1994 Palm Valley Seismic Survey

Interpretation Report

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Introduction

The Palm Valley Gas Field is a roughly east-west trending anticline located in the Amadeus Basin, some 140 km west of Alice Springs, in the Northern Territory (Fig 1). The palm trees that give the field its name are located along the edge of the field's outcropping southern flank.

The field was discovered in 1961 when the wildcat well Palm Valley No. 1 flowed gas at a rate of 20 MMCFD from the Ordovician Pacoota Sandstone. Since that time a further nine wells have been drilled, of which seven were completed for production. The field, which has now been on commercial production since 1984, is presently flowing approx. 20 MMCFGD from six wells.

The Palm Valley field is unique in Australia in that production is from fractures rather than directly from the matrix; gas "bleeds" from the matrix into the fracture network. While the matrix itself is too tight to sustain commercial flows, gas flows from fractures intersected while drilling have yielded two Australian onshore gas flow records (Palm Valley No. 2: 70 MMCFGD; Palm Valley No. 6B: 137 MMCFGD). Recently, the Palm Valley Joint Venture has committed substantial resources to studies of this fracture network in an effort to develop a reliable predictive model. Underpinning this work is a need for robust structural mapping; heretofore unavailable due to a paucity of seismic - in turn a result of the field's extremely rough topography.

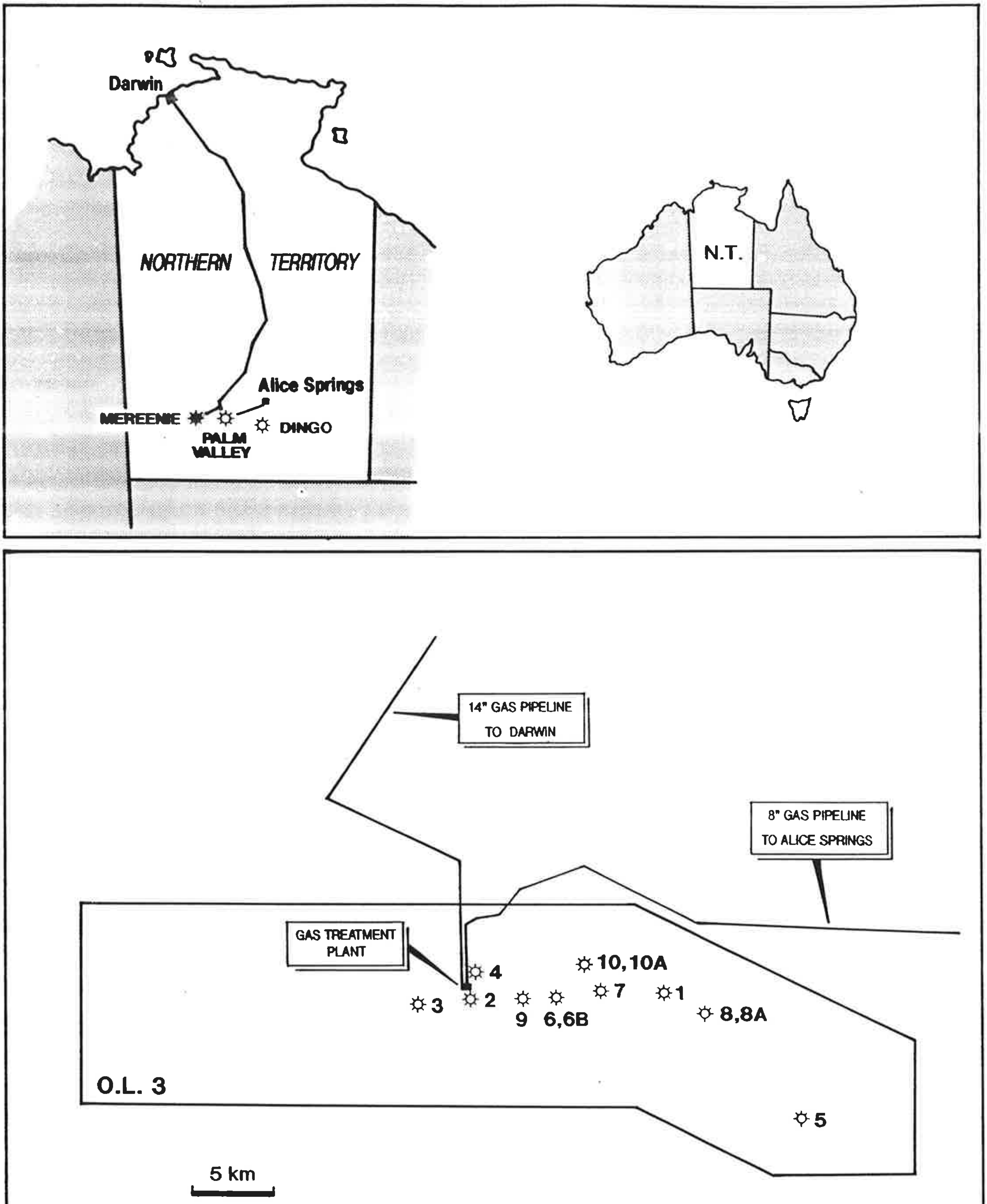
Prior to 1994, only two lines (2-2/71-PV2 and 71-PV3) had been acquired within the field itself and these were restricted to existing river and creek beds - all other lines were located around the periphery of the outcrop. Structural mapping over the main part of the field therefore relied heavily on well control and surficial dips. In 1994, the Palm Valley Joint Venture acquired 90 km of multifold seismic over the main body of the field in order to refine the structural mapping. This report presents the results of that work.

