वेदाहं समतीतानि वर्तमानानि चार्जुन ।
भविष्याणि च भूतानि मां तु वेद न कश्चन ॥

CAMBRIAN TRILOBITES FROM THE PARAHIO AND ZANSKAR VALLEYS, INDIAN HIMALAYA

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ABSTRACT—New collections of trilobites from the type section of the Parahio Formation in the Parahio Valley, Spiti, and from the Parahio, Karsha, and Kurgiakh formations in the Zanskar Valley, permit biozonation based on material precisely located within measured stratigraphic sections. Specimens preserved in limestone with mild tectonic deformation clarify the features of several Himalayan taxa known previously only from severely deformed specimens preserved in shale. A total of 75 trilobite taxa from the Cambrian of Spiti and Zanskar can be referred, questionably at least, at the generic level or below, and 61 of these are present in our new collections. This new material is assigned with confidence to 29 existing species, and to 12 new species. Three new genera, *Haydenaspis*, *Bhargavia*, and *Himalisania*, are established; new species include *Haydenaspis parvatya*, *Prozacanthoides lahiri*, *Probowmania bhatti*, *Xingrenaspis parthiva*, *X. shyamalae*, *Bhargavia prakritika*, *Kaotaia prachina*, *Gunnia smithi*, *Sudanamonocarina sinindica*, *Proasaphiscus simoni*, *Koldinia odelli*, and *Tarifera jelli*. Ten additional Himalayan forms are assigned at the generic level only, and another 11 are questionably assigned to genera or species. The zonation proposed includes 6 zones and 3 levels, including the *Haydenaspis parvatya* level, the *Oryctocephalus indicus* level, the *Kaotaia prachina* Zone, the *Paramecephalus defossus* Zone, the *Oryctocephalus salteri* Zone, the *Iranoleesia butes* level, the *Sudanomocarina sinindica* Zone, the *Lejopyge acantha* Zone, and the *Proagnostus bulbus* Zone. The sections span from the upper part of the informal Stage 4, Series 2 of the Cambrian System, about 511 Ma old, to the *Proagnostus bulbus* zone of the Guzhangian Stage near the top of Series 3, dated at about 501 Ma. This time interval is represented by about 2000 m of section, which is thick compared to similar intervals elsewhere and is consistent with high rates of sedimentation along the Himalayan margin at the time. The fauna resembles others from equatorial peri-Gondwanaland, with closest similarity to that of South China. It also bears strong affinity to the North China fauna. Juvenile trilobites are described for the first time from India. A new Chinese species, *Monanocephalus liquani*, is also described.

INTRODUCTION

ALTHOUGH CAMBRIAN trilobites have been known from the Himalaya for over a hundred years, the biostratigraphy of the Himalayan Cambrian remains poorly resolved. The great majority of these trilobites have been tectonically deformed (see Jell and Hughes, 1997), and the stratigraphic context of many previous collections is not well understood. Consequently, global assessments of Cambrian stratigraphy and paleogeography generally overlook the Himalayan region. A steep ridge along the north side of the Parahio valley of the Spiti and Lahaul district of Himachal Pradesh, India (Fig. 1), first studied by Sir Henry Hayden in the 1890's (Hayden, 1904; Reed, 1910) provides a continuous stratigraphic section (Myrow et al., 2006a) from which we have collected Cambrian trilobites at successive horizons. We have also collected several sections in the Zanskar Valley of the Ladakh region of Jammu and Kashmir, India (Myrow et al., 2006b), a region some 150 km northwest of the Parahio Valley (Fig. 1) and also part of the Tethyan Himalaya. Much of this new material is preserved in limestone and, while not entirely free from tectonic deformation, is of sufficient quality to permit direct comparison with well-preserved specimens from elsewhere.

This study presents systematic descriptions of our collections and clarifies taxonomic concepts based on these well-preserved specimens. Correlations between the Parahio and Zanskar Valleys are considered, and our new material is integrated with previous collections to construct a biostratigraphic scheme for this region for parts of the second and third series of the Cambrian System. We also consider the implications of our study for dating and correlation with other parts of the Himalaya and beyond.

GEOLOGICAL SETTING

The central part of the Himalaya, located between its eastern and western syntaxes, consists of four major lithotectonic zones to the south of the Indus-Tsangpo suture zone, the boundary with the Lhasa block of Tibet (Fig. 1.1). The collections described herein come from the northernmost of the four zones, the "Tethyan" or "Tibetan" Himalaya, and all belong to the upper part of the Haimanta Group (Myrow et al., 2006a). The Spiti and Zanskar valleys are adjacent drainage basins (Fig. 1.2), and the Parahio Formation has been recognized in both regions (Myrow et al., 2006a,b). It consists of siliclastic deltaic deposits with subordinate carbonate beds.

In Spiti, the Parahio Formation is unconformably overlain by the conglomeratic basal part of the Ordovician Thango Formation. Collections from the Parahio Valley of Spiti were made from (1) a section on a ridge on the northern side of the Parahio River (Fig. 2), which is where Hayden (1904) measured his original section, (2) from an outcrop on the banks of the south side of the Parahio River near the confluence with the Sumna River and, (3) the slopes on the east side of the Sumna River (see Appendix 1 for details of collection localities). Aspects of the lithostratigraphy and paleoenvironments of these sections, and the history of their interpretation, have been reviewed by Myrow et al. (2006a). Trilobites, bradorid arthropods, phosphatic brachiopods, and sponge spicules are found in carbonate grainstone beds that are interpreted to represent intermittent decreases in the supply of terrigenous siliciclastic sediment. The grainstone texture suggests reworking by ocean waves and currents. Although there is some evidence of silicification in these carbonate beds (Myrow et al., 2006a), acidic dissolution of the limestone did not yield silicified fossils other than sponge

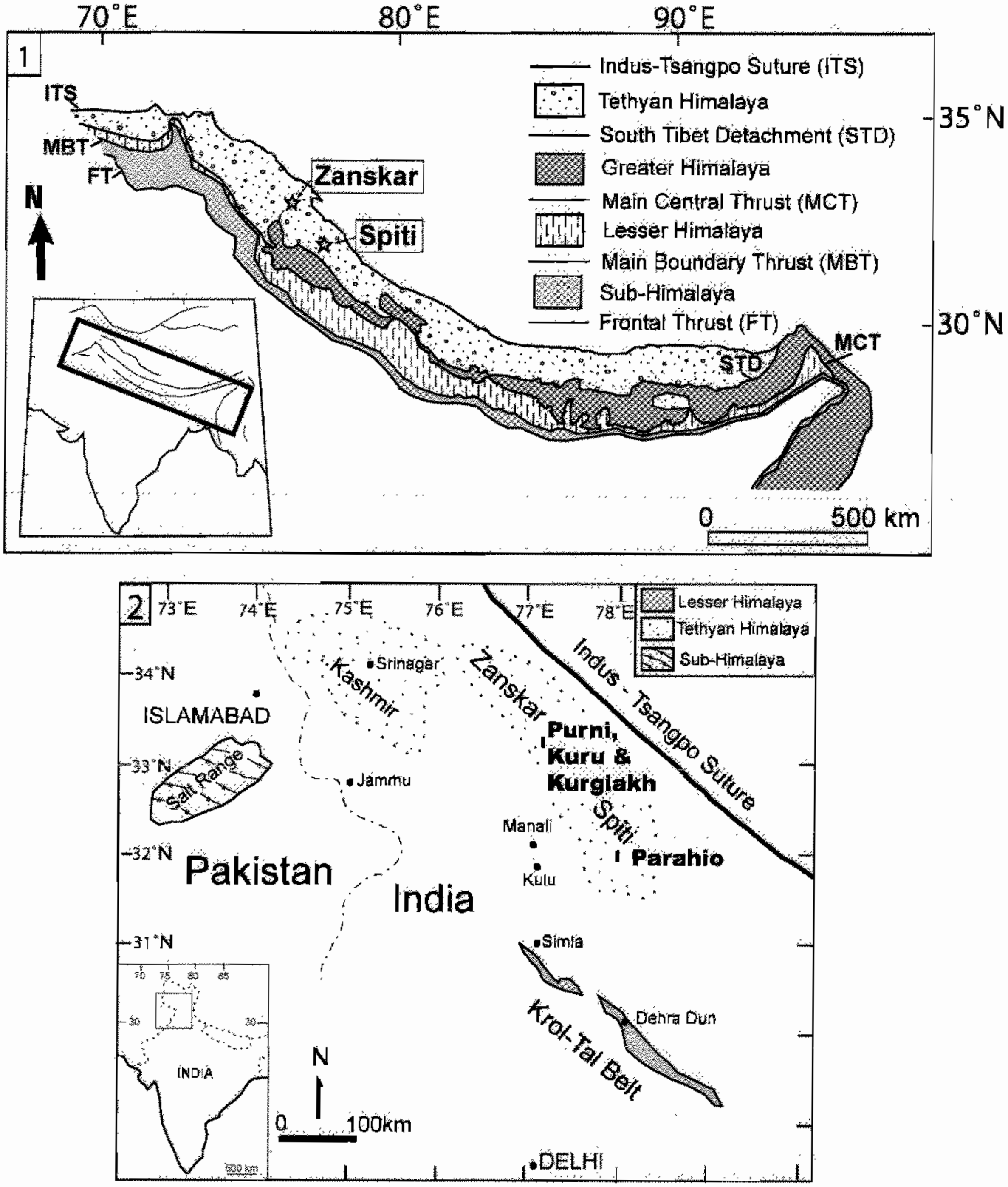


FIGURE 1—Location of the Spiti and Zanskar valleys within the Himalaya. *1*, showing position of Spiti/Zanskar region as part of the Tethyan Himalaya, the most northerly of four lithotectonic zones of the Himalaya. *2*, position of sections within the Zanskar and Spiti valleys, and other areas in the western and central Himalaya from which Cambrian trilobites are known.

spicules. However, it did liberate phosphatic brachiopods from each of the carbonate horizons that we have sampled.

Trilobites and brachiopods are also present in dark shale that appears to have accumulated in a low energy marine environment, below fair-weather wave base. Although the entire section of the Parahio Formation at this locality exceeds 1350 m in thickness, carbonate and dark shale facies typically form a small proportion of the total thickness of successive shoaling cycles, particularly in the lower parts of the section. This explains the limited number of beds bearing macrofossils (Fig. 3). Episodic delta-lobe switching led to nonsystematic stratigraphic changes in cycle and facies thickness (Myrow et al., 2006a). Thick carbonate beds near the top of the section are dolomitized and do not contain abundant trilobites, although a poorly preserved agnostoid shield was observed in one dolomite bed. In a few cases dolomite beds bear laminae

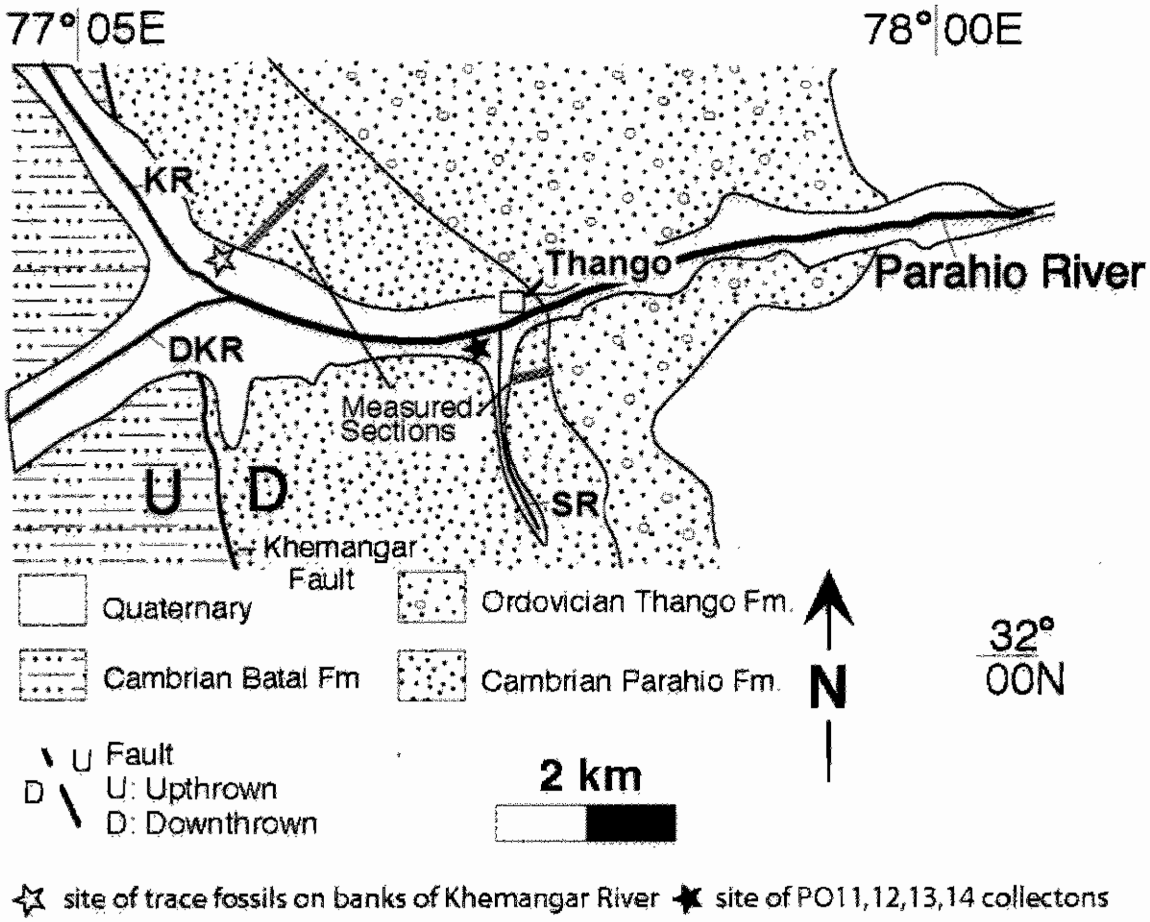


FIGURE 2—The position of the measured sections and other collecting sites in the Parahio River Valley, Spiti. Hayden's (1904) original section is the long section marked to the north of the Parahio and Khemangar Rivers. The collecting site of the trace fossils illustrated by Bhargava et al. (1982) and Parcha et al. (2005) is shown by the open star. KR indicates Khemangar River, DKR indicates Debsa Khad River, and SR indicates Sumna River.

rich in phosphatic brachiopods, and fossils described as conodonts have also been recovered from these beds (Bhatt and Kumar, 1980). Various trace fossils have been found at horizons scattered throughout the section.

In Zanskar (Fig. 5), the Parahio Formation is lithologically similar to its exposure in Spiti, although Zanskar may have been located in a slightly more distal setting (Myrow et al., 2006b). There the Parahio Formation is succeeded by the Karsha Formation, a thick red-weathering dolostone that represents a clear-water carbonate-platform setting and contains trilobites in its upper member (Myrow et al., 2006b) (Fig. 6). The Karsha Formation is conformably overlain by the Kurgiakh Formation (Fig. 6), which contains similar lithofacies to the Parahio Formation, and also bears Cambrian trilobites. The Kurgiakh Formation is unconformably overlain by the Ordovician molasse deposits of the Thaple Formation (Fig. 6), the lithological equivalent of the Thango Formation of the Parahio Valley. These relationships, along with the constraints provided by the trilobite biostratigraphy, suggest that in this sector of the Himalaya the Ordovician unconformity cut to deeper stratigraphic levels toward the southeast (Fig. 4).

We did not recover trilobites from carbonate beds in the Parahio Formation of Zanskar because these beds were almost entirely dolomitized (phosphatic brachiopods were collected from one of these beds, Fig. 6). We recovered trilobites from shale in the upper part of the Parahio Formation in the Purni section (Fig. 5), shortly beneath the contact with the Karsha Formation, and from a shale bed near the top of the Parahio Formation on the high slopes east of Kurgiakh village. Trilobites and phosphatic brachiopods were also recovered from several thin carbonate grainstone beds in the Teta Member of the Karsha Formation, and from shales in the overlying Surichun Member of the Kurgiakh Formation, both in the section opposite Kuru and in the section within Kurgiakh nulla (Figs. 5, 6).

PRIOR SYSTEMATIC AND BIOSTRATIGRAPHIC WORK

Previous systematic studies of Cambrian trilobites from Spiti and Zanskar, which include over ten publications, have been reviewed elsewhere (Jell and Hughes, 1997) with the exception of the following papers. Dungrakoti et al. (1977, pl. 30, fig. 1) figured a poorly preserved exoskeleton from the Kurgiakh nulla section that they attributed to the family Olenellidae. No specimen number or repository information was given for that fossil, and we have not been able to examine it. In the light of our results we consider their attribution unlikely to be correct, but we cannot recognize any diagnostic features in the published figure. Shah et al. (1996) and Kumar (1998) described and figured agnostoid and polymerid material from the Kurgiakh region of the Zanskar Valley, apparently from the north bank of the Tsarap Lingti River, a few kilometers east of Kurgiakh village. Our searches in that area did not relocate these levels, but we discuss this material

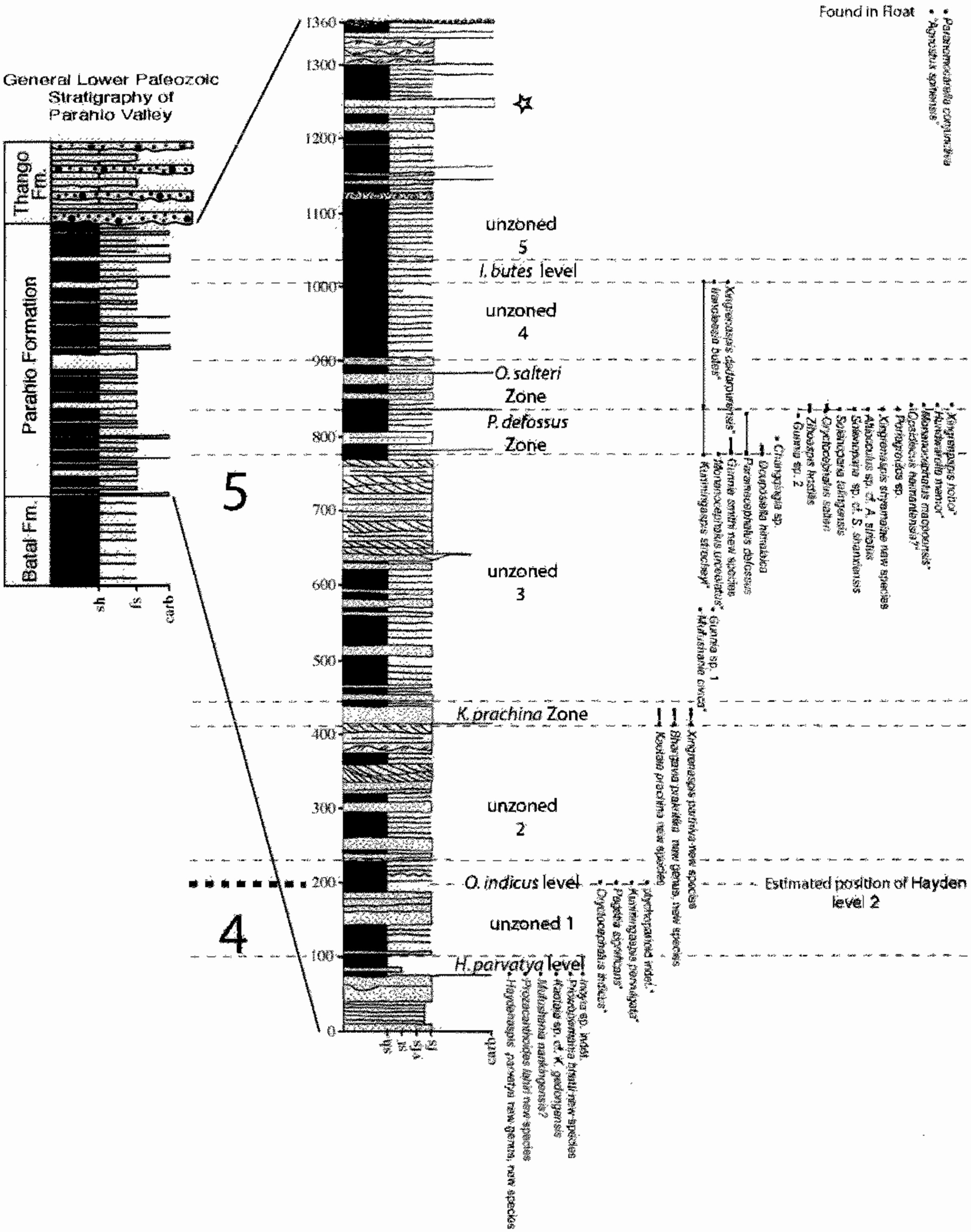


FIGURE 3—Composite stratigraphic section of the Cambrian rocks of the Parahio Formation in the Parahio Valley based on sections shown in Fig. 2, with trilobite occurrence, local ranges shown, and biozonation. Sedimentological and other details of the section are provided in Myrow et al. (2006a). The chart includes all trilobite species that we consider to be valid from this section, including those not recovered by us. * indicates species only known from shales. 4 and 5 refer to the new, informal stages of the Cambrian System. Here we represent the boundary between them at the first occurrence of *O. indicus*. Details of height in section and collection lithologies provided in Appendix 1 and 2. Note that the type specimens of *Agnostus spitiensis* Reed, 1910 are missing, and hence we are unable to verify the validity of this form. Open star indicates dolomite containing abundant acrotretid brachiopods. sh indicates shale. st indicates silt, vfs and fs indicates very fine sandstone and fine sandstone respectively, and carb indicates carbonate.

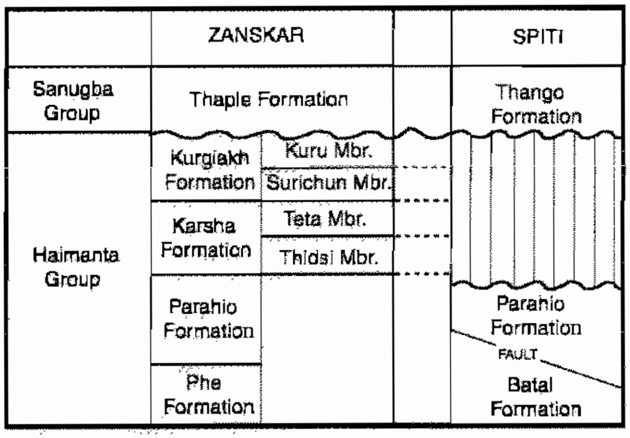


FIGURE 4—Lithostratigraphic correlation of the units considered in this work between the Zanskar and Spiti regions, based on Myrow et al. (2006b, fig. 2), and supported by the biostratigraphic zonation documented herein. Note that the contact between the Sanugba and Haimanta groups is an erosional unconformity in both sections, but that the entirety of the Karsha and Kurgiakh formations is missing in Spiti.

in the taxonomic discussions below, and estimate its stratigraphic position in our summary of the Cambrian biostratigraphy of this region (Fig. 6).

