Zitteliana 96, 2022, 153–178 | DOI 10.3897/zitteliana.96.87253

SNSB Bayerische Staatssammlung für Paläontologie und Geologie

ZITTELIANA
An International Journal of Paleontology and Geobiology

Jurassic bivalves from the Spiti area of the Himalayas, northern India

Franz T. Fürsich[1], Matthias Alberti[2], Dhirendra K. Pandey[3], Wagih S. Ayoub-Hannaa[4]

1 *Universität Erlangen-Nürnberg, GeoZentrum Nordbayern, FG Paläoumwelt, Lowenichstrasse 28, 91054 Erlangen, Germany*
2 *State Key Laboratory for Mineral Deposits Research, School of Earth Sciences and Engineering, Centre for Research and Education on Biological Evolution and Environment and Frontiers Science Center for Critical Earth Material Cycling, Nanjing University, Nanjing 210023, China*
3 *Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj, India*
4 *Geology Department, Faculty of Science, Minufiya University, El-Minufiya, Shibin El Kom, Egypt*

https://zoobank.org/191199E0-7F3E-4E09-A377-4ADFBF93A248

Corresponding author: Franz T. Fürsich (franz.fuersich@fau.de)

Academic editor: Alexander Nützel ♦ **Received** 2 June 2022 ♦ **Accepted** 26 July 2022 ♦ **Published** 11 August 2022

Abstract

The present study describes and illustrates six bivalve taxa from the Early Bathonian to Early Callovian Ferruginous Oolite Formation and 24 taxa from the Callovian to basal-most Cretaceous Spiti Shale Formation of the Spiti and Zanskar areas in the Indian Himalayas. The Spiti Shale Formation contains a low-diversity bivalve fauna that is concentrated in few horizons, particularly in the lower member of the formation. With few exceptions, the bivalves are poorly preserved. Bivalve taxa recorded by earlier studies are revised wherever possible. Several of the taxa, most of which are from mid- to outer shelf environments, are characteristic of the south-eastern margin of the Neotethys, but some are also closely related to forms occurring in Kachchh, a rift basin situated at the western margin of the Indian Craton.

Zusammenfassung

In der vorliegenden Arbeit werden sechs Muscheltaxa aus der Ferruginous Oolite Formation (unteres Bathonium bis unteres Callovium) und 24 Taxa aus der Spiti Shale Formation (Callovium bis unterste Kreide) im Gebiet von Spiti und Zanskar im indischen Himalaya beschrieben und abgebildet. Die Spiti Shale Formation enthält eine niedrig-diverse Muschelfauna, die nur in wenigen Lagen, vor allem im lower member der Formation auftritt. Die Muscheln sind bis auf wenige Ausnahmen schlecht erhalten. Frühere Bestimmungen der Muschelfauna werden revidiert wo immer möglich. Mehrere Taxa, die in Sedimenten des mittleren bis tieferen Schelf vorkommen, sind für den Südostrand der Neotethys charakteristisch. Andere sind eng verwandt aber nicht identisch mit Formen, die im Riftbecken von Kachchh am Westrand des indischen Kratons auftreten.

Keywords

Bivalvia, offshore shelf, Spiti Shale, taxonomy, Tethys Himalayas

Introduction

The Spiti Shale Formation of the Tethys Himalaya is a package of black shales with minor sandstone intercalations, which extends from northern Pakistan, via northern India and Nepal to southern Tibet (Fig. 1a). The rocks represent mainly outer shelf to upper slope deposits of the southern margin of the Neotethys. Macroinvertebrate assemblages are dominated by ammonites and belemnites that commonly occur in claystone concretions. Benthic macroinvertebrates (bivalves, gastropods, brachiopods) are restricted to a few widely spaced layers, while large parts of the formation do not contain any macrobenthos. In the Spiti area, the formation is dominated by dark-grey to black and often shaly argillaceous silt to silty clay with minor sandstone intercalatations. The Callovian to lowermost Cretaceous Spiti Shale Formation is underlain by the Ferruginous Oolite Formation, a unit of variable lithology (sandstones, shelly limestones, Fe-ooid bearing limestones). It contains a much richer benthic macrofauna, which is, however, usually difficult to extract from the well-cemented rocks. Here we describe bivalves, mainly from the Spiti Shale Formation, collected during two field trips to the area (2016, 2018). Although first documentations of bivalves from these Jurassic rocks reach back to the early nineteenth century (Herbert 1831; Everest 1833), they received further attention only in the mid-sixties of that century when Blanford (1864), Salter and Blanford (1865), and Stoliczka (1866) described a number of bivalve species. Holdhaus (1913) provided the first comprehensive treatment of the bivalve fauna, recording altogether 39 taxa. Since then only one further study dealt with this fossil group (Kanjilal and Pathak 1998). The latter authors recorded ten previously described taxa and updated their taxonomy. The purpose of the present study is to revise the bivalve fauna as a prerequisite for a palaeoecological study (Fürsich et al. 2021) aiming to document the benthic fauna inhabiting the mid to outer shelf regions of the southern Neotethys. Moreover, the present study permits the comparison of the poorly known deep shelf benthic bivalve fauna with the shallow shelf Jurassic fauna of the Kachchh Basin at the western margin of the Indian Craton and thus between the benthic fauna of shallow and deep shelf environments, the latter very poorly known.

Material and localities

The Spiti area, situated in northern Himachal Pradesh, contains extensive outcrops of the Jurassic sedimentary succession on top of the eastern shoulder of the Spiti Valley (Fig. 1b). Due to the gentle morphology, fresh outcrops are, however, rare being usually restricted to road cuts or cliffs of small streams. Most bivalve fossils come from the lower member of the Spiti Shale Formation, where they weather out from the soft shales or occur in thin shell beds. Very few specimens have been collected from the Ferruginous Oolite Formation. The co-ordinates of the localities from which bivalves have been collected are given in Table 1.

In the Middle member, bivalves are very scarce and usually found in mudrock concretions where they commonly form small clusters. In the Upper member, bivalves locally form loosely packed concentrations, in which the fossils are poorly preserved. Apart from some large and comparatively thick-shelled bivalves such as *Pruvostiella*, bivalves are well preserved only in concretions where they occur as composite moulds. Shells occurring in unconsolidated sediment are usually strongly crushed and fragmented by compaction and tectonic stress, which in some cases renders their identification difficult.

In contrast, the Spiti Shale Formation of the Zanskar Valley in northwestern Ladakh is almost barren of benthic fossils and only few bivalve specimens could be collected from the underlying Ferruginous Oolite Formation near the village of Zangla.

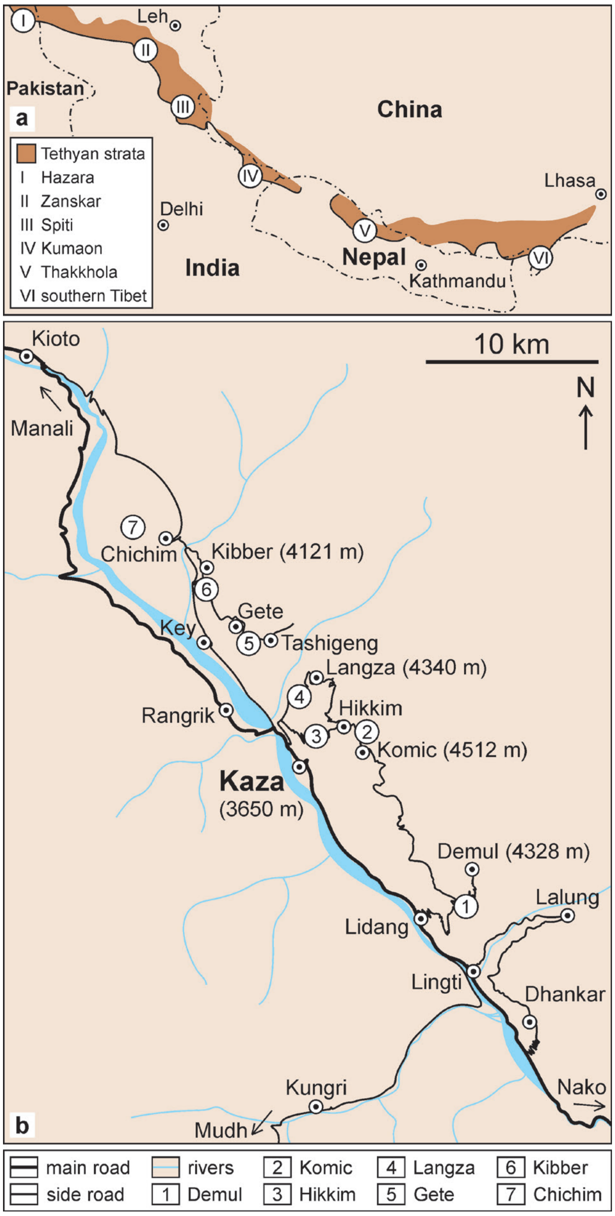


Figure 1. Outcrop belt of Tethyan strata in the Himalayas (a) and map of localities in the Spiti area that have been investigated (b).

Altogether more than 240 specimens have been collected from the localities shown in Figure 1b (see also Table 1). After washing them, they have been mechanically prepared where necessary. Before photography, the specimens have been coated with magnesium oxide. The material has been deposited in the collections of the Bayerische Staatssammlung für Paläontologie und Geologie in Munich (prefix: SNSB-BSPG 2020 XCIX).

Stratigraphy

The first stratigraphic subdivision of the Jurassic strata of the Indian Himalayas was published by Stoliczka (1866), who distinguished Lower and Upper Tagling Limestone (according to him Lower Jurassic), Clayey Slates, Spiti Shales (according to him Middle Jurassic), and Gieumal Sandstone (Upper Jurassic). Diener (1895: 583), based on

Table 1. Localities and their co-ordinates in the Spiti area and the Zanskar Valley, from which bivalves have been collected.

Locality	Co-ordinates	Stratigraphy
Chichim	32°20'40.6"N, 77°57'59"E	lower member
Chichim	32°20'40.6"N, 77°58'04"E	Ferruginous Oolite Formation
Langza A	32°16'16"N, 78°04'12"E	lower member
Langza B	32°16'08"N, 78°04'31"E	lower member
Langza C	32°16'03"N, 78°04'43"E	lower member
Langza D	32°16'04"N, 78°04'35"E	Ferruginous Oolite Formation
Kaza – Hikkim Road	32°14'34.6"N, 78°05'07.6"E	lower member
Kaza –Hikkim Road	32°14'19.6"N, 78°04'43.6"E	base of lower member
road close to pass to Demul	32°09'02"N, 78°10'29"E	upper member
roadside close to Komic	32°14'16"N, 78°06'21"E	middle member
Demul road	32°09'07"N, 78°10'19"E	upper member
Kibber	32°19'28"N, 78°00'26"E	lower member
close to pass to Tashigeng	32°17'44"N, 78°02'05"E	lower member
near Zangla (Zanskar Valley)	33°41'09.9"N, 76°58'17"E	Ferruginous Oolite Formation

Griesbach (1891), subdivided the Spiti Shales in Belemnites gerardi Beds, Chidamu Beds, and Lochambel Beds. The intensively folded and faulted succession made it virtually impossible to measure a single continuous section, which nearly a hundred years later led to disputes of the correct lithostratigraphic composition of the Spiti Shale Formation. Thus, Krishna (1983) distinguished only a lower and an upper member, whereas Pathak (1993) and Pandey et al. (2013) recognised three informal members named the lower, middle, and upper member, respectively (Text-fig. 2), a view followed here. Due to the lack of a continuous section, these members and their boundaries are, at present, very poorly defined. The lower member is characterized by argillaceous silt and silty clay containing common belemnites and bivalves, the latter occasionally concentrated in shell beds. At the base, the bivalve *Bositra* is abundant, followed by a low-diversity fauna dominated by *Palaeonucula*, *Pruvostiella*, and *Indogrammatodon*. In the middle member silt- and sandstones and some glauconitic shales with phosphorite nodules locally occur and the predominant lithology, silty clay/argillaceous silt, contains abundant mudrock concretions arranged in layers. Fossils are occasional ammonites and rare bivalves (*Retroceramus*, *Australobuchia*). The upper member is characterized by monotonous, unfossiliferous black shales, shales with mudrock concretions, ammonites and belemnites, and some loosely packed bivalve concentrations composed of *Australobuchia*, *Retroceramus*, and *Malayomaorica*. At the top, the succession coarsens into siltstones and fine- to coarse-grained sandstones. The contact to the overlying Lower Cretaceous sandstone-dominated Giumal Formation is gradual. The thickness of the Spiti Shale Formation is difficult to establish, but judging from the sections measured, which correspond only to segments of the complete succession, the formation is at least 110 m thick (Fürsich et al. 2021).

Lithostratigraphy		Metres	Age
Giumal Formation		~400	Albian –Berriasian
Spiti Shale Fm	upper member (Lochambel Beds)	<300	?Berriasian –Early Tithonian
	middle member (Chidamu Beds)		Early Tithonian –Kimmeridgian
	lower member (B. gerardi Beds)		Late Oxfordian –Middle Callovian
Ferruginous Oolite Fm		0-20	Early Callovian –Early Bathonian
Tagling & Para Fm		~600	?Middle Jurassic –Late Triassic

Figure 2. Jurassic stratigraphy of the Spiti area (modified from Alberti et al. 2021).

Based on ammonites, the Spiti Shale Formation in the Spiti area has been thought to range from the Oxfordian to the top of the Tithonian (e.g., Pathak 1993; Pandey et al. 2013), but according to Cariou et al. (1996) the age of the lower member is Callovian–Oxfordian. A more detailed discussion of the existing stratigraphic problems is found in Fürsich et al. (2021).

Taxonomy

We follow the classification scheme of Bouchet et al. (2010) and Carter et al. (2011). Size measurements were taken with a Vernier caliper. Length was abbreviated L, height H, right valve RV, and left valve LV. The synonymy lists contain, apart from the original combination, for the most part only occurrences documented from the Ethiopian faunal province and from other areas of the Himalayas.

Class Bivalvia Linnaeus, 1758
Subclass Protobranchia Pelseneer, 1889
Order Nuculida Dall, 1889
Family Nuculidae J. Gray, 1824

Genus *Palaeonucula* Quenstedt, 1930

Type species. *Nucula hammeri* Defrance, 1825.

Palaeonucula cuneiformis (J. de C. Sowerby, 1840)

Plate 1, figs 1–2

1831 *Modiola* – Herbert: 272, pl. 17, fig. 5.
1833 *Modiola* – Everest: 114: pl. 2, fig. 28a–c.
*1840 *Nucula*? *cuneiformis* – J. de C. Sowerby: pl. 22, fig. 4 and explanation.
1864 *Nucula cuneiformis*, Sowerby – Blanford: 135.
1908 *Nucula cuneiformis*, J. de C. Sowerby – Newton and Crick: 7, pl. 1, figs 5–7.
1913 *Nucula spitiensis* sp. nov. – Holdhaus: 428, pl. 95, figs 11–13.
1913 *Nucula hyomorpha* sp. nov. – Holdhaus: 430, pl. 95, figs 14–17.

1929 *Nucula cuneiformis* Newton – Weir: 5, pl. 4, figs 2–4.
?1930 *Nucula cuneiformis* Newton – Basse: 108. pl. 5, fig. 5.
?1939 *Nucula cuneiformis* Sow. – Stefanini: 219, pl. 24, fig. 3.
1940 *Nucula* (*Palaeonucula*) *cuneiformis* J. de C. Sowerby – Cox: 13, pl. 1, figs 5–10.
1940 *Nucula* (*Palaeonucula*) *kaoraensis* sp. nov. – Cox: 15, pl. 1, figs 11–14.
1956 *Nucula* (*Palaeonucula*) *kaoraensis* Cox – Agrawal: 51, pl. 7, fig. 3a.
1959 *Nucula cuneiformis* Sowerby – Jaboli: 46, pl. 6, fig. 3.
1980 *Palaeonucula kaoraensis* Cox – Kanjilal: 335, pl. 1, figs 8–10.
1980 *Palaeonucula cuneiformis* (J. de C. Sowerby) – Kanjilal: 334, pl. 1, figs 4–7.
1995 *Palaeonucula cuneiformis* (J. de C. Sowerby 1840) – Jaitly et al.: 155, pl. 1, figs 9–11, 13–17, text-figs 6–9 (pars). [non pl. 1, figs 8, 12, pl. 2, figs 1–2]
1998 *Palaeonucula cuneiformis* (J. de C. Sowerby 1840) – Kanjilal and Pathak: 30, pl. 1, fig. 1.

Material. Nine articulated specimens and two left valves from the lower member at Langza (SNSB-BSPG 2020 XCIX 26), 30 articulated specimens, one right and two left valves from the lower member along the Kaza – Hikkim road (SNSB-BSPG 2020 XCIX 27), four articulated specimens from the lower member at Langza (road side exposure) (SNSB-BSPG 2020 XCIX 28), four articulated specimens from the lower member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 29), three articulated specimens and one right valve from the lower member near Kibber (SNSB-BSPG 2020 XCIX 30), two articulated specimens from the Ferruginous Oolite Formation near Chichim (SNSB-BSPG 2020 XCIX 31), and three articulated specimens and one right and three left valves from the lower member at Langza locality 3 (SNSB-BSPG 2020 XCIX 32). The shells, several of which are fragmented, invariably suffered compactional and tectonic distortion.

