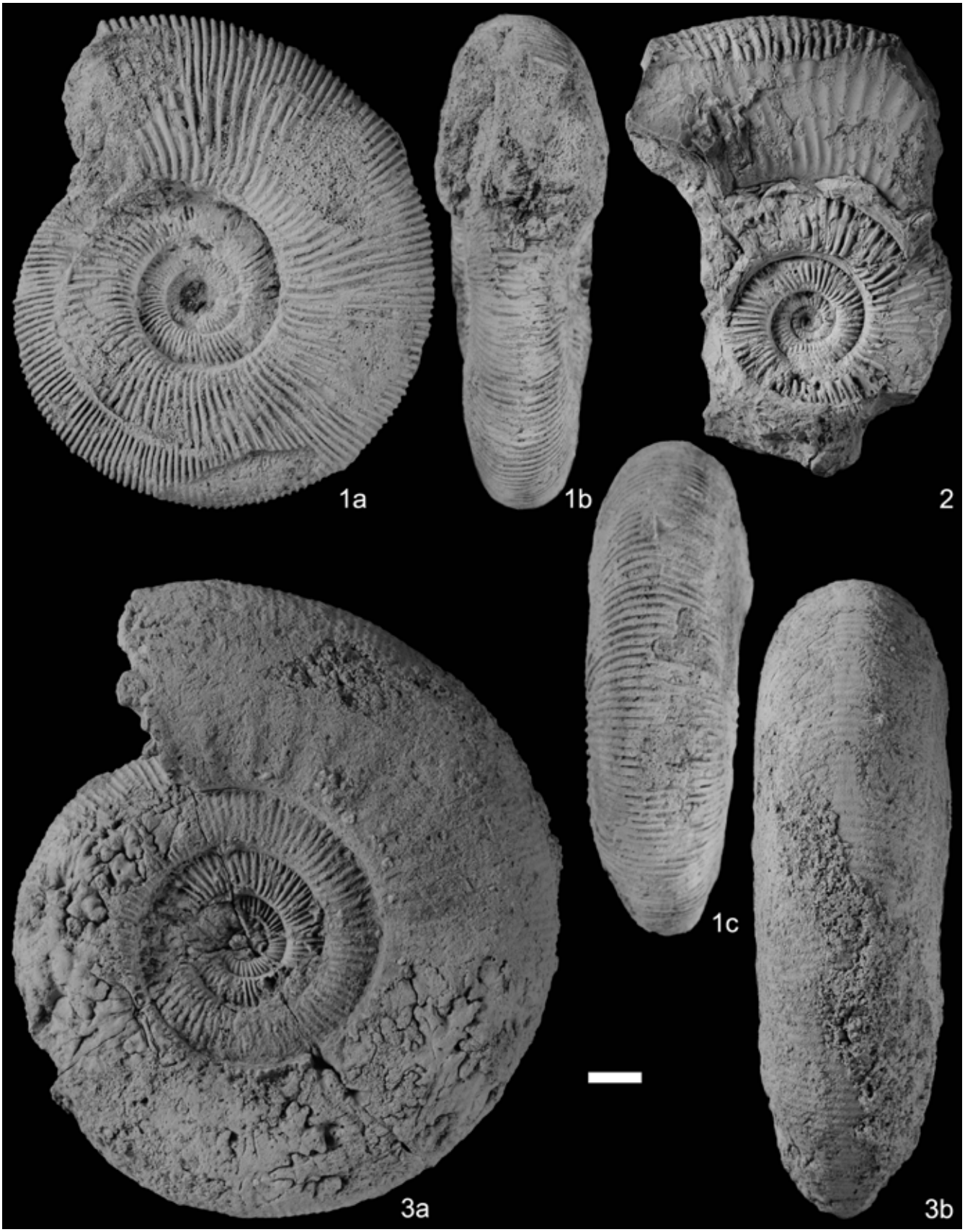
EXPLANATION OF PLATE II

(specimens are in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes denseplicatus*** (Waagen, 1875); (a) lateral view, (b) apertural view, and (c) ventral view; GZN2015I 08. 2. ***Virgatosphinctes denseplicatus*** (Waagen, 1875) var. ***rotunda*** Spath (1931); incomplete lateral view; GZN2015I 51. 3. ***Virgatosphinctes denseplicatus*** (Waagen 1875) var. ***striatissima*** Spath (1931); (a) lateral view with poorly preserved sutures and (b) ventral view; GZN2015I 22.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate II



Remarks: The genus *Virgatosphinctes* includes evolute ammonites of moderate to very large size (diameters can exceed 200 mm; Spath, 1931, p. 533). The ribs are prorsiradiate, straight to sinuous. The ornamentation often changes considerably during ontogeny. The inner whorls are characterized by mostly regularly bifurcating ribs with undivided ribs intercalated occasionally. In the middle whorls, the simple ribs disappear and trifurcating ribs occur. On the outer whorls, the trend continues with the appearance of more and more polygyrate ribs (first virgatotome, then fasciculate). Depending on the adult size of the morphospecies, only a certain stage within this trend is reached. The larger taxa show a thickening of the primary ribs which become more distant and less numerous. Simultaneously, the branching points become indistinct and eventually secondaries can disappear on the body whorl (compare Uhlig, 1910, p. 307; Spath, 1931; Arkell *et al*., 1957).

Virgatosphinctes denseplicatus (Waagen, 1875)
(Pl. I, fig. 5; Pl. II, fig. 1; Figs 6A-C, 7)

Perisphinctes denseplicatus sp. nov. – Waagen, 1875, p. 201, pl. 46, fig. 3a, b; pl. 55, fig. 1a, b.

Virgatosphinctes denseplicatus (Waagen) – Spath, 1931, p. 532, pl. 90, fig. 1; pl. 96, fig. 3a, b; pl. 77, fig. 3; pl. 102, fig. 4-1.-Yin and Enay, p. 672, fig. 4 (3, 4).

Material: Five specimens from the Umia Ammonite Beds; three from 3 km NE of Lakhapar (GZN2015I 07, 08, 10), and two from 3 km NW of Mundhan Village (GZN2015I 49, 56).

Dimensions (in mm):

specimen	**D**	**H (H/D)**	**T (T/D)**	**U (U/D)**	**H/T**
GZN2015I 08	89.0	50.0 (56)	31.0 (35)	32.0 (36)	1.61
GZN2015I 07	75.0	25.5 (34)	19.0 (25)	33.0 (44)	1.34
	at 69.5	24.0 (35)	22.0 (32)	28.0 (40)	1.09
Virgatosphinctes denseplicatus (Waagen) – Spath, 1931, p. 533 (lectotype)	137	44 (32)	42.5 (31)	59 (43)	1.03
Virgatosphinctes denseplicatus (Waagen) – Spath, 1931, p. 533	125	40 (32)	42.5 (34)	55 (44)	0.94
	at 100	31 (31)	29 (29)	46 (46)	1.07
Virgatosphinctes denseplicatus (Waagen) var. *blakei* – Uhlig, 1910, p. 313	92	31 (34)	30 (32)	39 (42)	1.03
Virgatosphinctes denseplicatus (Waagen) var. *blakei* – Spath, 1931, p. 533	87	30 (35)	28 (32)	35 (40)	1.09
Virgatosphinctes denseplicatus (Waagen) var. *inequalis* – Spath, 1931, p. 533	>200	65 (33)	52 (26)	-	1.25
Virgatosphinctes denseplicatus (Waagen) var. *inequalis* – Spath, 1931, p. 533	97	35 (36)	30 (31)	34 (35)	1.16

Description: Shell incomplete, only phragmocone, evolute. Whorl-section oval, compressed, with maximum thickness slightly above umbilical shoulder (Fig. 6A). Ornamentation consisting of thin, closely spaced, prorsiradiate primary ribs. In inner and middle whorls, ribs bifurcate regularly into rectiradiate, finer secondary ribs slightly above mid-lateral height. At larger diameters, trifurcating ribs appear and branching points become unclear (Fig. 6B, C). Secondary ribs pass straight across the ventral region. Single ribs and intercalatory secondary ribs rare. Umbilical shoulder moderately distinct, umbilical wall steep. Umbilical seam coinciding with branching point of ribs.

Remarks: *Virgatosphinctes denseplicatus* (Waagen, 1875) is a very variable species with respect to its dimensional proportions and ornamentation. The density of ribs varies considerably between specimens (Fig. 7; compare Spath, 1931), but in general, the number of ribs increases markedly with increasing phragmocone diameter. This trend is visible in the present specimens as well as in those described by Waagen (1875) and Spath (1931). While the ribs are mostly bifurcating in the inner and middle whorls, the ornamentation changes towards the body chamber where primary ribs become more distant and less numerous. This is illustrated by the specimen figured by Yin and Enay (2004). While the number of secondaries still increases (Fig. 7), the branching points of the primaries are more or less obscure. The lectotype figured by Waagen (1875) and described again by Spath (1931) shows that even the secondary ribs eventually disappear on the outer part of the body whorl.

Due to the large variability of the species in ribbing density and dimensions, Fig. 7 might serve only as a rough indication of the change in ornamentation during ontogeny. Especially the adult size of the phragmocone seems to differ considerably in the specimens described in literature. Waagen (1875) mentioned that the phragmocone reaches a diameter of about 110 mm with a change in ornamentation occurring already from 100 mm onwards with around 4 to 10 secondaries per primary rib. The present specimens are phragmocones with maximum diameters slightly above 90 mm. The specimen figured by Yin and Enay (2004) shows parts of the body chamber with the adult phragmocone having a diameter of around 80 to 90 mm. In contrast, Spath (1931, p. 533) describes several varieties of *Virgatosphinctes denseplicatus* reaching much larger sizes (occasionally septate up to a diameter of 200 mm). A much larger number of specimens is needed to reevaluate the status of these varieties, some of which might represent distinct species. At the moment, it seems more useful to consider *Virgatosphinctes denseplicatus* as a single, variable species, especially since the identification of the described variants does not lead to a higher biostratigraphic resolution.

In total, Spath (1931) described four variants, including var. *blakei*, var. *inequalis*, var. *rotunda*, and var. *striatissima*. *Virgatosphinctes denseplicatus* var. *blakei* attains a larger size and is characterized by more distant ribs compared to the lectotype. This low density of ribs is also similar to specimens described by Uhlig (1910, p. 313) from the Spiti Shales of northern India,

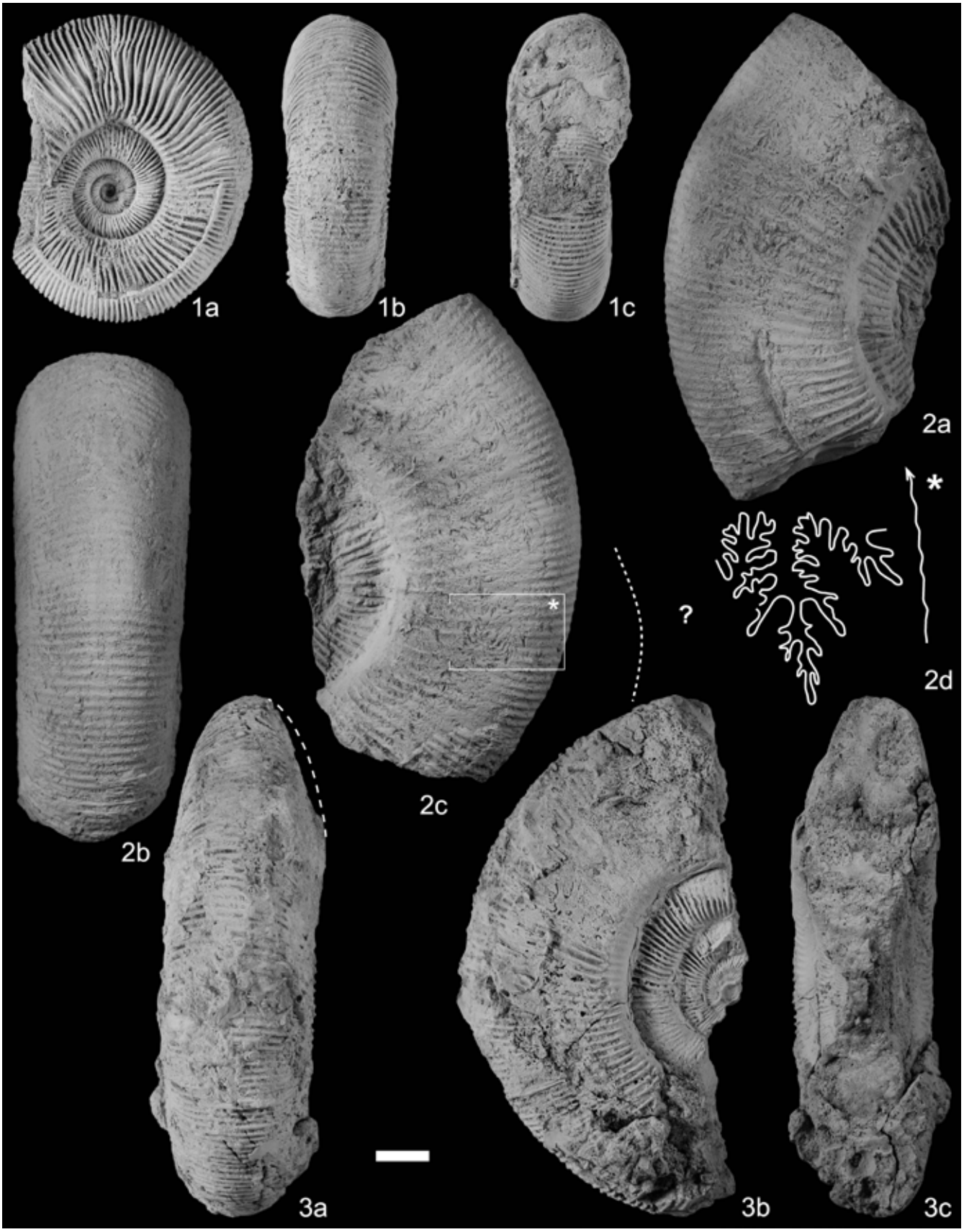
EXPLANATION OF PLATE III

(specimens in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes frequens*** (Oppel, 1865); (a) lateral view showing the style of ribbing, (b) ventral view, and (c) apertural view showing the sub-oval whorl section; GZN2015I 24. 2. ***Virgatosphinctes denseplicatus*** (Waagen, 1875) var. ***striatissima*** Spath (1931); (a, c) incomplete lateral views, (b) ventral view, and (d) incomplete suture; GZN2015I 20. 3. ***Virgatosphinctes*** cf. ***communis*** Spath, 1931; (a) ventral view, (b) lateral view, and (c) apertural view; GZN2015I 02.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate III



which Spath (1931, p. 534) consequently included in this variety. Another very large variety attaining diameters above 200 mm is called var. *inequalis*. It also shows comparatively distant ribs, but can be distinguished from var. *blakei* by its smaller umbilicus and, most importantly, by a more compressed whorl section (Spath, 1931, p. 533). *Virgatosphinctes denseplicatus* var. *rotunda* instead is characterized by a very rounded, mostly depressed whorl section. Finally, var. *striatissima* can be distinguished by its very fine and dense ribbing.

The present specimens match the lectotype and the description of the species by Waagen (1875). Specimen GZN2015I 07 can also be compared to var. *blakei*, due to its slightly lower ribbing density. Nevertheless, due to the absence of the body chamber and its comparatively small size, it has been left in the species.

Other similar species include *Virgatosphinctes communis* Spath, 1931. It can be differentiated from the present species by its more compressed, discoidal whorl shape (Spath, 1931, p. 535). Additionally, *V. communis* exhibits oblique folds on the smooth lateral surface near the aperture, whereas such oblique folds are absent in *V. denseplicatus*.

Previous records: Spath (1931, p. 535) described *Virgatosphinctes denseplicatus* from the Umia Ammonite Beds west of Soorka Hill, north of Mundhan, 3 km NE of Lakhapur, and from Sahera.

Virgatosphinctes denseplicatus (Waagen, 1875) var.
rotunda Spath, 1931
(Pl. II, fig. 2; Fig. 6D)

Virgatosphinctes denseplicatus (Waagen) var. *rotunda* nov. var. – Spath, 1931, p. 533, pl. 96, fig. 3a, b.

