

GAS HYDRATE STABILITY ZONE THICKNESS MAP OF INDIAN DEEP OFFSHORE AREAS - A GIS BASED APPROACH

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ABSTRACT

Natural gas hydrates, which have the potential of being an alternate energy resource, are known to occur worldwide in the sediments of the outer continental margins and in the polar regions in association with permafrost. The gas hydrates are stable under limited range of temperature and pressure conditions, which normally exist within few hundred meters of ocean sediments, in water depths greater than about 300 m.

For the first time, GIS software has been used to map potential areas for the gas hydrate occurrence in offshore regions around the Indian sub-continent. This was accomplished by estimating the gas hydrate stability zone (GHSZ) thickness from the spatial analysis of the physical parameters that control the formation and stability of gas hydrates. The required data (bathymetry, seabed temperature and geothermal gradient etc.) were obtained from published literature, digital data bases and unpublished sources. These data were supplemented with predicted values, in areas having insufficient measured data. The compiled data bases were stored as GIS coverages. The thickness of gas hydrate stability zone was computed by superimposing the GIS maps of individual parameters and solving the gas hydrate phase and pressure-temperature equations for each grid. The GHSZ thickness values in meters as well as in TWT (msec) were calculated over the entire region.

Although the GHSZ thickness map by itself does not propose the presence of gas hydrate, it can be used as an important indicator for assessing the gas hydrate potential over an area. The base of stability zone coincides with the bottom-simulating reflector (BSR), which is a characteristic acoustic signature at the base of the hydrate bearing sediments. The TWT map of the GHSZ thickness can therefore be effectively used while examining the seismic records to locate BSRs. Further, integration of this GHSZ map with the GIS data base of other geological attributes, such as sediment thickness, total organic carbon content (TOC) etc., will enable quick and efficient first order estimation of in-place hydrate resource. The GIS approach allows rapid updating of the data base and refinement of the results as and when more new data are available.

Key Words: Gas hydrate, Thickness, Indian deep offshore

INTRODUCTION

Natural gas hydrates, composed mainly of methane are known to occur worldwide in the sediments of the outer continental margins and in the polar regions in association with permafrost. Gas hydrates are ice-like crystalline solids composed of water molecules surrounding a gas molecule. One cubic meter of methane hydrate can contain up to 164 cubic meters of methane gas at standard conditions (Kvenvolden, 1993) and the estimated amount of gas in the hydrate reservoirs of the world greatly exceeds the volume of known conventional gas reserves.

The phase diagram (Figure 1), showing the boundary between free methane gas and methane hydrate for a pure water-methane system, provides a reasonable estimate of the pressure-temperature conditions under which natural gas hydrates will be stable on continental margins (cf. Miles, 1995). In tropical waters, the hydrate stability conditions are available in the areas having water depths in excess of 600m (cf. Macleod, 1982); however within the sediments the downward limit of this zone is controlled by the geothermal gradient. The thickness from the seafloor down to the depth of the base of the hydrate stability is considered as the thickness of the gas hydrate stability zone (GHSZ). This paper presents an overview of a first time effort to compute the GHSZ thickness using a Geographic Information System (GIS), for the offshore regions around India between 600m isobath and the outer limit of the anticipated legal continental shelf.

DATA

For the computation of the GHSZ thickness, the required bathymetry, seabed temperature and geothermal gradient data were obtained from digital data bases and published and unpublished sources. This data were supplemented with predicted values in areas having insufficient measured data.

The bathymetry data were compiled from the contours and spot soundings of published hydrographic charts. In addition, swath bathymetric data of three seamounts in the Arabian Sea (Bhattacharya et al, 1994) were also included. The seabed temperatures were computed by extrapolating (using Lagrange Polynomial) the available measured water column temperature profiles to the sea bottom depth. In places of data inadequacies the seabed temperatures were predicted from bathymetry and representative temperature profiles.

The geothermal gradient data were obtained mainly from the published data and maps (Wright and Loudon, 1989; Panda, 1994). In addition, geothermal gradient values were obtained from predicted heat flow values and mean thermal conductivity of marine sediments. The predicted heat flow values were computed using different procedures based on the genesis of the crustal rocks, such as heat flow versus crustal age relationship of Stein and Stein (1993) for regions of oceanic and hot spot derived crust, the heat flow versus crustal stretching factor (β) relationship (Mckenzie, 1978; Loudon et al., 1991) for the regions underlain by continental crust and a regression of heat flow and assumed crustal ages for the Andaman Sea region.

