



Stratigraphy and palaeoenvironment of the Bangkok Clay (Holocene) from Samut Sakhon Province, Central Thailand

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Abstract. This study investigates the lithostratigraphy and palaeoenvironmental conditions of Holocene sediments from five boreholes in the Lower Central Plain of Thailand, with a focus on ostracod assemblages and sedimentary facies. Lithostratigraphic analyses identified five lithologic units belonging to two distinct facies representing tidal–intertidal and prodelta environments. Ostracod analysis identified 15 species, representing genera found in the Indo-Pacific and South China regions, including *Neocyprideis*, *Sinocytheridea*, *Propontocypris*, *Hemicytheridea*, *Keijella*, *Neomonoceratina*, *Aglaiocypris*, *Lankacythere*, *Cytherella*, and *Stigmatocythere*. Ostracods recovered from tidal–intertidal facies suggest transportation from shallow marine environments to tidal channels, while the greater diversity in prodelta facies indicates a more stable and favourable environment. *Neocyprideis agilis* was found abundantly in the samples, marking the oldest known record of this species in the South China Sea during the Late Holocene. The facies succession is characterised by a fining-upward trend, reflecting a shift from Lower–Middle Holocene tidal channels and intertidal flats to a Late Holocene prodelta system. These findings clarify the depositional history of the Lower Central Plain, demonstrating how tidal and marine processes shaped a dynamic, tide-dominated palaeoenvironment throughout the Holocene.

1 Introduction

The Central Plain of Thailand is divided into the Upper and Lower Central Plains. The Upper Central Plain begins in Nakhon Sawan Province, where the Ping, Wang, Yom, and Nan rivers converge to form the Chao Phraya River. In contrast, the Lower Central Plain extends southward from Chainat, covering the flat, lowland areas along the Chao Phraya River (Sinsakul, 2000). The Lower Central Plain is composed of peneplains, terraces, and active alluvial fans along its marginal zones, while the central area is shaped by floodplains of the Chao Phraya, Mae Klong, Ta Chin, and Bang Pakong river systems (Takaya, 1971; Sinsakul, 1992; Choowong, 2011). Underneath the surface, the geology of the Lower Central Plain of Thailand remains poorly

understood due to thick, unconsolidated Quaternary sediments (up to 2000 m thick) that infill Late Tertiary horst and graben structures formed by block faulting (Nutalaya and Rau, 1984). These deposits represent a complex sequence of alluvial, fluvial, and deltaic sediments as shown by geologic maps and previous research (e.g. Rau and Nutalaya, 1983; Nutalaya and Rau, 1984; Dheeradilok, 1995; Sinsakul, 1992, 2000; Tanabe et al., 2003; Choowong, 2011).

The geomorphic evolution of this region was further influenced by Pleistocene sea-level fluctuations. During the Last Glacial Maximum (~20 ka), regression exposed the Sunda Shelf, creating terrestrial deposits (Hanebuth and Statterger, 2003). Postglacial transgression peaked around 8–7 ka, flooding the Gulf of Thailand and pushing the palaeoshoreline north of Ayutthaya (Tanabe et al., 2003;

Somboon and Thiramongkol, 1992). Holocene highstands in the palaeo-Gulf of Thailand have varied regionally from 7.3–6.5, 8.0–7.0, 8.9–5.6, and 6.5–6.0 ka (e.g. Somboon and Thiramongkol, 1992; Songtham et al., 2015; Nimnate et al., 2015; Surakiatchai et al., 2018). The Bangkok Clay, a Holocene marine clay formation that underlies recent sediments (Dheeradilok, 1995; Department of Mineral Resources, 2013), preserves evidence of marine transgression and regression. Palaeontological studies have documented abundant marine fossils in these deposits. In Samut Sakhon Province (southern Lower Central Plain), a 3380 ± 30 BP whale-fall located 15 km inland from the modern shoreline (Kawira and Saethien, 2021; Saethien, 2021) and associated assemblages of microgastropods, ostracods, foraminifera, diatoms, and palynomorphs (Ketwetsuriya and Dumrongrojwattana, 2021; Chitnarin et al., 2023; Rugmai et al., 2023) have been documented. Complementary evidence comes from Nakhon Nayok Province (central Lower Plain), where molluscs, stony corals, mud lobsters, barnacles, sea urchins, and fish fossils have been discovered (Jirapatrasilp et al., 2024). Moreover, previous older studies have documented groups of organisms including molluscs, foraminifers, and pollens (Chonglakmani et al., 1983; Robba et al., 1993, 2003, 2004, 2007; Tanabe et al., 2003; Songtham et al., 2007, 2015; Negri, 2009).

Ostracods are among the most well preserved microorganisms and serve as indicators of past environmental conditions. Their bodies are encased in calcareous bivalved shells, and they inhabit a wide range of aquatic and semi-terrestrial environments (Ruiz et al., 2005; Holmes and Chivas, 2002). Moreover, ostracods are widely used in studies of sea-level change, basin evolution, plate tectonics, and palaeoceanography (Rosenfeld and Vesper, 1977; Ruiz et al., 2000; Lytle and Wahl, 2005; Yasuhara and Yamazaki, 2005; Lamb et al., 2006; Yasuhara and Seto, 2006; Yasuhara et al., 2012). However, ostracod assemblages from subsurface deposits in the Lower Central Plain of Thailand remain poorly documented, limiting their utility for chronological and palaeoecological interpretations.

In this study, our analysis focused on sediments obtained from five boreholes penetrating Quaternary deposits within the Samut Sakhon Province, in the Central Plain. In addition, we incorporated sediments from the Phanom Surin shipwreck site in the same province, which represent the most recent deposits included in this study (Jumprong, 2019; Grote et al., 2021; Rugmai et al., 2020). The objectives of this study are (1) to analyse the lithology of the sediment samples and recognise distinct lithologic units, (2) to identify ostracod species and assemblages, (3) to conduct radiocarbon (C-14) dating to determine the age of the sediments, and (4) to interpret the palaeoenvironmental conditions during deposition.

