Marine and Petroleum Geology 58 (2014) 339–355

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Synthesis of deep multichannel seismic and high resolution sparker data: Implications for the geological environment of the Krishna–Godavari offshore, Eastern Continental Margin of India

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A R T I C L E I N F O

Article history:
Received 26 March 2014
Received in revised form
25 July 2014
Accepted 9 August 2014
Available online 19 August 2014

Keywords:
KG offshore
Gas hydrate
High resolution seismic reflection sparker data
High quality multichannel seismic data
Deep seated faults
Gas upthrust
Mud diapirism

A B S T R A C T

Proven hydrocarbon occurrence in the Krishna Godavari (KG) basin, a part of the Eastern Continental Margin of India initiated intense exploration activities to discern the potential hydrocarbon bearing structures/payoff zones. Recent discovery of gas hydrates in its offshore triggered detailed exploration measures adopting advanced seismic data acquisition techniques supported by deep drilling to understand its genesis. Interpretation of Multichannel Seismic (MCS) sections highlighted several distinct horizons from Lower Cretaceous to Recent in the sediment overburden, and the nature and configuration of the underlying crust. The sections also depicted the presence of growth faults, shale bulging, toe thrust faulting, delta progradation, active sliding/slumping, buried channels, pinchout structures and reflection free zones, indicating the different types of sedimentary processes, varied geological environments and neotectonic activity in the KG offshore. High resolution sparker (HRS) data revealed subsidence, gas/fluid expulsion pathways, occasional diapiric intrusions and growth faulting in the upper slope, and toe thrust faulting, upthrust and diapiric intrusions in the lower slope. The mid slope is characteried by a well stratified E–W trending basin bounded by upthrust and diapirism. The entire region is associated with gas escape features (blanking zones, columnar type gas vents, fault controlled mud/shale diapirs, large dimension gas saturated zones and pockmarks). The growth faults, shale bulging and toe thrusting seen in the MCS data since Oligocene time could be linked to shale diapirism, upthrust, gas/fluid expulsion, subsidence and mini-basin formation observed on the shallow HRS records. Synthesis of these datasets suggests that the distribution of gas hydrate in the shallow sediments may be controlled by the deeper structural and tectonic configuration. Therefore, knowledge about shallow sedimentary column and its connectivity with deeper strata through faults/fractures and other structural features, and the geological architecture are significantly important to evaluate the genesis of gas hydrates.

1. Introduction

Krishna-Godavari (KG) offshore basin (Fig. 1) drew the attention of oil majors due to its proven hydrocarbon potential over the past two and half decades. Persistent demand for oil and natural gas compelled the Ministry of Petroleum and Natural Gas, Government of India to search for an alternative to the conventional hydrocarbons. Gas hydrate, a consolidated form of pure methane gas could be a suitable substitute, if detected along the Indian offshore. These gas hydrate deposits are found to occur in marine slope sediments and permafrost regions, where low temperatures, high pressures and sufficient organic carbon are found (Kvenvolden, 1993). Several researchers used multichannel seismic reflection (MCS) data to infer gas hydrate occurrence by mapping bottom simulating reflector (BSR, an anomalous seismic reflector, and a gas hydrate related proxy) that represents the base of gas hydrate stability zone (Shipley et al., 1979; Kvenvolden, 1998; Hyndman et al., 1992). The gas hydrate fields of McKenzie Delta, Nankai Trough, Blake Ridge and Hydrate Ridge are the best known examples inferred using BSRs (Holbrook, 2001; Suess et al., 2001; Nouze et al., 2004; Dallimore and Collett, 2005).

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http://dx.doi.org/10.1016/j.marpetgeo.2014.08.006
0264-8172/

