Pacific Oil & Gas Pty. Limited

INTERPRETATION OF REPROCESSED SEISMIC DATA IN EP18 McARTHUR BASIN

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1 SUMMARY

The seismic data in EP18 acquired in 1990 and 1991 was reprocessed in 1992. This report presents an interpretation of the reprocessed data.

Four seismic horizons were interpreted: the Base Cambrian Unconformity, the Near Top "Jamison Sandstone" Seismic Marker, the Base "Jamison Sandstone" Unconformity and the Top Moroak Sandstone. The tops of the two sandstone units and the Base "Jamison Sandstone" Unconformity are mapped in depth. Isochrons of the seal units, "Hayfield Mudstone" and Kyalla Member, are also included.

The structure maps of the top and base of the "Jamison Sandstone" shows larger variations in relief than the top of the Moroak Sandstone. Four conceptual models, wrenching, thinning, unconformity topography at the base of the "Jamison Sandstone" and bar sand, are presented as possible explanations. However, the variations could also be due to noise in the data.

A structural closure at the top of the Jamison Sandstone is being drilled as **Shortland 1** at the time of writing.

2 INTRODUCTION

In 1990, the stratigraphic hole **Jamison 1** was drilled in EP18 on the basis of an apparent one-line roll-over on line SH90-103. This well had encouraging hydrocarbon indications recovering oil or gas in DSTs from two intervals.

Following the encouragement of **Jamison 1**, a large seismic survey around the well was carried out in May to August 1991. The data was collected by Western Geophysical and processed by Digicon.

The exploration well **Mason 1** was drilled in November to December 1991. The Near Top "Jamison Sandstone" Seismic Marker at this well was encountered 85 metres deeper than predicted. The well was dry.

Intensive investigations and processing tests were carried out to seek possible causes of the error (Robinson, 1992; Digital Exploration, 1992). After experimental processing, it became apparent that the static correction method used did not correctly represent the near-surface low velocity layer. It was causing an incorrect velocity analysis resulting in noise being stacked rather than the signal. The interpretation was confused by the noise.

As a result of the experiment, it was decided to reprocess all the seismic data with the three-layer refraction statics. This process proved to be capable of reducing noise significantly and helped in determining correct velocity functions. The reprocessed seismic sections have better definition of the major reflectors and allow more confident interpretation.

This report describes an interpretation of the reprocessed data. The maps display fewer faults than the previous interpretation, and also less short-wavelength structural variation is shown.

3 SEISMIC DATA

Within the present mapping area, 577km of seismic data were collected by Western Geophysical from May to August 1991 (Western Geophysical, 1991) in addition to the 70km of the 1990 Scarlet Hill Seismic Survey data (O'Sullivan *et al.*, 1991).

The data was processed originally by Digicon (Digital Exploration, 1991) and Horizon, (Simon-Horizon, 1991) respectively. Interpretation of the data from the original processing was presented by Suto (1991).

The data quality in the Jamison grid is generally poor. The poor quality is believed to be caused by severe ray path distortion in the cavernous Tindall Limestone and Antrim Plateau Volcanics (Robinson, 1992).

In an attempt to overcome this noise problem and to achieve a sufficient penetration to map seismic reflectors as deep as the Moroak Sandstone or deeper, a sweep weighted to the low frequency spectrum is used in the data acquisition.

In 1992, after a review of the **Mason 1** data, it was found that three-layer refraction statics resulted in an improved quality of the seismic data (Robinson, 1992). This technique was applied in the seismic data reprocessing over the entire Jamison grid (Digital Exploration, 1992).

The three-layer refraction statics was applied before velocity analysis. This improved the signal/noise ratio in the velocity scans leading to a more accurate stacking velocity function determination. Therefore, the method not only provided more precise static correction but also improved the stack response with more correct velocity function.

The magnitude of improvement in data quality varies. The continuity of the reflective horizons has generally been improved and the characters of reflectors have been made more consistent. Hence, confidence in the horizon ties is increased.

The most noticeable improvement in noise reduction is seen near the **Mason 1** location at Near Top of "Jamison Sandstone" level. The comparison demonstrates that a noise was stacked in the original processing and that the revised velocity function after three-layer refraction statics stacked a different event.

4 SEISMIC HORIZONS

The four main seismic horizons are interpreted over the Jamison - Mason grid: the Base Cambrian Unconformity, the Near Top "Jamison Sandstone" Seismic Marker, the Base of "Jamison Sandstone" Unconformity and the Top Moroak Sandstone. A stratigraphic table is presented on Plan PetNTcw4588.

4.1 Base Cambrian Unconformity

The Base Cambrian Unconformity is a regional unconformity in the area. All the structural events seem to predate this unconformity. The section above the unconformity consists of, from surface downwards, variable thicknesses of recent alluvium up to 150 metres, Cambrian limestone (Jinduckin Formation and Tindall Limestone), occasional

Cambrian basalt (Antrim Plateau Volcanics) and occasional Cambrian Sandstone (Bukalara Sandstone). Below the unconformity lies a shaley sequence informally called the "Hayfield Mudstone" all over the present mapping area.

