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REVISION OF DIAGNOSTIC FEATURES OF THE TRILOBITE GENUS *BHARGAVIA* (ELLIPSOCEPHALOIDEA) FROM THE PARAHIO VALLEY (SPITI), NORTHWEST HIMALAYA, INDIA

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ABSTRACT

In the light of additional material from the Cambrian successions of the Parahio valley (Spiti), the Ellipsocephalinae trilobite genus *Bhargavia* is rediagnosed. We also record the lowest occurrence of this taxon at 12.1 m above the *Oryctocephalus indicus* Zone (Cambrian Series 3, Stage 5). Earlier, the type species of *Bhargavia prakritika* was known from *Kaotaia prachina* Zone (Stage 5) at 233.4 m above the inferred *O. indicus* level. The present discovery, thus, indicates the lowest stratigraphic level of this taxon, which is equated with the upper part of the *Plagiura* Zone of Great Basin. Discovery of complete specimens of *Bhargavia prakritika* permits elaboration of its diagnostic characters, which earlier were based on cranidia and pygidia.

Keywords: Cambrian Series 3 (Stage 5), *Bhargavia prakritika,* Parahio Valley, Spiti

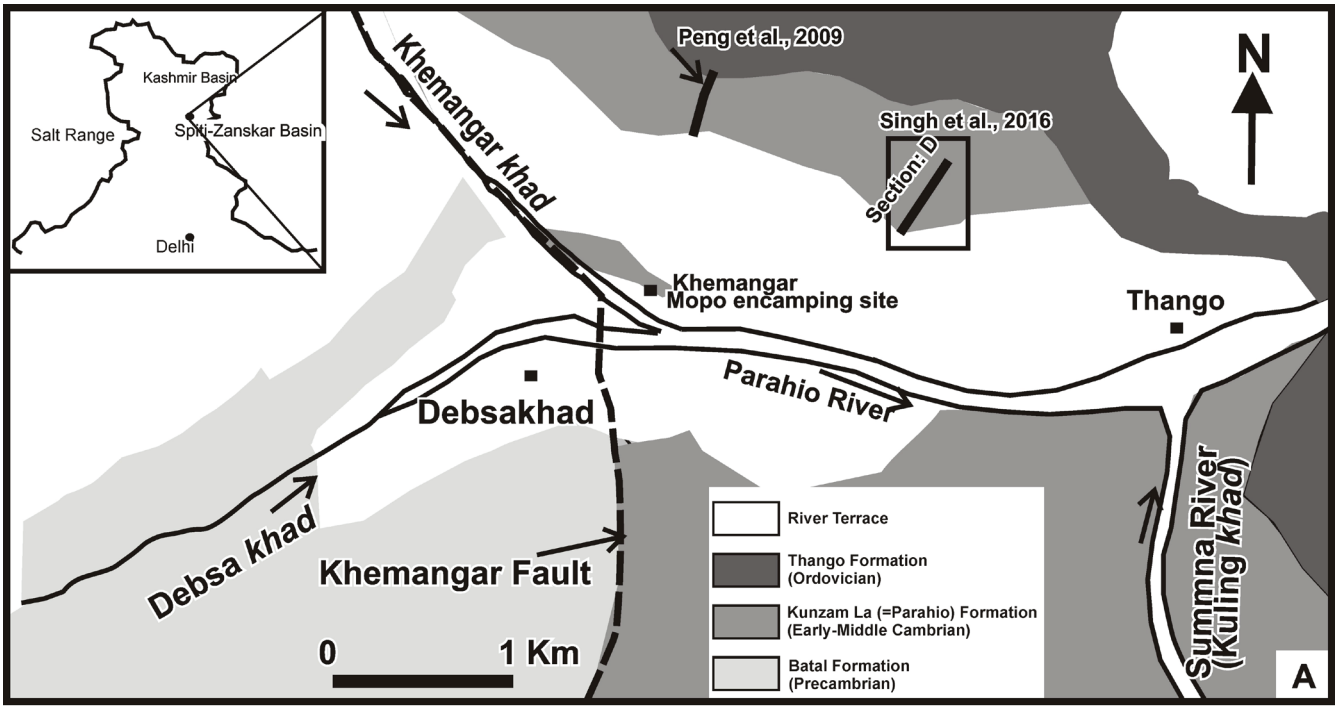
INTRODUCTION

Based on new collection of the Cambrian trilobites from the Parahio (Spiti) and Kurgiakh (Zanskar) valleys, Peng *et al*. (2009) proposed the formal Cambrian biozonation for the Indian Himalaya. In the Spiti region, three trilobite zones, three levels, and five unzoned levels were established within a 1360 m thick Cambrian succession exposed along the Parahio valley and Summna river sections. These trilobite zones and levels were arranged in ascending order as: *Haydenaspis parvatya* level, unzoned 1, *Oryctocephalus indicus* level, unzoned 2, *Kaotaia prachina* Zone, unzoned 3, *Paramecephalus defossus* Zone, *Oryctocephalus salteri* Zone, unzoned 4, *Iranolessia butes* level and unzoned 5 ranging in age from the Cambrian Series 2 (Stage 4) to Series 3 (Stage 5), spanning nearly 5 Ma time interval (Peng *et al*., 2009; Popov *et al.*, 2015). The Ellipsocephalinae genus *Bhargavia* (*B. prakritika,* Peng *et al.*, 2009) was reported from the limestone horizon that occurs within the *Kaotaia prachina* Zone marked at 433.4 to 439.67 m from the base of the Parahio valley section (Peng *et al.*, 2009). With respect to the inferred *O. indicus* level, *Kaotaia prachina* Zone occurs 233.4 m upward in the section (Peng *et al.