Description. Shell relatively large for genus (H: ~26 mm, L: 32.2 mm), thick-shelled, elongated-oval, strongly inequilateral, moderately inflated. Umbo broad, well-developed, terminal to subterminal, close to posterior end, opisthogyrate. Anterior end narrow to well-rounded, posterior end straight to slightly curved forming a blunt angle with the ventral margin, which describes a wide asymmetric curve with the ventral-most point of shell well anterior of mid-line. Anterodorsal margin straight, sloping; posterodorsal margin short, almost straight to slightly curved, passing gradually into posterior margin. Broad rounded ridge running from the umbo to the anterodorsal end, separating flank from flat, narrow anterodorsal part of shell. Lunule shallow, narrow, lanceolate. Second, equally rounded umbonal ridge running to the posteroventral corner of shell. Area heart-shaped slightly concave in articulated specimens. Surface of shell smooth except for growth lines, which vary in strength. Hinge poorly preserved, with characteristic taxodont teeth.

Remarks. As nearly all specimens are crushed to some extent, the original outline and inflation only rarely can be observed. Everest (1833), Blanford (1864), and Stoliczka (1866) regarded the common nuculid in the lower member of the Spiti Shale Formation as the species figured by J. de C. Sowerby (1840) as *Nucula*? *cuneiformis*, a highly variable species occurring from the Bathonian to the Kimmeridgian in the Kachchh Basin. Subsequent workers, however, followed a much narrower species concept and regarded the forms from the Spiti Shale Formation as different species. Holdhaus (1913) placed the bivalves in two new species, *Nucula spitiensis* and *N. hyomorpha*. He realised that the specimens were generally distorted, but argued that *N. hyomorpha* was always dorso-ventrally compressed, whereas *N. spitiensis* was laterally compressed. In this way, he clearly related the diagnostic features of the two species to their preservational state. According to Holdhaus (1913), the two species also differ in the shape of their anterodorsal shell portion, which is, however, influenced by the compaction styles. In the case of laterally flattened shells, this part usually cannot be observed. In fact, the style of distortion depends on the final burial position of the shells; they either became dorso-ventrally shortened when buried in growth position, or laterally flattened when post-humously they were reoriented by burrowers or excavated by currents, post-mortem. All intermediate preservational stages occur. In the former case, the inflation was artificially increased and in the latter case the length-height ration was decreased. All intermediate preservational stages occur. Cox (1940) regarded *N. spitiensis* and *N. hyomorpha* as synonyms and as a "linear descendent of *P. cuneiformis*. He followed a narrow species concept recognising two further similar species, *P. kaoraensis* and *P. blanfordi* in the Kachchh Basin, which were regarded junior synonyms of *P. cuneiformis* by Pandey and Agrawal (1984) and Jaitly et al. (1995).

The species is widespread in the Ethiopian faunal province, occurring from Madagascar to the Arabian Peninsula and from the Kachchh Basin to Rajasthan and the Himalayan shelf of the Indian Craton.

Palaeonucula stoliczkai Cox, 1940

Plate 1, fig. 3a, b

*1940 *Nucula* (*Palaeonucula*) *stoliczkai* sp. nov. – Cox: 20, pl. 1, figs 21–23.
1956 *Nucula* (*Palaeonucula*) *stoliczkai* Cox – Agrawal: 52, pl. 7, fig. 3b.
1980 *Palaeonucula stoliczkai* Cox – Kanjilal: 339, pl. 1, figs 13–14.
1995 *Palaeonucula stoliczkai* Cox 1940 – Jaitly et al.: 158, pl. 2, figs 7–8.

Material. One flattened articulated specimen from the Ferruginous Oolite Member at Langza (SNSB-BSPG 2020 XCIX 34).

Description and remarks. The laterally strongly compressed specimen (H: 8.6 mm, L: 11.9 mm) is rounded trigonal in outline and longer than high. The ventral margin is strongly convex, the anterior margin obliquely truncated, forming a blunt angle with the ventral margin and a very obtuse angle with the faintly convex anterodorsal margin. The posterior margin is narrowly rounded. The umbo is prominent. The rounded anterior umbonal ridge extends to the anteroventral margin. Due to the compressed nature of the shell, features such as lunule could not be observed. The surface of the shell is covered with fine commarginal growth lines. Internal features not seen.

Although the hinge could not be observed, the specimen can be safely placed in *P. stoliczkai* as it closely resembles Cox' species in outline.

Subclass Autobranchia Grobben, 1894
Order Arcida Gray, 1854
Family Cucullaeidae Stewart, 1930

Genus *Megacucullaea* Rennie, 1936

Type species. *Cucullaea kraussii* Tate, 1867.

Megacucullaea cf. *kraussii* (Tate, 1867)

Plate 1, fig. 4a, b

cf. 1850 *Cucullaea cancellata* – Krauss: 452, pl. 48, fig. 2a, b (non Phillips, 1829)

*cf. 1867 *Cucullaea kraussii* – Tate: 161.

cf. 1882 *Cucullaea Kraussi* Tate – Holub and Neumayr: 375, pl. 2, fig. 2a–c.

cf. 1940 *Cucullaea* (*Megacucullaea*) *kraussii* Tate – Cox: 57, pl. 4, figs 3–4.

cf. 1998 *Megacucullaea kraussi* (Tate, 1867) – Kanjilal and Pathak: 34, pl. 1, fig. 6.

Material. A single poorly preserved articulated internal mould with remains of shell from the lower member of the Spiti Shale Formation (Oxfordian) near Chichim (SNSB-BSPG 2020 XCIX 1).

Description. Specimen large, longer than high (L ~79 mm, H ~60 mm, I ~70), thick-shelled, strongly inflated. Maximum inflation at around one-third of shell height from umbo. Ventral margin faintly arched, anterior margin convex, forming an angle of ~90° with hinge margin. Posterior margin straight, oblique, posteroventral corner rounded. Umbones only partly preserved, prominent, straight, incurved, situated anterior of mid-line of shell. Posterodorsal carina distinct but rounded, posterodorsal area flat to slightly convex. Cardinal area large, largest width anterior of umbo, slightly concave. Ornamentation poorly preserved; there are at least four widely spaced, strong, rounded radial ribs with concave interstices. Hinge line straight, dentition and other internal features not seen.

Remarks. The two valves are sligthly laterally sheared. Moreover, the specimen may be somewhat compressed dorso-ventrally. In this case, the inflation would be lower and the height greater than decribed above, and the point of maximum inflation would also be slightly off. The umbones are only partly preserved.

The various Jurassic species of *Megacucullaea*, i.e. *M. eminens* Cox (1940, p. 59, pl. 4, figs 5–7), *M. kraussii* (Tate 1867, p. 161), and "*M.* sp. nov. aff. *C.* (*M.*) *eminens* Cox" of Agrawal (1956 p. 14, pl. 1, fig. 1) differ in outline and the number of radial ribs (*M. kraussii*: 6–8; M. eminens: 16–19; Agrawal's specimen: approximately 10). The present specimen is closest to *M. kraussii*, having a similar number of ribs, whereas in the other two species the number of ribs is distinctly higher. Due to the poor preservation of the specimen, a detailed comparison with *M. kraussii* is not possible. The material of Cox (1940, p. 57, pl. 4, figs 3–4) exhibits eight radial ribs, of which three are only faintly developed on one out of two specimens. Interestingly, *M. eminens* and *M. kraussii* co-occur in Upper Tithonian rocks of the Kachchh Basin. *M. eminens* Cox (1940, p. 59, pl. 4, figs 5–7) is shorter, carries about 16 radial ribs differing in strength (weak close to the umbonal carina and strong on the remainder of the shell), and the area posterior of the umbonal ridge is distinctly concave. "*Cucullaea Kraussi* Tate" of Barrabé (1929, p. 147, pl. 8, fig. 13) has more radial ribs and resembles *M. eminens*. The early Tithonian specimen figured as *Megacucullaea kraussii* by Kanjilal and Pathak (1998) has seven ribs.

Family Parallelodontidae Dall, 1898
Genus *Grammatodon* Meek & Hayden, 1861

Subgenus *Indogrammatodon* Cox, 1937

Type species. *Cucullaea virgata* J. de C. Sowerby, 1840.

Grammatodon (*Indogrammatodon*) *egertonianus* (Stoliczka, 1866)

Plate 1, figs 5–7; Fig. 3

1831 *Arca* sp. – Herbert: 272, pl. 17, fig. 6.

1833 *Arca* sp. – Everest: 114, pl. 2, fig. 27.

1864 *Cucullaea virgata* – Blanford: 136 (*non* J. de C. Sowerby, 1840).

*1866 *Macrodon Egertonianum* Stol. – Stoliczka: 89, pl. 8, fig. 7.

non 1908 *Parallelodon egertonianus*, Stoliczka – Newton and Crick: 5, pl. 1, figs 1–4.

1913 *Arca* (*Cucullaea*) *egertoniana*, Stoliczka – Holdhaus: 434, pl. 95, figs 1–10.

non 1935 *Parallelodon egertonianus* (Stoliczka) – Cox: 160.

non 1937 *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka) – Cox: 196, pl. 15, figs 10–11. (= *G.* (*I.*) *virgatus* J. de C. Sowerby, 1840)

non 1939 *Grammatodon egertonianus* (Stol.) – Stefanini: 222, pl. 24, figs 7–10. (= *G.* (*I.*) *virgatus* J. de C. Sowerby, 1840)

non 1959 *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka) – Jaboli: 48, pl. 5, fig. 12.

non 1976 *Cucullaea egertoniana* (Stoliczka) – Gu et al.:125, pl. 45, figs 1–6.

non 1983 *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka) – Gou and Li: pl. 2, fig. 6.

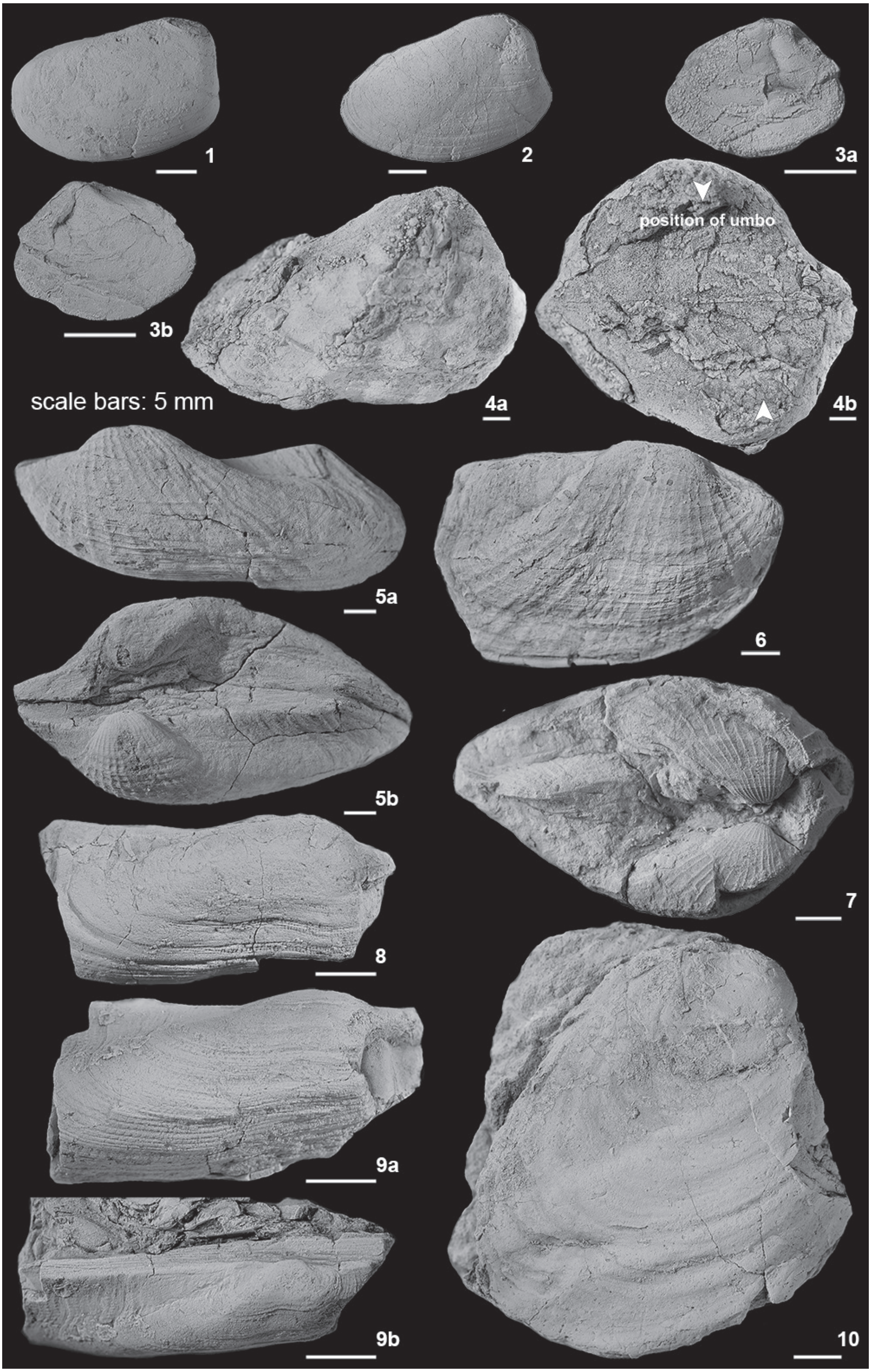

1
2
3a
3b
position of umbo
scale bars: 5 mm
4a
4b
5a
6
5b
7
8
9a
9b
10

Plate 1. (1, 2) *Palaeonucula cuneiformis* (J. de C. Sowerby, 1840). **1.** Left valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 26a). **2.** Left valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 26b). **(3)** *Palaeonucula stoliczkai* Cox, 1940. Laterally crushed articulated specimen, lower member at Langza (SNSB-BSPG 2020 XCIX 34); a, left valve view; b, right valve view. **(4)** *Megacucullaea* cf. *kraussii* (Tate, 1867). Internal mould of articulated specimen with remains of shell from the lower member near Chichim (SNSB-BSPG 2020 XCIX 1); a, right valve view; b, dorsal view. **(5–7)** *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka, 1866). **5.** Articulated specimen from the lower member near the pass to Tashigeng (SNSB-BSPG 2020 XCIX 4). a, left valve view; b, dorsal view. **6.** Laterally crushed articulated specimen from the lower member along the Kaza–Hikkim road (SNSB-BSPG 2020 XCIX 3b); right valve view. **7.** Dorso-ventrally compacted articulated specimen from the lower member at Langza (SNSB-BSPG 2020 XCIX 6); right valve view. **(8, 9)** *Grammatodon* (*Cosmetodon*) sp. from the lower member along the Kaza–Hikkim road. **8.** Right valve (SNSB-BSPG 2020 XCIX 2a). **9.** Right valve (SNSB-BSPG 2020 XCIX 2b). a, lateral view; b, dorsal view. **(10)** *Anopaea*? Fragmented right valve from the upper? member at Langza (SNSB-BSPG 2020 XCIX 67).

non 1997 *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka) – Gardner and Campbell: 495, fig. 5I.

1998 *Indogrammatodon egertonianus* (Stoliczka, 1865) – Kanjilal and Pathak: 34, pl. 1, fig. 3.

Material. Six right and four left valves and 18 articulated specimens in shell preservation from the lower member of the Spiti Shale Formation at Langza (SNSB-BSPG 2020 XCIX 5, 6, 8, 9), Kazam-Hikkim road (SNSB-BSPG 2020 XCIX 3), Kibber (SNSB-BSPG 2020 XCIX 7), and near the pass to Tashigeng (SNSB-BSPG 2020 XCIX 4). The specimens are invariably distorted due to compaction and partly incomplete.

Dimension. See Table 2.

Description. Shell rhomboidal to trapezoidal in outline, much longer than high (Fig. 3). Ventral margin straight to slightly sinuous, grading smoothly into curved anterior margin, which forms an angle of 80–90° with the hinge line. Posterior margin convex ventrally and straight, oblique dorsally, forming an angle of ~130° with hinge line. Hinge line straight. Posterodorsal carina pronounced near umbo, becoming rounded and indistinct towards posteroventral margin. Area posterior of umbonal ridge concave. Umbo situated one-third to two-fifths of hinge length from anterior end, forward directed and incurved. Ornamentation of right valve slightly differing from that of left valve. Number of radial ribs of right valve (16–19) larger than that of left valves (12–17). Radial ribs present only on flank and not posterior of the umbonal ridge, equally spaced except for the anteriormost part of shell where their distance is much wider. Rib density greatest at middle of flank. Ribs of left valve of equal strength, slightly stronger than those of right valve. No intercalatory ribs present. Ribs of right valve widely spaced, with intercalations of 1–2 weak secondaries towards posterior. Both valves with distinct commarginal growth rugae; at intersections of growth rugae and radial ribs small nodes are developed.

Ligament area long, relatively narrow, with numerous chevron-shaped grooves. Except for fragments of hinge no internal features seen. Hinge with 3–4 moderately long anterior teeth, arranged parallel to hinge margin anteriorly, converging towards ventral margin of hinge plate posteriorly. Posterior teeth longer, subparallel to dorsal margin of hinge. All teeth serrated. short central teeth not seen.

