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Paleomagnetic field variability and chronostratigraphy of Brunhes-Chron deep-sea sediments from the Bering Sea: IODP Expedition 323

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ABSTRACT

IODP Expedition 323 recovered six complete and replicate records of Brunhes-Chron paleomagnetic field variability (0–780,000 years BP) in 2820 m core depth below sea floor (CSF) of deep-sea sediments. On shipboard, we made more than 220,000 paleomagnetic measurements on the recovered sediments. Since then, we have u-channel sampled more than 300 m of Brunhes Chron sediments to corroborate our shipboard measurements and improve our paleomagnetic and rock magnetic understanding of these sediments. Several intervals of distinctive paleomagnetic secular variation (PSV) have been identified that appear to be correlatable among sites 1343, 1344, and 1345. One magnetic field excursion is recorded in sediments of sites 1339, 1343, 1344, and 1345. We identify this to be excursion 7α/Iceland Basin Event (192,000 years BP), which is also seen in the high-latitude North Atlantic Ocean (Channell et al., 1997). We have verified in u-channels the placement of the Brunhes/Matuyama boundary (780,000 years BP) at sites 1341 and 1343. Finally, we have developed a medium-quality relative paleointensity record for these sediments that is correlatable among the sites, even though it is still biased by large-amplitude environmental variability. On the basis of these observations we have built a magnetic chronostratigraphy of Expedition 323 sediments suitable for regional correlation and dating over the last 1 million years, and compared this with oxygen-isotope chronostratigraphy from sites U1339 and U1345.

1. Introduction

Integrated Ocean Drilling Program (IODP) Expedition 323 (Takahashi et al., 2011) recovered 5741 m of Quaternary and Pliocene sediments from seven sites (Fig. 1) in the Bering Sea (53.7–60.1°N). Note that CSF is meters core depth below seafloor and is generally equivalent to the previous Ocean Drilling Program (ODP) term meters below seafloor (MBSF); meters CCSF is meters core composite depth below seafloor and is generally equivalent to the previous ODP term meters composite depth (MCD). Four of the sites (U1339, U1343, U1344, and U1345) are located along the northern Bering Sea margin and are termed Bering Slope sites (1008–3184 m water depth); three of the sites (U1340, U1341, and U1342) are located in the south central Bering Sea along the deep-sea Bowers Ridge and are termed the Bowers Ridge sites (830–2150 m water depth). All seven sites share a depositional history that relates to ocean circulation in the Bering Sea (e.g., Takahashi, 2005) and its connections to more large-scale Northern Pacific circulation, which are driven by climate changes (e.g., Tanaka and Takahashi, 2005).

2820 m CSF of these Bering Sea sediments are Brunhes Chron in age (0–780,000 years BP) with 6 complete records of Brunhes Chron paleomagnetic field variability: site U1339 (23.1 cm/kyr average sediment accumulation rate), U1340 (16.0 cm/kyr), U1341 (10.6 cm/kyr), U1342 (3.2 cm/kyr), U1343 (23.7 cm/kyr), U1344 (34.6 cm/kyr). Site U1345 recovered only the last half of the Brunhes Chron at 23.0 cm/kyr. This sequence of sediments represents the highest-resolution composite record of potential Brunhes Chron geomagnetic field behavior ever recovered in the World. These records are located geographically between two high-latitude flux-lobes (Bloxham and Gubbins, 1985; Gubbins and Bloxham, 1987) situated at the core/mantle boundary, one below North America and the second below East Asia (Fig. 1). Fig. 1 also shows the locations of other complete Brunhes Chron sequences of paleomagnetic field variability previously recovered (Jansen et al., 1996; Backman et al., 2006; Channell et al., 2006). All of those sediment records have average sediment accumulation rates less than 18.0 cm/kyr (Table 1).

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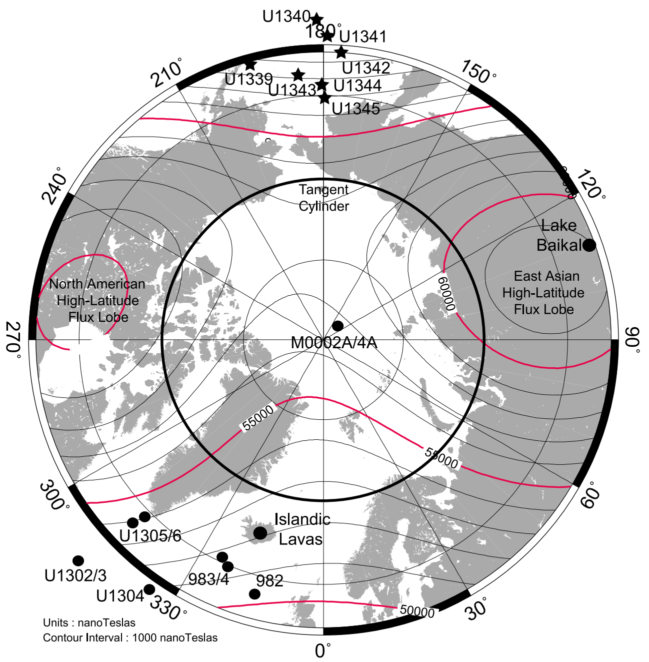

Fig. 1. Northern Hemisphere polar region showing the IODP Expedition 323 coring sites. Also shown is the current geomagnetic field intensity with high-intensity foci associated with the North American and East Asian flux lobes noted (International Geomagnetic Reference Field 2000, Mandea and Macmillan, 2000). Also shown are other high-latitude paleomagnetic records of Brunhes field variability (see Table 1).

