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AN ORGANISATION FOR A NATIONAL
EARTH SCIENCE INFRASTRUCTURE PROGRAM

Government of Western Australia
Department of Mines and Petroleum

Capricorn Transect: Experimental design, acquisition and processing

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AuScope 2007- 2011: Earth Imaging

- New equipment acquisition has been made to support passive seismology and magnetotellurics
- The concept of geotransects utilising a wide range of information is central to the AuScope model building on the 2003 Strategic Plan for the Earth Sciences.
- AuScope EI has supported reflection seismic and other data acquisition (passive seismic & MT) across areas of major scientific interest
- Transect program based on call for proposals through NCES Working party on Geotransects

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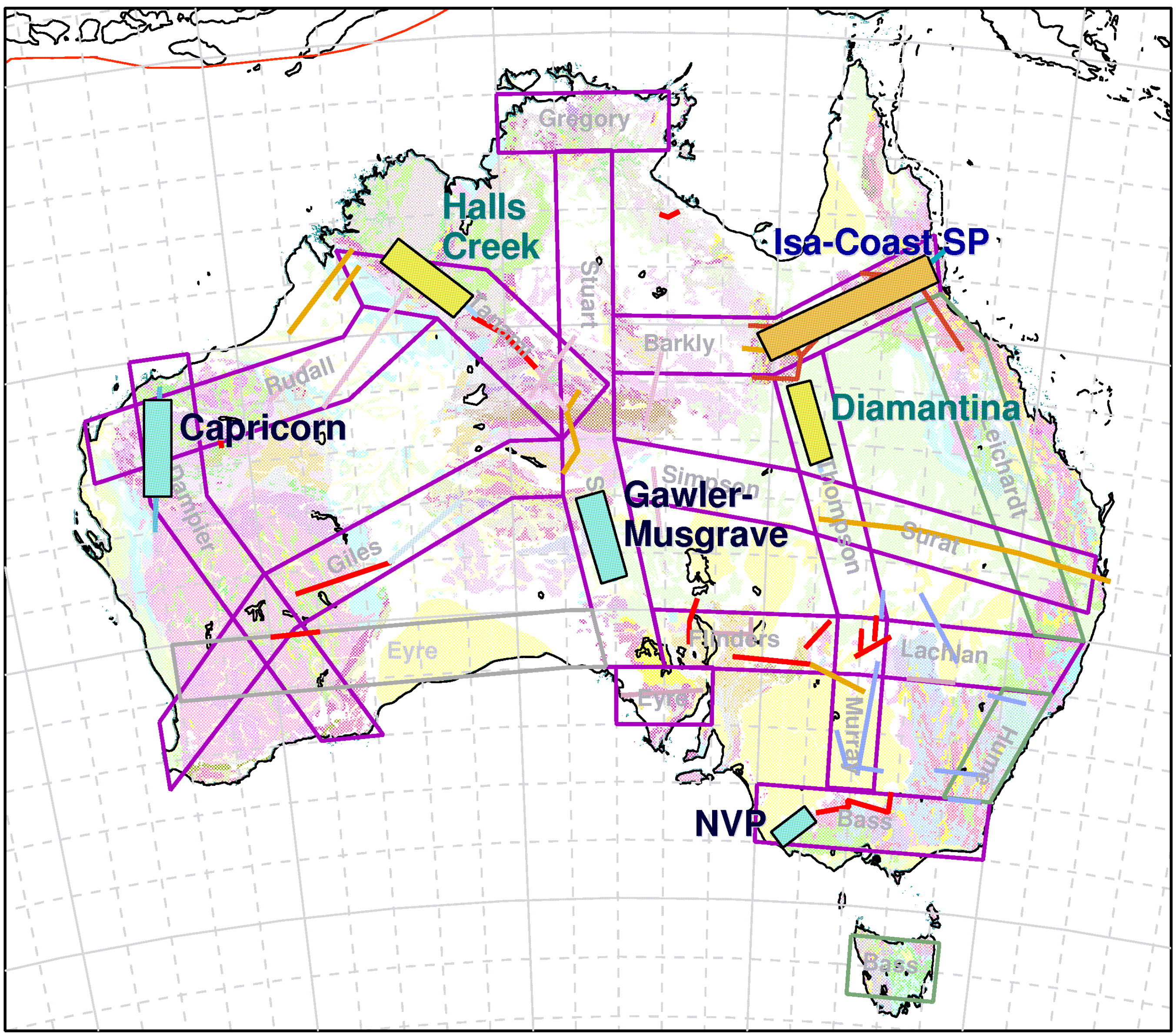
AuScope Transects



