PS Relationship Between Pore Pressure and Structural Model in "Passive Margin" Offshore Tarakan Sub-Basin, Northeast Kalimantan, Indonesia*

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Abstract

The Tarakan Sub-basin is situated in a passive margin and is located in the Northeastern part of Kalimantan. The presence of an overpressure zone is indicated from drilling activities in this area. Some wells were terminated by the operator before reaching the main target due to the overpressure occurrence. The purpose of this study is to determine the mechanism of structural development, pore-pressure prediction, and understanding the relationship between pore pressure and structural style in the study area. There are two structural styles recognized in the offshore of the Tarakan sub-basin. The proximal-shelf area deformation is dominated by normal-growth faults whereas the distal-slope area deformation is dominated by toe-thrusts. Gravitational sliding associated with a thick layer of Early Miocene shale was interpreted as the major cause of structural formation and is responsible for the appearance of structural variation in the shelf and slope area. The structural complexity within the research area has a role in controlling the distribution of pore pressure. This evidence is supported by the decreasing of overpressure magnitude distally, which is more dominated by contractional structures (toe-thrust) compared to the proximal area dominated by extensional structures (normal-growth faults). The top of overpressure is predicted at a depth of 2000-3500m TVDss in the Middle-Late Miocene shale interval. Change of overpressure generating mechanism is related to structural style changes within the extensional, contractional, and transitional area caused by fluid expansion, disequilibrium compaction, and a combination of both, respectively.

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PERTAMINA

RELATIONSHIP BETWEEN PORE PRESSURE AND STRUCTURAL MODEL IN "PASSIVE MARGIN" OFFSHORE TARAKAN SUB-BASIN, NORTHEAST KALIMANTAN, INDONESIA

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ABSTRACT

The Tarakan Sub-basin is situated in a passive margin, and is located in the Northeastern part of Kalimantan. The presence of overpressure zone is indicated from drilling activities in this area. Some wells were terminated by the operator before reaching the main target due to overpressure occurrence.

The purpose of this study is to determine the mechanism of structural development, pore-pressure prediction, and understanding the relationship between pore pressure and structural style in study area. There are two structural styles recognized in the offshore of the Tarakan sub-basin. The proximal-shelf area deformation is dominated by normal-growth faults whereas distal-slope area deformation is dominated by toe-thrusts. Gravitational sliding associated with a thick layer of early Miocene shale was interpreted as the major cause of structural formation and is responsible for the appearance of structural variation in the shelf and slope area.

The structural complexity within the research area has a role in controlling the distribution of pore pressure. This evidence is supported by the decreasing of overpressure magnitude distally, which is more dominated by contractional structures (toe-thrust) compared to the proximal area dominated by extensional structures (normal-growth faults).

Top of overpressure is predicted at a depth of 2000-3500m TVDss in Middle-Late Miocene shale interval. Change of overpressure generating mechanism is related to structural style changes within the extensional, contractional and transitional area caused by fluid expansion, disequilibrium compaction, and a combination of both, respectively.

