



TAXONOMY OF LATE BATHONIAN-OXFORDIAN AMMONITES FROM THE JAISALMER BASIN: IMPLICATIONS FOR INTRABASINAL LITHO- AND BIOSTRATIGRAPHIC CORRELATIONS

JITENDRA KUMAR SHARMA and DHIRENDRA KUMAR PANDEY*

DEPARTMENT OF GEOLOGY, UNIVERSITY OF RAJASTHAN, JAIPUR 302004;

E-MAIL: dhirendrap@hotmail.com

*CORRESPONDING AUTHOR

ABSTRACT

Late Bathonian-Oxfordian marine rocks exposed west of the village Kuldhar in the Jaisalmer Basin (western India) have yielded several time-diagnostic ammonites of the families Oppeliidae, Sphaeroceratidae, Reineckeidae, and Perisphinctidae. The paper contains taxonomic details and illustrations of 16 taxa. Records of ammonites by earlier workers and by the present authors suggest that the Bada Bag, Kuldhar, and Jajiya members represent Late Bathonian, Callovian, and Oxfordian age, respectively.

Keywords: Late Bathonian-Oxfordian, Jaisalmer Basin, Jaisalmer Formation, ammonites.

INTRODUCTION

The Jaisalmer Basin is a shelf basin situated at the western margin of the Indian craton (Fig. 1). Like the neighboring sedimentary basin of Kachchh, the Jaisalmer Basin is also well suited to study the relationship between organisms and their environment both in a spatial and a temporal context. Well preserved marine fossils, dinosaurs footprints, fresh water biotic elements, hardgrounds, condensed sequences, and shell beds have attracted the attention of palaeontologists, sedimentologists, and stratigraphers since 1826, when Impey visited the region (his observations were later published in Carter, 1861). Recently, Pandey *et al.* (2014) have summarized previous studies, in particular 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, 2009a, b, 2010, 2011, 2012), among others.

Lithostratigraphically, the Jurassic strata of the Jaisalmer Basin have been subdivided into the Lathi, Jaisalmer, Baisakhi, and Bhadasar formations in ascending order. While the Lathi Formation consists mainly of non-marine rocks, the Jaisalmer, Baisakhi, and Bhadasar formations are dominantly composed of marine strata (Table 1).

Table 1: Lithostratigraphic framework of the Jaisalmer Basin (after Das Gupta, 1975; Pandey *et al.*, 2014).

Formation	Member	Age
Bhadasar	Mokal	? E. Cretaceous
	Kala Dungar	Tithonian
Baisakhi	Lanela Rupsi Baisakhi	Ludharwa
Jaisalmer	Jajiya Kuldhar Bada Bag Fort Joyan Hamira	Oxfordian-Tithonian
Lathi	Thaiat Odamia	Bajocian-Oxfordian
		Early-Middle Jurassic (up to Bajocian)

The upper part of the Bada Bag Member, the Kuldhar Member, and the Jajiya Member of the Jaisalmer Formation are best exposed west of the village Kuldhar (Fig. 1). Pandey *et al.* (2010) distinguished four facies within these members in the study area. These facies units are (1) fossiliferous, partly bioturbated and cross-bedded packstone with hardgrounds (upper part of the Bada Bag Member), (2) fossiliferous, bioturbated silty marlstone with inter-beds of wacke- to packstones, occasionally oolitic (Kuldhar Member), (3) low-angle cross-bedded, argillaceous, silty marlstones with interbeds of fine-grained calcareous sandstone to sandy packstone (eastward extension of the Kuldhar Member) and (4) partly bioturbated, low-angle cross-bedded pack- to rudstone and fine- to medium-grained calcareous sandstone (Jajiya Member).

Kachhara and Jodhawat (1981) separated the Jajiya Member from the Kuldhar Member on the basis of a distinct lithology, but mentioned that the Jajiya Member has been separated out from the Kuldhar Member owing to its distinct age". In general, they assigned a Late Callovian-Oxfordian age to the Jajiya Member. This age was inferred based on the occurrence of *Lissoceratoides* (Late Callovian to Late Oxfordian), *Hecticoceras* (*Brightia*) (Late Callovian to Early Oxfordian), *Distichoceras* (Late Callovian to Early Oxfordian), *Epimayaites* (Middle Oxfordian), *Mayaites* (Middle Oxfordian), *Dhosaites* (Middle Oxfordian) and *Hubertoceras* (Middle to Late Callovian; see Kachhara and Jodhawat, 1981).

In the present paper, ammonites collected bed by bed from the three best sections; (1) Kuldhar Nala Section, 1.5 km west of the village Kuldhar (16 km southwest of Jaisalmer city) (Fig. 2), (2) Jajiya Scarp Section, 2.5 km west of the village Kuldhar, and (3) Jajiya River Section, 3.5 km west of the village Kuldhar (Pandey *et al.*, 2012, fig. 6; Pandey *et al.*, 2014, figs. 56, 59) are described and illustrated. The study demarcates the lithological boundaries between the Bada Bag and Kuldhar members as well as Kuldhar and Jajiya members. Furthermore, it precisely demarcates the Bathonian-Callovian and Callovian-Oxfordian boundaries in the sections.

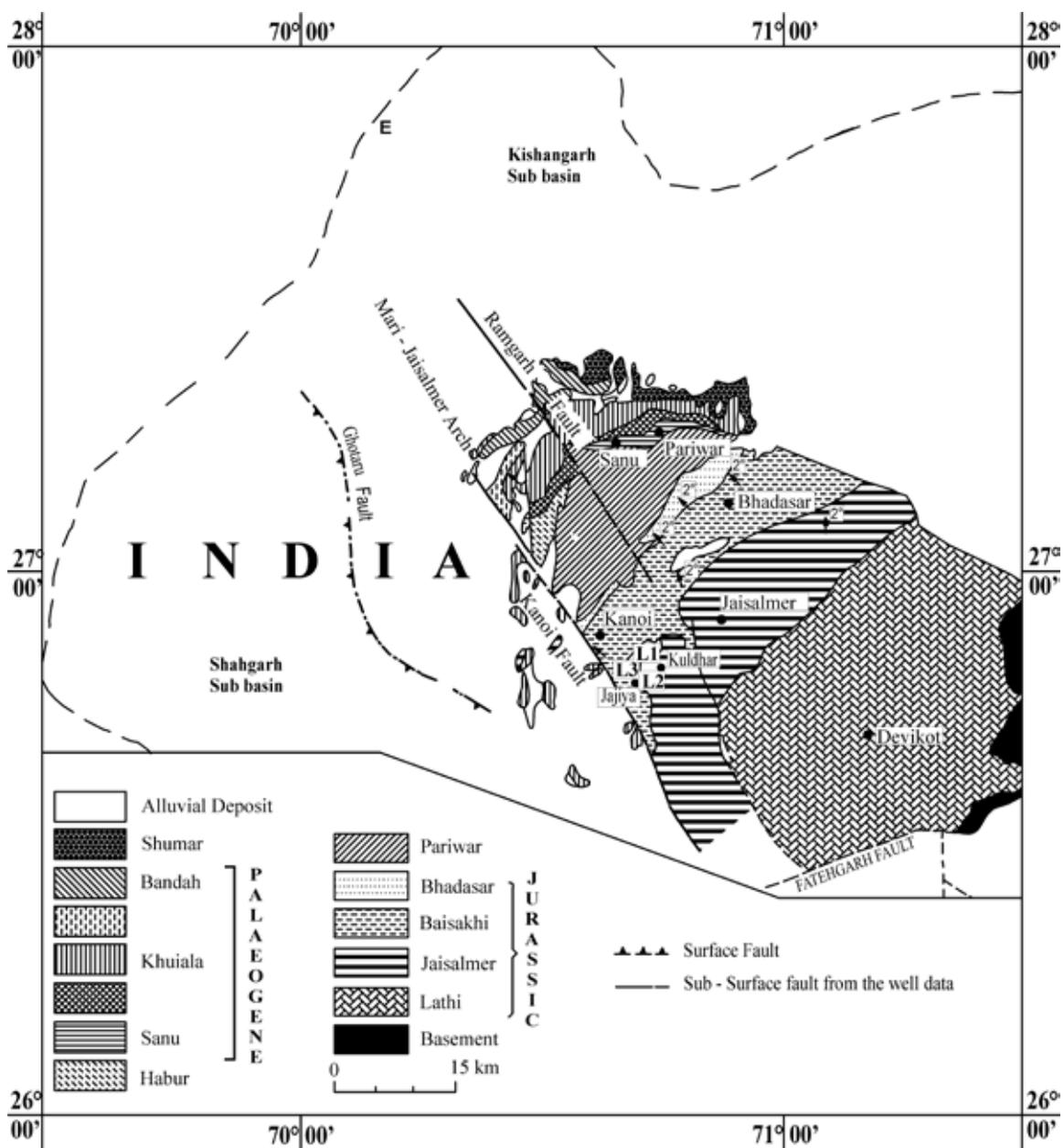


Fig. 1. Geological map of the Jaisalmer Basin (modified after Das Gupta 1975); L1: location of Kuldhar Nala Section, L2: Jajiya Scarp Section and L3: Jajiya River Section (modified after Pandey *et al.*, 2012, 2014, figs. 56, 59).

