

# *Gephyrocapsa kennettii* sp. nov., a new calcareous nannofossil species from the Middle Pleistocene, Solomon Sea, western equatorial Pacific

Chih-Kai Chuang<sup>1,2</sup>, Kuo-Yen Wei<sup>1,2</sup>, Horng-Sheng Mii<sup>3</sup>, Hui-Ying Suk<sup>1</sup> and Li Lo<sup>1,2\*</sup>

<sup>1</sup>Department of Geosciences, National Taiwan University, Taipei 10617, Taiwan

<sup>2</sup>Research Center for Future Earth, National Taiwan University, Taipei 10617, Taiwan

<sup>3</sup>Department of Earth Sciences, National Taiwan Normal University, Taipei 10677, Taiwan

\*corresponding author email: lilo115@ntu.edu.tw

**ABSTRACT:** Detailed examinations of middle Pleistocene sediments of ODP Hole 1115B and Core MD05-2925 in the Solomon Sea, southwest equatorial Pacific, reveal a distinctive new form of the calcareous nannofossil group of *gephyrocapsid* which has peculiar elongate kite-shaped slits on the distal shields of the coccolith. A new species, *Gephyrocapsa kennettii* sp. nov., is proposed and described in this study with SEM (scanning electron microscope) images. The coccolith of this new species is elliptical in shape, bearing 2 to 19 kite-shaped slits on the distal shield and a low-angle, raised arch-like bridge. The distal shield has fewer slits than *G. protohuxleyi* which has slits in between all elements. The bridge is orientated clockwise with a  $\sim 10^\circ$  angle to the long axis when viewed distally. The average length of the distal shield is  $3.26 \pm 0.22$  ( $1\sigma$ )  $\mu\text{m}$  ( $n = 36$ ), and, by definition, this new species belongs to the small *Gephyrocapsa* group. The chronologic range of this species is short, spanning only from 0.520–0.465 Ma. Its last occurrence datum is almost coeval with that of *Pseudoemiliania lacunosa* at the bottom of Marine Isotope Stage 12. Morphologically, *G. kennettii* sp. nov. is intermediate between *G. ericsonii* and *G. protohuxleyi* and considered to be a transitional species originated by hybridization between them.

**Keywords:** Calcareous nannofossil, *Gephyrocapsa*, ODP Hole 1115B, Solomon Sea.

## INTRODUCTION

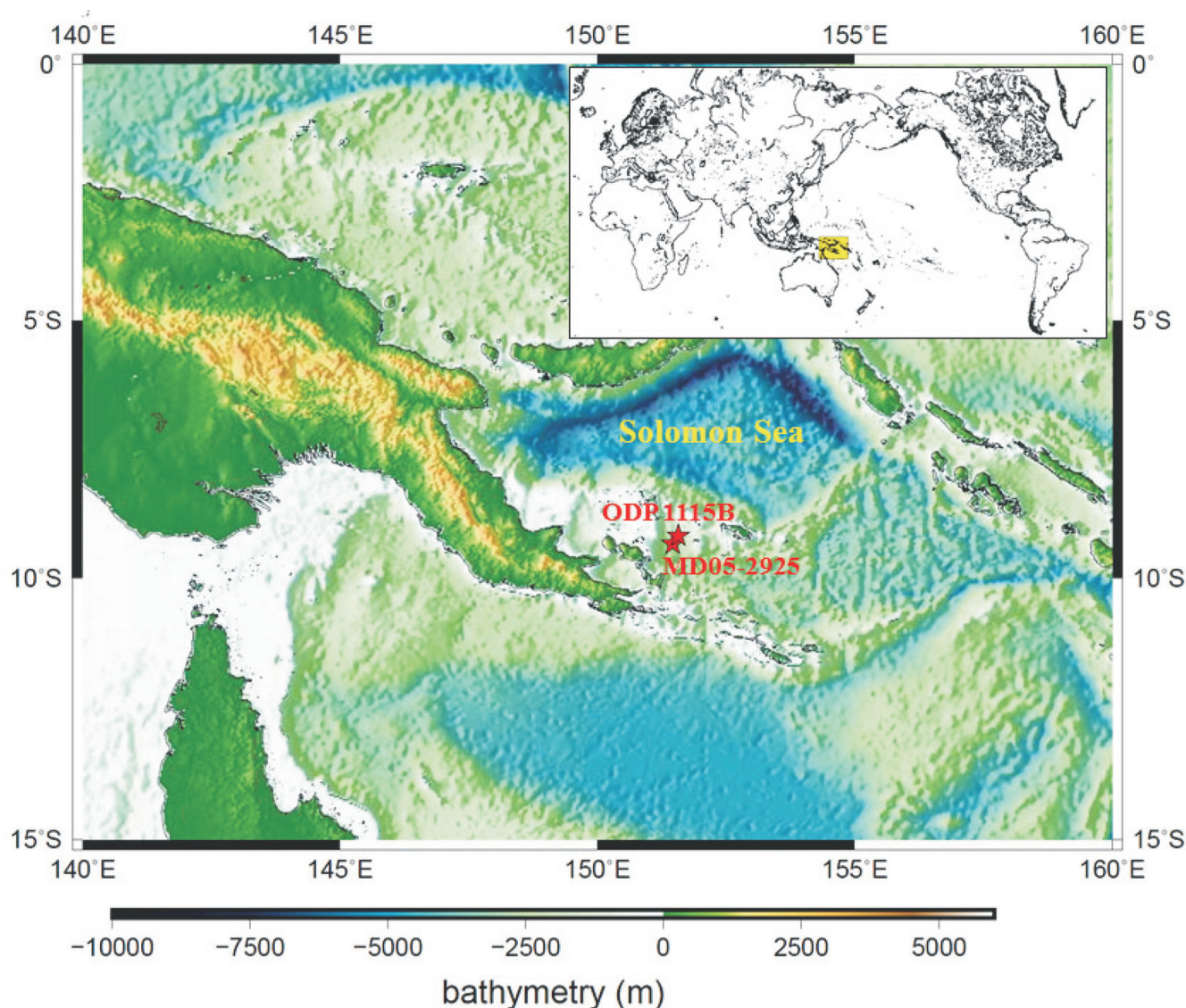
Coccolithophores are an important group of phytoplankton, underpinning food webs and carbon cycle in the ocean (Rost and Riebesell 2004). The two most abundant extant taxa belonging to the family Noëlaerhabdaceae, *Gephyrocapsa oceanica* (Kamptner 1943) and *Emiliania huxleyi* Lohmann (Hay et al. 1967), are genetically similar but have been placed in different genera based upon distinctive difference in morphology – presence of a bridge in the central portion of the placolith of *G. oceanica* whereas slits on the distal shields of *E. huxleyi* (Bendif and Young 2014). Along with *Reticulofenestra* and the extinct *Pseudoemiliania*, *Gephyrocapsa* has undergone repeated species radiations during the last 1.8 Ma, showing at least three major pulses of diversification and extinction (Hagino and Young 2015; Bendif et al. 2019). The considerable morphological variability has led to a plethora of species, subspecies and variants proposed by researchers under the genus *Gephyrocapsa*. The biological significance of the intra- and inter-species variation in the diverse morphological forms of *Gephyrocapsa* is not yet clear, but various efforts have been devoted to utilize them for stratigraphic correlation (e.g., Matsuoka and Okada 1990; Matsuoka and Fujioka 1992) and to relate them to oceanographic conditions (e.g., Bollmann 1997; Baumann and Freitag 2004).

