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Geological Controls on Gas Hydrates occurrence along Continental margins of Indian subcontinent

M. Ravi Santosh Kumar*, T. Veera Kumari, V.Triveni, M.S. Naidu, P. Prasada Rao, N.K. Thakur and B. Ashalatha

LCS Group, National Geophysical Research Institute, Uppal Road, Hyderabad. India

Summary

Studies of geologic and geophysical data from offshore India have revealed geologically distinct areas with seismically inferred gas hydrate occurrences along the passive continental margins of the Indian Peninsula. The Bottom Simulating Reflector (BSR) mapping alone is inadequate to infer gas hydrates as suggested by drilling results elsewhere. Therefore, to understand the subsurface distribution of gas hydrates along the continental margins of India, multi-disciplinary investigations have to be undertaken. The observed geophysical and geological anomalies such as pockmarks, gas upthrust zones, vents, blanking zones, diapirs, faulting etc., in addition to BSR favour the presence of gas hydrates in some of the Indian offshore regions. In the present study an attempt has been made to study the various geologic features and their significance on gas hydrate occurrence based on compilation of geological and geophysical data for understanding the geological controls on gas hydrates occurrences in eastern Indian offshore and analysis of single and multi-channel seismic sections for identification of structures related to gas hydrate formations in KeralaKonkan basin of western continental margin of India. In this context we have examined other evidences such as venting, pockmarks, faulting, blanking and diapirs have been examined to build up a case for the presence of gas hydrates. Fluid / gas escape features, diapirs and other structural features associated with gas hydrates formation have been identified. Several deep and shallow faults occurring in this region can provide pathways for vertical gas-fluid migration contributing to the biogenic methane in the shallow sediments.

Introduction

Gas hydrates occur abundantly in nature, both in Arctic regions and in marine sediments. Gas hydrate is a crystalline solid consisting of gas molecules, usually methane, each surrounded by a cage of water molecules. It looks very much like water ice. Methane hydrate is stable in ocean floor sediments at water depths greater than 300 meters, and where it occurs, it is known to cement loose sediments in a surface layer several hundred meters thick. Extraction of methane from hydrates could provide an enormous energy and petroleum feedstock resource. The worldwide amounts of carbon bound in gas hydrates is conservatively estimated to total twice the amount of carbon to be found in all known fossil fuels on Earth. Hydrates store immense amounts of methane, with major implications for energy resources and climate, but the natural controls on hydrates and their impacts on the environment are very poorly understood. There are numerous research projects underway to investigate the geological origin of gas hydrate, their natural occurrence, the factors that affect their stability, and the possibility of using this vast resource in the world energy scenario. NGHP Expedition 01 established the presence of gas hydrates in Krishna-Godavari, Mahanadi and Andaman basins. The expedition discovered one of the richest gas hydrate accumulations in the Krishna-Godavari Basin, the thickest and deepest gas hydrate stability zone in Andaman Sea and also established the existence of a fully-developed gas hydrate system in the Mahanadi Basin. These studies indicate the occurrence of gas hydrate is mostly controlled by the presence of fractures and/or coarser grained (mostly sand-rich) sediments (Collett et al., 2008). The present study indicates the association of deep faults, compression related faults bounding diapirs, over-pressured sediments, faulting within the shallow sediments columnar disturbances as positive indicators of vertical and lateral fluid flows and gas accumulations favoring formation of gas hydrates.

hairavi_06@yahoo.co.in

Theory and/or Method

The study area is shown in Figure.1. We have examined several stacked seismic sections in this region. Different fluid flow related or gas escape features like venting, pockmarks, diapirs and acoustically transparent sediments are associated with different geological features such as faulting have been observed in this area. The area is marked by several deep faults, some extending into shallow sediments and a few extending up to sea floor. Several shallow faults and seafloor collapse structures are observed in the seismic sections with discontinuity in shallow reflectors. Columnar disturbances are observed in shallow sediments. The seafloor in some locations is hummocky, probably representing pockmarks. Anomalous transparent zones representing gas charged sediments or upward flows. Sediment bulging due to over pressured sediments observed at several locations. Shale tectonics /diapers have been reported to occur within the Eocene, Oligocene, and Miocene to recent sediments. Fluid migration process could be one reason for the formation of weak BSR. Observation of deformations/changes in reflection characteristics /chaotic reflections within the sediments results with alteration in rock properties due to fluid flows.

