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SOLE DEVELOPMENT
(Patricia Baleen Extension)

Mapping and GRV Report

SD-01-RE-0012
Part C

March 2004

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1 INTRODUCTION

The Sole gas field is located in Retention License VIC/RL3 in the offshore Gippsland Basin, Victoria. The Sole 1 discovery well drilled in 1973 by Shell Development Australia, is located in an off-structure position on the south east flank of the Sole field.

The Sole 2 appraisal well was drilled at the crest of the Sole anticline in July 2002 and was located on a regular 1 x 1 km 2D seismic grid that had been reprocessed that year. This well proved the presence of a significant gas resource, with the well intersecting a 70+m gas column in high quality sandstones at the top of the Latrobe Group.

To improve the confidence in the gross reservoir volume range prior to making a field development decision, the Sole Joint Venture (OMVA, SANTOS and DGR) recorded 223km of 2D seismic lines (prefix GS02) over the field during January 2003. These lines were acquired using the MGC vessel “Polar Duke” and have a north-south line spacing of 250m and an east-west spacing of 500m.

This report describes the results of the mapping of the 2D data covering the gas field. Strong velocity field distortions emanating within the Miocene carbonates above the reservoir necessitate an unconventional interpretation workflow. Although these distortions create major TWT irregularities in the top reservoir and GWC reflectors, both are strong reflectors. Other than at the field edge, below seismic tuning thickness of these surfaces, the reservoir isopach may be accurately mapped from the interpretation of just these two reflectors and calibration of the gas sand interval velocity. A range of gross reservoir volumes has been derived based on various assumptions for the reflectors at the field edge.

2 SEISMIC DATA SET

The following lines and processing versions were interpreted during the project:

GS88B-97	PSTM Reprocessing by Robertson Research Australia (RRA) in 2002 (2 msec)
GS91A-1 to 16	PSTM Reprocessing by RRA in 2002 (2 msec)
EBR-99-10	PSTM Reprocessing by RRA in 2003 (1 msec)
GS02 series of lines	PSTM Processing by RRA in 2003 (2 msec), comprising 49% of the data

A synthetic seismogram for Sole 1 was prepared in 2002 after the sonic from the well had been edited to compensate for significant cycle skipping in the gas reservoir at the top of the Latrobe Group. All ’88 and ’91 2D data across the field was reprocessed in 2002 and was phase matched to tie the synthetic created from the edited sonic log. The GS02 and EBR data subsequently processed by RRA in 2003 were phased matched to tie the reprocessing they had completed in the previous year. All these 2D seismic lines are of good data quality with the top and base gas reflectors readily interpreted.

The data was loaded into OMVA’s Charisma seismic interpretation system for seismic TWT picking. These TWT values were then exported and loaded into OMVA’s Petrosys mapping and gridding package for the production of the final grids, maps and volumes.

3 WELL TIES

The interpreted seismic grid includes ties to three wells:

Sole 1	Drilled 1973
Sole 2	Drilled 2002
Dart 1	Drilled 1973

Sole 1 and 2 both intersected gas at the top of the Latrobe Group and both wells provide important stratigraphic and velocity control for the Sole field. Dart 1**,** located some 8.7 km west of Sole-2 was drilled in 1973 to test a stratigraphic trap, but was water wet and has been useful purely for stratigraphic calibration.

Based upon recent petrophysical interpretation (Part B), the following well intersections have been used to convert the seismic TWT isochores to isopach values:

	Sole 1	**Sole 2**
Top Gas mkb	810.2	771.0
Base Gas (GWC) mkb	828.2	841.5
Gas Isopach m	18.0	70.5

Updates to Part B have changed the gas sand thickness for Sole 1 to 17.9m and Sole 2 to 71.6m. These changes have minimal impact upon the GRV.

The results of this recent petrophysical work have shown that the GWC is not significantly different between the Sole 1 and 2 wells – Sole 1 at 818.2mss and Sole2 at 816.5mss. To the north of the Sole gas field the Latrobe Group is down faulted and thins significantly. This faulting and thinning limits direct water flow across the Sole gas field from the north. Due to the limited seismic coverage outside the field area and the absence of direct hydrological evidence for a tilted GWC, a “flat” GWC has been assumed for the field throughout this report. The GWC depth has been taken as 816.5mss based on the Sole 2 intersection which has been confirmed by wireline logs and pressure gradient in the well.

The extent of any downward movement in the GWC is uncertain between the 1973 drilling of Sole 1 and the 2002 GWC intersected in Sole 2. The 45 psi aquifer pressure depletion measured over the 29 years between the drilling dates for Sole 1 and Sole 2 would mean that the GWC would have moved down about 1 m, *if the Sole gas field is not filled to spill*. As no 3D exists over the field and with the lateral velocity changes in the overlying Miocene channelling, it is impossible to resolve if the field is filled to spill. For this work, a conservative approach on GRV has been taken and it is assumed that the GWC has not varied from 1973 to 2002 ie the field is filled to spill.

