Role of Thermal Parameters in Modelling Fracture Gradient and Overpressure Mechanism in Southern Part of West Baram Delta, Sarawak, Malaysia*

Wan Ismail Wan Yusoff[1], Wan Nur Athirah W Abd Muhaimi[1], Kurniawan Adha[1], and Nurhajeerah Mhd Hanapiah[1]

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[1]Department of Geosciences and Petroleum Engineering, Universiti Teknologi PETRONAS, Perak Darul Ridzuan, Malaysia (wanismail_wanyusoff@utp.edu.my)

Abstract

In oil and gas exploration and production, overpressure mechanism is one of the crucial parameters in estimating or predicting overpressures before drilling. The correct geo-pressure parameters, especially in deep reservoirs are required to improve drilling safety and preventing drilling hazards. Furthermore, efforts in modelling fracture gradients based on natural fracture is necessary to gauge the formation integrity so as to plan mud density in the drilling proposal. Thorough investigations are recommended for fracture gradients and overpressure mechanisms analysis to overcome the shortcomings in overpressure prediction. Correct estimation of fracture gradient is essential in planning for drilling a safer and an economic well. It is extremely important especially in the areas of abnormally pressured formations (Rocha et al., 1996). Moreover, understanding the nature of fractures is essential in order to gain a better outlook on the fracture gradient.

Analysis on fracture attributes, pore pressure, and the rock properties especially thermal conductivities for several selected wells in southern sector of West Baram Delta, Offshore Sarawak were carried out, to determine overpressure mechanisms, fracture gradients, and pore pressure and temperature gradients. The West Baram Delta, which was influenced by both gravity-driven deformation and regional stress, exhibits variation of growth faults, folds, and anticlines (Morley et al., 2008).

Discussion

A lot of research has been conducted to improve the forecasting of overpressure magnitude. This effort in determination of overpressure mechanism can be enhanced by inclusion of thermal mechanisms specially to account for very high pressure in deep reservoirs (Hoesni, 2004). The study was conducted by integration of rock physics and pore pressure trends analysis within the shale and sand intervals. The pore pressure, electric log, and thermal trends are used to determine predominant overpressure mechanism at each well. Meanwhile, theoretical methods to calculate fracture gradient from well logs using Ben Eaton methods was carried out. Comparison with the actual leak-off test fracture pressure was done to validate the accuracy of the fracture gradient model. In this study, six (6) wells have been selected to analyse the thermophysical properties within the overpressure intervals of wells MRI1, MRI2, MRI3, MRI4, MRI5, and MRI6 respectively. The top of overpressure in study area can be shown as in Figure 1.

From repeat formation test (RFT) and corrected bottom-hole temperature (BHT) data, the analysis of pore pressure and formation temperature trend in depth were carried out. The profile of pressure over temperature gradients (P/T) distribution with depths is shown in Figure 2. The pressure-temperature gradients, P/T accounted are within three (3) categories of pressure mechanisms, namely; normal compaction, disequilibrium compaction, and fluid expansion. Low P/T trend addressing characteristics of normal compaction pore pressure and the medium P/T belongs to disequilibrium compaction mechanism. While high P/T lie within the fluid expansion mechanism zone. Normal compaction is in <0.32 MPa/°C, disequilibrium compaction in 0.32-0.42 MPa/°C, and fluid expansion >0.42 MPa/°C. All wells have undergone through disequilibrium compaction overpressure mechanism; however, the fluid expansion mechanism also prevails except for MRI4 well, where disequilibrium compaction is the dominant.

Rate of sedimentation is believed to influence the distribution of overpressure. The overpressure is primarily caused by the expelled water from sediments and is being trapped within the rocks due to high sedimentation rate and low permeability of the sealing sediments. Figure 3 shows the sedimentation rate that contribute to the primary disequilibrium compaction mechanism generation in all the wells within the overpressure intervals. The rate was derived based on decompacted intervals during the deposition of the sediments.

