Journal of Micropalaeontology, **21:** 169–173. 0262-821X/02 $15.00

Echinidinium zonneveldiae sp. nov., a dinoflagellate cyst from the Late Pleistocene of the Baltic Sea, northern Europe

MARTIN J. HEAD
Godwin Institute for Quaternary Research, Department of Geography, University of Cambridge, Downing Place, Cambridge CB2 3EN, UK (e-mail: mh300@cam.ac.uk)

ABSTRACT – The dinoflagellate cyst species *Echinidinium zonneveldiae* sp. nov. is described from last interglacial (Eemian Stage; Upper Pleistocene) deposits of the southern Baltic Sea, where it contributes to the characterization of a diverse interglacial dinoflagellate flora represented by more than 50 species. *Echinidinium zonneveldiae* is a probable heterotrophic species and does not occur in the region today. The nomenclatural status of the genus *Echinidinium* Zonneveld, 1997 ex Head *et al.*, 2001a is clarified, and it is noted that two of the seven species assigned to *Echinidinium* are not validly described. *J. Micropalaeontol.* **21**(2): 169–173, December 2002.

INTRODUCTION

The Baltic Sea is presently one of the world's largest reservoirs of brackish water, with surface salinities only exceeding 10 psu to the southwest where the Danish Belt Sea, Kattegat and Skagerrak exchange Baltic Sea water with the much more saline North Sea. During the last interglacial (Eemian Stage; *c.* 128–116 ka), conditions were very different. Isostatic depression after the retreat of ice sheets of the preceding Saalian glaciation, together with rapid eustatic rise in the early Eemian, brought about a rapid and extensive marine inundation of the region (Fig. 1). A diverse fossil fauna and flora contained within Eemian marine deposits around the Baltic show that the Baltic Sea was warmer and considerably more saline than today. A less restricted connection to the North Sea is considered to have been largely responsible for the inflow of saline waters from the North Sea (Funder *et al.*, 2003).

I herein describe a new dinoflagellate cyst, *Echinidinium zonneveldiae* (Pl. 1), from Eemian deposits of the Baltic Sea, and compare it with the similar species '*Echinidinium transparantum*' Zonneveld, 1997 (Pl. 2), based on a re-examination of the holotype and paratype. This is part of a broader investigation into Eemian dinoflagellate cysts of the region conducted within the EC-funded BALTEEM project.

MATERIAL AND METHODS

Clays, silts and silty sand were collected from Eemian coastal outcrops at Mommark (10°02′50″E, 54°55′15″N) and Ristinge Klint (10°38′33″E, 54°49′44″N; Kristensen *et al.*, 2000) in Denmark, and a borehole at Licze (19°07′45″E, 53°44′45″N; Head *et al.*, 2001b) in Poland (Fig. 1). Samples were processed with cold dilute HCl (a few hours) and cold 60% HF (about four days), sieved using a 10 µm polyester mesh and mounted on microscope slides with glycerine jelly after light staining with safranin-o. Some residues were given brief ultrasonication, but no oxidation or alkali treatments were used. Microscope slides were examined using a Leica DMR microscope fitted with a Leica DC300 digital camera. All figured specimens of *Echinidinium zonneveldiae* sp. nov. are curated in the Micropalaeontology Division of the Palaeontology Department at the Natural History Museum, London, UK, under the registration numbers FD 640–FD 643.

RESULTS

Palynological investigations at Mommark, Ristinge Klint and Licze (Fig.1) have revealed a diverse dinoflagellate flora that reflects considerably higher surface salinities than today and comparable to those found in the modern Kattegat, namely up to about 18–24 psu (Head, unpublished). The presence of *Tuberculodinium vancampoae* at all sites indicates summer sea-surface temperatures several degrees warmer than today. Of the more than 50 dinoflagellate taxa presently reported from the Eemian of the Baltic, all are previously described with the

