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Source as a controlling factor on the quality and interpretation of sediment magnetic records from the northern North Atlantic

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ABSTRACT

Magnetic properties of eight particle size ranges from nine locations in Iceland and 26 locations in southern Greenland reveal the importance of source variation for our understanding of paleomagnetic and environmental magnetic records in the marine environment. These terrestrial samples show varying degrees of particle size dependence with all samples showing that the silt fraction possesses greater concentrations of ferrimagnetic minerals than either clay or sand. Fine pseudo-single domain (PSD) size magnetic grains dominate the magnetic assemblage of all Icelandic fractions. In contrast, Greenlandic samples possess greater variation in magnetic grain size; only fine silt and clay are as magnetically fine as the Icelandic PSD grains, while Greenlandic silts and sands are dominated by coarser PSD and multi-domain grains. These observations from potential marine sediment sources suggest that the silt size fraction is a likely driver for much of the concentration-dependent parameters derived from bulk magnetic records and that the magnetic grain size of the silt fraction can be used to discriminate between Icelandic and Greenlandic sources. Using these results to examine magnetic grain size records from marine sediment cores collected across the northern North Atlantic suggests that source, not just transport-controlled physical grain-size, has a significant impact on determining the magnetic grain size at a particular location. Homogeneity of magnetic grain size in Icelandic sediments at least partially explains the consistent quality of paleomagnetic records derived from cores surrounding Iceland and their ability to buffer large environmental changes.

1. Introduction

Magnetic studies of northern North Atlantic (NNA) deep sea sediments have provided invaluable paleo-geomagnetic information (Stoner et al., 1995a, 2007; Channell and Lehman, 1997; Channell et al., 2002; Mazaud and Channell, 1999; Mazaud et al., 2009), and have contributed to our understanding of past changes in ocean circulation (Rasmussen et al., 1996, 1997; Kissel et al., 1997, 1999, 2009; Snowball and Moros, 2003; Kanamatsu et al., 2009) and the dynamics of surrounding continental ice sheets (Robinson, 1986; Stoner et al., 1995b; Stoner and Andrews, 1999; Evans et al., 2007). The quality of these NNA magnetic records is facilitated by high rates of sediment transfer from the continents to the ocean through glacial erosion of the surrounding ferrimagnetically rich igneous and metamorphosed bedrock. Regional sourcing, (re)distribution, sorting, and focusing of sediment by ocean currents, coupled with a general lack of diagenetic transformations (Stoner and Andrews, 1999; Robinson et al., 2000; Watkins and Maher, 2003), act to define the sediment magnetic characteristics at any particular location, providing both stratigraphic and environmental information. Magnetic homogeneity is a preferred requirement for paleomagnetic studies, while variation in magnetic properties can indicate environmental change. Despite these different magnetic requirements, the NNA has consistently delivered high quality paleomagnetic and environmental magnetic records, often from the same core (e.g., Stoner et al., 1995a, 1995b, 2000; Kissel et al., 1997, 1999; Evans et al., 2007).

Variation in both sediment source and the extent of current related sorting is reflected in the physical properties of sediment deposited across the NNA (e.g., Robinson, 1986; Grousset et al., 1993; McCave et al., 1995; Revel et al., 1996; Bianchi and McCave, 1999; Hemming, 2004). While magnetic properties of sediments commonly possess strong particle size dependence (Oldfield et al., 1985; Oldfield and Yu, 1994; Rosenbaum and Reynolds, 2004; Hatfield and Maher, 2008, 2009; Rosenbaum et al., 2012), magnetic records of deep-sea sediments are usually acquired

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through measurement of bulk (whole sample) sediments, either via whole core, u-channel or discrete samples. Bulk measurement aggregates the contributions from all the different clastic size fractions and source lithologies into a single measurement that can either smooth or amplify source and/or sorting information in a way that can make interpretation of the bulk magnetic record potentially problematic. Similarly, bulk measurements make it difficult to ascertain why some paleomagnetic records work better than others. We know that the best paleomagnetic records are derived from sediments possessing a restricted magnetic grain-size range (e.g., King et al., 1983; Tauxe, 1993); however, we rarely understand where or how these grains are sourced, making it difficult to predict where high quality records are likely to be obtained.

How magnetic properties from different source regions vary with particle-size, how particle-size fractions vary through sedimentary processes (weathering, erosion, transportation, and deposition), and how this influences the sediment magnetic record at different locations across the NNA has rarely been considered when interpreting bulk environmental and paleomagnetic records. An evaluation of these influences and an understanding of their potential effects on the bulk sediment record of the NNA is therefore critical for any comprehensive evaluation. Here we present grain-size specific magnetic data from terrestrial glaciated terranes of Iceland and southern Greenland (Fig. 1). We then use these data to differentiate between these source regions, and begin to discuss the implications that both source and particle size variation may have for the interpretation magnetic records from different locations around the NNA.

