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Investigation of drilling challenges associated with Panna Formation, Western Offshore Basin, India

Abstract

In the recent years, exploration activity in Panna Formation has significantly increased owing to its potential hydrocarbon pools. Primary challenge in drilling Panna Formation includes well flows, losses and limitation of LWD tools under higher temperature for real-time monitoring. Stable mud weight window becomes narrow after 200m-250m thickness inside Panna Formation. Pore pressure seems to vary considerably from hydrostatic to 14.2ppg subject to thickness of Panna Formation and well locations in the field. Pore pressure ramp starts either from bottom of Lower Bassein or 120m-150m inside Panna Formation itself. There is clear shift in geothermal gradient associated with pore pressure ramp as seen in many wells. To delineate area with over pressure and identify its mechanism a comprehensive geomechanics study with lithology types has been carried out across 17 fields of Mumbai Offshore Basin (MOB). Petrophysical, geological and drilling related information are integrated by means of geomechanical models. Pore pressure, rock mechanical properties and stress profiles have been estimated in few wells to build robust Geomechanical model and estimate stable mud weight window. Analysis has outlined the occurrence of overpressure in two main broad areas. Two case studies will be discussed under current scope of paper with detailed analysis of geophysical logs with drilling events.

Introduction

Panna Formation is oldest Tertiary sedimentary unit of the MOB and is important from the point of hydrocarbon exploration due to the presence of source, reservoir and seal inside it. Panna Formation shales and coals act as a source rock in the basin. In addition, they also act as vertical and lateral seal for the coarser clastic reservoirs embedded within them.

One of the major challenge in exploration of Panna Formation is drilling related complications and associated nonproductive time (NPT). Drilling though Panna Formation has been challenging and has caused well flows in one area stabilized with mud weight greater than 15.8ppg. In another field, losses are observed at mud weights around 14.1ppg. These drilling challenges are varied across the basin and influence safety and cost of the explorations activity. The objective of this paper is to develop a better understanding of variation of observed formation overpressure and its mechanism.

Geology of Panna Formation.

Panna formation overlies Deccan Trap or crystalline basement and is overlain unconformably by Devgarh/Bassein/Belapur/Pipavav Formation. The formation is spread over the entire MOB except in the paleo-highs and is composed of sandstone and claystone at the bottom, overlain by a section of coal-shale alternation in the middle and succeeded by shale unit at the top. The development of the reservoir facies throughout the basin is undefined because of the lenticular nature of the sand deposition. Hence understanding the distribution of the reservoir facies within the formation is essential for fulfilling the exploration requirements. Gross lithology of reservoir facies in Panna formation is lithic/quartz wacke composed of quartz, rock fragments of granite & schist, heavy mineral like siderite, pyrite and iron oxide and clay minerals. Dominant clay minerals are chlorite, montmorillonite and illite (Kumar et.al, 2004). Panna Formation belongs to fluvial to shallow marine depositional environment. Boundary of Panna Formation is characterized by change in lithology from clastics to carbonates. Figure 1 shows the general lithostratigraphy of Mumbai Offshore Basin highlighting details of Panna Formation.

Workflow

Drilling complications in Panna formation, acquired drilling and logging data is gathered from 18 different areas of Mumbai Offshore Block. Geomechanical models incorporating formation pressure, vertical and horizontal stresses, elastic and strength properties are constructed. Crossplots between velocity versus density (Hoesni, 2004) and velocity versus effective stress (Bower's, 1994) has been utilized to establish the mechanism leading to this overpressure. Wells are correlated on a regional scale to ascertain the variation of lithofacies in correspondence to overpressure. Variation of geothermal gradients is also studied for Panna and associated Formations above.

Analysis Overview

In this section of the abstract, adopted workflow and analysis conducted in two fields (Figure 6) is summarized.