*, 2009, p. 4, Fig. 3). The present authors found *Bhargavia prakritika* at 12.1 m above the top of the confirmed *Oryctocephalus indicus* Zone (Singh *et al*., 2016) in the Parahio valley section, Spiti region (Figs. 1 & 3). The material collected at this newly discovered level comprises four partially complete exoskeleton and a few thoracic parts and ten poorly preserved cranidia. Thus, the present find extends the lower limit of this taxon in the Parahio valley section. The generic characters of this taxon were earlier based on the cranidia and pygidia. Discovery of complete specimens brings to light additional characteristic features which call for a detailed and additional generic description of the *B. prakritika.*

GEOLOGICAL SETTING, LITHO-STRATIGRAPHY AND PREVIOUS WORK

The Spiti region of the Zanskar-Spiti Basin lies north of the Greater Himalayan Zone (GHZ) and forms the part of the Tethyan Himalayan Zone (THZ). The Cambrian rocks in the Spiti region are exposed in the Chandra valley (Lahaul, west of Spiti)), the Kunzum Pass-Takche section, and in the Pin-Parahio valleys. The Parahio valley, the study area, is a subsidiary valley of the major Pin valley, which join at Sagnam village, is situated about 40 Km SW of Kaza town (Lahaul-Spiti district). The fossiliferous Cambrian rocks in the Parahio valley constitute the best studied Cambrian succession in the Himalaya (Fig.1A). The Cambrian of the Spiti region is grouped under the Haimanta Group (Srikantia, 1981; Bhargava and Bassi, 1998) which is subdivided into the Batal and the Kunzam La formations (Srikantia, 1981; Bhargava and Bassi, 1998). Only the uppermost part of the Cambrian Kunzam La Formation (Srikantia, 1981) is preserved in the Parahio valley. These rocks in the Parahio valley were more recently assigned to the Parahio Formation (Myrow *et al*., 2006 a,b), which was contested by various workers elsewhere (Bhargava, 2008, 2011; Virmani *et al*., 2015). Along the Parahio valley, a faulted contact exists between the Kunzam La (=Parahio) and the underlying Batal formations (Bhargava *et al*., 1982; Myrow *et al*., 2006a). The Kunzam La (= Parafid) Formation is overlain by the Ordovician arenaceous Thango Formation with an angular unconformity (Hayden, 1904; Fuchs, 1982; Bhargava and Bassi, 1998; Myrow *et al*., 2006a,b). The generalized stratigraphy of the Cambrian successions of the Spiti region is given in Fig.1B.

