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FIRST RECORD OF A PLATANISTOID CETACEAN FROM THE MIDDLE MIOCENE OF SOUTH KOREA

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The Superfamily Platanistoidea, whose name stems from the extant genus *Platanista*, constitutes a clade of Odontoceti that reached its acme in abundance and diversity during the Oligocene and Miocene (Reeves and Brownell, 1989; Muizon, 1994; Fordyce, 1994; Barnes, 2006; Barnes et al., 2010). *Platanista*, the endangered Ganges and Indus river dolphins, is the only extant genus of this once-diverse clade. Most fossil platanistoids were marine, and the only extant family, Platanistidae, was much more diverse ecologically than it is now: fossil members of platanistids have been found in brackish and fresh water sediments as well as marine deposits (Barnes and Reynolds, 2009).

The Superfamily Platanistoidea, originally proposed by Simpson (1945), has a confusing taxonomic history. As originally conceived, this superfamily included four families with extant representatives: Iniidae, Pontoporiidae, Lipotidae, as well as Platanistidae. Collectively platanistoids were referred to as river dolphins, even though there are no records of freshwater pontoporiids (Barnes, 1984). The paraphyly/polyphyly of this group was first recognized and then further developed in consecutive studies by Muizon (1984, 1987, 1988), and Superfamily Platanistoidea has been redefined to conform to a monophyletic group. The families Iniidae, Pontoporiidae, and Lipotidae are now usually classified in other odontocete superfamilies (Muizon 1991, 1994; Fordyce, 1994; Nikaido et al., 2001; but see Geisler and Sanders, 2003). Currently the Superfamily Platanistoidea is thought to include four extinct families: the Squalodontidae (Oligocene to Miocene), Waipatiidae (Oligocene to Miocene), Squalodelphinidae (Oligocene to Miocene), Allodelphinidae (Miocene), and possibly the extinct enigmatic family Dalpiazinidae (Oligocene to Miocene) (Barnes, 2006; Fordyce, 2006; Muizon, 2009; Barnes et al., 2010). Two other families, the Prosqualodontidae and the Patriocetidae, are recognized as platanistoids by some but not all authors (Fordyce, 2009; Muizon, 2009).

Among the Platanistoidea, allodelphinids and platanistids have extremely long rostra and symphyseal parts of the mandibles, whose lengths may reach more than 4 times the length of the braincase in some species (Barnes and Reynolds, 2009). There are no comparable living long-jawed odontocetes. Other characters shared by allodelphinids and platanistids are the presence of an anteroposteriorly elongate groove on the lateral side of the rostrum that follows the maxilla/premaxilla suture and a sulcus on the lateral side of the dentary, which extends the full length of the symphysis. It is also apparent that Allodelphinidae and the platanistid Subfamily Pomatodelphininae show a similar dorsoventral compression of the rostrum and the symphysis of the mandible (Barnes, 2006). Other features shared by allodelphinids and pomatodelphinines include the firmly ankylosed mandibular symphysis, the dorsally closed mesorostral groove on the anterior part of the rostrum, and single-rooted teeth.

A new specimen (KIGAM VP 201101) from South Korea that belongs to the Pomatodelphininae is reported in the present

study. It consists of the middle to anterior part of the rostrum, but lacking the anterior-most part, and a symphyseal portion of the mandible. This is the first report of pomatodelphinines from the Pacific and expands the known geographic range of the group.

Institutional Abbreviations—**CYU**, Cyber University, Tokyo, Japan; **GMNH**, Gunma Museum of Natural History, Tomioka, Japan; **IRSNB**, Institut royal des Sciences naturelles de Belgique, Brussels, Belgium; **KIGAM VP**, Korea Institute of Geoscience and Mineral Resources, Vertebrate Paleontology, Daejeon, Korea; **LACM**, Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A.; **MGPU**, Museo di Geologia e Paleontologia, dell'Università di Padova, Padua, Italy; **MNHN**, Muséum national d'Histoire naturelle, Paris, France; **NMW**, Naturhistorisches Museum, Vienna, Austria; **OU**, Geology Museum, Department of Geology, University of Otago, Dunedin, New Zealand; **UCMP**, University of California Museum of Paleontology, Berkeley, California, U.S.A.; **USNM**, United States National Museum, Washington, D.C., U.S.A.; **WU**, Waseda University, Tokyo, Japan.

