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Palaeoenvironmental reconstruction and biostratigraphy with marine palynomorphs of the Plio–Pleistocene in Tjörnes, Northern Iceland

Koen Verhoeven, Stephen Louwye *

Research Unit Palaeontology, Ghent University, Krijgslaan 281/S8, 9000 Ghent, Belgium

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ABSTRACT

Deposits from the Tjörnes Peninsula in northern Iceland enable the assessment of past ocean currents and the influence of the nearby island. Most palaeoecological studies with dinoflagellate cysts from the northern and central Atlantic focus on oceanic or shelf settings and deal with outer neritic and oceanic species. Dinoflagellate cyst studies of marginal marine settings are scarce and represent only short time intervals. The Tjörnes section however accommodates 1200 m of sediments that are mainly shallow marine. The sediments are attributed to the Lower Pliocene Tjörnes beds and the overlying Upper Pliocene to Pleistocene Breidavík Group. The dinoflagellate cysts and other marine palynomorphs from 68 samples from the Tjörnes beds and 20 samples from the Breidavík Group are studied. The deposits are divided into five dinoflagellate cyst assemblage zones (DAZ) and one barren interzone (BIZ). The changes in the assemblages proved to be independent of the changes in bathymetry of the sedimentary environment. Heterotrophic dinoflagellate cysts dominate in DAZ1. An abrupt impoverishment in species diversity is observed in DAZ2 when autotrophic species dominate the assemblage. Slightly preceding the entrance of Pacific molluscs in the area in unit 14 of the *Serripes* Zone, heterotrophic species (unit 12/13) re-enter the area in DAZ3. The marked decrease and return of the heterotrophic species does not relate to conditions of preservation, but may result from the loss of nutrients. The upper part of DAZ1 and the base of DAZ3 reflect major changes in the palaeoceanography and span a period during which the polar front may have moved temporarily from the area. The first event situated at the top of DAZ1 occurred in litholog unit 4 halfway the *Tapes* Zone between circa 5 and 4.8 Ma. The second event at the top of litholog unit 12 around 4.5 Ma has been linked to the shoaling of the Central American Seaway. Heterotrophic dinoflagellates disappear almost completely from the area during the deposition of the Pleistocene Breidavík Group (DAZ4-5). A transition from a heterotrophic dominated assemblage to an autotrophic dominated assemblage is observed in the Hörgi Formation (DAZ4a). An assemblage dominated by autotrophic cold water species, comparable to the present-day assemblage of the area north of Iceland, occurs from unit 10 in the Pleistocene Svarthamar Member on (DAZ5). This study underscores that the distribution of temperature sensitive dinoflagellate cysts is influenced by the availability of nutrients and changes in ocean currents.

1. Introduction

A shallow sedimentary basin formed during the Pliocene and Pleistocene near the Tjörnes Fracture Zone, a fault zone related to the Mid Atlantic Ridge passing through Iceland (Fig. 1A). The basin was interpreted as a fjord open to the north with sediment supply from the land in the south (Strauch, 1963). Shallow marine sediments as well as terrestrial sediments and lava flows accumulated and resulted in a 1200 m thick sequence. During the Pleistocene the Tjörnes basin was uplifted as a horst structure and the beds are now exposed in the coastal cliffs. The oldest part of the sequence is the Lower Pliocene Tjörnes beds consisting mainly of marine sandstones alternating with terrestrial lignites. Lava flows are of minor importance. The Höskuldsvík lavas separate the Tjörnes beds from the overlying Upper Pliocene to Pleistocene Breidavík Group (Figs. 1B and 2). This group encompasses fourteen glacial–interglacial cycles consisting of glacial till sediments, late-glacial outwash gravels and interglacial marine sediments (Fig. 2; Eiríksson, 1981). Recent lava flows cover the Quaternary glacial–interglacial deposits.

