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The Arkelli Chronozone: A new early Middle Bathonian standard ammonite zone for Kachchh, western India (southern Jurassic Tethys)

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Abstract

Based on the widespread distribution of the nominal and Madagascan ammonite species *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] in Kachchh (western India), a new early Middle Bathonian Arkelli Chronozone is proposed and correlated with the Western European early Middle Bathonian Progracilis Zone. The nominal species is now firmly established as a geographic subspecies of the Western European *P.* (*G.*) *progracilis* Cox and Arkell [M]. The recorded assemblage within the Kachchh Mainland from this chronozone now contain *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M], *Procerites hians* Waagen [M], *Procerites* (*Siemiradzkia*) cf. *verciacensis* [m], *Sivajiceras congener* (Waagen) [M and m], *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M and m], *P.* (*G.*) *progracilis* aff. *arkelli* Collignon [M], *P.* (*G.*) *intermedius* n. sp. [m], *Macrocephalites* cf. *etheridgei* Spath [m], *M. bifurcatus* transient aff. *bifurcatus* Boehm [m], *M. bifurcatus* transient *intermedius* (Spath) [M and m], *M. bifurcatus* transient cf. *intermedius* Boehm [M], *Macrocephalites triangularis* Spath [M and m], *Parapatoceras distans* (Baugier and Sauzé) [M], *Reineckeia* sp. A and B [M] and *Eutrephoceras* sp. [M]. Coeval sediments at the Island Belt had previously yielded the presence of *Procerites* cf. *schloenbachi*, *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus*, *M.* (*Clydomphalites*) sp. indet., *M.* aff. *hourcqui*, *Clydoniceras triangulare*, *C. pachchhamensis*, *Clydoniceras* sp. and *Bullatimorphites* (s.s.). These finds, thus, now extend the Kachchh non-macrocephalitid records to Saudi Arabia and on to the NW European localities, and for the macrocephalitids, into the High Himalayas and further outside the Indo-Madagascan Province, to the East Indies and into New Zealand. Recent nannofossil data from the same ammonite-yielding bed (the Yellow Bed at Jumara, Kachchh Mainland) is reinterpreted with updated chronology. New data suggests that this condensed Yellow Bed encompasses a 2.6 Ma interval spanning from 168.67 Ma (Late Bajocian; Garantiana Zone) to 166.07 Ma (Middle Bathonian; Morrisi Zone). However, for both Garantiana and Morrisi zones, the ammonite records are lacking in Kachchh, so far. Previous benthic foraminiferal data from the same bed had also yielded a broad Middle Bathonian age. Although, an integrated approach is employed here (using ammonite, foraminifers, nannofossils and lithostratigraphy), but for the Bathonian, among the fauna, the ammonites provide a far better age resolution. Globally, *Macrocephalites bifurcatus* transient cf. *intermedius* Boehm [M] is recorded here as the earliest macrocephalitid. Its evolutionary path follows from the Late Bajocian to Early Bathonian *Satoceras* to *Praetulites* and on to *M. bifurcatus* in the early Middle Bathonian. The *Macrocephalites* entry into Kachchh was possibly facilitated by a transgressive event (the T_{10} event of Hallam and Haq et al.'s ebbing LZA-2.2). This contribution also discusses the implications of these new records to regional and global biostratigraphy.

Key Words: Ammonites, Arkelli Chronozone, early Middle Bathonian, Middle Jurassic, Kachchh, western India, South Tethys

Zusammenfassung

Auf der Basis des weiträumigen Vorkommens des nominellen und madegassischen Ammonitentaxons *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] in Kachchh (Westindien) wird die Einführung einer neuen Arkelli Chronozone für das frühe Mittel-Bathonium vorgeschlagen und mit der westeuropäischen Progracilis Zone korreliert. Das nominelle Taxon wird als eine geographische Unterart der westeuropäischen *P.* (*G.*) *progracilis* Cox & Arkell [M] interpretiert, welche innerhalb der Arkelli Chronozone im Festland von Kachchh assoziiert ist mit *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M], *Procerites hians* Waagen [M], *Procerites* (*Siemiradzkia*) cf. *verciacensis* [m], *Sivajiceras congener* (Waagen) [M und m], *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M und m], *P.* (*G.*) *progracilis* aff. *arkelli* Collignon [M], *P.* (*G.*) *intermedius* n. sp. [m], *Macrocephalites* cf. *etheridgei* Spath [m], *M. bifurcatus* trans. aff. *bifurcatus* Boehm [m], *M. bifurcatus* trans. *intermedius* (Spath) [M und m], *M. bifurcatus* trans. cf. *intermedius* Boehm [M], *Macrocephalites triangularis* Spath [M and m], *Parapatoceras distans* (Baugier & Sauzé) [M], *Reineckeia* sp. A und B [M] sowie *Eutrephoceras* sp. [M]. Aus altersgleichen Sedimenten des Inselgürtels konnte bereits früher das Vorkommen von *Procerites* cf. *schloenbachi*, *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus*, *M.* (*Clydomphalites*) sp. indet., *M.* aff. *hourcqui*, *Clydoniceras triangulare*, *C. pachchhamensis*, *Clydoniceras* sp. und *Bullatimorphites* (s.s.) belegt werden. Diese Funde verbinden die Kachchh Nachweise nicht-macrocephaliider Ammoniten mit Saudi Arabien und weiter nach nordwest Europa, und, mit Hinsicht auf die Makrocephalitiden, mit der Himalaya-Hochebene und weiter zur Indo-Madegassischen Provinz, Ostindien und Neuseeland. Nannofossiliendaten aus der Ammoniten-Schicht (dem Yellow Bed bei Jumara, Kachchh Festland) weren neu interpretiert, und eine revidierte Chronologie wird erstellt. Die Ergebnisse deuten darauf hin, dass das kondensierte Yellow Bed eine Zeitspanne von etwa 2.6 Ma representiert, von 168.67 Ma (oberes Bajocium; Garantiana Zone) bis 166.07 Ma (mittleres Bathonium; Morrisi Zone). Allerdings sind aus keiner dieser beiden Ammoniten Zonen bislang Belegammoniten in Kachchh gefunden worden. Analysen benthischer Foraminiferen aus derselben Schicht deuten ebenfalls auf ein mittel-Bathonisches Alter hin. Obwohl dieser Arbeit ein integrativer Ansatz basierend auf Ammoniten, Foraminiferen, Nannofossilien und Lithostratigraphie zugrunde liegt, läßt sich feststellen, dass für das Bathonium die Ammoniten die beste Altersauflösung geben. *Macrocephalites bifurcatus* trans. cf. *intermedius* Boehm [M] wird als der früheste Vertreter der Macrocephalitiden vorgestellt. Seine Evolutionsgeschichte geht von *Satoceras* aus dem Ober-Bajocium und Unter-Bathonium über *Praetulites* zu *M. bifurcatus* im frühen Mittel-Bathonium. Die Einwanderung von *Macrocephalites* nach Kachchh wurde vermutlich durch ein Transgressionsereignis (das T_{10} event von Hallam & Haq et al.s ebbing LZA-2.2) ermöglicht. Die Bedeutung der neuen Funde und Erkenntnisse für die regionale und globale Biostratigraphie wird diskutiert.

Schlüsselwörter: Ammoniten, Arkelli Chronozone, frühes Mittleres Bathonium, Mitteljura, Kachchh, Westindien, südliche Tethys

1. Introduction

Recent studies of Middle Bathonian ammonites from Kachchh, western India (Fig. 1) have profoundly changed the Bathonian stratigraphy of the Kachchh Basin (Callomon 1993; Pandey & Callomon 1995; Jain 1996, 2013; Jain et al. 1996, 2013; Jain & Pandey 1997, 2000; Jain 2002; Roy et al. 2007; Jain & Desai 2014). The dominant ammonite genus, *Macrocephalites*, that once heralded the advent of Callovian in Kachchh (Krishna & Westermann 1985, 1987), now is known to occur in definite Middle Bathonian strata (Jain 1996, 2013; Jain et al. 1996, 2013; Jain & Pandey 1997, 2000; Jain 2002; Roy et al. 2007, Jain & Desai 2014). Similarly, the problem of *Macrocephalites* endemicity (i.e. occurrence within the Indo-Madagascan faunal Province) is now greatly reduced with several species (*M. dimerus*, *M. madagascariensis*, *M. lamellosus* and *M. formosus*) being recorded from European localities as well (Krishna & Cariou 1990, 1993) and several Indonesian forms (*Macrocephalites* cf. *etheridgei* [m], *M. bifurcatus* transient aff. *bifurcatus* [m], *M. bifurcatus* transient *intermedius* [M and m] and *M. bifurcatus* transient cf. *intermedius* [M]) are now known from the Kachchh Bathonian (Jain 2002, 2013; Roy et al. 2007).

The records of Bathonian non-macrocephalitid species invading Kachchh (Fig. 1d) is equally impressive, being of Arabian [*Micromphalites* aff. *hourcqui* Collignon: Jaitly and Singh, 1984 and *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell: Pandey & Callomon 1995; see also Enay et al. 2001; Mangold & Enay 2010], and European descent [*Leptosphinctes* sp.: Jaitly & Singh 1983, *Procerites* cf. or aff. *hodsoni* Arkell [M and m] and *Procerites* (*Siemiradzkia*) aff. *aurigera*: Jain et al. 1996; *Epistrenoceras* sp.: Waagen 1873–75; redescribed by Kayal & Bardhan 1998]. *Micromphalites*, a South Tethyan genus (from the Arabian Province; see Enay et al. 2001; Mangold & Enay 2010), has its origin in Early Bathonian strata with its subsequent migration to the Mediterranean and the Indo-Madagascan provinces in Middle Bathonian times (Enay et al. 2001; Mangold & Enay 2010). Some of the above mentioned forms are considered geographic subspecies such as the Indian-Madagascan *Procerites* (*Gracilisphinctes*) *arkelli* Collignon [M] (=*Procerites* (*Gracilisphinctes*) *progracilis arkelli* [M]) for the European early Middle Bathonian *P.* (*G.*) *progracilis* Cox & Arkell [M] (Pandey & Callomon 1995; Jain et al. 1996) and the Indian Middle-Latest Bathonian *Sivajiceras congener* Waagen [M], which co-occurs with *P.* (*G.*) *progracilis arkelli* [M] at Jumara (Kachchh; Jain 1996, 2013), for the European *Procerites imitator* Buckman [M] (Callomon 1993; Jain et al. 1996). Within the Subboreal Province, *P. imitator* occurs as a top most subzone of the Progracilis Zone (Dietze et al. 2007).

However, as impressive as the Bathonian record is, it is albeit very local, i.e. dome-specific or locality-specific. For instance, *Leptosphinctes* occurs only in the Island Belt (Pachchham Island; Fig.1a), and *Procerites* (*Siemiradzkia*) aff. *aurigera*, *Epistrenoceras* sp. and *Sivajiceras congener* occur only in the Kachchh Mainland (i.e. at Jumara; Fig. 1a). Interestingly, only *Procerites* (*G.*) *progracilis arkelli* [M]) occurs basin-wide, from the Island Belt (Pachchham; Pandey & Callomon 1995) to the Kachchh Mainland (Jumara: Jain 1996, 2013; Jain et al. 1996; Jain & Pandey 2000; Roy et al. 2007; Nara: Roy et al. 2007; Jhura: Jain et al. 1996; Fig. 1), thus, enabling precise basin-wide correlation of these early Middle Bathonian strata, for the first time (see also Jain 1996, 2013; Jain & Pandey 2000; Roy et al. 2007).

It is in this light that the present discovery of *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell along with Indonesian forms (*Macrocephalites* cf. *etheridgei* Spath [m], *M. bifurcatus* transient aff. *bifurcatus* Boehm [m], *M. bifurcatus* transient *intermedius* (Spath) [M and m] and *M. bifurcatus* transient cf. *intermedius* Boehm [M]) from the core of the Jumara Dome, the depocentre of the Kachchh Basin (Fig. 1), becomes significant.

These new finds, extend the Kachchh ammonite non-macrocephalitid records to Saudi Arabia and on to the NW European localities, and for the macrocephalitids, into the High Himalayas (Tibet: Wester-

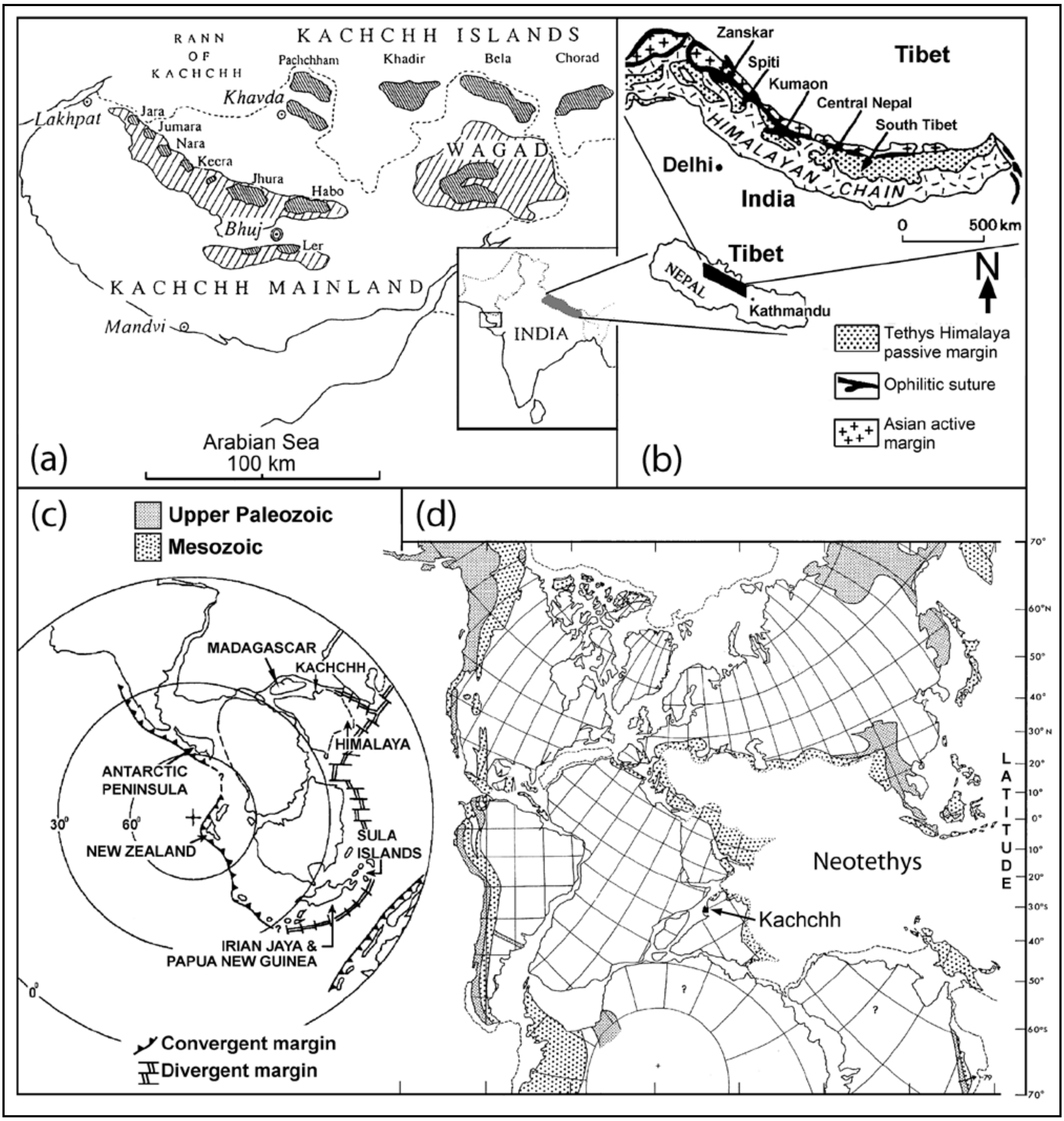

Figure 1: Jurassic localities. **(a)** Kachchh Middle Jurassic localities of the Mainland and Island belt. **(b)** Jurassic localities of the High Himalayas. **(c)** Jurassic tectonic configuration of mentioned ammonite-bearing regions mentioned in the text. **(d)** Position of Kachchh in context of Neotethys.

mann & Wang 1988; Yin 2010) and further outside the Indo-Madagascan Province, to the East Indies (Sula Island: Westermann and Callomon, 1988) and into New Zealand (M. cf. *etheridgei,* cited in Stevens 1974: p. 742) (Fig. 1).

However, it must be noted that faunistically, Kachchh is marked by patchy and dominating occurrences of differing ammonite species at coeval time intervals, with only few species having a pan-basin distribution (Jain & Pandey 2000). This patchy distribution has led to the erection of multiple zones and horizons. Hence, in this study, instead of single species dominance, an assemblage criterion is also used in constructing ammonite biozones. Interestingly, though, this patchy species occurrence mirrors lithological units, where a thick bed that forms a physiographic high in one dome, is perhaps only a metre thick in the neighbouring dome, just few kms apart. A good example is the stratigraphic marker Dhosa Oolite bed (E1) at Jumara which thins from Habo (18 m) to just a meter thick at Jara, from East to West (Fig. 1a).

2. Geological Settings

The Jurassic outcrops in Kachchh (Fig. 1a) constitute the Kachchh Mainland and the Island belt. On

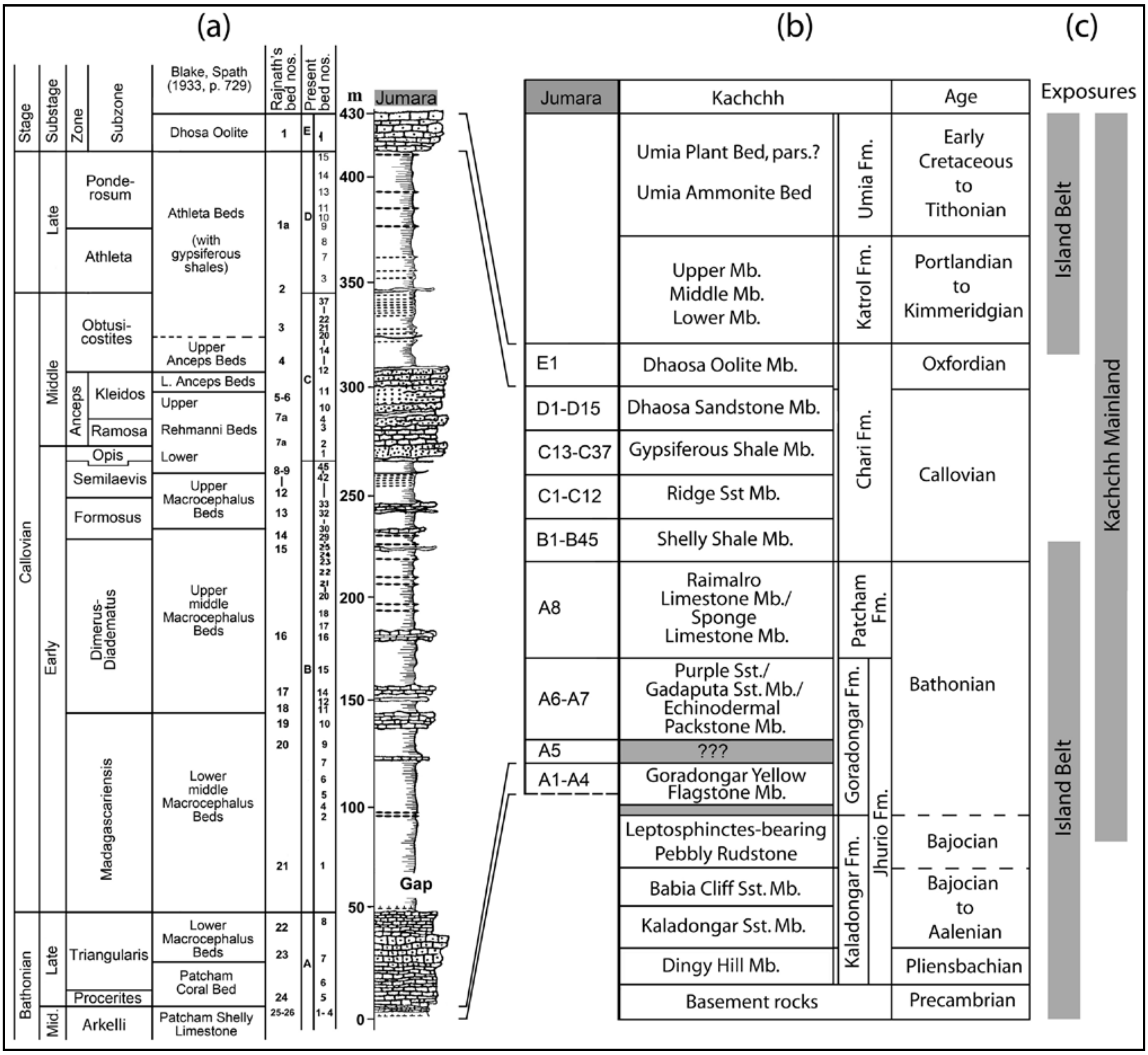

Figure 2: The Jumara Dome and Kachchh strartigraphy. **(a)** Biozones correlated with those of Spath (1927–33) and beds identified by Rajnath (1934) at Jumara. **(b)** Beds exposed at Jumara, the depocentre of the Kachchh basin are shown as part of the Kachchh stratigraphy. Recently, the lower age limit of the first marine transgression in Kachchh has been updated to the Pliensbachian–Toarcian boundary interval based on nannofossil evidences from the Dingi Hill Member (Rai & Jain 2013). **(c)** Jurassic exposures in Kachchh. Gray bars denote presence and extent of the Jurassic strata.

the "Mainland", the Middle Jurassic sediments occur in the eroded cores of anticlinal domes that follow East-West trending fault-bounded lineaments. The "Islands" or "Island belt" or "Kachchh Island" are small to moderate hills that rise from sand plains or salt-flats of the Rann (Fig. 1a; see also Biswas 1991). This contribution discusses new discoveries from the Bathonian strata exposed at Jumara and integrates earlier reports from coeval strata from Nara and Jhura domes (Kachchh Mainland) and those from the Pachchham Island (Fig. 1a).

2.1 Jumara

The Jumara Dome (Fig. 1a; N 23° 41´ 13.6˝ E; 69° 02´ 51´´), the depocentre of the basin is a classical Jurassic locality that exhibits not only the most expanded Callovian sequence for the Kachchh basin but also for the entire northern peri-Gondwana margin. The dome possesses 422 m thick sequence of Middle Jurassic strata (Fig. 2; Jain, 1996) constituting 8 beds in the Patcham Formation (Bathonian; A1–A8; 48 m), 46 beds in the Lower Chari Formation (Lower Callovian; B1–B45 and C1; 229 m), 37 beds in the Middle Chari Formation (Middle Callovian (C2–C37 and D1; 68 m) and 14 beds (D2–D15) in the Upper Chari Formation (Late Callovian; 74 m). Bed E1, the Dhosa Oolite bed (Early–?Middle Oxfordian) tops the Chari Formation.

Five marker beds are also identified at Jumara that span the entire Kachchh Basin (Fürsich et al. 2001). These are the early Middle Bathonian Yellow Bed

Table 1: Bathonian biozonation and correlation. Callomon (1993) dated his Fauna C as Middle Bathonian. Later Callomon and Pandey (1995) recorded several specimens of *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] from the Pachchham Island belt and suggested a Middle Bathonian age for the assemblage. No Zonation was put forward by them.

NORTHWESTERN EUROPE			SUB-MEDITERRANNEAN			WESTERN EUROPE			MADAGASCAR	KACHCHH				
Zones	Subzones			Horizons		Subzones	Zones		Zones	Roy et al. (2007)		Callomon (1993)	This study	
Clydoniceras DISCUS	Clydoniceras DISCUS	UPPER		Clydoniceras discus	UPPER	Clydoniceras DISCUS	Clydoniceras DISCUS		Triangularis	Faunal Horizons	Zones	*Macrocephalites triangularis* (Fauna D)	Not exposed	
	Clydoniceras HOLLANDI			Clydoniceras hollandi					Micromphalites HERQUI				Triangularis	A8-7
Oxycerites ORBIS			-NIAN	Epistrenoceras histricoides										A6
						Prohecticoceras RETROCOSTATUM	Prohecticoceras RETROCOSTATUM							
				Hemigarantia juli										?
				Prohecticoceras blanazense		Prohecticoceras BLANAZENSE				*Macrocephalites* triangularis	Triangularis			
Oxycerites HODSONI				Procerites quercinus						*Procerites hians*			Procerites	A5
				Wagnericeras fortecostatum	MIDDLE	Cadomites BREMERI	Cadomites BREMERI							
				Bullatimorphites bullatimorphus						*K.* cf. *etheridgei*	Etheridgei			
Morrisiceras MORRISI		MIDDLE	BATHO-	Morrisiceras morrisi		Morrisiceras MORRISI	Tulites SUBCONTRACTUS			*Prohecticoceras manjalense*				
Tulites SUBCONTRACTUS				Tulites subcontractus		Tulites SUBCONTRACTUS								
Gracilisphinctes PROGRACILIS				Gracilisphinctes progracilis		Gracilisphinctes PROGRACILIS	Gracilisphinctes PROGRACILIS		Gracilisphinctes PROGRACILIS	*Gracilisphinctes* cf. *arkelli*		*Gracilisphinctes arkelli**	Arkelli	A4
				Cadomites orbignyi										
Asphinctes TENUIPLICATUS		EARLY		Asphinctes tenuiplicatus	EARLY	Asphinctes TENUIPLICATUS	Zigzagiceras ZIGZAG							?A3-1
Zigzagiceras ZIGZAG	Oxycerites YEOVILENSIS			Oxycerites yeovilensis		Oxycerites YEOVILENSIS								
	Morphoceras MACRESCENS			Morphoceras macrescens		Morphoceras MACRESCENS								
	Parkinsonia CONVERGENS			Parkinsonia convergens		Parkinsonia CONVERGENS								

*Callomon (1993) identified Fauna B & C and dated them as Middle Bathonian

C: *Gracilisphinctes arkelli*
B: *Clydoniceras traingulare*
(Fauna B includes *Bullatimorphites* s.s.)

