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DIKELOCEPHALID TRILOBITES FROM THE *EOSAUKIA* FAUNA (UPPER FURONGIAN) OF THE TAEBAEK GROUP, KOREA

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ABSTRACT—The *Eosaukia* fauna is proposed for the upper Furongian trilobite assemblage from the interval spanning from the upper part of the Hwajeol Formation to the lowermost part of the Dongjeom Formation in the Taebaek Group, Taebaeksan Basin, Korea. It is characterized by the dominance of dikelocephalid trilobites comprising *Eosaukia micropora*, *E. bella*, *E. acuta*, *Mictosaukia* cf. *M. globosa*, and *Taebaeksaukia spinata* n. gen. n. sp. Taxonomic reappraisal of the genus *Mictosaukia* that has been employed as an upper Cambrian index taxon in eastern Gondwana reveals that more than half of the species of *Mictosaukia* belong in *Eosaukia*. This study clarifies the generic concept of *Eosaukia*, which provides a more reliable biostratigraphic correlation for the upper Furongian strata in eastern Gondwanan regions. The *Eosaukia* fauna is correlated with the ''*Mictosaukia*'' faunas from the upper Fengshanian of North China, upper Taoyuanian of South China, and upper Payntonian of Australia.

INTRODUCTION

THE FAMILY Saukiidae Ulrich and Resser, 1933 was one of the largest Furongian (late Cambrian) trilobite groups including more than 30 genera and hundreds of species reported mostly from Laurentia and Gondwana, but is now incorporated into the Dikelocephalidae Miller, 1889 (see Ludvigsen and Westrop in Ludvigsen et al., 1989). The ''saukiids'' are known to have flourished during the Sunwaptan Stage so that they have been important in establishing the biostratigraphic zonation in Laurentia (Bell et al., 1952; Berg, 1953; Grant, 1962, 1965; Winston and Nicholls, 1967; Longacre, 1970; Stitt, 1971, 1977; Westrop, 1986; Ludvigsen et al., 1989). Some of these dikelocephalids were also treated biostratigraphically significant in the upper Furongian of Australia, China, and Kazakhstan (see Geyer and Shergold, 2000). In particular, *Mictosaukia* has long been regarded as an index taxon for the uppermost Cambrian of eastern Gondwanan regions including Australia (Shergold, 1975), South China (Peng, 1984, 1992; Lu and Zhou, 1990), and North China (Zhou and Zhang, 1978; Kuo et al., 1982; Qian, 1985a, 1986; Zhou et al., 1985; Duan et al., 1986, 2005; Zhang and Jell, 1987; Chen et al., 1988; Zhu and Wittke, 1989; Zhang et al., 1995).

The uppermost Cambrian trilobite faunas of the Taebaek Group in Korea have hitherto been poorly known. Kobayashi (1935) established the *Dictyites* and *Eoorthis* zones within the Hwajeol Formation, which were collectively correlated with the Fengshanian of North China (Kobayashi, 1966). Although some dikelocephalids were reported from the *Dictyites* and *Eoorthis* zones (Kobayashi, 1935, 1960, 1966), inadequate taxonomy and the lack of precise stratigraphic data for the dikelocephalids and associated trilobites hampered the recognition of reliable biostratigraphic framework for the uppermost Cambrian in Korea.

Recently, Choi et al. (2003) reported the occurrence of ''saukiid''-dominated fauna from the uppermost part of the Hwajeol Formation and the lowermost part of the Dongjeom Formation, which corresponds in part to the previous *Eoorthis* Zone. Choi et al. (2004) renamed it as the ''*Mictosaukia*'' fauna based on a preliminary taxonomic study. Subsequent examination of the ''*Mictosaukia*''-bearing interval across the boundary between the Hwajeol and Dongjeom formations led to the discovery of additional fossiliferous horizons yielding well-preserved trilobite specimens.

This study mainly deals with the taxonomy of the dikelocephalid trilobites from the ''*Mictosaukia*'' fauna of the Taebaek Group, Taebaeksan Basin, Korea. Numerous specimens retaining the original convexity provide a good opportunity to review the concept of ''*Mictosaukia*'' and related genera. The results are beneficial in understanding the biostratigraphic and paleogeographic significance of the Dikelocephalidae.

GENERAL GEOLOGY AND FOSSIL LOCALITY

The Taebaeksan Basin is located at the central eastern part of the Korean peninsula (Fig. 1) and comprises 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 overlain unconformably by the Pyeongan Supergroup. The Joseon Supergroup is a shallow-marine siliciclastic-carbonate succession ranging in age from late early Cambrian to early Late Ordovician (Chough et al., 2000; Choi and Chough, 2005). The supergroup is subdivided into the Taebaek, Yeongwol, Yongtan, Pyeongchang, and Mungyeong groups (Choi, 1998). The Taebaek Group is mainly distributed in the eastern half of the Taebaeksan Basin (Fig. 1) and comprises in ascending order the Jangsan/Myeonsan, Myobong, Daegi, Sesong, Hwajeol, Dongjeom, Dumugol, Makgol, Jigunsan, and Duwibong formations (Kobayashi, 1966; Choi et al., 2004).

Kobayashi (1935, 1966) proposed five upper Cambrian trilobite biozones in the Hwajeol Formation: i.e., the *Prochuangia*, *Chuangia*, *Kaolishania*, *Dictyites*, and *Eoorthis* zones in ascending order. Kobayashi (1966) drew the Cambrian-Ordovician boundary at the base of the Dongjeom Formation, based on the recognition of the *Pseudokainella* Zone in the lower part of the Dongjeom Formation which was then considered Tremadocian in age.

Recently, Choi et al. (2003) recognized in ascending order the ''saukiid''-dominated, *Missisquoia*/*Onychopyge*, and kainellid-dominated faunas in the interval across the boundary between the Hwajeol and the Dongjeom formations. The Cambrian-Ordovician boundary in the Taebaek Group was suggested to occur within the kainellid-dominated fauna of the Dongjeom Formation based on the observation of *Yosimuraspis* Kobayashi, 1960, a lowermost Ordovician zonal taxon endemic to the Sino-Korean block (Kim and Choi, 2000).

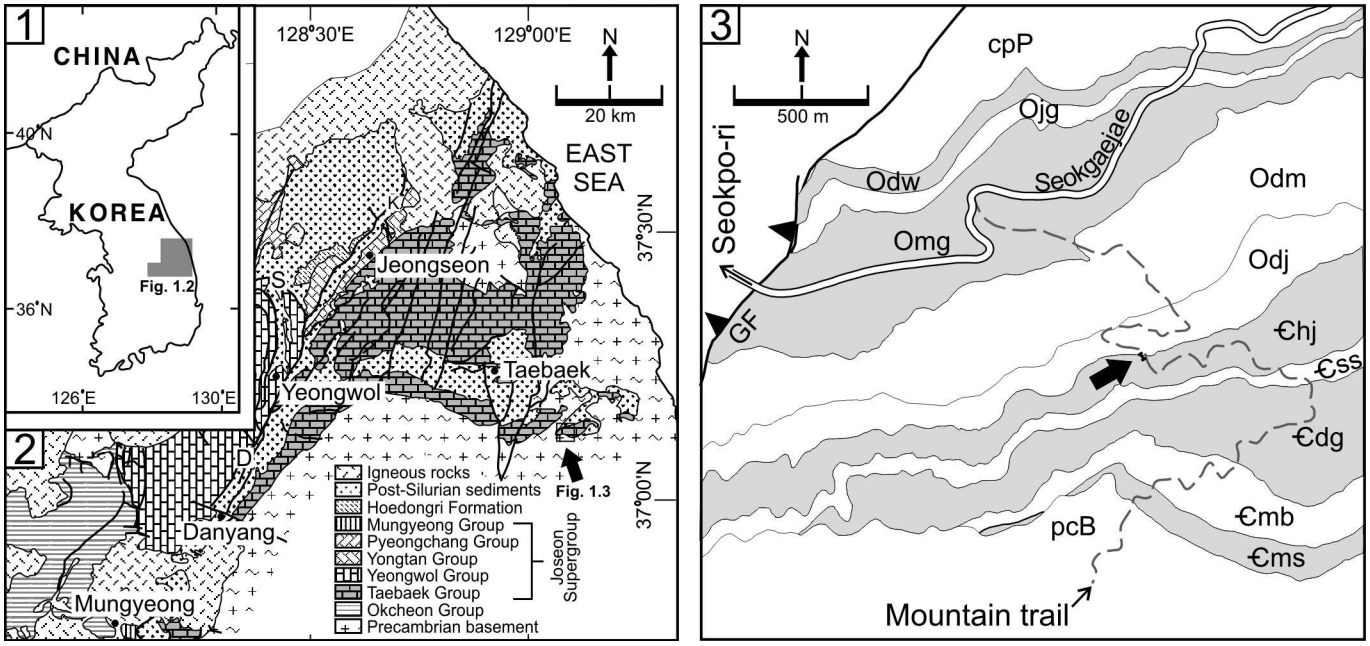

FIGURE 1—Locality maps: *1,* index map of the Korean peninsula showing the location of study area; *2,* simplified geological map focused on the distribution of the Taebaek Group, the arrow denotes the approximate location of Fig. 1.3; *3,* detailed geologic map showing the fossil locality (arrow) in the Seokgaejae section. Modified from Choi et al. (2004). Abbreviations: pcB = Precambrian Basement, Cms = Myeonsan Fm, Cmb = Myobong Fm, Cdg = Daegi Fm, Css = Sesong Fm, Chj = Hwajeol Fm, Odj = Dongjeom Fm, Odm = Dumugol Fm, Omg = Makgol Fm, Ojg = Jigunsan Fm, Odw = Duwibong Fm, cpP = Carboniferous-Permian Pyeongan Supergroup.

Subsequently, Choi et al. (2004) recognized the *Quadraticephalus* fauna from the interval below the "saukiid"-dominated fauna and renamed the "saukiid"-dominated fauna to the "*Mictosaukia*" fauna. Lee and Choi (2007) further refined the *Missisquoia*/*Onychopyge* and kainellid-dominated faunas to the *Pseudokoldinioidia* and *Richardsonella* faunas, respectively. In the mean time, Sohn and Choi (2005, 2007) formally proposed the *Asioptychaspis* and *Quadraticephalus* zones in the lower part of the Hwajeol Formation (Fig. 2). In short, the upper Furongian trilobite faunal succession in the Hwajeol and Dongjeom formations of the Taebaeksan Basin includes the *Asioptychaspis*, *Quadraticephalus*, "*Mictosaukia*", *Pseudokoldinioidia*, and *Richardsonella* faunas in ascending order, which replaced the *Dictyites*, *Eoorthis*, and *Pseudokainella* zones of Kobayashi (1966). This revised biostratigraphy provides a more reliable correlation of the upper Furongian strata of Korea, North China, and Australia (Choi et al., 2003; Sohn and Choi, 2007; Lee and Choi, 2007).

All of the trilobites described herein were collected from the interval across the boundary between the Hwajeol and the Dongjeom formations in the Seokgaejae section (geographic coordinates of N 37°04′19″ and E 129°08′39″), located at the southeastern corner of the Taebaeksan Basin, Korea (Fig. 1). The Seokgaejae section exposes a nearly complete succession (~1,100 m) of the Taebaek Group (Choi et al., 2004). The Hwajeol and Dongjeom formations yield well-preserved invertebrate fossils including trilobites, brachiopods, and echinoderms (Lee et al., 2005; Lee and Choi, 2007; Sohn and Choi, 2007). In the Seokgaejae section, the Hwajeol Formation (~50 m) is an alternating succession of limestone and shale layers, while the Dongjeom Formation (~90 m) consists predominantly of sandstone.

An approximately 20 m interval across the boundary between the Hwajeol and Dongjeom formations is characterized by the transition from the limestone nodule-bearing shale to thickly laminated fine-grained sandstone facies (Fig. 2). Silicified trilobite sclerites were recovered from severely weathered calcareous fine-grained sandstone or limestone nodule-bearing shale, whereas internal/external molds were obtained from thickly laminated fine-grained sandstone. This interval was divided into 57 units for lithologic description and fossil collection (Lee and Choi, 2007). The silicified dikelocephalid trilobites concerned in this study are all disarticulated and were collected from the ten units spanning an ~10 m interval across the boundary between the Hwajeol and the Dongjeom formations (Fig. 2). The collection includes a large number of cranidia (287), pygidia (76), librigenae (228), and some thoracic segments. Most of the specimens belong to the holaspid period with a small number of juveniles.

SYSTEMATIC PALEONTOLOGY

Morphological terms employed in this study generally follow those of Whittington and Kelly (1997), but the glabella used herein excludes the occipital ring. Descriptive terms for lateral glabellar furrows and facial sutures are quoted from Henningsmoen (1957). Terms for orientation are indicated in reference to standard plane: i.e., length always means sagittal or exsagittal distance, while width refers to transverse distance. All of the specimens are housed in the paleontological collections of Seoul National University with registered SNUP numbers.

