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The platacanthomyine rodent *Neocometes* from the Miocene of South Korea and its paleobiogeographical implications

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A left first lower molar of *Neocometes* from the Bukpyeong Formation, South Korea is more similar to *Neocometes similis* and *Neocometes* cf. *similis* from Europe than to *Neocometes orientalis* from Thailand, and is therefore referred to *Neocometes* aff. *similis*. The new discovery of *Neocometes* is important in that it is the first evidence in Asia to show close faunal affinity to European *Neocometes*. It is also of paleobiogeographic significance for the subfamily Platacanthomyinae, because it represents the easternmost occurrence of this subfamily in Eurasia, implying there was continuous gene flow between the *Neocometes* populations of eastern Asia and western Europe. The paleoclimatic interpretation for the Bukpyeong Formation based on the palynomorphs implies that *Neocometes* had wider climatic tolerances than either of the two extant platacanthomyine genera. The evolutionary stage of Korean *Neocometes* is comparable to material from European localities correlated with MN 4 and MN 5, which constrains the age of the Bukpyeong Formation to between 18 and 15.2 Mya.

Key words: Mammalia, Rodentia, Platacanthomyinae, *Neocometes*, paleobiogeography, Miocene, Bukpyeong Formation, South Korea.

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Introduction

In South Korea, Tertiary sediments are distributed as isolated small patches mainly in four localities along the eastern coast (Fig. 1). They are the Yangnam, Pohang, Yeonghae, and Bukpyeong basins (Yoon 1986). The first three of these basins are characterized by the deposition of non-marine sediments in the lower part of the section with a progressive transition to marine sediments higher in the section. The Bukpyeong Basin lacks marine sediments. Previous stratigraphic hypotheses based on marine fossils have led to problems of correlation between the four basins. Therefore, the complete stratigraphic correlation between Korean Tertiary basins needs to be resolved by additional lines of evidence, for example the detailed collecting of small land mammals from the lower terrestrial sediments of these basins, which have proven important for international correlations and chronology (Lindsay et al. 1980). Systematic fieldwork began for microvertebrate fossils in the Miocene Bukpyeong Formation of the Bukpyeong Basin in 2002. Through microvertebrate reconnaissance at several sites, two fossiliferous sandstone layers were found from one outcrop exposed in Jiga-dong (Fig. 1). From about 500 kg of sediment from those two fossiliferous layers two small rodent teeth were recovered, and were assigned to a sciurid, *Spermophilinus*, and an indeterminate cricetid, either *Democricetodon* or *Kowalskia* (Lee 2004). They were the first identifiable Tertiary small mammals from Korea. Since then, an average of 500 kg of sediment from the site has been shoveled into bags for transport to the laboratory for wet screening every year. Two new small mammal teeth, a chiropteran, and a platacanthomyine rodent, have been recovered from the matrix so far. The platacanthomyine rodent is identified as *Neocometes* aff. *similis* and is the subject of this paper.

The platacanthomyine fossil record, especially outside Europe is extremely poor (Mörs 2006), with previous Asian records restricted to Thailand (Mein et al. 1990; Chaimanee et al. 2007) and China (Qiu and Li 2003a). Therefore, the discovery of *Neocometes* in Korea is very important paleogeographically and paleobiologically. In addition, the genus *Neocometes* is useful for biochronology and subdivision of the Miocene, during an interval of about 7 Ma (from the middle Orleanian to the end of the Astaracian) in Europe (Fejfar 1999; Fejfar and Kalthoff 1999). Therefore, *Neocometes* clarifies the age of the Bukpyeong Formation, which previously was uncertain. The purpose of this paper is to provide a description of the new *Neocometes* tooth from the Buk-

