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Techniques in Exploration and Formation Evaluation for Gas Hydrates

Ramesh Chandra Y* & Sanjay Surya Y,
B.Tech Gas Engineering, 4th Year, University of Petroleum and Energy Studies, Dehradun.
E-mail: irameshchandra@gmail.com & sanjaysurya@gmail.com

Summary

Methane Hydrates form when water and methane are brought in contact within a specific temperature-pressure regime. The discovery of Hydrate Methane reservoir has generated considerable excitement since it is estimated to contain twice the energy in all known reserves of fossil fuels. In addition to their age, it appears that hydrates in nature are ubiquitous, with some probability of occurrence wherever methane and water are in close proximity at low temperature and elevated pressures. Because hydrates concentrate methane (at STP) by as much as factor of 164 and because less than 15% of the recovered energy is required for dissociation, hydrate reservoirs have been considered as a substantial future energy resource.

The different methods for exploring Gas Hydrate Formations are Seismic, Formation evaluation which includes Density or Neutron Porosity, Electrical Resistivity, NMR tools. The formation evaluation techniques are tools of growing importance, which allow the assessment of the risk, value and volume of petroleum in a prospect ahead of drilling. With the help of all the above parameters and their changes with depth the interpretations for characterization of the source rock and the potential can be done.

Introduction

Gas Hydrates are molecular compounds of gas and water, solid crystals forming at certain pressures and temperatures. Hydrates can be divided into two clear groups according to their genesis. Natural which form and exist in nature with out human intervention, and technogenic which form in technological systems created and controlled by man. Although natural and technogenic gas hydrates are identical in their essence, problems generated by both groups, methods of solution and research goals, consequences of the solutions are very different. In petroleum exploration and development, seismic data and formation evaluation are used to determine whether a potential oil or gas field is commercially viable. Essentially, it is the process of "recognizing a commercial well when you drill one". Compositional analysis of gas obtained from hydrate saturated cores can reveal a geological history of the formation and long stable or metastable state of hydrates in a specified region. It can also determine a thermo baric history in rock profile. Gas content in a zone of hydrate formation is variable and depends not only on temperature and pressure, but also on the direction of phase transition process.

Phase Diagram

Consequently, methane hydrates are thought to be widespread in both onshore permafrost regions of the North American and Russian Arctic and in the shallow continental shelves of the Arctic Ocean, where sub sea permafrost is found. Methane gas may be released to the atmosphere because of hydrate destabilization as a result of climatic warming and changes in sea level. Current models of climate predict a climatic warming and permafrost temperatures are known to have increased 2 - 4 °C during this century. With present knowledge, it is not possible to predict the amount of methane that is currently being released and that will be released by gas hydrate decomposition as a result of permafrost, especially sub sea permafrost, degradation as shown in figure 1.

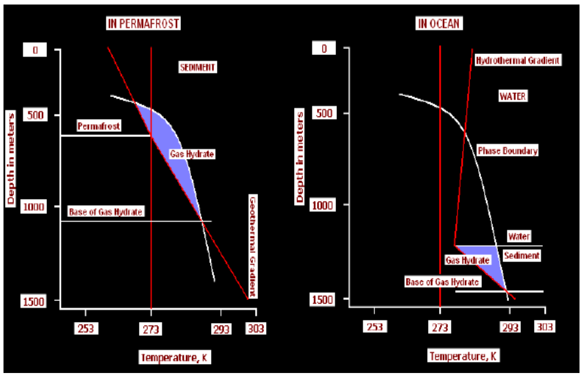

Figure 1: Shows the phase behavior of gas hydrates in permafrost and oceanic sediments. In case of the permafrost the gas hydrates occur at the temperatures ranging from 273 - 285°C and depth from 500 – 1000m, while in case of the deep sea sediments the temperature ranging from 278 – 293ºC and depth from 1200 – 1500m.

Geophysical Method in Phase-1

The seismic data is shooted, recorded, processed and analyzed to characterize the gas hydrates that are located in the deep waters. The objective is to perform the initial screening process were to identify possible key gas hydrate locations for subsequent reprocessing of seismic data and seismic modeling and analysis. This involved a search for hydrate features such as mounds, slumps, trapped gas, BSRs etc. Shown in figure 2.

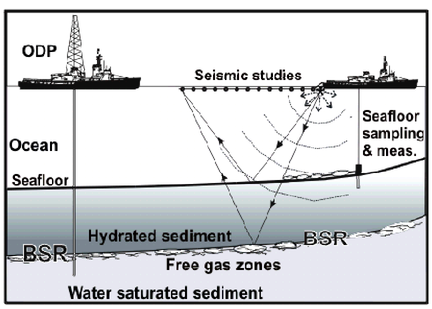

Figure 2: This shows the seismic studies conducted on gas hydrate zones in marine environment.