Field-1: This field is located in the southern side (Figure 6) of the MOB. To ascertain the origin of this high pore pressure, compressional slowness versus density crossplot is prepared for multiple wells. Figure 3 shows the results for well-A inside Area-1. Different colors on the plot indicates different Formations (refer legend). Data points belonging to Bassein, Devgarh and Panna Formation indicate that the overpressure mechanism is of hybrid nature which is also classified as Type-II mechanism (Kumar et.al, 2013).

In this well, pore pressure has been estimated by using Eaton's method and modifying its parameters based on drilling events encountered. Detailed pore pressure plot with drilling events, mud weights, leak off tests data and basic logs is shown in Figure 3. Based on the analysis, it is found that pore pressure ramp starts from the bottom of Bassein Formation and increases upto 15.8ppg inside Panna Formation.

To confirm Type-II mechanism, pore pressure gradient was plotted against neutron porosity (Figure 4). It is observed that pore pressure is independent of neutron porosity. Increase in pore pressure for shale facies (neutron porosity above 28% pu.) does not correlate with the proportional increase in neutron porosity.

To further understand the overpressure origin, bottom hole temperatures from different measurements were against different formations (Figure 5). It is found that geothermal gradients in the high-pressure Formations are higher as compared to normal pressure Formations. Figure 5 shows higher temperature values for Bassein, Devgarh and Panna Formations. This sudden increase in geo-thermal gradient might be because of presence of hotter volcanic rocks below Panna Formation.

Similar analysis is conducted for 16 more fields across WOB. Figure 6 summaries the maximum pore pressure observed in different fields. High pressure Panna Formation is demarcated by red dotted box on Figure 6. Two sperate zones one located in the northern side (Area-1) and other one on the southern side (Aera-2) of basin are found have overpressure Formations.

Field-2: Figure 6 shows a multi-well plot belonging to a different field lying inside Area-2 of WOB. Plot includes basic logs (gamma ray, resistivity, density-porosity and pore pressure with MDT/RFT measurements and mud weight. In this field, Panna Formation is found to have dual pore pressure. Initial 250m to 280m show hydrostatic pressure gradient and it increases upto 14.2ppg inside Panna Formation. From this multiwell analysis, it is also evident that overpressure region has higher percentage of coal lithofacies marked with fall in density and porosity.

Conclusions

Based on the comprehensive analysis conducted at different areas of Mumbai Offshore, key take away points are summarized below:

- Majority of the fields lying in the north region of Mumbai offshore have showed high pressure.
- Panna Formation has dual pressure regime with variation from hydrostatic(~8.6ppg) to maximum of 15.8ppg. In majority of the areas, pore pressure variation is related to the thickness and presence of coal inside Panna Formation. In general, areas with thicker Panna Formation has shown high pressure.
- Initiation of pressure ramp is variable and is observed in both overlying Lower Bassein Formation as well as inside Panna Formation.

- Trend of density versus velocity and effective stress versus velocity crossplots indicates overpressure is caused by hybrid mechanism which is categorized as Type-II. It suggests that the formation is recharged with extra fluid without a substantial increase in porosity.
- One possible phenomenon undergoing inside Panna is thermal cracking of hydrocarbons. This hydrocarbon Maturation in a “closed” environment could lead to overpressure. Literature indicates presence of montmorillonite and illite clays indicating all smectite might have been converted to illite at this temperature conditions.
- Higher geothermal gradient is observed while entering in the high-pressure Panna Formation.
- Some wells in proximity to faults are found to have overpressure in shallow layers possibly being charged through faults.
- High pressure Panna Formation is isolated from overlying normal pressure formations by setting a casing to prevent any losses. Coals inside Panna formation have also caused losses due to lower fracture gradient.

