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Research paper

Gas hydrate destabilization and methane release events in the Krishna–Godavari Basin, Bay of Bengal

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A B S T R A C T

Methane release events have been linked to global warming, alteration of the carbon cycle and influence on biota. However, unequivocal evidence of paleomethane release events are limited. We report several negative carbon stable isotope excursions in planktic and benthic foraminifera in a core (MD161-8) from the Krishna-Godavari (K–G) Basin, Bay of Bengal. The most negative $\delta^{13}C$ spikes are recorded during the marine isotope stages MIS-4 and at the transition of MIS-5 to 4. Occurrence of highly ^{13}C depleted (average $\delta^{13}C = -48 \pm 2.4‰$ VPDB) authigenic high magnesian calcite are also reported within this time window from the core MD161-8. In the present work an unequivocal explanation for the observed ^{13}C depletion in the marine planktic and benthic foraminifera is difficult to achieve solely from the optical/electron microscopy or C–O stable isotope ratio analyses due to possible influence of diagenetic alteration. We attribute the observed episodic methane expulsion events, as inferred from the negative $\delta^{13}C$ excursions and earlier reports on the occurrence chemosynthetic bivalves and Mo concentration anomaly to the destabilization of the base of gas hydrate stability zone (BGHSZ). Sea level drop and shale tectonics induced focused fluid flow are the two possible causes of hydrate destabilization discussed here. Shale tectonics were possibly responsible for creating fault systems which acted as the conduit for gas flow through the sediment column and subsequent seepage. Shale and salt tectonics in the passive continental margins being a globally observed phenomenon, its role as an important driving force for enhanced methane emission needs detailed investigation to understand the climatic perturbations through geologic time. Additional evidence of methane emission from site MD161-15 further supports the link between shale tectonics and methane emission.

1. Introduction

Perturbation in methane concentrations in the ocean-atmosphere system may cause global warming (Lashof and Ahuja, 1990) and alteration of the carbon cycle (Dickens, 2003). Vast reserves of methane hydrate, a crystalline form of methane–water complex (molar ratio 1:6) exist within the marine sediments at suitable temperature-pressure conditions subject to the availability of methane in excess of solubility (Kvenvolden, 1993; Sloan, 1998; Kvenvolden and Lorenson, 2001). Whereas, methane from shallow sub-seafloor (Hovland and Judd, 1992; Mazumdar et al., 2009a; Coffin et al., 2013) are additional sources of marine methane to the global budget. The terrestrial sources influencing the global methane budget include volcanic eruptions, natural wetlands, rice and paddy fields, enteric fermentation, coal mining, biomass burning, soil microseepage, geothermal activity (Chanton and Whiting, 1996; Judd et al., 2002; Kaplan, 2002; Etiope et al., 2008; Sanchez Goni et al., 2008) and ebullition from thermokarst lakes (Walter et al., 2006). Carbon stable isotope ratios of foraminifera (Kennett and Stott, 1991; Kennett et al., 2000, 2003; De Garidel-Thoron et al., 2004; Hill et al., 2004a; Uchida et al., 2004; Cook et al., 2011) as well as measurement of methane concentrations in the Greenland and Antarctic ice deposits (Chappellaz et al., 1997; Dällenbach et al., 2000; Wolff and Spahni, 2007) suggest repeated enrichment of methane concentrations in the ocean-atmosphere system. Methane enrichment has primarily been

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attributed to the hydrate destabilization due to increase in marine bottom water temperature during interstadials (Kennett et al., 2003; De Garidel-Thoron et al., 2004), depressurization from lowering of sea level or slope failure (Buffett and Archer, 2004; Archer, 2007).

Marked enrichment in methane concentrations in ancient water column/atmosphere has been inferred from the late Neoproterozoic (Kennedy et al., 2008), early Jurassic (Kemp et al., 2005), early Cretaceous (Jahren et al., 2001), Paleocene-Eocene (Dickens et al., 1995), Miocene (Panieri et al., 2009) and late Quaternary (Kennett et al., 2000; Hinrichs et al., 2003; De Garidel-Thoron et al., 2004). Methane enrichment episodes prior to Preborial-Younger Dryas transition has primarily been attributed to methane hydrate destabilization (Kennett et al., 2003). In contrast, δD_{CH4} (Sowers, 2006; Bock et al., 2010) and $^{14}CH_4$ (Petrenko et al., 2009) data from ice cores, suggest that marine methane hydrate degassing may not be the cause of atmospheric methane enrichment intervals through late Quaternary. Although, a significant volume of work (Wefer et al., 1994; Kennett et al., 2000; Smith et al., 2001; Hill et al., 2003; Kennett et al., 2003; De Garidel-Thoron et al., 2004; Panieri et al., 2012; Wang et al., 2013) correlate ^{13}C depletion in planktic and benthic foraminifera to ^{13}C depleted bicarbonate ion produced via aerobic/anaerobic oxidation of methane in water column/sediment–water interface, a significant number of publications attribute the ^{13}C depletion to diagenetic alteration of non-living foraminifera (Martin et al., 2004; Ohkushi et al., 2005; Wiedicke and Weiss, 2006; Uchida et al., 2008; Torres et al., 2010; Cook et al., 2011; Herguera et al., 2014). Diagenesis results in precipitation of authigenic carbonate into the shell cavities or recrystallization of shell ultrastructure. The controversy regarding the ^{13}C depletion in foraminifera and latter's association with methane emission is primarily due to the lack of routine/rapid methods for unequivocal selection of unaltered foraminifera shells. It is also difficult to understand cryptic alterations in apparently clean shells which may result in significant ^{13}C depletion.

