

PS Formation Pressure Correction to Enhance the Prediction of the OWC in a Normal Pressure Reservoir*

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Abstract

The oil-water contact (OWC) is defined as the depth of the bottom oil layer in an oil reservoir. It's especially important how we determine the position of the oil-water contact when a new reservoir is discovered, but only the pure oil zone is drilled through by the exploration wells. Generally based on the formation pressure acquired from the wireline formation testing and the theoretical basis of equal pressure at the fluid interfaces, there are two methods to predict the OWC in a normal pressure reservoir: 1) Linear diagram of oil and isobathic hydrostatic pressure vs depth; and 2) Semi-closed U-tube manometer physical model.

However there are several limitations during the practical application of the two methods. Firstly, the first method is set up depended on the assumption of homogeneous fluid density and the predicted depth is actually the free water level which has a gap to the real OWC. Secondly, due to the density variation of the crude oil components and compounds there could occur gravitational differentiation which leads to relatively lower crude oil density and viscosity as well as higher formation pressure on the top of the oil column, and that will influence the linear relationship of the pressure vs depth curve resulting in erroneous calculated OWC. Moreover, affected by the secondary gas cap sourced from the dissolved gas generated during the hydrocarbon accumulation and migration and crude oil biodegradation, the measured formation pressure is higher than the original one in the reservoir. Because of the above limitations, there are different degree errors between the forecasted results and the exact OWC according to reliable information from almost 50 developed reservoirs in the BZ oilfield, offshore Bohai Bay Basin in China. The maximum error is even up to 39m.

In this study, so as to obtain the correct OWC, we find ways to exclude the effects of reservoir fluid heterogeneity on the linear diagram of oil and isobathic hydrostatic pressure vs depth and recover the original oil pressure by eliminating the gas cap pressure from the measured pore pressure, by which the forecast errors will be reduced. According to the example applications, after utilizing the pressure correction into the two methods, an average forecast error has been greatly reduced to 1.3m in the BZ oilfield. Perfectly forecasting the OWC has important significance to estimate the hydrocarbons in place and formulate the more reasonable reservoir development programs.

Pressure Correction to Enhance the Prediction of the OWC in a Normal Pressure Reservoir

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1. Uncertainty and risk on the OWC prediction

Only the pure oil zone is penetrated, where is the position of the Oil-Water Contact?

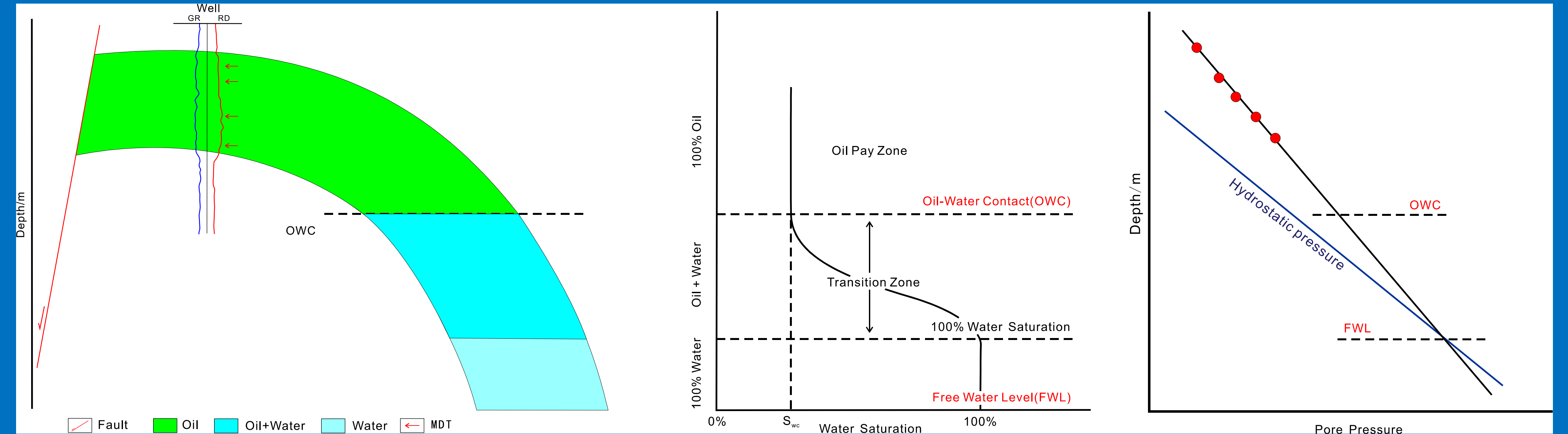


Fig.1 The normal pressure reservoir model and water saturation profile indicate that the contact achieved from the pore pressure and hydrostatic pressure VS depth plot is the Free Water Level, instead of the Oil-Water Contact in strict meaning.

Question: Unfortunately, the prediction depth by pore pressure and hydrostatic pressure VS depth plot is just the Free Water Level, and the position of Oil-Water Contact depends on **the thickness of the transition zone**.