The seismic signature of the unconformity varies from place to place. Angularity of the erosional truncation of the underlying "Hayfield Mudstone" is sometimes observed, however, it is very hard to distinguish from noise originating from the overlying limestone.

4.2 Near Top "Jamison Sandstone" Seismic Marker

The Near Top "Jamison Sandstone" Seismic Marker corresponds to the beginning of the gradual increase of the sonic log response near the base of the "Hayfield Mudstone". It is 19 metres above the top of the massive "Jamison Sandstone" at the **Jamison 1** and **Mason 1** wells.

The seismic marker presents a strong reflectivity, however continuity of the seismic horizon is often disturbed by the noise train from the limestone. It is extremely difficult to determine whether the discontinuous nature of the seismic horizon is due to the presence of faults or simply to noise contamination.

The geological nature of this seismic horizon is not firmly determined. The small sand pulse near the base of the "Hayfield Mudstone" was intersected consistently 19 metres above the top of massive "Jamison Sandstone" at **Jamison 1** and **Mason 1** Sonic log response starts to decrease a few metres above this sand and it corresponds to the seismic marker. As the distance between the two wells is small, 6.5 kilometres, the reliability of consistent presence and position of this sand over a large area is yet to be established, (see "Bar Sand Model", PetNTcw4798).

4.3 Base "Jamison Sandstone" Unconformity

The base of the "Jamison Sandstone" marks an unconformity. In the mapping area, the Kyalla Member of the McMinn Formation is always present under this unconformity.

The Kyalla Member is thickest to the south-west of **Mason 1** and thins in all directions away from this area.

The seismic character of the unconformity is variable depending on the acoustic impedance variation of the underlying facies of the Kyalla Member.

4.4 Top Moroak Sandstone

The strongest and most coherent reflection of the seismic section in the area is caused by the top of the Moroak Sandstone Member.

The gradational change in acoustic impedance at the top of the Moroak Sandstone and the low input frequency of the seismic signal resulted in a broad reflection character on the seismic section. Therefore, although the horizon is confidently traced, the accuracy and precision of this horizon pick cannot be expected to be very high.

5 STRUCTURAL MAPPING

The seismic data contains a considerable amount of cross-cutting noise mostly generated by the Cambrian limestone. This presents a difficulty in fault interpretation: continuity of the seismic horizons is often disrupted resulting in an appearance similar to faults.

The area is near the centre of a sedimentary basin and the current geological knowledge suggests that severe faulting is unlikely in the area. So many of the disruptions of the seismic horizons are not interpreted as a fault unless the feature is correlative from horizon to horizon or from line to line.

With this working model, some faults might be missed in interpretation. However, such faults missed in interpretation would have small displacement of formations and would not greatly affect the trapping geometry of hydrocarbon as shown on the final maps.

Time maps are drawn for all the four interpreted horizons (Plans PetNTcw4737, 4708, 4742 and 4709).

Isochron maps are prepared for the two shale intervals which provide regional seal to the underlying reservoir units (Plans PetNTcw4738 and 4718). The isochron maps of the Hayfield Mudstone and the Kyalla Member show sufficient seal is present within the entire study area of the present mapping. The two maps also show a similar overall trend of thinning to the east and west with the thickest area coinciding with the synclinal axis.

Depth conversion is performed for the top and base of the Jamison Sandstone and top of the Moroak Sandstone.

Initially the smoothed velocity method was used to calculate depth of the top of the "Jamison Sandstone" and the Moroak Sandstone. As the only available velocity referenced to the seismic reference datum (SRD) is the migration velocity function, it is used as the basic data. The migration velocity function is obtained as 95 percent of the stacking velocity function which is analysed every kilometre along the seismic lines (Digital Exploration, 1992). The migration velocity functions were merged with and interpolated to the interpreted horizon time of the top of the two sandstone units. The interpolated migration velocities are posted on the Plans PetNTcw4805 and 4804.

These velocity maps contain spurious lateral variation, some owing to different directions in stacking and others introduced by various sources of ambiguity in the method and analysis. Therefore the migration velocity is manually smoothed with an effort of removing the noise and of leaving trends geologically explicable. Unavoidably interpreter's subjectivity is introduced into the system.

The product of horizon time and the corresponding migration velocity was compared with the depth of the reflector at the wells and a conversion factor was calculated to tie the depths. The conversion factor to tie the Near Top "Jamison Sandstone" Seismic Marker to the top of the "Jamison Sandstone" depth is 0.89, while the factor for the top of the Moroak Sandstone is 0.91, for this particular time interpretation and smoothed migration velocity. The depth plans are enclosed (PetNTcw4740 and 4744).

