Overpressure and Seal Integrity Evaluation on Oligocene-Miocene Carbonates Reservoir in the Madura Strait Area of East Java Basin-Indonesia*

Iko Sagala[1], Syaeful Amin[1], and Yanyan Triyana[1]

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[1]Santos (Sampang) Pty. Ltd., Jakarta, Indonesia (iko.sagala@santos.com)

Abstract

Overpressure has been encountered in several wells in the Madura Strait area of the East Java Basin that were targeting the Oligocene-Miocene carbonate reservoirs. In exploration context, knowledge of overpressure becomes critical as a potential control on seal integrity for the Oligocene-Miocene carbonate reservoirs. As retention capacity is getting smaller, the risk of having mechanical failure of the top-seal increases, allowing hydrocarbons to escape. Retention capacity is defined as the least principal stress minus the pore pressure at the shallowest point in the reservoir. Leak off test (LOT) pressures are used as a measure of the least principal stress (Gaarenstroom et al., 1993). To evaluate the top seal integrity over the Oligocene-Miocene carbonates reservoir structures, we examined the overpressure and retention capacity distribution to find the relationship with the mechanical seal failure occurrence. The results can then be used for a better seal integrity risking for future Oligocene-Miocene carbonate prospects.

Discussion

The study area is structurally located in the Randublatung Zone; a main depocentre for bathyal sediments during the Miocene-Pliocene age (Figure 1 and Figure 2). The shallow marine carbonates complex (Kujung and Rancak sequences), developed on an offshore paleo-high were formed during the Oligocene-Early Miocene and then subsequently sealed by the Mid-Miocene Wonocolo bathyal shales. In the western portion of the study area, the top of Oligocene-Miocene carbonate is separated by an unconformity from Pliocene-Pleistocene deep marine volcaniclastic sediment derived from the uplifted volcanic arc in the south (Kusumastuti et al., 2002).

The basis for this study is formed by an integrated pore pressure and LOT pressures database from six offshore wells (Figure 3). Two wells (Well K and Well B) are located at the western area whereas the other four wells are located at the central area. Pore pressure data focused only on the Oligocene-Miocene carbonate reservoir, and on readings as measured during Wireline Formation Tests (WFTs), Drill Stem Tests (DSTs), and kick occurrence.

Geographically, the wells located in the central area tend to have greater overpressure magnitude compared to the wells located in the western area. The top overpressure at the western area (example well B) was encountered at the Pliocene-Pleistocene age sediments whereas the top overpressure at the central area (example well M) was at the Mid Miocene age Wonocolo sediments (Figure 3). The pore pressure trend from both wells shows a lithostatic parallel profile, indicates overpressure generated due to disequilibrium compaction. At well M, a sharp pressure transition zone at depth around 3200 mSS, corresponding to temperature 140°C, indicates additional overpressure generated by a secondary mechanism. The velocity-density cross plot (Bowers, 2001) of shales from well M also indicates unloading (fluid expansion) mechanism, with its signature of velocity reversal and constant density as the depth increases. The vitrinite reflectance data suggests that hydrocarbon generation was by the fluid expansion mechanism that contributed to the overpressure generation at well M (Figure 4).

The result of the retention capacity calculation cross plotted with the crestal depth is shown in Figure 5a where the well results are differentiated by colour: dry hole (blue) or hydrocarbon-bearing (green). The hydrocarbon discoveries tend to occur only in the western area as found in well B whereas structures in the central area were all dry. Dry hole analyses were performed in order to understand the reason for the dry hole. The well K was dry not due to mechanical seal failure, but due to thick thief sands development within the overlying seal of Wonocolo section. The C, N, M, and X wells recovered water during testing, but hydrocarbon shows were encountered in cuttings. This could be interpreted as a paleo-column of hydrocarbon which would imply that the structure has been charged and was then breached. A potential threshold value of retention of 1000 psi can be used where below this value a dry hole due to mechanical seal failure can occur. The retention capacity shows a geographical trend as the retention capacity less than 1000 psi tend to be occur only the central area.