The Cambrian rocks of the Parahio valley were studied by various workers (Stolickzka, 1865; Griesbach, 1891; Hayden, 1904; Srikantia, 1981; Bhargava *et al*., 1982, 1986; Kumar *et*



Age	Stoliczka (1865)	Griesbach (1891)	Hayden (1904)	Pascoe (1959)	Srikantia (1981)	Kumar et al., (1984)		Singh et al., (1991)	Myrow et al., (2006)	Singh et al., 2016
CAMBRIAN	"Bhabeh Series"	"Haimanta Series"	"Cambrian System"	Parahio series	Kunzam La Formation	Kunzam La Fm.	Parahio Member	Parahio Formation	Parahio Formation	Kunzam La (=Parahio) Formation
				Upper Haimanta series			Debsa Khad Member	Kunzam La Formation		
					Batal Formation	Batal Formation		Batal Formation	Batal Formation	Batal Formation

B

Fig.1. (A) Location of Spiti and the geological map of the Parahio valley. Inset shows the location of the studied section (D) with respect to the Parahio valley section illustrated by Peng *et al*. (2009); (B) A synthesis of the generalized stratigraphic terms used for the Cambrian of the Spiti region by various workers.

al., 1984; Shah and Paul, 1987; Singh *et al*., 1991; Bhargava and Bassi, 1998; Myrow *et al*., 2006; Bhargava, 2008, 2011; Peng *et al*., 2009; Parcha and Pandey, 2011; Hughes *et al*., 2013; Singh *et al*., 2011, 2015, 2016; Virmani *et al.*, 2015). Reed (1910) described trilobites collected by Hayden (1904) from the Parahio Valley, Spiti. Later, Shah and Paul (1987) recorded a few oryctocephalids. Jell and Hughes (1997) revised the trilobite fauna of the Himalaya and proposed an informal Cambrian zonation. Peng *et al*. (2009) defined the formal Cambrian biozonation in the Parahio valley (Spiti) and the Kurgiakh valley (Zanskar) Northwest. Singh *et al*. (2014) recorded *Yuehisienszella* from the Cambrian of the Parahio valley (Spiti). Singh *et al.* (2015, 2016) demarcated the *Oryctocephalus indicus* Zone in the Parahio valley.

Studied Section

The 280 m thick section of the Kunzam (=Parahio) Formation was measured on the left bank of the Parahio river along a steep slope of the Valley (Fig.1, Section D). The lithology of this section comprises thin to thickly bedded sandstone, calcareous sandstone, shale, siltstone, interbedded silty-shale and argillaceous limestone (Fig. 2). The trilobite fauna has been collected from four stratigraphic levels in the lowermost part of this section (Fig.2). Out of four levels, the lowest level is represented by the *Oryctocephalus indicus* Zone, which is equivalent to the Hayden horizon 2 (Singh *et al*., 2016). The presently discussed fossiliferous level lies 12.1 m above the *O. indicus* Zone which contains the Ellipsocephalinae trilobite genus *Bhargavia*. Fauna from other two levels, which lies above

