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Sub-Surface Characterization of the Gas Hydrate Bearing Volcanic Ash Sediments with Wireline Logs in Andaman Deep Waters, India.

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Abstract

Gas hydrates are solid ice like substances in which methane molecule is trapped in a cage like structure of water molecules, formed at high pressure and low temperature in continental self and permafrost Artic Region. Gas hydrate volume estimation within a particular geological setting depends on different reservoir parameters. Two of the important parameters, porosity and gas hydrate saturation can be derived from data obtained from downhole logging tools. The present paper attempts characterization of gas hydrate bearing volcanic ash sediments, estimation of sediments porosity and gas hydrate saturation in Andaman Deep Waters from Wireline log data acquired during National Gas Hydrate Programme (NGHP01) in 2006. Thorium vs. potassium cross plot indicates that the soft under compacted clayey sediments have smectiite as the dominant clay mineral which has a potential effect on resistivity log due to its high cation exchange capacity (CEC). Using an integrated approach to gas hydrate saturation estimation presence of hydrate has been indicated in volcanic ash beds in 200-600mbsf. The results from this approach have been validated with salinity derived saturation which is a direct indication of gas hydrates occurrence. The bottom simulating reflector (BSR) is at 600mbsf characterized by an increase in compressional and shear wave travel time (Δt) and decrease in electrical resistivity. Computed hydrate saturation by this integrated approach and log responses show presence of free gas below BSR which is further supported by recovered core studies.

Background

Growing energy demand and unstable oil prices has drawn the attention of the Geo-scientific community towards the alternatives energy resources available in nature. Gas hydrate resources according to conservative estimate are twice that of conventional oil and gas resources put together (Kvenolden, 1993) and hence need to be understood for geological occurrences, environment of deposition and methods for reserve estimation and production.

Gas hydrate also known clatharates is found in permafrost region and continental self at low temperature and high pressure conditions. The region of low temperature and high pressure (depth) in sub-surface environment is called gas hydrate stability zone (GHSZ). Gas hydrate are formed with a combination of water and gas molecule known as host and guest molecule respectively. Naturally occurring hydrate consists of methane as the host molecule in major cases which may be of biogenic and/or thermogenic origin. Thermogenic nature indicates deep source of methane supply and possibly a gas conduit from deep seated gas reservoir a good tool for understanding conventional reservior.

The Indian economy, with double digit growth rate, needs a lot of energy to meets its domestic demand. Ministry of Petroleum and Natural Gas, Govt. of India launched an ambitious National Gas Hydrate Program (NGHP) for gas hydrate exploration in Indian offshore. The primary objective of the program was to conduct scientific ocean drilling/coring, logging and analytical activities to assess the geologic occurrence, regional context and characteristics of gas hydrate deposits along the continental margins of India. The offshore operations were conducted from 28 April 2006 to the 19 August, 2006 with scientific vessel JOIDIS Resolution.

Geological Setting of Andaman Area and Data Acquisition:

The Andaman Basin came into existence as a result of collision process involving subduction of Indian Plate along the margins with the west Burmese Plate. The sedimentary succession in the basin range from Kalapani Group of Formation of cretaceous age to recent sediments. Volcanic intrusion occurred during pre-oligocene period affecting sedimentary strata at different levels. Hole NGHP01-17A is located 10° 45.19' N, 93° 6.7365' E in the Andaman Sea, water depth is 1344m (fig. 2) This hole was cored from sea bed to 673.3 mbsf to explore the possibility of gas hydrate deposition. The logged Hole NGHP01-17B is located 20m south of hole NGHP01-17A. The location map of Andaman offshore area is given in fig.-1 which lies on south eastern side of the country in Indian Ocean.

The wireline data as shown in table-I was acquired by M/s Schlumber, Maxis Logging Unit deployed on the ship under the supervision of Lamount Dohearthy Earth Observatory (LDEO), Columbia University, USA. Initial data management and some borehole corrections were applied at the LDEO. Initial expedition report and data was made available to the participating geo-scientists and institutions in Feb.-2008. A composite log recorded is presented in fig.-3 and shows that the log quality is reasonably good.

