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Provenance of bentonite layers in the Palaeocene strata of the Central Basin, Svalbard: implications for magmatism and rifting events around the onset of the North Atlantic Igneous Province

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ABSTRACT

A fold-and-thrust belt developed between Greenland and Svalbard during the Palaeogene, with an associated foreland basin forming in what is now Spitsbergen. This Central Basin is comprised of the Van Mijenfjorden Group, a ~2.3 km thick sandstone-shale dominated succession that contains prominent and laterally continuous bentonite layers in the lower formations. These altered tephra layers can be used as stratigraphic markers that connect the basin development with regional explosive volcanism and changes to relative plate motions. We sampled and analysed bentonites from nine borehole cores across the Central Basin. Each layer shows evidence of alteration, with mobile elements such as alkali and alkali earth metals particularly disrupted. However, immobile elements including rare earth elements (REE) and preserved igneous minerals retain a magmatic signature, allowing for comparisons with potential volcanic sources to be made. The majority of bentonites are both evolved and strongly alkaline, with chemical signatures that are much closer to the continental rift events around Ellesmere Island and North Greenland than to the early activity of the North Atlantic Igneous Province (NAIP). There is a clear difference between tephra layers in the mid Palaeocene versus late Palaeocene strata. The early bentonites have a REE signature comparable to the volcanics of the Kap Washington Group exposed in North Greenland. The later bentonites have likely come from volcanic centres in the Nares Strait that are also the source of abundant volcaniclastic sediments in the Judge Daly Promontory, Ellesmere Island. These findings suggest that a mid to late Palaeocene change in locus of volcanic provenance may reflect changes in relative plate motions related to the formation of the West Spitsbergen fold-and-thrust belt and the emplacement of the NAIP. However, the lack of bentonites matching NAIP sources suggests that explosive volcanism was of insufficient magnitude to lead to deposition in the Central Basin at this time.

1. Introduction

During major volcanic eruptions, tephra (airborne ejecta) can be distributed thousands of kilometres away from the source volcano (Baines and Sparks, 2005; Baines et al., 2008). The distal signal of explosive volcanism is manifested as volcanic ash layers. In cases where tephra deposits are preserved, tephrochronology can be used as a powerful method for dating, linking, and synchronizing geological, palaeoenvironmental, or archaeological events (e.g. Lowe, 2011). Tephra layers are easily eroded, leading to a low preservation potential. However, sedimentary sequences deposited in low-energy marine settings and/or in areas with rapid subsidence are ideal for preserving a more complete stratigraphy containing undisturbed ash layers. Geochemical analyses of bentonites can be used to correlate the ash layers to the volcanic eruptions from which they came, allowing for more refined interpretations concerning the nature and style of volcanism. Moreover, accurate radioisotopic dating of magmatic minerals using U-Pb and/or Ar-Ar methods allows tephra horizons to be powerful geochronological markers.

An example of a well preserved and continuous sedimentary sequence containing bentonite layers is the Palaeogene Central Basin of

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Spitsbergen, Svalbard (Harland, 1965, 1969). A change in relative plate motions in the mid to late Palaeocene led to dextral transpressive stress between Greenland and Eurasia (Pitman and Talwani, 1972; Kristoffersen, 1978; Fig. 1), resulting in the formation of the West Spitsbergen fold-and-thrust belt (Steel et al., 1981, 1985; Kleinspehn et al., 1989; Teyssier et al., 1995; Braathen et al., 1999). The Central Basin formed contemporaneously as a rapidly subsiding foreland basin adjacent to the mountain belt (Talwani and Eldholm, 1977; Müller and Spielhagen, 1990; Fig. 2). At the same time, significant explosive volcanism was occurring outside the basin, leading to a number of ash layers being deposited (Dypvik and Nagy, 1978). The sedimentary succession of the Central Basin contains prominent 1–30 cm thick bentonite horizons that are laterally continuous over tens of kilometres. The close proximities of the nascent rifting in the Norwegian Sea, the first phase of the North Atlantic Igneous Province (NAIP) on Greenland, and episodic rifting events in the Arctic (Fig. 1) means that there are a number of possible volcanic sources of the bentonite layers. Pinpointing the provenance of these bentonites would significantly improve our understanding of how the break-up of the North Atlantic and the opening of the Eurasia basin developed.

In this study we focus on the chemical compositions of bentonites across the Central Basin. A total of 52 samples from nine drill cores and samples taken *in situ* from mine workings are included. The bentonites are analysed for bulk major and trace element compositions, and using scanning electron microscopy (SEM) and electron microprobe (EMP) analyses on individual minerals. The aim of characterizing these bentonites is to compare the tephra layers with potential source volcanoes active during the Palaeocene, namely the continental rift volcanic suites in North Greenland and Ellesmere Island, and the NAIP (Fig. 1). Deriving the provenances of the bentonites provides a direct link between the tectonic forces causing the formation of the Central Basin, regional rifting events, and large igneous province emplacement.

