

## The First Record of the Pliocene Gilmore Fur Seal in the Western North Pacific Ocean

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**Abstract** A horizontal ramus of the right dentary with P<sub>4</sub> and M<sub>1</sub> referable to the extinct fur seal, *Callorhinus gilmorei* Berta and Deméré, 1986, is described from the Dainenji Formation in the Futaba district, Fukushima Prefecture, northeastern Japan. The geologic age of the pinniped-bearing horizon within the Dainenji Formation in the Futaba district is reevaluated based on the detailed analysis of associated fossil diatom assemblages. The age of the uppermost D<sub>4</sub> facies of the Dainenji Formation in the Futaba district, which produced the dentary of the Gilmore fur seal, is estimated to be late Late Pliocene, approximately between 2.7 and 2.4 Ma. Since the Gilmore fur seal had been previously known only from the Late Pliocene of California and Mexico, the specimen from the Dainenji Formation is the first record of this species in the western North Pacific and documents the circum North Pacific distribution of *Callorhinus* species since at least the Late Pliocene.

**Key words:** *Callorhinus gilmorei*, Otariidae, Pinnipedia, Late Pliocene, Dainenji Formation, Japan.

### Introduction

The origin and diversification of the Recent genera of the otariid pinnipeds (*i.e.*, fur seals and sea lions) have been thought to lie within the Pliocene (Repenning and Tedford, 1977; Repenning *et al.*, 1979; Barnes *et al.*, 1985). However, the poor fossil record of otariid pinnipeds during the Pliocene has limited our knowledge on the phylogeny and paleobiogeography of these taxa in the North Pacific Ocean.

Berta and Deméré (1986) described a new species of the modern fur seal genus *Callorhinus* as *C. gilmorei* from the Upper Pliocene San Diego Formation in San Diego, California (U.S.A.) and in La Joya, Baja California Norte (Mexico). This is at present the oldest record of a modern genus in the family Otariidae and partially filled a major gap in the history of fur seal diversification in the North Pacific Ocean.

In the present report, we provide a new record of *Callorhinus gilmorei* Berta and Deméré, 1986, from the Upper Pliocene Dainenji Formation in the Futaba district, Fukushima Prefecture, northeastern Japan. This is the first record of *C. gilmorei* from the western North Pacific realm and it provides additional information about the pale-

obiogeographic distribution of this taxon in the North Pacific Ocean.

In order to understand the chronostratigraphic distribution of the Gilmore fur seal in the North Pacific, the geologic age of the pinniped-bearing horizon within the Dainenji Formation in the Futaba district is reevaluated on the basis of the detailed analysis of fossil diatom assemblages.

The following institutional acronyms are used in this report: **LACM**, Section of Vertebrate Paleontology, Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A.; **NSM**, Division of Vertebrate Paleontology, National Science Museum, Tokyo, Tokyo, Japan; **SDSNH**, Department of Paleontology, San Diego Natural History Museum, San Diego, California, U.S.A.; **USNM**, Department of Paleobiology, National Museum of Natural History, Smithsonian Institution, Washington, D. C., U.S.A.

Superscripts on I, C, P, and M denote upper incisors, canines, premolars, and molars, respectively; subscripts denote lower counterparts.

### Dainenji Formation in the Locality Area

In the Futaba district, sedimentary rocks here assigned to the Dainenji Formation have long been called the "Tomioka Formation" since Tokunaga (1948) established its name (*e.g.*, Sugai *et al.*, 1957; Taketani *et al.*, 1986). However, Yanagisawa (1990) and Kubo *et al.* (1994) have clearly shown that the "Tomioka Formation" is undoubtedly identical with the Dainenji Formation of the Sendai Group exposed at its stratotype in Sendai City, Miyagi Prefecture, approximately 70 km north of the Futaba district. According to Kubo *et al.* (1994), the Dainenji Formation in the Futaba district is composed mainly of marine sandstone and diatomaceous mudstone, and is divided into five lithofacies ( $D_{1a}$ ,  $D_{1b}$ ,  $D_{1c}$ ,  $D_2$  and  $D_4$  in ascending order).

