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An Oligocene non-marine ostracod fauna from the Basgo Formation (Ladakh Molasse), NW Himalaya, India

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ABSTRACT – A small fauna of three species of non-marine cypridacean Ostracoda has been recovered from the Basgo Formation of the Ladakh Molasse in the North Western Himalaya, India. All three species are new and are described herein. They are: *Dongyingia sannionis* sp. nov., *Candona himalaica* sp. nov. and *Eucypris alpina* sp. nov. Previous palaeontological data from the Basgo Formation, although embracing a number of vertebrate and invertebrate groups and also charophytes, have been rather poor and have not allowed anything other than a somewhat conjectural age determination. However, the genus *Dongyingia* is only known elsewhere from the Upper Oligocene of China, where it is an abundant and characteristic component of non-marine sequences. The overall excellent preservation of the Ostracoda in this study militates against their having been derived and, thus, provides good evidence for a Late Oligocene age for the Basgo Formation. *J. Micropalaeontol.* **23**(1): 3–9, May 2004.

INTRODUCTION

This paper describes, for the first time, a small assemblage of ostracods from the molasse deposits in the zone of collision between India and Asia (Indus Suture Zone), in the Ladakh region of NW Himalaya. These molasse deposits (referred to variously as the Ladakh Molasse Group/Indus Molasse/Indus Group) occur in an approximately 2000 km long arcuate belt along the southern margin of the Transhimalayan magmatic arc, extending eastwards from Kargil township through Nyoma in eastern Ladakh into South Tibet. Palaeontological data from the Ladakh Molasse deposits are scanty and limited largely to vertebrates (e.g. Dixit *et al.*, 1971; Savage *et al.*, 1977; Sahni *et al.*, 1984; Nanda & Sahni, 1990, 1998; Kumar *et al.*, 1996). Freshwater molluscs remain the only invertebrates so far described (Stoliczka, 1874; Lydekker, 1883; De Terra, 1935; Sahni & Bhatnagar, 1962; Tewari & Dixit, 1971; Mathur, 1983), while the only palynological investigations have been carried out by Bhandari *et al.* (1977). It is important to note that most of the available palaeontological data on the Ladakh Molasse come from the Kargil area in western Ladakh where these deposits have been divided into three formations: Kargil, Tarumsa and Pashkyum, in ascending order (Bhandari *et al.*, 1977). The Kargil Formation, considered to be the oldest molasse unit of the Ladakh Molasse Group, has yielded vertebrates (including artiodactyls and rodents) that suggest a Late Oligocene–Early Miocene age (Nanda & Sahni, 1990, 1998; Kumar *et al.*, 1996).

Apart from the Kargil area, the molasse deposits exposed near Nyoma and Lyan and other localities in eastern Ladakh have also produced freshwater fish (Sahni *et al.*, 1984; ongoing investigations of two of us (SB and GVRP)), a rhinoceratoid *Juxia* (B. N. Tiwari, WIHG, Dehra Dun, pers. comm) as well as fossils of palm.

