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Character of Holocene paleomagnetic secular variation in the tangent cylinder: Evidence from the Chukchi Sea

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ABSTRACT

We have carried out a paleomagnetic study on three deep-sea cores from the Chukchi Sea (72°N) in order to characterize the Holocene paleomagnetic secular variation (PSV) in this high-latitude region. The Chukchi Sea lies within the geomagnetic-field tangent cylinder and PSV variability in this region might be expected to have a different pattern than PSV at sites located outside the tangent cylinder at lower latitudes. We have recovered correlatable directional PSV records and relative paleointensity records from all three cores. 15 radiocarbon dates were used to develop a chronostratigraphy for the PSV records. These records constitute the highest-resolution full-vector PSV records ever recovered from such high latitudes. We have compared our results with other previous studies from the region and find that our overall PSV is consistent with these other studies, although there are sometimes age differences up to 1000 years between correlatable PSV features. Our statistical PSV characteristics indicate that field variability (VGP angular dispersion) is lower than in regions just south of the Chukchi Sea and outside the tangent cylinder, but our records are probably not long enough to completely characterize PSV. However, our results are consistent with the only other published VGP angular dispersion results from inside the tangent cylinder (Antarctica, 79°S).

1. Introduction

The Chukchi Sea (Fig. 1) lies north of Alaska and forms part of the greater Arctic Ocean basin. Most of the Chukchi Sea and Arctic Ocean are poleward of 70°N latitude and lie within what is known geomagnetically as the tangent cylinder. The tangent cylinder is defined as that region within the Earth that is inside a cylinder whose axis is parallel with the Earth's rotation axis and whose radius is that of the inner core. This is a region where geomagnetic field intensity is historically lower than expected both at the Earth's surface and at the outer-core/mantle boundary (Fig. 1; Bloxham and Gubbins, 1985, 1987). It is hypothesized that geodynamo magnetic-flux-regeneration processes operating in the outer core within this region (e.g., Bloxham et al., 1989; Glatzmaier and Roberts, 1995) may be significantly different from areas outside the tangent cylinder.

This paper presents new high-resolution paleomagnetic secular variation (PSV) records from the Chukchi Sea. Our initial goal is to develop a consistent estimate of PSV and its pattern of variability within the tangent cylinder for the Chukchi-Sea region. Our ultimate goal is compare the Chukchi-Sea PSV records with PSV records from other lower-latitude regions to assess the space/time pattern of PSV and the extent to which the high-latitude tangent-cylinder region has a pattern of variability distinctive from the lower-latitude regions (see also St-Onge and Stoner, 2011).

Keigwin et al. (2006) collected a series of cores from the Chukchi Sea as part of a broad study of regional paleoclimate and sea-level rise associated with the last deglaciation. We have studied three of those cores (Fig. 1): piston cores JPC-15 (72.0°N, 206.6°E; 1295 cm, 1250 m water depth) and JPC-16 (72.0°N, 206.6°E; 1982 cm, 1310 m water depth) and gravity core GGC-19 (72.1°N, 204.5°E; 463 cm, 369 m water depth).

2. Magnetic measurements

Cores GGC-19, JPC-15 and JPC-16 were u-channeled for our paleomagnetic and rock magnetic studies. The initial NRMs of the u-channels were measured and then the u-channels were step-wise demagnetized in alternating magnetic fields (af) at 10 mT, 20 mT, 30 mT, 40 mT, and 60 mT and measured. All u-channel measurements were made at a 1-cm spacing. The u-channels were then given an artificial anhysteretic remanence