Methodology

The classification scheme into units is based on variation in log responses against sediments because of the bulk properties response of the gamma ray, density and neutron log and gas hydrate distribution dependent effect on sonic travel time and resistivity. NMR log is also affected by bulk properties of the sediments.

Gas hydrate preferably forms in larger pores and in coarser sediments and clay play an important role in pore size distribution. Clay minerals like kaolinite, smectite, illite and chlorite are characterized by a range of potassium and thorium content found in them. The industry standard thorium and potassium cross plot technique has been used to identify clay mineral present in the sediments logged. Volcanic ash bearing layers are characterized by high resistivity and high potassium content.

The sediments under study are soft and unconsolidated, recovered core samples in the hole NGHP01-17A show grain density 2.44 - 2.81 gm/cc. An average value of 2.67 gm/cc has been used to compute porosity from density. The resistivity of formation water (Rw) has been derived from salinity measure on extracted pore fluid from cores after carefully filtering less than 30ppm salinity value which may be because of gas hydrate dissociation. The Rw value was also corrected for temperature effect with sea floor temperature of 5.5° C and gradient of 20° C/Km. Considerably low temperature gradient were measured in Andaman area most probably due to high sedimentation rate and hence thicker gas hydrate stability zone (GHSEZ). Archie's equation:

$$\mathbf{Sw^{n} = (a\ Rw / Rt\ \text{ø}^{m})}$$

has been used to calculate water saturation, Sw. Gas hydrate saturation, Sh is given by:

$$\mathbf{Sh = 1 - Sw}$$

Pearson et al. (1993) have pooled the petrophysical parameters a, m and n for under compacted soft sediments, a=0.967, m=2.81 and n=1.96. The value of m was validated by computing Ro and comparing it with Rt in water bearing zone.

Discussion:

Based on the log response to under compacted sediments, following three distinct units have been identified:

Unit I 250-355mbsf

Unit Ii 355-600mbsf

Unit III 600-719mbsf

Unit I is characterized by large hole, high neutron porosity and low density 1.4-1.6 gm/c^3, Thorium and potassium in the interval is indicative of high clay content. Resistivity is 0.8-1.2 Ω.m and compressional travel time is high due to higher clay content.

Unit II is characterized by relatively good bore hole as compare to unit I. There is high resistivity peak at 387mbsf followed by high density and low sonic compressional travel time characteristic of authigenic carbonate rich nano fossil ooze. This feature is also clear in the hole NGHP01-17A the sedimentological core studies. The base of this unit is characterized by resistive events which are gas hydrate bearing. The resistive features in this interval with low density and high potassium content are volcanic ash bed and are gas hydrate bearing. Although no gas hydrate bearing cores were recovered in the hole but the IR (Infra Red) imaging done onboard clearly indicate the cooling anomaly and hence the presence of gas hydrate. Pore water freshening is the other indication of gas hydrate in this horizon. At 600 mbsf resistivity is decreasing, compressional travel time is increasing, this is an indication of base of gas hydrate stability zone.

Unit –III is below GHSZ where borehole condition has slightly deteriorated. There is an increase in Δ t in this unit indicating the absence of gas hydrate and presence of free gas also the reason for bottom simulating reflector (BSR) on seismic section.

Thorium and potassium content are 2 - 5.1 ppm and 0.4 – 1.0 % respectively. The values plotted in fig.- 5 shows that smectite is the dominant clay mineral with presence of illite and chlorite. Smectite has large specific surface area and high CEC and hence high bound water content with a characteristic effect to reduce resistivity.

Gas Hydrate Occurrence

Gas hydrate on well logs is identified by an increase in resistivity and decrease in acoustic wave travel time that are not accompanied by an increase in density. There are high resistivity streak followed by a corresponding increase in density because of presence of carbonaceous nano fossil ooze at 385mbsf, 440mbsf, 540mbsf, 556mbsf, 580mbsf etc. The other peaks in resistivity are volcanic ash bearing layers and are gashydrate bearing with gas hydrate saturation up 20% (fig. 6). In the lower part of unit-II with high resistivity the gas hydrate saturation is upto 30% (fig 6). The saturation below GHSZ is due to the presence of free gas.