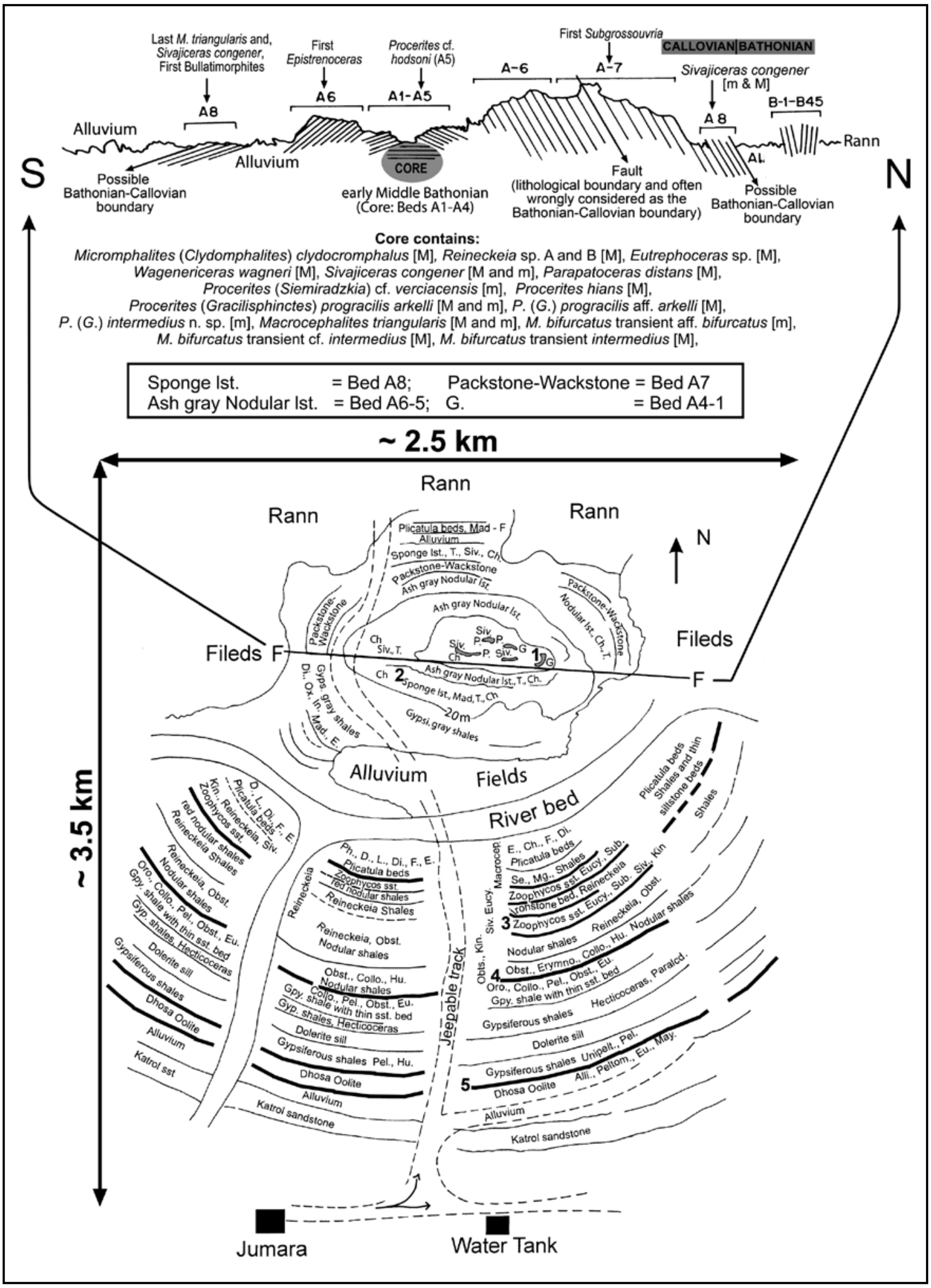

Figure 3: The distribution of beds and contained fauna within the Jumara Dome. **(a)** The North-South transect of the Bathonian beds (beds A1–A8 for the A–B section; see lower panel) exposed in the Jumara dome showing the position of the core and the ammonites identified for this study. **(b)** The distribution of beds and fauna in the entire Jumara Dome. The gray shaded portions (in the centre) mark the core of the Jumara Dome. Abbreviations used: G: This includes all fauna that is described in this contribution (except one from bed A2a; see Fig. 4a) and comes from the Yellow Bed (bed A4); T: *Macrocephalites triangularis*; Mad.: *M. madagascariensis*; Siv.: *Sivajiceras congener*; Ch: *Choffatia*; P: *Procerites*; Mad.-F: *M. madagascariensis* to *M. formosus* Zone fauna (for details see Jain and Pandey, 2000); Di: *M. dimerus*; Ox: *Oxycerites*; E: *M. elephantinus*; Ph: *Phlycticeras*; F: *M. formosus*; D: *M. diadematus*; L: *M. inflata* and *M. habyensis*; Se.: *M. semilaevis*; Mg.: *M. magnumbilicatus*; In.: *Indosphinctes*; Kin.: *Kinkiliniceras*; Si: *Sivajiceras kleidos*; R: *Reineckeiids*; Su: *Subkossmatia*; Collo.: *Collotia*; Obst.: *Obtusicostites*; Erymno.: *Erymnoceras*; Oro.: *Orionoides*; Pe: *Peltoceras*; Hu.: *Hubertoceras*; Eu.: *Euaspidoceras*; Paraccl.: *Paralcidia*; Unipelt.: *Unipeltoceras*; Alli.: *Alligaticeras*; Peltom.: *Peltomorphites*; May.: *Mayaites*; Gyp: Gypsiferous; lst.: Limestone; sst.: Sandstone. Five marker beds (Nos. 1 to 5) are: 1: Middle Bathonian Yellow bed (bed A4); 2: Late Bathonian Sponge Bed (bed A8); 3: Middle Callovian Ridge Sandstone (beds C1–C13); 4: Late Callovian Athleta Bed (bed D1) and, 5: Early–Middle Oxfordian Dhosa Oolite Bed (bed E1).

(= Goradongar Yellow Flagstone bed; Bed A4; Fig. 2), Late Bathonian Sponge Bed (Bed A8), Middle Callovian Ridge Sandstone (beds C1–C12), Late Callovian Athleta Bed (Bed D1) and the Early–Middle Oxfordian Dhosa Oolite (Bed E1; Fig. 2).

This contribution is based on the ammonite collections from the basal beds exposed at the core of the Jumara Dome (Beds A1–A4; Fig. 3) from 1991–2014. Faunal content for the Bathonian Patcham Formation at Jumara is also given (Fig. 4). Bed A4 has previously been correlated with the Goradongar Yellow Flagstone Member of the Pachchham Island (GYFM; Fig. 5) where the top 20 m has yielded an assemblage of early Middle Bathonian fauna of *Clydoniceras*, *Micromphalites,* and *Gracilisphinctes* (Pandey & Callomon 1995) (Fig. 5). The GYFM consists of a series of fine grained carbonates that are readily recognized across the basin by their weathered yellow colour (Jain et al. 1996) and hence, is an ideal stratigraphic marker bed. It is 30–40 m thick at Kaladongar (North Pachchham; Fig. 5b), 40 m thick at Sadhara (Goradongar, South Pachchham; Fig. 5b) and remains unchanged 50 km East at Khadir (Fig. 5b). The same member reappears at Jhura, 45 km SW of Goradongar (Fig. 5b), as a 40 m thick unit with interbeds of "Golden Oolite" where the early Middle Bathonian *P*. (*G*.) *progracilis* aff. *arkelli* [M]) has been recorded (the *Gracilisphinctes* sp. of Jain et al. 1996) (see also Fig. 4).

Jumara, the present study area, is barely 60 km WNW of Jhura (Figs 4, 5) and judging by the consistent thickness of the GYFM, it is safe to assume that it would also be present at its base (Fig. 5). Hence, on lithostratigraphic grounds this member has its extension within the Kachchh Mainland and also within the basal beds at Jumara (Beds A1–4; Fig. 5) and Jhura Domes (Jain et al. 1996; Fürsich et al. 2001) (Fig. 4). Not surprisingly, Bed A4, has also yielded the characteristic *P*. (*G*.) *progracilis arkelli* Collignon [M] and *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell, both recorded from the Pachchham Island Belt (Pandey & Callomon 1995).

2.2 Jhura

Jhura is situated 50 km southeast of Jumara (Fig. 1;

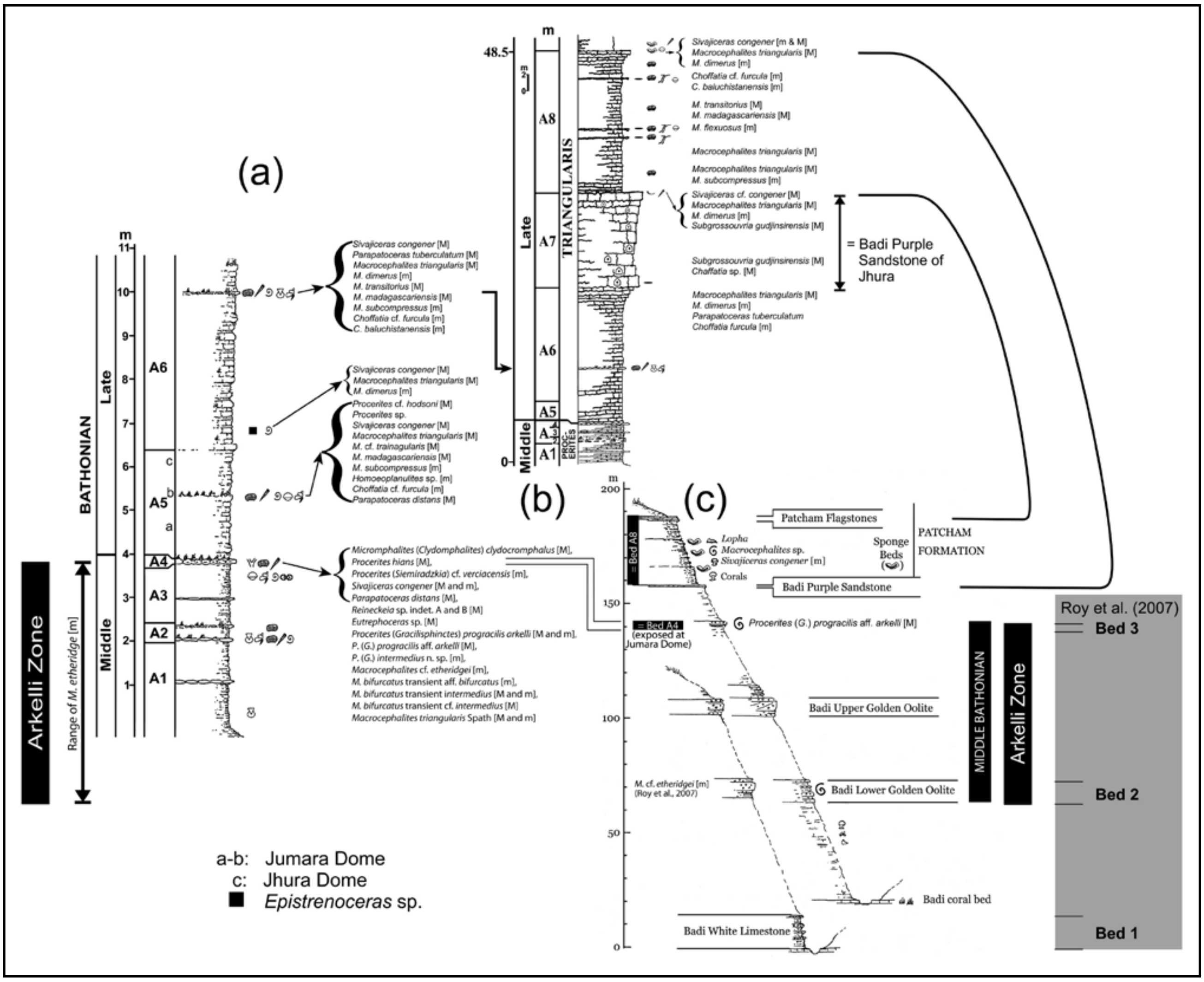

Figure 4: Bathonian biostratigraphy at Jumara (beds A1–A8) and Jhura Domes. **(a, b)** Bathonian biostratigraphy at Jumara (beds A1–A8). **(c)** Bathonian biostratigraphic correlation of Jumara (a, b) and Jhura Dome (c) strata. The ammonite fauna recorded by Roy et al. (2007) and their beds are also marked.

N 23° 24´ 54.2´´; E 69° 36´ 26.3´´). Overlying the oldest bed (a white limestone with shale and greyish yellow slabby limestone alternations; the Badi White Limestone = Bed 1 of Roy et al., 2007; Fig. 4c), the massive golden oolite and shale alternation have yielded *Macrocephalites* cf. *etheridgei* [m] (from Bed 2 of Roy et al. 2007) (Fig. 4c). Overlying this is the hard slabby greyish yellow limestone with thinner and distant golden oolite bands and shale alternations (Bed 3 of Roy et al. 2007; Fig. 4c) that has yielded the early Middle Bathonian *Gracilisphinctes* sp. (Jain et al. 1996; described and illustrated for the first time here as *P*. (*G.*) *progracilis* aff. *arkelli* [M]). *M*. *triangularis*, the ubiquitous Bathonian *Macrocephalites*, occurs in its upper part in greyish yellow limestone and marl alternations (Fig. 4c).

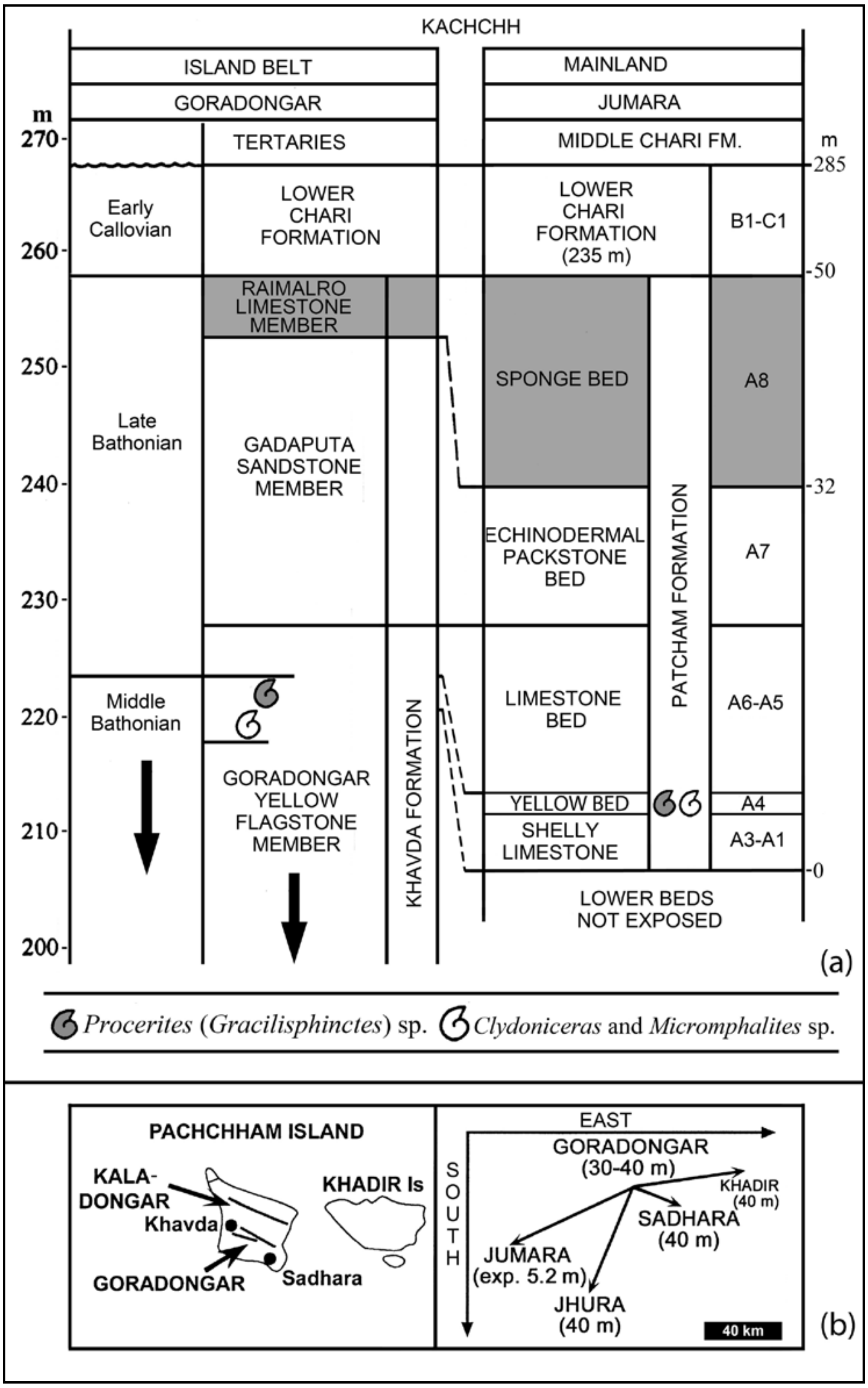

Figure 5: (a) Lithocorrelation of Bathonian beds between Pachchham Island (Island belt) and Jumara (Kachchh Mainland). **(b)** The distribution, extent and thickness variation of the Yellow Bed (bed A4 exposed at the core of the Jumara Dome) within the Kachchh basin (modified after Pandey & Callomon 1995).

2.3 Nara

This domal outcrop is situated 10 km southeast of Jumara (Fig. 1; N 23° 38´ 30´´; E 69° 07´ 30´´). The basal white limestone-marl alternations have recently yielded the Indonesian *Macrocephalites* cf. *etheridgei* Spath [m] along with abundant specimens of *Procerites* (*Gracilisphinctes*) cf. *arkelli*, *Prohecticoceras manjalense*, *Procerites hians* and *Choffatia* sp. (Roy et al. 2007). The stratigraphy given by Roy et al. (2007) is very broad and it is quite possible that some of the lower beds may be of Early Bathonian age as *Prohecticoceras*, a dominant genus (12 macroconch and 4 microconch specimens; Roy et al. 2007), elsewhere, had already appeared during the Early Bathonian (Hahn 1968; Elmi 1971; Torrens 1987) and its oldest species, *P. crassum* Elmi, in France, is known to span from the Early Bathonian Zigzag Zone up to the Middle Bathonian Subcontractus Zone. However, Roy et al. (2007) have clubbed their assemblage and given a broad Middle Bathonian age. Hence, a more detailed study is urgently needed for this dome.

3. Discussion

The co-occurrence of rare *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell with the abundant and nominal Madagascan *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] and the associated typical Indonesian Middle Bathonian ammonites (*Macrocephalites* cf. *etheridgei* [m], *M. bifurcatus* transient aff. *bifurcatus* [m], *M. bifurcatus* transient *intermedius* [M and m] and *M. bifurcatus* transient cf. *intermedius* [M]) suggest correlation of the Yellow Bed (bed A4) assemblage at Jumara (Mainland Kachchh) with the early Middle Bathonian NW European Progracilis Zone. These new Kachchh faunal finds also confirm the proposition of Pandey & Callomon (1995) that *P.* (*G.*) *arkelli* Collignon [M] is a geographic subspecies of the coeval European early Middle Bathonian *P.* (*G.*) *progracilis* Cox & Arkell [M]. The other associated fauna are *Eutrephoceras* sp. [M] and *Parapatoceras distans* (Baugier and Sauzé); the latter is the earliest record from Kachchh (see also Jain & Pandey 1997).

Contextually, it is very interesting to note that earlier, Spath (1928) had considered beds A1–A4 at Jumara to be of Early Bathonian age, and also noted in passing the presence of *Wagnericeras wagneri* (Spath 1928: p. 252). Krishna & Pathak (1994), also in passing, noted the presence of *Wagnericeras* and *Ebrayiceras* from the same Yellow Bed (bed A4) at Jumara (Fig. 4). They further noted two distinct assemblages in their overview of the Bathonian ammonites from Kachchh – a “Middle Bathonian *Gracilisphinctes*, *Micromphalites*, *Kheraiceras*, *Clydoniceras*, *Wagnericeras*, *Procerites*, *Siemiradzkia* and Morphoceratinae assemblage at Patcham [= Pachchham Island; Fig. 1a] and Jumara and another Late Bathonian *Procerites*, *Parachoffatia*, *Kheraiceras* and *Macrocephalites* assemblage at Jumara”. Krishna & Cariou (1993) and later Krishna & Pathak (1994) also noted *Morphoceras* from the Yellow Bed (bed A4). However, as none of these forms were illustrated or described, they are, for now, regarded as tentative records.

Assuming that the record of “*Morphoceras*” from bed A4 by Krishna and Pathak (1994) is authentic, then integrating it with the present assemblage poses a biostratigraphic problem as the *Morphoceras* Douvillé [M]-*Ebrayiceras* Buckman [m] pair that characterize the Early Bathonian Zigzag Zone, does not cross the Middle Bathonian boundary (see Fernández-López et al. 2009). *Ebrayiceras* Buckman, on the other hand, is known to range from Early to Middle Bathonian, as also *Micromphalites* Buckman (see Mangold 1970, 1997; Enay et al. 2001). However, most of the *Micromphalites* specimens, as recently interpreted, have come from the Zigzag Zone, not only in SE France (North of Tethys), but also in Morocco and Saudi Arabia (South of Tethys) (Enay et al. 2001; see also Mangold & Enay 2010). Thus, it is plausible that the condensed Yellow Bed (bed A4) from where all the recorded fauna has come from for this study, actually represents a time duration between the Early Bathonian Zigzag Zone and the early Middle Bathonian Progracilis Zone. But, so far, the lack of *Zigzagiceras* or associated fauna (for details see Fernández-López et al. 2009; Fernández-López & Pavia 2014) in western India strata, suggests the absence of the Early Bathonian Zigzag Zone. Hence, until the “*Morphoceras*” by Krishna and Pathak (1994) from the Yellow Bed (bed A4) is illustrated and described, the available documented evidence presented here suggest an early Middle Bathonian age for the Yellow Bed fauna.

Interestingly from the basal beds at Jumara (beds A4–A1; Fig. 4) Gupta & Singh (1996) have recorded a rich Middle Bathonian foraminiferal assemblage of *Garantella* cf. *stellata* (Middle Bajocian–Middle Bathonian), *Garantella ornata* (Middle Bajocian–?Callovian) and *Pseudomarssonella bipartite* (Early–Middle Bathonian) (for age designation see also Gordon 1970; Gradstein 1978; Gradstein et al. 1989) giving at least a Bajocian–Middle Bathonian age to the Yellow Bed (bed A4).

Recently, a well-diversified but moderately preserved nannofossil assemblage (Jain et al. 2013; Rai et al. 2013, 2014) from the Yellow Bed (bed A4; Fig. 5) have yielded *Axopodorhabdus cylindratus, Cyclagelosphaera margerelii, Calyculus* sp., *Diazomatolithus lehmanii, Discorhabdus criotus, Ethmorhabdus gallicus, Carinolithus magharensis*, *Lotharingius haufii, L. crucicentralis, L. sigillatus, L. velatus, Octopodorhabdus deccusatus, Staurolithites* sp., *Watznaueria barnesae, W. britannica W. manivitae* and *Zeugorhabdotus erectus*. The age of this assemblage is reinterpreted based on updated data (Bown & Co-

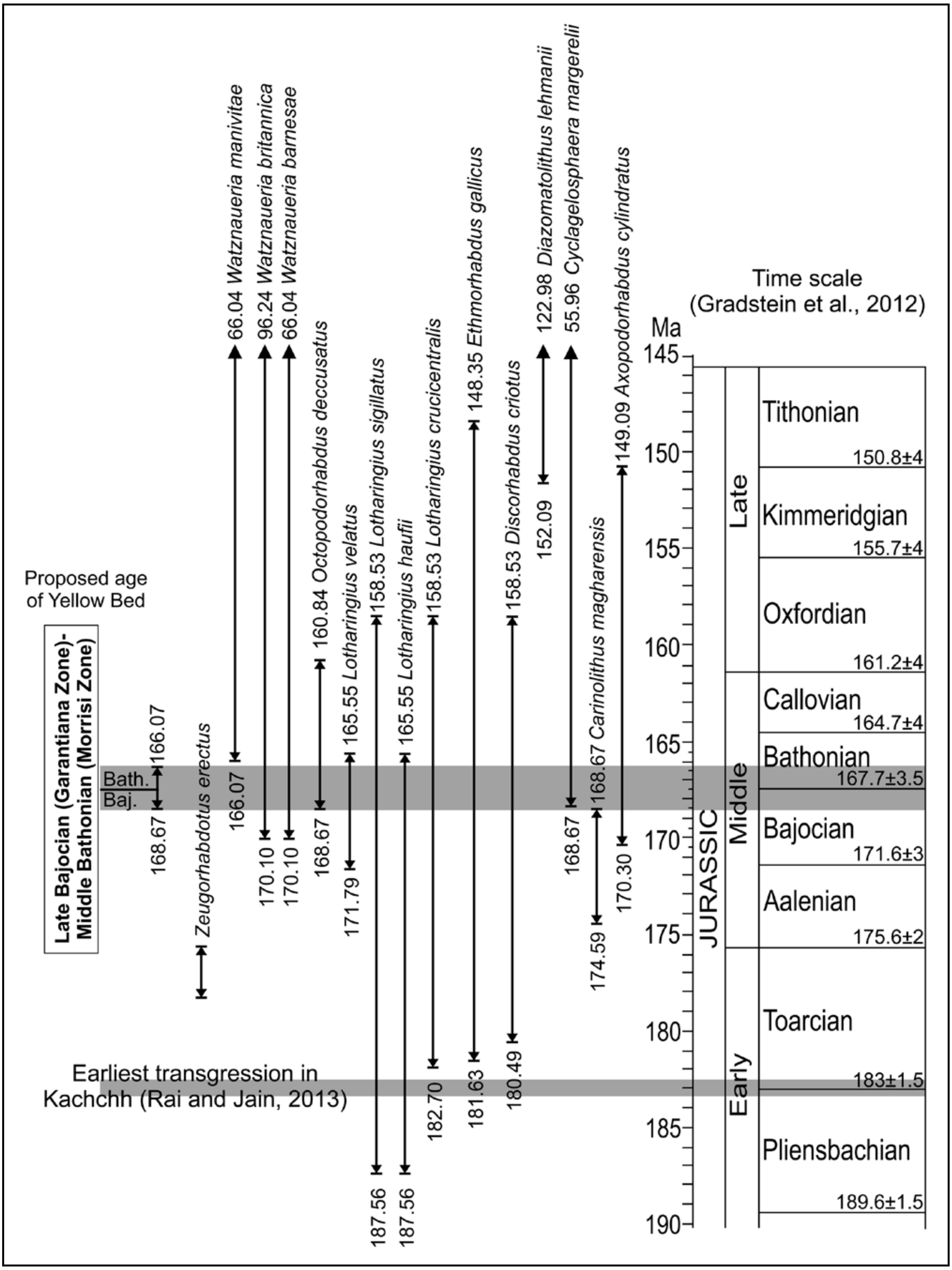

Figure 6: Nannofossil assemblage and the estimated age of the Yellow bed (bed A4) at Jumara (data from Rai et al. 2013; Jain et al. 2013).

oper 1998; Bown 1998; Asgar-Deen et al. 2011) and chronology (Gradstein et al. 2012). This has yielded an age straddling between the Late Bajocian Garantiana Zone (168.67 Ma) to the Middle Bathonian Morrisi Zone (166.07 Ma), spanning a duration of 2.6 Ma (Fig. 6). More fine age resolution with nannofossils is not possible (see Rai & Jain 2013 for a discussion). Interestingly, as the lower age limit of body fossils is being lowered (this study and Pandey et al. 2013), recently, from Jara, Jumara and Habo and from the Island belt, Waagad (see Fig. 1a), the presence or reworked Pliensbachian–Toarcian age nannofossils have now been documented suggesting that at least within the Kachchh basin, the earliest marine transgression occurred during the Pliensbachian–Toarcian boundary interval (Rai & Jain 2013). The earliest well-dated ammonite is still the Late Bajocian *Leptosphinctes* sp. (Jaitly & Singh 1983) from the Island Belt.

Lithostratigraphically also, it has already been well-established that the Yellow Bed (bed A4) exposed at Jumara is an equivalent to the early Middle Bathonian *"arkelli"* yielding Goradongar Yellow Flagstone Member (exposed at the Pachchham Island; Fig. 5) with its extension cropping out at Jhura also (Fig. 5; Jain et al. 1996).

Earlier, Roy et al. (2007) based on the occurrence of a single *M*. cf. *etheridgei* Spath [m] considered the Yellow Bed (bed A4) as part of their Etheridgei Zone and correlated the same with the duration spanning from the NW European Progracilis to Morrisi zones. *M*. cf. *etheridgei* Spath [m] not only co-occurs with the present assemblage from Jumara but also occurs in much lower starta at Jhura (a single specimen from bed 2 of Roy et al. (2007); see Fig. 4c), much below the *Procerites* (*Gracilisphinctes*) *progracilis* cf. *arkelli* [M] yielding bed (bed 3 of Roy et al. 2007; see Fig. 4).