Pressure-Temperature (P/T) gradients within the overpressure intervals in general is higher away and parallel to the coastline. The trend of higher P/T is also represented with the deeper top of overpressure zone over the region. The high P/T gradients can also be due to the deep expansion mechanism of overpressure. However, there is a higher P/T gradient near the onshore areas in the southeastern portion, that may be related to fracturing and due to recent tectonics (Adha et al., 2017).

Major factors controlling the fracture development are lithology and mineral composition, as well as abnormal high pressure (Ding et al., 2012). The fracture gradients' distributions over the area may influence the variability in P/T gradients. The relative changes of fracture gradient are inversely proportional to P/T gradient where higher fracture gradient occupies areas of low P/T gradients (Figure 4 and Figure 5).

Towards the northeastern offshore area, the P/T gradients increase probably due to occurrence of shale diapir with fluid expansion mechanism of overpressure (Yusoff et al., 2018). This is also an area of lower fracture gradient. The fracture gradient for the overpressure intervals is about 13 ppg to 16 ppg. In the southwest, near to the coastline, the P/T gradient is lower ranging from 0.4 to 1.2 MPa/°C while the fracture gradient is higher at 16 to 18 ppg. Whereas, in the expansion mechanism zone that dominates the northeastern, near the boundary with Brunei, the P/T gradient is low and fracture gradient is high. Compaction overpressure mechanism prevails in the northeast and southern coastal sector. The increase in P/T gradient and decreasing fracture gradient with depths shall decrease the effective stress window, that leads to smaller mud density windows for drilling plan.

Summary

Integration of thermal and logs data provides the significant analytical means in investigating the overpressure mechanisms and fracture gradient modelling. While using seismic velocity is a common method for overpressure prediction, subsequent contribution of thermal parameters in understanding the mechanisms of overpressure would enhance pore pressure prediction methodology. Thus, integrated thermophysical technique will compliment the current techniques, to investigate the overpressure mechanism as well as fracture gradient modelling. This will lead to enhancement of the methodology in pore and fracture pressure estimation for future oil and gas exploitation.

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References Cited

Adha, K., W.I.W.Yusoff, and L.A. Lubis, 2017, Investigation of Thermophysical Parameters Properties for Enhancing Overpressure Mechanism Estimation. Case Study: Miri Area, West Baram Delta: IOP Conference Series: Earth and Environmental Science, v. 88/1, p. 012-015.

Ding, W., C. Li, C. Li, C. Xu, K. Jiu, W. Zeng, and L. Wu, 2012, Fracture Development in Shale and Its Relationship to Gas Accumulation: Geoscience Frontiers, v. 3/1, p. 97-105. doi.org/10.1016/j.gsf.2011.10.001

Hoesni, M.J., 2004, Origins of Overpressure in the Malay Basin and Its Influence on Petroleum Systems: Ph.D Thesis, University of Durham, Durham, UK, 268 p.

Morley, C.K., M. Tingay, R. Hillis, and R. King, 2008, Relationship Between Structural Style, Overpressures, and Modern Stress, Baram Delta Province, Northwest Borneo: Journal of Geophysical Research: Solid Earth, v. 113/B9. doi.org/10.1029/2007JB005324

Rocha, L.A., S.A. Petrobras, and A.T. Bourgoyne, 1996, A New Simple Method to Estimate Fracture Pressure Gradient: SPE Drilling and Compaction, p. 153-159.

Yusoff, W.I.W., K. Adha, N.M. Hanapiah, and D.P. Ghosh, 2018, Major Controlling Factors of Overpressure Generation in West Baram Delta, Offshore Sarawak Basin: An Overview on Disequlibirum Compaction and Thermal Analysis Causing Overpressure Interval: Offshore Technology Conference Asia, 20-23 March, Kuala Lumpur, Malaysia, OTC-28231-MS, 15 p. doi.org/10.4043/28231-MS

Yusoff, W.I.W., 2008, Analysis of Overpressure Characters and Implication to Hydrocarbon Accumulations in West Baram Delta: Geopressure Conference and Exhibition, 2008, Durham. U.K.

