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Channel chasing in the D35 field offshore Sarawak

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Abstract: The D35 oilfield was discovered in 1983 and over the next seven years, six appraisal wells were drilled to test the reservoir and hydrocarbon distribution. The productive reservoirs comprise exclusively of channel deposits of Early to Middle Miocene age, which exhibit highly variable lateral reservoir distribution. Development drilling in the field began in 1993 with fifteen wells drilled from two platforms.

Results from this initial development campaign indicated that a secondary objective, the Cycle III Channel Sand was absent over much of the field. This resulted in a downward revision in the inplace oil volumes for this reservoir unit and downgraded its prospectivity.

As part of efforts to enhance the structural and stratigraphic understanding of D35 prior to further development, a 3D survey was acquired in 1995 aimed at giving superior lateral and vertical resolution. The initial result of the interpretation appears promising. Seismic amplitude extractions at and near the Cycle III Channel Sand level have revealed features which are diagnostic of reservoir geometry and has helped explain much of the disappointing results from the first round development. More significantly the new 3D has highlighted additional scope for hydrocarbon recovery from this reservoir.

DEVELOPMENT HISTORY

The D35 field is located in the Balingian geological province some 130 km offshore and to the northwest of Bintulu town Sarawak (Fig. 1). The field was discovered in 1983 following which 2 appraisal wells (D35-3, D35-4) were drilled encountering the hydrocarbon accumulation in the main field area. Between 1986 and 1990 a further 3 appraisal wells (D35-5, D35-6 plus D35-6 sidetrack and D35-7) were drilled to test the northern and western limits of the field. Development drilling in D35 was undertaken from late 1993 to early 1994 and comprised of 14 wells drilled from two drilling platforms D35DP-A and D35DP-B. First oil production came on stream in October 1994.

RESERVOIR FRAMEWORK

The hydrocarbon bearing reservoirs in D35 comprise of sandstones of Early to Middle Miocene age and are deposited within stratigraphic intervals which have been defined as the lower Cycle III and Cycle II sequence. The reservoirs were deposited in a river dominated, lower delta plain environment and are normally found as single sandbodies (up to 40+ ft) with somewhat variable lateral continuity. These sands are generally of good quality exhibiting porosities of up to 26 percent and permeabilities of Ca. 500–4,000 mD.

The lower Cycle III interval has an average thickness of around 700 ft, its top and base being defined by two coal markers i.e. the Cycle III coal marker and Base Cycle III, respectively. The interval consist's predominantly of shales which are intercalated with coal layers and thin sandstones. Only one well developed hydrocarbon-bearing sand i.e. Cycle III Channel sand, was penetrated in this interval in well D35-4. Well logs suggest that this 37 ft thick sandbody may be correlated with thinner hydrocarbon bearing sandbodies in D35-1 and D35-3, thus indicating a possible genetic relationship i.e. channel sandbody in D35-4 with crevasse splays in D35-1 and D35-3 (Fig. 2). Based on the interpreted facies relationship from these wells, two orientation models were put forward prior to the field's development.

1. Approximately SW-NE trending with wells D35-1 and D35-3 located on the east and west flanks respectively (Fig. 3).
2. Approximately W-E trending with wells D35-1 and D35-3 located to the north of the main channel axis (Fig. 4).

DEVELOPMENT RESULTS

Development drilling in D35 was primarily aimed at establishing production from the more prolific Cycle II reservoirs (about 75 percent of total in-place oil volumes) with the Cycle III Channel