SYSTEMATIC PALEONTOLOGY

CETACEA Brisson, 1762

ODONTOCETI Flower, 1864

PLATANISTOIDEA Simpson, 1945, sensu Barnes, 2006

PLATANISTIDAE Simpson, 1945, sensu Barnes, 2006

POMATODELPHININAE Barnes, 2002

gen. et sp. indet.

(Fig. 2)

Material—KIGAM VP 201101, a partial rostrum and the symphysis of mandible, adhered to each other, with teeth essentially in place. The anterior-most portion of each is not preserved.

Locality and Geological Setting—The specimen (KIGAM VP 201101) was found in a massive grey mudstone at the construction site of Hansin apartment complex in Uhyeon-dong, Bukgu, Pohang City, South Korea (latitude 36°03'01.34"N, longitude 129°21'28.84"E) in 1990 by an amateur fossil collector. Unfortunately the outcrop that yielded this specimen was completely destroyed by subsequent expansion of the city. Based on a geological map (Um et al., 1964), the fossil locality occurs in the Duho Formation, the uppermost unit of the Yeonil Group within the Miocene Pohang Basin (Fig. 1). It is composed of up to 250 m of dark grey siliceous mudstones and is widely distributed in the most eastern part of the Pohang Basin. The Duho Formation has produced a variety of fossils, including mollusks, foraminifera, nannofossils, siliceous microfossils, tasmantids, radiolarians, dinoflagellate flora, palynomorphs, and an incomplete kentriodontid upper jaw (Lim, 2005). These fossils indicate a Middle Miocene age for the Duho Formation. The depositional system of the Pohang Basin (Sohn et al., 1991) suggests that the Duho Formation was deposited during sea-level high-stand TB 2.6, which occurred between 12.5 and 10.5 Ma (Haq et al., 1987). In addition, the upper boundary of the Yeonil Group is approximately 10.5 Ma because at that time, uplift of the Pohang Basin

*Corresponding author.

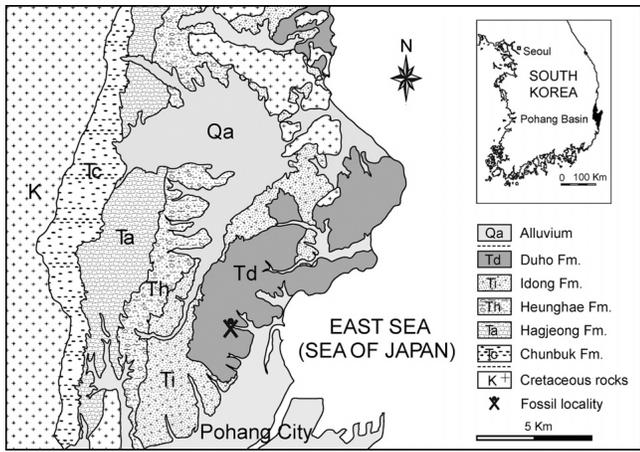


FIGURE 1. Geologic map of the northern part of the Pohang area (modified from Um et al., 1964) with Tertiary basins in South Korea (inset), depicting the fossil locality where KIGAM VP 201101 was collected.

began following the onset of compressional deformation along the southern part of the East Sea (Sea of Japan) (Ingle, 1992; Jolivet et al., 1994). Therefore, the Duho Formation is within the range of 10.5 to 12.5 Ma (late middle Miocene).