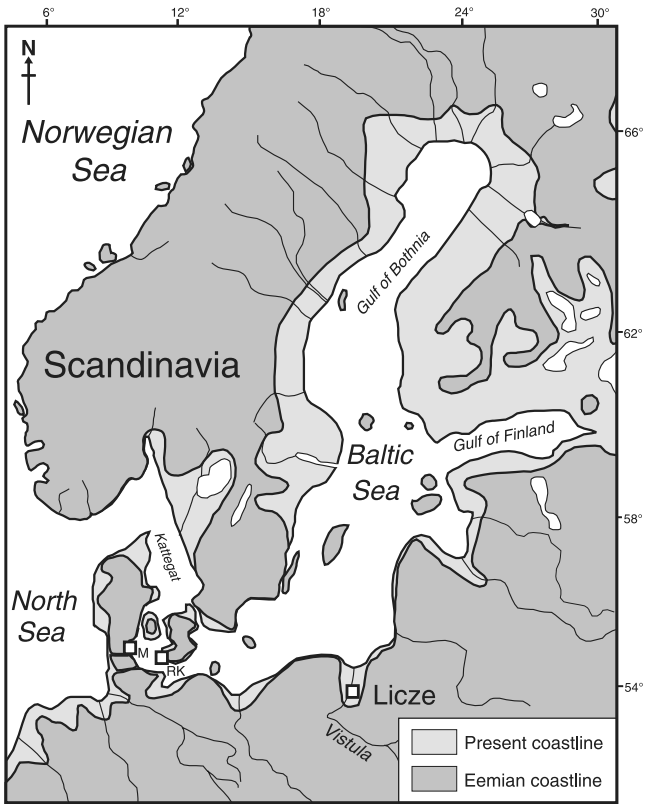
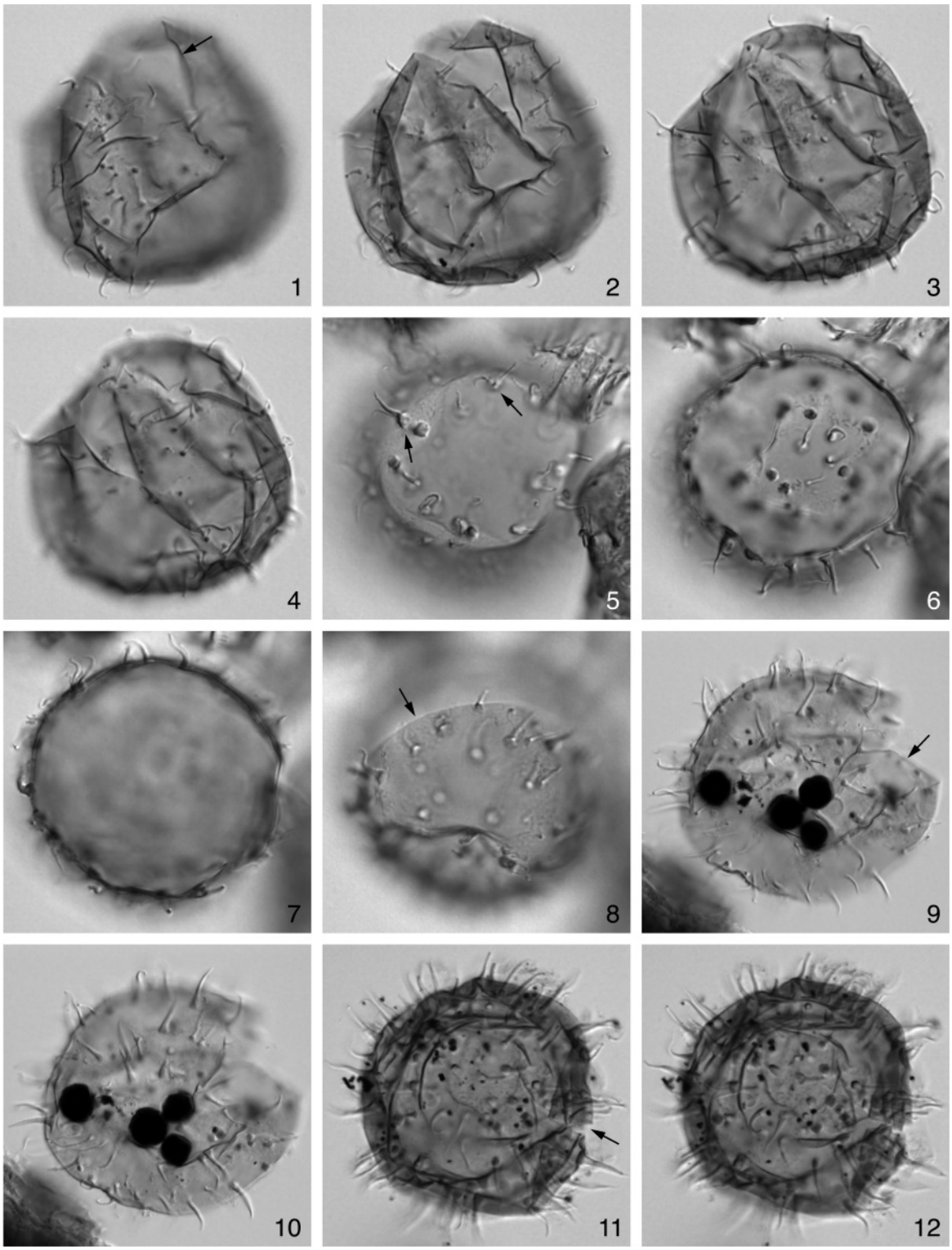