Refining the Cambrian biostratigraphy of the Himalaya requires the precise location of collections within continuous, measured stratigraphic sections. The most comprehensive attempt to date is that of Hayden (1904; Reed, 1910). Hayden's (1904, p. 14–15) section for the Parahio Formation at the type section accords with our own in terms of the identity and sequence of trilobite-bearing horizons and relative thicknesses between these horizons. However, Hayden's (1904) estimate of the total thickness of the Parahio Formation (362 m) is less than 25% of our own estimate (1360 m) for the same section. Hayden (1904, p. 13) argued that folding increased the apparent thickness of the section, but our work does not support that interpretation. We saw no evidence for structural complexity in the Parahio Formation other than minor faulting, and the trilobite collections occurred in a stratigraphic order consistent with that seen in other areas of Asia that have suffered little or no tectonism. Hayden (1904) recovered trilobites from five stratigraphic levels within his section: his levels 2, 4, 6, 9, and 13. We have recovered trilobite species from beds that represent each of these levels or their close equivalents with the exception of his level 2. We have also discovered two additional trilobite-bearing units located stratigraphically adjacent to those of Hayden's level 2 (Fig. 3).

Jell and Hughes (1997, fig. 4) presented a scheme for the correlation between the Parahio Valley and Zanskar regions, in addition to other parts of the Himalaya, but did not propose a formal biostratigraphic zonation for the region. Our work is consistent with the scheme that they proposed, and permits the recognition of a series of faunal levels and zones within the region.

The Hayden/Reed stratigraphy and our own differ from that presented in several other papers on the Cambrian trilobite biostratigraphy of the Parahio Valley (e.g., Shah and Sat Paul, 1987; Shah et al., 1988; Shah and Raina, 1990; Parcha, 1996, 1998). Those papers suggested that 12 fossiliferous horizons spanned parts of the traditional early, middle and late Cambrian across less than 400 m of Parahio Formation section and also mention an occurrence of *Redlichia* within the Parahio Valley section. Revisions by Jell and Hughes (1997) and the results of the present study indicate that the strata are nearly 1400 m thick and span much less of the Cambrian System. In addition, we did not recover any specimens of *Redlichia* or know of any *Redlichia* specimens previously recovered from this valley. Much of the material used to construct the alternative scheme has since been reassigned to different taxa (Jell and Hughes, 1997). However, these differences in the stratigraphic views extend beyond matters of taxonomic assignment. Our work is based on a stratigraphic section that was measured from base to top as we collected; the alternative scheme was made by estimating the relative stratigraphic positions of new findings with respect to older findings. Our inferred position of Hayden's level 2, which contains the important taxon *Oryctocephalus indicus*, is a projection, but it is based on our corrected estimates of the thickness of Hayden's section. We are explicit about the basis of this estimate and are reassured that this projected position is consistent with the recorded position of *O. indicus* in other sections worldwide.

FOSSIL PRESERVATION

Almost all of the Cambrian trilobites previously described from Spiti and Zanskar have suffered significant flattening and tectonic shearing due to their preservation in deformed fine-grained siliciclastic rocks (such as is evident in Figs. 35, 56, 57). Such deformation can also induce novel features that have mistakenly been considered of taxonomic significance in some cases (see Hughes and Jell, 1992). On the other hand, trilobite material preserved in fine-grained siliciclastic rocks is more commonly articulated than that preserved in limestone or silica (e.g., Fig. 35) (Hughes, 1995). Out of the 75 Himalayan taxa that are recognized in this monograph, 31 are known exclusively from fine-grained siliciclastic strata, 28 exclusively from carbonate, and 16 are known from both facies (Appendix 2). Thus, 44 taxa are now known from carbonate material, and for four species we have been able to associate isolated sclerites preserved in carbonate with articulated specimens preserved in siliciclastic strata, allowing a more nearly complete characterization of these taxa. All but one of the 14 previously described species that we failed to recover in our new collections are from siliciclastic strata.

Although our carbonate collections are not free from the effects of compaction and tectonic shearing, the degree to which these factors have influenced the fossils is generally modest compared to that in associated shales. In certain cases in which specimens have experienced simple shear, we have employed digital retrodeformation in an attempt to restore the original form in order to facilitate comparison with undeformed material known from elsewhere (Hughes and Jell, 1992). The degree to which tectonism influenced specimens preserved in carbonate varied within beds, with some specimens showing deformation and others apparently free from it, and our figures illustrate both conditions.

DIVERSITY AND BIOFACIES

The time spent at different collecting levels ranged from 2 to 6 person-days per level. With the exception of the unusually diverse limestone beds at the top of the Teta Member of the Karsha Formation, the diversity of polymerid trilobites among the levels varied between three and ten species, and most collections appear to be dominated by a relatively small number of taxa. There is a remarkable abundance of agnostoid species in the upper parts of the Teta Member of the Karsha Formation and in the Surichun Member of the Kurgiakh Formation. This sharp increase in agnostoid diversity is consistent with the pattern seen elsewhere, and documented in particular detail in South China (Peng and Robison, 2000), and does not require a local explanation.

Carbonate and siliciclastic beds bearing species of similar stratigraphic age occurred at several levels, and these provide

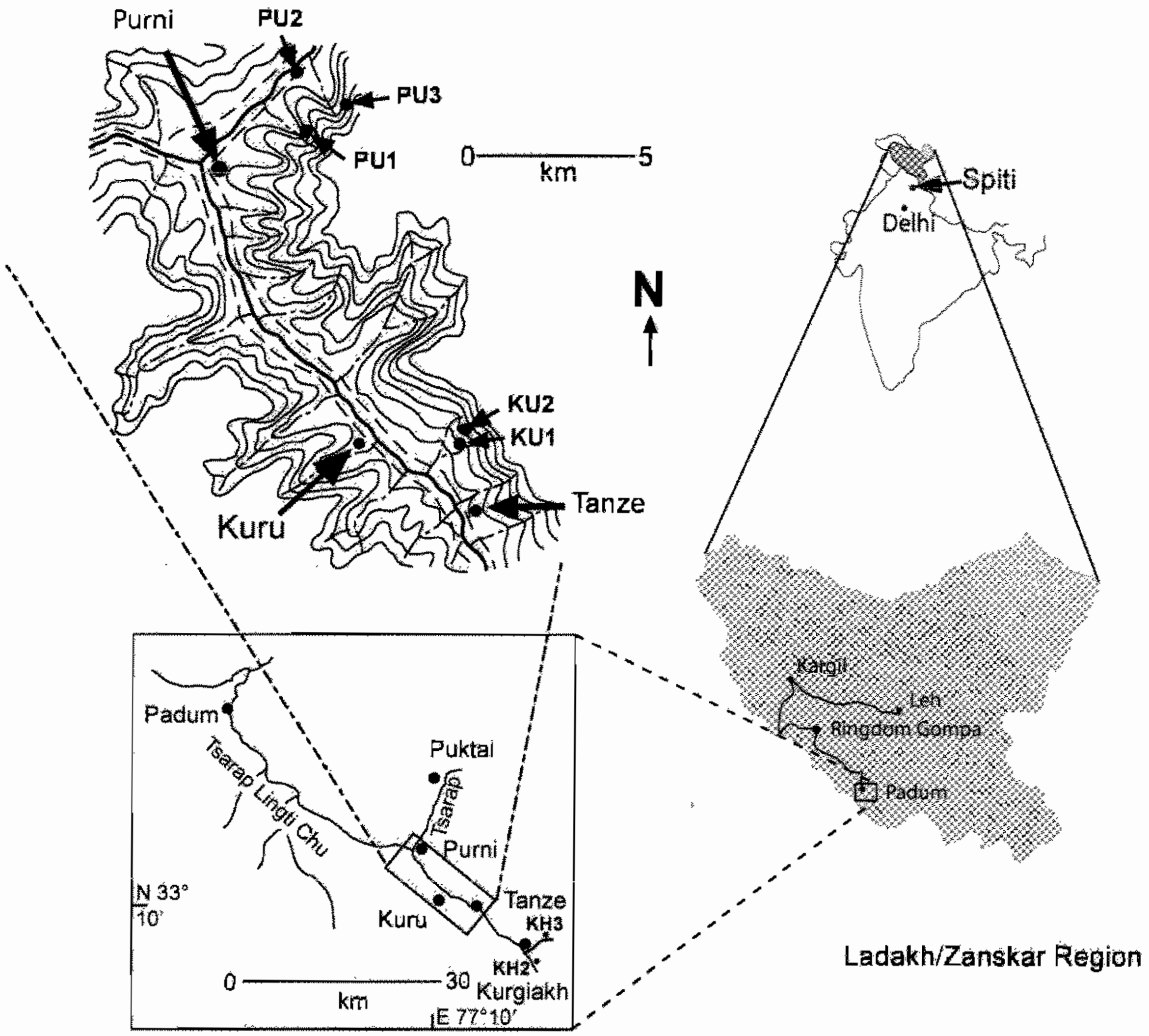


FIGURE 5—The position of the measured sections and collecting sites in the Zanskar Valley. KH2 and KH3 collecting sites near Kurgiakh: KU1 – Kuru 1 section, KU2 – Kuru 2 section, PU1 – Purni 1 section, PU2 – Purni 2 section, and PU3 – Purni 3 section.

some opportunity to assess the lithofacies preferences of species. The relatively long ranged ptychopariid *Kunmingaspis stracheyi* was abundant in shale beds from several horizons, but we did not record it in any of the carbonate beds that occurred within its stratigraphic range. On the other hand, we found many species in both carbonate and siliciclastic rocks. Biofacies differences between carbonate and siliciclastic facies are common among Cambrian trilobites (e.g. Ludvigsen and Westrop, 1983) and the occurrence of specific Himalayan taxa in both lithologies may suggest that the transitions between these facies in this setting did not reflect major shifts in paleoenvironment.

Kaotaia prachina n. sp. and *Bhargavia prakritika* n. gen. and sp. from the interval from 433.44 m to 439.67 m in the Parahio Valley section bore unusually thick exoskeletons. Thicker exoskeletons may suggest a need for robust shields in shallow water conditions (Fortey and Wilmott, 1991). However, the exoskeleton of the co-occurrent *Xingrenaspis parthiva* was apparently of normal thickness.

BIOSTRATIGRAPHY AND GLOBAL CORRELATION

The biostratigraphic zonation proposed here for the Tethyan Himalaya of northern India is based on the local occurrence of well-characterized taxa. Where age diagnostic taxa are restricted to single bed the term "level" is applied with the epithet of a species characteristic of that level. We apply the term "zone" when the eponymous species occurred in more than a single bed beneath the first appearance datum (FAD) of the next level or zone. Intervals of "no zonation" are indicated in thick, apparently barren, strata above levels or zones where further work is required to clarify the biostratigraphy. The base of each unit is defined by the FAD of the eponymous species and, where thick barren strata are absent, the base of the next overlying zone defines the top of each zone.

Our biostratigraphic study of Hayden's section in the Spiti Valley and three sections in the Zanskar Valley enable us to develop a formal biostratigraphic succession with six trilobite zones, three levels, and six intervals of no zonation for the Cambrian System of the Spiti and Zanskar Valleys (Figs. 3, 6). It spans an interval from the upper part of the as yet-unnamed global Stage 4 through the lower half of the Guzhangian Stage of the Cambrian System (Figs. 7–8). In ascending order these divisions are: the *Haydenaspis parvatya* level, interval 1 of no zonation, the *Oryctocephalus indicus* level, interval 2 of no zonation, the *Kaotaia prachina* Zone, interval 3 of no

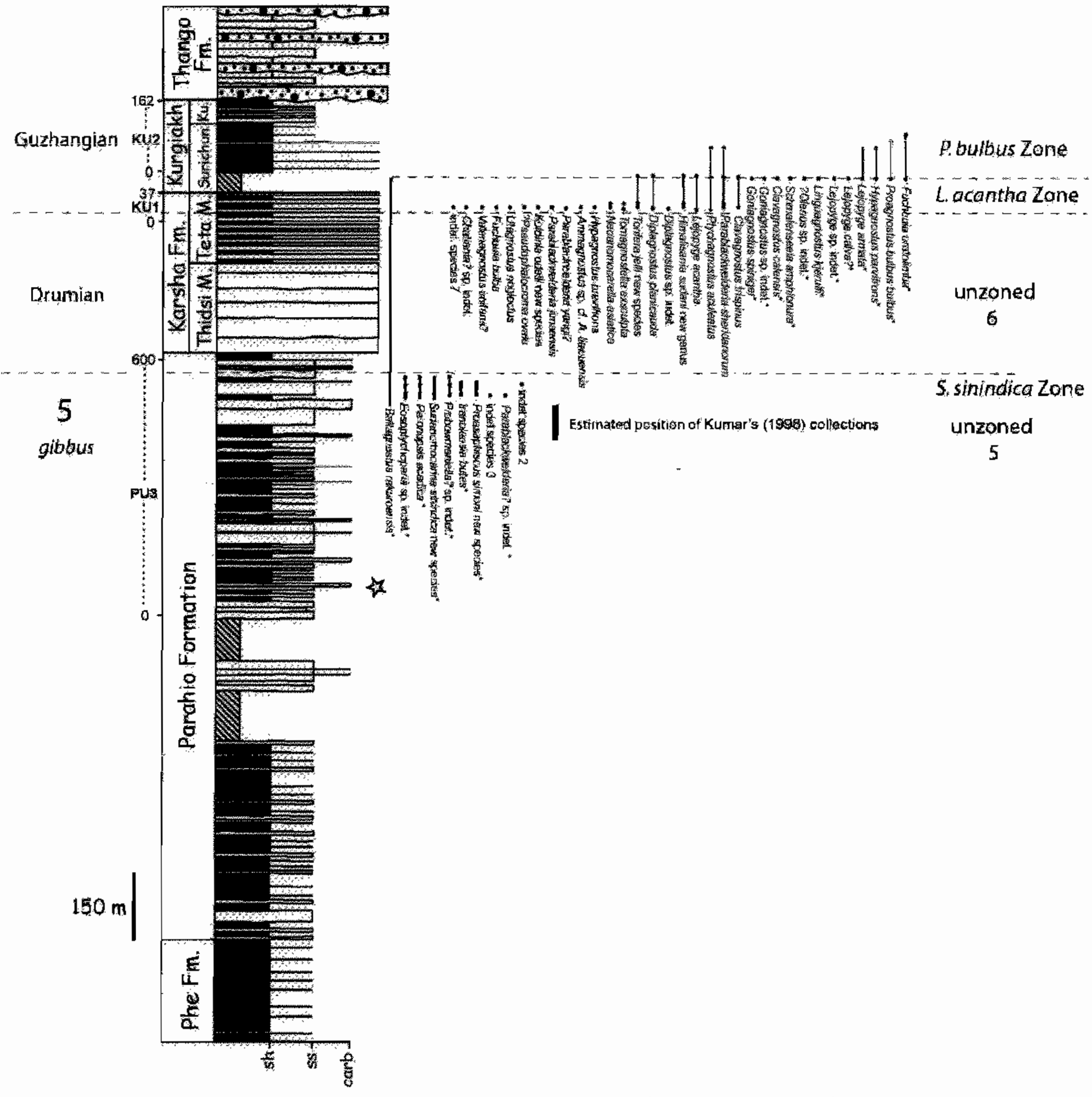
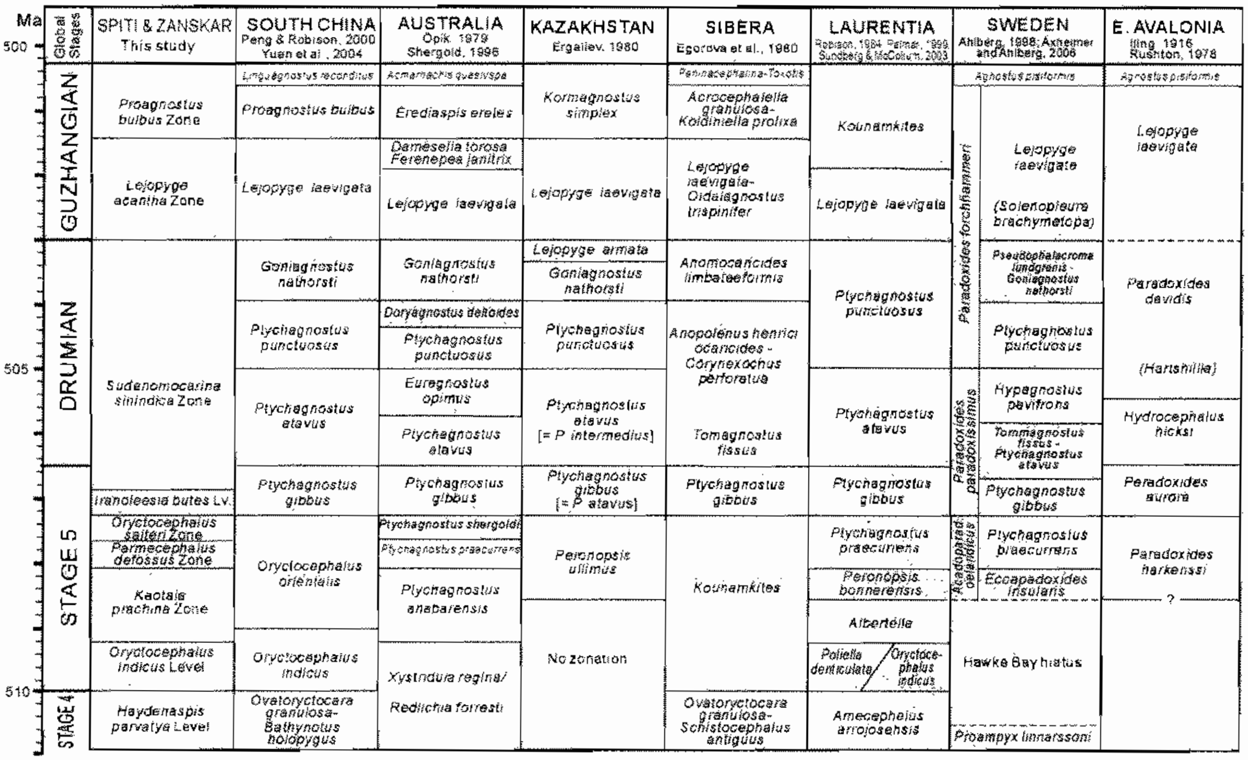


FIGURE 6—Composite stratigraphic section of the Cambrian rocks of the Parahio, Karsha and Kurgiakh Formations in the Zanskar Valley based on sections shown in Fig. 5, with trilobite occurrence, local ranges shown, and biozonation. Sedimentological and other details of the section are provided in Myrow et al. (2006b). * indicates species only known from shales. Measured sections containing material described herein are indicated. PU is Purni, KU is opposite Kuru. 5 refers to the new informal fifth stage of the Cambrian System. Open star indicates dolomite containing abundant acrotretid brachiopods. sh indicates shale, ss indicates sandstone, and carb indicates carbonate.

zonation, the *Paramecephalus defossus* Zone, the *Oryctocephalus salteri* Zone, interval 4 of no zonation, the *Iranoleesia butes* level, interval 5 of no zonation, the *Sudanomocarina sinindica* Zone, interval 6 of no zonation, the *Lejopyge acantha* Zone, and the *Proagnostus bulbus* Zone.

The relatively dense sampling of the beds of the Teta Member of the Karsha Formation and the overlying Surichun Member of the Kurgiakh Formation, coupled with the striking abundance of taxa, permits the recognition of a stratigraphically lower fauna characterized by the occurrence of *Lejopyge acantha* that is succeeded by a zone bearing *Proagnostus bulbus* (Fig. 6). A similar transition is known from multiple sections worldwide and provides grounds for constraining the age of these beds rather precisely (Fig. 7).

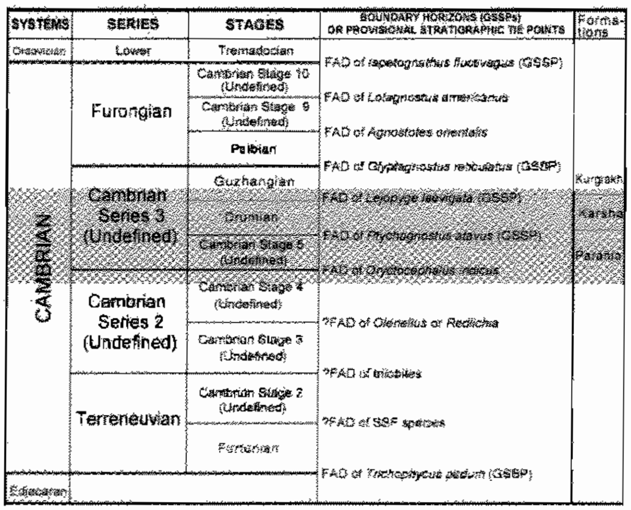
A striking characteristic of the biostratigraphic distribution of trilobite taxa from the Cambrian of Zanskar and Spiti is that trilobite-bearing beds are restricted to narrow stratigraphic intervals. Individual taxa were commonly collected from multiple horizons, sometimes of different lithology, within intervals around 10 m thick, but such horizons were



Ma	Global Stages	SPITI & ZANSKAR This study	SOUTH CHINA Peng & Robison, 2000 Yuan et al., 2004	AUSTRALIA Öpik, 1979 Shergold, 1996	KAZAKHSTAN Ergaliev, 1980	SIBERA Egorova et al., 1960	LAURENTIA Robison, 1984; Palmer, 1999; Sundberg & McCollum, 2003	SWEDEN Ahlberg, 1998; Axheimer and Ahlberg, 2006		E. AVALONIA Illing, 1916 Rushton, 1978
500	GUZHANGIAN	*Proagnostus bulbus* Zone	*Linguagnostus reconditus*	*Acmarhachis quasivespa*	*Kormagnostus simplex*	*Peninacephalina-Toxotis*	*Kounamkites*	*Agnostus pisiformis*		*Agnostus pisiformis*
			Proagnostus bulbus	*Erediaspis eretes*		*Acrocephalella granulosa-Koldiniella prolixa*		*Paradoxides forchhammeri*	*Lejopyge laevigata*	*Lejopyge laevigata*
		Lejopyge acantha Zone	*Lejopyge laevigata*	*Damesella torosa* *Ferenepea janitrix*	*Lejopyge laevigata*	*Lejopyge laevigata-Oidalagnostus trispinifer*	*Lejopyge laevigata*		*(Solenopleura brachymetopa)*	
				Lejopyge laevigata						
	DRUMIAN	*Sudenomocarina sinindica* Zone	*Goniagnostus nathorsti*	*Goniagnostus nathorsti*	*Lejopyge armata*	*Anomocarioides limbataeformis*	*Ptychagnostus punctuosus*		*Pseudophalacroma lundgrenis - Goniagnostus nathorsti*	*Paradoxides davidis*
					Goniagnostus nathorsti					
			Ptychagnostus punctuosus	*Doryagnostus deltoides*	*Ptychagnostus punctuosus*	*Anopolenus henrici ocarioides - Corynexochus perforatus*			*Ptychagnostus punctuosus*	
				Ptychagnostus punctuosus						*(Hartshillia)*
505			*Ptychagnostus atavus*	*Euagnostus opimus*	*Ptychagnostus atavus* [= *P intermedius*]		*Ptychagnostus atavus*	*Paradoxides paradoxissimus*	*Hypagnostus parvifrons*	*Hydrocephalus hicksi*
				Ptychagnostus atavus		*Tomagnostus fissus*			*Tommagnostus fissus - Ptychagnostus atavus*	
	STAGE 5	*Iranoleesia butes* Lv.	*Ptychagnostus gibbus*	*Ptychagnostus gibbus*	*Ptychagnostus gibbus* [= *P atavus*]	*Ptychagnostus gibbus*	*Ptychagnostus gibbus*		*Ptychagnostus gibbus*	*Paradoxides aurora*
		Oryctocephalus salteri Zone	*Oryctocephalus orientalis*	*Ptychagnostus shergoldi*	*Peronopsis ultimus*	*Kounamkites*	*Ptychagnostus praecurrens*	*Acadoparad. oelandicus*	*Ptychagnostus praecurrens*	*Paradoxides harkenssi*
		Paramecephalus defossus Zone		*Ptychagnostus praecurrens*						
		Kaotaia prachina Zone		*Ptychagnostus anabarensis*			*Peronopsis bonnerensis*		*Eccaparadoxides insularis*	?
					No zonation		*Albertella*	Hawke Bay hiatus		
		Oryctocephalus indicus Level	*Oryctocephalus indicus*	*Xystridura regina/ Redlichia forresti*			*Poliella denticulata* / *Oryctocephalus indicus*			
510	STAGE 4	*Haydenaspis parvatya* Level	*Ovatoryctocara granulosa-Bathynotus holopygus*			*Ovatoryctocara granulosa-Schistocephalus antiguus*	*Amecephalus arrojosensis*	*Proampyx linnarssoni*		

FIGURE 7—Correlation between the Cambrian biostratigraphy of Zanskar and Spiti with that of other regions. Note that, for the purpose of interregional comparison, the Himalayan levels and zones are here shown to encompass the interval from their first occurrence datum (FAD) until the FAD of the next zone or level. Lv. signifies level.

often separated by more than 100 m of unfossiliferous rock (Figs. 3, 6). Taxa that ranged over thick (~100 m or more) intervals include the agnostid *Ptychagnostus aculeatus* and probably also *Peronopsis acadica*, and polymerids including *Kunmingaspis stracheyi* and *Parablackwelderia sheridanorum*. Specimens of *Paramecephalus defossus* and *Shantungaspis himalaica* were collected from an interval that spanned about 80 m of the Parahio Formation in the Parahio Valley section.



