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YUEHSIENSZELLA (CAMBRIAN SERIES 2) TRILOBITE FROM THE PARAHIO VALLEY, SPITI REGION (ZANSKAR-SPITI SUB-BASIN), INDIA AND ITS BIOSTRATIGRAPHIC SIGNIFICANCE

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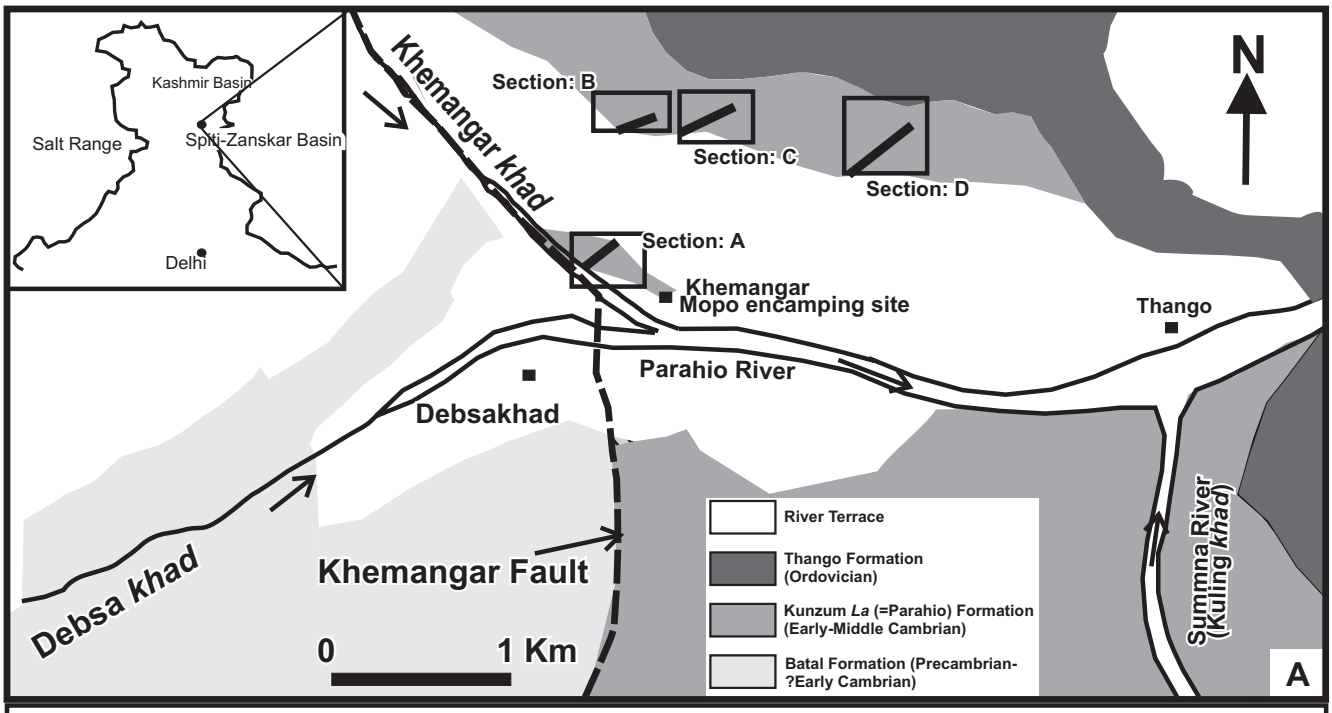
ABSTRACT

Cambrian trilobite taxon *Yuehsienszella* Chang, 1957 (Cambrian Series 2) is reported from the Kunzum *La* (=Parahio) Formation in the Parahio Valley, Spiti region of Zanskar-Spiti sub-basin, Northwest Himalaya. The taxon occurs 237 m below the *Oryctocephalus indicus* level (Cambrian Series 3, Stage 5) and indicates a late Tsanglangpuan age (Cambrian Series 2, Stage 4) for the level within the Kunzum *La* (=Parahio) Formation at the type section and hence revises the lower age limit to Tsanglangpuan age (Cambrian Series 2). *Yuehsienszella* is also known from the Cambrian succession of the Salt Range (Pakistan) where it occurs in association with the *Redlichia noetlingi*. In the Spiti region, *Redlichia noetlingi* is known from a float. The *in situ* specimen of *Yuehsienszella* from the Parahio Valley (Spiti region) supports the presence of equivalent level in the Cambrian of this area. A correlation of the lower Cambrian successions extending from the Salt Range (Pakistan) in the west to the Garhwal Himalaya in east is presented.

Keywords: Cambrian Series 2, *Yuehsienszella,* Kunzum *La* (=Parahio) Formation, Spiti, Himalaya

