

# **Distribution of Overpressure and its Prediction in Saurashtra Dahanu Block, Western Offshore Basin, India\***

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## **Abstract**

Overpressured formations are encountered in the Saurashtra Dahanu PEL Block, Western Offshore Basin, India. The block covers an area of 2500 sq. km. and six wells have been drilled so far for exploration of hydrocarbon to test prospectivity within Early Eocene to Early Miocene sequences. The thick basin fill of over 6000 m is characterized by high geothermal gradient and overpressure. The drilled well data indicate that overpressured formations occur at depths ranging from 1800 m to 3600 m within Early Eocene to Early Miocene strata. The overpressure was encountered in both limestone and shale sections in the area. Overpressure in Early Miocene limestone is confined in nature and overpressured pore fluid is developed probably due to fluctuating bathymetry and inability of pore fluid to escape. Since measured formation pressure data is scanty, the mud weight used while drilling is considered to be indicative of formation pressure where overpressure led to well activity. Normally it is assumed that mud weight used to control such well activity is higher than formation pressure. Drilling any high pressure and high temperature well is a costly affair in terms of well design and rig cost. We have used seismic interval velocity to predict overpressure in the Saurashtra Dahanu exploration block. Our analysis of plots of seismic interval velocity against time shows regression against zone of abnormal pressure. The well which did not show any regression in interval velocity vs. time plot did not encounter any high pressure while drilling. The acoustic well log analysis also show that travel time decreases within over-pressured zone. Our analysis can be used in the future locations to be drilled which may result in cost savings in terms of well design and rig cost and lead to smooth drilling of wells.

## Introduction

Overpressures are common in sedimentary basins all over the world and require careful pre-drill assessment and well planning for successful completion of any exploratory well. Overpressures, sometimes, called “geopressure” are common in subsurface rocks. A pore pressure fluid is overpressured if its pressure exceeds that of a hydrostatic pressure gradient at specific depth (Osborne and Swarbrick, 1997). They have been studied in detail in geophysics (Bethke, 1986) and geodynamics (Turcotte and Schubert, 1982). Loading during burial can generate considerable overpressure due to disequilibrium compaction during rapid subsidence of low permeability sediments (Osborne and Swarbrick, 1997)

The Saurashtra Dahanu PEL block covering an area of 2500 sq. km. is situated in the north of the Bombay Platform in Western Offshore Basin, India (Figure 1). The block is characterized by high pressure leading to well activity during drilling. Six wells have been drilled so far in this area out of which four have encountered high pressure in various proportions from different geological age strata. The well B-9-D (Figure 2) drilled in the western part up to Basaltic Basement did not show any abnormal well activity during drilling. Similarly, well B-9-B, was completed without any drilling complication as the well was drilled immediately after completing the well B-9-1 which encountered well activity during drilling. The mud weights were suitably modified while drilling this well. The interval velocity in the 3-D seismic volume, acoustic travel time log data, MDT pressure data, and mud weight data during drilling in drilled wells were analysed to configure the pressure distribution in the entire study area. The mud weights represent an upper limit close to formation pressure because the weight of the mud column in the well must be greater than formation pressure to avoid possibility of uncontrolled well activity leading to blow out (Lee and Deming, 2002). The present study attempts to address distribution of overpressure and its prediction in the block. Our analysis shows that seismic interval velocity may be used to predict overpressure in the undrilled locations in Saurashtra-Dahanu block and nearby areas for better well design and cost effectiveness and successful completion of exploratory well.

## Geological Background

The Saurashtra Dahanu block is situated to the north of the Bombay Platform, southwest of the Tapti-Daman area and east of the Saurashtra depression. It has an area of 2500 sq. km. with B-9 field in the northwestern part (Drilled wells B-9-A, B-9-B, B-9-C, and B-9-D) and B-12-9 field in the southeastern part (Drilled wells B-12-9-A and B-12-9-B). The sedimentary fill in the drilled wells range from 3000 to 4400 m. The deepest well, B-9-D, which encountered basaltic basement at a depth of 4250 m was terminated at 4433 m. The basin consists of sediments from Paleocene to Recent and overpressures have been encountered within Eocene, Early Oligocene, Late Oligocene, and Early Miocene respectively. The generalised stratigraphy is given in Figure 3.