SYSTEMS	SERIES	STAGES	BOUNDARY HORIZONS (GSSPs) OR PROVISIONAL STRATIGRAPHIC TIE POINTS	Formations
Ordovician	Lower	Tremadocian	FAD of *Iapetognathus fluctivagus* (GSSP)	
CAMBRIAN	Furongian	Cambrian Stage 10 (Undefined)	FAD of *Lotagnostus americanus*	
		Cambrian Stage 9 (Undefined)	FAD of *Agnostotes orientalis*	
		Paibian	FAD of *Glyptagnostus reticulatus* (GSSP)	
	Cambrian Series 3 (Undefined)	Guzhangian	FAD of *Lejopyge laevigata* (GSSP)	Kurgiakh
		Drumian	FAD of *Ptychagnostus atavus* (GSSP)	Karsha
		Cambrian Stage 5 (Undefined)	FAD of *Oryctocephalus indicus*	Parahio
	Cambrian Series 2 (Undefined)	Cambrian Stage 4 (Undefined)	?FAD of *Olenellus* or *Redlichia*	
		Cambrian Stage 3 (Undefined)	?FAD of trilobites	
	Terreneuvian	Cambrian Stage 2 (Undefined)	?FAD of SSF species	
		Fortunian	FAD of *Trichophycus pedum* (GSSP)	
Ediacaran				

FIGURE 8—The Cambrian sections of the Spiti/Zanskar region in the context of global Cambrian stratigraphy. The Himalayan sections (shaded portion) represent a relatively small proportion of the Cambrian System.

We interpret the restriction of most taxa to narrow stratigraphic intervals to reflect the paleoenvironment and accumulation history of these deposits: collections are localized near the boundaries of major shoaling cycles. The stratigraphic thickness between our oldest and youngest collections in the Parahio Valley, PO3 and PO10, is approximately 900 m. The Kaili Formation in Guizhou Province of the South China block represents a significantly longer temporal interval and is 326 m thick at its type section (Zhang et al., 1979). Similarly, while the stratigraphic interval between the base of the range of *Sudananomocarina sinindica* and *Proagnostus bulbus* is about 270 m in the Paibian type section at Paibi in northwestern Hunan (Peng and Robison, 2000), the same interval is apparently about double that thickness in Zanskar, where it is represented by the carbonate-rich Karsha Formation. Hence, the Indian sections are relatively thick, consistent with the interpretation of their being largely the products of deltaic deposition.

The average sediment accumulation rate calculated for the measured thickness of the Parahio Formation in the Parahio Valley section was 30.4 cm/1000 years, a high rate that is similar to time averaged accumulation rates in deltaic settings (Myrow et al., 2006a). Much of the time represented by the section was likely accommodated at disconformity surfaces and within stratigraphically condensed horizons associated with the boundaries between depositional cycles. For example, the transition between the top of the range of *P. defossus* and the first appearance of the fauna of the subsequent *Oryctocephalus salteri* Zone, occurs within a 3 m interval (Fig. 3). If the degree of faunal transition was related to temporal duration, more Cambrian time may be represented within that 3 meter interval than in the 80 m preceding it, which all bears the fauna of the *defossus* Zone.

The age of the interval studied herein is well constrained by many of the polymerid trilobites that are endemic to eastern Gondwana and that provide correlation with well established successions in China and Australia, and by the rich assemblages of agnostoids in the *Lejopyge acantha* and *Proagnostus bulbus* zones (Figs. 3, 6). The later enable a precise global correlation for those Tethyan Himalayan zones (Figs. 7, 8). The *Lejopyge acantha* zone correlates globally with the *Lejopyge laevigata* Zone and, as defined, the FAD of *Lejopyge laevigata* coincides with the base of the global Guzhangian Stage (Peng and Babcock, 2008; Peng et al., 2009). In addition to the agnostoids, the age of the interval studied is constrained by the occurrence of *Oryctocephalus indicus* in the lower part of the Parahio Formation in the Parahio Valley section. As one of the key international stratigraphic marker species for this time interval, the FAD of *Oryctocephalus indicus* is one of the criteria proposed for defining the base of the as-yet-unnamed global Stage 5 (Peng and Babcock, 2005; Babcock et al., 2005).

Haydenaspis parvatya *level.*—The oldest fauna in Hayden's section is recorded at 78.07 m above the base of the Parahio Formation, Parahio Valley, Spiti (Fig. 3), where the eponymous species, *Haydenaspis parvatya* n. gen. and sp., occurs in association with *Prozacanthoides lahiri* n. sp. and some basal ptychoparioids including *Probowmania bhatti* n. sp. and *Mufushania nankingensis?* The latter species is closely comparable to *M. nankingensis*, which occurs in the basal Maochuangian Stage and equivalent formations in China (Yuan et al., 2002), and suggests that this level is equivalent to the base of the Maochuangian as used in North China, or within the top part of the Duyunian Stage as used in South China. Globally, this level lies within the upper part of the as-yet-unnamed Stage 4 of the Cambrian System, and thus to the uppermost part of the second Series of the Cambrian System (Figs. 7, 8).

Oryctocephalus indicus *level.*—Unfortunately, we recovered no *O. indicus* (Reed, 1910) in our collections, but Hayden (1904) recovered the eponymous species in association with *Kunmingaspis pervulgata* (Reed, 1910), *Pageria significans* (Etheridge, 1902) and an undetermined ptychoparioid species from his level 2, in the lower part of the Parahio Formation in the same section (Fig. 3). An *Oryctocephalus indicus* Zone has been recognized in South China and in the Great Basin (Yuan et al., 2002; Sundberg and McCollum, 2003). Although neither the stratigraphical range nor FAD of *Oryctocephalus indicus* is precisely known in the Parahio Valley section, where our collections show species in common with his, the relative thicknesses of the stratigraphic intervals between Hayden's collecting horizons correlate well with our own, despite Hayden's (1904) significant underestimate of the total stratigraphic thickness of the entire section. Hence we can project the stratigraphic height of Hayden's *O. indicus* level within our section. We estimate the *O. indicus* level to be at about 200 m above the base of the measured section (Fig. 3), which also is the level at which a thick sandstone unit is succeeded by a thick shale, probably equivalent to the boundary between a large-scale shoaling cycle. Globally, the FAD of *O. indicus* will perhaps be used for defining the base of the as-yet-unnamed Stage 5 of the Cambrian System (Peng and Babcock, 2005; Babcock et al., 2005) (Figs. 7, 8). The Tethyan Himalayan *O. indicus* level in Spiti appears to correlate with the base of the Taijiangian Stage in South China and with a level within the basal part of Delamaran Stage, which is close to the boundary between the Delamaran and the underlying Dyeran stage in Laurentia. In South China, the base of the informal global Stage 5 lies at about the level of the top of the lower third of the Kaili Formation (Peng at al., 2004c; Yuan et al., 2002; Zhao et al., 2004) (Figs. 7, 8).

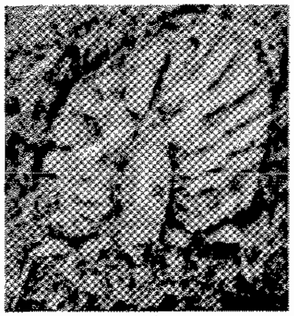
Kaotaia prachina *Zone.*—Three new species, *Kaotaia prachina* n. sp., *Bhargavia prakritika* n. gen. and n. sp., and *Xingrenaspis parthiva* n. sp., characterize this zone (Fig. 3). The lowest occurrence of the eponymous species is at 433.4 m above the base of the Parahio Formation in the Parahio Valley section, and the zone extends at least up to 439.67 m. The potential for correlation of the zone is limited because each of these species is new, but based on its inferred stratigraphic position above the *Oryctocephalus indicus* level and below that of *Paramecephalus defossus*, it must lie within the lower part of the informal global Stage 5. Both the occurrence of *Kaotaia* (sensu stricto), which ranges through the middle and upper parts of the Kaili Formation in South China (*O. indicus* Zone through *Oryctocephalus orientalis* Zone) (Zhang et al., 1980a; Yuan et al., 2002), and the occurrence of *Bhargavia* in the Great Basin, which occurs in the *Albertella* Zone of the Carrara Formation (Palmer and Halley, 1979), support this correlation.

At 580.2 m in the Parahio Valley section we collected *Gunnia* sp. 1 (Fig. 3). We estimate this to be equivalent to the position of Hayden's (1904) level 4, from which he collected material that we here attribute to *Mufushania* sp.

Paramecephalus defossus *Zone.*—The middle part of the Parahio Formation in Hayden's section contains a fauna including *Kunmingaspis stracheyi* (Reed, 1910), *Gunnia smithi* n. sp., *Paramecephalus defossus* (Reed, 1910), *Douposiella himalaica* (Reed, 1910), and *Changqingia* sp. *Monanocephalus urceolatus* (Reed, 1910) also belongs to the fauna (Hayden, 1904; Reed, 1910; Jell and Hughes, 1997) (Fig. 3). *Paramecephalus defossus* initially appears in shale 765.14 m above the base of the Parahio Formation and we infer this to be the site of Hayden's (1904) level 6. All species are confined to this zone except for *K. stracheyi*, which ranges upward into the *Oryctocephalus salteri* Zone. The interval occupied by this zone and the subsequent *O. salteri* Zone is probably correlated to the middle of the Taijiangian Stage of South China based on their faunal assemblage, and this correlation is discussed further below.

Oryctocephalus salteri *Zone.*—This zone contains the richest and most diverse trilobite assemblage within the Parahio Valley section (Fig. 3). It occurs within a 0.75 m interval on the north side of the Parahio Valley, where its base is at 835.66 m, and within an equivalent stratigraphic interval of no more than 10 m thickness at the northwestern end of the Sumna Valley, Spiti (Fig. 2). The lowest occurrence of the eponymous species is associated with *Ziboaspis hostilis* (Reed, 1910). Other trilobites belonging to this zone are from slightly higher levels from the Sumna Valley and include *Opsidiscus haimantensis?* (Reed, 1910), *Monanocephalus maopoensis* (Reed, 1910), *Hundwarella memor* (Reed, 1910), *Solenoparia talingensis* (Dames, 1883), *Solenoparia* sp. cf. *S. shanxiensis* (Zhang and Wang, 1985), *Altiocculus* sp. cf. *A. striatus* (Nan and Chang, 1980), *Xingrenaspis shyamalae* n. sp., *Poriagraulos* sp. indet., and *Gunnia* sp. 2. All these species are confined to this zone, which also contains a shale at 836.41 m above the base of the section on the north side of the Parahio Valley, which is the location of Hayden's (1904) level 9.

With the exceptions of *Altiocculus*, *Hundwarella*, and *Opsidiscus*, all of the genera in this and the underlying *Paramecephalus defossus* Zone occur in South China exclusively in formations belonging to the Taijiangian Stage (i.e., the Doupossu, Kaotai and the middle and upper Kaili formations), and in North China within formations belonging to the upper Maochuangian and lower Hsuchuangian stages. *Solenoparia talingensis* provides specific correlation with the upper Hsuchuang Formation in central Shandong Province, North China. In Australia, *Gunnia* is known from formations of the Ordian-early Templetonian stages, and Kruse (1990)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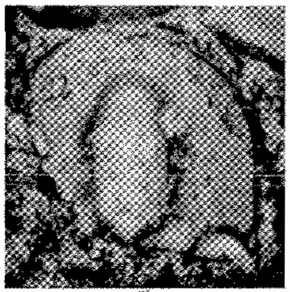
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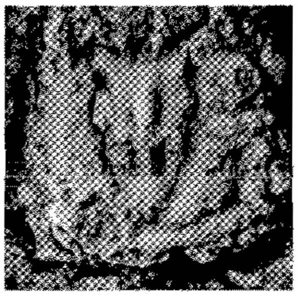
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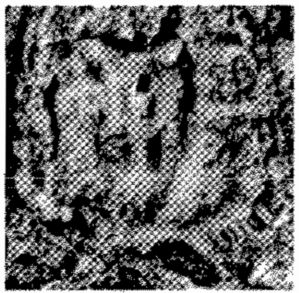
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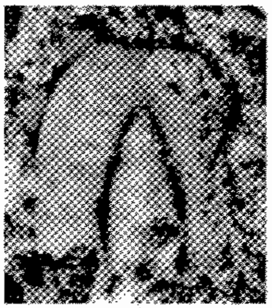
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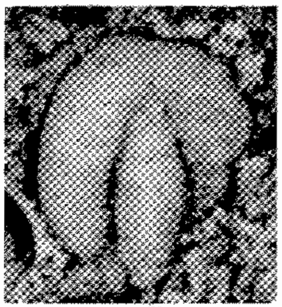
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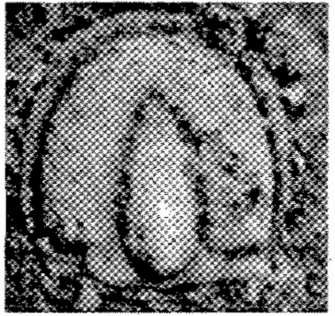
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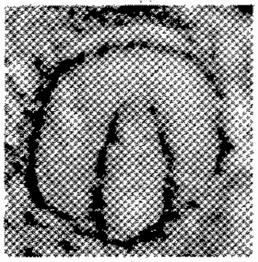
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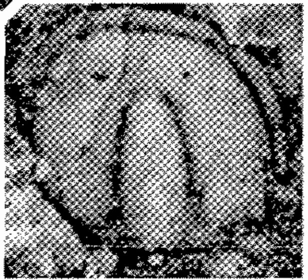
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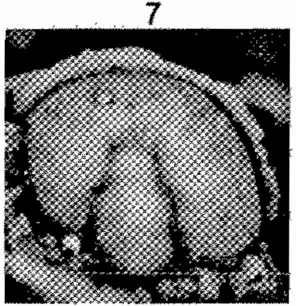
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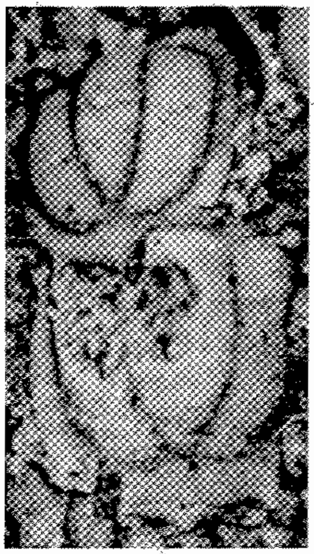
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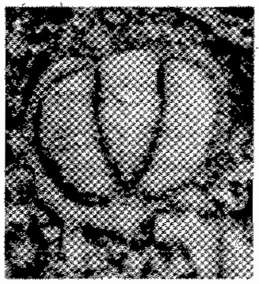
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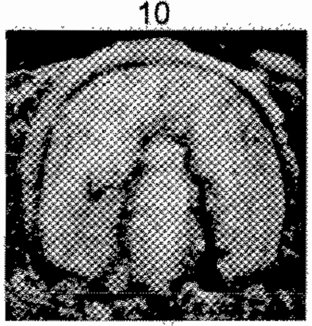
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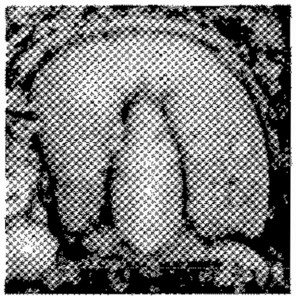
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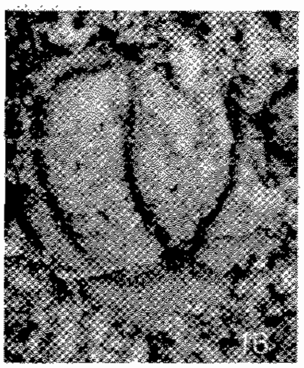

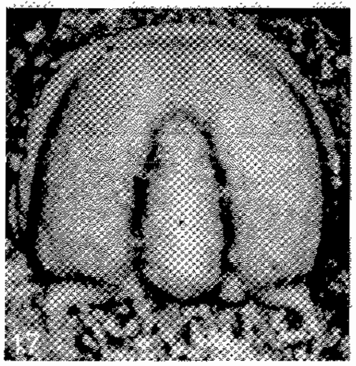

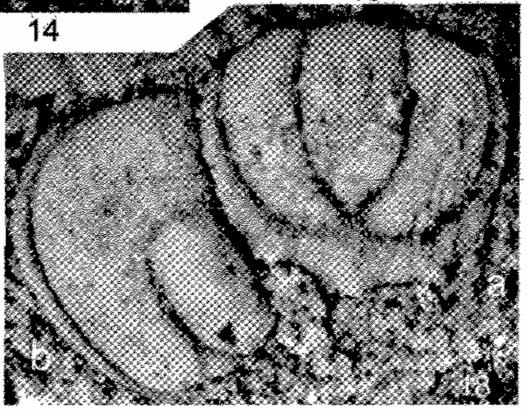

reported a post-*Redlichia* age for *G. lutea* in the Daly Basin, North Territory. *Opsidiscus* is a fairly widespread form, known from the middle Cambrian of Australia, the Altai Mountains, the Siberian Platform, Greenland, and Sweden. Taking these stratigraphic positions into account, the Tethyan Himalayan *Paramecephalus defossus* and *Oryctocephalus salteri* zones are best correlated with the middle Taijiangian Stage of South China, and with the upper Early or early Late Templetonian stages of Australia (Fig. 7).

Iranoleesia butes *level.*—Only the eponymous species occurs in this level in our collection, but a previously described specimen of the species *Xingrenaspis dardapurensis* (Reed, 1934) from Hayden's (1904) level 13 has also been reported to occur at this level, which is at about 1050 m above the base of the section (Fig. 3). Jell and Hughes (1997) suggested a latest Hsuchuangian age for this level, which corresponds to the late Taijiangian of South China (probably in the *Ptychagnostus gibbus* Zone). Although we did not recognize any level or zone that could be directly correlated between the Parahio Valley and Zanskar Valley sections using trilobites, the lowest trilobite-bearing beds that we recovered from the Parahio Formation in Zanskar (the *Sudanomocarina sinindica* Zone) may be only slightly younger than the uppermost trilobite beds we recognized in the Parahio Valley section (the *Iranoleesia butes* level), as the species *Iranoleesia butes* is common to both horizons.

Sudanomocarina sinindica *Zone.*—This zone occupies the topmost part of the Parahio Formation in the Purni 1 section in the Zanskar Valley (Fig. 6). *Sudanomocarina sinindica* n. sp. is the most common taxon, and has been collected from 6 beds, with its lowest observed occurrence at 500.32 m, where it is associated with *Peronopsis acadica* and *Eosoptychoparia* sp. Its highest observed occurrence is at 510.04 m in the section. Other species that also characterize the zone include *Proasaphiscus simoni* n. sp. and *Hundwarella memor?*, both of which occur within the range of the eponymous species. *Sudanomocarina* is known from the upper *Ptychagnostus gibbus* Zone through the basal *Lejopyge laevigata* Zone in South China, which is equivalent to the uppermost Taijiangian through basal Guzhangian stages, the *Peronopsis* [=*Euagnostus*] *opimus* Zone in Queensland, which corresponds to the upper part of the *P. atavus* Zone of South China, and to the *Crepicephalus* Zone in North China, which roughly corresponds to the *P. gibbus* and *P. atavus* zones of South China. This suggests a correlation of the *Sudanomocarina sinindica* Zone with the uppermost Taijiangian plus the overlying Wangcunian stages of South China or the Floran and Undillian stages of Australia (Shergold et al., 1985) (Fig. 7). The occurrence of *Proasaphiscus* in the eqnivalent interval in both South and North China supports this correlation. *Peronopsis acadica* has its upper boundary within this interval (Robison, 1995).

Lejopyge acantha *Zone.*—The Teta Member of the Karsha Formation in Kuru 1 section (Fig. 5) includes the most diverse trilobite assemblage yet known in the Himalaya, and is dominated by the presence of agnostoid taxa (Fig. 6). The agnostoid fauna collected includes *Ammagnostus* sp. cf. *A. laiwuensis* (Lorenz, 1906), *Clavagnostus trispinus* Zhou and Yang *in* Zhou et al., 1977, *Diplagnostus planicauda* (Angelin, 1851), *Diplagnostus* sp., *Hypagnostus brevifrons* (Angelin, 1851), *Lejopyge acantha* Robison, 1984, ?*Pseudophalacroma ovale* Yang, 1982, *Ptychagnostus aculeatus* (Angelin, 1851), *Tomagnostella exsculpta* (Angelin, 1851), *Utagnostus neglectus* Jago, 1976a, and *Valenagnostus imitans*? The associated polymerid trilobites in our new collections include *Chatiania*? sp., *Fuchouia bulba* Peng et al. 2004a, *Koldinia odelli* n. sp., *Himalisania sudani* (Jell and Hughes, 1997), *Neoanomocarella asiatica* Hsiang *in* Egorova et al., 1963, *Torifera jelli* n. sp., *Parablackwelderia jimaensis* (Yang *in* Lu et al., 1974a), *P. sheridanorum* (Jell and Hughes, 1997), and *P. yangi*? This fauna is clearly age equivalent to the *Lejopyge laevigata* Zone of South China (Peng and Robison, 2000; Peng et al., 2004a,b), and all these Himalayan agnostoid taxa are also common in the *Lejopyge laevigata* Zone in other parts of the world. This interval of the Teta Member of the upper Karsha Formation is referred to the *Lejopyge acantha* Zone. As noted by Peng and Robison (2000), the *L. laevigata* Zone of South China is correlatable with the *Solenopleura brachymetopa* Zone of Sweden (Westergård, 1946), and to the lower part of the revised *L. laevigata* Zone of Sweden, into which the Swedish *S. brachymetopa* Zone has recently been merged (Axheimer et al., 2006). Globally, the Himalayan *Lejopyge acantha* Zone can be correlated with the basal part of Guzhangian Stage as the base of the stage coincides with the FAD of *Lejopyge laevigata* (Peng et al., 2009) (Figs. 7, 8).