2. U-type mercury manometer physical model

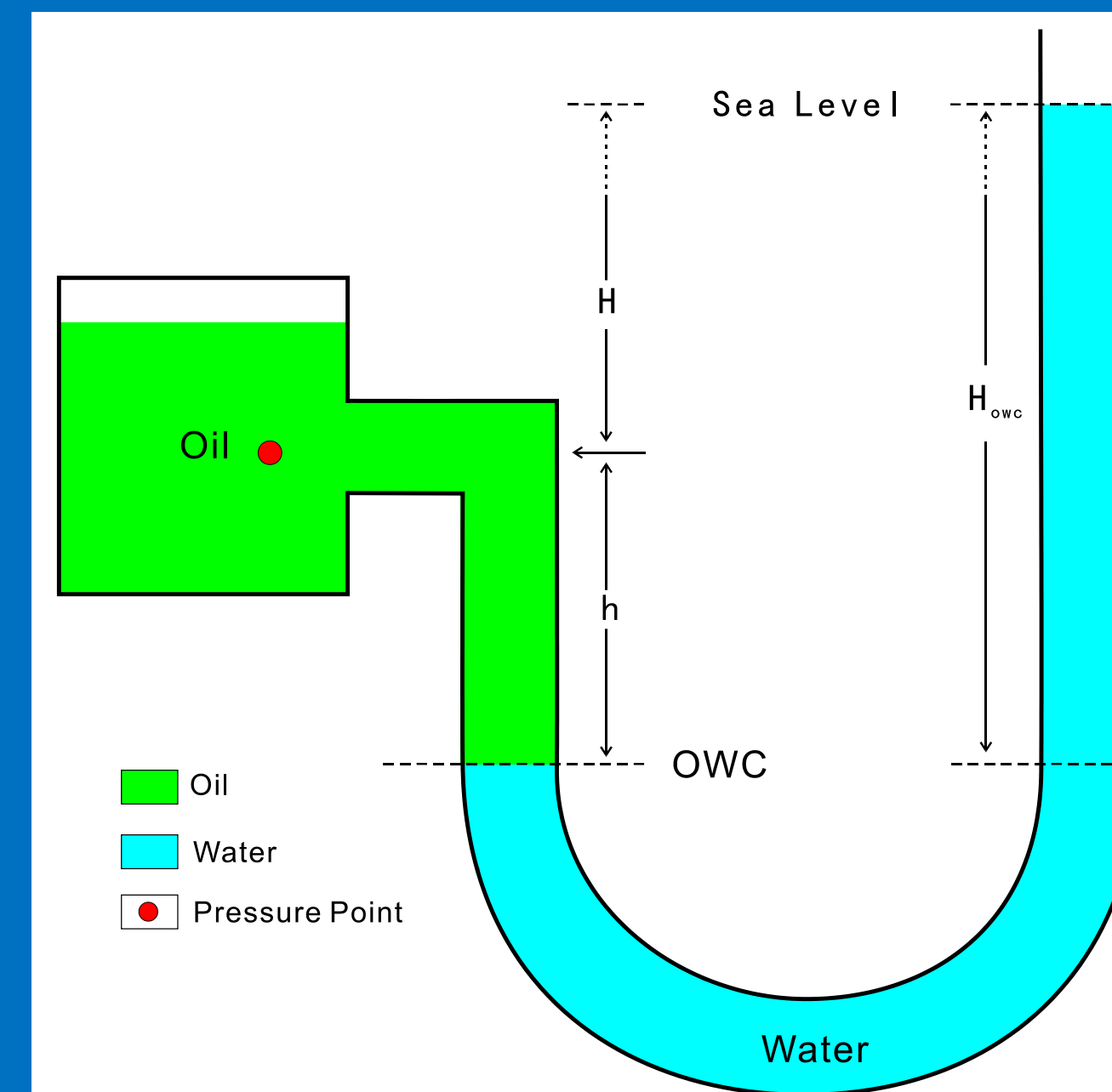


Fig.2 The application of U-type mercury manometer physical model into a normal pressure reservoir

Based on the principle of hydrostatics, U-type mercury manometer physical model is built and applicable into the normal pressure reservoir.

$$\text{Oil pay zone} \quad P_1 = P + \rho_o \cdot g \cdot h \quad (1)$$

$$\text{Hydrostatic network} \quad P_2 = P_0 + \rho_w \cdot g \cdot H_{OWC} \quad (2)$$

$$\begin{aligned} \text{Pore pressure in oil zone} \quad P &= P_0 + \rho_w \cdot g \cdot H_{OWC} - \rho_o \cdot g \cdot h \\ &= P_0 + \rho_w \cdot g \cdot H_{OWC} - \rho_o \cdot g \cdot (H_{OWC} - H) \end{aligned} \quad (3)$$

$$\text{Depth of the OWC} \quad H_{OWC} = \frac{P - P_0 - \rho_o \cdot g \cdot H}{(\rho_w - \rho_o) \cdot g} \quad (4)$$

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Where P_1 is pore pressure in oil pay zone, P_2 is hydrostatic pressure, P_0 is atmospheric pressure, ρ_o is the density of oil and ρ_w is the density of water, H is the depth of measured pressure and H_{OWC} is the depth of OWC, h is the distance between H and H_{OWC} .

3. Parameter selection (ρ_o & ρ_w) in the physical model

A case study on parameter selection in BZ28-34 oilfield, which has been found in 1984 and put into development in 2006, offshore Bohai Bay Basin in China.

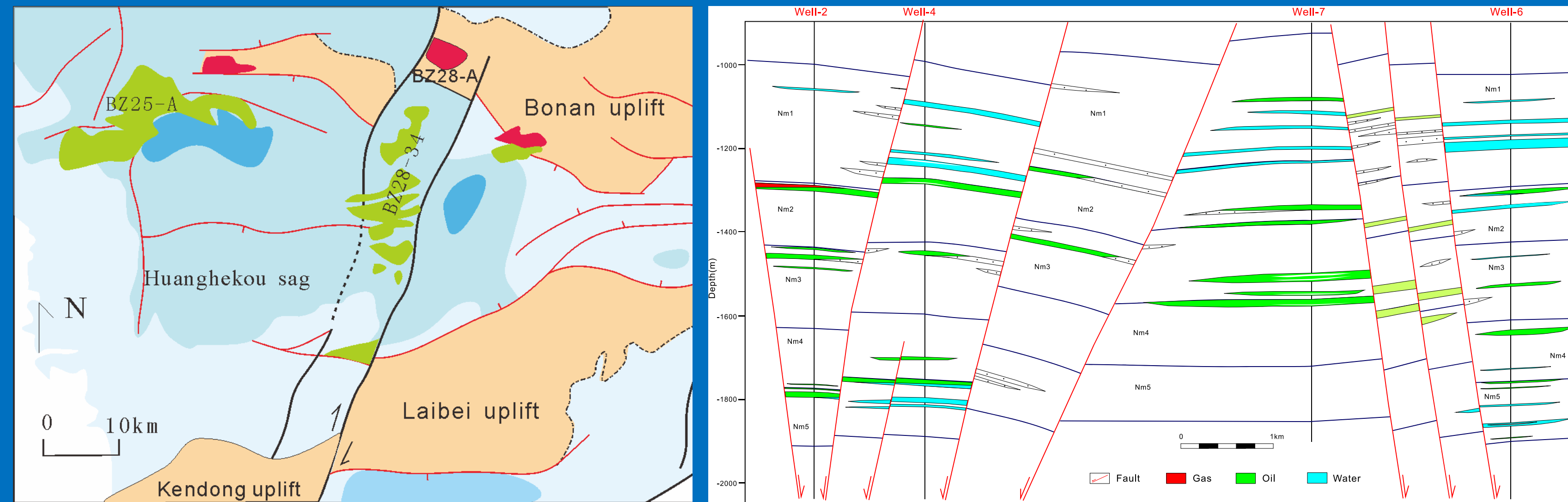


Fig.3 The regional location and shallow water delta & river system reservoir model of BZ28-34 oilfield