2 Materials and methods

2.1 Study site

This study analyses sediments from five boreholes and a nearby shipwreck site in Samut Sakhon Province, Central Thailand (Fig. 1). Borehole KU1 was in Ban Yang Subdistrict, Kratum Ban District, Samut Sakhon Province (13°40′06.9″ N, 100°13′13.6″ E), and reached a depth of 20 m. Borehole KU2 was in Ban Phaeo Subdistrict, Ban Phaeo District (13°36′11.6″ N, 100°11′21.2″ E), and drilled to 15 m. Borehole KU3, in Ampheang Subdistrict, Ban Phaeo District, Samut Sakhon Province (13°36′10.8″ N, 100°11′21.3″ E), had a depth of 10 m. Borehole KU4 was in Chai Mongkol Subdistrict, Mueang Samut Sakhon District, Samut Sakhon Province (13°32′22.8″ N, 100°11′22.8″ E), and was drilled from the surface at an altitude of −11 MSL to 20 m deep. Borehole KU5, located in Chai Mongkhon Subdistrict, Muang Samut Sakhon District, Samut Sakhon Province (13°32′51.0″ N, 100°11′37.0″ E), reached 34.5 m. These boreholes were strategically located across all three districts of Samut Sakhon Province, spanning in a north–south direction. Samples from the Phanom Surin (PS) shipwreck site were collected from a depth of 0.50 m below the surface. The site is located at a shrimp farm (13°33′24.1″ N, 100°23′29.9″ E), approximately 20 km east of the KU4 and KU5 boreholes.

2.2 Sedimentology and X-ray diffraction (XRD) analysis

The sediment samples were analysed for their physical and chemical properties, including colour, particle size, composition, and reaction with hydrochloric acid. X-ray diffraction (XRD) analysis was conducted to identify the mineral composition, with samples selected to represent each lithologic unit. The samples were selected from the distinct sedimentary characteristic and represent different major lithologic units. In this study we selected samples from units 2, 4, and 5. The sediment samples were dried, ground to a fine powder, and packed into sample holders for analysis using a BRUKER D2 Phaser. XRD patterns were recorded over 2θ angles ranging from 5 to 70° and 5 to 60°, with a step size of 0.02°. The resulting data were processed using Bruker Diffraction EVA software to identify the mineral phases, and the relative abundances of these phases were determined based on peak intensities. The mineralogical composition of each sample was then compared with a reference database from the study area to assess any changes in mineral composition.

2.3 Radiocarbon dating

To establish a clearer chronology of the studied levels and sites, shell material and organic-rich sediment layers from cores KU1, KU2, KU3, and KU5 were subjected to accelerator mass spectrometry (AMS) dating. A total of 20 samples

were initially sent to Beta Analytic for analysis. The second set of analyses, sponsored by the Synchrotron Light Research Institute (Thailand), included five samples of the deepest core (KU5). They comprised shells and organic sediments, which were also analysed at Beta Analytic. These cores were selected based on sediment composition, prioritising clay-rich sediment with a high content of organic matter suitable for dating, while excluding predominantly sandy units with low organic content.

2.4 Ostracod study

Although, 99 samples were collected from the five boreholes at 1 m intervals (see location site in Fig. 1). A total of 30 g of sediment from each sample was processed using the 15 % *w/v* hydrogen peroxide method (Horne and Siveter, 2016) to facilitate sediment particle separation. Disaggregated and originally unconsolidated clays, silts, and fine sands were wet-sieved to remove finer particles, with residues retained on 0.10 and 0.50 mm meshes. A similar procedure was applied to 40 sediment samples from the Phanom Surin shipwreck site (see location site in Fig. 1B), representing the levels below the shipwreck (sediments before sinking), at the same level as the shipwreck (coeval sedimentation), and above the shipwreck (sealed sediments). Although the available sample sizes were less than 10 g, the residues from wet-sieving were dried, hand-sorted under a stereomicroscope, and stored in labelled palaeontological slides. Well-preserved specimens were selected for scanning electron microscope (SEM) imaging using a JEOL/JSM-6010LV at Suranaree University of Technology. Ostracod species were identified following the classifications of Moore (1961) and Martens and Horne (2009).

3 Results

3.1 Lithologic units

The unconsolidated sediments from the bottom to the top of the sequence can be divided into six distinct units, with the complete lithostratigraphy observed in Borehole KU5 (Figs. 2, 3). Each unit is described as follows:

- *Unit 1.* This unit consists of yellowish-white silty clay containing less than 20 % very fine grained sand. It occurs below a depth of 33.5 m only in KU5. Ostracods and bivalves are not present in this unit.
- *Unit 2.* Composed of light-coloured, fine- to coarse-grained sands with pebbles, this unit contains 20 %–65 % sand-sized sediments. It occurs between 24.5 and 33.5 m only in KU5, with the sediments grading upward from medium- to coarse-grained. Mineral contents from XRD analysis from a depth of 28.25 m in KU5 contain quartz, calcite, kaolinite, muscovite, montmorillonite,

aragonite, microcline, albite, and gypsum (Fig. 2). Ostracods and bivalves are observed in this unit, specifically around 28–30 m of KU5.

- *Unit 3.* This unit features yellowish-white to reddish-brown layers interbedded with yellow stiff silty clay, silt, and silty clay containing less than 20 % very fine grained sand. It is present only in KU5 between 21.75 and 23.50 m; ostracods are present at the top of this unit.
- *Unit 4.* Comprising light-coloured, fine- to coarse-grained sands (20–65 %), this unit is observed between 14 and 20 m in KU1, between 13.5 and 15 m in KU2, between 3.5 and 20 m in KU4, and between 15.5 and 21.75 m in KU5. The selected sample for XRD analysis from 21.5 m in KU5 includes quartz, calcite, kaolinite, muscovite, montmorillonite, aragonite, pyrite, microcline, and albite (Fig. 2). Bivalves can be observed at around 14.5 m in KU2, 16 and 20 m in KU4, and 29 m in KU5, while ostracods can be found in this unit only in KU5 between 15.5 and 18 m and at the bottom of this unit. Roots are present at 20 m in KU5.
- *Unit 5.* Characterised by dark-grey, well-sorted silty clay with less than 20 % sand-sized sediments, this unit is observed across all boreholes. It occurs between 1.5 and 14 m in KU1, between 0 and 14 m in KU2, between 0 and 10 m in KU3, between 0 and 3.5 m in KU4, and between 2 and 15.5 m in KU5. XRD analysis of a sample from 13.00 m in KU5 identified quartz, kaolinite, microcline, aragonite, muscovite, montmorillonite, albite, gypsum, and halite (Fig. 2). Ostracods, bivalves, and roots can be observed at multiple depths within this unit.
- *Unit 6.* Found in KU1 from 0 to 1.5 m and in KU5 from 0 to 2 m, this unit consists of topsoil sediment composed of red and yellowish-brown silty clay. A distinct layer of reddish-brown oxidised silty clay with small fragments is present, with the reddish-brown colour indicating the presence of oxidised iron in the sediment. No ostracods or bivalves are observed in this unit.

The X-ray diffraction patterns from representative sediment samples of lithologic units 2 and 5 are presented in the Supplement.

