Northern Territory Government

InfoCentre

NT Minerals and Energy

Petroleum Exploration Reports

This file contains scanned images of hardcopy reports/data submitted to the Northern Territory Government under Petroleum Legislation.

Bringing Forward Discovery

This information is made available to assist future petroleum explorers and may be distributed freely.

Scanning information

The quality of the scan reflects the condition of the original hardcopy report/data.

InfoCentre

Call:	+61 8 8999 6443
Click:	geoscience.info@nt.gov.au www.minerals.nt.gov.au
Visit:	3rd floor Centrepoint Building Smith Street Mall Darwin Northern Territory 0800

A REVIEW OF SEISMIC DATA PROCESSING
AND ACQUISITION PARAMETERS
IN THE AMADEUS BASIN

by

R. Prefontaine & P. Griffiths

November, 1984

TABLE OF CONTENTS

INTRODUCTION

This report outlines Pancontinental Petroleum Limited's current thinking on the seismic data acquisition and processing problems experienced to date, principally in the highly structured and poor data quality areas in the OP 178 permit of the Amadeus Basin. The report discusses aspects of acquisition and/or processing of the conventional 1981 Undandita (48 channel), and the 1984 Glen Edith (120 channel) seismic surveys and draws comparisons between these and the 1024 channel sign bit recording conducted over one line U-4 of the Undandita prospect in 1982.

Seismic data quality in the Amadeus Basin ranges from excellent to poor. After examining and attempting to interprete all of the data in the OP 175/178 operating areas, two general observations should be noted:

- where beds are reasonably flat or synclinal, the data quality is good to excellent.
- where there are steep dips and outcrops or near surface subcrops, the seismic data is normally poor to very poor and in most cases not interpretable.

In this early stage of exploration in the Amadeus Basin, stratigraphy has yet to be adequately defined and initially, at least until stratigraphic trapping mechanisms can be sorted out and recognised, structural highs should be drilled.

Unfortunately, the bad seismic data areas are of economic interest as these areas are usually the prospective structural high zones where hydrocarbons can be trapped.

Most of the seismic data shot to date in the Amadeus Basin can be considered reconnaissance data suitable for defining leads and prospects. The next rounds of seismic in the OP 175/178 areas should be designed to detail the best leads and mature prospects for drilling.

Probable causes of the deterioration of seismic in these bad data areas are examined first. This is followed by a discussion of acquisition parameters designed to fine tune and focus this data. Processing parameters used to enhance the data are outlined next. Finally, some general conclusions and recommendations are made.

WHY DO WE HAVE BAD SEISMIC DATA AREAS?

From our work done to date it is probable that a number of contributing factors are responsible for the deterioration of seismic data quality in the Amadeus Basin. These include complex compression folding and faulting resulting in near vertical or overturned beds which can cause ray path scattering, a variable weathering and subweathering that leads to static problems, very high laterally varying velocities, and rocky outcrops which can cause poor coupling of vibrators. Further, acquisition and to a lesser extent processing parameters have not been finely tuned enough to solve these data problems. Although near vertical beds will never be seen and ray paths scattered through complex geology will never be retrieved using present seismic technology, we believe seismic data quality deterioration due to weathering, velocities, steep dips and in some cases, complex structuring can be minimized providing we can recognize and design seismic surveys to rectify the problems.

In the introduction, two observations of the seismic data quality in the Amadeus Basin were made, ie:-

- when beds are reasonably flat or synclinal, the data quality is good to excellent.
- when there are steep dips and outcrops or near surface subcrops, the seismic data is normally poor to very poor.

The probable reasons for this deterioration in the data quality can be seen by referring to the simple eroded anticline model shown in figure 1. The erosional remnants of the dipping beds and subsequent preferential erosion has left a sawtooth shaped weathering layer. These rapid variations of the weathering thickness will cause rapid static fluctuations which unless accurately resolved will be a major contributor to the deterioration of seismic data in the bad data zones. Where beds

Simple Fold Model Showing 'Sawtooth' Weathering Around Erosional Remnants Due to Preferential Erosion