Previous Work

Seismic

Three seismic surveys pre-date the 1994 program. The Magellan Petroleum 1965/66 Missionary Plains Seismic Survey acquired data over a large part of the northern Amadeus Basin. In the Palm Valley area, lines were shot in the Finke River and out into the Missionary Plains. The data, single-fold dynamite, was of generally good quality and has reprocessed well. Lines 2-2 and 2-5XB were reprocessed as part of the 1994 program.

The 1971 Palm Valley Seismic Survey was acquired for Magellan by Austral United and used Detcord as a source, with all the lines located in creeks or river beds. The data, mainly six-fold, ranges in quality from poor to good. All lines were reprocessed for inclusion in the 1994 program.



LOCATION MAP
PALM VALLEY FIELD

FIGURE 1

The 1973 Central Amadeus Seismic Survey was a regional weight-drop survey acquired by Ray Geophysical for Magellan Petroleum. Five lines were acquired at Palm Valley, three around the north and north-east flanks, one further out in the Missionary Plain and one attempted along the Palm Valley ridge road (this last line, 73-3-PV1, is unusable). Considering the limited bandwidth of the source, the data is generally fair to good. Three lines were reprocessed in conjunction with the 1994 program.

Table 1 details the parameters of the pre-1994 seismic data.

Palm Valley Pre-1994 Seismic

Date	Survey	Identifier	Source	Coverage	Group Int
1965	Missionary Plains	2-,3-	Dynamite	100%	1724 ft
1971	1971 Palm Valley	71-PV-	Detcord	600%	220 ft
1973	Central Amadeus	73-3-PV-	Weight-drop	1200%	140 m

Table 1

Gravity

Gravity data was acquired in the Palm Valley region in 1961 as part of a BMR (now AGSO) reconnaissance program. Further data was acquired in 1965 in conjunction with the Missionary Plains Seismic Survey. Additional data was later acquired during the Central Amadeus Seismic Survey (1973).

None of the gravity data to date is sufficiently densely sampled to materially contribute to structural mapping over the Palm Valley anticline.

1994 Palm Valley Seismic Survey

Acquisition

Approximately 90 km of 24-fold seismic data was acquired over the Palm Valley field in October 1994. The difficult nature of the Palm Valley terrain strongly influenced the program layout - most lines were located along ridge-tops; Enclosure 1 shows the final layout of the program. The configuration of the survey and the lack of surface cover precluded the use of Vibroseis; consequently the data, acquired by Geco-Prakla for the Palm Valley Joint Venture, was sourced by dynamite in a fully heli-supported operation. Three heliportable drills were used to drill 10m shotholes at a 150m intervals. Six kilogram charges were then detonated into a 480 channel split spread; group interval was 15m. Seven lines were acquired (M94-PV series) over the central and eastern portions of the field. It should be noted that the nature of the terrain combined with the use of helicopters for all personnel and equipment support ensured a logistically complex operation. The successful and safe completion of the program could not have been achieved without the professional and enthusiastic performance of the Geco-Prakla crews.

