8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-156

Pore Pressure Prediction: A Regional Approach

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Summary

Seismic Pore Pressure Prediction (PPP) provides volumetric estimates of pore pressure across reservoirs, fields and even at the basin scale. Pore pressure prediction performed across large areas can be used as a more qualitative exploration tool at a basin scale. These large volumes provide an overview of pressure and fluid behaviour within the basin and can be used to identify important features, such as the behaviour of faults, over-pressured compartments, Seal effectiveness etc. Such data can be used by geologists and reservoir engineers to improve understanding of hydrocarbon basins, identify potential drilling hazards and improve well positioning. The present paper summarises the PPP studies carried out over the entire Oil India Limited's (OIL) operational area in Upper Assam, and its implications on a regional scale is discussed.

Introduction

Pore Pressure Prediction (PPP) is a way of estimating from seismic data the pore-fluid pressures or more exactly over-pressures with depth prior to drilling a well. Accurate PPP at a particular well location provides a geoscientist and a drilling engineer with data required for planning of safe and economic drilling, designing optimised casing program thus saving overall valuable rig time. Such PPP's at various locations when integrated with basin study opens a new approach i.e. the geo-mechanical manner of studying the basin which facilitates a geo-scientist to improve structural definition, including identification of lateral compartment boundaries, resulting in better basin analysis, which supports the risk assessment of hydrocarbon prospects for better well positioning and planning. The application of PPP study on a broader regional scale is put forth in this paper.

Theory

As literature puts it overpressure is pore fluid pressure greater than normal pressure. Development of such overpressure means that fluid movement in the pores is retarded both vertically and laterally Figure-1 depicts a hypothetical reservoir case. The various important mechanisms leading to overpressure are:

1) Mechanical compaction disequilibrium (Hubbert and Rubey, 1959).
2) Clay dehydration and alteration due to burial diagenesis (Dutta, 1987a, chapter 2).
3) Dipping or lenticular permeable beds embedded in shales (Fertl, 1976).
4) Fluid expansion and Buoyancy (Fertl, 1976).
5) Tectonism/uplift and erosion (Dutta, 1987a, chapter 2).
6) Aquathermal pressuring (Barker, 1972; Dutta, 1987a, chapter 2).

Amongst the listed mechanisms, Compaction Disequilibrium is considered to be the potential cause of overpressure. However, it cannot generate very high pressures. Nonetheless detecting overpressure basically suggest for a look out to geologic settings encountering the above listed mechanisms. Overpressure regions in contrast to normal regions exhibit several changes in physical and elastic properties of the formation that significantly affect seismic velocities and reflection amplitudes which is the basis for seismic detection of pore pressure.

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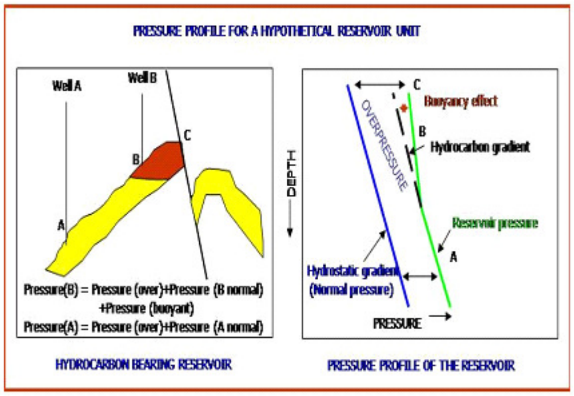

Figure 1: Pressure profile of a hypothetical Reservoir unit

Seismic based PPP methodology involves judicious estimation of seismic velocities calibrated to the geology such that they closely resemble the rock velocities of the area under study. These are further related to bulk properties and porosity of the rock to obtain required effective stresses, pore and overburden pressures. Shales are generally more responsive to overpressure than most rock types, alternatively most of the causes of overpressure encountered are mainly ascribed to shale deformation behaviour, hence are the preferred lithounits for overpressure detection and PPP interpretation.

Study Area

The area under study is shown in the Figure 2, which is the OIL's operational area in Upper Assam. Individual PPP studies at each of the highlighted locations (Figure 3) have been carried out and wells also drilled. These studies are further analysed to understand the pore pressure and relate it to a more regional scale.

