Original Article

A new species of the fossil murine rodent
from the Pinza-Abu Cave, the Miyako Island of the Ryukyu Archipelago, Japan

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Abstract：A new species of the fossil murine rodent of the genus *Rattus* is described by comparing with the living endemic species of *Diplothrix legata* on the islands of Okinawa and Amamioshima. The murine fossil specimens aged as the later part of Pleistocene were excavated from the Pinza-Ave cave, the Miyako Island of the Ryukyu Archipelago, Japan in 1983.

Key Words：Murinae, *Rattusmiyakoensis*, Miyako ancient rat, *Diplothrix legata*, Pinza-Abu, limestone cave deposits, Miyako Island, the Ryukyu Archipelago, late Pleistocene

Introduction

From the Pinza-Abu Cave, the Miyako Island of the Ryukyu Archipelago, Japan, a large number of murine rodents of fossil maxillae, mandibles, incisors, humeri, ulnae, pelves, femurs, and tibias, as well as one crown area between parietal ridges and one incomplete nasals and premaxillae with incisors were excavated in 1980-84 (Hasegawa, 1985). The deposits in the cave were estimated as 25,800 ± 900y. B. P. and 26,800 ± 1,300y. B.P. by the ^{14}C method (Hamada, 1985) or the fossil deer of *Capreolus miyakoensis* have been formed in the later part of Pleistocene by the F-contents (Matsuura, 1985). However, these murine fossils have been identified provisionally as *Diplothrix* cf. *legata* (Hasegawa, 1985a).

The purpose of this paper is to reexamine the fossil murine specimens recovered from the Pinza-Abu Cave, the Miyako Island (Hasegawa, 1985a), and to describe a new species by comparing with *Diplothrix legata*, which is a large living endemic murid rodent occurring on the islands of Amamioshima, Tokunoshima and Okinawa, the Ryukyu Archipelago, Japan (Musser and Carleton, 2005; Kaneko, 2008).

Materials and Methods

The fossil specimens examined in this study were 60 of isolated incomplete maxillae with molar teeth, 12 of isolated incomplete maxillae without molar teeth, 60 of isolated incomplete mandibles with molar teeth, 22 of isolated incomplete mandibles without molar teeth, one incomplete nasals and premaxillae with incisors, and one incomplete crown part of the skull composed of incomplete parietal, frontal and interparietal bones. These specimens were collected from the Pinza-Ave Cave, the Miyako Island of the Ryukyu Archipelago, Japan, in 1980-84 (Hasegawa, 1985a) and were housed in the Okinawa Prefecture Museum & Art Museum (see Appendix).

Specimens of living species for comparisons were as follows. Ten skulls of the living *Diplothrix legata*: seven skulls were collected from the Amamioshima Island; and three skulls from the Okinawa Island. These skulls of *Diplothrix legata* were housed in the National Science Museum, Tokyo (NSMT), and the Okinawa Prefecture Museum & Art Museum (OPM) (see Appendix).The holotypes of *Lenothrix legata* (BM 5.11.3.42: Thomas, 1906) and *Mus bowersii* var. *okinavensis* (NSMT-M34325: Namie, 1909) were examined in the Natural History, London, UK (BM) and the National Science Museum, Tokyo, Japan (NSMT) respectively. We followed Musser and Carleton (2005) who currently listed *Mus bowersii* var. *okinavensis* as a synonym of *Diplothrix lagata*. A young skull of *Bandicota indica* living in Taiwan is the Hasegawa's private collection, and skulls of *Rattus rattus* and *R. norvegicus* collected from Japan are the Kawaguchi's private collection, respectively. Acronyms used in the study are OPM-FV (fossil vertebrate specimens housed in the Okinawa Prefecture Museum & Art Museum) and NSMT-M (mammal specimens housed in the National Science Museum, Tokyo).

Dental terminology adopted in this study is diagramed in Fig. 1, following by Jacobs (1978). In describing the characteristics of molar morphology we noted the terminology taken by Musser (1981). The upper molars were abbreviated as M, the lower molars were m, and the 1st, 2nd, and 3rd molars were written as M1 or m1, and so on.

Following 15 dimensions were measured as illustrated in Fig.2: length of the upper first molar (LM1), length of the upper second molar (LM2), length of the upper third molar (LM3), width of the upper first molar (WM1), width of the upper second molar (WM2), width of the upper third molar (WM3); distance between the posterior edge of the attachment area of the superficial masticatory muscle and the anterior margin of alveoli of the first upper molar on the maxillae (ASM-M1); total length of the upper molars (TLUM); length of the lower first molar (Lm1),

length of the lower second molar（Lm2）, length of the lower third molar（Lm3）, width of the lower first molar（Wm1）, width of the lower second molar（Wm2）, width of the lower third molar （Wm3）; and total length of the lower molars（TLLm）. These measurements were read to the nearest 0.01 millimeter with a dial caliper（the minimum accuracy = 0.05 mm）.

Number of roots of each molar was given by the observation of the alveoli. The terminology of the alveoli was followed by Musser and Holden（1991）.

Statistical tests were performed following Sokal and Rohlf （1973）. The analysis of variance of the means of 15 measurements shows that there are no differences between the measurements between the right and left sides in the living *Diplothrix legata*. Thus, measurements on the right side of the upper and lower
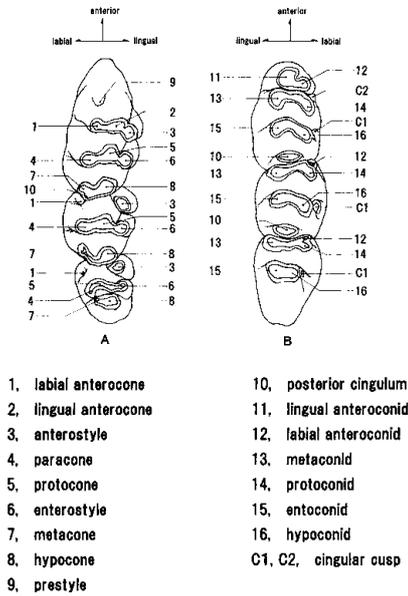

1, labial anterocone
2, lingual anterocone
3, anterostyle
4, paracone
5, protocone
6, enterostyle
7, metacone
8, hypocone
9, prestyle
10, posterior cingulum
11, lingual anteroconid
12, labial anteroconid
13, metaconid
14, protoconid
15, entoconid
16, hypoconid
C1, C2, cingular cusp

Figure 1 Occlusal views of the right maxillary molar row （A） and the right mandibular molar row （B） from the fossil *Rattus miyakoensis* illustrating structural terms. Terminology for molars was followed by Jacobs（1978）.
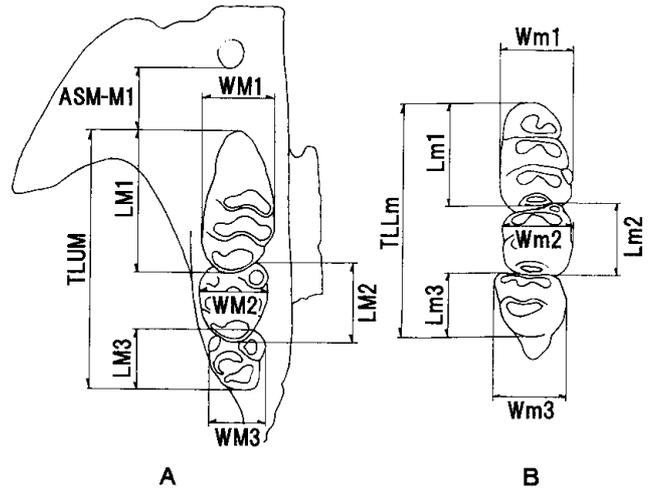