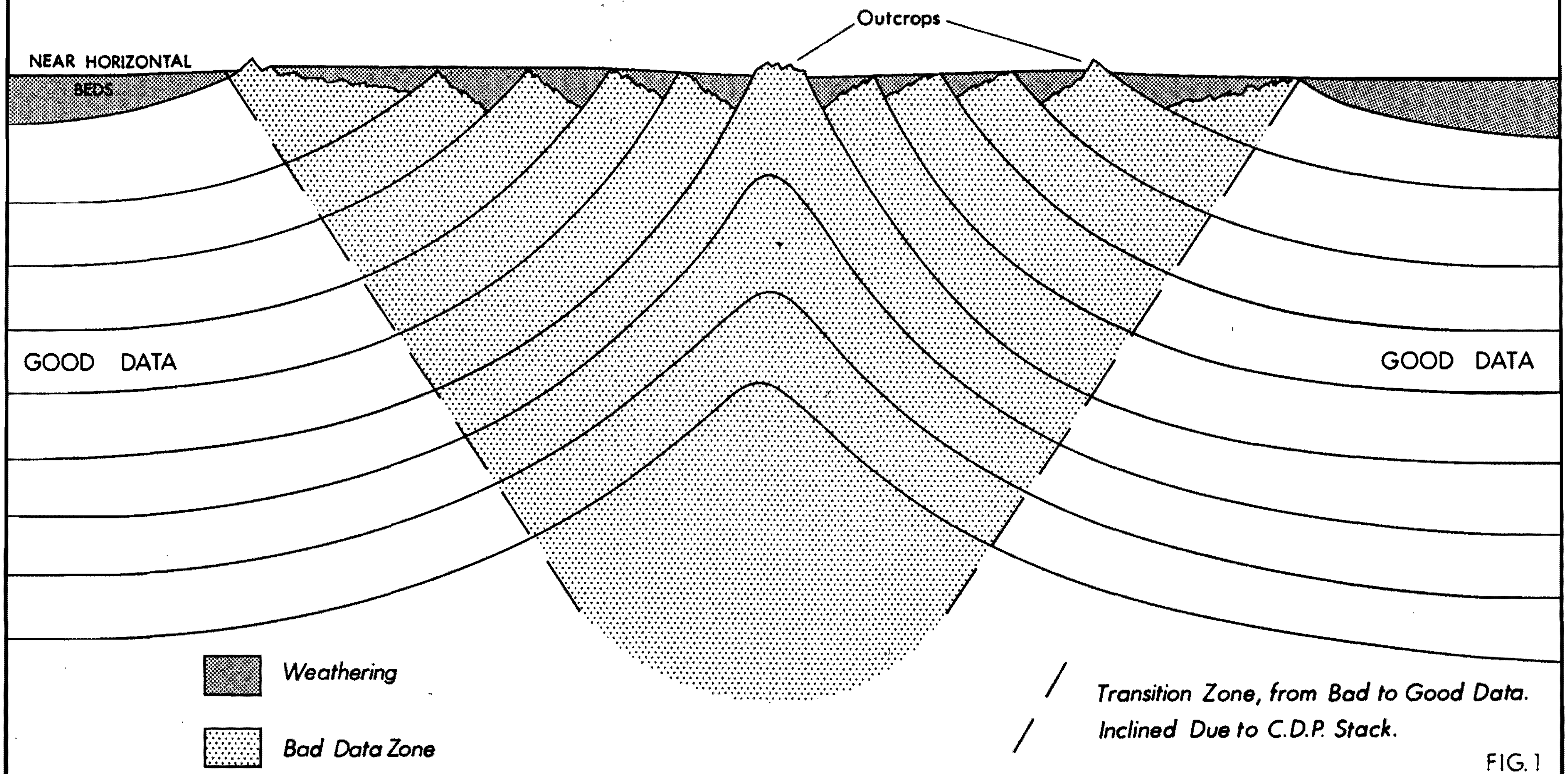


FIG. 1

are near horizontal or have a low angle dip, the weathering layer is more uniform and the static solution is more readily attainable. Hence the data quality is reasonable.

This sawtooth weathered pattern can be seen clearly on the 1024 channel Undandita seismic line U4A; a line that was reshot over a bad data segment of the conventional line U4. Figure 2 shows a migrated version of this line where a 5:1 decimation of the data has reduced the depth point interval (trace spacing) from 2.5 metres to 12.5 metres. Figure 3 shows the same portion of the 1981 line with a 25 metre depth point interval. The superior resolution of the shallow data using the 1024 channel system is obvious. The shallowest events between 70 and 200 milliseconds are thought to be the base or near the base of the weathering. On the 1981 line, neither the weathered layer nor the shallower reflectors above 0.8 seconds are really evident. Furthermore the shallow steeper dips (of the order of 30 degrees - 50 degrees) can be clearly seen on the 1024 channel decimated section.

In addition to better resolving the static problem, there are other contributing factors that allow the 1024 channel system to "see" the weathered layer and steeper dips.

(1) Spatial Sample:-

Initially the 1024 channel data had a CDP sampling interval of 2.5 metres but the decimation process increased this to 12.5 metres. However this is still half the sample interval of the 1981 data. Therefore, aliasing of steeply dipping beds due to horizontal sampling is reduced on the 1024 channel line. By processing all of the 1024 channels, a horizontal sampling interval of 2.5 metres further reduces alaising of the dipping reflectors.