Reflection

High Priority

Medium Priority

Passive Seismic

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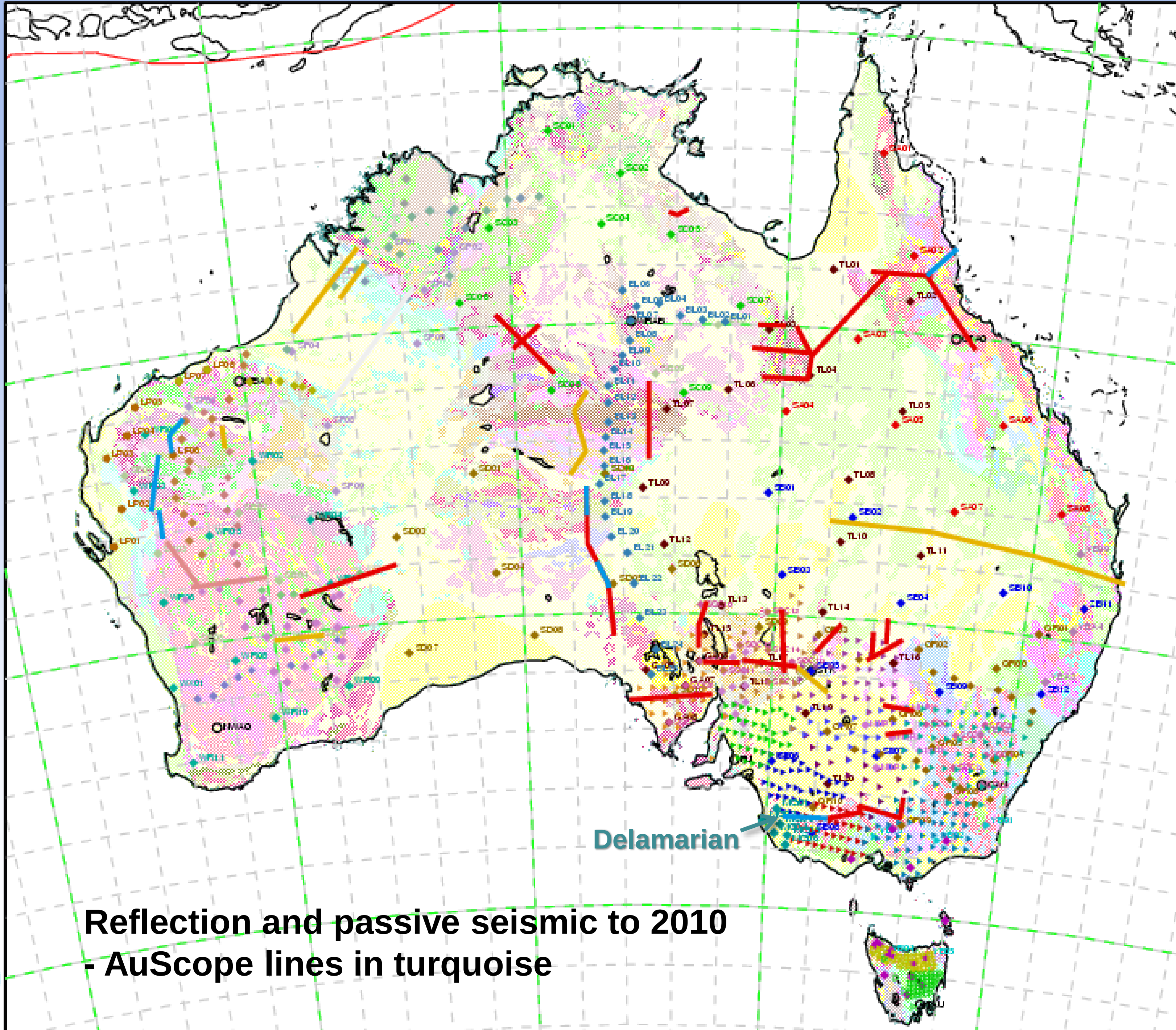
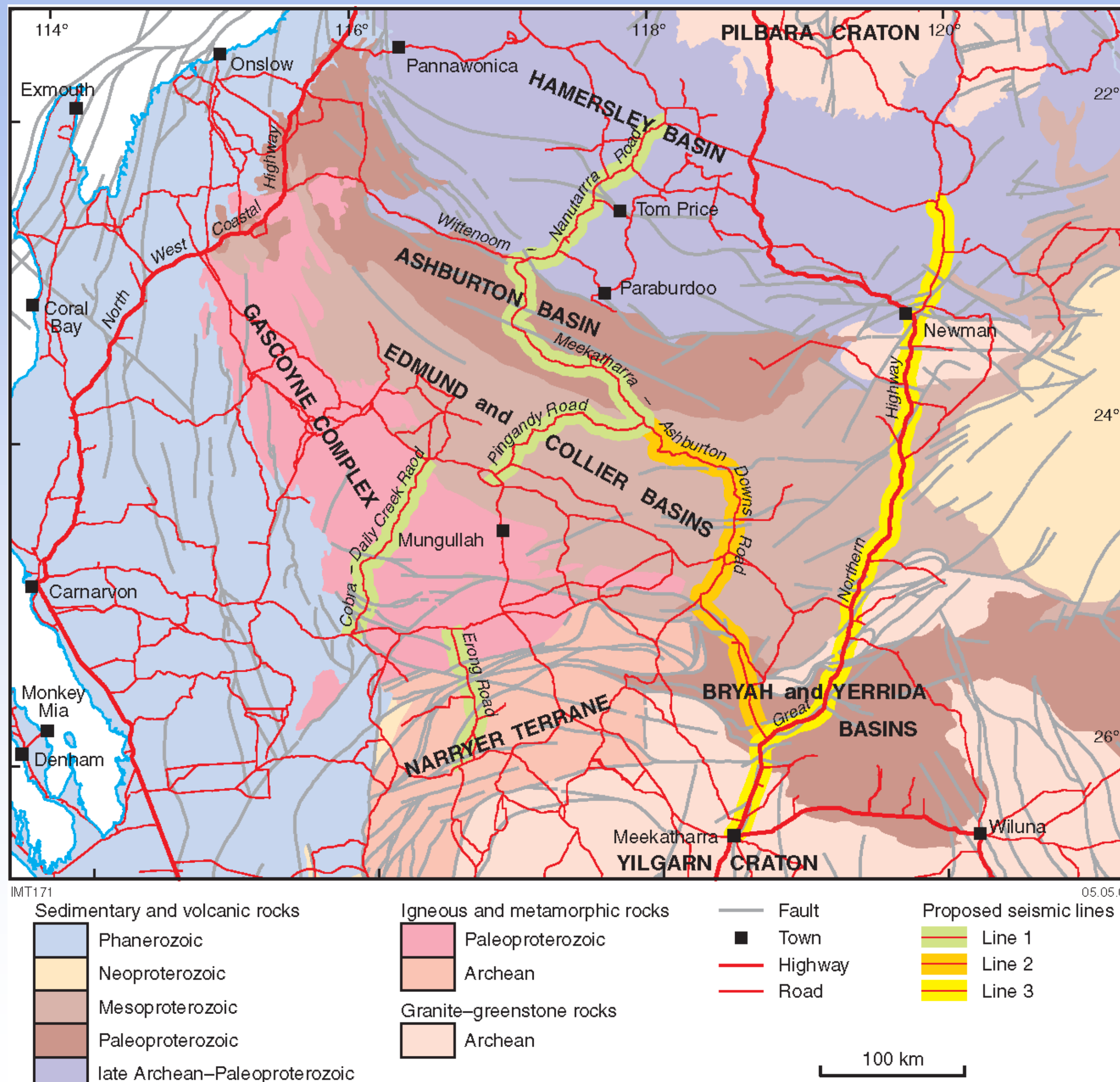