Interestingly, Garzanti & Van Haver (1988), who carried out a detailed study of the Ladakh Molasse interpreted a thick sedimentary sequence (Basgo and Temesgam Formations) resting unconformably on the granites of the Ladakh Batholith west of Leh, as pre-collisional, representing part of a forearc basin succession of the Transhimalayan arc-trench system. According to these authors, the Basgo and Temesgam Formations are continental (alluvial to deltaic) and of Maastrichtian–Early Eocene age. The Basgo Formation ('Unit de Basgo' of Baud *et al.*, 1982; 'Série de Basgo-Skinning' of Van Haver, 1984) was described by Garzanti & Van Haver (1988) as a 10–200 m thick unit comprising conglomerates, sandstones and lacustrine limestones and marls. They cited the evidence of ostracods (*in* Van Haver, 1984) in support of a Maastrichtian age for the Basgo Formation. However, Searle *et al.* (1990) discounted the possibility of Maastrichtian continental sedimentation in Ladakh and suggested that these ostracods may have been reworked into the molasse deposits. It is important to note that no description of these ostracods has yet been published. The present contribution is the first in which an ostracod fauna, albeit one of low diversity, is described from the Basgo Formation at two localities, near the village of Taruche, designated here as 'Tr 1' and 'Tr 2' (Fig. 1). The most productive section (Tr 2) occurs about 3 km west of the village, on an unmetalled track between Yangthang and Taruche. This section, measured by the two of us (GVRP and SB), is about 150 m thick (Fig. 2) and overlies the Ladakh granitoids with an erosional contact. The section consists mainly of sandstone and conglomeratic sandstone with intercalated hard, fossiliferous mudstone and siltstone beds. Fossils occur at least at ten levels in this section and include freshwater gastropods, cyprinid fishes and fragmentary bones. The ostracods described in this paper come from a level about 130 m above the contact of the Basgo Formation molasse with the underlying granites. The second locality (Tr 1), thought to be coeval with Tr 2, occurs about 100 m south of Taruche (Fig. 1), where the ostracod-yielding level comprises grey calcareous mudstones. Associated fossils in both these sections include mainly gastropod opercula, cyprinid fishes and charophytes. The ostracod assemblage described here comprises three new species, one of which is of some considerable stratigraphical potential and also has important zoogeographical significance.