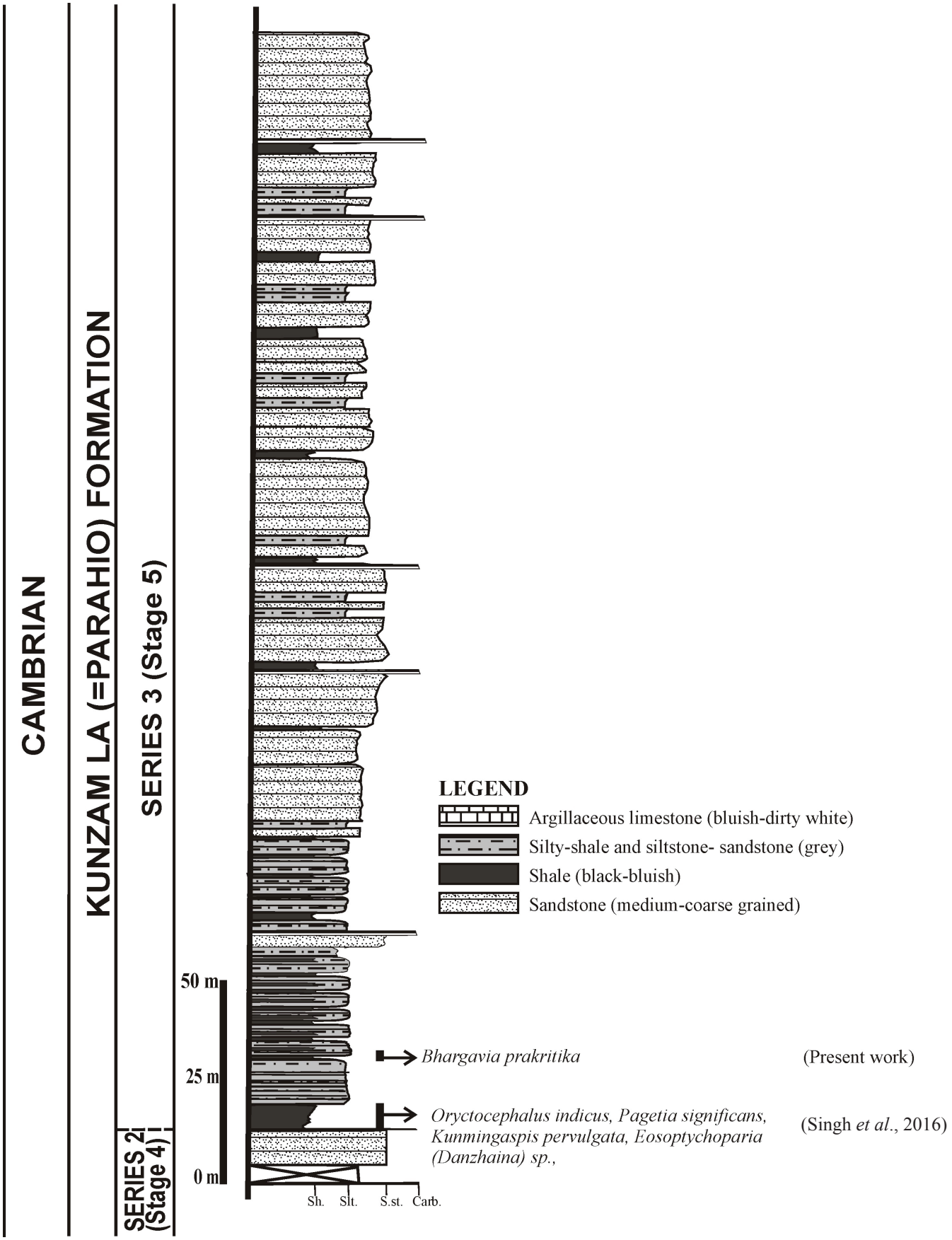


Fig.2. Detailed lithocolumn of the Kunzam La (=Parahio) Formation along the Section D in the Parahio valley showing stratigraphic position of *Bhargavia prakritika* bearing beds with respect to *Oryctocephalus indicus* bearing beds.

and below the *Bhargavia prakritika* bearing level, is under examination.

SYSTEMATIC PALAEONTOLOGY

We follow the morphological terminology of Whittington and Kelly in Kaesler (1997).

Order **Ptychopariida** Swinnerton, 1915
Superfamily **Ellipsocephaloidea** Matthew, 1887
Family **Ellipsocephalidae** Matthew,1887
Subfamily **Ellipsocephalinae**
Genus ***Bhargavia*** Peng *et al*., 2009

Type species (by monotypy): *Bhargavia prakritika*, Peng *et al*., 2009, p. 43, text figs. 27, 28 from the *Kaotaia prachina* Zone, Parahio Formation, Parahio Valley section, Spiti region; by original designation.