3.2 Geochronology

The calibrated ages indicate that the shell materials from KU1, found at depths of 1.5–2.0 m, correspond to a period ranging from approximately 3291 to 2945 calibrated years BP. Similarly, shell materials retrieved from depths of 3.0–3.5 m date to around 3177 to 2845 cal BP. Shells recovered from depths of 6.0–6.5 m and 7.5–8.0 m have calibrated ages ranging from 3368 to 3055 cal BP and

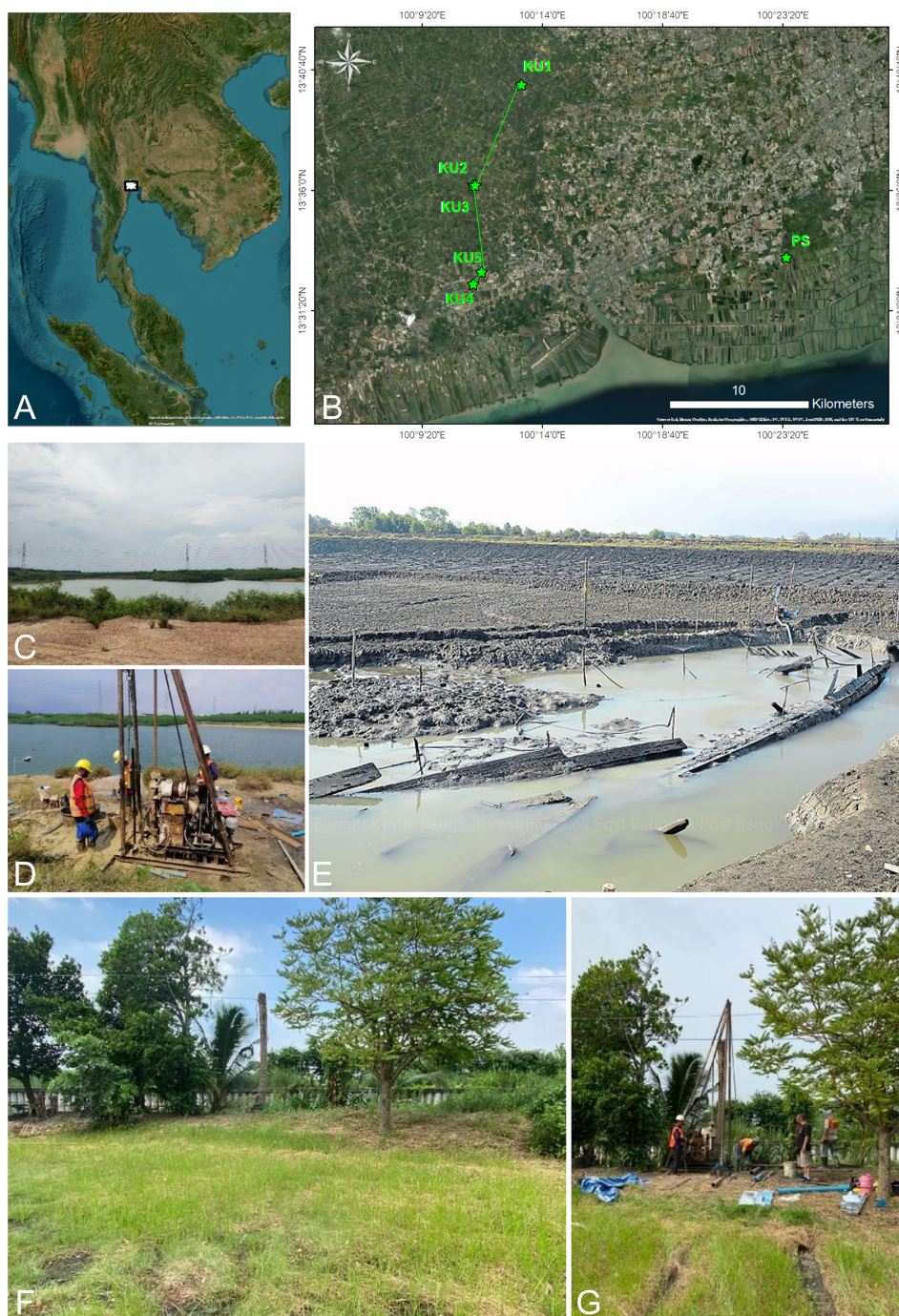


Figure 1. Map of study sites and borehole locations. (A, B) Sampling sites (maps are from Imagery © NASA, Map data © Google 2025). (C, D) Borehole KU4 area. (E) Phanom Surin shipwreck site (Bangkok Post, courtesy of Fine Arts Department). (F, G) Borehole KU2 area.

from 4242 to 3889 cal BP, respectively. Finally, the shell materials at 9.5–10.0 m are dated between approximately 4895 and 4558 cal BP (Fig. 3). A summary of the radiocarbon dates obtained in this study is presented in the Supplement.

In KU2, the calibrated ages show that shell materials found at depths of 8.5–9.0 m range from approximately 3867 to 3533 cal BP. Shells from depths of 12.0–12.5 m date to 4231

to 3881 cal BP, while the shell materials at 13.5–14.0 m have an age range of about 4440 to 4095 cal BP (Fig. 3).

In KU3, the calibrated ages show that shell materials found at depths of 0.75 m range from approximately 2756 to 2454 cal BP. Shells from depths of 6.75 m date to 3244 to 2903 cal BP, while the shell materials at 9.75 m have an age range of about 4242 to 3889 cal BP (Fig. 3).

