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BIOSTRATIGRAPHIC IMPLICATIONS OF THE RECORD OF GENUS *HIMALAYITES* FROM THE LATE TITHONIAN SEDIMENTS OF JAISALMER, WESTERN INDIA

SREEPAT JAIN[1] and RAHUL GARG[2]

[1]DG-2, 51C, SFS FLATS, VIKASPURI, NEW DELHI – 110018, INDIA
[2]DEPARTMENT OF GEOLOGY, UNIVERSITY OF LUCKNOW, LUCKNOW – 226 007, INDIA AND
BIRBAL SAHNI INSTITUTE OF PALAEOBOTANY, LUCKNOW, INDIA
[1]E-mail : sreepatjain@gmail.com

ABSTRACT

The occurrence of genus *Himalayites* Uhlig enables interprovincial correlation of Late Tithonian sediments worldwide. Recently, the occurrence of this genus was recorded from Kachchh (western India) and the distribution is now extended to the adjoining Jaisalmer basin. *H.* aff. *seideli* (Oppel) [M] is now recorded from the Rupsi Shale Member. Preliminary data from this Member indicates the creation of four new ammonite biozones – Alterniplicatus, Virgatosphinctoides, Kobelliforme and Himalayites. The earliest zone, Alterniplicatus, is marked by the abundance of *Torquatisphinctes* (*T. alterneplicatus*), followed by *Virgatosphinctes* (*V. densiplicatus* and *V.* sp.), a restricted and dominant occurrence of *Hildoglochiceras* (*H. kobelliforme*, *H. latistrigatum*, *H. nodosum* and *H.* cf. *planum*) and the topmost Zone is marked by the first appearance of the Late Tithonian genus *Himalayites*, respectively. The Alterniplicatus Zone is correlated with the latest Early Kimmeridgian Tethyan Divisum Zone, Virgatosphinctoides with Early Tithonian Darwini Zone, Kobelliforme with Early Tithonian Semiforme Zone and Himalayites with latest Tithonian Durangites spp. Zone.

Keywords: *Himalayites*, Late Jurassic, Rupsi Shale Member, Jaisalmer, western India

INTRODUCTION

The occurrence of the genus *Himalayites* Uhlig enables global interprovincial correlation for Late Tithonian sediments (Uhlig, 1910; Collignon, 1960; Fatmi, 1972; Krishna, 1982; Tavera, 1985; Pathak and Krishna, 1993) (Fig. 1). Originally recorded from the Tethys Himalaya, the occurrence of this genus has recently been extended to the Kachchh Basin, western India (Shome and Bardhan, 2007, 2009) (Figs. 1-2a). The present study documents the first record of *Himalayites* from the adjoining Jaisalmer Basin (Rajasthan) (Figs. 1-2b), thus expanding its distribution in the western part of the Indian Subcontinent.

The western sector of the Indian plate exposes a thick succession of sedimentary rocks ranging in age from Bajocian (Pandey and Fürsich, 1994) to late Early to early Middle Albian exposed around Jaisalmer (Krishna, 1987) (Fig. 2a). A fourfold lithostratigraphic framework for the Jurassic succession of the Jaisalmer Basin is followed here, dividing it into Lathi, Jaisalmer, Baisakhi and Bhadasar formations in ascending order (Table 1). The present study is restricted to the sediments of the Rupsi Shale Member (Baisakhi Formation), best developed in and around Rupsi village (70º49':27º00'). In the type section exposed in a scarp west of the Rupsi village, the Rupsi Shale consists of shale-sandstone intercalations with several thin ammonite rich bands (Fig. 2b). Dasgupta (1975) assigned Kimmeridgian age based on *Torquatisphinctes* rich ammonite assemblage. Garg *et al.* (1998) recorded agglutinated foraminiferal assemblages from the Rupsi Shale Member and assigned these to three ammonite associations viz. *Torquatisphinctes* (Kimmeridgian), *Torquatisphintes-Pachysphintes* (Kimmeridgian) and *Hildoglochiceras-Aulacosphintoides* (Lower Tithonian). Recently, Pandey and Krishna (2002) assigned early Tithonian age to the Rupsi Shale based on three ammonite biozones, viz. Virgatosphinctoides, Natricoides and Communis from bottom to top (Fig. 3a).

Record of the genus *Himalayites* is, therefore, extremely significant in the present context as it helps to re-evaluate the age of the Rupsi Shale Member. The present contribution summarizes the existing ammonite biostratigraphy of the Rupsi Shale Member (Pandey and Krishna, 2002; Prasad, 2006), besides listing new biozones recorded here based on the study of ammonite assemblages recovered from its type section and their calibration with the previous zonation schemes (Pandey and Krishna, 2002).

