

Upper Cambrian agnostoid trilobites from the Machari Formation, Yongwol, Korea

Trilobites agnostoïdés du Cambrien supérieur de la Formation Machari, Yongwol, Corée

Duck K. Choi ^{a,*}, Jeong Gu Lee ^b, Baek Cheor Sheen ^c

^a School of Earth and Environmental Sciences, NS80, Seoul National University, Seoul 151-742, Korea

^b Department of Natural History, National Science Museum, Taejon 305-705, Korea

^c Deokwon Girls' High School, San 59-2 Naebalsan-dong, Kangso-gu, Seoul 157-280, Korea

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Abstract

The Middle to Upper Cambrian Machari Formation in Korea is well known for abundant and diverse trilobites along with other invertebrate fossils. Based on recent reappraisal on the trilobites of the Machari Formation, eight trilobite zones have been proposed for the Upper Cambrian sequence: i.e., in ascending order the *Glyptagnostus stolidotus*, *Glyptagnostus reticulatus*, *Proceratopyge tenuis*, *Hancrania brevilimbata*, *Eugonocare longifrons*, *Eochuangia hana*, *Agnostotes orientalis* and *Pseudoyuepingia asaphoides* zones. Trilobites from the lower five zones and part of the *Pseudoyuepingia asaphoides* Zone have been already published elsewhere. In this paper, we describe the agnostoid trilobites of the upper three zones, *Eochuangia hana*, *Agnostotes orientalis* and *Pseudoyuepingia asaphoides* zones, of the Machari Formation. These comprise 24 species belonging to 13 genera, including one new genus (*Yongwolagnostus*) and ten new species (*Homagnostus? sulcatus*, *Ivshinagnostus alatus*, *Ivshinagnostus quadratus*, *Yongwolagnostus stenorhachis*, *Yongwolagnostus dubius*, *Nahannagnostus pratti*, *Pseudagnostus? dividius*, *Pseudagnostus medius*, *Pseudorhaptagnostus? urceus* and *Ammagnostus serus*). These biozones correlate well with middle Upper Cambrian zones established in South China, Australia, Kazakhstan, Siberia, and Canadian Rocky Mountains.

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Résumé

La Formation Machari (Cambrien moyen à supérieur) de Corée est bien connue pour l'abondance et la diversité de ses trilobites associés à d'autres fossiles invertébrés. Huit zones de trilobites sont proposées pour la séquence du Cambrien supérieur, basées sur une révision récente des trilobites de la Formation Machari. Ce sont, par ordre ascendant, les zones suivantes : *Glyptagnostus stolidotus*, *Glyptagnostus reticulatus*, *Proceratopyge tenuis*, *Hancrania brevilimbata*, *Eugonocare longifrons*, *Eochuangia hana*, *Agnostotes orientalis* et *Pseudoyuepingia asaphoides*. Les trilobites des 5 zones inférieures et d'une partie de la zone à *Pseudoyuepingia asaphoides* ont déjà été publiés ailleurs. Dans cet article, nous décrivons les trilobites agnostoïdés des trois zones supérieures de la Formation Machari : la zone à *Eochuangia hana*, à *Agnostotes orientalis* et à *Pseudoyuepingia asaphoides*. Ces zones comprennent 24 espèces appartenant à 13 genres. Un genre nouveau (*Yongwolagnostus*) ainsi que 10 espèces (*Homagnostus? sulcatus*, *Ivshinagnostus alatus*, *Ivshinagnostus quadratus*, *Yongwolagnostus stenorhachis*, *Yongwolagnostus dubius*, *Nahannagnostus pratti*, *Pseudagnostus? dividius*, *Pseudagnostus medius*, *Pseudorhaptagnostus? urceus* et *Ammagnostus serus*). Ces biozones se corrèlent bien avec les zones de la partie moyenne du Cambrien supérieur établies en Chine du Sud, en Australie, au Kazakhstan et dans les Montagnes Rocheuses du Canada.

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Keywords: Late Cambrian; Agnostoid trilobites; Korea; Biostratigraphy; Correlation

Mots clés : Cambrien supérieur ; Trilobites agnostoïdés ; Corée ; Biostratigraphie ; Corrélation

* Corresponding author.

E-mail address: dkchoi@snu.ac.kr (D.K. Choi).

1. Introduction

The Machari Formation in Korea is well known for abundant and diverse trilobites of Middle to Late Cambrian age, which has often been called the Machari fauna (Kobayashi, 1962). Based on the faunal content of the Machari Formation, Kobayashi (1962) established five biozones or faunas within the formation: namely, the *Tonkinella* fauna, *Eochuangia* fauna, *Komaspis-Iwayaspis* Zone, and *Olenus-Glyptagnostus* Zone in ascending order, and the *Hancrania* fauna was considered to be correlative with the *Olenus-Glyptagnostus* Zone. These biostratigraphic units of the Machari Formation were widely employed in Korea, until Lee et al. (1997) revised the aforementioned biostratigraphic scheme and proposed eight trilobite zones for the Upper Cambrian portion of the Machari Formation. They are the *Glyptagnostus stolidotus*, *Glyptagnostus reticulatus*, *Proceratopyge tenuis*, *Hancrania brevilimbata*, *Eugonocare longifrons*, *Eochuangia hana*, *Agnostotes orientalis* and *Pseudoyuepingia asaphoides* zones in ascending order.

This revised trilobite zonation of the Machari Formation provides an improved biostratigraphic framework for correlation with the Upper Cambrian zones established elsewhere. Trilobites from the lower five zones and part of the *Pseudoyuepingia asaphoides* Zone were already introduced by Lee and Choi (1994, 1995, 1996) and Choi and Lee (1995). The specific objective of this study is to describe the agnostoid trilobites from the upper three zones, *Eochuangia hana*, *Agnostotes orientalis*, and *Pseudoyuepingia asaphoides* zones, of the Machari Formation, which occur successively in a section exposed near Konggiri, Yongwol area (Fig. 1). The associated polymeroid trilobites will be dealt in a separate paper, as they require a more exhaustive taxonomic treatment.

2. Geology and stratigraphy

The Cambro-Ordovician sedimentary rocks in southern Korea, Choson Supergroup, occur in the Taebaeksan basin, eastern part of the Korean peninsula (Fig. 1). The sediments consist mainly of carbonate with subordinate sandstone and shale, and were presumably deposited in a shallow marine continental shelf fringing the Sino-Korean block in the early Paleozoic (Chough et al., 2000; Choi et al., 2001). Kobayashi et al. (1942) recognized five types of sequences within the Choson Supergroup, each with unique lithologic succession and geographic distribution; namely, the Tuwibong-, Yongwol-, Chongson-, Pyongchang-, and Mungyong-type Choson supergroups. Recently Choi (1998) proposed a revised stratigraphic nomenclature for the Choson Supergroup: viz., the Taebaek, Yongwol, Yongtan, Pyongchang, and Mungyong groups which replace the Tuwibong-, Yongwol-, Chongson-, Pyongchang-, and Mungyong-type Choson supergroups, respectively.

The Yongwol Group comprises the Sambangsan, Machari, Wagok, Mungok, and Yonghung formations in ascending

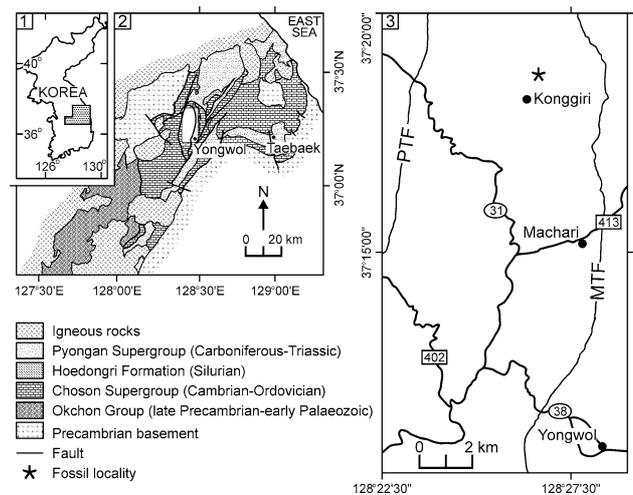


Fig. 1. Locality maps. 1. Map of the Korean peninsula showing the approximate location of 2. 2. Simplified geologic map of the Taebaeksan Basin. Open rectangle in center indicates the location of 3. 3. Index map of Yongwol area showing the fossil locality (Konggiri section) from which trilobites were recovered. Abbreviations: MTF – Machari Thrust Fault; PTF – Pyongchang Thrust Fault.

Fig. 1. Cartes des localités. 1. Carte de la péninsule de Corée montrant la localisation approximative de la zone indiquée en 2. 2. Carte géologique simplifiée du bassin de Taebaeksan. Le rectangle vide au centre indique la localisation de la zone 3. 3. Carte index de la région de Yongwol, montrant la localité fossilifère (coupe de Konggiri) ayant livré les trilobites. Abréviations : MTF – Machari Thrust Fault; PTF – Pyongchang Thrust Fault.

order (Yosimura, 1940). The lower three formations are assigned to the Cambrian, while the upper two to the Ordovician (Kobayashi, 1966). Although different views on the stratigraphy and geologic age of the Yongwol Group were presented in the past, recent studies on the lower Paleozoic strata of Yongwol area confirm the lithostratigraphic scheme proposed by Yosimura (cf. Choi, 1998 and references therein).

The Sambangsan Formation is the lowest unit of the Yongwol Group. The formation consists of purple and green siltstone and shale in the lower part and greenish gray or light brown, fine-grained, micaceous sandstone in the upper part. Middle Cambrian trilobites, such as *Megagraulos semicircularis* and *Metagraulos sampoensis*, occur commonly in greenish gray sandstone beds (Kobayashi, 1961; Choi et al., 1999). The Machari Formation (ca. 200 m thick) crops out in narrow belts in the thrust sheets west of the Machari thrust fault. The base of the Machari Formation is recognized by the occurrence of dark-gray argillaceous limestone and thick-bedded bioclastic grainstone to packstone beds which contain well-preserved Middle Cambrian trilobites of the *Tonkinella* fauna (Kobayashi, 1962). These beds are succeeded by a sequence of dark gray dolomitic limestone, shale, and clast-bearing lime mudstone, where *Lejopyge armata* and associated trilobites representing a late Middle Cambrian age have been documented (Hong et al., 2000). The middle part is dominated by dark-gray to black laminated shale with occasional intercalation of thin dolomitic limestone beds and yields diverse and abundant Upper Cambrian trilobites (Lee, 1995). The upper part consists of alternations of dark gray

dolomitic limestone and laminated black shale beds, showing a conspicuous banded appearance. This banded structure becomes progressively obscure in the uppermost part of the formation and grades into massive dolostone of the Wagok Formation. The Wagok Formation is a monotonous sequence (ca. 250 m thick) of light gray-to-gray massive dolostone and is assigned to the uppermost Cambrian based on the occurrence of trilobites and brachiopods (Kobayashi, 1960).

The Mungok Formation (up to 200 m thick) consists predominantly of carbonate with lesser amounts of shale, representing a shallow marine environment (Kim and Choi, 2002). The formation has been subdivided into four members based on the association of dominant lithofacies such as ribbon rock, grainstone to packstone, limestone conglomerate, and marlstone to shale facies (Park et al., 1994; Kim and Choi, 2000b). The basal Karam Member is composed mainly of ribbon rock and grainstone to packstone with intercalations of thin limestone conglomerate beds and chert layers. The Paeiljae Member consists largely of massive dolostone. The Chommal Member is characterized by alternations of ribbon rock and limestone conglomerate with intercalations of grainstone to packstone beds in the upper part. The uppermost Tumok Member comprises ribbon rock, grainstone to packstone, limestone conglomerate, and marlstone to shale. Fossils occur in the three stratigraphically separated intervals within the formation: the *Yosimuraspis* Zone at the lowermost part of the Karam Member consists dominantly of *Yosimuraspis* and subordinately of *Jujuyaspis* and *Elkanaspis* (Kim and Choi, 2000a); the *Kainella* Zone at the basal part of the Chommal Member includes *Kainella* and *Leiosteigium* (Kim and Choi, 1995, 1999); and the *Shumardia* Zone from the Tumok Member is dominated by cosmopolitan trilobite taxa with some endemic species (Choi et al., 1994). These faunal assemblages are partly correlated with the Tremadocian faunas of North China (Zhou and Zhang, 1985; Zhou and Fortey, 1986; Duan et al., 1986) and Australia (Shergold, 1991). The Yonghung Formation (over 400 m thick) consists of massive to thick-bedded, light- to dark-gray, finely to medium crystalline dolostone in the lower part and gray to bluish gray limestone in the upper part. Fossils are scarce, but include trilobites, brachiopods, cephalopods, conulariids, stromatoporoids and conodonts (cf. Choi, 1998).

3. Fossil locality

All of trilobite specimens described in this study were collected from a measured section (Konggiri section; 128°26'29"E and 37°18'42"N) of the Machari Formation, exposed along a hillside near Konggiri Village, Yongwol (Fig. 1). The Konggiri section measures about 53 m in thickness and represents the middle part of the Machari Formation. Good exposure reveals that the Machari Formation is overlain conformably by the Wagok Formation to the west, while to the east a poorly fossiliferous thick-bedded limestone sequence representing the upper part of the Machari

Formation is exposed. Consequently it is supposed that the fossiliferous Konggiri section representing the middle part of the Machari Formation is underlain in thrust contact by the thick-bedded upper part of the Machari Formation, although the contact is not exposed.

The Machari Formation in the Konggiri section consists of light gray-to-gray dolomitic limestone and argillaceous limestone (Fig. 2). The section is subdivided into 115 units which range from 10 to 110 cm in thickness and can be broadly differentiated into two parts: the lower part is dominated by laminated argillaceous limestone, while the upper part is largely composed of thinly- to medium-bedded dolomitic limestone. In addition, occasionally intercalated are massive dolostone beds (up to 50 cm in thickness) and shell layers of less than 2-cm-thick. The shell layers have sharp erosional surfaces and are composed of trilobites, brachiopods and unidentified algal remains. A couple of weakly bioturbated beds and chert layers are observed in the upper part. The Konggiri section comprises the *Eochuangia hana*, *Agnostotes orientalis*, and *Pseudoyuepingia asaphoides* zones in ascending order (Fig. 2).

4. Biostratigraphy and correlation

Lee et al. (1997) proposed eight Upper Cambrian trilobite zones in the Machari Formation: i.e., in ascending order the *Glyptagnostus stolidotus*, *Glyptagnostus reticulatus*, *Proceratopyge tenuis*, *Hancrania brevilimbata*, *Eugonocare longifrons*, *Eochuangia hana*, *Agnostotes orientalis* and *Pseudoyuepingia asaphoides* zones. The lower five zones will be described briefly, as they were already introduced in detail by Lee and Choi (1994, 1995) and Choi and Lee (1995). The *Glyptagnostus stolidotus* Zone comprises two agnostoid species, *G. stolidotus* and *Pseudagnostus josepha*, while the *Glyptagnostus reticulatus* Zone yields the nominal species, *Aspidagnostus stictus*, *Innitagnostus innitens*, *Peratagnostus obsoletus*, and *Olenus asiaticus* (Lee and Choi, 1994). The succeeding *Proceratopyge tenuis* Zone occupies a rather poorly fossiliferous interval (10–14 m thick) between the *Glyptagnostus reticulatus* and *Hancrania brevilimbata* zones and includes *Peratagnostus obsoletus*, *Pseudagnostus josepha*, *Proceratopyge tenuis*, and *Erixanium* sp. The *Hancrania brevilimbata* Zone consists of seven species including *Innitagnostus inexpectans*, *Peratagnostus obsoletus*, *Lisogoragnostus minor*, *Pseudagnostus josepha*, *Hancrania brevilimbata*, *Proceratopyge elongata*, and *Stigmatocare coreanica*. The *Eugonocare longifrons* Zone is relatively diverse in comprising nine trilobite species: viz., *Innitagnostus* sp., *Pseudagnostus josepha*, *Peratagnostus obsoletus*, *Lisogoragnostus minor*, *Kormagnostus* sp., *Erixanium similis*, *Eugonocare longifrons*, *Proceratopyge praelonga*, and *Irvingella typha*. These biozones are well correlated with lower Upper Cambrian biozones of South China (Lu and Lin, 1989; Peng, 1992; Peng and Robison, 2000), Australia (Öpik, 1967; Henderson, 1976; Shergold, 1982), Kazakhstan

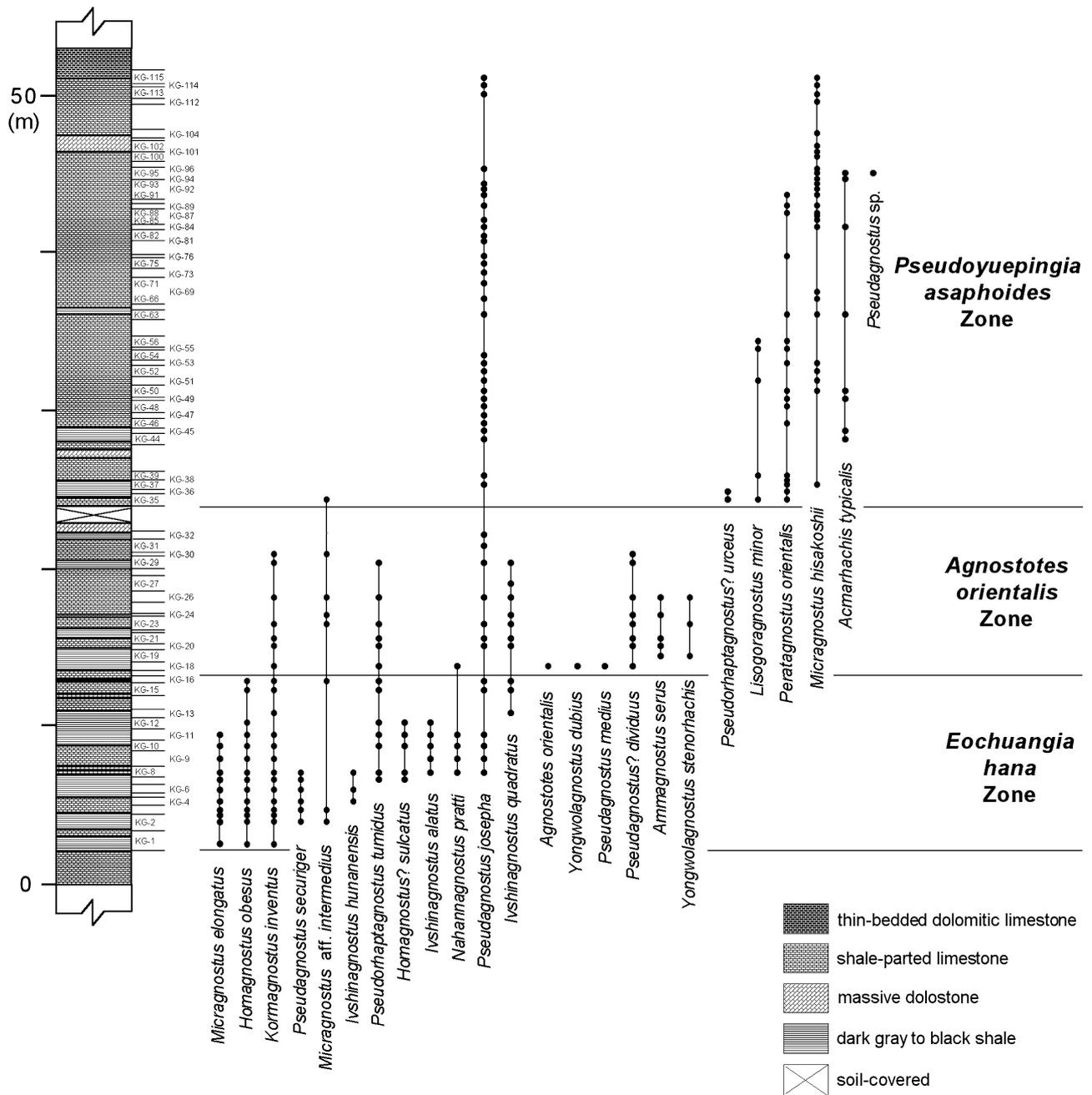


Fig. 2. Generalized lithologic column of the Machari Formation at the Konggiri section with occurrence of agnostoid trilobites and stratigraphic distribution of the biozones. Numbers with prefix KG represent the sampling units from which trilobites were collected.

Fig. 2. Colonne lithologique généralisée de la Formation Machari (coupe de Konggiri) avec la répartition des trilobites agnostoïdés et la distribution stratigraphique des biozones. Les nombres précédés de KG représentent les unités d'échantillonnage d'où proviennent les trilobites.

