Palaeogeography, Palaeoclimatology, Palaeoecology 449 (2016) 266–274

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

High-resolution organic carbon–isotope stratigraphy of the Middle Jurassic–Lower Cretaceous Agardhfjellet Formation of central Spitsbergen, Svalbard

M.J. Koevoets [a,*], T.B. Abay [b], Ø. Hammer [a,b], S. Olaussen [c,b]

[a] Museum of Natural History, University of Oslo, PO Box 1172, Blindern, Oslo 0318, Norway
[b] Department of Geosciences, University of Oslo, PO Box 1047, Blindern, Oslo 0316, Norway
[c] Department of Arctic Geology, University Centre in Svalbard, PO Box 156, Longyearbyen 9171, Norway

ARTICLE INFO

Article history:
Received 10 November 2015
Received in revised form 11 February 2016
Accepted 12 February 2016
Available online 22 February 2016

Keywords:
Chemostratigraphy
Arctic
Oxfordian
Kimmeridgian
Rock Eval

ABSTRACT

We present the first complete organic carbon–isotope curve from the Agardhfjellet Formation, central Spitsbergen (Svalbard). Samples from two drill cores (DH2 and DH5R) were analysed for $\delta^{13}C_{org}$, total organic carbon (TOC) and Rock Eval. Rock Eval, litho- and biostratigraphy demonstrate a similar development in the two cores, allowing construction of a composite $\delta^{13}C_{org}$ curve covering the Bathonian to lowermost Cretaceous. There are only weak correlations between Rock Eval parameters and $\delta^{13}C_{org}$, suggesting the isotopic signal is not mainly controlled by type of kerogen/maturation but rather reflects regional or global environmental changes. The carbon–isotope curves from the cores can be correlated with previously published curves from outcrops of the Slottsmøya Member and with more distant localities in the Barents Sea, Siberia, Great Britain and the Atlantic. Features in common with other published curves include a Callovian–Oxfordian positive excursion, a Kimmeridgian–Middle Volgian negative trend and a Middle Volgian negative excursion. These correlations allow refinement chronostratigraphy of the Jurassic of Svalbard.

1. Introduction

A long-term study that is currently being conducted at the Museum of Natural History in Oslo on the invertebrate fauna and palaeoenvironment of the Middle Jurassic to lowermost Cretaceous Agardhfjellet Formation of Spitsbergen requires high stratigraphical resolution. Biostratigraphical correlation between Spitsbergen and the offshore Barents Sea is limited by relatively long-ranging bivalve and foraminiferal biozones in the Jurassic, and the absence of ammonites in large parts of the section. The correlation of the high arctic to other palaeobiogeographic regions is even more problematic because faunas are often endemic. The development of a chemostratigraphic framework to support and refine the biostratigraphy is therefore a priority.

We focus here on carbon–isotope stratigraphy. Carbon–isotope curves are commonly used for correlation (Jarvis et al., 2015) but can also be interpreted in terms of environmental change. For example, faunal turnover of ammonites seems to have coincided with global carbon–isotope perturbations near the Triassic–Jurassic boundary (Guex, 2004) and in the Middle Jurassic (O'Dogherty et al., 2006).

Carbon–isotope correlation is commonly based on carbonate carbon ($\delta^{13}C_{carb}$). Unfortunately, the Middle Jurassic to Lower Cretaceous deposits of Spitsbergen lack continuous carbonates and calcified fossils are rare, inhibiting high stratigraphic resolution (Ditchfield, 1997; Hammer et al., 2012). In addition, attempts to obtain $\delta^{13}C_{carb}$ values from carbonate concretions or carbonate-cemented beds show significant diagenetic overprinting (Krajewski, 2004). The alternative, $\delta^{13}C_{org}$ from bulk sediment samples, provides a possible solution. This method has been used successfully in a number of studies for carbon curve correlation on regional and global scales in the Mesozoic (Cohen et al., 2007; Galfetti et al., 2007; Hammer et al., 2012; Zakharov et al., 2014). The $\delta^{13}C_{org}$ curve may or may not resemble the $\delta^{13}C_{carb}$ curve, but often shows the same overall trends (Hayes et al., 1999; Jenkyns, 2010; Meyer et al., 2013; Zakharov et al., 2014). Both Galfetti et al. (2007) and Hammer et al. (2012) concluded that features of atmospheric/oceanic carbon–isotope composition could be discerned in the $\delta^{13}C_{org}$ signal in the Triassic and Jurassic of Svalbard even if also affected by organic matter source, diagenesis, thermal maturation and weathering.