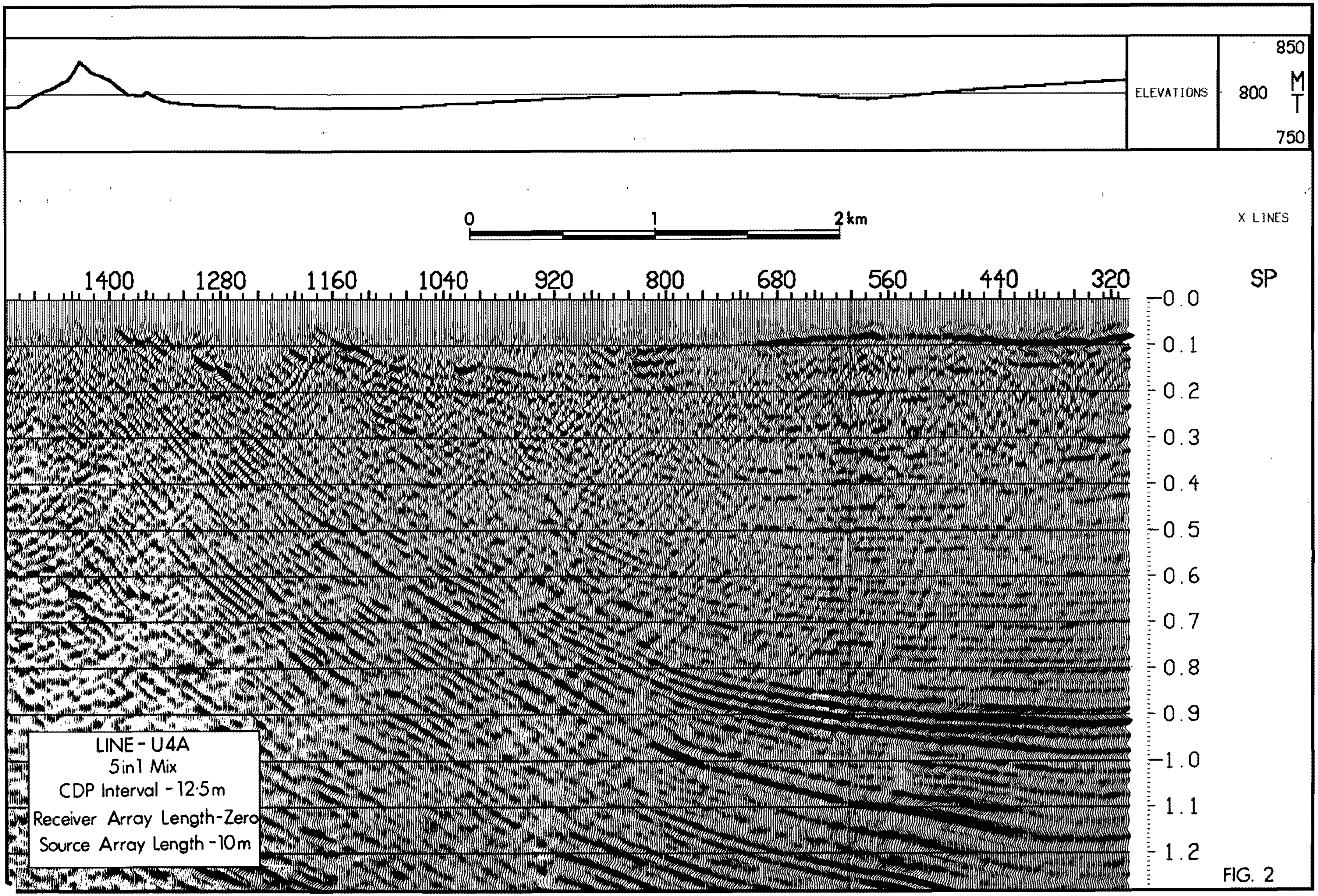
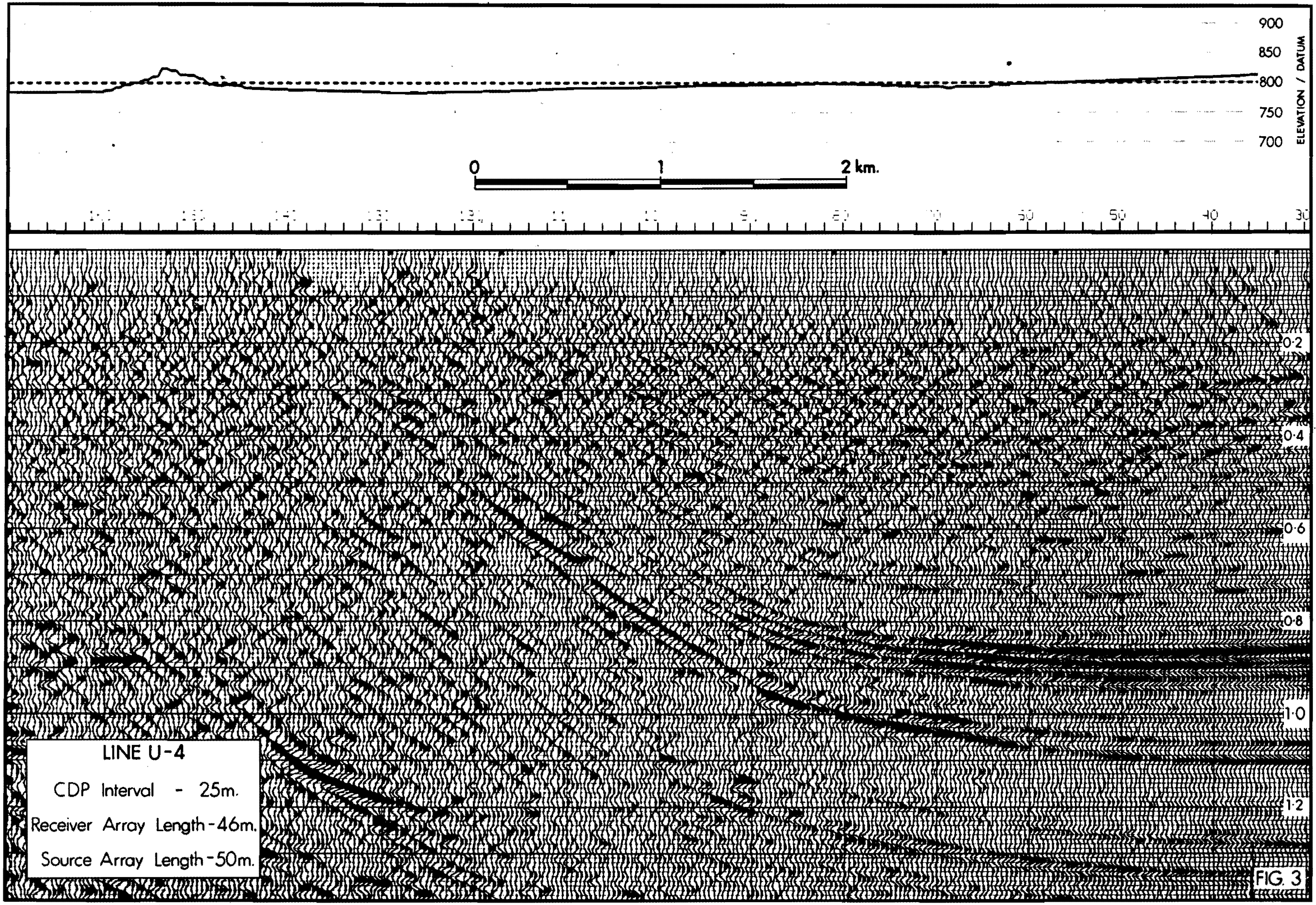