Stratigraphy of Study Area

The oldest rocks in Upper Assam basin are reported to be Palaeocene. The deepest unit is the Langpar, which is a shallow to marginal marine sandstone.

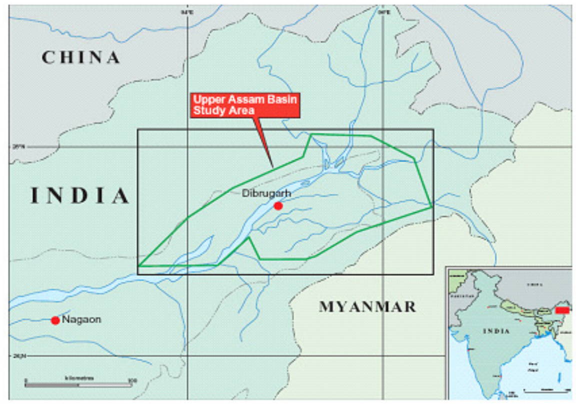

Figure-2: Map showing the study area.

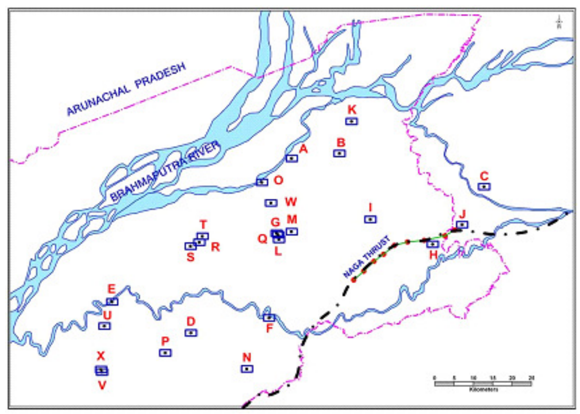

Figure-3: Basemap showing the Pore-Pressure based drilled locations.

This is overlain by the Lakadong and Therria Formations of the Early Eocene. This unit consists of sandstones, shales and coals deposited in shallow marine to lagoonal conditions. The overlying Narpuh Formation is a marine shale interval with local sandstones and limestones. The Prangs Formation overlies the Narpuh and consists of interbedded sandstones and shales. The Prangs and Narpuh are interpreted to be marine sequences. The overlying Kopili is also marine to lagoonal environment with interbedded limestones, sandstones and shales. The Kopili Formation is described as passing upwards from deep marine source rock shales into shallow marine to deltaic sandstones.

On the partly unconformable top of the Kopili more than 3,000 m of the upper Eocene and Oligocene Barail Group rocks of delta front and shallow marine sandstones were deposited. The overlying Tipam Group is a thick sequence dominated by fine grained sandstones. The Girujan clays overlay the Tipam Formation and the Girujan Clay is overlain by the Namsang Formation, which regionally are consolidated sandstones and clays deposited in continental environments. A lower sequence overlying the Namsang is interpreted to be Dhekiajuli Formation, comprising the upper Pliocene to Recent alluvium.

Individual PPP studies indicate that most of the overpressure encountered in the study area is believed to be mainly attributed to the Kopili fossiliferous fluvial shale formations with difference in the rate of burial of the depositions and tectonism of Naga Thrust.

Discussions

The individual PPP at each location were calculated using seismic data and other geological inputs with the Presgraf software (Figure 4) and wells were also drilled according to the estimated pore pressure. The PPP at each of the location were fairly reliable with estimated equivalent mud weights (EMW) comparable to actually used drilled mud weights. Thus a good pressure profile model with depth at each location is available. When these results are extrapolated to a regional scale it is observed that overpressures are encountered in the entire basin and more predominantly along the thrust with pore-pressures ranging from negligible values at foreland basin to high values very close to the thrust.

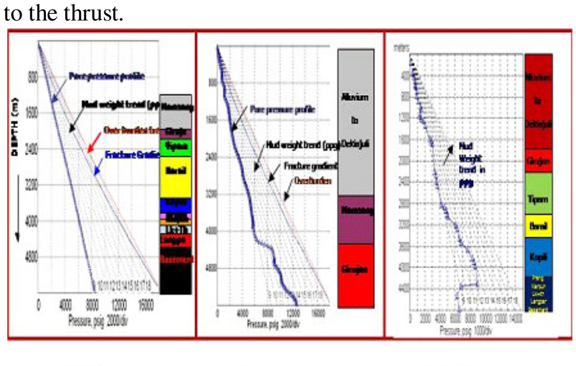

Figure-4: Pore-Pressure Profiles of few Locations indicated in Basemap.

