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Application of deterministic fault-seal analysis for fault-bounding trap: a case study in Than Nong 1B prospect, Block 05-1(a), Nam Con Son basin, offshore Vietnam

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ABSTRACT

Fault-seal analysis has long been applied for predicting potential hydrocarbon column for mitigating risk in exploration and appraisals. Than Nong 1B structure in Block 05-1(a), located nearby Dai Hung field, is a fault-bounding structure; thus, the fault seal capacity plays a major role in trapping hydrocarbon. In this study, the H50 reservoir is taken as an example of how fault-bounded prospects are evaluated in Block 05-1(a). For the case of Than Nong 1B, to meaningfully determine the potential of the structure, the fault geometric analysis is conducted to fully understand the 3D geometry of the structure. Moreover, vertical displacement of the faults is inspected to ensure the quality of input data and to understand how faults and horizons affect each other. After structural description conducted, the study applies all common methods of fault-seal analysis from the 1980s to the newest workflow published in 2016, such as 3D sand-shale juxtaposition analysis, SGR analysis, height-column-prediction algorithms by Yielding et al. (2010). The results of these methods are then combined by using Trap analysis workflow, proposed by Peter Bretan in 2017, to determine a unique location of fault leak point defining the trappable hydrocarbon column of the structure. The results suggest that the faults in Than Nong 1B prospect are able to hold a maximum column of 183 m hydrocarbon in H50 reservoir, significantly higher than the column of 125 m hydrocarbon defined by Fault-leak point. Furthermore, this study also proves that the Trap analysis is an effective method for evaluating structures with high level of fault linkage.

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1. Introduction

Block 05-1(a) in Nam Con Son basin, Vietnam offshore, with a proven petroleum system is well - known for its high degree of compartmentalization due to faulting activities. Moreover, there are many proven oil-producible structures and highly-potential prospects which are bounded by linkage of faults in the area (Figure 1). For that reason, one of the key issues in the Block 05-1(a) is to determine the fault-sealing capacity at prospect-scale. Therefore, it is critical to understand the characteristics of fault-bounding trap in the field to mitigate risks, uncertainties and to raise chance of success during exploration.

This paper will discuss a method proposed by Bretan (2017) to tackle problems of fault seal analysis for fault-bounding prospect. Moreover, by showing H50 as an example, it is aimed to provide a perspective of a general process in prospect assessment applied in Block 05-1(a).

2. Methodology

2.1. Fault-rock property

In this study, the Shale Gouge Ratio (SGR) is the only fault-rock property used to evaluate the sealing capacity. The SGR value is dependent on 02 variables: Shale volume (clay content of inspected beds) and the fault offset. Higher SGR usually implies better continuity of clay/shale smear and stronger seal membrane (Yielding et al., 2010). SGR value can be converted into predicted-hydrocarbon column by Bretan et al. (2003) or Yielding et al. (2010) equations by estimating capillary entry pressure.

2.2. Prediction of column height by its relationship with fault-rock property

Bretan et al. (2003) and Yielding et al. (2010) established empirical relationship between SGR and threshold pressure. The threshold pressure is equivalent to buoyancy pressure (Yielding et al., 2010) generated by an equivalent hydrocarbon or