Order ASAPHIDA Salter, 1864
Superfamily DIKELOCEPHALOIDEA Miller, 1889
Family DIKELOCEPHALIDAE Miller, 1889

Discussion.—The subfamily Saukiinae was established by Ulrich and Resser (1933) as a group of dikelocephalids having convex anterior and lateral borders of the cephalon, anteriorly marginal facial suture, and a relatively convex pygidium with concave border. Included were *Saukia* Walcott, 1914, *Calvinella* Walcott, 1914, *Tellerina* Ulrich and Resser, 1933, *Prosaukia* Ulrich and Resser, 1933, and *Saukiella* Ulrich and

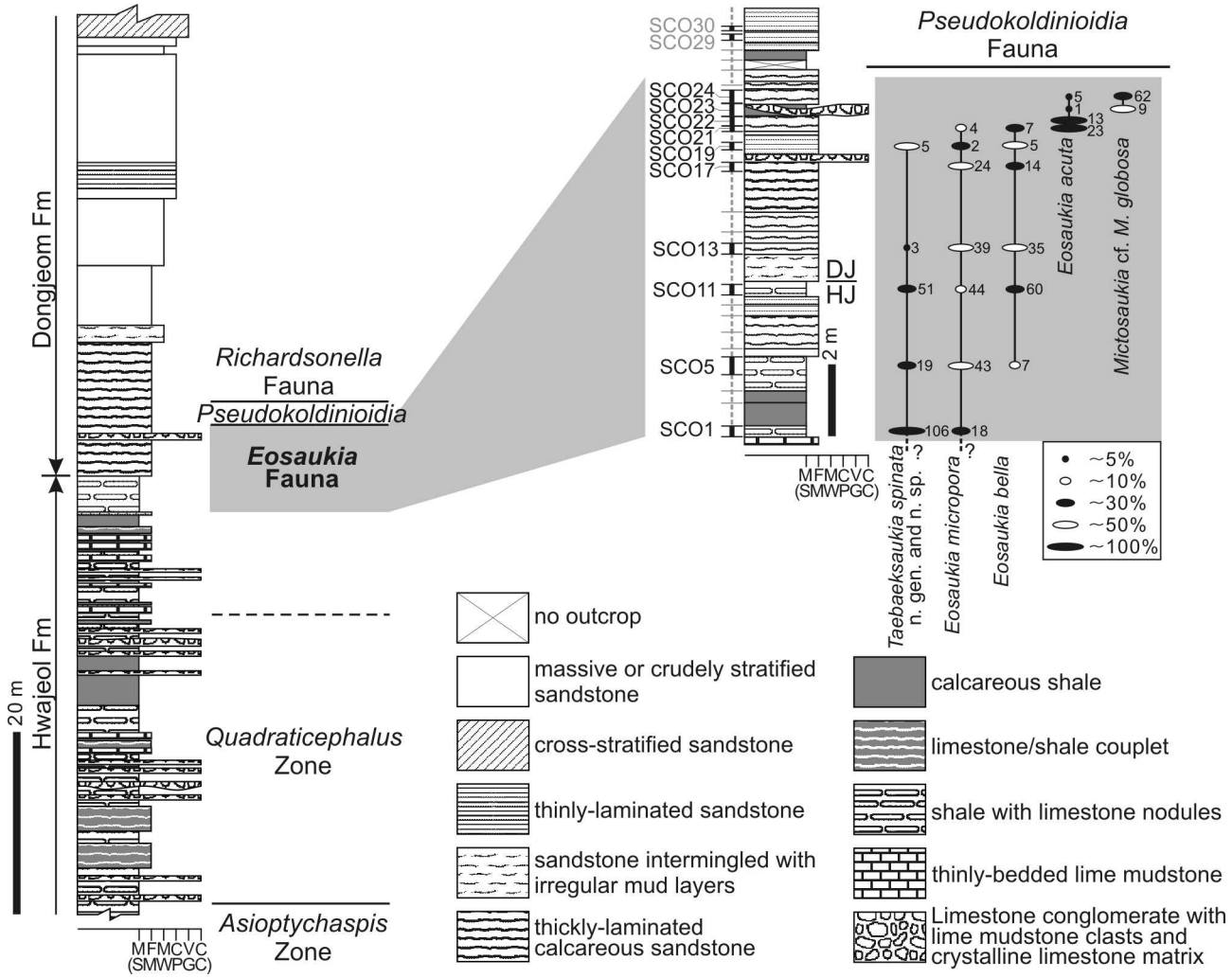

FIGURE 2—Lithologic columns of the Hwajeol Formation and the lower part of the Dongjeom Formation exposed at the Seokgaejae section, showing the biostratigraphy, studied interval, sampling units, and occurrences of dikelocephalids. The occurrences of dikelocephalid species in the section are indicated by relative abundance (transverse ellipses) and absolute number of specimens. The total number of identifiable trilobite sclerites in each unit is 160, 99, 438, 84, 48, 28, 45, 13, 29, and 209 in ascending order from SCO1 to SCO24. Abbreviations: MFMCVC = mudstone, fine-sandstone, medium-sandstone, coarse-sandstone, very coarse-sandstone, and conglomerate; SMWPGC = shale, limemudstone, wackestone, packstone, grainstone, and limestone conglomerate; DJ = Dongjeom Formation, HJ = Hwajeol Formation.

Resser, 1933. The subfamilial rank within the Dikelocephalidae was followed by subsequent studies (Kobayashi, 1933a; Sun, 1935; King, 1937; Raymond, 1937; Lu, 1954). However, taxonomy exercised by Ulrich and Resser (1933) for the saukiine genera and species has been often criticized (Raasch, 1951; Taylor and Halley, 1974; Labandeira and Hughes, 1994). Raasch (1951) suggested a possible ptychaspidid ancestry of the Saukiinae and raised the Saukiinae to the familial rank. Thereafter, the Saukiidae was considered as a ptychaspidoid (Hupé, 1955; Lochman, 1956; Moore, 1959; Shergold, 1972; Li and Yin, 1973; Yin and Li, 1978; Zhou et al., 1982; Peng, 1984). Close morphological similarity of saukiids with ptychaspidids also led to lower their rank to a subfamily of the Ptychaspididae Raymond, 1924 (Kobayashi, 1960; Longacre, 1970; Stitt, 1971, 1977; Taylor and Halley, 1974). Lately, Jell and Adrain (2003) assigned more than 30 genera to the Saukiidae.

On the other hand, Ludvigsen and Westrop (1983), while accepting the taxonomic treatment of Walcott (1914) and Ulrich and Resser (1933), considered the Saukiidae, Dikelocephalidae, and Ptychaspididae as sister taxa within the superfamily Dikelocephaloidea. Later, Ludvigsen and Westrop in Ludvigsen et al. (1989) noted that the Saukiidae has no synapomorphic characters and is paraphyletic, and accordingly they treated the Saukiidae to be a junior synonym of the Dikelocephalidae, which is followed herein.

Genus MICTOSAUKIA Shergold, 1975

Mictosaukia SHERGOLD, 1975, p. 142; SHERGOLD, 1991, p. 23.
Pseudocalvinella QIU, 1984, p. 337.

Type species.—*Tellerina orientalis* Resser and Endo in Endo and Resser, 1937 from the Wanwan Formation, Liaoning, North China (by original designation).

Diagnosis.—A genus of Dikelocephalidae with slightly convex cranidium; glabella parallel-sided to slightly constricted in middle; preglabellar area undifferentiated; anterior and lateral border wide; anterior border furrow nearly transverse abaxially; palpebral lobes located posteriorly to glabellar mid-length, detached from axial furrows but close to them. Pygidium subisopygous; axis narrow and multi-segmented; posterior border broad and concave.

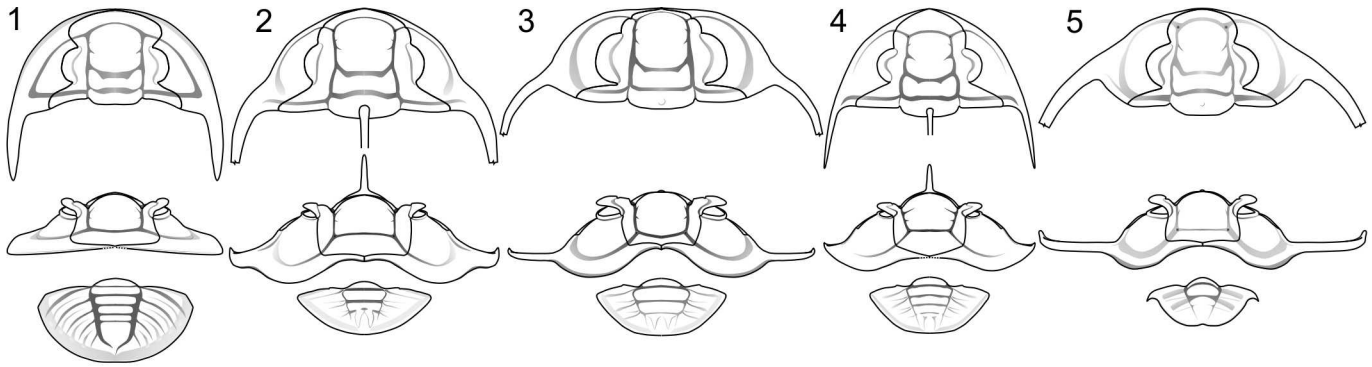

FIGURE 3—Schematic reconstructions of dikelocephalid trilobites described in this study: *1, Mictosaukia.* cf. *M. globosa*; *2, Eosaukia micropora*; *3, E. bella*; *4, E. acuta* and; *5, Taebaeksaukia spinata* n. gen. and n. sp. Cephala are shown in dorsal and frontal views, respectively, while pygidia are illustrated to show the relative size. Note the contrasting aspect in the direction of abaxial part of anterior border furrows, cephalic convexity, and relative size of pygidia.

Discussion.—*Mictosaukia* Shergold, 1975 was established based on *Tellerina orientalis* Resser and Endo in Endo and Resser, 1937 to accommodate some Gondwanan dikelocephalids that possess the combined morphological features of *Saukia* (narrow glabella) and *Tellerina* (relatively long preglabellar area). Shergold (1975) emphasized that *Mictosaukia* can be differentiated from *Saukia* in having the ''obliquely directed anterolateral cranidial marginal furrows'' (equivalent to the abaxial portions of anterior border furrow) and crenulation on the posterior portion of librigenal doublure (equivalent to vincular structure), and from *Tellerina* by shorter and more slender genal spines and narrower glabella with a more rounded anterior margin. Twelve species were transferred to *Mictosaukia*: *Ptychaspis acamus* Walcott, 1905, *P. callisto* Walcott, 1905, *P. bella* Walcott, 1906, *P. chinhsiensis* Sun, 1924, *Tellerina paichiaensis* Kobayashi, 1933a, *T. coreanica* Kobayashi, 1935, *Calvinella striata* Resser and Endo in Endo and Resser, 1937, *C. diversa* Endo in Endo and Resser, 1937, *Saukia globosa* Robison and Pantoja-Alor, 1968, *S. wirtzi* Wolfart, 1970, *S. rotunda* Kushan, 1973, and *S.* cf. *S. rotunda* Kushan (Dean, 1982). Subsequently established new species include *Mictosaukia perplexa* Shergold, 1975, *M. luanheensis* Zhou and Zhang, 1978, *M. dayangchaensis* Kuo and An in Kuo et al., 1982, *M. maculata* Qian, 1985b, *M. angustilimbata* Qian, 1986, *M. guizhouensis* Lu and Zhou, 1990, *M.* (*Mictosaukioidia*) *transita* Lu and Zhou, 1990, *M. combinata* Peng, 1992, and *M. distincta* Duan in Duan et al., 2005 (see also Shergold, 1991, p. 23).

A total of 22 species have hitherto been referred to *Mictosaukia*, but they can be morphologically divided into the two groups; *Mictosaukia paichiaensis* (Kobayashi, 1933a) cannot be evaluated due to poor preservation of a single cranidium, while *M. distincta* can be assigned to *Saukiella* Ulrich and Resser, 1933 in having a short preglabellar field (see Appendix 1). The first group is characterized by a gently downsloping anterior cranidial border, generally transverse abaxial portions of anterior border furrow, moderately large palpebral lobes located close to axial furrows, and a relatively large pygidium with four axial rings and wide and slightly concave posterior border (Fig. 3.1). The oblique direction of the abaxial parts of anterior border furrow, emphasized by Shergold (1975) as a distinct feature of *Mictosaukia*, is in fact variable among the species of the first group: convergent (*M. luanheensis* and *M.* cf. *M. globosa*), transverse (*M. chinhsiensis*, *M. striata*, and *M. wirtzi*), or slightly divergent forward to intersect preocular suture posterior to anterolateral cranidial corners (*M.* cf. *M. rotunda*). It is variable even within species (e.g., *M. orientalis*, *M. globosa*, and *M. rotunda*).

The second group is differentiated from the first group in having the anterior border downsloping as steep as the glabellar front, diagonally bent forward abaxial portions of anterior border furrow, relatively small palpebral lobes located away from the glabella, vincular structure on the librigenal doublure, and a small transverse pygidium with four or fewer axial rings and narrow border (Fig. 3.2–3.4). These characters, especially abaxial portions of anterior border furrow and vincular structure, were noticed by Shergold (1975) to differentiate *Mictosaukia* from other genera, but are in fact the diagnostic features of *Eosaukia* Lu, 1954. Hence, the species of the second group are transferred to *Eosaukia*, while those of the first group are retained in *Mictosaukia* (Appendix 1).

Mictosaukia is morpholgically similar to *Saukia* Walcott, 1914 and hence these genera seem to be phylogenetically related to each other. However, it is difficult to evaluate their relationship due to uncertain generic concepts of some Laurentian dikelocephalids (Raasch, 1951; Robison and Pantoja-Alor, 1968; Taylor and Halley, 1974; Ludvigsen and Westrop, 1983; Fortey, 1994). In this study *Mictosaukia* is provisionally differentiated from *Saukia* by its generally narrow glabella, narrow pygidial axis, and faint S2.

Pseudocalvinella Qiu, 1984, based on *P. spinosa* Qiu, 1984 from the upper Furongian of southern Anhui, South China is closely similar to *M. orientalis* or *M. striata* in lacking a preglabellar field and having relatively small palpebral lobes close to axial furrows, and slightly divergent preocular sutures. Tuberculate cranidia of *Pseudocalvinella spinosa* are indistinguishable from those of *M. striata*, and hence *P. spinosa* is herein treated as conspecific with *M. striata*. Accordingly, *Pseudocalvinella* becomes a junior subjective synonym of *Mictosaukia*.