The B-9 structure in the northwest is a northeast-southwest trending inversion structure formed due to reactivation of northeast-

southwest trending fault. However the intensity of the structural strain is more pronounced in the eastern part, where wells B-9-A, B, and C are drilled, as compared to western part, where B-9-D is drilled. The B-12-9 field in the southeastern part is located on a basement high and has been subjected to rotational movement. The strike slip movement has resulted in the structuring along B-12-9A and its northwestern corridor. The small structures formed are broadly east-west trending.

The Panna Formation of Paleocene to Early Eocene with mainly Type-III and Type-II organic matter is the dominant source rock unit. Hydrocarbon accumulation is proved within sands of Daman Formation of Late Oligocene age and Mahuva Limestones of Early Oligocene age. The migration is through deep seated faults where as shales provide effective top seals.

### **Overpressure Distribution and Prediction in the Area**

Six wells have been drilled in the area to explore Panna, Mahuva and Daman formations. Being a high pressure and high temperature area, the drilled wells witnessed drilling complications in terms of well activity in a number of wells. Only one well B-9-D has penetrated the entire sedimentary sequence in the area and terminated within basaltic basement. Daman Formation of Upper Oligocene age has produced hydrocarbon gas whereas Mahuva Formation of Lower Oligocene age flowed oil of high API. The overpressured sequences, as observed from well activity (Well completion reports) in the area are given in [Table 1](#).

We have plotted two way PSTM time against interval velocity ([Figure 4](#)) and acoustic travel time against depth ([Figure 5](#)) for all the six drilled wells in the area to configure any relationship between occurrence of overpressure in the area with lowering of seismic interval velocity and/or deviation in trend line on acoustic travel time corresponding to overpressure. Our analysis shows that overpressures encountered in well B-9-A at 2759 m and 3042/3066/3090 m correspond to lowering of seismic interval velocity from 2500 to 2800 milliseconds two way travel time ([Figure 4](#) and [Figure 5](#)). Lithologically, the intervals are characterized by limestone and shale alternations which were deposited in a fluctuating bathymetry (Kundu et al, 2007).

Similarly, in wells B-9-B and B-9-C also lowering of seismic interval velocity around 2500-2700 milliseconds two way travel time is attributed to overpressure. However, it may be noted that during drilling of well B-9-B, no well activity was observed which may be due to higher mud weight already used during drilling of this section with the drilling experience of well B-9-A. The mud weight used while drilling the overpressured section in well B-9-B was in the range of 13.6-13.9 ppg in the interval 2700 – 2800 m (Note the equivalent overpressured section was controlled with mud weight of 13.8 ppg in well B-9-A at 2759 m depth as given in [Table 1](#)).

In well B-9-C, another lowering of interval is observed around 1900 milliseconds which encountered water kick while drilling at 2390 m. A thick 90 meter, mainly limestone strata with thin intercalations of shale, were penetrated in this section. The MDT pressure of 5323 psi is calculated to be equivalent to 12.99 ppg mud weight. [Table 1](#) shows that mud weight which was required to control this

kick was 13.0 ppg mud weight.

In well B-12-9 A, lowering of seismic interval velocity around 2000 milliseconds and 2450 to 2800 milliseconds is observed where splashing of mud at well mouth was observed during drilling. These two way travel times correspond to depths of 2163 m, 2698 m, and 2804 m respectively where well activity was observed. The recorded reservoir pressure around 2800 m was measured to be around 16.4 ppg mud weight equivalent. The mud weight which was used to control the well activity at this depth was 16.8 ppg.

The well B-9-D was recently drilled to target depth of 4433 m and has penetrated the entire sedimentary sequence and terminated within weathered basaltic basement. In this well overpressure was not encountered while drilling the entire well. In well B-9-D, the equivalent section, where lowering of interval velocity is not seen (i.e. around 2500 milliseconds shown in rectangle in [Figure 4](#)) was drilled with mud weight of 13.1-13.5 ppg in the interval 2700 – 2900 m. The seismic interval velocity curve shows no apparent lowering in this well and follows almost a straight line compared to other wells where overpressures have been encountered. Lithologically this well also exhibits limestone and shale alternations in the target section.

Based on our study, we have demarcated the likely overpressured and normal pressured areas ([Figure 6](#)) in the study area. The time structure map close to Early Oligocene top shows that the area lying to the west show normally pressured area (shown with black dotted lines over the faults). Incidentally, the normally pressured area is bound by the northeast – southwest inversion fault in the eastern area bounding the B-9 structure (encompassing wells B-9 A and B-9-B) whereas in the southern area the east – west trending strike slip fault limits the normally pressured area.