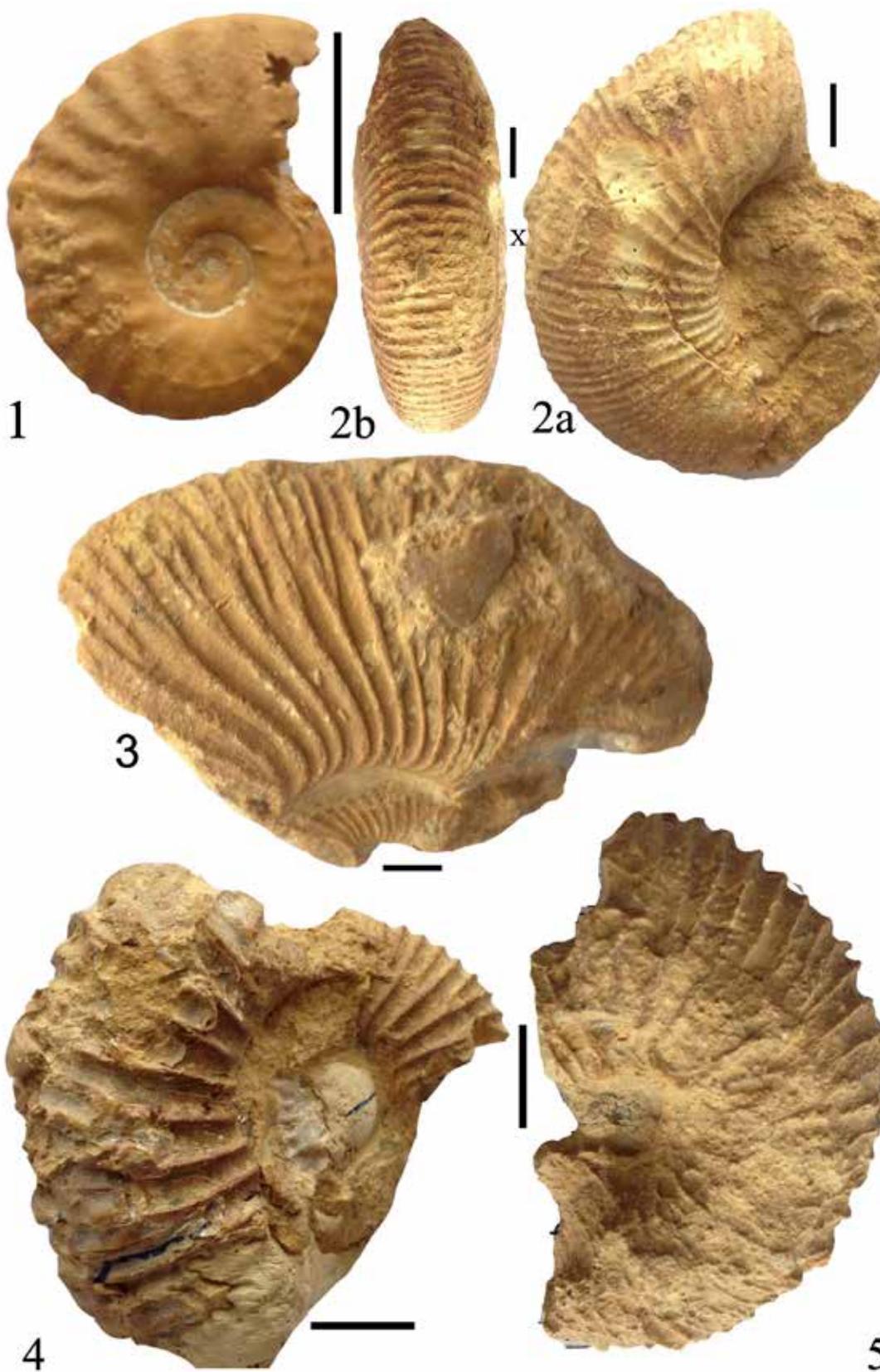
MATERIAL AND METHOD

The present study includes taxonomic descriptions and illustrations of 29 ammonite specimens, collected in several field sessions between 2005 and 2013. Most of the ammonite specimens are fragmentary, but otherwise well preserved and

represent phragmocones. Some of them are encrusted either from one side or from both sides by oysters and/or serpulids. The available collection includes an additional 56 ammonite specimens, but these are so fragmentary in nature that they could not be identified. Some specimens required preparation, but most of them, especially those recovered from soft marly

EXPLANATION OF PLATE I

1. *Prohecticoceras?* sp. from gypsiferous silty marl (Kuldhar Member) above bioturbated beds of the Bada Bag Member (Late Bathonian), Jajiya River Section, scale bar 1 cm, side view, RUC/JR/2010/68; 2a, b. *Epimayaites fulcoides* Spath from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section, scale bar 1 cm, RUC/JSC/2005/62. a) side view, b) ventral view. 3. *Epimayaites* aff. *lemoini* (Spath) from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section, scale bar 1 cm. Side view, RUC/JSC/2005/77. 4. *Dhosaites* cf. *elephantoides* Spath - ex gr. *primus* Spath from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section, scale bar 1 cm. Side view, RUC/JSc/2013/72. 5. *Dhosaites* cf. *elephantoides* Spath - ex gr. *primus* Spath from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section, scale bar 1 cm. Side view, RUC/JSc/2005/81.



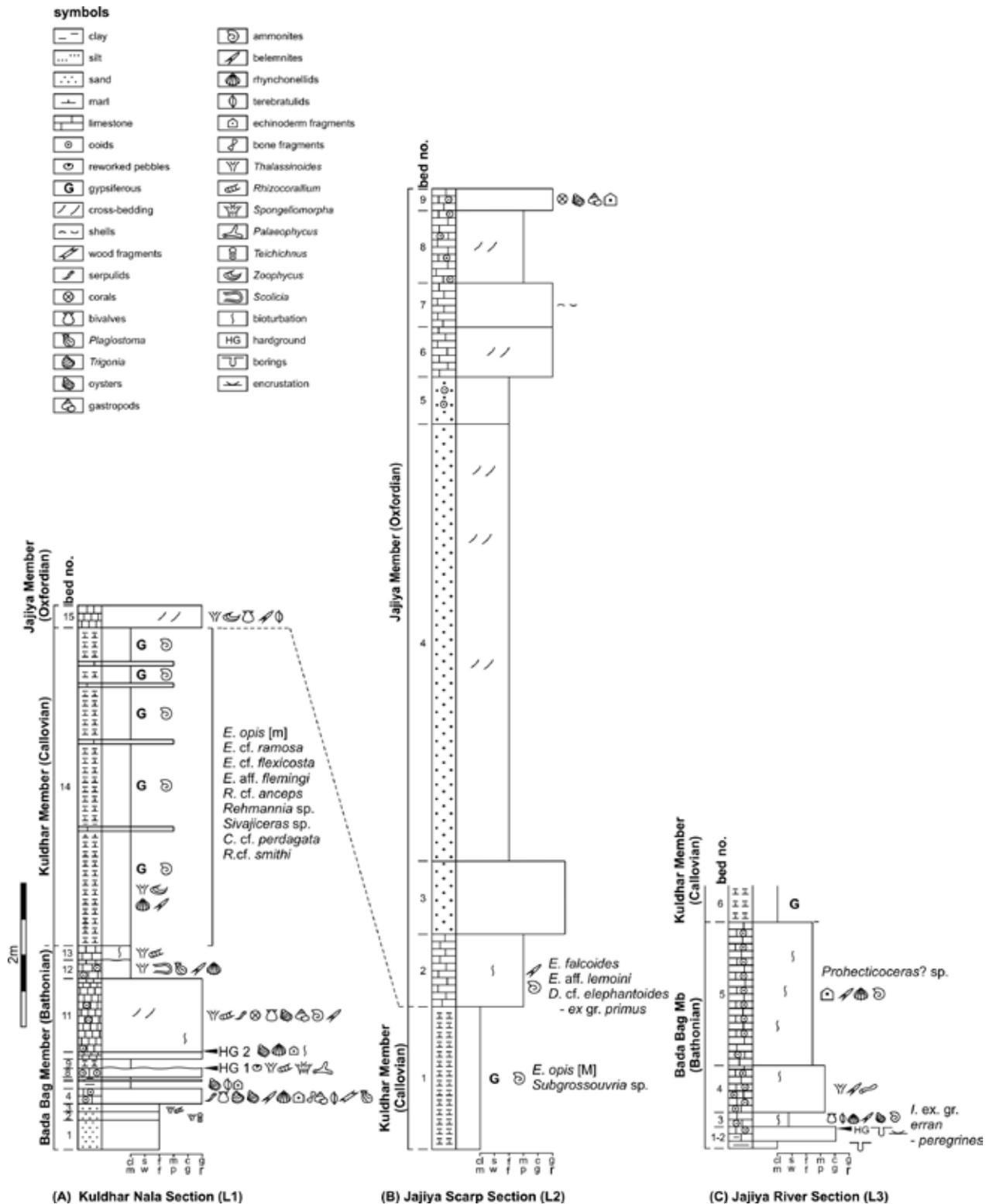
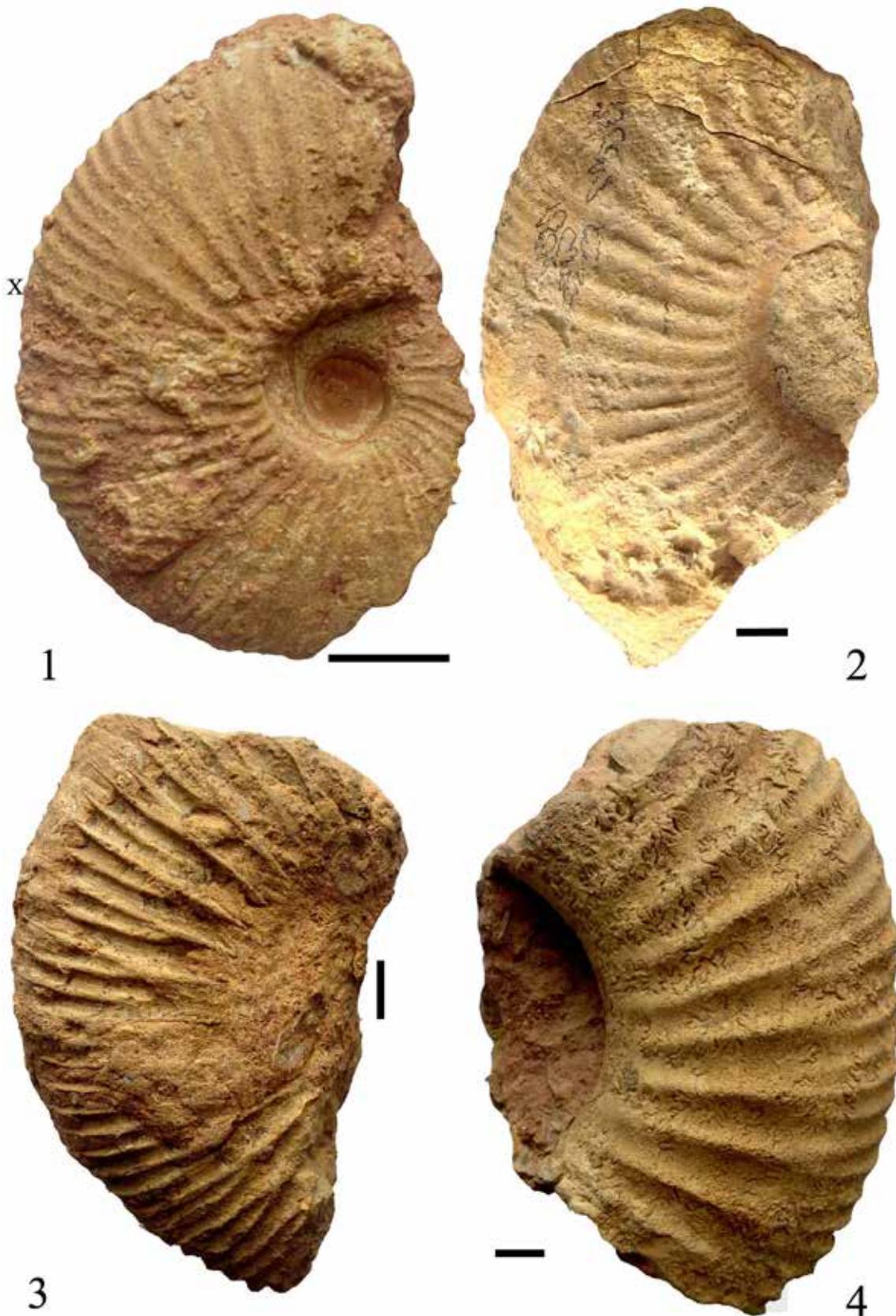


Fig. 2. Litholog of the three studied sections; (A) Kuldhar Nala Section (N26°51'53.45": E70°46'13.19"), (B) Jaijiya Scarp Section (N26°50'42": E70°44'59.94") (C) Jaijiya River Section (N26°50'36.89": E70°44'39.11").

