[EA]The Possibility of Hydrodynamic Trap in Tarakan Sub-Basin as an Explanation of the Existence of Water in an Identified Hydrocarbon Zone*

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Abstract

Tarakan Sub-basin has been proven as a prolific hydrocarbon area in North Kalimantan. Dealing with deltaic play system, subsurface challenges are to identify a thin reservoir, to image the complexity of geological structures, and to predict overpressure. Most wells in the Tarakan Sub-basin are identified with an overpressure zone.

A unique case occurred in the prospective zone of Well C which identified a hydrocarbon zone from wireline log, cutting oil show, and mud logging gas data but produced water during DST (Drill Stem Test). The hydrocarbon identification was also supported by formation pressure plot versus depth which gave a gradient value of 0.301 psi/ft. The value of this gradient indicates that the fluid filling the reservoir is a hydrocarbon.

An early hypothesis that was proposed explained that the hydrocarbons might not be trapped in that zone but already migrated and trapped to another zone. But this condition is hard to explain because if hydrocarbons had migrated, the responses from the wireline log and pressure gradient would have indicated water, not hydrocarbons.

Evaluation of that unique phenomena using comprehensive well data has been accomplished. Wireline logs, formation pressure, and water salinity are essential to identify the overpressure zone and hydrodynamic condition in the subsurface. The objective is to get better understanding of the water flow related to overpressure and water salinity as well as its implication to petroleum system.

The latest hypothesis is that the zone was filled with hydrocarbons, which is supported by wireline log and pressure gradient response, but there is a strong water drive mechanism caused by active hydrodynamic conditions in the reservoir. If this condition existed, then the contact between hydrocarbon and water might be tilted.

Introduction

The Neogene delta of the Tarakan Sub-basin was developed in Middle Miocene (Morley et al., 2017). The source sediment of the Tarakan Sub-basin delta system is coming from several feeding rivers as in the modern setting, which end up in an open marine setting of the Sulawesi Sea. Because of that setting, the delta sediment is strongly influenced by waves and tides that caused the sediment to disperse. Consequently, the delta of the Tarakan Sub-basin was not developed in a single deposition center but spreading widely along the Sulawesi Sea, bounded by the Maratua High and Samporna High.

An identified hydrocarbon zone has been tested with strong indications of hydrocarbons from well log and pressure data (Figure 1). Unfortunately, the result was water flowing from the zone. Many hypotheses have been proposed to explain the existence of water in the reservoir. One hypothesis proposed earlier was that the hydrocarbons had already migrated structurally to another place, so that the well testing produced water. This hypothesis was only a glance conclusion without thorough analysis from all related data. This one also triggered many questions especially about the data reliability.

Based on the later discussions, this hypothesis was unlikely to occur because if hydrocarbons had migrated, the responses from the wireline log will also change to indicates water, not strongly indicating hydrocarbons. In addition, the concept of migrated hydrocarbons is very difficult to explain the value of the pressure gradient of 0.301 psi/ft as described above. The robust analysis of all related well data, another hypothesis emerged about lateral reservoir drainage.

Lateral reservoir drainage is a hydrodynamic flow type driven by the difference in overpressure. It can lead to hydrodynamically tilted hydrocarbon water contact and open an opportunity of finding oil and gas in places where previously are not considered as potential traps. In principle, this hydrodynamic flow is similar to ‘classical gravity-driven hydrodynamic flow’ (Hubbert, 1953). The difference is only in the driving mechanism and its associated source of fluid for the fluid flow. In the lateral reservoir drainage, the source of fluid is overpressured mudrock, while in the classical gravity-driven, the source of fluid is meteoric water entering the reservoir from a higher elevation.

Comprehensive Well Result Analysis

An important information that was provided from the well and can lead to another hypothesis is pressure. From the pressure - depth plot (Figure 2) it was obvious that the tested zone is in an overpressured condition. The cuttings produced from drilling also showed the same condition with splintery caving occurred while drilling the tested zone. This condition was responded by increasing the mud weight from 11.2 ppg to 11.4 ppg. It can be concluded that overpressured shale pressure is between 11.2 ppg and 11.4 ppg. The reservoir pressure was 10.35 ppg that coming from well testing measurement. This indicates an estimation of 1 ppg difference of shale-sand pressure. This difference in pressure (often stated as sand-shale pressure discrepancy) indicates that the reservoir is in an active hydrodynamic condition, also known as lateral reservoir drainage (Ramdhan et al., 2018).