Reflection and passive seismic to 2010
- AuScope lines in turquoise

Capricorn Transect - Original Concepts

Multiple lines to provide complete Coverage of the Capricorn Orogen structures



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Capricorn Transect I

- Joint venture AuScope/GSWA with acquisition organised by GA
- Designed to provide a link from the Pilbara to the northern Yilgarn.
- Logistic considerations require a break at the Ashburton range, but possible to get close to equivalent positions along strike
- Generally good quality data along the three line segments
- Links to prior active/passive seismic experiments provide good control on structures

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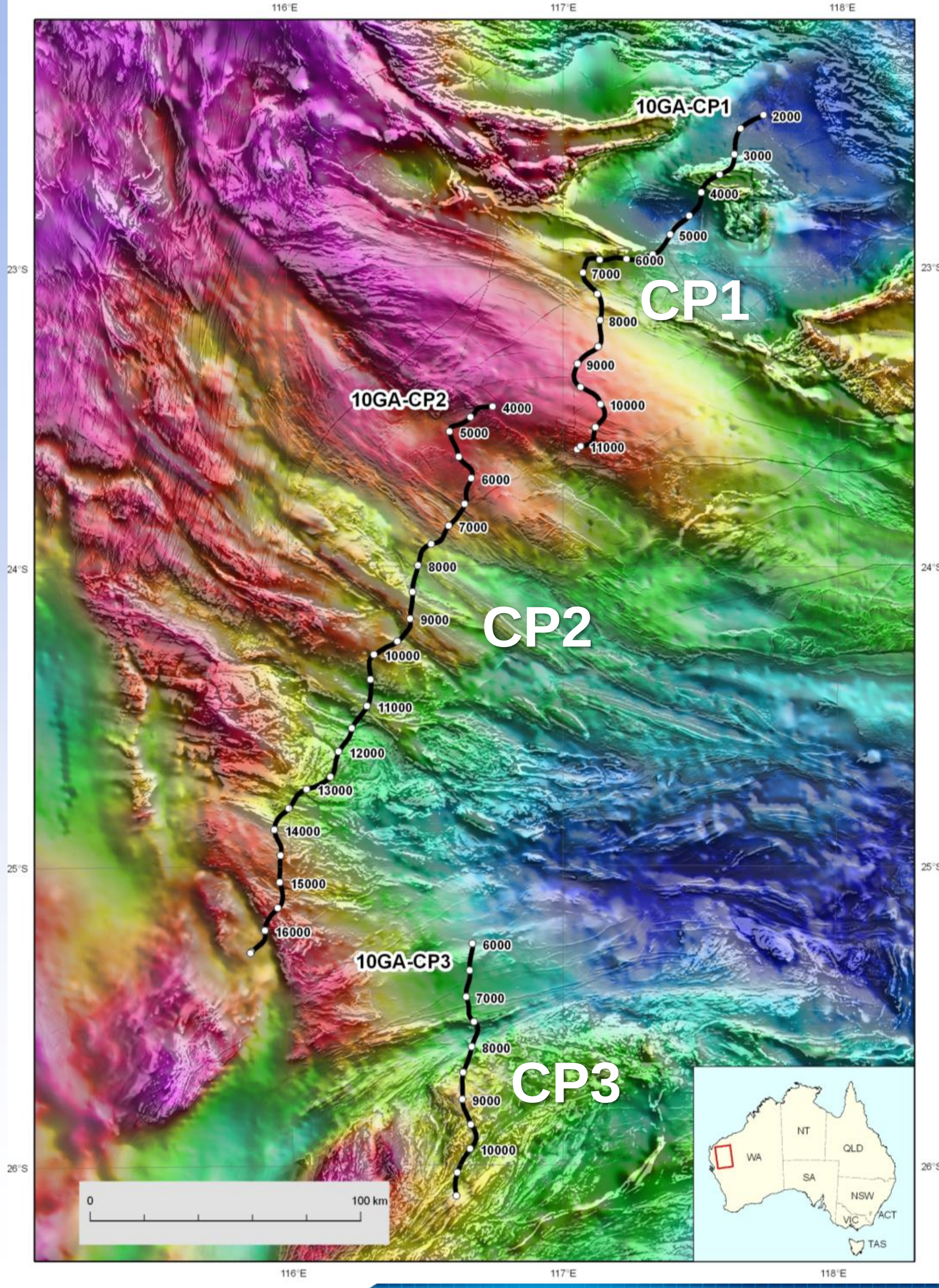
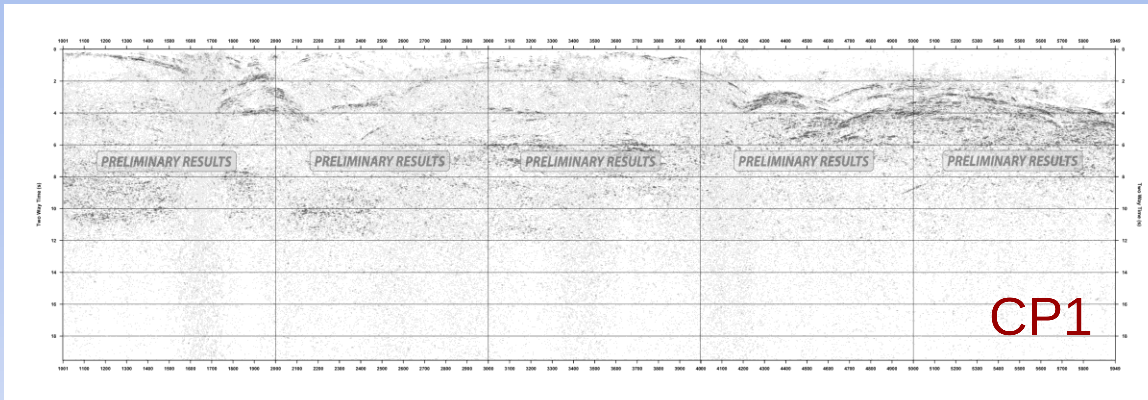
Capricorn Transect II