In a detailed examination of sediment samples from ODP Hole 1115B using SEM imaging, a previous undescribed, morphologically distinct small *gephyrocapsid* is recognized. Here we propose and describe a potential new species, *Gephyrocapsa kennettii*. Two major points are made: (1) this new species may

present a sympatric speciation by hybridization of two closely related *Gephyrocapsa* species and (2) its restricted occurrence range renders it a good age marker for the MIS (marine isotope stage) 12 and 13.

In the original definition of the genus *Gephyrocapsa* Kamptner (1943) all coccoliths that possess a single bar (bridge) across the central opening were included. Later on, Kamptner (1956) used the angle between the bridge and the short axis of the elliptical central area to distinguish *G. oceanica* var. *typica* Kamptner 1943 (high bridge angle) from *G. oceanica* var. *californiensis* Kamptner 1956 (low bridge angle). The first small *Gephyrocapsa* species (size: 2–3  $\mu\text{m}$ ), *G. aperta*, was described by Kamptner (1963). Pujos-Lamy (1976), Bréhéret (1978) and Samtleben (1980) further distinguished several morphotypes within the genus *Gephyrocapsa* mainly based on measurements of length, proportion of the central area and the bridge's angle and shape. Various combinations of size, bridge angle, roundness (ratio of width/length) and other descriptive features have resulted in the separation of quite a few morphospecies within the Quaternary *gephyrocapsid* complex (Matsuoka and Okada 1990; Sato and Takayama 1992; Raffi et al. 1993; Bollmann 1997; Jordan and Chamberlain 1997). Instead of giving a formal Latinized scientific name, some of those morphotypes were labeled with numbers or letters (e.g., Matsuoka and Okada 1990).

Recent advance in phylogenomic study has shed new light on the genetic affinity of various *Gephyrocapsa* morphospecies and other related taxa. As illustrated in a series genetic studies (Bendif et al. 2015; 2016; 2019), the phylogenies based on whole genome sequences of five species in the *Gephyrocapsa*-



