

# **Abnormal pressure occurrence in the Malay and Penyu basins, offshore Peninsular Malaysia — a regional understanding**

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**Abstract:** A majority of wells drilled in the Malay and Penyu basins were terminated due to abnormal pressure. Blowouts and the subsequent loss of technical data have always been a concern during drilling operations.

This study employs data from 94 exploratory wells spread throughout the Malay-Penyu Basin. The postdrill abnormal pressure predictive method used is pressure versus depth plots of data obtained from RFT (Repeat Formation Tester) readings.

Results indicate that abnormal pressure occurs in a progressively older units towards the basin margins. The margins of the Malay Basin and the entire Penyu Basin are found to be normally pressured. The onset of abnormal pressure appears to be abrupt in the northern and more gradual in the southern portion of the Malay Basin. Abnormal pressure in the Malay Basin is found to be neither depth dependent nor age related.

This phenomenon is crucial to the understanding of hydrocarbon migration and will enable the planning of safe and efficient drilling campaigns.

## **INTRODUCTION**

The study area comprises the entire Malay and Penyu Basins located offshore and sub-parallel to the east coast of Peninsular Malaysia. This large area extends approximately 700 km along its northwest-southeast axis and is 300 km wide. It is bordered by Thai Basin in the northwest and West Natuna Basin in the southeast (Fig. 1). The Malay and Penyu Basins contain up to 12,000 metres of Tertiary siliciclastic sediments in the depocentre which has been divided into several groups.

## **OBJECTIVES**

There are four (4) common reasons why drilling of a well is terminated, i.e. reservoirs are not economical in the deeper section, reservoirs are poorly developed, operational problems such as stuck pipe and abnormal pressure. The first well in the study area was drilled by EPMI in 1969. Since then 286 exploratory and appraisal wells have been drilled. Of these, statistics show that approximately 80% of the wells were terminated because the well is either abnormally pressured or in the anticipation of this phenomenon. Blowouts and the subsequent loss of technical data has always been a concern during drilling operations.

This study was therefore initiated which focused on the following:-

1. Does abnormal pressure occur at the same depth throughout the area?
2. Does abnormal pressure occur in specific stratigraphic intervals throughout the area?
3. Where are the high risk and low risk abnormally pressured areas?

## **PHYSICS OF ABNORMAL PRESSURE**

A state of abnormal pressure is considered to exist when the pressure exerted by the fluids within a rock at a specified depth varies from the hydrostatic pressure exerted by an equivalent column of water to that same depth (Bradley, 1975; Fertl, 1976; Hunt, 1990). The pressure gradient of a free-standing column of fresh water is 0.433 psi/ft (9.79 kPa/m). Any variation is considered abnormal. The terms abnormal pressure or overpressure and underpressure refer to values above and below this value (0.433 psi/ft) respectively.

## **DATABASE**

A total of ninety four (94) exploratory wells have been selected for this study which are geographically spread throughout both basins. They consists of sixty one (61) drilled by EPMI, HAMILTON OIL, three (3) by LASMO and one (1) by WMC (Fig. 2).

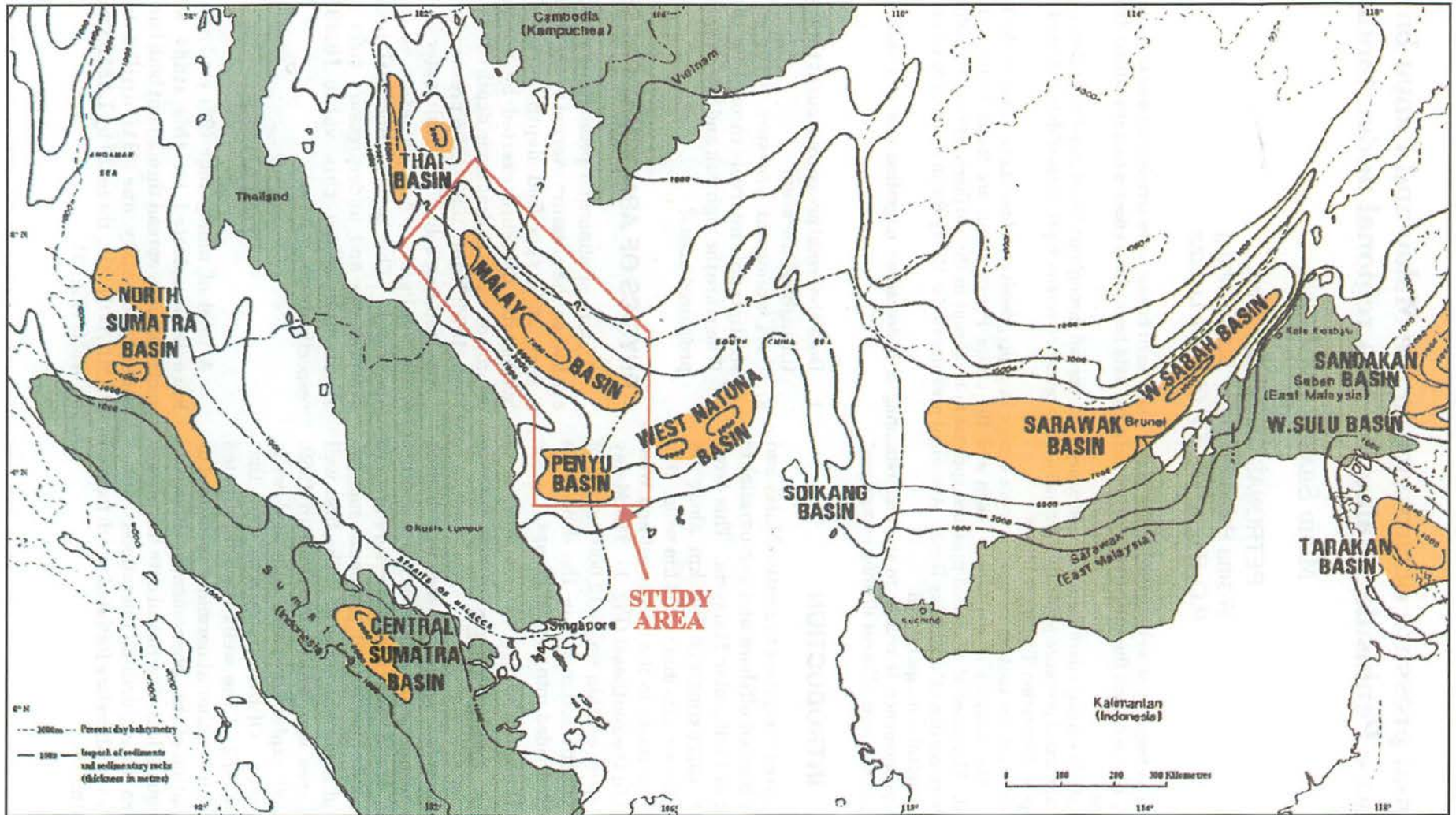


Figure 1. Tertiary sedimentary basins of Malaysia and adjacent territories (based on Hamilton, 1979).