Vertebrate fossils generally occur in the  $D_4$  facies in Tomioka Town in the Futaba district (Fig. 1), which is composed of mudstone with intercalated sandstone layers. At the cliff north of Oragahama Fishery Port, the  $D_4$  facies contains a sequence of submarine slide deposits which consist of a slide block (3–4 meter thick), pebbly very coarse- to coarse-grained sandstone containing abundant molluscan fossils (4 meter thick), and bedded medium-grained sandstone (1 meter thick), in ascending order (Fig. 2). NSM PV-20072, to be described below, was recovered in the pebbly sandstone unit as one of many single isolated skeletal elements found in association with abundant shallow water molluscs such as *Tugalia* sp., *Acmaea* sp., *Glycymeris yamaguchii* Hayasaka, 1956, and *Clinocardium hataii* Hayasaka, 1956. Therefore, fossils in the pebbly sandstone unit were apparently transported and deposited as biogenic clasts within the tractional load presumably derived from littoral and inner shelf areas.

Three diatom samples were collected from the mudstone above the pebbly sandstone unit (Fig. 2). The samples were processed following the methods of Akiba

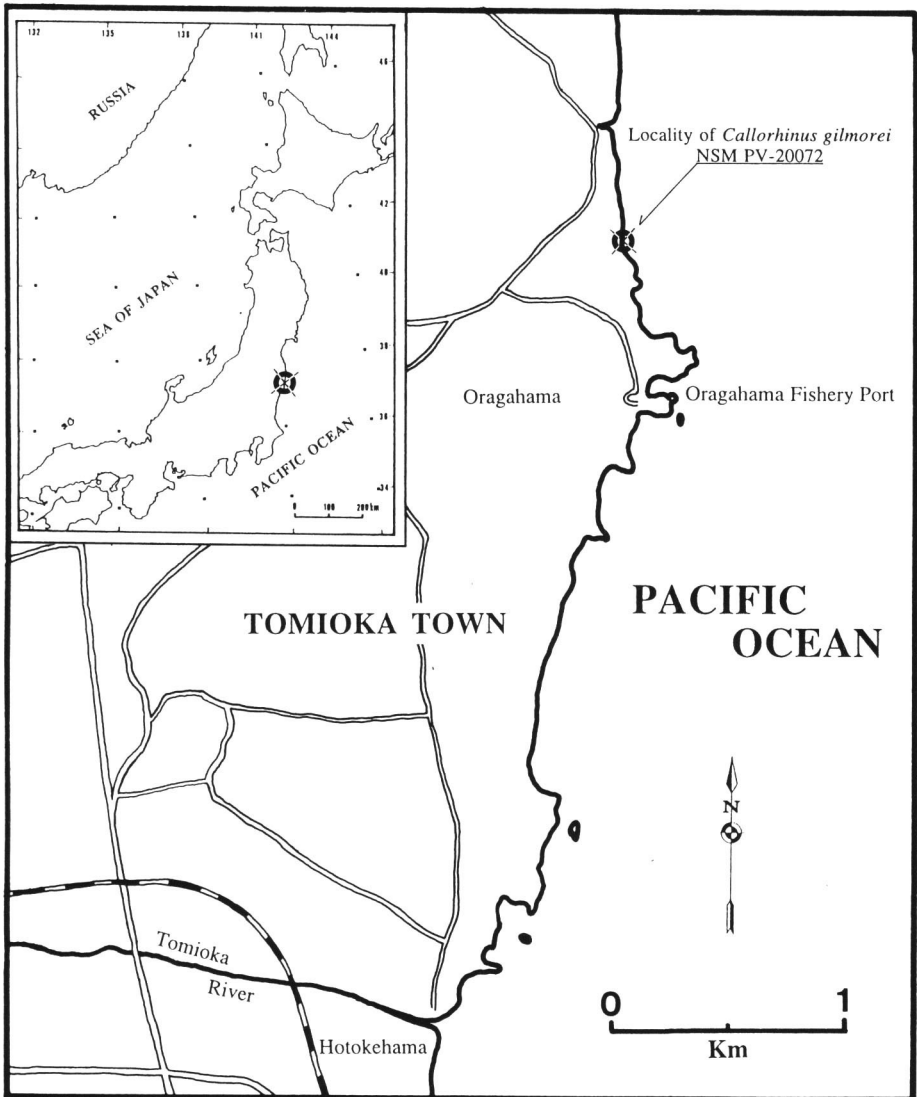


Fig. 1. Map showing the locality of *Callorhinus gilmorei* Berta and Deméré, 1986, NSM PV-20072, right dentary.

(1986). Abundant and relatively well-preserved diatoms are identified from all three samples (Table 1) and are assigned to the late Late Pliocene *Neodenticula koizumii* Zone (NPD 9) of Akiba (1986) based on the occurrences of *N. koizumii* and *Thalassiosira antiqua* and the absence of *Neodenticula kamtschatica* (Fig. 3). Furthermore, the absence of *Neodenticula seminae* (closed copula) indicates that these samples are

