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Quaternary Small Mammals from Site B of Mumyono-ana Cave on Miyako Island, Okinawa Prefecture, Japan

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ABSTRACT

Small mammal remains from Site B of Mumyono-ana Cave are studied systematically. The remains are allocated to one chiropteran form (*Hipposideros* sp.) and three rodent forms (*Microtus fortis, Rattus* sp. and *Diplothrix* sp.). Among the forms, *M. fortis* is highly predominant in number. The others are much fewer. *Hipposideros, M. fortis* and *Diplothrix* are now extinct on Miyako Island, of which *Diplothrix* is an endemic genus to the central Ryukyu Islands. The assemblage of the remains is considered to be of insular type, and may be of Late Pleistocene age, on the basis of the faunal comparisons with other localities not only in Japan but also in China. The morphology of the remains assigned to the four forms is described in detail.

INTRODUCTION

In February 2005, terrestrial mammal remains were discovered by R.Nakagawa and S.Nunami from two sites in a small cave on the southern part of Miyako Island (Fig.1). This cave was called Mumyono-ana Cave and investigated speleologically by the Society of Scientific Expedition, Ehime University (1977). It opens below the southern limestone wall of a depression on a flat cultivated field, and inclines inward to its end for about 20 m (Fig.2). The two sites are named Sites A and B here, which are situated near the western and eastern walls of the cave respectively. Brown mud with limestone breccia is deposited on a small area of the cave floor at Site B. In February 2006, about 5 kg of this mud were sampled and washed in water using 0.5mm mesh screens. The washing resulted in obtaining many small mammal remains, which were dominated by vole remains. At present, voles are absent from all over the Ryukyu Islands, and moreover terrestrial mammals except domestic and commensal forms do not inhabit Miyako Island. Thus the remains from Site B are important in reconstructing the past mammal faunas and in understanding morphological characters of the forms now extinct on the island.

In this paper, we describe the assemblage of the remains from Site B, and compare it with those of other localities. The

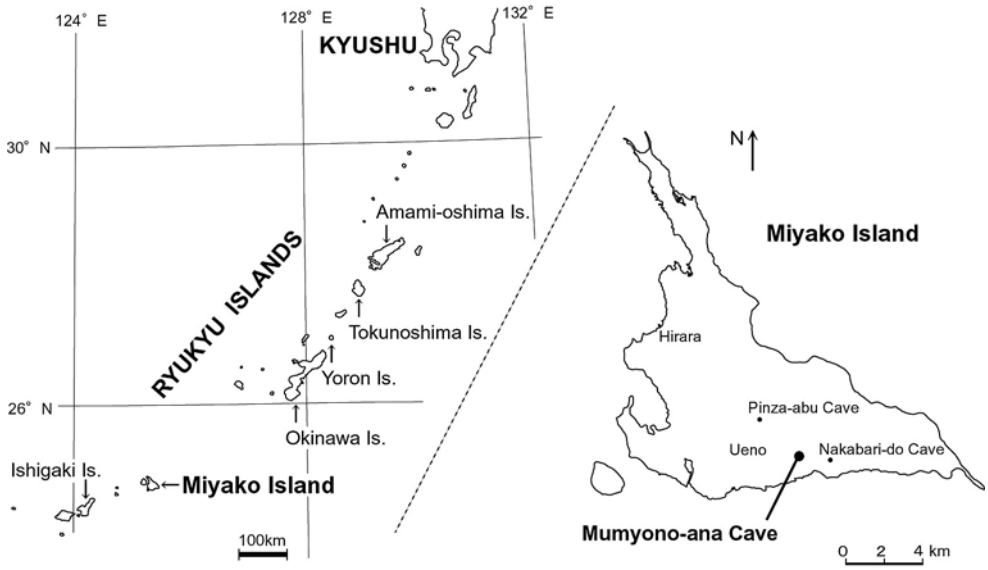

Fig. 1 Location map of Mumyono-ana Cave yielding the mammal remains described here.

