



**Geology, geochronology and geophysics  
of the north eastern Yilgarn Craton,  
with an emphasis on the  
Leonora-Laverton transect area**

**Proceedings of papers presented at an  
industry workshop held in Perth, 20 June, 2002**

**edited by**

**K.F. Cassidy**



**Geoscience Australia  
Record 2002/18**

## **Geoscience Australia**

Chief Executive Officer: Neil Williams

## **Department of Industry, Tourism and Resources**

Minister for Industry, Tourism and Resources: The Hon. Ian Macfarlane, MP

Parliamentary Secretary: The Hon. Warren Entsch, MP

© Commonwealth of Australia 2002

This work is copyright. Apart from any fair dealings for the purposes of study, research, criticism or review, as permitted under the Copyright Act, no part may be reproduced by any process without written permission. Inquiries should be directed to the Communications Unit, Geoscience Australia, GPO Box 378, Canberra ACT 2601.

**ISSN: 1039 0073**

**ISBN: 0 642 46747 1**

### **Recommended forms of reference to this publication are:**

a) For reference to an individual paper

CHAMPION, D.C. and CASSIDY, K.F., 2002, Granites in the Leonora-Laverton transect area, north eastern Yilgarn, *in* CASSIDY, K.F., editor, Geology, geochronology and geophysics of the north eastern Yilgarn Craton, with an emphasis on the Leonora-Laverton transect area: Geoscience Australia, Record 2002/18, 13-35.

b) For general reference to the publication

CASSIDY, K.F., editor, 2002, Geology, geochronology and geophysics of the north eastern Yilgarn Craton, with an emphasis on the Leonora-Laverton transect area: Geoscience Australia, Record 2002/18, 117p.

Geoscience Australia has tried to make the information in this product as accurate as possible. However, it does not guarantee that the information is totally accurate or complete. **THEREFORE, YOU SHOULD NOT RELY SOLELY ON THIS INFORMATION WHEN MAKING A COMMERCIAL DECISION.**

# Seismic data acquisition and processing – 2001 Northern Yilgarn seismic reflection survey (L154)

L.E.A. Jones<sup>1,2\*</sup>, B.R. Goleby<sup>1</sup>, D.W. Johnstone<sup>2</sup> and T.J. Barton<sup>2</sup>

<sup>1</sup> Predictive Mineral Discovery CRC, Geoscience Australia, Canberra, A.C.T., 2601

<sup>2</sup> Australian National Seismic Imaging Resource, Geoscience Australia, Canberra, A.C.T., 2601

\* E-mail: Leonie.Jones@ga.gov.au

## Introduction

The 2001 Northern Yilgarn seismic reflection survey (L154) was conducted in August/September 2001 and included the regional traverse consisting of lines 01AGS-NY1 and 01AGS-NY3, jointly sponsored by Geoscience Australia and the Geological Survey of Western Australia, in conjunction with the Predictive Mineral Discovery Cooperative Research Centre (*pmd*\*CRC). Two other lines, 01AGS-NY2 and 01AGS-NY4, were acquired in the Laverton Tectonic Zone under the auspices of Geoscience Australia and the Minerals and Energy Research Institute of Western Australia (MERIWA), involving AngloGold, Placer Dome and the University of Western Australia. The Australian National Seismic Imaging Resource (ANSIR) was responsible for seismic data acquisition (through its facilities manager Trace Energy Services), as well as for field QC and preliminary in-field processing.

The report is concerned only with lines 01AGS-NY1 and 01AGS-NY3. 01AGS-NY1 was a 384 km line, commencing in the vicinity of Leonora and extending to the east into the Officer Basin, whereas the much shorter 01AGS-NY3 lay entirely within the Officer Basin. The location of the lines is shown in [Figure 1](#).

## Acquisition

Most of the deep seismic reflection data was acquired along the edge of currently used and maintained shire roads or the Leonora-Laverton railway access road. The line was cleared for 01AGS-NY3. The station coordinates were surveyed using differential GPS by Dynamic Satellite Surveys (2001). A split-spread geometry was employed with the source nominally at the centre of the spread. The receiver groups were centred between the station pegs, while the source array was centred on the peg. Three IVI Hemi-60 (60,000 lb) vibrators were used in-line, using three varisweeps with moveup between sweeps.