INTRODUCTION

Until the last decade the biostratigraphy of the Himalayan Cambrian trilobites remained inadequately understood due to poor preservation and insufficient collection of trilobite fossils. In recent years new finds of trilobites and re-identification of previously recorded trilobites have contributed to a broad understanding of the Cambrian biostratigraphy and biozonation of the Himalaya (Jell and Hughes, 1997; Hughes and Jell, 1999; Hughes *et al.,* 2005; Peng *et al.,* 2009 and Singh, 2011, 2013). The first detailed work on Cambrian trilobites of the Himalaya, particularly from the Spiti region, was carried out by Reed (1910), wherein he described the collection of Hayden (1904) that came from a steep ridge exposed north of the Parahio River in the Parahio Valley. Jell and Hughes (1997) updated the taxonomy of the Cambrian trilobites of the Indian Himalaya and presented an informal Cambrian trilobite biozonation for the Indian Himalaya after the Chinese scheme of biozonation. They revised the trilobites previously described by Reed (1910) and established six trilobites bearing levels belonging to the middle Cambrian age (Maochuangian to Hsuchuangian Stages). More recently, Peng *et al.* (2009) presented a detailed Cambrian biostratigraphy with new collection of trilobites from the Parahio section (Spiti region) and the Zanskar region of the Northwest Himalaya and stated that the fauna belongs to upper part of the informal Stage 4 (Cambrian Series 2) to the Guzhangian Stage (near the top of Cambrian Series 3). Peng *et al.* (2009) stated that the trilobite fauna in the Spiti region ranges in age from Cambrian Series 2 (Stage 4) to Series 3 (Stage 5). They also opined that *Oryctocephalus indicus* level (Hayden level 2, 1904), which constitutes the lowest trilobite level of Reed (1910), is no older than the base of yet unnamed Cambrian Stage 5. Globally, the FAD of *Oryctocephalus indicus* is used for defining the base of the as yet- unnamed Stage 5 of the Cambrian system (Peng and Babcock, 2005, Babcock *et al.,* 2005). However, the matter is still under consideration within the Cambrian subcommission and a vote yet to be taken. Since the work of Hayden (1904), in last 108 years, the *Oryctocephalus indicus* level (Hayden level = 2) could not be located by any worker. While defining the Cambrian biozonation of the Indian Himalaya, Peng *et al.* (2009) also could not locate the *Oryctocephalus indicus* level in the Parahio Valley section and projected this level at ~200 m from the base of their measured section (see Peng *et al.,* 2009, fig.3). However, Peng *et al.* (2009) identified a new trilobite-bearing horizon, nearly 122 m below their projected *Oryctocephalus indicus* level, and named it as *Haydenaspis parvatya* level which contains the eponymous species *Haydenaspis parvatya*, *Prozacanthoides lahiri*, and some ptychoparioids including *Probowmania bhatti* and ?*Mufushania nankingensis*. In 2012 the present authors successfully located the Hayden level= 2 incorporating *Oryctocephalus indicus*, *Pagetia significance, Kunmingaspis pervulgata* and undetermined ptychoparid trilobite during an extensive sampling in the Parahio Valley. Unfortunately we could not locate *Haydenaspis parvatya* level in measured section along the Parahio Valley. Peng *et al.* (2009) assigned *Haydenaspis parvatya* level within the unnamed Cambrian Stage 4 of the Cambrian system, and thus to the uppermost part of the Series 2 of the Cambrian system. Here we report *Yuehsienszella* Chang 1957, a lower Cambrian (Series 2, Stage 4) trilobite from the Parahio Valley section, Spiti region (Fig. 1a), which also constitutes the type section of the Kunzum *La* (=Parahio) Formation of Myrow *et al.* (2006b). The present collection includes a complete specimen and a partially preserved thorax of *Yuehsienszella* from the stratigraphic level lies ~237 m below the *Oryctocephalus indicus* level (Cambrian Series 3) and thus the present find represents the oldest trilobite bearing level yet discovered in the Spiti region of the Zanskar-Spiti sub-basin, Northwest Himalaya. Following the stratigraphic range of this genus recorded in South China, a late Tsanglangpuan age (Cambrian Series 2, Stage 4) is proposed for the exposed lower part of the Kunzum *La* (=Parahio) Formation



Age	Stoliczka (1865)	Greisbach (1891)	Hayden (1904)	Pascoe (1959)	Srikantia et al., (1979) & Srikantia (1981)	Kumar et al., (1984)		Singh et al., (1991)	Myrow et al., (2006)	Bhargava (2008)
CAMBRIAN	"Babhes Series"	"Haimanta Series"	"Cambrian System"	Parahio series	Kunzum *La* Formation	Kunzum *La* Fm.	Parahio Member	Parahio Formation	Parahio Formation	Kunzum *La* Formation
				Upper Haimanta series			Debsa Khad Member	Kunzum *La* Formation		
					Batal Formation	Batal Formation		Batal Formation	Batal Formation	Batal Formation

B

Fig.1.(a) Simplified Geological map of the Parahio Valley, Spiti region of Zanskar-Spiti sub-basin (modified after Bhargava *et al*., 1982 and Myrow *et al*., 2006a); (b) Chart showing the lithostratigraphic classification and nomenclature used for the Cambrian of Spiti region by various workers.

at the type section, and the lower age limit of which is extended to the Tsanglangpuan Stage (Cambrian Series 2, Stage 4).