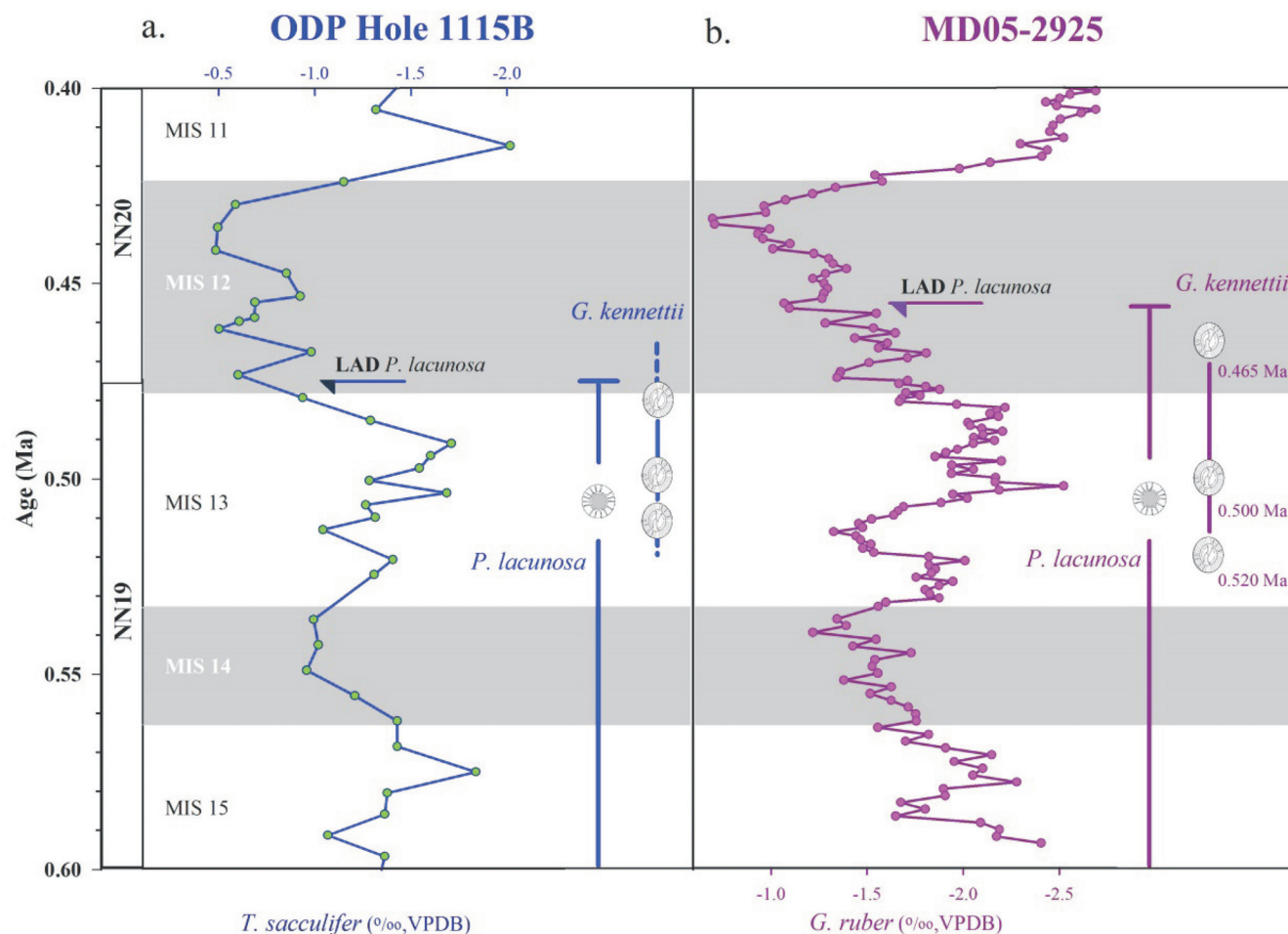
TEXT-FIGURE 1  
Location of ODP Hole 1115B and Core MD05-2925 (red stars) in the Solomon Sea, western equatorial Pacific.

*Emiliania* complex match well with that of morphologically defined taxonomy (e.g., Young et al. 2003). Noteworthy, all the studied strains of *E. huxleyi* were nested in the cluster of *Gephyrocapsa oceanica*, indicating a close phylogenetic relationship between these two species, and Bendif et al. (2019) recommended the name of *Gephyrocapsa huxleyi* should be used instead of *E. huxleyi*. On the other hand, strains of *G. muelleriae*, *G. ericsonii* and *G. parvula* (*Reticulofenestra parvula*) were clustered together (Bendif et al. 2019).

Regarding the presence of slits on their distal shields, there have been three major species of coccoliths: (1) *Emiliania huxleyi* (Hay et al. 1967) in Martini's (1971) nannofossil biozone NN21; (2) *Pseudoemiliania lacunosa* (Gartner 1969) within NN15 to NN19 and (3) *Gephyrocapsa protohuxleyi* (McIntyre 1970) in NN19. Among them, *Gephyrocapsa protohuxleyi* is the only species that possesses both bridge and slits. *Gephyrocapsa ericsonii* (McIntyre and Bé 1967), a small

*Gephyrocapsa*, is similar in morphology to *G. protohuxleyi* except they do not have any slits on the distal and proximal shield. Nevertheless, according to Samtleben (1980) some *G. ericsonii* specimens do have slits on their distal shield (Fig. 4 and 5 in Abb. 13) and were regarded to be transitional forms to *G. protohuxleyi*. The slits of those transitional forms are evenly distributed around the distal shield, being different from the kite-shaped slits on the new species *G. kennettii* presented in this study.

The new species, *Gephyrocapsa kennettii*, is found from the western equatorial Pacific with a short range between 0.520–0.465 Ma. It possesses characteristic features of both *Emiliania* and *Gephyrocapsa*, representing probably a short-lived hybridization origin. The unique features of this species, characterized with low-angle, raised arch-like bridge and several kite-shaped slits on the distal shield, are examined in detail under SEM.



TEXT-FIGURE 2

The estimated appearance ranges of new calcareous nannofossil species *Gephyrocapsa kennettii* and LAD *P. lacunosa* (last occurrence datum of *Pseudoemiliania lacunosa*) in ODP Hole 1115B (a.) and Core MD05-2925 (b.), Solomon Sea in MIS 13 and 12 with an estimated range of 0.520 to 0.465 Ma.