Line shot in three segments

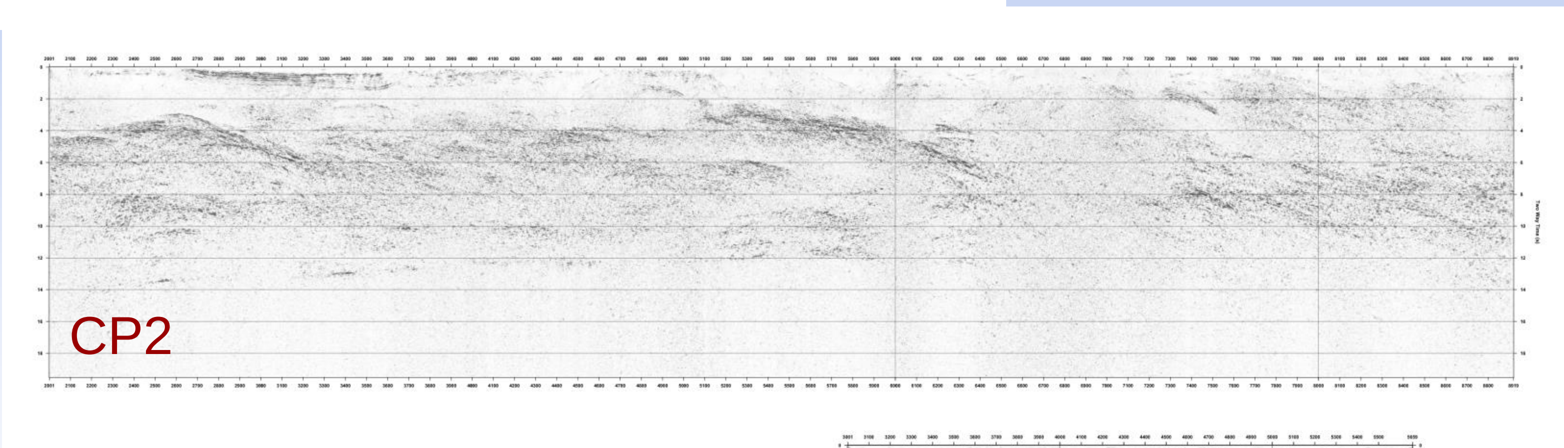
- CP1 – Hammersley and Ashburton Basin
- CP2 - Ashburton, Edmond & Collier Basins, Gascoyne Complex
- CP3 – Gascoyne, Narryer Terrane