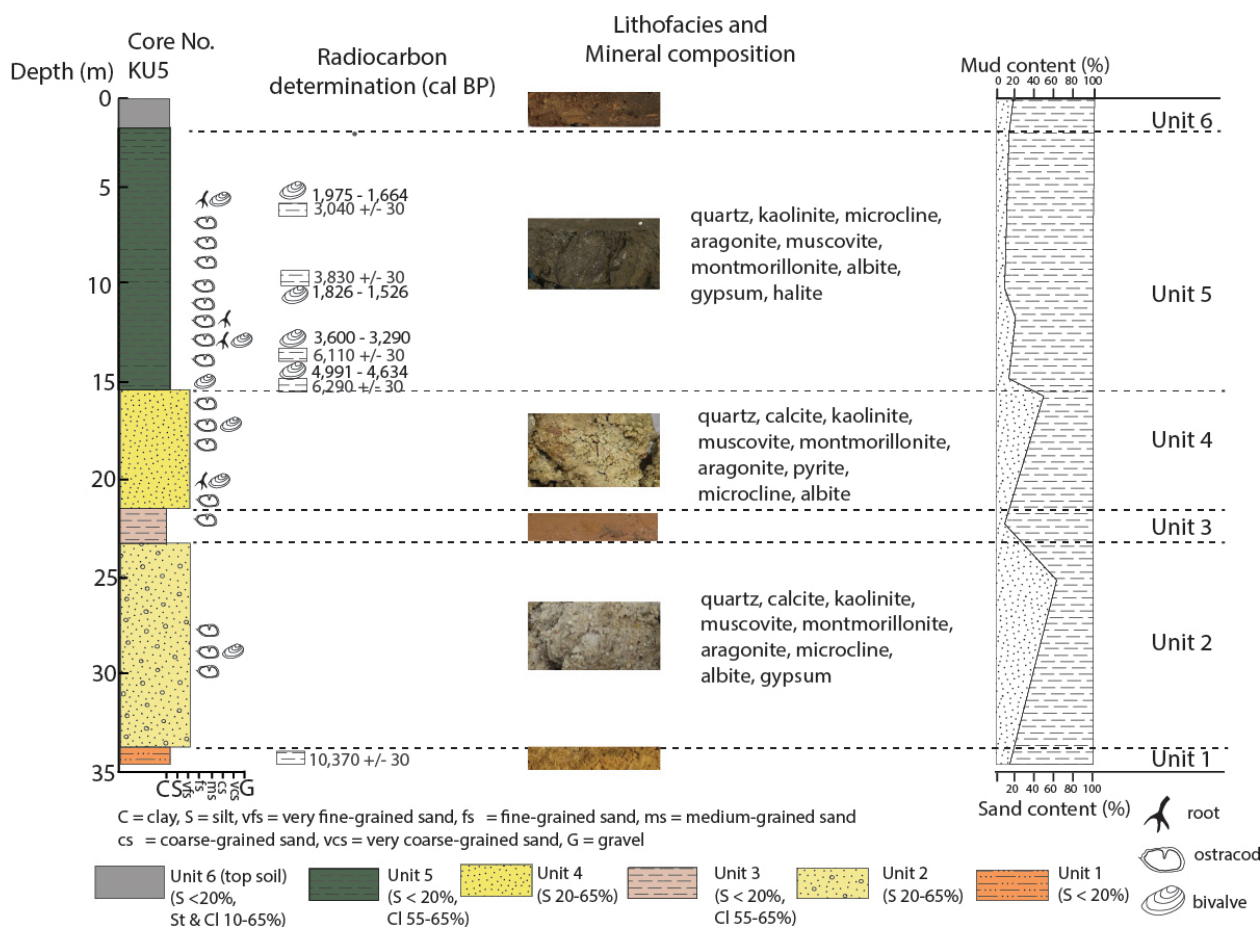


Figure 2. Lithologic column of Borehole KU5 showing lithologic units, mineral composition, occurrences of fossils, and radiometric dating results.

The calibrated ages of the shell materials retrieved from KU5 are as follows: 5.5–6.0 m (1975–1664 cal BP), 10.5–11.0 m (1826–1526 cal BP), 12.0–12.5 m (3600–3290 cal BP), and 14.5–15.0 m (4991–4634 cal BP), as shown in Figs. 2 and 3. Additionally, the calibrated ages of the organic sediments from KU5 are as follows: 6.0 m (3350–3165 cal BP), 10.25 m (4304–4146 cal BP), 13.75 m (7032–6888 cal BP), 15.0 m (7273–7160 cal BP), and 34.25 m (11 582–11 198 cal BP).

Differences were observed between the calibrated ages of shells and organic sediments, as the latter tend to appear older. This may result from the contribution of older, weathered material within the sediments. For this reason, greater reliance is placed on the shell ages when interpreting the chronology. As we do not have shell ages from the lowest unit in KU5, the age of this unit cannot be firmly designated. Nevertheless, the oldest sediment ages in KU5 do not extend beyond the lower boundary of the Holocene, estimated at 11 700 years BP (Walker et al., 2019). The dating results from this study suggest that the boundary of the Meghalayan

Stage (4200 years BP) is positioned above the lower part of Unit 5 (see Fig. 3; KU1, KU2, KU5).

3.3 Ostracod assemblages

A total of 2097 ostracod specimens were obtained from 99 sediment samples collected from boreholes KU1 to KU5. These specimens were identified as 15 species belonging to 10 genera and 7 families (Figs. 4 and 5). Additionally, 92 ostracod specimens were recovered from sediments of the Phanom Surin shipwreck site. The height and length ratio of *Neocyprideis agilis* from boreholes KU1 and 3 and the shipwreck site is presented in Fig. 6. A list of the ostracods recovered in this study can be found in the Supplement.

Given that KU5 is the deepest borehole in our study, the ostracod occurrences from this core are illustrated in Fig. 7 as a representative example.