Salinity of pore water extracted from core samples plotted with gas hydrate saturation (fig. 7) show a good correlation between pore water salinity and gas hydrate saturation. The intervals where gas hydrate saturation are high indicate low salinity due to dissociation of gas hydrate resulting into freshening effect.

Conclusion

Log analysis and evaluation reveal that gas hydrate occurs in thin volcanic ash bed layers. Gas hydrate saturation is 20% in these beds and in lower part of unit II it increases to 30%. Smectite is the dominant clay mineral with presence of illite and chlorite. A comparison of salinity of pore water extracted from cores and gas hydrate saturation calculated from log data show consistency in behaviour as expected.

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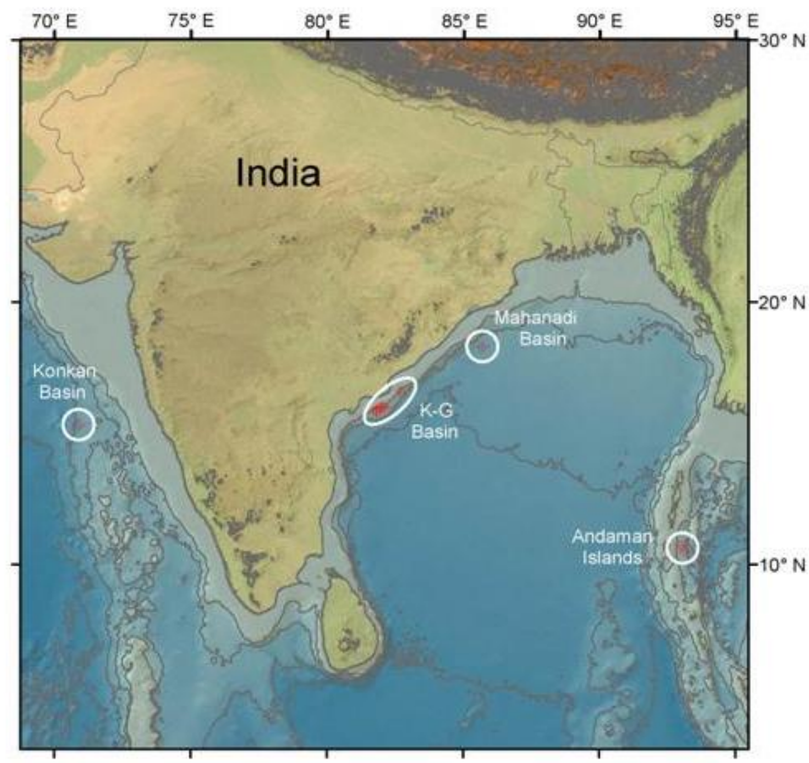