Our study, thus demonstrates, that seismic interval velocity as a tool can be used to predict overpressure in the Saurashtra-Dahanu exploration block. This will lead to reduced exploration cost in terms of rig design, casing design, and lower mud weights. This study was not intended to address the mechanism of over-pressuring in this block for which more studies will have to be undertaken.

### References

Bethke, C.M., 1986, Inverse hydrologic analysis of the distribution and origin of Gulf Coast-type geopressured zones: *Journal of Geophysical Research*, v. 91, p. 6535-6545

Kundu, R.N., T.K. Banerjee, J.P. Tiwari, M.M. Maindarkar, 2007, Biostratigraphy and sedimentological study of Upper Mahuva formations, Regional Geoscience Laboratory, Western Offshore Basin, Mumbai (ONGC unpublished report)

Osborne, M.J., and R.F. Swarbrick, 1997, Mechanism for generating overpressure in sedimentary basins: a re-evaluation: *AAPG*

Bulletin, v. 81, p. 1023-1041

Turcotte, D.L., and G. Schubert, 1982, *Geodynamics of Applications of Continuum Physics to Geological Problems*: Wiley, New York, New York, 450 p.

Well Completion reports of Wells B-9-A, B-9B, B-9-C, B-9-D, B-12-9- A, and B-12-9-B  
(Unpublished ONGC reports).

Youngman, L., and D. Deming, 2002, Overpressures in Anadarko Basin, southwestern Oklahoma: Static or Dynamic?: *AAPG Bulletin*, v. 86, p. 145-160.