It may also be noted that due to extremely slow drilling, the eastern portion of line M94-PV01 (sp 600-940) was abandoned; line M94-PV02 was subsequently extended north to provide a tie to line 73-3-PV2.

Data quality varies from poor to good across the survey. Strong coherent noise (1500m/sec; ~20-30 Hz) was observed on shot records in areas of higher elevation. Despite most of this noise being later removed by stacking, it had a detrimental effect on the data and as such the data quality can be seen to decrease as the surface elevation increases.

Processing

The data was processed by Western Geophysical Company of America ("Western") in Denver, Colorado, USA. Final and Migrated stacks were produced for all lines, as were additional stacks based on "modelled" trim statics. The modelled stacks were output on tape only.

A relatively straight-forward processing sequence was found to be most effective. Statics were computed using the refraction ("first-break") technique. The statics revealed a two-layer near-surface, with a generally thin weathering layer and a very fast sub-weathering layer (4750 m/sec). It may be noted that some "shingling" effects were present on some first-breaks, which complicated the picking. This was a factor in some of the problems encountered on line M94-PV05, which runs through the wells Palm Valley No.7 and Palm Valley No.10; there was a large mistie between the check shot data for the wells and the static corrections applied to the line. The line was ultimately bulkshifted by +40 mS (see below).

To assist in improving continuity, all lines had a weighted five trace mix applied at the end of the processing sequence.

Reprocessing

In addition to the processing of the 1994 data, selected pre-existing data was reprocessed by Western. The objective was not only to improve the quality of the older data, but to provide a consistent set of data for interpretation. In all cases, the reprocessing significantly improved the quality of the data. The reprocessed lines are detailed in Table 2.

Palm Valley 1994 Reprocessing

Line	Shotpoint range	Length (km)
2-2	5-39	14.0
2-5XB	1-26	14.0
71-PV2	63-132	7.4
71-PV3	133-181	6.6
71-PV4	2-36	4.8
71-PV5	38-61	3.4
73-3-PV2	All	13.3
73-3-PV3	All	21.6
73-3-PV4	All	19.6
	Total km	104.6

Table 2

Interpretation

The wells PV1, PV5, PV7, PV8, PV9 and PV10 are tied into the 1994 seismic. Synthetic seismograms were produced for these wells and also for PV4, which has a well velocity survey but is not presently tied into the seismic grid (the gas trunk line to Alice Springs and Darwin passes close to the PV4 wellsite and as such prevents the acquisition of dynamite seismic data). The wells PV2, PV3 and PV6 remain isolated from seismic.

Checkshot times for the Pacoota P1 were close to those picked on the seismic for PV1, PV5, and PV8 with an average difference of -5 mSec (seismic - checkshot). More substantive differences were noted on line M94-PV05. A review of the static profile on line M94-PV05 revealed a computed weathering layer that appeared to be anomalously thick - which in turn was causing a static overcorrection. Western re-examined the first-break data and confirmed a problem with the picking; a "shingling" effect on the first-breaks had resulted in incorrect picks - however, they were subsequently unable to satisfactorily correct the problem. Thus, for the purpose of interpretation, the line has been bulkshifted by +40 mSec, which results in a difference between the seismic and the PV7 checkshot of -5 mSec - consistent with that seen on the other well ties (original Pacoota P1 seismic pick at PV7: 758 mSec; PV7 checkshot time for the Pacoota P1: 803 mSec). It may be noted that a fault on that section, apparent between the wells, is likely to be an artefact of the statics problem and accordingly is marked only tentatively on the maps.

Table 3 details relevant data for all Palm Valley wells.