The depth of the Base "Jamison Sandstone" Unconformity is calculated by the "isopach-up" method. The "isopach-up" method is thought to be a logical depth conversion method to use for the following reasons: the top of the Moroak Sandstone is a relatively reliable seismic reflector; the velocity analyses for the aforementioned horizon are considered to be better than any of the other horizons; and the interval velocity of the Kyalla Member is fairly uniform. The thickness (isopach; more correctly isochore) of the Kyalla Member was calculated by multiplying a constant interval velocity of 4107 metres per second with the difference of interpreted travel times to the Base "Jamison Sandstone" Unconformity and the Top Moroak Sandstone. The thickness of the Kyalla Member was subtracted from the depth of the top of the Moroak Sandstone Unconformity obtained earlier, to reach the depth of the Base "Jamison Sandstone" Unconformity which in turn corresponds to the top of the Kyalla Member in the present mapping area (PetNTcw4741). This interval velocity was calculated to tie the wells, **Jamison 1** and **Mason 1**. The value, 4107 metres per second, corresponds to the interval transit time of 74.2 microseconds per foot, which largely agrees with ones observed by the sonic log of the Kyalla Member in **Jamison 1** and **Mason 1**.

6 DISCUSSION

The southern area of EP18 is one of the most difficult areas for seismic exploration in the world (Workman, 1991, *pers. comm.*). The cavernous Cambrian limestone and the underlying basalt are the main causes of the poor seismic data quality.

Every effort was made to improve the signal to noise ratio, through acquisition and processing. The keys to improvement in the data acquisition stage are higher fold, high number of geophones per group, and lower frequency sweeps. A smaller input energy was successfully tried in the subsequent surveys. In data processing, improvements are achieved by dip move-out correction and very careful velocity analysis, as well as three-layer refraction statics correction. Experience in this particular data set, especially in velocity analysis, plays an important role in data processing.

Interpretation of this seismic data is a difficult task particularly in recognition of faults and termination of reflectors. At this stage seismic facies analysis and sequence stratigraphic interpretation are beyond the limit of the data quality. Other forms of data displays such as colour-coded amplitude and instantaneous frequency and phase may help interpretation, but they are yet to be tried.

The interpretation presented in this report is based on the working model of little faulting. As discussed later, it may not be the case, but the working model is considered to be sufficient to determine the regional trend and the traps.

The structure maps of the horizons of the top and base of the "Jamison Sandstone" and the top of the Moroak Sandstone shows an unusual feature: the upper two horizons have more relief of short wave-length than the lowest horizon.

Four geological explanations are attempted; none of them are verified either affirmatively or negatively.

The first model is a wrench-style "flower fault" model (PetNTcw4797). If there are wrench faults in the area, and if they are interpreted as non-faulted structure according to the working model, then the interpretation would present more variation on the upper horizon than the lower.

The second model is based on the regional thinning of the Kyalla Formation to the east (PetNTcw4796). When strata with a regional thinning is mildly folded, the upper horizon forms an anticline, or a series of synclines and anticlines, while the lower horizon results in a mere change of gradient.

The third model focuses attention on the nature of the Near Top "Jamison Sandstone" Seismic Marker (PetNTcw4798). If the sand in the lower "Hayfield Mudstone" with which the seismic marker coincides at **Jamison 1** and **Mason 1** is not consistent over the area but intermittent like bar sand, then the interpreted seismic horizon would represent the top of either the bar sand or the massive sand whichever is the highest. This will result in a variable upper horizon.

The fourth model looks at the unconformity at the base of the Jamison Sandstone (PetNTcw4799). If the unconformity surface is originally not flat and it has some relief, it would be more variable than the top of the Moroak Sandstone relief. The top of the "Jamison Sandstone" may reflect this topography.

The fifth and non-geological possibility is that the interpretation is more disturbed by noise on upper horizons than lower horizons. This may be true, particularly because a definite interpretation of the base of "Jamison Sandstone" is difficult.

In the interpretation presented in this report, the Base "Jamison Sandstone" Unconformity has greater variation than the top of the Jamison Sandstone. It seems to support the "Thinning and Fold" model or the "Topography at Unconformity" model rather than the "Wrench" model or the "Bar Sand" model. However, considering the level of the noise, no definite conclusion is drawn at this stage.

The maps show two structural trends: north-south trend dominant in the east half of the area and northwest-southeast trend in the west. This suggests more than one structural episode in the area's history. The timing and sequence of the episodes is yet to be investigated.

The largest structural closure at the Jamison Sandstone level is observed on line MA91-109 about eight kilometres west of **Mason 1**. At the time of writing, the well **Shortland 1** is testing this structure (Torkington and Hibbird, 1992).