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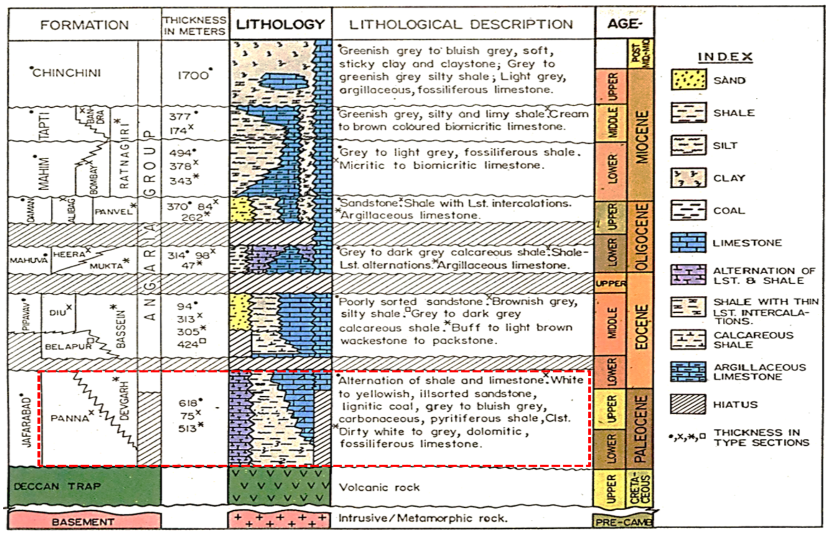

Figure 1: General lithostratigraphy of Mumbai Offshore Basin

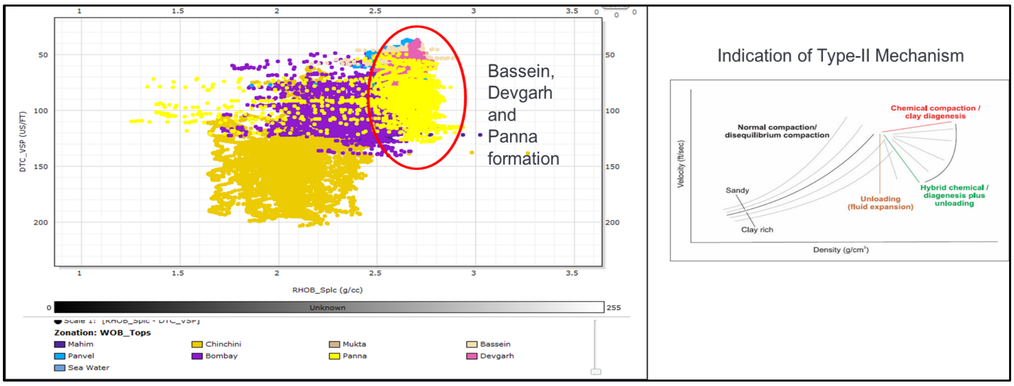

Figure 2: Well-A: Overpressure mechanism analysis using compressinal slowness and density crossplots.

