A FIRST FOSSIL RECORD OF THE TERRESTRIAL CRAB, *GEOTHELPHUSA TENUIMANUS* (MIYAKE & MINEI, 1965) (DECAPODA, BRACHYURA, POTAMIDAE) FROM OKINAWA ISLAND, CENTRAL RYUKYUS, JAPAN

BY

TOHRU NARUSE[1,5]), HIROAKI KARASAWA[2]), SHIGEMITSU SHOKITA[1]), TOSHIO TANAKA[3]) and MITSURU MORIGUCHI[4])

[1]) Department of Marine and Environmental Sciences, Graduate School of Engineering and Science, University of the Ryukyus, 1, Senbaru, Nishihara, Okinawa 903-0213, Japan

[2]) Mizunami Fossil Museum, Mizunami, Gifu 509-6132, Japan

[3]) Aichi Gakuin Junior College, Nagoya, Aichi 464-8650, Japan

[4]) Sango-Sha Schole, Naha, Okinawa 900-0022, Japan

ABSTRACT

Fossils of the terrestrial crab, *Geothelphusa tenuimanus*, are described. These fossils were collected from clay within the fissures that rift the limestone of the Middle Pleistocene Ryukyu Formation on Okinawa Island, Ryukyu Islands. The geological age of the fossil *G. tenuimanus* was estimated as Late Pleistocene, because they occurred in association with a fossil deer (*Cervus* sp.), which is already extinct on Okinawa Island. This is the first fossil record of a true freshwater crab from the Ryukyu Islands. In both fossil and extant specimens of *G. tenuimanus*, the longer movable fingers of the chelipeds usually have a stronger curvature, but the present fossil specimens contain higher numbers of strongly curved movable fingers than found in extant specimens. This difference may be caused by the fact that no sufficiently large extant specimens have been examined.

RÉSUMÉ

Des fossiles du crabe terrestre *Geothelphusa tenuimanus*, sont décrits. Ces fossiles ont été récoltés dans l'argile, à l'intérieur de fissures qui traversent le calcaire de la formation de Ryukyu du Pléistocène moyen dans l'île d'Okinawa (îles Ryukyu). L'âge géologique du fossile *G. tenuimanus* a été estimé au Pléistocène supérieur, car ils ont été trouvés en association avec un cerf fossile (*Cervus* sp.) qui est déjà éteint sur l'île d'Okinawa. C'est la première mention de la présence d'un vrai crabe d'eau douce fossile aux îles Ryukyu. Chez les spécimens fossiles comme chez les spécimens actuels de *G. tenuimanus*, les doigts mobiles des chélipèdes, quand ils sont plus longs, ont habituellement une plus forte courbure, mais les spécimens fossiles ont, en plus grand nombre, des doigts mobiles plus fortement recourbés que les spécimens actuels. Cette différence peut être dûe au fait que des spécimens actuels d'une taille suffisamment grande n'ont pu être examinés.

[5]) Corresponding author; Fax: +81.988958555; e-mail: k018555@eve.u-ryukyu.ac.jp

Crustaceana 76 (10): 1211-1218
Also available online: www.brill.nl

INTRODUCTION

True freshwater crabs are considered by some authors to be good indicators of biogeography, because of their life history and habitat (see Ng, 1988; Ng & Rodriguez, 1995). However, true freshwater crabs are poorly known as fossils (see Karasawa, 1997), and this makes any study of their biogeography difficult. Recently, one of us (MM) found a large number of fossils of *Geothelphusa tenuimanus* (Miyake & Minei, 1965) (Potamidae) in the limestone fissure sediments of the southern part of Okinawa Island, Central Ryukyus, Japan (fig. 1). In this report, we describe the fossils of *G. tenuimanus* and compare a few characters between fossil and extant forms.

