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High resolution Holocene paleomagnetic secular variation records from Bay of Bengal

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ABSTRACT

We present high resolution paleosecular variation (PSV) records up to 8 cal. kyr BP from three piston cores, MD161/8, MD161/11 and MD161/13 acquired in the Krishna–Godavari (KG) basin, Bay of Bengal. During the Holocene period, high sedimentation rates are recorded at MD161/8 (38.8–248.3 cm/kyr), MD161/11 (137–336 cm/kyr) and MD161/13 (~573 cm/kyr). Rock magnetic data analysis suggests that the remanence signal is carried by titanomagnetite/titanohematite grains in stable single domain (SSD)/pseudo single domain (PSD) state. The PSV records of MD161/11 and MD161/13 show good correlation in the uppermost sediments despite significant variation in the sedimentation rates; however, poor correlation of PSV records is observed for the core MD161/8 probably due to local effects. Paleoinclination records of MD161/8, MD161/11 and MD161/13 show a low between ~2.4 and 2.0 cal. kyr BP, an increase between 2.0 and 1.4 cal. kyr BP and a decrease towards the present. To varying degrees these trends can be observed in the other Asian PSV records of Shuangchiling (SCL) and Biwa lakes. However, the magnitude of the observed inclination anomaly in KG basin is higher (~40°) compared to those reported from SCL (~25°) and Biwa (~10°) lakes. Paleodeclination records of MD161/11 and MD161/13 show a decline between ~4.0 and 2.9 cal. kyr BP, an increase between 2.9 and 2.1 cal. kyr BP, a substantial decrease between ~2.1 and 1.0 cal. kyr BP and an increase towards the present. Similar trends can be observed in the other Asian PSV records of SCL and Biwa lakes with a minor age offset of 0.2–0.5 kyr. The available models CALS7k.2 and CALS10k.1 are evaluated for their capability in predicting the inclination and declination anomalies from the Asian regions. The CALS7k.2 model can predict most of the inclination anomalies while the CALS10k.1 is unable to predict many of them. The CALS7k.2 model shows that the observed inclination anomalies can be attributed to the presence of a strong non-axial dipolar magnetic field over the Bay of Bengal. More PSV records need to be constructed to better understand the anomalous non-axial dipolar field over the Bay of Bengal.

1. Introduction

Paleomagnetic studies are being carried out worldwide to establish high resolution paleosecular variation (PSV) records that can be used to correlate regional stratigraphies (Turner and Thompson, 1981, 1982; Hagstrum and Champion, 2002; St-Onge et al., 2003; Snowball et al., 2007; Barletta et al., 2010a,b; Snowball and Sandgren, 2002; Lund and Banerjee, 1985; Verosub et al., 1986; Creer and Tucholka, 1982; Lisé-Pronovost et al., 2009; Roberts et al., 2013) and to understand the geodynamo processes responsible for the Earth's magnetic field (Merrill et al., 1996; McFadden and Merrill, 1995). Historical observation of PSV data is available only for the last 400 years (Jackson et al., 2000). Prior to direct observations, the variation of Earth's magnetic field on millennial scale can be reconstructed using archeological materials and volcanic rocks as well as from rapidly deposited, well-dated lake/marine sedimentary sequences (e.g., Stockhausen, 1998; Ali et al., 1999; Frank et al., 2002; Vigliotti, 2006; Irurzun et al., 2006, 2008; Snowball et al., 2007). Most of the PSV records documenting the Holocene are from Europe (Vigliotti, 2006; Sagnotti et al., 2011; Stockhausen, 1998; Opdyke, 1972; Thompson, 1975; Turner and Thompson, 1981), North America (Creer and Tucholka, 1982; Lund and Banerjee, 1985; Verosub et al., 1986; Hanna and Verosub, 1989; Sprowl and Banerjee, 1989; King, 1983), central Asia (Gómez-Paccard et al., 2012; Peck et al., 1996; Nurgaliev et al., 1996; Nourgaliev et al., 2003) and South East Asia (Ali et al., 1999; Hyodo et al., 1999; Yang et al.,

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2009, 2013; Zheng et al., 2014). The scarcity of Holocene PSV records within 20° of the Equator limits our ability to understand time and space variability of the Earth's magnetic field and related geodynamo processes. Moreover, such high resolution PSV records are not available from the northern Indian Ocean. Therefore, we attempt to establish the high resolution and continuous PSV records from the high sedimentation regions of Krishna Godavari (KG) basin, Bay of Bengal, using three Calypso piston cores MD161/8 (~30 m, water depth = 1033 m, Lat = 15° 51.8624′N, Lon = 81° 50.0692′E), MD161/11 (~28 m, water depth = 1007 m, Lat = 15° 54.0217′N, Lon = 81° 48.1366′E) and MD161/13 (~29 m, water depth = 647 m, Lat = 16° 01.9684′N, Lon = 81° 42.7909′E) acquired onboard *M/V Marion Dufresne* in 2007. The PSV records are evaluated for their potential to act as a reliable tool for magnetic stratigraphy as well as to understand the geodynamo processes manifested over the Bay of Bengal.