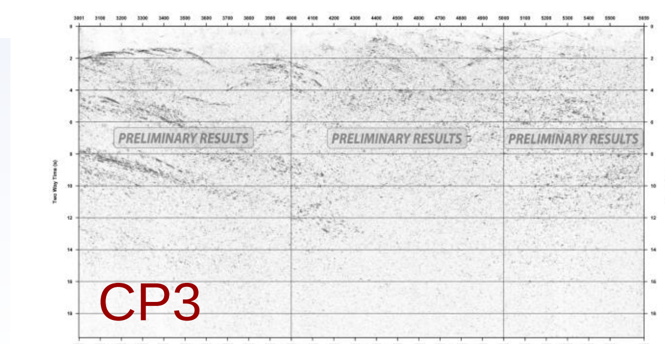


Reflection coverage from Pilbara to Yilgarn



Field stacks





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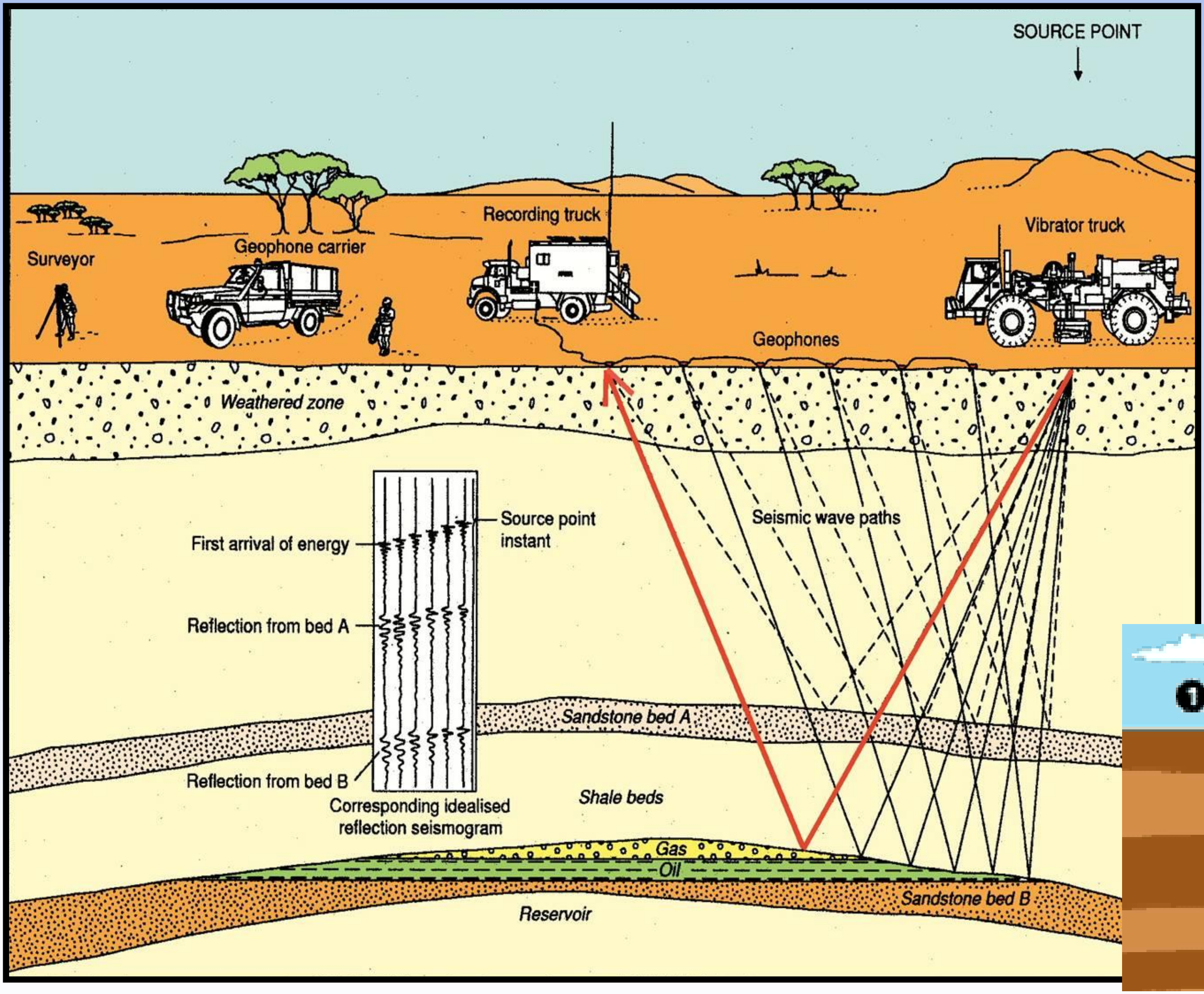
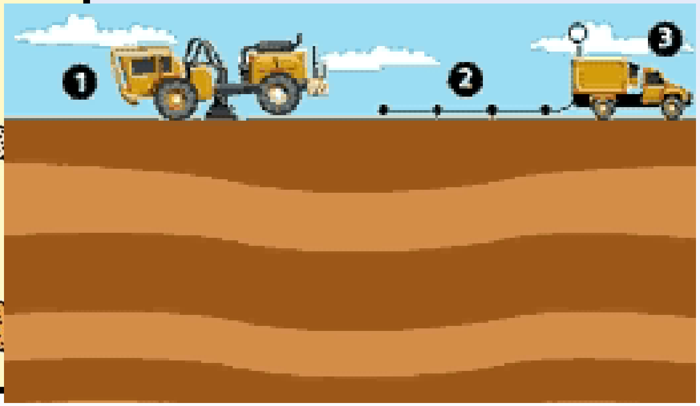
Seismic Reflection Acquisition





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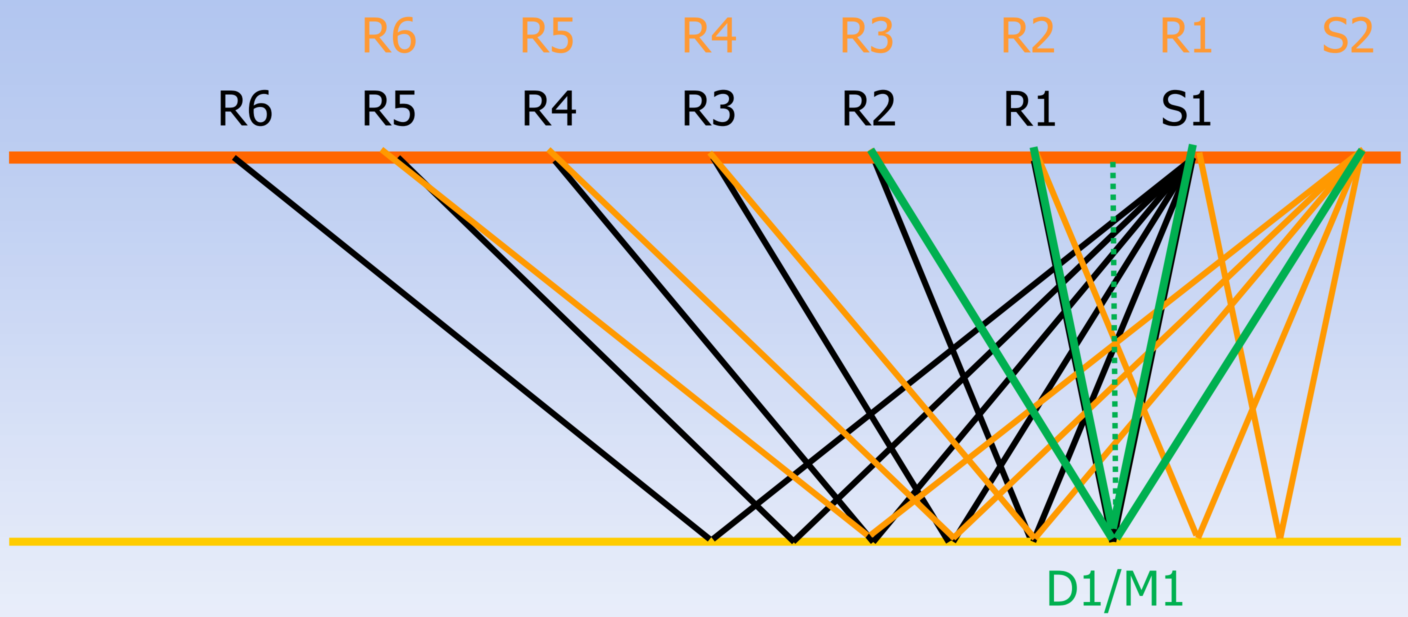
CMP (Common Mid Point) Method



