Foresee the Unforeseen: Modeling West Baram Delta Overpressure, Offshore Sarawak*

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Abstract

PETRONAS Carigali and Shell Sarawak Berhad commenced a drilling campaign in SK307 in 2011 that constituted the first HPHT wells to be drilled with a 15K capacity rig in the West Baram Delta. Understanding regional overpressure behavior will allow more accurate modeling of the pore pressure behavior for future HPHT exploration opportunities and robust well planning.

Data from 62 West Baram Delta wells (MDT/RFT, Mud weight, Kick, FIT, and LOT) indicates that the onset of overpressure occurs at different depths within these wells, which is both controlled structurally and stratigraphically.

Seismic velocity overpressure modeling was undertaken in 25 wells using both VP_VES Tau transform and Eaton exponent methods. Using a Tau function, it was observed that seismic velocities under predict the overpressure buildup. There is a large variation in Eaton exponents required to calibrate wells in the broader West Baram Delta and location specific exponents must be applied. A large number of 3D seismic datasets covered the area of interest and it was observed that short cable data (3 km) have limited use with poor match to well data. Datasets with 4.5 km cable length demonstrated more robust tie to the modeled wells.

Under-compaction overpressure was identified as the predominant overpressure mechanism in the region. Under-compaction was driven by the rapid sedimentation underneath the prograding delta. In the southern West Baram Delta, late inversion resulted in unloading due to the structural overprint. Observation showed a significant pressure increase beyond the under-compaction trend in

some wells which was inferred as inflationary overpressure. Prediction of this overpressure mechanism was difficult due to limited expression of seismic velocities and log responses.

The development of an integrated geological model incorporating all available well and seismic data underpins the prediction of overpressures in exploration prospects. Subsequently, this will significantly influence the well and subsurface target locations, well casing design (casing type and setting depth), mud weight program, evaluation, and well monitoring program for well planning.

Regional Setting

SK307 is located within the West Baram Delta province, offshore Sarawak (Figure 1). The western region of the delta is marked by the West Baram Line, a system of large, north-northwest trending, down-to-basin faults, that separate the delta from the older and stable Central Luconia province in the west. The eastern margin is defined by Moris-Jerudong Fault Line in Brunei, which separates the delta from the older inboard belt in offshore NW Sabah.

The Baram Delta is characterized by the deposition of north to northwest prograding, deltaic system since The Middle Miocene. Periods of delta progradation were separated by rapid transgressive events, represented by marine shale intervals, which also form the boundaries of sedimentary cycles. Each cycle exhibits depositional environments which vary from fluvio-marine to neritic. The entire delta developed during a period of rapid subsidence, relative to the more stable Central Luconia and Balingian Provinces to the west. In addition, syn-depositional NE-SW trending growth faults have locally influenced sediment thickness.

The total Tertiary sequence comprise of up to 9-10km of sediments. The sediment source for this sequence is predominantly from the catchment area of the present day Baram River.

The structural style of West Baram Delta is predominantly influenced by two phases of deformation. Gravity-induced, syn-depositional, NE-SW trending growth faults form large structures during the Middle Miocene, which are characteristic Baram delta tectonics. Basement induced compression; with wrench induced folding is only observed in the southern part of SK307. Finally, Quaternary uplift resulted in the uplift resulted in the emergence of the Borneo coast and land area, and the erosion of the younger cycles in the south.

Well Data and Methodology

Data from 62 West Baram Delta wells (MDT/RFT, Mudweight, Kick, FIT and LOT) was collated that indicates that the onset of overpressure occurs at different depths within these wells, which is both controlled structurally and stratigraphically (Figure 2).

Seismic velocity overpressure modeling was undertaken in 25 wells using both VP_VES Tau transform and Eaton exponent methods. Using a Tau function, it was observed that seismic velocities under predict the overpressure buildup (Figure 3). There is a large variation in Eaton exponents required to calibrate wells in the broader Baram Delta and location specific exponents must be applied.

A large number of 3D seismic datasets cover the area of interest and it was observed that short cable data (3km) have limited use with poor match to well data. Datasets with longer cable length demonstrates a more robust tie to the modeled wells (Figure 4).