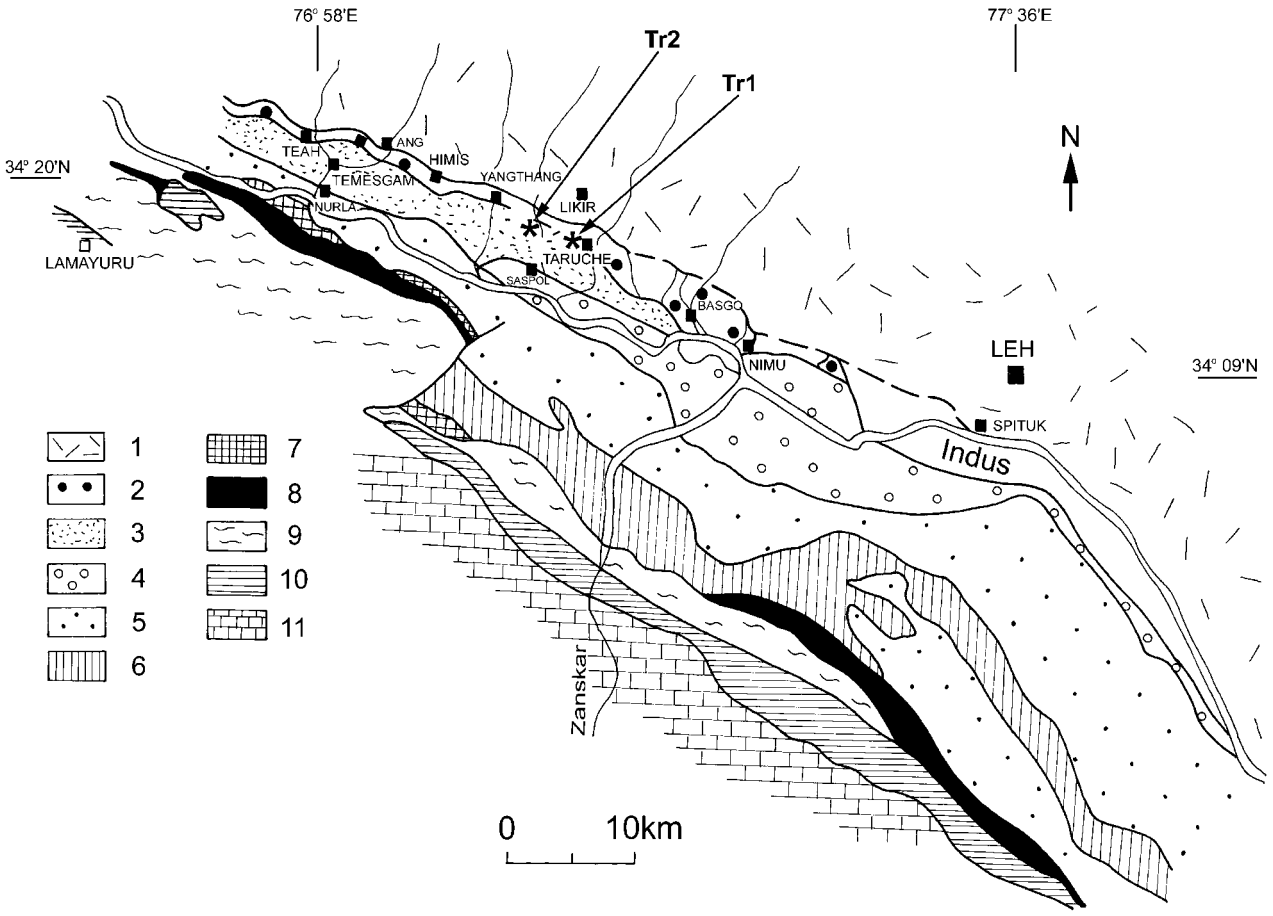


Fig. 1. Geological sketch map of part of Ladakh, Jammu and Kasmir State, India (modified after Garzanti & Van Haver, 1988), showing the ostracod localities. 1, Ladakh batholith; 2, Basgo Formation; 3, Temesgam Formation; 4, Nimu Formation; 5, Nurla Formation; 6, Nummulitic limestones; 7, Khalsi Limestone; 8, ophiolites and mélanges; 9, Nindam Unit; 10, Lamayuru Unit; 11, Zanskar carbonates. Ostracod-bearing localities (Tr 1 and Tr 2) are arrowed accordingly.

SYSTEMATIC DESCRIPTIONS

All type and figured specimens are deposited in the Bajpai Collection in the museum of the Department of Earth Sciences, Indian Institute of Technology (formerly University of Roorkee), with catalogue numbers prefixed RUSB. The following conventions are employed: RV, right valve; LV, left valve; C, articulated carapace; A, adult; juv., juvenile, rpc, radial pore canal; npc, normal pore canal. The size convention for adults, as used by the second author over many years for podocopid ostracods, is as follows: <0.40 mm – very small; 0.40–0.50 mm – small;0.50–0.70 mm – medium; 0.70–1.00 mm – large; >1.0 mm – very large.

Phylum **Crustacea** Pennant, 1777
Class **Ostracoda** Latreille, 1806
Order **Podocopida** G. W. Müller, 1894
Suborder **Podocopina** G. W. Müller, 1894
Superfamily **Cypridacea** Baird, 1845
Family **Cyprididae** Baird, 1845

Genus *Dongyingia* Li & Lai (*in* Hou *et al.*, 1988)

Remarks. This genus has previously been considered endemic to the Palaeogene of China. This is the first occurrence known to the authors outside China, where most records seem to cluster on or near the eastern seabord. *Dongyingia* evidently underwent something of an adaptive radiation, mainly in respect of its ornamentation, and Li & Lai (1988) list no fewer than 22 species. The genus is sometimes attributed erroneously to Bojie, 1978. This is not an author's name but an acronym of Bohai Jie Xing Lei, meaning the 'Bohai Ostracod Working Group' and taxonomic names in that work (see references) were *nomina nuda* until they were validated by subsequent acknowledgement of the individual authorship by the constituent members of the working group (which was done for the first time in Hou You-tang *et al.*, 1988); see Article 50 of the ICZN Code (Ride *et al.*, 1985), which was the operative edition of the Code at that time.

The subfamilial status of the genus is uncertain. The Chinese (Hou *et al.*, 1988 = ex 'Bojie', 1978) place it in their new subfamily Huabeininae, together with their new genera *Huabeinia*, *Tuozhuangia*, *Hebeinia*, *Camarocypris*, *Ninghainia*, etc. However, the present authors regard these as a somewhat heterogeneous group and leave the subfamilial position of *Dongyingia* in question at the moment.

