A study of Reservoir Connectivity in the Platong Field, Pattani Basin, Gulf of Thailand

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Abstract

The study area covers two development platforms, PLWD and PLWI in the Platong Field, Pattani Basin, Gulf of Thailand where the complex fluvial sand systems make it difficult to predict sand connectivity and pressure transmission. Several wells drilled from the PLWI platform encountered high pressure sands around 1830-1890 m. TVDSS and the cause of this high pressure was interpreted to be due to the effect from the water injection program in the PLWD platform area to the north. This study analyses and creates possible models to explain this pressure communication and the connectivity of the reservoir sands by the integration of well log analysis, seismic interpretation and formation pressure data. Two key sand systems were identified in the interval of interest; the injection sand system and the high pressure sand system. The injection sand is thick and a well defined channel system whereas the high pressure sands are more discontinuous. Many faults cut across these sand along a north-south trend making pressure transmission improbable along these stratigraphic pathways. On the other hand, pressure transmission within fault blocks is also unlikely due to the discontinuous nature of the narrow fluvial channel systems. The most likely explanation of the pressure transmission is a mix between short stratigraphic pathways within fault blocks and significant fault leakage, particularly across the smaller displacement faults. Observations from this study can be applied for future well planning in order to prevent water injection wells creating high pressure drilling hazards.

Keywords: Platong Field, Reservoir connectivity, Water disposal wells, Pressure transmission

1. Introduction

The main reservoirs in Pattani Basin are fluvial sands that have complex stratigraphic architectures in terms of reservoir geometries and continuity of sand. This study focuses on reservoir connectivity and pressure communication in the basin by analyzing a detailed well and seismic data set from the Platong field which is located in the center of the Pattani Basin.

The area of investigation is around the PLWD and PLWI platforms which are operating platforms in the southeast corner of the Platong Field.

The PLWI platform encountered some high pressure sands. One hypothesis for the presence of these high pressure sands is that several water disposal wells drilled earlier from the PLWD platform 6 kms to the north may somehow be connected to these high pressure sands and have created the observed overpressure (Figure 1). The question is, do the sand packages which were perforated in the PLWD disposal wells have some connectivity or relationship with the high pressure sands in PLWI and if so, along what tortuous path was the pressure transmitted

2. Methods

An integration of well log data, formation pressure data and seismic interpretation were used to create pressure transmission models. Well log characteristics based on gamma ray curves suggest the environmental deposition interpretation and also help to identified key marker horizons which defined the interval of interest and well to well correlation. In this study, RFT data was very important. It was used to help correlate sand packages and also to correlate normal pressure trends and high pressure and depleted zones in the interval of interest (Figure 2). To compare well log data to the seismic, synthetic seismograms were generated. The key markers (injection sand level and high pressure sand level) were interpreted as key horizons and then contoured to create two-way-time structural maps which were used to generate seismic attribute maps. Amplitude extraction maps were generated by using RMS (root mean square) amplitude attributes in order to define the channel geometries and point bar deposition in the interval of interest.

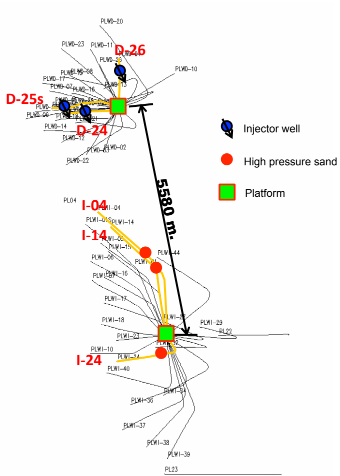

Figure 1. Location of PLWD and PLWI platforms showing location of water injection disposal wells in PLWD and wells that found high pressure sand in the PLWI area

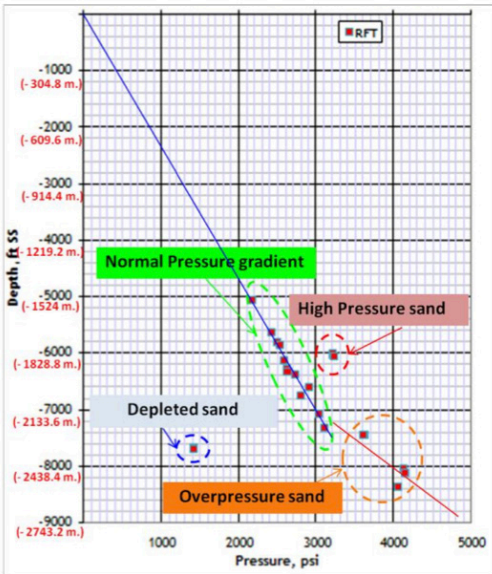

Figure 2. Typical formation pressure (RFT) data of a well in the central Pattani Basin.