Overpressure Mechanisms and Impact on Pore Pressure Prediction

Under-compaction identified as the predominant overpressure mechanism in the West Baram Delta (Figure 5). Under-compaction is driven by the rapid sedimentation underneath the prograding delta. In the southern West Baram Delta, late inversion results in unloading due to the structural overprint. Inflationary overpressures are inferred in some wells where significant overpressure increases are observed beyond the under-compaction trend.

A primary concern for pore pressure prediction in exploration prospects is the possibility of encountering inflationary overpressures (also termed late overpressures). Wells that have encountered inflationary overpressure are characterized by a lack of clear inversion in sonic and resistivity log profiles, with abrupt pressure increase, however with considerable variation in magnitude.

Rapid pressure increase has resulted in early TD of previous wells, interpreted to be due to is lateral communication of shallow reservoirs with deeper, under compacted sequences. Prediction of inflationary overpressure is difficult with limited expression observed in seismic velocities and log response. Although an integrated geological model can be applied to understand the reasons for such inflationary overpressures (both structurally and stratigraphically controlled), there is limited predictive capacity for exploration opportunities and this must be considered in well planning.

Conclusion

The development of an integrated geological model incorporating all available well and seismic data underpins the prediction of overpressures in exploration prospects. Subsequently this will significantly influence the well and subsurface target locations, well casing design (casing type and setting depth), mud weight program, and evaluation and well monitoring program for well planning.