Dongyingia sannionis sp. nov.
(Pl. 1, figs 15–20)

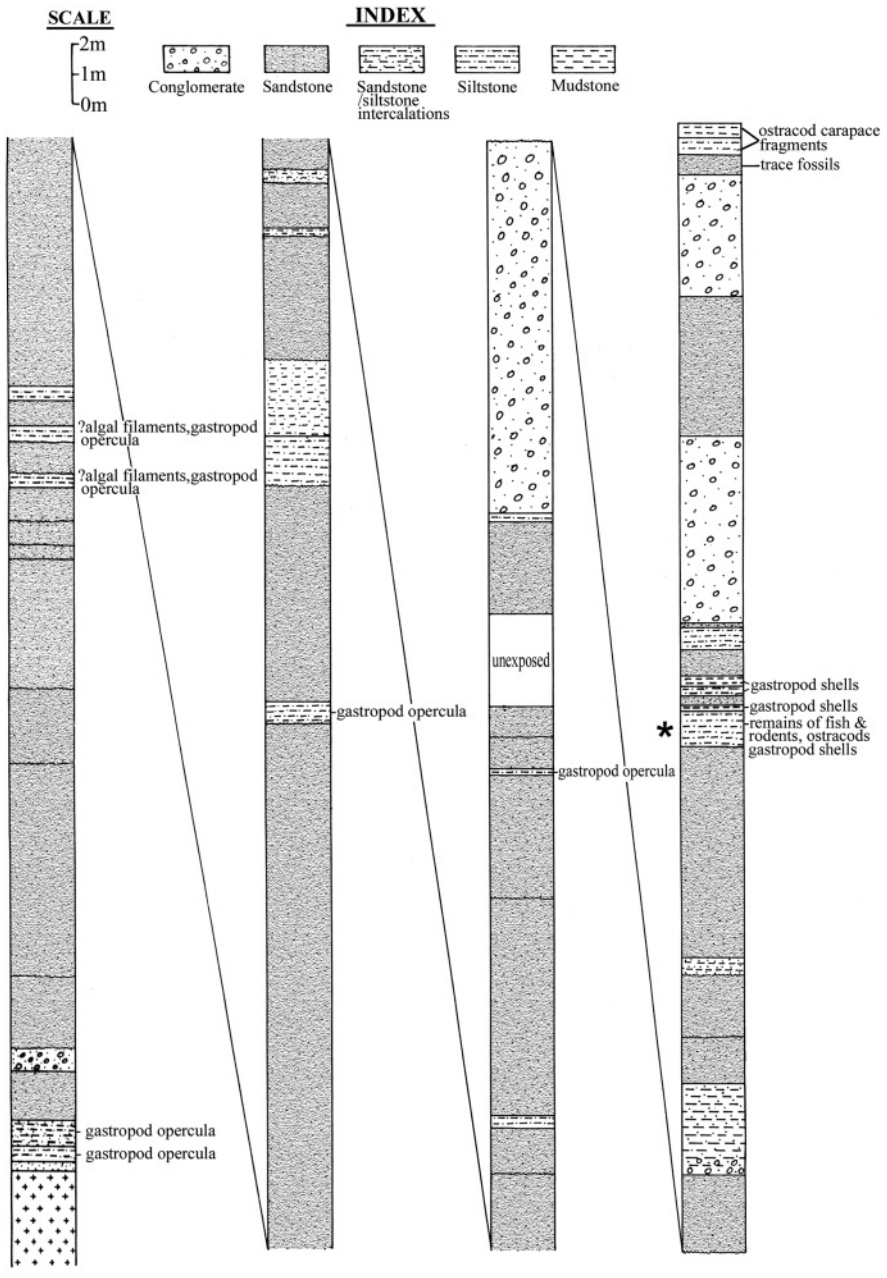


Fig. 2. Measured stratigraphical section at the locality Tr 2, 3 km west of Taruche village. The ostracod-bearing level within the Basgo Formation is marked by a star (*). The junction with the underlying Ladakh granitoids is shown, bottom left $^{+}_{+}{}^{+}_{+}$.

Derivatio nominis. L. *sannio*, *-onis*. Named after one who makes faces, grimaces; a buffoon. With reference to the fanciful resemblance this species has in lateral view to a face.