2. Geology of the study area

Krishna Godavari (KG) basin is a petroliferous basin in the Bay of Bengal. It is a pericratonic rift basin formed due to the breakup of Gondwanaland around 130 Ma years ago (Sastri et al., 1981; Rao, 2001; Powell et al., 1988; Scotese et al., 1988; Ramana et al., 1994). It encompasses an area of 28,000 sq. km onshore and 145,000 sq. km offshore (Ojha and Dubey, 2006) and stretches from the Ongole in south to the Vishakhapatnam in north. Thickness of onshore sediments varies between ~3 and 5 km which increases to ~8 km in offshore region (Prabhakar and Zutshi, 1993; Bastia, 2007). The thick sediment strata largely composed of montmorillonite clay (Rao, 1991) are brought by Krishna and Godavari rivers and their tributaries which originate in the Western Ghats and run over the provenance of Deccan trap basalts. Environmental magnetic studies by Sangode et al. (2007) showed higher magnetic susceptibility values in Godavari basin in comparison with those from other basins in Indian subcontinent.

The studied cores (MD161/8, MD161/11 and MD161/13) were acquired from the continental slope region of the KG basin (Fig. 1). Sedimentological studies show that the grain size of the sediment is predominantly clay (~70%) and silt (~30%) with traces of sand fraction (NIO, 2005). Further, X-ray analysis of clay minerals suggests the presence of montmorillonite clay with traces of illite and kaolinite. The dominant detrital magnetic minerals, as evident from the SEM–EDS analysis of the magnetic extracts, are titanomagnetite and titanohematite with varying amount of Ti/Fe ratio from 0.2 to 0.45 (Dewangan et al., 2013; Usapkar et al., 2014). The presence of sub-surface hydrates is confirmed in the KG basin from drilling/coring activities during NGHP Expedition 01 (Kumar et al., 2014). Geophysical signatures associated with fluid/gas migration have also been documented in KG basin indicating migration of methane gas through the sediment (Ramana et al., 2009; Dewangan et al., 2010; Ramprasad et al., 2011). Geochemical signatures related to a paleo-cold seep activity are also reported in KG offshore basin (Mazumdar et al., 2009). The geochemical processes such as anaerobic oxidation of methane (AOM) may significantly alter the magnetic minerals and affect the magnetic measurements. The detailed rock magnetic measurements of the core MD161/8 reveal dissolution of magnetic minerals and authigenic growth of secondary iron sulfides below 7 m related to methane seep (Dewangan et al., 2013), and such diagenetically altered sediments are not considered in the present study.

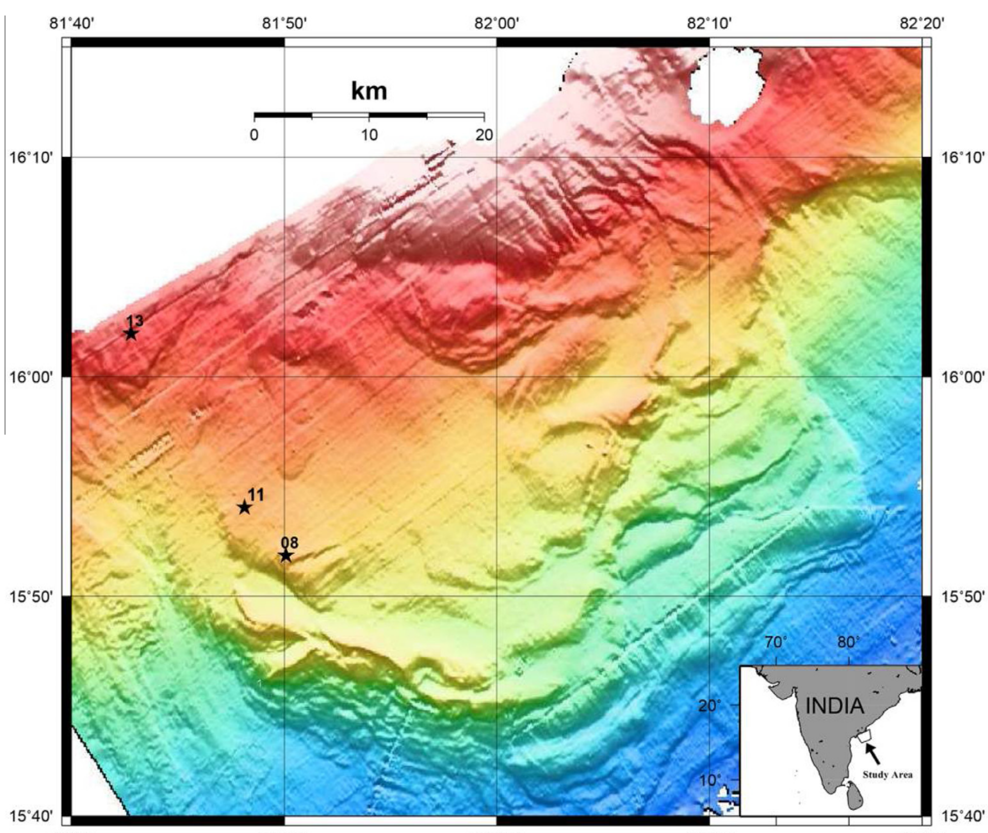

Fig. 1. Location map of the study area in the Krishna–Godavari offshore basin, Bay of Bengal. The black stars represent core locations MD161/8, MD161/11 and MD161/13. The zoom out of the study area is shown in the inset.