EXPLANATION OF PLATE II

Ammonite specimens collected from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section (figs. 1, 3, 4) and Jaijiya Scarp Section (fig. 2), scale bar 1 cm. 1. *Eucyloceras opus* (J. de C. Sowerby) [m], side view, RUC/KN/2008/25. 2. *Eucyloceras opus* (J. de C. Sowerby) [M], side view, RUC/JSC/2010/69. 3. *Eucyloceras cf. ramosa* (Spath), side view, RUC/KN/2008/16. 4. *Eucyloceras cf. flexicosta* (Prasad), side view, RUC/KN/2008/23.



sediments, needed only washing and soft brushing. For the systematic description mostly the classification of Arkell *et al.* (1957) has been followed, otherwise the references are given. The ammonites of the Kuldhar Member are derived from Bed no. 14 of the Kuldhar Nala Section (Fig. 2) and its lateral extension exposed at the base of the Jajiya Scarp Section.

The dimensions of the specimens were measured with the help of a Chinese digital caliper (Aero space), and the following conventional abbreviations have been used (Fig. 3):

- D: diameter of the shell
- H: height of the whorl at the measured diameter
- H/D: percentage of height of the whorl measured at the measured diameter
- T: thickness of the whorl at the measured diameter
- T/D: percentage of thickness of the whorl measured at the measured diameter
- U: diameter of the umbilicus along the line of the measured diameter

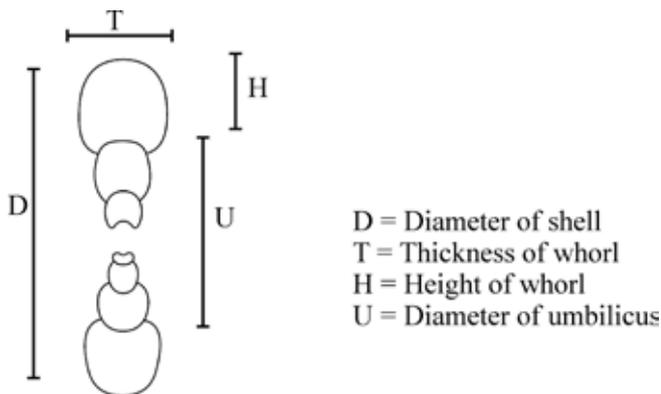


Fig. 3. Explanation of the measurements of ammonites and abbreviations used in the present study (modified after Pandey *et al.*, (2013).

- U/D: percentage of umbilicus with respect to diameter
- H/T: ratio between whorl height and thickness at the measured diameter

SYSTEMATIC DESCRIPTIONS

- Superfamily **Haplocerataceae** Zittel, 1884
- Family **Oppeliidae** Bonarelli, 1894
- Subfamily **Hecticoceratinae** Spath, 1925
- Genus **Prohecticoceras** Spath, 1928

(Type species: *Ammonites retrocostatus* de Grossouvre, 1888)

Prohecticoceras? sp.
 (Pl. I, fig. 1)

Material: One stray specimen (RUC/JR/2010/68) from

bioturbated beds of the Bada Bag Member (Late Bathonian), Jajiya River Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D)-without tubercle	U (U/D)	H/T
RUC/JR/2010/68	22.4	9.5 (42)	6.1 (27)	7.1 (31)	1.5

Description: Phragmocone, ornamentation consists of falcoid ribs with short (less than half of the whorl height), slightly prorsiradiate, thick, distant primary ribs branching into two rursiradiate secondary ribs. Ribs bend backwards at the branching points. Secondary ribs terminate at ventro-lateral edge with a slight bulge. Ventral area narrow, unicarinate.

Remarks: The keel is preserved only at the inner part of the last whorl. The specimen differs from *Hecticoceras Bonarelli* (1894) in having longer primary ribs, which are very short in *Hecticoceras*. Since the present specimen is a small phragmocone, which shows a very narrow ventral area, the specimen has been assigned to *Prohecticoceras* with qualification. *Prohecticoceras* Spath is a Late Bathonian taxon (Arkell *et al.*, 1957, L276). The present specimen has been collected from Middle Callovian gypsiferous silty marl of the Kuldhar Member, probably reworked from the underlying fossiliferous bioturbated rudstone of the Bathonian Bada Bag Member.

- Superfamily **Stephanocerataceae** Neumayr, 1875
 - Family **Sphaeroceratidae** Buckman, 1920
 - Subfamily **Mayaitinae** Spath, 1928
 - Genus **Epimayaites** Spath, 1928
- (Type species: *Stephanoceras transiens* Waagen, 1875)

Epimayaites falcoides Spath, 1928
 (Pl. I, fig. 2a, b)

Epimayaites falcoides nov. sp. - Spath, 1928, p. 242, pl. 38, fig. 6, pl. 40, fig. 6. - Spath, 1931 pl. 67, fig. 7a, b. - Basse and Perrodon, 1951, p. 62, pl. 1, fig. 9. - Collignon, pl. 49, figs. 244, 246, 1959 pl. 56, fig. 269. - Alberti *et al.*, 2015 figs. 24K-O, 30B, 31.

Material: Two specimens (RUC/JSc/2005/62-63) from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section.

Dimensions (in mm)

Specimen no.	D	H (H/D)	T (T/D)	U (U/D)	H/T
RUC/JSc/2005/62	70	32.5 (46)	25 (35)	11.8 (16)	1.3
<i>Epimayaites falcoides</i> Spath (Alberti <i>et al.</i> 2015)	70.6	34.3 (49)	21.4 (30)	11.0 (16)	1.60
<i>Epimayaites falcoides</i> Spath (1928, p. 243)	77	39 (50)	30 (39)	12 (16)	1.28
<i>Epimayaites falcoides</i> Spath (Collignon, 1959, pl. 56, fig. 269)	75	35 (47)	29 (39)	14 (19)	1.21
<i>Epimayaites patella</i> Spath (1928, p. 243) - holotype	66	31 (47)	22 (33)	13 (20)	1.42

EXPLANATION OF PLATE III

Ammonite specimens collected from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section, scale bar 1 cm. 1. *Eucycloceras* cf. *flexicosta* (Prasad), side view, RUC/KN/2008/01. 2. *Eucycloceras* cf. *flexicosta* (Prasad), side view, RUC/KN/2008/23. 3. *Eucycloceras* cf. *flexicosta* (Prasad), side view, RUC/KN/2008/21. 4. *Eucycloceras* aff. *flemingi* (Spath), side view, RUC/KN/2008/49.



1



2



3

Description: Shell consists of moderately large phragmocone and part of body chamber, compressed, involute. Whorl section oval with lateral surfaces merging smoothly into rounded ventral region with indistinct ventrolateral shoulder. Umbilical shoulder distinct, umbilical wall steeply inclined to almost vertical. Maximum inflation slightly below mid-lateral height. The ornamentation consists of dense, fine, flexuous ribs. Primary ribs originate at umbilical suture, run rursiradiately up to umbilical shoulder where ribs bend prorsiradiately with forward concavity on the inner part of the flank. Primary ribs show slight flexuous course and branch into two finer secondaries around mid-flank. Intercalatory secondary ribs common. The secondary ribs cross the ventral region with a prominent forward-directed sinuosity.

Remarks: The present specimens have a slightly smaller size of phragmocone than of *Epimayaites falcooides* described by Alberti *et al.* (2015) based on material from the Kachchh Basin. However, since all other typical characteristics of the taxon are present, it can be assigned to this species. *Epimayaites patella* Spath (1928, pl. 243, pl. 36, fig. 15) has been described as having less flexuous ribs, but is thought to fall within the range of intraspecific variability of *E. falcooides* (Alberti *et al.*, 2015).

Epimayaites aff. *lemoini* (Spath, 1924)
(Pl. I, fig. 3)

aff. *Epimayaites lemoini* (Spath) - Spath, 1928 p. 234, pl. 26, fig. 4a, b, pl. 34, fig. 1.

Material: One specimen (RUC/JSc/2010/77) from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section.

Description: Phragmocone involute, compressed, whorl section subtrigonal with subrounded ventral region and indistinct ventrolateral shoulder. Umbilical shoulder rounded, but distinct. Umbilical wall steeply inclined. Maximum inflation very near umbilical shoulder. The ornamentation consists of slightly flexuous ribs with primaries originating from umbilical wall near the umbilical shoulder and branching mostly into two secondaries slightly below the mid-lateral height. Generally, one free secondary rib is intercalated. Secondary ribs cross the ventral region with pronounced forward-directed sinuosity.

Remarks: The specimen is a small fragment of a phragmocone. It shows all characteristics of the genus *Epimayaites*. Due to the fragmentary nature, dimensions could not be measured and an assignment to a species is difficult. The thickness and density of ribs and whorl section resemble those of the inner whorls of *E. lemoini*, therefore, the specimen has been tentatively assigned to this species.

Genus *Dhosaites* Spath, 1924

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

Remarks: The genus *Dhosaites* includes small to moderately-sized ammonites characterized by coarse, sharp, mostly rectiradiate ribs. Ribs mostly pass straight across the venter (Alberti *et al.*, 2015). Compared to its Early Callovian

homeomorph *Kamptokephalites* Buckman, *Dhosaites* exhibits a comparatively wide umbilicus (Spath, 1928).

Dhosaites cf. *elephantoides* Spath, 1924 - ex
gr. *primus* Spath, 1928
(Pl. I, figs. 4, 5)

cf. *Stephanoceras elephantinum* Sowerby - Waagen, 1875, p. 124, pl. 31, figs. 3, 3a

cf. *Dhosaites elephantoides* n. sp. - Spath, 1928, p. 244, pl. 25, fig. 9; pl. 38, fig. 8a, b.

cf. *Dhosaites elephantoides* Spath - Prasad, 2006, p. 29, Pl.6, figs. 1a, 1b, 3.

cf. *Dhosaites primus* n. sp. - Spath, 1928, 245, pl. 32, fig. 5, pl. 37, fig. 1a, b, pl. 39, fig. 3, pl. 40, fig. 3, pl. 44, fig. 5a, b, 45, fig. 2a, b, pl. 49, figs. 3a,b, 4, 13).

Material: Two specimens (RUC/JSc/2013/72, RUC/JSc/2005/81) from bioturbated rudstone, Jajiya Member (Oxfordian), Jajiya Scarp Section.