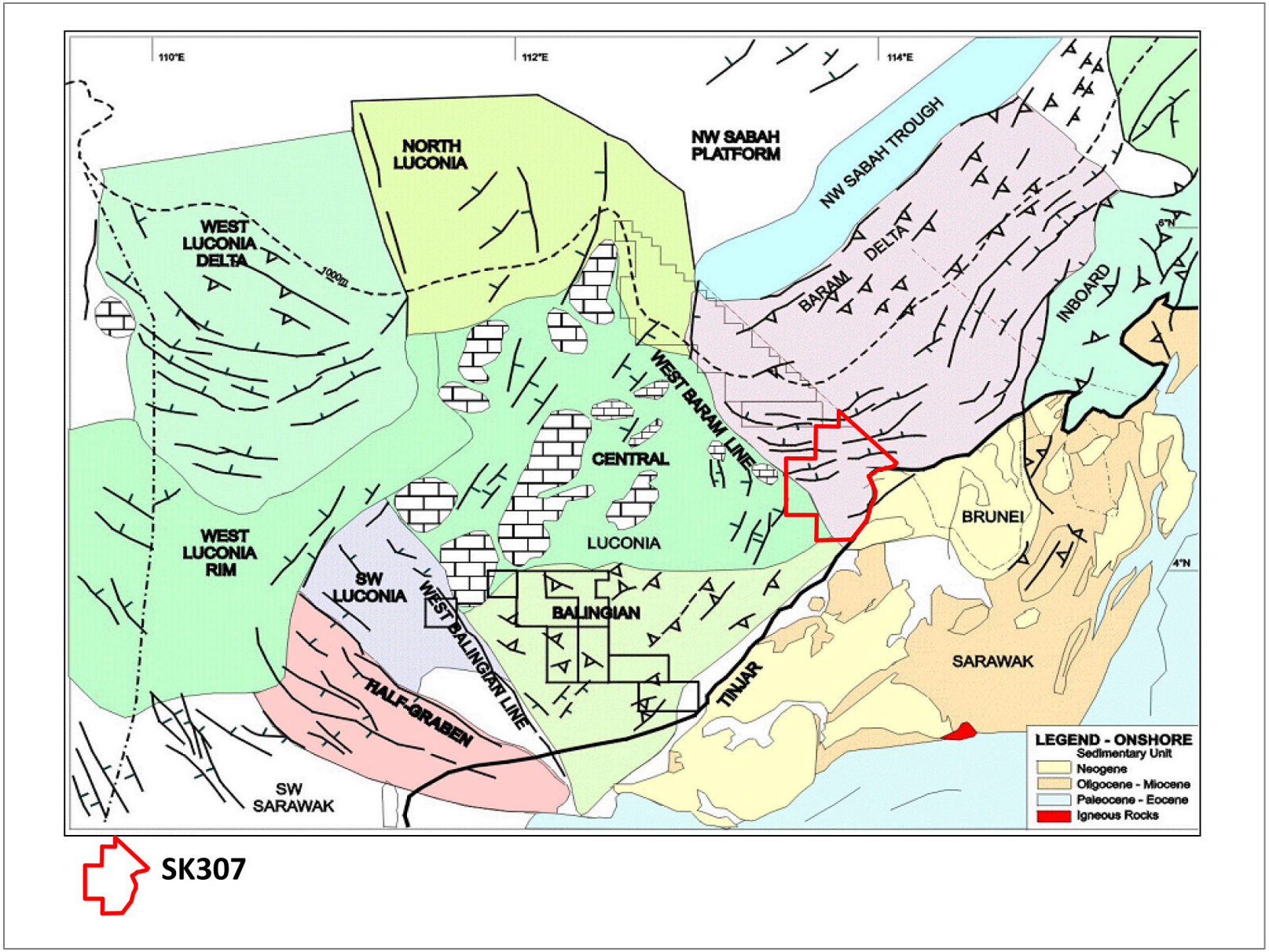

Figure 1 – Location map West Baram Delta, Sarawak, Malaysia

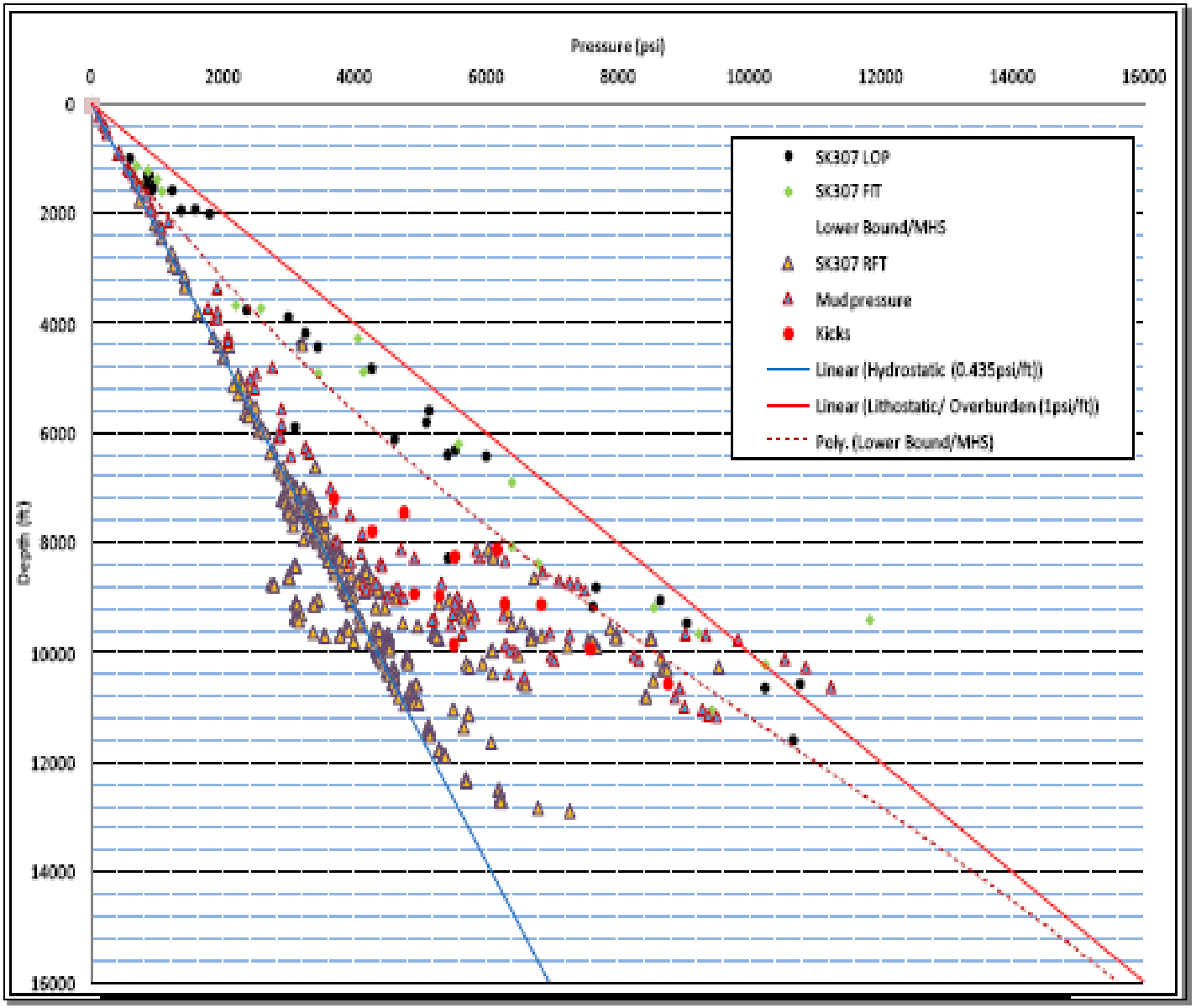

Figure 2 – West Baram Delta Well Pressure Data