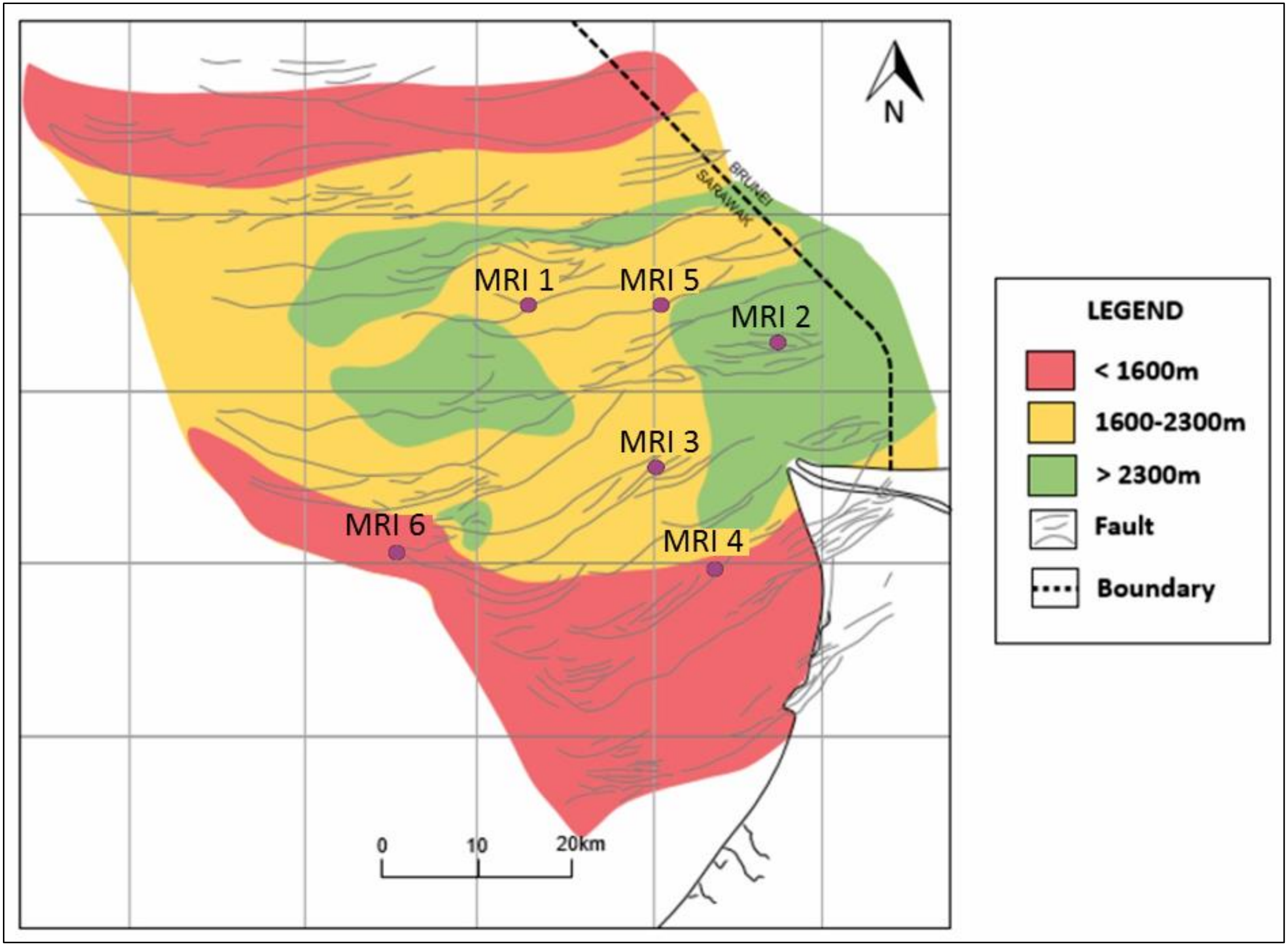

Figure 1. Map illustrating the depth of top of overpressure ranges between 1400-2900 m. The distribution of overpressure, which is deeper towards the medial shelf area, might be influenced by the different mechanisms (modified after Yusoff, 2008).