MICTOSAUKIA CF. M. GLOBOSA
(Robison and Pantoja-Alor, 1968)
Figures 3.1, 4

cf. *Saukia globosa* ROBISON AND PANTOJA-ALOR, 1968, p. 795, pl. 104, figs. 12–19.

cf. *Mictosaukia globosa* (ROBISON AND PANTOJA-ALOR). SHERGOLD, 1975, p. 143; SHERGOLD, 1991, p. 23.

Description.—Cranidium moderately convex, subtrapezoidal in outline. Glabella subrectangular, parallel-sided, ~1.5 times longer than wide in late meraspides and as long as wide

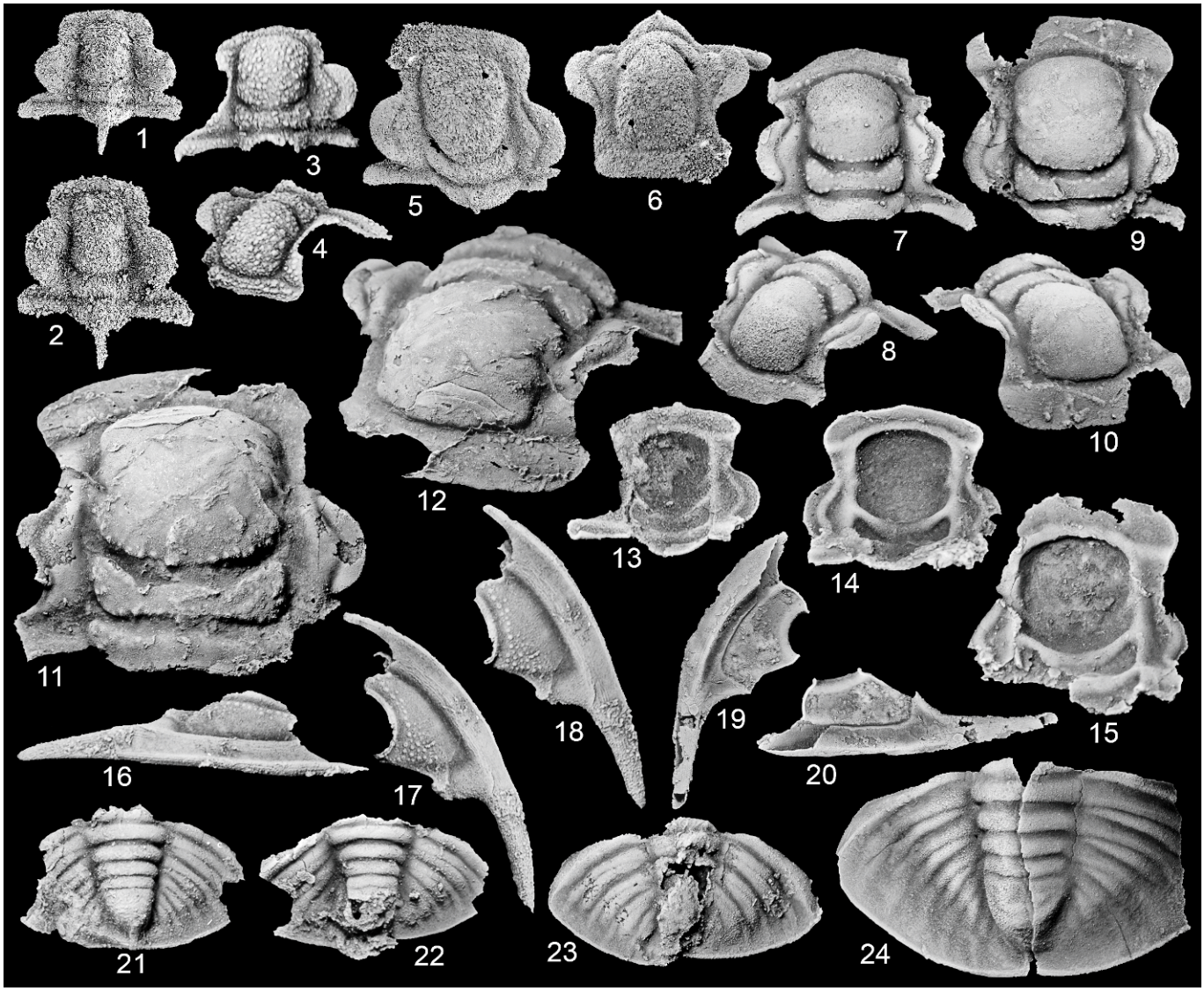

FIGURE 4—*Mictosaukia* cf. *M. globosa* Robison and Pantoja-Alor, 1968 from the upper part of the *Eosaukia* fauna of the Dongjeom Formation, Seokgaejae section, Taebaek Group, Taebaeksan Basin, Korea. *1, 2,* scanning electron microscopic (SEM) images of juvenile cranidia, SNUP3091 and SNUP3092 respectively, ×15; *3, 4,* SNUP3093, juvenile cranidium with tubercles covering the whole dorsal surface and subhorizontal abaxial parts of anterior border furrow; dorsal and oblique anterolateral views, ×10; *5, 6,* SEM images of SNUP3094, juvenile cranidium with a reduced occipital spine; dorsal and oblique anterior views, ×10; *7, 8,* SNUP3095, holaspid cranidium showing traces of lirae on anterior border and tubercles with limited distribution; dorsal and oblique anterolateral views, ×4; *9, 10,* SNUP3096, holaspid cranidium with a long preglabellar area; dorsal and oblique anterolateral views, ×4; *11, 12,* SNUP3097, large cranidium showing a relatively wide glabella, dorsal and oblique anterolateral views, ×3; *13–15,* SNUP3098, SNUP3099, and SNUP3100, ventral views of fragmentary cranidia; ×7, ×4, ×4; *16–18,* SNUP3101, librigena showing a striated lateral border and a genal spine and tubercles on adaxial part of librigenal field, lateral, dorsal, and inclined dorsal views, ×6; *19, 20,* SNUP3102, librigena showing a flat doublure folded upward below lateral border furrow, oblique ventral and lateral views, ×2; *21,* SNUP3103, pygidium showing straight axial furrows and relatively narrow and concave border, ×6; *22,* SNUP3104, pygidium with relatively wide anterior two axial rings, ×5; *23,* SNUP3103, pygidium showing effaced interpleural furrows and narrow but concave border, ×4; *24,* SNUP3106, largest pygidium with gently tapering axis and wide and concave border, ×3. All of the specimens, except SNUP3091, SNUP3092, and SNUP3094 from unit SCO23, are from unit SCO24.

in late holaspides; glabellar front broadly rounded; S1 transglabellar, deeply incised, arched rearward; S2 narrow, straight, oblique backward; S3 faint, narrow, oblique forward. SO simple but slightly curved forward medially; LO slightly wider than L1, medially as long as L1, bearing occipital spine or node in smaller cranidia, but lacking it in larger ones. Anterior cranidial margin gently curved forward; anterior cranidial border slightly longer than 10% of cranidial length, nearly uniform in length, weakly convex, moderately downsloping anteriorly, nearly transverse in small cranidia and broadly curved forward in large cranidia; anterior border furrow as deep as axial furrows, medially curved forward and laterally transverse in small cranidia (Figs. 4.1, 4.3) or directed slightly rearward in larger ones; preglabellar field absent. Fixigenal area narrow; palpebral area approximately ¼ of glabellar width at palpebral midpoint. Palpebral lobes arcuate, close to axial furrows, approximately ½ of glabellar length, defined by clearly incised palpebral furrow. Posterior area of fixigena very short, approximately 50% of glabellar width; posterior border furrow deep, transverse or slightly curved backward abaxially; posterior border short, becoming longer abaxially; posterior cranidial margin arched backward. Facial suture opisthoparian; anterior branches moderately divergent, straight to weakly convex, parallel-sided in small cranidia; posterior branches strongly divergent straight. Surface entirely tuberculate in small cranidia, but partly

tuberculate along SO, S1, and anterior border furrow in larger cranidia.

Librigena moderately convex, longer than wide. Genal field moderately downsloping abaxially, narrow. Eye socle elevated; eye socle furrow shallow. Lateral border as wide as anterior portion of genal field, uniform in width, defined by clearly incised lateral border furrow, prolonging backward into stout and long genal spine; genal spine directed backward; posterior border furrow confluent with lateral border furrow at acute angle; posterior border as long as width of lateral border; doublure flat, as wide as lateral border. Lateral border and genal spine ornamented with parallel lirae. Adaxial part of librigenal field tuberculate.

Pygidium moderately convex, subtriangular in outline. Anterior margin broadly rounded. Pygidial axis strongly convex, moderately tapering rearward, approximately 30% of pygidial width, with four axial rings and a terminal piece; articulating half ring as long as anteriormost axial ring; terminal piece twice as long as anteriormost axial ring, parabolic in outline; postaxial ridge faint. Pleural field slightly convex; pleural furrow deep and wide, gently curved backwards; interpleural furrow shallow but distinct, broadly curved; opisthopleurae extending faintly to pygidial margin whereas propleurae fading out before margin. Posterior border wide, comparatively wider in larger pygidia, concave. Surface smooth.

Material examined.—Sixteen cranidia, 44 librigenae, and 11 pygidia.

Occurrence.—Units SCO23 and 24, Dongjeom Formation, Taebaeksan Basin, Korea.

Discussion.—*Mictosaukia* cf. *M. globosa* is comparable to the species of *Mictosaukia* from Afghanistan, Iran, Turkey, and Mexico in having a relatively wide glabella and partially ornamented cranidial surface. However, *Mictosaukia* cf. *M. globosa* can be distinguished from *Mictosaukia wirtzi* from Afghanistan (Wolfart, 1970) which has densely-spaced tubercles on the glabella, shorter and more inflated palpebral lobes, lirae on librigenal field, narrow librigenal doublure, and a more acute genal angle. *Mictosaukia rotunda* from Iran (Kushan, 1973) is distinct in having densely-spaced tubercles on the entire glabella. *Mictosaukia* cf. *M. rotunda* from Turkey (Dean, 1982) differs in possessing a raised rim-like pygidial border. *Mictosaukia* cf. *M. globosa* of the present collection most closely resembles *Mictosaukia globosa* from Mexico in having a wide glabella in large cranidia and partly distributed tubercles on adaxial part of librigenal field. However, definite assignment to the species is pending, because a large pygidium at hand (Fig. 4.24) is subtriangular rather than elliptical as in *Mictosaukia globosa* of comparable size (Robison and Pantoja-Alor, 1968, pl. 104, fig. 19). In addition, *Mictosaukia* cf. *M. globosa* has less curved interpleural furrows and a wider pygidial border than *M. globosa*.

Genus Eosaukia Lu, 1954

Eosaukia Lu, 1954, p. 143; Kobayashi, 1957, p. 375; Kobayashi, 1960, p. 404; Lu and Zhou, 1990, p. 31; Shergold, 1991, p. 21; Fortey, 1994, p. 48.

Scolosaukia Sun, 1990, p. 102.

Mictosaukioidia Lu and Zhou, 1990, p. 34.

Type species.—*Eosaukia latilimbata* Lu, 1954 from the Sandu Shale, Guizhou, South China (by original designation).

Other species.—See Appendices 1 and 2.

Emended diagnosis.—A genus of Dikelocephalidae with strongly convex cephalon. Cranidium subtrapezoidal; preglabellar area undifferentiated; anterior border furrow abaxially well-defined and sharply bent toward anterolateral corners of cranidium; three pairs of glabellar furrows present; S2 and S3 very narrow, directed backward and forward respectively; palpebral lobes generally shorter than ½ of glabellar length, away from axial furrows; prominent apodemes on underside of anterolateral corners of glabella. Librigena with narrow lateral border and vincular structure on posterior doublure. Pygidium micropygous; axis with two to four axial rings; posterior border very narrow, rim-like.

Discussion.—*Eosaukia* was established on a single, fully articulated but slightly deformed specimen of *E. latilimbata* Lu, 1954 from Guizhou, South China and is distinguished from the typical Laurentian dikelocephalids such as *Saukia*, *Calvinella*, and *Tellerina* by the deep, abaxially diagonal anterior border furrow which sharply directs toward subangulate anterolateral corners of cranidium. The Laurentian genera have shallow abaxial portions of anterior border furrow that are slightly divergent to convergent forward. The abaxial portions of anterior border furrow of *Eosaukia* are strongly downsloping forwards in anterior view (Fig. 3). In addition, *Eosaukia* is distinct in having a small pygidium with four or less axial rings, a transversely elongated outline, and a narrow border (Lu, 1954; Kobayashi, 1957; Shergold et al., 1988; Shergold, 1991).

Scolosaukia Sun, 1990 was erected based on "*Calvinella*" *micropora*, which however clearly demonstrates the morphological features of *Eosaukia* (see below), and hence *Scolosaukia* is synonymized with *Eosaukia*. Another species of "*Scolosaukia*", *S. lineata* Sun, 1990, cannot be evaluated due to the poor preservation of the type cranidium. *Mictosaukioidia* Lu and Zhou, 1990 was established as a subgenus of *Mictosaukia* for those cranidia with small palpebral lobes and longer posterolateral projection of fixigena, which can however be accommodated within a range of morphological variation of *Eosaukia*.

Vincular structure on librigenal doublure is among the unique morphological features of *Eosaukia* (Figs. 5, 6; *E. buravasi* [Kobayashi, 1957, pl. 5, figs. 8–9], *E. perplexa* [Shergold, 1975, pl. 24, fig. 3], and *E. angustilimbata* [Qian, 1986, pl. 71, fig. 11; pl. 72, fig. 2]), and have not been documented in other dikelocephalids. In addition, silicified cranidia of *E. micropora* and *E. bella* in the present collections bear prominent apodemes on internal side of anterolateral corners of glabella (Figs. 5, 6).