MATERIALS AND METHODS

The fossil specimens of *Geothelphusa tenuimanus* were collected from clay deposited in the fissures that rift the limestone of the Middle Pleistocene Ryukyu Group, and which are exposed at Chinen Village (26°09.824′N 127°48.315′E) and Itoman City (26°07.444′N 127°41.597′E) on Okinawa Island (fig. 1). These fissures were recently discovered, because the Ryukyu Limestone has been dug and exploited to be used as a building material. Fossil crabs appeared to occur in the fissure deposits, in association with land snails [*Satsuma* cf. *mercatoria* (Pfeiffer, 1845), *Aegista* cf. *scepasma* (Reeve, 1854), *Zaptyx* sp., and Cyclophoridae gen. et sp. indet.] and a deer (*Cervus* sp.). Fossil crabs are patchily distributed in the fissures, and each patch was found to be densely packed with fossils. Palaeontological and geological studies have yet to be done on the present deposits. However, the occurrence of *Cervus* sp. suggests that the geological age of the deposits was the Late Pleistocene (Hasegawa, 1980; Kamei et al., 1988).

Eventually, a total of 102 specimens (91 fossil and 11 extant specimens) of *G. tenuimanus* was examined for this study. Movable fingers and chelae of both fossil and extant specimens were measured to the nearest 0.1 mm using a digital slide calliper (Mitsutoyo CD-20C).

Abbreviations are as follows: CL, carapace length; MFM, Mizunami Fossil Museum, Gifu, Japan; NSMT, National Science Museum, Tokyo, Japan; p, probability for the significance of r; r, correlation coefficient; RUMF, the Ryukyu University Museum, Fujukan, Okinawa, Japan; ZLKU, Zoological Laboratory, Kyushu University, Fukuoka, Japan (specimens examined have been transferred to the Kitakyushu Museum of Natural History and Human History, Fukuoka, Japan).

