Paläont. Z.	70	1/2	129–143	10 Abb.	Stuttgart, März 1996

On the earliest known occurrence of the Middle Jurassic ammonite genus *Reineckeia* in the Upper Bathonian of Jumara, Kachchh, western India

SREEPAT JAIN, Jaipur, JOHN H. CALLOMON, London & DHIRENDRA K. PANDEY, Jaipur*

With 10 figures

Abstract: Two specimens of the Middle Jurassic ammonite genus *Reineckeia* (sensu lato) have been found in the lowest beds of the Pachchham (Patcham) Limestones exposed in the core of the Jumara Dome, Kachchh (Kutch), Gujarat, western India. The stratigraphy is described in detail and the age bracketed to lie between latest Late Bathonian and Middle Bathonian, older than any previously described examples of this genus, either in India or in Europe (middle Early Callovian). The new finds are compared with other known pre-Callovian Reineckeiidae, notably those of the eastern borders of the Pacific, but the relationships are not close. The phylogenetic consequences are briefly discussed. The roots of the Reineckeiidae continue to lie hidden.

Kurzfassung: Zwei Exemplare der mitteljurassischen Ammonitengattung *Reineckeia* (sensu lato) wurden aus den untersten Schichten der Pachchham (Patcham) Limestones geborgen, die im Kern des Jumara Dome von Kachchh (Kutch), Gujarat, westliches Indien, aufgeschlossen sind. Die Stratigraphie dieser Schichten wird im Detail beschrieben. Das Alter der beiden Exemplare kann auf den Zeitraum zwischen dem spätesten Ober-Bathon und dem Mittel-Bathon eingegrenzt werden. Damit sind sie älter als alle anderen bekannten Funde der Gattung, ob aus Indien oder Europa (mittleres Unter-Bathon). Die neuen Funde werden mit anderen Reineckeiiden aus dem Prä-Callov verglichen, vor allem mit Formen vom Ostrand des Pazifiks, die jedoch keine engen Beziehungen aufweisen. Die Schlußfolgerungen für die Phylogenie der Gruppe werden kurz diskutiert. Die Wurzeln der Reineckeiidae liegen nach wie vor im Dunkeln.

Introduction

The Jurassic ammonites of Kachchh – Kutch of the older literature – are important for three reasons. The first is of regional significance. The Jurassic sediments of Kachchh are up to 1500 m thick, of which around 800 m are accounted for by the Middle Jurassic. They are developed in predominantly shallow-water facies that vary rapidly from place to place. They record therefore a complex and interesting history of basin development on a tectonically subsiding shelf during the early extensional phases of the separation of India from the rest of Gondwana. Any successful basin analysis, including its sequence stratigraphy and the evolution of its biotic palaeoecology, depends critically on close time-control and this can here be provided only by the ammonites as time-diagnostic guide-fossils.

The second reason is of wider provincial interest. The ammonite biostratigraphy of Kachchh epitomizes that of a distinct marine palaeobiogeographic province, the Indo-Malgach, Indo-Himalayan, Indo-East African or Ethiopean Province of authors, lying on cratonic Gondwana

---

* Addresses of the authors: SREEPAT JAIN and D. K. PANDEY, Department of Geology, University of Rajasthan, Jaipur, 302004 India; J. H. CALLOMON, University College London, 20 Gordon Street, London WC1H 0AJ, UK.

0031-0220/96/0070-0129 $ 3.75

along the southern borders of the former Neotethys and occupying what were widespread, shallow epeiric basins extending from Kenya via Madagascar, Kachchh, Jaisalmer and the Salt Range, to the Tethyan Himalaya shelf at the northern margin of the Indian Shield, in what is today Kashmir, Nepal and southern Tibet south of the Indus-Yarlung-Zangbo Suture (see e.g. WESTERMANN & WANG 1988). The ammonite faunas of this Province differ sufficiently from those of Europe to make it necessary to work out an independent regional standard chronostratigraphy. The rich ammonite faunas themselves have long been known from the descriptions in the classical monographs by WAAGEN (1875) and SPATH (1924, 1927–33) for Kachchh and the more synoptic catalogue by COLLIGNON (1958–60) for Madagascar. But their biostratigraphical successions were known only in rough outline and, in some cases, by inference through distant correlations with Europe. The thick stratigraphical development, excellence of outcrop and ease of access make the opportunities for detailed biostratigraphy in Kachchh unrivalled, and revisions are currently actively in progress.

The third reason is of the widest international interest. It is concerned with the interprovincial chronostratigraphical correlation of the local, provincial standard zonations that bioprovincialism of the guide-fossils has forced upon us. This requires an understanding of the evolution of the guide-fossils, here the ammonites, in a global framework of shifting endemisms with their consequent faunal migrations. These migrations could be dramatic: geographically distant and geologically instantaneous. They often surface in the geological record as regionally widespread and chronologically sharp "first appearances". Such migrational "events" can in turn define time-planes of great value for regional correlations, and many standard chronostratigraphical boundaries are based upon them. Almost as often, however, the migrations were into areas whose geology we know from ones whose geology we do not know: an ammonite genus or family makes an appearance that is "cryptogenic". As our knowledge expands regionally, so does the known distribution of the cryptogenic fossils; and in the absence of evidence to the contrary, there is a temptation to assume that the expanding record is one of cryptogenic first-appearances that were isochronous. A well-known example in the Middle Jurassic was provided by the genus *Macrocephalites,* whose first appearance in Europe and the western Tethys was taken to define the Bathonian-Callovian boundary and then used to recognise, by implication, this boundary world-wide, including Kachchh. New discoveries have caused this story to be drastically modified. A long line of pre-Callovian ancestors has now been recognized in regions in which sediments of such ages were previously not known. These turned out to be in the western Pacific (WESTERMANN & CALLOMON 1988). Subsequent colonization of the Tethys by the Macrocephalitinae was by westerly migration, which was gradual rather than instantaneous and which reached northern India (CARIOU et al. 1994), Kachchh (CALLOMON 1993) and even Europe (CALLOMON et al. 1989) already in Late Bathonian times.

We now describe new discoveries that drastically change also the known range of another quasi-cosmopolitan group much used in interprovincial correlations, that of the genus *Reineckeia.* It appears cryptogenically, suddenly and abundantly, in Europe and the western Tethys in the upper part of the Lower Callovian, at the base of the Gracilis Zone of the Submediterranean zonation (horizon III of CARIOU 1985), equivalent to a level a little above the base of the Koenigi Zone of the Subboreal zonation (CALLOMON et al. 1989). The most recently published earliest appearance in Kachchh lay somewhat higher, at the base of the Middle Callovian (CARIOU & KRISHNA 1988), deduced therefore to have been by easterly migration. It has now been found at Jumara at a level that is considerably lower, in beds that are certainly still of Upper Bathonian age – earlier than even the oldest known records in Europe. The phyletic roots of the Reineckeiinae have therefore also to be sought much earlier than has been assumed hitherto and cannot have lain in Europe.