EXISTING BIOSTRATIGRAPHY

Pandey and Krishna (2002) recognized three ammonite biozones - Virgatosphinctoides, Natricoides and Communis

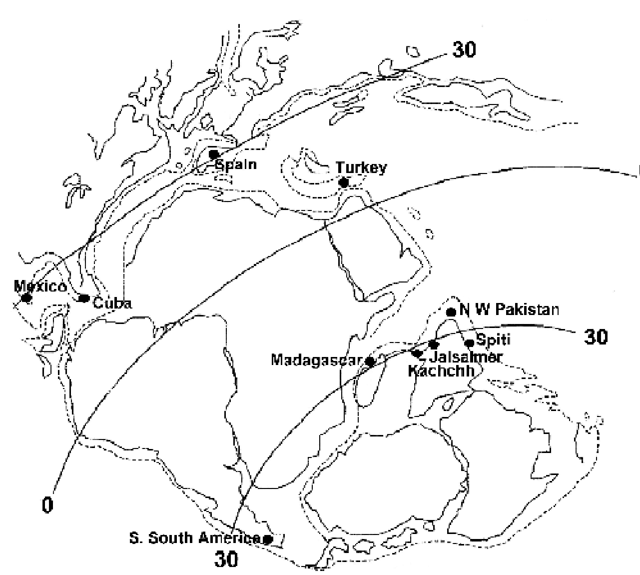


Fig. 1. Late Tithonian global distribution of Genus *Himalayites* (modified after Shome and Bardhan, 2009). It is interesting to note that *Himalayites* are essentially restricted within the 30°N and S latitude, an example where palaeotemperature probably played a role in the ammonite distribution and hence in their palaeobiogeography.

Table 1: Stratigraphic framework followed in this study for the Jaisalmer basin (after Das Gupta, 1975; Garg and Singh, 1983; Jain, 2007; Garg and Jain, 2012). Additionally, the four ammonite zones based on the acme abundance of genus *Torquatisphinctes*, *Virgatosphinctes*, *Hildoglochiceras* and *Himalayites* (from bottom to top respectively) identified in this study are also shown. Genus *Anavirgatites* has now been recorded from the overlying Late Tithonian Bhadasar Formation (Prasad, 2006).

DAS GUPTA, 1975			GARG AND SINGH, 1983			JAIN, 2007	GARG & JAIN, 2012		THIS STUDY	
Tithonian	BHADASAR FORMATION	Mokal Mb. Kala Dongar Mb.	BHADASAR FORMATION		Tithonian	Tithonian	Latest Tithonian	BHADASAR FORMATION	*Anavirgatites*	
Kimmeridgian	BAISAKHI FORMATION	Rupsi Mb. Ludharwa Mb.	JAISALMER FORMATION	Rupsi Shale Member	Earliest Tithonian-Latest Oxfordian	Earliest Tithonian-Latest Oxfordian	Late Tithonian - Kimmeridgian	BAISAKHI FORMATION	*Himalayites* *Hildoglochiceras* *Virgatosphinctes*	Tithonian
		Baisakhi Mb.		Baisakhi Member	Oxfordian	Oxfordian	Latest Oxfordian		*Torquatisphinctes*	Kimmeridgian
Callovo-Oxfordian	JAISALMER FORMATION	Kuldhar Mb.		Kuldhar Oolite Mb.	Middle-Early Callovian	Middle Callovian-Late Bathonain	Middle Callovian - Late Bathonain	JAISALMER FORMATION		
		Badabag Mb. Fort Mb. Joyan Mb. Hamira Mb.		Amarsagar Limestone Member	Late - Middle Bathonian		Late - Middle Bathonian Bajocian*			
Lias-Bathonian	LATHI FORMATION	Thiat Mb. Odania Mb.	LATHI FORMATION		Early - Middle Jurassic (in part)			LATHI FORMATION		