We present here, carbon–oxygen stable isotope ratios of planktic and benthic foraminifera and carbon isotope ratios of sediment organic matter and lipid extracts in a sediment core (MD161-8) from the Krishna–Godavari (K–G) Basin, Bay of Bengal (Fig. 1). Recently, paleo-cold seepage associated authigenic carbonate and chemosynthetic clam (*Calyptogena sp.*) shells have been reported from this site (Mazumdar et al., 2009b and 2011) and nearby site NGHP-10D (Collett et al., 2008). Based on ^{14}C and U/Th age dating of foraminiferal tests and authigenic carbonates respectively, a minimum age of 46–58 kyr was suggested for the methane expulsion events (Mazumdar et al., 2009a,b).

In this work we have investigated the possible influence of methane emission on carbon isotope ratio of planktic and benthic

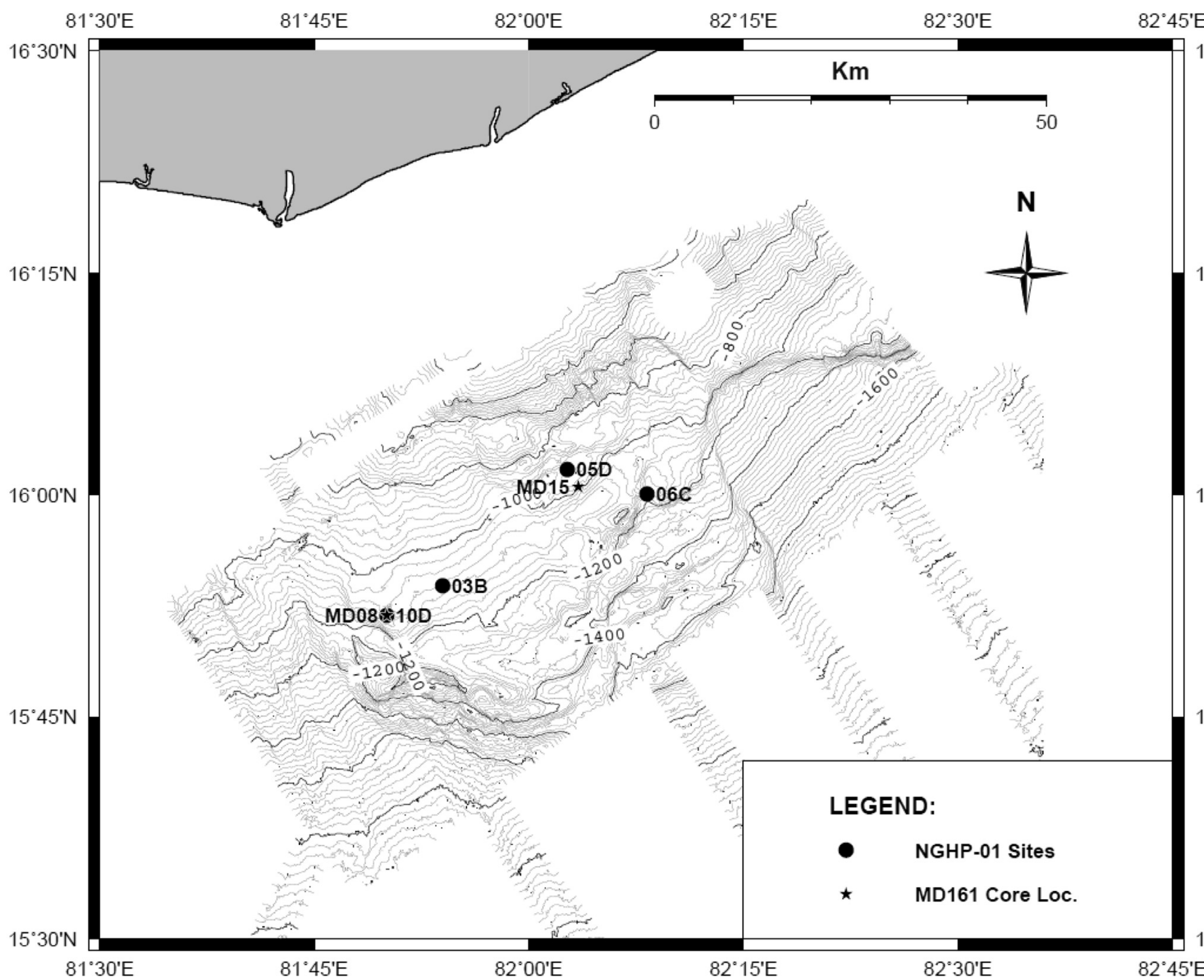

Figure 1. Contour map of K–G Basin showing core locations of MD161-8 and 15 and NGHP10-D, 5D and 6C.