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First Ordovician chitinozoans from Indian Gondwana — New evidence from the Shiala Formation

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ABSTRACT

The Shiala Formation of the Garhwal-Kumaon subbasin of the Tethyan Himalaya, has been sampled for chitinozoans in the Chamoli district of Uttarakhand, India. The greenish gray colored silty shale at the lower horizon of Shiala Formation yielded a relatively rich though poorly diverse assemblage of chitinozoans. The chitinozoans are mostly acceptably well-preserved. The assemblage is dominated by two species, i.e. *Belonechitina capitata* and *Belonechitina micracantha* with rare specimens of *Conochitina chydaea*. These microfossils are very poorly documented from the low-latitudinal part of Gondwana and this is the first time that they are reported from this part of globe. The chitinozoan data are from below the Ordovician–Silurian boundary as indicated by an acritarch study from the same section, which is in agreement with our identification of the species that suggest a Mid to Late Ordovician age.

1. Introduction

The Lower Paleozoic sequence of the study area in northern India is known as the Tethyan Himalaya or 'Tethys Himalayan Zone' (Fig. 1). Paleogeographic reconstructions (Torsvik and Cocks, 2009) indicate that the area was a part of the Gondwana paleocontinent situated at relatively low paleolatitudes, i.e. at ~25 to 30°S during the Ordovician–Silurian. The vast majority of Gondwanan, Lower Paleozoic sites of interest (i.e. yielding fossils and well-dated strata) were then situated at high latitude. So far, the only Gondwanan site located in low latitude to contain Ordovician chitinozoans is from an unspecified collection from the O2 Zone (Arenig) of the Canning Basin of Australia mentioned in an abstract by Achab and Millepied (1980). Here, we introduce Northern India as a second area where we can study low latitude, Lower Paleozoic chitinozoans on Gondwana.

The aim of the study is to test the potential for establishing a biozonation with chitinozoans that eventually could provide a more accurate dating for the different parts of the Shiala Formation and the wider Sumna Group. Chitinozoans have never been reported, without doubt, from India. As a corollary, chitinozoan data from the area, due to its inferred unique position in low-latitudinal Gondwana, could eventually provide important information for paleo-oceanographic reconstructions (Vandenbroucke et al., 2010).

2. Geological setting and stratigraphy

The Tethyan Himalaya sedimentary sequence extends north of the Himadri (Higher Himalaya) along the northern margin of the Indian plate and north of the Main Central Thrust. This marine sedimentary sequence can be traced along the entire length of the Himalaya from Nanga Parbat in the west to Namcha Barwa in the east. Toward the south, it rests on the Central Crystalline Complex of the Indian Shield (Fig. 1) and it consists of five sub-basins (inset in Fig. 1) (Vaidyanadhan and Ramakrishnan, 2008). The Tethyan Himalaya sedimentary sequence is largely continuous from the Precambrian to the Cretaceous, with the exception of the Carboniferous and Permian in the Garhwal region (see below), which are missing. Kumar et al. (1977) attributed the entire Tethyan Himalaya sequence to the Malla Johar Supergroup, and subdivided it into four groups. The present study concerns the Sumna Group which includes, in ascending order, the Garbyang, Shiala, Variegated and Muth formations (Heim and Gansser, 1939). The study area was later mapped by Shah and Sinha (1974) and Sinha (1989), who introduced a fifth formation, the Yong Limestone Formation, between the Shiala and the Variegated Formation (Fig. 2).

Heim and Gansser (1939) described the "Shiala Series" as a 400 to 500 m thick sandy shale with intercalated grayish marly limestones, containing brachiopods and other fossils. Gansser (1964) renamed the