(Ergaliev, 1980), and North America (Palmer, 1960,1962, 1965; Ludvigsen and Westrop, 1985; Pratt, 1992).

Based on the stratigraphic distribution of trilobites in the Konggiri section, three biostratigraphic zones, i.e., *Eochuangia hana*, *Agnostotes orientalis*, and *Pseudoyuepingia asaphoides* zones, are established. The base of each zone is defined either by the first appearance of the eponymous taxon or by an assemblage of fossils characterizing the zone, and its top is equivalent to the base of the succeeding zone. The stratigraphic ranges of agnostoid trilobites in the Konggiri

section are shown in Figure 2. Correlation with other parts of the world is summarized in Figure 3.

4.1. Eochuangia hana zone

The *Eochuangia hana* Zone occupies the lower 13 m interval of the Konggiri section (Fig. 2). It comprises 12 agnostoid species: i.e., *Homagnostus obesus* (Belt, 1867), *H.?* *sulcatus* nov. sp., *Micragnostus elongatus* (Chien, 1961), *M. aff. intermedius* (Palmer, 1968), *Kormagnostus inventus*

	KOREA	SOUTH CHINA	AUSTRALIA	KAZAKHSTAN	NORTH AMERICA	
					Great Basin	Mackenzie Mountains
UPPER CAMBRIAN	<i>Pseudoyuepingia asaphoides</i>	<i>Rhaptagnostus ciliensis</i> / <i>Onchonotellus cf. kuruktagensis</i>	<i>Peichianshania tertia</i> / <i>Peichianshania quarta</i>	<i>Oncagnostus kazakhstanicus</i>	<i>Plychaspis</i> / <i>Prosaukia</i>	
			<i>Peichianshania secunda</i> / <i>Prochuangia glabella</i>	<i>Pseudagnostus pseudangustilobus</i>		
	<i>Agnostotes orientalis</i>	<i>Agnostotes clavata</i> / <i>Irvingella angustilimbata</i>	<i>Wentsuia iota</i> / <i>Rhaptagnostus apsis</i>	<i>Ivshinagnostus ivshini</i>	<i>Irvingella major</i>	<i>Irvingella major</i>
			<i>Irvingella tropica</i>	<i>Pseudagnostus curtare</i>		
	<i>Eochuangia hana</i>				<i>Elvinia</i>	<i>Proceratopyge rectispinata</i> <i>Parabolinoidea calvimbata</i>
	<i>Eugonocare longifrons</i>	<i>Corynexochus plumula</i> / <i>Sinoproceratopyge cf. kiangshanensis</i>	<i>Stigmatoa diloma</i>		<i>Dunderbergia</i>	<i>Olenaspella evansi</i>
	<i>Hancrania brevilimbata</i>	<i>Innitagnostus inexpectans</i> / <i>Proceratopyge protracta</i>	<i>Erixanum sentum</i>	<i>Oncagnostus longifrons</i>		
	<i>Proceratopyge tenuis</i>		<i>Proceratopyge cryptica</i>		<i>Aphelaspis</i>	<i>Glyptagnostus reticulatus</i>
	<i>Glyptagnostus reticulatus</i>	<i>Glyptagnostus reticulatus</i>	<i>Glyptagnostus reticulatus</i>	<i>Glyptagnostus reticulatus</i>		
	M. CAMBRIAN	<i>Glyptagnostus stolidotus</i>	<i>Glyptagnostus stolidotus</i>	<i>Glyptagnostus stolidotus</i>	<i>Glyptagnostus stolidotus</i>	<i>Cedaria brevilifrons</i>
<i>Linguagnostus reconditus</i>				<i>Acmorhachis quasivespa</i>	<i>Kormagnostus simplex</i>	

Fig. 3. Correlation of the Upper Cambrian biozones of the Machari Formation with coeval ones of other parts of the world. Sources for each column are based on the following papers: Yongwol – Lee and Choi, 1994,1995,1996, and this study; South China – Lu and Lin, 1989, Peng, 1992; Australia – Öpik, 1967, Henderson, 1976, Shergold, 1980,1982,1993; Kazakhstan – Ergaliev, 1980; Great Basin – Palmer, 1965; Ludvigsen and Westrop, 1985; Mackenzie Mountains – Pratt, 1992.

Fig. 3. Corrélation des biozones du Cambrien supérieur de la Formation Machari avec des biozones d'âge comparable dans d'autres parties du monde. Sources pour chaque colonne : Yongwol – Lee et Choi, 1994,1995,1996, et cette étude ; Chine du Sud – Lu et Lin, 1989, Peng, 1992 ; Australie – Öpik, 1967, Henderson, 1976, Shergold, 1980,1982,1993 ; Kazakhstan – Ergaliev, 1980 ; Great Basin – Palmer, 1965; Ludvigsen et Westrop, 1985; Montagnes de Mackenzie – Pratt, 1992.

(Shergold, 1982), *Pseudagnostus josepha* (Hall, 1863), *P. securiger* (Lake, 1906), *Ivshinagnostus humanensis* (Peng, 1992), *I. alatus* nov. sp., *I. quadratus* nov. sp., *Pseudorhaptagnostus tumidus* (Sun, 1989), and *Nahannagnostus pratti* nov. sp. Of these, six species (*Micragnostus elongatus*, *Homagnostus obesus*, *H. ? sulcatus*, *Pseudagnostus securiger*, *Ivshinagnostus humanensis*, and *I. alatus*) are restricted to this zone, while *Pseudagnostus josepha* extends its range upwards from the *Proceratopyge tenuis* Zone and, along with the remaining five species, continues into the succeeding zones.

Eochuangia hana, the nominal taxon of *Eochuangia* fauna of Kobayashi (1962), occurs exclusively in this zone (Lee, 1995). Some of the agnostoids in the zone are long ranging (*Homagnostus obesus* and *Pseudagnostus josepha*), while other species are age-diagnostic in having relatively narrow stratigraphic ranges. In particular, three species of *Ivshinagnostus* occur successively in the *Eochuangia hana* and *Agnostotes orientalis* zones of the Konggiri section. The oldest species, *I. humanensis*, was known from the *Agnostotes clavatus-Irvingella angustilimbata* to *Rhaptagnostus ciliensis-Onchonotellus cf. kuruktagensis* zones of South China (Peng, 1992). *Ivshinagnostus ivshini* is restricted within middle Upper Cambrian *Ivshinagnostus ivshini* Zone of Kazakhstan (Ergaliev, 1980). *Kormagnostus inventus* was documented from the *Stigmatoa diloma* Zone (uppermost

Idamean) of Queensland, Australia (Shergold, 1982). *Pseudagnostus securiger* was widely known from more or less contemporaneous horizons including the upper *Olenus* Zone of England (Lake, 1906; Rushton, 1983), *Agnostotes clavatus-Irvingella angustilimbata* Zone of South China (Peng, 1992), and *Olenaspella regularis* Zone of Canada (Pratt, 1992). *Nahannagnostus* has been mainly reported from the upper Middle to lower Upper Cambrian, but *N. pratti* represents the youngest species of the genus and is also reported from the *Proceratopyge rectispinata* Zone of Canada (Pratt, 1992). The *Eochuangia hana* Zone yields some important polymeroid trilobites such as *Irvingella convexa* (Kobayashi, 1935), *I. megalops* (Kobayashi, 1962), *Changshania equalis* Sun, 1935 among others (Hong et al., 2003). The co-occurrence of *Irvingella* and *Changshania* from the *Changshania* Zone of North China (Zhang et al., 1995) suggests a correlation of the *Eochuangia hana* Zone with the *Changshania conica-Irvingella taitzhuoensis* Zone of North China.

4.2. *Agnostotes orientalis* zone

The *Agnostotes orientalis* Zone covers the interval of 13–24 m above the base of the Konggiri section (Fig. 2). The base of the zone is defined by the first appearance of *Agnostotes orientalis*, *Yongwolagnostus dubius*, *Pseudagnostus medius*, and *P. ? dividius*. This zone yields 12 agnostoid species: viz., *Kormagnostus inventus* (Shergold, 1982), *Micragnostus* aff. *intermedius* (Palmer, 1968), *Pseudagnostus josepha* (Hall, 1863), *Ivshinagnostus quadratus* nov. sp., *Pseudorhaptagnostus tumidus* (Sun, 1989), *Nahannagnostus pratti* nov. sp., *Agnostotes orientalis* (Kobayashi, 1935), *Yongwolagnostus dubius* nov. sp., *Y. stenorhachis* nov. sp., *Pseudagnostus medius* nov. sp., *P. ? dividius* nov. sp., and *Ammagnostus serus* nov. sp. The former six species range upwards from the preceding zones, while the next six species are confined to this zone. Two species, *Pseudagnostus josepha* and *Micragnostus* aff. *intermedius*, continue into the *Pseudoyuepingia asaphoides* Zone.

The genus *Agnostotes*, one of the most widespread and short-ranging trilobites in the Upper Cambrian, has been reported to occur in the *Agnostotes clavatus-Irvingella angustilimbata* Zone of South China (Lu and Lin, 1989; Peng, 1992), *Agnostotes tianshanicus* Zone of Tarim (Wang et al., 1985), *Irvingella tropica* Zone of Australia (Öpik, 1963), *Pseudagnostus curtare* Zone of Kazakhstan (Ergaliev, 1980), *Irvingella-Cedarella felix* Zone of Siberia (Lazarenko, 1966), and *Proceratopyge rectispinata* fauna of northwestern Canada (Pratt, 1992). Apart from the agnostoid trilobites, *Irvingella coreanica* and *I. major* constitute major elements of the *Agnostotes orientalis* Zone (Hong et al., 2003). The association of *Irvingella* and *Agnostotes* is also known in South China (Peng, 1992), Australia (Öpik, 1963; Shergold, 1982), Siberia (Lazarenko, 1966) and Canada (Pratt, 1992), which provides a firm basis for intercontinental correlation of the *Agnostotes orientalis* Zone (Fig. 3).



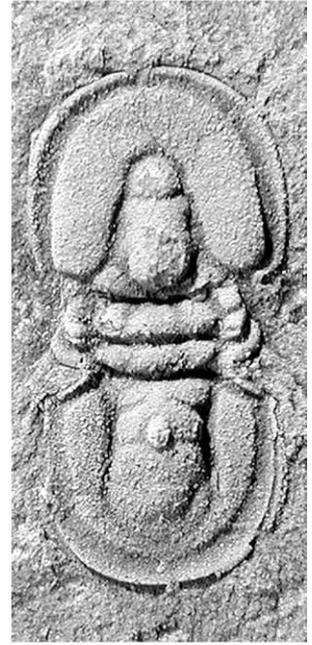
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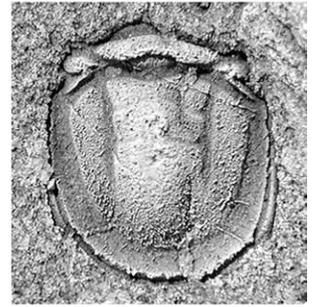
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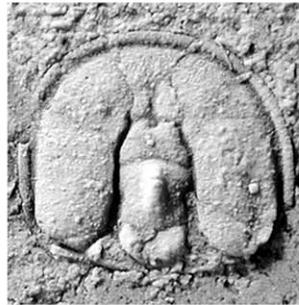
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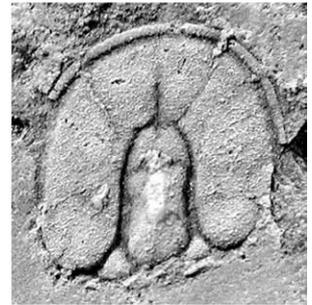
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4.3. *Pseudoyuepingia asaphoides* zone

The *Pseudoyuepingia asaphoides* Zone is recognized by the first appearance of *Peratagnostus orientalis* (Lazarenko, 1966), *Lisogoragnostus minor* (Kobayashi, 1962), and *Pseudorhaptagnostus urceus* nov. sp. in the Konggiri section. This zone covers a relatively long stratigraphic interval, 24–53 m above the base of Konggiri section (Fig. 2), and contains eight agnostoid species: aside from the species mentioned above, included are *Pseudagnostus josepha* (Hall, 1863), *P. sp.*, *Micragnostus* aff. *intermedius* (Palmer, 1968), *M. hisakoshii* (Kobayashi, 1968), and *Acmarhachis typicalis* (Resser, 1938). Two species, *Pseudagnostus josepha* and *Micragnostus* aff. *intermedius*, extend their ranges upwards from the lower zones, whereas the remaining six species made their first appearance in this zone. The commonly observed polymeroid trilobites within the zone are *Pseudoyuepingia asaphoides* and *Proceratopyge rectispinata*.

This zone may be partly comparable to the *Komaspiwayaspis* Zone of Kobayashi (1962), as *Pseudoyuepingia* (= *Iwayaspis*) *asaphoides* occurs exclusively within the zone. Of the agnostoid species, only three species are known outside the Korean peninsula. *Peratagnostus orientalis* is widespread in the middle Upper Cambrian sequences: i.e., the *Proceratopyge fenghwangensis* to *Agnostotes clavatus-Sinoproceratopyge kiangshanensis* zones (Lu and Lin, 1989) and *Rhaptagnostus ciliensis-Onchonotellus* cf. *kuruktagensis* zones of South China (Peng, 1992); *Wentsuia iota-Rhaptagnostus aphis* Zone of Australia (Shergold, 1980); *Irvingella-Cedarella felix* Zone of the Siberian Platform (Lazarenko, 1966); and Upper Cambrian of Alaska (Palmer, 1968). On the other hand, *Pseudagnostus josepha* and *Acmarhachis typicalis* have a relatively long stratigraphic range from the middle Middle to middle Late Cambrian in age (Peng and Robison, 2000), and thus are of limited biostratigraphic value.

In summary, although it seems impractical to attempt the zone-by-zone correlation of the biozones of the Machari Formation with other parts of the world, the *Eochuangia hana*, *Agnostotes orientalis* and *Pseudoyuepingia asaphoides* zones are collectively comparable to the middle Upper Cambrian ones elsewhere: namely, the lower Taoyua-

nian of South China, lower Iverian of Australia, upper Sakian of Kazakhstan, and uppermost Steptoean to lower Sunwaptan of Laurentia (Fig. 3; Geyer and Shergold, 2000).

5. Systematic paleontology

The suprageneric classification generally follows that of Shergold and Laurie (1997), supplemented by recent suggestion of Peng and Robison (2000). Morphological terms used herein are taken largely from Whittington and Kelly (1997) with additional terms from Robison (1984) and Shergold et al. (1990). The present material is stored at the paleontological collection of Seoul National University (SNUP).

Order AGNOSTIDA Salter, 1864

Family AGNOSTIDAE M'Coy, 1849

Subfamily AGNOSTINAE M'Coy, 1849

Genus *Homagnostus* Howell, 1935b

Type-species: *Agnostus pisiformis obesus* Belt, 1867 from the Lower Lingula Flags, Wales.

Remarks: the concept of *Homagnostus* is herein adopted rather broadly to comprise agnostoids with forward-tapering glabella and broad (tr.), long, but not reaching to the border furrow, parallel-sided or posteriorly slightly expanding pygidial axis (Palmer, 1960; Rushton, 1978; Pratt, 1992). Morphologically closely related genera to *Homagnostus* include *Oncagnostus*, *Connagnostus*, *Micragnostus*, *Trilobagnostus*, and *Eurudagnostus*. Apparently no clear distinction among these genera has been appreciated among investigators (see Shergold et al., 1990; Pratt, 1992; Nielsen, 1997). *Oncagnostus* Whitehouse, 1936 was erected based on *Agnostus hoi* Sun, 1924 from the *Changshania* Zone of China, which has, however, frequently been referred to *Homagnostus* (Lu, 1957; Palmer, 1960; Lu et al., 1965; Sun, 1989). *Connagnostus* Öpik, 1967 may be distinguished from *Homagnostus* by combined features of anteriorly located glabellar node and longer, parallel-sided pygidial axis. *Micragnostus* Howell, 1935a has generally no median preglabellar furrow and more slender (tr.) and shorter pygidial axis.

Homagnostus obesus (Belt, 1867)

Fig. 4(1–8)

1867. *Agnostus pisiformis* var. *obesus* - Belt, p. 295, pl. 12, Fig. 4.

Fig. 4. 1–8. *Homagnostus obesus* (Belt, 1867). 1. SNUP 601, internal mould of complete carapace, × 16. 2. SNUP 602, internal mould of complete carapace, × 16. 3. SNUP 603, internal mould of complete carapace, × 16. 4. SNUP 604, internal mould of complete carapace, × 14. 5. SNUP 605, internal mould of cephalon, × 12. 6. SNUP 606, internal mould of cephalon, × 12. 7. SNUP 607, internal mould of pygidium, × 14. 8. SNUP 605, internal mould of pygidium, × 14. 9–16. *Homagnostus? sulcatus* nov. sp. 9. SNUP 609, internal mould of cephalon, × 14. 10. Holotype, SNUP 610, internal mould of cephalon, × 14. 11. SNUP 611, internal mould of cephalon, × 14. 12. SNUP 612, internal mould of cephalon, × 12. 13. SNUP 613, internal mould of pygidium, × 16. 14. SNUP 614, internal mould of pygidium, × 14. 15. SNUP 615, internal mould of pygidium, × 12. 16. SNUP 616, internal mould of pygidium, × 12.

Fig. 4. 1–8. *Homagnostus obesus* (Belt, 1867). 1. SNUP 601, moule interne d'une carapace complète, × 16. 2. SNUP 602, moule interne d'une carapace complète, × 16. 3. SNUP 603, moule interne d'une carapace complète, × 16. 4. SNUP 604, moule interne d'une carapace complète, × 14. 5. SNUP 605, moule interne du céphalon, × 12. 6. SNUP 606, moule interne du céphalon, × 12. 7. SNUP 607, moule interne du pygidium, × 14. 8. SNUP 605, moule interne du pygidium, × 14. 9–16. *Homagnostus? sulcatus* nov. sp. 9. SNUP 609, moule interne du céphalon, × 14. 10. Holotype, SNUP 610, moule interne du céphalon, × 14. 11. SNUP 611, moule interne du céphalon, × 14. 12. SNUP 612, moule interne du céphalon, × 12. 13. SNUP 613, moule interne du pygidium, × 16. 14. SNUP 614, moule interne du pygidium, × 14. 15. SNUP 615, moule interne du pygidium, × 12. 16. SNUP 616, moule interne du pygidium, × 12.

1877. *Agnostus tumidosus* - Hall and Whitfield, p. 231, pl. 1, Fig. 32.

1935b. *Homagnostus obesus* (Belt, 1867) - Howell, p. 15, Fig. 12.

1958. *Agnostus (Homagnostus) obesus* Belt - Henningsmoen, p. 182, pl. 5, Figs. 13–16. (for additional synonymy).

1960. *Homagnostus tumidosus* (Hall and Whitfield) - Palmer, p. 63, pl. 4, Figs. 1, 2. (for additional synonymy).

1962. *Homagnostus comptus* - Palmer, p. 12, pl. 1, Figs. 12–15.

1968. *Homagnostus alaskensis* - Palmer, p. 24, pl. 7, Figs. 4, 9, 14, 15.

1980. *Homagnostus longiformis* - Ergaliev, p. 103, pl. 11, Fig. 18, pl. 12, Fig. 1.

1989. *Homagnostus tumidosus* (Hall and Whitfield) - Sun, p. 71, pl. 13, Figs. 13, 14, pl. 14, Fig. 1.

1992. *Homagnostus obesus* (Belt) - Pratt, p. 27, pl. 1, Figs. 26–38 (for additional synonymy).

1994. *Connagnostus lubricus* - Qian, p. 43, pl. 1, Figs. 5–8.

Material, horizon and locality: more than 100 specimens; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-1 to KG-16 of the Konggiri section, Yongwol.

Remarks: Pratt (1992) synonymized a number of species with *H. obesus*, while allowing a broad intraspecific morphological variability, which is followed in this study. Most specimens of the Machari Formation are preserved as dorso-ventrally compressed internal molds and thus are difficult to compare with other species of *Homagnostus* with confidence. Nevertheless, they display morphological features of *H. obesus* (sensu Pratt, 1992) in having unconstricted to weakly constricted acrolobes, vestigial preglabellar median furrow, and rather long pygidial axis with forward-convex F1, which does not connect across the axis. *Connagnostus lubricus* Qian, 1994 also falls within the morphological variation of *H. obesus* exhibited by Pratt (1992) and thus is considered a junior synonym of the latter species. It differs from *H. hoi*, which has broader and longer pygidial axis reaching to the border furrows.

Homagnostus? sulcatus nov. sp.

Fig. 4(9–16)

Etymology: from *sulcus*, furrow; referring to median sulcus on the anteroglabella.

