Summary
In this paper, we compare AVO analyses from four wells in the west of Shetland: Foinaven oil well (204/24A-2); Laggan gas well (206/1-2) and two prospect wells (204/17-1 and 204/18-1). Both the 204/17-1 and 204/18-1 failed to find hydrocarbons, where the early work indicated a Class III type AVO anomaly that would generally represent hydrocarbons. However, these studies demonstrate that both the amplitude anomalies conform to Class I type AVO. For the hydrocarbon bearing reservoirs encountered in 204/24A-2 and 206/1-2 both confirmed the presence of what was originally anticipated as a Class III type AVO anomaly. Although the analysis has focused on just four wells it shows that the appropriate use of AVO analysis forms a worthwhile tool for exploration. In a companion paper by Liu et al. (2006), we compare the spectral characteristics of data from the same four wells.
Introduction

Approximately 40 wells were positioned on an amplitude or AVO anomaly located within the Palaeocene west of Shetland but only nine encountered notable hydrocarbons. A large number of failed wells were positioned on interpreted AVO or high amplitude features believed to be coinciding with the termination or up dip limit/pinch-out edge of a sandstone interval (Loizou 2003, 2005). Moreover, the early work in a number of cases indicated that there was a high chance of hydrocarbons present and that the anomaly conformed to a Class III type. Four wells were chosen to perform an in depth AVO analysis for which the locations are shown on Fig. 1. The AVO analysis of the four wells is based on intervals encountered within the Palaeocene Vaila Formation, particularly the T31 to T36 interval. For this particular review the focus is on the examination of the offset stack data and the AVO cross plot analysis.

Comparison of AVO analyses from four wells

Foinaven well 204/24A-2 provides an excellent example of a soft/negative acoustic response that increases with offset angle (Figure 2). The well actually penetrated multiple reservoirs of Palaeocene T31 to T34 sandstones each with separate hydrocarbon contacts. Cross-plot analysis over a 12 ms window (2108 to 2120) relating to the shallower T31 sands shows a discrete, Class III AVO trend (Figure 3). The AVO cross-plot analysis (Figure 4) for the slightly deeper interval between 2130 to 2160 ms shows an impressive, and pronounced clear separation of sealing intra-formational shales, which exhibit a Class I to IV trend whilst the underlying T34 oil sands show an apparent Class III AVO response.

The Laggan gas accumulation was discovered in 1986 by the well 206/1-2 the second well from the study, which encountered gas pay in the Palaeocene, T35 Formation sandstones. The gas is contained in three separate sands totaling 62m which are equivalent to 33 ms of TWT (interval velocity of 3730m/sec) situated at a depth of 3815m TVDSS. This interval is represented on 3D seismic data by one event that is a result of tuning. Examination of the CDP gathers at the 206/1-2 well location shows a definite increase in amplitude with offset (Figure 5). A 20 msec interval extraction from the gas-bearing interval from the well location and cross-plot generated shows a distinct Class III AVO anomaly (Figure 6).

Well 204/18-1 was positioned on a high amplitude anomaly referred to as Assynt (Figure 7), located in the Foineaven Sub-basin was largely a geophysically driven prospect (Loizou et al. 2006). The amplitude anomaly was interpreted and seen by a number of major companies to
be a direct fairway analogue to discoveries such as Foinaven. However, compared to Foinaven, there is no evidence of true amplitude conformance with depth. The predominantly stratigraphic nature of the Assynt prospect relied heavily on the definition of a sealing mechanism. At the nearby Foinaven and Schiehallion Fields, the existence of a thick and dominantly mud-prone T35 lowstand wedge provides a ubiquitous top seal. The location of Assynt shows it to be downslope of, or even within the basinward equivalent of, this package. The Palaeocene T36 Shale/Tuff sequence would thus be required to provide the ultimate top seal to the Assynt prospect.

Figure 3. Well 204/24A-2 shows a Class III AVO mainly due to a thin gas cap within Palaeocene T34 sandstones.

Figure 4. Well 204/24A-2 shows clear separation of T33 shales (Class I to IV AVO) with deeper T32 hydrocarbon bearing sandstones (Class III AVO).

Figure 5. CDP gathers for well 206/1-2 showing amplitude increases with offset.

Figure 6. Well 206/1-2 shows a Class III AVO mainly.

Examination of the near and mid offset stacks at the 204/18-1 well (375 to 2241m) around 2.7msecs generally show strong high amplitude response, however, conversely on the far offsets (2241-3174m) the amplitudes are much weaker (Figure 8). The AVO and various attribute analyses conclusively show no evidence of hydrocarbon presence (Figure 9). More
significantly, post-drill AVO analysis of the Assynt amplitude anomaly categorically shows a Class 1 type AVO.

![Image](image1)

Figure 7. Well 204/18-1 (Assynt Prospect) positioned on a high amplitude anomaly.

Well 204/17-1 is located just 8.8 km to the southwest and marginally updip of the Assynt well 204/18-1 but was positioned on a smaller amplitude anomaly (Figure 10). Post drilling of 204/18-1 shows that overlying the Assynt anomaly is a non-sealing sequence comprising of predominantly thick sandstone and siltstone lithologies. Bearing this in mind at the 204/17-1 well location, the 3D seismic data does not categorically show any clear evidence that the lithology overlying the amplitude anomaly at the 204/17-1 location would be any different to that penetrated by the 204/18-1 well. Therefore, of particular importance is the necessity of a sealing lithology above the 204/17-1 anomaly to create an effective top seal.

![Image](image2)

Figure 8. CDP gathers from the 204/18-1 well primarily showing amplitude decrease with offset.

![Image](image3)

Figure 9. AVO cross-plot for 204/18-1 well showing typical Class I type AVO for the amplitude anomaly.

![Image](image4)

Review of the offset stacks for the 204/17-1 shows that the data is heavily muted to approximately 2540m and that the amplitudes observed at approximately 2.66msecs decrease with offset. Amplitude extraction over the high amplitude anomaly at the well location between 2660 to 2690 ms used for the AVO cross-plot clearly shows the key characteristics of a Class I type AVO anomaly. Coincidentally, the results of the well confirm very similar
lithologies immediately above the anomaly to those encountered at the 204/18-1 well (approximately 500 feet of sandstones overlying the anomalous zone). The seismic anomaly was actually induced by the interface that is characterized mainly by an interbedded succession of sandstones, shales and volcaniclastic tuffs.

Conclusions
In summary, both the 204/17-1 and 204/18-1 wells failed to find hydrocarbons, where the early work indicated a Class III type AVO anomaly that would generally represent hydrocarbons. However, these studies demonstrate clearly that both the amplitude anomalies conform to Class I type AVO suggesting the likelihood of hydrocarbons to be very limited. For the hydrocarbon bearing reservoirs encountered 204/24A-2 and 206/1-2 both confirmed the presence of what was originally anticipated as a Class III type AVO anomaly. Although the analysis has focused on just four wells it shows that the appropriate use of AVO analysis forms a valuable tool for exploration. Undoubtedly, what is also paramount before any AVO analysis is performed would be the understanding and suitability of the seismic data.

Figure 10. Location of wells 204/17-1 and 204/18-1. CDP gathers from well 204/17-1 showing amplitudes at the anomaly (2660msecs) decrease with offset.

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References