DESCRIPTION

General

The fossil consists of the middle to anterior part of the rostrum (but not the anterior-most end), and associated symphyseal portion of mandible, both armed with teeth that have conical crowns and smooth enamel. The rostrum and mandible are

compressed dorsoventrally, being wider than high. The rostrum is tightly appressed to the mandible, probably through sediment compaction and diagenesis during fossilization. Overall, the specimen is subcylindrical, dorsoventrally higher than wide posteriorly, transversely wider than high anteriorly. The total length of the specimen as preserved is approximately 39 cm, the total skull length presumably reaching a meter or so. It is separated into five pieces, and there is virtually no gap between each piece except for a substantial hiatus between the two most anterior pieces (Fig. 2). The rostrum attenuates anteriorly; the heights and widths of the five rostral pieces, from posterior to anterior, are 28.5 mm tall by 48.5 mm wide, 25.9 by 42.5 mm, 22 by 39 mm, 20.5 by 38 mm, and 14 by 35 mm. The mandible is also tapering in tandem with the rostrum; the heights and widths of the five mandibular pieces, from posterior to anterior, are 28.3 by 48.3 mm, 25 by 42.5 mm, 25 by 38.6 mm, 20.5 by 35 mm, and 17 by 30 mm. Given that the mandible and rostrum are closely appressed, the five sets of rostral and mandibular measurements are taken from the same frontal planes. The accuracy of these measurements may be compromised because the rostrum and mandible are slightly distorted, and the act of measuring was complicated by the fact that each cross-section is irregular in shape. Cross-sections visible at the ends of each piece reveal that the rostrum and mandible are quite dense with limited cancellous, or spongy, bone. The maxilla and the premaxilla are firmly fused to each other, with a distinctive deep groove following the presumed location of the maxilla/premaxilla suture. Similarly, the fused symphysis of the mandible carries a narrow, deep groove extending lengthwise on either side of the symphysis.

Premaxilla—The premaxillae, which are thick dorsoventrally and narrow transversely, contact with each other at the midline to close the mesorostral groove for the full length of the preserved rostrum. In the posterior part of the preserved rostrum, the premaxilla just lateral to the midline is more elevated than any other portion of the premaxilla, although it gradually becomes low and flattened anteriorly. The lateral margins of the premaxillae are almost parallel, imperceptibly tapering anteriorly. The right