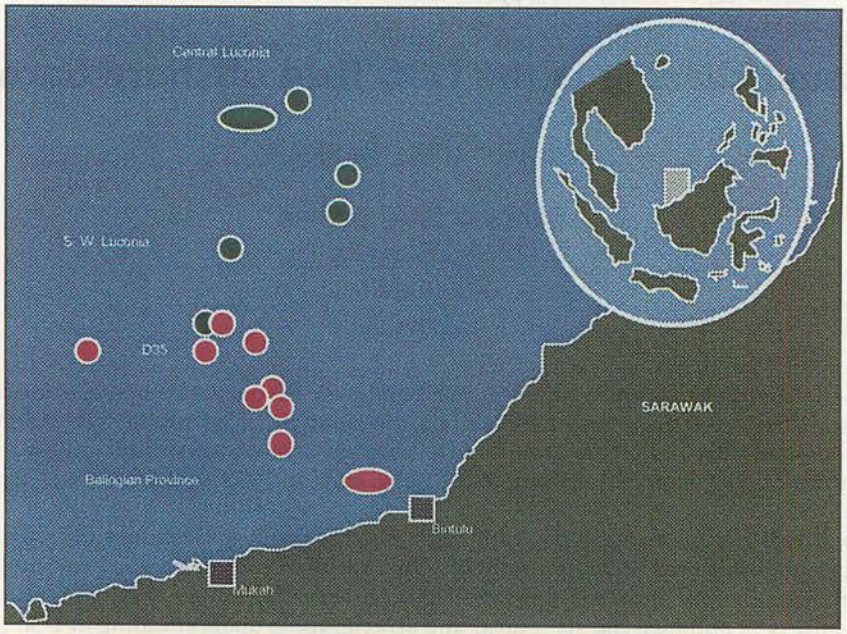

Figure 1. D35 location map.

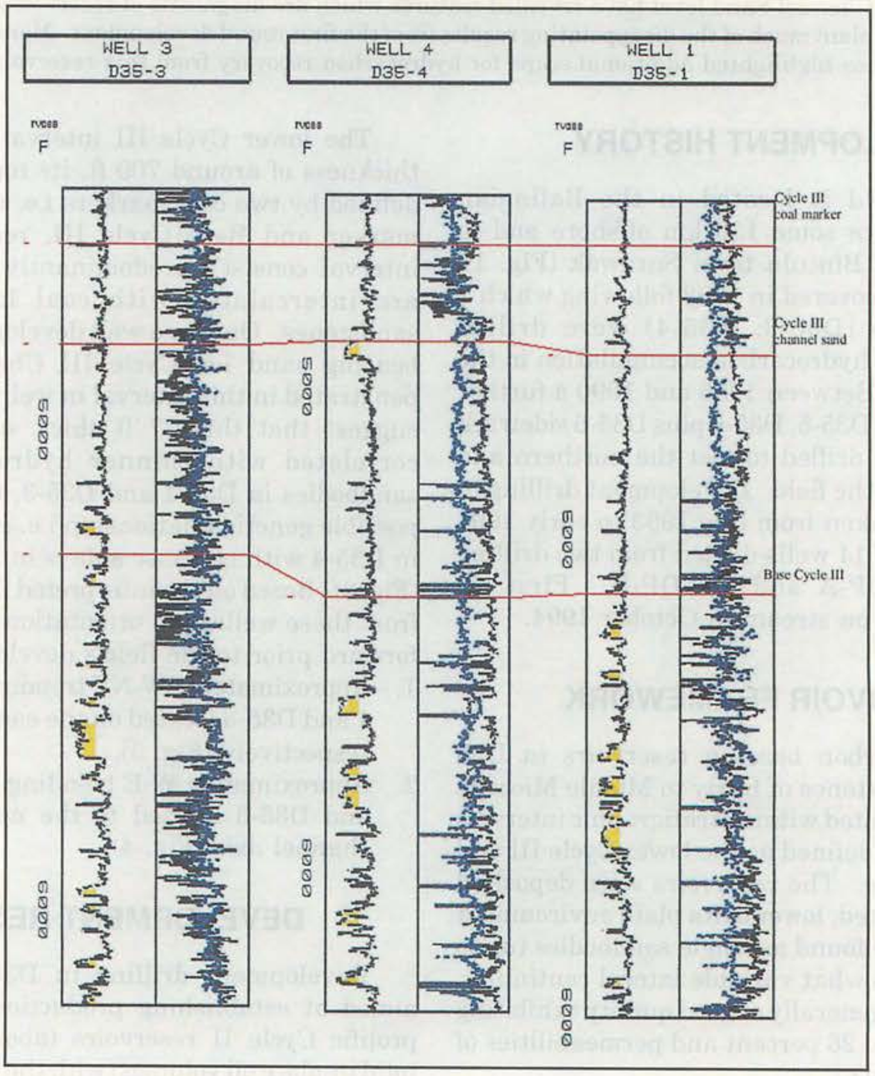

Figure 2. Prospective interval stratigraphy.

