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Source: Journal of Paleontology, 81(6):1454-1465. 2007.
Published By: The Paleontological Society
DOI: http://dx.doi.org/10.1666/06-040R.1
URL: http://www.bioone.org/doi/full/10.1666/06-040R.1

J. Paleont., 81(6), 2007, pp. 1454–1465

0022-3360/07/0081-1454$03.00

TRILOBITES OF THE *PSEUDOKOLDINIOIDIA* FAUNA (UPPERMOST CAMBRIAN) FROM THE TAEBAEK GROUP, TAEBAEKSAN BASIN, KOREA

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ABSTRACT—The *Pseudokoldinioidia* Fauna is a newly documented uppermost Cambrian trilobite assemblage from the Dongjeom Formation of the Taebaek Group, Taebaeksan Basin, Korea. It is characterized by low species diversity comprising six trilobite taxa: *Micragnostus chiushuensis*, *Koldinioidia typicalis*, leiostegiid genus and species indeterminate, *Pseudokoldinioidia perpetis*, *Onychopyge borealis*, and pilekiid genus and species indeterminate. Of these, special attention has been paid to *Pseudokoldinioidia perpetis*, which was originally assigned to *Missisquoia*, an index fossil for the uppermost Cambrian in Laurentia. *Pseudokoldinioidia* is restricted to eastern Asia, whereas *Missisquoia* is confined to Laurentia. The appearance of the *Pseudokoldinioidia* Fauna is interpreted as contemporaneous with the base of the '*Missisquoia*' *perpetis* Zone of North China, which in turn is correlated with the base of the *Missisquoia typicalis* Subzone of Laurentia. The associated *Koldinioidia* and *Onychopyge* make it possible to compare the *Pseudokoldinioidia* Fauna of Korea and North China with the latest Cambrian trilobite assemblages of South China, Australia, South America, and Mexico, and also suggests an interesting biogeographic connection among these areas in the latest Cambrian.

INTRODUCTION

TRILOBITES ARE among the most abundant fossil groups in Korea. They occur in the lower Paleozoic Joseon Supergroup of the Taebaeksan Basin, located in the central-eastern part of the Korean Peninsula (Fig. 1). The Joseon Supergroup ranges in age from late Early Cambrian to Middle Ordovician and is divided into five groups, based on different lithologic successions in different regions: i.e., the Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong Groups (Choi, 1998; Fig. 1.2). The stratigraphy of the Taebaek and Yeongwol Groups is well established thanks to relatively abundant occurrence of trilobites, whereas the other three groups are poorly fossiliferous and hence their internal stratigraphy is less completely resolved. The Taebaek Group is exposed in the eastern half of the Taebaeksan Basin and includes, in ascending order, the Jangsan/Myeonsan, Myobong, Daegi, Sesong, Hwajeol, Dongjeom, Dumugol, Makgol, Jigunsan, and Duwibong Formations (Kobayashi, 1966; Choi and Chough, 2005). The Cambrian–Ordovician boundary has been traditionally placed at the boundary between the Hwajeol and Dongjeom Formations (Kobayashi, 1966).

Choi et al. (2004a) presented a detailed account of the lithostratigraphy of the Taebaek Group in the southeastern corner of the Taebaeksan Basin, in which three trilobite assemblages from the lower part of the Dongjeom Formation were briefly mentioned. They were designated the *Mictosaukia*, *Missisquoia–Onychopyge*, and kainellid-dominated faunas. Of particular interest is the occurrence of *Missisquoia* Shaw, 1951, inasmuch as the genus *Missisquoia* was for some time employed as an index fossil for recognizing the base of the Ordovician in North America (Winston and Nicholls, 1967; Stitt, 1971, 1977; Loch et al., 1993; Ross et al., 1997). However, the recently ratified global standard stratotype section and point (GSSP) for the Cambrian–Ordovician boundary was set at a slightly younger level at the lowest occurrence of the conodont *Iapetognathus fluctivagus* Nicoll et al., 1999 (Cooper et al., 2001), thereby placing the *Missisquoia* Zone in the uppermost Cambrian (Miller et al., 2003). Recent reevaluation of the *Missisquoia–Onychopyge* fauna reveals that the specimens referred to *Missisquoia* are morphologically distinct from the Laurentian *Missisquoia*, and they are reassigned herein to another missisquoiid genus, *Pseudokoldinioidia* Endo, 1944, which is known from Liaoning, North China. Accordingly, the *Missisquoia–Onychopyge* fauna is herein renamed as the *Pseudokoldinioidia* Fauna. Despite the generic reassignment, the appearance of the *Pseudokoldinioidia* Fauna appears correlative with the base of the '*Missisquoia*' *perpetis* Zone of North China and the *Missisquoia typicalis* Subzone of the *Missisquoia* Zone in Laurentia. The objectives of this paper are to describe the trilobites of the *Pseudokoldinioidia* Fauna from the Dongjeom Formation of Korea and to discuss their stratigraphic and paleogeographic implications.

GEOLOGY AND STRATIGRAPHY

The Taebaeksan Basin occupies the central-eastern part of the Korean Peninsula (Fig. 1.1) and comprises mainly the Cambrian–Ordovician Joseon Supergroup and the Carboniferous–Permian Pyeongan Supergroup. The Joseon Supergroup rests unconformably on Precambrian granitic gneiss and metasedimentary rocks and is in turn overlain unconformably by post-Ordovician sedimentary rocks. The lower Paleozoic sedimentary rocks are shallow marine in origin and consist of limestone, sandstone, and shale. In the early Paleozoic, the Taebaeksan Basin was a shallow-marine, mixed siliciclastic-carbonate system with progressively greater depth to the west (Chough et al., 2000). This siliciclastic-carbonate system persisted throughout the Cambrian, but a high rate of carbonate accumulation in the Yeongwol area during latest Cambrian time resulted in development of a widespread carbonate platform across the Taebaeksan Basin in the Early Ordovician. Sedimentological features reveal that the carbonate platform in the Ordovician was characterized by low relief with shoals, lagoons, and tidal flats (Choi et al., 2001). Marine sedimentation ceased over the whole Taebaeksan Basin in the Late Ordovician, and most of the basin remained emergent through the mid-Paleozoic until a marine transgression in the Late Carboniferous.

The Joseon Supergroup is divided into the Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong Groups (Choi, 1998). The Taebaek Group was deposited in the eastern half of the Taebaeksan Basin (Fig. 1.2) and comprises, in ascending order, the Jangsan/Myeonsan, Myobong, Daegi, Sesong, Hwajeol, Dongjeom, Dumugol, Makgol, Jigunsan, and Duwibong Formations (Kobayashi, 1966; Choi et al., 2004a). The Dongjeom Formation, from which the present material was recovered, consists largely of light- to dark-gray sandstone with scattered shale and limestone layers. In the southeastern part of the Taebaeksan Basin, the Dongjeom Formation is divided into three informal members (Fig. 2). The lower member is dominated by thickly-laminated fine-grained sandstone intercalated with thinly-laminated or normally graded fine-grained sandstone layers. The middle member is composed largely of coarse-grained massive or cross-stratified sandstone. The upper member is characterized by fine- to medium-grained sandstone intermingled with mud layers and massive sandstone with intercalation of thin carbonate facies.

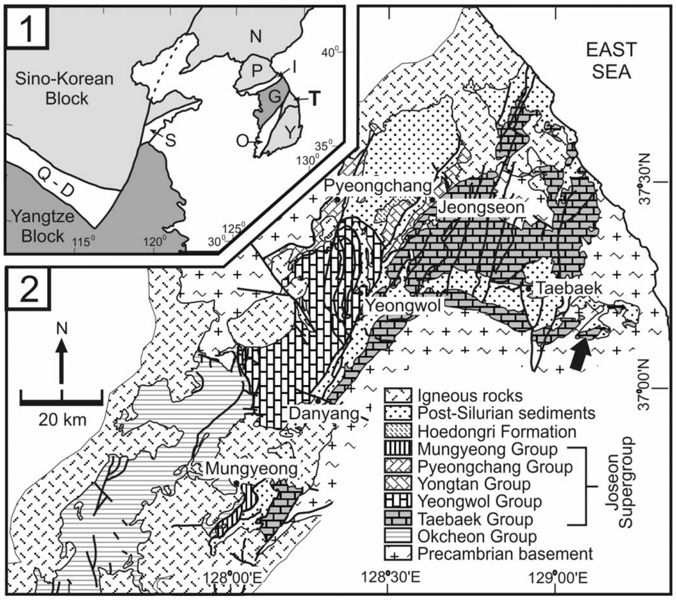

FIGURE *1*—Index maps. *1*, Tectonic map of the Korean peninsula and surrounding area showing the location of the Taebaeksan Basin. Q-D = Qinling-Dabie Belt, S = Sulu Belt, N = Nangnim Massif, P = Pyeongnam Basin, I = Imjingang Belt, G = Gyeonggi Massif, O = Okcheon Belt, T = Taebaeksan Basin, Y = Yeongnam Massif; *2*, Simplified geologic map showing the distribution of the lower Paleozoic Joseon Supergroup in the Taebaeksan Basin. The fossil locality of the *Pseudokoldinioidia* Fanua is indicated by a solid arrow near the eastern edge of the map. Modified from Choi et al. (2001).