As *Procerites* (*G.*) *progracilis arkelli* [M] is more widespread and cosmopolitan than *Macrocephalites* cf. *etheridgei* [m] within the Kachchh Basin, and the fact that the former is an age-equivalent geographic subspecies of the European *P*. (*G*.) *progracilis* Cox & Arkell [M], a larger basin-wide Arkelli Chronozo-

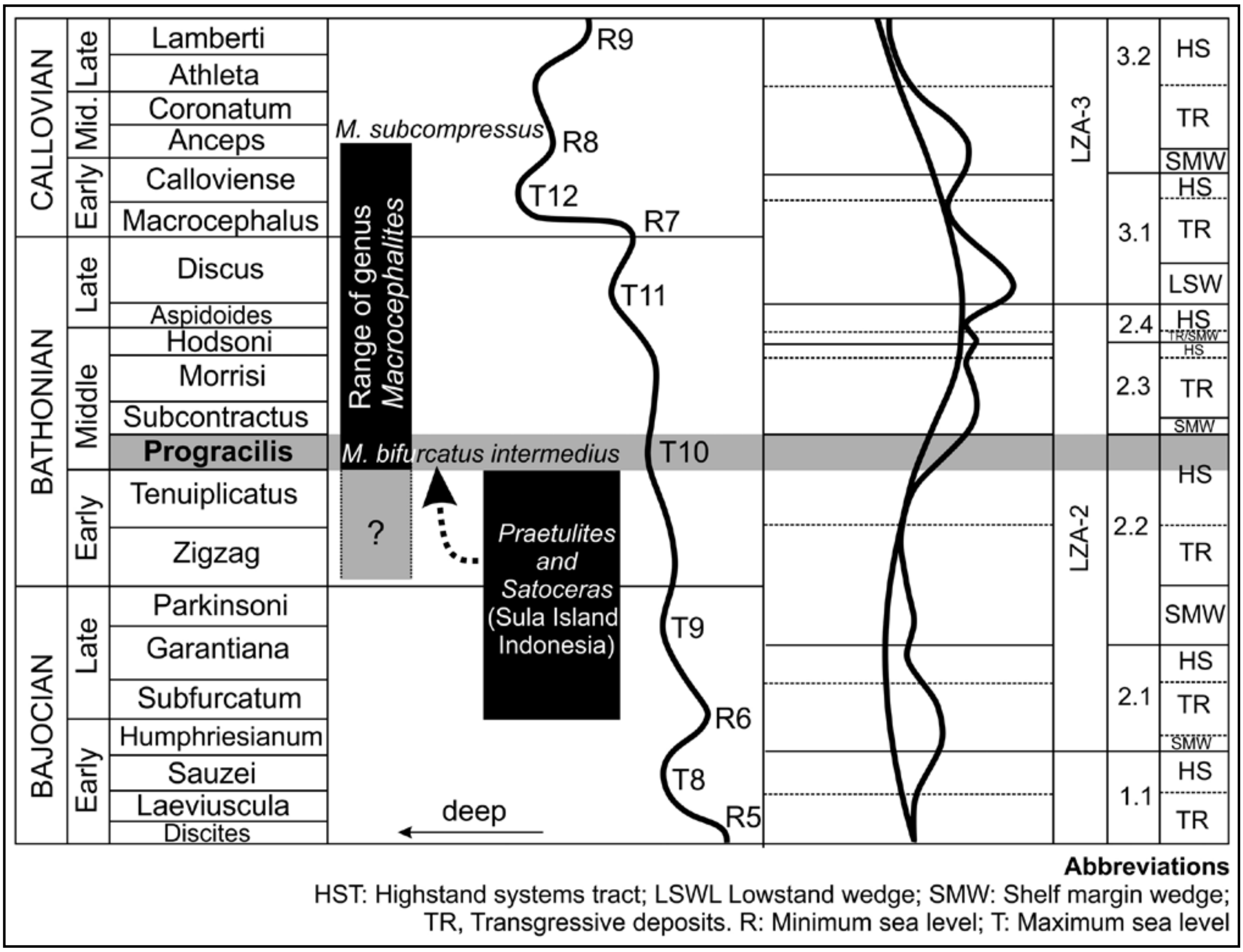

Figure 7: The proposed evolutionary path of *Macrocephalites* in Kachchh. The path follows from the Late Bajocian to Early Bathonian *Satoceras* to *Praetulites* (from Indonesia) and then to *M. bifurcatus* in early Middle Bathonian in Kachchh being facilitated by a global transgressive event (T_{10} event of Hallam & Haq et al.'s ebbing LZA-2.2). *Macrocephalites bifurcatus* transient cf. *intermedius* Boehm [M] is recorded here as the earliest macrocephalitid and the last representative is *Macrocephalites subcompressus* Waagen [m], Anceps Zone, Kleidos subzone (see Fig. 2; Jain & Pandey 2000).

ne of early Middle Bathonian age is proposed here. This would mean an Arkelli Chronozone extending from the Island belt (Pachchham; Pandey & Callomon 1995) to the Kachchh Mainland (Jumara to Nara and Jhura; for the latter up to the Badi Lower Golden Oolite bed where *M*. cf. *etheridgei* [m] has been recorded; Roy et al. 2007) (see Figs 1 and 4). The equivalent Etheridgei Zone of Roy et al. (2007), because of the rarity of the nominal species (*M*. cf. *etheridgei* [m]), its less widespread distribution (only in India and Indonesia) and the fact that it also co-occurs with the more cosmopolitan *P.* (*G.*) *progracilis arkelli* [M], is dropped here in favour of the new Arkelli Chronozone, correlated with the early Middle Bathonian Western European Progracilis Zone (Tab. 1).

4. On the age and occurrence of *Macrocephalites* in Kachchh

Westermann and Callomon (1988) had put forward two probable evolutionary models for the evolution of macrocephalitids – the first assumes the origin from the SW Pacific (South American) Eurycephalitinae. The anchor point being the presence of the dimorphic pair of *Xenocephalites-Lilloettia* (now identified as *Araucanites*; Westermann 2000), appearing already in the Late Bathonian *Xenocephalites-Lilloettia* assemblage of New Zealand (Westermann 1996). Contextually, macrocephalitids did not extend to New Zealand (Westermann 1996), making the second theory more credible – that of the origin of family Macrocephalitinae from the more cosmopolitan Sphaeroceratinae recorded from Sula Island and NW New Guinea (Westermann & Callomon 1988) (Fig. 7). The proposed evolutionary path follows from the Late Bajocian to Early Bathonian *Satoceras* to *Praetulites* and then to *Macrocephalites bifurcatus* in early Middle Bathonian (Westermann & Callomon 1988) (Fig. 7). This transition has also led to the loss of peristomal constriction and lateral nodes (sphaeroceratids characters) and the acquisition of sharp umbilical margin in macrocephalitids, now also recorded in specimens from the Yellow Bed (bed A4; this study) and also from the adjoining Nara and Jhura Domes (Roy et al. 2007); the absence of this sharp umbilical margin in any of the stratigraphically higher Kachchh macrocephalitid forms is noticeable. The additional record of *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M] from this study also dramatically deceases the age gap between *Satoceras* to *Praetulites* to *Macrocephalites*.

The presence of characteristic Epistominids and abundant belemnites from the Yellow bed (bed A4) (Gupta & Singh 1996) along with the mixed nannoflora and the largely bedded concentrations of the Yellow bed fauna (condensed sections) with very high faunal diversity (Jain 2014; communicated) suggests that the Yellow bed is a maximum flooding surface (see Gordon 1970; Gradstein 1978; Williamson & Stam 1988). A coeval and similar transgressive event is also noted in the Pachchham Island (Fürsich et al. 2001) and corresponds well with the T_{10} event of Hallam (1988) and Haq et al.'s (1987) LZA-2.2 sea level curve (Fig. 7). This event is also noted in Thakkhola (Central Nepal) where coeval Middle and Late Bathonian Indonesian macrocephalitids have been recorded in a highly condensed ironstone unit (Cariou & Enay 1999; bed Q1; for general explanation on ironstone formation see Sullivan et al. 2012). These authors (Cariou & Enay) have correlated this unit with the Retrocostatum Zone of Late Bathonian age. However, the presence of similar fauna now in Kachchh in undoubted Middle Bathonian sediments strongly favours the placement of this Napelese unit well within the Middle Bathonian interval. Contextually, the extension of a Middle Bathonian transgressive phase from Indonesia to Central Nepal and to Kachchh also favours the early entry of macrocephalitids to Nepal and to Kachchh and a westwards migration along the Gondwana margin with its roots in Indonesia, but in the early part of Middle Bathonian (Jain 2002). Interestingly, the Yellow Bed fauna is also similarly dominated by compressed and evolute forms of perisphinctids, like those recorded from coeval sediments in the Pachchham Island (Island belt; Fig. 3) and elsewhere in the world during this interval (Collignon 1958; Arkell 1952, 1957; Dietl 1990; Sandoval et al. 2001).

In summary, the Arkelli Chronozone assemblage in the Kachchh Mainland contains *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell, *Macrocephalites triangularis* Spath [M and m], *M. bifurcatus* transient aff. *bifurcatus* Boehm [m], *M. bifurcatus* transient *intermedius* (Spath) [M and m], *M. bifurcatus* transient cf. *intermedius* Boehm [M], *Procerites hians* [M and m], *Sivajiceras congener* [M], *Parapatoceras distans* [M], *Reineckeia* sp. indet. A and B [M], *Eutrephoceras* sp. [M], and *Procerites* (*Siemiradzkia*) cf. *verciacensis* [m] and at the Island Belt, *Procerites* cf. *schloenbachi*, *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus*, *M.* (*Clydomphalites*) sp. indet., *M.* aff. *hourcqui*, *Clydoniceras triangulare*, *C. pachchhamensis*, *Clydoniceras* sp. and *Bullatimorphites* (s.s.).

Although, an integrated approach like this (ammonite, foraminifers, nannofossils and lithostratigraphy) is imperative and should be the norm in better refining the age of an assemblage, zone or subzone, but for now, at least for the Bathonian, the ammonites provide a far better age resolution in Kachchh (Jain 2008, 2013). It is plausible that with more finds of index ammonites and marker nannofossils, the basal age of Yellow Bed (bed A4) and also of the proposed Arkelli Chronozone in Kachchh, will be refined and resolved.

Micromphalites (*Clydomphalites*) *clydocromphalus* Arkell [M], *Procerites* (*Gracilisphinctes*) *arkelli* [M and m], *Procerites* (*Gracilisphinctes*) *intermedius* n.

Table 2: The Bathonian biozonation at Jumara Dome. The ammonites listed here are mostly collected by the author (see Jain 1996, 2002, 2013, 2014; Jain et al. 1996; Jain & Pandey 1997, 2000). Those in bold are both dominant and nominal species. This table also incorporates records by various Kachchh workers form Jumara. These include those mentioned either in passing (such as *Wagenericeras wagneri*; Spath 1927–1933) or redescribed with actual documentation. The latter includes records of *Epistrenoceras* sp. (Kayal & Bardhan 1998), *Bullatimorphites* sp. [Bardhan et al. 1988, 2002; = inferred here as *Bullatimorphites* (*Kheraiceras*) cf. *hannoveranus*] and *Oxycerites* sp. [Roy et al. 2007; *Oxycerites* cf. *orbis*]. Those recorded from the Island Belt are also incorporated (Jaitly & Singh 1984; Pandey & Westermann 1988; Pandey & Callomon 1995). The Marker beds (in bold) are after Fürsich et al. (2001).

Age		**Kachchh (this study)**				**Common European elements at coeval levels (also recorded at Jumara)**	**Western Europe (North Tethyan) Biozonation (Cariou and Hantzpergue, 1997)**	
Stage	**Substage**	**Jumara bed nos. & Kachchh marker beds (in bold)**	**Zones**	**Ammonite assemblage recorded at Jumara (Nominal species are in bold)**	**Pachchham Island Belt**		**Zones**	**Subzones**
Late Bathonian	late	GAP					Discus	Clydoniceras discus
		A8; Sponge Beds (= Raimalro Lst.)	Triangularis	***Macrocephalites triangularis* [M],** *Sivajiceras congener* [M and m], *M. dimerus* [m], *Choffatia cf. furcula, C. balinensis, C. baluchistanensis, C. subbakeriae, Parapatoceras tuberculatum* and *Epimorphoceras decorum* [M].	*Macrocephalites triangularis* [M]	*Epistrenoceras* sp., *Bullatimorphites* cf. *hannoveranus, Oxycerites* sp., *Choffatia furcula, C. balinensis, C. baluchistanensis, C. subbakeriae*		Clydoniceras hollandi
		A7; Echinodermal Packstone		***Macrocephalites triangularis* [M],** *Sivajiceras congener* [M], *Choffatia cf. furcula*				
	middle	A6		***Macrocephalites triangularis* [M], *Epistrenoceras* sp.,** *Sivajiceras congener* [m], *Bullatimorphites* cf. *hannoveranus, Oxycerites* sp., *Choffatia* cf. *furcula, C. balinensis, C. baluchistanensis, C. subbakeriae*			Oxycerites orbis	Epistrenoceras histricoides
								Hemigarantia juli
								Prohecticoceras blanazense
	early	A5	Procerites	***Procerites* cf. *hodsoni*,** *Procerites* sp., *Macrocephalites triangularis* [M], *Homoeoplanulites* sp.		*Procerites hodsoni, Micromphalites* aff. *hourcqui*	Procerites hodsoni	Procerites quercinus
								Wagnericeras forticostatum
								Bullatimorphites bullatimorphus
Middle Bathonian	late	GAP					Morrisiceras morrisi	
							Tulites subcontractus	
	early	A4-A1; **Yellow Bed (A4) = upper part of Goradongar Yellow Flagstone Mb.**	Arkelli	***Procerites* (*Gracilisphinctes*) *progracilis arkelli*, *Micromphalites* (*Clydomphalites*) *clydocromphalus*,** *Procerites hians* [M], *Procerites* (*Gracilisphinctes*) *progracilis arkelli* [M and m], *Procerites* (*Gracilisphinctes*) *progracilis* aff. *arkelli* [M], *Procerites* (*Gracilisphinctes*) *intermedius* n. sp. [m], *Macrocephalites triangularis* [M and m], *M.* cf. *etheridgei* [m], *M. bifurcatus* transient aff. *bifurcatus* [m], *M. bifurcatus* transient *intermedius* [M and m], *M. bifurcatus transient* cf. *intermedius* [M], *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus, Sivajiceras congener* [M and m], *Parapatoceras distans* [M], *Reineckeia* sp. indet. A and B [M], *Procerites* (*Siemiradzkia*) cf. *verciacensis* [m]	***Procerites* (*Gracilisphinctes*) *progracilis arkelli* [M], *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus*,** *M.* (*Clydomphalites*) sp. indet., *Clydoniceras triangulare, C. pachchhamensis, Clydoniceras* sp., *Procerites* (*Gracilisphinctes*) cf. *schloenbachi, Bullatimorphites* (s.s.).	*Procerites* (*Gracilisphinctes*) *progracilis, Micromphalites* (*Clydomphalites*) *clydocromphalus, Procerites* (*Siemiradzkia*) *verciacensis*	Gracilisphinctes progracilis	

sp. [m], *Macrocephalites triangularis* [M and m], *Macrocephalites* cf. *etheridgei* [m], *M. bifurcatus* transient aff. *bifurcatus* [m], *M. bifurcatus* transient *intermedius* [M and m] and *M. bifurcatus* transient cf. *intermedius* [M] from Jumara, and *Procerites* (*Gracilisphinctes*) aff. *arkelli* Collignon [M] from Jhura, are described and illustrated.

5. Systematic Palaeontology

Ammonites described and illustrated in this study have come from two beds – A2a and A4, from the core of the Jumara Dome (Fig. 4). Bed A2 is a 0.50 m thick green packstone bed exposed in the northeastern part of the core (Fig. 3). The coral *Microsolena* is abundant here. Only a single *Macrocephalites* specimen is recorded from this bed, rest all have come from the Yellow Bed (bed A4). The Yellow Bed is a 0.20 m thick bioturbated packstone bed associated with abundant ammonites, bivalves, gastropods, brachiopods and corals. Both beds are exposed in small gullies within the core of the Jumara Dome. The strata has undergone extensive lateral faulting and weathering. Hence, most specimens, in general, from the Bathonian of Jumara are always fragmentary; rare forms have been found complete (see Spath 1927–33; Callomon 1993 for comments). The present collection is no different.

Therefore, the importance of this contribution is to record the presence of rare species and document their morphological characteristics by incorporating specimens collected previously by other workers and from coeval basin-wide strata. All specimens are part of the author's dissertation (Jain 1996) and are accordingly kept at the Palaeontology Laboratory, Geology Department, University of Rajasthan, Jaipur (India).

Genus *Micromphalites* Buckman, 1923

Type species *Ammonites micromphalus* Phillips, 1871: p. 177, pl. 10, fig. 38.

Subgenus *Clydomphalites* Arkell, 1952

Type species *Micromphalites (Clydomphalites) clydocromphalus* Arkell, 1952: p. 287, text-fig. 9, pl. 26, figs 1–7, 9; pl. 28, fig. 12.

Micromphalites (*Clydomphalites*) *clydocromphalus* Arkell, 1952 [M]

Figs 8–9; Appendix 1

1952	*Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell, p. 287, pl. 26, figs 1, 7, 9, pl. 28, fig. 12, text-fig. 9.
1958	*Micromphalites saint-oursi* Collignon, pl. 9, fig. 45 (Type).
1952	*Micromphalites* (*Clydomphalites*) cf. *clydocromphalus* Arkell – Pandey & Callomon, p. 127, pl. 1, figs 2, 3.
1987a	*Micromphalites clydocromphalus* Arkell – Enay et al., pl. 5, fig. 4.
2001	*Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell – Enay et al., p. 510, pl. 1, figs 1–9, pl. 2, fig. 1.

Material: One specimen from the Yellow Bed at Jumara (= bed A4; this study).

Description: Shell small and entirely septate (D = 58.4 mm). Phragmocone discoidal, involute (U/D = 0.18 at 42.7 mm to 0.11 at 58.4 mm), compressed (T/H = 0.40–0.43) with a keeled venter. Maximum inflation is at the umbilical shoulder. Inner whorls are not visible. Outer whorl displays broadly rounded primaries dividing into two straight secondaries (noted between at 42 to 50 mm shell diameter). The secondaries, with increasing shell diameter, are restricted to the outer third of flank height, thus, leaving the umbilical region smooth (Fig. 8a, b). After 50 mm, shell is smooth like *Clydoniceras*. The secondaries terminate in small nodes (Fig. 8b). Keel is not well preserved but appears serrated. Whorl-section is triangular (Fig. 8c, d).

Remarks: The general sculpture of the shell, i.e. whorl-section, ornamentation and dimensional proportions (Fig. 9) are similar to the type material described by Arkell (1952) from the middle Dhruma Formation (Middle Bathonian of Nejd, Jebel Tuwaiq, Juraita) from Saudi Arabia. In its general morphology, whorl-section and dimensional proportions the present specimen is also a close match with the equally septate *M.* (*C.*) cf. *clydocromphalus* Arkell recorded from the coeval early Middle Bathonian sediments of Pachchham Island, Kachchh (Pandey and Callomon, 1995, pl. 2, fig. 3; PG/240/8: D = 41 mm, T/H = 0.40 and U/D = 0.12) (see Fig. 9). The present specimen also closely matches with the specimen figured by Enay et al. (2001: pl. 1, fig. 3) from Limon (SE France) from the Zigzag Zone (Early Bathonian).

Recently Enay et al. (2001) established the position of *Micromphalites* from the Nevers area within the Zigzag Zone. They noted that the oldest known *Micromphalites* is probably from the Convergens (or Parvum) subzone of the Zigzag Zone in the Nièvre Département (?*Micromphalites*. sp. in Enay et al. 2001: p. 517, pl. 1, fig. 10) and that the greater part of known *Micromphalites* are from the Zigzag Zone, not only in the Nièvre Département, but also in Morocco and Saudi Arabia (Enay et al. 2001; see also Mangold & Enay 2010). However, the absence of any characteristic Zigzag Zone fauna at Jumara rules out the presence of any Early Bathonian strata here.

Superfamily Perisphinctoidea Buckman, 1920

Family Reineckeiidae Hyatt, 1900

Genus *Reineckeia* Bayle, 1878

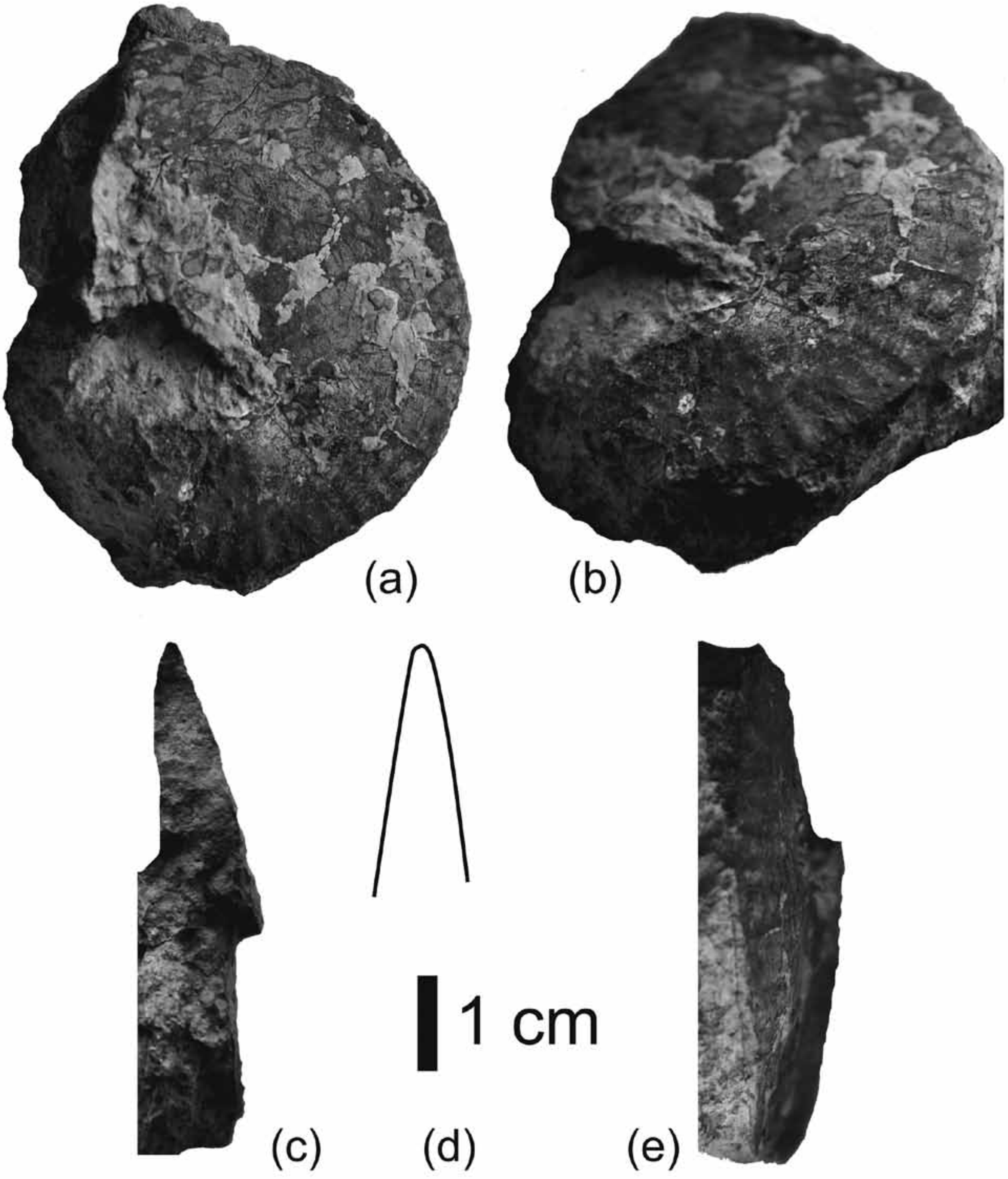

Figure 8: (a–e) *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M], specimen no. SJ/Ju/14/A4/1, Yellow Bed (bed A4), Jumara Dome. (a): Lateral view. (b): Laterl view at an angle to highlight ribbing pattern. (c): Apertural view. (d): Whorl-section reconstructed from (c). (e): Ventral view showing the narrow keel.

Reineckeia spp. indet. A and B [M]
Figs 10, 11

1996 *Reineckeia* (*Reineckeia*) *tyranniformis* Spath – Jain, p. 110, pl. 28, figs 1, 2.
1996 *Reineckeia* spp. indet. A and B [M] – Jain et al., p. 136, figs 4–8.

Remarks: The range of the cryptogenic genus *Reineckeia* Hyatt has recently been extended both upwards (Early Oxfordian, Andes: see Gröschke 1994; Gröschke & Kossler 1999) and downwards (from the Yellow Bed and bracketed between Late–Middle Bathonian; see Jain et al. 1996). This lower record is now dated as a definite early Middle Bathonian (this study). This previous record of two specimens

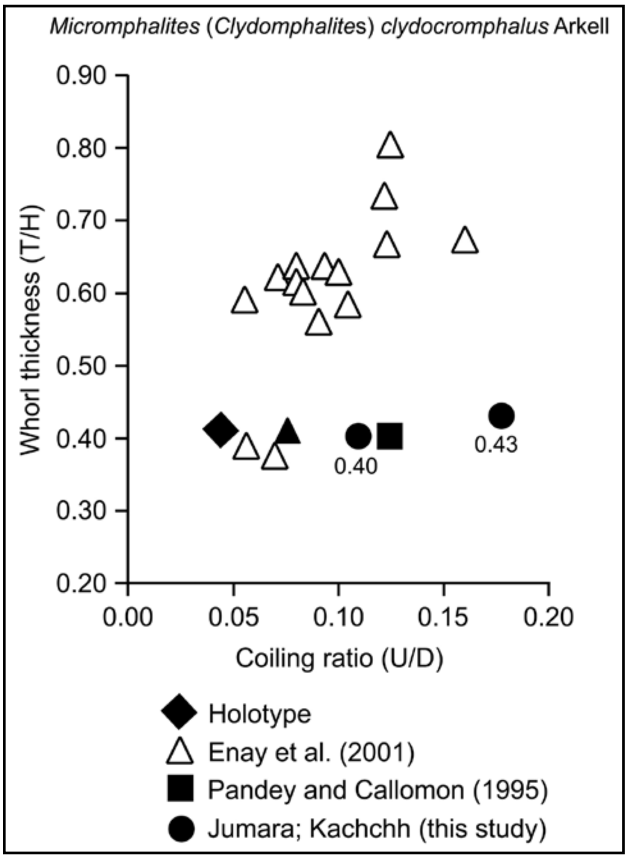

Figure 9: Comparative proportional dimensions (whorl thickness vs. coiling ratio) of *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M].

of *Reineckeia* (*Reineckeia* spp. indet. A and B [M]; Jain et al. 1996) (Figs 10, 11) now also firmly establishes Kachchh as the centre of evolution for the genus that previously was placed comfortably within the SW Pacific (Riccardi et al. 1989).

The presence and the new age assignment of these reineckeiid specimens from the Yellow Bed also brings back the question of the systematic position of *Epimorphoceras decorum* [M] (Waagen 1875: p. 208, pl. 57, fig. 3a–d) recorded much higher from "the highest beds of the Putchum group of Jumara" (= Sponge beds; bed A8; Latest Bathonian; see also Jain et al. 2006: p. 141). Spath (1928: p. 252) considered it as a reineckeiid and Jain et al. (1996) thought of it as an early reineckeiid of unknown affinity. Bardhan & Kayal (1999) considered it a Morphoceratid with close affinity with *Ebrayiceras sulcatum* (Zieten) and *E. jactum* Buckman. *Ebrayiceras* has been noted in passing by Krishna & Pathak (1994) from the Yellow Bed, making the proposition of Bardhan & Kayal (1999) more plausible. However, the basis tenet that both *Epimorphoceras* and *Ebrayiceras* share "tuberculate inner whorls" (Bardhan & Kayal 1999) could not be corroborated. More future finds might resolve this long standing problem.

Superfamily Perisphinctaceae Steinmann, 1890

Family Perisphinctidae Steinmann, 1890

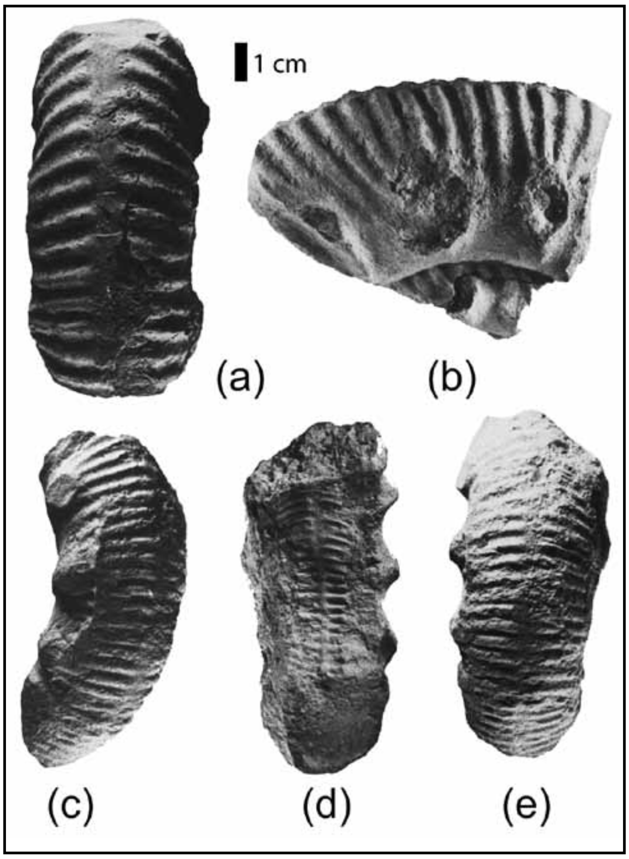

Figure 10: (a–e) *Reineckeia* sp. indet. A and B [M]. (a, b): *Reineckeia* sp. A, specimen no. Ju/27/57. This is a wholly septate fragment of inner and intermediate whorls. (c–e): *Reineckeia* sp. B, specimen no. Ju/27/58. This is a wholly septate fragment of inner and intermediate whorl with umbilical seam indicating presence of another whole whorl. All specimens are from the Yellow Bed (bed A4), Jumara Dome. For details on *Reineckeia* systematics, biostratigraphy and biogeography see Jain et al. (1996).