Material: Two specimens from the Umia Ammonite Beds; one from 1.5 km ESE of Katesar Temple (GZN2015I 51) and one from 3 km NW of Mundhan Village (GZN2015I 47).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 51	-	30.0	33.0	-	0.91
	at 57.5	19.0 (33)	21.5 (37)	22.0 (38)	0.88
Virgatosphinctes denseplicatus (Waagen) var. *rotunda* – Spath, 1931, p. 533	74	22 (30)	27 (37)	33 (44)	0.81

Description: Shell moderately large, fragment of phragmocone and body chamber, evolute, depressed, whorl section subrounded, ventral region broad (Fig. 6D). Ornamentation of fine, moderately dense, slightly prorsiradiate and sinuous primary ribs, regularly bifurcating above mid-lateral height; polygyrate branching into three secondary ribs developed only on body chamber. Secondary ribs slightly bending backwards, passing straight across ventral region. Primary ribs originating from umbilical side of moderately distinct umbilical shoulder, with slight forward-directed concavity at umbilical shoulder, becoming rectiradiate before bifurcating slightly before the umbilical suture of the next whorl. Constrictions present. Suture lines preserved.

Remarks: The specimens match *Virgatosphinctes denseplicatus* (Waagen) var. *rotunda* (Spath, 1931, p. 533, pl. 96, fig. 3a, b) by showing comparable proportionate dimensions and a similar broad ventral region. A specimen from 3 km northeast of Lakhapar illustrated by Spath (1931, pl. 102 fig. 4) as *Virgatosphinctes denseplicatus* (Waagen) var. *rotunda* has a slightly smaller umbilical diameter. Nevertheless, considering the variability of the species and the characteristic depressed whorl section, both specimens described here can be confidently assigned to var. *rotunda*.

The density of ribs is also similar to *Perisphinctes* (*Virgatosphinctes*) aff. *pompeckji* Uhlig (1910, p. 320, pl. 65, fig.1a-c), but the present specimens are depressed and the flanks are slightly more arched.

Previous records: Spath (1931) described this variety of *V. denseplicatus* from the Tithonian Umia Formation north of Mundhan and 3 km northeast of Lakhapar.

Virgatosphinctes denseplicatus (Waagen, 1875) var.
striatissima Spath, 1931
(Pl. II, fig. 3; Pl. III, fig. 2; Fig. 6E-G)

Virgatosphinctes denseplicatus (Waagen) var. *striatissima* nov. var. – Spath, 1931, p. 534.

Material: Four specimens from the Umia Ammonite Beds; three from 3 km NE of Lakhapar (GZN2015I 20-22), and one from 1.5 km ESE of Katesar Temple (GZN2015I 48).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 22	124.5	42.0 (34)	39.0 (31)	55.0 (44)	1.08
GZN2015I 20	-	38.5	35.0	-	1.10
	-	34.0	31.0	-	1.10
GZN2015I 21		36.0	33.0		1.09
Virgatosphinctes denseplicatus (Waagen) var. *striatissima* – Spath, 1931, p. 534	71	23 (33)	21 (30)	29 (41)	1.10

Description: Shell moderately large, incomplete, only phragmocone, evolute with subrounded to suboval, slightly compressed whorl section (Fig. 6E-G); maximum thickness slightly above umbilical shoulder. Ornamentation consisting of very thin, closely spaced, prorsiradiate primary ribs, which regularly bifurcate slightly above mid-lateral height into rectiradiate, still finer secondary ribs, which pass straight across the ventral region. Single ribs and intercalatory secondary ribs rare. Umbilical shoulder indistinct, wall steeply sloping. Sutures well preserved.

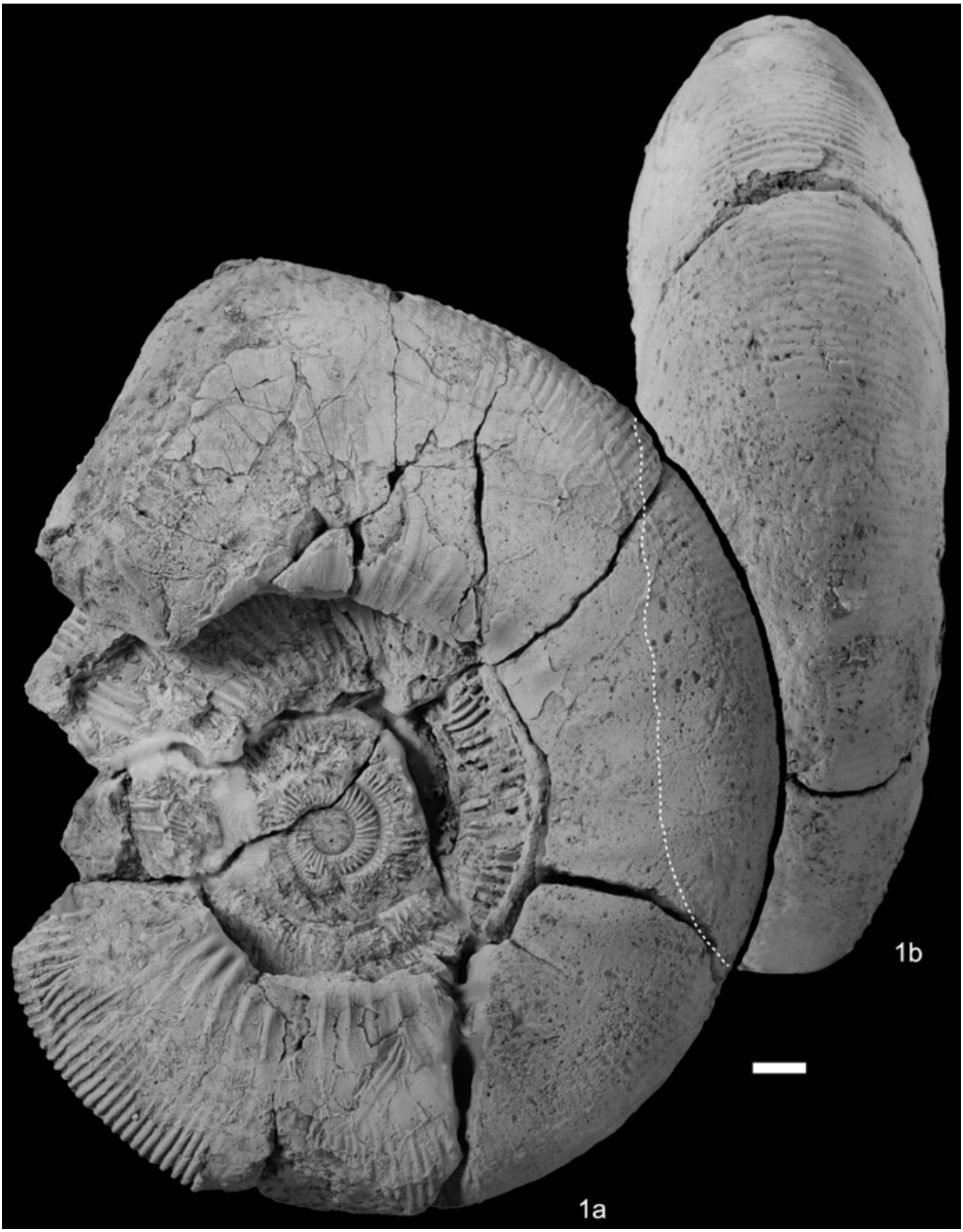
Remarks: These are moderately preserved phragmocones. The very thin and closely spaced ribs and the slightly compressed whorl section match *Virgatosphinctes denseplicatus* (Waagen, 1875) var. *striatissima* Spath, 1931. While the ribbing is similar

EXPLANATION OF PLATE IV

(specimen in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes frequens*** (Oppel, 1865); (a) lateral view and (b) ventral view; GZN2015I 23.

Plate IV



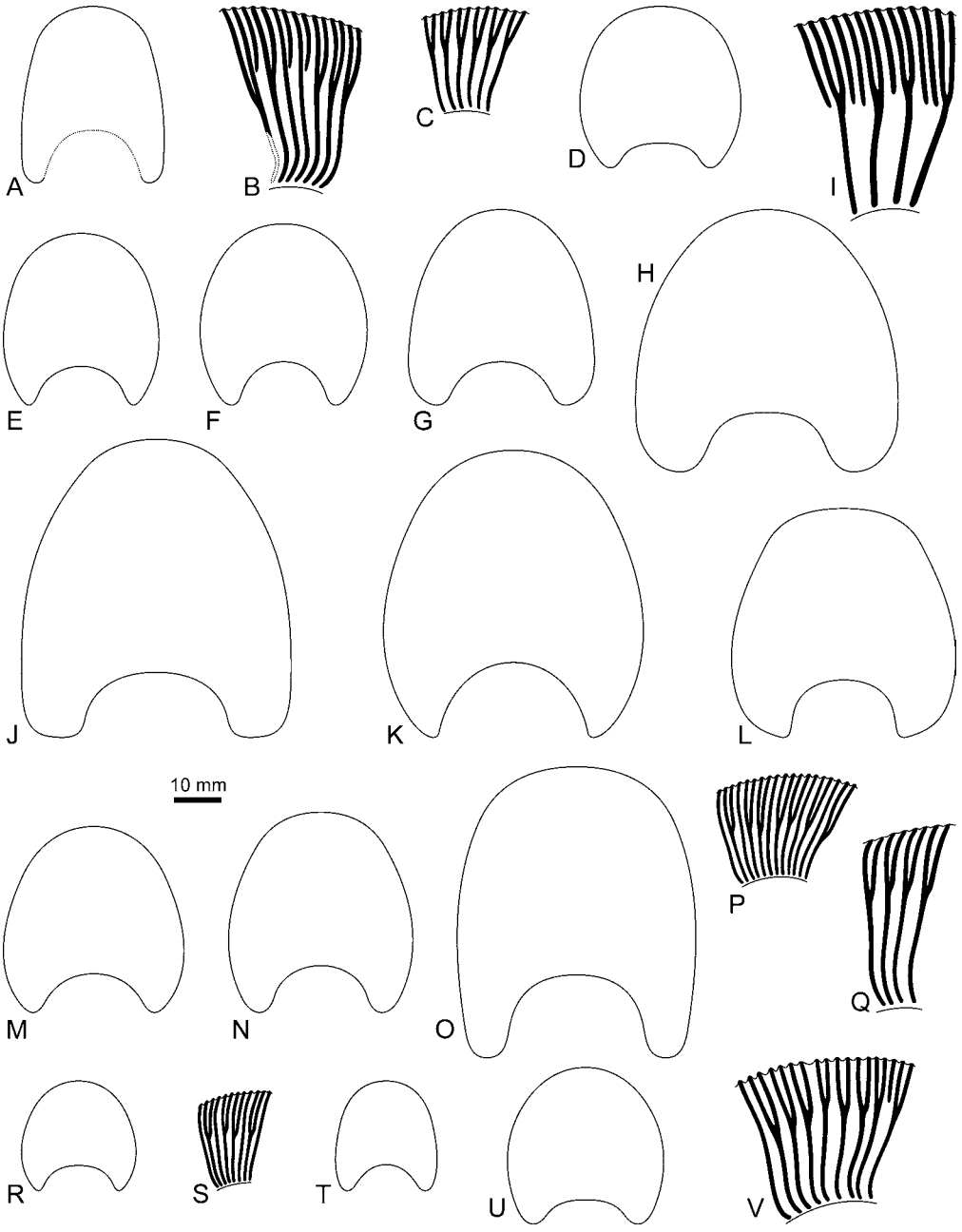


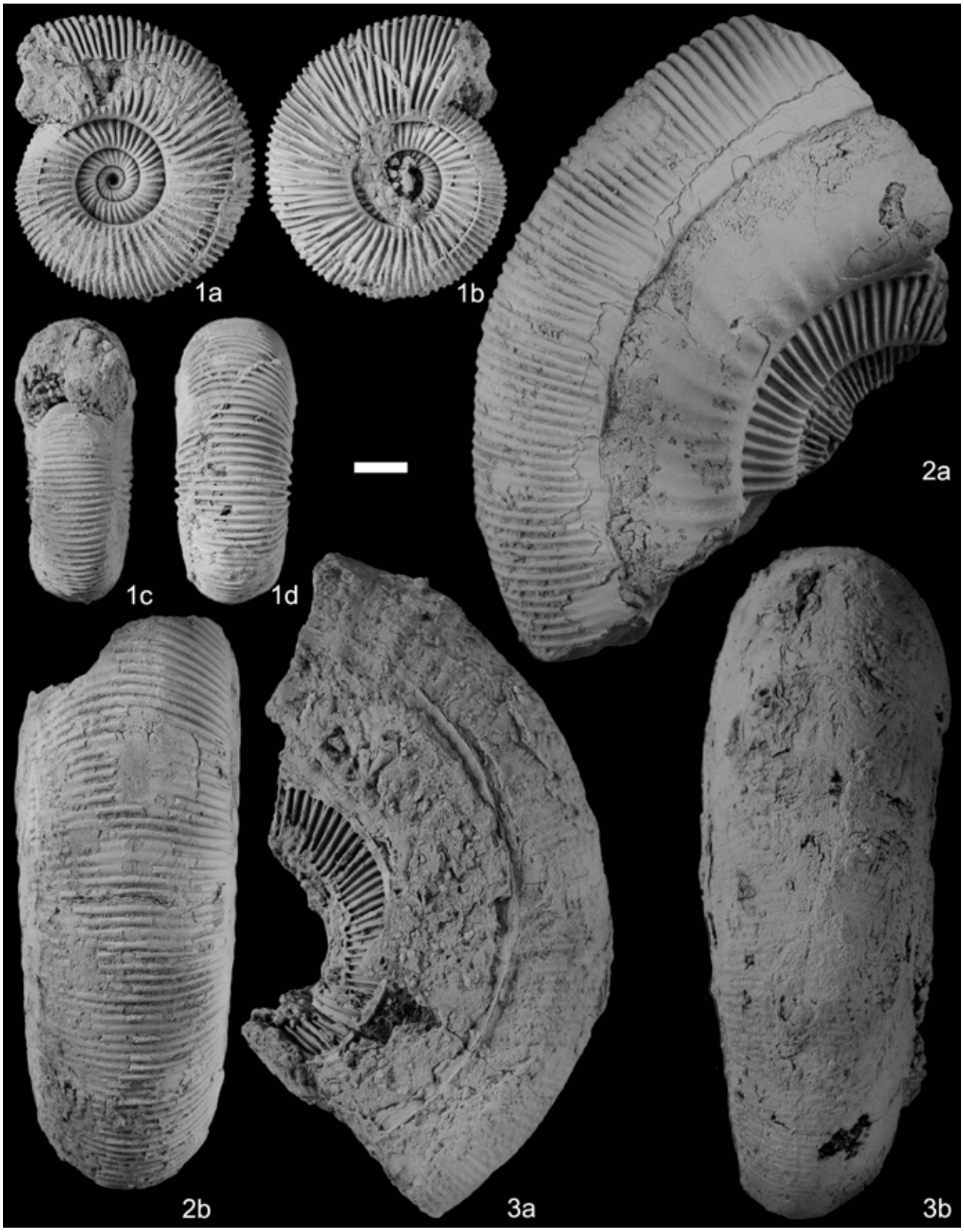
Fig. 6. A-C. *Virgatosphinctes denseplicatus* (Waagen, 1875). A. Whorl section at ca. 92 mm diameter; GZN2015I 08. B. Ribbing pattern on left side at ca. 90 mm diameter; GZN2015I 08. C. Ribbing pattern on right side at ca. 65 mm diameter; GZN2015I 07. D. *Virgatosphinctes denseplicatus* (Waagen, 1875) var. *rotunda* Spath, 1931. Whorl section at ca. 90 mm diameter; GZN2015I 51. E-G. *Virgatosphinctes denseplicatus* (Waagen, 1875) var. *striatissima* Spath, 1931. E. Whorl section at unknown diameter; GZN2015I 21. F. Whorl section at unknown diameter; GZN2015I 20; G. Whorl section at ca. 131 mm diameter; GZN2015I 22. H, I. *Virgatosphinctes frequens* (Oppel, 1865). H. Whorl section at ca. 165 mm diameter; GZN2015I 23. I. Ribbing pattern on right side at unknown diameter; GZN2015I 23. J-L. *Virgatosphinctes* cf. *frequens* (Oppel, 1865). J. Whorl section at unknown diameter; GZN2015I 25. K. Whorl section at unknown diameter; GZN2015I 55. L. Whorl section at unknown diameter; GZN2015I 26. M.-Q. *Virgatosphinctes subfrequens* (Uhlig, 1910). M. Whorl section at unknown diameter; GZN2015I 28. N. Whorl section at ca. 124 mm diameter; GZN2015I 32. O. Whorl section at ca. 180 mm diameter; GZN2015I 32. P. Ribbing pattern on right side at unknown diameter; GZN2015I 30. Q. Ribbing pattern on right side at unknown diameter; GZN2015I 29. R, S. *Virgatosphinctes* aff. *haughtoni* Spath, 1931. R. Whorl section at ca. 67 mm diameter; GZN2015I 09. S. Ribbing pattern on right side at ca. 45 mm diameter; GZN2015I 09. T-V. *Virgatosphinctes* aff. *pompeckji* (Uhlig, 1910). T. Whorl section at ca. 75 mm diameter; GZN2015I 43. U. Whorl section at unknown diameter; GZN2015I 44. V. Ribbing pattern on right side at ca. 85 mm diameter; GZN2015I 45.