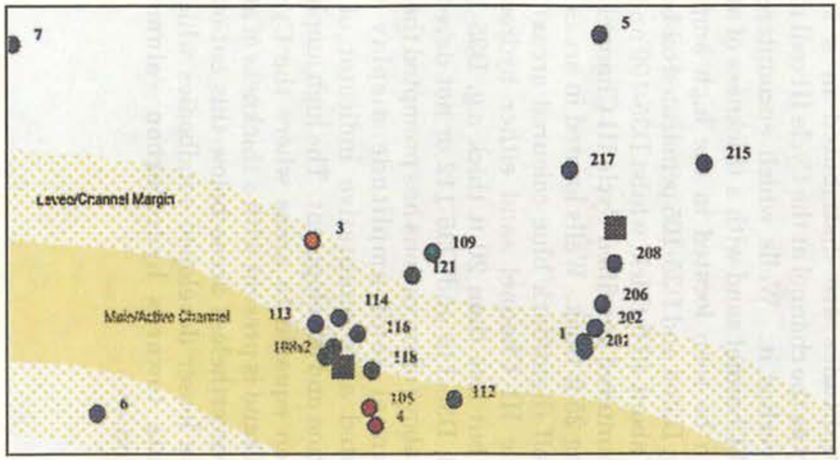

Figure 3. Cycle III Channel sand orientation scenario 1.

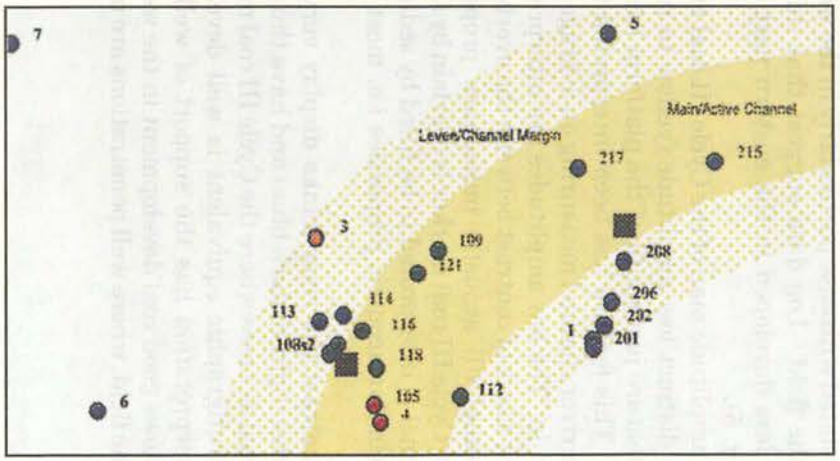

Figure 4. Cycle III Channel sand orientation scenario 2.

