Lambda-Rho Processing - Tool to reveal full Hydrocarbon Potentials: Onshore Nigeria Processing, Interpretation and Drilling Case History.
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Summary

During June 2004 a well A-1 was drilled in the Coastal Swamp, onshore block of Nigeria. (Figure 1)
The target of the drilling had been planned on seismic, which had rudimentary AVO processing applied.
Other wells in the area had shown good correlation between the seismic and hydrocarbon finds, however on well A-1 although hydrocarbons were detected they did not tie with the AVO anomalies seen in the seismic data.
Two more wells were about to be drilled from the same location into adjacent fault blocks so it was necessary to be sure that the seismic was telling the full picture.
A volume of data around the well site was extracted and reprocessed through a sequence that included Pre-Stack Time Migration to give migrated gathers.
Intercept and Gradient data were extracted to calculate a product gradient volume. Although anomalies could be seen on the product gradient it was not until the attributes were inverted and the calibrated Lambda-Rho calculated that the full potential of the seismic was revealed.

Introduction

The original seismic data had been processed in 1995 and was Onshore Nigeria. AVO attributes had been generated from the near and far stacks. On the basis of apparent AVO anomalies in the data a drilling program had been set out.
Drilling was going well with hydrocarbon being detected where AVO anomalies indicated it should be until at the beginning of June 2004 drilling was finished on Well A-1.
The well discovered hydrocarbons in Levels K2D0, K2D01, K3A0 and K3A04 but not from the levels the AVO anomalies had indicated.
This posed NAOC with a huge dilemma, as they were about to drill two more wells from the same location into adjacent fault blocks. The question was had they been lucky in finding hydrocarbon in the Well A-1 and if they continued with the drilling of the next two wells would they be so lucky again.
With the drilling crew on standby a solution was urgently required.

Geologic Setting

The area under review is located in the proximal part of the Coastal Swamp depobelt of the Niger Delta. It is located within a macrostructure that consists of a stratigraphic sequence formed by a prograding wedge thickening southwards. The age of the sequence is Middle Miocene. The depositional environments are from coastal/deltaic to shallow inner neritic. Two maximum flooding surfaces dated from 11.6 Ma to 13.4 Ma have been recognized and tied to the third order global depositional cycle.

Seismic Data

The 3D seismic data was acquired in 1993. The survey was acquired using a dynamite source. The bin size used was 25X25m with fold 16.
The far offset of the data was 3150m. This maximum offset at the target time of 2.5-3.0secs provided data with a maximum angle of 40° at 2.5secs, this angle diminishing quickly after this point coming to a barely acceptable angle of 28° at 3.0secs.

Processing

A 100km² block of data was processed through a sequence including Pre-stack Time Migration to output a 16km² dataset surrounding the well A-1 and the proposed sites for the next two wells A-2 and A-3 respectively.
The pre-stack time migrated gathers were the subject of an AVO analysis to output an intercept and gradient volume. From the intercept and gradient a product gradient volume was calculated. The product gradient volume confirmed the results of the original AVO processing but had more clarity.
P-wave reflectivity and S-wave reflectivity were also produced from the AVO processing, which in turn was inverted and used for calculation of Lambda-Rho and Mu-Rho volumes. This volume was calibrated using the new Well A-1. The result was dramatic, strong anomalies could now be seen at two of the main hydrocarbon producing levels in the well A-1 (K2D0, K2D01). (figure 2).
Interpretation

The Lambda-Rho and Mu-Rho volumes and cross-plots were used in a re-evaluation of the drill site for wells A-2 and A-3 respectively. On the basis of these data the trajectories of the wells were altered to the areas that were highlighted by the Lambda-Rho in the adjacent fault blocks. The drilling crew that had been preparing the next drill resumed drilling on wells A-2 and A-3 respectively with the new plans. Later that month it was confirmed that the well A-2 had correctly predicted hydrocarbons from two levels where the Lambda-Rho volume had indicated pay zones. (Figure 2 and 3). Well A-3 is yet to be drilled as at the time of this report.

Discussion of Results/Conclusions

Whilst the conventional AVO attributes, Intercept and Gradient, had succeeded in predicting hydrocarbons in some areas, in others this was not the case. The limited angle range at the reservoir depths may be a limiting constraint on the value of the classical AVO attributes. Lack of resolution over thinner reservoirs was also an issue in some areas, especially the deeper targets. From this data example and resulting success in drilling, the extra processing involved with the derivation of the Lambda-Rho and Mu-Rho attributes has proved a cost effective addition to the production processing sequence.

References


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Figure 1: Map of the Niger Delta with Studied area (insert)

Figure 2: Relative and Calibrated Lambda-Rho results

A-1 – \( \lambda_p \) WELL SEISMIC COMPARISON (Relative)

Oil Bearing Reservoirs:
K2D0, K2D01
K3A0, K3A04
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Figure 3: Well log versus Seismic tie