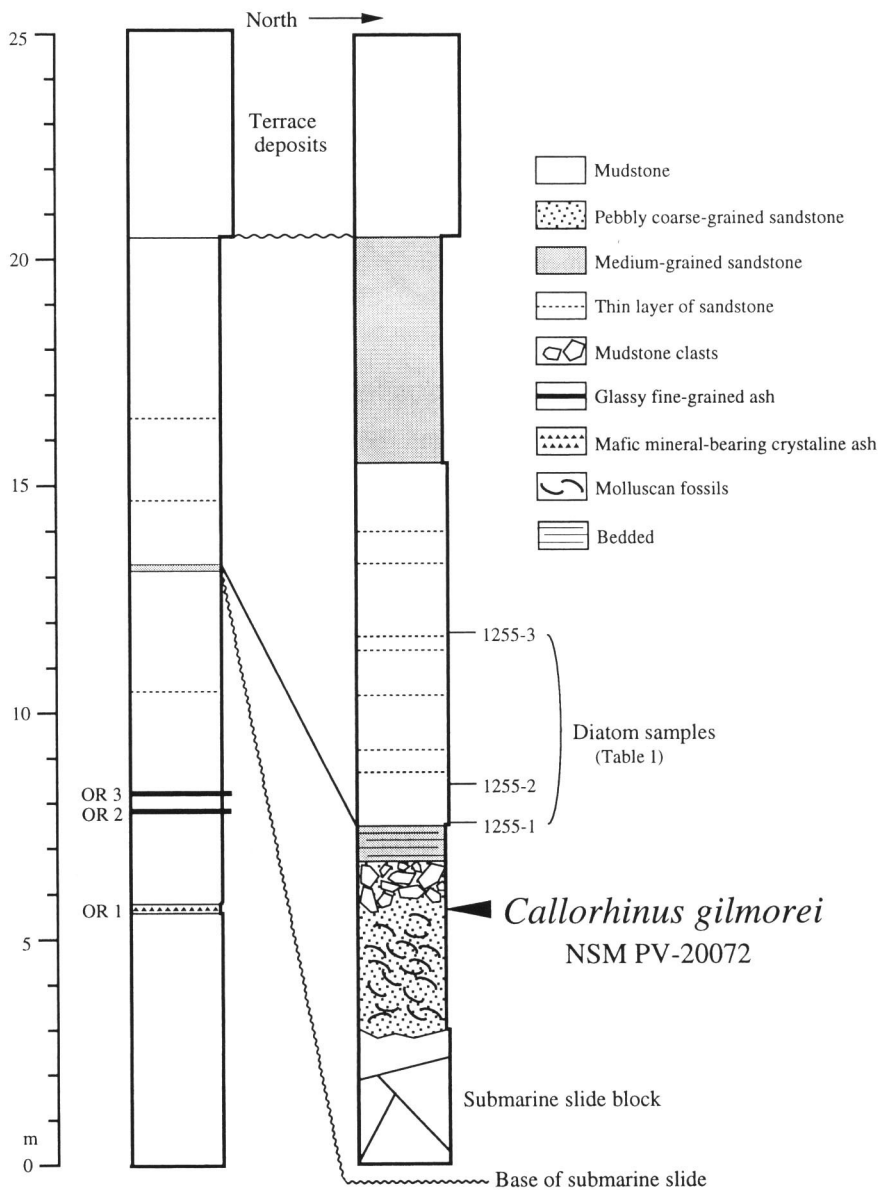


Fig. 2. Columnar sections of the Dainenji Formation at a cliff north of Oragahama Fishery Port, Tomioka Town, Fukushima Prefecture. OR 1–3: Volcanic ashes (see also Kubo *et al.*, 1994).

Table 1. Diatom species from the mudstone above the pebbly sandstone which produced *Callorhinus gilmorei* Berta and Deméré, 1986, NSM PV-20072.

Diatom zone	<i>N. koizumii</i> NPD 9		
	1255-1	1255-2	1255-3
Sample number (Ha-)			
Preservation	G	M	M
Abundance	A	A	A
<i>Actinocyclus curvatus</i> Janisch in Schmidt	4	1	4
<i>A. ochotensis</i> Jousé	+	1	+
<i>A. octonarius</i> Ehrenberg	+	—	2
<i>Actinoptychus senarius</i> (Ehrenberg) Ehrenberg	2	+	—
<i>Adoneis pacifica</i> Andrews	+	1	—
<i>Aulacoseira</i> spp.	+	—	1
<i>Azpeitia nodulifera</i> (Schmidt) Fryxell et Sims	+	—	1
<i>A. tabularis</i> (Grunow) Fryxell et Sims	1	—	—
<i>Cocconeis scutellum</i> Ehrenberg	+	1	—
<i>C. vitrea</i> Brun	—	1	—
<i>Coscinodiscus marginatus</i> Ehrenberg	—	1	1
<i>C. radiatus</i> Ehrenberg	+	—	—
<i>Cyclotella striata</i> (Kützing) Grunow	+	1	—
<i>Cymatosira debyi</i> Tempère et Brun	+	—	—
<i>Delphineis surirella</i> (Ehrenberg) Andrews	+	7	4