The Dongjeom Formation historically had yielded very few fossils. The *Pseudokainella* Zone was the only biozone established on a single specimen of *Pseudokainella iwayai* Kobayashi, 1953 in the lower part of the formation. This occurrence was a basis for placing the Cambrian-Ordovician boundary within the Taebaek Group at the base of the Dongjeom Formation (Kobayashi, 1966). Recent detailed paleontological investigations on the Taebaek Group have refined the biostratigraphy across the Cambrian–Ordovician boundary interval (Choi et al., 2003, 2004a). These studies recognized three trilobite assemblages across the boundary between the Hwajeol and Dongjeom Formations: in ascending order, *Mictosaukia*, *Missisquoia–Onychopyge*, and kainellid-dominated faunas (Choi et al., 2004a). The latter two faunas are renamed herein as the *Pseudokoldinioidia* and *Richardsonella* faunas, respectively (Fig. 2), to accommodate recent taxonomic revisions. Although these trilobite faunas have yet to be studied in detail, they generally indicate a close affinity with Upper Cambrian faunas elsewhere. The *Mictosaukia* Fauna has many taxa in common with the *Mictosaukia–Fatocephalus* fauna of North China (Zhou and Zhang, 1985; Duan et al., 1986; Chen et al., 1988), South China (Peng, 1984), and Assemblage 1 of the Pacoota Sandstone, Australia (Shergold, 1991). The *Pseudokoldinioidia* Fauna is equivalent in part with the *Missisquoia* Zone of North China (Zhou and Zhang, 1985; Duan et al., 1986) and North America (Stitt, 1977; Ross et al., 1997). The *Richardsonella* Fauna is most likely contemporaneous with the *Richardsonella–Platypeltoides* Zone (uppermost Cambrian) of North China (Chen et al., 1988).

FOSSIL LOCALITY AND MATERIAL

All of the trilobites considered in this study were collected from the lowermost part of the Dongjeom Formation, exposed along a

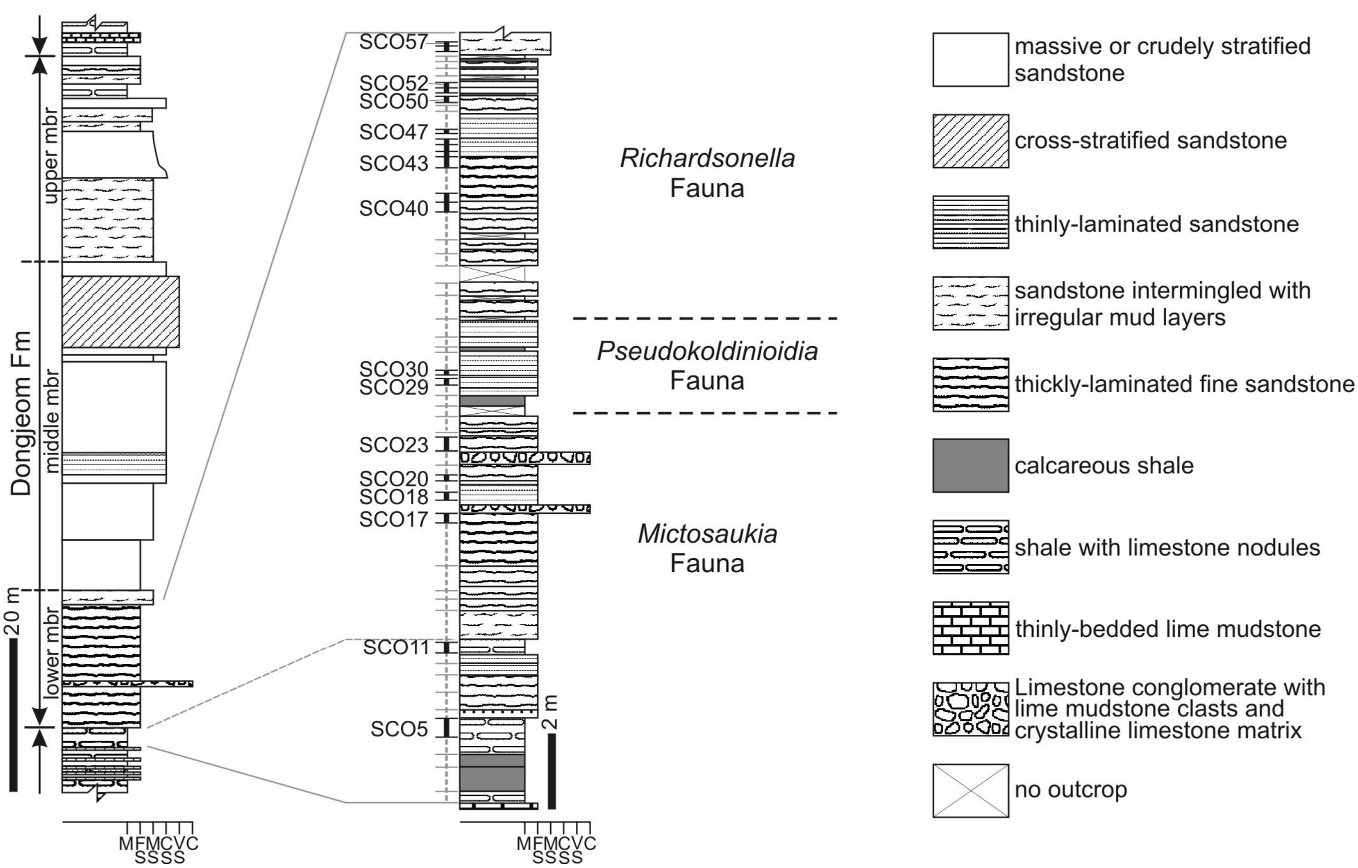

FIGURE *2*—Stratigraphic columns of the Dongjeom Formation showing lithology, sampling units, and trilobite faunas. Solid bars with unit number in the right column indicate the intervals from which trilobite specimens are collected.

mountain trail in the southeastern corner of the Taebaeksan Basin (Fig. 1.2). The mountain trail, called the Seokgaejae section, exposes a nearly complete succession (ca. 1,100 m thick) of the Taebaek Group (Choi et al., 2004a). The Hwajeol and Dongjeom Formations are well exposed and yield relatively well-preserved invertebrate fossils, including trilobites, brachiopods, and echinoderms (Lee et al., 2005). The Hwajeol Formation (ca. 50 m thick) is composed largely of alternating limestone and shale, while the Dongjeom Formation (ca. 90 m thick) consists predominantly of sandstone (Fig. 2).

Trilobites are relatively abundant in the transitional interval (ca. 20 m thick) across the boundary between the Hwajeol and Dongjeom Formations, which occupies the middle portion of the Seokgaejae section with geographic coordinates of 129°08′39″E and 37°04′19″N. The transitional interval shows gradual change from carbonate-dominated facies to siliciclastic-dominated facies. This interval was divided into 57 units for lithologic description and fossil collection. The units are variable in thickness, ranging from a few cm thick to ca. 50 cm thick, and are designated from bottom to top as SCO1, SCO2, SCO3, ... The SCO denotes the Cambrian–Ordovician boundary interval at the Seokgaejae section. Trilobites were collected from 20 units, while other units are unfossiliferous or contain brachiopods or echinoderm debris only. The *Pseudokoldinioidia* Fauna was recovered from two units, SCO29 and SCO30, which together span ca. 50 cm (Fig. 2) of thinly-laminated calcareous fine-grained sandstone. More than 130 trilobite specimens have been recovered as silicified sclerites from severely weathered rock samples. The collection includes cranidia, pygidia, librigenae, hypostomes, and thoracic segments. These trilobites are associated with isolated plates of rhombiferans, orthid brachiopods, and sponge spicules.

GEOLOGIC AGE AND CORRELATION

The *Pseudokoldinioidia* Fauna is characterized by relatively low species diversity. It includes one agnostoid and five polymerid trilobites: i.e., *Micragnostus chiushuensis* Kobayashi, 1931 (26.4%), *Koldinioidia typicalis* Kobayashi, 1931 (8.3%), leiostegiid gen. and sp. indet. (16.7%), *Pseudokoldinioidia perpetis* (Zhou and Zhang, 1985) (25.0%), *Onychopyge borealis* Zhou and Zhang, 1978 (22.2%), and pilekiid gen. and sp. indet. (1.4%).

Micragnostus chiushuensis is a long-ranging species in Upper Cambrian to Tremadocian strata. It was known largely from China, but also had been reported from Iran (Peng et al., 1999), North America (Dean, 1989; Westrop, 1995), and Argentina (Tortello et al., 1999; Tortello and Rao, 2000). The genus *Koldinioidia* Kobayashi, 1931 is widely distributed, having been reported from the Upper Cambrian to Tremadocian of Korea (Sohn and Choi, 2002), North China (Zhou and Zhang, 1985; Duan et al., 1986; Qian, 1986; Zhang and Jell, 1987; Zhu and Wittke, 1989), South China (Lu and Lin, 1984; Lu and Zhou, 1990; Peng, 1992), Australia (Shergold, 1975, 1991), Iran (Peng et al., 1999), Kazakhstan (Ergaliev, 1983), Mexico (Robison and Pantoja-Alor, 1968), and Bolivia (Přivyl and Vaněk, 1980). *Koldinioidia typicalis*, however, is more restricted within the uppermost Cambrian (*Mictosaukia–Fatocephalus* to *Richardsonella–Platypeltoides* Zones) of North China (Zhou and Zhang, 1985; Duan et al., 1986; Zhu and Wittke, 1989), with a putative occurrence from slightly older strata (*Archaeuloma taoyuanensis–Leiagnostus* cf. *bexelli* to *Mictosaukia striata–Fatocephalus* Assemblage Zones) in South China (Peng, 1984).