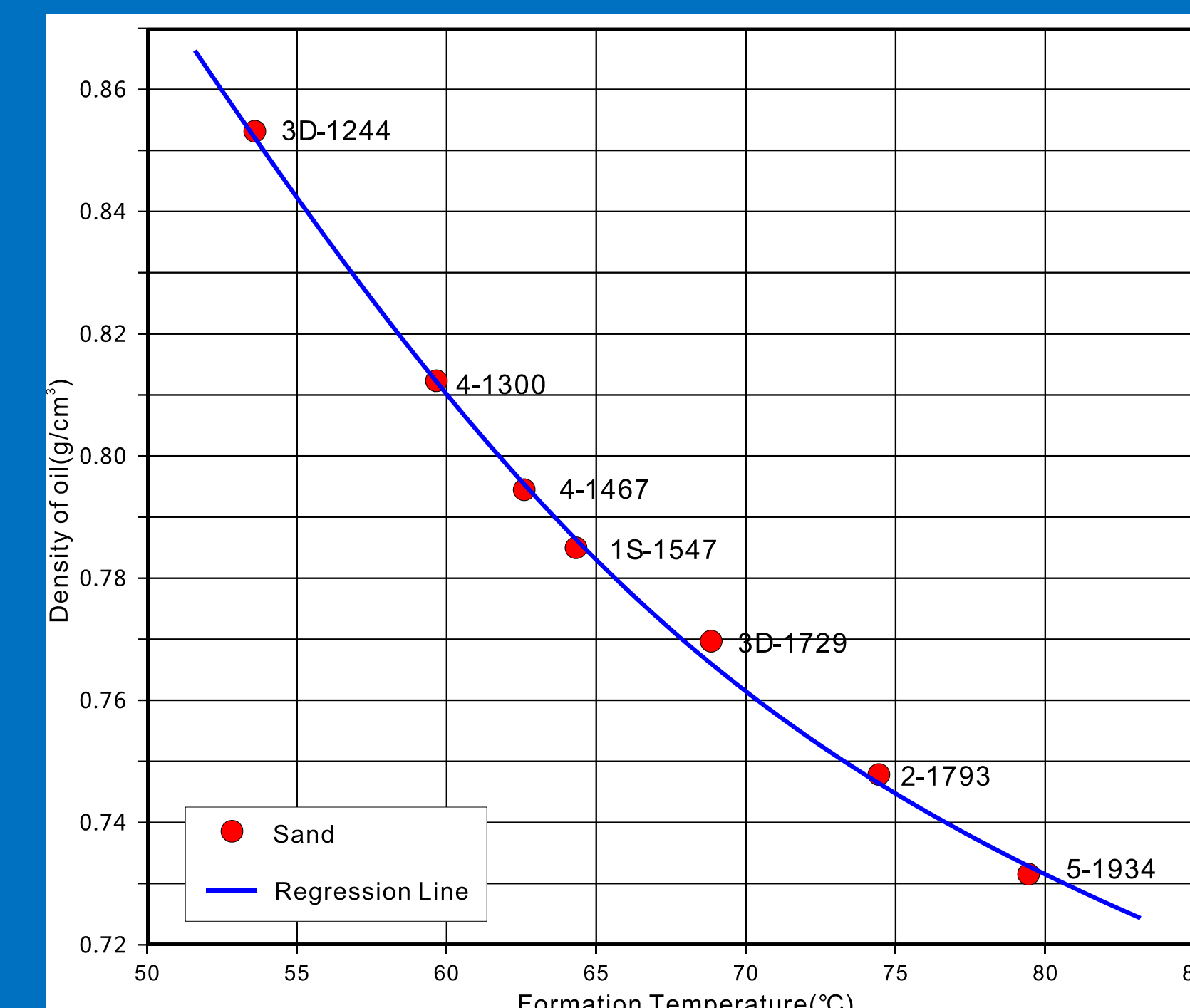


Fig.4 Plot of formation temperature VS density of oil

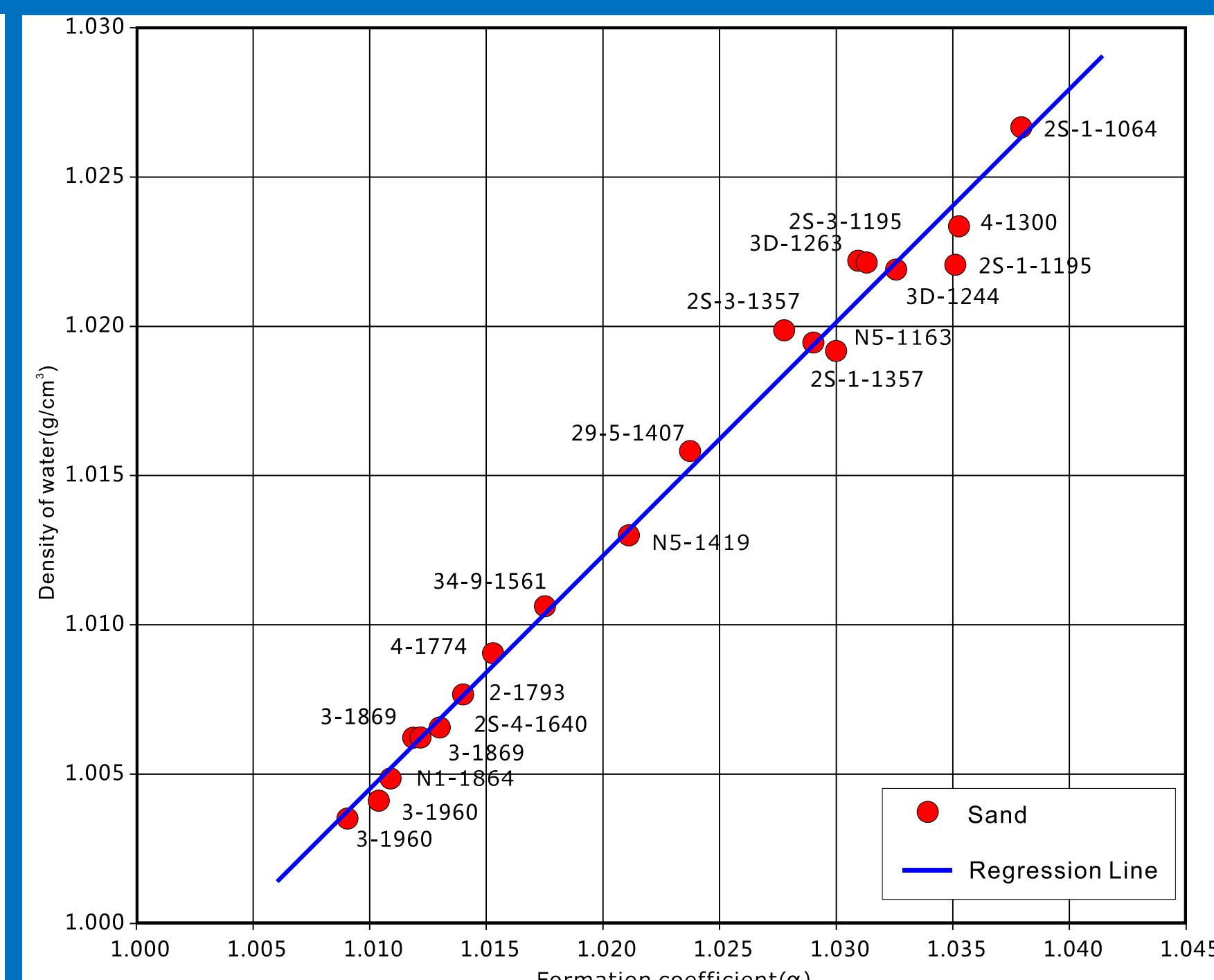


Fig.5 Plot of formation coefficient VS density of water

3.1 The density of oil (ρ_o)

Schmidt (1969) provided the empirical formula with the fluid density and formation temperature.

$$\rho_o = 0.0001 \cdot T^2 - 0.0173 \cdot T + 1.5036$$

Where T is the formation temperature (°C), and a is a constant.