Figure 2 Occlusal views of right maxilla （A） and right maxillary molar row （B） of the fossil *Rattus miyakoensis* showing limits of 15 measurements.
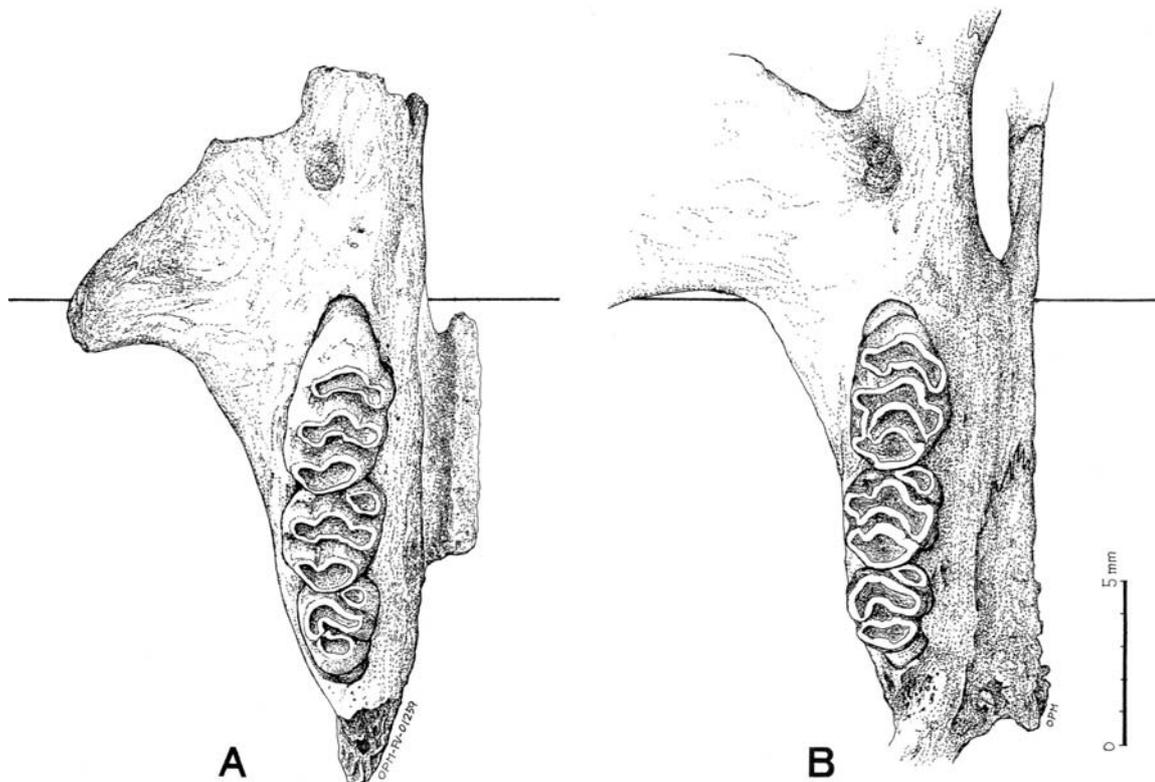

Figure 3 Occlusal views of the right maxilla of the fossil *Rattus miyakoensis* （A, the holotype, OPM-FV-01259） and the living *Diplothrix legata* from Okinawa （B, OPM- no number）. A horizontal line indicates the position of the anterior point of the first upper molar, where the molar root enters into the alveolar canal.
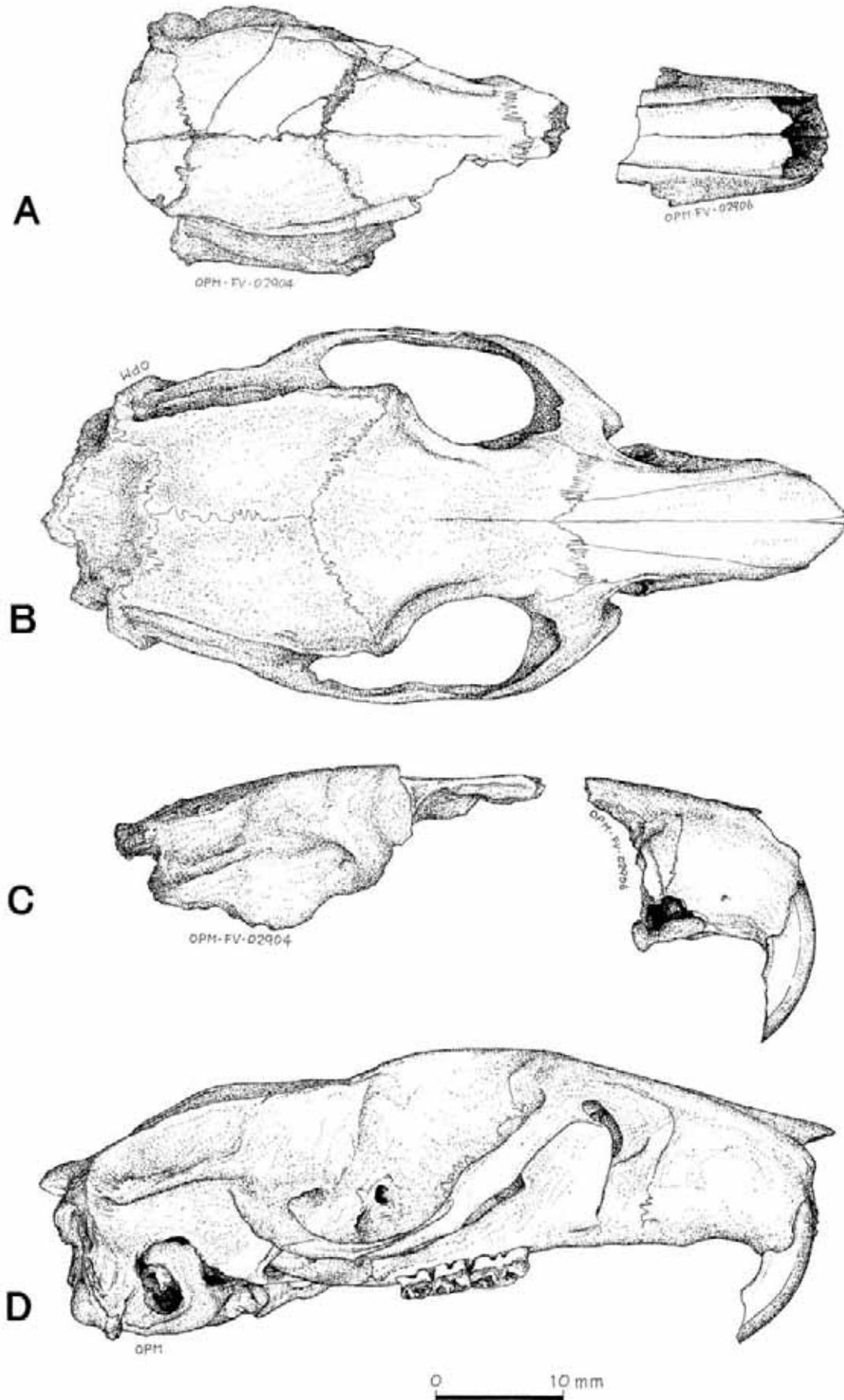
Figure 4 Dorsal（A - B）and lateral（C - D）views of the fossil *Rattus miyakoensis*（A and C）and the living *Diplothrix legata*.（B and D）. A and C: OPM-FV-02904 and OPM-FV-02906, B and D: OPM-no number. In c, the left side of the inciser is omitted.

molars are used in *D. lagata* in further analysis. In the fossil new species described below, measurements on the left and right sides are pooled.

Results

Taxonomic description:

Family Muridae

Subfamily Murinae

Rattus miyakoensis sp. nov.（Plate 1）

［Japanese name：Miyako Mukashi Nezumi, new］

［English name: Miyako Ancient Rat, new］

Holotype: OPM-FV-01259, the right maxilla with the first, second and third molars recovered from a deposit in the Pinza-Abu Cave （24°44′50″N, 125°20′08″E）, Ueno Village, Miyako County（Miyako Island）, Okinawa Prefecture in 1983 by Yoshikazu Hasegawa, one of the present authors. The holotype is deposited in the Okinawa Prefecture Museum & Art Museum（OPM）, Okinawa.