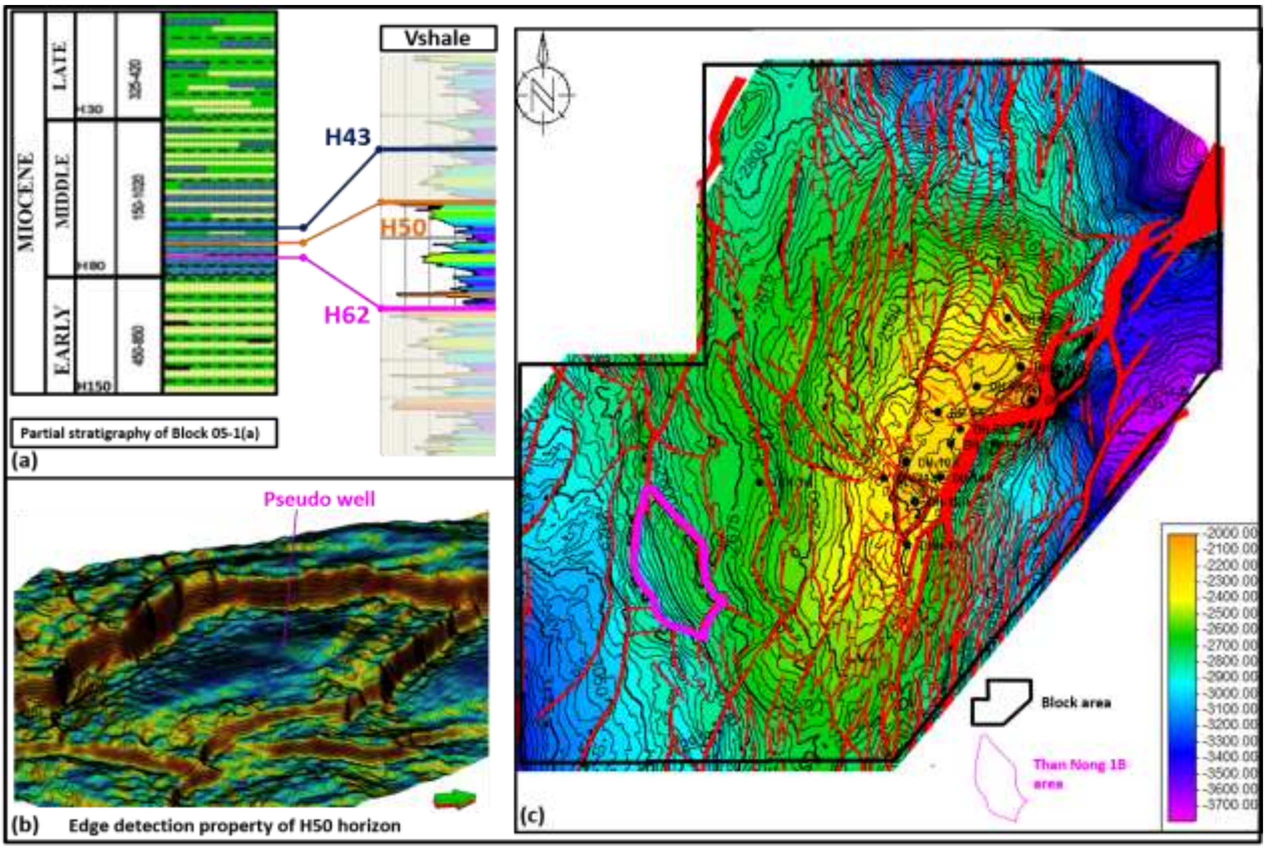


Figure 1. Brief introduction of study area: (a) Partial-stratigraphy & well log at nearby location: (b) Edge detection property map of H50 in Than Nong 1B area; and (c) H50 structural interpretation map.

across-fault pressure (Bretan et al., 2003) caused by different pressure between two sides of a fault. The SGR can then be converted into a maximum threshold pressure that it can support without leaking. In this study, the relationship between buoyancy pressure and SGR established by Yielding et al. (2010) is used to predict the potential hydrocarbon column height of Than Nong 1B prospect.

2.3. Trap analysis workflow

As long as the fault model contains the essential components (fault surfaces, fault-horizon intersection polygons, and fault branch lines), the Trap analysis technique can be used to analyze a trap that is limited by a single fault or by several intersecting faults (Bretan, 2017). The technique tries to determine the location on the juxtaposition of reservoirs versus reservoirs where the buoyancy pressure exceeds the capillary threshold pressure of the fault-zone material (Yielding, 2015). These locations on fault planes will be analyzed its sealing capacity; and the one that could hold the shallowest hydrocarbon contact above structural spill will be determined as Fault-Leak Point - abbreviated as “FLP” (Bretan, 2017). The predicted maximum contact, which can occur in the trap, will be defined by column dependent on seal at the leak point. Even if the prospect has not been re-charged and/or fault seal has failed with the reduction of maximum column, there should still remain a hydrocarbon column in the trap (Yielding et al., 2015).