The position of the top of overpressure in the Tarakan Sub-basin is gradually shallower to the West (Figure 3). This trend is similar to the stratigraphic correlation, but the trend of top overpressure correlation is more gentle than the stratigraphic correlation. This condition could create a significant differential pressure within the same stratigraphic unit so that fluid may flow.

The uncertainty of the fault behavior in this area became the main issue. The geomechanical analysis result showed that in the overpressured zone, stress regime in the well area are in critical condition (Figure 2). So, the fault located close to the well is interpreted as a leaking fault. This condition could create hydraulic communication between the down thrown part and the up thrown part.

Salinity analysis of this well shows that water salinity in the reservoir zone is at 6000 ppm. This salinity is close to fresh water, not brine as commonly found in deep reservoirs. This water is interpreted not from meteoric water (rainwater), considering the possibility that meteoric water could not penetrate to depth of 10,000 ft and because the reservoir is in an overpressure condition. It is unlikely that the "hydraulic head" of meteoric water can penetrate the overpressure zone.

The salinity - depth plot from the well is shown in Figure 4. It can be seen that the salinity decreases at the tested zone. This salinity trend is similar with the salinity trend in the Tunu Field in Kutei Basin, where at some level below the top overpressured zone, the salinity trend decreases (Said, 2017). This salinity value is interpreted by coming from clay dewatering. This process (reverse osmosis) can occur because of differential pressure generated by sand-shale pressure discrepancy and creates fluid flow.

The Possibility of Hydrodynamic Trap

A new hypothesis has been proposed based on comprehensive analysis as described previously. The new hypothesis is about lateral reservoir drainage which highlighted the role of overpressure in the tested zone that affected the hydrocarbon trapping mechanism. The hydrocarbons probably still be there but the accumulation moved downdip at the flank and the hydrocarbon contact might be tilted because of the hydrodynamic condition (Figure 5).

This hypothesis can explain why the tested zone produced water. The perforated interval could be located at the tip of hydrocarbon accumulation (Figure 5). Despite hitting the tip accumulation, the hydrocarbons could not move into the borehole because of the strong water drive. Figure 5 showed that the leaking fault could create hydraulic communication from the upthrown part to the downthrown part and blocked the hydrocarbon movement to the borehole.

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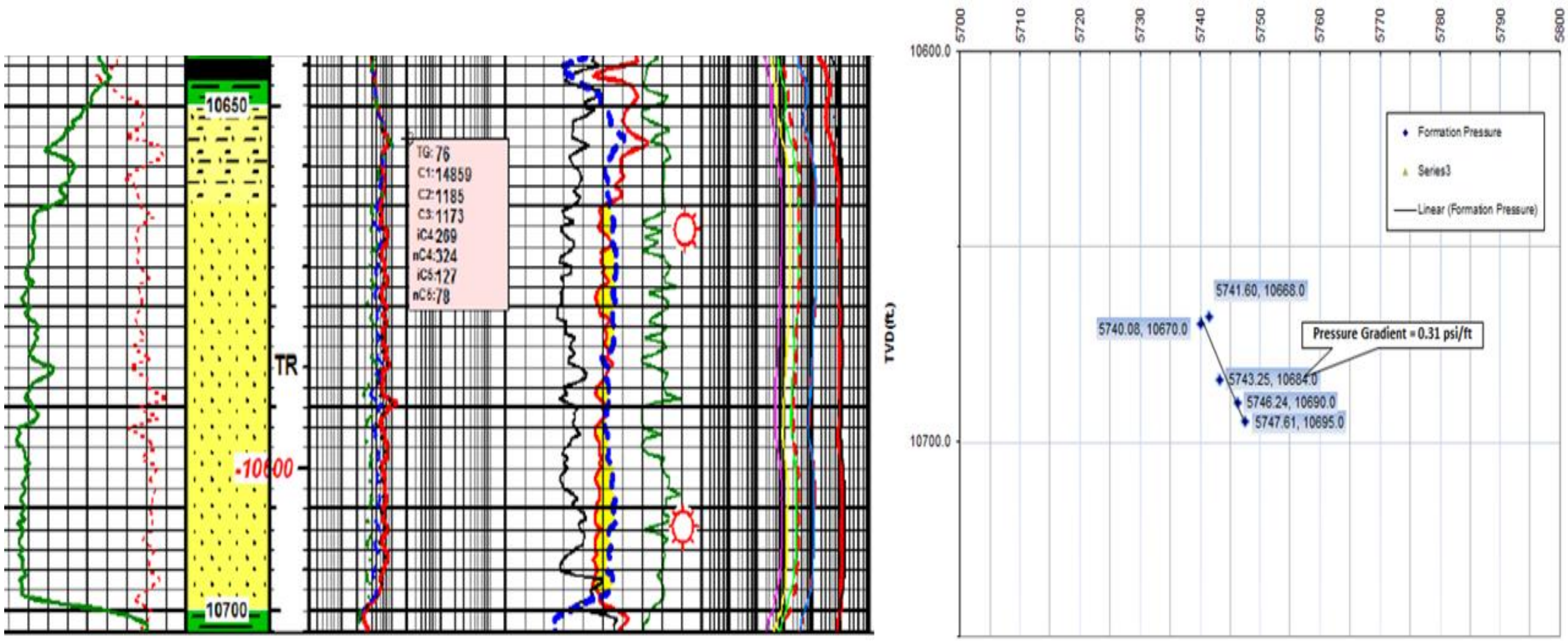