Proagnostus bulbus *Zone.*—The Surichun Member of the Kurgiakh Formation constitutes the *Proagnostus bulbus* Zone (Fig. 6). The KH3 collection from the Surichun La nulla section, north of Kurgiakh, Zanskar Valley, yields a diverse fauna with *Baltagnostus rakuraensis* (Kobayashi, 1935), *Clavagnostus calensis* Rusconi, 1950a, *Diplagnostus planicauda* (Angelin, 1851), *Fuchouia oratolimba* Yang *in* Zhou et al., 1997, *Goniagnostus spiniger* (Westergård, 1931)(see Jell and Hughes, 1997, Peng and Robison, 2000), *Goniagnostus* sp. indet., *Himalisania sudani* (Jell and Hughes, 1997), *Hypagnostus parvifrons* (Linnarsson, 1869), *Lejopyge acantha* Robison, 1984, *Lejopyge armata* (Linnarsson, 1869), *Lejopyge calva*?, *Lejopyge* sp., *Parablackwelderia sheridanorum* (Jell and Hughes, 1997), *Schmalenseeia amphionura* Moberg, 1903, *Torifera jelli* n. sp., *Hypagnostus parvifrons* (Linnarsson, 1869), *Linguagnostus kjerulfi* (Brögger, 1878), and *Proagnostus bulbus bulbus* Butts, 1926.

Proagnostus bulbus bulbus also occurs 97.44 m above the base of the Kuru 2 section (in collection KU2) on the north side of the Tsarap Lingti Chu, Zanskar Valley.

The eponym suggests a direct correlation to the *P. bulbus* Zone of South China. The presence of *Fuchouia oratolimba* in the *Proagnostus bulbus* Zone of both countries supports this correlation. The *Proagnostus bulbus* Zone of South China corresponds to the traditional *Lejopyge laevigata* Zone of Sweden (Peng and Robison, 2000), which corresponds only to

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FIGURE 9—Clavagnostidae from the Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1,2*, *Clavagnostus calensis* Rusconi, 1950a, cephalon from shale collected at KH3 locality in Surichun La nulla, Surichun Member, Kurgiakh Formation, Zanskar. WIHGF635, ×15. *3–5*, *Clavagnostus trispinus* Zhou and Yang *in* Zhou, Liu, Mong, and Sun, 1977 from limestone at 36.55 m (KU4 collection) above base of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu. *3*, cephalon, WIHGF701, ×13. *4, 5*, pygidium, WIHGF697A and -697B, ×11.5: *4*, WIHGF679A; *5*, latex of counterpart, WIHGF679B. *6–18a*, *Utagnostus neglectus* Jago, 1976 from limestone collected at 36.05 m above base (KU6 collection) above base of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu. *6–11, 13, 14, 17*, cephala: *6*, WIHGF609.10, ×32; *7*, WIHGF609.8, ×37.5; *8*, WIHGF609.2, ×36.25; *9*, WIHGF609.12, ×43.5; *10*, WIHGF609.13, ×29.5; *11*, WIHGF609.4, ×37; *12*, pygidium, WIHGF609.6, ×34.25; *13*, WIHGF609.7, ×33.5; *14*, WIHGF1007, ×22; *15*, two pygidia, WIHGF609.6, ×42; *16*, pygidium WIHGF1027.2, ×39; *17*, WIHGF609.3, ×31.75; *18*, pygidium (labeled 'a'), WIHGF609.5, with cephalon of *Hypagnostus brevifrons* WIHGF609.14. (labeled 'b'). ×37.5.

the upper half of the expanded *Lejopyge laevigata* Zone (Axheimer et al., 2006) (Figs. 7, 8).

Significant additional material from these sections.—The record of *Paranomocarella conjunctiva* (Reed, 1910) within a "limestone conglomerate" near "Changnu Encamping Ground" near the confluence of the "two main branches of the Parahio River" (Hayden, 1904, p. 17; Reed, 1910, p. 46) is problematical. We take this location to be where the Parahio River meets the Sumna River. Our collections PO11–PO14 were from a limestone outcrop on the south bank of the Parahio River near this point, but no limestone conglomerate was recorded there or anywhere in our stratigraphic analysis of the Parahio Formation. Furthermore, specimens collected from this level are clearly older than rocks elsewhere that bear *Paranomocarella* or *Szeaspis*. The only conglomerate that we have seen in the Parahio section is the Thango Formation itself, which is made up of locally derived clasts (Myrow et al. 2006a). The most parsimonious explanation is that the three specimens of *Paranomocarella conjunctiva* were derived from a clast within the Thango conglomerate, which accounts for the anomalously young age of these specimens compared to those known from Hayden's measured section. This is also consistent with our estimate of the age of the top of the Parahio Formation in Zanskar, which is younger than the top of the Parahio Formation in the Parahio Valley but older than the base of the known stratigraphic range of *Paranomocarella* and *Szeaspis*.

We were unable to relocate the site of Kumar's (1998) collection from the Kurgiahk region of the Zanskar Valley but, on the basis of inspection of the published figures, we consider it to contain *Peronopsis acadica*, *Eosoptychoparia* sp., and undetermined proasaphiscid and kooteniid trilobites. From this assemblage, and the location reported, we consider it to be stratigraphically situated within the interval spanning the *Iranoleesia butes* level to the *Sudanomocarina sinindica* Zone. From Kumar's (1998) description his locality may have been close to the site of our KH2 locality.

REGIONAL CORRELATION

Our refined biostratigraphic scheme accords with the general scheme presented by Jell and Hughes (1997), Hughes (1997) and Hughes and Jell (1999), and an updated, integrated review of the Cambrian biostratigraphy of the Himalaya will be published after we complete further systematic work on material from elsewhere in the Himalaya. Here we comment on the relationship between the Cambrian fauna of the Parahio Valley and that of the Pohru Valley of Kashmir, as this has recently been debated (Parcha, 2005a,b, 2006; Hughes, 2006).

With regard to the age of the youngest Cambrian Kashmiri faunas, regional correlations suggest that all Kashmiri taxa, including the damesellid material (Shah and Sudan, 1983, 1987a) and that described by Jell (1986) pre-date the level at which *Linguagnostus reconditus* first appears. As the FAD of *L. reconditus* defines the base of the traditional "late Cambrian", no "late Cambrian" trilobites are yet known from the Tethyan Himalaya of India. Hence, this conclusion applies not only to the Parahio Formation in the Parahio Valley, which has persistently been considered to range up into the late Cambrian (e.g. Reed, 1910; Parcha, 2008) but to all rocks in the Indian Tethyan Himalaya. However, Furongian trilobites are known from TH-equivalent rocks in Bhutan (Hughes et al., in review).

The biostratigraphy of well-sampled sections suggests that morphologically distinctive, eurytopic, and geographically widespread trilobites from the Nutunus Formation in Kashmir such as *Tonkinella breviceps* and *Bailiella lantenoisi* are younger than the *Paramecephalus defossus* Zone of the Parahio Formation, and likely correlate with the *Oryctocephalus salteri* Zone or *Iranoleesia butes* level in the upper part of the Parahio Formation. This conclusion, first proposed by Jell and Hughes (1997), is snpported by recent detailed work on the Cambrian stratigraphy of South China (Yuan et al., 2002) and other areas (Sundberg, 1994; Gozalo et al., 2003). Hence we reject the recent reassertion (Parcha, 2005a, 2006) of the view that trilobites from the lower part of the Nutunus Formation indicate temporal equivalence to the lower part of the Parahio Formation.

The occurrence of trilobites in Spiti and Zanskar is restricted to relatively narrow stratigraphic intervals within the unusually thick successions that resulted from deltaic deposition. Sampling intervals within such successions are expected to be restricted to narrow horizons of locally variable age. Hence, temporally sporadic preservation of trilobite-bearing facies likely contributes to the apparent "patchiness" of the local biostratigraphic record. In this context the absence of *T. breviceps* and *B. lantenoisi* in the Parahio Valley section is unremarkable, and may not require marked biofacies differentiation between the Kashmiri and Parahio Valley sections that has been invoked by some authors (e.g. Shah, 1993).

FAUNAL PROVINCIALITY

Tabulation of genera and species from Zanskar and Spiti in the context of global occurrence (Table 1) confirms differences in the geographic ranges of the agnostoid and polymerid components of the fauna (Jell and Hughes, 1997). Himalayan agnostoid genera were largely cosmopolitan in their distribution: the diverse agnostoid fauna of the Karsha and Kurgiakh formations is Guzhangian in age, a time interval particularly known for cosmopolitan agnostoid species (Brock et al., 2000). Although agnostoid species-level similarity is highest with faunas from South China, many of the species are recognized around the globe. The almost complete absence of agnostoids from Vietnam and Iran probably reflects the poor knowledge of the Cambrian faunas from these regions. Among the eodiscinids, *Opsidicus* had a sporadic but cosmopolitan distribution, whereas *Pagetia* was restricted to equatorial Gondwanaland.

Most Himalayan polymerid taxa have close relatives recovered from other regions, and these span a wide geographic range including Europe, Siberia, Kazakhstan, and North America. Cosmopolitan polymerid species include *Oryctocephalus indicus* and *Schmalenseeia amphionura*, and genera such as *Redlichia*, *Prozacanthoides* and *Torifera*, all of which occur on several Cambrian paleocontinents. A particularly notable distribution is that of *Koldinia*, of which we have a new species. Other *Koldinia* species are known only from Europe and Siberia. Likewise, the new genus *Bhargavia* is known from only the Himalaya and North America.

The great majority of Himalayan polymerid taxa have congeners within southern Asia, and the occurrence of common redlichiid, oryctocephalid, ptychopariid, solenopleurid, damesellid, and lisaniid taxa all evince equatorial peri-Gondwanan affinity. Among those Himalayan polymerids confidently assigned to either genera or species, shared occurrence is highest with South China. Ten out of 37 (27%) Himalayan species are common to both regions, and 24 out of the 31 (78%) Himalayan genera are also common to both. This supports a strong faunal link between these areas in the second and third series of the Cambrian System. Although this high degree of similarity may reflect particular proximity between these regions, documentation of faunas of this age from the Yangtze block is particularly comprehensive and this might inflate apparent similarity. Many Himalayan taxa are also common to North China [3 species (8%) and 17 genera (53%)] and to Australia [11 genera (34%)]. Thirteen Himalayan taxa (either genera or species) found in North China are

TABLE *1*—Distribution of Himalayan Cambrian trilobite genera and species from Zanskar and Spiti. Line signifies boundary between agnostoid and other trilobites. Italics indicate presence in region of specimens definitively assigned to genera or species, even though Himalayan assignments are questionable.

	South China	North China	Australia	Kazakhstan	Siberia	Europe	North America	Vietnam	Iran
Proagnostus bulbus bulbus	S	G	S	S	S	S	S		
Clavagnostus calensis	S	G	G	G	G	S	G		
Baltagnostus rakuroensis	G	S	S	G*					
Hypagnostus parvifrons	S	S	S	S	S	S	S		
Lejopyge armata	S	S	S	S	S	S	S		
Lejopyge acantha	S					S	S		
Lejopyge calva?	*S*								
Lejopyge sp. indet.									
Linguagnostus kjerulfi	S	S	S	S	S	S	G		
Goniagnostus spiniger	S		S	S	S	G			
Goniagnostus sp. indet.									
Utagnostus neglectus	S		S	G*			S		
Diplagnostus planicauda	S	G	S	S	S	S	S		
Diplagnostus sp. indet.									
Hypagnostus brevifrons	S	G	S	S	S	S	S		
?*Pseudophalocroma ovale*	*S*		*G*	*G*	*G*		*G*		
Ptychagnostus aculeatus	S	G	S	S*	S	S	S	G*	
Tomagnostella exsculpta	S	G	G	S	S	S	S		
Ammagnostus sp. cf. *laiwuensis*	G	G	G	G	G	G	G		
Valenagnostus imitans?	*S*		*S*	*G**		*G*			
Clavagnostus trispinus	S	G	G	G	G	S	S		
Peronopsis acadica	S	G	S	S	S	S	S		
Neoanomocarella asiatica	S			S					
Himalisania sudani	G								
Koldinia odelli					G	G			
Torifera jelli	G	G	G	G	G	G			G
Chatiania? sp. indet.	G								
Fuchouia bulba	S	G	G	G	G				
Fuchouia oratolimba	S								
Parablackwelderia jimaensis	S	G	G	S					
Parablackwelderia sheridanorum									
Parablackwelderia yangi?									
Parablackwelderia? sp. indet.									
Schmalenseeia amphionura	G		G		S	S			
Olenus? sp. indet.	*G*		*G*	*G*	*G*	*G*	*G*		
Sudanamonocarina sinindica	S		G		G				
Proasaphiscus simoni	G	G		G*	G			G	
Eosoptychoparia sp. indet.	G								
Probowmaniella? sp. indet.		*G*							
Poriagraulos sp. indet.		G							
?*Iranoleesia butes*	*G*	*S*						*S*	*G*
Xingrenaspis dardapurensis	G	G	G						
Xingrenaspis hoboi	S	S							
Xingrenaspis shyamalae									
Xingrenaspis parthiva									
Paranomocarella conjunctiva	G			G*					
Solenoparia talingensis	G	S							
Solenoparia sp. cf. *shanxiensis*									
Gunnia smithi	G		G						
Gunnia sp. 1									
Gunnia sp. 2									
Altioculus sp. cf. *striatus*	G						G		
Monanocephalus miaopoensis	G	G							
Monanocephalus urceolata									
Hundwarella memor	S	S		G	G			G	
Ziboaspis hostilis		G							
Opsidiscus haimantensis?			G		G	G	G		
Changingia sp. indet.	G	G							
Paramecephalus defossus	G								
Douposiella himalaica	G		G						
Kunmingaspis stracheyi	G								G
Kunmingaspis pervulgata									S
Kaotaia prachina	G	G							
Kaotaia sp. cf. *gedongensis*									
Bhargavia prakritika							G		
Oryctocephalus indicus	S		G		S	G	S	G	
Oryctocephalus salteri							S		
Pagetia significans	G	G	S						
Haydenaspis parvatya									
Prozacanthoides lahiri		G			G		G		
Mufushania civica	G								
Mufushania nankingensis	S								
Probowmania bhatti	G	G							
Inouyia sp. indet.		G						G*	
Redlichia noetlingi	S	G	G	G	G			G	S

* indicates assignments for which the original illustrations have not been seen by us. G = same genus. S = same species.

also recorded in South China, 6 Himalayan taxa are found in both North China and Australia and, of these, 5 taxa occur in these areas and South China. Our results are consistent with recent arguments (Peng et al. 2004a, b) that the Cambrian faunas of North and South China are not as distinctive as was previously supposed (e.g. Shergold, 1988) and also suggest closer affinity between the Himalaya and both South and North China than with Australia. The apparent absence from the Himalaya of xystridurids, nepeids, and mapaniids, which are common in Australia at this time, is notable and consistent with a higher degree of biogeographic separation between these regions. However, such cosmopolitan polymerids as *Centropleura* are also unknown in the Himalaya, and thus limited collecting and highly episodic preservation of the Himalayan fauna remains a plausible explanation for specific taxon absences. The small number of Himalayan taxa occurring in Vietnam and in Iran must relate partially to limited description of faunas from those regions.

The distribution of Himalayan trilobite taxa presented herein supports the paleogeographical conclusions of Jell and Hughes (1997), is consistent with recent summaries of regional paleobiogeography (Chang, 1998; Brock et al., 2000), and is in broad agreement with most current reconstructions of the paleogeography of Gondwanaland (e.g., Choi and Kim, 2006; Veevers et al., 2007; Torsvik and Cocks, 2008). The faunal similarities between South China and the Himalaya mirror the faunal and stratigraphic similarities in the first and second series of the Cambrian System, reviewed by Hughes et al. (2005), and we suggest a closer association between South China and the Himalayan margin than that advocated by Torsvik and Cocks (2008) for the fourth series of the Cambrian. Our results are consistent with the generally accepted view that Australia lay to the north and east of the Himalayan margin as part of core Gondwanaland and that South China and North China were "outboard" terranes, with closer connections to the Himalayan region.

SYSTEMATIC PALEONTOLOGY

The taxonomic section of this work is by Shanchi Peng and Nigel Hughes and new taxon names should be attributed to those authors. Terminology follows that of Whittington and Kelly (1997) with additional terminology for agnostids following Peng and Robison (2000). Pre-occipital glabellar length is specified as a comparative measure rather than glabellar length (sensu Whittington and Kelly, 1997) in those cases in which the occipital spine is confluent with the posterior margin of the occipital ring.

Systematic approach.—Mauy of the species described in this monograph are basal libristomate trilobites assigned to the order "Ptychopariida", a group widely acknowledged to be paraphyletic at best, and likely polyphyletic. Trilobites of this order are common in the three trilobite-bearing series of the Cambrian System, and the relationships among these trilobites have proved difficult to resolve. This is commonly referred to as the "ptychopariid problem" (Rasetti, 1948; Rushton and Hughes, 1996) and relates to the fact these trilobites commonly differ subtly in the relative proportions or degree of expression of a rather modest set of characters. This pattern of variation, combined with the abundance of members of the group and elevated levels of intraspecific variation among Cambrian trilobites (Webster, 2007), has led to the recognition of a vast number of ptychopariid genera and species, many of which are of questionable value.

Resolving the ptychopariid problem presents several challenges. While we anticipate that considerable synonymy among Cambrian ptychopariid species and genera will ultimately be justified, in most cases the extent of information available is so limited that a more conservative approach is appropriate. Where possible we have referred our new specimens to well described species in which the nature of intraspecific variation, ontogenetic or otherwise, can be evaluated to some degree. Where we have recognized new ptychopariid taxa, each is based on multiple specimens that are preserved with original relief, that span a range of sizes and, for all but two of the 12 new Himalayan species (whether ptychopariid or not), are based on more than a single sclerite type.

Repositories.—Those listed below include the following: Cincinnati Museum Center, Cincinnati, Ohio, USA (CMCP); Geological Survey of India, Kolkata, India (GSI); Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing, China (NIGP), and the Geological Museum, Wadia Institute of Himalayan Geology, Dehra Dun, India (WIHGF).

Class TRILOBITA Walch, 1771
Order AGNOSTIDA Salter, 1864
Family AMMAGNOSTIDAE Öpik, 1967
Genus AMMAGNOSTUS Öpik, 1967

Type species.—*Ammagnostus psammius* Öpik, 1967, p. 139; from the *Glyptagnostus stolidotus* Zone, O'Hara Shale, Queensland, Australia, by original designation.

Diagnosis.—See Peng and Robison (2000, p. 25).

Discussion.—Peng and Robison (2000) placed *Agnostoglossa* Öpik, 1967, *Glyptagnostus (Lispagnostus)* Öpik, 1967, and *Tentagnostus* Sun, 1989 in synonymy with *Ammagnostus* Öpik, 1967 and provided a revised diagnosis for the genus. Their generic concept is followed herein.

AMMAGNOSTUS SP. cf. A. LAIWUENSIS (Lorenz, 1906)
Figure 15.4–15.5

cf. *Agnostus fallax* var. *laiwuensis* LORENZ, 1906, p. 82–84, pl. 4, figs. 7, 8.

cf. *Ammagnostus laiwuensis* (Lorenz); PENG AND ROBISON, 2000, p. 27, fig. 20. (see for synonymy up to 2000); JAGO AND BROWN, 2001, p. 8, pl. 2, figs. G, K, L; JAGO, BAO AND BAILLIE, 2004, p. 25, figs. 3B–F; LIEBERMAN, 2004, p. 9–10, fig. 7.

Material.—A single pygidium and its external mould preserved in limestone (WIHGF825B.1).

Discussion.—A single pygidium from Zanskar with an axis that occupies the full length of the acrolobe and with an ogival posterior that is closely similar to that of *Peronopsis gullini* Jago (1976a, pl. 21 figs. 1–9), which was placed in synonymy with *Ammagnostus laiwuensis* (Lorenz, 1906) by Peng and Robison (2000). The Indian pygidium is left in open nomenclature as it differs in having more anteriorly placed posterolateral spines and a more deeply bowed posterior margin between the spines.

Occurrence.—In collection KU5 at 36.05 m above base of the Kuru 1 section opposite Kuru on the north side of the Tsarap Lingti Chu, Zanskar valley, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone.

Genus PROAGNOSTUS Butts, 1926

Type species.—*Proagnostus bulbus* Butts, 1926, p. 76 (in part); from the Middle Cambrian of Alabama, by original designation.

PROAGNOSTUS BULBUS BULBUS Butts, 1926
Figure 15.6, 15.7

Proagnostus bulbus BUTTS, 1926, p. 76 (in part), pl. 9, fig. 12, not 11; ROBISON, 1988, p. 41, figs. 8.9–8.15 (see for additional synonymy); PRATT, 1992, p. 30, figs. 8.9–8.15 (see for additional synonymy); PEGEL, 2000 p. 1015, 1016, fig. 12.2, fig. 13.1, 13.2; JAGO, BAO AND BAILLIE, 2004, p. 28, figs. 3G–Q.

Homagnostus fussus ROMANENKO, 1988; GOGIN AND PEGEL, 1997, p. 109–110, pl. 23, figs. 5, 7, 11.

Agnostid indet., JELL AND HUGHES, 1997, p. 98, pl. 30, figs. 14, 15.

Proagnostus bulbus bulbus BUTTS, 1926; PENG AND ROBISON, 2000, fig. 25.14–25.21.

not *Proagnostus bulbus sinensis* (PENG, 1987); PENG AND ROBISON, 2000, fig. 25.1–25.20 (see for additional synonymy).

New material.—One dorsal exoskeleton (WIHGF666) preserved in shale.

Discussion.—A single exoskeleton from opposite Kuru, Zanskar lacks most of the left side and has been deformed by transverse compression. The cephalic lateral border and the pygidial borders are also partially broken. This specimen has a preglabellar median furrow, a constricted acrolobe, a parallel-sided posteroglabella that is angular posteriorly and bears a broad and inward-impressed F2, and a long pygidial axis with the posteroaxis slightly expanded at the sides with F1 and F2 furrows that are largely effaced. The transglabellar furrow (F3) appears to be curved forward, but this, and the angularity of the posteroglabella, is likely the result of deformation. The observed features warrant assignment to *Proagnostus bulbus*.

Additional material including an exoskeleton and a pygidium described previously as Agnostid indet. from low in the Kurgiakh Formation at Kurgiakh, Zanskar (Jell and Hughes, 1997, pl. 30, figs. 14, 15). The exoskeleton has a transverse glabellar F3 that is diagnostic of the subspecies *Proagnostus bulbus bulbus*.

