

MICROPALAEONTOLOGY NOTEBOOK

Two rare silicoflagellate double skeletons of the Star-of-David configuration from the Eocene

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ABSTRACT – Two, rare double skeletons of *Corbisema* silicoflagellates have been observed from Early and Middle Eocene sediments. Both specimens are in the Star-of-David configuration, with the basal corners of each skeleton aligned with the middle of sibling basal sides. These specimens are of a species that has an elongate basal ring, which shows that skeletons are flipped 180° with respect to one another, rather than simply rotated.

KEYWORDS: *silicoflagellates, double skeletons, Eocene*

INTRODUCTION

The life cycle and biology of silicoflagellates are only partially understood – Loeblich *et al.* (1968) and Moestrup & Thomsen (1990) illustrated and discussed some basic biological parameters of living specimens, for example. One of the poorly documented aspects of silicoflagellate biology and fossil record is the formation of double skeletons, or doublets. Here, we focus on recent discoveries of unusual double skeletons from the Early and Middle Eocene.

Silicoflagellate double skeletons are rarely observed in the fossil record, since the two skeletons easily disarticulate during life, deposition and the processing of sediment samples. McCartney *et al.* (2010a) presented in this journal the first observed silicoflagellate double skeleton from the Cretaceous. This specimen was especially unusual because the basal rings of the sibling skeletons were rotated into a ‘Star-of-David’ configuration which is different from more typical double skeletons that have an alignment of the basal corners and spines. Two double skeletons of this configuration, also of the fossil genus *Corbisema* recorded here, were illustrated by Schulz (1928) from the Fur Formation of Denmark. Notably, however, other *Corbisema* double skeletons (Bachmann, 1970; Dumitrică, 1974; Bukry, 1987) are in the corner-aligned configuration.

Two more *Corbisema* double skeletons in the Star-of-David configuration have been recently observed and are presented in this paper. These specimens provide photographic evidence that the Star-of-David configuration persisted from the Late Cretaceous into the Cenozoic. Both specimens reported here are also of a species that has an elongate basal ring and thus show that the sibling skeletons are flipped 180° rather than rotated 30°, as could be interpreted from an equal-sided species of *Corbisema* (McCartney *et al.*, 2010a). Thus, the newly discovered specimens provide additional information on how the sibling skeletons relate to one another in the Star-of-David configuration.

SPECIMEN FROM THE IVDEL’ REGION, RUSSIA

Sediment samples of Cretaceous to Palaeogene age originating from multiple sites located in the Urals region of Russia were studied by Jousé (e.g. 1949, 1951) and recently relocated in the collection of the Geological Faculty, Moscow State University

(Witkowski *et al.*, 2012). No precise locality and age data are available for these samples, other than catalogue cards that usually give a general indication of the sampling region and a broad age assignment.

During a survey of Palaeogene samples from the Jousé sample suite, a double skeleton of *Corbisema hastata* (Lemmermann) Frenguelli (Frenguelli, 1940) was observed (Fig. 1a). The specimen is partially filled with matrix, which obscures the apical structures and pikes. However, it is the matrix that holds the sibling skeletons together. The specimen was found in sample 28, which – according to its accompanying catalogue card – was collected in ‘Ivdel’ region, eastern slopes of Northern Urals’, which is located in the Sverdlovsk District. Despite many hours of careful search in numerous slides of the same sample, no further double skeletons were found.

The precise age of the Ivdel’ specimen is unknown. The catalogue card for sample 28 states ‘Eocene’. Gleser (1964, 1966) reported on silicoflagellates and diatoms from two wells in the Ivdel’ area, with siliceous microfossil-bearing sediments dated as Early through Late Eocene. The diatom assemblage in sample 28 comprises rare *Solium exsculptum*, which is indicative of Early Eocene age (Fenner, 1985). This is consistent with the absence of *Distephanosira architecturalis*, a common Middle to Late Eocene zonal index species (Fenner, 1985). Therefore, an Early Eocene age seems appropriate for the double skeleton that we report from the Ivdel’ area.