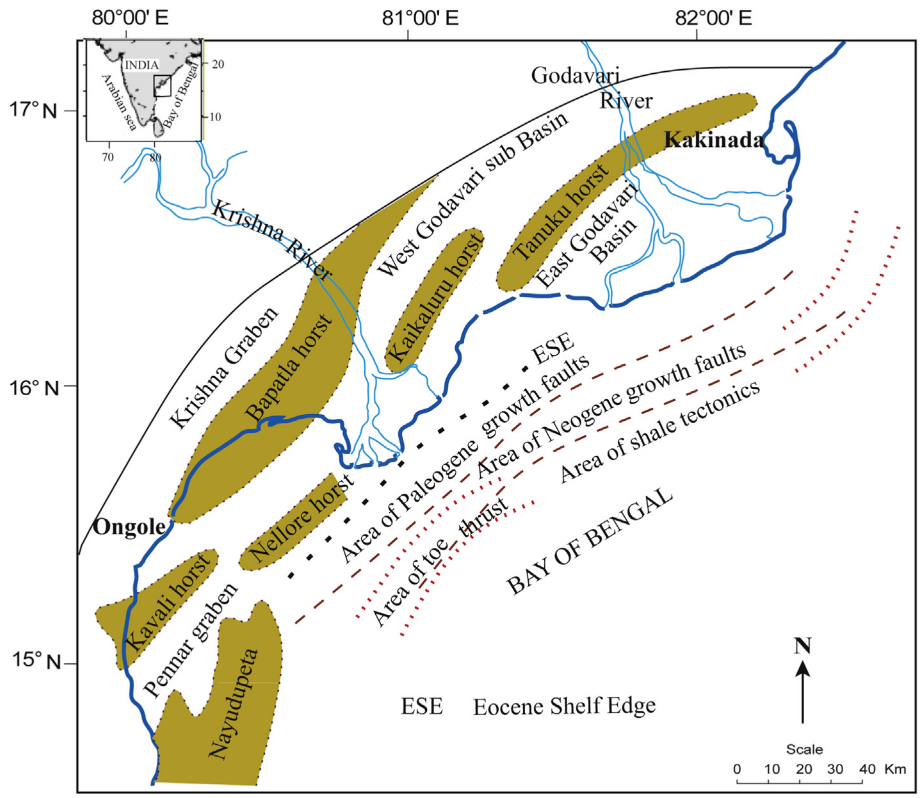

Figure 1. Map showing the structure and tectonic frame work of KG Basin, East Coast of India. The Krishna and Godavari are the two major perennial rivers flowing into the Bay of Bengal in the study area. The onshore is dominated by NE–SW trending horst and grabens. The Eocene Shelf Edge, Paleogene and Neogene growth faults, toe thrust fault and shale diapirism are some of the characteristic features of the KG offshore (Rao and Mani, 1993; Rao, 2001; Bastia and Nayak, 2006). Inset shows location of the KG Basin on the East Coast of India.

The resource map of India (NIO, 1997) in conjuncture with the inferred BSRs (NIO, 2001) suggested the likely occurrence of gas hydrates along the continental margins of India. Multidisciplinary investigations in the KG offshore (NIO, 2003), together with seismic results aided in selecting suitable locations for ground truthing. The subsequent drilling program onboard JOIDES Resolution confirmed the presence of a fully developed gas hydrate system in the KG and Mahanadi offshore areas, and the Andaman Sea under varied tectonic (passive and active margin) regimes/settings (Collett et al., 2008). Gas hydrate deposits are known to occur in different forms, i.e., disseminated, nodular, layered, massive (Sloan, 1990). The KG offshore is known for the occurrence of gas hydrate in fractures (Riedel et al., 2010) as well as in sand bearing beds (Riedel et al., 2011). The thickness of these hydrate zones varies from a few centimeters to few meters with an exception of one or two locations, where the thickness is > 100 m.

It is important to understand the subsurface geological environment, architecture of the upper and deeper sediments, associated structural elements and the basement configuration to infer the genesis and distribution of gas hydrates in a particular region. The conventional MCS data, though insufficient to estimate the potential of gas hydrates due to their unknown nature and lateral extent, can provide the complete architecture of the sediment column and acoustic basement. The High Resolution Sparker (HRS) system can detect fine scale structures as thin as 1–2 m within the upper few hundred meters sedimentary column. Since gas hydrates occur within the upper few hundred meters, the HRS system forms a powerful tool for its exploration. Integration and combined interpretation of the conventional MCS and HRS data is of utmost importance to link the shallow gas hydrate related structures to the characteristics of the deeper sediment overburden and underlying crust. To that extent, we have used the processed MCS sections (GXT-1, GXT-2, AD-1, AD-2 and AD-3) and HRS data in the present study to decipher the subsurface geology and relate the shallow structures to the deeper structural configuration. The HRS data in the KG offshore basin depicted the presence of several gas escape features, while the MCS data defined major geological boundaries, deeper sources of the shallow disturbances and growth faults extending up to Eocene.

2. Geological setting

The Eastern Continental Margin of India resulted due to the breakup of India from the contiguous Australia–Antarctica in the Early Cretaceous, and subsequent dispersion of the continents in time and space (Ramana et al., 1994). The Eastern Margin includes the Bengal and Mahanadi Basins in the north, and Krishna-Godavari (KG) and Cauvery Basins in the south, all petroliferous in nature. The onshore pericratonic KG Basin, in existence since the Jurassic, extends offshore beyond mid-slope (Rao, 2001; Sahu, 2005; Gupta, 2006). This basin extends between Kakinada in the north and Ongole in the south, and occupies an area of ~28,000 and ~145,000 sq. km on land and offshore respectively (Rao, 2001; Bastia, 2007). Some of the ~NE–SW trending horst and graben like onshore structures are seen extending offshore (Fig. 1). The lower slope region and further offshore is filled with the Cretaceous-Recent sediments (Curray et al., 1982; Pateria et al., 1992).

The onshore grabens filled with 3–6 km thick volcanic lava flows are intercalated with intertrappean clay, limestone and sand