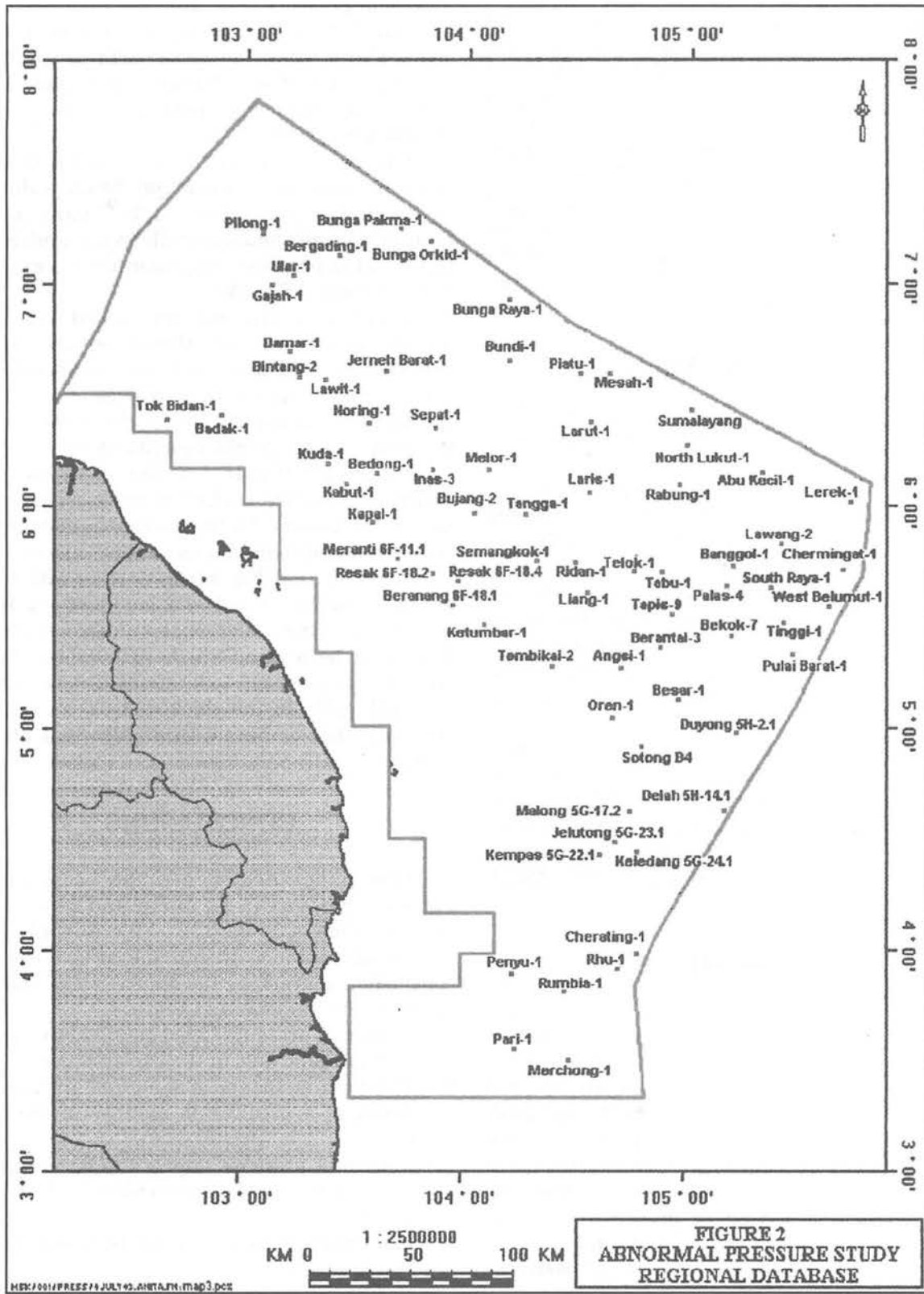


Figure 2. Abnormal pressure study, regional database.

## METHODOLOGY

There are several ways of identifying abnormal pressure such as by using velocity profiles and sonic transit time but they do not measure real formation pressure data. The introduction of the Repeat Formation Tester (RFT) to the exploration industry has made it possible to take a large number of accurate pressure measurements at various depths in a single well. All the pressure data, taken from primarily RFT's and DST's, have been selectively chosen as they are not supercharged and therefore valid tests. Plotting such data from the wells gives or indicates a clear picture of the onset of transition zone/mild abnormal pressure and top of abnormal pressure zone.

## DATA ANALYSES

Analyses of available data clearly indicate that there are three (3) distinct pressure characteristics in the study area, i.e.:

1. A normally pressured compartment as illustrated by the pressure profiles from Bunga Raya-1, Lerek-1, Jelutong 5G-23.1, Merchong-1 and Ketumbar-1 (Figs. 3-7).
2. A normally pressured compartment overlying a transition zone which forms a seal to an underlying abnormal pressure compartment as illustrated by the pressure profiles from Besar-1, Angsi-1, Semangkok Timur-1, Jerneh Barat-1 and Ular-1 (Figs. 8-12).
3. A normally pressured compartment overlying a transition zone which in turn is overlying an abnormal pressure compartment. The pressure then decreases to the normal water gradient beneath the abnormal pressure section as illustrated by the pressure profiles from Resak 6F-18.4 (Fig. 13).

## OBSERVATIONS

The relationship between the depth and the stratigraphy and the occurrence of abnormal pressure in the study area is best illustrated by the well cross-sections (Figs. 14-16). Figures 14 and 15 indicate that the abnormal pressure in the Malay Basin is at a structurally shallower depth in the centre of the basin and is deeper towards the basin margins. It also indicates that abnormal pressure in the Malay Basin occur in progressively older stratigraphic units towards the basin flanks. Based on existing well data, the margins of the basin are

Normally Pressured.

Two deep wells drilled in the Penyu Basin penetrated basement and did not encounter abnormal pressure (Fig. 16).

Mapping the distribution of abnormal pressure shows that it occurs along the northwest-southeast trending axis of the Malay Basin and is at a structurally shallower depth and deeper towards the margins (Figs. 17-18)

The control points (wells) show that the abnormal pressure in the Malay Basin is clustered in discrete envelopes and occurs in the stratigraphically younger units in the centre of the basin and in progressively older units towards the basin margins (Fig. 19).

There is sufficient measured maximum bottomhole pressure data throughout the basins to demonstrate that abnormal pressure tends to be severe and abrupt in the northwestern portion of the basin. Figure 20 shows the pore pressure gradient in mud weight equivalent values.

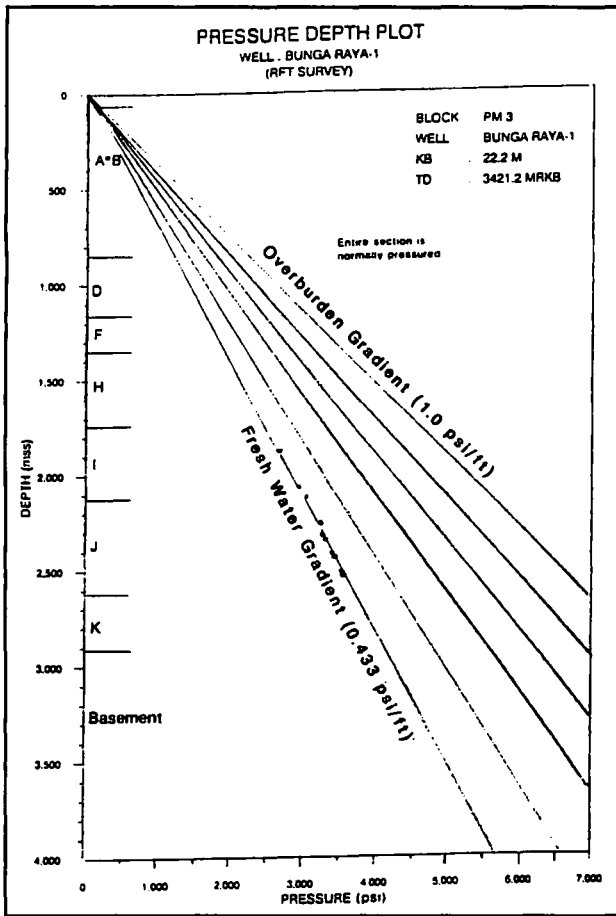
Figure 21 illustrates the position of the abnormal pressure surface in cross-section across the Malay Basin. All the current production and reserves found to date occur above this surface.