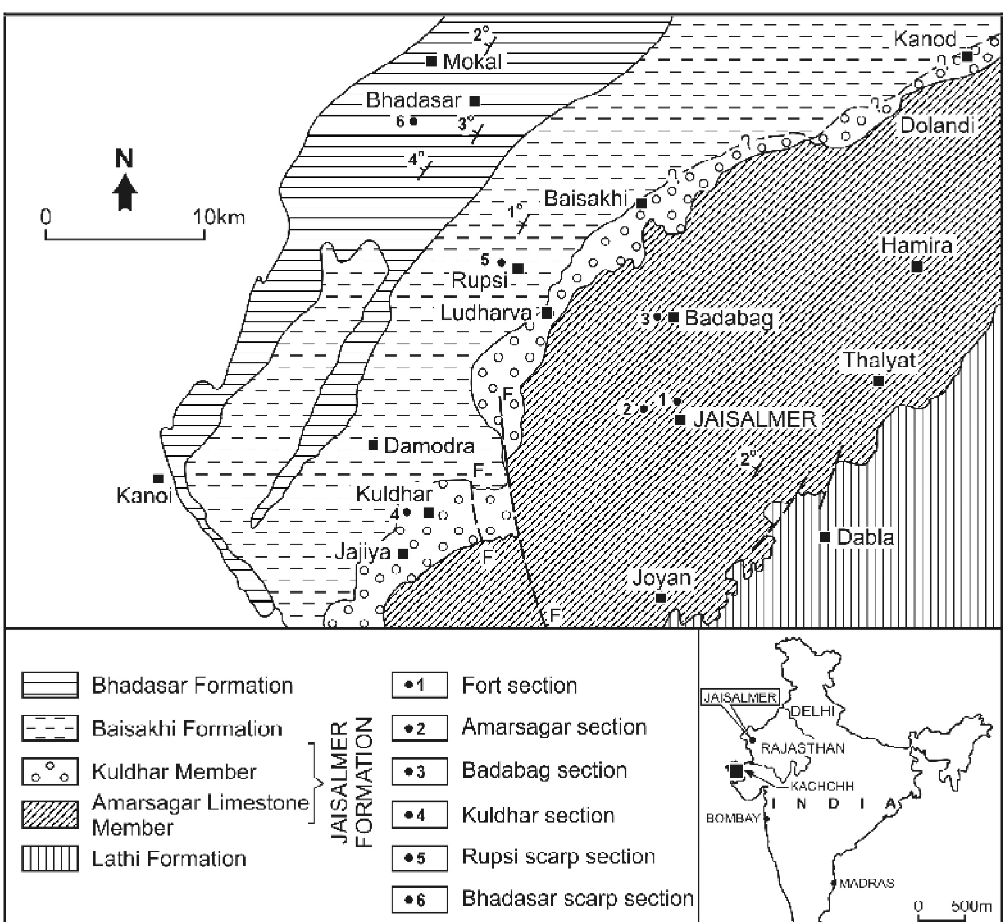


Fig. 2. Geological map of the Middle Jurassic localities of Kachchh and Jaisalmer, western India. (modified after Dave and Chatterjee,1996).

(from bottom to top) in the Rupsi Shale succession exposed at Rupsi village and assigned to Early Tithonian age (Fig. 3a) as summarized below.

The Virgatosphinctoides Zone (beds 1 to 2c of Pandey and Krishna, 2002 = sediments below bed JR5b of present work; Fig. 3b) yielded indeterminable virgatosphinctin fragments (Pandey and Krishna, 2002). This zone, based on the presence of the superjacent Natricoides Zone, was correlated with the Early Tithonian Tethyan Darwini Zone (Pandey and Krishna, 2002) (Table 2).

The succeeding Natricoides Zone is marked by the first appearance of *Aulacosphinctoides natricoides* (Uhlig) (from the base of bed 2d of Pandey and Krishna, 2002 = band 1 of bed JR5b of present work; Figure 3b) which is associated with forms of *Hildoglochiceras*, *Haploceras*, *Halcophyloceras* and *Virgatosphinctes*. This zone was correlated with the Tethyan Semiforme Zone (Pandey and Krishna, 2002) (Table 2).

The following Communis Zone is marked by the first appearance of *Virgatosphinctes communis* and *V. subfrequens* and associated with restricted occurrences of *V.* aff. *saharensis* and *Hildoglochiceras planum*. *Hildoglochiceras latistrigatum*, *H. kobelii*, *Haploceras* cf. *elintatum*, *Holcophyloceras mesolcunz*, *Aulacosphinctoides natricoides*, *A. doghlaensis*, *A. linoptychus*, *Virgatosphinctes pumpeckji* and *V. kafti* mark their last occurrence within this zone. This Zone was assigned to Early Tithonian age and correlated with the Tethyan Fallauxi Zone (Pandey and Krishna, 2002) (Table 2).

Pandey and Krishna (2002) further noted that both the basal Tithonian Pottingeri Zone (= Hybonotum Zone; Table 2) and the Kimmeridgian Stage at Jaisalmer are absent. However, Prasad (2006) recorded a single specimen of Early Kimmeridgian *Katroliceras* (*K.* sp. juv. *depressum*) from the Rupsi section, although, the author noted that the specimen was obtained from someone else (p. 50) and thus, may be stratigraphically loose. Interestingly, Prasad's illustrated study (Prasad, 2006) from Rupsi is in marked contrast with earlier works (Krishna *et al.,* 1996; Pandey and Krishna, 2002); the former (Krishna *et al.,* 1996) recording *Aulacosphinctoides* and *Virgatosphinctes* with no *Katroliceras* whereas the latter recording only *Katroliceras*. Thus, the age of the Rupsi section is highly controversial; ranging from Kimmeridgian (Das Gupta, 1975; Prasad, 2006)) to Kimmeridgian-early Tithonian (Garg *et al.,* 1998), whereas, the very existence of Kimmeridgian in the Jaisalmer basin has been discounted (Krishna *et al.,* 1996; Pandey and Krishna, 2002).