The primary method for mapping the occurrence of gas hydrate is to use the distribution of the BSR. However, evidence for substantial hydrate concentrations where there is no clear BSR has been obtained through detailed seismic interval velocity studies and electrical resistivity profiling. Thus the region of hydrate distribution based upon the BSR represents a minimum area. Known seismic characteristics indicative of hydrates are listed below.

- Presence of a BSR at base of the stability zone.
- Underlying areas showing amplitude attenuation or "wipe out" zones.
- Presence of gas and water in near surface sediments.

The seismic data have allowed mapping the regional distribution of the bottom-simulating reflection (BSR) which is characteristic phenomenon of many marine hydrates. The BSR in most low-frequency seismic sections is a single negative pulse that is almost the mirror image of the sea -floor reflection. The BSR reflection amplitude represents a decrease in seismic impedance of 20-30%. There is no continuous reflection above the BSR that indicates the top of a high-velocity hydrate layer, and no continuous reflection below it that represents the base of a low-velocity free gas layer as shown in figure 3.

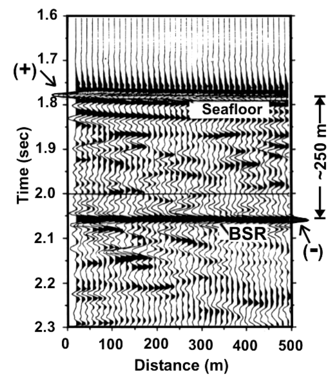

Figure 3: Example of strong BSR showing the simple negative reflection waveform, opposite to that of the seafloor.

To produce the observed waveforms the top of the hydrate layer must be gradational upward, and the base of the free gas layer beneath the BSR must be gradational downward as shown in figure 4.

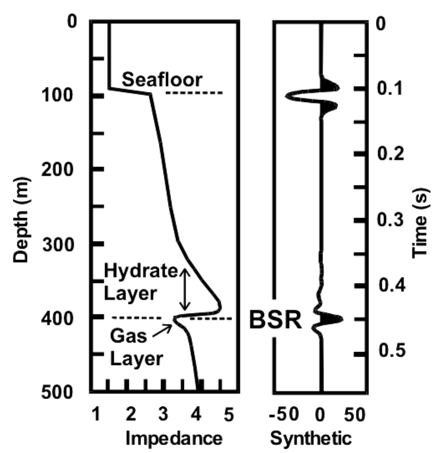

Figure 4: Simple synthetic seismogram that reproduces the main features of the BSRs. The seafloor reflections results mainly from the density contrast and the BSR mainly from the velocity contrast.

The main quantitative constraint on hydrate and gas concentrations is from very detailed multi channel interval velocities. In addition to velocities in the hydrate and gas zones, velocities to greater depth provide important information on the velocity-depth profile for no hydrate and no gas, which is a critical factor for quantitative estimates of hydrate and gas concentration as shown in the figure 5.

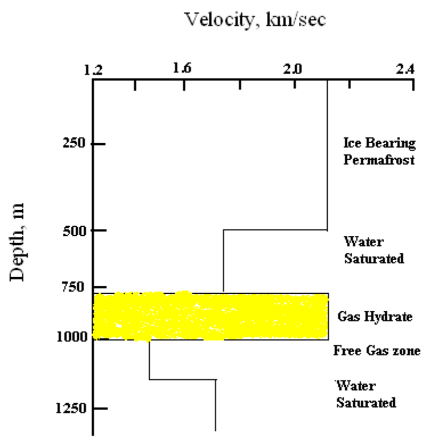

Figure 5: Permafrost and Gas Hydrate Acoustic Velocity Model

Coring and Formation Evaluation in phase-2

Formation Evaluation methods can be classified broadly according to whether they are used as drilling is progress, or whether are used after the hole, or at least a portion of it, has been drilled. In the first classification are the methods of coring and core analysis.

In second classification are the wire line logs, such as NMR logging, Neutron Porosity logging which is the final step in the evaluation program, may be used either as drilling progresses, or after extensive sections of the hole have been opened.

Core Analysis

Coring requires drilling with a special bit which will permit the recovery of a section of the rock that is being penetrated. On this sample, measurements can be made of porosity, permeability and the saturations of the oil, water and gas. Core analysis is a fundamental method that serves as a basis for calibration of all other logging tools.

It is slow, usually expensive and other methods are used as substitutes when ever possible. In addition to cores taken in the usual manner with the drill bit, small rock samples can be recovered from the side wall of the bore hole with the devices run on the logging cable. Samples obtained in this manner are generally much less diagnostic. Gas hydrates cores are mostly of piston type cores.

