Investigation of advanced seismic processing techniques; improving the resolution of near surface seismic data derived from deep crustal reflection seismic surveys.

By
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EXECUTIVE SUMMARY:

- Most of the seismic data collected by ANSIR is designed to image the deep crust and therefore requires long recording times. The purpose of this study was to investigate the possibility of reprocessing the first few seconds of these data, with the aim of improving the imaging of near surface geological features.

- Seismic line 99AGSY4 was chosen for this purpose. Located with the Eastern Goldfields province of Western Australia, the line intersects a deformed Archaean sedimentary succession. It was anticipated reprocessing will improve the resolution of the succession.

- Initial reprocessing, involving standard processing techniques, improved the resolution within the top 500 ms of the line. This was achieved by re-picking of the mutes.

- Advanced processing techniques, involving dip moveout processing and frequency-wavenumber filtering were investigated, but did not improve the expected improved resolution of the data.

- Pre-stack migration was found to have the largest effect on improving the quality of the data, and in changing the nature and characteristic of many of the reflectors. However, this was only a preliminary study and it is not clear if some of the changes are artefacts of the processing technique, or reflect geological reality.

- Further work in pre-stack migration and pre-stack depth migration is suggested as a means of clarifying these issues and further improving the data.

- Until this is achieved it is suggested that care be taken in interpreting the nature of the sedimentary units within the sedimentary succession.

INTRODUCTION:

An extensive 2D reflection seismic survey of the Kalgoorlie area of the Eastern Goldfields region of Western Australia was undertaken by the Australian Geodynamics Cooperative Research Centre (AGCRC) during 1999. The survey focussed on the delineation of the main structural elements of the region, aiding in the development of a 3D gold systems model.

The geology of the area imaged is Archaean in age, consisting of a sequence of 4-km thick basal ultramafic to mafic lavas and sills, overlain by a 1.5 km-thick felsic volcaniclastic sedimentary unit known locally as the Black Flag Group (BFG). The terrane has experienced granite intrusion, been metamorphosed to upper greenschist-lower amphibolite facies, and has been polydeformed and gold mineralised.

Seismic data were acquired using an ARAM24 seismic system, creating 16 second records, equivalent to approximately 50 km depth. The seismic data were processed using standard “hard rock” processing streams involving front end muting, amplitude balancing, spectral equalisation, frequency filtering, normal move-out correction, stacking and migration.

The purpose of this study was to use advanced seismic processing techniques to try and improve the top few seconds of the seismic record by reprocessing the first few seconds of the 16 second reflection seismic data.
**Fig. 1.** Location map of seismic line 99AGSY4, in Western Australia’s Archaean Yilgarn Craton. The section of line 99AGSY4 reprocessed by this study is highlighted in orange. The location of other seismic traverses within close proximity to 99AGSY4 are also shown.
DATA SELECTION:

Line 99AGSY4 (Fig. 1) was selected for reprocessing as it was anticipated that reprocessing may improving the resolution of the BFG sedimentary basin within the top two seconds of the line. Rather than reprocess the entire line, a 25 km segment of the line, between shot points 456 and 1102, was selected. Unprocessed data were transferred from SEGY tape to disk for processing. Data were initially processed to 3000 ms, however this was increased to 4000 ms after analysis of the reprocessed data indicated that it would be beneficial to do so.

INITIAL REPROCESSING

Initial reprocessing of line 99AGSY4 involved the application of standard seismic processing techniques to the raw seismic data files acquired during the survey, using the Disco-Focus processing program. Details of the seismic processing techniques utilised are provided below, and derivations from the 16 s processing of line 99AGSY4 are highlighted and discussed.

Geometry

Variation in the geometry of the defined CDP line results in variation in travel time between source and receivers at different locations of the survey. It is therefore necessary during seismic processing to consider the parameters governing variation in CDP line geometry. These parameters include line, the coordinates and elevation of each of the geophone stations. Pattern, which station is sequenced to which channel for a given shot; and source, the shot number, vibroseis location and pattern number. All of these parameters are defined in the Geometry module of the Focus program and stored within a database. The PROFILE module is used to assign geometry information from the seismic line to the seismic trace headers.

CDP line geometry parameters defined for initial 16 s processing of line 99AGSY4 were checked, and adopted for use in reprocessing the data.

Data Resampling

Resampling of seismic data allows the sampling frequency to be altered, changing the amount of data required for further processing, depending on the operators preference. The RESAMP module is used to specify resample rates within the Disco-Focus program.

During acquisition of seismic data for line 99AGSY4 the data were recorded at a sampling rate of 2 ms. For reprocessing of the line the seismic data were decimated and resampled to 4 ms, reducing the processing time.

First Breaks Picking

First breaks, also know as first arrivals, are the first onset in the seismic record of energy received from the seismic source. Any seismic activity recorded prior to first breaks is considered noise. It is essential that the first breaks are picked accurately for each of the seismic records, allowing the correlation of reflectors between each of the geophone group arrays. First breaks are picked interactively using the Focus program, which displays seismic records onscreen, facilitating the picking of first breaks. It is not however necessary to pick
the first breaks for every shot. The Focus module includes a Neural Network First Break Picking (FBNET) application, which can pick the first breaks and interpolate between shots. It is recommended that the results of FBNET are checked visually by the operator to remove any anomalies.

The first break picks undertaken during initial processing of line 99AGSY4 were examined and considered satisfactory for the purpose of reprocessing. However, as an exercise in familiarisation of seismic processing techniques, first breaks were picked by the operator for part of line 99AGSY4, but not incorporated in the new reprocessed job stream.

