

Extensive Occurrence and Genesis of Authigenic Carbonates from Krishna-Godavari offshore basin (Bay of Bengal): Possible Influence of Methane Hydrates Occurrences.

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Authigenic minerals and their by products are useful proxies for identifying the location of past and current natural gas hydrate occurrences and associated methane flux (Hovland et al 1987; Hovland and Judd 1988; von Rad et al 1996). In marine sediments, methane migrates upward and reacts with sulfate at the sulfate methane transition zone (SMTZ), and results in the formation of various authigenic minerals depending on the fluids, gases, and composition of the host sediments. The variety of authigenic minerals that are formed in cold seep environments provide diagnostic information on the chemistry of the diagenetic fluids, and their mineralogy, morphology and therefore can be used to indicate the magnitude of methane flux and the depth of SMTZ and consequently the presence of underlying methane gas hydrate deposits. Authigenic carbonates are indirect indicators of high methane flux regions which are common in areas overlying gas hydrate deposits in various geological settings (Hovland

et al 1987; Hovland and Judd 1988; von Rad et al 1996). Variety of authigenic carbonates are observed at numerous locations adjacent to gas seepages and pore fluid venting (Hovland, and Judd 1988; Han and Suess 1989) as individual slabs, thinly lithified pavements, vertical pillars, mushroom-like structures, microbial mats, dispersed crystal aggregates, carbonate build-ups and as micro-concretions (Hovland et al 1987). Precipitation and consequent preservation of authigenic carbonates is mainly due to increase in pore water bicarbonate [HCO₃⁻] ion concentration and is mainly due to anaerobic oxidation of methane (AOM) from gas hydrate system and concomitant sulphate reduction process in the sediment sequence.

In the northern Indian Ocean, occurrences of methane-derived authigenic carbonates are reported from the Krishna-Godavari basin, Eastern continental margins of India (Kocherla et al 2006; Mazumdar et al 2009a) and Makran accretionary prism off Pakistan (von Rad et al 1996; Von Rad et al 2000; Klauda and Sandler 2005) in the Arabian Sea. The continental slope region of the K-G basin is one of the promising petroliferous basins of India and the recent drilling work carried out onboard JOIDES Resolution Leg-3A (Collet et al 2008) confirmed the presence of massive authigenic carbonate nodules/concretions (Kocherla et al 2010) along with more than 100 m thick accumulation of gas hydrates in Krishna-Godavari offshore basin, and fully developed gas hydrate system in the Mahanadi offshore region in the Bay of Bengal (Collet et al 2008; Dewangan et al 2010; Mazumdar et al 2009; Ramana et al 2009; Ramana et al 2007; Kocherla et al 2006).

We report here the extensive occurrences of authigenic carbonate nodules/concretions from gas hydrate bearing sediments. Bulk mineralogical compositions by X-Ray diffractometry and EDS (Energy Dispersive Spectrum) analysis revealed that the carbonate nodules are composed dominantly of Siderites and High-Mg calcites (HMC) and occasionally Low-Mg calcites (LMC). Strontianite (SrCO_3), witherite (BaCO_3) and cerussite (PbCO_3) are present as inclusions in nodules. More than 100 such carbonate nodules/concretions from 17 cores (Fig.1) are recovered from the sediment sub-samples spread between 5-29 mbsf and are investigated for their occurrence, stratigraphic distribution, mineralogy geochemical and stable isotopic compositions (Fig.2). Megascopic and microscopic observations show that high-Mg calcite (HMC) is mostly grayish in color and hard, whereas siderite nodules are light brown to dark brown and soft to moderately hard in nature. The average thickness of the carbonate concretions range between 0.2- 12 cm (Fig.3).

The $\delta^{13}\text{C}$ values for Fe-rich friable siderite nodules vary from -16.38 to 6.42 ‰ VPDB and from -50.22 to -26.77 ‰ VPDB for high-Mg calcites. The $\delta^{18}\text{O}$ values for high-Mg calcites range from -0.31 to +8.12 ‰ VPDB and -15.70 to 8.80 ‰ VPDB for siderites. Interestingly in one of the station all the $\delta^{13}\text{C}$ values are positive. The very negative $\delta^{13}\text{C}$ VPDB ratios of HMC unambiguously indicate that the carbonates are predominantly derived from methane via Anaerobic Methane Oxidation (AOM).