Occurrence.—In shales from collection KU3, at an unspecified height in the interval between 97.44 m (KU2 collection) and 111.2 m (KU1 collection) above the base of the Kuru 2 section opposite Kuru in the Zanskar Valley, and at the Surichun La nulla site near Kurgiakh (KH3), near the base of the Kurgiakh Formation (Surichun Member); Guzhangian Stage, *Proagnostus bulbus* Zone. *Proagnostus bulbus* (s. l.) has a global distribution in Australia, Canada, China, England, Kazakhstan, Greenland, Russia and the USA; in South China *Proagnostus bulbus* is known in the eponymous zone and ranges up into the lower part of *Linguagnostus reconditus* Zone, but the subspecies *Proagnostus bulbus bulbus* is restricted almost exclusively to the *Proagnostus bulbus* Zone; middle Guzhangian (lower Kushanian) Stage.

Family CLAVAGNOSTIDAE Howell, 1937

Discussion.—To date this family includes only three valid genera, *Clavagnostus* Howell, 1937, *Aspidagnostus* Whitehouse, 1936, and *Utagnostus* Robison, 1964, each of which is regarded as a subfamily of the Clavagnostidae. Some genera, such as *Triadaspis* and *Nahannagnostus*, were previously also assigned to Clavagnostidae but have been transferred to other families or are regarded as doubtfully assigned. Based on *Clavagnostus* and *Aspidagnostus* respectively, Öpik (1967) erected subfamilies Clavagonostinae and Aspidagnostinae. This viewpoint was followed by Shergold et al. (1990) and Shergold and Laurie (1997), but was rejected by Pratt (1992) and Peng and Robison (2000), who favored the family undivided. In reviving *Clavagnostus (Paraclavagnostus)* Yang and Liu *in* Yang et al., 1991 as a valid taxon and elevating it to a full genus, Jago et al. (2004) established a third subfamily, the Utagnostinae. *Clavagnostus (Paraclavagnostus)* was previously regarded as a junior subjective synonym of *Clavagnostus* (Peng and Robison, 2000) but is herewith reconsidered to be synonymous with *Utagnostus* (see detailed discussion below under genus *Utagnostus*). In following Pratt (1992) and Peng and Robison (2000), we maintaiu Clavagnostidae at the familial rank and do not recognize subfamilies within it.

Genus CLAVAGNOSTUS Howell, 1937

Type species.—*Agnostus repandus* Westergård *in* Holm and Westergård, 1930, from the upper middle Cambrian of Sweden, by original designation.

Diagnosis.—See Peng and Robison, 2000, p. 38.

CLAVAGNOSTUS CALENSIS Rusconi, 1950a

Figure 9.1–9.2

Clavagnostus calensis RUSCONI, 1950a, p. 73, fig. 3; PENG AND ROBISON, 2000, p. 39, fig. 27 (see for complete synonymy).

Clavagnostus cf. *repandus* (WESTERGÅRD *in* Holm and Westergård, 1930); JELL AND HUGHES, 1997 (in part), p. 96, figs. 30.2, 30.3 not 30.1, 30.4–30.7 [=*Clavagnostus trispinus* ZHOU AND YANG *in* Zhou, Liu, Mong and Sun, 1977].

Clavagnostus sp., JELL AND HUGHES, 1997, p. 96, fig. 30.3.

New material.—One cephalic external mold (WIHGF635) preserved in shale.

Discussion.—A single newly recovered cephalon that is strongly scrobiculate is referred to *Clavagnostus calensis*. The cephalon has a pair of slender posterolateral border spines, and bears a firmly incised preglabellar median furrow. The glabella is lanceolate, accuminate in front, and approximately three-fifths of the cephalic length with a centrally-placed elongate node. The basal lobes are clearly defined, and subtriangular in shape. The glabellar posterior is not well preserved in this specimen but appears to be angular. Except for stronger scrobiculation and the slightly shorter proportions of the glabella, the features of this specimen agree well with those of *C. calensis*. Such differences are minor and are regarded as intraspecific variations.

The present specimen is closely similar to *C. spinosus* in glabellar shape and proportion but differs in the presence of scrobiculation and in the defined basal lobes. The glabella in both *C. repandus* and *C. trispinus* is more rounded than that of *C. calensis* and differs from the condition seen in this specimen.

The specimen illustrated from the same site in the Surichun La nulla (the site at which the new KH3 collection was made), Zanskar as *Clavagnostus* sp. by Jell and Hughes (1997) is hereby assigned to *C. calensis*. The accuminate glabella, the posterolateral spine, the pattern of scrobiculation, and the length of the glabella justify this assignment.

A cephalon from the Surichun La nulla site, Zanskar but attributed to *Clavagnostus* cf. *repandus* (Jell and Hughes, 1997, fig. 30.2) seems also to be conspecific. This specimen is similarly strongly scrobiculate, bears a clearly defined preglabellar median furrow, and has a glabella of similar length. As showed by the illustration, the glabella in this specimen looks less acuminate in front and less angular at the rear than our new material. However, we consider these differences to be the result of deformation associated with preservation in shale.

Occurrence.—The new collection has a single cranidium of *Clavagnostus calensis* in collection KH3 from the Surichun La nulla section north of Kurgiakh, Zanskar, Kurgiakh Formation (Surichun Member); Guzhangian Stage, *Proagnostus bulbus* Zone. In South China, this species occurs in the *Lejopyge laevigata* Zone and possibly also in the *Proagnostus bulbus* Zone (Peng and Robison, 2000).

CLAVAGNOSTUS TRISPINUS Zhou and Yang *in* Zhou, Liu, Mong and Sun, 1977

Figure 9.3–9.5

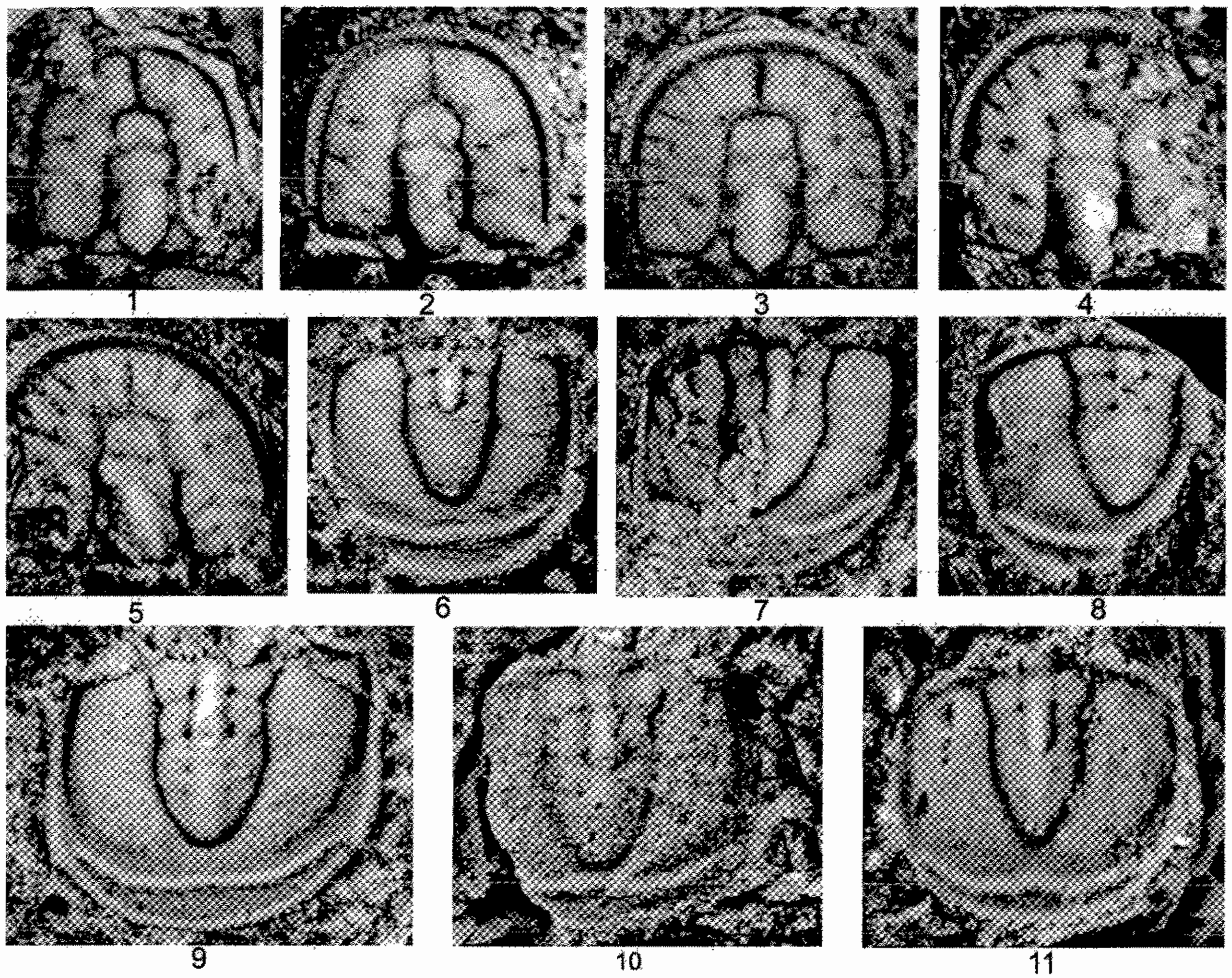


FIGURE *10*—*Diplagnostus* from limestone collected at 36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, Zanskár valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. All likely holaspid. *1–10, Diplagnostus planicauda* (Angelin, 1851): *1–5,* cephala. *1,* WIHGF1007, ×29.25; *2,* WIHGF602.3, ×31; *3,* WIHGF602.1, ×22; *4,* WIHGF1018.2, ×23.25; *5;* WIHGF722.1, ×14.75; *6–11,* pygidia; *6,* WIHGF717, ×12.75; *7,* WIHGF1018.1 ×14.5; *8,* WIHGF817.2, ×17.25; *9,* WIHGF1035, ×15.75; *10,* WIHGF859, × 15; *11, Diplagnostus* sp. indet., WIHGF1017, ×23.5.

Clavagnostus trispinus ZHOU AND YANG *in* ZHOU, LIU, MONG AND SUN, 1977, p. 108, pl. 36, fig. 4; PENG AND ROBISON, 2000, p. 41, fig. 29 (see for complete synonymy).

Clavagnostus cf. *repandus* WESTERGÅRD *in* Holm and Westergård, 1930); JELL AND HUGHES 1997 (in part), p. 96, figs. 30.4, 30.5, 20.7, ?30.1, 30.6 not 30.2 [= *Clavagnostus calensis* RUSCONI, 1950a.]

New material.—One cephalon (WIHGF701) and one pygidium (part WIHGF697A and counterpart WIHGF697B) preserved in limestone.

Discussion.—Peng and Robison (2000) rediagnosed and discussed the species. The significant features that suggest an assignment to *Clavagnostus trispinus* for the new material from the Teta Member of the Karsha Formation, opposite Kuru, Zanskar, include the absence of a preglabellar median furrow and the presence of a median border spine on the pygidium. The glabellar features, including an entire anterior lobe, a parallel-sided posteroglabella, a rounded anterior outline, and an angular posterior end, also support this assignment. Some of the specimens from the Kurgiakh Formation at Surichun La nulla compared with *Clavagnostus repandus* by Jell and Hughes (1997, fig. 30.4–30.7) may also be referable to *C. trispinus.* These specimens are rather poorly preserved, but the presence of a median border spine on the pygidium (Jell and Hughes, 1997, fig. 30.5 and possibly also fig. 30.7) prohibits assignment to *C. repandus*, as the absence of this feature distinguishes that species from *C. trispinus. Clavagnostus repandus* may differ further in having a less constricted anteroglabella and a more clearly defined and more anteriorly placed glabellar node.

Occurrence.—Disarticulated cephala and pygidia of *Clavagnostus trispinus* are present in limestones from collection KU4, at 36.55 m above the base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. In Zanskär, specimens now assigned to this species have previously been recorded (Jell and Hughes, 1997) from shales of the basal Kurgiakh Formation at Surichun La nulla (at the same site as the present KH3 collection) from the *Proagnostus bulbus* Zone. *Clavagnostus trispinus* is known from South China and Greenland, and found through most of the *Lejopyge laevigata* and *Proagnostus bulbus* zones (Peng and Robison, 2000). The present report extends its occurrence to the Tethyan Himalaya.

Genus UTAGNOSTUS Robison, 1964

Utagnostus ROBISON, 1964, p. 532–533; PENG AND ROBISON, 2000, p. 45 (see for synonymy up to 2000); SLOAN AND LAURIE, 2004, p. 197.

Clavagnostus (Paraclavagnostus) YANG AND LIU *in* Yang et al., 1991, p. 102; 1993, p. 132.

Paraclavagnostus YANG AND LIU *in* Yang et al., 1991; JAGO, BAO, AND BAILLIE, 2004, p. 31.

Type Species.—*Utagnostus trispinulus* Robison, 1964 from the Marjum Formation, upper part of middle Cambrian of western Utah, by original designation.

Diagnosis.—See Peng and Robison, 2000, p. 45.

Discussion.—*Clavagnostus (Paraclavagnostus)* Yang and Liu *in* Yang et al., 1991, also Jago et al. (2004), is here regarded to be synonymous with *Utagnostus.* Peng and Robison (2000, p. 37) considered the subgenus to be a junior synonym of *Clavagnostus*, but Jago et al. (2004) pointed out that *Clavagnostus (Paraclavagnostus)* is more closely related to *Utagnostus.* The later authors elevated the subgenus to generic status, and erected a new subfamily Utagnostinae Jago et al. (2004) to accommodate *Utagnostus* and *Paraclavagnostus.* We agree with Jago et al. (2004) that *Clavagnostus (Paraclavagnostus)* is not a synonym of *Clavagnostus* and is closely allied to *Utagnostus* but consider it as a junior synonym of *Utagnostus.* In their discussion, Jago et al. (2004, p. 31) emphasized that *Paraclavagnostus* can be differentiated from *Utagnostus* by two features: *Utagnostus trispinulus*, the type species of *Utagnostus*, has "a distinct transverse glabellar furrow and a longer, more expanding pygidial axis." However, as these features are highly variable within *Utagnostus* we do not consider them of value in generic definition. The ontogenies illustrated from Utah (Robison, 1964) and South China (Peng and Robison, 2000) demonstrate that such characters vary even within single species. Additional material from Utah shows that *Utagnostus songae*, which is characterized by a distinct transverse glabellar furrow, has an even narrower ogival postaxial region than *Clavagnostus (Paraclavagnostus) variatus*, the type species of *Paraclavagnostus.* The new material of *Utagnostus neglectus*, described below from Zanskar, provides further support for the suppression of *Paraclavagnostus* because there is variation in the presence or absence of the transglabellar furrow, suggesting that one of the features considered diagnostic for *Clavagnostus (Paraclavagnostus)* is an intraspecific variation in this case. All other diagnostic features given by Yang et al. (1991) for their genus seem of no more than specific significance at most. The lack of a transverse depression on the posteroaxis and the presence of a median border spine on the pygidial border are also shared by *Utagnostus.*

The concept of *Utagnostus* outlined by Peng and Robison (2000) is followed herein. *Utagnostus negleetus*, which was included in *Utagnostus* but transferred recently to *Paraclavagnostus* (Jago et al., 2004), is here reassigned back to *Utagnostus.* Peng and Robison (2000, p. 45–46) regarded that the marked reduction of the anteroglabella justified the assignment of *Utagnostus* to Clavagnostidae. The variable occurrence of the transverse glabellar furrow in our new material of *U. neglectus* from Zanskar provides additional support for this assignment. As mentioned above, we do not recognize subfamilies within Clavagnostidae and, given the suppression of *Clavagnostus (Paraclavagnostus)* as a junior synonym of *Utagnostus*, we further regard the differences between *Clavagnostus* and *Utagnostus* as insufficient to justify another subfamily, and thus reject Utagnostinae.

Occurrence.—In addition to the occurrence of *Utagnostus* in Utah, Australia (Tasmania and New South Wales), and the Canadian Rocky Mountains (Robison, 1964; Jago, 1976a, b; Westrop et al., 1996), the genus has also been reported from South China (Peng and Robison, 2000). This record of *U. neglectus* in Zanskar extends its distribution to the Tethyan Himalaya. The genus ranges from the *Ptychagnostus punctuosus* Zone through the *Proagnostus bulbus* Zone (Peng and Robison, 2000, p. 45).

UTAGNOSTUS NEGLECTUS Jago, 1976a

Figure 9.6–9.18a

Utagnostus neglectus JAGO, 1976a, p. 67, pl. 23, fig. 13; SHERGOLD AND LAURIE, 1997, p. 373, fig. 235.3c; PENG AND ROBISON, 2000, p. 45.

Utagnostus? nevel JAGO, 1976b, p. 5, pl. 2, figs. 9–10.

Paraclavagnostus neglectus YANG AND LIU *in* Yang et al., 1991; JAGO, BAO AND BAILLIE, 2004, p. 31.

Material.—More than 10 disarticulated cephala and pygidia on one piece of rock (WIHGF609.1–WIHGF609.13), cephalon (WIHGF1007) and pygidium (WIHGF1027.2), all preserved in limestone.

Discussion.—The disarticulated cephala and pygidia show the distinctive features that are identical in almost every respect to those of the complete exoskeleton named *Utagnostus neglectus* (Jago, 1976a, pl. 23, fig. 13, pl. 23, fig. 3) from Tasmania. The Tasmanian exoskeleton was recently transferred to *Paraclavagnostus* by Jago et al., (2004), but the new material from opposite Kuru, Zanskar justifies retaining its original assignment. According to Jago et al. (2004) the reason for excluding *U. neglectus* from *Utagnostus* is the undivided glabella that lacks a transverse glabellar furrow and a narrower pygidium than that of *U. trispinulus*, the type species of *Utagnostus.* However, the large sample from India shows that the transverse glabellar furrow is variably present. On some specimens the furrow is lacking, but on most specimens it is obscurely, weakly, or even clearly evident (Fig. 9.6, 9.9, 9.11, 9.13, 9.14) The pygidial axis of *U. neglectus* does not extend posteriorly as far as in full-grown pygidia of *U. trispinulus* but agrees well with that of meraspid or early holaspid specimens of *U. trispinulus* (Robison, 1964, pl. 2, figs. 27, 28; Peng and Robison, 2000, fig. 10). The morphology shown by the new material resembles the type species closely and warrants an assignment to *Utagnostus.*

Utagnostus neglectus and *Clavagnostus (Paraclavagnostus) variatus* Yang and Liu *in* Yang et al. (1991, pl. 1, figs. 4–7) are here considered to be synonymous. Previously, only a single specimen or few specimens have been available for each species, and these suggested a taxonomically significant difference in glabellar shape. The former has a lanceolate glabella that is sharply pointed in front, whereas the glabella of the latter bears a rounded front and is markedly constricted at the anteroaxis. However, the morphology of the glabellae of both species falls within the variation range evident among the new material from India, suggesting that *C. (P.) variatus* should be suppressed as a junior synonym. We follow Peng and Robison (2000) in placing *Utagnostus (?) nevel* and *U. neglectus* in synonymy. Although Jago et al. (2004) recently argued for the validity of *Utagnostus (?) nevel* on the basis of a narrow and more tapered pygidial axis, the large sample of Indian material suggests that this variation occurred intraspecifically.

Utagnostus neglectus characterized the *Lejopyge laevigata* I to III zones in Tasmania, Australia (Jago, 1976a, b), suggesting correlation of those zones with the KU6 collection.

Occurrence.—Disarticulated cephala and pygidia of *Utagnostus* occur in collection KU6 from 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. This species occurs in Australia, Canada, South China and the

United States, ranging from the base of *Goniagnostus nathorsti* Zone through the *Lejopyge laevigata* Zone (Peng and Robison, 2000).

Family DIPLAGNOSTIDAE Whitehouse, 1939
Genus DIPLAGNOSTUS Jaekel, 1909

Type species.—*Agnostus planicauda* Angelin, 1851; from the middle Cambrian of Sweden, by original designation. Westergård (1946) and some others have attributed the concept of this species to Tullberg (1880), but we follow Jaekel (1909), Shergold et al., (1990), and Jell and Adrain (2003) in attributing the concept to Angelin (1851).

Diagnosis.—See Peng and Robison, 2000, p. 48.

Discussion.—Jell and Hughes (1997, p. 94) pointed out that *Enetagnostus humilis* Whitehouse, 1936, the type species of *Enetagnostus*, and *Diplagnostus planicauda*, the type species of *Diplagnostus* are synonymous. Peng and Robison (2000), who discussed both the concepts of Diplagnostidae and *Diplagnostus* in some length, agreed with Jell and Hughes (1997) in placing *Enetagnostus* in synonymy of *Diplagnostus* and further suppressed *Tasagnostus* Jago, 1976a as a junior synonym of *Diplagnostus*. We follow the generic concept of Peng and Robison, although Jago and Brown (2001, p. 9) and Jago and Bentley (2007, p. 288) argued for the validity of *Tasagnostus* and regarded the genus as a possible ancestor of *Oidalagnostus*. Ontogenetic series of *Oidalagnostus* (Peng and Robison, 2000, fig. 42) shows that both genera differ in axial features, both in cephalon and pygidium, and in border zonation. The cephalic morphology of the Diplagnostidae is conservative and there is little difference among genera and species. The pygidia, however, are distinctive. Jago and Bentley (2007) also considered *Tasagnostus* to differ in lacking a median sulcus on the anterior lobe of the glabella, and in having a pair of transversely elongated pits that merge into a well incised furrow on the posteroaxis. However, the absence of a median sulcus does not justify generic differentiation, because this character varies within diplagnostid genera. In *Linguagnostus*, for example, the sulcus is notably developed in *L. kjerulfi* but absent in *L. paibiensis* (Peng and Robison, 2000, figs 38, 39). The paired pits that form the transverse depression vary similarly in *Ptychagnostus*: the type species *P. punctuosus* bears the transverse depression, but other species lack it (Peng and Robison, 2000, figs 49–55). Accordingly, we deem neither character to be of generic significance.

Diplagnostus is characterized by having a zonate pygidium that bears well developed furrows and a pair of posterolateral spines. The pygidial axis is constricted slightly at M2 and has a large ridge-like median node on M2 or on the anteroaxis. The posteroaxis, which is ogival in shape, is longer than the anteroaxis.

DIPLAGNOSTUS PLANICAUDA (Angelin, 1851)
Figure 10.1–10.10

Agnostus planicauda ANGELIN, 1851, p. 7, pl. 6, fig. 9.
Enetagnostus humilis WHITEHOUSE, 1936, p. 91, pl. 8, figs. 17–19.
Diplagnostus cf. *humilis* (Whitehouse); WHITTINGTON, 1986, p. 174, pl. 20, figs. 4–5.
Diplagnostus planicauda (Angelin); JELL AND HUGHES, 1997, p. 92, pl. 30, figs. 8–13; PENG AND ROBISON, 2000, p. 49, fig. 35 (see for complete synonymy by 2000); AXHEIMER AND AHLBERG, 2003, p. 144, figs. 4A–D.

New material.—Ten disarticulated cephala (WIHGF602.1, WIHGF602.3, WIHGF772.1, WIHGF1007, WIHGF1018.2) and pygidia (WIHGF717, WIHGF817.2, WIHGF859, WIHGF1018.1, WIHGF1035) from limestone.

