The Boris Oil Field in the Gulf of Mexico – a Geophysical Case Study

Brian Little
BHP Billiton, USA
Brian.B.Little@BHPBilliton.com

Guy Duncan
BHP Billiton, USA
Guy.Duncan@BHPBilliton.com

Karen Tomich
BHP Billiton, USA
Karen.Tomich@BHPBilliton.com

Carl Taylor
BHP Billiton, USA
Carl.H.Taylor@BHPBilliton.com

Michael E. Glinsky
BHP Billiton, USA
Michael.E.Glinsky@bhpbilliton.com

SUMMARY

The Boris oil field was discovered in 2001 in Green Canyon block 282 in the deep water mini-basin area of the Gulf of Mexico. The Boris discovery was followed by the drilling of the Boris North appraisal well in 2002. First oil from the Boris field was produced in early 2003 with recoverable reserves estimated at 10 to 35 million barrels of oil equivalent. The Boris reservoir shows up as a bright seismic amplitude anomaly in Pliocene-age sand. Seismic reprocessing for robust amplitude fidelity and the use of Kirchhoff prestack time migration were the main geophysical tools that led to the discovery of the field.

The Boris reservoir is steeply dipping at a depth of approximately 4500m. The original seismic data across the Boris field consisted of post-stack time migrated data that showed a broad, poorly defined amplitude with poor conformance to structure. After careful amplitude processing was input to prestack time migration, a bright well-defined amplitude 'appeared' on the seismic data with an excellent down-dip fit to structure. Concurrent with the reprocessing, a lithology and fluid prediction project was undertaken. Nearby well control was used to define rock property trends such as Vp versus depth, Vp versus Vs, and Vp versus density. The rock property trends were used to stochastically model the AVO response and the results were compared to the measured AVO response on the reprocessed seismic data. The results of the modelling showed that the fluid type at Boris was consistent with hydrocarbons. The Boris discovery well was drilled within three months of completing this reprocessing.

Key words: Boris Field, AVO, seismic processing. Gulf of Mexico.

INTRODUCTION

When exploring for amplitude plays, it is important that the data are processed in an amplitude preserving manner and that detailed lithology and fluid prediction modelling is performed. We use the Boris Field in the Gulf of Mexico as a case history to illustrate the importance of these processes.

The paper starts with a discussion of the geological aspects of the Boris Field. Next, we describe amplitude preserving seismic reprocessing that was performed on the seismic data and the results of Kirchhoff prestack time migration. The results of a lithology and fluid prediction study are presented, and lastly a comparison is made between the results of the studies and the drilling results.

GEOLOGICAL BACKGROUND

The Boris field is a two-well subsea tieback field located in the central Green Canyon play fairway, 100 miles from shore in approximately 700 m of water in the United States federal waters of the Gulf of Mexico (Figure 1). BHP Billiton acquired the Green Canyon block 282 lease in 1999 via a farm-in on the likelihood of a trap on the acreage. The prospect was further matured in 2001 as an exploration target as a result of imaging the associated field amplitude anomaly through proprietary reprocessing.

Figure 1. Location map.

The discovery well for the Boris field began drilling in August 2001 and subsequently began production in February 2003. An additional producer was drilled in the same reservoir in 2002 and began producing in September 2003. The two wells produce a reservoir thought to contain recoverable reserves in a range from 10 to 35 million barrels of oil equivalent. Cumulative production through March 2004 is approximately 7.5 million barrels of oil equivalent.

BHP Billiton holds a 50 percent equity interest and is the operator of the Boris oil field. Other partners in Boris include

ChevronTexaco and Noble Energy, Inc., each with a 25 percent interest.

The Boris field is a simple up-dip pinch-out trap of deepwater, turbidite "sheet" sands on the steep eastern flank of a typical Gulf of Mexico intra-slope mini-basin (Winker, 1996). The down-dip, western extent of the reservoir is controlled by an oil-water contact.

The Late Pliocene-age reservoir sand, called locally the B4, has excellent reservoir properties that support co-mingled flow rates higher than 25,000 barrels of oil equivalent per day from the two wells. The reservoir primarily consists of one oil pay approximately 100 feet thick with a net-to-gross of nearly 100% (see Figure 2). Sandstone porosity as estimated from electric logs and sidewall cores is about 30%, initial oil saturations about 80%, and permeability estimated from flow tests in a range from 500 millidarcies to 1300 millidarcies. The produced oil is a medium sour crude with 33 degree API gravity and about 1,700 scf/stbbl GOR. The pay sand is in an overpressure sedimentary section at approximately 13,800 feet subsea.