Figure 1. Hydrocarbon indication in wireline log signatures and pressure gradient plot.

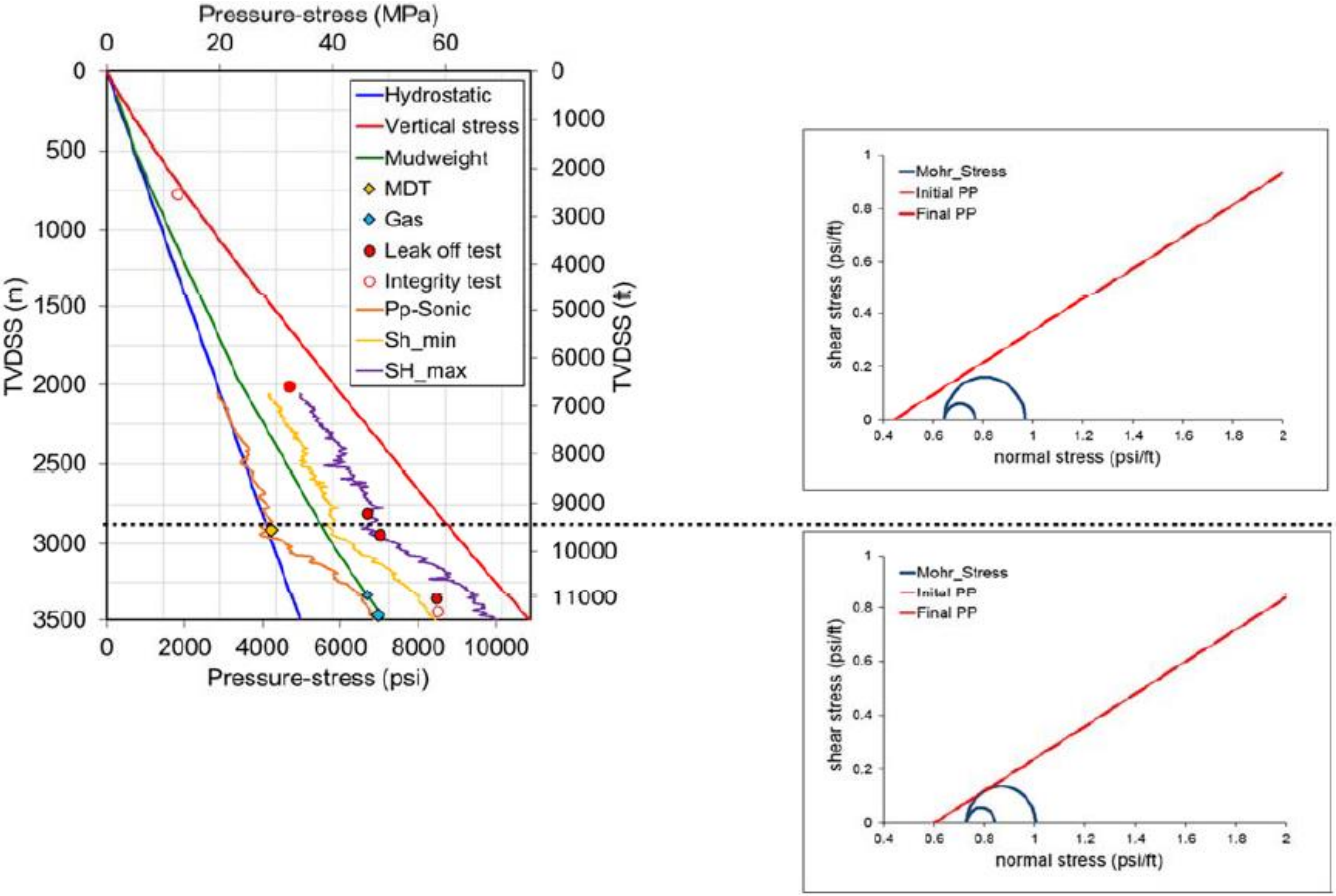

Figure 2. Pressure profile of Well C and stress conditions around well area. Overpressured zone (below the