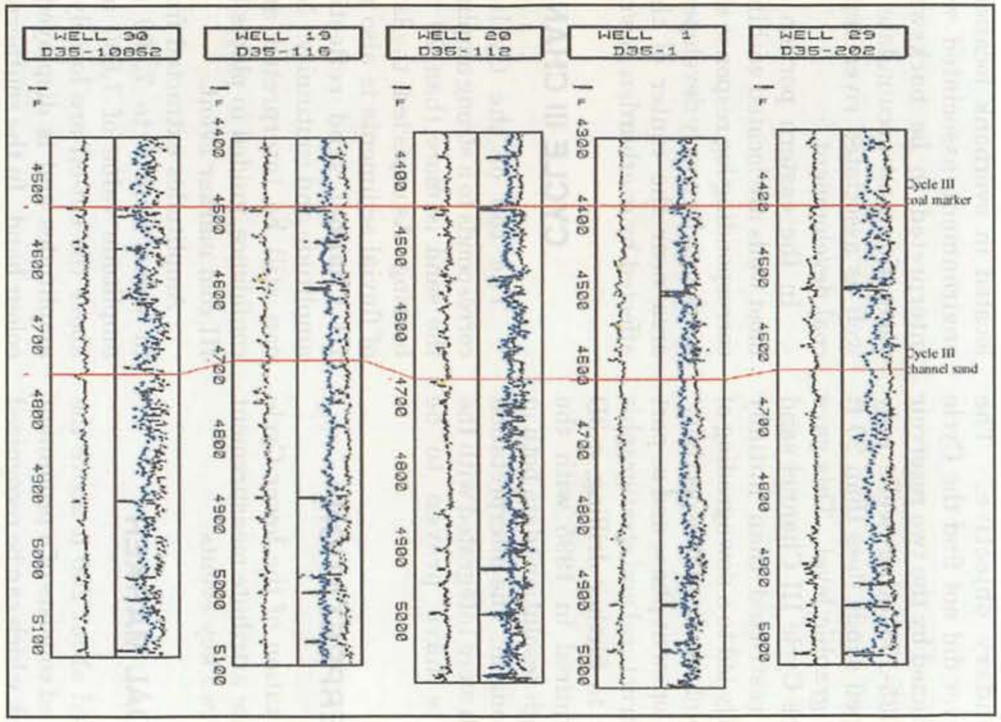

Figure 5. Lower Cycle III interval east-west correlation.

sand forming a secondary objective. The development wells however did not find the Cycle III Channel sand as predicted by the two reservoir models. Apart from D35-105 other wells only encountered less developed sands (less than 20 ft thick) at the same stratigraphic level. This gave reason to believe that the Cycle III Channel sand distribution was more restricted than initially modelled and consequently led to a downgrading of its in-place hydrocarbon volumes and prospectivity.

After the initial development phase and as part of efforts to improve the structural and stratigraphic delineation of D35 prior to further drilling, a 3D seismic survey was acquired in 1995 with the objective of acquiring "high resolution" data both in the vertical and spatial domain. The interpretation of this seismic data which were integrated with the recent drilling results have proven to be encouraging.

SEISMIC INTERPRETATION

The seismic interpretation of the lower Cycle III interval including trace attribute measurement was based primarily on two key events.

CYCLE III COAL MARKER

This marker is located about 200 ft above the Cycle III Channel sand and consists of a prominent coal layer of some 5 ft thick which can be recognized and correlated with ease particularly in the western half of the field. Log data suggest that this coal layer is less developed in the eastern part of the field (Fig. 5).

The amplitude map of the Cycle III coal marker shows a distinct low amplitude (yellow to red) U-shaped feature just south of the platform locations (Fig. 6). This feature has been interpreted as the bend of a river channel measuring on average about 700 m wide. The low amplitudes are interpreted to represent a lack of contrast between the overburden and channel fill acoustic impedance properties. Since the Cycle III coal marker is overlain by shales, the channel is interpreted to be filled by sediments having similar acoustic properties i.e. most likely clay.

In contrast the river banks display very high amplitudes (light to dark blue) and have thus been interpreted as areas where the Cycle III coal marker or its stratigraphic equivalent is well developed. This interpretation has the support of well data which shows good coal development in the western part of the field, where well penetrations are mainly located in overbank locations. The depositional environment associated with these areas are interpreted to be backswamps which support vegetation and accumulate muddy sediments as well as associated river deposits which promotes coal development.

In the eastern portion of the field however, most wells are located within the channel and their corresponding log response shows the Cycle III coal marker to be poorly developed or absent. The blank area near the center of the map defines areas affected by overburden gas/carbonate attenuation.

CYCLE III CHANNEL SAND

The top of the Cycle III Channel sand corresponds to a strong amplitude, peak event where the sand is more than 20 ft thick and is oil/gas bearing. As expected, the lateral variation typical of fluvial sediments is also mirrored by the Cycle III Channel sand reflection which varies in amplitude and continuity. Nevertheless the event can still be interpreted and autotracked with confidence, guided in places by the overlying Cycle III coal marker event.