Age: Würm: 25,800 ± 900y. B. P. and 26,800 ± 1,300y. B.P. by the ^{14}C method（Hamada, 1985）, or the later part of Pleistocene by the F - contents（Matsuura, 1985）.

Etymology: This species is named as "*miyakoensis*" due to the excavation site is located on the Miyako Island of the Ryukyu Archipelago, Japan.

Diagnosis: The posterior edge of the incisive foramen passes at the front margins of the molar rows. The most anterior point of the posterior arch of the antero-orbital plate approximately lies at the anterior margin near the anterior alveolus of M1（Fig. 3）.

The distance between the posterior edge of the attachment area of the superficial masticatory muscle and the anterior margin of alveoli of the first upper molar on the maxillae（ASM-M1）is slightly shorter（Fig. 3）.

A strong supraorbital ridge on the crown is about 1.9 mm in width, and extends backwards over the braincase, where the ridges on both sides are the widest in 17.6 mm on the middle

part of the parietals and are slightly narrow on the anterior and posterior parts of the same bones（Fig. 4）. The ridge connected with the frontal and parietal is smoothly curved without protruding forward and outward direction.

The M1, M2, and M3 have no posterostyle（= t7; Musser, 1981; the reference is the same in the following parentheses）（Fig. 5）. The M1 has a well-marked relatively long slope of the anterior part coming up to the grinding surface of M1. The total upper molar length（TLUM）is the largest among the all living species of the genus *Rattus*.

Description: The fossil is a large Murine rodent with brachydont. Molars form chevron-shaped lamina（Fig. 3）. The cusps of the upper molars slant posteriorly, and three cusps are well connected with the dentin space in the form of chevrons. On the contrary, the cusps of the lower molars slant anteriorly. Total molar length is about 11.4 mm in the upper and 10.5 mm in the lower（Table 1）.

The posterior edge of the incisive foramen penetrates at the anterior part of M1（Fig. 3）. The most anterior point of the posterior arch of the antero-orbital plate lies at the anterior part of M1.

A strong supraorbital ridge is 1.9 mm in width, and extends backwards over the braincase, where the ridges on both sides are the widest in 17.6 mm on the middle part of the parietals and are slightly narrow on the anterior and posterior parts of the same bones（Fig. 4）. The ridge connected with the frontal and parietal is curved smoothed linearly without protruding forward and outward.

The M1, M2, and M3 have no posterostyle. The M1 has an asymmetrical occlusal outline（Figs. 3 and 5）. The M1 has a well-marked relatively long slope of the anterior part coming up to the grinding surface of it. It is composed of three chevrons, in which the anterior two chevrons have three cusps and the third chevron has two cusps. The first chevron comprises the anterostyle （= t1）and lingual（= t2）and labial anterocones（= t3）. The anterostyleis slightly posterior to the lingual and labial anterocones. The anterolabial area of the anterostyle is connected with the posterolingual area of the lingual anterocone. There is a posterior connection between the lingual and labial anterocones. The la-

Table1.Lengths and widths of the upper and lower molars and ASM-Ml* in the living *Diplothrix legata* and the fossil *Rattus miyakoensis* .

Measurements	*Diplothrix legata***			*Rattus miyakoensis*			F-value
	N	Mean±SD (mm)	Range (mm)	N	Mean±SD (mm)	Range (mm)	
LM1	10	4.887 ± 0.214	4.64 — 5.31	60	6.003 ± 0.289	5.17—6.80	0.550*
LM2	10	3.153 ± 0.209	2.85 — 3.46	60	3.177 ± 0.226	2.65—3.61	0.850
LM3	10	2.714 ± 0.202	2.43 — 3.03	60	2.822 ± 0.170	2.38—3.18	1.404
TLUM	10	10.268 ± 0.523	9.67 — 11.35	60	11.346 ± 0.398	10.37—12.33	0.578*
WM1	10	3.057 ± 0.142	2.87 — 3.29	60	3.367 ± 0.144	3.02—3.70	0.974
WM2	10	2.850 ± 0.162	2.49 — 3.01	60	3.104 ± 0.126	2.68—3.37	1.644*
WM3	10	2.410 ± 0.165	2.16 — 2.65	60	2.422 ± 0.128	2.14—2.69	1.669*
Lm1	9	4.204 ± 0.146	3.97—4.51	60	4.466 ± 0.173	4.02—4.85	0.709
Lm2	9	3.080 ± 0.111	2.91—3.21	60	3.179 ± 0.187	2.72—3.54	0.354**
Lm3	9	2.960 ± 0.216	2.64—3.31	60	3.261 ± 0.155	2.95—3.63	1.940**
TLLm	9	9.991 ± 0.375	9.42—10.63	60	10.529 ± 0.353	9.66—11.21	1.128
Wm1	9	2.873 ± 0.118	2.68—3.08	60	2.933 ± 0.148	2.49—3.21	0.635
Wm2	9	2.888 ± 0.115	2.71—3.05	60	2.994 ± 0.143	2.73—3.28	0.573**
Wm3	9	2.501 ± 0.137	2.35—2.76	60	2.698 ± 0.126	2.40—3.03	1.179
ASM-M1	9	4.272 ± 0.437	3.52—4.95	35	3.139 ± 0.322	2.59—3.83	1.842*

*: 0.05<p<0.1, **:p<0.05

***: The holotype of *Mus bowersii* var. *okinavensis* was included.
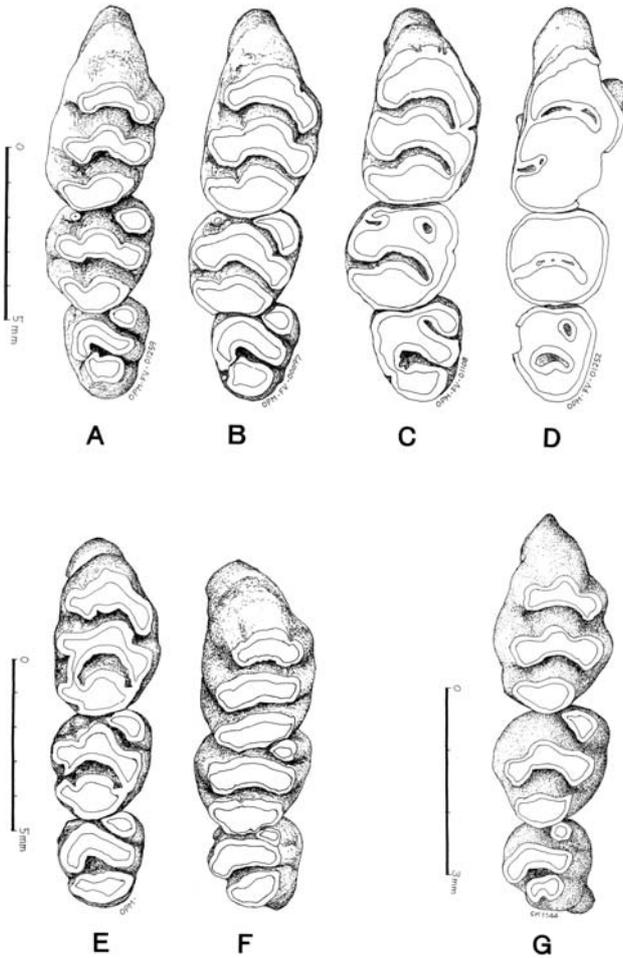
Figure 5 Occlusal views of the right maxillary molar row of *Rattus miyakoensis* (A - D), the living *Diplothrix legata* (E), the living *Bandicota indica* (F), and the living *Rattus rattus* (G). A: OPM-FV-01259, B: OPM-FV-00097, C: OPM-FV-01108, D: OPM-FV-01252, E: OPM no number, F: Hasegawa's private collection, G: Kawaguchi's private collection (SK1144).
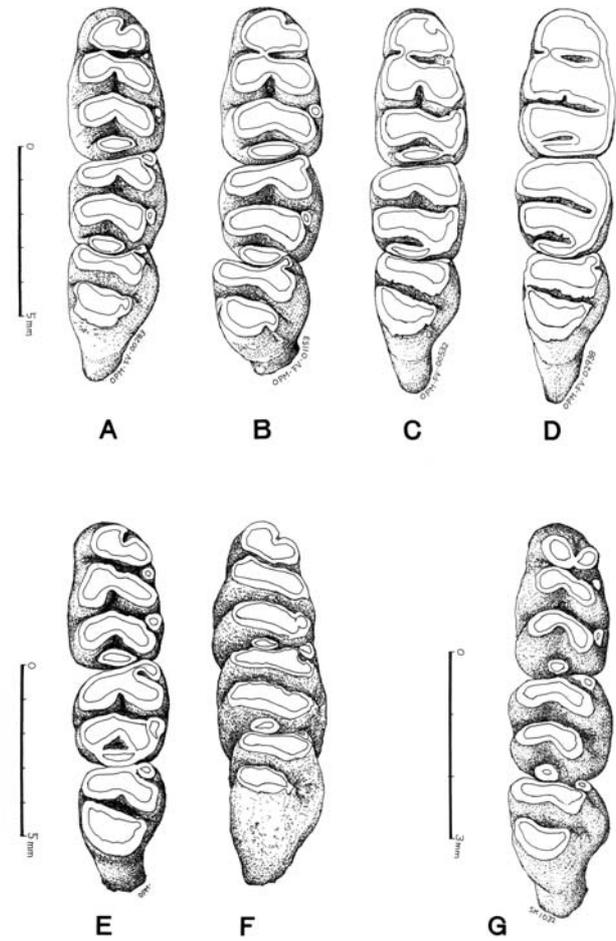