4. The prerequisites and foundation for the OWC prediction

4.1 Ensure the connectivity between sand bodies

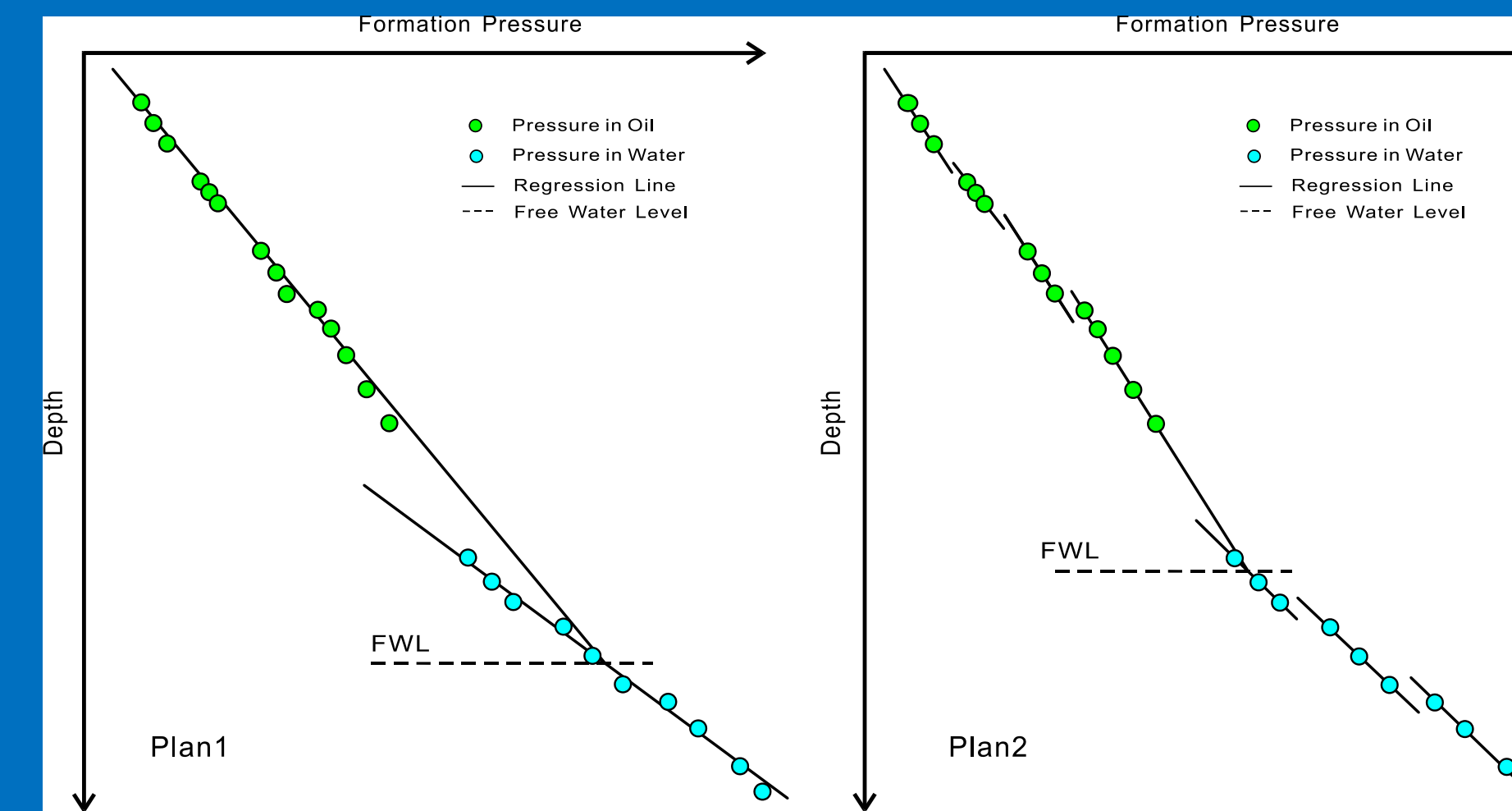


Fig. 6 Two plans for determination of sand bodies connectivity and the Plan2 is obviously appropriate

5. Advantages and applications in BZ28-34 oilfield

5.1 Ascertain the OWC in sand 6-1567

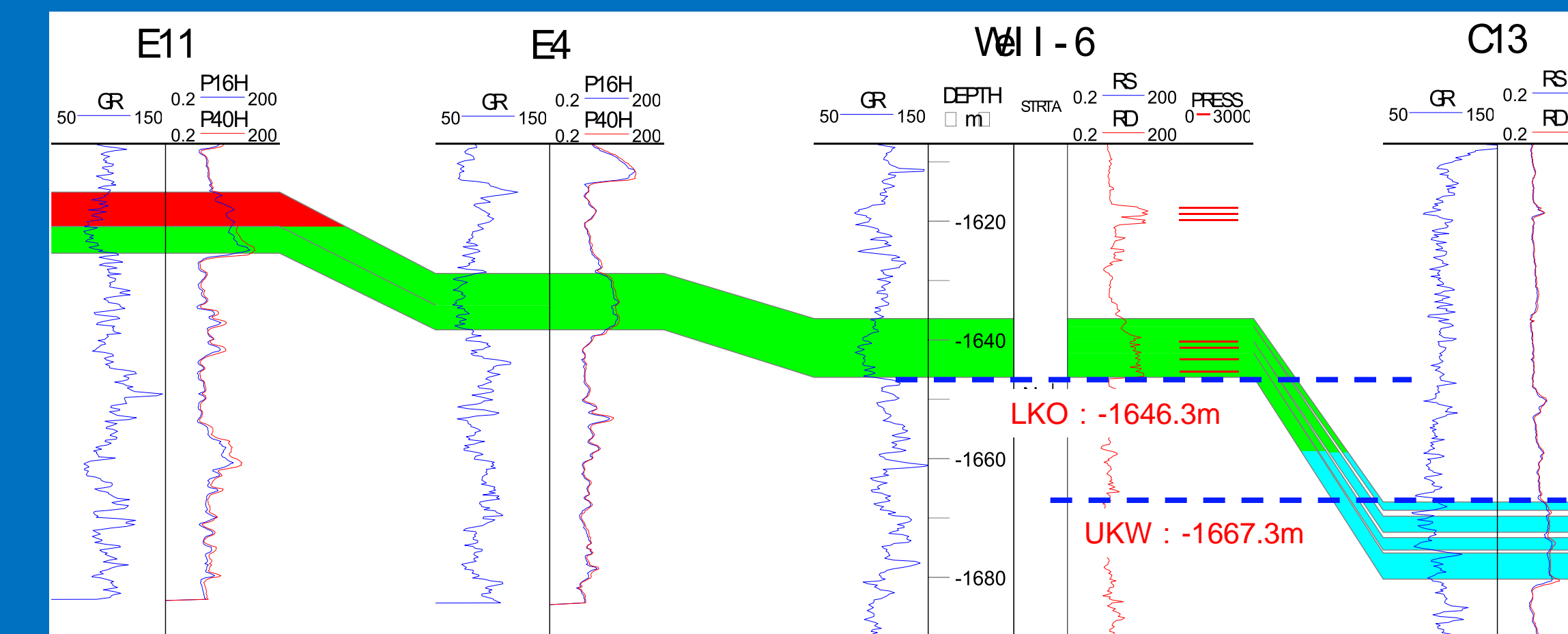


Fig.8 Cross-well correlation and reservoir model in Sand 6-1547 indicate that the OWC can be calculated utilizing the physical model in normal pressure

