LESSONS FROM COMBINED INTERPRETATIONS OF WIDE-ANGLE AND CONVENTIONAL REFLECTION DATA IN THE NORTHERN YILGARN, WESTERN AUSTRALIA

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Main objectives of wide-angle survey

- Test if it is possible to collect high-density wide-angle data at large offsets (60+ km), using a vibroseis source

- Supplement deep seismic reflection data with velocity information (mainly for the upper crust)

- Conduct a comparative study of seismic images of the crust, constructed from near vertical and wide-angle data
OUTLINE

• How to design a cost effective and scientifically productive wide-angle survey that would fit into reflection survey

• Development challenges in processing wide-angle vibroseis data

• Can we reduce the amount of data required to develop a velocity model?

• Using wide-angle velocity information to improve the geological model

• Comparison of wide-angle and reflection post stack data. What does it tell us?
Location of seismic lines, Northeastern Yilgarn, Western Australia

- Location of wide-angle seismic line (174 km). White dots represent vibration points. Red line (64 km) represents vibration points and recording array.

- Wide-angle data collected coincident to the deep seismic reflection transect (384 km).

Simplified geological map from GSWA database compilation (Groenewald et al., 2002)
Wide-angle survey statistics

- 120 short period instruments deployed (~ 500 m apart)
- Deep seismic reflection data collected along the same line
- 3 vibrators used as energy sources. 80 m spacing between source points. 3 variable sweeps, each 12s long
- Data were recovered from only 60 stations
- Final velocity model is based on data from the 60 stations
- Only 40 (the best !) common receiver gathers were used to produce the wide-angle stacked section
From seismic traces to velocity model

Raw non-correlated seismic traces

Cross-correlated seismic traces gathered in common receiver offsets, three sweeps stacked at every vibration point
From seismic traces to velocity model

Common receiver gather, up to 3 seismic events from different boundaries picked in the first arrivals

Major seismic events picked from common receiver gathers for 60 recording stations
From seismic traces to velocity model

The 2D velocity model was produced by forward modeling software, based on the ray-tracing algorithm of Zelt and Smith (1992).

The designed velocity model agrees with dense ray coverage.

Seismic events used for modelling of the upper crust.

Ray tracing diagram and travel time plot. Travel time plot shows observed (squares) and computed (lines) travel times.
Velocity model based on data from the 60 recording stations: first arrivals and wide-angle reflections

The upper crustal model consists of three layers over basement:

1. Thin upper layer (5.0 - 5.9 km/s).
2. 2 km thick high velocity body (6.4 - 6.7 km/s), interpreted as mafic rocks, restricted to the western part of the line at ~4 km depth.
3. 4 to 8 km thick relatively low velocity layer (6.0 - 6.1 km/s - granite-gneissic composition) at ~12 km depth in the western part of the line.
4. Basement (6.2 - 6.3 km/s).
SPECIFICICS OF THE LOWER CRUST MODEL
Wide-angle reflections contribute to modelling of lower crust, but not much ...

Major seismic events picked from common receiver gathers

Ray tracing diagram and travel time plot for two stations based on first arrivals and wide-angle reflections

Range of good matches can be achieved for velocity models within ± 500 m/s deviations, which is not sufficiently accurate
HOW DENSE DO WE NEED BOTH SHOT AND RECORDER INTERVALS?
Vibration Point interval: common receiver gathers, simply decimating traces

80 m vibration point interval utilised in the field

Preferred: vibration point interval every 240 m (every 4th trace)

Vibration point interval every 1.5 km (20th trace)

Vibration point interval every 3 km (40th trace)
Velocity model: To what extent is it a function of recording interval?

Increasing the recorder density does not significantly improve the velocity model in the upper crust.

In the upper 4 km, models A and B differ by 100 – 300 m/s.

5 recording stations with average spacing of 20 km

60 recording stations with average spacing of 1 km
Two important differences are:

1. The bottom of the high velocity body sits shallower (1.5 – 2.0 km) in model B, due to the increased ray coverage with the incorporation of more recorders, importantly more reflections from the bottom of this body have become available.

2. Deeper coverage in model B is because important arrivals from the lower crust were missing in the data set used to develop model A.
Recommendations for survey parameters interpreted from findings

1. How dense do we need both shot and recorder intervals?
   - 240 m - vibration point interval
   - 5-10 km – recorder interval; for building a velocity model
   - 1-1.5 km - recorder interval; for stacking wide-angle data

2. Require longer sweep (~30s ?) – to build lower crustal velocity model

3. Recording station sample rate of at least 4-6 msec - for better resolution of stacked sections
WIDE-ANGLE AND CONVENTIONAL REFLECTION – HOW DO THEY COMPARE?

VELOCITY MODEL AND REFLECTION SECTION
• The wide-angle survey supplements the reflection data by providing velocity information in the upper crust

• This creates an opportunity to compare the velocity model derived from wide-angle data with a structural image obtained from the deep seismic reflection data
Comparison of the wide-angle data velocity model with the reflection data interpretation

- The reflection data image structures within the upper crust quite well, but fail to detect long wavelength seismic velocity stratification.

- There is no obvious correlation between interpreted seismic reflection horizons and velocity boundaries.
The seismic velocity model derived from the wide-angle data was used to depth-convert the seismic reflection data.

The 2D velocity model derived from the wide-angle data converted to two-way time.

There is no substantial difference in the appearance of two-way time and depth scale images.
WIDE-ANGLE AND CONVENTIONAL REFLECTION – HOW DO THEY COMPARE?

WIDE-ANGLE AND CONVENTIONAL REFLECTION SECTIONS
Comparison of data from wide-angle and conventional reflection surveys

There are less reflections in the wide-angle data, *in this range of offsets*, due to the lower frequency range.
Stacked seismic section derived from wide-angle data

A basic processing stream was used to stack the wide-angle data for comparison with the conventional reflection section:

- Data was sorted into common receiver gathers;
- Refraction statics were applied;
- Normal moveout correction;
- Sort in CDP order;
- Stacked selected gathers;
- Bandpass filter;
- Signal enhancement;
- Amplitude balance.

The next slide will show stacked section zoom-in into this area.
Similarities and differences exist

Differences may be due to:
1. Lower frequency cut-off in wide-angle
2. Lower fold in wide-angle
3. Different NMO
4. Other technological differences

Potential for AVO (amplitude versus offset) analysis?
Conclusions

• The experiment has proved the effectiveness of using vibroseis source for collecting wide-angle data simultaneously with reflection survey

• Velocity model for the upper crust demonstrates the possibility of differentiating high velocity mafic rocks from low velocity rocks

• Wide-angle reflections from the lower crust are not sufficient to build an accurate velocity model, lower crustal refractions in the first arrivals are required to better constrain this model but unfortunately the signal was too weak to achieve this
Conclusions

- Reflection horizons and changes in reflectivity patterns mapped by the reflection technique will not necessarily coincide with velocity boundaries imaged by wide-angle reflection technology due to different wavelengths and different interference styles.

- The stacked wide-angle seismic section has some similarities and differences with the conventional reflection section, however more work is needed to identify if the wide-angle stacked section is of further use.

- A more accurate geological interpretation is possible using a combination of wide-angle and reflection seismic techniques.