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Pore pressure prediction in gas-hydrate bearing sediments of Krishna–Godavari basin, India

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ABSTRACT

Predrill estimate of pore pressure (PP) is important for well design especially in areas containing gas hydrate bearing sediments. Here we report the pressure distribution in the gas hydrate bearing sediments in Krishna–Godavari (K–G) basin predicted from the seismic data along two lines passing through the site 10 of Expedition-01 (Exp-01) conducted by the Indian National Gas Hydrate Programme (NGHP). A series of elastic parameters namely P-wave velocity (Vp), S-wave velocity (Vs), density (ρ), Vp/Vs, P impedance (Zp) and S impedance (Zs) were derived from seismic data using pre-stack inversion. First the PP estimated from a sonic transit time log was calibrated with pressure core measurements in the depth interval of 1060–1280 m. Its magnitude is found to be ranging from 10.5 to 12.9 MPa where the vertical stress varies from 10.7 to 13.4 MPa within the same depth interval. This estimated PP was next treated as a target log (desired output) and seismic attributes resulting from pre-stack seismic inversion were used as input parameters in the training of a multi-layered feedforward network (MLFN). Finally we use the trained network to generate a subsurface PP distribution map along two 2D multichannel seismic profiles (line-X and line-Y) passing through NGHP01-10 within a time interval of 1420–1620 ms corresponding to a depth interval of 1060–1280 m. This corresponds to sedimentary column from 22 to 242 mbsf. Our results demonstrate that the pressure remains hydrostatic within the gas hydrate bearing sediments and is mostly above-hydrostatic below the gas hydrate bearing zone.

1. Introduction

Gas hydrates are ice-like crystalline compounds composed of water molecules in a rigid lattice of cages containing molecules of natural gas and are stable under low temperature and high-pressure conditions. Typically, they are found in sediments within a few hundred meters below the seafloor in water depths of more than 500 m as well as in shallow sediments in permafrost regions depending on temperature, pressure, gas composition, and geothermal gradient. Gas hydrates are identified from seismic data mostly by detecting an anomalous reflector, known as the bottom simulating reflector (BSR), characterized by seismic attributes, like amplitude blanking, attenuation, velocity anomaly, chimneys, gas escape features, pockmarks, and amplitude variations with offset (e.g., Chand and Minshull, 2003; Ojha and Sain, 2009). The presence of gas hydrate in marine sediments is inferred primarily from BSR but other geophysical, geothermal and geochemical predictions are necessary to verify it (Paull et al., 2005; Coffin et al., 2007). Gas hydrate distributions in the sediments of the Krishna–Godavari (K–G) offshore basin have been inferred mostly from the occurrence of a BSR (Sain and Gupta, 2012) that lies at the predicted base of the gas hydrate stability zone (GHSZ). An increase in the system temperature and/or a reduction in the system pressure could result in gas hydrate dissociation and production of water and gas. The presence of gas hydrate is one of the problems encountered during development of conventional oil and gas fields in deepwater offshore. Note that casing stability is an important part of well design; therefore it is necessary to know casing behavior for wells drilled through the gas hydrate bearing sediments with prior knowledge of pore pressure (Berger et al., 2004). Predrill estimation of PP is a standard practice followed by many major oil companies. Pore pressure information guides the development of the mud schedule, casing program, rig selection and wellhead ratings (Chhajlani et al., 2002). Pore pressure analysis can also be useful in understanding the geological influences on maturation and migration of hydrocarbons, and their ultimate trapping in reservoirs that are reachable with the drill bit (Lim et al., 2009). In recent years, results of PP predicted from 2D/3D seismic have been used in alternative well locations to see the distribution of pressure with respect to structure and geology. In this paper, we describe a procedure of pore pressure prediction from 2D marine seismic data acquired over the NGHP 01-10 site in the K–G offshore basin, India (Fig. 1).