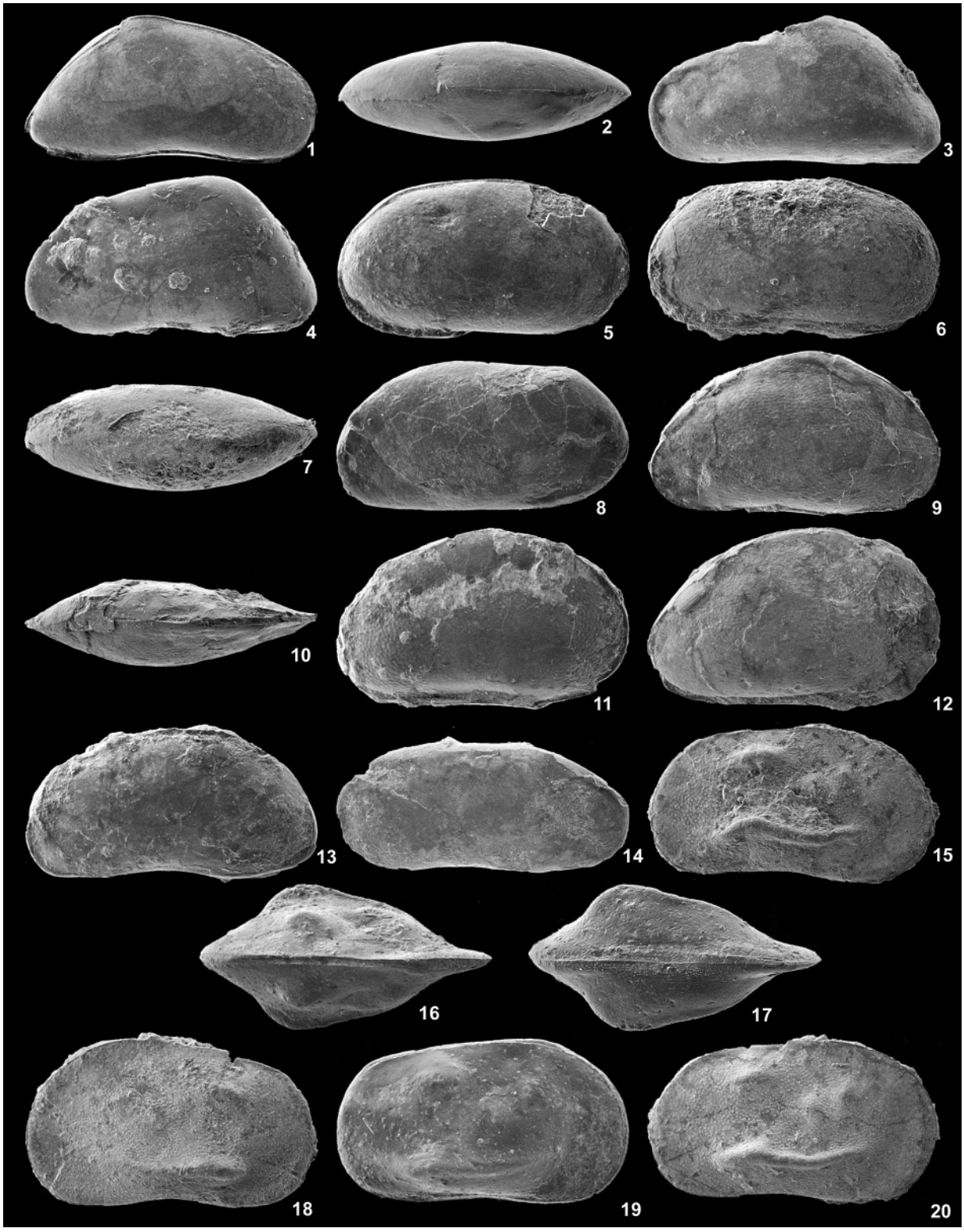
Diagnosis. A very large, subrectangular species of *Dongyingia* with rounded end margins, delicately papillate ornament, sinuous ventro-lateral rib and two tubercles on the lateral surface, one postero-dorsally, the other, subdivided into two, more centrally.