Table 2. Dimensions (in mm) and number of ribs of *Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka, 1866).

specimen	Length	Height	N ribs (RV)	N ribs (LV)
SNSB-BSPG 2020 XCIX 5a	84.8	-	-	-
SNSB-BSPG 2020 XCIX 5b	62.8	-	-	-
SNSB-BSPG 2020 XCIX 5c	63.2	>25.5	-	-
SNSB-BSPG 2020 XCIX 4	74.5	>30.6	18	14
SNSB-BSPG 2020 XCIX 3	54.8	-	19	14
SNSB-BSPG 2020 XCIX 6a	42.7	-	16	-
SNSB-BSPG 2020 XCIX 6b	35.6	-	15	-

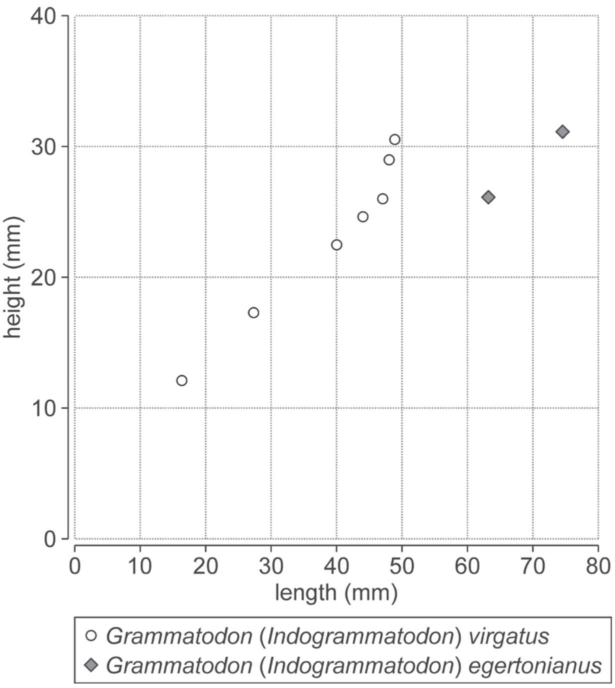


Figure 3. Length plotted against height of *Grammatodon* (*Indogrammatodon*) *virgatus* (J. de C. Sowerby, 1840) from the Callovian of Kachchh and *G.* (*I.*) *egertonianus* (Stoliczka, 1866) from the Spiti Shale Formation. Due to the distorted nature of nearly all specimens from the Spiti area, only two specimens yielded reasonable values.

Remarks. Nearly all specimens are distorted by compaction. Commonly, the dorso-ventral axis has been shortened suggesting that the individuals are preserved in growth position. Due to this distortion, the length-height ratio could not be calculated and the inflation could not be measured. *G.* (*I.*) *egertonianus* is closely related to *G.* (*I.*) *virgatus* (J. de C. Sowerby, 1840), which is widespread within the Ethiopian faunal province. It differs from the present species by being less elongated, having far more radial ribs on both valves, and the difference in ribbing between right and left valve is much more pronounced (see, for example, the specimens figured by Cox 1940, pl. 2, figs 22–30 from the Jurassic of Kachchh). These differences have already been noted by Stoliczka (1865). The specimens recorded as

Parallelodon egertonianus Stol. by Basse (1930, p. 109, fig. 3a, b) from Ethiopia, Newton and Crick (1908, p. 5, pl. 1, figs 1–4) from the Arabian Peninsula, Stefanini (1925, p. 171, pl. 31, figs 6–7) from Somalia, and Weir (1930, p. 81, pl. 9, figs 12, 12a) from Kenya are generally much shorter and more densely ribbed and belong to *G.* (*I.*) *virgatus* or related forms. This is probably also true of the material listed by Cox (1935) from the Kimmeridgian–Tithonian of Somalia The specimen of *P. egertonianus* Stoliczka figured by Trechmann (1923, p. 263, pl. 14, fig. 8) from the Jurassic of New Zealand is too poorly preserved to warrant a precise identification.

Subgenus *Cosmetodon* Branson, 1942

Type species. *Arca keyserlingii* d'Orbigny, 1850.

Grammatodon **(*Cosmetodon*) sp.**

Plate 1, figs 8, 9

?1998 ?*Parallelodon* sp. indet. – Kanjilal and Pathak: 33, pl. 1, fig. 2.

Material. Two right valves from the lower member at the Kaza–Hikkim road (SNSB-BSPG 2020 XCIX 2).

Description. Shell strongly elongated, hinge line long, straight, position of umbo distinctly anterior of mid-line of the shell. Shallow umbonal sulcus widening ventrally and resulting in slight indentation of ventral margin. Umbonal ridge broadly rounded, area posterior of umbonal ridge concave. Surface covered with numerous delicate radial riblets and fine commarginal growth lines and, towards ventral margin, with several commarginal grooves corresponding to growth halts. Cardinal area narrow, attaining its greatest width below umbo. Posterior teeth long, extending parallel to dorsal margin of hinge plate, anterior teeth shorter, oblique, and directed posteriorly towards point below the hinge line.

Remarks. The specimens, in which the anterior and posterior ends are missing, has been dorso-ventrally compacted. As a result, the two valves have become separated and slightly distorted so that the inflation has been artificially increased. Due to its poor preservation, an identification at the species level is not possible. However, the specimen exhibits the characteristic features of the subgenus *Cosmetodon*, such as a strongly elongated shell, long, straight hinge line, a position of the umbo distinctly anterior of the mid-line of shell, and a shallow umbonal sulcus that widens ventrally and is responsible for a slightly indented ventral margin.

Order Myalinida Paul, 1939
Family Inoceramidae Giebel, 1852

Genus *Anopaea* Eichwald, 1861

Type species. *Inoceramus lobatus* Auerbach & Frears, 1846.

***Anopaea*? sp.**

Plate 1, fig. 10

Material. Fragmented right valve from the upper? member at Langza (SNSB-BSPG 2020 XCIX 67).

Description and remarks. The specimen represents a poorly preserved, nearly flat posterior fragment of a right valve. It is ornamented with broad, irregular growth folds and superimposed fine commarginal growth lines. Two oblique shallow grooves extend for some distance towards the ventral margin.

As the outline of the specimen is not clear, its identification is questionable. *Inoceramus stoliczkai* Holdhaus (1913, p. 418, pl. 98, figs 10–11) from the Niti Pass, according to Crame (1981) and Zell et al. (2015) an *Anopaea*, differs in outline and in having well-spaced, far more acute commarginal folds.

Family Retroceramidae Koschelkina, 1980
Genus *Retroceramus* Koschelkina, 1959

Subgenus *Retroceramus* Koschelkina, 1959

Type species. *Inoceramus retrorsus* Keyserling, 1848.

Retroceramus **(*Retroceramus*) *haasti*** **(Hochstetter, 1863)**

Plate 2, figs 1, 2

1863 *Inoceramus haasti* sp. nov. – Hochstetter: 473, pl. 20, figs 1–2.

1982 *Retroceramus* (*Retroceramus*) *haasti* (Hochstetter, 1863) – Crame: 569, pl. 57, figs 1–4.

Material. Numerous fragments of internal moulds of single valves with remains of shell from the upper member, road cut close to Demul Pass (SNSB-BSPG 2020 XCIX 60–63).

Description and remarks. The specimens occur in loosely packed matrix-supported shell concentrations. The umbonal areas are not preserved, but the specimens are apparently quite large, the largest fragment measuring 135 mm in height. Preserved parts of moulds are more or less flat, with spaced commarginal folds, the distance between folds increasing ventrally. The folds are slightly asymmetric in cross-section, the ventral flank being steeper. Areas with preserved shell material show that the shells were very thin.

Despite the fragmentary nature of the material, the specimens can be safely referred to *Retroceramus* (*R.*) *haasti*, originally described by Hochstetter (1863) from Kimmeridgian strata of New Zealand, based on their large size, nearly flat shells, broad ventral area, and characteristic ornamentation. The species has been recorded in the past from the Kimmeridgian of New Zealand and Antarctica (Hochstetter 1863; Crame 1982; Crampton 1988).

Inoceramus hookeri of Salter (1865: 95, pl. 23, fig. 1 only) exhibits a similar ornamentation but differs in

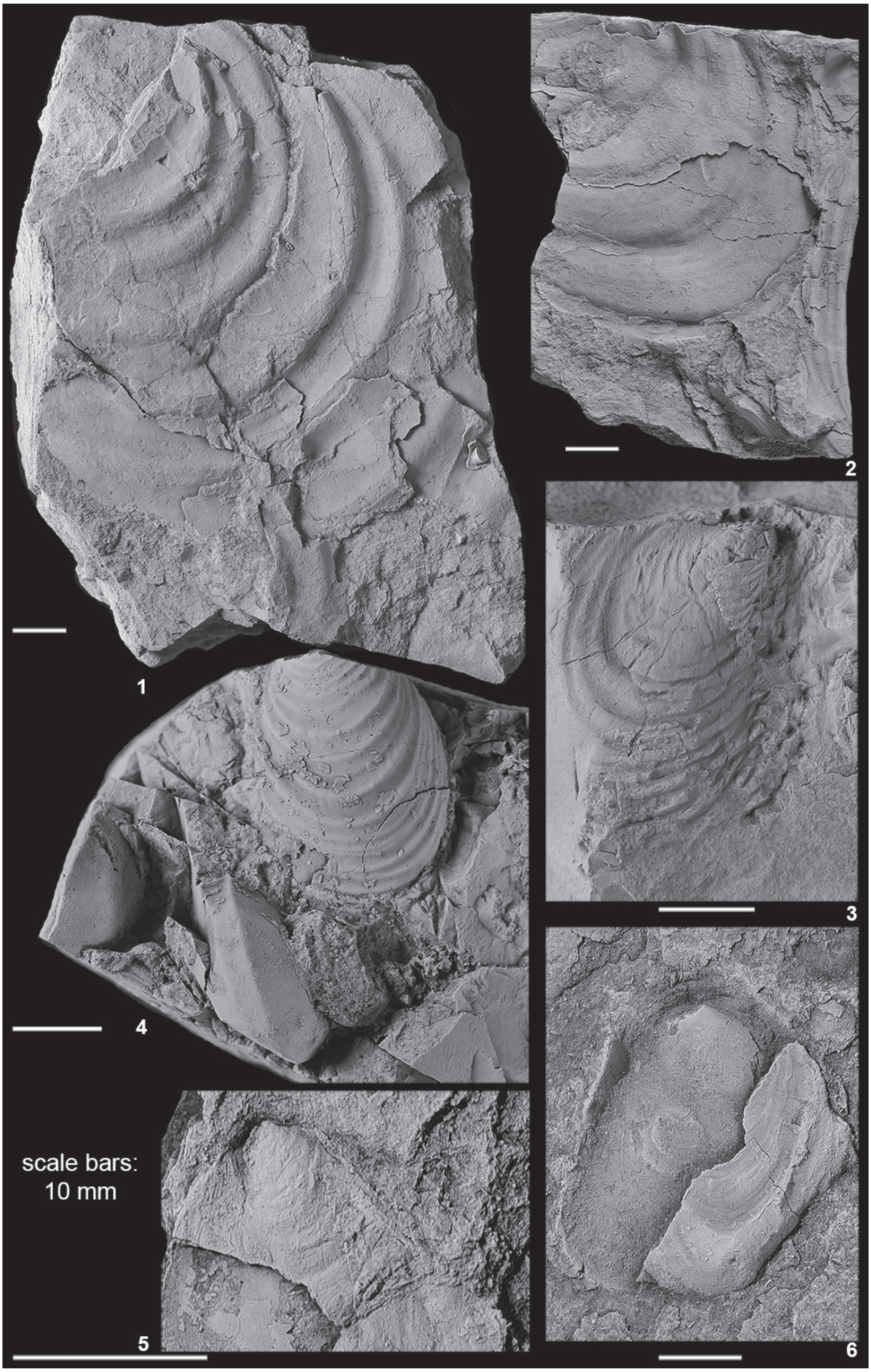


Plate 2. (1, 2) *Retroceramus* (*Retroceramus*) *haasti* (Hochstetter, 1863). **1.** Fragment of internal mould of single valve with remains of shell from the upper member, road cut close to Demul Pass (SNSB-BSPG 2020 XCIX 62a). **2.** Fragment of external mould of single valve with remains of shell from the upper member, road cut close to Demul Pass (SNSB-BSPG2020 XCIX 62b). **(3, 4)** *Retroceramus* (*Retroceramus*) *everesti* (Oppel, 1863). Fragmented internal moulds from the upper member near Demul. **3.** Right valve (SNSB-BSPG 2020 XCIX 65). **4.** Right valve (SNSB-BSPG 2020 XCIX 64). **(5, 6)** Gryphaeidae indet. from the upper member close to the Demul Pass **5.** Right valve (SNSB-BSPG 2020 XCIX 37). **6.** Right valve (SNSB-BSPG 2020 XCIX 38).

outline being rounded-rectangular. *Inoceramus haasti*, Hochstetter, 1863 has been transferred to *Retroceramus* (*Retroceramus*) by Crame (1982). The latter author regarded the species as characteristic of the Kimmeridgian – Early Tithonian.

***Retroceramus* (*Retroceramus*) *everesti* (Oppel, 1863)**

Plate 2, figs 3, 4

1831 *Ostrea*?, *Inoceramus*? – Herbert: 272, pl. 17, fig. 7.
?1833 *Inoceramus*(?) – Everest: 114, pl. 2, fig. 29.
*1863 *Inoceramus Everesti* Opp. – Oppel: 298.
?1865 *Inoceramus Hookeri*-N.Sp. var. *crenatulinus* – Salter: 95, pl. 23, fig. 2.
1913 *Inoceramus Everesti*, Oppel – Holdhaus: 415, pl. 98, figs 12–14.
1913 *Inoceramus gracilis* sp. nov. – Holdhaus: 417, pl. 98, fig. 15.
1982 *Retroceramus* (*Retroceramus*) *everesti* (Oppel, 1865) – Crame: 576: pl. 58, figs 5–11, pl. 59, figs 1–11.

Material. Internal mould of a left valve, locality and horizon unknown (SNSB-BSPG 2020 XCIX 66), and two internal moulds of right valves from the upper member near Demul (SNSB-BSPG 2020 XCIX 64–65). All specimens are fragmentary.

Description. Specimens small- to large-sized (H of largest specimen >70 mm), posteroventrally elongated but of variable obliquity, umbonal area well-inflated. Hinge line straight, moderately long; anterior margin weakly convex to straight, posterior margin gently curved, ventral margin well-rounded. Umbonal area narrowly rounded in cross-section, umbo small, prosogyrate. Posterodorsal area nearly flat; angle between dorsal and anterior margin approximately 90°. Valves ornamented with commarginal folds, asymmetric in cross-section with steeper dorsal flank. Folds regular to irregular, generally increasing in strength and distance towards ventral margin. Hinge features not seen.

Remarks. The species has been transferred to the genus and subgenus *Retroceramus* by Crame (1982). Crame (1982) regarded *Inoceramus hookeri* Salter, 1865 and *I. gracilis* Holdhaus, 1913 as junior synonyms, a view followed here. The species does not only occur on the northern shelf of the Indian craton but also in western Australia, New Zealand, Antarctica, and southern Chile (Crame 1982). According to Crame (1882), *R.* (*R.*) *everesti* has a stratigraphic range from the Upper Tithonian to Lower Berriasian. In the Spiti area, it occurs in the Upper Tithonian.

Holdhaus (1913) described four species of *Inoceramus*, of which only *R. everesti* (Oppel, 1863) and *R. haasti* ((Hochstetter, 1863) are recorded here. *I. gracilis* Holdhaus, 1913 is regarded synonymous with *R. everesti*, and *I. stoliczkai* Holdhaus and has been included in the genus *Anopaea* by Crame (1982). *Inoceramus* cf. *sularum* Boehm, 1907 of Holdhaus (1913: 420, fig. on p. 421) is too poorly preserved to be positively identified (see also Crame 1982).

Order Ostreida Férussac, 1822
Family Gryphaeidae Vyalov, 1936

Gryphaeidae indet.

Plate 2, figs 5, 6

Material. Four single valves, partly preserved as internal moulds, from the upper member close to the Demul Pass (SNSB-BSPG 2020 XCIX 37–38).

Description and remarks. The comparatively small (H: 11–19 mm), poorly preserved specimens are nearly flat and covered with irregular growth rugae. The available features preclude a precise identification. Possibly, they belong to the common Jurassic genus *Liostrea* Douvillé, 1904.

Family Aulacomyellidae Ichikawa, 1958

Genus *Bositra* De Gregorio, 1886

Type species. *Posidonia ornati* Quenstedt, 1851 (= *Posidonia Buchii* Roemer, 1836).

***Bositra buchii* (Roemer, 1836)**

Plate 3, figs 1, 2

*1836 *Posidonia Buchii* Nob. – Roemer: 81, pl. 4, fig. 8.
1930 *Posidonia ornati* Quenstedt – Weir: 83, pl. 10, figs 14–21.
?1935 *Posidonia somaliensis* sp. nov. – Cox: 166, pl. 15, figs 7–8.
1938 *Posidonia ornati* Quenstedt – Weir: 45, pl. 3, fig. 6.
1940 *Posidonia ornati* Quenstedt – Cox: 103, pl. 7, figs 10–11.
?1965 *Bositra somaliensis* (Cox) – Cox: 50, pl. 6, fig. 2.
1994 *Bositra buchii* – Oschmann: 424, fig. 9b–d.
1995 *Bositra buchii* – Oschmann: 33, fig. 10b–e.
1995 *Bositra buchi* (Roemer 1836) – Jaitly et al.: 175, pl. 8, figs 6–9.

Material. Numerous composite moulds from the basal silty black shales of the lower member at Langza (SNSB-BSPG 2020 XCIX 18–20).

Description. Small-sized, feebly inflated, generally longer than high, obliquely ovate but occasionally suborbicular composite moulds. Dorsal margin short, straight, remaining margins well-rounded. Umbo inconspicuous, not protruding beyond dorsal margin and situated slightly anterior of mid-line of shell. Surface covered with 16–18 broad, rounded commarginal ribs, separated by narrow interstices.

Remarks. *Bositra buchii* is a very widespread opportunistic byssate bivalve able to tolerate dysoxic conditions (Oschmann 1994). It occurs profusely in black silty shales at the base of the lower member at Langza, where it forms near-monospecific assemblages.

The species is morphologically quite variable in outline, as has been documented by Conti and Monari (1992). Whether the more orbicular *Bositra somaliensis* (Cox,

1935) from the Kimmeridgian of Somalia falls within the range of variation of *B. buchii* requires a study of the type material of that species.

