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Clavagellidae (Mollusca; Bivalvia) in Japan

By

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(Communicated by Ikuwo OBATA)

Abstract The Japanese species of the family Clavagellidae, a tube dwelling bivalve, are revised and referred to eight species in three genera, *Clavagella*, *Humphreyia*, and *Brechites*. Among the eight species, five are endemic to Japan and adjacent areas. They are *Clavagella* (*Stirpuliniola*) *ramosa*, *Humphreyia* (*Nipponoclava*) *kanazawensis*, *H.* (*N.*) *yokoyamai*, *H.* (*N.*) *gigantea*, and *Brechites* (*Brechites*) *nagahamai*. The other three species were originally described from and are mainly distributed in Australian and/or Indian waters. They are *Clavagella* (*Bryopa*) *lata*, *C.* (*Dacosta*) *australis*, and *Brechites* (*Foegia*) *novaezelandiae*, of which the second species is recorded for the first time in Japan. In addition to the above eight species, two specifically indeterminable clavagellids are also herein reported as *Clavagella* species indet. and *Humphreyia* (*Nipponoclava*) species indet.

Humphreyia (*Nipponoclava*) *kanazawensis* (early Middle Micoene), *H.* (*N.*) *gigantea* (late Miocene and Holocene), and *H.* (*N.*) *yokoyamai* (late Pliocene to early Pleistocene) are easily distinguishable from each other by their shell-sheath size. *Humphreyia* (*N.*) *yokoyamai* is occasionally preserved in life position. *Clavagella* (*Stirpuliniola*) *ramosa* ranges in time from Pleistocene to Holocene. *Clavagella* (*Bryopa*) *lata*, *C.* (*Dacosta*) *australis*, *Brechites* (*Brechites*) *nagahamai*, and *B.* (*Foegia*) *novaezelandiae*, are known in recent sediments of Japan.

Introduction

Clavagellids are extraordinary bivalves in morphology and ecology (SAVAZZI, 1982b; POJETA & SOHL, 1987). They have a tube-like calcareous adventitious crypt to which the left or both shells (bivalved juvenile hard parts) are cemented. The crypt is closed anteriorly by a calcareous plate perforated by a slit, and by series of pores or tubules. The crypt is open posteriorly, where siphonal collars may be developed. The Recent species live unattached in fine to coarse substrates, or bore and cement into hard substrates. Living free-burrowing clavagellids commonly cannot move actively. Their elongate vertical crypts act as an anchor within the sediments by their own length. They can kink the siphonal sheath according to growth when disturbed from life position, and can reach to the sediment surface after disturbance. These functions of the crypt are basic ecological strategies of free-burrowing clavagellids (SAVAZZI, 1982b).

Clavagellids first appeared in the Cenomanian of Europe (POJETA & SOHL, 1987). Some 60 valid species are known worldwide (SAVAZZI, 1982a). In Japan, eleven spe-

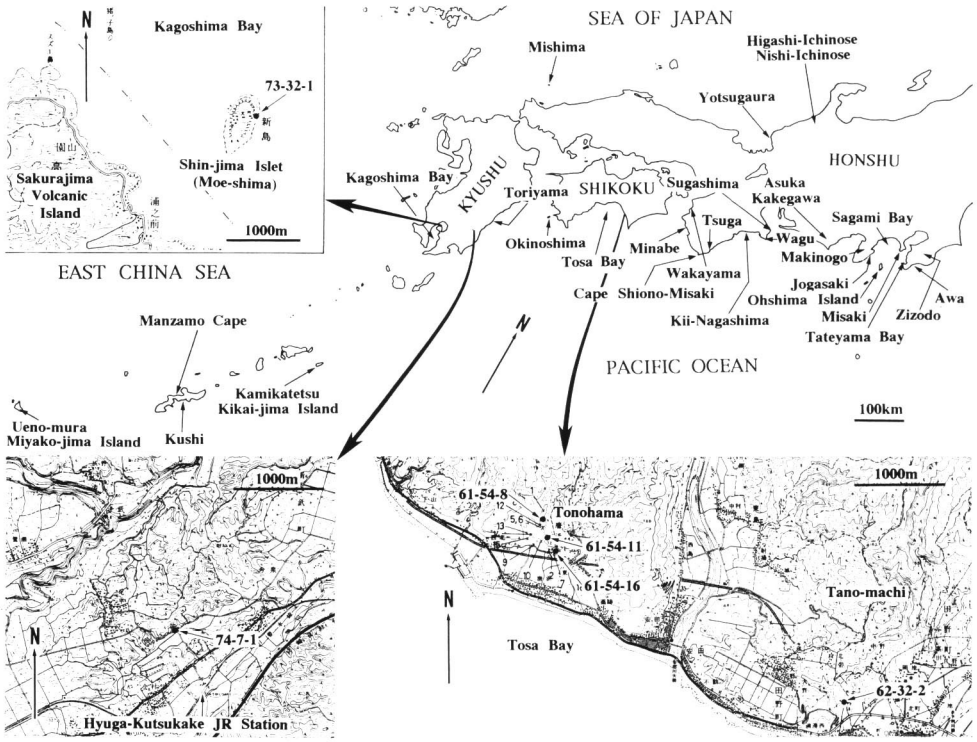


Fig. 1. Index map showing clavagellid localities and place names cited in this study. The following topographic maps of Geographical Survey of Japan are used: "Kagoshima" (1/50,000), "Aki" (1/25,000), "Nahari" (1/25,000), and "Tano" (1/25,000).

cies have been previously reported from Miocene to Holocene sediments. Among them, however, *Clavagella japoniva* YOKOYAMA, 1926b and *Penicillus* (*Penicillus*) sp. indet. of OMURA (1969) are not or may not be clavagellids. *Clavagella japonica* has been reidentified as an annelid tube (HABE, 1952b). *Penicillus* (*P.*) sp. indet. of OMURA (1969) is here considered to be an indeterminate taxon. OMURA (1969) considered his specimen to have two shells (bivalved juvenile hard parts) attached to the crypt but I cannot confirm their presence in his specimen. It is very difficult to determine whether his tube-like form is a clavagellid or some other taxon. Some studies reported *Brechites strangulatus* CHENU, 1843 from Japan (ABBOTT & DANCE, 1981) and from Okinawa (ABBOTT & DANCE, 1985; HIGO & GOTO, 1993), but I cannot confirm its occurrence in Japan. The aim of this study is to review taxonomically the remaining eight species of Japanese clavagellids.

Institutional abbreviations used in this study are as follows:

BM(NH): British Museum (Natural History).

FMMNH: Fukui Municipal Museum (Natural History) (Fukui 910, Japan).

GDLAKZ: Department of Geology, Faculty of Liberal Arts, Kanazawa University (Kanazawa City, Ishikawa 920, Japan).
IGSU-M: Institute of Geoscience, Shizuoka University-Mollusca (Shizuoka 422, Japan).
IMT: The Institute of Malacology, Tokyo (6–36, Midori-cho 3 chome, Tanashi City, Tokyo 188, Japan).
GIYU: Geological Institute, Yokohama National University.
NSM PM: National Science Museum, Tokyo, Paleontology, Mollusca (Tokyo 169, Japan).
NSMT-Mo: National Science Museum, Tokyo, Mollusca (Tokyo 169, Japan).
ORIUT: Ocean Research Institute, University of Tokyo (Tokyo 164, Japan).
YCM: Yokosuka City Museum (Kurihama, Yokosuka 238, Japan).

Systematic Description

The terminology of clavagellid hard parts is illustrated in fig. 7 of MAJIMA (1991), which adopted the usage by POJETA and SOHL (1987) who followed SAVAZZI's (1982a) suggestion and used the term "crypt" for all clacareous hard parts and the term "shell" only for the bivalved juvenile hard parts.

Terminology abbreviations used in Figs. 2–4, 6–8, 10–14 are as follows.

ap: **a**nterior **p**late.
csa: **c**onstriction between **s**hell sheath and **a**nterior plate.
lp: **l**ongitudinal **p**rominence on siphonal sheath.
pw: **p**ostero-dorsal **w**ing of right shell.
s: **s**hell (bivalved juvenile hard parts).
sc: **s**iphonal **c**ollars.
shs: **sh**ell **s**heath.
sre: **s**wollen and **r**ounded **e**nd of ridge developed along the hinge between shells.
ss: **s**iphonal **s**heath.
t: **t**ubules.

An index map of collection localities for the Japanese clavagellids is given in Fig. 1, in which fossil localities are illustrated in detail but localities for Recent specimens are given only as place names. Many Recent specimens deposited in the Institutes and Museums of Japan are not accompanied with detail locality data but only with a place name near where a specimen had been collected.

The supraspecific classification by SMITH (1976) who revised the Recent species of Clavagellidae and gave generic and subgeneric diagnoses for the family is adopted in the following description. SMITH (1976) evaluated juvenile-shell size and their positions on the crypt as generic characters, while the presence or absence of siphonal collars, shape and ornamentation of the siphonal sheath, and arrangement of tubules on the anterior plate were used as subgeneric characters.

Family Clavagellidae d'ORBIGNY, 1844

Remarks: SMITH (1976) recognized three genera in the family Clavagellidae based on the size and mode of fusion of the juvenile shell to the crypt. *Clavagella* LAMARCK, 1818 has a free right shell inside the shell sheath, while the left shell is fused to the shell sheath. *Humphreyia* GRAY, 1858 and *Brechites* GUETTARD, 1770 have both the shells fused to the shell sheath. *Humphreyia* differs fundamentally from *Brechites* in having very large shells in relative comparison with their own crypts.

Genus *Clavagella* LAMARCK, 1818

Type species: *Clavagella echinata* LAMARCK 1818, by subsequent designation (CHILDREN, 1823). Eocene, Paris Basin.

Diagnosis (after SMITH, 1976): Left shell fused to the crypt, right shell remaining free inside the shell sheath, and both adductors persistent in adult.

Remarks.—In modern waters, four subgenera are recognized in this genus, *Clavagella* s.s., *Bryopa* GRAY, 1847, *Dacosta* GRAY, 1858, and *Stirpuliniola* KURODA and HABE *in* KURODA *et al.*, 1971. Subgenera are distinguished on the basis of siphonal sheath ornamentation and mode of attachment of the crypt to the substratum. *Bryopa* has siphonal collars or prominent longitudinal ridges on the siphonal sheath, whereas the other three subgenera have a simple siphonal sheath without prominent ornamentation. The crypt of *Clavagella* s.s. is free or attached to a hard substratum by the anterior end only, but *Dacosta* is always embedded in and cemented to rock or other hard substrata, and has very obvious growth lines on the siphonal sheath. *Stirpuliniola* is always free in the substratum, and has branching expanded tubules at the anterior end, which distinguishes this subgenus from *Clavagella* s.s. that bears simple spine-like tubules on the anterior portion.

Subgenus *Bryopa* GRAY, 1847

Type species: *Clavagella aperta* SOWERBY, 1823, original designation. Living, Mediterranean and Mauritius (SMITH, 1976).

Diagnosis (after SMITH, 1976): Siphonal sheath and anterior part embedded in rock; posterior end of siphonal sheath often expanded in a series of collars or with complex longitudinal rigdes; anterior end with small holes and short tubules opposite the free right shell.

Clavagella (*Bryopa*) *lata* BRODERIP, 1834

Fig. 2–1a—3b

Clavagella lata BRODERIP, 1834, p. 116.

Clavagella (*Bryopa*) *lata* BRODERIP. APPUKUTTAN, 1974, p. 19–24, fig. 1, pl. 4; SMITH, 1976, p. 192–193, fig. 8 [contains extensive synonymy].