GEOLOGICAL SETTING, LITHO-STRATIGRAPHY AND PREVIOUS WORK

The Parahio River is a tributary of the Pin River; both confluence at Sagnam village, which is located 40 km SW of Kaza (sub-divisional headquarters) in the Spiti region (Zanskar-Spiti, sub-basin), Northwest Himalaya, India. The fossiliferous Cambrian rocks in the Parahio Valley (Spiti region) are well exposed and constitute the best studied Cambrian succession in the Himalaya (Fig.1a). Various names have been used for the Cambrian of the Spiti region and a considerable degree of avoidable confusion was introduced into the understanding of the Cambrian geology of the region by interchanging the litho-stratigraphic terminology (Stoliczka, 1865; Griesbach, 1891; Pascoe, 1959; Hayden, 1904; Srikantia *et al.,* 1978; Srikantia, 1981; Kumar *et al.,* 1984; Myrow *et al.,* 2006; Singh *et al.,* 1991, Bhargava, 2008, 2011; Virmani *et al., in press*). In addition, different workers reported variable thickness of the Cambrian succession in the Parahio Valley. Divergent opinions and nomenclatures pertaining to litho-stratigraphy of the Cambrian of the Spiti region are presented in a chart (Fig.1b). Stoliczka (1865) designated the Cambrian sequence of the Spiti region as "Bhabeh series". However, Griesbach (1891) used the term "Haimanta System" for the rocks overlying the Precambrian "Vaikrita System". Hayden (1904) adopted the term "Haimanta System" to include some unfossiliferous strata as well as fossiliferous Cambrian. Pascoe (1959) termed the fossiliferous part of the Haimanta of Hayden (1904) as the "Parahio Series". Srikantia *et al.* (1978) and Srikantia (1981) enlarged the scope of the term "Haimanta", by assigning it a group status that included a huge thickness of sediments overlying the Rohtang Gneissic Complex and underlying a calc-arenite sequence which was

designated as the Takche Formation. Srikantia's (1981) "Haimanta Group" broadly includes the "Cambrian System" and "Silurian System" of Hayden (1904). The Haimanta Group was subdivided into three formations, i.e. Batal, Kunzum *La* (*senso stricto*) and Thango in ascending order. Bhargava *et al.* (1988) and Bhargava and Bassi (1998) separated the Thango Formation from the "Haimanta Group" based on the transgressive-regressive cycles and presence of an angular unconformity between the Kunzum *La* and Thango formations. Kumar *et al.* (1984) further subdivided the Kunzum *La* Formation into two formal members namely the Debsa khad and Parahio. Singh *et al.* (1991) retained only lower part of the Kunzum *La* Formation, while its upper part was accorded a status of a distinct formation *viz.* the Parahio Formation (=Parahio Member of Kumar *et al.,* 1984), characterised by incoming of calcareous sediments. Myrow *et al.,* (2006b) overlooked the terminology used by Srikantia (1981), Kumar *et al.,* (1984) and Singh *et al.,* (1991) and proposed the term "Parahio Formation" to the "Parahio Series" of Pascoe (1959) and used the term Parahio Formation for the entire Kunzum *La* Formation, which has been contested on several grounds by Bhargava (2008) and Virmani *et al.* (*in press*). We used the term Kunzum *La* Formation due to wide acceptance of this term and its proved mapability over a vast area (Bhargava, 2008, 2011, Virmani et al., *in press*). The pioneer stratigraphic and paleontological studies on the Cambrian successions were carried out by Hayden (1904) and Reed (1910), which included significant contribution to the trilobites from the Spiti region. Later, Shah and Paul (1987) recorded oryctocephalid fauna from the Parahio Valley (Spiti region). More recently, Jell and Hughes (1997) and Peng *et al.* (2009) defined the Cambrian biozonation of the Spiti region along with Zanskar Valley. Bhargava *et al.* (1982, 1986); Bhargava and Srikantia (1985), Sudan *et al.* (2000), Sudan and Sharma (2001), Parcha *et al.* (2005), Parcha and Pandey (2011) and Virmani and Singh (2012) described trace fossils from the Spiti region.