<i>Hyalodiscus obsoletus</i> Sheshukova-Poretzkaya	+	1	1
<i>Melosira albicans</i> Sheshukova-Poretzkaya	3	—	+
<i>Neodenticula koizumii</i> Akiba et Yanagisawa	21	16	25
<i>N. sp. A</i>	3	6	1
<i>Nitzshia fossilis</i> (Frenguelli) Kanaya et Koizumi	+	2	3
<i>N. grunowii</i> Hasle	3	—	1
<i>N. reinholdii</i> Kanaya ex Barron et Baldauf	+	—	—
<i>Odontella aurita</i> (Lyngbye) Agardh	+	1	—
<i>Paralia sulcata</i> (Ehrenberg) Cleve	4	7	1
<i>Pseudopodosira elegans</i> Sheshukova-Poretzkaya	5	1	2
<i>Proboscia barboi</i> (Brun) Jordan et Priddle	2	2	3
<i>Stephanopyxis dimorpha</i> Schrader	2	3	4
<i>S. horidus</i> Koizumi	2	—	—
<i>S. turris</i> (Greville et Arnott) Ralfs	3	6	6
<i>Thalassionema nitzschioides</i> (Grunow) H. et M. Peragallo	32	30	33
<i>Thalassiosira antique</i> (Grunow) Cleve-Euler	3	5	3
<i>T. convexa</i> var. <i>aspinosa</i> Schrader	1	—	—
<i>T. gravida</i> Cleve	7	3	3
<i>T. nidulus</i> (Tempère et Brun) Jousé	—	1	—
<i>T. oestrupii</i> (Ostenfeld) Proshkina-Labrenko	2	1	1
<i>T. trifulta</i> Fryxell in Fryxell et Hasle	—	1	—
<i>T. spp.</i>	+	—	—
<i>Thalassiothrix longissima</i> Cleve et Grunow	—	—	+
Total number of valves counted	100	100	100
Resting spore of <i>Chaetoceros</i>	111	107	98

