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HIMALAYAN CAMBRIAN TRILOBITES

BY

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with 32 plates, 10 text-figures and 3 tables

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ABSTRACT. In the Himalaya of northern India and Pakistan, Cambrian trilobites are widespread and provide data to assess palaeogeography and to constrain tectonic models of Himalayan evolution. Collections from Kashmir, Spiti and the Salt Range, described early this century are revised taxonomically and recent collections from these areas and from the Zaskar Valley, Ladakh and the Krol-Tal Belt of the Lesser Himalaya are described. Cambrian sequences of these areas are correlated biostratigraphically with each other and with China. Himalayan Cambrian trilobites range in age from Tsanglangpuian to Kushanian. Previous suggestions that these faunas show marked provinciality within the region are rejected; they have strong generic and specific level affinities with faunas from China (particularly south-western China), Kazakhstan and Australia and cosmopolitan elements are known from several other parts of the world. The trilobite faunas do not suggest major environmental or structural separation between Himalayan basins during the Cambrian. Deposits in the Krol-Tal Belt contain only redlichiid trilobites of Early Cambrian (Tsanglangpuian) age. In the Salt Range, in the Pohru and Liddar Valleys, Kashmir and in Spiti, trilobite-bearing formations of this age are overlain by early Mid Cambrian strata. Late Mid Cambrian trilobites occur in Kashmir and the Zaskar Valley in Ladakh, but only in Kashmir are basal Late Cambrian sedimentary rocks confirmed. One new genus, *Shahaspis*, and three new species, *Xela mathurjoshi*, *Damesops sheridanorum* and *Eoshengia? sudani* are erected.

FOR over a hundred years Cambrian trilobites have been collected and described from the Indian subcontinent. Publications on these have become an essential part of the database on Himalayan geology, which has provided the models for several tectonic concepts. In recent decades there has been a marked increase in the number of publications on Cambrian trilobites from India, building on pioneering work conducted early this century by the Geological Survey of India. To realize fully the biostratigraphical and palaeogeographical potential of these finds it is necessary to illustrate and re-evaluate the type specimens of taxa described early this century and to assess the affinities of these forms in the context of recent advances in Cambrian palaeontology. We revise previously described Himalayan Cambrian trilobites and describe new collections from the Pohru Valley of Kashmir, the Parahio Valley of Spiti and the Zaskar district of Ladakh.

Cambrian trilobites were first described from southern Asia by Waagen (1889) who reported three species from the Salt Range; Redlich (1899) named one species from an older horizon in the same sequence. Cambrian faunas discovered in Spiti by Hayden (1904) and in Kashmir by Wadia (1934) were described by Reed (1910, 1934). Kobayashi (1934) described Cambrian trilobites collected by de Terra on a Yale University Expedition to Kashmir. King (1941) reviewed the Cambrian fauna of the Salt Range and described three new ptychoparioids. The significance of these studies has not been fully realized because they dealt mostly with tectonically distorted specimens, the distortion being responsible for an over-estimate of diversity, and because they preceded the surge in Chinese Cambrian trilobite studies of the last 30 years. Kobayashi (1967) reviewed these faunas, making numerous generic reassignments of Reed's species; he began to recognize Reed's overestimate of diversity, but did not eliminate tectonic distortion from species concepts.

More recent geological investigation of the Himalayan Cambrian, principally by officers of the Geological Survey of India, by Prof. S. K. Shah and colleagues at the University of Jammu, by various expeditions from overseas including those by Macquarie and Milan universities and by individual efforts, have greatly increased knowledge of the trilobite faunas. Major advances in Chinese Cambrian palaeontology, mainly through the work of Professors W. T. Zhang and Lu Yanhao, Nanjing Institute of Geology and Palaeontology, and their colleagues, provide a biostratigraphical framework for the Cambrian based on data from many parts of eastern Asia. Given the number of taxa in common and geographical proximity, it seemed logical that Himalayan faunas should be compared with those from the Chinese succession to see if they fit the same framework, a biostratigraphical scheme for the Himalayan region being notoriously difficult to establish independently, because of the extreme structural complexity.

To provide an up-to-date assessment of the significance of the Cambrian trilobite faunas of the Himalaya we have: revised previously described Himalayan Cambrian trilobites, particularly those of Reed (1910, 1934) which are illustrated photographically for the first time; described new forms from the Zaskar Valley, Ladakh; attempted correlations between the different outcrop areas in the

region; set the faunas into a biostratigraphical framework first defined in China; and re-assessed their palaeobiogeographical significance.

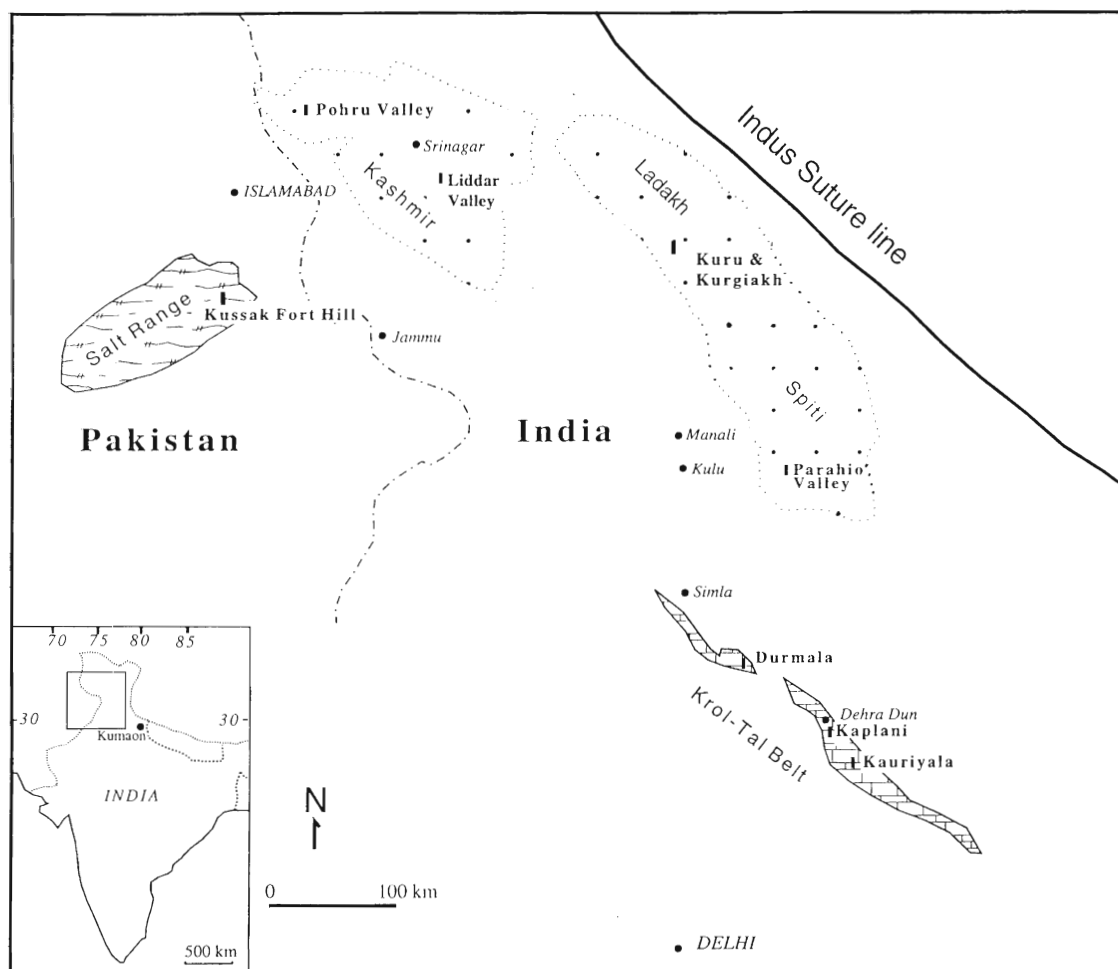
GEOLOGICAL SETTING

Cambrian sedimentary rocks occur in a series of structurally isolated areas including the Pohru and Liddar valleys in Kashmir, the Zaskar region in Ladakh, Spiti in Himachal Pradesh and the Kumaon area to the east (Text-fig. 1). These are situated within the High Himalaya and south of the Indus Suture Zone (Text-fig. 1; Brookfield 1993). Although Kashmir and Spiti were previously considered to be separate Palaeozoic basins (Wakhaloo and Shah 1965) there is no clear evidence to show that each was a discrete depositional entity, and structural complexity of the intervening areas makes it difficult to settle this question. Moreover, Brookfield (1993) interpreted the Himalaya as a passive plate margin during the early Palaeozoic; in this tectonic setting a range of disparate terranes along the margin would be highly unlikely. While sedimentation patterns in Kashmir are understood to some extent, more investigation is needed there and in the more rugged terrain to the east and north-east before the stratigraphy of the whole area can be outlined. The Salt Range in the Pakistan Himalaya and the Krol-Tal Belt of the Lesser Himalaya (Brookfield 1993) lie south of the High Himalaya but on the same side of the Indus Suture Zone. These areas are interpreted as shallower shelf environments closer to land, but not isolated from the deeper shelf to slope deposits of the High Himalaya. We deal with each separately, but our faunal study suggests that they were all part of one depositional area, in concurrence with Brookfield (1993).

In Spiti, Kashmir and Zaskar the Cambrian succession is transgressive; the lowest Cambrian is represented by inner-shelf deposits, and the Middle and Upper Cambrian by outer shelf and slope deposits (Shah 1971; Garzanti *et al.* 1986). The successions are clastic dominated, with minor carbonates.

Salt Range. The Salt Range lies between the Jhelum and Chenab rivers, between Lahore and Rawalpindi in north-eastern Pakistan. It is a structural unit on the Indian shield with a thick Proterozoic sequence overlain unconformably by Cambrian clastics which are in turn overlain unconformably by a thick Permian–Triassic sequence (Brookfield 1993). The lithostratigraphical section is that of King (1941, pl. 5) which does not correspond precisely in its terminology with that of Waagen or Redlich as there is considerable lateral variation in these units (Gee 1934). Trilobites occur in the *Neobolus* Shales and Magnesian Sandstone in the eastern part of the range. *Redlichia noetlingi* occurs at several localities in the upper *Neobolus* Shales, notably at Kussak Fort Hill (Gee 1934, p. 132; King 1941, p. 87) and in the Magnesian Sandstone (Schindewolf and Seilacher 1955, p. 133). There is some confusion in King's (1941) work as to the horizons of his fauna, as these are given slightly differently on different pages. *Chittidilla plana* occurs 'in shales near the top of the Magnesian sandstone series' (King 1941, p. 13). These shales are presumably above the dolomite and could be considered to be part of the next younger formation as inferred by Chang (1981). King (1941) noted that his *Ptychoparia geei* and *P. sakesarensis* (= *Yuehsienszella szechuanensis*) occur in the upper *Neobolus* Shale and lower Magnesian Sandstone at an horizon close to that of *Redlichia* (King 1941, p. 12). Chang (1981, table 1) indicated close correlation between this section in the Salt Range and that in eastern Yunnan both litho- and biostratigraphically. His identifications and correlations are confirmed herein.

North-western Kashmir. The Cambrian deposits of north-western Kashmir (Wadia 1934; Shah 1982) occur in the centre of a regional anticlinal structure as a series of outcrops separated by Tertiary and Quaternary sediments, making assessment of the stratigraphy difficult (Shah 1982). Several exposures or horizons contain only a single trilobite species making it difficult to fit them into a biozonation. Professor S. K. Shah and colleagues have established a lithostratigraphical column (Text-fig. 2) and developed a biostratigraphical scheme for the Cambrian of Kashmir (Shah 1982; Shah and Sudan 1982, 1987a, 1987b; Shah *et al.* 1988; Shah and Raina 1990) by correlating between sections within the Pohru Valley. However, we disagree with some of their identifications



TEXT-FIG. 1. Sketch map of the Indian Himalaya showing relative positions of various sections mentioned in the text and shown in Text-fig. 4. Areas shaded to indicate tectonic units of Brookfield (1993): sparse dots = High Himalaya; horizontal brickwork = lesser Himalaya; crossed ripples = Pakistan Himalaya.

and it is not always clear which material is indicated by names given in their stratigraphical columns. We are not in a position to suggest a biozonation for Kashmir but rather place the faunas in their most likely order (Text-fig. 2), without certainty of relative positioning or ranges of taxa, and then attempt to relate this to the Chinese scheme (Text-fig. 4).

Most Kashmiri specimens are preserved as composite moulds in green/grey ferruginous shales. No detailed sedimentological analysis of the Kashmiri Cambrian has been attempted, but the environment was apparently outer shelf to slope (Shah 1971; Brookfield 1993). Some exoskeletons are cracked and most have been tectonically deformed. Within the Nutunus Formation specimens generally occur as sparsely distributed articulated exoskeletons or as high density concentrations of disarticulated sclerites.

Redlichia takooensis occurs in grey shales of the upper Lolab Formation along a steep ridge south-west of the Putshai stream (Shah *et al.* 1980, p. 515). The Sagipura Formation is a local facies variation of the uppermost Lolab Formation (Shah 1982) but it is not recognizable regionally and is thus not employed in the composite section for the whole of Kashmir (Text-fig. 4). Most Middle

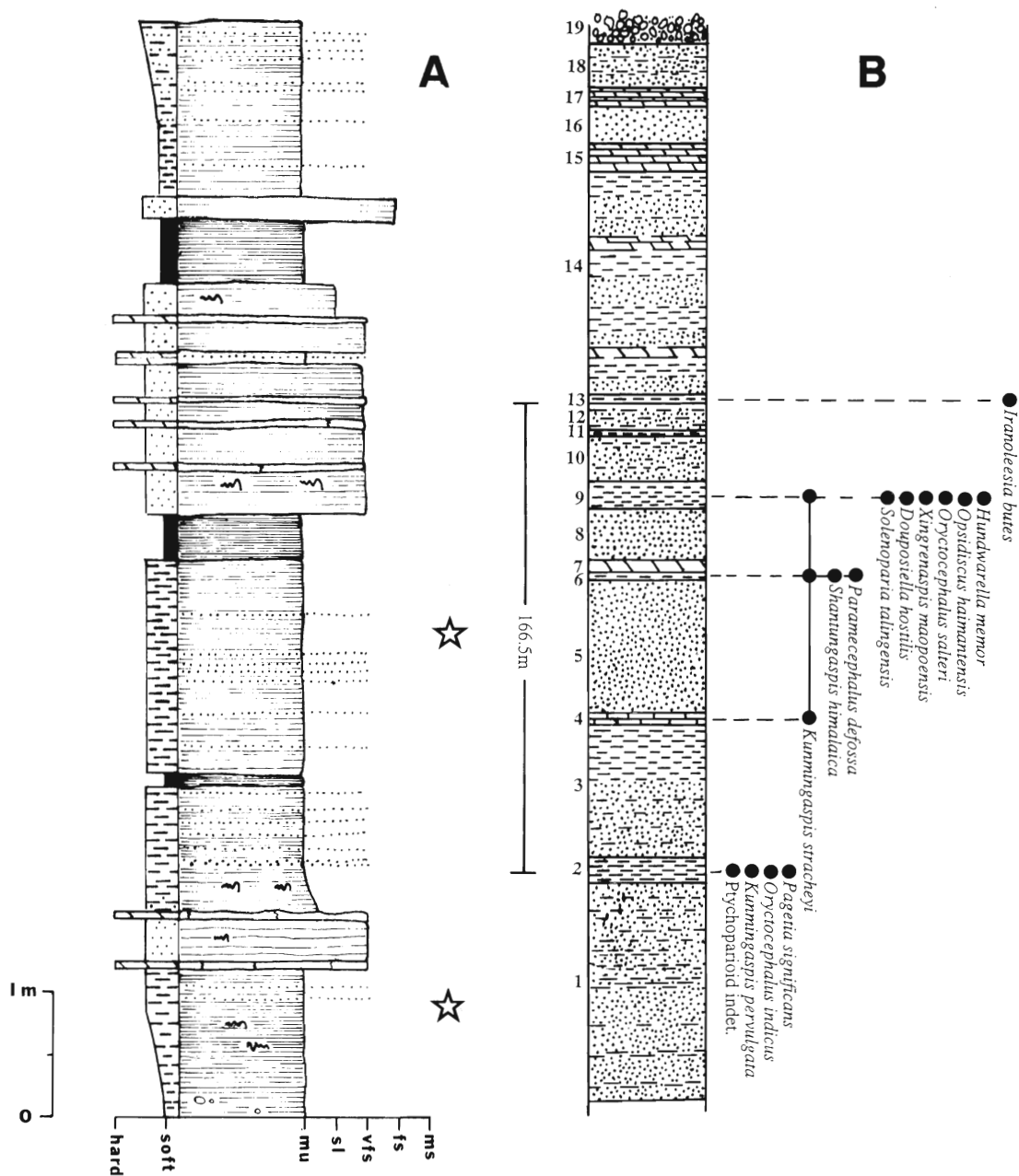
Lolab Fmn	Sagipura Fmn	Nutunus Fmn	Trahagam Fmn
	• <i>Redlichia takooensis</i> K		
		• <i>Bailiella lantenoisi</i> Z	
		• <i>Iranoleesia butes</i> Z	
		• <i>Hundwarella memor</i> Z	
		• <i>Tonkinella breviceps</i> Z	
		• <i>Baltagnostus</i> cf. <i>rakuroensis</i> Z	
			• <i>Bailiella lantenoisi</i> Tu
			• <i>Iranoleesia butes</i> Tu
			• <i>Xingrenaspis dardapurensis</i> Kh
			• <i>Shahaspis himalayensis</i> M
			• <i>Latilorenzella</i> sp. M
			• <i>Parachittidilla kashmirensis</i> M
			• <i>Damesella shergoldi</i> M
			• <i>Blackwelderia</i> sp. Tr
			• <i>Monkaspis</i> cf. <i>M. serrata</i> Tr
			• <i>Cyclolorenzella</i> sp. Tr

TEXT-FIG. 2. Composite section of the Cambrian of Kashmir with inferred relative positions of faunal horizons. Data are from Reed (1934), Wadia (1934), Jell (1986) and the many works of Shah and his co-workers. Sections from which the taxa were collected are indicated after each name by: K = Kupwara, Kh = Khanpura, M = Magam, Tr = Trahagam, Tu = Turkapur and Z = Zachaldor.

Cambrian specimens come from localities within a 5 km² area of the Talar Valley, about 8 km west of Hundwara. Kobayashi's (1934) material, from one of Hellmut de Terra's localities on a Yale University expedition in 1932–33, came from 'five miles from Handwara on road to Zachaldor in the Talar Valley...between Turkapur and bend of the Talar River'. This location corresponds to a Cambrian outcrop on Wadia's (1934) map at 34° 24'N, 74° 13'E.

Wadia (1934, p. 139) collected fossils from nine localities during 1928–31, but co-ordinates of his Cambrian localities do not correspond with the outcrop on the accompanying map. His locality 'Junction of the Rainawari footpath with road to Wadapur, 32° 24'N, 74° E' is apparently close to de Terra's locality. This is locality B-1 of Reed (1934, p. 5) and Reed's locality B 'Rainawari footpath' is presumably very close. Co-ordinates of Wadia's locality 'Foot of Frangteng Hill, 6861 feet, 34° 23'N, 74° 10'E' (Reed's localities A and A-1) specify a position some 5.5 km south of Frangteng Hill, on the south side of the Talar Valley. A more likely position may be at co-ordinates 34° 27'N, 74° 10'E, which lies just north of Frangteng Hill and is within an area of Cambrian outcrop marked on Wadia's map. The exact position of Wadia's locality 'One mile south of Rainawari, 34° 25'N, 74° 10'E, on the left bank cutting of the Talar stream, one mile WNW of Wadapur' is Reed's locality E, 1.75 miles west-north-west of Wadapur. Reed's localities B, B-1, D, E and H, de Terra's locality, Wadia's locality 'One mile north of Zachaldor on road from Hundwara, just where road cuttings begin', and ANU localities 10372, 10396 and 10398 all lie within the Cambrian shown on Wadia's map at Zachaldor. Shah (1982) showed a different distribution of Cambrian strata in the Zachaldor area from that of Wadia, and Suneja (1979) illustrated four sections in the vicinity of Zachaldor, but no information on stratigraphical positioning of faunas is available. ANU 10398 is in a gully just above a dam on the Talar River on the route from the Forest Rest House via Kiapur to Rainawari. ANU 10397 is a small quarry on the north side of the road, 1.6 km from the Forest Rest House along the road to Hundwara. The position of Reed's locality D 'near Sultanpur' is in front of the Forest Rest House, on the opposite side of the Talar River.

Wadia's locality 'One and a half miles south east of Dardapur 34° 29'N, 74° 28'E, Forest Rest House on the road to Nagmarg 34° 29'N, 74° 30'E' is Reed's locality G and lies some 22 km east-north-east of Hundwara. On Wadia's (1934) map the Forest Rest House is situated on Permian



TEXT-FIG. 3. A, section of the Surichun Member, the lower unit of the Kurgiakh Formation, as measured by NCH on the right bank of the Kurgiakh Nala on the same spur as the section given by Whittington (1986, fig. 1) but at a different scale. Hardness is indicated on the left of the column and grain size on the right; fs = fine sandstone; ms = medium sandstone; mu = mudstone; sl = siltstone; vfs = very fine sandstone. Open stars indicate fossil horizons. B, the section of Hayden (1904) and Reed (1910), above the Maopo encamping ground in Spiti; trilobite fauna as revised herein. Numbers to left of column indicate numbered Beds as in Reed (1910, p. 3).

volcanics of the Panjal Group. The nearest Cambrian on the map is about 1 km to the east. Geological maps of the Pohru Valley have been provided by Wadia (1934), Shah (1982) and Shah and Sudan (1987a, 1987b).

All material available in the type collections of the Geological Survey of India and several drawers of non-type material in the Indian Museum, Calcutta were examined. The following specimens could not be traced: *Agnostus* sp. (K26/519) (Reed 1934, p. 6); *Microdiscus* sp. (K26/528) (Reed 1934, p. 7); *Blountia*? sp. (K26/526) (Reed 1934, p. 21, pl. 2, fig. 18); *Corynexochus* sp. (K25/262) (Reed 1934, p. 12, pl. 2, fig. 16); *Chuangia*? sp. (K26/516) (Reed, 1934 p. 19, pl. 2, fig. 3).

South-eastern Kashmir. Cambrian trilobites occur at two horizons in the centre of an anticlinal structure in the Liddar Valley (Kumar and Singh 1983). Early Cambrian *Paokannia* came from brown, fine-grained sandstones about 15 m above the base of the Vel Member, Lolab Formation, near Vel Nagabal, 2 km south-east of Berar on the Anantnag–Pahalgam Road (Kumar and Verma 1987, p. 16). Near Karihul village, Middle Cambrian taxa occur in overlying green shales of the Karihul Formation (Kumar and Singh 1983, p. 38). The Cambrian lithostratigraphy appears to be comparable to that of the Pohru Valley, 150 km to the north-west (Kumar *et al.* 1984, p. 4).

Zaskar Valley, Ladakh. Cambrian deposits in the Zaskar Valley, Ladakh (Gaetani *et al.* 1986; Garzanti *et al.* 1986) represent a transgressive sequence subdivided into intertidal Phe Formation, the dolomitic shallow marine Karsha Formation and the silt-dominated, deeper water Kurgiak Formation with turbidites near the top. A similar transition to deeper water is evident in Kashmir and Spiti (Kumar *et al.* 1984), although extensive carbonate units are unknown in both these areas. Trace fossils suggest that the Precambrian–Cambrian boundary lies within the Phe Formation (Hughes and Droser 1992). Trilobites were first reported from Zaskar by Dungrakoti *et al.* (1974, 1975) but their identifications of Olenellidae, *Ptychoparia* sp. and *Asaphus* sp. in the Phe Formation are confusing; if accurate, they would suggest an age from the Lower Cambrian to post-Cambrian. Their *Asaphus* sp. (Dungrakoti *et al.* 1974, fig. 1) is identifiable as *Fuchouia* (cf. Whittington 1986 and Pl. 31, figs 4–5 and Pl. 32, fig. 8); their other two specimens are unidentifiable. Late Mid Cambrian trilobites described by Whittington (1986) were collected from the Surichun Member, the lower unit of the Kurgiak Formation, by the 1984 Italian Geological Expedition to Zaskar (Gaetani *et al.* 1986); a later (1986) expedition made further collections from the same horizon and locality and from a shaly intercalation (0.2 m) in the top of the brown dolomites of the Karsha Formation on the same spur (locality ZG-58). The Surichun Member comprises approximately 150 m of parallel laminated interbedded pelites and very fine sandstones, with occasional thin dolomite beds (Text-fig. 3A) and is overlain by at least 150 m of turbiditic silt and sandstones; it is interpreted as a transitional facies between outer shelf and slope environments (Garzanti *et al.* 1986).

One of us (NCH) collected trilobites both *in situ* and in scree on the north bank of the Kurgiak River opposite Kuru (Locality 5 of Garzanti *et al.* 1986, figs 1, 3) and at Garzanti *et al.*'s (1986, figs 1, 3) locality 3 in the Kurgiak Nulla, 3 km north of Kurgiak village. Mid Cambrian trilobites collected from lower in the Surichun Member, a few kilometres east of Kurgiak by Drs A. Dogra and Sat Paul, Jammu University are being described by the collectors.

At the Kurgiak locality, rocks dip at 22° to the west-north-west, are strongly cleaved and lie in faulted contact with the underlying Karsha Formation. The lithology consists of alternating grey/black pelitic and grey sandstone beds, with occasional thin dolomites (Text-fig. 3A). The section is dislocated by many small faults and contains abundant calcite veins. Occasional iron-rich nodules are present and the pelitic units commonly show wrinkled surfaces, such as produced experimentally by Dzulynski and Simpson (1966). The sandstones were probably deposited from high density suspension flows moving over cohesive muds. Tool marks on the bases of some sandstone beds indicate flows toward 310°. While the majority of beds show parallel lamination, horizontal bioturbation is common, although the ichnofabric index never exceeds 2 (Droser and

Bottjer 1986). *Planolites* are the most common traces: 10 mm diameter burrows filled with coarser sediment and possible back-filled burrows are present. Individual trails occur commonly on bedding surfaces (Whittington 1986, pl. 18, fig. 4). The thin dolomites commonly contain unpaired vertical burrows consistent with the clastic deposits representing deposition from sediment-laden density flows, whilst the dolomites represent periods of quiescence. The trilobites, mostly disarticulated in the pelites and very fine sandstones, are generally tectonically deformed and flattened. Opposite Kuru there are almost identical lithologies in thinner beds, which dip at 36° to the east.

Gupta and Shaw (1981) reported Cambrian trilobites with Czech affinities from the Phe Formation in the Kurgiakh and Doda valleys, Zaskar district. This report was queried by Whittington (1986) and the field data were refuted by Hughes and Droser (1992). Gupta and Shaw (1985) figured further Cambrian to Silurian trilobites purportedly from the Zaskar district of Ladakh and identical in morphology and preservational features with Czech species. These reports are ignored until verified independently (Talent *et al.* 1990).

Parahio Valley, Spiti, Himachal Pradesh. Hayden (1904) reported Cambrian deposits in the Parahio and Upper Pin valleys of Spiti (Text-fig. 1). Specimens described below are preserved in black shales and were collected from a section (Text-fig. 3B) in the 'steep hills on the left bank of the river above Maopo encamping ground' (Hayden 1904, p. 14). This section comprises approximately 360 m of shales, cross-bedded sandstones with interference ripples and occasional dolomitic limestones. The section is much faulted and is assigned to the Parahio Member of the Kunzam La Formation. The total thickness of the Parahio Member is estimated at 590 m (Kumar *et al.* 1984) but its sedimentology is poorly known (Bhargava *et al.* 1982).

The Spiti deposits containing trilobites are most commonly olive-black shales to very fine micaceous sandstones. The specimens are composite moulds infilled with iron oxide. Most have compression cracks and many are tectonically deformed. One slab (ANU10400.1) from Hayden's level 9 of the Parahio section contains hundreds of trilobite fragments, mostly broken thoracic segments, which show current alignment. Occasionally, specimens are preserved in limestone with original relief. The specimen of *Redlichia* was recovered as float. Inarticulate brachiopods, hyolithids (Reed 1910) and paraconodonts (Bhatt and Kumar 1980) occur in the section. Well-preserved trace fossils, including arthropod tracks, occur in the Parahio Member (Bhargava *et al.* 1982).

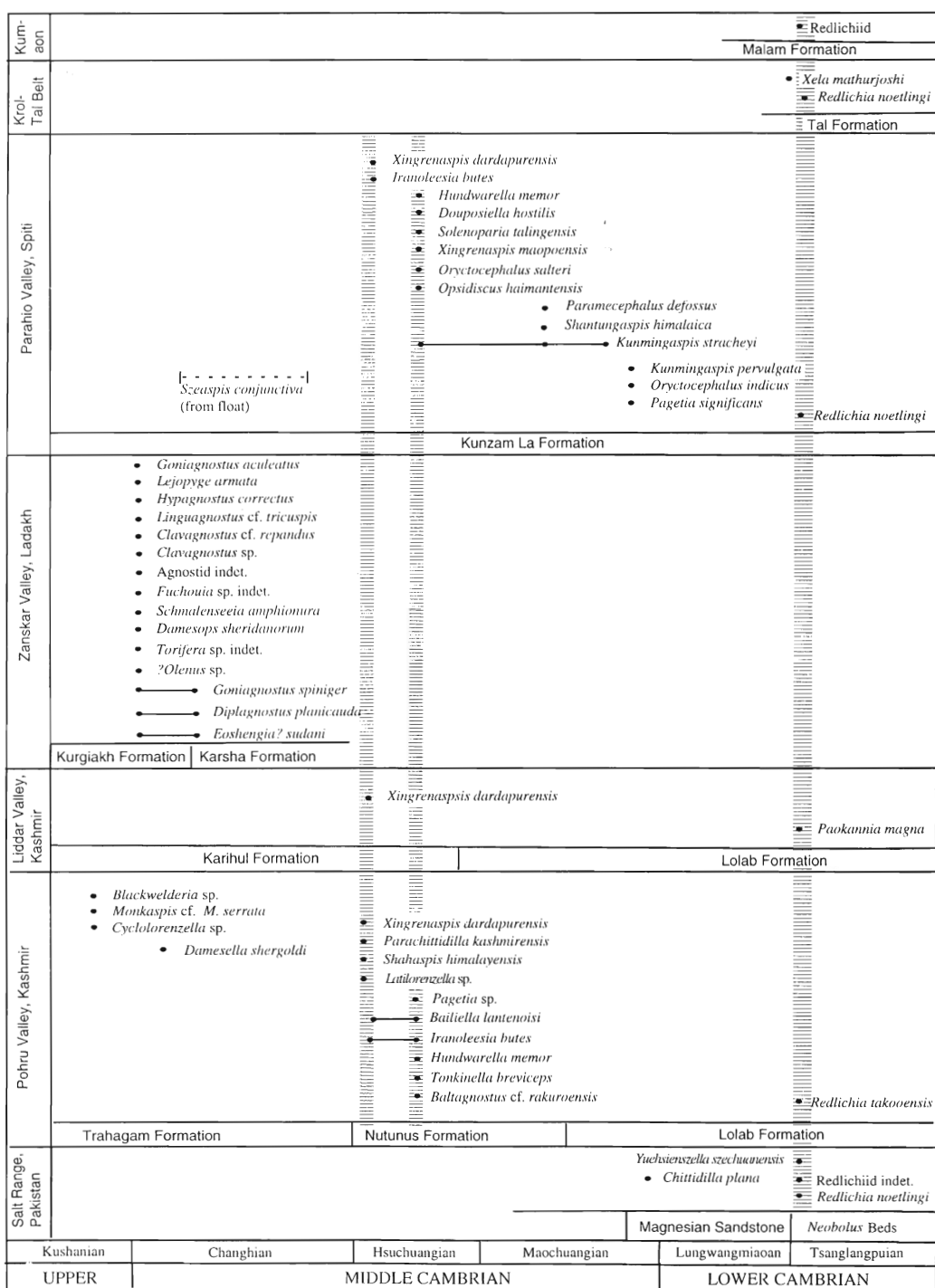
Available material in the type collections of the Geological Survey of India, Calcutta was examined but *Agnostus spitiensis*, GSI9760-9772, (Reed 1910, pl. 1, figs 1-3) could not be found. *Ptychoparia pervulgata*, GSI9831, (Reed 1910, pl. 3, fig. 18) and *Ptychoparia? hostilis*, GSI9848, (Reed 1910, pl. 4, fig. 7) have been damaged since Reed's description and are not considered.

Kumaon Himalaya, Uttar Pradesh. A single specimen from the Milam Formation of the Martoli Group, near Milam, Pithoragarh District, has been referred to the Redlichiida (Kacker and Srivastava 1993, p. 134), but awaits formal description.

Krol-Tal Belt. Trilobites from several localities within the Krol-Tal Belt of Himachal Pradesh and Uttar Pradesh occur in the upper part of the Arenaceous Member of the Lower Tal Formation in both the Mussoorie (on the Mussoorie-Tehri road near Kaplani Village) and Garhwal (near Kauriyala on the Rishikesh-Badrinath road) synclines (Rai and Singh 1983, p. 8; Joshi *et al.* 1989, p. 12). Redlichiids are also known from the green shales of the Phulchatti Member of the Upper Tal Formation in the western part of the Nigalidhar Syncline (Kumar *et al.* 1987) and in the Mussoorie Syncline, about 1 km south-south-west of Durmala (Mathur and Joshi 1989).

BIOSTRATIGRAPHY

On the basis of the taxonomic revisions presented below, an attempt is made to review the biostratigraphy within Himalayan regions, and to correlate between them (Text-fig. 4).



TEXT-FIG. 4. Comparison of faunal successions related to lithostratigraphical terminology (not to scale) in the Himalayan Cambrian relative to the Chinese stage succession (bottom). The vertical columns of dashes indicate those horizons which can be correlated between two or more areas, as mentioned in the text.

By reference to the Chinese Lower Cambrian succession (Zhang *et al.* 1980a; Zhang 1988) the low diversity fauna of *Redlichia*, *Yuehsienzella*, *Paokannia* and *Xela* which is the oldest trilobite fauna in most of the areas discussed above, is inferred to be approximately of late Tsanglangpuian age. It was not until the Chinese sequence became known that sense could be made of these sparse, poorly understood faunas of southern Asia and South Australia (Bengtson *et al.* 1990).

Continuous sections of parts of the Middle Cambrian are exposed in Spiti and the Zaskar Valley of Ladakh, although they are faulted and highly cleaved. In Kashmir, exposures are less continuous and stratigraphical relationships between various localities (Appendix 1) are not well known. Even within Wadia's localities, Reed (1934) noted that different horizons were represented in samples from one locality. However, the efforts at a zonal scheme by S. K. Shah and colleagues show that the faunas with *Tonkinella*, *Hundwarella*, *Bailiella* and/or agnostoids, eodiscoids and ptychopariids precede the *Shahaspis* (= *Bolaspidella* of Shah and Sudan 1982) fauna with *Bailiella* mostly in higher horizons than *Tonkinella* and *Hundwarella* having a longer range than either of them. All these faunas are Hsuehuangian by correlation with China. In all the material we have examined we have not seen *Bailiella lantenoisi* on the same slab of rock as either *Hundwarella memor* or *Iranoleesia butes*, nor have we seen the last two species together on one piece of rock. On the other hand, *Tonkinella breviceps* is commonly associated with *Hundwarella memor* on the same bedding planes. Our work provides little biostratigraphical information on this area, and we can only infer that *Hundwarella memor* occurs below *Iranoleesia butes*, as in Spiti. The extended ranges of *Iranoleesia butes* and *Bailiella lantenoisi* in Text-figure 4 take account of Reed's faunal lists and the work of S. K. Shah and colleagues. However, because illustrated specimens have yet to be linked to specific horizons in detailed sedimentary logs, the Cambrian biostratigraphy of Kashmir remains preliminary. We have not seen early Changhian fossils from Kashmir, since correlations with China indicate that *Iranoleesia butes*, *Bailiella lantenoisi* and the relatives of *Shahaspis himalayensis* are all upper Hsuehuangian. Damesellids (Shah and Sudan 1987b) from the lower part of the Trahagam Formation (conformable above the Nutunus Formation) occur above fossils described in this paper and appear conspecific with upper Middle Cambrian forms from China (Zhang and Jell 1987; Zhang 1988); thus correlation with the latest Changhian *Damesella-Yabeia* Zone (Zhang 1988) is suggested. *Monkaspis* and *Blackwelderia*? in the Trahagam Formation (Jell 1986) indicate the only late Cambrian (Kushanian) deposits presently known from Kashmir.

Kobayashi (1934) and Reed (1934) considered the Kashmiri and Spiti faunas to be coeval. Several recent papers have attempted to define accurate correlations between Kashmir and Spiti (Shah *et al.* 1988; Shah and Raina 1989, 1990). Shah and Raina (1990, fig. 1) suggested that *Hundwarella* and *Olenus* from Spiti (Hayden's (1904) Horizon 13) occur above *Damesella* and are of late Cambrian age. We consider that specimens assigned by Reed (1910) to *Olenus*?, *Dicelcephalus*? and *Bathyriscus*? (his Horizon 13 fauna), and those specimens assigned to *Tsinania* and *Spitella barachuensis* by Shah and Raina (1990, p. 44) and Shah *et al.* (1991, pp. 97, 101), belong to *Iranoleesia butes*. Thus we correlate Hayden's (1904) Horizon 13 in Spiti with that horizon high in the Nutunus Formation which contains *I. butes*. We consider *Hundwarella memor* (Reed, 1910) conspecific with many Kashmiri species described by Kobayashi (1934) and Reed (1934). Thus we correlate Hayden's Horizon 9 in Spiti with one slightly lower in the Nutunus Formation which contains *H. memor*. Implications of this correlation include: (1) specimens from Hayden's Horizon 13 (and those below) are older than the damesellid fauna of Kashmir; (2) no Upper Cambrian material has yet been described from Spiti; and (3) the faunal distinctness of Kashmiri and Spiti faunas is due in some measure to the different ages of these deposits.

We confirm Shah and Raina's (1989) assertion that proasaphiscid trilobites are useful for correlation within the Asian region. Proasaphiscid species are common to Kashmir, Vietnam, Siberia, Antarctica and China and genera are common to these areas, Iran and Turkey. The numerous synonymies established below reflect extreme taxonomic over-splitting of Cambrian trilobites (Hughes 1991). We predict that when further taxonomic revisions of Cambrian trilobites are completed the apparent endemism of those faunas will be reduced substantially.

The Kurgiakha fauna of Zaskar was discussed by Whittington (1986) and despite the report

herein of *Damesops*, a typical member of the Chinese Kushan fauna (Zhang 1988, p. 18), we concur with a latest Mid Cambrian age.

PROVINCIALISM AND PALAEOBIOGEOGRAPHY

Reed (1934, p. 1) suggested marked provincial differences between coeval Cambrian faunas from Kashmir and Spiti. Spiti faunas were considered to be of North American and European affinity (Reed 1910), whereas the Kashmiri fauna was thought to be similar to faunas from Vietnam (Reed 1934). This contrast has been interpreted as the result of a palaeoenvironmental gradient between shallow slope faunas (Spiti) and deep slope faunas (Kashmir) (Wakhaloo and Shah 1965). Others argued that the difference reflects deposition in different sedimentary basins (Gupta and Suneja 1977a), raising the possibility of suspect terranes within the Indian Himalaya. Pertinent to this question are the following. (1) Known fossiliferous sections in the two areas are not coeval for the most part (Text-fig. 4). We suggest apparent marked provinciality is largely the result of stratigraphical miscorrelation. Among the Middle Cambrian faunas those of Spiti are Maochuangian and lower Hsuehuangian whereas those of Kashmir are mostly upper Hsuehuangian. The Kurgian fauna of Ladakh is uppermost Changian, at the very end of the Middle Cambrian. (2) Himalayan Cambrian trilobite faunas are of relatively low diversity: in Kashmir trilobite faunas from individual sites often contain one species and never more than three or four, the taxa being common in slope settings in other Asian countries. *Shahaspis* is the only

TABLE 1. Distribution of Early and Mid Cambrian Himalayan trilobites elsewhere. G = same genus; S = same species.

	North America	Europe	Australia	Siberia	North China	South China	Vietnam	Iran
<i>Redlichia noetlingi</i>			G	G	G	S	G	S
<i>Redlichia takooensis</i>			S			S		
<i>Xela mathurjoshi</i>			G					
<i>Paokannia magna</i>						S		
<i>Pagetia significans</i>			S		G	G		
<i>Opsidiscus haimantensis</i>		G	G	G				
<i>Baltagnostus rakuroensis</i>	G		G		S			
<i>Oryctocephalus indicus</i>	G		G	G		S		
<i>Oryctocephalus salteri</i>								
<i>Tonkinella breviceps</i>	S			G	G	G	S	
<i>Yuehsienszella szechuanensis</i>						S		
<i>Kunmingaspis pervulgata</i>						G		S
<i>Kunmingaspis stracheyi</i>								
<i>Paramecephalus defossus</i>						G		
<i>Shantungaspis himalaica</i>					G			
<i>Douposiella hostilis</i>		G	G			G		
<i>Xingrenaspis maopoensis</i>						G		
<i>Xingrenaspis dardapurensis</i>						G		
<i>Solenoparia talingensis</i>					S			
<i>Bailiella lantenoisi</i>		G		G	S	S	S	
<i>Chittidilla plana</i>						S		
<i>Parachittidilla kashmirensis</i>					G	G		
<i>Hundwarella memor</i>				G	S	S	G	
<i>Iranoleesia butes</i>					S	G	S	G
<i>Szeaspis conjunctiva</i>					S			
<i>Shahaspis himalayensis</i>								
<i>Latilorenzella</i> sp.					G			

genus unique to Kashmir but its relatives are in China, Australia and Iran. Several polymerids, including *Tonkinella* and *Bailiella*, apparently had cosmopolitan distribution (Table 1). (3) Almost all Himalayan genera and several of the species are known from other areas, and most of these taxa are widespread peri-Gondwanan forms (Text-fig. 5). (4) The trilobite-bearing Himalayan Cambrian deposits accumulated on the outer continental shelf and slope. (5) Biostratigraphy of the Himalayan region is best integrated into the zonation established in China. The palaeontological evidence suggests a single biogeographical province within the Himalaya, with possible slight biofacies differentiation between some of the areas. The fauna is consistent with that of other peri-Gondwanan basins and provides no indication of any marked faunal anomalies.

The Lower and Middle Cambrian faunas bear greatest similarity at the species level to those from south (Zhang *et al.* 1980a) and north China (Zhang 1959; Zhang *et al.* 1980b; Zhang and Wang 1985; Zhang and Jell 1987), with seven and five species in common respectively. Fewer species in common with Australia, Vietnam and Iran probably reflect the fewer known taxa from those areas; greater numbers of taxa in common with these areas can be expected with further discoveries.

While the agnostoid-rich fauna from Zanskar is unknown elsewhere in the Himalaya, it is widely distributed (Table 2) through Sweden (Westergård 1946), Queensland (Öpik 1963, 1967),

TABLE 2. Distribution of the uppermost Middle Cambrian Kurgakh fauna in other areas. G = same genus; S = same species.

	Qld	Kazakh	Zhejiang	Qinling	Turkest	Sweden
<i>Goniagnostus spiniger</i>	S	G	S	G	G	S
<i>Lejopyge armata</i>	S	S	S	G	G	S
<i>Goniagnostus aculeatus</i>	S	S	S	S	S	G
<i>Diplagnostus planicauda</i>	S		S	S		S
<i>Linguagnostus tricuspid</i>	G		S	G	S	G
<i>Clavagnostus repandus</i>	G	G	G	S	G	S
<i>Hypagnostus correctus</i>	S	S	S	S	G	G
<i>Fuchouia</i> sp.	G		G	G		
<i>Schmalenseeia amphionura</i>						S
<i>Damesops sheridanorum</i>	G	G		G		
<i>Eoshengia?</i> <i>sudani</i>				G		
? <i>Olenus</i> sp.	G		G			G

Kazakhstan (Ergaliev 1980), Zhejiang (Lu and Lin 1989), Qinling (Yang 1993), Turkestan (Hajrullina 1973) and other parts of eastern Asia. It is interpreted as an oceanic fauna and thus unlikely to provide much palaeobiogeographical information.

Globally, the Himalayan Cambrian trilobite faunas are part of the Tollchuticook Province (Jell 1974) or East Asian Province with polymerid affinities to China and Australia (Table 1). The presumed oceanic species (oryctocephalids, *Bailiella*, and agnostoids) are consistent with outer shelf to slope environments and these cosmopolitan forms should not be relied upon as provincial indicators. Previously suggested affiliations with North American and European faunas were based largely on such forms.

These considerations of palaeobiogeography are of a general nature, and the details of taxa that indicate shelf, slope, etc. to allow comparisons in single biofacies are not yet available for Asia and are not yet applied widely in the Cambrian.

COMPUTER-GRAPHIC RESTORATION

Computer-graphic restorations of several specimens were attempted using an Apple Macintosh IIcx microcomputer and a Sharp JX-320 scanner. Photographs were scanned into the image processing package Adobe Photoshop version 2.0 at a resolution of 300 dots per inch (dpi) and adjusted to

correct for tectonic distortion (Hughes and Jell 1992). Images were filtered using 'unmask sharp' and 'despeckle' functions, and their tone adjusted using the 'levels' option. Images were then rescaled in QuarkXPress version 3.1, or Pagemaker version 4.0 and were printed on a Linotronic Image Setter 300 (resolution 2450 dpi, output 133 lines per inch). Some of the restorations, particularly those from material preserved with original relief, have not achieved perfect bilateral symmetry. This is possibly because the x - y plane of the strain ellipsoid is not parallel to bedding, and because of possible inaccuracies in determining the principal axis of extension. The restorations were achieved by aligning the image with the apparent x axis, and then shrinking this axis whilst holding the length of the y axis constant. This technique achieves an accurate restoration of lateral symmetry but slightly smaller than the original; it does not eliminate deformation from flattening. The images were placed into a page layout program and rescaled to their approximate original size; some were printed larger to provide greater detail. Strain ellipses in the lower left of restored images herein have their long axes in the direction of compression.

SYSTEMATIC PALAEOLOGY

Because the Cambrian faunas of the Himalaya are widely scattered, this section is arranged so that the faunas of different geographical areas are described separately. Exceptions to this arrangement occur where (1) a species occurs in more than one area (e.g. Spiti *Hundwarella memor* and *Iranoleesia butes* are treated with the Kashmir fauna) or (2) a particular taxonomic group is widespread (e.g. the redlichiods are dealt with together).

Sagittal or exsagittal dimensions are all referred to in terms of length; transverse dimensions are described in terms of width. Material described is housed in the following repositories: Geology Department, Australian National University (ANU); Invertebrate Paleontology Collection, Cincinnati Museum Center (CMCP); Geological Survey of India, Calcutta (GSI or GSIK); Palaeontological Collections, University of Jammu (KUF); Museum of Palaeontology, University of Milan (MPUM); Centre des Sciences de la Terre, Université Claude Bernard, Lyon (T); Peabody Museum at Yale University (YPM). The trilobite taxa revised herein but described originally by King (1937, 1941), Kobayashi (1934), Redlich (1899), Reed (1910, 1934) and Waagen (1889) were all indexed, and in some cases illustrated, by Sastry and Mamgain (1969). They used the citations and/or illustrations of the original authors directly; such citations are not repeated in synonymies provided herein.