Palm Valley Synthetic Seismograms

Well	Sonic Log	Density Log	Checkshot/ VSP	Synthetic Seismogram	Line Tie	Comments
PV 1	Y		Y	Enc 2	M94-PV06; sp 275 71-PV2; sp 118	
PV 2	Y				-	
PV 3	Y				-	
PV 4	Y	Y	Y	Enc 3	-	Density not used
PV 5	Y	Y	Y	Enc 4	M94-PV06; sp 1125	
PV 6	Y	Y		Enc 5	-	
PV 7	Y	Y	Y	Enc 6	M94-PV05; sp 465	
PV 8	Y		Y	Enc 7	M94-PV06; sp 465	
PV 9	Y	Y	Y	Enc 8	M94-PV04; sp 665	
PV 10	Y	Y	Y	Enc 9	M94-PV05; sp 342	

Table 3

Five horizons were mapped in time:

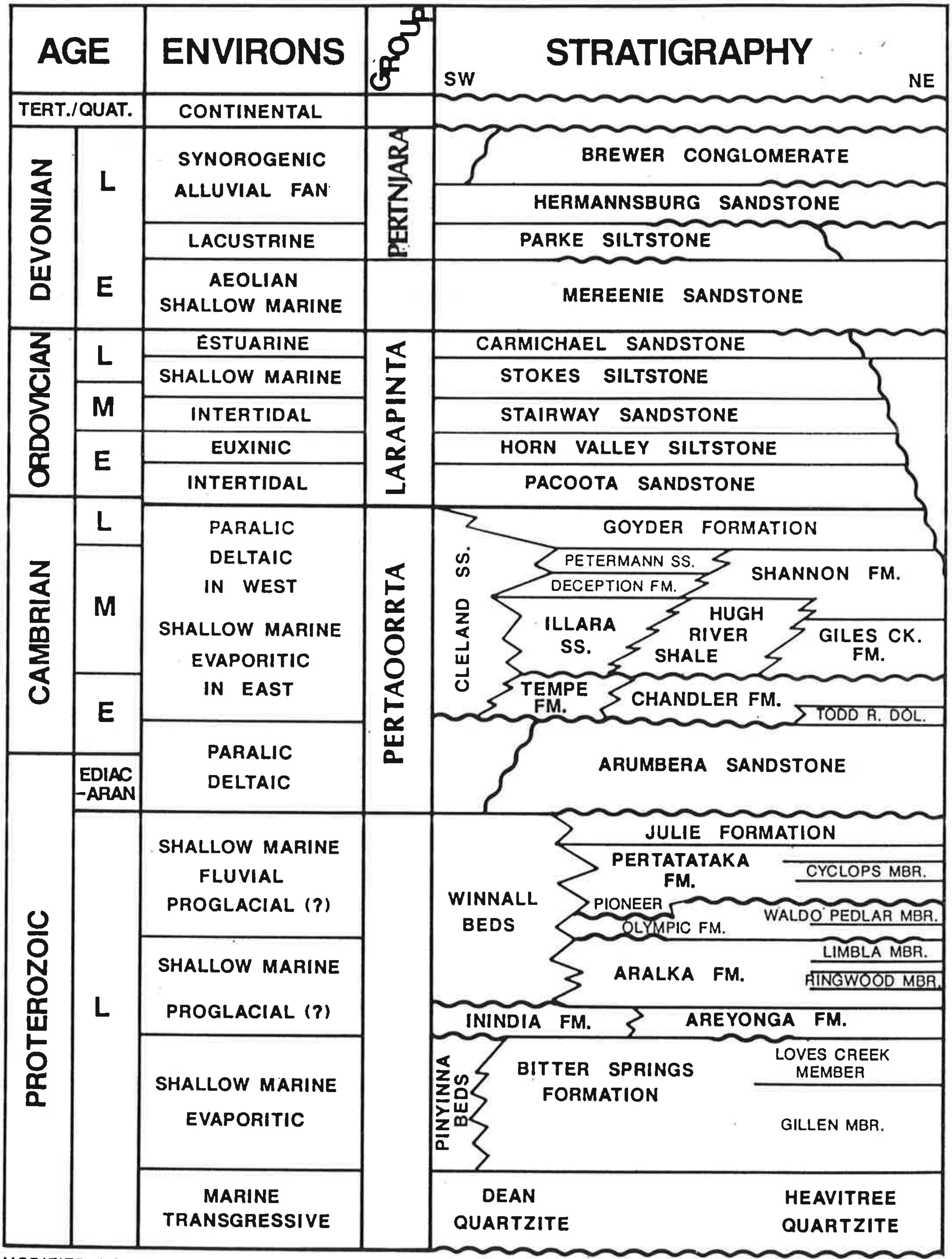
Pacoota P1 Sandstone
Pacoota P4 Sandstone
Marker 1 (Nr Top Arumbera A4 unit)
Marker 2 (Nr Top Julie Fm.)
Bitter Springs Fm.