850
800
750
M
T
ELEVATIONS
0
1
2 km
X LINES
SP
1400
1280
1160
1040
920
800
680
560
440
320
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
LINE - U4A
5in1 Mix
CDP Interval - 12·5m
Receiver Array Length-Zero
Source Array Length -10m

FIG. 2


900
850
800
750
700
ELEVATION / DATUM
0
1
2 km.
0·2
0·4
0·6
0·8
1·0
1·2
LINE U-4
CDP Interval - 25m.
Receiver Array Length - 46m.
Source Array Length - 50m.
FIG. 3

(2) Minimising the offset:-

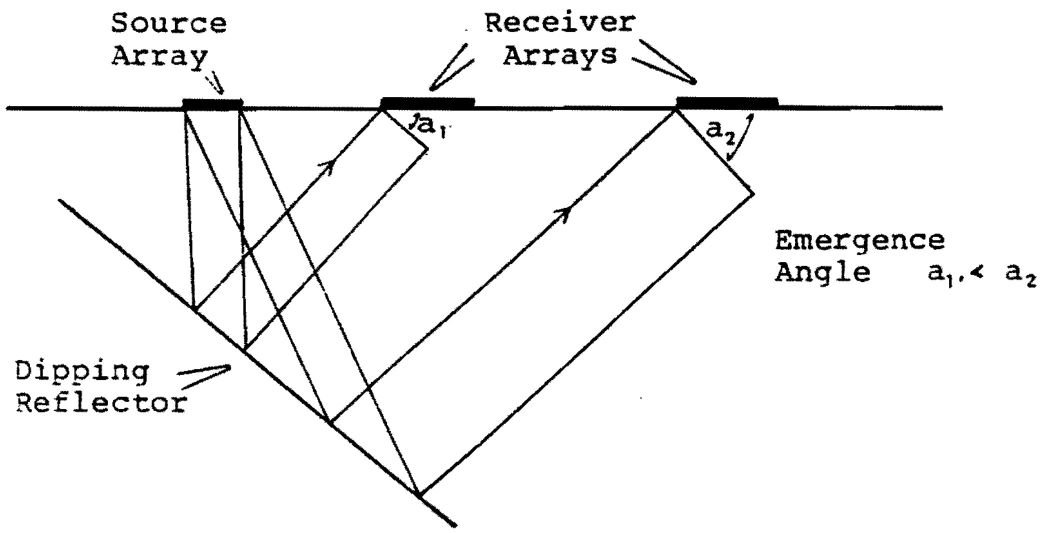
The 1981 data was recorded with a minimum offset of 175 metres compared to a "zero" offset for the 1024 channel data and thus the conventional recording missed the shallowest data. Being able to see the base (or near to the base) of the weathering obviously enables one to better understand the nature of the weathering (and hence the nature of the static problem) and also enables there to be a closer quality control of the static correction routines.

(3) Source and Receiver array lengths:-

The 1981 conventional survey used a 46 metre receiver array length and a 50 metre source array length whilst the 1024 channel system minimized the source length to approximately 10 - 15 metres and clumped the geophone arrays. Thus the data was shot with approximately point source and receivers. Longer source and receiver arrays, although normally beneficial in most areas to minimise low velocity, low frequency near surface noise (ground roll etc.), introduces problems in areas of steep dips and a rapidly varying weathering layer. The long receiver arrays can adversely affect the reflected energy from steeply dipping beds especially when one half of the split spread is recording data in a down dip sense. Both the amplitude and frequency content can be seriously reduced; ie, the array "smears" the reflected energy. Similarily, wavefronts will be grossly distorted by sawtooth weathering. This causes an intra-array statics problem which can not be resolved across a conventional array. Figure 4 illustrates this smearing when the seismic data is shot downdip. As figure 4 clearly shows, increasing source and receiver array lengths will increase smearing especially of the shallower data.