Resak 6F-18.4 (Fig. 13) proves that with a better geological approach and by using improved drilling techniques, penetration of the abnormal pressure zones can be accomplished. Therefore, there is tremendous potential to locate additional reserves of "black gold" in the thick and as yet undrilled section within or beneath the abnormal pressure zone.

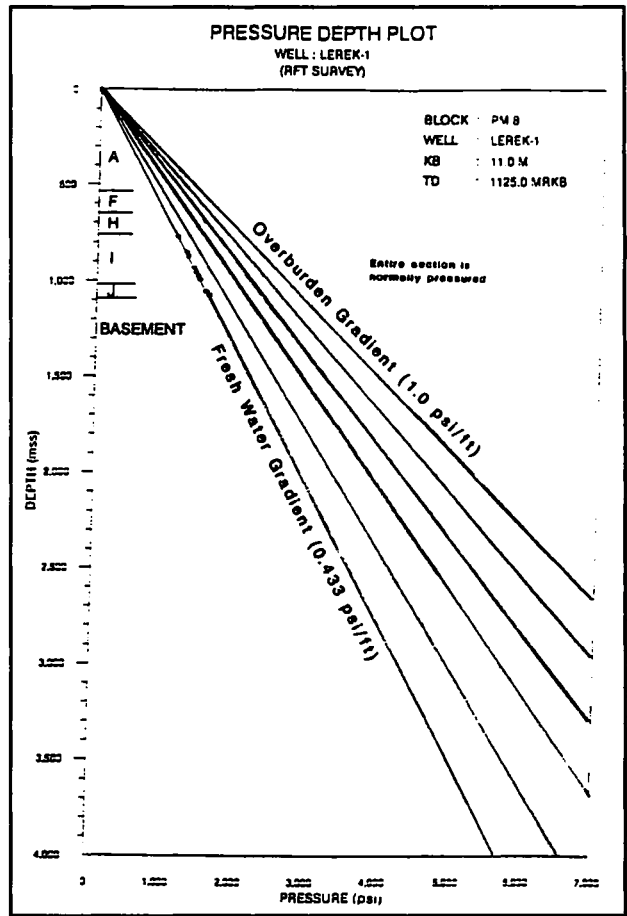
## CONCLUSIONS

This paper documents the occurrence of abnormal pressure in the Malay and Penyu Basins which provides a framework for more detailed study of this phenomenon within the area. The main conclusions concerning the occurrence of abnormal pressure are summarized below:-

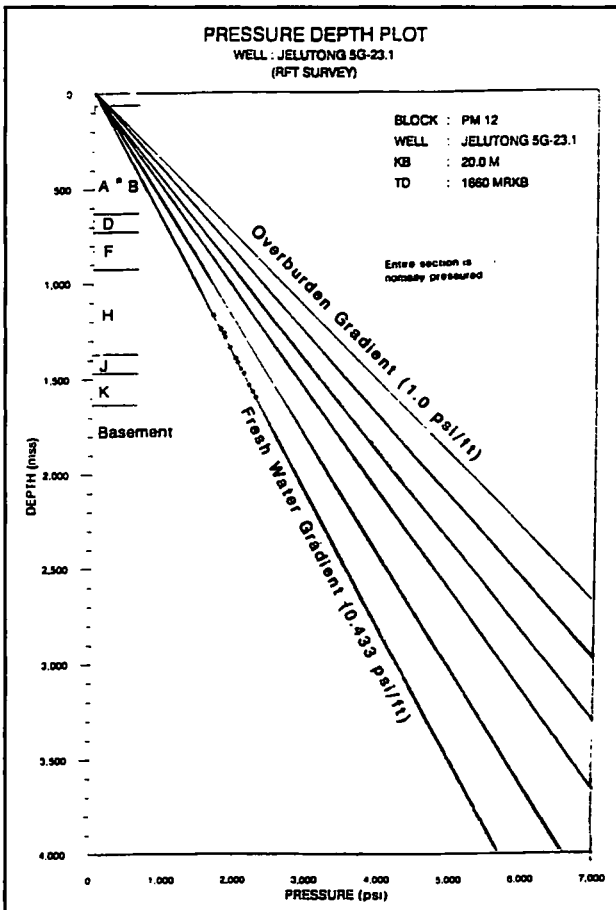
1. Abnormal pressure is not confined to a specific stratigraphic unit in the Malay Basin.
2. The depth to the top of abnormal pressure zone varies in a predictable manner in the Malay Basin.
3. Abnormal pressure appears to be abrupt and severe in the northwestern portion of the Malay Basin.
4. Abnormal pressure has not been noted in the Penyu Basin.