REFERENCES

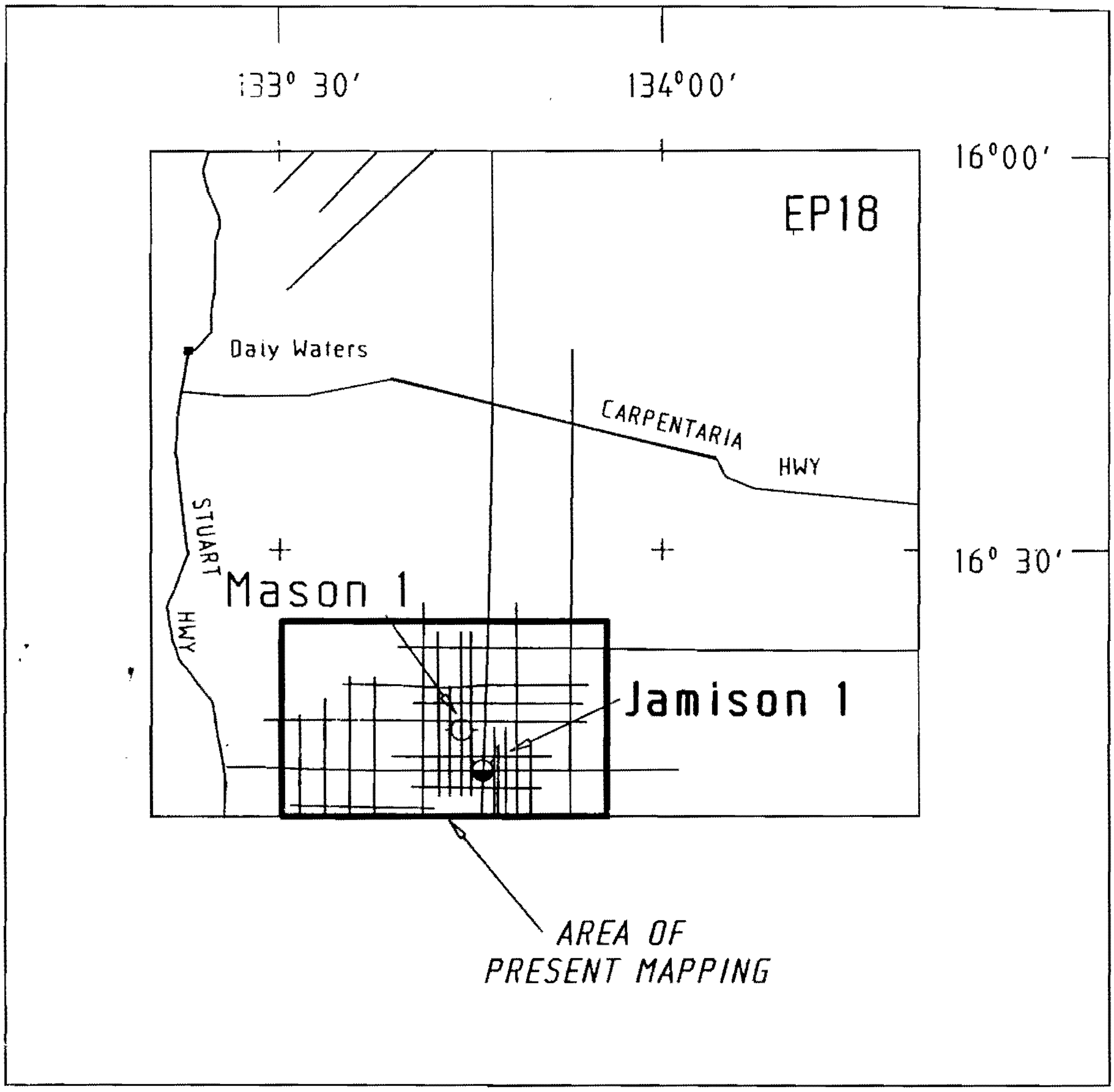
Digital Exploration, (1991)	Data Processing Report 1991 McArthur Seismic Survey , May-November 1991; CRAE Report No. 304453.
Digital Exploration Ltd, (1992)	Reprocessing Report 1992 McArthur Seismic Data, *in prep*.
O'Sullivan F.R., Matthes B. and Tobin S.P.C., (1991)	1990 McArthur Basin Seismic Survey EP24, EP18 Scarlet Hill/EP19 Elsey, Northern Territory, Final Report - Operations; CRAE Report No. 304237.
Robinson, V.A., (1992)	McArthur Basin Velocity Study, EP18; CRAE Report No. 304543.
Simon-Horizon Australia, (1991)	Seismic Data Processing Report, 1990 Scarlet Hill Seismic Survey; CRAE Report No. 304429.
Suto, K., (1991)	Interpretation of 1991 McArthur Seismic Survey Data, EP18; CRAE Report No. 304521.
Torkington, J. and Hibbird S., (1992)	Well Proposal **Shortland 1** EP18, McArthur Project Area; CRAE Report No. 304685.
Western Geophysical, (1991)	Field Operation Report, 1991 McArthur Seismic Survey for Pacific Oil & Gas Pty Limited; CRAE Report No. 304461.

KEYWORDS

Seismic survey, onshore, vibroseis, McArthur Basin, Beetaloo sub-Basin, petroleum, Proterozoic, Precambrian, **Jamison 1**, **Mason 1,** Geophysics, Northern Territory, Data Processing, Geophysical Interpretation.