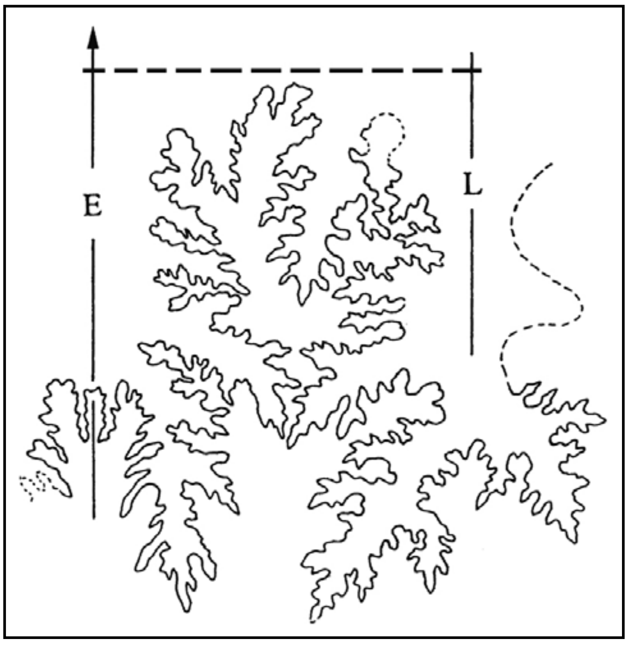

Figure 11: Spetal suture of *Reineckeia* sp. A. exposed at 45 mm whorl height, specimen no. Ju/27/57, Yellow Bed (bed A4), Jumara Dome.

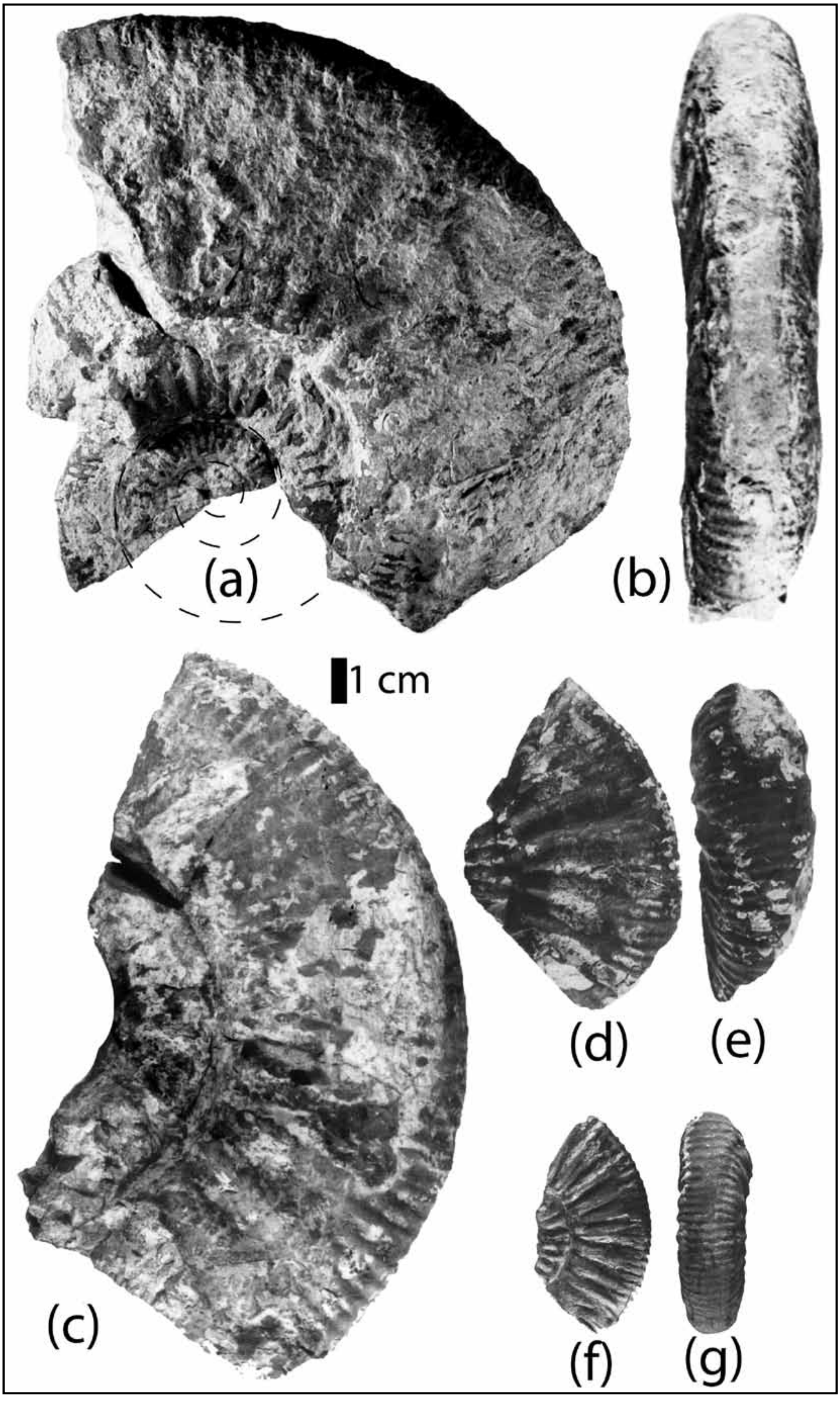

Figure 12: (a, b) *Procerites hians* Waagen [M], specimen no. Ju/27/5. (a): Lateral view. (b): Ventral view. **(c–g)** *Sivajiceras congener* (Waagen) [M and m]. (c–e): *Sivajiceras congener* (Waagen) [M]. (c): Lateral view, specimen no. Ju/27/56. (d, e): Specimen no. Ju/27/55. (d): Lateral view. (e): Ventral view. (f, g): *Sivajiceras congener* (Waagen) [m], specimen no. Ju/24/41, bed A6. (f): Lateral view. (g): Ventral view. All specimens, except (f, g) are from the Yellow Bed (bed A4), Jumara Dome.

Subfamily Zigzagiceratinae Buckman, 1920

Genus *Procerites* Siemiradzki, 1898

Type species *Ammonites procerus* Schloenbach, 1865 (=*Perisphinctes schloenbachi* Grossouvre, 1907).

Procerites hians (Waagen) [M]
(Fig. 12a, b)

1875 *Perisphinctes hians* Waagen, p. 153, pl. 57, Fig. 2a–c.
non 1924 *Kinkeliniceras*? cf. *hians* (Waagen) – Spath, p. 23.
1931 *Procerites hians* (Waagen) – Spath, pp. 286–287.
2007 *Procerites hians* (Waagen) – Roy et al., fig. 5.1–5.8
1996 *Procerites hians* (Waagen) – Jain, p. 122, pl. 22, fig. 4.

Material: Two specimens from the Yellow Bed at Jumara (bed A4 of this study).

Remarks: *Procerites hians* (Waagen) [M] which co-occurs with *Sivajiceras congener* (Waagen) [M] is a much larger form (Fig. 12). The Holotype of *P. hians* (Waagen) [M] is still septate at 215 mm and has a maximum estimated shell diameter of ~300 mm. *S. congener* (Waagen), on the other hand, is septate only up to 125 mm with a maximum estimated shell diameter of ~200 mm (Callomon 1993). However, Roy et al. (2007) have suggested a phragmocone length of 170 mm for *S. congener* (Waagen). In any case, the phragmocone diameter of *P. hians* exceeds the adult body chamber diameter of *S. congener* (Roy et al. 2007). Additionally, *S. congener* is also relatively more evolute (compare Fig. 12a with 12b).

In *S. congener*, at the body chamber (Fig. 12b at ~190 mm), the primaries become thick, bullae-like and bifurcate relatively higher on the flank. Both primaries and secondaries continue until the end of the adult body chamber without any sign of rib attenuation (Fig. 14c). However, in *P. hians*, ribbing becomes progressively weak at the body chamber, so much so that even secondaries disappear from the ventral region (Fig. 12a).

Callomon (1993) considered both *P. hians* (Waagen) and *S. congener* (Waagen) as conspecific, representing two extreme variant of a widely variable biological species. Roy et al. (2007) followed Spath (1931) is considering them as separate genera primarily on the basis of their size, ornamentation and stratigraphy. Contrary to Callomon (1993) and this study, Roy et al. (2007) noted that these two species have different stratigraphic distribution with a narrow zone of overlapping. *P. hians* being older, they therefore believed that these two species are not conspecific but instead form an evolutionary plexus (see also Spath 1931). *Sivajiceras*, thus, evolved from *Procerites* as an endemic genus which subsequently diversified in the Callovian, giving rise to the *Obtusicostites* Buckman [M]-*Hubertoceras* Spath [m] group.

However, in this study, both *Sivajiceras* and *Procerites* co-occur in the Yellow Bed (bed A4). *Procerites* disappears after bed A5, coinciding with the advent of strongly calcareous sediments (marls and limestones). *Sivajiceras*, on the other hand, continues until bed A8 (till the end of the marl-limestone regime; Fig. 2). Subsequently, following and during the Early Callovian siliclastic deposition, *Sivajiceras* disappears, only to re-appear during the re-deposition of the early Middle Callovian carbonates (limestones; bed C4; see Fig. 2a), giving rise to the *Obtusicostites* Buckman [M]-*Hubertoceras* Spath [m] group (as noted in bed C13; Fig. 2a).

This study, thus, suggests that both *Sivajiceras* and *Procerites* co-existed together during the early Middle Bathonian and that their evolution and subsequent proliferation was largly a facies controlled event.

Subgenus *Gracilisphinctes* Buckman, 1920

Type species: *Ammonites gracilis* Buckman, 1844 (non Zieten, 1830) (= *Procerites progracilis* Cox & Arkell, 1950), Middle Bathonian, Progracilis Zone, England.

Remarks: Bathonian Perisphinctidae are conventionally divided into the dimorphic pair of *Procerites* [M]-*Siemiradzkia* [m] (Early–early Late Bathonian) and *Parachoffatia* [M]- *Homoeoplanulites* [m] (Latest Bathonian–Early Callovian). The type-species of *Procerites* is of Early Bathonian age. Forms from Middle Bathonian and upwards have generally been assigned in part also to *Procerites* but mostly to *Gracilisphinctes*, either as distinct morphogenus (as done by Collignon 1958) or morphosubgenus of *Procerites* (as done by Arkell 1951–58) (see also Pandey & Callomon 1995 for a more detailed discussion). The forms described below resemble morphologically the group of *Gracilisphinctes* more closely than that of *Procerites* sensu stricto. Hence, *Gracilisphinctes* is retained as a chrono-subgenus of *Procerites*. Its type-species is of early Middle Bathonian age.

Procerites (*Gracilisphinctes*) *progracilis arkelli* Collignon

Macroconch
(Figs 13–16, 17a; Appendix 1)

1958 *Procerites* (*Gracilisphinctes*) *arkelli* – Collignon, pl. 6, figs 31–33 (Holotype; fig. 31a, b).
1958 *Gracilisphinctes lemoine* – Collignon, pl. 7, fig. 35 (Holotype).
1958 *Gracilisphinctes andranomantsyensis* – Collignon, pl. 7, fig. 36, 36a (Holotype).
1983 *Gracilisphinctes arkelli* Collignon – Singh et al., p. 823, fig. 2.
1984 *Gracilisphinctes* cf. *arkelli* Collignon – Jaitly & Singh, p. 319, fig. 2.
1995 *Procerites* (*Gracilisphinctes*) *arkelli* Collignon – Pandey & Callomon, pl. 1, fig. 8, pls 2–5.

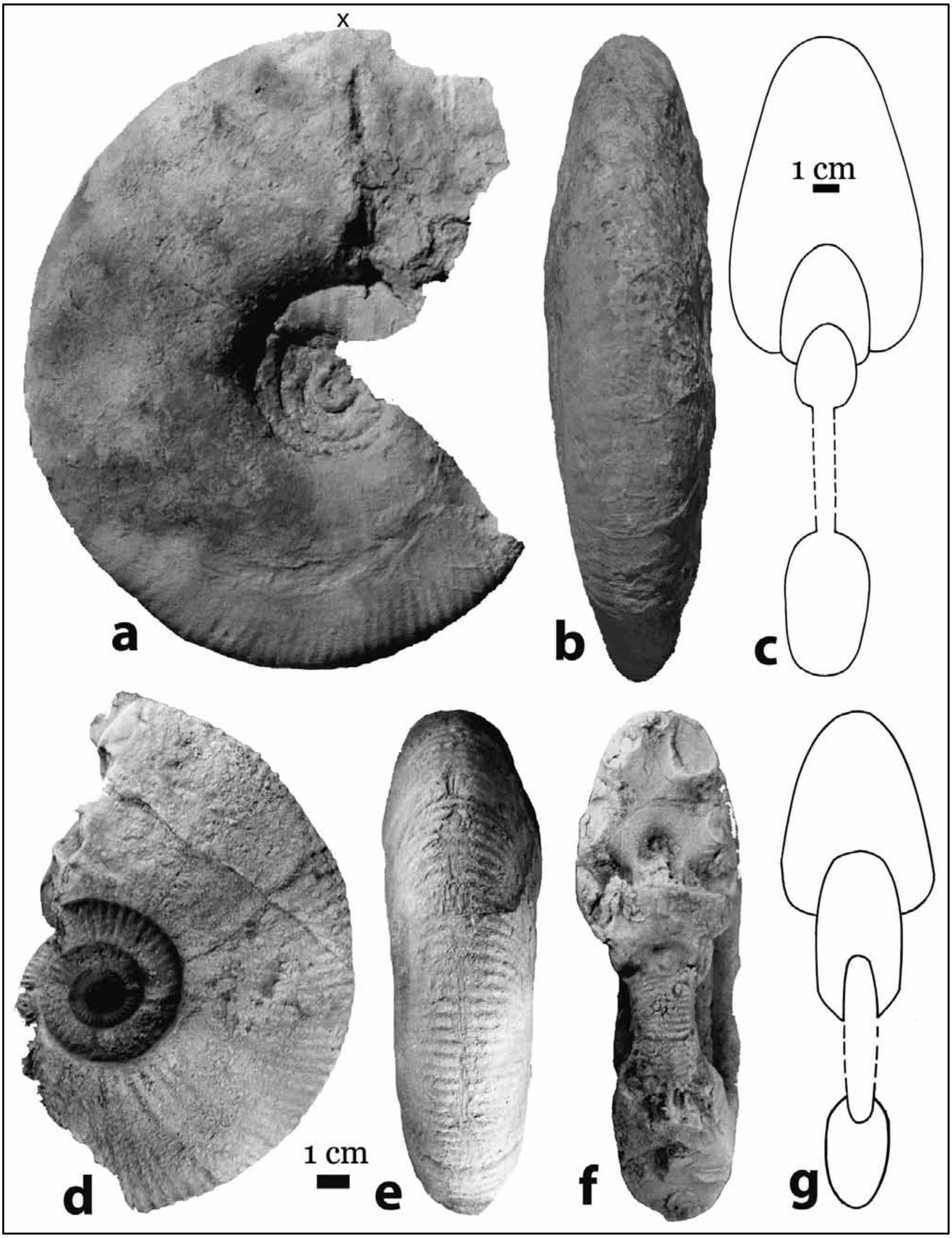

Figure 13: *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon, 1958 [M]. **(a–c)** Specimen no. Ju/27/59. (a): Lateral view. (b): Ventral view. (c): Whorl section. **(d–g)** Specimen no. Ju/27/60. (d): Lateral view. (e): Apertural view. (f): Ventral view. (g): Whorl section. All specimens are from the Yellow Bed (bed A4), Jumara Dome. Cross (x) marks the beginning of body chamber.

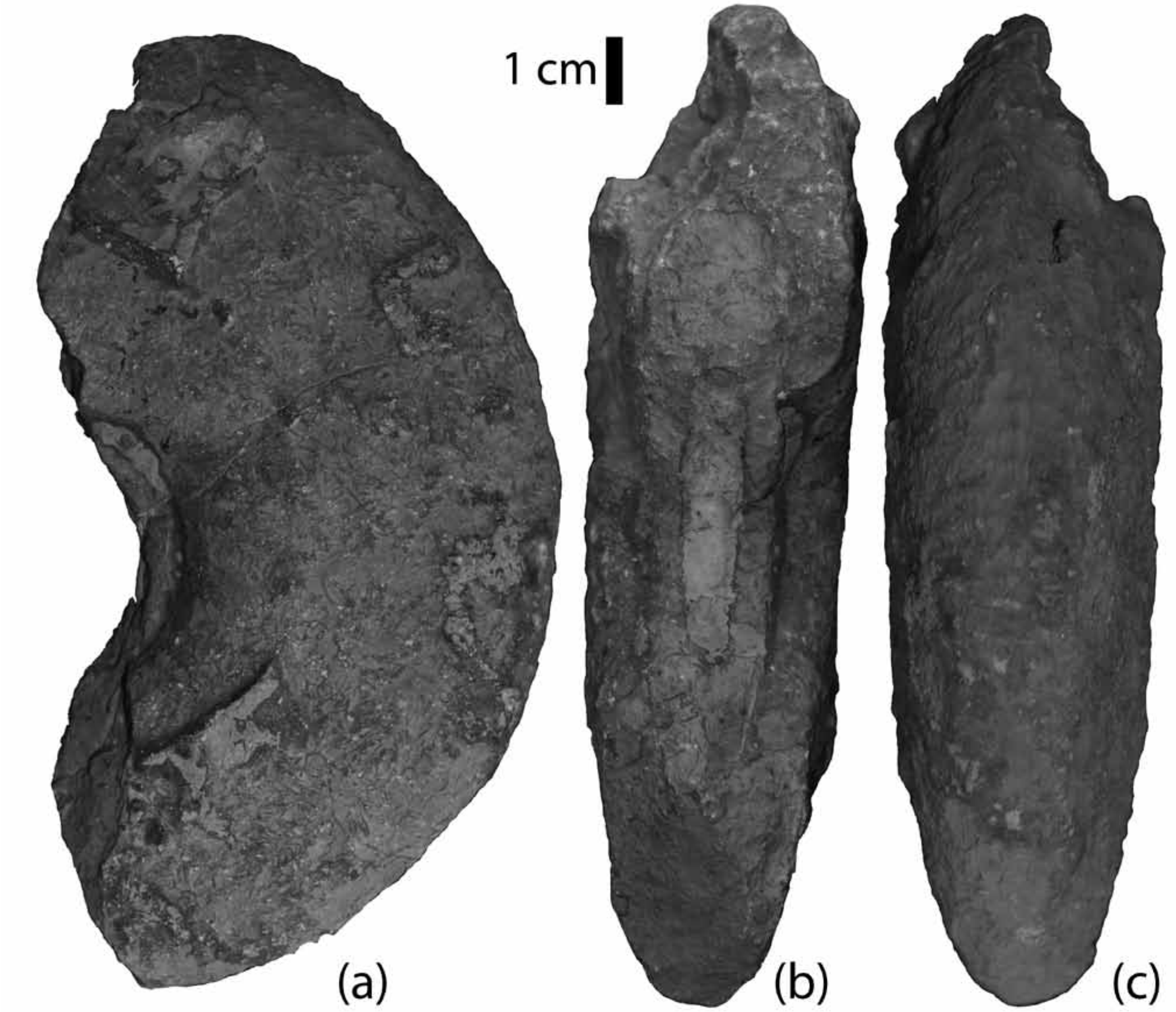

Figure 14: (a–c) *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon, 1958 [M], specimen no. Ju/SJ/2013/A4/13. (a): Lateral view. (b): Apertural view. (c): Ventral view. Yellow Bed (bed A4), Jumara Dome.

1996 *Procerites* (*Gracilisphinctes*) *arkelli* Collignon – Jain, p. 124, pl. 22, fig. 2
2000 *Procerites* (*Gracilisphinctes*) *arkelli* Collignon – Jain & Pandey, p. 3.
2002 *Procerites* (*Gracilisphinctes*) *arkelli* Collignon – Jain, p. 316.
2007 *Gracilisphinctes* cf. *arkelli* Collignon – Roy et al., p. 637, fig. 8.1–8.4.
non 2007 *Gracilisphinctes* cf. *arkelli* Collignon – Roy et al., p. 637, fig. 8.5–8.8.

Material: 4 specimens (Ju/27/4, Ju/A4/21, Ju/SJ/2013/A4/12-13). Ju/A4/21 has a fraction of the body chamber. Suture line shown in Fig. 15 is drawn from a fragmentary specimen no. Ju/SJ/2013/A4/12 (not illustrated). All specimens are from the Yellow Bed at Jumara (bed A4 of this study).

Description (Phragmocone): Phragmocone is large (260 mm), compressed (T/H = 0.71–0.92) and moderately evolute (U/D = 0.26–0.31). Inner whorls not well preserved but show strong, rectiradiate and regularly spaced primaries. On the outermost whorl of the phragmocone, the primaries disappear and only faint, prorsiradiate secondaries remain at the outer one-third of whorl height. Constrictions are prorsiradiate and strong on the inner whorls, numbering 3 per whorl. Whorl-section changes from subquadrate (at 135–140 mm diameter) to subtrigonal till the end of the phragmocone, at 260 mm (Fig. 13). Umbilical edge is well rounded. Suture line is typical *Gracilisphinctes*-type – moderately incised, delicately florid with the umbilical lobe being moderately retracted with several auxiliaries (Fig. 15).

Remarks: The present specimens, in dimensions (Fig. 16), ornamentation, presence of constrictions and whorl-section, closely resemble the Pachchham Island Belt specimens of *Procerites* (*Gracilisphinctes*)

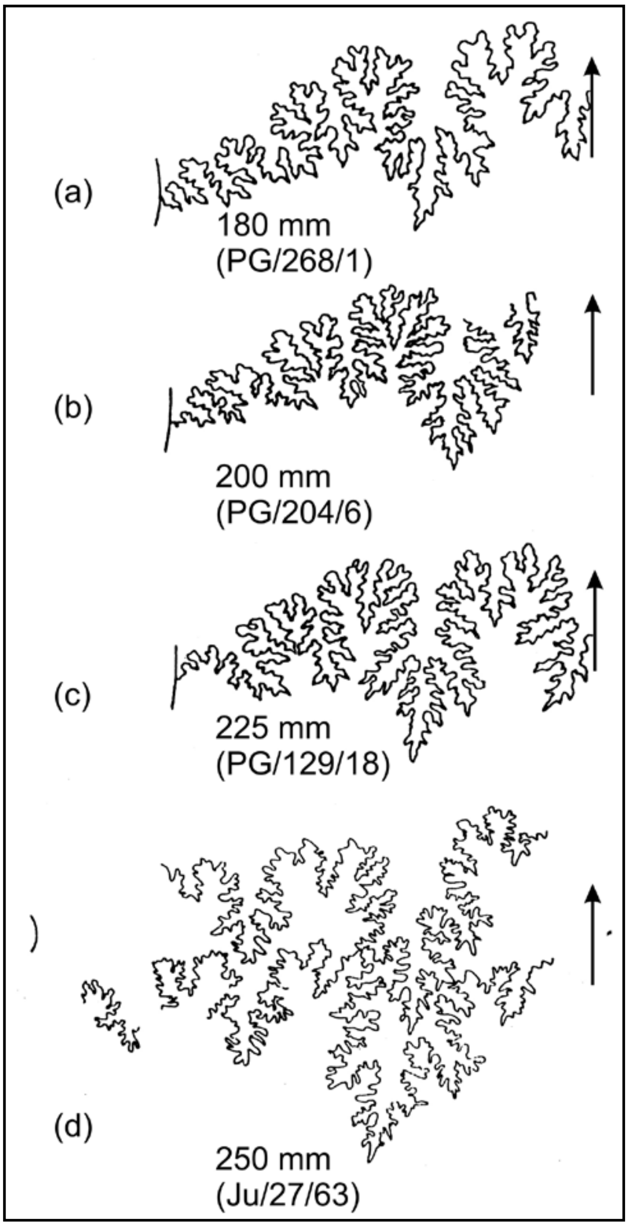

Figure 15: Suture lines of *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M]. **(a–c)** Refigured suture lines of Pachchham Island specimens from Pandey & Callomon (1995: text-fig. 3). **(d)** Specimen no. Ju/27/63, Yellow Bed (bed A4), Jumara Dome (this study; suture from a fragmentary specimen, not illustrated here).

arkelli Collignon [M] (Pandey & Callomon 1995; = *P.* (*G.*) *progracilis arkelli* Collignon [M]). The suture lines of both Jumara and Pachchham Island specimens exhibit patterns similar to middle and outer whorls (Fig. 13a–c ; refigured from Pandey & Callomon 1995: text-fig. 3). The trace of the umbilical seam on the outer most whorl of one of the specimens (Fig. 15a) suggests a maximum shell diameter between 420 to 430 mm, assuming that the body chamber occupies 3/4 of the body whorl. In any case, the phragmocone of this Jumara specimen (Fig. 13a) exhibits the largest shell diameter (260 mm), so far recorded from Kachchh. *P.* (*G.*) *progracilis* cf. *arkelli* recorded by Roy et al. (2007: fig. 8.1–8.3) from the same bed (bed A4 = Bed no. 1 of Roy et al. 2007) is a closely comparable form with one of the present specimen (Fig. 13d–g). However, his smaller fragmentary specimens (Fig. 8.4–8.8) may well be the inner whorls of a *Procerites* (*Siemiradzkia*). Jain et al. (1996) had already recorded the presence of *Procerites* (*Siemiradzkia*) cf. or aff. *verciacensis* (Lissajous) from this level.

Procerites progracilis figured by Dietl (1990: figs 3, 4) from the early Middle Bathonian Progracilis Zone in Swabia (NW Germany) is a closely comparable form. But most European *Procerites* a have broader venter, more ovate whorl-section (see Dietl 1990: fig. 6b) and slightly coarser secondaries (see Dietl 1990: figs 3, 4; see also Singh et al. 1983; Pandey & Callomon 1995).

Procerites progracilis hahni (Westermann & Jordan, 1990) from the early Late Bathonian Hodsoni Zone from NW Germany is also a closely comparable form, but differs in being more inflated and evolute (at 268 mm it has a U/D ratio of 0.38 as compared to 0.26 at 260 mm of the present specimen). Here (in NW Germany), within the Hodsoni Zone, the assemblage is of *Procerites hodsoni, P. progracilis hahni*, *Wagnericeras* cf. *arbustigerum*, *Procerites* (*Siemiradzkia*) *aurigera*, *Oxycerites* (*Mesoxyites*) *lechstedtensis* and *Cadomites bremeri*. The presence of *C. bremeri* from this Late Bathonian Hodsoni Zone confirms that part of this Zone is “coeval with the Western Tethyan Bremeri Zone of Middle Bathonian age” (Westermann & Jordan 1990) (Tab. 1). Both *P. hodsoni* and *P.* (*S.*) *aurigera* (see Jain et al. 1996: p. 134) together with *Wagnericeras* (*W. wagneri*; Spath 1931; Krishna & Pathak 1994) have already been recorded from the Yellow Bed (Bed A4; Figs 2, 3) at Jumara, Kachchh.

