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NOTE

# THE FIRST CYPRINID FISH AND SMALL MAMMAL FOSSILS FROM THE KOREAN PENINSULA

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Although vertebrate paleontology has lagged behind invertebrate paleontology in Korea, an increase in the rate of discovery of Cretaceous vertebrate fossils in recent years resulted in documentation of 38 localities from the fluvio-lacustrine Gyeongsang Supergroup (Hauterivian to Cenomanian) and recovery of fish, turtle, crocodilian, pterosaur, and dinosaur bones, and dinosaur eggs in nests, as well as dinosaur, bird, and pterosaur footprints (Lee et al., 2001). With respect to Tertiary mammals, Korea has generally been regarded as barren even though fossil mammals were reported from two localities in North Korea by Tokunaga (1933), Takai (1939), and Shikama (1943). They reported six perissodactyls and a carnivore from the Osu Formation (Eocene or Oligocene), Pongsan, Hwanghae Province, and cetacean, proboscidean, and rhinoceros specimens from the Phyonryuk Formation (Miocene), Kilju-Myongcheon, North Hamgyeong Province. These specimens are housed at the University of Tokyo Museum. There have been no subsequent published reports of fossil mammals from either North or South Korea.

During a field trip to the Tertiary basins (route B-1) for the Pacific Science Congress held in Seoul in 1987, fossils of turtles and a mammalian incisor were found and collected in the Bukpyeong Formation by a guest participant (Kim and Choi, 1988a). The incisor was the first specimen of a Tertiary mammal found in South Korea, but unfortunately is no longer in the country. I subsequently attempted to find vertebrate remains by screen-washing sediments of the Bukpyeong Formation. The emphasis was on small mammals because they have proven useful for biochronology (e.g., Lindsay et al., 1980).

Abundant, isolated freshwater fish teeth and two rodent molars were retrieved from the Bukpyeong Formation. The rodent teeth are the first identifiable Tertiary small mammals from Korea. These specimens provide new evidence bearing on the origin and relationships of East Asian freshwater fish and rodents. The purpose of this note is to document their presence in the Bukpyeong Formation and use them to help clarify the age of the formation. I also discuss the evolutionary and biostratigraphic significance of the specimens. The age of the Bukpyeong Formation has yet to be determined precisely. A Miocene or Pliocene age was indicated by palynomorphs and diatoms (Yu, 1971), latest Miocene or Pliocene by palynomorphs (Choi and Bong, 1986), and middle to late Miocene by plants (Lim and Choi, 1982).

## GEOLOGICAL SETTING

The Bukpyeong Basin is the northernmost of four Tertiary basins (Yangnam, Pohang, Yeonghae, and Bukpyeong) distributed along the eastern coast of South Korea (Yoon, 1986; Fig. 1). The Bukpyeong Basin section is divided into two units, the Bukpyeong Formation and Dogyeongri Conglomerate (Lim and Choi, 1982). The Bukpyeong Formation is 40 m thick, and composed of interbedded sandstone, mudstone, and conglomerate with thin seams of lignite (Fig. 2). It has produced freshwater diatoms (Yu, 1971; Lee, 1977), pelecypods and gastropods (Kim, 1970), palynomorphs (Yu, 1971; Choi et al., 1986, Kim et al., 1996), and plant fossils (Lim and Choi, 1982). Based on lithology and paleoecology, the Bukpyeong Formation represents distal alluvial fans associated with swamps and lakes (Lim and Choi, 1982; Kim et al., 1996). The unfossiliferous Dogyeongri Conglomerate (10 m thick) unconformably overlies the Bukpyeong Formation and is composed of crudely stratified beds possibly deposited by debris flows.