3. Results

3.1 Well log analysis

Depositional Environment Analysis

Based on regional stratigraphic correlation, the zone of interest lies within Sequence 4 in the upper Middle Miocene. The regional depositional environment interpretation of this interval is alluvial plain (alluvial terrace) and fluvial dominant systems with some local delta plains. In the study area this interval is composed of mainly non-marine dominant fluvial deposition as shown in a type log of the interval (Figure 3).

The well log characteristics based on the gamma ray curve show interpreted channel fill facies inter-bedded with overbank deposits. The overbank intervals are interpreted by the high gamma ray values between the channel fill facies that suggests a heterolithic lithofacies indicative of lower energy environments.

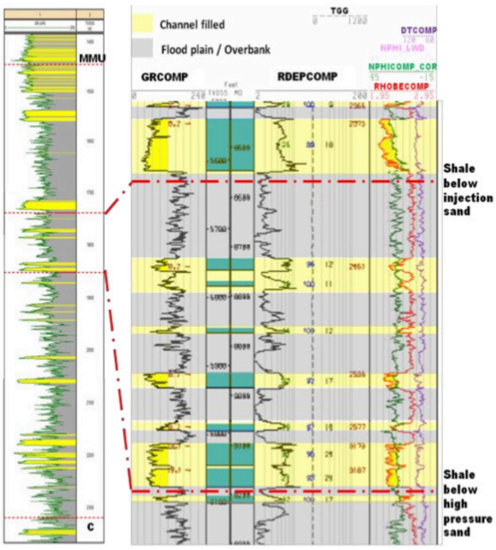

Figure 3. The interpretation of depositional environment in the zone of interest based on the gamma ray curve.

Well to Well Correlation

Two internal markers (the shale below water injection sand and the shale below high pressure sand) were defined and interpreted to represent the geological structure in this interval. The upper one is the shale below the top of the injector sand.

It shows high gamma ray, low resistivity, high density and low neutron log characteristics. The lower one is the shale below the high pressure sand encountered in the PLWI wells. The well log curve characteristics are the same for this marker as the upper marker.

Two main sand packages are of interest. The first and upper one is the thick sand that was perforated in well PLWD-26 and intersected in the other water injection wells
(Figure 4). The thickness of this sand package is around 18-27 m. From the well correlation, it is a fairly continuous sand package, thickening into the centre of the graben. Based on well log analysis, the fluid in this sand package is water. The second and stratigraphically lower sand package of interest was the high pressure sand interval penetrated in the PLWI-04, 14 and 24 wells at depth around 1830-1890 m. TVDSS (Figure 5). The average gross thickness of these high pressure sands is 10-12 m. and the overall package thins to the southern part of the area. This package is distinctly different from the upper sand package as it consists of numerous inter-bedded thin sands encased in shales.