To reduce uncertainty when evaluating the prospect, in this study, the prediction of maximum hydrocarbon column is controlled not only by the FLP, but also by extensively comparing other points below the FLP depth. If a location below FLP depth supports a shallower maximum contact comparing to which predicted by the FLP, a new maximum hydrocarbon contact will be chosen to replace the one defined by the FLP.

3. Application of fault seal analysis in H50 reservoir, Than Nong 1B prospect

3.1. Fault Geometric Analysis

Structural description of Than Nong 1B

The prospect is bounded by ThNCSPT_036, ThNCSPT_302, ThNCSPT_019, ThNCSPT_343, ThNCSPT_020, ThNCSPT_043 and ThNCSPT_300. Rather from being simple continuous structures, long 'single faults' are frequently demonstrated to be divided into en-echelon arrays (Needham et al., 2015). Even when the evolution of individual faults differs from those trends, the model predicts that faults within a system would rapidly acquire displacement-length scaling features that are compatible with previously established fault-growth trends (Freeman et al., 2010; Walsh et al., 2002). Due to the linkage, the faults bounding Than Nong 1B can be grouped as 02 ‘single’ faults that define the structure in the western and eastern parts of the prospect: ThNCSPT_036-302-019,ThNCSPT_343-020-043 and ThNCSPT_300 (Figure 2).

3.2. Vertical Displacement of Fault

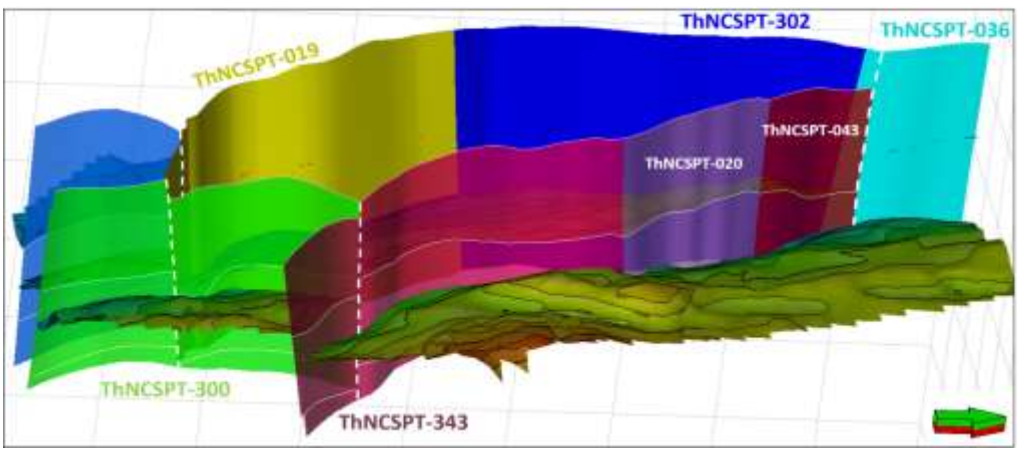
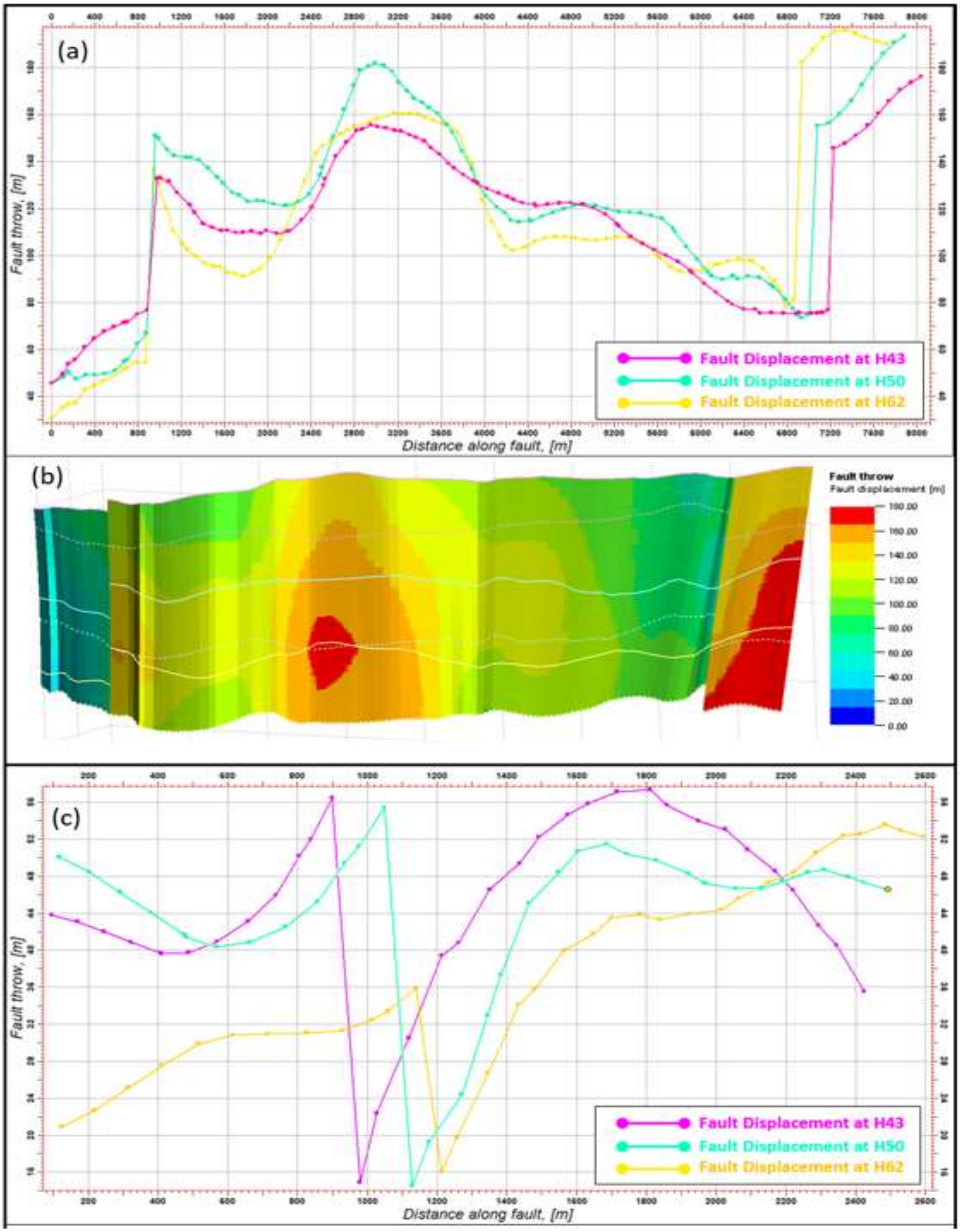