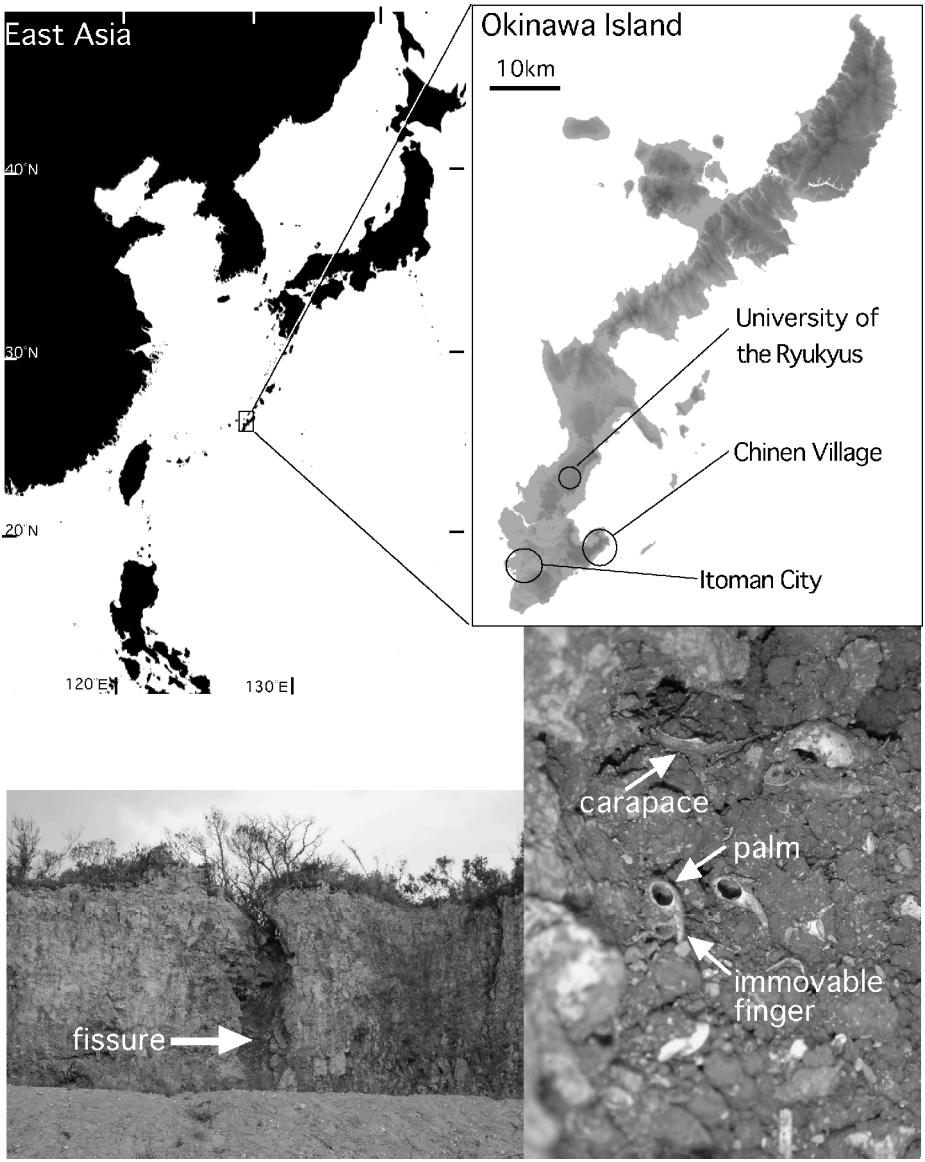

Fig. 1. Localities and aspects of the limestone fissures where fossils of *Geothelphusa tenuimanus* (Miyake & Minei, 1965) were found. Upper part, localities of limestone fissures on Okinawa Island in East Asia; lower left, one of the fissures that rift the limestone of the Middle Pleistocene Ryukyu Group at Chinen Village; lower right, fossils of *G. tenuimanus* in the limestone fissure sediments at Chinen Village.

SYSTEMATICS

Family POTAMIDAE

Genus *Geothelphusa*

Geothelphusa tenuimanus (Miyake & Minei, 1965) (fig. 2)

Potamon (*Geothelphusa*) *tenuimanus* Miyake & Minei, 1965: 377-382, pl. 21.
Geothelphusa levicervix — Bott, 1970: 155 (in addendum) [partim].
Geothelphusa tenuimana — Minei, 1968: 99, photo 13; Naruse, Shokita & Nagai, 2003 [in prep.] (including a complete synonymy).

Material examined. — (All specimens were collected at Okinawa Island.) Fossil specimens: 1 carapace, MFM142450, Chinen Village, 2001, coll. M. Moriguchi; 2 palms, MFM142451, Chinen Village, 2001, coll. M. Moriguchi; 6 dactyli, MFM142452, Chinen Village, 2001, coll. M. Moriguchi; 1 mandible, MFM142453, Chinen Village, 22 Oct. 2002, coll. M. Moriguchi and T. Naruse; 1 merus of cheliped, MFM142454, Chinen Village, 22 Oct. 2002, coll. M. Moriguchi and T. Naruse; 3 ambulatory leg segments, MFM142455, Chinen Village, 22 Oct. 2002, coll. M. Moriguchi and T. Naruse; 3 palms, RUMF-GF-10, Chinen Village, 2001, coll. M. Moriguchi; 13 palms, RUMF-GF-11, Chinen Village, 22 Oct. 2002, coll. M. Moriguchi and T. Naruse; 28 dactyli, RUMF-GF-12, Chinen Village, 2001, coll. M. Moriguchi; 33 dactyli, RUMF-GF-13, Chinen Village, 22 Oct. 2002, coll. M. Moriguchi and T. Naruse.