Fig.-1, Location map of Andaman site with coastal boundary

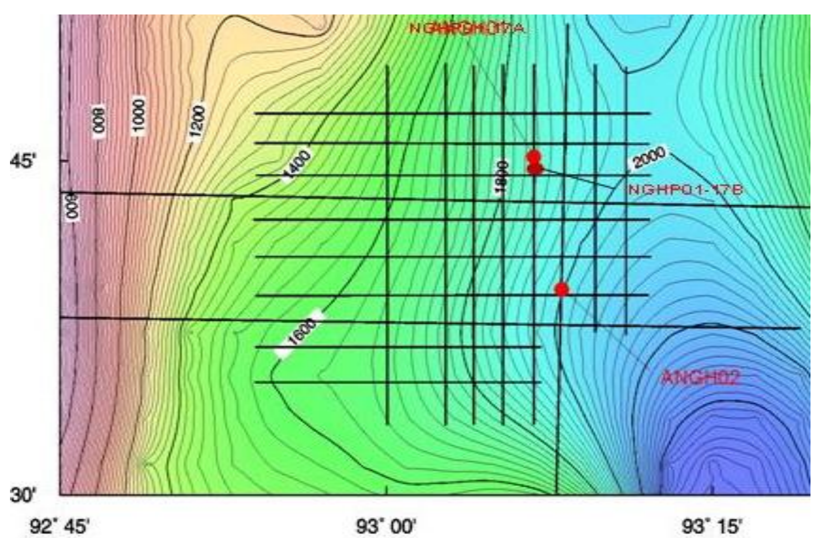

Fig. –2 Contoured Water Depth Map For NGHP01-17B and Vicinity

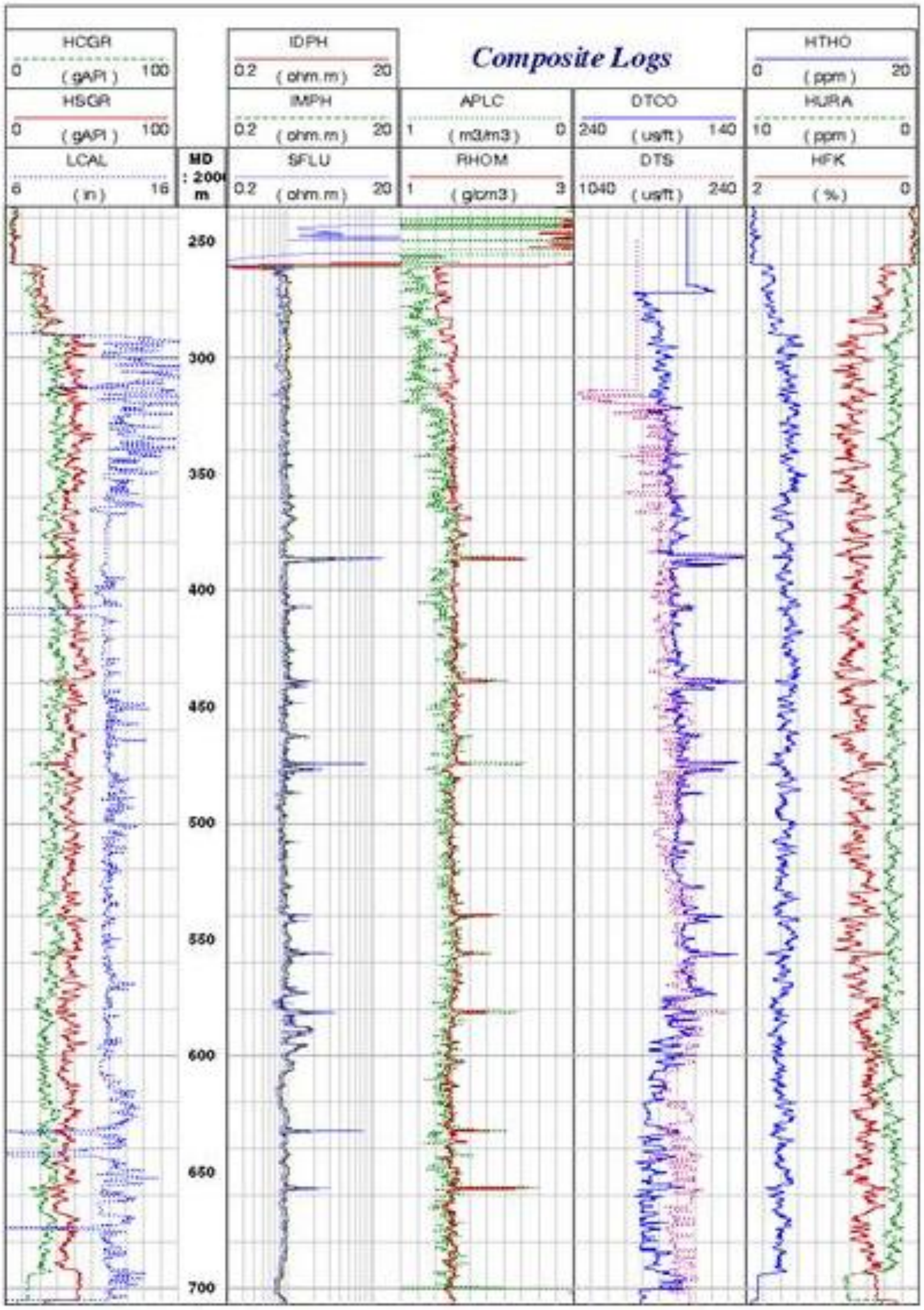

Fig-3 Composite logs of Hole NGHP01-17B, Andaman offshore.

