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Holocene ostracods (Crustacea) from a whale-fall excavation site from the Chao Phraya delta, Central Thailand

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Abstract. Late Holocene ostracods were recovered from marine sediments of the Chao Phraya delta at a whale-fall excavation site located fifteen kilometers on land in the Am Pang Subdistrict, Ban Paew District, Samut Sakhon Province, north of the Gulf of Thailand. Thirteen species belonging to seven genera are identified. The deposition environment of the succession is for the first time characterized. The ostracod assemblages suggest that the entire succession associated with the whale-fall deposited in a shallow marine environment such as estuary, bay, inner shelf, subtidal, under less than 20 meters water-depth, in brackish to normal salinity with high mud content and turbidity, on a muddy substrate. This analysis is an important step toward the first in-depth study of ostracods associated with modern and fossil shallow-water whale-falls.

Keywords. Ostracods, shallow-water whale-fall, Holocene, Bangkok Clay, Chao Phraya delta.

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Introduction

The discovery of a large whale skeleton in a privately excavated pit in Samut Sakhon Province in November 2020 raised questions about how this enormous animal deposited far away from the sea. The site was located about 15 kilometers north of the Gulf of Thailand shoreline and adjacent areas were covered by agricultural area and villages. The land owner reported the discovery to the Royal Thai Department of Mineral Resources and allowed geologists and their teams to perform detailed investigations and samplings. The first part of the skeleton that eroded out of the unconsolidated sediments at the bottom of the pit was caudal vertebrae, later 142 pieces in total were excavated and conserved (Fig. 1). The whole

12.5-meter-long skeleton has been identified as *Balaenoptera edeni* Anderson, 1879, and radiocarbon dating provided the age of 3380 ± 30 years BP (Kawira & Saethien 2021; Saethien 2021).

The sediments making up the pit wall are a part of the Holocene marine sediments of the Chao Phraya delta, also known as Bangkok Clay (Sinsakul 2000). The Holocene sediments unconformably overlay the Late Pleistocene Bangkok Stiff Clay (Rau & Nutalaya 1983). The Holocene sediments, including transgressive peaty (mangrove swamp) sediments in the lower part and regressive deltaic sediments in the upper part, were deposited in the paleo-Gulf of Ayutthaya. Sea water invaded northward as far as 100 km around 8000–7000 years BP, then the sea water retreated and delta and shoreline prograded southward forming the present delta plain and shoreline (Rau & Nutalaya 1983; Sinsakul 2000; Woodroffe 2000). Lithostratigraphy, paleontology and evolution of the Holocene deposits have been discussed elsewhere and the reader is referred to the following references for details (Somboon 1988; Somboon & Thiramongkol 1992; Sinsakul 2000; Songtham *et al*. 2000; Woodroffe 2000; Tanabe *et al*. 2003). Fossils of vertebrates, invertebrates as well as palynological materials embedded in the Holocene sediments provide evidence of the great variety of depositional environments within the Chao Phraya delta: from infralittoral, tidal flat, intertidal, mangrove swamps to shallow sea (8 to 10 meters deep) according to mollusk communities and crabs (Robba *et al*. 1993; Songtham *et al*. 2000; Negri 2009), from flood plain, transitional swamp, back swamp, mangrove forest to paleo gulf environments according to palynology (Hutangkura 2012; Songtham *et al*. 2015).

In this study, we examine ostracods recovered from silty clays collected from the whale-fall excavation site in order to better constrain the environment of deposition. At present, studies of Recent marine

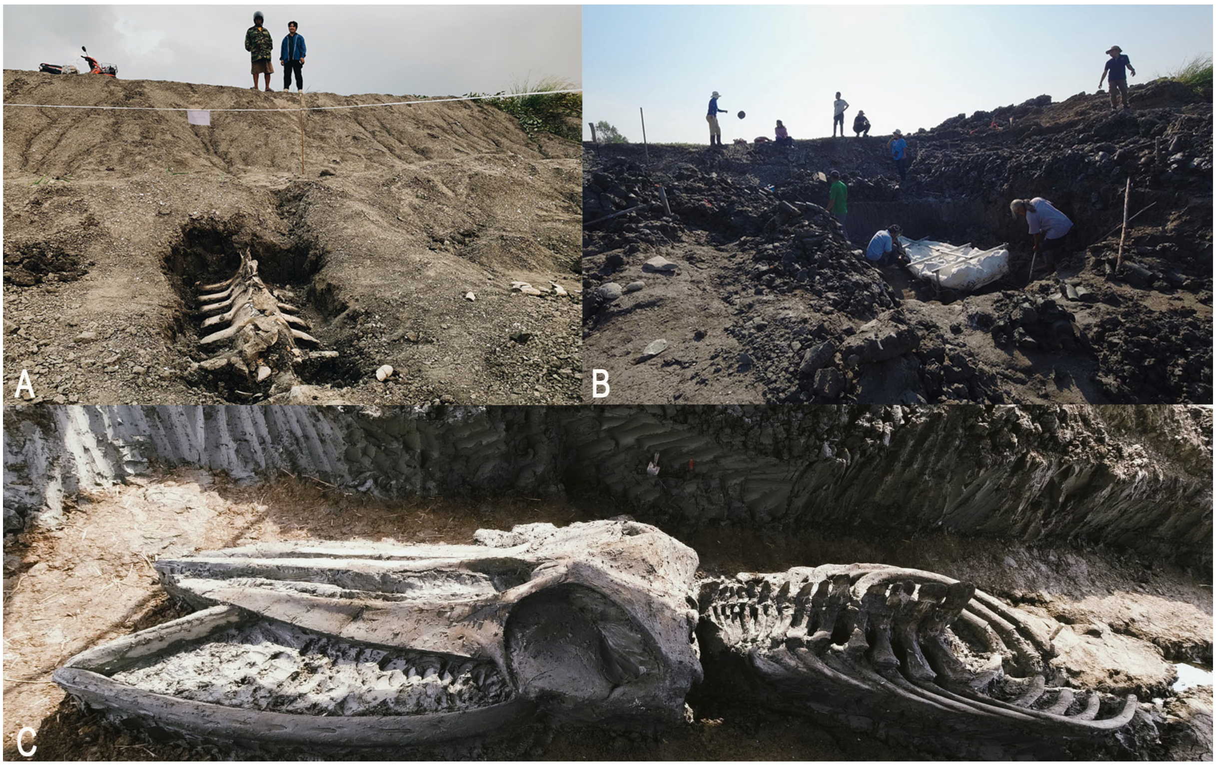

Fig. 1. Whale-fall excavation site, fifteen kilometers away from recent shoreline in Samut Sakhon Province, north of the Gulf of Thailand. **A**. First appearance of large skeletons eroded off the pit wall. **B**. The excavation during November–December 2020. **C**. Nearly complete, well preserved whale skeleton. All photos from ThaiWhales (https://www.facebook.com/thaiwhales/photos/?ref=page_internal).

ostracods along the coasts of Thailand are rare (Montenegro *et al*. 2004; Yamada *et al*. 2014; Forel 2021). Here, we provide taxonomic information on the Holocene marine ostracods and further discuss the change in shallow-water ostracod assemblages of the northern Gulf of Thailand. Whale-falls are rarely encountered on the sea-floor and associated ostracods remain practically unknown as they are in most cases reported without taxonomic details (e.g., Furushima *et al*. 2007; Danise *et al*. 2014). This contribution is therefore an important step in the knowledge of ostracods associated with shallow-water whale-falls. It is important to note that only one of the 10 samples studied here is co-eval with the whale deposition. The entire succession provides the baseline of the background ostracod assemblages in this area during the Holocene, that will be of crucial significance to understand the ostracod communities directly associated with and dwelling around the whale-fall in an ongoing in-depth study.

Material and methods

The sediment samples were collected from the pit which is situated approximately 10 kilometers northwest of Samut Sakhon city or 15 kilometers north of the shoreline (Fig. 2A–B). This area is located in the Recent delta plain of central Thailand, very close to the Tha Chin River. The lithostratigraphy of the area around the whale excavation consists of four sedimentary units, in ascending order (Fig. 3A): Pleistocene Stiff Clay found at 12.5 meters from ground surface; Shallow Marine Clay, SMC found at 3.5 meters depth (10-10.5 meters thick); Old Tidal Flat sediments, OTF found at 1 meter depth (2–2.5 meters thick); Topsoil about 1 meter thick (Nuamnim *et al*. 2021). The whale skeleton was embedded in the SMC unit, also known as the Bangkok Clay. The excavation site was on the eastern wall of a large pit developed for surface water reservoirs (Fig. 2C). The land surface was at 5 meters below mean sea level, the whale skeleton was exposed at about 1.5 meters depth, thus the whale was deposited at 6.5 meters below mean sea level. The pit was dug deeper than the skeleton to allow paleontological preparation. The lowest level of the pit was at 7 meters below mean sea level (Figs 2C, 3B).

Ten unconsolidated samples, labelled 20SS01A to 20SS06, were collected from the pit wall just below and above the skeleton level at regular intervals of 25 centimeters (Figs 3B, 4). The sediments were dense, greenish gray silty mudstone with small shell fragments. The 200-gram samples of wet clay were washed through a 125-micron sieve and dried. Seven of the ten samples yielded ostracods (Fig. 4). Ostracod specimens were picked and initially identified under a stereoscopic microscope. The specimens then were viewed using a JEOL/JSM-6010LV scanning electron microscope at the Suranaree University of Technology (Nakhon Ratchasima, Thailand) for detailed identification.

The ostracod classification in this study follows the general classification given in the *Treatise on Invertebrate Paleontology, Part Q, Ostracoda* (Moore 1961), Hartmann & Puri (1974) and Martens & Horne (2009). Thirteen species belonging to seven genera are identified (Fig. 4). Selected specimens of genera *Propontocypris* Sylvester-Bradley, 1947 (Pontocyprididae Müller, 1894), *Aglaiocypris* Sylvester-Bradley, 1947 (Candonidae Kaufmann, 1900), Sinocytheridea Hou, 1982 (Cytherideidae Sars, 1925) are shown in Fig. 5. Members of Schizocytheridae Howe, 1961 (*Neomonoceratina* Kingma, 1948) are shown in Fig. 6. Selected specimens of genera *Stigmatocythere* Siddiqui, 1971, *Keijella* Ruggieri, 1967 and *Pistocythereis* Gou, 1983 (Trachyleberididae Sylvester-Bradley, 1948) are shown in Fig. 7. Series of juvenile and adult specimens of *Keijella multisulcus* Whatley & Zhao, 1988 and *K. gonia* Zhao & Whatley, 1989 are shown in Figs 8–10.

Material repository

All specimens are stored in the Micropaleontology Collections of Suranaree University of Technology, Nakhon Ratchasima, Thailand, under collection numbers SUT-20SS-C001 to SUT-20SS-C350.