METHODOLOGY

For the creation of database and spatial analysis, a UNIX based ARC/INFO - Geographic Information System (GIS) has been used. Firstly, the compiled and edited data and maps were

used for manual preparation of contour maps of various parameters, which were scanned, digitized and converted into parameter-wise GIS coverages. The individual GIS coverages of bathymetry, seabed temperature and geothermal gradient were overlaid and a combined coverage was prepared. Following the analytical approach of Miles (1995), the individual parametric values of the combined coverage were considered, for computing the GHSZ thickness at each 10 nautical mile grid node by solving the simultaneous equations of pressure and temperature. These thickness values are in terms of meters below the sea floor, which were also converted into thickness in terms of 2-way travel time (TWT) in milliseconds using an assumed velocity structure.

RESULTS AND CONCLUSIONS

The spatial analysis of the GHSZ thickness map (Figure 2) suggests availability of 200-400 m thick stability zone over major part of the study area. In two areas, one southwest off Bombay and the other south of Bengal Delta, the GHSZ appears to be more than 800m thick. The GHSZ thickness map by itself does not propose the existence of gas hydrates in these areas, but if gas hydrates occur, it indicates the thickness of the hydrate stability zone. The TWT map of the GHSZ thickness will provide an indication of the potential depth where bottom simulating reflectors (BSRs) can be expected on seismic records. Integration of GHSZ map with GIS database of other geological attributes, such as sediment thickness, total organic carbon content (TOC) etc. will enable quick and efficient estimation of in-place hydrate resource.

These maps are based on existing and published data which obviously were not collected with the specific objective of this task, hence they provide only a gross preliminary appraisal of various parameters related to the occurrence of gas hydrates. These maps need to be refined and continuously updated using more ground truth data that will be collected with this specific objective. Since the data compiled for this work have been stored as GIS coverages, updating and refining can be accomplished efficiently and rapidly as and when required in future.

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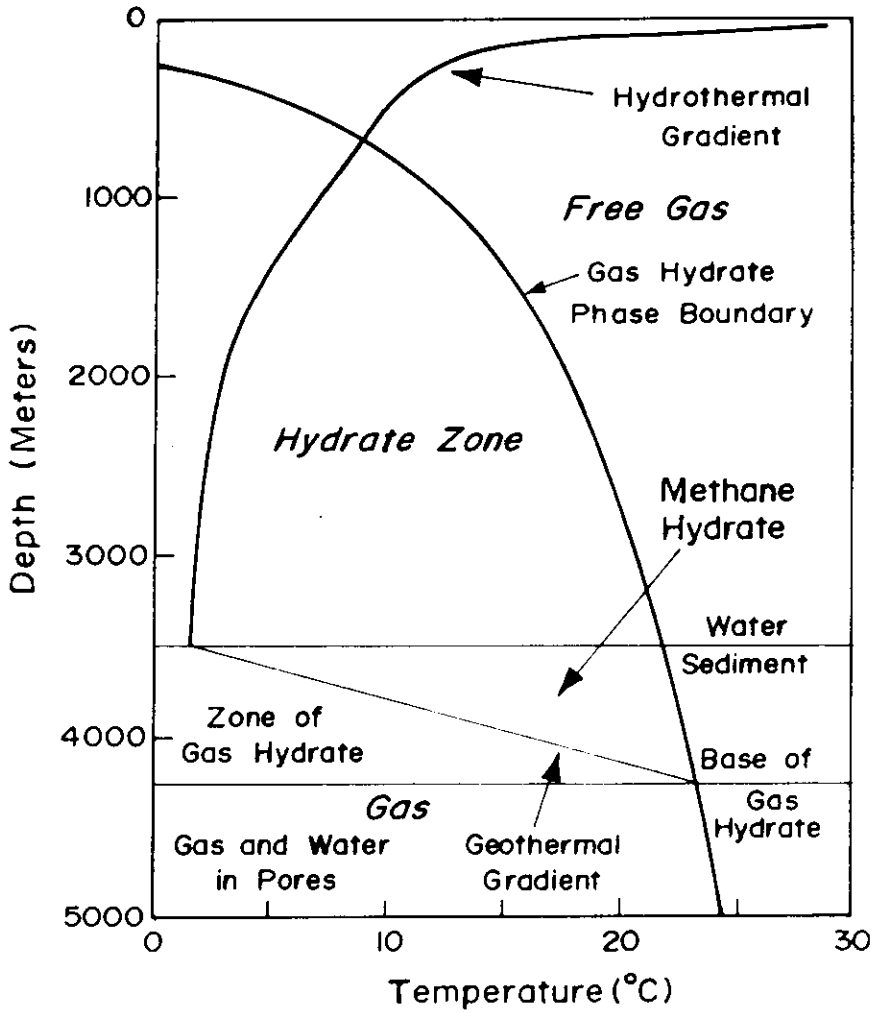