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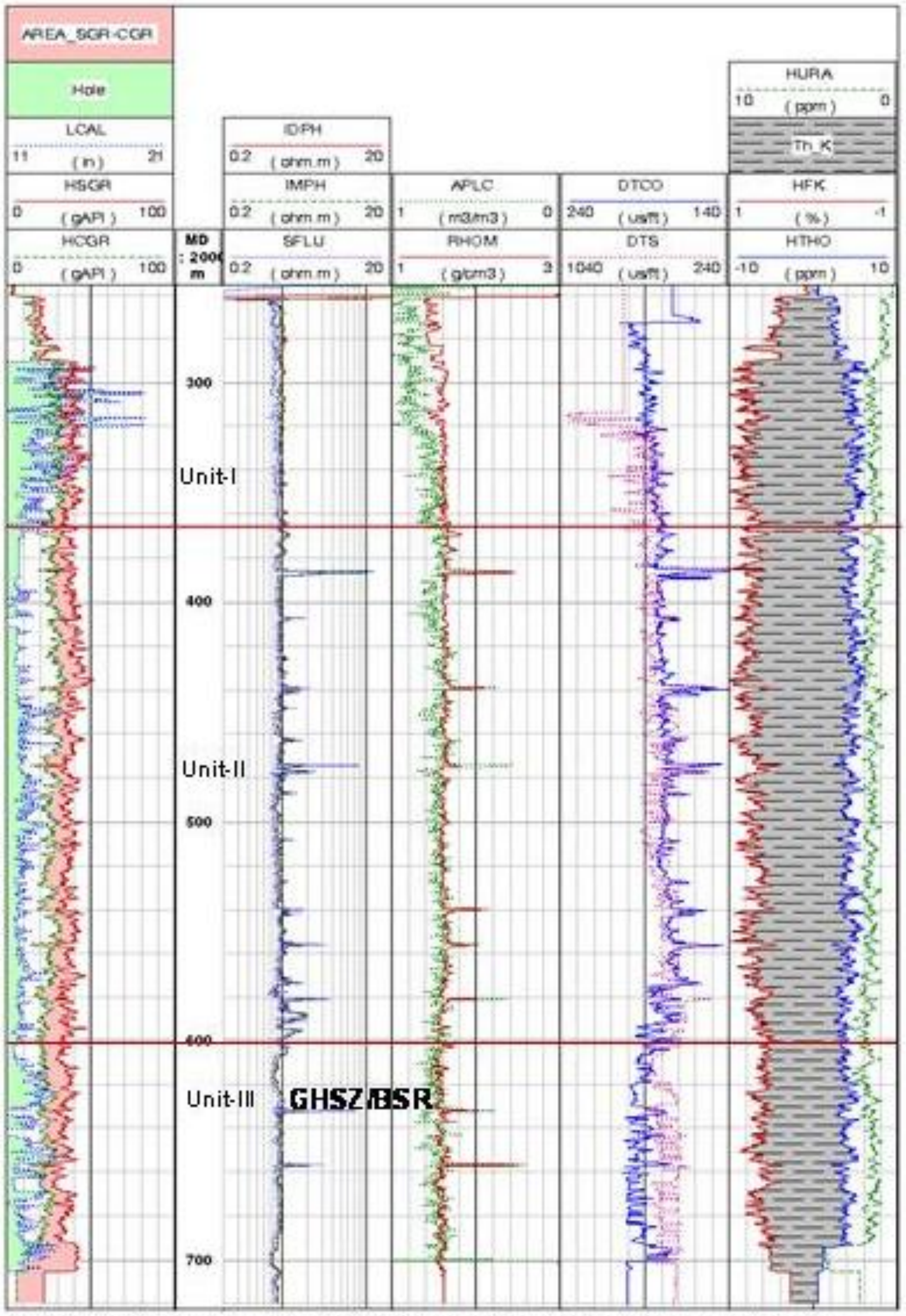