Sivajiceras congener (Waagen) which co-occurs with “*arkelli*” in the Yellow Bed (bed A4; see Fig. 12b–d) is a close match for the European *Procerites imitator* (Callomon 1993). Interestingly, published records suggest that *P.* ex gr. *imitator* (Buckman) is typical to the Progracilis Zone (Torrens 1980). Additionally, *P. imitator* also occurs in association with *P. progracilis, Wagnericeras suspensum* and *Procerites* (*Siemiradzkia*) aff. *aurigera* in the early Middle Bathonian Progracilis Zone (Dietl 1990: fig. 5; see also Page 1996).

When considered as a population (Fig. 16), the “*arkelli*” specimens from this study are close to specimens from both the Pachchham Island (Pandey & Callomon 1995) and with the Holotype and Paratype but not so much with the previously recorded specimens of Roy et al. (2007) from Jumara (Fig. 16).

The Kachchh “*arkelli*” population, like the macrocephalitids described later, also shows negative allometry of growth, being much more distinct after 100 m (Fig. 17a).

Microconch
(Fig. 18a, b; Appendix 1)

1996 *Gracilisphinctes lemoine* Collignon [m] – Jain, p. 122, pl. 22, fig. 4.

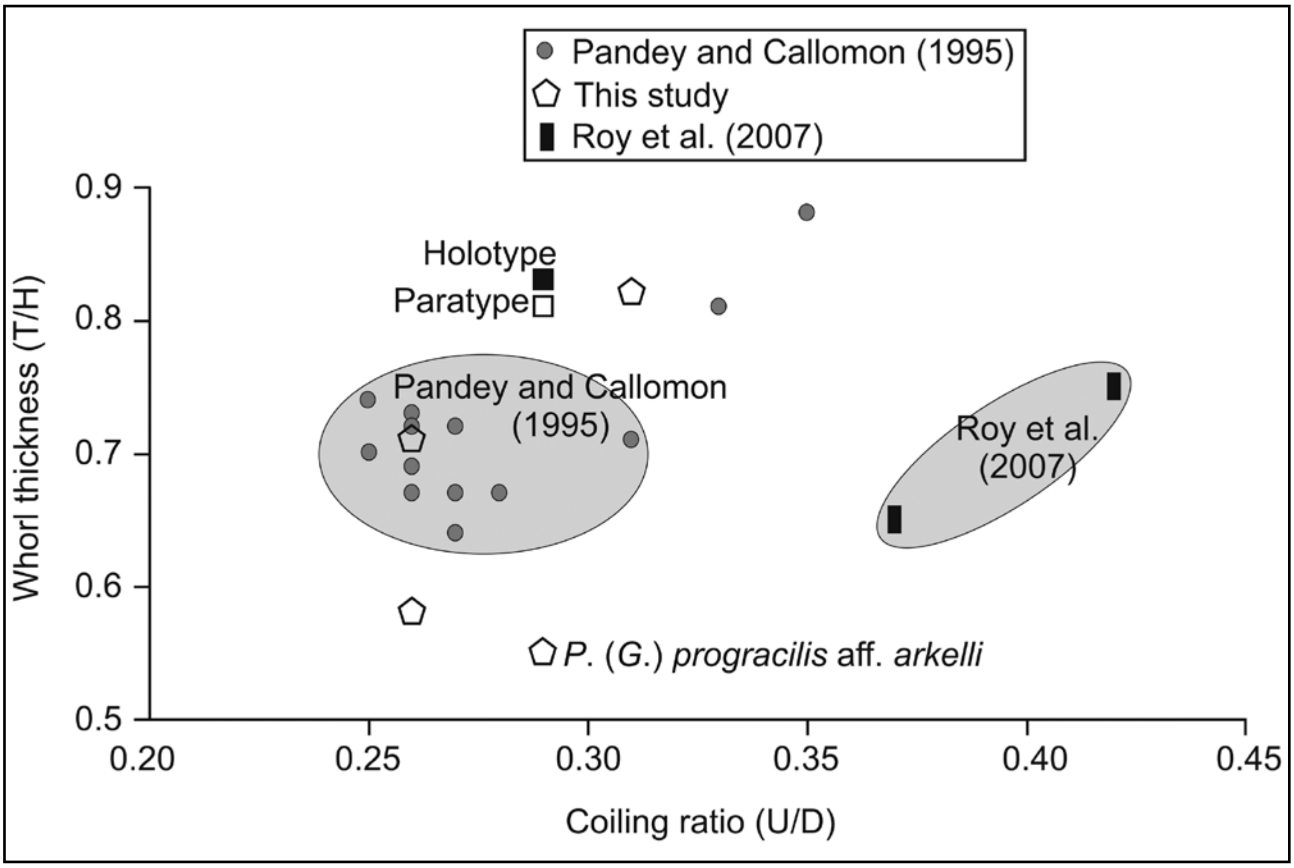

Figure 16: Population distribution of *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] (for data see Appendix 1).

Material: One nearly complete specimen from the Yellow Bed at Jumara (bed A4 of this study).

Description: Shell nearly complete (64 mm), evolute (U/D = 0.38–0.42), strongly planulate with subquadrate whorl section. Phragmocone measures 47 mm. Judging by the remains of the umbilical seam (Fig. 18a), maximum estimated shell diameter is between 80–90 mm. Umbilicus is wide and shallow with vertical umbilical walls that gradually become high and somewhat sloping with increasing shell diameter. Umbilical shoulder remains rounded throughout shell diameter. Umbilical edge is rounded and distinct. Venter is broadly tabulate. Shell bears 33–34 primaries and 73–74 secondaries per whorl. Primaries, throughout the shell diameter, are strong and rounded. They arise slightly rursidiate from just below the umbilical margin, then become rectiradiate and bifurcate slightly above mid-flank (~52–58% of flank height) with rare irregularly placed free single intercalatory (restricted to the outer third of whorl height), that crosses the venter straight. With shell growth, the ribs become increasingly coarse but maintain their round crested nature. Maximum inflation is at one third of whorl height. There are six forwardly inclined constrictions per whorl that cut the ribs obliquely and are bordered by lips. Suture line is faintly visible only to enable phragmocone-body-chamber demarcation (Fig. 18a).

Remarks: The presence of constrictions rule out the present specimens's affinity with both *Sivajiceras* Spath and *Procerites* Siemiradzki s.s., leaving it to be comfortably placed under subgenus *Gracilisphinctes* Buckman. Similar pattern and density of ribbing, general morphology and the presence of six constrictions replicates the inner whorls of the macroconch of *Procerites* (*Gracilisphinctes*) *lemoine* Collignon (1958: pl. 7, fig. 35); its holotype also has 6 constrictions but is somewhat more densely ribbed at comparable diameters (40–44 primaries per whorl). *P*. (*G*.) *lemoine* is a synonymy of *P*. (*G*.) *progracilis arkelli* Collignon (Pandey & Callomon 1995).

The present specimen also reproduces the ribbing patter of the *P*. (*G*.) *progracilis arkelli* [M] (Fig. 13d), in possessing secondaries that are straight at the middle stages and that which become slightly prorsiradiate with increasing shell diameter, crossing the venter straight. Additionally, besides having a similar pattern of ribbing, the present microconch also reproduces similar macroconch body shape, strongly planulate and compressed, but is slightly more evolute (U/D = 0.41–0.42 as compared to 0.29–0.35).

The other comparable form is the microconch of *Sivajiceras congener* (Waagen) (Callomon 1993) which co-occurs (compare with Fig. 18c–f; it is discussed later in the section). It closely resembles the present specimen in being equally evolute, planulate, compressed and possessing a similar shallow

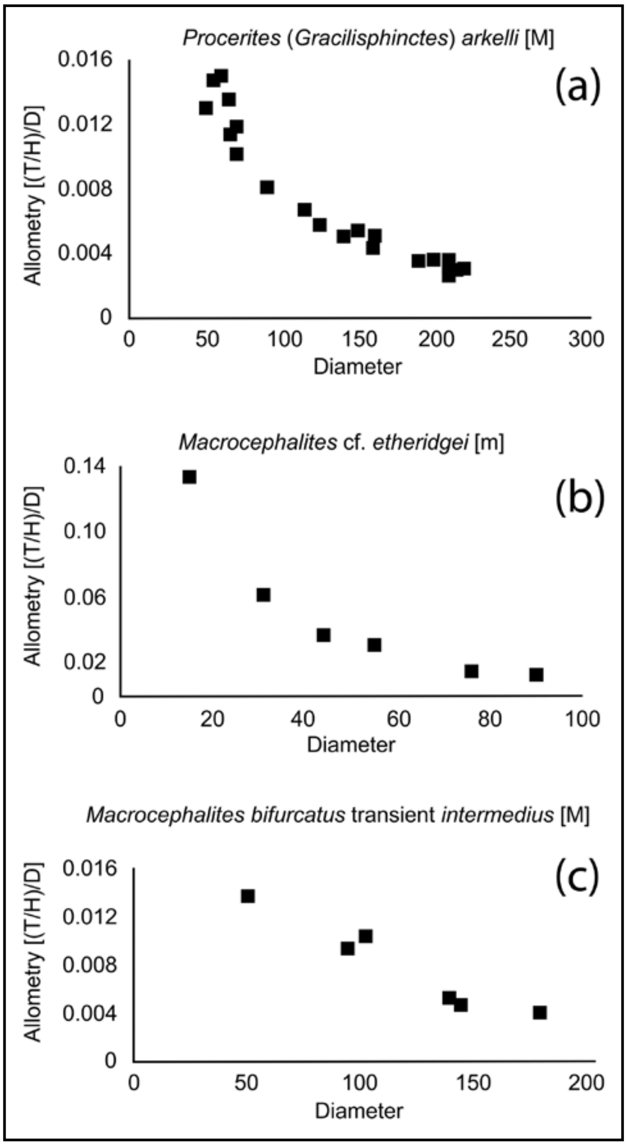

Figure 17: (a–c) Negative allometric growth (a): *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M]. (b): *Macrocephalites* cf. *etheridgei* (Spath). (c): *M. bifurcatus* transient cf. *intermedius* Boehm [M]. For data see Appendix 1.

and wide umbilicus. However, *S. congener* is very sparsely (distantly) ribbed, with primaries that consistently divide at mid flank height as opposed to mid to outer third of flank height in the present specimen (compare Fig. 18a with Fig. 18c). *S. congener* [m] is not at all constricted (Callomon 1993). Additionally, at the end of the aperture, the microconch of *S. congener* shows rursiradiate nature of secondary ribbing as opposed to prorsiradiate in the present specimen (compare Fig. 18a with 18c). The microconch of *S. congener* has larger number of secondaries as sheaves of 3–4 as compared to a bifurcating pattern with a single irregularly placed intercalatory in the present specimen. Additionally, in *S. congener*, ribbing is straight throughout as opposed to prorsiradiate in the present specimen (Fig. 18a).

The other comparable form is *Procerites* (*Siemiradzkia*) aff. *aurigera* (Dietl 1990: fig. 5) from the coeval Progracilis Zone. However *P.* (*S.*) aff. *aurigera* possesses a more radial ribbing pattern with a higher rib density. Moreover, the umbilical shoulder is much more rounded and with consistently sloping umbilical walls.

Procerites (*Gracilisphinctes*) *progracilis* aff. *arkelli* Collignon [M]
(Fig. 19a–d; Appendix 1)

Material: One fragmentary phragmocone (RUC1994I 1341) from Jhura Dome recorded ~20 m below the sponge yielding beds of the Patcham Formation on the ridge, east to Badi Section, (Fig. 4c). Previously, this specimen was mentioned in passing as *Gracilisphinctes* sp. (Jain et al 1996: p. 136).

Description (Phragmocone): Shell fragmentary with part of the phragmocone preserved. Whorl-section is ovate subtrigonal; lateral flanks are gently arched with maximum inflation at the lower third of whorl height. Venter is narrow and acutely rounded. Primaries are faintly developed. The secondaries are prorsiradiate, numbering ~26 per half whorl and restricted to the outer one-third of whorl height. These persist until the end of the phragmocone. Maximum reconstructed diameter is ~210 mm. Suture line is typically *Gracilisphinctes*-type (Fig. 19d).

Remarks: The specimen is poorly preserved but records the whorl-section, ornamentation and suture clearly (Fig. 19d). *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M], a co-occurring species at coeval interval (Jain 2002; Jain et al. 1996), and is a closely comparable form with a similar pattern of suture line (compare with Fig. 15). At a reconstructed diameter of 210 mm, the present specimen is equally evolute and falls well within the range of *P.* (*G.*) *progracilis arkelli* [M] (see Fig. 16). However, at comparable diameters, it is somewhat relatively compressed (T/H = 0.55 as compared to a range of 0.67–0.88 in *P.* (*G.*) *progracilis arkelli*).

P. (*G.*) aff. *progracilis* [M] (Arkell 1958: p. 198, pl. 28, fig. 1) is also a closely comparable form. At diameters of 200 mm, the "Cotswold Slates of Stroud" specimen is still septate and has a closely similar H/D (0.40 as compared to 0.38 in the present specimen) and U/D ratios (0.30 as compared to 0.29 in the present specimen), differing only in possessing a slightly lower T/H ratio (0.25 as compared to 0.21 in the present specimen). These small dimensional discrepancies may well be due to the slight erosion undergone by the present specimen. Secondaries, at the end of the phragmocone stage, in both *P.* (*G.*) aff. *progracilis* (Arkell 1958: p. 198, pl. 28, fig. 1) and the present specimen, are equally dense, prorsiradiate and restricted to the outer one-third of whorl height. Possibly, more finds might yield the presence of *P.* (*G.*) *progracilis* [M] s.s. in Kachchh. However, as of now, the present specimen compares well with

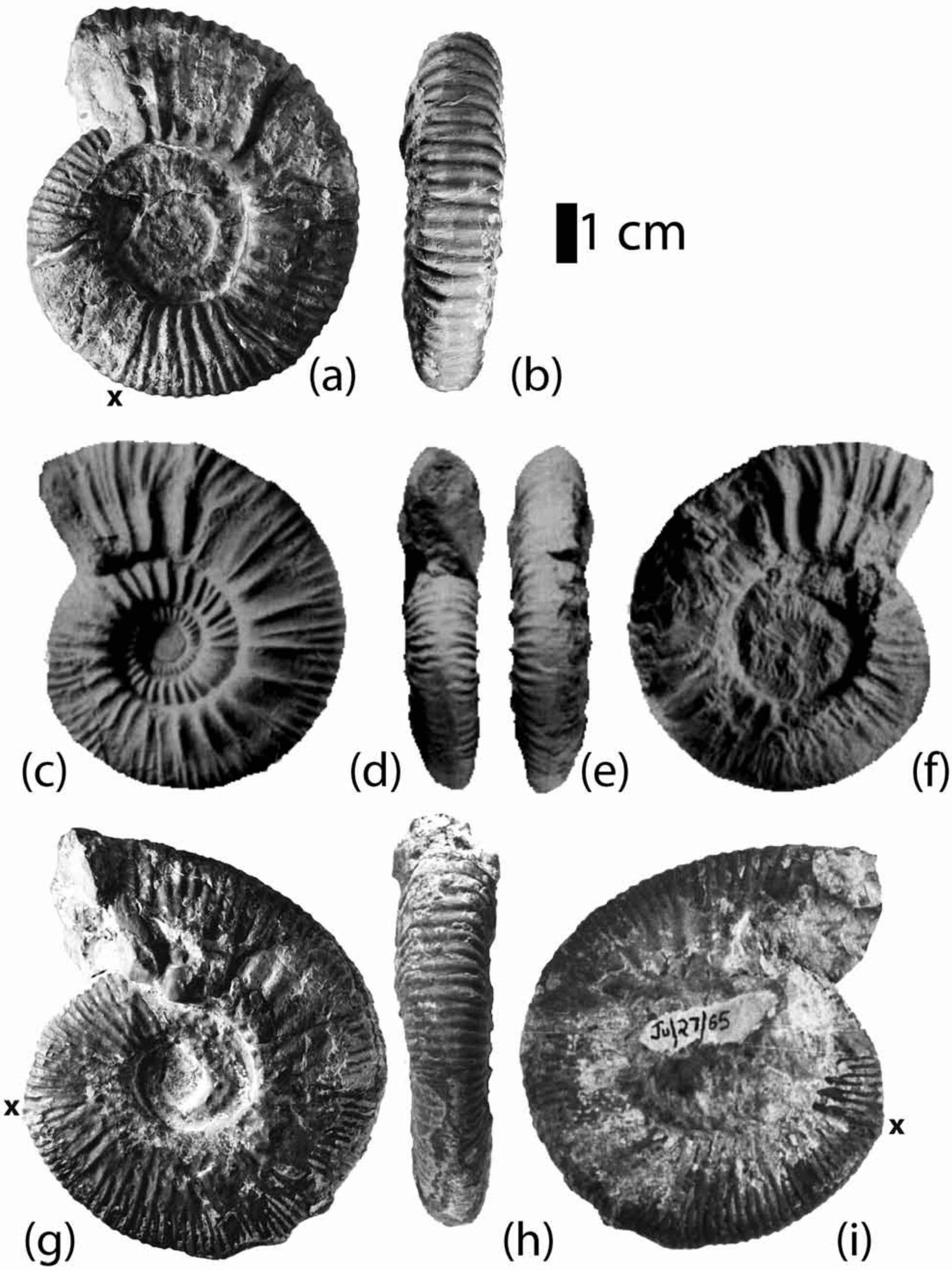

Figure 18: (a, b) *Procerites* (*Gracilisphinctes*) *prograсilis arkelli* Collignon [m], specimen no. Ju/27/61. (a): Lateral view. (b): Ventral view. Yellow Bed (bed A4), Jumara Dome. **(c–f)** *Sivajiceras congener* (Waagen) [m] (Refigured from Callomon 1993: fig. 2a–d). Bed A6, Jumara Dome. (c): Lateral view. (d): Apertural view. (e): Ventral view. (f): Lateral view. **(g–i)** *Procerites* (*Gracilisphinctes*) *intermedius* n. sp. [m], specimen no. Ju/27/65. (g): Lateral view. (h): Ventral view. (i): Opposite lateral view. Yellow Bed (bed A4), Jumara Dome (this study).

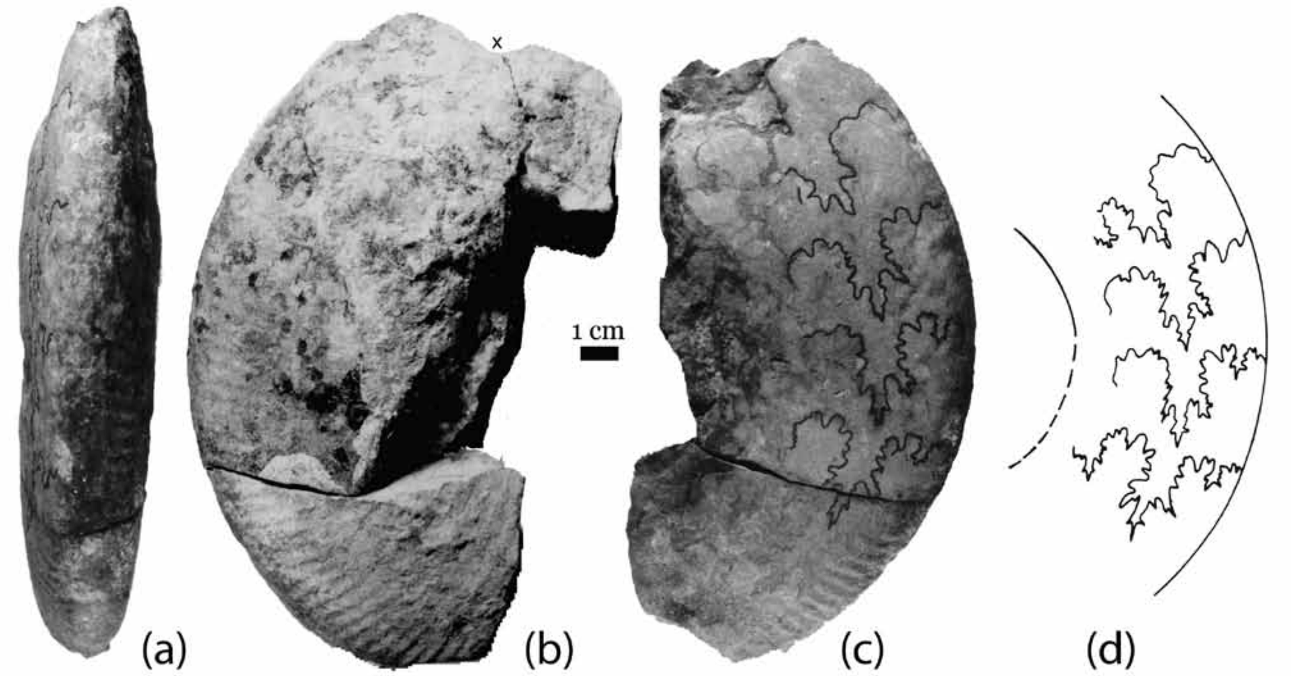

Figure 19: (a–d) *Procerites* (*Gracilisphinctes*) *prograciIis* aff. *arkelli* Collignon, 1958 [M] (=*Gracilisphinctes* sp. of Jain et al 1996: p. 136), specimen no. RUC1994I 1341. (a): Ventral view. (b): Lateral view. (c): Opposite lateral view. (d): Suture line. Jhura Dome (see also Fig. 4c).

the *P*. (*G*.) *progracilis arkelli* population (Fig. 16) in its general morphology, dimensional proportions and coeval stratigraphic level (Jain et al. 1996), but, due to its fragmentary nature, only it's affinity with *P*. (*G*.) *progracilis arkelli*) is established.

Procerites (*Gracilisphinctes*) *intermedius* n. sp. [m]
(Fig. 18g–i; Appendix 1)

1996 *Gracilisphinctes arkelli* Collignon [m] – Jain, p. 124, pl. 22, fig. 3.

Holotype: Specimen no. Ju/27/65.

Stratum typicum: Patcham Formation.

Locus typicus: Bed no. A4, Yellow Bed, in the core (north-eastern part) of the Jumara Dome, north-west of the village of Jumara (N23°41', E69°04').

Derivatio nominis: After the "intermediate" size of the specimen.

Material: One complete specimen (with lappet) from the Yellow Bed (bed A4 of this study).

Diagnosis: Shell small, tabulate, compressed and open coiled. Primaries, arising from the rounded umbilical margin, are rounded, closely spaced and remain strong throughout middle and outer whorls. At maturity (50 mm), they become bullate and slightly prorsiradiate, dividing at mid to outer third of flank height into 2 secondaries with an occasional single intercalatory. Secondaries sharp and rectiradiate and cross the broad tabulate venter, straight. Near the aperture, shell possess the characterestics *Gracilisphinctes*-type ribbing pattern; coarse bi or triplicate prorsiradiate ribbing. Shell marked by 3-4 prorsiradiate constrictions that follow ribbing. Whorl-section consistently trapezoidal. Lappet present.

Description: Shell tabulate, compressed (T/H = 0.76–0.87), open coiled (U/D = 0.29–0.30) with a rounded venter. Umbilical is wide and shallow. There are 44 primaries and 96 secondaries per whorl. Primaries arise from the rounded umbilical margin and are more or less straight until 31 mm but later become slightly prorsiradiate. Primaries are rounded, closely spaced and remain strong throughout middle and outer whorls. At maturity, they tend to somewhat swell. Primaries divide at mid to outer third of flank height into 2 secondaries with an occasional single intercalatory. Secondaries are sharp and rectiradiate and cross the broad tabulate venter, straight. With increasing shell diameter the secondaries become prorsiradiate. Near the aperture, shell possess the characterestics *Gracilisphinctes*-type ribbing pattern; coarse bi or triplicate prorsiradiate ribbing. Interesting to note is the transformation of primary ribs near the aperture, from being swollen (until the lower third to middle of whorl height; characterestics *Gracilisphinctes*-type ribbing pattern) to bullate primaries (occupying the lower third of whorl height). Lappet is noted at the end of the shell. Shell is marked by 3–4 prorsiradiate constrictions that follow the ribbing. Whorl-section is consistently trapezoidal. Due to the sudden opening of the whorl (i.e. maturity) at 50 mm, the shell has acquired an oval shape which

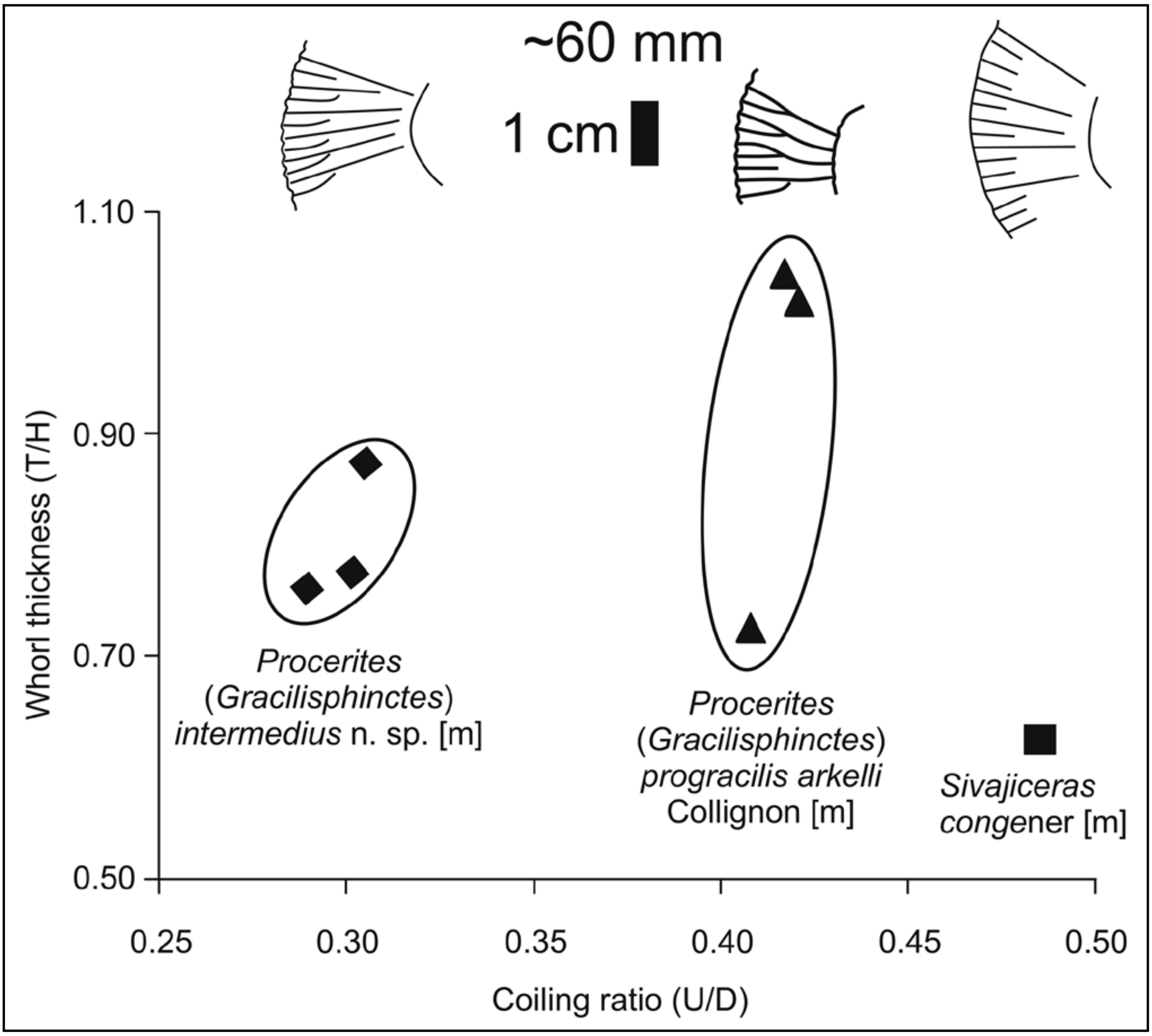

Figure 20: Comparative proportional dimensions (whorl thickness vs. coiling ratio) and ribbing pattern of *Procerites* (*Gracilisphinctes*) *intermedius* n. sp. [m], *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [m] and *Sivajiceras congener* (Waagen) [m] (from Callomon 1993: fig. 2a).

otherwise is circular. Suture line is faintly visible only to enable phragmocone-bodychamber demarcation.