Order Pectinida Gray, 1854
Family Buchiidae Cox, 1953

Genus *Australobuchia* Zakharov, 1981

Type species. *Aucella plicata* Zittel, 1864.

Remarks. The generic assignment of the two species described below is still under discussion. Most recent authors (e.g., Crame 1990; Hikuroa and Grant-Mackie 2008) follow Zakharov (1981), who regarded buchiids from high latitudes of the southern hemisphere as belonging to a different lineage than those from the northern hemisphere and therefore included them in his new genus *Australobuchia*. Other authors (e.g., Crame 1986, 1993) argue that more research is needed to understand the origin and evolution of the bipolar benthic faunas, which may have resulted from fragmentation of an originally wide distribution or by dispersal. The Spiti area at the northern margin of the Indian craton bordering the Neotethys during the Late Jurassic occupied a southern palaeolatitude between 20–30° according to the Paleolatitude Calculator of van Hinsbergen et al. (2015). The occurrence of high latitude southern taxa at relatively low latitudes can be explained by their restriction to outer shelf and slope environments where, due to upwelling, lower water temperatures prevailed (compare Alberti et al. 2021; Fürsich et al. 2021). In this context, isothermal submergence may explain the way polar faunas were able to cross the tropics (e.g., Crame 1993).

Australobuchia spitiensis (Holdhaus, 1913)
Plate 3, fig. 3

*1913 *Aucella spitiensis* n.sp. form. typ. – Holdhaus: 410, pl. 97, fig. 8–11.
?1913 *Aucella spitienis grandis* nov. form. – Holdhaus: 411, pl. 97, fig. 7.
?1913 *Aucella spitiensis superba* nov. form. – Holdhaus: 411, pl. 97, fig. 13.
?1913 *Aucella spitiensis extensa* nov. form. – Holdhaus: 411, pl. 97, fig. 12.
1959 *Buchia spitiensis* (Holdhaus) – Fleming: 898, figs 15, 16, 20C, D
1976 *Buchia spitiensis* (Holdhaus) – Wen: 85, pl. 21, fig. 1.
1976 *Buchia spitiensis* (Holdhaus) – Gu et al.: 151, pl. 46, figs 3–7.
1988 *Buchia spitiensis* Holdhaus 1903 – Li and Grant-Mackie: 253, fig. 2A, B.

Material. Composite moulds of one articulated and one right valve and external moulds of fragments of one right and one left valve from the middle member, roadside close to Komic (SNSB-BSPG 2020 XCIX 43) and from the upper member close to Demul Pass (SNSB-BSPG 2020 XCIX 43).

Description. Poorly preserved composite and external moulds, some with remains of shell, obliquely elongated, higher than long (H: 25.8 mm, L: 23.1 mm). Mould of right valve moderately inflated, with distinctly sloping anterior and posterior flank and inconspicuous umbo; mould of left valve strongly inflated, umbo prominent, beak incurved, prosogyrate. Anterior and posterior margins sub-parallel, weakly convex, ventral margin strongly convex. Surface covered with numerous growth folds of varying strength. Anterior auricle of right valve concave, tongue-like, not level with commissure but directed slightly towards left valve.

Remarks. Most specimens are strongly flattened and fragmentary so that diagnostic features are difficult to observe. *Australobuchia spitiensis* as described by Holdhaus (1913) varies considerably in outline and degree of obliquity. Holdhaus (1913) distinguished altogether four varieties (forma *typica*, forma *grandis*, forma *extensa*, and forma *superba*). Due to the limited information from the present specimens, we cannot evaluate these varieties. Our material corresponds most closely to his forma *typica*. The species is also common in the Mt. Everest region (e.g., Wen 1976).

Australobuchia blanfordiana (Stoliczka, 1866)
Plate 3, figs 4–5

1864 *Monotis concentricus* Blanford – Blanford: 136, pl. 4, figs 6–7.
non 1865 *Monotis concentricus* Blanford – Salter: 91, pl. 22, fig. 4.
*1866 *Ancella* [sic] *Blanfordiana*, Stol. – Stoliczkai: 88.
1913 *Aucella blanfordiana*, Stolczkai – Holdhaus: 412, pl. 98, figs 1–9.
1976 *Buchia blanfordiana* (Stoliczka) – Wen: 86, pl. 20, figs 1–6.
1976 *Buchia blanfordiana* (Stoliczka) – Gu et al. 150, pl. 46, figs 17–25.
1988 *Buchia blanfordiana* (Stoliczka 1866) – Li and Grant-Mackie: 252, fig. 2J–K.
2005 *Buchia blanfordiana* (Stoliczka) – Xia and Bai: 502, pl. 1, figs 5, 7, 8.

Material. One internal mould of a left valve from the middle? member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 44); one right valve, two right valve internal moulds, five left valveinternal moulds, and one crushed articulated specimen from the upper member close to the pass to Demul (SNSB-BSPG 2020 XCIX 44–46).

Description and remarks. The species differs from *A. spitiensis* in being less strongly oblique and less posteroventrally elongated. According to Holdhaus (1913, p. 413), the species is quite variable with respect to shape and ornamentation. Whether it is, in fact, conspecific with *A. spitiensis* cannot be evaluated with the present poorly preserved material.

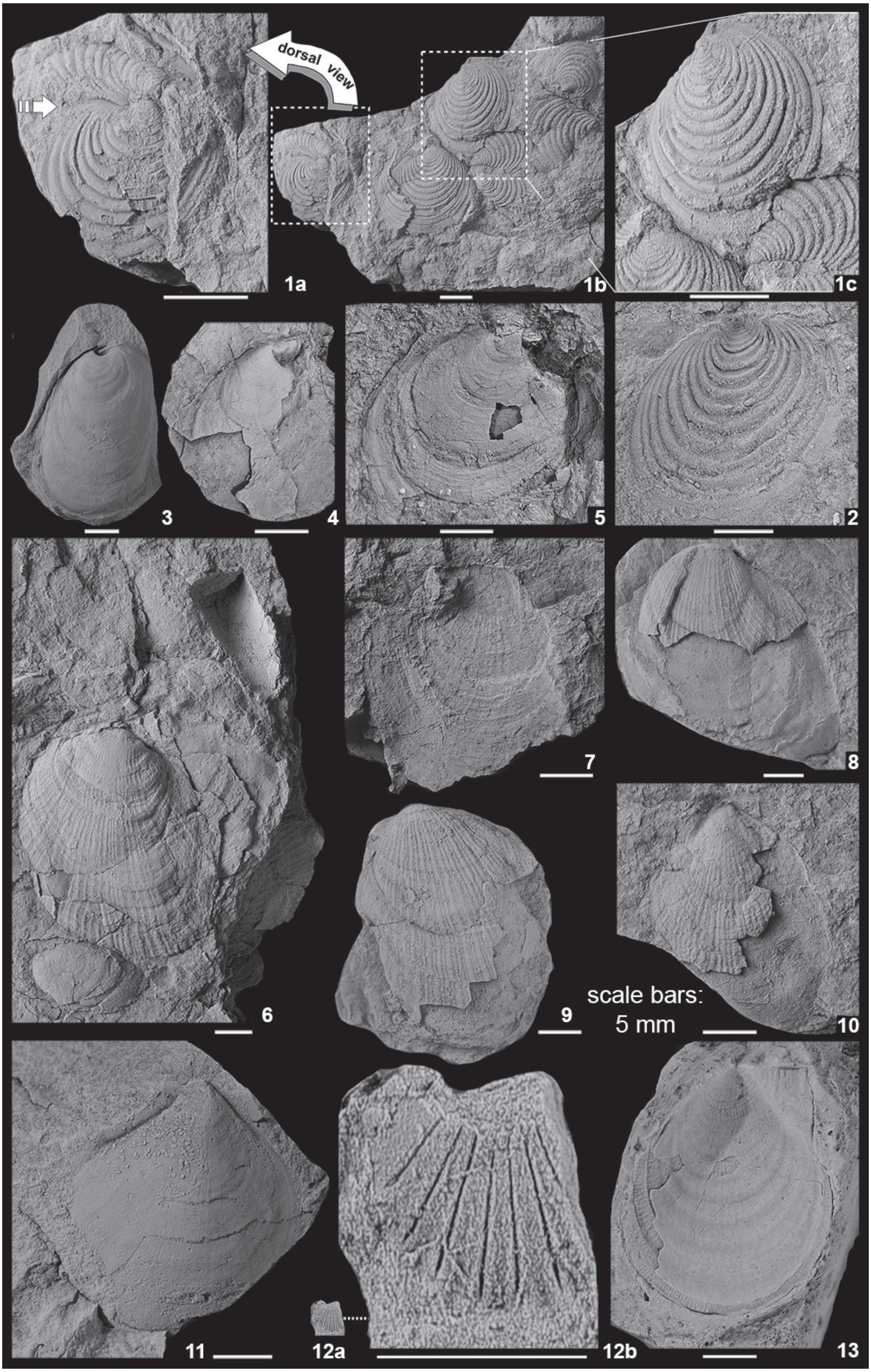

dorsal view
1a
1b
1c
3
4
5
2
6
7
8
9
10
scale bars:
5 mm
11
12a
12b
13

Plate 3. (1, 2) *Bositra buchii* (Roemer, 1836). Composite moulds from the lower member at Langza. **1.** a, articulated specimen in butterfly position, dorsal view (SNSB-BSPG 2020 XCIX 18a); b, c, single valves, lateral view (SNSB-BSPG 2020 XCIX 18b). **2.** External mould of right valve (SNSB-BSPG 2020 XCIX 19). **(3)** *Australobuchia spitiensis* (Holdhaus, 1913). Composite mould of articulated specimen from the middle member, roadside close to Komic; right valve view (SNSB-BSPG 2020 XCIX 43). **(4–5)** *Australobuchia blanfordiana* (Stoliczka, 1866). upper member close to Demul Pass. **4.** Right valve (SNSB-BSPG 2020 XCIX 46). **5.** Right valve (SNSB-BSPG 2020 XCIX 45). **(6–10)** ?*Malayomaorica* sp. upper member close to Demul Pass. **6.** Left valve (SNSB-BSPG 2020 XCIX 51a). **7.** Right valve interior (SNSB-BSPG 2020 XCIX 52). **8.** Fragment of right valve (SNSB-BSPG 2020 XCIX 51b). **9.** Left valve (SNSB-BSPG 2020 XCIX 51c). **10.** Fragment of right valve (SNSB-BSPG 2020 XCIX 51d). **(11)** *Entolium* (*Entolium*) *corneolum* (Young & Bird, 1822). Internal mould of a left valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 15). **(12)** *Propeamussium* (*Propeamussium*) sp. Internal mould of a small fragment from the lower member at Langza (SNSB-BSPG 2020 XCIX 12). a, natural size; b, enlarged. **(13)** *Camptonectes* (*Camptochlamys*) *obscurus* (J. Sowerby, 1818). Left valve interior from the lower member near the pass to Tashigeng (SNSB-BSPG 2020 XCIX 13).

Genus *Malayomaorica* Jeletzky, 1963

Type species. *Aucella malayomaorica* Krumbeck, 1923.

Malayomaorica? sp.

Plate 3, figs 6–10

Material. Numerous right and left valves preserved as composite moulds or with remains of shell, generally strongly compacted and often fragmented, from the upper member close to Demul Pass (SNSB-BSPG 2020 XCIX 51–52).

Description and remarks. The poorly preserved specimens are characterized by a feebly inflated right valve and a strongly inflated left valve. The height distinctly exceeds the length of the shell, which is slightly oblique, the ventralmost part being posterior of the mid-line. The anterior margin is well-rounded, the posterior margin sub-straight, the ventral margin strongly curved. The right valve anterior auricle is directed towards the left valve; the byssal notch is well-developed. The surface of the shell is covered with faint radial riblets in addition to faint commarginal growth rugae.

The different outline and the radial riblets distinguish the material from *Buchia*. Due to the poor preservation and lack of detailed hinge information the specimens are only tentatively placed in *Malayomaorica*. This is the first documentation of the genus from the Indian Himalayas.

Family Oxytomidae Ichikawa, 1958

Genus *Meleagrinella* Whitfield, 1885

Type species. *Avicula curta* Hall, 1852.

Meleagrinella? sp.

Material. A single right valve from the top of the lower member at Komic (SNSB-BSPG 2020 XCIX 16).

Description and remarks. The small, slightly crushed specimen (H: 3.5 mm) is suborbicular and nearly flat. The dorsal margin is long and straight, the anterior, posterior and ventral margins are well rounded. There is no sign of a posterior wing, the dorsal margin forming a blunt angle with the posterior margin. The umbo is small, more or less mesial, and not protruding beyond the dorsal margin. The shell thin, and ornamented with remains of spaced commarginal riblets. The annterior auricle is small but has a deep byssal notch.

Right valves of *Meleagrinella* are generally regarded as having a small pointed posterior wing (Cox 1969), which is apparently lacking in the present specimen. For this reason, it is referred to the genus *Meleagrinella* with reservation. The *Meleagrinella* sp. indet. of Kanjilal and Pathak (1998, p. 35, pl. 1, fig. 4) is difficult to evaluate and comes from the upper part of the Spiti Shale Formation.

Family Entoliidae Teppner, 1922
Genus *Entolium* Meek, 1865

Subgenus *Entolium* Meek, 1865

Type species. *Pecten demissus* Phillips, 1829 (= *Entolium demissum* Meek, 1865).

Entolium (*Entolium*) *corneolum* (Young & Bird, 1828)

Plate 3, fig. 11

*1828 *Pecten corneolus* – Young and Bird: 234, pl. 9, fig. 5.
1924 *Pecten* (*Entolium*) *demissum* Phillips – Hennig: 14, pl. 2, figs 1–2.
1933 *Pecten* (*Entolium*) *solidus* Roemer – Dietrich: 65, pl. 8, figs 118, 119.
1938 *Entolium demissum* (Phillips) – Weir: 46, pl. 3, fig. 8.
1939 *Entolium demissum* (Phillips) – Stefanini: 179, pl. 22, figs 2–3.
1965 *Entolium corneolum* (Young & Bird) – Cox: 1965: 51.
1981 *Entolium* (*Entolium*) *corneolum* (Young & Bird) – Kanjilal: 265, pl. 1, fig. 1.
1995 *Entolium* (*Entolium*) *corneolum* (Young & Bird, 1828) – Jaitly et al.: 193: pl. 18, figs 8–9.

Material. Internal mould of a left valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 15).

Description. Disc subovate, smooth, poorly inflated. Length 21.7 mm, height >25 mm. Auricles well demarcated from disc, only partly preserved, anterior auricle apparently larger than posterior one. Anterior, posterior, and ventral margin forming a semi-circle.

Remarks. The specimen can be referred to *Entolium* (*E.*) *corneolum* without doubt, based on its outline, even though no shell is preserved. Left valves of *E. corneolum*, *E. lunare* (Roemer, 1839), and *E. orbiculare* (J. Sowerby, 1817) are very similar, but differ with respect to stratigraphic and/or geographic distribution (Johnson 1984).

Family Pectinidae Rafinesque, 1815
Genus *Camptonectes* Agassiz in Meek, 1864

Subgenus *Camptochlamys* Arkell, 1930

Type species. *Pecten intertextus* Roemer, 1839.

Camptonectes (*Camptochlamys*) *obscurus* (J. Sowerby, 1818)
Plate 3, fig. 13

*1818 *Pecten obscura* – J. Sowerby: 3, pl. 205, fig. 1.
1852 *Camptonectes indicus* sp. nov. – Cox: 25, pl. 3, figs 1–4.
?1939 *Camptonectes Germaniae* (d'Orb.) – Stefanini: 171, pl. 19, fig. 11.
1956 *Camptonectes indicus* Cox – Agrawal: 77, pl. 9, fig. 5.
1968 *Camptonectes indicus* Cox – Maithani: 505, pl. 33, fig. 6.
1979 *Camptonectes* (*Indonectes*) *obscurus* (J. Sowerby) subgen. nov. – Kanjilal: 120, fig. 6.
1983 *Camptonectes* (*Indonectes*) *obscurus* (J. Sowerby) – Singh and Jaitly: 47, pl. 1, fig. 5.
1995 *Camptonectes* (*Camptochlamys*) *obscurus* (J. Sowerby, 1818) – Jaitly et al.: 196, pl. 19, figs 7–8.

Material. A single left valve partly in shell preservation, seen from the interior, from the lower member near the pass to Tashigeng (SNSB-BSPG 2020 XCIX 13).

Description. Shell suboval, higher than long (H: 22.2 mm, L: ~20 mm), moderately inflated, anteroventral, posteroventral and ventral margins rounded and regularly curved; antero- and posterodorsal margins of disc sub-straight. Anterior auricle large, distinctly set off from anterodorsal flank, which is more steeply sloping than posterodorsal flank. Tip of umbo and posterior auricle missing, anterior and posterior margin of disc also not fully preserved. Disc ornamented with thin, sharp, regularly spaced commarginal ribs and numerous thin divaricate radial grooves, separated by smooth, flat intervals about twice the width of the grooves. Umbonal area with thin radial riblets. Anterior auricle covered with spaced commarginal riblets intersected by thin radial riblets, creating a reticulate pattern.

Remarks. The specimen closely corresponds to the diagnosis of *Camptonectes* (*Camptochlamys*) *obscurus* as given by Johnson (1984). So far, the species has not been recorded from the Himalayan shelf of the southern Tethys, but it occurs in the Callovian of the Kachchh Basin further south (Cox 1952; Jaitly et al. 1995) and possibly also in other parts of the Ethiopian faunal province (e.g., as *Camptonectes germaniae* (d'Orbigny, 1850) in Somalia; Stefanini 1939 p. 171, pl. 19, fig. 11).