Dimensions (in mm):

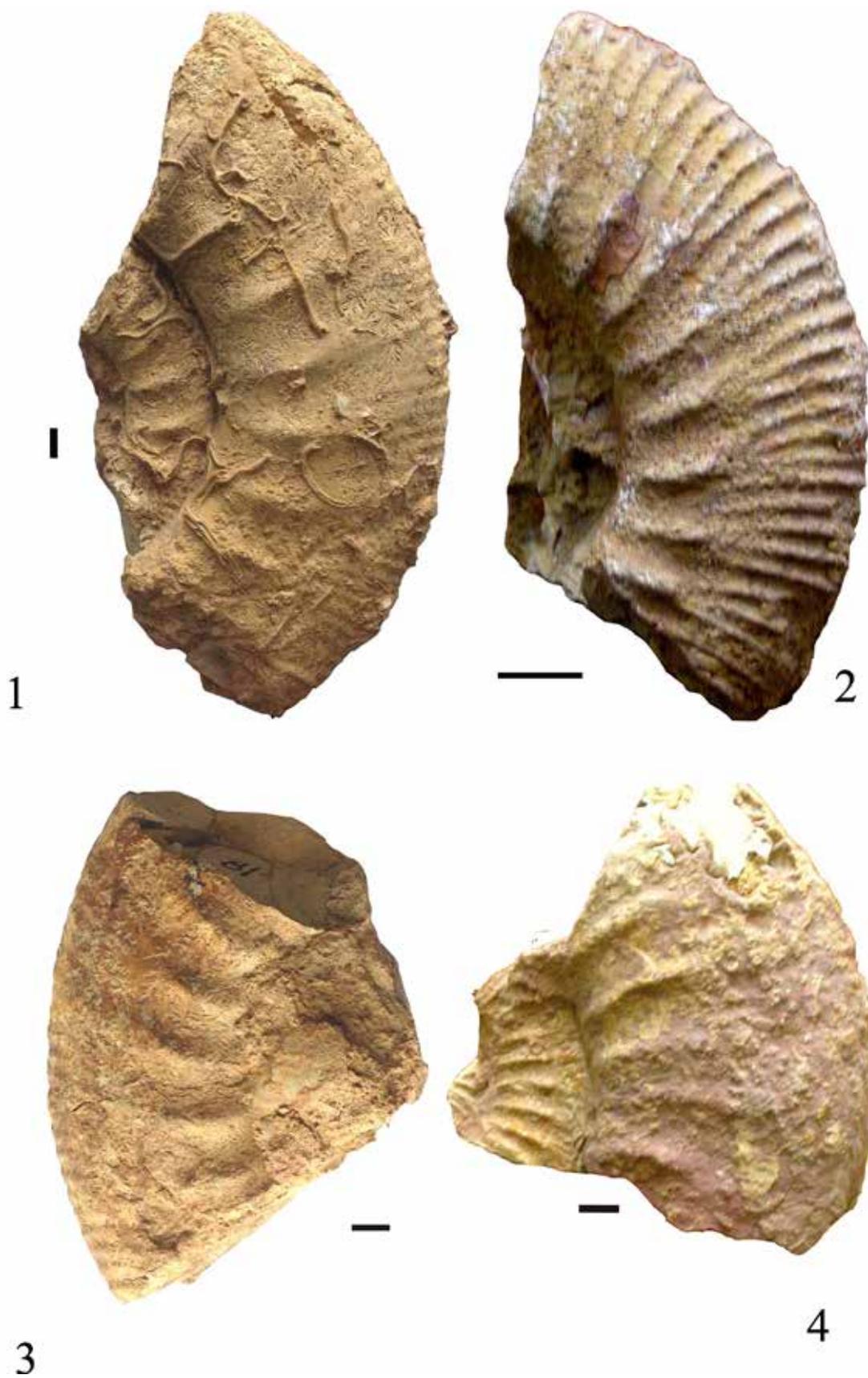
Specimen no.	D	H (H/D)	T (T/D)	U (U/D)	H/T
RUC/JSc/2013/72	48.8	23 (47)	26.4 (54)	15.8 (32)	0.87
RUC/JSc/2005/81	57.8	23.5 (40)	26.5 (45)	ca 17 (29)	0.88
<i>Stephanoceras elephantinum</i> Sowerby (Waagen 1875, p. 125)	26	11.5 (44)	15 (57)	9 (34)	0.76
<i>Dhosaites elephantoides</i> Spath (Prasad, 2006, p. 30)	55	19.5 (35.4)	ca 23 (41.8)	20 (36)	0.84
<i>Dhosaites elephantoides</i> Spath (1928, p. 244; Waagen's larger specimen)	108	42.1 (39)	62.6 (58)	42.1 (39)	0.67
<i>Dhosaites primus</i> Spath (1928, p. 246)	45	19.8 (44)	23.8 (53)	13.9 (31)	0.83
<i>Dhosaites otoitoides</i> Spath (1928, p. 245)	67	28.8 (43)	30.8 (46)	20.1 (30)	0.93

Description: Phragmocone moderately evolute, slightly depressed. Whorl-section circular. Ornamentation consists of sharp, slightly prorsiradiate, bifurcating ribs. Primary ribs bifurcating below mid-lateral height. Primary ribs rarely run undivided. Secondary ribs, more or less of equal thickness to the primary ribs, cross the ventral region with slight forward directed sinuosity. Secondary ribs show zigzag pattern.

Remarks: The specimens are fragments of phragmocones with at least two whorls each. Traces of suture lines are visible. These are poorly preserved specimens and are partially encrusted with oysters and serpulids. The coiling, whorl shape, and ornamentation are similar to several species of *Dhosaites*, but are closest to *Dhosaites elephantoides* Spath (1928, p. 244, pl. 25, fig. 9, pl. 38, fig. 8a, b; see also Waagen 1875, p. 124, pl. 31, figs. 3, 3a) and *Dhosaites primus* Spath (1928, p. 245, pl. 32, fig. 5, pl. 37, fig. 1a, b, pl. 40, fig. 3, pl. 45, fig. 2a, b, pl.

EXPLANATION OF PLATE IV

Ammonite specimens collected from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section, scale bar 1 cm. 1. *Reineckeia* cf. *smithi* Spath, side view, RUC/KN/2008/06. 2. *Reineckeia* cf. *smithi* Spath, side view, RUC/KN/2008/24. 3. *Reineckeia* cf. *smithi* Spath, side view, RUC/KN/2008/18. 4. *Reineckeia* aff. *anceps* (Reinecke), side view, RUC/KN/2008/17.



49, figs. 3a, b, 4) from the Kachchh Basin. Owing to their poor preservation, the specimens have been assigned to *Dhosaites* cf. *elephantoides* Spath, 1924 - ex gr. *primus* of Spath (1928). These two species differ in the whorl section of their outer whorls; *elephantoides* is depressed, whereas *primus* is compressed. *Dhosaites otoitoides* Spath (1928, p. 245, pl. 44, fig. 1a, b) is also a comparable species but according to Spath (1928, p. 246) its ribs are more distant than in *primus*, which could be a variety.

Subfamily Eucycloceratinae Spath, 1928

Remarks: Jana *et al.* (2005) have recorded dimorphism in the morphospecies of the two previously described morphogenera *Eucycloceras* and *Subkossmatia* of the subfamily Eucycloceratinae. In addition, they combined these two morphogenera, *Eucycloceras* Spath and *Subkossmatia* Spath. The genus *Eucycloceras* has been retained owing to page priority over the genus *Subkossmatia* Spath (1924). The microconch and macroconch differ in size and ornamentation on the body chamber, which occupies three-quarters of the last whorl. Microconchs generally exhibit isocostate ribbing, whereas macroconchs possess variocostate ribbing; prorsiradiate primary ribs become increasingly longer, coarser and blunter with growth. The secondary ribs project strongly forward on the venter near the aperture of microconchs, whereas in macroconchs they disappear near the aperture.

Genus Eucycloceras Spath, 1924

(Type species: *Stephanoceras eucyclum* Waagen, 1875; subsequent designation by Spath (1924, p. 28), now recognized to be a junior synonym of *Ammonites opis* J. de C. Sowerby, 1840; see Jana *et al.* (2005).

Eucycloceras opis (J. de C. Sowerby, 1840) [m]
(Pl. II, fig. 1)

Ammonites opis n. sp. - J. de C. Sowerby, 1840, pl. 23, fig. 9 [m].

Stephanoceras opis (J. de C. Sowerby) - Waagen, 1875, p. 141, pl. 36, figs. 1-3.

Stephanoceras eucyclum n. sp. - Waagen, 1875, p. 142, pl. 35, fig. 1.

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

Material: One specimen (RUC/KN/2008/25) from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D) - without tubercle	U (U/D)	H/T
RUCKN/2008/25	58	27 (45)	16 (27)	11.5 (19)	1.7
<i>Stephanoceras opis</i> (J. de C. Sowerby) (Waagen, 1875, p. 141, pl. 36, fig. 3)	50	24 (48)	20 (40)	12 (24)	1.2

Description: Specimen small, consisting of phragmocone and part of the body chamber, moderately evolute after maturity, outer whorl compressed, preceding whorl depressed (H: 9.5 mm, T: 11 mm), and involute. Ornamentation consists of prorsiradiate, feebly variocostate ribs, bifurcating at mid-lateral height with occasionally additional secondary ribs. Primary ribs show slight forward-directed concavity at umbilical shoulder, increasingly slightly longer and coarser with growth. Secondary ribs with forward-directed sinuosity. Umbilical wall steep to vertical.

Remarks: The present specimen is very small and slightly abraded on one side, therefore the dimensional proportions mentioned above are not precise. The general morphology and ornamentation matches *Eucycloceras opis* (J. de C. Sowerby). The ribs are not isocostate as mentioned by Jana *et al.* (2005), but feebly variocostate. However, the small size and the indication of opening at a small diameter suggest that it is a microconch.

Eucycloceras opis (J. de C. Sowerby, 1840) [M]
(Pl. II, fig. 2)

Eucycloceras eucyclum (Waagen) - Spath 1928, p. 209, pl. 23, fig. 4a-b, pl. 25, fig. 4 [M].

Material: One specimen (RUC/JSc/2010/69) from gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Jajiya Scarp Section.

Description: Phragmocone moderately evolute, compressed, discoidal, whorl section oval with slightly arched lateral surfaces which merge with moderately acutely rounded ventral region via convex ventro-lateral shoulders. Maximum inflation at mid-lateral height. Ornamentation consists of thick prorsiradiate, variocostate ribs. Primary ribs branching into two at mid-lateral height. Additional secondary ribs may occur. Primary ribs show forward-directed concavity between umbilical shoulder and mid-lateral height. Secondary ribs show forward-directed sinuosity. Umbilical wall steep.

Remarks: The specimen is a small fragment of a phragmocone of a large specimen. The ornamentation, whorl outline, and umbilical diameter match *Stephanoceras eucyclum* described by Waagen (1875, p. 142, pl. 35, fig. 1). Due to its large adult size, it can be considered to be the macroconch of *E. opis* as defined by Jana *et al.* (2005).