PROPOSED BIOSTRATIGRAPHY

Thus, owing to the above mentioned discrepancy in age and faunal content, we re-investigated this important outcrop and stratigraphically precisely located rich and diverse ammonite assemblages recovered from the type section of the Rupsi Shale (Fig. 3). Our study suggests erection of four ammonite zones based on the acme of genus *Torquatisphinctes*, *Virgatosphinctes*, *Hildoglochiceras* and *Himalayites*, from bottom to top, respectively (Fig. 3 ; Table 2). However, the last zone is based on the singular presence of the genus *Himalayites* which is described and illustrated here.

In the Type section, at Rupsi scarp, the basal sediments (JR2; Fig. 3) yielded abundant small specimens (30) of genus *Torquatisphinctes* (*T. alterneplicatus* var. *neglecta* and *T. alterneplicatus* var. *depressum*; Fig. 4a-d) and accordingly assigned to latest Early Kimmeridgian age (a more comprehensive taxonomic study will be published elsewhere). Similar abundance of *T. alterneplicatus* in the adjoining Kachchh Basin also comes from the latest Early Kimmeridgian Alterneplicatus Zone (Krishna *et al.,* 1996), equivalent to the Tethyan Divisum Zone (Table 2). This Alterniplicatus Zone is now extended to Jaisalmer (Table 2).

The Alterneplicatus Zone is followed by the abundance of *Virgatosphinctes* represented by *V. densiplicatus*, *V.* sp., and *V. subfrequens* (JR4; Fig. 3) and is assigned an Early Tithonian age. It is equated with the Virgatosphinctoides Zone of Pandey and Krishna (2002) and correlated with the Early Tithonian Darwini Zone (Table 2).

The succeeding zone is marked by the restricted and dominant occurrence of *Hildoglochiceras* (*H. kobelliforme*, *H. latistrigatum*, *H. nodosum* and *H.* cf. *planum*) associated with *Aulacosphinctoides* sp. of Early Tithonian age. This is equivalent to the Natricoides Zone identified by Pandey and Krishna (2002) and is based on the abundance of *Aulacosphinctoides natricoides* found associated with several species of *Hildoglochiceras* and equated with the Early Tithonian Tethyan Semiforme Zone (Table 2). Our investigation did not yield *A. natricoides* but several fragmentary specimens of *Aulacosphinctoides* were recorded. Based on the common and restricted occurrence of *Hildoglochiceras*, the Kobelliforme Zone is named on the abundance of *Hildoglochiceras kobelliforme* (a more comprehensive taxonomic study of the ammonite assemblages will be published elsewhere). This zone is equated with the Natricoides Zone of Pandey and Krishna (2002) and correlated with the Tethyan Semiforme Zone (Table 2).

The topmost zone is marked by the first appearance of the Late Tithonian genus *Himalayites* (from 8th band of bed JR5c = bed 2q of Pandey and Krishna, 2002; Figs. 3). This record (Fig. 4f-i) comes from within the Communis Zone (Fig. 3a) of Pandey and Krishna (2002) which is based on the abundance of *Virgatosphinctes communis* and was correlated with the late Early Tithonian Tethyan Fallauxi Zone (Pandey and Krishna, 2002) (Table 2). However, as *Himalayites* is now recorded from this zone and that it is also a global index of Late Tithonian sediments (Leanza, 1980; Tavera, 1985; Cecca, 1999; Shome *et al.,* 2004; Shome and Bardhan, 2007, 2009) hence, part of the Communis Zone of Pandey and Krishna (2002) (Fig. 3) is now dated as latest Tithonian and accordingly equated with the Tethyan Durangites spp. Zone (Table 2) (see also Benzaggagm and Atrops, 1997, p. 139).

DISCUSSION

Based on the present record of *Himalayites* and rich ammonite assemblages from various stratigraphic levels, the age of the Rupsi Shale Member is revised and better constrained between latest Early Kimmeridgian and Late Tithonian (Table 2). The present study also extends palaeobiogeographic distribution of *Himalayites* to the Jaisalmer Basin that has been recorded globally in coeval Late Tithonian sediments. Its introduction in western India (both in Kachchh and Jaisalmer; Fig. 1) and in the Himalayan region (Krishna, 1983; Oloriz and Tintori, 1990; Westermann and Wang, 1988; Enay and Cariou, 1997; Enay and Cariou, 1999; Yin and Enay, 2004) is attributed to rising Late Tithonian sea level (Haq *et al.*, 1987; Hallam, 1988) that facilitated the opening of a new seaway connections among otherwise isolated or semi-