Bryopa lata (BRODERIP). NAKAMINE & HABE, 1980, p. 39, pl. 4, figs. 2, 3.

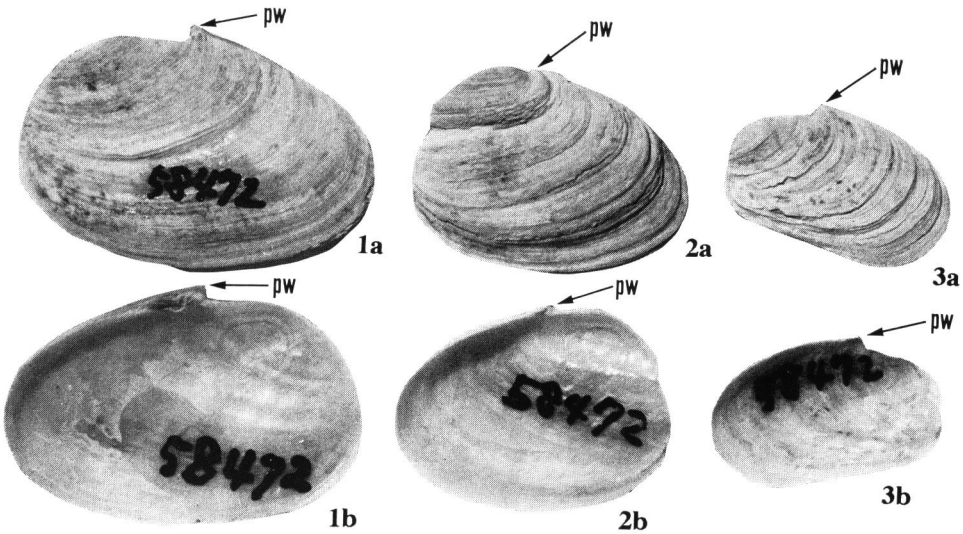


Fig. 2–1a—3b. *Clavagella* (*Bryopa*) *lata* BRODERIP, 1834 from Kushi, Nago City, Okinawa Prefecture, southern Japan. Holocene. X2. 7. NSMT-Mo58472. Outer view (1a, 2a, 3a) and inner view (1b, 2b, 3b) of free right shells. Note postero-dorsal wing (arrow **pw**) that characterizes the species.

Holotype: BM(NH) 1950. 10. 16. 1 (SMITH, 1976, fig. 8) from "Pacific Ocean" (BRODERIP, 1834, locality unknown in detail).

Stratigraphic and geographic occurrence: Holocene, Indo-Western Pacific. Kushi. Nago City, Okinawa Prefecture, southern Japan (Fig. 2); Philippines (SMITH, 1976); southwestern India (SMITH, 1976); and Gulf of Mannar, southeastern India (APPUKUTTAN, 1974).

Discussion: Three right shells were available for study (Fig. 2). APPUKUTTAN (1974) characterized this species on the basis of siphonal collars (plaited ruffles) at the posterior end of the siphonal sheath. *Clavagella* (*Dacosta*) *australis*, the most similar species, has a simple posterior end of the siphonal sheath (Fig. 3–2a—3). MORTON (1984) pointed out that it is very difficult to distinguish these two species without observing this character. However, these species can also be distinguished on the presence or absence of the postero-dorsal wing on the right shell: *C.* (*D.*) *australis* lacks a distinct postero-dorsal wing while *C.* (*B.*) *lata* possesses one (arrow **pw** in Fig. 2). Although the crypts of the available three shells were not observed in this study, I identified these specimens as *C.* (*B.*) *lata* based on the possession of the postero-dorsal wing on the right shell. The available specimens vary from 17.5 mm to 11.4 mm in shell length, which falls within the individual variation of the species (APPUKUTTAN, 1974: 10–18 mm in shell length).

Subgenus *Dacosta* GRAY, 1858

Type species: *Clavagella australis* SOWERBY, 1830 (Figs. 3–1a—3), monotypy. Living, Japan, Thailand, and Australia.

Diagnosis (after SMITH, 1976): Siphonal sheath circular to ovoid in section, with a simple posterior end and obvious growth lines; shell sheath with short tubules. Anterior usually embedded in rock or other hard substrata.

Clavagella (*Dacosta*) *australis* SOWERBY, 1830

Fig. 3–1a—3

Clavagella australis SOWERBY, 1830, p. 3; ABBOTT & DANCE, 1981, p. 375 [unnumbered fig.]

Clavagella (*Dacosta*) *australis* (SOWERBY). SMITH, 1971, p. 143–145, pl. 10, figs. 9, 10 [contains extensive synonymy]; ABBOTT & DANCE, 1985, p. 375 [unnumbered fig.]; MORTON, 1984, p. 489–508, figs. 1–16.

Clavagella (*Dacosta*) *australis australis* (SOWERBY). SMITH, 1976, p. 193–195, fig. 11.

Clavagella japonica HABE *in* KOYAMA *et al.*, 1981, p. 189–190, pl. 3, fig. 3 [not *Clavagella japoniva* YOKOYAMA, 1926b=an annelid tube (HABE, 1952b)].

Lectotype: BM(NH) 198249, designated by MORTON (1984, p. 492).

Stratigraphic and geographic occurrenve: Holocene, Indo-Western Pacific. Tsuga, Koza-cho, Wakayama Prefecture, central Japan (HABE *in* KOYAMA *et al.*, 1981); Uenomura, Miyako-gun (Miyako-jima Island), Okinawa Prefecture, southernmost Japan (Fig. 3–1a—3); Andaman Sea-side of southwestern Thailand (MORTON, 1984); eastern South Africa (KILBURN, 1974, as *Clavagella mullerae* KILBURN, 1974); and southeastern Australia (SMITH, 1971, 1976; MORTON, 1984).

Discussion: The characters of the Japanese specimens, such as the siphonal sheath bearing obvious growth lines and a simple posterior end, and many short tubules around the shell sheath that are attached and cemented to the hard substrata, unite the Japanese specimens with *Clavagella* (*Dacosta*) *australis*.

This species shows individual variation on the shape of free-right shell (SMITH, 1976), ranging from rectangular (Fig. 3–1a—b) to circular (SMITH, 1971, figs. 9, 10) in shape. MORTON (1984) commented that "the shell of *C. australis* is variable in shape, possibly depending upon the shape of burrow."

Japanese specimens have a weak longitudinal prominence (arrow **lp** in Fig. 3–3) on both the ventral and dorsal sides of the siphonal sheath, giving them an oval shape in cross section. In this character, the Japanese specimens seem to be slightly different from SMITH's (1976) Australian specimens that have a circular siphonal sheath in cross section. I consider this species to show some local variability in both ornamentation and form of the siphonal sheath. SMITH (1976) classified *Clavagella* (*Clavagella*) *mullerae* KILBURN, 1974 as a subspecies of *Clavagella* (*Dacosta*) *australis*. The former has an elliptical spihonal sheath in cross section due to a medium longitudinal

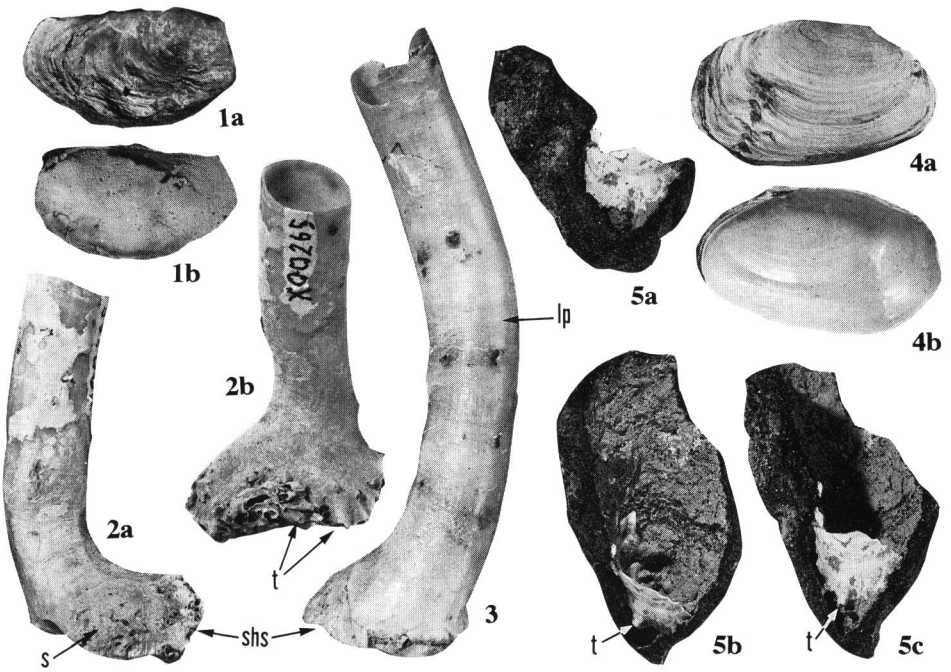


Fig. 3–1a—5c. 1a—3: *Clavagella* (*Dacosta*) *australis* SOWERBY ,1829 from Ueno-mura, Miyako-gun (Miyako-jima Island), Okinawa Prefecture, southernmost Japan, Holocene; outer (1a) and Inner (1b) views of free right shell, ×2.7, NSMT-Mo69953; right-lateral (2a) and dorsal (2b) views of crypt, ×2.0, NSMT-Mo69954; left-lateral view (3) of crypt, ×2.0, NSMT-Mo69955. 4a—5c: *Clavagella* sp. from Minabe, Wakayama Prefecture, Pacific side of central Japan, Holocene, NSMT-Mo58853; outer (4a) and inner (4b) views of free right shell, ×2.8; crypt embedded in hard substratum (5a—5c), ×1.9.

constriction.

Clavagella japonica HABE *in* KOYAMA *et al.* (1981) is synonymized here with *C.* (*D.*) *australis* for the first time. HABE *in* KOYAMA *et al.* (1981) characterized *C. japonica* as having a slightly compressed siphonal sheath in cross section owing to weak dorsal and ventral longitudinal ridges on it. As pointed out above, however, this character falls in the individual variation of *C.* (*D.*) *australis*.

This is the first record of *Clavagella* (*Dacosta*) *australis* from Japanese waters. Although this species has been recorded sporadically in the southeastern Thailand, eastern South Africa, and southeastern Australia as listed in stratigraphic and geographic occurrence above, it may be distributed extensively in Indo-Western Pacific waters.

Subgenus *Stirpuliniola* KURODA & HABE *in* KURODA *et al.*, 1971

Type species: *Clavagella ramosa* DUNKER, 1882, original designation. Pleistocene and Holocene, Japan and adjacent waters.

Diagnosis: Crypt long, not attached to hard substratum; siphonal end simple, circular in section; anterior plate weakly developed, with a distinct central slit and complex series of branching tubules.

Remarks: KURODA and HABE *in* KURODA *et al.* (1971) proposed a new genus *Stirpuliniola* based on a single species, *Clavagella ramosa* DUNKER, 1882, and characterized the genus as having no siphonal collars at the posterior end of the crypt. In this character, the genus differs from *Stirpulina* STOLICZKA, 1870 that has distinct siphonal collars at the posterior end of the crypt (SMITH, 1976).

Clavagella (*Stirpuliniola*) *ramosa* DUNKER, 1882

Fig. 4–1a—5c

Clavagella ramosa DUNKER, 1882, p. 172, pl. 16, figd. 1, 2; HIRASE, 1954, p. 124, pl. 20, fig. 4; KURODA & HABE, 1952, p. 17; SHIKAMA, 1955, p. 593; OKUTANI, 1983, p. 12, pl. 47, fig. 8.