older than the first occurrence of *N. seminae* which lies in the lower part of the *N. koizumii* Zone. Thus the D<sub>4</sub> facies is correlated with the lower part of the *N. koizumii* Zone between the base of this zone (2.7 Ma) and the first occurrence of *N. seminae* (2.4 Ma).

### Systematic Paleontology

Class Mammalia Linnaeus, 1758  
 Order Carnivora Bowdich, 1821  
 Infraorder Arctoidea Flower, 1869  
 Parvorder Pinnipedia Illiger, 1811  
 Family Otariidae Gill, 1866  
 Genus *Callorhinus* Gray, 1859

*Diagnosis of genus*: Reduced premaxillary (*i.e.*, transverse width of premaxilla less than 40% of nasal length as defined by Repenning *et al.*, 1971); lower cheek tooth row short (*i.e.*, a tooth row less than 75% of distance from P<sub>1</sub> to the ascending ramus as defined by Berta and Deméré, 1986); facial angle less than 125° (Repenning *et al.*, 1971); and mandibular foramen anteroventrally directed (Berta and Deméré, 1986).

*Included species*: *Callorhinus gilmorei* Berta and Deméré, 1986, Late Pliocene, California, Mexico, and Japan; *C. ursinus* (Linnaeus, 1758), Middle Pleistocene to Recent, circum-North Pacific.

### *Callorhinus gilmorei* Berta and Deméré, 1986

(Fig. 4; Table 2)

*Callorhinus gilmorei* Berta and Deméré, 1986: 112.

*Diagnosis of species*: A species of the genus *Callorhinus* distinguished from *C. ursinus* by having a smaller I<sup>3</sup>; double-rooted P<sup>2</sup> to P<sup>4</sup>; closely spaced M<sup>1</sup> and M<sup>2</sup>; double-rooted P<sub>3</sub> and P<sub>4</sub>; and a long, shallow pterygoid process on the dentary that forms a ventromedial shelf (Berta and Deméré, 1986).

*Holotype*: SDSNH 25176, partial young adult female skeleton including left I<sup>3</sup> and P<sup>2</sup>; right upper C, I<sup>1</sup> or I<sup>2</sup>, and P<sup>1</sup>; left I<sub>2</sub> and P<sub>1-3</sub>; right dentary with I<sub>1</sub>, P<sub>2-3</sub>, and M<sub>1</sub>; left and right innominates each lacking posterior one-third of pubis and ischium; ribs; thoracic, lumbar, and caudal vertebrae; all associated and from the same individual; collected from the Late Pliocene lower member of the San Diego Formation (ca. 3.0–2.0 Ma), SDSNH locality 3174-D, San Diego, California, U.S.A.

*Previously referred specimens*: Other specimens from the San Diego Formation, San Diego, California (U.S.A.) and La Joya, Baja California Norte (Mexico) are listed in Berta and Deméré (1986) and are deposited at LACM, SDSNH, and USNM.

*Newly referred specimen* : NSM PV-20072, a right dentary fragment with P<sub>4</sub> and M<sub>1</sub>, probably of a female individual; collected by Yukio Yanagisawa on 15 March, 1997.

*New locality* : NSM PV-20072 was found at a coastal cliff, 600 meters north of Oragahama Fishery Port, Oragahama, Tomioka Town, Futaba County, Fukushima Prefecture, northeastern Japan, 37°21'59" North latitude, and 141°02'22" East longitude (Fig. 1).