Figure 6 Occlusal views of the right mandibular molar row of *Rattus miyakoensis* (A-D), the living *Diplothrix legata* (E), the living *Bandicota indica* (F), and the living *Rattus rattus* (G). A: OPM-FV-00283, B: OPM-FV-01153, C: OPM-FV-00532, D: OPM-FV-02938, E: OPM no number, F: Hasegawa's private collection, G: Kawaguchi's private collection (SK1032).

bial anterocone is slightly posterior relative to the lingual anterocone. The lingual anterocone is the largest cusp in the first chevron. The second chevron comprises the paracone (= t6), protocone (= t5), and enterostyle (= t4). The paracone and the enterostyle are at about the same level and slightly posterior relative to the protocone. There is a posterior connection between the paracone and the protocone, or between the protocone and the enterostyle. The protocone is the largest cusp of the second chevron. The third chevron comprises the metacone (= t9) and hypocone (= t8) joined by a posterior connection. The hypocone is larger than the metacone. The posterior cingulum sometimes present in six of 60 specimens as a small notch but much reduced (see Fig. 1). This posterior cingulum when present has a shallow valley between the metacone and the cingulum. At the anterior margin of M1, one or two minute prestyles is rarely present on the precingulum at the base of juncture of the lingual and labial anterocones in four of 60 specimens: one prestyle is present in OPM-FV- 00118, 00441, and 01279, and two prestyles in OPM-FV-02878. A small accessory cusp is found on the labial border of M1 between the paracone and metacone in four specimens among 60 ones (OPM-FV- 00095, 00444, 00480, and 01056).

The M2 has a rounded occlusal outline and comprises five major cusps (paracone, protocone, enterostyle, metacone and hypocone) arranged in two chevrons (Figs. 3 and 5). The first chevron comprises the enterostyle, protocone and paracone. The protocone is larger than the paracone or enterostyle. The paracone and the enterostyle are at about the same level and slightly posterior relative to the protocone. There is a posterior connection between the paracone and the protocone, or between the enterostyle and the protocone. The hypocone is larger than the metacone. The hypocone connects posteriorly with the metacone to form the second chevron. The anterostyle is prominent and confluent weakly with the labial anterocone. A small round cusp of the labial anterocone is present in 40 of 46 specimens with an unworn molar (Table 2). Neither lingual anterocone nor accessory cusp is present.

The M3 has a trapezoid occlusal outline tapering posteriorly (Figs. 3 and 5). It has two well defined chevrons. The first chevron is composed of paracone, protocone and enterostyle. The paracone and enterostyle are at about the same level and slightly posterior relative to the protocone. The protocone is closer to the paracone than the enterostyle. The second chevron is

composed of the metacone and hypocone. The size of the metacone is smaller than that of the hypocone. The metacone is close to the enterostyle, but well separated from the paracone. The anterostyle is a large cusp at the anterolingual margin of the tooth. The labial anterocone is low and rather like a cingulum at the anterolabial border of the tooth, if it present. The labial anterocone occurs in 13 among 24 specimens with an unworn molar (Table 2).

The m1 is roughly a trapeziform and has six major cusps (protoconid, metaconid, hypoconid, entoconid, labial anteroconid and lingual anteroconid) formed in three chevrons (Figs. 3 and 6). There is no medial anteroconid (= anterocentral cusp). The lingual anteroconid (= anterolingual cusp) and labial anteroconid (= anterolabial cusp) are connected posteriorly to form the first chevron. The labial anteroconid is smaller than the lingual anteroconid and slightly posterior to it. The metaconid and protoconid are connected anteriorly to form the second chevron. The protoconid is slightly posterior relative to the metaconid. The hypoconid and entoconid are connected anteriorly to form the third chevron. The hypoconid is slightly posterior to the entoconid. The posterior cingulum is an isolated flattened oval at the posterior margin of the teeth between the hypoconid and entoconid. Except for 22 specimens with wearing molars, one cingular cusps (C1 = posterior labial cusplet) is not present, the C1 and C2 (= anterior labial cusplet) occur together in 19 specimens, and the C2 alone is developed in 19 specimens on the labial cingulum among 38 specimens.

The m2 has a trapezoidal occlusal outline tapering posteriorly (Figs. 3 and 6). It comprises four major cusps (metaconid, protoconid, entoconid and hypoconid) arranged in two transverse chevrons. The metaconid and protoconid unite anteriorly to form the first chevron. The entoconid and hypoconid are connected anteriorly to form the second chevron, and the latter is posterior relative to the former. The posterior cingulum is an isolated flattened oval at the posterior margin of the teeth between the hypoconid and entoconid. A labial anteroconid (= anterolabial cusp) is developed at the anterolabial corner of the tooth and is connected to the protoconid. Except for 36 specimens with wearing molars, one cingular cusp (C1 = posterior labial cusplet) is completely visible on the labial cingulum among 24 specimens.

The m3 is triangular in occlusal outline (Figs. 3 and 6). It comprises four major cusps (metaconid, protoconid, entoconid and hypoconid) arranged in two transverse chevrons. The metaconid and protoconid are connected anteriorly to form the first chevron. The metaconid and protoconid are at about the same level. The entoconid and hypoconid are joined anteriorly to
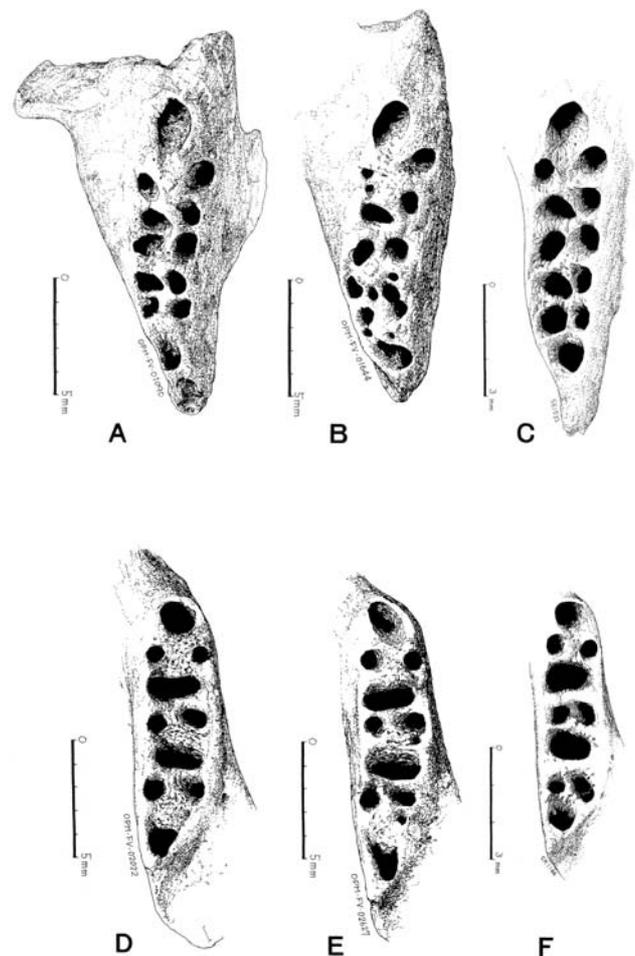