Amplitudes extracted from this horizon range in value from 0 to 7,500 (Fig. 7). Taking an amplitude value of 1,600 as cut-off, amplitudes above the cut-off are loosely referred to as "high" amplitudes and is displayed in the yellow to red colour band. In the southern part of the field these high amplitudes are distributed in a similar geometry as the channel at the Cycle III coal marker which overlies it. Wells which encountered the Cycle III Channel sand with a thickness of at least 25 ft can be seen located in the high amplitude areas e.g. D35-4 and D35-105 penetrated oil-bearing sands of about 40 ft thick, whilst D35-109 and D35-121 encountered gas filled Cycle III Channel sands averaging 25 ft thick. Wells located in areas below the cut-off (light/dark blue coloured areas) found the Cycle III Channel sand either hydrocarbon bearing but less than 20 ft thick e.g. D35-108S2, D35-116, D35-118 and D35-112 or not developed.

The above observations has prompted the Cycle III Channel sand amplitude display to be interpreted as a qualitative indicator of sand distribution and development. The high amplitudes have been equated to areas where the Cycle III Channel sand is present with a thickness of at least 20 ft. Nevertheless areas below this cut-off may still have lesser developed sandbodies which can contribute towards hydrocarbon volume and production.

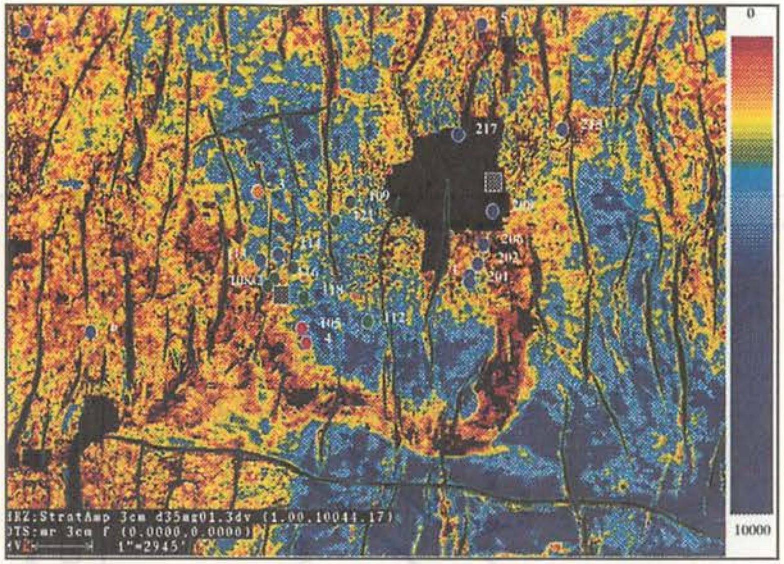

Figure 6. Cycle III coal marker amplitude display.

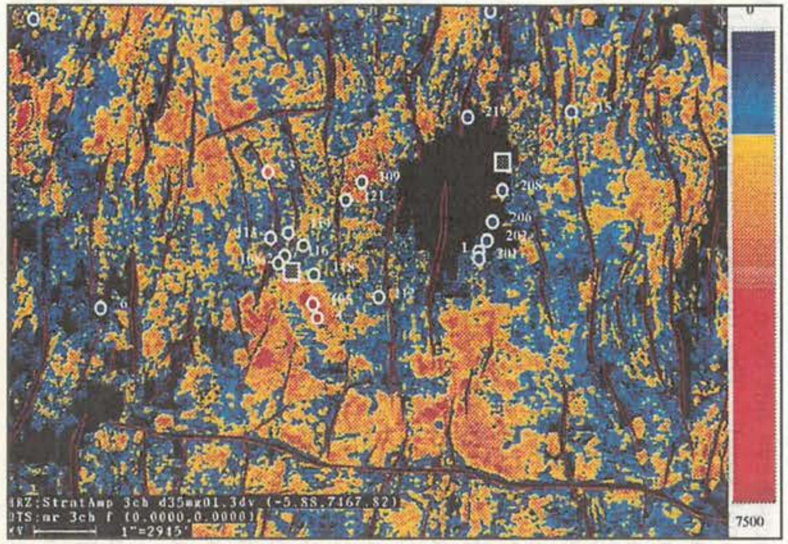

Figure 7. Cycle III Channel sand amplitude display.