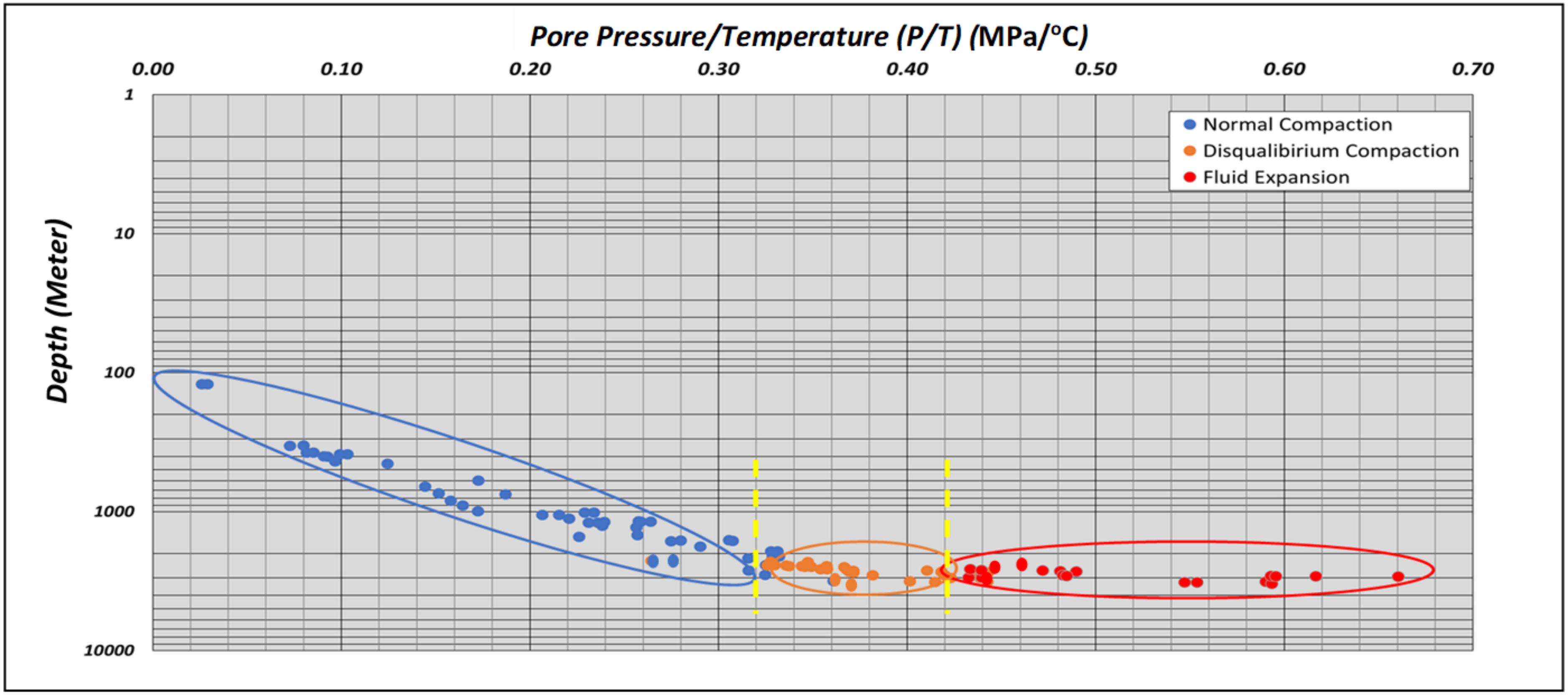

Figure 2. The trend of pressure/temperature distribution from all the wells. The trend had positive relation to depth, where the unloading (expansion) possessed the highest values of pressure/temperature (P/T) gradient.