Anatomical abbreviations

AB	=	anterior border
ADB	=	anterodorsal border
AVB	=	anteroventral border
DB	=	dorsal border
H	=	height
Hmax	=	maximum of height
L	=	length
Lmax	=	maximum of length
LV	=	left valve
midH	=	mid-height
midL	=	mid-length

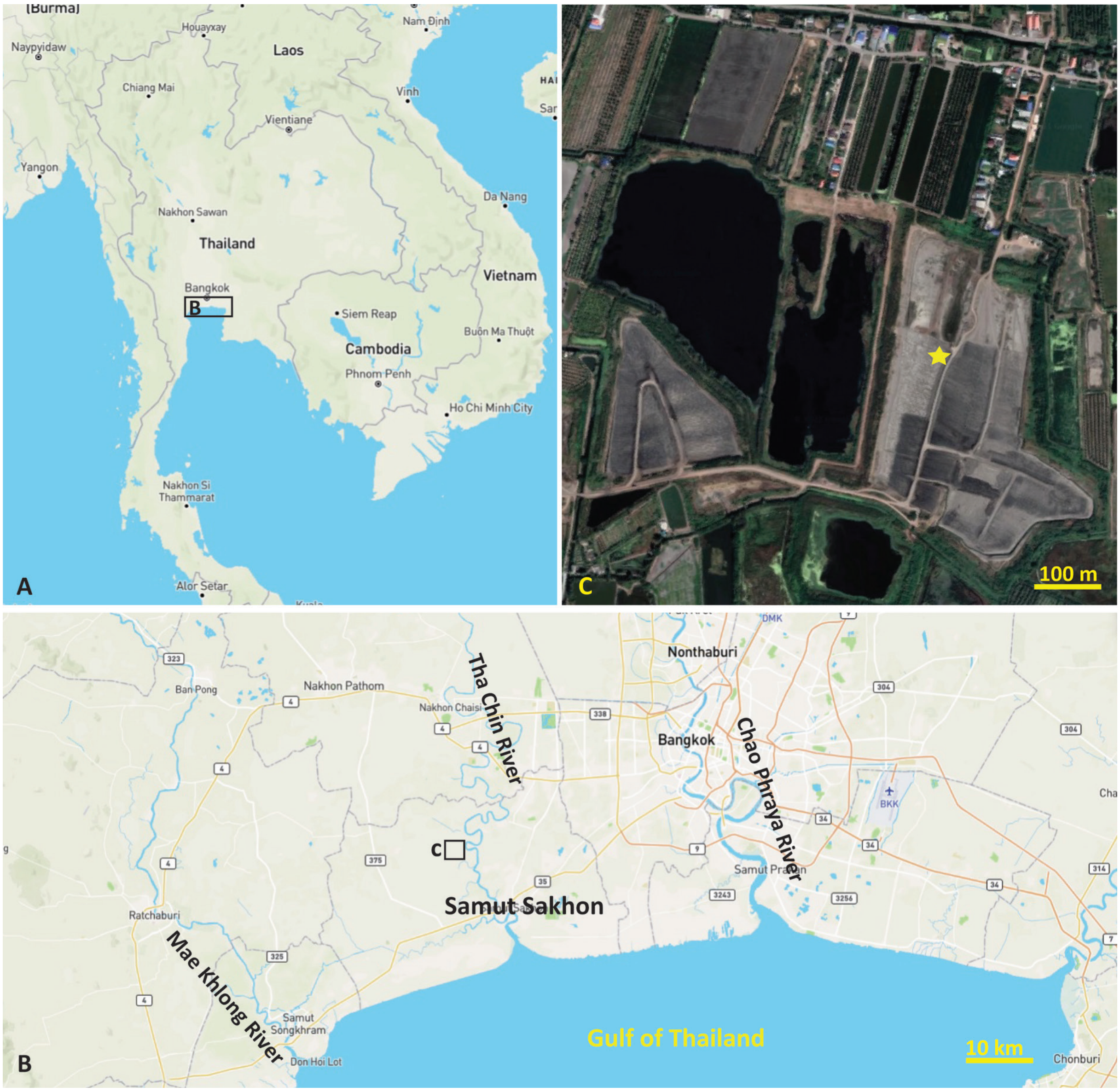

Fig. 2. Map of the studied section. **A–B**. Position of the study area at the northern coast of the Gulf of Thailand. **C**. Location of the whale-fall excavation site in Samut Sakhon Province (Google Map, 2021).

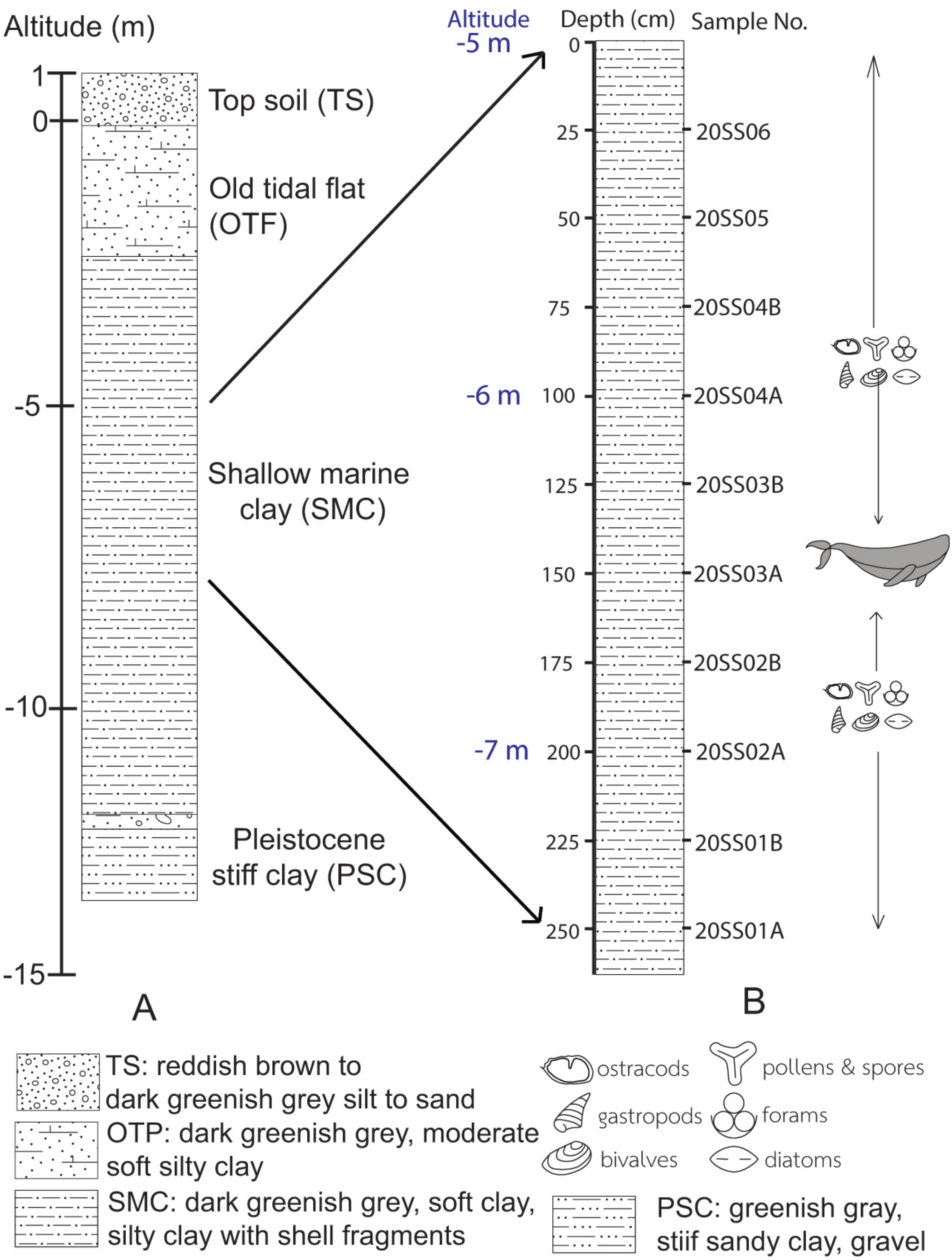

Fig. 3. Lithostratigraphy of the studied section at whale-fall excavation site in Samut Sakhon Province. **A**. Lithologic log modified after Nuamnim *et al*. (2021). **B**. Lithologic log of the studied section (this study).

PB = posterior border
PDB = posterodorsal border
PVB = posteroventral border
RV = right valve
VB = ventral border

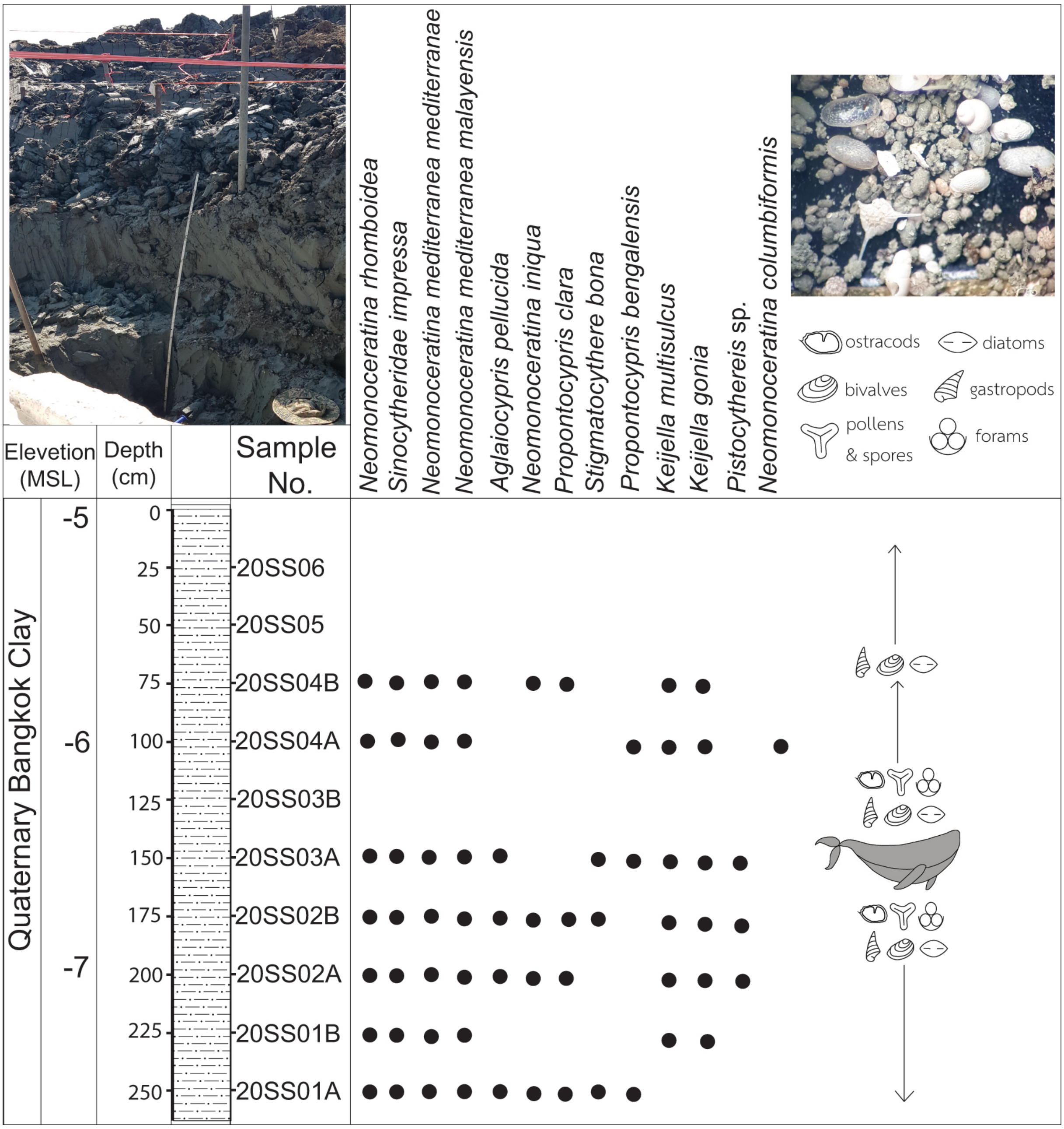

Fig. 4. Distribution of Holocene ostracods below and above the whale skeleton level at the whale-fall excavation site in Samut Sakhon Province, north of Gulf of Thailand.