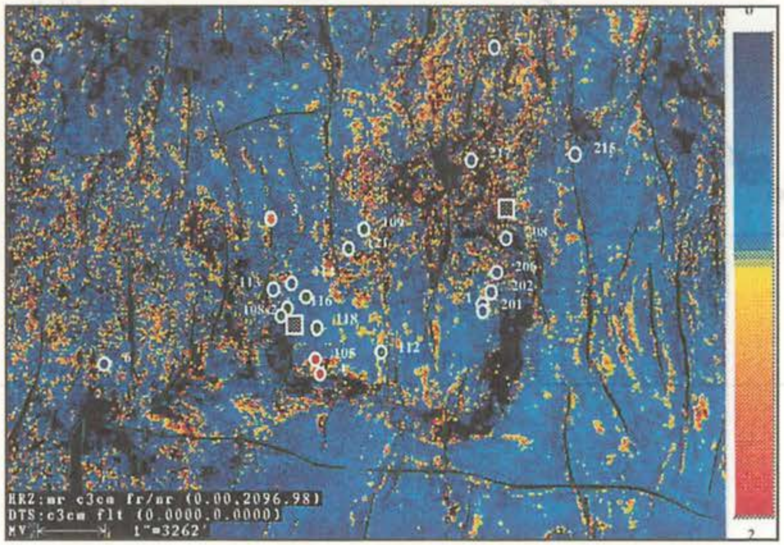

Figure 8. Cycle III coal marker far/near offset amplitude display.

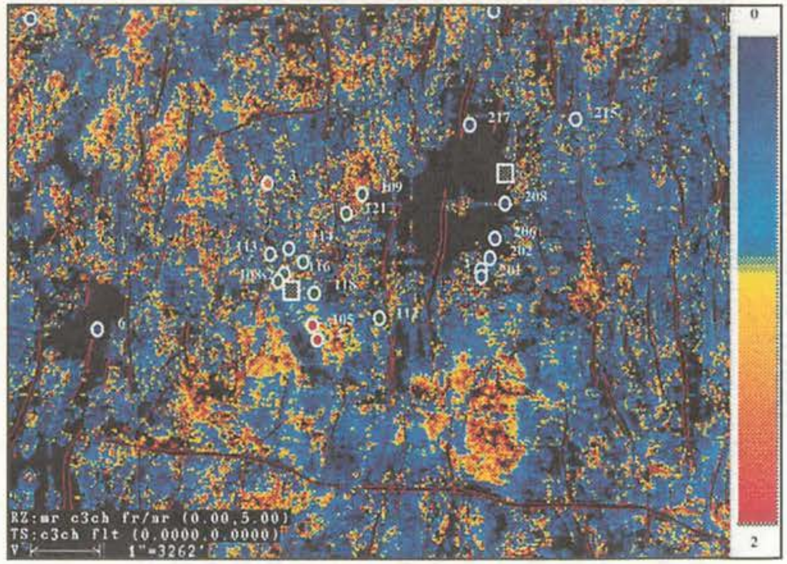

Figure 9. Cycle III Channel sand far/near offset amplitude display.

AMPLITUDE VARIATION WITH OFFSET (AvO) SUPPORT

An area of concern with the above interpretation is that some of the high amplitudes at the Cycle III Channel sand horizon maybe related to coal layers.

To ascertain if this is the case, amplitudes extracted from the far-offset seismic data were divided by the near-offset amplitudes. Based on modelled seismic response, amplitudes which are due to coals decreases with offset and therefore have a Far/Near ratio which is less than unity. The Far/Near amplitudes at the Cycle III coal marker horizon confirms this and demonstrate ratios that are less than one covering all areas (Fig. 8). The Cycle III Channel sand Far/Near amplitudes however show values around unity or greater in areas that are above the 1,600 full-offset cut-off (Fig. 9). This confirms at least that the Cycle III Channel sand amplitude response are not due to coals, although it is still uncertain whether the response is hydrocarbon related.

FLUID CONTACTS

Another uncertainty related to the Cycle III Channel sand concerns its fluid distribution, specifically the depths of the gas-oil-contact (GOC) and oil oil-water-contact (OWC). Presently these contacts have not been observed in the Cycle III Channel sand. The deepest gas-down-to (GDT) was encountered at 4752'ss in D35-121, and the shallowest oil-up-to (OUT) at 4843'ss in D35-105. Production test carried out in D35-4 indicates that the GOC is no deeper than 4803'ss. This agrees well with a possible GOC of 4800'ss derived from gas and oil RFT pressure data.