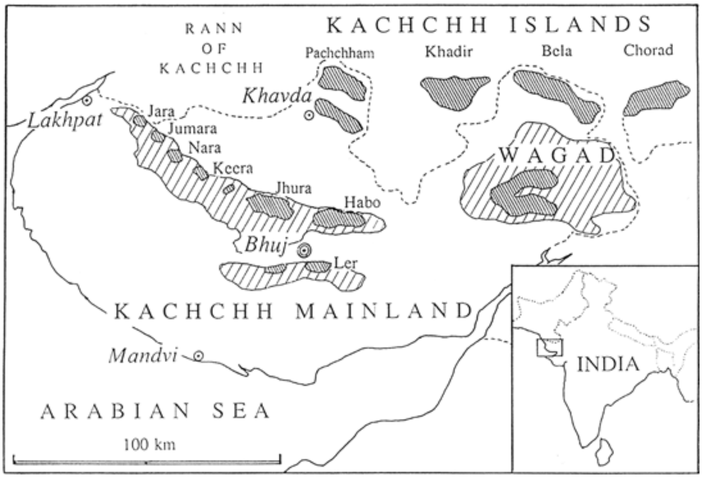

Fig. 1. Map of the Jurassic outcrops in Kachchh, India, with some important localities. Close hatching: Middle Jurassic. Wide-hatching: Upper Jurassic.

Localities and stratigraphy

The outcrops of Jurassic rocks in Kachchh are shown in Fig. 1. On the "Mainland," the Middle Jurassic surfaces only in the eroded cores of anticlinal domes that form inliers in an otherwise nearly flat-lying cover of younger beds. These domes themselves follow more or less E–W trending fault-bounded lineaments and probably mark the sites of concealed Tertiary intrusions. Their names are mostly derived from those of nearby villages. The "Islands" are areas of low to moderate relief rising out of the salt-flats or sandy plains of the Rann or Banni. They consist mostly of the erosional remnants of gently S to SW-dipping fault-blocks and the youngest Jurassic rocks preserved in them range from Middle Jurassic (Callovian) in the west to Upper Jurassic (Oxfordian) in the east. The new discoveries described here came from the core of the Jumara Dome at the western end of the Mainland.

A number of attempts have been made at lithostratigraphical classification of the 800 m or so of Middle Jurassic sediment (e.g. Biswas 1980), but because of the rapid changes of facies, none is yet comprehensively satisfactory. A partial revision recently proposed for the Goradongar range on Pachchham (the more southerly of the two indicated in Fig. 1) (Fürsich et al. 1994), combined with traditional names going back to Waagen (1875) and Spath (1933), can be successfully applied to the Mainland domes. It is summarized in Fig. 2.

The lowest beds exposed in the Jumara Dome lie in the Pachchham Formation (formerly Patcham Formation), so named despite the fact that the only stratigraphical succession, to which the name was originally applied, lay on the Mainland, specifically at Jumara. In introducing the name, Waagen admittedly claimed to be following notes made during a visit in 1871–72 by Stoliczka, whose untimely death curtailed any further descriptions, and it could well be that Stoliczka, having already correlated the lowest beds at Jumara with their widely distributed and much more prominent equivalents on Pachchham (Wynne 1872: 53), chose to name both after the latter locality.

The first to publish a detailed account of the succession at Jumara was Raj Nath (1932), summarized, with identifications of the ammonites, by Spath (1933: 739–740). This account has formed the basis of most of the descriptions that have appeared since (e.g. Cariou & Krishna

Katrol Formation		Kimmeridgian–Tithonian
– regional non-sequence		
Chari Formation (300-400 m)	Upper: Dhosa Oolite	L. Oxfordian
	Athleta Beds	U. Callovian
	Middle: Anceps/Rehmanni Beds	M. Callovian
	Lower: Macrocephalus Beds	L. Callovian
Pachchham Formation (3-50 m)	Pachchham Limestones of Jumara Raimalro Limestone of Pachchham	U. Bathonian
Khavda Formation (400 m +)	Gadaputa Sandstone Member	?
	Goradongar Yellow Flagstone Mb.	M. Bathonian
	Middle Sandstone Member	?
	... ...	
	[Kaladongar Formation of BISWAS, 1980]	U. Bajocian
– base not seen		

Fig. 2. Summary of the lithostratigraphy of the Middle Jurassic sediments of the Kachchh Mainland and Pachchham Island. The Kaladongar Formation as originally defined ranged upwards to include much of what has now been redefined as the Khavda Formation (Fürsich et al. 1994).

1988: 153). Raj Nath's section extends from the lowest beds exposed in the core up to and including the Dhosa Oolite. It was divided, in descending order, into beds 1 (Dhosa Oolite, top) – 26 (Patcham Shelly Limestone in Spath 1933, bottom). Unfortunately, his account was so general that it has been difficult to recognize many of the beds again in the field. The more detailed account predicted by Spath never appeared. A copy of Raj Nath's Thesis in the library of London University gives a few more details. These allow some of his beds to be more closely identified, but even this is of relatively little interest today as newly-recorded descriptions of the whole section are now available (to be published).

The outcrops at Jumara fall into two parts. The beds of the Pachchham Formation, Raj Nath's beds (RN) 22–26, form an elliptical inner dome whose major axis trends E–W. Among the higher beds exposed are resistant carbonates forming semi-elliptical ridges on the north side, dipping at up to 20° northwards into the Rann, with scarps facing into the core occupied by the quasi-horizontal recessive, softer carbonates below. The inner dome is surrounded by a ring of superficial deposits covering the outcrop of the very soft, shaly lowest beds of the overlying Chari Formation. The contact between Pachchham and Chari Formations is therefore not seen at Jumara. The higher beds of the Chari Formation then crop out in ever-widening partial ellipses surrounding the core on the south and east sides, lost in the north by faulting, with resistant/recessive lithologies marked by a relief of further ridges, scarps and valleys, capped by an outermost prominent ridge of Dhosa Oolite.

