kraepelini species complex (Acari: Macrochelidae) with two new species. Can J Zool 64: 212–217

40 Wilson DS (1982) Genetic polymorphism for carrier preference in a phoretic mite. Ann Entomol Soc America 75: 293– 296

41 Wilson DS (1983) The effect of population structure on the

evolution of mutualism: a field test involving burying beetles and their phoretic mites. Amer Nat 121: 851-870

42 Wilson DS, Knollenberg WG (1987) Adaptive indirect effects: the fitness of burying beetles with and without their phoretic mites. Evol Ecol 1: 139–159

NTRODUCTION

Forest echinethariold call and a have searcely been mand because the echinethariolds have furtilite tests with rest connective peaks and poons calcifed encodes [19]. Estant because and the prover and the test has been for the last and the prover melider [7, 18, 19]. As the lips records, any two travile species of echinothariosis have been reported [9]. One species is *Leitage theres florts* from the Upper frequencies of the branch Challs [20], and mather is America an should from the Provene of sites Zealand [4, 19]. No peak photenocuments has been reported to far [19].

The set along the Pacific count of the Ispencer man shand is so extensively appleted that some groups of organmic known the where doly toget the deep set scenes to derive there in relatively shallower scatter. Echinetheridads are been of such groups, and a considerable number of species of the order can be found. The extent species of echicotion with found on the bottom of or shallower from the sport subsystemes in the logenesis cause such to 5 species of the chile found on the bottom of or shallower from the sport subsystemes in the logenesis cause such to 5 species of the chile found on the bottom of or shallower from the sport subsystemes in the logenesis cause such to 5 species of the chile found on the bottom of or shallower from the species in the found on the bottom of the station is the species of the creation of the species cause such to 5 species of the chile found on the bottom of the station of the station in the found on the species cause such the found the creation of the species of the found the species of the creation of the species of the found the species of the species in the species of the found the species of the species in the found the species of the found the species is the first of the species of the found the species of the found to the species of the found the species of the species is shown the species of the found the species is the found to the species of the found the species is the bottom of the species of the found the species is an interval to the found to the species of the found the species is the found to the species of the found the species is an interval to the species is an interval to the species is an interval to the found to the species of the found the species is the found to the species of the species is an interval to the species of the species is an interval to the species of the species is an interval to the species of the species is an interval to the species of the species of the species is an interval to the species of the species is an interval to the specie

Museum depends before as the Morgania Group are distributed winish in the southern here of Alets Prefecture : The Group is one-coursed by company data marine food

tecopied associaty 7, 2004

laugh domaining of hollyst and mesoperage meentaine [14]. Recently: we becaused a large human of despress forths operating unles, ochicolderms controlerate and mollers. Irain conditions and humanice Easts in the Morecaki throug. Among these come spectrum is of dig Phermonomianistic were found.

To the presum paper, a feasil phononomain species is a described an the basis of seven species and its attinity with B' basismum is discussed.

MATERIALS

The Monteries Groups & decremented in Subrechnike and Honolas fitting Islands in Allance Bay, and the southern offse of the Chila Contockels in Architermenta alternation of monteries (Fig. 1). The private is astalianted and international weight are the Higmake. Toyotaken, Yappens, and Allance Barthageum to precedents order [14] The frace photonermatic measures (ci. 17 species) show the Toyotaken and Yamani Permanus (Fig. 1: Long J.-3) and were benefits for tefficience and the statements of the temptal home benefits for tefficience and the statements of the temptal home benefits for tefficience and the statements of the temptal home benefits for tefficience and the statements of the temptal home

The scored age of the Leichers and Tanian Formation was existent to be Mindle Microsof. ALLS Marid, D. 5 Ma [16, 15]. But event contratigned in mices being on plantance of Resemble result contratigned in mice [0] downed from the Antifannes are from Mindlere to age. These domains from the Antifannes are from Mindlere to age. These domains on the Antifannes are from Mindlere to age. These domains of the Antifannes are from Mindlere to age. These domains of the Antifannes are from Mindlere to age. These domains of the Antifannes are from Mindlere to age. These domains of the Antifannes are from Mindlere to age. These domains of the Antifan and the Antitantha, achieve and plantatenes of production and the Antifan the Mindle and plantatenes of the Antifan are also from Exceed 10; ballysi [17] Echanolds were also the and another the formations