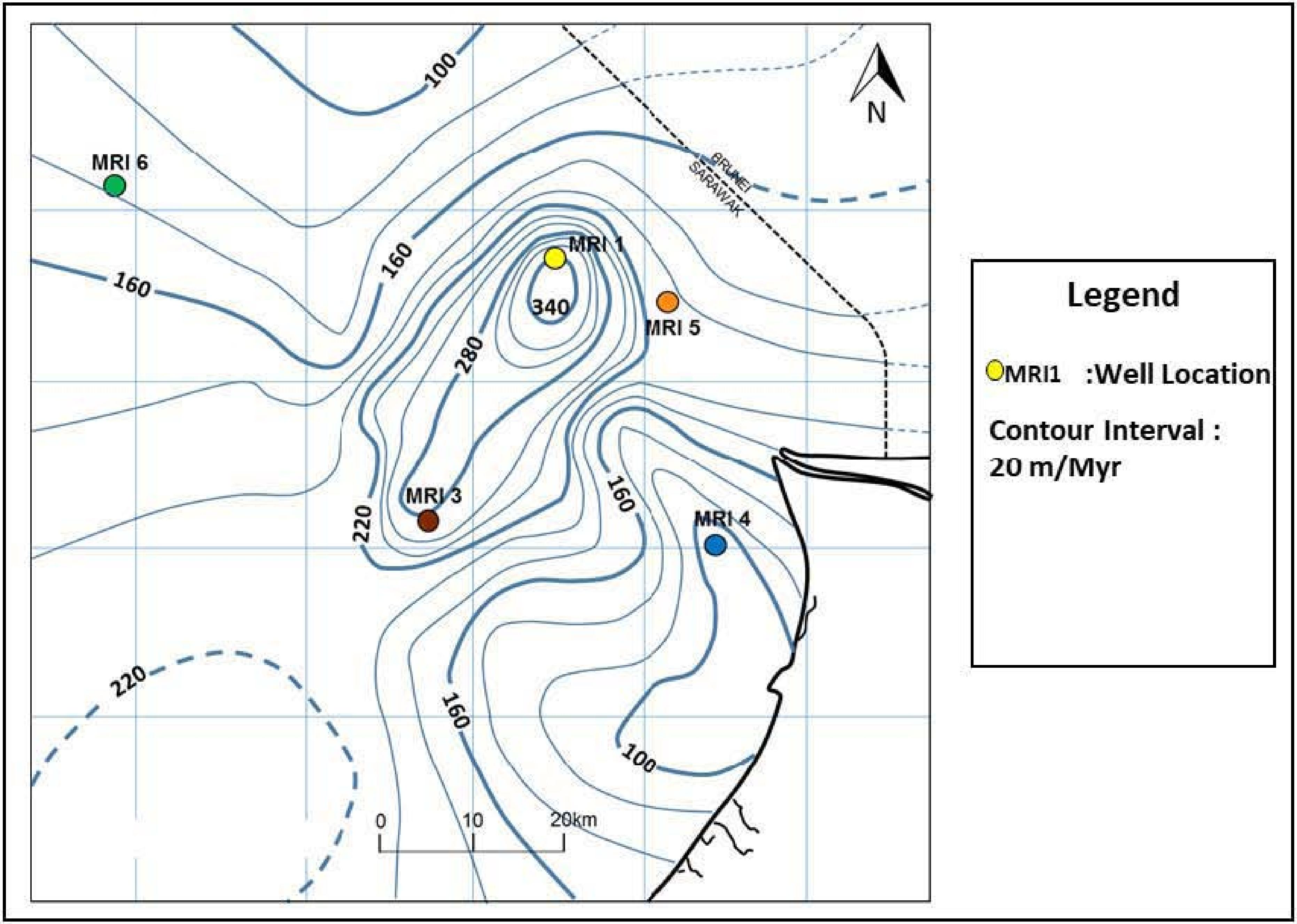

Figure 3. The rate of sedimentation within overpressure zones in study area.

