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A 17,000 yr paleomagnetic secular variation record from the southeast Alaskan margin: Regional and global correlations

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A B S T R A C T

High-resolution sedimentary records on two cores from the Gulf of Alaska margin allow development of a ∼17,400-yr reconstruction of paleomagnetic secular variation (PSV). General agreement between the two records on their independent chronologies confirms that local PSV is recorded, demonstrating that such archives, notwithstanding complexities due to variable sedimentary regimes, deposition rates, and diagenetic conditions, provide meaningful information on past changes of the geomagnetic field. Comparisons with other independently dated sedimentary paleomagnetic records from the NE Pacific indicate largely coherent inclination records that in combination create a NE Pacific sedimentary inclination anomaly stack (NEPSIAS) capturing the common signal over an area spanning >30° longitude and latitude from Alaska through Oregon to Hawaii. Comparisons of NEPSIAS with high quality declination records from the northern North Atlantic (NNA) show that negative (shallow) inclination anomalies in NEPSIAS are associated with eastward NNA declinations while positive (steep) inclination anomalies in NEPSIAS are associated with westward NNA declinations. Comparison of these directional records to regional geomagnetic intensities over the past ∼3000 yrs in North America and back nearly 8000 yrs in the Euro/Mediterranean region, are consistent with a driving mechanism of oscillations in the relative strength of the North American and Euro/Mediterranean flux lobes. The persistence of these dynamics through the Holocene implicates a long-lived organizing structure likely imposed on the geomagnetic field by the lower mantle and/or inner core. These observations underscore a fundamental connection between directional PSV in the North Pacific with that of the North Atlantic, supporting the potential for long-distance correlation of directional PSV as a chronostratigraphic tool.

1. Introduction

1.1. Paleomagnetic secular variation

Averaged over tens of thousands of years, Earth's magnetic field can be approximated by a geocentric axial dipole (GAD) (Merrill et al., 1996). However, at any given moment the geomagnetic field expressed at Earth's surface deviates substantially from this idealized morphology (Jackson et al., 2000). Field morphology changes with time, displaying variable tilt of the best-fitting dipole relative to Earth's axis of rotation, as well as non-dipole structures (Merrill et al., 1996). Incomplete understanding of what drives deviation from a GAD, in conjunction with the unresolved temporal and spatial scales over which non-dipolar structures persist (Bloxham and Gubbins, 1987) precludes accurate prediction of future geomagnetic field behavior and hinders our ability to reconstruct past field morphologies. Historical reconstructions indicate the existence of persistent concentrations of geomagnetic flux, such as the Canadian and Siberian flux lobes, which may result from organizing structure imposed on the geomagnetic field by lower mantle heterogeneity (Bloxham and Gubbins, 1987). Patterns of paleomagnetic secular variation (PSV) are unlikely to be random, and the interplay of dipolar and non-dipolar components of the field may allow us to understand the dynamics of geomagnetic change.

Observation-based reconstructions of the global geomagnetic field (Constable et al., 2016; Nilsson et al., 2010, 2011, 2014), as well as dynamo modeling studies (Amit et al., 2011) sug-

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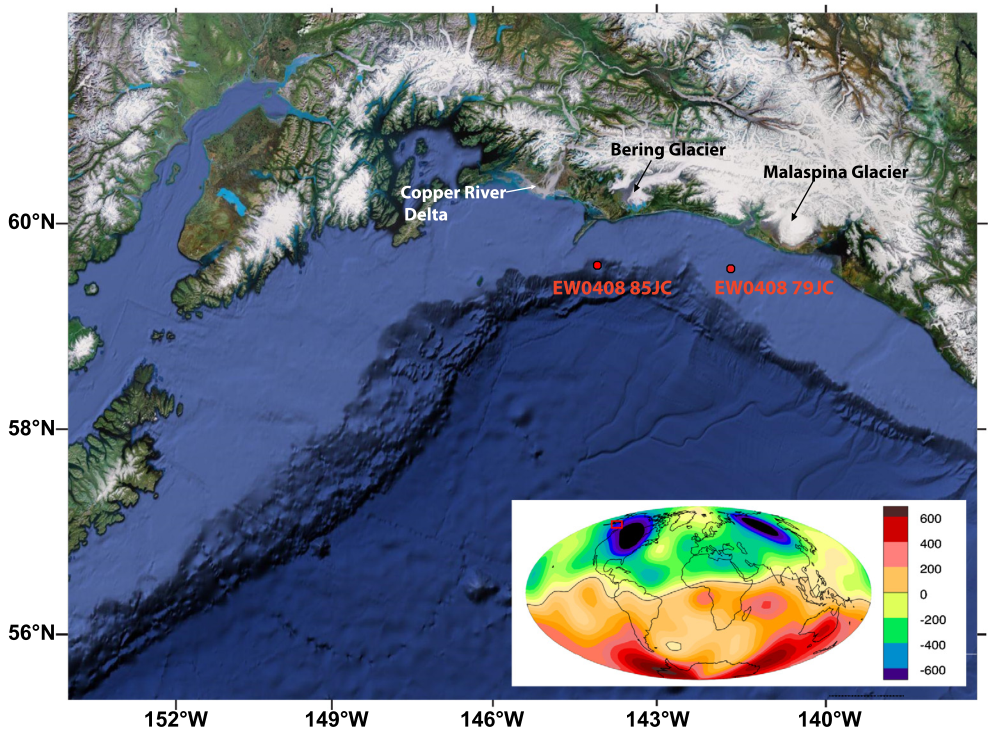