Eosaukia micropora (Qian, 1985a)
Figures 3.2, 5

Calvinella micropora Qian, 1985a, p. 81, pl. 18, figs. 1–9; Qian, 1986, p. 281, pl. 72, figs. 6, 9, 10, *non* 7; pl. 73, figs. 2, 6, 11; Duan, An, and Zhao, 1986, p. 49, pl. 7, figs. 1–7.

Calvinella granulosa Zhang and Wang, 1985, p. 474, pl. 143, figs. 2–4.

Mictosaukia aff. *walcotti* (Mansuy) Zhou and Zhang, 1985, p. 106, pl. 5, figs. 11, 12.

Calvinella latilimbata Duan and An in Duan, An, and Zhao, 1986, p. 49, pl. 7, figs. 8–10.

Scolosaukia lanceata Sun, 1990, p. 104, pl. 1, figs. 4–6.

Scolosaukia micropora (Qian). Sun, 1990, p. 105, (in part) pl. 1, figs. 8, 9, 12, *non* 10, 11.

Emended diagnosis.—A species of *Eosaukia* with long occipital and genal spines. Cranidium densely tuberculate, except on occipital spine and palpebral lobes which are ornamented with lirae; palpebral lobes small, semicircular. Pygidium transversely elongate; axis approximately 30% of

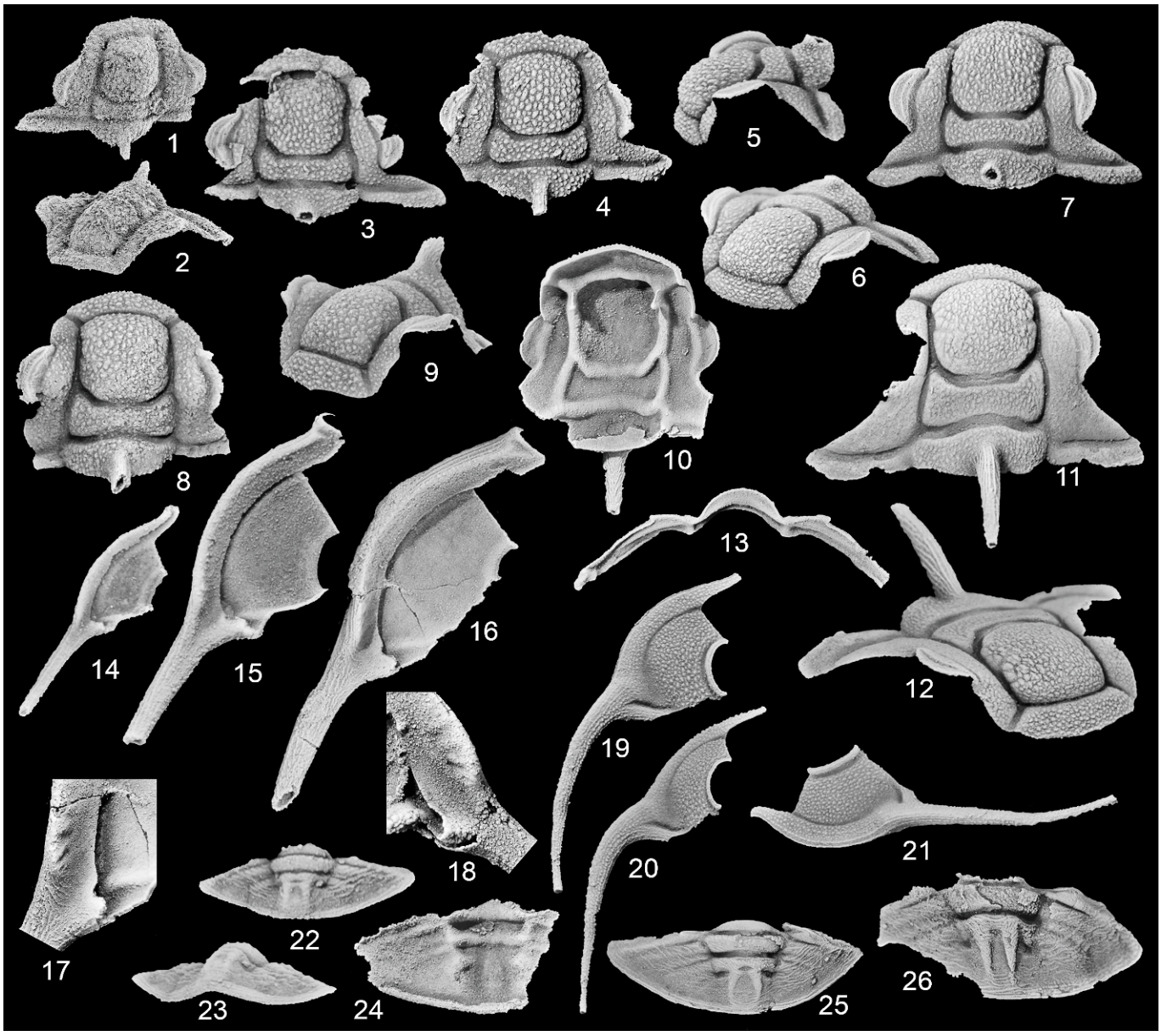

FIGURE 5—*Eosaukia micropora* (Qian, 1985) from the *Eosaukia* fauna of the Hwajeol and Dongjeom formations, Seokgaejae section, Taebaek Group, Taebaeksan Basin, Korea. *1, 2,* SNUP3107 from unit SCO11, SEM images of juvenile cranidium with a short occipital spine, faint tubercles, apodemal pits, and diagonally running abaxial part of anterior border furrows, dorsal and oblique anterolateral views, ×5; *3,* SNUP3108 from unit SCO19, early holaspid cranidium showing a gently constricted glabella, ×5; *4,* SNUP3109 from unit SCO11, holaspid cranidium, ×5; *5–7,* SNUP3110 from unit SCO1, slightly distorted cranidium showing diagonal direction of abaxial part of anterior border furrow, oblique lateral, oblique anterolateral, and dorsal views, ×5; *8, 9,* SNUP3111 from SCO5, cranidium, dorsal and oblique anterolateral views, ×5; *10,* SNUP3112 from unit SCO5, cranidium showing prominent apodemes and long occipital spine, ×4; *11, 12,* SNUP3007 from unit SCO5, large cranidium showing relatively small palpebral lobes and a long occipital spine, dorsal and oblique anterolateral views, ×4; *13,* SNUP3113 from unit SCO1, anterior view of thoracic segment, ×3.3; *14,* SNUP3114 from unit SCO5, ventral view of small librigena, ×8; *15,* SNUP3115 from unit SCO1, ventral view of nearly complete librigena, ×6; *16, 17,* SNUP3116 from unit SCO5, ventral view of large librigena showing lirae on doublure, panderian structures, and vincular notches at genal angle, ×4, ×6; *18,* SNUP3117 from unit SCO17, ventral view of fragmentary librigena showing vincular notches, ×6; *19–21,* SNUP3118 from unit SCO1, librigena with strongly curved genal spine and linearly aligned fine tubercles on genal spine, inclined dorsal, dorsal, and oblique lateral views, ×4; *22, 23,* SNUP3119 from unit SCO5, small pygidium with narrow border, dorsal and oblique posterior views, ×9; *24,* SNUP3120 from unit SCO11, ventral view of pygidium showing narrow doublure, ×5; *25,* SNUP3121 from unit SCO11, large pygidium with two axial rings and two longitudinal ridges on terminal piece, ×4; *26,* SNUP3122 from unit SCO11, large pygidium showing prominent ridges on terminal piece, ×4.

pygidial width, with two axial rings and a terminal piece bearing two longitudinal ridges.

Material examined.—Ninety-five cranidia, 50 librigenae, 15 pygidia, and 9 thoracic segments.

Occurrence.—Units SCO1, 5, 11, 13, 17, 19, and 21; Hwajeol and Dongjeom formations, Taebaeksan Basin, Korea; see Appendix 2 for other occurrences of the species.

Description.—Cranidium convex, trapezoidal in outline. Glabella 1.1 to 1.3 times longer than wide, gently tapering forward; glabellar front straight in late meraspis and rounded in holaspis; axial furrows deep; preglabellar furrow as deep as axial furrows; pair of stout and long apodemes on underside of anterolateral corners of glabella; S1 transglabellar, laterally bent forward; S2 very narrow, directed backward; S3 faint,

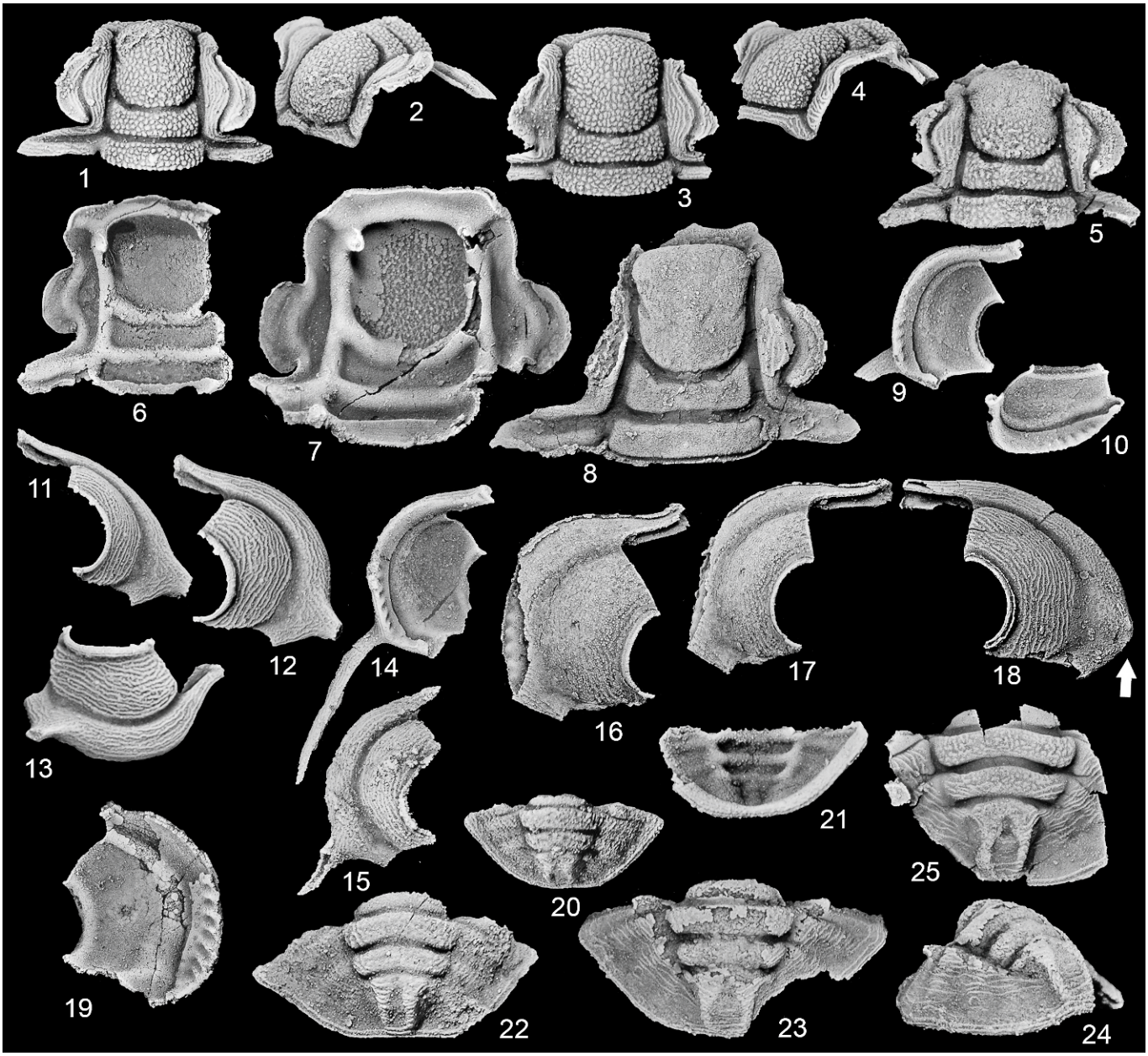

FIGURE 6—*Eosaukia bella* (Walcott, 1906) from the *Eosaukia* fauna of the Hwajeol and Dongjeom formations, Seokgaejae section, Taebaek Group, Taebaeksan Basin, Korea. *1, 2,* SNUP3006 from unit SCO11, cranidium showing a short anterior border and a vestigial occipital node, dorsal and oblique anterolateral views, ×7; *3, 4,* SNUP3123 from unit SCO11, incomplete cranidium with weakly constricted glabella, dorsal and oblique anterolateral views, ×6; *5,* SNUP3124 from unit SCO13, cranidium with anteriorly constricted glabella, ×4; *6,* SNUP3125 from unit SCO11, ventral view of cranidium showing prominent apodemes, ×4; *7,* SNUP3126 from unit SCO11, ventral view of large cranidium showing prominent apodemes, diagonal direction of abaxial part of anterior border furrow, and short anterior border, ×4; *8,* SNUP3127 from unit SCO13, exfoliated large cranidium showing a weakly constricted and elongated glabella, relatively short palpebral lobes, and long preocular suture, ×3.5; *9, 10,* SNUP3128 from unit SCO11, librigena showing distinct vincular furrows, inclined ventral and lateral views, ×5; *11–13,* SNUP3129 from unit SCO5, librigena showing striated prosopon, dorsal, inclined dorsal, and oblique lateral views, ×5; *14,* SNUP3130 from unit SCO5, ventral view of librigena showing distinct vincular notches and a long genal spine, ×5; *15,* SNUP3131 from unit SCO13, librigena with relatively narrow base of genal spine, ×5; *16, 17,* SNUP3132 from unit SCO11, large librigena showing a long preocular suture and impression of vincular structure under exfoliated test, inclined dorsal and dorsal views, ×4; *18,* SNUP3133 from unit SCO11, large librigena with a long preocular suture, arrow denotes genal angle lacking genal spine, ×4; *19,* SNUP3134 from unit SCO13, ventral view of fragmentary librigena showing vincular notches, ×3; *20,* SNUP3135 from unit SCO11, small pygidium with two distinct axial rings and longitudinal ridges on terminal piece, ×9; *21,* SNUP3136 from unit SCO11, ventral view of pygidium with narrow doublure, ×9; *22,* SNUP3137 from unit SCO11, pygidium showing outline of terminal piece, distinct longitudinal ridges on terminal piece, and narrow border, ×9; *23, 24,* SNUP3138 from unit SCO13, pygidium with strong convexity, fulcral processes close to axis, and steeply downsloping pleural area, dorsal and oblique lateral views, ×6; *25,* SNUP3139 from unit SCO11, large pygidium showing prominent longitudinal ridges on terminal piece, ×5.