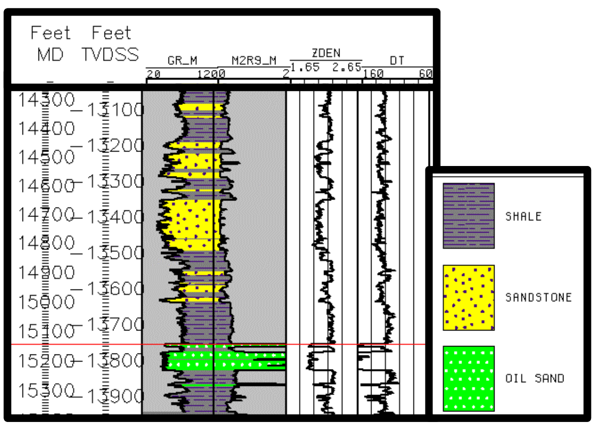

Figure 2. Electric log of oil pay sand.

METHODOLOGY AND RESULTS

Seismic Reprocessing

The original seismic data across the Boris field consisted of post-stock time migrated data. The data were acquired using a dual source shot into six streamers, resulting in 39 fold data with a 12.5 m inline spacing and a 40 m cross-line spacing. A simplified outline of the original processing sequence is given in Table 1. An amplitude extraction performed on the B4 horizon shows a poorly defined amplitude with poor conformance to structure (see Figure 3).

1.	Deterministic Designature
2.	Inverse Q (amplitude and phase)
3.	Short Gapped Deconvolution
4.	Radon Demultiple
5.	Flex Binning
6.	3D DMO and Stack
7.	Scaling (destripe)
8.	Deconvolution after Stack
9.	FXY filter
10.	Migration

Table 1. Outline of the original processing sequence.

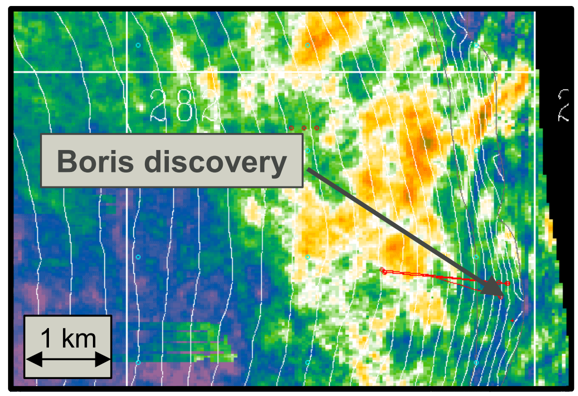

Figure 3. Amplitude extraction on the original seismic data.

The main concern with the original processing was that it was not amplitude preserving and that the post stack imaging was not suited to the steep dips at Boris which are in excess of 30 degrees. In particular, it was felt that the two passes of statistical deconvolution and the post stack scaling step may have introduced subtle amplitude distortion (see Duncan, 1998), and that Kirchhoff prestack time migration would be better suited for imaging a steeply dipping feature.

The reprocessing was started in December 2000 and completed in the first quarter 2001. Table 2 gives a simplified outline of the processing sequence used for reprocessing. Note that the statistical deconvolution and scaling steps have been removed, and that Kirchhoff prestack time migration has been substituted for the DMO/post stack time migration used in the original processing. In addition, three passes of migration velocity analysis were used for the reprocessing.

1.	Deterministic Designature
2.	Radon Demultiple
3.	Regularization
4.	Inverse Q (phase only)
5.	3 -Pass Migration Velocity Analysis
6.	3D Kirchhoff Prestack Time Migration
7.	Residual Velocity Analysis

Table 2. Outline of the processing sequence used for reprocessing

Figure 4 shows an amplitude extraction performed on the B4 horizon on the reprocessed data. The amplitude extraction shows a clearly defined amplitude anomaly with excellent conformance to structure.

Figure 5 shows a seismic line from the original processing. There is no evidence of an amplitude anomaly on the original data. Figure 6 shows a seismic line from the reprocessed dataset at the Boris well location. The amplitude anomaly at Boris shows many of the hallmarks of a good direct hydrocarbon indicator: (i) excellent conformance to structure; (ii) rapid down-dip turnoff of amplitude; and (iii) phase consistent with a low acoustic impedance event.