STUDIED SECTIONS

During the present investigation, four sections have been studied in

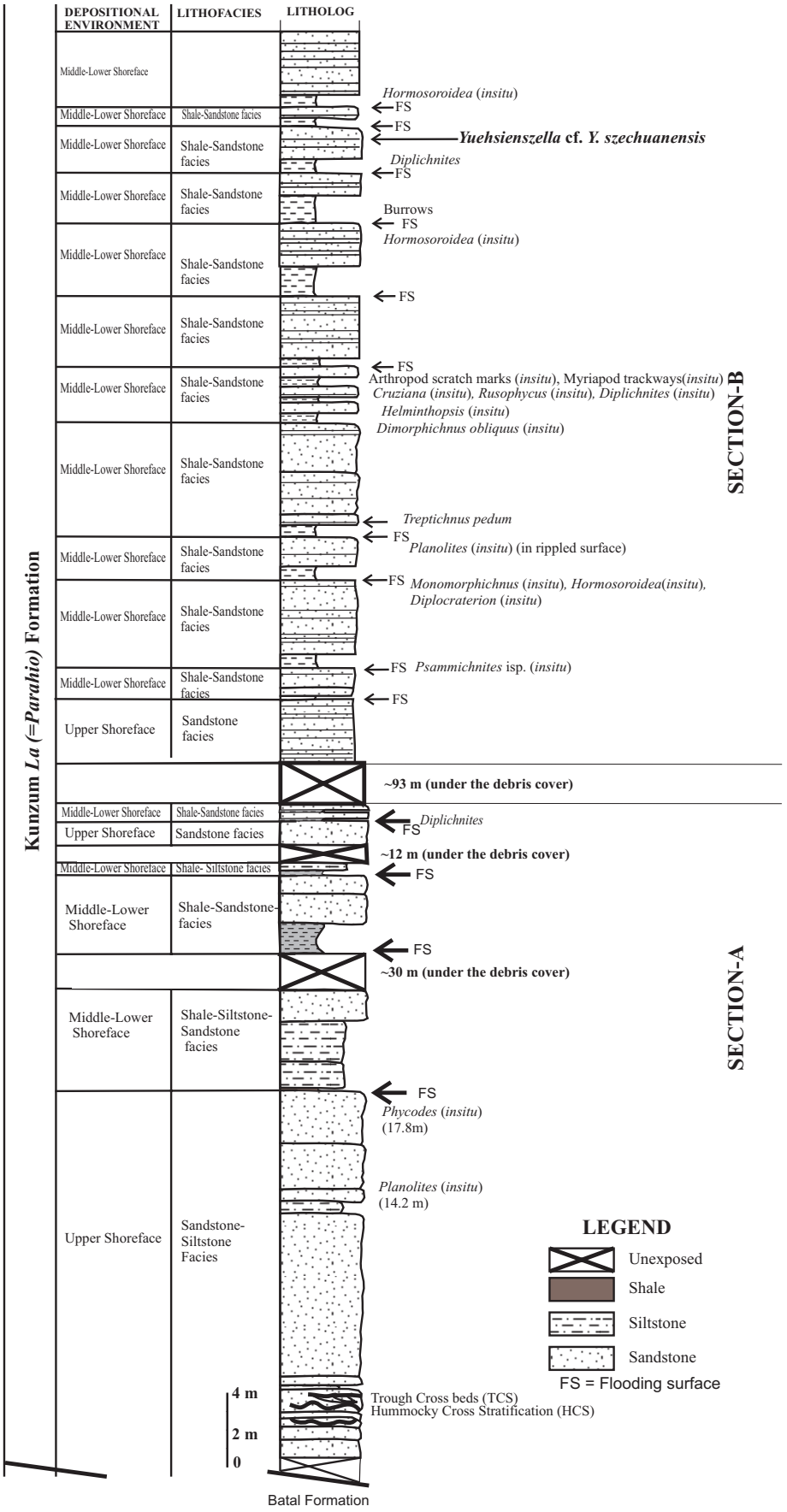


Fig. 2. Lithostratigraphic column of the lower Part of the Kunzum *La* (=Parahio) Formation measured along Sections A and B with stratigraphic position of the lower Cambrian trilobite and trace fauna.

detail from lower and middle parts of the Kunzum *La* (=Parahio) Formation in the Parahio Valley (Fig.1.a).

Section A: It is 61m thick succession consisting of massive sandstone in lower part and siltstone, sandstone and shale alteration in upper part. This section represents the trace fossil locality of Bhargava *et al.* (1982) along the north bank of the Khemangar *khad* and forms lowermost exposed part of the Kunzum *La* (=Parahio) Formation in the Parahio Valley. The body fossils have not been so far recorded along this section.

Section B: It is 42 m thick and comprises sandstone, carbonate sandstone and shale cycles. It represents the lower part of the Kunzum *La* (=Parahio) Formation. This section lies nearly 93 m (covered by debris and grass) above the Mopo encamping ground (Section A) in the NE direction along the steep slope (see Section B, Fig.1a).The rocks along this section yielded abundant and diverse assemblage of trace fossils (Virmani and Singh, 2012) and two specimens of the trilobite taxon *Yuehsienszella*.

Section C: Measuring 237 m, it is constituted of shale, sandstone and carbonate alternations. It occupies a position between the *Yuehsienszella* and *Oryctocephalus indicus* levels.

Section D: It is 280 m thick and forms middle part of the Kunzum *La* (=Parahio) Formation. The *Oryctocephalus indicus* level lies in basal part of this section. It is constituted of thin to thickly bedded sandstone, shale and carbonate alternations. The trilobite fauna has been collected from four stratigraphic levels along this section, the lowest represents *Oryctocephalus indicus* level (Hayden level 2).

The present paper deals with the lower part of the Kunzum *La* (=Parahio) Formation. Lithocolumns of sections A and B (Fig.2) illustrate the stratigraphic positions of the lower Cambrian trilobite *Yuehsienszella* and the trace fossils. There is quite a difference in stratigraphic thicknesses measured by various authors. Hayden (1904) measured 362 m of the Cambrian succession at the Parahio section in which the *Oryctocephalus indicus* level is located at 33 m from the base of the section (see Jell and Hughes, 1997, fig.3, p.11), whereas Myrow *et al.* (2006) and Peng *et al.* (2009, fig.3) measured 1360 m composite log along the Parahio and Sumna River sections and stated that the total thickness measured by Hayden (1904) is less than 25% of the true thickness. Below the projected *Oryctocephalus indicus* level, Peng *et al.* (2009) measured nearly a succession of 200 m and recorded a new trilobite level, i.e. *Haydenaspis parvatya* which lies nearly 122 m below the probable estimated level of *Oryctocephalus indicus* bearing beds. The trilobite *Yuehsienszella* (late Tsanglungpuan age, Cambrian Series 2, Stage 4), which is recorded in present work, occurs ~237 m below the confirmed and "rediscovered" *Oryctocephalus indicus* level (Cambrian Series 3, Stage 5) along the Parahio Valley section, Spiti Himalaya (Fig. 3).