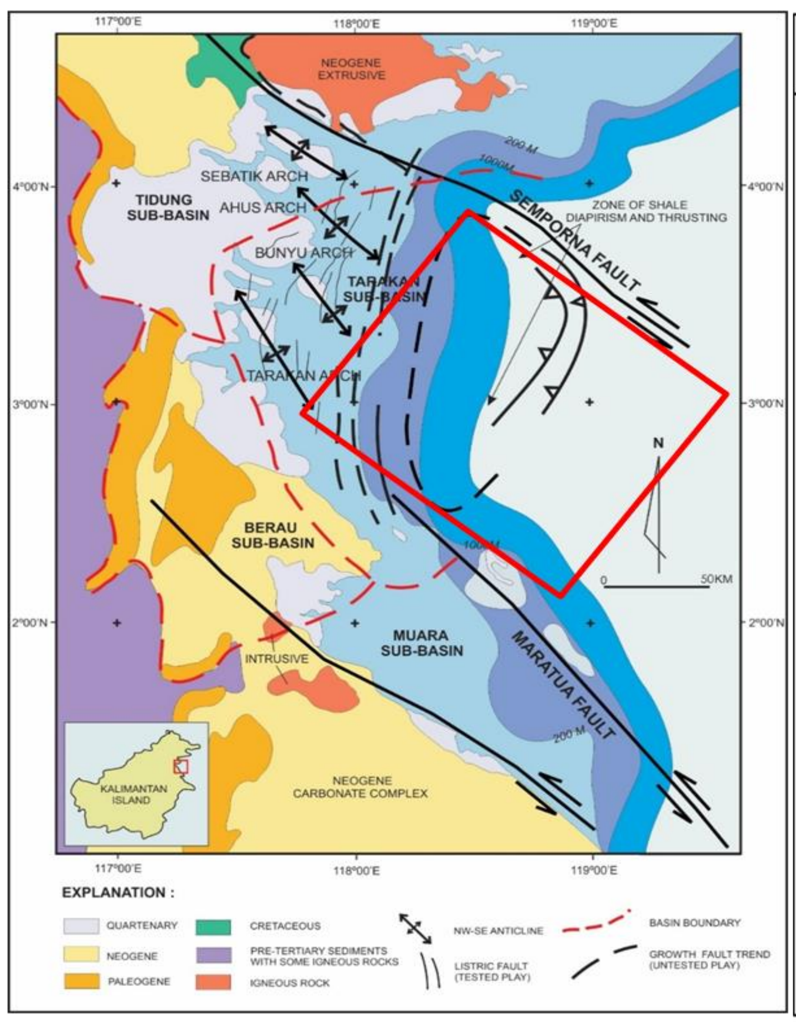
INTRODUCTION

The Tarakan sub-basin, a passive deltaic margin located in northeast Kalimantan, is mostly located offshore and includes Bunyu and Tarakan Island. It lies between the Tidung sub-basin to the north and the Berau and Muara sub-basins in the south. To the west, the sub-basins are bounded by the Sekatak Ridge and open towards the Makassar Strait to the east in where deposition still occurs. The Muara sub-basin located at the southern-most part of the Tarakan Basin lies directly next to Mangkalihat Ridge (Biantoro et al, 1996).

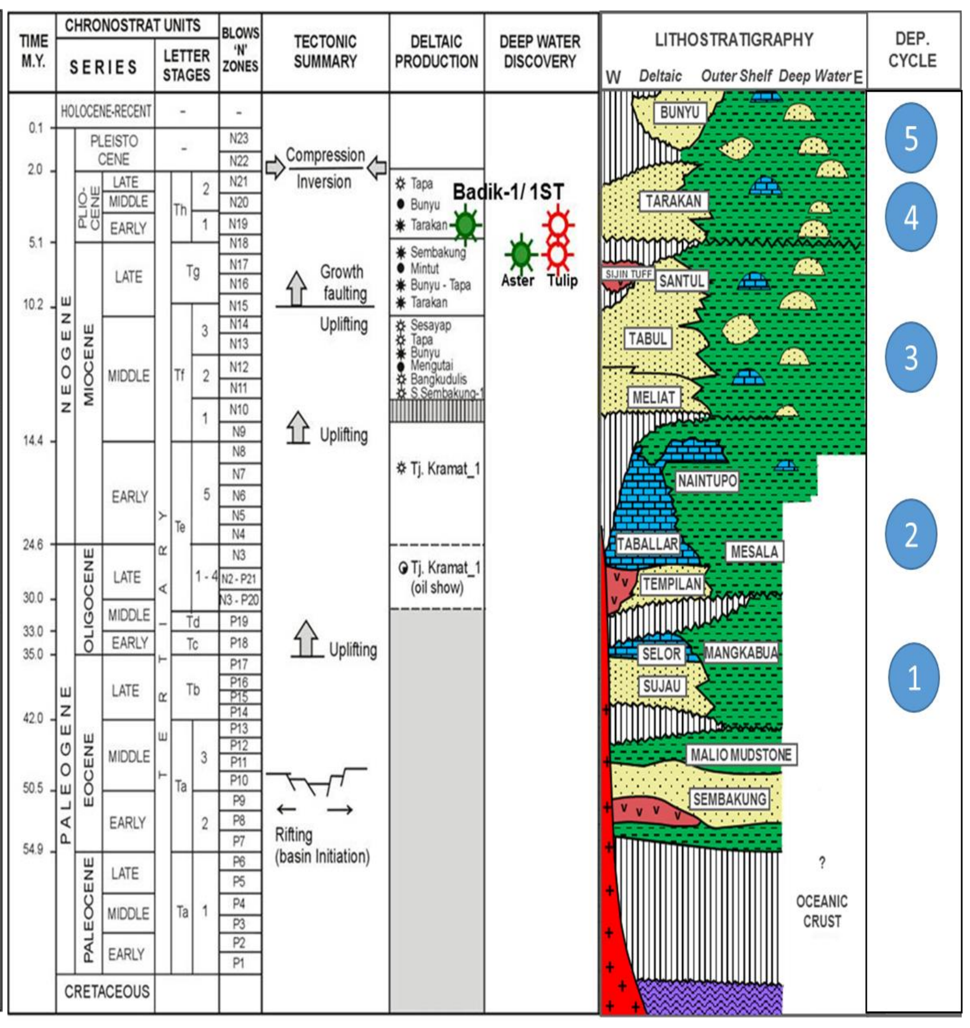
The depocenter area in the Tarakan offshore is characterized by thin-skinned deformation dominated with normal faults, growth faults and toe thrusts due to gravitational sliding. Generally, the depocenter area can be subdivided into an extensional, transitional and contractional area.