To study the type specimens housed in the Geological Survey of India, Calcutta, NCH made latex casts of all available specimens; epoxy replicas of the internal moulds were made from these casts

EXPLANATION OF PLATE 1

Figs 1–15. *Redlichia noetlingi* (Redlich, 1899). 1–2, 4, 7–12, upper part of *Neobolus* Beds, Kussak Fort Hill, Salt Range. 1–2, 4, cranidia. 1, GSI7232 (1709), lectotype; $\times 2.25$. 2, GSI7233 (1710); $\times 3$. 4, GSI7329 (1712); $\times 2.25$. 7, GSI7237 (1715); latex cast from external mould of posterior thoracic segment; $\times 4$. 8–12, librigenae. 8, GSI7240b (1716); latex cast, $\times 3.5$. 9, GSI7234 (1717); $\times 3$. 10, GSI7238b (1718); $\times 2$. 11, GSI7235a (1719); $\times 8$. 12, GSI7235b (1720); $\times 4.5$. 3, GSI9773 (1711); ravine west-south-west of Muth, Spiti; $\times 2$. 5, GSI20208 (1713); near Ganog, Simur District, Himachel Pradesh, Krol-Tal Belt; latex cast; $\times 1.75$. 6, GSI20273 (1714); upper part of Arenaceous Member, Tal Formation, south-east of Kauriyala on Rishikesh-Badrinath Highway, Uttar Pradesh, Krol-Tal Belt; $\times 2.75$. 13–15, cranidia from near Ganog, Simur District, Himachel Pradesh, Krol-Tal Belt. 13, GSI20209 (1721); $\times 2.5$. 14, GSI20213 (1722); $\times 3.25$. 15, GSI20210 (1723); $\times 3.5$.

Specimens in figs 1–2, 4 and 9 were figured by Redlich 1899, pl. 1, figs 1–2, 8 and 3 and by King 1941, pl. 3, figs 1, 3, 2 and 4, respectively. Specimens in figs 7 and 11 were figured by Redlich 1899, pl. 1, figs 6 and 4, respectively. Specimen in fig. 3 was illustrated by Reed 1910, pl. 1, fig. 14. Specimens in figs 5, 13–15 were figured by Kumar *et al.* 1987, as fig. 3a–3b, 3f and 3c, respectively. Specimen in fig. 6 was figured by Joshi *et al.* 1989, pl. 1, figs 1–3.



where the original specimen was an internal mould and, unless otherwise stated, the illustrations herein are of these replicas. Numbers in brackets after GSI specimen numbers refer to the Cincinnati Museum Center collection in which the casts and replica moulds are housed.

Order REDLICHIIA Richter, 1933
Family REDLICHIIAE Poulsen, 1927
Genus REDLICHIA Cossmann, 1902

Type species. By original designation; *Hoeferia noetlingi* Redlich, 1899, from the Lower Cambrian of the Salt Range, Pakistan.

Redlichia noetlingi (Redlich, 1899)

Plate 1, figures 1–15; Plate 2, figures 1–3

- v*1899 *Hoeferia noetlingi* Redlich, p. 3, pl. 1, figs 1–8.
- v1910 *Redlichia noetlingi* (Redlich); Reed, p. 7, pl. 1, fig. 14.
- 1937 *Redlichia chinensis* Walcott; King, p. 4, pl. 1, fig. 2.
- 1939 *Redlichia noetlingi* (Redlich); Whitehouse, p. 188 [lectotype chosen].
- v1941 *Redlichia noetlingi* (Redlich); King, p. 3, pl. 3, figs 1–9; pl. 4, figs 1–10.
- 1955 *Redlichia noetlingi* (Redlich); Schindewolf and Seilacher, p. 293, pl. 6, figs 1–15; pl. 7, figs 1–6.
- 1974 *Redlichia noetlingi* (Redlich); Lu *et al.*, p. 86, pl. 32, fig. 4.
- 1974 *Redlichia noetlingi* (Redlich); Wolfart, p. 25, pl. 3, figs 4–8.
- 1980a *Redlichia noetlingi* (Redlich); Zhang *et al.*, p. 116, pl. 14, figs 1–5; pl. 15, fig. 5.
- v1987 *Redlichia noetlingi* (Redlich); Kumar *et al.*, p. 659, fig. 3a, c, f.
- v1987 *Redlichia* sp. Kumar *et al.*, p. 659, figs 3b, d–e, 4a–b.
- v.1987 Trilobite gen. et sp. indet. Kumar *et al.*, p. 659, fig. 4c–f.
- v?1989 *Redlichia* cf. *noetlingi* (Redlich); Joshi *et al.*, p. 540, pl. 1, figs 1–3.

Material. Lectotype GSI7232 (Redlich 1899, pl. 1, fig. 1) (designated Whitehouse 1939, p. 188), from the *Neobolus* Shale, eastern Salt Range, Pakistan. Himalayan material: GSI7233–7239 (Redlich 1899, pl. 1, figs 2–8; King 1941, pl. 3, figs 1–4), from type locality. GSIK33/591a–r (King 1941, pl. 3, figs 5–9; pl. 4, figs 1–10), from Kusak Fort Hill. GSI9773, from a ravine west-south-west of Muth, Spiti. GSI20208–20219, Tal Formation, western Nigalidhar Syncline, near Ganog, Himachal Pradesh. GSI20273, Arenaceous Member, Tal Formation, south-east of Kauriyala on the Rishikesh–Badrinath Highway, Uttar Pradesh.

Diagnosis. Glabellar furrow S1 continuous but shallowing across axis; S2 much shallower, not continuous across axis. Palpebral lobes narrow and short for the genus, posterior opposite SO, anterior opposite S3. Palpebral furrow and furrow in front of eye ridge well-impressed.

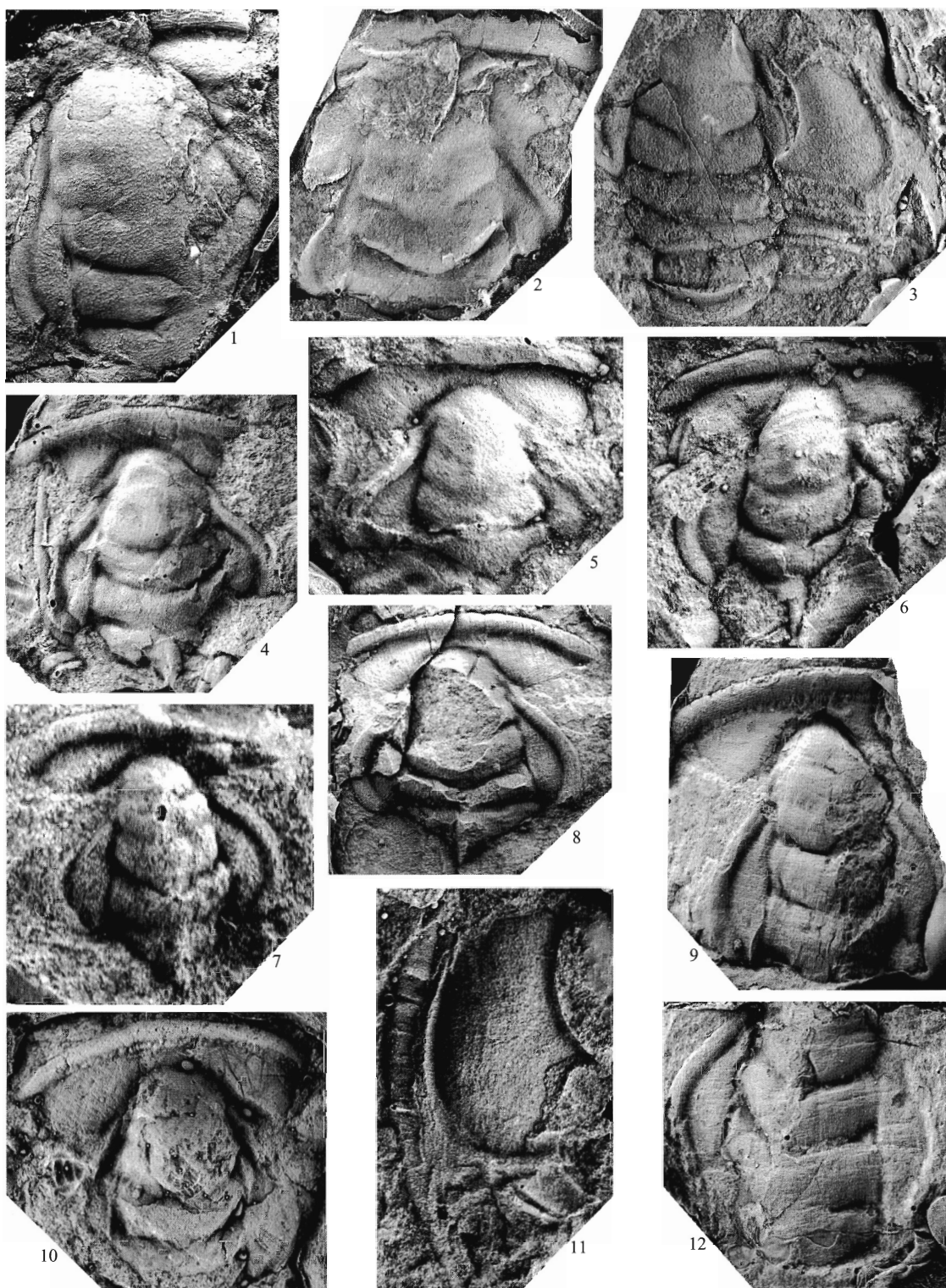
Description. Glabella reaching anterior border furrow, widest at midpoint of L1, lateral margins subparallel

EXPLANATION OF PLATE 2

Figs 1–3. *Redlichia noetlingi* (Redlich, 1899); near Ganog, Simur District, Himachal Pradesh, Krol-Tal Belt. 1, GSI20211 (1724); cranium; $\times 1.75$. 2, GSI20214 (1725); anterior portion of cranium; $\times 2.75$. 3, GSI20212 (1726); portion of cephalon and anterior thorax; $\times 2$.

Figs 4–12. *Redlichia takooensis* Lu, 1950; upper Lolab Formation, along a steep ridge south-west of Putshai stream, Lolab Valley, Kashmir. 4–10, cranidia. 4, GSI20250b (1727); latex cast; $\times 2.5$. 5, GSI20254a (1728); $\times 5$. 6, GSI20251 (1729); $\times 4.5$. 7, GSI20254b (1730); small cranium showing relatively large eyes; $\times 13.25$. 8, GSI20249 (1731); specimen damaged since original illustration; $\times 2.5$. 9, GSI20252a (1732); latex cast; $\times 2.75$. 10, GSI20250a (1733); $\times 3$. 11, GSI20254c (1734); librigena; $\times 5.25$. 12, GSI20252b (1735); latex cast of cranium; $\times 2.75$.

Specimens in figs 1–3 were figured by Kumar *et al.* 1987, figs 3d, 4a and 3e, respectively. The specimen in fig. 8 was figured by Raina and Razdan 1975, fig. 1, and by Shah *et al.* 1980, pl. 1, fig. 1. Specimens in figs 4–7 and 9–10 were figured by Shah *et al.* 1980, pl. 1, figs 8, 5, 10, 7, 13 and 2, respectively.



anterior of S1, anterior margin rounded. S1 continuous, oblique inwards and backwards, shallower medially, confluent with axial furrow. S2 oblique, crossing half glabellar width, confluent with axial furrow. S3 narrow, weak. SO shallower medially, confluent with axial furrow. Border convex, of uniform length. Palpebral lobe posterior opposite SO, midpoint opposite anterior of S1, anterior opposite S3 and continuing unchanged in direction or cross section into eye ridge which is confluent with axial furrow at very low angle just anterior to S3. Palpebral furrow deep. Preocular fixigena crossed by deeply incised furrow parallel with and adjacent to eye ridge. Preocular suture diverges at *c.* 50° to sagittal axis.

Remarks. Redlich (1899) recognized *R. noetlingi* var. *angusta*, which is elongate and narrow, and *R. noetlingi* var. *lata* which is short and wide. King (1941) demonstrated that this variation is due to tectonic deformation. Specimens assigned to *Redlichia* cf. *knjazevi* by Shah *et al.* (1980) lie within this range of variation (King 1941). Intraspecific variation among Iranian *R. noetlingi* (Wolfart 1974, p. 27) is similar to that among Indian *R. noetlingi*; we concur with Wolfart's (1974) opinion that other redlichiid species may be synonymous with *R. noetlingi*.

R. noetlingi is the only species occurring in the High (Spiti) and Lesser (Krol-Tal Belt) Himalayan thrust slices of Brookfield (1993) and in the Salt Range (Pakistan Himalaya). Only in China is it known in a sequence of faunas; there it occurs in the upper Tsanglangpuian and lower Lungwangmiaoan stages. Its occurrence in Iran with *Yuehsienzella* suggests a similar age across southern Asia. In the absence of contrary evidence, isolated occurrences of *R. noetlingi* indicate horizons within its range in China.

Redlichia takooensis Lu, 1950

Plate 2, figures 4–12

- v.1975 *Redlichia* cf. *noetlingi* (Redlich); Raina and Razdan, p. 64, fig. 1.
- v.1980 *Redlichia noetlingi* Redlich; Shah *et al.*, p. 513, pl. 1, figs 1–3, 7–9.
- v.1980 *Redlichia* cf. *knjazevi* Repina; Shah *et al.*, p. 513, pl. 1, figs 4, 10, 12–13.
- v.1980 *Tungusella obesa* Repina; Shah *et al.*, p. 514, pl. 1, figs 5–6.
- v.1990 *Redlichia takooensis* Lu; Jell in Bengtson *et al.*, p. 271, fig. 181 [with full synonymy].

Material. Holotype (Lu *et al.* 1965, pl. 9, fig. 1 and Zhang *et al.* 1980a, pl. 23, fig. 13). Himalayan material: GSI20249–20254, from the southern side of the Lolab Valley *c.* 3.5 km west of Sogam (34° 30' 30"N, 74° 20' 30"E), Kashmir, in the Early Cambrian Lolab Formation.

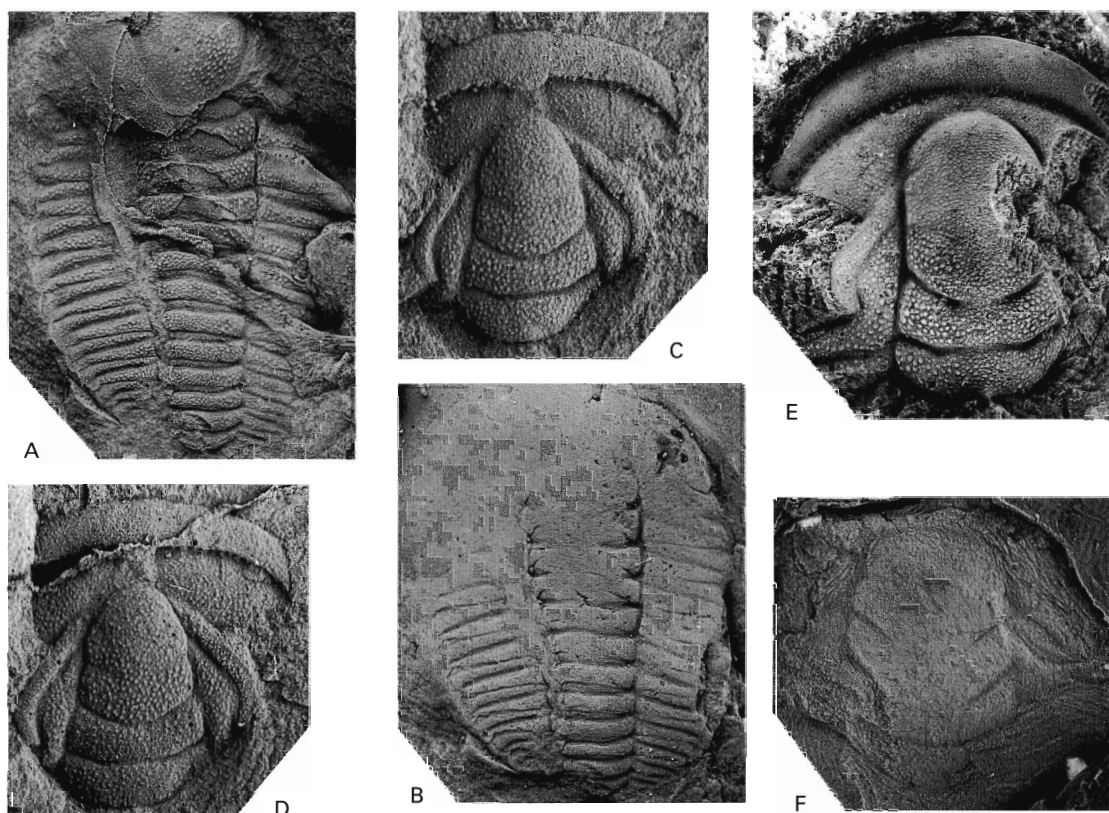
Description. See Jell (in Bengtson *et al.* 1990, p. 271), but with following notes on intraspecific variation or new information. Glabellar anterior in anterior border furrow (Pl. 2, fig. 6) as in South Australian material or behind the border furrow as in most Chinese specimens (Zhang in Zhang *et al.* 1980a, pl. 23, figs 11–13) but the same range of variation as in Chinese material (cf. Zhang *et al.* 1980a, pl. 23, fig. 14). S1 and S2 may be continuous across the axis as in some Chinese specimens. Posterior of palpebral lobe posterior to occipital furrow.

Remarks. The occipital spine is distinctive of this species (Jell, in Bengtson *et al.* 1990) and separates it from *R. noetlingi*, *R. knjazevi* Repina, 1966 and *Tungusella*. These two Siberian taxa have the posterior of their palpebral lobes much farther laterally from the axial furrow than in *R. takooensis*. We assign all the material of Shah *et al.* (1980, pl. 1, figs 1–13) from west of Sogam to *R. takooensis*. Differences used by Shah *et al.* (1980) to separate taxa from the one locality are here interpreted as due to tectonic deformation.

Family DOLEROLENIDAE Kobayashi, in Kobayashi and Kato, 1951

Genus XELA Jell, in Bengtson *et al.*, 1990

Type species. By original designation; *Xela drene* Jell, in Bengtson *et al.*, 1990, from the Lower Cambrian (*Pararaia janeae* Zone) of South Australia.



TEXT-FIG. 5. A–D, *Xela mathurjoshi* sp. nov. A–B, GSI20248 (1993); latex cast from external mould and internal mould, of incomplete specimen; $\times 3$ (Mathur and Joshi 1989, fig. 4). C–D, GSI20247 (1994); internal mould and latex cast from external mould of holotype cranium; $\times 7$ (Mathur and Joshi 1989, fig. 3). E, *Xela drenea* Jell, in Bengtson *et al.*, 1990; NMVP127161; holotype cranium from Flinders Ranges, South Australia; $\times 2$. F, GSI20274; unidentifiable cranium described as *Tungusella* cf. *obesa* in Joshi *et al.* 1989; $\times 2$.

Xela mathurjoshi sp. nov.

Text-figure 5A–D

v.1989 *Redlichia noetlingi* (Redlich); Mathur and Joshi, p. 269, fig. 3.

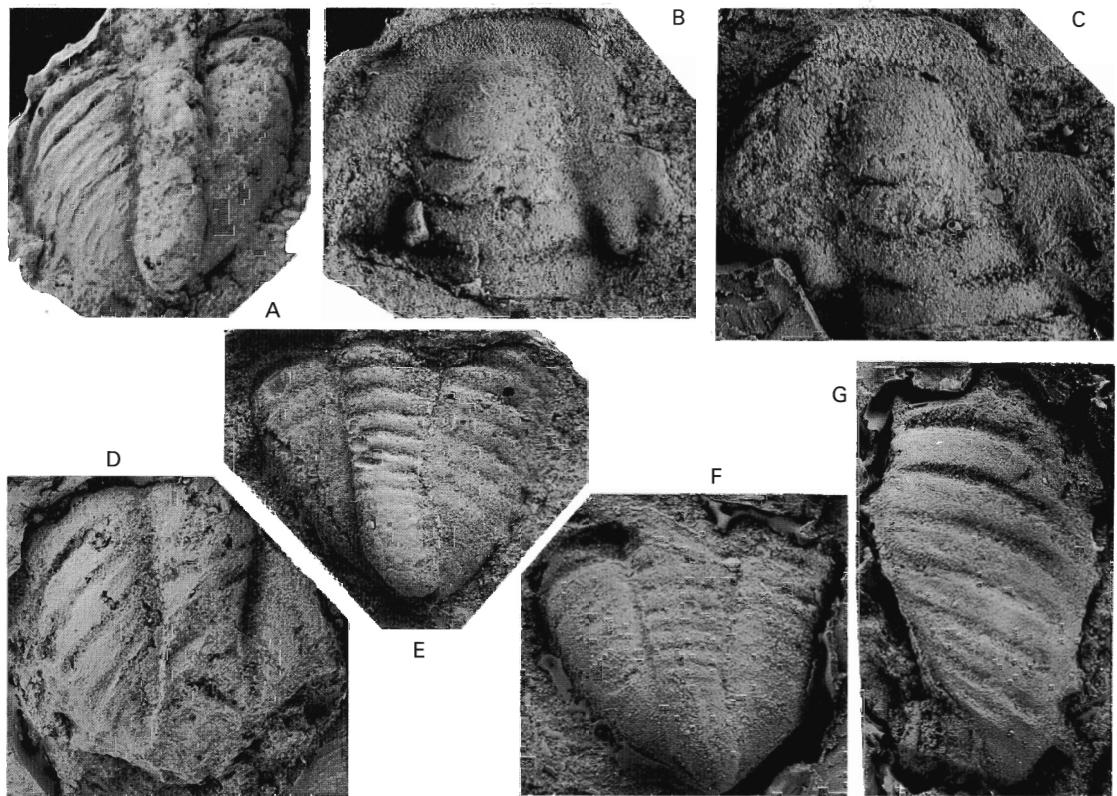
v.1989 trilobite gen. indet. Mathur and Joshi, p. 269, fig. 4.

Derivation of name. For V. K. Mathur and Ashutosh Joshi who first recorded this material.

Material. Holotype GSI20247 (Mathur and Joshi 1989, fig. 3); paratype GSI20248 (Mathur and Joshi 1989, fig. 4), both from greenish grey shales of the Early Cambrian Phulchatti Member, Tal Formation c. 1 km south-south-west of Durmala (30°25'50"N; 78°10'45"E) on the northern limb of the Mussoorie Syncline, Uttar Pradesh.

Diagnosis. Plectrum well-developed, prelabellar field long.

Description. Glabella sub-conical, tapering forward to well rounded anterior, 1.5 times as long as basal width; S1 continuous across axis, gently convex posteriorly, sharply impressed; S2 shallow, discontinuous across axis, a straight line posteroaxially from axial furrow; S3 barely apparent. SO sharply impressed, central third



TEXT-FIG. 6. *Paokannia magna* Qian and Yao, in Zhang *et al.*, 1980a; Vel Member of the Lolab Formation near Vel Nagabel, Anantnag district, south-east of Srinagar. A, GSI20264 (1995); internal mould of pygidium; $\times 2$. B–C, GSI20270 (1996); latex casts from external mould and internal mould, of cranidium; $\times 4$. D, GSI20263 (1997); internal mould of pygidium; $\times 3$. E–F, GSI20266 (1988); latex casts from external mould and internal mould of pygidium; $\times 3$. G, GSI20267 (1999); internal mould of fragmentary pygidium; $\times 2$.

transverse, lateral parts running forward to axial furrow. LO of uniform length, with faint posteromedian tubercle. Preglabellar field about as long as border sagittally, crossed by strong median plectrum. Border furrow well-impressed, with row of pits, with steep anterior wall but gentle posterior slope. Anterior border gently convex, of uniform length except at sagittal plectrum. Eye ridge running from anterior corners of glabella at low angle to axial furrow, wide, with convex to subquadrate section. Palpebral lobes narrow, close to axial furrow (interocular cheek 1.5 times width of palpebral lobe), continuous from eye ridge, of characteristic 'J' or 'hockey stick' shape, with posterior tip lateral from axial furrow by width of the palpebral lobe. Preocular facial suture leaving eye ridge some distance lateral to the axial furrow, diverging forward at *c.* 60° to sagittal line. Posterolateral cephalic limb as long as LO proximally. Thorax of at least 12 segments. Axis wide, tapering posteriorly, without spines. Pleurae with well-impressed diagonal pleural furrow, pleural extremities not preserved, with steeply sloping anterolateral facets becoming narrower and smaller posteriorly. Dorsal surface, except in furrows, with coarse tubercular ornament.

Remarks. This species is separated from *X. drenea* (Text-fig. 5E) only by the length of the preglabellar field and development of a strong plectrum. *X. drenea* is interpreted as indicating the Tsanglangpuian or Botomian, and there are no data to suggest a different age for this Indian occurrence.

Family YINITIDAE Hupé, 1953

Genus PAOKANNIA Ho and Li, 1959

Type species. By original designation; *Paokannia chinensis* Ho and Li, 1959, from the Tsanglangpuian of northern Hubei, China.

Paokannia magna Qian and Yao, in Zhang *et al.*, 1980a

Text-figure 6A–G

- 1980a *Paokannia magna* Qian and Yao, in Zhang *et al.* p. 197, pl. 55, fig. 13; pl. 56, figs 1–2.
 v.1987 *Paokannia* sp. Kumar and Verma, p. 132, pl. 1, figs 2–5, 7, 9.
 v.1987 *Paokannia* sp. cf. *angulata* Zhang; Kumar and Verma, p. 132, pl. 1, figs 6, 12.
 v.1987 *Paokannia magna* Qian and Yao; Kumar and Verma, p. 132, figs 8, 10–11.

Material. Holotype NIGP37884 (Zhang *et al.* 1980a, pl. 55, fig. 13), from the Early Cambrian Yingzuyan Formation, northern Sichuan. Himalayan material GSI20262–20272, from the medial Early Cambrian Vel Member, Lolab Formation near Vel Nagabel, Hapatnar Valley, Anantnag district south-east of Srinagar, Kashmir.

Description. Glabella sub-conical, truncated anteriorly, SO and S1 shallowing over axis; anterior border convex, broadly pointed anteromedially; anterior border furrow long, poorly impressed; interocular cheeks narrow; posterior of palpebral lobe opposite midlength of L1. Pygidium sub-triangular; seven pleural segments, but more than ten axial rings; large bulbous axial terminus reaching posterior margin; five pairs of stout marginal spines, one pair on each of five anterior segments.

Remarks. Kumar and Verma (1987) distinguished three species on the basis of pygidial outline, number of pygidial segments, and pleural furrows. It appears that these were the features used, despite Kumar and Verma's (1987) paper having the 'Remarks' section under *P. magna* apparently referring to *P. sp. cf. angulata*, and the heading for the latter missing; it appears that some text is missing at the foot of the first column on page 132 of their paper. Kumar and Verma (1987, figs 7, 11) illustrated both ends of the range of variation in pygidial outline; these are laterally and longitudinally compressed specimens, respectively. The number of pygidial segments is determined as number of pleural segments; there are considerably more axial than pleural segments. Well-impressed furrows on the pleural areas are pleural furrows and less well-impressed ones are interpleural furrows, usually high on the pleural ribs. The latter are not always apparent, probably due to the varying extent and direction of deformation. However, the number of pleural furrows (including the anterior border furrow) is seven on each of Kumar and Verma's (1987) three taxa where they can be counted or confidently inferred. Kumar and Verma (1987) also separated *Paokannia* sp. on its well-developed pleural furrows. Impressions of the furrows seems to be correlated with the degree of deformation (more deformation, better impressed furrows); impression of the furrows could not be considered to be a specific discriminator given the type of preservation. Therefore, the Indian *Paokannia* material of Kumar and Verma (1987) is herein taken to represent one species. Internal and external cranidial moulds are almost identical (Text-fig. 6B–C), so it can be expected that the same would be so in the pygidium.

Ten species of *Paokannia* have been erected in China (*triangulata* Ho and Lee, 1959 and Lee, 1978 are homonyms); four other taxa are in open nomenclature. Species concepts are not always clear, but features diagnosing *P. magna* above make it distinctive: the convex anterior border without discrete anterior border furrow, shape of the anterior border due to the course of facial sutures, position of the palpebral lobe, well-impressed SO and S1 shallowing medially.

SALT RANGE

Material described in this section comes from the eastern Salt Range, Pakistan unless stated otherwise.

Order REDLICHIIA Richter, 1933

Redlichiid indet.

Plate 3, figure 5

v*1889 *Olenus indicus* Waagen, p. 97, pl. 1, fig. 3.1941 *Olenus indicus* Waagen; King, pl. 1, fig. 5.

Material. GSI4114, a cranial fragment consisting of the anterior of the glabella, anterior part of left fixigena and posterior part only of anterior border from the upper *Neobolus* Shales at Chél Hill near Kussak.

Remarks. This specimen is so fragmentary as to be almost completely unidentifiable. King (1941, p. 14) suggested placement in *Blackwelderia* Walcott, based on the coarse ornament. Among tuberculate redlichiids (Zhang *et al.* 1980a, pl. 27; pl. 43, figs 4–6, 8–9) may be found a more likely placement. We advocate isolating Waagen's specific name unless better material becomes available.

Order PTYCHOPARIIDA Swinnerton, 1915 emend. Fortey, 1990

Family ANTAGMIDAE Hupé, 1953

Genus YUEHSIENSZELLA Chang, 1957

Type species. By original designation; *Ptychoparia szechuanensis* Sun, 1939, from the Lower Cambrian of Sichuan.

Yuehsienszella szechuanensis (Sun, in Lu, 1939)

Plate 3, figures 1–4, 8–13

- 1939 *Ptychoparia szechuanensis* Sun in Lu, p. 20, pl. 1, figs 1–12.
 v.1941 *Ptychoparia geei* King, p. 10, pl. 1, figs 6–7.
 v.1941 *Ptychoparia sakasarensis* King, p. 12, pl. 1, figs 8–9; pl. 2, figs 1–4.
 1964 *Yuehsienszella magna* Chang, p. 27, pl. 1, fig. 8.
 1980a *Yuehsienszella szechuanensis* (Sun); Zhang *et al.*, p. 300, pl. 99, figs 1–2; pl. 100, figs 1–17; pl. 101, figs 1–2.
 1980a *Yuehsienszella magna* (Sun); Zhang *et al.*, p. 303, pl. 101, fig. 3.
 1980a *Yuehsienszella* sp. 1 Zhang *et al.*, p. 304, pl. 101, fig. 4.
 1980a *Yuehsienszella* sp. 2 Zhang *et al.*, p. 304, pl. 101, figs 5–6.
 1980a *Yuehsienszella* sp. 3 Zhang *et al.*, p. 304, pl. 101, fig. 7.

EXPLANATION OF PLATE 3

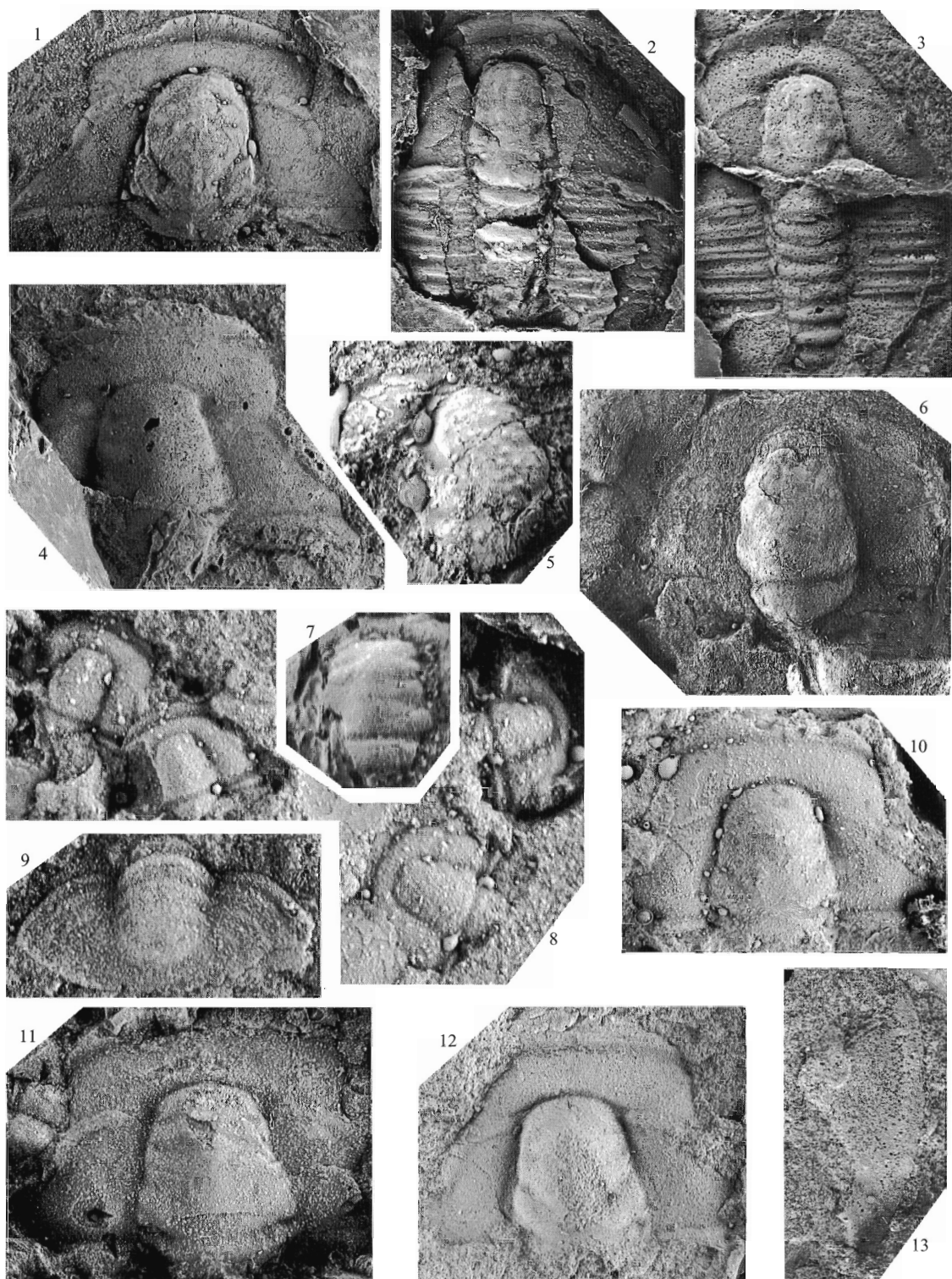
Figs 1–4, 8–13. *Yuehsienszella szechuanensis* (Sun, 1939); upper *Neobolus* beds, Kussak Fort Hill, Salt Range, Pakistan. 1, GSI17257 (1857); cranidium; $\times 3.25$. 2–3, GSI17256 (1858); cephalon and anterior thorax; $\times 3$. 3, latex cast. 4, GSI17258b (1859); latex cast of cranidium; $\times 5.75$. 8, GSI17261 (1860–1863); four cranidia; $\times 10$. 9, GSI 17260 (1864); pygidium; $\times 8$. 10, GSI17258a (1865); cranidium; $\times 5$. 11, GSI17259 (1866); cranidium; $\times 5$. 12, GSI17258a (1865); latex of external mould of fig. 10; $\times 5$. 13, GSI17263 (1867); librigena, latex cast, $\times 4.5$.

Fig. 5. Redlichiid indet.; uppermost *Neobolus* beds, Chél Hill, Salt Range, Pakistan; GSI4114 (1868); partial cranidium; $\times 5.75$.

Fig. 6. cf. *Yuehsienszella szechuanensis* (King, 1941); Magnesian Sandstone, Kussak Fort Hill, Salt Range, Pakistan; GSI17252 (1869); cranidium; $\times 3.5$.

Fig. 7. cf. *Yuehsienszella szechuanensis* (King, 1941); uppermost *Neobolus* beds, Kussak Fort Hill, Salt Range, Pakistan; GSI4112 (1870); cranidium; $\times 10$.

Specimens in figs 1–2, 8–11 and 13 were figured by King 1941, pl. 1, figs 7, 6; pl. 2, figs 2, 1; pl. 1, figs 8–9 and pl. 2, fig. 4, respectively. Specimens in figs 5 and 7 were figured by Waagen 1889, pl. 1, figs 3 and 1, and by King, 1941, pl. 1, figs 5 and 4, respectively. The specimen in fig. 6 was figured by Redlich 1901, pl. 1, fig. 21.



1980a *Yuehsienszella* sp. 4 Zhang *et al.*, p. 304, pl. 98, fig. 18.

1980a *Yuehsienszella* sp. 5 Zhang *et al.*, p. 304, pl. 98, fig. 19.

Material. GSI17256–17263, from east-north-east of Chittidil Rest House.

Diagnosis. See Zhang *et al.* 1980a.

Remarks. King's (1941) Salt Range material may vary slightly in proportions of the glabella, dimensions of the anterior border, frontal area and course of the eye ridge, but comparison with the Chinese species suggests that these variations are intraspecific. In the Salt Range material the glabella appears to be more distinctly truncate anteriorly than rounded as in the Chinese material, but comparison with mature specimens from China (Zhang *et al.* 1980a, pl. 101, figs 1–2) shows that identical glabellar shapes are known in the two areas, with some variation in this feature in each population. The eye ridge meeting the axial furrow at the level of the rear of the anterior glabellar lobe is distinctive of the genus.

cf. *Yuehsienszella szechuanensis* (Sun, in Lu, 1939)

Plate 3, figure 6

v.1899 *Ptychoparia richteri* Redlich, p. 4, pl. 1, figs 21–22.

Material. GSI7252, Early Cambrian Purple Sandstone at Kussak Fort Hill.

Remarks. Redlich (1899) acknowledged that the corroded surfaces and lack of thorax and pygidium prevent certain identification. However, he described the eye ridge reaching the axial furrow at the level of S3 which is indicative of Lower Cambrian ptychoparioids such as *Yuehsienszella*. We compare it with the co-occurring *Y. szechuanensis* but the occipital spine may indicate a separate species. The occipital spine is not in the sagittal line in one of Redlich's (1899, pl. 1, fig. 21) specimens, suggesting that it may be a broken spine lying fortuitously beneath the rear of LO; the second specimen was not available to us. Since Redlich (1899) illustrated them as occipital spines we accept his interpretation.

cf. *Yuehsienszella szechuanensis* (Sun, in Lu, 1939)

Plate 3, figure 7

v.1889 *Conocephalites warthi* Waagen, p. 94, pl. 1, fig. 1.

v.1941 *Ptychoparia warthi* (Waagen); King, pl. 1, fig. 4.

Material. GSI4112, an incomplete cranidium, from the Early Cambrian upper *Neobolus* Shales, Kussak Fort Hill.

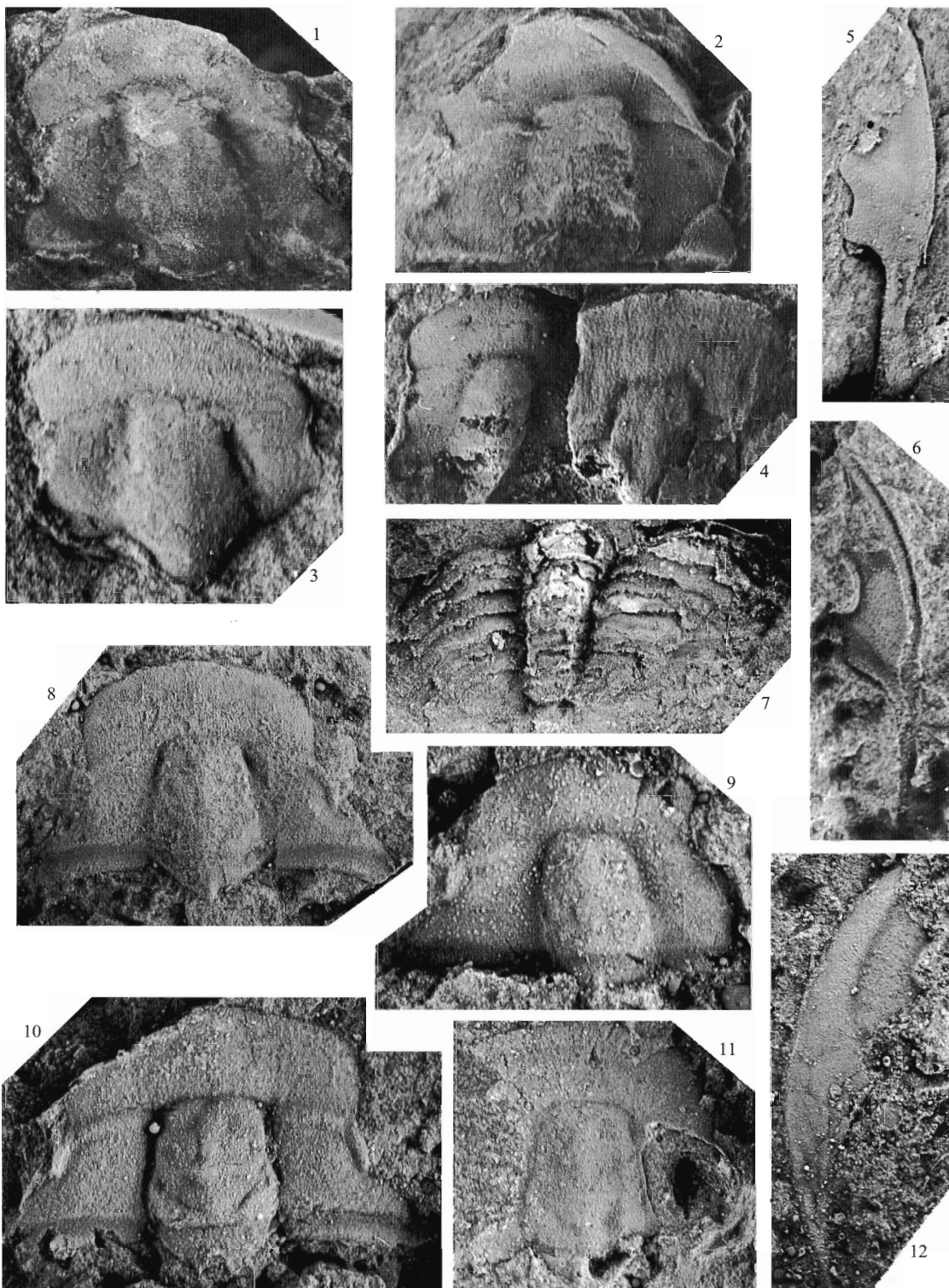
Remarks. This cranidium is not as complete now as it was when illustrated by Waagen or King. It is probably a juvenile of the co-occurring *Yuehsienszella szechuanensis* in the absence of more information.

EXPLANATION OF PLATE 4

Figs 1–7. *Parachittidilla kashmirensis* (Shah, Parcha and Raina, 1991) from ANU10398, Hundwara Tehsil, Pohru Valley, Kashmir. 1–2, 4 and 6 are internal moulds; 3, 5 and 7 are latex casts. 1, ANU49467; cranidium; $\times 6$. 2, ANU49468; cranidium; $\times 6$. 3, ANU49469; cranidium; $\times 8$. 4, ANU49470; cranidium; $\times 8$. 5, ANU49471; librigena; $\times 5$. 6, ANU49472; librigena; $\times 5$. 7, ANU49473; pygidium and posterior thorax; $\times 6$.

Figs 8–12. *Chittidilla plana* King, 1941; purple shales near the top of the Magnesian Sandstone, Kussak Fort Hill, Salt Range, Pakistan. 8–11, cranidia. 8, GSI17264 (1871), holotype; $\times 5$. 9, GSI17267b (1872); $\times 9$. 10, GSI17265 (1873); $\times 8$. 11, GSI17266 (1874); $\times 5$. 12, GSI17267a (1875); librigena; $\times 7$.

Specimens in figs 8–9 and 11–12 were figured by King 1941, pl. 2, figs 5–8, respectively.



JELL and HUGHES, *Parachittidilla*, *Chittidilla*

Family AGRAULIDAE Raymond, 1913

Genus CHITTIDILLA King, 1941

Type species. By original designation; *C. plana* King, 1941, from the lower Middle Cambrian of the Salt Range.

Chittidilla plana King, 1941

Plate 4, figures 8–12

- v*1941 *Chittidilla plana* King, p. 13, pl. 2, figs 5–8.
- 1941 *Paragraulos kunmingensis* Lu, p. 85, pl. 1, fig. 7a–b.
- 1957 *Paragraulos kunmingensis* Lu; Lu, p. 270, pl. 140, fig. 13.
- 1965 *Paragraulos kunmingensis* Lu; Lu *et al.*, p. 235, pl. 40, figs 21–22.
- 1978 *Paragraulos kunmingensis* Lu; Lee, p. 221, pl. 97, fig. 1.
- 1978 *Chittidilla nanchuanensis* Lee, p. 220, pl. 97, fig. 2.
- 1978 *Paragraulos leiboensis* Lee, p. 221, pl. 97, figs 3, 6.
- 1978 *Paragraulos jinshajiangensis* Lee, p. 221, pl. 97, fig. 4.
- 1978 *Chittidilla plana* King; Lee, p. 219, pl. 97, fig. 5.
- 1978 *Chittidilla emeishanensis* Lee, p. 220, pl. 97, figs 8–9.
- 1978 *Chittidilla transversa* Qian and Yao; Lee, p. 220, pl. 97, fig. 10.
- 1978 *Paragraulos lianhuashiensis* Lee, p. 221, pl. 97, figs 13–14.
- 1980a *Chittidilla nanjiangensis* Lu and Zhang, in Zhang *et al.*, p. 376, pl. 121, figs 1–3.
- 1980a *Chittidilla yunshancunensis* Lu and Zhang, in Zhang *et al.*, p. 377, pl. 121, figs 4–5.
- 1980a *Chittidilla transversa* Qian and Yao, in Zhang *et al.*, pl. 121, figs 1–3.
- 1980a *Chittidilla similis* sp. nov. Lu and Zhang, in Zhang *et al.*, p. 375, pl. 122, figs 1–5.
- 1980a *Chittidilla yunnanensis* sp. nov. Lu and Zhang, in Zhang *et al.*, p. 375, pl. 122, figs 6–9.
- 1980a *Chittidilla (Diandongaspis) polocunensis* sp. nov. Lu and Zhang, in Zhang *et al.*, p. 379, pl. 122, figs 10–11.
- 1980a *Chittidilla oblonga* sp. nov. Lu and Zhang, in Zhang *et al.*, p. 376, pl. 123, figs 1–2.
- 1980a *Chittidilla (Diandongaspis) laevigata* Lu and Zhang, in Zhang *et al.*, p. 379, pl. 123, figs 3–4.
- 1980a *Chittidilla (Diandongaspis) diandongensis* Lu and Zhang, in Zhang *et al.*, p. 378, pl. 123, figs 5–13; pl. 124, fig. 2.
- 1980a *Chittidilla (Diandongaspis) brevicata* Lu and Zhang, in Zhang *et al.*, p. 378, pl. 124, fig. 1.
- 1993 *Chittidilla oblonga* Lu and Zhang; Yang, p. 189, pl. 15, figs 8–9.
- 1993 *Chittidilla nanjiangensis* Lu and Zhang; Yang, p. 189, pl. 15, figs 10–11.

Material. Holotype, GSI17264; GSI17265–17267, from shales near the top of the Magnesian Sandstone, Salt Range.

Description. King (1941) indicated a glabella with straight sides tapering forward, three pairs of lateral glabellar furrows, short blunt occipital spine, wide fixigena, no anterior border furrow, transverse eye ridge leaving axial furrow at rear of anterior glabellar lobe, a palpebral lobe opposite the middle third of the glabella, preocular facial sutures almost parallel, a strong genal spine, and blunt thoracic pleural spines.