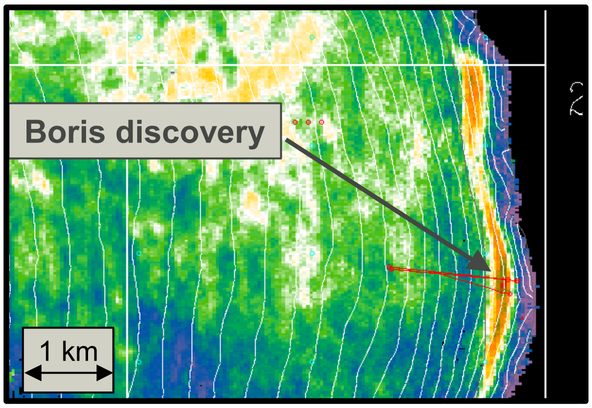

Figure 4. Amplitude extraction on the reprocessed seismic data. Depth contours are in feet and the contour interval is 200 ft.

Tests performed during the reprocessing showed that prestack time migration was very important in imaging the Boris amplitude anomaly and placing it in approximately the correct lateral position. A velocity error as low as two percent could shift the anomaly by 150 m. Since Boris is a relatively narrow feature, a critical step was to perform multiple passes of migration velocity analysis to ensure that Boris was positioned correctly.

Lithology and Fluid Prediction

The lithology and fluid prediction study consisted of three main steps. Firstly, petrophysical analyses were conducted on nearby wells to determine the rock property trends of end member sand and shales. These trends provide the link for the AVO modelling (Castagna, et al., 1993) that is conducted next, which consists of stochastic AVO modelling. Lastly, the modelling was compared with the seismic amplitude anomaly observed on the seismic data at Boris.

Petrophysical analysis consisted of picking the elastic properties (ie, Vp, Vs and density) of end member sand and shales. Only regions of the log which the petrophysicist determine are good quality are used. The uncertainty of each pick was also determined. The result of the petrophysical analysis were rock property trends of the form:

Sand

$Vp = C_1 + C_2*depth$ +/- error

$\phi = C_3 + C_4*Vp$ +/- error

$Vs = C_5Vp + C_6$ +/- error

Shales

$Vp = C_7 + C_8*depth$ +/- error

$\rho = C_9*Vp^{C10}$ +/- error

$Vs = C_{11}Vp + C_{12}$ +/- error

Where C_1 to C_{12} are constants.

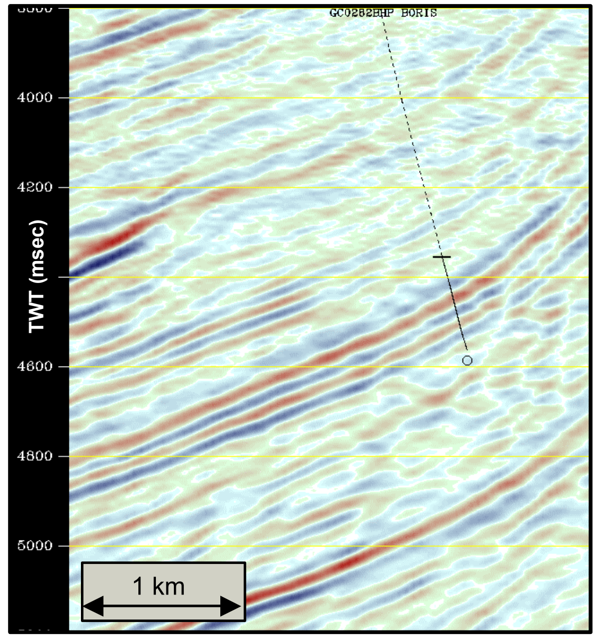

Figure 5. Seismic line from the original processed data across Boris.