More than the spectrum of the puper monomous and same entropy and an operation of the second state of the second s evolution of annualisms a field test involving brothes and the probagotic midd. Min. A high 4201-200 and

- S. Wilson D.S. Knollenberg W.G. (1987). Adaptive indicate efforts and a market W. Europei Samper and and Albana Mull parters. and S. Wilson M. 1992 1993.
- save the Million of Million of Selance and Collare of James

REFERENCES

- Antel & (1994) Phinete relationship of associations managerishaniting Mornschröhlar (Ararina Managerisan) The kongenty Arn Encomplian Armetria 32, 394-383 Rected & (1910) Lista il marve specie e polisi genera di Jaciet
- Mantanian e. e. Sk. (1971) Theorem Events in Industrial Measurements, Eventschehen, Astronomica 13 244–251.
- Borgettinn NG, Konstens EV (1960) The environmental environ (Commonidate Militricheficilies in the USSR Parsen an Ja 30 154
- Hinter DA, Wilson JYS (1998) Provide firmer a multi-Behavioral and fire leaving adaptations to calibrate have and the consequcosts of action prices about in host communities. In "Milese boulogical and Deviatorizary Analysis of Late Hinter Parterns" Ed by MA House, Chemman & Holl, pp. 1-23
- Christie JE, 19980. A new weater of Allgree (Meanstanais) "stratecidae) train Britain. Acknologie 24, 247–242.
- Cicoladi B. (2002). Macrochelio entris Param. Neuromparata accurring in Malifial droppings in the parameter encountries hely. Ann Econor Emirror 40, (2–64.
- Contra Mi (1900) The environment of summarized with Contra na Automatic (1.) (Collections, Schladbaudder) in turnet / Linux See Zuol 43, 23-45
- ⁹ Conta Mi (1967) Notes on macanubadel demonstrative west present mod copied buckles in Israel. II. Tures here constrained inter-Matrocheles poremic complex, add, others at their bushess. Activelying 9, 304–320.
- and count streets Acardional St. (1962)
- Events GO, Britsening F (1936) Inviting miles of the subfracery Macrochilking: Transitik (Commission - Milerrochichidae), Hust Br Mus and Hier (Zoud) a 1945.
- 2 Eleans Ger Hyan K.B. (1997) Milles of the groups Macrowskies Easte Odersengerstantic and existence with copyrist free data in the calibretensive of the Hermith Armonate (Stational Harristy) "Bud Hermitian and That (Zeod) in \$27-001
- 3 Lines GOA Streak IC, Machenane D (1981) The Terratural Activity of the British Isley. An Introduction to their Marphotos, Supp. Restors, and Completendon, 2 Introduction and Brokey, Introduction Machenan, London.
- M. Kubipers, M.S., Brepeteren, M.J. (1977) A Rey and the Scale inhibiting Main. Managingunata Treat Inst. Advant. Sci. USSIT. Compared, 718 pp.
- S provide (s. 1911) one (all (1971)). The manyord makers of string benefities in according of provide and string. How for more superior and the field
- Hushine KS (2007) Minor delta ale anticara stater sando a sconsegue traving Minor deltana. Aust I Zood in 335 Di Hushine 7 Cas Leonit A Check Lie el Saparere Insectal y Selling Paramot In Presidentia Laboratori Facility of Aproxidure & aske Connectly Facility.