In contrast much higher carbon isotope values of the siderites suggest dynamic interstitial water conditions perhaps due to formation and dissociation of gas hydrates at sub-surface depths. The above observations indicate that the carbon source for the formation of authigenic carbonates were gas hydrates below, and the carbonates were formed from the flow of methane-enriched fluids through

fracture network formed because of shale diapirism. The detailed genetic framework is under investigation for comprehensive understanding of the process involved.

The cores were collected as part of our gas hydrate exploration program on board Marion Dufresne cruise (MD161, May 2007) 17 long (30-50 m) piston cores were recovered under various geological environment viz., mud diapirs, mass flows, and hemipelagic sediments over a water depths range of 647-2079 m from KG Basin, Bay of Bengal. One of the objectives of the Gas-hydrate research program at National Institute of Oceanography Goa is to establish the diagenetic finger prints/proxies in the sediments that are associated with the gas-hydrate formation and dissociation. Since occurrence of authigenic carbonates can help to decipher the source of gas seepages in an area we undertook a study of authigenic carbonates from the shallow sediments of KG offshore basin characterized by shallow gas hydrate deposits (Kocherla et al 2006; Mazumdar et al 2009a; Kocherla et al 2010; Naehr et al 2007; Feng et al 2009; Peckmann et al 2009). In the present study we report on the extensive occurrence of methane-derived authigenic carbonate nodules/concretions in gas hydrate bearing sediments of K-G basin Eastern continental margin of India and discuss their origin based on their mineralogy, morphology, geochemical and stable isotopic compositions.