## MATERIAL AND METHODS

Fieldwork for microvertebrates focused on finding fossiliferous beds in which small bones and loose teeth would be concentrated, for example in the bases of river channels and small floodplain gullies. Teeth and other resistant parts such as jaw fragments are expected in such facies (Voorhies, 1969; Korth, 1979). Therefore, bulk sampling was confined to the lignite and sandstone beds where coarse sandstone was associated with pebbles or soil-formed nodules, because fossils in microvertebrate sites are coarser than clay or fine-sand sizes. For reconnaissance, I selected four sites around Jiga-dong, the locality found in 1987, and three near Daegu-dong (Fig. 1). An average of 30 kg of sediment per sample was taken to the laboratory for wet screening. Among 43 reconnaissance samples at the seven sites, two from sandstone beds of the Jiga-dong area produced abundant fish teeth (Fig. 2). An additional 550 kg of matrix was collected from these fossiliferous sandstone layers. A total of 579 fish and two rodent teeth were recovered. Most are well preserved and are dark gray to almost black in color.

**Institutional Abbreviation**—The specimens described are housed in the vertebrate fossil collections of the Geological Museum in the Korea Institute of Geoscience and Mineral Resources, Daejeon, South Korea (prefix **KIGAM VP**).

**Anatomical Abbreviations**—**MDD**, mesodistal diameter (length); **LBD**, labiobuccal diameter (width); **M/m**, upper/lower molar.

## CYPRINID PHARYNGEAL TEETH

Fossil fish specimens recovered from the Bukpyeong Formation consist of 16 isolated leuciscine teeth and 563 cyprinine pharyngeal teeth identifiable to the family Cyprinidae (Table 1; Fig. 3). All the cyprinine pharyngeal teeth are assigned to *Cyprinus* sp., and appear to be different from the extant carp, *Cyprinus carpio*. The lower pharyngeal teeth of *C. carpio* comprise three tooth rows (termed A, B, and C), and their shapes are distinctive (Kodera, 1982). In Bukpyeong *Cyprinus* sp., tooth A1 bears a distally pointed hook on the center of the top, although the occlusal surface is flattened in large specimens (Fig. 3A). The hook is usually more prominent than that of the extant species. In occlusal view, tooth A1 is ellipsoidal with MDD longer than LBD. The observed range of MDD in A1 teeth is 1.3 to 7 mm. Tooth A2 in the Bukpyeong *Cyprinus* usually has one or two grooves on the grinding surface, in contrast with three in the extant carp (Fig. 3B). The mesial groove is deeper and longer than the distal one. Both grooves open labially. A worn A2 tooth shows a large dentine facet exposed on a worn out distal groove (Fig. 3C). LBD of A2 teeth are greater than MDD; the mean ratio of LBD/MDD is 1.39. Tooth A3 is different from the others in having a low occlusal surface angle (average of 45 degrees) between the occlusal surface and tooth axis (Fig. 3D), while the occlusal surfaces of teeth A1, A2, and B1 are usually perpendicular to the tooth axis. One strong groove is developed along the mesial margin of tooth A3, and opens labially. Tooth B1 is smaller than the teeth of row A (Fig. 3E), and has a somewhat rounded occlusal surface, with has two grooves. Both grooves are nearly straight compared with curved grooves in teeth A2 and A3. The ratio of LBD/MDD on B1 averages 0.85.

In China, Neogene fish faunas occur in the Shanwang Formation (late early Miocene) of Shanwang, Linqu, Shandong Province, and in the Mahui Formation (late Miocene) and Gaozhuang Formation (early Pliocene), Yüshe, Shanxi Province. No pharyngeal tooth of the typical *Cyprinus* type has been found on any fish from the Shanwang Formation (Young and Tchang, 1936; Zhou, 1990). The first appearance of *Cyprinus* is in the Gaozhuang Formation (Liu and Su, 1962; Chang and Chow, 1986). The oldest fossil *Cyprinus* is early Pliocene in age (Chang