Figure 7 Ventral views of the upper alveoli (A-C) and dorsal views of the lower alveoli (D-F) in the fossil *Rattus miyakoensis* (A, B, D and E) and the living *Rattus rattus* (C and F). Both A and D are the most frequent patterns, respectively. Both B and E are exceptional patterns with supplemental smaller rootlets, respectively. A: OPM-FV-01090, B: OPM-FV-01644, D: OPM-FV-02022, E: OPM-FV-02627, F: Kawaguchi's private collection (SK1144).

form the second chevron. A labial anteroconid is developed at the anterolabial corner of the tooth. Except for 35 specimens with wearing molars, one cingular cusp (C1) is developed alone on the labial cingulum in six among 25 specimens.

Alveolar patterns for upper and lower molar roots are illustrated in Fig. 7. The M1 has a large anterior, a medium-sized labial, a medium-sized posterior, and two medium-sized lingual roots on

Table 2. Frequencies of the occurrence of labial anterocone on M2 and M3 between the living *Diplothrix legata* and the fossil *Rattus miyakoensis*.

	M2			M3		
	labial anterocone present	labial anterocone absent	Total	labial anterocone present	labial anterocone absent	Total
*Diplothrix legata**	7	3	10	8	2	10
Rattus miyakoensis	40	6	46	13	11	24
Total	47	9	56	21	13	34
	G/q = 1.214 (p>0.05)			G/q = 1.364 (p>0.05)		

*: The holotype of *Mus bowersii* var. *okinavensis* was included.

both sides with one exception, which has a bifid labial root (Fig. 7- A and 7- B). The M2 has four roots of about equal size on both sides with one exception, which has two additional smaller roots (Fig. 7-B). The M3 has two small anterior roots along with a wide posterior root on both sides. However, there is an additional smaller root in six among 12 specimens and there are two additional small roots in one among 12 specimens (Fig. 7-B).

The m1 has a large anterior and posterior roots joined with smaller labial and lingual roots without exception (Figs. 7- D and 7- E). The m2 has a pair of small anterior roots and a wide posterior root with one exception, which has an additional small root (Fig. 7-E). The m3 has a pair of small anterior roots and a large posterior root. However, several specimens of the m3 have an additional smaller root, respectively (Fig. 7- E: OPM-FV-01475 and 02627 on the right side; OPM-FV-01114, 01661, 02829, 02832, and 02838 on the left side).

Comparison :   The species of this new taxon is referred to the genus *Rattus,* because the alveolar and occlusal patterns of the upper and lower molars as well as the number of roots in respective molars is similar to *Rattus* (for example, *R. rattus* and *R. norvegicus*).

The new fossil *Rattus miyakoensis* is distinct from other living and fossil species of *Rattus* in having the largest size of molar length. According to the current taxonomic results of the living species of *Rattus* (Musser and Carleton, 2005), 66 species are listed and 13 species group have not been unsolved among them. The crown or alveolar molar length is tabulated among these 53 living species as well as five fossil species of *Rattus* (Table 3). These species of *Rattus* has 4.3-9.7 mm in the alveolar length of M1-M3, and 3.9-9.3 mm in the crown length of M1-M3. Therefore, *R. miyakoensis* has the longest molar series among species of *Rattus.*

Rattus miyakoensis is distinguished from the living *Diplothrix lagata* in the shape of the temporal ridges, the relative positions of the antero-orbital plate and the incisive foremen, and the outer shape of the M1. First, *R. miyakoensis* has a strong supraorbital ridge, which is about 1.9 mm in width, and extends backwards over the braincase, where the ridges on both sides are the widest in 17.6 mm on the middle part of the parietals and are slightly narrow on the anterior and posterior parts of the same bones (Fig. 4). *Diplothrix legata*, on the other hand, has a prominent upturned blade-like ledge on either side of the interorbital and this is a diagnostic character of the genus *Diplothrix* (Thomas, 1916; Fig. 4). Secondary, the posterior edge of the incisive foramen passes at the front margins of the first molar in *R. miyakoensis*, but the edge is located slightly in front of the margins of molar rows in *Diplothrix* (Fig. 3). Thirdly, the most anterior point of the posterior arch of the antero-orbital plate lies at the anterior part of M1 in *R. miyakoensis*, although it presents forward the anterior part of M1 in *D. legata* (Fig. 3). The reason is that the slope of the anterior part coming up to the grinding surface of M1 is relatively elongated forwardly in *R. miyakoensis* than in *D. legata.*

Rattus miyakoensisis was compared with the living *Bandicota indica.* A large murine rodent of *B. indica* is distributed in South East Asia including Taiwan, which is the close to the Miyako Island, where the new fossils were excavated. Because each molar of *B. indica* has simple wide chevrons with vague

cusps (Figs. 5 and 6), *R. miyakoensisis* is distinguished from *B. indica*.

The molar measurements of *Rattus miyakoensis* indicate the resemblance to that of *Diplothrix legata* with some exceptions. First, each range of 15 measurements of the upper and lower molars is overlapped between *R. miyakoensis* and *D. legata* (Table 1). Means are slightly larger in *R. miyakoensis* than in *D. legata* except for ASM-M1: the mean of ASM-M1 is shorter in *R. miyakoensis* than in *D. legata*. In adding to this, the analysis of variance shows statistically insignificant in 12 measurements except for the Lm2, Lm3, and Wm2. Second, scatter diagrams of the relationship between the length and the width of the upper and lower respective molars are overlapped between *R. miyakoensis* and *D. legata* except for the relationship between the length and the width in the first upper molar (LM1 and WM1) and between ASM-M1 and LM1 (Figs. 8 and 9): in these two relationships there is a clear tendency of the separation of *R. miyakoensis* from *D. legata* in two clusters. Therefore, frequency polygons of ASM-M1 and LM1 show bimodally distributions with two peaks, respectively, indicating different species (Fig. 10).

Discussion

As regards the distribution of native rodent species on the islands of the Ryukyu Archipelago, the living endemic species of *Diplothrix legata* was found on the islands of Amamioshima, Okinawa, and Tokunoshima (Musser and Carleton, 2005; Kaneko, 2008). Furthermore, *Tokudaia osimensis, T. muenninki*, and *T. tokunoshimensis* occur on these three islands, respectively (Kaneko, 2008). On the other hand, there is no living native rodent on the Miyako Island.

Studies on morphological characteristics of the living *Diplothrix legata* published until now have been very scarce except for Thomas (1906,1916), Aoki (1915), Tokuda (1941) and Kawamura (1989). According to Thomas (1906), *D. legata* has not a minute supplementary median cusp (= anterior central cusp) at the outer end of the m1, but has the two minute anterior median cusps (= C1 and C2; anterior labial cusplet and posterior labial cusplet) on m2. He further noted that the supplementary median cusp is not found. Thomas (1916) gave a definition of the genus *Diplothrix* separating from the genus *Lenothrix* that the great breadth of the crown area between the parietal ridges is broader than the length and gives a quite different aspect of the upper view of the skull such as the greater projection forward of the zygomatic plate. Thomas (1916) remarked upon the characteristics of M1 and M2 without an antero-external supplementary cusp and those on M3 as consisting of internal and median cusps in the posterior lamina (= we use "posterior chevron") in *Diplothrix*.