3.2 The density of water (ρ_w)

$$\text{Equation (3): } H \rightarrow H_{OWC}, h \rightarrow 0, P = P_0 + \rho_w \cdot g \cdot H_{OWC} \quad (4)$$

$$\text{Formation coefficient: } \alpha = \frac{P_0 + \rho_w \cdot g \cdot H_{OWC}}{\rho^{Hydro} \cdot g \cdot H_{OWC}} = \frac{P_0}{g \cdot H_{OWC}} + \rho_w \quad (5)$$

Formation coefficient (α) leads a linear scale with the density of water (ρ_w) for a normal pressure reservoir in BZ28-34 oilfield, where $\rho^{Hydro}=1$.

4.2 Exclude the fluid heterogeneity factor

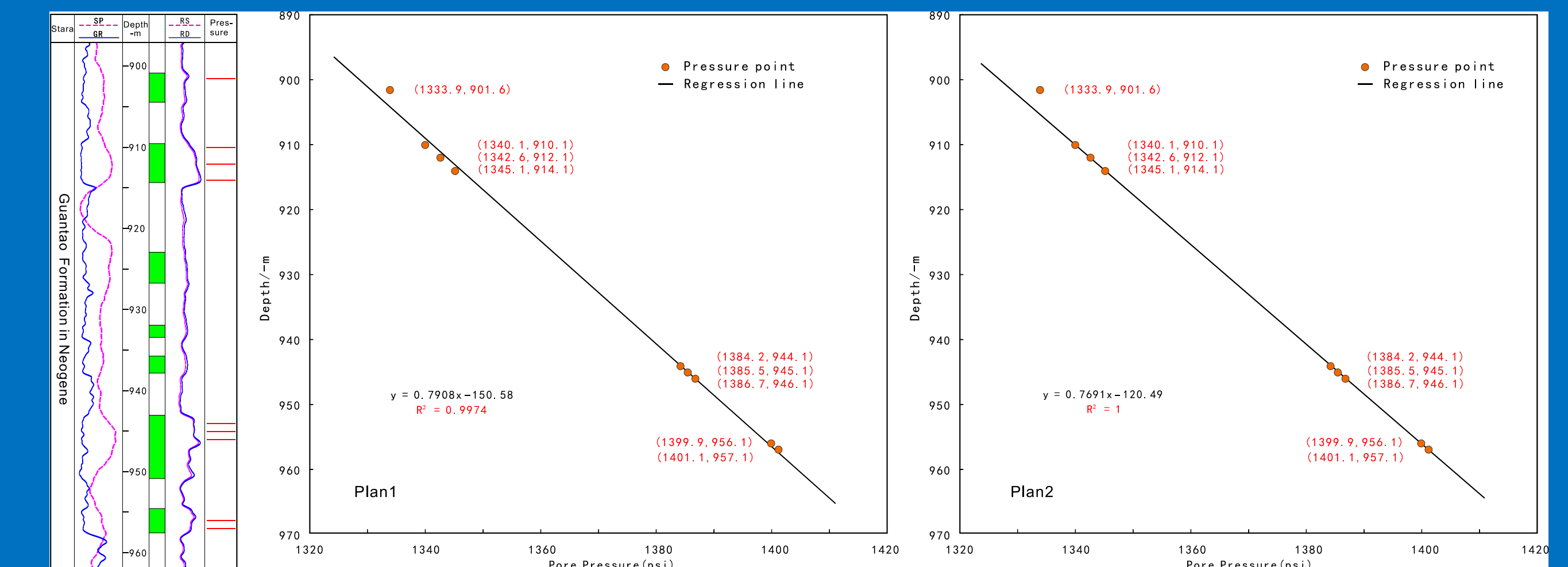
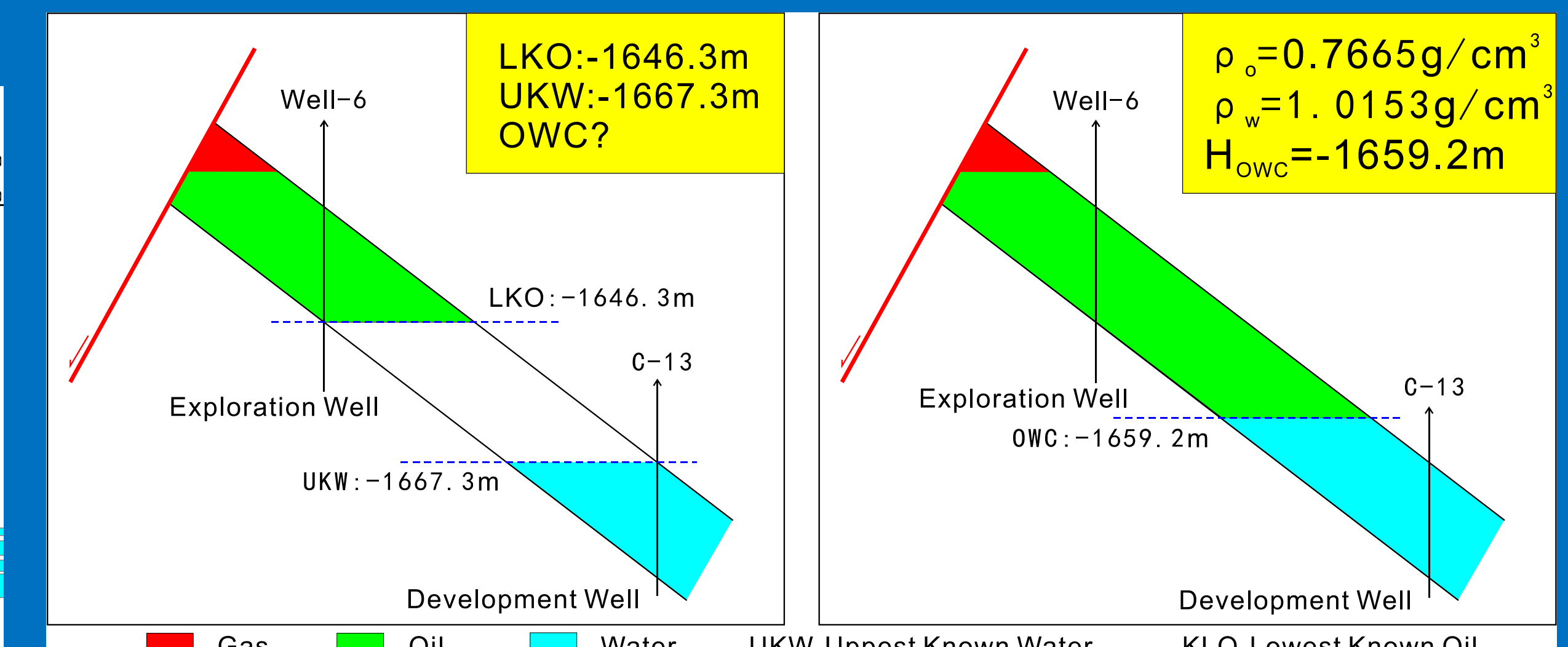