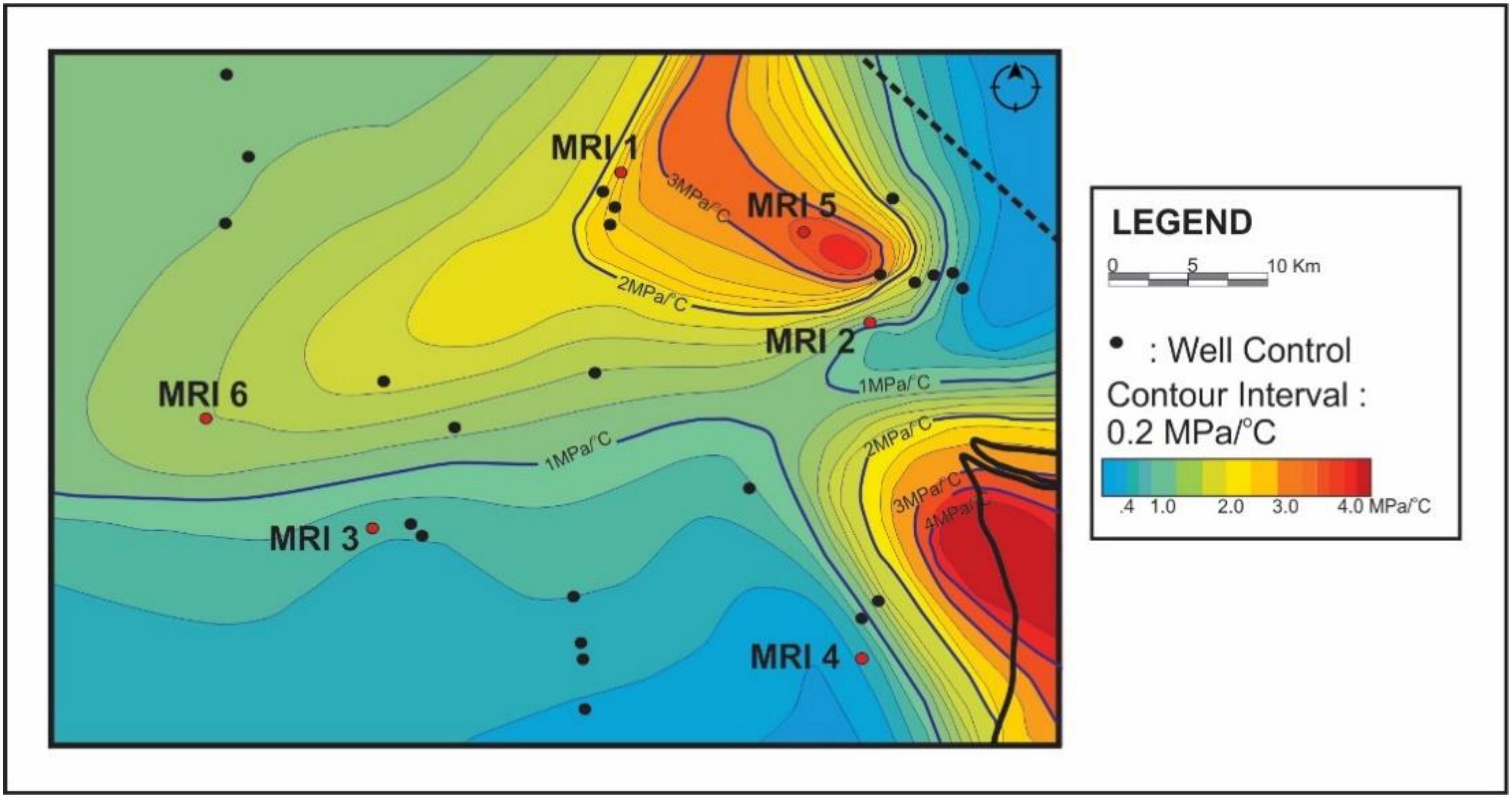

Figure 4. The distribution of pressure/temperature gradient at overpressure interval. P/T gradient is low in area of disequilibrium compaction, whereas it is high in area of fluid expansion mechanism (modified after Yusoff, 2008).