Remarks: The closest comparable forms are the microconchs of *P*. (*G*.) *progracilis arkelli* (Fig. 18a, b) and *Sivajiceras congener* (Waagen) (Fig. 18c–f) that co-occur together but differ both in their ribbing pattern as well as in their dimensional proportions (Fig. 20). There are no other comparable forms.

Superfamily Stephanocerataceae Neumayr, 1875
Family Sphaeroceratidae Buckman, 1920
Subfamily Macrocephalitinae Salfeld, 1921

Genus *Macrocephalites* Zittel, 1884

Type species: *Ammonites macrocephalus* Schlotheim, 1813, Lemoine, 1910; Neotype designated and described by Callomon, 1971; ICZN opinion 1275 (1984, see Callomon, 1980).

Macrocephalites cf. *etheridgei* (Spath) [m]
(Figs 21a–f, 22; Appendix 1)

var. 1890 *Stephanoceras* allied to *S. lamellosus* Etheridge, p. 175, pl. 29, fig. 1.
cf. 1910 *Macrocephalites magnumbilicatus* Lemoine p. 48, pl. 3, fig. 1.
cf. 1910 *Macrocephalites elephantinus* Lemoine p. 48, pl. 4, fig. 8.
cf. var. 1912 *Macrocephalites keeuwensis* γ, var. *bifurcata* Boehm p. 163, text-figs 74, 75, pl. 41, fig. 2a, b.
var. 1912 *Macrocephalites keeuwensis* δ var. *bifurcata* Boehm, p. 166, pl. 44, fig. 4a–c.
var. 1928 *Kamptokephalites etheridgei* Spath p. 200, pl. 69, fig. 3 [for Etheridge 1890, cast of Holotype refigured].
cf. 1933 *Kamptokephalites misorobensis* Spath p. 821 [for *Macrocephalites elephantinus* of Lemoine 1910, pl. 4, figs 8, 9(?)].
cf. 1936 *Pleurocephalites malvaranensis* Besairie p. 126, pl. 8, fig. 1.
cf. 1958 *Pleurocephalites malvaranensis* Collignon pl. 17, fig. 75.

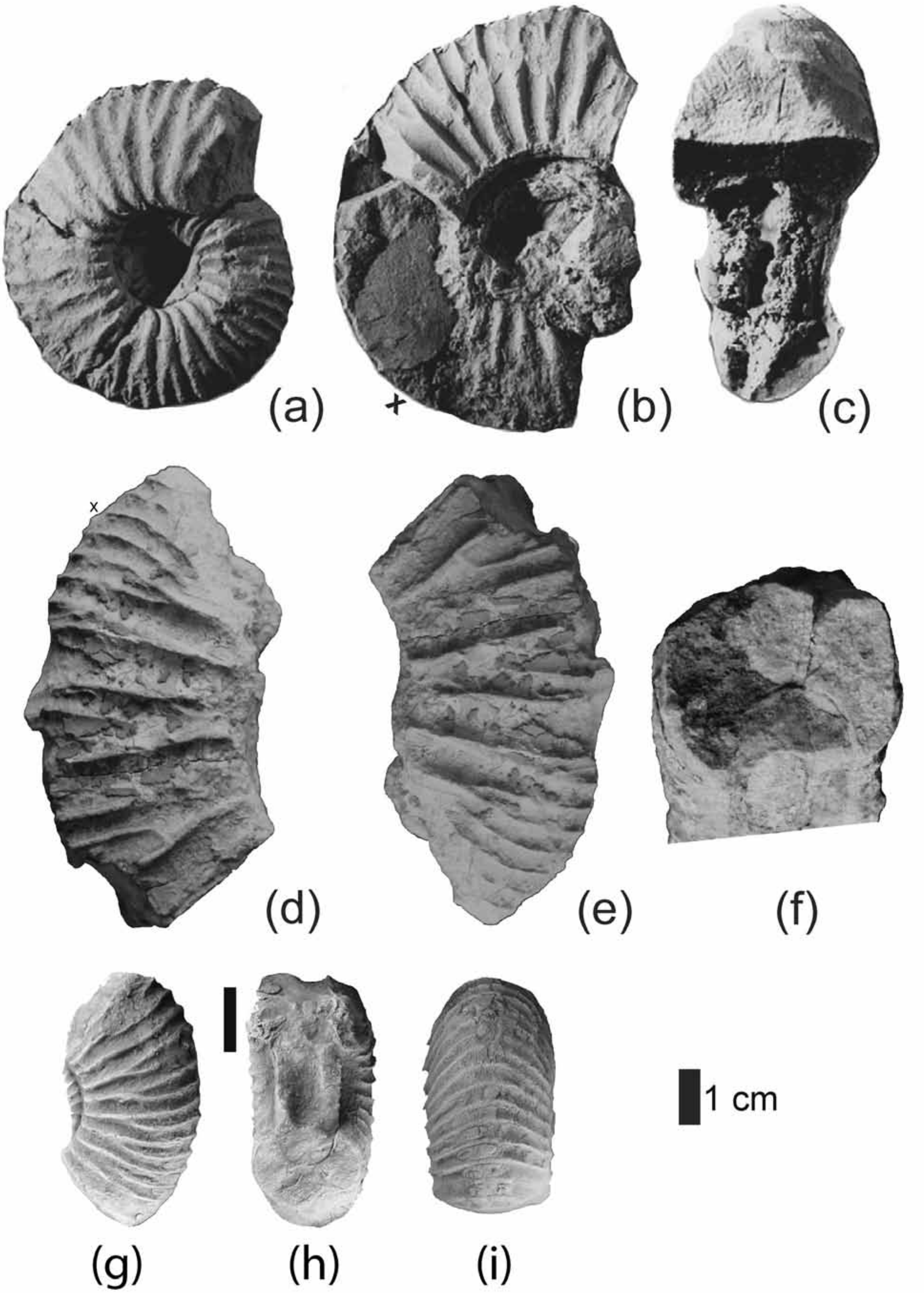

Figure 21: *Macrocephalites* cf. *etheridgei* (Spath) [m]. **(a)** Specimen no. JUM 1000 collected from Bed 2 of Jhura (see Fig. 4c for its stratigraphic position) (refigured from Roy et al. 2007); **(b, c)** Specimen no. JUM/ETH/1 collected from white limestone bed of Nara (refigured from Roy et al., 2007). **(d–f)** Specimen no. Ju/SJ/2013/A4/14, Yellow Bed (bed A4) from Jumara. **(g–i)** *Macrocephalites bifurcatus* transient aff. *bifurcatus* Boehm [m], specimen no. Ju/SJ/1999/A4/1, Yellow Bed (bed A4) from Jumara.

cf. 1958 *Kamptokephalites amboromohantensis* Collignon pl. 19, fig. 82.
1988 *Macrocephalites*? cf. *etheridgei* (Spath) – Westermann & Wang, p. 319, pl. 21, figs 3, 4.
1988 *Macrocephalites* cf. *etheridgei* (Spath) – Westermann & Callomon, p. 69, pl. 13, figs 4, 5; pl. 14, figs 1, 2.
2007 *Kamptokephalites* cf. *etheridgei* Spath – Roy et al., fig. 10.1–10.3

Material: Three specimens, each from Jumara, Jhura and Nara, respectively. SJ/JUM/2013/1 collected from the Yellow Bed at Jumara (= bed A4; this study); JUM 1000 collected from Bed 2 of Jhura (by Roy et al. 2007; Fig. 21a; see Fig. 4 for stratigraphic position); JUM/ETH/1 (see Fig. 21b, c) collected from white limestone bed of Nara (Roy et al. 2007). Roy et al. (2007: p. 643) noted that their specimen number JUM 1000 comes from Bed no. 2 of the Jhura Dome (Fig. 4c of this study), however, in their plate explanation i.e. in their Fig. 10.3, the same specimen has been recorded from Bed no. 2 of Jumara Dome (i.e beds A5–6 of present work; see Fig. 4a, b for stratigraphic position). However, *M*. cf. *etheridgei* (Spath) is not recorded in their lithology for Jumara (their fig. 2). Hence, this could well be a typographical error; writing Jumara instead of Jhura.

Description: Shell is depressed (T/H = 1.14–2.0) and very evolute (U/D = 0.29–0.36). It is septate until ~90 mm with a maximum estimated shell diameter of ~150 mm (assuming that the bodychamber occupies ¾ of the whorl). Whorl thickness (T/H) decreases with increasing shell diameter; from 2.00 at 15 mm to 1.16 at 90 mm. The whorl-section changes from subovate (in early and middle whorls) to semicircular (at end-phragmocone stage; see Fig. 21c, f). Flanks are short and curved. Venter remains broad and round throughout shell growth. Umbilicus is very wide, with vertical umbilical walls and a narrowly rounded ventral margin. Ribbing is prominent, distant and mostly biplicate; bifurcating at lower third of flank height and increasingly becoming sharply crested. Primaries arise rursiradiately from the umbilical slope and after crossing the umbilical margin, project forward and then go straight up to the lower third of flank height. Secondaries are straight and cross the venter with a slight forward projection. At the end-phragmocone stage, there are 12–13 primaries and 24–25 secondaries per half whorl and at the bodychamber stage, there are 14–15 primaries and 29–30 secondaries per half whorl. The persistence of strong biplicate ribbing even at the adult bodychamber stage suggests that all these are microconchs. Suture line visible but cannot be drawn.

Remarks: *Macrocephalites* cf. *etheridgei* Spath [m] was first described from the Sula Island (Indonesia; see Fig. 1d) where majority of specimens were recorded from the Middle Bathonian strata, except for one *M.* aff. *etheridgei*, which was recorded from a much higher Late Bathonian *Macrocephalites keeuwensis* association (Westermann & Callomon 1988). *M.* aff. *etheridgei* is a less evolute and smaller form (Fig. 22) in comparison with the stratigraphically earlier and typical Middle Bathonian *M.* cf. *etheridgei*. The latter also possesses a somewhat denser ribbing pattern with weaker ventral projections (Westermann & Callomon 1988). Interestingly, all Kachchh specimens (this study and Roy et al. 2007) mirror the Middle Bathonian Sula Island *M.* cf. *etheridgei* morphology (see Fig. 21a–f).

The closest comparable Indonesian Middle Bathonian is *Macrocephalites bifurcatus* transient *bifurcatus* Boehm [m] recorded from Keeuw (Sula Island; Westermann & Callomon 1988: p. 51, pl. 9, fig. 7a–c; Lectotype). However, *M. bifurcatus* transient *bifurcatus* is smaller and compressed (Fig. 22). It also possess a distinctly bifurcating ribbing pattern, with shorter primaries and a less arcuate bend of primaries at the umbilical shoulder (see Fig. 21g–i). Westermann & Callomon (1988: p. 71) also noted that for these two (*etheridgei* and *bifurcatus*), the adult body chambers are ‘hard to distinguish’ but that the phragmocones of *M.* cf. *etheridgei* are ‘consistently more depressed’ (compare Figs 21f with 23a of this study).

The Madagascan Late Bathonian species of *Kamptokephalites misorobensis* Spath, *Pleurocephalites maevaranensis* Besairie and *K. amboromohantensis* Collignon (Collignon 1958) from the M. triangularis Zone (Tab. 1) are also a close match and have accordingly been synonymized with *M.* cf. *etheridgei* (Westermann & Callomon 1988). However, Roy et al. (2007) believe that *K. amboromihatensis* (which comes from the same stratigraphic level), is much larger, and hence that it is closer to the latest Early Callovian Kachchh form, *M. magnumbilicatus* (Waagen). However, considering the range of size noted in *M.* cf. *etheridgei* (Fig. 22), Westermann & Callomon’s (1988) suggestion is upheld here.

Another comparable Indian Kachchh form is the stratigraphically higher *Macrocephalites dimerus* (Waagen) [m] which spans from Late Bathonian to Earliest Callovian (Jain & Pandey 2000; Jain 1998, 2012). However, *M. dimerus* is a much smaller and less evolute form (Fig. 22), possessing a fine and irregularly biplicate ribbing pattern.

Macrocephalites bifurcatus transient aff. *bifurcatus* Boehm, 1912 [m]
(Figs 21g–i, 22, 23a, b; Appendix 1)

1912 *Macrocephalites keeuwensis* β var. *bifurcata* Boehm, p. 162, pl. 39, figs 1, ?2, ?text-fig. 71.
1928 *Idiocycloceras bifurcatum* (Boehm) sp. – Spath, p. 206.
1978 *Macrocephalites subtrapezinus* dimorphe microconque *intermedium* – Thierry, p. 128, pl. 7, figs 4a, b, 5a, b, ?6a, b.
1988 *Macrocephalites bifurcatus* transient *bifurcatus* Boehm – Westermann & Callomon, p. 51, pl. 9, figs 4–7 (7: Lectotype refigured, microconch).

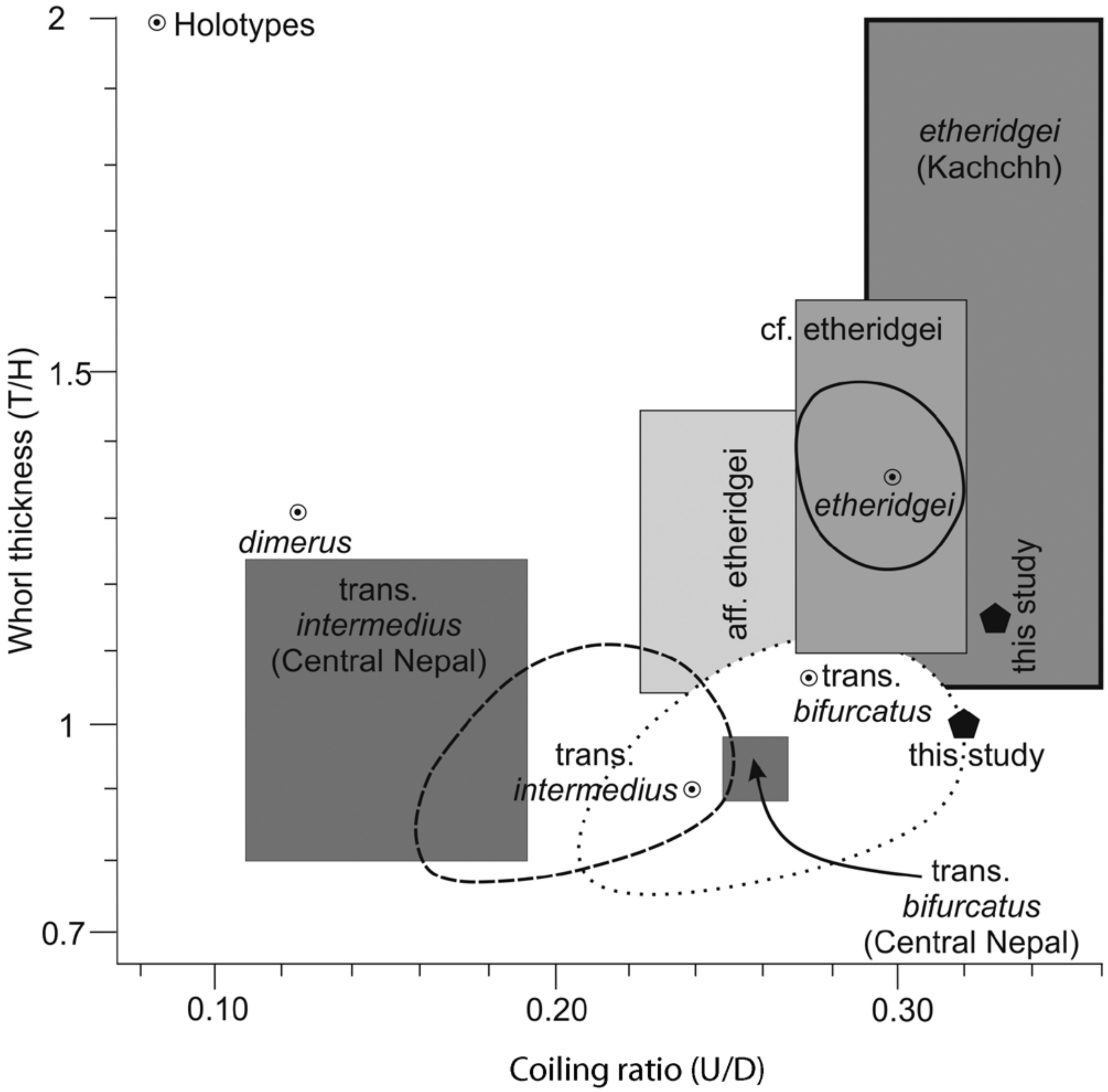

Figure 22: Comparative proportional dimensions (whorl thickness vs. coiling ratio) of macrocephalitid species discussed in this study.

1994 *Macrocephalites bifurcatus* Boehm – Cariou et al., p. 96.
1999 *Macrocephalites bifurcatus* transient *bifurcatus* Boehm – Cariou & Enay, fig. 5.1, p. 707.

Material: One septate and fragmentary specimen (SJ/Ju/1999/A4/1) from the Yellow Bed at Jumara (bed A4 of this study).

Description: Shell small, septate, highly evolute (U/D = 0.32), slightly depressed (T/H = 1.08) with a maximum estimated shell diameter of 80–90 mm. Ribbing strong and moderately dense with 16–18 primaries and 34–36 secondaries per half whorl. Primaries sharp, arising from the upper part of the vertical umbilical wall with a moderate forward inclination at the umbilical margin, strictly bifurcating just below mid-flank height. Secondaries, at the point of branching, are slightly curved (rursiradiate) and then, are strongly projected, crossing the venter with a forward ventral sinus. Flanks are subparallel to gently arched, merging into a narrowly rounded venter. Whorl-section semicircular (Fig. 23a). Suture line has retracted lobes (Fig. 23b), characteristic of Indonesian forms (compare with Westermann & Callomon 1988: p. 52, text-fig. 13).

Remarks: The present specimen in its whorl section, shell morphology, dimensional proportions and suture line (Figs 21g–i, 23a, b) matches well with the

Middle Bathonian Lectotype microconch of *Macrocephalites bifurcatus* transient *bifurcatus* Boehm of Assemblage IV from Keeuw (Sula Island) (Westermann & Callomon 1988: p. 51, pl. 9, fig. 7a–c). The present specimen also falls well within the general range of dimensions exhibited by the Indonesian microconch (Fig. 22).

The other comparable Indonesian microconch is that of *Macrocephalites* cf. *etheridgei* (Spath) (Westermann & Callomon 1988: p. 69, pl. 14, fig. 1a–c). However, this is a far more compressed form (Fig. 22) with a distinctly bifurcating ribbing pattern that lacks the slight curved backward bend of secondaries, at the point of branching (see Fig. 21a–f).

No Kachchh macrocephalitid form so compressed and evolute has ever been recorded at such a low level. Additionally, all Kachchh macrocephalitids lack the characteristic retracted lobes so common in Indonesian forms (Westermann & Callomon 1988: text-fig. 13), the curved backward bend of secondaries, at the point of their branching and the sharp umbilical edge (Fig. 21g).

However, stratigraphically higher in Middle Callovian strata, the present specimen matches well with species of Genus *Idiocycloceras*, Eucycloceratinae Spath (=*Idiocycloceras perisphinctoides* Spath [m]; see Jain 2012: p. 34, pl. 12, fig. a; Anceps Zone). This morphological correspondence has also been noted previously (Westermann & Callomon 1988) and is comparable in the degree of involution, possession of coarse ornamentation, similar whorl-section and a protracted suture line; the first lateral lobe is relatively larger, strongly trifid and slightly asymmetric; second lateral lobe and auxiliary lobes are distinctly developed. However, the adult microconch of *I. perisphinctoides* [m] is much larger (93–130 mm as compared to 70–90 mm of the present specimen; see Jain, 2012 for comparison). Furthermore, in *M. bifurcatus* [m], the primaries bifurcate just below or at mid-flank at all growth stages, a typical macrocephalitin character, but in *I. perisphinctoides* [m] they bifurcate above mid-flank and at a much later stage (see also Jana et al. 2005; Jain 2012: p. 34, pl. 12, fig. a).

Stratigraphic remarks: In Indonesia, *M. bifurcatus* transient *bifurcatus* [m] comes from Assemblages III and IV (=*Macrocephalites bifurcatus* Association) from the Wai Miha valley (locality 3F1; Sula Islands) of late Middle Bathonian age (Westermann & Callomon 1988: pp. 9–11). Assemblages II–IV has yielded rare *Cadomites* cf. *rectelobatus* which in Europe is typically of late Middle Bathonian age (Bremeri Zone; Tab. 1). Interestingly, the highest part of Assemblage IV have, however, yielded *Bullatimorphites* (*Bullatimorphites*) *ymir* (Oppel) and *B.* (*B.*) cf. *costatus* which in the Mediterranean Europe occurs in the Late Bathonian Hodsoni Zone (Tab. 1).

The older collections from the Wai Miha valley (Indonesia) have also yielded a single fragmentary specimen of *Asphinctites* cf. *pinguis* (Grossouvre) that firmly dates the strata as late Early Bathonian. In the Submediterranean Europe, *Asphinctites* is a characteristic morphoceratid genus of late Early Bathonian age (Westermann & Callomon 1988: p. 19). Additionally, the presence of ?*Lissoceras ferrifex* there, also suggests affinities with the Mediterranean Middle Bathonian. Other typical Middle Bathonian species include "*Sphaeroceras*" [*Tulites* (*Rugiferites*)] *godohensis* and "*Sphaeroceras*" [*T.* (*R.*) or *Bullatimorphites*] *sofanus* (see Boehm 1912). The former, closely resembles *T.* (*R.*) *pleurophorus* Buckman from the Middle Bathonian of Dorset, England. Westermann & Callomon (1988: p. 19) noted that the two specimens of *T. sofanus* from "Keeuw" closely resemble specimens mainly from the lower part of the Middle (? to early Late) Bathonian of Spain, S. E. France, Austria and Hungary.

In Nepal (Fig. 1b), *M. bifurcatus* transient *bifurcatus* [m] has been recorded from the Late Bathonian Apertus Zone (Unit Q2: Bed 8 at Dangar Dzong and Bed 10 at Damodarkund) and correlated with the Indonesian M. apertus-mantataranus Association (Westermann & Callomon 1988). The Nepalese assemblage at Damodarkund includes *Macrocephalites apertus* Spath [M], *M. mantataranus* Boehm [M], *M. bifurcatus* transient *bifurcatus* Boehm [m], *M. bifurcatus* transient *intermedius* (Spath) [M], *Homoeoplanulites* (*Parachoffatia*) aff. *evolutum* and *Oxycerites sulaensis* Westermann & Callomon (1988). The coeval bed at Dangar Dzong has also yielded *M. bifurcatus* transient *bifurcatus* Boehm [m].

However, these alleged Late Bathonian occurrences of *M. bifurcatus* transient *bifurcatus* [m] in Nepal pose a stratigraphic problem in Kachchh where, based on faunal content and lithostratigraphy, the *bifurcatus*-yielding Yellow Bed (bed A4 of this study) definitely belongs to early Middle Bathonian age. Could it be that the "centre of origin" of these "Indonesian" species actually lies in Kachchh, as is the case for *Reineckeia*, whose origins was once considered to lie in the SW Pacific (Jain et al. 1996)? Or that the Nepalese and other Late Bathonian assemblages are actually of early Middle Bathonian age? More specimens and stratigraphically controlled collections from Kachchh and elsewhere might resolve this issues. But, for now, in Kachchh, based on lithostratigraphy and faunal content, the *bifurcatus*-*etheridgei*-*arkelli* yielding Yellow Bed (bed A4) is dated as a definite early Middle Bathonian.

Macrocephalites bifurcatus transient *intermedius* (Spath, 1928)

Macroconch

(Figs 22, 23d–f, 24; Appendix 1)

1912 *Macrocephalites keeuwensis* Boehm, p. 162, pl. 40, fig. 1.

1988 *Macrocephalites bifurcatus* transient *intermedius* (Spath) – Westermann & Callomon, pl. 4, figs 1–3, pl. 5, figs 1–4; pl. 6, figs 1–5.

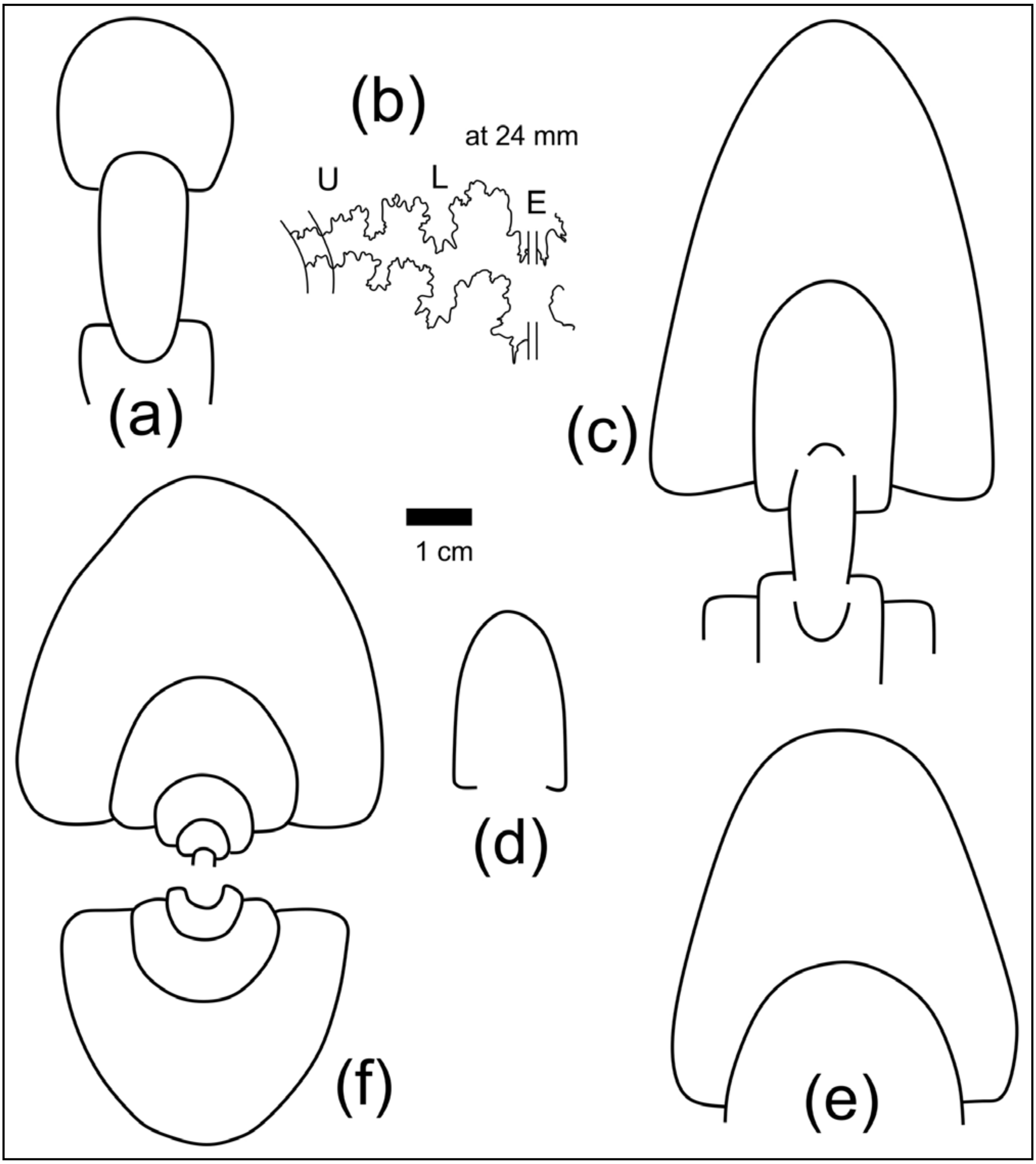

Figure 23: Whorl sections and suture line. **(a, b)** *M. bifurcatus* transient aff. *bifurcatus* Boehm [m], specimen no. SJ/Ju/1999/A4/1. (a): Whorl section. (b): Suture line drawn at 24 mm diameter. **(c)** *M. bifurcatus* transient cf. *intermedius* Boehm [M], specimen no. SJ/Ju/1999/A4/2. **(d–f)** *M. bifurcatus* transient *intermedius* (Spath) [M]. (d): Specimen no. SJ/Ju/1999/A4/3. (e): Specimen no. SJ/Ju/1999/A4/4. (f): Specimen no. SJ/Ju/1999/A4/5. All specimens are from the Yellow Bed (bed A4), Jumara Dome.

