



CALLOVIAN AMMONITES FROM A CONDENSED HORIZON IN THE KULDHAR MEMBER OF THE NORTHEASTERN JAISALMER BASIN (RAJASTHAN, INDIA) AND THEIR BIOSTRATIGRAPHIC IMPLICATIONS

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ABSTRACT

Previously, Callovian ammonites in the Jaisalmer Basin of western India were mostly known from the type locality of the Kuldhar Member at the Kuldhar River Section in the southwestern part of the basin. At this locality, the succession can be subdivided into six ammonite zones and subzones. For the first time, the present article describes ammonites collected from a riversection (N27°07'06.60", E71°05'24.72"), 1 km west of the village Kanod. In contrast to the type section, the Kuldhar Member in the northeastern Jaisalmer Basin is strongly condensed. Most of the ammonites occur within a 30-cm-thick bed of sandy, bioclastic siltstone with bored concretions. They belong to the genera *Hecticoceras*, *Eucycloceras*, *Idiocycloceras*, *Sivajiceras*, *Obtusicosites*, *Kinkeliniceras* and *Hubertoceras*. The assemblage is time-averaged ranging from the late Early Callovian to the early Late Callovian in age. The condensed nature of the sediment is also evident by abundant oysters and serpulids encrusting the ammonite shells. In total, twelve ammonite taxa are described and illustrated with a discussion on their biostratigraphic potential.

Keywords: Callovian, ammonites, taxonomy, condensation, biostratigraphy, Jaisalmer Basin, India.

INTRODUCTION

The sedimentary succession of the Jaisalmer Basin (Fig. 1) preserves a significant part of the Jurassic history of marine environmental changes and ecosystem evolution at the southern margin of the Tethys at a palaeolatitude of ca. 25°S. The basin attracts geoscientists due to the diverse features of the Jurassic succession including abundant well preserved marine fossils, dinosaur footprints, hardgrounds, condensed sequences, soft-sediment deformation structures, shell beds, sedimentary structures, and well developed sedimentary sequences of third-order cycles (e.g., Pieńkowski *et al.*, 2015; Alberti *et al.*, 2017). Recently, Pandey *et al.* (2014) summarized the most important previous studies, particularly those of Das Gupta (1975), Kachhara and Jodhawat (1981), Krishna (1980a, b, 1987), Kalia and Chowdhury (1983), Mahendra and Banerji (1989), Fürsich *et al.* (1992, 2006), Pandey and Choudhary (2007), and Pandey *et al.* (2006a, b, 2009, 2010, 2011, 2012).

Lithostratigraphically, the Jurassic succession of the Jaisalmer Basin has been divided into the Lathi, Jaisalmer, Baisakhi and Bhadasar formations (Fig. 2). The type sections of these formations are mostly located in the western part of the basin. However, additional good outcrops of the Jaisalmer and Baisakhi formations can be found further east (e.g., between the village Hamira and Kala Dungar Temple, in the Kala Dungar Hills, and between the villages Kanod and Deva). In the present study, a 5-m-thick succession, exposed along a river valley (N27°07'06.60", E71°05'24.72"), 1 km west of the village Kanod, on the right side of the Kanod-Kala Dungar Temple road, is investigated (Figs 1, 3). Despite its limited

thickness, the section comprises the Bada Bag, Kuldhar, and Jajiya members of the Jaisalmer Formation as well as the basal-most Baisakhi Formation. The basal part of the succession, the Bada Bag Member, is exposed near the distal end of the river and consists of limestones with horizontal burrow systems (mostly *Planolites*, *Palaeophycus*, *Rhizocorallium commune*, and *Thalassinoides*). The hardgrounds present in this interval are important marker beds which can be followed through large parts of the Jaisalmer Basin (Fürsich *et al.*, 1992). The Bada Bag Member is coarsening-upwards, its top formed by an oolitic rudstone with reworked pebbles and fossils (e.g., belemnites, bivalves). The overlying Kuldhar Member can be divided into two horizons. The lower consists of a 30-cm-thick calcareous sandy siltstone with reworked concretions and abundant fossils (brachiopods, echinoderm fragments, serpulids, belemnites, and ammonites; Bed 10 in Fig. 3). This horizon has yielded ammonites discussed in the present article. The upper part of the Kuldhar Member consists of fossiliferous clay or shale with scattered isolated bivalves, gastropods, and rare ammonites (Bed 11 in Fig. 3). The following Jajiya Member is represented by a prominent fossiliferous rudstone with common, large rhynchonellid brachiopods (*Gibbirhynchia* sp.). The top of the section is formed by gypsiferous clay or silt of the basal-most Baisakhi Formation.

The present article describes and illustrates the ammonites collected at this new locality in the northeastern Jaisalmer Basin. Additionally, it represents the first record of a condensed horizon in this part of the basin and therefore is of regional importance for intrabasinal correlations as well as reconstructions of the depositional history.

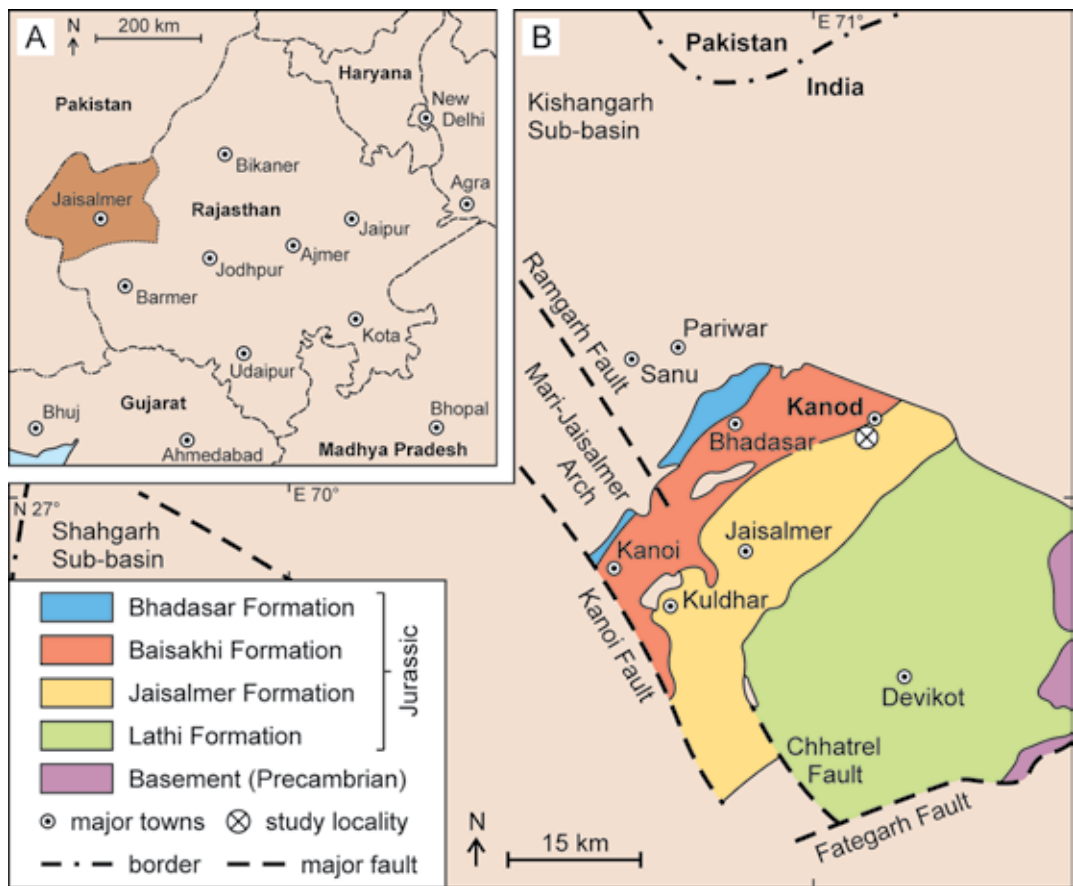


Fig. 1. A. Sketch map of Rajasthan showing the position of the Jaisalmer District. B. Geological map of the Jaisalmer Basin (modified after Das Gupta, 1975; Pandey *et al.*, 2014).

MATERIAL AND METHODS

Thirty-three ammonite specimens from the Kuldhara Member (Jaisalmer Formation; Beds 10 and 11 in Fig. 3), exposed along a river valley (N27°07'06.60", E71°05'24.72"), 1 km west of the village of Kanod in the northeastern Jaisalmer Basin, are described and illustrated. These ammonites, together with significant field data, were collected during several field surveys between 2009 and 2012. They are kept in the collections of the Department of Geology of the University of Rajasthan in Jaipur, India. For the systematic study, mostly the classification of Arkell *et al.* (1957) has been followed; additional references of regional importance are also given. The dimensions of the specimens were measured with the help of a digital caliper (Aerospace). The following conventional abbreviations have been used (compare Fig. 4):

D: diameter of the shell; H: height of the whorl at the measured diameter; H/D: ratio between height of the whorl and diameter; T: thickness of the whorl at the measured diameter; T/D: ratio between thickness of the whorl and diameter; U: diameter of the umbilicus at the measured diameter; U/D: ratio between umbilicus and diameter; H/T: ratio between height and thickness of the whorl at the measured diameter.

The ammonite specimens (prefix RUC) are housed in the Department of Geology, University of Rajasthan, Jaipur 302004 (Rajasthan, India).