Fig.7 Two plans for crude oil property study and the Plan2 excludes fluid heterogeneity factor

Pore pressure corresponds with crude oil volume in normal pressure



$$\rho_o = 0.7665 \text{ g/cm}^3$$

$$\rho_w = 1.0153 \text{ g/cm}^3$$

$$H_{OWC} = -1659.2 \text{ m}$$

UKW-Uppermost Known Water KLO-Lowest Known Oil

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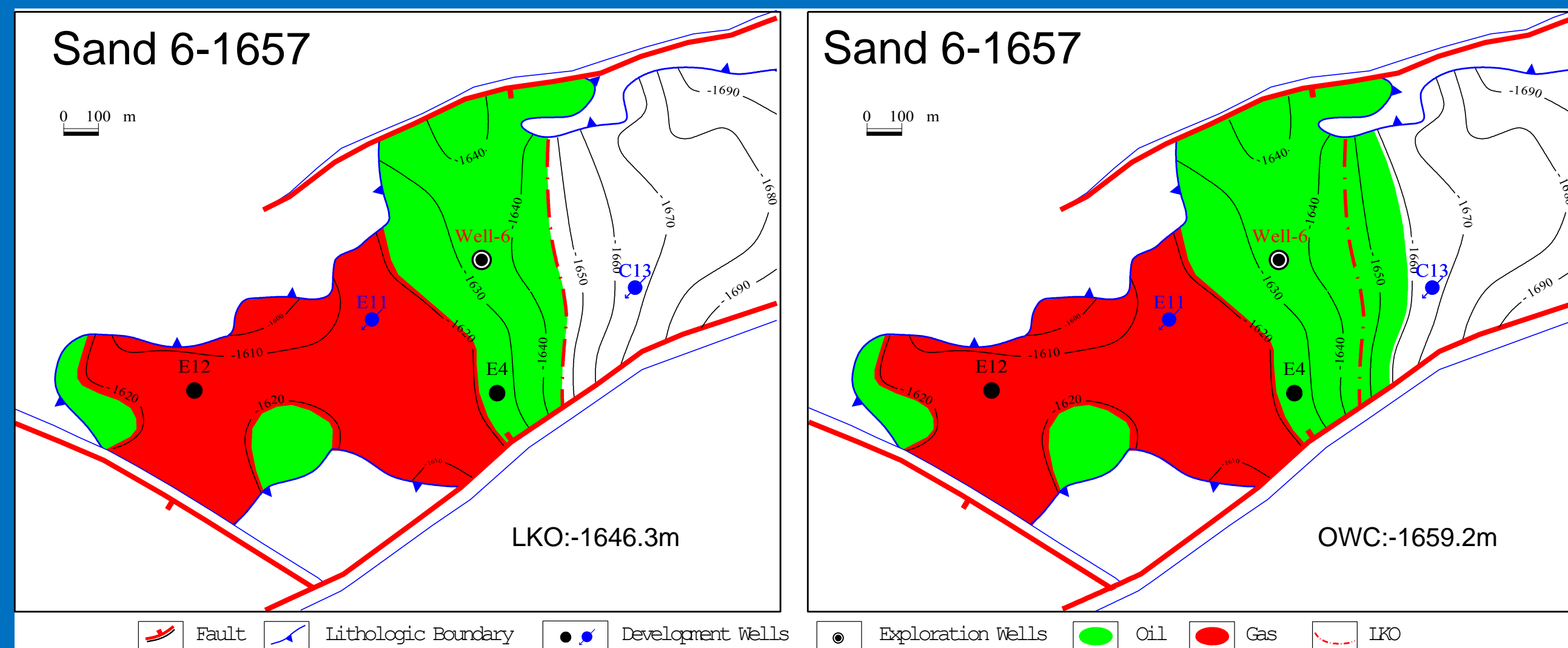


Fig.9 The contrast in oil bearing areas while the OWC is determined by the physical model