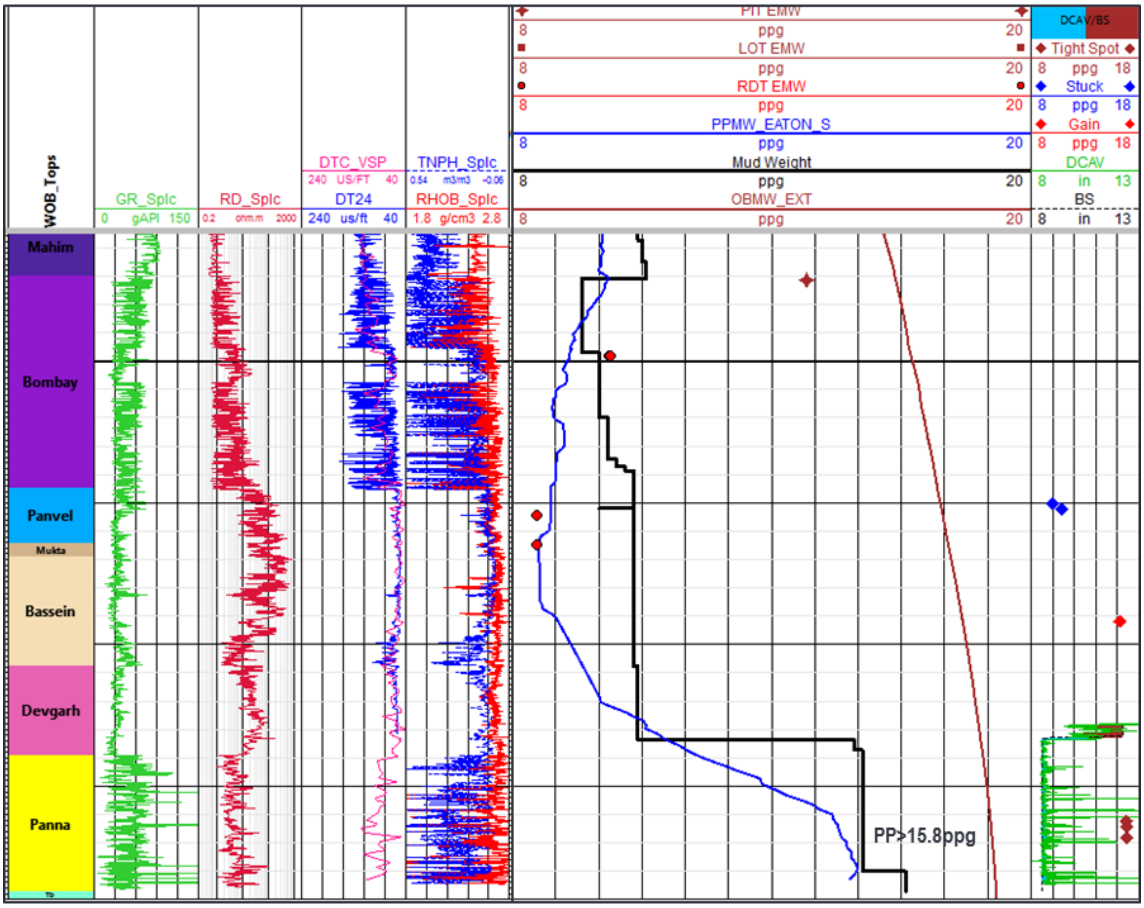

Figure 3: Well-A: Estimated pore pressure with basic logs

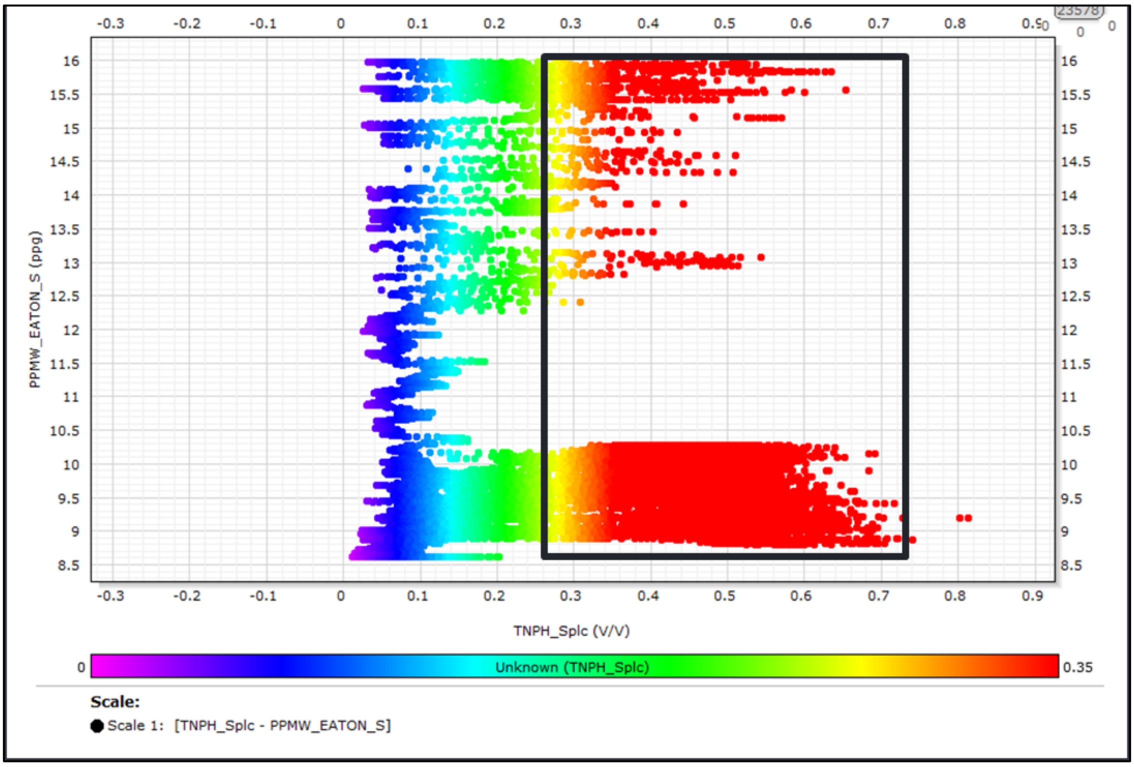

Figure 4: Well-A: Porosity dependance of shales in high pressure zones.