1994 *Macrocephalites bifurcatus* transient *intermedius* (Spath) – Cariou et al., p. 96.
1999 *Macrocephalites bifurcatus* transient *intermedius* (Spath) – Cariou & Enay, p. 708, figs 5.3–5.6, 6.1.
2007 *Macrocephalites* cf. *bifurcatus* transient *intermedius* (Spath) – Roy et al., p. 641–643, fig. 9.1–9.9.
2010 *Macrocephalites* cf. *bifurcatus intermedius* (Spath) – Yin, p. 105, pl. 4, figs 7–9, pl. 5. figs 1–3.

Material: Three septate specimens (SJ/Ju/1999/A4/3-5) from the Yellow Bed at Jumara (bed A4 of this study).

Description: At 45–55 mm, the shell is septate, very involute (U/D = 0.15), compressed (T/H = 0.70) and densely ribbed (Fig. 24a–e). Preserved inner whorl shows fine and sharp costation with 15 primaries and 34 secondaries per half whorl. Primaries arise rursiradiately from the umbilical seam and then are strongly prorsiradiate near the sharp umbilical edge, dividing below mid-flank height into two forwardly inclined secondaries with a rare single intercalatory. Secondaries cross the venter straight. Flanks are slightly converging into a narrow but rounded venter. Umbilical wall is vertical and overhanging. The whorl-section is subtrapezoidal (Fig. 23d).

At 95 mm, the shell is still septate, increasingly ivolute (U/D = 0.14), moderately inflated (T/H = 0.90), with a narrower umbilicus (Fig. 24f–h). Costation becomes dense with ~19 primaries per half whorl. Primaries arise rursiradiately from the umbilical seam and then become strongly prorsiradiate near the sharp umbilical edge. They divide below the mid-flank height into two projected secondaries with rare single intercalatories that crosses the venter straight. Whorl-section is subtrapezoidal (at 55 mm) to somewhat subtriangular (at 95 mm) (Fig. 23e) with a vertical and overhanging umbilical wall. At 95 mm, sharp umbilical shoulder defines the maximum whorl width, with gently curved converging flanks and a broadly rounded venter. The overhanging umbilical wall partly occludes the subcyclindrical umbilicus. Umbilical wall remains vertical.

At 103 mm, the shell is still septate, increasingly involute (U/D = 0.12), inflated (T/H = 1.07) with a deep narrow umbilicus (Fig. 24i–k; whorl section: Fig. 23f). Inner whorl are cadiconic and increasingly become broadly rounded (at 26 mm, T/H = 1.36; at 50 mm, T/H = 1.33; at 72 mm, T/H = 1.12; at 103 mm, T/H = 1.07). At 103 mm, only moderately fine prorsiradiate secondaries are present that occupy the third of the whorl height. Sharp umbilical shoulder defines the maximum whorl width, followed by an increasingly curved and converging flanks with a narrowly rounded venter.

Remarks: The Jumara specimens show the characteristic sharp umbilical edge and negative allometry (Fig. 17c), so common in Indonesian macrocephalitids (Westermann & Callomon 1988).

The smaller specimen (Fig. 24a–e) in morphology and dimensional proportions closely match the inner whorls of the involute compressed variety (Variety B; Westermann & Callomon 1988: p. 56) of *Macrocephalites bifurcatus* transient *intermedius* (Spath) [M] (Westermann & Callomon 1988: p. 54, pl. 7, fig. 2a–c) from the Wai Kalepu locality (Sula Island; Assemblage II) of coeval late Middle Bathonian age strata. The closest comparable Kachchh form is *Macrocephalites subtrapezinus* (Waagen) [M] (Waagen 1875: p. 137, pl. 33, fig. 4a–c) from late Early Callovian strata. *M. subtrapezinus* has a closely comparable ornamentation, but it differs in being more evolute, depressed and open coiled, with sloping umbilical walls and a distinctly rounded umbilical edge. The pronounced ventral sinus in *M. subtrapezinus* is absent in the present specimen. *Macrocephalites dimerus* (Waagen) (Waagen 1875: p. 132, pl. 33, figs 2a–c and 3a, b), is another comparable form, but differs in being more depressed with nearly cadiconic inner whorls. Ornamentation in *M. dimerus* is decided coarser and more distant with an umbilical edge that is distinctly rounded.

The larger specimen (Fig. 24f–h), in morphology, dimensional proportions, pattern of ornamentation and whorl-section matches closely with Variety B of *M. bifurcatus* transient *bifurcatus* Boehm [M] (Westermann & Callomon 1988: pl. 4, fig. 3a–c). It also matches with *Macrocephalites madagascariensis* Lemoine, but as in all Kachchh macrocephalitids, the latter lacks the sharp umbilical edge, noted in the present specimens.

Westermann & Callomon (1988: p. 56) distinguished two macroconch varieties of *M. bifurcatus* transient *intermedius* (Spath); the small macroconchs with depressed and evolute inner whorls that constitute Variety A belonging to Assemblages II, VIII and XI (their pl. 5, figs 1, 2; compare with Fig. 23f and 24k of present work) and Variety B that possesses compressed and evolute inner whorls, but resembles Variety A in outer whorls except for slightly more open coiling and stronger ornamentation (their pl. 5, fig. 3a, b) (Figs 23d, e and 24a–h of present work). They further noted that the “bodychambers of compressed morphs thus have only blunt and more or less sparse ribs or weak corrugations on the venter and outermost flanks. These ribs become obsolete on some extremely compressed variants, particularly those with triangular section, while the more inflated forms have more prominent, distant and longer secondaries reaching well onto the flanks”.

Thus, in Kachchh, both varieties (A and B) of *Macrocephalites bifurcatus* transient *intermedius* (Spath) are recoded; the compressed Variety B (Fig. 24a–h), dominates in both Indonesia and Kachchh.

Microconch
(Fig. 25; Appendix 1)

1912 *Macrocephalites keeuwensis* β Boehm, p. 162, pl. 38, fig. 3a, b.
non 1978 *Macrocephalites subtrapezinus* dimorphe microconche, morphe *intermedius* (Spath) – Thierry, p. 198, pl. 7, figs 5–7, text-fig. 65.
1988 *Macrocephalites bifurcatus* transient *intermedius* (Spath) – Westermann & Callomon, p. 54, pl. 7, figs 1–5.
1996 *Macrocephalites subcompressus* (Waagen) – Jain, p. 81, pl. 10, fig. 2, pl. 11, fig. 2a, b.

Material: Three septate specimens (Ju/27/602-3; Ju/SJ/2013/A4/14) from the Yellow Bed at Jumara (bed A4 of this study).

Description: The shell is of medium diameter (~115 mm), moderately involute (U/D = 0.11) and compressed. Ornamentation is dense (22–23 primaries and 48–50 secondaries per half whorl) and sharp. Phragmocone measures 84 mm, and is

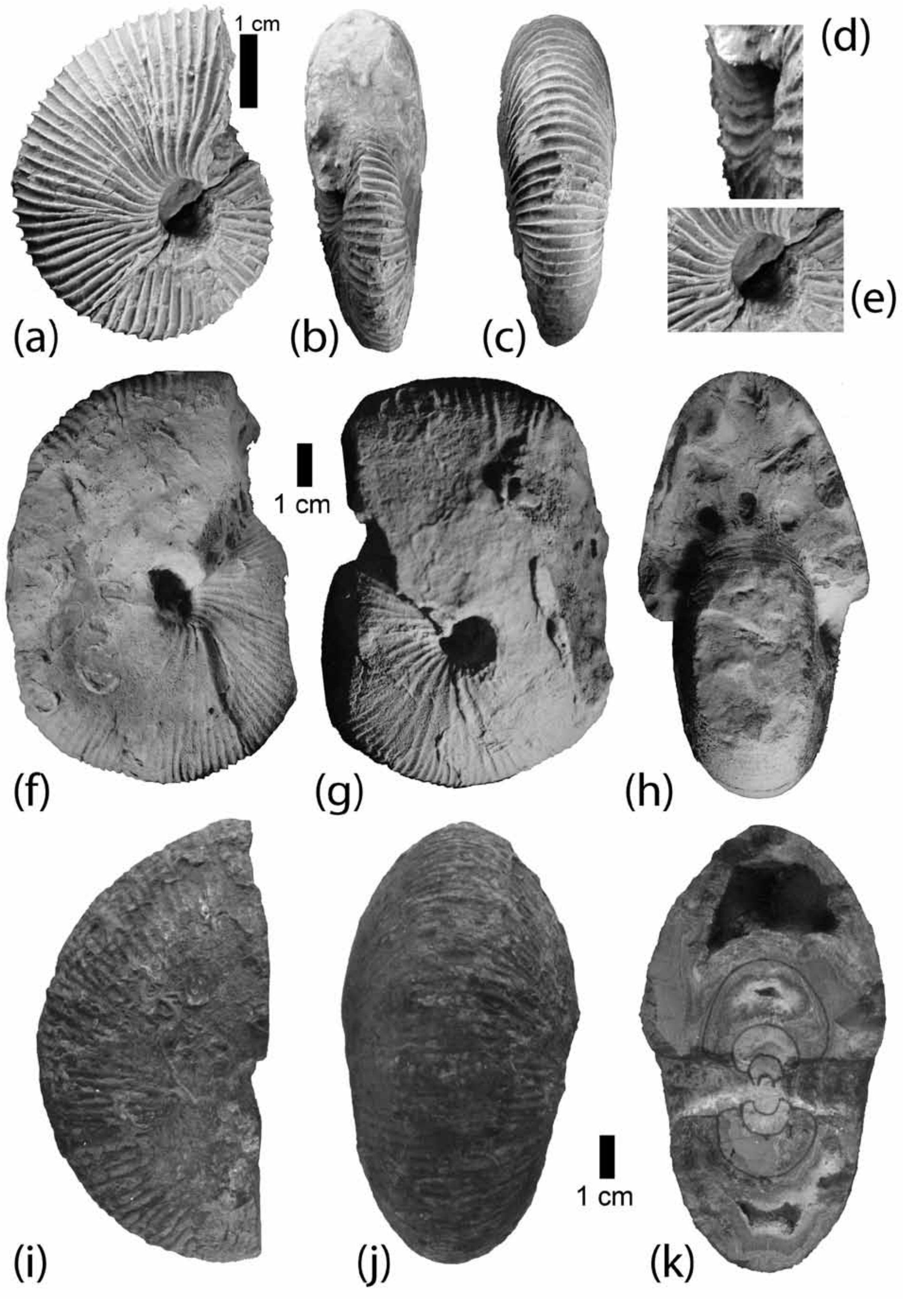

Figure 24: *Macrocephalites bifurcatus* transient *intermedius* (Spath, 1928) [M]. **(a–h)** Variety B. (a–e): Specimen no. SJ/Ju/1999/A4/3. (a): Lateral view. (b): Apertural view. (c) Ventral view. (d): Close up of the umbilical margin showing the nature of primary ribbing. (e): Close up of the umbilical region showing the sharp overhanging umbilical edge. (f–h): Specimen no. SJ/Ju/1999/A4/4. (f): Lateral view. (g): Opposite lateral view. (h): Ventral view. **(i–k)** Variety A. Specimen no. SJ/Ju/1999/A4/5. (i): Lateral view. (j) Ventral view. (k): Apertural view. All specimens are from the Yellow Bed (bed A4), Jumara Dome.

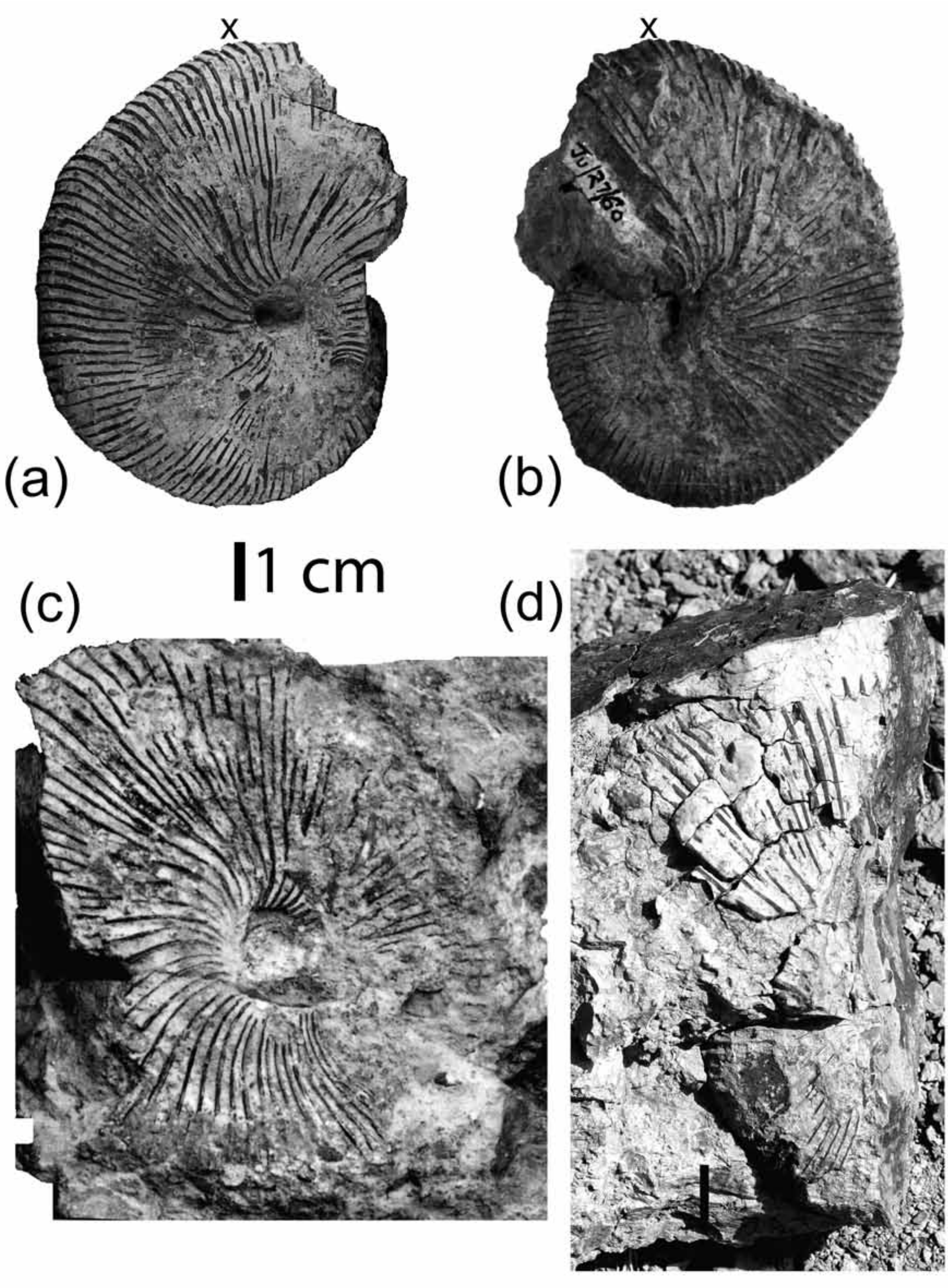

Figure 25: *Macrocephalites bifurcatus* transient *intermedius* (Spath, 1928) [m]. **(a, b)** Specimen no. Ju/27/602. (a): Lateral view. (b): Opposite lateral view. **(c)** Specimen no. Ju/27/603, Lateral view. **(d)** Specimen no. SJ/Ju/2013/A4/14, Lateral view. All specimens are from the Yellow Bed (bed A4), Jumara Dome.

moderately involute, with a subrectangular whorl section. The umbilical walls are vertical with a sharp umbilical margin. Flanks are gently converging with a somewhat broad and evenly rounded venter. Primaries arise obliquely on the umbilical wall, curve with a slight adoral concavity across the umbilical margin and reach with gently projection to almost mid-flank. There are two secondaries (rarely three) with a single intercalatory. Secondaries, that arise variable within the mid-flank region, number 48–50 per half-whorl. They are more or less markedly rectiradiate and cross the venter straight. The umbilical edge remains sharp; the flanks become subparallel with a somewhat broad and slightly tabulate venter. The bodychamber is approximately half whorl long and egresses strongly. The aperture is simple, without constriction, and is marked by the crowding of ribs (Fig. 25a–c). The ornamentation on the bodychamber increases somewhat in spacing but remains sharp and distinct. Here, the primaries tend to project more strongly than on the phragmocone and thus tend to be more strongly concave, ending more clearly at a maximum elevation, or just below mid-flank. The secondaries continue to arise at somewhat uneven whorl-height. They tend to be radial at first (Fig. 25c, d), crossing straight over the venter, but later project and arch convexly (Fig. 25a, b).

Remarks: The present specimens (Fig. 25) replicate the inner whorls of the macroconch *Macrocephalites bifurcatus* transient *intermedius* Boehm and in general morphology and dimensional proportions and coiling (Fig. 24a–e).

The other closely comparable form is the most abundant Forma flexuosa variety of *Macrocephalites keeuwensis* Boehm [m] (= including *Dolikephalites flexuosus* Spath; Westermann & Callomon 1988: p. 63, pl. 11, fig. 5a–c; pl. 12, figs 1–4). Of these, pl. 12, fig. 4 from Assemblage VI (the Early Callovian M. *keeuwensis* Association from Sula Island) is a close approximation. However, *M. keeuwensis* Boehm [m] and its morphs are decidedly more evolute (U/D = 0.15–0.20) with a distinctly more tabulate venter.

Both *Macrocephalites flexuosus* Spath [m] (1928: p. 210, pl. 32, fig. 4) and *M. flexuosus* Collignon [m] (1958: pl. 18, fig. 77) are comparable forms. However, these typical Early Callovian microconch's (now under *Macrocephalites keeuwensis* Boehm [m]) are more evolute (U/D = ~0.20) with a more flexuosus ribbing pattern.

The Late Bathonian–Early Callovian *Macrocephalites subcompressus* (Waagen) [m] is also a comparable form but possess a much wider umbilcus (U/D = ~0.18–0.21), a distinct ventral sinus, a broadly rounded venter, higher vertical umbilical walls with a characteristic opening of the shell that results in a step-like umbilicus. At maturity, it is also a somewhat larger form (~135 mm) (see also Thierry 1978: p. 267). Additionally, all Kachchh forms lack the characteristic sharp umbilical edge noted in the present specimens.

Macrocephalites bifurcatus transient cf. *intermedius* Boehm [M]
(Figs 22, 23c, 26a–e; Appendix 1)

var 1912 *Macrocephalites keeuwensis* Boehm, p. 162, pl. 40, fig. 1a, b.
1988 *Macrocephalites bifurcatus* transient *intermedius* (Spath) – Westermann & Callomon, p. 54, pls. 4–6, text-figs 15–17

Material: Two fragmentary specimens; one from Bed A2a (sp. no. SJ/Ju/1999/A2a/1; Fig. 26a, b) and another from the Yellow Bed (bed A4; SJ/1999/A4/2; Fig. 26c–e) from the Jumara Dome.

Description: Shell septate, large, moderately compressed (T/H = 0.68 at 145 mm to 0.73 at 180 mm), moderately involute (U/D = 0.09 at 145 mm to 0.10 at 180 mm) with a maximum estimated shell diameter of 300 mm (assuming that the body chamber occupies ¾ of a whorl). Shell is septate until 180 mm. Coarse primaries persist between 90 mm (Fig. 26c) to 130 mm (Fig. 26a, b), then fade out, leaving a smooth umbilical region where only coarse rectiradiate secondaries persist. Primaries arise from just below the umbilical margin with a slight adoral concavity near the umbilical region, branching into 2 or rarely 3 closely spaced rectiradiate secondaries. Primaries divide at the middle to the lower third of the flank height near the point of maximum inflation. Secondaries are coarse, prorsiradiate and distant, numbering 35–40 per half whorl, restricted to the outer third of the flank. Between 130 to 145 mm, the secondaries become more distant and coarse and remain so until the end of the phragmocone at 180 mm. Umbilicus is small and deep with subvertical and high umbilical walls, with a pronounced undercutting (well demonstrated in Fig. 26c–e). Maximum inflation is slightly away from the sharp umbilical edge. Whorl-section changes from being subtrapezoidal at 80–100 mm to subtriangular at 135–150 mm (Fig. 23c).

Remarks: The present specimens (Fig. 26) in their general morphology, dimensional proportions and whorl-section strongly resemble the macroconchs of *Macrocephalites bifurcatus* transient *bifurcatus* (Westermann & Callomon 1988: pl. 4, fig. 1, pl. 6, figs 1, 2).

The larger specimen (Fig. 26a, b) recorded from the earliest bed (Bed A2a; see Fig. 4a) at Jumara (and also the earliest macrocephalitid, globally), in its general morphology, dimensional proportions, suture line and whorl section, strongly resemble the macroconch specimens of *Macrocephalites bifurcatus* transient *bifurcatus* (Westermann & Callomon 1988: pl. 6, fig. 1; Cariou & Enay 1999: p. 708, fig. 6.1).

The smaller specimen (Fig. 26c–e), with its triangular whorl section, general morphology and dimensional proportions matches well with the compressed macroconch variant of *M. bifurcatus* transient *intermedius* (Spath) (see Westermann & Callomon 1988: pl. 6, fig. 2) recorded from locality A, Assemblage IX, of New Guinea from late Middle Bathonian sediments (Westermann & Callomon 1988).

The smaller specimen (Fig. 26c–e) can also be compared with the Early Callovian Madagascan *Macrocephalites formosus* transient *triangularis* Spath from the Saolala province, Andranomov (Thierry 1978: p. 291, figs 104a, 106d; p. 296, pl. 24, fig. 5a, b). Westermann & Callomon (1988: p. 59) have already considered this species as representing a junior synonymy of the Late Bathonian *M. mantataranus* Spath [M] from Keeuw. Interestingly, adult Macroconch specimens of *M. mantataranus* from this locality “belong to an exceptionally small macroconchiate form” of a phragmocone not ex-

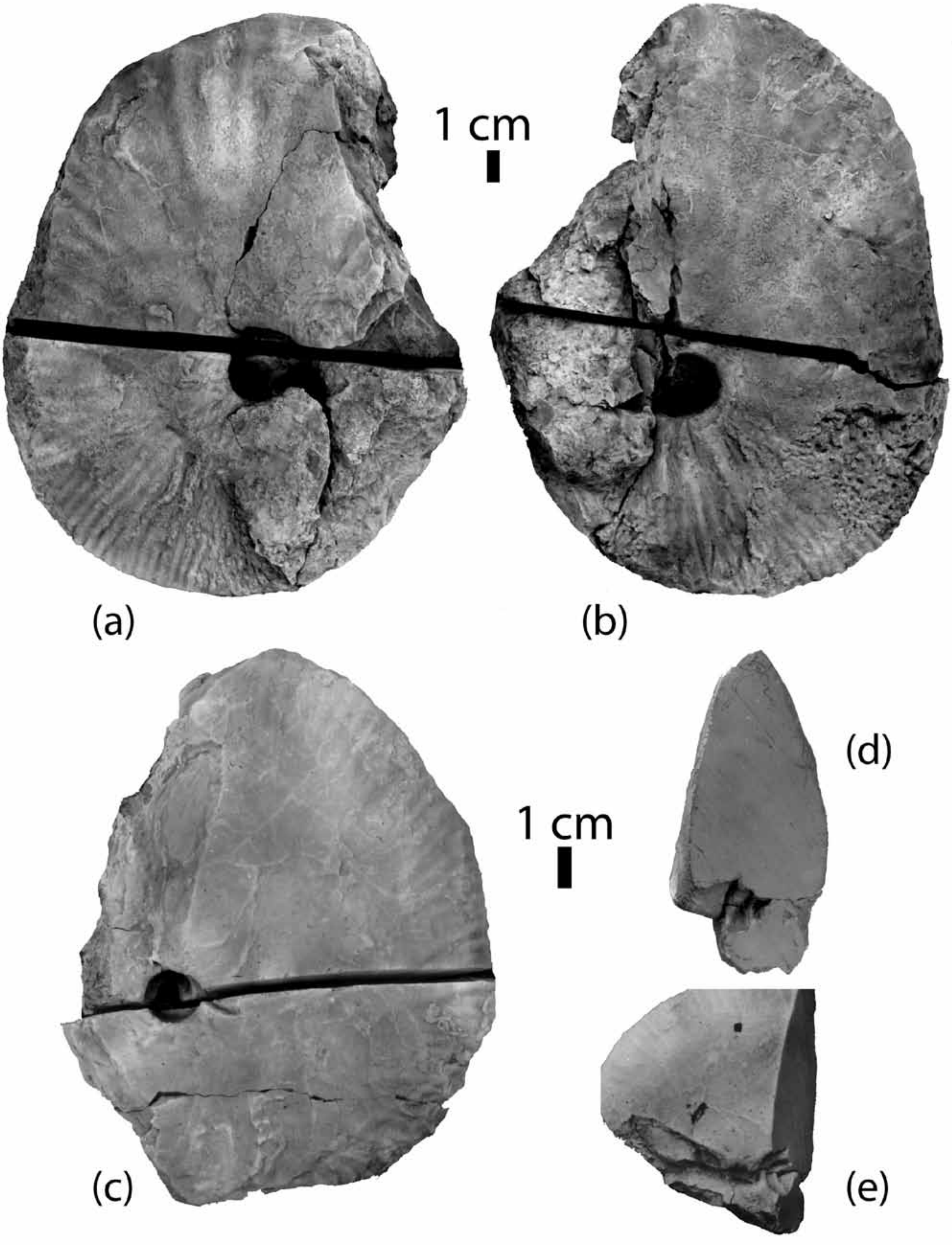

Figure 26: *Macrocephalites bifurcatus* transient cf. *intermedius* Boehm [M]. **(a, b)** Specimen no. SJ/Ju/1999/A2a/1, Bed A2a, Jumara Dome. This is the earliest macrocephalitid, globally. (a): Lateral view. (b): Opposite lateral view. **(c–e)** Specimen no. SJ/Ju/1999/A4/2, Yellow Bed (bed A4), Jumara Dome. (c): Lateral view. (d): Ventral view. (e): Opposite lateral view showing the sharp umbilical edge.