The following is a partial description of a section through the Pachchham Formation in the inner core. The lowest beds (Fig. 3) are clearly differentiated only in shallow gullies or stream-cuttings in the eastern half of the inner dome, and numerous small faults break up the outcrops. The succession has therefore to be pieced together. From above:

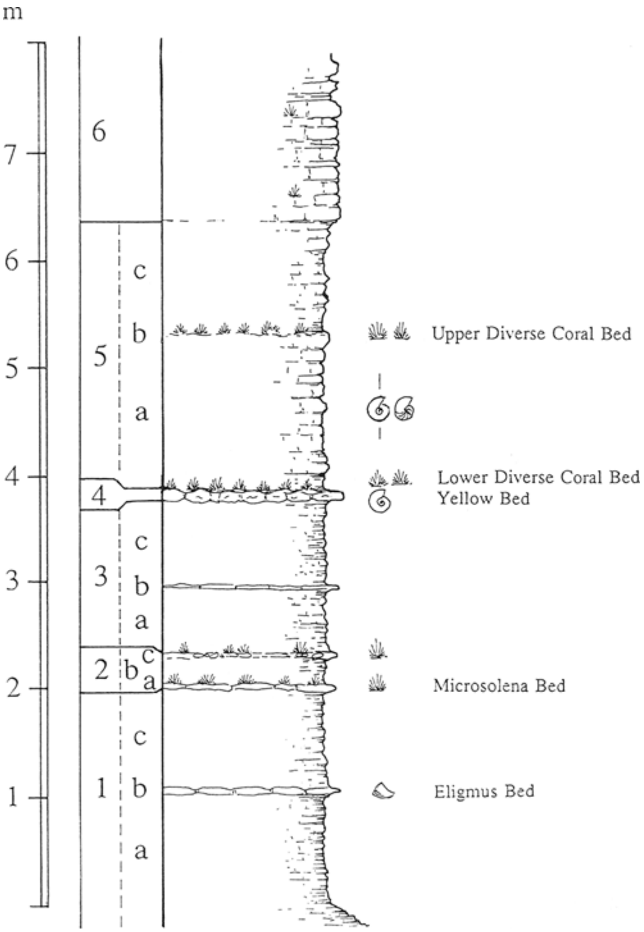

Fig. 3. Weathering profile through the lowest beds of the Pachchham Limestones – the Coral Beds (Raj Nath 24–26) – exposed in the core of the Jumara Dome.

Chari Formation

B1. Shales, soft, fine-grained, lowest part not exposed

– contact not seen

Pachchham Formation

A6–8: Lower Macrocephalus Beds of Spath and Raj Nath, RN22–24

A8. Jumara Sponge Beds (RN 22). Limestones, well-bedded, in many alternating courses of hard and soft micrite, white, some nodular and burrowed, with three layers of cobbles of remanié early-diagenetic concretions, heavily bored and sometimes encrusted, at +7, +8 and +14.5 m above base. Abundant sponges throughout but more concentrated at some levels, silicified, beautifully preserved and weathered out in profusion. Also diverse and abundant rhynchonellids, occasional terebratulids, rare corals; some bivalves, including *Lopha*; nautiloids: *Paracenoceras jumarense* (Waagen). Ammonites: *Macrocephalites triangularis* Spath [M], typical and variants resembling *M. verus* to *M. madagascariensis*, and [m]; *Sivajiceras congener* (Waagen) [M] and [m] (see Callomon 1993) seen...18 m

A7. Echinoderm packstone (RN 23). Calcarenite packstone of echinodermal bioclasts in fine-sandy matrix, in several courses, some cross-bedded, hard, resistant, weathering light brown, resembling and in the past mistaken for sandstone, forming the semi-elliptical ridge bordering the core on the north side, sparsely fossiliferous. *Sivajiceras* cf. *congener* [m], *Macrocephalites triangularis* ...12 m
– sharp boundary

A6. Limestones (RN 24 pars), fine-grained, micritic, weathering white to cream, well-bedded, in many courses, mostly sparsely fossiliferous. A more persistent, prominent bed marks a small platform, with corals, at + 5 m, a coarsely bioclastic shell-bed with *Eligmus* and corals lies at + 4 m, and further corals occur scattered throughout. Rare ammonites: *M. triangularis* [M], *M.* cf. *dimerus* (Waagen) [m] in top 1–2 m, and impressions of perisphinctids ...14 m
– passing down into

A4–5: Jumara Coral Beds (Patcham Coral Beds of Spath, and RN24 pars and RN 25):

A5. Limestones, fine-grained, micritic, marly, well-bedded as in A6, in part bioturbated, more abundantly fossiliferous, especially with corals:
– 5b: Upper Diverse Coral Bed, c. 1 m up
– 5a: nautiloids (*Procymatoceras* cf. *intumescens* (Waagen), very large and fairly common) and ammonites (*Procerites* cf. or aff. *hodsoni* Arkell [M] and [m], common but crushed)
– sharp boundary

A4. Lower Diverse Coral Bed and Yellow Bed (RN 25). Limestone, harder calcarenitic biomicrite or packstone, bioturbated, somewhat rubbly and ferruginous, weathering yellow. Highly fossiliferous: a lawn of corals now embedded in the upper part of the bed, with a diverse fauna of bivalves, brachiopods and gastropods. Ammonites not uncommon but usually fragmentary or crushed, the test often preserved in dark, recrystallized calcite: *Procerites hians* (Waagen), *P.* cf. or aff. *hodsoni* Arkell [M], *Siemiradzkia* cf. or aff. *verciacensis* (Lissajous) [m], *Macrocephalites triangularis* [M] and [m], *Reineckeia* sp. ...0.1–0.2 m

A1–3: Patcham Shelly Limestones of Spath and Raj Nath (RN26):

A3 Marls or marly limestones, light, soft, recessive, poorly exposed
– 3b: thin bed of shell-brash, hard, platy, weathering brown, c. 0.5 m above base ...1.5 m

A2. *Microsolena* Bed. Marly limestones with two thin packstone interbeds supporting layers of corals:
– 2c: packstone, harder, thin, with bored pebbles, overlain by as assemblage of well-spaced corals of low diversity
– 2a: another packstone, thin, overlain by an almost monospecific layer of large, round heads of *Microsolena* ...c. 0.5

A1. Marls or soft, micritic limestones, white, seen in gullies
– 1b: *Elligmus* Bed: packstone, rubbly, shelly, thin, with abundant bivalves ...seen c. 1–2 m
– lower beds not exposed

The Sponge Beds, A8, are most clearly seen on the north-western dip-slope above the Packstone, running into the Rann. They are also extensively exposed to the south-west of the core, lying almost horizontally and traversed by the track leading to the Rann. Although "some sponges" were noted by Raj Nath (1932) in passing, the failure to give any prominence to such an abundant feature in subsequent publications seems surprising. The Lower Coral and Yellow Beds, A4, were recorded by Raj Nath (1930) as a single "25. Thin brown calcareous bed, 6 inches [0.15 m]". The highly diverse fauna, first described by Gregory (1990), has recently been revised by Pandey & Fürsich (1993) and interpreted ecologically by Fürsich et al. (1994). Where the softer overlying beds have been removed by erosion in the centre of the dome, the weathered-out corals cover the ground in profusion.