Exploration activities in this basin have been very intensive. Out of the 45 exploration wells drilled, ten discoveries were made (Hidayati et al, 2007). The drilling activity has successfully proved the presence of hydrocarbons in structural and stratigraphical traps or a combination of both, which are associated with complex structures such as growth faults and toe-thrusts. The presence of overpressure was encountered during drilling, especially when penetrating Middle – Late Miocene sediments. Hence, some wells had to be terminated by the operator before reaching the main target. However, there has been no regional pore pressure study aimed to comprehend the relationship between pore pressure characteristics and complex structural style within this basin.

In this study, pore pressure was then predicted by analysing wireline logs combined with drilling data by using Eaton's empirical formula, while geochemical data were used to predict overpressure generating mechanism, whereas cross plot between density vs sonic (Dutta-Katahara plot) and cross plot between vertical effective stress (VES) vs sonic velocity (Bowers plot) was made to strengthen the overpressure generating mechanism analysis. At the end of the paper, the relationship between pore pressure characteristics and the structural style found in offshore Tarakan sub-basin will thus be demonstrated.

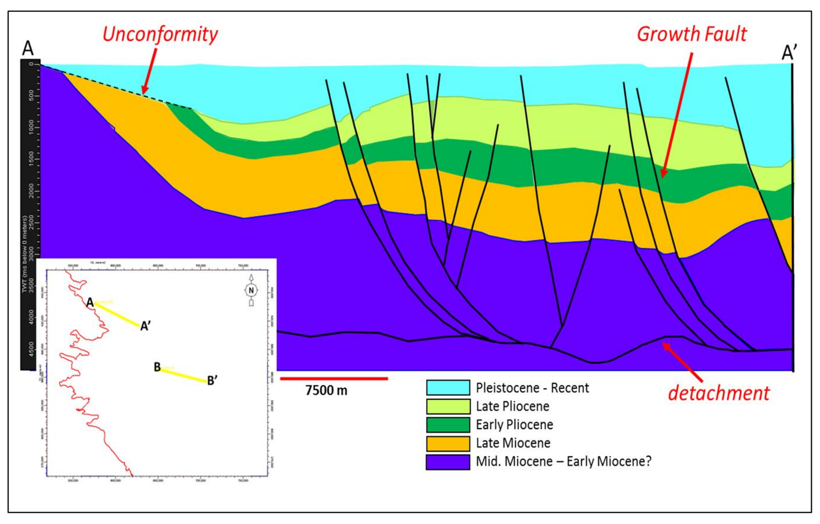


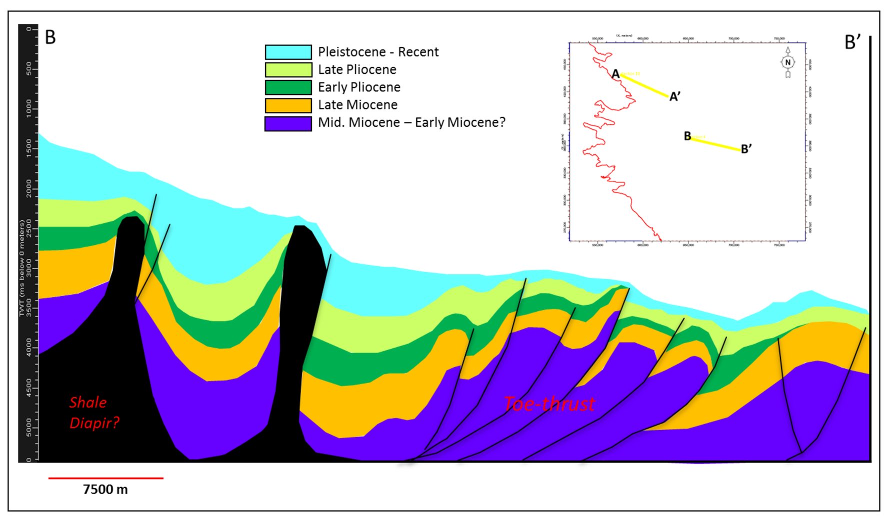
Tectonic Framework of Tarakan (Modified after Pertamina BPPKA, 1996), red square: research area.