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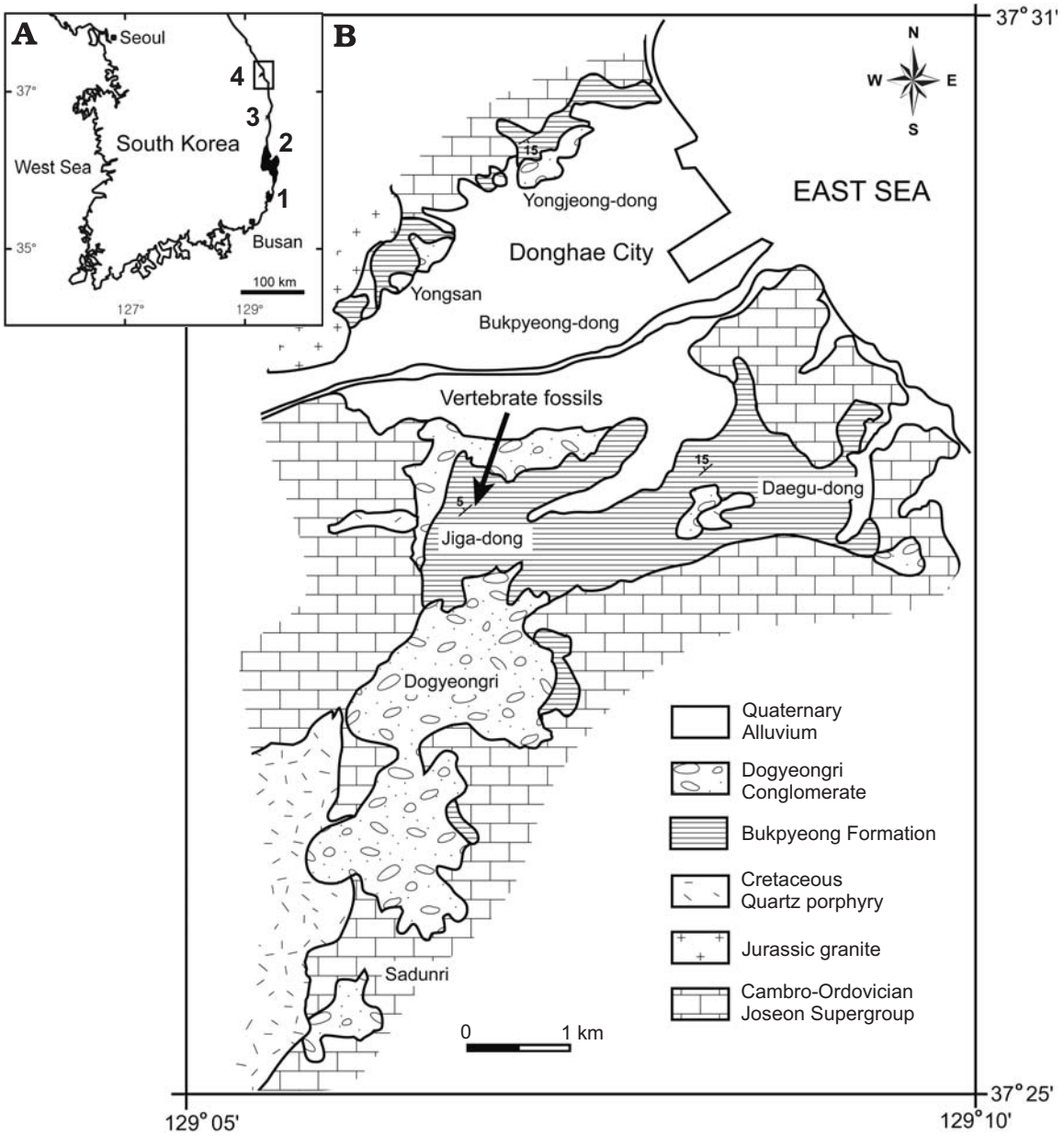


Fig. 1. Location of Tertiary basins in South Korea (**A**) and geologic map of the Bukpyeong area (**B**), indicating the Jiga-dong site (arrow): (1) Yangnam Basin, (2) Pohang Basin, (3) Yeonghae Basin, (4) Bukpyeong Basin.

pyeong Formation and to discuss the evolutionary and biostratigraphic significance of the specimen.