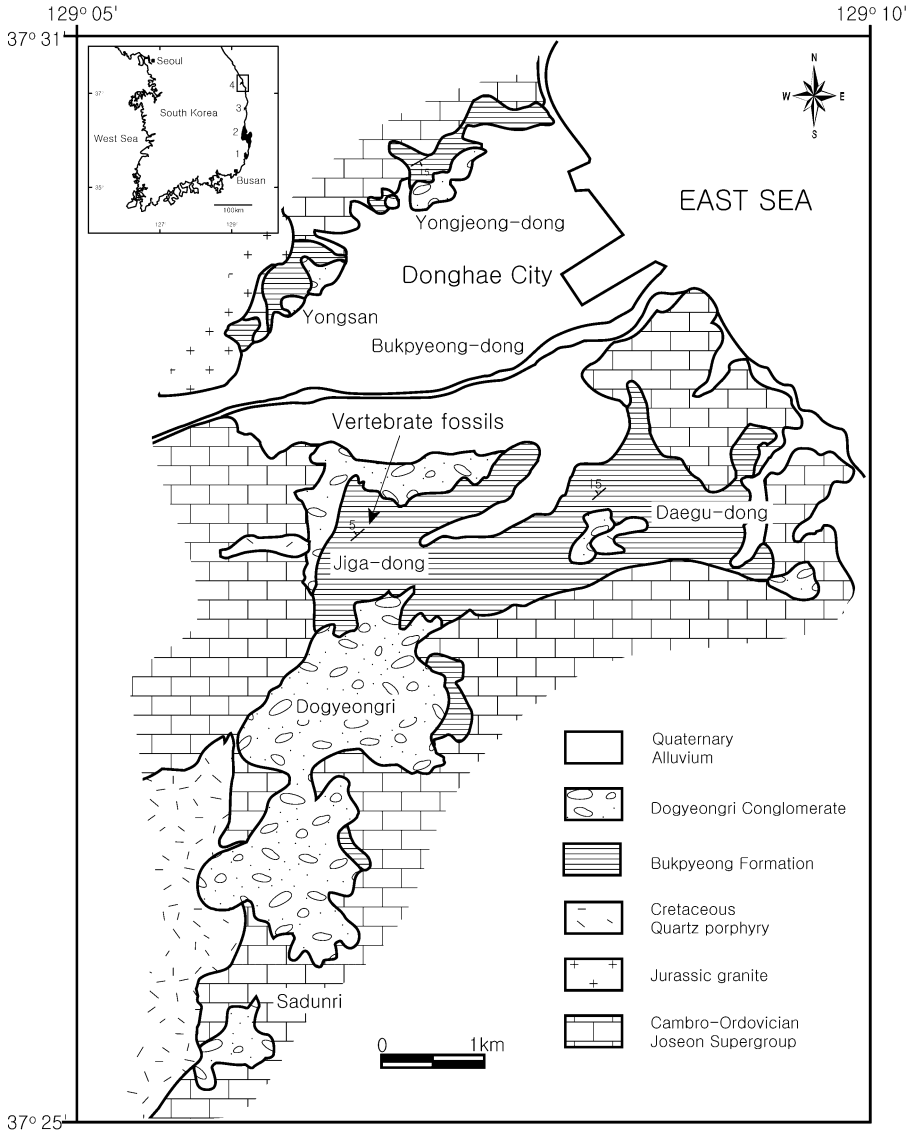


FIGURE 1. Location of Tertiary basins in South Korea (inset) and geologic map of the Bukpyeong area: (1) Yangnam Basin, (2) Pohang Basin, (3) Yeonghae Basin, (4) Bukpyeong Basin.

