Pyxis – A study in cost-efficient near-field exploration, discovery and appraisal

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INTRODUCTION AND SETTING

The 2015 Pyxis-1 vertical exploration well was drilled in Production Licence WA-34-L, approximately 10 km north of the crest of the Pluto Field (Tilbury, 2009) in the Carnarvon Basin, Australia (Figure 1). The well was targeting Upper Jurassic (Oxfordian) aged J40 – J47 (after Marshall, 2013) sands in an amplitude-defined, combined dip, stratigraphic and fault-bound trap (Figure 2). Pyxis-1 encountered a 22.3 m, excellent quality sand, with an interpreted gas-water contact (GWC) immediately above the base of the sand.

SUMMARY

Realising and protecting the value of near-field exploration and appraisal is a constant challenge, especially during the recent low oil price cycles. This paper discusses the 2015 Pyxis gas discovery, and the means by which a cost effective and value driven approach to data acquisition and optimisation drove the opportunity.

The Pyxis field is situated approximately 10 km from the drilling manifold and centre of the Pluto Field. We will demonstrate how targeted studies, a carefully selected well location and data gathering programme when combined with a seismic survey synergies with the nearby Pluto Field, delivered a cost-effective, single-well discovery and appraisal.

Pre-drill economic viability of Pyxis was challenged by the stratigraphic nature of the trap, significant seismic data issues, sub-tuning reservoir thickness and limited offset-well information. Opportunistic data gathering and cost-effective, detailed Quantitative interpretation (QI) work allowed these challenges to be overcome, and the prospect to be drilled.

In the success case, the Pyxis-1 exploration well was planned to acquire sufficient data to obviate the need for further appraisal. Post-discovery evaluation continued the low-cost approach, using new Pluto Field seismic to assist reservoir characterisation.

We conclude that this modest-sized, near-field opportunity has been optimized in terms of potential economic viability by using appropriate technology, targeted appraisal, and integration with nearby field activities.

Key words: Pyxis; Pluto; near-field exploration; appraisal; J40; seismic amplitude.

INTRODUCTION AND SETTING

Pyxis faced multiple challenges along its path to discovery, primarily due to the difficulty in defining the prospect with any certainty. This presentation describes techniques employed to better assess its value pre-drill, and to further define the field post-drill for evaluation in terms of potential economic development.

By utilising synergies with work on nearby field developments, and by selection of an optimal location and data acquisition...
program for the discovery well, a highly cost-effective near-field discovery and appraisal was achieved.

**GEOLOGICAL MODEL**

Pre-drill the geological model for Pyxis was one of a transgressive sand deposited on the regional Oxfordian Unconformity, and this remains valid post drill. The model relies on preservation of reworked Jurassic sediments occurred in local depositional lows. Reservoir thickness was not expected to exceed 25 m, hence would generally fall below conventional seismic resolution (i.e. below tuning thickness), and might exist undetected on seismic up to a thickness of a few metres. This presented the challenge of identifying the target sand presence and distribution to de-risk the play, further complicated by few offset well intersections of sand at this stratigraphic level. Pre-2008, intersections that were available had not been encouraging in terms of sand thickness, extent or quality. The availability of open file Wheatstone data confirmed significant reservoir quality within the area, such that revised Pyxis prospect volumetrics could include potentially commercial outcomes.

**SEISMIC IMAGING**

The Pyxis discovery is situated beneath the continental slope in water depths ranging between 400 to 1,000 m. The presence of large seabed channels and steep dips in the overburden, together with the variable water depth, result in seismic ray-bending effects which reduce the quality of imaging and attenuate amplitudes over the eastern parts of the field (Figure 3). The seismic image was improved using the most modern de-multiple and pre-stack depth migration (PreSDM) workflows available at the time, however this did not completely resolve the issue (Tilbury, 2009).

To overcome the seismic amplitude issue, a very simple window balancing method was used to balance the amplitude washouts and merge points. This technique involved taking an RMS amplitude over a large window (500 ms) over a relatively uniform interval of the seismic. Amplitude maps were then balanced by dividing by the balancing window amplitude, thereby boosting areas of anomalously low amplitude and attenuating areas of anomalously high amplitudes. This method allowed the amplitude anomaly covering the prospect to be defined in a more consistent manner (Figure 5).

**AVO AND QI STUDIES**

The Pyxis structure straddled the boundary between two good quality seismic datasets, the 2004 Pluto 3D survey and a 2008 combined-survey dataset incorporating the 2006 Willem 3D beyond the northern limit of the Pluto 3D (Figure 4). These two datasets were merged post-stack to provide a continuous depth image across the Pyxis structure, with a join at the northern limit of the Pluto 3D. However, the merged dataset, whilst providing a consistent depth image, could not resolve the differences in amplitudes across the merge point, due to the water depth variability and complex overburden.
Quantitative interpretation was used to predict lithology and fluid content in the prospect using offset well information. This included the creation of simple wedge models to illustrate the seismic resolution, and the amplitude response to various reservoir effectiveness outcomes. The introduction of multiple cemented layers within a relatively thick (>10 m) sand, as observed in offset wells (Figure 6), reduces the acoustic impedance (AI) significantly at seismic bandwidth. This results in an inability to observe the hydrocarbon bearing reservoir using either amplitude or AI volume. This led to increased confidence that the high amplitudes demonstrated at Pyxis were hydrocarbon bearing and of significant thickness and reservoir quality. The weaker, disseminated amplitude responses could then be attributed to changes in fluid fill, reduction in reservoir effectiveness (by cementation), changes in reservoir thickness or some combination of these.

