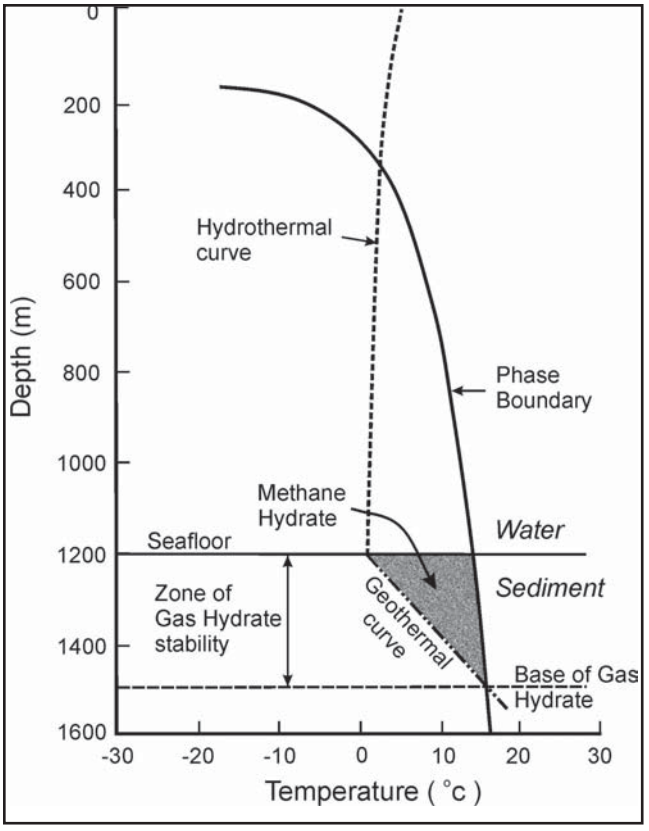

Fig. 1. A schematic phase diagram of submarine gas-hydrates and the stability zone (modified after Sloan, 1998)

is hard to quantify the amount of free-gas. So we restrict our calculation of hydrates saturation and physical parameters up to the BSR depth only.

Porosity and Density

To determine the porosity at the seafloor, first we prepare a nomogram of P-wave velocity (V_P) versus seafloor porosity (ϕ). For a given porosity ( ), can be calculated using the two-phase weighted equation of Nobes et al. (1986) as

$$\frac{1}{V_P} = \frac{W\phi}{V_1} + \frac{(1-W\phi)}{V_2} \quad (1)$$

where W is the weighting factor and is taken as 1.2. Due to unconsolidated nature of marine sediment V_1 and V_2 used in equation (1) are calculated as

$$\frac{1}{\rho_b V_1^{\,2}} = \frac{1-\phi}{\rho_m V_m^{\,2}} + \frac{\phi}{\rho_w V_w^{\,2}} \quad (2)$$

and

$$\frac{1}{V_2} = \frac{1-\phi}{V_m} + \frac{\phi}{V_w} \quad (3)$$

where V_m and V_w are the P-wave velocities of sediment matrix and water respectively. ρ_b, and are the densities of the sediment as a whole, matrix and water respectively. We use = 4.50 km/s, V_w =1.5 km/s, ρ_m =2.76 g/cc, =1.05g/cc for sandy sediments (Minshull and White, 1989) in the study area. The velocities for assumed seafloor porosities at steps of 1% are determined using equations (1), (2) and (3), and the nomogram is shown in Figure 3(a). Associated with the seafloor velocity of 1.78 km/s, we find the seafloor porosity as 54%. Error in velocity will produce error in all other parameters. Assuming ±5% error in the seafloor velocity, i.e. velocity varying between 1.69 and 1.87 km/s produces seafloor porosity from 49.5% to 59%. Background porosity, (z) at any depth, z below the seafloor for unconsolidated marine sediments can be calculated using the Athy's law (1930) as

$$\phi(z) = \phi_0 e^{(z/k)} \quad (4)$$

where is the porosity at the seafloor, which is already calculated. Using the compaction factor ( ) equal to 1.44/km (Minshull and White, 1989), we calculate the background porosity-depth function along with the error bounds (Figure 3(b)). The porosity at BSR is determined as 38.3% that can vary from 35% to 41.8% due to ±5% error in velocity.

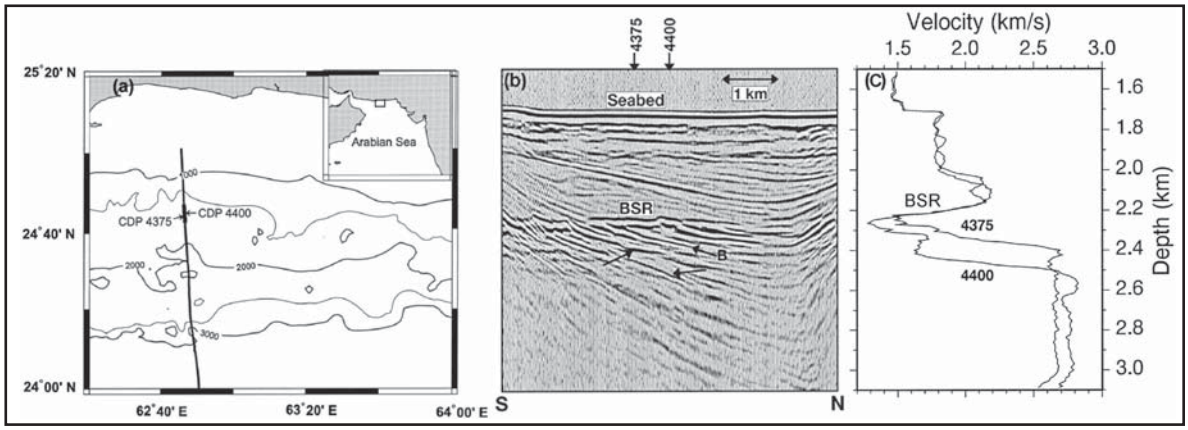

Fig. 2. (a) Location of the study area (represented by rectangle) in the Makran accretionary prism in the Arabian Sea, (b) Seismic section along thick solid line covering CDPs 4375 and 4400, displaying clear BSR at 495 m below seafloor and cutting across dipping strata (c) Velocity depth function derived using full waveform inversion at CDPs 4375 and 4400 (after Sain et al., 2000).