Age and Correlation

The age of the *Reineckeia* newly discovered in the Yellow Bed of Jumara cannot be precisely determined by direct correlation with the primary chronostratigraphic standards of western Tethys because the associated fauna, although suggestive, is not by itself sufficiently time-diagnostic. Indirect estimates therefore resolve themselves into bracketing between the nearest datable horizons above and below.

The upper stratigraphic age-limit is effectively set by that of the Pachchham Formation of Jumara as a whole. This has long been debated. Its assignment by Spath (1933: 873) to the Bathonian was on nomenclatural grounds, involving the definition of the Callovian Stage and its boundaries. This was clarified by Arkell (1933: 327) after a detailed biostratigraphic revision of the English Cornbrash. It was probably the origin of the idea, already mentioned, that the cryptogenic first appearance of *Macrocephalites* marked a sharp, widespread and isochronous evolutionary event at the base of the Callovian, and hence, more tentatively perhaps, that beds containing this genus must everywhere also be of Callovian age. The discovery of *Macrocephalites* in beds of indisputably Late Bathonian age (DIETL 1981) resolved this circular argument. The possibility that the Pachchham Formation might then also be still Late Bathonian was mooted by KRISHNA & WESTERMANN (1985) on grounds, apparently, that beds containing a similar assemblage of ammonites, that characterized by the *triangularis* (bio-) zone of SPATH (latterly standard Triangularis Zone of e. g. KRISHNA & CARIOU 1990), occur also in Madagascar where "its Late Bathonian, rather than earliest Callovian, age is suggested by ammonoid associations," which were however unspecified. Subsequently, the question of the Callovian or Bathonian age of the *triangularis* assemblage of Jumara was again left open in the descriptions of new collections made at Jumara (KRISHNA & WESTERMANN 1987) from what appear to have been beds A6–A8 (RN 22–24). Yet further collections made by us include the typical *M. triangularis* as variants of what is found in both A6 and A8.

The question was recently re-examined by one of us (CALLOMON 1993) in a critical review of the faunal elements other than the equivocal *Macrocephalites*. New evidence has come from two sources. The first lies in the perisphinctids. These are fairly abundant in the Sponge Beds, A8 (RN 22), but are almost invariably crushed and fragmentary. They include the species *Perisphinctes congener* WAAGEN 1875, since become type-species of a new genus *Sivajiceras* created by SPATH (1928). Comparison with possible Upper Bathonian or Lower Callovian contemporaries in Europe was also inconclusive. The Indian forms differ significantly from both, but resemblance was closest with forms from the Upper Bathonian.

The second source of information lies in the family Tulitidae. Representatives have been recorded from several levels in the Lower Chari Formation. They can all be unequivocally assigned to the genus *Kheraiceras*, which in Europe ranges from uppermost Bathonian (Discus Zone) through most of the Lower Callovian. Some of the Indian specimens appear even to be conspecific with the most typical European form, *Kh. bullatum* (D'ORBIGNY). A single specimen recorded from lower levels by BARDHAN et al. (1988) is however different. It came from a "cream-coloured limestone 15 m below the Patcham-Chari boundary" at Jumara, in a Patcham Formation said to be 114 m thick, associated with *M. triangularis*, *Procerites hians*, *Sivajiceras congener* and *Paracenoceras jumarense*. But no details are given as to where the Patcham-Chari boundary is drawn. A reference to an earlier account (DATTA & BARDHAN 1986) is of no more help, although here the Patcham Formation is claimed to be only 20 m thick. The two most likely possibilities are therefore either near the base of the Sponge Beds, A8, or somewhere in the limestones between the Packstone, A7, and the Yellow Bed, A4. This specimen is not a typical *Kheraiceras*. It lacks the characteristically extreme cadicone, densely-ribbed phragmocone with massively contracted, smooth adult bodychamber, retaining blunt but strong ribbing to the end. Its morphology is still close to that of the ancestral *Bullatimorphites* s. s. Among European species, it most closely resembles *B.* cf. *hannoveranus* (ROEMER 1911) (pl. 8, fig. 1; HAHN 1971, pl. 7, fig. 3), from the Upper Bathonian, Orbis Zone, of Germany and, closest of all, *B.* cf. *hannoveranus* in MANGOLD (1970: 303, figs. 96, 97), from the Upper Bathonian, Retrocostatum Zone of the southern Jura. It is of course never wholly safe to date a bed solely on the strength of one ammonite, but the balance of probabilities now points positively and very strongly to an Upper Bathonian age for the Pachchham Limestones of Jumara, which was the conclusion reached previously (CALLOMON 1993).

A lower limit to the stratigraphic age cannot be estimated at Jumara itself, for no diagnostic ammonites have been found there below the Yellow Bed. It can however be done by lithostratigraphic correlation. In Pachchham, the Pachchham Formation of Jumara undoubtedly finds its equivalents in the Raimalro Limestone Member, for, amongst other similarities, the characteristic micritic white limestone facies of this formation is found only once in the whole of the thick Middle Jurassic pile in all of Kachchh, over which it extends with remarkable uniformity. It is well and completely exposed also in the Jhura Dome (Fig. 1), where it is 50–60 m thick (to be published) and largely made up of sponge beds just like those of Jumara. The Raimalro Limestone of Pachchham is underlain by up to 25 m of variable siliciclastic Gadaputa Sandstones that thin southwards, for at Jhura they appear to be represented by only a residual sandy, shelly pebble-bed no more than a metre thick. Underlying the sandstone is a second series of fine-grained carbonates, the Goradongar Flagstones, thick, widespread and easily recognised by their yellow colour when weathered. This member is 30–40 m thick in Galandongar, northern Pachchham, 40 m thick at Sadhara, Goradongar, southern Pachchham, and occurs little changed on Khadir island, 50 km to the east. It contains lenticular developments of "Golden Oolite" and the top 20 m are particularly rich in fossils, including ammonites: *Clydoniceras triangulare* Pandey & Agrawal, *C. pachchhamense* P. & A., *Micromphalites* cf. *clydocromphalus* Arkell, *Gracilisphinctes arkelli* Collignon (fairly common), *Bullatimorphites* s. s. sp. nov., but no *Macrocephalites.* This assemblage indicates unambiguously an anchorpoint of Middle Bathonian age. The Goradongar Flagstones reappear in the Jhura Dome, 45 km SW of Goradongar, undiminished in thickness (at least 40 m) and unchanged in facies, including prominent interbeds of "Golden Oolite" and a specimen of *Gracilisphinctes.* From Jhura to Jumara is 60 km WNW, and it is hard to imagine that the Goradongar Flagstones would have totally disappeared over such a distance, in view of their constancy over similar distances in other directions. It seems safe to assume, therefore, that they underlie also the lowest beds of Pachchham Limestone seen at Jumara. The age of the *Reineckeia* in the Yellow Bed is therefore bracketed between late (but not latest) Upper Bathonian above and Middle Bathonian below.