Remarks. Most distinctive of *Chittidilla* is its lack of an anterior border furrow. Zhang and Jell (1987) discussed the Agraulidae and probable synonymy of *Paragraulos* Lu, 1941 with *Chittidilla*; that synonymy is confirmed herein. Lu and Zhang (in Zhang *et al.* 1980a) erected *C. (Diandongaspis)*, distinguished by its faint anterior border furrow and slightly divergent preocular facial sutures. King (1941) indicated the preocular sutures as ‘practically straight forward’ (as in *C. (Diandongaspis)*). Even in the type material there is a faint anterior border furrow and the fact that the border furrow on the librigena (Pl. 4, fig. 12) runs up to the facial suture indicates that it must have continued onto the cranidium. Lu and Zhang (in Zhang *et al.* 1980a) erected six species of *Chittidilla* and four of *C. (Diandongaspis)*. Five occur at horizon EY103 and all the specific features quoted are interpreted here as intraspecific variation. The same is true for the seven species reported (Lee 1978) from Sichuan. *Kermanella lata lata* Wolfart, 1974 and *K. lata minuta* from south-eastern Iran are referred to *Chittidilla* following Lu and Zhang (in Zhang *et al.* 1980a).

SPITI

Unless stated otherwise the material described in this section comes from the Parahio River Section in Spiti (Hayden 1904; Reed 1910). Numbered horizons in the text are those shown by Hayden and Reed.

Order AGNOSTIDA Salter 1864a

Superfamily EODISCOIDEA Raymond, 1913

Family EODISCIDAE Raymond, 1913

Genus PAGETIA Walcott, 1916

Type species. By original designation; *Pagetia bootes* Walcott, 1916, from the Middle Cambrian (*Bathyriscus-Elrathina* Zone) of British Columbia, Canada.

Pagetia significans (Etheridge, 1902)

Plate 5, figures 1–4, 7–11, 15

- v*1902 *Microdiscus significans* Etheridge, p. 3, pl. 2, figs 5–9.
- v1910 *Microdiscus Griesbachi* Reed, p. 6, pl. 1, figs 4–11.
- v1936 *Pagetia significans* (Etheridge); Whitehouse, p. 81, pl. 8, figs 4–5 [*non* pl. 8, figs 1–3].
- 1943 *Pagetia (Eopagetia) significans* (Etheridge); Kobayashi, p. 40.
- 1943 *Pagetia (Mesopagetia) griesbachi* (Reed); Kobayashi, p. 40.
- 1944a *Pagetia (Eopagetia) significans* (Etheridge); Kobayashi, p. 63.
- 1944a *Pagetia (Mesopagetia) griesbachi* (Reed); Kobayashi, p. 66.
- v.1975 *Pagetia significans* (Etheridge); Jell, p. 35, pls 14–15.
- non1995 *Pagetia greisbachi* (Reed); Shah *et al.*, p. 221, pl. 1, figs e–f; pl. 2, figs a, d, g.

Material. Lectotype AMF9138a (Jell 1975, pl. 14, fig. 1), from the Middle Cambrian (*Xystridura templetonensis* Zone) of central Australia (chosen Whitehouse 1936, p. 83). Himalayan material GSI9763–9770 (Reed 1910, pl. 1, figs 4–11), from Horizon 2.

Remarks. Whitehouse (1936) and Jell (1975) assigned *P. griesbachi* to *Pagetia* on Reed's (1910) illustrations. An articulated specimen (Pl. 5, fig. 4) has a typical pagetiid, two-segmented thorax. Most of Reed's types are internal moulds lacking the terminal axial spine and, even in external moulds, tectonic deformation has collapsed the cavity left by dissolution of the fine terminal axial spine. Internal moulds have a broken pygidial axial posterior where the spine would be expected. Careful preparation of external moulds is necessary to show the terminal axial spine on many species of *Pagetia*, particularly those in deformed terrigenous sediments. Comparison of Himalayan internal moulds (Pl. 5, figs 4–11) with other well-preserved ones (Jell 1975, pl. 4, figs 6, 10–11; pl. 11, figs 5–6) supports the assumption of a terminal axial spine in the Spiti material. Whitehouse (1936) separated *P. griesbachi* and *P. significans* on the number of pygidial pleural furrows and size, but a growth series of *P. significans* (Jell 1975, pl. 15) shows that the number of pygidial pleural furrows increases with growth. Immature *P. significans* pygidia and Spiti pygidia of the same size are identical.

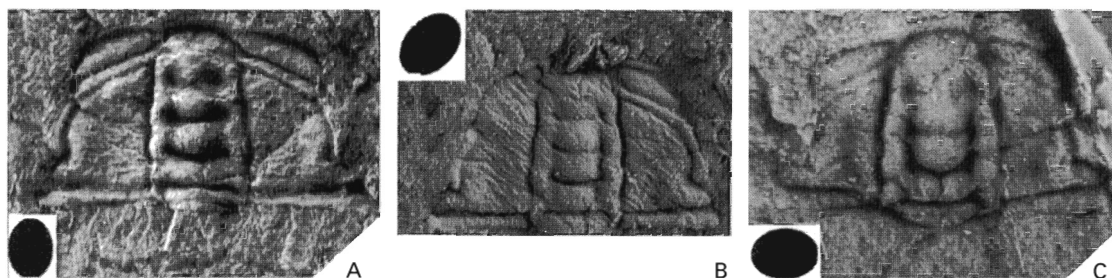
Genus OPSIDISCUS Westergård, 1949

Type species. By original designation; *Aulacodiscus bilobatus* Westergård, 1946, from the Middle Cambrian (*Lejopyge laevigata* Zone) of Västergötland, Sweden.

Opsidiscus haimantensis (Reed, 1910)

Plate 5, figures 6, 12–14

- v*1910 *Microdiscus haimantensis* Reed, p. 7, pl. 1, figs 12–13.



TEXT-FIG. 7. *Oryctocephalus indicus* (Reed, 1910); restoration of cranidia from Plate 5, figures 16 (A), 19 (B) and 18 (C).

Material. Lectotype GSI9771 (Reed 1910, pl. 1, fig. 12) (selected herein); paralectotypes GSI9772 (Reed 1910, pl. 1, fig. 13); other material ANU49455; from Horizon 9.

Remarks. This species was described accurately by Reed. The anterior border with scrobicules as closely spaced, barely perceptible furrows normal to the margin, the eye high on the lateral slope of the cheek, no facial suture, and convex pygidium without terminal axial spine all indicate *Opsidiscus*. The weak anterior border ornament, long, wide preglabellar depression, broadly rounded glabellar anterior and six-segmented pygidial axis separate this species within the genus.

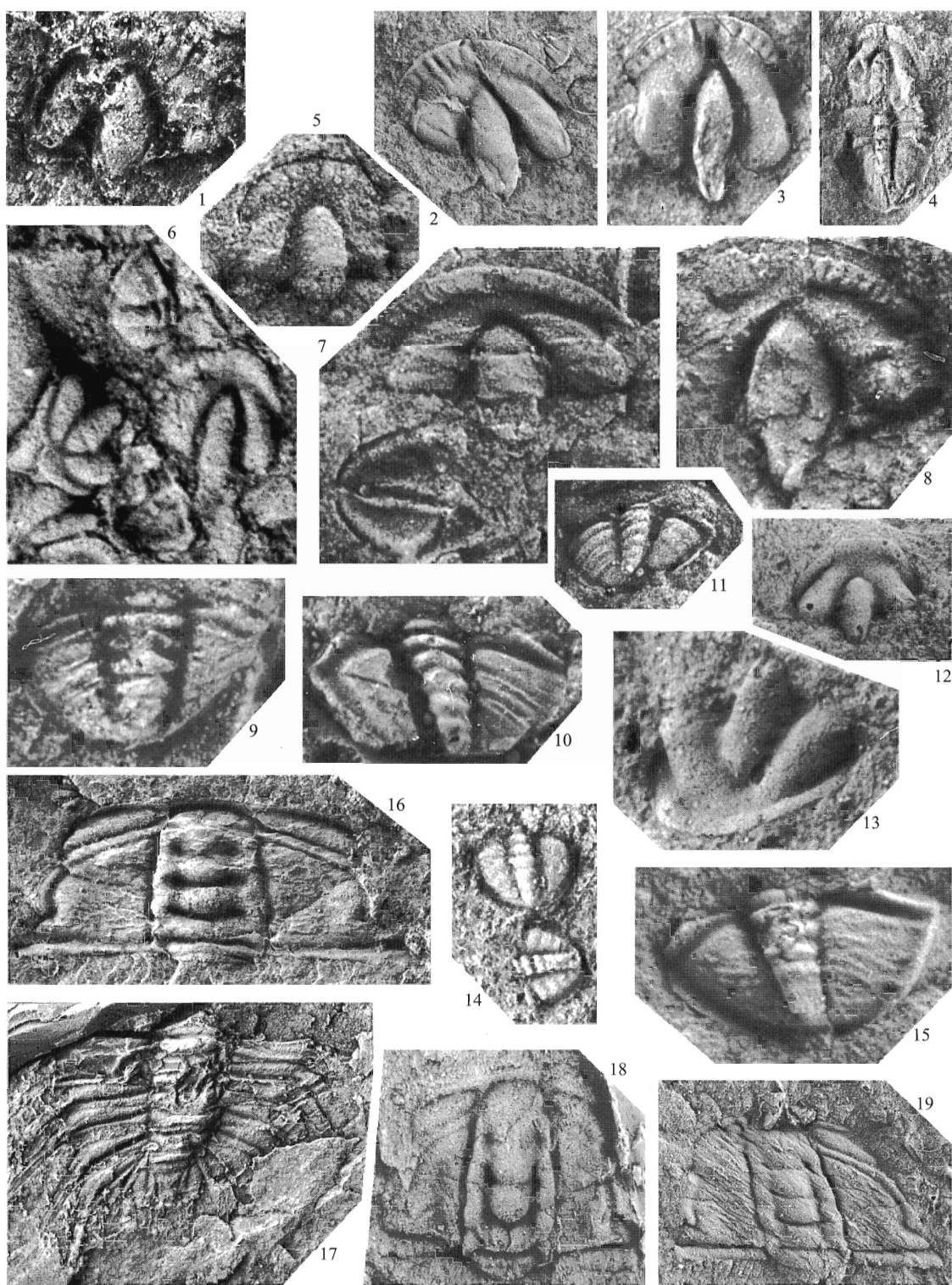
Order CORYNEXOCHIDA Kobayashi, 1935
Family ORYCTOCEPHALIDAE Beecher, 1897
Genus ORYCTOCEPHALUS Walcott, 1886

Type species. By original designation; *O. primus* Walcott, 1886 from the Mid Cambrian Pioche Shale, Nevada.

Remarks. *Oryctocephalus primus* was erected on a holotype cranium and a pygidium with five pleural segments. Shergold (1969, p. 17) restricted the genus to forms with six pygidial pleurae and assigned Walcott's paratype pygidium to *Oryctocephalites*. However, as Walcott's specimens are

EXPLANATION OF PLATE 5

Figs 1–4, 7–11, 15. *Pagetia significans* (Etheridge Jr, 1902); Horizon 2, Spiti. 1, GSI9764 (1736); cranium; $\times 14$. 2, GSI9765 (1737); cranium, latex cast; $\times 9$. 3, GSI9766a (1738); cranium; $\times 17.5$. 4, GSI9766b (1739); latex cast; $\times 11$. 7, GSI9767 (1740); cranium and external mould of pygidium; $\times 5$. 8, GSI9763 (1741); cranium; $\times 20$. 9, GSI 9770 (1742); pygidium; $\times 20$. 10, GSI9769 (1743); pygidium; $\times 10$. 11, GSI9768a (1744); pygidium; $\times 10$. 15, GSI9768b (1745); pygidium, latex cast; $\times 22$.
Fig. 5. *Pagetia* sp. cf. *P. jinnanensis* Lin and Wu, in Zhang *et al.*, 1980a; ANU49453; 1.6 km from Forest Rest House, on road to Hundwara, Kashmir; cranium, internal mould; $\times 15$.
Figs 6, 12–14. *Opsidiscus haimantensis* (Reed, 1910); Horizon 9, Spiti. 6, ANU49454; latex cast, cranidia and pygidium; $\times 15$. 12–13, GSI9771 (1746); cranium, latex cast; $\times 10$. 13, anterolateral oblique view. 14, GSI9772 (1747); pygidia; $\times 12$.
Figs 16–19. *Oryctocephalus indicus* Reed, 1910; Horizon 2, Spiti. 16, GSI9782 (1748); cranium; $\times 7$. 17, GSI9774 (1749), holotype; pygidium and thoracic posterior; $\times 5$. 18, GSI9783 (1750); cranium, latex cast; $\times 10$. 19, GSI9781 (1751); cranium, latex cast; $\times 6$.
Specimens in figs 1–3, 7–14 and 16–19 were illustrated by Reed 1910, pl. 1, figs 5–8, 4, 11, 10, 12–13, 23, 15, 24 and 22, respectively.



from the same locality and bed and are the only oryctocephalids from that locality it seems likely that they are conspecific, which would mean that *Oryctocephalus* (as constituted at present) contains taxa with either five or six or three (*O. indicus* below) pygidial pleurae. Whittington (1995) and Palmer and Halley (1979) declined to use the number of pygidial pleurae to distinguish these genera. We follow Whittington (1995) in restricting *Oryctocephalites* to the type species until it is better understood. The two Spiti oryctocephalids come from distinct horizons (2 and 9) and do not appear to be sister taxa.

Oryctocephalus indicus (Reed, 1910)

Plate 5, figures 16–19; Text-figure 7A–C

- v*1910 *Zacanthoides indicus* Reed, p. 9, pl. 1, fig. 1
- v.1910 *Oryctocephalus* cf. *reynoldsi* Reed; Reed, p. 12, pl. 1, figs 22–24.
- 1944a *Oryctocephalus indicus* (Reed); Kobayashi, p. 33.
- 1967 *Oryctocephalus indicus* (Reed); Kobayashi, p. 487, text-figs 7, 11a–b.
- 1974 *Oryctocephalus incurvus* Lu and Chien, in Lu *et al.*, p. 101, pl. 39, fig. 8.
- 1980a *Oryctocephalus* cf. *incurvus* Lu and Chien; Zhang *et al.*, p. 270, pl. 96, figs 13–15.
- 1980a *Oryctocephalus* sp. Zhang *et al.*, p. 270, pl. 96, fig. 16.
- 1983 *Oryctocephalops incurvus* (Lu and Chien); Lu and Qian, p. 26, pl. 3, figs 6–7.
- 1983 *Oryctocephalops tongrenensis* Lu and Qian, p. 27, pl. 3, figs 4–5.

Material. Holotype, pygidium plus partial thorax, GSI9774 (Reed 1910, p. 9, pl. 1, fig. 15); other material GSI9781–9783 (Reed 1910, pl. 1, figs 22–24); all from Horizon 2. NIGP21508 (Lu *et al.* 1974, pl. 39, fig. 8), NIGP38281–38284 (Zhang *et al.* 1980a, pl. 96, figs 13–16), from south-western China.

Diagnosis. Glabella parallel-sided; S1–S3 isolated from axial furrow, connected across axis by transverse furrows. Pygidium of three segments; axis of three rings and elongate postaxial section; pleural and interpleural furrows well-impressed; pleural segments and their marginal spines decreasing in size posteriorly.

Description. Glabella parallel-sided, with rounded anterolateral corners and slightly curved anterior margin protruding into anterior border. S1–S3 as rounded pits laterally in exsagittal line, becoming progressively shallower to anterior, each pair transversely connected by shallow furrow that arches slightly posteriorly. S3 transverse furrow effaced in some specimens, S2 shallower than S1. S4 narrow, confluent with axial furrow at point where eye ridge meets axial furrow. SO transverse, also joining pair of deeper lateral pits, not connecting with axial furrow, deeply incised; LO of uniform length, curving forward a little laterally. Cranial border upturned, shortest where excavated by glabella, elongate at glabellar anterolateral corners. Border furrow deeply incised, anterior margin steep. Fixigenae twice width of glabella. Eye ridges strong, at c. 45° to exsagittal line from anterior of palpebral lobe to axial furrow opposite S4. Palpebral lobe weakly arcuate, 0.2–0.3 of glabellar length, posterior just behind S1, anterior opposite midpoint of L2. Palpebral furrow distinct, parallel to elongate kidney-shaped lobe. Posterior border furrow confluent with axial furrow, transverse, deeply incised abaxially. Posterolateral border short. Thoracic segments sharply geniculate at fulcrum close to margin. Marginal spines becoming longer on more posterior segments, stout, straight, hollow. Pygidium wider than long, of three segments plus elongate terminus extending to posterior margin, with three pairs of marginal spines and three axial rings. Pleural and interpleural furrows well-impressed, extending on to (pleural) or to base (interpleural) of marginal spines.

Preservation. The three cranidia are tectonically deformed, affecting the outline and prominence of various characters. One (Pl. 5, fig. 19) shows a strong eye ridge on the right cheek, which runs approximately parallel to cleavage, whereas the eye ridge on the left cheek, which is normal to cleavage, is almost obscured. However, restoration of the cranidia using the computer technique described above provides pre-deformation morphology (Text-fig. 7) to allow comparison with other species. The pygidium is both incomplete and deformed, but its anterior pleural margin is clear against matrix and the discrete anterior margin of the half ring is also well defined.

Remarks. Reed (1910, p. 9) interpreted the holotype as having six thoracic segments and a short

pygidium with two pairs of marginal spines. However, close scrutiny reveals that the third from last pair of marginal spines belongs to a segment which is separated from the next posterior segment over the lateral pleural areas, but is fused with the pygidium over proximal parts of the pleurae and the axis; the pygidium comprises three segments, as in the Chinese *O. incurvus* and *O. tongrenensis* which we consider synonymous. Reed (1910) interpreted the pygidial axis as consisting of five rings; the anterior two are short and wide, being the rings of the first two pleural segments, the third is longer and posteriorly rounded to sub-triangular and has the third pleural segment terminating at its anterolateral corner, indicating part of that segment. His fourth and fifth rings are much less clear and probably are not segments but vaguely defined parts of the axial terminal piece. On the cranidium the parallel-sided to possibly evenly anteriorly tapering glabella, along with the transverse furrows joining the pits of S1–S3, distinguish this species from the *O. reynoldsi* group of North America and Australia. The articulated Chinese specimens (Lu and Qian 1983) confirm the association of cranidium and pygidium in Spiti.

Oryctocephalus salteri Reed, 1910

Plate 6, figures 1–8

- v*1910 *Oryctocephalus salteri* Reed, p. 11, pl. 1, figs 16–21.
- 1935 *Oryctocephalus salteri* Reed; Kobayashi, p. 146.
- 1969 *Oryctocephalus salteri* Reed; Shergold, p. 17.
- v.1987 *Oryctocephalus salteri* Reed; Shah and Sat Paul, p. 191, pl. 1, figs f–h, o.
- v.1987 *Oryctocephalus opiki* Shergold; Shah and Sat Paul, p. 188, pl. 1, figs a–e, i–n.
- v.1987 *Oryctocephalites* cf. *sulcatus*; Shah and Sat Paul, p. 192, pl. 1, fig. i.

Material. Lectotype (here selected) GSI9779 (Reed 1910, pl. 1, fig. 20); other material GSI9775–9776, 9778–9780, ANU49455; all from Horizon 9. KUF532–545, from left bank of Parahio Valley near Thango (Shah and Sat Paul 1987).

Diagnosis. S2 and S3 pits isolated. Pygidial spines of even extent. Postaxial region 30 per cent. or more of pygidial length.

Description. Length to width ratio about 1.3:1. Axis convex, about 0.25 of width. Subisopygous; thorax with seven segments; genal spine extending beyond first thoracic segment. Glabella expanded anteriorly, widest at L3, with rounded anterolateral corners and slightly curved anterior margin. S1 deeply incised, transversely connected by shallow furrow that arches slightly posteriorly. S2 and S3 pit-like, isolated, deeply incised. S4 narrow, pit-like, weakly incised. SO transverse, shallow medially, connecting with axial furrow, deeply incised; LO with convex posterior margin. Cranial border short, upturned, narrow in front of glabella. Border furrow deeply incised, anterior margin steep. Fixigenae twice width of glabella. Eye ridges strong, running at 45° from anterior of palpebral lobe to axial furrow opposite S4. Palpebral lobe gently arcuate, 0.2–0.3 of glabellar length, posterior opposite S1, anterior opposite S3. Palpebral furrow well-impressed. Posterior border furrow confluent with axial furrow, transverse, deeply incised abaxially. Posterolateral border area narrow. Librigena narrow. Border furrow weakly incised. Genal spine narrow. Thorax of seven segments, each sharply geniculate at fulcrum. Propleurae wide, extended into sharp, posteriorly directed marginal spines. Pleural furrow extending to base of pleural spines, deeply incised. Pygidium sub-semicircular, wider than long. Axis narrow, tapering posteriorly, of five segments plus terminus, 0.6 of pygidial length, anteriorly about 0.2 of pygidial width. Pleural furrows sharply and deeply incised, extending to base of marginal spines. Marginal spines of even extent, posteriorly directed, extensions of propleurae. Interpleural furrows poorly impressed. Six pleural segments each with marginal spine. Post-axial ridge tapering and extending to posterior margin.

Preservation. The groove in the genal spine mentioned by Reed (1910, p. 12) is probably a crack due to collapse of the hollow genal spine. Well-preserved material assigned to *O. opiki* by Shah and Sat Paul (1987) has pygidial spines of even extent and is thus indistinguishable from *O. salteri*. Fracture of many of the marginal spines makes interpretation of the bases of these spines difficult. They appear to be extensions of the propleurae (Pl. 4, fig. 7), although in some cases pro- and opisthopleurae may merge beyond the termination of the pleural furrow (Pl. 6, fig. 4).

Remarks. *O. salteri* and *O. alexandriensis* (Shergold, 1969) have marginal pygidial spines of uniform length but the former has a shorter pygidial axis (70 per cent. of pygidial length vs 80 per cent.) and this is a distinguishing feature from most other species. *O. salteri* appears distinct in the genus because of a relatively short pygidial axis, short anterior and posterior pygidial pleural bands with anterior longer near margin, well impressed pleural and interpleural furrows, and marginal spines of circular section and more-or-less uniform length. It differs from *O. opiki* in each of these features. In the cephalon the S1 pits are barely joined across the axis.

Order PTYCHOPARIIDA Swinnerton, 1915 emend. Fortey, 1990

Family PTYCHOPARIIDAE Matthew, 1887

Genus KUNMINGASPIS Chang, 1964

Type species. By original designation; *Kunmingaspis yunnanensis* Chang, 1964, from the lower Middle Cambrian of south-western China.

Remarks. Although Zhou *et al.* in Zhang *et al.* (1980a) assigned *Kunmingaspis* to Antagmidae Hupé, 1953, the variety of Chinese ptychoparioids suggests that this family is poorly defined and understood (see also Rasetti 1955); the concept of assigning all primitive or Lower Cambrian ptychoparioids to this family is no longer supportable. *Kunmingaspis* belongs to the Lower and lower Middle Cambrian ptychoparioid complex of south-western China which includes *Xingrenaspis*, *Nangaops*, *Jiumenia*, *Wuxunaspis*, *Eosoptychoparia*, *Sanhuangsania* and *Pachyaspis* (*Danzhaina*) amongst others (Zhang *et al.* 1980a). Among Chinese forms only Lower Cambrian *Yuehsienszella* Chang, 1957 and basal Middle Cambrian *Kunmingaspis* have 13 thoracic segments. *Yuehsienszella* has comparatively truncated pleural tips and eye ridges meeting the axial furrow near the posterior of the anterior glabellar lobe, whereas *Kunmingaspis* has well-developed facets, posteriorly recurved thoracic pleural tips and eye ridges meeting the axial furrow near the anterolateral glabellar corners, as in the Himalayan forms. Moreover, its short palpebral lobe and long posterior cranial limb are features of the Himalayan species. *Kermanella lata* Wolfart, 1974, from south-east Iran, has 13 thoracic segments, short palpebral lobes and other typical ptychoparioid features but its truncated thoracic pleural tips and course of the eye ridge assign it to *Yuehsienszella*. Implications of the co-occurrence of *Redlichia noetlingi* and *Yuehsienszella* in Iran are discussed under the former species above.

Kunmingaspis pervulgata (Reed, 1910)

Plate 6, figures 9–11; Plate 7, figures 1–13

- v*1910 *Ptychoparia pervulgata* Reed, p. 26, pl. 3, figs 6–19.
- 1944a *Ptychoparia pervulgata*; Kobayashi, p. 33.
- 1967 *Ptychoparia pervulgata*; Kobayashi, p. 487, fig. 7.15.
- 1987 *Ptychoparia pervulgata*; Kobayashi, p. 120, fig. 4.

EXPLANATION OF PLATE 6

Figs 1–8. *Oryctocephalus salteri* Reed, 1910; Horizon 9, Spiti. 1, GSI9775 (1752); cranidium; $\times 8.5$. 2, GSI9776 (1753); pygidium; $\times 10$. 3, GSI9777 (1754); pygidium; latex cast; $\times 10$. 4, GSI9780 (1755); posterior cranidium, thorax and pygidium; $\times 8$. 5, GSI9779 (1756); dorsal exoskeleton; $\times 10$. 6, restoration of GSI9779. 7, ANU49455; pygidium, internal mould; $\times 10$. 8, GSI9778 (1757 and 1758); cranidium and pygidium; $\times 13$.

Figs 9–11. *Kunmingaspis pervulgata* (Reed, 1910); Horizon 2, Spiti. 9, GSI9824 (1759); cranidium; $\times 8.5$. 10, GSI9825 (1760); cranidium; $\times 7$. 11, GSI9828 (1761); cranidium; $\times 10$.

Specimens in figs 1–5 and 8–11 were illustrated by Reed 1910, pl. 1, figs 16–18, 21, 20 and 19 and pl. 3, figs 11–12 and 15, respectively.

JELL and HUGHES, *Oryctocephalus*, *Kunmingaspis*

Material. Lectotype (here selected) GSI9819 (Reed 1910, pl. 3, fig. 6); paralectotypes GSI9820–9832; all from Horizon 2.

Diagnosis. Glabella conical; S2 and S3 effaced; occipital spine short, stout at base, strongly tapered; palpebral midpoint anterior of glabellar midpoint. Thoracic pleural tip with blunt spine, becoming recurved posteriorly just in front of pygidium.

Description. Length to width ratio *c.* 1.75:1. Axis narrow, *c.* 0.15 of width. Thorax of 13 segments. Glabella conical, widest at posterior of L1, tapering anteriorly, with subangular anterolateral corners and weakly curved anterior margin. S1 running posteroaxially from axial furrow to finish very close to SO, not crossing central third of glabella, weakly incised. S2 and S3 indistinct. SO well-impressed. LO longest sagittally, posterior margin gently convex. Occipital spine of similar length to palpebral lobe. Axial furrow shallowing in front of glabella. Frontal area 45–60 per cent. of glabellar length. Preglabellar field twice length of anterior border. Preocular facial suture diverging at 15° from exsagittal line. Preocular fixigenal width twice basal glabellar width. Eye ridge prominent, tubular, confluent with axial furrow at anterolateral corner of glabella. Palpebral lobe *c.* 0.25–0.40 of glabellar length. Palpebral midpoint anterior of glabellar midpoint. Librigena narrow, with flattened tubular border, convex doublure, sparse terrace ridges and genal spine. Thorax of 13 segments, with well-impressed pleural furrows, with short, blunt pleural spine becoming curved in posterior part of thorax. Pygidium semi-elliptical; axis 0.35 of width, with three rings and subangular terminus not reaching posterior margin. Pleural furrows well-impressed, terminating in small pits at very narrow border. Interpleural furrows shallow. Three pleural segments.

Preservation. Sagittal compression has enhanced S1 in GSI9823 (Pl. 7, fig. 1), and all exoskeletons exhibit tectonic wrinkling.

Intraspecific variation. The occipital spine has a broader base and is longer relative to the glabella in small specimens (Pl. 6, fig. 11). In larger cranidia this spine is reduced (Pl. 7, fig. 3). Eyes decrease from *c.* 0.45 glabellar length in small (pre- holaspid?) specimens (Pl. 6, fig. 11) to *c.* 0.25 at glabellar length 3.5 mm (Pl. 7, fig. 1). Although eye size is probably ontogenetically controlled, 3.5 mm is not the largest cranidium, implying phenotypic variation about a generalized ontogenetic trend. Other ontogenetic trends include a relative decrease in the width of the fixigenae and in length of the anterior border. These trends give the glabella a more dominant appearance in large holaspides. Relative length of the frontal area varies, but apparently not ontogenetically.

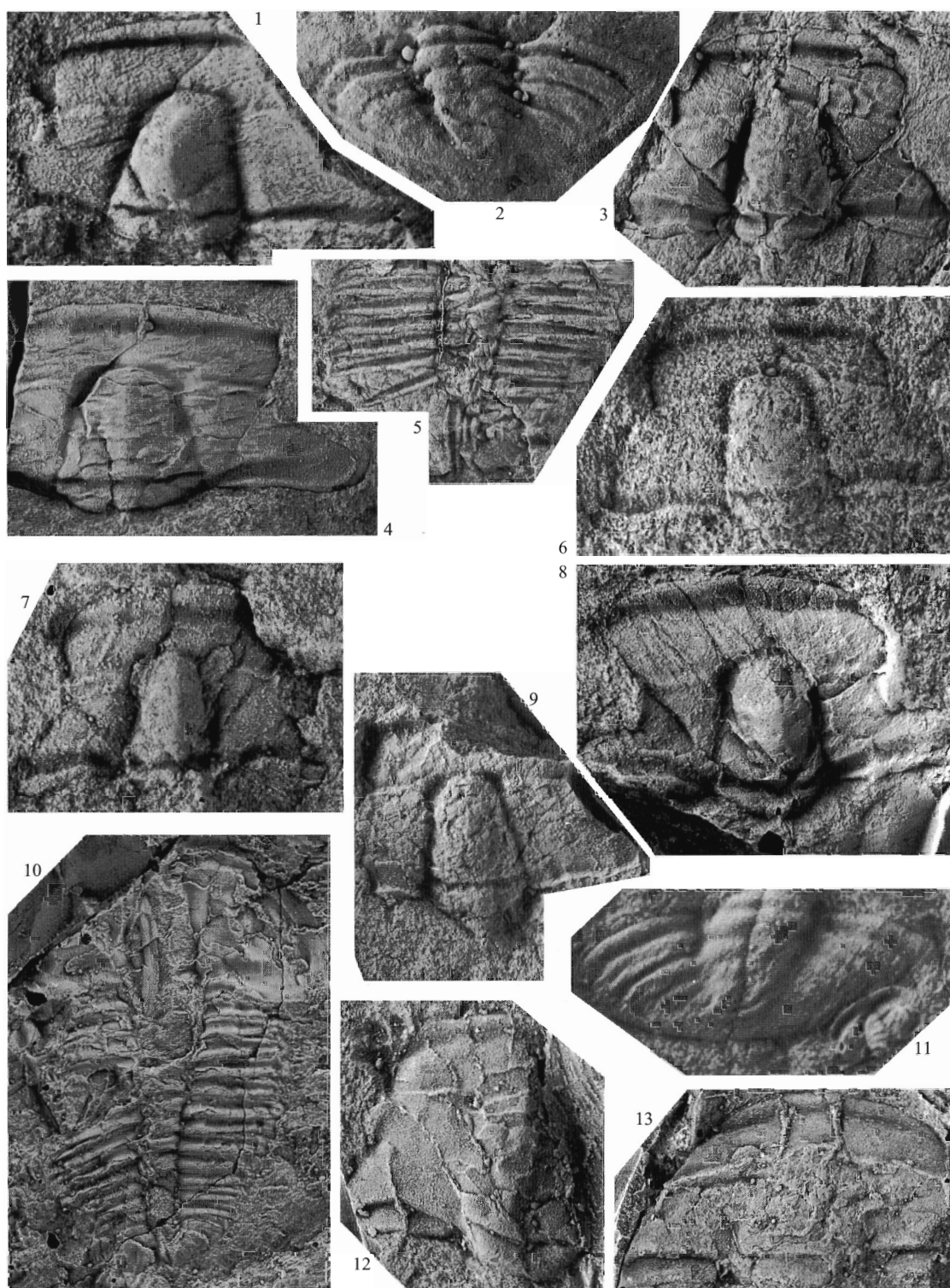
Remarks. Reed (1910, p. 37) acknowledged that this species ‘varies to some extent’ and recognized a variety characterized by a quadrate glabella and a reduced occipital spine. These specimens (Pl. 6, fig. 11; Pl. 7, fig. 4) do not merit recognition as a variety, because they lie within the range of intraspecific variation described above.

Agraulos? fervidus Reed (1910, p. 42, pl. 5, figs 20–21) is preserved in a different matrix, with fractures through the exoskeleton rather than distortion; this indicates that the enclosing matrix behaved much more competently under stress than did that of the specimens assigned by Reed (1910) to *pervulgata*, which appears to have reacted in a more fluid way. It is therefore difficult to compare the two sets of material. However, *Agraulos? fervidus*, recorded by Reed (1910) from the

EXPLANATION OF PLATE 7

Figs 1–13. *Kunmingaspis pervulgata* (Reed, 1910); Horizon 2, Spiti. 1, GSI9823 (1762); cranidium; $\times 7$. 2, GSI9832 (1763); pygidium; $\times 7.5$. 3, GSI9819 (1764); cranidium; $\times 6$. 4, GSI9827 (1765); cranidium; $\times 4.5$. 5, GSI9830 (1766); partial thorax, latex cast; $\times 4$. 6, GSI9821 (1767); cranidium; $\times 9$. 7, GSI9826 (1768); cranidium; $\times 8$. 8, GSI 9822 (1769); cranidium; $\times 5.5$. 9, GSI9820 (1770); cranidium; $\times 7$. 10, GSI9829 (1771); $\times 5$. 11, GSI9766c (1772); pygidium with cranidium of *Pagetia significans*; $\times 15.5$. 12, GSI9889 (1773); cranidium; $\times 5.5$. 13, GSI9888 (1774); cranidium; $\times 4.5$.

Specimens in figs 1–10 and 12–13 were illustrated by Reed 1910, pl. 3, figs 10, 19, 6, 14, 17, 8, 13, 9 and 7 and pl. 5, figs 21 and 20, respectively.



same horizon, resembles *K. pervulgata* in all details except that it appears to lack an occipital spine, although the internal moulds available could be incomplete in that area. Nevertheless, the occipital spine is not evident on some specimens assigned by Reed (1910) to *pervulgata* and, as discussed below, some variation in this feature may ultimately lead to synonymy of *pervulgata* and *stracheyi*. As these two specimens almost certainly belong to this co-occurring taxon, they are assigned tentatively to *pervulgata*. The very poor specimen assigned by Reed (1910) to *Agraulos* aff. *roberti* Matthew may also belong to this species but is left in open nomenclature (Pl. 15, fig. 13).

Kunmingaspis stracheyi (Reed, 1910)

Plate 8, figures 1–12; Plate 9, figures 1–9; Plate 10, figures 1–13; Plate 11, figures 6–8

- v*1910 *Ptychoparia stracheyi* Reed, p. 21, pl. 2, figs 8–13.
- v.1910 *Ptychoparia spitiensis* Reed, p. 18, pl. 1 figs 25–31, pl. 2, figs 1–5.
- v.1910 *Ptychoparia* sp. Reed, pl. 2, fig. 6.
- v.1910 *Ptychoparia spitiensis*? Reed, pl. 2, fig. 7.
- v.1910 *Ptychoparia urceolata* Reed, p. 23, pl. 2, figs 14–16.
- v.1910 *Ptychoparia admissa* Reed, p. 25, pl. 2, figs 22–23; pl. 3, figs 1–5.
- v.1910 *Ptychoparia consocialis* Reed, p. 24, pl. 2, fig. 19 [non pl. 2, figs 17–18, 20–21].
- v.1910 *Agraulos? simulans* Reed, p. 43, pl. 5, fig. 22.
- v.1910 *Ptychoparia (Liostracus) civica* Reed, p. 30, pl. 4, figs 2–3.
- 1939 *Lyriaspis stracheyi* (Reed); Whitehouse, p. 203.
- 1939 *Lyriaspis spitiensis* (Reed); Whitehouse, p. 203.
- 1939 *Lyriaspis admissa* (Reed); Whitehouse, p. 203.
- 1967 *Ptychoparia (Lyriaspis?) stracheyi* Reed; Kobayashi, p. 485.
- 1967 *Ptychoparia (Lyriaspis?) spitiensis* Reed; Kobayashi, p. 485, fig. 14.
- 1967 *Ptychoparia (?) admissa* Reed; Kobayashi, p. 486.
- 1967 *Annamitia civica* (Reed); Kobayashi, p. 487, fig. 2.

Material. Lectotype (here selected) GSI9798 (Reed 1910, pl. 2, fig. 8), paralectotypes GSI9799–9803 (Reed 1910, pl. 2, figs 9–12), from Horizon 6. Other material, GSI9843, 9844 (Reed 1910, pl. 4, figs 2–3), Horizon 4. GSI9773–9797 (Reed 1910, pl. 1, figs 25–31; pl. 2, figs 1–7), GSI9804–9806 (Reed 1910, pl. 2, figs 14–16), GSI9871 (Reed 1910, pl. 5, fig. 3), from Horizon 6. GSI9809, 9812–9818 (Reed 1910, pl. 2, figs 19, 22–23; pl. 3, figs 1–5), from Horizon 9.

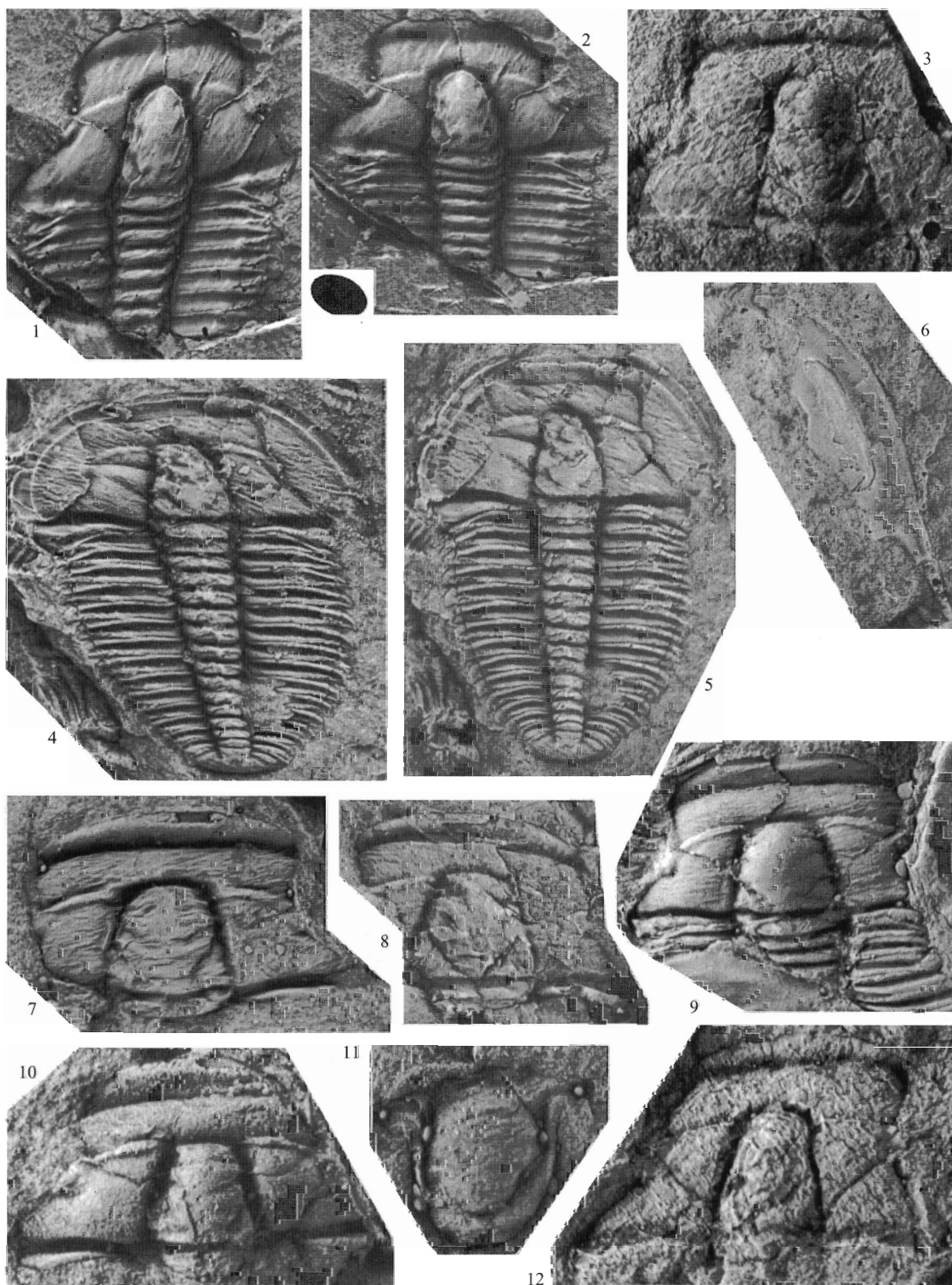
Diagnosis. Glabella conical, with S1–S4 (S4 often not evident in distorted material). SO with median node. Palpebral midlength opposite midlength of L2, palpebral lobes short and narrow. Thoracic pleural tips with blunt posterolateral spines becoming more posteriorly curved towards rear. Cranidial surface finely granulose.

Description. Length to width ratio *c.* 1.5:1. Thorax 40–55 per cent. of dorsal length in holaspides, with 13 segments. Axis narrow. Genal spine extending to fifth thoracic segment. Glabella conical, widest at posterior of L1, tapering anteriorly, with subangular anterolateral corners and gently convex anterior margin. S1 poorly impressed, running posteroaxially from axial furrow at *c.* 45° to sagittal line, not continuous across axial fifth of axis. S2 running posteroaxially from axial furrow at low angle to transverse; S3 running anteroaxially from

EXPLANATION OF PLATE 8

Figs 1–12. *Kunmingaspis stracheyi* (Reed, 1910); Horizon 6, Spiti. 1, GSI9795 (1775); cranidium and anterior thorax; $\times 4$. 2, restoration of GSI9795. 3, GSI9805 (1776); cranidium; $\times 4.75$. 4, GSI9798 (1777); lectotype, latex of external mould of dorsal exoskeleton; $\times 6$. 5, restoration of GSI9798. 6, GSI9797 (1778); librigena, latex cast; $\times 4$. 7, GSI9799 (1779); cranidium; $\times 5.5$. 8, GSI9800 (1780); cranidium; latex cast; $\times 3$. 9, GSI9803 (1781); cranidium and anterior thorax; $\times 7.5$. 10, GSI9801 (1782); cranidium; $\times 13$. 11, GSI9796 (1783); hypostome; $\times 9$. 12, GSI9806 (1784); cranidium; $\times 5$.

Specimens in figs 1, 3–4 and 6–12 were illustrated by Reed 1910, as pl. 2, figs 5, 15, 8, 7, 9–10, 13, 11, 6 and 16, respectively.



axial furrow at low angle to transverse, neither crossing central third of glabella. LO longest sagittally. Occipital tubercle low. Frontal area 45–70 per cent. of glabellar length. Preglabellar field twice length of anterior border, which is longest sagittally, flattened, tubular. Preocular suture diverges at 10–20° to axis. Preocular fixigenal width more than twice basal glabellar width. Eye ridge prominent, running from axial furrow at or just posterior of anterolateral corner of glabella. Palpebral lobe 0.15–0.30 of glabellar length. Palpebral midpoint opposite midpoint of L2. Librigena narrow, with genal caeca. Border and doublure convex. Genal spine hollow, with sharp tip near fourth or fifth thoracic segment. Rostral plate (Pl. 8, fig. 4) as wide as glabellar base, lateral margins chevron-shaped. Hypostome (Pl. 8, fig. 11) elongate, with short anterior border and wings, with lip-like posterior border, and faint posterior border furrow. Thoracic segments with deep pleural furrow terminating laterally at base of short, posterolaterally directed and curved spine. Free pleural posterior margin sigmoidal in anterior segments, straight in posterior segments. Fulcrum *c.* two-thirds pleural width from axial furrow. Pygidium semi-elliptical; axis 0.35 pygidial width, of three rings and posteriorly rounded terminus. Postaxial region short. Pleural furrows deeply incised, terminating before very narrow border. Doublure more than one-fifth pygidial width.

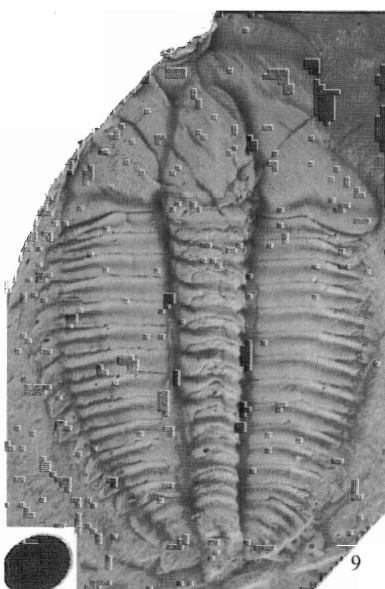
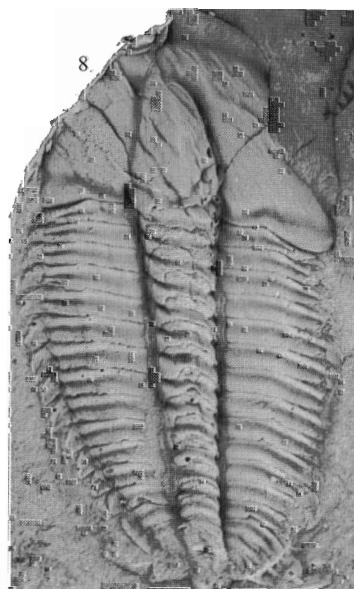
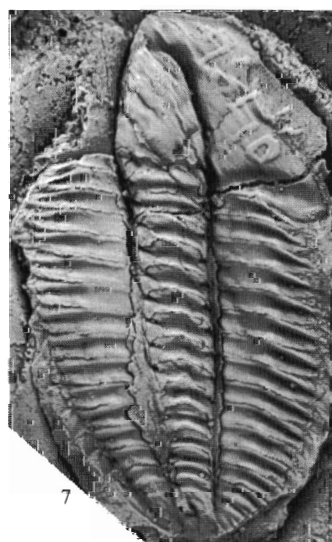
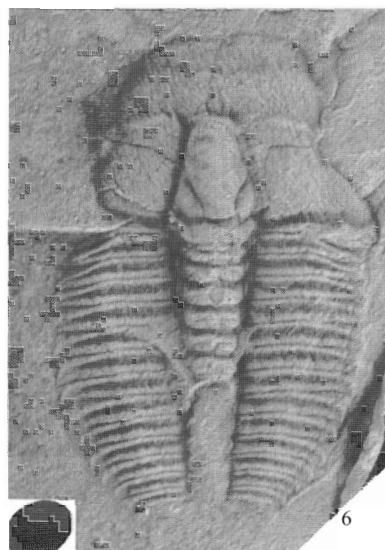
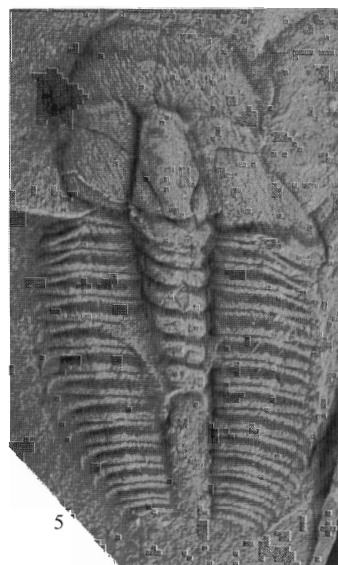
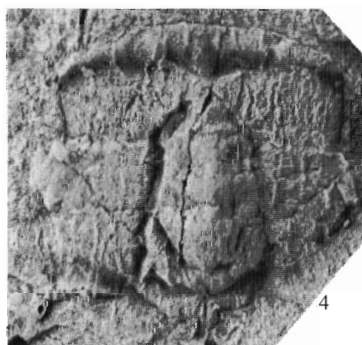
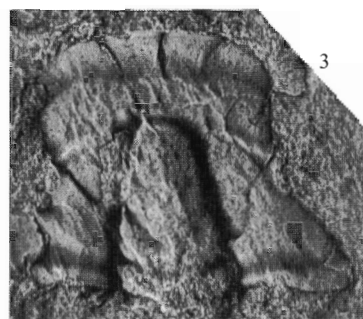
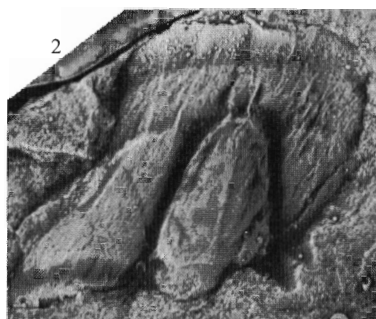
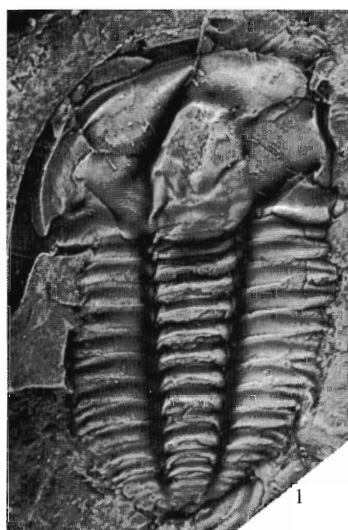
Preservation. All specimens are tectonically deformed and many show wrinkled surfaces. The differing effects of deformation on relative proportions can be marked (Pl. 8, fig. 12) such that left and right posterior cranial borders are different, yet the glabella has suffered only slight deformation. Variation in the angle between the preocular suture and the exsagittal line is much increased by deformation. The suite of characters which Reed (1910, p. 22) considered useful for differentiating between *K. stracheyi* and *K. spitiensis* includes 'the shorter and broader headshield, the shorter, more scarcely carinate glabella, the smaller, more inflated preglabellar area, the more upturned and less flattened border, the more horizontal ocular ridges'. All these differences would be expected if Reed's (1910) *P. stracheyi* had been compressed sagittally and his *P. spitiensis* elongated sagittally. Wrinkle orientation in these specimens parallels their direction of elongation, confirming that tectonics has been responsible for these differences. Reed (1910, p. 24) considered *P. urceolata* to be characterized by the urceolate or pitcher-shaped glabella. This characteristic is taphonomic because whilst the right side of the glabella in GSI9806 (Pl. 8, fig. 12) is indented the left side is not.