LOCALITY

Tanumbirini : SE53-2



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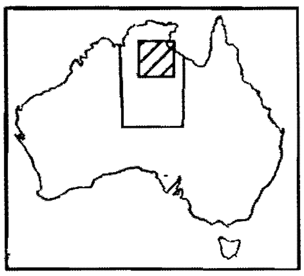
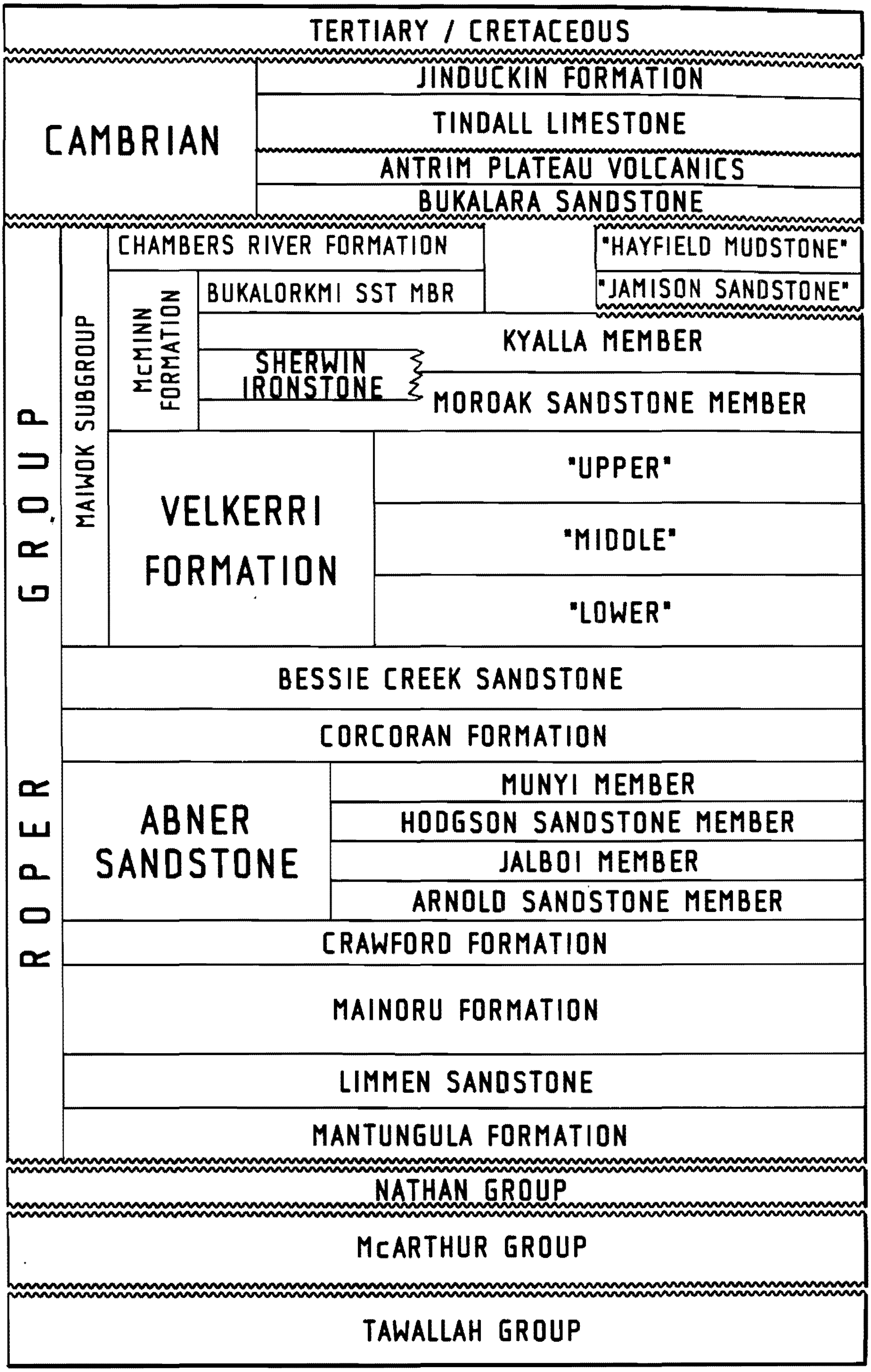
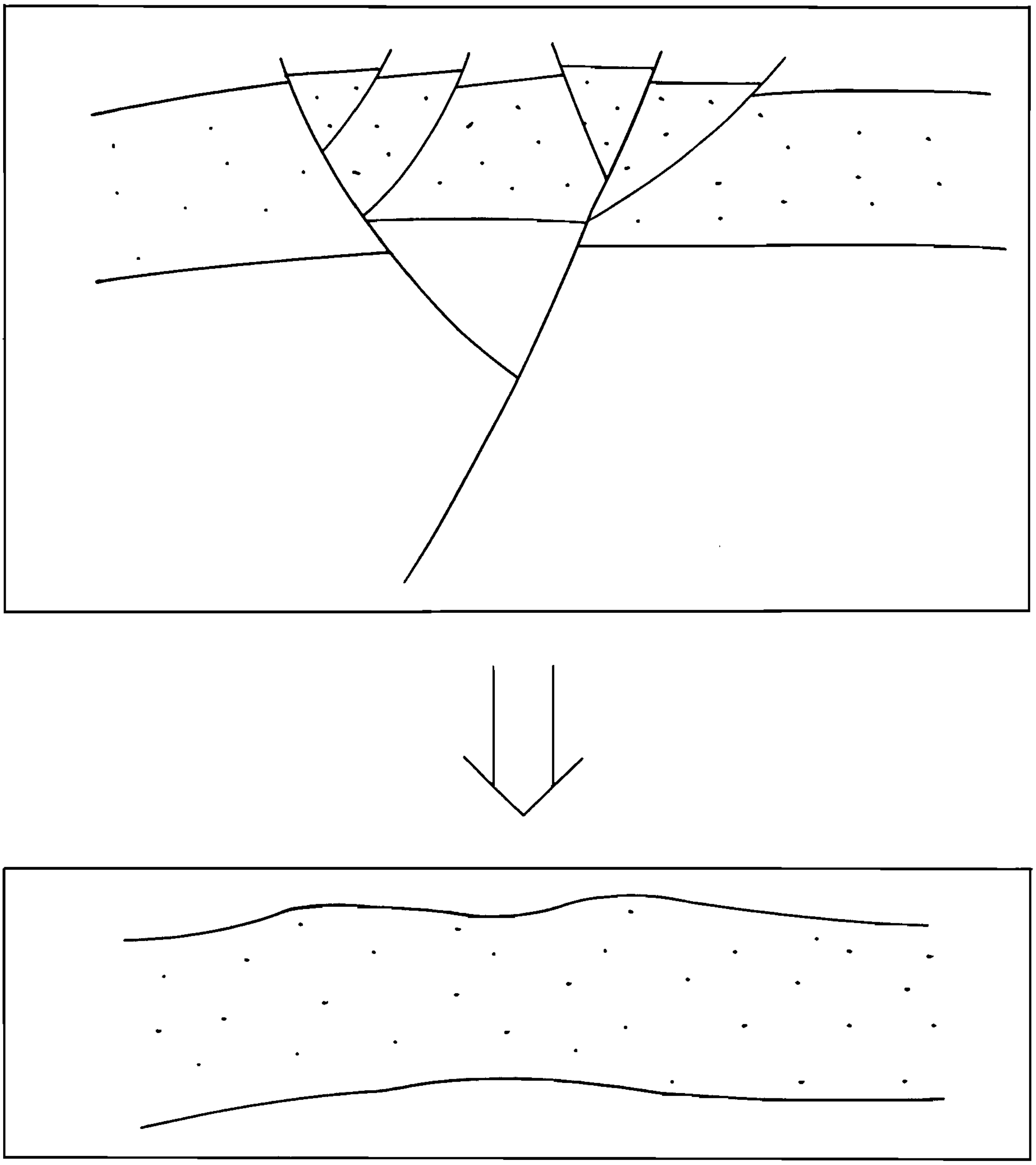