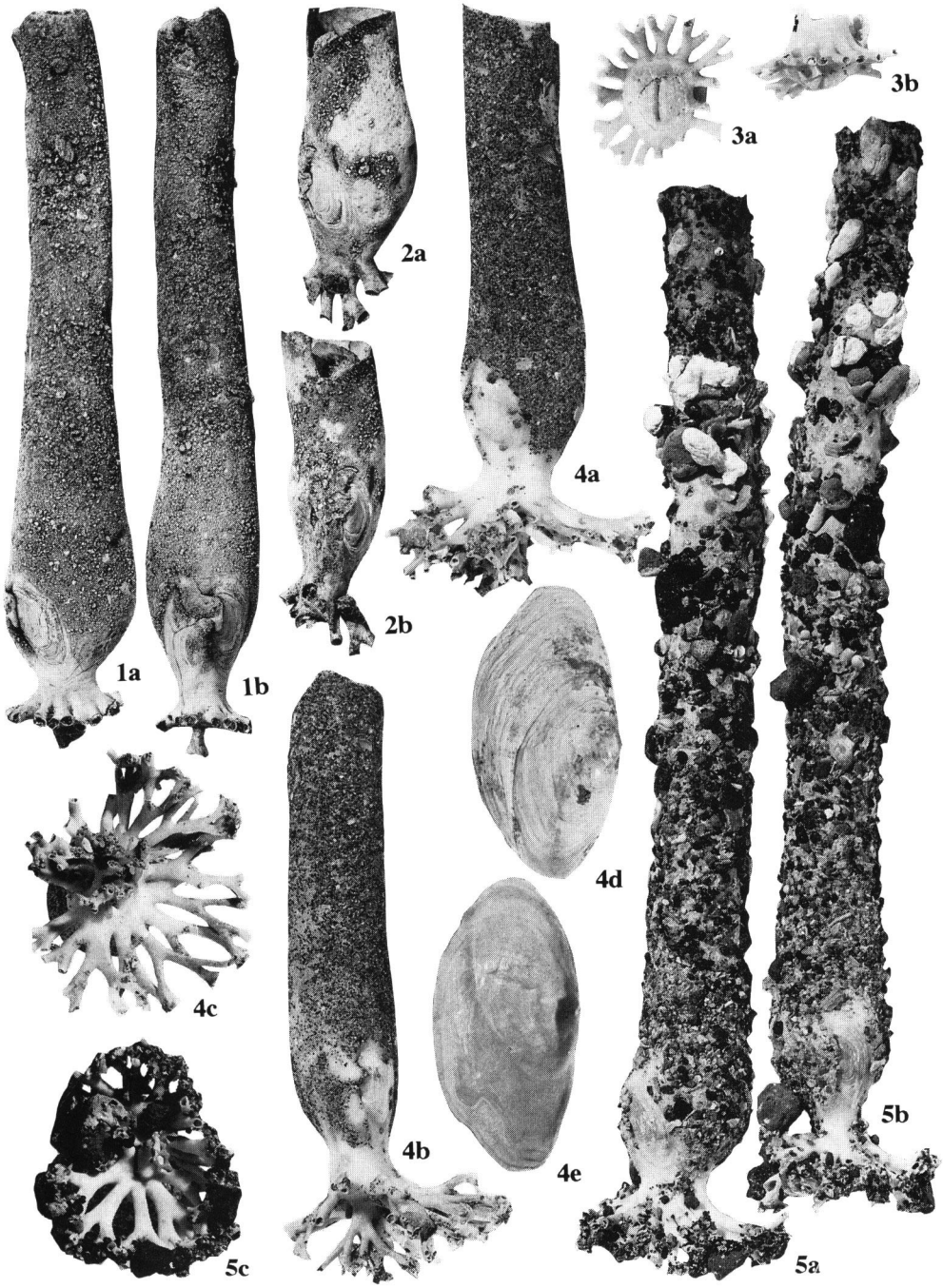
Clavagella (*Stirpulina*) *ramosa* DUNKER. FUJITA, 1929, p. 62; HIRASE, 1934, p. 12, pl. 20, fig. 4; HABE, 1952a, p. 268, fig. 713 [a caption error, as "*Penicillus* (*Warnea*) *giganteus* (SOWERBY)"]; HABE, 1952b, p. 122, pl. 18, fig. 19; KIRA, 1954a, p. 124, 165, pl. 62, fig. 24; KIRA, 1954b, p. 124, 165, pl. 62, fig. 24; SHIKAMA, 1954, p. 64–65, pl. 3, figs. 3a–c, 4; KIRA, 1959, p. 168, pl. 62, fig. 24; KIRA, 1960, p. 168, pl. 62, fig. 24; KIRA, 1962, p. 184, pl. 63, fig. 24; KUBOTA, 1962, p. 147; HORIKOSHI *et al.*, 1963, p. 140; SHIKAMA, 1964a, p. 96, pl. 56, fig. 11; KURODA & HABE *in* OKADA *et al.*, 1965, p. 305, fig. 1158; NAKAYAMA, 1965, p. 91; HABE & KOSUGE, 1967, p. 170, pl. 63, fig. 25; SMITH, 1976, p. 196, figs. 13, 14; MATSUMOTO, 1979, p. 116.

Stirpuliniola ramosa (DUNKER). KURODA *et al.*, 1971, p. 729 [in Japanese], 481 [in English], pl. 103, fig. 20; HIGO, 1973, p. 392; HABE, 1977, p. 315, pl. 66, fig. 4; HABE *in* KOYAMA *et al.*, 1981, p. 190; MATSUKUMA, 1986, p. 343, unnumbered fig; MATSUKUMA *et al.*, 1991, p. 188, pl. 153, fig. 13.

Stirpulina ramosa (DUNKER). HABE & OKUTANI, 1975, p. 147 [unnumbered fig.], 249.

Brechites ramosa (DUNKER). ABBOTT & DANCE, 1981, p. 375 [unnumbered fig.]; LAI, 1988, p. 160, fig. 460.

Fig. 4–1a—5c. *Clavagella* (*Stirpuliniola*) *ramosa* DUNKER, 1882. All ×1.1 excluding 4d, 4e (×2.7). 1a—b: NSM PM15519 from GIYU loc. no. 73–32–1, Shin-jima Islet, Kagoshima Prefecture, Holocene [2720±65 years B.P. (HAYAMI, 1984, p. 130)] Moeshima Shell Bed, left-lateral (1a) and dorsal (1b) views of crypt. 2a—b: NSM PM15520 from Shin-jima Islet, Kagoshima Prefecture (unknown in detail), Holocene Moeshima Shell Bed, left-lateral (2a) and dorsal (2b) views of crypt. 3a—b: NSMT-Mo51668 from Kamikatetsu, Kikai-jima Island, Kagoshima Prefecture, upper Pleistocene Wan Formation, anterior (3a) and lateral (3b) views. 4a—e: NSMT-Mo69956 from off Pacific side of central Japan (between Cape Shiono-Misaki and Oshima Island; 124–131 m in depth), Holocene, left-lateral (4a), dorsal (4b), anterior (4c) views of crypt (posterior end broken and missing), outer (4d) and inner (4e) views of right shell. 5a—c: NSMT-Mo69957 from Japan (unknown in detail), Holocene, left-lateral (5a), dorsal (5b), and anterior (5c) views of crypt.


1a
1b
2a
2b
3a
3b
4a
4b
4c
4d
4e
5a
5b
5c

Brechites (*Stirpuliniola*) *ramosa* (DUNKER). ABBOTT & DANCE, 1985, p. 379 [unnumbered fig.].

Type: Type material unknown (SMITH, 1976); type locality, "Hama Kôorh-hama mo-men" (DUNKER, 1882), Wakayama (KURODA *et al.*, 1971), Pacific side of central Japan.

Stratigraphic and geographic occurrence: Pleistocene to Holocene, Japan and Taiwan.

Pleistocene.

SHIKAMA (1954). Jizodo, Kisarazu City, Chiba Prefecture (locality unknown in detail). From pumiceous fine-grained sands yielding many individuals of *Lovenia* aff. *subcarinate* (GRAY) of the middle Pleistocene Jizodo Formation. Specimen illustrated by SHIKAMA (1954, pl. 3, figs. 3a–c).

Kamikatetsu, Kikai-cho (Kikai-jima Island), Oshima-gun, Kagoshima Prefecture. From the upper Pleistocene Wan Formation. Fig. 4–3a—b.

Holocene (in stratum).

GLYU loc. no. 73–32–1. Sea cliff of the southwestern corner of Shin-jima (Moe-shi-ma) Islet, Sakura-jima-cho, Kagoshima-gun, Kagoshima Prefecture. One specimen from pumiceous sandstone bearing many molluscs of the Holocene Shinjima Fossiliferous Sand [2720±65 years B.P. (sample Ms of HAYAMI, 1984)].

Holocene (living): Tateyama Bay, southern Chiba Prefecture, Pacific side of central Japan (FUJITA, 1929); Misaki, southern Kanagawa Prefecture, Pacific side of central Japan (YCM3621: HORIKOSHI *et al.*, 1963); Sagami Bay, Kanagawa Prefecture, Pacific side of central Japan (KURODA *et al.*, 1971); Kii-Nagashima, Mie Prefecture, Pacific side of central Japan (MATSUMOTO, 1979); Minabe, Wakayama Prefecture, Pacific side of central Japan (HABE *in* KOYAMA *et al.*, 1981); Off Kochi (Tosa Bay), Kochi Prefecture, Pacific side of southwestern Japan (NAKAYAMA, 1965; OKUTANI, 1983); Kagoshima Bay, Kagoshima Prefecture, Pacific side of southern Japan (specimen of ORIUT); Off Yotsugaura, Fukui Prefecture, Sea of Japan side of central Japan (FMMNH198.04: KUBOTA, 1962); Formosa Strait, Taiwan (LAI, 1988).

Discussion: This species is characterized by a simple posterior end without siphonal collars. Although SMITH (1976) mentioned that "many of the specimens of *C. ramosa* in collections have the siphonal end of the tube broken and it is uncertein that no plaited ruffles exist in complete specimens" and the siphonal end of the crypt "may be expanded in a series of plaited ruffles," there is no siphonal collars at the posterior end of the crypt in all of the complete large specimens I examined. Although SAVAZZI (1982a, b) considered, as a function, the siphonal collar to prevent further sinking to the soft substrate, some free-living clavagellids including the present species do not have siphonal collar [*Brechites* (*Penicillus*) and *B.* (*Foegia*)] and some embedded clavagellids in hard substratum have it [*Clavagella* (*Bryopa*)].