very narrow, directed forward. SO simple in meraspis but composite in holaspis, as deep as axial furrows; LO approximately 20% of cranidial length, slightly wider than L1, bearing stout occipital spine. Anterior cranidial margin rounded or bluntly pointed medially; anterior border 10% to 12% of cranidial length, convex, steeply downsloping anteriorly, nearly uniform in length; preglabellar field absent. Fixigenal area as wide as palpebral lobe, approximately 30% of glabellar width at palpebral midpoint. Palpebral lobes semicircular, located at glabellar midlength, 35% to 40% of

cranidial length, defined by shallow but distinct palpebral furrows. Posterior area of fixigena triangular, 10% to 15% of cranidial length; posterior border furrow transverse to abaxially bent forward, as deep as SO; posterior border short, abaxially becoming longer; posterior margin gently arched backward. Facial suture opisthoparian; anterior branches short, convergent forward, straight in late meraspis, convex in holaspis; posterior branches nearly transverse in smaller specimens, but divergent straight in larger specimens. Surface densely tuberculate except on palpebral lobes and occipital spine which are ornamented with lirae; tubercles polygonal in plan view, variable in size, less distinct in juvenile specimens, larger on glabella anterior to S1, crudely linearly aligned parallel to anterior margin on anterior border.

Librigena convex, longer than wide. Genal field steeply downsloping abaxially, narrow and high. Eye socle elevated, uniform in height; eye socle furrow moderately deep. Lateral border narrow, as steep as genal field, defined by clearly-incised lateral border furrow, prolonging into slender and long genal spine; genal spine oblique-backward at genal angle, directed rearward posteriorly. Posterior border narrow and short; posterior border furrow deeper than lateral border furrow, but not confluent with lateral border furrow. Doublure as wide and steep as lateral border, keeled at genal angle; small panderian notch and protuberance present near genal angle in larger specimens; three vincular notches at posterior end of keeled doublure in large specimens; doublure sagittaly straight with no space for rostral plate, slightly curved ventrally to form beak-like short process when articulated with conterpart librigena. Genal field and lateral border densely tuberculate; genal spines ornamented with lirae; tubercles larger on adaxial part of genal field.

Pygidium transversely elliptical in outline, moderately convex. Anterior margin broadly rounded; fulcral process distinct, close to axis. Pygidial axis strongly convex, moderately tapering backward, reaching posterior border, approximately 30% of pygidial width, with two axial rings and terminal piece; articulating half ring shorter than anteriormost axial ring; articulating furrow deep; first axial ring strongly tapering backward; second axial ring and terminal piece gently tapering backward; inter-ring furrows as deep as articulating furrow in large specimens; terminal piece as long as approximately 50% of axis excluding articulating half ring; two longitudinal ridges on terminal piece emerging from second axial ring. Pleural and interpleural furrows straight, slightly directing backward, abaxially and posteriorly faint; interpleural furrows shallower than pleural furrows. Posterior border narrow, rim-like, defined by shallow and faint border furrow. Surface covered with anastomosing lirae roughly parallel to posterior margin.

Discussion.—Curiously enough, no formal description was provided for *Eosaukia micropora*, when the species was erected in 1985 (Qian, 1985a, 1986). Hence, *E. micropora* is fully described herein. The species is characterized by a relatively long, triangular posterior area of fixigenae, a long occipital spine, densely tuberculate prosopon, and a transversely elliptical pygidium with two axial rings and two longitudinal ridges on the terminal piece, which are connected to the second axial ring. The pygidium assigned to *E. micropora* by Qian (1986, pl. 72, fig. 7) is better assignable to *E. acuta* (Kuo and Duan in Kuo et al., 1982) in being longer and in having three distinct axial rings and a relatively bulbous terminal piece.

This species resembles *E. walcotti* (Mansuy, 1915), but differs in having a longer glabella with a more rounded anterior margin, narrow and faint S2, a longer occipital spine, two longitudinal ridges on the terminal piece, and the absence of oblique ridges on pygidium which differentiate pleural field from posterior border (Mansuy, 1915, pl. 3, figs. 1x, 1z). Librigenae of *E. micropora* are also different from those of *E. walcotti* (Mansuy, 1915, pl. 3, figs. 1q–s) in that the genal spine is longer and slightly bent outward at genal angle.

Calvinella granulosa Zhang and Wang, 1985 is indistinguishable from *E. micropora* in cranidial morphology. *Mictosaukia* aff. *walcotti* (Zhou and Zhang, 1985, pl. 5, figs. 11, 12) is poorly preserved, but the granulose cranidium with trace of occipital spine, and the transverse pygidium with one distinct axial ring and two longitudinal ridges on terminal piece connected to obscurely-defined second axial ring, are reminiscent of *E. micropora* (Fig. 5.26). The relatively wide cranidium, long anterior cranidial border, and large and long occipital spine of *Calvinella latilimbata* Duan in Duan et al., 1986 are also diagnostic features of the large specimens of *E. micropora*. *Scolosaukia lanceata* Sun, 1990 was differentiated from *S. micropora* by the anteriorly pointed anterior cranidial border, but the silicified cranidia on hand demonstrate a morphological variation of broadly rounded to bluntly acuminate anterior cranidial margin (Figs. 5.1–5.12).

Eosaukia bella (Walcott, 1906)
Figures 3.3, 6

Ptychaspis bella Walcott, 1906, p. 585; Walcott, 1913, p. 180, pl. 17, fig. 9; Kobayashi, 1931, p. 180, pl. 22, fig. 6; Kobayashi, 1933a, p. 129 (list only).

Calvinella bella (Walcott). Kobayashi, 1933b, p. 253 (list only); Hsiang in Lu, Chang, Chu, Chien, and Hsiang, 1965, p. 449, pl. 88, fig. 5.

Mictosaukia bella (Walcott). Shergold, 1975, p. 143; Shergold, 1991, p. 23; Zhang and Jell, 1987, p. 237, pl. 117, fig. 10; pl. 118, fig. 5.

Emended diagnosis.—A species of *Eosaukia* with tuberculate glabella and genal field ornamented with lirae; anterior border very short; palpebral lobes relatively long and wide. Librigena with forwardly diverging posterior margin; genal spines long, diverging backward and gently curving backward abaxially. Pygidium strongly convex; axis wider than 40% of pygidial width, with two axial rings and a terminal piece bearing two longitudinal ridges.

Material examined.—Sixty cranidia, 45 librigenae, and 20 pygidia.

Occurrence.—Units SCO5, 11, 13, 17, 19, and 21; Hwajeol and Dongjeom formations, Taebaeksan Basin, Korea; see Appendix 1 for other occurrences of the species.

Description.—Cranidium convex, subrectangular in outline. Glabella approximately 1.4 times longer than wide, gently tapering forward in small specimens and slightly constricted at middle in large specimens; glabellar front straight to broadly rounded; axial furrows deep; preglabellar furrow as deep as axial furrows; a pair of stout apodemes on underside of anterolateral corners of glabella; S1 transglabellar, laterally bent forward; S2 very narrow, directed backward; S3 faint, very short, directed forward. SO simple, as deep as axial furrows; LO shorter than 20% of cranidial length, slightly wider than L1; occipital node very small in small specimens, but absent in large specimens. Anterior cranidial margin transverse or broadly rounded; anterior border very short, steeply downsloping anteriorly, relatively long in front of anterolateral corners of glabella; preglabellar field absent. Fixigenal area narrow, approximately 30% of glabellar width

at palpebral midpoint. Palpebral lobes crescentic, located slightly behind glabellar midlength, more than 40% to 50% of cranidial length, defined by deep and sinuous palpebral furrows. Posterior area of fixigena short, shorter than 10% of cranidial length; posterior border furrow transverse, as deep as SO; posterior border short, nearly uniform in length; posterior margin nearly transverse. Facial suture opisthoparian; anterior branches short, convergent forward, weakly convex; posterior branches strongly divergent backward, convex. Glabella and occipital ring densely tuberculate; tubercles variable in shape; palpebral lobes, fixigenae, and anterior border ornamented with closely-spaced lirae.

Librigena very convex, longer than wide. Genal field steeply downsloping abaxially, narrow and high, uniform in width. Eye socle elevated, uniform in height; eye socle furrow moderately deep. Lateral border narrow, as steep as genal field, prolonging into slender and long genal spine; lateral border furrow confluent with posterior border furrow, shallow and wide at genal angle; genal spine oblique-backward at genal angle, curved backward, absent in large specimens; genal base wide. Posterior border wider than lateral border; posterior border furrow curved forward, as deep as lateral border furrow; posterior margin gently curved forward. Doublure as wide and steep as lateral border, small panderian notch and protuberance present; six vincular notches at posterior half of doublure when preserved; doublure sagittaly straight with no space for rostral plate, slightly curved ventrally to form beak-like short process when articulated with counterpart librigena. Surface ornamented with closely-spaced anastomosing lirae.

Pygidium convex, semicircular in outline. Anterior margin nearly transverse to broadly rounded; fulcral process distinct, close to axis. Pygidial axis strongly convex and tapering backward, reaching posterior border, approximately 40% of pygidial width, with two axial rings and terminal piece; articulating half ring shorter than anteriormost axial ring; articulating furrow deep; inter-ring furrows as deep as articulating furrow in large specimens; second inter-ring furrow shallow in small specimens; terminal piece shorter than 50% of axial length excluding articulating half ring; two longitudinal ridges present on terminal piece, not connecting to second axial ring. Pleural and interpleural furrows straight, slightly directing backward, abaxially and posteriorly faint; interpleural furrows shallower than pleural furrows. Posterior border very narrow, rim-like, defined by shallow and faint border furrow. Surface covered with anastomosing lirae aligned subparallel to posterior margin.

Discussion.—*Eosaukia bella* was a poorly known species established on an imperfect cranidium, which is characterized by tuberculate glabella, short anterior border, large and crescentic palpebral lobes, and narrow fixigenae ornamented with lirae (Zhang and Jell, 1987, pl. 117, fig. 10; pl. 118, fig. 5). It is distinguished from *E. micropora* in possessing a shorter anterior border, no occipital spine, and a comparatively narrow pygidium with well-defined two axial rings. In addition, lateral and posterior border furrows on librigena are confluent to form a broadly rounded furrow.

This species shows interesting morphological changes with growth: palpebral lobes become shorter and anterior branches of facial sutures get longer (Figs. 6.1–6.8); and genal spines become shorter and eventually disappear in large specimens (Fig. 6.18). A librigena lacking a genal spine was also reported for *E. angustilimbata* (Qian, 1986, pl. 71, fig. 9; pl. 72, figs. 3, 4).

EOSAUKIA ACUTA (Kuo and Duan in Kuo, Duan, and An, 1982)
Figures 3.4, 7

Calvinella acuta KUO AND DUAN IN KUO, DUAN, AND AN, (in part) 1982, p. 19, pl. 3, fig. 12, *non* fig. 11.
Calvinella triangula QIAN, 1985a, p. 81, pl. 17, figs. 12–14.
Mictosaukia striata (RESSER AND ENDO IN ENDO AND RESSER). QIAN, 1986 (in part), pl. 71, fig. 7.
Calvinella micropora QIAN. QIAN, 1986, (in part), pl. 72, fig. 7.

Material examined.—Thirty-three cranidia, two librigenae, and seven pygidia.

Occurrence.—Units SCO21, 22, 23, and 24; Dongjeom Formation, Taebaeksan Basin, Korea; see Appendix 2 for other occurrences of the species.

Description.—Cranidium convex, subtrapezoidal in outline. Glabella 1.3 times longer than wide, gently tapering forward; glabellar front transverse to broadly rounded; axial furrows deep; preglabellar furrow as deep as axial furrows; a pair of short apodemes on underside of anterolateral corners of glabella; S1 transglabellar, deep, laterally bent forward, very shallow medially in small cranidia; S2 narrow, as deep as S1, directed backward; S3 faint, very narrow, transverse. SO simple but medially curved forward in large specimens, as deep as axial furrows; LO approximately 15% of cranidial length, as long as L1, slightly wider than L1, bearing short occipital spine. Anterior cranidial margin medially angulate; anterior border 20% of cranidial length, convex, steeply downsloping anteriorly; preglabellar field absent. Fixigenal area approximately 30% of glabellar width at palpebral midpoint. Palpebral lobes crescentic, located at glabellar midlength, 30% to 40% of cranidial length, defined by clearly-incised palpebral furrows. Posterior area of fixigena triangular, 15% to 18% of cranidial length; posterior border furrow transverse, as deep as SO; posterior border short; posterior margin transverse. Facial suture opisthoparian; anterior branches short, parallel-sided, slightly convex in small specimens, straight in large specimens; posterior branches divergent backward. Glabella and fixigenae densely tuberculate; tubercles circular in plan view, variable in size, crudely linearly aligned parallel to anterior margin in anteriormost part of anterior border; occipital spine ornamented with lirae; palpebral lobes smooth.