Pacific Oil & Gas Pty Limited			
McARTHUR BASIN *EP 18* *LOCATION PLAN*			
REF.	SE 53	DRAFTING	M.C.
SCALE	1 : 1 000 000	CHECKED	K.S.
AUTHOR	K.S.	REPORT	304629
DATE	NOV 92	PLAN No.	PetNTcw 4809

ROPER GROUP STRATIGRAPHY



AMENDED JULY '92
PetNTcw 4588



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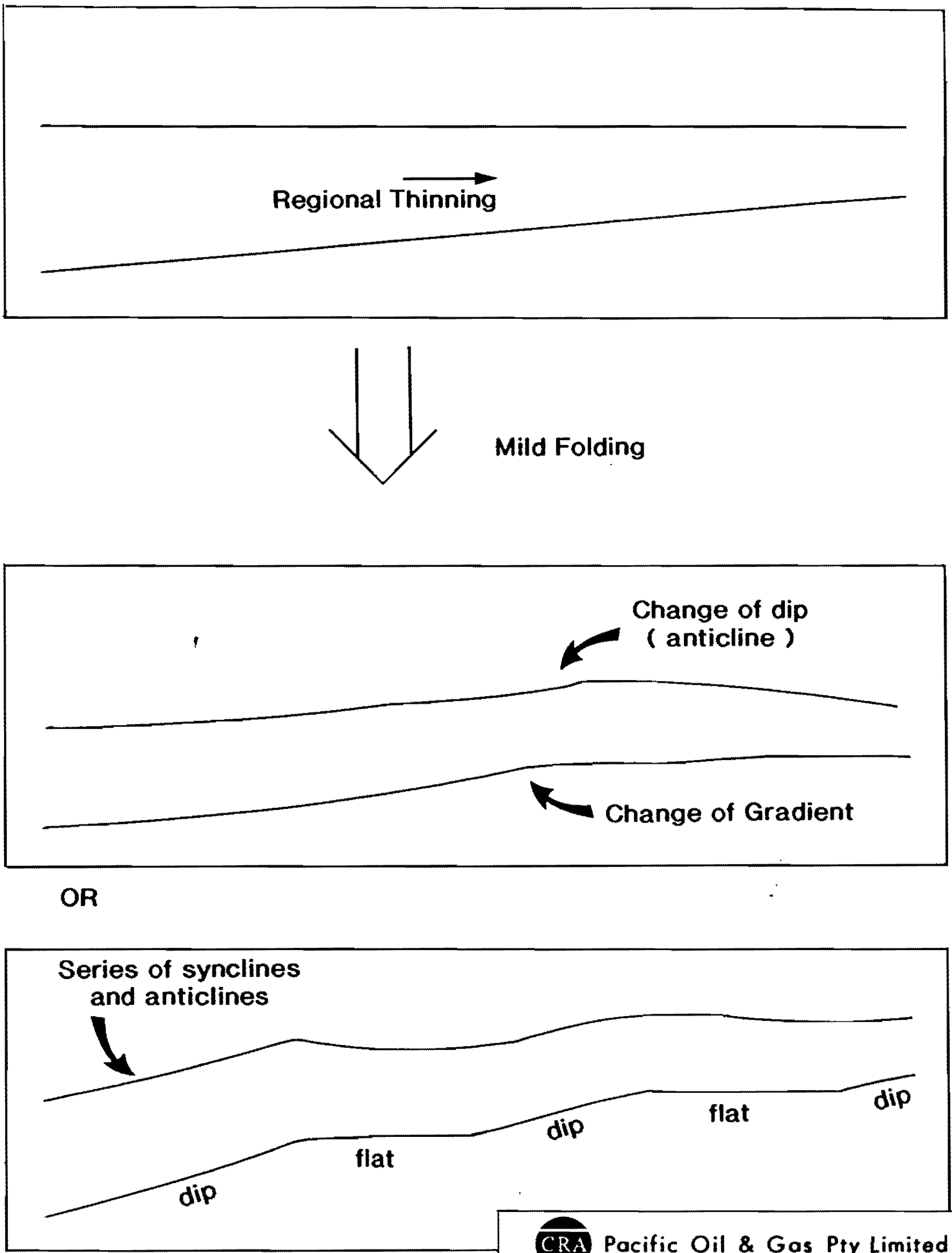
WRENCH MODEL

