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The Paleocene–Eocene thermal maximum (PETM) in Svalbard — clay mineral and geochemical signals

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ABSTRACT

For the first time the Paleocene–Eocene Thermal Maximum (PETM) interval has been identified in drillcores and field outcrops from the Paleogene Central Basin in Svalbard, based on mineralogical and geochemical information. Grumantbyen and Frysjaodden formations, a more than 300 m thick Paleogene interval, representing deltaic, delta-influenced marine shelf and deep water slope environments. The PETM has been recognized in the deepest and most distal deposits in the lower parts of the Frysjaodden Formation. Here, this global event is displayed in clay mineralogical distributions as significantly increased kaolinite abundances reflecting a period with intensified chemical weathering in the land areas surrounding this Paleogene basin. The period was characterized by dominantly reducing sea floor conditions, as seen in the Th/U distribution and the well developed parallel lamination in the pyrite-rich shales; all to be expected during an interval with increased temperature and precipitation.

1. Introduction

1.1. Project background

The Paleogene period displayed marked global climatic changes and the Paleocene–Eocene Thermal Maximum (PETM, formerly called Late Paleocene Thermal Maximum – LPTM) was characterized by severe climatic shifts. This event was recognized globally in the early 1990s and has been a paleoclimatical focus of attraction since then (Kennett and Stott, 1991; Koch et al., 1992; Röhl et al., 2010; Sluijs et al., 2006; Zachos et al., 1993). This well-documented temperature excursion represents a short period of global warming on a background of general greenhouse climate. It changed the Arctic surface waters to possible average summer temperatures of 23 to 24 °C, before retaining to cooler temperatures. The duration of this warm period is still not sufficiently constrained, but it may have lasted for more than 200,000 years (Röhl et al., 2010).

Our study forms parts of the pACE (Paleo Arctic Climates and Environments) project, which is a WUN (Worldwide Universities Network) originated project, comprising scientists from a wide selection of universities (http://www.wun.ac.uk/pACE/index.html). The primary goal of pACE is both to reconstruct Arctic paleoenvironmental and paleoclimatic conditions during the Paleocene–Eocene greenhouse episode (PETM) 55 Ma (million years) ago and during the subsequent transition to Eocene and towards modern Icehouse conditions (~45–40 Ma).

The Paleogene succession of the Cenozoic central basin of Svalbard (Fig. 1) includes Paleocene and Eocene formations composing the Van Mijenfjorden Group (Fig. 2). The studied Svalbard successions across the Paleocene–Eocene transition are well exposed in outcrops and present in several exploration cores drilled by Store Norske Spitsbergen Grubekompani (SNSK) (Fig. 2). The PETM investigations of the pACE project covers a wide field of research including palynological and stable isotopes analyses, micropaleontological, geochemical, sedimentological, and mineralogical issues (Charles, pers.com., 2010; Cui, pers.com., 2010; Nagy, pers.com., 2010; White, pers.com., 2010). The present paper focuses on the sedimentological, stratigraphical, and mineralogical composition of the formations. Parallel studies of Nagy (pers.com., 2010) will present the main micropaleontological and stratigraphical results.

1.2. Geographical and geological setting

The archipelago of Svalbard is located at the margin of the Arctic Ocean, at the northwestern corner of the Eurasian continental plate, about midway between mainland Norway and the North Pole.

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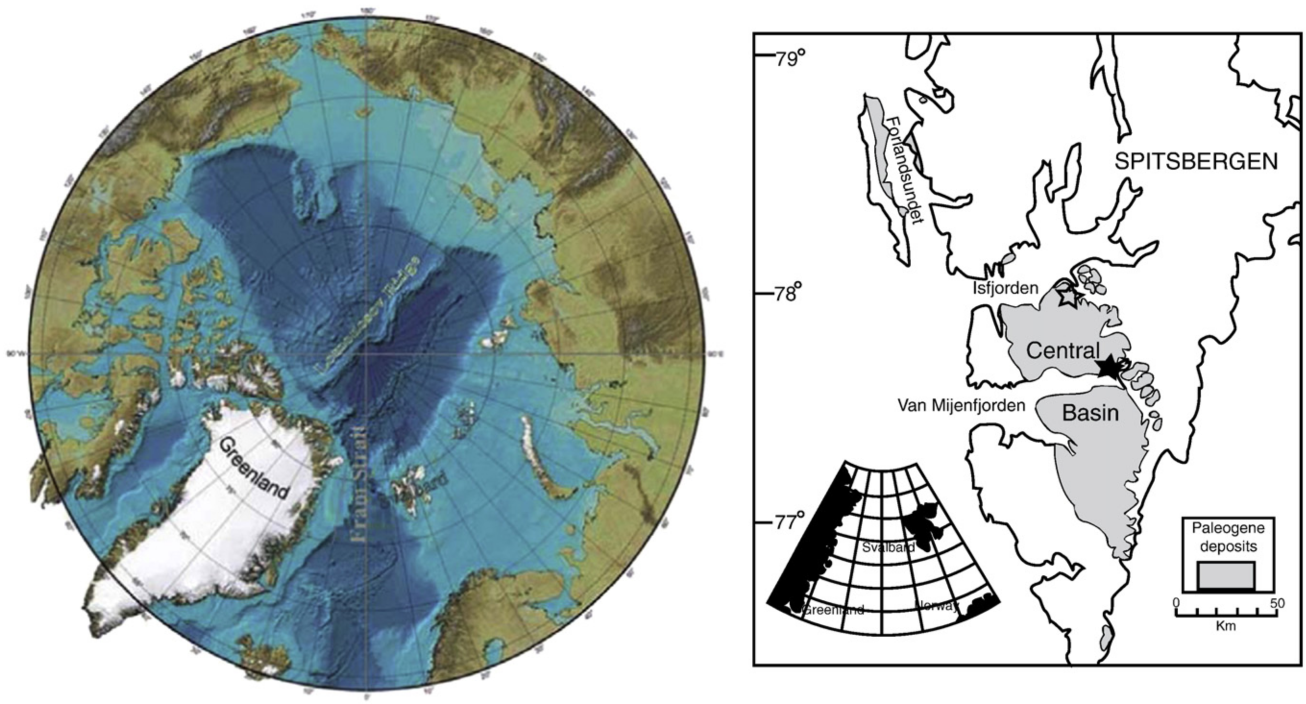