For the OWC, a large (800 ft) uncertainty exist which is attributed to the absence of pressure data in water-bearing lower Cycle III sands. Pressures taken in water-bearing sands above the Cycle III Channel sand is overpressured by 40 psi above hydrostatic (Fig. 10). The intersection between this trend and the oil gradient at 5900'ss, has been taken as the deepest possible OWC. This implies a maximum oil column of 1,148 ft if we assume the shallowest possible GOC equivalent to the GDT.

At the other extreme, acquifer pressure data from the upper Cycle II results in a trend which is overpressured by 150 psi above hydrostatic. This trend intersects the oil gradient at 5070'ss. Taking this depth as the shallowest POWC and using deepest possible GOC scenario i.e. 4803'ss results in a minimum oil column of 267 ft.

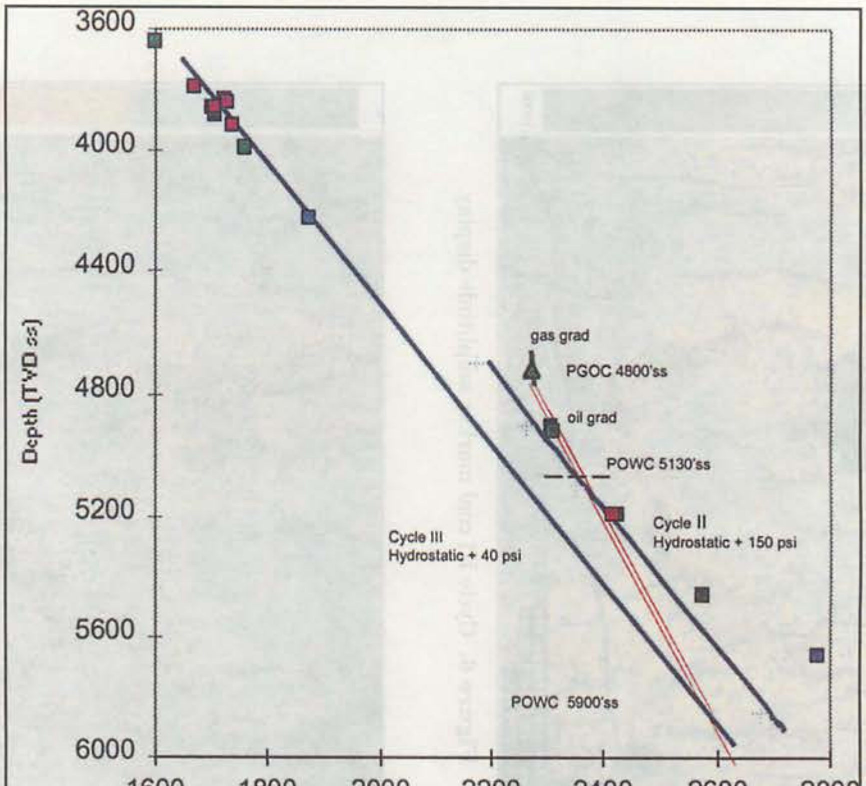

Figure 10. Cycle III pressure plot.

The present hydrocarbon volume estimate for the Cycle III Channel sand takes a prudent approach and assumes that the lower Cycle III acquifer pressure is similar to the upper Cycle II. This results in a base case oil column of around 330 ft.

CONCLUSIONS

Key conclusions that can be drawn from the integrated Cycle III study are as follows:

- There is good correlation between Cycle III Channel sand thickness and its seismic amplitude.
- The Cycle III coal marker/Cycle III Channel sand depositional model based on seismic amplitudes (meandering channel) is consistent with well results.
- Wells drilled during the first phase development were not optimally located to develop the Cycle III Channel sand.
- Use of qualitative AvO analysis has enabled discrimination between different lithological response, and has given confidence that the Cycle III Channel sand amplitudes are caused by sand.
- Analysis of fluid distribution and reservoir pressure data suggest a large potential upside in oil column length for the Cycle III Channel sand.
- The present Cycle III Channel sand distribution are better constrained (based on seismic amplitudes) and show several untested areas with potential for hydrocarbon development.

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