Cimatti Field – An example of using seismic amplitude to determine in-place resource

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SUMMARY

The Cimatti oil field is located in the Exmouth sub-basin offshore Western Australia. The area has good 3D seismic coverage and the Jurassic Macedon Member reservoir is associated with anomalously high seismic amplitude. These anomalous amplitudes can be used to estimate the thickness of the reservoir sand.

The Cimatti-1 well was drilled in November 2010 and intersected a 15.4m TVD column of high net-gross, oil saturated sand. No oil-water contact was observed. An appraisal sidetrack (Cimatti-2) followed immediately with the aim of testing a downdip area near the edge of the field to the northwest. Cimatti-2 deliberately targeted an area with about half the seismic amplitude of the discovery and intersected a 6.8 m TVD of oil saturated sand. Mapping, engineering and economic studies were carried out following the discovery and in 2018 a drilling program of production and injection wells commenced.

The tuning thickness of the wavelet extracted from the seismic data is 22 m. Mapping of the top and base reservoir reflections indicates that the reservoir thickness across the field is less than the tuning thickness. In such a case the seismic amplitude is related to net sand thickness. A linear relationship between bed thickness and seismic amplitude was established using the two data points (Cimatti-1 and Cimatti-2) and a sand thickness map of the field was produced. This map was then used to calculate an estimated in-place resources above an assumed oil-water contact.

During development drilling in 2018 Schlumberger’s Geosphere tool was used to determine the position of the near horizontal well bore relative to the top and bottom of the reservoir and hence the sand thickness could be estimated. These Geosphere based estimates were made at several places along the well paths and confirmed the amplitude – thickness relationship derived from the near vertical wells several years earlier.

Key words Cimatti Field, Macedon Member, seismic amplitude, net pay

INTRODUCTION

The Cimatti oil field is one of three accumulations that make up the Greater Enfield Development project. It is located 55km northwest of Exmouth in WA-28-L in the Exmouth sub-basin of Western Australia (Figure 1). WA-28-L was awarded in 2004 and current interests are Woodside 60% and Mitsui 40%. Cimatti is situated immediately northwest of the Enfield oil and gas field on a downthrown fault terrace (Figure 2). Enfield ceased production in 2018.

The 1998 Vincent and 2000 Indian seismic surveys provide good 3D seismic coverage and Cimatti is characterised by anomalously high seismic amplitudes of the single cycle Macedon Member reflection (Figure 2). In 2010, Cimatti-1 was drilled to test an area of high seismic amplitude and because a follow up location was included in pre-drill planning the discovery well was immediately followed by Cimatti-2, a sidetrack appraisal.

Figure 1. Location map of Cimatti Field, offshore Western Australia.

Cimatti-1 was drilled in November 2010 as a deviated exploration well to a total depth of 2455mRT in a water depth of approximately 550 m. The primary objective was to test the hydrocarbon potential of the Macedon Member of the Lower Barrow Group. The well was successful and intersected a 15.4m TVD gross sand with a nett thickness of 13.8 m TVD in the oil saturated Macedon Member.

The sidetrack Cimatti-2 intersected an area of distinctly lower seismic amplitude 430 m to the northwest of the discovery well. Cimatti-2 had a total depth of 2616 mRT and 6.8 m TVD gross pay (5.7 m TVD net). No oil-water contact was intersected in either well. Prior to drilling it was recognised that the reservoir thickness was below the seismic tuning thickness and an...
appraisal well was planned to target an area about half the amplitude of the Cimatti-1 location. This allowed an estimate of the amplitude-thickness function to be made while maintaining the objective of penetrating a viable thickness of reservoir sand. If too low an amplitude was targeted there was a risk that no reservoir would be found; too high an amplitude and there would be insufficient discrimination between the different measurements to define an accurate trend.

Figure 2. Depth structure map of Cimatti Field shows monoclinal dip to the north. Bottom hole locations of Cimatti-1 & 2 and well track of the production well CIM01 are shown in white. M is the location of the maximum seismic amplitude.