## MATERIALS AND METHODS

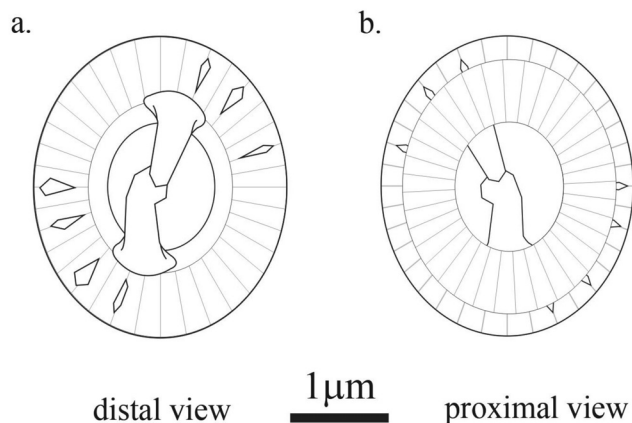
### Study sites and age models

ODP Hole 1115B (151°34'E, 9°11'S, water depth 1149 m) and MD05-2925 (151°28'E, 9°21'S, water depth 1642 m) were retrieved from the Solomon Sea, the southern periphery of the Western Pacific Warm Pool (text-fig. 1). Owing to their shallow water depths and pelagic setting the contained calcareous microfossils are abundant and well preserved without any clear differential dissolution associated with the glacial-interglacial cycles (Lo et al. 2017).

The age models of ODP Hole 1115B has been established using oxygen isotope stratigraphy based on planktonic foraminifera *Trilobatus sacculifer* (300–355 µm, without sac) with combination of magneto- and biostratigraphy (Chuang et al. 2018). The LAD (last occurrence datum) of *Pseudoemiliania lacunosa* was identified at 0.476 Ma based on quantitative counting of the species specimens (please check methods in Chuang et al. 2018).

The age model of the uppermost 19 meters of MD05-2925 has been reported for the last 0.365 Ma established by AMS<sup>14</sup>C dating of surface-dwelling planktonic foraminifera and mixed benthic foraminiferal oxygen isotope stratigraphy (Lo et al. 2017). This current study continues to extend the record to the depth interval of 19–28.4 m by following the same analytic procedures. Briefly, we picked 10 to 12 planktonic foraminifera *Globigerinoides ruber* (white, 250–300 µm, sensu stricto) and several mixed benthic foraminifera (mainly *Uvigerina* spp., >250 µm) from sieved sediments. The removal of surface impurities of the picked specimens was done by immersion in methanol with ultrasound vibration, and the specimens were rinsed in sodium hypochlorite to remove organic substances and then washed in de-ionized water. Stable oxygen and carbon isotope analysis was done with the Micromass IsoPrime mass spectrometer at the Department of Earth Sciences of National Taiwan Normal University. The isotopic data are reported relative to Vienna Pee Dee belemnite (V-PDB) standard through the calibration of NBS-19 (National Bureau of Standards; δ<sup>13</sup>C = 1.95‰,





TEXT-FIGURE 3

A schematic sketch of the new species *Gephyrocapsa kennettii* coccolith distal (a.) and proximal (b.) view.

$\delta^{18}\text{O} = -2.20\text{‰}$ , Lo et al. 2013). Average reproducibility based on replicate analyses of NBS-19 was  $\pm 0.03\text{‰}$  (1 standard deviation) for  $\delta^{13}\text{C}$  and  $\pm 0.08\text{‰}$  for  $\delta^{18}\text{O}$  ( $n = 9$ ).

Both oxygen isotopic records of ODP Hole 1115B and MD05-2925 have been correlated to the global benthic foraminiferal composite LR04 curve (Lisiecki and Raymo 2005). In sum, the extended part of Core MD05-2925 covers the age interval of 0.365–0.594 Ma (text-fig. 2). The last occurrence of *Pseudoemiliana lacunosa* from MD05-2925 is identified at 2245–2250 cm, which corresponds to 0.449–0.450 Ma (similar age in western Atlantic Ocean for Raffi et al. 2006), slightly younger than the age of 0.476 Ma in ODP Hole 1115B.

#### Coccolith measurements

Traits such as coccolith size, elliptical outline and a bridge crossing the central opening, characterize the morphology of *gephyrocapsids*, easily to be observed under polarized optical microscope at 1000x magnification. But, on the other hand, the detailed features, including the shape and the number of slits present on the shields are hard to discern under light microscope because of its limited resolution. We used the FE-SEM (Field Emission Scanning Electron Microscopy) housed at the Department of Geosciences in National Taiwan University to obtain high quality photographic images at 30–60 thousands magnification.

We found a new *Gephyrocapsa* form in both cores in the sediments of 0.520–0.465 Ma (text-fig. 2). Morphometric measurements of the digitized SEM micrographic imageries were conducted using free software ImageJ, a Java based application program for analyzing image (<https://imagej.en.softonic.com>). The length and width on the distal shield and the angle between the diagonal bridge and the long axis of the distal shield (Plate 1) were measured. The scale was set as 1  $\mu\text{m}$  equals to 160 to 240 pixels (40–60 thousands magnification). The measurement error was less than 0.01  $\mu\text{m}$  throughout the measurement.