Onychopyge Harrington, 1938 was originally erected from the Tremadocian of Argentina (Harrington and Leanza, 1957) and subsequently was documented from the uppermost Cambrian of Australia (Shergold, 1975) and North China (Zhou and Zhang, 1978; Lu et al., 1984; Qian, 1986), and the Tremadocian of Mexico (Robison and Pantoja-Alor, 1968), Bolivia (Suárez-Soruco, 1975; Přivyl and Vaněk, 1980), South China (Peng, 1984, 1990), and Tasmania (Jell, 1985). However, the new GSSP for the Cambrian–Ordovician boundary (Cooper et al., 2001) redefines some previous Tremadocian occurrences for *Onychopyge* as uppermost Cambrian in age. One example is the occurrence of *O. riojana* Harrington, 1938 from the lower part of the *Parabolina frequens argentina* Zone of Argentina (Tortello and Esteban, 1999). In any event, *Onychopyge* has a relatively long stratigraphic range from Upper Cambrian to lower Tremadocian. The oldest species, *O. primitiva* Lu et al., 1984 from Nei Mongol of North China, was reported from the *Sinoeremoceras* Assemblage (upper Fengshanian) of North China. Younger species include *O. tricuspis* Lu et al., 1984 and *O. peculiaris* Lu et al., 1984 from Nei Mongol, *O. borealis* from the '*Missisquoia*' *perpetis* to *Richardsonella–Troedssonia* Zones of North China (Zhou and Zhang, 1985; Qian, 1986; Duan et al., 1986), and *O. assula* Shergold, 1975 from the *Cordylodus proavus* Zone of Australia. The early Tremadocian representatives are *O. austrina* Peng, 1984 from the *Hysterolenus–Onychopyge* Zone of South China (Peng, 1990), *O. parkerae* Jell, 1985 from Tasmania, *O.* sp. from New Zealand (Wright et al., 1994), several species of *Onychopyge* from Argentina (Harrington, 1938; Harrington and Leanza, 1957), *O. branisi* Suárez-Soruco, 1975 and *O. tarijensis* Přivyl and Vaněk, 1980 from Bolivia, and *O. sculptura* Robison and Pantoja-Alor, 1968 from Mexico. The stratigraphic and geographic occurrences of *Onychopyge* suggest that the genus may have originated from Nei Mongol of North China in Late Cambrian times, subsequently migrated into other regions of Gondwana, and eventually became extinct during the Tremadocian.

Pseudokoldinioidia is a missisquoiid genus endemic to China and Korea. The oldest species are *P. granulosa* Endo, 1944, *P. taiziheensis* Duan et al., 1986, and *P. hemicycla* Duan et al., 2005, all from the *Ptychaspis–Tsinania* Zone (early Fengshanian) of Liaoning, North China. Uppermost Cambrian species includes *P. perpetis* and *P. funingensis* Duan et al., 2005 from the *Mictosaukia–Fatocephalus* and '*Missisquoia*' *perpetis* Zones of North China and *P. expansa* Lu and Zhou, 1990 from the *Mictosaukia guizhouensis* Zone of Guizhou Province, South China. *Pseudokoldinioidia perpetis* has been most frequently reported from the Sino-Korean Block, including Nei Mongol, Shanxi, Hebei, Shandong, Liaoning, and Jilin Provinces of China and Korea. The sole Ordovician occurrence of the genus is *P. encrinuroides* Lu and Zhou, 1990 from the lower Tremadocian of Guizhou Province, South China.

In summary, closely comparable faunas to the *Pseudokoldinioidia* Fauna are widespread in North China (Zhou and Zhang, 1985; Duan et al., 1986; Qian, 1986). The co-occurrence of *Pseudokoldinioidia perpetis* and *Onychopyge borealis* from the '*Missisquoia*' *perpetis* Assemblage Zone (Zhou and Zhang, 1985; Qian, 1986; Chen et al., 1988) and the lower part of the *Richardsonella–Troedssonia* Zone (equivalent to the '*Missisquoia*' *perpetis* Assemblage Zone) of North China (Duan et al., 1986) clearly indicate that the *Pseudokoldinioidia* Fauna of Korea is contemporaneous at least in part with those units in North China (Fig. 3).

It is not easy to correlate the *Pseudokoldinioidia* Fauna with those outside of the Sino-Korean Block, as its constituent species have rarely been found in other parts of the world. The occurrences of *Koldinioidia*, *Pseudokoldinioidia*, and *Onychopyge* in South China allow only imprecise correlation with the *Pseudokoldinioidia* Fauna (Fig. 3). Peng (1984) recovered *Koldinioidia* cf. *typicalis* from the *Archaeuloma taoyuanensis–Leiagnostus* cf. *bexelli* to *Mictosaukia striata–Fatocephalus* Assemblage Zones and *Onychopyge austrina* from the *Hysterolenus–Onychopyge* Assemblage Zone of Hunan Province. Therefore the *Pseudokoldinioidia* Fauna can be correlated with part of the interval between the *Archaeuloma taoyuanensis–Leiagnostus* cf. *bexelli* and *Hysterolenus–Onychopyge* Assemblage Zones of South China

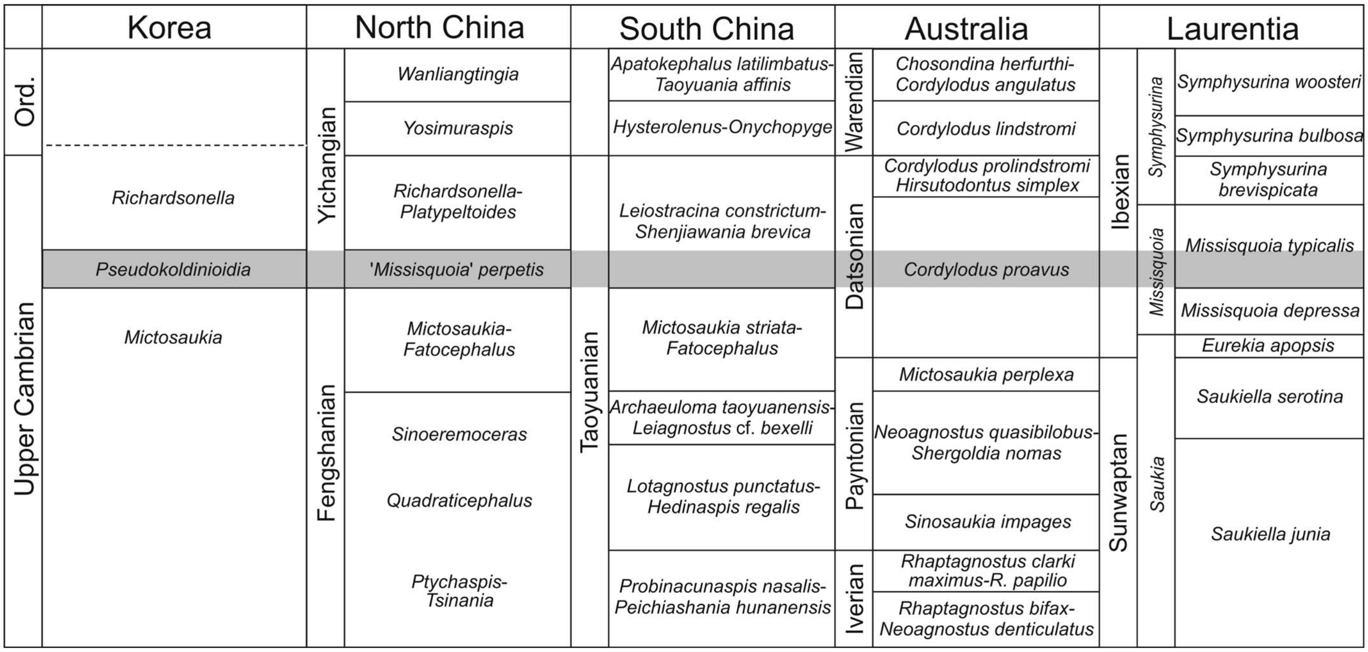

FIGURE 3—Stratigraphic correlation of the *Pseudokoldinioidia* Fauna of Korea with coeval zones of other parts of the world. Modified from Shergold (1988), Geyer and Shergold (2000), Choi et al. (2003), and Miller et al. (2003).

(Fig. 3). Lu and Zhou (1990) recorded *Pseudokoldinioidia expansa* and *P. encrinuroides* from the *Mictosaukia guizhouensis* and overlying *Troedssonia wimani–Pseudokoldinioidia expansa* Assemblage Zones of Guizhou Province, both of which are assigned to the uppermost Cambrian to lower Tremadocian.

Trilobite-based correlation with Australia is also difficult, even though *Koldinioidia* and *Onychopyge* have been documented there. *Koldinioidia* cf. *cylindrica* (Shergold, 1972) and *K. payntonensis* Shergold, 1975 from the Iverian and Payntonian Stages seem to represent early forms of the genus, while *Onychopyge assula* was recovered from the uppermost Cambrian *Cordylodus proavus* Zone (Datsonian) of Queensland (Shergold, 1975) and is therefore closer in age to the *Pseudokoldinioidia* Fauna. *Onychopyge parkerae* from Tasmania is associated with a fauna of Tremadocian affinity (Jell, 1985). Elsewhere, both *Koldinioidia* and *Onychopyge* occur in the strata across the Cambrian–Ordovician boundary interval in Mexico (Robison and Pantoja-Alor, 1968) and South America (Harrington and Leanza, 1957; Přivyl and Vaněk, 1980). These co-occurrences of *Koldinioidia* and *Onychopyge* suggest that the Sino-Korean Block had a biogeographic link with South America and Mexico in the early Paleozoic, even though they were located far away from each other.