A summary of acquisition parameters is given in [Table 1](#). Further details are provided by Barbour (2001). The main differences between the long regional line (01AGS-NY1) and the Officer Basin line (01AGS-NY3) are the group interval, VP interval and source move-up, and the sweep frequency ranges, which were designed to give higher resolution in the Officer Basin sedimentary rocks.

**Table 1 Summary of acquisition parameters for the regional lines in Survey L154**

<i>LINE</i>	<i>01AGS-NY1</i>	<i>01AGS-NY3</i>
AREA	Leonora to Lake Yeo (WA)	East of Lake Yeo (WA)
DIRECTION	W to E	SW to NE
LENGTH	384 km	52.62 km
STATIONS	992 - 10592	1040 - 2794
CDP RANGE	1984 - 20862	2080 - 5509
GROUP INTERVAL	40 m	30 m
GROUP PATTERN	12 in-line @ 3.33 m	12 in-line @ 2.5 m
# VIBE POINTS	4780	1226
VP INTERVAL	80 m	30 m and 60 m
SOURCE TYPE	3 x IVI Hemi-60	3 x IVI Hemi-60
SWEEP TYPE	3 x 12 s: 7-56 Hz, 12-80 Hz, 8-72 Hz	3 x 8 s: 8-72 Hz, 12-100 Hz, 6-80 Hz
SOURCE PAD-PAD	15 m	15 m
SOURCE MOVE-UP	15 m	10 m
# CHANNELS	240	240
FOLD (NOMINAL)	60	120 and 60
RECORD LENGTH	16/18 s @ 2 ms	16 s @ 2 ms

## Processing

The final processing flow, including migration, for 18 s of data is shown in [Table 2](#) for line 01AGS-NY1. For adequate resolution, only 4 ms sampling is required. Essentially the same flow was used for 16 s of data for line 01AGS-NY3.

The processing flow was designed to be as simple as possible, with the aim of enhancing reflections and preserving amplitudes. Some key processing steps are discussed briefly, concentrating on those necessary for understanding the data prior to seismic interpretation, and those that resulted in the most improvement in data quality.

**Table 2 Final processing flow for 01AGS-NY1**

[1]	line geometry and crooked line definition (fixed CDP interval)
[2]	field segy to 'disco' data format; resample to 4 ms
[3]	quality control displays and trace edits
[4]	spectral equalization (with removable 1000 ms AGC)
[5]	common mid point sort (bin wide open)
[6]	gain recovery (spherical divergence option)
[7]	trace amplitude balance across user defined gates
[8]	surgical air wave mute
[9]	bulk shift +100 ms
[10]	application of refraction statics, datum 350 m (AHD)
[11]	application of automatic residual statics
[12]	bandpass filter
[13]	velocity analysis using velex, 1st pass after refraction statics, 2nd pass after automatic residual statics
[14]	normal moveout correction (15% stretch mute)
[15]	common mid-point stack (alpha trimmed mean)
[16]	trace amplitude balance
[17]	finite difference migration with dip corrected velocities
[18]	bandpass filter
[19]	signal enhancement (digistack 0.85)
[20]	linear gain and trace amplitude scaling