Also there will possibly be greater data degradation on the furthest offsets as the emergence angle (a) increases.

FIGURE 4



A point source - point receiver array will be unaffected by "sawtooth weathering". Furthermore there will be no smearing of energy reflected from steeply dipping beds even when the data is shot in a down dip sense. However, a point source-point receiver will allow all of the low velocity, low frequency surface noise to be recorded, and the more recent practise has been to filter out some of the ground roll with small arrays up to 10 metres in length. The array length would be decided through field experimentation.

Moving onto the latest 120 channel, 1983 Glen Edith Survey, PPL see parallels between the data quality problems experienced in 1981 over Undandita and this survey. Figure 5 shows a migrated section of line GE-46 which illustrates good data deteriorating to bad data as the dips increase. Although the CDP interval is 10 metres (group interval is 20 metres), which is less than that for the decimated 1024 channel section (Figure 3), the minimum offsets were 110 to 130 metres and the source and receiver arrays were 58 metres and 66 metres respectively. It is now felt that the statics problem has not been sufficiently resolved, that the shallowest data has been missed and that the long arrays have unsolvable intra array statics and have smeared the data

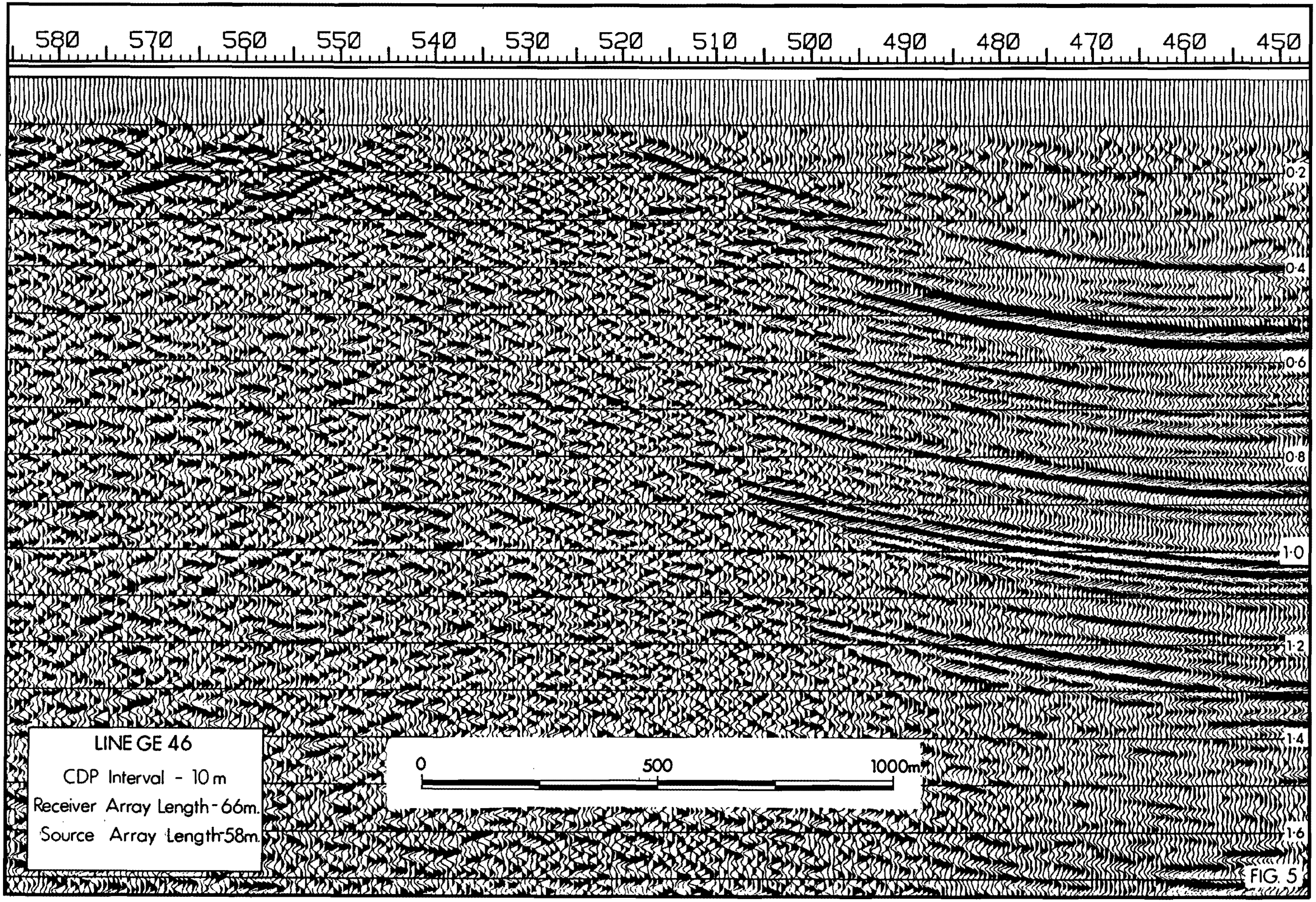

580 570 560 550 540 530 520 510 500 490 480 470 460 450
0·2
0·4
0·6
0·8
1·0
1·2
1·4
1·6
LINE GE 46
CDP Interval - 10 m
Receiver Array Length - 66m.
Source Array Length-58m.
0
500
1000m

FIG. 5

FUTURE SEISMIC ACQUISITION AND PROCESSING

Regarding acquisition parameters and methods for future seismic surveys in the Amadeus Basin, it is obvious that PPL must make some changes. As outlined earlier, the bad data areas suffer from problems detrimental to acquiring good seismic data. However, now that the major contributing factors for the poor data have been recognized, acquisition parameters can be fine tuned enough to minimize the negative results of these factors on our seismic data.