Results

Taxonomic descriptions

Class Ostracoda Latreille, 1806
Subclass Podocopa Müller, 1894
Order Podocopida Müller 1894
Sub-order Podocopina Sars, 1866
Superfamily Cypridoidae Baird, 1845
Family Candonidae Kaufmann, 1900

Genus ***Aglaiocypris*** Sylvester-Bradley, 1947

Type species

Aglaiocypris pulchella (Brady, 1868) subsequently designated by Sylvester-Bradley (1947).

Aglaiocypris pellucida Mostafawi, 2003
Fig. 5A–C

Aglaiocypris pellucida Mostafawi, 2003: 71, figs 51a–c.

Aglaiocypris? sp. 5 – Maddocks 1969: 7, figs 31r–t.
Aglaiocypris sp. – Paik 1977: 28: 42, pl. 7 figs 3, 141–143, pl. 10 fig. 181.
Bythocypris sp. A. – Jain 1978: 94, fig. 2d.
Aglaiocypris pellucida – Wang *et al*. 2018: 324, figs 2l–o.

Dimensions

L = 0.542–0.569 millimeters; H = 0.250–0.275 millimeters; H/L = 0.45–0.49.

Distribution

Modern distribution: West coast of India, Recent (Jain 1978); Persian Gulf, Recent (Maddocks 1969; Paik 1977; Mostafawi 2003)

Fossil distribution: Hang Hau Formation, Lei Yue Mun, Hong Kong, Holocene (Wang *et al*. 2018); Bangkok Clay (samples 20SS01A, 02A, 02B, 03A), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

Aglaiocypris pellucida Mostafawi, 2003 is diagnosed by the following characters: thin, flat and obtuse carapace with triangular lateral outline, largely rounded AB and PB, Hmax located centrally, DB convex at LV, slightly angulated at RV, moderate overlapping of RV on LV all around, VB straight at RV, concave at LV, numerous normal pores. The present record is the first occurrence of *Aglaiocypris pellucida* in Thailand as, until now, this species was only known from the Persian Gulf (Maddocks 1969; Paik 1977; Mostafawi 2003), western coast of India (Jain 1978) and in Holocene deposits of Hong Kong (Wang *et al*. 2018). The size of the examined specimens is similar to the Holocene specimens recovered in Hong Kong (Wang *et al*. 2018) but they are smaller than the extant type material from the Persian Gulf (Mostafawi 2003).

Superfamily Pontocypridoidea Müller, 1894
Family Pontocyprididae Müller, 1894

Genus ***Propontocypris*** Sylvester-Bradley, 1947

Type species

Pontocypris trigonella Sars, 1866 by original designation.

Propontocypris bengalensis Maddocks, 1969
Fig. 5D–F

Propontocypris (Schedopontocypris) bengalensis Maddocks, 1969: 34, fig. 31a, c, f.

Propontocypris bengalensis – Mostafawi 2003: 71, fig. 48a–b. — Wang *et al*. 2018: 325, fig. 2h–i.
Pontocypris sp. A. – Bate 1971: 246, pl. 1 figs 1g, 2g. — Bonaduce *et al*. 1983: pl. 5 figs 7–8.
Propontocypris sp. C. – Paik 1977: 42, pl. 7 fig. 140, pl. 10 fig. 179.

Dimensions

L = 0.467–0.493 millimeters; H = 0.213–0.246 millimeters; H/L = 0.44–0.51.

Distribution

Modern distribution: Persian Gulf (Maddocks 1969; Mostafawi 2003); Bay of Bengal and Sri Lanka (Maddocks 1969); Persian Gulf (Bate 1971; Paik 1977); Red Sea (Bonaduce *et al*. 1983).

Fossil distribution: Hang Hau Formation, Lei Yue Mun, Hong Kong, Holocene (Wang *et al*. 2018); Bangkok Clay (samples 20SS01A, 03A, 04A), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work).

Remarks

Propontocypris bengalensis Maddocks, 1969 is diagnosed by its small compressed carapace, suboval outline, Hmax located anterior to midL, long ABD, round AB with small radius of curvature, straight VB, round PB with large radius of curvature, slight overlapping of LV on LV around the carapace. Carapaces are delicate, usually yellow, white or transparent. The examined specimens are smaller than those from the Holocene of Hong Kong (L = 0.52–0.53 millimeters; H = 0.27–0.28 millimeters) reported by Wang *et al*. (2018).

Propontocypris clara Zhao, 1988
Fig. 5G–H

Propontocypris clara Zhao in Wang *et al*. 1988: 230, pl. 36 figs 3–5.

Propontocypris clara – Ruan 1989: 118, pl. 20 fig. 24. — Tanaka *et al*. 2009: pl. 1 fig. 1. — Wang *et al*. 2018: 326, fig. 3a–d.

Dimensions

L = 0.38–0.493 millimeters; H = 0.213–0.246 millimeters; H/L = 0.44–0.51.

Distribution

Modern distribution: East China Sea (Wang *et al*. 1988); Northern Xisha Trench, South China Sea, China (Ruan 1989); Northeastern coast of Vietnam, Vietnam (Tanaka *et al*. 2009).

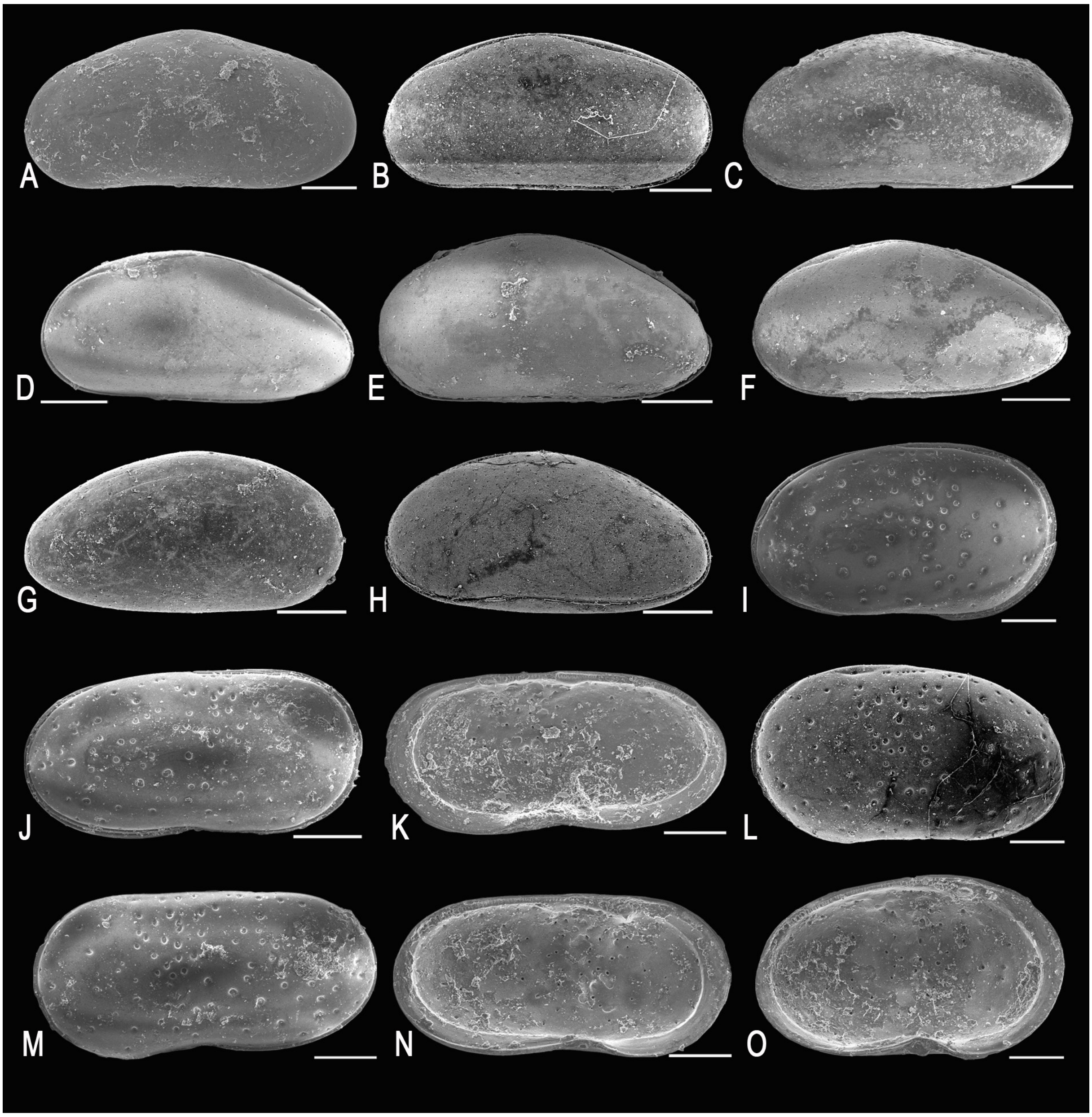

Fig. 5. Holocene ostracods from Samut Sakhon Province, Central Thailand. **A–C**. *Aglaiocypris pellucida* Mostafawi, 2003. **A**. Carapace, right lateral view, SUT-20SS-C003. **B**. Carapace, left lateral view, SUT-20SS-C007. **C**. Carapace, left lateral view, SUT-20SS-C003. – **D–H**. *Propontocypris bengalensis* Maddocks, 1969. **D**. Carapace, left lateral view, SUT-20SS-C012. **E**. Carapace, left lateral view, SUT-20SS-C020. **F**. Carapace, left lateral view, SUT-20SS-C014. **G**. Carapace, right lateral view, SUT-20SS-C027. **H**. Carapace, left lateral view, SUT-20SS-C022. – **I–O**. *Sinocytheridea impressa* (Brady, 1869). **I**. Carapace, female, right lateral view, SUT-20SS-C063. **J**. Carapace, male, right lateral view, SUT-20SS-C040. **K**. Internal view of right valve, male, SUT-20SS-C049. **L**. Carapace, female, left lateral view, SUT-20SS-C071. **M**. Carapace, male, left lateral view, SUT-20SS-C071. **N**. Internal view of left valve, male, SUT-20SS-C048. **O**. Internal view of left valve, female, SUT-20SS-C064. Scale bars = 0.1. mm.