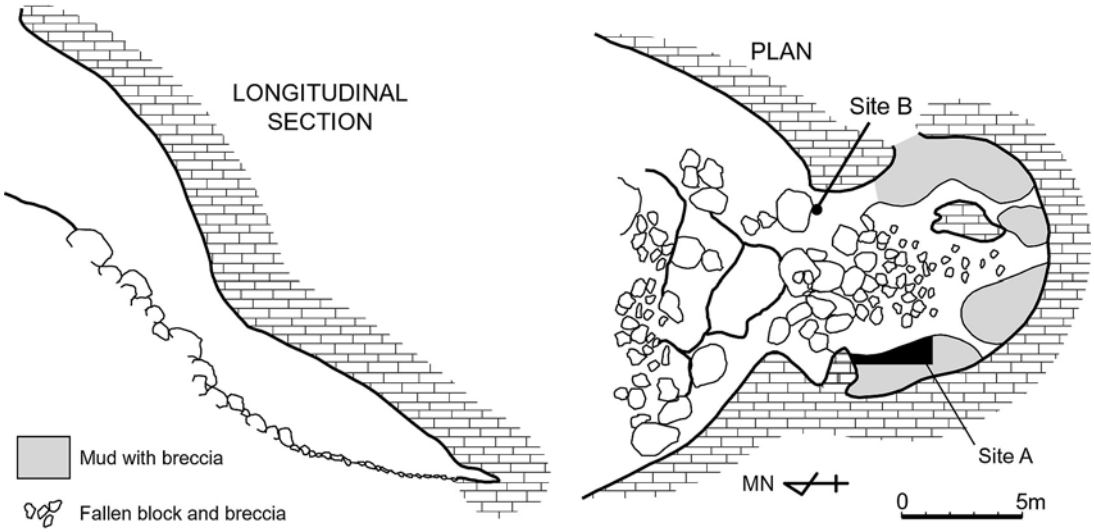

Fig. 2 Longitudinal section and plan of Mumyono-ana Cave.

systematic descriptions of the remains are also given to clarify their morphological characters. After the sampling at Site B, manifold excavations at Site A have produced a great number of mammal remains, which are being studied and will be described in a series of separate papers.

Faunal composition and age

The remains from Site B are allocated to one chiropteran and three rodent forms (Table 1). Thus the assemblage of this site comprises only four forms, and is much lower in diversity than those of small mammals known from Quaternary cave and fissure sediments in Honshu-Shikoku-Kyushu which are described in Kawamura (1988) and others. Moreover, the present assemblage includes *Diplothrix* which is a murine rodent genus endemic to the central part of the Ryukyu Islands. These suggest that the assemblage of Site B is of insular type.

Among the four forms, *Hipposideros* sp. (leaf-nosed bat), *Microtus fortis* (reed vole) and *Diplothrix* sp. are now absent from Miyako Island. But the genus *Rattus* includes commensal species which now inhabit this island. As regards the abundance of the four forms, *M. fortis* is highly predominant, while the others are much fewer (Table 1).

On the other hand, the assemblage of Site B does not include small mammal genera characteristic to the Early Pleistocene of China (for example, *Mimomys, Borsodia, Allophaiomys* and *Chardinomys;* see Fig. 5 of Zhang *et al.,* 2008), but includes an extant species (*M. fortis*) which is known from the Middle and Late Pleistocene as well as the present in China. Thus the assemblage can be assigned to the Middle Pleistocene or later periods. Unfortunately, no localities yielding Middle Pleistocene and Holocene small mammal remains are known from Miyako Island. Pinza-Abu Cave, the only locality yielding abundant small mammal remains on this island (Fig.1), is considered to be of Late Pleistocene age on the basis of the radiocarbon dates of charcoal from the sediments of the cave. The assemblage of Pinza-Abu Cave comprises two chiropteran species such as *Rhinolophus cornutus* and *R.ferrumequinum,* and five rodent forms such as *Microtus fortis, M.oeconomus, M.epiratticeps, M.* sp. and *Diplothrix* cf. *legata* (Department of Education, Okinawa Prefectural Government, 1985), although the allocation of the chiropterans is problematic, and *Microtus* seems to be oversplitted. The occurrences of the two genera now extinct on this island (*Microtus* and *Diplothrix*) are common to this assemblage and that of Site B of Mumyono-ana Cave. This may suggest that the assemblage of Site B is of Late Pleistocene age, although evidence is too scarce to determine its geological age more

Table 1 Faunal composition of the small mammal assemblage from Site B of Mumyono-ana Cave. The total numbers of the maxillae, mandibles and molars referred to each form are shown.

Taxon	Specimen number
Chiroptera	
Hipposideros sp.	2
Rodentia	
Microtus fortis	43
Rattus sp.	2
Diplothrix sp.	3

clearly.