Age	Formation	Member
?Early Cretaceous Tithonian	Bhadasar	Mokal
		Kolar Dungar
Tithonian - Oxfordian	Baisakhi	Lanela
		Rupsi
		Basal
Oxfordian	Jaisalmer	Jajiya
Callovian		Kuldhara
M.-L. Bathonian		Bada Bag
Early Bathonian - Bajocian		Fort
		Joyan
Bajocian - Early Jurassic	Lathi	Thaiat
		Odania

Fig. 2. Lithostratigraphic framework of the Jurassic strata of the Jaisalmer Basin (modified after Das Gupta, 1975; Alberti *et al.*, 2017).

SYSTEMATIC PALAEOLOGY

- Class **Cephalopoda** Cuvier, 1797
- Subclass **Ammonoidea** Zittel, 1884
- Order **Ammonitida** Hyatt, 1889
- Suborder **Ammonitina** Hyatt, 1889

Table 1. Dimensions of the collected ammonite taxa, partly compared to literature data.

	D	H (H/D)	W (W/D)	U (U/D)	H/W
<i>Hecticoceras cf. hecticum</i> (Reinecke, 1818)					
RUC2009Kanod F13	-	15.0	10.0	-	1.50
<i>Eucycloceras opis</i> (J. de C. Sowerby, 1840)					
RUC2009Kanod F36	86.0	44.0 (0.51)	29.0 (0.33)	18.0 (0.20)	1.51
Waagen, 1875: p. 142	130	57 (43)	48 (36)	33 (25)	1.18
Waagen, 1875: p. 141	50	24 (48)	20 (40)	12 (24)	1.20
<i>Idiocycloceras</i> sp. ind.					
RUC2009Kanod F3	-	23.0	24.5	-	0.93
<i>Sivajiceras paramorphum</i> (Waagen, 1875)					
RUC2009Kanod F28	-	71.0	56.0	-	1.30
RUC2009Kanod F45	~210	66.0 (0.31)	~44 (0.20)	84.0 (0.40)	1.50
RUC2009Kanod F38	178.0	~65 (0.36)	48.0 (0.26)	65.0 (0.36)	1.44
RUC2009Kanod F45	175.0	61.0 (0.34)	-	65.0 (0.37)	-
RUC2009Kanod F8	-	61.0	43.0	-	1.41
RUC2009Kanod F28	-	51.0	38.0	-	1.34
Waagen, 1875: p. 162	145	54 (0.37)	41 (0.28)	54 (0.37)	1.31
Waagen, 1875: p. 162	52	18 (0.34)	21 (0.40)	22 (0.42)	0.85
<i>Sivajiceras aureum</i> Spath, 1930					
RUC2009Kanod F30	-	48.0	41.0	-	1.17
RUC2009Kanod F31	-	46.0	41.0	-	1.12
RUC2009Kanod F51	125.0	46.0 (0.36)	~40 (0.32)	48.0 (0.38)	1.15
RUC2009Kanod F32	122.0	45.0 (0.36)	40.0 (0.32)	42.0 (0.34)	1.12
RUC2009Kanod F30	-	41.0	33.0	-	1.24
RUC2009Kanod F47	-	34.0	29.0	-	1.17
Spath, 1931: p. 291	169	56 (0.33)	46 (0.27)	70 (0.41)	1.21
Spath, 1931: p. 291	105	40 (0.38)	34 (0.32)	36 (0.34)	1.17
Spath, 1931: p. 292	115	44 (0.38)	40 (0.35)	38 (0.33)	1.08
<i>Sivajiceras</i> sp. A					
RUC2009Kanod F10	-	67.0	45.0	-	1.48
RUC2009Kanod F29	-	62.0	45.0	-	1.37
RUC2009Kanod F46	-	58.0	41.0	-	1.45
RUC2009Kanod F11	-	55.0	38.0	-	1.44
RUC2009Kanod F7	150.0	51.0 (0.34)	36.0 (0.24)	48.0 (0.32)	1.41
RUC2009Kanod F7	119.0	47.0 (0.39)	33.0 (0.27)	42.0 (0.35)	1.42
RUC2009Kanod F44	111.0	42.0 (0.37)	~29 (0.26)	39.0 (0.35)	1.44
<i>Sivajiceras cf. besairiei</i> Collignon, 1958					
RUC2009Kanod F55	-	60.0	49.0	-	1.22
Collignon, 1958: fig. 84	310	90 (0.29)	70 (0.23)	153 (0.50)	1.29
<i>Obtusicosites obtusica</i> (Waagen, 1875)					
RUC2009Kanod F50	-	37.0	31.0	-	1.19
RUC2009Kanod F33	-	36.0	30.0	-	1.20
RUC2009Kanod F23	-	33.0	30.0	-	1.10
RUC2009Kanod F49	-	32.0	29.0	-	1.10
RUC2009Kanod F35	-	22.0	23.0	-	0.95
Spath, 1931: p. 297	156	65.5 (0.42)	53 (0.34)	47 (0.30)	1.24
Spath, 1931: p. 297	90	37 (0.41)	38 (0.42)	30 (0.33)	0.98
<i>Kinkeliniceras kinkelini</i> (Dacqué, 1910)					
RUC2009Kanod F34	73.0	30.0 (0.41)	24.0 (0.32)	25.0 (0.34)	1.25
RUC2009Kanod F39	64.0	26.0 (0.40)	21.5 (0.33)	21.5 (0.33)	1.20
Spath, 1931: p. 307	66	27 (0.41)	22 (0.33)	19 (0.29)	1.24
<i>Hubertoceras aff. mutans</i> (Waagen, 1875)					
RUC2009Kanod F15	49.0	19.5 (0.39)	15.0 (0.30)	19.0 (0.38)	1.30
RUC2009Kanod F20	26.0	10.0 (0.38)	8.0 (0.30)	10.0 (0.38)	1.25
Waagen, 1875: p. 151	83	29 (0.34)	19 (0.22)	31 (0.37)	1.52
<i>Hubertoceras hubertus</i> Spath, 1931					
RUC2009Kanod F21	51.0	20.0 (0.39)	~18 (0.35)	19.5 (0.38)	1.11
RUC2009Kanod F22	51.0	20.5 (0.40)	18.0 (0.35)	19.5 (0.38)	1.13
Spath, 1931: p. 320	73	25 (0.34)	22 (0.30)	28 (0.38)	1.13

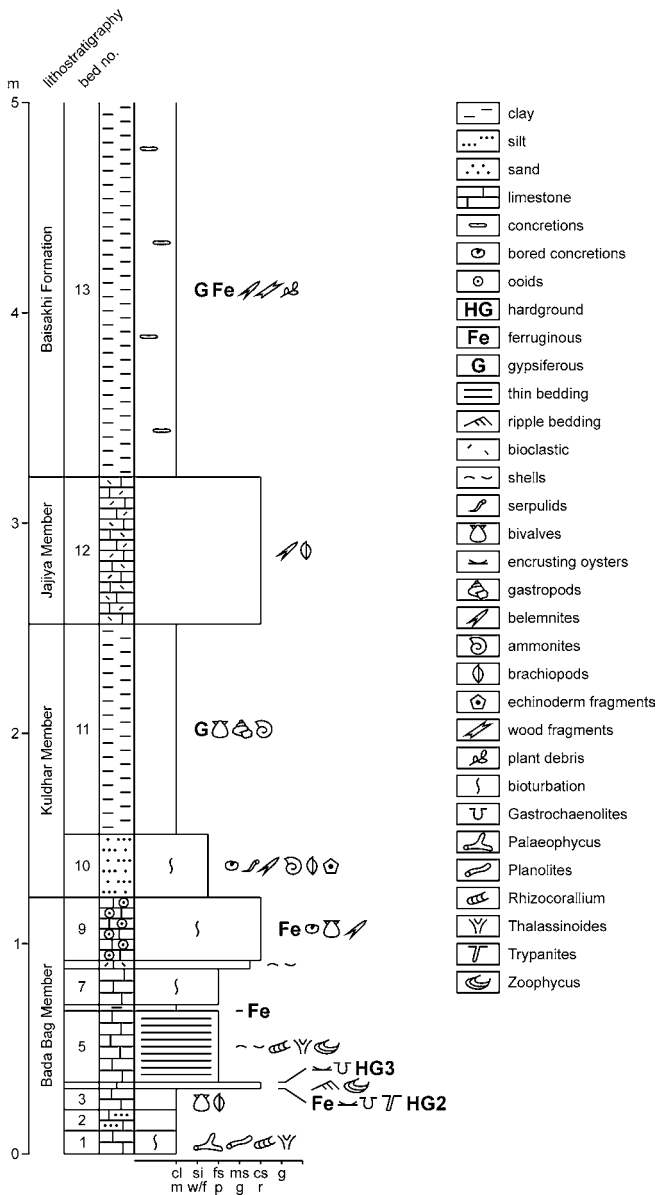


Fig. 3. Kanod River Section (N027°07'06.60", E71°05'24.72"), 1 km west of the village Kanod, on the right side of Kanod-Kala Dugar Temple road, northeast of the Jaisalmer city, cl: clay, si: silt, fs: fine sand, ms: medium sand, cs: course sand, g: gravel, m: mudstone, w/f: wackestone/floatstone, p: packstone, g: grainstone, r: rudstone. The ammonites described in the paper are mainly from bed 10.

Superfamily **Haplocerataceae** Zittel, 1884
 Family **Oppeliidae** Bonarelli, 1894
 Subfamily **Hecticoceratinae** Spath, 1925
 Genus **Hecticoceras** Bonarelli, 1893
 Type species *Nautilus hecticus* Reinecke, 1818

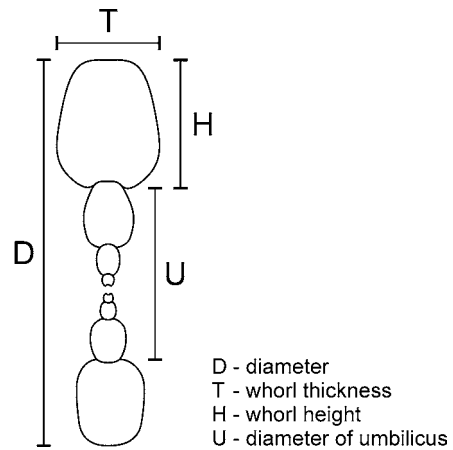


Fig. 4. Measured dimensions of the ammonites and abbreviations used in the present study (modified after Alberti *et al.*, 2011).