**Refractor Velocity Model**

A velocity model was constructed from the first arrival offset overlay, using the First Break Solutions tool from the Focus menu. The velocity model provides basic velocity information for the weathering layer and the refractor, allowing the calculation of refraction statics.

A velocity of 1700 m/s was determined for the near surface weathering layer, in agreement with the weathering velocity interpreted during initial processing of the line. During reprocessing, a velocity of 6150 m/s was determined for the refractor at the base of the weathering layer, which is a slightly faster velocity than determined during initial processing ($v = 5500$ m/s).

**Refraction Statics**

Refraction statics are used to correct for travel time variations due to near-surface effects. Within the Disco-Focus program, the REFSOL module is used for calculating refraction static solutions, considered as both long and short wavelength components. The primary control of the long wavelength component is line geometry and the velocity of the refractor, whereas the short wavelength component is primarily controlled by near-surface weathering and elevation effects. The REFSOL module models these effects and computes short and long period refraction statics from first arrival times.

The determination of a new refractor velocity of 6150 m/s from the refractor velocity modelling necessitated the calculation of new refraction statics for the reprocessed data. The consequence of which was a slight shift in the refraction statics, resulting in a slight decrease in reflector depth. In real terms this does not equate to a significant difference between the initial and reprocessed data.

**Automatic statics**

Another method of calculating refraction statics involves the use of a stack power optimization algorithm which automatically corrects for near-surface travel time variations. The algorithm is designed to correlated peaks from different traces within specified gates / time domains, once a normal moveout (NMO) correction has been applied. This method of statics correction is known as automatic statics, and is achieved by using the STATIC R module of the Disco-Focus program.

Automatic statics were applied during the reprocessing of line 99AGSY4, however no significant improvement was achieved in comparison to the refraction statics calculated...
from the REFSOL module. Because of this, refraction statics calculated from the REFSOL module were used for all further processing.

Muting
Muting removes unwanted noise from the seismic record by reducing the amplitude of the negative and positive peaks of a seismic trace to zero for a given time window. Muting is commonly used to remove noise such as first breaks and ground roll from the seismic record. The Disco-Focus program allows for muting to be applied to the data in different ways. Front or tail end muting can be picked manually in the interactive Focus mode, which then interpolates muting between picks. Alternatively, stretch muting can be applied after a NMO correction/stretch. Stretch muting uses a specified velocity function to calculate mute times for varying offsets.

Variation in the degree and type of muting applied to the seismic data produced significant differences in the quality of the near surface reflection data, especially within the first 300 ms. Stretch muting was found to be too severe, muting desired reflection data within the first 300 ms. Specifying less severe stretch mute parameters resulted in the proliferation of high amplitude reflections within the first 100 ms, most likely due to undesired ground roll.

Careful interactive mute picking was found to produce the best results in imaging reflectors in the upper most domain of the seismic record. The new mute picks produced greater resolution in the first 500 ms, relative to the mute picks from the initial 16 s processing of line 99AGSY4.

Velocity analysis
Prior to initiating seismic processing techniques such as NMO and Migration it is necessary to produce a velocity model for the seismic section. The Disco-Focus program has several means of velocity analysis and modelling. The VELEX module performs a series of NMO corrections to CDP gathers using velocity functions specified by the operator in the DEFINE velocity definition module. Displays are produced, allowing the operator to pick velocities equating to the best alignment of peaks within the seismic traces. The specified velocities are then used to produce a velocity model. Another means of velocity analysis within the Disco-Focus program is the Constant Velocity Analysis (CVA) module. Constant Velocity Analysis applies NMO corrections of varying specified velocities to the seismic profile, producing varying displays of the line. From these displays velocity analysis is assessed visually and velocities picked for construction of the velocity model.

Using the VELEX module velocities were picked and a new velocity model was constructed for line 99AGSY4. The model (VELY4V1), modelled velocity variations within the data to a much greater precision than the model initially used for the processing of the line (veldefn). During velocity modelling it was noted that the ideal velocity picks for 99AGSY4 required a large velocity inversion of approximately 1200 m/s at approximately 1700 ms two-way time. Other smaller velocity inversions were also required at other locations on the line. Unfortunately the Disco-Focus program does not allow large velocity inversions to be incorporated in velocity modelling, necessitating smoothing of the new velocity model. After an iterative smoothing process the new velocity model was accepted by the Disco-Focus program, but was considered redundant as it no longer reflected the
variation observed from the velocity analysis. For this reason it was decided to use the initial velocity model (VELDEFN), for NMO and migration purposes. Later during the pre-stack migration process 13 velocity models were constructed and tested using the VELEX and CVA modules. The results of the different velocity models will be discussed in the advanced processing section below.

**Normal moveout correction**

The normal moveout (NMO) correction is applied to seismic data to correct for the variation in reflection arrival times at different geophone groups due to the variable offset between source and receivers along the line. Because the difference in reflection arrival time is a function of both geophone offset and velocity of the rock it is necessary to specify a velocity model during the NMO correction process.

As discussed above in the velocity analysis section, various velocity models were constructed and trialled during seismic processing. The velocity model developed during initial processing of the line (VELDEFN), was considered adequate for applying the NMO correction to the data.

**Common-midpoint data stacking**

If multi-channel data are collected during a seismic survey the signal to noise ratio within a single seismic trace can be greatly enhanced by summing, or “stacking” an ensemble of common midpoint traces. Different stacking methods can be utilised using the Disco-Focus program. The STACK module sums trace ensembles, whereas the MEDSTK module provides median stacking of the data.