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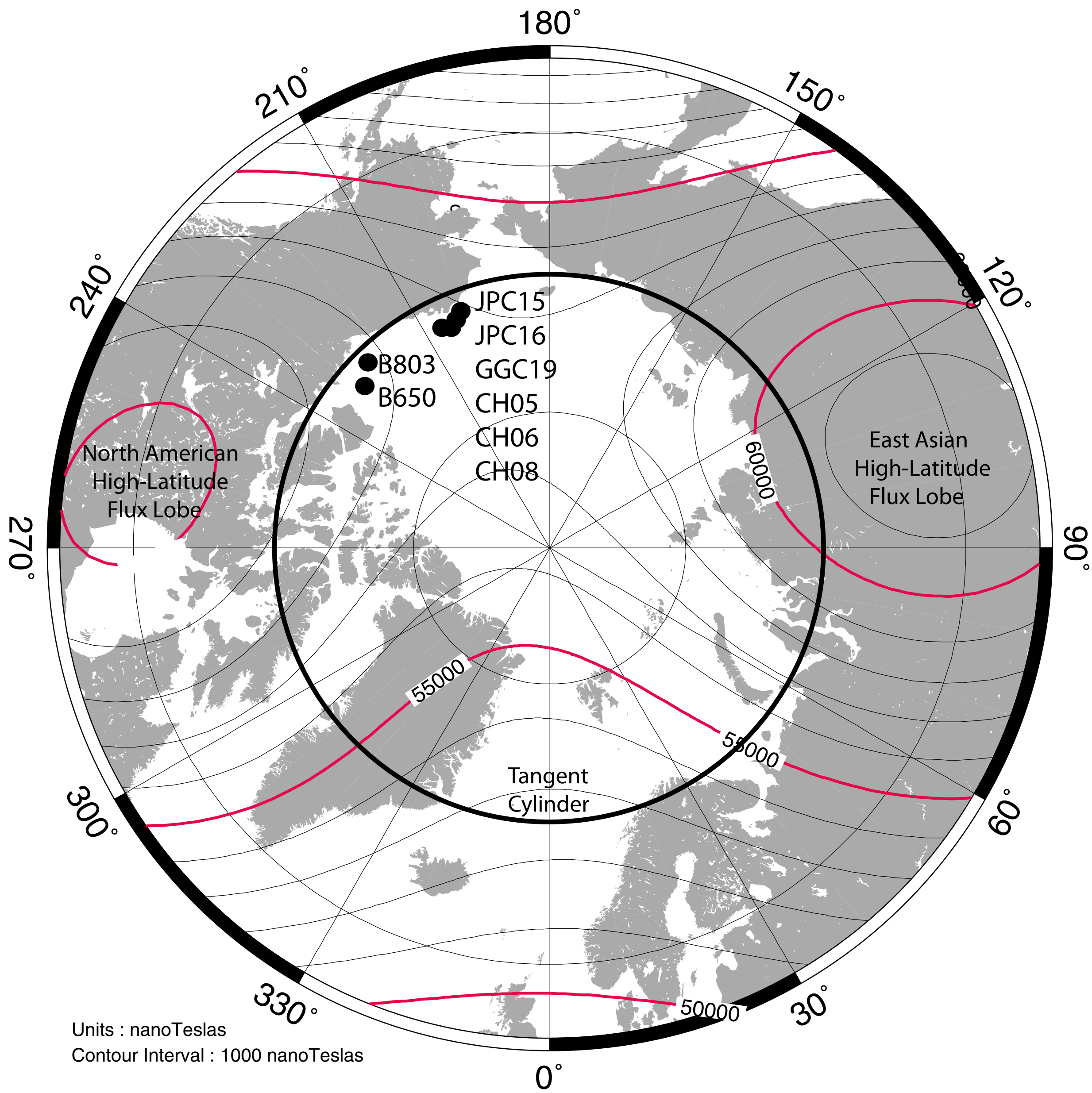

Fig. 1. Map of the Northern Hemisphere polar region showing the current (2005 AD) magnetic field intensity (Olsen et al., 2006) and the location of cores discussed in this paper.

(ARM, 100 mT af, 0.05 mT steady field), which was measured and then stepwise af demagnetized at 10 mT, 20 mT, and 40 mT and measured. Finally, all u-channels were given a saturation isothermal remanence (SIRM, 1 T steady field), which was measured and then stepwise demagnetized at 10 mT, 20 mT, and 40 mT and measured. Selected u-channels also had their ARMs and SIRMs stepwise af demagnetized at 10 mT, 30 mT, and 60 mT steps to match the NRM demagnetization.

Fig. 2 shows the directional variation of selected samples from JPC-15 and JPC-16 under af demagnetization. It is clear that almost all samples have a single paleomagnetic direction that is demagnetized between 10 and 60 mT, which demagnetizes toward the origin. This simple characteristic remanence (ChRM) typically has maximum angles of deviation (MAD) of less than 3°. There is commonly a 'viscous' magnetic overprint, which is demagnetized by 10 mT, but on occasion, the overprint may extend to 20 mT. The simple ChRM is normally associated with more than 70% of the total NRM.

Fig. 3 shows the normal pattern of NRM, ARM, and SIRM intensity loss for selected samples from JPC-15 and JPC-16 under increasing af demagnetization. The NRM intensity loss under af demagnetization is strongly coherent over the entire core length. Most samples have median destructive fields (MDFs) of 35–45 mT. The ARM intensity loss is similar to that of the NRM and suggests that the NRM is carried by a fine-grained magnetite/titanomagnetite. Darby et al. (2009, 2012) have analyzed the anhydrous Fe oxide minerals (45–250 mm) in these sediments and determined the average sediment grain size in JPC-16 to be ~6 mm (very fine silt) using a Malvern 2000 particle size analyzer. The Fe grains are typically black and detrital (anhedral) in