¹⁶ Reduction and the state of the state

- rearranting (1) and point of a rearrant point of a rearrant of a rearran
- 1000. And average in the second and the second of the second when the second when the second when the second se
- 20 Inhistoria & (1972) Up the messarighment of other associated with the interconnectivity bards, Mondechantal advantation (1) Annes Zone (Append 20, 98-10)
- Article Start Anno 30 142-182
- 14 Induces & Classic Mathematics leafgrand. In "Restrictions of the Miles and Taxis of Appart' Ed Dr.S. Phare. Zahasian Milesen Kashish, Kholla, Taxas, op 81-91 (to Indonesit)
- ated will the provide of logica (ii). See Rea Matery and Shenemonic is Cold (Se are 172)
- 26 Control perce MI (1992) Gaterrated policy (Control-rider), Plane and vigopi) associated with searching d becakes (Control prices, Scinabasedae) in Hole car. Acta Zoof Bei 37 12-26.
- 27 Astrony GW (1978) A Machani of Activology, Second Edimen, Oregon/Scong Univ. Inco. Storus, Inc., Cardadia, 208 pp.
- 28 Allantz GW (1901) This was gladies carries involve of Ma Tracheles (Acaris, Macroscholiclas) from southean Africa fra 1 -Acarel 7: 4.16
- ¹⁵ Nowitz, OW (1983) "Afters' and budget it correct separate of damp brinding first, with graduit reference to the Macrochender in "Richarders' Constituted Passe by Macro De Ty MA Hoy, Cil. Commendated, C. Spentituted, Place by Macro E. Syntax Mov, Cil. Commendated, C. Spentituted, Place by Macro De Ty MA Hoy, Cil. Commendated, C. Spentituted, Place by Macro De Ty Mark, Sphere Patter in actor. SD4, Research, privat, 498
- ⁴⁴ Kiama GW, Malazi JJ (1972) Studies an phonotic specificity, in Martuchedo morphysical and M polymerican Kannie and Manori (Acari Marbuchedan) workdate of exotophic Scanshasiles. Appropria 14: 303–340
- Kranza GW, "Whitakan HO in (2008) Aline, of the genue Manuachers (Acard Managanalabar near detect with seal source ands in North-American Acardiacher 20, 229-2397
- Landyner E. (1961) Reserve demonstration of Induktionary semi-mouth (1 Muller) is promptionally only only mouthing with careful Decilies in The down Reproduction: Development and Like theory Stateger. Ed in R. Schwarz, FW Murphy, pr 135-452
- Manutan h. Derferen G. Kasen Afrikash. On de Aydurdin george a layes. Tai Rey Japan & Jat-pai
- Sheber JK, Schwein Hitz (1993) Distance in carner platee mee onli eskiharin ut reproductive in tathin nervour autority bianda bina canaly (Acor), Paramiterati (rong-pharmacily on huw membrin distangleriti ancine Eucl. (r. 1982-11) 22 JUkuta I.A.). Menga 1998 april 20 Septielous Arrens 2013
- Ann May Nur Her (Ser 13) 10 we are
- Lapan' Esi in 'né figan di manga kanan Karinka Kanan Terten.
- Resident BR (1991) Addition of the reliantwenty between beining bordes, surgebories are and the mate, Providentes, according to the T-Addit Cold by spin-all
- 4 Takuka G. (1994) A range species in the grant devicemental (Acasy Meterscheduling) from bontiners lapur. Algoridation 20 (1) provid.
- Watter Dit, Kenner O'W'Elstein Description of the Milerochilter

First Fossil Record of the Family Phormosomatidae (Echinothurioida: Echinoidea) from the Early Miocene Morozaki Group, Central Japan

SHONAN AMEMIYA¹, YOSHIAKI MIZUNO² and SUGURU OHTA³

¹Misaki Marine Biological Station, University of Tokyo, Miura-shi, Kanagawa 238-02, ²Tokai Fossil Society, 9-21, Sawashita-cho, Atsuta-ku, Nagoya, Aichi 456, ³Ocean Research Institute, University of Tokyo, 1-15-1, Minamidai, Nakano-ku, Tokyo 164, Japan

ABSTRACT—A fossil echinothurioid echinoid is described from the Early Miocene Morozaki Group in the Chita Peninsula of Aichi Prefecture, central Japan. Based on geological observations, the fossil species is supposed to be the inhabitant of the bathyal zone. The diagnosis of the species is as follows: A small body size for an echinothurioid, large and deep areoles in the oral side, slender teeth with a sharp point, and a large peristome area. From the supposed habitat and the diagnosis, this species is considered to be identical with or a direct ancestor of *Phormosoma bursarium*, a common extant species in the bathyal zone of the Indo-Pacific region including the southern coasts of the Japanese main islands. This is not only the first fossil record in the world of the family Phormosomatidae, but also the third fossil species for the order Echinothurioida.

