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Authors: NARA, MASAKAZU, and HAGA, MASAKAZU

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The youngest record of trace fossil *Rosselia socialis*: Occurrence in the Holocene shallow marine deposits of Japan

MASAKAZU NARA[1] AND MASAKAZU HAGA[2]

[1]*Center for Marine Environmental Studies, Ehime University, Bunkyo-cho 2-5, Matsuyama 790-8577, Japan (e-mail: nara@sci.ehime-u.ac.jp)*

[2]*Department of Earth Sciences, Faculty of Science, Chiba University, Chiba 263-8522, Japan*

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Abstract. The trace fossil *Rosselia socialis* Dahmer, 1937 is a thickly mud-lined and spindle-shaped tube oriented vertically or obliquely to the bedding plane. It is known to record detailed information on the paleoenvironment. Although it has been reported from Lower Cambrian to upper Pleistocene deposits, no Holocene specimens have previously been found. Well preserved specimens of *R. socialis* are herein reported from the Holocene shallow marine deposits at Shima, Tako Town, Chiba Prefecture, central Japan, co-occurring with some prehistoric earthenware vessels that were made from 9950 to 2950 yrs. B.P. This is the youngest record of *R. socialis*.

Key words: Holocene, Japan, *Rosselia socialis*, the youngest record, trace fossil

Introduction

The trace fossil *Rosselia socialis* Dahmer, 1937 is a thickly mud-lined and spindle-shaped tube, oriented vertically or obliquely to the bedding (Nara, 1995, 1997, 2002). It is interpreted as the dwelling tube of a probable terebellid (or a possible trichobranchid) polychaete (Nara, 1995). *R. socialis* is characterized by broad environmental distribution mainly in shallow marine settings. In the Pleistocene deposits of Japan, for example, it occurs in various settings such as from slope to middle shoreface, shelf sandridge, bay, lagoon, tidal flat, flood-tidal delta, and estuary (Nara, 2002). *R. socialis* is known to record detailed and dynamic paleoenvironmental information, such as daily changes of bottom water energy and relative frequency of depositional events (Nara, 1995, 1997, 2002), and thus would be helpful for high-resolution paleoenvironmental reconstruction of such environments.

The trace fossil also shows remarkably wide stratigraphic and geographic distributions: Lower Cambrian of Greenland (Pickerill and Peel, 1990), lower Devonian of Germany (Dahmer, 1937; Schlirf *et al.*, 2002; Nara *et al.*, 2004), Permian of Australia (McCarthy, 1979), Mississippian to Pennsylvanian of the United States (Chamberlain, 1971, 1978; Nara, un-

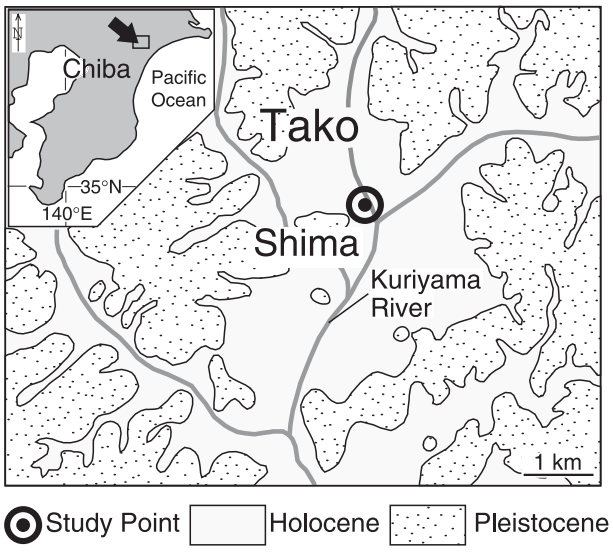

Figure 1. Map showing the study point, Shima, Tako Town, Chiba Prefecture, central Japan. It is situated by the Kuriyama River, where alluvial lowlands are developed along the river.