Fossil distribution: Hang Hau Formation, Lei Yue Mun, Hong Kong, Holocene (Wang *et al*. 2018); Bangkok Clay (samples 20SS01A, 02A, 02B, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

Propontocypris clara Zhao, 1988 is characterized by its small and delicate carapace, subtriangular in lateral view, with Hmax located in front of midL, rounded AB, slightly concave VB, narrowly rounded PB, round normal pores. *Propontocypris clara* is distinguished from *P. bengalensis* by the location of Hmax. The examined specimens are smaller than those reported from Holocene sediments of Hong Kong (L = 0.497–0.526 millimeters; H = 0.280–0.274 millimeters; Wang *et al*. 2018).

Suborder Cytherocopina Baird, 1850
Superfamily Cytheroidea Baird, 1850
Family Cytherideidae Sars, 1925

Genus ***Sinocytheridea*** Hou, 1982

Type species

Sinocytheridae latiovata Hou in Hou *et al*., 1982, junior synonym of *Sinocytheridea impressa* (Brady, 1869) following the revision of Whatley & Zhao (1988a).

Sinocytheridea impressa (Brady, 1869)
Fig. 5I–O

Cytheridae impressa Brady, 1869: 158, pl. 16 figs 13–14.
Cyprideis yehi Hu & Yeh, 1978: 157–159, pl. 3 figs 10–13.
Sinocytheridea sinensis Hou in Guan *et al.*, 1978: 240, pl. 65 figs 1–5.
Sinocytheridae latiovata Hou & Chen in Hou *et al.*, 1982: 164–165, pl. 72 figs 10–20.
Sinocytheridae longa Hou & Chen in Hou *et al.*, 1982: 165, pl. 72 figs 1–9.
Eucytheridae sinobesani Hu, 1984: 76, pl.10, figs. 27, 28.

Sinocytheridea impressa – Whatley & Zhao 1987: 24, pl. 1 figs 8–10. — Montenegro *et al*. 2004: pl. 2 figs 6–7. — Alberti *et al*. 2013: 341. — Yamada *et al*. 2014: 110. — Hong *et al*. 2017: 58; 2019: 596. — Cheung *et al*. 2019: 9. —Tanaka *et al*. 2019: fig. 7. — Tan *et al*. 2021: fig. 2(10).

Dimensions

L = 0.515–0.567 millimeters, H = 0.250–0.317 millimeters, H/L = 0.45–0.49 (males; Fig. 5J–K, M–N).

L = 0.477–0.700 millimeters, H = 0.246–0.410 millimeters, H/L = 0.52–0.59 (females; Fig. 5I, L, O).

Distribution

Tanaka *et al*. (2019) recently reviewed and presented the distribution of extant and fossil *Sinocytheridea impressa* around the eastern margin of Eurasia, from the Sea of Japan to South China Sea. The reader is referred to their work for details. Here, we list some occurrences of the species.

Modern distribution: Japan (Tanaka *et al*. 2019); China (Zhao & Wang 1988, 1990; Cheung *et al*. 2019); Hong Kong (Brady 1869; Hong *et al*. 2017, 2019); Central Vietnam (Tan *et al*. 2021). Mae Khlong estuary, NW Gulf of Thailand, Thailand (Montenegro *et al*. 2004); Klong Thom, Krabi, Andaman estuary, Thailand (Yamada *et al*. 2014).

Fossil distribution: Upper Pliocene, Japan (Yamada *et al*. 2002); Middle Pleistocene, Japan (Ishizaki 1990; Irizuki *et al*. 2005). Pliocene, China (Hou & Gou 2007); Pliocene to Pleistocene, China (Lee & Paik 1992; Hu & Tao 2008); Quaternary, China (Huang 1985; Hou *et al*. 1982; Alberti *et al*. 2013); Pleistocene to Holocene, Hong Kong (Cao, 1998); Bangkok Clay (samples 20SS01A, 01B, 02A, 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

Carapaces of *Sinocytheridea impressa* (Brady, 1869) are characterized by flat, elongate to oval lateral outline, long hinge, slightly concave VB, with scattered sieve type pores on carapace surface. Sexual dimorphism clear: males are longer and slender with AB and PB nearly of equal size, Hmax located anteriorly but not distinct; females are shorter, with AB larger than PB, Hmax located anterior to midL and distinct. The juvenile carapaces are very delicate and transparent.

Family Schizocytheridae Howe in Moore, 1961
Subfamily Schizocytherinae Mandelstam, 1960

Genus ***Neomonoceratina*** Kingma, 1948

Type species

Neomonoceratina columbiformis Kingma, 1948 by original designation.

Preliminary remarks

Members of the genus *Neomonoceratina* can be classified into five groups based on the ornamentation of their carapaces (Zhao & Whatley 1988): *N. columbiformis* group, *N. iniqua* group, *N. koeningswaldi* group, *N. macropora* group and *N. spinosa* group. The specimens investigated here belong to the *N. columbiformis* and *N. iniqua* groups. The *N. columbiformis* group is characterized by a smooth or finely punctate intercostal surface and includes *N. columbiformis*, *N. mediterranea* (Ruggieri, 1953), *N. mediterranea malayensis* Zhao & Whatley, 1988. Conversely, the *N. iniqua* group is characterized by a reticulate surface consisting of polygon fossae, thin muri and finely punctate sola, fringed AB with small denticles. In the present material, *N. iniqua* (Brady, 1868), *N. bataviana* (Brady, 1868), *N. delicata* Ishizaki & Kato, 1976, *N. chenae* Zhao & Whatley, 1988 are representatives of this *N. iniqua* group.

Neomonoceratina iniqua (Brady, 1868)
Fig. 6A–C

Cytherura iniqua Brady 1868: 64, pl. 8 figs. 3–6.
Trachyleberis? vjetnamica Schneider, 1971: 261, figs e–f.
Neomonoceratina diptera Hu & Yang, 1975: 108, pl. 1 figs 19–20.

Cytherura iniqua – Brady 1886: 130, pl. 39 figs 31–33.
Neomonoceratina sp. A – Paik 1977: 42, pl. 2 figs 24–28, pl. 8 fig. 148.
Neomonoceratina iniqua – Zhao & Whatley 1988: 566, pl. 1 figs 7–12; 1989: 171. — Dewi 1993: 60. — Hussain 1998: 4, pl. 1 fig.11 — Al-Jumaily & Al-Sheikhly 1999: 217, fig. 15. —Mostafawi 2003: 56, fig. 6. — Montenegro *et al*. 2004: pl. 2 fig. 4. — Gopalakrishna *et al*. 2007: pl. 1 fig. 10. — Fauzielly *et al*. 2012: fig. 3(6); 2013: fig. 6(10). — Baskar *et al*. 2013: fig. 3(4). — Hussain & Kalaiyarasi 2013: fig. 11.2(a–b). — Forel 2021: fig. 4d–e. — Tan *et al*. 2021: fig. 2(7).

Dimensions

L = 0.542–0.592 millimeters; H = 0.267–0.292 millimeters, H/L = 0.48–0.50.

Distribution

Modern distribution: Java Sea (Brady 1868; Dewi 1993, 2000; Fauzielly 2013; Fauzielly *et al*. 2012, 2013); Iraq (Al-Jumaily & Al-Sheikhly 1999); east India (e.g., Hussain & Mohan 2001; Hussain *et al*. 2007); southeast India (e.g., Hussain 1998; Hussain *et al*. 2004, 2007, 2013a; Baskar *et al*. 2013; Hussain & Kalaiyarasi 2013); southwest India (e.g., Hussain *et al*. 2013b; Gopalakrishna *et al*. 2007); west India (e.g., Bhatia & Kumar 1979); Sri Lanka (Iwatani *et al*. 2014); Persian Gulf (Paik 1977; Mostafawi 2003; Mostafawi *et al*. 2010); Malaysia (e.g., Zhao & Whatley 1989; Ramlan & Noraswana 2009, 2010); Vietnam (Tan *et al*. 2021); Mae Khlong river mouth, north west Gulf of Thailand (Montenegro *et al*. 2004); southwestern coast of Peninsular Thailand, Ao Nun, Satun Province, Andaman Sea (Forel 2021);

Fossil distribution: Bangkok Clay (samples 20SS01A, 02A, 02B, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remark*s*

Neomonoceratina iniqua (Brady, 1868) is characterized by its reticulate surface with thin muri and polygon fossae, indistinct and short posterodoral rib, long median rib from anterior to posterocentral region, and venterolateral rib terminating into a simple spine. Sexual dimorphism is well expressed with longer and slender male carapaces while female carapaces are shorter and higher. This is the first discovery of the species from Holocene sediments.

Neomonoceratina rhomboidea (Brady, 1968)
Fig. 6D–I

Cytheropteron rhomboideum Brady 1968: 65, pl. 8 figs 10–12.

Neomonoceratina rhomboidea – Hanai *et al*. 1980: 154. — Zhao & Whatley 1988: 569, pl. I figs 20–21, pl. II figs 1–3.

Dimensions

L = 0.400–0.778 millimeters, H = 0.206–0.467 millimeters, H/L = 0.40–0.67.

Distribution

Modern distribution: Batavia, Java, Indonesia (Brady 1968); Jason Bay, southeast Malaysia (Zhao & Whatley 1988).

Fossil distribution: Bangkok Clay (samples 20SS01A, 01B, 02A 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work).

Remark

Neomonoceratina rhomboidea (Brady, 1968) can be recognized by the inflated carapace, a weak and shallow reticulation, a thin median rib and alalike posteroventral inflation and relatively large, sieve type, normal pore canals.

Neomonoceratina columbiformis Kingma, 1948
Fig. 6J

Neomonoceratina columbiformis – Kingma 1948: 95, pl. 10 fig. 8a–f.

Neomonoceratina columbiformis – Keij 1979: 61, pl. 1 figs 1–4, pl. 2 figs 5–6. — Zhao & Whatley 1988: 565, pl. 1 fig. 1.

non *Neomonoceratina columbiformis* – Keij 1979: 166, pl. 1 fig. 11.