dashed line) is in critical stress condition.

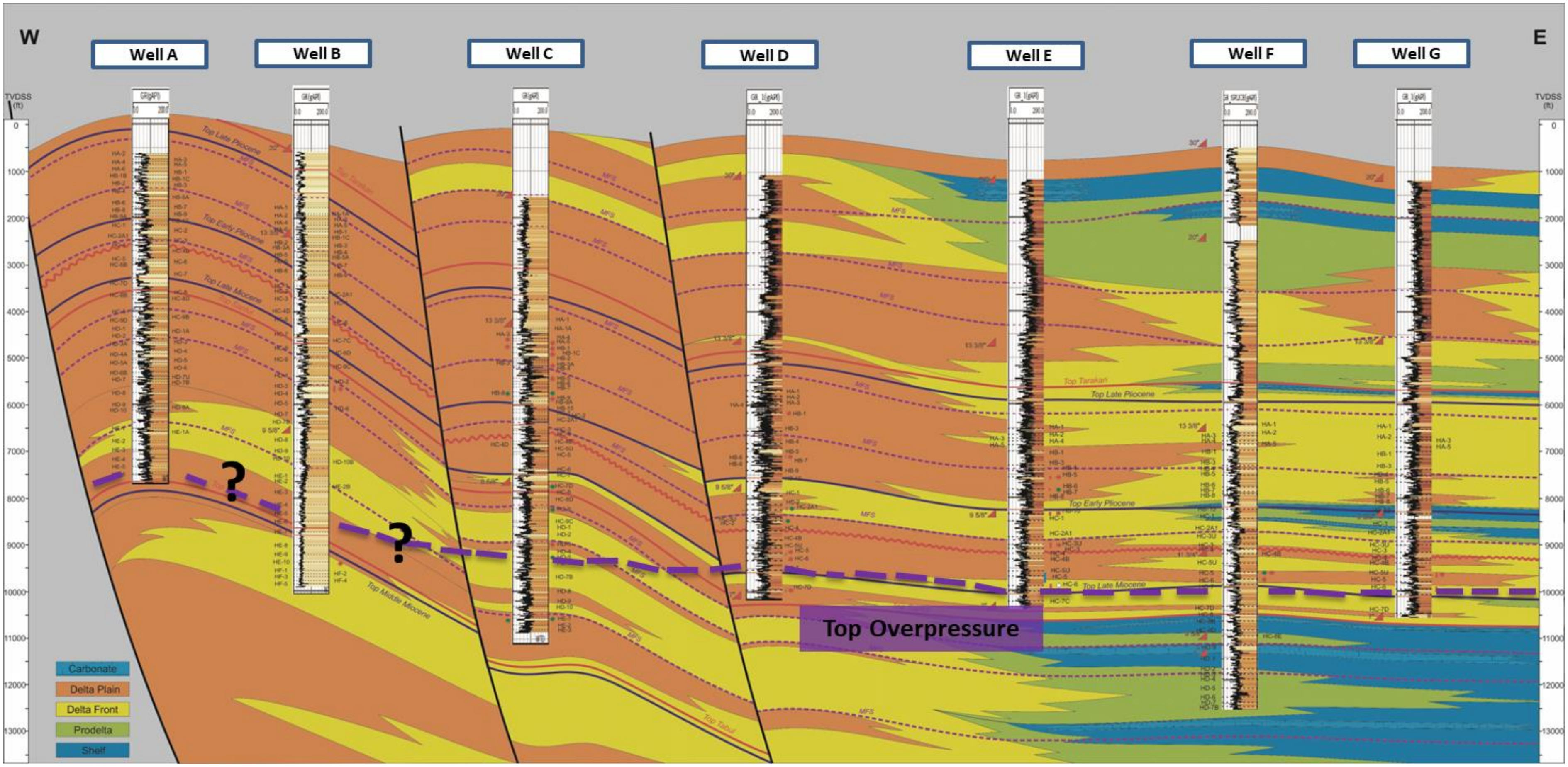

Figure 3. Well geologic correlation to illustrate the depositional environment W-E across Well A through Well B with information of Top Overpressure.