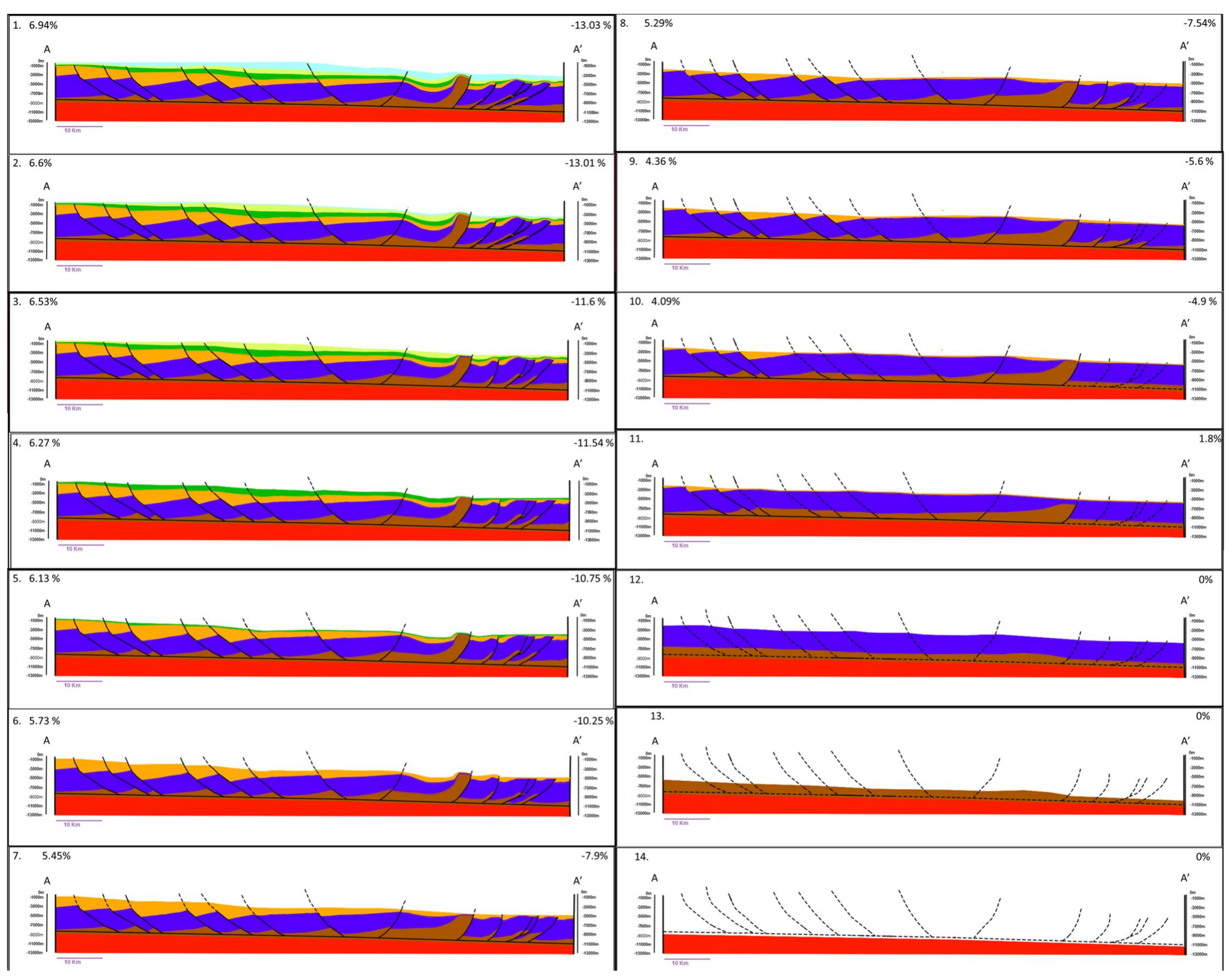
Generalized Stratigraphic Column of Tarakan Basin (after Heryanto et al. 1992).