An additional two horizons, the Horn Valley Siltstone and Marker 0 (?Nr Top Chandler or equivalent) were also picked but not mapped. All picked horizons are shown on Enclosure 10, an interpreted copy of line M94-PV04. It may be noted that the Pacoota P4 pick was made one leg below the top (this was easier to follow) and as such the top P4 is approx 25 mSec higher than the P4 pick.

The stratigraphic relationship between the mapped horizons is detailed in Figure 2. The two-way time maps are included as Enclosures 11-15. All time picks are relative to seismic datum (800m asl).

As noted above, data quality is variable. In particular, the portions of lines M94-PV02 and M94-PV03 that pass over the topographic crest of the field are difficult to interpret. It is, however, considered likely that this data quality deterioration is primarily related to low signal strength rather than complex structuring and so the contouring reflects this approach. This is supported by data on line M94-PV06, which follows the ridge line between the wells PV8 and PV5 - although the data on this portion of the line also falls off in quality, it remains interpretable and shows no evidence of complex structuring or faulting.

Misties are apparent along the northern margin where strike lines (73-3-PV2,3,4) have



MODIFIED AFTER JACKSON, McKIRDY & DECKELMAN, 1984

AMADEUS BASIN
GENERALISED STRATIGRAPHY

FIGURE 2

been acquired along the dipping flank of the structure. In most cases the misties are not considered to be consequential; they are principally a geometric effect - a result of a strike line imaging structure updip of its actual location. The dip lines are used to guide the contours through these intersections. In some cases there may also be minor positioning problems with the older data (significant survey errors in the 1973 data were discovered - and corrected - during the 1994 seismic program) that contribute to some of the misties.

Of note however, is the intersection of 2-2 and 73-3-PV3 where a substantial mistie is present (+92 mSec). While this is apparently due to line 73-3-PV3's strike orientation along the flank, the structural dip in that area, as evidenced on line 2-2, is steep enough to cause the strike line to image significantly updip of its physical location, resulting in a unusually large mistie. The north-western end of 73-3-PV4 is similarly affected by its relative position. Thus the picked times on those parts of 73-3-PV3 and 73-3-PV4 are not considered absolute and are used for guidance only.

Bulkshifts were not required for the new or reprocessed data (with the exception of line M94-PV05). Otherwise, ties were generally good; a shift was required for 2-1, but is likely to be a consequence of positioning problems. Line 73-3-PV5 was shifted to tie to the 800m datum as were lines 3-4, 3-5 and 3-C - which had been processed to a 550 m datum.

Bulkshifts

Line	Bulkshift	Comment
2-1	-46	Positioning error?
73-3-PV5	90	Line not reprocessed
3-4	155	Processed to 550m asl datum
3-5	155	Processed to 550m asl datum
3-C	155	Processed to 550m asl datum

Table 4

Depth Conversion

Pacoota P1

Depth conversion to the Pacoota P1 was effected by using an average velocity from seismic datum. The velocity map (Enc. 16) is relatively simple; data is tied to all wells except PV2 and PV3 (which are isolated from the grid) and follows the gross shape of the field as defined by the time maps. A mild velocity saddle is located at PV9, suggesting that the static correction on line M94-PV04 may be slightly over-estimated. Table 5 details velocity data used to create the map.