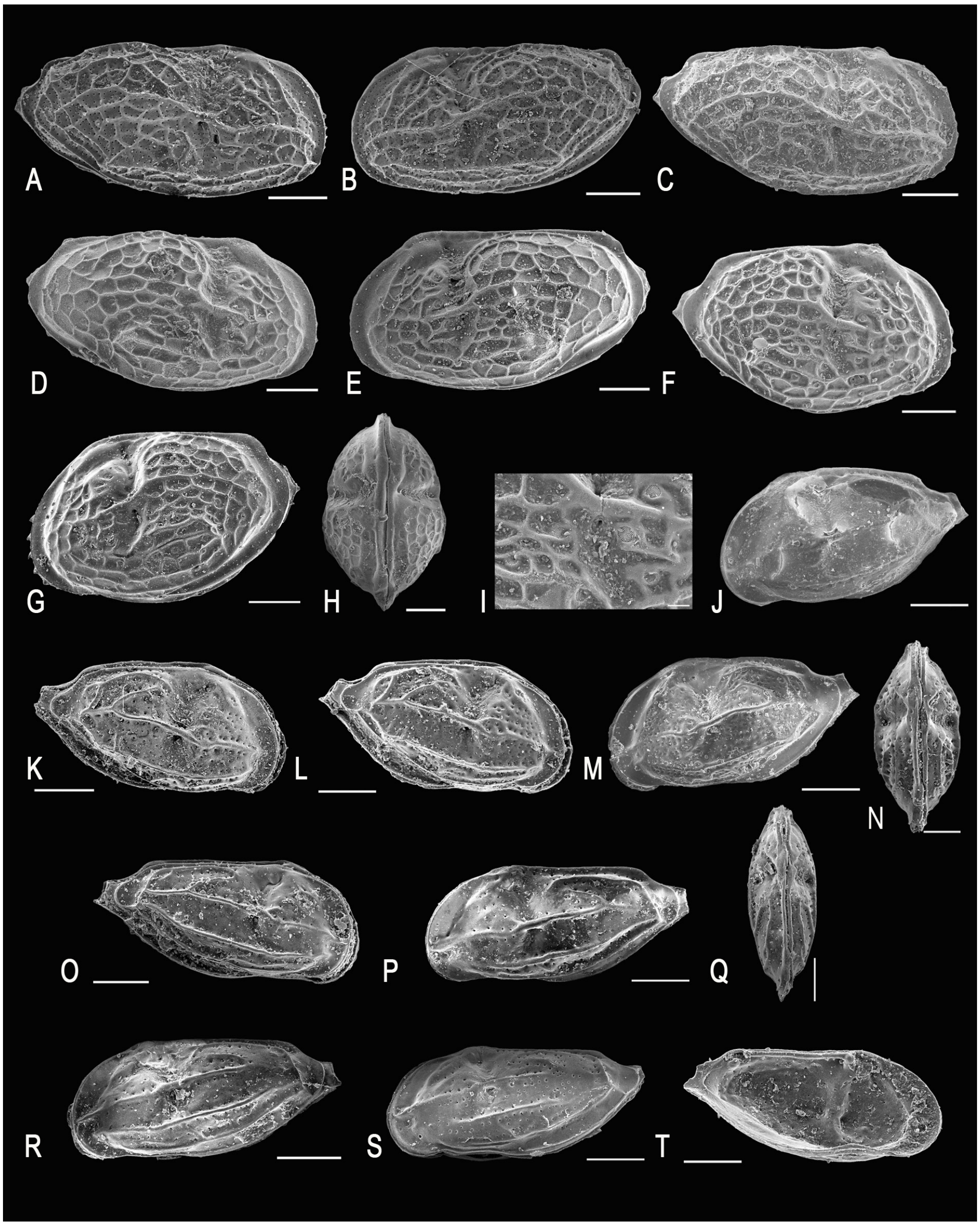

Fig. 6. Holocene ostracods from Samut Sakhon Province, Central Thailand. **A–C**. *Neomonoceratina iniqua* (Brady, 1868). **A**. Valve, male, right lateral view, SUT-20SS-C097. **B**. Valve, male, left lateral view, SUT-20SS-C095. **C**. Valve, male, right lateral view, SUT-20SS-C093. – **D–I**. *Neomonoceratina rhomboidei* (Brady, 1968). **D**. Carapace, male, right lateral view, SUT-20SS-C113. **E**. Carapace, male, right lateral view, SUT-20SS-C120. **F**. Carapace, female, right lateral view, SUT-20SS-C099. **G**. Carapace, female, left lateral view, SUT-20SS-C107. **H**. Carapace, female, dorsal view, SUT-20SS-C114. **I**. Sieve pores. – **J**. *Neomonoceratina columbiformis* Kingma, 1948. Carapace, left lateral view, SUT-20SS-C181. – **K–N**. *Neomonoceratina mediterranea mediterranea* (Ruggieri, 1953). **K**. Carapace, female, right lateral view, SUT-20SS-C167. **L**. Carapace, female, right lateral view, SUT-20SS-C173. **M**. Carapace, female, left lateral view, SUT-20SS-C164. **N**. Carapace, female, dorsal view, SUT-20SS-C174. – **O–T**. *Neomonoceratina mediterranea malayensis* Zhao & Whatley, 1988. **O**. Carapace, male, right lateral view, SUT-20SS-C159. **P**. Carapace, male, left lateral view, SUT-20SS-C157. **Q**. Carapace, male, dorsal view, SUT-20SS-C161. **R**. Carapace, male, left lateral view, SUT-20SS-C152. **S**. Carapace, male, left lateral view, SUT-20SS-C141. **T**. Valve, male, internal view of left valve, SUT-20SS-C160. Scale bars = 1 mm.

Dimensions

L = 0.440 millimeters, H = 0.240 millimeters, H/L = 0.55.

Distribution

Modern distribution: Malacca Strait (Zhao & Whatley 1988); Jakarta Bay, Indonesia (Fauzielly *et al*. 2013); Klong Thom, Krabi, Andaman estuary, Thailand (Yamada *et al*. 2014).

Fossil distribution: Pliocene, Sumatra (Kingma 1948; Keij 1979); Bangkok Clay (sample 20SS04A), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work).

Remark

Neomonoceratina columbiformis Kingma, 1948 is very rare in our material but it can be recognized by its non-ornamented carapace with curved posterodorsal rib and oblique median rib.

Neomonoceratina mediterranea mediterranea (Ruggieri, 1953)
Fig. 6K–N

Paijenborchella (Neomonoceratina) mediterranea Ruggieri, 1953: 4–7, figs 1–5.

Paijenborchella (Neomonoceratina) mediterranea – Keij 1954: 288, pl. 5 fig. 15, pl. 16 fig. 12, 361, pl. 3 figs 12–13. — Morales 1966: 80, pl. 7 fig. 2a–c.
Neomonoceratina sp. Swain 1955: 643, pl. 64 fig. 14.
Neomonoceratina mediterranea – Morkhoven Van 1963: 369, fig. 604. — Teeter 1975: 473, fig. 17k. — Gou *et al*. 1981: 171, pl. 82 figs 11–12. — Hou *et al*. 1982: 219, pl. 80 figs 24–30. — McKenzie & Pickett 1984: fig. 4y–z.
Neomonoceratina mediterranea mediterranea – Zhao & Whatley 1988: 565, pl. 1 figs 2–3.
Neomonoceratina sp. (pars) – Forel 2021: 7, fig. 4g–h

Dimensions

L = 0.400–0.778 millimeters; H = 0.206–0.467 millimeters; H/L = 0.46–0.60.

Distribution

Modern distribution: Southwestern coast of Peninsular Thailand, Ao Nun, Satun Province, Andaman Sea (Forel 2021).

Fossil distribution: Pliocene of southeast China, Quaternary of east China, East of Australia, Recent of Eastern Mediterranean, the Philippines, Indonesia, Australia, the Caribbean and Gulf of Mexico (see details in Zhao & Whatley 1989); Bangkok Clay (samples 20SS01A, 01B, 02A, 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

Neomonoceratina mediterranea mediterranea (Ruggieri, 1953) is recognized by its small carapace with two short oblique posterodorsal ribs, a long median rib, one venterolateral rib and one ventral rib. The posterodorsal and venterrodorsal ribs connect with median rib in the posterior area. The carapace surface is finely punctate. Two of the three specimens identified as *Neomonoceratina* sp. in Forel (2021) are here re-attributed to *N. mediterranea mediterranea* (Forel 2021: fig. 4g–h).

Neomonoceratina mediterranea malayensis Zhao & Whatley, 1988
Fig. 6O–T

Neomonoceratina mediterranea malayensis Zhao & Whatley, 1988: 566, pl 1 figs 4–6.

Neomonoceratina sp. – Forel 2021: 7, fig. 4f.

Dimensions

L = 0.433–0.480 millimeters; H = 0.187–0.213 millimeters; H/L = 0.39–0.47.

Distribution

Recent distribution: Jason Bay, southeastern Malay Peninsula, Malaysia (Zhao & Whatley 1989); Southwestern coast of Peninsular Thailand, Ao Nun, Satun Province, Andaman Sea (Forel 2021).

Fossil distribution: Bangkok Clay (samples 20SS01A, 01B, 02A, 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

The size and H/L ratio of *N. mediterranea malayensis* are smaller than those of *N. mediterranea mediterranea.* Punctae on the surface are restricted to the base of the ribs while they are rare on the smooth intercostal surface. *Neomonoceratina mediterranea malayensis* was first recovered from shallow water sediments of the Jason Bay, in Malay Peninsula (Zhao & Whatley 1988). This species was also found along the Andaman coast of Thailand (Forel 2021: fig. 4f).

Family Trachyleberididae Sylvester-Bradley, 1948

Genus ***Stigmatocythere*** Siddiqui, 1971

Type species

Stigmatocythere obliqua Siddiqui, 1971 by original designation

Stigmatocythere bona Chen, 1982
Fig. 7G–I

Stigmatocythere bona Chen in Hou *et al*., 1982: figs 153–154.

Stigmatocythere bona – Whatley & Zhao 1988b: 9, pl. 6 fig. 19. — Dewi 1993: 69, figs 153–154. — Montenegro *et al*. 2004: pl. 2 fig. 8. — Forel 2021: 8, fig. 5d–e.

Dimensions

L = 0.407–0.678 millimeters, H = 0.221–0.360 millimeters, H/L = 0.41–0.58.

Distribution

Modern distribution: Java Sea (Dewi 1993, 2000); Malacca Straits (Whatley & Zhao 1988); Sedili River, Jason Bay (Zhao & Whatley 1989); Vietnam (Tan *et al*. 2021); Sri Lanka (Iwatani *et al*. 2014); Mae Khlong River mouth, north west Gulf of Thailand (Montenegro *et al*. 2004); Southwestern coast of Peninsular Thailand, Ao Nun, Satun Province, Andaman Sea (Forel 2021).