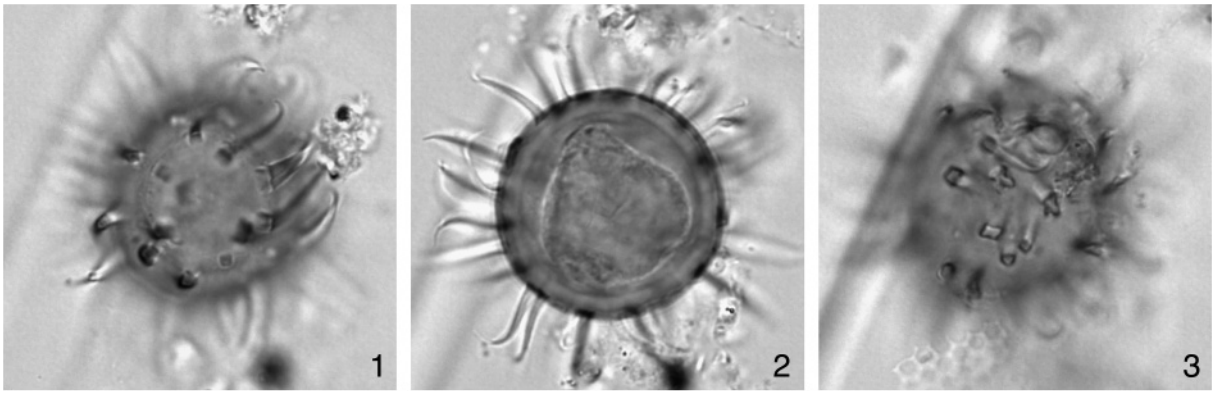