The seismic also clearly shows extensive salt pillowing underlying the structure in the Bitter Springs Formation - this is best seen on line M94-PV04 (Enc. 10), which crosses the central part of the field. It is likely that minor deformation occurred at Palm Valley as early as the Late Proterozoic and this later became a focus for substantive salt emplacement (and consequent growth) during the Alice Springs Orogeny. It is possible that the structuring at Palm Valley at that time was sufficient to absorb some of the compressive forces that were responsible for the Gardiner Range Fault, which dies out just south of Palm Valley.

The orientation of the Palm Valley faulting is also of interest - while the faulting was originally controlled by Late Proterozoic movement, it may be noted that the fault trend, as it extends north-easterly (to the 2-2 / 73-3-PV3 intersection) appears to intersect the dying western end of the Waterhouse anticline.

Although the Waterhouse faulting has actually died out east of Palm Valley (in fact east of of line 2-1) there is a pronounced slope-break at shotpoint 21 on line 2-1 that is clearly an extension of the Waterhouse trend. A similar, although less obvious, slope-break can also be seen on line 2-2 (sp 12.5), only 3 km or so north of Palm Valley No. 1, that may be linked back to that same trend (Fig 3). Thus it appears that the very steep dips seen on the north-eastern flank of Palm Valley (and in fact the "corner" itself) are a result of the westerly end of the Late Proterozoic Waterhouse structuring extending to Palm Valley and having then been further deformed during the Alice Springs Orogeny.

In regard to the Palm Valley field itself, at all levels the primary orientation is WSW-ENE, effectively controlled by the faulting. However, as the feature extends southwest of the well PV9 there is a slight crestal offset to the south, creating a secondary closure south of PV3. Although the seismic data is not optimal in this region, the offset model is supported by the north-northeasterly azimuth of dips at the Pacoota level in PV3 and also by an analogous tight juxtaposition of folds in the James Range only 25 km south east of the field. Accordingly, it may be that while the gross Palm Valley structure trends WSW-ENE, in detail the two closures may have a more east-west orientation. In either case, it is likely that a well drilled south or southwest of PV3 will intersect the Pacoota at a higher structural level.