INTRODUCTION

Fossil echinothurioid echinoids have scarcely been found because the echinothurioids have flexible tests with rich connective tissue and poorly calcified ossicles [19]. Extant echinothurioids are divided into two families, Echinothuriidae and Phormosomatidae [7, 18, 19]. As the firm records, only two fossile species of echinothurioids have been reported [19]. One species is *Echinothuria floris* from the Upper Cretaceous of the British Chalk [20], and another is *Araeosoma thetidis* from the Pliocene of New Zealand [4, 19]. No fossil phormosomatid has been reported so far [19].

The sea along the Pacific coast of the Japanese main island is so extensively exploited that some groups of organisms known elsewhere only from the deep sea seems to occur there in relatively shallower waters. Echinothurioids are one of such groups, and a considerable number of species of the order can be found. The extant species of echinothurioids found on the bottom of or shallower than the upper bathyal zone in the Japanese coast include 5 species of the Echinothuriidae: Asthenosoma ijimai from the infralittoral zone, Araeosoma owstoni and Hapalosoma gemmiferum from the circalittoral (lower sublittoral covering the edge of continental shelf) zone, and Calveriosoma gracile and Hygrosoma hoplacantha from the upper to middle bathyal zone [1, 2, 8, 10-13, 16, 21], and one species of the Phormosomatidae, that is Phormosoma bursarium from the upper bathyal zone [8, 10-13, 16]. However, fossil specimens of echinothurioids have never been reported from Japan.

Miocene deposits known as the Morozaki Group are distributed widely in the southern area of Aichi Prefecture. The Group is characterized by extremely rich marine fossil

Accepted January 7, 1994 Received April 17, 1992 fauna consisting of bathyal and mesopelagic assemblage [14]. Recently, we obtained a large amount of deep-sea fossils comprising fishes, echinoderms, crustaceans and molluscs, from sandstone and mudstone beds in the Morozaki Group. Among those, some specimens of the Phormosomatidae were found.

In the present paper, a fossil phormosomatid species is described on the basis of seven specimens, and its affinity with *P. bursarium* is discussed.

MATERIALS

The Morozaki Group is distributed in Saku-shima and Himakashima Islands in Mikawa Bay, and the southern edge of the Chita Peninsula in Aichi Prefecture situated in central Japan (Fig. 1). The group is subdivided into four formations which are the Himaka, Toyohama, Yamami, and Utsumi Formations in ascending order [14]. The fossil phormosomatid specimens examined were collected with many other echinoderm species (ca. 17 species) from the Toyohama and Yamami Formations (Fig. 1: Locs. 1–3) and were found in the tuffaceous sandstone beds deposited in the bathyal zone between around 500 m to 1,000 m depth or more [5].

The geologic age of the Toyohama and Yamami Formations was estimated to be Middle Miocene, 15.5 Ma to 16.5 Ma [14, 15]. But recent biostratigraphic studies based on planktonic foraminifers [3] and paleomagnetic study [6] showed that the formations are Early Miocene in age. These formations contain various kinds of fossil species including phormosomatid echinoids. They are composed of benthic, nektonic and planktonic organisms such as fishes, crustaceans, molluscs and protozoans having inhabited various depth zones from littoral to bathyal [17]. Echinoids were abundant and accounted for more than a half of the echinoderm specimens collected from the formations.

More than ten specimens of fossil phormosomatids were collected. Six of them (MFM 38057–38060, MI 01, SA 01) are almost intact, and others are fragmental. The fossil specimens examined in this study are deposited in the Mizunami Fossil Museum (MFM 38057–38060), the Misaki Marine Biological Station (MMBS A1), and in the private collections of Y. Mizuno (MI 01) and F. Sakakura (SA 01).

MFM 38057, 38060, and MI 01 were found in a tuffaceous sandstone bed of the lower part of the Yamami Formation (Fig. 1: Loc. 2), together with crinoids, ophiuroids, crustaceans and molluses.

MFM 38057 was collected from a sandstone bed of the uppermost part of the Toyohama Formation (Fig. 1: Loc. 1), together with asteroids and ophiuroids.

MFM 38058 and SA 01 was collected from a tuffaceous mudstone bed of the middle part of the Yamami Formation (Fig. 1: Loc. 3), together with asteroids, ophiuroids, crustaceans, molluscs and fishes.

The living specimens of *Phormosoma bursarium* (MMBS P1-P7) for comparison were collected from Suruga Bay at 550 m in depth.