et al., 1996). In Japan, fossils of typical *Cyprinus* first appear in the Ueno Formation (early Pliocene) of the Kobiwako Group (''Iga Cyprinid Fauna'', Nakajima, 1986). A2 teeth from the Ueno Formation are similar to those of the Bukpyeong Formation in terms of number of grooves and MDD/LBD ratio (Nakajima et al., 1983). In addition, the ratio of *Carassius* to *Cyprinus* increases in the younger formations of the Kobiwako Group. *Cyprinus* and *Carassius* are the most common extant genera of the subfamily Cyprininae in East Asia, but the latter first appears during the Pliocene of China and Japan (Nakajima, 1994). The absence of *Carassius* in conjunction with abundant primitive *Cyprinus* sp. suggests that the Bukpyeong Formation is about the same age as the Ueno Formation, rather than upper formations of the Kobiwako Group. The Ueno Formation was deposited in ''Paleo-lake Ohyamada'' between about 3.1 to 3.5 Ma (Nakajima and Nakai, 1994). The pharyngeal teeth of *Cyprinus* from the Bukpyeong Formation suggest that carp have lived in the Korean Peninsula since the early Pliocene.

## RODENT TEETH

Two rodent teeth, each representing a different family, were recovered from the Bukpyeong Formation. KIGAM VP 200313 (Fig. 4A) is either a right M1 or M2 of a sciurid (length, 1.9 mm; width, 2.4 mm). It is referred to *Spermophilinus* based on its subquadrate shape, unexpanded protocone, slightly convergent protoloph and metaloph, lack of protoconule, indistinct metaconule, and weak mesostyle (Bruijn and Mein, 1968). *Eutamias* is distinguished from *Spermophilinus* by its smaller size (Qiu, 1991, 1996). *Spermophilinus* has a long geologic range (early Miocene to early Pliocene) in Europe (Bruijn, 1999) and is also known from the Songshan fauna (Pliocene), Tianzhu, Gansu Province, China (Zheng and Li, 1982).

KIGAM VP 200314 (Fig. 4B) is a right M1 of a cricetid belonging to either *Democricetodon* or *Kowalskia* (length, 1.8 mm; width, 1.2 mm). It is characterized by an asymmetrical shape, narrow anterocone, and anterior cingulum closing the anterior lingual sinus and connecting the anterocone. The anterocone is almost unsplit and lacks pronounced labial and lingual anteroconules. The protoloph and metaloph are simple and the paracone and metacone are tilted backwards. The metaloph extends transversely to the hypocone. The paracone, metacone, protocone, and hypocone are slightly alternating. The tooth generally more resembles those of *Democricetodon* rather than *Kowalskia* (Daxner-Höck et al., 1996). However, the most primitive species of *Kowalskia* (late Vallesian) morphologically combine *Democricetodon* and *Kowalskia* characters (Kälin, 1999). In addition, variability within these spe-

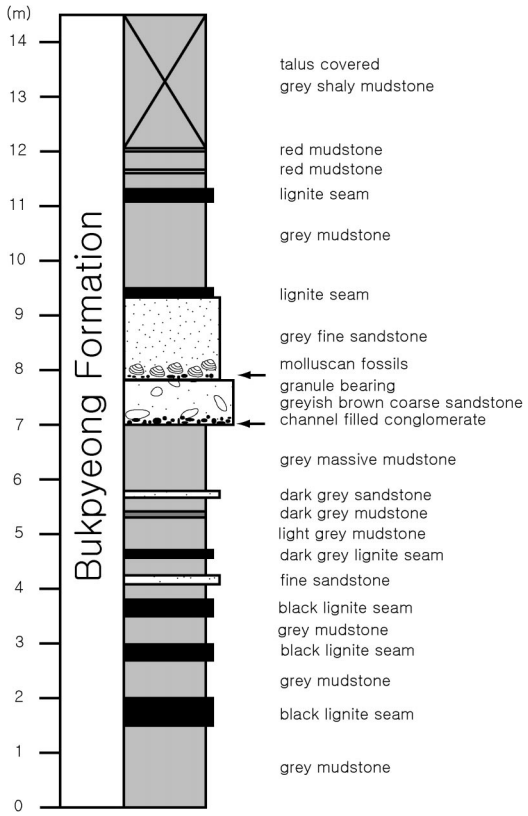


FIGURE 2. Columnar section of Jiga-dong fossil site (see Fig. 1), Bukpyeong Basin, South Korea. Arrows indicate the microvertebrate fossil horizons.

cies is sometimes very high. Therefore, it would be premature to make a positive identification based upon a single tooth. More specimens, including lower molars need to be recovered, especially the m1.