Fig. 1. Site map showing the bathymetry of the Gulf of Alaska, as well as the locations of shelf core EW0408-79JC and slope core EW0408-85JC. The locations of the major sediment sources to the margin, which include drainages from the Bering and Malaspina glaciers as well as the Copper River, are labeled. Inset map (modified from Constable et al., 2016) shows the historical time averaged (1590–1990 C.E) vertical component of the magnetic field at the core/mantle boundary (Jackson et al., 2000); the position of the Gulf of Alaska on the western edge of the North American flux lobe is outlined in red. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

gest that oscillations of flux concentrations at a few recurrent locations could be drivers of mid-latitude PSV. However, alternative conceptual drivers of centennial-to millennial-scale PSV variability, including drift of non-dipole field sources, remain plausible (Nilsson et al., 2010, 2014). Beyond the last 5000 yrs, high-quality observations of PSV behavior are concentrated in the Atlantic sector of the northern hemisphere (Constable et al., 2016; Stoner et al., 2013), while those from the Pacific sector (Verosub et al., 1986; Peng and King, 1992; Geiss and Banerjee, 2003; Lisé-Pronovost et al., 2009) remain rare and have limited temporal resolution and/or chronological control. More detailed records, extending further back in time and covering a larger geographic range, are needed to facilitate a better understanding of the spatial dynamics of the geomagnetic field.

Continental margin sediments can provide greatly expanded, and in many cases well-dated, paleomagnetic records from widely distributed locations. However, interpretations of these records are complicated by variable sedimentation rates, lithogenic sources, transport mechanisms, and diagenetic conditions. Here we reconstruct PSV from the continental margin of the Gulf of Alaska using jumbo piston cores, as well as their attendant trigger (gravity) cores and multi-cores designed to preserve the sediment/water interface; all were collected during R/V Ewing cruise EW0408 in 2004 (Fig. 1). Independent marine radiocarbon chronologies and lithologic variability assessed through computerized tomographic (CT) scans support development of continuous high resolution PSV records that span ~6200 cal ybp on the open continental shelf (Site EW0408-79JC; 59.53°N, 141.76°W, 158 m water depth) and ~17,000 cal ybp from a small depositional basin on adjacent Kayak slope (Site EW0408-85JC; 59.56°N, 144.15°W, 682 m water depth). Comparisons with other independently dated PSV records allow us to evaluate coherence throughout the NE Pacific as well as the relationship of NE Pacific PSV to records from the North Atlantic, Europe, and global field reconstructions.

1.2. Geologic setting: the Gulf of Alaska

The Gulf of Alaska is a tectonically active, glaciated margin. Sedimentation is overwhelmingly terrigenous, with major sources including the drainages of the Bering and Malaspina Glaciers, as well as the Copper River (Fig. 1). Modern accumulation rates on the shelf range from ~0.1–3 cm/yr (Jaeger and Nittrouer, 2006), and expanded lithogenic depositional sequences potentially allow for PSV reconstructions at a resolution impossible to capture in slowly-accumulating deep-sea sediments.

Although there is an opportunity to record the geomagnetic field at high-resolution, marine continental margin records are prone to a variety of complications. The sediment supply to the northeast Gulf of Alaska is diverse, associated with both the proximal erosion of the St. Elias Range by the Bering and Malaspina glaciers, as well as potential distal delivery from the Copper River catchment; these source diverse lithologies that differ in magnetic properties (Cowan et al., 2006), potentially complicating interpretations of normalized remanence. Additionally, while benthic oxygen levels on the margin have been increasing through the Holocene, the early Holocene and late deglacial intervals experienced episodes of benthic hypoxia (Davies et al., 2011; Addison et al., 2012). This can lead to degradation of paleomagnetic records via destruction of primary iron-bearing magnetic remanence carriers during bacterially-mediated anaerobic sulfate reduction (Karlin and Levi, 1983; Tarduno and Wilkinson, 1996), and/or production of secondary magnetic minerals (Roberts et al., 2012).

2. Methods

2.1. Bulk sediment properties

Magnetic susceptibility (MS) and gamma-ray attenuation (GRA) bulk-density data were measured shipboard on whole cores on a