STRUCTURAL STYLE AND STRUCTURAL DEVELOPMENT



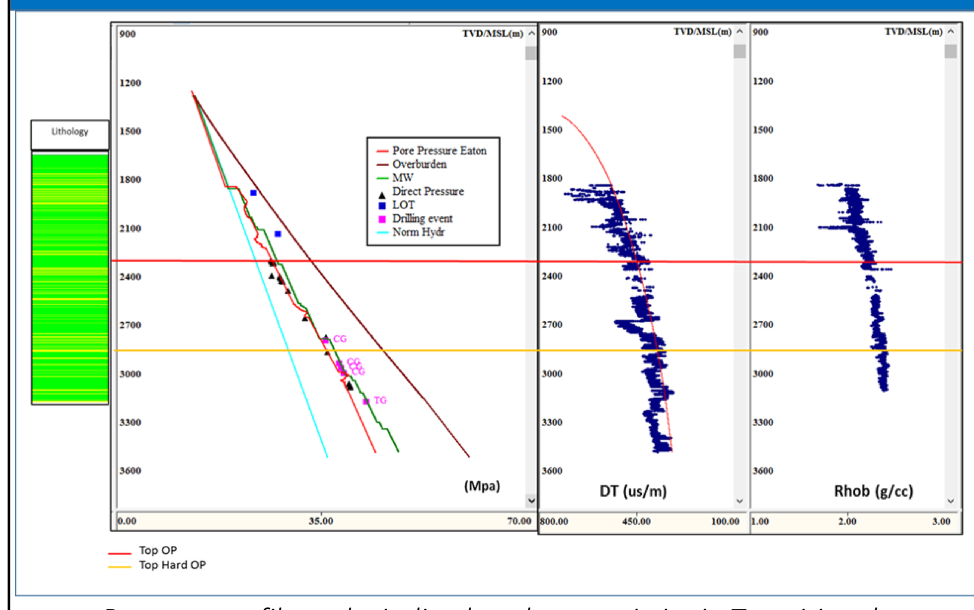


Line A-A' : Structural style in northern part of extensional area. This area is dominated by growth faulting, the unconformity found in the western part of this area and is likely to continue to the west onshore as a result of an active transform movement along the wrench faults during Pliocene-Pleistocene period. The Detachment is shallower than detachment in the central of offshore Tarakan sub-basin. Line B-B' : Structural style in transitional – contractional area. This area is dominated by thrust faulting and associated shale diapir ?.

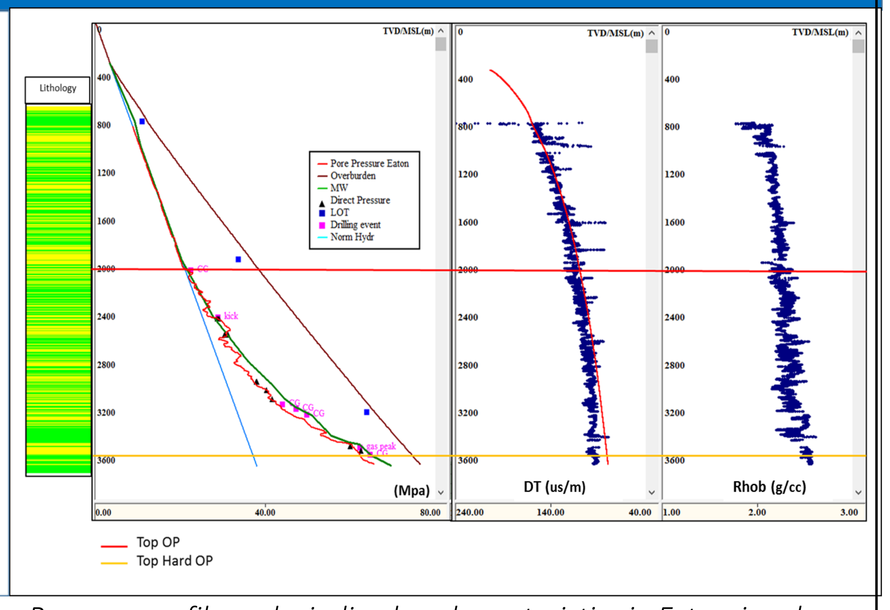


The deformation occurred in only one deformation phase starting in upper Early Miocene; thus affecting the Early Miocene Shale and created normal and thrust faults simultaneously. During deformation, the younger sediment was deposited as synorogenic sediment until this day.