Hecticoceras cf. hecticum Reinecke, 1818
 (Pl. I, fig. A-C; Table 1)

cf. 1818 *Nautilus hecticus* sp. nov. - Reinecke, p. 70, pl. 4, figs 37, 38.
 cf. 1957 *Hecticoceras (Hecticoceras) hecticum* (Reinecke) - Arkell *et al.*, L276, fig. 324, 2a, b.
 cf. 2006 *Hecticoceras hecticum* Reinecke - Prasad, p. 15, pl. 1, fig. 2, pl. 19, fig. 1.

Material: 2 fragmentary specimens (RUC2009Kano F12, F13) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Fragments of small phragmocones, compressed with sub-parallel flanks. Ornamentation consists of prorsiradiate, strong, sharp ribs originating near the umbilical shoulder. Ribs thicken considerably towards the ventrolateral edge where they form small, pointed tubercles. The venter exhibits a fine keel passing across the ribs. Inter-rib space uniform, twice as wide as the rib thickness. Suture lines moderately preserved.

Remarks: The whorl section and ornamentation in the present specimens match those of *Hecticoceras hecticum* illustrated by Arkell *et al.* (1957) and Prasad (2006). However, due to the poor preservation of the whorl fragments, they have been assigned to the species only tentatively.

Previous record from the western margin of the Indian subcontinent: Prasad (2006) recorded *Hecticoceras hecticum* from 2.5 km southwest of the village Kanod.

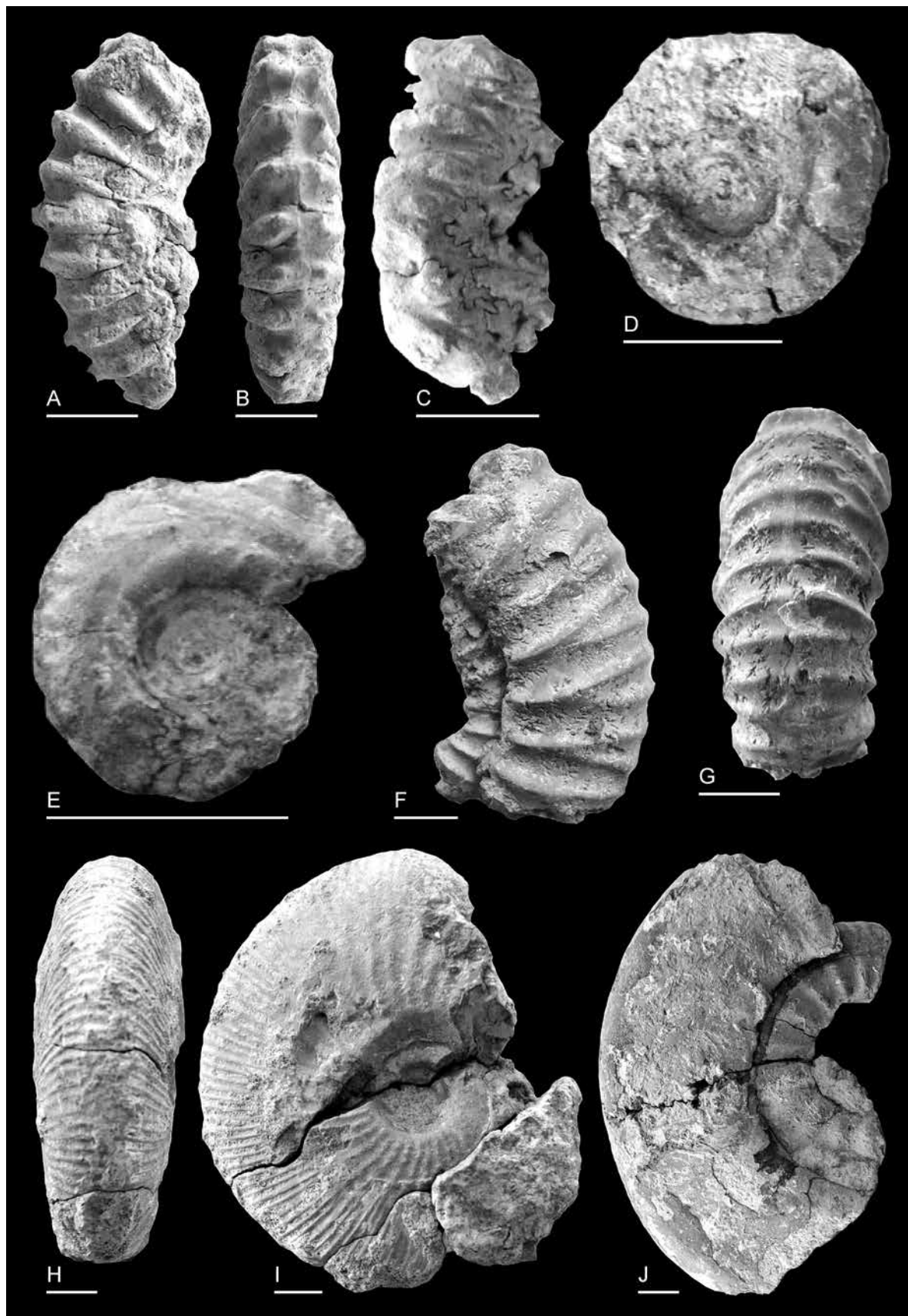
Age: *Hecticoceras hecticum* ranges from the Early Callovian (e.g., Europe) to the Middle Callovian (e.g., beds with *Reineckeia*, Jaisalmer Basin; Prasad, 2006).

Hecticoceratinae Spath, 1925
 (Pl. I, figs. D, E)

Material: 2 specimens (RUC2009Kano F26, F27) from Bed 11 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

EXPLANATION OF PLATE I

Ammonites from the Kanod River Section (scale bars = 10 mm). A-C. *Hecticoceras cf. hecticum* (Reinecke, 1818) from Bed 10. (A) RUC2009Kano F13, lateral view; (B) RUC2009Kano F13, ventral view; (C) RUC2009Kano F12, oblique view showing suture lines. D, E. Hecticoceratinae from Bed 11. (D) RUC2009Kano F26, lateral view; (E) RUC2009Kano F27, lateral view. F, G. *Idiocycloceras* sp. ind. from Bed 10. (F) RUC2009Kano F3, lateral view; (G) RUC2009Kano F3, ventral view. H, I. *Eucycloceras opis* (J. de C. Sowerby, 1840) from Bed 10. (H) RUC2009Kano F36, ventral view; (I) RUC2009Kano F36, lateral view. J. *Sivajiceras paramorphum* (Waagen, 1875) from Bed 10. RUC2009Kano F8, lateral view.



Description and remarks: The specimens represent small, poorly preserved nuclei of phragmocones. Specimen RUC2009Kanod F26 is slightly crushed and does not show remains of any ornamentation, except a shallow spiral groove running along the middle of the flank-, whereas RUC2009Kanod F27 in addition, exhibits traces of ribbing on the outer half of the last preserved whorl. Suture lines can be observed in the latter specimen. The coiling, shape of the whorl section, and ornamentation clearly suggest an assignment to the Hecticoceratinae. As no information on the ventral region is available, no further identification is possible.

Age: Due to their stratigraphic position (Bed 11 in Fig. 2) it seems likely that both specimens have a Late Callovian age.

Superfamily *Stephanocerataceae* Neumayr, 1875

Family *Sphaeroceratidae* Buckman, 1920
(according to Jana *et al.* 2005)

Subfamily *Eucycloceratinae* Spath, 1928

Genus *Eucycloceras*, Spath 1924

Type species *Stephanoceras eucyclum* Waagen, 1875

Eucycloceras opis J. de C. Sowerby, 1840
(Pl. I, figs. H-I, I; Table 1)

1840 *Ammonites opis* sp. nov. - J. de C. Sowerby, pl. 23, fig. 9.

1875 *Stephanoceras opis* (J. de C. Sowerby) - Waagen, p. 141, pl. 36, figs 1-3. 1875 *Stephanoceras eucyclum* sp. nov. - Waagen, p. 142, pl. 35, fig. 1a, b, c.

1928 *Eucycloceras eucyclum* (Waagen) - Spath, p. 209, pl. 23, fig. 4a, b, pl. 25, fig. 4, pl. 27, fig. 7a, b.

2005 *Eucycloceras opis* (J. de C. Sowerby) - Jana *et al.*, p. 898, pls 1-4; pl. 5, figs 1-4, text-figs 9-12 (see also for extensive synonymy).

2006 *Eucycloceras eucyclum* (Waagen) - Prasad, p. 25, pl. 5, fig. 2a, b, pl. 19, fig. 3. 2016 *Eucycloceras opis* (J. de C. Sowerby) - Sharma and Pandey, p. 258, pl. 2, fig. 1.