Librigena convex, longer than wide. Genal field steeply downsloping abaxially, narrow and high. Lateral border narrow, as steep as genal field, defined by lateral border furrow shallowing posteriorly, prolonging into stout and short genal spine; genal spine directed rearward, slightly curved inward posteriorly. Posterior border narrow and short; posterior border furrow narrow, transverse adaxially and backward-directed abaxially, deeper than lateral border furrow, not confluent with lateral border furrow. Surface ornamented with closely-spaced lirae or linearly aligned tubercles except on smooth abaxial genal field and genal angle.

Pygidium convex, semicircular in outline. Anterior margin nearly transverse. Axis strongly convex and tapering backward, reaching posterior border, approximately 40% of pygidial width, bearing three axial rings and terminal piece; articulating half ring as long as anteriormost axial ring; articulating furrow deep; inter-ring furrows as deep as articulating furrow; second inter-ring furrow shallow in small specimens; terminal piece approximately 40% of axial length excluding articulating half ring; two low longitudinal ridges on terminal piece, connecting to third axial ring. Pleural and

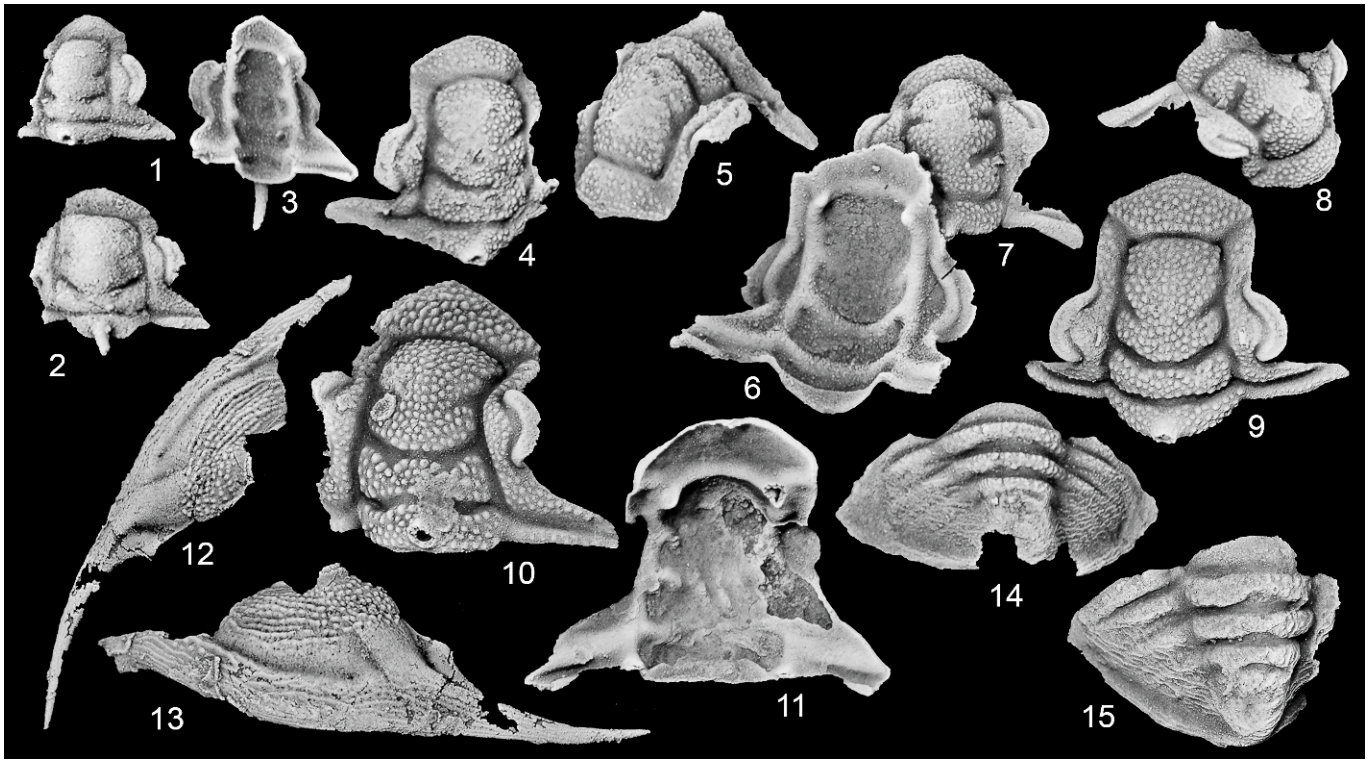

FIGURE 7—*Eosaukia acuta* (Kuo and Duan in Kuo, Duan and An, 1982) from the *Eosaukia* fauna of the Dongjeom Formation, Seokgaejae section, Taebaek Group, Taebaeksan Basin, Korea. *1,* SNUP3140, juvenile cranidium showing medially faint S1 and clearly incised diagonal abaxial parts of anterior border furrow, ×10; *2,* SNUP3141, cranidium with a short occipital spine, ×8; *3,* SNUP3142, ventral view of cranidium with short apodemes and a long occipital spine, ×10; *4, 5,* SNUP3143, cranidium showing apodemal pits and densely spaced tubercles, dorsal and oblique anterolateral views, ×; *6,* SNUP3144, ventral view of cranidium with a long preglabellar area and blunt apodemes, ×6; *7, 8,* SNUP3145, cranidium, dorsal and oblique anterolateral views, ×6; *9,* SNUP3146, cranidium showing apodemal pits, clearly incised diagonal abaxial parts of anterior border furrow and S1, ×6; *10,* SNUP3147, large cranidium with large tubercles and relatively short palpebral lobes, ×5; *11,* SNUP3148, ventral view of cranidium showing incomplete apodemes, ×5; *12, 13,* SNUP3149, librigena showing linearly aligned tubercles on librigenal field, ×4; *14,* SNUP3150, pygidium with three axial rings, low longitudinal ridges on terminal piece, and narrow border, ×8; *15,* SNUP3151, large pygidium, ×5. All of the specimens, except SNUP3141 from unit SCO24 and SNUP3149 from SCO 22, are from SCO21.

interpleural furrows straight, directed backward, abaxially and posteriorly faint; interpleural furrows shallower than pleural furrows. Posterior border narrow, rim-like, defined by shallow and faint border furrow. Surface covered with tubercles on axis and with anastomosing lirae on pleural area aligned subparallel to posterior margin.

Discussion.—*Eosaukia acuta* is characterized by its relatively long and triangular preglabellar area and three pygidial axial rings. Qian (1985a) established *Calvinella triangula* based on a cranidium assigned to *Calvinella acuta* Kuo and Duan in Kuo et al. (1982, pl. 3, fig. 3b), which shows slightly longer anterior border with angulate anterior margin. However, as illustrated by Qian (1985a), length and degree of angulation of the anterior margin is variable. Therefore, *Calvinella triangula* is considered conspecific with *C. acuta*. A pygidium referred to *Calvinella acuta* Kuo and Duan in Kuo et al., 1982, pl. 3, fig. 11 is better assignable to *Pileaspis* Sun, 1990 as it has an obsolete terminal piece and a narrow pleural field which is differentiated from the wide border ornamented with anastomosing lirae.

Eosaukia acuta is comparable to *E. mansuyi* (Hsiang in Lu et al., 1965) from the Furongian of Vietnam in having a long and triangular preglabellar area and three pygidial axial rings. However, the latter is distinct in possessing an acutely pointed preglabellar area, a bulbous glabella prominently encroaching onto preglabellar area anterior to anterior end of the fixigenae, and more clearly incised pleural and interpleural furrows on pygidium.

Genus TAEBAEKSAUKIA new genus

Type species.—*Taebaeksaukia spinata* n. sp.

Diagnosis.—A genus of Dikelocephalidae with very shallow anterior and lateral border furrows; anterior border furrow abaxially wide and obliquely bent forward; preglabellar area short, undifferentiated; palpebral lobes crescentic, large; genal spine long and slender; micropygous pygidium with pauci-segmented axis and a pair of short marginal spines at anterolateral corners.

Etymology.—Referring to the Taebaek Group.

Discussion.—*Taebaeksaukia* n. gen. morphologically resembles *Eosaukia* in having abaxial parts of the anterior cranidial border furrow bent forward diagonally to the anterolateral corners of cranidium, a small pauci-segmented pygidium, and apodemes on internal side of the anterolateral corners of the glabella, but differs in possessing relatively shallow and wide abaxial parts of the anterior cranidial border furrow and lateral border furrows, palpebral lobes located close to axial furrows, no vincular structure on ventral surface of librigena, and a clearly-defined pygidial axial ring. This genus is distinguished from other dikelocephalids in bearing a pair of short spines at the anterolateral corners of the pygidium.

TAEBAEKSAUKIA SPINATA new species
Figures 3.5, 8

Diagnosis.—A species of *Taebaeksaukia* with densely tuberculate prosopon on cephalon; palpebral lobes anteriorly

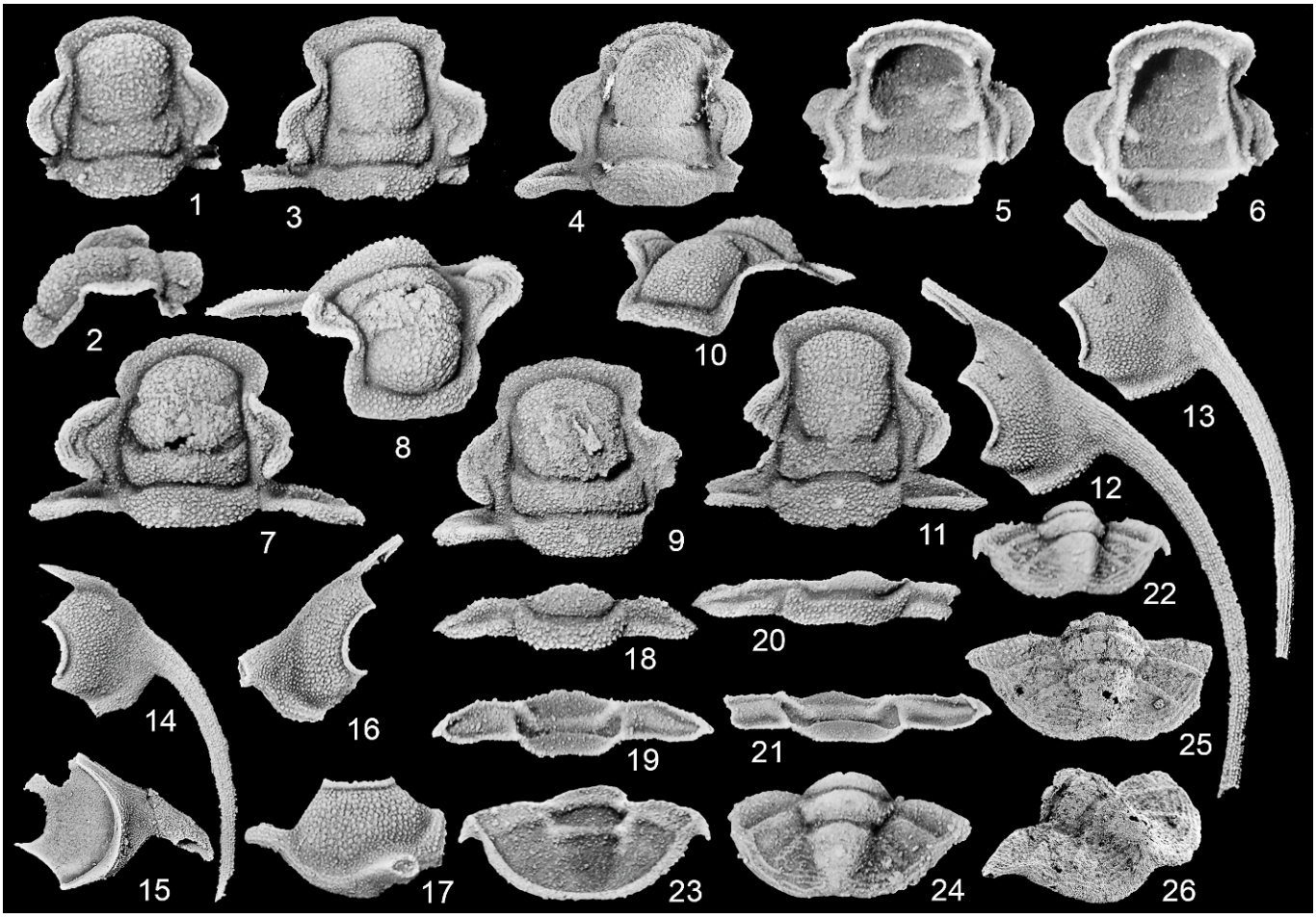

FIGURE 8—*Taebaeksaukia spinata* n. gen. n. sp. from the *Eosaukia* fauna of the Hwajeol and Dongjeom formations, Seokgaejae section, Taebaek Group, Taebaeksan Basin, Korea. *1, 2,* SNUP3152, small cranidium showing very shallow diagonally directing abaxial portions of anterior border furrow, dorsal and oblique lateral views, ×10; *3,* SNUP3153, cranidium with a relatively long preglabellar area and an occipital node, ×9; *4,* SEM image of SNUP3154, cranidium with striated palpebral lobes, ×9; *5,* SNUP3155, ventral view of cranidium with a relatively wide glabella and apodemes, ×9; *6,* SNUP3156, ventral view of cranidium with a relatively narrow glabella and apodemes, ×9; *7, 8,* SNUP3157, cranidium with a relatively wide glabella, faint oblique abaxial portions of anterior border furrow, shallow apodemal pits, and a vestigial occipital node, dorsal and oblique anterolateral views, ×8; *9,* SNUP3158, cranidium with a vestigial occipital node, ×6; *10, 11,* SNUP 3159, holotype, cranidium with a relatively narrow and gently tapering glabella, dorsal and oblique anterolateral views, ×6; *12, 13,* SNUP3160, librigena with faint lateral and posterior border furrow, narrow lateral border, and linearly aligned fine tubercles on the long genal spine, dorsal (×6) and inclined dorsal (×5) views; *14,* SNUP3161, librigena with a long genal spine, ×4; *15,* SNUP3162, ventral view of fragmentary librigena with folded doublure, ×4; *16, 17,* SNUP3163, librigena with fine tubercles, dorsal and lateral views, ×7; *18, 19,* SNUP3164, thoracic segment with pleural marginal spines, dorsal and ventral views, ×8; *20, 21,* SNUP3165, thoracic segment with pleural marginal spine and small panderian notch and protuberance, dorsal and ventral views, ×5.5; *22,* SNUP3166, small pygidium with a pair of anterolateral spines and one axial ring, ×10; *23,* SNUP3167, ventral view of pygidium showing a narrow doublure and a pair of spines, ×10; *24,* SNUP3168, pygidium with parabolic terminal piece reaching posterior margin, ×10; *25, 26,* SEM images of SNUP3169, pygidium showing straight ridges on posterior band of pleurae, dorsal and oblique posterolateral views, ×10. All of the specimens, except SNUP3162, SNUP3163, SNUP3168, and SNUP3169 from SCO11, are from the unit SCO1.

close to axial furrows; genal spine long and slender; pygidium with clearly-defined anteriormost axial ring; terminal piece parabolic in outline, constricted; straight ridges on posterior pleural bands.