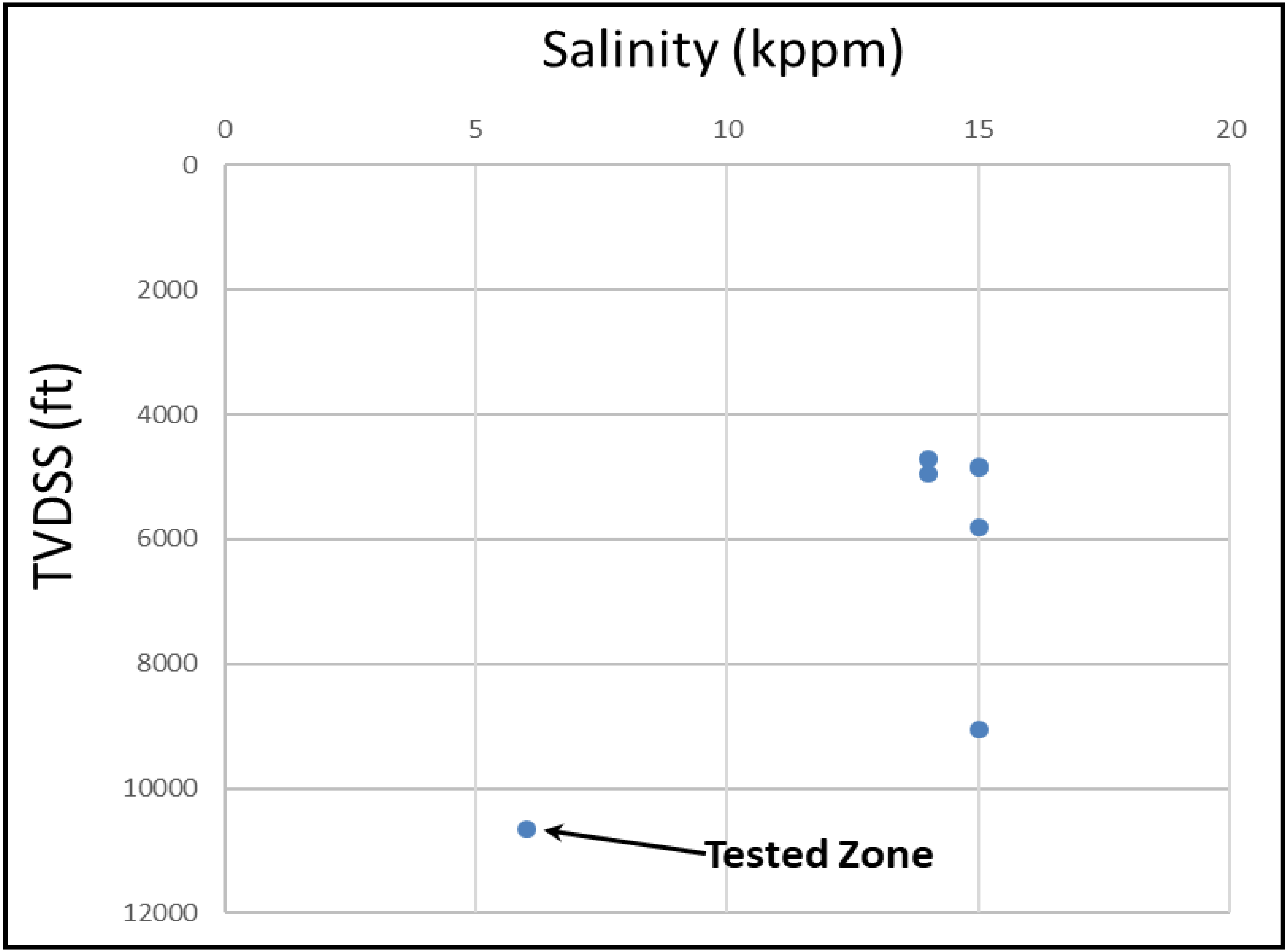

Figure 4. Depth vs Water Salinity crossplot from Well C.