To understand why the mechanical seal failure tend to occur only at the central area, we examined the relationship between the retention capacity, structural relief height, depositional environment, and Wonocolo overlying sediment thickness. This was done for the whole Oligocene-Miocene carbonate structures. The carbonate build-up type developed both in the central and western areas has a range of structural relief of 450 m to 1000 m. In contrary, the deep-water carbonate type at the central area tend to have a low structural relief height within a range of 150 m to 250 m. No relationship can be established between the structural relief and the retention capacity (Figure 5b). The retention capacity trend can be easily differentiated from the thickness of the overlying Wonocolo sediments (Figure 5c). In the western area where the retention capacity is greater than 1000 psi, the structures were overlaid with thin Wonocolo sediments (100 to 250 m). Whereas, in the central area where the retention capacity is less than 1000 psi, the structures were overlaid with thicker Wonocolo sediments (1100 to 3300 m). In addition, the deep-water carbonates tend to have thicker overlying Wonocolo sediments and greater overpressure magnitude compare to the carbonate build up type; hence a deep-water carbonate type should increase the likelihood of mechanical seal failure.

Summary

This study reveals that overpressure and retention capacity demonstrate a correlation with the mechanical seal failure occurrence. Overpressured wells in the western area tend to have moderate-high retention capacity and preserve hydrocarbon. Whereas, overpressured wells in the central area tend to have low retention capacity and are more prone to mechanical seal failure. The overpressure magnitude tendency is greater in the central area as the overpressures were mainly generated by a disequilibrium compaction mechanism with an additional secondary mechanism of hydrocarbon generation. It is inferred that greater thickness of the overlying Wonocolo sediments act as the primary control of the low retention capacity of the Oligocene-Miocene carbonate structures. As a final output, by using the overlying

Wonocolo sediment thickness, a seal integrity risking map for Oligocene-Miocene carbonate structures can be defined (Figure 6). High risk of mechanical seal failure tends to be distributed thorough out the central area, expressed as a low retention capacity (< 1000 psi) area. In the western area, the risk of having mechanical seal failure is relatively low given the retention capacity pressures are still relatively moderate-high (> 1000 psi).

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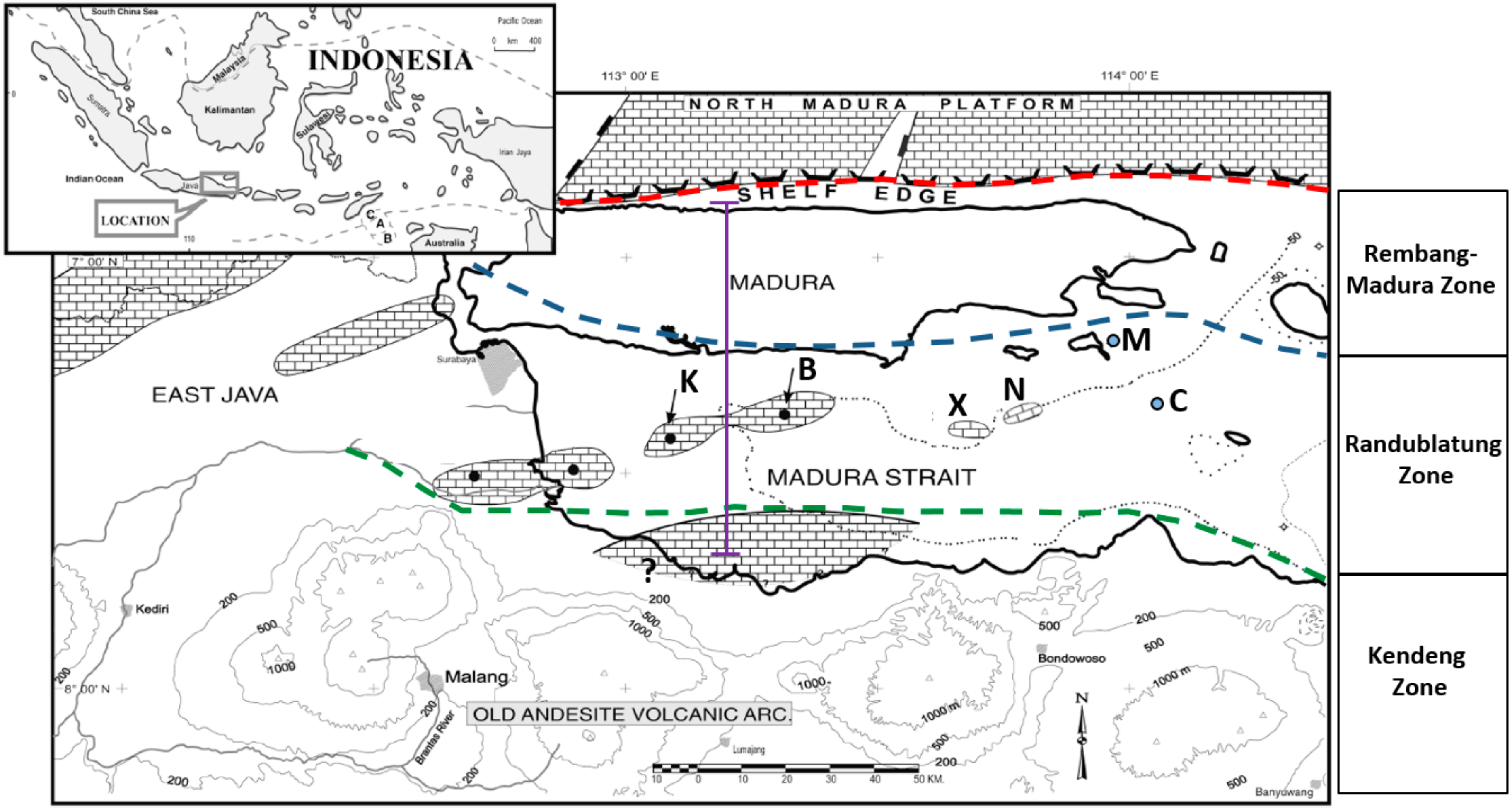