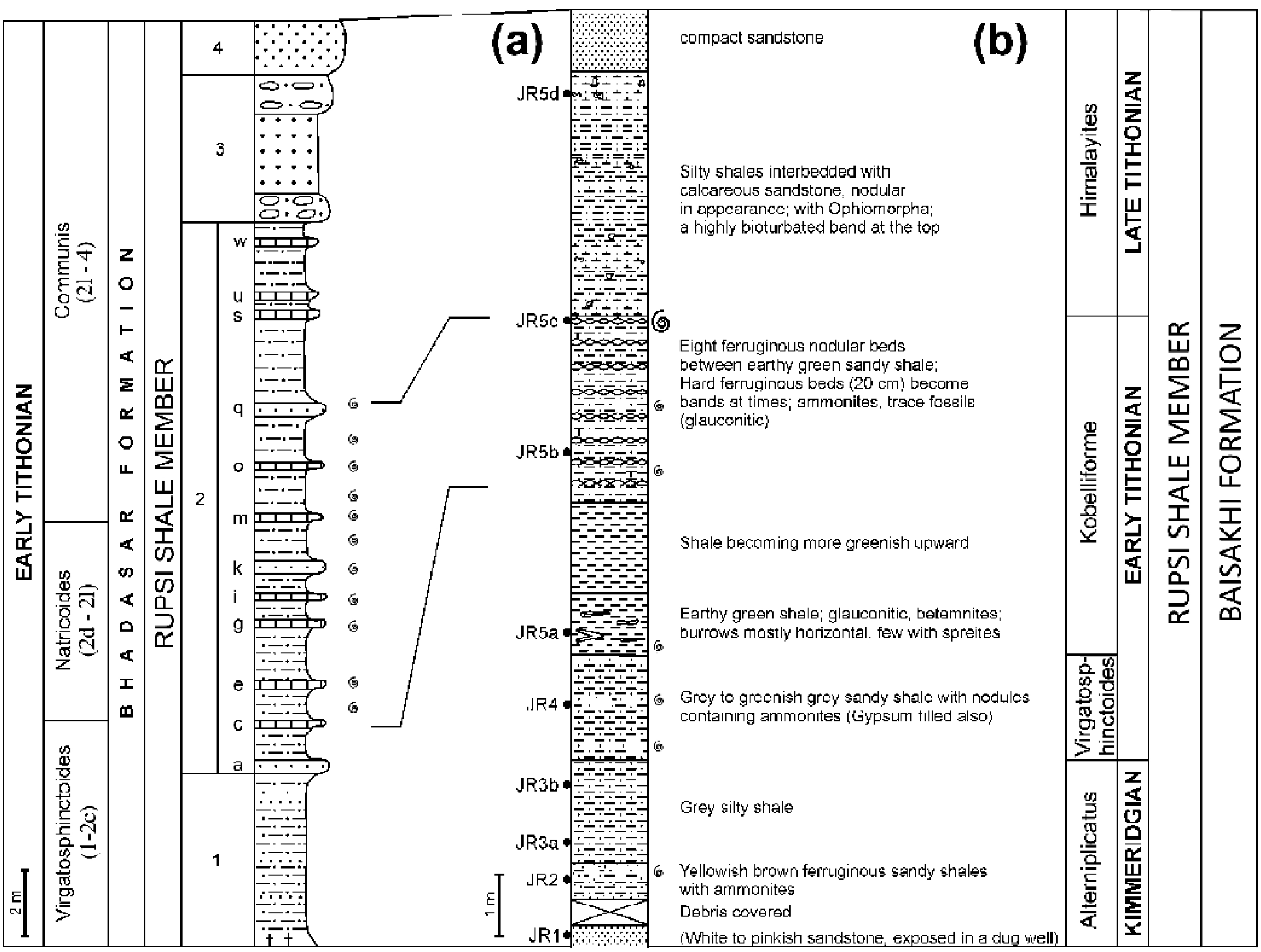


Fig. 3. Correlation of beds exposed at Rupsi (Jaisalmer, western India) as recorded by Pandey and Krishna (2002) (a) and this study (b).

isolated outcrops *in tropical latitudes* basins (largely restricted between 30° N and 30° S; Fig. 1; see also Shome and Bardhan, 2009).

SYSTEMATIC PALAEONTOLOGY

All dimensions are measured in millimeter where D = whorl diameter, U = umbilical diameter, T = whorl thickness and H = whorl height, M = macroconch and Ph = phragmocone.