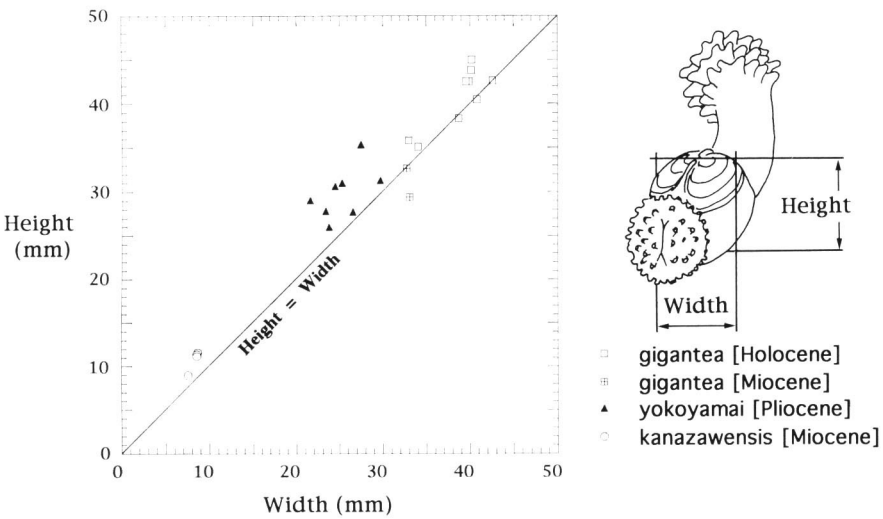


Fig. 5. Scatter diagram of height and width of the shell sheath of *Humphreyia* (*Nipponoclava*) *kanazawensis*, *H.* (*N.*) *yokoyamai*, and *H.* (*N.*) *gigantea*. These three species are distinguishable in shell sheath size which is considered to be genetically controlled (see text). Measured specimens are as follows. *H.* (*N.*) *kanazawensis*: GDLAKZ250029, 250030, 250031, and 250032. *H.* (*N.*) *yokoyamai*: NSM PM15521, 15522, 15523, 15524, 15525, 15526, 15534, 15536. *H.* (*N.*) *gigantea* (Miocene specimens): NSM PM15470 and 15472. *H.* (*N.*) *gigantea* (Holocene specimens): NSMT-Mo57018, 59733, 60117, 60663, 69958, 69960, 69962, 69963, and 69964.

Clavagella sp.

Fig. 3–4a—5c

Stratigraphic and geographic occurrence: Holocene, Japan. Minabe, Wakayama Prefecture, Pacific side of central Honshu.

Discussion: One specimen consisting of an entire right free shell and anterior fragments of the shell sheath that is embedded in a hard sandstone was available for this study. Because the specimen is embedded in rock, this species may be assigned to either *Bryopa* or *Dacosta*. But subgeneric assignment is difficult because these two subgenera are distinguished from each other by the ornamentation of the siphonal sheath, which is entirely missing in this specimen. *Bryopa* has a siphonal collar but *Dacosta* does not have it. The anterior fragment of the shell sheath bears short, spine-like tubules that are a common character of both *Bryopa* and *Dacosta*. The right shell is semicircular in form with a prominent umbo, and lacks a posterodorsal wing (arrow **pw** in Fig. 2), and therefore is distinguishable from *Clavagella* (*Baryopa*) *lata*. Further taxonomic treatment is not possible until better material becomes available.

Genus *Humphreyia* GRAY, 1858

Type species: *Aspergillum strangei* ADAMS, 1852, monotypy. Living Australia.

Diagnosis (after SMITH, 1976): Shells large, both fused to crypt, and forming dorsal half of the shell sheath; crypt round to angular in section; siphonal sheath simple or with well-developed siphonal collars; anterior end with short tubules commonly without organization into fringe or disc; vestige of posterior adductor muscle persistent in the adult.

Remarks: This genus is mostly characterized by the two large shells fused entirely to the crypt. SMITH (1976) recognized two living subgenera in this genus, *Humpheryia* s.s. and *Nipponoclava* SMITH, 1976. The former is distinguished from the latter in having a siphonal sheath with simple posterior end and with angular transverse section, and a crypt usually attached to hard substrate.

Subgenus *Nipponoclava* SMITH, 1976

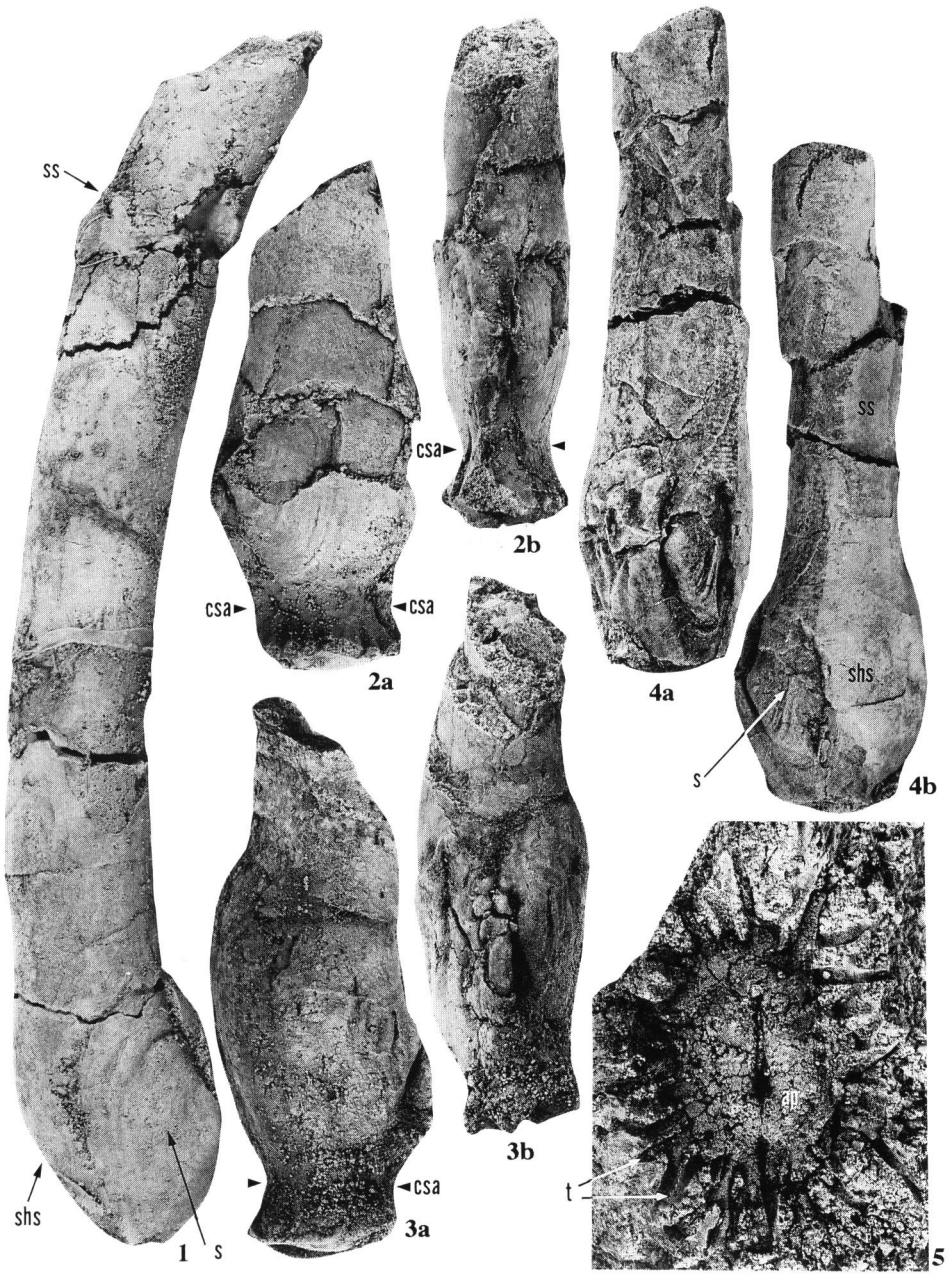
Type species: *Aspergillum giganteum* SOWERBY, 1888 (Figs. 10, 11, 12), original designation. Micoene and Holocene, Japan and adjacent waters.

Diagnosis (after SMITH, 1976): Crypt long, circular to ovoid in section, siphonal end bearing well developed siphonal collars; shells large, both fused to dorsal half of shell sheath; short but distinct longitudinal ridge developed along the hinge line between shells, abruptly broken its continuity at umbonal part where both the interrupted ends of ridge are rounded and may be swollen (arrow **sre** in Figs. 7–1b, 11–1b, 12–2); anterior end with many rows of short but wide tubules that may be branched and developed into a weak fringe around a distinct anterior plate.

Remarks: This subgenus is endemic to Japan and includes four speices *Humphreyia* (*Nipponoclava*) *kanazawensis* (OMURA, 1969), *H.* (*N.*) *yokoyamai* (SHIKAMA, 1954), *H.* (*N.*) *gigantea* (SOWERBY, 1888), and *H.* (*N.*) species indet. The three former species are distinguishable from each other in the size of the shell sheath (Fig. 5). *Humphreyia* (*Nipponoclava*) *kanazawensis* has a very small shell sheath, while *H.* (*N.*) *gigantea* has a very large one. *Humphreyia* (*Nipponoclava*) *yokoyamai* is intermediate in size between the two species above.

The shell-sheath size is an important charactr in clavagellid specific classification (Fig. 5). Because both shell sheath and anterior plate do not have growth lines, the formation of them has been inferred to be one time event in younger stage and size of them has been considered to be no change after their formation (SAVAZZI, 1982a,

Fig. 6–1—5. *Humphreyia* (*Nipponoclava*) *kanazawensis* (OMURA, 1969) from road cut, 120 m west of Nishi-Ichinose bridge, Nishi-Ichinose-machi, Kanazawa City, Ishikawa Prefecture. Early Middle Miocene Sunagozaka Formation. All (×1.7) are internal molds except for 5 (external mold of anterior plate). 1: GDLAKZ 250029, paratype, right-lateral view of crypt. 2a—b: GDLAKZ 250031, paratype, left-lateral (2a) and dorsal (2b) views of shell sheath. 3a—b: GDLAKZ 250032, holotype, left-lateral (3a) and dorsal (3b) views of hell sheath. 4a—b: GDLAKZ 250030, paratype, dorsal (4a) and right-lateral (4b) views of crypt. 5: GDLAKZ 250028a, paratype, anterior view.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1982b). After the formation of both shell sheath and anterior plate the crypt growth is restricted in the posterior elongation of siphonal sheath that has distinct growth lines. Therefore, the shell-sheath size is not controlled by the age of crypt, but is probably controlled genetically with some range of individual variation brought about by the accidental circumstances of the habitat. On the contrary, the crypt length is less important for the specific classification because the length of the siphonal sheath gradually or periodically increases with growth.

Humphreyia (*Nipponoclava*) *kanazawensis* (OMURA, 1969)

Figs. 5, 6-1—5

Penicillus (*Warnea*) *kanazawensis* OMURA, 1969, p. 30, pl. 3, figs. 1, 2, 5–9, pl. 4, figs. 1–12, pl. 5, figs. 4–6; OGASAWARA, 1976, p. 47–48, pl. 1, figs. 17, 18 [as "*kanazawaensis*"]; MASUDA & NODA, 1976, p. 129.

Holotype: GDLAKZ 250032 (Fig. 6–3a—b) from the road cut, 120 m west of Nishi-Ichinose Bridge, Nishi-Ichinose-machi, Kanazawa City, Ishikawa Prefecture (locality Kanazawa of OMURA, 1969, fig. 2), early Middle Miocene Sunagozaka Formation.

Stratigraphic and geographic occurrence: Early Middle Miocene, Japan.