EXPLANATION OF PLATE V

(specimens in natural size except Fig. 1a-d)

1. ***Virgatosphinctes frequens*** (Oppel, 1865); (a, b) lateral views showing the style of ornamentation, (c) apertural view, and (d) ventral view; GZN2015I 37 (scale bar = 6.7 mm). 2. ***Virgatosphinctes frequens*** (Oppel, 1865), fragment; (a) lateral view and (b) ventral view; GZN2015I 36 (scale bar = 10 mm). 3. ***Virgatosphinctes*** cf. ***frequens*** (Oppel, 1865), fragment; (a) lateral view and (b) ventral view; GZN2015I 26 (scale bar = 10 mm).

Plate V



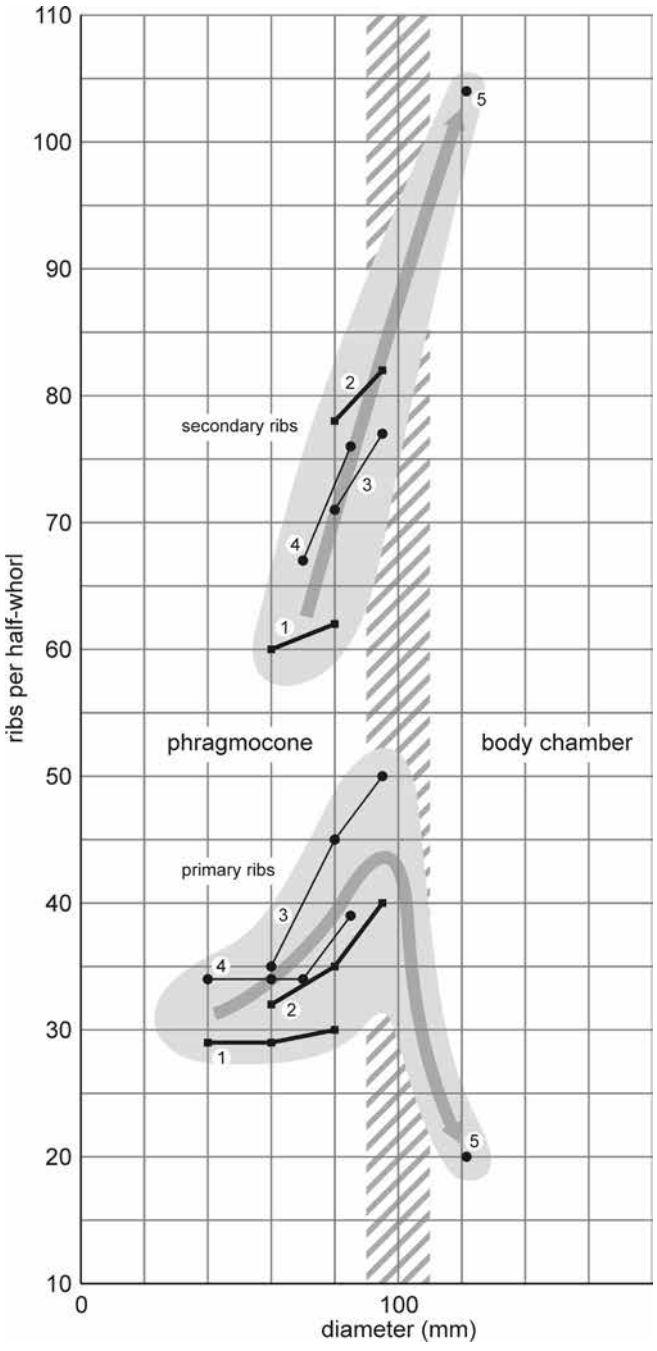


Fig. 7. Rib curves of *Virgatosphinctes denseplicatus* (Waagen, 1875). Illustrated are the numbers of primary and secondary ribs per half-whorl as a function of the diameter (1: GZN2015I 07; 2: GZN2015I 08; 3: constructed from Waagen, 1875, pl. 46, fig. 3a; 4: constructed from Spath, 1931, pl. 90, fig. 1; 5: constructed from Yin and Enay, 2004, fig. 4 (4)).

in all present specimens, the whorl section shows considerable variability (Fig. 6E-G).

Previous records: Spath (1931) described this variety of *V. denseplicatus* from the Tithonian ('Lower Umia Group') north of Mundhan and west of Soorka.

Virgatosphinctes cf. *communis* Spath, 1931
(Pl. III, fig. 3)

cf. *Virgatosphinctes communis* sp. nov. – Spath, 1931, p. 535, pl. 90, fig. 2; pl. 91, fig. 4.

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 02).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 02	96.5	33.0 (34)	26.5 (27)	~38.0 (39)	1.25
Virgatosphinctes communis Spath – Spath, 1931, p. 536	230	80.5 (35)	69 (30)	92 (40)	1.17
Virgatosphinctes communis Spath – Spath, 1931, p. 535	127	44 (35)	39 (31)	50 (39)	1.13

Description: Shell fragment of a phragmocone, evolute with subtrigonal, compressed whorl section; maximum thickness near umbilical shoulder. Ornamentation consisting of thin, closely spaced, prorsiradiate primary ribs with slight concavity near umbilical shoulder. Ribs regularly bifurcating into finer secondaries, at or below mid-lateral height, passing straight across the ventral region. Single ribs rare. Umbilical shoulder rounded and indistinct. Umbilical seam coinciding with branching point of ribs.

Remarks: Spath (1931, pp. 532, 536) differentiated *Virgatosphinctes communis* from *Virgatosphinctes denseplicatus* by its consistently more discoidal and involute whorl shape. According to Spath (1931), this is the most common species of all "Umia *Virgatosphinctes*" (probably referring to the Umia Ammonite Beds). However, there are some transitional forms between both species (Spath, 1931, p. 536). The present specimen has a perfect discoidal shape with a subtrigonal whorl section. Since only a part of the phragmocone is preserved, differences in the body chambers between the two species cannot be observed. *Virgatosphinctes communis* is a very large ammonite being septate until diameters above 260 mm and reaching adult sizes of possibly more than 550 mm as suggested by incomplete specimens described by Spath (1931).

Virgatosphinctes frequens (Oppel, 1865)
(Pl. III, fig. 1; Pl. IV, fig. 1; Pl. V, figs 1, 2; Figs 6H, I, 8)

Ammonites frequens sp. nov. – Oppel, 1865b, p. 295, pl. 87.

Perisphinctes (*Virgatosphinctes*) *frequens* Oppel – Uhlig, 1910, p. 325, pl. 63, figs 1a-c, 2, 3a-c; pl. 75, fig. 1a-c; pl. 75A, fig. 1a-c.

Virgatosphinctes frequens (Oppel) – Collignon, 1960, pl. 154, fig. 620. – Yin and Enay, 2004, p. 672, fig. 4 (2).

Material: Seven fragmentary specimens from the Umia Ammonite Beds, 1.5 km ESE of Katesar Temple (GZN2015I 23, 24, 33, 36, 37, 41, 42).

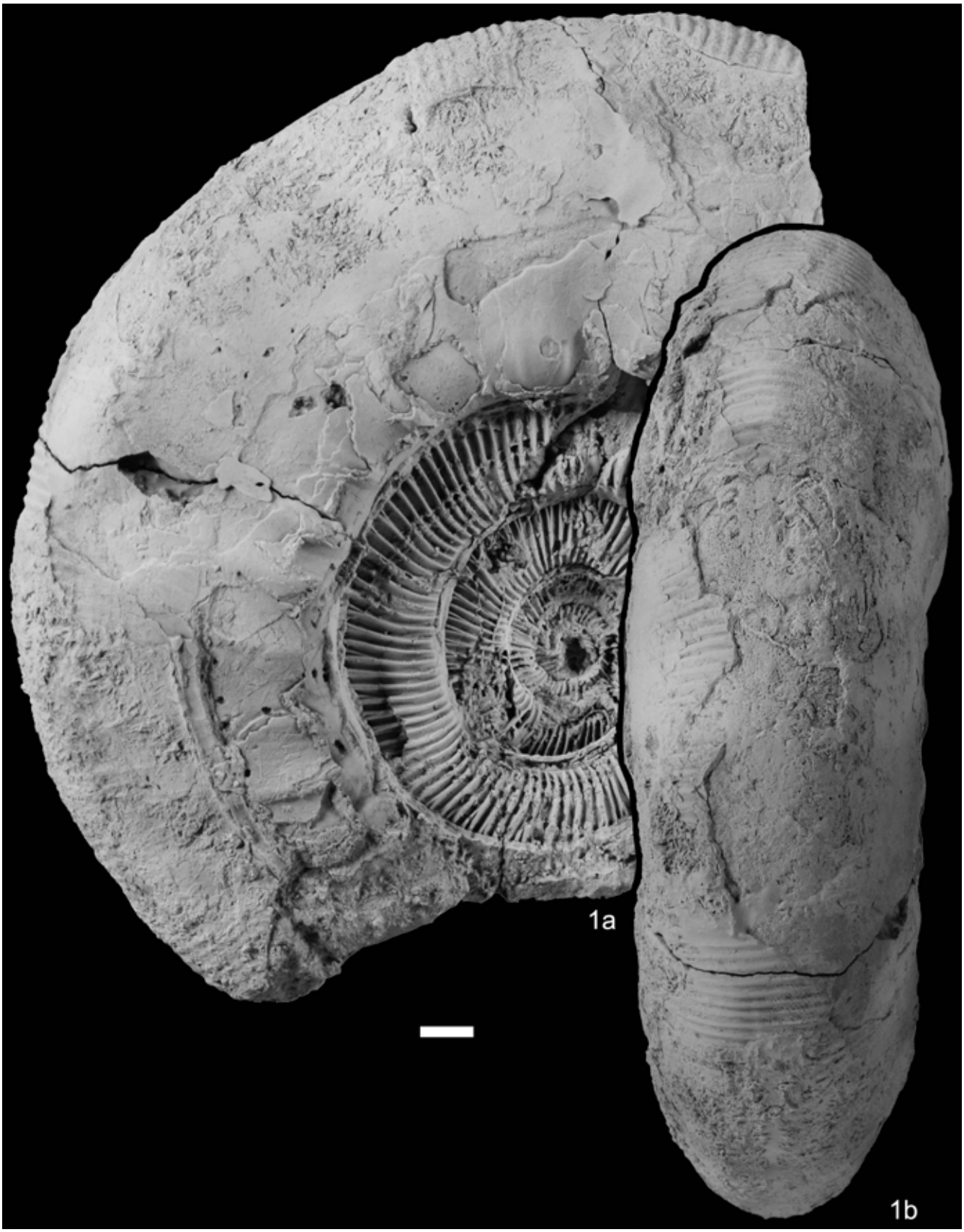
Dimensions (in mm):

EXPLANATION OF PLATE VI

(specimen in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes*** cf. ***frequens*** (Oppel, 1865), fragment; (a) lateral view and (b) ventral view; GZN2015I 25.

Plate VI



specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 23	181.0	69.0 (38)	57.0 (31)	79.0 (44)	1.21
	at 164.0	56.5 (34)	55.6 (34)	72.5 (44)	1.02
	at 153.5	51.0 (33)	52.0 (34)	63.0 (41)	0.98
GZN2015I 36	-	43.5	40.5	-	1.07
GZN2015I 24	57.5	20.0 (35)	21.0 (37)	21.0 (37)	0.95
GZN2015I 37	34.0	12.5 (37)	14.3 (42)	13.5 (40)	0.87
Virgatosphinctes frequens (Oppel) – Uhlig, 1910, p. 325	179	62 (35)	56.3 (31)	69 (39)	1.10
Virgatosphinctes frequens (Oppel) – Uhlig, 1910, p. 325	161	56.5 (35)	59 (37)	64 (40)	0.96
Virgatosphinctes frequens (Oppel) – Uhlig, 1910, p. 325	122	43.3 (35)	44 (36)	49 (40)	0.98
Virgatosphinctes frequens (Oppel) – Uhlig, 1910, p. 325	99	35.5 (36)	34 (34)	37.5 (38)	1.04
Virgatosphinctes frequens (Oppel) – Collignon, 1960, fig. 620	88	29 (33)	27 (31)	38 (43)	1.07
	at 86	30 (35)	27 (31)	35 (41)	1.11
Virgatosphinctes frequens (Oppel) – Uhlig, 1910, p. 325	79.5	31 (39)	29 (36)	26 (33)	1.07

Description: Shell large, evolute, consisting of phragmocone (diameter: 120 mm) and more than half of the last whorl as body chamber. Whorl height almost equal to whorl width, only outer part of the body whorl slightly more compressed. Whorl section of inner whorl rounded and of outer whorl suboval (Fig. 6H); maximum thickness at around one-fourth of whorl height. Ornamentation consisting of prorsiradiate primary ribs, thin, sharp, and closely spaced on inner whorls, becoming thicker and more distant towards the end of phragmocone, gradually turning blunt, rounded, and still more distant on body chamber. Primary ribs originating rectiradiate slightly above umbilical seam, bending forward at umbilical shoulder. On inner whorls primary ribs bifurcate regularly at mid-lateral height. On the middle whorls some trifurcating (polygyrate) ribs appear and eventually dominate. Subsequently, the branching points become indistinct and intercalatory secondaries occur (Fig. 6I). Secondary ribs are bending slightly backwards, showing more or less rectiradiate orientation, and passing straight across the ventral region. Secondary ribs increase in number towards the outer part of body chamber, while primaries become less (Fig. 8). Umbilical shoulder indistinct, rounded, merging smoothly with umbilical wall. Constrictions present.

Remarks: The proportional dimensions and ornamentation of the present specimens match the description and illustration of *Virgatosphinctes frequens* (Oppel, 1865) by Uhlig (1910). Especially diagnostic is the whorl shape, style of ribbing, and change in ornamentation during the ontogeny. The distance between primary ribs increases suddenly from around 7 mm at the end of the phragmocone to 11 mm at the beginning of the body chamber (compare the decrease in the number of primary ribs on the body whorl in Fig. 8). This change, together with the large adult size suggests that the specimen is a macroconch.

There are several comparable species described and illustrated by Uhlig (1910). They differ with respect to the combination of proportional dimensions, whorl shape, and ornamentation. *V. frequens* can be distinguished from all other species of the genus in having a compressed outer whorl combined with secondary ribs bent backwards (Fig. 6I). Uhlig (1910, p. 327), while describing the ammonites of the Spiti Shales in the Indian Himalayas, considered the five Kachchh specimens designated as *Perisphinctes frequens* (Oppel) by Waagen (1875, p. 200, pl. 44, figs 2, 3) as a different species on the basis of fewer ribs and a thicker whorl section near the umbilical wall. While the different ribbing is quite obvious, the difference in the whorl section is, in fact, minimal. Uhlig (1910, p. 327) included these Kachchh specimens in his new species *V. subfrequens* (described below). Later on, Spath (1931, p. 536) re-designated them again as a new species, *V. oppeli*. It is interesting to note that both Waagen (1875, p. 200) and Spath (1931, p. 537) observed that constrictions, which are one of the important characters of *V. frequens*, are missing in the specimens from Kachchh. *V. oppeli* differs from the Himalayan species in the ribbing of the inner whorls, since there is "no triplication in *V. oppeli* until a diameter of 60-70 mm is reached" (Spath, 1931, p. 537), whereas this is noticeable already in the inner whorls of *V. frequens* from the Spiti Shales, which also exhibit constrictions. In the illustrations of material from Madagascar by Collignon (1960) there are no constrictions visible, nor did the author mention this feature in the accompanying short descriptions.