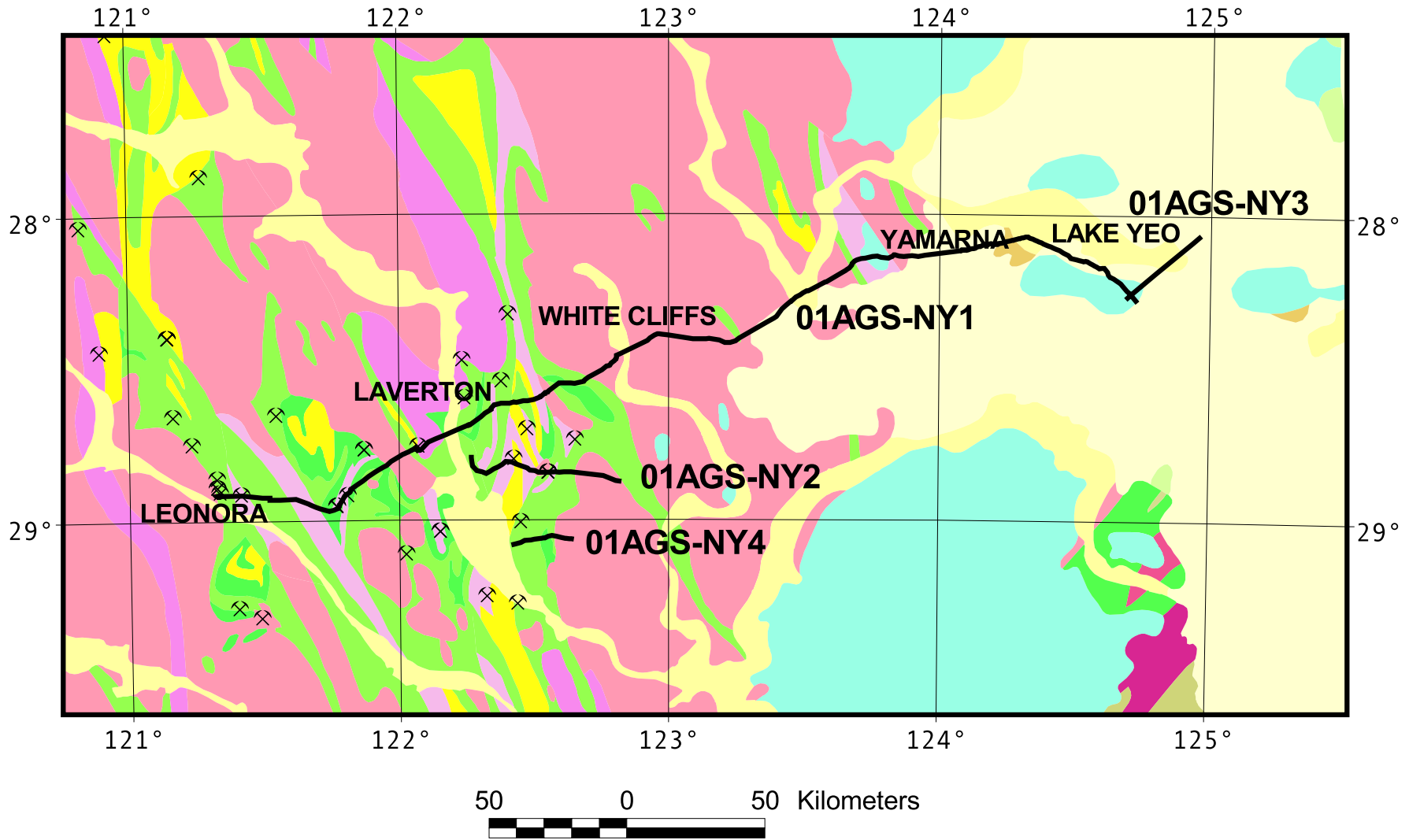


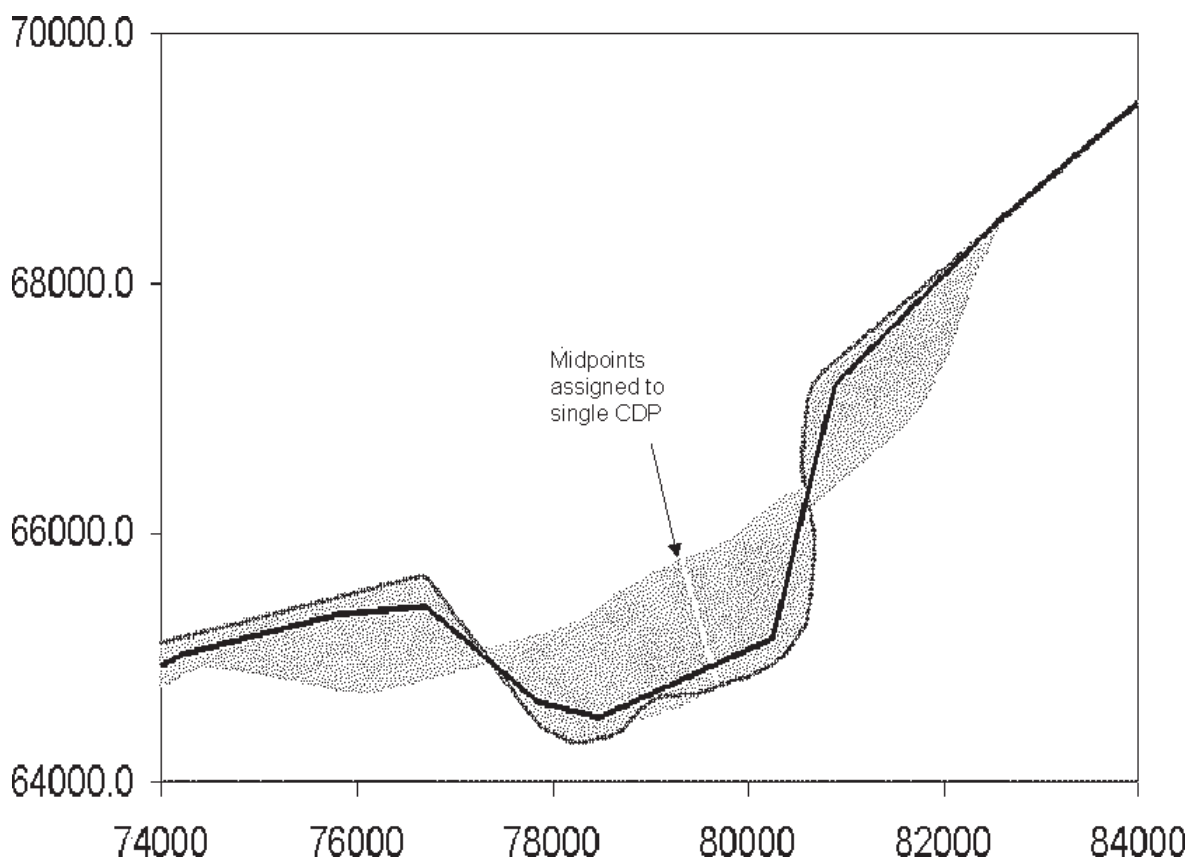
Figure 1 Location of the 2001 Northern Yilgarn seismic reflection survey, overlain on a simplified solid geology map. Archaean greenstone units are as follows: mafic and ultramafic rocks - green, felsic volcanic and sedimentary rocks - yellow, granitoids - pink, gneiss - purple; overlying Paleozoic units in cream and blue; Cainozoic unit in pale yellow

### *Crooked line definition and CMP/CDP sort*

Ideally, for a horizontal reflector, the midpoint between a source and receiver pair lies vertically above the depth point (or reflecting point) for that pair, so that identifying seismic traces with a common midpoint (CMP) amounts to finding traces with a common-depth-point (CDP). For dipping reflectors, this correspondence no longer holds, but the CDP terminology is so entrenched in seismic processing that it is used in place of the more correct term “common midpoint”. Note that midpoint spacing along a straight line is half the receiver group interval.

Crooked line processing was necessary for 01AGS-NY1, due to bends in the existing roads. In the crooked line case, the midpoints do not always lie along the line defined by the surveyed stations. The CDP line is defined as a smoother representation that follows the highest density of midpoints, while keeping as close as possible to the original line (Fig. 2). A seismic trace is then assigned to a particular CDP on the basis of its midpoint location, that is, to the nearest CDP.