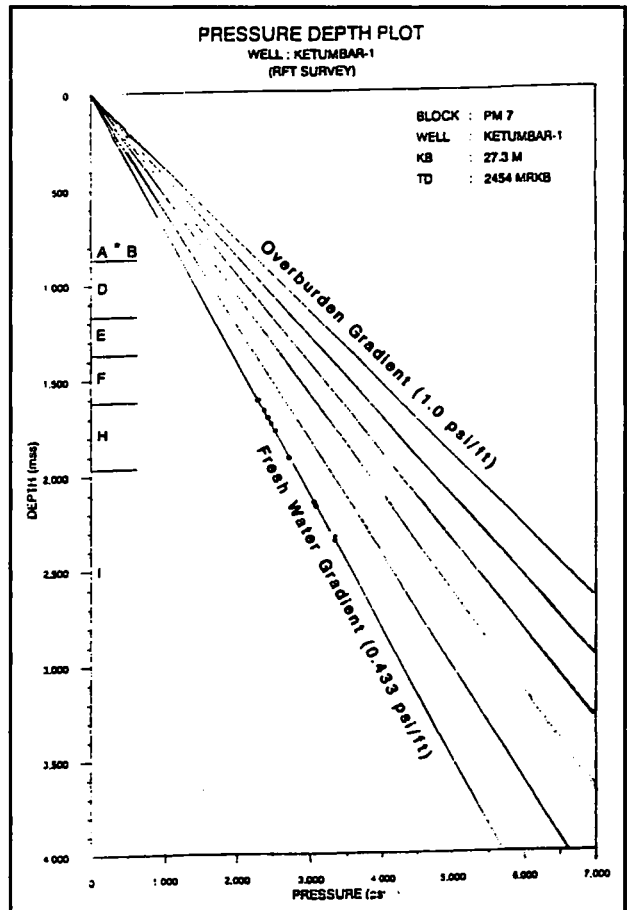
**Figure 3. Northwest Malay Basin.**



**Figure 4. East Malay Basin.**



**Figure 5. Southern Malay Basin.**



**Figure 6. West Malay Basin.**

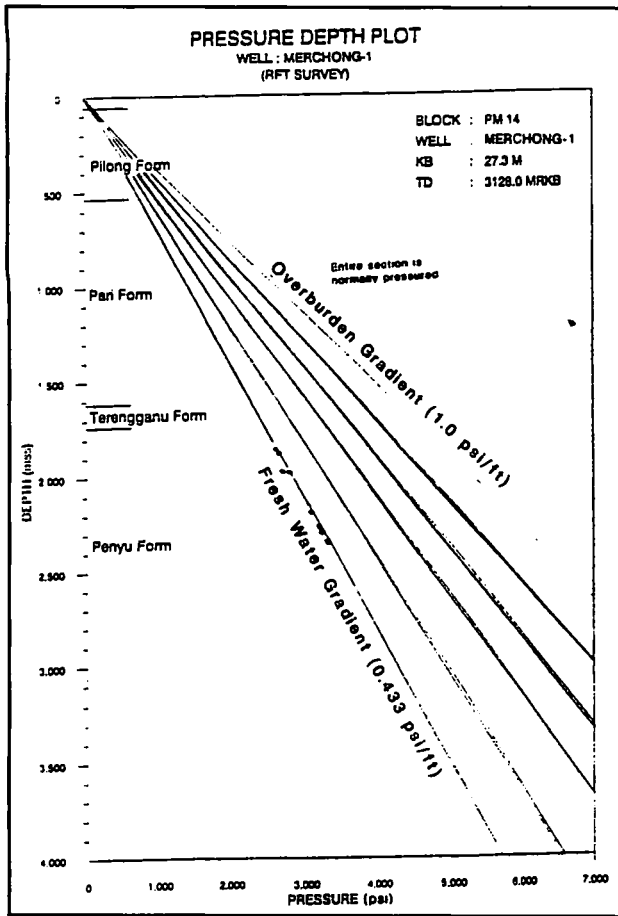


Figure 7. Southern Penyau Basin.

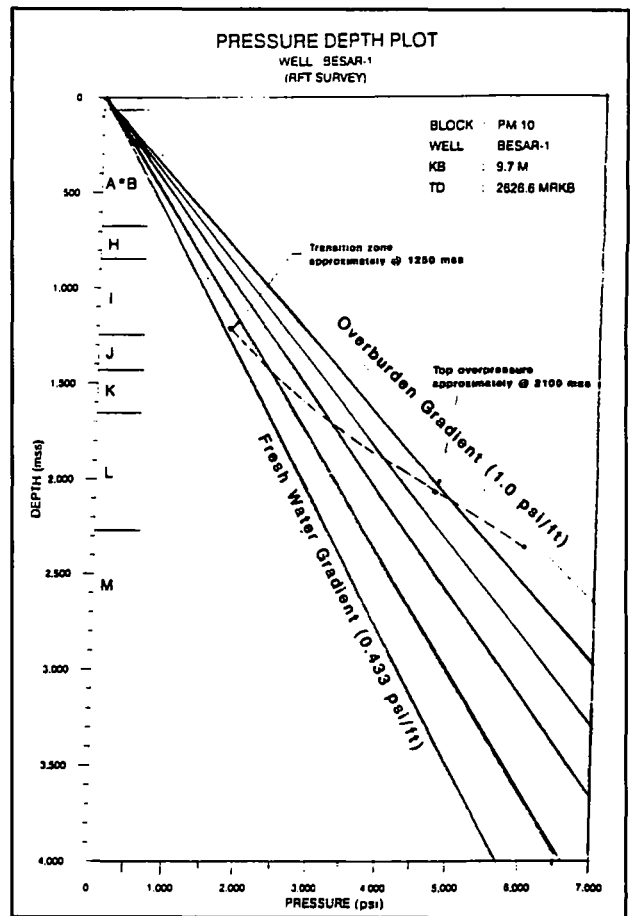


Figure 8. Southeast Malay Basin.

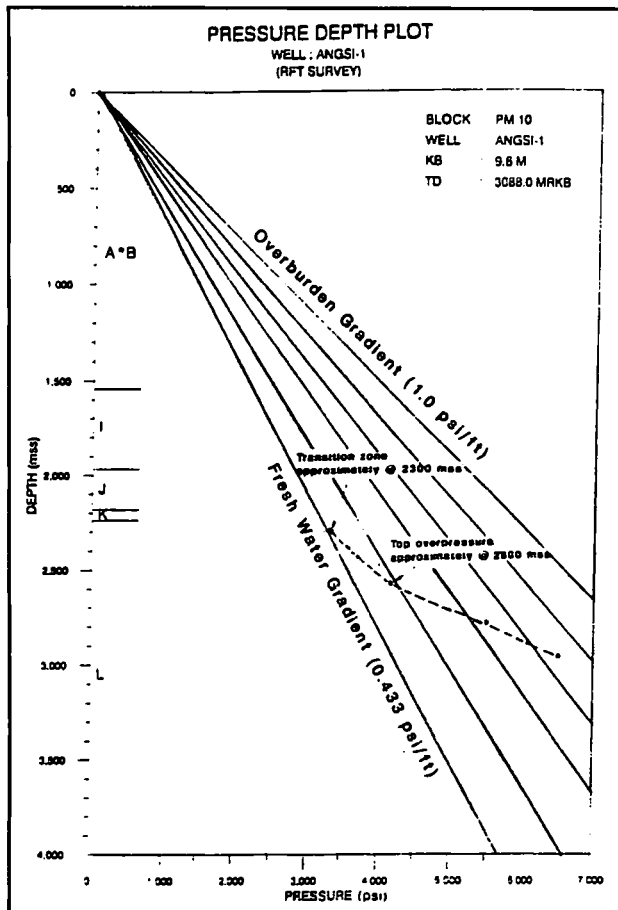


Figure 9. Southeast Malay Basin.

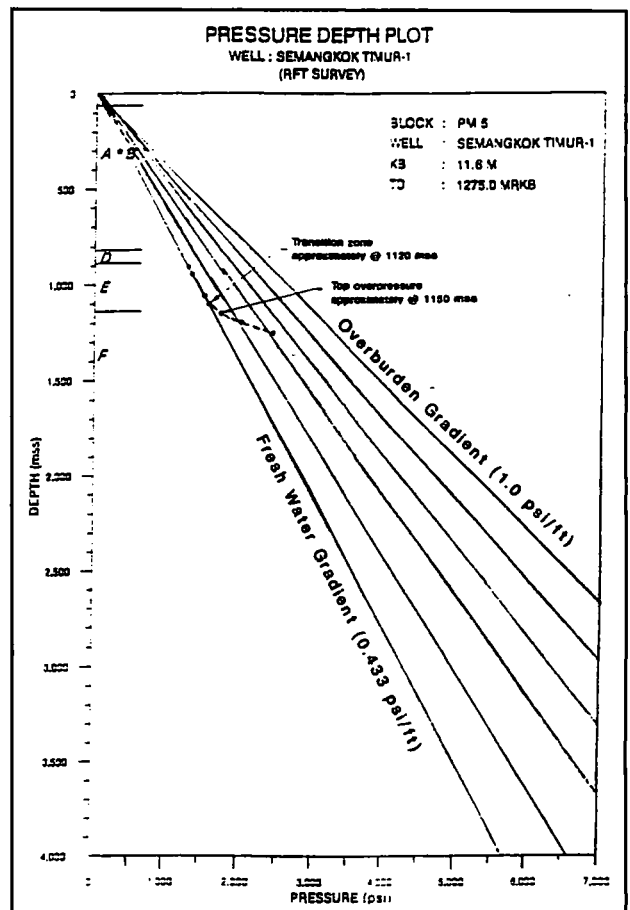


Figure 10. Central Malay Basin.