In the past, '*Missisquoia*' in North China (Zhou and Zhang, 1985; Qian, 1986; Chen et al., 1988) was considered to be a good biostratigraphic marker for correlation with Laurentia: i.e., the '*Missisquoia*' *perpetis* Zone was correlated with the *Missisquoia typicalis* Subzone of Laurentia (Shergold, 1988; Chen et al., 1988). However, '*Missisquoia*' in North China is morphologically distinct from the Laurentian *Missisquoia* (see below) and therefore its biostratigraphic significance should be reassessed. Fortunately, detailed information on the trilobite and conodont assemblages across the Cambrian–Ordovician boundary intervals is available both in North China (Zhou and Zhang, 1985; Duan et al., 1986; Qian, 1986; Chen et al., 1988) and Laurentia (Ross et al., 1997; Miller et al., 2003). Chen et al. (1988) equated the '*Missisquoia*' *perpetis* Zone of North China with the middle part of the *Cordylodus proavus* Zone, based on the occurrence of *Fryxellodontus inornatus* Miller, 1969. Similarly the bases of the *Missisquoia typicalis* Subzone of the *Missisquoia* Zone and the *Fryxellodontus inornatus* conodont Subzone of the *Cordylodus proavus* Zone correspond precisely in Laurentia (Ross et al., 1997; Miller et al., 2003). Therefore, the revised taxonomy of the missisquoiids in eastern Asia does not alter the previous biostratigraphic framework. In short, the base of the '*Missisquoia*' *perpetis* Zone of North China, equivalent to the lowest occurrence of the *Pseudokoldinioidia* Fauna of Korea, is still confidently correlated with the base of the *Missisquoia typicalis* Subzone of Laurentia (Fig. 3).

SYSTEMATIC PALEONTOLOGY

The morphological terms generally follow Whittington and Kelly (1997), but the term 'glabella', as used here, excludes the occipital ring. Descriptive terms for glabellar furrows and facial sutures are adopted from Henningsmoen (1957). All of the specimens described in this paper are reposited in the paleontological collections of Seoul National University, Korea, under the registered SNUP numbers.

Order AGNOSTIDA Salter, 1864
Suborder AGNOSTINA Salter, 1864
Family AGNOSTIDAE M'Coy, 1849
Subfamily AGNOSTINAE M'Coy, 1849
Genus MICRAGNOSTUS Howell, 1935

Type species.—*Agnostus calvus* Lake, 1906 from the Tremadocian of Wales (by original designation).

Discussion.—Since Fortey (1980) proposed that *Micragnostus* can be distinguished from *Geragnostus* Howell, 1935 by its transverse and straight F3 and posteriorly located glabellar node, a number of Upper Cambrian and Lower Ordovician agnostids were transferred to *Micragnostus* (Ludvigsen et al., 1989; Sun, 1989; Nielsen, 1997). Nonetheless, the generic concept of *Micragnostus* does not appear to be resolved in relation to closely comparable genera such as *Homagnostus* Howell, 1935, *Oncagnostus* Whitehouse, 1936, *Trilobagnostus* Harrington, 1938, and *Innitagnostus* Öpik, 1967 (Shergold and Sdzuy, 1984; Ludvigsen et al., 1989; Sun, 1989; Shergold et al., 1990; Pratt, 1992; Nielsen, 1997; Peng et al., 1999; Choi et al., 2004b). Among others, *Micragnostus* may be distinguishable from *Homagnostus* by the absence of median preglabellar furrow and comparatively shorter pygidial axis (Robison and Pantoja-Alor, 1968; Fortey, 1980).

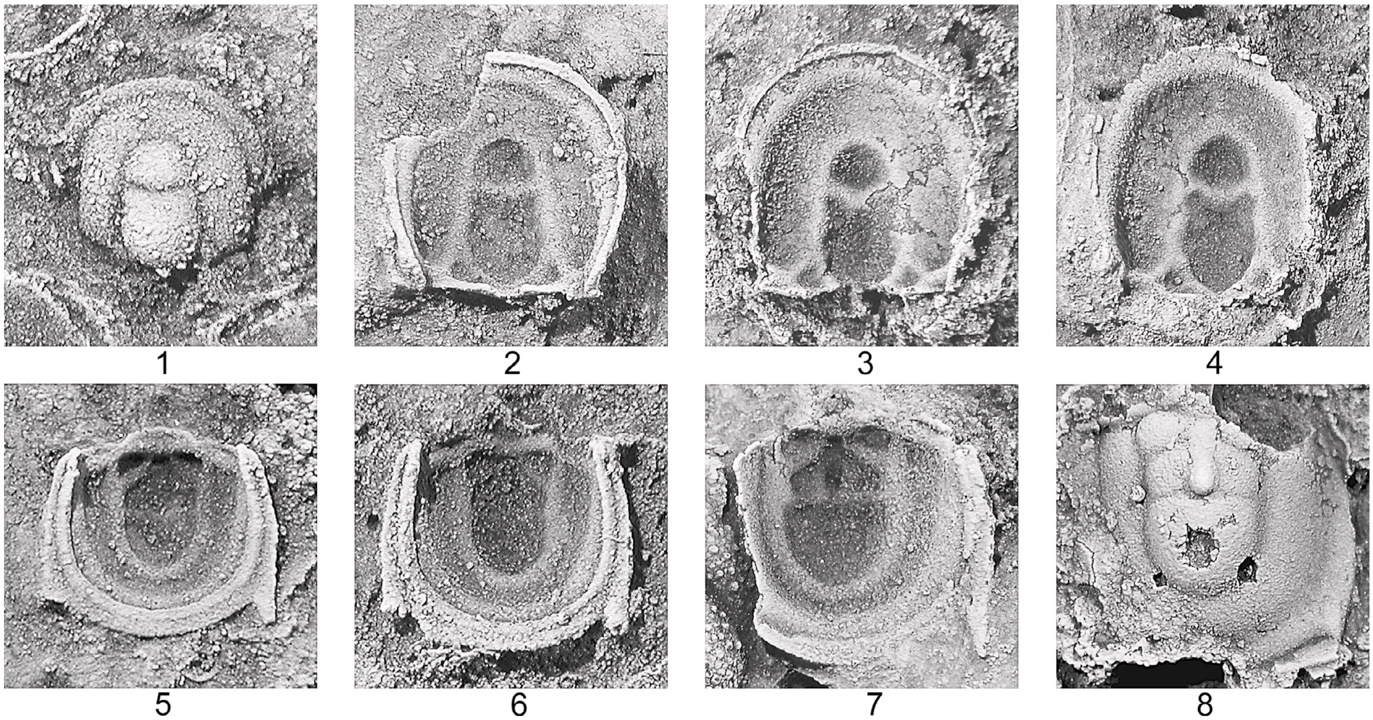

FIGURE 4—*Micragnostus chiushuensis* (Kobayashi, 1931) from the *Pseudokoldinioidia* Fauna, Dongjeom Formation, Seokgaejae section, Taebaeksan Basin, Korea. *1*, SNUP3026, incomplete small cephalon, ×12; *2*, SNUP3009, ventral surface of incomplete cephalon, ×11; *3*, SNUP3027, incomplete cephalon showing backwardly bent transglabellar furrow and faint F2, ×9; *4*, SNUP3028, incomplete large cephalon showing faint F2 and vestige of median preglabellar furrow, ×7; *5*, SNUP3029, ventral surface of nearly complete pygidium with narrow axis and broad border and doublure, ×14; *6*, SNUP3030, ventral surface of incomplete pygidium, ×14; *7*, SNUP3031, ventral surface of partly broken pygidium with relatively wide axis and long spine, ×9; *8*, SNUP3032, large pygidium with narrow axis, ×9.

MICRAGNOSTUS CHIUSHUENSIS (Kobayashi, 1931)
Figure 4

Agnostus chiushuensis KOBAYASHI, 1931, p. 173, pl. 22, figs. 1–5; ENDO *in* ENDO AND RESSER, 1937, p. 315, pl. 70, fig. 2; pl. 73, figs. 7–9.
Geragnostus spinosus CHIEN, 1961, p. 93, pl. 1, figs. 8–9.
Geragnostus intermedius PALMER, 1968, p. 24, pl. 12, figs. 1–2; ROBISON AND PANTOJA-ALOR, 1968, p. 776, pl. 97, figs. 1–10; STITT, 1977, p. 36, pl. 1, fig. 1.
Geragnostus (*Micragnostus*) *chiushuensis* (Kobayashi). ZHOU AND ZHANG, 1978, p. 6, pl. 1, figs. 1–2; LU AND LIN, 1984, p. 48, pl. 1, figs. 4–8; PENG, 1984, p. 315, pl. 1, figs. 3–7; ZHOU AND ZHANG, 1985, p. 65, pl. 1, figs. 6–9; pl. 3, figs. 8–12; pl. 13, figs. 1–4; pl. 15, figs. 1–5; pl. 18, figs. 1–2; pl. 20, figs. 1–4; pl. 22, figs. 16–18; pl. 17, figs. 8–14; QIAN, 1985a, p. 65, pl. 9, figs. 5–7, 12b; pl. 19, fig. 3b; pl. 20, fig. 5a; DUAN, AN, AND ZHAO, 1986, p. 30, pl. 1, figs. 1–3, 4a, 5–6; pl. 8, fig. 20b; pl. 21, fig. 3b; pl. 22, fig. 7b; pl. 26, fig. 3b; DEAN, 1989, p. 15, pl. 1, figs. 2–11; ZHU AND WITTKE, 1989, p. 209, pl. 1, figs. 3–6.
Geragnostus (*Micragnostus*) sp. ZHOU AND ZHANG, 1978, p. 7, pl. 1, fig. 3.
Homagnostus zhuangliensis QIAN, 1985b, p. 138, pl. 1, figs. 1, 10–11.
Micragnostus intermedius (Palmer). PRATT, 1988, p. 1597, figs. 8l–r.
Micragnostus chiushuensis (Kobayashi). SUN, 1989, p. 72, pl. 2, figs. 1–8; WESTROP, 1995, p. 15, pl. 1, figs. 14–16; RAO AND TORTELLO, 1998, p. 38, figs. 4a–f; PENG, GEYER, AND HAMDI, 1999, p. 12, fig. 3.
Geragnostus (*Micragnostus*) *elongatus* CHIEN. LU AND ZHOU, 1990, p. 12, pl. 1, figs. 1–3.
Trilobagnostus chiushuensis (Kobayashi). TORTELLO, RÁBANO, RAO, AND ACEÑOLAZA, 1999, p. 9. figs. 3a–c; TORTELLO AND RAO, 2000, p. 69, figs. 3a–c.