SYSTEMATIC DESCRIPTION

Order Echinothurioida Claus, 1880 Family Phormosomatidae Mortensen, 1934 Subfamily Phormosomatinae Mortensen, 1934 Genus Phormosoma Thomson, 1872 Phormosoma sp. cf. P. bursarium A. Agassiz, 1881

Diagnosis: 1, a small body size for an echinothurioid; 2, large and deep areoles in the oral side; 3, slender teeth with a

sharp point; 4, a large peristome area.

Description: This description is based on six intact (MFM 38057-38060, MI 01, SA 01) and one fragmental (MMBS A1) specimens. The test is circular and rather small in size for an echinothurioid with the diameters ranging from 48 mm to 118 mm (Table 1). The size is comparable to that of Phormosoma bursarium, an extant species, but somewhat larger than the other extant species, P. placenta, P. rigidum, and P. verticillatum, none of which reaches a larger size than 90 mm in diameter [8]. Specimens are squashed along the oral-aboral axis. In most specimens, the oral side is well preserved (Fig. 2), but the aboral side is damaged heavily, or lost. The oral side of the test looks like a honey-comb (Figs. 2, 3), because the areoles of the primary tubercles in the oral side are very large and deep. The five pieces of teeth in the lantern are slender with sharp points (Figs. 2, 4). The areoles in the aboral side, in contrast to the oral side, are small and not so deep (Fig. 4). The peristome area is large (Figs. 2, 4), although not so large as in P. bursarium (Table 1). Interambulacra on the oral side are almost 2.5 times as broad as ambulacra, somewhat larger (ca. twice) than in P. bursarium. Plates are large, not numerous. An ambulacral plate is composed of a large primary plate and two small demiplates which are situated at the side of the lower edge of the primary plate (Fig. 3). Three pairs of pores are found on these plates. A pair of pores is situated in the margin of the primary plate. Another pair of pores is on each demiplate.

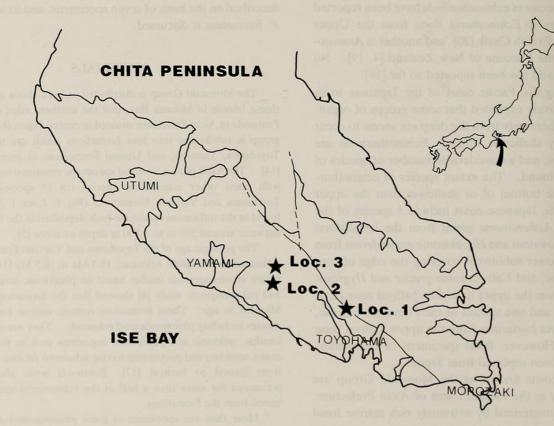


FIG. 1. Map showing the Toyohama and Yamami Formations and Localities 1-3 (Locs. 1-3) in the Morozaki Group in the Chita Peninsula, from where the Miocene phormosomatid specimens were collected. Curved arrow shows the location of the Chita Peninsula in the Japanese main islands.

Phormosoma sp.				P. bursarium			
Cat. No.	test diameter (A) (mm)	peristome diameter (B) (mm)	B/A	Cat. No.	test diameter (A') (mm)	peristome diameter (B') (mm)	B'/A'
AFM 38060	48	15	0.31	MMBS P1	78	30	0.38
MFM 38058	63	17	0.27	MMBS P2	79	24	0.30
MI 01	74	23	0.31	MMBS P3	79	28	0.35
MFM 38057	82	21	0.26	MMBS P4	89	33	0.37
MFM 38059	100	25	0.25	MMBS P5	92	28	0.30
SA 01	118	31	0.26	MMBS P6	94	36	0.38
				MMBS P7	109	36	0.33
Mean			0.277		Contraction (0.344
\pm S.D.			± 0.027				± 0.033

TABLE 1. Size distribution of tests and peristomes in fossil Phormosoma sp. and living Phormosoma bursarium

There are five to six pairs of primary plates in each ambulacrum on the oral surface, and an ambulacral primary tubercle is on each primary plate. The size of the primary tubercles is almost equal except in the ones situated along the peristome which are somewhat smaller than others.