Figure 1. The simplified Early Miocene paleogeography at Madura Strait area of the East Java Basin (modified from Kusumastuti et al., 2002). The six wells/structures within this study are located in the Randublatung Zone.

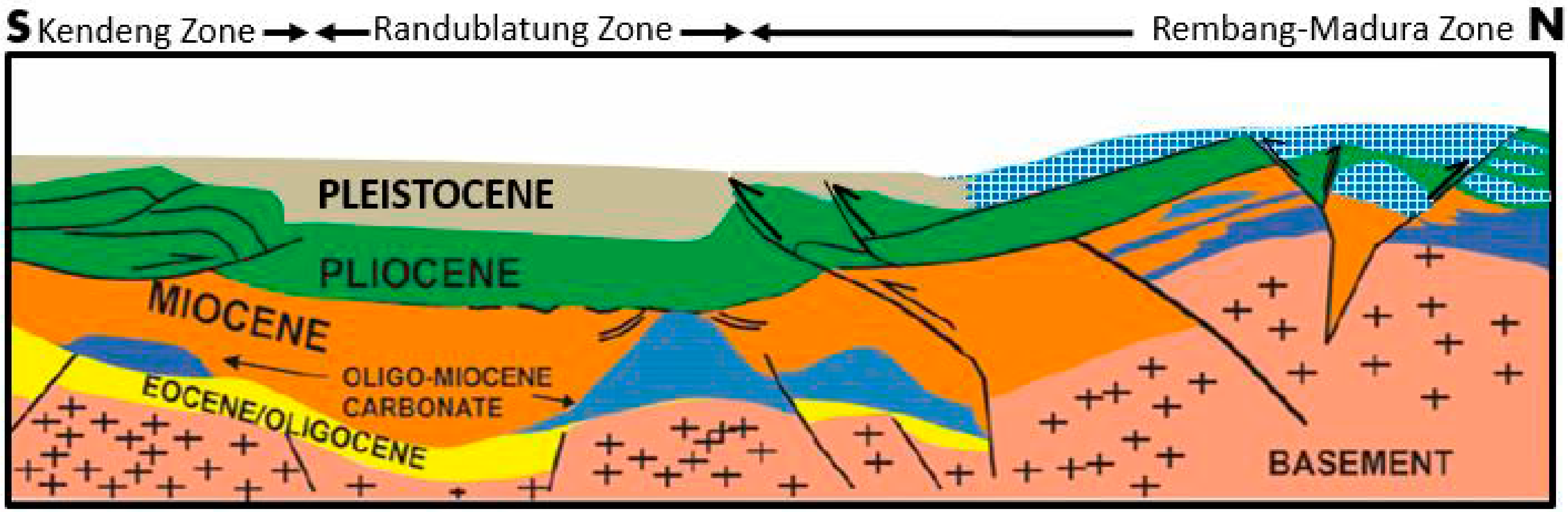

Figure 2. The north-south cross section shows depocentre configuration at the Randublatung Zone (modified from Latief et al., 1990).