Material examined.—Fourteen cephala and 19 pygidia; all but three cephala and three pygidia show ventral surface.

Occurrence.—*Pseudokoldinioidia* Fauna; Unit SCO29; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—*Micragnostus chiushuensis* has been known to display a range of morphological variations in degree of glabellar tapering, length and width ratio of pygidial axis, and deliquiateness of border furrows (Lu and Lin, 1984; Peng, 1984; Zhou and Zhang, 1985; Peng et al., 1999). Some specimens even show the vestige of a median preglabellar furrow (Palmer, 1968; Robison and Pantoja-Alor, 1968; Peng et al., 1999). Such a vestige was interpreted to indicate gradual loss of the furrow in transitional populations derived from *Homagnostus* (Robison and Pantoja-Alor, 1968).

The broad species concept of *M. chiushuensis* is clearly reflected in the synonymy presented by Peng et al. (1999), which is generally accepted herein. However, some of the species in the synonym list of Peng et al. (1999) should be excluded from *M. chiushuensis*: *Homagnostus comptus* Palmer, 1962 from the *Glyptagnostus reticulatus* Zone of Nevada by wider cranidium and laterally inflated lateral glabellar lobes; *Geragnostus* (*Micragnostus*) *mutabilis* Ergaliev, 1980 from the uppermost Cambrian of Kazakhstan by small and triangular anterior glabellar lobe; *Connagnostus lubris* Qian, 1994 from the *Chuangia* Zone (lower Upper Cambrian) of North China by considerably broad pygidial axis; and *M. intermedius* (Palmer, 1968) by Ludvigsen et al. (1989) from the Sunwaptan of Newfoundland by the presence of distinct median preglabellar furrow. On the other hand, *Geragnostus spinosus* Chien, 1961 and *Geragnostus* (*Micragnostus*) *elongatus* Chien, 1961 in Lu and Zhou (1990) from the uppermost Cambrian of Guizhou, South China are better assignable to *M. chiushuensis*.

Order PTYCHOPARIIDA Swinnerton, 1915
Suborder PTYCHOPARIINA Richter, 1932
Family SHUMARDIIDAE Lake, 1907
Genus KOLDINIOIDIA Kobayashi, 1931

Type species.—*Koldinioidia typicalis* Kobayashi, 1931 from the Upper Cambrian of Liaoning Province, North China (by original designation).

Diagnosis.—A shumardiid with parallel-sided or gently tapering glabella; anterolateral lobes absent to weakly developed; preglabellar furrow effaced or well-defined.

Discussion.—The holotype of *Koldinioidia typicalis* from Liaoning, North China was poorly preserved (Kobayashi, 1931). Subsequent studies (Shergold, 1975; Zhang and Jell, 1987) suggested that lack of preglabellar furrow can serve as a diagnostic feature of the species. Zhou and Zhang (1985) erected a new genus *Akoldinioidia* to accommodate the forms with well-defined preglabellar furrow among species referred formerly to *Koldinioidia*, an action that was subsequently endorsed by Qian (1986), Duan et al. (1986), Peng (1992), and Peng et al. (1999). The morphological variability and related taxonomic problems within the Cambrian shumardiids were thoroughly discussed by Shergold (1991), who treated *Akoldinioidia* as a junior synonym of *Koldinioidia*. Shergold's concept of *Koldinioidia* is followed in this study.

KOLDINIOIDIA TYPICALIS Kobayashi, 1931
Figure 5.1–5.4

Koldinioidia typicalis KOBAYASHI, 1931, p. 187, pl. 22, figs. 8b, 9; LU, CHANG, CHU, CHIEN, AND HSIANG, 1965, p. 155, pl. 25, figs. 11–12; ZHANG AND JELL, 1987, p. 242, pl. 119, fig. 13.
Koldinioidia infrequens RESSER AND ENDO *in* ENDO AND RESSER, 1937, p. 229, pl. 57, fig. 14.
Koldinioidia cf. *typicalis* Kobayashi. PENG, 1984, p. 326–327, pl. 15, figs. 12–14.
Shumardia (*Koldinioidia*) *typicalis* (Kobayashi). ZHOU AND ZHANG, 1985, p. 72–73, pl. 1, figs. 15–17; pl. 3, figs. 6–7; pl. 18, figs. 6–7; pl. 20, figs. 9–11; pl. 22, fig. 20; pl. 24, fig. 14; pl. 26, figs. 15–20; pl. 28, fig. 8; DUAN, AN, AND ZHAO, 1986, p. 32–33, pl. 1, figs. 17–24; pl. 9, fig. 6d; pl. 15, fig. 11b; ZHU AND WITTKE, 1989, p. 211, pl. 2, figs. 1–5; pl. 3, figs. 1–2.

Diagnosis.—A species of *Koldinioidia* with moderately to strongly effaced preglabellar furrow on dorsal shield and weakly developed anterolateral glabellar lobes.

Material examined.—Six cranidia including two showing ventral sides.

Occurrence.—*Pseudokoldinioidia* Fauna; Unit SCO29; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—Although few specimens are available, silicified cranidia reveal important features of dorsal and ventral morphology. The preglabellar furrow is completely effaced on the dorsal surface, but is indicated by sharp contrast in convexity on the ventral side. The ventral surface shows that the glabella is more or less parallel-sided with slightly expanded anterior lobe, which supports the generic concept of *Koldinioidia* by Shergold (1975, 1991).

Order CORYNEXOCHIDA Kobayashi, 1935
Superfamily LEIOSTEGIACEA Bradley, 1925
Family LEIOSTEGIIDAE Bradley, 1925
Leiostegiid genus and species indeterminate
Figure 5.5–5.18

Material examined.—Eleven cranidia, five librigenae, six pygidia, and eight hypostomes.

Occurrence.—*Pseudokoldinioidia* Fauna; Units SCO29 and SCO30; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—The present material is too poorly preserved to be assigned to the generic level with certainty. Diverse opinions exist on the taxonomy of Cambrian leiostegiids and there seems to be no general agreement on the matter (Kobayashi, 1960; Öpik, 1967; Shergold, 1975; Zhou and Zhang, 1978, 1985; Duan et al., 1986). Nevertheless, the specimens on hand fit well with the general morphology of the family in having trapezoidal glabella, no preglabellar field, obsolete glabellar furrows, and semicircular pygidium with a width greater than its length.

Various leiostegiids have been reported from the Cambrian–Ordovician boundary intervals of the Sino-Korean Block (Zhou and Zhang, 1978, 1985; Kuo et al., 1982; Qian, 1986; Duan et al., 1986; Kim and Choi, 1999). Among these leiostegiids, the present material is most closely comparable to *Leiostegium* (*Leiostegium*) *granum* Kuo and An in Kuo et al., 1982 illustrated by Zhou and Zhang (1985) from the '*Missisquoia*' *perpetis* Assemblage Zone of Jilin Province, North China in possessing less rounded anterior glabellar margin, narrow pygidial axis, indistinct pygidial border furrow, and strongly effaced pleural furrows in pygidia. The present hypostomes bear resemblance with those associated with *Leiostegium granum* and *L. planilimbatum* Kuo and Duan in Kuo et al., 1982 from the lower part of the *Richardsonella–Troedssonia* Zone (equivalent to the '*Missisquoia*' *perpetis* Zone) of Jilin Province, North China.

Family MISSISQUOIIDAE Hupé, 1955

Discussion.—Hupé (1955) erected the family Missisquoiidae under a new superfamily Olenoidae. Shergold (1975) first recognized *Parakoldinioidia* Endo in Endo and Resser, 1937 as a member of the Missisquoiidae and assigned the Missisquoiidae to the superfamily Leiostegiacea belonging to the Corynexochida, where it has remained in subsequent studies (Ludvigsen, 1982; Fortey and Shergold, 1984; Westrop, 1986; Ludvigsen et al., 1989). Shortly after, a new missisquoiid genus *Tangshanaspis* was described by Zhou and Zhang (1978) from China. Ludvigsen (1982), however, synonymized *Tangshanaspis* with *Missisquoia*, while Fortey (1983) treated *Missisquoia* as a junior synonym of *Parakoldinioidia*. Jell and Stait (1985) put *Tasmanocephalus* Kobayashi, 1936 from Tasmania into the Missisquoiidae and also suggested that *Parakoldinioidia* has a priority over *Missisquoia* and *Lunacrania* Kobayashi, 1955. In this study, *Missisquoia* is treated as a valid genus distinguished from both *Tangshanaspis* and *Parakoldinioidia* in glabellar morphology: i.e., *Missisquoia* has forward-tapering or elliptical glabella, whereas the latter two genera are characterized by constricted glabella.