Genus *Chlamys* Röding, 1798

Subgenus *Chlamys* Röding, 1798

Type species. *Pecten islandicus* Müller, 1776.

Chlamys (*Chlamys*) cf. *textoria* (Schlotheim, 1820)
Plate 4, fig. 2

cf. 1820 *Pectinites textorius* – Schlotheim, p. 229.
cf. 1952 *Chlamys* (*Chlamys*) *ambigua* (Münster) – Cox: 4, pl. 1, figs 2–4.
cf. 1965 *Chlamys subtextoria* (Münster) – Cox: 55, pl. 7, fig. 8.
cf. 1984 *Chlamys* (*Chlamys*) *textoria* (Schlotheim 1820) – Johnson: 163, pl. 6, figs 10–12, pl. 7, figs 1–21, pl. 8, figs 1–3, 5–20, ?4, text-figs 146–157.
cf. 1995 *Chlamys* (*Chlamys*) *textoria* (Schlotheim 1820) – Jaitly et al.: 197, pl. 20, figs 3–7.

Material. A single, incomplete right valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 11).

Description. Somewhat abraded right valve with ventral part missing. Early disc suborbicular, equilateral, poorly inflated. Auricles well-demarcated from disc. Posterior auricle relatively small, forming obtuse angle with disc. Disc with ~19 radial plicae plus some very faint ones near anterior and posterior end. Number of plicae increasing ventrally by bifurcating. No growth lines or commarginal lamellae seen due to poor preservation.

Remarks. The poorly preserved specimen can be placed in *Chlamys* (*C.*) *textoria* with reservation only.

Genus *Spondylopecten* Roeder, 1882

Subgenus *Plesiopecten* Munier-Chalmas, 1887

Type species. *Pectinites subspinosus* Schlotheim, 1820.

Spondylopecten (*Plesiopecten*) *subspinosus* (Schlotheim, 1820)
Plate 4, fig. 3

1820 *Pectinites subspinosus* – Schlotheim: 223.
1938 *Plesiopecten subspinosus* (Schlotheim) – Weir: 50, pl. 3, fig. 18.
1952 *Chlamys* (*Plesiopecten*) *subspinosa* (Schlotheim) – Cox: 18, pl. 1, figs 9–12.
1995 *Spondylopecten* (*Plesiopecten*) *subspinosus* (Schlotheim 1820) – Jaitly et al.: 194, pl. 18, figs 14–15.

Material. One composite mould of a right valve and one external mould from the upper part of the lower member at the Hikkim-Kaza road (SNSB-BSPG 2020 XCIX 23).

Description. Specimens small (H: 5.4 mm; K: 5.8 mm), suborbicular, equilateral, weakly inflated. Auricles large, distinctly separated from disk, anterior one incomplete.

Surface of composite mould covered with 11–13 positive radial structures interpreted herein as corresponding to radial ribs, which are angular and show a tendency to bifurcate towards the ventral margin.

Remarks. Despite the poor preservation of the specimens (lack of shell), they can be safely assigned to *S.* (*Plesiopecten*) *subspinosus*, based on the number and angularity of their ribs (compare Johnson 1984, p. 84).

Genus *Radulopecten* Rollier, 1911

Type species. *Pecten hemicostatus* Morris & Lycett, 1853.

Radulopecten cf. *fibrosus* (J. Sowerby, 1816)

Plate 4, fig. 4a, b

cf. 1816 *Pecten fibrosus* – J. Sowerby: 84, pl. 136, figs 1–2.

Material. A single fragment of a right valve from the lower? member near Demul (SNSB-BSPG 2020 XCIX 39).

Description and remarks. Although the specimen does not allow to infer the shape of the bivalve, the ornamentation is so characteristic that it can be placed in the genus *Radulopecten* without any doubt. The shell is covered with broad, nearly flat-topped radial plicae, separated by much narrower shallow sulci. The radial plicae are crossed by spaced, narrow commarginal lamellae. The ornamentation closely resembles that of *Radulopecten fibrosus* (J. Sowerby, 1816). For this reason, the specimen is tentatively placed in that species.

Pectinidae indet.

Plate 4, fig. 5

Material. Slightly distorted fragment of a single valve from 5–8 m below the top of the lower member along the Kaza-Hikkim road (SNSB-BSPG 2020 XCIX 17).

Description. Specimen small (H: 9.6 mm), higher than long. Disc moderately inflated, rounded triangular; auricles distinctly set off from disc, large, incomplete. Disc covered with approximately 12 coarse, rounded radial ribs, differing in strength.

Remarks. The poor preservation (incomplete shell, compactional/tectonic distortion) precludes a more precise identification of the specimen, which to some extent resembles *Spondylopecten*, the ribbing of which is, however, far more regular.

Family Propeamussiidae Abbott, 1954
Genus *Propeamussium* De Gregorio, 1884

Subgenus *Propeamussium* De Gregorio, 1884

Type species. *Pecten* (*Propeamussium*) *ceciliae* De Gregorio, 1884.

Propeamussium (*Propeamussium*) sp.

Plate 3, fig. 12

Material. One internal mould of a single valve (SNSB-BSPG 2020 XCIX 12) and several small fragments from the lower member at Langza.

Description and remarks. The internal mould of a fragment displays seven radial grooves, which correspond to internal ribs. The complete shell might have carried 8–9 ribs. These ribs end just before the ventral margin.

While the specimen undoubtedly can be referred to *P.* (*Propeamussium*), identification at the species level is impossible. The only Upper Jurassic species recognized by Johnson (1984) is *P.* (*P.*) *nonarium* (Quenstedt, 1858, p. 795, pl. 98, fig. 4), which is restricted to Europe and differs from the present specimen by relatively short internal ribs, which end well before the ventral margin.

Order Limida Moore, 1952
Family Limidae Rafinesque, 1815

Genus *Plagiostoma* J. Sowerby, 1814

Type species. *Plagiostoma giganteum* J. Sowerby, 1814.

Plagiostoma? sp. A

Plate 4, fig. 7a, b

Material. A strongly crushed single valve with remains of shell from the lower member at Langza (SNSB-BSPG 2020 XCIX 35).

Description and remarks. The very poorly preserved specimen cannot be identified with certainty. The surface of the apparently rounded triangular-ovate specimen is covered with numerous faint, rounded, radial riblets.

Plagiostoma? sp. B

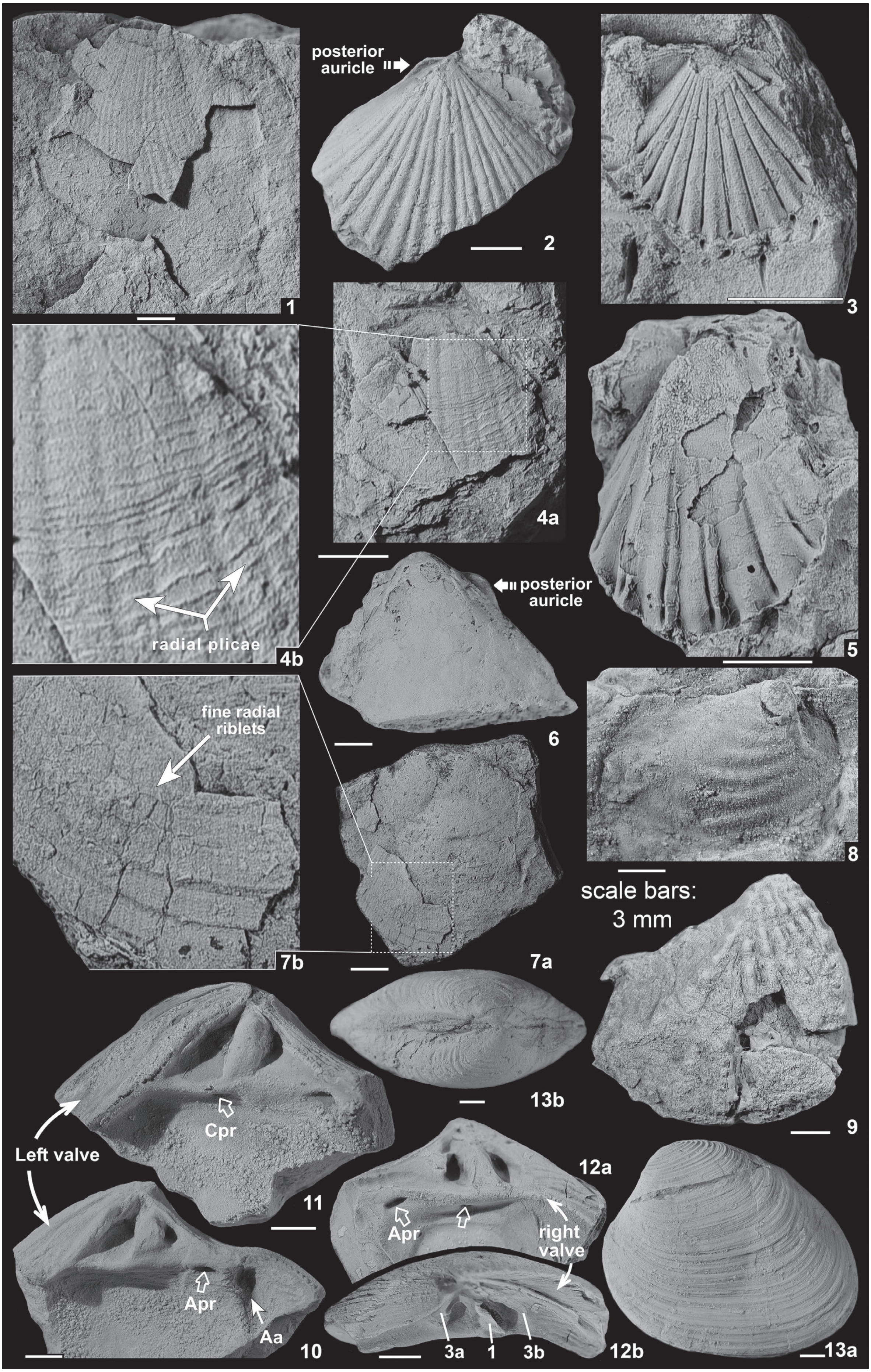
Plate 4, fig. 6

Material. A fragmented left internal mould with remains of the inner shell layer from the Ferruginous Oolite Formation near Zangla (SNSB-BSPG 2020 XCIX 36).

Description and remarks. As the ventral part of the specimen is missing, its outline remains unknown, but most likely was obliquely triangular-ovate. The hinge line is short and straight, the umbo orthogyrate, the posterior auricle distinctly set off from the flank. The shell surface is ornamented with indistinct remnants of radial ribs. It differs from *Plagiostoma*? sp. A in outline and style of ribbing. The few features that can be observed all support the placement of the specimen in *Plagiostoma* or a related genus.

Genus *Ctenostreon* Eichwald, 1862

Type species. *Ostracites pectiniformis* Schlotheim, 1820.



1
posterior auricle
2
3
4a
radial plicae
4b
posterior auricle
5
6
fine radial riblets
7b
7a
8
scale bars: 3 mm
9
13b
Cpr
Left valve
11
12a
Apr
right valve
Apr
Aa
10
3a
1
3b
12b
13a

Plate 4. (1) *Camptonectes* (*Camptochlamys*) sp. from the upper member close to Demul Pass (SNSB-BSPG 2020 XCIX 14). **(2)** *Chlamys* (*Chlamys*) cf. *textoria* (Schlotheim, 1820). Incomplete right valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 11). **(3)** *Spondylopecten* (*Plesiopecten*) *subspinosus* (Schlotheim, 1820). Internal mould of right valve from the lower member at the Kaza–Hikkim road (SNSB-BSPG 2020 XCIX 23). **(4)** *Radulopecten* cf. *fibrosus* (J. Sowerby, 1816). a, b, Fragment of a right valve from the ?lower member near Demul (SNSB-BSPG 2020 XCIX 39). **(5)** Pectinidae indet. Slightly distorted internal mould of a single valve from the lower member along the Kazan–Hikkim road (SNSB-BSPG 2020 XCIX 17). **(6)** *Plagiostoma*? sp. B. Strongly crushed single valve with remains of shell from the lower member at Langza (SNSB-BSPG 2020 XCIX 35). **(7)** *Plagiostoma*? sp. A. a, b, Fragmented left internal mould with remains of the inner shell layer from the Ferruginous Oolite Formation near Zangla (SNSB-BSPG 2020 XCIX 36). **(8)** *Trigonia*? sp. Right internal mould from the top of the Ferruginous Oolite Formation at Zangla (SNSB-BSPG 2020 XCIX 24). **(9)** *Vaugonia* (*Orthotrigonia*) sp. Poorly preserved right valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 25). **(10–13)** *Pruvostiella* (*Pruvostiella*) *hermanni* (Oppel, 1863). **10.** Hinge of left valve from the lower member close to the pass to Tashigeng; Aa, anterior adductor scar; Apr, anterior pedal retractor scar (SNSB-BSPG 2020 XCIX 54b). **11.** Hinge of left valve from the lower member at the Kaza–Hikkim road cut; Cpr, central pedal retractor scar (SNSB-BSPG 2020 XCIX 59). **12.** Hinge of right valve from the lower member close to the pass to Tashigeng; Apr, anterior pedal retractor scar. a, lateral view; b, dorsal view (SNSB-BSPG 2020 XCIX 54b). **13.** Articulated specimen from the lower member at Langza (SNSB-BSPG 2020 XCIX 59a). a, left valve view; b, dorsal view.

Ctenostreon sp.

Material. One small fragment from the Ferruginous Oolite Formation near Chichim (SNSB-BSPG 2020 XCIX 21).

Description and remarks. The very small fragment of a thick shell carries large, rounded, somewhat irregular radial ribs. The fragment can be differentiated from the genus *Trichites* by lacking the prismatic shell structure of the latter, and from large ribbed oysters such as *Actinostreon marshii* by the rounded nature of the ribs. The fragment is too small to warrant photographic documentation.

Infraclass Heteroconchia Hertwig, 1895
Order Trigoniida Dall, 1889
Family Trigoniidae Lamarck, 1819

Genus *Trigonia* Bruguière, 1789

Type species. *Venus sulcata* Hermann, 1781.

Trigonia? sp.
Plate 4, fig. 8

Material. A single right internal mould from the top of the Ferruginous Oolite Formation at Zangla (SNSB-BSPG 2020 XCIX 24).

Description and remarks. The internal mould shows the typical commarginal ribs of the flank and a weak sulcus anterior of the marginal carina. As no information about the area is available, it cannot be decided whether the specimen belongs to *Trigonia* s.s. or to the genus *Indotrigonia*.

Family Myophorellidae Kobayashi, 1954
Genus *Vaugonia* Crickmay, 1930

Subgenus *Orthotrigonia* Cox, 1952

Type species. *Trigonia duplicata* J. Sowerby, 1819.

Vaugonia (*Orthotrigonia*) sp.
Plate 4, fig. 9

Material. A single poorly preserved right valve from the lower member at Langza (SNSB-BSPG 2020 XCIX 25).

Description and remarks. The specimen (H: 22.7 mm, L: 24.5 mm) exhibits the typical ornamentation of *Orthotrigonia* such as steep subvertical tuberculated ribs on the flank, commarginal tuberculated to spinose ribs in the umbonal area, a tuberculated marginal carina, and a commarginally striated area. The specimen resembles *V.* (*Orthotrigonia*) *kutchensis* (Kitchin, 1903: 84, pl. 8, figs 7–9) from the Kachchh Basin, but due to its poor preservation an identification at the species level is not possible.

Clade Heterodonta Neumayr, 1884
Order Carditida Dall, 1889
Family Astartidae d'Orbigny, 1844

Genus *Pruvostiella* Agrawal, 1956a

Emended diagnosis. Equivalve, inequilateral shell, generally longer than high, thick-shelled. Inner shell margin crenulated; umbonal area depressed and ornamented with spaced, well-developed, commarginal ribs asymmetric in cross-section; remaining shell smooth except for growth lines. Hinge with serrated teeth. Right valve with 2–3 cardinals and 1 anterior and 1 posterior lateral. Left valve with 2–3 cardinals and 1 anterior and 1 posterior lateral. Distinct pedal retractor muscle scar developed below the hinge line and close to the anterior adductor muscle scar. Inner shell margin crenulated.

Remarks. *Pruvostiella* was erected by Agrawal (1956a: 435) as a subgenus of *Neocrassina* for specimens from the Oxfordian Dhosa Oolite of Kachchh, western India. The main diagnostic feature of his new subgenus is the umbonal region, which is distinctly depressed, with small beaks and ornamented with spaced, well-developed commarginal ribs, which are asymmetric in cross-section with a steeper slope dorsally. The ribs fade after 10–15 mm to be replaced by irregular growth lines. Agrawal (1956a)

Table 3. Species included in the genus *Pruvostiella* (* previously included by Agrawal 1956a).