Terminology and measuring method

In the systematic description of the chiropteran remains, we use the terminology and measuring method for teeth of Japanese Quaternary insectivores given by Kawamura (1992, 1993), because the chiropteran remains have the same basic structure as that of the insectivores. As for the rodent remains, we follow the terminology and measuring method given by Kawamura (1988). All the measurements were taken with a Nikon measurescope (MM-11) with a Nikon digital counter (CM- 6S).

Systematic description

Among the remains obtained, we describe the maxillae, mandibles and molars identifiable at generic or specific level. The described specimens are given tentative specimen numbers prefixed by MKN, and are tentatively stored at the Department of Earth Sciences, Aichi University of Education, under care of R.Nakagawa.

Order Chiroptera Blumenbach, 1779
Suborder Microchiroptera Dobson, 1875
Family Rhinolophidae Gray, 1825
Genus ***Hipposideros*** Gray, 1831
Hipposideros sp.
(Fig. 5 ; 1－2)

Material —

1 right mandibular fragment with M_1 (MKN-0173), 1 right M_3 (MKN-0220).

Description

M_1 —

M_1 has a trapezoidal outline in occlussal view, whose lingual margin is slightly convex lingually. The anterior half of the W-shape ridge is nearly as large as its posterior half. The hypoconulid is well developed, and protrudes posteriorly. It is well separated from the entoconid, so that the valley between them is relatively broad. The ectocingulid is not undulated, and is almost straight in buccal view. The length and width of M_1 measure 2.51mm and 1.66mm respectively.

M_3 —

M_3 has an occlusal outline considerably different from that of M_1, because its talonid is strongly reduced. The entoconid and hypoconulid is placed much more buccally than those of M_1, so that the lingual border of the talonid extends posterobuccally in occlusal view. The hypoconid is indistinct and much lower than that of M_1. The hypoflexid is relatively broad. The ectocingulid is convex ventrally in buccal view. The length and width of M_3 measure 2.35 and 1.44mm respectively.

Discussion

The molars described above are undoubtedly assigned to microchiropterans, because they have the W-shaped ridge characteristic to this group. Two microchiropteran families such as Rhinolophidae and Vespertilionidae are known from the present Japan as well as the Quaternary of the same area. The molars are coincident with those of Rhinolophidae which comprises only two genera such as *Rhinolophus* and *Hipposideros* in the present and Quaternary of Japan. The molars are distinguishable from *Rhinolophus* in having the characters described above, which are well coincident with those of *Hipposideros*.

Hipposideros now distributes in the vast area of the Oriental Region (Corbet and Hill, 1992). Ishigaki Island (Fig.1) is placed on the northeastern limit of its distribution, and thus *Hipposideros* is now absent from Miyako Island. This genus comprises many species, but we do not have enough data to distinguish them by molar morphology. Thus we allocate the present molars only to *Hipposideros* sp. A subfossil mandible of the same form was recently reported from Nakabari-do Cave on Miyako Island (Hirasawa *et al.,* 2008; Fig.1).

Order Rodentia Bowdich, 1821
Family Arvicolidae Gray, 1821
Genus ***Microtus*** Schrank, 1798
Microtus fortis Büchner, 1889
(Fig. 3)

Microtus fortis, Büchner 1889. *Wiss. Res. Przewalski's Cent.-Asien. Reisen, Zool.,* 1, 99. (not available)

Microtus calamorum, Thomas 1902. *Ann. Mag. Nat. Hist.,* Ser. 7, 10, 167.

Microtus michnoi, Kashchenko 1910. *Ezhegodnik Zoologicheskogo Muzeya Akademii Nauk SSSR,* 15, 288-293. (not available)

Microtus pelliceus, Thomas 1911. *Ann. Mag. Nat. Hist.,* Ser.8, 7, 383.

Microtus dolichocephalus, Mori 1930. *Annot. Zool. Jap.,* 12, 420.

Material —

1 right maxillary fragment with M^1 (MKN-0224), 5 left M^1 (MKN-0353, 0354, 0355, 0356, 0741), 5 right M^1 (MKN-0384, 0385, 0386, 0387, 0388), 1 left M^2 (MKN-0409), 2 right M^2 (MKN-0429, 0750), 2 left M^3 (MKN - 0445, 0446), 4 right M^3 (MKN-0458, MKN-0459, MKN-0460, MKN-0461), 1 left mandible with I, M_1 and M_2 (MKN-464), 1 left mandibular fragment with M_2 (MKN-0471), 1 right mandible with I and M_1 (MKN-0463), 1 right mandible with M_1 (MKN-0470), 1 right mandibular fragment with M_2 (MKN-0473), 5 left M_1 (MKN-0603, 0604, 0605, 0606, 0607), 2 right M_1 (MKN-0623, 0624), 4 left M_2 (MKN-0648, 0649, 0650, 0651), 4 right M_2 (MKN-0675, 0676, 0677, 0679), 2 left M_3 (MKN-0695, 0696), 1 right M_3 (MKN-0712).