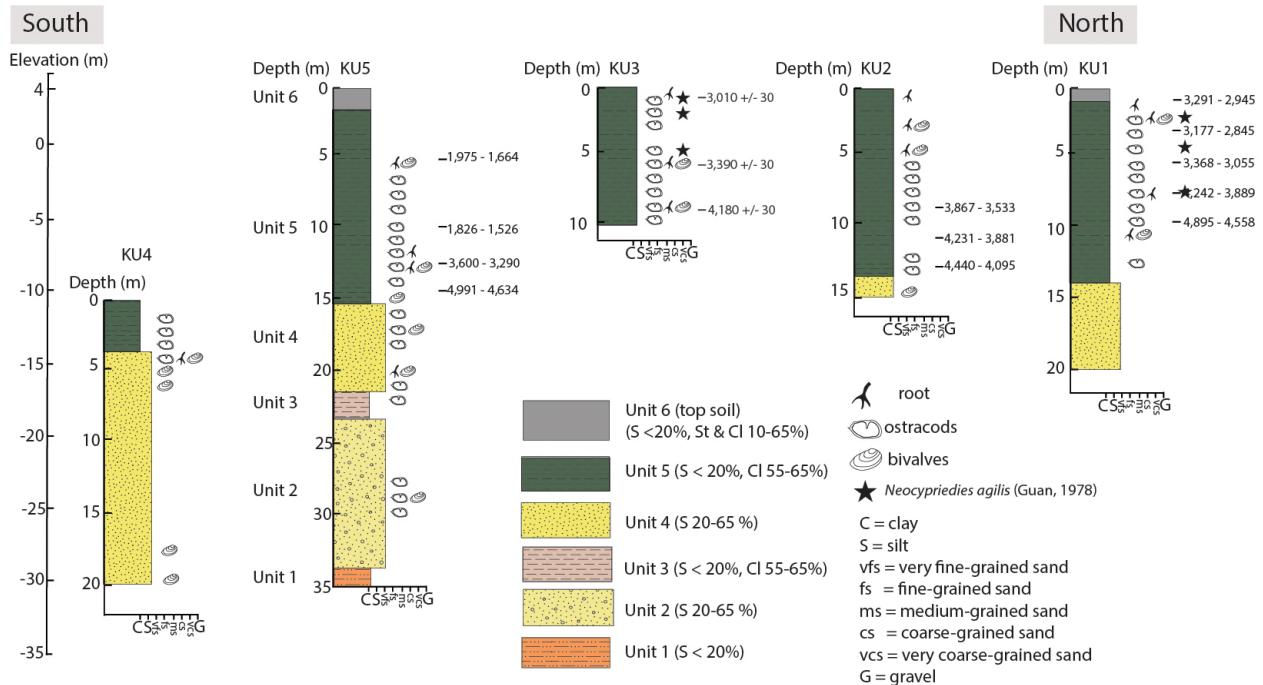


Figure 3. Lithologic columns of boreholes KU1 to KU5, positioned in the north–south direction.

4 Discussion

4.1 Lithostratigraphy

The six lithologic units identified in this study are interpreted as belonging to two distinct sedimentary facies: Facies I (tidal flat and tidal channel) consisting of units 1, 2, 3, and 4; Facies II (prodelta) represented by Unit 5, in ascending order. Although recent floodplain topsoils cover the study area, the topsoil is only observed in KU1. The boundary between the two facies lies at a depth of approximately 15 m, corresponding to the base of Unit 5. The age of this boundary, determined from shell materials, is approximately 4991–4634 years BP, while organic sediments suggest a possible age of around 6290 years BP (see Supplement). The sediments of Facies II are interpreted as deposits during the Late Holocene. While the lower boundary of Facies I remains uncertain, C-14 dating from sediments at the boundary between units 1 and 2 indicates an age of 10 370–10 400 cal BP, suggesting that the entirety of Facies II consists of Holocene sediments. Each facies is characterised by its lithology and geochemical properties.

4.1.1 Facies I: tidal flat and tidal channel

Units 1, 2, 3, and 4 are categorised as Facies I, characterised by fine- to coarse-grained sediments. According to James and Dalrymple (2010), channel-bottom deposits in the more seaward regions may contain substantial shell debris and mud clasts. The characteristics of units 2 and 4 align with de-

scriptions of channel-bottom deposits in tidal systems (Barwis, 1978; Smith, 1987; James and Dalrymple, 2010). Tidal currents play a critical role in transporting sediments within tidal channels (Fenies and Faugères, 1998), resulting in the coarse-grained sediments found in these units. Therefore, units 2 and 4 are interpreted as tidal channel deposits, likely formed in estuarine or deltaic systems.

The sediments in units 1 and 3 correspond to the intertidal zone, as they typically consist of sandy materials that gradually transition into mud, a common feature in sheltered areas associated with tidal channels (James and Dalrymple, 2010). As the tidal flat extends seaward, it transitions from river-dominated to marine-influenced conditions. Based on the lithology, units 1 and 3 are identified as intertidal deposits.

4.1.2 Facies II: prodelta

Facies II encompasses lithologic Unit 5, which represents fine-grained sedimentary deposits formed during the Late Holocene. The sediments are predominantly composed of well-sorted, calcareous, dark-grey silty clay, with a smaller proportion of fine-grained sand. Halite is present in this unit, distinguishing it from the units in Facies I. According to James and Dalrymple (2010), these sediments are interpreted as prodelta muds that extend seaward and gradually transition into fine-grained sediments on the distal basin floor. These deposits often contain calcareous components and may evolve into delta-front facies as they approach the landward direction.