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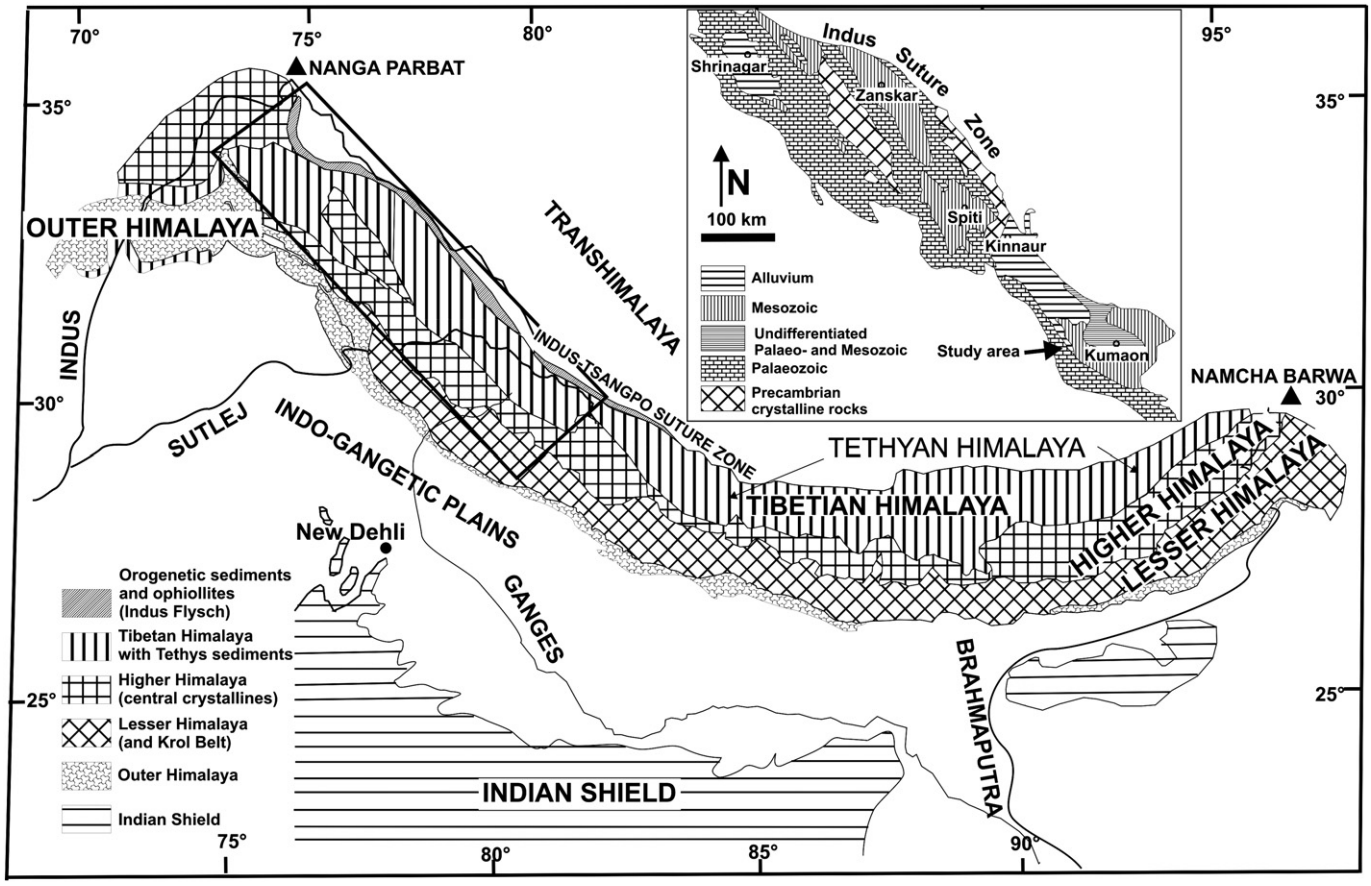

Fig. 1. General map of northern India and surrounding countries, showing the major structural units of the Himalaya from Nanga Parbat to Namcha Barwa and south of the Indus-Tsangspo suture zone. The inset shows the Indian part of the Tethyan Belt with the location of four subbasins with Paleozoic sedimentary sequences belonging to the Tethyan Himalaya (after Gansser, 1964).

unit "Shiala Formation". Shah and Sinha (1974) and Sinha (1989) described the formation as a succession of shales with bands of calcareous arenites and an increasing arenaceous component towards the top. The Shiala Formation's depositional environment ranges from subtidal in the lower part of the formation, to intertidal and shallow-coastal in the upper part (Kumar et al., 1977). It is conformably covered by the Yong Limestone Formation (Fig. 2).