SYSTEMATIC PALAEONTOLOGY

The specimens (CAS BPS 1080 and 1081) are housed in the repository of the CAS Geology Department, PU. The specimen

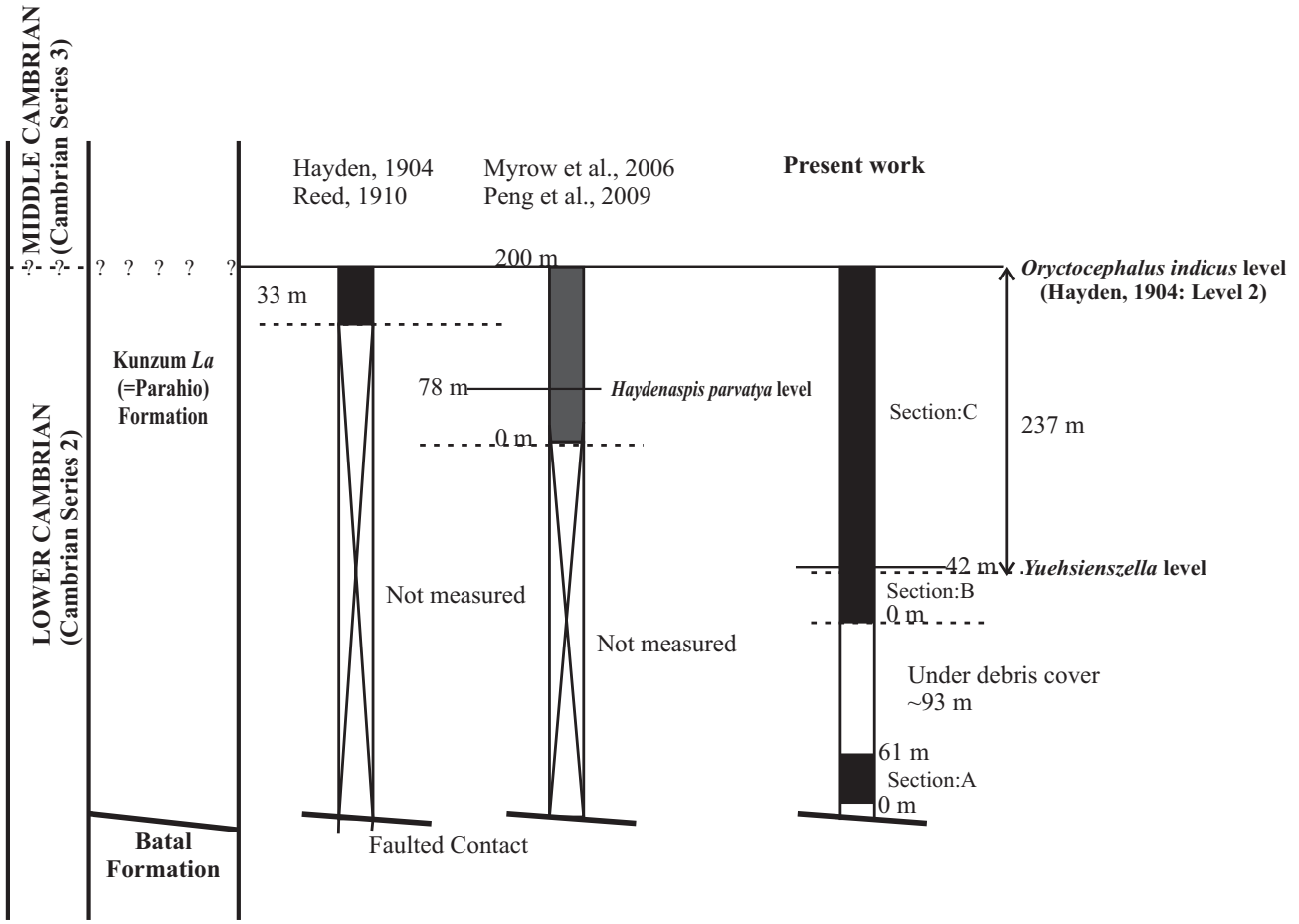


Fig. 3. A comparative account of the lithostratigraphic columns measured by Hayden (1904), Myrow *et al.* (2006), Peng *et al.* (2009) and the present work from *Oryctocephalus indicus* level up to the faulted contact of Batal and Kunzum *La* (=Parahio) formations along the Parahio Valley, Spiti region of Zanskar-Spiti sub-basin.

CAS BPS 1080 is the rubber cast. The specimens were coated with India ink and magnesium oxide prior to photography.

Order **Ptychopariida** Swinnerton, 1915 emend. Fortey, 1990

Superfamily **Ptychopariacea** Matthew, 1887

Family **Antagmidae** Hupe, 1953

Genus **Yuehsienszella** Chang (Zhang), 1957

(Type species: By original designation; *Ptychoparia szechuanensis* Sun, 1939 from the lower Cambrian of Sichuan; *Yuehsienszella szechuanensis* (Sun, in Lu, 1939)

Yuehsienszella cf. *Y. szechuanensis* (Sun, in Lu, 1939)
(Fig. 5, a-d)

Material: Two specimens, one partially complete (rubber cast CAS BPS 1080), another incomplete thorax part (CAS BPS 1081), from the Kunzum *La* (=Parahio) Formation, Parahio Valley, Spiti region, India

Diagnosis: See Zhang *et al*., 1980

*Description***:** Dorsal exoskeleton elongated, ovate, 19 mm in length. Cranidium semicircular and convex, glabella more or less conical, strongly convex, border narrow and convex, preglabellar field moderately long (sag.), sloping towards border, glabellar furrows weakly incised, palpebral lobe small midpoint situated opposite middle of cephalon, eye moderate, eye ridges faintly preserved meet glabella at rear end of the anterior lobe, occipital ring pronounced, broader at the midpoint, shortening extrasagitally on either side, thorax composed of thirteen segments, axial ring convex, tapers posteriorly and narrower than the pleurae. Pleural segments wide and flattened with outer portion slightly bent backwards. Pygidium poorly preserved, small in size.