In late 1980s and 1990s, missisquoiid trilobites were frequently reported in China. Zhou and Zhang (1985) introduced a new species, *Missisquoia perpetis*, from North China. Qian (1985b) and Duan et al. (1986) established several new species of *Pseudokoldinioidia* from North China and allocated them to the Missisquoiidae. Recently Zhang and Peng (1998) proposed a new missisquoiid genus *Fuzhouwania* from the *Kaolishania pustulosa* Zone of Shandong and Liaoning Provinces, North China. Duan et al. (2005) added new species of *Parakoldinioidia* and *Pseudokoldinioidia* from Hebei Province, North China.

Shergold et al. (1988), in a comprehensive discussion on the Missisquoiidae, included *Parakoldinioidia*, *Missisquoia*, *Tangshanaspis*, *Lunacrania*, and *Pseudokoldinioidia* in the family, but preferred familial assignment of *Tasmanocephalus* to the Styginidae. Jell and Adrain (2003) listed six genera under the family Missisquoiidae: *Fuzhouwania*, *Hardyia* Walcott, 1924, *Lunacrania*, *Parakoldinioidia*, *Pseudokoldinioidia*, and *Tasmanocephalus*; *Missisquoia* was synonymized with *Parakoldinioidia*. Missisquoiidae is therefore in dire need of more rigorous taxonomic review, which is unfortunately beyond the scope of this study.

Genus PSEUDOKOLDINIOIDIA Endo, 1944

Pseudokoldinioidia ENDO, 1944, p. 72; QIAN, 1985b, p. 152; DUAN, AN, AND ZHAO, 1986, p. 41; LU AND ZHOU, 1990, p. 44.

Type species.—*Pseudokoldinioidia granulosa* Endo, 1944 from the *Tsinania canens* Zone of the Yenchou Formation, Liaoning Province, China (by original designation).

Diagnosis.—Cranidium convex, semicircular; glabella broad, expanding forward, without longitudinal median glabellar furrow; palpebral lobes moderate in size, centered at or behind glabellar mid-point; eye ridges present; glabellar front and anterior border in contact tightly; anterior border short and broadly arched. Pygidium strongly convex and semicircular; pygidial axis with five to seven axial rings and a terminal piece; pleural and interpleural furrows clearly incised; one to two anterior pleurae marginally spinose; border narrow, convex, and uniform in width.

Discussion.—*Pseudokoldinioidia* was originally poorly understood due to inadequate illustration and inaccessibility of the type material. Recent studies from China (Duan et al., 1986; Lu and Zhou, 1990) made it possible to characterize its morphological

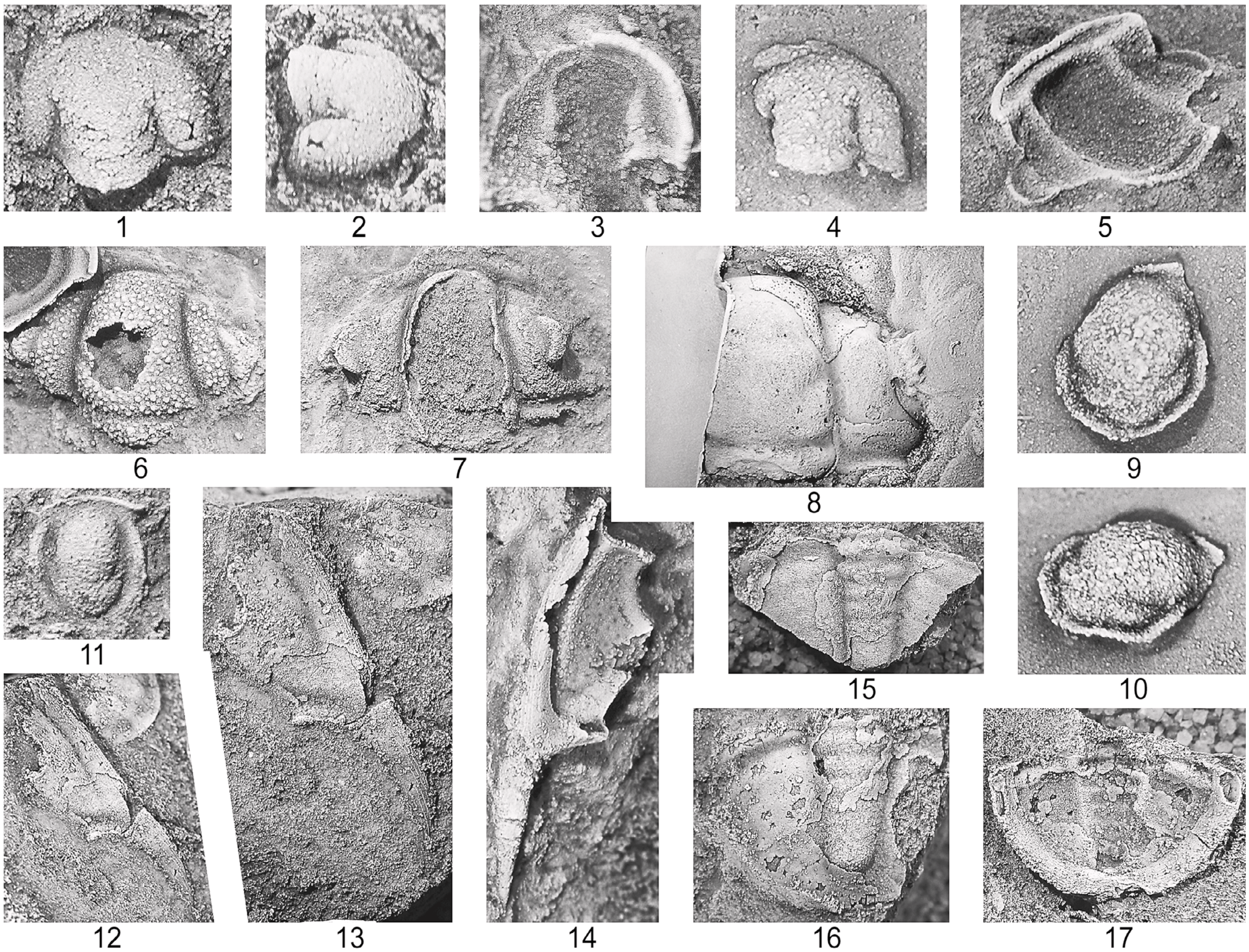

FIGURE 5—*1–4, Koldinioidia typicalis* Kobayashi, 1931 from the *Pseudokoldinioidia* Fauna, Dongjeom Formation, Seokgaejae section, Taebaeksan Basin, Korea. *1*, SNUP3033, slightly distorted cranidium with occipital node, plan view, ×17; *2*, antero-lateral view of SNUP3033, ×16; *3*, SNUP3034, ventral surface of incomplete cranidium clearly showing the position of preglabellar furrow, ×21; *4*, SNUP3035, partly broken isolated specimen showing stout acute genal angle, ×19. *5–17*, leiostegiid genus and species indeterminate. *5*, SNUP3036, oblique view of partially preserved cranidium showing ventral aspect of anterior border and preocular facial suture which is nearly unobservable in plan view due to steep slope, ×10; *6*, SNUP3037, incomplete cranidium showing pustulate dorsal surface, ×6; *7*, SNUP3038, incomplete cranidium with abraded dorsal surface, ×3.5; *8*, SNUP3039, latex cast of partially exfoliated cranidium, ×3.5; *9,* SNUP3040, partly broken isolated hypostome, plan view, ×12; *10*, postero-lateral view of SNUP3040, ×12; *11*, SNUP3041, nearly complete small hypostome, ×13; *12,* SNUP3042, dorsal surface of partly exfoliated librigena, ×2.3; *13*, oblique view of SNUP3042 showing lirae on abaxial margin, ×2.8; *14*, SNUP3043, oblique view of ventral surface of librigena showing lirae on doublure and pits in genal field, ×5.5; *15*, SNUP3044, partly preserved dorsal surface of pygidium showing very faint anterior pleural furrows on exfoliated pleural field, ×2.2; *16*, SNUP3045, adaxially exfoliated dorsal surface of incomplete pygidium showing nearly smooth pleural field, ×2.4; *17*, SNUP3046, ventral surface of partly exfoliated incomplete pygidium showing lirae on doublure, ×2.8.

features, which are included in the generic diagnosis. *Pseudokoldinioidia* has been frequently compared with closely related genera, such as *Parakoldinioidia* and *Missisquoia*. *Parakoldinioidia* is readily distinguished from *Pseudokoldinioidia* by its constricted glabella, presence of longitudinal median glabellar furrow, bluntly triangular anterior border, and low convexity of cranidium. Zhou and Zhang (1985) interpreted the forwardly expanding glabella of *Pseudokoldinioidia* as a trait suitable for use at the species level within *Missisquoia*, citing a broad spectrum of glabellar shapes displayed by species within the genus. Certainly *Missisquoia* displays a variety of glabellar morphologies; e.g., forwardly tapering (*M. typicalis* Shaw, 1951) and bulging in the middle (*M. inflata* Winston and Nicholls, 1967). However, no species displays an anteriorly expanding glabella. *Pseudokoldinioidia* invariably has a forwardly expanding glabella, by which it can be differentiated from *Missisquoia*.