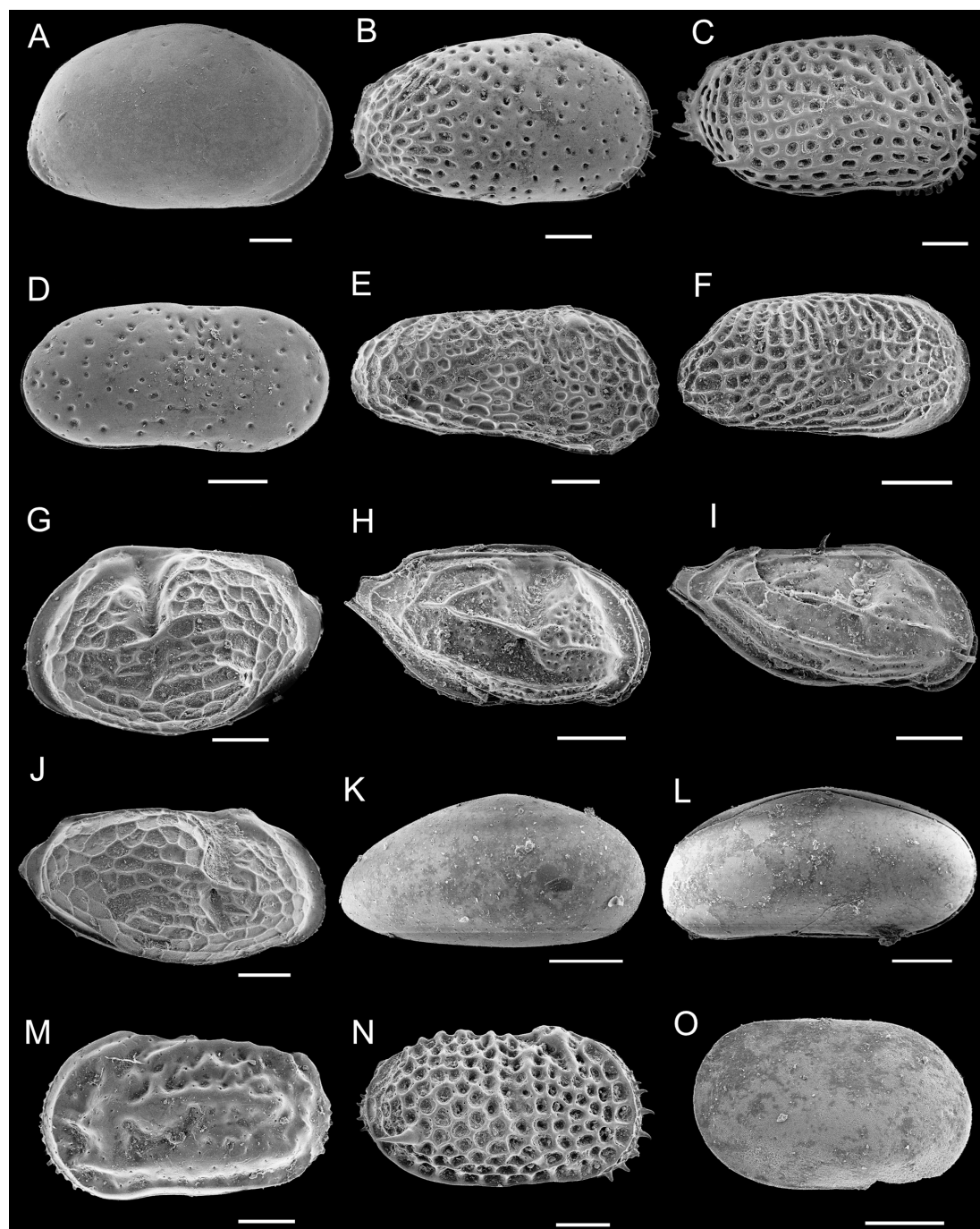


Figure 4. Scanning electron microscopic photographs of ostracods from Holocene boreholes, Samut Sakhon Province, Central Thailand. (A) *Neocyprideis agilis*, right valve, SUT-25BHKU-008; (B) *Keijella multisulcus*, right valve, SUT-25BHKU-063; (C) *Keijella gonina*, right valve, SUT-25BHKU-115; (D) *Sinocytheridea impressa*, right valve, SUT-25BHKU-041; (E) *Hemicytheridea reticulata*, right valve, SUT-25BHKU-051; (F) *Hemicytheridea cancellata*, right valve, SUT-25BHKU-057; (G) *Neomonoceratina rhomboidei*, left valve, SUT-25BHKU-147; (H) *Neomonoceratina mediterranea mediterranea*, right valve, SUT-25BHKU-151; (I) *Neomonoceratina mediterranea malayensis*, lateral valve, SUT-25BHKU-150; (J) *Neomonoceratina iniqua*, right valve, SUT-25BHKU-139; (K) *Propontocypris bengalensis*, right valve, SUT-25BHKU-153; (L) *Aglaiocypris pellucida*, right valve, SUT-25BHKU-162; (M) *Stigmatocythere bona*, left valve, SUT-25BHKU-171; (N) *Lankacythere coralloides*, right valve, SUT-25BHKU-169; (O) *Cytherella* sp., right valve, SUT-25BHKU-187. Scale bar = 0.1 mm.

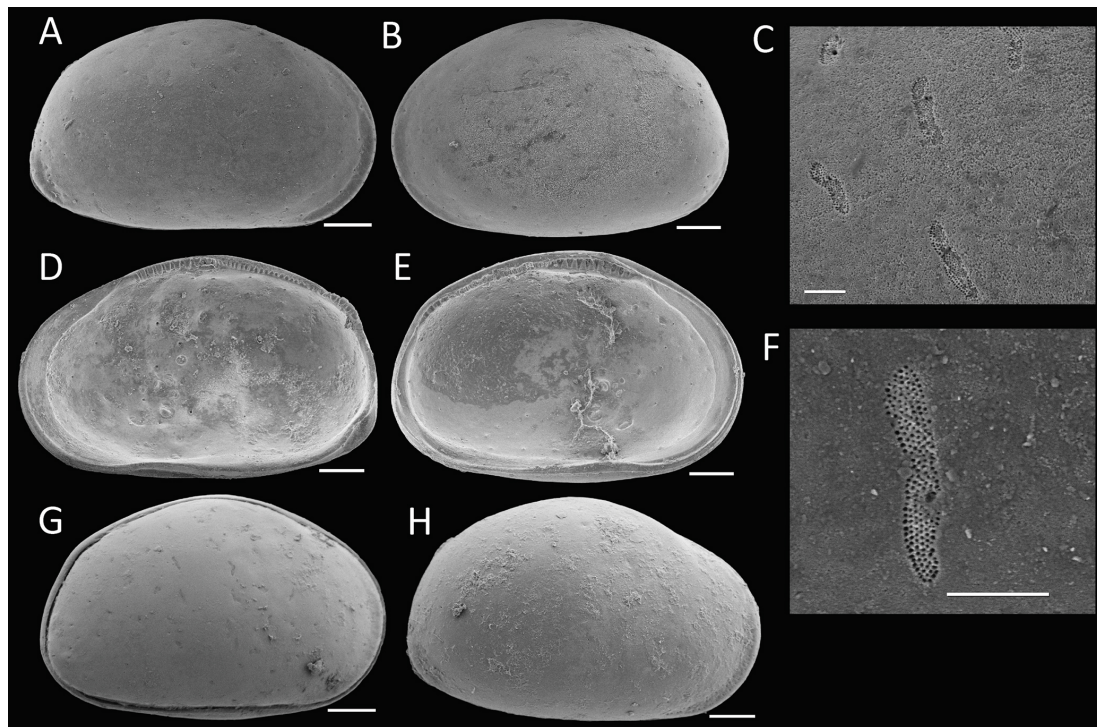


Figure 5. Scanning electron microscopic photographs of *Neocyprideis agilis* from Holocene sediments in Samut Sakhon Province in Central Thailand and in the Gulf of Thailand. (A–F) Specimens from Borehole KU3: (A) right valve, SUT-25BHKU-005; (B) left valve, SUT-25BHKU-017; (D) internal view of the right valve, SUT-25BHKU-005; (E) internal view of the left valve, SUT-25BHKU-001; (C, F) sieve pores; (G, H) specimens from the Phanom Surin shipwreck site, right lateral of complete carapace, SUT-25PS-001; (H) right valve, SUT-25PS-002. Scale bar = 0.1 mm, except (C, F) = 0.02 mm.

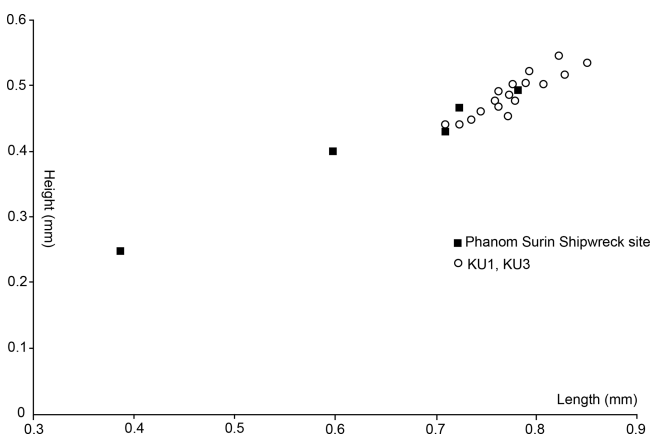


Figure 6. Height and length ratio of *Neocyprideis agilis* from Samut Sakhon Province in the Lower Central Plain of Thailand.