- Depth point D1/M1 is sampled by R1 for Shot 1, R3 for Shot 2 and R5 for Shot 3 (not shown).
- All paths with common midpoint are brought into a gather – 75 fold sampling for Capricorn survey

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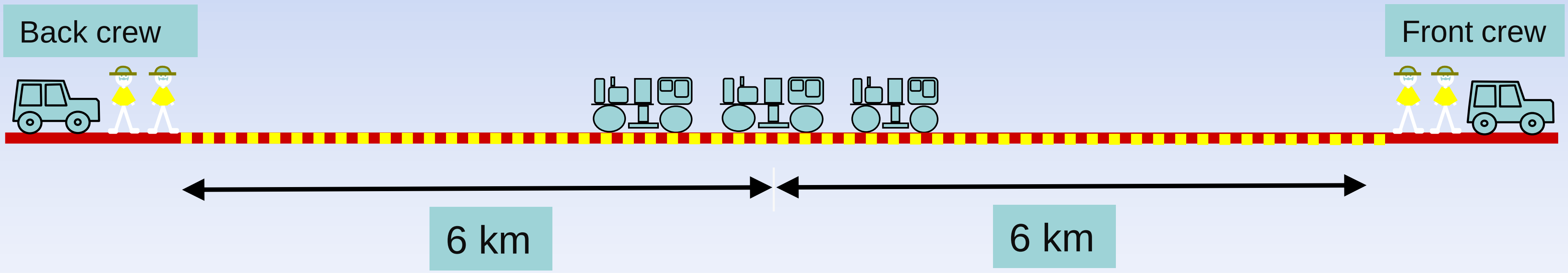
Seismic Acquisition

Symmetrical split spread with maximum 6 km offset

300 channels, receiver groups at 40 m intervals



(not to scale!)

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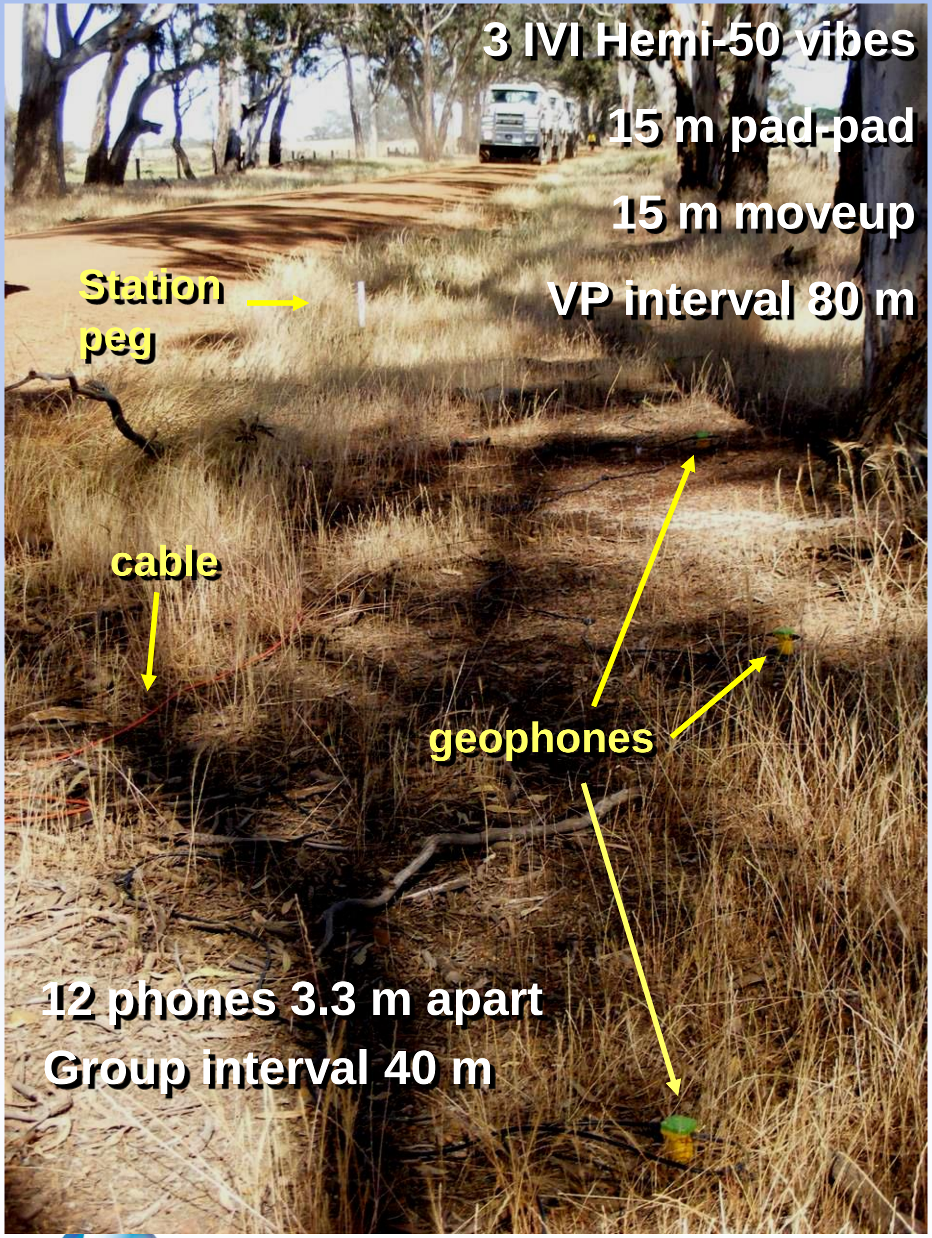
Acquisition Parameters