Family **Barriasellidae** Spath, 1922
Subfamily **Himalayitinae** Spath, 1925
Genus ***Himalayites*** Uhlig in Böehm, 1904

Type species: *Himalayites treubi* Uhlig in Böehm, 1904 by Douvillé, 1912

General Discussion: Based on similar shell morphology, Shome and Bardhan (2007, 2009) clubbed some of Uhlig's (1910) species (12 in number) and gave macroconchiate and microconchiate status to these. The macroconchs [M] display ontogenetic changes in their ribbing pattern. The inner whorls start with an initial two to three secondaries and a tubercle at the point of ribfurcation. The middle whorls (phragmocone) have four to five secondaries and a tubercle that increasingly becomes stronger. At the body chamber, the numbers of secondaries are reduced to two to three and the tubercle becomes robust. *Himalayites seideli, H. hollandi* and *H. stoliczkai* are macroconchs. The microconchs [m] on the other hand possess bifurcating and non-tuberculate ornamentation at early and middle whorls and bi - or trifurcating ribs with tubercles on the body chamber. The ventral furrow is prominent and persists until the end of the shell. Microconchs are always small measuring between 46 to 53 mm and retain the early features of the macroconchs. *Himalayites hyphasis* and *H. ventricosus* are microconchs [m]. Additionally, the macroconchs [M] are larger with robust tuberculation on the body chamber, whereas the microconchs [m] are smaller with biplicate ribs and a prominent ventral furrow.

Himalayites aff. *seideli* (Oppel) [M]
(Fig. 4g-h)

Ammonites seideli Oppel, 1865, part 4, p. 238, pl. 80, figs. 3a-b (Lectotype). – *Himalayites seideli* (Oppel), Uhlig, 1910, p. 140, pl. 39, figs. 2a-b, pl. 40, fig. 1.
Himalayites depressus Uhlig, 1910, p. 151, pl. 42, figs. 2a-b.
Himalayites hoplitiformis (Oppel), Uhlig, 1910, p. 148, pl. 40, figs. 2a-c.
Himalayites sp. Krishna and Pathak, 1994, p. 217, pl. 3, fig. 5.
Himalayites seideli (Oppel): Shome and Bardhan, 2007, p. 224, pl. 1, figs. 1-6, pl. 2, figs. 1-4. - Shome and Bardhan, 2009, p. 224, pl. 5, figs. c-d.

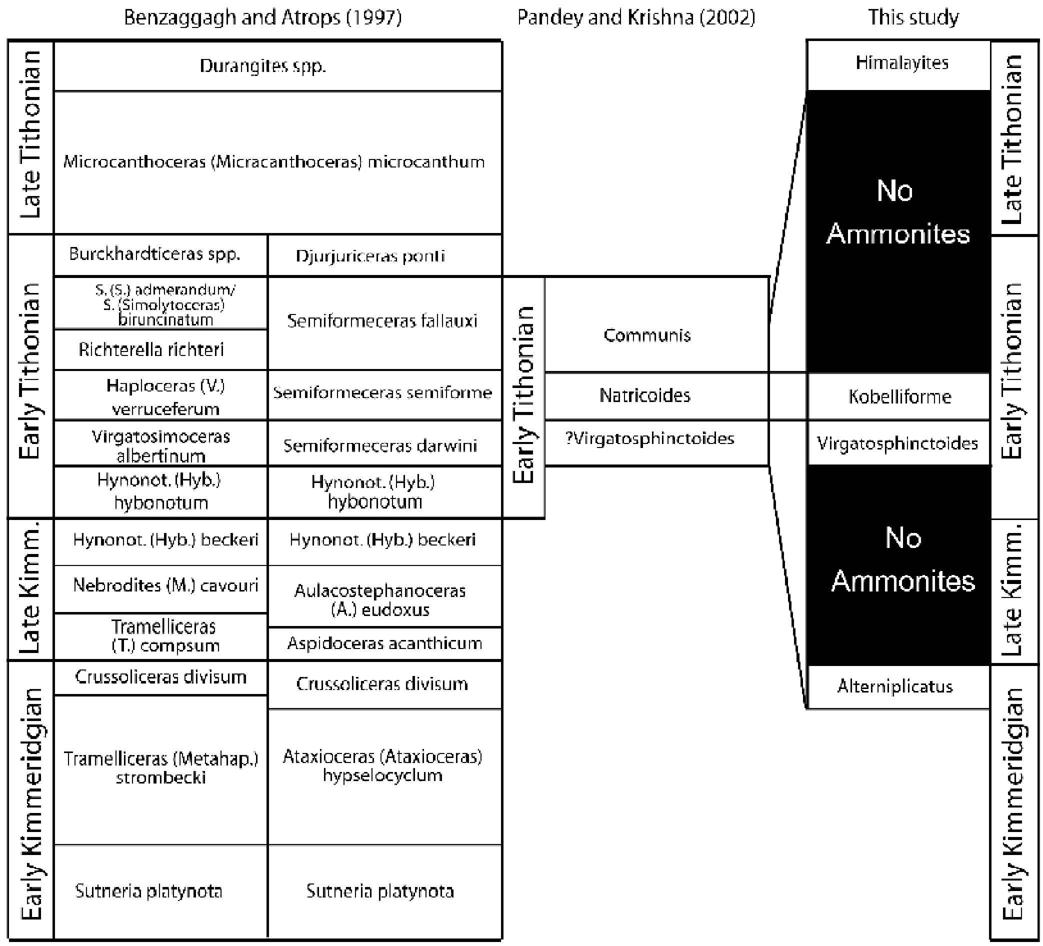
*Dimensions**:

Phragmocone	D	H	T	U	T/H	U/D
At phragmocone	~75.5	20.5	28.5	~30.9	1.39	~0.41

*Measurements are in mm. Note that D, U and U/D are approximations.