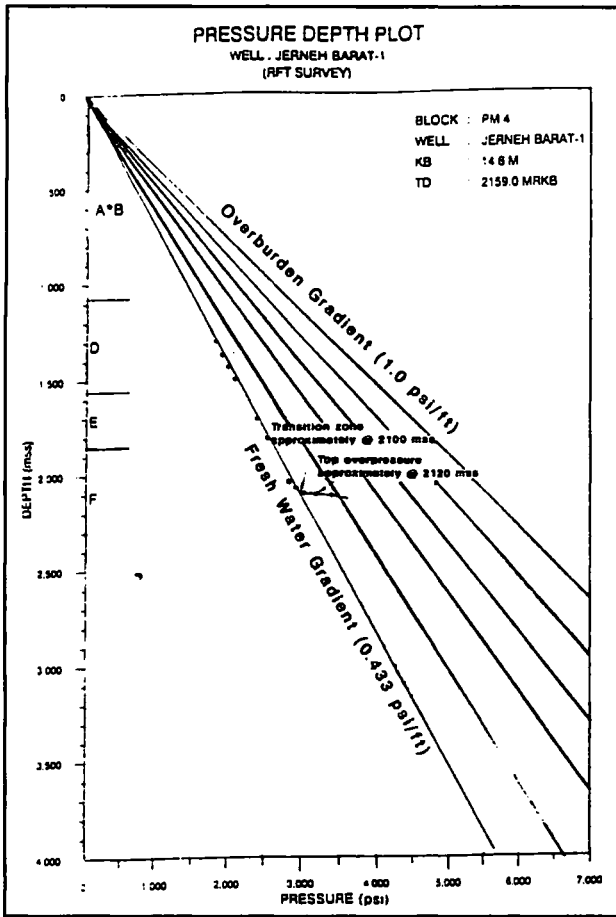


Figure 11. Northwest Malay Basin.

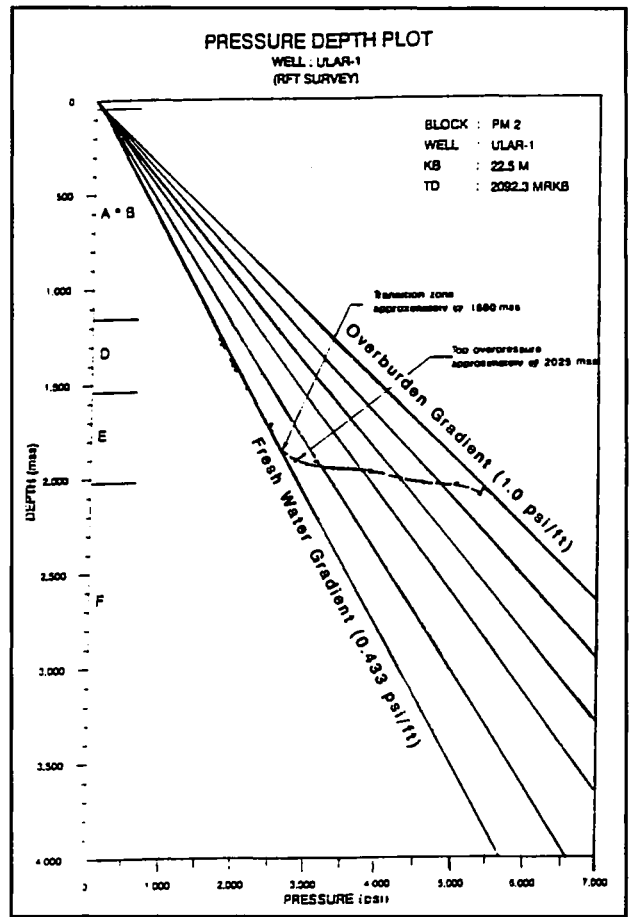


Figure 12. Northwest Malay Basin.

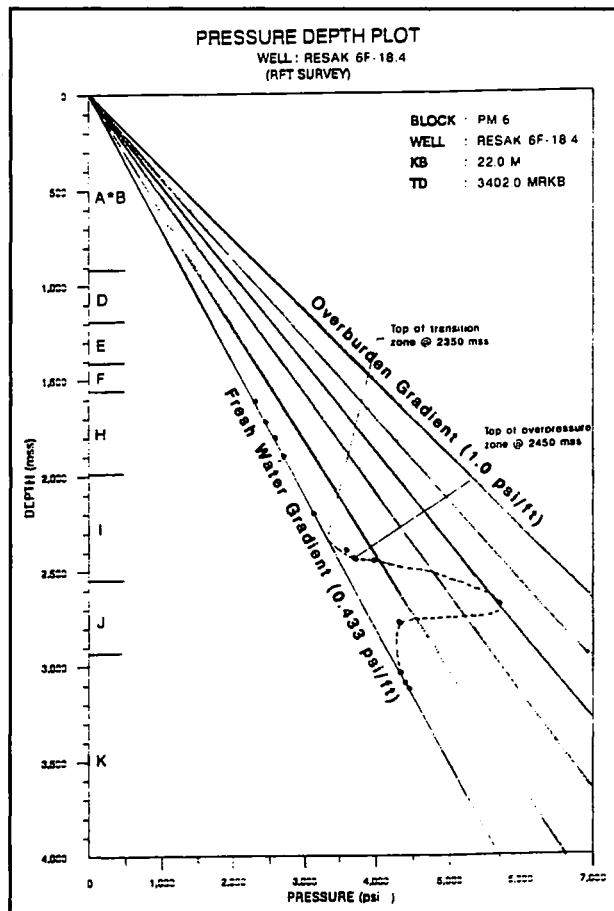


Figure 13. West Malay Basin.

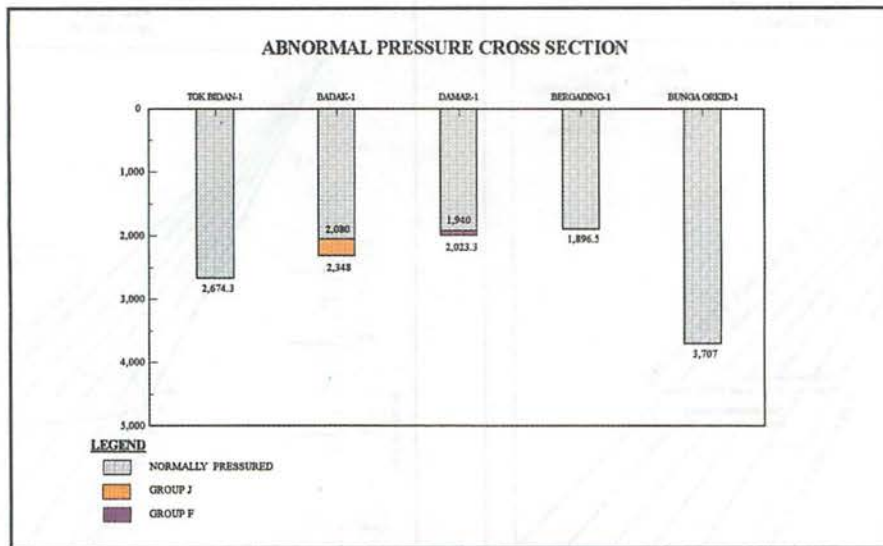


Figure 14. Northwest Malay Basin.