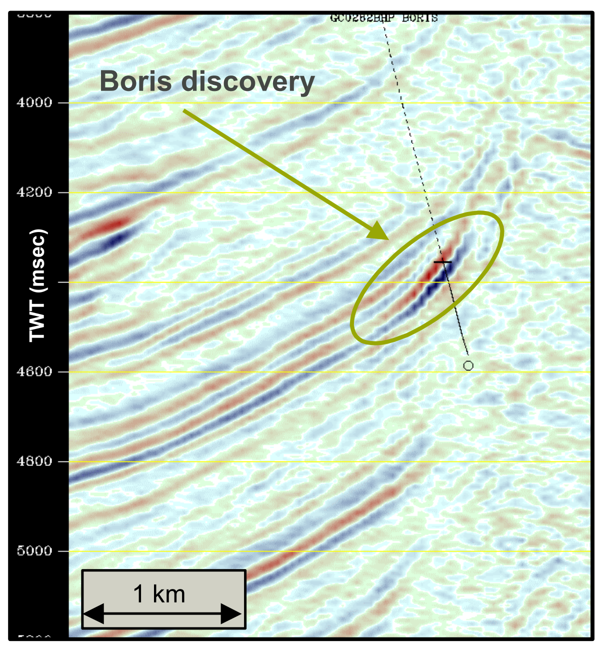

Figure 6. Seismic line from the reprocessed seismic data across Boris.

The rock property trends were used in conjunction with an estimate of the fluid properties to perform stochastic AVO modelling. Figure 7 shows the results of the modelling for a full angle stack. The curves in Figure 7 show that on average, a shale-to-oil sand reflection coefficient has amplitude that is approximately 3.5 times brighter than a shale-to-brine sand reflection coefficient. Modelling for gas sands resulted in a response approximately 6.0 times brighter than the brine response. Amplitude extractions performed on the reprocessed seismic data resulted in an 'on structure' to 'off-structure' amplitude ratio of approximately 3.0. This value was close to, and within the range, predicted for the oil sand case. The AVO modelling also predicted an increase in amplitude with offset that was consistent with the response measured on the seismic data. The results of the lithology and fluid prediction study were integrated into the prospect risking, using a similar methodology as presented in Glinsky, et al., (2004).

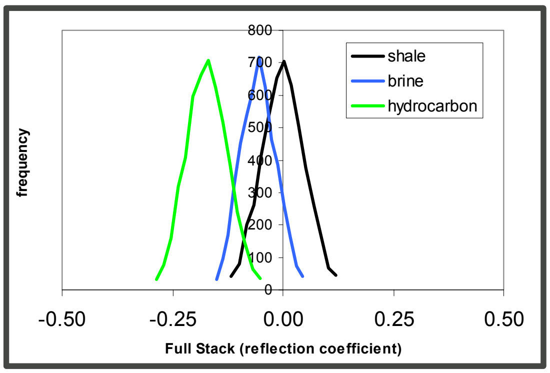

Figure 7. Stochastic AVO modelling showing the full angle stack response for the shale-to-shale case, the shale-to-brine sand case and the shale-to-hydrocarbon (oil) case.

Well Result

Following on from the seismic reprocessing and the lithology and fluid prediction study, the Boris #1 well was spudded in August 2001. Oil was intersected within the B4 Pliocene-aged sand at the level of the amplitude anomaly. The Boris discovery was followed by the drilling of the Boris North appraisal well in 2002. First oil from the Boris field was produced in February 2003 with recoverable reserves estimated at 10 to 35 million barrels of oil equivalent. Cumulative production through March 2004 is approximately 7.5 million barrels of oil equivalent.

CONCLUSIONS

The careful seismic reprocessing presented in this paper was the critical step that led to the discovery of the Boris Field. Without reprocessing, the Boris Field would almost certainly remain undiscovered.

This case study clearly illustrates the importance of using an amplitude friendly processing sequence, and the use of pre-stack imaging when exploring in a steeply dipping environment. Once an amplitude friendly dataset has been produced, then lithology and fluid prediction modelling can be used with confidence.

REFERENCES

Castagna, J.P., Batzle, M.L., and Kan, T.K., 1993, Rock physics – The link between rock properties and AVO response, in Offset Dependent Reflectivity – Thoery and Practice of AVO Analysis, J.P. Castagna and M. Backus, eds. Investigations in Geophysics, No. 8, SEG, Tulsa, 135-171.

Duncan, G., 1998, Simple versus complicated seismic processing in the Exmouth Sub-basin: Expl. Geophys.

Glinsky, M., Duncan, G., Jamieson, M., and Morrison, A., 2004, Application of integrated risking on a South African Propsect: to be presented at 66th EAGE Conference and Exhibition.

Winker, C.D., 1996, "High resolution seismic stratigraphy of a late Pleistocene submarine fan ponded by salt-withdrawal mini-basin on the Gulf of Mexico continental slope: *Proceedings of the 1996 Offshore Technology Conference*, Paper OTC 8024, May 6-9, 1996, Houston, Texas, p. 619-628.