Figure 1

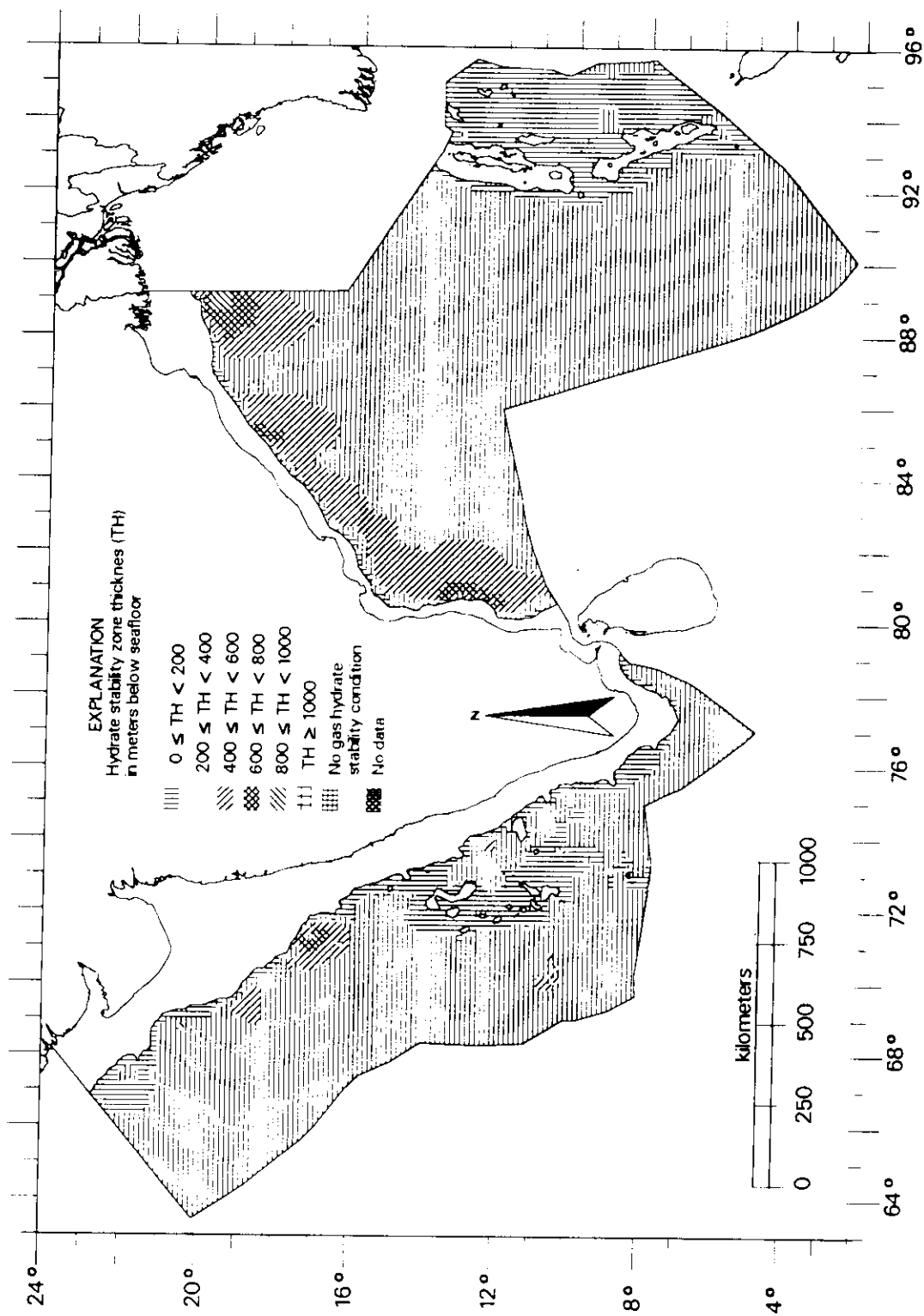


Figure 2