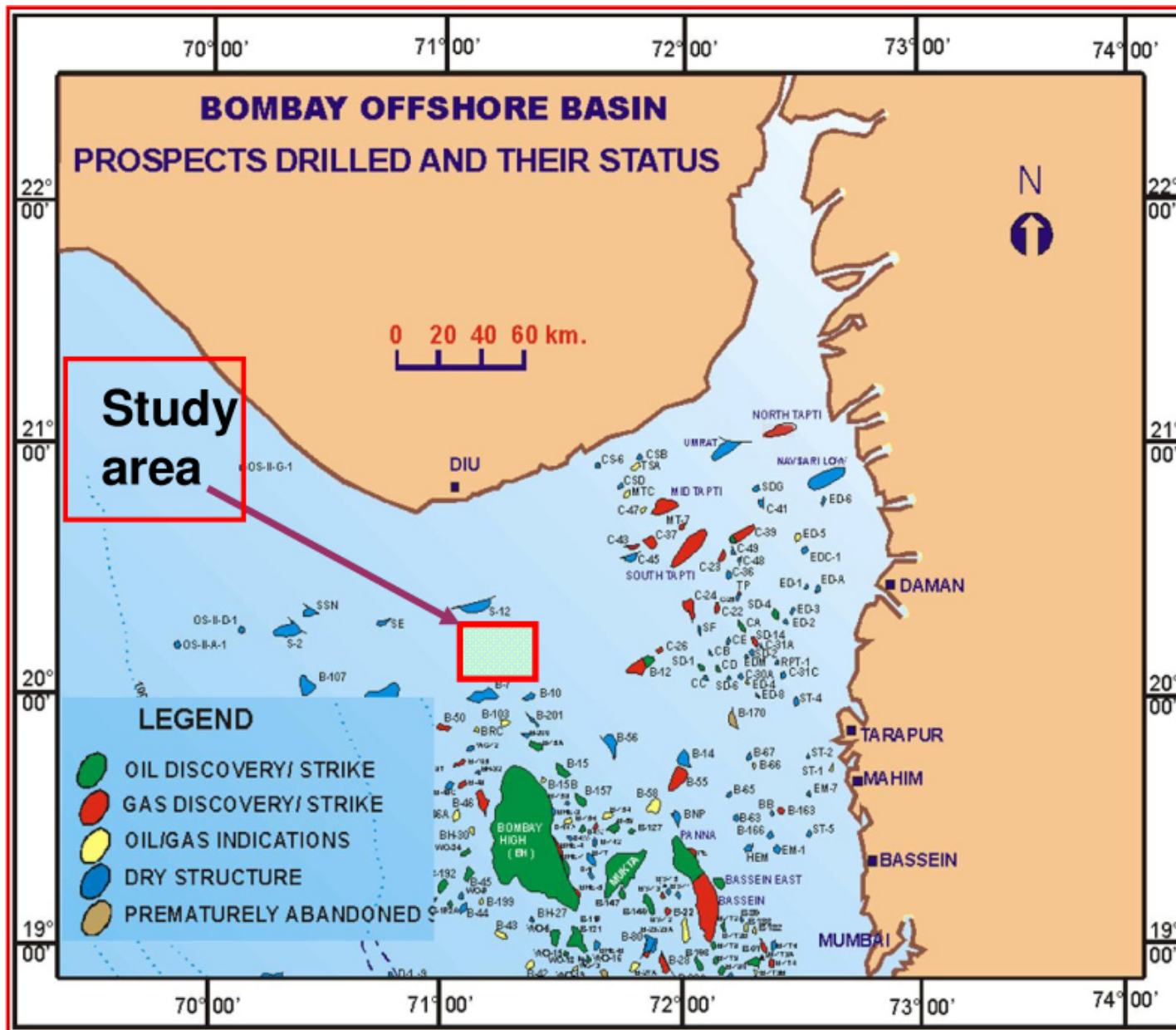


Figure 1. Map showing the study area.