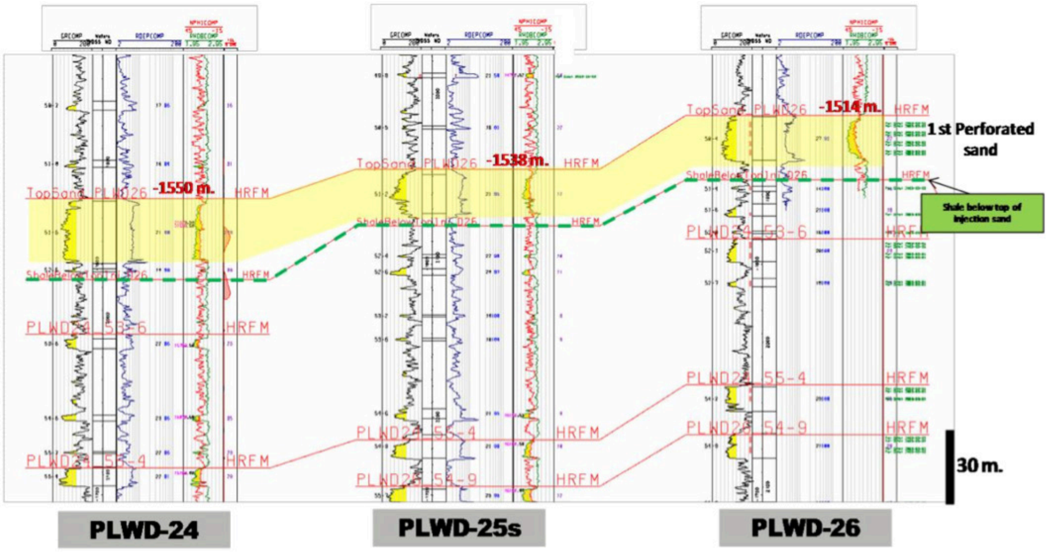

Figure 4. Well correlation in PLWD area showing sands perforated for water disposal

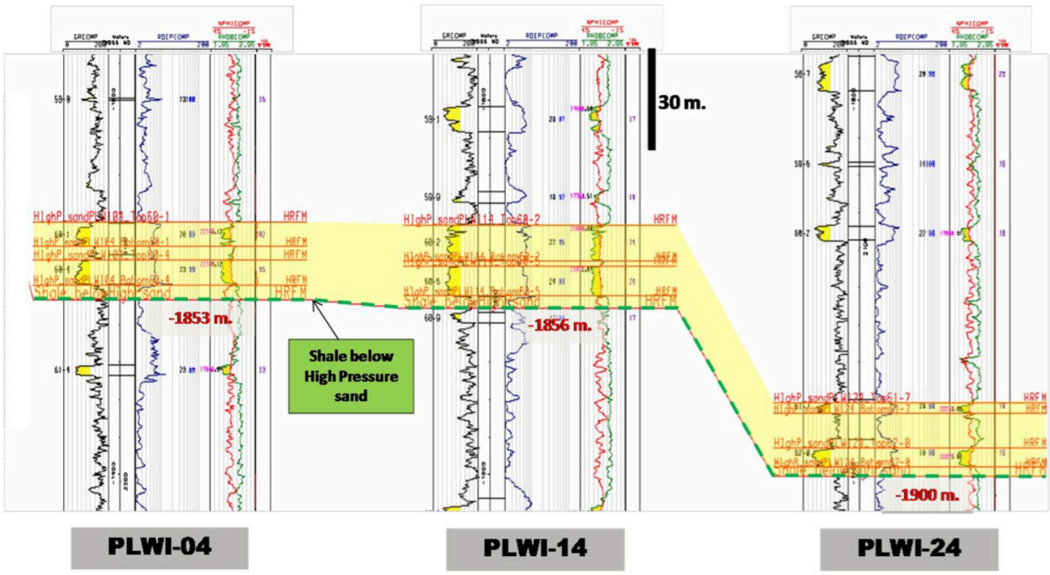

Figure 5. Well correlation in PLWI area showing high pressure sands.

Formation Pressure Data

In the study area pressure data (RFT and BHP data) was available for 21 wells. However, the pressure data from the water injection well PLWD-24 and the high pressure wells in PLWI were of most interest. In the PLWD-24 the sands could be divided into 3 trends; the normal pressure sands, a high pressure sand and the depleted sands (Figure 2). Note that the high pressure sand in this well of around 3130 psi was affected by water injector wells in the nearby PLWC platform to the north. The depleted zones are caused by long term production from nearby wells drilled from the PLWD platform. In the PLWI platform area the high pressure wells PLWI-04, 14 and 24 found high pressure zones around 3180 – 3200 psi at depths of roughly 1830 m. TVDSS. Other wells adjacent to the high pressure wells showed good correlation of the high pressure sand intervals but no pressure data could confirm whether they were overpressured or not.

3.2 Seismic analysis

Structural Interpretation

Based on the horizon interpretation, the geological structure in this area shows a dominant north-south trending graben system consisting of a complex of synthetic and antithetic normal faults (Figure 6). The displacement of normal faults is fairly low. Most of the faults are west dipping faults in the area of interest along the trend of the injector and high pressure wells. A representative seismic line orientated E-W across the study area shows the complex structural style of many east and west dipping faults forming an overall graben (Figure 7).