REF.			
SCALE	N/A	DRAFTING	M.C.
AUTHOR	K.S.	REPORT	
DATE	Nov. 1992	PLAN No	PetNTcw4797

If a wrench fault is present and not interpreted as a fault, the upper horizon appears to have more relief than the lower.

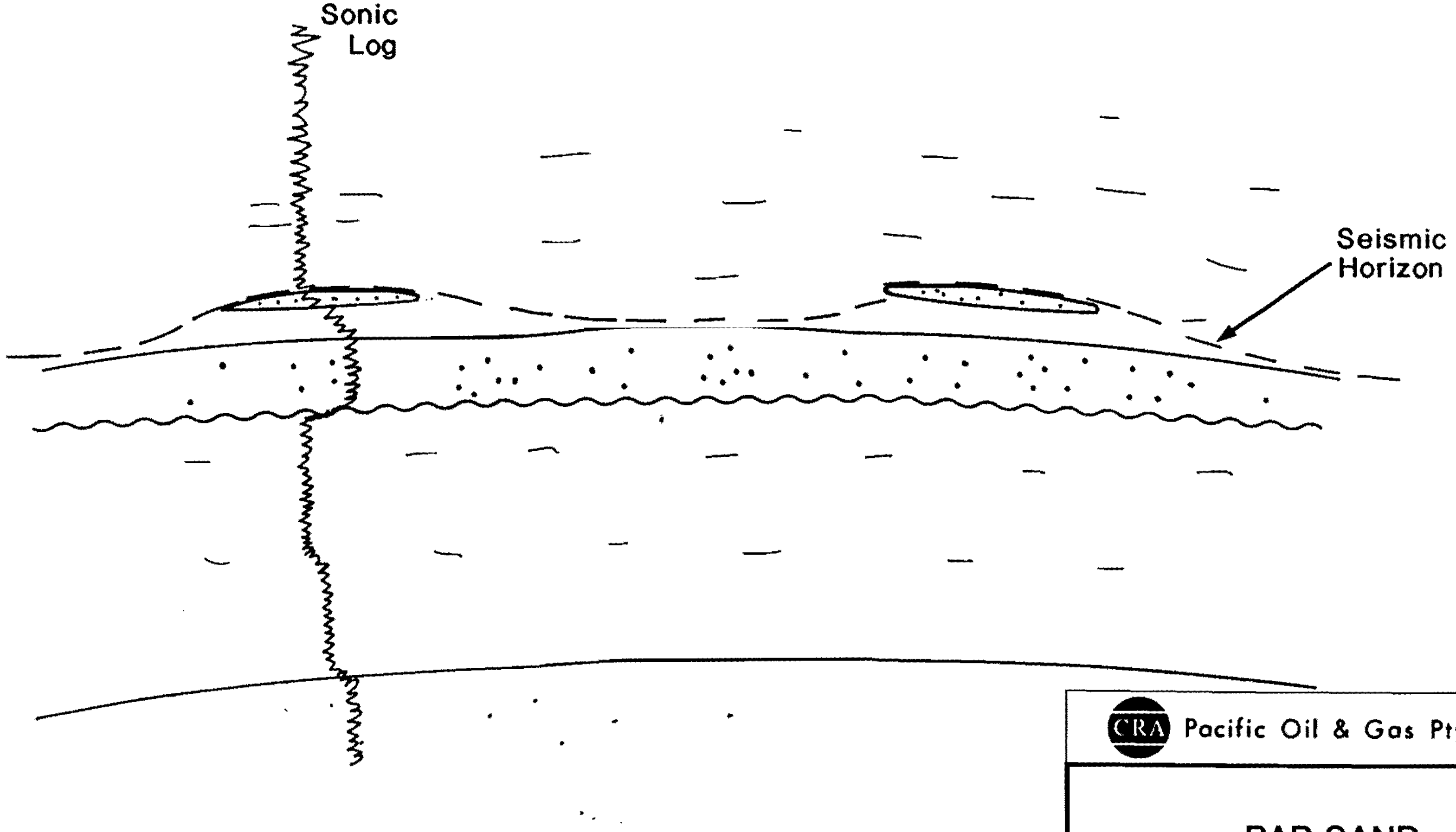


CRA Pacific Oil & Gas Pty Limited

THINNING and FOLD MODEL

REF.			
SCALE	N/A	DRAFTING	M.C.
AUTHOR	K.S.	REPORT	304629
DATE	Nov. 1992	PLAN No	PetNTcw4796

When strata with a regional thinning are folded, the upper horizon presents a series of synclines and anticlines while the lower horizon merely change its dip.