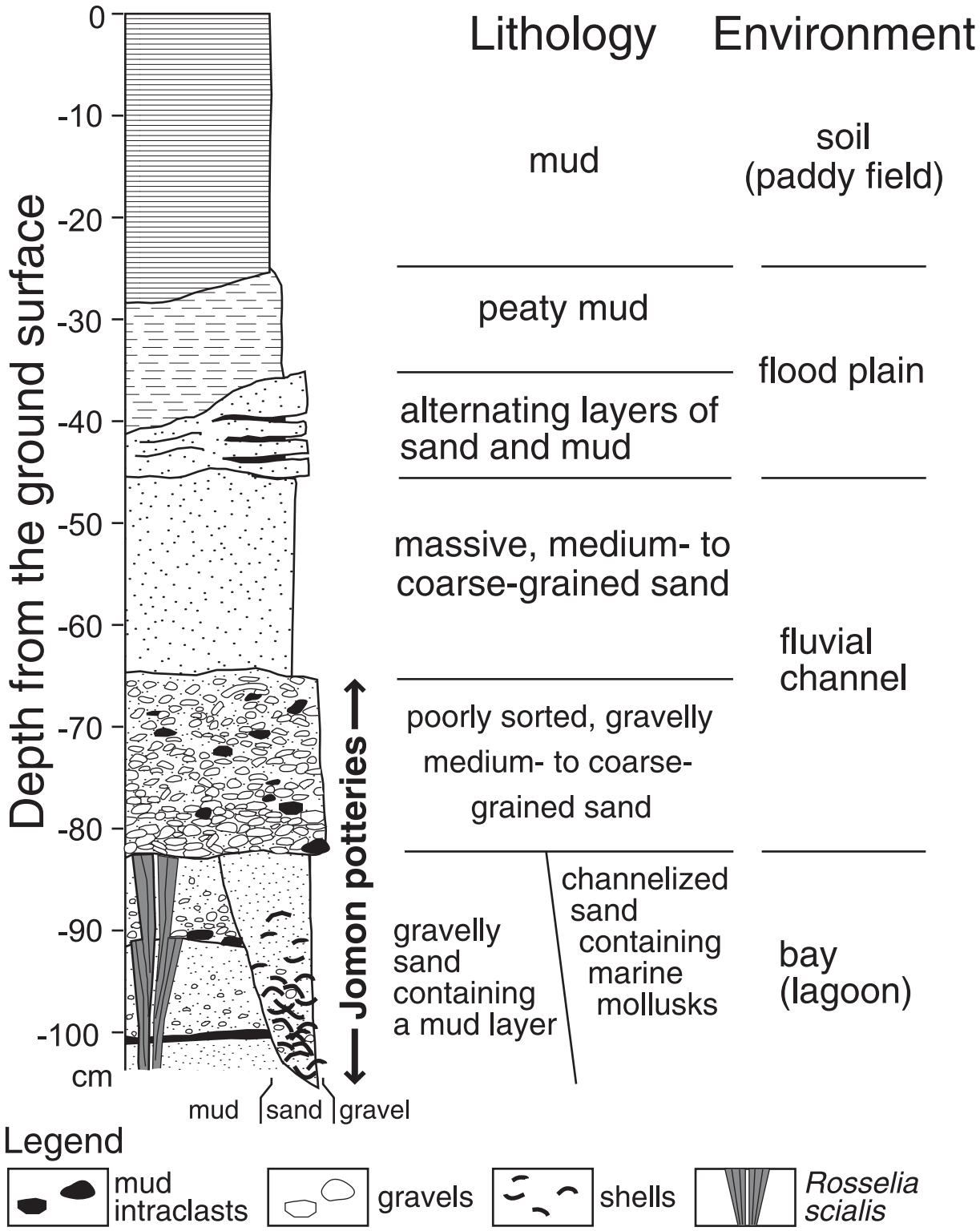

Figure 2. Columnar section of a subsurface succession at the sampling point. Well preserved specimens of *Rosselia socialis* are found from unconsolidated sand containing a thin mud layer in the lowest unit. Jomon potsherds are found from the *R. socialis*-bearing deposit (Board of Education of Tako Town, 1997). See text for detail.

published data), Jurassic of England (Nara, unpublished data), Cretaceous of North America (e.g., Howard, 1966; Chamberlain, 1978; Frey and Howard, 1985, 1990; Vossler and Pemberton, 1989; MacEachern and Pemberton, 1992; Walker and Bergman, 1993; Pemberton *et al*., 1992, 2001), Oligocene of Japan (Nara, unpublished data), Miocene of Japan (Kotake and Nara, 1995), Miocene of Austria (Uchman and Krenmayr, 1995), Pliocene and Pleistocene of Japan (Kikuchi, 1966; Collaborative Research Group on Lebensspuren, 1989; Tokuhashi, 1992; Suganuma *et al*., 1994; Nara, 1995, 1997, 1998, 2002), and Pleistocene of Italy (D'Alessandro and Bromley, 1986). Despite such a wide areal and temporal distribution, no modern burrow comparable to *R. socialis* has been found.