Material : 1 specimen (RUC2009Kanod F36) from Bed 10 of the section in the river valley, 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description : Wholly septate fragment of a moderately large, moderately evolute phragmocone. Whorl section compressed with subtrigonal outline, slightly arched flanks and acutely rounded venter. Ornamentation consists of prorsiradiate primary ribs, which are thin and sharp on the inner whorls and gradually become thicker and blunt on the outer whorl. Primary ribs originate on umbilical wall, run slightly rursiradiately on umbilical wall, turn prorsiradiate at umbilical shoulder creating a slight forward-directed concavity. Primary ribs branch irregularly at mid-lateral height into three secondaries. At a diameter of 86 mm, secondary ribs number 58 per half whorl. Secondaries are thinner than primary ribs and cross the venter with slight forward-directed convexity. Inter-rib space variable, but wider than the rib thickness. Umbilical wall steep, umbilical shoulder prominent. Suture line poorly preserved.

Remarks: The dimensions and ornamentation in the present specimen closely match *Eucycloceras opis*. Pandey (1983: 394-400) described somewhat similar material from the Kachchh Basin as *Dolikephalites*, but this genus differs in having less prorsiradiate ribs and a smaller diameter of the umbilicus.

Previous records from the western margin of the Indian subcontinent: Waagen (1875) recorded *Eucycloceras opis* from a series of localities and stratigraphic units in the Kachchh Basin thereby covering a large time interval. Spath (1928) recorded the species from the Keera Dome in the Kachchh Basin. More recently, Jana *et al.* (2005) gave a detailed account of the species in the Kachchh Basin and showed that it is much more confined in stratigraphic occurrence, being restricted to the upper Lower to lower Middle Callovian of the Chari Formation. Within the Jaisalmer Basin, Prasad (2006) recorded *Eucycloceras opis* from the Kuldhar Member of the Jaisalmer Formation east of the village Pohar and 1 km south of the village Kuldhar. Sharma and Pandey (2016) recorded it from gypsiferous silty marl of the Kuldhar Member in the Kuldhar Nala Section.

Age: According to the recent discussion by Jana *et al.* (2005), *Eucycloceras opis* occurred from the late Early Callovian to the early Middle Callovian (Semilaevis to Anceps zones). Krishna (2017) recorded the species from the same interval, but only from the Eucyclum to Ramesa subzones.

Genus *Idiocycloceras* Spath, 1928

Type species *Idiocycloceras perisphinctoides* Spath, 1928

Idiocycloceras sp. ind.

(Pl. I, fig. F, G; Table 1)

Material: 1 specimen (RUC2009Kanod F3) from Bed 10 of the section in the river valley, 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Small whorl fragment of an evolute phragmocone. Whorl section depressed with slightly arched flanks and rounded venter. Ornamentation consists of prorsiradiate, coarse, moderately sharp primary ribs originating at the umbilical shoulder. Primary ribs branch into two at the centre of the flank. Secondary ribs have more or less the same thickness as the primary ribs. Adapertural secondary ribs cross the venter with slight forward-directed convexity, whereas adapical secondary ribs remain straight. Inter-rib space variable, wider than rib thickness. Umbilical wall short and steep. Suture lines well preserved.

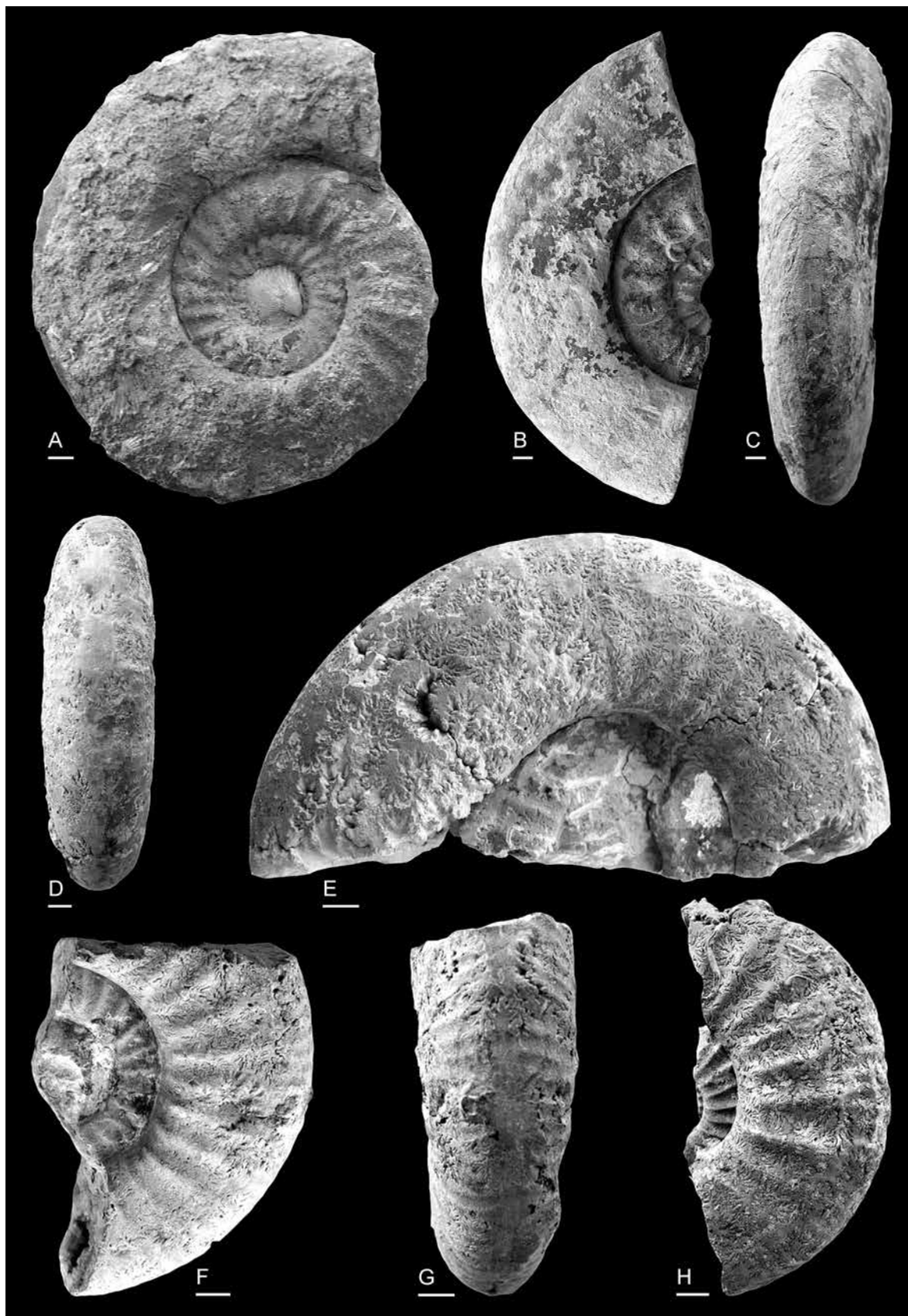
Remarks: Due to the poorly preserved nature of the present specimen, it cannot be safely assigned to any species of *Idiocycloceras*. Its ribbing pattern is close to that of *Idiocycloceras singulare* as described by Spath (1928: 216), which has been later synonymized with *Idiocycloceras perisphinctoides* by Jana *et al.* (2005). Other specimens of *Idiocycloceras*, described by Spath (1928) as *I. perisphinctoides* (Spath, 1928: 215, pl. 36, fig. 3, pl. 38, fig. 3a-c) and *I. dubium* (Spath, 1928: 217), show more closely spaced ribs.

Previous records from the western margin of the Indian subcontinent: Waagen (1875) and Spath (1927-1933) recorded *Idiocycloceras* from different localities in the Kachchh Basin.

Age: Jana *et al.* (2005) synonymized most species of *Idiocycloceras* described earlier by Spath (1927-1933) from the Kachchh Basin. They found an early Middle Callovian age for the remaining *Idiocycloceras perisphinctoides* (Anceps Zone).

EXPLANATION OF PLATE II

Ammonites from the Kanod River Section (scale bars = 10 mm). A-E. *Sivajicerias paramorphum* (Waagen, 1875) from Bed 10. (A) RUC2009Kanod F45, lateral view; (B) RUC2009Kanod F28, lateral view; (C) RUC2009Kanod F28, ventral view; (D) RUC2009Kanod F38, ventral view; (E) RUC2009Kanod F38, lateral view. F-H. *Sivajicerias aureum* Spath, 1930 from Bed 10. (F) RUC2009Kanod F30, lateral view; (G) RUC2009Kanod F30, ventral view; (H) RUC2009Kanod F31, lateral view.



Superfamily *Perisphinctaceae* Steinmann, 1890

Family *Perisphinctidae* Steinmann, 1890

Subfamily *Sivajiceratinae* Dutta and Bardhan, 2016

Genus *Sivajiceras* Spath, 1928

Type species *Perisphinctes congener* Waagen, 1875

Sivajiceras paramorphum Waagen, 1875

(Pl. I, figs. J; Pl. II, figs. A-E; Table 1)

1875 *Perisphinctes paramorphus* sp. nov. - Waagen, p. 162, pl. 46, figs 1a, b, 2a, b, pl. 47, fig. 3.

1931 *Sivajiceras paramorphum* (Waagen) - Spath, p. 288, pl. 63, fig. 1a, b.

Material: 4 specimens (RUC2009Kanod F8, F28, F38, F45) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Phragmocone evolute, innermost whorls depressed, outer whorls increasingly compressed with subtriangular whorl section. Flanks slightly arched, maximum inflation at one-third of lateral height, umbilical shoulder rounded, venter acutely rounded. Inner whorls ornamented with thick ribs originating at the umbilical suture. Ribs are rursiradiate on umbilical wall and turn prorsiradiate on umbilical shoulder. Primary ribs branch into two secondaries at the center of the flank, i.e. along the umbilical suture of the succeeding whorl. Secondary ribs thinner than inter-rib space, free secondary rib between two adjacent pairs of secondary ribs. Secondary ribs cross the venter with slight forward-directed convexity. Constrictions distinct, at least three per whorl, noticed by sudden change in the forward inclination of ribs. Whorls become smooth after 150 mm diameter. Suture lines well preserved.