Historical background - The genus *Bhargavia* was established by Peng *et al.*, (2009) for trilobites which bear posterior border furrow confluent with the posterior margin of occipital ring, and occur in the *Kaotaia prachina* Zone of the Cambrian informal Stage 5 in the Parahio valley (Peng *et al.*, 2009). The type species *Bhargavia prakritika* was compared with *Syspacephalus obscurus* Palmer and Halley (1979) of the *Albertella* Zone (South Great Basin). Peng *et al.*, (2009) classified the genus under the Ellipsocephalinae as it is morphologically comparable to the *Kingaspis* Kobayashi, 1935 and the *Kingaspidoides* Hupe 1953. However, some features are strikingly different; the palpebral lobe in *Kingaspis* and *Kingaspidoides* is situated posterior to the mid-length of the cranidium, with a divergent anterior branch of the facial suture and a cranidium of lower convexity (Peng *et al*., 2009).

Emended diagnosis of the genus: A highly effaced ellipsocephalinean, small, micropygous ptychopariid with a thick exoskeleton, total length not exceeding 1.5 cm; cranidium subtrapezoidal in outline, gently rounded at front, with a weak sagittal keel; palpebral and pre-occipital glabellar furrows obscure; posterior border furrow confluent with posterior margin of occipital ring; glabella, conical to trapezoidal, strongly convex, with four pairs of unevenly spaced lateral furrows including an adaxially bifurcated S1, straight or slightly concave sides, and rounded anteriolateral corners; frontal area clearly divided into anterior border and preglabellar field; librigenal spine present, convex in outline, reaching upon fourth thoracic segment with a spine; eye ridge parallels cranidial anterior margin, with inner and emerging into axial furrow, anterior branch of facial suture convergent; posterior branch running rearward and somewhat outward; thorax with ten to eleven segments, decreasing in width posteriorly, pleural segments are wide and flat with outer portion slightly bent backward; pygidium small and transverse.

Occurrence: The new occurrence is recorded 12.1 m above the *Oryctocephalus indicus* Zone, Kunzam La (=Parahio) Formation (Singh *et al*., 2016) in the Parahio Valley section, Spiti.

Bhargavia prakritika Peng *et al*., 2009
(Figs. 3.1 – 3.15)

Material: Material studied herein comes from the Parahio valley, Spiti. Illustrated specimens are housed in the repository of the Center of Advanced Study in Geology, Panjab University, and Chandigarh, India, numbered with the prefix as CAS/T/-1301 to 1322. Material includes four partially complete exoskeletons, eleven cranidia, four incomplete thoracic segments, two pygidia and three liberiginae. They are preserved in fine-to medium-grained calcareous sandstone.

Diagnosis: As per the emended diagnosis of the genus

Description: Exoskeleton ellipsoidal in shape and micropygous. Cranidium strongly effaced, sub trapezoidal in shape, anterior margin moderately rounded and convex with anterior border furrow. Liberiginae preserved with long and thick librigenal spine reaching up to fourth thoracic segment in posterolateral direction. Weakly defined axial furrow showing a mere change in relief between glabella and fixigenae. Preglabellar furrow is inconspicuous. Palpebral lobes distinct, narrow located at midpoint of cranidium anterior to occipital furrow. Eye ridges very narrow, not so distinct merging with axial furrow at anterolateral margins of glabella. Posterior border furrow deep forming a continuous arch and confluent with posterior margin of occipital ring. The branches of posterior border directed rearward and outward forming a projection of a narrow triangle. Pygidium simple, transverse, subovate in outline with down sloping pleural regions.