Material, horizon and locality: holotype cephalon, SNUP 610 (Fig. 4(10)); paratypes SNUP 609, 611–616; more than 30 specimens; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-7 to KG-12 of the Konggiri section, Yongwol.

Description: cephalon subcircular, with narrow border and nondeliquiate border furrow. Acrolobe constricted, with smooth genal field; median preglabellar furrow incompletely

developed. Glabella about three-fifths of cephalic length; anteroglabella semicircular or trapezoidal in outline, with clearly-impressed frontal sulcus; F3 convex forwards; posteroglabella weakly constricted across F2, with rounded basal culmination; elongate glabellar node occupying most of M3; F2 weakly impressed and directed forwards. Basal lobes simple, small and subtriangular.

Pygidium subcircular, with deliquiate border furrow. Acrolobe constricted, with smooth pleural field. Axis relatively wide and long, but not reaching to border furrow, constricted across M2, with maximum width at posteroaxial mid-length; M1 transversely rectangular; F1 convex forwards; M2 longer (sag.) than M1; F2 transverse to directed backwards, interrupted by elongate axial node; axial node located immediately behind F1 and crossing F2; posteroaxis subcircular with a tiny secondary median node on posterior one-third of posteroaxis. Posterolateral spines very short.

Remarks: *Homagnostus? sulcatus* is characterized by constricted acrolobes, anteroglabella with median sulcus, elongate glabellar node, and posteriorly expanding pygidial axis with a secondary median node. The presence of frontal sulcus on anteroglabella is the most distinctive feature of this species, which precludes its definite assignment to *Homagnostus*. The anteroglabella with frontal sulcus is also known in other agnostoid genera, such as *Glyptagnostus*, *Agnostotes*, *Tomagnostus*, *Diplagnostus*, and *Linguagnostus*, but all of these genera have distinct pygidial morphology, by which this species can be easily differentiated. The frontal sulcus in the present collection is variably developed: in some specimens it is indicated by a shallow indentation, while in others well-developed frontal sulcus nearly divides the anteroglabella into the two parts, forming a bilobed anteroglabella. Cephalically *Homagnostus? sulcatus* bears a resemblance to *Innitagnostus inexpectans* (Kobayashi, 1938) in having a trapezoidal anteroglabella with sulcus, but their pygidia are different from each other.

Genus *Micragnostus* Howell, 1935a

Type-species: *Agnostus calvus* Lake, 1906 from the Tremadocian of Wales.

Remarks: following the proposal for distinction of *Micragnostus* from *Geragnostus* by Fortey (1980), a large number of Upper Cambrian to Lower Ordovician agnostoids was subsequently transferred to *Micragnostus* (Ludvigsen et al., 1989; Sun, 1989; Nielsen, 1997). Still, diverse views on the generic concept of *Micragnostus* have been exercised in relation to closely related genera such as *Trilobagnostus*, *Eurudagnostus*, *Innitagnostus*, and *Homagnostus* (Shergold and Sdzuy, 1984; Ludvigsen et al., 1989; Sun, 1989; Shergold et al., 1990; Pratt, 1992; Nielsen, 1997). In this study, *Micragnostus* is defined to accommodate forms with slender, short, and parallel-sided glabella, no or weakly-developed median preglabellar furrow, and relatively narrow, short, parallel-sided pygidial axis. *Trilobagnostus* and *Rudagnostus* are treated junior synonyms of *Micragnostus*.

Micragnostus elongatus (Chien, 1961)

Fig. 5(1–7)

1961. *Geragnostus elongatus* - Chien, p. 93, pl. 1, Fig. 1.1962. *Homagnostus hisakoshii* - Kobayashi, (pars), p. 30, pl. 8, Fig. 13 (only).1990. *Geragnostus* (*Micragnostus*) *elongatus* Chien - Lu and Zhou, p. 12, pl. 1, Figs. 1–3.2002. *Micragnostus* aff. *elongatus* (Chien) - Sohn and Choi, p. 63, Figs. 3A–J.

Material, horizon and locality: more than 50 specimens; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-1 to KG-11 of the Konggiri section, Yongwol.

Remarks: the present material may be best assignable to *Micragnostus elongatus* reported from the Upper Cambrian to Tremadocian of South China (Chien, 1961), but shows slight differences from its holotype in possessing constricted acrolomes and deliquiate border furrows on both shields. On the other hand, recent collections of the species from South China (Lu and Zhou, 1990) and Korea (Sohn and Choi, 2002) demonstrated that specimens assigned to *M. elongatus* exhibit a morphological variability in acrolome constriction and width of border furrows. In these respects, *M. elongatus* also shares some morphological features with *M. vilonii* (Harrington and Leanza, 1957) from the Upper Cambrian and Lower Ordovician of Argentina, which may eventually prove to have a priority over *M. elongatus*.

Micragnostus hisakoshii (Kobayashi, 1962)

Fig. 5(8–13)

1962. *Homagnostus hisakoshii* Kobayashi, (pars), p. 30, pl. 8, Figs. 1, 2, 9, 10.

Material, horizon and locality: more than 50 specimens; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-37 to KG-114 of the Konggiri section, Yongwol.

Remarks: specimens assigned originally to *Homagnostus hisakoshii* by Kobayashi (1962) actually represent several species: only four specimens belong to *H. hisakoshii*, while the remaining specimens are herein reassigned to *Amarhachis typicalis* (pl. 8, Fig. 6, 7), *Ammagnostus serus* nov. sp. (pl. 8, Fig. 11, 12), *Micragnostus elongatus* (pl. 8, Fig. 13), or *Micragnostus* aff. *intermedius* (pl. 8, Fig. 4, 8, 14). The holotype of *H. hisakoshii*, though poorly preserved, is characterized by its small size, forward-tapering glabella, rearward-tapering pygidial axis, and strongly deliquiate border furrows. These morphological features can be better accommodated with *Micragnostus* and consequently this species is transferred to the genus.

Micragnostus hisakoshii is distinguished from *Micragnostus elongatus* (Chien, 1961) by its smaller anteroglabella and rounded posteroaxial rear. *Micragnostus innocens* (Clark, 1923) differs from *M. hisakoshii* in having larger anteroglabella and unconstricted pygidial acrolome. *Trilobagnostus haudei* Shergold and Szalay, 1984 has strongly backward curved transglabellar furrow (F3), constricted

cephalic acrolome, and long pygidial axis. This species also resembles *Micragnostus strictus* Sun, 1989 from the *Kaolishania* Zone in having narrow cephalic border, rudimentary preglabellar median furrow, deliquiate border furrow, constricted acrolome, and posteriorly convergent pygidial axis, but differs in having broader and parallel-sided pygidial axis. Cephalae of *Micragnostus hisakoshii* are also similar to those of *M. intermedius* (Palmer, 1968), but its pygidia have a narrower and rearward-tapering pygidial axis.

Micragnostus aff. *intermedius* (Palmer, 1968)

Fig. 6(1–8)

1962. *Homagnostus hisakoshii* - Kobayashi, (pars), p. 30, pl. 8, Figs. 4, 8, 14 (only).

Material, horizon and locality: fifty specimens; *Agnostotes orientalis* Zone to the basal part of the *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-23 to KG-35 of the Konggiri section, Yongwol.

Description: cephalon subcircular with nondeliquiate border furrow. Acrolome unconstricted, with smooth genal field. Preglabellar median furrow vestigial. Glabella two-thirds of cephalic length; anteroglabella semicircular, separated by transverse F3; posteroglabella notched by deep F1 and F2 with elongate node behind F2. Basal lobes small, simple, and subtriangular.

Pygidium subcircular, wider than long, with nondeliquiate border furrow. Acrolome unconstricted, with smooth pleural field. Axis more or less parallel-sided, ca. three-fourths of pygidial length, moderately wide covering 45% of pygidial width; M1 and M2 tripartite; F1 and F2 furrows transverse, interrupted by prominent elongated axial node; posteroaxis a little longer than anteroaxis, slightly expanding posteriorly, with broadly rounded posterior margin and a tiny terminal node at rear. Posterolateral spines short, situated at level or rear of posteroaxis.

Remarks: the present specimens are most closely comparable to *Micragnostus intermedius* from the Upper Cambrian of North America (Palmer, 1968; Robison and Pantoja-Alor, 1968; Stitt, 1977; Ludvigsen et al., 1989), but they are in general poorly preserved and dorso-ventrally flattened and thus are assigned to the species with reservation. Of the specimens assigned to *Homagnostus hisakoshii* by Kobayashi (1962: pl. 8, Figs. 1–14), three specimens (pl. 8, Fig. 4, 8, 14) are referable to *Micragnostus* aff. *intermedius*. This species also bears some resemblance to *M. chiushuensis* (Kobayashi, 1931) and *M. innocens* (Clark, 1923). However, the pygidium of *M. chiushuensis* from North China has strongly deliquiate border furrows (cf. Sun, 1989), while that of *M. innocens* is characterized by its narrower pygidial axis and deliquiate border furrow (cf. Ludvigsen et al., 1989). It may also be comparable to *Innitagnostus medius* Shergold, 1980 from Australia and *Innitagnostus distinctus* Xiang and Zhang in Wang et al., 1985, but differs in having a broader (tr.) and posteriorly rounded pygidial axis. *Micragnostus mutabilis* (Ergaliev, 1980) has broader border and deliquiate border furrows.

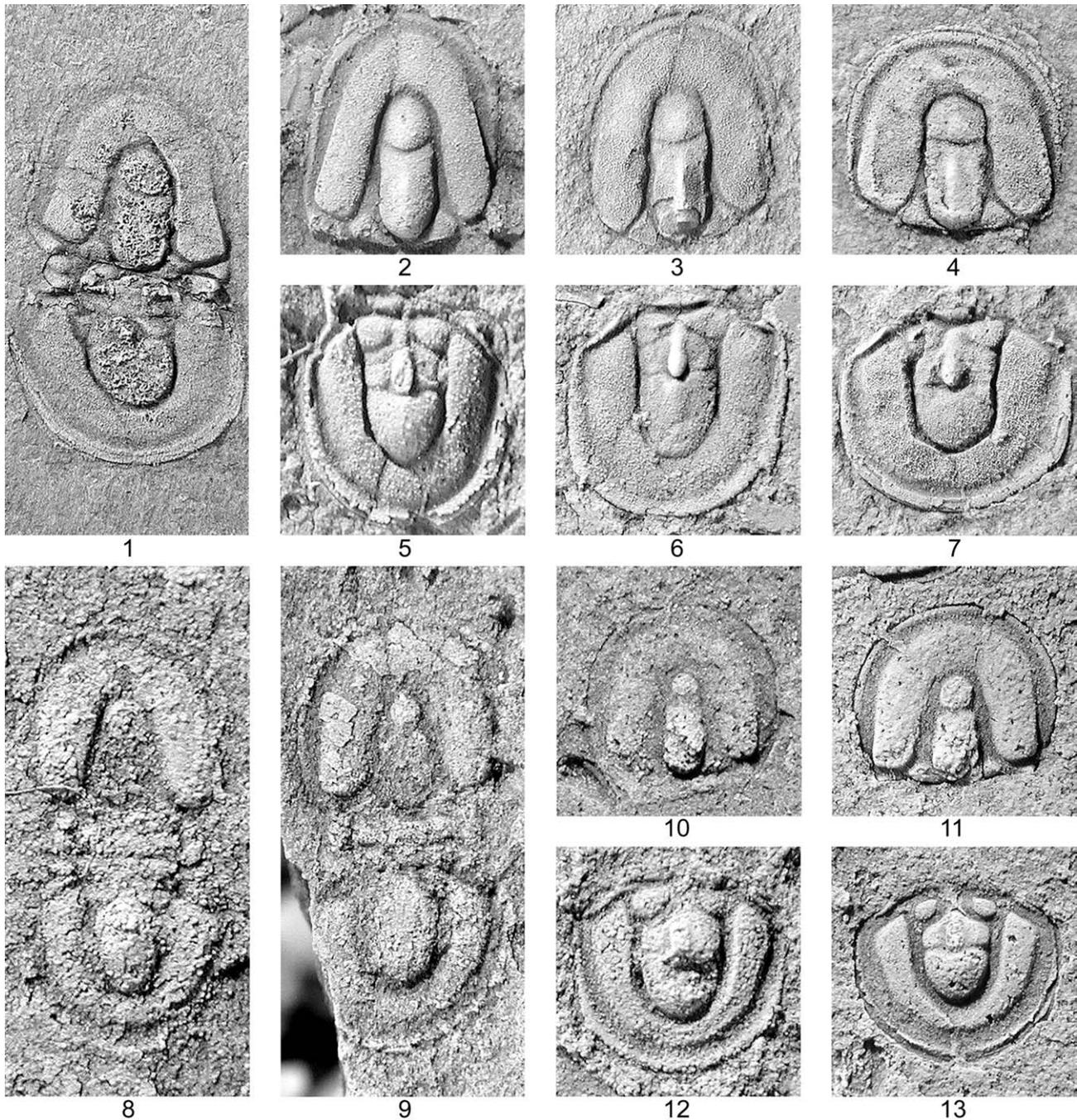


Fig. 5. 1–7. *Micragnostus elongatus* (Chien, 1961). 1. SNUP 617, internal mould of carapace, $\times 12$. 2. SNUP 618, internal mould of cephalon, $\times 14$. 3. SNUP 619, internal mould of cephalon, $\times 14$. 4. SNUP 620, internal mould of cephalon, $\times 12$. 5. SNUP 621, internal mould of pygidium, $\times 16$. 6. SNUP 622, internal mould of pygidium, $\times 14$. 7. SNUP 623, internal mould of pygidium, $\times 12$. 8–13. *Micragnostus hisakoshii* (Kobayashi, 1962). 8. SNUP 624, internal mould of carapace, $\times 20$. 9. SNUP 625, internal mould of carapace, $\times 14$. 10. SNUP 626, internal mould of cephalon, $\times 16$. 11. SNUP 627, internal mould of cephalon, $\times 14$. 12. SNUP 628, internal mould of pygidium, $\times 18$. 13. SNUP 629, internal mould of pygidium, $\times 14$.

Fig. 5. 1–7. *Micragnostus elongatus* (Chien, 1961). 1. SNUP 617, moule interne d'une carapace, $\times 12$. 2. SNUP 618, moule interne du céphalon, $\times 14$. 3. SNUP 619, moule interne du céphalon, $\times 14$. 4. SNUP 620, moule interne du céphalon, $\times 12$. 5. SNUP 621, moule interne du pygidium, $\times 16$. 6. SNUP 622, moule interne du pygidium, $\times 14$. 7. SNUP 623, moule interne du pygidium, $\times 12$. 8–13. *Micragnostus hisakoshii* (Kobayashi, 1962). 8. SNUP 624, moule interne d'une carapace, $\times 20$. 9. SNUP 625, moule interne d'une carapace, $\times 14$. 10. SNUP 626, moule interne du céphalon, $\times 16$. 11. SNUP 627, moule interne du céphalon, $\times 14$. 12. SNUP 628, moule interne du pygidium, $\times 18$. 13. SNUP 629, moule interne du pygidium, $\times 14$.

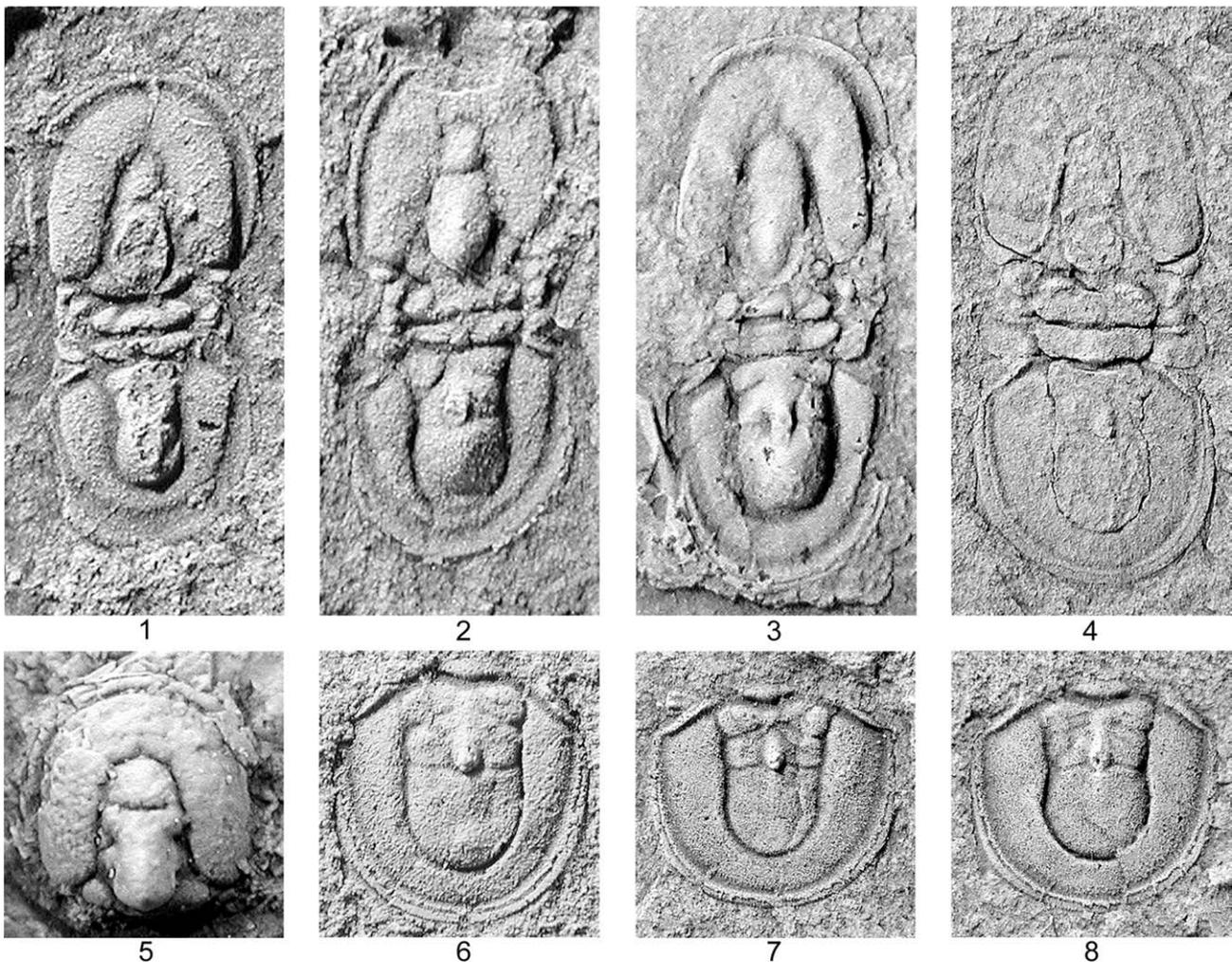


Fig. 6. *Micragnostus* aff. *intermedius* (Palmer, 1968). 1. SNUP 630, internal mould of carapace, $\times 22$. 2. SNUP 631, internal mould of carapace, $\times 20$. 3. SNUP 632, internal mould of carapace, $\times 16$. 4. SNUP 633, internal mould of carapace, $\times 10$. 5. SNUP 634, cephalon, $\times 20$. 6. SNUP 635, internal mould of pygidium, $\times 12$. 7. SNUP 636, internal mould of pygidium, $\times 10$. 8. SNUP 637, internal mould of pygidium, $\times 10$.

Fig. 6. *Micragnostus* aff. *intermedius* (Palmer, 1968). 1. SNUP 630, moule interne d'une carapace, $\times 22$. 2. SNUP 631, moule interne d'une carapace, $\times 20$. 3. SNUP 632, moule interne d'une carapace, $\times 16$. 4. SNUP 633, moule interne d'une carapace, $\times 10$. 5. SNUP 634, céphalon, $\times 20$. 6. SNUP 635, moule interne du pygidium, $\times 12$. 7. SNUP 636, moule interne du pygidium, $\times 10$. 8. SNUP 637, moule interne du pygidium, $\times 10$.

Genus *Ivshinagnostus* Ergaliev, 1980

Type-species: *Ivshinagnostus ivshini* Ergaliev, 1980 from the Upper Cambrian (Sakian) of Maly Karatau, Kazakhstan.

Ivshinagnostus alatus nov. sp.

Fig. 7(1–8)

Etymology: from *alatus*, winged; referring to the wing-like posterolateral pygidial border.

Material, horizon and locality: holotype pygidium, SNUP 643 (Fig. 7(6)); paratypes SNUP 638–642, 644–645; more than 20 specimens; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-8 to KG-12 of the Konggiri section, Yongwol.