Description

Mandible —

The mental foramen opens just anterior to the anterior border of M_1. The lower masseteric crest is well developed, while the upper masseteric crest is indistinct. The area between the molar row and ascending ramus is deeply pocketed. The height of the horizontal ramus at M_1 mearures 4.41mm along the lingual face in MKN-0463. The maximum thickness of the horizontal ramus also measures 3.24mm in MKN-0463, and 3.21mm in MKN-0464.

Molar —

The molars are unrooted, and have rich cementum in the reentrant angles. The salient angles are pointed. The triangles are alternating in position, and are closed except in M_3 and in T3 and T4 of some M^3. The enamel layers of the molars clearly thin at the bottoms of the reentrant angles. The *Microtus*-type enamel differentiation is distinct in most of the specimens, where the enamel layers on the concave sides of the triangles are clearly thicker than those of the convex sides. The measurements of the molars are given in Table 2.

In M^1, an anterior loop and four triangles are observed on its occlusal surface. Three salient angles are present on its lingual and buccal sides. LSA4 is absent in all M^1.

M^2 has an anterior loop and three triangles on its occlusal surface. Two and three salient angles are observed on its lingual and buccal sides respectively. LSA4 and an additional angle on the anterior wall of T3 are never seen in all M^2.

In M^3, three triangles are present between the anterior and posterior loops. The isthmus between T3 and T4 is broader in two specimens (16 and 19 of Fig.3), but it is closed or narrower in the remaining four. The posterior loop is C-shaped, and LSA5 is well developed. Thus four salient angles are observed on the lingual side of M^3 totally. On the buccal side of the posterior loop, a weak angle (BSA4) is observed in two specimens (16 and 18 of Fig.3), while it is absent in the remaining four.

M_1 has five closed triangles between the anterior and posterior loops. The anterior loop is simple in shape. LSA5 is distinct, but LRA5 is shallow or absent. The buccal face of the anterior loop is convex buccally, so that BRA4 is absent.

M_2 has four triangles and a posterior loop on its occlusal surface. The anterolingual wall of T3 or T4 is concave, where cementum is deposited. The anterobuccal wall of T4 is slightly concave, and little cementum is attached there.

M_3 has two dentine fields and a posterior loop on its occlusal surface. The anterolingual wall of the anterior dentine field is slightly concave. The posterior dentine field is broader than the anterior dentine field, but narrower than the posterior loop. BRA2 is shallower than BRA1 which is much shallower than the lingual reentrant angles. BSA3 is blunt and indistinct.

Discussion

The allocation of the present specimens to the genus *Microtus* is indicated by the following characters: The mandible has the area deeply pocketed between the molar row and ascending ramus. The molars are unrooted and cemented, and have well-differentiated enamel layers. M^3 and M_1 have more than two and three triangles respectively.

The uniformity in size and morphology also indicates that the specimens belong to a single species of *Microtus.* Among many living species of *Microtus, M. fortis* shows the dental characters well coincident with those of the present specimens. Namely, M^3 has a C-shaped posterior loop, and M_1 has a simple anterior loop where LRA5 is shallow or absent, and BRA4 is absent. On the other hand, the specimens are distinguishable from the other living species of *Microtus,* judging from our observation of many specimens of the living species as well as the descriptions and figures by Tokuda (1941), Ognev (1950), Gromov and Polyakov (1977), and Niethammer and Krapp (1982). The specimens are, therefore, assigned to *M. fortis.*

As regards fossil species from eastern Asia, the present specimens differ from *M. epiratticeps* by Young (1934), *M. com-*