Institutional abbreviation.—KIGAM VP, Korea Institute of Geoscience and Mineral Resources, Vertebrate Paleontology, Daejeon, South Korea.

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). Tertiary basin sediments unconformably overlie the Cambro-Ordovician Joseon Supergroup, which contains Jurassic–Cretaceous granite intrusions. The Bukpyeong Basin Tertiary section is divided into two units: the lower Bukpyeong Formation and the upper Dogyeongri Conglomerate (Lim and Choi 1982). These formations dip gently into the center of the basin at 5 to 15°. The Bukpyeong Formation is 40 m thick, and composed of interbedded sandstone, mudstone, conglomerate, and thin seams of lignite. It has produced freshwater diatoms (Yu 1971; Lee 1977), pelecypods, gastropods (Kim 1970), palynomorphs (Yu 1971; Choi and Bong 1986; Kim et al. 1996), and plant macrofossils (Lim and Choi 1982). Based on lithology and paleoecology, the Bukpyeong Formation appears to represent distal alluvial fans associated with swamps and lakes (Lim and Choi 1982;

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Kim et al. 1996). This conclusion was reinforced by the discovery of freshwater fish teeth, including abundant cyprinine pharyngeal teeth and some leuciscine teeth (Lee et al. 2003). A Miocene or Pliocene age for the Pukpyeong Formation was indicated by palynomorphs and diatoms (Yu 1971); latest Miocene or Pliocene by palynomorphs (Choi and Bong 1986); and middle to late Miocene by plant macrofossils (Lim and Choi 1982). The Dogyeongri Conglomerate (10 m thick) unconformably overlies the Bukpyeong Formation and is composed of poorly sorted, crudely stratified beds of conglomerate, possibly deposited by debris flows. The Dogyeongri Conglomerate is not fossiliferous.

Systematic paleontology

Order Rodentia Bowdich, 1821

Subfamily Platacanthomyinae Alston, 1876

Genus *Neocometes* Schaub and Zapfe, 1953

Type species: *Neocometes brunonis* Schaub and Zapfe, 1953, Neudorf Spalte 1 (Middle Miocene), Slovakia.

Neocometes aff. *similis* Fahlbusch, 1966

Fig. 2.

Material.—KIGAM VP 200315, a complete left first lower molar from the Jiga-dong site of the Bukpyeong Formation (Miocene) in Donghae City, South Korea.

Description.—The specimen is a well-preserved, two-rooted tooth although the mesiolabial part of the anterolophid is slightly damaged. The enamel is dark brown and black in color. The maximum length and width of the crown is 2.0 mm and 1.25 mm, respectively. Two relatively long roots of equal length are nearly perpendicular to the crown. The boundary between the crown and the root both on the labial and lingual sides is not straight but wavy. The total height of the tooth is 2.3 mm (Fig. 2), including the roots, although the tooth pattern is lophodont and relatively low-crowned. In occlusal view, the tooth shows a pear-like outline as the mesial portion is a little narrower and more round than the distal portion. Six transverse ridges are separated by five synclines (Ia, I, II, III, IV). These ridges show a medium stage of wear, but the labial side is higher crowned than the lingual side. Although the synclines are curved mesially in the labial region in occlusal view, their lingual angles to the longitudinal axis vary at each syncline (30° in Ia, 75° in I, 85° in II, 90° in III and IV). The inclination of the ridges (difference from the perpendicular) also gradually decreases from mesial to distal. While synclines II and III are widely and deeply open both lingually and labially, synclines I and IV are slightly open only lingually and syncline Ia is completely closed by the anterolophid and the anterior transverse ridge. The anterior basin is divided by the anterior transversal extra ridge (= "Vorderer Quersporn"), but the metalophid is connected with the junction of the anterolophid and the anterior transversal extra ridge labially so that syncline I is open only lingually. Syncline Ia is asymmetrically divided into two small basins by the connection of the anterolophid with an anterior transversal extra ridge. The lingual basin is slightly larger than the labial one. The enamel ridge of the smaller basin in syncline Ia is connected with the mesial enamel ridge of the anterolophid. Syncline II is open labially and lingually between the mesolophid and the metalophid. The mesolophid is curved labially parallel to the curvature of the metalophid so that the protoconid is located more mesially than the mesoconid. The mesolophid is not connected with any ridges and overlaps the positions of the protoconid and mesoconid. Syncline III between the mesolophid and the posterior transversal extra ridge is the deepest and longest among all synclines. The entoconid–hypoconid is connected with the posterolophid labially. The latter is nearly parallel to the posterior transversal extra ridge, but relatively short. The hypoconid is more distinct than the entoconid. Syncline IV is slightly open lingually.