The discovery of *Spermophilinus* and *Democricetodon* or *Kowalskia* from the Bukpyeong Formation indicates that squirrels and hamsters lived in Korea during late Tertiary. The phylogenetic relationships between the Bukpyeong *Spermophilinus* and the extant chipmunk (*Eutamias sibiricus*) in Korea is unclear until more fossils are available. The Bukpyeong tooth of *Democricetodon* or *Kowalskia* demonstrates that this clade had dispersed to the eastern margin of Asia from more western parts of Eurasia by the late Tertiary. However, they failed to reach Japan (Tomida, pers. comm., 1999) or North America.

*Spermophilinus* and *Democricetodon* or *Kowalskia* have bunodont teeth; by comparison with related extant species (Nowak, 1991), the Bukpyeong species probably lived mainly in closed habitats. Extant cricetids are generally limited to modern temperate zones. The two rodents suggest that the habitat sampled at Bukpyeong was a temperate forest. Such a conclusion is consistent with previous paleoenvironmental interpretations for the Bukpyeong Formation based upon fossil plants and palynomorphs (Lim and Choi, 1982; Choi et al., 1986; Kim et al., 1996).

TABLE 1. Number of cyprinid teeth recovered from the Bukpyeong Formation, Korea.

| Taxon | Number of specimens |
|---|---|
| Cyprininae | |
| *Cyprinus* sp. | 563 |
| A1 tooth | 210 |
| A2 tooth | 219 |
| A3 tooth | 84 |
| B1 tooth | 50 |
| Leuciscinae | |
| Gen. and sp. indet. | 16 |

## DISCUSSION

Despite the obvious limitations of isolated teeth and small sample sizes, the Bukpyeong microvertebrates are significant in that they help constrain the age of the Bukpyeong Formation. Previous correlations based on marine fossils between the Bukpyeong Basin and other basins in Korea have not been well resolved. Korean Tertiary basins, with the exception of the Bukpyeong Basin, are characterized by deposition of nonmarine sediments in the lower part of the section with a progressive transition to marine sediments higher in section. Unfortunately, extensive studies using invertebrate micropaleontology (e.g., Lee, 1975; Kim, 1984; Yun et al., 1990) to define stratigraphic and sedimentary environments are restricted to the upper portions of these basins, which contain the marine invertebrate fossils. The lower portions of these basins, on the other hand, are still very poorly known in terms of vertebrate fossils, although some plant fossils (e.g., Janggi flora, Huzioka, 1972) have been described from the Geumgwandong Shale of the Janggi Group in the Yangnam Basin. Turtle specimens (*Amyda* sp.) from the Dogogdong Formation of the Yeonghae Basin (Kim and Choi, 1988b) and some undescribed marine fish specimens from the Pohang Basin were the only vertebrate fossils from Tertiary sediments in South Korea until the present study. A more complete biostratigraphic correlation between Korean Tertiary basins could be done with extensive