Holotype. Carapace, RUSB 6165.

Material. Thirty-eight specimens.

Type locality and level. 3 km west of Taruche village, Ladakh (Tr 2); grey siltstone; Basgo Formation, Upper Oligocene.

Description. Very large. Subrectangular in lateral view; saggitate in dorsal and ventral views, more strongly laterally compressed anteriorly than posteriorly. Anterior margin broadly and evenly rounded, with apex at mid-height. Posterior margin more narrowly and less regularly rounded; apex between mid-height and sub-ventral. Dorsal margin straight, sloping gently towards the posterior. Ventral margin with wide median concavity. Overall ornament of minute papillae which become lineated parallel to the margin ventrally. There is a strong, sub-alar ventro-lateral rib, which terminates equidistantly from both end



Explanation of Plate 1.

figs 1–8, 13, 14. *Candona himalaica* sp. nov.: **1**, **2**, holotype, female carapace, RUSB 6169, right lateral and dorsal views, respectively, ×50; **3**, paratype, female carapace, RUSB 6170, left lateral view, ×45; **4**, paratype, female carapace, RUSB 6171, left lateral view, ×50; **5**, paratype, A-1 juvenile carapace, RUSB 6172, right lateral view, ×58; **6**, **7**, paratype, A-1 juvenile carapace, RUSB 6173, right lateral and dorsal views, respectively, ×63; **8**, paratype, A-1 juvenile carapace, RUSB 6174, left lateral view, ×62; **13**, paratype, male carapace, RUSB 6175, ×50; **14**, paratype, male carapace, RUSB 6176, ×47. **figs 9–12.** *Eucypris alpina* sp. nov.: **9**, **10**, holotype, carapace, RUSB 6177, right lateral and dorsal views, respectively, ×44; **11**, paratype, carapace, RUSB 6178, right lateral view, ×34; **12**, paratype, carapace, RUSB 6179, right lateral view, ×47. **figs 15–20.** *Dongyingia sannionis* sp. nov.: **15**, paratype, carapace, RUSB 6165, right lateral view, ×27; **16**, **17**, **19**, holotype, carapace, RUSB 6166, dorsal, ventral and right lateral views, respectively, ×24; **18**, paratype, carapace, RUSB 6167, left lateral view, ×25; **20**, paratype, carapace, RUSB 6168, right lateral view, ×26.

margins; thickest and convex posteriorly, narrower anteriorly and concave. A short rib-like tubercle occurs dorso-laterally at about two-thirds of the distance from the anterior margin. Another feature, comprising two small sub-conical tubercles, situated on the same oblique elevation, occurs dorsal of mid-height and at about one third of the distance from the anterior margin. All these elevations are in some way associated with pores. Valves subequal. Eye spot apparently absent. Internal features not seen.

Distribution. Apparently confined to the type locality (Tr 2).

Dimensions	Length (mm)	Height (mm)	Width (mm)
Holotype C, RUSB 6165	1.80	1.02	0.91
Paratype C, RUSB 6166	2.03	1.07	0.93
Paratype C, RUSB 6167	1.92	1.10	0.92
Paratype C, RUSB 6168	1.85	1.02	0.91

Remarks. Placed in *Dongyingia* on account of the distinctive 'face-like' ornament of tubercles and ventro-lateral rib. It differs from all other known species of the genus in being more elongate, and lacks the strong LV>RV overlap of some of the Chinese species. Its shape is essentially subrectangular, while Chinese species of the genus (*in* Hou *et al*., 1988, ex 'Bojie', 1978), especially those described from the Dongying Formation of the Bohai Bay Basin, to the south and southeast of Beijing, are subquadrate. The Chinese taxa are also very large. Some, such as *D. biglobicostata* Li & Lai (*in* Hou *et al*., 1988), are even longer than our largest Ladakh specimen, exceeding 2 mm in length. The present species differs from *D. inflexicostata* Li & Lai (*in* Hou *et al*., 1988), in that it has three lateral tubercles and the ventro-lateral rib is not strongly convex at mid-length. *D. biglobicostata*, moreover, has a much shorter and thicker ventro-lateral rib and lacks lateral tubercles. *D. floricostata* Li & Lai (*in* Hou *et al*., 1988), differs from *D. sannionis* sp. nov, in that the former as well as being delicately punctate, is covered with numerous lateral tubercles of various shapes and sizes, while *D. impolita* Cai & Shan (*in* Hou *et al*., 1988) lacks lateral ornament. All these Chinese records are from the Bohai Bay Basin, which is a large, NE-SW trending structure, extending for several hundreds of kilometres.