During an archaeological excavation that was carried out in the Holocene deposits at Shima, Tako Town, Chiba Prefecture, central Japan, well preserved specimens of *R. socialis* were discovered, cooccurring with some prehistoric earthen vessels, known as Jomon pottery, which provides chronological information. The aim of this paper is to describe the youngest record of *R. socialis* based on these specimens.

Geologic background

The Holocene deposits in the area studied form lowlands along the Kuriyama River, which runs into the Pacific Ocean about 15 km downstream (Figure 1). The deposits infill incised valleys, formed during the last glacial period (18–20 ka), which cut through the underlying Pleistocene sediments. The specimens of *Rosselia socialis* were discovered from the subsurface, less than 1 meter below the present surface of a paddy field, during the excavation of the Kuriyama River Ruins carried out from 2nd to 30th June, 1996, which was directed by the Board of Education of Tako Town.

Rosselia socialis occur in the lowest unit of the section (Figure 2). The *R. socialis*-bearing sediment consists of unconsolidated, gravelly, medium- to coarse-grained sand with intervening thin mud drapes (tidally influenced? bay deposits) (Figures 2, 3). It is cut by apparently massive, channelized, gravelly sand containing fossils of intertidal to shallow marine fauna, such as *Crassostrea gigas*, *Meretrix lusoria*, and *Balanus* sp. (tidal? channel deposits). They are erosively covered by a fining-upward succession composed of