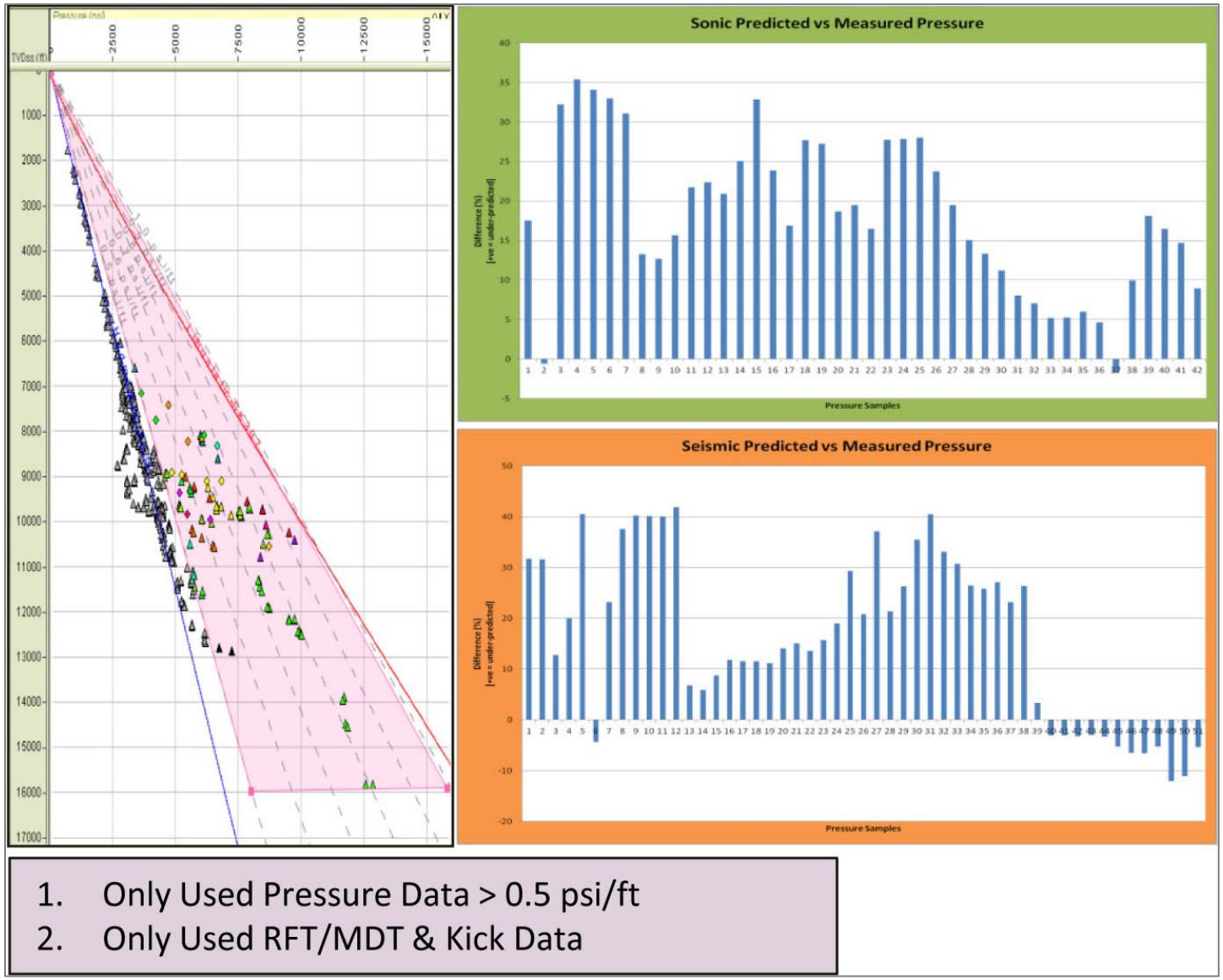

Figure 3 – Statistical Analysis of Tau method modeling against measured pressure

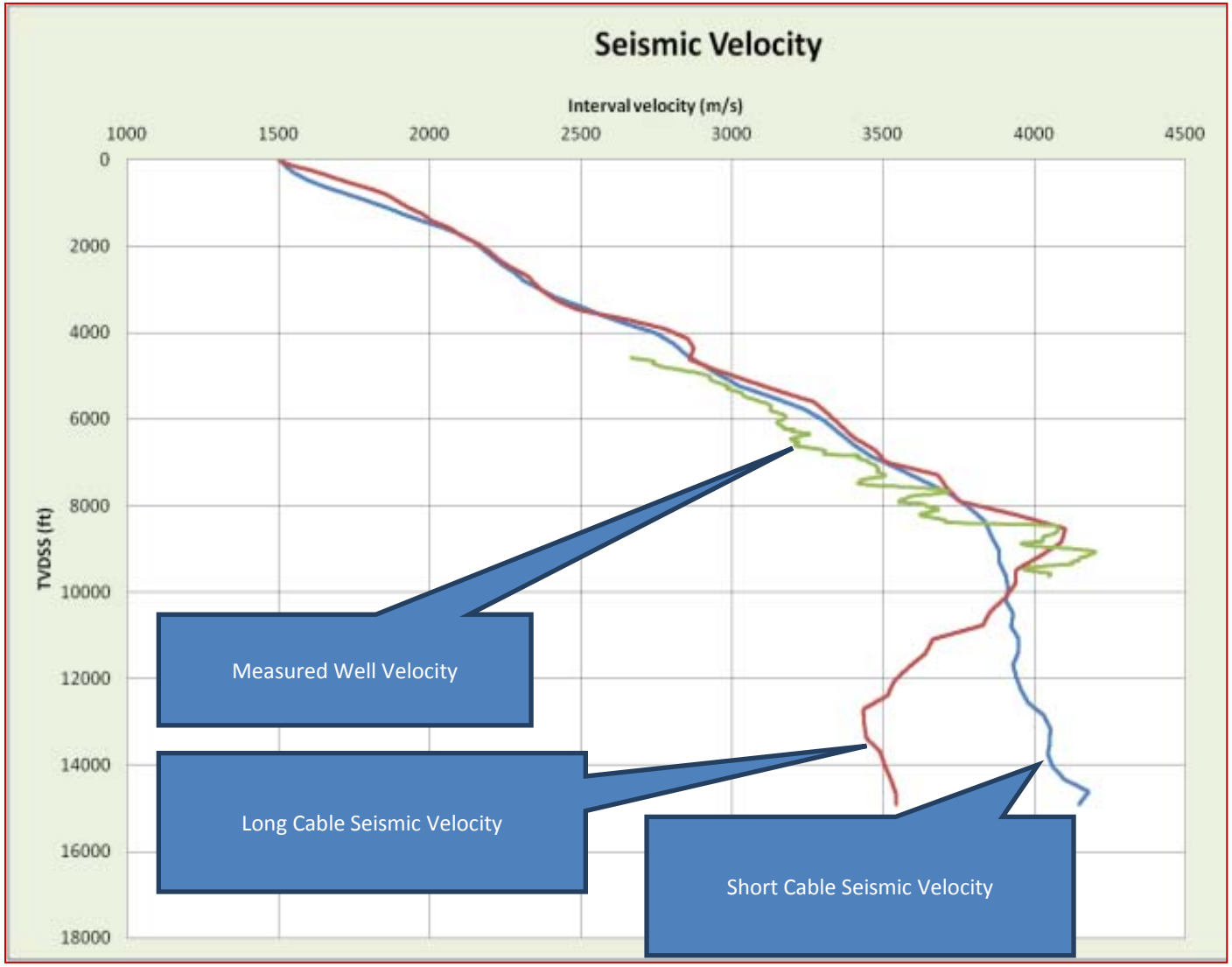