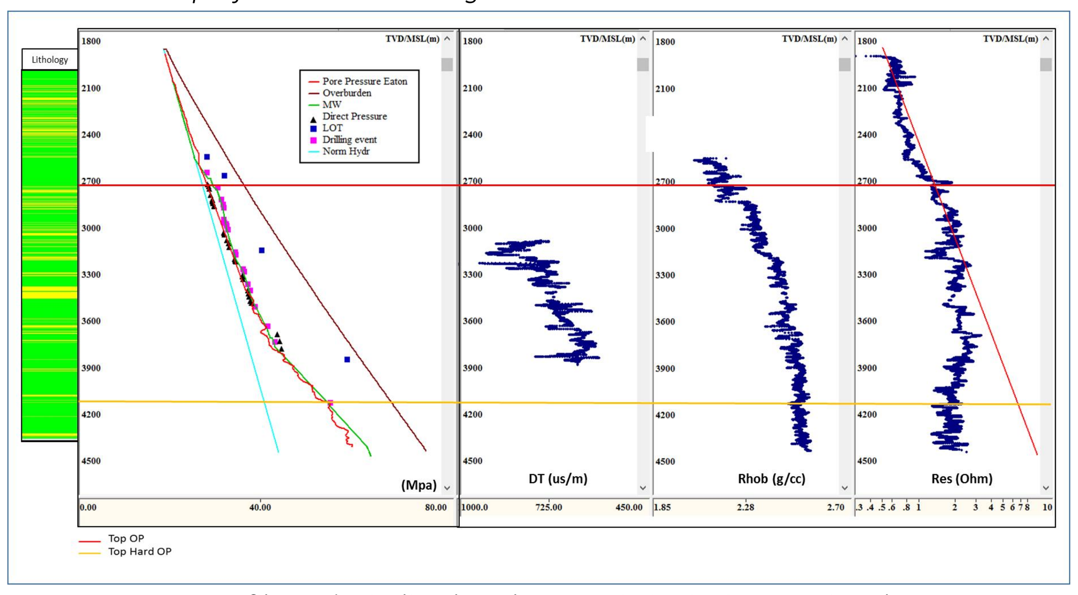
PRESSURE PROFILE AND WIRELINE LOG CHARACTERISTICS



Pressure profile and wireline log characteristics in Transitional area



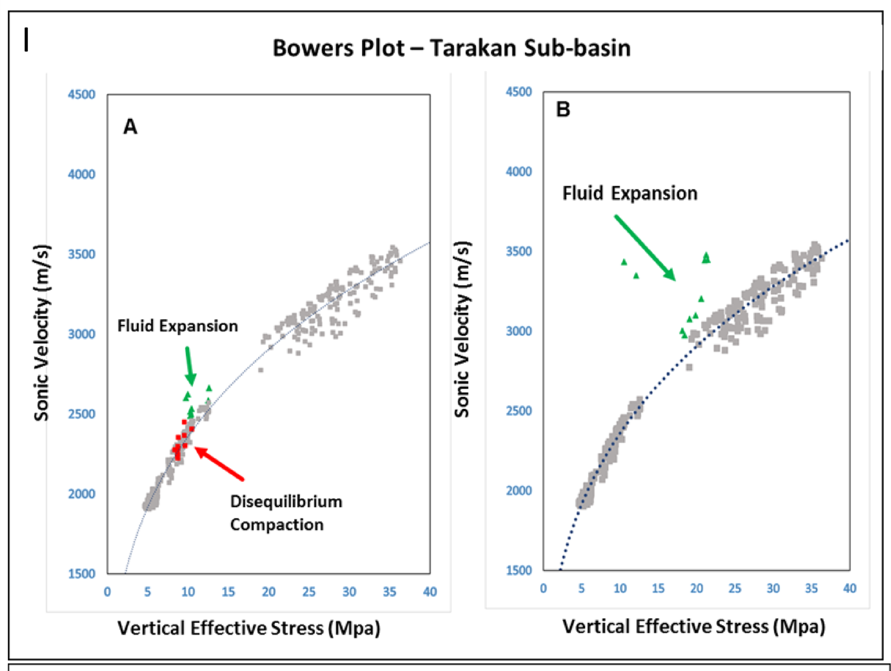
Pressure profile and wireline log characteristics in Extensional area