Figure 2. Fault model of Than Nong 1B structure.

Displacement variation in each fault are generally consistent from horizon to horizon. However, there are usually abrupt changes in the fault displacement near the branch-line, inspecting vertical displacement of fault is essential in evaluating Than Nong 1B prospect. This inspection allows the process of quality control of seismic interpretation not only to identify irregularities, but also to investigate how reservoir strata are disturbed and juxtaposed (Needham et al., 2015). Results of fault displacement analysis (Figure 3) could only be used to qualitatively predict the critical points of interested reservoirs when combining with fault-rock properties, such as SGR, because fault seal is still form even with fault displacement smaller



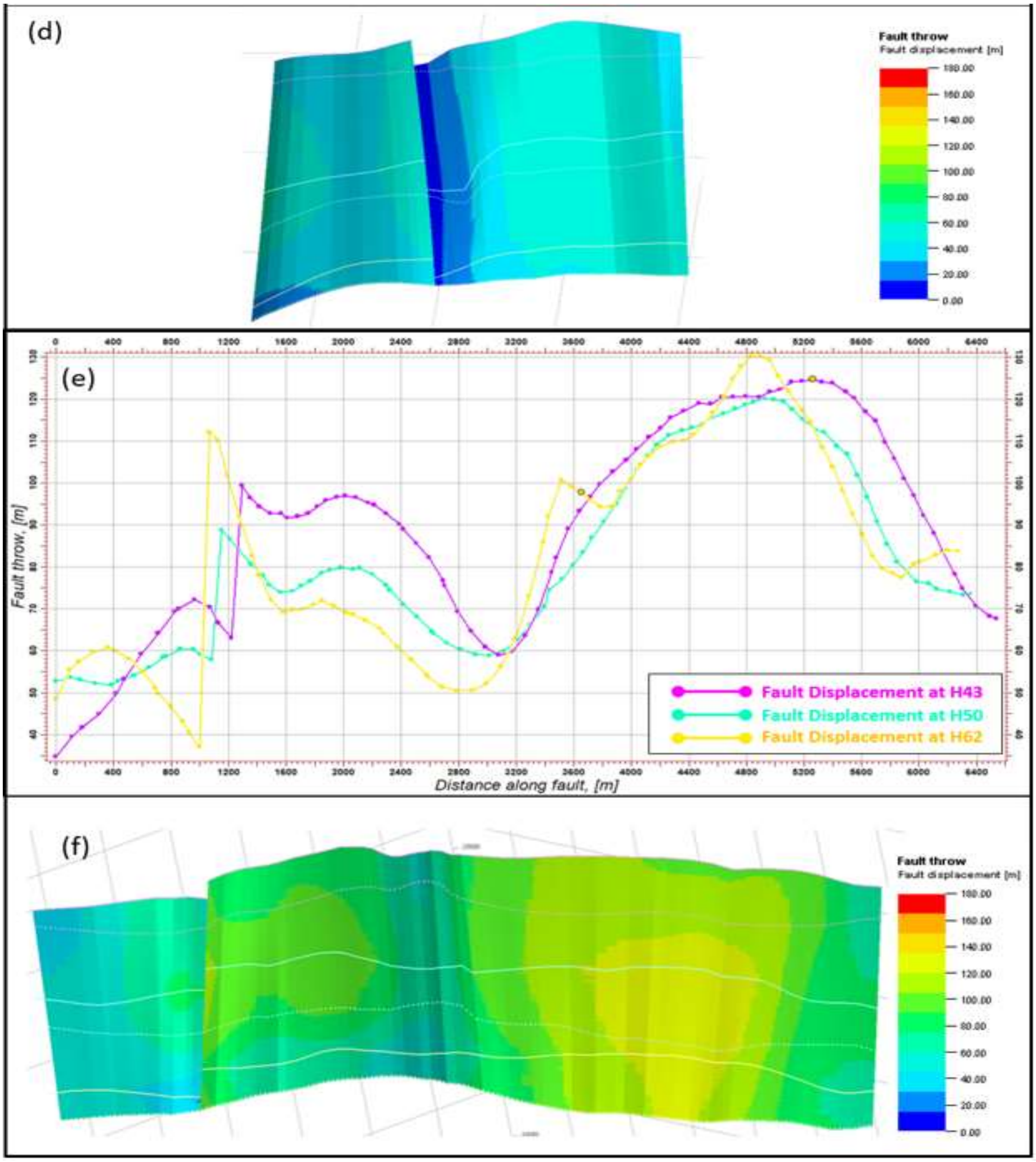


Figure 3. (a) Vertical displacement profile of Fault ThNCSPT-019-302-306; (b) Vertical displacement property mapped on Fault 019-302-306; (c) Vertical displacement profile of Fault ThNCSPT-300; (d) Vertical displacement property mapped on Fault ThNCSPT-300; (e) Vertical displacement profile of Fault ThNCSPT-043-343-020; and (f) Vertical displacement property mapped on Fault ThNCSPT-043-343-020.

than reservoir thickness due to the content of the fault rock (Hardman & Booth, 1991). Stratigraphy of Block 05-1(a) and referenced well logs for Than Nong 1B show that there is high chance of stacked-sand reservoir with thickness varying differently so that displacement inspection alone cannot determine the capacity of fault seal in this structure. For these reasons, fault geometry inspection of Than Nong 1B is conducted not only at main target H50, but also at its upper and lower horizon H43 and H62, respectively.