Description: cephalon subrectangular, longer than wide. Acrolobe strongly constricted, with smooth genal field. Border narrow; border furrow deliquiate. Median preglabellar furrow absent. Glabella 65% of cephalic length; anteroglabella small, fan-shaped, posteriorly delimited by V-shaped F3; posteroglabella parallel-sided, with weak constriction

across glabellar midpoint, small node on glabellar mid-length and strongly angulate basal culmination. Basal lobes of moderate size triangular.

Pygidium quadrangular, widening rearwards, widest between posterolateral spines. Acrolobe unconstricted to weakly constricted, with smooth pleural field. Border narrow but widening rearwards; border furrow strongly deliquiate, attaining maximum width near posterolateral corners. Axis 70% of pygidial length, tapering progressively backwards, and ending with acutely pointed rear; F1 and F2 transverse and weakly impressed; F2 interrupted by small, elongate axial node; posteroaxis longer than anteroaxis, with a small terminal node short in front of its rear end. Posterolateral spines short.

Remarks: *Ivshinagnostus alatus* nov. sp. is characterized by its small, fan-shaped anteroglabella delimited by V-shaped transglabellar furrow and relatively short pygidial axis with acutely pointed rear. A meraspid pygidium

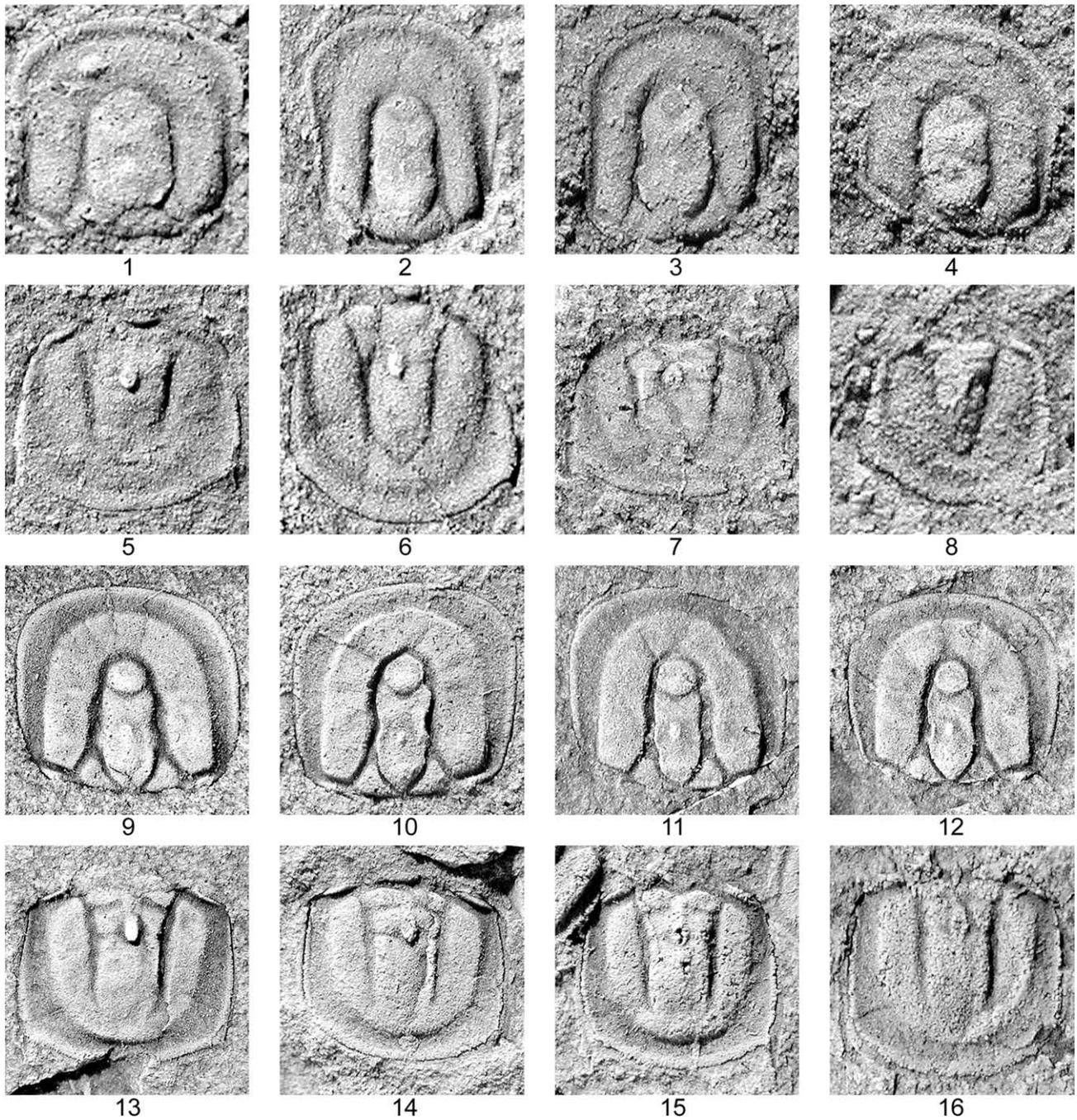


Fig. 7. 1–8. *Ivshinagnostus alatus* nov. sp. 1. SNUP 638, internal mould of cephalon, $\times 24$. 2. Holotype, SNUP 639, internal mould of cephalon, $\times 18$. 3. SNUP 640, internal mould of cephalon, $\times 22$. 4. SNUP 641, internal mould of cephalon, $\times 22$. 5. SNUP 642, internal mould of pygidium, $\times 16$. 6. SNUP 643, internal mould of pygidium, $\times 24$. 7. SNUP 644, internal mould of pygidium, $\times 16$. 8. SNUP 645, internal mould of meraspid pygidium, $\times 28$. 9–16. *Ivshinagnostus hunanensis* Peng, 1992. 9. SNUP 646, internal mould of cephalon, $\times 10$. 10. SNUP 647, internal mould of cephalon, $\times 12$. 11. SNUP 648, internal mould of cephalon, $\times 12$. 12. SNUP 649, internal mould of cephalon, $\times 10$. 13. SNUP 650, internal mould of pygidium, $\times 10$. 14. SNUP 651, internal mould of pygidium, $\times 10$. 15. SNUP 652, internal mould of pygidium, $\times 10$. 16. SNUP 653, internal mould of pygidium, $\times 14$.

Fig. 7. 1–8. *Ivshinagnostus alatus* nov. sp. 1. SNUP 638, moule interne du céphalon, $\times 24$. 2. Holotype, SNUP 639, moule interne du céphalon, $\times 18$. 3. SNUP 640, moule interne du céphalon, $\times 22$. 4. SNUP 641, moule interne du céphalon, $\times 22$. 5. SNUP 642, moule interne du pygidium, $\times 16$. 6. SNUP 643, moule interne du pygidium, $\times 24$. 7. SNUP 644, moule interne du pygidium, $\times 16$. 8. SNUP 645, moule interne d'un pygidium de méraspidé, $\times 28$. 9–16. *Ivshinagnostus hunanensis* Peng, 1992. 9. SNUP 646, moule interne du céphalon, $\times 10$. 10. SNUP 647, moule interne du céphalon, $\times 12$. 11. SNUP 648, moule interne du céphalon, $\times 12$. 12. SNUP 649, moule interne du céphalon, $\times 10$. 13. SNUP 650, moule interne du pygidium, $\times 10$. 14. SNUP 651, moule interne du pygidium, $\times 10$. 15. SNUP 652, moule interne du pygidium, $\times 10$. 16. SNUP 653, moule interne du pygidium, $\times 14$.

(Fig. 7(8)) has an axis tapering progressively rearwards. *Ivshinagnostus ivshini* possesses a subcircular anteroglabella and wider (tr.) pygidial axis with broadly rounded rear; *I. hunanensis* Peng, 1992 has a circular anteroglabella and longer pygidial axis with broadly rounded, often effaced, posterior rear; and *I. quadratus* nov. sp. has subquadrate shields, small circular anteroglabella, less deliquiate border furrow, and rearward-directed posterolateral spines.

Ivshinagnostus hunanensis Peng, 1992

Fig. 7(9–16)

1992. *Ivshinagnostus hunanensis* - Peng, p. 20, Figs. 8A–H, 9.

Material, horizon and locality: more than 50 specimens; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-4 to KG-8 of the Konggiri section of Yongwol.

Remarks: *Ivshinagnostus hunanensis* is characterized by its forwardly diverging cephalon, strongly deliquiate border furrows, and long pygidial axis with rounded, often effaced, posterior rear. Specimens from the Machari Formation agree well with the description of *Ivshinagnostus hunanensis* given by Peng (1992), but have somewhat narrower pygidial axis.

Ivshinagnostus quadratus nov. sp.

Fig. 8(1–8)

Etymology: from *quadratus*, quadrate; referring to the quadrate shields of this species.

Material, horizon and locality: holotype cranidium, SNUP 655 (Fig. 8(2)); paratypes SNUP 654, 656–661; additional 20 specimens; *Eochuangia hana* and *Agnostotes orientalis* zones (middle Upper Cambrian) of the Machari Formation; units KG-13 to KG-29 of the Konggiri section, Yongwol.

Description: cephalon subquadrate, as long as wide, with narrow border and subdeliquiate border furrow. Acrolobe constricted; median preglabellar furrow absent. Glabella 65% of cephalic length (sag.); anteroglabella circular, well defined by concave-forward F3; posteroglabella parallel-sided, with angulate basal culmination and small node on glabellar midpoint. Basal lobes of moderate size triangular, delimited by deep basal furrows.

Pygidium subquadrate. Acrolobe unconstricted, with smooth pleural field. Border narrow, but posterolaterally prolonged into long and prominent posterolateral spines; border furrow deliquiate. Axis about 65% of pygidial length, tapering progressively backwards, ending with bluntly pointed rear; axial furrow deep in anterior half, progressively shallowing rearwards; anteroaxis as long as posteroaxis; F1 and F2 transverse, weakly incised; M2 with a bulbous axial node extending short onto posteroaxis.

Remarks: *Ivshinagnostus quadratus* nov. sp. represents the youngest species of the genus in the Machari Formation. It is comparable to *I. ivshini*, but differs in having a more or less parallel-sided glabella, narrower pygidial axis, and longer posterolateral pygidial spines.

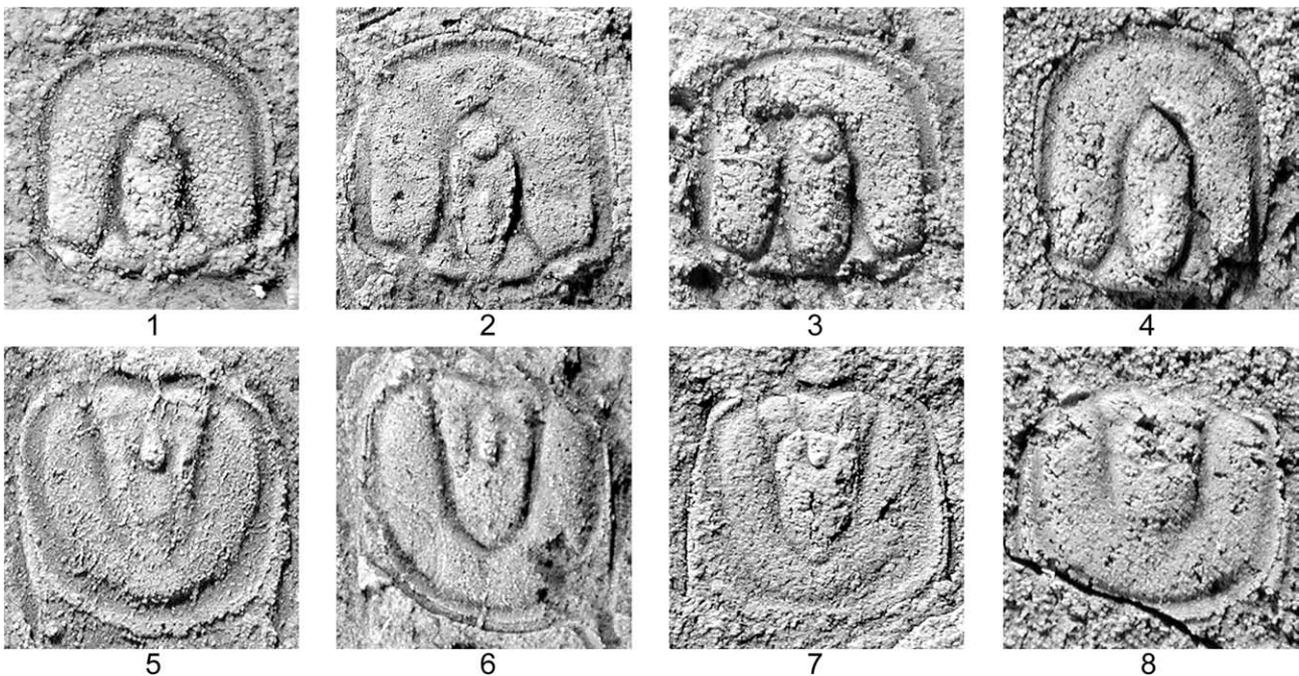


Fig. 8. *Ivshinagnostus quadratus* nov. sp. 1. SNUP 654, internal mould of cephalon, $\times 12$. 2. Holotype, SNUP 655, internal mould of cephalon, $\times 12$. 3. SNUP 656, internal mould of cephalon, $\times 12$. 4. SNUP 657, internal mould of cephalon, $\times 16$. 5. SNUP 658, internal mould of pygidium, $\times 14$. 6. SNUP 659, internal mould of pygidium, $\times 14$. 7. SNUP 660, internal mould of pygidium, $\times 16$. 8. SNUP 661, internal mould of pygidium, $\times 14$.

Fig. 8. *Ivshinagnostus quadratus* nov. sp. 1. SNUP 654, moule interne du céphalon, $\times 12$. 2. Holotype, SNUP 655, moule interne du céphalon, $\times 12$. 3. SNUP 656, moule interne du céphalon, $\times 12$. 4. SNUP 657, moule interne du céphalon, $\times 16$. 5. SNUP 658, moule interne du pygidium, $\times 14$. 6. SNUP 659, moule interne du pygidium, $\times 14$. 7. SNUP 660, moule interne du pygidium, $\times 16$. 8. SNUP 661, moule interne du pygidium, $\times 14$.

Subfamily PSEUDAGNOSTINAE Whitehouse, 1936

Genus *Acmahachis* Resser, 1938

Type-species: *Acmahachis typicalis* Resser, 1938 from the Nolichucky Formation, Alabama.

Remarks: *Acmahachis* was erected to embrace the agnostoid trilobites with a long pygidial axis, which is strongly constricted across M2 and reaches medially to the border furrow with an acuminate posterior extremity. Palmer (1962) considered *Oedorhachis* Resser, 1938 and *Cyclagnostus* Lermontova, 1940as junior synonyms of *Acmahachis*. Robison (1988) however demonstrated that *Oedorhachis* is distinct in having an angulate glabellar culmination and zonate pygidial border. *Wanagnostus* Qiu in Qiu et al., 1983 from China was synonymized with *Acmahachis* by Shergold et al. (1990). Peng and Robison (2000) added *Oxyagnostus* Öpik, 1967 to the synonym list of *Acmahachis*.

Suprageneric relationship and taxonomic assignment of *Acmahachis* had been controversial in the past: Howell (1959) placed *Acmahachis* under the family Agnostidae, whereas *Cyclagnostus* was assigned to the family Pseudagnostidae; Palmer (1962) suggested possible affinities of *Acmahachis* with genera of the Pseudagnostidae; and Öpik (1967) and Shergold (1980) on the other hand assigned *Acmahachis* to the family Agnostidae based on the interpretation that it is non-deuterolobate. Recently Shergold et al. (1990) regarded the subfamilial status of *Acmahachis* to be uncertain, but retained it under the family Agnostidae. Mean-

while Pratt (1992) presented a different opinion on the nature of the pseudagnostid pygidial axis: viz., the deuterolobe does not differ from a posterior axial lobe of other agnostids, and subsequently *Acmahachis* was placed under the subfamily Pseudagnostinae of Agnostidae. Pratt's (1992) interpretation was endorsed by Peng and Robison (2000). In this study, *Acmahachis* is placed under the subfamily Pseudagnostinae of Agnostidae, following the procedure by Pratt (1992) and Peng and Robison (2000).

Acmahachis typicalis Resser, 1938

Fig. 9(1–8)

1938. *Acmahachis typicalis* - Resser, p. 47, pl. 10, Figs. 4, 5.

1938. *Homagnostus acutus* - Kobayashi, p. 172, pl. 16, Figs. 16b, 18–22.

1940. *Cyclagnostus elegans* - Lermontova, p. 127, pl. 49, Figs. 10, 10a.

1961. *Acmahachis acuta* (Kobayashi) - Rasetti, p. 109, pl. 23, Figs. 1–8.

1962. *Homagnostus hisakoshii* - Kobayashi, (pars), p. 30, pl. 8, Figs. 6, 7.

1967. *Cyclagnostus quasivespa* - Öpik, p. 109, pl. 59, Figs. 1–7.

1980. *Acmahachis hybrida* - Shergold, p. 20, pl. 11, Figs. 1–6, text-fig. 8.

1980. *Acmahachis karatauensis* - Ergaliev, p. 96, pl. 4, Fig. 18.

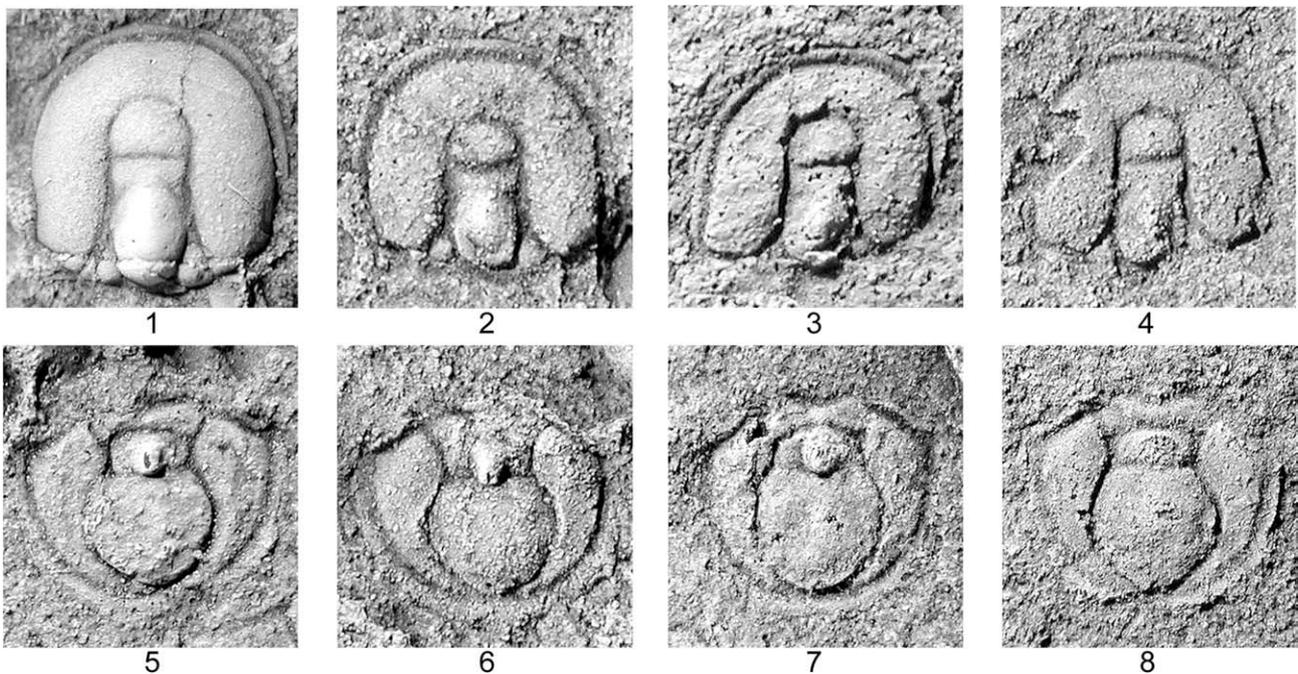


Fig. 9. *Acmahachis typicalis* Resser, 1938. 1. SNUP 662, cephalon, $\times 14$. 2. SNUP 663, internal mould of cephalon, $\times 18$. 3. SNUP 664, internal mould of cephalon, $\times 18$. 4. SNUP 665, internal mould of cephalon, $\times 16$. 5. SNUP 666, internal mould of pygidium, $\times 14$. 6. SNUP 667, internal mould of pygidium, $\times 14$. 7. SNUP 668, internal mould of pygidium, $\times 12$. 8. SNUP 669, internal mould of pygidium, $\times 12$.