*Formation and age* : As discussed above, NSM PV-20072 was collected from the uppermost D<sub>4</sub> facies within the Dainenji Formation of the Sendai Group (Fig. 2);

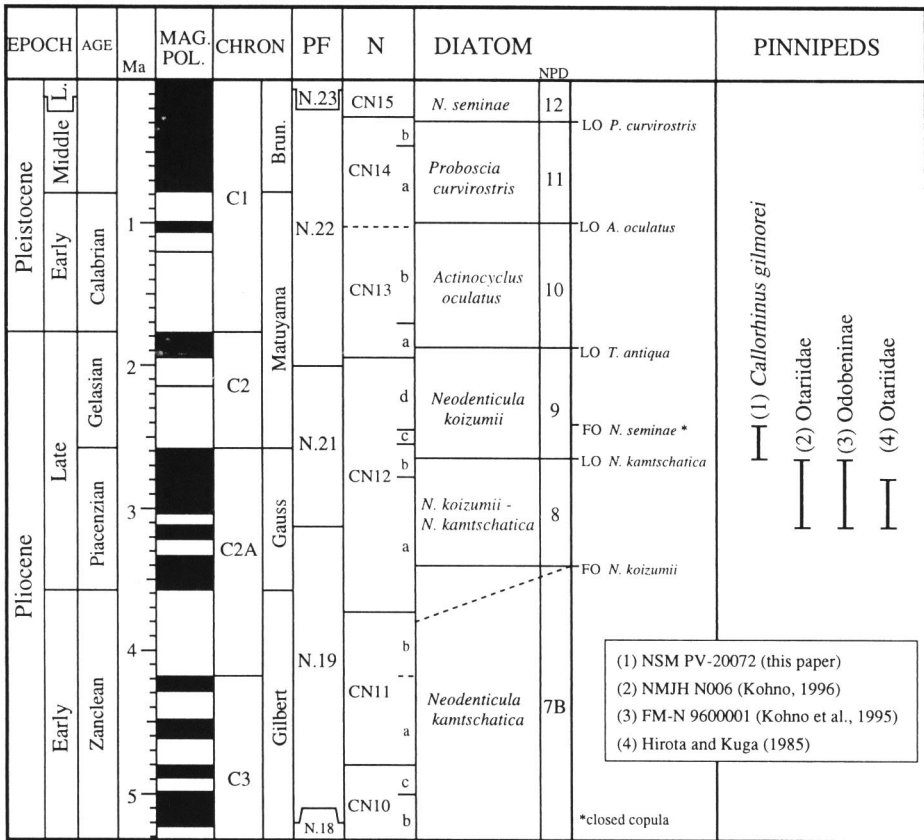


Fig. 3. Ages of *Callorhinus gilmorei* Berta and Deméré, 1986, NSM PV-20072, and previously reported pinniped specimens from the Dainenji Formation (Hirono and Tomioka Formations of Taketani *et al.*, 1986) in Tomioka and Naraha Towns, Fukushima Prefecture. Geomagnetic polarity time scale and microfossil biochronology after Cande and Kent (1995) and Berggren *et al.* (1995). PF: Planktonic Foraminifera zonation (Blow, 1969); N: Calcareous nannofossil zonation (Okada and Bukry, 1980); Diatom zonation (Akiba, 1986); Diatom chronology after Barron and Gladenkov (1995) and Yanagisawa and Akiba (in prep.).

late Late Pliocene, Gelasian Age of European marine chronostratigraphy, approximately 2.7–2.4 Ma (Fig. 3).

*Associated fauna*: Some pinniped teeth assignable to large sea lions and many cetacean remains have been collected from the same horizon as NSM PV-20072, though these as yet are undescribed. Kohno (1996) summarized previous studies on the fossil pinnipeds from the Dainenji Formation (Hirono and Tomioka Formations of Taketani *et al.*, 1986) in the Futaba district and recognized the presence of at least a tusked odobenine walrus (see also Kohno *et al.*, 1995) and small and large otariids (see also Hirota and Kuga, 1985). The chronostratigraphic distribution of these taxa is summarized in Figure 3.