#### SYSTEMATIC PALEONTOLOGY

Family NOËLAERHABDACEAE Jerkovic 1970 emend. Young and Bown 1997

Genus *Gephyrocapsa* Kamptner 1943

*Gephyrocapsa kennettii* Chih-Kai Chuang, Kuo-Yen Wei, Horng-Sheng Mii, Hui-Ying Suk and Li Lo sp. nov.

Plate 1, figures a–b; Plate 2, figures a–n

**Morphology Description:** Placolith, oval in plain view, convex distally, concave proximally with a large elliptical central pore and a bridge crossing the pore on the distal surface of the shield. It is characterized by the presence of several elongate, kite-shaped slits on the distal surface. These slits developed along with the elements sutures (schematic sketch of new species, text-fig. 3). The longest lengths of the distal shield are generally less than 4  $\mu\text{m}$ , attributing this species to be a member of the small *Gephyrocapsa* group (<4  $\mu\text{m}$ , Raffi et al. 1993).

**Holotype:** Plate 1, figure a, of this study, from ODP Hole 1115B, 3H2W, 90–92 cm, electron micrograph plate stored at National Taiwan Museum, Museum catalog B01015 and B01016.

**Isotypes:** Plate 2, figures a–n. of this study, from ODP Hole 1115B, 3H2W, 90–92 cm, Museum catalog B01015 and B01016 (National Taiwan Museum).

A total of 36 specimens including the holotype and isotypes were measured. This sample contains abundant, well-preserved specimens of *G. kennettii*. The main characteristics of this species are described quantitatively in below:

1) The lengths of the distal shield range from 2.9 to 3.6  $\mu\text{m}$ , with an average of  $3.26 \pm 0.22$  (1 $\sigma$ )  $\mu\text{m}$  ( $n = 36$ ). The width measures between 2.4 to 3.1  $\mu\text{m}$ , with an average of  $2.71 \pm 0.21$  (1 $\sigma$ )  $\mu\text{m}$  ( $n = 36$ ). Ratio of the two axes is averaged to be  $0.83 \pm 0.02$  (1 $\sigma$ ), ( $n = 36$ ).

2) The new species is characterized with its elongate kite-shaped slits on the distal shields and a low-angle, raised arch-like bridge. The numbers of slits range from 2 to 19 in the Isotypes sample, the common numbers of slits range from 3 to 8 ( $n = 30$ ). But on the proximal shield there is no slit at all. This differs from any other similar *Gephyrocapsa* species. For instance, *G. protohuxleyi* has many slits both on the distal and proximal shield (Plate 1, figure c–d.).

3) A bridge arches obliquely across the central pore on the distal side, orientated clockwise with a  $\sim 10^\circ$  angle ( $10.5^\circ \pm 1.5^\circ$ , 1 $\sigma$ ,  $n = 36$ ) with the longest axis when viewed from the distal side. This fixed and small angle differentiates the species from the rest species of *Gephyrocapsa* genus, since most of them have their bridges at much wider and random angles with the long axis (Bollmann 1997; Flores et al. 1999).

4) *Gephyrocapsa kennettii* has a large opening in the central area. This makes the species differ from other small *Gephyrocapsa* (e.g., *G. ericsonii* and *G. protohuxleyi*). These other small *gephyrocapsid* specimens have reticulo-central structure opening (Plate 1, figure c–d and Plate 2, figure o–p).

**Derivation of name:** *Gephyrocapsa kennettii* is named in honor of Dr. James P. Kennett, Santa Barbara Campus, University of California for his distinctive contribution to paleoceanography.

TABLE 1

List of sediment samples studied in ODP Hole 1115B and MD05-2925. # indicates revised composite depth of ODP Hole 1115B. Please check Chuang et al. (2018) for details.

| Core       | Samples      | Depth* (cm) <sup>#</sup> | Age (Ma) | Number of <i>G. kennettii</i> specimens |
|------------|--------------|--------------------------|----------|---|
| ODP 1115B  | 3H3W 95–97   | 2113                     | 0.521    | 0                                       |
|            | 3H3W 35–37   | 2053                     | 0.510    | 12                                      |
|            | 3H2W 90–92   | 1958                     | 0.500    | 44                                      |
|            | 3H1W 100–102 | 1818                     | 0.480    | 7                                       |
|            | 3H1W 0–2     | 1718                     | 0.461    | 0                                       |
| Depth (cm) |              |                          |          |   |
| MD05-2925  | 2602–2603    | 2602                     | 0.520    | 11                                      |
|            | 2511–2512    | 2511                     | 0.500    | 37                                      |
|            | 2307–2308    | 2307                     | 0.465    | 21                                      |

### STRATIGRAPHIC DISTRIBUTION

Besides the holotype and isotypes designated from sample ODP Hole 1115B, 3H2W 90–92 cm (depth\* at 1958 cm, ~0.5 Ma). *Gephyrocapsa kennettii* specimens have been recognized by SEM examination of sediment of other intervals in the same core (3H1W 100–102 cm, 3H3W 35–37 cm), and sediments from the nearby Site MD05-2925 at several stratigraphic depths, including samples of 2511–2512 cm, 2307–2308 cm and 2602–2603 cm. We also scrutinized samples from 3H1W 0–2 cm and 3H3W 95–97 cm of ODP Hole 1115B under SEM but none of *G. kennettii* was found (detail sample list in Table 1).