Fig. 1. Eemian hydrography and geography of the Baltic Sea region during maximum inundation in the early Eemian, *c.* 128 ka (based on Funder *et al.*, 2003). M, Mommark; RK, Ristinge Klint.



Explanation of Plate 1. figs 1–12. *Echinidinium zonneveldiae* sp. nov. from the Eemian (last interglacial) of Denmark and Poland. All illustrations are interference contrast images; magnification varies for each specimen: **1**–**4**, holotype, upper through lower foci, arrow indicates theropylic archeopyle extending halfway around the cyst; central body max. diameter 47.5 μm (Mommark, Denmark, section 2a, 200–205 cm, slide 2, EF U24/4; FD 640); **5**–**8**, upper through lower foci, arrow in **5** shows three process arising from a single base, arrow in **8** indicates theropylic archeopyle extending three-quarters of the way around the cyst; central body max. diameter 48 μm (sample 37, depth 96.30–96.40 m; slide 2, EF H20/3, Licze, Poland; FD 641); **9**–**10**, upper and mid foci, arrow indicates theropylic archeopyle extending halfway around the cyst; central body max. diameter 50 μm (sample 37, depth 96.30–96.40 m; slide 2, EF D49/0, Licze, Poland; FD 642); **11**–**12**, upper and mid foci, arrow indicates probable theropylic archeopyle, central body max. diameter 41.5 μm (sample 46, depth 97.20–97.30 m; slide 1, EF N23/0, Licze, Poland; FD 643).



Explanation of Plate 2. figs 1–3. Holotype of '*Echinidinium transparantum*' Zonneveld, 1997 from sediment trap MST 8B (Zonneveld & Brummer, 2000, fig. 1) suspended at a depth of 1265 m in the Arabian Sea off Somalia. Illustrations are in bright field illumination; upper through lower foci; note solid, nearly colourless processes, and irregularly rectangular process bases and, in **2**, note preserved cell contents; central body diameter 25 μm × 25 μm.

exception of a few taxa including *Echinidinium zonneveldiae* sp. nov. This cyst is considered to be that of a heterotrophic dinoflagellate on account of its similarity with other protoperidiniacean dinoflagellates (which are mostly heterotrophs) and its brown-coloured wall, also a feature of most heterotrophic dinoflagellates (Brenner & Biebow, 2001). A major control on its distribution is therefore likely to have been food supply. *Echinidinium zonneveldiae* never constitutes more than about 2% of the dinoflagellate assemblage and is very rare at Ristinge Klint but persistent at Mommark and Licze. It is similar to '*Echinidinium transparantum*' Zonneveld, 1997, a species described but not validly published from a sediment trap in the Arabian Sea (Zonneveld, 1996, 1997; Zonneveld & Brummer, 2000). The small but consistent differences between these two morphotypes suggest that they are separate species sharing a close evolutionary relationship. Nevertheless, the possibility that they are ecophenotypes of the same species cannot be dismissed given the lower-than-normal salinities that characterize the Eemian Baltic compared with fully marine salinities of the modern Arabian Sea. More studies of '*Echinidinium transparantum*' are needed to assess its full range of variability.

SYSTEMATIC DESCRIPTIONS

Division **Dinoflagellata** (Bütschli, 1885) Fensome *et al.*, 1993
Subdivision **Dinokaryota** Fensome *et al.*, 1993
Class **Dinophyceae** Pascher, 1914
Subclass **Peridiniphycidae** Fensome *et al.*, 1993
Order **Peridiniales** Haeckel, 1894
Suborder **Peridiniineae** (autonym)
Family **Protoperidiniaceae** Balech, 1988
Subfamily **Protoperidinioideae** Balech, 1988
or
Subfamily **Diplopsalioideae** Abé, 1981

Discussion. See Head *et al*. (2001a, p. 629) for discussion of the validation of the names Protoperidiniaceae and Protoperidinioideae.

Genus *Echinidinium* Zonneveld, 1997 ex Head *et al.*, 2001a
1997 *Echinidinium* Zonneveld: 325.
2001a *Echinidinium* Zonneveld; Head *et al*.: 633.

Type of genus. Holotype of *Echinidinium granulatum* Zonneveld, 1997 ex Head *et al.*, 2001a.

Accepted species. *Echinidinium bispiniformum* Zonneveld, 1997, pp. 329, 331, 333, pl. 4, figs 1–4, text fig. 7.

Echinidinium delicatum Zonneveld, 1997, pp. 333, 334, pl. 4, figs 5–7, text fig. 8.

Echinidinium granulatum Zonneveld, 1997, pp. 325, 327, 328, pl. 2, figs 1–8, text fig. 4; ex Head *et al.*, 2001a, p. 633.

Echinidinium karaense Head *et al.*, 2001a, pp. 633, 634, pl. 3i–o, figs 1, 5.