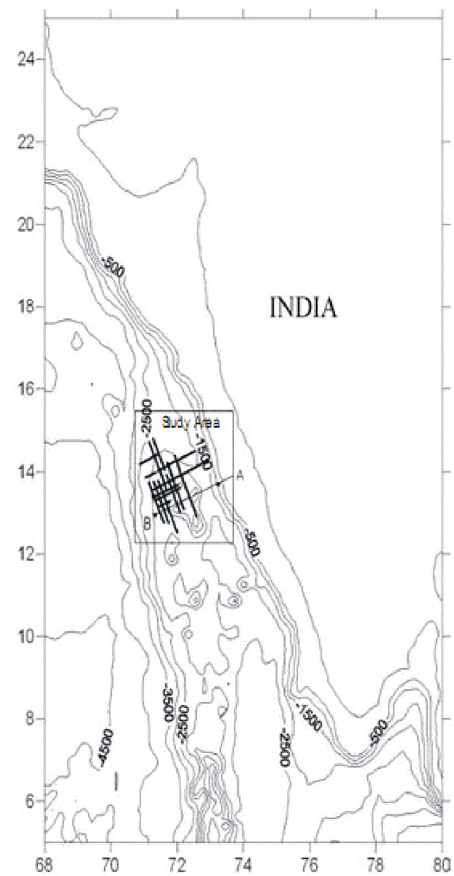

Figure 1: Location of the study area showing multi-channel seismic data track lines and bathymetry of western continental margin of India (isobaths are given in meters).

In the study area venting of gas and pockmarks are observed associated with different geologic features (Figure 2). Venting of gas and pockmarks are associated with faults and where overlying sediments are acoustically transparent. The acoustically transparent zone is generally attributed to hydrate-enriched sediments. Fluid/gas venting is clearly seen through the transparent sediments and reaching the sea floor. The columnar disturbances originating within the sediments are probable indicators of fluid/gas venting. The fault can act as a conduit for the upward migration of fluids and gas, which causes thermal instability, and the venting of gas may be due to the dissociation of gas hydrates. Enhanced fluid migration can result in destruction of the sediment layering, and this usually happens in active fault zones. Pockmarks are prominent features on the seafloor originated by the escape of gas from seabed. These Vshaped depressions are originated by expulsion of gas from over-pressured shallow gas pockets, dispersing the fluid and gas filled sediments into the water column (Hovland and Judd, 1988) or by intensive continuous fluid discharge hindering sediment deposition around the seep. Pockmarks are underlain by acoustic blankings. The weakening of reflections is known as blanking which are caused by the reduction of impedance contrast because of cementation of sediment by gas hydrate. The acoustic blanking zones below the pockmarks are probably related to the source of the gas. Acoustic disturbances in a narrow vertical column below almost every pockmark can be seen. These disturbances may indicate the paths of the upward migration of gas and associated pore fluids (Chow et al., 2000).

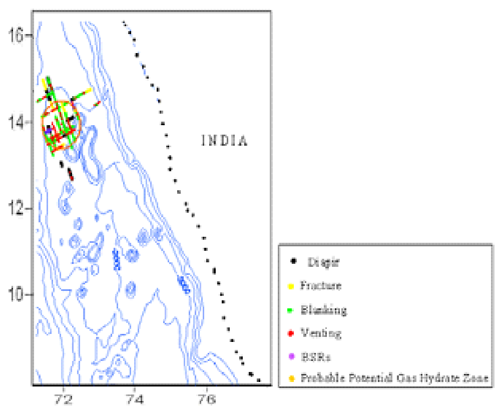

Figure 2: Map showing various geological features known to be associated with gas hydrate formations.

Conclusions

The presence of BSRs seismic characteristics observed in this study further support the earlier studies for occurrence of gas hydrates overlying free gas (Satyavani et al, 2002; Naidu et al., 2008) and related geochemical proxies (Ramana et al, 2006) generally believed to be associated with Gas hydrates. Shallow faults and columnar disturbances ending at small depressions on sea floor indicate fluid/gas seepages into sea water. The identified domal structures and bulging within the sediment layers are probable resultants of over pressured sediments. Chaotic reflections within the sediment layers and broken nature of the reflective horizons within the hydrate stability zone in association with seafloor pockmarks are probably suggestive of past/present hydrate dissociation processes. The tectonic complexity of the area seems to be playing important role in vertical and lateral migration of hydrocarbons from deeper layers. The sand layers within the Pleistocene to Recent sediments may be continuous source of methane. This must be contributing a significant contribution of methane/gas concentration/ sediments which is supported by the reported geochemical anomalies.

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