During the last two decades, eight species and one subspecies were added to *Pseudokoldinioidia* in China: *P. perpetis* (Zhou and Zhang, 1985), *P. bifurcata* Qian, 1985b, *P. perpetis wennanensis* An in Duan et al., 1986, *P. huinanensis* Duan and An in Duan et al., 1986, *P. taiziheensis* Duan and An in Duan et al., 1986, *P. expansa* Lu and Zhou, 1990, *P. encrinuroides* Lu and Zhou, 1990, *P. hemicycla* Duan in Duan et al., 2005, and *P. funingensis* Duan in Duan et al., 2005. However, *Pseudokoldinioidia bifurcata* from the Upper Cambrian of Anhui Province is too poorly preserved to assess the specific diagnosis. Duan et al. (1986) systematically explored *Pseudokoldinioidia* and were able to differentiate the genus from other allied genera such as *Missisquoia*, *Parakoldinioidia*, and *Tangshanaspis*. We basically concur with the proposal of Duan et al. (1986) with some modification: *Missisquoia perpetis* Zhou and Zhang, 1985 is transferred to *Pseudokoldinioidia*; a new subspecies, *P. perpetis wennanensis* An in Duan

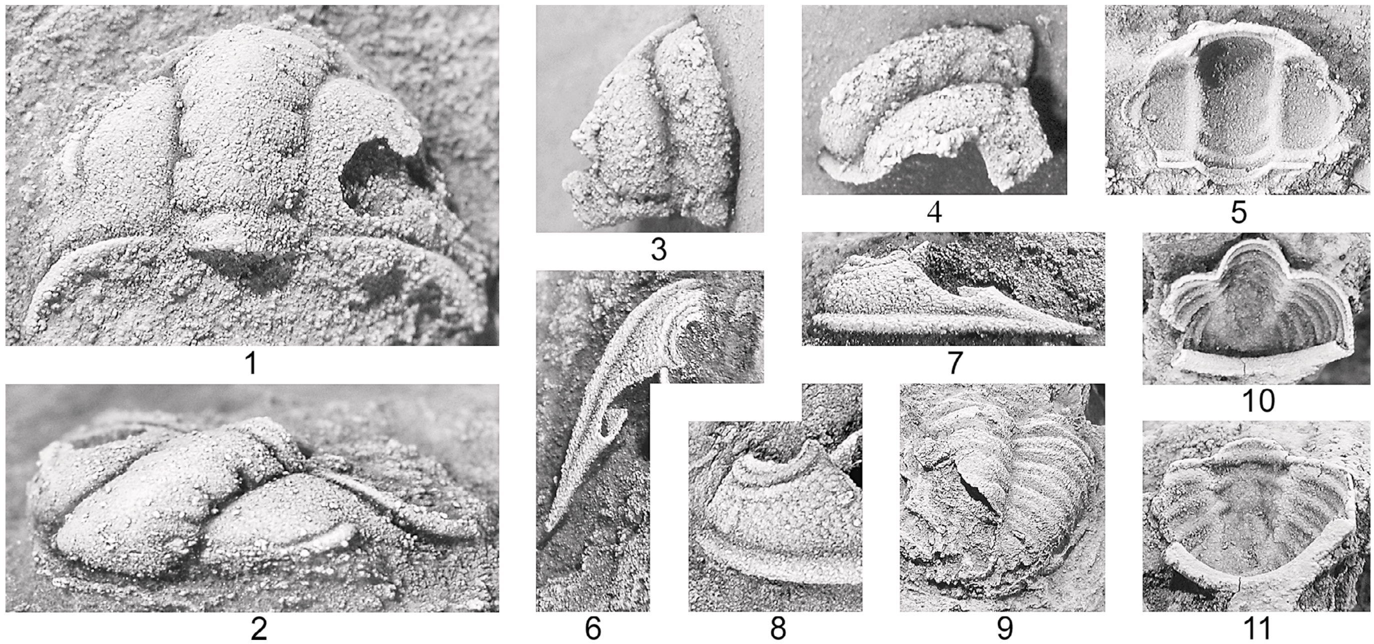

FIGURE 6—*Pseudokoldinioidia perpetis* (Zhou and Zhang, 1985) from the *Pseudokoldinioidia* Fauna, Dongjeom Formation, Seokgaejae section, Taebaeksan Basin, Korea. *1*, SNUP3024, partly broken and slightly distorted cranidium, ×9; *2*, oblique anterior view of SNUP3024, ×10; *3*, SNUP3047, incomplete isolated cranidium, ×9; *4*, lateral view of SNUP3047, ×10; *5*, SNUP3011, ventral surface of cranidium, ×5; *6,* SNUP3048, nearly complete librigena, dorsal view, ×7; *7*, lateral view of SNUP3048, ×7; *8*, enlarged oblique view of SNUP3048 showing eye socle area, ×10; *9*, SNUP3049, incomplete pygidium showing pustulate prosopon and distinct interpleural furrows, ×4; *10*, SNUP3012, anterior view of ventral surface of partly broken pygidium showing strong convexity, ×9; *11*, plan view of SNUP3012, ×9.

et al., 1986, can be accommodated within the morphological spectrum of *P. perpetis*; *Pseudokoldinioidia huinanensis* is difficult to evaluate due to poor illustration and is provisionally retained within the genus; and cranidia of *Pseudokoldinioidia taiziheensis* Duan and An in Duan et al., 1986 from the *Ptychaspis–Tsinania* Zone display the morphological features of the genus, but the pygidia assigned to the species cannot be accommodated within *Pseudokoldinioidia*.

PSEUDOKOLDINIOIDIA PERPETIS (Zhou and Zhang, 1985)
Figure 6

Leiostegium (*Alloleiostegium*) *punctatum* ZHOU AND ZHANG, 1978 (in part), p. 13, pl. 2, fig. 8.

Missisquoia perpetis ZHOU AND ZHANG, 1985, p. 93, pl. 4, figs. 6–7; pl. 8, figs. 5–7; pl. 18, figs. 8–12; pl. 21, figs. 1–4; pl. 22, figs. 13–15; pl. 23, figs. 13–15; pl. 24, figs. 5–10; pl. 25, figs. 4–6; pl. 27, figs. 1–2; pl. 28, fig. 12; QIAN, 1986, p. 272, pl. 70, figs. 8–9.

Pseudokoldinioidia perpetis (ZHOU AND ZHANG). DUAN, AN, AND ZHAO, 1986, p. 41, pl. 3, figs. 1–14.

Pseudokoldinioidia perpetis wennanensis AN *in* DUAN, AN, AND ZHAO, 1986, p. 42, pl. 3, fig. 15.

Diagnosis.—A species of *Pseudokoldinioidia* having palpebral lobes located slightly posterior to glabellar midpoint, relatively wide fixigenal area (ca. two-thirds of glabellar width), strongly convex semicircular pygidium with well defined pleural and interpleural furrows, and pustulate prosopon.

Material examined.—Eleven incomplete cranidia, 18 pygidia, and three librigenae.

Occurrence.—*Pseudokoldinioidia* Fauna; Unit SCO29; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—*Pseudokoldinioidia perpetis* is characterized by forwardly less expanding glabella and more anteriorly located palpebral lobes than early forms such as *P. hemicycla* and *P. taiziheensis* from the *Ptychaspis–Tsinania* Zone of North China. These morphological changes with time may represent evolutionary trends within the *Pseudokoldinioidia* lineage. *Pseudokoldinioidia expansa* from South China differs from *P. perpetis* in having narrower fixed cheeks and more transverse pygidium.

Suborder ASAPHINA Salter, 1864
Family CERATOPYGIDAE Linnarsson, 1869
Genus ONYCHOPYGE Harrington, 1938

Type species.—*Onychopyge riojana* Harrington, 1938 from the *Parabolina argentina* Zone (uppermost Cambrian to Tremadocian) of La Rioja, Argentina (by original designation).

Diagnosis.—Ceratopygiid characterized by large palpebral lobes with well-defined palpebral furrows. Preglabellar field absent to very short. Glabella slightly expanding or tapering forward; narrow and elongate bacculae located close to glabellar base. S1 abaxially bifurcate and deeply incised. Anterior border upturned. Postocular suture nearly transverse. Pygidial axis with two to seven rings, weakly to strongly tapering rearward; commonly extending into postaxial ridge. Macropleural first anterior segment with wide pleural furrows prolonged into a distinct pair of spines. Posterior pleural fields smooth to faintly segmented.

Discussion.—Since *Onychopyge* was established in 1938, a total of 19 species have been assigned to the genus: nine species from North China, one from South China, four from Argentina, two from Bolivia, two from Australia, and one from Mexico. Of the Chinese species, *O. primitiva*, *O. cylindrica* Lu et al., 1984, and *O. brevica* Lu et al., 1984 from Nei Mongol share many morphological features such as strongly tapering pygidial axis with blunt terminal piece, distinct postaxial ridge, moderately broad border, smooth pleural field, and rearward-directed stout macropleural spines, and hence are considered to be conspecific. *Onychopyge primitiva* has a priority over the latter two. *Onychopyge sinica* Zhou and *O. elongata* Zhou *in* Lu et al. (1984) from Gansu Province, northwestern China are also indistinguishable from each other and the latter is considered a junior synonym of the former.