300 channel ->75 fold

RECORD 20 s @ 2 ms

3 x 12 s vari sweeps
6 - 64 Hz
10 - 90 Hz
8 - 76 Hz

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Seismic Data Recording and QC

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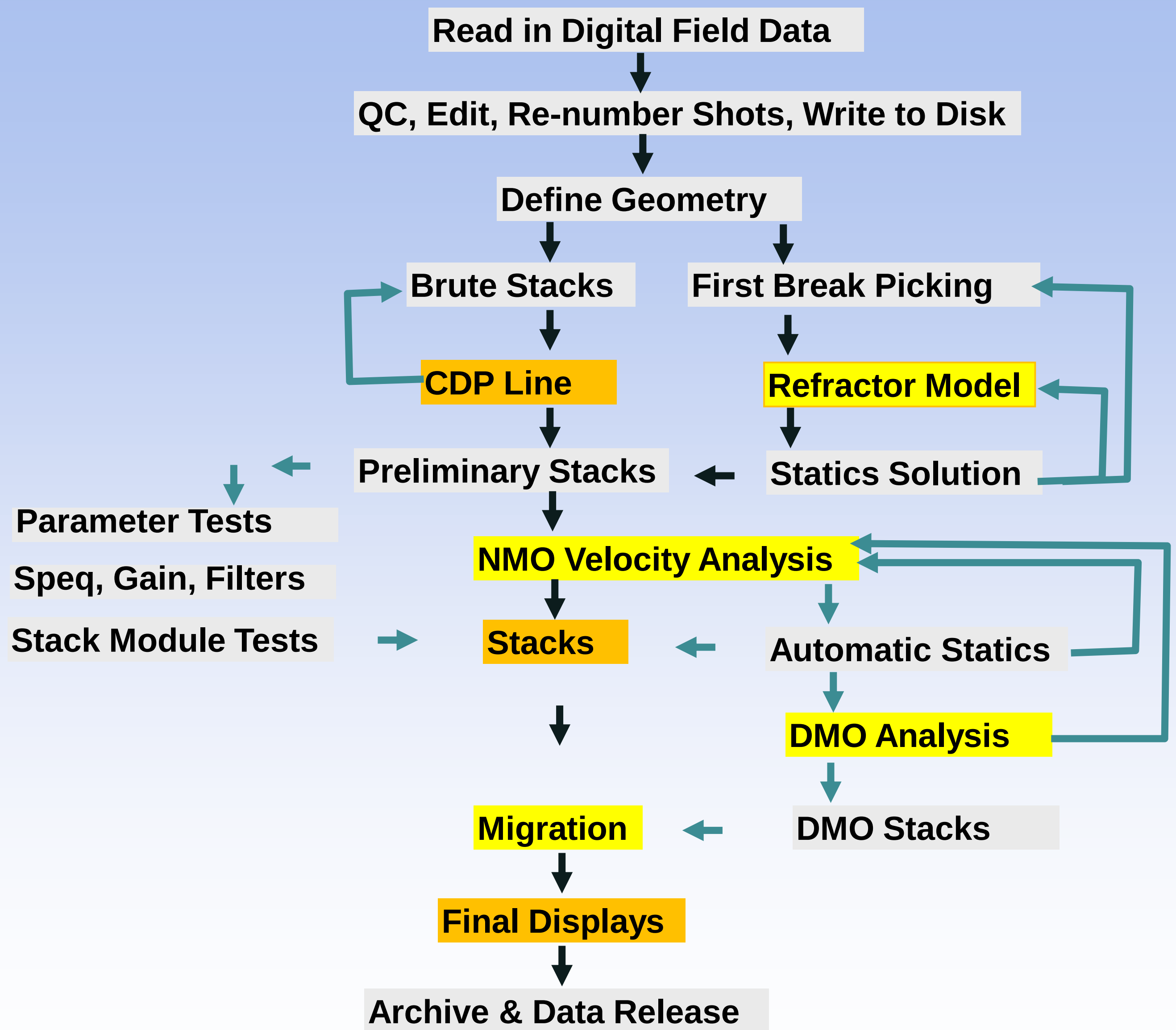
Seismic Processing



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Key Reflection Processing Steps

- **Crooked line geometry definition** - including CDP line
- **CDP sort** - collects traces with common mid point
- **Refraction statics** – correct for time delays in regolith
- **Spectral equalisation** - suppresses low f noise
- **NMO correction** - corrects for source-receiver offset
- **DMO correction** - allows imaging of steep reflectors
- **Common mid-point stack** – improves signal to noise
- **Migration** - moves reflectors to correct positions
- **Coherency enhancement** - amplifies coherent events