Uhlig (1910, p. 326) mentioned that *V. frequens* is a highly variable species. However, this statement has to be considered carefully because of the characteristic change in whorl shape and ornamentation during ontogeny. A comparison of fragmentary specimens of different sizes might therefore lead to an exaggerated impression of the morphological variability of the species.

The backwards bending of the secondary ribs is also seen in *Virgatosphinctes bleicheri* (de Loriol, 1873) as illustrated by Waagen (1875, p. 194, pl. 55, fig. 4) with a specimen from the Umia Formation of the "Goorpoor" area. However, in this case, the ribs are thicker and sparser than in *V. frequens*.

Previous Records: Uhlig (1910) described *V. frequens* from the Spiti Shales of the Indian Himalayas.

Virgatosphinctes cf. *frequens* (Oppel, 1865)
(Pl. V, fig. 3; Pl. VI, fig. 1; Fig. 6J-L)

cf. *Ammonites frequens* sp. nov. – Oppel, 1865b, p. 295, pl. 87.

cf. *Perisphinctes* (*Virgatosphinctes*) *frequens* Oppel – Uhlig, 1910, p. 325, pl. 63, figs 1a-c, 2, 3a-c; pl. 75, fig. 1a-c; pl. 75A, fig. 1a-c.

EXPLANATION OF PLATE VII

(specimens in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes subfrequens*** Uhlig, 1910; (a, b) lateral views of fragment and (c) apertural view showing the sub-rounded whorl section with strongly convex flanks; GZN2015I 28 2. ***Virgatosphinctes subfrequens*** Uhlig, 1910; (a, b) lateral views of fragment and (c) ventral view; GZN2015I 27.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate VII

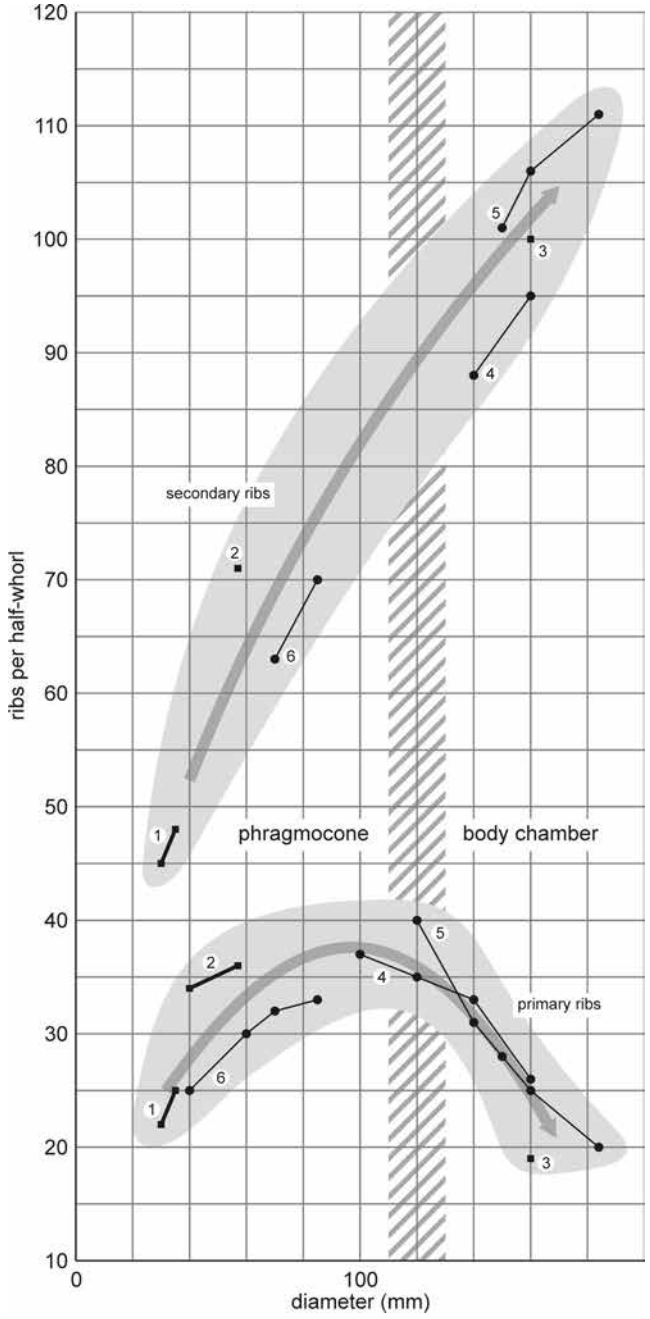


Fig. 8. Rib curves of *Virgatosphinctes frequens* (Oppel, 1865). Illustrated are the numbers of primary and secondary ribs per half-whorl as a function of the diameter (1: GZN2015I 37; 2: GZN2015I 24; 3: GZN2015I 23; 4: constructed from Uhlig, 1910, pl. 75, fig. 1a; 5: constructed from Uhlig, 1910, pl. 75A, fig. 1a; 6: constructed from Collignon, 1960, pl. 154, fig. 620).

Material: Three fragmentary specimens from the Umia Ammonite Beds; two from 1.5 km ESE of Katesar Temple (GZN2015I 25, 26), and one from 3 km NW of Mundhan Village (GZN2015I 55).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 55	-	68.0	59.0	-	1.15
GZN2015I 25	~185	66.0 (36)	56.0 (30)	82.0 (44)	1.18

Description: Shell large, only phragmocone preserved, evolute, inner whorls depressed, outer whorl compressed. Whorl section slightly variable, inner whorls rounded, outer whorls suboval with a maximum thickness between one-fourth and one-half of whorl height (Fig. 6J-L). Ornamentation consisting of thin, sharp, moderately spaced, prorsiradiate primary ribs on inner whorls, becoming blunt, rounded, and widely spaced on the outer part of the phragmocone. Primary ribs crossing the umbilical shoulder with a slight forward-directed bend. On inner whorls, primaries bifurcate below mid-lateral height with at most two single ribs intercalated. Point of bifurcation below umbilical seam of next whorl. On outer whorls, the primary ribs branch into at least four fine secondary ribs. Secondary ribs bent slightly backward, passing straight across the venter. Suture well preserved.

Remarks: The present specimens are poorly preserved. Whether all secondary ribs on the outer part of the phragmocone originate from the thick, blunt primary ribs or are in fact intercalatory ribs cannot be ascertained. The proportional dimensions and ornamentation including the backwards bending of the secondary ribs in the present specimens match *V. frequens* as described above. However, the phragmocone of specimen GZN2015I 25 is much larger in diameter (at least 185 mm instead of around 120 mm). In specimen GZN2015I 26 the secondary ribs appear to form bundles. In this respect it is similar to *Umiaites rajnathi* Spath, 1931 illustrated by Shome and Bardhan (2009a, p. 12, pl. 6, figs d, f), but in *U. rajnathi* this ornamentation begins quite early in ontogeny, while the present specimen has thin, sharp, bifurcating primary ribs on the inner whorls. Furthermore, *U. rajnathi* is much more compressed (compare Spath, 1931, p. 548).

Virgatosphinctes subfrequens (Uhlig, 1910)
(Pl. VII, figs 1, 2; Pl. VIII, figs 1, 3; Fig. 6M-Q)

Perisphinctes (*Virgatosphinctes*) *subfrequens* sp. nov. – Uhlig, 1910, p. 327, pl. 49, fig. 1a-d; pl. 61, fig. 1a-d.

Material: Ten fragmentary specimens from the Umia Ammonite Beds; nine from 1.5 km ESE of Katesar Temple (GZN2015I 27, 28, 30, 31, 32, 34, 38-40), and one from 3 km NE of Lakhapar (GZN2015I 29).

EXPLANATION OF PLATE VIII

(specimens in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes subfrequens*** Uhlig, 1910; (a) lateral view of fragment, (b) ventral view, and (c) lateral view; GZN2015I 30. 2. ***Virgatosphinctes*** aff. ***haughtoni*** Spath, 1931; (a) lateral view, (b) ventral view; GZN2015I 09. 3. ***Virgatosphinctes subfrequens*** Uhlig, 1910; (a) ventral view and (b) lateral view; GZN2015I 32.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate VIII

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 32	170.0	58.0 (34)	50.0 (29)	75.0 (44)	1.16
GZN2015I 28	-	39.5	38.0	-	1.04
	-	32.0	31.5	-	1.02
GZN2015I 27	-	39.0	36.0	-	1.08
	79.0	26.5 (34)	21.0 (27)	33.0 (42)	1.26
Virgatosphinctes subfrequens (Uhlig) – Uhlig, 1910, p. 327	116	40.8 (35)	37 (32)	43 (37)	1.10
Virgatosphinctes subfrequens (Uhlig) – Uhlig, 1910, p. 327	95.5	32 (34)	29.7 (31)	41 (43)	1.08

Description: Shell large, only phragmocones preserved, evolute; whorl section subrounded to suboval, compressed with slightly arched flanks (Fig. 6M-O); maximum thickness slightly below mid-lateral height. Ornamentation consisting of prorsiradiate primary ribs, thin, sharp, and closely spaced on inner whorls (Fig. 6P, Q), becoming thicker and distant before reaching the end of the phragmocone. Primary ribs originating rursiradiately on umbilical wall, turn prorsiradiately above umbilical shoulder to form a slight forward-directed concavity. Primaries bifurcate around mid-lateral height on inner whorls and turn polygyrate on outer whorls branching into three fine secondary ribs. The first branching point is below mid-lateral height and the second one is posterior to the first at mid-lateral height. Secondary ribs maintain a prorosiradiate orientation and cross the venter with a slight forward-directed sinuosity. Umbilical shoulder indistinct, merging smoothly with umbilical wall. Constrictions present. Suture well preserved.

Remarks: The compressed whorl shape, the prorsiradiate secondary ribs, and the slight ventral sinuosity differentiate these specimens from *Virgatosphinctes frequens* as described above. Uhlig (1910) differentiated the species from *V. frequens* additionally on the basis of its fewer secondary ribs, a feature which is not so pronounced in the present specimens. Specimens described as *Perisphinctes frequens* by Waagen (1875, p. 200, pl. 44, figs 2, 3) were assigned by Uhlig (1910) to this species, but later re-designated as *Virgatosphinctes oppeli* by Spath (1931, p. 536).

The specimens GZN2015I 30, 38-40 are small fragments of inner whorls showing also single intercalatory ribs, but in general the ornamentation is similar to that of the inner whorls of the larger specimens. They have been included in this species particularly because of the slight forward-directed sinuosity of the secondary ribs on the venter.

Previous records: Uhlig (1910) described *V. subfrequens* from the Spiti Shales of the Indian Himalayas.

Virgatosphinctes aff. *haughtoni* Spath, 1931
(Pl. VIII, fig. 2; Fig. 6R, S)

aff. *Virgatosphinctes haughtoni* sp. nov. – Spath, 1931, p. 534, pl. 77, fig. 6a, b (holotype).

Material: Two fragmentary specimens from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 09, 12).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 09	66.5	21.0 (32)	24.0 (36)	26.5 (40)	0.86
GZN2015I 09	at 63.0	18.0 (29)	23.5 (37)	26.0 (41)	0.77
Virgatosphinctes haughtoni Spath – Spath, 1931, p. 534	78	26 (33)	29 (37)	34 (44)	0.89

Description: Shells small, only phragmocones, evolute, depressed. Whorl section suboval to subquadrangular in outline with maximum thickness at one-fourth of whorl height (Fig. 6R). Ornamentation consising of very thin and closely spaced prorsiradiate primary ribs. Most primaries bifurcate regularly at the centre of the flank into secondary ribs of similar thickness. Secondary ribs cross the venter with slight forward-directed sinuosity. Single ribs common (Fig. 6S). In total, there are 47 primary and 72 secondary ribs per half whorl at a diameter of 65 mm. Umbilical shoulder indistinct, wall not discernible. Umbilical seam coinciding with branching point of ribs. Suture well preserved.

Remarks: Only the inner part of the phragmocone was available for study. Spath (1931, p. 534) compared the Madagascan species *Virgatosphinctes haughtoni* with two varieties of *V. denseplicatus* (Waagen), i.e var. *striatissima* and var. *rotunda* (see descriptions above). While var. *striatissima* has a similar dense ornamentation, it differs by its compressed whorl section. In contrast, var. *rotunda* has a comparable depressed whorl, but shows markedly coarser ribs than the present specimens. The Madagascan species has been assigned an Early Tithonian age, whereas the present specimens have been recorded associated with Late Tithonian ammonites. Owing to the incomplete nature of the specimens they have been assigned to the species only tentatively.

Virgatosphinctes cf. *oppeli* Spath, 1931
(Pl. IX, fig. 1)

cf. *Perisphinctes frequens* Oppel – Waagen, 1875, p. 200, pl. 44, figs 2, 2a, 3, 3a.

cf. 1931 *Virgatosphinctes oppeli* sp. nov. – Spath, p. 536.

Material: One fragmentary specimen from the Umia Ammonite Beds, 1.5 km ESE of Katesar Temple (GZN2015I 52).

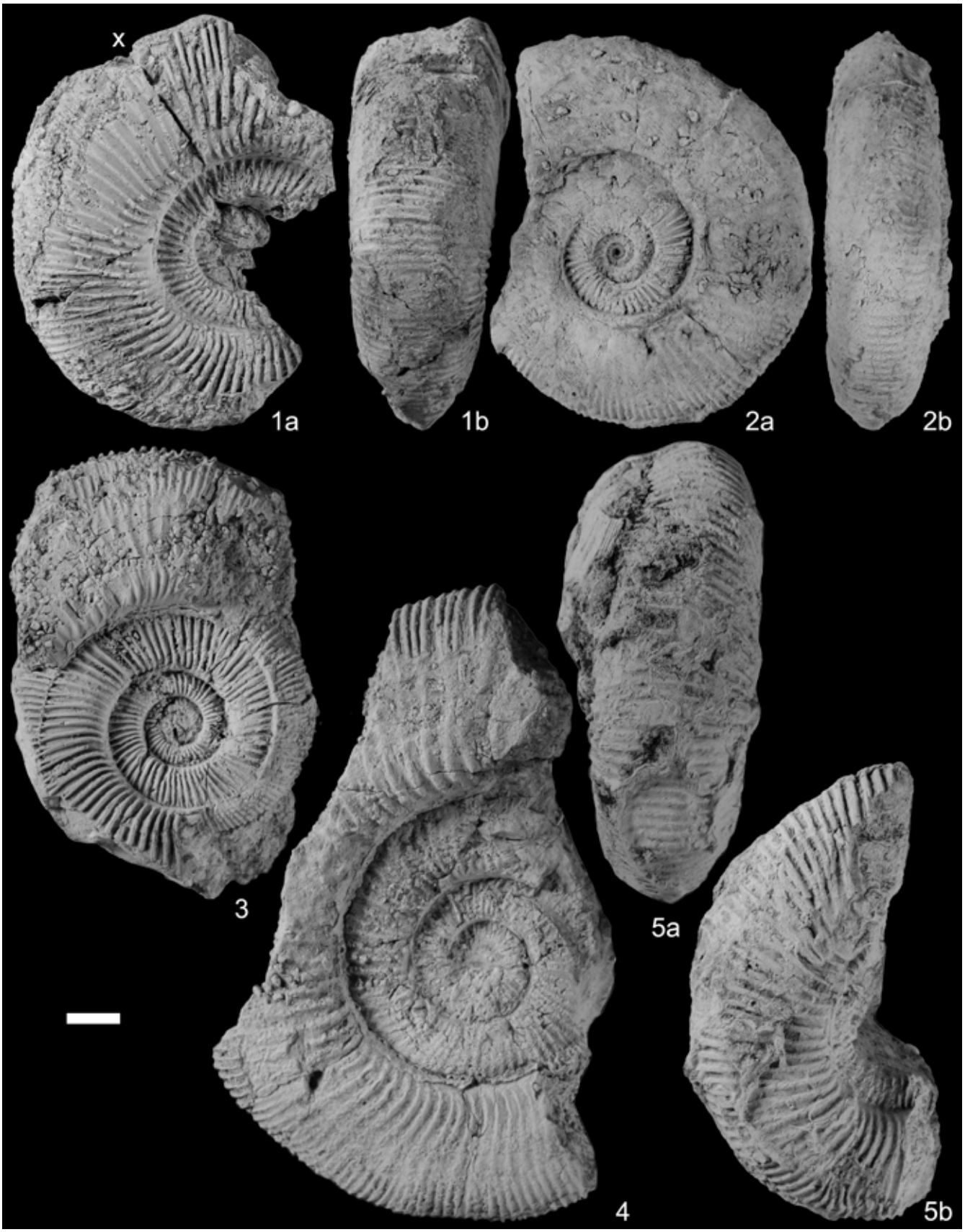
EXPLANATION OF PLATE IX

(specimens in natural size; scale bar = 10 mm)