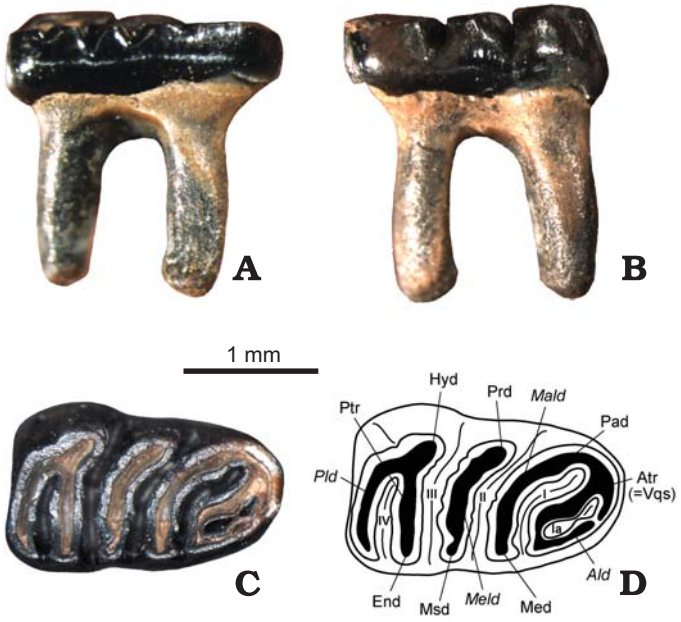


Fig. 2. Platacanthomyine rodent *Neocometes* aff. *similis* from the Miocene Bukpyeong Formation, South Korea. KIGAM VP 200315, left first lower molar in lingual (**A**), labial (**B**), occlusal (**C**) views; **D**, dental terminology used in the text. Abbreviations: Ald, anterolophid; Atr (= Vqs), anterior transversal extra ridge (= "Vorderer Quersporn"); End, entoconid; Hyd, hypoconid; Mald, metalophid; Med, metaconid; Meld, mesolophid; Msd, mesoconid; Pad, paraconid; Pld, posterolophid; Prd, protoconid; Ptr, posterior transverse extra ridge; Ia, I, II, III, and IV, synclines (= anterofossette, parafossette, mesofossette, metafossette, and posterofossette, respectively).

Comparisons.—The tribe Platacanthomyini (subfamily Platacanthomyinae) includes the living genera *Platacanthomys* and *Typhlomys*, and the fossil genus *Neocometes*. Living *Platacanthomys* and *Typhlomys* are monospecific (e.g., *Platacanthomys lasiurus* Blyth, 1859, and *Typhlomys cinereus* Milne-Edwards, 1877), but *Platacanthomys* has one fossil species from the late Miocene (about 9 Mya, Ni and Qiu 2002) of China (*P. dianensis*, Qiu 1989) and four extinct species of *Typhlomys* were described from late Miocene and Quaternary sediments of China (*Typhlomys primitivus*, *Typhlomys hippa-*

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rionum, *Typhlomys intermedius*, and *Typhlomys macrourus*; Qiu 1989; Zheng 1993). The dental morphology of these two genera is easily distinguished from that of *Neocometes*. The latter has more open synclines and the inclination of ridges and synclines to the longitudinal axis of the crown is steeper than in *Platacanthomys* and *Typhlomys* (Fejfar and Kalthoff 1999). KIGAM VP 200315 fits well with the dental characters of *Neocometes*, such as lingually and labially opened synclines II and III, and synclines III and IV oriented nearly 90°.