Fault ThNCSPT-019-302-306 and ThNCSPT-043-343-020 have large vertical displacement, especially at their centers. If predicted contact is deeper than structural spill, the fault ThNCSPT-019-302-036 will be the prospect's key element in defining down-dip potentials due to its substantially large displacement. Fault ThNCSPT-019-302-036's displacement reaches up to 180 m and consistent shapes across horizons H43, H50 and H62. These features imply that it probably owns a high sealing capacity and the quality of structural input is reliable to implement further assessment.

In contrast, critical points possibly present at this fault ThNCSPT-300. This fault even has 15 m of vertical displacement in some areas, especially nearby its intersection with another faults.

3.3. Fault-seal analysis using Trap analysis workflow

3.3.1. From Pseudo-stratigraphy to Juxtaposition and Seal capacity analysis

At the time the study conducted, there has not been any well drilled at Than Nong 1B prospect, so that a drilled well at nearby area is used for stratigraphy assumption. The result is then used as pseudo-stratigraphy of Than Nong 1B, which than any points at FLP depth (Figure 5).

can be utilized for 1D Juxtaposition analysis (Knipe et al., 1997) and/or can be distributed conformably throughout structure to assume fault-rock properties for 3D assessment (Clarke et al., 2005; Yielding et al., 2010). The static geological model is populated with shale volume values calculated from Gamma ray. The property is then transformed into SGR by combining with the vertical displacement of the faults. Also, based on the established cut-off values of Shale volume and Porosity, the the so-called Sand and Shale facies are generated. These facies are, subsequently, used to identify possible leak points at Sand-on-Sand positions (Figure 4).

3.3.2. Fault seal analysis using Trap analysis workflow

The results show that the predicted depth of the FLP (2738 mSS) in the H50 interval is substantially shallower than the spill point (2924 mSS). Predicted maximum contact depth of H50 is controlled by the weakest point found below FLP. This location supports a much shallower contact

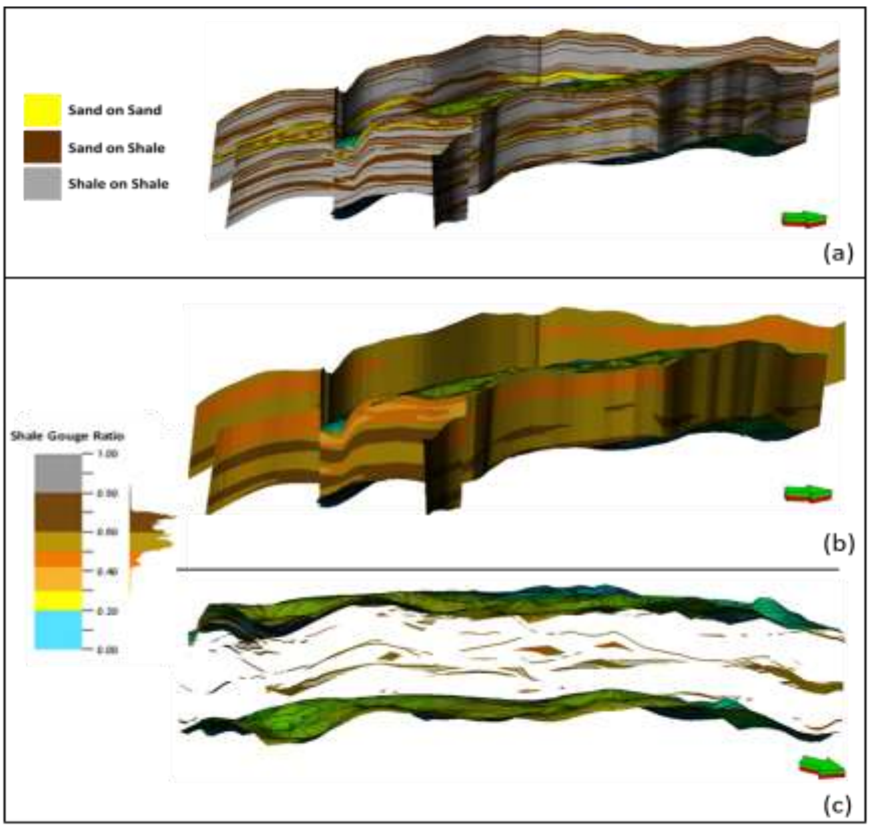


Figure 4. (a) 3D Sand-Shale Juxtaposition; (b) SGR of H50 reservoir; and (c) SGR at Sand-on-Sand positions.