Remarks: The present specimens match *Sivajiceras paramorphum* as described by Spath (1931) and Waagen (1875) in ornamentation, whorl shape, and dimensional proportions. In a recent review, Dutta and Bardhan (2016) synonymized most of the species of *Sivajiceras* described by earlier authors with *Sivajiceras paramorphum*. Indeed, it seems likely that many described taxa are merely part of a morphologically variable biospecies. This could be proven, if the different taxa are found in the same horizon and transient forms exist. However, the present specimens of *Sivajiceras* are from a condensed horizon and show signs of reworking. Consequently, it cannot be safely assumed that they lived at the same time. It is similarly possible that the taxa described by Spath (1931) and others form part of an evolutionary lineage, in which the different morphospecies are separated by short time intervals and consequently occur in different horizons where sedimentary rates are higher. Until this has not been investigated in detail, it seems justified to keep the different species separated. *Sivajiceras paramorphum* can be distinguished from *Sivajiceras kleidos* (Spath, 1931: 289) by its smaller umbilicus, thicker and more distant primary ribs, and the disappearance of ornamentation on the outer whorl of the phragmocone. *Sivajiceras aureum* is another comparable species, but has a slightly wider umbilicus and thinner as well as denser ribs (see below).

Previous records from the western margin of the Indian subcontinent: Waagen (1875) and Spath (1931) recorded

Sivajiceras paramorphum from the Golden Oolite of Keera Dome in the Kachchh Basin.

Age: Following Krishna (2017), *Sivajiceras paramorphum* occurs within the Middle Callovian including parts of the Anceps and Obtusicosta zones (Paramorphum and Obtusicosta subzones).

Sivajiceras aureum Spath, 1930

(Pl. II, figs. F-H; Pl. III, figs A-F; Table 1)

1875 *Perisphinctes* cf. *funatus* (non Oppel) - Waagen, p. 155, pl. 47, fig. 2a, b [synonymized by Spath 1931].

1931 *Sivajiceras aureum* Spath - Spath, p. 291, pl. 51, fig. 3, pl. 60, fig. 9a, b, pl. 64, figs 5a, b, 6a, b.

1931 *Sivajiceras* sp. ind. nov. - Spath, p. 292, pl. 66, fig. 1a-c, pl. 79, fig. 6.

Material: 5 specimens (RUC2009Kanod F30, F31, F32, F47, F51) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Phragmocones large, evolute. Whorl section compressed with slightly arched flanks and rounded venter. Ornamentation consists of coarse, moderately rounded primary ribs which originate rursiradially and faintly near the umbilical suture. Ribs turn slightly prorsiradiate on the flank, thereby creating a slight forward-directed concavity at the umbilical shoulder. On the inner whorls, primaries bifurcate at the centre of the flank with a free secondary rib between two adjacent pairs of secondary ribs. On the outer whorl, primaries trifurcate at the centre of the flank. Secondary ribs thinner than inter-rib spaces. Secondary ribs cross the venter with slight forward-directed convexity. The inter-rib space between primary ribs gradually increases towards the outer whorl. Umbilical wall steep. Suture lines well preserved.

Remarks: The dimensions, rib pattern, and whorl shape of the present specimens match *Sivajiceras aureum*. The morphological features and dimensions of the present specimens also match material described as *Sivajiceras* sp. ind. nov. by Spath (1931). The dimensions can also be compared with those of *Kinkeliniceras kinkelini* (see below), but this species has a markedly different ornamentation.

Previous records from the western margin of the Indian subcontinent: Waagen (1875) and Spath (1927-1931) recorded *Sivajiceras aureum* from the Golden Oolite of Keera Dome in the Kachchh Basin. *Sivajiceras* sp. ind. nov. of Spath (1931) comes from Keera Dome, Walakhavas, and the Ler-Hamundra ellipse in the Kachchh Basin

Age: Spath (1933) assigned an Early to early Middle Callovian age to the species (Rehmanni and lower Anceps Zone; Spath, 1933).

Sivajiceras sp. A

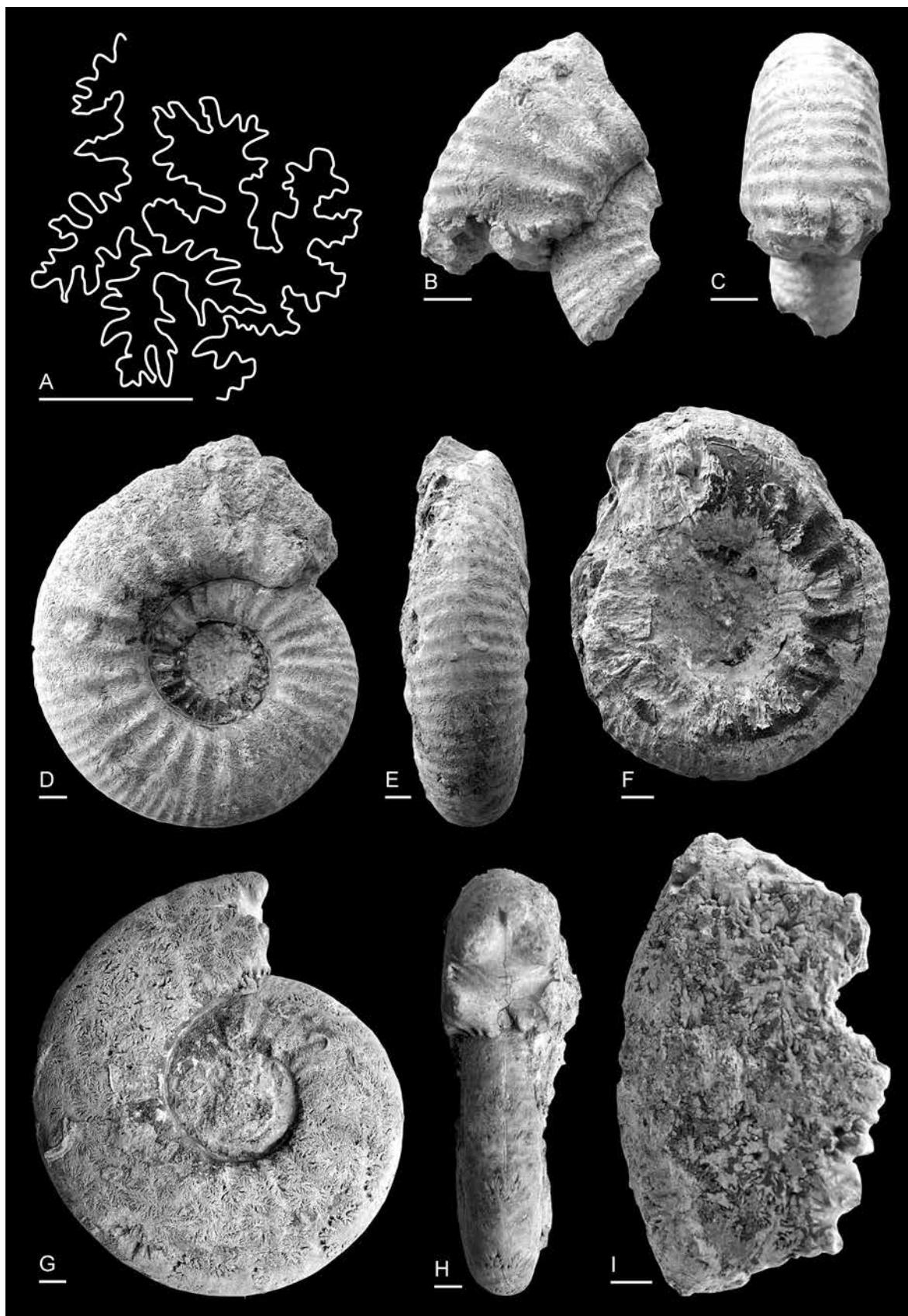
(Pl. III, figs. G-I; Pl. IV, figs. A-F; Table 1)

aff. 1931 *Sivajiceras* sp. ind. nov. - Spath, p. 292, pl. 66, fig. 1a-c, pl. 79, fig. 6.

Material: 6 specimens (RUC2009Kanod F7, F10, F11, F29, F44, F46) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

EXPLANATION OF PLATE III

Ammonites from the Kanod River Section (scale bars = 10 mm). A-F. *Sivajiceras aureum* Spath, 1930 from Bed 10. (A) RUC2009Kanod F31, part of the suture line; (B) RUC2009Kanod F47, lateral view; (C) RUC2009Kanod F47, ventral view; (D) RUC2009Kanod F32, lateral view; (E) RUC2009Kanod F32, ventral view. (F). RUC2009Kanod F51, lateral view. G-I. *Sivajiceras* sp. A from Bed 10. (G) RUC2009Kanod F7, lateral view; (H) RUC2009Kanod F7, apertural view; (I) RUC2009Kanod F10, lateral view.



Description: Fragments of large, evolute phragmocones. Whorl section compressed, flanks sub-triangular, nearly flat to slightly arched, and venter moderately narrowly rounded. Inner whorls show thick primary ribs originating rursiradiately on umbilical wall and turning prorsiradiately on flank. Outer whorls with gradually thinner ribs or are entirely smooth. Primaries branch into three secondary ribs at mid-flank. Secondaries feeble, thinner than the inter-rib spaces, crossing the venter with slight forward-directed convexity. Umbilical wall steep. Suture lines well preserved.