Echinidinium zonneveldiae sp. nov.

Invalidly published species. *Echinidinium aculeatum* Zonneveld, 1997, pp. 328, 329, pl. 3, figs 1–5, text fig. 5.

Echinidinium transparantum Zonneveld, 1997, pp. 329, pl. 3, figs. 6–10, text fig. 6.

Remarks. *Echinidinium* is a modern cyst genus whose type is a specimen collected from a sediment trap suspended within the water column (Zonneveld, 1996, 1997; Zonneveld & Brummer, 2000). The type lacks demonstrable stratigraphic relations because it was never incorporated into strata, and for nomenclatural purposes therefore cannot be considered a fossil (ICBN Art. 13.3, Greuter *et al.*, 2000). Latin diagnoses were not given by Zonneveld (1997) although these were required for valid publication of the genus *Echinidinium* and the name of its type, *Echinidinium granulatum* (ICBN Art. 36.2). Head *et al.* (2001a) provided Latin diagnoses for these taxa, and so fulfilled requirements for their valid publication.

Neither '*Echinidinium aculeatum*' nor '*E. transparantum*' were validly published in Zonneveld (1997) because their holotypes were similarly collected from sediment traps, and Latin diagnoses were not provided. Because the holotypes of *Echinidinium bispiniformum* and *E. delicatum* are from ocean floor sediments,

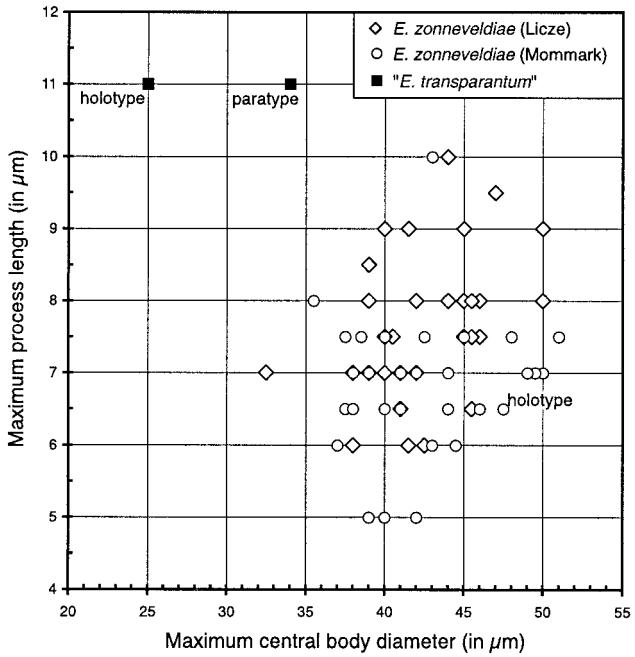


Fig. 2. *Echinidinium zonneveldiae* sp. nov. compared with the holotype and paratype of '*E. transparantum*' Zonneveld, 1997, showing maximum central body diameter vs maximum process length.

they have a stratigraphic context and can be treated as fossils. A Latin diagnosis is therefore not required for these species.

Echinidinium zonneveldiae sp. nov.
(Pl. 1, figs 1–12; Fig. 2)

Derivation of name. Named for Karin A. F. Zonneveld in recognition of her work on the genus *Echinidinium*.

Diagnosis. A species with light- to medium-brown spheroidal central body; and a thin, smooth to ornamented wall bearing solid processes that taper to fine points. Processes are less strongly coloured than the central body, and are circular in transverse cross-section for most of their length, but at least some become irregularly rectangular at base; shafts are smooth. The archeopyle is theropylic, forming a long straight split.

Holotype. Specimen FD 640 (Pl. 1, figs 1–4). Sample: Mom 2a, 200–205 cm; slide 2. England Finder reference U24/4.

Material. Upper Pleistocene (Eemian) of the southern Baltic sites at Mommark, Ristinge Klint and Licze.

Locality and horizon. Holotype: Mommark, Denmark, depth 920.5 cm.