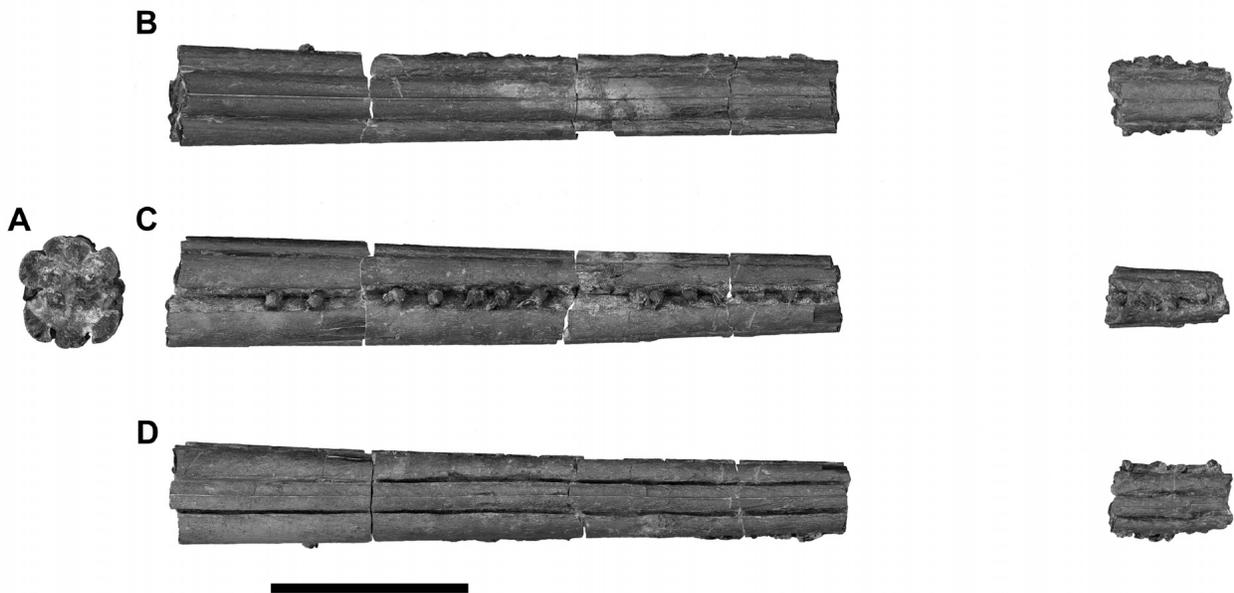


FIGURE 2. Rostrum of Pomatodelphininae, gen. et sp. indet. (KIGAM VP 201101). A, cross-sectional view; B, dorsal view; C, right lateral view; D, ventral view. Scale bar equals 10 cm.

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premaxilla is narrower than the left, being more apparent posteriorly (proximally). The proportion of premaxillae to maxillae on the dorsal surface of the rostrum progressively increases from posterior to anterior; it exceeds that of the corresponding maxilla anteriorly, whereas the premaxillae occupy less than half the rostral width posteriorly. The premaxillary sac fossa and premaxillary foramen are not preserved. The premaxilla is almost exclusively composed of compact bone.

Maxilla—The maxilla is firmly fused with the premaxilla. Along the maxilla/premaxilla suture, the maxilla faces dorso-medially and lateral to this, the maxilla bears a distinct ridge throughout its entire preserved length. On the dorsal surface of the rostrum, the widths of the maxillae rapidly decrease anteriorly and cause the rostral width to attenuate (the widths of premaxillae are not much changed fore-and-aft). The lateral face of the maxilla is gently convex. Judging from the cross-sections of the rostrum, the ventral surfaces of the maxillae are convex on either side of a midline groove. Along the lateral margin of the maxilla is a row of alveoli with teeth. The maxilla is quite dense with some cancellous bone.

Mandible—The mandibular symphysis is fused and dorsoventrally compressed. The mandible is firmly cemented to the rostrum by pyritized and indurated sediment, and teeth of the upper and lower jaws interdigitate each other. From the cross-section it is recognized that the dorsal surface of the symphyseal portion of the mandible is convex on either side of a midline groove. On the ventral surface, there are narrow, deep longitudinal grooves on each side of the mandibular symphysis. The mandible is largely composed of dense bone with minor cancellous tissue.

Teeth—All preserved teeth are single-rooted, homodont, and apparently functional, and indicate that this individual was polyodont. The crowns of all preserved teeth are essentially the same in size and shape; each is about 7.7 mm in height, slender, conical with a pointed apex, medially re-curved, and covered with enamel that lacks ornamentation, such as striations or grooves. Each crown is distinctly bent at the neck of tooth, making an angle of 30–35° with the longitudinal axis of the swollen root, which reaches its greatest diameter (ca. 8.5 mm) at a point a few millimeters toward the root from the enamel-cementum boundary (Fig. 3). At least 18 teeth on the right and at least 21 teeth on the left are preserved in alveoli of the maxillae, whereas a few teeth are preserved in the lower jaw. Teeth are widely spaced, approximately 19 mm apart on-center along the posterior portion of the rostrum and 17 mm apart along the anterior preserved portion. The tips of some of the teeth of the upper jaw are sticking into the lower jaw, presumably as a result of dorsoventral compaction after burial.

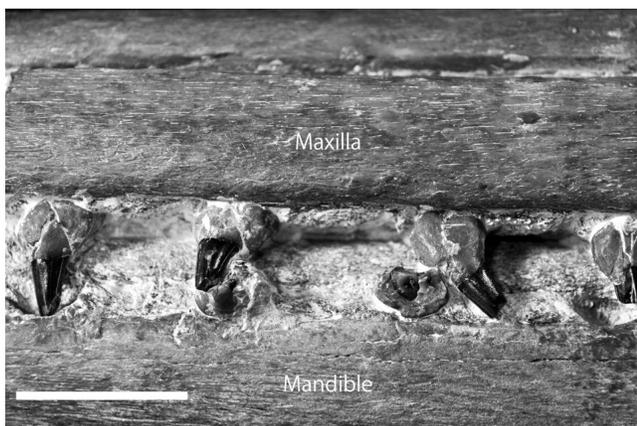


FIGURE 3. Close-up of teeth of Pomatodelphininae, gen. et sp. indet. (KIGAM VP 201101). Scale bar equals 2 cm.