Fig. 9. *Acmahachis typicalis* Resser, 1938. 1. SNUP 662, céphalon, $\times 14$. 2. SNUP 663, moule interne du céphalon, $\times 18$. 3. SNUP 664, moule interne du céphalon, $\times 18$. 4. SNUP 665, moule interne du céphalon, $\times 16$. 5. SNUP 666, moule interne du pygidium, $\times 14$. 6. SNUP 667, moule interne du pygidium, $\times 14$. 7. SNUP 668, moule interne du pygidium, $\times 12$. 8. SNUP 669, moule interne du pygidium, $\times 12$.

1980. *Acmahachis longispinus* - Ergaliev, p. 97, pl. 4, Fig. 19.

1980. *Acmahachis punctatus* - Ergaliev, p. 97, pl. 4, Fig. 12.

1983. *Wanagnostus anhuiensis* - Qiu in Qiu et al., p. 30, pl. 11, Figs. 6, 7.

1987. *Cyclagnostus yaogongbuensis* - Lu and Lin in Peng, p. 77, pl. 1, Figs. 8–11.

1992. *Acmahachis typicalis* Resser - Pratt, p. 38, pl. 4, Figs. 1–3.

1992. *Acmahachis acuta* (Kobayashi) - Pratt, p. 39, pl. 4, Figs. 4–22.

2000. *Acmahachis typicalis* Resser - Peng and Robison, p. 21, Fig. 13 (for additional synonymy).

Material, horizon and locality: more than 40 specimens; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-44 to KG-96 of the Konggiri section, Yongwol.

Remarks: although there have been reported more than a dozen of species either assigned or assignable to *Acmahachis*, no reliable morphological features for differentiating species among *Acmahachis* are appreciated. Recently Pratt (1992), allowing a range of intraspecific morphological variation, synonymized *Cyclagnostus quasivespa* and *Cyclagnostus yaogongbuensis* with *A. typicalis* and three Kazakhstan species (*A. karatauensis*, *A. longispinus*, and *A. punctatus*) with *A. acuta*. Peng and Robison (2000) went further to put all of *Acmahachis* species, except *Oxyagnostus apicula* Öpik, 1967 and *Acmahachis hybrida* Shergold, 1980,

to the type species: *Acmahachis apicula* (Öpik, 1967) was diagnosed as having more advanced position of glabellar node, narrower anteroaxis, and more expanding posteroaxis than *A. typicalis*; and *Acmahachis hybrida*, which occurs stratigraphically much higher, was provisionally distinguished from *A. typicalis* by its narrower borders and fully developed, though weak, median preglabellar furrow. The present material is stratigraphically correlative with *Acmahachis hybrida*, but the median preglabellar furrow is effaced or incompletely developed. The Australian specimens also show variably developed median preglabellar furrow and consequently we suggest that *A. hybrida* be synonymous with *A. typicalis*.

Genus *Agnostotes* Öpik, 1963

Type-species: *Agnostotes inconstans* Öpik, 1963 from the Pomegranate Limestone, Queensland, Australia.

Agnostotes orientalis (Kobayashi, 1935)

Fig. 10(1–7)

1935. *Agnostus* (*Ptychagnostus*?) *orientalis* - Kobayashi, p. 105, pl. 14, Figs. 11, 12.

1963. *Agnostotes orientalis* (Kobayashi) - Öpik, p. 44.

1966. *Glyptagnostotes elegans* - Lazarenko, p. 42, pl. 2, Figs. 1–12.

1980. *Glyptagnostotes elegans* Lazarenko - Ergaliev, p. 101, pl. 12, Fig. 8.

2000. *Agnostotes* (*Pseudoglyptagnostus*) *orientalis* (Kobayashi) - Zhang, p. 96, text-figs. 1A-B.

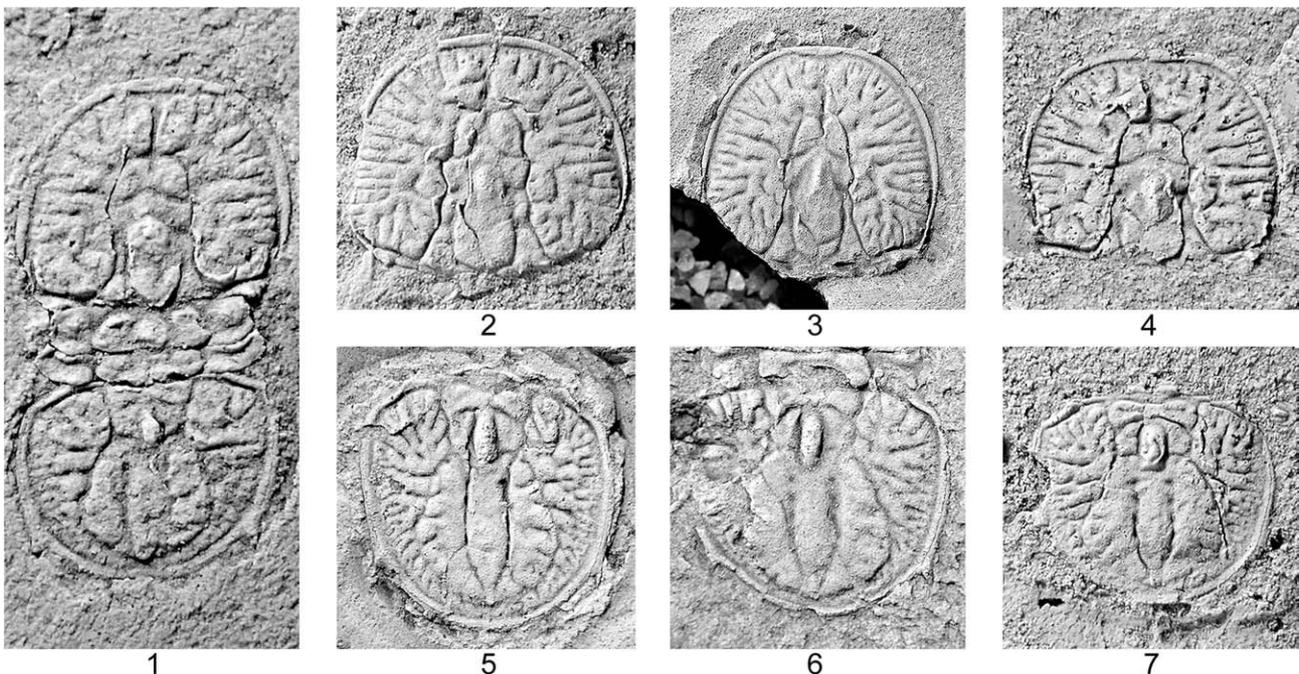
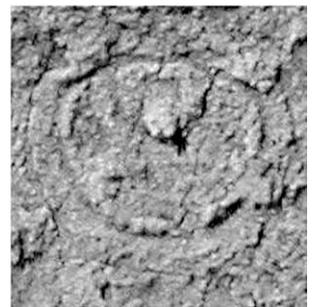
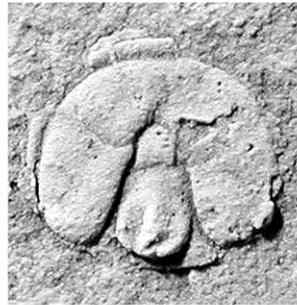


Fig. 10. *Agnostotes orientalis* (Kobayashi, 1935). 1. SNUP 670, internal mould of carapace, $\times 12$. 2. SNUP 671, internal mould of cephalon, $\times 6$. 3. SNUP 672, internal mould of cephalon, $\times 4$. 4. SNUP 673, internal mould of cephalon, $\times 8$. 5. SNUP 674, internal mould of pygidium, $\times 6$. 6. SNUP 675, internal mould of pygidium, $\times 6$. 7. SNUP 676, internal mould of pygidium, $\times 6$.

Fig. 10. *Agnostotes orientalis* (Kobayashi, 1935). 1. SNUP 670, moule interne d'une carapace, $\times 12$. 2. SNUP 671, moule interne du céphalon, $\times 6$. 3. SNUP 672, moule interne du céphalon, $\times 4$. 4. SNUP 673, moule interne du céphalon, $\times 8$. 5. SNUP 674, moule interne du pygidium, $\times 6$. 6. SNUP 675, moule interne du pygidium, $\times 6$. 7. SNUP 676, moule interne du pygidium, $\times 6$.



Material, horizon and locality: more than 70 specimens; *Agnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; unit KG-18 of the Konggiri section, Yongwol.

Description: cephalon subcircular. Acrolobe unconstricted and strongly scrobiculate; scrobicules consisting of alternating long and short radial furrows around periphery of acrolobe and pits or short furrows close to glabella; border narrow; border furrow nondeliquate; median preglabellar furrow fully developed. Glabella about two-thirds of cephalic length; anteroglabella trapezoidal in outline, with well-defined frontal sulcus; F3 convex forwards; posterglabella with elongate median node level with or in front of F2; F2 transverse or directed forwards; F1 emerging from anterior tip of basal lobe and directed strongly forwards. Basal lobes triangular, slightly elongate, undivided; basal furrow angulate.

Pygidium subcircular, longer than wide. Acrolobe weakly constricted and scrobiculate, with radial furrows of variable length, often extending onto lateral portion of posteroaxis. Anteroaxis about one-fourth of pygidial length, tapering backwards; M1 shorter (sag.) than M2; F1 convex forwards and impressed laterally; F2 transverse, interrupted by axial node; axial node elongate, covering sagittally most of M2 and crossing over F2; posteroaxis ovoid to subpentagonal, about 60% of pygidial length and 45–60% of pygidial width; intranotular axis lanceolate with a tiny terminal node, up to nine pairs of notulae in notular furrows. Pygidial posterolateral spines short.

Remarks: the type material of *Agnostotes orientalis* (Kobayashi, 1935) has recently been examined in detail by Zhang (2000), but its holotype is too poorly preserved to show the morphological features with clarity. In this study, we provide an emended description of the species based on numerous, well-preserved specimens. It is characterized by its ovoid to subpentagonal posteroaxis and lanceolate intranotular axis. Larger pygidia have in general subpentagonal posteroaxis, while smaller ones bear a broadly ovoid posteroaxis. In this respect, this species is closely similar to, and cannot be distinguished from *Glyptagnostotes elegans* Lazarenko, 1966 from Siberia and Kazakhstan, which is herein regarded as a junior synonym of *A. orientalis*. *Agnostotes*

clavatus (Lu, 1964) has a slightly different scrobiculation, subrectangular anteroglabella, circular or broadly oval posteroaxis, and posteriorly tapering intranotular axis.

Genus *Yongwolagnostus* nov. gen.

Etymology: after the district of Yongwol to which the fossil locality belongs.

Type-species: *Yongwolagnostus stenorhachis* nov. sp. from the *Agnostotes orientalis* Zone of the Machari Formation, Korea.

Diagnosis: a comparatively small agnostoid having subrectangular cephalon with non-deliquate border furrow, no median preglabellar furrow, narrow and forward-tapering glabella with small anteroglabella. Subcircular pygidium with unconstricted acrolobe and broad border; anteroaxis tapering backwards; posteroaxis only indicated by divergent furrows in its anterior portion; short pygidial spines situated retrally.

Remarks: *Yongwolagnostus* nov. gen. is characterized by its small size, narrow forward-tapering glabella, poorly-defined posteroaxis, non-deliquate border furrow, and broad pygidial border. The furrows defining posteroaxis are reminiscent of those of *Pseudagnostus* or *Acmarrhachis*. Cephalae of *Yongwolagnostus* bear some resemblance to those of *Utagnostus* Robison, 1964 in having a small circular anteroglabella, but their pygidia are different from each other. *Idolagnostus* Öpik, 1967 has comparable pygidial morphology to *Yongwolagnostus*, but its axial furrows completely enclose the axis.

Yongwolagnostus stenorhachis nov. sp.

Fig. 11(1–11)

Etymology: from *stenos*, narrow and *rhachis*, axis; referring to narrow glabella and pygidial axis.

Material, horizon and locality: holotype carapace, SNUP 677 (Fig. 11(1)); paratypes SNUP 678–687; more than 30 specimens; *Agnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; units KG-19, KG-23, and KG-26 of the Konggiri section, Yongwol.

Description: cephalon subrectangular, wider than long, with non-deliquate border furrow. Acrolobe unconstricted to weakly constricted, smooth; median preglabellar furrow ves-

Fig. 11. 1–11. *Yongwolagnostus stenorhachis* nov. gen. and nov. sp. 1. Holotype, SNUP 677, internal mould of carapace, × 22. 2. SNUP 678, internal mould of cephalon, × 16. 3. SNUP 679, internal mould of cephalon, × 20. 4. SNUP 680, internal mould of cephalon, × 18. 5. SNUP 681, internal mould of cephalon, × 18. 6. SNUP 682, internal mould of cephalon, × 18. 7. SNUP 683, internal mould of cephalon, × 20. 8. SNUP 684, internal mould of pygidium, × 14. 9. SNUP 685, internal mould of pygidium, × 20. 10. SNUP 686, internal mould of pygidium, × 16. 11. SNUP 687, internal mould of pygidium, × 18. 12–18. *Yongwolagnostus dubius* nov. gen. and nov. sp. 12. Holotype, SNUP 688, internal mould of carapace, × 24. 13. SNUP 689, internal mould of cephalon, × 24. 14. SNUP 690, internal mould of cephalon, × 18. 15. SNUP 691, internal mould of cephalon, × 24. 16. SNUP 692, internal mould of pygidium, × 26. 17. SNUP 693, internal mould of pygidium, × 24. 18. SNUP 694, internal mould of pygidium, × 26.

Fig. 11. 1–11. *Yongwolagnostus stenorhachis* nov. gen. et nov. sp. 1. Holotype, SNUP 677, moule interne d'une carapace, × 22. 2. SNUP 678, moule interne du céphalon, × 16. 3. SNUP 679, moule interne du céphalon, × 20. 4. SNUP 680, moule interne du céphalon, × 18. 5. SNUP 681, moule interne du céphalon, × 18. 6. SNUP 682, moule interne du céphalon, × 18. 7. SNUP 683, moule interne du céphalon, × 20. 8. SNUP 684, moule interne du pygidium, × 14. 9. SNUP 685, moule interne du pygidium, × 20. 10. SNUP 686, moule interne du pygidium, × 16. 11. SNUP 687, moule interne du pygidium, × 18. 12–18. *Yongwolagnostus dubius* nov. gen. et nov. sp. 12. Holotype, SNUP 688, moule interne d'une carapace, × 24. 13. SNUP 689, moule interne du céphalon, × 24. 14. SNUP 690, moule interne du céphalon, × 18. 15. SNUP 691, moule interne du céphalon, × 24. 16. SNUP 692, moule interne du pygidium, × 26. 17. SNUP 693, moule interne du pygidium, × 24. 18. SNUP 694, moule interne du pygidium, × 26.

tigial, indicated by short indentation in front of glabella. Glabella narrow, tapering forwards, about 30% of cephalic width and 55–60% of cephalic length; axial furrow clearly impressed; anteroglabella small, subcircular to subtriangular; F3 transverse; posteroglabella tumid, with rounded basal culmination; glabellar node on posterior one-third of posteroglabella. Basal lobes small, simple, subtriangular. A pair of prominent posterolateral spines deflected diagonally.

Thorax with wide and tripartite axial rings.

Pygidium subcircular, slightly wider than long. Acrolobe unconstricted and smooth. Border wide, much wider than cephalic border; border furrow non-deliquiate. Axis narrow, occupying one-third of pygidial width; anteroaxis subpentagonal, tapering strongly backwards; M1 delimited by weakly developed F1; M2 narrower (tr.) than M1; F2 chevronate; axial node with rounded tip occupying most of M2; posteroaxis defined only in its anterior portion by weakly diverging axial furrows; a small terminal node on rear end. Posterolateral pygidial spines situated retrally.

Remarks: *Yongwolagnostus stenorhachis* nov. sp. is differentiated primarily from *Y. dubius* nov. sp., a stratigraphically earlier form (see below), by its narrower glabella and pygidial axis. Pygidium of *Pseudagnostus* (*Pseudagnostus*) sp. described by Ludvigsen (1982: p. 47) is comparable with *Yongwolagnostus stenorhachis* in having weakly divergent furrows and similar articulating devices, but bears prominent pygidial spines.

Yongwolagnostus dubius nov. sp.

Fig. 11(12–18)

Etymology: from *dubius*, confused; referring to indiscernible pygidial axis.

Material, horizon and locality: holotype carapace, SNUP 688 (Fig. 11(12)); paratypes SNUP 689–694; more than 20 specimens; *Agnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; unit KG-18 of the Konggiri section, Yongwol.

Description: cephalon subquadrate, as long as wide. Acrolobe weakly constricted, with smooth genal field; preglabellar median furrow absent; border of moderate width flattened; border furrow nondeliquiate. Glabella two-thirds of cephalic length, divided into two lobes by transverse and clearly incised F3; anteroglabella small, semicircular, encircled by shallow axial furrows; axial furrow defining posteroglabella deeply incised and weakly tapering forwards; posteroglabella parallel-sided to tapering forwards, much wider than anteroglabella, with weak indication of segmentation, obtusely angulate culmination, and small node lying behind glabellar mid-point. Basal lobes small, simple, triangular.

Pygidium subcircular, as long as wide. Acrolobe unconstricted and smooth. Border wide, approximately 10% of pygidial length; border furrow nondeliquiate. Axis about one-half of pygidial width; axial furrows totally effaced posterior to M2; F1 and F2 obsolete, but constricted across M2; axial node prominent; posteroaxis undefined. Pygidial posterolateral spines very short.

Remarks: *Yongwolagnostus dubius* nov. sp. is easily distinguished from *Y. stenorhachis* by its wider glabella and axis, and totally effaced pygidial posteroaxis. The cephalon of *Idolagnostus* sp. described by Shergold (1982) from the *Stigmatia diloma* Zone of Australia is similar to that of *Y. dubius*.

Genus *Nahannagnostus* Pratt, 1992.

Type-species: *Pseudagnostus nganasanicus* Rozova, 1964 from the Nganasan Gorizont of Siberia.

Nahannagnostus pratti nov. sp.

Fig. 12(1–8)

1992. *Nahannagnostus?* sp. - Pratt, p. 37, pl. 6, Figs. 24, 25.

Etymology: after B.R. Pratt who erected the genus *Nahannagnostus* in 1992.

Material, horizon and locality: holotype, SNUP 695 (Fig. 12(1)); paratypes SNUP 696–702; more than 30 specimens; *Eochuangia hana* and *Agnostotes orientalis* zones (middle Upper Cambrian) of the Machari Formation; units KG-8 to KG-11, and KG-18 of the Konggiri section, Yongwol.

Description: cephalon subcircular, as long as wide, with narrow border and nondeliquiate border furrow. Acrolobe unconstricted and smooth. Median preglabellar furrow fully developed. Glabella 55 to 60% of cephalic length; anteroglabella small, circular to subtriangular; F3 transverse; posteroglabella strongly convex, parallel-sided or weakly tapering forwards, with small node on glabellar mid-point and obtusely angulate glabellar culmination. Basal lobes simple, subtriangular.

Pygidium semicircular, as long as wide, with narrow border and deliquiate border furrow. Acrolobe constricted and smooth. Axis long and broad, nearly reaching to border furrow and occupying anteriorly about 60% of pygidial width; M1 wider (tr.) than M2; F1 bent forwards; F2 transverse, interrupted by elongate axial node; axial node occupying most of M2; posteroaxis gently expanding posteriorly to form broadly rounded posterior margin. Posterolateral spines very short.