Family **Candonidae** Daday, 1900
Subfamily **Candoninae** Daday, 1900
Genus *Candona* Baird, 1845
Candona himalaica sp. nov.
(Pl. 1, figs 1–8, 13, 14)

Derivatio nominis. L., with reference to the occurrence of this species in the Himalaya.

Diagnosis. A large to very large species of *Candona*, in which the female is very strongly bevelled postero-dorsally, while the male is rounded in this area. Spindle-shaped in dorsal view. A-1 juveniles almost equally rounded anteriorly and posteriorly.

Holotype. Female carapace RUSB 6169.

Material. Forty-three carapaces.

Type locality and level. 100 m south of Taruche village, Ladakh ('Tr 1'); grey calcareous mudstone; Basgo Formation, Upper Oligocene.

Description. Large to very large. Strongly sexually dimorphic, with males much less angular postero-dorsally and posteriorly than females; juvenile instars of very different shape from adults. Adult females are strongly bevelled postero-dorsally in both valves and are strongly umbonate dorsally at two-thirds the length from the anterior margin. Males are gently convex postero-dorsally and, although the greatest height is in the posterior third, the dorsal margin is slightly convex and not umbonate. In both sexes the anterior margin is rather narrowly rounded, with the apex a little below mid-height in females but sub-ventral in males. The ventral margin is shallowly concave medianly. Smooth. Left valve a little larger than right. Internal features not seen. A-1 juveniles have both end margins equally rounded.

Distribution. Known only from Taruche (both Tr 1 and Tr 2).

Dimensions	Length (mm)	Height (mm)	Width (mm)
Holotype Female C, RUSB 6169	0.98	0.49	0.34
Paratype Female C, RUSB 6170	1.08	0.53	0.35
Paratype Female C, RUSB 6171	0.98	0.52	0.34
Paratype A-1 juv. C, RUSB 6172	0.84	0.44	0.30
Paratype A-1 juv. C, RUSB 6173	0.78	0.41	0.29
Paratype A-1 juv. C, RUSB 6174	0.79	0.40	0.29
Paratype Male C, RUSB 6175	0.98	0.52	0.35
Paratype Male C, RUSB 6176	1.05	0.47	0.35

Remarks. This large and strongly dimorphic candonid is quite similar to many Cenozoic and Recent species, in which the pronounced postero-dorsal truncation of the female carapace is thought to be a copulatory adaptation (McGregor & Kesling, 1969). An extreme example of this is the Quaternary and Recent species *C. acuminata* (Fischer, 1855) from Europe and North America, or the European Recent species *C. hyalina* (Brady & Robertson, 1870). Modern taxonomy would now place many Recent species of '*Candona*' in other related genera (e.g. *Fabaeformiscandona)* on soft-part characteristics and, indeed, it is to *Fabaeformiscandona* (erected by Krstic, 1972) that those aforementioned species would now belong. Distinguishing these genera on carapace features alone, however, is difficult and for this reason the use of *Candona* for our fossil species is thought to be the most sensible under the circumstances.

The nearest study, both in age and geography, is by Bhatia (1968) on the Pleistocene ostracods of the Upper Karewas of Kashmir. That fauna, which contains seven species of *Candona*, is of very modern aspect and none of the species resembles *C. himalaica* sp. nov. *Candona shandongensis* Li & Lai (*in* Hou *et al*., 1988, ex 'Bojie', 1978), from the Upper Oligocene of China, is more triangular in shape. No species of the genus known to the authors closely resembles the present material.