DISCUSSION

For much of the Miocene, longirostrine odontocetes were more diverse and abundant than today. Examples include Eurhinodelphinidae, Eoplatanistidae, Lipotidae, and some Kentriodontidae as well as the platanistoid taxa Allodelphinidae and Pomatodelphininae. One of the salient features shown by KIGAM VP 201101 is the almost mirror image symmetry between the upper and lower jaws, with longitudinal grooves following the premaxilla-maxilla suture on the rostrum similar to grooves on either side of the fused mandibular symphysis. Some features related to the rostrum and mandible are shared by platanistoids, eurhinodelphinids, eoplatanistids, lipotiids, and pontoporiids; but the unique combination of a pronounced longitudinal groove following the premaxilla/maxilla suture, a fused elongate symphyseal portion of the mandible with a deep, narrow groove lateral to the symphysis, a dorsoventrally flattened rostrum and the symphyseal part of the mandible, and a mesorostral groove closed dorsally in the mid- to anterior part of the rostrum is seen only in the platanistid subfamily Pomatodelphininae (Platanistidae) or the platanistoid family Allodelphinidae (Barnes, 2006).

It is not easy to distinguish the Pomatodelphininae from the Allodelphinidae on the basis of the rostrum and symphyseal part of the mandible. The atlas and tympanic bulla of the allodelphinid *Allodelphis pratti* (UCMP 83791) also resemble those of a pomatodelphinine *Zarhachis* (see Barnes and Reynolds, 2009). The teeth do seem to distinguish these otherwise similar groups. Although single-rooted teeth with medially curved, slender, and pointed crowns are shared by both allodelphinids and pomatodelphinines, the shape of root is clearly diagnostic. The swollen rooted teeth of the Korean specimen are most similar to those of *Pomatodelphis* (USNM 187414, USNM 6684) and *Zarhachis* (USNM 10485, USNM 16633). In all known allodelphinids the roots are posteriorly re-curved and slender (Kimura and Ozawa, 2002, Barnes et al., 2010), which is a primitive condition for odontocetes. Morgan (1994), who carefully examined morphological variation of long-beaked dolphins from the Bone Valley Formation of Florida, where the type and other species of *Pomatodelphis* were uncovered, did not note differences in tooth morphology, only to size. For these reasons, KIGAM VP 201101 seems closer to the subfamily Pomatodelphininae (sensu Barnes, 2002, including *Zarhachis* or *Pomatodelphis*) than to any other group of odontocete. The asymmetry of the premaxillae is also consistent with the idea that KIGAM VP 201101 belongs to the Pomatodelphininae (Lambert, 2006), although, as Kellogg (1959) pointed out, the degree of symmetry of the premaxilla appears to vary. KIGAM VP 201101, however, does differ from the known species of pomatodelphininae in the narrow exposure of the premaxilla on the dorsal face of the rostrum. It is uncertain whether this unique feature reflects minor intraspecific variation or whether it indicates a new species of pomatodelphinine. Because KIGAM VP 201101 is fragmentary, we assign it to Pomatodelphininae genus and species indeterminate until more complete specimens are discovered. Nevertheless, the occurrence of the pomatodelphinine odontocete from the North Pacific is very important from a paleozoogeographical point of view because, prior to this discovery, it was thought that only the Allodelphinidae were present in the North Pacific as a long-beaked counterpart of the coeval species of North Atlantic and Paratethyan Pomatodelphininae (Lambert, 2006; Lambert et al., 2008; Barnes and Reynolds, 2009; Barnes et al., 2010).

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