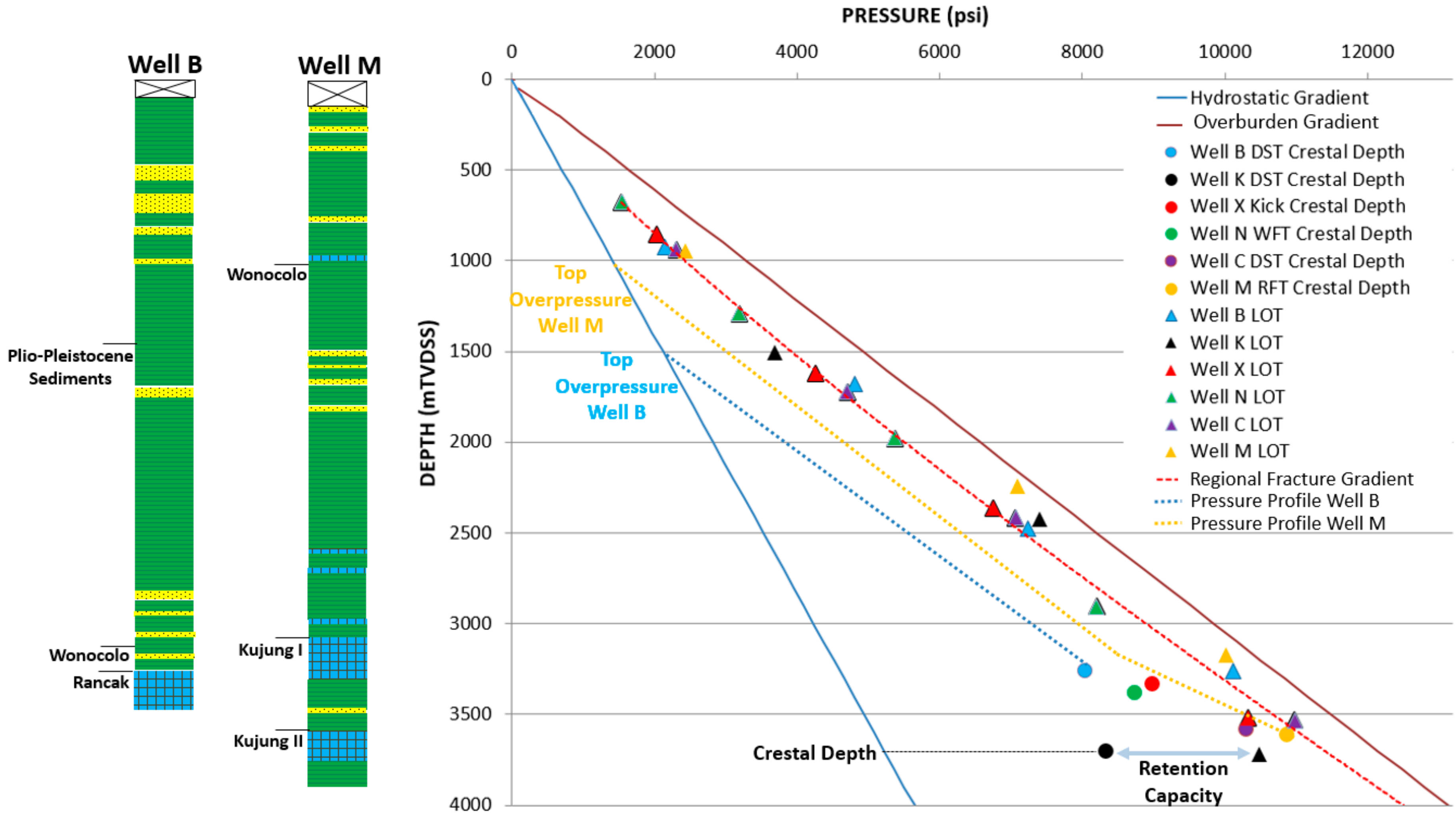

Figure 3. The pressure-depth plot showing pore pressures and leak off test (LOT) pressures. The Oligocene-Miocene carbonates reservoir are overpressured in Madura Strait area, where the central area wells have greater overpressure magnitude compared to the western area wells. An example of retention capacity definition at K structure where (LOT pressure minus the pore pressure) at the crestal depth.