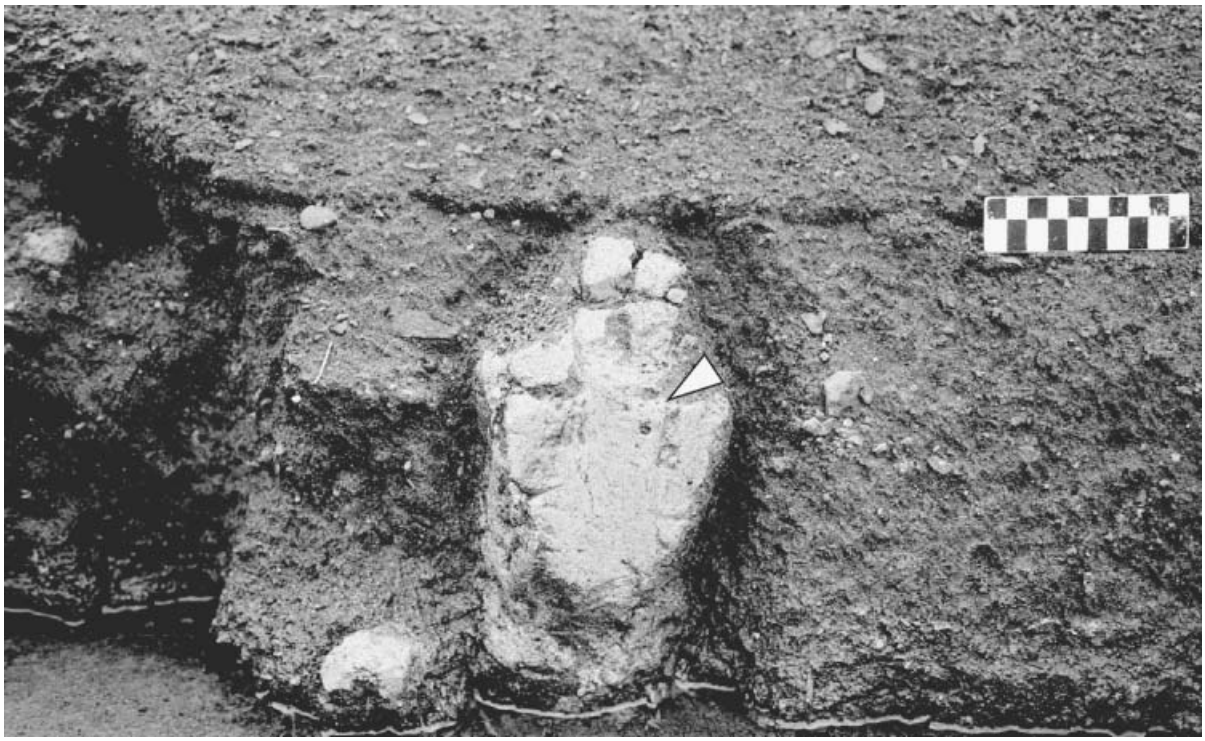

Figure 3. Outcrop photograph. *R. socialis* consisting of twofold stacked segments is seen. The trace fossil is truncated by fluvial gravelly sand. The stacking point is shown with a triangle. Scale is 10 cm long. Nearly vertical to bedding.

clast-supported sandy gravel, medium- to fine-grained sand (fluvial channel deposits), alternating layers of sand and mud (levee deposits), peaty mud (marsh deposit), and soil of the paddy field, in ascending order (Figure 2).

The *R. socialis*-bearing sand and the overlying sandy gravel contain fragments of Jomon pottery most of which were made during the Earliest to Early Jomon periods (Board of Education of Tako Town, 1997), that lasted from approximately 8000 to 2500 BC (Hall, 2001), i.e., 9950 to 4450 yrs. B.P. The youngest vessels can be classified as the Kasori B3 style (K. Harada of Buried Cultural Properties Center of Katori County, 1998 pers. comm.), which were made in the Late Jomon period, that lasted from approximately 1500 to 1000 BC (Hall, 2001), i.e., 3450 to 2950 yrs. B.P.

Although the *R. socialis*-bearing beds contain no macro- or microfossils indicating the environment of deposition, *R. socialis* is a marine trace fossil as noted earlier, and the beds are covered with sands containing shallow marine shells. Thus the beds were probably accumulated in a shallow marine environment. Judging from the distribution pattern of the Holocene deposits, the depositional setting was interpreted as an enbayment of drowned valleys. This view is supported by an analysis on paleogeographic development which showed that the area was probably an embayment of a lagoon during the Early to Late Jomon period (Moriwaki, 1979) (Figure 4). The Jomom pottery is interpreted to have been transported from a subaerial environment in the vicinity via fluvial and/or nearshore currents. The embayment was then filled up and emerged around the beginning of the Latest (Final) Jomon period (Moriwaki, 1979), ca. 1000 BC (Hall, 2001), i.e., 2950 yrs. B.P.

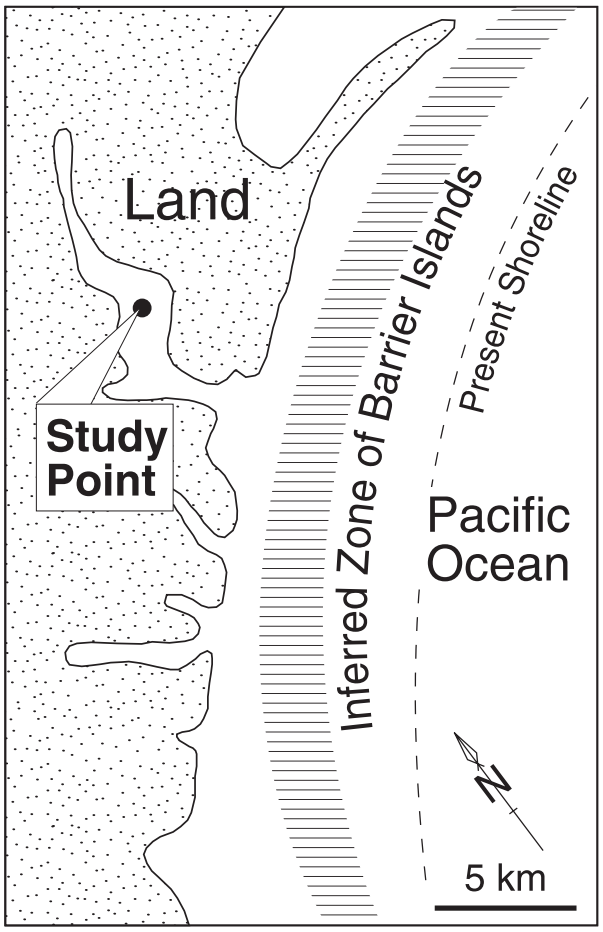

Figure 4. Reconstructed paleogeography during ca. 4000–3000 yrs.B.P. The studied site was probably an embayment of a lagoon which was separated from the Pacific Ocean by barrier islands. Modified after Moriwaki (1979).