Figure 5: Well-A: Increase in geothermal gradient inside high pressure Bassein, Devgarh and Panna Formations

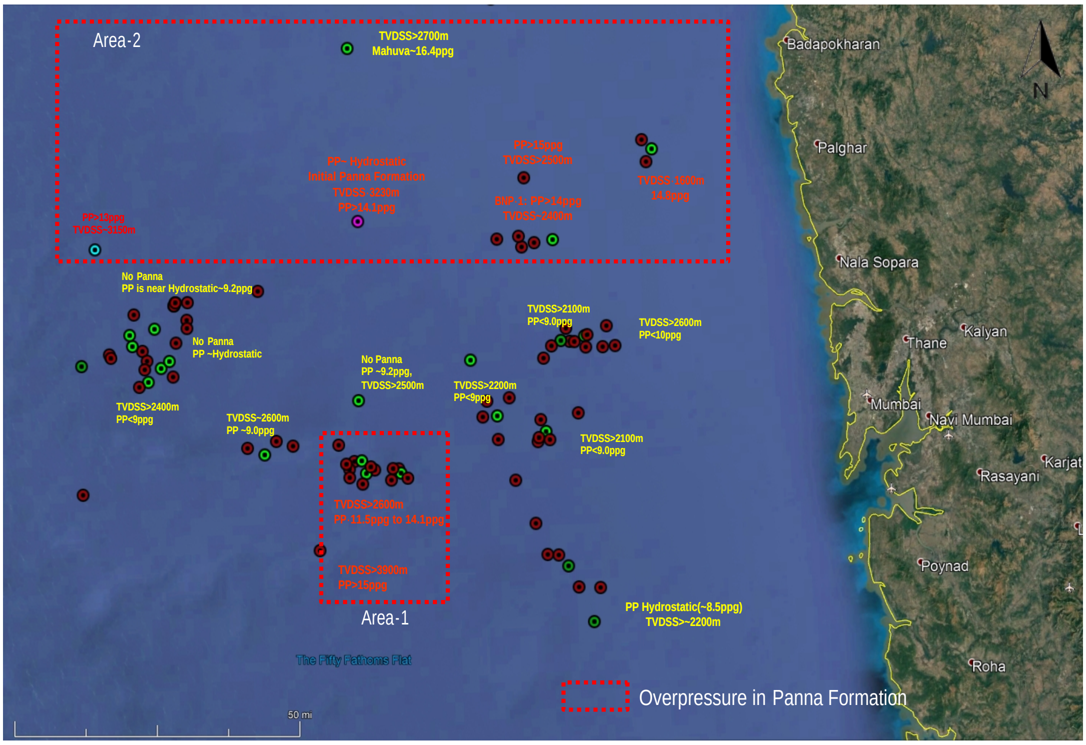

Figure 6: Overview of Pore pressure variation in Panna Formation across Mumbai Offshore.