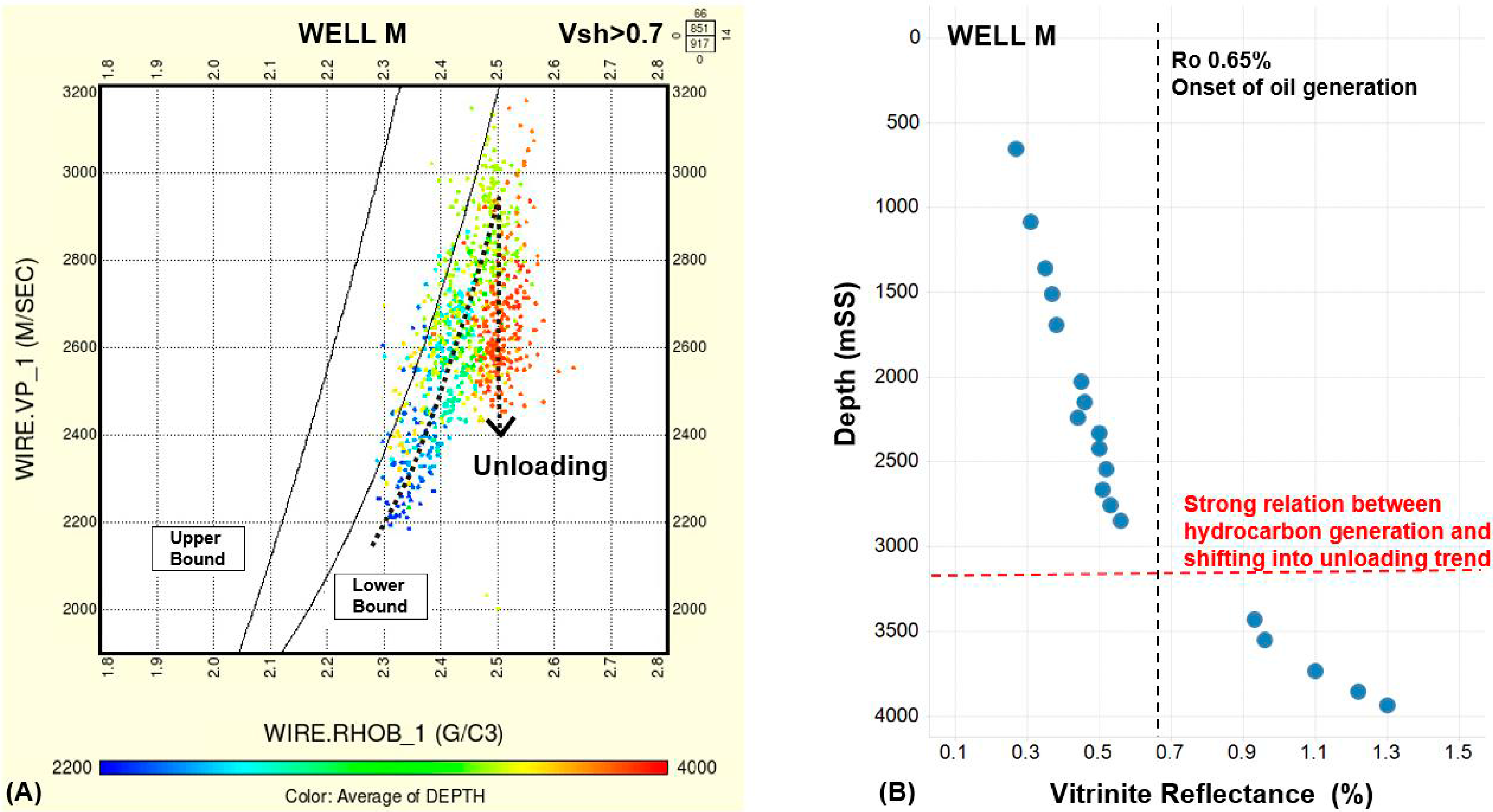

Figure 4. (A) Velocity vs density cross plot (Bowers, 2001) in shale lithology from well M to identify overpressure generating mechanism. The signature of velocity reversal and constant density is identified as unloading (fluid expansion) overpressure mechanism. (B) Vitrinite reflectance data from well M suggest that the overpressure due to fluid expansion mechanism is a result of hydrocarbon generation.