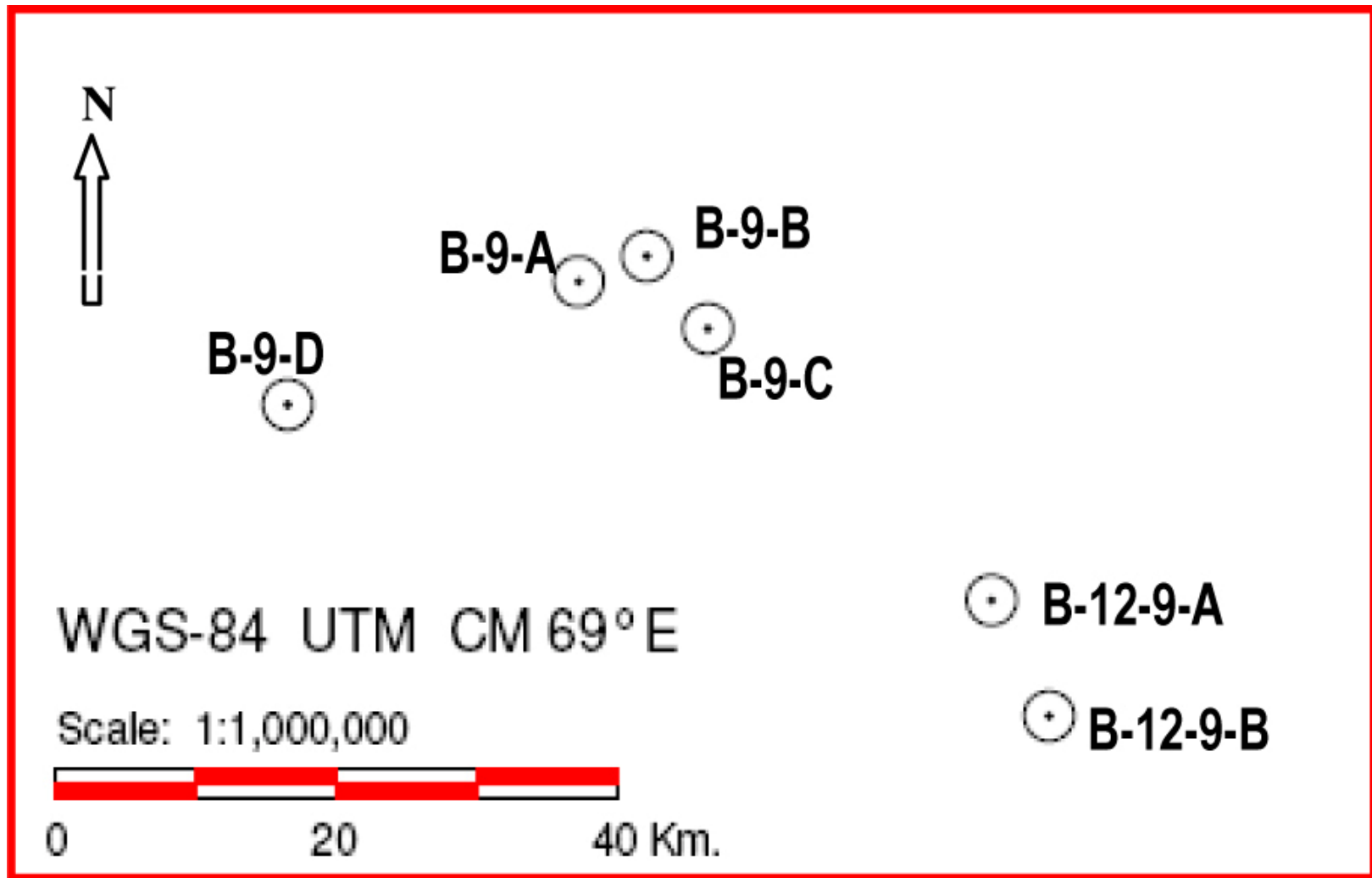


Figure 2. Location map showing position of wells drilled in the study area.



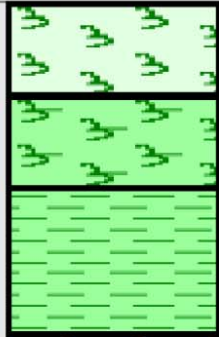
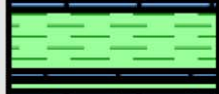





Age	Formation	Thickness (m)	Lithology	Environment of Deposition	Bathymetry (m)
Recent to Late Miocene	Chinchini	1430			
Middle Miocene	Bandra & Tapti	400		Carb. platform Prodelta	
Early Miocene	Mahim & Bombay	600		Pre_delta Poorly agitated platform interiors	
Late oligocene	Daman	480		Tidal flat & near shore environment	20-30
Early Oligocene	Mahuva	520		Shallow open marine	10-30 40-100
Eocene to Paleocene	Panna	570		Inner Neritic Open circulation shelf	10-20
Creataceous	Deccan Trap	400(+)			

Figure 3. The generalised stratigraphy of the area.



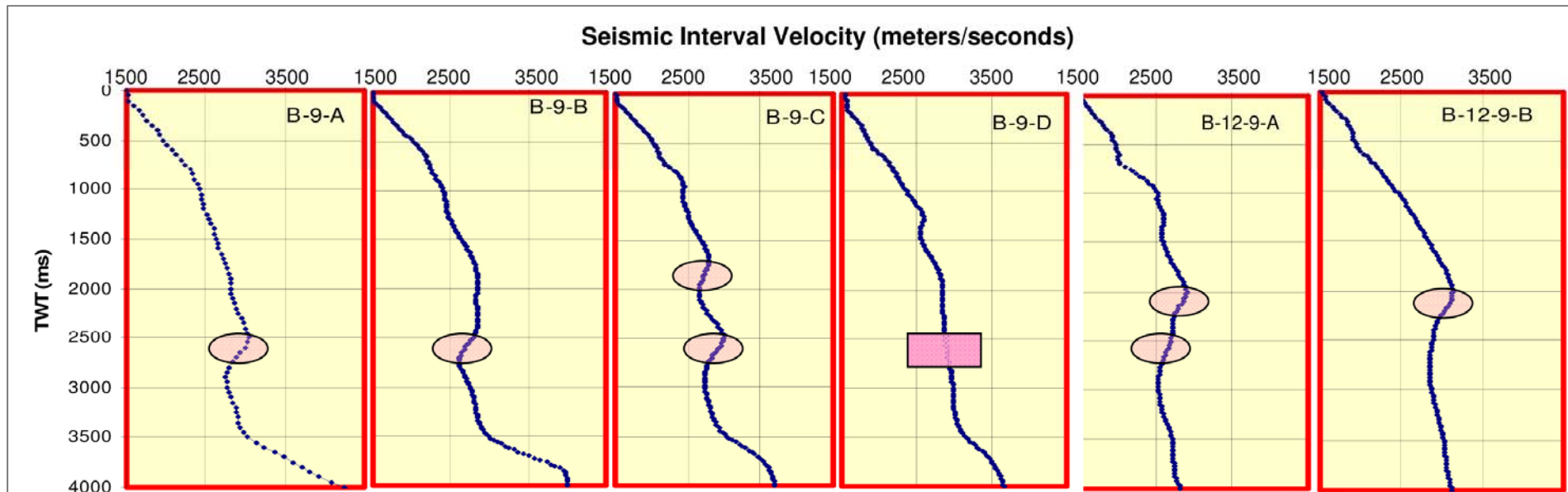


Figure 4. Plot of seismic interval velocity (in 'X' axis in meters/seconds) against Two Way Travel Time (in 'Y' axis in milliseconds) showing lowering of velocity in overpressured zones (marked in circle). Note that in B-9-D there is no deviation in the trend line (marked in rectangle).