Based on the maximum estimated pore pressure values, the study area can possibly be demarcated into three pressure units (Figure 5), unit-I where high values are found in Eocene formations (Figure-6), unit-II the foreland basin has normal to slight variation in pressures and unit-III laying close to the thrust, the high pressures encountered are in MioceneOligocene formations (Figure 7).

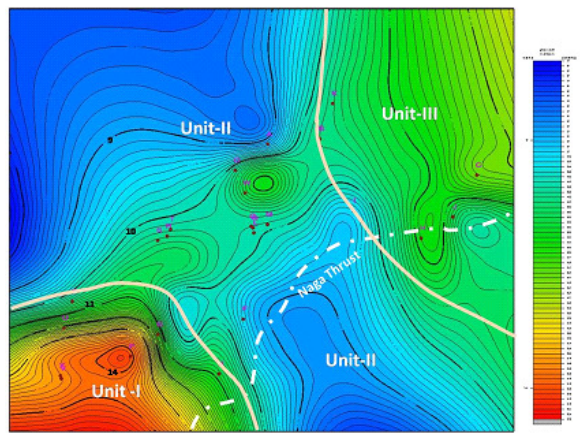

Figure-5: Maximum Pore-Pressure Contour map showing three pressure compartments.

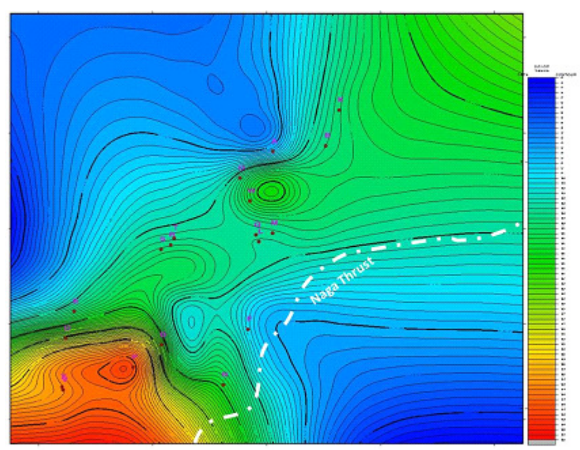

Figure-6: Contour map showing pore-pressure in Eocene Formation.

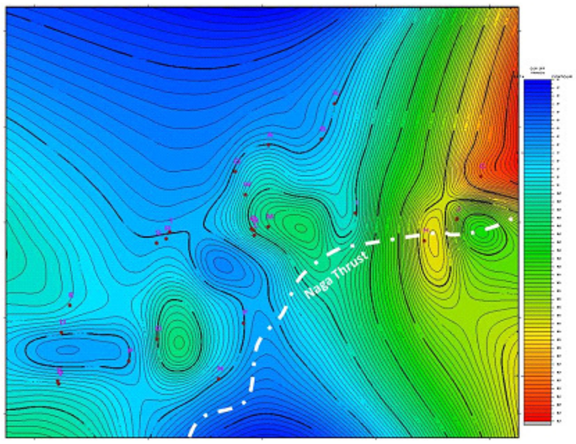

Figure-7: Contour map showing pore-pressure in MioOligocene Formation.

From these observations, it is inferred that the major causes of overpressure in these three zones could be attributed to compaction disequilibrium in the Eocene shales (different rate of deposition, Unit-I and unit-II) and Thrust related overpressures in unit-III. These results could prove fruitful to a Geo-scientist in Basin Analysis Study as now the Basin can be divided into pressure compartments which will be helpful in future well planning and positioning. These inputs can further be useful for understanding the geo-mechanical behaviour of the Basin and also for optimum planning of drilling and casing policy.

Conclusion

Pore pressures at all locations of the area under study were collectively used to study the pressure pattern on the entire basin. From this study we were able to identify few potential drilling hazardous compartments and this regional analysis also provided the probable answer to the main reason of the encountered anomalous pressures. This will be a valuable input for a geoscientist for improved understanding of the Basin.

Acknowledgements

Authors thank Oil India Ltd. (OIL) for permitting to submit this paper. We acknowledge the support extended by Processing Section and TEAM members of OIL.

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