What direct evidence there is comes from the associated perisphinctids. Although not well preserved, the material is sufficiently abundant to give an indication of the variability. Both macro- and microconchs are represented. Collectively, they are seen to differ from those of the Sponge Beds (A8, with *Sivajiceras congener*) and to be assignable without difficulty to the genera *Procerites* [M] and *Siemiradzkia* [m], as found in the Hodsoni Zone of the early Upper Bathonian of Europe. The Yellow Bed is with little doubt also the source of the holotype of *Procerites hians* (Waagen) (1875: 153, fig. 2), as deduced from its characteristic lithology (Waagen collection, Calcutta) and newly-collected topotypes. Waagen himself recorded it from "the coral beds of the Putchum group " of Jumara. It represents the compressed, involute, fine-ribbed end-form of the variability and its name may be used to label the assemblage as a whole.

Systematic descriptions

Family Reineckeiidae Hyatt 1900

Genus *Reineckeia* Bayle 1878

Reineckeia spp. indet. *A, B* [M]

Figs. 4–8

Material: Two fragments A, B, of inner whorls of macroconchs (Dept. of Geology, University of Rajasthan, Jaipur, nos. RUC JU/27/57, -58, Jain coll.)

Horizon and Locality: Jumara, Pachchham Limestones, Bed A4, the Yellow Bed. Upper Bathonian.

Figs. 4–5. *Reineckeia* sp. *A* (RUC Ju/27/57), fragment of inner and intermediate whorls, wholly septate. Figs. 6–8. *Reineckeia* sp. *B* (RUC/27/58), fragment of an intermediate whorl, wholly septate with umbilical seam indicating former presence of another whole whorl. 4–8: Jumara, Pachchham Limestones, Yellow Bed, A4.

4

5

6

7

8

Description: The larger specimen (A) shows parts of two whorls at former diameters of the shell estimated to have been roughly 170 and 100 mm. It is wholly septate. Coiling evolute: whorl-section on the outer whorl subquadrate, whorl-height and whorl-breadth about 26 % of the diameter at 170 mm, rounded depressed on the inner whorl, ?24 % and 27 % respectively at 100 mm. Ribbing strong and coarse: primaries with strong, distant tubercles on both whorls, secondaries only slightly prorsiradiate, issuing indistinctly from the primaries, with intercalatories and clearly defined ventral smooth band. The smaller specimen (B) consists of a fragment of one whorl estimated to have had a diameter of c. 90 mm. It is also wholly septate and an umbilical seam indicates the former presence of at least another whole whorl. Coiling again evolute, whorl-section coronate depressed, whorl-height and width 27 % and c. 40 % of the diameter respectively. Ribbing strongly tuberculate, the tubercles not more than 10 per whorl, secondaries as in (A). Imprint of an inner whorl shows similar secondary ribbing on a very broad external margin, suggesting that the coronate whorl-section was already developed at quite small diameters.

Parts of two septal sutures are visible on specimen A. They have been sketched in Fig. 9. The points to note are that they are florid and deeply incised, with long, slender lobes, and a lateral lobe that is strongly asymmetrical. The umbilical lobe is barely visible but appears to be strongly retracted and highly ornate, with many auxiliaries. The general plan and style agree closely with the typical example illustrated by CARIOU (1984: 21, fig. 9) in a *Reineckeia anceps* from the early Middle Callovian, or SPATH (1928: pl. 47, fig. 7) in *R. tyranniformis* from Keera, of comparable age. That of a late form, a *Collotia* from the Upper Callovian of England (ARKELL 1939: 186, fig. 2) also has a highly asymmetrical lateral lobe.

Comparisons: The two specimens could well be conspecific. No attempt has been made to give them even an approximate specific name, for even if a close match could be found with corresponding parts of some specimen of one of the innumerable nominal species of *Reineckeia* already in the literature, no conclusions of general interest could be drawn, either stratigraphical or systematic, in a group as highly ornate and variable as the present. The European representatives have been exhaustively reviewed by CARIOU (1984b). The earliest species there, assigned to the genus *Rehmannia*, all tend to have more perisphinctid-like inner whorls: compressed, densely ribbed, with primaries that are bullate but hardly as coarsely tuberculate and depressed as specimen *B*, Figs. 6–8. Forms as strongly tuberculate from early stages on-

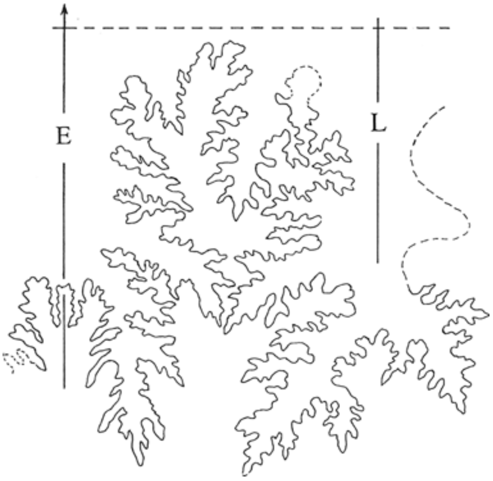

Fig. 9. Septal suture partly exposed on the specimen shown in Figs. 4–5 at a whorl-height of 45 mm.

wards occur in Europe at only much higher horizons: *Reineckeia* s.s., e.g. *R. tyranniformis* Spath (sensu Cariou 1984b: pl. 39) or *R. stuebeli* (Steinmann) (sensu Cariou 1984b: pl. 40), from the Jason Zone, Middle Callovian. But in all these, the late middle and outer whorls become much more inflated and involute than in specimen *A* from Jumara.