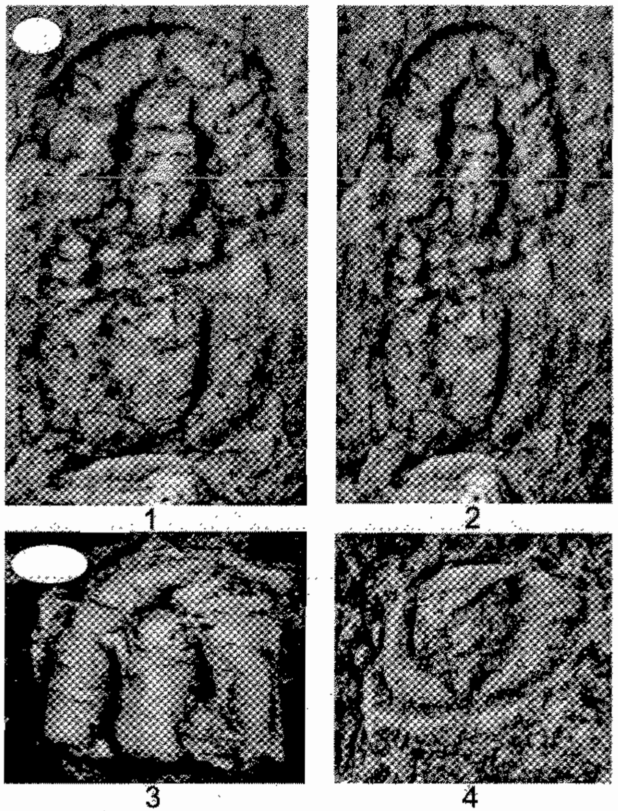


FIGURE 11—*Baltagnostus rakuroensis* (Kobayashi, 1935) from shales collected at the KH2 and KH3 localities of Zanskar. *1–3*, from the Surichun Member, Kurgiakh Formation, Surichun La nulla, Zanskar valley; *1*, *2*, WIHGF641, KH3, ×16; *1*, retrodeformation showing inferred strain ellipse; *2*, original dorsal exoskeleton; *3*, cephalon, WIHGF637, KH3, retrodeformation showing inferred strain ellipse, ×15.25; *4*, pygidium, WIHGF633B, KH2, from the uppermost Parahio Formation, east of Kurgiakh village, ×14.75.

Discussion.—Peng and Robison (2000) discussed intraspecific variation within this species. The diagnostic characters of *Diplagnostus planicauda* specimens from Zanskar are: the median preglabellar furrow firmly incised, transglabellar furrow transversely sinuous or curved anteriorly, median node elongate, M2 slightly expanded, F2 weakly impressed; pygidial F1 firmly impressed, F2 moderately impressed, axial node elongate to cylindrical, terminates just posterior of F2; anterior border ridge wide (tr.), gently curved, distinct from posterior border ridge; posterolateral spines weakly developed or absent.

Diplagnostus planicauda displays variation in the length of the cephalic border furrow. The material illustrated from Zanskar by Jell and Hughes (1997) has a relatively long (sag.) border furrow, but there is considerable variation in this length among the Hunan material illustrated by Peng and Robison (2000). The cephala from opposite Kuru, illustrated here, have a short cephalic border furrow. In contrast to the Chinese material, the Zanskar specimens have a more anteriorly rounded glabella and show more variation in the length of the auxiliary furrow. The anterior of the glabella of the specimens illustrated by Yang et al. (1993) and Peng and Robison (2000) is quadrate or subquadrate, while the Zanskar material reported here and by Jell and Hughes (1997) has a more anteriorly rounded glabella.

Occurrence.—New material includes disarticulated cephala and pygidia of *Diplagnostus planicauda* Angelin, 1851 from

36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. In Zanskar this species has previously been recorded (Jell and Hughes, 1997) from shales of the basal Kurgiakh Formation at Surichun La nulla (at the same site as to the present KH3 collection), which is the base of the *Proagnostus bulbus* Zone. This species has a global distribution, and in South China ranges from the *Ptychagnostus atavus* Zone to the *Lejopyge laevigata* Zone (Peng and Robison, 2000).

DIPLAGNOSTUS sp. indet.

Figure 10.11

Diplagnostus sp., PENG AND ROBISON, 2000, p. 50, fig. 36.

Material.—One pygidium (WIHGF1017) from limestone.

Discussion.—A single pygidium, also from the KU6 collection, resembles the pygidia assigned to *Diplagnostus* sp. from South China in having a sinuous anterior ridge on the zonate posterior border and a proportionally short axis that bears a tiny secondary node on the terminal postaxis. A minor difference is that the Zanskar pygidium has a slender and more evenly tapered axis. This specimen is possibly an aberrant form of *D. planicauda*.

Occurrence.—In collection KU6 from 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone.

BALTAGNOSTUS Lochman *in* Lochman and Duncan, 1944

Type species.—*Proagnostus? centerensis* Resser, 1938b, p. 48, pl. 10, figs. 18, from the middle Cambrian Conasauga Group of Alabama, by original designation.

Diagnosis.—See Peng and Robison, 2000, p. 50.

Discussion.—We follow Shergold and Laurie (1997) in recognizing *Baltagnostus* and *Pseudoperonopsis* as distinct genera. *Pseudoperonopsis* differs in lacking a zonal posterior border of the pygidium, which is a synapomorphy of Diplagnostidae. Robison (1964, *in* Jell and Robison, 1978) and Peng and Robison (2000) discussed the generic concept of *Baltagnostus*, which is followed herein. The genus is characterized by a variably expressed median preglabellar furrow, an unsegmented or weakly segmented pygidial axis with a crescentic pygidial posterior border that is either commonly zonate with a collar or simplimarginate, and has a pair of posterolateral spines.

BALTAGNOSTUS RAKUROENSIS (Kobayashi, 1935)

Figure 11

Agnostus rakuroensis KOBAYASHI, 1935, p. 103, pl. 14, figs. 17, 18; pl. 21, figs. 1, 2.

Pseudoperonopsis syrma ÖPIK, 1979, p. 44, pl. 11, fig. 7.

Pseudoperonopsis ancisa ÖPIK (in part), 1979, p. 45, pl. 11, fig. 5 only.

Peronopsis liaotungensis (RESSER AND ENDO, 1937); NAN, 1980, p. 485, pl. 200, figs. 9, 11.

Baltagnostus rakuroensis (Kobayashi); ZHANG AND JELL, 1987, p. 39–40, pl. 1, figs. 1–15; pl. 2, figs. 1–6, 8; pl. 3, fig. 10 (see for synonymy).

Pseudoperonopsis rakuroensis (Kobayashi); SUN, 1989, p. 88, pl. 6, fig. 16; pl. 7, figs. 1–7; GUO, ZAN AND LUO, 1996, p. 45, pl. 1, figs. –16; pl. 8, figs. 7–12.

Baltagnostus cf. *rakuroensis* (Kobayashi); JELL AND HUGHES (in part), 1997, p. 57, pl. 16, figs. 2–5, *non* fig. 1 [=*Peronopsis acadica* (HARTT *in* Dawson, 1868)].

New material.—One exoskeleton (WIHGF641), one cephalon (WIHGF637) and one pygidium (WIHGF633B), all strongly deformed.

Discussion.—Our material bears scrobicles, whereas some material assigned to *Baltagnostus rakuroensis* does not (e.g. Zhang and Jell, 1987, pl. 1, figs 1, 4, 5). However, intraspecific variation in the presence of scrobicles is evident within material from North China (see Zhang and Jell, 1987, pl. 1, fig. 2), as also occurs in other agnostoid species such as *Ptychagnostus atavus* (see Robison, 1984, fig. 11). Two pairs of lateral furrows are present on the pygidial axis in the Zanskari material, as in some specimens from North China (Zhang and Jell, pl. 2, fig. 8). Specimens assigned by Jell and Hughes (1997) to *Baltagnostus* cf. *rakuroensis* from Kashmir may belong to different species. The single cephalon that was compared by Kobayashi (1934, pl. 1, fig. 1) with Korean *Agnostus rakuroensis* Kobayashi, 1935 is here considered referable to *Peronopsis scutalis* (Salter *in* Hicks, 1872), whereas the specimens from the Nutunus Formation near Nutunus, Pohru Valley, Kashmir are probably not conspecific with Kobayashi's cephalon but are assignable to *Baltagnostus rakuroensis* because these specimens compare well in both the cephalic and pygidial characters with the type material of *B. rakuroensis* from Korea, as well as the specimens from North and Northeast China (Zhang and Jell, 1987). These features include the presence of an incomplete preglabellar median furrow, the transverse glabellar F1, the absence of F1 and F2 on the pygidial axis, and the shape and proportions of the axis. The new material from Kuru, Zanskar is also assigned to *B. rakuroensis*. Although the specimens are deformed, their observed features seem identical with those from Nutunus, Kashmir.

Occurrence.—In collections KH2 and KH3 from near Kurgiakh, Zanskar Valley, Kurgiakh Formation. KH2 is quite high upon the south-facing slopes, east of the village along the Zanskar valley, and is from the upper part of the Parahio Formation. KH3 is from the Surichun La nulla section north, of Kurgiakh, Zanskar; Guzhangian Stage, *Proagnostus bulbus* Zone. Another Indian occurrence is at about 1.5 km west of Nutunus, Pohru Valley, Kashmir. This species is also known from the middle Cambrian of North and Northeast China, North Korea, and Australia.

Family PERONOPSIDAE Westergård, 1936

Genus PERONOPSIS Hawle and Corda, 1847

Peronopsis HAWLE AND CORDA, 1847, p. 115.

Mesagnostus JAEKEL, 1909, p. 397.

Acadagnostus KOBAYASHI, 1939, p. 113.

Axagnostus LAURIE, 1990, p. 318.

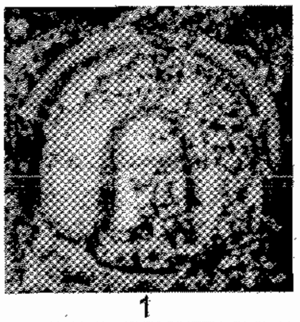
Type species.—*Battus integer* Beyrich, 1845 from the *Paradoxides gracilis* Zone of Czech Republic (Bohemia); by monotypy.

Diagnosis.—See Robison, 1994, p. 42; 1995, p. 302.

Discussion.—Robison (1994, 1995) discussed the concept of *Peronopsis* and concluded that it is preferable to adopt a broad concept for the genus that can accommodate a variety of agnostoids with phylogenetically basal characters. A number of genera including *Acadagnostus* were suppressed as synonyms of *Peronopsis* (Robison, 1964, 1994, 1995). Several species of *Acadagnostus* were described from Kashmir and Zanskar in Ladakh (Shah and Sudan, 1987a; Shah et al., 1996) and have been synonymized by Jell and Hughes (1997) with *Baltagnostus* cf. *rakuroensis*. In following Robison's concept most of these species are now reassigned to *Peronopsis*.

PERONOPSIS ACADICA (Hartt *in* Dawson, 1868)

Figure 12.1–12.12; Figure 15.12, 15.13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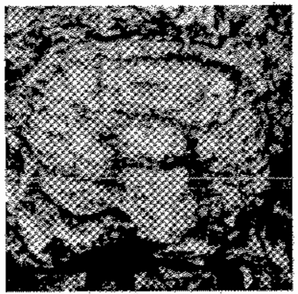
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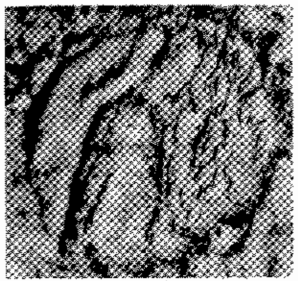
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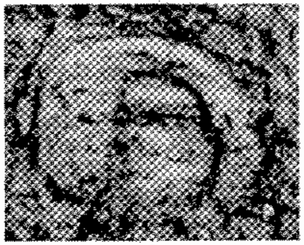
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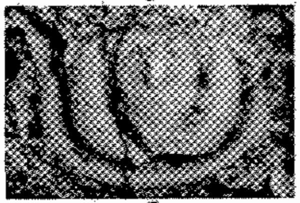
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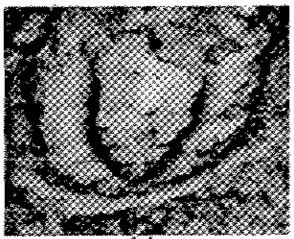
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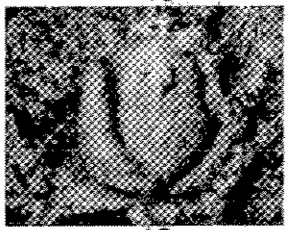
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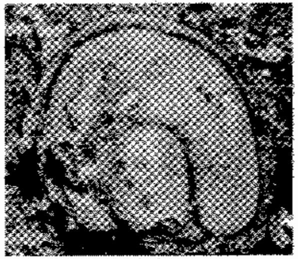
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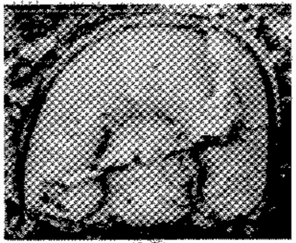
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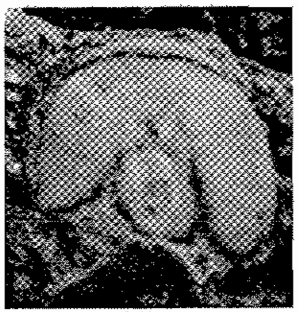
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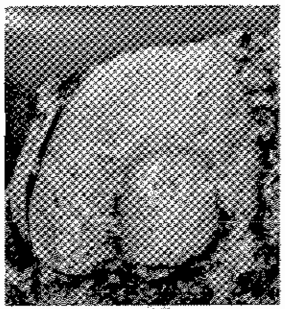
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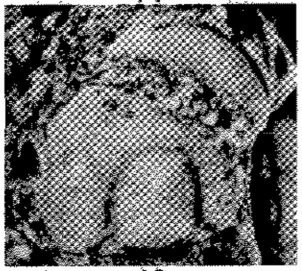
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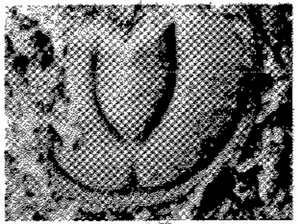
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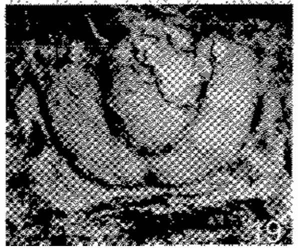
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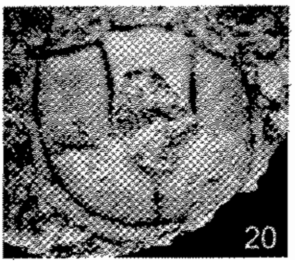
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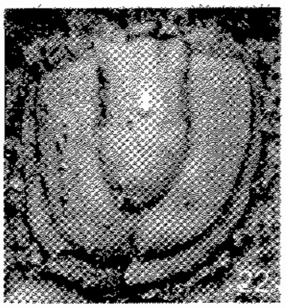
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Agnostus acadicus HARTT *in* Dawson (in part), 1868, p. 655, pl. 5, fig. 229 (cephalon only).
Peronopsis cf. *tramitis* ÖPIK, 1979; SHAH AND SUDAN, 1987a, p. 49, pl. 1, figs. a, c, d, p; text-fig. 1b, d.
Peronopsis amplaxis ROBISON, 1982; SHAH AND SUDAN, 1987a, p. 52, pl. 1, figs. b, h, r; text-fig. 1f, 1k.
Peronopsis sp. A; SHAH AND SUDAN, 1987a, p. 55, pl. 1, fig. g; text-fig. 1i.
Peronopsis sp. B; SHAH AND SUDAN, 1987a, p. 56, pl. 1, figs. f, j; text-fig. 1a, h.
Acadagnostus acadicus (Hartt); SHAH AND SUDAN, 1987a, p. 57, pl. 1, fig. m, text-fig. 1l.
? *Acadagnostus scutalis* (SALTER *in* Hicks, 1872); SHAH AND SUDAN, 1987a, p. 58, pl. 1, figs. e, n; text-fig. 1c.
? *Acadagnostus* sp., SHAH AND SUDAN, 1987a, p. 58, pl. 1, fig. l; text-fig. 1j.
Pentagnostus cf. *anabarensis* LERMONTOVA, 1940; SHAH AND SUDAN, 1987a, p. 59, pl. 1, fig. i; text-fig. 1g.
Peronopsis acadica (Hartt); ROBISON, 1995, p. 302–305, figs. 1.1–1.3 (see for synonymy).
Diplagnostus sp., SHAH, PARCHA AND RAINA, 1995, p. 221, pl. 1, figs. g, i, j. k, ?h; pl. 2, figs. b, f. h; text-fig. 1d, e, f.
? *Acadagnostus scutalis* (Salter), SHAH, KUMAR AND SUDAN, 1996; p. 952, figs. 2.1, 2.2, 2.5.
Peronopsis tramitis ÖPIK, 1979; SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.8–2.10, 2.21.
Peronopsis cf. *longinqua* ÖPIK, 1979; SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.7, 2.11, 2.17.
Peronopsis (Itagnostus) cf. *elkedraensis* (ETHERIDGE JR., 1902); SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.14, 2.16, 2.19.
Peronopsis sp., SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.22, 2.24, 2.25.
Peronopsis amplaxa ROBISON, 1982; SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.3, 2.4, 2.6, 2.13.
Diplagnostus floralis ÖPIK 1979; SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.18, 2.23.
Doryagnostus magister WHITEHOUSE, 1936; SHAH, KUMAR AND SUDAN, 1996, p. 952, figs. 2.12, 2.15, 2.20.
Baltagnostus cf. *rakuroensis* (Kobayashi); JELL AND HUGHES (in part), 1997, p. 57–58, pl. 16, fig. 1 only.

New material.—One exoskeleton (WIHGF870.3), and more than 10 disarticulated cephala (WIHGF134.2, WIHGF581, WIHGF587.1, WIHGF870.4, WIHGF873.2, WIHGF874.3, WIHGF1013, WIHGF1014.2) and pygidia (WIHGF139, WIHGF606, WIHGF628, WIHGF874.1), all from siltstones, all deformed.

Discussion.—When examining the type material of *Agnostus acadicus* Hartt, which includes a cephalon and a pygidium, Robison (1995) regarded each syntype to represent a separate species. The cephalon was chosen as representative of *Agnostus acadica*, and the syntype pygidium was reassigned to *Hypagnostus parvifrons*. As rediagnosed, *Agnostus acadica* is characterized by having a relatively long and wide pygidial axis that bears an acutely angular end. Species including *Peronopsis fallax* are regarded as junior synonyms. The new material from India is poorly preserved, but the observed features warrant an assignment to *Peronopsis acadica*. These features include a subquadrate cephalic outline, a glabella with the anterior lobe rounded anteriorly, a straight or slightly rearward-bowed transglabellar furrow (T3), a subcylindrical posteroglabella with a rounded posterior end, simple basal lobes, a wide pygidial axis that is pointed posteriorly and slightly constricted at M2, with a short posteroaxial median furrow, and a relatively broad border furrow in both cephalon and pygidium.

Peronopsis-like agnostoids from Zanskar and Kashmir were assigned to a diverse array of species, some of which were referred to derived genera (Shah and Sudan, 1987a; Shah et al., 1996). We consider that these agnostoids are from the equivalent interval to the beds yielding our new material, and that most of them bear close similarity with the new material referred here to *Peronopsis acadica*. Accordingly, they are transferred to *P. acadica* above.

Peronopsis acadica is morphologically similar to *Baltagnostus rakuroensis* Kobayashi, which is also known from Zanskar and Kashmir, in its cephalic shape and other features, but it lacks a median preglabellar furrow on the cephalon and the asymmetrical collar on the pygidium. The latter differs further in having an angular rather than rounded posterior end of the glabella. Given the lack of a preglabellar median furrow, collar, and the nature of the glabella, we place these Indian specimens in *P. acadica*. For a more comprehensive discussion of *P. acadica* see Robison (1994, 1995).

Occurrence.—New, disarticulated specimens of *Peronopsis acadica* (Hartt, 1872) are from siltstones and shales from 500.32 m (PI14 collection), 501.72 m (PI15 collection), 504.04 m (PI20 and PI21 collections) and 510.04 m (PI17 collection) above the base of Purni Valley section 3, Parahio Formation, on east side of the Tsarap River, south of Phuktal Gompa, Zanskar valley, *Sudanomocarina sinindica* Zone, uppermost part of the informal global Stage 5 of the Cambrian System (or upper Taijiangian Stage as used in South China). This species has a global distribution in the middle Cambrian with a composite range from the *Ptychagnostus praecurrens* Zone to the *Ptychagnostus punctuosus* Zone (Robison, 1994).

Genus HYPAGNOSTUS Jaekel, 1909

Type species.—*Agnostus parvifrons* Linnarsson, 1869 from the middle Cambrian of Sweden, by original designation.

Diagnosis.—See Peng and Robison, 2000, p. 60.

Discussion.—The genus *Hypagnostus* is characterized by the effacement of the anteroglabella, the lack of inter-ring furrows and spines on the pygidium and the presence of a weak median node on the pygidial axis. Species of *Hypagnostus* are variable and many characters have been used to define them. It has been suggested by Peng and Robison (2000) that variability within the genus has led to the group being taxonomically over-split.

←

FIGURE *12*—Peronopsidae from the Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1–12*, *Peronopsis acadica* (Hartt *in* Dawson, 1868) from shales collected at 500.32 m (PI14 collection), 501.72 m (PI15 collection), 502.04 m (PI16 collection), 504.04 m (PI21 collection) and 510.04 m (PI17 collection) above base of Purni Valley section 3, Parahio Formation, on east side of Tsarap River, south of Phuktal Gompa, Zanskar valley. All holaspid. *1–6*, cephala: *1*, WIHGF1013, PI15, ×20; *2*, WIHGF587.1, PI14, ×9.5; *3*, WIHGF873.2, PI21, ×15; *4*, WIHGF873.4, PI21, ×18; *5*, WIHGF870.4, PI21, ×11.5; *6*, WIHGF874.3, PI21, ×27.5; *7, 8, 11, 12* pygidia: *7*, WIHGF628, PI17, ×8; *8*, WIHGF139, PI15, ×9.25; *9,10*, dorsal shield, WIHGF870.3, PI21, ×26; *9*, original; *10*, retrodeformation with inferred strain ellipse. *11*, WIHGF874.1, PI21, ×14. *12*, WIHGF606, PI15, ×12.5. *13–22*, *Hypagnostus brevifrons* (Angelin, 1851) from limestone collected at 36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, Zanskar valley: *13, 14, 16–18*, cephala: *13*, WIHGF612.1, ×17.5; *14*, WIHGF612.3, ×9.5; *15, 19–22*, pygidia; *15*, WIHGF719, ×11.75; *16*, WIHGF726.1, ×11; *17*, WIHGF1019.3, ×14; *18*, WIHGF1027.1, ×12; *19*, WIHGF728, ×10.75, *20*, WIHGF732, ×8.25; *21*, WIHGF726.2, ×11.75; *22*, WIHGF724, ×9.75.