During re-processing of line 99AGSY4 both median and normal stacking of the data was tested. Normal stacking was arbitrarily chosen as the default method for stacking the seismic section, because neither technique generated a relative improvement in data compared to the other technique.

**Filtering**

Filters are designed to alter data within specified time-space domains of the seismic section. Filters can be designed to pass or reject data, and often involve a tapering function to reduce the edge effect at the margin of the spatial extent of the filter. Basic filters can be constructed within the FILTER module of the Disco-Focus program.

A tapered Bandpass filter was used for reprocessing line 99AGSY4. Data below a frequency of 20 Hz was rejected, as was data above 90 Hz.

**Data enhancement**

Several modules of the Disco-Focus program are designed to enhance the visualisation and continuity of the seismic data, allowing for greater ease in interpreting reflectors and structures.

DIGISTK is a signal enhancement module designed to enhance coherent reflectors within a given region, improving the alignment of peaks and continuity of reflectors. Prior to
running the DIGISTK module, the SIGNAL module is used to identify coherent traces within a specified time domain and of a specified dip angle. During reprocessing of line 99AGSY4 the SIGNAL module was used to identify for enhancement reflectors with dip angles between -50 and 50°. The DIGISTK module was run at least once, but usually twice in the processing stream.

Prior to plotting a seismic section it may be desirable to improve the appearance of the section by equalising the relative amplitude of the seismic traces, reducing the contrast between areas of strong and weak amplitude. The BALANCE module is a time-variant equalization scaling module designed for this purpose. Gates can be specified by the operator to enhance specific domains of the seismic section. The TSCALE module is similar to the BALANCE module in that it is designed to enhance the appearance of a seismic section by reducing the contrast between traces of varying amplitude. By selecting the Automatic Gain Control (AGC) function within the TSCALE module a scalar is applied to all traces within a specified gate.

Both TSCALE and BALANCE were tested in enhancing the appearance of the data from line 99AGSY4. The TSCALE AGC function, with 500 ms gate size, was chosen as the preferred method of amplitude balancing during reprocessing.

Migration

The angle of a dipping horizon and velocity variation within a package of rocks causes reflectors to be recorded at different locations at the surface relative to their true subsurface location. Migration is the process of correcting for this offset in the seismic record, imaging the reflectors in their correct subsurface position. The process of migration involves complex inversion calculations and is susceptible to changes in velocity, necessitating a defined velocity model. Various migration options are available in the Disco-Focus program. Post-stack migration can be achieved using the MIGFX module in conjunction with a predefined velocity model.

Line 99AGSY4 was migrated using the MIGFX post-stack migration module. Permutations of four different velocity models, some without velocity inversions, were tested for use in migrating the data. Variations of the MV2Y4 velocity model were found to produce the best results in migrating the line. Migrating at 100 % of the velocity of model MV2Y4 produced large wavefront-shaped events, or smiles, on the migrated section. The smiles are artefacts of inaccurate migration velocities, and were reduced or eliminated by migrating the section at slower velocities. At 50 % of the velocity of model MV2Y4 the migration artefacts were removed from the migrated section (Fig. 2).

RESULTS AFTER INITIAL REPROCESSING:

The main result achieved in reprocessing of line 99AGSY4 was an improvement in data quality within the first 500 ms of the section (Fig. 3). The improvement in data resolution was primarily due to changes in the muting parameters, which removed noise and allowed the interpretation of structures within the first 500 ms of the seismic profile. Some of the newly visible structures align with structures within the Black Flag Beds previously interpreted from surface mapping and magnetics.
Fig. 2a S N CDP
**Fig. 2.** (Pages 10 and 11.) Comparison of different post-stack migration velocities on the appearance of the seismic section 99AGSY4. The BFB sedimentary basin is centred on CDP 3500, and extends to approximately 1500 ms two way time. With a migration velocity 50% of the velocity model, Figure 2a has less “smiles,” or migration artefacts than Figure 2b, which was migrated at 75% of the velocity model. Areas of poor migration are highlighted by the green ellipses in Figure 2b.

**Fig. 3.** (Pages 13 and 14.) Comparison of the first 1000 ms of line 99AGSY4 both before (Fig. 3a) and after reprocessing (Fig. 3b). Reprocessing has clarified structures within the first 500 ms of the line, as highlighted by the green ellipse in Figure 3b. Some of the reflectors, as highlighted by the red lines in Figure 3b, are more continuous in the reprocessed section and align with the location of faults in the BFB which were identified by surface mapping and magnetics, represented by the red vertical bars on the CDP line.
Fig. 3b
ADVANCED PROCESSING TECHNIQUES:

After initial reprocessing of line 99AGSY4 it was apparent that additional work was required to further enhance the seismic data to create a marked improvement relative to the original 16 s processing. Advance seismic processing techniques which are not routinely used by ANSIR during the processing of deep crustal reflection data were examined for this purpose. Details of the techniques and their effect on the reprocessed data are discussed below.

*Dip moveout processing*

If a reflector is horizontal, the common-midpoint method of reflection seismic surveying results in multiple receiver stations imaging a common reflection point, allowing the stacking of traces and an improved signal to noise ratio. However if the reflector is dipping, there is no longer a common reflection point and common-midpoint stacking will produce reflection point smear, resulting in imperfect stacking. The problem of reflection point smear can be corrected for by dip moveout (DMO) processing, which corrects reflection point smear by creating apparent common-reflection-point gathers, applying a convolution and performing a NMO correction which is not dependent on the dip angle.

