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Research paper

Batiacasphaera bergenensis and *Lavradosphaera elongata* — New dinoflagellate cyst and acritarch species from the Miocene of the Iceland Sea (ODP Hole 907A)

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ABSTRACT

A detailed palynological investigation of the almost continuous middle through upper Miocene sediment sequence of ODP Hole 907A in the Iceland Sea revealed the presence of a new species of the dinoflagellate cyst genus *Batiacasphaera*, and a new species of the acritarch genus *Lavradosphaera*. *Batiacasphaera bergenensis* sp. nov. and *Lavradosphaera elongata* sp. nov. are both morphologically distinctive and have well-defined stratigraphic range tops that are independently constrained by the pristine paleomagnetic record of Hole 907A. Both species disappeared within a narrow interval across the middle to late Miocene boundary, when small-scale glaciations on Greenland were large enough to reach sea level. The distinct morphology of the proposed species and their highest occurrence in this critical interval highlights their potential for future biostratigraphic application in the Miocene of the high northern latitudes, an area important for understanding the Late Cenozoic transition into a bipolar glaciated world.

1. Introduction

The high northern latitudes are of crucial importance for global climate due to the Arctic amplification, a process that includes a variety of feedback mechanisms related to the Greenland ice sheet, the formation of perennial/seasonal sea ice cover, and the production of North Atlantic Deep Water (e.g. Serreze and Barry, 2011). It is commonly assumed that the high latitudes also played a decisive role during the Miocene period when Earth's climate was finally pushed into the bipolar glaciated mode of today (e.g. Flower and Kennett, 1994; Zachos et al, 2008). Despite their importance, detailed reconstructions of paleoenvironmental changes that occurred across this period are still seriously hampered by insufficient temporal control on marine sedimentary sequences, primarily due to the rare occurrence of traditionally used calcareous microfossils in these deposits (e.g. Fronval and Jansen, 1996; Matthiessen et al., 2009a). In consequence, organic-walled dinoflagellate cysts (dinocysts) and acritarchs gained increased attention owing to their relatively high abundance and diversity in this realm.

The past decades witnessed significant progress in the application of dinocysts for biostratigraphic correlations and paleoenvironmental reconstructions in the Neogene of the North Atlantic, North Pacific, and the Arctic and subarctic seas (e.g. Bujak and Matsuoka, 1986; Head et al., 1989a; Manum et al., 1989; De Schepper et al., 2011; Schreck et al., 2012), whereas acritarchs have only been recently recognized as a useful microfossil group to tighten Neogene biostratigraphy in the high northern latitudes (e.g. Matthiessen et al., 2009b; Schreck et al., 2012; De Schepper and Head, 2013; Verhoeven et al., 2013). Notwithstanding, the stratigraphic potential of both groups has not been fully explored yet and numerous Neogene species still remain in open nomenclature to date (e.g. Poulsen et al., 1996; De Schepper and Head, 2013; Schreck et al., 2013). Moreover, Mudie (1989) mentioned uncertainties regarding the equivalence of high northern latitude Neogene taxa reported by different workers as different taxonomic concepts have been applied.

During a detailed palynological investigation on Neogene sediments of Iceland Sea ODP Hole 907A, more than 40 undescribed dinocyst and acritarch taxa have been recognized (Schreck et al., 2013), and two potentially useful new dinocyst species have been described previously (Schreck et al., 2012). Herein we describe a new dinocyst species, *Batiacasphaera bergenensis* sp. nov., and a new acritarch species, *Lavradosphaera elongata* sp. nov., which both have well defined stratigraphic range tops in the Iceland Sea. The revised paleomagnetic record of Site 907 (Channell et al., 1999) allows calibration of the ranges to the latest Astronomical Tuned Neogene Time Scale (ATNTS; Hilgen et al., 2012) for independent age control, and we discuss their occurrence in relation to paleoclimatic changes that occurred across the Middle to Late Miocene in the high northern latitudes in order to evaluate their potential for future biostratigraphic application. Given their distinct

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morphology and restricted range, both species may improve biostratigraphic control in the cold-water domain of the Norwegian–Greenland Sea, an area critical for understanding the Late Cenozoic development of Earth's climate.

2. Material and methods

ODP Leg 151 Hole 907A was drilled on the eastern Iceland Plateau (69°14.989′ N, 12°41.894′ W; 2035.7 m water depth; Fig. 1), and provides an almost continuous middle through late Miocene sediment sequence that mainly consists of unlithified silty clay and clayey silt (Shipboard Scientific Party, 1995). The revised age model for Site 907 is based on magnetic polarity stratigraphy (Shipboard Scientific Party, 1995; Channell et al., 1999), but is independently supported by four silicoflagellate datums in the Miocene interval (Fig. 2; see Channell et al., 1999; and Schreck et al., 2012 for detailed discussion of the age model). The ages of the polarity chron boundaries given by Channell et al. (1999) have been updated to the ATNTS 2012 (Hilgen et al., 2012), and therefore, this age model allows assigning numerical ages for each sample and bioevent.