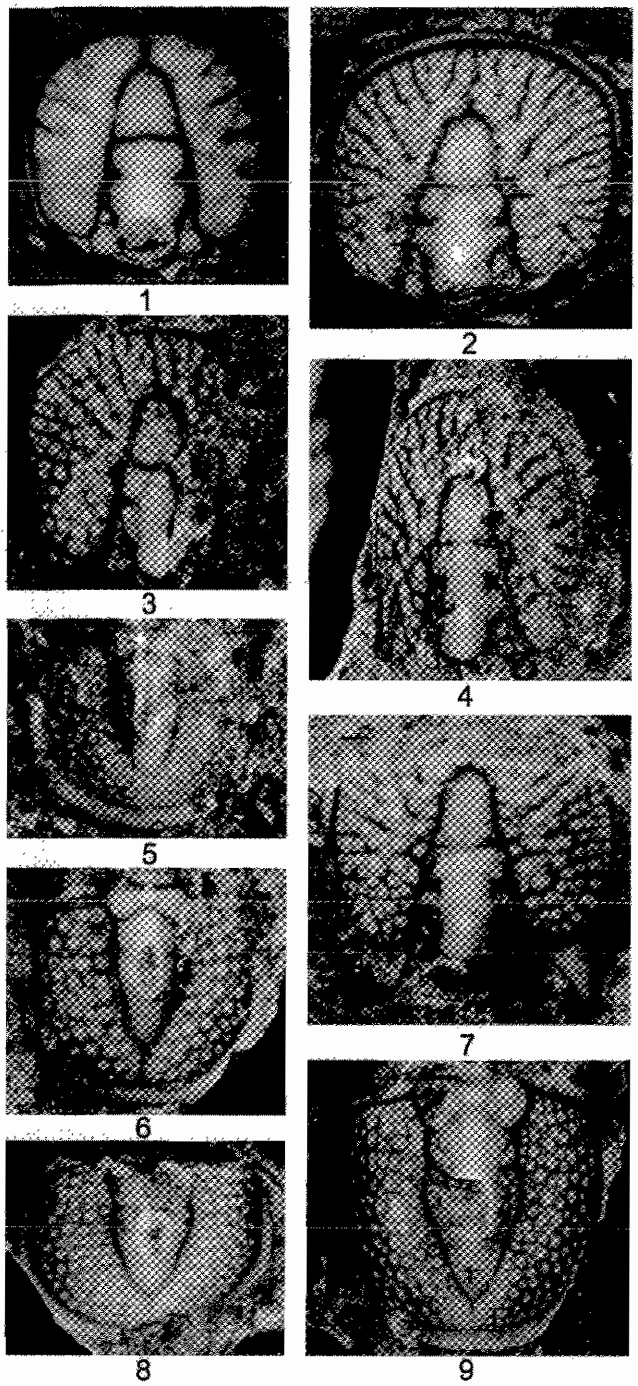


FIGURE *13*—*Ptychagnostus aculeatus* (Angelin, 1851) from limestone collected at 36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. All holaspid except for 1. *1–4,7*, cephala; *5, 6, 8, 9*, pygidia. *1*, meraspid, WIHGF1017.2, ×27; *2*, WIHGF1037.2, ×8.5; *3*, WIHGF696.2, ×9.75; *4*, WIHGF602.4, ×10.25; *5*, WIHGF727.1, ×10.25; *6*, WIHGF1010.1, ×14.5; *7*, WIHGF1008.2, ×11; *8*, WIHGF1033, ×8.0; *9*, WIHGF817, ×8.

HYPAGNOSTUS BREVIFRONS (Angelin, 1851)
Figure 9.18b; Figure 12.13–12.22, Figure 15.10

Agnostus brevifrons ANGELIN, 1851, p. 6, pl. 6, fig. 4.
Hypagnostus brevifrons (Angelin); PENG AND ROBISON, 2000, p. 63 (see for synonymy up to 2000); JAGO AND BROWN, 2001, p. 8, pl. 2, H.

Material.—Over 10 disarticulated cephala (WIHGF609.14, WIHGF612.2, WIHGF612.3, WIHGF726.1, WIHGF1019.1, WIHGF1027.1) and pygidia (WIHGF602.2, WIHGF719, WIHGF724, WIHGF726.2, WIHGF728, WIHGF732).

Discussion.—The characteristic features of the Indian specimens referable to *Hypagnostus brevifrons* are: cephalic F3 uniformly curved; pygidial axis parallel-sided or slightly constricted at M2 with a median axial node and a bluntly rounded posterior end, axis of variable length; median postaxial furrow present, variably impressed.

Hypagnostus brevifrons is similar to *H. correctus*, also reported from the Himalaya (Jell and Hughes, 1997), in all cephalic features. Following Peng and Robison (2000, p. 62), we consider *H. correctus* to be a junior synonym of the variable species *H. parvifrons*. The pygidium of *H. brevifrons* is distinguished from type specimens of *H. correctus* by having a more posteriorly rounded axis. In the original species description of *H. correctus* Öpik (1967) used the presence of a median postaxial furrow to distinguish *H. correctus* from *H. brevifrons*. However, Peng and Robison (2000) observed that in rare specimens of *H. brevifrons* a median postaxial furrow is present. The new specimens from opposite Kuru are placed in that species because of the rounded shape of the pygidial axis along with the median postaxial furrow. More generally, *Hypagnostus parvifrons* is distinguished from *H. brevifrons* in several cephalic and pygidial characters: the cephalic F3 in *H. parvifrons* forms a low-angle chevron shape, while in *H. brevifrons* F3 is uniformly curved. The pygidial axis in *H. parvifrons* is acuminate but *H. brevifrons* has a blunt pygidial axis. Of the specimens assigned by Jell and Hughes (1997) to *Hypagnostus correctus* we consider that only the specimens illustrated in their plate 29 figs. 1 and 6 belong to this species. The other specimens are better referred to species of *Lejopyge*.

Occurrence.—All available specimens of *Hypagnostus brevifrons* Angelin, 1851 are from limestones in the KU6 collection from 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. This species has a long stratigraphic distribution, ranging from the *Ptychagnostus punctuosus* Zone to the *Glyptagnostus stolidotus* Zone in Hunan, South China (Peng and Robison, 2000).

Family PTYCHAGNOSTIDAE Kobayashi, 1939
Genus PTYCHAGNOSTUS Jaekel, 1909

Type species.—*Agnostus punctuosus* Angelin, 1851,p. 8, from the middle Cambrian of Andrarum, Scania, southern Sweden, *Ptychagnostus punctuosus* Zone, by original designation.

Discussion.—This genus is characterized by a smooth or scrobiculate cephalon with a median preglabellar furrow and a median node on the glabellar M2 or M3. The glabella is conical in shape and is unequally divided by F3. The pygidial axis has a slight constriction at M2 and is shorter than the acrolobe. F1 and F2 are of subequal depths and spines may or may not be present. We follow Robison, 1984; Westrop et al., 1996, and Peng and Robison, 2000 in regarding *Triplagnostus* Howell, 1935; *Solenagnostus* Whitehouse, 1936; *Pentagnostus* Lermontova, 1940; *Huarpagnostus* Rusconi, 1950b; *Canotagnostus* Rusconi, 1951; *Acidusus* Öpik, 1979; *Aotagnostus* Öpik, 1979; *Aristarius* Öpik, 1979; *Zeteagnostus* Öpik, 1979; and probably *Myrmecomimus* Öpik, 1979 as junior synonyms of *Ptychagnostus*.

PTYCHAGNOSTUS ACULEATUS (Angelin, 1851)
Figure 13, Figure 15.8–15.9

Agnostus aculeatus ANGELIN, 1851, p. 8, pl. 6, fig. 12.

Goniagnostus (Allobodochus) aculeatus (Angelin); JELL AND HUGHES, 1997, p. 88, pl. 28, figs. 3–4.

Ptychagnostus aculeatus (Angelin); PENG AND ROBISON, 2000, p. 68 (see for synonymy).

New material.—More than 12 disarticulated cephala (WIHGF602.4, WIHGF669.2, WIHGF696.2, WIHGF1008.2, WIHGF1017.2, WIHGF1037.2) and pygidia (WIHGF 671B, WIHGF727.1, WIHGF731, WIHGF817, WIHGF1010.1, WIHGF1033).

Discussion.—Peng and Robison (2000, p. 68) discussed the generic assignment of this species at some length. The diagnostic features are: pustulate dorsal surface; scrobiculate genae; triangular, acuminate glabella, weakly tripartite longitudinally; glabellar furrows firmly impressed; basal lobe firmly delineated; posterolateral cephalic spines present; acuminate pygidial axis, widest at M1; posterolateral spines absent.

Ptychagnostus aculeatus was previously reported from Zanskar by Jell and Hughes (1997), who referred the species to *Goniagnostus*. Peng and Robison (2000) discussed the classification problem of *aculeatus* and concluded that it is more closely allied to *Ptychagnostus* than to *Goniagnostus*. These authors support the suggestions by Westergård (1946) that *aculeatus* may be part of a phylogenetic lineage containing *Ptychagnostus atavus* and *P. punctuosus*. A meraspid cephalon in the new material of *aculeatus* (Fig. 13.1) shows no difference from *Ptychagnostus atavus* except for surface granulation, and this provides more evidence to support Westergård's (1946) suggestion. Accordingly, *aculeatus* is here classified within *Ptychagnostus*.

Occurrence.—Disarticulated cephala and pygidia of *Ptychagnostus aculeatus* Angelin, 1851 are in collection KU6 from 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member), and in the KU2 collection, 97.44 m above the base of the Kuru 2 section. They have also previously been recorded from the KH3 collection from the Surichun La nulla section north of Kurgiakh, Zanskar, Kurgiakh Formation (Surichun Member) (Jell and Hughes, 1997, pl. 28, figs. 3, 4); Guzhangian Stage, *Lejopyge acantha* Zone and *Proagnostus bulbus* Zone. This species is found in the *Lejopyge laevigata* Zone in South China (Peng and Robison, 2000), establishing a correlation of collection KU6 within that zone in South China.

Genus GONIAGNOSTUS Howell, 1935

Type species.—*Agnostus nathorsti* Brøgger, 1878, p. 68; from the middle Cambrian *Lejopyge laevigata* Zone of Sweden, by original designation.

Discussion.—Öpik (1979) subdivided *Goniagnostus* into three subgenera, whereas Westrop et al. (1996) considered it as a subgenus of *Ptychagnostus*. In following Öpik's subgeneric classification, Jell and Hughes (1997) assigned specimens of *Goniagnostus* collected from Zanskar to the subgenus level. Peng and Robison (2000) rejected both Öpik's and Westrop et al.'s classifications of *Goniagnostus* and maintained it at generic rank. Jago and Brown (2001) agreed.

GONIAGNOSTUS sp. indet.
Figure 15.14

Material.—One dorsal exoskeleton (WIHGF844).

Discussion.—A single, very poorly preserved exoskeleton is referred to this genus. Several characters allow confident generic assignment, but preclude identification at the specific level. Features indicating *Goniagnostus* include the long, subtriangular anteroglabella with a longitudinally tripartite posteroglabella, the strongly convex posterior half of the median part of the posteroglabella, the sinuous transverse glabellar furrow, the strongly scrobiculate acrolobe on the cephalon, the longitudinally tripartite division of the pygidial anteroaxis, the posteroaxis bearing a depression, and the firmly defined median postaxial furrow. The lack of coarse pustules or reticulate prosopon formed by the coalescence of fine pustules on the pygidial pleural field excludes assignment to *G. fumicola* or *G. spiniger*. Affinity is more likely with *G. nathorsti* or *G. scarabaeus*.

Occurrence.—In collection KH3 from the Surichun La nulla section north of Kurgiakh, Zanskar, Kurgiakh Formation (Surichun Member); Guzhangian Stage, *Proagnostus bulbus* Zone.

Genus LEJOPYGE Hawle and Corda, 1847

Type species.—*Battus laevigatus* Dalman, 1828, p. 136, from the middle Cambrian *Lejopyge laevigata* Zone of Sweden; by original designation.

Discussion.—The genus *Lejopyge* varies in the degree of effacement of the dorsal furrows. Early species have well developed furrows, while younger species are almost entirely effaced (Robison, 1984; Robison, 1994; Peng and Robison, 2000). The emended diagnosis of Robison (1994) is followed here.

Kobayashi (1939) erected the subfamily Ptychagnostinae but placed *Lejopyge* in Lejopyginae Harrington *in* Kobayashi, 1939. Lejopyginae is commonly regarded as a junior synonym of Ptychagnostinae (Öpik, 1967). In following Öpik (1967, 1979) Jell and Hughes (1997) assigned Indian specimens of *Lejopyge* and *Goniagnostus* to the family Agnostidae, subfamily Ptychagnostinae, the later having been elevated to family-level by Robison (1984). Robison's (1984) diagnosis for the family Ptychagnostidae is followed here and thus *Lejopyge* is placed in that family.

LEJOPYGE ACANTHA Robison, 1984
Figure 14.5–14.11; Figure 15.11

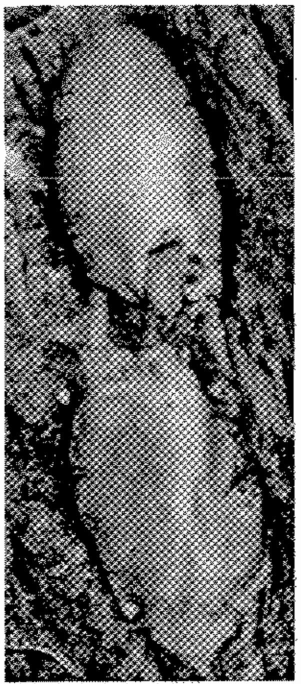
Lejopyge acantha ROBISON, 1984, p. 38, fig. 21.

? *Lejopyge laevigata* (DALMAN, 1828); WHITTINGTON (in part), 1986, p. 174, pl. 19, figs. 1, 3; pl. 20, fig. 1; not pl. 19, fig. 2 [?=*L. calva*].

New material.—Four cephala (WIHGF650, WIHG F726.3, WIHGF811, WIHGF1019.2) and two pygidia (WIHGF 602.5, WIHGF651).

Diagnosis.—*Lejopyge* with posterolateral spines on the cephalon and on the posterior thoracic segment, and without posterolateral spines on the pygidium; cephalic axial furrows relatively effaced compared to other species; cephalic border furrows effaced to moderately defined; pygidium with moderately wide border.

Discussion.—This species was well illustrated and described when erected, although Robison (1984) omitted mention of the cephalic lateral border furrows and borders. Well-preserved specimens (Robison, 1984, figs. 21.2a, b, 21.7a, b) show clearly that the borders are thin and well defined. The new material from Zanskar is almost identical to the type specimens of *Lejopyge acantha* from Utah and Nevada in every respect, including the presence of the posterolateral cephalic spines evident on the right side of one specimen (Fig. 14.6) and from the bases of the broken spines in another specimen (Fig. 14.8), the comparatively less effaced axial furrows, the similarly rounded cephalic outline, the presence of thin lateral borders, and the absence of pygidial border spines. A minor difference, which is regarded as intraspecific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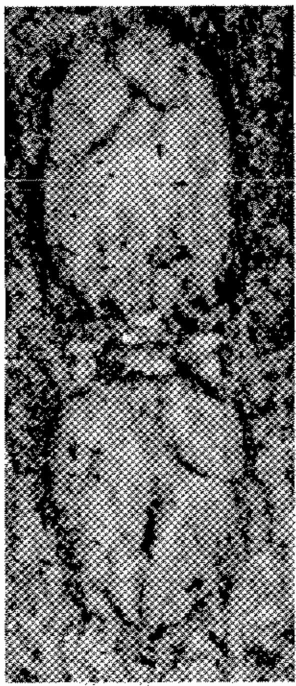
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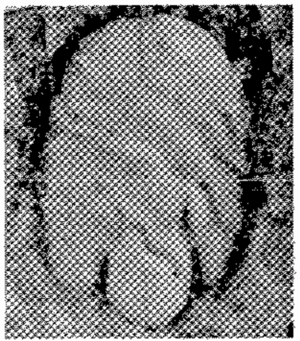
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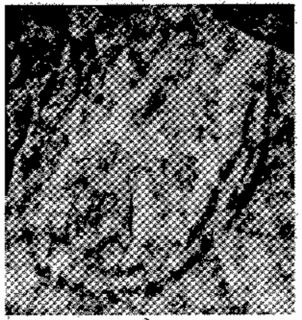
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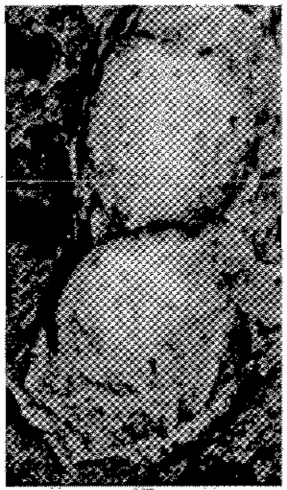
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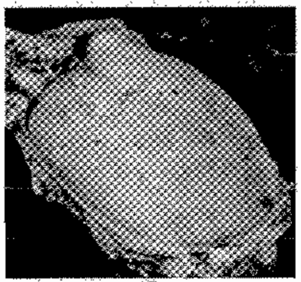
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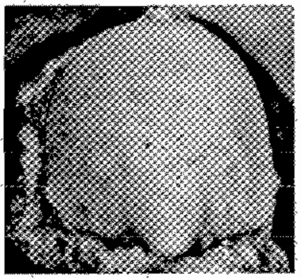
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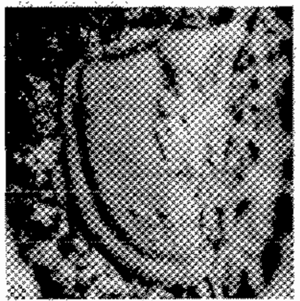
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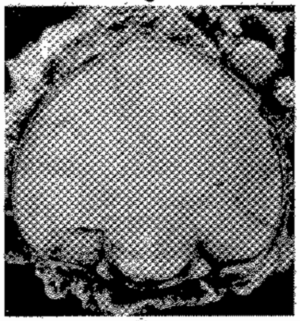
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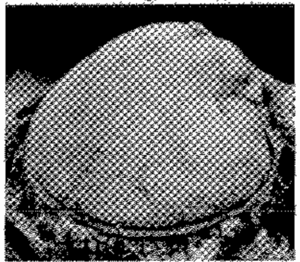
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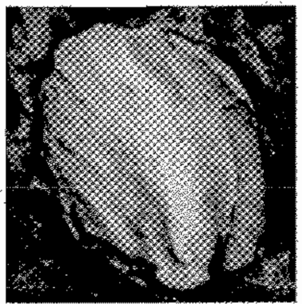
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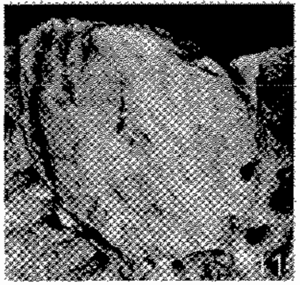
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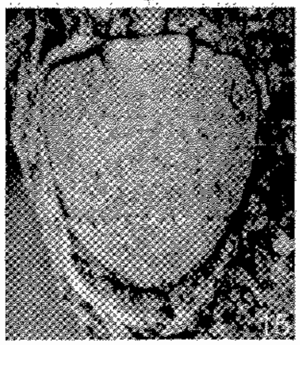
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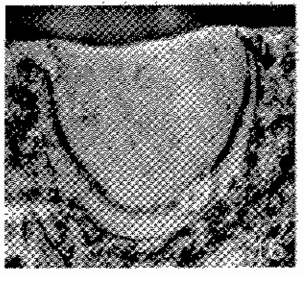
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variation, is that the pygidial borders of the Zanskari pygidia narrow forward less acutely than in the type material.

Occurrence.—In limestones of the KU6 collection from 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. This is the first record of this species outside of Laurentia. Other Indian material includes some of the specimens assigned by Whittington (1986) to *L. laevigata* from the site of our KH3 collection, and indicates that in Zanskar *L. acantha* ranges into the *Proagnostus bulbus* Zone. In Nevada (Robison, 1984), it is from the lower *Lejopyge laevigata* Zone in association with *Ptychagnostus aculeatus* in collection 155 (the base of member B, Emigrant Spring Formation).

LEJOPYGE ARMATA (Linnarsson, 1869)
Figure 14.1–14.4

Agnostus laevigata var. *armata* LINNARSSON, 1869, p. 82, pl. 2, figs. 58–59.

Lejopyge laevigata armata (DALMAN, 1828); LU AND CHIEN, 1964, p. 30, pl. 19, figs. 1–2.

Lejopyge armata (Linnarsson, 1869); JELL AND HUGHES, 1997, p. 90, pl. 28, figs. 5–13; pl. 29, 7–15; PENG AND ROBISON, 2000, p. 77, fig. 61 (see for synonymy up to 2000).

New material.—Two dorsal exoskeletons (WIHGF652, WIHGF669.1), one cephalon (WIHGF642), and one pygidium (WIHGF634).

Discussion.—*Lejopyge armata* differs from *L. laevigata* (Dalman, 1828) and *L. acantha* Robison, 1984 in having posterolateral spines on both cephalon and pygidium. *Lejopyge laevigata* bears no posterolateral spines on the cephalon and, except for having extremely tiny ones in rare cases, no such spines on the pygidium. *Lejopyge acantha* has cephalic posterolateral spines, but can be differentiated by having comparatively more effaced axial furrows, and by lacking pygidial posterolateral spines.

Jell and Hughes (1997, pl. 28, figs. 5–13, pl. 29, figs. 7–15) reported the occurrence of *Lejopyge armata* in Zanskar on the basis of tectonically deformed specimens from shales. The new material from Zanskar is similarly deformed tectonically but shows clearly posterolateral spines on the cephalon (Fig. 14.1) or the pygidium (Fig. 14.2, 14.4). Weak axial furrows and faint pygidial border furrows are observed on exoskeletons in the new material (Fig. 14.1, 14.2), but the associated cephalon (Fig. 14.3) exhibits characters of *L. armata* with firmly defined axial furrows that define the posterior half of the posteroglabella and an acutely rounded glabellar rear. The rather effaced appearance of the exoskeletons is interpreted as the result of poor preservation rather than being of specific significance.

Occurrence.—Specimens assigned to *Lejopyge armata* are in shales from the KH3 collection in the Surichun La nulla section north of Kurgiakh, Zanskar, Kurgiakh Formation (Surichun Member) (also see Jell and Hughes, 1997), and at 97.44 m (KU2 collection) in the Kuru 2 section opposite Kuru in the Zanskar Valley, Kurgiakh Formation (Surichun Member); Guzhangian Stage, *Proagnostus bulbus* Zone. In northwestern Hunan, South China this species ranges from the *Lejopyge laevigata* Zone to the *Proagnostus bulbus* Zone (Peng and Robison, 2000).

LEJOPYGE sp. indet.
Figure 14.12–14.14

Material.—Three dorsal exoskeletons (WIHGF643, WIHGF647, WIHGF650) and two cephala.

Discussion.—Several exoskeletons assigned to *Lejopyge* are poorly preserved and deformed. No axial furrows are preserved, but pygidial border furrows are indicated. The smallest exoskeleton (Fig. 14.12) resembles that described recently from southwestern Tasmania that was assigned to *L. laevigata* (Jago and Brown, 2001, pl. 1, fig. P), and is closely comparable in both morphology and size. Other exoskeletons from Zanskar are also closely similar to the specimens of *L. laevigata* from Tasmania (Jago and Brown, 2001, pl. I, figs. L, M) in the degree of effacement. However, other specimens of *L. laevigata* in Jago and Brown's collection seem less effaced than the Zanskari material.