The other part of the world, in which early Reineckeiidae were endemic, lies along the eastern margins of the Pacific. Apart from scattered, allochthonous records, the best-known occurrences are in Guerrero, southern Mexico, and in the Andean Cordillera of northern Chile, Mendoza and Neuquen. The ammonite biostratigraphy of these regions, including that of Reineckeiidae in particular, has recently been reviewed by Sandoval et al. (1990) for Mexico, and Riccardi et al. (1989) and Riccardi & Westermann (1991) for the southern Andes. The succession are sufficiently similar to be encompassed by a common standard zonal chronostratigraphy around the Bathonian-Callovian boundary, summarized in Fig. 10. The correlations with the European standards are those suggested by Riccardi et al. (1989) in the references cited above, anchored at the base by the common occurrence of *Epistrenoceras* in the early Steinmanni Zone of Mexico and the late Retrocostatum Zone of Europe, and at the top by the common occurrence of *Hecticoceras proximum* and *H. boginense* in Europe and Mendoza.

The oldest Reineckeiidae appear in the Steinmanni Zone, both in Mexico and in the southern Andes. They belong, however, to the strongly variocostate genus *Neuqueniceras* rather than to *Reineckeia* (including *Rehmannia*). In this genus, the inner whorls are perisphinctid in the sense

<table>
<tr><th>East Pacific</th><th colspan="2">Europe</th><th></th></tr>
<tr><th>Zones</th><th>Subzones</th><th>Zones</th><th></th></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Hecticoceras
PROXIMUM</td><td>Indosphinctes
PATINA</td><td rowspan="3">Macrocephalites
GRACILIS</td><td rowspan="5">Lower
CALLOVIAN</td></tr>
<tr><td rowspan="3">Neuqueniceras
BODENBENDERI</td><td>... ... ...</td></tr>
<tr><td>Rehmannia
REHMANNI</td></tr>
<tr><td rowspan="2"></td><td rowspan="2">Macrocephalites
HERVEYI</td></tr>
<tr><td>Eurycephalites
VERGARENSIS</td></tr>
<tr><td rowspan="2">Lilloettia
STEINMANNI</td><td colspan="2">Clydoniceras DISCUS</td><td rowspan="5">Upper
BATHONIAN</td></tr>
<tr><td rowspan="3"></td><td rowspan="2">Prohecticoceras
RETROCOSTATUM</td></tr>
<tr><td rowspan="2"></td></tr>
<tr><td></td></tr>
</table>

Fig. 10. Summary of the standard zonations around the Bathonian-Callovian boundary in Europe and the Eastern Pacific.

that they are very evolute, serpenticonic with rounded whorl-section, and have non-tuberculate primary ribbing with simple, biplicate or triplicate secondaries that cross the venter with only the merest hint of a mid-ventral interruption. Found by themselves, or as microconchs, small specimens would hardly be recognizable as reineckeids at all. The typical reineckeid depressed coiling and ribbing with strong, distant primary tubercles set in quite sharply only at intermediate and adult stages of macroconch ontogeny. Somewhat higher in the succession, in the lower Bodenbenderi Zone, the perisphinctid stage of ontogeny retreats into the innermost whorls ("palingenesis", the opposite of proteogenesis) and reineckeid morphology sets in at already quite early stages, at diameters of 30–40 mm. These later forms are described as subgenus *N. (Frickites)* JEANNET. Finally, the upper Bodenbenderi Zone sees the appearance of typical, fully-formed reineckeids assignable without difficulty to the same group as that described in Europe as *Rehmannia. Neuqueniceras* is unknown in Europe and the western Tethys. It was separated from the typical reineckeids as a Pacific provincial subfamily Neuqueniceratinae by CARIOU (1984a).

The specimens from Jumara do not appear to belong to *Neuqueniceras* s. s., for the coronate morphology is already fully formed at diameters very much less than 100 mm (Figs. 7, 8). They could, as far as this character is concerned, belong to *N. (Frickites)*. But there are other differences. In *N. (Frickites)* the secondary ribbing on the outer whorl fades in a way quite different from that in specimen *A*, Figs. 4–6. The septal sutures are also different. Those of *Neuqueniceras* and *Frickites* are relatively simple, with broad-stemmed and only moderately incised principal lobes (RICCARDI & WESTERMANN 1991: text-figs. 11, 13; SPATH 1928: pl. 46, fig. 2). All the indications are, therefore, that the Jumara specimens belong to true Reineckeiinae rather than to Neuqueniceratinae.

Discussion

The phylogeny of the Reineckeiidae continues to be mysterious. Until a decade ago, a close resemblance between the earliest known European forms (*Rehmannia*) and pene-contemporaneous Pseudoperisphinctinae of the genus *Homoeoplanulites* BUCKMAN [m]/ *H. (Parachoffatia)* MANGOLD [M] suggested that the latter might be the root. Subsequently, the discovery that the Pacific Reineckeiidae seemed to form an evolutionary succession from *Neuqueniceras* via *Rehmannia* to *Reineckeia* s. s. and that the earliest *Neuqueniceras* was already of Bathonian age, made it seem natural to suppose that Late Bathonian *Neuqueniceras* was the root. The sudden cryptogenic appearance of Reineckeiinae (*Rehmannia*) in the western Tethys was ascribed to immigration from Mexico eastwards, through the emergent North Atlantic along the Hispanic Corridor (CARIOU 1984a: 247). Either way, that left the question as to the origin of the Reineckeiinae of Kachchh and Jaisalmer. The first appearance there seemed to be even later then those in the western Tethys, viz. at the very summit of the Lower Callovian (CARIOU & KRISHNA 1988). Colonization of India would then have to have been by immigration from the west, part of a "major biogeographic event" (p. 167). The new finds at Jumara now tell us that Reineckeiinae appeared to have been fully formed well before their first appearance even in the western Tethys, in the middle Lower Callovian, and certainly much earlier than had been thought in India. Everything now points to an origin to the east – in the Pacific – as with so many other cryptogenic groups.