The present study is confined to a segment of one of the five sub-basins of the Tethyan Himalaya: the Garhwal region of the Kumaon sub-basin (inset in Fig. 1). It is situated in the Chamoli district of the Uttarakhand State, in India. Due to the altitude of the study area, varying between 3500 and 6000 m, its upper reaches snow-covered throughout the year, and due to the scarcity of access roads, field-work was limited to the Sumna-Rimkhim section in the Yong Valley. The Lower Paleozoic rocks are well-exposed around Sumna (30°40′N & 80°50′E), near the confluence of the rivers Yong and Kio, Sumna can be reached following a road from Dehradun passing Chamoli and Joshimath to Malari (30°41′ N:79°53′E), and from there on ascending a mule track (inset in Fig. 2).

The Shiala Formation has a rich fauna and flora content, including brachiopods, bryozoans, conodonts and acritarchs. All of these have been used for dating. The lithostratigraphy and faunal content of the formation were established along the Kiogad valley, east of Sumna (Fig. 2) by Sinha (1989).

Shah and Sinha (1974) and Sinha (1989) assigned a Mid to Late Ordovician age to the Shiala Formation based on these four brachiopod or bryozoan assemblage zones: the *Rafinesquina alternata* zone, the *Monotrypa* zone, the *Rafinesquina aranea* zone and the *Orthis* (*Dalmanella*) *testudinaria* zone. It should be mentioned that the biozones were established by Sinha (1989) in the Kiogad section, a few km to the east of the section sampled in the present study.

Goel et al. (1987) collected samples from the basal part of Shiala Formation at 2.350 km west of the Sumna-Taptapani mule track (inset in Fig. 2) and they recovered a large number of conodont elements from their sample ST1. From the succinct description of the sample locality it was, however, not possible for us to locate the sample exactly in the stratigraphy (Fig. 3). Based on the presence of the conodont index species *Amorphognatus tvaerensis* they dated the sediments at that level to the Caradoc, i.e., Sandbian to lower Katian in modern international terminology (Bergström and Leslie, 2010, and references therein).

Khanna and Sah (1983) and Khanna et al. (1985) were the first to mention the presence of chitinozoans and other palynomorphs in the area. Sinha et al. (1996, 1998) recorded rich assemblages of acritarchs from several samples in the Shiala Formation, used to identify three distinct local assemblage zones. The *Baltisphaeridium longispinosum* var. *longispinosum-Multiplicisphaeridrium ornatum* Assemblage Zone (Zone I) established in samples from the Sumna-Rimkhim section, collected between 2.310 and 2.320 km from Sumna along the mule track (inset in Fig. 2), was assigned a Caradoc to early Llandovery age. The *Domasia trispinosa–Deunffia monospinosa* Assemblage Zone (Zone II) was established in samples taken between 2.320 and 2.355 km along the same mule track. The assemblage in their sample R8 was particularly diverse and rich. Time ranges of different species of the genera *Domasia*, *Deunffia* and *Geron* restrict the age of this level to Llandovery-Wenlock. The Ordovician–Silurian boundary therefore should be located high within the Shiala Formation itself, i.e. lower than thought up-until-then. A third assemblage zone in the upper part of the Shiala Formation was dated as Wenlock to early Ludlow and the overlying Yong Limestone Formation containing a fourth assemblage zone was dated to the early Ludlow. They also mentioned the presence of chitinozoans (Sinha et al., 1996, 1998).