Remarks: Our specimens closely resemble in morphological characters to *Yuehsienszella* illustrated by Zhang *et al.* (1980). The comparison of our specimens with the *Yuehsienszella* (Zhang *et al.,* 1980) indicates presence of 13 thoracic segments, conical and strongly convex glabella, pleural segments wide and flattened with outer portion slightly bent backwards. These characters are closer to *Yuehsienszella* (Zhang *et al.,* 1980). In China, *Yuehsienszella* ranges from late lower Cambrian *Palaeolenus* Zone to *Pteroredlichia chinensis* Zone (Zhang *et*

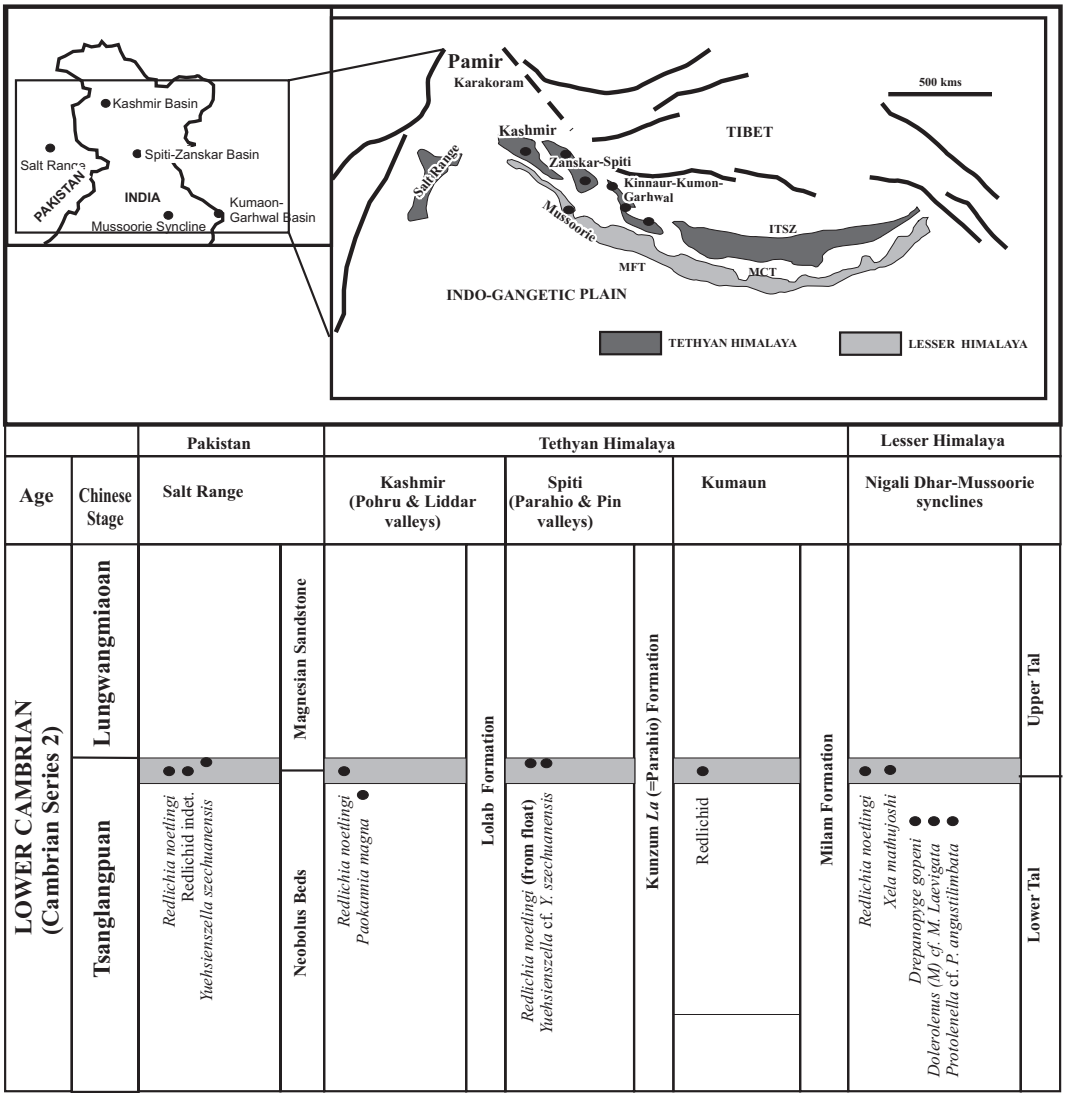


Fig.4. A regional correlation of the lower Cambrian successions in the Indian subcontinent from Salt Range (Pakistan) in the west to NigaliDhar-Mussoorie synclines (Lesser Himalaya) in the east with reference to the stratigraphic position of late Tsanglangpuan (Cambrian Series 2) trilobite levels.