1. ***Virgatosphinctes*** cf. ***oppeli*** Spath, 1931; (a) lateral view and (b) ventral view; GZN2015I 52. 2. ***Virgatosphinctes*** aff. ***pompeckji*** (Uhlig, 1910); (a) lateral view and (b) ventral view; GZN2015I 43. 3. ***Virgatosphinctes*** aff. ***pompeckji*** (Uhlig, 1910); lateral view showing trichotomous ribs on the body chamber; GZN2015I 46. 4. ***Virgatosphinctes*** aff. ***pompeckji*** (Uhlig, 1910); lateral view; GZN2015I 45. 5. ***Virgatosphinctes*** sp. indet.; (a) ventral view of fragment and (b) lateral view; GZN2015I 35.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate IX



Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 52	73.2	29.0 (40)	28.0 (38)	-	1.04
	-	15.0	19.0	-	0.79
Virgatosphinctes oppeli Spath – Waagen, 1875, p. 201	100	34 (34)	34 (34)	41 (41)	1.00
Virgatosphinctes oppeli Spath – Waagen, 1875, p. 201	50	18 (36)	22 (44)	21 (42)	0.82

Description: Shell small, incomplete, consisting of phragmocone and a small part of the body chamber, evolute. Inner whorls depressed with subrounded whorl section, outer whorl compressed and subtrigonal. Maximum thickness just above umbilical shoulder. Ornamentation consisting of fine, moderately dense, regularly bifurcating primary ribs, branching at mid-lateral height. Secondary ribs thinner, following the same orientation and crossing the venter with slight forward-directed sinuosity. Primary ribs rursiradiate, originating just below the umbilical edge, turning prorsiradiate thereby producing a concavity at the umbilical edge, then turning a little backwards at one-fourth of lateral height, giving a slight sinuosity to primary ribs. Umbilical edge moderately distinct, lower part of wall smooth. Suture lines preserved.

Remarks: The present specimen is poorly preserved. Its proportionate dimensions, whorl-section, and ornamentation are similar to the specimens illustrated by Waagen (1875). Spath (1931, p. 536) considered these specimens described by Waagen (1875) as *Perisphinctes frequens* different from the Himalayan *V. frequens* in lacking trifurcating primary ribs until a diameter of 60 to 70 mm, while such ribs are already present in *frequens* at a much earlier stage. In addition, they lack constrictions. Due to the poor preservation of the present specimen the presence or absence of constrictions could not be determined. The larger specimen described by Waagen (1875) is still septate at a diameter of 100 mm, while the present specimen already shows part of the body chamber at a diameter of 73 mm. Due to its poor preservation and the mentioned differences, it has been assigned to the species only tentatively.

Virgatosphinctes aff. *pompeckji* (Uhlig, 1910)
(Pl. IX, figs 2-4; Fig. 6T-V)

aff. *Perisphinctes* (*Virgatosphinctes*) *pompeckji* sp. nov. – Uhlig, 1910, p. 320, pl. 65, fig. 1a-c.

Material: Four specimens from the Umia Ammonite Beds, 3 km NW of Mundhan Village (GZN2015I 43-46).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 45	116.5	37.5 (32)	33.5 (29)	54 (46)	1.12
GZN2015I 43	76.8	23.0 (30)	21.0 (27)	33.0 (43)	1.10
GZN2015I 44	62.5	21.0 (34)	17.5 (28)	28.0 (45)	1.20
Virgatosphinctes pompeckji (Uhlig) – Uhlig, 1910, p. 320	123	42 (34)	36.5 (30)	50 (41)	1.15
Virgatosphinctes intermedius (Uhlig) – Uhlig, 1910, p. 319	115	35.5 (31)	32.5 (28)	52 (45)	1.09

Description: Small, incomplete phragmocone and body chamber, evolute. Whorl section oval to subtrigonal, compressed with slightly arched lateral flanks and maximum thickness slightly above umbilical shoulder (Fig. 6T, U). Ornamentation of phragmocone consisting of thin, moderately spaced, prorsiradiate primary ribs originating slightly below umbilical shoulder and regularly bifurcating into finer secondary ribs at or slightly above mid-lateral height (Fig. 6V). Secondary ribs bent backwards to follow rectiradiate orientation and crossing the venter with slight forward-directed sinuosity. On the body chamber polygyrate branching into three secondary ribs common. Single ribs and intercalatory secondary ribs rare. Umbilical shoulder moderately distinct, wall smooth, steeply sloping. Constrictions distinct.

Remarks: Specimen GZN2015I 45 seems to exhibit parts of the peristome with part of the rostrum. Three of the specimens (GZN2015I 44-46) show trichotomous ribs on the body chamber. The dimensional proportions and ornamentation (thickness, density, and pattern of ribs) resemble *Virgatosphinctes pompeckji* (Uhlig, 1910), but the shape of the whorl in the illustration of Uhlig (1910) appears slightly more compressed due to a greater whorl height and rather flattened flanks of the whorls. In the present specimens the flanks are slightly arched (Fig. 6T, U). In this respect they are closer to *Virgatosphinctes intermedius* as described by Uhlig (1910, p. 319, pl. 66, fig. 1a-d), but in this species the ribbing of the inner whorls is sparse. The presence of trifurcating ribs is unknown for *V. pompeckji*, because the outermost part of the body chamber is missing in the specimen of Uhlig (1910). In the present specimens, trichotomous ribs appear only very close to the peristome. *Virgatosphinctes denseplicatus* described above differs from this species by having a denser ribbing, a smaller umbilicus, and a greater whorl height-diameter ratio.

Virgatosphinctes sp. indet.
(Pl. IX, fig. 5)

Material: One fragmentary specimen from the Umia Ammonite Beds, 1.5 km ESE of Katesar Temple (GZN2015I 35).

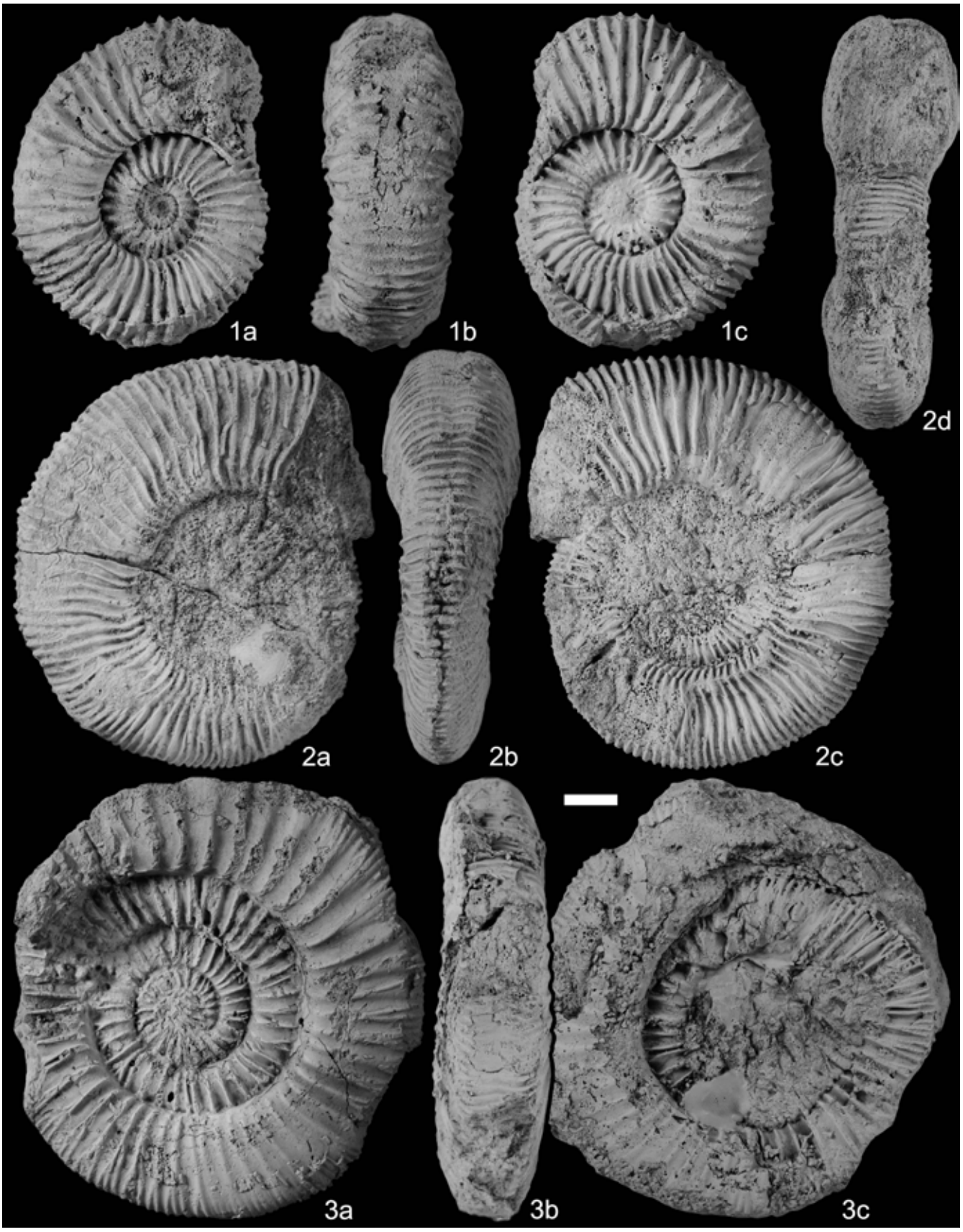
EXPLANATION OF PLATE X

(specimens in natural size except fig. 1a-c)

1. ***Micracanthoceras microcanthum*** (Oppel, 1865); (a, c) lateral view and (b) ventral view showing the ventral groove; GZN2015I 03 (scale bar = 6.7 mm).
2. ***Paraulacosphinctes*** aff. ***transitorius*** (Oppel, 1865); (a, c) lateral view showing the thin, sharp, sinuous, and prorsiradiate primary ribs, (b) ventral view, and (d) apertural view showing the subrectangular whorl section; GZN2015I 11 (scale bar = 10 mm).
3. ***Parapallasiceras spitiensis*** (Uhlig, 1910); (a, c) lateral view showing the branching of primary ribs into two and/or three at or above the mid-lateral height of specimen and (b) ventral view; GZN2015I 14 (scale bar = 10 mm).

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate X



Description: Shell fragmentary, representing part of phragmocone, evolute, depressed. Whorl section suboval with slightly arched flanks and strongly arched ventral region. Ornamentation consisting of thin, sharp, moderately spaced, prorsiradiate primary ribs originating slightly rursiradiately from umbilical wall and turning prorsiradiately above umbilical shoulder, thus forming a slight forward-directed concavity. Near mid-lateral height primaries branch irregularly into two; single ribs developed occasionally. Secondary ribs maintaining prorsiradiate orientation and crossing the venter with slight forward-directed sinuosity. Umbilical shoulder moderately distinct, merging smoothly with umbilical wall.

Remarks: Although the present specimen is only a fragment of a single whorl, the ornamentation is adequate enough to assign it to *Virgatosphinctes*. The variability in the branching point of the ribs and the occasional occurrence of single ribs resemble *V. denseplicatus* var. *inequalis*, but the illustration of this variety by Waagen (1875, pl. 46, fig. 3) shows a considerably denser ornamentation. *V. occultefurcatus* (Waagen, 1875) is also close in ornamentation but compressed (Waagen, 1875, p. 195, pl. 50, fig. 4a, b).

Genus ***Parapallasiceras*** Spath, 1925

(Type species: *Berriasella praecox* Schneid, 1915)

Remarks: Arkell *et al*. (1957) described the genus as small, constricted, with lappets, ventral groove, and simple, biplicate ribbing. Subsequently, Tavera (1985) also included forms in the genus which have polygyrate or more complex ribs on the outer whorl (see also Oloriz and Tintori, 1991, p. 474).

Parapallasiceras spitiensis (Uhlig, 1910)

(Pl. X, fig. 3; Fig. 9A)

Perisphinctes (*Aulacosphinctes*) *spitiensis* sp. nov. – Uhlig, 1910, p. 351, pl. 41, fig. 1a-c.

Parapallasiceras spitiensis (Uhlig) – Oloriz and Tintori, 1991, p.475, pl. 24, figs 1a, b, 2.

Material: One specimen from the Umia Ammonite Beds, 1.5 km ESE of Katesar Temple (GZN2015I 14).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 14	81.5	24.5 (30)	20.0 (25)	42.5 (52)	1.23
Parapallasiceras spitiensis (Uhlig) – Uhlig, 1910, pl. 41, fig. 1a-c	74	21 (28)	22 (30)	37 (50)	0.95

Description: Shell incomplete, evolute, outer three-fourth of the whorl representing the body chamber. Whorl section subrectangular, compressed with slightly arched flanks and sulcate ventral region. Ornamentation consisting of thin (inner whorls) to gradually thicker (outer whorls), sparse, prorsiradiate primary ribs, which occasionally bifurcate, but mostly branch into three secondaries, rarely arranged in bundles, mostly polygyrate at or above mid-lateral height (Fig. 9A). Secondary ribs thinner, closely spaced, terminating just before reaching the mid-ventral region leaving a smooth mid-ventral surface. At a diameter of 85 mm, there are 23 primary and 69 secondary ribs per half-whorl. Constrictions present. Space between primary ribs increasing after each constriction. Umbilical shoulder rounded, umbilical wall low. Suture lines well preserved.

Remarks: No tubercle is seen either at the point of branching or at the termination of ribs along the ventral region. The shell is broken at several sides but the diagnostic characters mentioned in the description are sufficient to assign this specimen to *Parapallasiceras spitiensis* (Uhlig, 1910). Uhlig (1910) figured three specimens to illustrate this species. The third figure (Uhlig, 1910, pl. 41, fig. 1a-c) is a rather incomplete specimen showing only the phragmocone. The ornamentation at the end of the phragmocone matches very well that of the present specimen. The trichotomous ribs at the end of the phragmocone continue on the body chamber as can be seen in the present specimen. With advancing growth, a fourth secondary rib (either developed as an intercalatory or branching out from the primary rib) appears. The first two specimens of Uhlig (1910, pl. 33, figs 1a-c, 3a-c), although smaller in size, already show parts of the body chamber. However, they exhibit mostly biplicate and only occasionally triplicate ribs and less dense ornamentation. Therefore, and until some intergradational specimens are available, the present authors exclude these two specimens from this species. In fact, both specimens match better *Aulacosphinctes moerikeanus* as described by Oppel (1863, p. 281, pl. 80, fig. 2 a, b) and Uhlig (1910, p. 350, pl. 33, fig. 2a-c). Uhlig (1910) placed the species originally into *Aulacosphinctes*, but Tavera (1985) assigned it to *Parapallasiceras*, a view which is followed here. Arkell *et al*. (1957) mentioned the presence of lappets in *Parapallasiceras*, indicating that the associated species represent microconchs. The current species shows a change in ornamentation on the body chamber reminiscent of macroconchs. This character, which can also be seen in the illustration by Uhlig (1910), has not been discussed by previous authors (Tavera, 1985; Oloriz and Tintori, 1991), who described only inner whorls.