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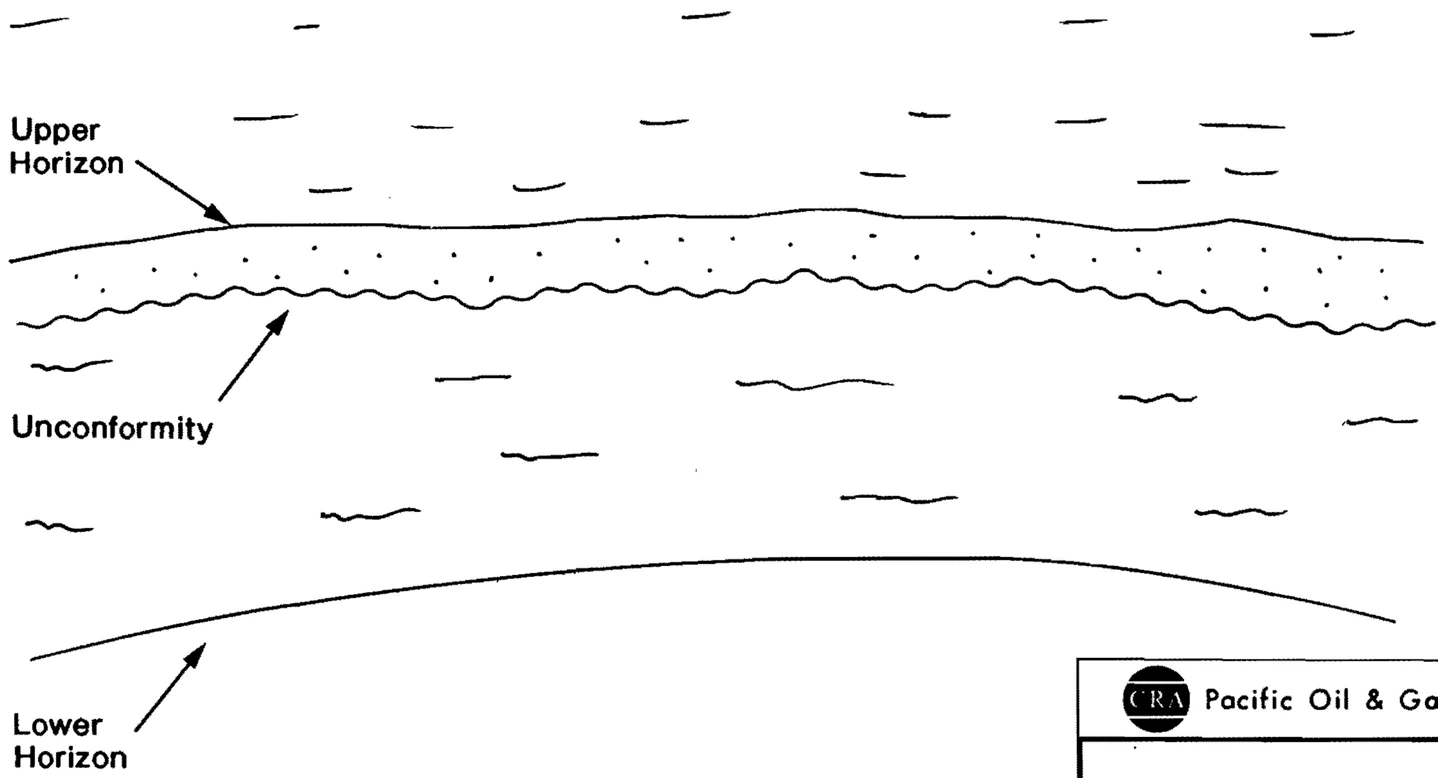
BAR SAND MODEL

REF.			
SCALE	N/A	DRAFTING	M.C.
AUTHOR	K.S.	REPORT	304629
DATE	Nov. 1992	PLAN No	PetNTcw4798

If the sand represented by the seismic marker is intermittent, the seismic marker will follow an inconstant boundary.



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TOPOGRAPHY at UNCONFORMITY MODEL

REF.			
SCALE	N/A	DRAFTING	M.C.
AUTHOR	K.S.	REPORT	
DATE	Nov. 1992	PLAN No	PetNTcw4799

The unconformity surface may have a high-frequency variation.