Remarks: In original diagnosis of Peng *et al*. (2009, p.45), one testaceous cranidium (WIHGF 668.1) was assigned as holotype. In the emended diagnosis of the genus, the characters of thorax and liberiginae are emphasised, based on articulated specimen of *Bhargavia prakritika* from the Parahio valley section. Since diagnosis provided by the Peng *et al*., 2009 is based on the cranidium (figs. 27.15-27.17), a few generic characters, are emended. The genus *Bhargavia* is morphologically comparable to *Kingaspis* and *Kingaspidoides* but differs in characters, i.e. palpebral lobes are just against the mid-length of cranidium; on the contrary in *Bhargavia prakritika*, these lobes are situated posterior to the mid-length of the cranidium. Furthermore, anterior branch of facial suture is convergent in *Bhargavia* whereas divergent in *Kingaspis*. Anterior glabellar corner is evenly rounded in *Bhargavia* but expanded in *Kingaspis* and lastly the former has bifurcated S_1 rather than simple S_1 which is a characteristic feature of the latter. Liñán *et al*. (2003) established a close relationship between *Kingaspis* and *Kingaspidoides* and, considered both as subgenera under the name *Kingaspis*. Peng *et al.* (2009) considered *Syspacephalus obscurus* recovered from *Albertella* Zone of California (Palmer and Halley, 1979) to resemble *Bhargavia prakritika* in most of the morphological characters. Both the taxa can also be distinguished on the basis of some of the features. The extremely small size (< 1 cm) of *Syspacephalus obscurus* differentiates it from *Bhargavia prakritika* which is comparatively larger in size (1.0 to 1.5 cm); longer preglabellar field and anterior border in *S. obscurus;* and in *B. prakritika* the anterior branches of the facial suture converge forward while in *S. obscurus* it runs forward parallel to the sagital axis. The anterior branches of facial suture are sub-parallel to slightly convergent in *S. obscurus*; these are convergent in *B. prakritika*. Ornamentation of *S. obscurus* consists of densely packed uniform granules, which lack in *B. prakritika*. We could not decipher small axial node lying posterior to mid-point of occipital ring in *B. prakritika*, possibly due to preservational variant as our specimens are from the calcareous-sandstone layer rather than the limestone.

STRATIGRAPHIC LEVEL AND CORRELATION

Peng *et al*. (2009) described the specimens of *Bhargavia prakritika* from the limestone horizon (PO15, Fig.3, p. 4), which occurs 433.5 m within the *Kaotaia prachina* Zone (433.5 m-