The sonic logs for both Sole wells have problems with either cycle skipping or washouts and cannot be used in unedited form to determine the gas sand interval velocity. Prior to the drilling of Sole 2, a gas sand interval velocity of 2118m/sec had been derived from the Sole 1 edited sonic log. The gas sand interval velocity has since been confirmed from the checkshot times in the Sole 2 well, which give a value of 2100 m/sec. This has been used in the conversion of the isochron to isopach for the gas field. A VSP was recorded in Sole 2 but a good tie for both the Top Latrobe and GWC could not be achieved unless the VSP is stretched/squashed by about 10 msec to match the seismic (Figure C1). This may be due to ray path distortion in the seismic section caused by the large velocity decrease at the top gas.

The isopach ties at the wells using 2100 m/sec velocity (see Mapping below) are:

Well	**Isopach**	**Seismic Isopach**	**Difference (Seismic-Well)**
Sole 1	18.0	20.0	2.0m thick
Sole 2	70.5	72.0	1.5m thick

The differences between actual and predicted using an interval velocity of 2100m/sec are less than or equal to one sample for all lines (bar the EBR line). This is considered to be an excellent tie, showing the quality of the seismic data, the accuracy of the seismic picks and the suitability of the gas sand interval velocity of 2100m/sec.

4 HORIZONS

As the purpose of this mapping was to determine the Top Depth Structure and GRV of the Sole field, only two horizons were mapped:

- **Top Latrobe** (equates to top porosity or Top Gas over the field) and
- **Gas Water Contact** (GWC, Figures C2 - C14).

These reflectors are located at approx 800msec TWT.

Based upon the Sole 1 synthetic, which was used to tie the 2002 reprocessing, the Top Latrobe is a strong peak, whist the GWC is interpreted as a trough. The Top Latrobe is readily autotracked over the gas field. To the south and west of gas field, the top Latrobe has been eroded by channelling at the base of the Lakes Entrance Formation. In these areas the Top Latrobe is a much weaker event, but can still be correlated. The GWC reflector is slightly weaker, and cannot be autotracked due to the tuning thickness at the edges of the gas field. The gas-bearing volume of the field edge is more difficult to determine.

Three field limit cases have been interpreted based on differences in the GWC character at the field extremities as follows (Figure C15):

- Minimum case (Min) - Limit of tuning bright amplitudes was used as a minimum case
- Most likely limit of gas (ML) – with the edge of the gas based upon amplitude variations at Top Latrobe just outside the GWC tuning. If the subtle amplitude changes were not present, the GWC limit was determined by a projection of the GWC dip into the Top Latrobe reflector
- Max case (Max) - pushing the gas limit as far as possible, using amplitude character and erosion limits for the Top Latrobe.

The range covered by the ML and Max cases cover gas column thicknesses not resolvable from seismic, namely less than about 8 to 10m.

5 MAPPING

Due to the impact of major lateral velocity variations in the younger Miocene channels, a top down depth conversion cannot be accurately determined. This can be seen in Figures C7 & C8 where there is at least a 55 msec TWT variation in the GWC, which is flat in depth. As a result, **an isochron tied to the flat GWC** was used as the basis for producing the depth maps in this report.

The procedure used was:

i) Interpret and map Top Latrobe and GWC

ii) Grid, smooth and contour the differences (Enclosure C1).

iii) Using a velocity of 2100m/sec determine an isopach for the gas bearing interval (Enclosure C2).

iv) Tie this to the Sole 1 and Sole 2 wells for the 2002 GWC gas sand thickness values. This was achieved using a kriging algorithm with radius of 500m (Enclosure C3).

v) This calibrated isopach map was then subtracted from the GWC of 816.5mss to produce the Top Latrobe Structure Map (Enclosure C4).

The isopach and structure maps show a "bloated Z" shape for the Sole gas field, with the northern lobe, the main culmination drilled at Sole 2 and the south east Sole 1 lobe (Enclosures C3 & C4). The aerial extent and shape of the structure are similar to that interpreted prior to the drilling of Sole 2 and the mapping confirms that the appraisal well was drilled close to the absolute crest of the structure. The axis of the central culmination of the field is cross-cut by three normal faults striking NW-SE. These faults have a maximum throw of 3 to 17m. Prior to the 2003 seismic becoming available, only one NE-SW-trending fault had been interpreted along the axial part of the structure. The fault pattern interpreted from the 1 x 1 km 2D seismic grid had clearly aliased the infield fault pattern.