The Disco-Focus module CMPDMO was utilised to apply common-midpoint dip moveout corrections to the reprocessed data from line 99AGSY4. Despite the existence of 45° dipping reflectors within the seismic data, DMO processing did not result in significant improvements of the seismic section relative to seismic sections which had not been corrected for DMO. This result precluded DMO processing during further attempts to refine the data.

*Frequency-wavenumber filtering*

It is possible that reflectors of varying dip will produce reflections of varying frequency and wavenumber. It is therefore possible to design a frequency-wavenumber (f-k) filter which will accentuate traces of specific frequency and wavenumber and enhancing the corresponding reflectors of specified dip.

Frequency-wavenumber analysis of line 99AGSY4 was undertaken using the Disco-Focus module FKANYLZ. Areas of near horizontal and high-angle dip were visually identified from the seismic plots and their time location domains noted for f-k analysis. The FKANYLZ module was utilised to produce displays of the specified f-k domains. Interpretation of the f-k analysis plots indicated that there was a subtle difference in the f-k domains of flat and dipping reflectors from 99AGSY4, allowing the application of f-k filtering. Tapered Hanning pass f-k filters were built using the FKBUILD module, and were applied to the seismic job stream using the module FKAPPLY.

Frequency-wavenumber filtering did not improve the data as expected. When applied to the entire section, all f-k information other than that specified by the f-k filter was rejected, resulting in a constant dip throughout the seismic section, to the deficit of all other structural information. Furthermore, varying the f-k filter to accentuate either low or high-angle dip structures resulted in only slight variation in the seismic sections produced. When applied to small distinct domains of the seismic section, the f-k filter produced the same result of constant dip, but to a limited spatial extent. The study of f-k analysis and filtering on line 99AGSY4 highlights the point that reflectors produce reflections that are the result of the
complex interaction of different frequencies. Trying to filter the frequency and wavenumber resulted in a seismic section of false seismic information.

**Pre-stack migration**

As discussed above in the Initial Processing section of this report, migration is the process of shifting the location of reflectors on a seismic section to the location which represents their correct subsurface position. Post-stack migration was undertaken during the initial processing stage of this study. Pre-stack migration, or true migration before stacking (TMBS) was investigated as a means of further improving the quality of the seismic data, and is not a standard ANSIR processing technique. Rather than migrating the stacked seismic data, TMBS migrates groups of common offset gathers prior to stacking of the data.

The Disco-Focus module MIGTX was used to perform pre-stack migration of the data from line 99AGSY4. Prior to running MIGTX the NMO correction was removed, VSTACK was used to vertically sum the seismic traces, and a common offset range of 40 CDP gathers was specified for migration. After migration mutes were reapplied, the NMO correction was applied and the data were stacked. A copy of the Disco-Focus job stream used for pre-stack migration is provided in Appendix 1.

Pre-stack migration is extremely susceptible to variations in the velocity model. Using both discrete velocity analysis and constant velocity analysis 13 velocity models were constructed for the purpose of improving the pre-stack migration of the data. The processing of pre-stack migration requires data velocity models be applied to four processes; to apply and then remove NMO corrections, to perform pre-stack migration, and then to reapply the NMO correction. The velocity model used for pre-stack migration was constructed to best approximate the actual velocity of the rocks being imaged, taking into account the slow velocity associated with the weathering zone, with the model increasing from 4500 m/s at 100 ms to 6700 m/s at 3000 ms.

After many iterations and experiments, pre-stack migration provided noticeable improvement in the quality of the seismic section relative to post-stack migration. In some areas, such as the northern margin of the BFB basin, one or two strong reflectors were resolved from what was previously a group of reflectors, and the dip angle of the reflectors was steepened (Fig. 4). Smiles or artefacts within the data were reduced, the detachment surface was better resolved, and the dip of the basal reflectors within the BFB were altered (Fig. 5).

Pre-stack migration has resulted in significant changes in the data relative to post-stack migration, however the computer intensive nature of the technique resulted in only a preliminary investigation of pre-stack migration by this study. Running a single pre-stack migration job of the limited shot range of line 99AGSY4 investigated by this study required approximately 9 hours of processing time. Running a pre-stack migration job of the entire line would take much longer. Also, creating the processing job is much more labour intensive than for pre-stack migration as all of the offsets have to be specified manually. Further iterations are necessary to fully test the benefits of pre-stack migration on the data from this study.
Fig. 4. (Pages 17 and 18.) Comparison of post-stack migration (Fig. 4a) with pre-stack migration (Fig. 4b) of line 99AGSY4. Pre-stack migration has steepened and better resolved the reflectors at the northern margin of the BFB sedimentary basin, as highlighted by the green ellipses in Figure 4.

Fig. 5. (Pages 20 and 21.) Enlarged view of the BFB sedimentary basin imaged by line 99AGSY4. Figure 5a shows the basin migrated post-stacking, whereas Figure 5b shows pre-stack migration. The basal reflectors within the basin are flatter within the pre-stack section (green ellipse; Fig. 5b) relative to the post-stack section (Fig. 5a). These sections highlight the variation in reflector characteristics that can be achieved by different seismic processing techniques, and the care that should be taken when making geological interpretations.
IMPLICATIONS FOR GEOLOGICAL INTERPRETATION:

Seismic reprocessing of line 99AGSY4, and in particular application of pre-stack migration has changed the characteristics of some of the reflectors relative to initial processing of the line. This in turn has implications for enhancing the geological interpretation of the area, specifically the internal geometry of the sedimentary packages within the BFB basin. However, because pre-stack migration was not investigated to the degree that further iterations would not improve the data quality, it is not clear if the reduction in amplitude of the lower basal reflectors of the BFB sediments (Fig. 5b) is an artefact of the pre-stack migration technique, or equates to actual fine-scale geological variations. Because of this uncertainty it is suggested that care be taken when making geological interpretations of the internal sedimentary packages within the BFB sedimentary basin.