Extant specimens: 1 male, CL 27.1 mm, ZLKU 9726 (holotype), Motobu Peninsula, Aug. 1960, coll. S. Chinen; 1 male, CL 26.3 mm, RUMF-ZC-50, Motobu Peninsula, June 1990; 1 male, CL 22.4 mm, RUMF-ZC-10, Tamagusuku Village, 16 May 1998, coll. T. Sasaki and H. Tamura; 1 male, CL 22.5 mm, RUMF-ZC-11, Ohgimi Village, 30 Sep. 1998, coll. T. Hayashi; 1 male, CL 24.4 mm, NSMT-Cr15114, Kunigami Village, 26 Dec. 1998, coll. S. Shokita, T. Nagai, Y. Fujita, A. Kawakami, and H. Kawaguchi; 1 male, CL 17.5 mm, RUMF-ZC-46, Kunigami Village, 26 Dec. 1998, coll. S. Shokita, T. Nagai, Y. Fujita, A. Kawakami, and H. Kawaguchi; 1 male, CL 23.5 mm, HMNH-C7, Tamagusuku Village, 25 May 1999, coll. H. Tamura; 1 male, CL 19.7 mm, HMNH-C167, Ohgimi Village, 3 Jan. 2001, coll. H. Yoshigou, M. Iwao, and M. Iwasaki; 1 male, CL 23.5 mm, HMNH-C168, Ohgimi Village, 3 Jan. 2001, coll. H. Yoshigou, M. Iwao, and M. Iwasaki; 1 male, CL 23.5 mm, RUMF-ZC-51, Tamagusuku Village, 21 May 2001, coll. T. Naruse; 1 male, CL 25.4 mm, RUMF-ZC-47, Kunigami Village, 30 Jan. 2002, coll. T. Naruse.

Description of fossils. — Carapace poorly preserved, smooth, longitudinally flattened, gently convex transversely; frontal margin nearly straight, cristate; upper orbital margin concave, cristate; postorbital and postfrontal cristae indistinct, gradually rising posteriorly; regions not marked, but cervical, urogastric, and branchiocardiac grooves visible. Chelae well preserved; palm relatively flattened

Fig. 2. Fossils of *Geothelphusa tenuimanus* (Miyake & Minei, 1965). a, Carapace, dorsal view (MFM142450); b, carapace, frontal view (MFM142450); c, palm of male major chela (MFM142451); d, palm of male minor or female chela (MFM142451); e, "straight" movable finger of chela (MFM142452); f, "slightly curving" movable finger (MFM142452); g, "curving" movable finger (MFM142452); h, "strongly curving" movable finger (MFM142452); i, mandible (MFM142453); j1, merus of cheliped (MFM142454); j2, 3, segments of ambulatory legs (MFM142455); j4, dactylus of ambulatory leg (MFM142455). Scales: a-h, j, 10 mm; i, 5 mm.