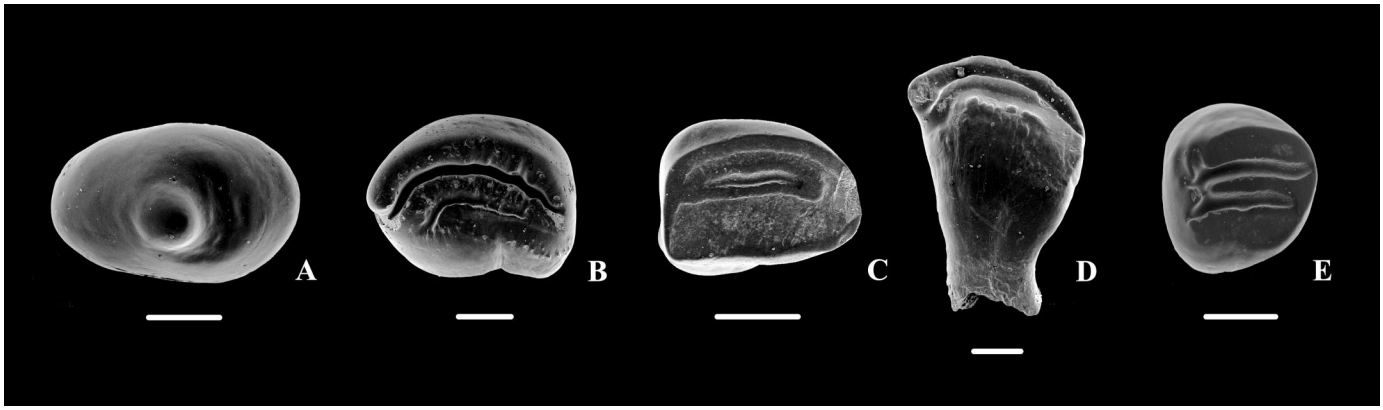


FIGURE 3. Pharyngeal teeth of *Cyprinus* sp. from the Bukpyeong Formation, Pliocene of South Korea. **A**, A1 tooth, KIGAM VP 200302. **B**, left A2 tooth, KIGAM VP 200309. **C**, right A2 tooth, KIGAM VP 200306. **D**, left A3 tooth, KIGAM VP 200310. **E**, left B1 tooth, KIGAM VP 200311. Scale bars equal 500 μm.

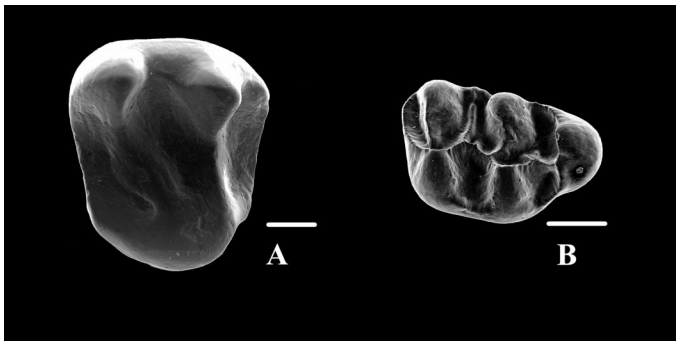


FIGURE 4. Rodent teeth in occlusal view from the Bukpyeong Formation, Pliocene of South Korea. **A**, *Spermophilinus* sp., KIGAM VP 200313, right M1 or M2. **B**, *Democricetodon* or *Kowalskia* sp., KIGAM VP 200314, right M1. Scale bars equal 500 μm.

collecting of land mammals and other vertebrates from the lower terrestrial strata. My initial study in the Bukpyeong Formation demonstrates that microvertebrates including mammals are present in these units, and suggests that they may be recovered from other basins as well.

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## LITERATURE CITED

Bruijn, H. de. 1999. Superfamily Sciuroidea; pp. 271–280 *in* G. E. Rössner, and K. Heissig (eds.), The Miocene Land Mammals of Europe. Verlag Dr. Friedrich Pfeil, München.

Bruijn, H. de., and P. Mein. 1968. On the mammalian fauna of the Hipparion-Beds in the Calatayud-Teruel Basin (Prov. Zaragoza, Spain). Part V. The Sciurinae. Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Serie B 71:75–90.

Chang, M. M., and C. C. Chow. 1986. Stratigraphic and geographic distributions of the Late Mesozoic and Cenozoic fishes of China; pp. 529–539 *in* T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura (eds.), Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes. The Ichthyological Society of Japan, Tokyo.