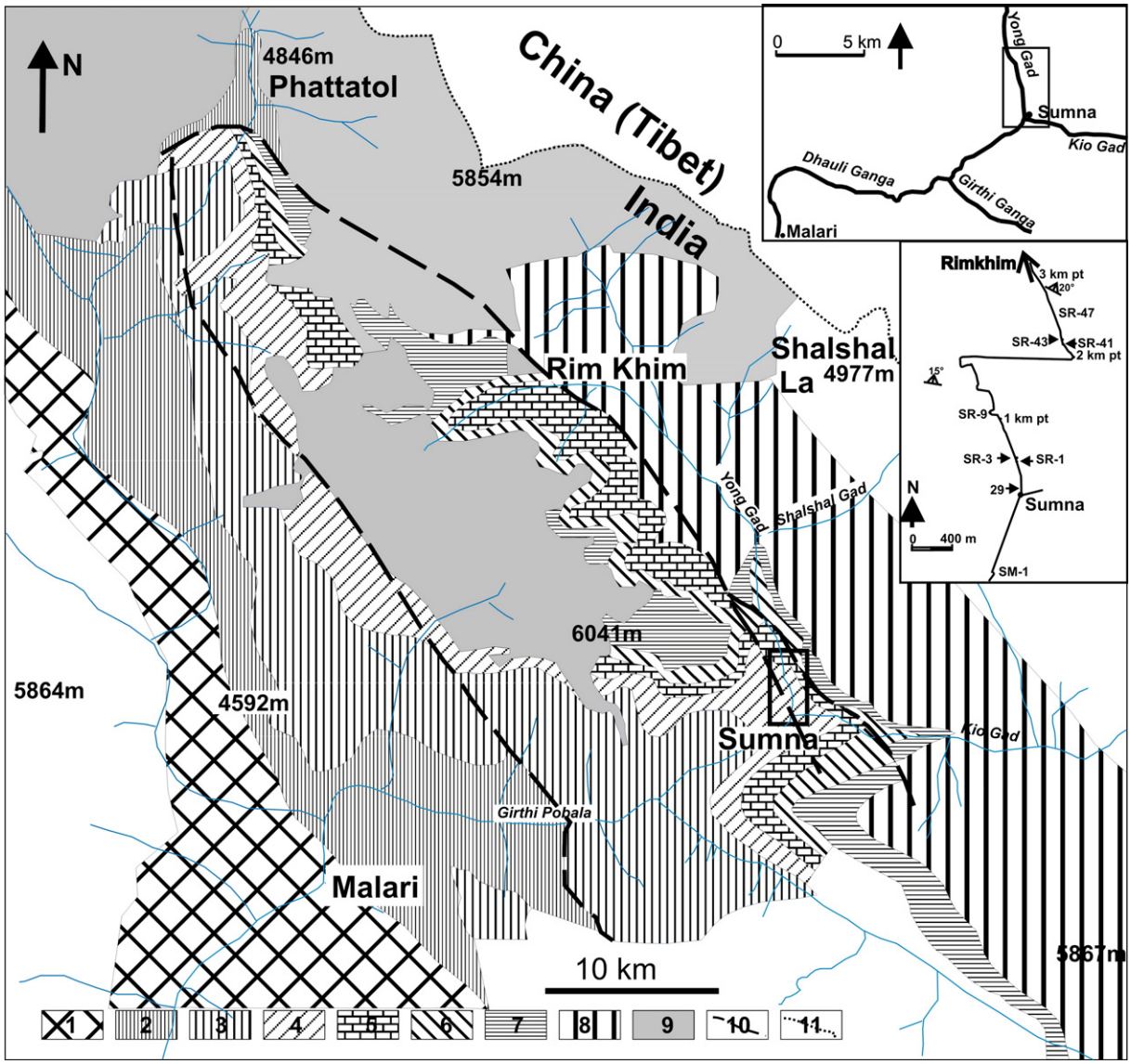

Fig. 2. Geological map of the Malari-Sumna-Rhimkim-Lapthal area of the Thethyan sedimentary sequence of Higher Garhwal Himalaya, India (after Sinha, 1989). Upper inset: Road map from Malari to Sumna. Lower inset: Location of the sampling sites in the section on Sumna-Rimkhim mule track along the Yong river in kilometers uphill starting from Sumna. 1: Vaikrita Group; 2: grouping of the Ralam Formation and the Martoli Group, plus the Cenozoic Tourmaline Granite; 3: Garbyang Formation; 4: Shiala Formation; 5: Yong Limestone Formation; 6: Variegated Formation; 7: Muth Quarzite formation; 8: grouping of Sangcha Malla Formation, Giumal Sandstone formation, Spiti Shale formation, Lapthal Formation, Kioto Formation, Kalapani Limestone/Kuti Formation and the Kuling Shale-Fenestella Shale formation. 9: glaciers; 10: faults; 11: international border.