Description of specimens

Rosselia socialis in the area studied is composed of a vertical, sediment-filled, cylindrical shaft surrounded by a thick, muddy lining (Figures 3, 5). The lining consists of nested concentric laminae. The sediment within the central shaft is lithologically similar to that of the host sediment. The diameters of the shaft and the lining range from 0.8 to 1.5 (average 1.1) cm and from 3.5 to 10.5 (average 9) cm, respectively. All the specimens are erosively truncated in their upper part by the overlying fluvial deposits, and are of Nara's (1997) stacked type. The maximum number of the stacked segments is three or more. The lower ends of most specimens were not observed, because they were buried in the host sediment and were not allowed to be dug out as an archeological study was in progress at the site during this observation, except for a short specimen composed of 2 segments (Figure 5.1). The maximum length observed is 25 cm, the original length, however, is unclear due to truncation of the upper part and concealment of the lower part.

Discussion and conclusions

In spite of its wide geographic and stratigraphic occurrence, a recent counterpart of *Rosselia socialis* and extant animals that make the identical traces have not been found, as noted earlier. Rindsberg and Gastaldo (1990) reported an *R. socialis*-like structure from Holocene deposits of the lower Mobile Delta, Alabama. Rindsberg (1992) also found similar structures from Holocene deposits of the eastern Mississippi Sound of Alabama. However, their structures comprise aper-