The separation of the Sole North and Sole 2 lobes have been investigated by several rounds of seismic and the following points are noted (Figures C9 & C10):

- The older seismic has no increase in amplitude beneath the low separating these two lobes, whilst the GS02 seismic lines have a number of amplitude anomalies under this low.
- Inversion processing of line EBR-99-10 was undertaken by Eagle Bay Resources and *no gas* was detected under this low. As this line is the most easterly line through the low separating the two lobes the ML case interpretation doesnot include gas communication under this low. However Line GS02-02-022 has bright amplitudes at this location; this may be interpreted as showing an incomplete phase match between the 2002 reprocessing and the 2003 processing. It may also indicate that the GS-02 lines have more side lobe energy than the earlier data.
- Based upon the results on the E-W line through this low (GS02-02-022, Figures C9 & C10) the Max case gas has been pushed outwards to the limit of bright amplitudes seen on line GS02-02-22
- In the time domain the separation is quite obvious but due to the effect of the velocity variations in the overlying Miocene channels, the depth picture is always less precise.

The likely connection of the Sole 1 and 2 lobes had been evident on previous interpretations. The most recent seismic data, specifically line GS02-10-021 (Figures C11 & C12), confirmed that there is gas communication between these two lobes. However the gas has a maximum thickness of around 10m through the saddle area.

As noted in Horizons above, the gas limit has been interpreted for 3 cases and these are presented in Enclosures C4 to C6. These limits of the GWC do not incorporate uncertainty in the possible contouring over the gas field.

No other gas anomalies were noted on the seismic lines traversing VIC/RL3. Thus no other exploration or development options exist within VIC/RL3.

6 GRV

6.1 Variables

The main variables that have a bearing on the GRV range determination are:

1 Pick uncertainty

2 Contouring uncertainty

3 Gas Sand Interval Velocity

4 GWC depth

1 As noted in the previous section of this report, the seismic data quality is very good and the top and base gas horizons are easily interpreted. Some jitter is evident on the autotracked picks but when the picks are gridded there is a smoothing effect upon the data, acting some what like a box car filter over the picks. This smooths out any possible picking variations along any seismic line, thereby reducing bias and errors.

2 The current seismic grid is 250m N-S and 500m E-W. The Fresnel Zone of the seismic data has a radius at top and base gas of about 130 to 150m. This will also apply to the 2D migrated data, as the Fresnel Zone is collapsed back to an ellipse with the original Fresnel Zone radius perpendicular to the 2D line. Thus the top and base gas for the entire field area has been sampled with the current 250m-spaced N-S grid. This significantly limits contouring options over the field.

3 The average gas sand interval velocity is centered upon a value of 2100 m/sec. This is the value obtained form the Sole 2 checkshots over a thick gas column and is very close to the Sole 1 velocity of of 2118 m/sec. As Sole 2 intersected the thickest gas section for the field, and Sole 1 a much thinner section, the average gas sand interval velocity is considered to have a tight range. Thus P1 and P99 values have been assigned to 2200 m/sec and 2000m/sec. This gives the following tight range for the gas sand velocity:

P1	2200m/sec
P10	2153m/sec
P50	2098m/sec
Mean	2098m/sec
P90	2043m/sec
P99	2000m/sec

4 The GWC depth intersected in the 2 wells differs by some 1.5m. Sole 1 has a GWC of 818mss with Sole 2 being 816.5mss. Based upon work by A Ion (Appendix CB) these are considered to be well within possible errors expected. A value of 816.5mss has been used in this report. Recent work places the absolute GWC at 817.0mss with an uncertainty of +-0.4m (Appendix CC).

6.2 Current Mapping

The GRV was determined within the Petrosys mapping package, using the Volumetric option. The Top Structure/Gas is the Most Likely Case (ML) with a GWC of 816.5mss.

For the ML case map (Enclosure C4) the area and volume are:

Area 19.69 sq km

Volume 494.5 MMm^3

These compare well with the values obtained for the PSTM mapping of the 2002 reprocessing 1x1 km grid. Based on that data the previous seismic interpretation had indicated a GRV of 505 MMm^3, including a 30 MMm^3 wedge beyond the seismic tunning limit.

6.3 GRV Range

The Min, ML and Max maps generated for the Sole gas field only vary in form outside the limit of the bright amplitudes (Mapping). The Min map has been generated as a subset of the ML map by using the tighter limit imposed by excluding the gas wedge outside of the tuning limit. Thus possible structural variation between the seismic lines over the main part of the field has not varied between the different maps. As noted earlier with a line spacing of 250m N-S the unmigrated Fresnel Zones perpendicular to the shooting axis for the NS lines will slightly overlap at the Top Latrobe and GWC. This means that the whole field is having an effect on the 2D seismic data interpreted.

Using the Min and Max maps the GRV Range is:

	2003	2002 PSTM (1x1km)
P10	**536.7**	669.2
P50	**509.6**	526.0
P90	**483.9**	413.0

The mapping has confirmed that the Sole feature is a relatively simple structure. There is limited, simple faulting and as noted previously, good reflectors for top and base gas. Thus a deterministic approach has been used for the GRV range. This range is quite tight but appropriate when considering data quality etc. The effect of the variation in Velocity (+- 50m/sec = +- 12 MMm^3) and GWC (+- 0.5m = +- 10 MMm^3) is minimal and easily fits within the above range.

A statistical approach was also attempted but is considered less accurate (Appendix CA).