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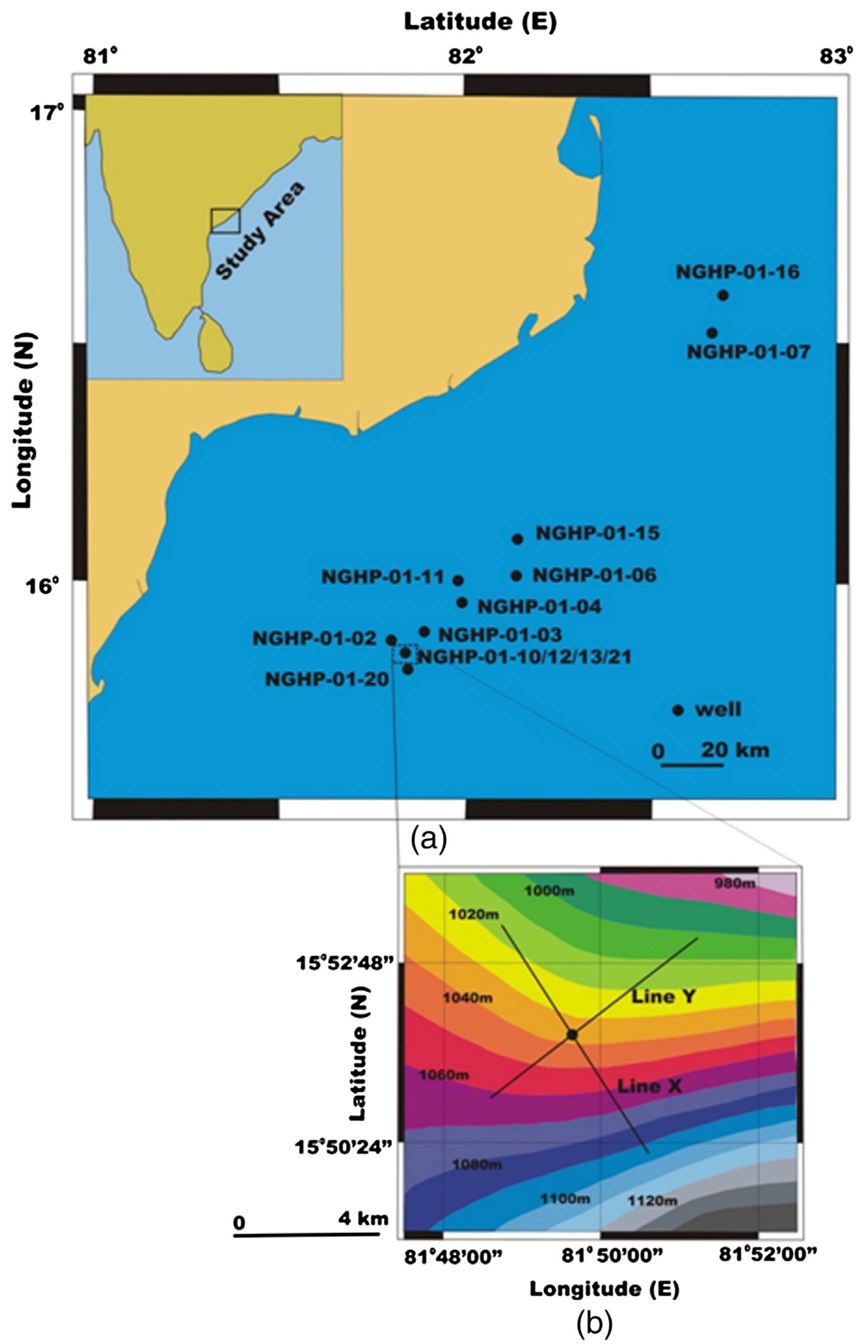

Fig. 1. (a) Location map of study area in K–G basin and (b) Bathymetry map containing line X and line Y passing through site NGHP-01-10/12/13/21.

2. Study area

The K–G basin located near the midportion of the eastern continental margin of India (ECMI) is a petroliferous basin, producing oil and gas. It contains a large number of structures and traps, which have been identified for drilling in the land and offshore parts of the basin (Rao, 2001). The regional seismic section shows an 8 km thick pile of Mesozoic and Tertiary sedimentary sequences (Rao, 2001). This sediment deposition covers a vast range of geologic settings such as costal basin, delta, shelf-slope apron, deep-sea channel, and deepwater fan complex. The basin has emerged as one of the frontier areas for future hydrocarbon exploration—after the multi-trillion cubic feet supergiant gas discovery in the recent years (Bastia et al., 2010). The basin has significant hydrocarbon potential both in the Tertiary delta as well as in the channel–levee–overbank play types in deepwater. The early Cretaceous sequence represents rifted geometry where as the Tertiary sequence is characterized by the occurrence of few very bright amplitude packages (Fig. 2) suggesting numerous vertically stacked sinuous deep-water channel–levee complexes (Bastia, 2006). Drill well results show that the sand to shale ratio within these channels is very high providing an excellent reservoir facies for petroleum accumulation (Bastia et al., 2010). High sedimentation rate ranging 20 to 25 cm/ky (Rao and Mani, 1993) and a total organic content of 1.5 to 2.0% (Kundu et al., 2008) serve as favorable conditions for appreciable amount of methane generation in this basin. The discovery of conventional gas and gas hydrate deposits along the K–G continental passive margin provides major impetus to study the basin in great detail (e.g. Riedel et al., 2010). The K–G offshore basin comprises predominantly claystone with minor sand and siltstone bands (Ramana et al., 2009). Wide-spread occurrences of BSRs coinciding with the base of the gas hydrate stability zone indicates gas hydrates