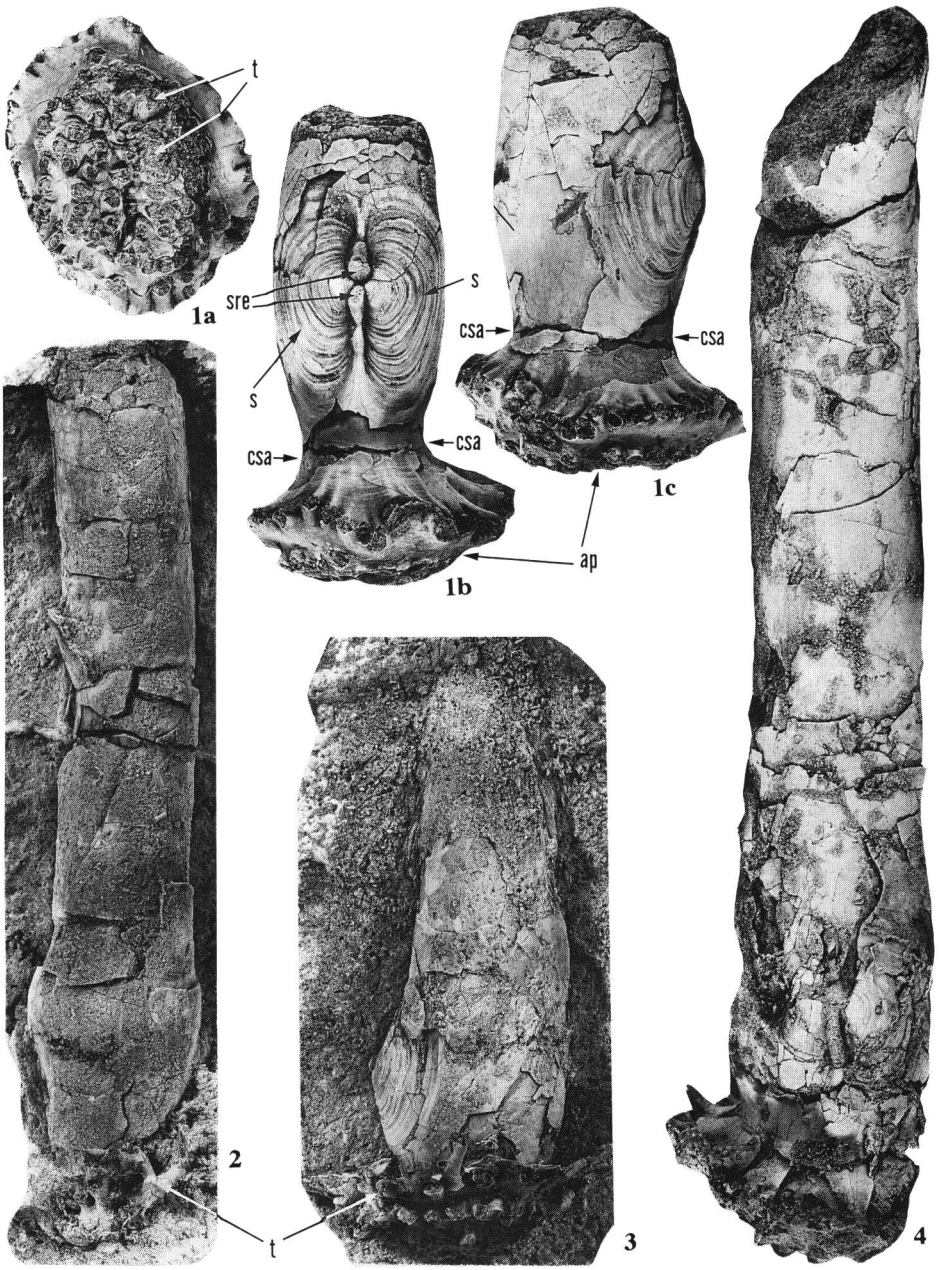
OMURA (1969). Type locality. From the dark-colored tuffaceous sandstone bearing *Operculina complanata* HANZAWA and many molluscan fossils of the Sunagozaka Formation. (See OMURA, 1969, p. 27–28 and fig. 2).

OGASAWARA (1976). River cliff of Asano-grawa River at Higashi-Ichinose, Kanazawa City, Ishikawa Prefecture. From medium-grained sandstone of the Sunagozaka Formation.

Discussion: The available materials consist of internal and external molds (Fig. 6). These specimens have two large shells, both attached to the crypt on the dorsal side. The specimen illustrated by OGASAWARA (1976, pl. 11, fig. 18) has a siphonal collar at the posterior end of siphonal sheath. These characters indicate that the present species is a member of *Nipponoclava*.

This species is distinguishable from other species of *Humphreyia* (*Nipponoclava*) in its very small shell sheath (Fig. 5). As discussed in the remarks section of this subgenus, shell-sheath size is considered to be important in specific classification.

Fig. 7–1a—4. *Humphreyia* (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954). All ×0.85. 1a—c: NSM PM15526 from Kakegawa, Shizuoka Prefecture (unknown in detail), ? upper Pliocene Ukari Formation, anterior (1a), dorsal (1b), and right-lateral (1c) views of crypt. 2: NSM PM15527 from GIYU loc. no. 61–54–11, Ikenotani Valley, Tonohama, Aki City, Kochi Prefecture, upper Pliocene Ananai Formation, left-lateral view of crypt. 3: NSM PM15528 from GIYU loc. no. 61–54–8, Ikenotani Valley, Tonohama, Aki City, Kochi Prefecture, upper Pliocene Ananai Formation, left-lateral view of crypt. 4: NSM PM15529 from GIYU loc. no. 52–56–8c, Asuka, Kakegawa City, Shizuoka Prefecture, upper Pliocene Ukari Formation, dorsal view of crypt (note specimen dorso-ventrally depressed).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This species has a distinct constriction between the shell sheath and the anterior plate (arrow **csa** in Fig. 6–2a—3a).

Humphreyia (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954)

Figs. 5, 7–1a—4, 8, 9

Brechites (*Warnea*) *yokoyamai* SHIKAMA, 1954, p. 63–64, pl. 3, figs. 1a—b.

Penicillus (*Warnea*) *yokoyamai* (SHIKAMA). SMITH, 1962, p. 174.

Foegia yokoyamai (SHIKAMA). SHIKAMA, 1964b, pl. 49, fig. 28; SHIKAMA, 1970, pl. 49, fig. 28.

Nipponoclava yokoyamai (SHIKAMA). MAJIMA, 1991, p. 785–792, figs. 2–6 [contains extensive synonymy].

Lectotype: UMUT CM23537 (designated by MAJIMA, 1991), from northern slope of hill near the boundary between Yasuda-machi and Tano-machi, about 600 m northeast of the shrine at Ono, Tano-machi, Aki-gun, Kochi Prefecture, Pacific side of southwestern Japan (HATAI & NISIYAMA, 1952). Upper Pliocene Ananai Formation of Tonohama Group.

Stratigraphic and geographic occurrence: Upper Pliocene and lower Pleistocene, Japan.

Upper Pliocene (Shizuoka Prefecture).

SHIKAMA (1954). Kakegawa district (unknown in detail). Probably from the Ukari Formation of the Kakegawa Group. Fig. 7–1a—c.

IGSU loc. nos. 52–56–8A, 52–56–8B, and 52–56–8C. Asuka, Fukuroi City. From the bioturbated silty sands of the Ukari Formation of the Kakegawa Group. See MAJIMA (1991).

GIYU loc. no. 52–56–8C (=IGSU loc. no. 52–56–8C, see MAJIMA, 1991).

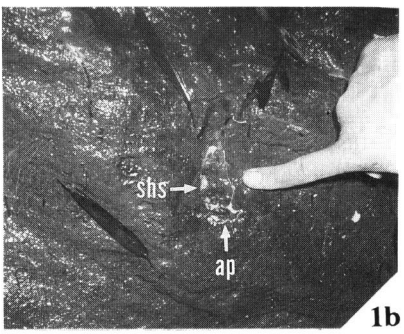
Upper Pliocene (Kochi Prefecture, from the Ananai Formation of the Tonohama Group).

YOKOYAMA (1926a). Type locality.

IGSU loc. nos. 61–54–1, 61–54–4, and 61–54–6. Tonohama area. From the bioturbated silty sands. See MAJIMA (1991).

Fig. 8–1a—3b. Mode of fossil occurrence of *Humphreyia* (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954). 1a—c: GIYU loc. no. 61–54–8, Ikenotani Valley, Tonohama, Aki City, Kochi Prefecture, upper Pliocene Ananai Formation, panoramic view (1a) and specimens preserved in life position (1b, NSM PM15528 (Fig. 7–3) and 1c, NSM PM15530) of outcrop. 2a—b: GIYU loc. no. 61–54–11, Ikenotani Valley, Tonohama, Aki City, Kochi Prefecture, upper Pliocene Ananai Formation, autochthonous specimen (2a, NSM PM15527 (Fig. 7–2)) in, and panoramic view (2b) of outcrop. 3a—b: GIYU loc. no. 61–54–4, Yasuda-machi, Aki-gun, Kochi Prefecture, upper Pliocene Ananai Formation, allochthonous or parautochthonous specimens (3a) in, and panormaic view (3b) of outcrop. Note three specimens (1b, 1c, 2a) preserved in life position with crypt nearly normal to the bedding plane and anterior portion downward (Fig. 9), whereas the crypts of the two specimens in 3a are oriented randomly.

1a



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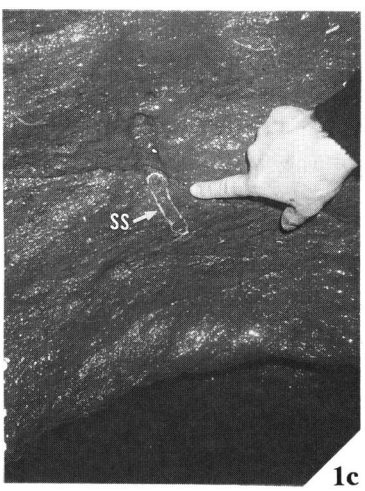

1c

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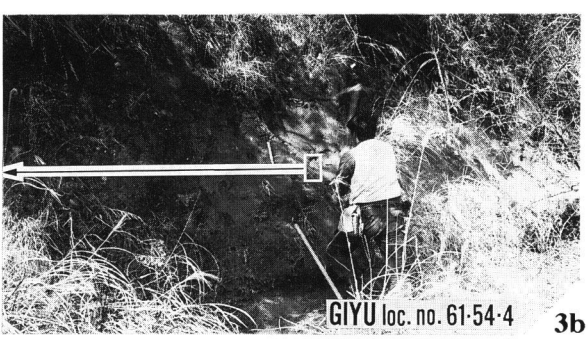
2b

3a



3b

GIYU loc. no. 61–54–4 (=IGSU loc. no. 61–54–4, see MAJIMA, 1991). Fig. 8–3a—b.

GIYU loc. no. 61–54–8. Cliff in a small valley (Ikenotani valley), about 300 m upstream of valley entrance, Tonohama, Aki City. Two specimens preserved in life position from a massive, bioturbated silty sands sporadically bearing molluscan fossils. Figs. 7–3, 8–1a—c.

GIYU loc. no. 61–54–11. Head of a valley branch of the Ikenotani valley, Tonohama, Aki City. One specimen preserved in life position from poorly stratified silty sandstone that sporadically yields molluscan fossils. Figs. 7–2, 8–2a—b.

GIYU loc. no. 61–54–16. Hill-side cliff, Tonohama, Aki-City. From weathered silty sand bearing many molluscan fossils.

GIYU loc. no. 62–32–2. Tunnel construction field, about 1200 m west northwest of the Naharigawa Bridge, Tano-machi, Aki-gun. From a sandstone block in the construction field.

Lower Pleistocene.

IGSU loc. no. 72–40–2. Toriyama, Koyu-gun, Miyazaki Prefecture. From sandstone float block of the Takanabe Formation of the Miyazaki Group. See MAJIMA (1991).