Occurrence.—In shales from the KH3 collection in the Surichun La nulla section north of Kurgiakh, Zanskar, Kurgiakh Formation (Surichun Member); Guzhangian Stage, *Proagnostus bulbus* Zone.

Genus PSEUDOPHALACROMA Pokrovskaya, 1958

Type species.—*Pseudophalacroma crebrum* Pokrovskaya, 1958, p. 79 [=*Pseudophalacroma dubium* (Whitehouse, 1939)]; from middle Cambrian *Prohedinia–Forchhammeria–Anomocarioides limbataeformis* Zone of Siberia, by original designation.

?PSEUDOPHALACROMA OVALE Yang, 1982
Figure 14.15–14.16

? *Pseudophalacroma ovale* YANG, 1982, p. 302, pl. 2, fig. 1; PENG AND ROBISON, 2000, p. 82, fig. 67. (see for synonymy).

Material.—A possibly enrolled exoskeleton (WIHGF703), and one pygidium (WIHGF609.1) preserved in limestone.

Discussion.—Both specimens are partially broken. The shield has an ovate outline and relatively wide lateral borders that markedly widen rearward. These features are almost identical to those of *Pseudophalacroma ovale* Yang from South China (Yang, 1982; Lu and Lin, 1989; Peng and Robison, 2000). The Zanskari specimens differ from the typical specimens of South China in having incomplete, deeply incised axial furrows at the anterior of the axis and, probably, a pair of posterolateral spines, as a wide spine base is apparent in one specimen (Fig 14.16). Both of these features are characteristic of *Lejopyge*, questioning both the generic and

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FIGURE *14*—*Lejopyge* and *Pseudophalacroma* from the Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1–4, Lejapyge urmata* (Linnarson, 1869) from shales of the Surichun Member, Kurgiakh Formation. Collected at 97.44 m. (KU2 collection) in Kuru 2 section opposite Kuru on the north side of the Tsarap Lingti Chu, and at the KH3 locality in Surichun La nulla, Zanskar: *1*, dorsal shield, WIHGF669.1, KU2, ×24; *2*, dorsal shield, WIHGF652, KH3, ×23.5; *3*, cephalon, WIHGF642, KH3, ×11; *4*, pygidium, WIHGF634, KH3, ×21. *5–11, Lejopyge acantha* Robison, 1984 from limestone collected at 36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, and from the Surichun Memher, Kurgiakh Formation at the KH3 locality in Surichun La nulla: *5, 6*, cephalon, WIHGF811, KU6, ×12; *5*, oblique right lateral view; *6*, dorsal view. *7*, pygidium, WIHGF602.5, KU6, ×18.75. *8, 9*, cephalon, WIHGF726.3, KU6, ×9.75; *8*, dorsal view; *9*, oblique left lateral view. *10*, cephalon, WIHGF650, KH3, ×15.25. *11*, pygidinm, WIHGF651, KH3, ×7. *12–14, Lejopyge* sp. indet., dorsal exoskeleton, from the Surichun Member, Kurgiakh Formation at the KH3 locality in Surichun La nulla: *12*, WIHGF647, ×30; *13*, WIHGF643, ×12; *14*, WIHGF650, ×27. *15, 16, ?Pseudophalacroma ovale* Yang, 1982, from limestone collected at 36.05 m above base (KU6 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, pygidia. *15*, possibly enrolled dorsal exoskeleton, showing pygidium with cephalic margin evident at the pygidial posterior, WIHGF703, ×10.75. *16*, partial pygidium, WIHGF609.1, ×26.25.

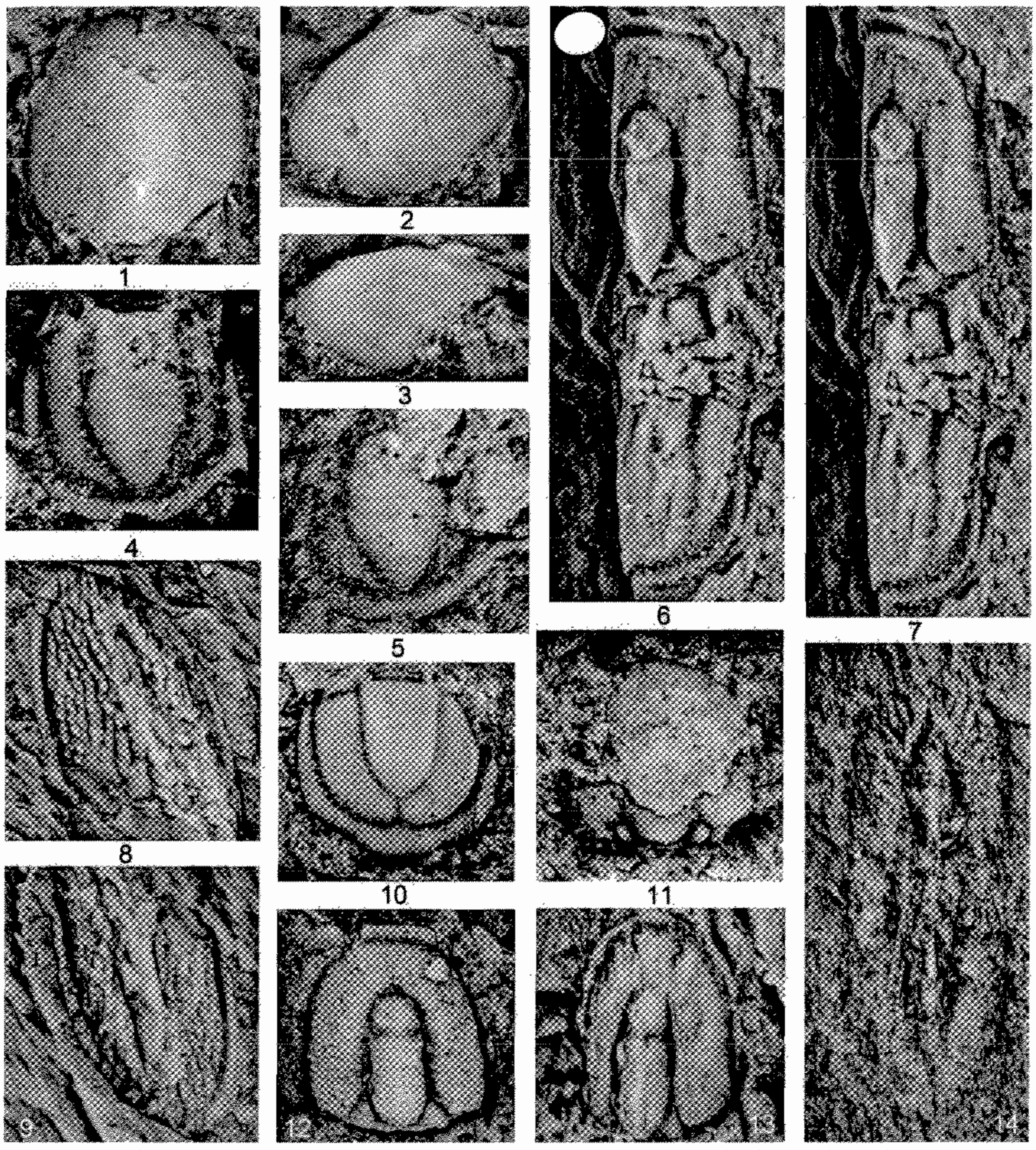

FIGURE *15*—Other Agnostida from the Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1–3, Valenagnostus imitans* (Öpik, 1961)?, cephalon, WIHGF756, from limestone collected at 36.05 m above base (KU7 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, ×8: *1,* dorsal view; *2,* left anterior oblique lateral view; *3,* left posterior oblique lateral view. *4, 5, Ammagnostus* sp. cf. *A. laiwuensis* (Lorenz, 1906), pygidium from limestone collected at 36.05 m above base (KU5 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu: *4,* WIHGF825B.1, ×16.25; *5,* latex of WIHGF825B.1, ×16.25. *6, 7, Proagnostus bulbus bulbus* Butts, 1926, dorsal shield, WIHGF666, at about 100 meters (KU3 collection) above the base of the Kuru 2 section, Surichun Member, Kurgiakh Formation on the north side of the Tsarap Lingti Chu, ×14.75: *6,* retrodeformation of *7* with inferred strain ellipse; *7,* original. *8, 9, Ptychagnostus aculeatus* (Angelin, 1851) collected at 97.44 m. (KU2 collection) in Kuru 2 section opposite Kuru on the north side of the Tsarap Lingti Chu, Surichun Member, Kurgiakh Formation: *8,* latex of external mold of cephalon, WIHGF669.2, ×8; *9,* latex of external mold of pygidium, WIHGF671B, ×14. *10,11,* from 36.05 m above base (KU6 collection) above base of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu: *10, Hypagnostus brevifrons* (Angelin, 1851), pygidium, WIHGF602.2, ×15; *11, Lejopyge acantha* Robison 1984, cephalon, WIHGF1019.2, ×10.5; *12,13, Peronopsis acadica* (Harit, 1868), cephala from shales collected at 500.32 m (PI14 collection), and 504.04 m (PI21 collection) above base of Purni Valley section 3, Parahio Formation, on east side of Tsarap River, south of Phuktal Gompa, Zanskar valley: *12,* latex of external mold, WIHGF1014.2, PI14, ×14; *13,* WIHGF134.2, PI21, ×12; *14, Goniagnostus* sp. indet., dorsal exoskeleton, WIHGF844, KH3 locality in Surichun La nulla, Surichun Member, Kurgiakh Formation, ×7.25.

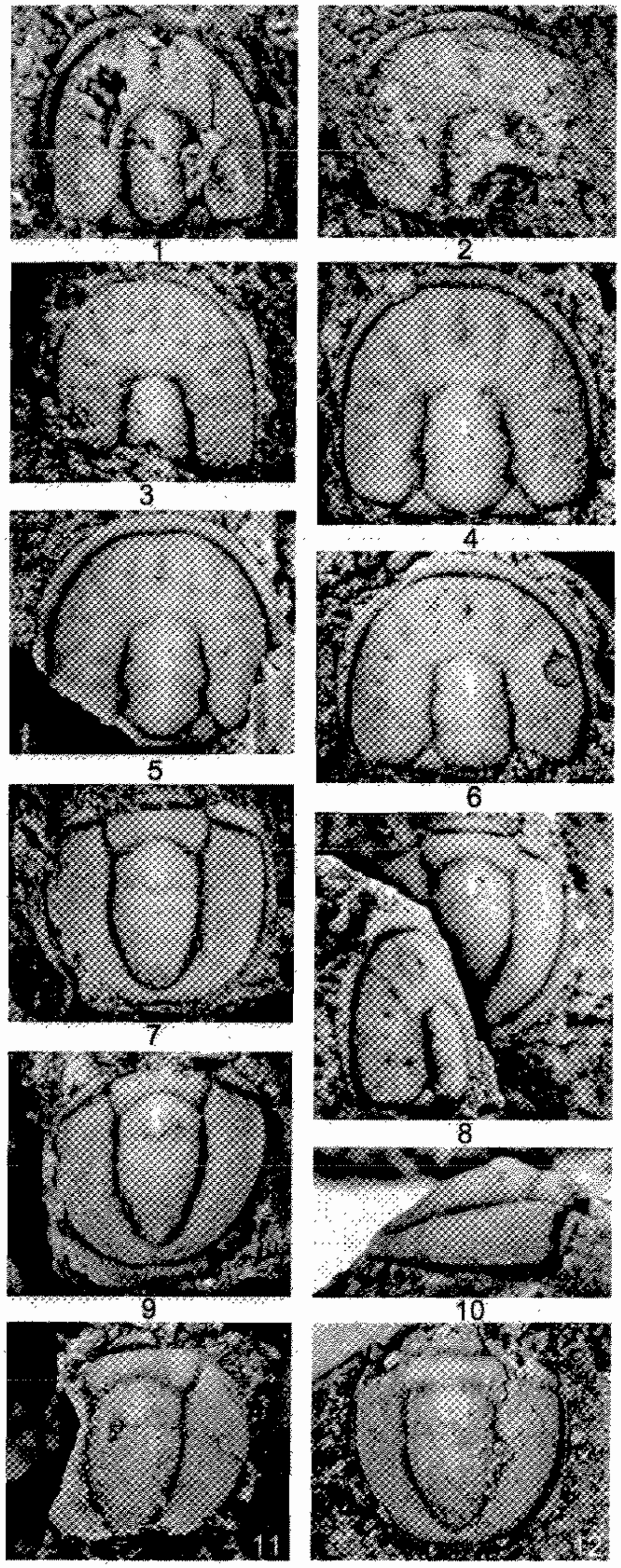

FIGURE *16*—*Tomagnostella exsculpta* (Angelin, 1851) from limestones collected at 36.05 m (KU6 collection) and at 36.55 m (KU4 collection) above base of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1–6*, cephala. *1*, WIHGF727.2, KU6, ×17.5; *2*, WIHGF1027.3, KU6, ×15; *3*, WIHGF720, KU6, ×10.75; *4*, WIHGF1038, KU6, ×12.75; *5*, WIHGF1010.2, KU6, ×12.75; *6*, cephalon, WIHGF735.1, KU6, ×11.5. *7–12*, pygidia. *7*, *10*, WIHGF701, KU6, ×12; *7*, dorsal view; *10*, right lateral view; *8*, cephalon, WIHGF735.1 and pygidium, WIHGF735.2, KU6, ×10. *9*, *11*, *12*, pygidia: *9*, WIHGF1019.1, KU6, ×12.25; *11*, WIHGF612.2, ×9; *12*, WIHGF1039, ×8.25.

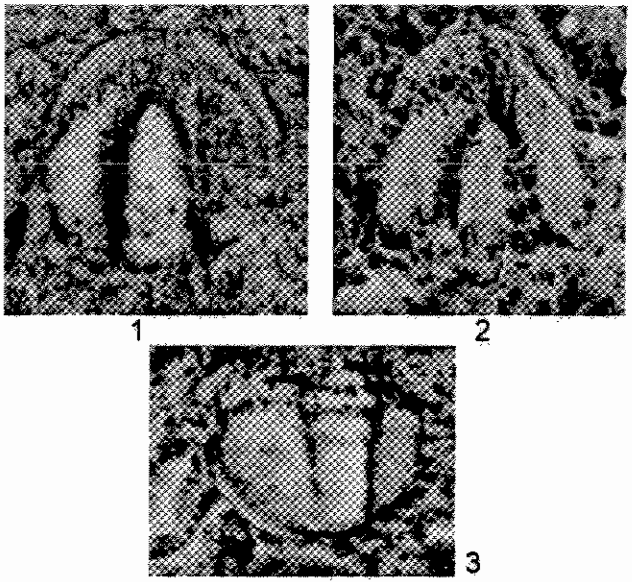

FIGURE *17*—*Opsidiscus haimantensis* (Reed, 1910)? from shale at 836.41 m above the base (PO26 collection) of the Parahio Valley section, Spiti region, Parahio Formation. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1–2*, cranidia: *1*, WIHGF909.2, ×19.25; *2*, WIHGF906.3, external mold, WIHGF906.3, ×23.25. *3*, external mold of pygidium, WIHGF906.4, ×16.5.

specific assignment, and therefore the Zanskar specimens are left in open nomenclature.

Occurrence.—Specimens assigned to ?*Pseudophalacroma ovale* Yang, 1982 are from limestone of the KU6 collection at 36.05 m above base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone.

Genus TOMAGNOSTELLA Kobayashi, 1939

Type species.—*Agnostus exsculptus* Angelin, 1851, p. 7; from the Andrarum limestone, middle Cambrian of Sweden, by original designation.

Discussion.—Although *Tomagnostella* is similar to *Hypagnostus* in many aspects of the cephalic morphology, in *Tomagnostella* there is a posteromedial node on M3, and M2 is expanded. The pygidia of the two genera are distinguishable by the axial furrows. *Tomagnostella* has a firmly-incised F1 and variably developed F2, but there are no pygidial axial furrows in *Hypagnostus*.

TOMAGNOSTELLA EXSCULPTA (Angelin, 1851)

Figure 16

Agnostus exsculptus ANGELIN (in part), 1851, p. 7, pl. 6, fig. 8 (cephalon only).

Tomagnostella exsculpta (Angelin); PENG AND ROBISON, 2000, p. 84, fig. 69 (see for synonymy up to 2000); PENG ET AL.,

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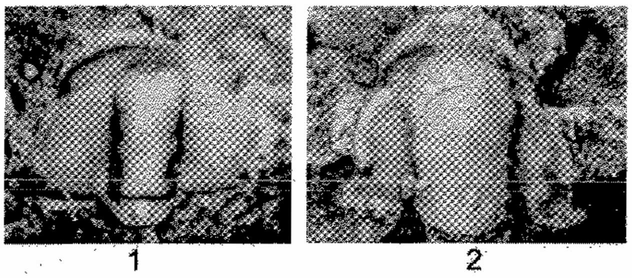

FIGURE *18*—*Chatiania*? sp. indet. from limestone collected at 36.05 m above the base (KU5 collection) of the Kuru 1 section opposite Kuru, Teta Member, Karsha Formation, on the north side of the Tsarap Lingti Chu, Zanskar valley. Specimens darkened with India ink and coated with magnesium oxide prior to photography. *1*, ?late meraspid cranidium, WIHGF833.1, ×22.75; *2*, cranidium, WIHGF833.2, × 6.75.

2001b, p. 159, fig. 10.3–10.4; PENG ET AL., 2005, p. 130, fig. 13.3–13.4.

Material.—Six cephala (WIHGF720, WIHGF727.2, WIHGF735.1, WIHGF1010.2, WIHGF1027.3, WIHGF1038) and five pygidia (WIHGF612.2, WIHGF701, WIHGF735.2, WIHGF1019.1, WIHGF1039).

Discussion.—The diagnostic features of these specimens are: long, narrow, pygidial axis that is nearly the length of the acrolobe; F1 firmly impressed, anteriorly arcuate; M2 with large median node.

Tomagnostella exsculpta differs from *T. sulcifera* in the length of the pygidial axis and in the development of cephalic scrobiculae. *T. exsculpta* has an axis that is almost the length of the acrolobe and poorly developed to imperceptible scrobiculae. *Tomagnostella sulcifera* has moderately developed scrobiculae and a pygidial axis that is shorter than the acrolobe.

The cephala and pygidia from Zanskar conform in all morphological respects to those of specimens from South China (Peng and Robison, 2000), permitting them to be assigned to this species.

Occurrence.—From limestones 36.05 m (KU6 collection) and 36.55 m (KU4 collection) above the base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. This species ranges from the *Ptychagnostus punctuosus* Zone to the *Glyptagnostus stolidotus* Zone in South China (Peng and Robison, 2000).

AGNOSTIDS OF UNCERTAIN FAMILIAL AFFINITY
Genus VALENAGNOSTUS Jago, 1976a

Type species.—*Agnostus nudus* var. *marginata* Brøgger, 1878, from the middle Cambrian, Krekling, Norway, by original designation.

VALENAGNOSTUS IMITANS (Öpik, 1961)?
Figure 15.1–15.3

? *Grandagnostus imitans* ÖPIK, 1961, p. 65, pl. 23, figs. 12–15; pl. 24, figures 5–7.
? *Valenagnostus imitans* (Öpik); JAGO, 1976a, p. 146; PENG AND ROBISON, 2000, p. 96, fig. 80 (see for synonymy); JAGO, BAO AND BAILLIE, 2004, figs. 5B–G, N.

Material.—Cephalon (WIHGF756).

Discussion.—A single, almost completely effaced cephalon is characterized by a rounded outline, moderate convexity, a posteriorly placed glabellar node, and very narrow lateral borders defined by shallow border furrows. The cephalon is identical in all observed respects to the cephala assigned to *Valenagnostus imitans* from Queensland, Australia (Öpik, 1961; Jago, 1976a; Jago et al., 2004) and northwestern Hunan, South China (Peng and Robison, 2000), but lack of an associated pygidium prevents a confident assignment.

Occurrence.—From limestones of collection KU7, 36.05 m above the base of the Kuru 1 section opposite Kuru, Zanskar, Karsha Formation (Teta Member); Guzhangian Stage, *Lejopyge acantha* Zone. In South China, *Valenagnostus imitans* occurs from the *Ptychagnostus punctuosus* Zone to the *Linguagnostus reconditus* Zone (Peng and Robison, 2000).

Suborder EODISCINA Kobayashi, 1939
Superfamily EODISCOIDEA Raymond, 1913
Family EODISCIDAE Raymond, 1913
Genus OPSIDISCUS Westergård, 1949

Type species.—*Aulacodiscus bilobatus* Westergård, 1946, from the middle Cambrian (*Lejopyge laevigata* Zone) of Västergötland, Sweden, by original designation.

OPSIDISCUS HAIMANTENSIS (Reed, 1910)?
Figure 17

? *Microdiscus haimantensis* REED 1910, p. 7, pl. 1, fig. 12–13.
? *Opsidiscus haimantensis* (Reed); JELL AND HUGHES, 1997, p. 31–32, pl. 5, figs. 6, 12–14.

New material.—Two flattened and distorted cranidia (WIHGF906.3, WIHGF909.2), and one pygidium (WIHGF906.4).

Discussion.—Jell and Hughes (1997) restudied the specimens from the Parahio Valley, Spiti, described originally by Reed (1910) as *Microdiscus haimantensis* Reed, and transferred the species to *Opsidiscus*. The new material from the same locality is poorly preserved, but overall characters suggest a tentative assignment to that species.

Occurrence.—In shale from 836.41 m above the base of the section (PO26 collection) on the north side of Parahio Valley, Spiti; Parahio Formation, *Oryctocephalus salteri* Zone, informal global Stage 5 of the Cambrian System.

Order CORYNEXOCHIDA Kobayashi, 1935
Family DOLICHOMETOPIDAE Walcott, 1916
Genus CHATIANIA Yang *in* Zhou, Liu, Mong and Sun, 1977

Type species.—*Chatiania chatianensis* Yang *in* Zhou, Liu, Mong and Sun (1977, p. 136, pl. 43, figs. 14, 15) from the *Liostracina-Chatiania* Zone of the Huaqiao Formation, Chatian, Fenghuang, northwestern Hunan, China, by original designation.

CHATIANIA? sp. indet.
Figure 18

Material.—Two cranidia, including those of a meraspid (WIHGF833.1) and a holaspid (WIHGF833.2).

Discussion.—Except for having a very short preglabellar field and an effaced occipital furrow in the holaspid, these cranidia are closely comparable to those assigned to *Chatiania* [=*Parachatiania*] *expansa* by Yuan and Yin (1998, pl.3, figs. 1, 4) and Peng et al., (2004a, pl. 4, figs. 1–14). The shared features include an effaced, forward expanded glabella with a rounded front, a narrow palpebral field, a gently curved, moderately sized palpebral lobe lying opposite the mid-point of the cranidium, and a strongly divergent posterior branch of the facial suture that encloses a short, blade-shaped posterolateral projection. However, the presence of a preglabellar field prevents confident generic assignment of these Zanskari specimens, and until more material is available, they are left in open nomenclature.

Occurrence.—In limestones from collection KU5 at 36.05 m above base of the Kuru 1 section opposite Kuru on the north side of the Tsarap Lingti Chu, Zanskar valley, Karsha