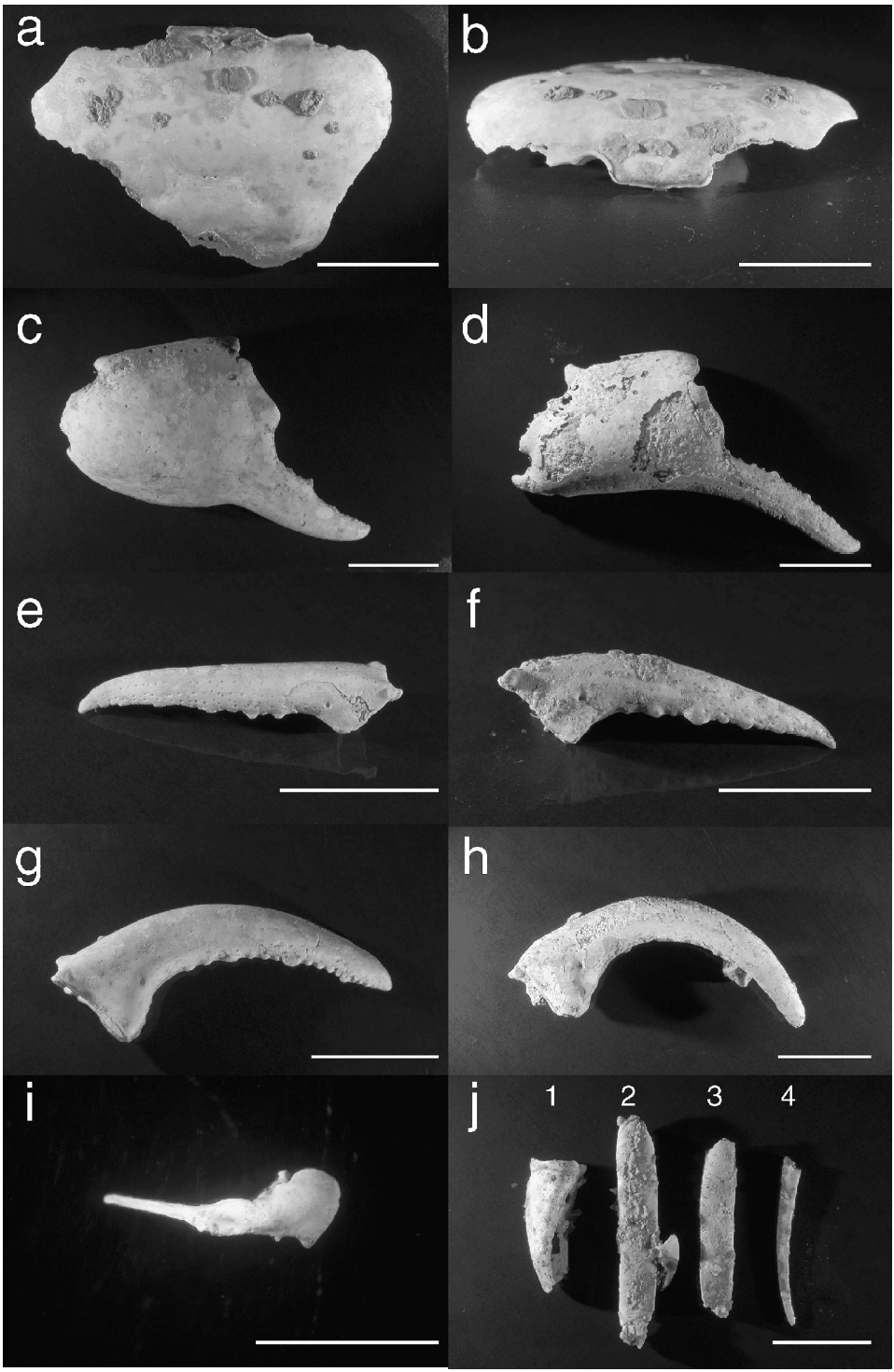
a
b
c
d
e
f
g
h
i
j
1
2
3
4

TABLE I
Measurements of the chelae of fossil and extant *Geothelphusa tenuimanus* (Miyake & Minei, 1965) (in mm)

	Fossil	Extant
Max. chela palm length	18.6	20.6 $Y = 0.92CL-5.70$
	(n = 13)	(n = 11 $r = 0.91$ $F = 19.11$ $p < 0.01$)
Max. chela palm width	18.0	19.2 $Y = 0.98CL-8.85$
	(n = 14)	(n = 11 $r = 0.81$ $F = 7.39$ $p = 0.02$)
Max. movable finger length	31.2	26.9 $Y = 1.30CL-11.70$
	(n = 65)	(n = 11 $r = 0.83$ $F = 8.63$ $p = 0.01$)

laterally and mesially, in some specimens palms about as long as high; in some specimens chelae with ventrally directed immovable finger; cutting edge toothed, two large teeth present on proximal 1/3 and proximal 2/3, proximal one largest. Movable fingers of chelae also well preserved, fingers of larger (major) chela strongly curved inwards; movable finger with two large teeth, each tooth located slightly distal of each corresponding large tooth of immovable finger.

Mandible, carpus of cheliped, and dactylus, as well as segments of ambulatory legs preserved.

Remarks. — The fossil specimens examined in this study agree very well with Naruse et al.'s (2003 [in prep.]) detailed redescription of *Geothelphusa tenuimanus*. The strongly reduced post-frontal and post-orbital cristae, as well as the very strongly flattened carapace, are characteristic features of *G. tenuimanus*. The flattened palm and the dentition of both the immovable and movable fingers, as well as the long and slender ambulatory dactyli, are also diagnostic features.