*Description*: NSM PV-20072 is the posterior half of the horizontal ramus of a

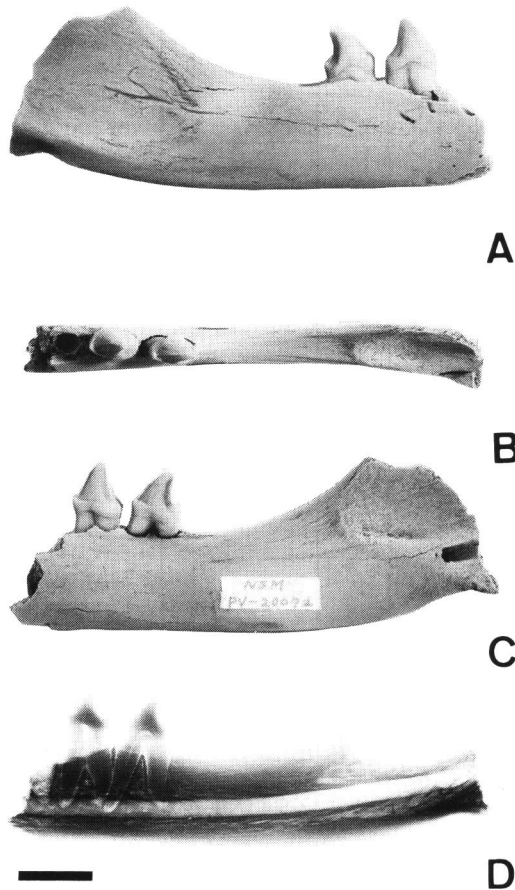


Fig. 4. *Callorhinus gilmorei* Berta and Deméré, 1986, NSM PV-20072, right dentary from the Dainenji Formation, coated with a sublimate of ammonium chloride for photography. A, lateral; B, occlusal; C, medial; D, medial (X-ray) views. Scale bar equals 1 cm.



right dentary with  $P_4$  and  $M_1$  in place. Based on its slenderness and size, NSM PV-20072 is probably a female. The horizontal ramus is long, thin and slender, and has parallel dorsal and ventral margins. The bone surface of the ramus is smooth. A small mental foramen is seen beneath the  $P_3$  alveoli. The alveoli as preserved indicate that the  $P_3$  was double-rooted. The  $P_4$  and  $M_1$  are also distinctly double-rooted (Fig. 2 D). The cheek tooth row is straight with teeth moderately spaced and is on the dorsal margin of the ramus. The coronoid process is very thin and broad at the base. The masseteric fossa on the lateral surface of the coronoid process is relatively deep and large in area. The pterygoid fossa on the medial surface of the coronoid process is relatively shallow, but well delimited. The mandibular foramen is small and lies anterior to the pterygoid process. Although it is slightly damaged, the anterior margin of this foramen is directed anteriorly or anterodorsally. The digastric prominence is very weak and turned smoothly up to the pterygoid process. The pterygoid process slopes ventromedially but is almost broken away. The condyloid process is also broken away, but the breakage suggests that it was located at the same level as the tooth row.

The right  $P_4$  and  $M_1$  are preserved in place in the dentary. Both are double-rooted with divergent roots. Each tooth is proportionally small to the dentary and high crowned with weakly developed lingual cingulum. No accessory cusp is developed on the lingual cingulum in either tooth. The crown of the  $P_4$  forms a simple pointed cusp that gently slopes posteriorly. The enamel surface of the crown is smooth. There is a small anterior accessory cusp at the base of the crown. The  $M_1$  also has a simple pointed cusp, and is inclined posteriorly. There are small, but distinct anterior and posterior accessory cusps at the base of the crown, of which the posterior one is more prominent.