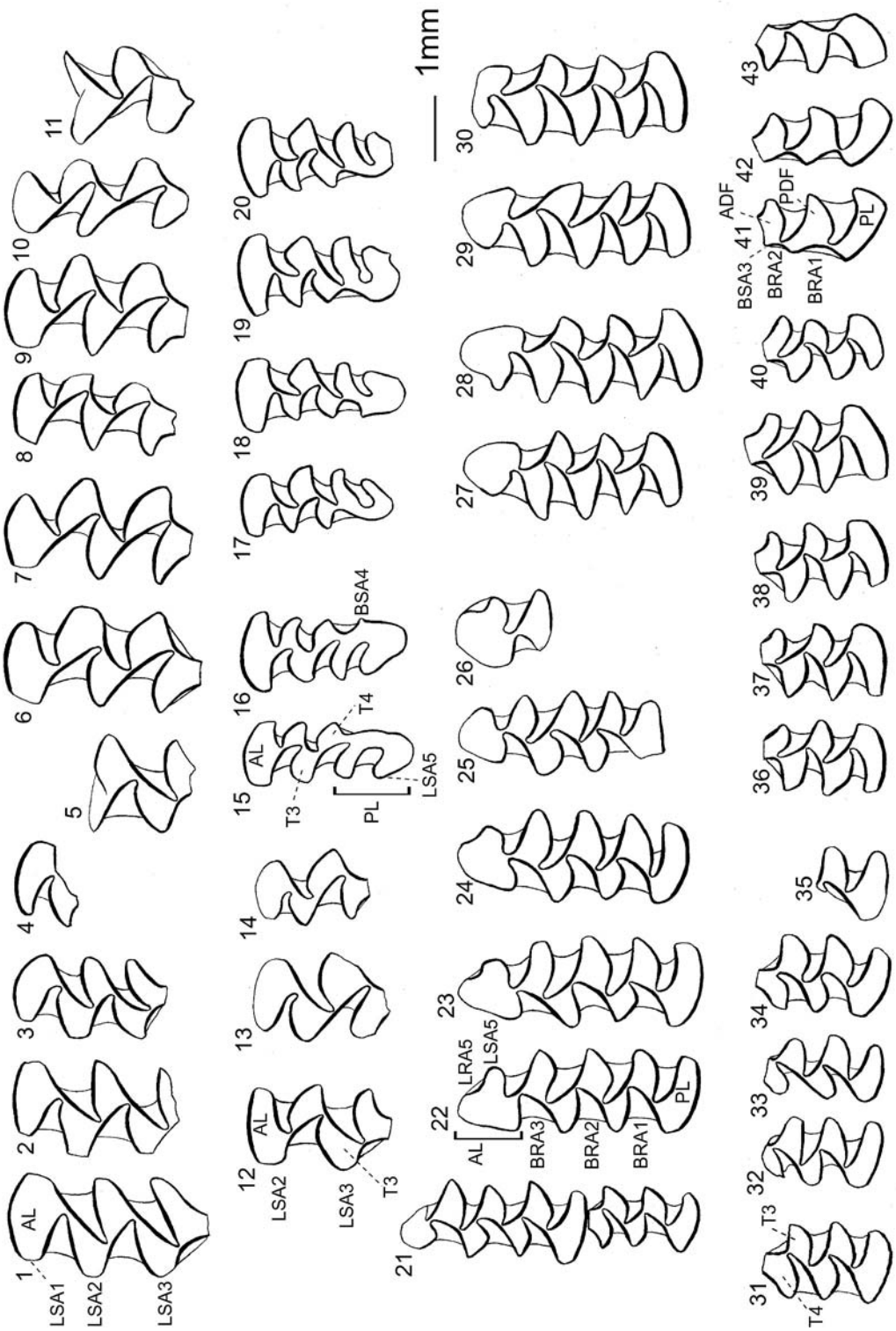

Fig. 3 *Microtus fortis* from Site B of Mumyono-ana Cave. Occlusal patterns of the molars. 1–5: left M^1 (1: MKN-0353, 2: MKN-0355, 3: MKN-0356, 4: MKN-0741, 5: MKN-0354), 6–11: right M^1 (6: MKN-0224, 7: MKN-0384, 8: MKN-0385, 9: MKN-0388, 10: MKN-0387, 11: MKN-0386), 12: left M^2 (MKN-0409), 13–14: right M^2 (13: MKN-0429, 14: MKN-0750), 15–16: left M^3 (15: MKN-0445, 16: MKN-0446), 17–20: right M^3 (17: MKN-0458, 18: MKN-0459, 19: MKN-0460, 20: MKN-0461), 21: left M_1 and M_2 (MKN-0464), 22–26: left M_1 (22: MKN-0606, 23: MKN-0607, 24: MKN-0603, 25: MKN-0605, 26: MKN-0604), 27–30: right M_1 (27: MKN-0463, 28: MKN-0470, 29: MKN-0623, 30: MKN-0624), 31–35: left M_2 (31: MKN-0471, 32: MKN-0649, 33: MKN-0650, 34: MKN-0651, 35: MKN-0648), 36–40: right M_2 (36: MKN-0473, 37: MKN-0675, 38: MKN-0676, 39: MKN-0677, 40: MKN-0679), 41–42: left M_3 (41: MKN-0695, 42: MKN-0696), 43: right M_3 (MKN-0712). ADF: anterior dentine field, AL: anterior loop, BRA: buccal reentrant angle, BSA: buccal salient angle, LRA: lingual reentrant angle, LSA: lingual salient angle, PDF: posterior dentine field, PL: posterior loop, T: triangle.