From the present investigation, Thomas (1916)'s remark on "an antero-external supplementary cusp on M1 and M2" mentioned above would be mistaken for "M2 and M3", because the antero-external supplementary cusp is named as the labial anterocone on M2 and M3, and M1 has a large labial anterocone (see Fig.5). In 10 specimens of the living *Diplothrix legata* examined, the occurrence or the absence of the labial anterocone is the same between both sides of M2 or M3, and seven ones have the anterocone on M2 and eight ones on M3. No statistical independency was found between the frequencies of *Rattus*

Table 3. Measurements (range) of the greatest length of skull (GLS), alveolar length of maxillary molar row (ALM1-3) or crown length of maxillary molar row (CLM1-3) in 53 species of the living *Rattus* following the classification of Musser and Carleton (2005), in seven species of the fossil *Rattus* as well as *Rattus miyakoensis* and *Diplothrix legata*. Numbers of specimens are shown in parentheses for each measurement.

Scientific name	GLS(mm)	ALM1-3(mm)	CLM1-3(mm)(N)	References
Present Study				
Rattus miyakoensis	-	10.4-12.3 (60)	-	Present report
*Diplothrix legata**	46.2-61.6 (9)	9.7-11.4 (10)	-	Present report
Living Species				
Ruttus adustus	-	8.7 (1)	-	Musser and Heaney, 1985
R. andamanensis	37.1-45.4 (28)	-	6.2-7.6 (28)	Ellerman, 1961
R. arfakiensis	-	-	5.5 (1)	Tate, 1951
R. argnetiventer	41.2-46.9 (14)	7.6-8.5 (15)	-	Musser, 1972
R. arrogans	30.6-37.0 (168)	4.8-6.3 (168)	4.3-5.9 (168)	Taylor et al., 1982
R. baluensis	36.0-44.1 (28)	6.4-7.7 (29)	-	Musser and Newcomb, 1983
R. blangorum	36.8-38.4 (2)	-	6.2(1)**	Miller, 1942
R. bontanus	42.2-49.9 (10)	8.1-9.5 (12)	-	Musser, 1984
R. burrus	38.8-46.7 (13)	7.4-7.9 (15)	-	Musser and Heaney, 1985
R. colletti	34.3-42.0 (29)	6.3-7.5 (36)	5.8-6.7 (36)	Taylor and Horner, 1973
R. elaphinus	41.5-48.7 (18)	-	6.5-7.1 (17)	Musser and Holden, 1991
R. exulans	28.3-38.2 (763)	4.3-6.2 (763)	3.9-5.8 (763)	Taylor et al., 1982
R. feliceus	50.7-54.3 (3)	-	8.2-9.0 (5)	Musser and Holden, 1991
R. fuscipes	34.1-46.9 (623)	4.9-8.7 (737)	4.6-7.7 (735)	Taylor and Horner, 1973
R. giluwensis	34.8-37.8 (12)	6.4-6.9 (12)	6.1-6.5 (12)	Taylor et al., 1982
R. hoffmanni	37.7-46.1 (45)	-	6.4-7.7 (24)	Musser and Holden, 1991
R. jobiensis	45.9-53.1 (8)	7.9-8.5 (8)	7.1-7.8 (8)	Taylor et al., 1982
R. koopmani	52.5 (1)	-	8.7 (1)	Musser and Holden, 1991
R. leucopus	37.5-54.2 (244)	5.9-8.7 (244)	5.6-8.0 (244)	Taylor et al., 1982
R. losea	33.0-43.5 (157)	6.2-6.7 (10)	-	Musser and Newcomb, 1985
R. lugens	43.0-50.8 (38)	7.3-8.5 (35)	-	Musser and Heaney, 1985
R. lutreolus	35.0-43.3 (211)	6.3-9.0 (273)	5.8-8.2 (273)	Taylor and Horner, 1973
R. marmosurus	42.5-46.9 (10)	7.0-8.0 (11)	-	Musser, 1971
R. mindorensis	-	-	6.5 (1)	Thomas, 1898
R. mollicomulus	-	-	6.6 (1)	Musser and Holden, 1991
R. mordax	37.4-51.9 (111)	6.3-9.7 (111)	5.8-8.8 (111)	Taylor et al., 1982
R. niobe	30.0-35.8 (1253)	4.4-5.9 (1253)	4.1-5.7 (1253)	Taylor et al., 1982
R. nitidus	38.0-46.1 (3)	6.9-7.2 (3)	6.4-6.5 (3)	Taylor et al., 1982
R. norvegicus	-	-	6.8-8.8 (31)	Miller (1912)
R. novaeguineae	36.2-45.0 (78)	6.1-7.5 (78)	5.8-6.9 (78)	Taylor et al., 1982
R. omichlodes	-	-	5.0-6.0 (5)	Misonne, 1979
R. osgoodi	31.0-36.2 (15)	5.3-6.0 (16)	-	Musser and Newcomb, 1985
R. palmarum	38.6-54.0 (75)	7.3-9.0 (75)	-	Musser and Califia, 1982
R. pelurus	46.4-54.2 (5)	-	7.8-9.3 (5)	Sody, 1941
R. pococki	-	-	5.1 (1)	Tate, 1951
R. praetor	37.4-54.9 (89)	6.1-9.3 (89)	5.9-8.7 (89)	Taylor et al., 1982
R. pyctoris	33.6-38 (7)***	-	5.8-6.8 (7)***	Hu and Wang, 1984
R. rattus	36.4-47.5 (78)	5.8-7.2 (78)	5.3-7.2 (78)	Taylor et al., 1982
R. richardsoni	33.9-39.8 (41)	5.4-6.4 (41)	5.0-6.0 (41)	Taylor et al., 1982
R. salocco	46.0 (1)	-	7.7 (1)	Tate and Archbold, 1935
R. satarae	42.4-43.0 (4)	-	6.5-6.9 (4)	Ellerman, 1961
R. simalurensis	42.8-50.9 (23)	7.5-8.3 (24)	-	Musser and Heaney, 1985
R. sordidus	34.1-43.5 (126)	6.2-8.4 (147)	5.8-7.9 (147)	Taylor and Horner, 1973
R. steini	33.3-44.9 (591)	5.5-7.8 (591)	5.0-7.8 (591)	Taylor et al., 1982
R. stoicus	46.4-55.1 (21)	7.6-8.7 (24)	-	Musser and Heaney, 1985
R. tanezumi	-	-	6.3-7.4 (11)	Tokuda, 1941
R. tawitawiensis	41.0-46.5 (3)	7.9-8.2 (3)	-	Musser and Heaney, 1985
R. tiomanicus	34.6-39.6 (91)	6.1-7.6 (93)	-	Musser and Heaney, 1985
R. tunneyi	33.1-42.2 (246)	6.2-8.0 (287)	5.5-7.4 (286)	Taylor and Horner, 1973
R. vandeuseni	34.5-36.4 (6)	5.9-6.3 (6)	5.7-5.9 (6)	Taylor et al., 1982
R. verecundus	33.6-41.8 (235)	5.4-6.8 (235)	5.2-6.6 (235)	Taylor et al., 1982
R. villosissimus	37.0-45.0 (108)	6.5-8.9 (136)	6.0-8.0 (138)	Taylor and Horner, 1973
R. xanthurus	45.4-50.2 (4)	8.1-9.5 (4)	-	Musser, 1984
Fossil Species				
R. casimcensis	-	-	7.6-7.7*****	Radulescu and Samson, 1973
R. dobrogicus	-	-	7.5	Terzea, 1973
R. haasi	-	-	7.5*****	Tchernov, 1968
R. jaegeri	-	-	6.8-8.0(22)****	Chaimanee, 1998
R. trinilensis	-	-	5.7(1)*****	Musser, 1982

miyakoensis and those of *D. legata* by the G-test with the Williams' adjustment（Sokal and Rohlf, 1973: Table 2）.