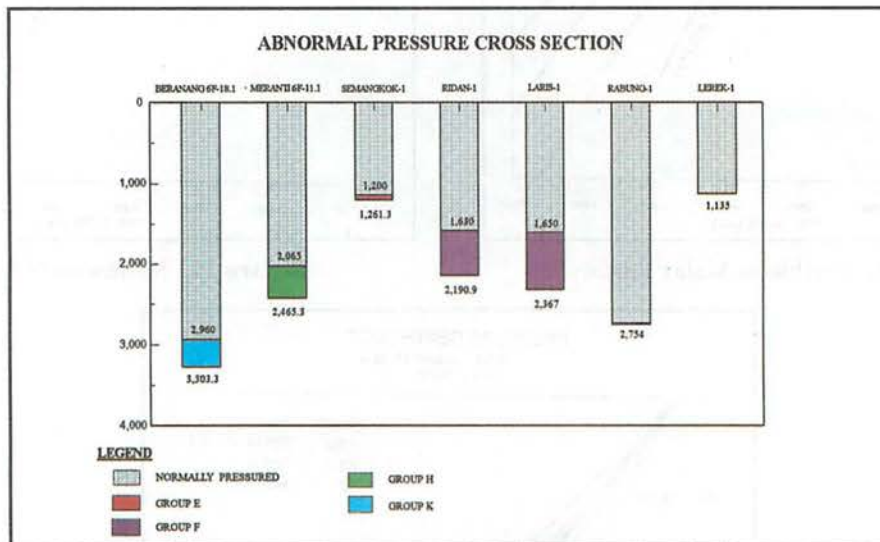


Figure 15. Central Malay Basin.

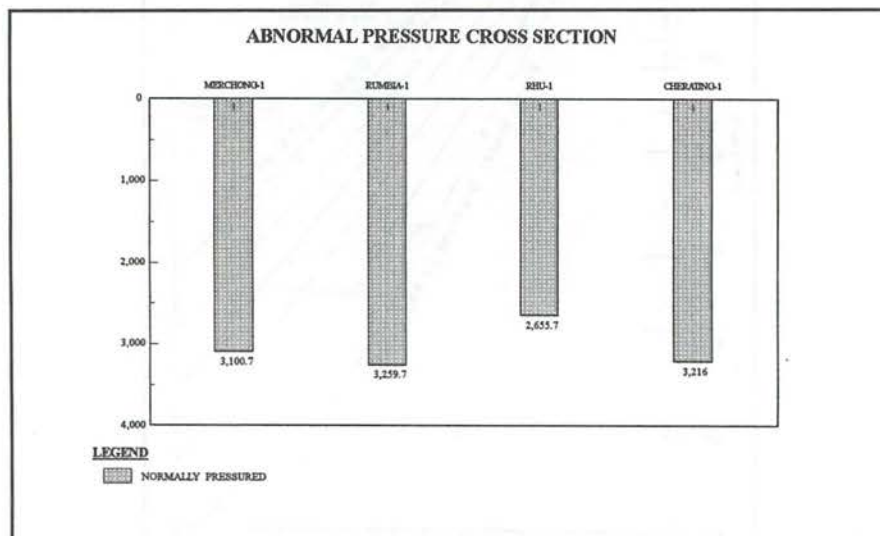


Figure 16. Southern Penyu Basin.



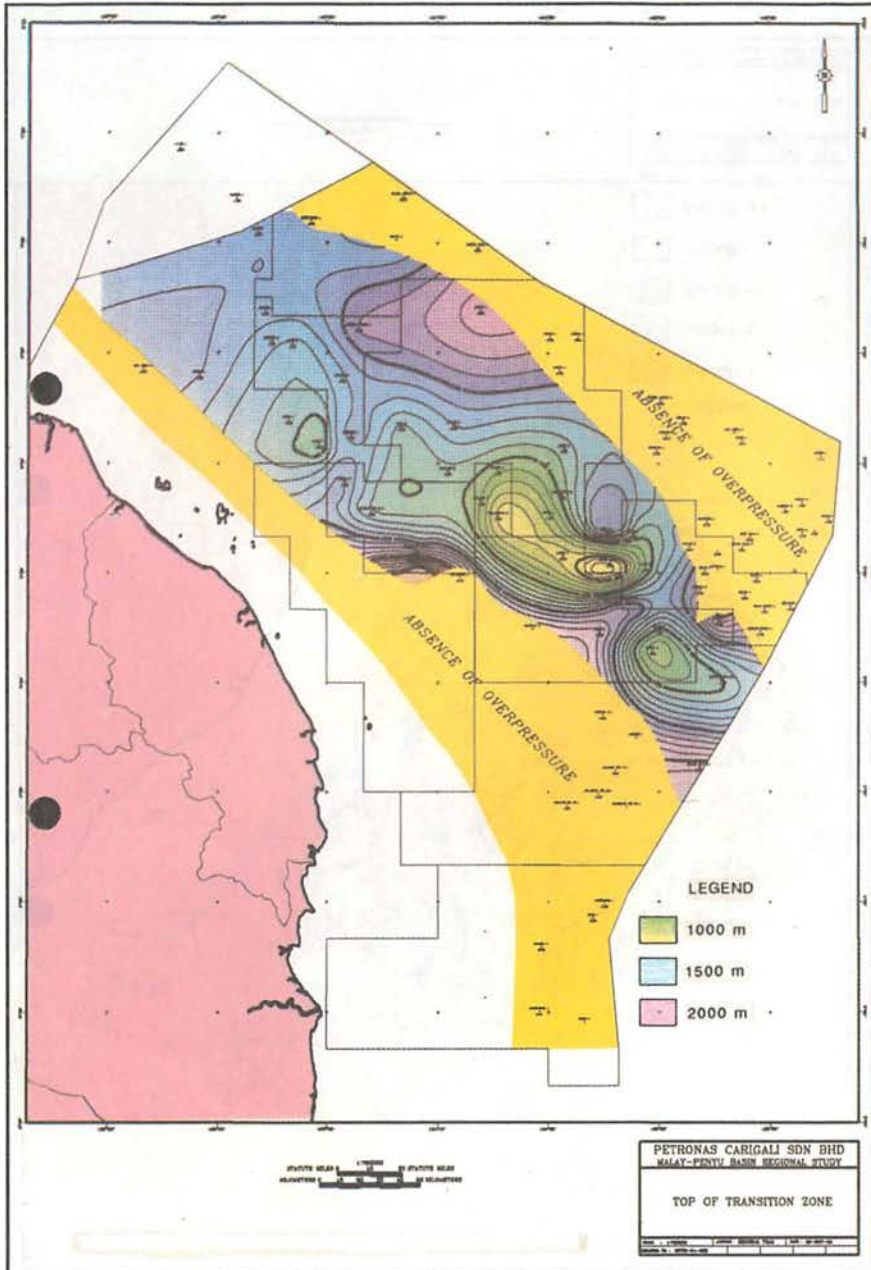


Figure 17. Depth structure map (top of transition zone).