Table 2. Measurements of the right dentary of *Callorhinus gilmorei* Berta and Deméré, 1986, NSM PV-20072, from the Dainenji Formation, in millimeters. Parenthesis indicates measurements as preserved. "a" indicates measurements of alveoli. "e" indicates estimated measurements.

NSM PV-20072	
Total length	(65.4)
Depth of horizontal ramus behind $P_3$	14.1e
Width of horizontal ramus behind $P_3$	6.2
Depth of horizontal ramus behind $M_1$	13.7
Width of horizontal ramus behind $M_1$	4.7
$P_3$ anteroposterior diameter	—
$P_3$ transverse diameter	3.2a
$P_4$ anteroposterior diameter	6.9
$P_4$ transverse diameter	3.9
$M_1$ anteroposterior diameter	6.6
$M_1$ transverse diameter	4.0

### Discussion

NSM PV-20072 is characterized by a slender horizontal ramus; a pterygoid process that forms a ventromedial shelf; relatively small, double-rooted  $P_3$  and  $P_4$  with no accessory cusp on lingual cingula of at least  $P_4$ ; and small adult size. All these characters are identical to the characteristics of the holotype dentary of *Callorhinus gilmorei* that is known from the Upper Pliocene San Diego Formation, California (Berta and Deméré, 1986). In addition to the above mandibular characters, *C. gilmorei* also has such characters as a small  $I^3$ , double-rooted  $P^2$  to  $P^4$ , and closely spaced  $M^1$  and  $M^2$  in contrast to the derived conditions of these characters in *C. ursinus* (Berta and Deméré, 1986). Therefore, all of the diagnostic cranial, dental, and mandibular characters as can be observed are interpreted to be plesiomorphies. In this respect, the fossil fur seal is apparently more primitive than the living Northern fur seal as has already been pointed out by Berta and Deméré (1986). Based on the osteological characteristics and their chronostratigraphic distribution as well as their paleobiogeographic distribution as will be discussed below, the Gilmore fur seal of Late Pliocene age and the living Northern fur seal might have been end members in a series of ancestor-descendant "species" undergoing anagenesis in the North Pacific Ocean.

As for the paleobiogeographic distribution, the Gilmore fur seal had been previously known only from the eastern North Pacific realm. Thus, the new record from the Dainenji Formation documents the circum North Pacific distribution of this species like the living Northern fur seal. As is the case for the most extinct pinnipeds, however, it is difficult to determine the distribution range and/or migratory pattern of *C. gilmorei* with certainty. But the locality records give an outline of at least the distribution range of this species.

In the case of the living Northern fur seals, they have some restricted breeding areas and considerably wider migratory areas (Kenyon and Wilke, 1953; Scheffer, 1958; King, 1983). According to these authors, the main areas where the Northern fur seals breed are restricted to some islands in the Bering Sea and off Sakhalin, over  $50^\circ$  North latitude. They migrate southward from those islands during winter and spring, then return again to their breeding grounds in summer. The southern limits of their migratory areas are at the Boso Peninsula, Honshu, central Japan, at about  $35^\circ$  North latitude in the western North Pacific (Wada, 1971), and at San Diego, California, U.S.A., at about  $33^\circ 10'$  North latitude in the eastern North Pacific (Huey, 1942).

In the case of the late Middle Pleistocene Northern fur seals known from the Shimokita district, northern Japan, at about  $41^\circ 30''$  North latitude, the locality area was not the breeding area on the basis of the segregation pattern of the developmental ages and gender of individuals as evidenced by the population sample of canine teeth (Hasegawa *et al.*, 1987).

On the analogy of the distribution range and/or migratory pattern of the Middle

Pleistocene and Recent Northern fur seals mentioned above, the locality area (the Futaba district) of the Gilmore fur seal in the western North Pacific as well as that (southern California and northern Baja California) in the eastern North Pacific might not have been the breeding areas latitudinally but the migratory areas for the Gilmore fur seals. However, whether or not the breeding grounds of the Gilmore fur seal had been separated northerly from those locality areas like that of living Northern fur seals is presently uncertain due to limited available information.

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