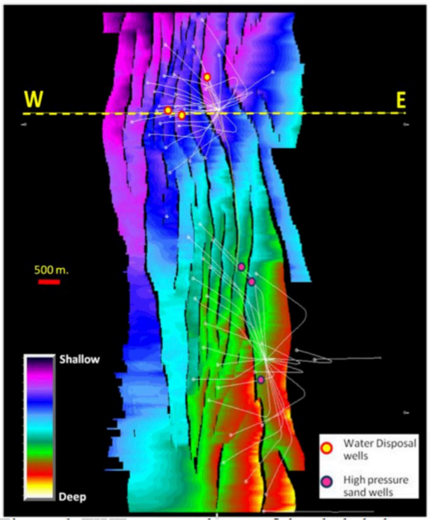

Figure 6. TWT structural map of the shale below the top of injection sand, which represents the structural style of the area. It shows the dominant north-south structural trend.

Stratigraphic Interpretation

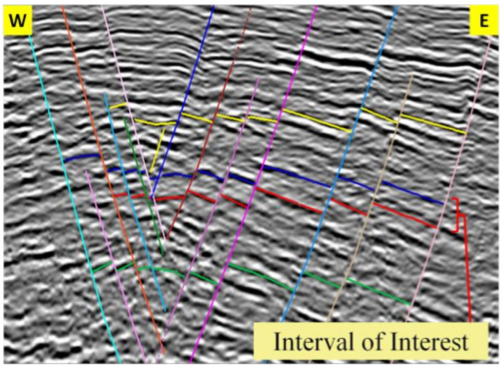

Figure 7. Seismic cross-section W-E shows the interval of interest (Blue = injection sand level, Red = high pressure sand level).

Sand body geometries were identified by using RMS amplitude maps covering the appropriate intervals of interest. For the injection sand level the resulting RMS map shows several high amplitude areas which have channel like geometries with associated point bar deposition (Figure 8). The boundaries of the high amplitude areas are well defined. This injection sand shows very strong amplitude and looks quite continuous on the seismic profile possibly because this sand section is quite thick and covers a wide area based on the well log correlation. Of particular note is that the interpreted channel system cuts right across the extensive fault system which implies that these faults are post-deposition of this interval. In comparison, the sand packages associated with the high pressure sands in the PLWI area have different characteristics. The resulting RMS map shows low to moderate amplitude variations. They are quite scattered in the zone around the water disposal wells in the north but show moderate to high continuity and amplitude in the area around the high pressure wells location. This interval on the seismic section shows discontinuous reflectors which are not widespread. However, in the northeast and southwest of the study area the RMS map shows quite high amplitudes with channel like geometries and associated point bar deposition (Figure 8). As with the upper sand system, these sands cut across faults which are post-deposition of this interval.

4. Discussion

Using a combination of the structural contour maps, RMS attribute maps, well log correlation and formation pressure data a number of hypotheses can be put forward related to sand connectivity, fault seal capacity and pressure communication in the study area.

The hypotheses can be divided into 3 based on the potential pathways that the pressure could have traveled between source and sink, and each one tests pre-conceived ideas about fault seal or transmission capacity as well as sand inter-connectivity in this part of the Pattani Basin.

Hypothesis 1: Pressure transmission within fault blocks

Based on the structural maps the injector well (PLWD-26) is located in the same fault block as the high pressure wells (PLWI-04, 14 and 24). The RMS amplitude maps of both key