The absence of burrowing structures in this unit is likely due to high sedimentation rates and fluctuations in salinity within the deltaic environment, which may have inhibited bioturbation processes (James and Dalrymple, 2010). The sediments of this unit align with the lithostratigraphic description of Unit IIb (deltaic and shallow marine sediments), Subunit 1 (prodelta and seafloor sediments), as documented

by Tanabe et al. (2003). Moreover, studies on microfossils, such as microgastropods, ostracods, foraminifera, and paly-nomorphs from a whale-fall excavation site near KU4 and KU5, have reported similar lithostratigraphic units that correspond closely to the sediments in this unit (Ketwetsuriya and Dumrongrojwattana, 2021; Chitnarin et al., 2023; Rug-mai et al., 2023). The consistency between the findings of this study and previous research further supports the interpretation of Unit 5 as representing prodelta deposits associated with deltaic and shallow marine environments.

4.2 Ostracod assemblages

4.2.1 Ostracod ecology

Previous studies have documented similarities in faunal compositions among Cenozoic to recent ostracod assemblages in the Indo-Pacific and South China regions, including the Indian Ocean, the Persian (Arabian) Gulf, the South China Sea, and the Gulf of Thailand (e.g. Montenegro et al., 2004; Pugliese et al., 2006; Hong et al., 2019; Tanaka et al., 2019; Forel, 2021; Tan et al., 2021; Chitnarin et al., 2023).

A total of 15 species from 10 genera and 9 species from 7 genera were recovered from the KU and PS sediments, respectively. Among these, *Keijella gonia* is widely distributed

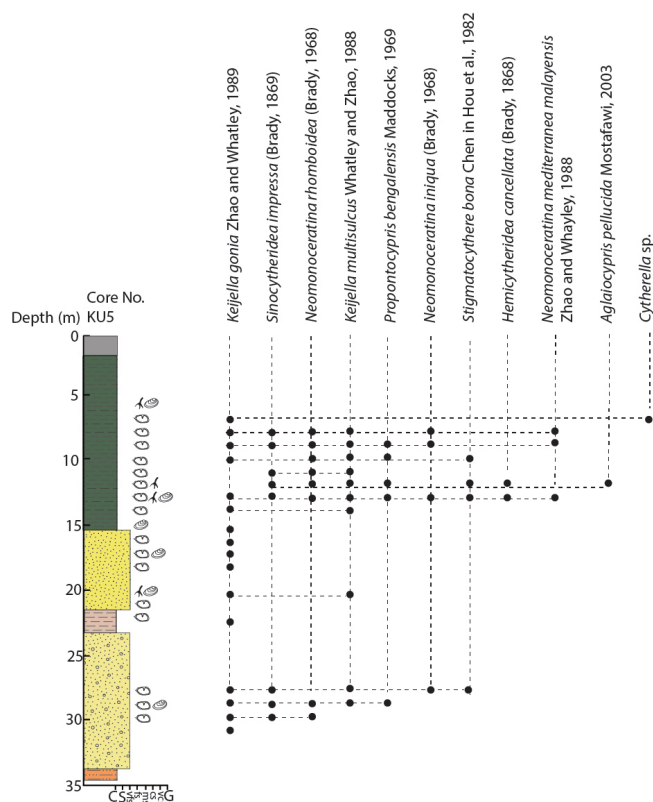


Figure 7. Occurrence and distribution of ostracods in borehole KU5, Samut Sakhon Province, in the Lower Central Plain, Thailand.

across units 2, 3, 4, and 5 (in KU5) and across PS sediments. *K. gonia*, *Sinocytheridea impressa*, *Neomonoceratina rhomboidea*, *N. iniqua*, *N. mediterranea mediterranea*, *Stigmatocythere bona*, and *Propontocypris bengalensis* are present in units 2 and 5. *Lankacythere coralloides* occurs in units 4 and 5, while *Hemicytheridea cancellata* and *Cytherella* sp. are found exclusively in Unit 5. *Neocyprideis agilis*, *K. multisulcus*, and *N. mediterranea malayensis* are recorded in both Unit 5 and PS sediments. In contrast, *Hemicytheridea reticulata* is present only in PS sediments and is absent from the core sediments.

Keijella gonia and *K. multisulcus* exhibit adaptability to a wide range of environmental conditions, enabling their persistence even in salinity-limited environments (Montenegro et al., 2004). Substrate type plays a critical role in their preservation, with silty clay and clay sediments being more conducive to ostracod preservation, whereas sandy and coarse sediments are less favourable (Montenegro et al., 2004). In this study, *K. gonia* was found in both muddy and sandy substrates (units 2, 3, 4, and 5), and *K. multisulcus* was found in units 2, 4, and 5 and PS.

Keijella gonia, *K. multisulcus*, *Sinocytheridea impressa*, *Stigmatocythere bona*, and *Neomonoceratina iniqua* occur in units 2 and 5. These species may demonstrate adaptability to

fluctuating conditions, consistent with their classification as widespread taxa according to Montenegro et al. (2004) and Pugliese et al. (2006). *K. gonia* occurs in the broadest vertical range (1–32 m), indicating eurytolerance to variables such as salinity, substrate type, and energy conditions.

The occurrence of *Sinocytheridea impressa* in units 2 and 5 is a bioindicator of marine-influenced benthic ecosystems, reflecting euryhaline conditions with nutrient-rich muddy substrates (Tan et al., 2021; Chitnarin et al., 2023). While this species typically inhabits stable marine settings, its presence in Facies I (tidal flat/channel) as isolated valves suggests post-mortem transport via tidal currents from adjacent shallow marine areas (see discussion in Sect. 4.2.2). Similarly, *Stigmatocythere bona*, a known marine taxon of East and South China Sea shelves (Whatley and Zhao, 1988; Tan et al., 2021), was identified in Facies II (prodelta). Its occurrence aligns with lithological evidence of marine conditions and corroborates prior records from Thai coastal sediments (Montenegro et al., 2004; Forel, 2021). The occurrences of *K. multisulcus*, *K. gonia*, *Stigmatocythere bona*, *Neomonoceratina iniqua*, *N. rhomboidea*, *N. mediterranea malayensis*, *Propontocypris bengalensis*, and *Sinocytheridea impressa* at a whale-fall excavation site, dated to approximately 3380 BP, further suggest their persistence and wide distribution in the region (Chitnarin et al., 2023).