CONCLUSIONS / RECOMMEDATIONS:

Reprocessing of seismic line 99AGSY4 has resulted in several changes in the nature of the reflectors within the seismic section relative to the initially processed section. Data quality has been improved within the top 500 ms of the line, and pre-stack migration has changed the characteristics of some of the reflectors.

Other processing techniques, including dip moveout processing and frequency-wavenumber filtering were investigated as a means of improving the resolution of the seismic section, however no noticeable improvements in reflector quality were achieved.

Pre-stack migration has improved the data within some areas of line 99AGSY4, and created uncertainties in others. It is suggested that further work in refining the pre-stack migration of the data would help resolve these issues, and potentially be of great value in elucidating the nature and characteristics of the reflectors within the BFB sequence or some similar deformed sedimentary package. Once this has been achieved, pre-stack depth migration should also be investigated as a tool for improving the data. Until these migration issues are resolved, a degree of uncertainty should be considered when interpreting the nature of the sedimentary packages within the BFB sedimentary basin.
APPENDIX I:

```
*JOB L150 99AGSY4
*CALL IN 4000
SRCHTR /d/seismic/11/land/land_seis/L150/99agsy4_new/*
FILNAM (ieee)/d/seismic/11/land/land_seis/L150/99agsy4_new/..data2/99agsy4/sortcdp_4s.dsk
CATNAM sortcdp_4s.dsk
ORDER FILE
RANGE 4337 2669 1 1
** ---------------------------
*CALL PROFILE 20 999
** ---------------------------
*CALL PROFILE                 20      999
** ---------------------------
*CALL RESAMP 4
*if range soffset -4800 4800
** ---------------------------
call balance cdp chan 1 240
gates 1
800 3900 800 3900
800 3900 800 3900
*CALL EDIT shot rec-stat
ALL OMIT 462
*CALL EDIT shot rec-stat
ALL OMIT 463
*CALL EDIT shot rec-stat
ALL OMIT 983
** ---------------------------
*CALL HEADPUT fbsh-lst
ATTRI shot refsoly4LSTATICS shot NOINTERP
*CALL HEADPUT fbst-lst
ATTRI rec-statrefsoly4LSTATICS station NOINTERP
*CALL HEADPUT fbsh-rst
ATTRI shot refsoly4RSTATICS shot NOINTERP
*CALL HEADPUT fbst-rst
ATTRI rec-statrefsoly4RSTATICS station NOINTERP
** ---------------------------
*CALL STATIC MULTI
fbsh-lstAPPLY
fbst-lstAPPLY
fbsh-rstAPPLY
fbst-rstAPPLY
** ---------------------------
*CALL HEADPUT SHT-STR STORE FLOAT
ATTRI SHOT stry44 SHOT SHOT NOINTERP
*CALL HEADPUT REC-STR STORE FLOAT
ATTRI REC-STATstry44 REC REC STATION NOINTERP
*CALL STATIC MULTI
SHT-STR APPLY
REC-STR APPLY
** ---------------------------
*CALL MUTE SHOT OFFSET 20
ON 456
-4546 476 -3841 452 -3588 408 -1375 276
-140 40 220 40 380 100 1117 244
2996 404 4752 444
ON 466
-4546 476 -3841 452 -3588 408 -1375 276
-140 40 220 40 380 100 1117 244
2996 404 4752 444
ON 476
-4546 476 -4202 444 -3863 372 -3841 452
-3824 368 -3599 348 -3588 408 -3562 348
-3012 348 -1375 276 -140 40 220 40
380 100 1117 244 2996 404 4752 444
ON 486
-4546 476 -4496 408 -4265 396 -4227 400
```
-4620 592 -3578 576 -3499 532 -3498 568
-3458 564 -3418 552 -3018 520 -2059 388
-1139 248 -59 88 9 7 148 695 8
1339 368 2528 500 2565 532 2634 544
2637 508 2656 464 2673 516 2703 544
2738 544 2783 524 2843 552 4468 580
4572 672 4759 632
ON 1066
-4656 524 -2859 456 -1579 360 -260 96
180 100 1860 340 4472 648
ON 1076
-4656 524 -2859 456 -1579 360 -260 96
180 100 1860 340 4472 648
ON 1086
-4656 524 -2859 456 -1579 360 -260 96
180 100 1860 340 4472 648
ON 1096
-4656 524 -2859 456 -1579 360 -260 96
180 100 1860 340 4472 648

** ---------------------------------------------
if range cdp 1 99999
*CALL NMO veldefn
*call scale 1 .5
** ---------------------------------------------
*IF RANGE offset 0 4800
*IF RANGE offset 0 40
*CALL HDRMATH
HCML offset 0 offset
HCADD offset 20 offset
*RESET
*IF RANGE offset 41 80
*CALL HDRMATH
HCML offset 0 offset
HCADD offset 60 offset
*RESET
*IF RANGE offset 81 120
*CALL HDRMATH
HCML offset 0 offset
HCADD offset 100 offset
*RESET
*IF RANGE offset 121 160
*CALL HDRMATH
HCML offset 0 offset
HCADD offset 140 offset
*RESET
*IF RANGE offset 161 200
*CALL HDRMATH
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HCADD offset 180 offset
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*IF RANGE offset 201 240
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*RESET
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*CALL HDRMATH
HCML offset 0 offset
HCADD offset 260 offset
*RESET
*IF RANGE offset 281 320
*CALL HDRMATH
HCML offset 0 offset
HCADD offset 300 offset
*RESET
*IF RANGE offset 321 360