Eucycloceras cf. *ramosa* (Spath, 1928)
(Pl. II, fig. 3)

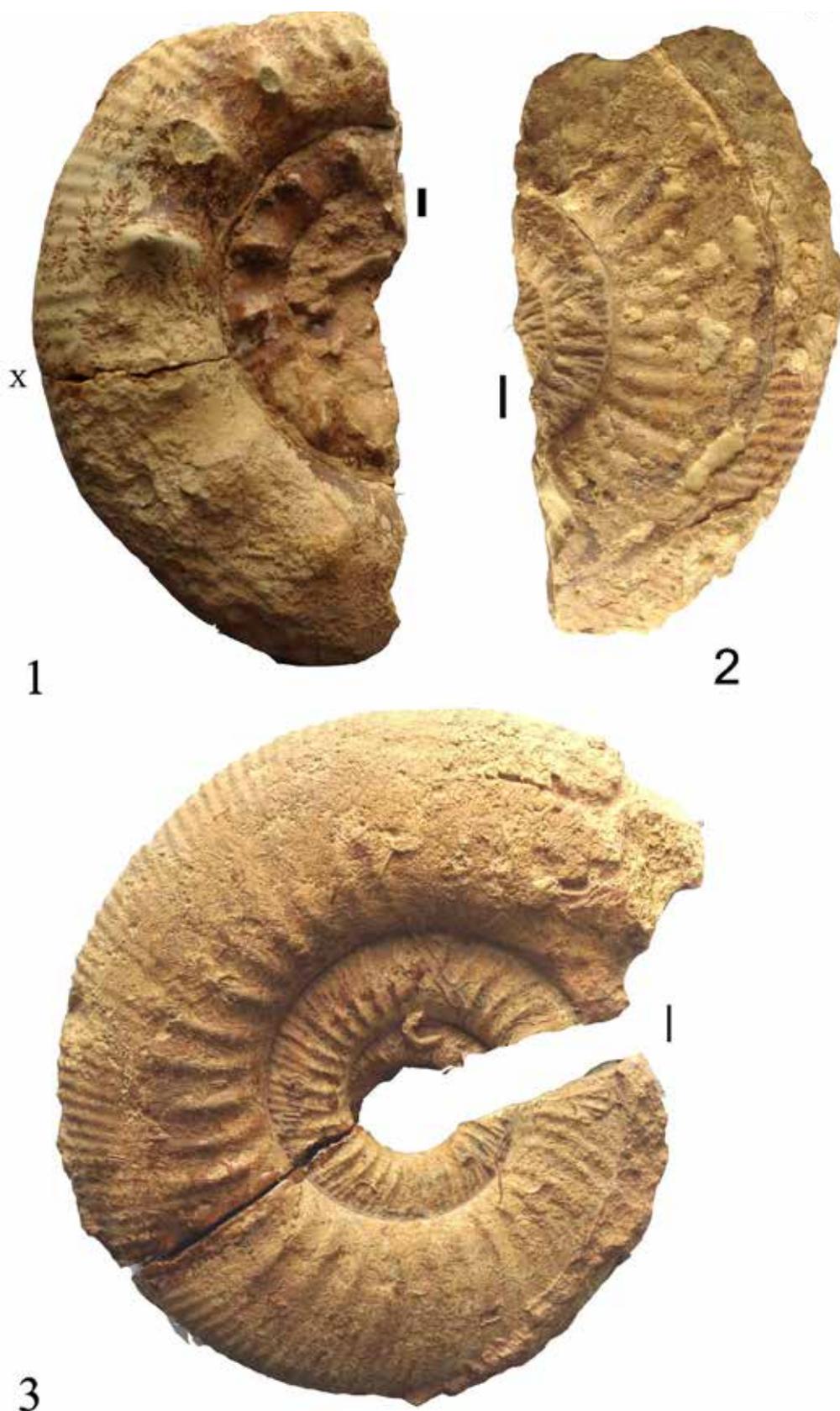
cf. *Subkossmatia ramosa* n. sp. - Spath, 1928, p. 214, pl. 41, fig 1a, b.

Material: Two specimens (RUC/KN/2008/4, 16) from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section.

Description: Phragmocone evolute, compressed, whorl section oval. Ornamentation consists of slightly prorsiradiate, sharp biplicate ribs, occasionally with a third secondary rib. Secondary ribs cross ventral region with forward-directed sinuosity.

EXPLANATION OF PLATE V

Ammonite specimens collected from bed no. 14, gypsiferous silty marl, Kuldhar Member (Middle Callovian), Jaisalmer Formation, Kuldhar Nala Section, scale bar 1 cm. 1. *Reineckeia* cf. *smithi* Spath, side view, RUC/KN/2008/22. 2. *Rehmannia* sp., side view, RUC/KN/2008/02. 3. *Rehmannia* sp., side view, RUC/KN/2008/19.



Remarks: The specimens match well *Subkossmatia ramosa* Spath (1928, p. 214, pl. 41, fig. 1a, b) with respect to whorl section and ornamentation. However, due to their fragmentary nature they have been assigned to this species with qualification only.

Eucycloceras cf. *flexicosta* (Prasad, 2006)
(Pl. II, fig. 4, Pl. III, figs. 1-2)

cf. *Subkossmatia flexicosta* n. sp. - Prasad, 2006 p. 28, pl. 6, fig. 5a, b, pl. 9, fig. 2a, b.

Material: Four specimens (RUC/KN/2008/1, 21, 23, 29) from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Description: Phragmocone evolute, compressed, whorl section broadly oval. Ornamentation consists of slightly prorsiradiate, flexicostate, sharp primary ribs, biplicating at mid-lateral height, occasionally with a third secondary rib. Secondary ribs cross ventral region with pronounced forward-directed sinuosity.

Remarks: These are fragments of phragmocones. They differ from *Subkossmatia flemingi* Spath (1928, p. 205, pl. 38, fig. 1a-c), which also has a broadly ovate whorl section, but an indistinct umbilical shoulder. In the present specimens the umbilical shoulder is moderately distinct. The flexicostate ribbing in the present specimens is similar to *Subkossmatia flexicosta* Prasad (2006).

Eucycloceras aff. *flemingi* (Spath, 1928)
(Pl. III, fig. 3)

aff. *Subkossmatia flemingi* n. sp. - Spath, 1928, p. 205, pl. 38, fig. 1a-c.

Material: One specimen (RUC/KN/2013/49) from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D)	U (U/D)	H/T
RUC/KN/2013/49	60	31 (51)	30 (50)	10.5 (17)	1.0
<i>Subkossmatia flemingi</i> Spath (1928, p. 205, pl. 38, fig. 1a-c)	82	27 (32)	25 (31)	26 (31)	1.4

Description: Phragmocone involute, opening of shell starts with beginning of body chamber, whorl section compressed, broadly oval. Ornamentation consists of prorsiradiate, sharp primary ribs, regularly biplicating at mid-lateral height. Secondary ribs cross ventral region with pronounced forward-directed sinuosity. Umbilical shoulder distinct on the inner whorl, becoming moderately distinct on the body chamber, where the wall is moderately high, steep, and smooth.

Remarks: The specimen consists of both phragmocone and part of the body chamber. The whorl outline is similar to *Subkossmatia flemingi* Spath (1928, p. 205, pl. 38, fig. 1a c),

which also has a broadly ovate whorl section but with indistinct umbilical shoulder. In the present specimen the umbilical shoulder is moderately distinct, a feature similar to *Subkossmatia flexicosta* Prasad (2006, p. 28, pl. 6, fig. 5a, b, pl. 9, figs. 1a, b, 2a, b), but our specimen does not show the flexicostate ribbing. The dimensions obtained from the specimen illustrated by Spath (1928) show differences to the present specimen, which therefore has been placed only in the affinity of the species.

Superfamily **Perisphinctaceae** Steinmann, 1890

Family **Reineckeidae** Hyatt, 1900

Subfamily **Reineckeinae** Cariou, 1984

Genus **Reineckeia** Bayle, 1878

(Type species: *Nautilus anceps* Reinecke, 1818)

Reineckeia cf. *smithi* Spath, 1928

(Pl. IV, figs. 1-4)

cf. *Reineckeia smithi* n. sp. - Spath, 1928, p. 263, pl. 27, fig. 1

Material: Five specimens (RUC/KN/2008/06, 9, 18, 22, 24) from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Description: Phragmocones evolute, whorl section compressed, subtrigonal with maximum thickness at inner one-third lateral height and acutely rounded venter. Ornamentation consists of thick, distant, prorsiradiate primary ribs with slight forward concavity, and tubercles on the inner whorls, gradually becoming elongated on the outer whorl. Primary ribs originating from umbilical shoulder branching into four secondary ribs and two intercalatory secondary ribs between two adjacent primary ribs. Secondary ribs leaving a narrow smooth area at the middle of the venter, which they cross with slight forward-directed sinuosity. Suture lines well preserved, flord with long and deeply incised external lobe, broad, incised lateral saddle and slightly oblique or asymmetrical retracted auxiliaries of umbilical lobe.

Remarks: Specimens consist of small to large fragments of phragmocones. One of the specimens (RUC/KN/2008/06) is heavily encrusted by serpulids and oysters on one side. The ornamentation, such as thick, distant, prorsiradiate primary ribs with tubercles branching into four secondary ribs and two intercalatory secondary ribs between two adjacent primary ribs and a narrow ventral smooth area, agrees with the generic characters of *Reineckeia* Hyatt. Most of the species of *Reineckeia* described from the Kachchh Basin (Waagen, 1875; Spath, 1928; Jain *et al.*, 1996) or from Jaisalmer Basin (Prasad, 2006) are depressed. The closest comparable species to the present specimen is *Reineckeia smithi* Spath (1928, p. 263, pl. 27, fig. 1). Owing to the fragmentary nature of the present specimen, it has been assigned to this species only tentatively.