The number of the molar roots may be taxonomically significant. However, the number has not been investigated except for five roots in M1（Tokuda, 1941）, confirming in the present study.

Several fossil specimens of *Diplothrix legata* had been excavated from the following localities: Tokunoshima Island（Tomida et al., 1990）; Minatogawa site, Okinawa Island, and the Tanabaru-cave and Amagawa-do, Miyako Island（Kowalski and Hasegawa, 1976）; and Gajanbira, Okinawa Island（Kawamura, 1989）. Fossils from Tokunoshima Island were aged probably as the Early Modern Ages（Tomida et al., 1990）, whereas fossils from the sites of Okinawa and Miyako Islands were aged as the late Pleistocene（Kowalski and Hasegawa, 1976; Kawamura, 1989）. In order to revise their identification, we adopt the length （LM1）and width（WM1）of the first upper molar（Figs.8 and 9）: the measurements given by Kawamura（1989）and the estimation of the measurements from a picture with a scale （LM1=4.78 mm and WM1 = 2.96 mm）due to lacking the record in Tomida et al.（1990）. Fig. 8-A indicates that the two respective fossils are identified as *D. legata*. On the contrary, four fossils of lower molars from the Miyako Island identified as *D. legata* （Kowalski and Hasegawa, 1976）has been postponed, because the size and shape of the lower molar are impossible to discriminate *D. legata* from *Rattus miyakoensis*（Fig. 9）. Therefore, in the later Pleistocene, *D. legata* was distributed on the Okinawa Island, while *R. miyakoensis* was found only on the Miyako Island.

As for fossil rodents of *Tokudaia, T. osimensis* was excavated from the islands of Okinawa and Ie in the late Pleistocene or Holocene（Kowalski and Hasegawa, 1976; Hasegawa et al., 1978; Kawamura, 1989）, though the fossils had been identified as *T. osimensis* before *muenninki* and *tokunoshimensis* were assigned as two distinct species. Thus, on the Okinawa Island, there are *Diplothrix legata* and *Tokudaia* sp. in the living and fossil. On the other hand, on the Miyako Island, as well as fossil *Rattus miyakoensis* in this study fossil *Microtus fortis* and *M. oeconomus*（Rodentia, Arvocolinae）were excavated in the later Pleistocene（25,800 ± 900y. B. P. and 26,800 ± 1,300y. B.P.: Kaneko and Hasegawa, 1995）. It follows that there is a clear difference between the islands of Miyako and Okinawa in the living and fossil rodents.

Species assemblages of fossil mammals as well were clearly different between the islands of Okinawa and Miyako, except for fossils of Proboscidae and *Sus* sp.: because the systemstic position of these fossils is still undear. On the Okinawa Island, *Cervus astylodon* and *Dicrocerus* sp.（Artiodactyla, Cervidae） were found in the later Pleistocene（16,600 ± 300y. B. P., 18,250 ± 650y. B. P. and 18,800 ± 400y.B. P.: Oshiro, 2001）. On the Miyako Island, on the other hand, *Capreolus miyakoensis* （Artiodactyla, Cervidae）and *Felis* sp.（Carnivora, Felidae） were excavated（Zhen and Hasegawa, 1985; Hasegawa, 1985a） in the later Pleistocene（25,800 ± 900y. B. P. and 26,800 ± 1,300y. B.P.: Hamada, 1985）, and there is no fossil of *Cervus astylodon* and *Dicrocerus* sp. Hasegawa（1985b）considered that the fossil mammalian fauna of the Miyako Island would be related to the Chinese Continent just before the period of the later Pleistocene, because the fossil *Capreolus miyakoensis* has a strong resemblance to the continental form（Zhen and Hasegawa, 1985）as well as the presence of *Felis* sp., *Microtus fortis* and *M. oeconomus* （Kaneko and Hasegawa, 1995）.

There has been much controversy on the geological formation of the Ryukyu Archipelago. According to Ota（1998）and Otsuka and Takahashi（2000）, there are recently five hypotheses on the Cenozoic paleogeographical maps of the Ryukyu Archipelago. Ota（1998）showed three hypotheses based on sedimental and bathymetric data（Kizaki and Oshiro, 1977）, sedimental and microfossil data（Ujiié, 1990; Ujiié et al., 1991）or the data of stratigraphy, tectonostructure and geomorphy（Kimura, 1996）, respectively, adding to a modified hypothesis of Kizaki and Oshiro（1977）based on phyologeography of the living reptiles and amphibians as well as the geographical patterns of these taxa. On the contrary, Otsuka and Takahashi（2000）modified a hypothesis of Kimura（1998）based on fossil mammals and reptiles excavated from the Ryukyu Archipelago. However, now we are too difficult to discuss how these species were formed on the Miyako Island in accordance with geohistorical changes of these paleogeographical maps in the Ryukyu Archipelago, because we are insufficient of data in detail on the relationship of respective fossil and living species with those of the Continent and adjacent islands. Thus, the discussion will be left in future.

Acknowledgements

Footnotes for Table3

*: The holotype of *Mus bowersii* var. *okinavensis* is included.

**:Ned Gilmore measured.

***: These data were based on the measurements of *R. rattoides* in China (Hu and Wang, 1984),

because Musser and Carleton (2005) synonymized *R. rattoides* for *R. pyctoris*.

****: Total molar length was taken by adding each three molars isolated. Sample size (N) means the

minimum number among that of each three molars isolated.

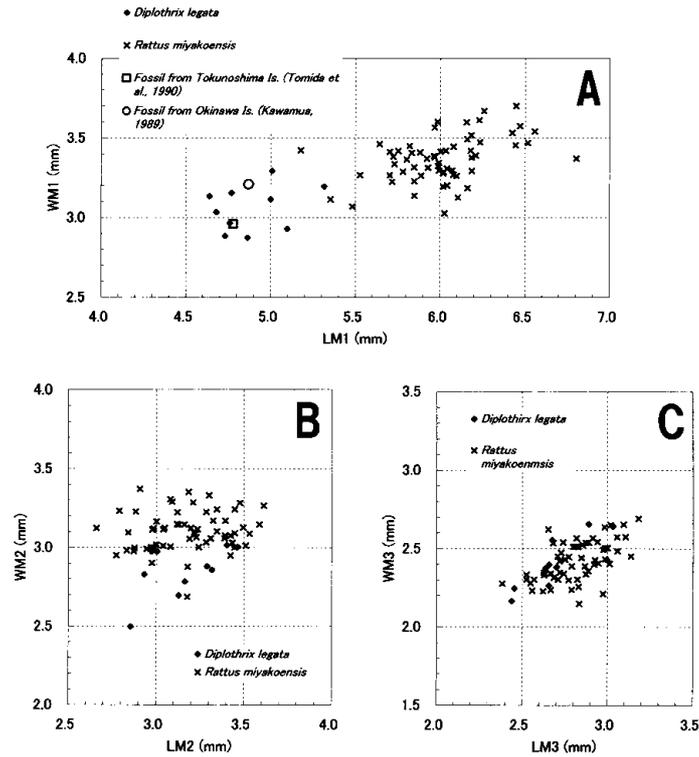*****:Alveolar length of lower molar row.