Figure 4 – Well – Seismic Velocity Comparison

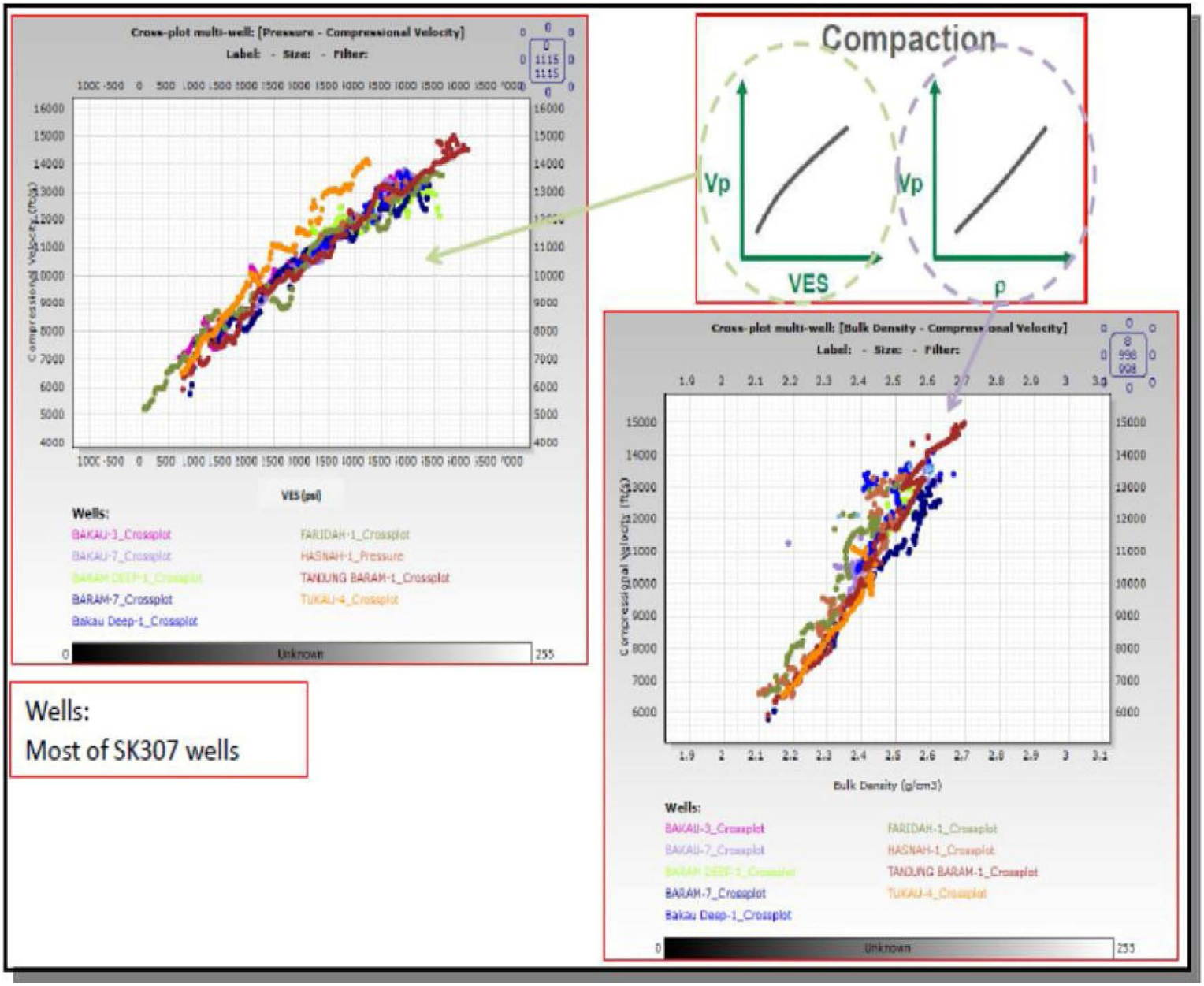

Figure 5 – Porosity (Sonic velocity) vertical effective stress plots for most of the SK 307 overpressure wells showing that all points lie on the loading curve, indicating under-compaction as the main overpressure generating mechanism.