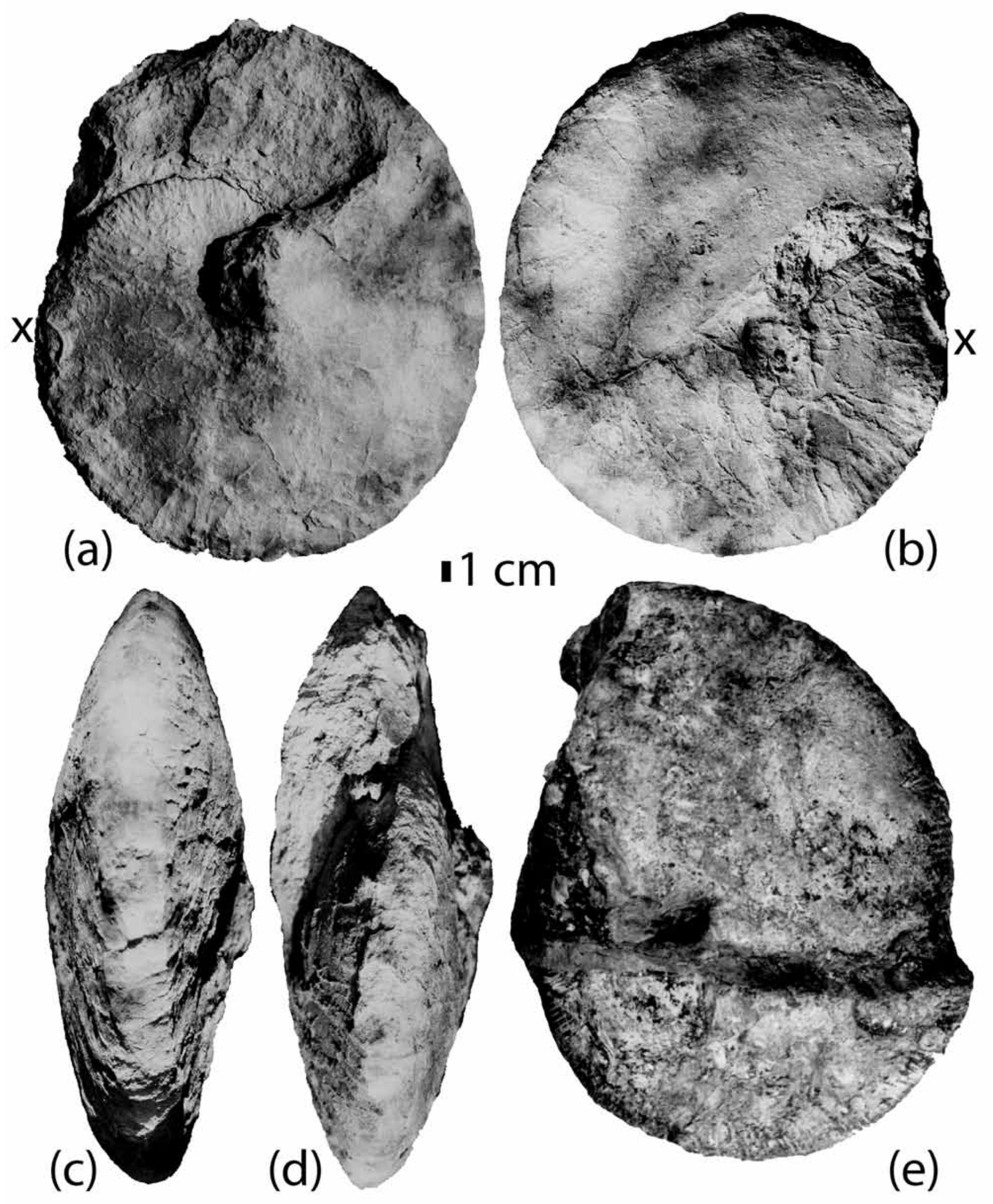

Figure 27: *Macrocephalites triangularis* Spath [M]. **(a–d)** Specimen no. SJ/Ju/1999/A4/6. (a): Lateral view. (b): Opposite lateral view. (c) Ventral view. (d): Apertural view. (e): Specimen no. SJ/Ju/1999/A4/8. Lateral view. All specimens are from the Yellow Bed (bed A4), Jumara Dome. Cross (x) marks the beginning of body chamber.

ceeding 96 mm (Westermann & Callomon 1988: p. 61). However, the present specimen is still septate even at 145 mm. Additionally, *M. mantataranus*, at comparable diameter, is much more discoidal and possesses finer ribbing pattern (Westermann & Callomon 1988).

In its equally involute and discoidal form, the present specimen also closely compares with the Kachchh macroconch specimens of *Macrocephalites triangularis* (Spath, 1928), which has also been recorded from the same bed. However, at comparable diameters, *M. triangularis* [M] is distinctly more densely and finely ribbed and more involute (Fig. 27). Additionally, the umbilical smoothening in *M. triangularis* [M] does not occur at the phragmocone stage, which measures 185–190 mm, clearly a much larger form. Moreover, in *M. triangularis* [M], the secondaries are also much sharper and denser at the body chamber (Fig. 27).

Macrocephalites formosus (Sowerby) [M], which occurs stratigraphically much higher and spans from Late Bathonian (Jain 2008) to the entire Early Callovian (Jain & Pandey 2000), has a similar smooth umbilical region, but differs in lacking sharp umbilical edge and high overhanging umbilical walls (Fig. 26c–e). Moreover, *M. formosus* has a slightly coarser ornamentation with a much less pronounced triangular whorl section. The inner whorls of *M. formosus* are also considerably more depressed (see Spath 1928: p. 177, pl. 24, fig. 2c).

Macrocephalites triangularis Spath, 1928

Macroconch
(Fig. 27a–e; Appendix 1)

1928 *Macrocephalites triangularis* Spath, p. 180, pl. 21, fig. 1a, b
1958 *Macrocephalites triangularis* Spath – Collignon, pl. 14, fig. 70a, pl. 15, fig. 70b.
1978 *Macrocephalites formosus* (Sowerby) transient *triangularis* Spath – Thierry, p. 289, pl. 24, figs 2–4.
1978 *Macrocephalites semilaevis* (Waagen) – Thierry, p. 373, pl. 20, fig. 1.
1987 *Macrocephalites triangularis* Spath – Krishna & Westermann, p. 1573, pl. 1, fig. 1, non figs 2, 3a, b
1994 *Macrocephalites triangularis* Spath – Cariou et al., p. 96
1996 *Macrocephalites triangularis* Spath – Jain, p. 77, pl. 8, figs 3, 4, pl. 9, figs 2, 3
1996 *Macrocephalites triangularis* Spath – Datta et al., p. 450, pls 1, 2
1998 *Macrocephalites triangularis* Spath – Prasad, p. 26, pl. 2, fig. 2a, b
1999 *Macrocephalites triangularis* Spath – Cariou & Enay, p. 712, figs 7.2–7.7, 8.1–8.2.
2000 *Macrocephalites triangularis* Spath – Jain & Pandey, p. 7.
2002 *Macrocephalites triangularis* Spath – Jain, p. 314.
2007 *Macrocephalites triangularis* Spath – Roy et al., p. 643, fig. 9.10–9.15.
2007 *Macrocephalites triangularis* Spath – Jain, p. 85, pl. 1, figs c, d
2008 *Macrocephalites triangularis* Spath – Jain, p. 4, fig. 3.5–3.6.
2012 *Macrocephalites triangularis* Spath – Jain, p. 8, pl. 2, figs a–c.

Material: Four large macroconch [M] specimens with broken body chambers (Fig. 27a–d; sp. no. SJ/Ju/1999/A4/6) and two completely septate macroconch [M] specimens (Fig. 27e: sp. no. SJ/Ju/1999/A4/7) from the Yellow Bed (bed A4 of this study) from the Jumara Dome. Bed A8, top most bed of the Patcham Formation, Jumara Dome.

Description: Shell is large, compressed and involute with an acutely rounded venter. Primaries below 45–50 mm are prorsiradiate, fine, sharp and closely spaced, dividing at the lower third of whorl height into 2–3 prorsiradiate secondaries with an occasional single intercalatory. There are 12–13 primaries and 35–38 secondaries at 50–60 mm shell diameter. At this stage, primaries arise from the vertical umbilical wall with a slight adoral concavity and the secondaries cross the venter straight. Whorl-section at this stage is subtriangular. Flanks are slightly flat to slightly arched with a narrowly rounded venter. Umbilical edge is rounded.

At the 60–130 mm stage, ribbing becomes somewhat more prominent and distant. Surface bears thin to thick, straight to slightly adorally concave primaries, which arise from the umbilical shoulder, branching into 2 or 3 prorsiradiate secondaries, very rarely 4, at about lower third of the flank height, and then pass straight over the arched venter. Primary ribs persist only up to 120–125 mm, well before the end of the phragmocone, leaving coarse secondaries on the outer third of the whorl height. In another septate specimen primaries disappear at 90 mm (not illustrated here). The number of ribs per whorl increases with shell diameter (12–13 primaries and 37–39 secondaries at ~60 mm; 15–16 primaries with 68–72 secondaries at 120 mm). Lateral flanks slightly arched and converging in an acutely rounded venter. Maximum width is near the umbilical edge. Whorl-section is subtriangular. Umbilicus is deep and small with steep, almost vertical walls with rounded edges. The Holotype is a septate macroconch (128 mm) with smooth inner flanks (at 90–95 mm; Spath 1928: pl. 21, text-fig. 1a, b).

At 130 to 185 mm stage, shell assumes the typical disc shape. Laterals strongly arched, meeting the acutely narrow venter. Inner flank is smooth but coarse secondaries persist at the outer third, crossing the venter straight. Umbilical wall distinct and slanting.

At the 185–350 mm diameter, only coarse to blunt secondaries are left, restricted to the outer third of the flank, crossing the venter straight. Phragmocone measures 215 mm with a maximum estimated diameter of 300–375 mm (Fig. 27).

Remarks: The poorly preserved septate specimens illustrated by Datta et al. (1996: pl. 2, text-figs 1, 5) that also possess smooth inner flanks until 90 mm (Datta et al. 1996: pl. 2, text-fig. 1), compare closely with the septate Holotype, a macroconch as well as the present specimen illustrated in Fig. 27e. Datta et al.'s (1996) specimens exhibits primary ribs up to a diameter of more than 100 mm, although, according to Spath (1928), the primaries disappear by this diameter.

Macrocephalites cf. *triangularis* Spath [M] (Singh et al. 1979: pl. 1, text-fig. 5; Mouwana Dome, Bela Island; see Fig. 1a) in its general morphology compares closely with *M. madagascariensis* Lemoine

[M], although its whorl-section and umbilical dimensions fall within the range of *M. triangularis* Spath [M]. *M.* aff. *triangularis* from the same bed (Singh et al. 1979: pl. 1, text-fig. 1, pl. 4, text-fig. 1), shows typical "*triangularis*" type of ornamentation (sharp and dense ribbing), but again has a much rounded venter and a wider umbilicus (U/D = 0.12–0.16), close to typical *M. madagascariensis* Lemoine [M] morphology.

The two alleged Pachchham Island specimens of *M. triangularis* Spath [M] (Pandey 1982: p. 387, pl. 31, text-fig. 1; pl. 32, text-fig. 1) from their bed 26, NW of Paiya (Goradongar, Pachchham Island; see Fig. 1a) and *M.* cf. *triangularis* Spath (Krishna & Westermann 1987: pl. 1, fig. 3a, b) have coarser ornamentation, less arched periphery, slightly greater U/D ratio and a somewhat rounded venter. These specimens are in fact more close to *M. madagascariensis* [M] than to typical *M. triangularis* [M]. Interestingly, in the alleged Early Callovian Pachchham Island occurrences of *M. triangularis* Spath (Pandey 1982), the ornamentation is decidedly coarser, laterals are less arched and venter is more rounded and the umbilicus slightly larger (U/D = 0.12–0.16); a morphology close to typical *M. madagascariensis* Lemoine [M]. That this stratum is Early Callovian is in contention, also.

Macrocephalites formosus (Sowerby) [M] also resembles of *M. triangularis* Spath [M], but the former is much younger, possesses depressed inner whorls and has a characteristic fasciculate ribbing pattern. However, both species have similar umbilical smoothening and triangular whorl section, but only at the adult stage. Recently and interestingly, both species have been recorded from definite Late Bathonian sediments and were recorded associated with the characteristic Bathonian *Sivajiceras congener* Waagen [M] in the adjoining Jaisalmer basin, western India (Jain, 2007).

Macrocephalites triangularis Spath [M] closely resembles the Indonesian *M. mantataranus* Boehm [M] (Westermann & Callomon 1988: p. 59, pl. 10, text-figs 1–5, 11, 18) recorded from the Late Bathonian Apertus Zone. However, *M. triangularis* attains a maximum shell diameter of 350–375 mm, compared to 150 mm of *M. mantataranus* Boehm, which has much sharper and denser costation. A comparison with the growth curves and single plots for whorl thickness and coiling ratio of *M. triangularis* [M] Spath and *M. mantataranus* Boehm [M] (data from Boehm 1912; Thierry 1978; Westermann & Callomon 1988; Cariou & Enay 1999) indicates that *M. triangularis* Spath [M] is also much more involute and compressed (Fig. 28).

European *Macrocephalites jaquoti* Douvillé [M], similar to *M. cannizaroi* Douvillé [M], is much smaller and the latter has a much rounded whorl section, than *M. triangularis* Spath [M].

Microconch
Fig. 29a–c

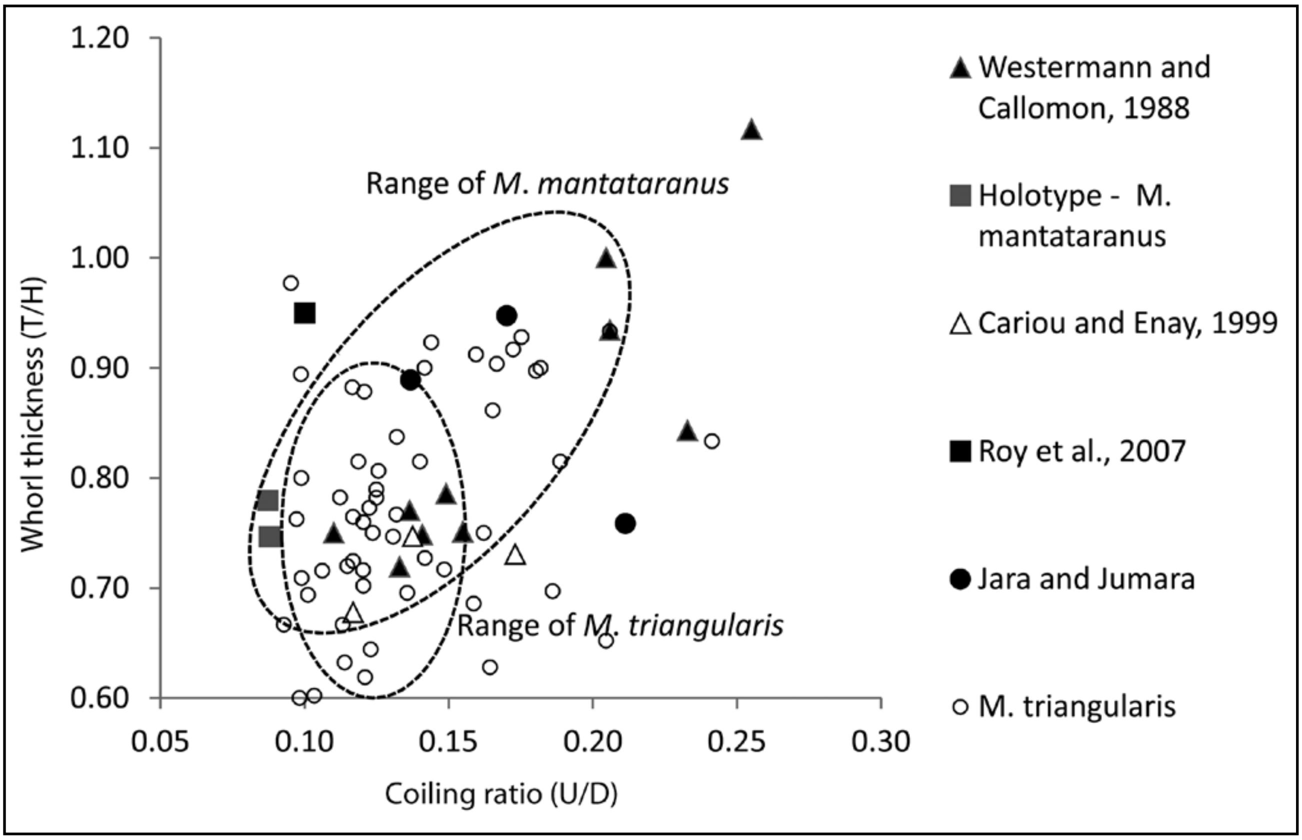

Figure 28: Comparative proportional dimensions (whorl thickness vs. coiling ratio) of *Macrocephalites mantataranus* Boehm [M] and *Macrocephalites triangularis* Spath [M]. Available data suggests that *M. triangularis* Spath [M] is much more involute and compressed.

1996 *Macrocephalites triangularis* Spath – Jain, p. 77, pl. 8, fig. 2
non 1996 *Macrocephalites triangularis* Spath – Datta et al., p. 450, pl. 2, figs 1, 5

Allotype locality: North of the village of Jumara, in the northern flank, North-East of the core of the Jumara Dome, Kachchh, western India (Fig. 1a).

Allotype: One complete specimen, sp. no. Ju/27/158, SJ collection, University of Rajasthan, Jaipur, western India.

Type horizon: Yellow bed (bed A4), North-East of the core of the Jumara Dome.

Diagnosis: Shell small, compressed and involute with an acutely rounded venter. Primaries are sharp, fine, prorsiradiate, concave at umbilical region, dividing at the lower third of flank height. After 50 mm, they devide at mid-flank height into 2–3 prorsiradiate secondaries with an occasional single intercalatory, that crosses the venter straight. The secondaries disappear much before the phragmocone stage, are then restricted to outer third of flank height. Umbilical wall is vertical with rounded umbilical edges. Phragmocone flanks are slightly flat to gently arched, gradually becoming strongly arched, with increasing shell diameter. Whorl-section is subtriangular. Phragmocone measures 78 mm. Maximum estimated shell diameter is ~120 mm.

Description: Shell is small, compressed and involute with an acutely rounded venter. Umbilical wall is vertical with rounded umbilical edges. Whorl-section remains subtriangular. At the phragmocone stage, the flanks are slightly flat to gently arched, gradually becoming strongly arched. Primaries arise from the below the rounded umbilical edge, rursiradiately and persist until 62 mm diameter. They are sharp, fine, prorsiradiate, concave at umbilical region, and divide at the lower third of flank height until 50 mm diameter, then at the mid-flank height, into 2–3 prorsiradiate secondaries, with an occasional single intercalatory. The prorsiradiate secondaries cross the venter straight. These disappear much before the phragmocone stage, and are then restricted to the outer third of flank height. At this stage, the secondaries are somewhat coarse, and cross the venter straight. Phragmocone measures 78 mm. Estimated shell diameter is 115–120 mm.

Remarks: Datta et al. (1996: p. 453) noted that the "phragmocone attains a diameter of about 105–110 mm" and primaries "disappear at about 90 mm", but this resembles the adult macroconch phragmocone (90–125 mm) where primaries disappear by 90 mm (Datta et al. 1996; see Fig. 27e, a completely septate specimen). The phragmocone of a complete microconch specimen, measures only 78 mm and primaries disappear by 62 mm (Fig. 29). Thus, based on the available data, the specimen illustrated by Datta et al. (1996) on their pl. 2, fig. 1d might well be a juveni-

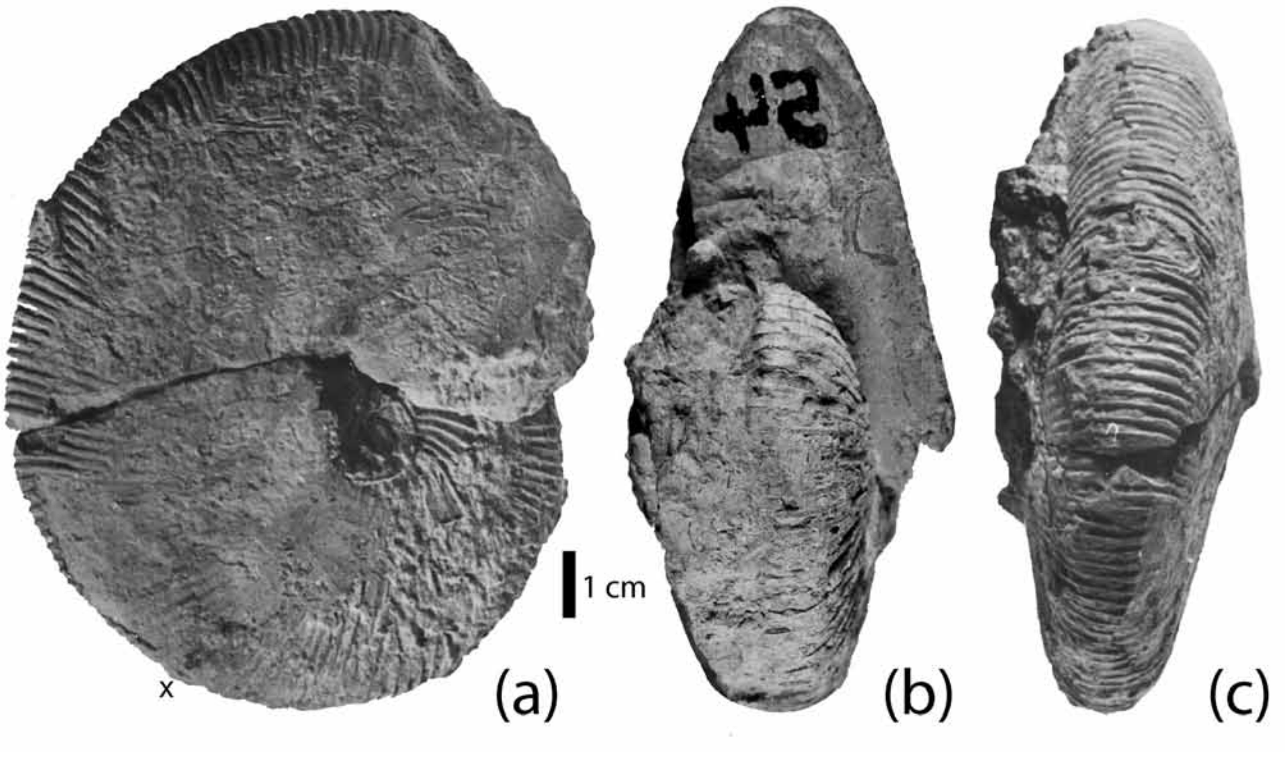

Figure 29: *Macrocephalites triangularis* Spath [m]. **(a–c)** specimen no. Ju/27/158, Yellow Bed (bed A4), Jumara Dome. (a): Lateral view. (b): Apertural view. (c) Ventral view.

le macroconchs and another specimen (pl. 2, fig. 5) is too small to differentiate between the sexes; it is most likely an inner whorl.

6. Conclusion

Based on the widespread distribution of the nominal and Madagascan *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M] in Kachchh (western India), a new early Middle Bathonian Arkelli Chronozone is proposed and correlated with the Western European early Middle Bathonian Progracilis Zone. *P.* (*G.*) *progracilis arkelli* Collignon [M] is now established as a geographic subspecies of the Western European *P.* (*G.*) *progracilis* Cox and Arkell [M]. The recorded ammonite assemblage from this chronozone, within the Kachchh Mainland now contain *Micromphalites* (*Clydomphalites*) *clydocromphalus* Arkell [M], *Procerites hians* Waagen [M], *Procerites* (*Siemiradzkia*) cf. *verciacensis* [m], *Sivajiceras congener* (Waagen) [M and m], *Procerites* (*Gracilisphinctes*) *progracilis arkelli* Collignon [M and m], *P.* (*G.*) *progracilis* aff. *arkelli* Collignon [M], *P.* (*G.*) *intermedius* n. sp. [m], *Macrocephalites* cf. *etheridgei* Spath [m], *M. bifurcatus* transient aff. *bifurcatus* Boehm [m], *M. bifurcatus* transient *intermedius* (Spath) [M and m], *M. bifurcatus* transient cf. *intermedius* Boehm [M], *M. triangularis* Spath [M and m], *Parapatoceras distans* (Baugier & Sauzé) [M], *Reineckeia* sp. indet. A and B [M] and *Eutrephoceras* sp. [M], whereas coeval sediments at the Island Belt have yielded *Procerites* cf. *schloenbachi*, *Micromphalites* (*Clydomphalites*) cf. *clydocromphalus*, *M.* (*Clydomphalites*) sp. indet., *M.* aff. *hourcqui*, *Clydoniceras triangulare*, *C. pachchhamensis*, *Clydoniceras* sp. and *Bullatimorphites* (s.s.). These finds, thus, extend the Kachchh non-macrocephalitid records to Saudi Arabia and on to the NW European localities, and for the macrocephalitids, into the High Himalayas and further outside the Indo-Madagascan Province, to the East Indies and into New Zealand. Recent nannofossil data from the same ammonite-yielding bed (the Yellow Bed at Jumara) is reinterpreted with updated chronology. This new data suggests that the Yellow Bed encompasses a 2.6 Ma interval spanning from 168.67 Ma (Late Bajocian; Garantiana Zone) to 166.07 Ma (Middle Bathonian; Morrisi Zone). Previous benthic foraminiferal data from the same bed had also yielded a Middle Bathonian age. Although, an integrated approach is employed in this study (using ammonite, foraminifers, nannofossils and lithostratigraphy), but for the Bathonian, ammonites provide a far better age resolution in Kachchh. Globally, *Macrocephalites bifurcatus* transient cf. *intermedius* Boehm [M] is recorded here as the earliest macrocephalitid. Its evolutionary path follows from the Late Bajocian to Early Bathonian *Satoceras* to *Praetulites* and on to *M. bifurcatus* in the early Middle Bathonian and the *Macrocephalites* entry into Kachchh is suggested to be facilitated by a transgressive event - T_{10} event of Hallam & Haq et al.'s ebbing LZA-2.2).

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Appendix 1. Dimensions (in mm) used in this study.

Species name	Locality	Specimen no.	Stage	D	H	T	U	T/H	U/D	Allometry [(T/H)/D]	Figure no.
Micromphalites (*Clydomphalites*) *clydocromphalus* Arkell [M]	Yellow bed (bed A4), Jumara (this study)	Ju/SJ/2014/A4/1	at phragmocone	43,72	21,49	9,26	7,77	0,43	0,18		8
			at phragmocone	58,40	30,80	12,40	6,40	0,40	0,11		
Procerites (*Gracilisphinctes*) *progracilis arkelli* Collignon [M]		Ju/27/59	at body chamber	260	95,5	55	68	0,58	0,26	0,002	13a–c
			at phragmocone	161,1	52,3	43	50,6	0,82	0,31	0,005	13d–g
		Ju/SJ/2013/A4/13	at phragmocone	140,6	53,3	38,1	37	0,71	0,26	0,005	14
Procerites (*Gracilisphinctes*) *progracilis arkelli* Collignon [m]		Ju/27/60	at body chamber	63,66	21,94	16,43	26,78	0,75	0,42		18a–b
			at phragmocone	47,05	16,78	15,46	17,80	0,92	0,38		
Procerites (*Gracilisphinctes*) *progracilis* aff. *arkelli* Collignon [M] (= *Gracilisphinctes* sp. of Jain et al., 1996)	Jhura (Jain et al., 1996)	RUC1994I 1341	at phragmocone	~210	79,6	~44	60	0,55	~0.29	0,003	19
Procerites (*Gracilisphinctes*) *intermedium* n. sp. [m]	Yellow bed (bed A4), Jumara (this study)	Ju/27/65	at body chamber	75,41	21,53	16,38	21,83	0,76	0,29		18g–i
			at phragmocone	61,40	19,34	15,00	18,52	0,78	0,30		
			at phragmocone	50,57	14,54	12,71	15,41	0,87	0,30		
Macrocephalites cf. *etheridgei* (Spath) [m]		Ju/SJ/2013/A4/14	at phragmocone	~90	36	41,8	~30	1,16	~0.33	0,013	21d–f
Macrocephalites bifurcatus transient aff. *bifurcatus* Boehm [m]		SJ/Ju/2000/A4/1	at phragmocone	~65	24,2	26	~21	1,08	~0.32	0,017	21g–i
Macrocephalites bifurcatus transient *intermedius* (Spath) [M]		SJ/Ju/1999/A4/3	at phragmocone	51	26,5	18,6	7,6	0,7	0,15	0,014	24a–e
		SJ/Ju/1999/A4/4	at phragmocone	95	57	51	12	0,89	0,13	0,009	24f–h
		SJ/Ju/1999/A4/5	at phragmocone	103	52,5	56	12	1,07	0,12	0,010	25–k
Macrocephalites bifurcatus transient *intermedius* (Spath) [m]		Ju/27/602	at phragmocone	83,3	–	–	9	–	0,11		25a–b
		Ju/27/603	at body chamber	112,8	–	–	12,45	–	0,11		25c
		Ju/SJ/2013/A4/14	at body chamber	101,8	–	–	–	–	–		25d
Macrocephalites bifurcatus transient cf. *intermedius* Boehm [M]		SJ/1997/A4/2	at body chamber	~145	88,6	~60	12,8	0,68	~0.09	0,005	26c–e
		SJ/Ju/1999/A2a/1	at phragmocone	180	117	~85	18,6	0,73	0,10	0,004	26a–b
				140	95	70	17,8	0,74	0,13	0,005	
Macrocephalites triangularis Spath, 1928 [M]		SJ/Ju/1999/A4/6	at body chamber	212,5	115	–	21,5	–	0,10		27a–d
		SJ/Ju/1999/A4/7	at body chamber	254	145,7	88,6	20	0,35	0,08		not figured
		SJ/Ju/1999/A4/8	at body chamber	298	158	110	25,4	0,37	0,09		27e
Macrocephalites triangularis Spath, 1928 [m]		Ju/27/158	at phragmocone	60	31,4	21	11	0,67	0,18		29
			at phragmocone	78,6	44,7	36	13	0,81	0,17		
			at body chamber	101,6	58,6	37	14,6	0,63	0,14		