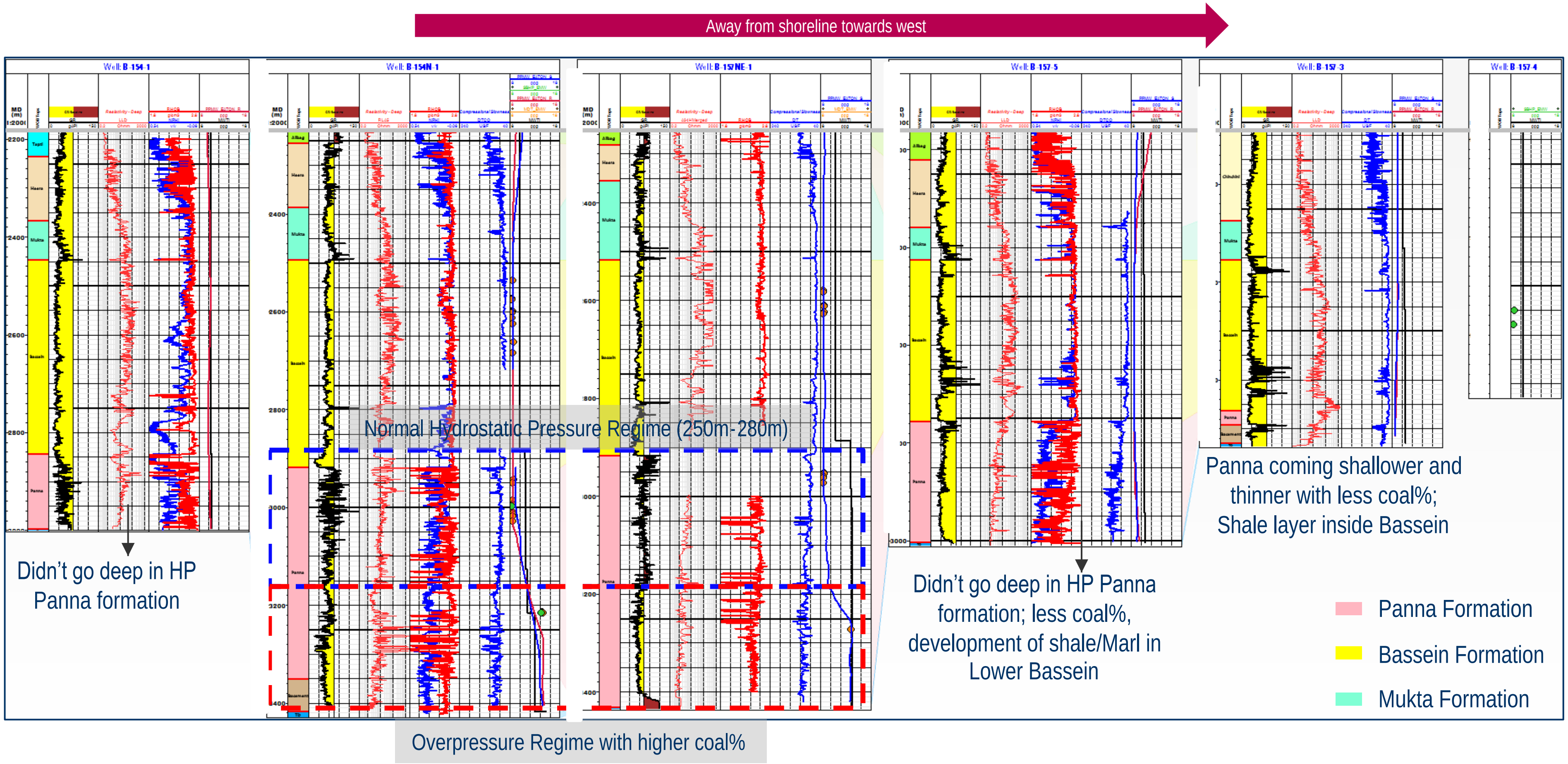

Figure 7: Multiwell plot showing pore pressure variation with thickness and lithology