For all future seismic shooting in the Amadeus Basin the following rules should apply:-

1. the spread should be designed such that group interval is minimized while spread length maximized.

2. both group and source array lengths should be minimized.

3. calibration of static profiles using upholes must be done in the Basin.

These points are elaborated on as follows:-

1. Shortening the group interval reduces alaising of the steeply dipping beds and therefore the seismic can "see" steeper dips. Also, there is an increase in redundancy for the statistical static computation methods.

   A longer spread (to the limit where the far traces just record some reflective energy), increases moveout which results in the possibility a more definitive velocity analysis than a smaller moveout from a shorter spread. This is especially important where the seismic velocities are high as in the Amadeus Basin.

2. Minimizing the group and source array lengths minimizes smearing of steeply dipping beds and the effect of sawtooth weathering on intra-array statics problems. The increase surface noise not filtered by traditional array lengths can be filtered out in the processing centre using F-K filters or by computer array simulation (beam stearing). These were not used on line U-4 and the latter in particular may be of great benefit.

3. Due to the hardness of the shallow Tertiary (silcrete) and/or Pertnjara sandstones below the weathered layer, drilling the required minimum 20 metres into the sub-weathering rock to obtain valid uphole information is slow and eats bits. For this reason, upholes are expensive in this region and therefore the location of each uphole should be carefully selected. It may be possible to select uphole locations based on initial brute stacks and in that way efficiently sample the extremes in weathering.

With these rules in mind, there are two alternative methods of shooting seismic; ie, conventional and 1000 channel+ systems.

By using a 1000+ channel (full word or sign-bit) recording system, split spread with short source and receiver array lengths (say 10 metres) and 5 metre group intervals will give a maximum offset of approximately 2,500 metres. All the criteria required to minimize the steep dip and sawtooth weathering problems have been met.

An attractive feature of this method is that stacked sections can be done in the field. Some advantages can be gained from this. One is that since often the base of weathering can seem on these sections, upholes can be more optimumly placed. Another advantage not easily capitalized on in the Amadeus Basin due to the CLC, is that the layout of the survey could change to close off anomalies as more information is gained.

To maximise the fold within the bad data areas and minimise migration edge effects, the line length on each side of the bad data areas should be at least a spread and half long (3.7 kilometres in the case of a 1024 channel system).

Since processing and acquisition costs increase with the number of VP's, consider the following table for a 1024 channel system which is based on a price quote from Horizon of $25/record. The processes included in this price are:-

- array simulation or alternatively F-K filtering
- deconvolution before stack
- 3:1 or 4:1 trace decimation to give a 10-15 metre depth point interval.
- residual statics passes
- velocity analysis
- wave equation migration
- scaling, DAS, films

TABLE 1

VP Interval	Fold	Cost/km to Process
5m	512	$5,000
10m	256	$2,500
20m	128	$1,250
40m	64	$ 625
80m	32	$ 312

Line U4A was originally processed 128 fold using a 20 metre V.P. interval and a 2.5 metre depth point interval at a cost per kilometre of $1,250.

PPL believes that a 40 metre V.P. interval giving 64 fold will be sufficient. However, field experimentation should be done to determine these parameters.

The other alternative would be to record using a conventional 120 channel system in a single sweep mode. To achieve the same minimum CDP spacing of 2.5 metres and spread length as the 1024 channel system, the group spacing should be 40 metres and the source spacing must be single sweeps every 5 metres over a 40 metre interval giving 60 fold CDP coverage.

When deciding on which recording mode to use it is important to compare their effectiveness in terms of energy output and operational efficiency. Table 2 compares the Total Sweep Time (number of sweeps x sweep length) or vibrator effort per

- VP
- kilometre
- C.D.P.

for the 120 channel single sweep mode and the 1024 channel system. For this comparison 12 second sweeps are used. In the single sweep mode, 8 sweeps are required every 5 metres over a 40 metre interval. The 1024 channel system would sum the 8 sweeps at the one location every 40 metres. Also shown are the 1983 survey recording parameters. Thus from the Table it can be seen that for approximately the same fold, the vibrator effort per kilometre is the same for the two modes, however, the vibrator effort per CDP (ie per trace on a seismic section) is approximately eight times less in the single sweep mode. As we are looking at a low S:N area, this reduction in energy input in the single sweep mode for approximately the same field effort and hence cost is cause for concern. In other words, to ensure the best data quality, an 8 fold increase in field effort and a subsequent rise in acquisition costs using the single sweep mode would occur. Even if a 10 metre, 512 channel system was more desirable the single sweep mode would still require a 4 fold increase in field effort.