Remarks. In noting that specimens assigned to *P. spitiensis* had 10–13 thoracic segments, Reed (1910, p. 19) overlooked the fact that thoracic segments are crushed through the occipital exoskeleton in two specimens (Pl. 9, fig. 1; Pl. 10, fig. 6); all articulated specimens have 13 segments. Reed (1910, p. 22) suggested that *K. stracheyi* had 14 segments, but the type material shows only 13. GSI9794 (Reed 1910, pl. 2, fig. 4) and GSI9785 (Reed 1910, pl. 1, fig. 26) are part and counterpart (Pl. 9, figs 7–8). Reed (1910) acknowledged that co-occurring *spitiensis* and *stracheyi* are closely related but he separated them with a long list of cranial and thoracic features which all involve proportions; the distinctions he recognized are all due to different directions of stress in the shale. *K. stracheyi* is distinguished from *K. pervulgata*, which it closely resembles, by its lack of an occipital spine. However, as the occipital spine is variable within *P. pervulgata* and as preservational differences could be responsible for other differences, these taxa may prove synonymous when better preserved material is known.

Agraulos? simulans Reed is a cranidium of this species in which the glabellar furrows have been

EXPLANATION OF PLATE 9

Figs 1–9. *Kunmingaspis stracheyi* (Reed, 1910); Horizon 6, Spiti. 1, GSI9784 (1785); $\times 3$. 2, GSI9788 (1786); cranidium; $\times 3.75$. 3, GSI9790 (1787); cranidium; $\times 4$. 4, GSI9804 (1788); cranidium; $\times 6$. 5–6, GSI9793 (1789); cranidium and thorax, latex cast from external mould; $\times 6$. 6, computer-graphic restoration. 7, GSI9794 (1790a); $\times 3$. 8–9, GSI9785 (1790b). 8, latex cast from external mould of GSI9794; $\times 3$ (internal and external moulds were given different GSI numbers by Reed 1910). 9, computer-graphic restoration. Specimens in figs 1–5 and 7–8 were illustrated by Reed 1910, pl. 1, figs 25, 29, 31; pl. 2, figs 14, 3–4 and pl. 1, fig. 26, respectively.



obliterated by tectonic forces and the occipital furrow, most of the left side, anterior border and right anterolateral corner are concealed by matrix. Glabellar shape, size and position of the palpebral lobe, and size of the posterolateral cephalic limb indicate its placement in *K. stracheyi*. *Ptychoparia admissa* of Reed (1910), from a higher horizon (9) of the Parahio section, is also placed in synonymy because of the close comparison with longitudinally compressed cranidia of *stracheyi* from Horizon 6 of this section which share the apparently squatter glabella, shorter preglabellar field, more convex anterior border, identical thorax of 13 segments and pygidium. Reed's description of the cranidial surface as coarsely granulose in *admissa*, finely granulose in *spitiensis* and smooth or minutely punctate in *stracheyi* depends very much on the amount and style of deformation. Specimens in the steely black mudstone shale from Horizon 9 tend to have their fine detail better preserved than the more stretched and 'smeared' specimens from Horizon 6 and so the more obvious surface ornament of *admissa* should not be taken as a distinctive feature. In all other features that can be considered not dependent on deformation, this species fits within the range shown by specimens from Horizon 6.

Ptychoparia civica was the only species reported by Reed (1910) from Horizon 4. Although incomplete, it is apparently undistorted; this preservation is rare in the Spiti samples. A latex cast from an external mould [on the piece of limestone bearing the type of *Acrotreta parahioensis* (Reed 1910, pl. 6, figs 18–21; GSI9910)] shows the short palpebral lobe. An incomplete pygidium (Pl. 11, fig. 8) is identical to that of *K. stracheyi*. Apparent distinguishing features of this limestone cranidium are due to its different preservation; there is little to distinguish this species from *K. stracheyi* or *K. pervulgata* except that in the latter, specimens the same size as those from Horizon 4 have a more prominent occipital node. It is here referred to *K. stracheyi* but considered immature; it does, however, provide the best understanding of the undistorted character of this species. It is significant that its glabellar shape and surface ornament most closely resemble those of Reed's *admissa* which is the least distorted of material here referred to *stracheyi*. Kobayashi (1967, p. 487) referred *P. civica* and *P. defossus* to *Annamitia*, presumably because they resemble *A. spinifera* (Mansuy, 1916) in possession of an occipital spine. Width of the fixigenae, shape of the glabella, and orientation of the preocular sutures distinguish *civica* and *defossus* from *A. spinifera*. Moreover, the occipital node is much shorter in *civica* than in *defossus* and these taxa are distinguished in several other characteristics.

Genus XINGRENASPIS Yuan and Zhou, in Zhang *et al.*, 1980a

Type species. Xingrenaspis xingrenensis Yuan and Zhou, in Zhang *et al.*, 1980a (= *Elrathia hoboi* Resser and Endo, 1937), from the Middle Cambrian (Hsuehuangian) of Guizhou, China.

Xingrenaspis maopoensis (Reed, 1910)

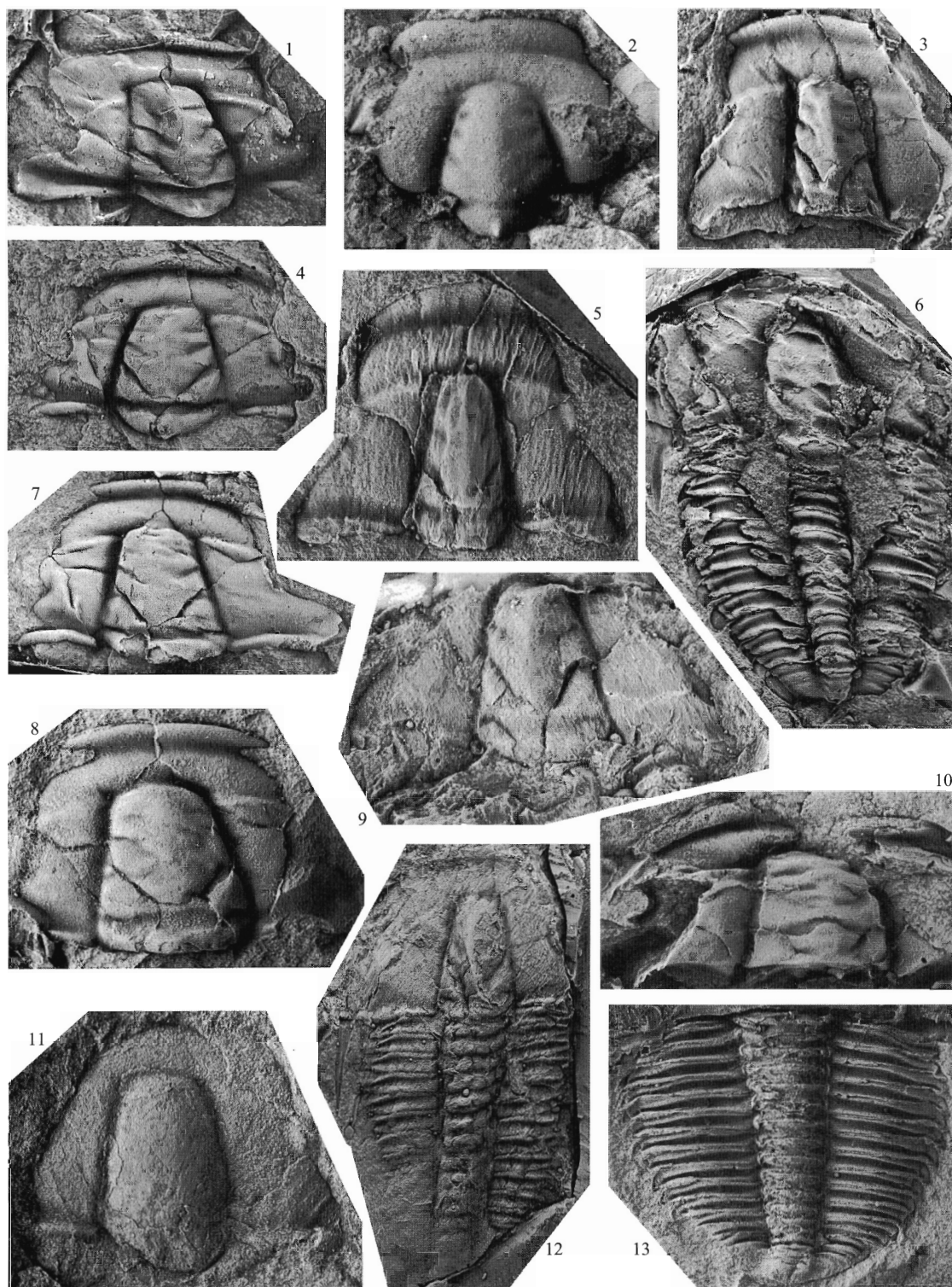
Plate 11, figures 9–13

- | | |
|--------|---|
| v*1910 | <i>Ptychoparia maopoensis</i> Reed, p. 28, pl. 3, figs 20–25. |
| 1967 | <i>Ptychoparia maopoensis</i> Reed; Kobayashi, p. 486. |

EXPLANATION OF PLATE 10

Figs 1–13. *Kunmingaspis stracheyi* (Reed, 1910) from Spiti. 1, 3–4, 7–8, 10, 13, from Horizon 9; 2, from Horizon 4; 5–6, 9, 11–12, from Horizon 6. All cranidia except for whole exoskeletons in 6 and 12, and thorax in 13 which belongs with cranidium in 10. 1, GSI9814 (1791); latex cast showing fine surface ornament; $\times 4$. 2, GSI9843 (1792); $\times 7.5$. 3, GSI9809 (1793); $\times 5$. 4, GSI9816 (1794); latex cast showing fine surface ornament; $\times 4$. 5, GSI9786 (1795); $\times 5.25$. 6, GSI9792 (1796); $\times 2.75$. 7, GSI9815 (1797); latex cast; $\times 4$. 8, GSI9812 (1798); $\times 7$. 9, GSI9789 (1799); $\times 4$. 10, GSI9813 (1800); $\times 7.5$. 11, GSI9890 (1801); $\times 5$. 12, GSI9791 (1802); $\times 2$. 13, GSI9813 (1803); $\times 5.25$.

Specimens in figs 1–13 were illustrated by Reed 1910, pl. 3, fig. 1; pl. 4 fig. 2; pl. 2, fig. 3; pl. 1, fig. 27; pl 2, fig. 2; pl. 3, fig. 2; pl. 2, fig. 22; pl. 1, fig. 30; pl 2, fig 23; pl. 5, fig. 22 and pl. 2, figs 1 and 23, respectively.



Material. Lectotype (here selected) GSI9833; paralectotypes GSI9834–9838, all from Horizon 9.

Diagnosis. Occipital spine short, stout. Doublure on librigena wide, smooth. Genal spine wide, as long as half thorax. Palpebral lobe of moderate length. Posterolateral cephalic limb wide and sub-rectangular, with rounded lateral margin.

Description. Reed's (1910) description is accurate except that none of the types has a glabella with 'lateral furrows represented by 3 pairs of small sub-equidistant pits' – they are obsolete in the available specimens; GSI9835 allows accurate counting of the 12 thoracic segments; and the facial suture curves adaxially just before reaching posterior cephalic margin so that the librigena has a projection along the posterior cephalic margin.

Remarks. The cranium is similar to that of *K. stracheyi* or *K. pervulgata* except for its larger palpebral lobe. However, the librigena with wide doublure and large genal spine and thorax with 12 segments are distinctive. Whilst the number of thoracic segments varies within some genera and even some species, especially where large numbers of specimens are available, it does appear constant, as far as we know, among the Himalayan and Chinese ptychoparioids discussed herein. Zhou *et al.* (in Zhang *et al.* 1980a, pl. 109, fig. 1) illustrated the holotype of *X. xingrenensis* with a more robust genal spine than in most typical ptychoparioids, although it is not as strong as in *X. maopoensis*.

Genus SHANTUNGASPIS Chang, 1957

Type species. *Ptychoparia aclis* Walcott, 1905, from the Middle Cambrian (Maochuangian) of Shandong, China.

Remarks. Zhang and Jell (1987, p. 73) incorrectly described an occipital spine in this genus; LO has a median tubercle near the posterior. The Spiti material has a very subdued tubercle in the same position.

Shantungaspis himalaica (Reed, 1910)

Plate 11, figures 1–5

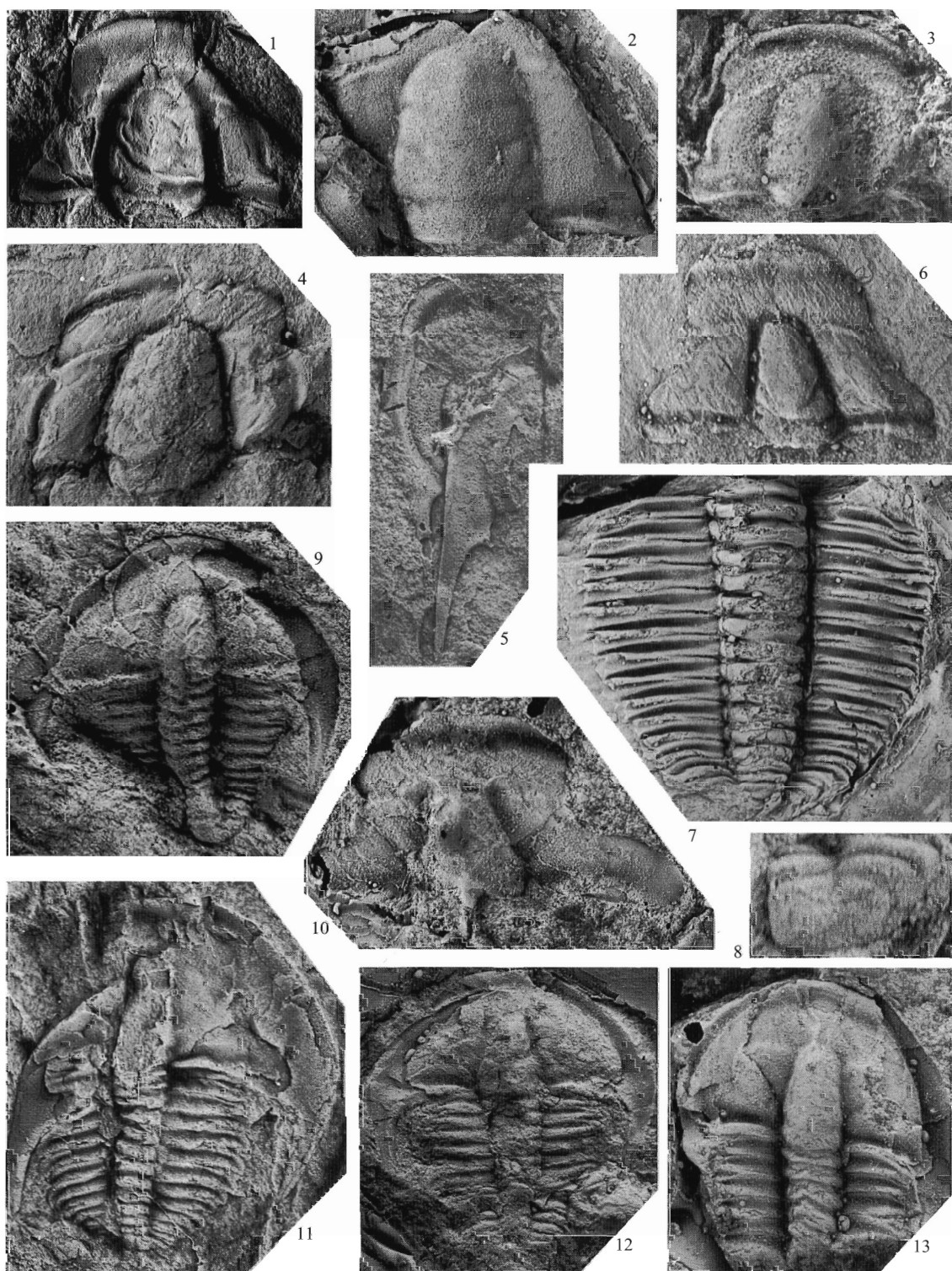
- v*1910 *Ptychoparia? himalaica* Reed, p. 36, pl. 4, fig. 27; pl. 5, figs 1–4.
1967 *Megagraulos? himalaicus* (Reed); Kobayashi, p. 486.

Material. Lectotype (here selected) GSI9869 (Reed 1910, pl. 5, fig. 1); paralectotypes GSI9868, 9870–9872 (Reed 1910, pl. 4, fig. 27; pl. 5, figs 2–4); other specimen GSI9848 (Reed 1910, pl. 4, fig. 6), all from Horizon 6.

Diagnosis. Glabella subquadrate, tapering gently forward, with broadly rounded anterior; glabellar furrows almost transverse, usually bifurcating at adaxial ends; palpebral lobe gently curved,

EXPLANATION OF PLATE 11

- Figs 1–5. *Shantungaspis himalaica* (Reed, 1910); Horizon 6, Spiti. 1–4, cranidia; 5, librigena. 1, GSI9870 (1804); × 5. 2, GSI9868 (1805); × 5. 3, GSI9872 (1806); × 9. 4, GSI9869 (1807), holotype; × 5. 5, GSI9871 (1808); × 5.5.
Figs 6–8. *Kunmingaspis stracheyi* (Reed, 1910) from Spiti. 6, GSI9787 (1809); Horizon 6; cranium; × 7. 7, GSI9817 (1810); Horizon 9; thorax and pygidium; × 4. 8, GSI9843b (1811); Horizon 4; pygidium; × 14.
Figs 9–13. *Xingrenaspis maopoensis* (Reed, 1910); Horizon 9, Spiti. 9, GSI9833 (1812); dorsal exoskeleton; × 4.5. 10, GSI9838 (1813); cranium; × 4.75. 11, GSI9837 (1814); × 5. 12, GSI9834 (1815); × 3.75. 13, GSI9836 (1816); cephalon and anterior thorax; × 7.5.
Specimens in figs 1–7 and 9–13 were illustrated by Reed 1910, pl. 5, fig. 1; pl. 4, fig. 27; pl. 5, figs 4, 1 and 3; pl. 1, fig. 28; pl. 3, fig. 4 and pl. 3, figs 20, 25, 24, 21 and 23, respectively.



JELL and HUGHES, *Shantungaspis*, *Kunmingaspis*, *Xingrenaspis*

posterior tip just abaxial to anterior tip, moderately long, situated between the midlength of L1 and S2; anterior border short, of uniform length.

Description. Glabella strongly convex (tr.), gently tapering forward, with broadly rounded anterior; axial furrow well impressed, shallowing in front of glabella. S1 running slightly posteroaxially from axial furrow, bifurcate adaxially with anterior branch transverse. S2 transverse from axial furrow, weakly bifurcate adaxially, with two branches just anterior and posterior of transverse line. S3 running just forward of transverse from the axial furrow. Glabellar furrows poorly impressed. LO of uniform length, with very small node near posterior margin. Frontal area about one-third of cephalic length; anterior border of uniform length, short, convex. Eye ridge meeting axial furrow at anterior corner of glabella, running posterolaterally. Palpebral lobe narrow, curved, with posterior tip just abaxial to anterior tip but almost in exsagittal line, upturned laterally. Preocular facial suture diverging forward, curving adaxially across border over fair distance so that anterior of librigena must have a long, slender dorsal projection. Librigena smooth, with long genal spine; doublure flat marginally, geniculate dorsally along inner half.

Remarks. Generic assignment is based on glabellar shape and furrows, palpebral position and frontal area and anterior border size and shape. When the thorax and pygidium are found, the generic assignment may need to be re-assessed.

Genus *PARAMECEPHALUS* Zhou and Lin, in Zhang *et al.*, 1980a

Type species. By original designation; *Amecephalus sinicus* Zhou, in Lu *et al.*, 1974, from the Mid Cambrian (Maochuangian) Kaotai Formation of Guizhou.

Remarks. Among ptychoparioid genera with long concave frontal areas and small pygidia, Rasetti (1951) distinguished *Alokistocare* from *Amecephalus* on the narrower interocular cheeks and straight rather than falcate thoracic pleural tips. Zhou (in Lu *et al.* 1974), with only cranidia available, correctly assigned his Chinese species *sinicus* to *Amecephalus* as Kobayashi (1967) had done with Reed's (1910) poorly preserved cranidia of *defossus*. Zhou and Lin (in Zhang *et al.* 1980a) illustrated articulated specimens from south-western China which showed a much larger pygidium and shorter frontal area. On this basis they erected *Paramecephalus* for the Chinese species. Reed's (1910) Himalayan species *defossus* is known from incomplete distorted cranidia so its assignment is not certain, but the shorter frontal area suggests *Paramecephalus* rather than *Amecephalus*. Its long occipital spine is a unique feature among these trilobites, but is not of generic significance.

Paramecephalus defossus (Reed, 1910)

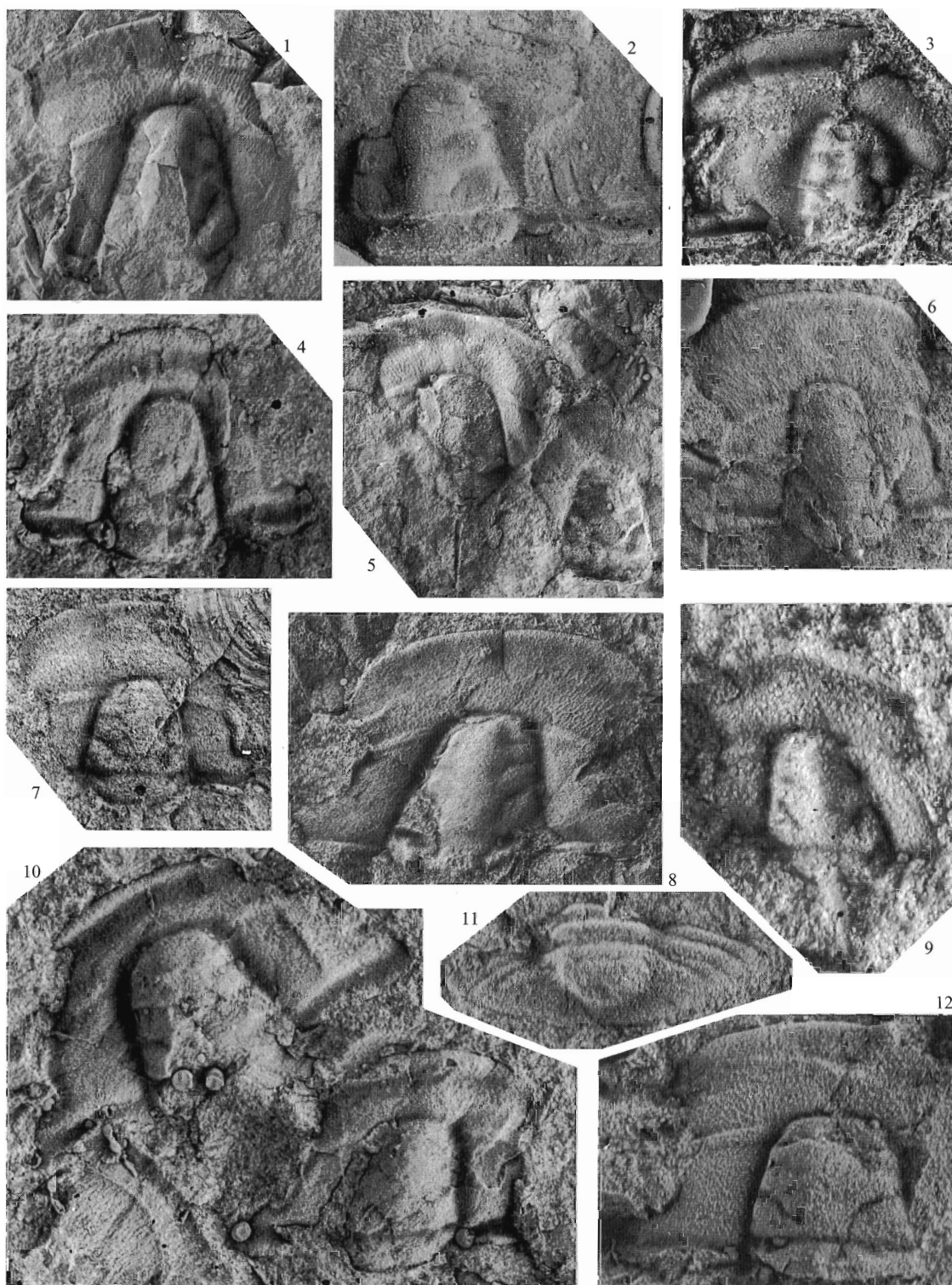
Plate 12, figures 1–2, 4–12

v*1910 *Ptychoparia defossa* Reed, p. 25, pl. 3, figs 26–28; pl. 4, fig. 1.
1967 *Amecephalus defossa* (Reed); Kobayashi, p. 487.

Material. Lectotype (here selected) GSI9842 (Reed 1910, pl. 4, fig. 1); paralectotypes GSI9839–9841 (Reed 1910, pl. 3, figs 26–28; other material: cranidium on GSI9914 with *Obolella cf atlantica*, ANU49458–49460; all from Horizon 6.

EXPLANATION OF PLATE 12

Figs 1–2, 4–12. *Paramecephalus defossus* (Reed, 1910). 1–2, 4–10, 12, cranidia; 11, pygidium; all from Horizon 6, Spiti. 1, GSI9839a (1817); × 5. 2, GSI9839b (1818); × 6. 4, GSI9842b (1820); × 8. 5, GSI9840 (1821); × 4. 6, ANU49458; × 5. 7, GSI9914b (1822); latex cast; × 6. 8, GSI9842a (1823); lectotype; × 4.5. 9, GSI9840 (1824); × 10. 10, GSI9842c (1825 and 1826); × 6. 11, ANU49459; × 10. 12, ANU49460; × 8.
Fig. 3. cf. *Paramecephalus defossus* (Reed, 1910); Horizon 6, Spiti; GSI9847 (1819); cranidium; × 6.5.
Specimens in figs 1, 3, 5 and 8–9 were illustrated by Reed 1910, pl. 3, fig. 26; pl. 4, fig. 6; pl. 3, fig. 27; pl. 4, fig. 1 and pl. 3, fig. 28, respectively.



Diagnosis. Occipital spine long, circular in section. Surface pustulose.

Description. Glabella conical, with truncated anterior; three pairs of well-impressed lateral glabellar furrows and S4 barely visible low in the axial furrow just behind anterolateral corner of glabella. S1 bifurcate adaxially, more noticeable on immature specimens (Pl. 12, fig. 7). S2 transverse, also adaxially bifurcate. LO elongate medially, with median spine which is circular in section, of fairly uniform diameter and half glabellar length. Frontal area half glabellar length, gently concave in sagittal section, with poorly defined border furrow, with well-developed caecal network. Eye ridges running posterolaterally from axial furrow just behind transverse line, of two parallel trunks. Palpebral lobes moderately long, curved, of uniform width, with anterior and posterior extremities almost in same exsagittal line. Posterolateral cranial limb sub-rectangular, probably twice as wide as long, of uniform length with rounded lateral extremity. Pygidium transverse; axis of two segments plus sub-semicircular terminus reaching close to posterior margin; pleural areas of two segments each; one interpleural and two pleural furrows well-impressed and reaching margin; border furrow defined only by change of slope, well away from margin anteriorly but meeting margin posteriorly on sagittal line.

Remarks. This species is distinguished within the genus by the occipital spine. While it is confidently assigned to *Paramecephalus*, knowledge of its thorax is desirable to make absolutely certain of the assignment.

cf. *Paramecephalus defossus* (Reed, 1910)

Plate 12, figure 3

v*1910 *Ptychoparia (Conocephalites) hesterna* Reed, p. 32, pl. 4, fig. 6.
1967 *Parahiolites hesterna* (Reed); Kobayashi, p. 486.

Material. GSI9847 (Reed 1910, pl. 4, fig. 6) [= holotype, by monotypy, of *Ptychoparia (Conocephalites) hesterna*, Reed, 1910] from Horizon 6.

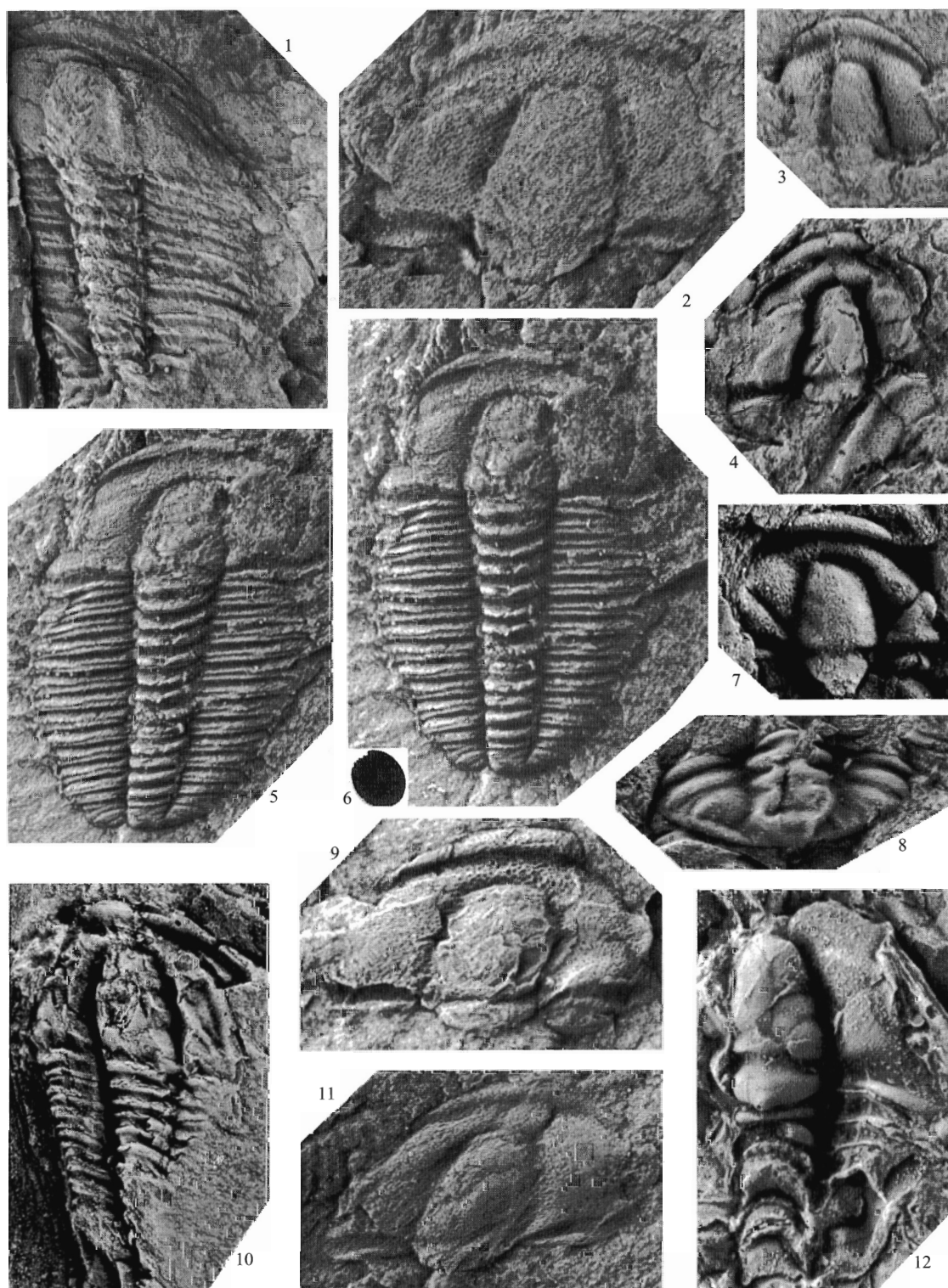
Remarks. This cranidium was said by Kobayashi (1967) to be unlike that of any other genus, so he erected *Parahiolites*. Of the features he used to characterize the genus, the lack of eye ridges is invalid, as one is seen on the right-hand side (Pl. 10, fig. 3); size and position of the palpebral lobe, expanded preglabellar area, and shape of the glabellar furrows (cf. Pl. 12, figs 3, 7–8, 12) match *Paramecephalus defossus*; the triangular lateral glabellar furrows of *hesterna* are evident in a more laterally compressed cranidium (Pl. 12, fig. 8) and may be interpreted as the result of crushing the short bifurcations of these furrows. Numerous cranidia of *P. defossus* (Pl. 12, figs 2, 4, 6–7, 10, 12), not figured by Reed (1910), but on the same slabs as the figured types, are assigned to this species and most exhibit the sigmoidal S1. Variation in their glabellar proportions and in definition of the anterior border furrow suggests a series between *defossus* and *hesterna*.

Although there is a case for synonymy of *hesterna* and *defossus* there is no confirmation of an occipital spine in the type of *hesterna* so definitive assignment cannot be achieved. Moreover, such a synonymy would see *Parahiolites* as senior to *Paramecephalus* with the concept of the widespread genus resting on the incomplete poorly preserved type specimen. For these reasons we restrict *Parahiolites* to the type specimen, for which no conclusive synonymy can be provided but which resembles closely the co-occurring *P. defossus*.

EXPLANATION OF PLATE 13

Figs 1–12. *Douposiella hostilis* (Reed, 1910); Horizon 9, Spiti. 1, GSI9850 (1827); cephalon and anterior thorax; $\times 6$. 2, GSI9851 (1828); cranidium; $\times 10$. 3, GSI9862 (1829); cranidium, latex cast; $\times 6.75$. 4, GSI9863 (1830); cranidium; $\times 7.5$. 5, GSI9853 (1831); lectotype; dorsal exoskeleton; $\times 9.5$. 6, restoration of GSI9853. 7, GSI9861 (1832); cranidium, latex cast; $\times 10$. 8, ANU49461; pygidium; $\times 10$. 9, GSI9854 (1833); cranidium; $\times 10$. 10, GSI9864 (1834); cephalon and anterior thorax; $\times 7$. 11, GSI9852 (1835); cranidium; $\times 10$. 12, GSI9858 (1836); cranidium with disarticulated thoracic segments; $\times 10$.

Specimens in figs 1–5 and 7–12 were illustrated by Reed 1910, pl. 4, figs 9–10, 21–22, 12, 20, 13, 23, 11 and 17, respectively.



Genus DOUPOSIELLA Lu and Chang, in Lu *et al.*, 1974

Type species. Douposiella douposiensis Lu and Chang, in Lu *et al.*, 1974, from the lower Middle Cambrian of Guizhou, China.

Douposiella hostilis (Reed, 1910)

Plate 13, figures 1–12; Plate 14, figures 1–13

- v*1910 *Ptychoparia? hostilis* Reed, p. 33, pl. 4, figs 7–13a.
 v1910 *Ptychoparia? praeterita* Reed, p. 35, pl. 4, figs 14–26.
 1967 *Solenopleura praeterita* (Reed); Kobayashi, p. 488.
 1967 *Solenopleura hostilis* (Reed); Kobayashi, p. 488.

Material. Lectotype GSI9853 (here selected) (Reed 1910, pl. 4, fig. 12); paralectotypes GSI9848–9852, 9854; other material ANU49461–49463; all from Horizon 9.

Diagnosis. Glabella sub-conical, palpebral lobes opposite midpoint of glabella, exoskeleton punctate, with or without occipital spine.

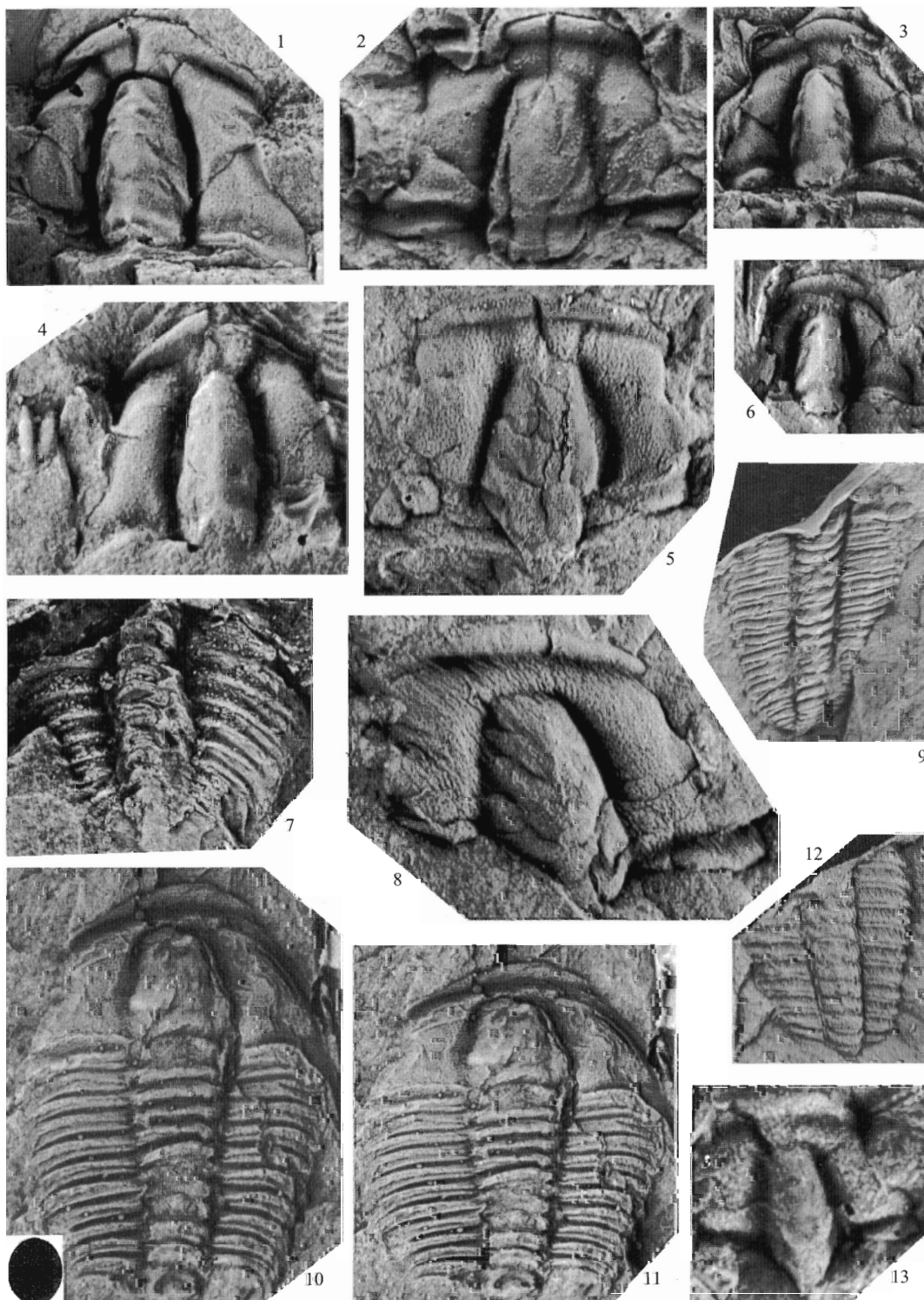
Description. Length to width ratio *c.* 1.3:1. Axis *c.* 0.2 of width. Thorax of 13 segments; genal spine extending beyond fourth thoracic segment. Glabella conical, widest at posterior of L1, tapering anteriorly, with subangular anterolateral corners and straight to slightly convex anterior margin. S1 running postero-axially from axial furrow, well impressed. S2 and S3 weakly impressed, more or less transverse. LO longest sagittally, with short broadly based occipital spine in some specimens but without a spine in others. Frontal area *c.* 25 per cent. of glabellar length. Preglabellar field longer than anterior border, which is of uniform length, convex, tubular. Anterior border furrow well-impressed, with flat posterior and steep anterior slope. Preocular sutures diverging at *c.* 10° to exsagittal line. Fixigenae inflated laterally. Eye ridge confluent with axial furrow at anterolateral corner of glabella. Palpebral lobe *c.* 0.25–0.3 glabellar length, midpoint opposite glabellar midpoint. Posterior border furrow well-impressed, lengthening and swinging forward distally. Cranial surface densely punctate. Librigena narrow, with fine genal spine. Thirteen thoracic segments, with blunt pleural tips. Pygidium sub-elliptical. Axis wide, composed of two or more rings. Pleural furrows well-impressed. Interpleural furrows weak. Two or more pleurae present.

Preservation. Tectonic deformation is responsible for most of the variation. Sagittally shortened specimens have a more quadrate glabella. Two different lithologies are evident from this horizon giving rise to different types of preservation. (1) In the lighter coloured, more micaceous siltstone layers the trilobites have practically no vertical relief as well as being tectonically skewed. Reed's specimens of *P.? hostilis* come from this lithology. (2) In the steely black, extremely fine-grained mudstone layers trilobites are preserved with most of their relief intact and in some cases increased tectonically. Reed's *P.? praeterita* occurs in this lithology. However, the densely packed punctae and occipital spine identify this species as suggested by Kobayashi (1967, p. 487). It is extremely important in the identification of this species that external moulds are examined because for some specimens it is only in the latex casts from these that the punctae and occipital spine are evident;

EXPLANATION OF PLATE 14

Figs 1–13. *Douposiella hostilis* (Reed, 1910); Horizon 9, Spiti. 1–6, cranidia showing perforated surface. 1, GSI 9856 (1837); $\times 7.5$. 2, GSI9855 (1838); $\times 9.5$. 3, GSI9861 (1839); $\times 6$. 4, GSI9857 (1840); $\times 9$. 5, ANU49462; latex cast, cranidium; $\times 8$. 6, GSI9860 (1841); $\times 12.75$. 7, GSI9867 (1842); portion of articulated thorax; $\times 8$. 8, ANU49463; cranidium, latex cast; $\times 10$. 9, GSI9865 (1843); thorax and pygidium, latex cast; $\times 4.5$. 10, GSI9849 (1844); cephalon and anterior thorax; $\times 5$. 11, restoration of GSI9849. 12, GSI9866 (1845); thorax and pygidium, latex cast; $\times 6$. 13, GSI9859 (1846); small cranidium; $\times 15$.

Specimens in figs 1–4, 6–7, 9–10 and 12–13 were illustrated by Reed 1910, pl. 4, figs 15, 14, 20, 16, 19, 26, 24, 8, 25 and 16, respectively.



confusion with *Solenoparia talingensis* may arise where internal moulds only are used and identifying the species from deformed incomplete specimens can be difficult.

Remarks. Cranidia with and without occipital spines are interpreted as intraspecific variants because no other features seem to differ between these specimens.

Iranoleesia abundans (Wittke, 1984) from Iran and 'genus and species undetermined A' of Dean (1982), from Turkey, which we assign to *Iranoleesia*, have a densely punctate exoskeleton, but it is not ubiquitous in this genus. Therefore, punctae should not be used to separate genera. This was further demonstrated by Wittke (1984) in describing three Iranian species from two different families with this type of exoskeleton. That exoskeletal ornament is not a generic discriminator is significant in assigning this species.

The conical glabella, short convex border, wide fixigenae, thoracic pleurae and pygidium ally *P.?* *hostilis* with the ptychoparioids. It is assigned to *Douposiella* by comparison with the numerous Chinese species (Lin and Lee 1978, pl. 161, figs 1, 5–6, 11–14, 16; Zhang *et al.* 1980a, pl. 120, figs 1–10) which are described from internal moulds (so that the surface of the exoskeleton is unknown) that have the same glabella shape, short convex anterior border and palpebral lobes. At present it is separated from the Chinese species by the occipital spine and punctate surface but this will need reassessment if external moulds become available from China.

Parasolenopleura linnarssoni brevicauda Westergård (1953, pl. 6, figs 13–14) is similar in glabellar shape, cranial proportions, in having 13 thoracic segments, and in the pygidium. While it may be separated from the Asian species by its granular ornament and shorter palpebral lobe, it should probably be assigned to *Douposiella*. Similarly, *Tongshania* Qiu and Lin, *in* Qiu *et al.*, 1983 from the lower Middle Cambrian of eastern China and including *T. cf. tongshanensis* of Kruse (1990, pl. 7) may prove to be a junior synonym of *Douposiella*.

Ptychoparioid indet.