Chang, M. M., Y. Y. Chen, and H. W. Tong. 1996. A new Miocene xenocyprinine (Cyprinidae) from Heilongjiang Province, northeast China and succession of late Cenozoic fish faunas of East Asia. Vertebrata PalAsiatica 34:165–183.

Choi, D. K., and P. Y. Bong. 1986. Neogene palynomorphs from lignite beds of Bukpyeong and Yeonghae areas, Korea. Journal of the Paleontological Society of Korea 2:1–17.

Choi, D. K., P. Y. Bong, and H. Y. Lee. 1986. Palynology of the Bukpyeong Formation, Bukpyeong area, Korea. Report KR-86-(B)-3, Korea Institute of Energy and Resources, Seoul, 49 pp.

Daxner-Höck, G., V Fahlbusch, L. Kordos, and W. Wu. 1996. The Late Neogene cricetid rodent genera *Neocricetodon* and *Kowalskia*; pp. 221–226 *in* R. L. Bernor, V. Fahlbusch, and H.-W. Mittmann (eds.), The Evolution of Western Eurasian Neogene Mammal Faunas. Columbia University Press, New York.

Huzioka, K. 1972. The Tertiary floras of Korea. Journal of the Mining College, Akita University, Series A, Mining Geology 5:1–83.

Kälin, D. 1999. Tribe Cricetini; pp. 373–387 *in* G. E. Rössner, and K. Heissig (eds.), The Miocene Land Mammals of Europe. Verlag Dr. Friedrich Pfeil, München.

Kim, B. K. 1970. A study on the Neogene Tertiary deposit in Korea. The Journal of the Geological Society of Korea 6:77–96.

Kim, B. K. 1984. Cenozoic biostratigraphy of South Korea. Palaeogeography, Palaeoclimatology, Palaeoecology 46:85–96.

Kim, B. K., and D. K. Choi. 1988a. Vertebrate fossils discovered from the Tertiary basins of the eastern coast area (expectation). Journal of the Paleontological Society of Korea 4:170.

Kim, B. K., and D. K. Choi. 1988b. Mud turtle remains from the Dogogdong Formation (Miocene), Yeonghae area, Korea. Journal of the Paleontological Society of Korea 4:160–165.

Kim, J. Y., Y. K. Koh, C. H. Chung, and H. G. Kim. 1996. Paleoecology of Neogene palynoflora from the Bukpyeong Formation, Donghae area, Korea. Journal of the Paleontological Society of Korea 12: 168–180.

Kodera, H. 1982. Morphodifferentiation of the pharyngeal teeth of the carp, *Cyprinus carpio* Lenné. Tsurumi University Dental Journal 8: 179–212.

Korth, W. W. 1979. Taphonomy of microvertebrate fossil assemblages. Annals of the Carnegie Museum 48:235–285.

Lee, Y. G. 1975. Neogene diatoms of Pohang and Kampo areas, Kyungsangbug-do, Korea. The Journal of the Geological Society of Korea 11:99–114.

Lee, Y. G. 1977. On the fossil diatoms in the Bukpyeong Formation, Bukpyeong area, Gangweondo, Korea. The Journal of the Geological Society of Korea 13:23–40.

Lee, Y.-N., K.-M. Yu, and C. B. Wood. 2001. A review of vertebrate faunas from the Gyeongsang Supergroup (Cretaceous) in South Korea. Palaeogeography, Palaeoclimatology, Palaeoecology 165:357–373.

Lim, S. B., and Y. J. Choi. 1982. Geology and Lignite Resources of Bukpyeong Area, Gangweondo, Korea. KIER Bulletin 35, Korea Institute of Energy and Resources, Seoul, 38 pp.

Lindsay, E. H., N. D. Opdyke, and N. M. Johnson. 1980. Correlation of Siwalik faunas; pp. 309–319 *in* L. L. Jacobs (ed.), Aspects of Vertebrate History: Essays in Honor of Edwin Harris Colbert. Museum of Northern Arizona Press, Flagstaff.

