Using equation (2), we calculate the bulk density at the seafloor as 1.82 g/cc corresponding to velocity (1.78 km/s) and porosity (54%) at the seafloor. The background density as a function of depth and the error bounds (Figure 3(c)) are calculated using the porosity - bulk density (ρ_b) relation as per Nobes et al. (1986).

(5)

The average density for the Makran region is determined as1.98g/cc, which can vary from 1.9 g/cc to 2.04 g/cc due to assumed error in velocity.

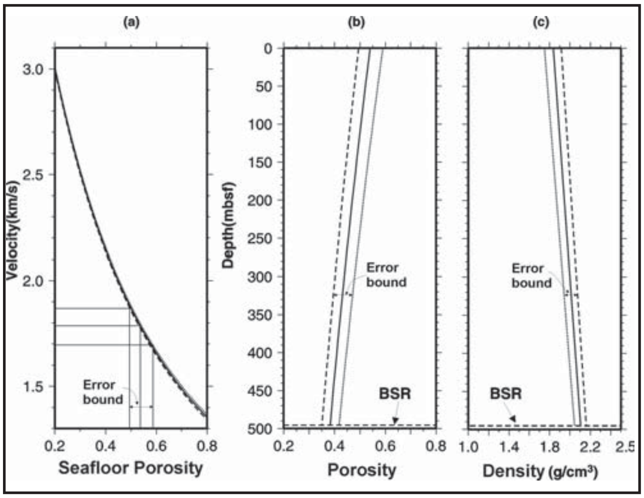

Fig. 3. (a) The nomogram of velocity versus seafloor porosity along with the lower- and upper-bounds, (b) Background porosity-depth function along with the lower- and upper-bounds, (c) Background density-depth function along with the lower- and upper-bounds.

Hydrates Saturation

Under the assumption of gas-hydrates saturation, increasing with depth and becoming maximum at BSR, we calculate the hydrates saturation at BSR as follows. A nomogram (Figure 4) of V_P versus gas-hydrates saturation is prepared by varying the hydrates saturation from 0 to 80% at interval of 1% using the three-phase weighted equation of Lee et al. (1996) as

$$\frac{1}{V_P} = \frac{W\phi(1-S)}{V_1} + \frac{1-W\phi(1-S)}{V_2} \tag{6}$$

and V_2 used in equation (6) are calculated as

$$\frac{1}{\rho_b V_1^{\ 2}} = \frac{1-\phi}{\rho_m V_m^{\ 2}} + \frac{S\phi}{\rho_h V_h^{\ 2}} + \frac{(1-S)\phi}{\rho_w V_w^{\ 2}} \tag{7}$$

and

(8)

Here, (=0.92 g/cc) and (=3.3 km/s) are the density and P-wave velocity of pure hydrates respectively, and ρ_b (=2.1 g/cc) is the density at BSR (Figure 4). = 4.50 km/s and ϕ =38.3% are used. Corresponding to the maximum P-wave velocity (2.2 km/s) at BSR, we calculate the hydrates saturation as 13%. The maximum hydrates saturation may vary between 12.5% and 13.5% due to assumed error in velocity. Assuming 0% hydrates saturation at 285 m below seafloor and maximum hydrates saturation at the BSR, the saturation gradient is calculated as 0.057 %/m, which is required to calculate the thermal conductivity and the resistivity of hydrated sediments.

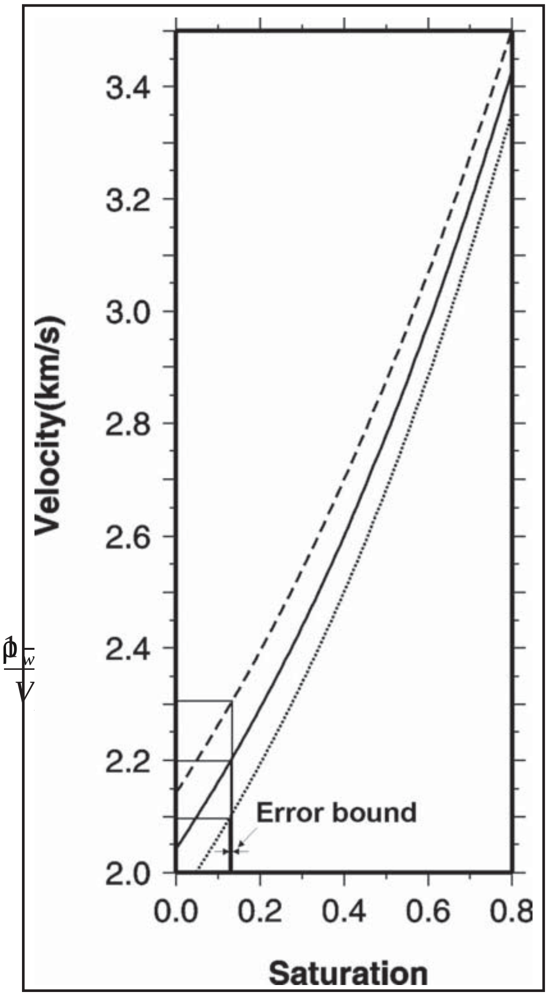

Fig. 4. The nomogram of velocity versus gas-hydrates saturation calculated using the porosity at the BSR along with the lower- and upper-bounds.

Geothermal Gradient

Using the water depth versus seafloor temperature curve (Figure 5) obtained from the real data, we find the seafloor temperature as 4^{0}C corresponding to the water depth of 1715 m. The water and the sediments upto the BSR is converted to an equivalent pressure of 27.23 Mpa that corresponds to the BSR temperature of 21^{0}C (Figure 6). The difference in temperatures at the BSR and seafloor divided by the depth of BSR below the seafloor yields the geothermal gradient of 34.34 ^{0}C/km. The ±5% error in assumed velocity changes the pressure at BSR from 27 to 27.5 Mpa that hardly affect the geothermal gradient estimated for the region.