Remarks: *Nahannagnostus pratti* sp. nov. is characterized by its small anteroglabella and broadly expanding posteroaxis encircled by axial furrow and can be distinguished from *N. nganasanicus* (Rozova, 1964) which has no or very small anteroglabella and rearward-divergent pygidial axial furrow reaching to the border furrow. Pratt (1992) recognized two species of *Nahannagnostus*, *N. nganasanicus* (Rozova, 1964) and *N. logani* Pratt, 1992, whereas Peng and Robison (2000) considered *N. logani* to be a junior synonym of *N. nganasanicus*. The genus has been known to occur mainly in the upper Middle Cambrian (*Cedaria minor* Zone in Canada and *Proagnostus bulbosus* Zone in South China) to lower Upper Cambrian (*Glyptagnostus stolidotus* Zone), but *Nahannagnostus?* sp. was documented from the *Proceratopyge rectispinata* Zone (uppermost Steptoean) in Canada

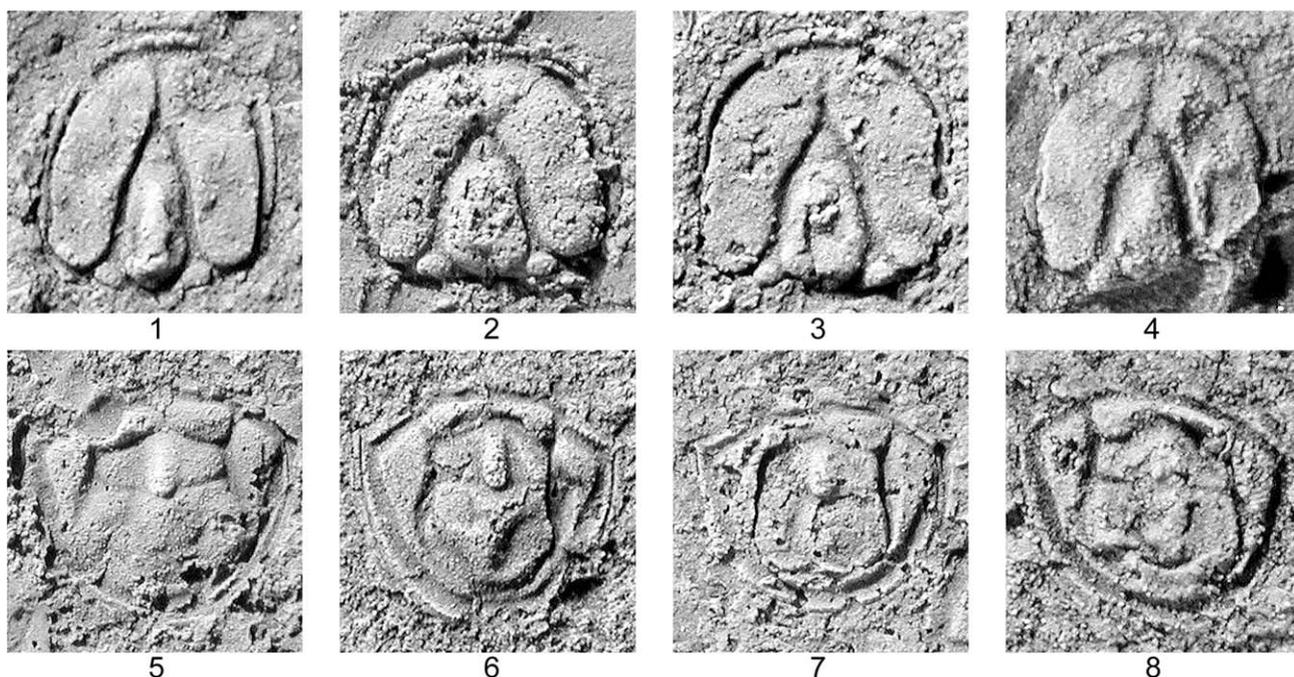


Fig. 12. *Nahannagnostus pratti* nov. sp. 1. Holotype, SNUP 695, internal mould of cephalon, $\times 22$. 2. SNUP 696, internal mould of cephalon, $\times 18$. 3. SNUP 697, internal mould of cephalon, $\times 18$. 4. SNUP 698, internal mould of cephalon, $\times 20$. 5. SNUP 699, internal mould of pygidium, $\times 16$. 6. SNUP 700, internal mould of pygidium, $\times 18$. 7. SNUP 701, internal mould of pygidium, $\times 16$. 8. SNUP 702, internal mould of pygidium, $\times 20$.

Fig. 12. *Nahannagnostus pratti* nov. sp. 1. Holotype, SNUP 695, moule interne du céphalon, $\times 22$. 2. SNUP 696, moule interne du céphalon, $\times 18$. 3. SNUP 697, moule interne du céphalon, $\times 18$. 4. SNUP 698, moule interne du céphalon, $\times 20$. 5. SNUP 699, moule interne du pygidium, $\times 16$. 6. SNUP 700, moule interne du pygidium, $\times 18$. 7. SNUP 701, moule interne du pygidium, $\times 16$. 8. SNUP 702, moule interne du pygidium, $\times 20$.

(Pratt, 1992). Two cephalons assigned to *Nahannagnostus*? sp. are closely similar to and indistinguishable from those of *N. pratti*. In Korea, *Nahannagnostus pratti* occurs in the *Eochuangia hana* and *Agnostotes orientalis* zones, correlative to the *Proceratopyge rectispinata* Zone of Canada.

Genus *Pseudagnostus* Jaekel, 1909

Type-species: *Agnostus cyclopyge* Tullberg, 1880 from the Upper Cambrian of Sweden.

Remarks: Shergold (1977), in a review of the genus *Pseudagnostus*, recognized three subgenera within *Pseudagnostus*, namely *Pseudagnostus* (*Pseudagnostus*), *P.* (*Pseudagnostina*), and *P.* (*Sulcatagnostus*). This view has been widely employed in subsequent studies (e.g., Ergaliev, 1980; Rushton, 1983; Lu and Lin, 1989; Shergold et al., 1990; Peng, 1992), whereas Pratt (1992) recently warranted these subgenera to be separate genera. On the other hand, Peng and Robison (2000) expanded the generic concept of *Pseudagnostus* to embrace several pseudagnostine genera such as *Litagnostus* Rasetti, 1944, *Pseudagnostina* Palmer, 1962, *Rhaptagnostus* Whitehouse, 1936, *Sulcatagnostus* Kobayashi, 1937, and *Xestagnostus* Öpik, 1967. The taxonomic treatment by Peng and Robison (2000) is followed in this study.

Pseudagnostus? *dividuus* nov. sp.

Fig. 13(1–8)

Etymology: from *dividuus*, divided; referring to the divided basal lobes.

Material, horizon and locality: holotype cephalon, SNUP 705 (Fig. 13(3)); paratypes SNUP 703–704, 706–710; additional 30 specimens; *Agnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; units KG-18 to KG-30 of the Konggiri section, Yongwol.

Description: cephalon subovoid, as long as wide. Acrolobe unconstricted; preglabellar median furrow obsolete to fully developed; genal field smooth. Border broad and flattened; border furrow nondeliquiate. Glabella spindle-shaped, with broadly rounded anterior margin and posterior culmination; glabellar node small, elongate, located at level with or just in front of glabellar midpoint; glabellar furrows effaced. Basal lobes triangular and divided.

Pygidium subquadrate, as long as wide. Acrolobe strongly constricted; pleural field smooth. Border broad and flattened; border furrow subdeliquiate to deliquiate. Anteroaxis trapezoidal, tapering rearwards; M1 shorter than M2; F1 transverse, weakly impressed; F2 gently curved rearwards; axial node elongate, expanding posteriorly, with shallow posterior sulcus, occupying most of M2; posteroaxis expanding posteriorly, indented at rear, with a tiny terminal node. Pygidial posterolateral spines short.

Remarks: *Pseudagnostus*? *dividuus* nov. sp. is characterized by its divided basal lobes, which have not been known in other species of *Pseudagnostus*. In addition, glabellar morphology of this species is unusual for *Pseudagnostus*, as its glabellar furrows are totally effaced. However, its pygidium is typical of *Pseudagnostus* and hence this species is assigned to the genus *Pseudagnostus* with reservation.

Pseudagnostus josepha (Hall, 1863)

Fig. 13(9–16)

1863. *Aagnostus josepha* - Hall, p. 178, pl. 6 Figs. 54, 55.1935. *Pseudagnostus josepha* (Hall) - Kobayashi, p. 1081935. *Pseudagnostus primus* - Kobayashi, p. 108, pl. 14, Figs. 6–10.non 1961. *Pseudagnostus primus* Kobayashi - Kobayashi, p. 189, pl. 13, Figs. 20, 21.1962. *Pseudagnostus primus* Kobayashi - Kobayashi, p. 31, pl. 3, Figs. 15–17 (?); pl. 5, Figs. 8–12.1996. *Pseudagnostus* sp. - Lee and Choi, p. 151, pl. 1, Figs. 2–12.2000. *Pseudagnostus josepha* (Hall) - Peng and Robison, p. 16, Fig. 10 (for additional synonymy)**Material, horizon and locality:** more than 100 specimens; *Eochuangia hana* to *Pseudoyuepingia asaphoides* zones (middle Upper Cambrian) of the Machari Formation; units KG-8 to KG-115 of the Konggiri section, Yongwol.**Remarks:** *Pseudagnostus josepha* (Hall, 1863) has been thoroughly treated by Peng and Robison (2000), which is basically followed in this study. They treated *P. primus* from the Machari Formation to be a junior synonym of *P. josepha*. However, the specimens assigned to *Pseudagnostus primus* by Kobayashi in 1961 has a subquadrate shield and shorter glabella and can be better accommodated with *Pseudorhaptagnostus*. Kobayashi (1962) also illustrated eight specimens of *P. primus* from the Machari Formation. Of these, five specimens (pl. 5, Figs. 8–12) display the features of *P. josepha*, while three specimens (pl. 3, Figs. 15–17) can not be evaluated due to poor preservation.*Pseudagnostus medius* nov. sp.

Fig. 14(1–8)

Etymology: from *medius*, middle; referring to the intermediate morphology between *Pseudagnostus* and *Acmarrhachis*.**Material, horizon and locality:** holotype pygidium, SNUP 723 (Fig. 14(5)); paratypes SNUP 719–722, 724–726; 45 specimens; *Aagnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; unit KG-18 of the Konggiri section, Yongwol.**Description:** cephalon subcircular, slightly wider than long. Acrolobe unconstricted; preglabellar median furrow fully developed; genal field smooth. Border narrow; border furrow nondeliquate. Glabella convex, about two-thirds of cephalic length; anteroglabella semicircular; F3 transverse or weakly concave forwards; anterolateral lobes, separated from rest of posteroglabella by chevronate F2; posteroglabella parallel-sided, with weak constriction across M2, rounded culmination, and strongly elongate node lying behind anterolateral lobes. Basal lobes of moderate size triangular, connected behind glabella to form a narrow band. Cephalic posterolateral spines short, bluntly pointed.

Pygidium subquadrate, slightly wider than long. Acrolobe constricted; pleural field smooth. Border as broad as border furrow; border furrow subdeliquate to deliquate. Anteroaxis

narrow and tapering rearwards; F1 and F2 weakly impressed and transverse; axial node prominent, elongate, occupying most of M2, and extending onto posteroaxis; posteroaxis subpentagonal, with shallow longitudinal depression representing notular axis along sagittal line; a distinct terminal node on posterior extremity. Posterolateral spines short.

Remarks: *Pseudagnostus medius* nov. sp. is restricted to the lowermost 30 cm interval of the *Aagnostotes orientalis* Zone. It is characterized by its small size and pygidium with narrow anteroaxis and subpentagonal posteroaxis enclosed by axial furrow. In these respects, this species displays an intermediate morphology between *Pseudagnostus* and *Acmarrhachis*. The species with similar posteroaxis are *Pseudagnostus ampullatus* Öpik, 1967, *Oxyagnostus apicula* Öpik, 1967 and *Acmarrhachis?* sp. by Palmer (1962: pl. 2, Figs. 9, 10.). *Pseudagnostus ampullatus* differs *Pseudagnostus medius* nov. sp. in that posteroaxis is well defined, but in other characteristics the two species are very comparable. *Acmarrhachis apicula* also resembles *Pseudagnostus medius* sp. nov., but differs in having effaced preglabellar median furrow, constricted pygidial acrolobe, and more oblong posteroaxis (cf. Peng and Robison, 2000).*Pseudagnostus securiger* (Lake, 1906)

Fig. 14(9–15)

1906. *Aagnostus securiger* - Lake, p. 20, pl. 2, Fig. 11.1937. *Sulcatagnostus securiger* (Lake) - Kobayashi, p. 451.1977. *Pseudagnostus* (*Sulcatagnostus*) *securiger* (Lake) - Shergold, p. 86, pl. 15, Fig. 13.1983. *Pseudagnostus* (*Sulcatagnostus*) *securiger* (Lake) - Rushton, p. 120, pl. 15, Figs. 4, 5, 11, 15, 16.1988. *Proagnostus securiger* (Lake) - Robison, p. 411992. *Sulcatagnostus securiger* (Lake) - Pratt, p. 35, pl. 5, Figs. 5–9.1992. *Pseudagnostus* (*Sulcatagnostus*) *hunanensis* (Lake) - Peng, p. 27, Figs. 12H–P.**Material, horizon and locality:** six cephalata and six pygidia; *Eochuangia hana* Zone (middle Upper Cambrian) of the Machari Formation; units KG-2 to KG-8 of the Konggiri section, Yongwol.**Remarks:** *Pseudagnostus securiger* was the type species of *Sulcatagnostus* Kobayashi, 1937, which was diagnosed by its trispinose pygidium and was often regarded as a subgenus of *Pseudagnostus* (Shergold, 1977; Rushton, 1983; Peng, 1992). Recently, Peng and Robison (2000) broadened the generic concept of *Pseudagnostus*, by which *Sulcatagnostus* was suppressed to be a junior synonym of *Pseudagnostus*. Aside from *Pseudagnostus securiger*, four species were previously assigned to *Sulcatagnostus*: viz., *S. quruquensis* Lu in Lu et al., 1974; *P. (S.) rugosus* Ergaliev, 1980; *P. (S.) (?) dubius* Lu and Lin, 1989; and *P. (S.) hunanensis* Peng, 1992. Of these, *S. quruquensis* and *P. (S.) rugosus* were excluded from *Sulcatagnostus* by Rushton (1983) based on the absence of pygidial median spine. The assignment of *P. (S.) (?) dubius* to the subgenus is difficult to evaluate due to poor

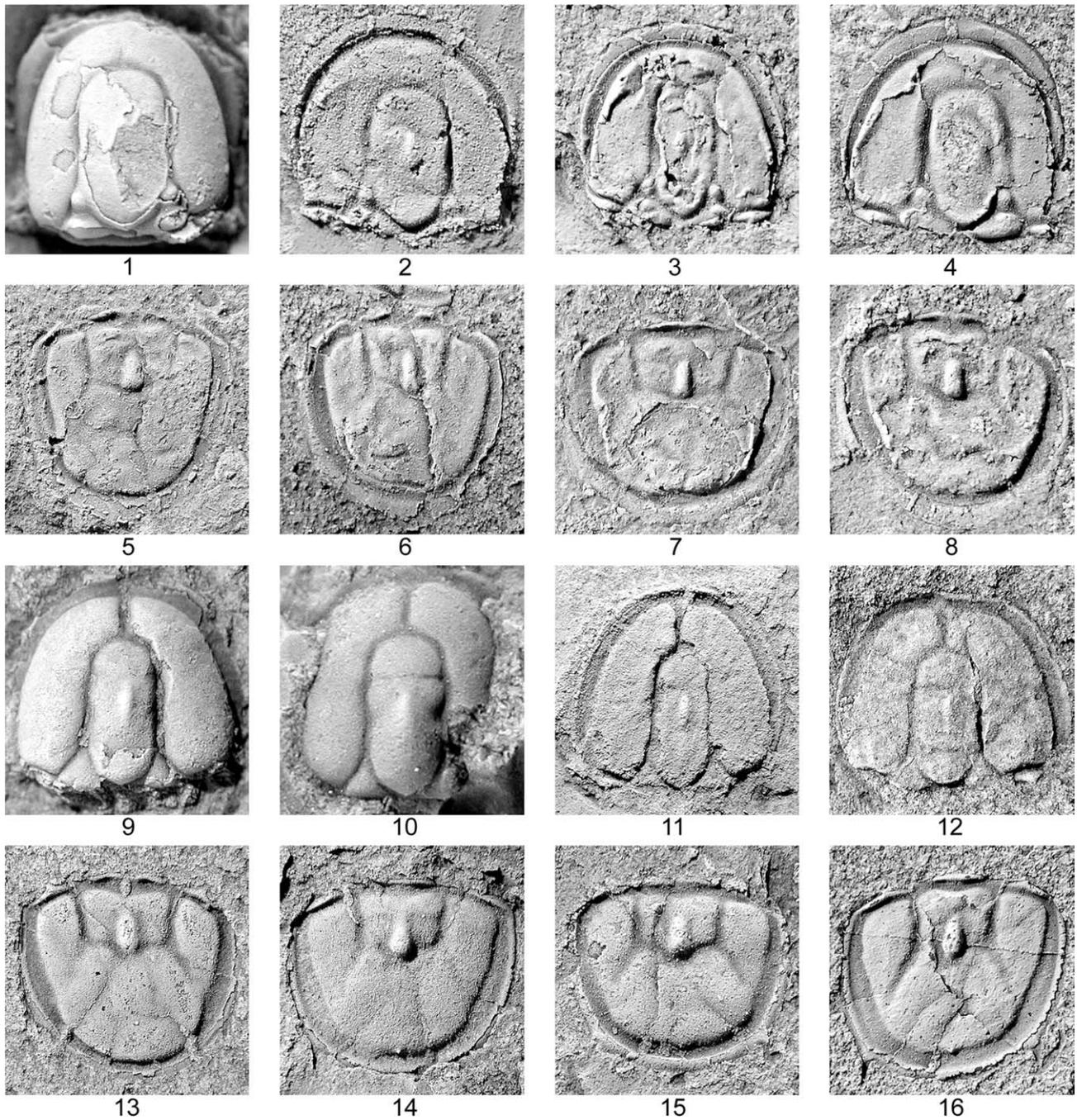


Fig. 13. 1–8. *Pseudagnostus? dividuus* nov. sp. 1. SNUP 703, cephalon, $\times 12$. 2. SNUP 704, internal mould of cephalon, $\times 10$. 3. Holotype, SNUP 705, internal mould of cephalon, $\times 10$. 4. SNUP 706, internal mould of cephalon, $\times 10$. 5. SNUP 707, internal mould of pygidium, $\times 6$. 6. SNUP 708, internal mould of pygidium, $\times 8$. 7. SNUP 709, internal mould of pygidium, $\times 8$. 8. SNUP 710, internal mould of pygidium, $\times 12$. 9–16. *Pseudagnostus josepha* (Hall, 1863). 9. SNUP 711, cephalon, $\times 10$. 10. SNUP 712, cephalon, $\times 10$. 11. SNUP 713, internal mould of cephalon, $\times 8$. 12. SNUP 714, internal mould of cephalon, $\times 8$. 13. SNUP 715, internal mould of pygidium, $\times 6$. 14. SNUP 716, internal mould of pygidium, $\times 8$. 15. SNUP 717, internal mould of pygidium, $\times 8$. 16. SNUP 718, internal mould of pygidium, $\times 8$.

Fig. 13. 1–8. *Pseudagnostus? dividuus* nov. sp. 1. SNUP 703, céphalon, $\times 12$. 2. SNUP 704, moule interne du céphalon, $\times 10$. 3. Holotype, SNUP 705, moule interne du céphalon, $\times 10$. 4. SNUP 706, moule interne du céphalon, $\times 10$. 5. SNUP 707, moule interne du pygidium, $\times 6$. 6. SNUP 708, moule interne du pygidium, $\times 8$. 7. SNUP 709, moule interne du pygidium, $\times 8$. 8. SNUP 710, moule interne du pygidium, $\times 12$. 9–16. *Pseudagnostus josepha* (Hall, 1863). 9. SNUP 711, céphalon, $\times 10$. 10. SNUP 712, céphalon, $\times 10$. 11. SNUP 713, moule interne du céphalon, $\times 8$. 12. SNUP 714, moule interne du céphalon, $\times 8$. 13. SNUP 715, moule interne du pygidium, $\times 6$. 14. SNUP 716, moule interne du pygidium, $\times 8$. 15. SNUP 717, moule interne du pygidium, $\times 8$. 16. SNUP 718, moule interne du pygidium, $\times 8$.