Fig-4, Lithostratigraphic classification, Unit-I bad bore hole, high apparent neutron porosity, resistivity about 1 Ohm-m and Gamma ray40-50API, Unit-II, Good Bore Hole, apparent neutron porosity60-70% resistivity 1-1.5 Ohm-m, Gas Hydrate Bearing, Unit-III: Bad borehole, GR:- 40-50API, apparent neutron porosity: 60-70% and resistivity 0.6-1.1 Ohm-m. Below GHSZ at 608m corresponding to BSR on seismic line.

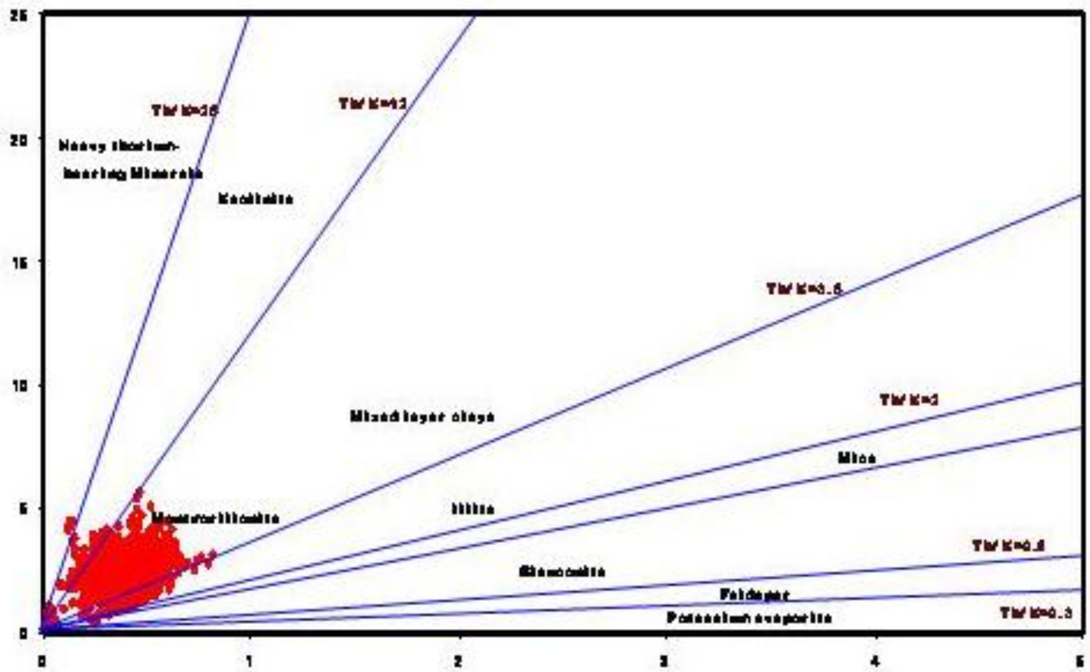

Fig.- 5, Thorium vs. potassium plot shows that montmorillonite is the dominant clay mineral with little contribution of Illite and chlorite