Fossil distribution: East China, Pliocene and Quaternary (Hou *et al*. 1982; Gou *et al*. 1983); Bangkok Clay (samples 20SS01A, 02B, 03A), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

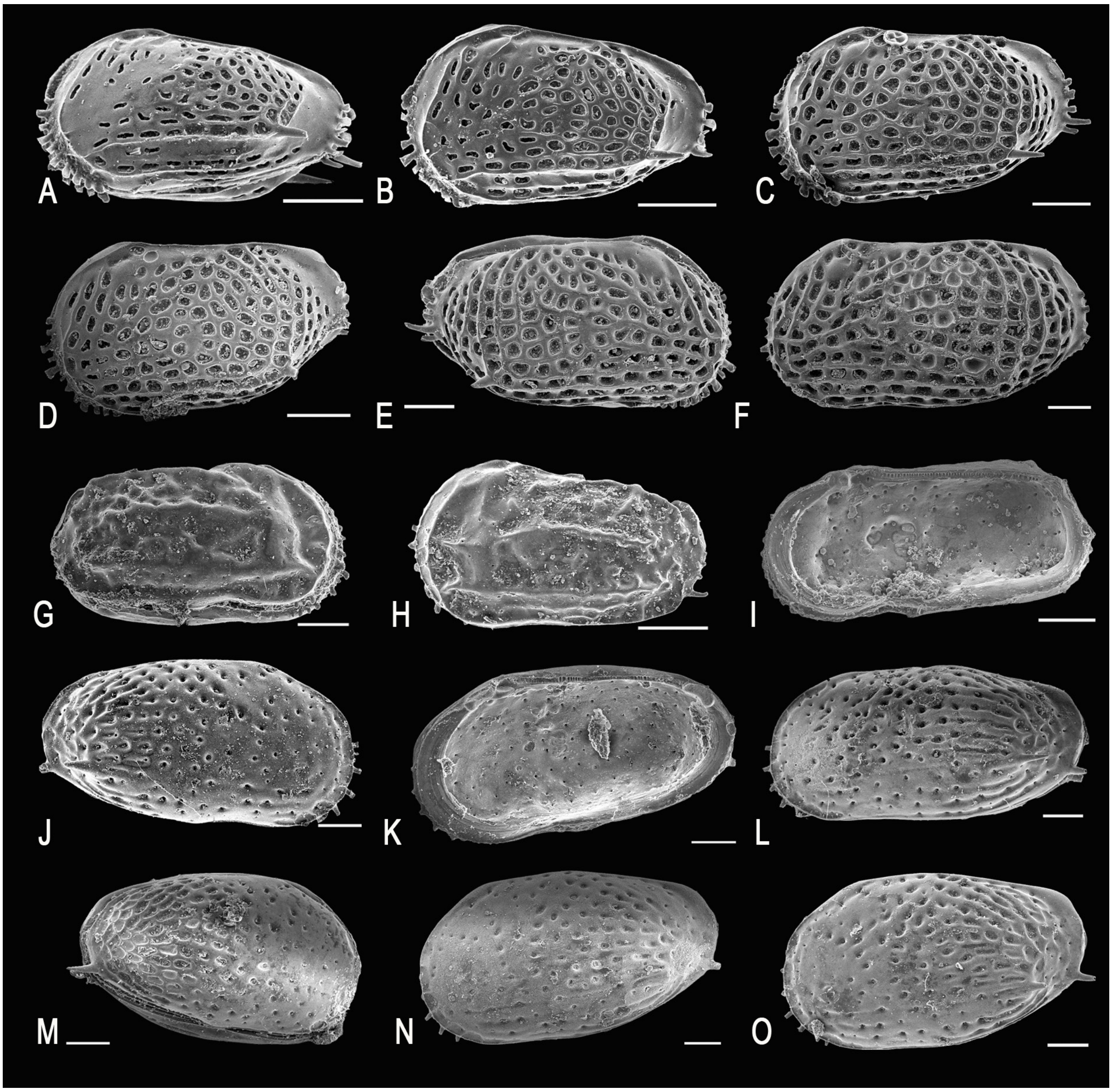

Fig. 7. Holocene ostracods from Samut Sakhon Province, Central Thailand. **A–E**. *Keijella gonia* Zhao & Whatley, 1989. **A**. Carapace, left lateral view, SUT-20SS-C310. **B**. Carapace, left lateral view, SUT-20SS-C311. **C**. Carapace, left lateral view, SUT-20SS-C312. **D**. Carapace, right lateral view, SUT-20SS-C288. **E**. Carapace, right lateral view, SUT-20SS-C286. – **F**. *Pistocythereis* sp. Carapace, right lateral view, SUT-20SS-C305. – **G–I**. *Stigmatocythere bona* Chen in Hou, Chen, Yang, Ho, Zhou & Tian, 1982. **G**. Carapace, right lateral view, SUT-20SS-C201. **H**. Carapace, left lateral view, SUT-20SS-C200. **I**. Valve, internal view of right valve, SUT-20SS-C190. – **J–O**. *Keijella multisulcus* Whatley & Zhao, 1988. **J**. Valve, juvenile, right lateral view, SUT-20SS-C231. **K**. Valve, juvenile, internal view of right valve, SUT-20SS-C213. **L**. Carapace, male, left lateral view, SUT-20SS-C225. **M**. Carapace, female, left lateral view, SUT-20SS-C242. **N**. Carapace, female, left lateral view, SUT-20SS-C206. **O**. Carapace, female, left lateral view, SUT-20SS-C243. Scale bars = 0.1. mm.

Genus ***Keijella*** Ruggieri, 1967

Type species

Cythere hodgii Brady, 1866 subsequently designated by Ruggieri (1967).

Keijella multisulcus Whatley & Zhao, 1988
Figs 7J–O, 8A–I, 9

Keijella multisulcus Whatley & Zao, 1988: 15, fig. d.

Dimensions

L = 0.325–0.875 millimeters; H = 0.175–0.444 millimeters; H/L = 0.45–0.59 (Fig. 9).

Distribution

Modern distribution: Malacca Strait (Whatley & Zhao 1988b); Malaysia (Omar *et al*. 2017); Mae Khlong River mouth, north west Gulf of Thailand (Montenegro *et al*. 2004); southwestern coast of Peninsular Thaiand, Ao Nun, Satun Province, Andaman Sea (Forel 2021).

Fossil distribution: Bangkok Clay (samples 20SS01B, 02A, 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remark

Dimorphism of *Keijella multisulcus* can be recognized by the subrectangular shape with H/L ratio less than 0.50 in the male (Fig. 7L) and the subovate shape with a higher H/L ratio in the female (Fig. 7M–O). The juvenile carapaces are sub-triangular in lateral view with Hmax located anteriorly at one third of L, Lmax is located below midH in both valves. The ventral longitudinal carina is prominent in young juveniles (Fig. 8G–H) and extends into a small spine (posteroventral spine). The ventral longitudinal carina is faint and becomes obscured in the larger juvenile stage (Fig. 8A–F). Small conical posterior marginal denticles and a large terminal posteroventral spine are observed in juveniles. Figure 9 shows H and L plot of the species which clearly demonstrates that sexual dimorphism can be differentiated in adult specimens.

Keijella gonia Zhao & Whatley, 1989
Figs. 7A–E, 10

Keijella gonia Zhao & Whatley, 1989: 181, pl. 3 figs 7–10, 16.

Keijella gonia – Montenegro *et al*. 2004: pl. 1 fig. 8. — Forel 2021: 8, fig. 5h–i.

Dimensions

L = 0.380–0.710 millimeters; H = 0.187–0.380 millimeters; H/L = 0.49–0.62.

Distribution

Modern distribution: Mae Khlong River mouth, north west Gulf of Thailand (Montenegro *et al*. 2004); Sedili River, Jason Bay (Zhao & Whatley 1989); Central Vietnam (Tan *et al*. 2021); Indonesia (Fauzielly 2013); Southwestern coast of Peninsular Thailand, Ao Nun, Satun Province, Andaman Sea (Forel 2021).

Fossil distribution: Bangkok Clay (samples 20SS01B, 02A, 02B, 03A, 04A, 04B), whale excavation site, Samut Sakhon Province, Thailand, Late Holocene (this work, Fig. 4).

Remarks

Keijella gonia is easily recognized by the distinct angle formed by the posteroventral intersection of vertical and horizontal muri extending into a spine, sometimes sharp and long. The carapace is subrectangular in lateral view, strongly reticulated. Well-preserved specimens show laterally compressed anterior and posterior marginal denticles, especially along AVB. Prominent postero-marginal spines are distinct and located below the marginal denticles especially in juvenile specimens (Fig. 7A–C). Figure 10 shows H and L plots of *K. gonia* compared to the types from Malaysia (Zhao & Whatley 1989), the specimens from Thailand consist of adults and juveniles.