Material: One fragmentary septate specimen from the 8th band of bed JR5c (Fig. 3b), Rupsi, Rupsi Shale Member

Table 2: Correlation of the Tethyan (Mediterranean and Submediterranean) Kimmeridgian-Tithonain biozones (modified after Benzaggagm and Atrops, 1997) with those identified by Pandey and Krishna (2000) and this study from Jaisalmer (western India). Benzaggagm and Atrops (1997, p. 139) recorded *Himalayites* from the Durangites Zone of latest Tithonian age.



(Jaisalmer, western India).

Description: Shell, evolute (U/D = ~0.41), depressed (T/H = 1.39), strongly ornamented with moderately sharp ribs. Estimated maximum shell diameter is ~75 mm. Primaries are fine and rectiradiate, arising from below the rounded umbilical shoulder. They persist until 43-54% of flank height, thence are surmounted by a strong and pyramidal tubercle. The tubercle sits on the point of ribfurcation from where four slightly prorsiradiate moderately sharp and rounded secondaries arise. The secondaries cross the broadly rounded and somewhat flattened venter with a perceptible ventral furrow. Between one primary and the other, two intercalatories are present of which one of them is at times free. Umbilical wall is high and somewhat slanting. Umbilical shoulder is broadly rounded. Whorl section is cadiconic. Suture line is highly frilled with a broad and deep bi-fid lateral lobe.

Remarks: The present fragmentary specimen in terms of its characteristic ornamentation (ribbing pattern), presence of robust tubercles, distinct ventral furrow, highly frilled suture line and dimensional proportions, closely matches the lectotype of *Himalayites seideli* (Oppel) [M] (1865, p.140, pl. 80, figs. 3a-b; refigured by Shome and Bardhan, 2007, pl. 1, figs. 1-3; Shome and Bardhan, 2009, pl. 5, figs. c-d). Shome and Bardhan (2007) further noted that in *H. seideli* (Oppel) [M] the "inner whorls [are] weakly tuberculate with bifurcating secondary ribs which may be bunched into three to four on the adult phragmocone. The number of secondary ribs drops to two to three in the body chamber.". This suggests that the present fragmentary specimen is part of the phragmocone and is also indicated by its septate nature.

The present specimen is also a close match to *Himalayites depressus* Uhlig (1910, p. 148, pl. 40, figs. 2a-d; GSI Type No. 9998; refigured by Shome and Bardhan, 2007, p. 227, pl. 2, figs.1-2). Like the present specimen *H. depressus* not only possesses three to four prorsiradiate secondaries with a robust tubercle at the point of ribfurcation (Shome and Bardhan 2007, p. 227, pl. 2, Figs. 1-2) but is also equally depressed (T/H = 1.40; Shome and Bardhan, 2007, p. 226, pl. 2, fig. 2). Additionally, the whorl section is also a close match with the present specimen (compare Pl. 1, Figure h with Pl. 2, fig. 2 of Shome and Bardhan 2007). *H. depressus* is considered a depressed variant of *H. seideli* (Oppel) [M] (Shome and Bardhan, 2007).

H. hoplitiformis Uhlig (1910, p. 151, pl. 42, figs. 2a-c; GSI Type No. 10004; refigured by Shome and Bardhan 2007, p. 226, pl. 2, figs. 3-4) based on the strong resemblance of adult character represented in *H. seideli* (body chamber displaying strong, flexuous with two secondaries and robust tubercles) has also been considered a junior synonym of *H. seideli* (Shome