Plate 15, figure 13

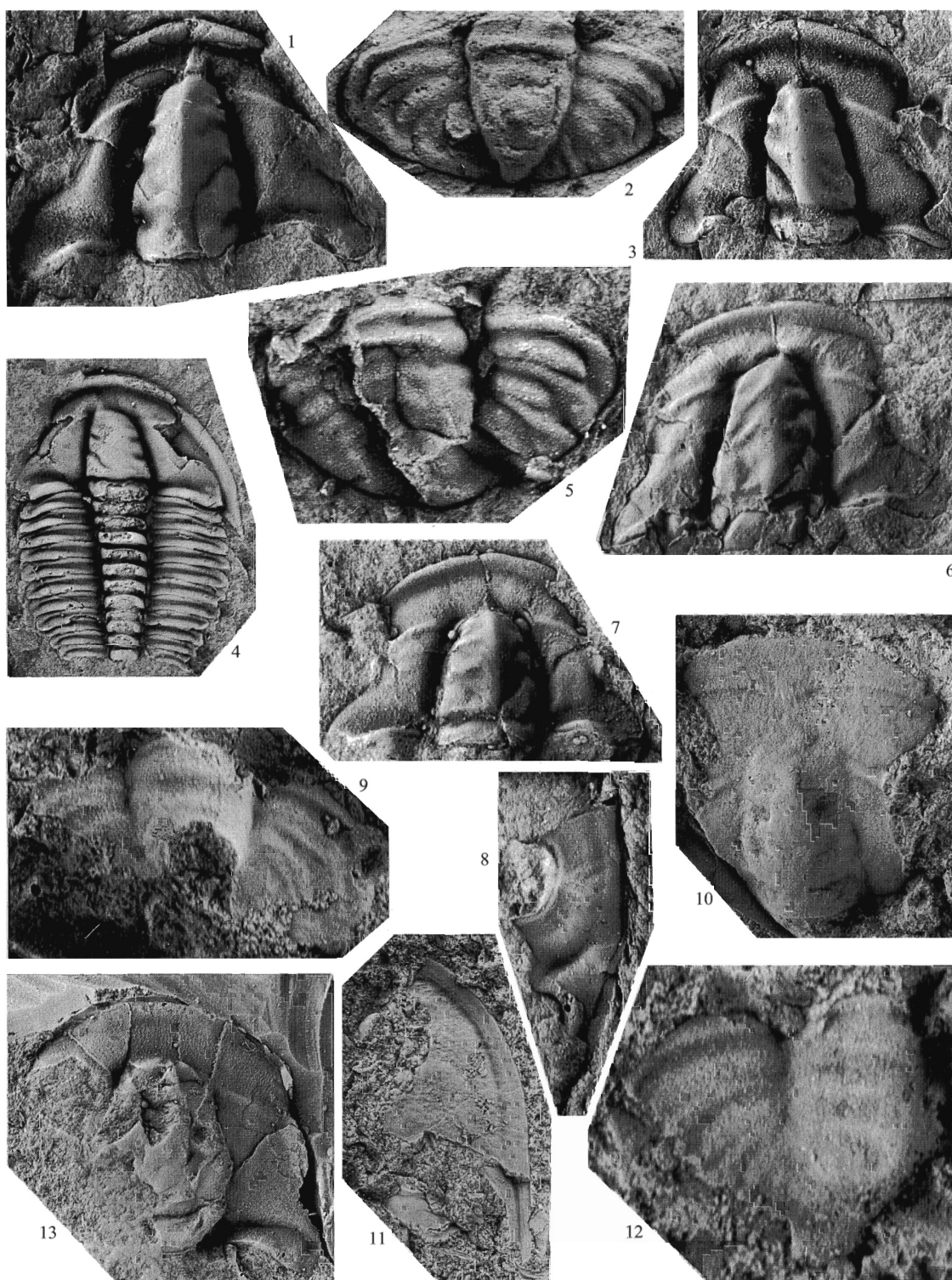
- v*1910 *Agraulos* aff. *roberti* Matthew; Reed, p. 42, pl. 5, fig. 19.
1935 *Chondroparia reedi* Kobayashi, p. 207.

Material. GSI9887, from Horizon 2.

Remarks. This specimen is too poorly preserved to allow generic assignment. Palpebral lobe length and glabellar width suggest *Shantungaspis himalaica* but it may be a laterally compressed specimen of the co-occurring *Kunmingaspis pervulgata*. Because of the large posterolateral cranial limb and convex glabella standing well above the cheeks it cannot be assigned either to *Agraulos* or to *Chondroparia*.

EXPLANATION OF PLATE 15

- Figs 1–8. *Solenoparia talingensis* (Dames, 1883); Horizon 9, Spiti. 1. GSI9808 (1847); cranidium; $\times 5$. 2. ANU49464; pygidium; $\times 8$. 3. GSI9807 (1848); cranidium; $\times 5.5$. 4. GSI9818 (1849); cranidium and thorax, latex cast; $\times 3.5$. 5. ANU49465; pygidium; $\times 8$. 6. GSI9810 (1850); cranidium; $\times 5.5$. 7. GSI9811 (1851), lectotype; cranidium; $\times 6.5$. 8. ANU49466; librigena; $\times 8$.
Figs 9–12. *Szeaspis conjunctiva* (Reed, 1910); Changnu Encamping Ground, Spiti. 9. GSI9892b (1852); pygidium; $\times 8.25$. 10. GSI9892a (1853); cranidium; $\times 6.25$. 11. GSI9893 (1854); librigena; $\times 4$. 12. GSI9891 (1855); partial pygidium; $\times 11.5$.
Fig. 13. Ptychoparioid indet.; Horizon 2, Spiti; GSI9887 (1856); cranidium; $\times 3.75$.
Specimens in figs 1, 3–4, 6–7 and 10–13 were illustrated by Reed 1910, pl. 2, figs 18, 17; pl. 3 fig. 5; pl. 2, figs 20–21 and pl. 5, figs 23, 25, 24 and 19, respectively.



JELL and HUGHES, *Solenoparia*, *Szeaspis*, ptychoparioid

Family SOLENOPLURIDAE Angelin, 1854

Genus SOLENOPARIA Kobayashi, 1935

Type species. By original designation; *Ptychoparia (Liostracus) toxus* Walcott, 1905, from the Middle Cambrian (Hsuehuanian) of Shandong, China.

Solenoparia talingensis (Dames, 1883)

Plate 15, figures 1–8

- v*1910 *Ptychoparia consocialis* Reed, p. 24, pl. 2, figs 17–18, 20–21 [non pl. 2, fig. 19].
 1967 *Ptychoparia admissa* Reed; Kobayashi, p. 487.
 1987 *Solenoparia talingensis* (Dames); Zhang and Jell, p. 89, pl. 39, figs 9–10; pl. 40, figs 1–2 [with full synonymy].

Material. Holotype K287/91 Humboldt Museum, Berlin, from the Changhsia Formation in Liaoning. Himalayan material GSI9807, 9808, 9810, 9811, ANU49464–49466; all from Horizon 9.

Diagnosis. Surface finely granulose. Three pairs of lateral glabellar furrows weakly impressed, low on sides of steeply convex glabella. Palpebral lobes moderately long, situated level with L2.

Description. Reed's (1910, p. 24) description is accurate and matches those of Schrank (1976), Walcott (1913, for *Anomocarella subrugosa*) and Resser and Endo (1937, for *Elrathia? perconvexa*); only additional information is provided here. Librigena with distinct low eye socle, wide convex border, short stout genal spine and flat sloping genal field. Thorax of 11 segments preserved (Pl. 15, fig. 4) but not necessarily complete; fulcral point about half-way between axial furrow and lateral margin; articulating facet wide, short, with curved posterior margin of next anterior segment fitting the upper margin perfectly. Lateral termination blunt, with pointed posterolateral tip to each segment, but not spinose. Pleural furrow well-impressed, remaining in midlength throughout, finishing some distance before lateral termination. Pygidium twice as wide as long, strongly convex; axis of two rings and long terminus that extends to posterior margin; pleural areas with well-impressed pleural and interpleural furrows that meet before running to margin (making posterior pleural band appear much narrower than anterior band, which reaches margin). Border furrow extremely weak, close to margin; border narrow, crossed by amalgamated pleural and interpleural furrows. Posterior part of articulating half-ring of second pygidial segment visible.

Remarks. Reed (1910, p. 67) correctly allied his *Ptychoparia consocialis* with *Ptychoparia lilia* Walcott, 1906 and both species are now assigned to *Solenoparia*. The identical granulose surface, lateral glabellar furrows and palpebral lobe show that *consocialis* and *talingensis* are synonymous. The Himalayan specimens are internal moulds whereas Dames' specimens from north-eastern China are mostly preserved with their original exoskeleton. In the internal moulds the anterior border represents the filling of the border and has a sharp upturned edge as opposed to the convex roll on the external surface of limestone specimens. Zhang and Jell (1987, pl. 39, figs 9–10) figured a cranidium that is partially decorticated across the anterior border, showing the same sharp upturned edge of the internal mould, so this is not a distinguishing feature.

The pygidium assigned here matches those of this genus diagnosed by Zhang and Wang (1985, pl. 114, fig. 14; pl. 115, fig. 5), and all have the distinctive joining of pleural and interpleural furrows. This feature is the most distinctive among those quoted by Sundberg (1994, p. 53) as diagnostic of his Ehmaniellidae, and *S. talingensis* along with several other Asian genera exhibit the other characters of this family. The same pygidial features are present in Solenopleuridae (Westergård 1953, pl. 2, figs 8, 10) which also have similar cranidia. Sundberg assigned only North American genera and an Antarctic one to the Ehmaniellidae, which he did not compare with any extra-North American families. Detailed discussion of Ehmaniellidae is outside the scope of this paper, and we retain tentatively the traditional family placement of *Solenoparia*.

Family PROASAPHISCIDAE Chang, 1963

Genus SZEASPIIS Chang, 1959

Type species. By original designation; *Szeaspis reticulata* Chang, 1959 (= *Anomocare conjunctiva* Reed, 1910).

Remarks. In erecting *Spitiaspis* Kobayashi (1967, p. 488) characterized it by a combination of three glabellar pits, strong median cusp of the frontal border and tuberculate axial pygidial rings. The first two of these are features of *Szeaspis* and although Reed (1910, pl. 5, fig. 24) showed tubercles on the pygidial axial rings, neither the figured pygidium nor the second pygidium on the same piece of limestone bears such tubercles. As the only species attributed to this genus by Kobayashi is synonymous with a species of *Szeaspis*, *Spitiaspis* is regarded as a junior subjective synonym.

Szeaspis conjunctiva (Reed, 1910)

Plate 15, figures 9–12

- v*1910 *Anomocare conjunctiva* Reed, p. 45, pl. 5, figs 23–25.
- 1937 *Proasaphiscus centronatus* Resser and Endo, p. 259, pl. 37, figs 17–20.
- 1967 *Spitiaspis conjunctiva* (Reed); Kobayashi, p. 488.
- 1987 *Szeaspis centronatus* (Resser and Endo); Zhang and Jell, p. 153 [with full synonymy].

Material. Lectotype (here selected) GSI9892a; paralectotypes GSI9891, 9892b, 9893 plus another pygidium on same piece of limestone as GSI9891; all from the Changnu camping ground, Spiti. Lectotype of *Szeaspis centronata*, USNM86874a (Zhang and Jell 1987, pl. 65, fig. 5), from the Changhia Formation at Jinjiachengzi, Liaoning.

Remarks. Shape of the glabella, nature of its furrows, length and position of eye line, extension of the border furrow down the genal spine, length to width ratio of the pygidium, geniculate first pygidial pleural furrow, short postaxial ridge and all but a few features of *S. conjunctiva* match exactly with *S. centronata*. The few minor differences are in proportions of the preglabellar field and anterior border and strength of the median border cusp (or rudimentary plectrum); these vary in several species of *Szeaspis* (Zhang and Jell 1987, p. 153). Although provenance of the sample is not known within Hayden's (1904) section it can be taken to indicate Changhian strata somewhere in the drainage basin.

KASHMIR

Order AGNOSTIDA Salter 1864a

Superfamily AGNOSTOIDEA McCoy, 1849

Family DIPLAGNOSTIDAE Whitehouse, 1936

Genus BALTAGNOSTUS Lochman, in Lochman and Duncan, 1944

Type species. By original designation; *Proagnostus? centerensis* Resser, 1938, from the Middle Cambrian of Alabama.

Baltagnostus cf. rakuroensis (Kobayashi, 1935)

Plate 16, figures 1–5

- v.1934 *Agnostus cf. rakuroensis* Kobayashi, p. 297, fig. 1.
- 1987 *Baltagnostus rakuroensis* (Kobayashi); Zhang and Jell, p. 39, pl. 1, figs 1–15; pl. 2, figs 1–6, 8; pl. 3, fig. 10 [with full synonymy].
- v.1987a *Peronopsis cf. tramitis* Öpik; Shah and Sudan, p. 49, pl. 1, figs a, c–d, p.
- v.1987a *Peronopsis amplexis* Robison; Shah and Sudan, p. 52, pl. 1, figs b, h, r.
- v.1987a *Peronopsis extensa* Shah and Sudan, p. 54, pl. 1, figs k, o, q.
- v.1987a *Peronopsis* sp. A Shah and Sudan, p. 55, pl. 1, fig. g.
- v.1987a *Peronopsis* sp. B Shah and Sudan, p. 56, pl. 1, figs f, j.

- v.1987a *Acadagnostus acadicus* (Hartt); Shah and Sudan, p. 57, pl. 1, fig. m.
 v.1987a *Acadagnostus scutalis* (Salter); Shah and Sudan, p. 58, pl. 1, figs e, n.
 v.1987a *Acadagnostus* sp. Shah and Sudan, p. 58, pl. 1, fig. l.
 v.1987a *Pentagnostus* cf. *anabarensis* Lermontova; Shah and Sudan, p. 59, pl. 1, fig. i.

Material. YPM14337 (Kobayashi 1934, fig. 1), from green ferruginous shales with *Tonkinella*, along the road between Turkapur and the bend on the Talar River, about 8 km west of Hundwara on the road to Zachaldor (= KB). KUF497–512 (Shah and Sudan 1987a, pl. 1, figs a–r), from the lower Nutunus Formation in their *Solenopleura–Tonkinella* Zone, about 1.5 km west of Nutunus, Pohru Valley.

Remarks. Kobayashi (1934, pl. 1, fig. 1) compared a single agnostoid cranidium with the Korean *Agnostus rakuroensis* Kobayashi, 1935, which also occurs in north-east China, and was transferred to *Baltagnostus* by Zhang and Jell (1987). Kobayashi's Kashmiri cranidium has a rounded glabellar posterior; we interpret this as a result of tectonic deformation which has also shortened the basal glabellar lobes. Because of the small size of agnostoid morphological features we found it impossible to remove strain from these specimens using the method applied elsewhere in this paper. The glabellar posterior is obtusely angular in some specimens. The nine Kashmiri agnostoid taxa of Shah and Sudan (1987a) are variously deformed in a manner similar to Kobayashi's specimen. Taxonomic assignments of none of these specimens are certain and there are no features available to accept confidently more than one species among the 18 specimens illustrated. *Peronopsis* sp. nov. of Shah and Sudan (1987a, pl. 1, fig. k) appears to have a distinctive posteriorly narrowed glabella, but differential compression (splitting is evident near the rear of the glabella) could account for this feature.

Agnostoids are apparently comparatively rare in Kashmir although Shah *et al.* (1995) indicated that they are widespread. *Triplagnostus kashmirensis* Shah, Parcha and Sahni, 1995 is difficult to interpret from its holotype which is an incomplete, distorted internal mould; the third, anteriormost glabellar lobe seems likely to be due to the vagaries of preservation and would need to be demonstrated in more specimens before being accorded any biological reality. This is assuming that the specimen is a cephalon, which from the illustration is by no means certain. Some of their other material assigned to this species (e.g. Shah *et al.* 1995, pl. 1, figs c–d, g; text-fig. 1f) may well belong to *B. rakuroensis* but some other specimens seem to represent new taxa. Careful preparation, preferably of latex casts from external moulds, and study of large numbers of specimens to determine the range of deformed specimens belonging to one species will be necessary to interpret properly the agnostoid material of Shah *et al.* (1995).

In Spiti, only three agnostoid specimens (Reed 1910, pl. 1, figs 1–3) are known and they come from a conglomerate pebble; they are currently lost from or misplaced in the GSI collections. While it is tempting to compare these Spiti agnostoids with the Kashmiri specimen as Kobayashi (1934, p. 297) did, the different lithology and associated species suggest that they may not belong together, despite a superficial similarity.

Superfamily EODISCOIDEA Raymond, 1913

Family EODISCIDAE Raymond, 1913

Genus PAGETIA Walcott, 1916

Pagetia sp. cf. *P. jinnanensis* Lin and Wu, in Zhang *et al.*, 1980b

Plate 5, figure 5

- 1995 *Pagetia greisbachi* (Reed); Shah *et al.*, p. 221, pl. 1, figs e–f; pl. 2, figs a, d, g.
 1995 *Pagetia* sp. Shah *et al.*, p. 221, pl. 2, figs c, e, i.

Material. ANU49453, from 1.6 km east of the Zachaldor Forest Rest House on the road to Hundwara, Talar Valley, Kashmir. KUF675a, 676, 678a, 679–680, 682a, 684a–b (Shah *et al.* 1995, pl. 1, figs e–f; pl. 2, figs a, c–e, g, i), from the Srinagar–Kupwara Road in the Nutunus section near Wodhapura Bridge (on the left bank of the Pohru River).

Remarks. These difficult to identify, internal moulds resemble a group of Chinese lower Hsuehuanian species lacking or with only rudimentary occipital spine and with little change of slope and weak axial furrow between pygidial axis and pleural field; this species group is well exemplified by *P. jinnanensis*. The Kashmiri pygidia of Shah *et al.* (1995) are particularly like the Chinese forms, but given their state of preservation and lack of external details we leave them in open nomenclature, most closely compared to the Chinese species.

Order CORYNEXOCHIDA Kobayashi, 1935
Family ORYCTOCEPHALIDAE Beecher, 1897
Subfamily ORYCTOCEPHALINAE Beecher, 1897
Genus TONKINELLA Mansuy, 1916

Type species. *T. flabelliformis* Mansuy, 1916, from the Mid Cambrian Siao-pin-tchai Horizon, Tonkin (now Vietnam); by monotypy.

Remarks. Suvorova (1964) considered Oryctocephalinae and Tonkinellinae to have very similar cranial features and separated them on pygidia, notably by the lack of interpleural furrows and marginal spines in the latter. Whittington (1995) separated Oryctocephalidae into two subfamilies based on the presence (Oryctocephalinae) or absence (Oryctocarinae) of genal spines and thoracic and pygidial pleural spines; he tentatively assigned *Tonkinella* to Oryctocephalinae because of its genal spines. If *Tonkinella* were to be placed in Oryctocarinae it would need to be considered intermediate between the subfamilies, as the genal spines are hardly likely to have evolved a second time after being lost at the inception of the subfamily. Whittington (1995) noted that *Tonkinella* is the youngest known oryctocephalid, and so could not have given rise to the older Oryctocarinae. Therefore, we follow Whittington's (1995) classification.

Tonkinella breviceps Kobayashi, 1934

Plate 16, figures 6–15; Plate 17, figures 1–4

- v*1934 *Tonkinella breviceps* Kobayashi, p. 300, pl. 1, figs 2–6.
- v*.1934 *Tonkinella kashmirica* Reed, p. 9, pl. 1, figs 3–8.
- v*.1934 *Tonkinella kashmirica?* Reed, p. 9, pl. 1, fig. 9.
- v*.1934 *Tonkinella quadrifida* Reed, p. 11, pl. 1, fig. 10.
- v*.1934 *Dolichometopus subtuberculatus* Reed, p. 12, pl. 1, fig. 12.
- v*.1934 *Hundwarella? remota* Reed, p. 26, pl. 2, fig. 7.
- non1935 *Tonkinella breviceps* Kobayashi; Kobayashi, p. 150, pl. 15, figs 6, 8–9.
- 1994 *Tonkinella breviceps* Kobayashi; Sundberg, p. 35, fig. 24 [with extensive synonymy].

Material. Lectotype (here selected) YPM14327 (Kobayashi, 1934, pl. 1, fig. 2); paralectotypes YPM14330, 14335, 32862–32864, from green ferruginous shales on road between Turkapur and the bend on the Talar River, about 8 km west of Hundwara on road to Zachaldor (= KB). Other material GSI15599–15607, 15624 (Reed 1934, pl. 1, figs 3–10, 12; pl. 2, fig. 7).

Diagnosis. See Sundberg (1994, p. 35).

Description. The species has been described comprehensively from undistorted limestone specimens by Sundberg (1994). On the mainly internal moulds from Kashmir, furrows appear deeper and there is a very weak medial invagination in the anterior glabella margin (the latter is barely apparent in Sundberg's (1994, fig. 24.1) figure). Rostral-hypostomal plate uniformly short, with slight bulge at midline, convex, rostral suture exsagittal. Hypostome conterminant, longer than wide. Posterior rounded. Border extremely short, upturned. Median body ovate. Median furrow dividing convex anterior lobe. Thorax of at least five segments. Axis convex. Pleural furrow well-impressed in midlength of segment.

Preservation. In one cranium (Pl. 17, fig. 1) glabellar furrows are not apparent, but we suggest that this is due to its poor preservation. Conversely, compression may enhance subtle furrows (e.g. interpleural furrows on Pl. 17, fig. 4).

Ontogeny and intraspecific variation. Reed (1934) distinguished *T. quadrifida* from *T. kashmirica* on the S4 glabellar furrow, its relatively large eyes and slightly different overall shape. Variations in the prominence of S4 and in overall shape appear to be compaction-related. A size-related decrease in the relative length of the eye within the sample suggests that this feature is ontogenetically controlled, as in many trilobites (Hughes 1994). Prominence of the median tubercle is apparently size-independent.

Remarks. The species name dates from Kobayashi's 1934 paper, even though he indicated it as 'new' in his 1935 paper; the order of publication must have been other than anticipated. The impact of this re-ordering of publication has been the assumption of syntype status by his Kashmiri material; the Korean specimens of Kobayashi (1935) are not types and are referred to another species. The lectotype (Pl. 16, fig. 8) is sagittally compressed; other fossils on the same bedding plane are compressed in the same direction.

Priority of Kobayashi's (1934) work over Reed's (1934) is clear through Reed's (1934, p. 37) reporting of Kobayashi's (1934) paper in a postscript. The only fragmentary librigena available (Pl. 16, fig. 12) is too poorly preserved to provide details. The hypostome (Reed 1934, pl. 1, fig. 9) questionably assigned to *T. kashmirica* agrees with the description above and compares closely with that of Kobayashi (1934, pl. 1, fig. 5) which is typically oryctocephalid (cf. Shergold 1969, pl. 1, fig. 4; pl. 2, fig. 4; pl. 8, fig. 11). Shergold's (1969, p. 34) 'border roll' represents the posterior lobe of the median body.

Sundberg (1994) illustrated pygidia with five or six pleural ribs and included specimens with three to five pygidial axial rings so a degree of intraspecific variation in pygidial segmentation is acknowledged, but within the Kashmiri material the number is constant in pygidia ranging in length from 0.8–7.0 mm.

Pygidia from Korea (Kobayashi 1935, pl. 15, figs 8–9) have the large pygidial posterior axial lobe typical of *T. stephensis*; although the associated cranium (Kobayashi 1935, pl. 15, fig. 6) appears to have a broad anteriorly transverse glabella it is a tiny specimen (< 2 mm long). We tentatively assign all Kobayashi's Korean material to *T. stephensis*.

Gupta (1967) reported *Tonkinella stephensis*, *Wenckhemnia sulcata*, and *Ogygopsis klotzi* from Zachaldor, Kashmir, but his figures of these species were reproduced illustrations of specimens from

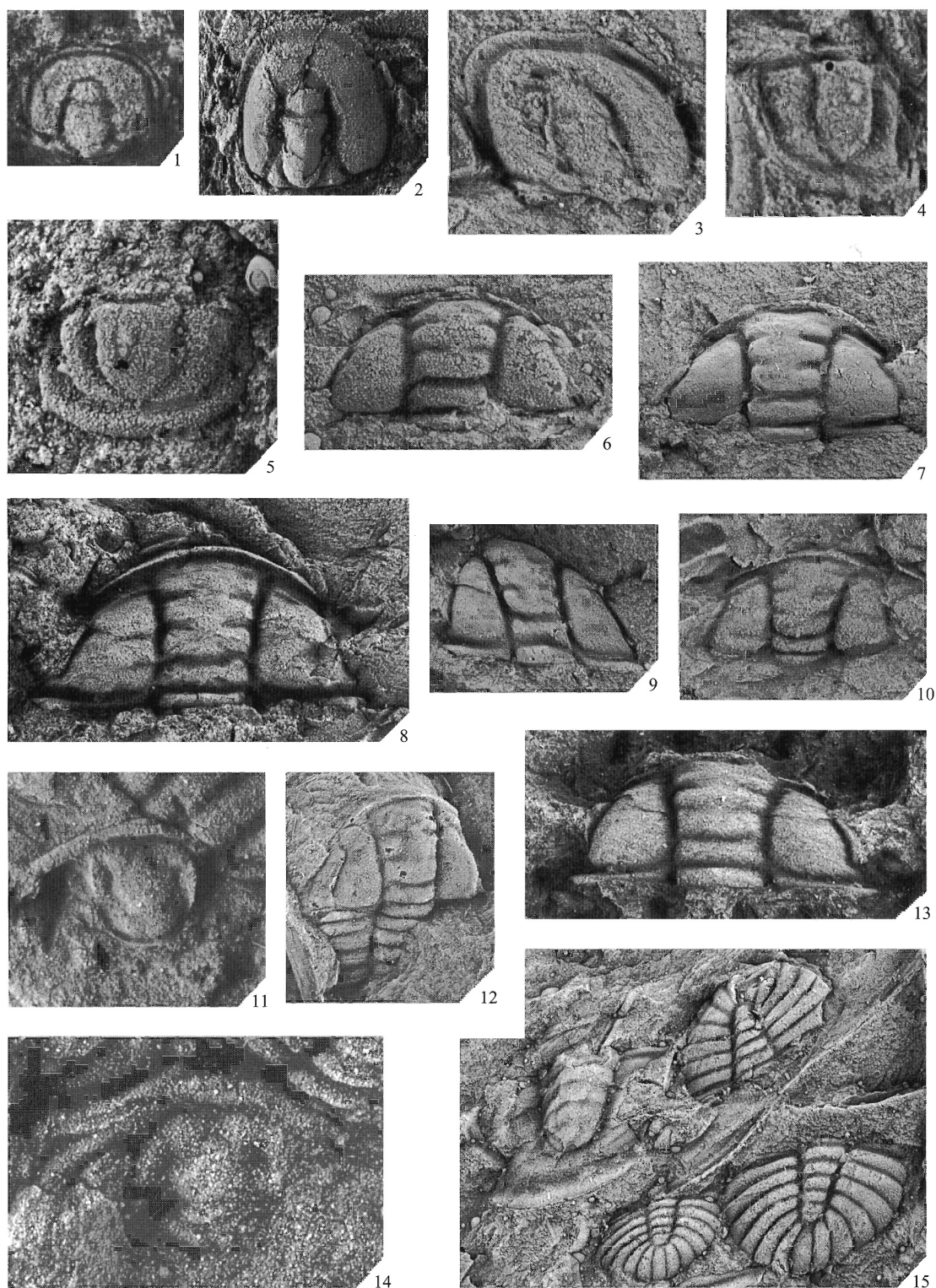
EXPLANATION OF PLATE 16

Figs 1–5. *Baltagnostus* cf. *rakuroensis* (Kobayashi, 1935). 1–3, cranidia. 1, YPM14337; $\times 18$. 2, KUF496 (1876); $\times 8$. 3, KUF510.1 (1877); latex cast; $\times 11$. 4, KUF510.2 (1878); pygidium; $\times 15$. 5, KUF501 (1879); pygidium; $\times 13.5$.

Figs 6–15. *Tonkinella breviceps* Kobayashi, 1934. 6–11, cranidia. 6, GSI15602 (1880); $\times 9$. 7, GSI15599 (1881); $\times 6$. 8, YPM14327, lectotype; $\times 7.5$. 9, GSI15601 (1882); $\times 6$. 10, GSI15606 (1883); latex cast; $\times 6$. 11, YPM32862; $\times 8.5$. 12, GSI15600 (1884); cephalon and anterior thorax, latex cast; $\times 5.5$. 13–14, hypostomes. 13, YPM32864; $\times 10$. 14, GSI15605 (1885); $\times 11$. 15, three pygidia and a cranium of *Hundwarella memor*; GSI15604 (1886–1890); $\times 6$.

Figs 1, 8, 11 and 13 are internal moulds from c. 8 km west of Hundwara on road to Zachaldor; figs 2–5 are from the lower part of the Nutunus Formation, c. 1.5 km west of Nutunus, Pohru Valley; figs 6–7, 9–10, 12 and 14–15 are from 2.8 km west-north-west of Wadapur.

The specimen in fig. 1 was illustrated by Kobayashi 1934, fig. 1. Specimens in figs 2 and 4–5 were illustrated by Shah and Sudan 1987a, pl. 1, figs k, e and r, respectively. Specimens in figs 6–7, 9–10, 12 and 14–15 were illustrated by Reed 1934, pl. 1, figs 6, 3, 5, 10, 4, 9 and 8, respectively.



JELL and HUGHES, *Baltagnostus*, *Tonkinella*

British Columbia published by Rasetti (1951) and this report must be disregarded (Talent *et al.* 1990).

Order PTYCHOPARIIDA Swinnerton, 1915, emend. Fortey, 1990

Family CONOCORYPHIDAE Angelin, 1854

Genus BAILIELLA Matthew, 1885

Type species. Conocephalites baileyi Hartt, 1868.

Diagnosis. Without pair of furrows running forward from the axial furrow to anterior border furrow; anterior border of uniform length.

Remarks. Distinction between *Conocoryphe*, *Bailiella* and *Bailiaspis* was addressed by Westergård (1950). He separated *Bailiella* on the absence of the anterior extensions of the axial furrow to the border furrow, and on the course of the facial suture across the border furrow just onto the cheek. *Bailiella lantenoisi* (Mansuy, 1916) (Zhang and Jell 1987, pl. 35, figs 1–5) lacks the anterior extensions of the axial furrow and has a facial suture that remains on the lateral border and does not cross the border furrow. Generic distinction cannot continue to rest on the combination of Westergård's two features. We use the lack of anterior extensions of the axial furrow to separate *Bailiella* from *Conocoryphe* as a pragmatic approach until the family is adequately reviewed.

In a discussion to illustrate his contention that Conocoryphoidea is polyphyletic (with which we agree), Fortey (1990, p. 563) suggested that *Conocoryphe* and *Meneviella* on the one hand and *Bailiella* on the other had lost their eyes in different ways, based on length of the eye ridges and the course of the facial sutures (or width of the fixigenae). We doubt that the latter, either at the margin or slightly on to the border, has much phylogenetic significance, as numerous variations between the two extremes have been illustrated. Eye ridges consist of two parallel (probably overlying) caeca of different function (Jell 1978). The homologue of *Bailiella*'s 'short marooned eye ridge' is evident in *Meneviella venulosa* (see Hutchinson 1962, pl. 16, fig. 6a–b) as the anterior caecum which stops a short distance from the axial furrow whereas the other caecum continues almost to the genal angle. The longer caecum, serving the distal parts of the cheek, is evident in *Bailiella tenuicincta* (Hutchinson, 1962, pl. 15, fig. 3, left) just as Fortey reported it in *Conocoryphe* and *Meneviella*. Thus the eye ridges in *Bailiella*, *Conocoryphe* and *Meneviella* are fully homologous and do not support an argument that these genera lost their eyes in different ways.

Reed's two species of *Conocoryphe* were reassigned to *Bailiella* by Shah (1973, p. 85) because the 'preglabellar area does not bear transverse furrow[s]'. His 'transverse furrows' refer to the anterior extension of the axial furrows, as discussed herein.

EXPLANATION OF PLATE 17

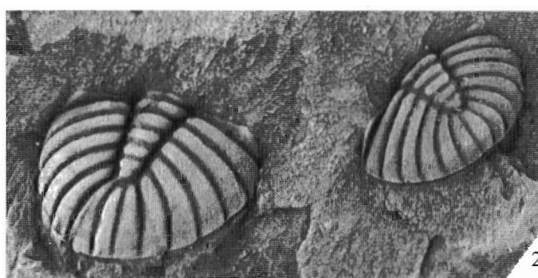
Figs 1–4. *Tonkinella breviceps* Kobayashi, 1934. 1, GSI15607 (1891); 2.8 km west-north-west of Wadapur; cranidium; $\times 8$. 2–4, pygidia. 2, YPM14335 (left), YPM32863 (right); about 8 km west of Hundwara on road to Zachaldor; internal mould; $\times 4$. 3, GSI15603 (1892); Rainawari footpath, Hundwara; $\times 4$. 4, GSI15624 (1893); 2.8 km west-north-west of Wadapur; $\times 6$.

Figs 5–13. *Bailiella lantenoisi* (Mansuy, 1916); from the foot of Frangteng Hill, except where stated otherwise. 5, GSI15598 (1894); 2.8 km west-north-west of Wadapur; cephalon and anterior thorax; $\times 4$. 6–7, 9–11, cranidia. 6, GSI15594 (1895); $\times 4$. 7, GSI15593 (1896); $\times 4$. 8, GSI15597 (1897); near Sultanpur, cephalon and anterior thorax, latex cast; $\times 2$. 9, GSIK25/252 (1898); locality unknown, Hundwara Tehsil; cranidium showing weak eye ridges; $\times 6.5$. 10, GSI15595 (1899); $\times 4$. 11, GSI15596 (1900); $\times 3$. 12, reproduction of original figure of GSI15596 from Reed 1934. 13, GSIK26/513 (1901); locality uncertain, Hundwara Tehsil; latex cast; $\times 4$.

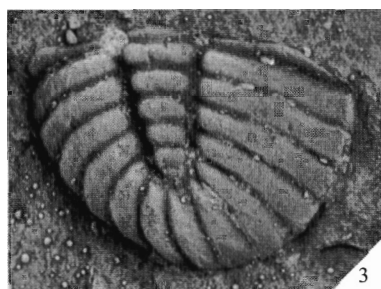
Specimens in figs 1, 3–8 and 10–12, were illustrated by Reed 1934, pl. 1, figs 12 and 7 and pl. 2, figs 7, 13, 10, 9, 11 and 12, respectively. The specimen in fig. 2 was illustrated by Kobayashi 1934, fig. 6.



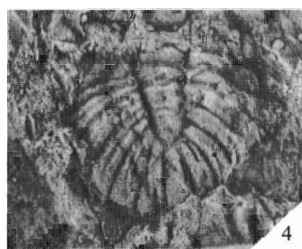
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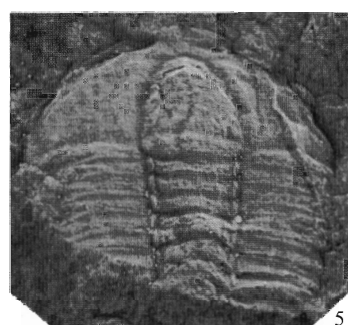
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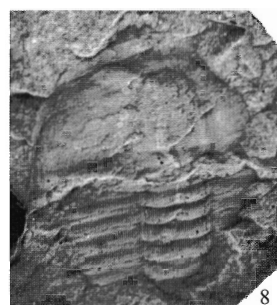
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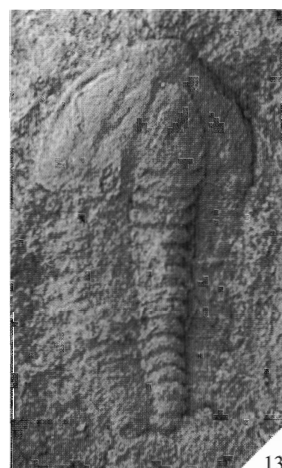
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12



13

Bailiella lantenoisi (Mansuy, 1916)

Plate 17, figures 5–13; Plate 18, figures 1–3; Text-figure 8

- v*1916 *Conocoryphe lantenoisi* Mansuy, p. 30, pl. 4, figs 6–7; pl. 5, fig. 3.
v*.1934 *Conocoryphe frangtengensis* Reed, p. 7, pl. 2, figs 9–12.
v*.1934 *Conocoryphe sejuncta* Reed, p. 8, pl. 2, figs 13–14.
v*1973 *Bailiella frangtengensis* (Reed); Shah, p. 84, fig. 1e–f, 2b.
v*1973 *Bailiella sejuncta* (Reed); Shah, p. 87, figs 1a–d, 2a, c.
v*1973 *Holocephalina wadii* Shah, p. 88, figs 1i, 2d.
v*1973 *Holocephalina wakhloo* Shah, p. 90, figs 1k, 2e.
v*1973 *Conocoryphe reedi* Shah, p. 91, figs 1h, j, 2f.
v*1973 *Bailiaspis* sp. Shah, p. 92, fig. 1g.
1977 *Bailiella lantenoisi* (Mansuy); Zhou *et al.*, p. 146, pl. 45, figs 12–13.
1980 *Bailiella lantenoisi* (Mansuy); Nan, in Han *et al.*, p. 490, pl. 201, figs 15–17.
1980b *Bailiella lata* sp. nov. Wu and Lin, in Zhang *et al.* p. 53, pl. 2, figs 9–11.
1981 *Bailiella lantenoisi* (Mansuy); Zhang and Yuan, p. 168, pl. 3, fig. 10.
1982 *Bailiella elegans* Li, in Zhou *et al.*, p. 239, pl. 60, fig. 16; pl. 61, fig. 1.
1985 *Bailiella lantenoisi* (Mansuy); Zhang and Wang, p. 360, pl. 110, figs 5–6.
1985 *Bailiella lata* Wu and Lin; Zhang and Wang, p. 360, pl. 110, figs 13–14.
1985 *Bailiella hebeiensis* Zhang and Wang, p. 360, pl. 110, fig. 12.
1985 *Bailiella huoshanensis* Zhang and Wang, p. 361, pl. 110, figs 2–4.
1985 *Bailiella pingshanensis* Zhang and Wang, p. 361, pl. 110, fig. 7.
1985 *Bailiella wutaishanensis* Zhang and Wang, p. 361, pl. 110, figs 8–10.
1985 *Bailiella wuanensis* Zhang and Wang, p. 361, pl. 110, fig. 11.
1985 *Bailiella transversa* Zhang and Wang, p. 361, pl. 110, fig. 15.
v*1987 *Bailiella lantenoisi* (Mansuy); Zhang and Jell, p. 81, pl. 35, figs 1–7 [with full synonymy].

Material. Lectotype (here selected) T228, Centre des Sciences de la Terre, Université Claude Bernard, Lyon (Mansuy 1916, pl. 4, fig. 6b), an incomplete but articulated external mould from Tien-Fong, north Vietnam. Paralectotypes T229–T230 (Mansuy 1916, pl. 4, figs 6c, 7), internal moulds of cranidia from the type locality. Kashmiri material GSI15593–15596 from KA, GSI15597 from KE, GSI15598 from KD. KUF383a, KUF477–489, from the same Cambrian outcrop as Wadia's collections; localities listed are: Zachaldor, 34°25'N, 74°12'E and Turkapura, 34°24'N, 74°13'E (Shah 1973). KUF486 is preserved in a coarse siltstone band at one of these localities (S. K. Shah, pers. comm.).

Diagnosis. *Bailiella* with facial suture running within border.

Description. This species was described adequately by Zhang and Jell (1987, p. 81).

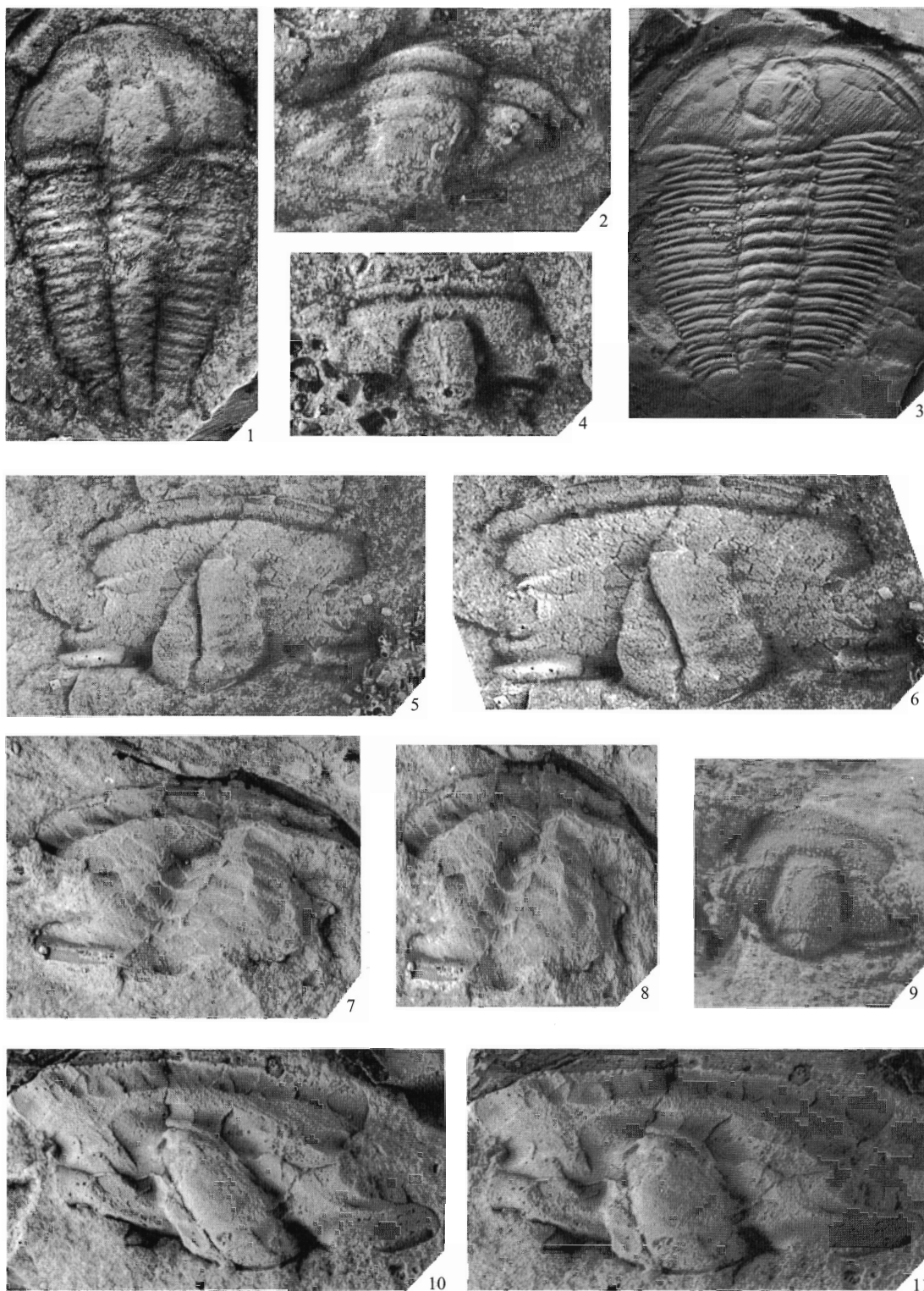
Ontogeny and intraspecific variation. In the Kashmiri population variation in the length of the frontal area, impression of the glabellar and border furrows, expression of the median occipital node and depression of the preglabellar field are due to deformation.

EXPLANATION OF PLATE 18

Figs 1–3. *Bailiella lantenoisi* (Mansuy, 1916). 1, KUF486 (1902); Zachaldor; $\times 3$ (holotype of *Holocephalina wadii* Shah, 1973). 2, GSIK25/249 (1903); from foot of Frangteng Hill; pygidium; $\times 7$. 3, KUF477 (1904); Zachaldor; $\times 2$.

Figs 4–11. *Xingrenaspis dardapurensis* (Reed, 1934); from 2.4 km south-east of Dardapur except where stated otherwise, cranidia. 4, GSI15619/2 (1905); $\times 7.5$. 5–6, GSI15619/1 (1906); $\times 4$. 6, computer-graphic restoration. 7–8, GSI K26/528/3 (1907); $\times 5$. 8, computer-graphic restoration. 9, ANU49474; from just past the Forest Rest House on the Talar River, 8 km west of Hundwara; $\times 10$. 10–11, GSIK26/528/1 (1908); $\times 4.75$. 11, computer-graphic restoration.

Specimens in figs 1 and 3 were illustrated by Shah 1973, figs 1i and 1a respectively. Specimens in figs 4–5 were illustrated by Reed 1934, pl. 2, fig. 17 and pl. 1, fig. 1, respectively.



Remarks. Reed (1934) distinguished his *B. sejuncta* and *B. frangtengensis* mainly on the former having genal spines. However, close examination of the types shows that genal spines are not present and with the other characters used to distinguish the two species being compaction-related, they are considered synonymous.

Reed (1934, p. 9) questionably referred two Kashmiri specimens to *Conocoryphe* (*Ctenocephalus*?). These specimens cannot be identified in the GSI collections and we assign all conocoryphids from Kashmir held by GSI to *Bailiella lantenoisi*.

Shah (1973) reported four conocoryphid genera in the Nutunus Formation, Baramula District, Kashmir. The pervasive tectonic deformation in Shah's and Wadia's material and an understanding of variation in *B. lantenoisi* in Asia indicate that Shah's specimens are conspecific. *Holocephalina wakhaloosi* was drawn (Shah 1973, fig. 2e) with an apparently distinctive pointed anterior margin but the drawing appears to be exaggerated when compared with the photograph and, moreover, this specimen is the most elongate or laterally compressed of those figured. Lateral compression has induced an angular anterior margin in several different Himalayan species (cf. Pl. 20, fig. 10; Pl. 12, figs 1, 4); this feature cannot be considered specifically distinctive, far less generically significant.

Material figured as *B. frangtengensis* by Gupta and Shaw (1983) lies within the range of variation of *B. lantenoisi* as diagnosed herein. However, provenance of this material is dubious (Talent *et al.* 1990).

If the position of the facial suture on the dorsal surface proves taxonomically insignificant the synonymy list should be extended to include species from Newfoundland (Hutchison 1962), Spain (Sdzuy 1961; Liñan and Gozalo 1986) and France (Courtesole 1973).

Family PTYCHOPARIIDAE Matthew, 1887

Genus XINGRENASPIS Yuan and Zhou, in Zhang *et al.*, 1980a

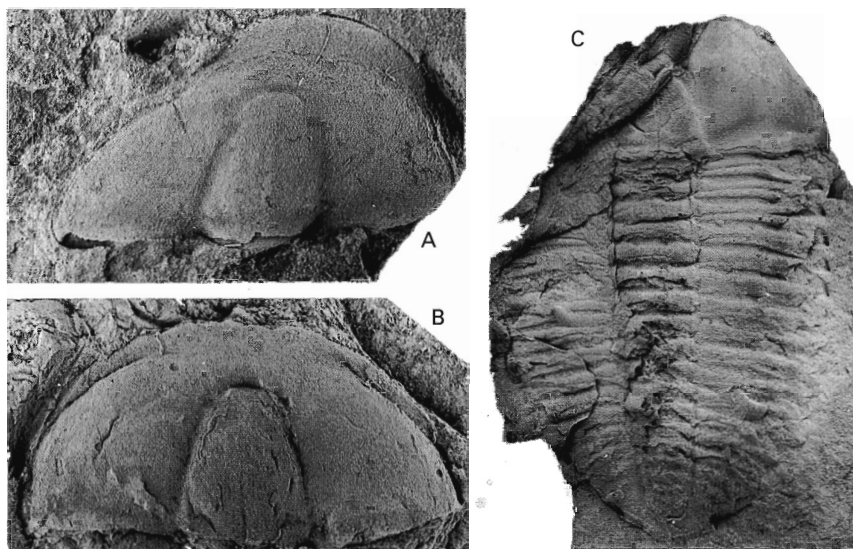
Xingrenaspis dardapurensis (Reed, 1934)

Plate 18, figures 4–11; Plate 19, figures 1–2; Plate 26, figures 1–11

- v*.1934 *Ptychoparia dardapurensis* Reed, p. 22, pl. 1, fig. 1.
- v*.1934 *Solenopleura*? sp. Reed, p. 20, pl. 2, fig. 17.
- v*.1983 *Ptychoparia* sp. Kumar and Singh, p. 548, fig. 2.
- v*.1983 *Ptychoparella* sp. Kumar and Singh, p. 548, fig. 3.
- v*.1983 *Caborcella* sp. Kumar and Singh, p. 548, figs 6–8.
- ?v1983 Gen. indet. Kumar and Singh, p. 548, fig. 9.
- v*.1988 *Hundwarella kingi* Shah *et al.*, p. 51, pl. 1, figs h–i.
- ?1991 *Cyclolorenzella* sp. Shah *et al.*, p. 90, pl. 1, figs c, f, i.
- v*.1991 *Spitella barachuensis* Shah *et al.*, p. 98, pl. 2, fig. c.