Neocometes is known from three species: *Neocometes orientalis*, *Neocometes similis*, and *Neocometes brunonis*. *Neocometes orientalis* from Thailand is quite different from Korean *Neocometes* because its lingual synclines tend to close (Mein et al. 1990), thus exhibiting similarity to extant *Typhlomys* (Chaimanee et al. 2007).

Korean *Neocometes* is most similar morphologically to *N. similis* from Dolnice 2, Czech Republic (Fejfar 1974) and Erkertshofen 2, Germany (type locality of Fahlbusch 1966). The dental structure of KIGAM VP 200315 is strikingly similar to *N. similis* (specimen number 73355) from Dolnice 2, Czech Republic (Fejfar 1974: fig. 31-1), the only difference being that the former (length 2.0 mm) is a little larger than the latter (length 1.83 mm). Intermediate forms between *N. similis* and *N. brunonis* were called *Neocometes* cf. *similis* by Fejfar (1999) and Fejfar and Kalthoff (1999). They also interpreted the European Miocene record to demonstrate evolution from *N. similis* to *N*. cf. *similis* to *N. brunonis*. Morphological changes are modest with only increasing size of the low-crowned molars recognized. The size of KIGAM VP 200315 falls into the range of *N. brunonis* rather than *N. similis* (Fejfar and Kalthoff 1999: fig. 2). However, Daxner-Höck (1998) demonstrated that the first lower molar of *N. similis* (length 2.0 mm, width 1.3 mm) from Oberdorf 4 (MN 4) overlaps with *N. brunonis* in size. The large Oberdorf specimen is essentially the same size as Korean *Neocometes* (length 2.0 mm, width 1.25 mm). Large *Neocometes* teeth were also reported by Aguilar et al. (1997) from Ste Catherine 2 and 9 in France. They indicate that size is not an absolute criterion to identify *Neocometes* species. In addition, Fejfar (1974) divided *Neocometes* teeth into morphotype A and morphotype B by the labial connection of the metaconid–paraconid ridge with the anterolophid. Morphotype A makes up 100% of the sample of first lower molars of *N. similis* from Erkertshofen (type locality), but it is still present in 40% of *N. brunonis* from Neudorf (type locality; Fejfar 1974; Schötz 1981). However, the typical characteristic of *N. brunonis* is the separation of the anterolophid into stylids (= morphotype B, Fejfar 1999; Fejfar and Kalthoff 1999). KIGAM VP 200315 belongs to morphotype A (= archaic stage, sensu Fejfar 1974).

Applying Fejfar's (1999) proposed chronospecies-model for the evolution of *Neocometes* in the European Miocene to Korean *Neocometes*, in which *N. similis* (MN 4) gives rise to *N*. cf. *similis* (MN 5), which gives rise to *N. brunonis* (MN 6 and MN 7/8), it is reasonable that KIGAM VP 200315 should be assigned to *N.* aff. *similis*, at least until more fossils are available.