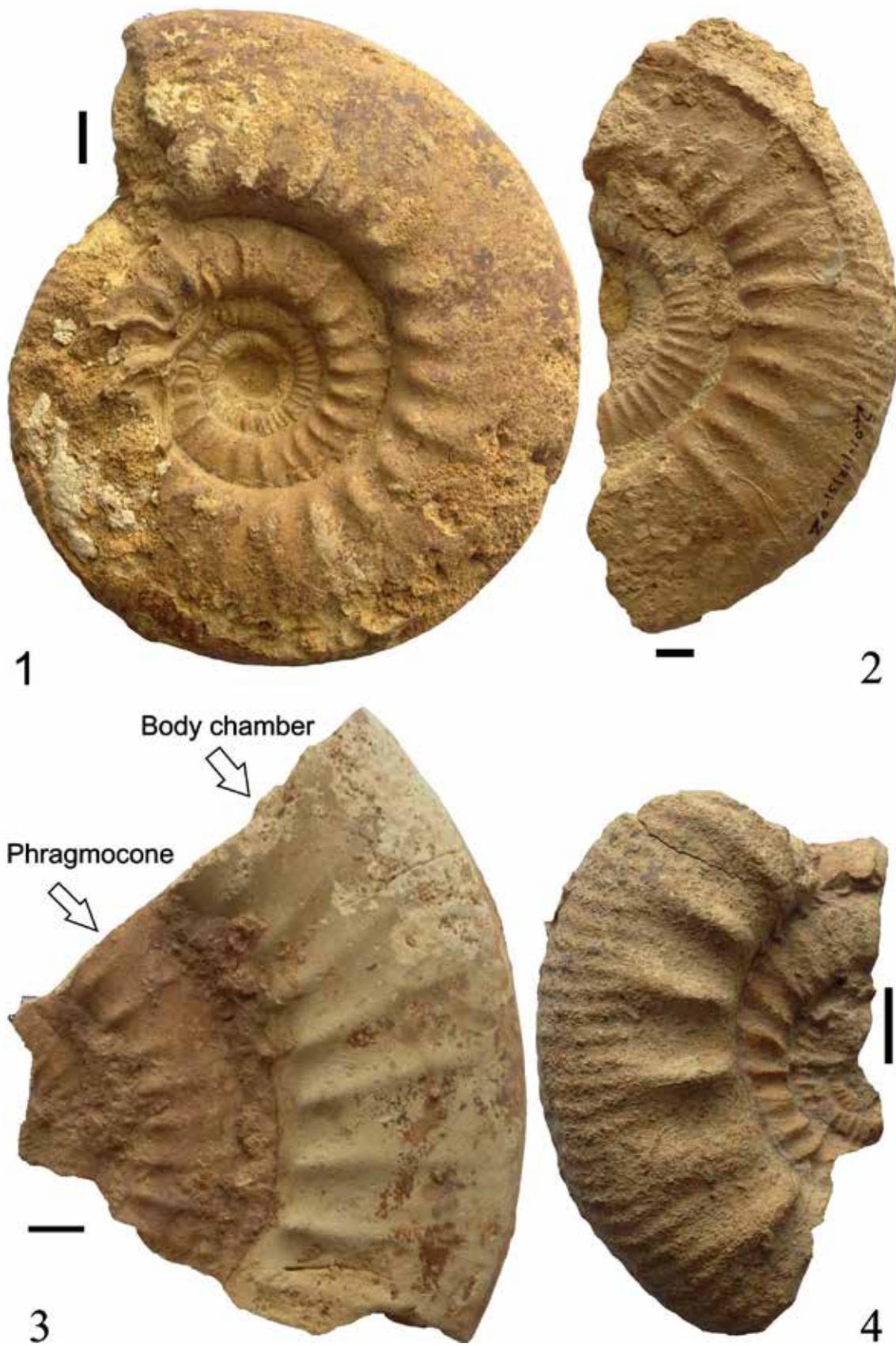
Reineckeia aff. *anceps* (Reinecke, 1818)

(Pl. V, fig. 1)

aff. *Reineckeia anceps* (Reinecke) - Spath, 1928, p. 255, pl. 44, fig. 6.

EXPLANATION OF PLATE VI

1. *Sivajicerus* sp. from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section, scale bar 1 cm. Side view, RUC/KN/2013/59. 2. *Indosphinctes* ex gr. *errans - peregrinus* Spath from Bada Bag Member (Late Bathonian), Jaisalmer Formation, Jajiya River Section, scale bar 1 cm. Side view, RUC/KN/2010/40. 3. *Choffatia* cf. *perdagata* Waagen from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section, scale bar 1 cm. Side view, RUC/KN/2008/20. 4. *Subgrossouvria* sp. from bed no. 1, Kuldhhar Member (Middle Callovian), Jajiya Scarp Section, scale bar 1 cm. Side view, RUC/KN/2013/70.



Material: One specimen (RUC/KN/2008/17) from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D) - without tubercle	U (U/D)	H/T
RUC/KN/2008/17	130	37.5 (28)	40.4 (31)	60 (46)	0.92
	at 98	26.5 (27)	31.4 (32)	46 (46)	0.84
	at 74	21 (28)	27 (36)	33.5 (45)	0.77

Description: Specimen incomplete, consisting of phragmocone and part of body chamber, evolute, whorl section depressed, reniform, subrounded to suboval with maximum thickness at mid-lateral height (inner whorls) to one-third of lateral height (outer whorl). Venter obtusely rounded. Umbilical shoulder indistinct. Ornamentation consists of thick, distant, prorsiradiate primary ribs with a single row of strong bullets at mid-lateral height, which become increasingly thicker. Primary ribs originating from umbilical shoulder branching from the bullets into several secondary ribs. About 17-18 secondary ribs occur between three adjacent bullets. Secondary ribs cross the ventral region with slight forward-directed sinuosity. Suture lines well preserved, more or less similar to that of *Reineckeia* cf. *smithi* Spath described above.

Remarks: The smooth ventral area is not distinct. Perhaps the specimen represents an internal composite mould. The ornamentation, such as thick, distant, prorsiradiate primary ribs with strong bullets branching into several secondary ribs, agrees with the generic character of *Reineckeia* Hyatt. *Reineckeia anceps* Reinecke (Spath, 1928, p. 255, pl. 44, fig. 6; Collignon, 1958, pl. 28, fig. 123) is a depressed taxon, but smaller. *Reineckeia tyranniformis* Spath (1928, p. 260, pl. 46, fig. 1) is another comparable species, but much larger (350-400 mm in diameter). The present specimen cannot have been larger than 280 mm in diameter. The dimensional proportions of *Reineckeia tyranniformis* are slightly different (D: 350, H/D: 28, T/D: 28, U/D: 50) compared to those of the present specimen. In all probability proportions and size of the present specimen are intermediate between the two species discussed above.

Genus *Rehmannia* Schirardin, 1956
(Type species: *Ammonites rehmanni* Oppel, 1857)

Rehmannia sp.
(Pl. V, figs. 2, 3)

Material: Two specimens (RUC/KN/2008/02, 19) from Bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D) without tubercle	U (U/D)	H/T
RUC/KN/2008/02	145	43 (29)	31 (21)	53 (36)	1.3

Description: The specimens are parts of phragmocones. They are evolute, display a compressed suboval whorl section with slightly arched flanks. The maximum thickness is at one-third of whorl height and the ventral region moderately narrowly rounded. Ornamentation consists of moderately thick, varicostate, prorsiradiate ribs with forward-directed concavity.

Primary ribs thick, distant, originating from umbilical shoulder rursiradiately, bending forward at umbilical shoulder, branching into two to three on the inner whorls and into three strongly prorsiradiate secondary ribs on the outer whorls with a fourth secondary rib remaining more or less free. Secondary ribs cross the ventral region with slight forward-directed sinuosity leaving a narrow mid-ventral smooth region. Umbilical wall short, smooth, shoulder rounded. Constrictions prorsiradiate, shallow.

Remarks: One of the specimens (RUC/KN/2008/019) is encrusted by oysters and serpulids on both sides. The morphological features match *Rehmannia* Schirardin (1956), but a more precise identification is not possible.

Family *Perisphinctidae* Steinmann, 1890

Subfamily *Proplanulitinae* Buckmann, 1921

Genus *Sivajicerias* Spath, 1928

(Type species: *Perisphinctes congener* Waagen, 1875)

Sivajicerias sp.

(Pl. VI, fig. 1)

Material: Two specimens (RUC/KN/2013/59, 45) from bed no. 14, gypsiferous silty marl, Kuldhhar Member (Middle Callovian), Jaisalmer Formation, Kuldhhar Nala Section.

Dimensions (in mm):

Specimen no.	D	H (H/D)	T (T/D)	U (U/D)	H/T
RUC/KN/2013/59	100	30 (30)	21.7 (21.7)	35 (35)	1.38
<i>Sivajicerias</i> sp. A (RUC2009 Kanod F44; after Swami 2013, p 81)	111	42 (37)	ca 29 (26)	39 (35)	1.44
<i>Sivajicerias</i> sp. A (RUC2009 Kanod F7; after Swami 2013, p. 81)	150 119	51 (34) 47 (39)	36 (24) 33 (27)	48 (32) 42 (35)	1.41 1.42

Description: Specimens are parts of phragmocones. They are medium-sized, evolute, compressed. Whorl-section subtriangular with slightly arched flanks, narrow ventral region, and maximum thickness at one-eighth of the whorl height, i.e. just above the umbilical shoulder. Ornamentation consists of prorsiradiate, thick primary ribs, originating rursiradiately at the centre of the umbilical wall and branching into more than two, probably three, secondary ribs at mid-lateral height. Secondary ribs feeble, thickness equal to inter-rib space, crossing the ventral region with slight forward-directed sinuosity. Umbilical wall steep, shoulder distinct.

Remarks: The specimens are incomplete and fragmentary, slightly abraded, encrusted with oysters and serpulids. The ornamentation and dimensional proportions of the specimens compare well with the specimens designated as *Sivajicerias* sp. A by Swami (2013).

Previous record: Swami (2013) from Kanod (Jaisalmer Basin).

Subfamily *Proplanulitinae* Buckman, 1921

Genus *Indosphinctes* Spath, 1930

(Type species: *Ammonites calvus* J. de C. Sowerby, 1840)

Indosphinctes ex gr. *errans* - *peregrines* Spath, 1931

(Pl. VI, fig. 2)

cf. *Indosphinctes errans* n. sp. - Spath, 1931, p. 334, pl. 55, fig. 5.

cf. *Indosphinctes peregrines* n. sp. - Spath, 1931, p. 335, pl. 62, fig. 5.

cf. *Indosphinctes errans* Spath - Prasad, 2006, p. 31, pl. 8, fig. 6.

cf. *Indosphinctes peregrines* Spath - Prasad, 2006, p. 32, pl. 9, fig. 5.

Material: One specimen (RUC/JR/2010/40) from the Bada Bag Member (Late Bathonian), Jaisalmer Formation, Jajiya River Section.

Description: Phragmocone evolute, compressed with suboval whorl section and broadly rounded ventral region, flanks only slightly arched, slope increases rapidly from ventrolateral shoulder, maximum inflation at mid-lateral region. Ornamentation consists of thick, slightly prorsiradiate primary ribs, originating at the centre of the umbilical wall and branching into three fine secondary ribs at mid-lateral height with one secondary rib between two adjacent primary ribs. Maximum thickness of primary ribs at umbilical shoulder, gradually becoming lower before branching. Secondary ribs crossing the ventral region with slight forward-directed sinuosity. Secondary ribs gradually fading on the outer side. Umbilical suture coincides with the height of branching. Umbilical wall short and steep.

Remarks: The specimen represents only a small fragment of a phragmocone. The diameter of the umbilicus, outline of the whorl section, and ornamentation match *Indosphinctes errans* Spath (1931, p. 334, pl. 55, fig. 5, see also Prasad 2006, p. 31, pl. 8, fig. 6) and *I. peregrines* (Spath 1931, p. 335, pl. 62, fig. 5, see also Prasad 2006, p. 32, pl. 9, fig. 5). Due to lack of information on the dimensional proportions, the specimen could be identified only to the generic level. On the basis of its similarity it has been assigned to the group of species in question.