For both lines, the CDP line was defined with a constant CDP interval (20 m for 01AGS-NY1 and 15 m for 01AGS-NY3). Since the CDP line is shorter than the line of stations, the CDP number will be less than twice the station number. A common midpoint sort gathers the data into sets of traces with the same midpoint (or CDP); these traces will later be stacked (added together) after correction for travel time differences for different source-receiver offsets. The stacked seismic data is displayed as a section along the CDP line, the annotated stations being merely those closest to the CDP locations.



**Figure 2** Illustration of crooked line geometry, with X and Y coordinates in metres. The grey line is the surveyed station line. The black line is the CDP line. Shaded area is the spread of midpoints. Unshaded strip perpendicular to the CDP line shows midpoints assigned to a single CDP

### *Refraction statics and datums*

Statics corrections are applied to remove variability in seismic travel times due to surface topography, or variations in regolith thickness or velocity (or a combination of these). The travel times of refracted waves, recorded as the first arrivals in seismic reflection data, are analysed to obtain a model of the main refracting interface, that is, the regolith/bedrock boundary (Fig. 3). Refraction statics are calculated by (1) subtracting the vertical travel time calculated for the lower velocity regolith, and (2) adding the vertical travel time calculated from datum to bedrock at a higher replacement velocity.

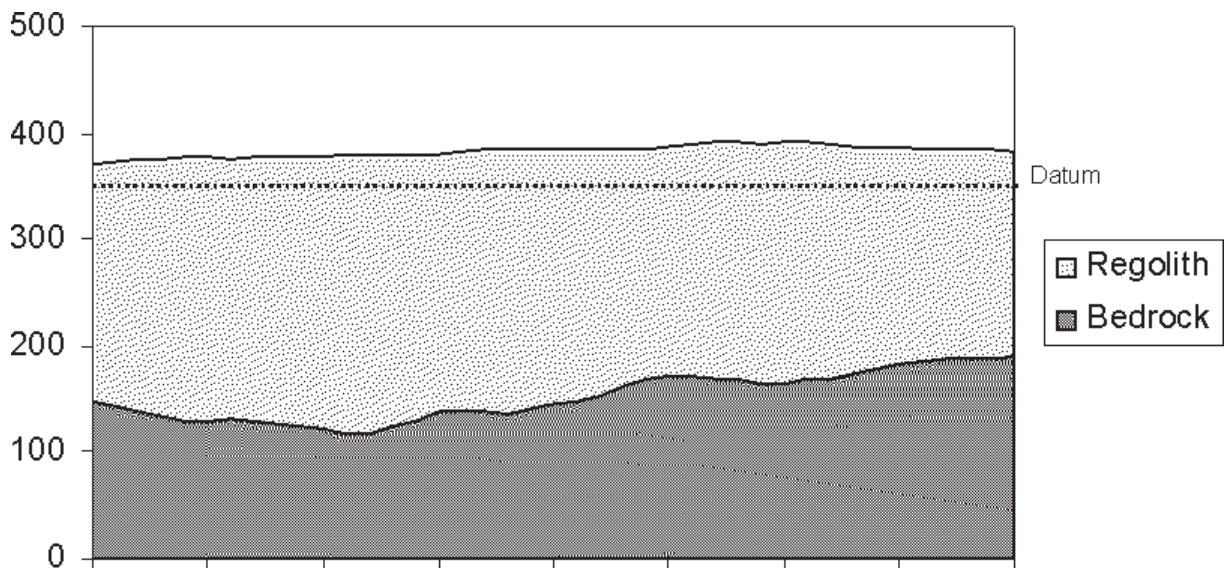
For both lines 01AGS-NY1 and 01AGS-NY3, a datum of 350 m (AHD) was used in calculating statics. For 01AGS-NY3, a replacement velocity of 4000 m/s was used. Since 01AGS-NY1 crossed the boundary between Archaean craton (bedrock velocity ~6000 m/s) and Proterozoic/Palaeozoic basins (bedrock velocity ~4500 m/s), a variable replacement velocity was required: 5500 m/s for stations 992 to 9500, 4500 m/s for stations 10200 to 10592, with linear interpolation in between.