Remarks: The ribbing pattern and proportional dimensions of the present specimens match the material described as *Sivajiceras* sp. ind. nov. by Spath (1931), but the whorl section is more compressed, and the venter is more narrowly rounded. The specimens are also close to *Sivajiceras aureum*, but the whorl section is more compressed.

Previous records from the western margin at the Indian subcontinent: The material of Spath (1931) comes from Keera Dome, Walakhavas, and the Ler-Hamundra ellipse in the Kachchh Basin.

Age: Spath (1931) assigned an Early Callovian age to his material (Rehmanni Zone).

Sivajiceras cf. *besairiei* Collignon, 1958
(Pl. IV, fig. G; Table 1)

cf. 1958 *Sivajiceras besairiei* sp. nov. - Collignon, pl. 20, fig. 84, 84a.

Material: 1 fragmentary specimen (RUC2009Kanod F55) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Fragment of a body chamber of an evolute shell. Whorl section compressed with slightly arched flanks and rounded venter. Umbilical wall narrow.

Remarks: The dimensions, whorl-section and smooth lateral surface of the body chamber match *Sivajiceras besairiei* as illustrated by Collignon (1958). The species is closely related to *Sivajiceras kleidos* described by Spath (1931: 289), but the latter exhibits coarser ribbing. Since the present specimen is only a poorly preserved fragment of the body whorl, it has been assigned to the species only tentatively.

Age: Collignon (1958) assigned a late Early Callovian age to *Sivajiceras besairiei* (Semilaevis Zone).

Genus ***Obtusicoelites*** Buckman, 1921
Type species *Perisphinctes obtusicoelita* Waagen, 1875
Obtusicoelites obtusicoelita Waagen, 1875
(Pl. IV, figs. H-O; Table 1)

1875 *Perisphinctes obtusicoelita* sp. nov. - Waagen, p. 146, pl. 38, figs 1a, b, 2, 3a, b.

1931 *Obtusicoelites obtusicoelita* (Waagen) - Spath, p. 296, pl. 55, fig. 2, pl. 64, fig. 3a, b.

2006 *Obtusicoelites obtusicoelita* (Waagen) - Prasad, p. 33, pl. 6, fig. 2, pl. 7, figs 3, 6a, b.

2016 *Obtusicoelites obtusicoelita* (Waagen) - Dutta and Bardhan, p. 35, figs 6b, 10, 11a-m, 12a-l.

Material: 5 specimens (RUC2009Kanod F23, F33, F35, F49, F50) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Fragments of evolute phragmocones. Whorl section with broadly rounded flanks and narrowly rounded venter, depressed in inner whorls, gradually becoming more compressed towards outer whorls. Ornamentation consists of moderately coarse, sharp primary ribs originating at umbilical suture, crossing the umbilical wall rursiradiately and turn prorsiradiately on the flank with forward-directed concavity. Primaries branch slightly above mid-lateral height into two secondary ribs on the inner whorls and three on the outer whorls, more or less of same thickness. Occasionally free secondaries occur between two pairs of secondary ribs. Inter-rib space variable but mostly wider than thickness of rib. Suture lines well preserved.

Remarks: All the specimens are fragmentary in nature. Their proportional dimensions and ribbing patterns match *Obtusicoelites obtusicoelita* as described by Spath (1931). *Obtusicoelites obtusicoelita* can be distinguished from *Obtusicoelites buckmani* (Spath, 1931: 300) by its slightly smaller umbilicus and finer ribbing. Considering its ribbing pattern, specimen RUC2009Kanod F33 is somewhat closer to *Obtusicoelites buckmani*, but its whorl shape and dimensions match *Obtusicoelites obtusicoelita*.

Previous records from the western margin at the Indian sub continent: *Obtusicoelites obtusicoelita* is well known from the Callovian strata of the Kachchh Basin, where it has been recorded by a series of authors at several localities (e.g., Waagen, 1875; Spath, 1931; Dutta and Bardhan, 2016; Krishna, 2017). Within the Jaisalmer Basin, Prasad (2006) recorded the species from the Kuldhar Member of the Jaisalmer Formation, 3 km southwest of the village Kanod.

Age: Following Krishna (2017), *Obtusicoelites obtusicoelita* first appeared in the late Middle Callovian (*Obtusicoelita* Zone) and continued into the Late Callovian (*Athleta* Zone). Dutta and Bardhan (2016), however, recorded the species already from the early Middle Callovian (*Anceps* Zone) onwards.

Genus ***Kinkeliniceras*** Buckman, 1921
Type species *Proplanulites kinkelini* Dacqué, 1909

Kinkeliniceras kinkelini Dacqué, 1909
(Pl. V, figs. A-D; Table 1)

1909 *Proplanulites kinkelini* sp. nov. - Dacqué, in Dacqué and Krenkel, p. 168.

1910 *Proplanulites kinkelini* Dacqué - Dacqué, p. 36, pl. 5, fig. 1, pl. 6, figs 1-3, text-fig. 17.

1931 *Kinkeliniceras kinkelini* (Dacqué) - Spath, p. 307, pl. 58, fig. 3a, b, pl. 62, figs 7a, b, 10.

2016 *Kinkeliniceras kinkelini* (Dacqué) - Dutta and Bardhan, p. 47, fig. 17a-l.

Material: 2 specimens (RUC2009Kanod F34, F39) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

EXPLANATION OF PLATE IV

Ammonites from the Kanod River Section (scale bars = 10 mm). A-F. *Sivajiceras* sp. A from Bed 10. (A) RUC2009Kanod F44, lateral view; (B) RUC2009Kanod F44, apertural view; (C) RUC2009Kanod F46, lateral view; (D) RUC2009Kanod F46, ventral view; (E) RUC2009Kanod F11, lateral view; (F) RUC2009Kanod F29, lateral view. G. *Sivajiceras* cf. *besairiei* Collignon, 1958 from Bed 10. RUC2009Kanod F55, lateral view. H-O. *Obtusicoelites obtusicoelita* (Waagen, 1875) from Bed 10. (H) RUC2009Kanod F23, lateral view; (I) RUC2009Kanod F33, lateral view; (J) RUC2009Kanod F33, ventral view; (K) RUC2009Kanod F35, lateral view; (L) RUC2009Kanod F35, ventral view; (M) RUC2009Kanod F49, lateral view; (N) RUC2009Kanod F50, lateral view; (O) RUC2009Kanod F50, lateral view.

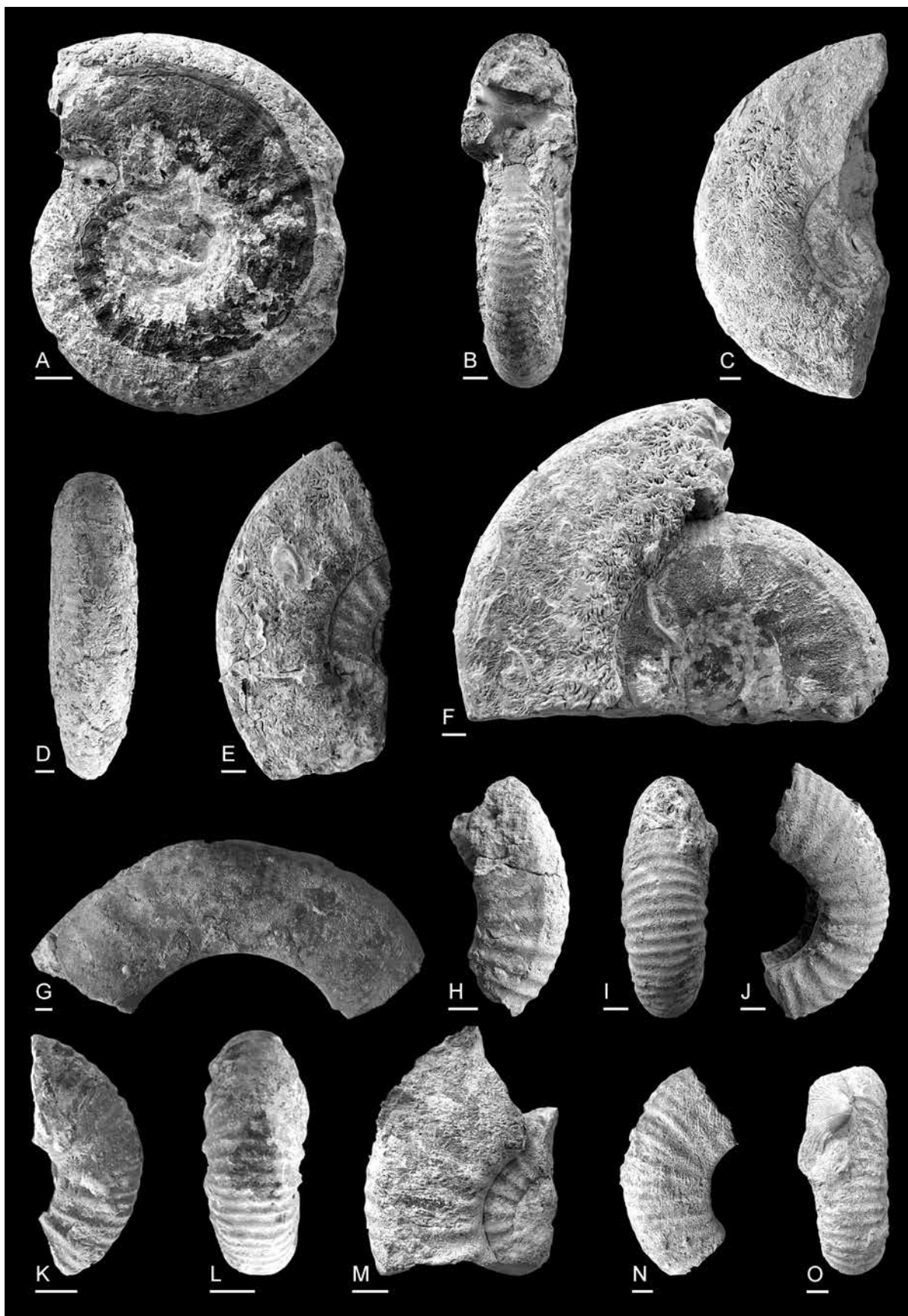


Table 2. Callovian ammonites recorded in the present study from the northeastern Jaisalmer Basin (biostratigraphic ranges according to Spath, 1927-1933; Collignon, 1958; Jana *et al.*, 2005; Prasad, 2006; Dutta and Bardhan, 2016; Krishna, 2017).