Previous record: Early Callovian Kuldhara Member, Jaisalmer Formation (Prasad, 2006).

Subfamily Pseudoperisphinctinae Schindewolf, 1925

Genus Choffatia Siemiradzki, 1898

(Type species: *Perisphinctes cobra* Waagen, 1875)

Remarks: Several species of the genus *Choffatia* have been described from the Callovian strata of the Kachchh and Jaisalmer basins. Early workers did not recognize intraspecific variability and sexual dimorphism as we understand them now. Bardhan *et al.* (2012) described three dimorphic species based on material deposited in the Geological Survey of India, Kolkata, and on systematically collected additional specimens. These species are: *Choffatia recuperoi* (Gemmellaro, 1873), *Choffatia cobra* (Waagen, 1875), and *Choffatia perdagata* (Waagen, 1875). For the first time, the authors described lappeted microconchs of these three species. The macroconchs show simple apertures. According to Bardhan *et al.* (2012), these species show intergrading shell morphologies. Consequently, they had difficulties to distinguish them qualitatively. Statistically, *C. cobra* is the most evolute, depressed, and strongly ribbed form, whereas *C. perdagata* is the most involute, compressed, and weakly ribbed form. *C. recuperoi* occupies an intermediate position.

Choffatia cf. perdagata (Waagen, 1875)
(Pl. VI, fig. 3)

Perisphinctes perdagata n. sp. - Waagen, 1875, p. 158, pl. 44, figs. 1, 1a.-Collignon, 1958, pl. 26, fig. 108. Bardhan *et al.*, 2012, p. 40, figs. 9A-K, 10A-L, 11A-L, 12A-L, 13C (see also for extensive synonymy).

Material: Two specimens (RUC/KN/2008/20, RUC/JSc/2013/57) from bed no. 14, gypsiferous silty marl, Kuldhara Member (Middle Callovian), Jaisalmer Formation, Kuldhara Nala Section.

Description: Shell large, evolute, planulate, compressed, whorl section oval with maximum thickness near umbilical shoulder. Flanks gently arched, merging smoothly with narrowly rounded ventral region. Ornamentation consists of thick, prorsiradiate, dense primary ribs on the inner whorls, becoming distant on the outer whorls, branching into two at mid-lateral height. Umbilical shoulder moderately distinct, umbilical wall short and gently inclined.

Remarks: One of the specimens is a small fragment of the phragmocone and body chamber of a large shell (RUC/JSc/2008/20), the other specimen is only a fragment of the phragmocone (RUC/JSc/2013/57). The latter specimen shows moderately preserved suture lines (compare with Fig. 13 of Bardhan *et al.*, 2012). Constrictions are not so evident in this fragmentary specimen. Ornamentation and whorl section in the present material are similar to those of *Choffatia perdagata* (Waagen, 1875). On the basis of a statistical analysis, Bardhan *et al.* (2012) merged several species of *Choffatia* from the Kachchh Basin described by earlier works. Due to the small number of specimens and their fragmented nature the material has been assigned to *Choffatia cf. perdagata* (Waagen).

Genus Subgrossouvria Spath, 1924

(Type species: *Perisphinctes aberrans* Waagen, 1875)

Subgrossouvria sp.
(Pl. VI, fig. 4)

Material: One specimen (RUC/JSc/2013/70) from gypsiferous silty marl, Kuldhara Member (Middle Callovian), Jaisalmer Formation, Jajiya Scarp Section.

Description and remarks: The specimen represents the fragment of a phragmocone consisting of four whorls. The outer surface is abraded and encrusted by serpulids and oysters. Phragmocone evolute, whorl section subcircular, slightly depressed (H/T: 0.65 to 0.60). Ornamentation on innermost preserved whorl consists of thin, prorsiradiate primary ribs, which gradually become coarser and on the last preserved whorl become thick and distant. Points of branching on the preceding whorls are hidden under succeeding whorls. The thick primary ribs branch into two much thinner secondary ribs. Of two additional free secondary ribs, one may appear at a quarter of whorl-height between two thick primary ribs or may originate from primary ribs at a slightly lower whorl height, producing a virgatotome-like appearance, the other one remain free. There are 27 secondary ribs between 6 primary ribs. The secondary ribs cross the ventral region with sharp forward bend and show a zigzag pattern. Suture lines well preserved showing ventral lobe, first lateral saddle, first lateral lobe, and second lateral saddle. Constrictions are moderately deep, slightly forwardly oblique.

The ornamentation, particularly the sinuosity on the ventral region matches specimens from the Anceps Bed of the Jumara Dome, Kachchh Basin illustrated by Spath (1931, p. 378, pl. 94, fig. 2a, b) as *Subgrossouvria* sp. nov.? aff. *gudjinseresis* (Waagen). The present specimen differs from *Subgrossouvria gudjinseresis* (Waagen) (Spath, 1931, p. 379, pl. 42, fig. 5a, b) by the sinuosity of the secondary ribs in the ventral region, which in *gudjinseresis* are straight. The zigzag pattern of ribs in *Subgrossouvria* sp. nov.? aff. *gudjinseresis* (Waagen) is not clear in the present specimen. The specimen is also comparable with *Subgrossouvria sparsibullata* Prasad (2006: p. 31, pl. 7, fig. 4, pl. 8 fig. 5) in general shell morphology and ornamentation, but in *sparsibullata* the secondary ribs cross the ventral region straight.

TAXONOMIC REMARKS

The ammonites recorded in the present work belong to four families; Oppeliidae, Sphaeroceratidae, Reineckeidae and Perisphinctidae. The maximum number of taxa is represented by the family Sphaeroceratidae (Table 2).

Table 2: List of ammonite taxa recorded from Upper Bathonian - Oxfordian sediments of the Jaisalmer Basin.

Species	No. of specimens	Age	Lithostratigraphic unit
Family Oppeliidae Bonarelli, 1894			
<i>Prohecticoceras?</i> sp.	1	Late Bathonian	Bada Bag Member
Family Sphaeroceratidae Buckman, 1920			
<i>Epimayaites</i> aff. <i>lemoini</i> (Spath, 1924)	1	Oxfordian	Jajiya Member
<i>Epimayaites falcoides</i> Spath, 1928	2	Oxfordian	Jajiya Member
<i>Dhosaites</i> cf. <i>elephantoides</i> Spath, 1924 - ex gr. <i>primus</i> Spath, 1928	2	Oxfordian	Jajiya Member
<i>Eucycloceras opis</i> (J. de C. Sowerby, 1840) [m]	1	Middle Callovian	Kuldhar Member
<i>Eucycloceras opis</i> (J. de C. Sowerby, 1840) [M]	1	Middle Callovian	Kuldhar Member
<i>Eucycloceras</i> cf. <i>ramosa</i> (Spath, 1928)	2	Middle Callovian	Kuldhar Member
<i>Eucycloceras</i> cf. <i>flexicosta</i> (Prasad, 2006)	4	Middle Callovian	Kuldhar Member
<i>Eucycloceras</i> aff. <i>flemingi</i> (Spath, 1928)	1	Middle Callovian	Kuldhar Member
Family Reineckeidae Hyatt, 1900			
<i>Reineckeia</i> cf. <i>smithi</i> Spath, 1928	5	Middle Callovian	Kuldhar Member
<i>Reineckeia</i> aff. <i>anceps</i> (Reinecke, 1818)	1	Middle Callovian	Kuldhar Member
<i>Rehmannia</i> sp.	2	Middle Callovian	Kuldhar Member
Family Perisphinctidae Steinmann, 1890			
<i>Sivajiceras</i> sp.	2	Middle Callovian	Kuldhar Member
<i>Indosphinctes</i> ex gr. <i>errans</i> - <i>peregrines</i> Spath, 1931	1	Late Bathonian	Bada Bag Member
<i>Choffatia</i> cf. <i>perdagata</i> (Waagen, 1875)	2	Middle Callovian	Kuldhar Member
<i>Subgrossouvria</i> sp.	1	Middle Callovian	Kuldhar Member

One of the most crucial aspects of the study was to differentiate taxonomically macrocephalitids (Family Macrocephalitidae Buckman) and their homeomorphic equivalents within the subfamily Mayaitinae Spath. The genus *Dhosaites* is a small to moderately-sized ammonite characterized by coarse, sharp, mostly rectiradiate ribs. Ribs mostly pass straight across the venter (Alberti *et al.*, 2015). In comparison to its homeomorph equivalent from the Early Callovian *Kamptokephalites*

Buckman, *Dhosaites* Spath exhibits a comparatively wide umbilicus (Spath, 1928). In a situation where it is difficult to separate *Kamptokephalites* Buckman and *Dhosaites* Spath due to scanty material, this criterion can be useful.

LITHO- AND BIOSTRATIGRAPHIC REMARKS

The scanty outcrops and the soft silty marly nature of the sediments of the Kuldhar Member together with a repetition of similar lithologies in the uppermost part of the Bada Bag Member and the basalmost part of the Jajiya Member, initially posed difficulties in correlating the successions at the three studied localities: Kuldhar Nala Section, Jajiya River Section, and Jajiya Scarp Section, west of the village Kuldhar in the Jaisalmer Basin. Most outcrops in the study area are not suitable for measuring stratigraphic successions. However, very careful observations in the field, collections of some early Middle Callovian ammonites such as *Eucycloceras opis* (J. de C. Sowerby), *E. cf. ramosa* (Spath), *E. cf. flexicosta* (Prasad), *E. aff. flemingi* (Spath), *Reineckeia* cf. *smithi* Spath, *R. aff. anceps* (Reinecke), and *Rehmannia* sp. resolved the problem of correlating the strata in the study area with those of the type locality, the Kuldhar River Section. Based on ammonites the silty marly sediments of the Kuldhar Member can be safely assigned a Callovian age. The top of the member at the Kuldhar River Section is Late Callovian and at the base of the Jajiya Scarp Section it is early Middle Callovian in age. A gradual thinning of the member from Kuldhar to Jajiya villages is observed.