Description.—Cranidium convex, subtrapezoidal in outline; anterior cranidial margin broadly rounded; posterior cranidial margin transverse. Glabella convex, gently tapering forward, broadly rounded in front, approximately 85% of preoccipital cranidial length, approximately 40% of cranidial width at L1; 1 to 1.2 times longer than wide; axial furrows moderately deep, slightly curved outward at L1 and inward at anterior end of palpebral lobes; S1 abaxially deep and forwardly directed, medially shallow; S2 short and narrow, oblique backward. SO composite, abaxially deep and parallel to S1, adaxially slightly arched forward and shallow but clearly incised. LO approximately 20% of cranidial length; occipital node faint. Preglabellar furrow shallower than or as deep as axial furrows; a pair of short apodemes on underside of anterolateral corners of glabella. Preglabellar area short, weakly convex, downsloping forward, undifferentiated into preglabellar field and anterior border, nearly uniform in width; anterior margin weakly pointed medially. Palpebral lobes approximately 65% of glabellar length, crescentic, close to axial furrows, located between SO and S2; palpebral midpoint slightly behind abaxial end of S1; anterior end of palpebral lobe very close to axial furrow; posterior end a little away from axial furrow. Palpebral area approximately 30% of glabellar width; posterior area of fixigena approximately 70% of LO width, short. Facial suture opisthoparian; anterior branches divergent forward and then curved inward, slightly convex;

posterior branches strongly divergent rearward. Posterior border furrow deep, transverse; posterior border short and transverse. Surface covered with small and densely-spaced tubercles except on palpebral lobes; palpebral lobes ornamented with faint lirae.

Librigena convex, longer than wide. Genal field convex. Eye socle elevated; eye socle furrow narrow and shallow. Lateral border furrow shallow, wide, and very faint at genal angle; lateral border narrow, prolonging rearward into slender and long genal spine; base of genal spine broad. Posterior border furrow only distinct adaxially; posterior border curved forward abaxially. Surface ornamented with densely-spaced small tubercles except on genal spine where smaller tubercles are linearly aligned; tubercles on genal field slightly larger adaxially.

Thoracic segment convex; articulating half ring as long as axial ring; articulating furrow deep, transverse medially and bent forward abaxially; axial ring uniform in length, transverse medially and bent forward abaxially. Pleura narrow, divided by clearly-incised pleural furrow; articulating facet short and narrow; anterior band abaxially extending into short pleural spine; fulcrum located at halfway between axial furrow and lateral tip. Doublure narrow; panderian notch and protuberance small. Axial ring and posterior band of pleura tuberculate.

Pygidium semicircular in outline, with a pair of short spines at anterolateral corners. Pygidial axis moderately tapering rearward, approximately 35% of pygidial width; anteriormost axial ring clearly differentiated; terminal piece parabolic in outline, constricted anterior to mid-length, reaching posterior margin; axial furrow moderately deep, shallowing backward. Pleural furrow straight, oblique backward, long, band-like, deepening backward; interpleural furrow shallow, slightly oblique backward; pleural and interpleural furrows reaching inner margin of posterior border; anterior band of anteriormost pleura abaxially extending into short border spines; transverse ridges on posterior band of pleura. Pygidial border very narrow, rim-like; doublure narrow. Surface mostly covered by anastomosing lirae parallel to posterior border except tuberculate anterior band of anteriormost pleura.

Etymology.—From (L.) *spina*, spine; referring to a pair of marginal spines on pygidium.

Type.—Holotype, cranidium, SNUP3159 (Figs. 8.10, 8.11), from the unit SCO1, Hwajeol Formation, Seokgaejae section, Korea.

Other materials examined.—More than 80 cranidia, 80 librigenae, five thoracic segments, and 14 pygidia.

Occurrence.—Units SCO1, 5, 11, 13, and 19; Hwajeol and Dongjeom formations, Taebaek Group, Taebaeksan Basin, Korea.

GEOLOGIC AGE AND CORRELATION

The "*Mictosaukia*" fauna of the Taebaeksan Basin (Choi et al., 2004) is characterized by the dominance of the dikelocephalid species described above. The specimens referable to the dikelocephalids represent more than 50% of the collection in abundance: *Eosaukia micropora* (15.2%), *E. bella* (11.2%), *E. acuta* (3.7%), *Mictosaukia* cf. *M. globosa* (6.2%), and *Taebaeksaukia spinata* n. gen. n. sp. (16.1%). The total number of trilobite specimens recovered in this study is approximately 1,150. *Eosaukia acuta* and *Mictosaukia* cf. *M. globosa* are restricted to the uppermost 1 m thick interval (SCO 21 to 24), whereas *Taebaeksaukia spinata*, *Eosaukia micropora*, and *E. bella* occur in the lower 8.5 m thick interval (SCO1 to 21) (Fig. 2). Based on the dominance of *Eosaukia*, the "*Mictosaukia*" fauna is renamed herein as the *Eosaukia* fauna. At present, the lower boundary of the *Eosaukia* fauna cannot be defined because trilobites are rare in the interval below. Provisionally, the *Eosaukia* fauna is considered to be underlain by the *Quadraticephalus* Zone (Sohn and Choi, 2007; Fig. 2).

Aside from the dikelocephalids mentioned above, the *Eosaukia* fauna comprises *Micragnostus*, *Koldinioidia*, *Changia*, *Haniwa*, and *Pagodia* (Choi et al., 2003). Choi et al. (2003) preliminarily correlated the "*Mictosaukia*" fauna with the uppermost Cambrian *Fatocephalus* fauna of the Yeongwol Group in the Taebaeksan Basin, the *Mictosaukia-Fatocephalus* zones of North and South China, and the Assemblage 1 of the Pacoota Sandstone of Australia. The taxonomic reappraisal on the dikelocephalids made in this study enables correlation of the *Eosaukia* fauna more accurately with the trilobite faunas from other parts of the world.

The taxonomic reassessment of *Mictosaukia* reveals that it is confined to the uppermost Cambrian (Appendix 1); although *Mictosaukia globosa* (Robison and Pantoja-Alor, 1968) from Mexico, *M. wirtzi* (Wolfart, 1970) from Afghanistan, and *M.* cf. *M. rotunda* (Kushan in Dean, 1982) from Turkey were originally reported to occur in the lower Tremadocian, their latest Cambrian age has been confirmed by recent studies (Fortey, 1994; Peng et al., 1999; Landing et al., 2007). Notably, the occurrences of *Mictosaukia* are restricted to the *Mictosaukia* faunas in North China (Appendix 1; Resser and Endo in Endo and Resser, 1937; Nan, 1976; Kuo et al., 1982; Qian, 1985a, 1986; Zhou and Zhang, 1978, 1985; Zhang and Wang, 1985; Duan et al., 1986; Zhang and Jell, 1987; Zhu and Wittke, 1989). In South China, *Mictosaukia* ranges from the "*Pseudocalvinella*" assemblage (Qiu, 1984), equivalent to the middle Fengshanian of North China, to the *Mictosaukia striata-Fatocephalus* Zone (uppermost Fengshanian; Peng, 1983, 1984, 1992) (Appendix 1).

Eosaukia is endemic to Gondwana, reported mainly from the Furongian of South China and North China (Fig. 9; Appendices 1, 2). The oldest species of *Eosaukia* is *E. combinata* from the *Probilacunaspis nasalis-Peichiashania hunanensis* Zone of Hunan, South China (Peng, 1992), equivalent to the lower Fengshanian of North China (Geyer and Shergold, 2000). The stratigraphic occurrence data and the geographic distribution of *Eosaukia* suggest that it may have originated from South China during the early Fengshanian and rapidly diversified and dispersed into other areas of Gondwana during late Fengshanian.

In summary, the *Eosaukia* fauna of the Taebaeksan Basin is closely comparable to the upper Fengshanian *Mictosaukia* faunas of North China (Fig. 9), which is supported by the co-occurrence of *Mictosaukia* and *Eosaukia*. Although correlation of the *Eosaukia* fauna with those outside of the Sino-Korean block is not easy, it is noteworthy that a number of species referable to *Eosaukia* also occur in the upper Furongian of South China, equivalent to the upper Fengshanian in North Chinese standard (Appendices 1, 2). *Mictosaukia striata* in South China was reported from the *Mictosaukia striata–Fatocephalus* Zone of Hunan (Peng, 1983, 1984, 1992) and the middle Fengshanian-equivalent "*Pseudocalvinella*" assemblage of southern Anhui (Qiu, 1984; Appendix 1). Therefore, the *Eosaukia* fauna of Korea can be correlated with the interval including the *Mictosaukia striata–Fatocephalus* Zone and possibly slightly older horizons of South China, which is contemporaneous with the upper Fengshanian of North China (Fig. 9).

The *Eosaukia* fauna is also comparable, but less convincingly, with the upper Payntonian "*Mictosaukia*" *perplexa*

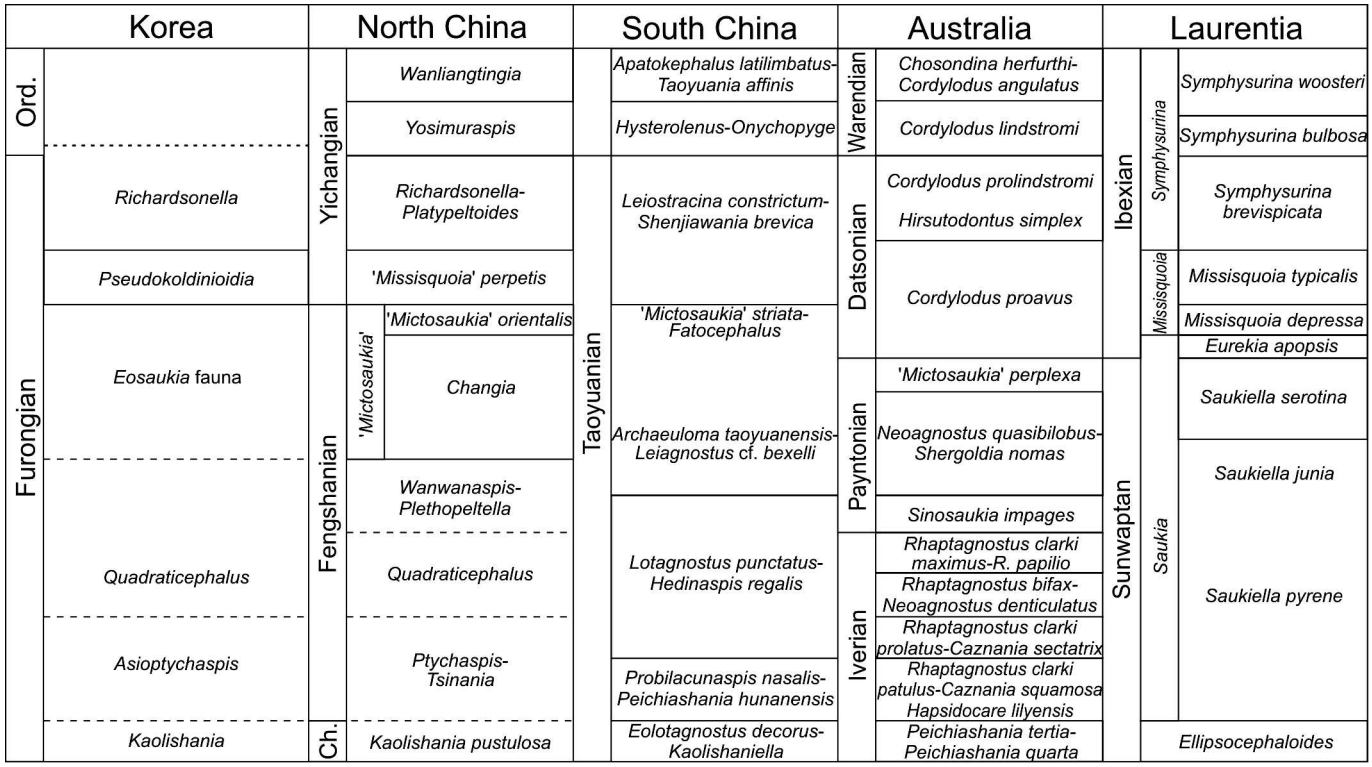

FIGURE 9—Biostratigraphic correlation of the *Eosaukia* fauna of the Taebaek Group, Taebaeksan Basin, Korea with the biozones of other parts of the world. Modified from Zhou et al. (1985), Geyer and Shergold (2000), Miller et al. (2003), Zhang (2003), and Lee and Choi (2007).