3. Methods and materials

The samples for this chitinozoan study were collected by one of us (H.N. Sinha) in the Shiala Formation in 2005 and 2009. The six samples analyzed are taken from outcrops exposed in the Yong Gad valley, north-north-west of the confluence of the Yong and the Kio rivers at the locality Sumna (Fig. 2). More specifically, the sampled localities along the Sumna-Rimkhim mule track section (sample number starting with SR), are measured in distance from Sumna, using the existing milestones along the track: SR1 at 0.500 km; SR3 at 0.525 km; SR9 at 1.230 km; 29 is taken below sample SR1 (very close to the confluence of Yong and Kio rivers — Fig. 2); SR41 at 2.200 km and SR43 at 2.228 km. The sample SM1 is collected along the Sumna-Malari mule track. The position of the samples along the mule track is shown in the inset in Fig. 2 and their position in the lithostratigraphical column in Fig. 3.

About 30 g of rock has been processed following the standard procedure for chitinozoans extraction described by Paris (1981). The figured specimens are stored in the collections of the Department of Geology and Soil Science of Ghent University, rock samples and the permanent palynological slides are stored in the Department of Geology of Vinoba Bhave University.

3.1. Results from the chitinozoans and discussion

In samples SM 1, SR3, SR9, SR 47 and SR 50 no organic-walled microfossils were found and sample 29 yielded only a poorly preserved chitinozoan, as well as numerous melanosclerites. Out of nine dissolved samples, only three were productive. Sample SR1 contains a large number of chitinozoans (17 chitinozoans per gram of rock), whereas sample SR41 and SR43 produced a small amount of chitinozoans (1–2 chitinozoans per gram of rock) (see Table 1). The chitinozoans are moderately well-preserved and some specimens preserved their three-dimensional form. However, early diagenetically grown pyrite has often destroyed the finer features of the tegument ornamentation. The three samples SR1, SR41, SR43 contain the same, poorly diverse chitinozoan assemblage. It is dominated by two species, *Belonechitina capitata* and *Belonechitina micracantha* (Plate I).

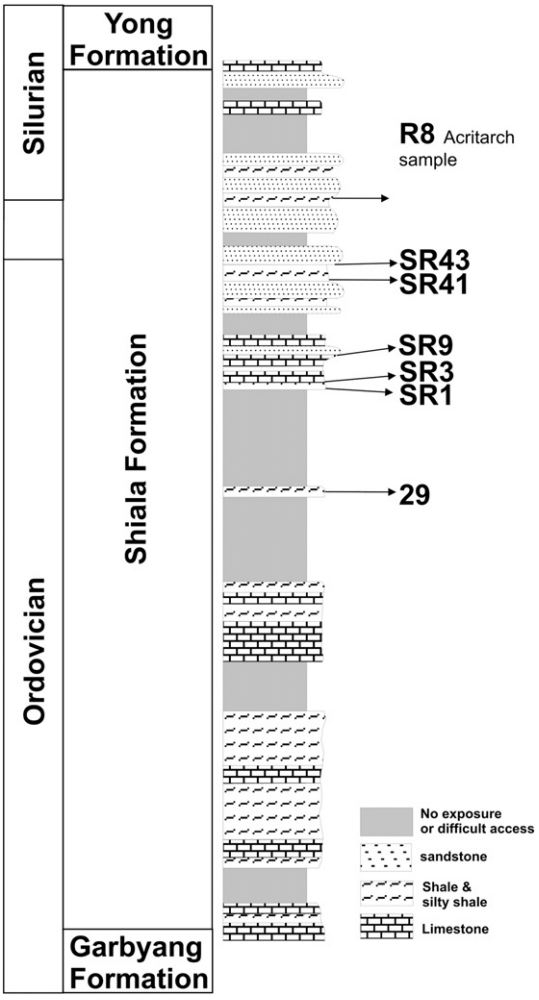

Fig. 3. Lithostratigraphical column of the Shiala Formation and surrounding units, with location of the three productive samples and sampling levels mentioned in the text.