28
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 340 offset
RESET

*IF
RANGE offset 361 400
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 420 offset
RESET

*IF
RANGE offset 401 440
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 460 offset
RESET

*IF
RANGE offset 481 520
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 500 offset
RESET

*IF
RANGE offset 521 560
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 540 offset
RESET

*IF
RANGE offset 561 600
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 580 offset
RESET

*IF
RANGE offset 601 640
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 620 offset
RESET

*IF
RANGE offset 641 680
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 660 offset
RESET

*IF
RANGE offset 681 720
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 700 offset
RESET

*IF
RANGE offset 721 760
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 740 offset
RESET

*IF
RANGE offset 761 800
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 780 offset
RESET

*IF
RANGE offset 801 840
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 820 offset
RESET

*IF
RANGE offset 841 880
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 860 offset
RESET *IF
RANGE offset 881 920
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 900 offset
RESET *IF
RANGE offset 921 960
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 940 offset
RESET *IF
RANGE offset 961 1000
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 980 offset
RESET *IF
RANGE offset 1001 1040
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1020 offset
RESET *IF
RANGE offset 1041 1080
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1060 offset
RESET *IF
RANGE offset 1081 1120
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1100 offset
RESET *IF
RANGE offset 1121 1160
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1140 offset
RESET *IF
RANGE offset 1161 1200
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1180 offset
RESET *IF
RANGE offset 1201 1240
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1220 offset
RESET *IF
RANGE offset 1241 1280
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1260 offset
RESET *IF
RANGE offset 1281 1320
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1300 offset
RESET *IF
RANGE offset 1321 1360
CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1340 offset
RESET
*IF
RANGE offset 1361 1400
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1380 offset
*RESET
*IF
RANGE offset 1401 1440
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1420 offset
*RESET
*IF
RANGE offset 1441 1480
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1460 offset
*RESET
*IF
RANGE offset 1481 1520
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1500 offset
*RESET
*IF
RANGE offset 1521 1560
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1540 offset
*RESET
*IF
RANGE offset 1561 1600
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1580 offset
*RESET
*IF
RANGE offset 1601 1640
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1620 offset
*RESET
*IF
RANGE offset 1641 1680
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1660 offset
*RESET
*IF
RANGE offset 1681 1720
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1700 offset
*RESET
*IF
RANGE offset 1721 1760
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1740 offset
*RESET
*IF
RANGE offset 1761 1800
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1780 offset
*RESET
*IF
RANGE offset 1801 1840
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1820 offset
*RESET
*IF
RANGE offset 1841 1880
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1860 offset
*RESET
*IF
RANGE offset  1881    1920
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  1900    offset
*RESET
*IF
RANGE offset  1921    1960
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  1940    offset
*RESET
*IF
RANGE offset  1961    2000
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  1980    offset
*RESET
*IF
RANGE offset  2001    2040
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2020    offset
*RESET
*IF
RANGE offset  2041    2080
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2060    offset
*RESET
*IF
RANGE offset  2081    2120
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2100    offset
*RESET
*IF
RANGE offset  2121    2160
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2140    offset
*RESET
*IF
RANGE offset  2161    2200
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2180    offset
*RESET
*IF
RANGE offset  2201    2240
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2220    offset
*RESET
*IF
RANGE offset  2241    2280
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2260    offset
*RESET
*IF
RANGE offset  2281    2320
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2300    offset
*RESET
*IF
RANGE offset  2321    2360
*CALL HDRMATH
HCML   offset  0       offset
HCADD offset  2340    offset
*RESET
*IF
RANGE offset  2361    2400
*CALL HDRMATH
HCML   offset  0       offset
HCADD   offset  2380    offset
  *RESET
  *IF
RANGE   offset  2401    2440
  *CALL   HDRMATH
HCADD   offset  2420    offset
  *RESET
  *IF
RANGE   offset  2441    2480
  *CALL   HDRMATH
HCADD   offset  2460    offset
  *RESET
  *IF
RANGE   offset  2481    2520
  *CALL   HDRMATH
HCADD   offset  2500    offset
  *RESET
  *IF
RANGE   offset  2521    2560
  *CALL   HDRMATH
HCADD   offset  2540    offset
  *RESET
  *IF
RANGE   offset  2561    2600
  *CALL   HDRMATH
HCADD   offset  2580    offset
  *RESET
  *IF
RANGE   offset  2601    2640
  *CALL   HDRMATH
HCADD   offset  2620    offset
  *RESET
  *IF
RANGE   offset  2641    2680
  *CALL   HDRMATH
HCADD   offset  2660    offset
  *RESET
  *IF
RANGE   offset  2681    2720
  *CALL   HDRMATH
HCADD   offset  2700    offset
  *RESET
  *IF
RANGE   offset  2721    2760
  *CALL   HDRMATH
HCADD   offset  2740    offset
  *RESET
  *IF
RANGE   offset  2761    2800
  *CALL   HDRMATH
HCADD   offset  1780    offset
  *RESET
  *IF
RANGE   offset  2801    2840
  *CALL   HDRMATH
HCADD   offset  2820    offset
  *RESET
  *IF
RANGE   offset  2841    2880
  *CALL   HDRMATH