Species included in the genus *Pruvostiella*	occurrence	age
**Astarte unilateralis* J. de C. Sowerby, 1840a: 327, pl. 21, fig. 14	Kachchh	Callovian–Oxfordian
**Astarte major* J. de C. Sowerby, 1840b: 718 pl. 61, fig. 1	Kachchh	Kimmeridgian–Tithonian
**Astarte hermanni* Oppel, 1863: 273, 297	Himalayas	Oxfordian
**Astarte scytalis* Holdhaus, 1913: 444, pl. 100, figs 2–3	Himalayas	Oxfordian
**Astarte spitiensis* Stoliczka, 1866: 91, pl. 9, fig. 1.	Himalayas	Oxfordian
Astarte hiemalis Stoliczka: 91, pl. 9, figs 2–3.	Himalayas	Oxfordian
**Astarte muelleri* Daqué, 1910: 31, pl. 4, fig. 5	East Africa	?Callovian-?Kimmeridgian
**Astarte stefanini* Basse, 1930: 110, pl. 5, fig. 9	Ethiopia	Kimmeridgian
Astarte krenkeli Dietrich, 1933: 40, pl. 4, figs 62, 64, 66	East Africa	Tithonian
**Astarte* sp. A Nicolai, 1950–1951: 45, pl. 4, fig. 11	Madagascar	Late Oxfordian
Astarte sp. B Nicolai, 1950–1951: 45, pl. 5, fig. 1	Madagascar	Late Oxfordian
**Astarte freneixae* Agrawal, 1956a: 436, pl. 21, figs 5–6	Kachchh	Oxfordian
Seebachia (*Eoseebachia*) *elongata* Fürsich, Heinze & Jaitly, 2000: 96, pl. 6, fig. 25, pl. 8, figs 2–7, pl. 9, fig. 2, pl. 10, fig. 1, text-figs 16–18	Kachchh	Kimmeridgian–Tithonian
Seebachia (*Eoseebachia*) *sowerbyana* (J. de C. Sowerby, 1840) – Fürsich et al. 2000: 92, pl. 6, fig. 24, pl. 7, figs 1–5, pl. 8, fig. 1, pl. 10, fig. 5, text-figs14–16	Kachchh	Kimmeridgian–Tithonian

included a number of astartids in *Pruvostiella* (Table 3). *Pruvostiella* is here elevated to generic rank.

Fürsich et al. (2000: 92; 2019, p. 174) created *Eoseebachia* as a subgenus of *Seebachia* Holub & Neumayr, 1881 and accommodated *Astarte major* J. de C. Sowerby, 1840 and their new species *elongata* in this subgenus. Although these species are related to *Seebachia*, they are clearly more closely related to *Pruvostiella*, as the former genus is strongly elongated, wedge-shaped and has a distinct posterior umbonal ridge. *Eoseebachia* is, therefore, moved from *Seebachia* to *Pruvostiella*.

Gardner and Campbell (2002, p. 328) regarded *Pruvostiella* as a junior synonym of *Neocrassina* Fischer, 1886, a view not followed here. The depressed, flattened umbo, the corresponding distinct break in the growth spiral of the shell, and the distinctly serrated cardinal teeth are consistent features of many large astartids from the Ethiopian faunal province (Table 3).

Pruvostiella (*Pruvostiella*) appears to be restricted to the Callovian–Oxfordian time interval of the Ethiopian Faunal Province (Madagascar, East Africa, India) and possibly occurs also in the Kimmeridgian of New Zealand (Trechman 1923; Marwick 1953), whereas *Pruvostiella* (*Eoseebachia*) occurs from the Late Oxfordian to the Late Tithonian (and probably earliest Cretaceous) in the same area (e.g., Dietrich 1933; Cox 1965). *Eoseebachia* differs from *Pruvostiella* s.s. by being up to three times larger, generally more elongated and by having a lunule with a lower length-width ratio.

J. de C. Sowerby (J. de C. Sowerby, 1840, pl. 61, fig. 1) erected *Astarte major* for the large astartids from the Upper Jurassic of Kachchh. Blanford (1864), Stoliczka (1866), and Holdhaus (1913) regarded moderately-sized astartids from the Himalayas also as *Astarte major* J. de C. Sowerby, 1840. Whereas Blanford (1864, p. 135, …"undoubtedly identical") was quite confident, Holdhaus only tentatively regarded the large astartids from Spiti to belong to Sowerby's *Astarte major* from Kachchh. Holdhaus (1913) erroneously regarded that Sowerby's name was preoccupied by *Astarte elegans major* Zieten (1833: 82, pl. 62, fig. 1). Therefore, Holdhaus (1913, p. 443) erected the replacement name *Astarte sowerbyana* for the forms from the Himalayas and Kachchh. It is clear that the Kachchh species differs from the Spiti material. The specimens from the Spiti Shale are placed herein in *P.* (*Pruvostiella*) *hermanni* (Oppel, 1863). The large astartid from Kachchh represents Sowerby's *A. major* and the species is assigned to *Pruvostiella* (*Eoseebachia*), because it is much closer to *Pruvostiella* than to *Seebachia* (see above). Thus, in the Kachchh Basin four species of *Pruvostiella* occur: *P.* (*Eoseebachia*) *major* (J. de C. Sowerby, 1840), *P.* (*Eoseebachia*) *elongata* Fürsich, Heinze & Jaitly, 2000, *P.* (*Pruvostiella*) *unilateralis* (J. de C. Sowerby, 1840), and *P.* (*Pruvostiella*) *freneixae* Agrawal, 1956a. In the Himalayas, in contrast, the species group is represented by *P.* (*Pruvostiella*) *hermanni* (Oppel, 1863).

Subgenus *Pruvostiella* Agrawal, 1956a

Type species. *Astarte* (*Pruvostiella*) *freneixae* Agrawal, 1956a.

Emended diagnosis. As for genus.

Pruvostiella (*Pruvostiella*) *hermanni* (Oppel, 1863)

Plate 4, figs 10–13, Plate 5, figs 1–6; Fig. 4

1831 *Unio*? and *Trigonia*? – Herbert 272, pl. 17, fig. 4, 4a.
1833 *Unio*? – Everest: 114, pl. 2, fig. 26.
*1863 *Astarte hermanni* Opp. – Oppel: 273, 297.
1865 *Astarte unilateralis* Sow. – Salter: 97, pl. 23, fig. 10. (non Sowerby, 1840).
1866 *Astarte unilateralis*, Sow. 1840 – Stoliczka: 90. (non Sowerby, 1840).
1866 *Astarte spitiensis* Stol. – Stoliczka: 91, pl. 9, fig. 1.
1866 *Astarte hiemalis* Stol. – Stoliczka: 91, pl. 9, figs 2–3.
1913 *Astarte scytalis* sp. nov. – Holdhaus: 444, pl. 100, figs 2–3.
1913 *Astarte sowerbyana* sp. nov. – Holdhaus: 443, pl. 99, figs 12, 13, 15, pl. 100, fig. 1.
1913 *Astarte spitiensis* Stoliczka – Holdhaus: 444, pl. 100, figs 4–8.
1913 *Astarte hermanni* Oppel 1863 – Holdhaus: 440, pl. 99, figs 7–11, 14.
1923 *Astarte spitiensis* Stol. – Trechmann: 279, pl. 13, fig. 1.
1923 *Astarte* cf. *scytalis* Holdhaus – Trechmann: 280, pl. 13, fig. 3.
1923 *Astarte* cf. *sowerbyana* Holdhaus – Trechmann: 280, pl. 13, fig. 2.
?1929 *Astarte scytalis* Holdhaus – Weir: 5, pl. 3, fig. 20.
1935 *Astarte scytalis* Holdhaus – Cox: 180, pl. 19, figs 4–5.
1953 *Astarte spitiensis* Stol. – Marwick: 107, pl. 11, figs 13, 15.

non 1956b *Astarte* (*Pruvostiella*) *spitiensis* Stoliczka – Agrawal: 109, pl. 10, fig. 3. (non Stoliczka).
?1959 *Astarte scytalis* Holdhaus – Jaboli: 49, pl. 6, fig. 6.
1998 *Neocrassina* (*Pruvostiella*) *unilateralis* (J. de C. Sowerby, 1840) – Kanjilal & Pathak: 35, pl. 1, fig. 8. (non Sowerby, 1840).
1998 *Neocrassina* (*Pruvostiella*) *sowerbyana* (Holdhaus, 1913) – Kanjilal & Pathak: 35, pl. 1, fig. 9.

Material. Three right valves, four left valves, 16 articulated specimens, and two hinge fragments from the lower member at Langza (SNSB-BSPG 2020 XCIX 53, 57, 58, 59), two right valves, one left valve, 17 articulated valves, and six hinge fragments from the lower member at the Kaza–Hikkim road cut (SNSB-BSPG 2020 XCIX 55a, b), and two right valves, one left valve, nine articulated specimens and six hinge fragments from the lower member close to Tashigeng (SNSB-BSPG 2020 XCIX 54a, b).

Dimensions. See Fig. 4.

Description. Shell highly variable in outline, longer than high (Fig. 4), moderately inflated. Anterodorsal margin concave, anteroventral margin convex, grading smoothly into the broadly arched ventral margin. Posteroventral margin well-rounded, posterodorsal margin faintly convex. Umbo prosogyrate, distinctly depressed, situated approximately one-fifth to one-eighth of shell length from the anterior end. Beaks small, lunule elongated, deep, bordered by sharp ridge (Plate 5); escutcheon lanceolate, bordered by distinct ridge. Ligament opisthodetic. Ornamentation consisting of widely spaced commarginal ribs in umbonal area only and extending for 10–15 mm ventrally. Remaining surface covered with irregular growth lines.

Hinge of right valve with three cardinals, 3b thin and inconspicuous, and one posterior lateral. Left valve with two cardinals and one short anterior and posterior lateral,

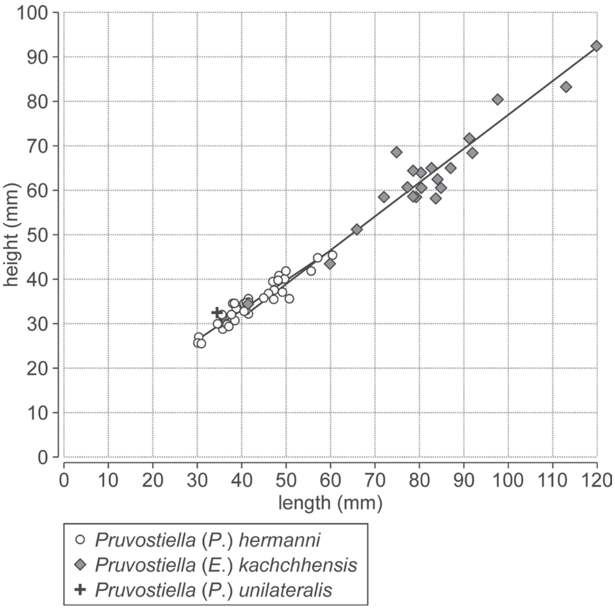


Figure 4. Length plotted against height of *Pruvostiella* (*P.*) *hermanni* from the Spiti Shale Formation and of the holotypes of *P.* (*P.*) *unilateralis* (J. de C. Sowerby, 1840) and *P.* (*Eoseebachia*) *major* (J. de C. Sowerby, 1840) (= *Seebachia* (*E.*) *sowerbyana* (J. de C. Sowerby, 1840) in part).

respectively. Two pedal retractor muscle scars developed right underneath hinge plate, one more or less mesial, the second one close to the anterior adductor muscle scar. Inner shell margin strongly crenulated.

Remarks. Due to their high morphological variability the specimens from the Spiti Shale Formation have been accommodated in several species in the past. Stoliczka (1866) recognised *Astarte spitiensis*, *A. unilateralis*, and *A. hiemalis* and Holdhaus (1913) *A. sowerbyana*, *A. hermanni*, *A. scytalis* and *A. spitiensis*, all occurring in the lower member where they form a characteristic association together with *Palaeonucula cuneiformis* and *Grammatodon* (*Indogrammatodon*) *egertonianus* (Fürsich et al. 2021). Apart from the fact that intermediate forms exist between these species, usually two to four of these morphotypes co-occur within individual horizons. On ecological grounds it is highly unlikely that several closely related species with a more or less identical mode of life repeatedly co-occur within a community, and we therefore regard these forms as representing a single species, even though the end members of the morphological range are quite disparate. The oldest available name is *Pruvostiella* (*P.*) *hermanni* (Oppel, 1863).

Several authors (e.g., Cox 1965: 88; Stoliczka 1866; Holdhaus 1913; Gardner and Campbell 2002) assumed that the species occurs also in the Kachchh Basin on the western margin of the Indian Craton where it has been named *Astarte major* by J. de C. Sowerby (1840). However, the Kachchh specimens, although undoubtedly closely related, are more than three times the size of the Himalayan forms and thus unlikely conspecific. Gardner and Campbell (2002, p. 346) placed most of the large astartids from the Tethys Himalaya in *Neocrassina unilateralis* (J. de C. Sowerby, 1840), a view not followed here. *Pruvostiella* (*P.*) *hermanni* occurs from the Tethys Himalaya to New Zealand (Trechmann 1923; Marwick 1953).

The record of *Astarte scytalis* Holdhaus from the Kimmeridgian? of East Africa (Weir 1929, p. 5, pl. 3) is doubtful. The specimen may represent a juvenile *Pruvostiella* (*Eoseebachia*) *major*.

Genus *Nicaniella* Chavan, 1945

Subgenus *Nicaniella* Chavan, 1945

Type species. *Astarte communis* Zittel & Goubert, 1861.

Nicaniella (*Nicaniella*) cf. *polymorpha* (Contejean, 1860)

Plate 5, fig. 7a–d

cf. 1860 *Astarte polymorpha* Contej. – Contejean: 266, pl. 11, figs 13–16.

Material. A single articulated specimen from the lower member, Kaza–Hikkim road (SNSB-BSPG 2020 XCIX 42).

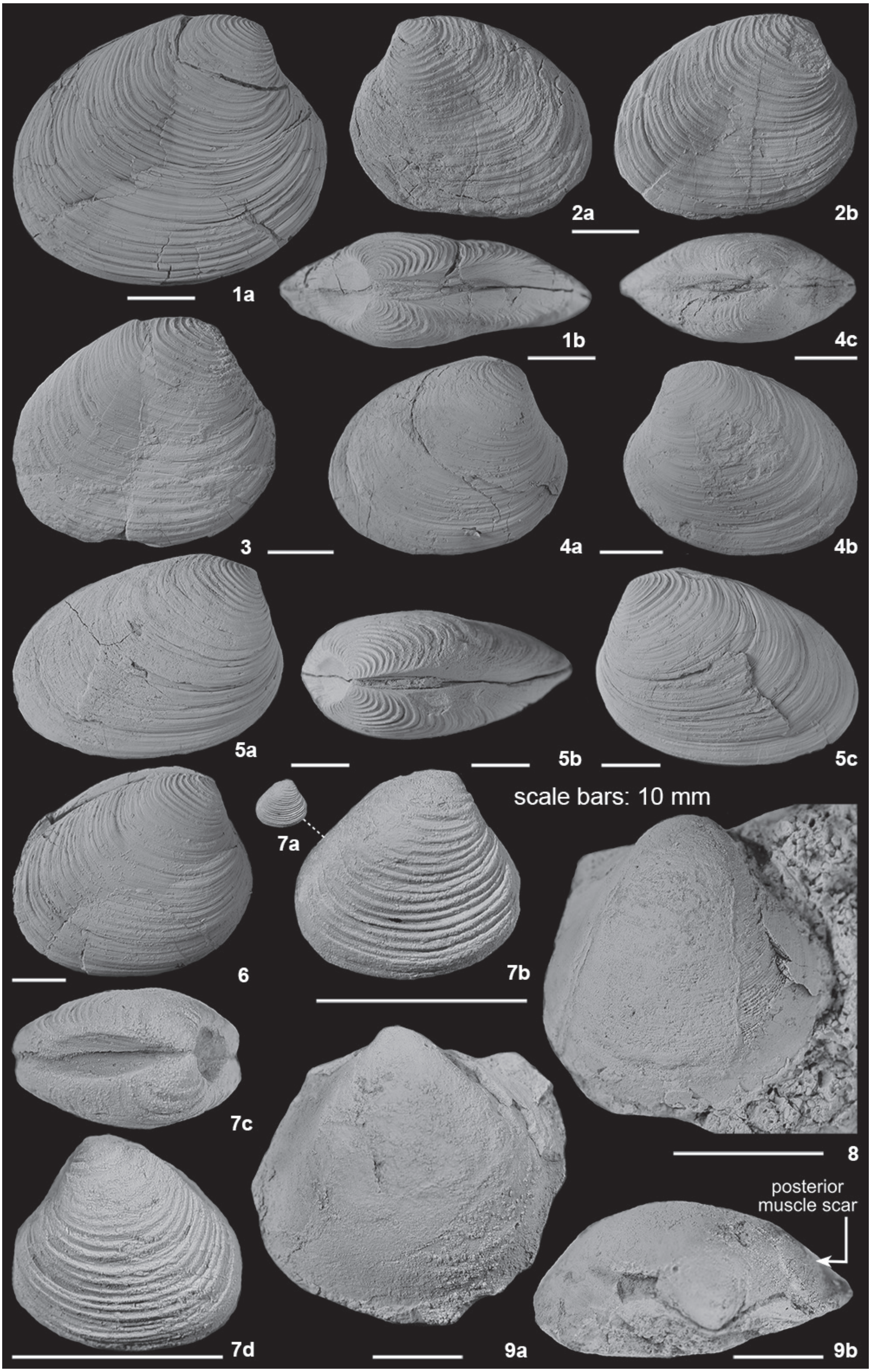

1a
1b
2a
2b
3
4a
4b
4c
5a
5b
5c
6
7a
7b
7c
7d
8
9a
9b
scale bars: 10 mm
posterior
muscle scar

Plate 5. (1–6) *Pruvostiella* (*Pruvostiella*) *hermanni* (Oppel, 1863). **1.** Crushed articulated specimen from the lower member at Langza (SNSB-BSPG 2020 XCIX 53). a, left valve view; b, dorsal view. **2.** Crushed articulated specimen from the lower member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 54a). a, left valve view; b, right valve view. **3.** Crushed articulated specimen from the lower member at the Kaza–Hikkim road cut (SNSB-BSPG 2020 XCIX 55a). **4.** Articulated specimen from the lower member at Langza (SNSB-BSPG 2020 XCIX 59b). a, right valve view; b, left valve view. **5.** Articulated specimen from the lower member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 54b). a, right valve view; b, dorsal view; c, left valve view. **6.** Crushed articulated specimen from the lower member at the Kaza–Hikkim road cut (SNSB-BSPG 2020 XCIX 55b). **(7)** *Nicaniella* (*Nicaniella*) cf. *polymorpha* (Contejean, 1860). Articulated specimen from the lower member at the Kaza–Hikkim road cut (SNSB-BSPG 2020 XCIX 42). a, right valve view, natural size; b, enlarged; c, dorsal view; d, left valve view. **(8)** *Cryptocardia* sp. Right internal mould with remains of shell from the lower member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 40). **(9)** *Integricardium* (*Integricardium*) *bannesianum* (Contejean, 1860). Right internal mould with remains of shell from the Ferruginous Oolite Formation near Zangla (SNSB-BSPG 2020 XCIX 41). a, lateral view; b, dorsal view.