Material. Lectotype (here selected) GSI15619 (Reed 1934, pl. 1, fig. 1), paralectotype GSI15619 (Reed 1934, pl. 2, fig. 17). Other topotype material includes a further specimen on GSI15619, GSIK26/528/1 and GSIK26/528/3. All from a brown indurated siltstone from KG. Other material: ANU49474, from a green shale from a gully on the northern bank of the Nulla, just past a dam on route from Zachaldor Forest Rest House to Rainawari, via Kiapur; GSI19650–19657, from the Karihul Section, Liddar Valley, eastern Kashmir; KUF546–547, 549, from Khanpura, north-western Kashmir; KUF629, from Horizon 13, Spiti.

Description. Glabella conical, widest at posterior of L1, tapering anteriorly, with angular anterolateral corners and straight to slightly convex anterior margin. S1 bifurcate, not crossing central third of glabella, weakly impressed, posterior branch oblique posteroaxially, anterior branch narrow. S2 and S3 faint. LO longest sagittally, posterior margin convex. Axial furrow shallowing in front of glabella. Fossulae distinct. Frontal area c. 50 per cent. of occipito-glabellar length. Preglabellar field longer than anterior border, which is of uniform length, flattened, tubular. Preocular suture diverging at c. 20° to exsagittal line. Preocular fixigenal width twice occipital width. Eye ridge prominent, tubular, confluent with axial furrow just posterior of anterolateral corner. Palpebral lobe c. 0.3 of glabellar length. Thorax of at least ten segments, with strongly convex axis; each segment with well-impressed pleural furrow occupying most of the segment. Pygidium unknown.



TEXT-FIG. 8. *Bailiella lantennoisi* (Mansuy, 1916); syntypes from the Middle Cambrian of Tien-Fong, north Vietnam, in the collections of the Université Claude Bernard, Lyon, France. A, T230, paralectotype; internal mould of cranidium; $\times 2$ (Mansuy 1916, pl. 4, fig. 7). B, T229, paralectotype; internal mould of cranidium; $\times 1.5$ (Mansuy 1916, pl. 4, fig. 6c). C, T228, lectotype (chosen herein); latex cast from external mould of articulated but incomplete specimen; $\times 1.8$ (Mansuy 1916, pl. 4, fig. 6b).

Preservation. The specimens are preserved as internal moulds and have been both cracked and tectonically deformed. Computer-aided restorations of the cranidia (Pl. 18, figs 5–8, 10–11) are closer to the original proportions and are the basis for the description. A smaller specimen in green shale from near Zachaldor with a longer anterior border, effaced glabellar furrows and a median occipital tubercle (Pl. 18, fig. 9) is tentatively assigned here.

Remarks. This species is assigned to *Xingrenaspis* because it has bifurcate S1, poorly impressed lateral glabellar furrows, an anteriorly tapering glabella with subangular anterolateral corners and moderately sized palpebral lobes.

Although this apparently widespread (north-western and eastern Kashmir and Spiti) species has potential for correlating the enclosing sections it should not be relied upon too heavily as it has an extremely generalized cranidium, and available material is extremely variable following tectonic distortion.

Although the holotype cranidium of *Spitella barachuensis* Shah, Parcha and Raina, 1991 appears to have well-impressed glabellar furrows it is longitudinally compressed and the transverse furrows across the glabella are due to tectonic crinkling. The transverse grooves across the glabella are neither symmetrical nor in the appropriate places or shapes to be glabellar furrows. Its convex anterior border and preglabellar field are also due to longitudinal compression. Taking this compression into account we consider *S. barachuensis* to be a junior subjective synonym of *X. dardapurensis*.

Family AGRAULIDAE Raymond, 1913

Genus PARACHITTIDILLA Lin and Wu, in Zhang *et al.*, 1980b

1991 *Amurticephalus* Shah *et al.*, p. 91.

Type species. By original designation; *Parachittidilla xiaolinghouensis* Lin and Wu, in Zhang *et al.*, 1980b, from the Middle Cambrian (Hsuehuangian) of southern Shanxi.

Parachittidilla kashmirensis (Shah, Parcha and Raina, 1991)

Plate 4, figures 1–7

- v.1991 *Pedinocephalus kashmirensis* Shah, Parcha and Raina, p. 92, pl. 1, figs a, d, g, k, p.
 v.1991 *Amurticephalus elongatus* Shah, Parcha and Raina, p. 92, pl. 1, figs b, e, h, l-m.
 v.1991 *Walcottaspis* sp. Shah *et al.*, p. 91, pl. 1, fig. j, n.
 v.1991 *Haniwa transversa* Shah *et al.*, p. 96, pl. 1, fig. o; pl. 2, figs i, m, q-r, u.

Material. Holotype Shah *et al.* (1991, pl. 1, fig. g); catalogue number not indicated but within the range KUF613–620. KUF606–620, 626–628, from the Magam Section, above *Bolaspidella* (= *Shahaspis*) horizon. ANU49467–49473, from a small gully just above a dam on track approximately 3 km west-north-west from Zachaldor Forest Rest House. The relation of this horizon to that of the *Tonkinella* fauna, which occurs close by, is not certain.

Description. Glabella tapering forward to truncated anterior; glabellar furrows not impressed; SO weak or absent; LO slightly longer medially. Frontal area convex, without border furrow (very rudimentary in some specimens). Eye ridges evident on most specimens; palpebral lobes relatively short, strongly convex laterally, kidney-shaped; palpebral furrow distinct; preocular facial suture diverging, rounded across anterior border. Posterolateral limb narrow, long. Probable conspecific librigena smooth, flat, with angular section at margin; long genal spine with flat upper surface. Probable conspecific pygidium with wide, flat border; axis narrow, of at least three rings plus terminus, with low postaxial ridge. Pleural furrows poorly impressed (possibly due to preservation).

Remarks. Whereas Shah *et al.* (1991) compared this material to a number of Upper Cambrian forms, the complete (or almost complete) lack of an anterior border furrow is not shared with any of those taxa except *Walcottaspis* which is of much greater dimensions, with well-impressed axial and palpebral furrows and with much narrower interocular cheeks. Moreover, Shah *et al.* (1991) separated at generic level specimens that were compressed longitudinally and laterally, but there are no distinctive features other than relative proportions; hence the synonymy above. The ANU material matches well with that of Shah *et al.* (1991) and although not certainly associated, a librigena and pygidium plus part of a thorax, probably belong to this species. Glabellar shape, lack of glabellar furrows, long featureless frontal area, prominent palpebral lobes and narrow posterolateral cephalic limbs indicate placement in *Parachittidilla*. This genus differs from *Chittidilla* King, 1941 in the tapering as opposed to parallel-sided glabella, the convex preglabellar field without border furrow, so a close relationship has been inferred; in fact the two genera may prove to be synonymous when fully understood. The distribution of *Chittidilla* in Iran (King 1941) and south-western China (Zhang *et al.* 1980a) is paralleled by that of *Parachittidilla* in Kashmir and northern China.

Genus SHAHASPIS gen. nov.

Derivation of name. For Professor S. K. Shah of Jammu University, in honour of his many contributions to the Cambrian geology of India.

Type species. *Bolaspidella himalayensis* Shah and Sudan, 1982. The genus is monotypic.

Diagnosis. Glabella tapering forward, truncated anteriorly, with straight sides producing angular anterolateral corners from which emanate the eye ridges; LO expanded posteriorly into short, stout, flattened spine; preglabellar field slightly swollen medially; anterior border strongly convex, elongate, tapering laterally; palpebral lobe short, narrow, kidney-shaped, upturned.

Remarks. Shah and Sudan (1982) illustrated numerous internal moulds and assigned them to the upper Middle Cambrian North American genus *Bolaspidella*. Although there is a general resemblance to the latter, *Shahaspis* is distinguished by: glabella with truncated anterior, straight converging sides and incomplete occipital furrow, depressed preglabellar field with hint of medial swelling, more inflated and more sharply tapering anterior border, narrow posterolateral glabellar

limb, occipital spine triangular in plan and evenly tapering from base as wide as glabella. Shah *et al.* (1985) sought to justify assignment to *Bolaspidella* by quantitative assessment, following some doubt being expressed by Robison (*in* Kumar 1983). Three points which prevent us from accepting their conclusions are: (1) Shah *et al.* (1985, p. 11) stated that there is no distortion in their specimens and it could have no effect on their calculations. However, all the figured specimens, which are specifically stated to be part of the measured specimen set, together with numerous unfigured specimens in the University of Jammu collection, and presumably part of the measured set, are in our opinion distorted to some degree. (2) The parameters used by Shah *et al.* (1985) for comparison are general ones; many Cambrian trilobites from a wide variety of lineages have comparable values for these parameters. However, this does not make the forms congeneric. (3) Shah *et al.* (1985) made no comparison with any other trilobites to see if these measurements could distinguish their populations from those of other trilobite species.

Any resemblance to *Bolaspidella* is attributed to convergence because *Bolaspidella* is a member of Menomonitidae, whilst *Shahaspis* gen. nov. is considered to belong to Agrauidae as a descendant of *Parachittidilla* or similar form.

Affinities of the Kashmiri species upon which this genus is based are with elements of the Chinese Hsuehuangian fauna and with *Chelidonocephalus* (particularly *C. alifrons* King, 1937) from Iran. This is based largely on the structure of glabella and the frontal area. Forms with the same aggregate of features as *Shahaspis* are not known at present but its glabella is almost identical to that of *Parachittidilla* from which genus the frontal area differs only in having a depressed preglabellar field. The style of occipital spine in this Kashmiri species is characteristic of some Agrauidae and Lorenzellidae (see Zhang and Jell 1987). The truncated glabella is common in Agrauidae, Wuaniidae and some Inouyiidae and Lorenzellidae. The frontal area is reminiscent of that in the Changhian *Taitzuia*(?) *abnormis* Zhang and Yuan, *in* Zhang *et al.*, 1980b, but its glabella is structured differently. We suggest that *Shahaspis* evolved from *Parachittidilla* by depression of the preglabellar field. It is a large species by comparison with most Wuaniidae, Lorenzellidae, etc., so if Cope's Rule applies it would not be a good candidate to give rise to those families. However, as it possesses features reminiscent of several of them it probably had fairly close common ancestry. It is assigned to Agrauidae on its glabellar structure and style of occipital spine (see Zhang and Jell 1987, pl. 47, fig. 14) and general form; the structure of its frontal area is generically distinct but homologous with other family members.

Fortey and Rushton (1976, p. 337) discussed the structure of the frontal area in *Chelidonocephalus* using the terms 'true' and 'false' border furrows. They considered the more posterior one to be homologous with the border furrow of other trilobites that have only one border furrow. This conclusion was based on the belief that the inflation in front of the glabella is an inflation of the plectrum, but we suggest the alternative that it is the preglabellar field that is inflated. Zhang and Jell (1987, p. 118) discussed the frontal area of Wuaniidae and Ordosiidae in relation to possible ancestors *Eotaitzuia* and *Chittidilla*, concluding that the strong transverse furrow immediately at the anterior of the glabella is not the homologue of the border furrow in other trilobites such as Ptychopariidae where only one transverse furrow crosses the frontal area. The latter authors used 'pseudoborder furrow' for 'true' border furrow of the former authors. These concepts are clearly opposed to each other although they could be descriptions of different structures, as Öpik (1967, pp. 57, 59) contended that plectrum and frontal boss are not homologous and that each is found in several different superfamilies or orders, suggesting that each evolved several times.

Öpik (1976, p. 17) recognized the transverse pseudoborder furrow in front of the eye ridge in ellipsocephalids as having some taxonomic significance and Geyer (1990) illustrated many members of that family displaying the feature very clearly. This feature is more prominent in some genera than in others, and the variation in the course of this furrow is best exemplified in Geyer's (1990) work where several species show the furrow to have migrated forward or the eye ridges to have moved back so that there is an area of the fixigena between the eye ridge and the pseudoborder furrow formerly adjacent to the eye ridge (e.g. Geyer 1990, pl. 6, fig. 12; pl. 8, figs 15–16; pl. 9, fig. 3; pl. 54, figs 1, 5, 7). In the Mid Cambrian, this same evolution of the pseudoborder furrow away

from the eye ridge occurred in eastern Asia among another group of ellipsocephalid descendants. The pseudoborder furrow is subdued in *Chittidilla* (numerous specimens in Zhang *et al.* 1980a, pls 121–124) and is distinct from the border furrow. In *Parachittidilla* the distal end of the pseudoborder furrow has just moved forward away from the eye ridge (Zhang *et al.* 1980b, pl. 5, fig. 8) and the border furrow is evident farther forward. In *Inouyops abnormis* both furrows are well-impressed and the pseudoborder furrow is retained at the eye ridge (Zhang *et al.* 1980b, pl. 5, fig. 10). In *Latilorenzella* (= *Wuania*), the pseudoborder furrow has moved forward away from the eye ridge but remains transverse (Zhang *et al.* 1980b, pl. 6, fig. 7) and the border furrow is obliterated by the expansion of the border. In *Inouyella* the pseudoborder furrow arches laterally from the glabellar anterior and joins the border furrow at or before the facial suture (Zhang and Jell 1987, pl. 47, fig. 1; Zhang *et al.* 1980b, pl. 4, figs 4, 6) and the border furrow is evident anteriorly. Ordosiidae, including *Poshania*, evolved from this group in the late Mid Cambrian, probably through *Eotaitzia* or like form (Zhang and Jell 1987, p. 109) in which the border furrow had already been obliterated by expansion of the frontal area. We suggest that the furrow defining an anterior rim in Ordosiidae is the pseudoborder furrow that has migrated forward away from the eye ridge and its shape, arching anterolaterally from the front of the glabella, is reminiscent of that in *Inouyella* where the border furrow is also evident. Following this reasoning we interpret that in *Chelidonocephalus* the more anterior frontal area furrow ('false' border furrow of Fortey and Rushton 1976) is the homologue of the border furrow in other trilobites such as the ptychoparioids while the more posterior furrow arching anterolaterally away from the glabellar anterior is the pseudoborder furrow ('true' border furrow of Fortey and Rushton 1976).

In this way we interpret *Shahaspis* as exhibiting a distinct border furrow behind a convex border and a poorly impressed pseudoborder furrow that is forward of the eye ridge and convex anteriorly as it runs anterolaterally from the anterior corners of the glabella.

Fortey and Rushton (1976) considered *Chelidonocephalus* to be 'most nearly related' to *Poshania* Chang, 1957 and 'probably unrelated' to *Peichishania*, *Inouyella*, *Ordosia* and *Taitzia*. We agree with Zhang and Jell (1987, p. 109) that *Poshania* is a member of Ordosiidae based on cranial and particularly pygidial features and place *Chelidonocephalus* tentatively in this family but certainly in the group of eastern Asian families that includes Ordosiidae, Wuaniidae, Inouyiidae, Lorenzellidae, Agrauiidae and probably Diceratocephalidae. We suggest that this group of families evolved from Agrauiidae (Zhang and Jell 1987, p. 118) which in turn evolved through the early ptychoparioids from Ellipsocephaloidea in the Early Cambrian (Geyer 1990, fig. 37). It is, therefore, not surprising to find similar frontal area structure in *Namanoia* (noted by Zhang 1959) or in ellipsocephalids from Morocco (Geyer 1990).

Jell (1986) commented on this Kashmiri material as described and figured by Shah and Sudan (1982) with internal moulds, indicating relationship to Inouyiidae and Wuaniidae and an early Mid Cambrian age. Latex casts from the external moulds of the type material confirm this comment, and detailed comparisons along with co-occurrence with *Latilorenzella* sp. suggest a late Hsichuanian age.

Shahaspis himalayensis (Shah and Sudan, 1982)

Plate 27, figures 1–2, 4–5, 7–8, 10–11

- v*.1982 *Bolaspidella himalayensis* Shah and Sudan, p. 237, pl. 1, figs a–d, f–g, i, k.
- v*.1982 *Bolaspidella costatus* Shah and Sudan, p. 242, pl. 1, fig. j.
- v*.1982 *Bolaspidella magamensis* Shah and Sudan, p. 243, pl. 1, fig. e.
- v*.1982 *Bolaspidella* sp. nov.? Shah and Sudan, p. 244, pl. 1, fig. h.

Material. Holotype KUF492a; other material KUF492–495 (Shah and Sudan 1982, pl. 1) and ANU49484. Shah and Sudan (1982) gave a map and clear description of the collecting locality for their material; ANU49484, from a small quarry on the north side of the road from Magam to Hundwara, about 1.6 km from Magam, which is at the same horizon as that which yielded the type specimens.

Description. Glabella strongly convex, tapering forward to sharply truncated anterior. SO incomplete over axis; S1–S3 poorly impressed, running posteroaxially up sides of glabella but not crossing axis, with S3 almost transverse and coming from a definite pit in the axial furrow, so that the anterolateral corner of the glabella appears to be expanded and on some specimens to be connected to the fixigenae by a long low ridge across the axial furrow. Preglabellar furrow sharp, distinct. LO expanded posteriorly into spine with base as wide as axis and with length about half that of the rest of the glabella. Preglabellar field shorter than anterior border, depressed well below border but with low central swelling in most specimens defined by the preocular furrow from the anterior corners of the glabella to the border furrow at the facial suture. Anterior border strongly convex, elongate in front of glabella then tapering strongly laterally; in a few specimens very faint pointed projections of the border appear to be directed back at the axial furrow, one on either side. Interocular cheeks narrow. Eye line indistinct on exterior; palpebral lobes short, strongly curved, situated at or behind midlength of glabella (without occipital spine). Posterior border furrow deep, geniculate anteriorly beyond lateral fulcral point; large flat inclined facet behind the furrow beyond the fulcral point.

Remarks. Shah and Sudan (1982) recognized four species among the illustrated internal moulds. We have examined latex casts from external moulds of topotypes and the type specimens, and consider that features quoted as specifically distinctive are due to tectonic deformation. The small, poorly preserved specimen (ANU 49484) from a sandy shale is associated with *Latilorenzella* sp.

Family WUANIIDAE Zhang and Jell, 1987

Genus LATILORENZELLA Kobayashi, 1960

1963 *Wuania* Chang, p. 472.

1987 *Latilorenzella* Zhang and Jell, p. 122 [with synonymy].

Type species. By original designation; *Agraulos divi* Walcott, 1905, from the Hsuehuangian (*Sunaspis* Zone) of Shandong.

Latilorenzella sp.

Plate 27, figures 3, 6, 9

Material. ANU49485–49487, from a small quarry on the north side of the road from Magam to Hundwara about 1.6 km from Magam, which is at the same horizon as yielded the type specimens of *Shahaspis himalayensis*.

Description. Glabella rectangular, with truncated anterior; lateral furrows not evident. Occipital lobe extended posteriorly but rounded and not spinose. Preglabellar field depressed, short. Anterior border highly inflated medially, with strongly convex anterior margin. Palpebral lobe short, strongly convex, situated behind midlength of glabella. Posterolateral cephalic limb narrow and long.

Remarks. These extremely poorly preserved specimens (mostly external moulds) are similar to *Wuania luna* and *W. elongata* of Zhang *et al.* (1980b) from the Hsuehuangian of southern Shanxi and other Chinese species referred to *Wuania*. *Wuania* was synonymized with *Latilorenzella* by Zhang and Jell (1987) to which the Kashmiri specimens are referred. Their poor, incomplete preservation precludes specific assignment.

Family PROASAPHISCIDAE Chang, 1963

Remarks. This family was discussed in an Asian context by Zhang and Jell (1987, p. 141) but not its relationship with Asaphiscidae Raymond, 1924 (p. 408) erected for several Cambrian trilobites with relatively large pygidia and few thoracic segments that had some resemblance to Asaphidae. Raymond (1937, p. 1108) added several more genera to his family and reiterated his lack of confidence in this being a natural grouping. Fortey and Chatterton (1988) defined Asaphida principally on the median suture, so both Asaphiscidae and Proasaphiscidae are excluded because at least some of them have rostral plates. These were demonstrated in *Asaphiscus* by Robison (1964), *Lioparia* by Zhang and Jell (1987), and *Blainia* by Fortey (1990) of Asaphiscidae, and in

TABLE 3. Correlation matrix for 6 linear dimensions measured on 132 proasaphiscid cranidia from Kashmir and Spiti. The dimensions are: occipito-glabella length (B1); frontal area length (F1); palpebral lobe length (C); occipital ring width (K); prepalpebral glabella width (J4); and frontal area width (J2). (Abbreviations illustrated in Hughes and Jell 1992.)

	B1	F1	C	K	J4	J2
B1	1.000	0.803	0.443	0.880	0.878	0.885
F1	0.803	1.000	0.710	0.631	0.618	0.674
C	0.443	0.710	1.000	0.254	0.173	0.280
K	0.880	0.631	0.254	1.000	0.963	0.963
J4	0.878	0.618	0.173	0.963	1.000	0.965
J2	0.885	0.674	0.280	0.963	0.965	1.000

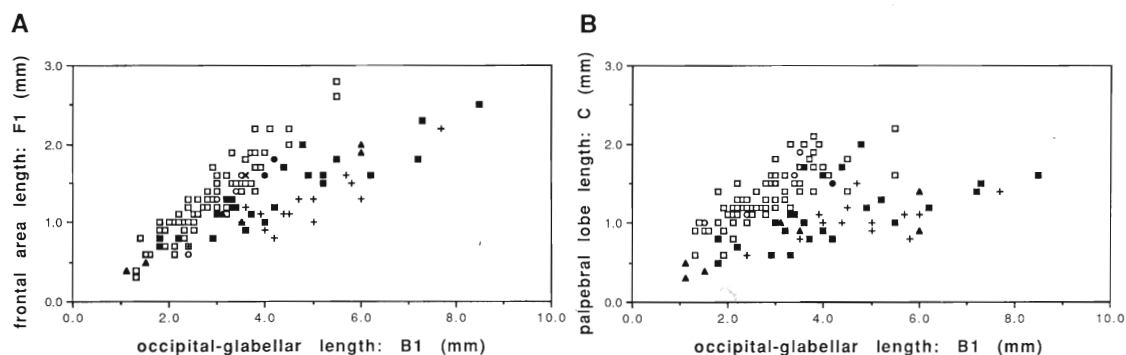
Proasaphiscus by Zhang and Jell (1987) and *Hundwarella* herein (Pl. 21, fig. 1) of Proasaphiscidae.

Although Asaphiscidae and Proasaphiscidae seem difficult to separate, we prefer to retain them as separate families given that the phylogeny of this group is poorly understood. Since the contents of each family are not clear, separation is here based on comparison of the two nominate genera. In *Asaphiscus* as compared with *Proasaphiscus* the cephalon and pygidium are more nearly the same size, the glabella is less quadrate and is anteriorly rounded, genal spines are lacking and thoracic pleural tips lack the posteriorly curved spines.

Among Himalayan proasaphiscids there is considerable morphological variation, some of which is due to tectonic deformation. We have demonstrated that several of Reed's (1934) Kashmiri proasaphiscid species are best considered as a single morphospecies (Hughes and Jell 1992) and have extended this analysis herein to include all well-preserved proasaphiscid cranidia from the Himalaya. The techniques and dimensions used have been detailed by Hughes and Jell (1992).

The data set comprising 132 specimens was standardized by calculating z-scores of the log10 values of each dimension prior to PCA, to remove the effects of differences in the size ranges of the dimensions. Correlations between occipital-glabella length (B1) and width measurements (K, J4, J2) are consistently higher than for correlations among length measurements (Table 3). As deformation decreases the value of length/width correlations, this pattern suggests that morphological variation due to tectonic deformation accounts for a smaller proportion of the total variation than predeformational variation. Plots (Text-fig. 9) of biometric relationships indicate two morphotypes, characterized by differences in the relative lengths of the frontal area and of the palpebral lobes. The short-eyed, short frontal area morph is here referred to *Iranoleesia butes*, and the long-eyed, long frontal area morph to *Hundwarella memor*. Plots (Text-fig. 10) of the first through third principal components show a clear separation of specimens assigned to *H. memor* from those of *I. butes*. Plots of the first two principal components demonstrate a similar ontogenetic trend for both taxa (Text-fig. 10A), with small specimens of both taxa scoring low on PC1 and high on PC2. Specimens assigned to *I. butes* have markedly higher scores on PC2 than similar sized specimens belonging to *H. memor*. The two taxa are not discriminated on PC3 (Text-fig. 10B). All specimens from Kashmir, except those from Turkapur, are assigned to *H. memor*, as are specimens from Spiti Level 9, and some of Dr Sat Paul's Spiti specimens for which stratigraphical data are not available. All other specimens from Spiti, and those from Turkapur in Kashmir, are assigned to *I. butes*.

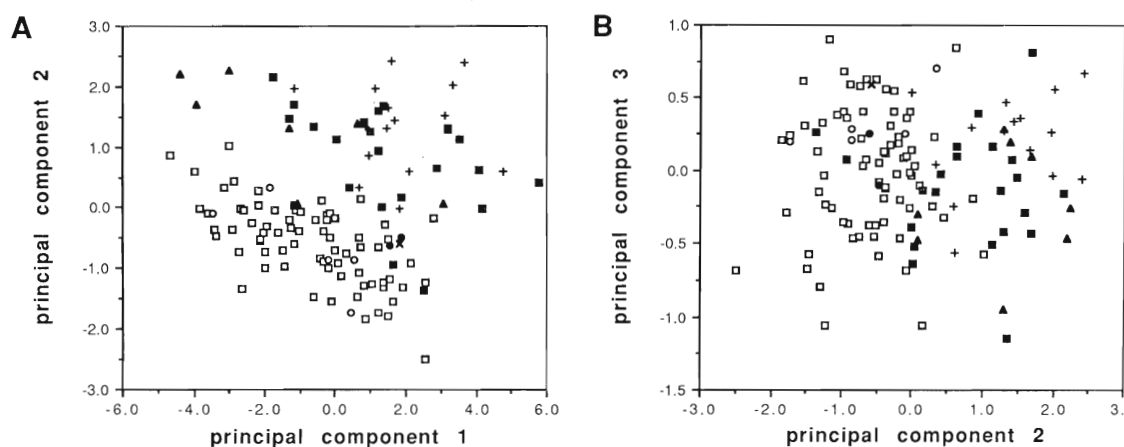
The first three principal components account for 97.5 per cent. of the variance within the sample. Principal component 1 (PC1), which accounts for 75.2 per cent. of the variance, has direction cosines of 0.452, 0.392, 0.226, 0.443, 0.438, 0.449 for variables B1, F1, C, K, J4, J2, respectively. Each variable correlates significantly (at $p < 0.01$) with scores on principal component 1, suggesting that PC1 reflects overall size, as is commonly the case in PCA. However, as both the value of the directional cosines are not all equal and the angle between PC1 and a hypothetical vector of



TEXT-FIG. 9. Bivariate plots of relationships between occipital-glabella length, B1 and frontal area length, F1 (A) and palpebral lobe length, C (B) in 132 proasaphiscid cranidia from localities in (1) Kashmir: Rainawari indicated by an open square; Wadapur indicated by an open circle; Sultanpur by a cross and Turkapur by a plus sign, and (2) Spiti: Horizon 9 of Hayden (1904) indicated by a solid circle; Horizon 13 by a solid triangle; and a collection from Spiti made by Dr Sat Paul indicated by a solid square. Kashmir localities are discussed in the text and in Shah *et al.* (1988).

isometry is 11.4° ($p < 0.05$), PC1 also contains an element of shape variation. This variation probably represents similar growth allometries in the palpebral lobes and frontal areas of both taxa.

Principal component 2 accounts for 19.3 per cent. of the variance and has direction cosines -0.005 , -0.420 , -0.786 , 0.250 , 0.312 , 0.216 for variables B1, F1, C, K, J4, J2, respectively. The very strong negative loadings of both frontal area and eye length suggest that these characters describe most of the shape variation within the sample. Variation in these characteristics discriminates *H. memor* and *I. butes*. Each width measurement (K, J4, J2) has significant correlation with PC2 (at $p < 0.05$). As they are all positive and of similar magnitude, and as two of the three length measures are strongly negative (and B1 is almost zero), tectonic deformation may be responsible for a portion of the variation accounted for by this axis (see Hughes and Jell 1992). However, this variation is overwhelmed by the original, pre-deformational variation within the sample. Principal component 3 accounts for 3.0 per cent. of the variance in the sample and has directional cosines -0.267 ,



TEXT-FIG. 10. Plot of the first three principal components in sample of 132 proasaphiscid cranidia from localities in Kashmir and Spiti. Spiti. Legend of points on these plots indicate localities as detailed in caption to Text-figure 11.

—0.687, 0.555, 0.320, 0.072, 0.204 for variables B1, F1, C, K, J4, J2, respectively. The markedly different pattern of loading of frontal area length and eye length may suggest that whilst these characters covary when describing the differences between *H. memor* and *I. butes*, within individual taxa they are negatively allometric with respect to one another (as has been documented in *H. memor* [Hughes and Jell, 1992]). Principal components 4–6 account for 2.5 per cent. of the total variance and have not been considered further.

Genus HUNDWARELLA Reed, 1934

1953 *Anomocaraspis* Ivshin, p. 125.

Type species. By original designation; *Hundwarella personata* Reed, 1934 (= *Ptychoparia (Conocephalites) memor* Reed, 1910), from the Middle Cambrian of Kashmir.

Emended diagnosis. Fixed cheeks narrow, thoracic pleural tips falcate, thorax of nine thoracic segments.

Remarks. Shah and Raina (1989) described several species of *Hundwarella* from the Cambrian of Kashmir and Spiti and considered *Iranoleesia* King, 1955 to be a junior synonym of *Hundwarella* following Kobayashi (1944b). Thus they included both of King's species (*pisiformis* and *falconi*) in *Hundwarella*. Fortey and Rushton (1976) chose to retain *Iranoleesia* until asaphiscid systematics are better known and referred *I. falconi* to *Anomocarella*. Our findings above suggest *Hundwarella* and *Iranoleesia* are separate genera. Shah and Raina (1989) referred both of King's (1937) species, and three of *Iranoleesia* described by Gupta and Suneja (1977b), to *Hundwarella*. Gupta and Suneja's (1977b) work is not considered as it has not been independently verified.

Reed's (1934) *Anomocare? perfunctum* appears to have a distinctive medial expansion of the anterior border with the most extreme development in the cranidia figured by Shah *et al.* (1995, pl. 1, figs 4, 10). However, a great deal of variation is evident in the anterior border following deformation and in each case deformation appears to have been at about 45° to the sagittal line, so we contend that this is the result of deformation. If it proves to be a biological distinction it would still be an extremely close relative, probably a subspecies of *H. memor*. Relationships between *I. butes* and *I. pisiformis* are discussed below.

Hundwarella memor (Reed, 1910)

Plate 19, figures 3–13; Plate 20, figures 1–12; Plate 21, figures 1–10; Plate 22, figures 1–2

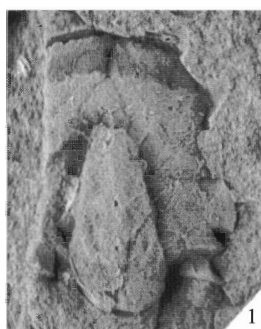
- v*1910 *Ptychoparia (Conocephalites) memor* Reed, p. 31, pl. 4, figs 4–5.
- v*.1934 *Anomocarella memor* (Reed); Kobayashi, p. 301, figs 9–13.
- v*.1934 *Anomocare hundwarensense* Reed, p. 13, pl. 1, fig. 2.
- v*.1934 *Anomocare suspectum* Reed, p. 16, pl. 1, fig. 19.

EXPLANATION OF PLATE 19

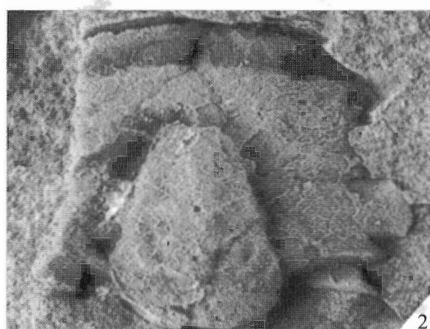
Figs 1–2. *Xingrenaspis dardapurensis* (Reed, 1934); GSI15619/3 (1909); 2.4 km south-east of Dardapur; cranidium; × 4. 2, computer-graphic restoration.

Figs 3–13. *Hundwarella memor* (Reed, 1910); cranidia. 3–4, horizon 9, Spiti. 3, GSI9845 (1910); × 6. 4, GSI9846 (1911), lectotype; × 6.5. 5–6, Parahio Valley, Spiti; 5, KUFSSPB5/6 (1912); × 6. 6, KUFSSPB5/31 (1913); × 6. 7–9, about 8 km west of Hundwara on road to Zachaldor; internal moulds. 7, YPM14334; × 12. 8, YPM32867; × 9. 9, YPM14336; × 7. 10, 12–13, from 2.8 km west-north-west of Wadapur. 10, GSI15625 (1914); × 8. 12, GSI15621 (1916); × 10. 13, GSI 15614 (1917); × 6. 11, GSI15615 (1915); Rainawari footpath; × 10.

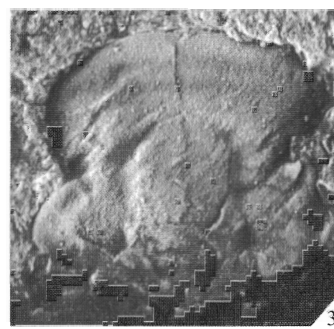
Specimens in figs 3–4 were illustrated by Reed 1910, pl. 4, figs 4–5, respectively. Specimens in figs 7–9 were illustrated by Kobayashi 1934, figs 11 and 13. Specimens in figs 10–13 were illustrated by Reed 1934, pl. 1, figs 13, 20, 19 and 11, respectively.



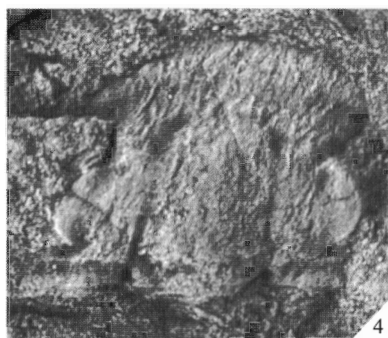
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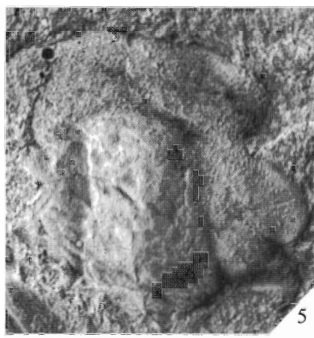
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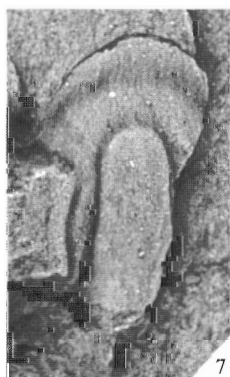
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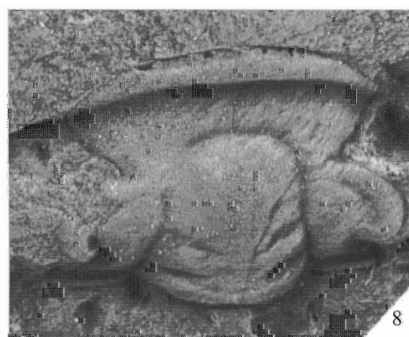
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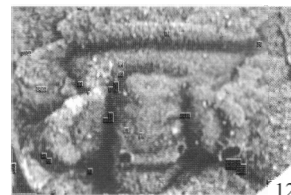
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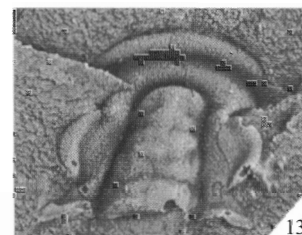
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- v*.1934 *Anomocare dimotum* Reed, p. 17, pl. 1, fig. 20.
 v*.1934 *Anomocare novatum* Reed, p. 15, pl. 2, fig. 4.
 v*.1934 *Anomocare? perfunctum* Reed, p. 14, pl. 1, figs 15–18.
 v*.1934 *Solenopleura lydekkeri* Reed, p. 20, pl. 1, fig. 14.
 v*.1934 *Hundwarella personata* Reed, p. 25, pl. 2, figs 5–6.
 v*.1934 *Saukia (Briscoia?) vagans* Reed, p. 23, pl. 1, fig. 11.
 v*.1934 *Prosaukia middlemissi* Reed, p. 27, pl. 1, fig. 13.
 v*.1937 *Asaphiscus suni* Resser and Endo, p. 182, pl. 37, figs 11–14.
 1955 *Psilaspis (Entorachis) memor* (Reed); Kobayashi, p. 94.
 1962 *Koptura hundwarensis* (Reed); Kobayashi, p. 110.
 1965 *Eymekops (?) suni* (Resser and Endo); Zhang, in Lu *et al.*, p. 306, pl. 55, figs 12–15.
 v.1987 *Proasaphiscus suni* (Resser and Endo); Zhang and Jell, p. 148, pl. 64, figs 3–8.
 1987 *Anomocarella (Entorachis) memor* (Reed); Kobayashi, p. 120, fig. 1.
 1992 *Hundwarella personata* (Reed); Hughes and Jell, figs 7–9.
 1995 *Anomocaraspis hundwarensis* (Reed); Shah *et al.*, p. 34, pl. 1, figs 2, 5.
 1995 *Anomocaraspis globosa* Shah *et al.*, p. 37, pl. 1, figs 4, 10.
 1995 *Anomocaraspis perfuncta* (Reed); Shah *et al.*, p. 36, pl. 1, figs 1, 3, 7, 11–12.
 1995 *Anomocaraspis kupwarensis* Shah *et al.*, p. 36, pl. 1, figs 6, 8–9.

Material. Lectotype (here selected) GSI9846 (Reed 1910, pl. 4, fig. 5), from Horizon 9, Spiti. Paralectotype GSI9845, from same locality. Other Indian material: YPM14322, 14328, 14330, 14334–14336, 32865, 32863, 32866–32868, from green ferruginous shales along road between Turkapur and the bend on the Talar River, c. 8 km west of Hundwara on road to Zachaldor (Reed's 1934 locality B-1). GSI15608–15612, Rainawari (Reed's 1934 localities B and B-1); GSI15613–15615, 15622, from 2.8 km west-north-west of Wadapur (Reed's 1934, locality E); GSI15623, from near Sultanpur (Reed's 1934, locality D); ANU10372/1–10372/21, from roadcut just past the Forest Rest House on the Talar River; ANU10397, from a small quarry on north side of road 1.6 km east of the Forest Rest House along the road to Hundwara; ANU10399, from just above a drain on east side of road, near Zachaldor Forest Rest House; KUFSSPB5/6, /31, from the Parahio Valley, Spiti, collected by Dr Sat Paul.

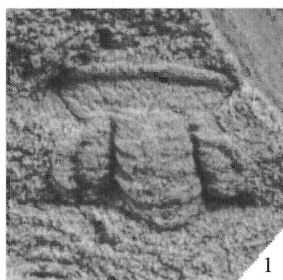
Diagnosis. Large palpebral lobes, frontal area c. 50 per cent. of glabellar length, more in larger specimens.

Description. Dorsal shield length to width ratio c. 1.5:1, subisopygous, thorax of nine segments, about half total length. Axis convex, tapering evenly posteriorly. Genal spine extending beyond fifth thoracic segment. Glabella widest at midlength of L1, with subparallel lateral margins anterior of S1, with rounded anterolateral corners and curved anterior margin. S1 crescentic, strongly curved, two-thirds of glabellar width, connecting with axial furrow, anterior part weaker than posterior; S2 transverse, one-half glabellar width, deepest distally, not confluent with axial furrow; S3 oblique inwards and forwards, deepest abaxially. Glabella lacks ornament. SO deepest abaxially, shallow in axial half. LO with transverse posterior margin. Axial furrow shallowing in front of glabella, with deep fossulae. Frontal area 25–35 per cent. of cranial length. Preglabellar field flat to declined, 60–75 per cent. of frontal area length. Anterior border furrow and border crescentic. Border inflated, posterior margin with five or more unevenly spaced pits developed along its width in some specimens. Preocular sutures diverging forward at approximately 35–45° to the sagittal line, then curving adaxially across

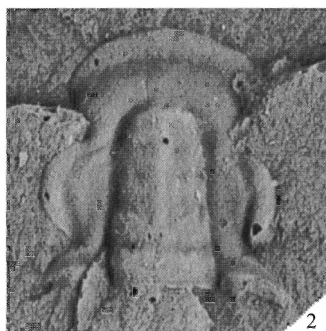
EXPLANATION OF PLATE 20

Figs 1–12. *Hundwarella memor* (Reed, 1910); cranidia. 1, ANU49476; 8 km west of Hundwara; $\times 10$. 2, GSI15613 (1918); 2.8 km west-north-west of Wadapur; $\times 6$. 3, GSI15623 (1919); near Sultanpur; $\times 6$. 4–8, 10–11, from Rainawari footpath. 4, GSI15618 (1920); $\times 6$. 5, GSI15610 (1921); $\times 5$. 6, GSI15611 (1922); $\times 6$. 7–8, GSI15612 (1923); $\times 6$. 8, computer-graphic restoration. 10–11, GSI15609 (1925); $\times 6$. 11, computer-graphic restoration. 9, 12, GSI15622 (1924); 2.8 km west-north-west of Wadapur; $\times 6$. 12, latex cast.

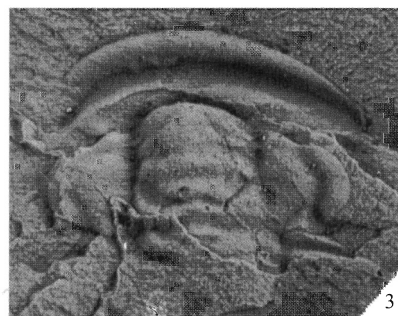
Specimens in figs 2–7 and 9–10 were illustrated by Reed 1934, pl. 2, figs 4, 6; pl. 1, figs 14, 16–18; pl. 2, fig. 5 and pl. 1, fig. 15, respectively.



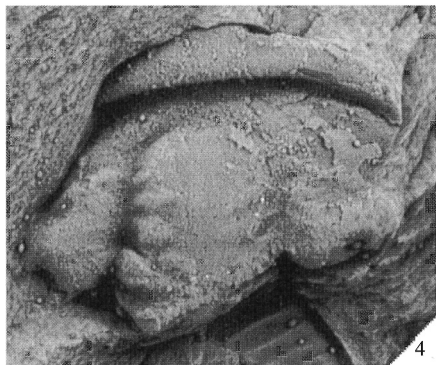
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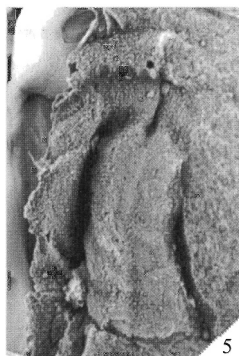
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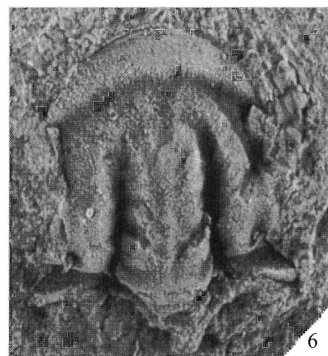
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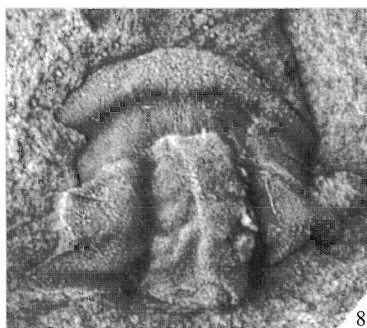
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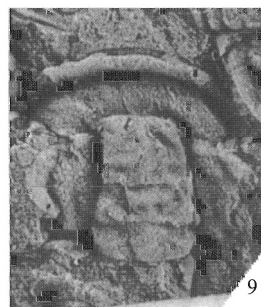
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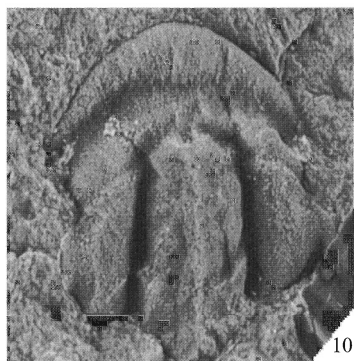
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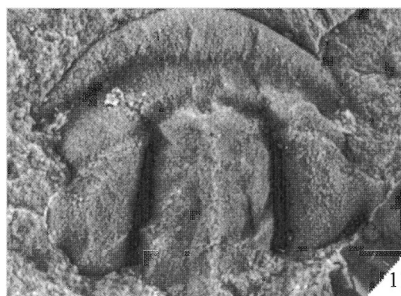
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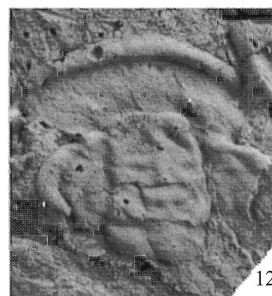
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border and extending along anterior margin of cephalon. Eye ridge confluent with axial furrow just posterior of anterolateral corner of glabella. Fixigena narrowest opposite L4. Palpebral lobe arcuate, 45–60 per cent. of occipital–glabellar length, relatively larger in small specimens. Palpebral furrow firmly incised. Palpebral lobe midlength opposite L2 midlength. Posterolateral border area short, equal to or less than width of LO. Posterior border transverse adaxially, oblique outwards distally. Posterior marginal furrow well impressed, confluent with axial furrow at midlength of LO. Librigena with arcuate lateral margin, convex border, well-impressed border and posterior marginal furrows confluent at base of genal spine. Genal spine of similar length to cranidium, narrow, tubular. Eye socle vertical. Doublure similar width to border. Rostral plate short, width unknown, with concave lateral margins. Hypostome natant, sub-rectangular, elongate. Median body oval, anterior lobe almost reaching anterior margin, posterior lobe crescentic. Median furrow complete, shallow adaxially. Maculae absent. Lateral border narrower than posterior border. Thoracic axis *c.* one-fifth of pleural width. Axial furrow well impressed. Anterior margin of each segment transverse for short distance from axial furrow to fulcral point, then curving sigmoidally to posterior. Articulating facet broad. Posterior margin sigmoidal in anterior segments, more smoothly curved in posterior segments. Pleural tip posteriorly directed, sharply pointed in medial segments, more rounded in anterior and posterior segments. Pleural bands of equal length, separated by long well-impressed sigmoidal pleural furrow. Doublure extending adaxially beneath pleural spines. Pygidium semicircular, wider than long. Margin entire. Axis convex, tapering evenly posteriorly, *c.* four-fifths of pygidial length and one-quarter of width. Axis of four or five rings plus terminus. Pleurae convex, crossed by four or five oblique pleural furrows. Border furrow distinct. Border convex, narrow, of uniform width. Doublure as wide as border.

Preservation. Material from the type locality shows wrinkling of the cuticle (Reed 1910). Wrinkling has been recorded in trilobites from elsewhere, such as poorly calcified olenellids (Harrington 1959), *Paradoxides* (Bergström and Levi-Setti 1978), and trilobites interpreted to represent post-moult individuals where full calcification had not been completed (Miller and Clarkson 1980; Whittington 1980; Speyer 1985). However, the ubiquitous wrinkling in Spiti material and its concordance with cleavage direction suggests that it is a result of tectonic deformation.