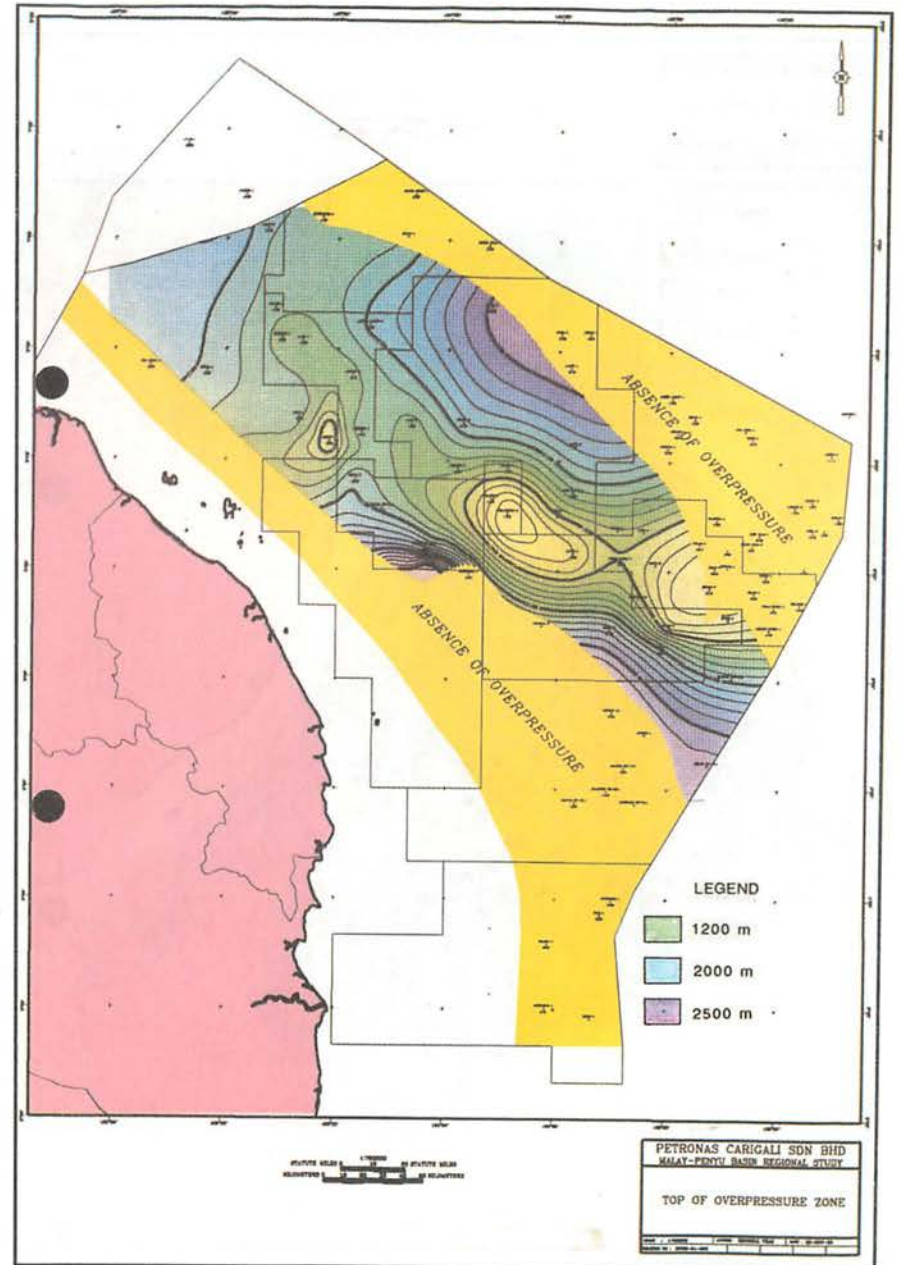


Figure 18. Depth structure map (top of abnormal pressure).

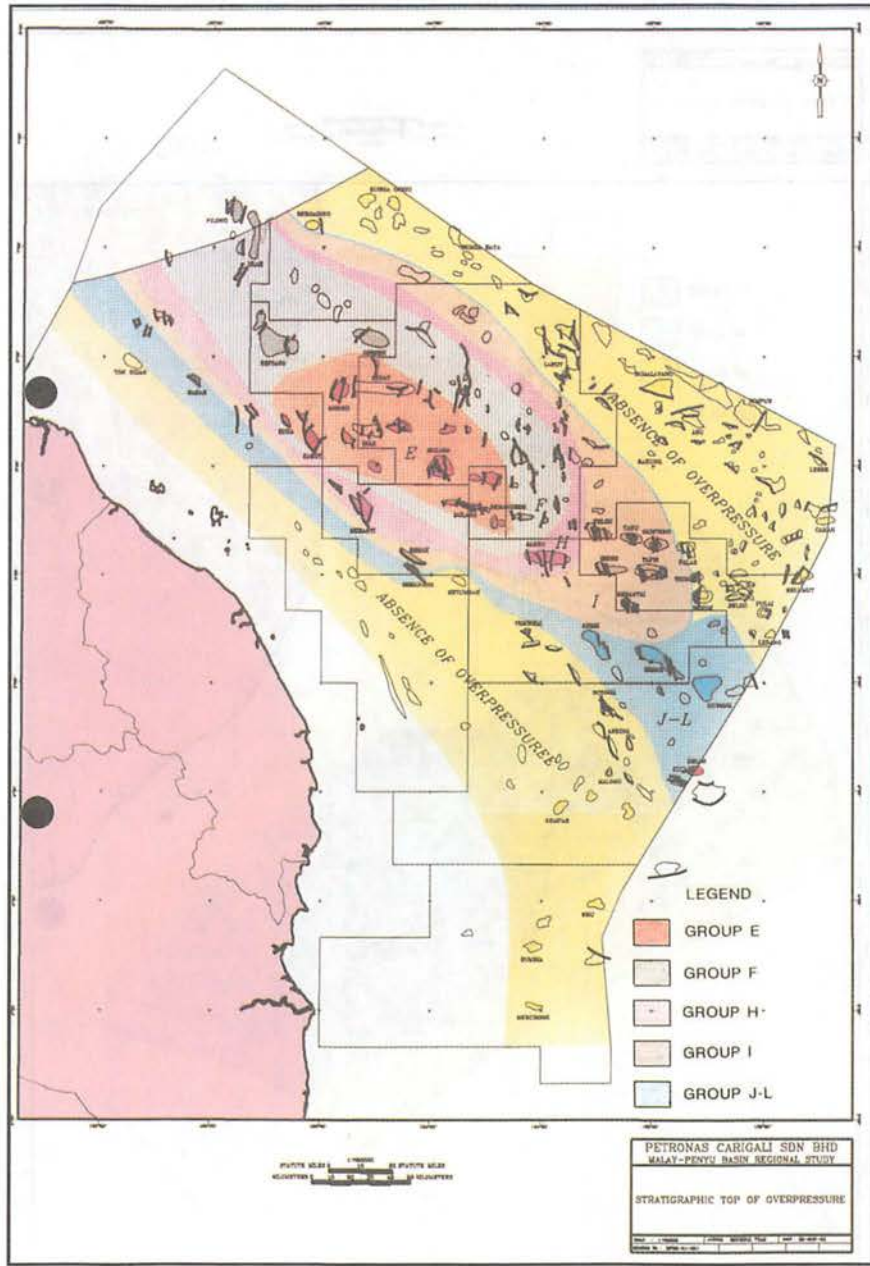


Figure 19. Stratigraphic unit top of abnormal pressure.