This leaves unresolved the relationship between these early Indian Late Bathonian *Reineckeia* and the Late Bathonian – Early Callovian *Neuqueniceras* of the eastern Pacific. One explanation would be that they shared a common root even earlier and then evolved in parallel, reconverging morphologically in the Middle Callovian. The similarities at these higher levels between Andean and European forms are, however, so close and extensive that such an explanation seems highly improbable. A second explanation would be a modification of the first: a common root with a continuing, evolving, common gene-pool, morphological differentiation between southern Tethyan and eastern Pacific populations being at geographical subspecific level, followed by rehybridization – the evolutionary model of so-called reticulated speciation (SYLVESTER-BRADLEY 1977; and see CALLOMON 1985: 75). There remains a third possibility: that *Neuqueniceras* is in fact rather older than has been assumed. The correlation of the Steinmanni Zone with the latest Bathonian of Europe rests essentially on the identification of two species. The first is *Hecticoceras (Prohecticoceras) blanazense* ELMI (RICCARDI et al. 1989: pl. 4, figs. 1–6) from Caracoles in northern Chile and from Mexico. The second is *Epistrenoceras histricoides* (ROLLIER), as interpreted by SANDOVAL et al. (1990: 121, pl. 9, figs. 6–8). And while the levels of these in Europe are not in doubt, there is always the question whether their ranges and levels in e. g. the eastern Pacific have to be the same – especially in a short-lived, cryptogenic form such as *Epistrenoceras*, whose earlier history is also unknown. What the correct explanation is remains to be seen.

Finally, the discovery of *Reineckeia* in the lowest Pachchham Limestones of Jumara may ease the solution of another mystery of long standing, that of the systematic position of *Perisphinctes decorus* WAAGEN (1875: 208, pl. 57, fig. 3a–c), from "the highest beds of the Putchum group of Jumara" (– the Sponge Beds?). The monotypic holotype appears still to be the only specimen known. Its affinities have been long debated (see review by SPATH 1928: 252). Derivation has been postulated from Parkinsoniidae or from Morphoceratidae, but so has that of the Reineckeiidae themselves. In the event, even if a "transitional form" from some uncertain ancestor, justifying the creation of a new generic name *Epimorphoceras*, the species was firmly placed by SPATH in the Reineckeiidae. The discovery of other Reineckeiidae from similar levels makes this assignment now perhaps more plausible. So does the septal suture of *E. decorum* (WAAGEN 1875: 57, fig. 3c). It has a form, with asymmetrical lateral lobe, almost identical with that of specimen *A* shown in Fig. 9. But again, there is no resemblance between *Epimorphoceras* and *Neuqueniceras*.

Conclusions

The discovery of two fragmentary specimens of *Reineckeia* in the lowest beds exposed at Jumara have extended the known range of this genus significantly back in time, from the middle Early Callovian into the Late Bathonian. The consequences of this for our understanding of the phylogenetic history of one of the major families of Middle Jurassic ammonites are profound: the supposed centre of evolution has to be moved eastwards, from its previous position comfortably in the western Tethys, whose Middle Jurassic is well known, into the Pacific, whose Middle Jurassic history remains largely unknown. The ultimate roots of the Reineckeiidae continue to remain concealed. It is perhaps also ironic that at the same time as the known range of this family has been extended downwards, it has also been extended upwards, well into the Lower Oxfordian of the Andes (GRÖSCHKE 1994). Deductions of biogeographic connections and migrations based on first and last appearances of cryptogenic genera are highly vulnerable to new discoveries, and should be regarded with caution.

Acknowledgements

SREEPAT JAIN expresses his indebtedness to Sri K. C. KULISH who generously supported him during his studies for a Ph.D, of which the present work forms a part. J.H.C. acknowledges with gratitude a travel-grant from the Natural Environmental Research Council (U.K.) in support of field-work in Kachchh. The authors wish also to thank F. T. FÜRSICH (Würzburg) and A. K. JAITLY (Varanasi) for their help in the field, Dr. G. DIETL (Stuttgart) for tracing the septal suture shown in Fig. 9, and Mr P. H. BHATTI (Bhuj) for his unfailing kindness and logistic support in Kachchh.

References

Arkell, W. J. 1933. The Jurassic System in Great Britain. – 681 pp., Oxford (Clarendon Press).

– 1939. The ammonite succession at the Woodham Brick Company's pit, Akeman Street Station, Buckinghamshire, and its bearing on the classification of the Oxford Clay. – Quarterly Journal of the Geological Society **95**: 135–222, 4 pls., London.

Bardhan, S., Datta, K., Khan, D. & Bhaumik, D. 1988. Tulitidae genus *Bullatimorphites* from Upper Bathonian Patcham Formation, Kutch, India. – Newsletters on Stratigraphy **20**: 21–27, Stuttgart.

Biswas, S. K. 1980. Mesozoic rock-stratigraphy of Kutch, Gujarat. – Quaterly Journal of the Geological, Mining and Metallurgical Society of India **49**[1977]: 1–51, Calcutta.

Callomon, J. H. 1985. The evolution of the Jurassic ammonite family Cardioceratidae. – Special Papers in Palaeontology **33**: 49–90, 4 pls., London.

– 1993. On *Perisphinctes congener* Waagen, 1975, and the age of the basal Patcham Limestones in the Middle Jurassics of Jumara, Kutch, India. – Geologische Blätter von NO-Bayern **43**: 227–246, 2 pls., Erlangen.

Callomon, J. H.; Dietl, G. & Niederhöfer, H. J. 1989. Die Ammonitenfaunen-Horizonte im Grenzbereich Bathonium/Callovium des Schwäbischen Juras und deren Korrelation mit W-Frankreich und England. – Stuttgarter Beiträge zur Naturkunde, (B) **148**: 1–13, Stuttgart.

Cariou, E. 1984a. Structure, origine et paléobiogéographie de la famille des Reineckeiidae, Ammonitina, du Jurassique moyen. – Comptes rendus de l'Académie des Sciences, Paris, (II) **298**: 245–248, Paris.

– 1984b. Les Reineckeiidae (Ammonitina, Callovien) de la Tethys occidentale. Dimorphisme et évolution. Étude à partir des gisements du centre-ouest de la France. – Documents du Laboratoire de Géologie Lyon, hors série **8**: 460 pp., 69 pls., Lyon.

– 1985. Biostratigraphic subdivision of the Callovian Stage in the Subtethyan province of ammonites, correlations with the subboreal zonal scheme. – [In:] Michelsen, O. & Zeiss, A. (eds.) International Symposium on Jurassic Stratigraphy, Erlangen 1984, **2**: 315–326, Copenhagen (Geological Survey of Denmark).

Cariou, E. & Krishna, Jai 1988. The Tethyan Reineckeiinae of Kachchh and Jaisalmer (west India): systematic, biostratigraphic and biogeographic implications. – Palaeontographica, (A) **203**: 149–170, 5 pls., Stuttgart.