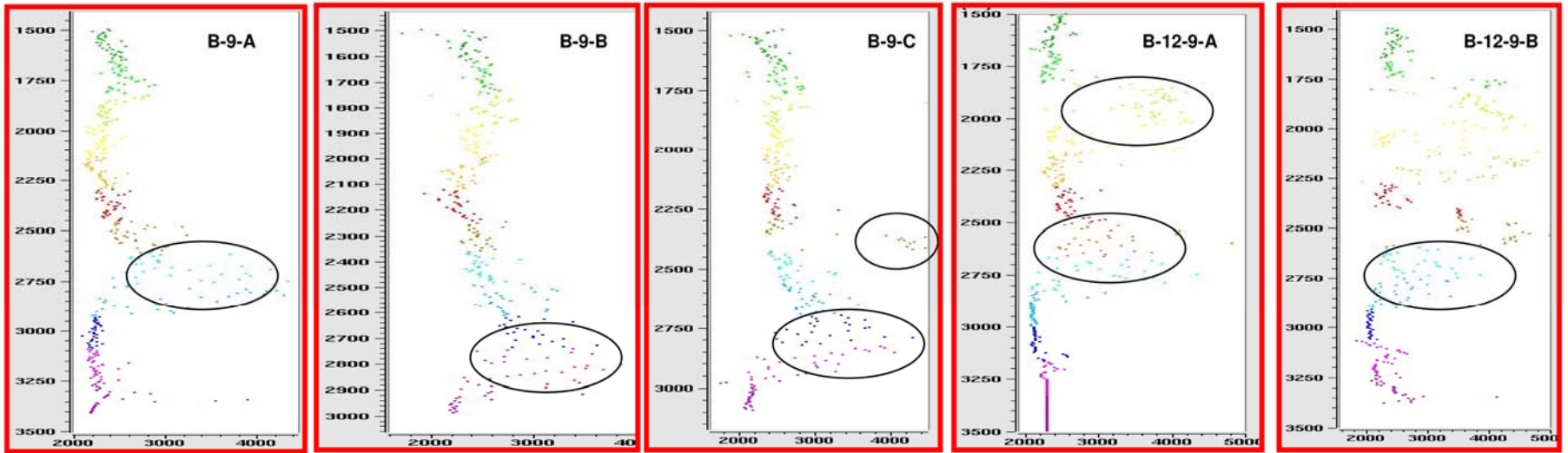


Figure 5. Plot of sonic travel time (in 'X' axis in meters/seconds) against depth (meters) showing lowering of velocity against overpressured zone (marked in circle).