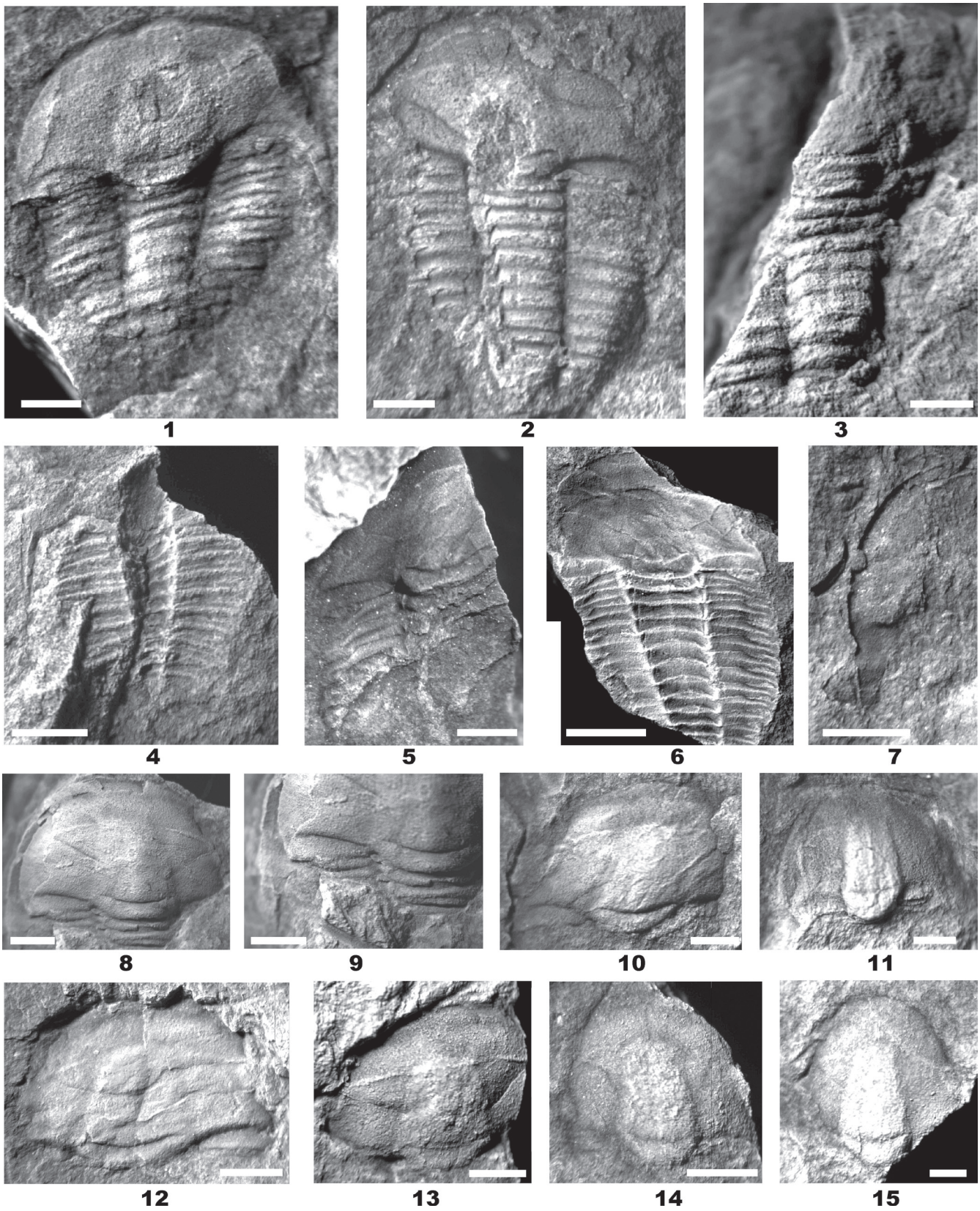


Fig.3. *Bhargavia prakritika* from calcareous sandstone layers in the Section D, Parahio Valley, Spiti, India, scale bar= 2 mm; (1) & (2) partially preserved exfoliated exoskeleton, CAS/T/-1301 and CAS/T-1302, (3)broken exoskeleton, CAS/T/- 1303a, (4) incomplete, broken, mold of thorax, CAS/T/- 1319, (5) incomplete, broken cranidium and poorly preserved thorax, CAS/T/- 1305, (6) broken exoskeleton, CAS/T/- 1317,(7) exfoliated liberigene, CAS/ T/- 1314, (8) nearly complete, well preserved, exfoliated cranidium CAS/T/- 1308, (9) closer view of the spine, CAS/T/- 1308, (10-15) exfoliated cranidium, CAS/T/-1306, CAS/T/-1315, CAS/T/-1321, CAS/T/-1307, CAS/T/-1322.

to- 439.67m) above the base of their measured section. The zone occurs 233.4 m above the inferred *Oryctocephalus indicus* level (Peng *et al*., 2009, Fig.3, p.4). These authors correlated the occurrences of the *Bhargavia prakritika* in the *Kaotaia prachina* Zone with the *Albertella* Zone of the Great Basin (Palmer and Halley, 1979), which stratigraphically lies just above the *O. indicus* biozones (Sundberg and McCollum, 2003). The *O. indicus* biozones (Sundberg and McCollum, 2003) is the outer shelf equivalent of the *Plagiura-Poliella* Zone (Lochman-Balk and Wilson, 1958) in Laurentia (Sundberg and McCollum, 2003). Our specimens are from the calcareous silty-sandstone layers which lie 12.1 m above the confirmed *Oryctocephalus indicus* Zone (Singh *et al*., 2016) and its occurrence is suggestive of an early part of the Middle Cambrian (Cambrian Series 3, Stage 5). We correlate the new level of *Bhargavia prakritika* with the upper part of *Plagiura* Zone of the Great Basin (Palmer and Halley, 1979). Furthermore, some species of Antarctica have been assigned to different genera like *Glabella*? *pitans, Kingaspis*? *convexa* and *Kingaspis*? sp., (Palmer and Gatehouse, 1972; Palmer and Rowell, 1995) but the liberiginae associated with these species lack liberigina spine; however, our specimens show distinct and well-defined liberiginae with spine. The Antarctic species distinctly differs from the *B. prakritika* and are morphologically similar to *Kingaspis*.

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Palaeontological Society of India, Lucknow

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(1) Name of the award

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ANNOUNCEMENT

Prof. S.K. Singh Memorial Gold Medal is awarded every year by the society for the best paper published in the Journal of the Palaeontological Society of India.