Figure 8 Scatter diagrams of the relationship between the length and width of the upper molars in the fossil *Rattus miyakoensis* and the living *Diplothrix legata*. A: the relationship between LM1 and WM1, B: the relationship between LM2 and WM2, C: the relationship between LM3 and WM3. From A, the fossils excavated from either the Tokunoshima Island（Tomida et al., 1990）or the Okinawa Island（Kawamura, 1989）were identified as *D. legata*.
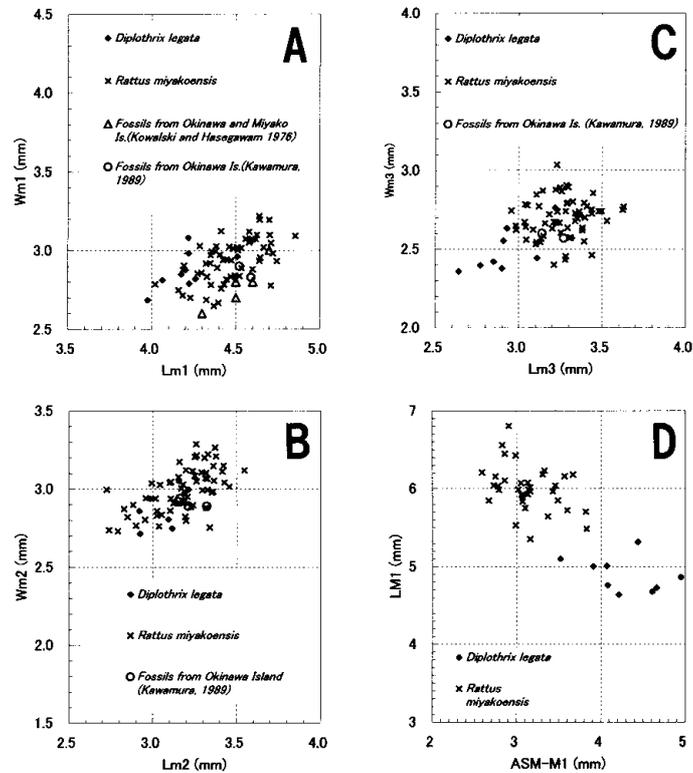

Figure 9 Scatter diagrams of the relationship between the length and width of the lower molars（A-C）and the relationship between ASM-M1 and LM1（D）in the fossil *Rattus miyakoensis* and the living *Diplothrix legata*. A: the relationship between Lm1 and Wm1, B: the relationship between Lm2 and Wm2, C: the relationship between Lm3 and Wm3. From A-C, the fossils excavated from either the Tokunoshima Island（Tomida et al., 1990）or the Okinawa Island（Kawamura, 1989）were not able to identify as *D. legata* or *R. miyakoensis*.
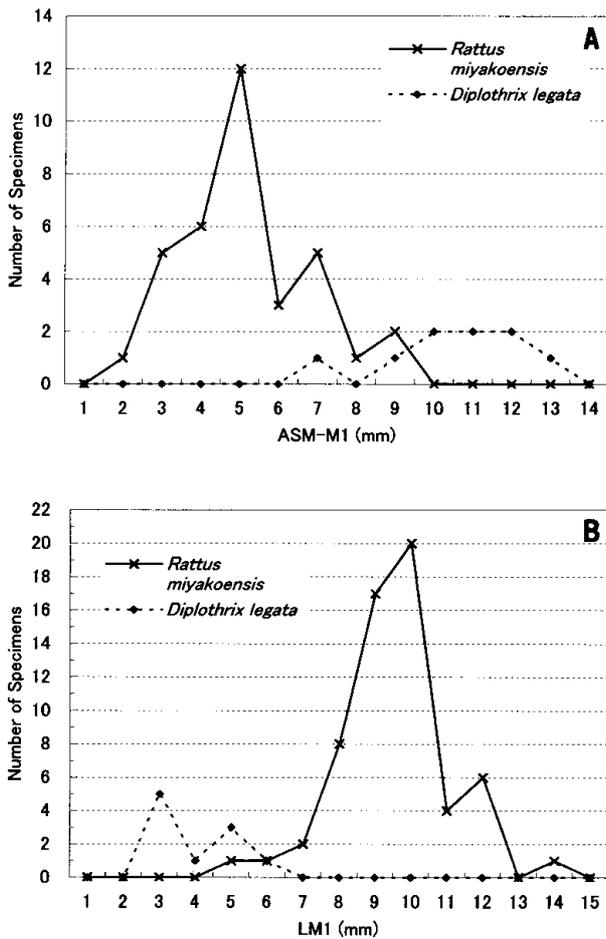
Figure 10 Frequency polygons of the number of specimens examined in ASM-M1 (A) and LM1 (B) of the fossil *Rattus miyakoensis* and the living *Diplothrix legata*.

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Appendix

Registration number of the specimens examined in this study

Fossil specimens

Rattus miyakoensis sp. nov.

Left maxilla with molar teeth: OPM-FV- 00118, 00261, 00319, 00441, 00444, 00453, 00462, 00465, 00601, 00644, 00651, 01002, 01056, 01263, 01279, 01283, 01576, 01580, 01584, 02212, 02254, 02261, 02267, 02330, 02419, 02423, 02666, 02885, 02886, 02929.

Left maxilla without molar teeth: OPM-FV- 00436, 02276.

Right maxilla with molar teeth: OPM-FV- 00091, 00092, 00095, 00097, 00098, 00099, 00253, 00480, 00493, 00592, 01023, 01024, 01050, 01096, 01102, 01108, 01110, 01113, 01226, 01252, 01259 (the holotype), 01261, 01636, 01641, 02335, 02658, 02876, 02878, 02935, 02937

Right maxilla without molar teeth: OPM-FV- 00353, 00485, 00492, 01090, 01644, 02185, 02197, 02199, 02219, 02280.

Left mandible with molar teeth: OPM-FV- 00104, 00112, 00113, 00505, 00516, 00517, 00520, 00589, 00590, 00635, 01016, 01019, 01119, 01139, 01335, 01337, 01338, 01341, 01369, 02632, 02680, 02684, 02685, 02686, 02689, 02692, 02879, 02880, 02882, 02913.

Left mandible without molar teeth: OPM-FV- 00523, 01059, 01114, 01661, 01665, 02210, 02386, 02620, 02829, 02832, 02838.

Right mandible with molar teeth: OPM-FV- 00078, 00083, 00086, 00093, 00278, 00279, 00283, 00286, 00431, 00532, 00614, 00616, 00623, 01153, 01451, 01497, 01500, 01501, 01515, 01611, 02004, 02007, 02303, 02305, 02463, 02687, 02855, 02901, 02938, 02939.

Right mandible without molar teeth: OPM-FV- 00333, 01299, 01305, 01450, 01452, 01475, 02022, 02038, 02472, 02501, 02627.

Parietal bones, frontal bones, and interparietal bone: OPM-FV- 02904

Living specimens

Diplothrix legata

Skull: NSMT-M 8426, 8815, 9218, 9539, 10198, 11459, 14376, 28666, 34325 (the holotype of *Mus bowersii* var. *okinavensis* Namie, 1909); OPM no number; BM 5.11.3.41 (the holotype of *Lenothrix legata* Thomas, 1906. The measurements of this holotype is not included in tables 1-3.

Plate 1
Occlusal views（A-B）of the right maxillae with a molar row（A）, occlusal views of the alveoli of the right maxillae, lateral views（C-D）of the right mandible with a molar row（C）and without molars（D）, a dorsal view of the cranium part（E）and a lateral view of nasal and premaxillae with the incisors（F）of the fossil *Rattus miyakoensis*. Occlusal patterns of the right upper molars（G）and the right lower molars（H）of the fossil *Rattus miyakoensis*. A: OPM-FV-01259（the holotype）, B: OPM-FV-01090, C: OPM-FV01153, D: OPM-FV-02022, E: OPM-FV-02904, F: OPM-FV-02906.G: OPM-FV-01259（the holotype）, H: OPM-FV-01153.

琉球列島宮古島ピンザアブ洞窟で発掘された新種のネズミ亜科化石

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要旨：齧歯目ネズミ科ネズミ亜科の*Rattus*属の化石新種を記載した．記載に当たっては沖縄島と奄美大島産の現生固有種であるケナガネズミ*Diplothrix legata*と比較した．このネズミ亜科化石は1983年に琉球列島宮古島のピンザアブ洞窟から発掘され，更新世後期とされるものである．

キーワード：ネズミ亜科，ミヤコムカシネズミ，ケナガネズミ，ピンザアブ洞，洞窟堆積物，宮古島，琉球列島，後期更新世

Plate 1

A-F: 10mm

G,H: 10mm