HCADD   offset  2860    offset
  *RESET
  *IF
RANGE   offset  2881    2920
  *CALL   HDRMATH
HCMUL offset 0 offset
HCADD offset 2900 offset
*RESET
*IF
RANGE offset 2921 2960
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 2940 offset
*RESET
*IF
RANGE offset 2961 3000
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 2980 offset
*RESET
*IF
RANGE offset 3001 3040
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3020 offset
*RESET
*IF
RANGE offset 3041 3080
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3060 offset
*RESET
*IF
RANGE offset 3081 3120
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3100 offset
*RESET
*IF
RANGE offset 3121 3160
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3140 offset
*RESET
*IF
RANGE offset 3161 3200
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3180 offset
*RESET
*IF
RANGE offset 3201 3240
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3220 offset
*RESET
*IF
RANGE offset 3241 3280
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3260 offset
*RESET
*IF
RANGE offset 3281 3320
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3300 offset
*RESET
*IF
RANGE offset 3321 3360
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3340 offset
*RESET
*IF
RANGE offset 3361 3400
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 3380 offset
*RESET
*IF
RANGE offset 3401 3440
*CALL HDRMATH
HCADD offset 3420 offset
*RESET
*IF
RANGE offset 3441 3480
*CALL HDRMATH
HCADD offset 3460 offset
*RESET
*IF
RANGE offset 3481 3520
*CALL HDRMATH
HCADD offset 3500 offset
*RESET
*IF
RANGE offset 3521 3560
*CALL HDRMATH
HCADD offset 3540 offset
*RESET
*IF
RANGE offset 3561 3600
*CALL HDRMATH
HCADD offset 3580 offset
*RESET
*IF
RANGE offset 3601 3640
*CALL HDRMATH
HCADD offset 3620 offset
*RESET
*IF
RANGE offset 3641 3680
*CALL HDRMATH
HCADD offset 3660 offset
*RESET
*IF
RANGE offset 3681 3720
*CALL HDRMATH
HCADD offset 3700 offset
*RESET
*IF
RANGE offset 3721 3760
*CALL HDRMATH
HCADD offset 3740 offset
*RESET
*IF
RANGE offset 3761 3800
*CALL HDRMATH
HCADD offset 3780 offset
*RESET
*IF
RANGE offset 3801 3840
*CALL HDRMATH
HCADD offset 3820 offset
*RESET
*IF
RANGE offset 3841 3880
*CALL HDRMATH
HCADD offset 3860 offset
*RESET
*IF
RANGE offset 3881 3920
*CALL HDRMATH
HCADD offset 3900 offset
*RESET
*IF
RANGE   offset  3921    3960
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  3940    offset
*RESET
*IF
RANGE   offset  3961    4000
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  3980    offset
*RESET
*IF
RANGE   offset  4001    4040
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4020    offset
*RESET
*IF
RANGE   offset  4041    4080
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4060    offset
*RESET
*IF
RANGE   offset  4081    4120
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4100    offset
*RESET
*IF
RANGE   offset  4121    4160
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4140    offset
*RESET
*IF
RANGE   offset  4161    4200
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4180    offset
*RESET
*IF
RANGE   offset  4201    4240
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4220    offset
*RESET
*IF
RANGE   offset  4241    4280
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4260    offset
*RESET
*IF
RANGE   offset  4281    4320
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4300    offset
*RESET
*IF
RANGE   offset  4321    4360
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4340    offset
*RESET
*IF
RANGE   offset  4361    4400
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4380    offset
*RESET
*IF
RANGE   offset  4401    4440
*CALL   HDRMATH
HCML   offset  0       offset
HCADD  offset  4420    offset
*RESET
*IF
RANGE offset 4441 4480
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 1460 offset
*RESET
*IF
RANGE offset 4481 4520
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4500 offset
*RESET
*IF
RANGE offset 4521 4560
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4540 offset
*RESET
*IF
RANGE offset 4561 4600
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4580 offset
*RESET
*IF
RANGE offset 4601 4640
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4620 offset
*RESET
*IF
RANGE offset 4641 4680
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4660 offset
*RESET
*IF
RANGE offset 4681 4720
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4700 offset
*RESET
*IF
RANGE offset 4721 4760
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4740 offset
*RESET
*IF
RANGE offset 4761 4800
*CALL HDRMATH
HCMUL offset 0 offset
HCADD offset 4780 offset
*RESET
** ---------------------------
*IF
RANGE soffset -99999 -1
*CALL HDRMATH
HCMUL offset -1 soffset
*RESET
*IF
RANGE soffset 0 99999
*CALL HDRMATH
HCMUL offset 1 soffset
*RESET
** ---------------------------
*CALL SORT 240 90000
MAJOR cdp REVERSE
MINOR soffset NORMAL
** ---------------------------
*CALL VSTACK 1 cdp soffset KEEP
GROUPS 1 240 NOPAD ALL
-4780 -4740 -4700 -4660 -4620 -4580 -4540 -4500
-4460 -4420 -4380 -4340 -4300 -4260 -4220 -4180
-4140 -4100 -4060 -4020 -3980 -3940 -3900 -3860
-3820 -3780 -3740 -3700 -3660 -3620 -3580 -3540
-3500 -3460 -3420 -3380 -3340 -3300 -3260 -3220
-3180 -3140 -3100 -3060 -3020 -2980 -2940 -2900
-2860 -2820 -2780 -2740 -2700 -2660 -2620 -2580
-2540 -2500 -2460 -2420 -2380 -2340 -2300 -2260
-2220 -2180 -2140 -2100 -2060 -2020 -1980 -1940
-1900 -1860 -1820 -1780 -1740 -1700 -1660 -1620
-1580 -1540 -1500 -1460 -1420 -1380 -1340 -1300
-1260 -1220 -1180 -1140 -1100 -1060 -1020 -980
-940 -900 -860 -820 -780 -740 -700 -660
-300 -260 -220 -180 -140 -100 -60 -20
0 60 100 140 180 220 260 300
340 380 420 460 500 540 580 620
660 700 740 780 820 860 900 940
980 1020 1060 1100 1140 1180 1220 1260
1300 1340 1380 1420 1460 1500 1540 1580
1620 1660 1700 1740 1780 1820 1860 1900
1940 1980 2020 2060 2100 2140 2180 2220
2260 2300 2340 2380 2420 2460 2500 2540
2580 2620 2660 2700 2740 2780 2820 2860
2900 2940 2980 3020 3060 3100 3140 3180
3220 3260 3300 3340 3380 3420 3460 3500
3540 3580 3620 3660 3700 3740 3780 3820
3860 3900 3940 3980 4020 4060 4100 4140
4180 4220 4260 4300 4340 4380 4420 4460
4500 4540 4580 4620 4660 4700 4740 4780