The Macedon Member unconformably overlies the Dupuy Formation and forms the basal part of the Barrow Group (Scibiorski et al., 2005). It was deposited as a low stand turbidite with initial canyon incision and bypass into shallow confined basins. As accommodation space increased with rising sea level, low stand deltas formed and amalgamated beds developed in a low stand shoreline prior to a regional transgression and deposition of the more shaley Muiron Member. The last stage of the Macedon Member’s deposition at Cimatti can be seen on the amplitude map which has a sinuous, low amplitude feature running from south to north. This is interpreted as a Muiron Member mudstone filling a pre-existing channel which was cut into and eroded possibly all the Macedon reservoir sands. The Macedon Member has excellent reservoir properties and in the Cimatti wells averages 23.9% porosity and 850 mD permeability. While it is primarily a structural trap the Cimatti Field has a stratigraphic component provided by thinning of the Macedon Member sandstones to the south and west as indicated by the reflection strength. To the south the up-dip closure is provided by a small, east-west striking fault that offsets the thin reservoir sand, juxtaposing it against shaley units. The reservoir sands have good porosity and modelling based on surrounding wells shows good porosity sands have a high amplitude response in this area.

Figure 3. Seismic amplitude map - showing peak amplitude in a window across the Macedon Member seismic pick.

**SEISMIC AMPLITUDE**

The Macedon Member seismic reflection in the Cimatti field area is represented by a strong peak (on the SEG negative polarity displays). This reflector is a single cycle and has an elevated amplitude compared to surrounding areas. The amplitude anomaly has an amorphous form with little identifiable characteristics apart from a sinuous low amplitude feature, interpreted to be a shale filled channel, running from south to north and separating the western and eastern areas of the field. This channel is interpreted as the last feature to be preserved in a wider channel belt which is represented by moderate to high seismic amplitudes (Figure 3).

A two-way time (TWT) thickness map of the Macedon Member shows that over the extent of the amplitude anomaly there is little change in time difference (or thickness) between the top and base reflections suggesting the reservoir is thinner than the tuning thickness. Below tuning thickness, the separation between top and base reflectors is constant as the embedded wavelet cannot be compressed to include higher frequencies as the bed thins (Figure 4).

Initial calculation of resource was based on the premise that the seismic response of thin beds results in an amplitude that is proportional to the net sand content. With the Cimatti-1 and Cimatti-2 wells and the added constraint that the line passes through the origin (Figure 5) a linear function can be defined.
A wavelet was extracted from the Cimatti seismic data and used for modelling the tuning response and determining the tuning thickness (Figure 4). This wavelet has a tuning peak at 9 ms which equates to a thickness of 22 m assuming a velocity of 2500 m/s. Also, assuming the maximum amplitude in the field area is at the tuning thickness a further point could be used to establish the amplitude-thickness relationship. The highest amplitude in the area (point M) is assumed to be at tuning and hence 22 m thick.

The line of best fit to the four points (0, Cimatti-1, Cimatti-2 and M) was then used to define the linear function which in turn was used to calculate the reservoir thickness map.

DEVELOPMENT DRILLING

Development of the Cimatti Field commenced in 2018 with the near horizontal drilling of two water injection and a production well. These wells were planned to be drilled in areas of bright seismic amplitude. To ensure the accurate placement of the production and injection wells Schlumberger’s reservoir mapping while drilling service, the Geosphere tool was used. This tool has a large depth of investigation which allows the identification of bedding and contacts away from the well using real time stochastic inversion (Figure 6). With this tool it was possible to determine the position of the near horizontal well bore relative to the top and bottom of the reservoir and calculate the sand thickness at several points along the well path.

Figure 5. Amplitude vs Thickness plot – Cimatti 1 and Cimatti-2 define a linear trend (blue dots). M is the maximum amplitude in the field and is assumed to be at the tuning thickness of 22 m.

These Geosphere based thickness estimates confirmed the validity of the amplitude – thickness relationship derived several years earlier. One of the development wells drilled through the dim channel feature and intersected a sand estimated to be 2-3 metres thick (the right hand side of Figure 6) and supported a connection between the eastern and western parts of the field.

Figure 4. Tuning curve calculated using wavelet extracted from seismic data near Cimatti wells. Tuning peak (blue arrow) is close to 9 ms which equates to 22 m (assuming a velocity of 2500 m/s). Note TWT thickness remains relatively constant below the tuning thickness.

CONFIRMATION

The thickness interpreted from the Geosphere results was calculated at numerous points along the path of a development well (CIM01) and plotted against the seismic amplitude of the reservoir reflection at each point. A line of best fit was calculated and is shown in Figure 7. This trend was found to match the trend defined by the exploration wells several years earlier.

CONCLUSIONS

The use of seismic amplitudes to determine reservoir thickness map was successfully employed at Cimatti and was used to calculate the gross rock volume of the field. An estimate of in-place hydrocarbon volumes above a nominated oil-water contact was calculated from the gross rock volume. Verification of this method was provided by the interpreted reservoir thickness seen in the development wells.

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