Discussion: This species is mostly characterized by its intermediate size between *H.* (*N.*) *kanazawaensis* and *H.* (*N.*) *gigantea* (Fig. 5). Although the size of the present species and *H.* (*N.*) *gigantea* partially overlap (Fig. 5), they are distinguishable from

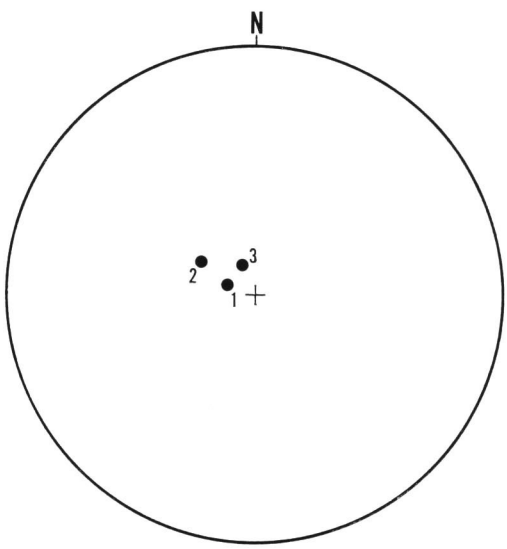


Fig. 9. Lower hemisphere projection for anterior-posterior axes of NSM PM15528 (1, see Figs. 7–3, 8–1b), NSM PM15530 (2, see Figure 8–1c), and NSM PM15527 (3, see Figs. 7–2, 8–2a) of *Humphreyia* (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954) from the upper Pliocene Ananai Formation, Kochi Prefecture. Each axis is corrected for dip. These three specimens are in life position and oriented nearly normal to the bedding plane with the anterior downward.

each other in crypt morphology. Generally speaking, *H.* (*N.*) *yokoyamai* has a laterally compressed crypt and a distinct constriction between the shell sheath and the anterior plate (arrow **csa** in Fig. 7–1a—c), whereas *H.* (*N.*) *gigantea* possesses a nearly circular crypt in transverse section and constriction between shell sheath and anterior plate is absence or very weak (Figs. 10, 11, 12). As pointed out by MAJIMA (1991), the two species probably preferred different environments. *Humphreyia* (*Nipponoclava*) *yokoyamai* is preserved in life position in silty sands whereas *H.* (*N.*) *gigantea* is found in coarser sediments.

In the Ananai Formation, two modes of occurrence for *H.* (*N.*) *yokoyamai* are recognized (Fig. 8). This species is preserved nearly normal for the bedding plane (Fig. 9), with their anterior downward, at GIYU loc. nos. 61–54–8 (Fig. 8–1a—c) and 61–54–11 (Fig. 8–2a—b) where molluscan fossils occur sporadically in bioturbated silty sands. This orientation is identical with the living orientation of *H.* (*N.*) *gigantea* as demonstrated by OKUTANI and SOYAMA (1987). On the other hand, *H.* (*N.*) *yokoyamai* is randomly oriented in GIYU loc. no. 61–54–4 (Fig. 8–3a—b) where molluscan fossils are matrix-supported but concentrated in bioturbated silty sands. Because original sedimentary structures were destroyed by strong bioturbation, it is difficult to judge whether the clavagellids at loc. 61–54–4 had been reworked in situ by bioturbation or transported from other place by physical events.

Humphreyia (*Nipponoclava*) *gigantea* (SOWERBY, 1888)

Figs. 10–1a—2, 11–1a—2c, 12–1—4

Aspergillum giganteum SOWERBY, 1888, p. 290; PILSBRY, 1895, p. 136, pl. 3, fig. 1.

Not *Aspergillum giganteum* SOWERBY [=*Humphreyia* (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954)]. YOKOYAMA, 1926a, p. 368, pl. 42, figs. 1, 2; HATAI & NISIYAMA, 1952, p. 30.

Penicillus giganteus (SOWERBY). KURODA & HABE, 1952, p. 28.

Penicillus (*Warnea*) *giganteus* (SOWERBY). Habe, 1952a, p. 269, fig. 712 [a caption error, as "*Clavagella* (*Stirpulina*) *ramosa* DUNKER"]; HABE, 1952b, p. 122–123, pl. 10, fig. 10; KIRA, 1954a, p. 124, 165, pl. 62, fig. 25; KIRA, 1954b, p. 124, 165, pl. 62, fig. 25; KIRA, 1959, p. 168, pl. 62, fig. 25; KIRA, 1960, p. 168, pl. 62, fig. 25; TAKI *in* OKADA *et al.*, 1960, p. 43, pl. 22, fig. 4; KUBOTA, 1962, p. 147; IKEDA & TADA, 1963, p. 49.

Brechites giganteus (SOWERBY). SHIKAMA, 1955, p. 593 [as "*gigantens*"].

Brechites (*Warnea*) *giganteus* (SOWERBY). SHIKAMA, 1954, pl. 3, figs. 2a–b; SHIKAMA, 1964a, p. 96, fig. 173; NAKAYAMA, 1965, p. 91.

Penicillus (*Foegia*) *giganteus* (SOWERBY). SMITH, 1962a, p. 173; KIRA, 1962, p. 184, pl. 63, fig. 25; KURODA & HABE *in* OKADA *et al.*, 1965, p. 305, fig. 1158; HABE & KOSUGE, 1967, p. 170, pl. 63, fig. 26; OMURA, 1969, pl. 3, fig. 4; HIGO, 1973, p. 392.

Penicillus giganteus (SOWERBY). HABE & OKUTANI, 1975, p. 147 [unnumbered fig.], 234–235.

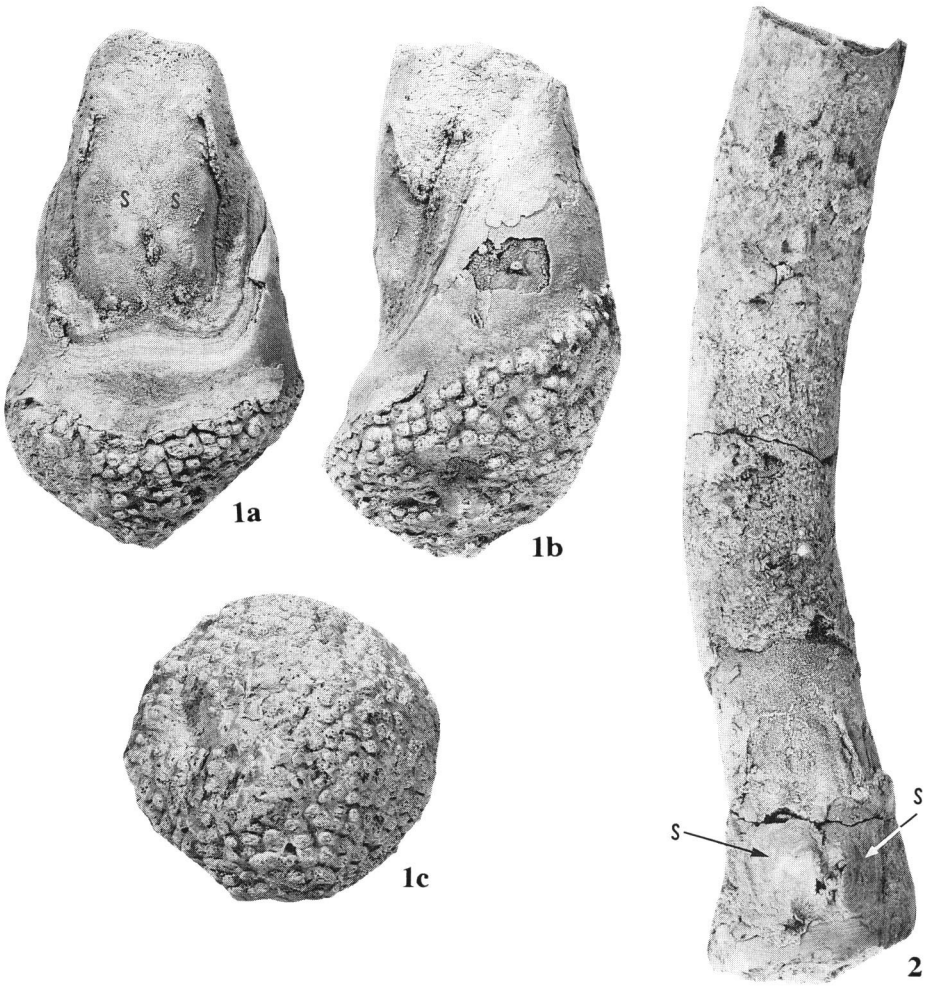


Fig. 10–1a—2. *Humphreyia* (*Nipponoclava*) *gigantea* (SOWERBY, 1888) from Makinogo, Shuzenji-cho, Tagata-gun, Shizuoka Prefecture (see fig. 1 of KASE and KATAYAMA, 1981). ×1.0. 1a—c: NSM PM15470, dorsal (1a), left-lateral (1b), and anterior (1c) views of crypt; siphonal sheath is missing. 2: NSM PM15471, dorsal view of crypt; anterior plate is missing.

Not *Penicillus giganteus* (SOWERBY). MAKIYAMA, 1959, pl. 54, figs. 1, 1a, 2, 2a [=*Humphreyia* (*Nipponoclava*) *yokoyamai* (SHIKAMA, 1954)].

Humphreyia (*Nipponoclava*) *gigantea* (SOWERBY). SMITH, 1976, p. 197–199, figs. 16, 17; POJETA & SOHL, 1987, figs. 1–1, 1–2, 1–3.

Nipponoclava gigantea (SOWERBY). HABE, 1977, p. 313, pl. 66, fig. 3; KURODA & HABE *in* UCHIDA *et al.*, 1979, p. 331, fig. 1174; MATSUKUMA, 1986, p. 342, unnumbered fig. on p. 343; MAJIMA, 1991, figs. 7–1a—3b; MATSUKUMA *et al.*, 1991, p. 188, pl. 153, fig. 14.

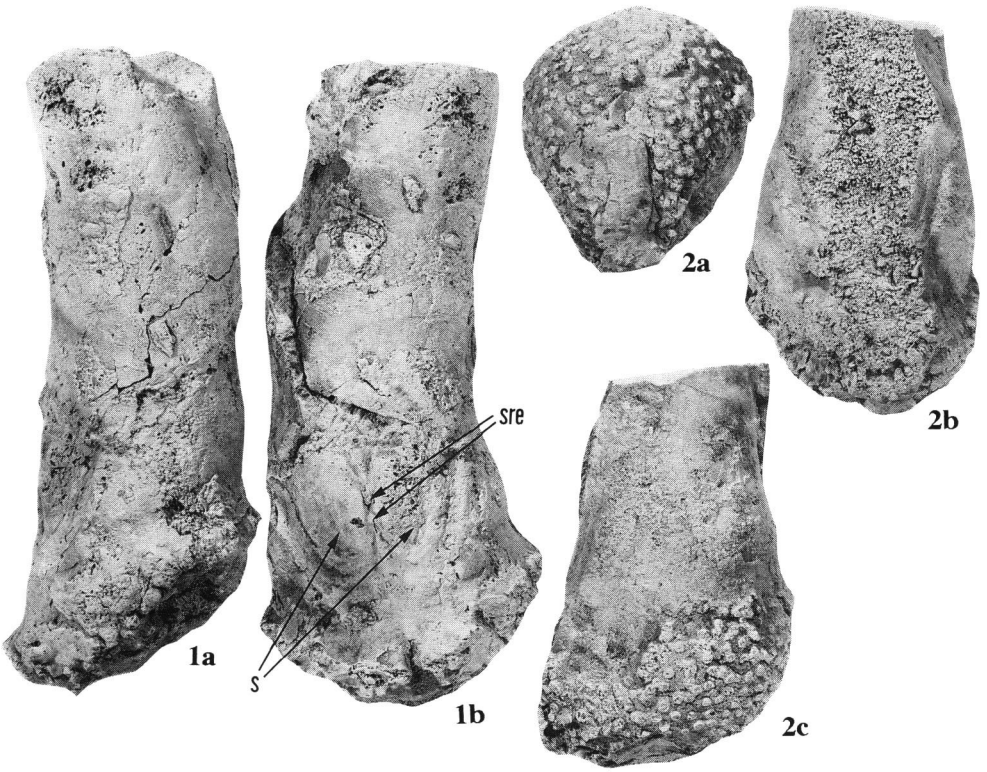


Fig. 11–1a—2c. *Humphreyia* (*Nipponoclava*) *gigantea* (SOWERBY, 1888) from Makinogo, Shuzenji-cho, Tagata-gun, Shizuoka Prefecture (see fig. 1 of KASE and KATAYAMA, 1981). ×0.95. 1a—b: NSM PM15472, left-lateral (1a) and dorsal (1b) views of crypt; anterior plate is missing. 2a—c: NSM PM15473, anterior (2a), dorsal (2b), and left-lateral (2c) views of crypt; siphonal sheath and dorsal part of shell sheath including shells are missing.