The central position of the Tjörnes cliffs in the northern Atlantic and their easy accessibility make them a unique location for palaeontological, palaeoclimatical and palaeoceanographical studies. Bárdarson (1925) described in the Tjörnes beds 25 shell bearing marine units (1–25) and 10 lignites (A–J), and divided the sequence into three mollusc taxon-range biozones: the *Tapes* Zone, the *Mactra* Zone and the *Serripes* Zone (Figs. 1 and 2). Other palaeontological studies focussed on marine molluscs (Strauch, 1972; Norton, 1975, 1977; Gladenkov et al., 1980; McCoy, 2007; Símonarson and Eiríksson, 2008; Símonarson and Leifsdóttir, 2008), ostracods (Cronin, 1991) and dinoflagellate cysts (dinocysts)

* Corresponding author. Tel.: +32 92644611; fax: +32 92644608.
E-mail address: Stephen.Louwye@UGent.be (S. Louwye).

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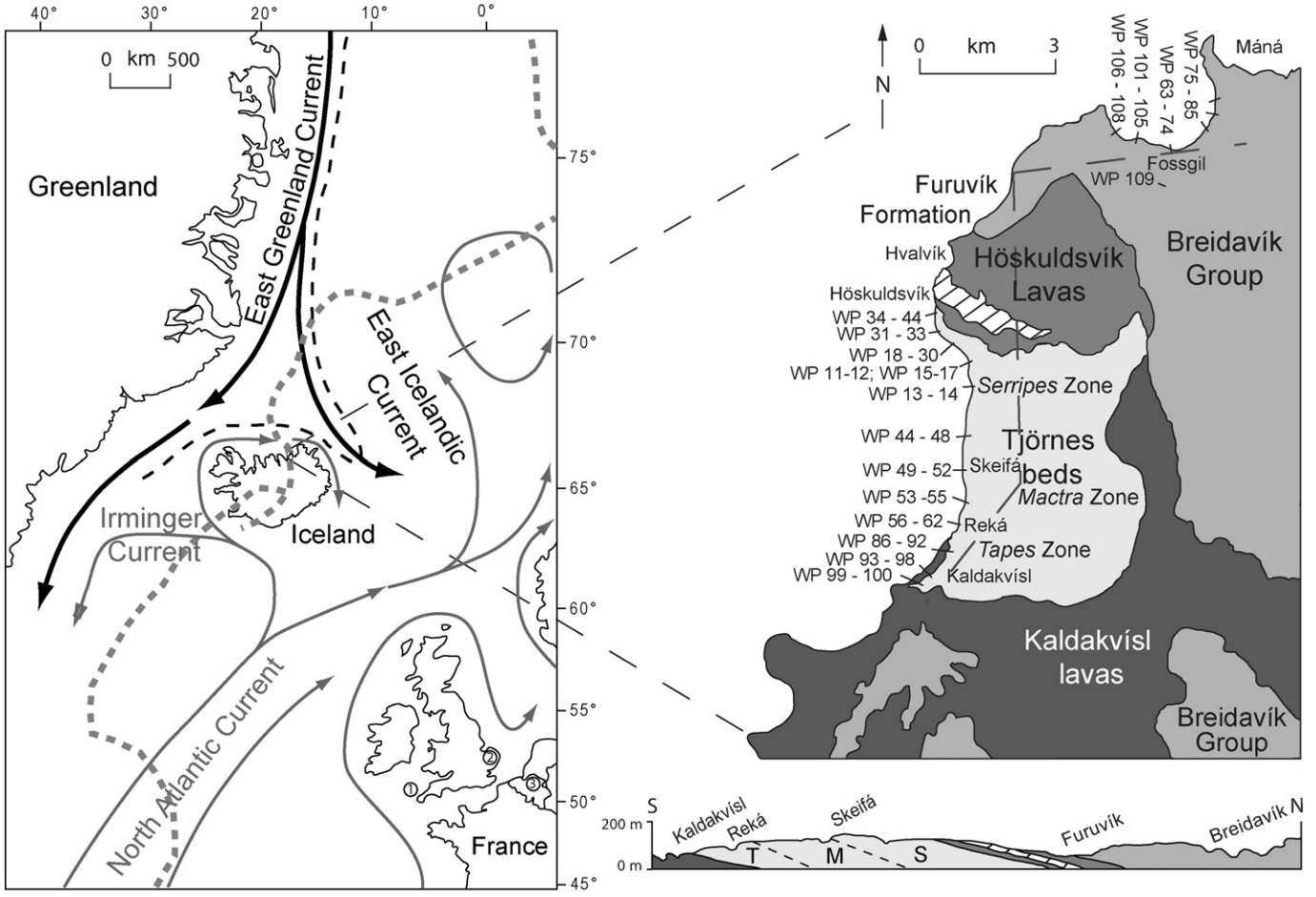