Table 2 Measurements of the molars of *Microtus fortis* from Site B of Mumyono-ana Cave in mm. The length and width of the crown are given.

Specimen	Length	Width
M^1		
MKN-0224	3.09	1.79
MKN-0353	3.25±	1.66
MKN-0354	—	1.56
MKN-0355	—	1.63±
MKN-0356	2.34	1.41
MKN-0384	2.99	1.77
MKN-0387	2.89	1.65
MKN-0388	2.94	1.65
M^2		
MKN-0409	2.36	1.40
MKN-0429	2.18	1.29
MKN-0750	—	1.19

Specimen	Length	Width
M^3		
MKN-0445	2.76	1.10
MKN-0446	2.74	1.30
MKN-0458	2.35	1.11
MKN-0459	2.70	1.22
MKN-0460	2.47	1.29
MKN-0461	2.61	1.32
M_1		
MKN-0463	3.46	1.37
MKN-0464	—	1.32
MKN-0470	3.87	1.49
MKN-0603	3.64	1.47
MKN-0605	3.35	1.30
MKN-0606	3.78	1.40
MKN-0607	3.85	1.51
MKN-0623	3.57	1.43±
MKN-0624	—	1.49

Specimen	Length	Width
M_2		
MKN-0464	1.77	1.08
MKN-0471	2.13	1.18
MKN-0473	1.95	1.22
MKN-0649	—	1.26±
MKN-0650	1.88±	1.21±
MKN-0651	2.10	1.04
MKN-0675	2.09±	1.43
MKN-0676	2.10	1.26
MKN-0677	2.22	1.40
MKN-0679	1.94	1.22±
M_3		
MKN-0695	—	1.23
MKN-0696	2.25	1.10
MKN-0712	1.94	0.94

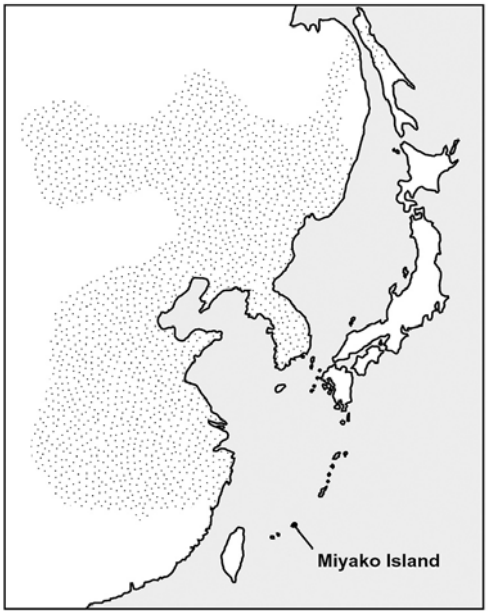

Fig. 4 Present distribution of *Microtus fortis* after Corbet (1978). Miyako Island is outside of its distribution.

plicidens by Pei (1936), *M. epiratticepoides* by Kawamura (1988) and *M. minoeconomus* by Zheng and Cai (1991) in the morphology of the anterior loop of M_1. However, they are similar to some specimens referred to *M. brandtioides* by Young (1934) and Pei (1936, 1940), which seem to be assignable to *M. fortis,* as pointed out by Zheng and Li (1990).

The present distribution of *M. fortis* covers a wide area of eastern Asia from Transbaikalia and Sakhalin to southern China, which includes the Korean Peninsula (Fig.4). This species is, however, absent from Hokkaido, Honshu-Shikoku-Kyushu, the Ryukyu Islands and Taiwan. Miyako Island is considerably remote from its present distribution. The remains of *M. fortis* from Mumyono-ana Cave confirm that this species had a wilder distribution in the Late Pleistocene or some other periods than at the present.