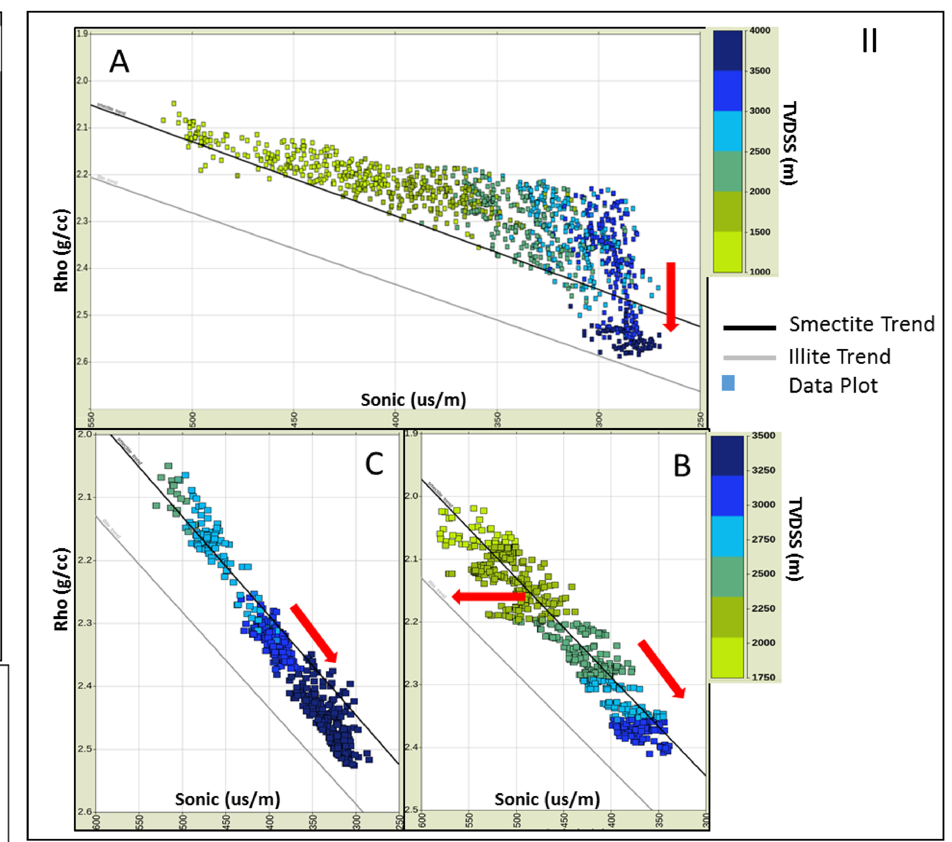


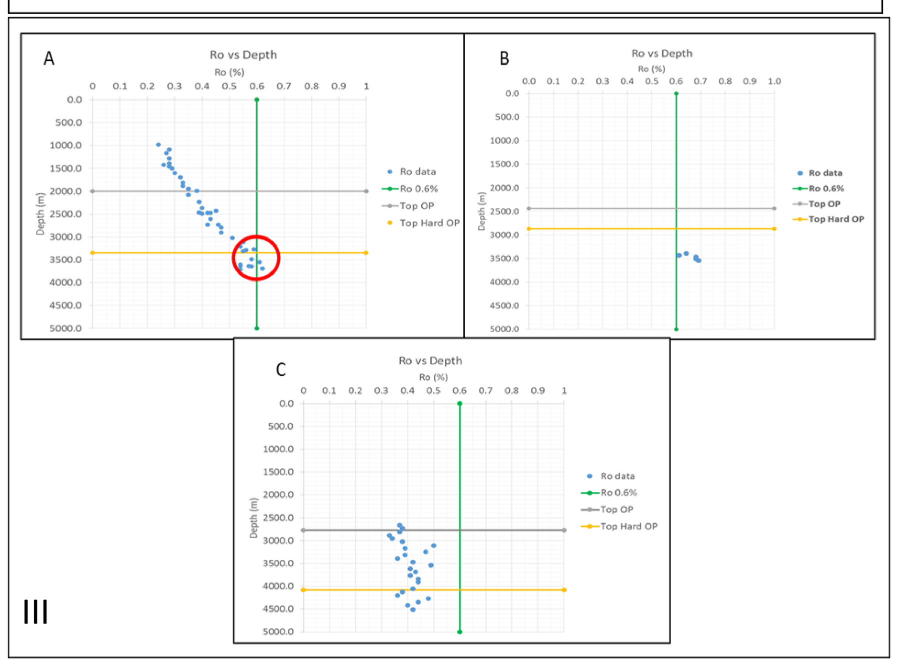
Pressure profile and wireline log characteristics in Contractional area