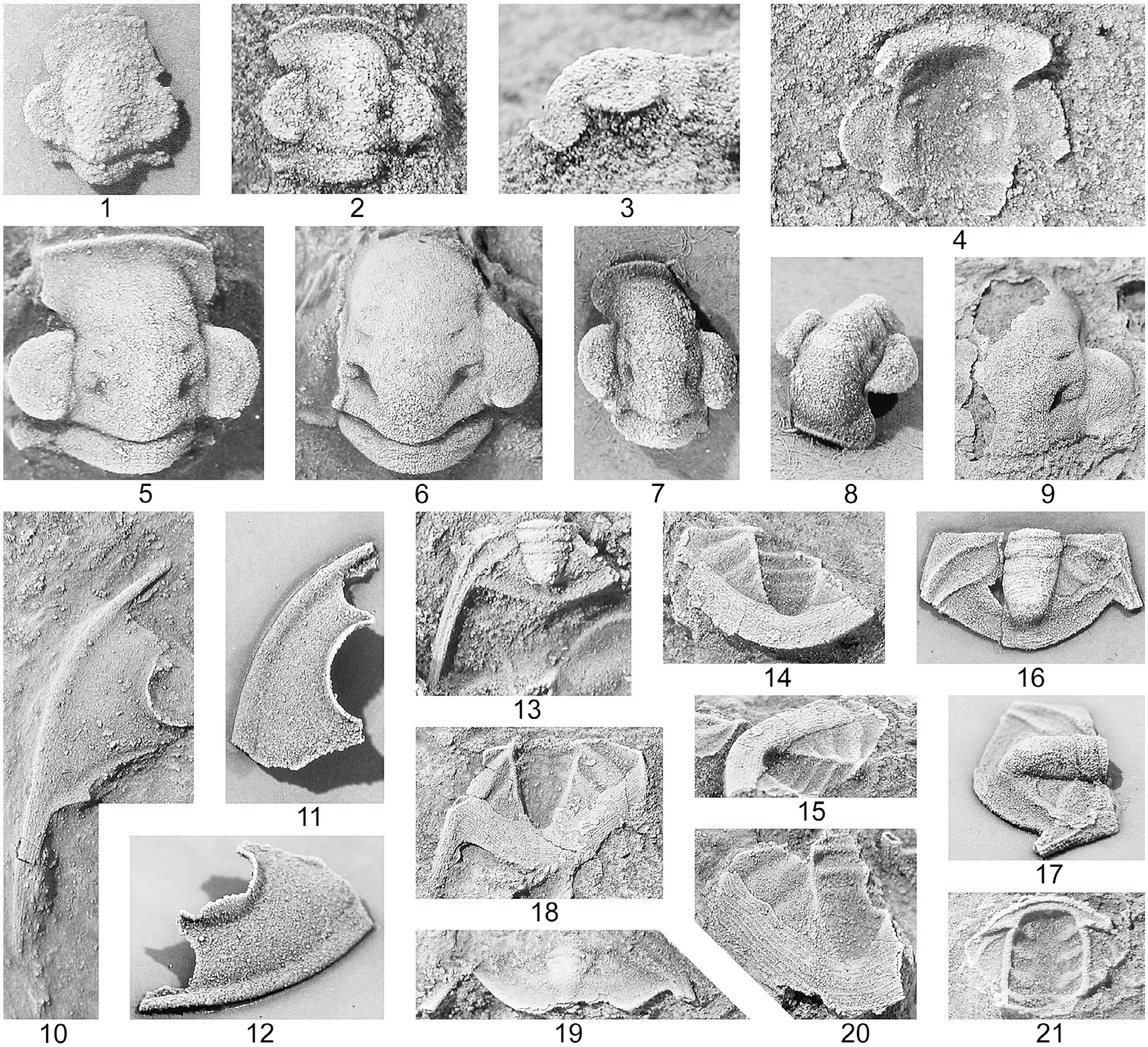

FIGURE 7—*1–20*, *Onychopyge borealis* Zhou and Zhang, 1978 from the *Pseudokoldinioidia* Fauna, Dongjeom Formation, Seokgaejae section, Taebaeksan Basin, Korea. *1*, SNUP3050, juvenile cranidium with relatively long preglabellar field, ×15; *2*, SNUP3051, slightly distorted early holaspid cranidium showing strong convexity and upturned anterior border, ×10; *3*, lateral view of SNUP3051, ×10; *4*, SNUP3052, ventral surface of incomplete cranidium, ×9; *5*, SNUP3013, nearly complete but slightly distorted cranidium, ×7.5; *6*, SNUP3053, incomplete large cranidium, ×5; *7*, SNUP3054, laterally compressed isolated cranidium, ×8.8; *8*, oblique anterior view of SNUP3054, ×9; *9*, SNUP3055, partially preserved large cranidium, ×4.5; *10*, SNUP3056, nearly complete librigena, ×5; *11*, SNUP3057, dorsal surface of isolated librigena, plan view, ×7; *12*, oblique anterior view of SNUP3057, ×8; *13*, SNUP3025, partly broken small pygidium with long macropleural spine and no postaxial ridge, ×10; *14*, SNUP3058, ventral surface of pygidium showing indented doublure margin medially, plan view, ×8; *15*, oblique view of SNUP3058, ×8; *16*, SNUP3059, dorsal surface of relatively large pygidium showing less tapering axis with strong convexity and no postaxial ridge, plan view, ×6; *17*, oblique lateral view of SNUP3059, ×6; *18*, SNUP3060, ventral surface of incomplete pygidium with rapidly tapering axis and relatively broad doublure, ×4.5; *19*, SNUP3061, partially preserved pygidium showing low convexity of terminal piece and faint postaxial ridge, ×6; *20*, SNUP3062, ventral surface of incomplete pygidium, ×6. *21*, Pilekiid genus and species indeterminate from the *Pseudokoldinioidia* Fauna, Dongjeom Formation, Seokgaejae section, Taebaeksan Basin, Korea. SNUP3063, ventral surface of incomplete cranidium, ×7.

ONYCHOPYGE BOREALIS Zhou and Zhang, 1978
Figure 7.1–7.20

Onychopyge borealis ZHOU AND ZHANG, 1978, p. 17, pl. 1, figs. 24a–b; ZHOU AND ZHANG, 1985, p. 137, pl. 13, figs. 12–14; pl. 24, fig. 12; DUAN, AN, AND ZHAO, 1986, p. 80, pl. 25, figs. 4–7.

Onychopyge depressa QIAN, 1986, p. 299, pl. 80, figs. 1–6, 11, text-fig. 116.

Diagnosis.—A species of *Onychopyge* having a transversely elliptical pygidium with relatively short macropleural spines directed obliquely rearward.

Material examined.—Sixteen cranidia (including two late meraspid specimens), 15 holaspid pygidia, and nine librigenae.

Occurrence.—*Pseudokoldinioidia* Fauna; Units SCO29 and SCO30; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—*Onychopyge borealis* was first established based on an incomplete cranidium from the *Onychopyge–Leiostegium*

(*Alloleiostegium*) Assemblage Zone of Lulong, Hebei Province, and later Zhou and Zhang (1985) assigned several pygidia from the '*Missisquoia*' *perpetis* Zone of Hunjiang, Jilin Province to the species. Both the type cranidium and pygidia are however poorly preserved so that it is difficult to characterize their morphological features with clarity. *Onychopyge depressa* Qian, 1986 from the *Alloleiostegium latilum*– '*Missisquoia*' *perpetis* Assemblage Subzone of the Dayangcha section, Hunjiang, Jilin Province was distinguished from *O. borealis* by its slender glabella and a depression in the preglabellar field. One of the cranidia (Qian, 1986, pl. 80, fig. 6) assigned to *O. depressa* with reservation is nearly identical to *O. borealis*. In addition, pygidia of *O. depressa* cannot be objectively differentiated from those of *O. borealis*. Therefore *O. depressa* is treated as a junior synonym of *O. borealis*. Duan et al. (1986) collected additional material of *Onychopyge* from the same locality of Qian (1986) and assigned it to *O. borealis*. It seems appropriate to suggest that all of these specimens from North China and Korea represent a single species, *O. borealis*, displaying a range of intraspecific variation.

It is also interesting that pygidia illustrated by Qian (1986) can be divided into two groups: one with more rapidly tapering axis and well-defined postaxial ridge (Qian, 1986, pl. 80, figs. 2–3) and the other with gently tapering axis and faint postaxial ridge (Qian, 1986, pl. 80, figs. 4–5, 11). Similar dimorphic pygidia were also recognized in the collections of *O. austrina* (Peng, 1984) and *O. borealis* (Zhou and Zhang, 1985), respectively. The occurrence of dimorphic pygidia in the three independent collections might reflect sexual dimorphism.

Valid species of *Onychopyge* in Asia include *O. borealis*, *O. primitiva*, *O. tricuspis*, *O. peculiaris*, *O. sinica*, and *O. austrina*. *Onychopyge borealis* is easily distinguished from other species by its transversely wider pygidia with comparatively short macropleural spines directing obliquely rearward. Pygidia of *O. primitiva* and *O. tricuspis* have backward-directed macropleural spines of moderate length, while those of *O. austrina* have oblique backward-directed very long macropleural spines. *Onychopyge sinica* is readily distinguishable from the other species by its slender and long pygidial axis with five to six axial rings.

Order PHACOPIDA Salter, 1864
Suborder CHEIRURINA Harrington and Leanza, 1957
Superfamily CHEIRUROIDEA Harrington and Leanza, 1957
Family PILEKIIDAE Sdzuy, 1955
Pilekiid genus and species indeterminate
Figure 7.21

Material examined.—One cranidium.

Occurrence.—*Pseudokoldinioidia* Fauna; Unit SCO29; Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—This incomplete specimen shows ventral side only, but may be assignable to the Pilekiidae based on the forwardly gently tapering glabella. It seems unprofitable to compare it with any pre-existing genera of the family due to its poor preservation.

ACKNOWLEDGMENTS

We are grateful to J. F. Taylor (Indiana University of Pennsylvania) and an anonymous reviewer for providing many insightful and helpful remarks on the manuscript. Thanks are extended to S. R. Westrop (University of Oklahoma) for his constructive suggestions which greatly improved the final version of the manuscript. Financial support for this study has come from the Korea Research Foundation (Grant No. R14-2003-017-01000-0). This paper is a contribution of the BK 21 Project of the School of Earth and Environmental Sciences, Seoul National University.

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ACCEPTED 31 JULY 2006