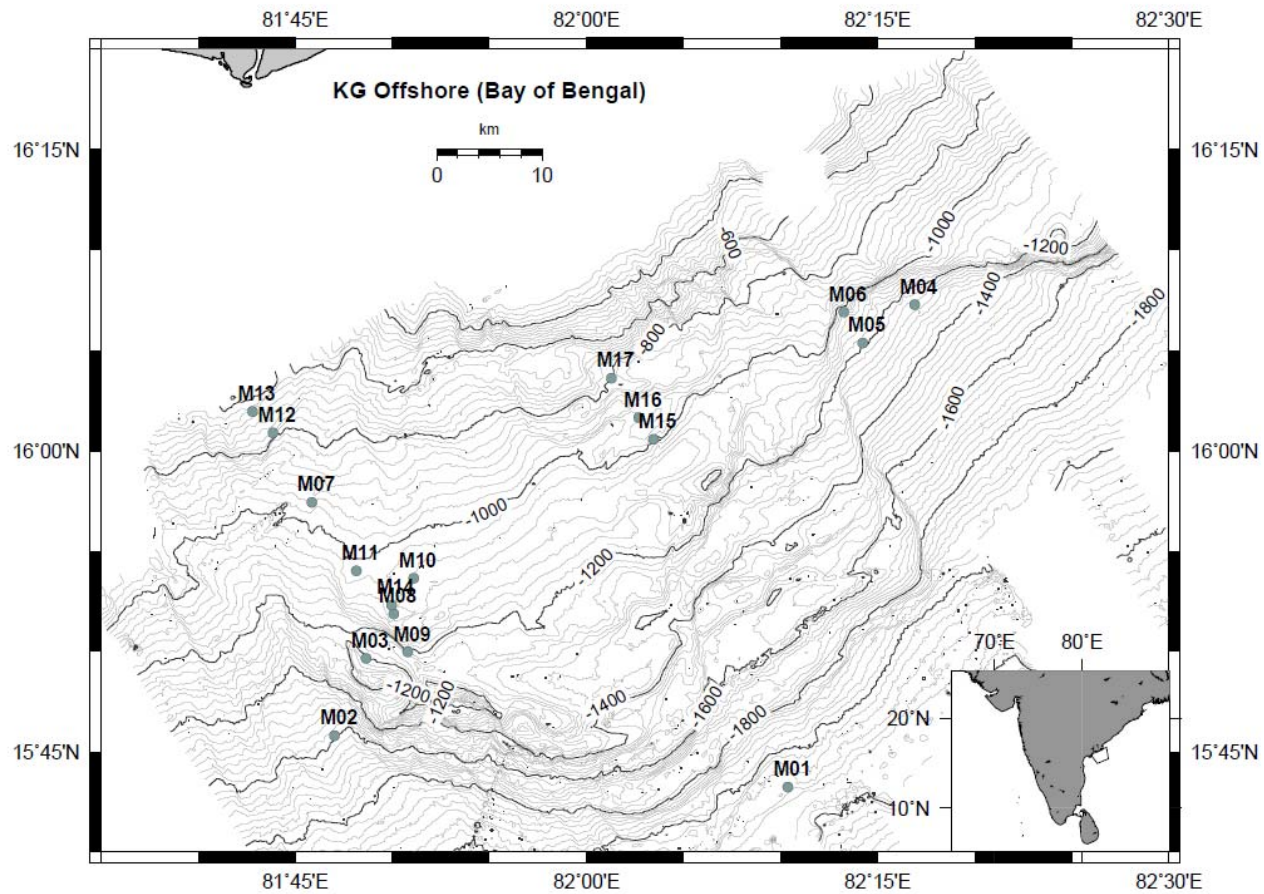


Fig.1 Core location and bathymetry map of the study area in the K-G offshore basin (Bay of Bengal) Eastern continental margin of India.