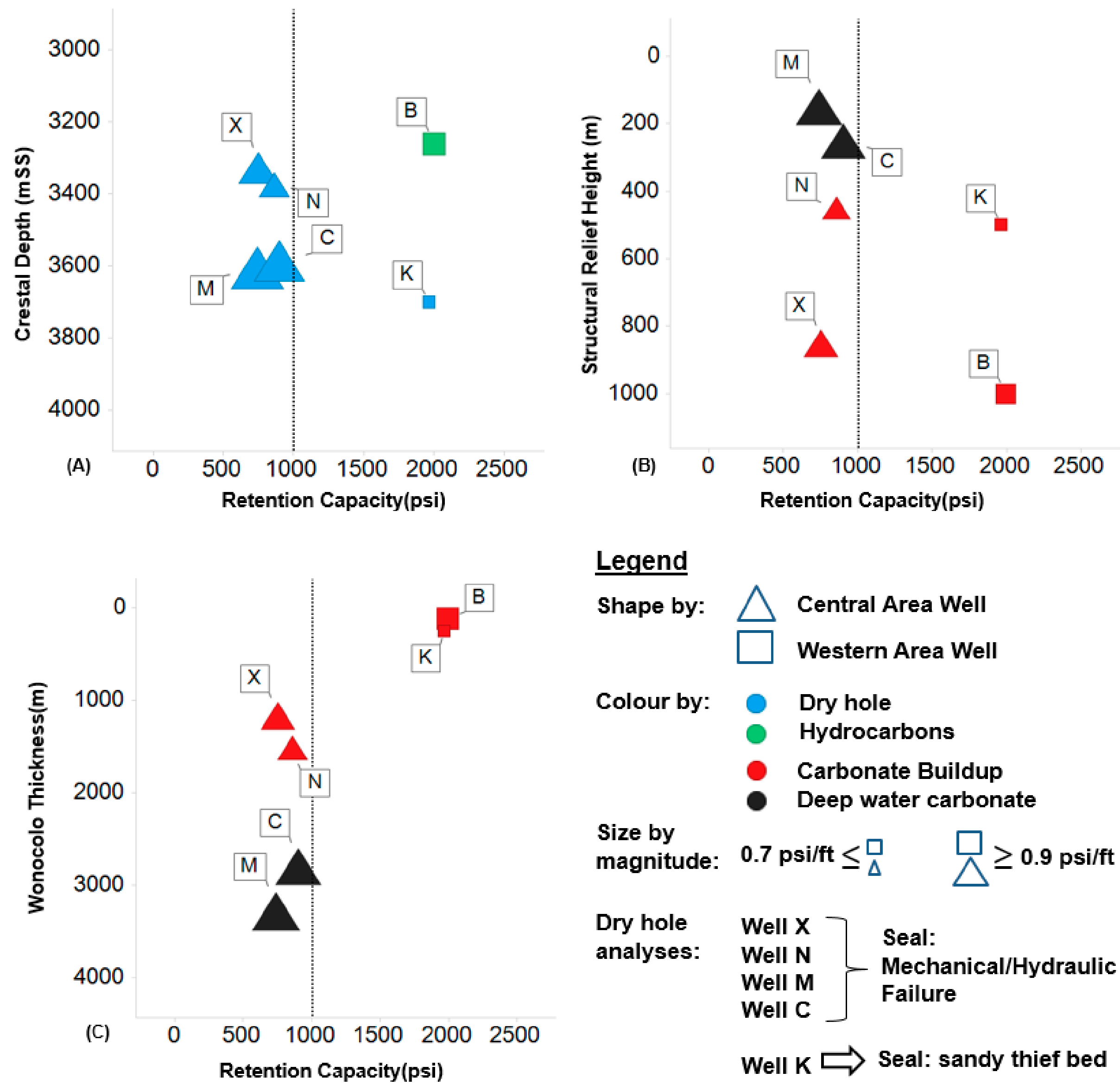

Figure 5. The cross plots used to examine the relationship between mechanical seal failure with the retention capacity, structural relief height, and Wonocolo sediments thickness. (A) A potential threshold value of retention of 1000 psi can be used where below this value a dry hole due to mechanical seal failure can occur. (B) No relationship can be established between the structural relief heights with the retention capacity. (C) Mechanical seal failure tends to occur at central area where the structures are overlain with thicker overlying Wonocolo sediments (1100 to 3300 m).