Discussion

Neocometes is very rare in Asia. *Neocometes orientalis* was first described from the Mae Long deposits of the Li Basin (Mein et al. 1990). The dental characters of *N. orientalis* differ from typical European *Neocometes* and its small size was considered primitive (Mein et al. 1990; Mein and Ginsburg 1997). Because a "platacanthomyid" was identified from late early Miocene (17 Mya) strata in the Siwaliks of Pakistan (Flynn 2003), it was suggested that platacanthomyids originated in Asia (Musser and Carleton 2005) and reached into Europe as far as Spain by late early Miocene (de Bruijn and Moltzer 1974). Carleton and Musser (1984) further suggested that platacanthomyids likely originated from some Eocene or Oligocene, probably Asian, muroid stock. However, Mörs (2006) argued against a platacanthomyine affiliation for the Siwalik specimen. Moreover, recent discovery of *N*. cf. *orientalis* in the Na Khaem Formation of the Mae Moh Basin in Thailand shows that the Na Khaem Formation (12.3 ~ 13.12 Mya) is equivalent to Mae Long deposits of the Li Basin (Chaimanee et al. 2007). Thus, the age of the Mae Long fauna, including *N. orientalis* is 3 ~ 5 Ma younger than previously thought. In addition, Chaimanee et al. (2007) pointed out that distinct morphological characters of *N. orientalis* and *N*. cf. *orientalis*, such as the closure of the ectoloph on the upper molars and the complete endolophid on the lower molars, occur in living *Typhlomys* and are never encountered among European *Neocometes*. They concluded that the Thai samples need to be referred to a new genus that is closely related to the extant *Typhomys*.

A single molar (*Neocometes* sp.) from the Shanwangian (early Miocene) of Sihong (MN 4) in eastern China (Qiu and Li 2003a) has not been described in detail, but it is comparable to *N. orientalis* (Zhuding Qiu, personal communication 2009). Therefore, it is important that the Korean *Neocometes* is the first report to show close faunal affinity of an Asian population to European *Neocometes*. It was argued that there was no continuous gene flow between the *Neocometes* populations of Asia and western Europe based on the phylogenetic reinterpretation of *N. orientalis* (Chaimanee et al. 2007). However, the Korean specimen represents the easternmost occurrence of the genus *Neocometes* in Eurasia and is more similar to European species than Thai species. The paleobiogeogarphic range of European *Neocometes* now extends from Spain (de Bruijn and Moltzer 1974) to Korea, beyond eastern China and the range of *N. orientalis* (Qiu and Li 2003a).

The paleoecology of the genus *Neocometes* is interpreted as similar to its living relatives, being arboreal with a frugivorous to granivorous diet, but in Europe it is found in slightly drier conditions as indicated by their more frequent records in karst fissure sites as compared to low-energy water-deposited sediments (Fejfar 1999). However, Kowalski (1993) implied that the contemporaneous occurrence of *Neocometes* in the Miocene of Europe and Thailand could indicate a continuous distribution of tropical forests. Abundant tropical elements

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from Hambach 6C, Germany in MN 4 to MN 5 (the northwesternmost outpost of terrestrial Miocene faunas in Europe), including *Neocometes* aff. *similis*, imply that *Neocometes* were tropical dwellers (Mörs 2006). In addition, the Sihong fauna (especially the association of catarrhine primates with *Neocometes* sp.) indicate that platacanthomyines lived in warm and moist tropical or subtropical habitats (Harrison and Gu 1999; Qiu and Li 2003b). However, the paleoenvironment of the Bukpyeong Formation is considered to be temperate based upon its fossil palynomorph assemblage, comprising predominantly conifers and subordinately deciduous angiosperms (Choi and Bong 1986; Kim et al. 1996: table 1). If the paleoclimatologic interpretation for the Bukpyeong Formation based on the palynomorphs is true, it implies that *Neocometes* lived in wider climatic zones than the two extant platacanthomyine genera (*Platacanthomys* and *Typhlomys*), which now live in tropical or subtropical forests of southern and southeastern Asia (southern India, southeastern China, Thailand, and Vietnam).

The occurrence of *N*. aff. *similis* from the Bukpyeong Formation is also significant in that it constrains the age of Bukpyeong Formation. The evolutionary stage of Korean *Neocometes* is comparable to material from European localities correlated with MN 4 and MN 5, which constrains the age of Bukpyeong Formation to between 18 Mya (Burdigalian, late early Miocene) and 15.2 Mya (Langhian, early middle Miocene) (Steininger et al. 1996).

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