Genus *Eucypris* Vávra, 1891
Eucypris alpina sp. nov.
(Pl. 1, figs 9–12)

Derivatio nominis. L. With reference to the high altitude of the type locality of this species (*Eucypris* is feminine).

Diagnosis. A very large species of *Eucypris*, with a very delicately punctate ornament, well-rounded anterior and bluntly pointed posterior with sub-dorsal apex.

Holotype. Carapace RUSB 6177.

Material. Eleven specimens.

Type locality and level. 100 m south of Taruche village, Ladakh ('Tr 1'); grey calcareous mudstone; Basgo Formation, Upper Oligocene.

Description. Very large. Irregularly subovate in lateral view; narrowly subhastate in dorsal view, widest in posterior third. Anterior margin rounded, with apex at about mid-height. Posterior margin with long, gently convex postero-dorsal slope and bluntly pointed apex well below mid-height. Dorsal margin asymmetrically convex about the point of greatest height, which is some one-third the distance from the anterior margin; posterior part sloping towards posterior apex without noticeable cardinal angle. Ventral margin with very shallow concavity. Left valve slightly larger than right with overlap around the entire free margin. Ornament a delicate punctation which, where the outer layer of the shell has been removed, appears as micro-papillation. Internal features not seen.

Distribution. Known only from Taruche (both Tr 1 and Tr 2).

Dimensions	Length (mm)	Height (mm)	Width (mm)
Holotype C, RUSB 6177	1.10	0.62	0.33
Paratype C, RUSB 6178	1.44	0.86	0.34
Paratype C, RUSB 6179	1.03	0.62	0. 33

Remarks. This large, punctate species of *Eucypris* is not closely related to any species of the genus known to the authors. *E. fida* Shi & Yang (*in* Hou *et al*., 1988, ex 'Bojie', 1978), from the Upper Oligocene of the Bohai Basin, China, is rather similar in dorsal view, but is smooth and much less strongly pointed posteriorly.

CONCLUSIONS

Previous palaeontological evidence from this deposit (Basgo Formation) has been somewhat scanty and its chronological implications rather conjectural. Garzanti & Van Haver (1988) have employed, as yet unpublished, ostracod data to suggest that the Basgo Formation is of Maastrichtian age. Vertebrate evidence suggests an Oligo-Miocene age for part of the molasse in the Kargil area (Nanda & Sahni, 1990, 1998; Kumar *et al*., 1996). The few known radiometric dates of the underlying Ladakh granitoids indicate two main crystallization ages: *c.*60 Ma and 102 Ma, Late Palaeocene and Early Cretaceous (Albian), respectively (Honegger *et al*., 1982; Scharer *et al*., 1984; ongoing work of Dr S. Singh, Roorkee). More recently, Weinberg & Dunlap (2000) have argued that the granites near Leh may represent the last major magmatic activity (around 50 Ma, Middle Eocene) and that this activity may have occurred possibly in response to the disruption of subduction of Tethyan oceanic crust due to the initiation of continental collision between India and Asia.

The discovery of the genus *Dongyingia* in the Basgo Formation is of considerable significance because this molasse deposit, resting unconformably on the Ladakh Batholith, has been dated as Maastrichtian (Garzanti & Van Haver, 1988; see also Bajpai & Prasad, 1998). *Dongyingia* is previously known only from the Upper Oligocene of China. The present species, *D. sannionis* sp. nov. is very similar morphologically to its Chinese counterparts and there seems little question that they are contemporary. There is strong evidence, therefore, that the part of the molasse from which this species comes is also of Late Oligocene age. The Maastrichtian age assigned by Garzanti & Van Haver (1988) is not supported by the present ostracod data. *Dongyingia* is only known elsewhere in the Bohai Basin (Yang, 1982) of eastern China. Its presence in Ladakh could indicate the presence in the Upper Oligocene, of non-marine aquatic connections between the two areas, However, while probably a good indication of proximity, it is not necessarily the case given the propensity of many Cypridacea to be transported by wind as encysted, desiccation and freeze-resistant eggs (Whatley, 1990, 1992).

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