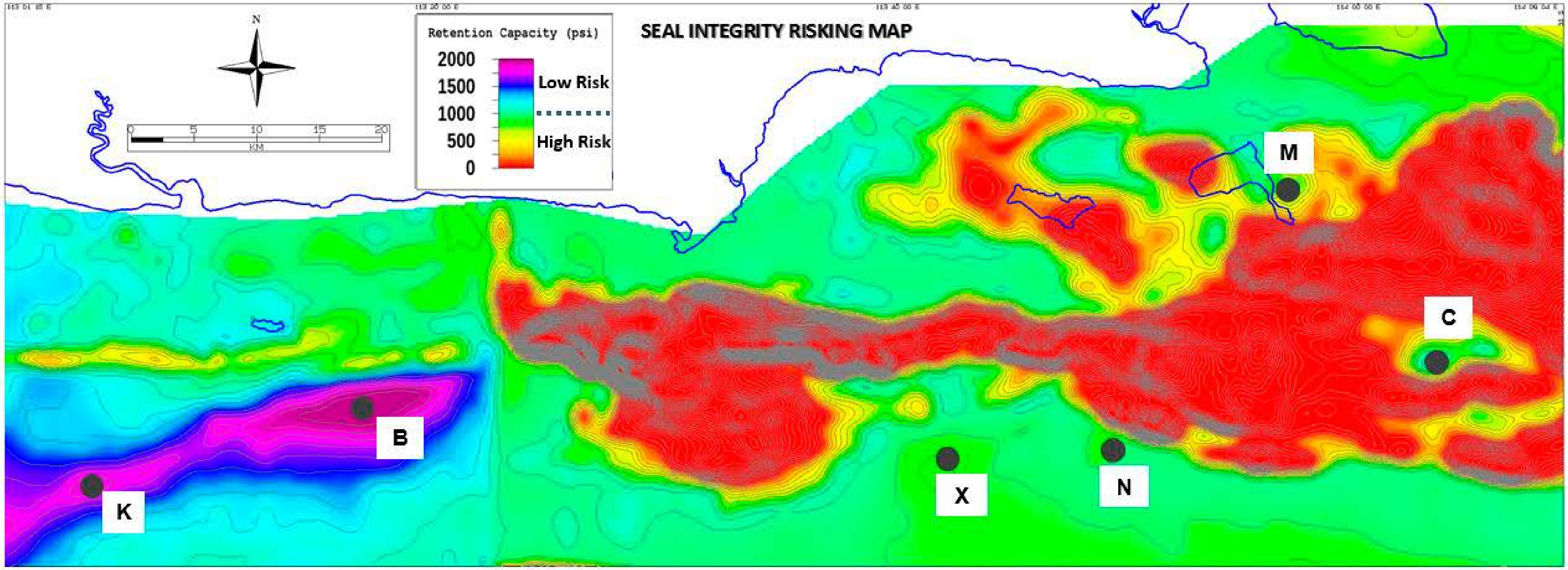

Figure 6. Retention capacity map was created using Wonocolo-Kujung isopach surfaces to help assess the seal integrity risking. Higher risk of mechanical seal failure tends to be distributed thoroughout the central area, expressed as a low retention capacity (< 1000 psi) area. The Oligocene-Miocene carbonate structures in western area tend to have lower risk of having mechanical seal failure, expressed by retention capacity pressures greater than 1000 psi.