SPECIMEN FROM THE LOMONOSOV RIDGE, ARCTIC OCEAN

A second specimen of *C. hastata* (Fig. 1b) has been found recently by KA in a sample from Integrated Ocean Drilling Program Leg 302 (also known as the Arctic Coring Expedition; ACEX). This specimen can be confidently dated as Middle Eocene in age (for detailed stratigraphy see Stickley *et al.*, 2008). A detailed presentation of the silicoflagellates from this expedition is provided by Onodera & Takahashi (2009). Both skeletons are complete, with exterior surfaces covered with a reticulate ornamentation and the interior surfaces being smooth.

The major axes of the sibling skeletons roughly coincide, with the basal elements near the major axis corner of each skeleton in

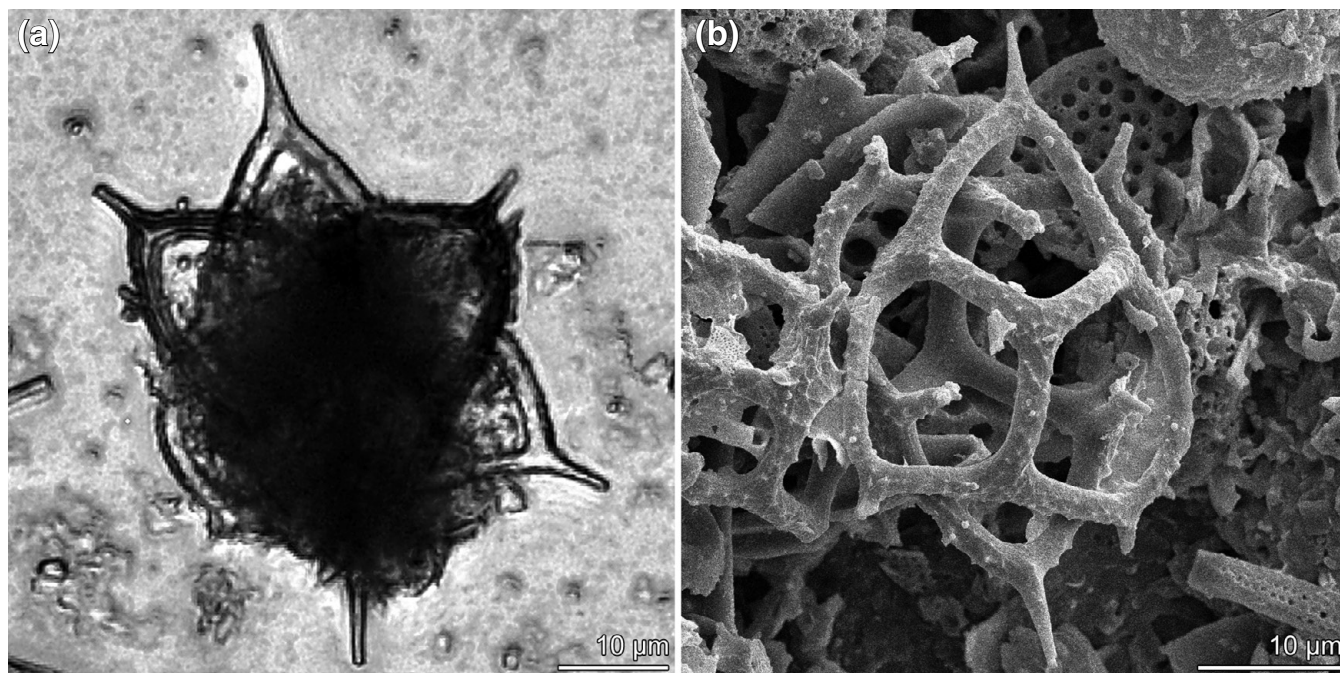


Fig. 1. Double skeletons of *Corbisema hastata* (Lemmermann) Frenguelli in the Star-of-David configuration: (a) light photomicrograph, sample 28, Ivdel' region, Russia; (b) scanning electron micrograph, IODP sample 302-4A-11X-4W, 63–64 cm, Lomonosov Ridge, Arctic Ocean.

contact with the short basal side of the other. There are six points of contact along the abbasal surfaces of the pair, with pikes of each skeleton roughly centred between the basal elements near each corner of the sibling. The basal sides of each skeleton rest in a plane with no deflection of the elements near the points of contact. Two of the pikes are visible. These are prominent, arch in the general direction of the apex of the sibling skeleton and appear to terminate between the basal corner and apex. Whereas the major axis spine of each skeleton appears to lie in the basal plane, the other two basal spines are shorter and point abapically.