Previous records: The specimen of Uhlig (1910, pl. 41, fig. 1a-c) has been collected from the Spiti Shales of the Indian Himalayas (Jandu, Sherik River).

Family **Ataxioceratidae** Buckman,1921

Subfamily **Paraulacosphinctinae** Tavera, 1985

Genus ***Paraulacosphinctes*** Schindewolf, 1925

(Type species: *Ammonites senex* Oppel, 1868)

Remarks: Schindewolf (1925, p. 329) characterized the genus *Paraulacosphinctes* as having prorsiradiate, sharp, comparatively dense ribs which turn forwards near the venter. Furthermore, the ribs show a marked bend at the umbilical shoulder. The shells of *Paraulacosphinctes* are comparatively involute to moderately evolute with a compressed whorl section. Characteristic is a groove on the ventral side which can be

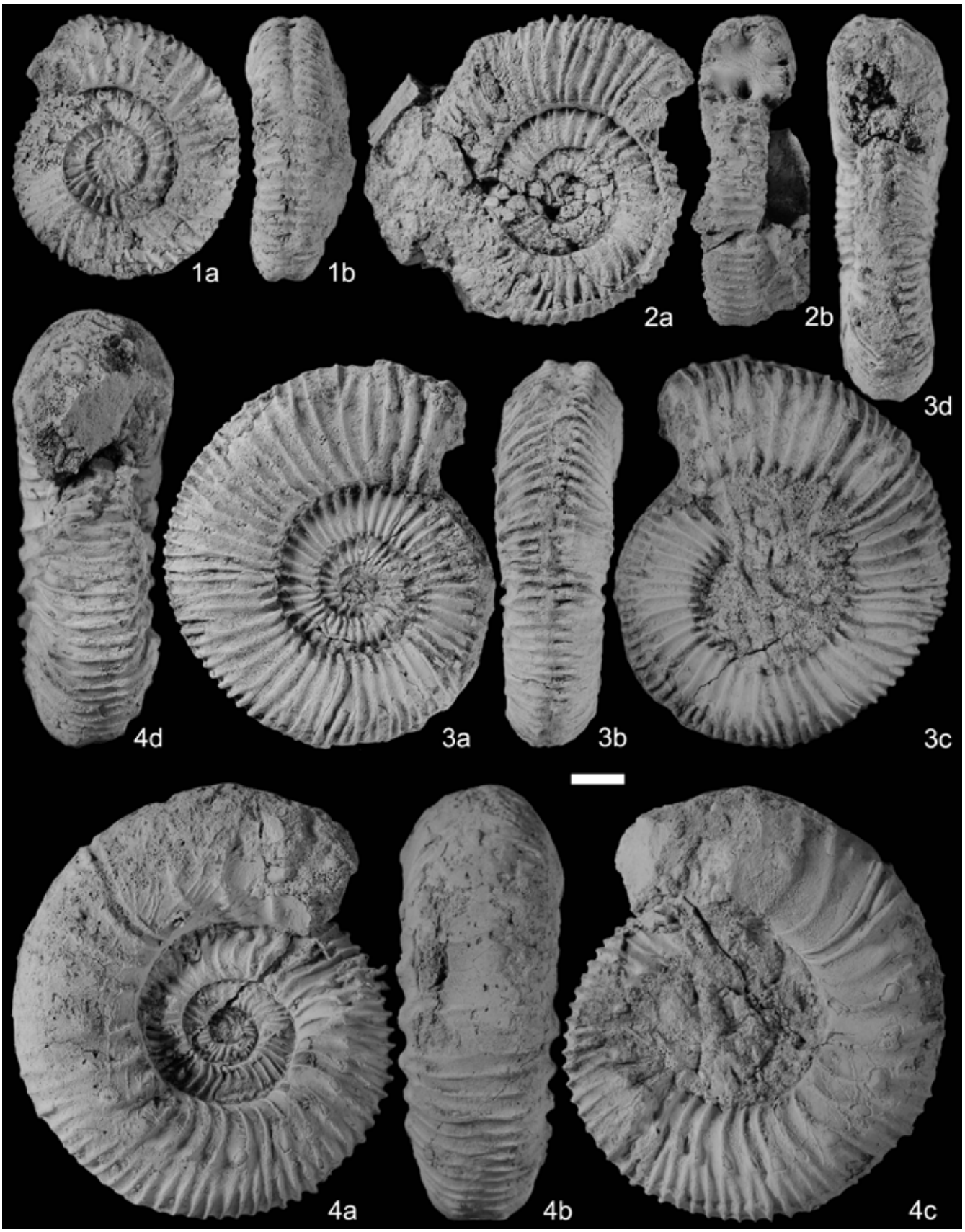
EXPLANATION OF PLATE XI

(specimens in natural size; scale bar = 10 mm)

1. ***Micracanthoceras microcanthum*** (Oppel, 1865); (a) lateral view and (b) ventral view showing the ventral groove; GZN2015I 13. 2. ***Micracanthoceras microcanthum*** (Oppel, 1865); (a) lateral view and (b) apertural view showing ventro-lateral tubercles; GZN2015I 50. 3. ***Micracanthoceras*** aff. ***fraudator*** (Zittel, 1868); (a, c) lateral views showing the slight sinuosity or forward-directed concavity of primary ribs, (b) ventral view, and (d) apertural view showing the subrectangular whorl section with nearly flat flanks; GZN2015I 05. 4. ***Himalayites*** sp.; (a, c) lateral views, (b) ventral view, and (d) apertural view; GZN2015I 06.

Journal of the Palaeontological Society of India
Volume 61 (2), December, 2016

Plate XI



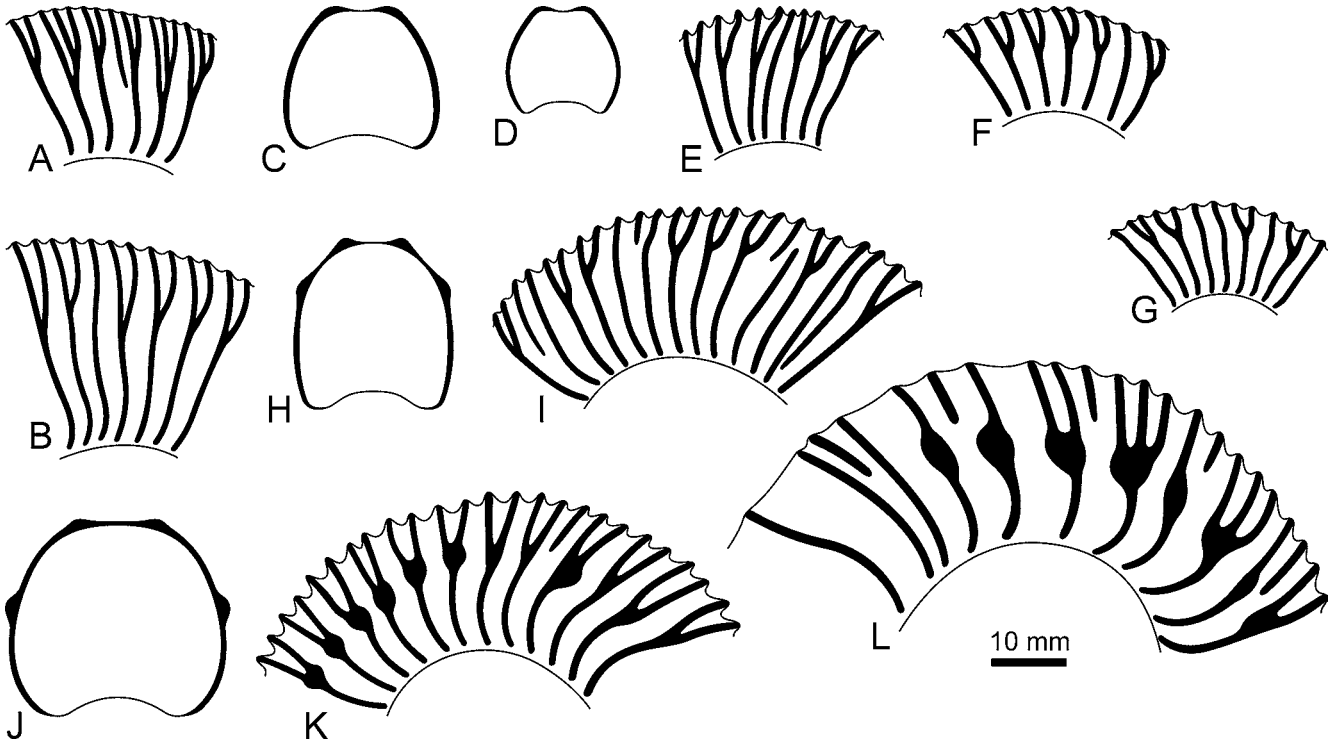


Fig. 9. A. *Parapallasiceras spitiensis* (Uhlig, 1910). Ribbing pattern on left side at ca. 65 mm diameter; GZN2015I 14. B. *Paraulacosphinctes* aff. *transitorius* (Oppel, 1865). Ribbing pattern on left side at ca. 78 mm diameter; GZN2015I 11. C-G. *Micracanthoceras microcanthum* (Oppel, 1865). C. Whorl section at ca. 60 mm diameter; GZN2015I 50. D. Whorl section at ca. 50 mm diameter; GZN2015I 13. E. Ribbing pattern on right side at ca. 60 mm diameter; GZN2015I 50. F. Ribbing pattern on left side at ca. 47 mm diameter; GZN2015I 13. G. Ribbing pattern on left side at ca. 37 mm diameter; GZN2015I 04. H, I. *Micracanthoceras* aff. *fraudator* (Zittel, 1868). H. Whorl section at ca. 70 mm diameter; GZN2015I 05. I. Ribbing pattern on right side at ca. 60 mm diameter; GZN2015I 05. J-L. *Himalayites* sp. J. Whorl section at ca. 80 mm diameter; GZN2015I 06. K. Ribbing pattern on right side at ca. 60 mm diameter; GZN2015I 06. L. Ribbing pattern on left side at ca. 80 mm diameter; GZN2015I 06.

smooth, particularly in the outer whorls (compare Tavera, 1985). Soon after its first description, the genus was considered to be a synonym of *Sublithacoceras* Spath, 1925 (e.g., Spath, 1931, p. 446; Arkell *et al*., 1957), but again it was used since the 1970s (compare Tavera, 1985). *Sublithacoceras* is characterized by still denser and finer primary ribs and longer secondaries. In the Kachchh Basin, members of the genus might be confused with *Aulacosphinctes*, which also has a prominent groove on the venter. Nevertheless, *Aulacosphinctes* has more evolute shells and comparatively rectiradiate, stronger, more distantly spaced, and rather straight ribs (e.g., Schindewolf, 1925).

Paraulacosphinctes aff. *transitorius* (Oppel, 1865)
(Pl. X, fig. 2; Figs 9B, 10)

aff. *Ammonites transitorius* sp. nov. – Oppel, 1865, p. 554.

aff. *Ammonites transitorius* Oppel – Oppel in Zittel, 1868, p. 103, pl. 22, figs 1-4, 6 (non fig. 5).

aff. *Paraulacosphinctes transitorius* (Oppel) – Tavera, 1985, p. 84, pl. 11, figs 1-5; fig. 7A-D.

aff. *Paraulacosphinctes* cf. *transitorius* (Oppel) – Arkadiev, 2011, p. 240, figs 1-4.

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 11).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 11	80.0	28.0 (35)	26.5 (33)	~35 (44)	1.06

Description: Shell incomplete, only part of phragmocone, evolute. Whorl section subrectangular, compressed with either ventral groove (inner part of last whorl) or tabulate ventral region (outer part of last whorl). Ornamentation consisting of thin, sharp, sinuous, prorsiradiate primary ribs, bifurcating above mid-lateral height (Figs 9B, 10). Secondary ribs slightly thinner, occasionally bending forwards near the ventral shoulder or running slightly rectiradially. Secondaries either terminating with a slight heightening before the ventral groove (particularly on inner part of last whorl) or becoming thick along the ventro-lateral edge and thin while crossing through the ventral groove. Intercalatory ribs occur, starting slightly above the umbilical shoulder. Suture lines well preserved.

Remarks: The specimen is the crushed inner part of the last whorl of the phragmocone. It matches the descriptions and illustrations of *Paraulacosphinctes transitorius* (Oppel, 1865). Nevertheless, the present specimen has a slightly lower rib density (Fig. 10) and the species has not been recorded in Kachchh before. Due to these reasons and until more material has been collected, it has been placed only into the affinity of the species.

The closest comparable form known from the Kachchh Basin is *Aulacosphinctes occultefurcatus* as described by Waagen (1875) and Spath (1931) from the same stratigraphic interval and locality. However, the specimens described by Spath (1931) are very small (max. diameter about 55 mm) and they all appear to be the innermost parts of phragmocones. Furthermore, they have more distant and comparatively straight ribs.

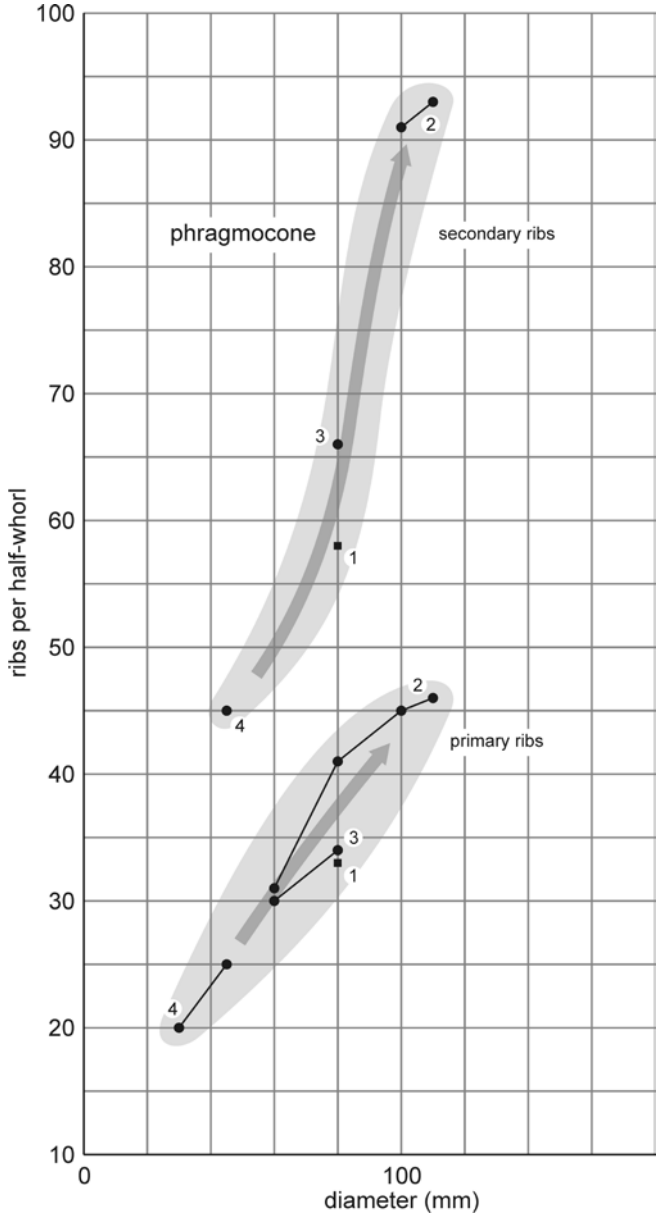


Fig. 10. Rib curves of *Paraulacosphinctes* aff. *transitorius* (Oppel, 1865). Illustrated are the numbers of primary and secondary ribs per half-whorl as a function of the diameter (1: GZN2015I 11; 2: constructed from Zittel, 1868, pl. 22, fig. 1b; 3: constructed from Zittel, 1868, pl. 22, fig. 2b; 4: constructed from Zittel, 1868, pl. 22, fig. 6b).