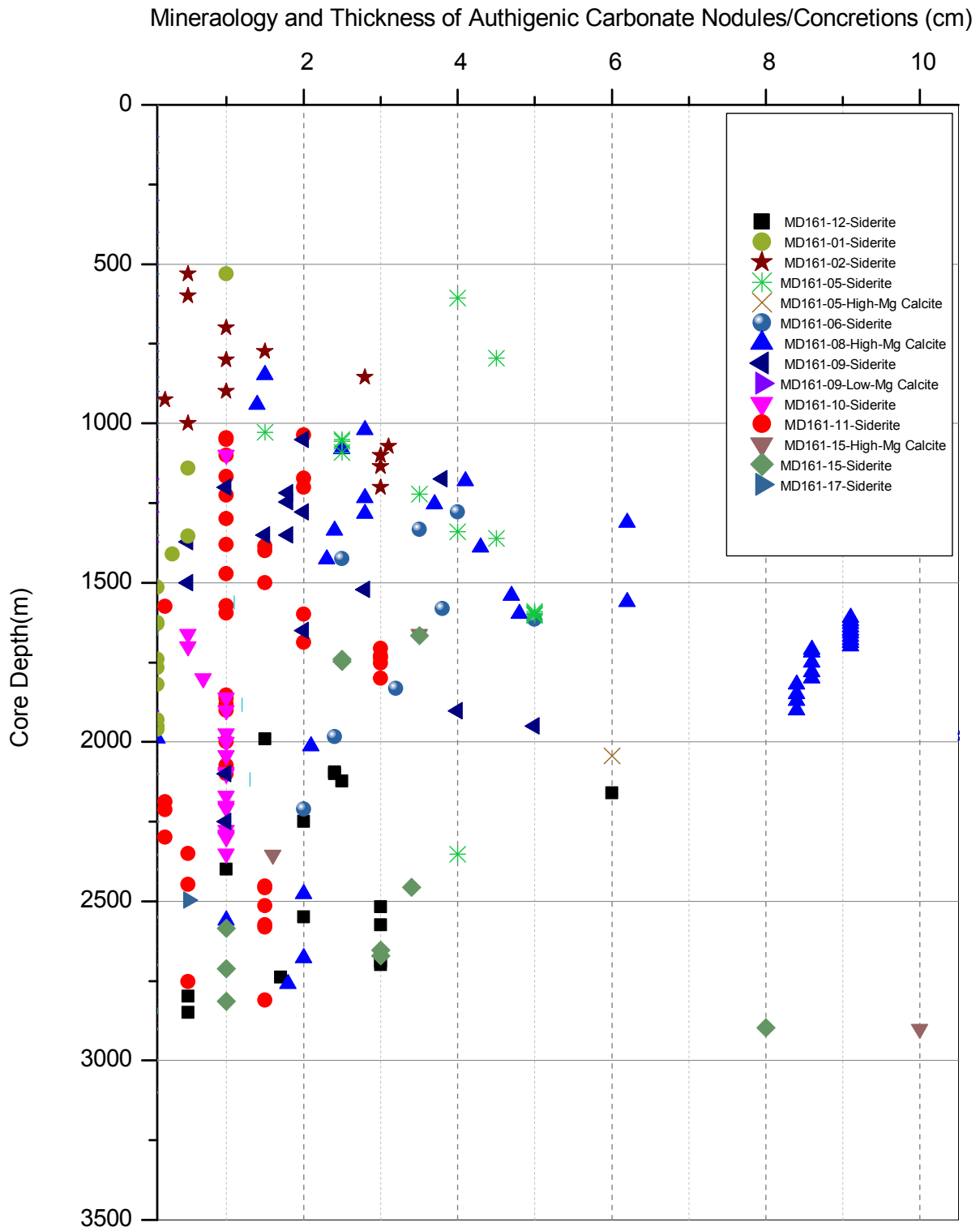


Fig. 2. Occurrence, thickness and depth distribution of Authigenic Carbonate precipitates and their mineralogy in MD161 stations 1-17 in the Krishna-Godavari offshore basin, East coast of India.

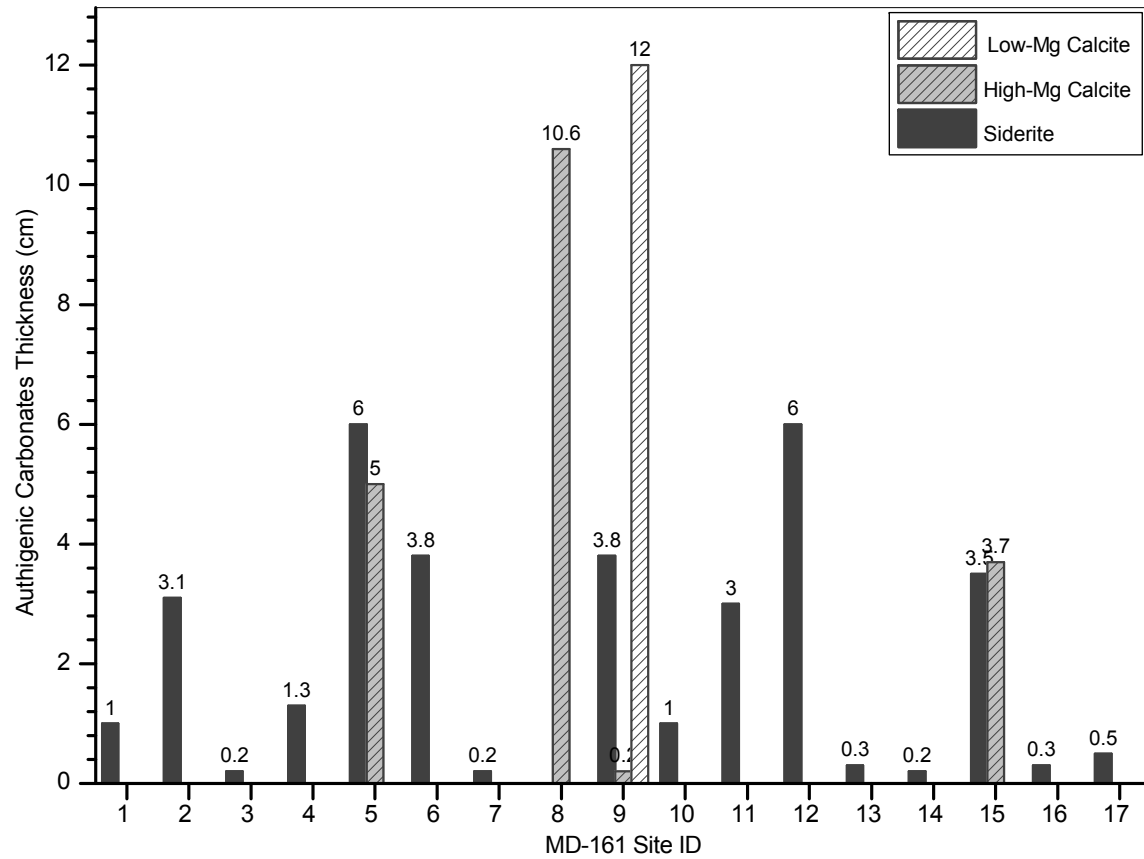


Fig. 3. Occurrence distribution and average thickness of Authigenic Carbonate Nodules/Concretions in MD161 stations 1-17 in the Krishna-Godavari offshore basin, East coast of India.