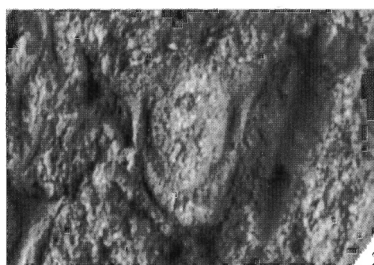
Preservation accounts for the differences that Reed (1934) and Shah *et al.* (1995) considered specifically important in the material here assigned to *Hundwarella memor*. Measurements of the same dimension on internal and external moulds show considerable variation. For example, the preglabellar field occupies 70 per cent. of the frontal area in the internal mould GSI15608, whereas in the external mould it occupies 64 per cent. (Pl. 21, figs 8–9). Furrows tend to be more strongly incised, and therefore better preserved, in external moulds. Where tectonic distortion has been parallel to the sagittal axis, glabellar furrows have commonly been obscured, whereas in specimens which experienced transverse compression furrows have been compressed and enhanced resulting in the ‘peculiar furrows’ (Reed 1934, p. 25) in *Hundwarella*. This is best exemplified where two cranidia are preserved at right angles to each other (Hughes and Jell 1992, fig. 7); in this figure the upper left cranidium in A would belong to Shah *et al.*’s (1995, pl. 1, fig. 1) *Anomocaraspis perfuncta* whereas the lower right cranidium would belong to their *A. hundwarensis* (Shah *et al.* 1995, pl. 1, fig. 2). Kobayashi (1934, fig. 11) showed the same differences in cranidial morphology through deformation of cranidia at right angles to each other. Although S1 is wide it was not originally continuous. Specimens of *H. memor* from Rainawari (Pl. 20, figs 4–7, 10) are elongated in the sagittal direction, which accentuates their relief and resulted in Reed’s recognition of *A.*?

EXPLANATION OF PLATE 21

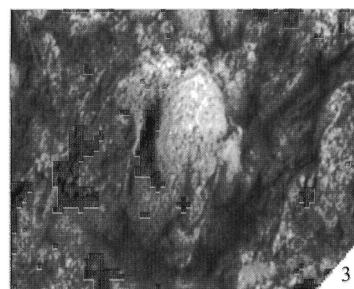
Figs 1–10. *Hundwarella memor* (Reed, 1910). 1–7, about 8 km west of Hundwara on road to Zachaldor. 1, YPM32868; librigena; $\times 10$. 2–3, hypostomes. 2, YPM32865; $\times 20$. 3, YPM32993; $\times 20$. 4, ANU49477; pygidium, latex cast; $\times 6$. 5, YPM14332 and YPM32866; pygidium and two articulated thoracic segments; $\times 7$. 6, YPM14328, pygidium; $\times 8$. 7, ANU49478; latex cast; $\times 6$. 8–10, Rainawari footpath. 8, GSI15608 (1926); latex cast; $\times 5$. 9–10, GSI15608 (1926); $\times 5$. 10, original illustration from Reed 1934. Specimens in figs 1–2 and 5–6 were illustrated by Kobayashi 1934, figs 13, 10, 12 and 9, respectively. The specimen in figs 9 and 10 was illustrated by Reed 1934, pl. 1, fig. 2.



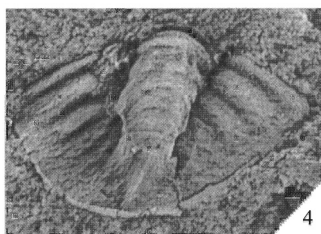
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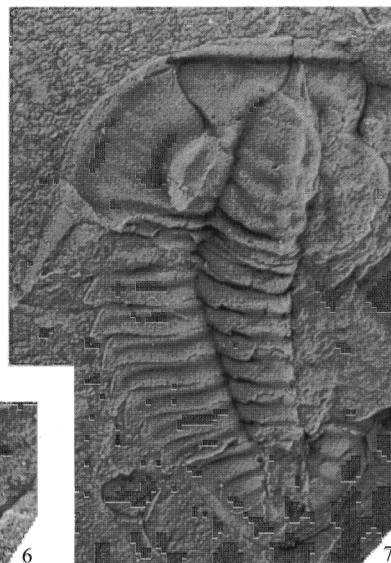
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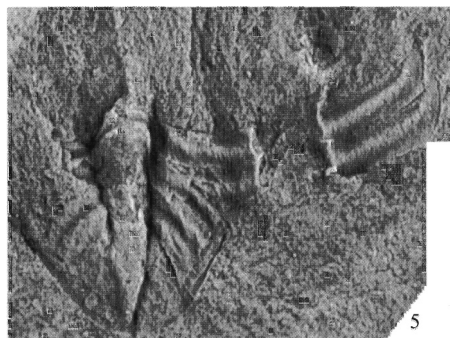
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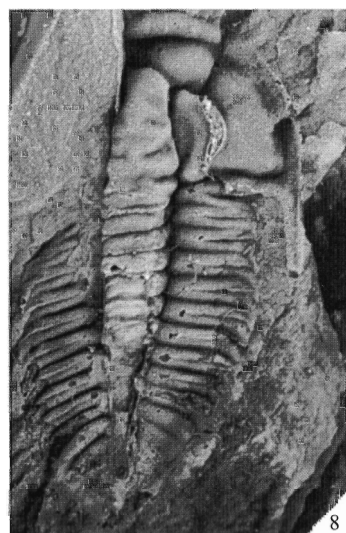
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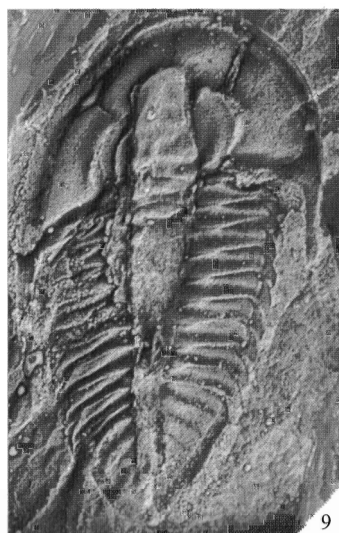
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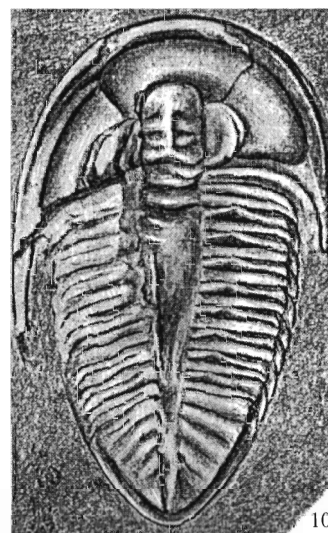
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perfunctum. Tectonic deformation of *H. memor* has been detailed elsewhere (Kobayashi 1967; Hughes and Jell 1992).

Ontogeny and intraspecific variation. Dorsal exoskeletons longer than 8 mm have nine thoracic segments and four or five segments in the pygidium and are almost certainly holaspides. A specimen 2.8 mm long has seven thoracic segments and six segments in the pygidium (Pl. 22, fig. 1). Eye length is negatively allometric with respect to glabellar length. In the smallest cranidia (late meraspid) the palpebral lobe is *c.* 65 per cent. of the occipital–glabellar length (Pl. 20, fig. 1). In large holaspides the palpebral lobe is *c.* 45–50 per cent. of the occipital–glabellar length. Wide scatter about this growth trend is the result of relatively inhomogeneous tectonic deformation, but may also reflect a flexible growth relationship. In contrast with the negative allometry of the eye, there is slight positive allometry of the frontal area (Hughes and Jell 1992), with the frontal area becoming proportionately longer with growth.

Remarks. Specimens assigned herein to *Hundwarella memor* were assigned to nine species from five genera by Reed (1910, 1934). Reed's identifications have frequently been questioned (Shah 1982; Jell 1986; Shah and Raina 1989) and his report of the uppermost Cambrian *Saukia* and *Prosaukia* in rocks also containing Middle Cambrian *Tonkinella* and *Bailiella* has long been a source of confusion. The new assignment removes this confusion, as *H. memor* is of medial Middle Cambrian age suggested by correlation using some co-occurring species with sections in other parts of the world.

Suneja (1977) described *Hundwarella fuchsi* from Zachaldor, on a single, incomplete specimen which closely resembles *H. memor* in all available features. Synonymy is suggested based on the illustrations.

Although the palpebral lobe is narrower and the pygidial doublure wider in *Proasaphiscus suni* (Resser and Endo, 1937) it is otherwise identical to *H. memor* and the Chinese species is here considered a junior synonym. *Proasaphiscus yabei* Resser and Endo, in Kobayashi, 1935, differs from *H. memor* only in its possession of eleven, rather than nine, thoracic segments and in its effaced posterior pleural furrows on the pygidium. Cranidia and pygidia attributed to *Szeaspis* closely resemble *H. memor*, and complete specimens of *S. iddingsi* (Walcott, 1911) also possess nine thoracic segments (Zhang and Jell 1987). *H. memor* differs from *S. iddingsi* in the length of the frontal area, and in the pygidial outline. It also lacks a faint plectrum which is characteristic of some *Szeaspis*, but is not preserved in *S. iddingsi*. Several of the cranidia assigned to *Anomocarella falconi* and *Abharella magnocula* by Wittke (1984) are very similar to cranidia of *H. memor*, but narrow pygidia and hypostomes with maculae distinguish the Iranian material.

Genus IRANOLEESIA King, 1955

*non*1862 *Irania* deFilippi, p. 380.

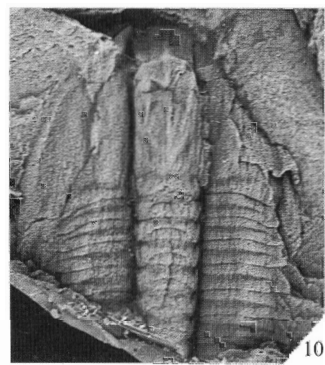
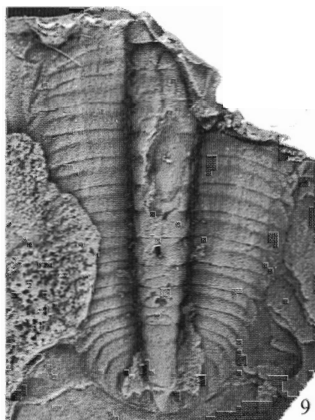
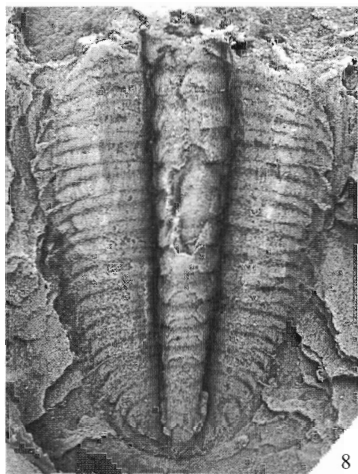
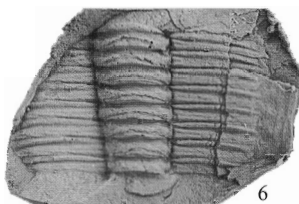
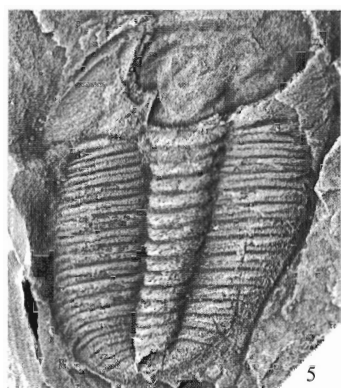
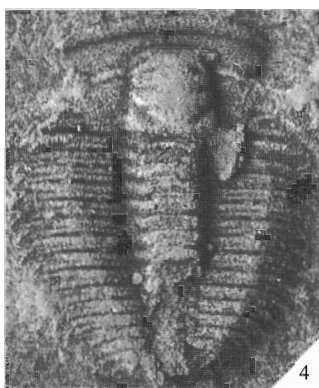
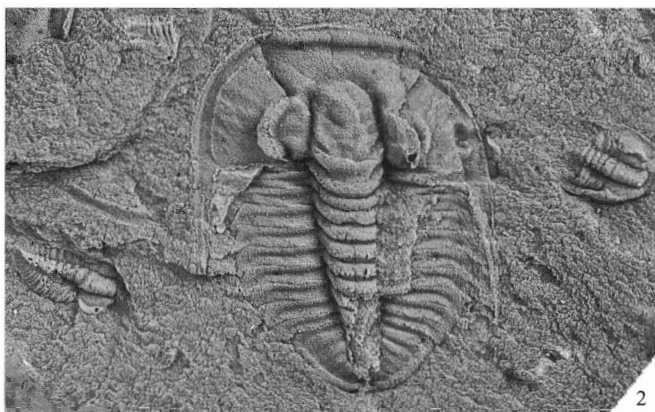
*non*1904 *Irania* Douville, p. 319.

EXPLANATION OF PLATE 22

Figs 1–2. *Hundwarella memor* (Reed, 1910); 8 km west of Hundwara. 1, ANU49479; dorsal view of internal mould; $\times 6$. 2, ANU49480; latex cast from external mould; $\times 6$.

Figs 3–10. *Iranoleesia butes* (Walcott, 1905); Horizon 13, Spiti; all dorsal views. 3, GSI9886 (1927); exoskeleton lacking librigenae; $\times 4.75$. 4, GSI9884 (1928); exoskeleton lacking librigenae; $\times 9$. 5, GSI9882 (1929); whole exoskeleton; $\times 4.5$. 6, GSI9879 (1930); latex cast from external mould of eight thoracic segments; $\times 2$. 7, GSI9880 (1931); partial pygidium; $\times 7$. 8–9, GSI9875 (1932); thorax and pygidium. 8, internal mould; $\times 5.5$. 9, latex cast from external mould; $\times 5$. 10, GSI9873 (1933); laterally compressed cephalon and anterior of thorax; $\times 5$.

Specimens in figs 3–10 were illustrated by Reed 1910, pl. 5, figs 18, 16, 14, 11–12, 7 and 5, respectively.



- 1937 *Irania* King, p. 12.
 1955 *Iranoleesia* King, p. 86.
 1968 *Michaspis* Egorova and Savitzky, p. 68.
 1980b *Heyelingella* Zhang and Yuan in Zhang *et al.*, p. 74.

Type species. By original designation; *Irania pisiformis* King, 1937, from the Middle Cambrian, north-west of Shiraz, Iran.

Emended diagnosis. Fixed cheeks relatively wide. Glabella slightly tapering, with truncate anterior margin and sagittal emargination (i.e. furrow apparently not impressed or extremely shallow for short section across sagittal line).

Iranoleesia butes (Walcott, 1905)

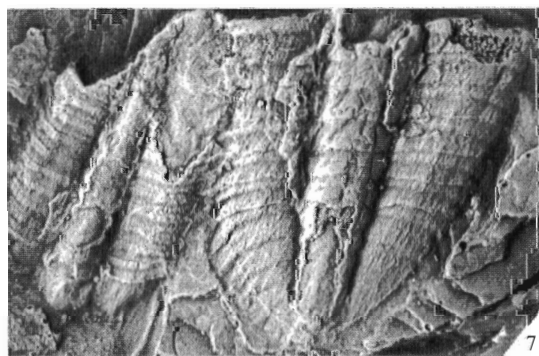
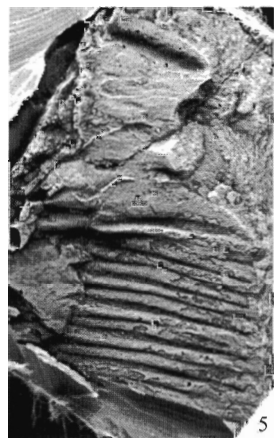
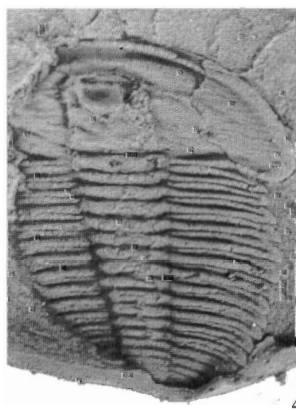
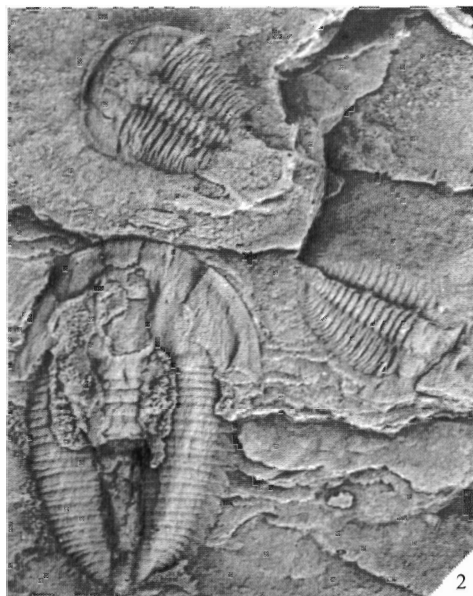
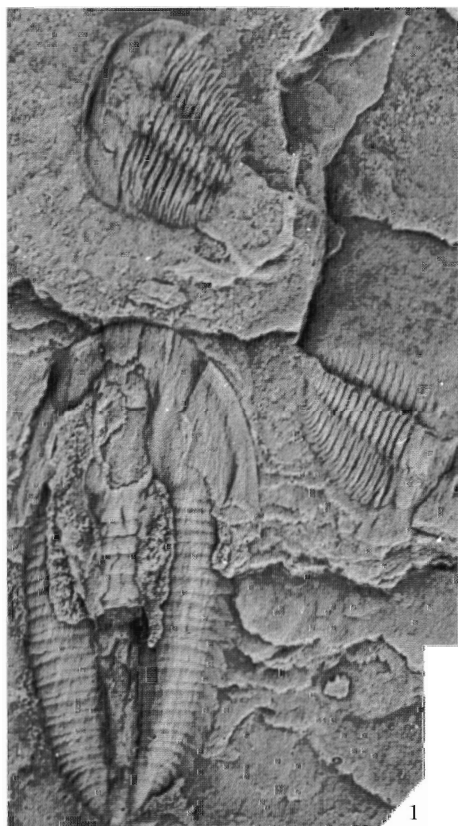
Plate 22, figures 3–10; Plate 23, figures 1–7; Plate 24, figures 1–8; Plate 25, figures 1–10

- v*1905 *Anomocare? butes* Walcott, p. 49.
 v*1905 *Anomocare tatian* Walcott, p. 53.
 v*1910 *Olenus? haimantensis* Reed, p. 40, pl. 5, figs 14–18.
 v*1910 *Dicellosephalus? interpres* Reed, p. 38, pl. 5, figs 9–13.
 v*1910 *Bathyriscus? stoliczkai* Reed, p. 37, pl. 5, figs 5–8.
 v*1913 *Anomocarella butes* (Walcott); Walcott, p. 199, pl. 19, figs 7, 7a–d.
 v*.1913 *Anomocarella tatian* (Walcott); Walcott, p. 206, pl. 21, figs 1, 1a [non fig. 1b].
 v*1913 *Ptychoparia (Emmrichella) eriopia* (Walcott); Walcott, p. 136, pl. 13, fig. 4a [non fig. 4].
 v*1913 *Anomocare latelimbatus* Dames; Walcott, p. 191, pl. 18, fig. 2e [non figs 2, 2a–d].
 1916 *Conokephalina termieri* Mansuy, p. 26, pl. 4, fig. 1a–d.
 1916 *Conokephalina tienfongensis* Mansuy, p. 27, pl. 4, fig. 2a–g, k [non figs 2h–i].
 v*1934 *Chuangia wadapurensis* Reed, p. 18, pl. 2, fig. 1.
 v*1934 *Chuangia? subangulata* Reed, p. 19, pl. 1, fig. 21.
 v*1934 *Chuangia? sp.* Reed, p. 19, pl. 2, fig. 2.
 v?1934 *Changshania? nupera* Reed, p. 22, pl. 2, fig. 15.
 v*.1937 *Proasaphiscus affluens* Resser and Endo, p. 265, pl. 48, figs 1–13.
 1942 *Psilaspis butes* (Walcott); Resser, p. 47.
 1942 *Psilaspis tatian* (Walcott); Resser, p. 47.
 1944b *Manchuriella (Hundwarella) termieri* (Mansuy); Kobayashi, p. 135.
 1944b *Manchuriella (Hundwarella) tienfongensis* (Mansuy); Kobayashi, p. 135.
 1962 *Hundwarella termieri* (Mansuy); Kobayashi, p. 85.
 1962 *Hundwarella tienfongensis* (Mansuy); Kobayashi, p. 85.
 1965 *Proasaphiscus butes* (Walcott); Zhang, in Lu *et al.* p. 285, pl. 49, figs 17–18.
 1965 *Proasaphiscus affluens* (Walcott); Zhang, in Lu *et al.* p. 285, pl. 49, figs 12–16.
 1967 *Hundwarella termieri* (Mansuy); Kobayashi, p. 469.
 1967 *Olenus(?) haimantensis* (Reed); Kobayashi, p. 487.
 1967 *Bathyriscus(?) stoliczkai* (Reed); Kobayashi, p. 487.
 1967 *Dicellosephalus(?) interpres*; Kobayashi, p. 487.
 1968 *Michaspis librata* Egorova and Savitzky, p. 68, pl. 10, figs 1–2.
 1969 *Michaspis librata* Egorova and Savitzky, p. 257, pl. 57, figs 1–7; pl. 58, figs 1–5.
 1980b *Proasaphiscus quadratus* Wu and Lin, in Zhang *et al.*, p. 68, pl. 7, figs 1–3.

EXPLANATION OF PLATE 23

Figs 1–7. *Iranoleesia butes* (Walcott, 1905); Horizon 13. 1, GSI9876 (1934–1936); three dorsal exoskeletons; × 6. 2, computer graphic restoration. 3, GSI9878 (1937); cranidium, latex cast from external mould; × 4. 4, GSI9883 (1938); latex cast from external mould of dorsal exoskeleton; × 6. 5, GSI9881 (1939); right side of cranidium and anterior thorax; × 3.5. 6, GSI9877 (1940); cranidium; × 5.5. 7, GSI9874 (1941); posterior of thorax and pygidium; × 5.

The specimens in figs 1–7 were illustrated by Reed 1910, pl. 5, figs 8, 10, 15, 13, 9 and 6, respectively.



- 1980b *Heyelingella shuiyuensis* Zhang and Yuan, in Zhang *et al.*, p. 74, pl. 8, fig. 6.
 1980b *Heyelingella zhongtiaoshanensis* Zhang and Yuan, in Zhang *et al.*, p. 75, pl. 8, fig. 7.
 1985 *Proasaphiscus yangchengensis* Zhang and Wang, p. 415, pl. 124, fig. 9.
 1985 *Proasaphiscus hejinensis* Zhang and Wang, p. 417, pl. 124, fig. 10.
 1985 *Yujinia magna* Zhang and Wang, p. 422, pl. 125, fig. 12.
 1985 *Yujinia jiaokouensis* Zhang and Wang, p. 423, pl. 125, fig. 13.
 1985 *Honania zhongyangensis* Zhang and Wang, p. 439, pl. 129, fig. 12.
 1985 *Honania huoshanensis* Zhang and Wang, p. 440, pl. 129, fig. 13.
 1987 *Hundwarella haimantensis* (Reed); Kobayashi, p. 119.
 1987 *Proasaphiscus butes* (Walcott); Zhang and Jell, p. 143, pl. 39, fig. 12; pl. 55, fig. 6; pl. 56, figs 4–8; pl. 57, figs 1–13; pl. 58, figs 1–4.
 v*.1988 *Hundwarella transversa* Shah, Sharma, Parcha and Raina, p. 49, pl. 1, figs a–b, o–p.
 v*.1988 *Hundwarella convexa* Shah, Sharma, Parcha and Raina, p. 50, pl. 1, figs c–g, k, n.
 v*.1988 *Hundwarella interpres* (Reed); Shah, Sharma, Parcha and Raina, p. 51, pl. 1, figs j–k, q–s, v.
 v*.1988 *Hundwarella rushtoni* Shah, Sharma, Parcha and Raina, p. 53, pl. 1, figs l–m, t–u.
 v1991 *Olenus haimantensis* (Reed); Shah *et al.*, p. 94, pl. 2, figs a–b, e, h, p.
 v1991 *Spitella barachuensis* Shah, Parcha and Raina, p. 97, pl. 2, fig. v [non fig. c].
 v1991 *Tsinania* sp. Shah *et al.*, p. 101, pl. 2, figs f, s–t.
 v?1991 *Blountia subangulata* Shah, Parcha and Raina, p. 98, pl. 2, figs g, j–k, o.

Material. Lectotype, USNM58168 (Walcott 1913, pl. 19, fig. 7); designated Zhang and Jell (1987); from Beishan, 6.2 km south of Liaoyang, Liaoning; *Bailiella-Lioparia* Zone, Hsuehuang Formation. Himalayan material GSI9873–9886, from Horizon 13, Spiti (Reed 1910); KUF570–601, from Thango section, Spiti. ANU 10372.22, from Rainawari (Reed's locality B or B-1); GSI15616 (Reed 1934, pl. 2, fig. 1), GSI15617 (Reed 1934, pl. 1, fig. 21), GSI15620, from a very fine grained sandstone, 2.8 km west-north-west of Wadapur (Reed's locality E), Hundwara Teshil, Kashmir; KUF 550–555, 557–569, from Turkapur, Hundwara Teshil; ANU48481–49483, from just past the Zachaldor Forest Rest House on the Talar River, 8 km west of Hundwara; KUF644–646, from the Parahio section, Spiti.

Diagnosis. Thorax of 12 segments. Frontal area *c.* 25 per cent. of glabellar length, less in larger specimens, lacking perforation of the exoskeleton. Spectrum absent.

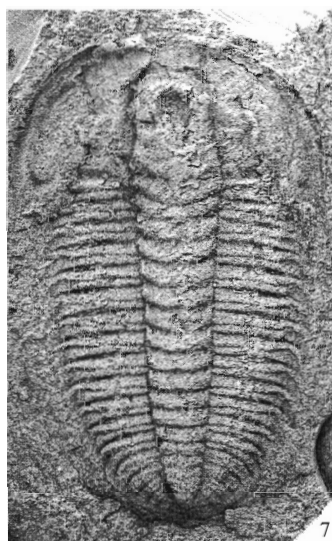
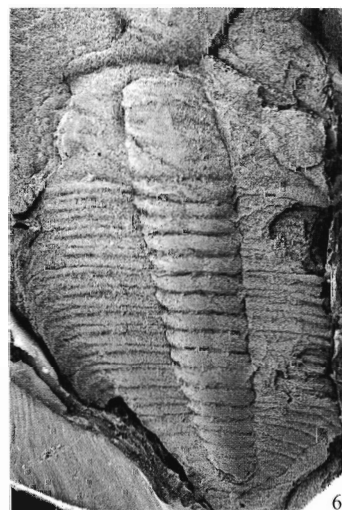
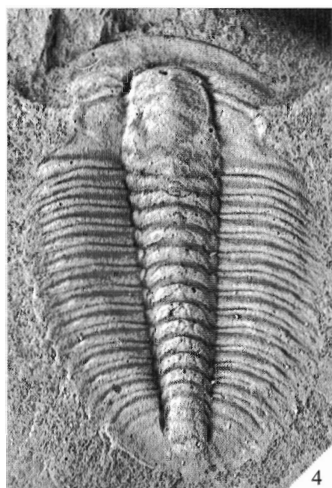
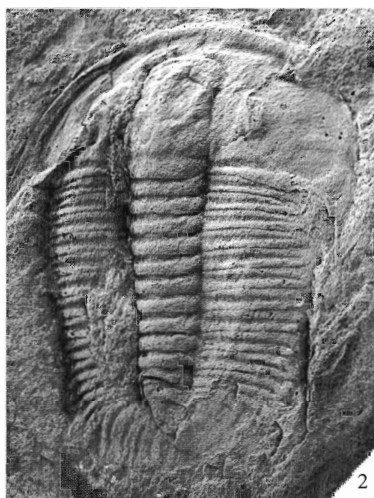
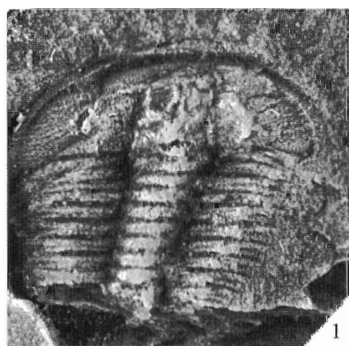
Description. This species was described in detail by Zhang and Jell (1987). Additional characters observed in the Indian material are listed below. Dorsal shield length to width ratio about 1.5:1, subisopygous, thorax with 12 segments in holaspide, about one-half of total length. Genal spine extends beyond fourth thoracic segment. Hypostome sub-rectangular, elongate. Thoracic axial rings transverse, about one-quarter of pleural width. Pleural anterior margin transverse from axial furrow, curving posteriorly from fulcrum. Posterior margin smoothly curved. Pleural tip posterolaterally directed, sharply pointed in medial segments, more rounded in anterior and posterior segments. Pleurae equally divided. Pleural furrow firmly incised, broad near axis. Doublure narrow.

Preservation. Variation in relative proportions of cranidia of *I. butes* is consistent with the range of tectonic deformation seen in *H. memor* (Hughes and Jell 1992). Such variation has misled some

EXPLANATION OF PLATE 24

Figs 1–8. *Iranoleesia butes* (Walcott, 1905). 1, GSI9885 (1942); Horizon 13, Spiti; cephalon and anterior thorax; $\times 10$. 2, KUFH3 (1943); Turkapur, Hundwara Tehsil; dorsal exoskeleton; $\times 3.75$. 3–4, 6, dorsal exoskeletons lacking librigenae. 3, KUF571 (1944); Thango section, Spiti; $\times 2.5$. 4, KUF570/75 (1945); Turkapur, Hundwara Tehsil; latex cast from external mould; $\times 4$. 6, KUF590 (1947); Spiti; $\times 3$. 5, KUF570 (1946); Thango section, Spiti; cranidium and anterior thorax; $\times 3.5$. 7, KUFSPA61 (1948); dorsal exoskeleton; Spiti; $\times 3.5$. 8, GSI 9873 (1949); latex cast from external mould of cranidium and cephalon and anterior thorax; $\times 3.5$.

The specimen in fig. 1 was illustrated by Reed 1910, pl. 5, fig. 17. Specimens in figs 3, 5 and 6, were figured by Shah *et al.* 1988, pl. 1, figs r, j and m, respectively.



workers (e.g. Shah *et al.* 1988) into recognizing several species. The 'triangular tract' of S1, which supposedly distinguishes Shah *et al.*'s (1988) *H. convexa* and *H. transversa* from *H. interpres*, is caused by compressional furrow enhancement in sagittally compressed specimens, just as in *H. memor* (Hughes and Jell 1992).

Ontogeny and intraspecific variation. No pre-holaspides are known. There is a progressive reduction in the relative length of the eye and of the frontal area with growth. The relatively large eye in the holotype is due to the small size of this specimen, as it lies on the same ontogenetic trajectory as much larger specimens possessing smaller eyes.

Remarks. Shale specimens are rarely as well preserved as those from limestones. Tectonic deformation may obscure critical features and, although deformation can be removed using the methods we have employed, there is inevitably some information that has been permanently destroyed. In suggesting that the Indian material is conspecific with a Chinese species from limestone we have determined that material is similar in all characters. It is remotely possible that there is more than a single species among the Indian material we assign to *I. butes*, but we doubt that further analysis could provide a firm basis for it.

Shah *et al.* (1988) described *H. kingi* from Khanpura in their 'Bolaspidella' Zone. It is preserved in blue/green shales of different induration to those from Wadapur, Turkapur and Zachaldor. The fossils from Khanpura have preserved more of their original relief. The breadth of the fixigenae, which appear slightly inflated, and the short posterolateral border area distinguish this species from *I. butes*. It is assigned elsewhere (see above) to *Xingrenaspis dardapurensis*.

Shah *et al.* (1988) and Shah and Raina (1989) presented an evolutionary scenario in which *H. memor* formed the base of a species lineage culminating in *H. interpres* and *H. rushtoni* in Spiti (both assigned to *I. butes*). In Spiti the first appearance of *H. memor* is stratigraphically below that of *I. butes*. This relationship may be true in Kashmir, but structural complexity and poor exposure make determination of stratigraphical relationships difficult in that region. Our analysis suggests that *Iranoleesia* is more primitive than *Hundwarella*. *I. butes* occurs stratigraphically below *H. memor* in China (Zhang and Jell 1987), casting further doubt on the significance of stratigraphical relationships within the Himalaya when assessing phylogeny.

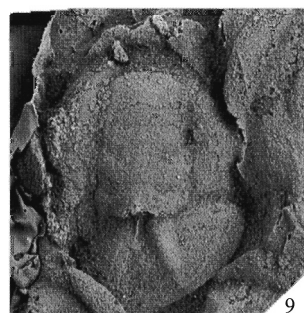
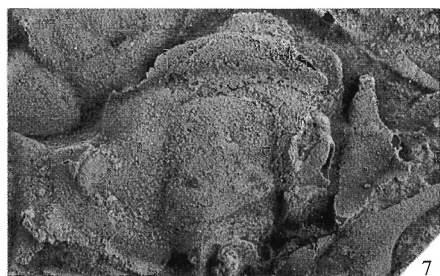
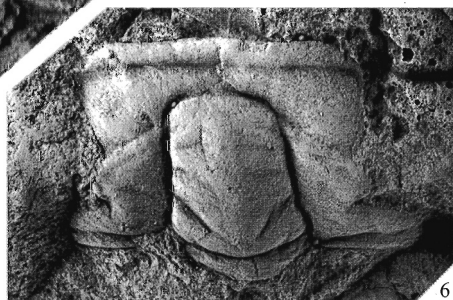
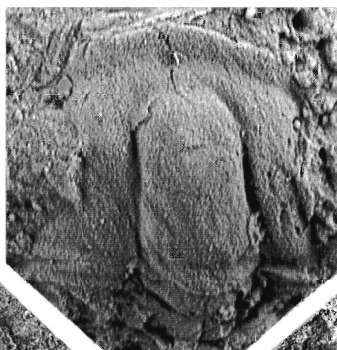
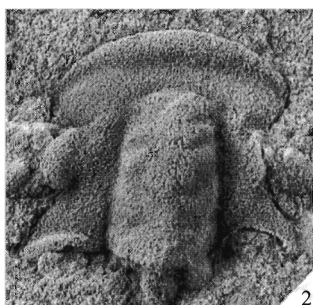
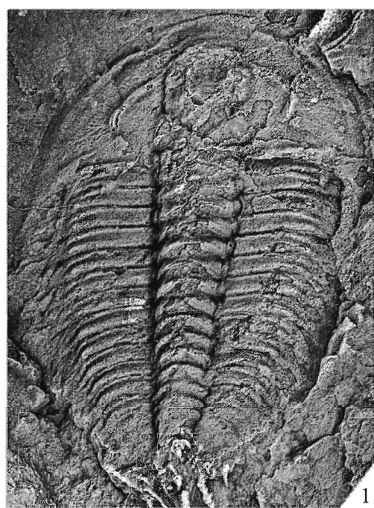
Our concept of *Iranoleesia* includes all specimens considered indicative of Late Cambrian strata by Reed (1910, 1934), namely *Olenus*, *Dikelocephalus*, *Saukia* and *Prosaukia* and by Shah *et al.* (1991), namely *Olenus haimantensis*, *Spitella barachuensis* [excluding the holotype], *Hundwarella interpres*, *H. rushtoni* and *Tsinania* sp. Thus, we consider the fossiliferous sections examined by Hayden (1904) in Spiti to be of medial Mid Cambrian age.

The Kashmiri material of Gupta and Suneja (1977b) and Gupta and Shaw (1983) attributed to *Iranoleesia* lies within the range of variation shown by *I. butes* and its localities are consistent with independent reports of the occurrence of this species. However, these records should be viewed with caution (Talent *et al.* 1990). *Anomocare guptai* (Suneja, 1977) from Zachaldor (illustration

EXPLANATION OF PLATE 25

Figs. 1–11. *Iranoleesia butes* (Walcott, 1905). 1–3, latex casts from external moulds; from road cut just past the Forest Rest House on the Talar River, 8 km west of Hundwara. 1, ANU49481; articulated exoskeleton; $\times 2$. 2, ANU49482; cranium; $\times 6$. 3, ANU49483; articulated exoskeleton; $\times 3$. 4–10, cranidia. 4, KUF644 (1950); Horizon 13, Spiti; $\times 6$. 5, KUF562 (1966); Turkapur, Kashmir; $\times 5.5$. 6, KUF555 (1967); Horizon 13, Spiti; $\times 3.5$. 7–11 from 2.8 km west-north-west of Wadapur; all latex casts from external moulds on same piece of rock. 7, GSI15616 (1968); $\times 4$. 8, GSI15617a (1969); $\times 4$. 9, GSI15617b (1970); $\times 4$. 10, GSI15620 (1971); $\times 5$. 11, GSI15617c (1972); pygidium; $\times 4$.

Specimens in figs 7–8, 10–11 were illustrated by Reed 1934, pl. 2, fig. 1; pl. 1, fig. 21 and pl. 2, figs 15 and 2, respectively.



retouched) closely resembles *I. butes*, but is known only from Suneja's original specimen which we have not seen. It is almost certainly a junior synonym.

Iranoleesia pisiformis (King, 1937) is very similar to *I. butes*. The holotype is poorly preserved (Fortey and Rushton 1976, pl. 9, fig. 6) and does not show the sagittal embayment in the front of the glabella. This feature is present on external surfaces of other Iranian specimens of *I. pisiformis* (Wittke 1984, pl. 1, figs 1, 3) and on the internal moulds of at least some (Fortey and Rushton 1976, pl. 9, fig. 8; Wittke 1984, pl. 1, fig. 7). In addition, the exoskeleton of *I. pisiformis* appears to have been densely punctate. Punctuation is evident in other taxa from Spiti (Reed 1910) but not in *I. butes*. We consider that the punctate surface separates the species. This is supported by the midlength of the eye lying opposite L1 in *I. pisiformis*.

ZANSKAR VALLEY, LADAKH

Most of the material described in this section comes from the late Mid Cambrian Kurgiakh Formation on the north bank of the Surichun la nulla (SLN), about 4 km north-east of Kurgiakh.

Order AGNOSTIDA Salter, 1864a
 Superfamily AGNOSTOIDEA McCoy, 1849
 Family AGNOSTIDAE McCoy, 1849
 Subfamily PTYCHAGNOSTINAE Kobayashi, 1939
 Genus GONIAGNOSTUS (ALLOBODOCHUS) Öpik, 1979

Type species. By original designation; *Ptychagnostus* (*Goniagnostus*) *fumicola* Öpik, 1961, from the upper Middle Cambrian of western Queensland.

Goniagnostus (*Allobodochus*) *aculeatus* (Angelin, 1851)

Plate 28, figures 3–4

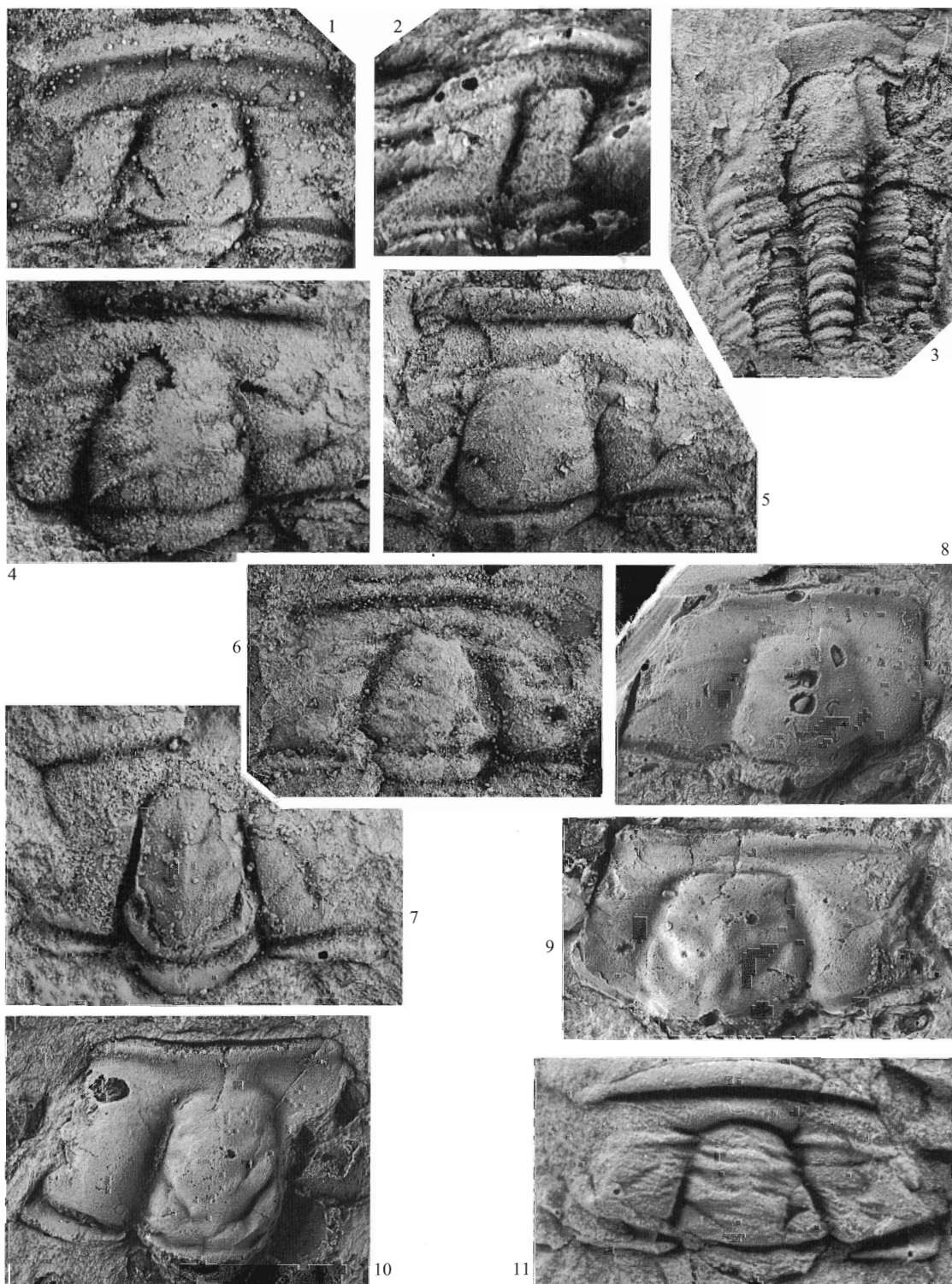
Material. MPUM7215–7216, from SLN.

Remarks. These two cranidia are distorted differently, one (Pl. 28, fig. 3) is barely distorted, perhaps slightly shortened, whereas the other is considerably narrowed. However, the salient features of *aculeatus* are evident, namely, the coarse pustulose ornament over axis and cheeks, long narrow basal lobes, well-impressed transverse furrow defining the large bell-shaped anterior lobe, and radial scrobicules. Pustules on the glabella separate it from *G. fumicola* and the lack of posterolateral spines distinguish it from *G. spiniger* (Westergård, 1931) (see Laurie 1989).

EXPLANATION OF PLATE 26

Figs. 1–11. *Xingrenaspis dardapurensis* (Reed, 1934). 1–7, from limonitized shale near Karihul, Liddar Valley, Kashmir. 1, GSI19650 (1973); $\times 6$. 2, GSI19651 (1974); $\times 10$. 3, GSI19657 (1975); damaged cranidium and anterior ten segments of thorax; $\times 7$. 4, GSI 19655b (1976); damaged cranidium; $\times 8$. 5, GSI19655a (1977); damaged cranidium; $\times 7$. 6, GSI19656 (1978); damaged cranidium; $\times 5$. 7, GSI19654 (1979); $\times 8$. 8–10, Khanpura, Kashmir; cranidia. 8, KUF549 (1980); $\times 4$ –5. 9, KUF546 (1981); $\times 3$ –7.5. 10, KUF547 (1982); $\times 4$. 11, KUF629 (1983); Horizon 13, Spiti; cranidium; $\times 13$.

All specimens are epoxy replicas of internal moulds except figs 3–5 which are latex casts from external moulds. Specimens in figs 1–3, 5–7 were figured by Kumar and Singh, 1983, figs 2–3, 9, 7–8 and 6, respectively. Specimens in figs 9–10 were figured by Shah *et al.* 1988, pl. 1, figs i and h. The specimen in fig. 11 was figured by Shah *et al.* 1991, pl. 2, fig. c.



Goniagnostus (Allobodochus) spiniger (Westergård, 1931)

Plate 28, figures 1–2

Material. CMCP1550, from SLN and MPUM7214, from the top of the underlying late Mid Cambrian Karsha Formation at the same locality.

Remarks. The one poorly preserved cranidial internal mould is laterally compressed, has scrobicules on the cheek in typical arrangement (but apparently without the long arcuate scrobicule at the glabellar anterior) and shows the general proportions of the glabellar lobes and posterior node, but most importantly it shows long strong spines on the posterior border. Although slight tectonic crinkling has concealed the pygidial pleural ornament almost everywhere, the most anterior pleural area still shows the fine pustulose coalescing ornament which characterizes *G. (A.) spiniger* (Laurie 1989). Although the bases of the posterior marginal spines are not evident, the tip of the right marginal spine is preserved and shows it to be quite long as in *G. (A.) spiniger*. The anterior pygidial axial ring is divided into three as in *G. (A.) spiniger* but its central lobe is smaller than in illustrated specimens of *G. (A.) spiniger*; however this could not be considered a species discriminator. These features, particularly the spines on posterior cephalic and pygidial borders, are indicative of *G. (A.) spiniger* despite their poor preservation.

Genus LEJOPYGE Corda, in Hawle and Corda, 1847

Type species. *Battus laevigatus* Dalman, 1828.

Lejopyge armata (Linnarsson, 1869)

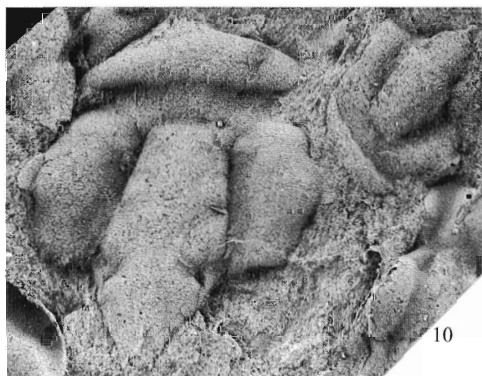
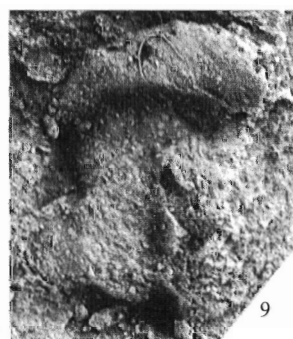
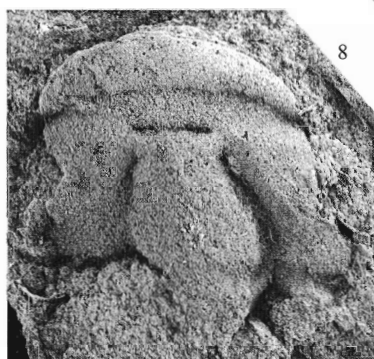
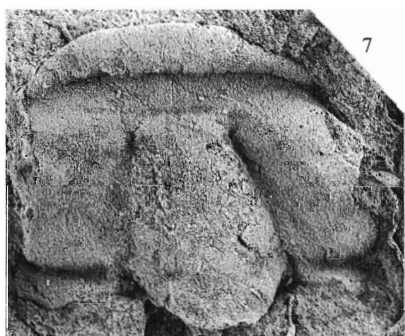
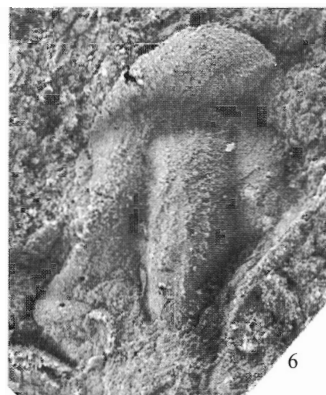
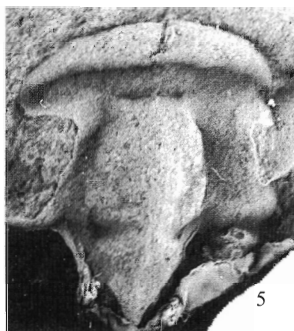
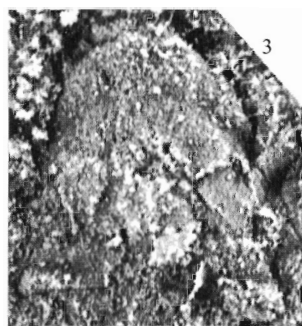
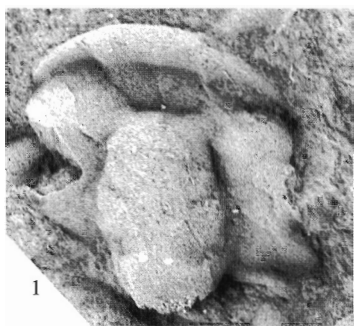
Plate 28, figures 3–13; Plate 29, figures 7–15

Material. CMCP1551–1555 and MPUM7217–7220, 7225–7233, from SLN.