It appears obvious by examining table 2 that by using a 1000+ channel system we will get more energy per V.P.; with a small depth point interval and long offsets as required to minimize alaising of steeply dipping bed and still input sufficient energy per CDP.

TABLE 2

System	Fold	Group Interval	VP Interval	Sweep Configurations (12 sec sweeps)	TST/VP (sec)	TST/KM (sec)	TST/CDP (sec)	DP Interval	Records/ km
120 channel (single sweep)	60	40	5	8 x (1 x 12) single	12	2400	720	2.5m	25
1024 channel	64	5	40	8 x 12 sum	96	2400	6144	2.5m	25
120 channel conventional 1983 Parameters	20	20	80	12 x 16 sum	192	2400	3840	10.0m	12.5

TST = Sweep length x number of sweeps

TST/VP = Total sweep time per vibrating point in seconds

TST/CDP = Fold x TST/VP

TST/KM = Number of V.P.'s/KM x TST/VP

DP Int. = Depth Point Interval

CURRENT PROCESSING OF THE GLEN EDITH SURVEY

With any seismic processing task there are two main factors which can enhance or hurt the data; namely statics and velocities. If these are done correctly, about 90% of the job is done. Other processing parameters such as deconvolution operators, scaling, frequency filters etc. will not be discussed here except to say that although these parameters are important they will not be a main contributing factor to "make or break" the data.

(1) Statics:

To ensure meaningful static calibrations (ie. check low frequency static computation), upholes should be done at least at intersections and end points. These upholes must be tied in to check the "front end" surface consistant refraction statics computed by this processing contractor (whether they are hand or automatically picked). Furthermore, residual static passes before each velocity analysis should resolve 'high frequency' static adjustments.

For processing the 1983 Glen Edith surveys, an automatic first breaks picking routine was used to calculate the static corrections. Although individual records in the bad data areas showed some primary energy, stacked records lacked coherent events suggesting a poor stack. The prime causes of a bad stack in this area are thought to be poor statics and/or velocities.

To try to improve the stack the bad data part of one line:- line GE 46 S.P. 430-1080 (called line GE-S46), were isolated and reprocessed using different statics and velocities. Surface consistent statics were carefully calculated by hand as opposed to the previous automatic routine. Subsequent prudent velocity analysis and migration led to little improvement.

Two passes of automatic residual statics computation were made before each velocity analysis. It appears that the poor stack may have been caused by the application of the residual statics routine.

In areas of complex geology, problems occur when automatic residual statics are applied. These problems can be so severe that the static computed as applied to the data can destroy the stack. The processing of our latest 1983 survey used a residual static method which iterates automatically and makes separate estimations of residual normal movement and dip.

The minimum requirement for residual statics programmes is that the dip of the reflectors within the data window is reasonably well defined and that the NMO or stacking velocities are approximately correct. Thus the seismic section has some degree of reflection continuity. In the poor data areas in question, reflection continuity is almost non existent. Obviously the minimum requirements cannot easily be met.

This poor reflector continuity can make the data so noisy as to appear random. Tests have shown that applying automatic residual statics on random data without inputting a dip model produces a random residual static correction. Residual static runs on the same random data with a dip model applied will produce a static correction which can produce events that mirror the input models.

It appears that since the initial residual statics on the 1983 data were run without a dip model, a random residual static could have been applied.

One solution attempted previously was to input a dip model supplied by the client. the problem with this approach as mentioned above is that the dip model must be correct, otherwise apparent coherent events which are not real are produced. There are several instances on older vintage Amadeus seismic where the apparent dip on seismic is contrary to the true dip as indicated by surface mapping. Introduction of these pseudo events, which have been enhanced by coherency filtering has made interpretation difficult, confusing and often frustrating. Since the dip model is normally interpretative in the bad data areas, there is a good chance that the resultant static applied can create pseudo events that mirror the interpretation and not the real structure.

Instead of using a dip model of the whole section for residual statics computation, a model designed within a window of less structured portions of the seismic section with some potential for real coherent events can be used. This could be, for example, a window below the lowest glide plane where most of the complicated structuring has occurred above this plane.

In the case of the Glen Edith area, the structuring of the beds below the Base Cambrian unconformity appear much less complicated than the beds above. Therefore, the window for the residual static computation for the test line GE-S46 was outlined between the Base Cambrian unconformity and basement. Iterative residual statics computations were done. The latest attempt using this approach has resulted in only minor improvement.

(2) Velocities:

Since velocities are very high and can vary dramatically, not only from area to area, but even along traverses in the Basin, optimum stacking velocity computation has been extremely difficult to date. In order to rationalise velocity picking after the initial pass, an interpretation of the brute stacks was attempted such that random dips were not stacked. This approach had only moderate success as an interpretation in the bad data areas is obviously difficult.

(3) Independent processing of each side of the Spread:

The majority of data has been processed using the full spread. Recently an attempt was made to process the front spread and back spread independently such that the data would be processed in an up-dip and down-dip sense. It was thought that the data shot in an up-dip and sense would be less affected by array orientated problems as has been discussed previously.