Description. The central body is spheroidal and light to medium brown in colour. The central body wall is less than 0.3 μm thick, with no visible stratification between processes. The outer surface of the wall is smooth, sometimes with sparsely scattered granules or spinules; the inner surface is smooth, faintly granulate or faintly granulorugulate but occasionally more strongly ornamented. Processes are somewhat irregularly distributed over the entire surface of the cyst, but no clear tabulation pattern is apparent. Processes are solid, have smooth shafts, taper to fine points; and are less strongly coloured than central body. Process bases are circular to irregularly rectangular in cross-section, with some irregularly rectangular bases occurring on each cyst. Above their base, processes are always circular in cross-section. Maximum process width varies from *c.* 1.3 to 3.0 μm; wider processes are always expanded at base. Thicker and thinner processes occur on the same specimen. Processes are mostly of about the same length, but occasional slender processes as short as 2 μm may occur on some specimens (e.g. the holotype). A single process usually arises from each base; but on rare specimens some bases may give rise to as many as three processes (e.g. Pl. 1, figs 5–8). The archeopyle is theropylic, presumably cingular, resulting in a long and nearly straight split that may extend at least half way around the cyst; no accessory sutures were seen.

Dimensions. Holotype: central body 47.5 × 45.0 μm, process length 2.0 × 6.5 μm, process width at base 0.5–1.8 μm. Range based on 31 specimens from Licze, Poland: central body maximum diameter 32.5(42.50)50.0 μm, standard deviation 3.72; maximum process length 6.0(7.73)10.0 μm, standard deviation 1.05. Range based on 31 specimens from Mommark, Denmark: central body maximum diameter 35.5(42.52)51.0 μm, standard deviation 4.25; maximum process length 5.0(6.85)10.0 μm, standard deviation 0.97. Specimens have mostly compressed preservation. See also Figure 2.

Remarks. This species differs from all others of the genus, with the exception of '*Echinidinium transparantum*' below, in the presence of solid tapering processes that arise from irregularly rectangular process bases.

The variable ornament seen on the inner surface of the central body wall is often not evenly distributed (e.g. both smooth and faintly granulate areas on the holotype) and may be partly controlled by preservation.

'*Echinidinium transparantum*' Zonneveld, 1997
(Pl. 2, figs 1–3; Fig. 2)

1996 cf. Protoperidinium sp. 3 Zonneveld: 151, pl. 1, figs 7, 10.
1997 *Echinidinium transparantum* Zonneveld: 329, pl. 3, figs 6–10, text-fig. 6.

Remarks. Observations of the holotype and paratype broadly agree with the description of this species by Zonneveld (1997). An aperture was not seen on either holotype or paratype, but was reported by Zonneveld as being a simple split (Zonneveld, 1997). The central body wall is thin (less than 0.3 μm) and has an almost smooth surface, with faint, irregular granulation just visible under interference contrast microscopy. Occasional scattered granules (0.5 μm or less) and spinules are also present. There is no visible stratification of the wall between processes. On both specimens process bases vary from circular to irregularly rectangular, processes becoming circular in cross-section distally. On the holotype, processes are all of similar length

(*c*. 9–10 μm); on the paratype they are mostly of similar length (*c*. 10–11 μm) but also include a few thin (0.5 μm) shorter (*c*. 7 μm) processes. Central body dimensions for the holotype are 25 μm × 25 μm (not 28.4 μm as stated in Zonneveld, 1997), and 33 μm × 34 μm for the paratype.

This species differs from *Echinidinium zonneveldiae* sp. nov. in its smaller size and relatively longer processes (Fig. 2). More detailed observations of additional specimens are needed to determine whether these features offer a consistent means of separating these species.

ACKNOWLEDGEMENTS

This study has received funding from the European Union (Contract No. ENV4-CT98-0809, the BALTEEM project). I am grateful to K. A. F. Zonneveld (Bremen University) for the loan of type material, and P.L. Gibbard (University of Cambridge), leader of the BALTEEM project, for support. It is a pleasure to thank L. Marks (Polish Geological Institute, Warsaw) and P. Kristensen (University of Aarhus) for supplying samples, and both R. Harland (Bingham, UK) and Stephen Louwye (Ghent University) for their helpful reviews of the manuscript. A Visiting Fellowship at Wolfson College, Cambridge is gratefully acknowledged.