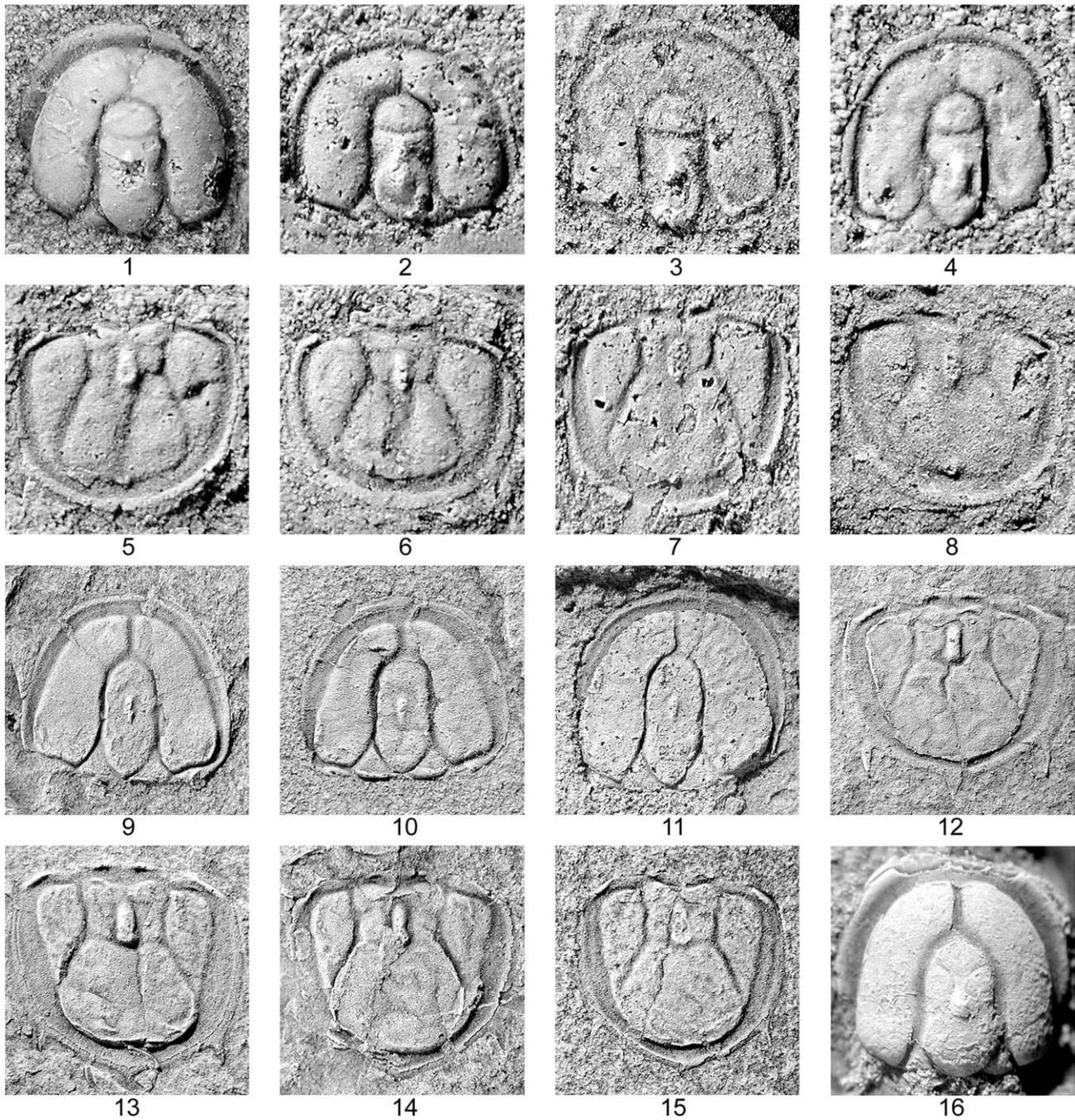


Fig. 14. 1–8. *Pseudagnostus medius* nov. sp. 1. SNUP 719, cephalon, $\times 14$. 2. SNUP 720, internal mould of cephalon, $\times 16$. 3. SNUP 721, internal mould of cephalon, $\times 14$. 4. SNUP 722, internal mould of cephalon, $\times 16$. 5. Holotype, SNUP 723, internal mould of pygidium, $\times 16$. 6. SNUP 724, internal mould of pygidium, $\times 18$. 7. SNUP 725, internal mould of pygidium, $\times 14$. 8. SNUP 726, internal mould of pygidium, $\times 16$. 9–15. *Pseudagnostus securiger* (Lake, 1906). 9. SNUP 727, internal mold of cephalon, $\times 6$. 10. SNUP 728, internal mold of cephalon, $\times 6$. 11. SNUP 729, internal mould of cephalon, $\times 8$. 12. SNUP 730, internal mould of pygidium, $\times 8$. 13. SNUP 731, internal mould of pygidium, $\times 6$. 14. SNUP 732, internal mould of pygidium, $\times 8$. 15. SNUP 733, internal mould of pygidium, $\times 8$. 16. *Pseudagnostus* sp. SNUP 734, cephalon, $\times 10$.

Fig. 14. 1–8. *Pseudagnostus medius* nov. sp. 1. SNUP 719, céphalon, $\times 14$. 2. SNUP 720, moule interne du céphalon, $\times 16$. 3. SNUP 721, moule interne du céphalon, $\times 14$. 4. SNUP 722, moule interne du céphalon, $\times 16$. 5. Holotype, SNUP 723, moule interne du pygidium, $\times 16$. 6. SNUP 724, moule interne du pygidium, $\times 18$. 7. SNUP 725, moule interne du pygidium, $\times 14$. 8. SNUP 726, moule interne du pygidium, $\times 16$. 9–15. *Pseudagnostus securiger* (Lake, 1906). 9. SNUP 727, moule interne du céphalon, $\times 6$. 10. SNUP 728, moule interne du céphalon, $\times 6$. 11. SNUP 729, moule interne du céphalon, $\times 8$. 12. SNUP 730, moule interne du pygidium, $\times 8$. 13. SNUP 731, moule interne du pygidium, $\times 6$. 14. SNUP 732, moule interne du pygidium, $\times 8$. 15. SNUP 733, moule interne du pygidium, $\times 8$. 16. *Pseudagnostus* sp. SNUP 734, céphalon, $\times 10$.

preservation of specimens, although Pratt (1992) and Peng (1992) independently suggested that the species from South China may possibly belong to the type species of *Sulcatagnostus*. *Pseudagnostus* (*Sulcatagnostus*) *humanensis* was primarily distinguished from *P. securiger* by the absence of scrobiculation which is however not a diagnostic feature of *P. securiger* (cf. Pratt, 1992: p. 35). Consequently *P. (S.) humanensis* is treated as a junior synonym of *P. securiger*.

Pseudagnostus sp.

Fig. 14(16)

Material, horizon and locality: one cephalon; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; unit KG-96 of the Konggiri section, Yongwol.

Description: cephalon subcircular, as long as wide. Acrolobe unstricted; preglabellar median furrow completely developed; genal field smooth. Border as wide as border furrow. Glabella ca. two-thirds of cephalic length; anteroglabella subrhomboidal, clearly defined by V-shaped F3; posteroglabella with gently rounded culmination and elongate node lies immediately behind well-defined anterolateral lobes. Basal lobes triangular, relatively small.

Remarks: the cephalon on hand differs from *Pseudagnostus josepha* in having V-shaped transglabellar furrow and more advanced glabellar node. *Pseudagnostus* sp. is closely comparable to *Pseudagnostus praecurrens* Ergaliev, 1980 in over-all cephalic morphology. However, as the pygidium of this species is not available, it is left under open nomenclature.

Genus *Pseudorhaptagnostus* Lermontova, 1951

Type-species: *Pseudorhaptagnostus simplex* Lermontova, 1951 from the Upper Cambrian of Boshchekul, Kazakhstan.

Remarks: the taxonomic status of *Pseudorhaptagnostus* was discussed at length by Nielsen (1997) who considered it a valid senior synonym of *Neagnostus Kobayashi, 1955*.

Pseudorhaptagnostus tumidus (Sun, 1989)

Fig. 15(1–10)

1989. *Neagnostus tumidus* - Sun, p. 80, pl. 5, Fig. 13; pl. 14, Figs. 3–14; pl. 15, Figs. 2–15.

Material, horizon and locality: more than 50 specimens; *Eochuangia hana* and *Agnostotes orientalis* zones (middle Upper Cambrian) of the Machari Formation; units KG-6 to KG-29 of the Konggiri section, Yongwol.

Remarks: *Pseudorhaptagnostus tumidus* (Sun, 1989) was established from the *Kaolishania* Zone of Shantung, China. Specimens from the Machari Formation agree well with the diagnosis and description of *P. tumidus* given by Sun (1989), but show slight differences from the Chinese material in having a more deliquiate border furrow and narrower border. These features are not considered to be of specific significance and may have resulted from the differential mode of preservation: the Chinese specimens retain the origi-

nal convexity in limestone, whereas the Korean ones are invariably preserved flattened in calcareous shale.

Pseudorhaptagnostus? urceus nov. sp.

Fig. 15(11–16)

Etymology: from *urceus*, vase; referring to the vase-shaped pygidial axis.

Material, horizon and locality: holotype pygidium, SNUP 749, (Fig. 15(15)); paratypes SNUP 745-748, 750; eleven specimens; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-35 to KG-36 of the Konggiri section, Yongwol.

Description: cephalon subquadrate, slightly wider than long. Acrolobe strongly constricted; preglabellar median furrow shallow, but fully developed; genal field smooth. Border moderately wide and convex; border furrow deliquiate. Glabella about 60% of cephalic length, parallel-sided, weakly constricted across F2; anteroglabella subrhomboidal, with weakly acuminate anterior tip; F3 V-shaped; anterolateral lobes well-defined, forming a spectaculate condition; F2 faintly defined by shallow notches; glabellar node small, slightly elongate, level with glabellar midpoint; glabellar culmination angulate. Basal lobes triangular and simple.

Pygidium subpentagonal, wider than long. Acrolobe weakly constricted; pleural field smooth. Border relatively wide and flat; border furrow deliquiate, widest near posterolateral spines. Anteroaxis weakly tapering posteriorly; F1 presumably transverse; F2 shallow but clearly impressed, interrupted by axial node; M2 longer (sag.) than M1; axial node occupying most of M2, extending short distance onto posteroaxis; posteroaxis circular, clearly defined by encircling axial furrow with a small terminal node on rear end. Pygidial posterolateral spines prominent, projected posteriorly.

Remarks: *Pseudorhaptagnostus? urceus* nov. sp. has a comparable pygidial axis to *P. canadensis* (Billings, 1860) (cf. Ludvigsen et al., 1989), but differs in having clearly developed V-shaped transglabellar furrow (F3), narrower border, and less deliquiate border furrow. Cephalically, this species has morphological features of *Pseudorhaptagnostus*, while its pygidia are unusual in having a well-defined and broadly rounded posteroaxis. Thus, this species is provisionally assigned to *Pseudorhaptagnostus*. *Agnostus adchinensis* Schrank, 1975, the type species of *Tentagnostus* Sun, 1989, also has a similar pygidial axis to *Pseudorhaptagnostus urceus*. However, pygidia of *Agnostus adchinensis* have broader axis, clearly developed F1 and F2, and rearward-widening border and the associated cranidia are clearly different from those of *Pseudorhaptagnostus*.

Family AMMAGNOSTIDAE Öpik, 1967

Genus *Ammagnostus* Öpik, 1967

Type-species: *Ammagnostus psammis* Öpik, 1967 from the O'Hara Shale of Queensland, Australia.

Ammagnostus serus nov. sp.

Fig. 16(1–8)

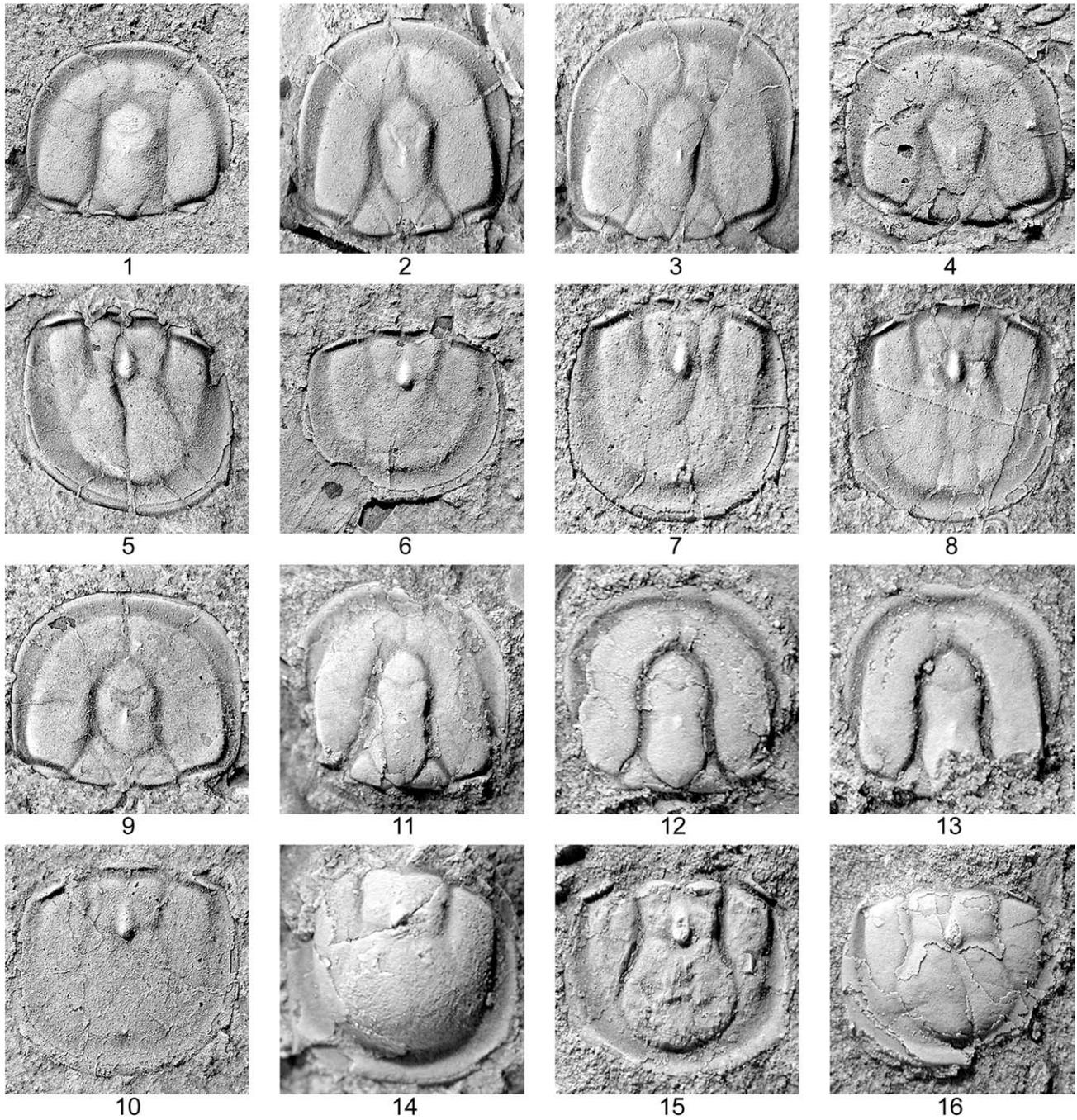


Fig. 15. **1–10.** *Pseudorhaptagnostus tumidus* (Sun, 1989). **1.** SNUP 735, cephalon, $\times 6$. **2.** SNUP 736, internal mould of cephalon, $\times 6$. **3.** SNUP 737, internal mould of cephalon, $\times 6$. **4.** SNUP 738, internal mould of cephalon, $\times 6$. **5.** SNUP 739, internal mould of pygidium, $\times 6$. **6.** SNUP 740, internal mould of pygidium, $\times 6$. **7.** SNUP 741, internal mould of pygidium, $\times 8$. **8.** SNUP 742, internal mould of pygidium, $\times 6$. **9.** SNUP 743, internal mold of cephalon, $\times 6$. **10.** SNUP 744, internal mold of pygidium, $\times 8$. **11–16.** *Pseudorhaptagnostus urceus* nov. sp. **11.** SNUP 745, cephalon, $\times 8$. **12.** SNUP 746, cephalon, $\times 16$. **13.** SNUP 747, cephalon, $\times 16$. **14.** SNUP 748, pygidium, $\times 12$. **15.** Holotype, SNUP 749, internal mould of pygidium, $\times 10$. **16.** SNUP 750, pygidium, $\times 8$.

Fig. 15. **1–10.** *Pseudorhaptagnostus tumidus* (Sun, 1989). **1.** SNUP 735, céphalon, $\times 6$. **2.** SNUP 736, moule interne du céphalon, $\times 6$. **3.** SNUP 737, moule interne du céphalon, $\times 6$. **4.** SNUP 738, moule interne du céphalon, $\times 6$. **5.** SNUP 739, moule interne du pygidium, $\times 6$. **6.** SNUP 740, moule interne du pygidium, $\times 6$. **7.** SNUP 741, moule interne du pygidium, $\times 8$. **8.** SNUP 742, moule interne du pygidium, $\times 6$. **9.** SNUP 743, moule interne du céphalon, $\times 6$. **10.** SNUP 744, moule interne du pygidium, $\times 8$. **11–16.** *Pseudorhaptagnostus urceus* nov. sp. **11.** SNUP 745, céphalon, $\times 8$. **12.** SNUP 746, céphalon, $\times 16$. **13.** SNUP 747, céphalon, $\times 16$. **14.** SNUP 748, pygidium, $\times 12$. **15.** Holotype, SNUP 749, moule interne du pygidium, $\times 10$. **16.** SNUP 750, pygidium, $\times 8$.

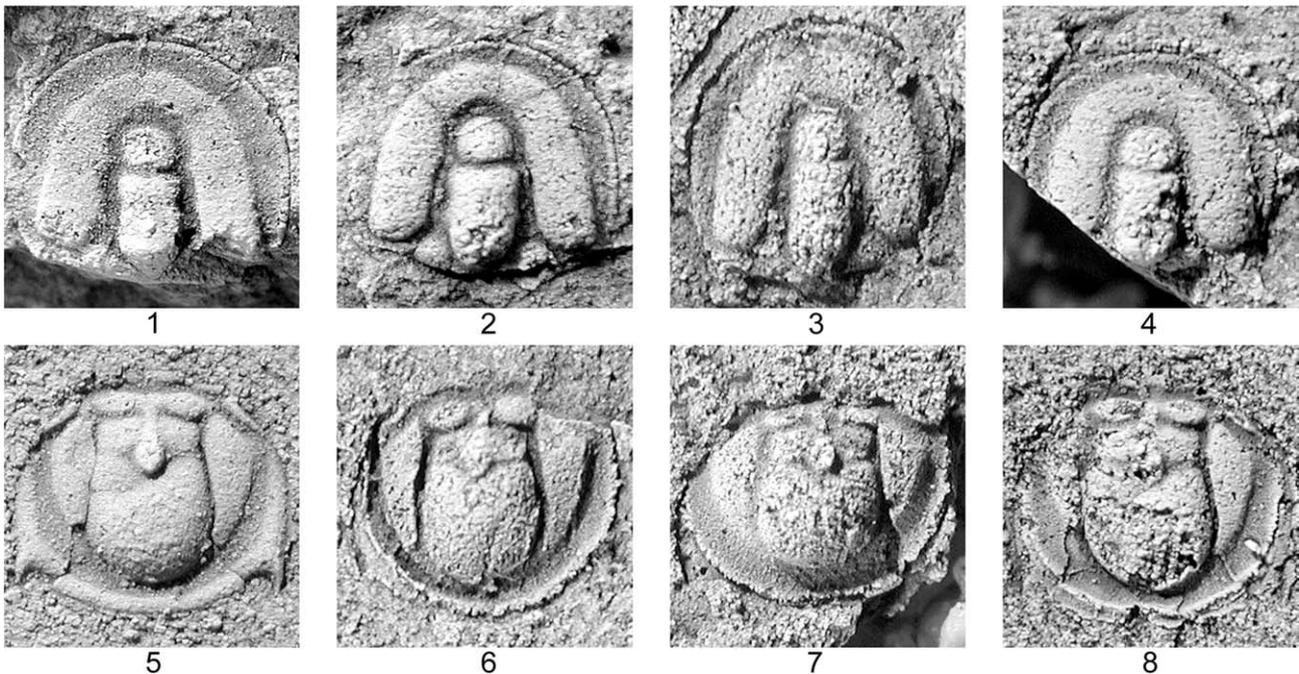


Fig. 16. *Ammagnostus serus* nov. sp. 1. SNUP 751, internal mold of cephalon, $\times 14$. 2. SNUP 752, internal mould of cephalon, $\times 16$. 3. SNUP 753, internal mould of cephalon, $\times 18$. 4. SNUP 754, internal mould of cephalon, $\times 18$. 5. SNUP 755, latex cast of external mould of pygidium, $\times 16$. 6. Holotype, SNUP 756, internal mould of pygidium, $\times 18$. 7. SNUP 757, internal mould of pygidium, $\times 16$. 8. SNUP 758, internal mould of pygidium, $\times 16$.

Fig. 16. *Ammagnostus serus* nov. sp. 1. SNUP 751, moule interne du céphalon, $\times 14$. 2. SNUP 752, moule interne du céphalon, $\times 16$. 3. SNUP 753, moule interne du céphalon, $\times 18$. 4. SNUP 754, moule interne du céphalon, $\times 18$. 5. SNUP 755, moulage d'un moule externe du pygidium, $\times 16$. 6. Holotype, SNUP 756, moule interne du pygidium, $\times 18$. 7. SNUP 757, moule interne du pygidium, $\times 16$. 8. SNUP 758, moule interne du pygidium, $\times 16$.

1962. *Homagnostus hisakoshii* - Kobayashi, (pars) p. 30, pl. 8, Figs. 11, 12.

Etymology: from *serus*, late; referring to the youngest occurrence of the genus.