Previous work on the organic carbon–isotope record in the Jurassic of Spitsbergen focused on the Slottsmøya Member (Hammer et al., 2012). The Slottsmøya Member has been researched extensively because of the presence of hydrocarbon paleoseeps, richness in both invertebrate and vertebrate fossils and the possible evidence for the Mjølnir impact (Dypvik et al., 2006; Hammer et al., 2011; Hurum et al., 2012; Hammer et al., 2013). We here extend the organic carbon–isotope curve to the entire Agardhfjellet Formation. In addition, unlike previous work based on outcrop material that may be disturbed by weathering, we use core materials from the CO_2 Svalbard project

---

[*] Corresponding author.
E-mail address: m.j.koevoets@nhm.uio.no (M.J. Koevoets).

http://dx.doi.org/10.1016/j.palaeo.2016.02.029

(Sand et al., 2014), providing a continuous record from the Middle Jurassic (Bathonian) to the lowermost Cretaceous.

2. Geological setting

The Svalbard archipelago is located between 74° and 81° North and between 10° and 35° East, on the Barents Sea shelf. The rocks in Svalbard range from the Archean to Quaternary in age and form an uplifted part of the NW margin of the Barents Shelf (Harland et al., 1997). Dextral movement between Svalbard and East Greenland along the De Geer Zone (i.e., the Hornsund Fault Zone), related to the opening of the North Atlantic Ocean, caused oblique compression and the development of the West Spitsbergen fold-and thrust belt and the Tertiary Central Basin (Eldholm et al., 1987; Braathen et al., 1995; Leever et al., 2011). Svalbard and the entire Barents Sea region have been subjected to significant tectonic activity and glacial erosion during the last few million years (Dimakis et al., 1998). Based on vitrinite analysis, Throndsen (1982) estimated a net uplift of the west-central Spitsbergen of nearly 3.5 km. A recent study by Marshall et al. (2015) suggested that the base of the Paleocene has experienced a maximum burial temperature of 120 °C in the center of the Tertiary Central Basin and 100 °C at the basin margins with a geothermal gradient of approximately 50 °C/km. The current geothermal gradient is near 40 °C/km (Braathen et al., 2012). The outcrops and wells in this study are near the center of the Tertiary Central Basin. The Agardhfjellet Formation is approximately 700 to 1000 m below the basal Tertiary unconformity. Based on the results of Marshall et al. (2015), the succession may have been exposed to temperatures between 150 °C and 170 °C. Local heating from Early (Barremian–Aptian) Cretaceous magmatic dyke–sill intrusions is a common feature in Svalbard (Minakov and Podladchikov, 2012; Brekke et al., 2014; Senger et al., 2014) but seems to be of little importance in the Jurassic of the study area (Braathen et al., 2012).

The Middle Jurassic to lowermost Cretaceous sediments of the Agardhfjellet Formation were mainly deposited in an inner to outer shelf environment with periodic oxygen-deficient bottom waters. The formation consists of black paper shales and grey siltstones with subordinate sandstones, carbonates and glauconites. The formation thickness ranges from 100 to 250 m in Spitsbergen to less than 50 in the eastern islands (Dypvik et al., 1991; Mørk et al., 1999a; Krajewski, 2004; Hammer et al., 2012). Based on foraminiferal and ammonite biostratigraphy, the formation extends from the Upper Bathonian to the lowermost Cretaceous (Wierzbowski, 1989; Nagy and Basov, 1998; Nagy et al., 2009). This study involves the Agardhfjellet Formation in the central part of Spitsbergen, which is divided into four members (Dypvik et al., 1991; Mørk et al., 1999a): the Oppdalen Member (approx. Upper Bathonian–Oxfordian), the Lardyfjellet Member (approx. Lower Kimmeridgian), the Oppdalssåta Member (approx. Upper Kimmeridgian–Lower Volgian) and the Slottsmøya Member (Lower Volgian–Upper Volgian, crossing the Jurassic/Cretaceous boundary) (Dypvik et al., 1991; Nagy and Basov, 1998; Mørk et al., 1999a; Hammer et al., 2012). For the purposes of this paper, we have defined the base Agardhfjellet Fm. as the base of the first silt above the sands of the Brentskardhaugen and/or Marhøgda Bed, in accordance with the definition of Mørk et al. (1999b) and Mørk et al. (1999a).