Family **Berriasellidae** Spath, 1923
Subfamily **Himalayitinae** Spath, 1924
Genus ***Micracanthoceras*** Spath, 1925
(Type species: *Ammonites microcanthus* Oppel, 1865)

Remarks: See Bulot *et al*. (2014).

Micracanthoceras microcanthum (Oppel, 1865)
(Pl. X, fig. 1; Pl. XI, figs 1, 2; Figs 9C-G, 11)

Ammonites microcanthus sp. nov. – Oppel, 1865a, p. 555.

Ammonites microcanthus (Oppel) – Zittel, 1868, p. 93, pl. 17, figs 3, 5 (non 1, 2, 4).

Micracanthoceras aff. *microcanthum* (Oppel) – Spath, 1931, p. 543, pl. 92, fig. 3a, b.

Himalayites (*Micracanthoceras*) *microcanthum* (Oppel) – Roman, 1936, p. 22, pl. 4, fig. 6.

Micracanthoceras cf. *microcanthum* (Oppel) – Shome and Bardhan, 2009a, p. 6, pl. 4, figs a-g.

Micracanthoceras microcanthum (Oppel) – Salazar and Stinnesbeck, 2015, p. 19, fig. 15 (see also for extensive synonymy).

Material: Four specimens from the Umia Ammonite Beds; two from 3 km NE of Lakhapar (GZN2015I 03, 04) and two from 1.5 km ESE of Katesar Temple (GZN2015I 13, 50).

Dimensions (in mm) :

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 13	50.0	12.0 (24)	15.0 (30)	25.0 (50)	0.80
GZN2015I 04	40.0	12.0 (30)	13.5 (34)	18.0 (45)	0.89
GZN2015I 03	36.2	12.2 (34)	16.4 (45)	15.0 (41)	0.74

Description: Shell small, incomplete, only phragmocone, evolute. Whorl section subrectangular, depressed with sulcate venter and slightly arched flanks (Fig. 9C, D). Ornamentation consisting of thin, sharp, sparse, prorsiradiate primary ribs, bifurcating at mid-lateral height (inner whorls) to above mid-lateral height (middle whorls) into thinner secondary ribs (Fig. 9E-F). Small, but distinct tubercles occur at some of the branching points on middle and outer whorls. Secondary ribs slightly more forwardly inclined, attaining maximum height and thickness at the ventro-lateral edge forming elongated tubercles and then either terminate or become thin before reaching the ventral groove. Secondary ribs cross the venter with slight forward-directed sinuosity. Occasionally, two to four bifurcating ribs alternate with a single rib producing a zigzag pattern on the venter (galloping; *sensu* Pandey *et al*., 2012). The generally common occurrence of single ribs leads to a relative low number of secondaries compared to primaries (Fig. 11). Occasionally, single ribs are just intercalatories and associated with shallow constrictions. Primary ribs originate at the umbilical shoulder leaving the umbilical wall smooth. Umbilical shoulder moderately distinct gradually merging into the wall. Suture lines well preserved.

Remarks: The ornamentation, including the tubercles at the bifurcation points of the ribs and at the ventro-lateral shoulder, as well as the characteristic ventral groove, supports the assignment of the specimens to the genus *Micracanthoceras* Spath, 1925. The ornamentation and whorl section match *Micracanthoceras* aff. *microcanthum* (Oppel, 1865) illustrated by Spath (1931). The present specimens and most of those described in the literature are only fragments of phragmocones. Zittel (1868, pl. 17, figs 1, 2) illustrated a wholly septate specimen with a diameter of 142 mm, but mentioned fragments pointing to a maximum adult shell diameter of at least 500 mm. Interestingly, the rib curve shows drastic changes already on the inner and middle whorls long before the end of the phragmocone (Fig. 11). Most striking is a decrease in primary and secondary ribs from between 80 to 100 mm diameter onwards. The present specimens also differ from the specimen illustrated by Zittel (1868, pl. 17, fig. 4), which is characterized by a non-sulcate venter and presence of very regular tubercles at the ventro-lateral edge.

Shome and Bardhan (2009a) included a specimen described as *Perisphinctes occultefurcatus* by Waagen (1875) into their *Micracanthoceras* cf. *microcanthum* (Oppel). However, *Aulacosphinctes occultefurcatus* (Waagen, 1875) differs in having a considerably more compressed whorl section. In addition, Waagen (1875, p. 196) mentioned that *A. occultefurcatus* is “without distinct umbilical walls... and

covered with strong and rather numerous ribs, which originate near the umbilical suture" rather than having a characteristic smooth umbilical wall and primary ribs originating around the umbilical edge as in the case of the present specimens and typical of *M. microcanthum*. The ribs are much denser in *A. occultefurcatus* than in the present specimens and tubercles are lacking. Unfortunately, the specimens illustrated by Shome and Bardhan (2009a, p. 6, pl. 4, figs f-g) from the same locality, 2 km NE of Lakhapar, are not well prepared and therefore some of the characters diagnostic of *M. microcanthum* could not be observed. Only figures f and g in their article show tubercles very clearly.

The dimensional proportions and ornamentation of the present specimens are also comparable to *Micracanthoceras fraudator* of Zittel (1868, p. 110, pl. 21, figs 1-3) and specimens placed into this taxon's affinity by Spath (1931, p. 545, pl. 109, fig. 15). However, this species seems to have a somewhat finer and denser ribbing (especially at larger diameters; Figs 11, 12). *Micracanthoceras brightoni* Spath (1931, p. 544, pl. 101, figs 6, 11a, b) is much more inflated and has a slightly smaller umbilical diameter.

Previous records: The species has previously been described from the Umia Ammonite Beds of the Umia Formation at Sahera (Spath, 1931) and 2 km NE of Lakhapar (Shome and Bardhan, 2009a).

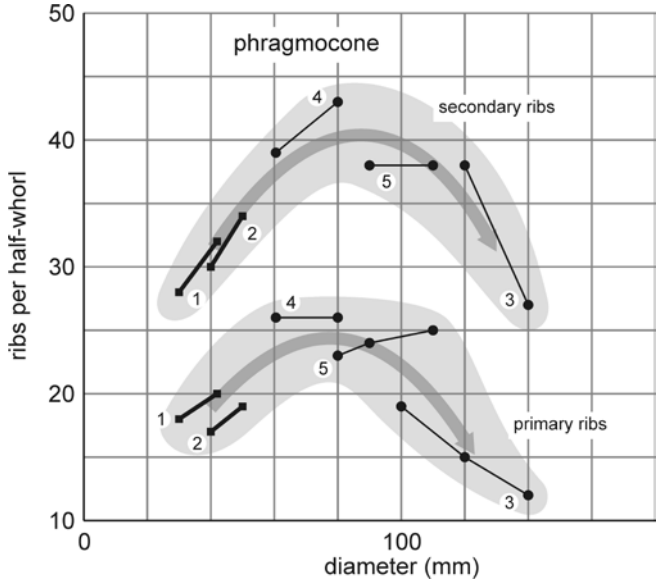


Fig. 11. Rib curves of *Micracanthoceras microcanthum* (Oppel, 1865). Illustrated are the numbers of primary and secondary ribs per half-whorl as a function of the diameter (1: GZN2015I 03; 2: GZN2015I 13; 3: constructed from Zittel, 1868, pl. 17, fig. 2; 4: constructed from Zittel, 1868, pl. 17, fig. 3b; 5: constructed from Spath, 1931, pl. 92, fig. 3a).

Micracanthoceras aff. *fraudator* (Zittel, 1868)
(Pl. XI, fig. 3; Figs 9H, I, 12)

aff. *Ammonites fraudator* sp. nov. – Zittel, 1868, p. 110, pl. 21, figs 1-3.

Material: Two specimens from the Umia Ammonite Beds; one from 3 km NE of Lakhapar (GZN2015I 05) and one from 1.5 km ESE of Katesar Temple (GZN2015I 53).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 05	72.0	22.0 (31)	21.5 (30)	33.5 (47)	1.02
GZN2015I 53	54.3	16.3 (30)	15.0 (28)	~27 (50)	1.09
Micracanthoceras fraudator (Zittel) – Zittel, 1868, p. 110	135	43 (32)	41-49 (30-36)	61 (45)	1.05-0.88

Description: Shell moderately large, incomplete, only phragmocone, evolute. Whorl section subrectangular, compressed, with flat flanks converging like a dome to sulcate ventral region (Fig. 9H). Ornamentation consisting of thin, sharp, moderately sparse, prorsiradiate primary ribs, bifurcating at outer fourth of lateral height into slightly thinner secondary ribs with sharp to blunt or very small but distinct tubercle at point of bifurcation or attaining there maximum thickness and height. Secondary ribs either slightly more forwardly inclined or following the same orientation giving altogether a broad forward-directed concavity to the ribs or rarely being slightly sinuous (Fig. 9I). Secondary ribs thickening and forming an elongated tubercle at the ventro-lateral edge and terminating before reaching the ventral groove. Single ribs common, producing a zigzag pattern (galloping) on the venter. Constrictions shallow. Primary ribs originating from umbilical seam. Umbilical shoulder moderately distinct, grading in a regular curve into the low to indistinct umbilical wall.

Remarks: The ornamentation, including the occurrence of tubercles at the bifurcation points of the ribs as well as the presence of a ventral groove suggest the assignment of the present specimens to *Micracanthoceras* Spath, 1925. The compressed whorl section and the ornamentation are also slightly similar to *Aulacosphinctes occultefurcatus*, but in addition to displaying tubercles on the flank, the present specimens also differ from this species in possessing a dome-shaped whorl section.

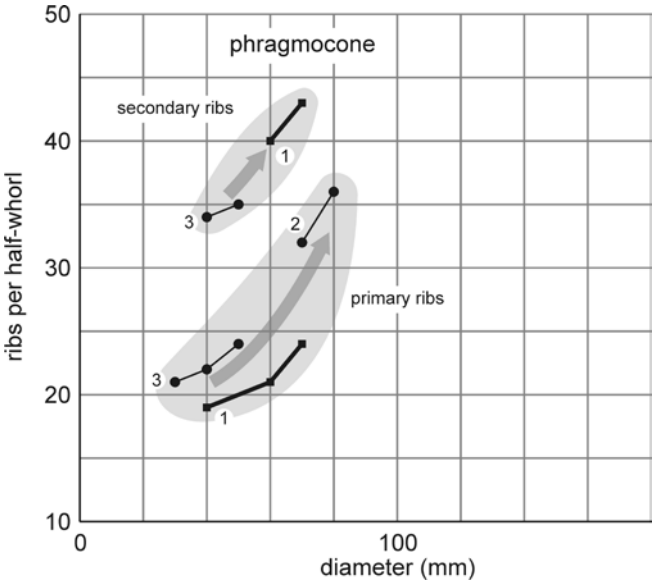


Fig. 12. Rib curves of *Micracanthoceras* aff. *fraudator* (Zittel, 1868). Illustrated are the numbers of primary and secondary ribs per half-whorl as a function of the diameter (1: GZN2015I 05; 2: constructed from Zittel, 1868, pl. 21, fig. 1a; 3: constructed from Zittel, 1868, pl. 21, fig. 3).

Micracanthoceras n. sp. aff. *fraudator* (Zittel, 1868) as described by Spath (1931, p. 545, pl. 109, fig. 15) shows a comparable ornamentation. The difference in whorl section might be attributed to the poor preservation of the specimen figured by Spath (1931). *Micracanthoceras fraudator* as illustrated by Zittel (1868) exhibits a similar ornamentation, but apparently lacks a ventral groove at least at a larger diameter. However, Zittel (1868) has mentioned a shallow median furrow on the ventral side of the inner whorls (also see Spath, 1931, p. 540).

Zittel (1868) mentioned that the ornamentation does not change considerably on the body whorl supporting the interpretation that this species represents a microconch. In fact, the number of ribs increases until a diameter of more than 80 mm (Fig. 12) with a similar ribbing pattern continuing until diameters of at least 135 mm (see Zittel, 1868, pl. 21, fig. 1a).

Due to the incomplete preservation of the present specimens, they have been placed only into the affinity of the species.

Genus ***Himalayites*** Uhlig in Böhm, 1904
(Type species: *Himalayites treubi* Uhlig in Böhm, 1904)

Remarks: *Himalayites* has slightly compressed inner whorls which become more and more rounded and ultimately depressed during ontogeny. While the inner whorls show a biplicate and simple ribbing similar to *Aulacosphinctes*, the middle and outer whorls are characterized by a row of tubercles at the branching points of ribs. The venter carries a median groove or smooth band, which might disappear on the last whorl (Arkell *et al*., 1957, p. L356).

Himalayites sp.
(Pl. XI, fig. 4; Fig. 9J-L)

Material: One specimen from the Umia Ammonite Beds, 3 km NE of Lakhapar (GZN2015I 06).

Dimensions (in mm):

specimen	D	H (H/D)	T (T/D)	U (U/D)	H/T
GZN2015I 06	82.2	26.0 (32)	29.0 (35)	33.0 (40)	0.90
	81.5	23.5 (29)	30.0 (37)	36.5 (45)	0.78
	80.0	24.5 (31)	28.5 (36)	33.0 (41)	0.86

Description: Shell incomplete, only phragmocone preserved, evolute, depressed. Whorl section subrounded with faintly arched venter (Fig. 9J). Ornamentation consisting of sharp, sparse, prorsiradiate primary ribs, which branch near mid-lateral height, into two (inner whorls) or three (outer whorls) secondary ribs (Fig. 9K, L). Branching point with thick tubercle in middle and outer whorls. Primary ribs originate at umbilical seam rursiradiately, turn prorsiradiately at umbilical shoulder, and cross the flank with a slight forward-directed concavity between the lower third to fourth of lateral height. Secondary ribs are slightly bent backwards and pass straight across the venter, attaining maximum height at the ventro-lateral edge and thinning slightly at the mid-ventral region. Rarely, a secondary rib appears as an intercalatory. Distances between ribs almost double from a diameter of 70 mm onwards, which coincides with the onset of trifurcation. At a diameter of 75 to 80 mm a slightly oblique constriction is followed by a parabola. Umbilical edge obtusely rounded, wall high, steep, slightly arched. Suture lines preserved.

Remarks: The shell seems to be broken off at the end of the phragmocone. The inner part of the outer whorl is slightly compressed and gives the appearance of a subrectangular whorl section but without a ventral groove. At the beginning of the last whorl only two of the ribs terminate at the mid-ventral region with signs of ventral tubercles but this character does not continue on either side. This results perhaps from distortion. The tubercles at the branching points of the ribs are almost continuous and intercalatory single ribs are very rare. These morphological features match the genus *Himalayites* Uhlig in Böhm, 1904.

Himalayites sp. A described by Shome and Bardhan (2009a, p. 10, pl. 5, fig. a, b) from the Kachchh Basin shows more distant ribs even at a very small diameter (~55 mm) and a more rounded whorl section. All species of *Himalayites* illustrated form Madagascar by Collignon (1960) and from the Spiti Shales of the Indian Himalayas by Uhlig (1910; see also Shome and Bardhan, 2007; Jain and Garg, 2012) show a different ornamentation. In particular, they lack the almost continuous row of tubercles at the branching points and the intercalatory single ribs of the present specimen. *Spiticeras tripartitum* (Hupé, 1854) is also a comparable species, but is much larger, has a coarser ribbing, and a wider umbilicus (Salazar Soto, 2012, p. 160).

BIOSTRATIGRAPHY

Spath (1931-1933) described two broad groups of ammonites in the Tithonian succession of the Kachchh Basin. The first exclusively consists of *Virgatosphinctes denseplicatus* and its varieties, whereas the second group is characterised by taxa with coarser ribs, a ventral groove, and rows of tubercles. Though both groups were recorded from a single lithostratigraphic unit, i.e. the Lower Umia Group, Spath also mentioned that the second group evolved from the first (1931, p. 541). Bardhan *et al*. (2007) also noticed this evolutionary trend from species with a fine ornamentation without coronation or a ventral groove (upper Lower – lower Upper Tithonian) to forms with coarser ribs, a ventral groove, and rows of tubercles (Upper Tithonian) and compared it to observations from the Spiti Shales of Nepal (Enay and Cariou, 1997), Pakistan (Fatmi, 1972), and Madagascar (Collignon, 1960).