The first species, *Belonechitina capitata*, has, according to Nõlvak and Grahn (1993), a time range from the upper Darriwillian to Lower Sandbian. Nõlvak (2006, 2008) extends its time range well into Katian. Vandenbroucke (2008a) and Vandenbroucke et al. (2005, 2008, 2009) reported it from the Caradoc of Avalonia, and Paris (1990) from the Upper Ordovician of Gondwana (also see Oulebsir and Paris, 1990). The second species, *Belonechitina micracantha*, is a (stratigraphically and spatially) wide ranging species, reported in largely the same time range. The obtained chitinozoan age is consistent with the conodont data (Goel et al., 1987) and with the position of the Ordovician–Silurian boundary, inferred to lie below sample R8 based on acritarch data (Sinha et al., 1998) (Plate I).

Conochitina chydaea from the sample SR 41 and SR 43 is only found in low numbers. This species has been reported a.o. from the Upper Ordovician in Britain (Vandenbroucke, 2008b). As always, when recovered from assemblages with preservation issues, this 'smooth' species may in fact represent poorly-preserved spiny belonechitinids, e.g. *B. micracantha*, with which they share the same general vesicle morphology.

A single poorly preserved specimen of *Angochitina* is reported, although it could also belong to the genus *Nevadachitina*.

4. Conclusions

We document the first undisputable evidence for the occurrence of Ordovician chitinozoans in India and low-latitudinal Gondwana. Our data therefore illustrate the potential to further use this group in the area. Chitinozoans date the Shiala Formation to the Mid to Late Ordovician. This is in agreement with previous conodont and shelly fauna information, and acritarch data from higher in the section.

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Table 1
List of the chitinozoan species, concentration and weight of rock dissolved per productive sample in the Sumna-Rimkhim section.

Formation	Sample number	Km along mule track from Sumna	Palynological preparation number	*Belonechitina capitata*	*Belonechitina micracantha*	*Transitional forms Belonechitina capitata and B. micracantha*	*Belonechitina spp.*	*Conochitina chydaea*	*Conochitina spp.*	*Conochitinidae*	*Angochitina spp.*	*Chitinozoa indet.*	Total number of chitinozoans	Total weight dissolved rock (g)	Number of chitinozoans per gram of dissolved rock
Shiala Fm.	SR 43	2.228 km	08-2033 + 09-2178	4	0	2	1	3	5	0	1	6	22	31.1	0.7
	SR 41	2.200 km	08-2032 + 09-2177	8	4	7	9	2	22	2	1	9	64	31.3	2
	SR 1	0.500 km	08-2026 + 09-2176	64	53	31	10	0	2	4	0	0	494	29.5	16.8
	29	Just north of Sumna	10-2249	0	0	0	1	0	0	0	0	0	1	10.0	0.1

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Plate I. *Belonechitina micracantha* & *Belonechitina capitata*. All measurements in micrometers (L×Dp, or L×Dp×Dc). For abbreviations, see Paris (1981): L — total length, Dp — chamber diameter, Dc — diameter of oral tube, Lc — length of oral tube. (see page 122)

1. *Belonechitina micracantha* (sample SR1); 150×65×42.
2. *Belonechitina micracantha* (sample SR1); 158×78×48.
3. *Belonechitina micracantha* (sample SR1); 141×65×43.
4. *Belonechitina micracantha* (sample SR1); 160×88×55.
5. *Belonechitina micracantha* (sample SR1); 158×78×53.
6. *Belonechitina micracantha* (sample SR1); 238×83×58.
7. *Belonechitina micracantha* (sample SR1); 192×96×56.
8. *Belonechitina capitata* (sample SR1); 225×52×40.
9. *Belonechitina capitata* (sample SR1); 148×70.
10. *Belonechitina capitata* (sample SR1); 132×66.
11. *Belonechitina capitata* (sample SR1); 169×60.
12. *Belonechitina capitata* (sample SR1); 130×73.
13. *Belonechitina capitata* (sample SR1); 118×68.
14. *Angochitina sp.* (sample SR43); 126×55×45.