One of the authors (MM) observed freshly dead *G. tenuimanus* in the limestone fissure of Chinen Village. This may imply that freshly dead individuals or exuviae of extant *G. tenuimanus* may be contained in the limestone fissure sediments. However, although *G. tenuimanus* is the most terrestrial form among all known true freshwater crabs currently distributed on Okinawa Island, and it is always associated with karst areas (Gima & Shokita, 1980; Minei, 1981; Yoshigou, 1999; Naruse et al., 2003 [in prep.]), *G. tenuimanus* prefers slightly retentive soil (Naruse et al., 2003 [in prep.]), not like completely dried fissure sediments (fig. 1). It is likely that the occurrence of freshly dead *G. tenuimanus* was an accident. Most *G. tenuimanus* parts, as well as the fossils of a deer, *Cervus* sp., which is already extinct on Okinawa Island, are buried together in the clay of the limestone fissures. Furthermore, *G. tenuimanus* parts occur very densely. It is difficult to assume that exuviae or trapped extant *G. tenuimanus* have been accumulated to such extents in recently, artificially exposed limestone fissures. These observations thus suggest that the *G. tenuimanus* parts found in the limestone fissures are indeed fossils.

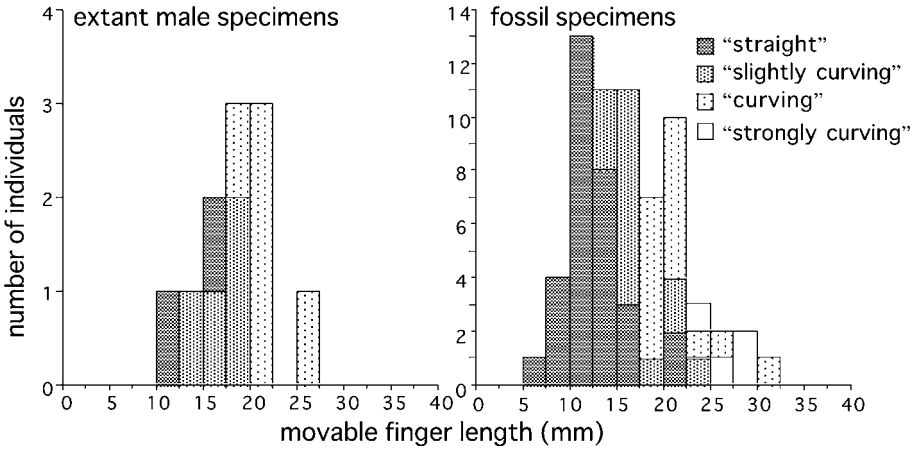

Fig. 3. Relationship between curvature and length in movable fingers of chelipeds of fossil and extant *Geothelphusa tenuimanus* (Miyake & Minei, 1965). The degree of curvature was classified into four types, viz., "straight", "slightly curving" (dorsal margin curving), "curving" (both dorsal and ventral margins curving), and "strongly curving". Note that fossil specimens probably contain both male and female movable fingers.

DISCUSSION

Size of the fossil specimens. — Only well preserved chelae were measured. Table I shows the measurements of the chelae of both fossil and extant specimens. Fossil specimens have a greater maximum length of the movable finger. The movable finger length in extant specimens is strongly correlated with the CL ($r = 0.83$, $p = 0.01$). If the fossil specimens have the same relationship between the length of the movable finger and CL, the maximum CL can be estimated as 32.99 mm instead of 27.1 mm (holotype, ZLKU 9726) in extant specimens. Thus, fossil material of *Geothelphusa tenuimanus* contains larger individuals than the extant specimens examined in this study.

Shape of the movable finger. — The movable fingers found vary in their curvature (fig. 3). The degree of curvature was classified into four types: "straight" (fig. 1e); "slightly curving" (dorsal margin curving, fig. 1f); "curving" (both dorsal and ventral margins curving, fig. 1g); and "strongly curving" (fig. 1h). In both fossil and extant specimens, "slightly curving" and "curving" types appeared to occur in the same size-group (12.5-14.9 mm finger-size-group and 17.5-19.9 mm finger-size-group, respectively). In the 64 fossil movable fingers, only 4 fingers (6.25%) showed the "strongly curving" type, and they are longer than 23.0 mm. On the other hand, no "strongly curving" type was found in extant specimens. The only extant specimen, that has a movable finger longer than 23.0 mm, is the holotype (26.9 mm). This apparent discrepancy in the data may, however, be caused by the fact that no sufficiently large extant specimens have been obtained for the present study.