In general, there were only minor improvements seen. On the "front spread" section, the shallow data down to 500 milliseconds, which was shot in an up-dip sense was definitely superior to the "back spread" section and to a lesser extent the "full spread" section though overall definition of this and the deeper data is still very vague.

(4) Other Ideas:

To date, PPL has and limited success in improving the poor data zones. We are currently relooking at the latest residual statics application and will study the residual statics profile for any low frequency trend which may suggest a weathering pattern (e.g. the sawtooth pattern). The field datum statics profile does not show any real variation over the poor data zone. If there is a trend we will apply this trend to the field statics and re-run residual statics. If this approach shows any promise we will then attempt to iteratively update the velocity/residual statics estimations as follows.

Firstly velocities based on previous data, or preliminary velocity analysis should be applied before the first residual statics run.

After the first residual statics adjustment has been applied, velocity analysis at CDP's specified by the client should be done using constant velocity stacks. Following this analysis, a second residual static pass should be applied. At the same common depth points where the first velocity analysis were done the next step is to run a second velocity analysis using a more sophisticated velocity scan approach.

For these analyses the central velocity function should be the stacking velocity curve calculated from the CVS's (ie. the central curve will vary across the section). Theoretically, using a programme like GSI's VELSCAN, this should give the optimum stacking velocity. However, no processor in this country currently has the ability to dynamically change the central velocity function for velocity scans across a section without a lot of manual input. Only a simple software modification is required since the intital CVS's are digitized. We will request this approach be used in the future and to be successful in their bid for the job the processor must make the modification. Digicon at PPL's suggestion have now made this modification to their velocity analysis package.

Migration velocities can then be calculated from the smoothed second velocity analysis results. Migration before stack is also an option but is prohibitively expensive.

Before summing up acquisition and processing one more item in regard to processing should be brought up. Most of the seismic data processed to date with the exception of the 1983 shooting has been coherency filtered. This is a very common process, frequently recommended by processors and often useful to help define gross structural configurations on regional type data. However, applying a coherency filter to seismic data may do more harm than good. It removes subtle lateral seismic character changes which could indicate facies changes or small faults. Also, within bad data areas, a coherency filter tends to introduce unreal 'wormy' events which do not have anything to do with primary reflections or normal seismic noise. Lastly, as well as enhancing primary events, coherency filters can also enhance coherent noise. Since most of our future seismic work will be detailing programmes, coherency filtered sections will not be done.

CONCLUSION AND RECOMMENDATIONS

The probable causes of the deterioration of seismic data quality within the bad data zones in the Amadeus Basin are:-

1. complex geology which results in steep dips and ray path scattering.

2. "sawtooth" weathering causing static problems.

3. highly laterally varying rock velocities which makes velocity computation difficult.

4. rocky outcrops which can cause poor coupling of vibrators.

Ray paths scattered through complex geology cannot be retrieved but problems with statics, velocities and alaising due to steep dips can be minimized through careful planning of seismic acquisition and processing parameters designed to address these problems. Poor coupling of vibrators can be reduced by possibly reducing the drive level.

For seismic acquisition in the Amadeus Basin the following rules should apply:-

1. the group interval should be minimized with the spread length maximized.

2. both group and source array lengths should be minimized.

3. upholes should be done at least at every intersection and ends of lines. If it is possible to map the weathering in the field (due to field processing), then upholes should be placed such that all of the weathering extremes are sampled.

We suggest the following field parameters (subject to experimentation) for the next rounds of seismic in the Basin:-

- source vibroseis
- 1000+ or 500+ channel recording system (full word or sign bit recording)
- far offset : 2500 metres
- near offset : less than 30 metres
- group interval : 5 metres or 10 metres
- VP interval : 40 metres
- source array length: as small as is practical
- receiver array length : 10 metres

Note that a field trip must be made before going to tender on this job once the line layout is finalized. This field trip should check for the usual surface problems detrimental to seismic field acquisition and determine whether or not a 10 metre source for vibrators can be approximated (i.e. vibrators bunched two abreast).

As well as the usual processing parameters, to enhance the data the following points should be observed:-

- F-K filter or array simulation before stack to minimize low frequency near surface noise and improve reflection continuity and S:N.

- upholes must be tied in to calibrate the front end surface consistant refraction statics computed by the processing contractor. Alternatively, upholes alone may be the only valid method of obtaining field statics in light of the suspected "sawtooth" weathering pattern and hence rapidly varying refracters.

- careful applications of residual statics is a necessity. If the data is poor use a window on least structured beds to determine residual statics on each section. The window must be determined from brutes and must be checked and changed (if necessary) after each pass of residual statics/velocity analysis.

- at least two velocity analyses should be done during processing; the first using CVS's. For the second velocity analysis, velocity scans should be run with the central velocity function being the stacking velocities calculated from the CVS's.

- a coherency filter should not be applied to the data.

Drawing from present day seismic technology we believe these recommendations represent the optimum seismic acquisition and processing parameters for the Amadeus Basin.

As a final comment, PPL recognises that these areas are immensely complex. At the present time we are applying 2-D techniques to solve a 3-D problem. Once we have (hopefully) defined the seismic pulse sufficiently, the only real way to resolve these overthrust regions in the Amadeus will be with 3-D seismic (most probably after an initial good oil flow !!).