Later researchers proposed the presence of five ammonite zones from the Tithonian sediments of the Kachchh and the neighbouring Jaisalmer Basin: the Pottingeri, Virgatosphinctoides, Natricoides, and Communis zones of the Lower Tithonian and the Denseplicatus Zone of the Upper Tithonian in ascending order (Fig. 13; Krishna *et al*., 1996, 2011; Pandey and Krishna, 2002; Pandey *et al*., 2013a). In addition, Bardhan *et al*. (2007) proposed that the Upper Tithonian ammonite assemblage of the Kachchh Basin represents the three Upper Tithonian biozones of the Mediterranean Province, viz. Simplisphinctes, Transitorius, and Durangites (Tavera *et al*., 1986; Cecca, 1999). A list of all Upper Tithonian ammonites hitherto known from the Kachchh Basin (Table 1) supports this correlation to the Tethyan framework, because it includes characteristic representatives of the Microcanthum (including the Simplisphinctes and Transitorius subzones) and Durangites zones. However, it must be noted that the distinction of these zones and subzones in the Kachchh Basin is still ambiguous. This is partly due to the fact that most of the respective ammonites are recorded from a level corresponding to a maximum flooding zone (Fürsich and Pandey, 2003), in which some suffered reworking.

Table 1. List of the Upper Tithonian ammonites recorded by previous authors from the Kachchh Basin. Data from Waagen (1875), Spath (1931), Krishna *et al*. (1996), Shome *et al.* (2004, 2005), Bardhan *et al*. (2007), and Shome and Bardhan (2009a). Please note that not all names are revised.

Aspidoceras wynnei Waagen, 1875
Aulacosphinctes occultefurcatus (Waagen, 1875)
Blanfordiceras sp. A
Corongoceras cf. *lotenoense* Spath, 1925
Corongoceras sp. A
Durangites cf. *heilprini* (Aguilera, 1895)
Durangites sp. A.
Durangites sp. B
Haploceras cf. *tomephorum* Zittel, 1870
Himalayites sp. A
Holcophylloceras silesiacum (Oppel, 1865)
Micracanthoceras brightoni Spath, 1931
Micracanthoceras cf. *microcanthum* (Oppel, 1865)
Micracanthoceras aff. *microcanthum* (Oppel, 1865)
Micracanthoceras sp. aff. *fraudator* (Zittel, 1868)
Pterolytoceras sutile (Oppel, 1863)
Tithopeltoceras lakhaparense Shome et al., 2005
Umiaites rajnathi Spath, 1931
Virgatosphinctes communis Spath, 1931
Virgatosphinctes denseplicatus (Waagen, 1875)
Virgatosphinctes frequens (Oppel, 1865)
Virgatosphinctes haughtoni Spath, 1931
Virgatosphinctes multifasciatus (Uhlig, 1910)
Virgatosphinctes oppeli Spath, 1931
Virgatosphinctes saheraensis Spath, 1931
Virgatosphinctes subfrequens (Uhlig, 1910)

The subdivision of the Upper Tithonian of the Kachchh Basin was also studied by Shome and Bardhan (2009b, p. 2), who mentioned that the "Umia Member can be divided into two broad ammonite assemblages". While the lower part is dominated by species of *Micracanthoceras* Spath, 1925, *Aulacosphinctes* Uhlig, 1910, and by *Virgatosphinctes denseplicatus* (Waagen, 1875), the upper unit is characterized by the appearance of additional genera such as *Tithopeltoceras* Arkell, 1953, *Corongoceras* Spath, 1925, *Durangites* Burckhardt, 1912, *Himalayites* Uhlig in Böhm, 1904, and *Blanfordiceras* Cossmann, 1907 (Shome *et al*., 2004, 2005; Shome and Bardhan, 2009b, p. 3).

The Upper Tithonian zonal index ammonite *Virgatosphinctes denseplicatus* is widely distributed and has been recorded in a number of areas including Kachchh, Jaisalmer, the Indian Himalayas, Pakistan, Tibet, Madagascar, Argentina, and Antarctica (Waagen, 1875; Spath, 1931; Collignon, 1960; Fatmi, 1972; Thomson, 1979; Leanza, 1980; Xiaochi and Grant-Mackie, 1988; Howlett, 1989; Kiessling *et al*., 1999; Yin and Enay, 2004). Further specimens, placed in close proximity to the species, have been collected in Mexico and Cuba (Imlay, 1939; Myczynski, 1989).

In the Jaisalmer Basin, *Virgatosphinctes denseplicatus* is also characteristic of the Tithonian occurring together with *Virgatosphinctes communis* Spath, 1931, *V. oppeli* Spath, 1931, *V. subfrequens* Uhlig, 1910, *Aulacosphinctes* spp., *Corongoceras* spp., *Kossmatia* sp., and *Substeueroceras alticostatum* Imlay, 1939 in the so-called Denseplicatus Zone (Pandey and Krishna, 2002; Pandey *et al*., 2014). The last two taxa were recorded by one of the authors (DKP) from the uppermost part of the Kolar Dongar Member of the Bhadasar Formation in the Jaisalmer Basin (Pandey *et al*., 2014, p. 79). According to Pandey and Krishna (2002), they belong to the Denseplicatus Zone, but it might be possible that they actually represent another higher zone in the uppermost Tithonian.

A species of *Virgatosphinctes* resembling *V. denseplicatus* has been recorded by Imlay (1943, p. 535, pl. 89, figs 1-4) from the Jurassic of Mexico and correlated with the basal Upper Tithonian (Enay, 1972, p. 377, 378; see also Imlay, 1980, p. 33). The occurrence of *Kossmatia* from a higher horizon than the record of *Virgatosphinctes* in the same Mexican section is comparable to the situation in the Jaisalmer Basin. Considering the presence of *Virgatosphinctes denseplicatus* in the Upper Tithonian, its record from the Lower Tithonian of Madagascar by Collignon (1960) should be reinvestigated.

The present study, concentrating on the ammonite fauna of the Umia Ammonite Beds, suggests four distinct ammonite levels. These are the Hildoglochiceras Horizon overlain, in ascending order, by the Denseplicatus, Microcanthum, and Frequens ammonite zones (Fig. 13). These biozones can be found well exposed in a ca. 10-m-thick succession exposed on the southern slope of the last ridge, about 1.5 km ESE of Katesar temple, whereas they cannot be distinguished in the Lakhapar section. Krishna *et al*. (1996, fig. 5) recognised two zones (Communis and Denseplicatus) and five subzones in the Mundhan section (Fig. 13). The present study modifies this biostratigraphic scheme and reveals that the Katesar section displays a better biostratigraphic succession of Tithonian ammonites.

***Hildoglochiceras* Horizon (level 1 in Fig. 3)**

The ammonite fauna of this horizon consists of a lone specimen of *Hildoglochiceras latistrigatum*. Other fossils are small bivalves (*Megacucullaea, Nicaniella, Trigonia*) and gastropods. This horizon is well exposed at the core of the anticline of the Katesar section, about 2 km ESE of Katesar Temple. It is characterised by a 10-cm-thick conglomerate with pebbles of fine sandy siltstone or laminated fine-grained sandstone in a ferruginous silty fine-grained sandstone matrix. *Hildoglochiceras* has always been found below an ammonite assemblage consisting of *Virgatosphinctes denseplicatus*, *V. communis*, *Aulacosphinctes occultefurcatus*, *Micracanthocras microcanthum*, *Himalayites* sp. etc. (e.g., Arkell, 1956; Krishna *et al*., 1982; Krishna, 1983a, b; Krishna and Pathak, 1994; Pathak and Krishna, 1995; Garg *et al*., 2003). It has been correlated with upper Lower Tithonian ammonite zones (Enay, 2009, figs 21-23). Krishna *et al*. (1982, p. 583) assigned their *Hildoglochiceras - Virgatosphinctes* assemblage to the Middle Tithonian. Following previous workers (e.g. Enay, 2009), this zone is correlated with the middle Lower Tithonian Semiforme standard European Ammonite Zone (Fig. 13).

Denseplicatus Zone (level 2 in Fig. 3)

The ammonites of this zone include *Virgatosphinctes denseplicatus*, *V. denseplicatus* var. *striatissima*, *V. denseplicatus* var. *rotunda*, and *V.* aff. *pompeckji*. Other co-occurring fossils are bivalves (*Seebachia*), belemnites, and large wood fragments. This unit is also well exposed in the Katesar section (in the upper part of the western slope of the first anticlinal ridge counting from the core of the anticline), about 1.6 km ESE of Katesar Temple. It is characterised by thin beds of bioturbated (*Thalassinoides*), strongly ferruginous, glauconitic fine sandy siltstone.

According to Krishna *et al*. (1996), the first appearance of *V. denseplicatus* marks the beginning of the Denseplicatus Zone. The present study corroborates this observation. However, the

stage	substage	Tethyan zones	Kachchh Basin					
			present study				Krishna et al., 1996, 2011 Pandey & Krishna, 2002 Pandey et al., 2013a	
			Katesar section		Mundhan section	Lakhapar section		
Tithonian	Upper	Durangites	Frequens Zone	*Virgatosphinctes frequens* *V. subfrequens*		*Himalayites* sp. *M. microcanthum* *M.* aff. *fraudator* *Paraulacosphinctes* aff. *transitorius* *V. denseplicatus* *V. denseplicatus* var. *striatissima* *V. subfrequens* *V.* cf. *communis* *V.* aff. *haughtoni* *Holcophylloceras* sp. *Ptychophylloceras ptychoicum*	Frequens Oppeli Denseplicatus	Denseplicatus
		Microcanthum	Microcanthum Zone	*Micracanthoceras microcanthum* *M.* aff. *fraudator* *Parapallasiceras spitiensis*				
	Lower	Ponti	Denseplicatus Zone	*V. denseplicatus* var. *striatissima* *V. denseplicatus* var. *rotunda*	*V. denseplicatus* *V. denseplicatus* var. *rotunda* *V.* aff. *pompeckji*		Subfrequens	Communis
		Fallauxi					Communis	
		Semiforme	*Hildoglochiceras* Horizon	*Hildoglochiceras latistrigatum*				Natricoides
		Darwini					Biplicatus Rajnathi Perrinsmothi	Virgatosphinctoides
		Hybonotum					Sparsicosta Pottingeri	Pottingeri

Fig. 13. Correlation of upper Lower to Upper Tithonian ammonite zones of the Kachchh Basin with the standard Tethyan scheme.

Denseplicatus Zone corresponds to the upper Lower Tithonian (Fallauxi and Ponti zones) and is not Late Tithonian in age as proposed by Krishna *et al*. (1996). This interpretation is based on the stratigraphic position of this ammonite zone below the *Micracanthoceras microcanthum* yielding horizon in the Katesar section (Fig. 13). It is interesting to note that Pandey and Krishna (2002, p. 23) considered the Ponti Zone as the lowermost zone of the Upper Tithonian, whereas Pandey *et al*. (2013a) reconsidered it to mark the uppermost part of the Lower Tithonian.

Microcanthum Zone (level 3 in Fig. 3)

The ammonites of this zone include *Micracanthoceras microcanthum*, *Micracanthoceras* aff. *fraudator*, and *Parapallasiceras spitiensis* (Fig. 13). Other fossils are rare, except for large *Thalassinoides* traces. This unit is also very well exposed in the Katesar section (in the lower part of the western slope of the first anticlinal ridge counting from the core of the anticline), about 1.5 km ESE of Katesar Temple. It is characterised by thin beds of bioturbated, glauconitic sandy siltstone with ferruginous siltstone concretions and scattered coarse quartz granules.

Micracanthocras microcanthum is a zonal index fossil of the Upper Tithonian known to occur from the Mediterranean Tethys (Enay and Geyssant, 1975; Bardhan *et al*., 2007) to the eastern margin of the palaeo-Pacific in Chile (Salazar and Stinnesbeck, 2015). It has been recorded from many regions, including Europe (Zittel, 1868), northern Africa (Roman, 1936), and the Himalayas (Oppel, 1865b). According to the standard ammonite zonation, the appearance of this zonal species marks the lower boundary of the Upper Tithonian (Enay, 2009, p. 61, 64). Until now, this species had been recorded from the Kachchh Basin only with qualification, due to the poor preservation of previously collected specimens (Spath, 1931; Shome and Bardhan, 2009a).

Frequens Zone (level 4 in Fig. 3)

The ammonites of this zone include *Virgatosphinctes frequens* and *V. subfrequens* (Fig. 13). Other fossils are bivalves (*Gryphaea*, *Megacucullaea)* and belemnites. This horizon is also very well exposed in the Katesar section (on the western slope of the first anticlinal ridge counting from the core of the anticline), about 1.5 km ESE of Katesar Temple. It is a thin bed of ferruginous, glauconitic fine-grained sandstone overlying a bioturbated, medium-grained sandstone containing wood fragments.

Krishna *et al*. (1996) recognised a Frequens Subzone within their Denseplicatus Zone (compare Fig. 13) and regarded *V. frequens* as a zonal fossil. The first occurrence of *V. frequens* marks the base of their subzone. Furthermore, according to Krishna *et al*. (1996), the Subfrequens Subzone of the Communis Zone is marked by the first appearance of *V. subfrequens*. Therefore, the first occurrence of *V. subfrequens* in the Kachchh Basin is slightly ambiguous because Krishna *et al*. (1996) did not give information on the lithology from which they collected the species. Hence, it is very difficult to correlate the different subzones in the field. The present record of *V. subfrequens* together with *V. frequens* may show its upper range. The other ammonites listed by Krishna *et al*. (1996) as occurring in their Frequens Subzone should have been described and figured to facilitate their evaluation. According to Krishna *et al*. (1996), the Frequens Subzone represents the top of the Upper Tithonian in the Kachchh Basin. The findings of the present study agrees with this observation (Fig. 13).

Based on Uhlig (1910) it is difficult to ascertain the level of *Virgatosphinctes frequens* within the succession of the Spiti Shales of the Himalayas. Collignon (1960, fig. 619) recorded it from the Upper Tithonian (his "Zone à Aulacosphinctes Hollandi"). Later on, this species has been recorded by Yin and Enay (2004, p. 672, fig. 4-2) from the Menkadun Formation (Pure section) in eastern Himalayan Tibet. In the Pure section, *Virgatosphinctes frequens* occurs together with *V. denseplicatus* below the Upper Tithonian *Haplophylloceras pingue* Ryf, 1962 (Yin and Enay, 2004, p. 677).

Condensed sequence in Lakhapar area

The Umia Ammonite Beds in the Lakhapar area are distinctly

condensed (Fürsich and Pandey, 2003) and contain ammonites ranging in age from Early to Late Tithonian. The fauna comprises *Paraulacosphinctes* aff. *transitorius*, *Himalayites* sp., *Holcophylloceras* sp*., Micracanthocras microcanthum*, *M*. aff. *fraudator*, *Ptychophylloceras ptychoicum*, *Virgatosphinctes denseplicatus*, *V*. *denseplicatus* var. *striatissima*, *V*. cf. *communis*, *V*. aff. *haughtoni*, and *V*. *subfrequens* (Fig. 13).

Holcophylloceras and *P*. *ptychoicum* show long stratigraphic ranges in the Kachchh Basin (e.g., Pandey *et al*., 2013b). Species of *Himalayites* are geographically widely distributed in the Upper Tithonian Microcanthum Zone (Enay, 2009). *Paraulacosphinctes transitorius* is an index ammonite of the Upper Tithonian Transitorius Subzone (Zittel 1868, p. 106; Tavera, 1985; Arkadiev, 2011; Vasicek and Skupien 2016). Together with the occurrence of *Micracanthoceras microcanthum* and *M*. aff. *fraudator*, this suggests that the upper limit of the condensed sequence in the Lakhapar area includes at least the lower Upper Tithonian Microcanthum Zone. The assemblage of *Virgatosphinctes* cf. *communis* and *V. denseplicatus* together with its varieties suggests the presence of ammonite zones younger than the Semiforme Zone (in the Kachchh Basin, this is the horizon bearing *Hildoglochiceras latistrigatum*) and older than the Microcanthum Zone. Thus in the standard biostratigraphic scale the condensed sequence in Lakhapar area ranges from the Fallauxi Zone to at least the Microcanthum Zone and possibly the lower Durangites Zone (Fig. 13).

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