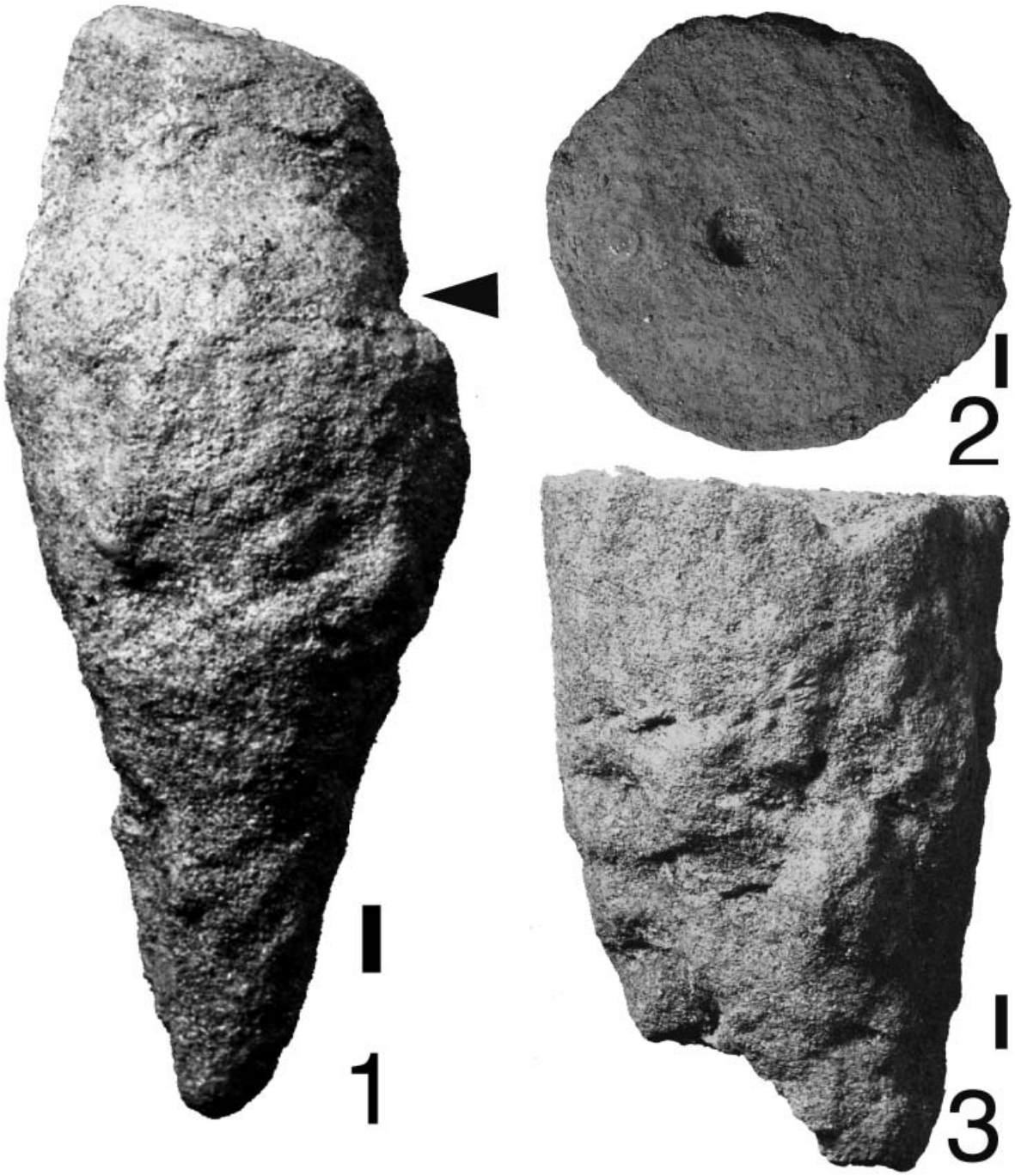

Figure 5. Photographs of selected specimens of *R. socialis*. 1. Specimen composed of two stacked segments. Point of stacking is shown by a triangle. 2. Cross-section of a fragmental specimen. Concentrically arranged, alternating laminae of sand and mud are faintly seen. 3. Lateral view of the specimen 2. Scale bars are 1 cm long.

tural parts of probable crustacean burrow networks of *Thalassinoides* isp. (Rindsberg and Gastaldo, 1990), and are clearly distinguished from *R. socialis*, because *R. socialis* is a discrete trace fossil and is not a part of other burrow systems (Nara, 1995).

Later, Gingras *et al*. (1999) reported modern terebellid burrows having a concentrically laminated and bulbous lining from tidal flats of Willapa Bay, Washington. This is slightly similar to *R. socialis* in morphology. Based probably on this observation, Pemberton *et al*. (2001, p. 315) made a reconstruction of the *R. socialis* animal, which resembled closely that of Nara (1995). The structures reported by Gingras *et al*. (1999) are, however, morphologically different from *R. socialis* in the strict sense, because they actually are U-shaped burrows lined entirely with thick muddy materials, although their upper parts are swollen like *R. socialis* (Gingras, 1999, pers. comm.). Meanwhile, aside from ichnotaxonomy, Gingras' observation showed that the terebellids certainly were able to produce a muddy bulbous lining like that of *R. socialis*. This supports Nara's (1995) view of the trace maker.

On the other hand, the previous youngest record of *R. socialis* was late Pleistocene (Nara, 1997). The Holocene specimens described here cooccur with Kasori B3 style Jomon potteries which are interpreted to have been produced approximately from 3450 to 2950 yrs. B.P. Thus, this is the youngest record of *R. socialis*. As the fossil record of *R. socialis* dates back to the early Cambrian period (Häntzschel, 1975; Pickerill and Peel, 1990), it is unreasonable to consider that the trace makers, probably belonging to Terebellidae (Nara, 1995), are now extinct.

As noted earlier, *R. socialis* is known to record paleoenvironmental information in detail (Nara, 1995, 1997, 2002). In order to understand the paleoecology of *R. socialis* clearly, and to establish the significance of the trace as a paleoenvironmental tool, experiments using living tracemakers would be most useful (cf. Seilacher and Seilacher, 1994). As Quaternary *R. socialis* have been found from deposits of tidal-flats (Nara, 2002) or shallow bay (this study) origin, modern burrows strictly comparable to *R. socialis* are expected to be found from such environments where observation can easily be made. Therefore, discovery of the living *R. socialis* makers would be highly desirable.

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