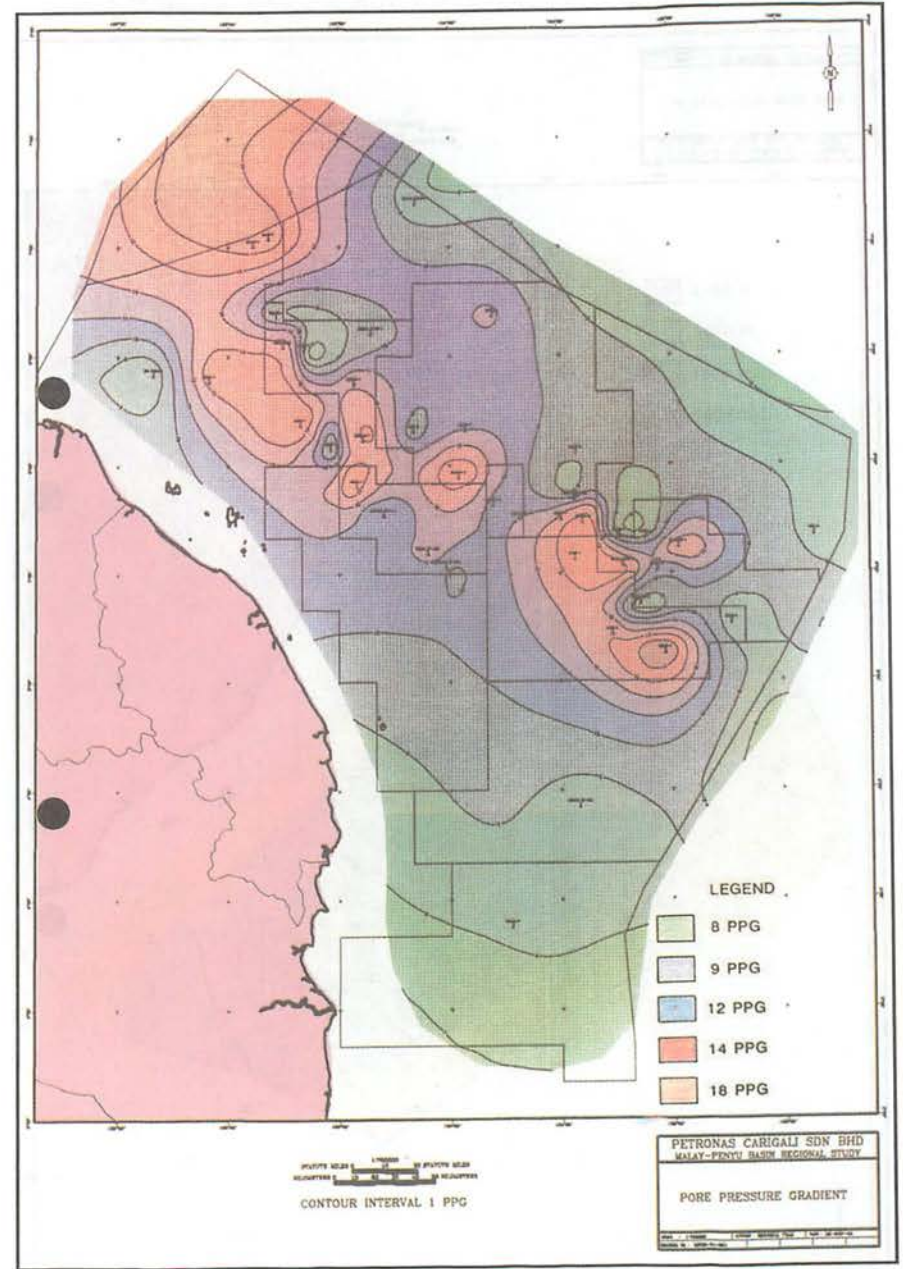


Figure 20. Pore pressure gradient in mud weight equivalent.

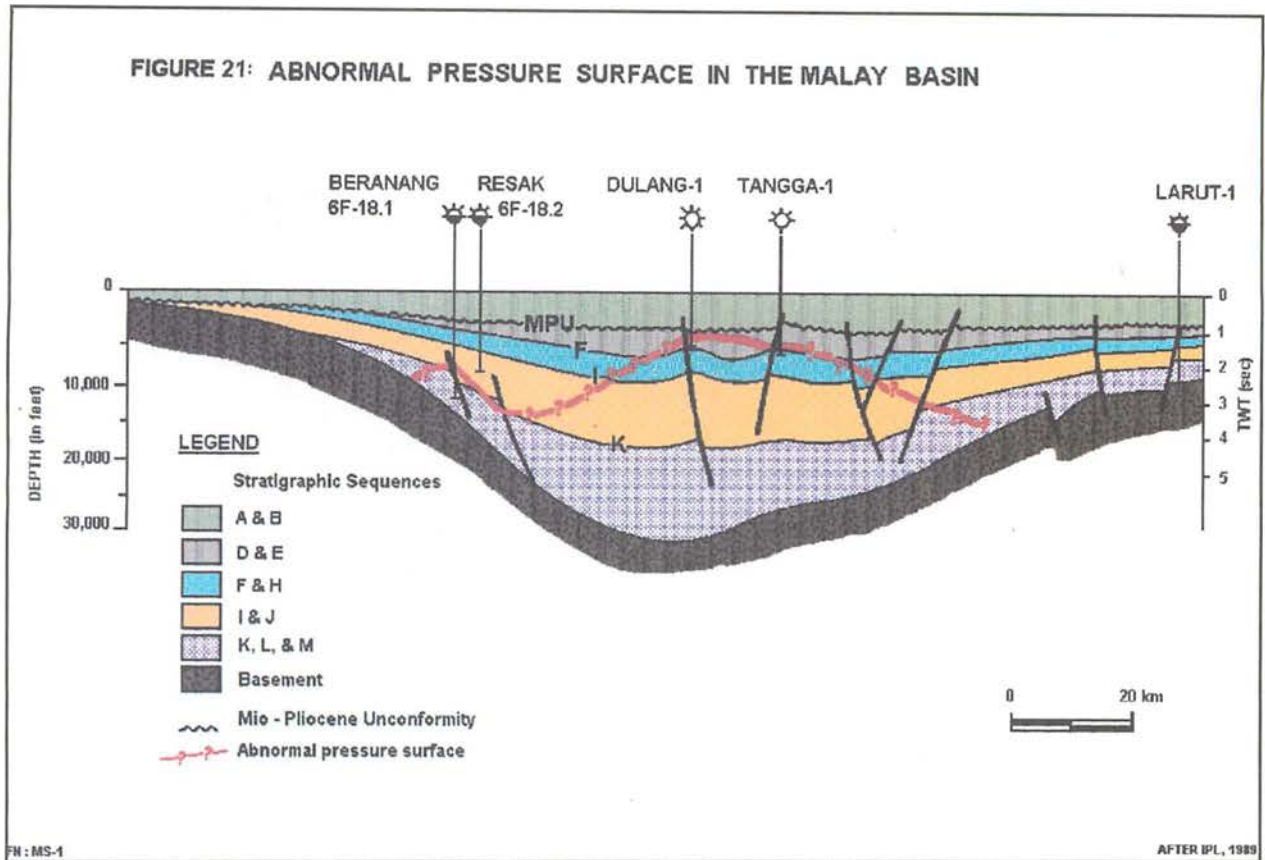


Figure 21. Abnormal pressure surface in the Malay Basin.

## FURTHER STUDIES

Temperature profiles, reservoir fluids, rock strengths and porosity-permeability values need to be studied to gain a better understanding of the possible causes of this phenomenon in the study area.

## RECOMMENDED DRILLING PROCEDURES

1. Use BOP stacks with a higher pressure rating of 15,000 psi or more.
2. To penetrate abnormally pressure zone:-
  - set intermediate casing shoe at the top of transition zone.
  - drill abnormally pressured zone using a high mud weight.
  - cased off abnormally pressured zone when penetrated.
  - drill ahead with normal mud weight.

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