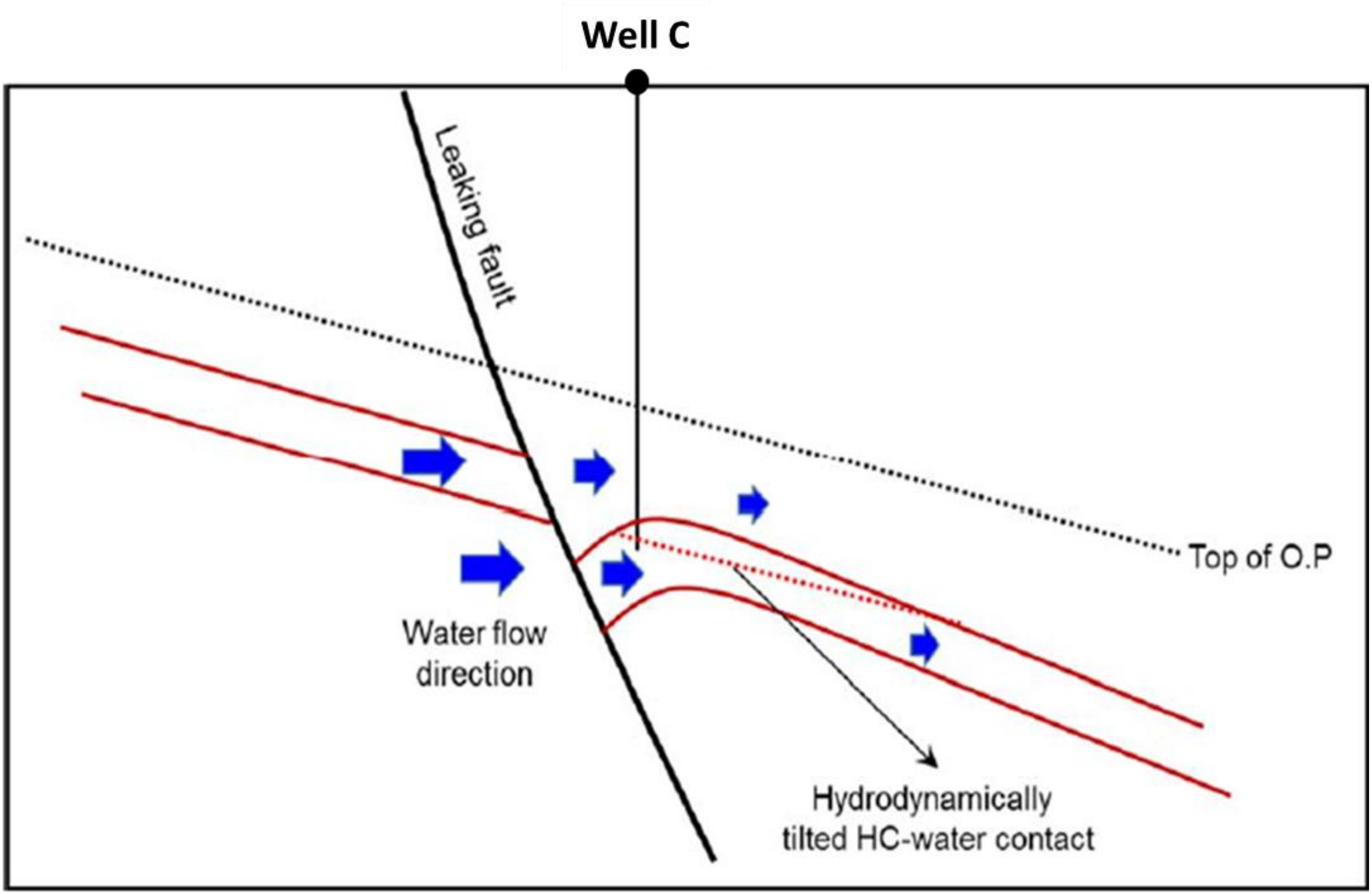

Figure 5. Conceptual hydrodynamic trap in Well C location shows the possibility of tilted hydrocarbon contact.