Fig. 1. A: Overview of the present-day surface currents of the North Atlantic Ocean with indication of the study area in northern Iceland. Warm water currents are indicated with thin grey arrows, cold water currents with broader black arrows (adapted from Marret et al., 2004). The Mid-Atlantic Ridge is indicated with a thick, grey dotted line. The position of the Polar Front around Iceland (black dashed line) is after Knudsen and Eiríksson (2002). The location of the cross section is indicated by a dashed, dark grey line. The encircled numbers 1–3 indicate shallow marine Pliocene deposits: (1) the St. Erth Beds, (2) the England Crags and (3) the Belgian Pliocene sands. B: Geological map of the study area, located on the western part of the Tjörnes Peninsula. An approximately north–south cross section of the area is given (dashed line on map), modified and simplified after Einarsson et al. (1967) and Eiríksson (1981), together with the sample locations and numbers.

(Verhoeven et al., 2011; Verhoeven and Louwye, 2012). Cronin (1991) recorded foraminifers but these proved difficult to extract from the consolidated siliciclastic matrix. Akhmetiev et al. (1978) made a preliminary study on the diatoms from lignites C and F, respectively in the *Tapes* Zone and the *Mactra* Zone. The diatoms however are poorly preserved, of mixed age and ecological preference and therefore the analysis was not pursued. Past sea water temperatures of the Tjörnes beds were estimated with oxygen isotopes (Buchardt and Símonarson, 2003). Eiríksson (1981, 1985) studied in detail the sedimentology of the Breidavík Group.

The organic-walled dinocysts from the Tjörnes beds and the overlying Breidavík Group were studied by Verhoeven et al. (2011) and allowed a more refined age attribution than the earlier studies (Einarsson et al., 1967; Albertsson, 1978; Buchardt and Símonarson, 2003; Símonarson and Eiríksson, 2008) and the reconstruction of the depositional history. It was established that the base of the Tjörnes beds was deposited during post-Miocene times and the top of the *Serripes* Zone around 4.0 Ma (Fig. 2). The Pacific molluscan invasion around the *Mactra*/*Serripes* Zone boundary is dated c. 4.5 Ma. Two major hiatuses of c. 700 ka occur, one between the top of the *Serripes* Zone and the Höskuldsvík lavas and one between the Furuvík Formation and the Hörgi Formation, the last formation being dated around 2.2 Ma (Fig. 2). The rest of the Breidavík Group extends from then on to recent times. The Tjörnes beds and Breidavík Group also contain pollen and spores, the study of which contributed to our knowledge of the water depth and the coastal landscape (Verhoeven et al., 2013). Only a few other shallow marine deposits of comparable age and holding well-preserved dinocyst assemblages are known from the northern and central Atlantic (Figs. 1A and 2). The Tjörnes assemblages have been compared with those of the St. Erth Beds in southwest England (±2.1–1.95 Ma), several crag deposits in southeast England (4.4–1.8 Ma) and the Belgian Pliocene sands (5–2.76 Ma).

The present study details the marine palynomorph record from the Tjörnes Peninsula and presents a new biozonation for the most complete Neogene and Pleistocene sedimentary sequence onshore Iceland. The marine palynomorph record was furthermore interpreted in terms of palaeoecological preference of dinocysts to gain further insight in the palaeoceanographical and palaeoclimatological changes in the northern Atlantic realm.

2. Previous palaeoenvironmental studies

A combined sedimentological/malacological study of the Tjörnes beds by Buchardt and Símonarson (2003) indicated a slightly fluctuating sea level during deposition of the *Tapes* Zone and the lower part of the *Mactra* Zone. Sediment supply was more or less in sync with the subsidence rate and intertidal sandstones and beach gravels alternating with lignites, remnants of coastal marshes, were deposited. Strong bottom currents transported molluscan shells of deeper water to the coastal area as revealed by the allochthonous taphocoenoses of epi- and infaunal molluscs present in the entire Tjörnes beds (Norton, 1975).