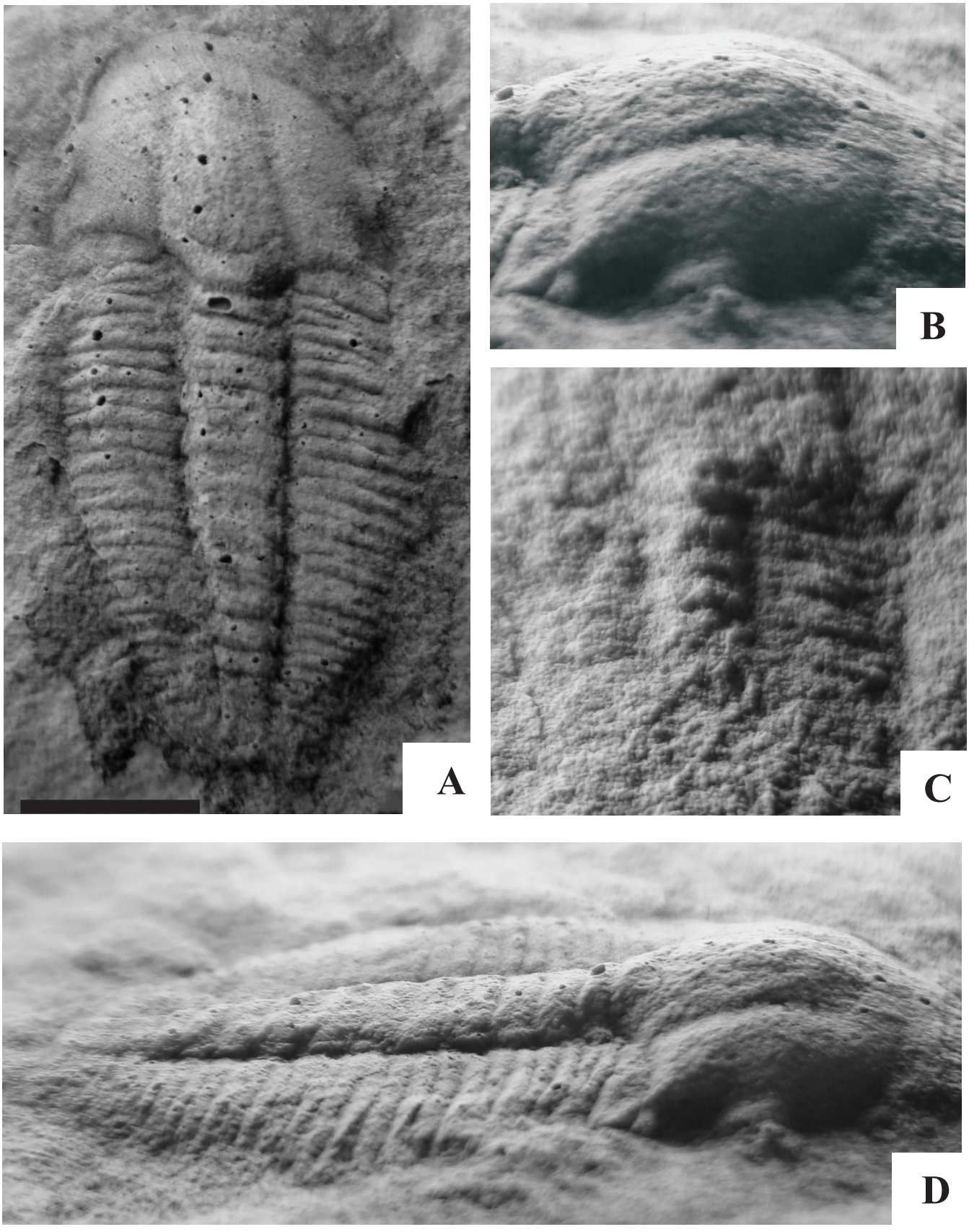


Fig. 5. ***Yuehsienszella*** from the lower part of the Kunzum *La* (=Parahio) Formation, Parahio Valley, Spiti region of Zanskar-Spiti sub-basin. Specimens coated with magnesium oxide prior to photomicrography. Scale bar= 1 cm. A-D ***Yuehsienszella*** cf. ***Y. szechuanensis*** (a) Rubber cast of the specimen CAS BPS 1080, (b) lateral view of the head, (c) another specimen CAS BPS 1081showing the thoracic part, (d) lateral view of the specimen CAS BPS 1080.

al., 1980). Jell and Hughes (1997) grouped *Ptychoparia geei* and *Ptychoparia sakesarensis* (King, 1941) as *Yuehsienszella szechuanensis* (Sun, in Lu, 1939) from the lower Cambrian purple Magnesium Sandstone, Kussak Fort Hill, Salt Range (Pakistan). Our specimens from the Kunzum *La* (=Parahio) Formation (Spiti region) differ from those illustrated from the Salt Range (Pakistan) in shape of cranidium and glabella. Jell and Hughes (1997) noted that the intraspecific variation is notable in this genus, which we attribute to preservation state. *Xilingxia* Lu (Zhang *et al.,* 1980) is similar to *Yuehsienszella* but differs in having a narrower and depressed preglabellar field, a broader cranidium and longer glabella, and a narrower axial lobe of both the thorax and pygidium. *Xiangqianaspis* Zhou (Zhang *et al*., 1980) is also similar in morphology to *Yuehsienszella* but differs in having longer palpebral lobes, a less tapered glabella, deep and prominent glabellar furrows, and a relatively broader anterior cranidial border. *Xiaomajiella* Zhu (Zhang *et al*., 1980) apparently similar to *Yuehsienszella* differs in having a narrower preglabellar field, small palpebral lobes, glabellar front arcuately rounded, anterior sections of facial sutures parallel, and a less arcuate anterior border (Zhang *et al*., 1980a).