The different types of core analysis for gas hydrates consists of

1. C T Scan
2. Raman Spectroscopy

1. CT Scan

The portable device could help researchers determine how to best extract the vast quantities of natural gas hidden under the world's oceans and permafrost. Medical CT scanner can image a wave of methane hydrate dissociating in a sand mixture.

They can splice hundreds of x-ray scans into one cross-sectional image could enable researchers to map the distribution of gas hydrates in core samples. This can analyze more than 500 feet of core sample, enabling researchers to generate the most detailed log of permafrost cores ever recorded. And the system worked in subzero temperatures.

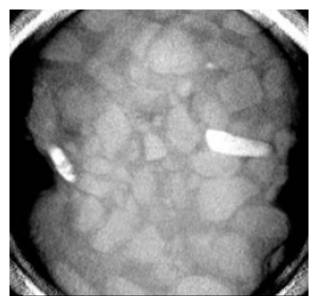

Figure 6: Methane Hydrate core sample under CT scan.

2. Raman Spectroscopy

Typically, a sample is illuminated with a laser beam. Light from the illuminated spot is collected with a lens and sent through a monochromator. Wavelengths close to the laser line (due to elastic Raleigh scattering) are filtered out and those in a certain spectral window away from the laser line are dispersed onto a detector.

The Raman Effect occurs when light impinges upon a molecule and interacts with the electron cloud of the bonds of that molecule. A molecular polarizability change or amount of deformation of the electron cloud, with respect to the vibrational coordinate is required for the molecule to exhibit the Raman Effect. The amount of the polarizability change will determine the intensity, whereas the Raman shift is equal to the vibrational level that is involved as shown in the following figure.

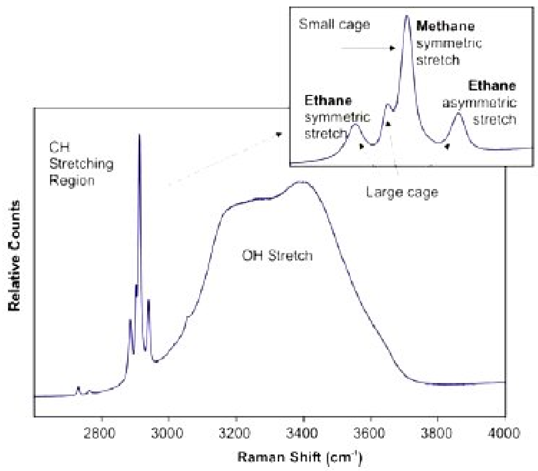

Figure 7: Spectrum obtained due to Raman scattering.

Well Logging

After a section of hole has been drilled, it is customary to run one or more of the wire line logging tools depending on the complexity of the interpretation problem. These devices may measure the electrical, magnetic, radioactive or acoustic properties of the formations. The measured information is displayed continuously as function of depth on a strip chart or log.

Well logging for Gas Hydrates mainly consists of

1. Latero Logging
2. NMR Logging
2. Density Logging

1. Latero Logging

Multiple-electrode arrays extend the depth of investigation. A better representation of True Formation resistivity (Rt) is obtained. Formation Resistivity can be measured when four electrodes are used. Two electrodes – one on the surface and one downhole on the tool are used to generate an electrical current in the formations in and around the electrodes. The voltage measured between two points can be calculated as follows

$V_{MN} = R \times I/4\pi \times ((1/ r_{AM}-1/r_{AN})-(1/r_{BM}-1/r_{BN}))$ $F = a / \varphi^m$

The constants (a) and (m) are related to lithology. Cementation factor (m) in cemented sandstone or a porous limestone is 2.0 and (a) is equal to 1.0. Porosity of 10, 20, 30 percent results in a Formation resistivity Factor of 100, 25, 11. Notice these three Formation Resistivity factors are the same as calculated with F = Ro/Rw above.

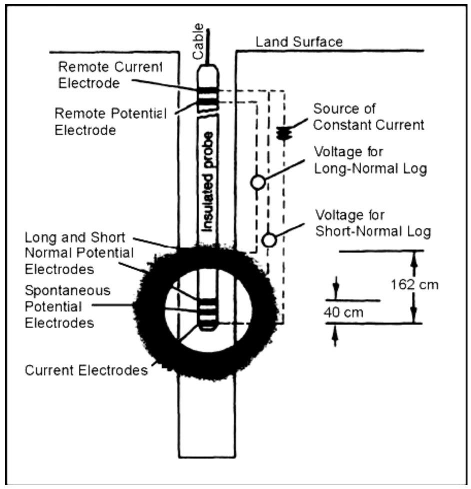

Figure 8: Principle of Latero logging

2. NMR Logging

A new logging method based on measurements of the nuclear magnetic properties of the hydrogen contained in the formation fluids. It appears that the log can successfully represent the amount of pore space containing fluid that is free to move, and in some cases it can distinguish between oil and water.

