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Gas Hydrate Stability Thickness along Indian continental margins

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Summary

The Gas Hydrate stability thickness (GHST) map along the margins of India was prepared from available bathymetry, sea bottom temperature and geothermal gradient. Since the bottom simulating reflector (BSR) is often associated with the base of the gas hydrate stability zone, the map helps to identify BSR, more accurately. The map is also useful to the explorationist to set a depth window within which proxies for gas hydrates can be looked into. The BSR represents the boundary between the hydrates-bearing sediments above and gas-bearing sediments below. Several parameters like sedimentary thicknesses, rate of sedimentation, total organic carbon content and seabed temperature in the deep water regions indicate good prospects of gas hydrates in the vast Indian offshore. Most of the deep water regions in India are yet to be covered by acquiring seismic data sets. So, it is essential to prepare the GHST map along the Indian margins, which will provide a useful guidance for identifying the BSR, the prime marker for gas hydrates. Rao et al. (1998) first published the GHST map using the analytical approach of Miles (1995) based on the-then available data. A similar exercise was carried out by Rastogi et al. (1999) using GIS based approach. During the last ten years, lot of new data sets have been generated and published, using which we have modified the GHST map along the margins of India. This fills the gap to better serve for the identification of gas hydrates along the margins of India.

Keywords: *Bathymetry, Sea bottom temperature, Geothermal gradient, GHST*

Introduction

Gas Hydrates are solid, ice like compound substances formed of cubic crystalline lattices of water and gas, under conditions of low temperature, high pressure and adequate gas concentrations. The above conditions can be met in permafrost regions (>150m) and also in the offshore continental margins where water depths exceed 450 m. The presence of gas hydrate in offshore continental margins has been inferred mainly from anomalous seismic reflectors (i.e., BSRs) that coincide with the predicted phase boundary at the base of gas hydrate stability zone. BSR mark the interface between higher sonic velocity, hydratecemented sediment above and lower sonic velocity, uncemented sediment with free gas below. This BSR is generally characterized by polarity reversal, crosscutting of sedimentary strata, seafloor mimicking which is observed in seismic section and often the depth to the BSR increases with increasing water depth.

A total volume of 1894 TCM of methane gas is predicted in the form of gas hydrates within the Indian exclusive economic zone (Kalachand Sain & Harsh Gupta, 2007). So, it is essential to identify the prospective regions. Many researchers have estimated the gas hydrate stability thickness (GHST) at different areas using varying methods. In this paper, GHST is derived using the analytical approach of Miles (1995) i.e. from the phase equilibrium curve of methane, hydrostatic pressure, seafloor temperature, bathymetry and geothermal gradient. The thickness values thus obtained are contoured and GHST contour map was prepared. This GHST map helps to identify BSR and serves as a guide to the explorationists by setting a depth window within which proxies for gas hydrates can be looked into. This predicted thickness map is validated i.e. there is good resemblance when computed depth is compared with observed depth from NGHPdrilling. In addition, contour maps of sea bottomtemperature, geothermal gradient, sediment thickness andheat flow of the Indian offshore were also prepared.

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The data sources taken from initial reports of NGHP expedition 2006, Global Heat Flow database, NIO profiles, IIOE atlas, General Bathymetric Chart of Oceans & some from publications. The addition of lithostatic, or overburden, pressure of the sediment to hydrostatic pressure will potentially increase the thickness of the hydrate layer but may also change the thermal conductivity of the sediment. The hydrostatic pressure assumption is only valid at shallow sub-bottom depth, but at most BSR depth is less significant than the accuracy to which we can determine the other parameters.

Procedure

The gas hydrate phase diagram and P-T equations (Miles, 1995) are used to calculate the thickness of the gas hydrate stability in the marine environment. The equation below represents the gas hydrate P–T phase diagram and valid between 0 ^{0}C to 30 ^{0}C and salinity of 33.5% is given by a fourth order polynomial

$$p = 2.8074023 + 0.1559474 \times T_z + 0.048275 \times T_z^2 - 0.00278083 \times T_z^3 + 0.00015922 \times T_z^4 \quad \text{--------- (1)}$$

Where P is the pressure in MPa and T is the temperature in ^{0}C. The temperature – depth function from the sea-bottom temperature (T_0) and geothermal gradient is given by

$$T_z = T_0 + \frac{dT}{dZ} z \quad \text{--------- (2)}$$

The pressure to depth converted equation is given by

$$p = [(1 + c_1)D + c_2 D^2] \times 10^{-2} \quad \text{--------- (3)}$$

Where,

$$D = z_0 + z = z_0 + [(T_z - T_0)/(\frac{dT}{dZ})] \quad \text{--------- (4)}$$

Here Zo is bathymetry and Z is the depth below seafloor in meters. $c_1 = [5.92 + 5.25\sin^2(lat)] \times 10^{-3}$; lat is the latitude in degrees and $c_2 = 2.21 \times 10^{-6}$. Substituting the depth equation in eq (3) & resulting equation is equated with eq (1) gives a fourth order polynomial equation i.e. in the form of

$$k_1 T_z^4 + k_2 T_z^3 + k_3 T_z^2 + k_4 T_z + k_5 = 0 \quad \text{--------- (5)}$$

Where k_1, k_2 **, ………………………..,** are constants.

The solutions for eq (5) are calculated by using Newton Raphson Method which has a convergence rate of degree two. The algorithm for above program is coded in C language in such a way that, it will result in a single Positive Real root. The resulting root is substituted in eq (2) to get Gas Hydrate Stability Thickness which is also coded in c language .Gas Hydrate Stability Thickness values thus obtained is contoured by using the surfer software and is shown in Fig.1. The predicted thickness value obtained lies well within the sediment thickness value at that location.