PALM VALLEY FIELD

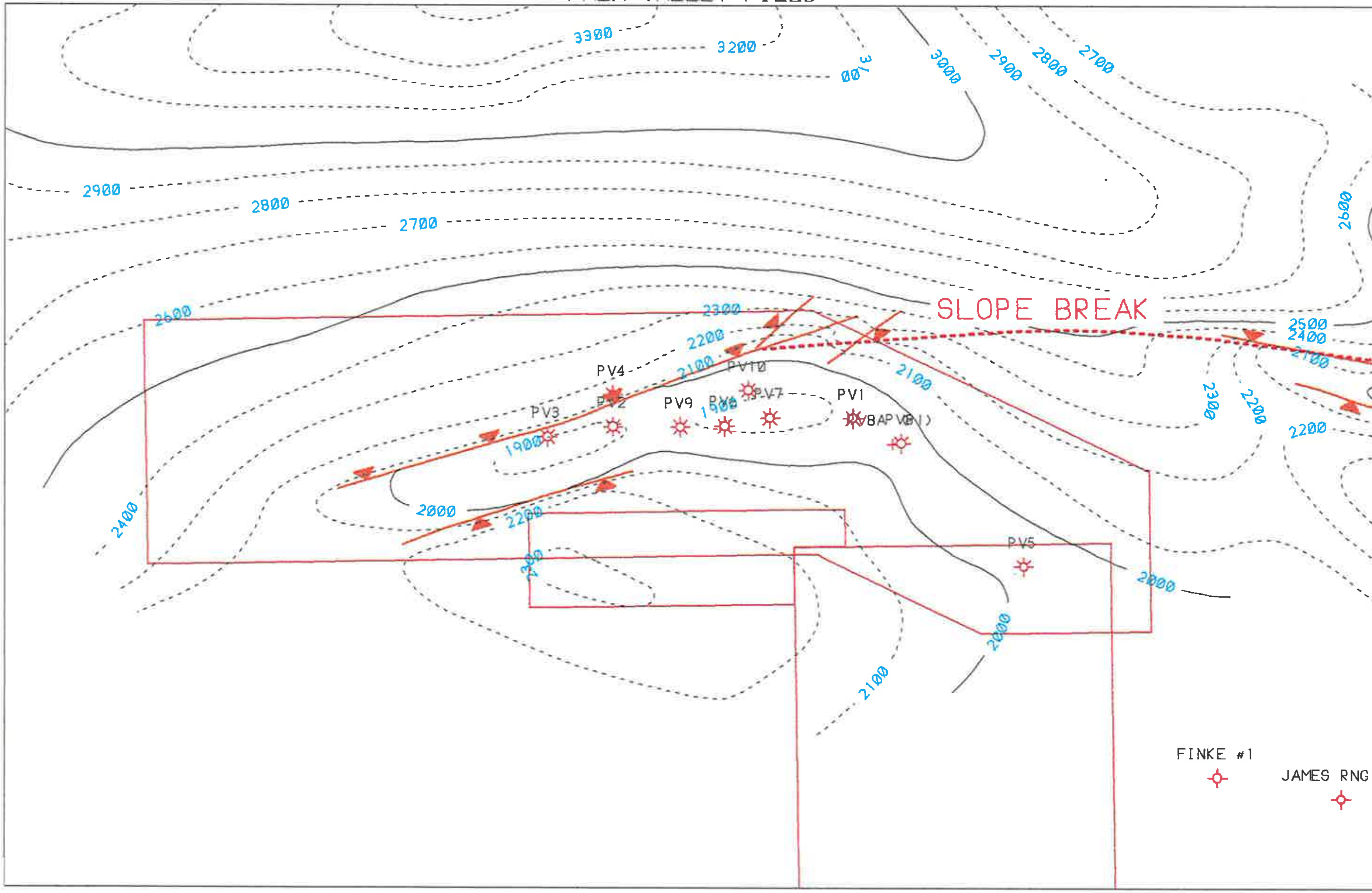


FIG 3

TWT TOP BITTER SPRINGS SHOWING WATERHOUSE / PALM VALLEY SLOPE BREAK TREND

Conclusions and Recommendations

Based on the new mapping, it is clear that the Palm Valley Gas Field still has substantial "upside" potential. Not only has the mapping at the Pacoota level indicated the presence of a subordinate offset structure south/south-west of Palm Valley 3 but it has also revealed a previously undocumented relationship between the Palm Valley and Waterhouse structures. The implications of this latter point require further investigation, but it is clear that our understanding of the fracture model in the Ordovician can only be enhanced by more fully understanding the field's structural history.

Specific recommendations are as follows:

- Reprocess line M94-PV05.

  There is room for improvement on this line, as was noted in the main text of this report. Specifically, the reprocessing should be focussed on improving the statics model.

- Acquire additional seismic

  Acquire additional seismic data in the western part of the lease and also within the Finke Gorge. It is clear that additional data (say 2 lines; 35 km) is critical if the westerly extent of the gas field is to be adequately mapped; similarly there is value in reacquiring data in the Finke River gorge (one line; 15 km). This would assist in defining the field's north-easterly extent and would allow a better definition of the deep structuring.

- Program an appraisal well south-west of Palm Valley 3.

  Subject to the completion of the projects above and to the logistics of being able to place a rig in that part of the field, consideration should be given to drilling an appraisal well to confirm the field's structural configuration south-west of Palm Valley 3. A well on line M94-PV02, sp 440, will intersect the Pacoota Sandstone in a crestal position at a structural level similar to that at PV1. A subsequent infill well should be able to target a crestal Pacoota position at least 50 metres further updip.

- Review deep gas potential

  The seismic interpretation shows closure at all mapped horizons, including what is mapped as the near top Arumbera Sandstone. Consideration should be given to assessing the potential of the Arumbera Sandstone (the main reservoir at the Dingo Gas Field) to reservoir and produce gas at Palm Valley. It is anticipated that the Arumbera A1 unit could be intersected at approx 3500 metres depth.

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