Two logging runs are necessary to get the maximum information. The free fluid log is made as a continuous log over the length of the hole. Points of interest are then selected for the second type of measurement which requires stopping the instrument for short periods of time and obtaining the nuclear magnetic relaxation curves.

$$\text{Hydrocarbon Saturation} = \frac{\text{DPHI - TNMR}}{\text{DPHI}}$$

DPHI – Density Porosity , TNMR – NMR Porosity

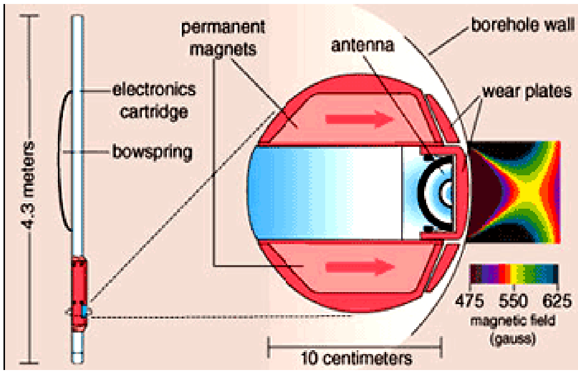

Figure 9: Principle of NMR logging tool.

2. Density Logging

Density logging tool works on the principle of neutron interaction with, the nuclide present in the formation. The tool response to the hydrogen index of the formation, which can be related to the total porosity of the formation. This log is used for litho logy identification, porosity estimation and detection of gas and light hydrocarbon bearing formations.

The Neutron Density logging tool measures the density and in turn the porosity of the formation by the interaction of the secondary gamma rays. As in case of the oil zones and water zones the density of the hydrogen ions is more and so the secondary gamma rays does not get slowed down. But in case of the gas horizons as the density of hydrogen ions is less than in case of the oil and water so the secondary gamma rays gets slowed down and the reading is measured.

$$\text{Porosity } \Phi = \frac{\text{Density of Matrix} - \text{Bulk Density}}{\text{Density of Matrix} - \text{Fluid Density}}$$

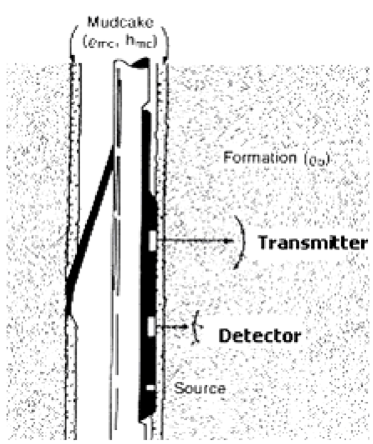

Figure 10: Shows the principle of a Density logging tool.

Interpretation

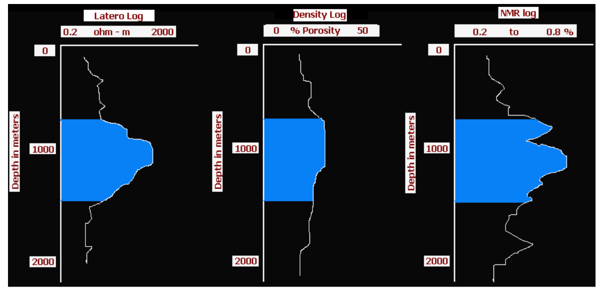

Figure 11: This figure shows the correlation of different logs (1. Latero Log, 2. Neutron Porosity Log, 3. NMR Log) and gas hydrate bearing horizons.

Latero Log: But although gas hydrates fill the pore space (the porosity) of the formation, they act like a solid, and will create a very low signal indicative of non-mobile fluids, within a formation that is known to have porosity, confirms the presence and quantity of gas hydrates for which the resistivity will be more.

NMR Log: In case of the NMR the provision porosity logs also exhibit anomalous low-porosity zones within the interval of expected gas hydrate stability.

Density Log: An increase is observed relative to ice and relative to the decrease in the free gas zone.

Conclusion

Natural Gas Hydrates are powerful mineral energy resources and their use will significantly improve the energy balance of the world in future decades.

Natural Gas Hydrates with efficient production can provide human kind with cheap, ecological energy for many decades.

So because of the above reasons, for production of Gas Hydrates the formation evaluation is necessary.

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