Manuscript received 20 June 2002
Manuscript accepted 7 August 2002

REFERENCES

Abé, T.H. 1981. Studies on the family Peridiniidae. An unfinished monograph of the armoured Dinoflagellata. *Publications of the Seto Marine Biological Laboratory, Special Publication Series,* **6**: 1–409.

Balech, E. 1988. Los dinoflagelados del Atlántico Sudoccidental. *Publicaciónes Especiales Instituto Español de Oceanografía,* **1**: 1–310.

Brenner, W.W. & Biebow, N. 2001. Missing autofluorescence of recent and fossil dinoflagellate cysts – an indicator of heterotrophy? *Neues Jahrbuch fur Geologie und Paläontologie, Abhandlungen,* **219**: 229–240.

Bütschli, O. 1885. Erster Band. Protozoa. *Dr. H.G. Bronn's Klassen und Ordnungen des Thier-Reiches, wissenschaftlich dargestellt in Wort und Bild.* C.F. Winter'sche Verlagshandlung, Leipzig and Heidelberg, 865–1088.

Fensome, R.A., Taylor, F.J.R., Norris, G., Sarjeant, W.A.S., Wharton, D.I. & Williams, G.L. 1993. A classification of living and fossil dinoflagellates. *Micropaleontology Special Publication,* **7**: 1–351.

Funder, S., Demidov, I. & Yelovicheva, Y. 2003. Hydrography and mollusc faunas of the Baltic and White Sea–North Sea seaway in the Eemian. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **184**: 275–304.

Greuter, W., McNeill, J., Barrie, F.R. *et al.* 2000. International Code of Botanical Nomenclature (Saint Louis Code). *Regnum Vegetabile,* **138**: 1–474.

Haeckel, E. 1894. *Systematische Phylogenie. Entwurf eines natürlichen Systems der Organismen auf Grund ihrer Stammegeschichte, I. Systematische Phylogenie der Protisten und Pflanzen.* Reimer, Berlin, 1–400.

Head, M.J., Harland, R. & Matthiessen, J. 2001a. Cold marine indicators of the late Quaternary: the new dinoflagellate cyst genus *Islandinium* and related morphotypes. *Journal of Quaternary Science,* **16**: 621–636.

Head, M.J., Gibbard, P.L. & Grøsfjeld, K. 2001b. Dinoflagellates and hydrography of the last interglacial (Eemian Mikulino) in the Baltic Sea–White Sea region. *Baltic Sea Science Congress, November 25–29, Stockholm University, Sweden, Abstract Volume: 79*.

Kristensen, P., Gibbard, P.L., Knudsen, K.L. & Ehlers, J. 2000. Last interglacial stratigraphy at Ristinge Klint, South Denmark. *Boreas,* **29**: 103–116.

Pascher, A. 1914. Über Flagellaten und Algen. *Berichte der Deutschen Botanischen Gesellshaft,* **36**: 136–160.

Zonneveld, K.A.F. 1996. Palaeoclimatic and palaeo-ecologic changes in the Eastern Mediterranean and Arabian Sea regions during the last deglaciation: a palynological approach to land–sea correlation. *LPP Contributions Series (LPP Foundation, Utrecht),* **3**: 1–199.

Zonneveld, K.A.F. 1997. New species of organic walled dinoflagellate cysts from modern sediments of the Arabian Sea (Indian Ocean). *Review of Palaeobotany and Palynology,* **97**: 319–337.

Zonneveld, K.A.F. & Brummer, G.-J.A. 2000. (Palaeo-)ecological significance, transport and preservation of organic-walled dinoflagellate cysts in the Somali Basin, NW Arabian Sea. *Deep-Sea Research, II,* **47**: 2229–2256.