ACKNOWLEDGEMENTS

We are grateful to Dr. Peter K. L. Ng (National University of Singapore) for his advice and comments of an earlier version of this manuscript.

REFERENCES

BOTT, R., 1970. Die Süßwasserkrabben von Europa, Asien, Australien und ihre Stammesgeschichte. Eine Revision der Potamoidea und der Parathelphusoidea. (Crustacea, Decapoda). Abh. Senckenbergischen naturf. Ges., **526**: 1-338.

GIMA, H. & S. SHOKITA, 1980. Distribution of potamonid crabs in the Yona River of Okinawa Island, the Ryukyus. Biol. Mag. Okinawa, **18**: 9-15. [In Japanese with English abstract.]

HASEGAWA, Y., 1980. Notes on vertebrate fossils from Late Pleistocene to Holocene of Ryukyu Islands, Japan. Quart. Res., **18**: 263-267. [In Japanese with English abstract.]

KAMEI, T., Y. KAWAMURA & H. TARUNO, 1988. Mammalian stratigraphy of the Late Neogene and Quaternary in the Japanese Islands. Mem. geol. Soc. Japan., **30**: 181-204. [In Japanese with English abstract.]

KARASAWA, H., 1997. *Geothelphusa dehaani* (White, 1847), a fossil land crab from the fissure deposits of Yage, Inasa-cho, Shizuoka Prefecture, Japan. Sci. Rep. Toyohashi Mus. nat. Hist., **7**: 25-26. [In Japanese.]

MINEI, H., 1968. Fresh-water crabs of Japan. Nat. Stud., **14**: 94-99. [In Japanese.]

— —, 1981. Distribution and general habitat of the freshwater crabs of Japan. In: T. YAMAGUCHI (ed.), Ecological studies of coastal marine and freshwater crabs. [Report for the Grant-in-Aid for Co-operative Research, 1978-1980]: 79-92. (Ministry of Education, Tokyo). [In Japanese.]

MIYAKE, S. & H. MINEI, 1965. A new fresh-water crab, *Potamon* (*Geothelphusa*) *tenuimanus* sp. nov. from Okinawa-jima, the Ryukyu Islands. Sci. Bull. Fac. Agric., Kyushu Univ., **21**: 377-382, pl. 21. [In Japanese with English summary.]

NARUSE, T., S. SHOKITA & T. NAGAI, 2003 [in prep.]. On the taxonomy of the terrestrial crab, *Geothelphusa tenuimana* (Crustacea: Decapoda: Brachyura: Potamidae), of Okinawa Island, Central Ryukyus, Japan.

NG, P. K. L., 1988. The freshwater crabs of Peninsular Malaysia and Singapore: i-viii, 1-156, 4 col. pls. (Shinglee Press, Singapore).

NG, P. K. L. & G. RODRIGUEZ, 1995. Freshwater crabs as poor zoogeographical indicators: a critique of Bănărescu (1990). Crustaceana, **68**: 636-645.

YOSHIGOU, H., 1999. Potamidae (Crustacea: Decapoda: Brachyura) of Japan. Journ. Hiba Soc. nat. Hist., **191**: 17-26, pls. 1-2. [In Japanese.]

Note. — Though various authors have referred to *Geothelphusa tenuimanus* as "*Geothelphusa tenuimana*", this is not correct. As "manus" is a Latin noun, not an adjective, under articles 31.2 and 32.3 of the International Code on Zoological Nomenclature (1999) the original spelling is to be preserved.

T. NARUSE, on behalf of the Authors;
L. B. HOLTHUIS and J. C. VON VAUPEL KLEIN,
on behalf of the Editorial Board

First received 24 June 2003.
Final version accepted 20 July 2003.