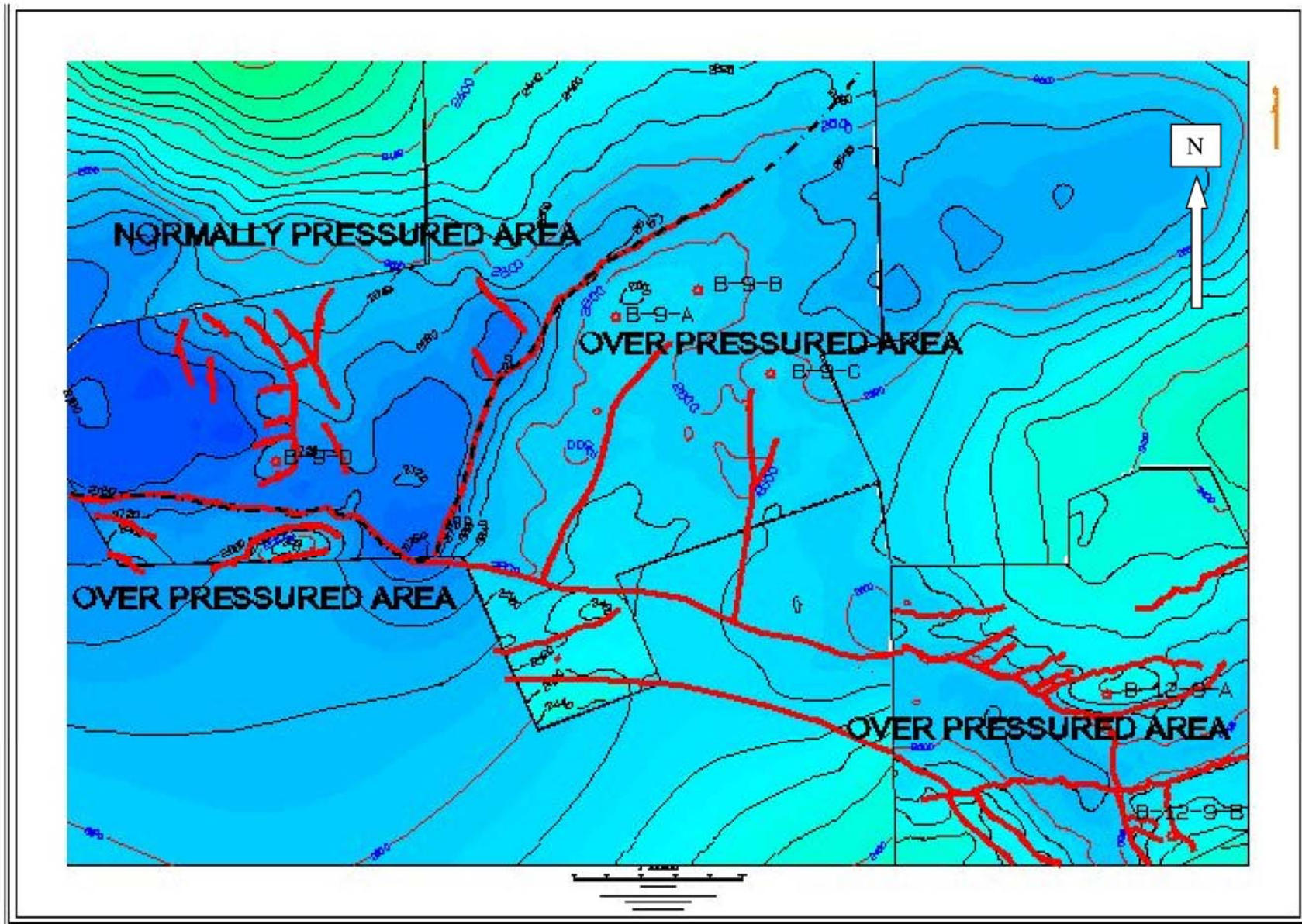


Figure 6. The time structure map close to top of Early Oligocene showing the normally pressured area and overpressured area in the study area. The area west of north east – south west inversion fault and north of east – west striking strike slip fault.

Sl. No.	Well	Depth (M.D.) in Meters	Formation	MW used (ppg)	Nature of well activity	MW used to control (ppg)
1	B-9-A	2759	Mahuva	12.7	While drilling at 2753m, drill break was observed followed by gas bubbling along with total gas of 19% in MLU	13.8
2	B-9-A	3042/ 3066/ 3090	Mahuva	14.0	Well activity with total gas of 8.9% - 9.9% in MLU besides self flow and gas bubbling at well mouth.	14.8
3	B-9-C	2390	Bombay	11.9	While pulling out string for coring, observed self flow and pit gain of 6 bbl/hour.	13.0
4.	B-9-C	3116/ 3130	Mahuva	14.4	While drilling at 3116m, pit gain of 3 bbl in 10 minutes was observed.	15.6
5	B-12-9-A	1880/ 1887/ 1930	Bombay	10.5	Observed self flow, pit gain and detected total gas in MLU unit.	12.1
6	B-12-9-A	2163	Daman	12.1	During pipe connection observed self flow of 100 bbl/hr, reduction in mud wt and drop in viscosity and total gas 8% in MLU.	12.5
7	B-12-9A	2698	Mahuva	13.4	Self flow and total recorded gas in MLU 52%.	14.0
8.	B-12-9A	2804	Mahuva	14.0	Heavy splashing of mud at well mouth, total gas 40%.	16.8
9	B-12-9B	2159	Bombay	11.5	During drilling self flow was observed.	12.7
10	B-12-9-B	3547	Panna	16.7	Observed 3% increase in flow rate during drilling but no self flow during static condition. Tried to kill with mud wt. of 17.3 ppg but observed mud loss. Terminated well at 3565m under mud loss and mud pit gain condition.	17.8

Table 1. Nature of well activity, mud weights used during drilling, and mud weights used to control the well activity.