Among the identified species, *Neocyprideis agilis* was found to be the most abundant, with individuals exhibiting a range of sizes. *Neocyprideis agilis* is characterised by a strongly convex dorsal margin, with a distinct posterior cardinal angle, and a broadly rounded anterior margin. This species was first described from Pliocene deposits in Guan et al. (1978), within the genus *Cytheridea*. It was later reattributed to *Neocyprideis* by Montenegro et al. (2004) and has since been documented across the Indo-Pacific region, including in the northwestern Gulf of Thailand (Montenegro et al., 2004), in Hong Kong (Hong, 2016), and as living specimens in Indonesia (Wouters, 2005). Excluding the Pliocene record, this species may have dispersed in the South China Sea region during the Holocene transgression. Its earliest Holocene occurrence is recognised in Unit 5 of this study, corresponding to the Late Holocene.

Neocyprideis agilis is present in Unit 5 (KU1 and KU3) and PS (Fig. 3), assigned to the Meghalayan Stage. The sieve pores of the valves are oblong (Fig. 5C and F); the irregular sieve pores are not recognised in our materials. Sieve pore morphology is known to have ecological significance in species such as *Cyprideis torosa*; however, corresponding reports for *Neocyprideis agilis* are lacking. Records from the Mahakam River delta in Indonesia, a river mouth in Thailand, and mudflat sediments in Java where living specimens have been found (Wouters, 2005) suggest that this species shows a preference for fine-grained environments.

Jirapatrasilp et al. (2024) reported Middle Holocene materials (8784–5318 cal yr BP) from Nakhon Nayok Province, in the central area of the Lower Central Plain, including

diverse molluscs, invertebrates, shark teeth, and fish remains. Certain molluscan taxa, such as *Cerithidea obtusa* (de Lamarck, 1822) and *Pirenella incisa* (Hombron and Jacquinot, 1848), suggest the presence of mangrove forests and intertidal mudflats, indicating environments associated with nearby rivers and estuaries. The presence of sharks, cutlassfish, and stingrays further points to coastal, shallow marine, and brackish habitats. Although we had the opportunity to examine sediment samples from their study, they contained neither brackish nor marine ostracods. According to their study, the biological materials were dated to the Northgrippian Stage, which presents results that differ from ours. Even if units 2–4 of our sequence are contemporaneous with this interval, the depositional settings must have been different, as the characteristic biological materials reported by Jirapatrasilp et al. (2024) were absent from our samples. Taken together, the ostracod assemblage points to a shallow marine environment with significant contributions of terrigenous sediments (Chitnarin et al., 2023; Rugmai et al., 2023). The presence of *Neocyprideis agilis* in the Late Holocene sediments supports influences of marginal marine environments, particularly deltas and tidal flats (Wouters, 2005).

4.2.2 Transport and taphonomy

The results of our study, particularly from Borehole KU5, show that ostracods occur in sediments at depths of up to 30 m, which may correspond to the Middle Holocene. However, all identified species are marine rather than brackish. The occurrences of *Sinocytheridea impressa*, *Stigmatocythere bona*, *Neomonoceratina iniqua*, and *Sinocytheridea impressa* in Unit 2; *Keijella multisulcus* in units 2 and 4; and *Keijella gonia* in units 2, 3, and 4 may be explained by transportation through tidal processes, possibly via tidal flats or channels. The high ratio of valves to carapaces among the recovered specimens suggests transportation prior to deposition (Boomer et al., 2003). This process was likely influenced by tidal currents, particularly in high-energy zones where tidal waves impact the shelf (James and Dalrymple, 2010). These findings suggest that the faunas may have been transported from shallow marine environments to the tidal channel environment via tidal currents. Unit 5, interpreted as prodelta muds, is notable for its diversity of ostracod species and their ecological preferences.

Rugmai et al. (2020) reported that pollen from the Phanom Surin shipwreck site was dominated by mangrove assemblages, with minor contributions from lowland and back-mangrove plants. They interpreted that the ship sank in a mangrove area influenced by tidal processes. In our samples, *Neocyprideis agilis* from the PS sediments are smaller in size compared to populations from the boreholes (see Fig. 6), and tidal sorting may have played a role in their deposition at the shipwreck site.

5 Conclusions

Based on the lithostratigraphic and geochemical data analysis of sediment from five boreholes and a shipwreck site in Samut Sakhon Province, two distinct sedimentary facies were identified in the study area. Facies I (tidal flat and tidal channel) includes units 1, 2, 3, and 4. Unit 1 is composed of yellowish-white silty clay, while Unit 2 consists of sand, silt, clay, and gravel, suggesting deposition in a tidal channel environment with low sediment salinity. Unit 3 exhibits reddish-brown interbedded silty clay, indicative of oxidation and laterisation processes, whereas Unit 4, characterised by yellowish-white-brown silty clay with shell fragments, represents intertidal deposits. Facies II (prodelta) from Unit 5 consists of calcareous dark-grey silty clay, fine-grained sand, and halite, interpreted as marine clay deposited in a prodelta environment.

Ostracods were recovered from the sediments, with 15 species identified across the boreholes. The presence of 10 genera, *Neocyprideis*, *Sinocytheridea*, *Propontocypris*, *Hemicytheridea*, *Keijella*, *Neomonoceratina*, *Aglaiocypris*, *Lankacythere*, *Cytherella*, and *Stigmatocythere*, suggests a faunal composition typical of the Indo-Pacific and South China regions. The occurrence of ostracods in units 2, 3, and 4 suggests transportation by tidal currents from shallow marine environments to tidal channels. In contrast, Unit 5 exhibits greater ostracod diversity, indicating a more stable and favourable environment for ostracod preservation. The high ratio of valves to carapaces in the recovered specimens suggests that the ostracods were transported over a short distance before deposition.

Neocyprideis agilis, a species documented at several locations across the Indo-Pacific region and described from living specimens in Indonesia, is found abundantly in core samples and river mouth sediments within the inner Gulf of Thailand. The occurrence of *N. agilis* in the South China Sea region dates back to the Late Holocene, as evidenced by its presence in Unit 5 of this study. The identified sedimentary facies reflect an upward-fining succession influenced by the interplay of fluvial, tidal, and marine processes during the Holocene Epoch. These findings suggest that the palaeoenvironment of the study area likely transitioned from tidal deposits in the Early and Middle Holocene to a deltaic environment, ranging from intertidal to prodelta conditions, during the Late Holocene.

Data availability. Data are included in the Supplement.

Supplement. The supplement related to this article is available online at <https://doi.org/10.5194/jm-44-541-2025-supplement>.

Author contributions. LW contributed to conceptualisation, designed laboratory experiments, carried out formal analyses, and wrote original drafts and visualisations. AC contributed to conceptualisation, validation, resource acquisition, writing (review), visualisations and editing, supervision, and project administration. CK carried out the investigation and reviewed the article. PT contributed to the formal analysis, writing the discussion, and editing the article.

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