Penicillus (*Nipponoclava*) *gigantea* (SOWERBY). MATSUMOTO, 1979, p. 116.
Brechites giganteus (SOWERBY). ABBOTT & DANCE, 1981, p. 375 [unnumbered fig.].
Brechites (*Nipponoclava*) *giganteus* (SOWERBY). ABBOTT & DANCE, 1985, p. 379 [unnumbered fig.].
Penicillus sp. cf. *P. giganteus* (SOWERBY). KASE & KATAYAMA, 1981, p. 35.

Holotype: BM(NH) 88611 (SMITH, 1976, figs. 16, 17), from Japan (SOWERBY, 1888).

Stratigraphic and geographic occurrence: Late Miocene and Holocene, Japan and Holocene, East China Sea.

Late Miocene.

KASE and KATAYAMA (1981). Exposure in a valley about 1.5 km east of Makinogo, Shuzenji-cho, Tagata-gun, Shizuoka Prefecture. From a small fossiliferous lime-

stone body of upper Miocene Kaden (=Kadono) Formation (See fig. 1 and p. 34 of KASE and KATAYAMA, 1981). Figs. 10, 11.

Holocene (in stratum).

SHIKAMA (1955). Shin-jima (Moe-shima) Islet (locality unknown in detail). From his Moeshima Shell Bed (?=Holocene Shinjima Fossiliferous Sand).

Holocene (living): Awa, Chiba Prefecture, Pacific side of central Japan (FMMNH 239.29: KUBOTA, 1962); Jogasaki, Izu Peninsula, Shizuoka Prefecture, Pacific side of central Japan (NSMT-Mo59733, 60117, 60663); Sugashima, Wagu, and Kii-Nagashima, Mie Prefecture, Pacific side of central Japan (MATSUMOTO, 1979); Minabe, Wakayama Prefecture, Pacific side of central Japan (Fig. 12); Okinoshima Island, Kochi Prefecture, Pacific side of southwestern Japan (NAKAYAMA, 1965); Around Sakurajima Volcanic Island, Kagoshima Bay, Kagoshima Prefecture, Pacific side of southern Japan (SAKASHITA, 1974); Mishima Island, Yamaguchi Prefecture, Sea of Japan side of southwestern Japan (IKEDA & TADA, 1963); East China Sea (NSMT-Mo57018).

Discussion: This species is characterized by its large shell sheath (Fig. 5), a weak or indistinct constriction between the shell sheath and the anterior plate, and a relatively circular crypt in transverse section. In the relative comparison with their own crypt sizes, the shells of this species may be smaller than both *H.* (*N.*) *kanazawensis* and *H.* (*N.*) *yokoyamai*. Shells of *H.* (*N.*) *gigantea* are restricted in dorsal part of the shell sheath, not extending to the lateral sides. In the latter two species, shells are greatly extended to the lateral sides. The number of tubules on the anterior plate seem to be more (Figs. 10–1c, 11–2a) than both *H.* (*N.*) *kanazawensis* (Fig. 6–5) and *H.* (*N.*) *yokoyamai* (Fig. 7–1a), although it is difficult to count them in many modern specimens whose anterior plates are covered with coarse gravel and/or shell fragments (Fig. 12–1—4). This species probably prefers coarser sediments than *H.* (*N.*) *yokoyamai* and *H.* (*N.*) *kanazawensis*, both of which occur in silty sands or sands.

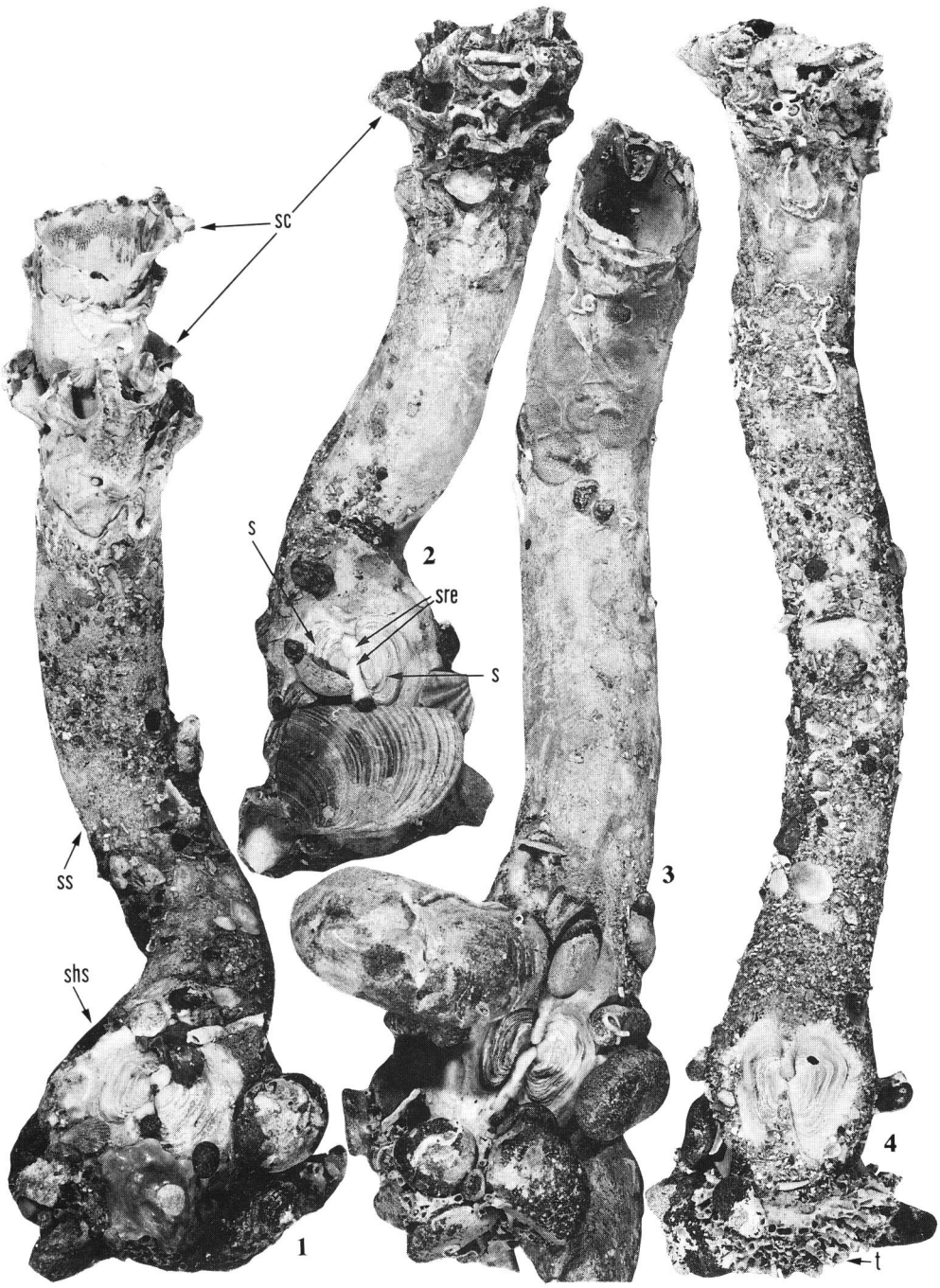
KASE and KATAYAMA (1981) reported the present species from the late Miocene of the Izu Peninsula as *Penicillus* sp. cf. *P. giganteus* (Sowerby) and their specimens are illustrated in Figs. 10 and 11 of this paper. These Miocene specimens are assigned to *H.* (*N.*) *gigantea* on the basis of the indistinct constriction between the shell sheath and the anterior plate, many tubules on the anterior plate, circular shape in transverse section, relatively smaller shells in comparison with their own crypt, and the large shell sheath. Shell sheath size overlaps with larger specimens of *H.* (*N.*) *yokoyomai* (Fig. 5), but the two species are distinguishable from each other by other characters described above.

Humphreyia (*Nipponoclava*) species

Fig. 13–1a—b

Stratigraphic and geographic occurrence: Pliocene, Kyushu, Japan.

Fig. 12–1—4. *Humphreyia* (*Nipponoclava*) *gigantea* (SOWERBY, 1888) from Minabe, Wakayama Prefecture. Holocene. ×0.7. All dorsal views of crypts. 1, NSMT-Mo69959; 2, NSMT-Mo69960; 3, NSMT-Mo69961; and 4, NSMT-Mo69962.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GIYU loc. no. 74–7–1. Road cut at Kutsukake, about 750 m north from Hyuga-Kutsukake JR Station, Tano-machi, Miyazaki-gun, Miyazaki Prefecture. From strongly bioturbated silty sandstone bearing many molluscan fossils of the lower Pliocene Tano Formation (upper part) of the Miyazaki Group. Figs. 13–1a—b.

Discussion: A poorly preserved clavagellid was collected from the lower Pliocene of Miyazaki Prefecture, Kyushu. This specimen has a large left shell that fuses the crypt (Fig. 13–1a), a well developed anterior plate (arrow **ap** of Fig. 13–1a) that suggests a free living mode of life, and a siphonal collar on the siphonal sheath (arrow **sc** of Fig. 13–1b), all of which indicate that this specimen is classifiable in *Humphreyia* (*Nipponoclava*). Because right half of the shell sheath is missing, the right shell fused probably to the crypt can not be observed in this specimen.

Genus *Brechites* GUETTARD, 1770

Type species: *Aspergillum vagniferum* LAMARCK, 1818, by subsequent designation (STOLIZCKA, 1871). Living, Indian Ocean and western Australia.

Diagnosis (after SMITH, 1976): Both shells fused to crypt, small in size; crypt circular in transverese section.

Remarks: SMITH (1976) recognized three living subgenera within this genus *Brechites* s.s., *Penicillus* BRUGUIERE, 1798, and *Foegja* GRAY, 1847. The first bears siphonal collars at the posterior end, a depressed but exposed shells, and often an indistinct fringe of tubules. The second has a simple siphonal end, shells with only their umbos exposed, and a distinct fringe of tubules in a single row. The third possesses a simple siphonal end, shells with only their umbos exposed, and an indistinct anterior plate without a fringe of tubules. All modern species of this genus live freely in the substrate.