India's Exclusive economic zone (coast to 200 nautical miles) boundary, where a country has the right to use both the living and nonliving resources in the water column, sea surface and subsurface is also mapped in the Fig.1. India, traditionally a seafaring country, has a wide EEZ (exclusive economic zone) of about 2 million sq km all along the 7500 km long coastline around it. The living and nonliving resources in this exclusive economic zone of India constitute around two-thirds of the landmass of the country.

Propagation of error

- Except NGHP data, all other input data are not collected specifically for Gas Hydrate exploration.
- Depth of investigation of in-situ measurement probe is different from depth of occurrence of BSR.
- Considering Mean values for some Sea bottom temperature data which is taken from IIOE atlas.
- Error from Mathematical calculations.

In spite of all these errors, we had a good resemblance when computed depth is compared with obtained BSR depth from a seismic profile.

Table 1:

Location	Longitude	Latitude	Calculated Depth(m)	BSR Depth in a seismic profile (m)(From NGHP Report)	Percentage of error
Andaman	93.11	10.75	615.4	608	1.2
Mahanadi	85.66	18.97	209.3	205	2.1
K.G basin	82.04	16.03	123.0	125	1.1
K.G basin	82.68	16.52	188.5	188	0.2
K.G basin	81.99	15.99	154.9	150	3.2
K.G basin	82.09	16.06	107.5	109	1.3
K.G basin	82.68	16.59	171.9	170	1.1

Conclusions

1. Highest thickness above 700m is observed towards western side of Andaman offshore.

2. In the Western continental margin the thickness is in the range of 170-400m, Maximum thickness is observed in deep Saurashtra Offshore & deep Bombay Offshore where the thickness is above 350m.

3. In the Eastern continental margin the thickness is in the range of 100-350m while in eastern side of Andaman offshore the thickness is 600m.

4. One of the reasons may be, low Geothermal gradient i.e. 20 ^{0}C/100m as we seen from geothermal gradient map & also due to high sedimentation rate in Andaman offshore. This low geothermal gradient in Andaman could be due to the relatively cool plate being subducted .

5. The computed thickness will be more accurate if the data is more reliable i.e. data is specifically collected for gas hydrate exploration like NGHP expedition data.

6. This map serves as a guide to the explorationists for detecting proxies for gas hydrates investigation using various geophysical, geochemical, microbiological and geological methods

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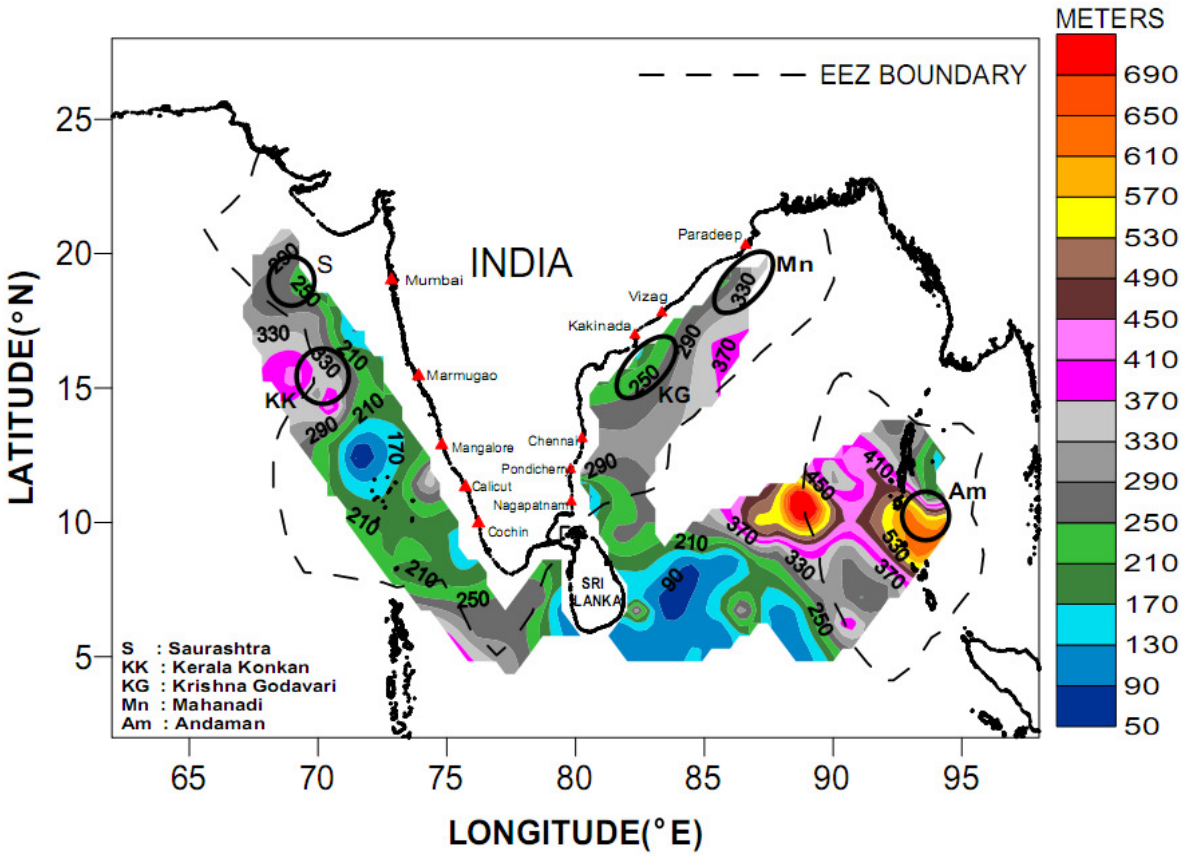

Fig.1: Gas Hydrate Stability Thickness contour map of Indian offshore in meters