Based on the age model described above, *G. kennettii* existed between 0.520 to 0.465 Ma in the Solomon Sea (text-fig. 2). Its short appearance qualifies this species as a good age marker for the uppermost of MIS13 and the lowermost of MIS 12, straddling the boundary of NN19 and 20, and sheds new light for detailed stratigraphic correlation as well as biogeographic study in equatorial regions.

### DISCUSSION

The genus *Gephyrocapsa* in the Pleistocene embraces a complex of species. *Gephyrocapsa ericsonii* (McIntyre and Bé 1967) is a common small *Gephyrocapsa* form. It is characterized by being small (coccolith length ~ 2 µm) and having a highly arched bridge made of two blade-like elements (McIntyre and Bé 1967). In the Solomon Sea core sediments, *G. ericsonii* (Plate 2, figure o.), *G. protohuxleyi* (Plate 2, figure p.) and *G. kennettii* co-existed.

*Gephyrocapsa kennettii* has a very short occurrence range. In contrast, *G. protohuxleyi* originated at 1.78 Ma (Haq et al. 1977; Obradovich et al. 1982) and it is still living at present (Winter et al. 1978). Matsuoka and Okada (1990) differentiated two types of *G. protohuxleyi*: *G. protohuxleyi* (s.s.) and *G. protohuxleyi* var. A. *Gephyrocapsa protohuxleyi* var. A, presented in high abundance before the extinction level of *P. lacunosa* with varied durations in the Pacific and Indian Ocean (0.75–0.62 Ma in the northwestern Pacific Ocean, Matsuoka and Okada 1989;

1.2–0.46 Ma in the Indian Ocean, Matsuoka and Okada 1990) whereas *G. protohuxleyi* (s.s.) has existed for the last 0.3 Ma (Matsuoka and Okada 1990). In Matsuoka and Okada (1989, 1990) *G. protohuxleyi* var. A was grouped in small *Gephyrocapsa* (< 2.5 µm) and considered as one of the variants belonging to *G. protohuxleyi*. Since the chronologic range of *G. protohuxleyi* var. A (1.2–0.46 Ma, Matsuoka and Okada 1990) overlaps with that of *G. kennettii*, we need to examine in detail whether these two taxa belong to a common species or not. A total of five electron micrographs of *G. protohuxleyi* var. A were shown in their Plates by Matsuoka and Okada (1989, 1990). All the micrographs show the presence of slits all around the distal shields and one of them clearly on the proximal shield. The slits between the elements extend all the way to the rim, making the margins of distal shields rugged. The elements of the distal shields are no longer or barely T-shaped, being distinctively different from that of *G. kennettii*. Plate 1 of this current study demonstrates the difference as well.

It has been suggested that the sequence *Gephyrocapsa* sp.-*G. protohuxleyi* and *E. huxleyi* represents a phylomorphogenetic lineage (McIntyre 1970; Matsuoka and Okada 1990) where the so-called *G. protohuxleyi* var. A (Matsuoka and Okada, 1989) represents the transitional type between the typical *G. protohuxleyi* (s.s.) and *G. ericsonii* (McIntyre 1970). Some specimens of the *G. protohuxleyi* var. A observed by Matsuoka and Okada (1990) do not have slits, in showing a transitional gradation nature from small *Gephyrocapsa* to slited *G. protohuxleyi*. This is consistent with the observation by Samtleben (1980) who observed that some *G. ericsonii* specimens bear slits and considered them to be transitional forms to *G. protohuxleyi*. This is in part why *G. protohuxleyi* was once considered to be a synonym of *G. ericsonii* (Cros and Fortuño 2002).

*Gephyrocapsa ericsonii* and *G. aperta* have been treated as members of a closed related small-sized *Gephyrocapsa* complex that shows several dominant peaks prior to the origination of *E. huxleyi* ever since 0.77 Ma (Toledo et al. 2016). *Gephyrocapsa aperta* itself has existed at least for the last 2 Ma (Hine and Weaver 1998). Throughout the whole Quaternary, both *G.*

The hybridization interpretation is supported by recent studies of the extant *Gephyrocapsa/Emiliania* complex. In a morphological and phylogenetic study of three coccolithophore strains corresponding to *G. muelleriae* Bréhéret, Bendif et al. (2015) found that both plastidial and mitochondrial gene phylogenies placed these strains within the *E. huxleyi* clade and well separated from the *G. oceanica* isolates. It was suggested that hybridization and introgression between *Emiliania* clade and older *Gephyrocapsa* clades has occurred in the near past and the genus *Emiliania* might be better placed in the genus *Gephyrocapsa* (Bendif and Young 2014; Bendif et al. 2015). Such kind reticulate evolution might have involved more genus and species belonging to the family Noëlaerhabdaceae, including *Emiliania*, *Gephyrocapsa* and *Reticulofenestra parvula* (Bendif et al. 2016; 2019). Furthermore, the findings of combination coccospheres of one heterococcolith being associated with two or even three kinds of holococcolithophorids has led to the suggestion that hybridization occurs between the gametes of two haploid holococcoliths (Geisen et al. 2002). In summary, it appears that all such gene phylogenetic studies suggest that hybridization does exist among these small Noëlaerhabdaceae coccolithophores although morphologically they are recognizable as different genus and species.