Table 1
Brunhes records of high-latitude field variability.

Site	Latitude	Brunhes Sed. (CCSF (m))	Sed. Rate (cm/ky)
ODP Leg 162			
980	55.0°N	87	11.1
981	55.0°N	55	7.0
982	57.5°N	20	2.5
983	60.0°N	91	11.5
984	60.5°N	108	13.8
IODP Expedition 302			
M0002A/4A	87.9°N	14.3	1.8
IODP Expedition 303/306			
U1302/3	50.2°N	115	14.7
U1304	53.3°N	140	17.9
U1305	57.5°N	125	16.0
U1306	58.2°N	120	15.4
U1307	58.5°N	35	4.5
U1314	56.3°N	60	7.7
IODP Expedition 323			
U1339	54.6°N	200	25.6
U1340	53.4°N	135	17.3
U1341	54.0°N	90	11.5
U1342	54.8°N	28	3.6
U1343	57.6°N	205	26.3
U1344	59.1°N	300	38.5
U1345	60.1°N	170+[a]	25.0

The site has at least 170 m of Brunhes-aged sediment.

[a] U1345 coring did not reach the Brunhes/Matuyama boundary.

More than 220,000 paleomagnetic measurements were made on the IODP Expedition 323 cores during the cruise (Takahashi et al., 2011) and more than 300 m of the Brunhes Chron sediments have been more recently u-channeled and selectively demagnetized to corroborate the shipboard measurements and further assess the paleomagnetic and rock magnetic character of the sediments. This paper summarizes our shipboard paleomagnetic measurements, further new analysis of our shipboard measurements, and new u-channel paleomagnetic studies, which corroborate shipboard measurements. This paper describes the overall paleomagnetic field variability recovered from these sediments during the Brunhes Chron and develops a magnetic chronostratigraphy that can be used to correlate the sediments among the seven sites.

2. Shipboard paleomagnetic measurements

Shipboard paleomagnetic measurements commonly measured the initial natural remanence (NRM) of the archive-half-round core sections in at least one hole at each site. The NRMs were then step-wise demagnetized in alternating magnetic fields at 10 mT, 15 mT, and 20 mT to assess the relative strength and ease of removal of a viscous remanence (VRM), which is ubiquitously present in IODP cores (e.g., Lund et al., 2003). Shipboard measurements between 10 mT and 20 mT almost always had good reproducible directions and appeared to effectively remove the VRM. Other holes were commonly only demagnetized at 20 mT. The shipboard paleomagnetic secular variation records from all 7 sites are summarized and plotted in Takahashi et al. (2011).

Several stratigraphic parameters, including magnetic susceptibility, have been used to correlate holes at each site and develop a modified depth scale (meters CCSF) that provides a correlation resolution among holes of ~10 cm (Takahashi et al., 2011). This modified depth scale has been used to correlate the 20 mT demagnetized paleomagnetic directions among all holes at each site and build a composite paleomagnetic secular variation record for each site (Takahashi et al., 2011) for the Brunhes Chron (0–780,000 years BP). The paleomagnetic directions in individual holes had occasional anomalies, which we associate with ice-rafted debris (IRD) or localized sediment disturbances that were not correlatable between holes at each site. These directions were removed from the paleomagnetic records. The remaining directional variability in each hole (>95% of each record) was correlatable between holes (see examples below). The cores were oriented to North during the coring process, but unresolved errors limited the accuracy of core reorientation to $\sim\pm 20°$ at best. For our analysis, we preferred to reorient each core (~9.5 m in length, 38,000–90,000 years in duration) by rotating each core's mean declination to 0° declination. This methodology permitted us to develop a composite paleomagnetic record of Brunhes Chron paleomagnetic field variability from each site. The only limitation is that paleomagnetic declination variability longer in duration than ~50,000 years will be subdued or lost.

3. New paleomagnetic measurements

3.1. Paleomagnetic secular variation

We have now carried out new paleomagnetic measurements on 300 m of selected cores, which were sampled using u-channels. U-channels remove a column of sediment, 2 × 2 cm in cross-section, from the split face of a core. These u-channels should provide the most undisturbed sediment for paleomagnetic measurements. U-channels are taken from the same cores that were used for the shipboard paleomagnetic studies. We have carried out detailed paleomagnetic measurements on these cores to compare with the shipboard measurements and assess the extent to which the shipboard measurements are a reasonably faithful record of paleomagnetic field variability.

All u-channels were initially measured at 20 mT alternating field (AF) demagnetization and then step-wise AF demagnetized at 5–10 mT steps up to 100 mT. Fig. 2 shows Zijderveld demagnetization plots for four selected u-channel horizons to document the