Material, horizon and locality: Holotype pygidium, SNUP 756 (Fig. 16(6)); paratypes SNUP 751-755, 757-758; more than 20 specimens; *Agnostotes orientalis* Zone (middle Upper Cambrian) of the Machari Formation; units KG-19 to KG-26 of the Konggiri section, Yongwol.

Description: cephalon subcircular, wider than long, with narrow border and deliquiate border furrow. Acrolobe unstricted and smooth. Preglabellar median furrow absent. Glabella more or less parallel-sided, two-thirds of cephalic length; anteroglabella subcircular, narrower than posteroglabella; F3 transverse, gently concave forwards; anterolateral lobes weakly defined; posteroglabella 45% of cephalic length, with rounded glabellar culmination and a small node level with weakly impressed F2. Basal lobes of moderate size triangular.

Pygidium subcircular, wider than long, with narrow border and deliquiate border furrow. Acrolobe unstricted and non-scribulate. Axis pyriform, long, reaching to border furrow, about one-half of pygidial width; M1 and M2 rectangular; F1 and F2 interrupted by elongate axial node; posteroaxis longer (sag.) than anteroaxis, with a small terminal node. Posterolateral spines long.

Remarks: *Ammagnostus* has hitherto been known to occur in the upper Middle to lower Upper Cambrian strata (Shergold and Laurie, 1997; Peng and Robison, 2000; Sher-

gold et al., 2000). Consequently, *Ammagnostus serus* sp. nov. from the *Agnostotes orientalis* Zone (middle Upper Cambrian) represents the youngest species of the genus. It can be distinguished from other species of *Ammagnostus* by its subcircular shields, narrower glabella, and relatively longer posteroaxis. *Formosagnostus formosus* Ergaliev, 1980 has comparable pygidia, but its cranidia are distinct in having a well-defined preglabellar median furrow.

Genus *Kormagnostus* Resser, 1938

Type-species: *Kormagnostus simplex* Resser, 1938 from the Nolichucky Formation (Upper Cambrian), Tennessee, USA. Robison (1988) proposed that *K. simplex* be a junior synonym of *Agnostus seclusus* Walcott, 1884.

Kormagnostus inventus (Shergold, 1982)

Fig. 17(1–6)

1982. *Kormagnostella inventa* - Shergold, p. 25, pl. 6, Figs. 12–17.

2000. *Kormagnostus inventus* (Shergold) - Peng and Robison, p. 35.

Material, horizon and locality: more than 100 specimens; *Eochuangia hana* and *Agnostotes orientalis* zones (middle Upper Cambrian) of the Machari Formation; units KG-1 to KG-30 of the Konggiri section, Yongwol.

Remarks: the generic concept of *Kormagnostus* has been expanded to include forms lacking pygidial spines (Peng and Robison, 2000), by which *Kormagnostella* Romanenko in Romanenko and Romanenko, 1967 became a junior syn-

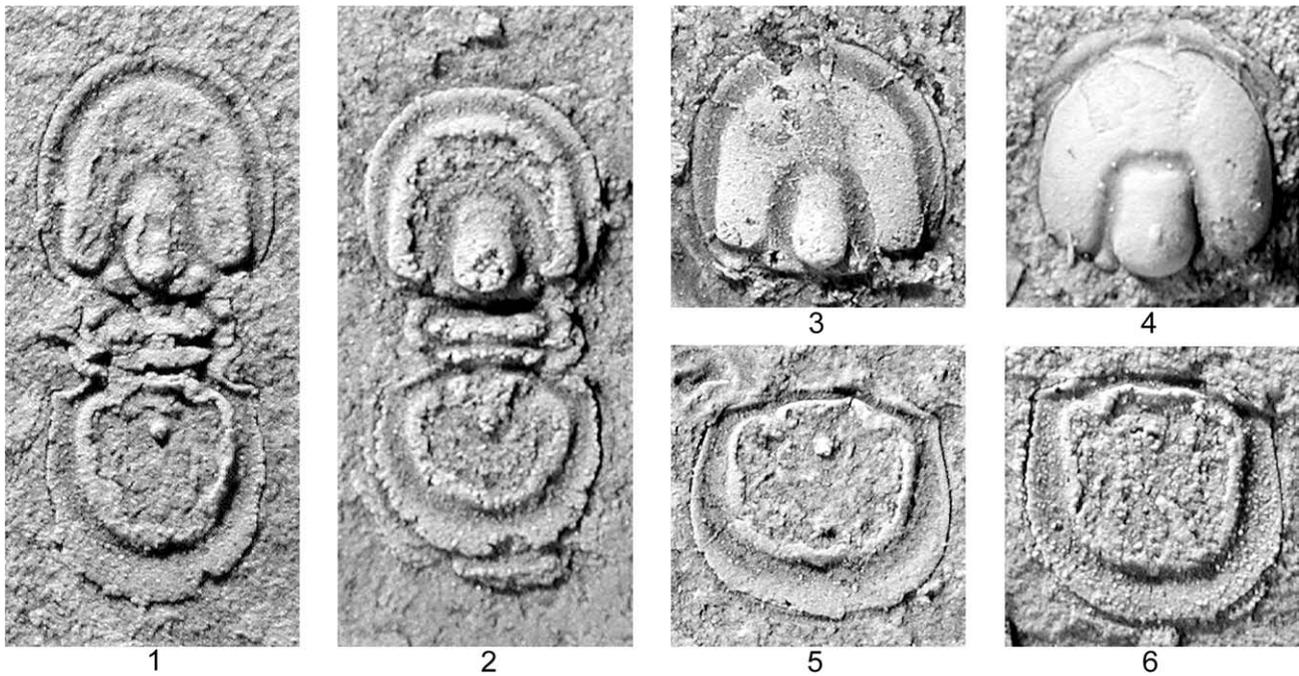


Fig. 17. *Kormagnostus inventus* (Shergold, 1982). 1. SNUP 759, moule interne d'une carapace, $\times 20$. 2. SNUP 760, moule interne d'une carapace, $\times 24$. 3. SNUP 761, moule interne du céphalon, $\times 18$. 4. SNUP 762, céphalon, $\times 20$. 5. SNUP 763, moule interne du pygidium, $\times 16$. 6. SNUP 764, moule interne du pygidium, $\times 16$.

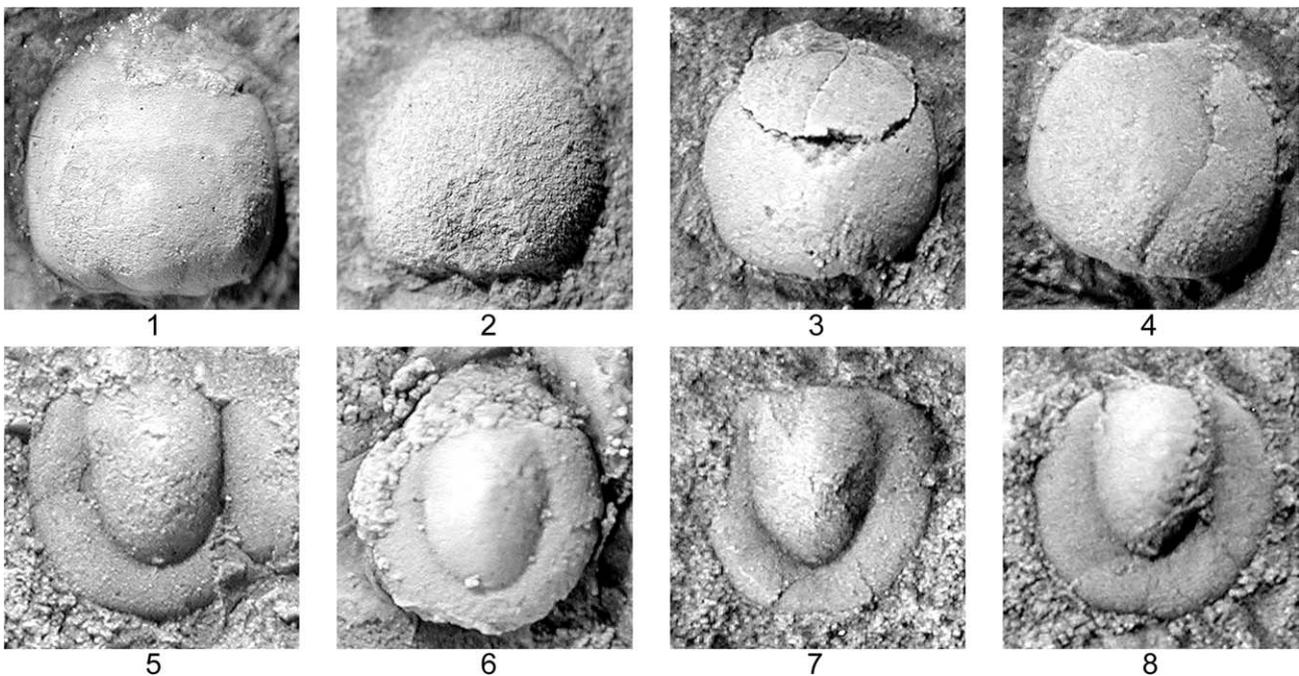


Fig. 18. *Lisogoragnostus minor* (Kobayashi, 1962). 1. SNUP 765, moule interne du céphalon, $\times 12$. 2. SNUP 766, moule interne du céphalon, $\times 8$. 3. SNUP 767, moule interne du céphalon, $\times 20$. 4. SNUP 768, moule interne du céphalon, $\times 20$. 5. SNUP 769, moulage d'un moule externe du pygidium, $\times 22$. 6. SNUP 770, moule interne du pygidium, $\times 22$. 7. SNUP 771, moule interne du pygidium, $\times 22$. 8. SNUP 772, moule interne du pygidium, $\times 24$.

onym of *Kormagnostus*. The specimens on hand conform well with *K. inventus* (Shergold, 1982), although the Korean specimens are relatively larger than the Australian ones and have more strongly deliquiate border furrows on pygidia. *Kormagnostus inventus* can be distinguished from *K. minutus* (Schrank, 1975) by its less forward-tapering posteroglabella, narrower pygidial axis, and strongly deliquiate border furrows. In addition, *K. inventus* has been reported from the stratigraphically higher horizons than *K. minutus*: i.e., *Kormagnostus minutus* occurs in the *Prochuangia* Zone of North China (Schrank, 1975) and the *Proagnostus bulbosus* to the *Linguagnostus reconditus* zones of South China (Peng and Robison, 2000), whereas *K. inventus* has been reported from the *Stigmatotoa diloma* Zone in Australia (Shergold, 1982) and the *Eochuangia hana* and *Agnostotes orientalis* zones of Korea.

Family PERONOPSIDAE Westergård, 1936

Genus *Lisogoragnostus* Rozova in Lisogor et al., 1988

Type-species: *Lisogoragnostus kalisae* Rozova in Lisogor et al., 1988 from the Middle Cambrian of Kazakhstan.

Remarks: the generic concept of *Lisogoragnostus* has been thoroughly reviewed by Peng and Robison (2000: p. 64).

Lisogoragnostus minor (Kobayashi, 1962)

Fig. 18(1–8)

1962. *Phalacromina minor* - Kobayashi, p. 28, pl. 9, Fig. 9.

1995. *Phalagnostus minor* (Kobayashi) - Lee and Choi, p. 19, pl. 2, Figs. 8–11.

Material, horizon and locality: ten specimens; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-35 to KG-56 of the Konggiri section, Yongwol.

Description: cephalon subcircular, totally effaced, non-scribulate; border absent. Pygidium subcircular and entirely effaced except for axial furrow; border absent. Axis strongly convex, one-half of pygidial width, and three-fourths of pygidial length; axial node faintly discernible about middle of axis and small terminal node on posteroaxial extremity.

Remarks: *Lisogoragnostus minor* is closely similar to *L. shergoldi* (Pratt, 1992) and *L. mictus* Peng and Robison, 2000, but can be distinguished from the latter two species by the lack of anterolateral border furrows in pygidia. Its occurrence in the *Pseudoyuepingia asaphoides* Zone documents the youngest example of *Lisogoragnostus*.

Family UNCERTAIN

Genus *Peratagnostus* Öpik, 1967

Type-species: *Peratagnostus nobilis* Öpik, 1967 from the Upper Cambrian of Queensland, Australia. Peng and Robison (2000) suggested that *Peratagnostus nobilis* be a junior synonym of *P. obsoletus* (Kobayashi, 1935).

Peratagnostus orientalis (Lazarenko, 1966)

Fig. 19(1–10)

1966. *Cyclopagnostus orientalis* - Lazarenko, p. 39, pl. 1, Figs. 1–10.

1968. *Peratagnostus hillardensis* - Palmer, p. 26, pl. 10, Figs. 17, 18, 23, 24.

1980. *Peratagnostus orientalis* (Lazarenko) - Shergold, p. 23.

1980. *Peratagnostus* sp. cf. *P. nobilis* Öpik - Shergold, p. 24, pl. 11, Fig. 12.

1989. *Peratagnostus distinctus* - Lu and Lin, p. 112, pl. 13, Figs. 2–4.

1989. *Peratagnostus zhejiangensis* - Lu and Lin, p. 13, Figs. 5, 6.

1992. *Peratagnostus hillardensis* Palmer - Peng, p. 22, Fig. 8T.

Material, horizon and locality: thirty specimens; *Pseudoyuepingia asaphoides* Zone (middle Upper Cambrian) of the Machari Formation; units KG-35 to KG-93 of the Konggiri section, Yongwol.

Description: cephalon with narrow border and nondeliquiate border furrow; glabella defined only in its posterior extremity; subtriangular basal lobes clearly defined by basal furrows; occipital band narrow and contiguous with basal lobes. Pygidium with broad border and nondeliquiate border furrow; axis relatively well-defined, gently tapering axial furrows, and occupying three fourths of pygidial length; posterolateral spines absent.

Remarks: it may not be easy to differentiate the species of *Peratagnostus* due to variable effacement observed among specimens assigned to *Peratagnostus*. Palmer (1968) originally differentiated *P. hillardensis* from other species of *Peratagnostus* by the presence of cephalic border and relatively short (sag.) pygidial axis. These features are clearly visible in *Peratagnostus orientalis* (Lazarenko, 1966), which thus has a priority over *P. hillardensis*. Similarly, *P. distinctus* Lu and Lin, 1989 and *P. zhejiangensis* Lu and Lin, 1989 from South China, both of which have a cephalic border, can be accommodated within the concept of *P. orientalis*. On the other hand, Pratt (1992) considered *P. hillardensis*, *P. distinctus*, and *P. zhejiangensis* to be junior synonyms of *P. nobilis*, while allowing a range of morphological variability observed from the collections of Canada. This procedure has been subsequently upheld by Peng and Robison (2000), who went further to suggest that *P. nobilis* be a junior synonym of *P. obsoletus* (Kobayashi, 1935).

However, we consider that the presence of a cephalic border has a taxonomic significance: i.e., *Peratagnostus orientalis* can be distinguished from *P. obsoletus* by its narrow cephalic border and more clearly impressed pygidial axial furrows. In addition, a scrutiny of stratigraphic occurrence of *Peratagnostus* reveals that forms assignable to *P. obsoletus* have been mainly reported from the upper Middle to lower Upper Cambrian strata (Korea – Lee and Choi, 1994, 1995; China – Egorova et al., 1963; Peng, 1992; Peng and Robison, 2000; Australia – Öpik, 1967; Kazakhstan – Ergaliev, 1980;

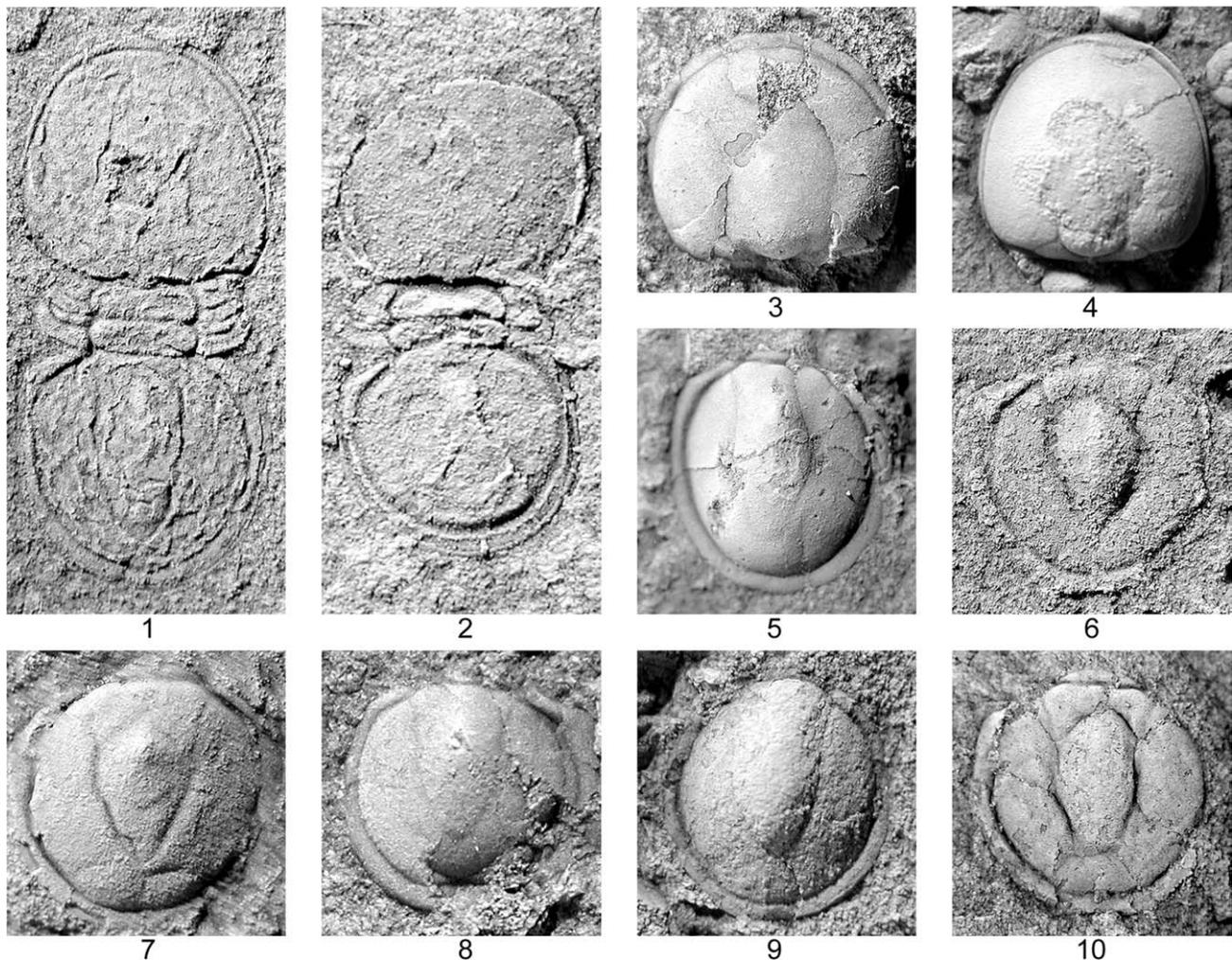


Fig. 19. *Peratagnostus orientalis* (Lazarenko, 1966). 1. SNUP 773, internal mold of carapace, $\times 10$. 2. SNUP 774, internal mold of carapace, $\times 16$. 3. SNUP 775, cephalon, $\times 8$. 4. SNUP 776, cephalon, $\times 14$. 5. SNUP 777, pygidium, $\times 8$. 6. SNUP 778, internal mould of pygidium, $\times 8$. 7. SNUP 779, pygidium, $\times 8$. 8. SNUP 780, pygidium, $\times 14$. 9. SNUP 781, pygidium, $\times 8$. 10. SNUP 782, pygidium, $\times 8$.

Fig. 19. *Peratagnostus orientalis* (Lazarenko, 1966). 1. SNUP 773, moule interne d'une carapace, $\times 10$. 2. SNUP 774, moule interne d'une carapace, $\times 16$. 3. SNUP 775, cephalon, $\times 8$. 4. SNUP 776, cephalon, $\times 14$. 5. SNUP 777, pygidium, $\times 8$. 6. SNUP 778, moule interne du pygidium, $\times 8$. 7. SNUP 779, pygidium, $\times 8$. 8. SNUP 780, pygidium, $\times 14$. 9. SNUP 781, pygidium, $\times 8$. 10. SNUP 782, pygidium, $\times 8$.

Canada – Hutchison, 1962; Pratt, 1992; and Europe – Westergård, 1947; Rushton, 1978, 1983), whereas *P. orientalis* is restricted within the middle Upper Cambrian sequence (Korea – this study; China – Lu and Lin, 1989; Peng, 1992; Australia – Shergold, 1980; Alaska – Palmer, 1968; and Siberia – Lazarenko, 1966).

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