Family Muridae Illiger, 1811

Genus ***Rattus*** Fischer de Waldheim, 1803

Rattus sp.

(Fig. 5 ; 3 - 4)

***Material* —**

1 left maxillary fragment with M^1 (MKN-0763), 1 left M^2 (MKN-0764).

Description

M^1 —

The anterior chevron extends almost straight linguobuccally, and the anterostyle does not shift posteriorly. The labial anterocone is strongly reduced, and confluent with the central cusp of the chevron (lingual anterocone). The middle chevron runs almost parallel to the anterior chevron, and its posterior margin is slightly arcuate anteriorly. This chevron comprises three cusps clearly distinguishable from each other. The posterior chevron is composed of the hypocone and metacone. The former is much larger than the latter. The posterostyle is completely absent. The length and width of the crown measure 3.42 and 1.96 mm respectively. The crown is moderate in height, and is as high as that of *Apodemus*. The cervical line is slightly convex dorsally on the buccal and lingual faces. This tooth has five roots, of which the most anterior one is the largest.

M^2 —

The anterostyle is a large independent cusp attached on the anterolingual face of the crown. The labial anterocone is observable, but it is low and faint. The morphology of the middle and posterior chevrons, and the crown height are the same as those of M^1. The length and width of the crown measure 2.44 and 1.86mm respectively. The cervical line is straight and almost horizontal on the buccal and lingual faces. This tooth has four roots, of which the posterolingual one is the smallest. The remaining three are nearly the same in size.

Discussion

The specimens described above are assigned to *Rattus* sp., because the occlusal patterns of the crowns, the numbers and arrangements of the roots, and the sizes of the crowns resemble those of the genus *Rattus.* Among the species of the genus, we compared the specimens with two commensal species, *R. rattus* and *R. norvegicus.* The comparison has revealed that the specimens are very similar to the latter species. However, we do not determine them specifically, because a great number of the other species known from the present Palaearctic and Oriental Regions (Corbet, 1978; Corbet and Hill, 1992) cannot be compared with the specimens.

As regards the Ryukyu Islands, remains of *Rattus* were reported from Late Pleistocene (?) sediments of Ishisukuyama on Ishigaki Island (Hasegawa and Nohara, 1978) and from Holocene sediments of Nishiku Fissure on Yoron Island (Azuma, 2007). Thus the occurrence of the present specimens is regarded as a new record of *Rattus* in fossil state from Miyako Island.