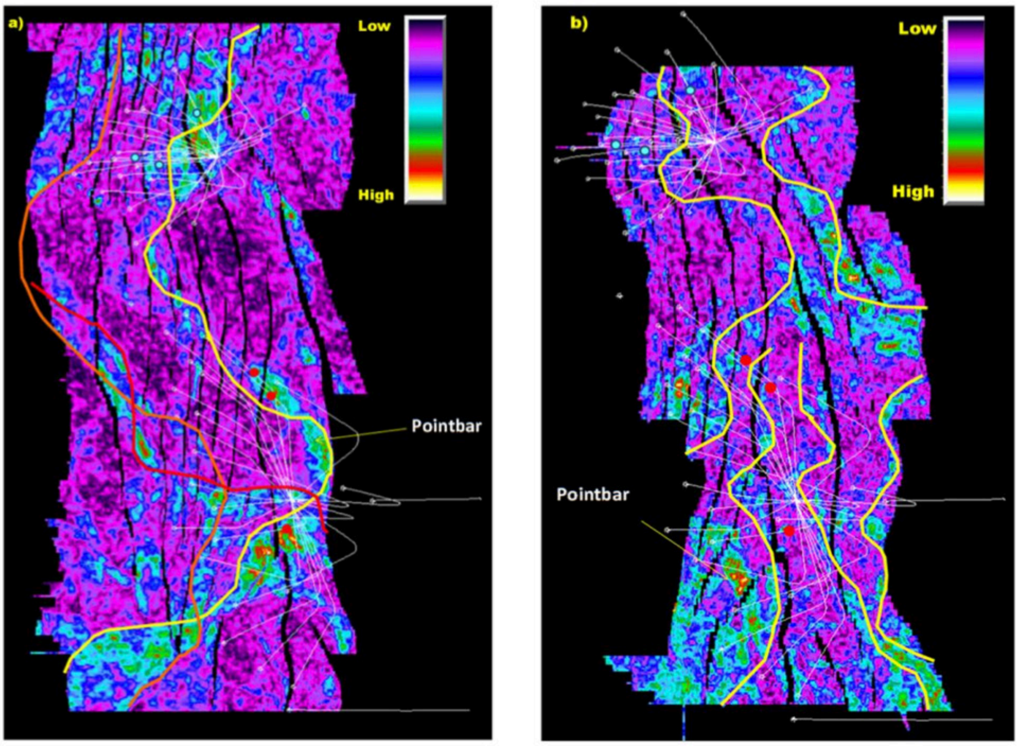

Figure 8. Meandering channel interpretation on RMS Amplitude map of (a) the injector sand system and (b) the high pressure sands system

sand systems show features that are interpreted to be meandering channels and pointbars (Figure 27). Neither of these sand systems shows a clearly defined purely stratigraphic path of communication between the injector and high pressure wells without relying on across fault transmission.

However, the first hypothesis of pressure transmission to test is that the high pressure might be transmitted from the injector well (PLWD-26) and passed along the same fault block by the inter-connection of sand packages or fractures in the interval.

A potential pathway is shown for example in Figures 9. The argument against this hypothesis is that there is a distinct stratigraphic separation of the two main sand systems. The injection sand system is shallower and separated from the high pressure sand system by around 150 m. and as well the lower sand system is quite discontinuous along these potential pathways. Therefore it is quite hard to see how pressure transmission could go this route because the high shale to sand fraction in this section would block or seal the pressure before it could pass through to the high pressure sand wells.

Hypothesis 2: Pressure transmission passes through multiple fault blocks (along channel sand system)

Another possible way that the pressure from the injector well can pass to the high pressure sand wells is by pressure transmission along the well defined injector channel sand system, the pressure leaking through the many normal faults en route (Figure 10). The RMS amplitude map that represents the injection sand shows the trend of the channel sand systems which have been cut by numerous normal faults post-deposition. In the Pattani Basin faults can act as both pressure seals and pressure migration pathways. In this case the injector well could have moved water into the formation below that was at a lower pressure (due to depletion) and these depleted sands communicated laterally with other sand packages so that the pressure was transmitted from one sand package to another within the meander belt system. Although there are many faults that cut the sand packages, some may be leaking faults and the pressure may still pass through depending on lithological juxtaposition and fault smear effects. There are some arguments against this model, as there are several faults with significant throw associated with them so it is possible to have some faults that would seal the pressure transmission along this potential pathway. As well, the sand packages within a meandering river system often have shale breaks which isolate individual pointbars which would make the pressure transmission even more unlikely along this pathway.

Hypothesis 3: Pressure transmission passes through a few faults and along fault blocks

Another way that the pressure from the injector wells can be transmitted to the high pressure sand wells is by transmission of the pressure along fault blocks in part combined with transmission across a few leaking faults which have relatively small throw