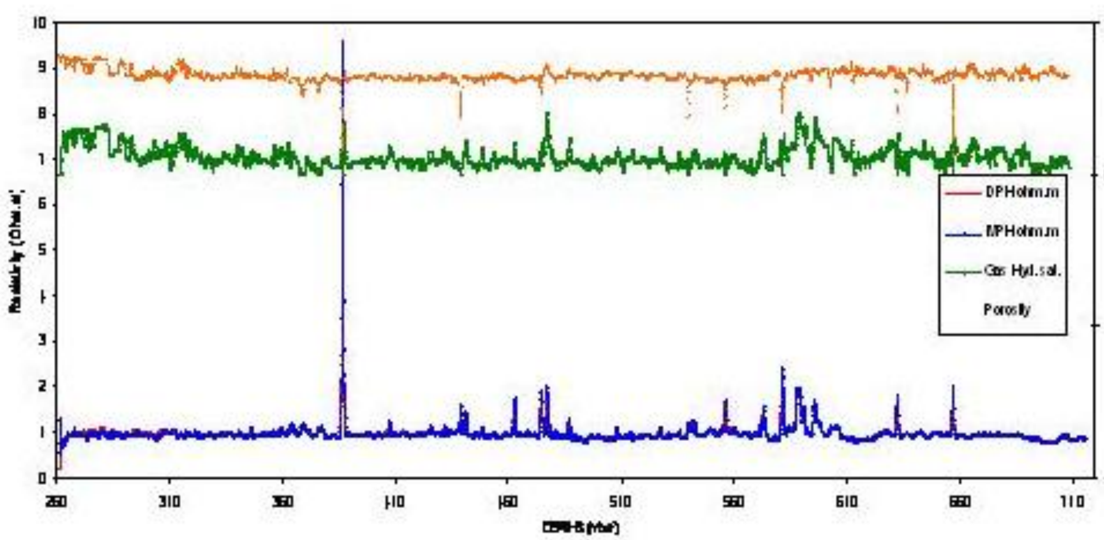

Fig. -6, Gas Hydrate saturation computed with Archie's method with resistivity and density porosity

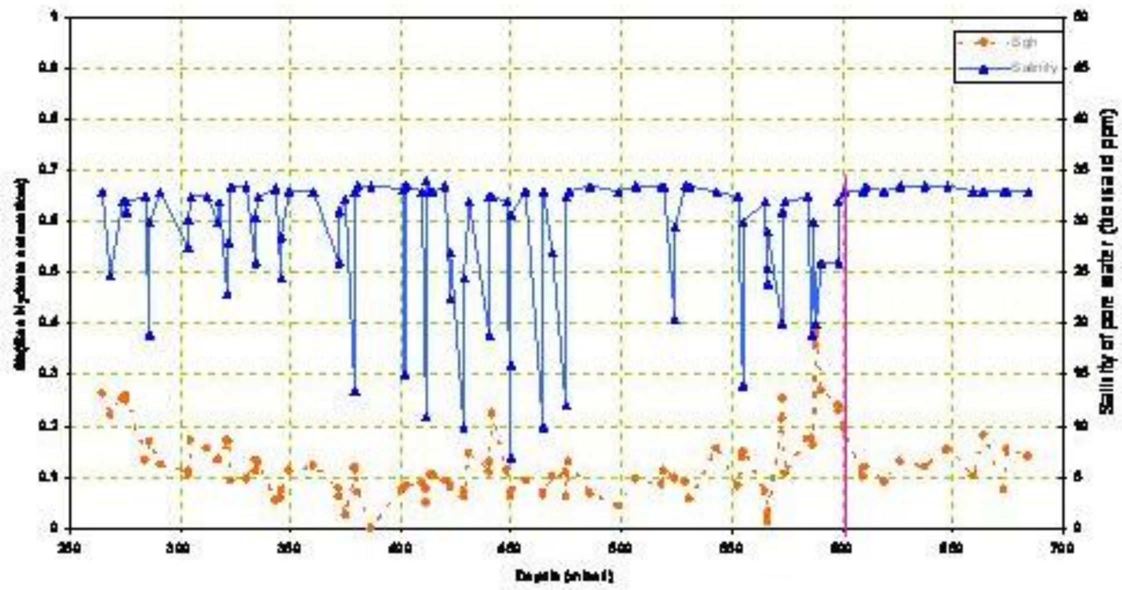

Fig.-7, Gas hydrate saturation and pore water salinity Correlation. High gas hydrate saturations corresponds to low salinity of pore water. freshening is a result of gas hydrate dissociation

Table-I Wireline Logging Data in Hole NGHP01-17B

Run No.	Tool string	Top Depth(mbsf)	Bottom Depth (mbsf)
1.	DIT/HLDS/APS/HNGS	0	233
		265	716
2.	FMS/DSI/GPIT/SGT (Pass1)	280	718
	(Pass2)	265	718
3	VSI (28 Good Stations)	330	630