Also, the weakest point below FLP has a much weaker sealing capacity with SGR value of 29% comparing to 40% at FLP. The H50 interval's maximum contact depth is above structural spill, and is at depth of 2796 mSS. These findings suggest that the potential of H50 should be able to contain hydrocarbon contact above the spill's depth even when leakage occurs (Table 1).

4. Discussion and conclusion

The evaluation for H50 reservoirs of Than Nong 1B prospect once again proves the efficiency of Bretan's 2016 method that, to meaningfully determine hydrocarbon contacts in a potential fault trap, all criteria must be analyzed as a single coherent element from 3D geometrical relation, fluid properties to the transforming algorithms, etc. The method proves that it is able to combine different approaches that have been established since the 1980s, such as Allan diagram, algorithms for height column prediction, etc.

The H50 reservoir of Than Nong 1B is predicted to have a hydrocarbon column up to 181 m, above the spill depth. Further investigation of the prospect should be taken in the future. Also, the method could be widely applied for almost prospects within Block 05-1(a).

Contribution of authors

Anh Tuan Truong - conceptualization, supervision, reviewing and editing; Tam Trung Le - conceptualization, supervision, reviewing and editing; Nhan Duc Dang - conceptualization, supervision, reviewing and editing; Tuan Anh Do - structural interpretation, data curration; Lap Quoc Lai - reviewing and editing; Lan Tien-Hoang Nguyen - data curration, assessment and interpretation, original draft writing.

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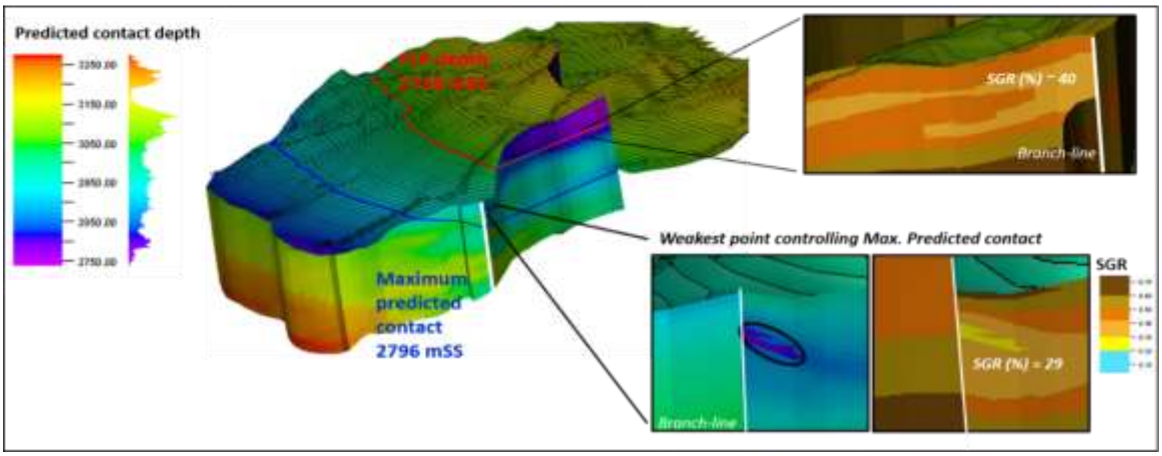

Figure 5. Determination of FLP and hydrocarbon maximum predicted contact.

Table 1. Result of H50 fault seal analysis by Bretan's 2017 method.

SGR to hydrocarbon height column algorithm	Spill Point (mSS)	Depth of the FLP (mSS)	Location of FLP	Column height at the FLP (m)	Depth of Maximum Predicted Contact (mSS)	Total column height in the trap (m) from Crest at 2613
Buoyancy pressure calibration (Yielding et al., 2010)	2924	2738	ThNCSPT-300	125	2796	183

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