DISCUSSION

Recent study of modern double skeletons (McCartney *et al.*, unpublished observations) suggests that the skeletal morphology of the apical structure is transposed from the mother to the daughter skeleton through the centre of the cell. This produces nearly identical skeletons with the same sinistral rotations of the apical ring or bridge, as seen from apical view, often observed in Neogene and Recent silicoflagellates. In the Star-of-David skeletons observed thus far, this applies also to the basal ring, so that the corners of three-sided *Corbisema* and five-sided *Vallacerta* (McCartney *et al.*, 2010b) are transposed across the centre of the cell to place the corners aligned with the middle of the opposite side of the sibling skeleton.

However, while modern silicoflagellates show a transposition of the apical elements across the cell to the sibling skeletons, the elements of the basal ring are apparently not transposed. If transposition included the basal ring in modern silicoflagellates, then in morphologies with an odd number of basal sides, each basal corner of the mother skeleton would be transposed across the cell to the daughter to be aligned with the mother's opposite basal side. The fossil three-sided corner-aligned double skeletons, as well as

Recent five- and seven-sided *Distephanus*, are connected at the basal sides, corners and spines. The differences between the corner-aligned and Star-of-David groups, however, may not be a simple transposition of the basal ring, but rather some other factor.

Thus far, no corner-aligned three-sided silicoflagellate skeletons have been available for scanning electron microscope (SEM) examination. One of the key questions is how the pikes are positioned, if present. When observed from lateral view, three-sided silicoflagellates do not have the zig-zag basal ring, typical of modern *Dictyocha* and *Distephanus* (McCartney *et al.*, unpublished observations) which helps project the pikes into the region of the sibling skeleton. Except for the Ivdel' specimen, which has the central area obscured by matrix, all the three-sided Star-of-David specimens have pikes, and most are prominent. Other three-sided silicoflagellates, such as *Corbisema archangelskiana* (Schulz) Frenguelli (Frenguelli, 1940) and *C. geometrica* Hanna (Hanna, 1928), have less prominent pikes or no pikes, and it remains to be determined whether these may be associated with the other configuration. Of the corner-aligned *Corbisema*, only the one illustrated by Bukry (1987), which is somewhat disarticulated, appears to have obvious pikes.

The rarity of fossil double skeletons in the literature suggests that less aggressive sample processing techniques should be used to reduce disaggregation of preserved specimens. Dumitrică (1974) observed double skeletons of several silicoflagellate taxa in strewn material treated in HCl, but not H₂O₂. Samples treated with H₂O₂ did not yield double skeletons (Dumitrică, pers. comm. 2012). The specimen from Ivdel' shows that clay-rich samples with fine-grained matrix may help to hold the skeletons together. Examination of coprolites for double skeletons should also be pursued, although this is a time-consuming process and photography of specimens can be difficult.

CONCLUSIONS

Rare specimens of the Star-of-David configuration have been observed among three-sided silicoflagellates from the Palaeogene. These could represent a group of silicoflagellates distinct from other taxa that have corner-aligned basal rings, which is the only configuration found in modern waters. Unfortunately, at present the only way to distinguish between these groups is through the observations of double skeletons, which are extremely rare in the fossil record. In order to increase the likelihood of finding fossil double skeletons, more careful techniques for the preparation of sediments for study need to be developed.

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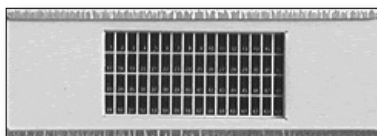
REFERENCES