There are four to six interambulacral plates in each column on the oral surface. The number of primary tubercles on an interambulacral plate decreases adapically from 3 (for the outermost 1–2 plates), 2 (for the inner 2 plates) to 1 (for the 1–2 plates adjacent to the peristome). Secondary and miliary tubercles are not preserved. The spines preserved on the marginal fringe of the test of MFM 38058 are short and slender (Fig. 5). The apical system is not preserved well.

Remarks: The specimens from the Morozaki Group have large and deep areoles in the oral side, slender teeth with a sharp point, a large peristome area, and a comparatively small body size. These characteristics clearly indicate that they belong to the genus *Phormosoma* Thomson, 1872. Four extant species belonging to the genus *Phormosoma* have so far been reported [8]. Their distributional ranges are as follows:

P. placenta Thomson, 1872: Northern Atlantic from Iceland and the Davis Strait down to the Azores and the Gulf of Guinea, and to the West Indies, 215–2500 m depths.

P. verticillatum Mortensen, 1904: Indian Ocean, from the Bay of Bengal to the Arabian Sea, 1165–1925 m depths.

P. rigidum A. Agassiz, 1881: Off New Zealand, 1260 m depth.

P. bursarium A. Agassiz, 1881: Indo-Pacific, from the Natal Coast and the Arabian Sea to Australia, New Caledonia, Japan, and the Hawaiian Islands, overall depth range in records 170–2340 m, and dominate between depths of 500–1700 m on the continental slope of the Pacific coast of Japan.

The Morozaki specimens have affinity with *P. bursarium* in some morphological characters such as the test size, or the arrangement of ambulacral plates and pore pairs on the plates, although some differences are also found between

them in the peristome area and in the relative width of the ambulacra and interambulacra.

Their habitats seem also to be similar, and a great number of living specimens of P. bursarium have been trawled and sometimes gregarious paches of them were photographed on the silty mud bottoms of the bathyal zone along the southeastern coast of Japanese main islands including the area off the Chita Peninsula [12]. The depth range of Calveriosoma gracile and Hygrosoma hoplacantha overlaps with that of P. bursarium in the above locations. However, the usual habitats of them are segregated. The former two species prefer sandy mud bottom on the topographic highs swept by strong bottom currents expecting the occasional drifting sea algae as facultative vegetarians [9, 12], whereas the latter species predominates on the silty mud floor where the regime of bottom water movement is relatively calm. If the habitat of the fossil species is the same as that of the extant species, the taphonomy of the soft-shelled sea urchin in the taffaceous sandstone in a formation of Morozaki Group suggests instantaneous burial beneath turbidity currents. The present Phormosoma specimens were collected together with four other echinoid species, 13 species of other echinoderms and with some fishes, crustaceans and molluscs from tuffaceous sandstone beds deposited in the bathyal zone. The four echinoid species are Temnopleurus sp. (upper bathyal member), Brissopsis sp. (upper to middle bathyal member), a diadematid and a scutellid (littoral members). Their habitats today range from the littoral to bathyal zones, suggesting that some of the fossils have been brought from shallower bottoms into the bathyal zone by turbidity flows and/or episodic disasters involving the littoral, midwater and upper continental slope realms.

The fossil specimens found in the Morozaki Group can be identical with or a direct ancestor of P. bursarium, although the information obtained from the present fossil specimens is still insufficient to identify the species exactly. This is the first fossil record in the world of the family Phormosomatidae, and is also the third unequivocal fossil species for the order Echinothurioida [19].



Amemiya, Shonan, Mizuno, Yoshiaki, and Ohta, Suguru. 1994. "First Fossil Record of the Family Phormosomatidae (Echinothurioida : Echinoidea) from the Early Miocene Morozaki Group, Central Japan." *Zoological science* 11, 313–317.

View This Item Online: <u>https://www.biodiversitylibrary.org/item/125367</u> Permalink: <u>https://www.biodiversitylibrary.org/partpdf/71358</u>

Holding Institution Smithsonian Libraries and Archives

Sponsored by Biodiversity Heritage Library

Copyright & Reuse Copyright Status: In Copyright. Digitized with the permission of the rights holder. License: <u>http://creativecommons.org/licenses/by-nc-sa/3.0/</u> Rights: <u>https://www.biodiversitylibrary.org/permissions/</u>

This document was created from content at the **Biodiversity Heritage Library**, the world's largest open access digital library for biodiversity literature and archives. Visit BHL at https://www.biodiversitylibrary.org.