species	bed no.	age	ammonite zones	ammonite subzones
Family Opeletiidae Bonarelli, 1894				
<i>Hecticoceras</i> cf. <i>hecticum</i> (Reinecke, 1818)	10	Early-Middle Callovian	-	-
Hecticoceratinae	11	Late Callovian	-	-
Family Macrocephalitidae Buckman, 1922				
<i>Eucycloceras opis</i> (J. de C. Sowerby, 1840)	10	Early-Middle Callovian	Semilaevis-Anceps	Opis/Eucyclum-Ramosa
<i>Idiocycloceras</i> sp. ind.	10	?Middle Callovian	?Anceps	-
Perisphinctidae Steinmann, 1890				
<i>Sivajiceras paramorphum</i> (Waagen, 1875)	10	Middle Callovian	Anceps-Obtusica	Paramorphum-Obtusica
<i>Sivajiceras aureum</i> Spath, 1930	10	Early-Middle Callovian	?Semilaevis-Anceps	-
<i>Sivajiceras</i> sp. A	10	Early Callovian	?Semilaevis	-
<i>Sivajiceras</i> cf. <i>besairiei</i> Collignon, 1958	10	Early Callovian	Semilaevis	-
<i>Obtusicosites obtusica</i> (Waagen, 1875)	10	Middle-Late Callovian	Anceps-Athleta	?Ramosa-Depressum
<i>Kinkeliniceras kinkelini</i> (Dacqué, 1909)	10	Middle-Late Callovian	Obtusica-Athleta	Obtusica-Depressum
<i>Hubertoceras</i> aff. <i>mutans</i> (Waagen, 1875)	10	Middle-Late Callovian	Anceps-Athleta	Paramorphum-Depressum
<i>Hubertoceras hubertus</i> Spath, 1931	10	Middle-Late Callovian	Obtusica-Athleta	Catillus-Depressum

Description: Phragmocone small (D = ca. 42 and 73 mm), moderately evolute, with onset of body chamber preserved in one of the specimens (RUC2009Kanod F39). Whorl section compressed, oval, with slightly arched flanks and rounded venter. Ornamentation consists of moderately coarse, sharp primary ribs originating at umbilical suture, crossing the umbilical wall rursiradially and turning rectiradially on the flank thereby forming a forward-directed concavity at the umbilical shoulder. Primary ribs slightly sinuous, uniformly thick, branching into two secondary ribs at the centre of the flank. Secondary ribs number 31-33 per half-whorl at a diameter of 64 mm, occasionally free secondary ribs occur between two pairs of secondary ribs. Inter-rib space variable, but wider than rib thickness. Umbilical wall slightly steep. Suture lines well preserved.

Remarks: The morphological features and dimensions of the present specimens, match *Kinkeliniceras kinkelini* as illustrated by Spath (1931).

Previous records from the western margin of the Indian subcontinent: Spath (1931) recorded this species from Fakirwari in the Kachchh Basin. Dutta and Bardhan (2016) noted it from Keera Dome in the Kachchh Basin.

Age: Krishna (2017) assigned a late Middle to Late Callovian age (Obtusica to Athleta zones) to *Kinkeliniceras kinkelini*.

Genus *Hubertoceras* Spath, 1930

Type species *Perisphinctes omphalodes* Waagen, 1875

Hubertoceras aff. *mutans* Waagen, 1875
(Pl. V, figs. E-G; Table 1)

aff. 1875 *Perisphinctes mutans* sp. nov. - Waagen, p. 151, pl. 39, fig. 1a, b.

aff. 1931 *Hubertoceras mutans* (Waagen) - Spath, p. 318, pl. 54, fig. 8a, b, pl. 56, fig. 7a, b, pl. 57, fig. 6a, b, pl. 60, fig. 1a, b, pl. 62, fig. 6.

aff. 2006 *Hubertoceras mutans* (Waagen) - Prasad, p. 33, pl. 17, fig. 7, pl. 19, fig. 4, pl. 20, fig. 7.

Material: 2 specimens (RUC2009Kanod F15, F20) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

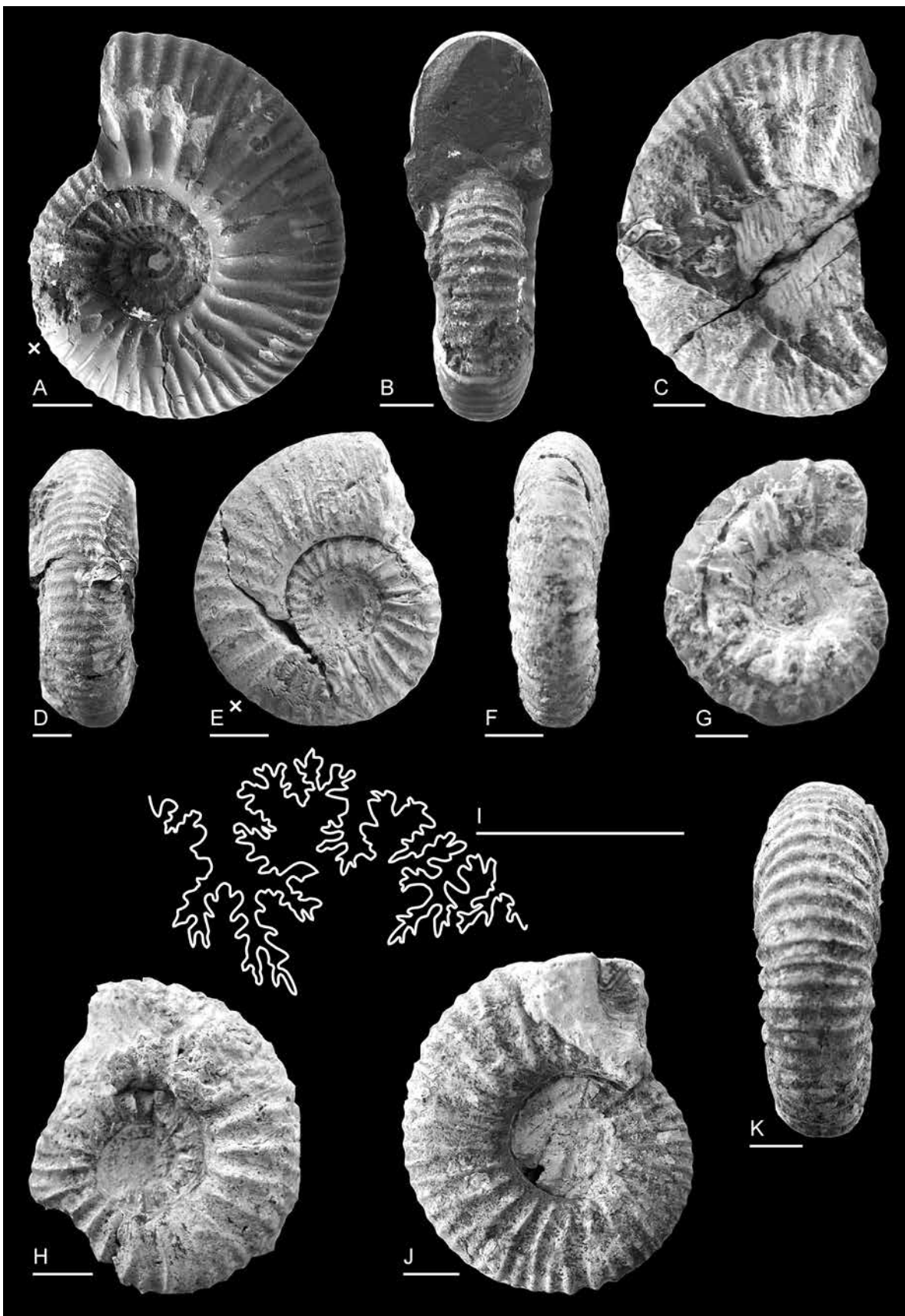
Description: Shell small, with phragmocone (D = 39 mm) and small part of body chamber preserved, evolute. Whorl section compressed, flanks slightly arched, and venter acutely rounded. Ornamentation consists of sharp primary ribs originating at umbilical suture, crossing the umbilical wall rectiradially to rursiradially and continuing the flank rectiradially where they abruptly turn slightly prorsiradially. Primary ribs branch into secondary ribs of more or less the same thickness, but free secondary ribs are also intercalated at three-fourth of lateral height. Inter-rib space variable, but mostly wider than rib thickness. Umbilical wall steep. Suture lines in parts well preserved.

Remarks: The ornamentation and umbilical diameter of the present specimens match *Hubertoceras mutans*, but they are less compressed. In this aspect the present specimens are somewhat similar to *Hubertoceras hubertus* as described by Spath (1931: 320), which also shows a similar umbilical diameter. *Hubertoceras hubertus*, however, possesses a larger phragmocone and exhibits more consistently bifurcating ribs (see below). *Hubertoceras mutans* can be distinguished from *Hubertoceras arcicosta* (Waagen, 1875: 316) by its smaller umbilicus.