It is important to note that prior to application of statics a bulk shift of +100 ms was applied. This was done to prevent shallow information being removed and to keep the processing approximately surface referenced (the average two-way static being of the order of 100 ms). Thus, the 100 ms line on the processed seismic data corresponds to the 350 m datum.

### *Spectral equalisation and filtering*

A key processing step that reduces low frequency noise and enables reflections to be seen is spectral equalisation, or balancing in the frequency domain. This is particularly critical at shallow depths where the fold is lower and where source-generated noise interferes with reflections. The automatic gain control (AGC), used as part of the spectral balancing algorithm, was removed afterwards in order to preserve amplitudes for later processing steps, particularly migration.

Bandpass filters were also applied to suppress high and low frequency noise. Prior to final



**Figure 3 Refractor model near the eastern end of line 01AGS-NY1, showing lower velocity regolith overlying higher velocity bedrock. Elevations are metres above sea level and horizontal extent is 8 km**

display, a bandpass filter with more limited range at large two-way travel time (TWT) was aimed at improving appearance of deeper reflections that would have lost any true high frequency due to attenuation in the earth.

### ***Stacking velocity analysis and median stack***

Another critical processing step is the correction of seismic data for the offset dependence of travel time, the normal moveout (NMO) correction, which depends (inversely) on seismic velocity and two-way travel time. With the appropriate choice of velocity for NMO correction, a reflection event will add constructively when the traces of a common-midpoint gather are stacked. In the shallow section (less than 1 to 2 s TWT), the quality of the stack is quite sensitive to changes in the stacking velocity, but becomes progressively less so for the deeper data.

Stacking seismic traces improves the signal to noise ratio. An improved technique for suppressing large bursts of noise, such as vehicle noise, is a type of median stack. The alpha trimmed mean stack examines trace amplitudes at each sample time, and omits a designated percentage of the highest and lowest amplitudes from the stack, in this case 15 percent at each end.

### ***Migration***

On an unmigrated final stack section with  $V/H=1$ , no reflectors will be visible at angles greater than  $45^\circ$ . Migration is the process of moving the recorded reflections into their true spatial location. Thus, dipping reflectors will be steepened, shortened and moved up dip. Diffractions from discontinuities, such as reflector terminations at faults, are collapsed in the process. Stacking velocities corrected for dip were used as the migration velocities.

### ***Coherency enhancement***

A signal enhancement algorithm (digistack) was applied for final display only to the stacked and migrated data. Digistack enhances events that are coherent across several traces, thus making reflections stand out better against background noise.

### ***Example of processed seismic data***

A small window of migrated data within the Laverton Tectonic Zone illustrates the quality of acquisition and processing along line 01AGS-NY1 (Fig. 4). This is typical of the data, showing east-dipping reflectors that can be imaged almost to the surface. Data quality is good to excellent along most of the traverse, with obvious reflectors throughout the crust to the Moho.

## **Conclusions**

The regional seismic reflection data have been processed to a high standard, facilitating interpretation of geological structure throughout the crust from the near surface. Detailed processing in selected areas to enhance particular features of interest may be of benefit at some future date.

## **Acknowledgements**

Ed Chudyk is thanked for his contribution in picking first arrivals and stacking velocities for the western half of line 01AGS-NY1 and part of line 01AGS-NY3. This paper is published with the permission of the Chief Executive Officer, Geoscience Australia and the Chief Executive Officer, Predictive Mineral Discovery CRC, and is GeoCat number 40416.