Based on the revised magnetostratigraphy of Channell et al. (1999), 120 samples, covering the period from *c.* 14.5 to 2.5 Ma, have been examined for their palynological content on a ~100 ka resolution. Fifteen cm^3 sediments were freeze-dried, weighed, and processed using standard palynological techniques (e.g. Wood et al, 1996), including treatment with cold HCl (10%) and cold HF (38–40%), and sieving over 6 μm mesh. The residue has been mounted with glycerine jelly on microscope slides. The results of the detailed palynological investigation are published by Schreck et al. (2012, 2013), and all slides are stored at the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany. The slides containing all illustrated specimens of *Batiacasphaera bergenensis* sp. nov. and *Lavradosphaera elongata* sp. nov. are housed in the Invertebrate Section of the Department of Palaeobiology, Royal Ontario Museum, Toronto, Ontario, Canada, under the catalogue numbers ROM 63053–63054.

For this study, a detailed taxonomic analysis was performed with a Zeiss Axioplan 2 microscope at 100× magnification. Transmitted light photomicrographs were taken with a ProgRes C5 digital camera. Scanning electron microscopy has been carried out with a Philips XL 30 ESEM at the Marine Geology and Paleontology Department of the Alfred Wegener Institute, Bremerhaven, Germany.

3. Results and discussion

This study formally describes a new dinocyst species, *Batiacasphaera bergenensis* sp. nov., and a new acritarch species, *Lavradosphaera elongata* sp. nov., from the diverse and moderate to well preserved Miocene palynomorph assemblage of ODP Hole 907A in the Iceland Sea (Fig. 1). The good to moderate preservation of palynomorphs is notably evident among co-occurring protoperidiniacean cysts, e.g. *Cristadinium cristatoserratum* and *Barssidinium graminosum*, which are light to dark brown in colour and show no evidence of oxidative damage. The independent magnetostratigraphic age control of ODP Hole 907A (Fig. 2; Channell et al., 1999) allows the calibration of the stratigraphic ranges to the ATNTS 2012 and assesses numerical ages for their highest (HO) and lowest (LO) occurrence as follows (Fig. 3).

In Iceland Sea ODP Hole 907A, *Batiacasphaera bergenensis* sp. nov. has a total stratigraphic range from the uppermost Langhian (13.68 Ma) into lower Tortonian (11.09 Ma), and both LO and HO are comparatively well constrained by adjacent magnetic polarity reversal boundaries (Figs. 2 and 3). *B. bergenensis* sp. nov. occurred shortly after the Middle Miocene Climate Transition (MMCT, 14.2–13.7 Ma), during which cooler arctic surface waters likely reached the Iceland Plateau due to the establishment of a proto-East Greenland Current and a ice drift pattern across the Fram Strait similar to today (Jakobsson et al., 2007; Knies and Gaina, 2008; Schreck et al., 2013). It exhibits low abundance (*c.* 0.3% of the total dinocyst assemblage) in the lowermost Serravallian, but a significant acme (47%) occurs at ~13.39 Ma. This acme coincides with a brief warming in the Iceland Sea and sea surface temperatures (SSTs) of around 20 °C, which are presumably related to the influence of warmer waters branching off the Norwegian–Atlantic Current (Schreck et al., 2013). Temperate conditions likely prevailed on the Iceland Plateau during most of the subsequent Serravallian, but alkenone SSTs show a slight decrease (Schreck et al., 2013) and *Batiacasphaera bergenensis* sp. nov. occurs only sporadically throughout this interval. However, it is a common constituent (1–8%) of the palynomorph assemblages in the lowermost Tortonian again, where its highest occurrence is magnetostratigraphically-calibrated to 11.09 Ma just below Subchron C5n.2n (Figs. 2 and 3). The range top might be related to the glacial inception in the Iceland Sea as depicted by the onset of predominantly siliciclastic deposition, the

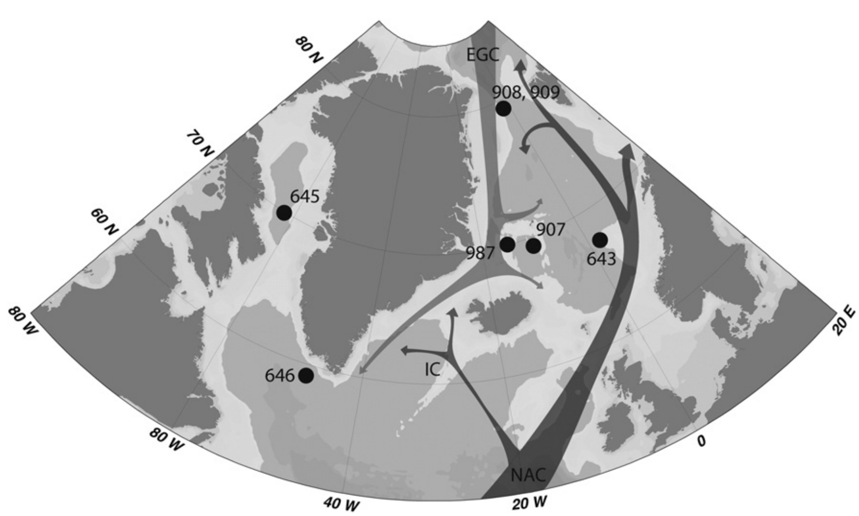

Fig. 1. Location of ODP Site 907 and other sites discussed in the text, and schematic present day oceanography of the Norwegian–Greenland Sea (modified from Blindheim and Østerhus, 2005). Light grey arrow refers to the cold waters of the East Greenland Current (EGC), and dark grey arrows refer to warmer waters of the Norwegian–Atlantic Current (NAC), and the Irminger Current (IC).