Previous records from the western margin of the Indian subcontinent: Waagen (1875) and Spath (1931) recorded *Hubertoceras mutans* from a series of localities throughout the Kachchh Basin. Within the Jaisalmer Basin, Prasad (2006) recorded the species from the Kuldhar Member of the Jaisalmer Formation, 1 km south of the village Kuldhar.

EXPLANATION OF PLATE V

Ammonites from the Kanod River Section (scale bars = 10 mm). A-D. *Kinkeliniceras kinkelini* (Dacqué, 1909) from Bed 10. (A) RUC2009Kanod F39, lateral view; (B) RUC2009Kanod F39, apertural view; (C) RUC2009Kanod F34, lateral view; (D) RUC2009Kanod F34, ventral view. E-G. *Hubertoceras* aff. *mutans* (Waagen, 1875) from Bed 10. (E) RUC2009Kanod F15, lateral view; (F) RUC2009Kanod F15, ventral view; (G) RUC2009Kanod F20, lateral view. H-K. *Hubertoceras hubertus* Spath, 1931 from Bed 10. (H) RUC2009Kanod F21, lateral view; (I) RUC2009Kanod F22, suture line; (J) RUC2009Kanod F22, lateral view; (K) RUC2009Kanod F22, ventral view.



		Northern Tethyan margin ¹		Kachchh (southern Tethyan margin) ²		Jaisalmer (southern Tethyan margin)		Bed 11
		zones		zones		Kuldhar River ³	Kanod River Section ⁴	
				subzones		subzones	zones	
Callovian	Upper	Lamberti	Ponderosum	Ponderosum	?			Bed 10 (condensed horizon)
		Athleta	Athleta	Depressum Pseudorion	?	Athleta		
	Middle	Coronatum	Obtusica	Catillus Obtusica	?	Obtusica		
		Anceps	Anceps	Paramorphum Kleidios Ramosa	?	Anceps		
	Lower	Gracilis	Semilaevis	Opis/Eucyclum	Opis/Eucyclum		Semilaevis	
				Semilaevis	Semilaevis			
				Formosus	Formosus			
		Chrysoolithicus	Diadematus	?				
			Chrysoolithicus	?				
	Bullatus	Madagascariensis	Madagascariensis	Madagascariensis				

¹Cariou and Hantzpergue, 1997

²Krishna et al., 2009, 2011; Krishna, 2017

³Krishna, 1987; Chatterjee, 1990; Prasad, 2006; Jain, 2008; Pandey et al., 2014; Sharma and Pandey, 2016

⁴present study

Fig. 5. Biostratigraphic framework for the Callovian of the Kachchh and Jaisalmer basins.

Age: Krishna (2017) assigned a late Middle to Late Callovian age (Anceps to Athleta zones) to *Hubertoceras mutans*.

Hubertoceras hubertus Spath, 1931
(Pl. V, figs. H-K; Table 1)

1931 *Hubertoceras hubertus* sp. nov. - Spath, p. 320, pl. 52, fig. 7, pl. 55, fig. 6, pl. 56, fig. 4, pl. 57, fig. 4a-c, pl. 59, fig. 1, pl. 68, fig. 11.

Material: 2 specimens (RUC2009Kanod F21, F22) from Bed 10 of the section in the river valley 1 km west of the village Kanod, northeastern Jaisalmer Basin.

Description: Small, moderately evolute phragmocones. Whorl section slightly compressed, flanks slightly arched with rounded venter. Ornamentation consists of thin and sharp ribs on the inner whorls which turn coarser, and less sharp towards the end of the outer whorl. Primary ribs originate at umbilical suture slightly rursiradiately and turn prorsiradiately at the umbilical shoulder with slight forward-directed concavity. Primary ribs bifurcate slightly above the mid-flank. Free secondary ribs are rarely intercalated. At a diameter of 51 mm, secondary ribs number 25 per half whorl. Secondaries are very slightly thinner than primary ribs and cross the venter with slight forward-directed convexity. Inter-rib space uniform, wider than rib thickness. Umbilical wall steep. Suture line well preserved.

Remarks: The morphological features and proportional dimensions of the present specimens match *Hubertoceras hubertus* as described by Spath (1931). *Hubertoceras dhosaense* illustrated by Spath (1931: 319, pl. 79, fig. 1a, b) differs in having coarser ribs and a smaller umbilicus. *Hubertoceras mutans* described above shows a more compressed shell and denser ribs. *Hubertoceras omphalodes* is also more compressed (Waagen, 1875: 150, pl. 38, fig. 2a, b).

Previous records from the western margin of the Indian subcontinent: Spath (1931) recorded this species from Ler, Fakirwari, Walakhavas, Samatra, and Rudramata in the Kachchh Basin.

Age: Krishna (2017) assigned a latest Middle to Late Callovian age (Catillus Subzone of the Obtusica Zone to Athleta Zone) to the species.

DISCUSSION

Nearly all the ammonites described and illustrated in the present work have been collected from a condensed horizon in the northeastern Jaisalmer Basin. Most of them are incomplete and fragmentary in nature. However, their ornamentation is preserved and mostly proportional dimensions for comparisons could be measured. The ornamentation has been found to be a very useful character in the identification of these late Early to early Late Callovian ammonites. The specimens belong to three families, i.e. Oppeliidae, Macrocephalitidae, and Perisphinctidae. Most of the taxa are members of the Perisphinctidae (Table 2).

Biostratigraphy

Although palaeontological research in the Jaisalmer Basin has continued for more than a century, the biostratigraphic framework is less refined than in the neighbouring Kachchh Basin with its more expanded Jurassic succession (Krishna, 1987; Pandey et al., 2009, 2014; Fürsich et al., 2013). Within the Callovian strata of the Kachchh Basin seven ammonite zones have been demarcated. These are the Madagascariensis, Chrysoolithicus, Semilaevis, Anceps, Obtusica, Athleta, and Ponderosum zones in ascending order (Fig. 5; Krishna et al., 2009, 2011; Krishna, 2017). In the Jaisalmer Basin, these zones can be best studied at the Kuldhar River (16 km southwest of the city Jaisalmer), the type section of the Kuldhar Member (Chatterjee, 1990; Prasad, 2006; Jain, 2008). At this locality, Krishna (1987) recorded five ammonite assemblage zones (*Macrocephalites madagascariensis* a.z., *Macrocephalites transitorius* a.z., *Subkosmatia opis* a.z., *Reineckeia anceps* a.z., and *Callotia gigantea* a.z.) ranging in age from Early to

Middle Callovian. Prasad (2006) recorded one more ammonite zone, the *Properisphinctes* Zone, of a Late Callovian age (based on the record of *P. aff. bernensis* from ash grey shales in the Rupsi Village Section). The present authors have further observed the genera *Obtusocostites* and *Peltoceras* in horizons at the Kuldhar River Section, which are younger than those mentioned by Krishna (1987). These previous studies and the ammonites recorded in the present study, although from a different locality in the Jaisalmer Basin, suggest that most of the Callovian ammonite zones of the Kachchh Basin are also present in the Jaisalmer Basin. However, even at the best preserved Kuldhar River Section in the southwestern Jaisalmer Basin, these zones are less expanded than in the Kachchh Basin, indicating at least condensation of several subzones (Pandey *et al.*, 2014: 88). This agrees well with signs of reworking and/or prolonged exposure of fossils in the Callovian of the Jaisalmer Basin, in which ammonites commonly show encrustations by oysters and serpulids. The Callovian Kuldhar Member can be traced from its type locality both west- and eastwards. Towards the west, the succession narrows down to a maximum of two meters, yielding the index species *Eucycloceras opis* (Sharma and Pandey, 2016). In the east, the Callovian sediments are well exposed along the river section described in the present article. At this locality, the Kuldhar Member contains also reworked concretions and encrusted fossils. The ammonite taxa recorded from one horizon (Bed 10) have been well documented in the Kachchh Basin (e.g., Spath, 1927–1933) and belong to different ammonite zones (Table 2). Their co-occurrence, together with reworked concretions, in a single 30-cm-thick horizon suggests strong condensation during the time of deposition.

Depositional setting

The sedimentary succession at the locality studied records many changes in the depositional setting. The Bathonian Bada Bag Member is dominated by limestones which reflect changes in the energy conditions. The hardgrounds at the base of the section represent sediment starvation during a sea-level highstand, but the topmost bed of the unit is a rudstone reflecting high-energy conditions in a shallow setting. Towards the Callovian Kuldhar Member a shift from carbonate to siliciclastic sedimentation is apparent. This is strikingly similar to the Kachchh Basin, where the same shift has been connected to a change from a more arid climate in the Bathonian to more humid weather conditions in the Callovian (Fürsich *et al.*, 2005). Increased rainfalls can be expected to bring more siliciclastics into the basin, which indeed dominate the Kuldhar Member. The reworked concretions at the Bathonian-Callovian boundary in the Jaisalmer Basin point to a transgression, during which net sediment accumulation is low. The following Callovian strata are fine-grained, bioturbated siliciclastics pointing to sediment starvation in a low-energy setting during a sea-level highstand (possibly a maximum flooding zone).

CONCLUSIONS

The Jaisalmer Basin provides a unique opportunity to study a condensed horizon of late Early to early Late Callovian age. The ammonite taxa recorded in the present study and by earlier workers show that most Callovian ammonite zones are present in the Jaisalmer Basin. However, the succession is much thinner in the Jaisalmer Basin compared to the neighbouring Kachchh Basin. The occurrence of ammonites encrusted by oysters and serpulids further indicate sediment starvation.

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