Prof. Jin-Phi Lin (NIGPAS, China) has confirmed the identification as *Yuehsienszella* (personal communication to BPS). However, Prof. N. C. Hughes is of the opinion that the form described here as *Yuehsienszella* belongs to *Bhargavia prakritika* (Cambrian Series 2, Stage 4). Since a doubt was raised about the identification of the *Yuehsienszella*, we thought it better to seek another opinion. Consequently, we approached Prof Peter Jell. In his communication to ONB, Prof Jell writes, "the comparison with *Bhargavia*, one difference is the distance between the anterior of the glabella and the anterior border. In *Bhargavia* this distance is short that is the glabella reaches closer to the anterior border furrow. In *Yuehsienszella*, this distance is greater in adults but in juveniles it is the same as in *Bhargavia*. This would suggest an evolutionary lineage with *Yuehsienszella* evolving to *Bhargavia* as stratigraphy suggests. In the present specimen, it appears to have the glabella to anterior border distance intermediate between *Yuehsienszella* and *Bhargavia*, so I would think its age is somewhere in between the two*"*. Since the aim of any research is to arrive at truth, we do not wish to suppress the dissenting opinion of Prof N. Hughes. The controversy in the identification of this important trilobite will receive the attention of Cambrian trilobite experts all over the globe and finally the truth shall triumph.

BIOSTRATIGRAPHIC SIGNIFICANCE

Jell and Hughes (1997), Hughes (1999), Peng *et al.* (2009) and Singh (2011, 2013) used traditional Chinese Cambrian Scheme for defining the Cambrian biozonation of the Himalaya. The same scheme is followed in the present paper along with the international scheme of Cambrian System. The Lower Cambrian trilobite biostratigraphy of the Indian subcontinent is poorly constrained. Except for the record of *Redlichia* from the Pohru Valley and *Paokannia magna* from the Liddar Valley (both from Kashmir sub-basin, Tethyan Himalaya, India); *Redlichia noetlingi*, *Xelamathur joshi*, *Drepanopyge gopeni*, *Dolerolenus (Malungia) cf. M. laevigata* and *Protolenella cf. P. angustilimbata* from Nigalidhar-Mussoorie synclines (Lesser Himalaya, India) and *Yuehsienszella szechunensis* and *Redlichia noetlingi* from the Salt Range (Pakistan), no other trilobite of the Lower Cambrian age is known from the Indian subcontinent. In the Spiti region, the *Redlichia noetlingi* is known from a float (Hayden, 1904). Jell and Hughes (1997) estimated its stratigraphic position and interpreted an age equivalent to the late Tsanglangpuan Stage (Cambrian Series 2) of the Cambrian System. The present record of *Yuehsienszella* from the Parahio Valley of the Spiti region indicates the oldest stratigraphic level of the trilobite so far recorded from this region and provides an important constraint on the age of the lower part of the Kunzum *La* (=Parahio) Formation. According to Jell and Hughes (1997), the low-diversity fauna of *Redlichia*, *Yuehsienszella, Paokannia* and *Xela* in the Chinese lower Cambrian succession occurs at late Tsanglangpuan age (Zhang *et al*., 1980). In the Indian subcontinent, *Yuehsienszella* is also known from the Lower Cambrian (late Tsanglangpuan Stage) of the Salt Range, Pakistan (King, 1941; Jell and Hughes, 1997). In Kussak Hill (Salt Range, Pakistan), this genus occurs just above or together with the *Redlichia noetlingi* (King, 1941; Gee 1934, Jell and Hughes, 1997). In the Tethyan Himalaya, *Paokannia magna* from the Kashmir sub-basin (Kumar and Verma, 1987) may belong to *Paokannia-Sichuanolenus* Zone (Zhou and Yuan, 1980) and represents the oldest known trilobite of late Tsanglangpuan Stage of the Lower Cambrian. *Redlichia* has been recorded from the Pohru Valley (Kashmir), Nigali Dhar-Mussoorie synclines (Lesser Himalaya), Salt Range (Pakistan) and Spiti Valley (from float). This form belongs to *Palaeolenus* Zone of Kunming region (Zhou and Yuan, 1980). The *Palaeolenus* Zone overlies the *Paokannia- Sichuanolenus* Zone and characterizes the fifth zone in the Tsanglangpuan Stage in the Kunming region of China. *Yuehsienszella* in the Kussak Hills, Salt Range (Pakistan) occurs with *Redlichia noetlingi* (King, 1941; Jell and Hughes, 1997), hence belongs to *Palaeolenus* Zone (late Tsanglungpuan). Jell and Hughes (1997) project the *Redlichia noetlingi* level in Spiti at the top of Tsanglangpuan age (Cambrian Series 2). The present record of *Yuehsienszella* from Spiti points to the presence of equivalent level in the lower part of the Kunzum *La* (=Parahio) Formation. Regional correlation of the Lower Cambrian strata in the Indian subcontinent stretching from the Salt Range (Pakistan) in the west to the Nigali Dhar-Mussoorie synclines (Lesser Himalaya) in the east (Fig. 4) indicates that the *Redlichia*-bearing beds or equivalent strata represent a late Tsanglungpuan age (top of Cambrian Series 2). The record of this genus from the Spiti region and particularly from the lower part of the Kunzum *La* (=Parahio) Formation is significant. Its presence revises the lower age limit of the Kunzum *La* (=Parahio) Formation to Tsanglangpuan age. We propose Cambrian Series 2 (Tsanglungpuan) to Series 3 (Hsuchuangian) for the Kunzum *La* (=Parahio) Formation at the Parahio Valley section.

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