***
** Remove NMO**
*
call runmix 3 within median
CALL NMO veldefn NMOREM
**
** ---------------------------
call balance cdp chan 1 120
gates 1
800 3900 800 3900
gates 99999
800 3900 800 3900
**
** ---------------------------
call MIGTX 2500 velgeo3 20 INTRP
***VSCALE 0.825
SOFFSET -4780 40
-4780 -4740 -4700 -4660 -4620 -4580 -4540 -4500
-4460 -4420 -4380 -4340 -4300 -4260 -4220 -4180
-4140 -4100 -4060 -4020 -3980 -3940 -3900 -3860
-3820 -3780 -3740 -3700 -3660 -3620 -3580 -3540
-3500 -3460 -3420 -3380 -3340 -3300 -3260 -3220
-3180 -3140 -3100 -3060 -3020 -2980 -2940 -2900
-2860 -2820 -2780 -2740 -2700 -2660 -2620 -2580
-2540 -2500 -2460 -2420 -2380 -2340 -2300 -2260
-2220 -2180 -2140 -2100 -2060 -2020 -1980 -1940
-1900 -1860 -1820 -1780 -1740 -1700 -1660 -1620
-1580 -1540 -1500 -1460 -1420 -1380 -1340 -1300
-1260 -1220 -1180 -1140 -1100 -1060 -1020 -980
-940 -900 -860 -820 -780 -740 -700 -660
-300 -260 -220 -180 -140 -100 -60 -20
0 60 100 140 180 220 260 300
340 380 420 460 500 540 580 620
660 700 740 780 820 860 900 940
980 1020 1060 1100 1140 1180 1220 1260
1300 1340 1380 1420 1460 1500 1540 1580
1620 1660 1700 1740 1780 1820 1860 1900
1940 1980 2020 2060 2100 2140 2180 2220
2260 2300 2340 2380 2420 2460 2500 2540
2580 2620 2660 2700 2740 2780 2820 2860
2900 2940 2980 3020 3060 3100 3140 3180
3220 3260 3300 3340 3380 3420 3460 3500
3540 3580 3620 3660 3700 3740 3780 3820
3860 3900 3940 3980 4020 4060 4100 4140
4180 4220 4260 4300 4340 4380 4420 4460
4500 4540 4580 4620 4660 4700 4740 4780

**
** ---------------------------
call SORT 240 30000
MAJOR CDP REVERSE
MINOR SOFFSET normal
**
** ---------------------------
call SCALE 1 1.8
**
-------------------------------------------------------------
38
*CALL DSKWRT ..../data2/99agsy4/Migpre_4s13.dsk
FOCUS
** ---------------------------
RESET
RESET
RESET
*END

*JOB L150 99AGSY4
*CALL IN 4000
SRCHSTR
/d/seismic/11/land/land_seis/L150/99agsy4_new/*
FILNAM
(ieee)/d/seismic/11/land/land_seis/L150/99agsy4_new/..../data2/99agsy4/Migpre_4s13.dsk
CATNAM
Migpre_4s13.dsk
ORDER FILE
PKEYS
4337 2669
** ---------------------------
**CALL NMO vel3700
** ---------------------------
*CALL FILTER shot
FREQ
KEYDEF 1
BANDSL 51
0 4000 20 36 90 36
*CALL SIGNAL 11 5 150 75 -50 50
10 0.1
*CALL DIGISTK 0.9
** ---------------------------
call medstk
trim .2 10
** ---------------------------
*CALL DSKWRT ..../data2/99agsy4/MigPstky4_4s13_2.dsk
FOCUS
** ---------------------------
*CALL SIGNAL 11 5 150 75 -50 50
10 0.1
*CALL DIGISTK 0.9
** ---------------------------
*CALL FILTER shot
FREQ
keydef 1
BANDSL 51
0 1000 18 36 85 36
1500 2000 16 36 75 36
2500 3000 14 36 70 36
3500 4000 12 36 65 36
*call AGC 500
** ---------------------------
*CALL SECPLOT RL VA 31.75 4.72
PLOTOPT m0_2065_oy_q
TITLE NewStkjob velgeo3 PStk Mig13_2. medstk
LABEL cdp-stat40 1 cdp 40
TRANGE 0 4000
TIMING 2 0 1 0 NO YES NO
** ---------------------------
*END