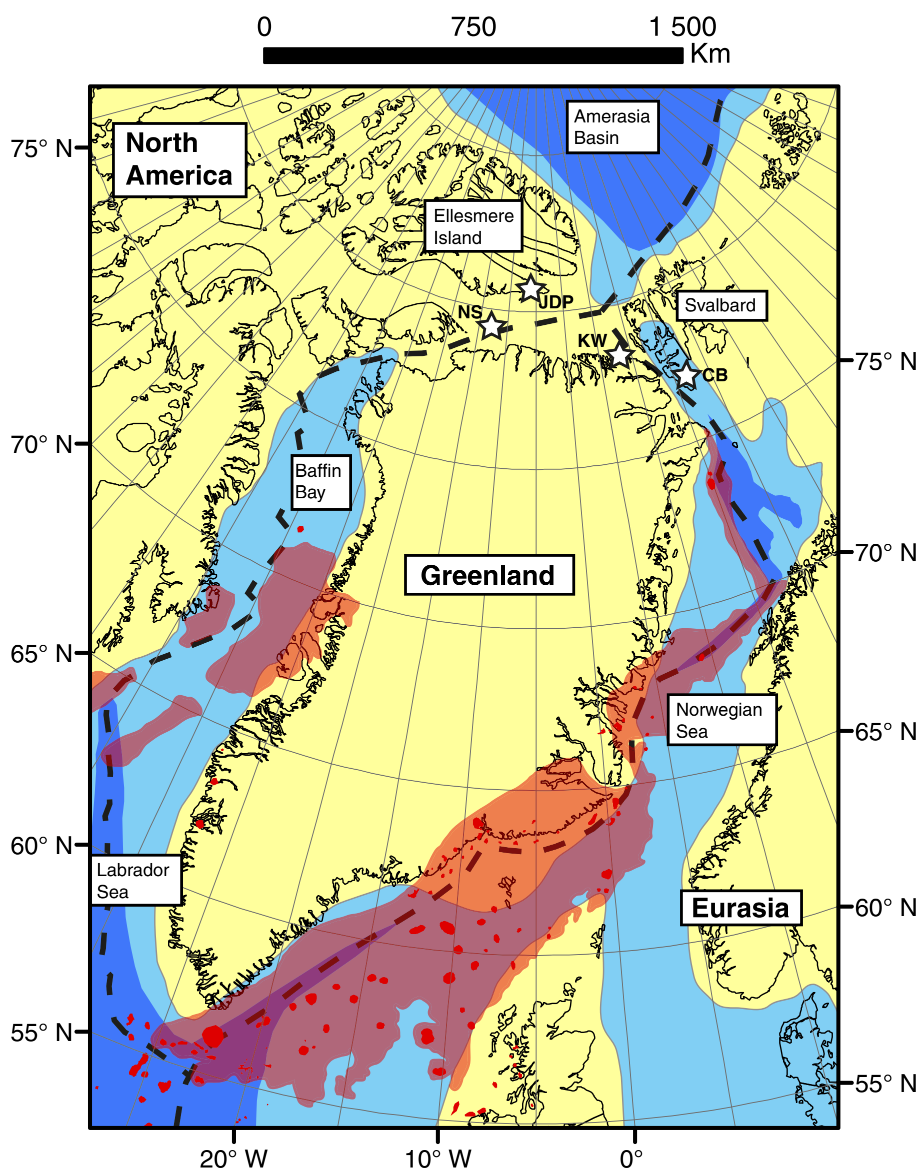

Fig. 1. A plate reconstruction at 55 Ma (modified from Tessensohn and Piepjohn, 2000; and Piepjohn et al., 2013) around the time of North Atlantic breakup. Palaeo-shorelines and marine seaways are indicated in blue (from Golonka, 2009). Present day coastlines are shown in black, dashed black lines indicate plate boundaries. The red overlay areas denote the known extent of the North Atlantic Igneous Province (NAIP) at that time (e.g. Jerram and Widdowson, 2005; Nelson et al., 2015), with some of the known individual volcanic centres labelled in opaque red. The white stars denote the locations of the Central Basin (CB) in Svalbard, the Kap Washington Group (KW), the Judge Daly Promontory (JDP), and the estimated location of the Nares Strait (NS) volcanic centre that was the source of volcaniclastic deposits at the JDP. The Eurekan deformation that affected Ellesmere Island is not fully restored in this figure. There was a possible shallow marine connection to the Amerasia Basin from the Central Basin at the time. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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