The core data used in this study were obtained from the UNIS CO2 LAB (Fig. 1; Dallmann et al., 2001). These drillings were done as part of the CO_2 project in Svalbard to investigate the possibilities of CO_2 storage in Triassic sandstones and get a better understanding of the geology (Sand et al., 2014). Well DH5R is situated in the UNIS CO2 LAB well park in Adventdalen southeast of Longyearbyen, while DH2 was drilled 7 km northwest of DH5R, close to the airport (Braathen et al., 2012).

The thickness of the Agardhfjellet Formation in both the DH2 and DH5R wells is about 250 m. The base of the Agardhfjellet Formation in DH2 was set at 732 m, at the boundary with the underlying, coarse-grained Knorringfjellet Formation. The top of the formation was set at 481 m, at a glauconitic bed which is interpreted as part of the Myklegardfjellet Bed (Dypvik et al., 1992). The base of the Agardhfjellet Formation in DH5R was placed at 671 m. The top of the formation was not identified in DH5R because of a thick diamictic interval there (Fig. 2).

The stratigraphy of the Agardhfjellet Formation in the two cores is very similar to the outcrop at Janusfjellet, ca. 10 km to the northeast (Dypvik et al., 1991; Mørk et al., 1999a; Hammer et al., 2012) (Fig. 2). The Oppdalen Member consists mainly of dark grey siltstones/

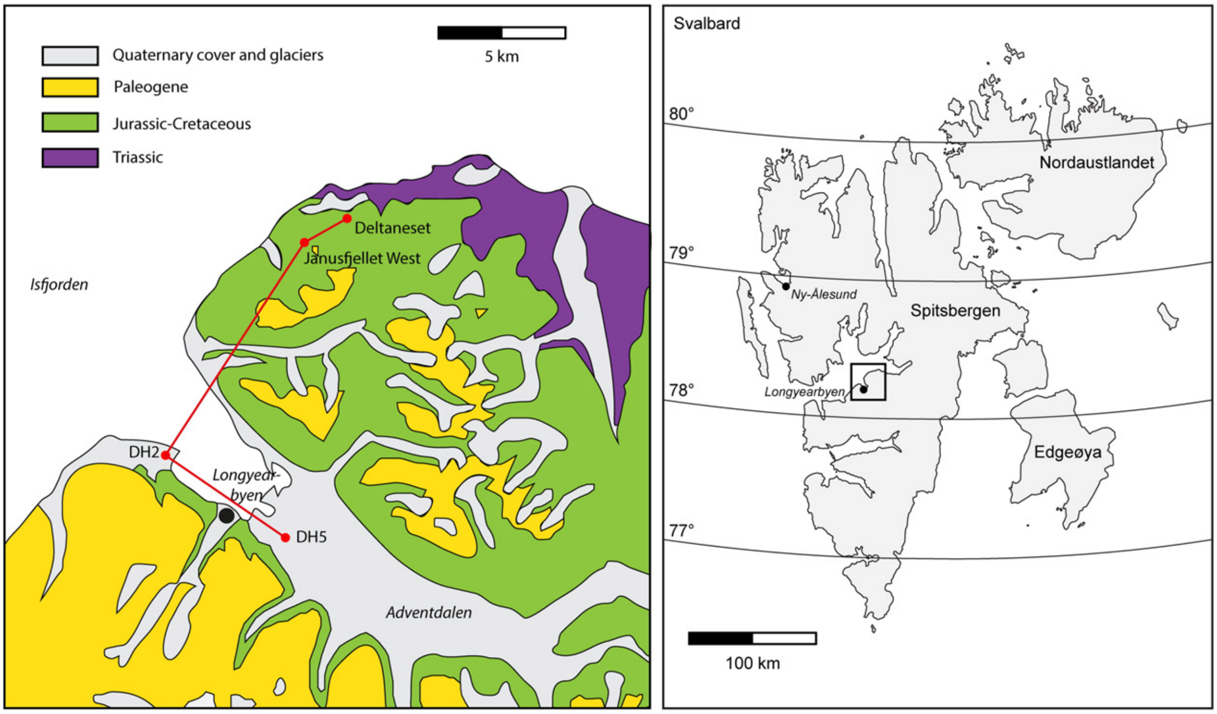

Fig. 1. Geological map of study area, on the left it shows the drill-hole locations near Longyearbyen and field locations Deltaneset and Janusfjellet West, Spitsbergen, Svalbard. The geological map is modified from Dallmann et al. (2001)