Liu, H. T., and T. T. Su. 1962. Pliocene fishes from Yüshe, Shansi. Vertebrata PalAsiatica, 6:1–47.

Nakajima, T. 1986. Pliocene cyprinid pharyngeal teeth from Japan and East Asia Neogene cyprinid zoogeography; pp. 502–513 *in* T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura (eds.), Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes. The Ichthyological Society of Japan, Tokyo.

Nakajima, T. 1994. Succession of cyprinid fauna in Paleo-lake Biwa; pp. 433–439 *in* K. Martens, B. Goddeeris, and G. Coulter (eds.), Speciation in Ancient Lakes. Archiv für Hydrobiologie Beiheft, Ergebnisse der Limnologie 44.

Nakajima, T., K. Matsuoka, H. Yoshida, and S. Okuyama. 1983. Fossil pharyngeal teeth of cyprinids from the Ohyamada Clay Member of the Iga Formation of the Kobiwako Group at Nakamura, Ohyamada-mura, Mie Prefecture, Japan. Bulletin of the Mizunami Fossil Museum 10:143–150.

Nakajima, T., and K. Nakai. 1994. Lake Biwa; pp. 43–54 *in* K. Martens, B. Goddeeris, and G. Coulter (eds.), Speciation in Ancient Lakes. Archiv für Hydrobiologie Beiheft, Ergebnisse der Limnologie 44.

Nowak, R. M. 1991. Walker's Mammals of the World, 5th ed. The Johns Hopkins University Press, Baltimore and London, 1629 pp.

Qiu, Z. D. 1991. The Neogene mammalian faunas of Ertemte and Harr Obo in Inner Mongolia (Nei Mongol), China.—8. Sciuridae (Rodentia). Senckenbergiana Lethaea 71:223–255.

Qiu, Z. D. 1996. Middle Miocene Micromammalian Fauna from Tunggur, Nei Mongol. Science Press, Beijing, 216 pp.

Shikama, T. 1943. A new Eocene creodont from the Pongsan coal mine, Korea. Bulletin of the Biogeographic Society of Japan 13:7–11.

Takai, F. 1939. Eocene mammals found from the Pongsan (Hozan) coal field, Korea (Chosen). Journal of the Faculty of Science, Imperial University of Tokyo (section 2) 5:199–217.

Tokunaga, S. 1933. A list of the fossil land mammals of Japan and Korea with descriptions of new Eocene forms from Korea. American Museum Novitates 627:1–7.

Voorhies, M. R. 1969. Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. Contributions to Geology, University of Wyoming, Special Paper 1:1–69.

Yoon, S. 1986. Tectonic history of the Tertiary Pohang and Yangnam Basins, Korea; pp. 637–644 *in* H. Nakagawa, T. Kotaka, and Y. Takayanagi (eds.), Essays in Geology: Professor Nobu Kitamura Commemorative Volume, Sendai.

Young, C. C., and T. T. Tchang. 1936. Fossil fishes from the Shanwang Series of Shantung. Bulletin of the Geological Society of China 15:197–206.

Yu, C. J. 1971. The Tertiary fossil pollen and diatoms from Bukpyong, Korea. Bulletin of the Geological Survey of Korea 13:449–484.

Yun, H., K. H. Paik, S. Chang, and S. Yi. 1990. Microfossils assemblages from the Bomun area: a study on the nannoplankton from the Neogene formation, Pohang, Korea. Journal of Paleontological Society of Korea 6:1–63.

Zheng, S., and Y. Li. 1982. Some Pliocene lagomorphs and rodents from locality 1 of Songshan, Tianzhu, Ganzu Province. Vertebrata PalAsiatica 20:35–44.

Zhou, J. J. 1990. The Cyprinidae fossils from Middle Miocene of Shanwang Basin. Vertebrata PalAsiatica 28:95–127.

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