Matsuoka and Okada (1990) documented three size variation cycles of *Gephyrocapsa* during the past 1.8 Myr, each of them showed a gradual expansion of size diversity and then punctuated by an abrupt reduction of size variance. Hagino and Young (2015) named these three cycles MO (Matsuoka–Okada) cycles. As inferred from relaxed molecular clock of the genome sequence data, the most recent common ancestor of the extant

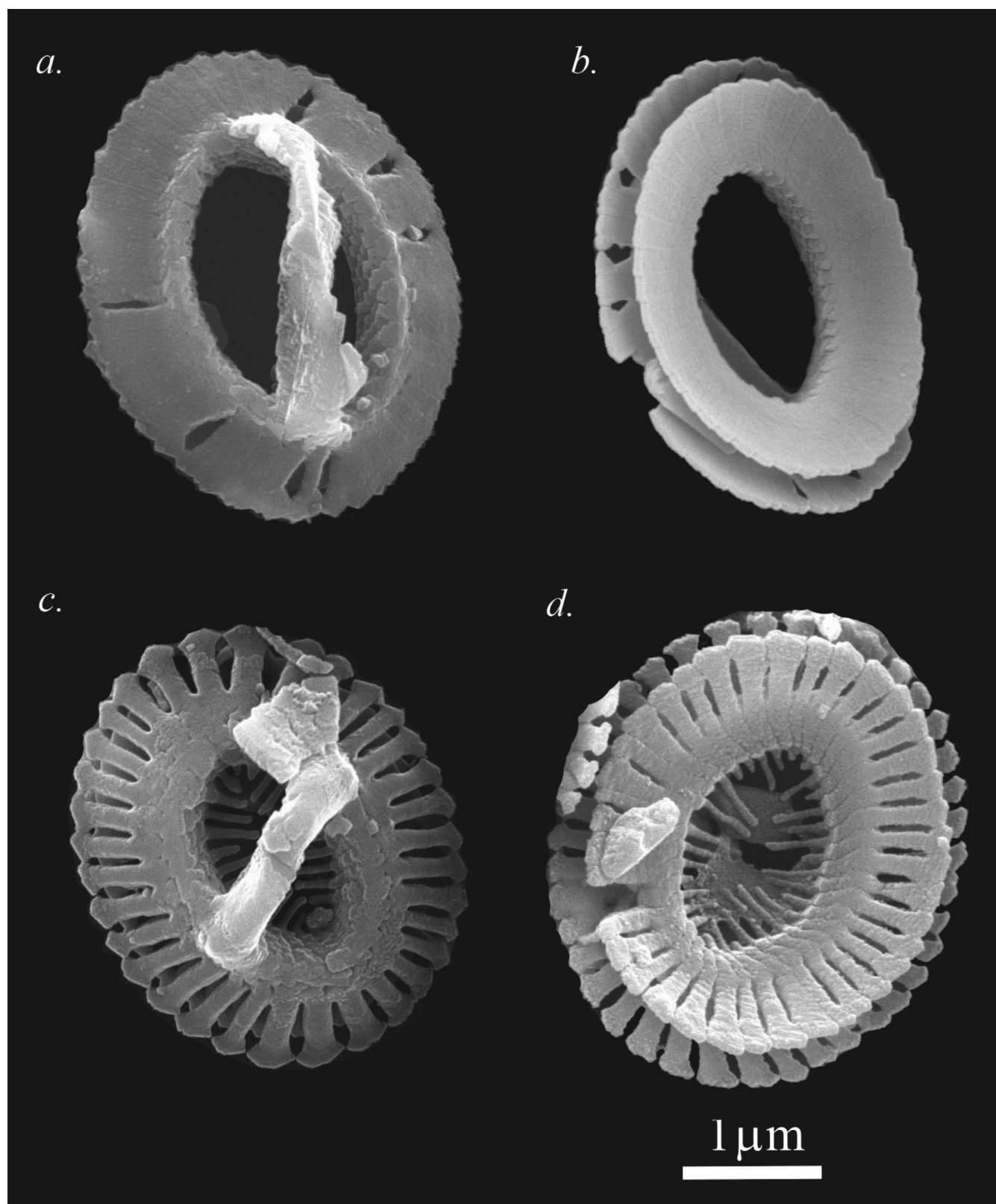
*Gephyrocapsa* species (*G. oceanica*, “*G. huxleyi* and *G. parvula* as defined by Bendif et al. 2019) arose around 0.553 Ma, signifying the onset of the last MO cycle. The origination of *G. kennettii* (0.520 Ma) occurred coincides with the early part of this radiation pulse. Concomitantly, a series of other pronounced evolutionary events took place in the Noëlaerhabdaceae family during the first half of the MO cycle 3: (1) a sudden increase of *G. caribbeanica* at about 0.56 Ma (Baumann and Freitag 2004); (2) the extinction of *Pseudoemiliania lacunosa* at about 0.47–0.45 Ma (Hagino and Young 2015; Chuang et al. 2018); (3) a gradual increase of large and medium-sized *Gephyrocapsa* at the expense of small *Gephyrocapsa* and *G. caribbeanica* at about 0.28 Ma (Baumann and Freitag 2004); (4) the first appearance of *E. huxleyi* at about 0.290–0.255 Ma (Hagino and Young 2015; Chuang et al. 2018). The short-lived appearance of *G. kennettii* is just one of the evolutionary events manifested in this phase of species radiation of *Gephyrocapsa*. We should emphasize that the onset of the latest pulse of *Gephyrocapsa* coincided with the end of the MPT (Mid-Pleistocene Transition) when the regular, high-amplitude 100-kyr periodicity became dominant the marine oxygen isotope variation. The larger fluctuation in sea surface temperature and greater migration of oceanic fronts (Flores et al. 1999; Bard and Rickaby 2009) at this time might have enhanced geographic isolation for marine protists and facilitated speciation.