- Bachmann, A. 1970. Silicoflagellaten aus dem oberösterreichischen Egerien (Oberoligozän). *Verhandlungen der Geologischen Bundesanstalt*, **2**: 275–305.
- Bukry, D. 1987. Eocene siliceous and calcareous phytoplankton, Deep Sea Drilling Project Leg 95. *Initial Reports of the Deep Sea Drilling Project, Scientific Results*, **95**. US Government Printing Office, Washington, DC, 395–415.
- Dumitrică, P. 1974. *Silicoflagelatele Miocene din Romania. Silicoflagelatele miocene din Romania*. Teza de doctorat, Universitatea din Bucuresti, Facultatea de Geologie-Geografie, Bucuresti, 224pp.
- Fenner, J. 1985. Late Cretaceous to Oligocene planktic diatoms. In Bolli, H.M., Saunders, J.B. & Perch-Nielsen, K. (eds) *Plankton Stratigraphy*. Cambridge University Press, Cambridge, **2**: 713–762.
- Frenguelli, J. 1940. Consideraciones sobre los silicoflagelados fósiles. *Revista del Museo de la Plata, Paleontología*, **7**: 37–112.
- Gleser, Z.I. 1964. Silicoflagellatae fossiles novae URSS. *Novitates Systematicae Plantarum Non Vascularium*, **1**: 46–58.
- Gleser, Z.I. 1966. Silicoflagellatophyceae. Nauka, Moskva (translated from Russian by Israel Program for Scientific Translations, Jerusalem, 1970), 363pp.
- Hanna, G.D. 1928. Silicoflagellata from the Cretaceous of California. *Journal of Paleontology*, **1**: 259–263.
- Jousé, A.P. 1949. Algae diatomaceae aetatis supernecretaceae ex arenis argillaceis systematis fluminis Bolschoy Aktay in declivitate orientali Ural Borealis. *Notulae systematicae e Sectione Cryptogamica Instituti Nomine V.L. Komarovii Academiae Scientiarum U.R.S.S.*, **6**: 65–78.
- Jousé, A.P. 1951. Diatomeae et silicoflagellatae aetatis Cretae superne e Montibus Uralensibus Septentrionalibus. *Notulae systematicae e Sectione Cryptogamica Instituti Nomine V.L. Komarovii Academiae Scientiarum U.R.S.S.*, **7**: 42–65.
- Loeblich, III, A.R., Tappan, H. & Loeblich, A.R. Jr 1968. *Annotated Index of Fossil and Recent Silicoflagellates and Ebridians with descriptions and illustration of validly published Taxa*. Geological Society of America, Memoirs, **106**, 319pp.
- McCartney, K., Harwood, D.M. & Witkowski, J. 2010a. A rare double skeleton of the silicoflagellate *Corbisema*. *Journal of Micropalaeontology*, **29**: 185–186.
- McCartney, K., Witkowski, J. & Harwood, D.M. 2010b. Early evolution of the silicoflagellates during the Cretaceous. *Marine Micropalaeontology*, **77**: 83–100.
- Moestrup, Ø. & Thomsen, H.A. 1990. *Dictyocha speculum* (Silicoflagellata, Dictyochophyceae), studies on armoured and unarmoured stages. *Biologiske Skrifter*, **37**: 1–22.
- Onodera, J. & Takahashi, K. 2009. Taxonomy and biostratigraphy of middle Eocene silicoflagellates in the central Arctic Basin. *Micropalaeontology*, **55**: 209–248.
- Schulz, P. 1928. Beiträge zur Kenntnis fossiler und rezenter Silicoflagellaten. *Botanisches Archiv*, **21**: 225–292.
- Stickley, C.E., Koç, N., Brumsack, H.-J., Jordan, R.W. & Suto, I. 2008. A siliceous microfossil view of middle Eocene Arctic paleoenvironments: A window of biosilica production and preservation. *Paleoceanography*, **23**: 1–19, PA1S14, <http://dx.doi.org/10.1029/2007PA001485>
- Witkowski, J., Harwood, D.M. & Kulikovskiy, M. 2012. Observations on Late Cretaceous marine diatom resting spore genera *Pseudoaulacodiscus* and *Archaeogoniothecium* gen. nov. *Nova Hedwigia Beiheft*, **326–328**: 78–94.

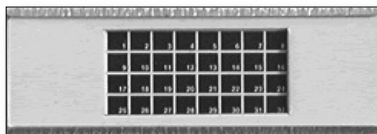
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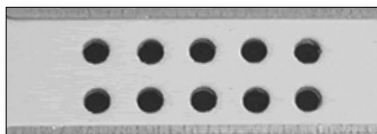
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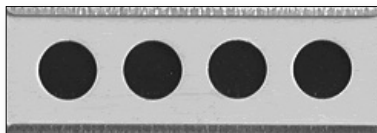
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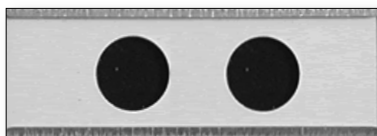
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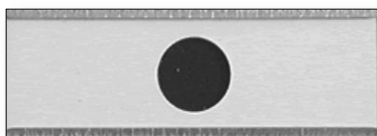
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