Subgenus *Brechites* s.s.

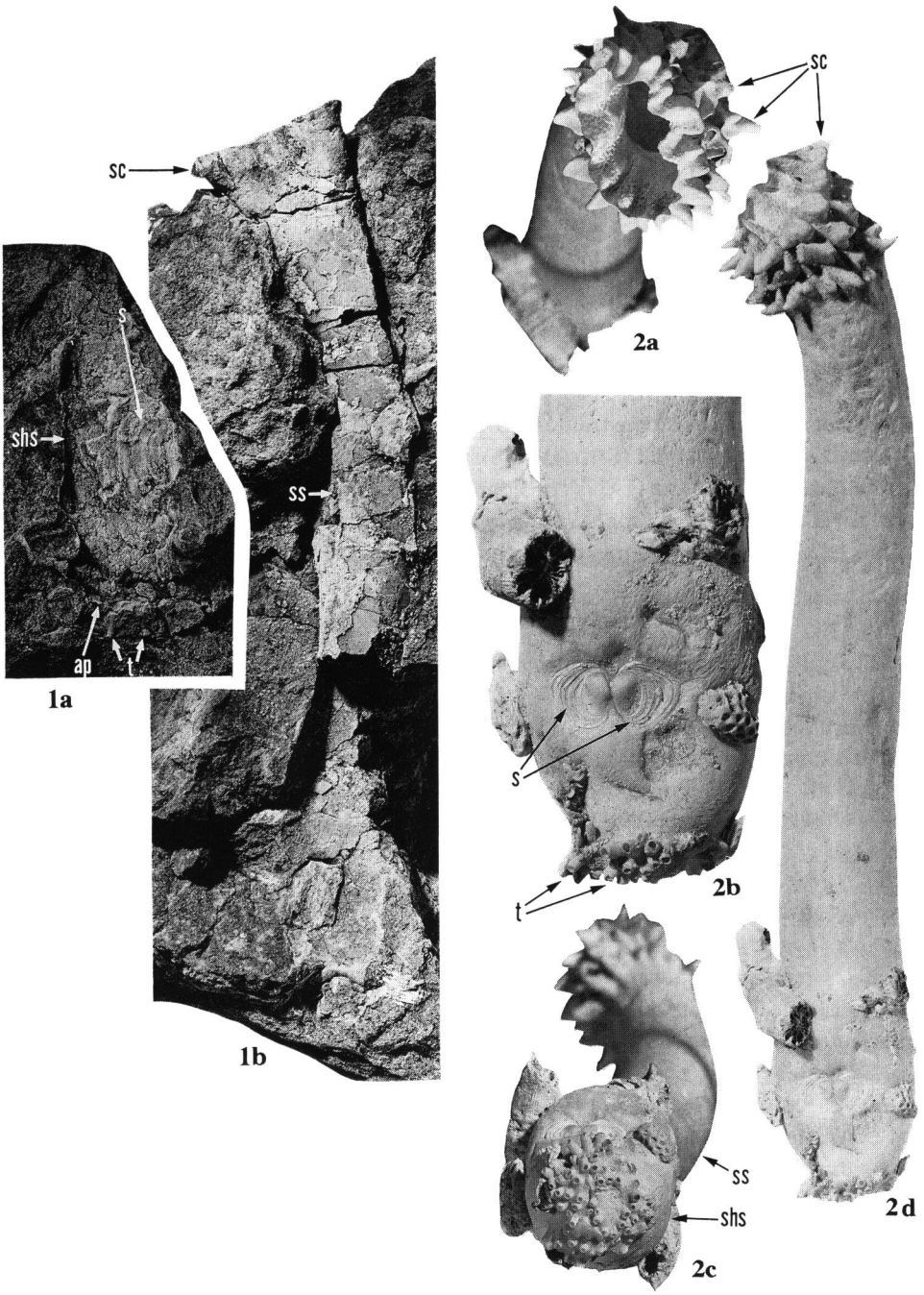
Diagnosis (after SMITH, 1976): Siphonal end ornamented with a series of collars; fringe of tubules often indistinct but tubules may form a series; shells depressed and small, but with obvious growth lines.

Brechites (*Brechites*) *nagahamai* (KOSUGE, 1979)

Fig. 13–2a—d

Penicillus (*Warnea*) *nagahamai* KOSUGE, 1979, p. 23, pl. 4, figs. 11–14.

Fig. 13–1a—2d. 1a—b: *Humphreyia* (*Nipponoclava*) species indet. from GIYU loc. no. 74–7–1, Kutsukake, Tano-machi, Miyazaki-gun, Miyazaki Prefecture. Lower Pliocene Tano Formation. ×0.9. NSM PM15531. Right-lateral (external mold: 1a) and left-lateral (internal mold of siphonal sheath and external mold of shell sheath: 1b) views of crypt. 2a—2d: *Brechites* (*Brechites*) *nagahamai* (KOSUGE, 1979) from off Manzamo Cape, Okinawa Mainland, Okinawa Prefecture, southern Japan. Holotype. Holocene. IMT-79–13. Posterior (2a: ×1.0), anterior (2c: ×1.0), dorsal (2d: ×0.9. 2b: ×1.4) views of crypt.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Holotype: IMT-79-13 (Fig. 14-1a—d), from off Manzamo Cape, Okinawa Mainland, Okinawa Prefecture (at about 30 m deep). The crypt was buried in coral sand up to the siphonal aperture (KOSUGE, 1979).

Stratigraphic and geographic distribution: Holocene. Only known in the type locality.

Discussion: Characters such as the small and depressed shells with obvious growth lines, the distinct series of siphonal collars, and the indistinct fringer of tubules, indicate that this specimen is a member of *Brechites* (*Brechites*). This species is very similar to *B.* (*B.*) *vagniferus australis* (CHENU, 1843), but differs in the degree of development of both the anterior plate and the siphonal collar. In *B.* (*B.*) *nagahamai*, the anterior plate is not well developed and the fringe of tubules never be presence. The siphonal collar of this species is well developed. In *B.* (*B.*) *vagniferus australis*, the anterior plate is large in size, bears a short fringe of tubules, and is connected to the shell sheath by a weak constriction (SMITH, 1976). The siphonal collar of *B.* (*B.*) *vagniferus australis* is small (SMITH, 1976).

NAKAMINE and HABE (1979) considered the present species to be a southern local form of *Humphreyia* (*Nipponoclava*) *gigantea* (SOWERBY), but it differs distinctly in crypt size, shell size and degree of development of anterior plate.

Subgenus *Foegia* GRAY, 1847

Type species: *Aspergillum novaezelandiae* LAMARCK, 1818 (Fig. 14-1a—c), monotypy. Living, Japan and Australia.

Diagnosis (after SMITH, 1976): Siphonal end simple; anterior plate often indistinct, without a fringe of tubules; exposed shells umbos only, distinctly depressed.

Brechites (*Foegia*) *novaezelandiae* (BRUGUIERE, 1789)

Fig. 14-1a—c

Penicillus novaezelandiae BRUGUIERE, 1789, p. 129.

Brechites (*Foegia*) *novaezelandiae* (BRUGUIERE). SMITH, 1971, p. 152–154, pl. 12, figs. 20–23 [contents extensive synonymy]; SMITH, 1976, p. 204, fig. 32; SMITH, 1978, fig. 1 [holotype of *Aspergillum agglutinans* LAMARCK, 1818].

Foegia novaezelandiae (BRUGUIERE). NAKAMINE & HABE, 1980, p. 40, pl. 5, figs. 1, 2.

Type (SMITH, 1976): No type material found. Type locality is the Swan River area of Western Australia.

Stratigraphic and geographic occurrence: Holocene. Kushi, Okinawa Prefecture, Japan (Fig. 14-1a—c) and Australia (SMITH, 1976).

Discussion: One broken specimen consisting of the anterior half of the crypt was available for study (Fig. 14). It has a small anterior plate bearing a tight cluster of tubules without any fringe, and small, depressed shells consisting only of their umbos. These characters unite the specimen with *B.* (*F.*) *novaezelandiae*.

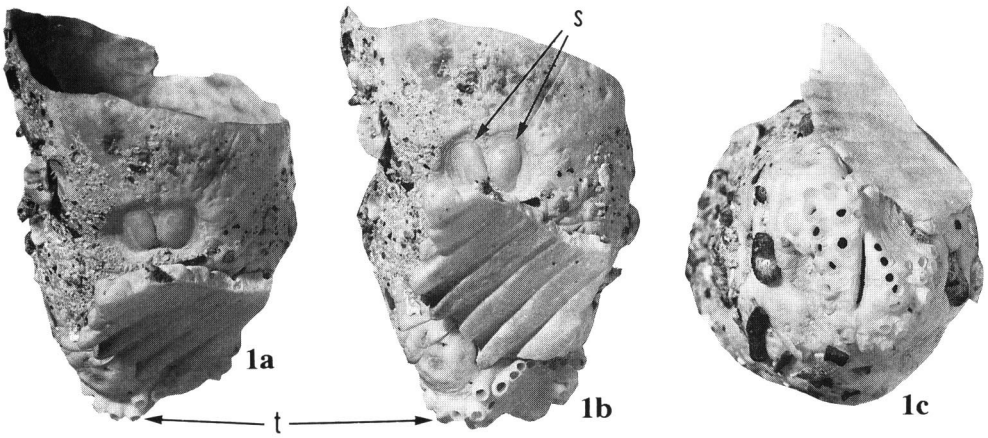

Fig. 14–1a—1c. *Brechites* (*Foegia*) *novaezelandiae* (BRUGUIERE, 1789) from Kushi, Okinawa mainland, Okinawa Prefecture, southern Japan. Holocene. NSMT-Mo59954. ×2.1. Postero-dorsal (1a), dorsal (1b), and anterior (1c) views of crypt. Siphonal sheath is missing.

Although this species is previously known only from western and northern Australian waters (SMITH, 1971), it may be widely distributed in the Western Pacific waters from Japan to Australia.

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Appendix

Transfer of clavagellid specimens of MAJIMA (1991): Clavagellid specimens studied by MAJIMA (1991) are transferred from Institute of Geosciences, Shizuoka University to National Science Museum, Tokyo and given repository numbers of National Science Museum, Tokyo, as follows.

Nipponoclava gigantea (SOWERBY): IGSU-M-012→NSMT-Mo69963. IGSU-M-117→NSMT-Mo69964. IGUS-M-118→NSMT-Mo69965.

Nipponoclava yokoyamai (SHIKAMA): IGSU-M-013→NSM PM15532. IGSU-M-014→NSM PM15533. IGSU-M-015→NSM PM15534. IGSU-M-016→NSM PM 15535. IGSU-M-017→NSM PM15536. IGSU-M-018→NSM PM15537. IGSU-M-019→NSM PM15538. IGSU-M-020→NSM PM15539. IGSU-M-021→NSM PM 15540. IGSU-M-022→NSM PM15541. IGSU-M-023→NSM PM15542. IGSU-M-024→NSM PM15543. IGSU-M-025→NSM PM15544. IGSU-M-026→NSM PM 15545. IGSU-M-027→NSM PM15546. IGSU-M-028→NSM PM15547. IGSU-M-029→NSM PM15548. IGSU-M-030→NSM PM15549. IGSU-M-031→NSM PM 15550. IGSU-M-032→NSM PM15551. IGSU-M-033→NSM PM15552. IGSU-M-034→NSM PM15553. IGSU-M-035→NSM PM15568.