5.2 Ensure the edge water in sand 6-1546

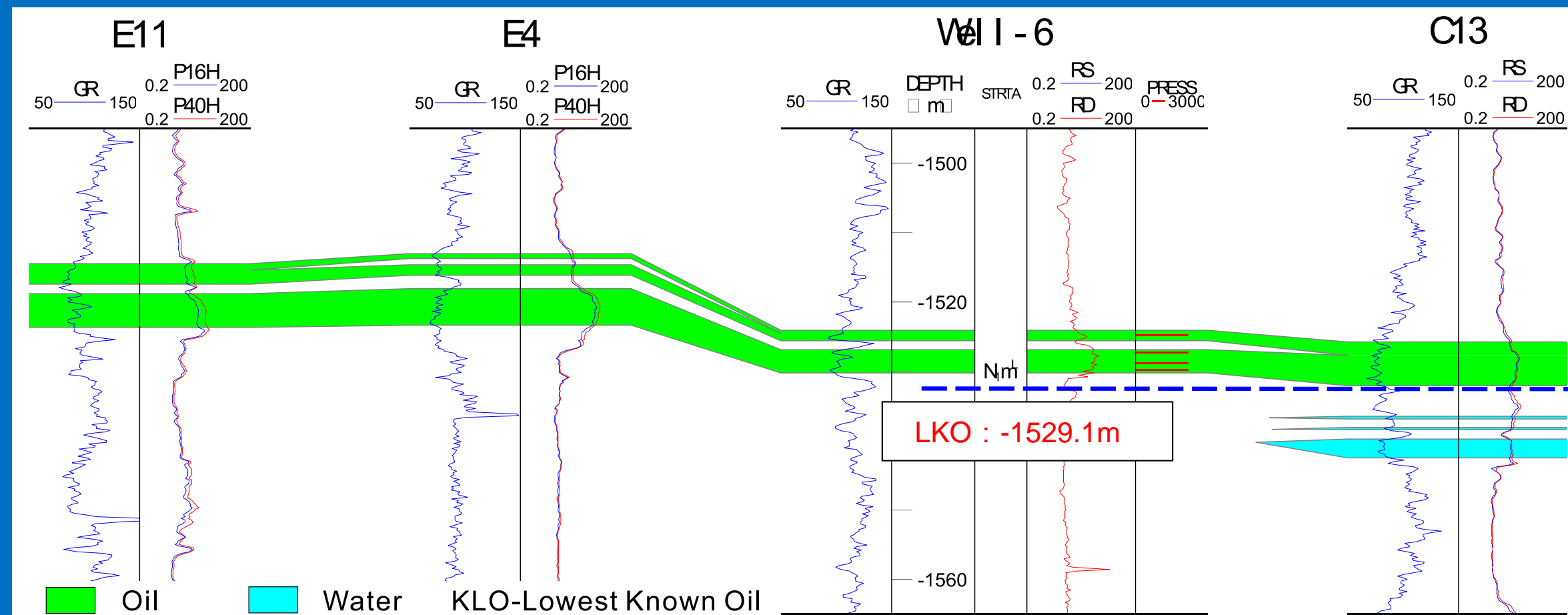


Fig.10 Cross-well correlation exhibits that it is unknown whether the water layer (-1533.5 ~ -1539.5m) in C13 is affiliated to the edge water of Sand 6-1546