Zone of Queensland based on the occurrences of *E. perplexa* and *E. solitaria* (Fig. 9), and with the Assemblage 1 of Northern Territory on *E.* sp. cf. *E. walcotti* in Australia (Shergold, 1991). The occurrences of *E. walcotti* in Vietnam (Mansuy, 1915, 1916), *E. buravasi* in Thailand (Kobayashi, 1957; Shergold et al., 1988), *E.* cf. *E. walcotti* in Oman (Fortey, 1994), *Mictosaukia globosa* in Mexico, *M. wirtzi* in Afghanistan, *M. rotunda* in Iran, and *M.* cf. *M. rotunda* in Turkey suggest a biogeographic link between the Sino-Korean block and peri-Gondwanan regions during the latest Cambrian.

It is difficult to correlate the *Eosaukia* fauna with the biozones of Laurentia owing to the lack of co-occurring dikelocephalid taxa. The *Mictosaukia orientalis* Subzone of North China, correlatable with the *Eosaukia* fauna, has been correlated with the ''*Missisquoia*'' *depressa* Subzone of Laurentia based on the occurrence of *Tangshanaspis* (Zhou et al., 1985; Lee et al., 2008). In addition, the *Pseudokoldinioidia* fauna underlain by the *Eosaukia* fauna in the Taebaek Group was treated contemporaneous with the uppermost Cambrian ''*Missisquoia*'' *perpetis* Zone of North China and the ''*Missisquoia typicalis*'' Subzone of North America, which overlies the *Mictosaukia orientalis* and ''*Missisquoia*'' *depressa* subzones, respectively (Lee and Choi, 2007). This correlation is also consistent with the result based on the conodont successions 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). Therefore, the *Eosaukia* fauna is correlatable with the interval below the ''*Missisquoia*'' *typicalis* Subzone, including the lower Ibexian ''*Missisquoia*'' *depressa* Subzone, and the upper part of the *Saukia* zone where dikelocephalids occur in abundance (Fig. 9).

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APPENDIX *1*—Taxonomic reassessment and occurrences of the 22 species which were previously assigned to *Mictosaukia*. The first group is retained to *Mictosaukia*, while the second group is assignable to *Eosaukia*. The "—" represents information not available.

Species described	Reference	Formation	Biozone (age)	Locality	Other occurrences/synonymy	Reassessment
First group						
Tellerina paichiaensis	Kobayashi, 1933a, p. 130	—	*Tsinania canens* Zone	Liaoning, N. China		difficult to assess
Mictosaukia distincta	Duan in Duan et al., 2005, p. 197	Fengshan/ Chaomidian	late Fengshanian	Liaoning/Jilin, N. China		*Saukiella distincta*
Ptychaspis chinhsiensis	Sun, 1924, p. 64	—	late Cambrian	Liaoning, N. China		*Mictosaukia chinhsiensis*
Calvinella striata	Resser and Endo in Endo and Resser, 1937, p. 189	Wanwan	associated with "*Tellerina*" *orientalis* and *Koldinioidia infrequens*	Liaoning, N. China	Yin and Li, 1978, p. 517, Maotian Fm., Guizhou, S. China; =*Pseudocalvinella spinosa* Qiu, 1984, p. 337, Tangcun Fm., S. Anhui, S. China; =*Mictosaukia striata* in Peng, 1984, p. 350, *Mictosaukia striata-Fatocephalus* Zone, Hunan, S. China; Qian, 1985a, p. 81, *Mictosaukia-Fatocephalus* Zone, Jilin, Inner Mongolia, Shanxi, N. China; Zhou and Zhang, 1985, p. 104, *Mictosaukia* Zone, Liaoning, Jilin, Inner Mongolia, Shanxi; Qian, 1986, p. 278, *Mictosaukia striata* Zone, Jilin, N. China	*Mictosaukia striata*
Tellerina orientalis	Resser and Endo in Endo and Resser, 1937, p. 293	Wanwan	associated with "*Calvinella*" *striata*, and *Koldinioidia infrequens*	Liaoning, N. China	=*Mictosaukia orientalis* in *Mictosaukia orientalis* Zone, N. China (Zhou and Zhang, 1978, p. 7; Zhou and Zhang, 1985, p. 102; Zhang and Wang, 1985, p. 474; Zhang and Jell, 1987, p. 235; Zhu and Wittke, 1989, p. 228); =*Saukia acamus* var. *fengtiensis* Sun, 1935, p. 47, *Saukia acamus* Zone, Shakuotun Fm., Liaoning; =*Tellerina qingshuiheensis* Nan, 1976, p. 340, Fengshan Fm., Inner Mongolia, N. China	*Mictosaukia orientalis*
Saukia globosa	Robison and Pantoja-Alor, 1968, p. 795	Tiňu	early Tremadocian	Mexico		*Mictosaukia globosa*
Saukia wirtzi	Wolfart, 1970, p. 43	—	early Tremadocian	Afghanistan		*Mictosaukia wirtzi*
Saukia rotunda	Kushan, 1973, p. 157	Mila	*Alborsella* Zone	Iran		*Mictosaukia rotunda*
Mictosaukia luanheensis	Zhou and Zhang, 1978, p. 8	Fengshan	*Mictosaukia orientalis* assemblage	Hebei, N. China	Zhang and Wang, 1985, p. 474, Fengshan Fm., Shanxi; Zhou and Zhang, 1985, p. 104, *Mictosaukia orientalis* Zone, Jilin, Shanxi; Duan et al., 1986, p. 48, *Mictosaukia-Fatocephalus* Zone, Jilin; Zhu and Wittke, 1989, p. 228, *Mictosaukia orientalis* Zone, Hebei, N. China	*Mictosaukia luanheensis*
Saukia cf. *S. rotunda* Kushan, 1973	Dean, 1982, p. 91	Seydişehir	early Tremadocian	Turkey		*Mictosaukia* cf. *M. rotunda*
Mictosaukia dayangchaensis	Kuo and An in Kuo et al., 1982, p. 19	Fengshan	*Mictosaukia* Zone	Jilin, N. China	Duan et al., 1986, p. 49, *Mictosaukia-Fatocephalus* Zone, Jilin, N. China	*Mictosaukia striata* by Zhou and Zhang (1985)

APPENDIX *1*—Continued.

Species described	Reference	Formation	Biozone (age)	Locality	Other occurrences/synonymy	Reassessment
Second group						
Ptychaspis acamus	Walcott, 1905, p. 69	Fengshan	late Fengshanian	Shandong, N. China	Zhang and Jell, 1987, p. 236, Fengshan Fm., Shandong, N China	*Eosaukia acamus*
Ptychaspis callisto	Walcott, 1905, p. 72	Fengshan	late Fengshanian	Shandong, N. China		*Eosaukia callisto*
Ptychaspis bella	Walcott, 1906, p. 585	Fengshan	late Fengshanian	Shanxi, N. China	Kobayashi, 1931, p. 180, Chiushukou Shale, Liaoning; =*Calvinella bella* in Lu et al., 1965, p. 449; =*Mictosaukia bella* in Zhang and Jell, 1987, p. 237, Fengshan Fm., Shanxi, N. China; *Eosaukia* fauna, Korea	*Eosaukia bella*
Tellerina coreanica	Kobayashi, 1935, p. 316	Hwajeol	*Eoorthis* Zone	Korea		*Eosaukia coreanica*
Calvinella diversa	Endo in Endo and Resser, 1937, p. 363	Wanwan	latest Furongian	Liaoning, N. China		*Eosaukia diversa*
Mictosaukia perplexa	Shergold, 1975, p. 144	Chatsworth Limestone	*Mictosaukia perplexa* Zone	Queensland		*Eosaukia perplexa*
Mictosaukia maculata	Qian, 1985b, p. 147	Tangcun	late Fengshanian	S. Anhui, S. China		*Eosaukia maculata*
Mictosaukia angustilimbata	Qian, 1986, p. 276	—	*Mictosaukia-Fatocephalus* Zone	Jilin, N. China		*Eosaukia angustilimbata*
Mictosaukia (*Mictosaukioidia*) *transita*	Lu and Zhou, 1990, p. 34	Maotian	*Mictosaukia guizhouensis* Zone	Guizhou, S. China		*Eosaukia transita*
Mictosaukia guizhouensis	Lu and Zhou, 1990, p. 33	Maotian	*Mictosaukia guizhouensis* Zone	Guizhou, S. China	Synonymized with *Calvinella elongata* Xiang in Sun and Xiang, 1979, p. 10, Baoshan Fm., Yunnan, S. China	*Eosaukia elongata*
Mictosaukia combinata	Peng, 1992, p. 53	Shenjiawan	*Probilacunaspis nasalis-Peichiashania hunanensis* Zone to *Lotagnostus* (*Distagnostus*) *celatus-Charchaquia glabrescens* Subzone	Hunan, S. China		*Eosaukia combinata*

APPENDIX 2—List of other species of *Eosaukia* including their occurrences, synonymy, and nomenclatural change. The "—" represents information not available.

Species described	Reference	Formation	Biozone (age)	Locality	Other occurrences/ synonymy	Reassignment
Eosaukia latilimbata	Lu, 1954, p. 145	Sandu Shale	lower Furongian	Guizhou, S. China	Luo, 1974, p. 657, Baoshan Fm., Yunnan; Luo, 1983, p. 13, Baoshan Fm., Yunnan, S. China	*Eosaukia latilimbata*
Eosaukia buravasi	Kobayashi, 1957, p. 310	—	upper Furongian	Thailand	Shergold et al., 1988, p. 310, terminal Furongian, Tarutao Fm., Thailand; =*Mictosaukia buravasi* in Sun and Xiang, 1979, p. 12, Baoshan Fm., Yunnan	*Eosaukia buravasi*
Eosaukia sp. cf. *E. walcotti* (*Mansuy*)	Shergold, 1991, p. 22	Pacoota Sandstone	Assemblage 1	Northern Territory		*Eosaukia* sp. cf. *E. walcotti*
Eosaukia cf. *E. walcotti* (Mansuy)	Fortey, 1994, p. 49	Andam	uppermost Furongian	Oman		*Eosaukia* cf. *E. walcotti*
Ptychaspis walcotti	Mansuy, 1915, p. 22	—	upper Furongian	Vietnam	Mansuy, 1916, p. 33 (non pl. 5, figs. 10e, figs. 11a,b), Vietnam; Sun, 1924, p. 68, Shahuotun Lm., Liaoning, N. China; Kobayashi, 1935, p. 315, *Dictyia* Zone, Korea; =*Calvinella walcotti* in Sun and Xiang, 1979, p. 11, Baoshan Fm., Yunnan, S. China	*Eosaukia walcotti*
?*Calvinella solitaria*	Shergold, 1975, p. 141	Ninmaroo	*Mictosaukia perplexa* Zone	Queensland		*Eosaukia solitaria*
Calvinella micropora	Qian, 1985a, p. 81	Fengshan	*Mictosaukia-Fatocephalus* Zone	Jilin, N. China	*Mictosaukia-Fatocephalus* Zone, Jilin (Qian, 1986, p. 281; Duan et al., 1986, p. 49); Sun, 1990, p. 105, Fengshan Fm., Hebei; =*Calvinella granulosa* Zhang and Wang, 1985, p. 474, Fengshan Fm., Hebei; =*Calvinella latilimbata* Duan and An in Duan et al., 1986, p. 49, *Mictosaukia-Fatocephalus* Zone, Jilin; =*Mictosaukia* aff. *walcotti* (Mansuy) in Zhou and Zhang, 1985, p. 106, *Changia* Subzone, Jilin; =*Scolosaukia lanceata* Sun, 1990, p. 104, Fengshan Fm., Hebei; *Eosaukia fauna*, Korea	*Eosaukia micropora*
Calvinella acuta	Kuo and Duan in Kuo et al., 1982, p. 19	Fengshan	*Mictosaukia* Zone	Hebei, N. China	*Calvinella triangula* Qian, 1985a, p. 81, Fengshan Fm., Jilin; *Mictosaukia striata* in Qian, 1986, p. 278, pl. 71, fig. 7 (pygidium), *Mictosaukia striata* Zone, Jilin; *Calvinella micropora* in Qian, 1986, p. 281, pl. 72, fig. 7 (pygidium), *Mictosaukia-Fatocephalus* Zone, Jilin, N. China; *Eosaukia* fauna, Korea	*Eosaukia acuta*
Prosaukia? *mansuyi*	Hsiang in Lu et al., 1965, p. 448	—	Fengshanian	Yunnan, S. China	erected on *Ptychaspis angulata* Mansuy described in Mansuy, 1916	*Eosaukia mansuyi*
Metacalvinella latilimbata	Luo, 1983, p. 13	Baoshan	upper Fengshanian	Yunnan, S. China	=*Calvinella walcotti* in Luo, 1974, p. 659, *Calvinella* Zone, Bocaitian Fm., Yunnan; =*Eosaukia latilimbata* in Lu and Zhou, 1990, p. 32, *Mictosaukia guizhouensis* Zone, Maotian Fm., Guizhou; =*Eosaukia rectangula* Lu and Zhou, 1990, p. 32, *Mictosaukia guizhouensis* Zone, Maotian and Sandu Fms., Guizhou, S. China	*Eosaukia rectangula*