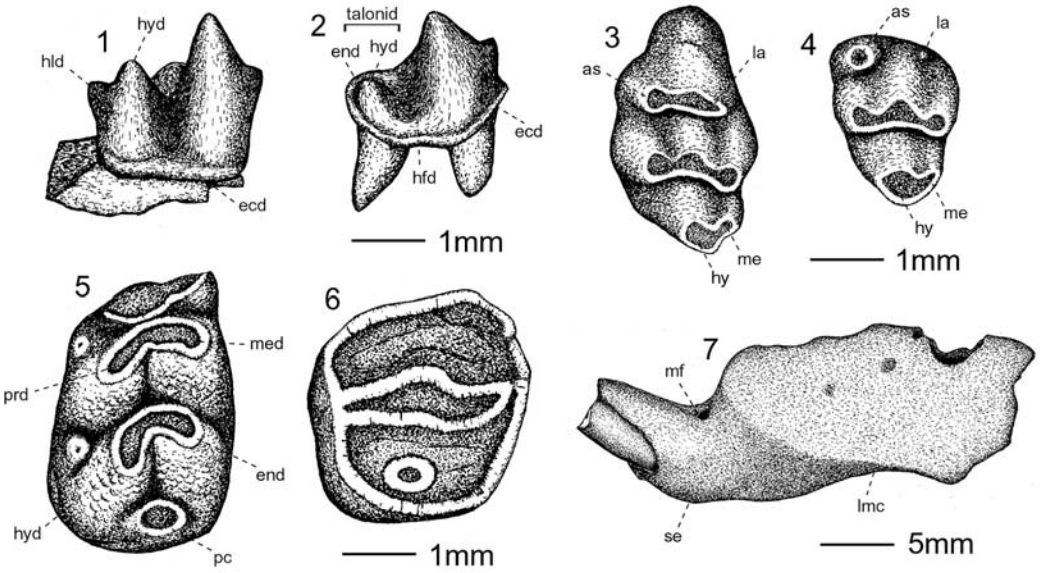

Fig. 5 *Hipposideros* sp. (1－2), *Rattus* sp. (3－4) and *Diplothrix* sp. (5－7) from Site B of Mumyono-ana Cave. 1: right mandibular fragment with M_1 (MKN-0173), 2: right M_3 (MKN-0220), 3: left M^1 (MKN-0763), 4: left M^2 (MKN-0764), 5: left M_1 (MKN-1140), 6: right M_2 (MKN-1185), 7: left mandible with I (MKN-1078). as: anterostyle, ecd: ectocingulid, end: entoconid, hfd: hypoflexid, hld: hypoconulid, hy: hypocone, hyd: hypoconid, la: labial anterocone, lmc: lower masseteric crest, me: metacone, med: metaconid, mf: mental foramen, pc: posterior cingulum, prd: protoconid, se: symphyseal eminence.

Genus ***Diplothrix*** Thomas, 1916

Diplothrix sp.

(Fig. 5 ; 5 - 7)

Material —

1 left mandible with I (MKN-1078), 1 left M_1 (MKN-1140), 1 right M_2 (MKN-1185).

Description

Mandible and lower incisor —

The mental foramen opens somewhat anterior to the most anterior root of M_1 which is barely preserved, and is situated on the dorsobuccal face of the diastema. The symphyseal eminence is weak, and situated below the mental foramen. The lower masseteric crest is strong, and runs posteroventrally from the point just posterodorsal to the mental foramen. The area between the molar row and ascending ramus is narrow and not pocketed. The alveolar sockets for M_1, M_2 and M_3 are four, three and three in number, respectively. The lower incisor has a triangular section with round corners. Its enamel-covered surface is smooth, not striated, and orange in color.

The height of the horizontal ramus at M_1 along the lingual face measures 9.15mm, while the maximum thickness of the ramus measures 5.25mm.

M_1 —

The anterior part of the anterior chevron is lost. This chevron is separated from the middle chevron by a narrow but deep groove. A small conical accessory cusp is observed at the buccal entrance of the groove. The metaconid is placed more anteriorly than the protoconid. The middle chevron is well separated from the posterior chevron by a deep and broad groove. At the buccal entrance of the groove, there is another small accessory cusp. The posterior cingulum forms an independent conical cusp, which has an elliptical outline elongated linguobuccally in occlusal view, and is much larger than the buccal accessory cusps. The width of the crown measures 2.74mm.

The crown is moderate in height, and somewhat higher than that of *Apodemus.* Its enamel surface is somewhat rugged. The cervical line is weakly undulated on the buccal and lingual faces. There are four roots, such as anterior, linguo-central, bucco-central and posterior roots. The anterior and posterior roots are much larger than the two central roots.

M_2 —

The crown is considerably worn, so that the labial anteroconid completely blends into the dentine field of the anterior chevron. This field is continuous to that of the posterior chevron on the buccal side. This indicates that the valley between the anterior and posterior chevrons is originally shallower in its buccal part than in the central and lingual parts. The valley between the posterior chevron and posterior cingulum forms an enamel island in the dentine field of the posterior chevron. On the buccal and lingual faces, the cervical line ascends anteriorly. M_2 has three roots, of which the posterior one is the largest and elongated linguobuccally. The anterobuccal root is much smaller than the posterior one, but is also elongated linguobuccally. The anterolingual root is the smallest of the three and has a round section. The length and width of the crown measure 3.16 and 3.05mm respectively.

Discussion

The specimens described above are well coincident with the mandible and teeth of *Diplothrix legata* in morphology and size, as far as the preserved parts are concerned. This species belongs to the monospecific genus *Diplothrix* which now distributes only on three islands (Okinawa, Tokunoshima and Amami-oshima Islands) of the central Ryukyu Islands (Fig.1). Its remains are known from the Late Pleistocene cave and fissure sediments and Holocene archaeological sites on Okinawa Island (Kowalski and Hasegawa, 1976; Kawamura, 1989). Large murine remains from Pinza-Abu Cave on Miyako Island were also assigned to *D.* cf. *legata* by Department of Education, Okinawa Prefectural Government (1985). The present specimens are easily distinguishable from the corresponding parts of the other murine rodents from Japan by their large size, but the morphological information obtained from them is limited. Owing to the insufficient comparison, we refer them only to *Diplothrix* sp.

Acknowledgments

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