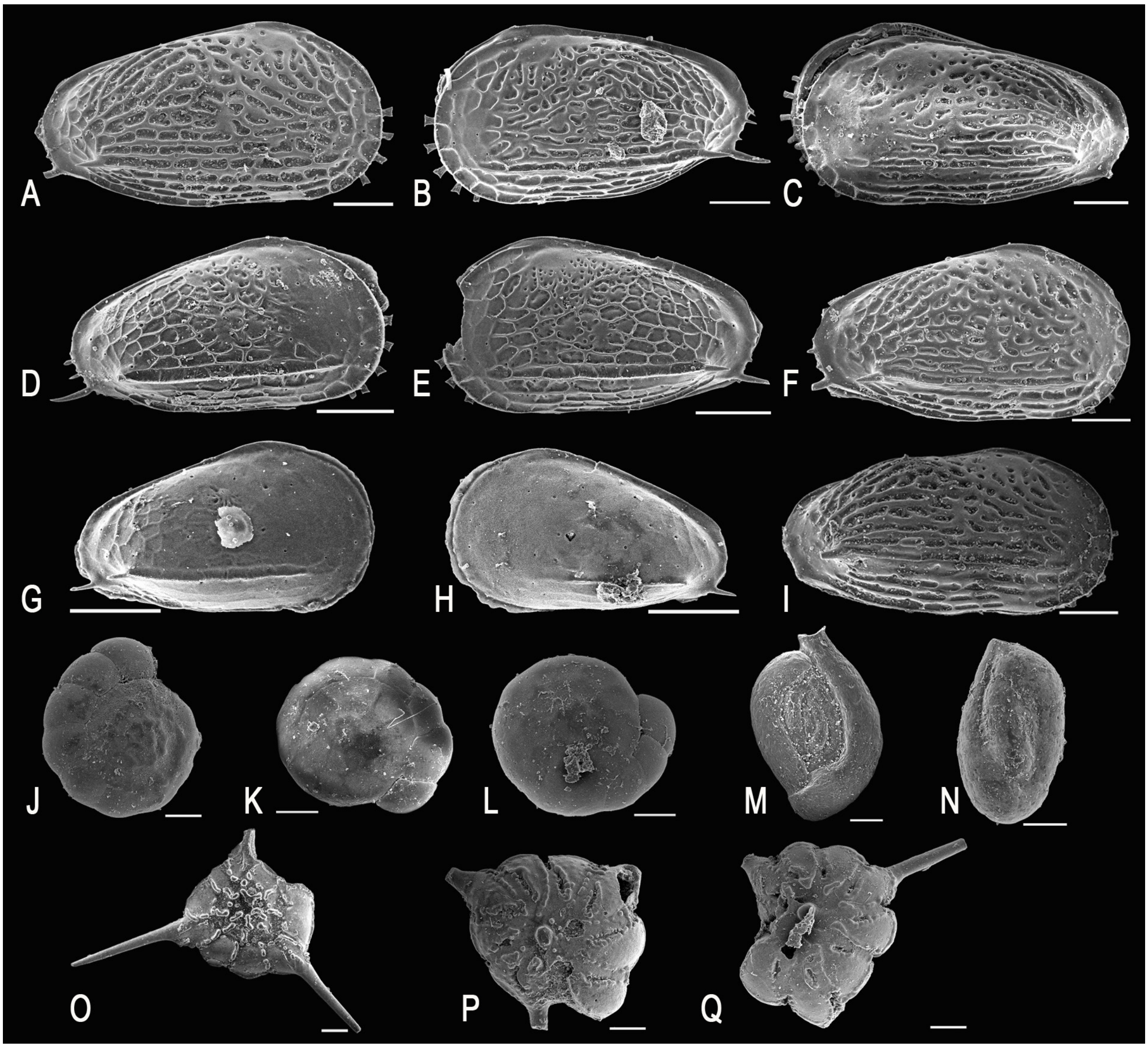

Fig. 8. Holocene ostracods from Samut Sakhon Province, Central Thailand. **A–I**. *Keijella multisulcus* Whatley & Zhao, 1988. **A**. Valve, juvenile, right lateral view, SUT-20SS-C254. **B**. Valve, female, left lateral view, SUT-20SS-C269. **C**. Carapace, juvenile, left lateral view, SUT-20SS-C270. **D**. Valve, juvenile, right lateral view, SUT-20SS-C267. **E**. Valve, juvenile, left lateral view, SUT-20SS-C286. **F**. Valve, juvenile, right lateral view, SUT-20SS-C253. **G**. Valve, juvenile, right lateral view, SUT-20SS-C272. **H**. Valve, juvenile, left lateral view, SUT-20SS-C273. **I**. Valve, female, right lateral view, SUT-20SS-C257. – **J–L**. *Ammonia tepida* (Cushman, 1926), spiral side, SUT-20SS-F001. – **M**. *Spiroloculina* sp., side view, SUT-20SS-F002. – **N**. *Quinqueloculina* sp., side view, SUT-20SS-F003. – **O–Q**. *Asterorotalia pulchella* (d'Orbigny, 1839), side view, SUT-20SS-F004-6. Scale bars = 0.1 mm.

Genus ***Pistocythereis*** Gou, 1983

Pistocythereis sp.
Fig. 7F

Dimensions

L = 0.670–0.778 millimeters; H = 0.330–0.400 millimeters; H/L = 0.49–0.54.

Remarks

Five specimens of *Pistocythereis* sp. were found from samples 20SS02A, 02B, 03A. They can be differentiated from *Keijella gonia* by the larger carapace without posteroventral spine at intersection of vertical and horizontal muri.

Discussion

Taxonomic composition and diversity

Seven of the 10 silty clay samples, each weighing 200 grams, from the total thickness of 2 meters at the whale-excavation site yielded ostracods (Fig. 4). The specimens studied here are both disarticulated valves and complete carapaces. Thirteen species belonging to seven genera and five families are here identified. To discuss the composition and diversity of the ostracod assemblages, the specimens of each species were counted articulated plus a higher number of left or right valves (Nützel & Kaim 2014; Haussmann & Nützel 2015). 1869 specimens were sorted, the relative abundance of each taxon through the entire section was calculated. The family Trachyberididae is the most abundant (52.71% of the specimens) including *Keijella multisulcus* (31.38%), *Keijella gonia* (19.62%), *Stigmatocythere bona*

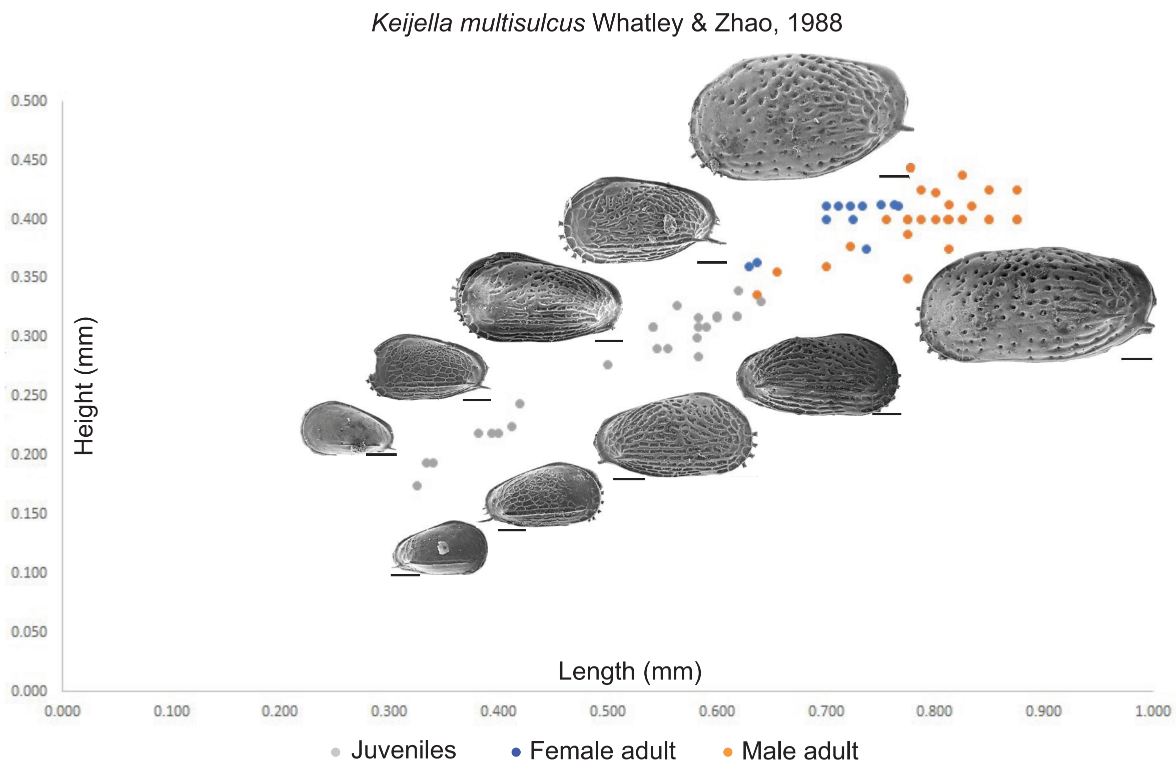

Fig. 9. Height and length scatter plot of *Keijella multisulcus* Whatley & Zhao, 1988 found at the whale-fall excavation site in Samut Sakhon Province, north of the Gulf of Thailand. Scale bars = 0.1 mm.

(1.58%) and *Pistocythereis* sp. (0.26%). The family Schizocytheridae is the second most abundant, accounting for 24.83% of the species; it is only represented by the genus *Neomonoceratina* including: *N. rhomboidae* (14.77%), *N. mediterranea* (4.69%), *N. mediterranea malayensis* (3.69%), *N. iniqua* (1.69%), and *N. columbiformis* (0.05%). *Sinocythere impressa* (16.89%) is the only representative of the family Cytherideidae. The family Pontocyprididae (*Propontocypris bengalensis* and *P. clara*) is 4.52% and the family Candonidae (*Aglaiocypris pellucida*) is 1.05% of the specimens.

Stratigraphical and geographical distributions

The ostracods reported in this study are from sediments around the whale skeleton which is dated to 3380±30 years (Kawira & Saethien 2021; Saethien 2021). All seven genera including *Aglaiocypris*, *Propontocypris*, *Sinocytheridae*, *Neomonoceratina*, *Stigmatocythere*, *Keijella* and *Pistocythereis* are frequent components of Cenozoic to Recent ostracod faunas from the Indo-Pacific and South China region (e.g., Hong *et al*. 2019; Tanaka *et al*. 2019; Forel 2021; Tan *et al*. 2021), Indian Ocean (e.g., Hussain *et al*. 2004; Nishath *et al*. 2015) and Persian Gulf (Mostafawi 2003). In terms of species, Table 1 summarizes the spatial distributions of the species which are already known from previous works. Of these, six species have previously been reported from Recent sediments of Thailand: *K. multisulcus*, *K. gonia*, *S. bona*, *N. iniqua*, *S. impressa* from Mae Khlong River mount, Phetchaburi Province (Montenegro *et al*. 2004); *K. multisulcus*, *S. impressa*, *N. iniqua*, *N. columbiformis*, *S. bona* from Klong Thom estuary, Krabi Province (Yamada *et al*. 2014); *K. gonia*, *S. bona*, *N. iniqua*, from Ao Nun, Satun Province (Forel 2021). It should be noted that the works of Yamada *et al*. (2014) and Forel (2021) were conducted on the Andaman Sea, not the Gulf of Thailand.

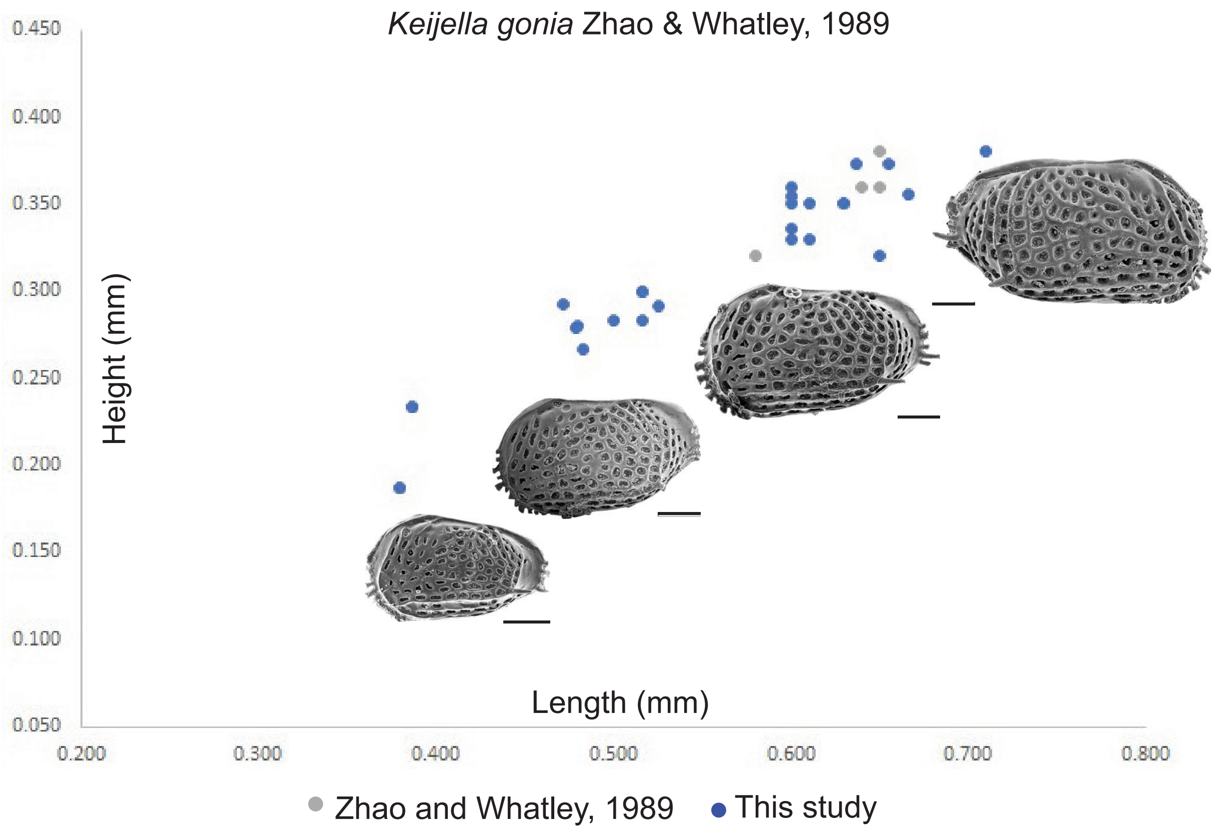

Fig. 10. Height and length scatter plots of *Keijella gonia* Zhao & Whatley, 1989 from Malaysia (grey circles) compared with specimens found from the whale-fall excavation site in Samut Sakhon Province, north of the Gulf of Thailand (blue circles). Scale bars = 0.1 mm.