Description. Specimen small-sized (H: 9.1 mm; L: 9.7 mm), rounded-triangular, slightly longer than high, moderately inflated. Anterodorsal margin concave, anteroventral margin convex, ventral margin faintly curved, posterodorsal margin long, straight, sloping, forming a rounded angle with the slightly truncated posteroventral margin. Umbones mesial, conspicuous, prosogyrate. Lunule oval, deeply sunk, bordered by sharp carina. Escutcheon long, lanceolate, sharply demarcated, extending to posterior end. Ventral shell margin strongly crenulated. Shell surface covered with 22 closely set, sharp commarginal ribs which are more widely spaced in the umbonal area. Internal features not seen.

Remarks. Among the numerous Jurassic species of *Nicaniella*, the specimen is closest to *Nicaniella polymorpha* (Contejean,1860: 266, pl. 11, figs 13–16) from the Kimmeridgian of eastern France in outline and ornamentation, but that species is known only from its drawings. Therefore, we place our specimen in this species with reservation.

Order Cardiida Ferrusac, 1822
Family Cardiidae Lamarck, 1809

Genus *Cryptocardia* Palmer, 1974

Type species. *Cryptocardia bajocensis* Palmer, 1974.

Cryptocardia sp.
Plate 5, fig. 8

Material. A single right valve internal mould with remains of shell from the lower member close to the pass to Tashigeng (SNSB-BSPG 2020 XCIX 40).

Description. Specimen small, subequilateral, well-inflated, nearly as long as high (H: 17.2 mm; L: 16.6 mm). Umbo mesial, prominent, broad, protruding beyond hinge line, orthogyrate; beaks slightly prosogyrate and distinctly incurved. Anterior margin convex, ventral margin broadly arched, posterodorsal margin oblique, nearly straight, grading smoothly into rounded posteroventral margin. Posterodorsal margin forming a rounded shoulder with posterior margin. Two narrow parallel grooves, separated by equally narrow shell interval, extending from posterior side of umbo to posteroventral end of shell. Shell surface covered with fine, dense, commarginal striae. Hinge features not seen.

Remarks. The diagnostic feature of *Cryptocardia*, two parallel radial ridges on the inside of the right valve, are clearly seen in the present internal mould as grooves. The genus has been erected by Palmer (1974) based on material from Pliensbachian to Callovian strata. Palmer established four new species based on differences in the outline of the shell and the size of the umbones. The present specimen cannot be accommodated in any of the four species, but is closest to his *C. morrisi* from the Callovian of Tanzania. As only a single specimen is available, we refrain from creating a new species and, instead, keep it in open nomenclature.

Genus *Integricardium* Rollier, 1912

Subgenus *Integricardium* Rollier, 1912

Type species. *Cardium dupinianum* d'Orbigny, 1844.

Integricardium (*Integricardium*) *bannesianum* (Contejean, 1860)
Plate 5, fig. 9

1860 *Cardium bannesianum* Contej. – Contejean: 276, pl. 15, figs 1–5.
1959 *Cardium bannesianum* Contejean – Jaboli: 59, pl. 7, fig. 9.
1995 *Integricardium* (*Integricardium*) *bannesianum* (Contejean 1860) – Jaitly et al.: 115, pl. 12, figs 14–18, text-figs 27–28.

Material. A single right internal mould with remains of shell from the Ferruginous Oolite Formation near Zangla (SNSB-BSPG 2020 XCIX 41).

Description. Specimen relatively small for the species (H: 32 mm), suborbicular, nearly equilateral, moderately inflated. Margins slightly damaged but anterior and posterior margins apparently regularly rounded, ventral margin broadly curved. Umbo mesial, orthogyrate. With very faint posterior umbonal ridge. Shell surface covered with commarginal growth lines but lacking posterior radial striae.

Remarks. The latter feature distinguishes species the genus *Integricardium* from *Protocardia*. The specimen falls in the range of variation of *I.* (*I.*) *bannesianum* and therefore has been placed in that species. According to Dietrich (1933), the closely related *I.* (*I.*) *propebanneianum* (Dietrich, 1933, p. 50, pl. 6, figs 92–93) differs in possessing, in contrast to *I.* (*I.*) *bannesianum*, a pallial sinus, a stronger

Table 4. List of bivalve taxa encountered in the Spiti Shale Formation of the Spiti area.

Palaeonucula cuneiformis (J. de C. Sowerby, 1840)
Palaeonucula stoliczkai Cox, 1940
Megacucullaea cf. *kraussii* (Tate, 1867)
Grammatodon (*Indogrammatodon*) *egertonianus* (Stoliczka, 1865)
Grammatodon (*Cosmetodon*) sp.
Meleagrinella? sp.
Bositra buchii (Roemer, 1836)
Australobuchia spitiensis (Holdhaus, 1913)
Australobuchia blanfordiana (Stoliczka, 1865)
Malayomaorica? sp.
Retroceramus (*Retroceramus*) *haasti* (Hochstetter, 1863)
Retroceramus (*Retroceramus*) *everesti* (Oppel, 1863)
Anopaea? sp.
Entolium (*Entolium*) *corneolum* (Young & Bird, 1828)
Pectinidae indet.
Propeamussium (*Propeamussium*) sp.
Chlamys (*Chlamys*) cf. *textoria* (Schlotheim, 1820)
Radulopecten cf. *fibrosus* (J. Sowerby, 1816)
Spondylopecten (*Plesiopecten*) *subspinosus* (Schlotheim, 1820)
Camptonectes (*Camptochlamys*) *obscurus* (J. Sowerby, 1818)
Gryphaeidae indet.
Plagiostoma? sp. A
Plagiostoma? sp. B
Ctenostreon sp.
Trigonia? sp.
Cryptocardia sp.
Nicaniella (*Nicaniella*) *polymorpha* (Contejean, 1860)
Pruvostiella (*Pruvostiella*) *hermanni* (Oppel, 1863)

Table 5. List of bivalves described by Stoliczka (1866) from the Spiti Shale Formation. Where possible, the taxonomic name has been revised.

Stoliczka (1866)	present taxonomic name
Ostrea sp. (aff. *flabelloides* Lam.)	*Actinostreon*
Pecten lens	*Camptonectes* (*C.*) *lens*
Amusium sp. cf. *Pecten solidus* Trautsch.	*Entolium* (*E.*) *corneolum*
Aucella blanfordiana Stol.	*Australobuchia blanfordiana* (Stoliczka)
Aucella leguminosa Stol.	*Australobuchia leguminosa* (Stoliczka)
Lima sp. (like *L. rigida*)	*Plagiostoma*
Inoceramus hookeri Salter	*Retroceramus*
Macrodon egertonianum Stol.	*Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka)
Nucula sp. (resembling *N. subovalis* Goldf.)	*Palaeonucula*
Nucula cuneiformis Sow.	*Palaeonucula cuneiformis* (J. de C. Sowerby)
Cyprina trigonalis Blanf.	?
Trigonia costata	*Trigonia* (*Trigonia*)
Astarte unilateralis	*Pruvostiella* (*P.*) *hermanni* (Oppel)
Astarte major Sow.	*Pruvostiella* (*P.*) *hermanni* (Oppel)
Astarte spitiensis Stol.	*Pruvostiella* (*P.*) *hermanni* (Oppel)
Astarte hiemalis Stol.	*Pruvostiella* (*P.*) *hermanni* (Oppel)
Homomya tibetica Stol.	*Arcomya*?

posterior umbonal ridge and a less strongly curved ventral margin. A detailed investigation of the type material is required to clarify the relationship of the two species.

Concluding remarks

Most parts of the nearly exclusively siliciclastic Spiti Shale Formation in the Spiti area represent middle to to outer shelf environments. Benthic macroinvertebrates are absent from large parts of the succession, and in other parts they are very rare. The reason are unsuitable conditions at the sea floor, in particular the lack of oxygen, partly caused by upwelling (Fürsich et al. 2021). Most of the fossils occur in the lower member, where a near-monospecific Bositra buchii association and a low-diversity association dominated by *Palaeonucula cuneiformis*, *Grammatodon* (*Indogrammatodon*) *egertonianus*, and *Pruvostiella* (*P.*) *hermanni* are common (Fürsich et al. 2021). All in all, relatively few bivalve taxa occur in the formation, which spans

Table 6. List of bivalve taxa described by Holdhaus (1913) from the Spiti Shale Formation. Where possible, the present taxonomic status has been added. Where no material was available to us, often only a new generic assignment is proposed.

Holdhaus (1913)	present taxonomic status
Avicula spitiensis Oppel, 1863	*Oxytoma*
Pseudomonotis inornata sp. nov.	?
Pseudomonotis amoena sp. nov.	?
Aucella leguminosa Stoliczka, 1866	*Australobuchia leguminosa* (Stoliczka, 1866)
Aucella spitiensis sp. nov.	*Australobuchia spitiensis* (Holdhaus, 1913)
Aucella spitiensis form. typ.	*Australobuchia spitiensis* (Holdhaus, 1913)
Aucella spitiensis grandis nov. form.	*Australobuchia spitiensis*? (Holdhaus, 1913)
Aucella spitiensis superba nov. form.	*Australobuchia spitiensis*? (Holdhaus, 1913)
Aucella blanfordiana Stoliczka, 1866	*Australobuchia blanfordiana* (Stoliczka, 1866)
Aucella? *formosa* sp. nov.	*Australobuchia*?
Inoceramus everesti Oppel, 1863	*Retroceramus everesti* (Oppel, 1863)
Inoceramus gracilis sp. nov.	*Retroceramus everesti* (Oppel, 1863)
Inoceramus stoliczkai sp. nov.	*Anopaea stoliczkai* (Holdhaus, 1913)
Inoceramus cf. *sularum* Boehm, 1907	?
Lima melancholica sp. nov.	*Limatula*?
Lima tristicula sp. nov.	?
Lima roberti Oppel, 1863	*Plagiostoma*
Lima spitiensis sp. nov.	*Plagiostoma*
Pecten inertulus sp. nov.	?
Pecten sp.	?
Ostrea sp.	*Actinostreon*
Nucula spitiensis sp. nov.	*Palaeonucula cuneiformis* (J. de C. Sowerby, 1840)
Nucula hyomorpha sp. nov.	*Palaeonucula cuneiformis* J. de C. Sowerby, 1840)
Nucula kibberiana sp. nov.	*Palaeonucula stoliczkai* Cox, 1940
Nucula sp.	*Palaeonucula*
Nucula dieneri sp. nov.	*Rollieria*
Leda sp.	?
Leda? sp.	?
Arca (*Cucullaea*) *egertoniana* Stoliczka, 1866	*Grammatodon* (*Indogrammatodon*) *egertonianus* (Stoliczka, 1866)
Trigonia spitiensis sp. nov.	*Trigonia* (*Trigonia*)
Astarte hermanni Oppel, 1863	*Pruvostiella* (*P.*) *hermanni* (Oppel, 1863)
Astarte sowerbyana sp. nov.	*Pruvostiella* (*P.*) *hermanni* (Oppel, 1863)
Astarte scytalis sp. nov.	*Pruvostiella* (*P.*) *hermanni* (Oppel, 1863)
Astarte spitiensis Stoliczka, 1866	*Pruvostiella* (*P.*) *hermanni* (Oppel, 1863)
Pleuromya spitiensis sp. nov.	*Pleuromya*
Cosmomya egregia sp. nov.	*Cosmomya egregia* Holdhaus, 1913
Homomya tibetica Stoliczka, 1866	*Arcomya* ?
Goniomya uhligi sp. nov.	*Goniomya*
Pholadomya? *problematica* sp. nov.	?

the time interval between the Callovian and the earliest Cretaceous. In the present account, 24 taxa are described from the Spiti Shale Formation (Table 4), six additional ones from the Ferruginous Oolite Formation. Stoliczka (1866) described 17 bivalve taxa from the two formations, whereby after taxonomic revision only 13 remain valid (Table 5). In the most extensive account published so far, Holdhaus (1913) described 37 bivalve taxa from the Indian Himalayas, chiefly from the Spiti area, of which around 30 remain after sorting out synonymies (Table 6). Some faunal elements, such as *Australobuchia*, *Malayomaorica*, and *Retroceramus*, are also known from the southeastern margin of the Neotethys (e.g., New Zealand, Indonesia). Others, in particular *Provostiella* (*P.*) *hermanni* and *Grammatodon* (*Indogrammatodon*) *egertonianus*, are closely related but not identical to forms from the Kachchh Rift Basin situated at the western margin of the Indian Craton.

Acknowledgments

We thank Jörg Habermann, Suraj Bhosale, and Chaskar Ketan for assisting us in the field and the Alexander von Humboldt Foundation for financial support in the framework of their Research Group Linkage Programme. MA thanks the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDB26000000) and the Second Tibetan Plateau Scientific Expedition and Research of the Ministry of Science and Technology of China (2019 QZKK0706) for financial support. The manuscript benefitted by the constructive reviews of Baran Karapunar, Munich, and Simon Schneider, Cambridge.

References

Agrawal SK (1956a) Contribution à l'étude stratigraphique et paléontologique du Jurassique du Kutch (Inde). Annales du Centre d'Études et de Documentation Paléontologiques 19: 1–188.

Agrawal SK (1956b) Sur un nouveau sous-genre et deux espèces nouvelles d'*Astarte* du Jurassique de Kutch (Inde). Bulletin de la Société géologique de France, sér. 6, 5: 433–439. https://doi.org/10.2113/gssgfbull.S6-V.7-9.433

Agrawal SK (1956c) Deux lamellibranchs intéressants de la série de Katrol dans le Kutch (Inde). Bulletin de la Societé géologiques de France, sér. 6, 6: 13–19. https://doi.org/10.2113/gssgfbull.S6-VI.1-3.13

Alberti M, Fürsich FT, Pandey DK, Andersen N, Garbe-Schönberg D, Bhosale S, Chaskar K, Habermann JM (2021) First record of stable isotopes ($\delta^{13}C$, $\delta^{18}O$) and element ratios (Mg/Ca, Sr/Ca) of Middle to Late Jurassic belemnites from the Indian Himalayas and their potential for palaeoenvironmental reconstructions. Journal of Palaeogeography 10: e24. https://doi.org/10.1186/s42501-021-00103-2

Auerbach J, Frears H (1846) Notices sur quelques passages de l'ouvrage de M. Murchison, E. de Verneuil et le Comte A. de Keyserling: Géologie de la Russie d'Europe et des montagnes de l'Oural. Bulletin de la Société Impériale des Naturalistes de Moscou 19: 486–506.

Barrabé L (1929) Contribution à l'étude stratigraphique et pétrographique de la partie médiane du pays Sahalave (Madagascar). Mémoires de la Société Géologique de France, Nouvelle Série, no. 12, 5(3–4): 1–270.

Basse É (1930) Contribution à l'étude du Jurassique supérieur (Faciès Corallien) en Éthiopie et en Arabie Méridionale. Mémoires de la Société Géologique de France, nouvelle série, 6 (3–4), no. 14: 105–148.

Blanford HP (1864) On Dr. Gerard's collection of fossils from the Spiti Valley, in the Asiatic Society's Museum. Journal of the Asiatic Society of Bengal 32: 124–138.

Bouchet P, Rocroi J-P, Bieler R, Carter JG, Coan EV (2010) Nomenclator of bivalve families with a classification of bivalve families. Malacologia 52: 1–184. https://doi.org/10.4002/040.052.0201

Cariou E, Enay R, Alméras Y (1996) Découverte d'une faune d'ammonites callovienne dans les Spiti Shales himalayens à Spiti et chronostratigraphie compare des successions du Jurassique moyen et supérieur de Spiti et du Népal central (Thakkhola). Comptes Rendus de l'Académie des Sciences Paris 322: 861–868.

Carter JG, Altaba CR, Anderson KC, Araujo R, Biakov R, Bogan AE, Campbell DC, Campbell M, Chen J-H, Cope JCW [and 41 further authors] (2011) A synoptical classification of the Bivalvia (Mollusca). Paleontological Contributions 4: 1–47.

Contejean C (1860) Étude de l'étage Kimméridgien dans les environs des Montbéliard et dans le Jura. Mémoires de la Société d'Emulation du Departement du Doubs, Troisième Série 4: 1–352.

Conti MA, Monari S (1992) Thin-shelled bivalves from the Jurassic Rosso Ammonitico and Calcari a Posidonia formations of the Umbrian-Marchean Apennine (Central Italy). Paleopelagos 2: 193–213.

Cox LR (1935) Jurassic Gastropoda and Lamellibranchia. In: WH MacFayden (Ed.) The geology of British Somaliland. II. Mesozoic paleontology of British Somaliland 8: 148–197.