AVO studies were performed on offset wells, showing that amplitudes varied little with offset, but confirmed that gas-fill demonstrates significantly brighter amplitudes than brine.

Multiple seismic attributes and inversion products were created using the Pluto wells, all of which indicated that Pyxis was highly likely to be hydrocarbon bearing. Much of this work was completed in conjunction with IQI studies for Pluto Field development, thereby reducing exploration project costs.

**WELL LOCATION**

The marginal economics of the prospect pre-drill would not support multiple exploration and appraisal wells, therefore in the case of a discovery as much information had to be acquired as possible in a single well. Therefore targeting a well location was a challenge due to the variable nature of the seismic anomaly forming the basis of the Pyxis prospect.

Multiple well locations were investigated and ultimately a location was selected (Figure 2) that would be optimal for testing the brightest amplitudes, and in case of discovery support a sidetrack option to test the weaker, disseminated amplitudes. This would therefore provide reservoir and fluid information bracketing the key uncertainties in the Pyxis prospect.

All well designs had to be sufficiently flexible to be drilled with a rig of opportunity, therefore reducing cost compared to that of a single well campaign.

**DATA ACQUISITION**

The data acquisition program for Pyxis was designed to acquire appraisal-level information. This included VSP, fluid sampling, image logs, full waveform sonic and mineralogy logs. Additionally, full-barrel core was planned on the confirmation of hydrocarbons, a practice that was not common to the company at the time.

![Figure 6. Offset wells: colour is V-shale fraction; blue curve is AI, red Poisson’s ratio. Note high-AI streaks (cement).](image)

Pyxis-1 intersected a 22.3 m gas bearing Oxfordian Eliassen Formation reservoir, very close to expectations (Figure 7). Excellent quality logs were obtained, and 27 m of full barrel core over the reservoir. The reservoir interval at Pyxis-1 has an average porosity of 30% and a net-to-gross of 100% with an average permeability of 2,200 mD. The interpretation of the wireline logs, along with fluid sampling, led to the interpretation of a GWC at the base of the sand. Intersection of the GWC, along with the excellent quality logs, fluid samples and core obtained, allowed for the abandonment of the well without invoking the sidetrack option. The core was then used to perform geomechanical studies to assist in rock strength evaluation, petrophysical reservoir characterisation and sedimentological studies. Due to the comprehensive dataset obtained in the well, development studies could proceed with no further appraisal drilling.

**POST DISCOVERY APPRAISAL**

The Pyxis discovery has been evaluated as a possible tie-back to the Pluto Field development, which came on production in 2012, and acquired a combined new high-definition 3D survey (HD3D) and 4D monitor survey in 2015-16 (Tilbury, 2018). The Pluto HD3D was extended to the north to provide the first coverage in a single survey of Pyxis (Figure 4). High quality PreSDM processing of this dataset delivered a much-improved image of the Pyxis reservoir with minimal incremental investment attributable to the evaluation of Pyxis.

Pyxis-1 drilled the reservoir at one of the thickest points as mapped, while most of the reservoir lies below tuning thickness. After enhancing the vertical resolution of the seismic data via a bandwidth optimisation procedure, the tuning thickness was estimated at 15 m. A simple wedge model was created to understand and estimate the actual reservoir
thickness from a combination of apparent thickness (between top and base seismic loops) and the top reservoir amplitude (Figure 8). As noted earlier, partial cementation of the sands, as seen in offset wells, had to be factored into understanding the seismic response at the reservoir, and was considered as an additional factor affecting thickness and hence volumetric uncertainty.

![Figure 8. Wedge modelling of Pyxis sand without cementation and with two 1-metre cement streaks. Sand wedge ranges from 0 to 25 m thickness.](image)

The Pyxis-1 well data, combined with new, high quality seismic data, and a thorough geophysical and geological analysis led to the building of a suite of static and dynamic reservoir models addressing the range of uncertainties affecting any possible development. Study of the core established that the sands can be ascribed to a middle shoreface environment, and on this basis a range of facies distributions were built into the static models, including the possibility of associated upper and lower shoreface sands also within the area of interest. Various modern and outcrop/field analogues were used to guide the modelling.

While estimates of recoverable gas volumes span a significant range, it is still considered that the reservoir has been adequately characterised using the Pyxis-1 dataset and new seismic data, with no need for further appraisal drilling.

**CONCLUSIONS**

Success in near-field exploration is proven to have the potential to deliver high value projects – provided that value is not eroded either by costly appraisal or by under-appraisal. Pyxis was initially viewed as too high risk and uncommercial, however, via opportunistic data gathering and low-cost study work, the revised chance of success and the expected range of gas volumes justified the cost of an exploration well.

The subsequent challenge was to optimize the potential value of the discovery, through cost-effective appraisal. This was achieved by careful consideration of appraisal requirements during planning of the exploration well and its data gathering programme, and by use of new seismic acquired for the Pluto Field. Thus Pyxis development studies could be carried out with no appraisal drilling and at minimal additional cost.

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**REFERENCES**