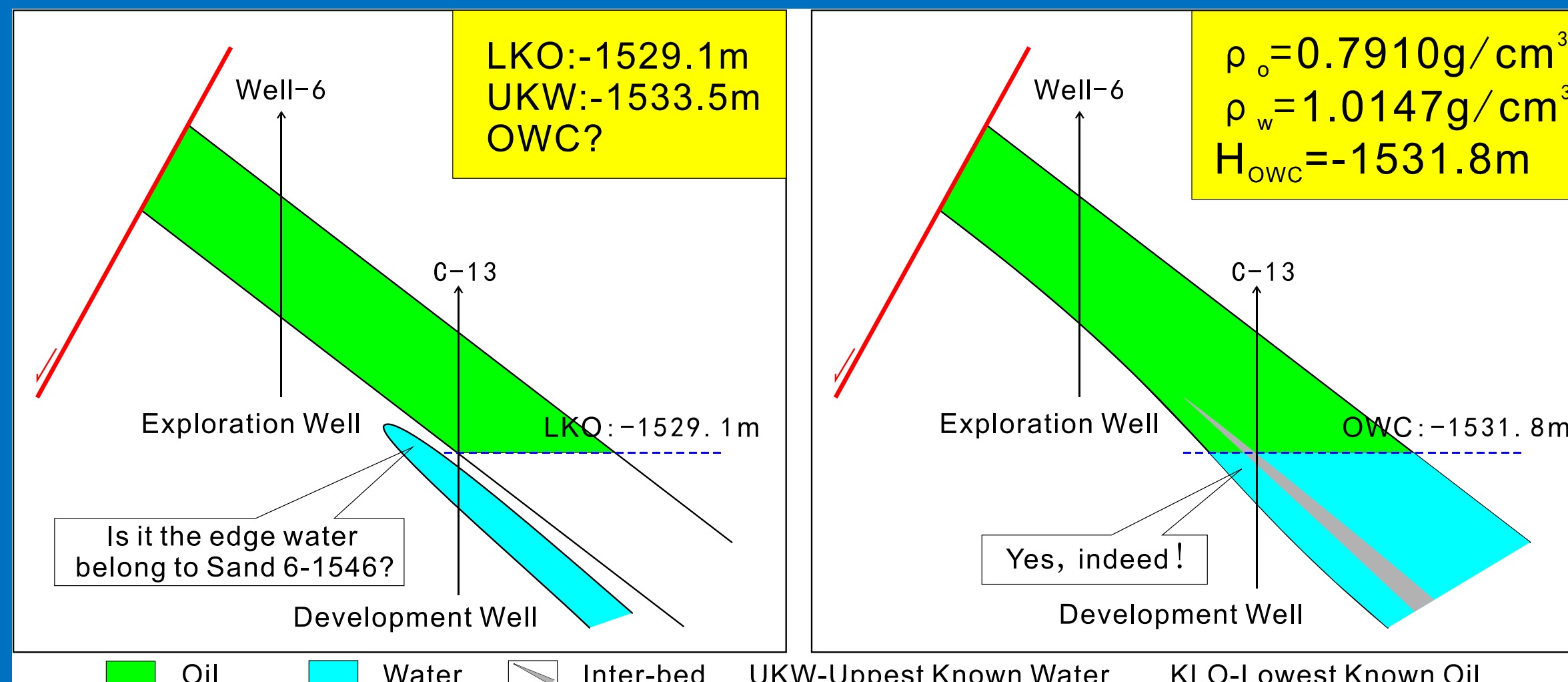


Fig.11 The edge water in C13 of Sand 6-1546 is confirmed by the OWC calculation

5.3 Decrease the deviation in Sand 5-1419

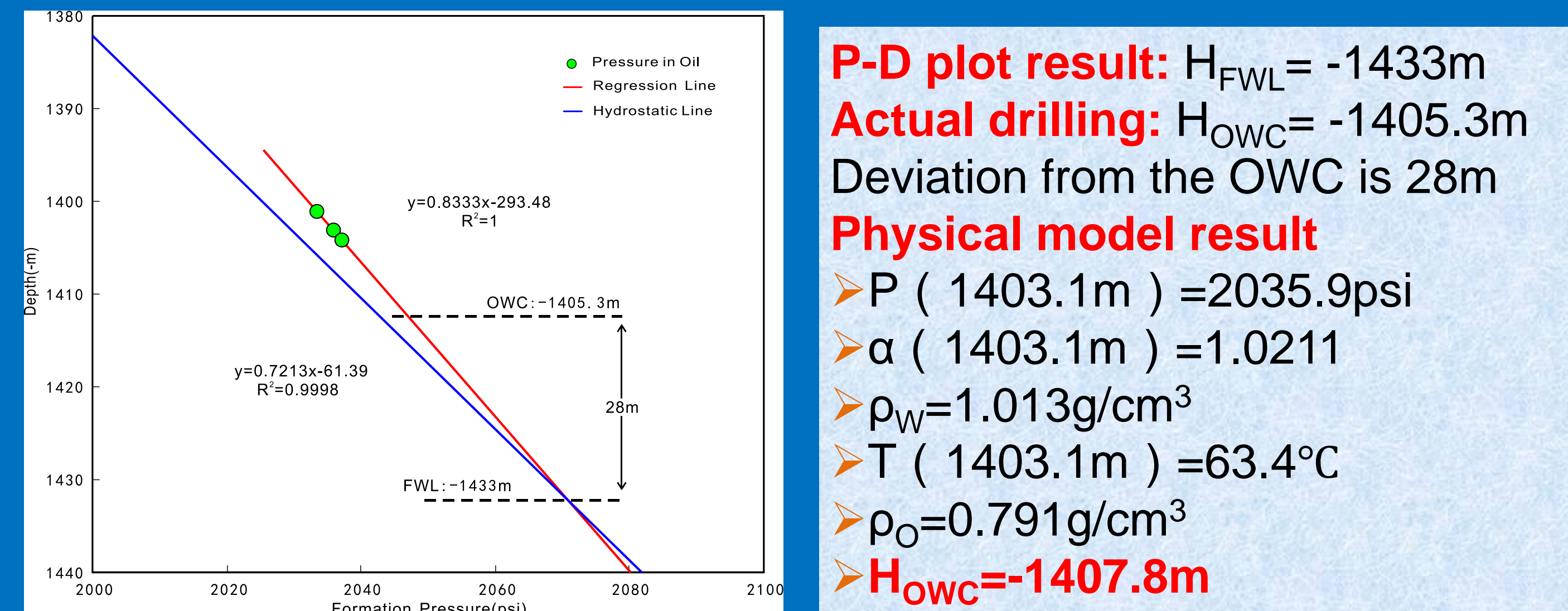


Fig.12 The FWL given by the linear rule is deviated 28m from the actual drilling result

5.4 Reduce the prediction error in Sand 4-1300

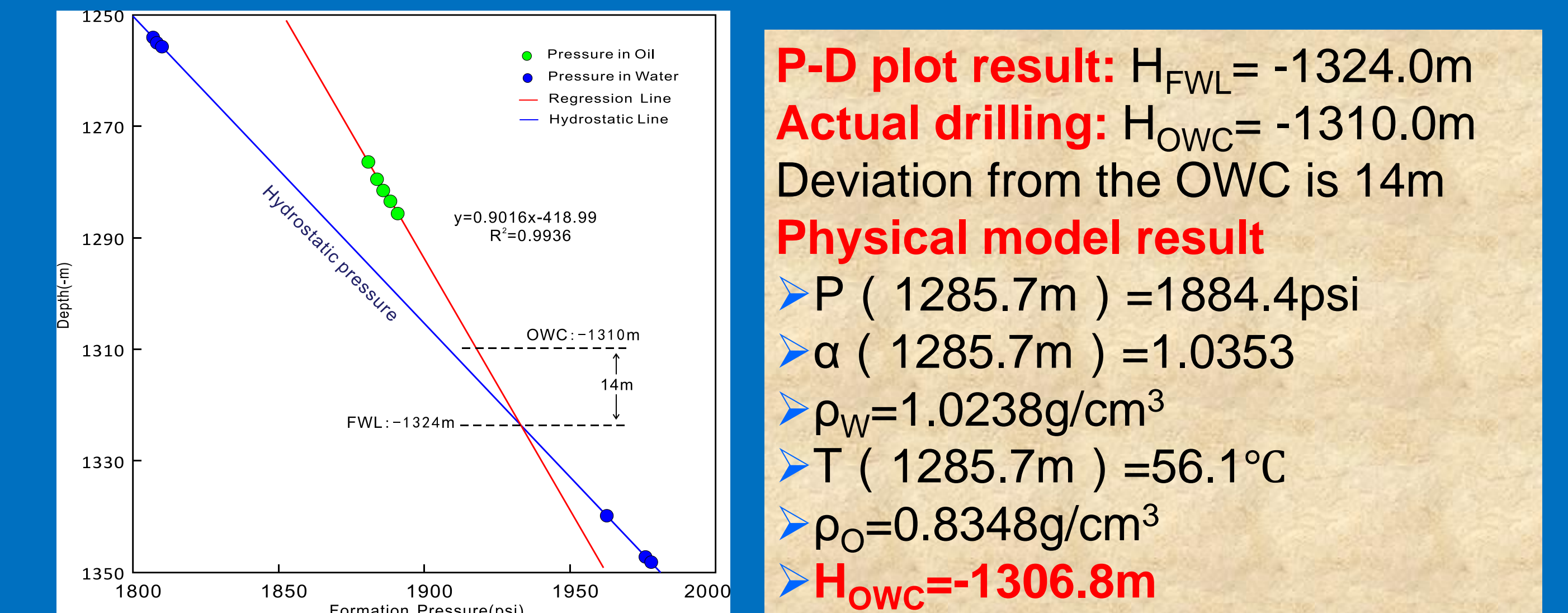


Fig.13 The FWL given by the linear rule is deviated 14m from the actual drilling result

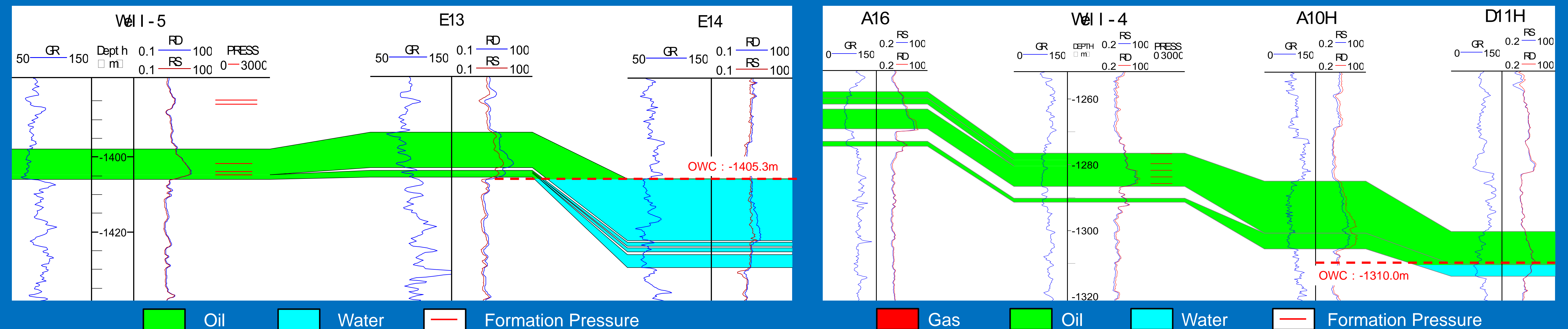


Fig.14 The values on the OWC in the actual drilling and physical model results are very approximate in more than 50 normal reservoir of BZ34-24 oilfield, such as Sand 5-1419, Sand 4-1300, Sand 6-1657&1546 and so on.

6. Discussion and conclusion

- 1) Parameters selection on density of oil and water, and function building on density of oil (ρ_o) VS formation temperature (T) and density of oil (ρ_w) VS formation coefficient (α) within a reservoir system are the critical criterion for the accurate OWC prediction.
- 2) Perfectly forecasting the OWC utilizing the physical model has led an important significance to estimate the oil in place and formulate the more reasonable reservoir development programs.
- 3) We will continue to strive for the excellent OWC prediction and application of Wireline Formation Testing in a challenging business landscape. Please contact me at email qiangeng@outlook.com if you have any thoughts about these, looking forward to hearing from you.