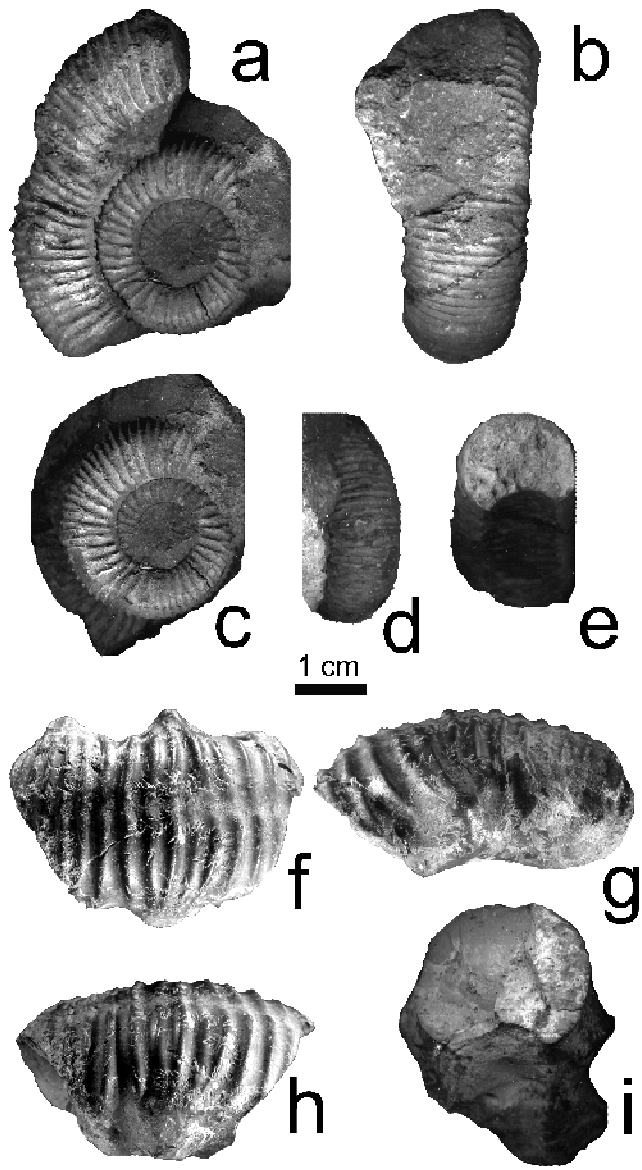


Fig. 4. a-e: *Torquatisphinctes alterneplicatus* var. *neglecta* from bed JR2, the earliest ammonite from the Rupsi section (Fig. 3b). Bar represent 1 cm. a: Lateral view; b: Ventral view of a; c: Lateral view of the inner whorl of a; d: Ventral view of c; e: Apertural view of c; f-i: *Himalayites* aff. *seideli* (Oppel) [M] from the 8th band of bed JR5c, the latest ammonite from the Rupsi section (Fig. 3b). f: Ventral view; g: Lateral view; h: Opposite lateral view; i: Apertural view. Note the break in ribbing on the ventral side and the presence of a strong tubercle.

and Bardhan 2007). Additionally, the whorl section of the present specimen (pl. 1, fig. h) closely matches that of *H. hoplitiformis* Uhlig (1910, pl. 40).

The other macroconchiate [M] *Himalayites hollandi* Uhlig (1910, p. 144, pl. 39, figs. 1a-d; Shome and Bardhan 2007, p. 226, pl. 2, figs. 5-7), the largest of all the species (still septate at 120 mm diameter) is less depressed (T/H varies from 1.15 to 1.17) with only two to three secondaries (Shome and Bardhan 2007).

Himalayites stoliczkai Uhlig [M] (1910, p. 146, pl. 38, fig. 1 a-d; GSI Type No. 9988; Shome and Bardhan 2007, p. 229, pl. 3, figs. 1-3) is a small form (48 mm) with polyfurcate ribs (four to five secondries) at the outer whorl.

Tavera (1985) described several small species of *Himalayites* from Spain, which have equally depressed whorl section and evolute shell with a broad venter. Among these, *H. coroniformis* and *H. cortazari*, have an equally dense ribbing pattern (3 to 4 secondaries per single primary rib) but the primaries are more closely spaced and the tubercles, that are also situated on the ribfurcation, migrate towards the outer-flank with growth.

The present specimen also matches well with the type species *Himalayites treubi* Uhlig [M] (Arkell et al., 1957, p. L357, figs. 468-5a-b; = *H. nederburghi* Boehm, Westermann 1992, p. 552, pl. 86, figs. 5a-b) in possessing four prorsiradiate secondaries with a robust tubercle at the point of ribfurcation with 2 intercalatories that unlike the present specimen extend the entire whorl. The present specimen is also somewhat more depressed.

The microconchs [m] *Himalayites hyphasis* Blanford (1863, p. 132, pl. 4, figs. 2a-b; Shome and Bardhan 2007, p. 229, pl. 3, figs. 7-10) and *H. ventricosus* Uhlig (1910, p. 145, pl. 38, figs. 4a-d; Shome and Bardhan 2007, p. 229, pl. 3, figs. 4-6) are much smaller with biplicate ribs.

Himalayites sp. A [m], from Lakhapar (Kachchh; Fig. 1a), though, equally fragmented (Shome and Bardhan, 2009, p. 10, pl. 4, figs. a-b) is less depressed (T/H = 1.12) with a fine and dense ribbing pattern; the primaries splitting into two prorsiradiate and equally strong secondaries, typical of a microconch [m].

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