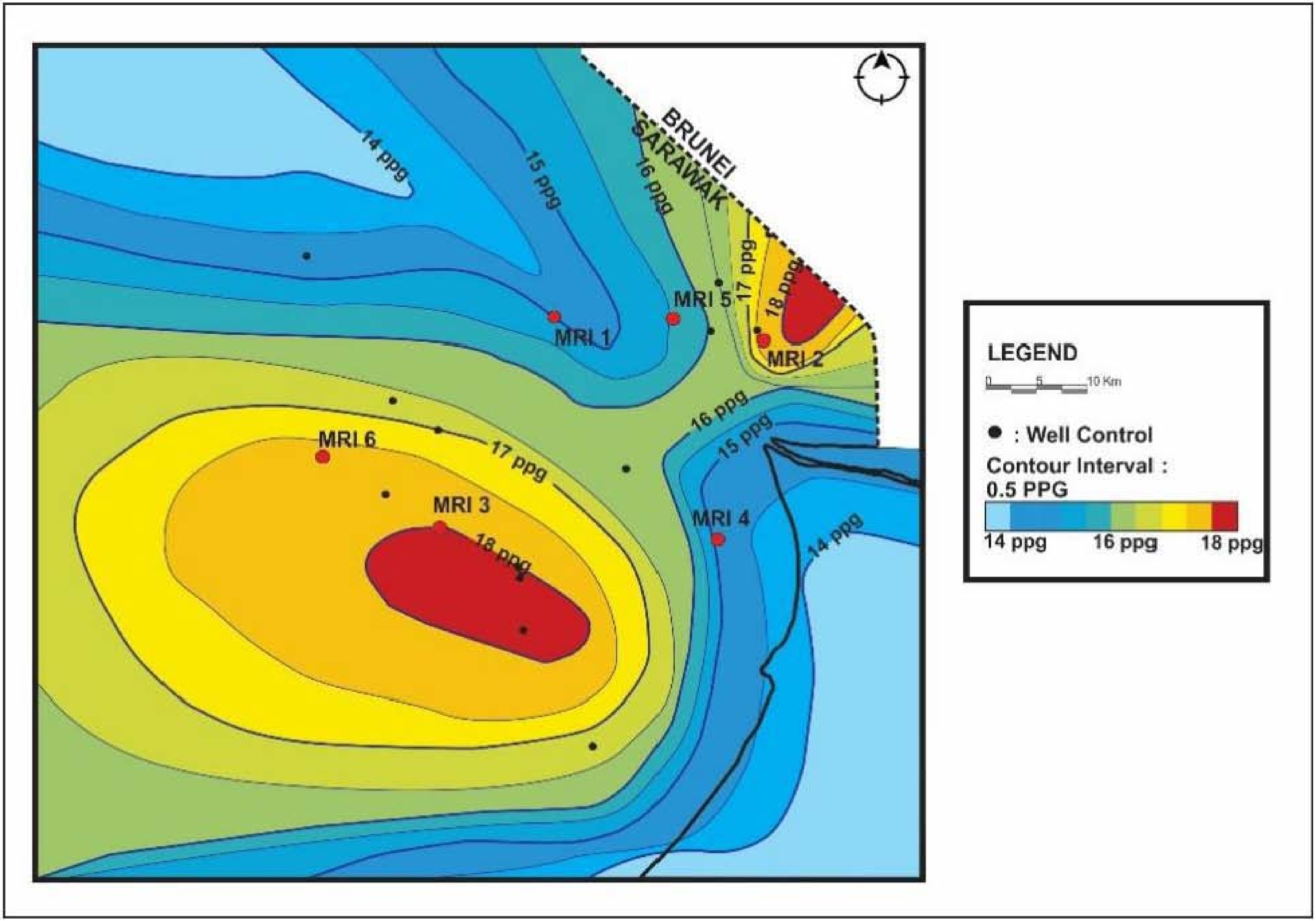

Figure 5. Map showing the distribution of fracture gradient in study area. The fracture gradient ranges from 15 ppg to 18 ppg.