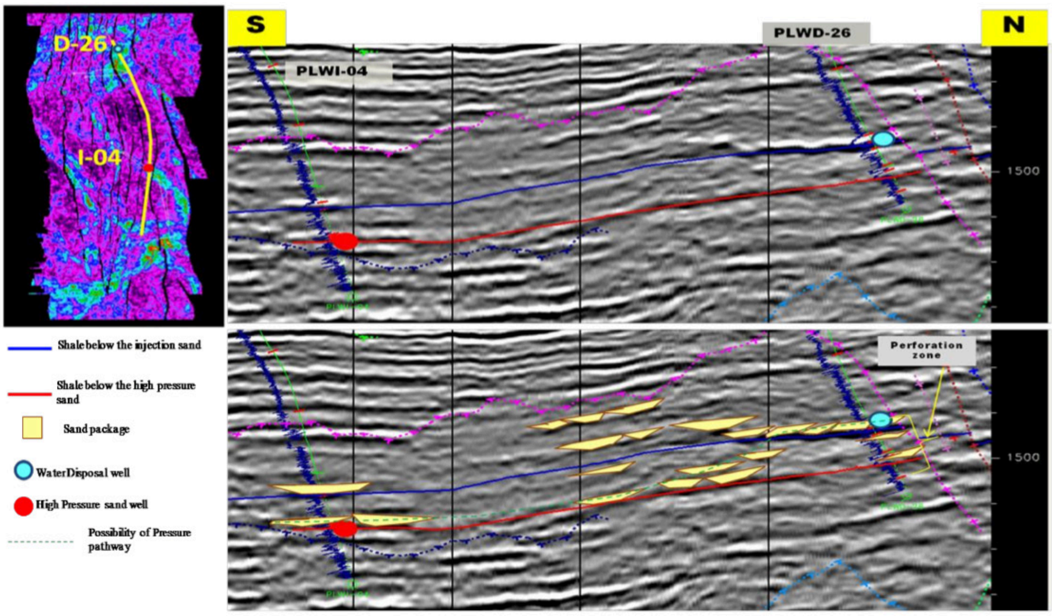

Figure 9. The stratigraphic and seismic interpretation for the pressure transmission model in the same fault block.

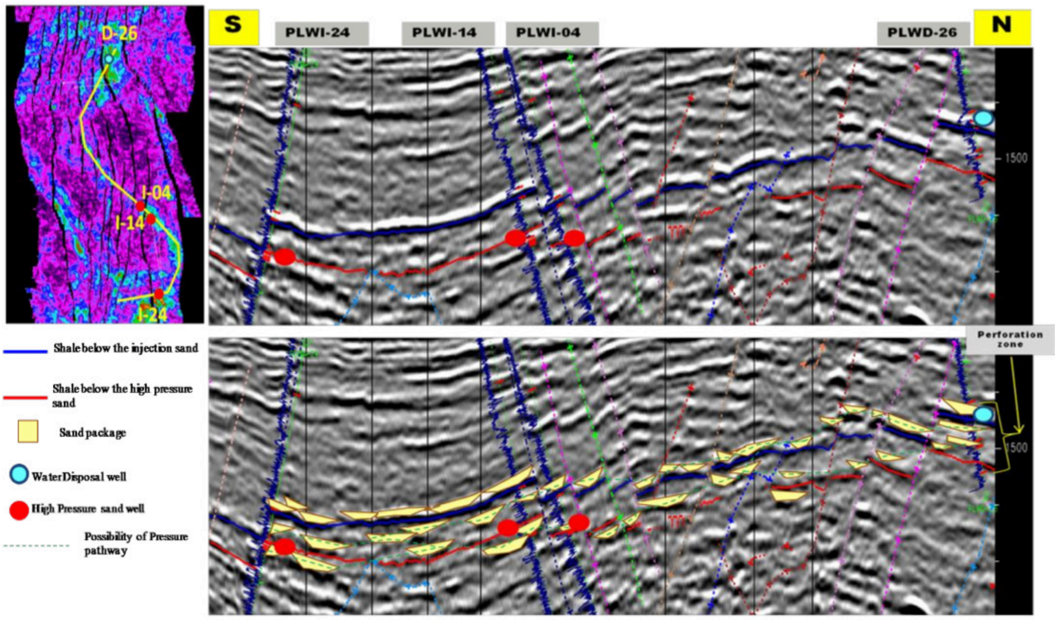

Figure 10. The stratigraphic and seismic interpretation for the pressure transmission model through multiple fault blocks

(Figure 11). This model is a hybrid of the two previous models. For this model, the pressure still passes within fault blocks but uses leaking faults as a pressure pathway where sand on sand juxtaposition occurs. In this way pressure transmission from the injector wells to the high pressure sand wells is plausible. The number of fault breaks in this model are less than the second model, so it decreases the opportunity of pressure sealing by non-leaking faults.