## CONCLUSION

# PLATE 1

- a *Gephyrocapsa kennettii* sp. nov. Holotype, distal view, ODP Hole 1115B 3H2W 90–92 cm.
- b *Gephyrocapsa kennettii* sp. nov., proximal view, MD05-2925 2511–2512 cm.
- c *Gephyrocapsa protohuxleyi*, distal view, MD05-2925 2602–2603 cm.
- d *Gephyrocapsa protohuxleyi*, proximal view, ODP Hole 1115B 5H6W, 35–37 cm.





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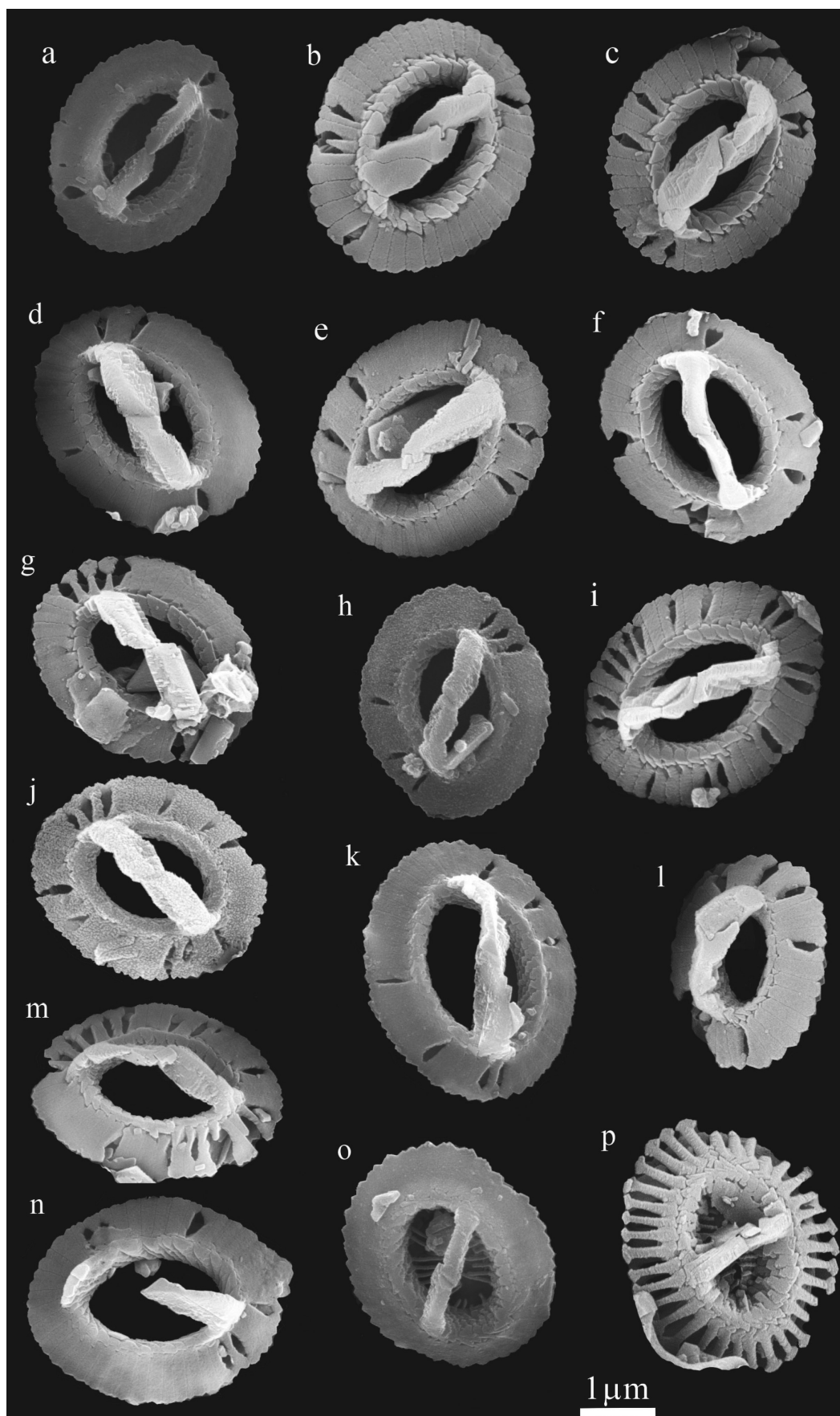
## PLATE 2

Scanning electron micrographs. Scale bar represents 1 µm.

- a-n *Gephyrocapsa kennettii* sp. nov., in ODP Hole 1115B 3H2W, 90–92 cm. Isotypes, distal view.
- o *G. ericsonii*, distal view, in ODP Hole 1115B 3H2W, 90–92 cm.

- p *G. protohuxleyi*, distal view, in ODP Hole 1115B 3H2W, 90–92 cm.





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