The Eaton method using sonic and resistivity logs is used to predict pore pressure in all wells within this basin and depends on log data availability. The result using this method coincides with direct pressure measurement data as validation with slight changes in exponent value. The exponent values of 3-3.5 were used for sonic log and 1.2 for resistivity log. Top overpressure is predicted within depth of 2000-3500m TVDss in Middle-Late Miocene shale interval

OVERPRESSURE GENERATING MECHANISM

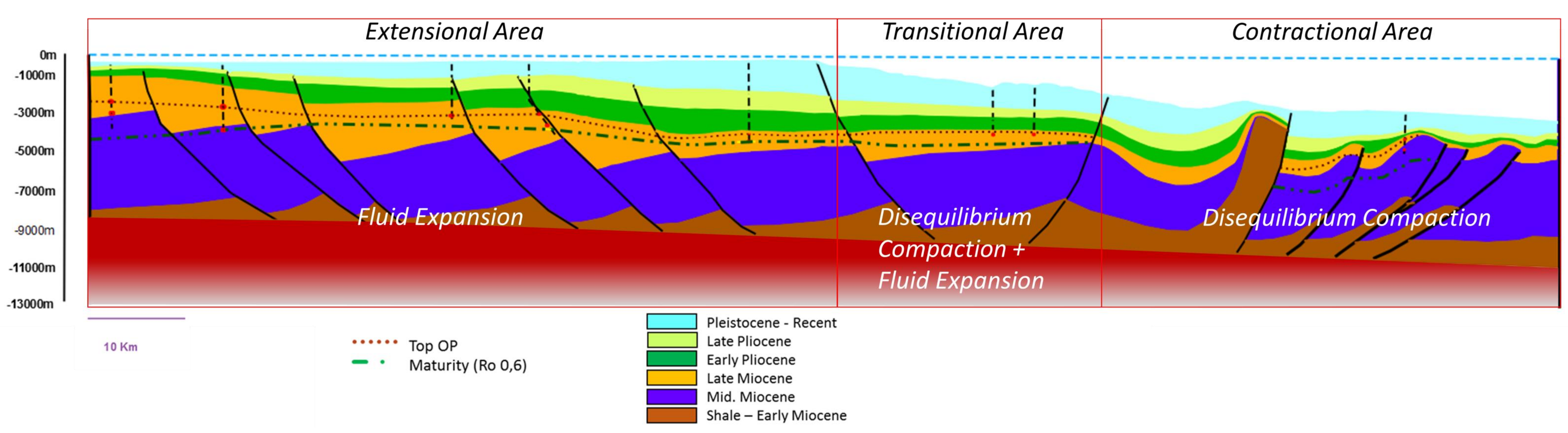






I. The Example of Bowers plot type in offshore Tarakan sub-basin shows possible fluid expansion paths and mix fluid expansion-loading paths for mudrocks; (A) Transitional area, (B) Extensional area. II. Dutta-Katahara Plot of Tarakan sub-basin. Red arrow shows trend of data plot; (A) Extensional area, (B) Transitional area, (C) Contractional area. III. The Example of Ro vs Depth Plot of Tarakan sub-basin. Red circle indicate that maturity coincides with overpressure; (A) Extensional area, (B) Transitional area, (C) Contractional area.

DISCUSSION



Overpressure origin caused by fluid expansion is distributed within the extensional area due to hydrocarbon maturity of the Middle Miocene – Late Miocene shale-dominated layer. Based on geochemical data in the study area, only Ro data from wells located in the extensional area show that the top of maturity coincides with overpressure. The presence of an abnormal pressure at a shallower depth may be related to the vertical transfer from a hard overpressured zone through a vertical conduit such as a fault. This is likely due to the continuous activity of normal and growth faults from Middle Miocene to present day within the extensional area.

In the contractional area, overpressure generating mechanism is likely caused by disequilibrium compaction due to rapid sedimentation of Miocene sediments. This evidence is supported by the V-sedimentation model introduced by Hidayati et al (2007) in where V-sedimentation is higher in the toe thrust area than the growth faulting area and reaches approximately 900-1100 ft/my.

A combined mechanism between disequilibrium compaction and fluid expansion is distributed within the transitional area between the extensional and contractional area. Generally, disequilibrium compaction is caused by rapid sedimentation in a deeper zone. Hence, overpressuring is a result of a competition between the rate of fluid escape and rate of vertical compaction due to the increase in gravitational loading caused by on-going sedimentation. It then will be transferred vertically to a shallower zone through an active fault. One evidence of vertical transfer or inflation is the presence of a shale/mud diapir.

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