Fig. 1. The left map illustrates the geographical location of Svalbard on the margin of the Arctic Ocean (Jakobsson et al., 2008). The right map shows the Central Paleogene Basin of Spitsbergen (the largest island in the Svalbard archipelago), marked by grey signature. The Nordenskiöldfjellet section and borehole BH9/05 are marked by open and filled stars, respectively.
Modified from Nagy (2005).

Svalbard is separated from northeastern Greenland by the deep water Fram Strait (Fig. 1).

The northern part of Svalbard (Fig. 1) is partly covered by Devonian sedimentary rocks dipping below the Late Paleozoic/Mesozoic and Cenozoic strata in southern regions (Harland, 1997; Ritzmann et al., 2002; Steel and Worsley, 1984). A western coastal province comprises the West Spitsbergen fold-and-thrust belt. This high relief zone was formed due to the transpression between Svalbard and Greenland during the initial opening of the North Atlantic–Arctic basins (Engen and Faleide, 2005; Faleide et al., 2008).

Steel and Worsley (1984) interpreted the Paleogene Central Basin on Spitsbergen to represent two main evolutionary stages: i) Paleocene strike slip and ii) Eocene compression. Bruhn and Steel (2003) argued that the evolution of the Central Spisbergen basin can be explained by a single, compressional, foreland-basin scenario. The major tectonic evolution can be deduced from offshore seismic lines along a major intraplate transform fault zone west of Spitsbergen (Engen and Faleide, 2005; Faleide et al., 2008; Ritzmann et al., 2002).

The Paleocene beds had a mainly easterly sedimentary source area (Mesozoic formations), while the Eocene sediments were derived from the western fold and thrust belt (Precambrian, Paleozoic and Mesozoic formations) (Bruhn and Steel, 2003). These stages are well preserved both offshore and onshore in the Paleogene Central Spitsbergen Basin, as observed in seismic reflection surveys (Ritzmann et al., 2002). The Central Basin may be regarded as a minor foreland basin or as a piggyback basin due to the uplift and loading from the West Spitsbergen fold and thrust belt (Ponten and Björklund, 2009).

1.2.1. Paleogeography

The Paleogene epoch has been shown to be one of the most climatically dynamic periods in Earth history (e.g. Dickens et al., 1995; Röhl et al., 2010; Sluijs et al., 2006; Zachos et al., 1993). Conditions were changing from greenhouse environments with possible higher levels of carbon dioxide, methane and water vapour in the late Cretaceous towards ice-covered poles in the relatively cold Neogene period.

At the Paleocene–Eocene transition climatic conditions were initially thought to have developed gradually through the Paleogene. The results of subsequent research conducted by DSDP (Deep Sea Drilling Project) and ODP (Ocean Drilling Project) in the 1970's and 1980's as well as the IODP activity (Integrated Ocean Drilling Program) including the ACEX (Arctic Coring Expedition in 2004) revealed short and rapid temperature excursion, rather than gradual climatic changes (Kennett and Stott, 1991; Moran et al., 2006; Zachos et al., 1993). The Paleocene Eocene Thermal Maximum (PETM) is the most prominent episode of climatic change, and its recognition plays a major role in the reconstruction of Paleogene climate.

In Eocene, paleomagnetic data indicate a "paleoSvalbard" latitude of 71°–72°N, about 6° south of its present location (Dalland, 1976).

Based on analyses of conifers from early Paleocene to early Eocene horizons, an annual mean temperature of 15–18 °C has been suggested for the Svalbard region (Schweitzer, 1980). Compared to the current mean temperature for similar latitudes today (Troms, Norway, varying from – 4.4 (January) to 11.8 (July) (http://www.met.no), the Paleogene climate was much warmer. The modern correspondent species (*Metasequoia glyptostroboides*) of the megafossil conifers (*Metasequoia occidentalis*) present in the Central Paleogene Basin indicate a climate characterized by rainfall which was moderate to absent in the winter and heavy in the summer season (Schweitzer, 1980).

1.2.2. Stratigraphical Arctic/Northern Hemisphere Paleocene–Eocene correlation

The Van Mijenfjorden Group is sediment infill of the Paleogene Central Basin successions of Spitsbergen (Fig. 2). The group can tectonostratigraphically be divided into a lower (mainly Paleocene) and an upper (mainly Eocene) part. The observed clastic sediment supply from eastern sources (from paleocurrent data) dominated throughout the accumulation of the Firkanten, Basilika and Grumantbyen formations,