Species of the family Trachyberididae are the most abundant and observed in this study, and they are also common species found in the Gulf of Thailand, Malacca Strait and Java Sea. *Keijella multisulcus* is restricted to Thailand and Malaysia (Zhao & Whatley 1988a, 1988b; Montenegro *et al*. 2004; Yamada *et al*. 2014; Forel 2021). *Keijella gonia* has been reported from Thailand and Malaysia and extended to Vietnam and Indonesia (Fauzielly 2013; Tan *et al*. 2021). *Stigmatocythere bona* is widely dispersed from Thailand, Malaysia, Indonesia (Dewi 1997) and Sri Lanka (Iwatani *et al*. 2014).

The family Schizocytheridae is the second abundant one in this study. They are very diversified in China and Malaysia (Zhao & Whatley 1988a, 1988b). Five species, namely *Neomonoceratina rhomboidae*, *N. mediterranea mediterranea*, *N. mediterranea malayensis*, *N. columbiformis* and *N. iniqua* are recovered in this study. *Neomonoceratina columbiformis* was reported from the Andaman Sea coast (Yamada *et al*. 2014). *Neomonoceratina iniqua* has been reported from the Andaman Sea coasts (Yamada *et al*. 2014; Forel 2021), Vietnam (Tan *et al*. 2021) and Japan (Ishizaki & Kato 1976).

From Table 1 *Sinocytheridae impressa* is the only species linked with the fauna from China Sea. Hong *et al*. (2019) classified the living *S. impressa* to the Subtropical Group which is dispersed from the East China Sea to the Indo-Pacific area. Tanaka *et al.* (2019) critically reviewed the occurrences of *S. impressa* from the Sea of Japan to the South China Sea and expressed that the species has records back to the Late Pliocene. *Sinocytheridae impressa* has been recovered from Recent marine sediments of Vietnam (Tanaka *et al*. 2009; Tan *et al*. 2021) and Thailand (Montenegro *et al*. 2004; Yamada *et al*. 2014). The discovery of *S. impressa* in this study reveals that *S. impressa* has inhabited in the Gulf of Thailand since at least 3300 years ago.

Paleoenvironmental interpretation

Most of the ostracod species found in this study are typical South China-Indo-Pacific shallow water taxa. The composition of the successive assemblages is quite consistent from the lower to the upper part of the section (2 meters) as shown in Figs 3–4. Thus, there should not be any abrupt change of lithology and/or ostracods before and after the whale was deposited. However, there is still a question why the samples 20SS03B, 20SS05, 20SS06 were barren of ostracods. In this study, 1187 carapaces and 1455 valves in total were sorted. The relative proportion of carapaces and valves is relatively stable across the section, ranging from 47% to 57% of complete carapaces (Table 2). Carapace features such as surface ornamentation, spines, muscle scars can be observed in many specimens suggesting that they were buried quickly after death and had been shortly transported (Oertli 1971; Frenzel & Boomer 2005). All assemblages are composed of a mixture of adults of both sexes, juveniles (*K. multisulcus*, *K. gonia*, *S. impressa*) as well as complete carapaces of tiny species such as *N. mediterranea mediterranea* and *N. mediterranea malayensis*, and delicate and transparent carapaces of *A. pellucida*, *P. bengalensis* and *P. clara*. These characteristics all indicate a relatively low energy biocoenosis (Whatley 1983; Frenzel & Boomer 2005).

The environmental distribution of *S. impressa* within the South China Sea and the Indo-Pacific region is relatively well characterized (Zhao & Whatley 1988; Yasuhara & Seto 2006; Tanaka *et al*. 2009, 2012, 2019; Alberti *et al*. 2013; Wang *et al*. 2018; Hong *et al*. 2019). Accordingly, *S. impressa* prefers euryhaline, eurythermal, and usually correlates with a nutrient rich mud substrate. It can be tolerant to turbid and low dissolved oxygen conditions. It preferentially occurs in shallow water (< 20 meters) and thrives in a wide range of environments such as inner shelf, sublittoral to intertidal, estuary and brackish water. *Sinocytheridae impressa* is also a good bioindicator of Recent benthic marine ecosystems as it has strong correlations with mud and nutrient-rich muddy to fine sandy environments (Hong *et al*. 2021a, 2021b; Tan *et al*. 2021).

Table 1. Geographical distributions of Holocene ostracods from the marine Bangkok Clay in Samut Sakhon Province, north of the Gulf of Thailand.

Region	References/Species	*Aglaiocypris pellucida*	*Propontocypris clara*	*P. bengalensis*	*Neomonoceratina columbiformis*	*N. mediterranae mediterranae*	*N. mediterranae malayaensis*	*N. iniqua*	*N. rhomboidae*	*Sinocytheridae impressa*	*Keijella multisulcus*	*K. gonia*	*Stigmatocypris bona*
Japan	Ishizako & Kato 1976							*					
	Tanaka *et al.* 2019									*			
China	Cheung *et al.* 2019									*			
	Gu *et al.* 2019									*			
	Tanaka *et al.* 2019									*			
	Yan *et al.* 2020									*			
Hong Kong	Whatley & Zhao 1987									*			
	Yim *et al.* 1988									*			
	Wang *et al.* 2018	*	*	*						*			
	Hong *et al.* 2019									*			
Vietnam	Tanaka *et al.* 2009		*							*			
	Tan *et al.* 2021							*		*		*	
Thailand	Montenegro *et al.* 2004							*		*	*	*	*
	Yamada *et al.* 2014				*			*		*	*		
	Forel 2021							*			*	*	*
Malaysia	Zhao & Whatley 1988a, 1988b				*	*	*	*	*		*		
	Zhao & Whatley 1989				*	*		*			*	*	*
	Ramlan & Noraswana 2009; 2010												
	Noraswana *et al.* 2014												
	Omar *et al.* 2017										*		
Indonesia	Dewi 1997							*					*
	Fauzielly 2013				*			*				*	
Sri Lanka	Iwatani *et al.* 2014							*					*
India	e.g., Bhatia & Kumar 1979; Hussain *et al.* 2004; 2007; 2013a; 2013b							*					
Persia Gulf	Mostafawi 2003	*		*				*					
	Paik 1977							*					

Compared with previous research in Thailand, the studied ostracod assemblage is similar to those from the Mae Klong River Mouth (Montenegro *et al.* 2004), located about 30 km southwest of the studied section (Fig. 2, Table 1). In terms of bathymetry, Montenegro *et al.* (2004) and Pugliese *et al.* (2006) considered that *K. multisulcus*, *K. gonia*, *N. iniqua*, *S. impressa* and *S. bona* correspond to a group of species that have a wide depth range because of their extensive occurrence at depth less than 18 meters. *Neomonoceratina iniqua* and *S. impressa* tolerate diverse substrate types but are absent from sand

Table 2. Relative proportions of carapaces and valves per productive sample.

Sample	Carapaces (%)	Valves (%)
20SS04_B	43	57
20SS04_A	53	47
20SS03_A	48	52
20SS02_B	37	63
20SS02_A	45	55
20SS01_B	46	54
20SS01_A	53	47

whereas *K. gonia* and *S. bona* prefer silty sand to silt. They also suggested that autochthonous ostracods were not found at stations with a salinity of 20–22‰, the rich and abundant assemblages being present at high values of salinity, dissolved oxygen content and pH. But the ostracods were not recovered from sediments collected in the Mae Khlong River channel and on the tidal flat.

The assemblage studied here from about 3000 years ago may represent conditions prior to the onset of significant anthropogenic contamination. The abundance of *S. impressa* in this study should correspond to coastal and estuarine areas with a wide range of salinity and muddy and silty substrates (e.g., Zhao & Wang 1988; Tanaka *et al*. 2009, 2019; Hong *et al*. 2019, 2021b) and the infralittoral zone (Pugliese *et al*. 2006).

The ostracod assemblage from the whale-fall excavation site therefore points to a shallow-water marine environment such as estuary, bay, inner shelf, subtidal zone, (< 20 meters depth), with a brackish to normal salinity (> 22‰), a high mud content and turbidity, on muddy substrates. The depositional environment was stable and clam before and after the whale sank. The radiocarbon dating provided an age of 3380 ± 30 years for the whale itself (Kawira & Saethien 2021; Saethien 2021), while the sediments below and above were a little older and younger, respectively. Good preservation of the skeleton owes to suitable bathymetric depth in calm condition and rapid depositional rate during sea water regression (Tanabe *et al*. 2003). In our samples, the ostracods, foraminifers and micro-mollusks are also well-preserved (Figs 4 and 8). Benthic foraminifers such as *Ammonia tepida* (Cushman, 1926) (Fig. 8J–L), *Spiroloculina* sp. (Fig. 8M), *Quinqueloculina* sp. (Fig. 8N), *Asterorotalia pulchella* (d'Orbigny, 1839) (Fig. 8O–P) are abundant in all samples. *Asterorotalia pulchella* is known to be associated with a water depth of 21–25 m in the Strait of Malacca (Minhat *et al*. 2021) and the inner shelf of the Sunda Shelf (Szarek *et al*. 2006). *Ammonia tepida* prefers areas with a high organic matter composition (Minhat *et al*. 2021).

In this study, we examined ostracods from Holocene sediments below and above the whale-fall skeleton found in Am Pang Subdistrict, Ban Paew District, Samut Sakhon Province. The locality is onshore, about fifteen kilometers away from the Recent shoreline of northern Gulf of Thailand. Numerous carapaces and valves were recovered and identified. Thirteen species were recognized. The present analysis of the ostracod assemblage provides the first characterization of the Holocene environment associated with the whale-fall. The ostracods typically correspond to a shallow marine assemblage indicating infralittoral zone at water depth less than 20 meters, brackish to normal salinity, high mud content and turbidity. The depositional environment might be estuary, bay, or inner shelf.

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