Remarks. The effaced shields (axial furrows usually evident adjacent to thorax on both shields, disappearing away from thorax; more obvious on internal than external surfaces), lack of a cephalic border, spines on posterior cephalic and pygidial borders, constriction of acrolobes adjacent to pygidial marginal spines and well-developed pygidial border confirm the specific identity of this widely variable (both in tectonic distortion and, presumably, in original morphology) material. It should be noted that of all the effaced agnostoid shields in the collection, including many that are not illustrated, none could be shown to lack definitely the border spines or, in the case of pygidia, the constrictions of the acrolobe, so they are all assigned to *L. armata* or considered indeterminate. Whittington's (1986, pl. 19, figs 1–3; pl. 20, fig. 1) four illustrated cranidia are considered indeterminate as the posterior border is not well exposed in any of them. Of Whittington's illustrated pygidia (1986, pl. 19, figs 1–2) the border of the first is not preserved, but there is a suggestion of a constriction of the acrolobe on the right side, and on the second the constriction of the acrolobe is well displayed on the left side even though the border spine is not evident; therefore we assign these two complete specimens to *L. armata*, following the criteria discussed by Laurie (1989).

EXPLANATION OF PLATE 27

Figs 1–2, 4–5, 7–8, 10–11. *Shahaspis himalayensis* (Shah and Sudan, 1982); cranidia, latex casts from external moulds; Trahagam Formation, Magam, Kashmir. 1, KUF495a (1984); $\times 5.75$. 2, ANU49484; $\times 12$. 4, KUF495b (1985); $\times 4.5$. 5, KUF495c (1986); $\times 6$. 7, KUF495e (1987); $\times 3.75$. 8, KUF495f (1988); $\times 5.25$. 10, KUF495d (1989, 1990); $\times 4$. 11, KUF495g (1991, 1992); $\times 4$.
Figs. 3, 6, 9. *Latilorenzella* sp.; cranidia; Trahagam Formation, Magam, Kashmir. 3, 6, latex casts from external moulds. 3, ANU49485. 6, ANU49486. 9, ANU49487, internal mould. All $\times 10$.



Family SPINAGNOSTIDAE Howell, 1935
 Subfamily SPINAGNOSTINAE Howell, 1935
 Genus HYPAGNOSTUS Jaekel, 1909

Type species. Agnostus parvifrons Linnarsson, 1869.

Hypagnostus correctus Öpik, 1967

Plate 29, figures 1–6

Material. CMCP1556–1557, from steep slopes on the Kurgiah River about 1 km east of Kuru and MPUM7221–7224, from SLN; uppermost Middle Cambrian.

Remarks. This species is identified by its short glabella, long unsegmented pygidial axis with median node at high point and wide pygidial border of more or less uniform width. Öpik (1967) recorded it from his Middle to Upper Cambrian Passage, *Erediaspis eretes* and *Cyclagnostus quasivespa* Zones and these are now considered latest Mid Cambrian (Daily and Jago 1975). In China, *H. correctus* and a number of closely related if not synonymous species have been reported from latest Mid Cambrian sequences in many areas including Sichuan (Yang 1993), Zhejiang (Lu and Lin 1989), Hunan and Guizhou (Yang 1978). The record from Kazakhstan (Ergaliev 1980, pl. 4, fig. 13) has a pygidial axis occupying only half or a little more of the pygidial length; it is referred to *H. correctus minor* Lu and Lin, 1989.

Family DIPLAGNOSTIDAE Whitehouse, 1936
 Genus DIPLAGNOSTUS Jaekel, 1909

Type species. Agnostus planicauda Angelin, 1851, from the Middle Cambrian of Sweden.

Diplagnostus planicauda (Angelin, 1851)

Plate 30, figures 8–13

Material. CMCP1560–1562 and MPUM7239, 7241, from SLN; MPUM7240, from the top of the Karsha Formation, at the same locality.

Remarks. Whittington (1986) compared this taxon to *D. humilis* (Whitehouse, 1936) from western Queensland, apparently following the concept of Öpik (1961), who did not examine Whitehouse's collections. Appraisal of Whitehouse's material, which will be the subject of another paper,

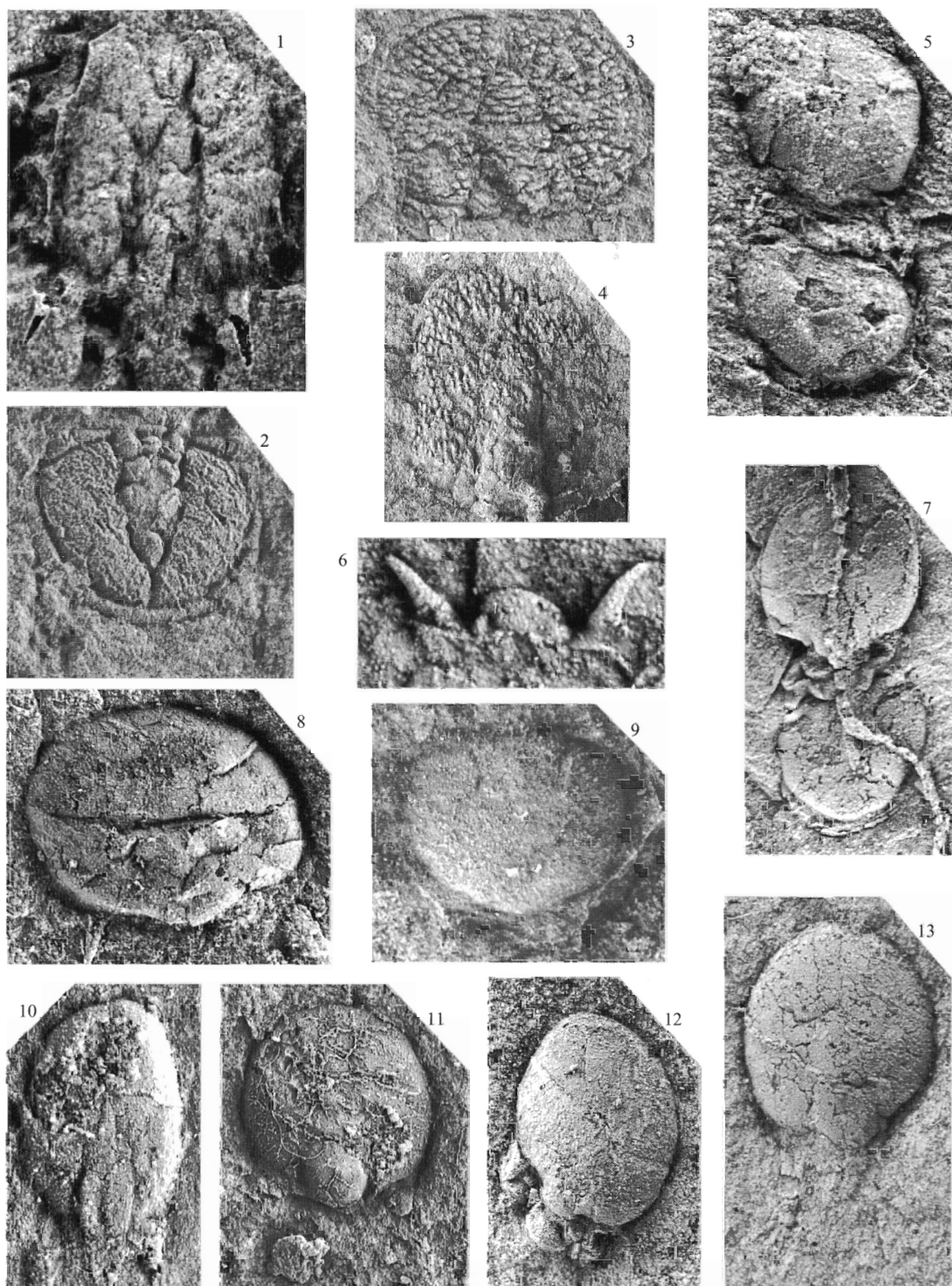
EXPLANATION OF PLATE 28

Figs 1–2. *Goniagnostus (Allobodochus) spiniger* (Westergård, 1931). 1, MPUM7214; cephalon; × 10. 2, CMCP1550; pygidium; × 10.

Figs 3–4. *Goniagnostus (Allobodochus) aculeatus* (Angelin, 1851); cranidia. 3, MPUM7215; × 10. 4, MPUM7216; × 7.

Figs 5–13. *Lejopyge armata* (Linnarsson, 1869). 5, CMCP1551; dorsal exoskeleton; × 10. 6, MPUM7217; anterior view of thoracic segment showing spines on pleurae; × 20. 7, MPUM7218; dorsal exoskeleton; × 10. 8, MPUM7219; cephalon; × 8. 9, CMCP1552; cephalon; × 10. 10, CMCP1553; cephalon; × 10. 11, CMCP1554; cephalon; × 8. 12, MPUM7220; cephalon and thoracic segment; × 10. 13, CMCP1555; cephalon; × 10.

All are dorsal views of latex casts from external moulds except figs 1–2, 5, 9 and 11, which are internal moulds; all specimens from SLN, Zanskar.



JELL and HUGHES, *Goniagnostus*, *Lejopyge*

indicates that *humilis* and *planicauda* are synonyms, as proposed by Yang (1993). The major difference in the Zanskar material is the much wider cephalic border furrow with the more rounded glabellar anterior and less obvious division of the anterior glabellar furrow being minor differences. Yang (1993, pl. 6, fig. 13) assigned a cranidium with a border furrow as wide as that in the Zanskar material to this species and we agree with him that it is a variable species which should contain the forms with wide border furrows.

Genus LINGUAGNOSTUS Kobayashi, 1939

Type species. Agnostus kjerulfi Brögger, 1878, from the upper Middle Cambrian of Sweden.

Linguagnostus cf. *tricuspis* (Lermontova, 1940)

Plate 30, figures 16–17

Material. MPUM7242–7243, from SLN.

Remarks. The anteromedial pit in the glabella, angulate glabellar posterior, large triangular basal lobes, short pygidial axis with long median tubercle extending over anterior three-quarters of its length, and with distinct transverse dumbbell-shaped depression just behind the axis, distinct posterior collar well in front of posterior margin and three small posterior marginal spines (one axial, two posterolateral) together are typical of *L. tricuspis*, but the preglabellar and postaxial median furrows are not characteristic. A rudimentary preglabellar median furrow is seen on the type cephalon (Khalfin, 1960, pl. 18, fig. 1a) and on a few illustrated specimens of *L. kjerulfi* (Westergård 1946, pl. 9, fig. 31; Yang 1993, pl. 7, fig. 2) and *K. arcticus* (Holm and Westergård 1930, pl. 1, fig. 26) but none are as well impressed as in the Zanskar cephalon. Among illustrated pygidia of *Linguagnostus* none shows such a discrete postaxial median furrow as in our specimen, and only *L. gronwalli* (Westergård 1946, pl. 8, fig. 30) approaches the condition seen in the Zanskar specimen, but its furrow is shorter.

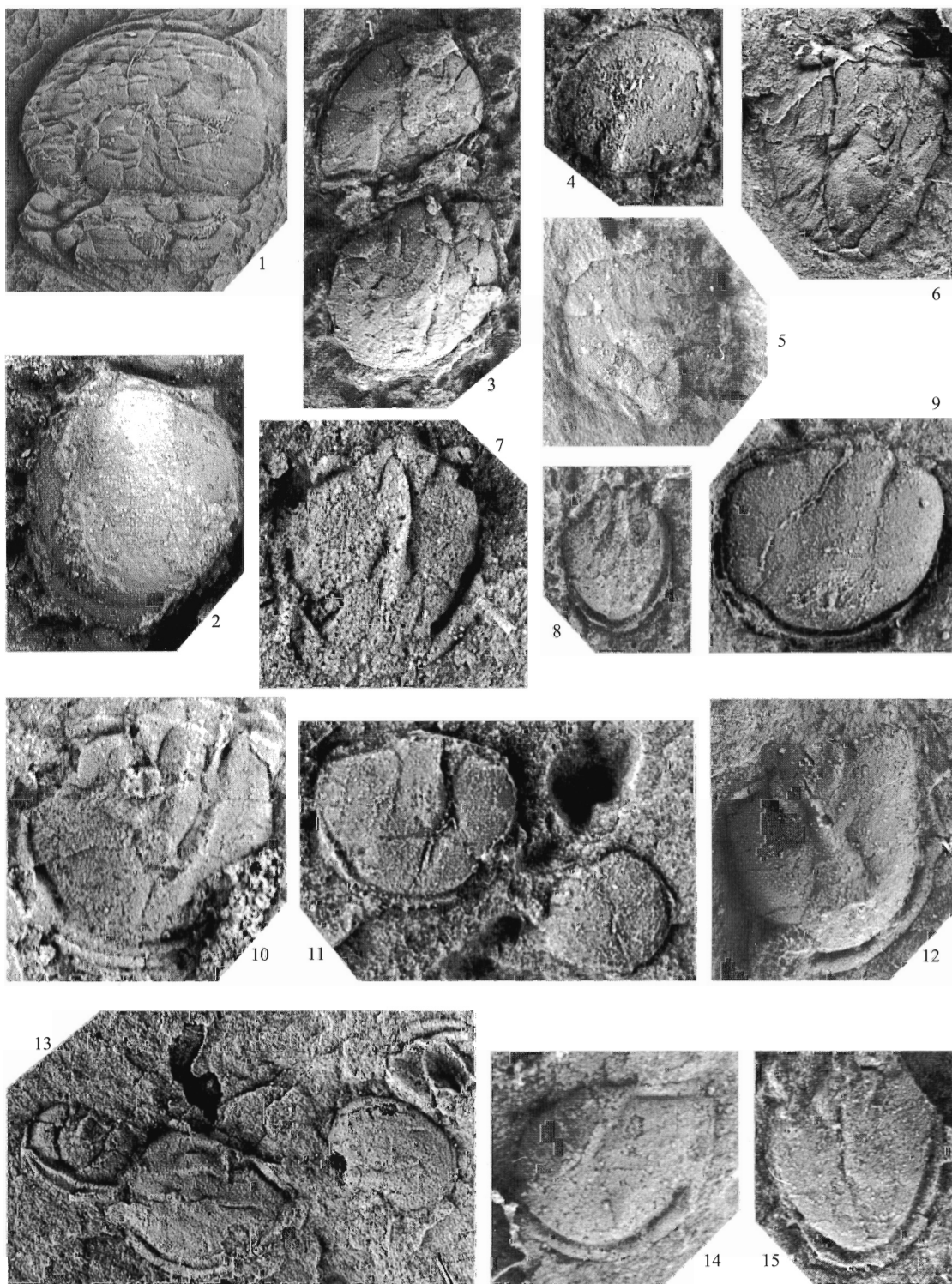
In a number of illustrated pygidia there appears to be a shallow postaxial median depression, and we interpret this to be the case in our Zanskar specimen, with the sharpness of the furrow being enhanced by postdepositional tectonics. This is suggested because there are numerous longitudinal (parallel to the postaxial median furrow) tectonic crinklings, because (1) the furrow extends beyond the collar to the posterior margin to one side of the median spine, (2) under close examination it exhibits some variation from a straight line, particularly behind the collar, and (3) this is an internal mould where the expression of such depressions are usually more noticeable than on external surfaces of exoskeletons. Similar enhancement of the preglabellar median furrow in the associated cephalon could also be inferred from the direction of compression on that specimen. We place this material in open nomenclature.

EXPLANATION OF PLATE 29

Figs 1–6. *Hypagnostus correctus* Öpik, 1967. 1, CMCP1556; steep slopes on the north side of the Kurgiakh River, about 1 km east of Kuru; cranidium and two thoracic segments; $\times 10$. 2, MPUM7221; pygidium; $\times 8$. 3, MPUM7222; dorsal exoskeleton; $\times 10$. 4, CMCP1557; cranidium; $\times 10$. 5, MPUM7223; cranidium; $\times 10$. 6, MPUM7224; pygidium; $\times 8$.

Figs 7–15. *Lejopyge armata* (Linnarsson, 1869); pygidia. 7, MPUM7225; $\times 10$. 8, MPUM7226; $\times 10$. 9, MPUM7227; $\times 10$. 10, MPUM7228; $\times 10$. 11, MPUM7229; $\times 12$. 12, MPUM7230; $\times 10$. 13, MPUM7231; $\times 7$. 14, MPUM7232; $\times 10$. 15, MPUM7233; $\times 12$.

All are dorsal views of latex casts from external moulds, except figs 1–5, 8–9, 11 and 15 which are internal moulds; all specimens from SLN, Zanskar except where stated otherwise.



Family CLAVAGNOSTIDAE Howell, 1937

Genus CLAVAGNOSTUS Howell, 1937

Type species. Agnostus repandus Westergård, in Holm and Westergård, 1930 from the upper Middle Cambrian of Sweden.

Clavagnostus cf. *repandus* (Westergård, in Holm and Westergård, 1930)

Plate 30, figures 1–2, 4–7

Material. CMCP1558–1559 and MPUM7234–7237, from SLN.

Remarks. The damaged complete specimen (Pl. 30, fig. 1) has a long, narrow glabella and although its anterior is not preserved there is enough to indicate that it is not of the short sharply pointed type seen in other cephala (Pl. 30, fig. 3). We conclude, therefore, that two species of *Clavagnostus* are present and that all the pygidia are conspecific with the articulated specimen. The type of glabella places the material in the *C. repandus* group of Jago and Daily (1974). Although both cranidia appear to have rudimentary preglabellar median furrows, close examination shows these to be the result of tectonic deformation, as is the grooving on the cheek areas that might be interpreted as scrobiculation. On each cranidium the posterior of the glabella is poorly preserved so that the basal lobes are not clear, but they must either be very small and inconspicuous or not defined. This is similar to *C. repandus* (Jago and Daily 1974, pl. 11, figs 1, 3) where basal lobes are poorly differentiated. Pygidial marginal spines are situated well to the rear as in *repandus*. It is not possible to be certain of the shape and impression of the pair of axial pits used by Jago and Daily (1974) to discriminate species, because of tectonic deformation. Despite the difficulties of interpretation due to deformation, this material is very similar to well-preserved specimens of *C. repandus*, with no obvious distinguishing features.

Clavagnostus sp.

Plate 30, figure 3

Material. MPUM7238, from SLN.

Remarks. This poorly preserved cranidium has a short, anteriorly pointed glabella, a weak preglabellar median furrow, broad squared glabellar base and possibly weak pits (enhanced by the deformation) on the cheeks. Pitting is known in *C. lanceolatus* Lu and Lin (1989, pl. 2, fig. 2) which also has a broad based glabella without basal lobes. Other features are not species diagnostic and

EXPLANATION OF PLATE 30

Figs 1–2, 4–7. *Clavagnostus* cf. *repandus* (Westergård, in Holm and Westergård, 1930). 1, CMCP1558; dorsal exoskeleton; $\times 10$. 2, MPUM7234; cephalon; $\times 10$. 4, MPUM7235; cephalon; $\times 10$. 5, MPUM7236; pygidium; $\times 15$. 6, CMCP1559; pygidium; $\times 15$. 7, MPUM7237; pygidium; $\times 15$.

Fig. 3. *Clavagnostus* sp.; MPUM7238; cephalon; $\times 10$.

Figs 8–13. *Diplagnostus planicauda* (Angelin, 1851). 8, CMCP1560; cephalon; $\times 10$. 9, MPUM7239; pygidium; $\times 15$. 10, CMCP1561; cephalon; $\times 10$. 11, MPUM7240; pygidium; $\times 8$. 12, CMCP1562; cephalon and thoracic segment; $\times 15$. 13, MPUM7241; pygidium; $\times 10$.

Figs 14–15. Agnostid indet. 14, CMCP1563; dorsal exoskeleton; $\times 12$. 15, CMCP1564; pygidium; $\times 10$.

Figs 16–17. *Linguagnostus* cf. *tricuspis* (Lermontova, 1940). 16, MPUM7242; cephalon; $\times 12$. 17, MPUM7243; pygidium; $\times 10$.

All are dorsal views of latex casts from external moulds except figs 1, 5, 8, 10–11, 14–15 and 17 which are internal moulds; all specimens are from SLN, Zanskar.



since it could belong to either of Jago and Daily's (1974) *burnsi* or *sulcatus* groups, it is placed in open nomenclature.

Agnostid indet.

Plate 30, figures 14–15

Material. CMCP1563–1564, from SLN.

Remarks. The articulated specimen has a narrow glabella with long anterior lobe and obtusely angular posterior, probably a preglabellar median furrow, narrow cephalic border and border furrow, extremely wide pygidial axis with low median node towards anterior, possibly constricted pygidial acrolobe, extremely narrow pleural areas and narrow border. These features are not diagnostic but they separate this specimen from the other agnostoids of this faunule. Without the preglabellar median furrow it could be a peronopsid, but it is not a ptychagnostid. Its most likely placement is within Agnostidae, possibly *Agnostus* or *Homagnostus*.

Order CORYNEXOCHIDA Kobayashi, 1935

Family DOLICHOMETOPIDAE Walcott, 1916

Genus FUCHOUIA Resser and Endo, *in* Kobayashi, 1935

Type species. By original designation; *Bathyriscus manchuriensis* Walcott, 1911, from the Middle Cambrian of north-east China.

Fuchouia sp. indet.

Plate 31, figures 4–5; Plate 32, figure 8

Material. MPUM 6006A (Whittington 1986, pl. 20, figs 2–3), 6006B (Whittington 1986, pl. 19, fig. 5), MPUM7244–7245, 7252, from SLN.

Remarks. The three further pygidia here assigned to *Fuchouia*, when considered along with those of Whittington (1986) from the same site, indicate some variation. He noted six axial rings plus the terminus but our specimens suggest four or five axial rings plus the terminus. In Whittington's pygidia interpleural furrows are not seen, whereas in ours (Pl. 31, figs 4–5) well-impressed interpleural furrows are evident. However, the available material is insufficient to determine whether more than one species is represented.

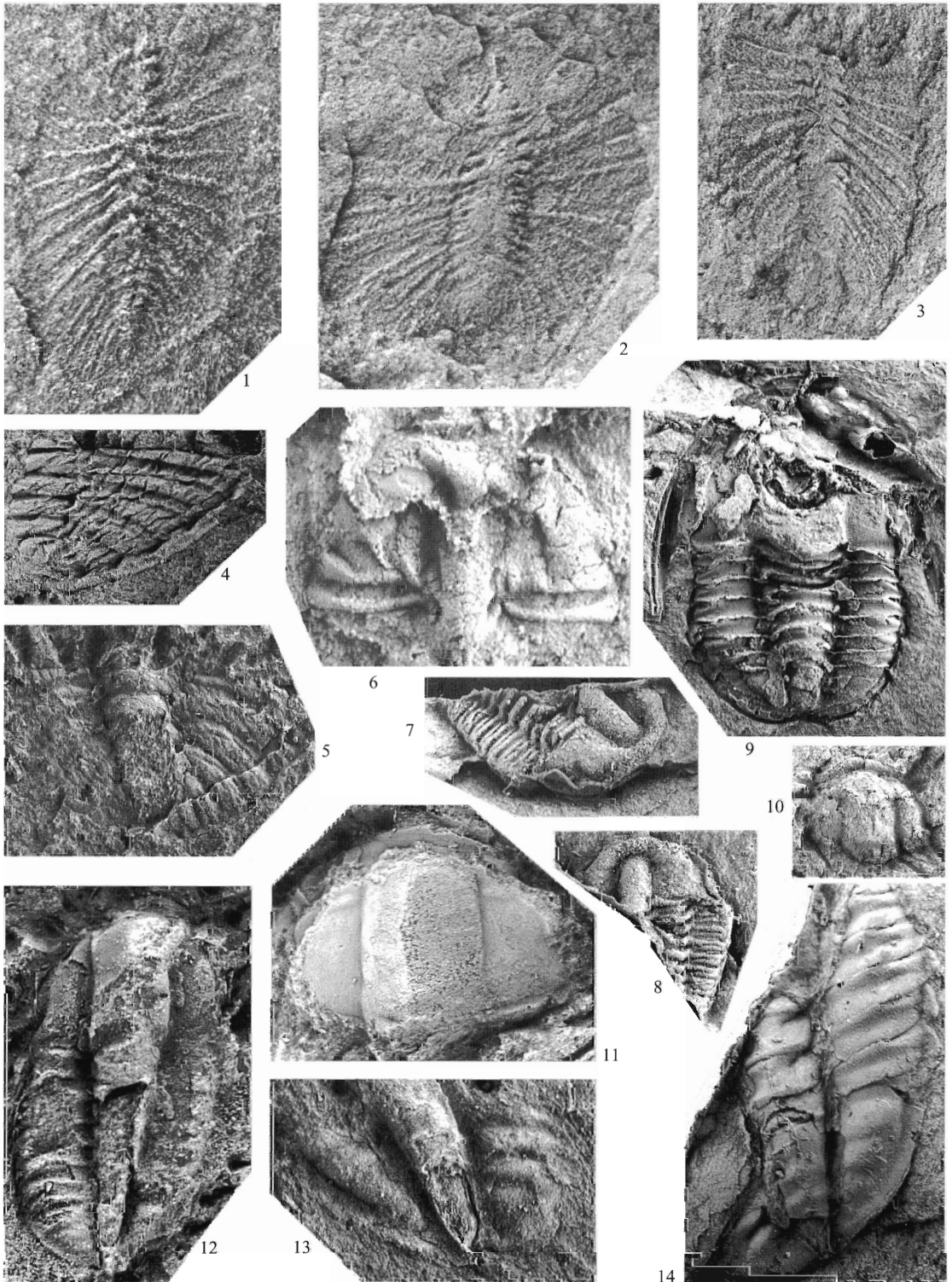
EXPLANATION OF PLATE 31

Figs 1–3. *Schmalenseeia amphionura* Moberg, 1903; articulated dorsal exoskeletons, all on a single piece of rock. 1, CMCP1565; $\times 15$. 2, CMCP1566; $\times 15$. 3, CMCP1567; dorsal exoskeleton lacking cephalon; $\times 10$. Figs 4–5. *Fuchouia* sp. indet.; pygidia. 4, MPUM7244; $\times 5$. 5, MPUM7245; $\times 4$.

Figs 6–8. *Torifera* sp. nov. 6, MPUM7246; cranidium; $\times 10$. 7–8, CMCP1568; latex cast from external mould of damaged cranidium and partial thorax in anterolateral oblique and dorsal views, respectively; $\times 6$.

Figs 9–14. *Eoshengia? sudani* sp. nov. 9, MPUM7247; dorsal exoskeleton; $\times 5$. 10, MPUM7253; small cranidium; $\times 3$. 11, MPUM7248; cranidium; $\times 5$. 12, MPUM7249, holotype; dorsal exoskeleton; $\times 10$. 13, MPUM7250; pygidium; $\times 10$. 14, CMCP1569; thoracic posterior and pygidium; $\times 7$.

All are dorsal views of latex casts from external moulds, except figs 2–5 and 9–12 which are internal moulds; all specimens are from SLN, Zanskar.



JELL and HUGHES, Himalayan Cambrian trilobites

Order UNCERTAIN
 FAMILY BURLINGIIDAE Walcott, 1908
 Genus SCHMALENSEEIA Moberg, 1903

Type species. By original designation; *Schmalenseeia amphionura* Moberg, 1903, from the lowest Upper Cambrian of Sweden.

Schmalenseeia amphionura Moberg, 1903

Plate 31, figures 1–3

Material. The types are cited by Rushton (1978, p. 273) who designated the lectotype as Lund University LO 1660T (Rushton 1978, pl. 25, fig. 17) and paratypes as LO 1661–1663, 1666, 1667. Himalayan specimens are CMCP1565–1567, from SLN.

Remarks. This species has been discussed by Westergård (1922), Jago (1972), Rushton (1978) and Whittington (1981, 1994). The Zanskar specimens reported here are poorly preserved on weathered shale partings and do not add to understanding of the genus. The tapering glabella, well-impressed lateral glabellar furrows, median preglabellar ridge, axial nodes on each segment from LO as far as the pygidium and the rectangular thoracic pleural shape with anterior and posterior ridges on each pleura are all typical for this species, but as Whittington (1994) pointed out, a number of very similar ones, which may or may not be synonymous, need clarification to stabilize species concepts in this genus. This occurrence in Zanskar in slope deposits and in association with numerous agnostoids fits with the world-wide distribution in outer shelf or slope deposits as noted by Whittington (1994).

Family DAMESELLIDAE Kobayashi, 1935

Genus DAMESOPS Chu, 1959

- 1959 *Damesops* Chu, p. 69.
- 1967 *Meringaspis* Öpik, p. 323.
- 1974 *Paradamesops* Yang, in Lu *et al.*, p. 86.
- 1978 *Paradamesops* Yang; Yang, p. 58.
- 1980 *Meringaspis* Öpik; Ergaliev, p. 149.

Type species. By original designaion; *Damesops convexus* Chu, 1959, from the lower Upper Cambrian (Kushanian) of northern Jiangsu.

Remarks. Öpik (1967) did not compare *Meringaspis* with *Damesops* but considered its pygidial structure unique, noting a few other damesellids with similar cranidia. Yang (in Lu *et al.* 1974) distinguished *Paradamesops* from *Damesops* and *Meringaspis* on the posterior pygidial structure, and from the latter genus also on the position of the palpebral lobes. The pygidial rear between the macropleurals sixth pair of marginal spines is rounded in *Paradamesops*, has a single flat median projection in *Meringaspis* and has a pair of similarly flat triangular projections in *Damesops*. These are considered specific differences since the posterior border is similarly wide in each genus, with the only difference being the number of projections. The palpebral lobes are situated anteriorly in *Damesops* and *Paradamesops* but more to the posterior in *Meringaspis*. However, the Zanskar species described herein would be classified in *Paradamesops* on the pygidial structure but in *Meringaspis* on the position of the palpebral lobes. We therefore conclude that neither of these features is generically distinctive.

Damesops sheridanorum sp. nov.

Plate 32, figures 1–7, 9

?1986 family and genus indeterminate Whittington, p. 178, pl. 19, fig. 4.

Derivation of name. For John and Rae Sheridan who helped in the field and collected the holotype.

Material. Holotype CMCP1574 and paratype CMCP1571, from the Kurgiak Formation in steep slopes on Kurgiak River about 1 km east of Kuru; paratypes MPUM7251 and CMCP1570, 1572, 1573, from SLN; upper Middle Cambrian.

Description. Whole exoskeleton *c.* 0.7 as wide as long, of low convexity, with pleural areas horizontal. Glabella truncated anteriorly at border furrow, with well-impressed lateral furrows starting at axial furrow. S1 distinct, reaching almost to sagittal line, forked adaxially but with anterior arm of fork barely perceptible. SO continuous, with transverse central portion and anteriorly directed lateral portions; LO shorter laterally, transverse and of uniform length over axial two-thirds, with low median node. Anterior border strongly upturned. Eye ridges running posterolaterally from just behind the anterolateral glabellar corners to short, slightly stalked palpebral lobes situated at about the level of the glabellar midlength. Preocular facial suture converging slightly forward. Postocular facial suture sigmoidal, defining a long, wide posterolateral cranial limb. Rostral plate wider than glabella, rostral suture apparently along anterior margin, with regular comarginal terrace lines continuous across rostral plate onto librigenal doublures. Hypostome and long anterior wings joined suturally to rostral plate in conterminant condition, more than half glabellar length, but narrower than glabella. Librigena wide, with poorly impressed but wide border furrow, with long genal spine extending almost half thoracic length. Thorax of 12 segments. Axis strongly convex, standing above flat pleurae, tapering slightly towards posterior; articulating half rings large, almost as long (sag.) as axial ring. Pleurae with well-impressed pleural furrows occupying most of length of each segment, with short anterior and posterior pleural bands; free pleurae beyond fulcral points as long curving spines; facets not evident but presumably short, wide and ill-defined. Pygidium large, with axis of more than six rings (preservation prevents an accurate count), with macropleural marginal spines at front and back, the posterior one being markedly longer than any other, with four pairs of shorter, finer, marginal spines between the macropleural ones; posterior of pygidium between last spines with smoothly curved margin, crossed by one pleural furrow, with wide doublure, which widens posteriorly, with distinct comarginal terrace lines throughout.

Remarks. Although the available material is poorly preserved and markedly distorted, its morphology is so distinctive as to allow confident generic placement. The truncated glabella, small palpebral lobes, macropleural first and sixth pygidial marginal spines, with four pairs of smaller spines between, and wide doublure with comarginal terrace lines are distinctive. The holotype (Pl. 32, fig. 6) is the first articulated specimen reported for the genus and the retrodeformed reconstruction (Pl. 32, fig. 7) provides the first appreciation of relative proportions of cephalon to pygidium and an entire thorax. Whittington's (1986, pl. 19, fig. 4) indeterminate specimen almost certainly belongs to this taxon; the long pygidial marginal spine, thoracic segments and strong terrace lines on doublure are indicative but not conclusive.

D. sheridanorum is distinguished from the type species in its lack of the flat posterior pygidial projections and in having its palpebral lobes situated at about the glabellar midlength. *D. sheridanorum* differs from the Chinese *D. jimaensis* Yang (in Lu *et al.* 1974) and *D. laterilobatus* Yang (1978) in its posterolaterally directed eye ridges, much longer pygidial marginal spines and better impressed, straighter S1 reaching much closer to the axis, and it differs from the Kazakh *D. karatauensis* Ergaliev, 1980 in its posterolaterally directed eye ridges, its longer pygidial marginal spines and its smaller pygidial posterior between the last marginal spines.

Family DICERATOCEPHALIDAE Lu, 1954

Genus TORIFERA Wolfart, 1974

Type species. By original designation; *Torifera triangularis* Wolfart, 1974 from the Kushanian of central Afghanistan.

Remarks. Synonymy of Aulacodigmatidae Öpik 1967 and Diceratocephalidae was pointed out by Zhang and Jell (1987, p. 131) who then assigned *Torifera* to the latter. It should be noted that the Himalayan species of *Torifera*, described below, has eight thoracic segments, as does *Aulacodigma* Öpik, 1967.

Torifera sp. nov.

Plate 31, figures 6–8

1986 *Cyclolorenzella?* sp. ind. Whittington, p. 175, pl. 18, figs 2–3.*Material.* CMCP1568 and MPUM6005, 7246, from SLN.

Description. Glabella tapering very slightly forward, anteriorly truncated; SO shallow over axis, well-impressed and oblique up side of glabella laterally, LO with broad based, flat, occipital spine. Axial furrow well-impressed, more steeply sided on glabella than on cheeks. Preglabellar field convex, continuous with fixed cheeks laterally (not divided from them by any furrows). Anterior border a simple rim on the steep anterior slope, flattening out laterally on librigena. Low baccula at posteroproximal corner of fixigena. Palpebral lobe short, arcuate, level with anterior glabellar lobe. Eye line transverse, distinct. Posterolateral cranial limb long but very narrow, with well-impressed, long, posterior border furrow, with short, strongly convex posterior border joining occipital ring and becoming flatter and longer distally beyond fulcral line. Thorax of eight segments; each pleura with short elevated anterior and posterior bands and long, deep pleural furrow occupying most of the segment.

Remarks. The above supplements Whittington's (1986) description, but the material is still insufficient to name the new species. MPUM6005 and 7246 both have eight thoracic segments and the former shows the broad librigena and genal spine typical for *Torifera*. This material is assigned to the latter genus rather than to *Cyclolorenzella* because of the wider axial furrows, the flat occipital spine, the transverse eye ridges, small palpebral lobes and the short anterior border. *Torifera* sp. nov. differs from the type species by its less tapering glabella, shorter anterior border, lack of surface ornament, and narrower fixigenae. The exoskeleton was apparently thin, as suggested by its folding on fixigena (Pl. 31, fig. 6) before fracture.

Family LISANIIDAE Zhang, 1963

Genus EOSHENGIA Yang, 1978

Type species. By original designation; *Eoshengia subquadrata* Yang, 1978 from the uppermost Middle Cambrian of eastern Guizhou.

Eoshengia? *sudani* sp. nov.

Plate 31, figures 9–14

Etymology. For Dr C. S. Sudan of Jammu University, in honour of his work on the Cambrian palaeontology of India.

Material. Holotype MPUM7249; paratypes MPUM7247, 7250, 7253, CMCP1569, from SLN; MPUM7248, from the Karsha Formation at the same locality.

Diagnosis. Anterior border short, flat to declined; palpebral lobes moderately long; moderately

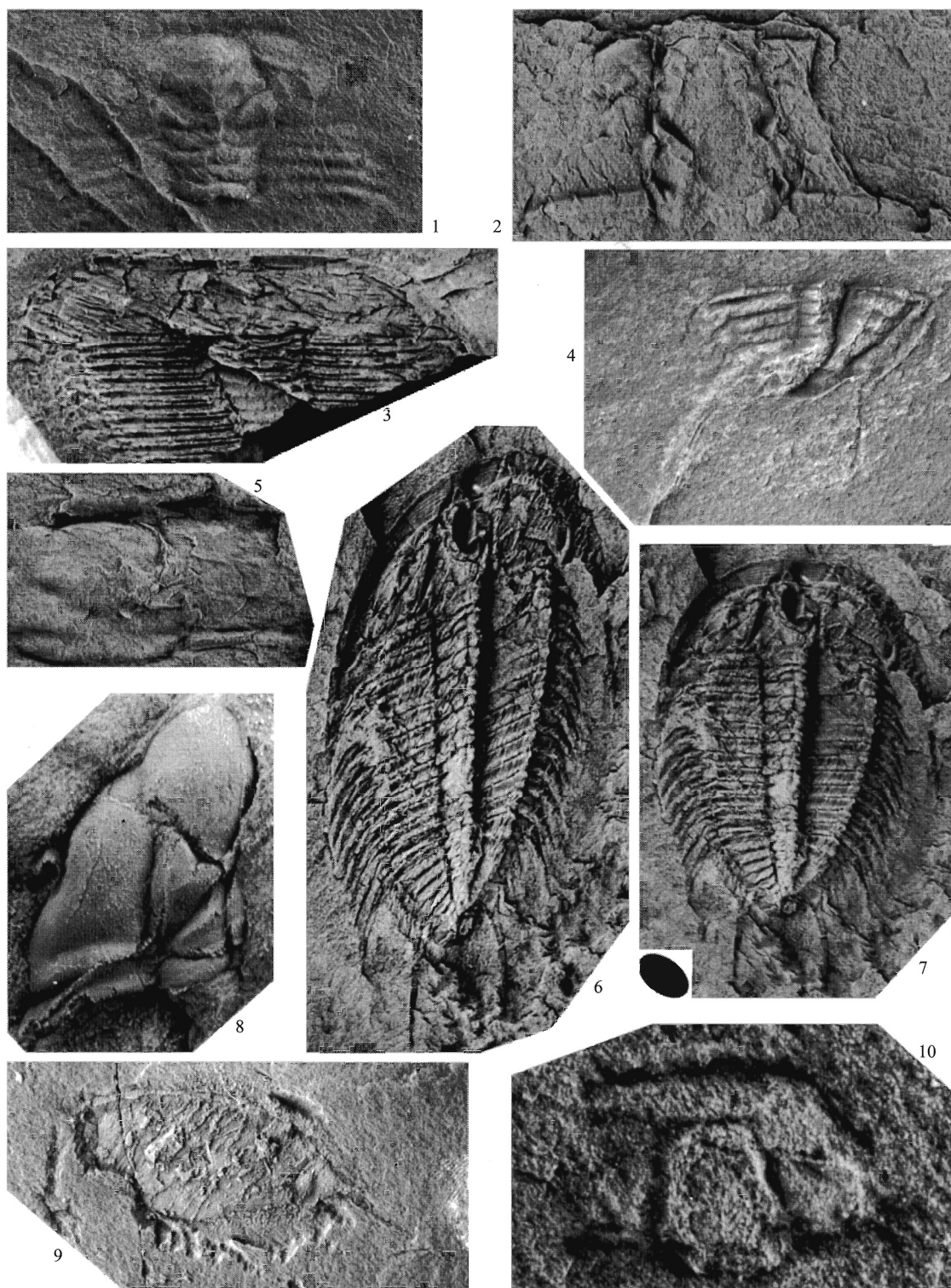
EXPLANATION OF PLATE 32

Figs 1–7, 9. *Damesops sheridanorum* sp. nov. 1, MPUM7251; cranium and anterior thorax; $\times 2$. 2, CMCP1570; cranium; $\times 4$. 3, CMCP1571; cranium and anterior thorax; $\times 2$. 4, CMCP1572; pygidium; $\times 5$. 5, CMCP1573; latex cast from external mould, cranium; $\times 3$. 6–7, CMCP1574; holotype, exoskeleton with hypostome impressed onto glabella; $\times 4$. 7, computer-graphic restoration. 9, CMCP1575; librigena; $\times 4$.

Fig. 8. *Fuchouia* sp. indet.; MPUM7252; latex cast from external mould of incomplete cranium; $\times 4$.

Fig. 10. *Olenus?* sp. CMCP1576; cranium; $\times 12$.

Figs 1–2, 4–5 and 8–10 are from SLN, Zanskar; 3 and 6–7 are from the steep slopes on the north side of the Kurgiakh River, about 1 km east of Kuru, Zanskar.



JELL and HUGHES, *Damesops*, *Fuchouia*, *Olenus*?

wide interocular cheeks; occipital spine lacking; seven thoracic segments; pygidial axis of three rings plus terminus.

Description. Glabella rectangular, extending to anterior border furrow; S1–S3 extremely weak; SO weak, transverse. Axial furrow defined only by change in slope from glabella to cheek. Anterior border flat, gently declined, long frontally, tapering laterally where facial suture cuts across at low angle. Palpebral lobe narrow, moderately long, gently curved, situated forward of glabellar midlength; interocular cheek more than half glabellar width. Posterolateral cephalic border long, narrow, gently declined. Preocular facial sutures parallel, meeting eye ridge far from the axial furrow. Rostral plate and hypostome discrete, with rear of latter level with rear of palpebral lobe; cephalic doublure with comarginal terrace lines extending on to genal spine (outer terrace lines) or curving onto the posterior cranial doublure (inner terrace lines); distinct groove on outer part of doublure shallowing anteriorly but extending along genal spine. Genal spine extending beyond midlength of thorax. Thorax of seven segments, each with: shallow diagonal pleural furrow; broad flat posterior pleural band; wide short facet; and slightly recurved, pointed pleural tip. Axis tapering posteriorly. Pygidium transverse; axis strongly convex, of three weakly defined rings and elongate terminus extending to posterior margin. Pleural field crossed by three shallow, distinct pleural furrows; low, smooth pleural ribs decreasing in length posteriorly. Border uniformly narrow; doublure a little wider, with slight posteromedian indentation at rear of axis; indistinct border furrow marked by change of slope from pleural field.

Remarks. Generic concepts within Lisaniidae are not always clear and few articulated specimens are available. The present species is assigned tentatively to *Eoshengia* because of the flat anterior border, wider interocular cheeks and short palpebral lobes but these are not obvious generic features. Complete specimens of *E. constricta* Zhang, 1981 (Yang 1991, pl. 16, figs 1–2) each have nine thoracic segments so that the two specimens of *E. ? sudani* each with seven segments, seem to be specifically distinct and the number of thoracic segments may be variable within the genus. These are unlikely to be meraspide exoskeletons, given their size.

Poor preservation, damage to available material, and poor understanding of specific criteria among Chinese species of *Eoshengia* make discrimination of this new species difficult. Its lack of occipital spine, moderately wide interocular cheeks, moderately long palpebral lobes, short, flat to declined border and pygidial axis of only three rings plus terminus separate it from known members of Lisaniidae. Most similar may be *E. paratenuis* Yang (1993, pl. 16, figs 5–8), which has a very similar pygidium but has an upturned anterior border and narrower glabella. *Shengia ortholimnata* Zhang, 1981 is similar in cranial proportions but has an upturned anterior border and more pygidial axial rings.

Family OLENIDAE Burmeister, 1843

Genus OLENUS Dalman, 1827

Type species. By original designation; *Entomostracites gibbosus* Wahlenberg, 1821 from the Upper Cambrian of Sweden.

Olenus? sp.

Plate 32, figure 10

Material. CMCP1575–1576, from SLN.

Remarks. The quadrate glabella, transverse eye ridge, short, kidney-shaped palpebral lobe, general proportions of brim and upturned anterior border and wide librigena with narrow border, short, fine genal spine and long posterior section of the facial suture all suggest Olenidae. However, the oldest known representative of the Olenidae is *O. alpha* Henningsmoen, 1957 from the *Agnostus pisiformis* Zone of Scandinavia, a zone younger than that suggested by the agnostoid fauna accompanying this species. Henningsmoen considered origin of the olenids from latest Mid Cambrian *Andrarina* (a contemporary of the Zanskar fauna) but dismissed such a lineage as that Middle Cambrian genus is more advanced than *Olenus*. The Zanskar species is too poorly preserved to be interpretable in

detail but it appears most similar to the early species of *Olenus* and may well be an important link in olenid origins; only the more posterior origin of the eye ridge at the axial furrow and smaller glabella (in relation to total cranidial area) are unlike *Olenus*. Unfortunately, this material cannot provide any further information because of its rarity and poor preservation, but it does support a search for olenid origins in any part of the world in the uppermost Middle Cambrian because, as noted by Öpik (1963), the Olenidae drifted across the oceans, settling in many far-flung places, sometimes developing large populations.

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APPENDIX – KASHMIR LOCALITIES

Reed's (1934) localities are referred to in the text by his prefixes (A–I) preceded by a K for Kashmir and are listed below with their trilobite faunas after the taxonomic revision above.

KA – Foot of Frangteng Hill

Bailiella lantenoisi

KB – Rainawari footpath

Tonkinella breviceps

Hundwarella memor

KD – near Sultanpur

Bailiella lantenoisi

Hundwarella memor

KE – 2.8 km (1.75 miles) west-north-west of Wadapur

Baltagnostus? rakuroensis

Bailiella lantenoisi

Tonkinella breviceps

Hundwarella memor

Iranoleesia butes

KG – 2.4 km (1.5 miles) south-east of Dardapur

Xingrenaspis dardapurensis

KI – 4 km (2.5 miles) north of Marhaum (Pishaltong Pass)

Tonkinella breviceps