Cox LR (1937) Notes on Jurassic Lamellibranchia. II. On *Indogrammatodon*, a new subgenus from the Jurassic of the Indo-African province. Proceedings of the Malacological Society 22: 194–198. https://doi.org/10.1093/oxfordjournals.mollus.a064315

Cox LR (1940) The Jurassic lamellibranch fauna of Kachh (Cutch). Memoirs of the Geological Survey of India, Palaeontologica Indica, New Series (9), 3(3): 1–157.

Cox LR (1952) The Jurassic lamellibranch fauna of Cutch (Kachh). No. 3, Families Pectinidae, Amusiidae, Plicatulidae, Limidae, Ostreidae and Trigoniidae (Supplement). Memoirs of the Geological Survey of India, Palaeontologica Indica, New Series (9), 3(4): 1–128.

Cox LR (1965) Jurassic Bivalvia and Gastropoda from Tanganjika and Kenya. Bulletin of the British Museum (Natural History), Geology, Supplement 1: 1–213. https://doi.org/10.5962/p.310409

Cox LR (1969) Family Oxytomidae Ichikawa, 1958. In: RC Moore (Ed.) Treatise on Invertebrate Paleontology, Part N, Mollusca 6, Bivalvia, vol. 1: N344–N3346 Boulder (Geological Society of America), and Lawrence (University of Kansas Press).

Crame JA (1981) The occurrence of *Anopaea* (Bivalvia: Inoceramidae) in the Antarctic Peninsula. Journal of Molluscan Studies 47: 206–219.

Crame JA (1982) Late Jurassic inoceramid bivalves from the Antarctic Peninsula and their stratigraphic use. Palaeontology 25: 555–603.

Crame JA (1993) Bipolar molluscs and their evolutionary implications. Journal of Biogeography 20: 145–161. https://doi.org/10.2307/2845668

Crampton JS (1988) Comparative taxonomy of the bivalve families Isognomonidae, Inoceramidae and Retroceramidae. Palaeontology 31: 965–996.

Defrance JML, Blainville H-MD (1825) Manuel de Malacologie et de Conchyliologie. Paris (FG Levrault), 664 pp. https://doi.org/10.5962/bhl.title.11582

De Gregorio A (1884) Nota intorno ad alcune nuove conchiglia mioceniche de Sicilia. Il Naturalista Siciliano 3: 119–120.

Diener C (1895) Ergebnisse einer geologischen Expedition in den Central-Himalaya von Johar, Hundes und Painkhanda. Denkschriften der kayserlichen Akademie der Wissenschaften, Mathematisch-Naturwissenschaftliche Classe 2: 533–608.

Dietrich WO (1933) Zur Stratigraphie und Paläontologie der Tendaguru-Schichten. Palaeontographica, Supplement 7, Reihe 2: 1–86.

Everest R (1833) Memorandum on the fossils shells discovered in the Himalayan Mountains. Asiatic Researches 18: 107–114.

Fleming CA (1959) *Buchia plicata* (Zittel) and its allies, with a description of a new species, *Buchia hochstetteri*. New Zealand Journal of Geology and Geophysics 2: 889–904. https://doi.org/10.1080/00288306.1959.10422755

Fürsich FT, Heinze M, Jaitly AK (2000) Contributions to the Jurassic of Kachchh, western India. VIII. The bivalve fauna. Part IV. Subclass Heterodonta. Beringeria 27: 63–146.

Fürsich FT, Alberti M, Pandey DK, Chaskar K, Bhosale S (2021) Facies analysis and palaeoecology of the Jurassic Spiti Shale Formation in the Spiti area, Northern India. Journal of Palaeogeography 10: 438–462.

Grant CW (1840) Memoir to illustrate a geological map of Cutch. Transactions of the Geological Society London, 2nd ser., 5: 289–329. pls. 21–26; London (With appendix A systematic list of organic remains, the plants determined by Mr. John Morris, and the remainder by Mr. James de Carl Sowerby, and plate captions by J. de C. Sow., 327–329). https://doi.org/10.1144/transgslb.5.2.289

Griesbach CL (1891) Geology of the Central Himálayas. Memoirs of the Geological Survey of India, Palaeontologia Indica 23: 1–232.

Gou Z, Li XC (1983) Preliminary investigation of Jurassic bivalve fauna in Nyalam county, Xizang (Tibet). Contribution to the geology of the Qinghai-Xizang (Tibet) Plateau 11: 199–230. [In Chinese]

Gu Z, Huang B, Chen C, Wen S, Ma Q, Lan X, Xu J, Liu L, Wang D, Qiu R, Huang Z, Zhang Z, Chen J, Wu P (1976) Fossil Lamellibranchiata of China. Science press, Beijing, 522 pp. [In Chinese]

Hall J (1852) Palaeontology of New-York: Containing descriptions of the organic remains of the lower middle division of the New-York system. Albany (C. van Benthuysen), 362 pp.

Hennig E (1924) Der mittlere Jura im Hinterlande von Daressalaam (Deutsch-Ostafrika). Monographien zur Geologie und Paläontologie. Serie 2 Heft 2: 131 pp., Berlin (Borntraeger).

Herbert JD (1833) On the organic remains in the Himalaya. Gleanings in Science 3: 265–272.

Hermann J (1781) Brief über einige Petrefacten.. Der Naturforscher 15: 115–134.

Hikuroa D, Grant-Mackie J (2008) New species of Late Jurassic *Australobuchia* (Bivalvia) from the Murihiku Terrane, Port Waikato–Kawhia region, New Zealand. Alcheringia 32: 73–98. https://doi.org/10.1080/03115510701757555

Hochstetter F von (1863) Neu-Seeland. Stuttgart (Cotta), 555 pp.

Holdhaus K (1913) Fauna of the Spiti Shales (Lamellibranchiata and Gastropoda). Memoirs of the Geological Survey of India, Palaeontologia Indica Series 15, 5, Part 2, Fasc. No. 4: 397–456.

Holub E, Neumayr M (1882) Über einige Fossilien aus der Uitenhage-Formation in Süd-Afrika. Denkschriften der Kaiserlichen Akademie der Wissenschaften Wien, mathematisch-naturwissenschaftliche Classe 44: 267–276.

Jaboli D (1959) Fossili giurassici dell' Harar (Africa Orientale). Brachiopodi, Lamellibranchi e Gasteropodi. Missione Geologica dell' Azienda Generale Italiana Petroli (A.G.I.P.) nella Dancalia Meridionale e sugli Altipiani Hararini (1936–1938), vol. 4, Documentazione Paleontologica, parte prima. Roma, Accademia Nazionale dei Lincei: 2–100.

Jaitly AK, Fürsich FT, Heinze M (1995) Contributions to the Jurassic of Kachchh, Western India. IV. The bivalve fauna. Part I. Subclasses Palaeotaxodonta, Pteriomorphia.., and Isofilibranchia. Beringeria 16: 147–257.

Johnson ALA (1984) The palaeobiology of the bivalve families Pectinidae and Propeamussiidae in the Jurassic of Europe. Zitteliana 11: 3–235.

Kanjilal S (1979) Jurassic *Camptonectes* (Bivalvia) from the Habo Hill, District Kutch, Gujarat, W. India. Journal of Molluscan Studies 45: 115–124.

Kanjilal S (1980) Studies on Jurassic Nuculids (Bivalvia) from the Habo Hill, District Kutch, Gujarat. Proceedings of the 3rd Indian Geological Congress, Poona: 331–346.

Kanjilal S (1981) On some pteriomorph and heterodont Bivalvia from the Jurassic rocks of Habo Hill, District Kutch (Gujarat), W. India. Proceedings of the National Science Academy 46: 264–286.

Kanjilal S, Pathak DB (1998) Spiti Shale bivalves from Chichim and Gate, Spiti Valley, Himachal Pradesh, India. Himalayan Geology 19: 29–37.

Keyserling AA, Middendorf A (1848) Fossile Mollusken. Reise in den äusserten Norden und Osten Sibiriens 1(1): 1–20.

Kitchin FL (1903) The Jurassic fauna of Cutch. The Lamellibranchiata, genus *Trigonia*. Memoirs of the Geological Survey of India, Palaeontologica Indica, series 9, 3, pt. 2, (1): 1–122.

Knight RI, Morris NJ (2019) Revision of the British Lower Jurassic Arcoidea (Bivalvia): palaeobiological, palaeoecological and evolutionary implications. Historical Biology 32(9): 1176–1205. https://doi.org/10.1080/08912963.2019.1575373

Krauss F (1850) Über einige Petrefacten aus der Unteren Kreide des Kaplandes. Nova Acta Academiae Caesareae Leopoldino-Carolinae Germanicae Naturae Curiosorum 22: 439–464.

Krishna J (1983) Callovian–Albian ammonoid stratigraphy and palaeobiogeography in the Indian sub-continent with special reference to the Tethys Himalaya. Himalayan Geology 11: 43–72.

Krumbeck L (1923) Brachiopoden, Lamellibranchiaten und Gastropoden aus der oberen Trias der Insel Seran (Mittel-Seran). Palaeontographica, Supplement 4(3): 185–246.

Li X, Grant-Mackie JA (1988) Upper Jurassic and Lower Cretaceous *Buchia* (Bivalvia) from southern Tibet, and some wider considerations. Alcheringia 12: 249–268. https://doi.org/10.1080/03115518808619127

Marwick J (1953) Divisions and faunas of theHokonui system (Triassic and Jurassic). New Zealand Geological Survey Paleontological Bulletin 21: 1–141.

Maithani JBP (1968) Some new species of the Jurassic gastropods and lamellibranchs from the Habo Dome, Kutch and their usefulness in correlation. Records of the Geological Survey of India 95: 491–522.

Meek FB (1865) Description of fossils from the auriforous slates of California. Geological Survey of California, Geology 1: 477–482.

Morris J, Lycett J (1851–1855) A monograph of Mollusca from the Great Oolite. Palaeontographical Society Monographs 1, (1851) Univalves: 1–130; 2, (1853) Bivalves: 1–80; 3, (1855) Bivalves: 81–147.

Müller CF (1776) Zoologiae Danicae PÜrodromus, seu Animalium Daniae et Norvegiae Indigenarum, characteres, nomina et synonyma imprimis popularium. Copenhagen, 282 pp. https://doi.org/10.5962/bhl.title.63795

Newton RB, Crick GC (1908) On some Jurassic Mollusca from Arabia. Annals and Magazine of Natural History, Series 8, 2: 1–29. https://doi.org/10.1080/00222930808692446

Nicolai M (1950–1951) Paléontologie de Madagascar. XXIX. Étude de quelques gisements fossilifères du sud-ouest de Madagascar. Annales de Paléontologie 36: 141–168 (1950); 37: 1–46 (1951).

Oppel A (1863) Ueber ostindische Fossilreste aus den secundären Ablagerungen von Spiti und Gnari-Khorsum in Tibet. Palaeontologische Mittheilungen aus dem Museum des Königlichen Bayerischen Staates, no. IV: 267–304. https://doi.org/10.5962/bhl.title.15040

Orbigny A d' (1844) Paléontologie francaise terrains crétacés. 3 Mollusques. Paris (G. Masson), 807 pp.

Orbigny A d' (1850) Prodrome de Paléontologie stratigraphique universelle des animaux mollusques et rayonées. Paris (G. Masson), 1: 394 pp.; 2: 428 pp.

Oschmann W (1994) Adaptive pathways of benthic organisms in marine oxygen-controlled environments. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 191: 393–444.

Oschmann W (1995) Black shales models: an actualistic approach. Europal 8: 26–35.

Palmer CP (1974) A new genus of Jurassic bivalve mollusc ancestral to *Globocardium*. Palaeontology 17: 165–178.

Pandey B, Pathak DB, Krishna J (2013) Preliminary remarks on new ammonoid collection from freshly exposed succession of the Spiti Formation between Lidang and Giumal, Spiti Valley, Himachal Himalaya, India. Himalayan Geology 34: 124–134.

Pandey DK, Agrawal SK (1984) Bathonian – Callovian Molluscs of Gora Dongar, Pachchham "Island" District Kachchh, Gujarat). Quarterly Journal of the Geological Mining & Metallurgical Society of India 56: 176–196.

Pathak DB, Krishna J (1993) Preliminary remarks on the biostratigraphic relevance of the ammonoid collections from Spiti Shale Formation, Tethys Himalaya, India. Himalayan Geology 16: 207–221.

Phillips J (1829) Illustrations of the geology of Yorkshire. York (Wilson), 192 pp.

Quenstedt FA (1851) Handbuch der Petrefactenkunde. Tübingen (Laupp & Siebeck), 1: 528 pp.

Quenstedt FA (1858) Der Jura. Tübingen (Laupp), 823 pp.

Roemer FA (1835–1836, 1839) Die Versteinerungen des norddeutschen Oolithen-Gebirges. Hannover, Hahn, 1. Lfg.: I–VI + 1–74 (1835); 2. Lfg.: 75–134 (1836); 3. Lfg.: 135–218 (1836); Nachtrag: I–IV, 1–59 (1839).

Salter JW, Blanford HP (1865) Jurassic Gasteropoda and bivalves. In: Salter JW, Blanford HP. Palaeontology of Niti in the northern Himalaya I. Descriptions of the Palaeozoic and Secondary fossils: 89–111, Calcutta (O.T. Cutter Military Orphan Press).

Schlotheim EF von (1820) Die Petrefactenkunde. Gothenburg (Bekker), 437 pp.

Singh CSP, Jaitly AK (1983) Studies on the Jurassic pectinid clams from Kaladongar Hill, Pachchham Island, Kachchh. Journal of the Palaeontological Society of India 28: 43–49. https://doi.org/10.1127/njgpm/1983/1983/91

Sowerby J (1812–1822) The Mineral Conchology of Great Britain. 1(1): 9–32 (1812); 1(2): 33–96 (1813); 1(3): 97–178 (1814); 179–236 (1815); 2(1): 1–28 (1815); 2(2): 29–116 (1816); 2(3):117–194 (1817); 2(4): 195–239 (1818); 3(1): 1–40 (1818); 3(2): 41–98 (1819); 3(3): 99–126 (1820); 3(4): 127–186, 4(1): 1–16 (1821); 4(2): 17–104 (1822), London (Meredith).

Sowerby J de C (1840) see Grant (1840).

Stefanini G (1925) Description of fossils from South Arabia and British Somaliland. In: OH Little (Ed.) The Geography and Geology of Makalla (South Arabia). Geological Survey of Egypt, Cairo: 143–221.

Stefanini G (1939) Molluschi dell Giuralias della Somalia. Gasteropodi e Lamellibranchi. Palaeontographica italica 32(Supplement 4): 203–270.

Stoliczka F (1866) Geological sections across the Himalayan Mountains from Wangtu Bridge on the River Sutlej to Sungdo on the Indus, with an account of the formations in Spiti, accompanied by a revision of all known fossils from that district. Memoirs of the Geological Survey of India 5: 1–154.

Tate R (1867) On some Secondary fossils from South Africa. Quarterly Journal of the Geological Society 23: 139–175. https://doi.org/10.1144/GSL.JGS.1867.023.01-02.24

Trechmann CT (1923) The Jurassic rocks of New Zealand. Quaterly Journal of the Geological Society London 79: 243–312. https://doi.org/10.1144/GSL.JGS.1923.079.01-04.16

van Hinsbergen DJJ, de Groot LV, van Schalk SJ, Spakman W, Bijl PK, Sluijs A, Langereis C, Brinkhuis H (2015) A paleolatitude calculator for paleoclimate studies. PLoS ONE 10: e0126946. https://doi.org/10.1371/journal.pone.0126946

Weir J (1929) Jurassic fossils from Jubaland, East Africa, collected by V.G. Glenday, and the Jurassic geology of Somaliland. Monographs of the Geological Department of the Huntarian Museum, Glasgow University no. 3: 1–63.

Weir J (1930) Mesozoic Brachiopoda and Mollusca from Mombasa. Monographs of the Geological Department of the Huntarian Museum, Glasgow University no. 4: 77–102.

Weir J (1939) The Jurassic faunas of Kenya with descriptions of some Brachiopoda and Mollusca. Monographs of the Geological Department of the Huntarian Museum, Glasgow University no. 5: 21–60.

Wen S, Lan X, Chen J, Zhang Z, Chen C, Gu Z (1976) Fossil Lamellibranchs from Mt. Qomolangma region: Report of Scientific Expedition to the Mt. Qomolongma region (1966–1968). Palaeontology 3: 1–152. [Beijing (Science Press)] [in Chinese with English abstract]

Xia Z, Bai Z (2005) Recent approach to *Buchia* biostratigraphy from ntethyan Himalaya area. Daxue Xuebao 41: 523–529.

Young G, Bird J (1828) A geological survey of the Yorkshire coast. Whitby (Clark), 235 pp.

Zell P, Crame JA, Stinnesbeck W, Beckmann S (2015) The bivalve *Anopaea* (Inoceramidae) from the Upper Jurassic–lowermost Cretaceous of Mexico. Journal of South American Earth Sciences 60: 92–103. https://doi.org/10.1016/j.jsames.2015.03.004

Zhakharov VA (1981) Buchiidae and the biostratigraphy of the boreal Upper Jurassic and Neocomian. Trudy Institut Geologii I Geofizii Sibirskoe Otdelenie, Akademiya Nauk SSSR 45: 1–271. [In Russian]

Zieten CH von (1830–33) Die Versteinerungen Württembergs. (1) 1830: 1–16; (2) 1831: 17–32; (3) 1832: 33–64; (4) 1833: 65–96, Stuttgart.

Zittel KA von (1864) Fossile Mollusken und Echinodermen aus Neu-Seeland. Reise der Osterreichischen Fregatte "Novara" urn die Erde, Geol. Theil 1(2): 17–68.

Zittel KA von, Goubert E (1861) Déscription des fossiles du Coral-rag de Glos (Calvados): Lamellibranchiata et Gasteropoda. Jounal de Conchyliologie 9: 192–208, 373–374.