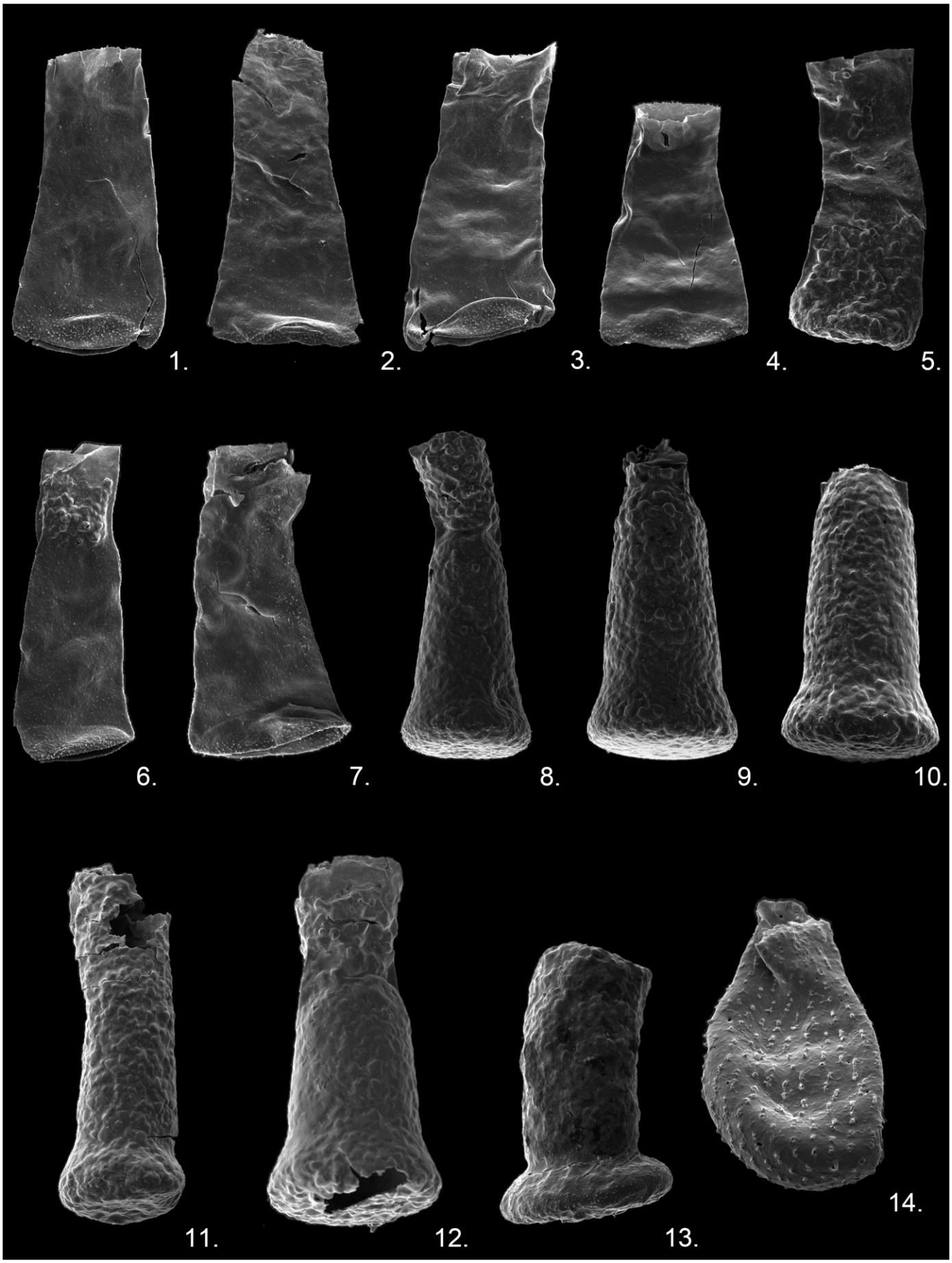

Plate I. (*caption on page 121*).