2. Materials and methods

A large proportion of the lithogenic sediment in the NNA results from glacial erosion of Iceland and Greenland (Ruddiman, 1977; Laine, 1980; Larsen et al., 1994; Prins et al., 2002). The geology of Iceland (and east-central Greenland) is dominated by Neogene and Paleogene flood basalts (Jakobsson, 1972; Pedersen et al., 1997). The Precambrian rocks in southern Greenland can be further divided into three geological terranes (Fig. 1); the Ketilidian Mobile Belt (KMB) is primarily juvenile Proterozoic crust consisting of voluminous granitic intrusions, while the Archean Block (AB) and the Nagssugtoqidian Mobile Belt (NMB) are crystalline Archean basement rocks that remained undeformed or were metamorphosed during the Proterozoic, respectively (Fig. 1; Kalsbeek and Taylor, 1985; Korstgård et al., 1987; Escher and Pulvertaft, 1995). Throughout the text we use the term "Greenlandic" in reference to sediment sourced only from these three southern Greenlandic terranes. To characterize these NNA terrestrial sediment sources we collected sediment from streams draining actively glaciated watersheds of Iceland and the three southern Greenlandic terranes (Fig. 1). Bulk magnetic properties were first measured prior to grain-size separation. Sand was isolated through sieving at 63 μm. Half of the <63 μm fraction was settled according to Stoke's Law to attain bulk silt (3–63 μm) and clay (<3 μm) fractions. The remainder of the <63 μm fraction was sieved and settled to create four silt fractions: 45–63 μm, 32–45 μm, 20–32 μm, 10–20 μm and a fine silt/clay fraction <10 μm which is at the boundary defining cohesive/non-cohesive sediment transport (e.g., McCave et al., 1995; McCave and Hall, 2006). All bulk and fractionated samples were immobilized in plastic 8 cc discrete sample boxes prior to measurement of magnetic susceptibility and magnetic remanence; 200 mg gelatin caps were used for hysteresis measurements. Mass normalized magnetic susceptibility (MS) was measured at 0.47 kHz on a Bartington MS2B. Mass-normalized anhysteretic remanent magnetization (ARM) was imparted at 100 mT in a 0.05 mT d.c. biasing field and mass-normalized isothermal remanent magnetization (IRM) was acquired at 100, 300, and a 1000 mT saturation IRM field (SIRM). ARM and IRM were measured on a 2G Enterprises cryogenic magnetometer along with MS in the Paleo-and-Environmental Magnetism Laboratory at Oregon State University. Hysteresis parameters (M_{rs}, M_s, H_c, and H_{cr}) were

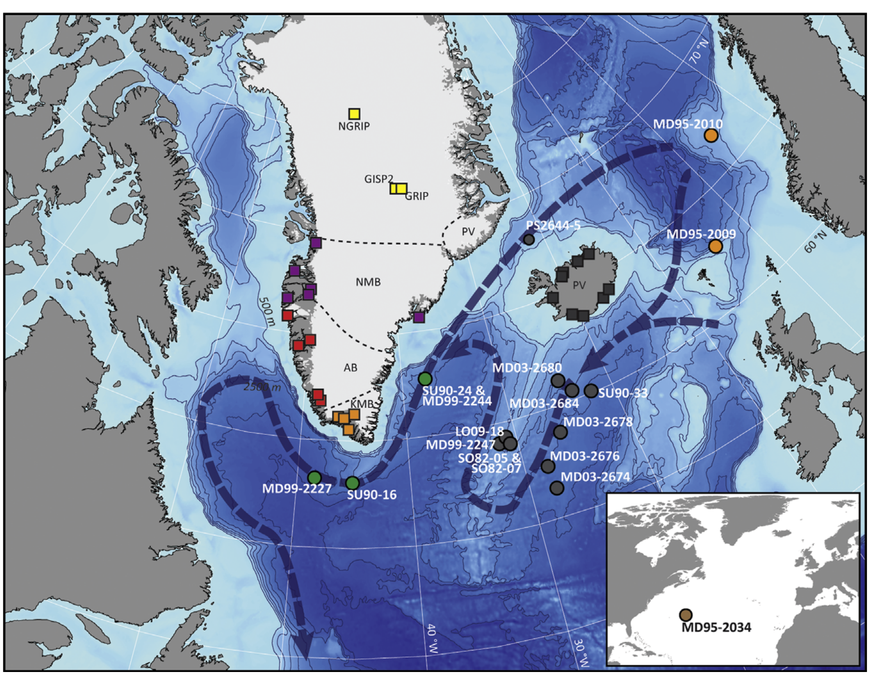

Fig. 1. Location of terrestrial stream sediment samples collected from the Paleogene Volcanics (PV) of Iceland (black squares), and the Ketilidian Mobile Belt (KMB; orange squares), the Archean Block (AB; red squares) and the Nagssugtoqidian Mobile Belt (NMB; purple squares) terranes of southern Greenland. The location of the Greenland Ice cores sites (GRIP, GISP2, and NGRIP; yellow squares) are also shown for reference. Core locations (circles) are color coded as per their spatial groupings in Fig. 5. The path of major bottom water currents as components of North Atlantic Deep Water (NADW) is also shown. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)