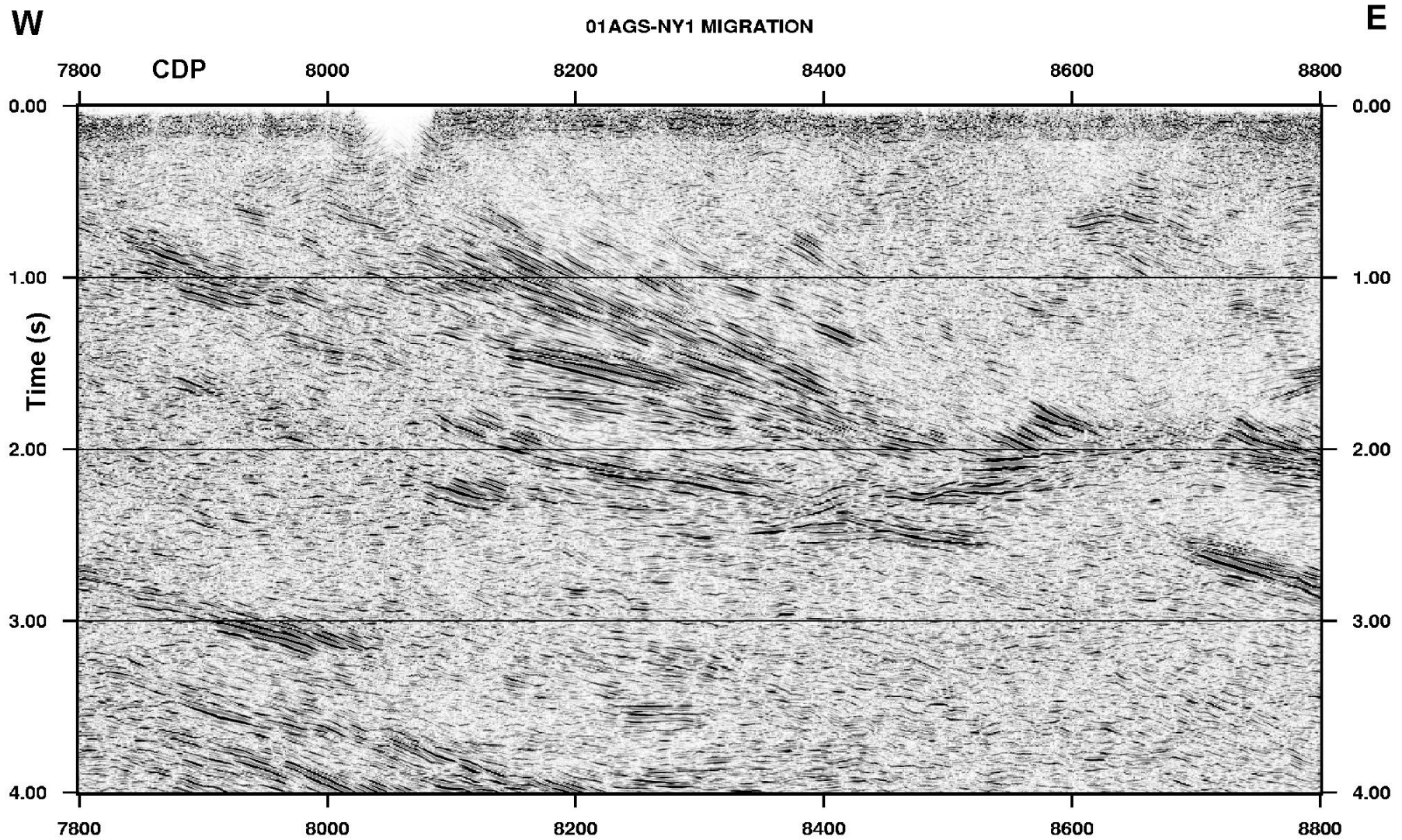


Figure 4 Small part of migrated section for 01AGS-NY1. Horizontal axis is CDP and vertical axis is two-way travel time (s).  $V/H = 1$ , assuming an average crustal velocity of 6 km/s. Horizontal extent is 20 km and vertical extent is 12 km. Shallow section is missing through Laverton township where the IVI Hemi-60 vibrators could not be operated

## **References**

- BARBOUR, S., 2001, Final Operations Report, North Yilgarn seismic survey, Western Australia, 2001.
- Dynamic Satellite Surveys, 2001, Final Operations Report on the AGSO 2001 Yilgarn 2D Seismic Survey for Trace Energy Services Pty Ltd, July-August 2001: Dynamic Satellite Surveys, Report 01-66.