The Jajiya Member, in contrast, is well exposed because of its well cemented nature. It consists of bioturbated or cross-bedded limestones (pack- to rudstones) and sandstones, with reworked corals; rudstone with *Stylina* cf. *girodi* Étallon, and *Isastrea helianthoides* (Goldfuss) (Pandey *et al.*, 2009b), and contains large-sized rhynchonellids and terebratulids, turritiform gastropods, and ammonites (Kachhara and Jodhawat, 1981; Pandey *et al.*, 2010, 2014). The ammonites such as *Lissoceratoides* (Late Callovian to Late Oxfordian), *Hecticoceras* (*Brightia*) (Late Callovian to Early Oxfordian), *Distichoceras* (Late Callovian to Early Oxfordian), *Epimayaites* (Middle Oxfordian), *Mayaites* (Middle Oxfordian), *Dhosaites* (Middle Oxfordian) and *Hubertoceras* (Middle to Late Callovian) suggest in general a Middle Callovian to Oxfordian age for the Jajiya Member (Kachhara and Jodhawat 1981, Pandey *et al.*, 2012). Krishna (1987) and Prasad (2006) recorded *Peltoceratoides semirugosus*, *Mayaites*, *Epimayaites*, *Dhosaites*, *Paryphoceras*, *Dichotomosphinctes*, and *Dichotomoceras*, suggestive of an Early to Late Oxfordian age, from the topmost beds of the Kuldhar River Section. These beds are ooid-bearing rudstones and lithologically quite different from the underlying silty marls of the Kuldhar Member. Therefore, they should be grouped within the Jajiya Member (Pandey *et al.*, 2012). On the basis of the earlier records of ammonites discussed above it can be inferred that in the study area the Jajiya Member ranges from Early to Late Oxfordian, and not from Middle Callovian to Oxfordian. Contextually, the Kuldhar Member is assigned a Callovian and the Jajiya Member an Oxfordian age.

CONCLUSIONS

The stratigraphic distribution of Late Bathonian-Oxfordian ammonites of the families Oppeliidae, Sphaeroceratidae,

Reineckeidae, and Perisphinctidae described and illustrated here and those recorded by earlier workers (Kachhara and Jodhawat, 1981, Pandey, *et al.* 2010, 2012, 2014) and the lithology of the Kuldhar (silty marls) and Jajiya (pack- to rudstone and sandstone) members, suggests that the two members are very distinct. The Kuldhar Member represents Callovian, whereas the Jajiya Member represents Oxfordian strata. The ooid-bearing pack- to rudstone bed exposed at the top of the Kuldhar River Section (Prasad, 2006, p. 5) and at the base of the Jajiya Scarp Section exposed to the west of the village Kuldhar have been grouped within the Jajiya Member. The base of the ooid-bearing pack- to rudstone beds marks the boundary between the Kuldhar and Jajiya members. The bed at the top of the Kuldhar River Section has yielded the Early Oxfordian ammonite *Peltoceratoides* (Prasad, 2006). This inclusion of the ooid-bearing pack- to rudstone bed in the Jajiya Member is in contrast to the suggestion of earlier workers (Krishna, 1987; Prasad, 2006).

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REFERENCES

- Alberti, M., Pandey, D.K., Hethke, M. and Fürsich, F.T. 2015. Ammonites of the subfamily Mayaitinae Spath, 1928 from the Oxfordian of Kachchh, western India. *Geobios*, **48**: 85-130.
- Arkell, W.J., Kummel, B. and Wright, C.W. 1957. Mesozoic Ammonoidea, p. L80-L437. In: Moore, R.C. (Ed.), *Treatise on Invertebrate Paleontology*. Part L, Mollusca 4, Cephalopoda, Ammonoidea. The Geological Society of America and the University of Kansas Press, New York and Lawrence.
- Bardhan, S., Dutta, R., Chanda, P. and Mallick, S. 2012. Systematic revision and sexual dimorphism in *Choffatia* (Ammonoidea: Perisphinctoidea) from the Callovian of Kutch, India. *Palaeoworld*, **21**: 29-49.
- Basse, E., and Perrodon, M. 1951. Macrocephalitides du sud-ouest de Madagascar: Macrocephalitidae, Eucycloceratidae, Mayaitidae. Récoltes de la mission É. Basse 1930-31, t. 3065, *Mémoires de la Société Géologique de France*, pp. 1-100.
- Bonarelli, G. 1894. *Hecticoceras*, novum genus Ammonidarum. *Bollettino della Società Malacologica Italiana*, **18** (1893): 73-104.
- Cariou, E. 1984. Structure, origine et paléobiogéographie de la famille des Reineckeidae, Ammonitina, du Jurassique moyen. *Comptes rendus de l'Académie des Sciences, Paris*, (II) **298**: 245-248.
- Carter, H.J. 1861. On the contribution to the geology of western India including Sind and Baluchistan. *Journal Royal Asiatic Society*, **6** (21): 161-206.
- Collignon, M. 1958-1960. Atlas des fossiles caractéristiques de Madagascar. Fascicule I-IV. Service géologique, Tananarive: 175 pls.
- Das Gupta, S.K. 1975. A revision of Mesozoic - Tertiary stratigraphy. *Indian Journal of Earth Sciences*, **2**: 77- 94.
- Fürsich, F.T., Oschmann, W., Singh, I.B. and Jaitly, A.K. 1992. Hardgrounds, reworked concretion levels and condensed horizons in the Jurassic of western India: their significance for basin analysis. *Journal of the Geological Society*, London, **149**: 313-331.
- Fürsich, F.T., Pandey, D.K., Kashyap, D. and Wilmsen, M. 2006. The trace fossil *Ctenopholeus* Seilacher and Hemleben, 1966 from the Jurassic of India and Iran: distinction from related ichnogenera. *N. Jb. Geol. Paläont. Mh.*, (11): 641-654.
- Jain, S., Callomon, J.H. and Pandey, D.K. 1996. On the earliest known occurrence of the Middle Jurassic ammonite genus *Reineckeia* in the Upper Bathonian of Jumara, Kachchh, western India. *Paläontologische Zeitschrift*, **70**: 129-143.
- Jana, S.K., Bardhan, S. and Halder, K. 2005. Eucycloceratin ammonites from the Callovian Chari Formation, Kutch, India. *Palaeontology*, **48**: 883-924.
- Kachhara, R.P. and Jodhawat, R.L. 1981. On the age of Jaisalmer Formation, Rajasthan, India. *Indian Colloquium of Micropaleontology and Stratigraphy*, 247.
- Kalia, P. and Chowdhury, S. 1983. Foraminiferal biostratigraphy, biogeography and environment of the Callovian sequence, Rajasthan, northwestern India. *Micropalaeontology*, **29**: 223-254.
- Krishna, J. 1980a. Uncoiled ammonites of Middle Albian (Lower Cretaceous) age from Habur Series, Jaisalmer, Rajasthan. *Journal of the Palaeontological Society of India*, **23-24**: 49-54.
- Krishna, J. 1980b. Correlation of Callovian (late Middle Jurassic) - Albian (late Lower Cretaceous) ammonoid and micro-fossil assemblage from sedimentary basins around Indian shield. - VIII Indian Colloquium on Micropalaeontology and Stratigraphy, abstracts: 9-10.
- Krishna, J. 1987. An overview of Mesozoic stratigraphy of Kutch and Jaisalmer basins. *Journal of the Palaeontological Society of India*, **32**: 136-149.
- Mahendra, K. and Banerji, R.K. 1989. Textural study and depositional environment of sand grains from rocks of Jaisalmer Formation, Jaisalmer District, Rajasthan, India. *Journal of the Geological Society of India*, Bangalore, **33** (3): 228-242.
- Pandey, D.K., Alberti, M., and Fürsich, F.T. 2013. Ammonites from the Oxfordian (Bifurcatus Zone) strata of Gangta Bet, Kachchh, western India. *Journal of the Palaeontological Society of India*, **58** (2): 139-174.
- Pandey, D.K. and Choudhary, S. 2007. Sequence stratigraphic framework of Lower to lower Middle Jurassic sediments of the Jaisalmer Basin, India. *Beringeria*, **37**: 121-131.
- Pandey, D.K., Choudhary, S., Tej Bahadur, Swami, N. and Sha, J. 2012. A review of the Lower - lowermost Upper Jurassic lithostratigraphy of the Jaisalmer Basin, western Rajasthan, India - an implication on biostratigraphy. *Volumina Jurassica*, **10**: 61-82.
- Pandey, D.K., Fürsich, F.T. and Sha, J. 2009a. Intrabasinal marker intervals - A case study from the Jurassic basin of Kachchh and Jaisalmer, western India. *Science in China Series D-Earth Science*, **52**: 1924-31.
- Pandey, D.K., Fürsich F. T., Baron-Szabo, R. 2009b. Jurassic corals from the Jaisalmer Basin, west Rajasthan, India. *Zitteliana*, **A48/49**: 13-37.
- Pandey, D.K., Fürsich, F.T., and Alberti, M. 2014. Stratigraphy and palaeoenvironments of the Jurassic rocks of the Jaisalmer Basin - Field Guide. *Beringeria*, Special Issue, **9**: 1-111.
- Pandey, D.K., Sha, J. and Choudhary, S. 2006a. Depositional history of the early part of the Jurassic succession on the Rajasthan shelf, western India. *Progress in Natural Science*, **16**: 176-185.
- Pandey, D.K., Sha, J. and Choudhary, S. 2006b. Depositional environment of Bathonian sediments of the Jaisalmer Basin, Rajasthan, Western India. *Progress in Natural Science*, Boundary, Events and correlation, Beijing, 163-75.
- Pandey, D.K., Sha, J. and Choudhary, S. 2010. Sedimentary cycles in the Callovian - Oxfordian of the Jaisalmer Basin, Rajasthan, Western India. *Volumina Jurassica*, **53**: 131-162.
- Pandey, D.K., Swami, N., Sharma, J. and Choudhary, S. 2011. Occurrence of sediment starve intervals during Oxfordian in the Jaisalmer Basin, Rajasthan. Abstract volume, National Conference on Stratigraphy, Palaeontology and Palaeoenvironment, 33-34.
- Prasad, S. 2006. Ammonite biostratigraphy of Middle to Late Jurassic rocks of Jaisalmer Basin, Rajasthan, India. *Palaeontologica Indica*, **52**: 1-146.
- Sowerby, J. de C. 1840. Description of fossils procured by Capt. Smee and Col. Pottinger in Cutch and the desert to the north-east of Cutch. Transactions of the Geological Society London, 5, explanation of plate 61.

- Spath, L.F.** 1924. On the Blake collection of ammonites from Kachh, India. *Memoirs of the Geological Survey of India, Palaeontologia Indica, New Series* 9, 1, 1-29.
- Spath, L.F.** 1927-1933. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). Parts I-VI. *Memoirs of the Geological Survey of India, Palaeontologia Indica, new series* 9, Calcutta, 2: part I, 1-71, pls. 1-7 [1927]; part II, 72-161, pls. 8-19 [1928a]; part III, 162-278, pls. 20-47 [1928b]; part IV, 279-550, pls. 48-102 [1931a]; part V, 551-658, pls. 103-124 [1931b]; part VI, 659-945, pls. 125-130 [1933].
- Swami, N.** 2013. Depositional environment and sequence stratigraphy of Jurassic sediments in northeastern part of the Jaisalmer Basin. *Unpublished Ph.D Thesis, University of Rajasthan.*
- Waagen W.** 1873-1875. Jurassic fauna of Kutch. The Cephalopoda. *Memoirs of the Geological Survey of India, Palaeontologia Indica, series 9, Calcutta, 1:* part I, 1-22, pls. 1-4 [1873]; part II, 23-76, pls. 5-14 [1875a]; part III, 77-106, pls. 15-24 [1875b]; part IV, 107-247, pls. 25-60 [1875c].

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