However shale breaks and low permeability barriers still could be a concern in this model. If the sand packages are isolated sands or there are some shale breaks between the sand packages, the pressure will be blocked and cannot move to another sand. Then the pressure from the injectors cannot transmit to the high pressure sand wells. In this type of scenario it is interpreted that leaking faults are significant pressure transmission pathways. If they are high displacement faults however the pressure may not pass through them. This pressure transmission model relies on connectivity of the sand packages over relatively short distances within fault blocks combined with transmission across a few small faults with good sand to sand juxtaposition. This means there is less opportunity to find pressure trapping faults. In summary, small faults in sandy intervals are leaky based on this analysis whereas higher displacement faults are less likely to leak. Sand connectivity within fault blocks is highly variable and appears to have only limited influence on the transmission of pressures in these systems.

5. Conclusions

Using an integration of well logs, seismic data and formation pressure data to study pressure transmission the following observations can be made:

- The depositional environment of the interval of interest is a fluvial system. The RMS amplitude map of the top of injection sand shows very clear channel and point bar geometries.
- There are three hypotheses of pressure connectivity; pressure trans-

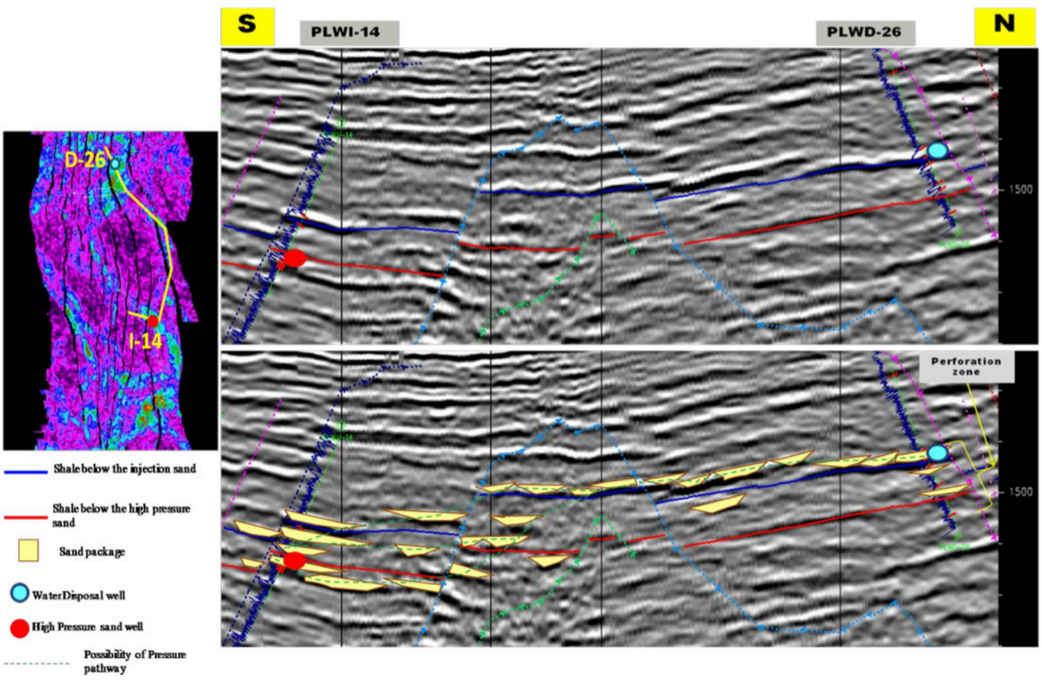

Figure 11. The stratigraphic and seismic interpretation for the pressure transmission model using faults and along fault blocks

mission within fault blocks, pressure transmission passing through multiple fault blocks along a channel sand system, and pressure transmission passing through a combination of faults and within fault blocks.

• The most likely model is the hybrid, with pressure interpreted to pass through a few faults because pressure transmission within fault blocks is difficult over long distances because of potential shale barriers blocking the pressure transmission and pressure passing through multiple faults has a high probability of finding non-leaking faults.

• All faults have potential to leak in this setting but small faults are interpreted to be more likely to leak in these types of depositional systems.

This study helps in our understanding of pressure transmission in complexly faulted fluvial systems and this knowledge can be applied in the placement of future water disposal wells avoiding the possibility of creating potential drilling hazards.

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