Cariou, E.; Enay, R.; Bassoullet, J. P. & Colchen, M. 1994. Biochronologie du Jurassique moyen de la Thakkhola (Népal central) et biogéographie du domaine himalayen. – Comptes rendus de l'Académie des Sciences, Paris, (II) **318**: 93–99, Paris.

Collignon, M. 1958–60. Atlas des fossiles caractéristiques de Madagascar. Fasc. I–VII. – 28 pp., 175 pls., Tananarive (Service Géologique).

Datta, K. & Bardhan, S. 1986. A note on the biostratigraphy of the Jurassic rocks of Jumara dome, Kutch, Gujarat. – Science and Culture **52**: 169–171, Calcutta.

Dietl, G. 1981. Über *Macrocephalites* (Ammonoidea) aus dem Aspidoides-Oolith und die Bathonium/Callovium Grenzschichten der Zollernalb (SW-Deutschland). – Stuttgarter Beiträge zur Naturkunde, (B) **68**: 1–15, Stuttgart.

Fürsich, F. T.; Pandey, D. K.; Callomon, J. H.; Oschmann, W. & Jaitly, A. K. 1994. Contributions to the Jurassic of Kachchh, western India. II. Bathonian stratigraphy and depositional evironment of Sadhara Dome, Pachchham Island. – Beringeria **12**: 95–125, 2 pls., Würzburg.

Gregory, J. W. 1900. Jurassic fauna of Cutch. The corals. – Memoirs of the Geological Survey of India, Palaeontologia Indica, (IX) **2** (2): 1–195, 26 pls., Calcutta.

Gröschke, M. 1994. The Reineckeiidae of the Callovian of northern Chile: stratigraphy and paleobiogeography. – Abstracts, 4th International Congress on Jurassic Stratigraphy and Geology, Argentina 1994: 19, Mendoza.

Hahn, W. 1971. Die Tulitidae S. Buckman, Sphaeroceratidae S. Buckman und Clydoniceratidae S. Buckman (Ammonoidea) des Bathoniums (Brauner Jura ε) im südwestdeutschen Jura. – Jahreshefte des Geologischen Landesamt Baden-Württemberg **13**: 55–122, 9 pls., Freiburg.

Krishna, Jai & Cariou, E. 1990. Ammonoid faunal exchanges during Lower Callovian between the Indo-East African and Submediterranean Provinces: implications for the long-distance east-west correlations. – Newsletters on Stratigraphy **23**: 109–122, Stuttgart.

– 1993. The Tethyan Macrocephalitinae: evolutionary, environmental and dispersal strategies. – Geobios, Mémoire special **15**: 217–226, Lyon.

Krishna, Jai & Westermann, G. E. G. 1985. Progress report on the Middle Jurassic ammonite zones of Kachchh, W India. – Newsletters on Stratigraphy **14**: 1–11, Stuttgart.

– 1987. Faunal associations of the Middle Jurassic ammonite genus *Macrocephalites* in Kachchh, western India. – Canadian Journal of Earth Sciences **24**: 1570–1582, 6 pls., Ottawa.

Pandey, D. K. & Fürsich, F. T. 1993. Contributions to the Jurassic of Kachchh, Western India. I. The coral fauna. – Beringeria **8**: 3–69, 11 pls., Würzburg.

Riccardi, A. C. & Westermann, G. E. G. 1991. Middle Jurassic ammonoid fauna and biochronology of the Argentine-Chilean Andes. IV. Bathonian-Callovian Reineckeiidae. – Palaeontographica, (A) **216**: 111–145, 20 pls., Stuttgart.

Riccardi, A. C.; Westermann, G. E. G. & Elmi, S. 1989. The Middle Jurassic Bathonian-Callovian ammonite zones of the Argentine-Chilean Andes. – Geobios **22**: 553–597, 11 pls., Lyon.

Raj Nath 1930. Palaeontology and stratigraphy of the Jurassic rocks of Cutch, India. Part I. Study of the Jurassic brachiopoda of Cutch, and geology and stratigraphy of Jumara area. – Unpublished Ph.D. thesis, University of London, 86 pp., London.

– 1932. A contribution to the stratigraphy of Kutch. – Quarterly Journal of the Geological, Mining and Metallurgical Society of India **4**: 161–174, Calcutta.

Roemer, J. 1911. Die Fauna der Aspidoides-Schichten von Lechstedt bei Hildesheim. – Inaugural-Dissertation, 64 pp., 12 pls., Göttingen.

Sandoval, J.; Westermann, G. E. G. & Marshall, M. C. 1990. Ammonite fauna, stratigraphy and ecology of the Bathonian-Callovian (Jurassic) Tecocoyunga Group, south Mexico. – Palaeontographica, (A) **210**: 93–149, 20 pls., Stuttgart.

Spath, L. F. 1924. On the Blake collection of ammonites from Kachh, India. – Memoirs of the Geological Survey of India, Palaeontologia Indica, New Series **9**: 29 pp., Calcutta.

– 1927–33. Revision of the Jurassic cephalopod fauna of Kachh (Cutch). – Memoirs of the Geological Survey of India, Palaeontologia Indica, New Series **9** (2): 945 pp., 130 pls., Calcutta.

Sylvester-bradley, P. C. 1977. Biostratigraphical tests of evolutionary theory. – [In:] Kauffman, E. G. & Hazel, J. E. (eds.) Concepts and methods of biostratigraphy: 41–63, Stroudsburg/Pa.

Waagen, W. 1875. Jurassic fauna of Kutch. The Cephalopoda. – Memoirs of the Geological Survey of India, Palaeontologia Indica, Series IX, Jurassic fauna of Kutch **1**, parts 2–4: 23–247, pls. 5–60, Calcutta.

Westermann, G. E. G. & Callomon, J. H. 1988. The Macrocephalitinae and associated Bathonian and Early Callovian (Jurassic) ammonoids of the Sula Islands and Papua New Guinea. – Palaeontographica, (A) **203**: 1–90, 19 pls., Stuttgart.

Westermann, G. E. G. & Wang, Y.-G. 1988. Middle Jurassic ammonites of Tibet and the age of the Lower Spiti Shales. – Palaeontology **31**: 295–339, London.

Wynne, A. B. 1872. Memoir on the geology of Kutch, to accompany the map compiled by A. B. Wynne and F. Fedden during the seasons 1867–1868 and 1868–1869. – Memoirs of the Geological Survey of India **9**: 293 pp., maps, Calcutta.

Eingang des Manuskriptes am 5. Januar 1995;
Annahme durch die Schriftleitung am 25. Februar 1995.