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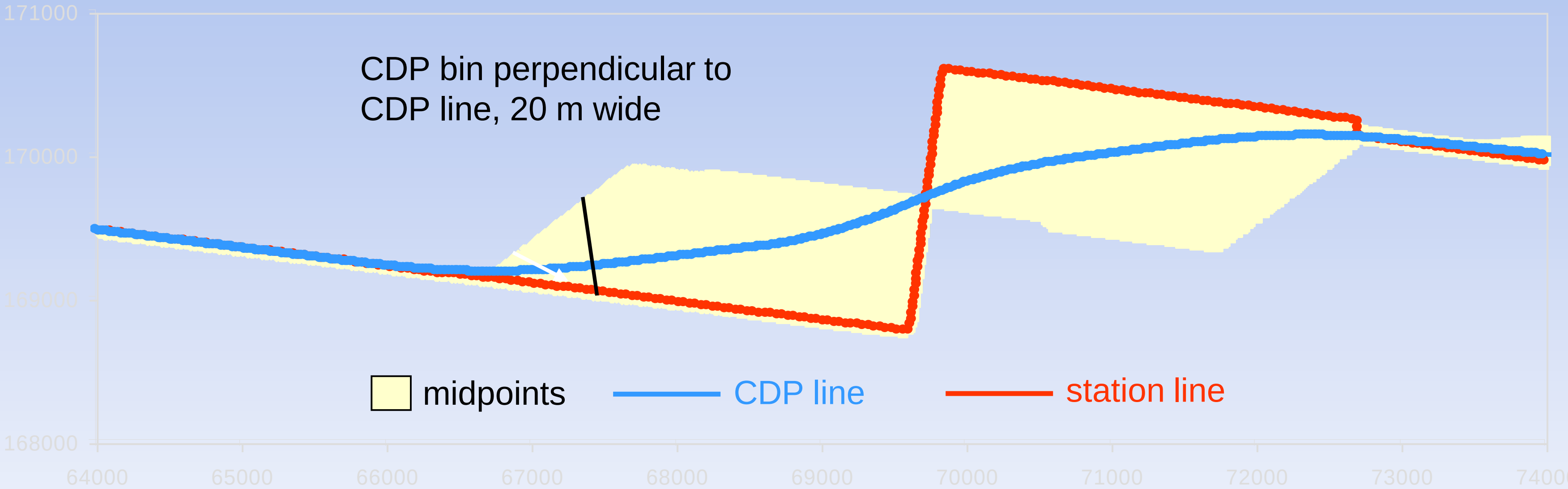
Geometry and CDP Sort - Crooked Line

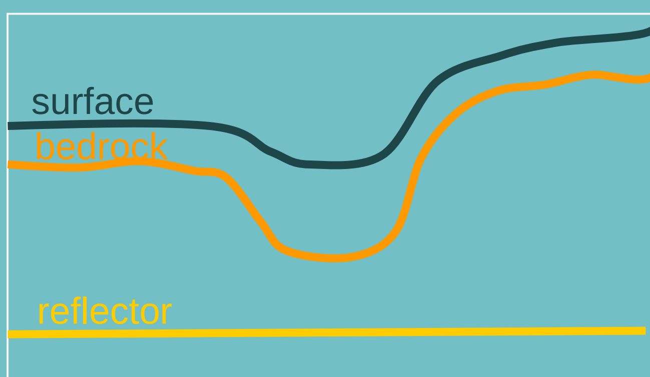


Allows for the scatter of midpoints. A best fitting CDP line is defined. Shot-receiver midpoints are assigned to the nearest CDP bin. Traces are then sorted into CDP gathers. The processed seismic section follows the CDP line.

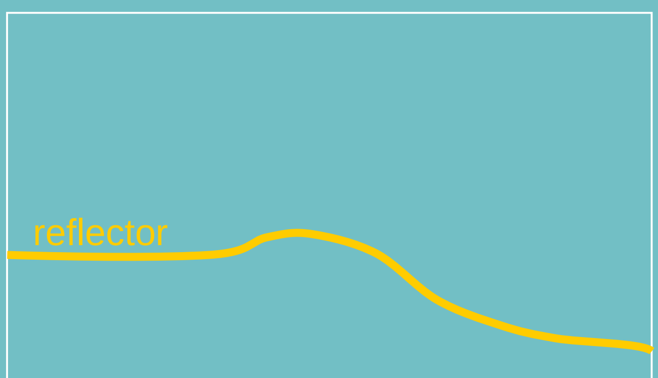
Refraction Statics Calculation

Refraction statics calculated from first arrivals on shot records, fine tuned by automatic residual statics, correct for time delays due to topography and low velocity regolith

- Short wavelength variations in two way travel time (TWT) misalign reflections and degrade the stack (sum of traces)



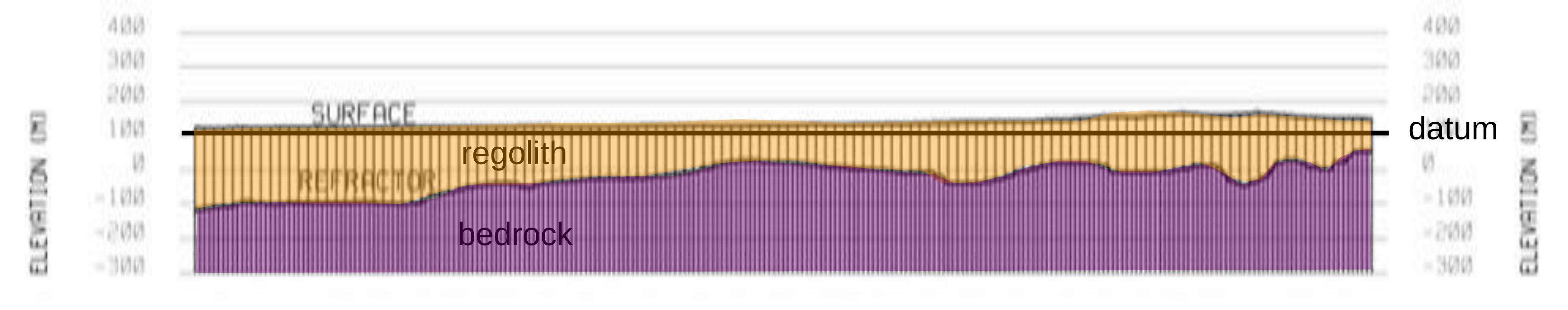
Depth



Time

- Long wavelength variations in TWT create spurious structure on seismic sections

Refraction Statics Calculation



- Subtract two way travel time in lower velocity regolith
- Add two way travel time from datum to bedrock at bedrock velocity
- Zero time on section normally corresponds to datum
- Size of static shift depends on datum

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Stacking (NMO) Velocity Analysis

NMO correction corrects for source/receiver offset

Stacking velocity is the velocity giving best stack

Velocity analysis is:

- **Done every 4 km (on average) along lines**
- **Repeated after dip moveout (DMO) correction**
- **Most critical and difficult in top 1 second**
- **Used as starting point for migration velocity**

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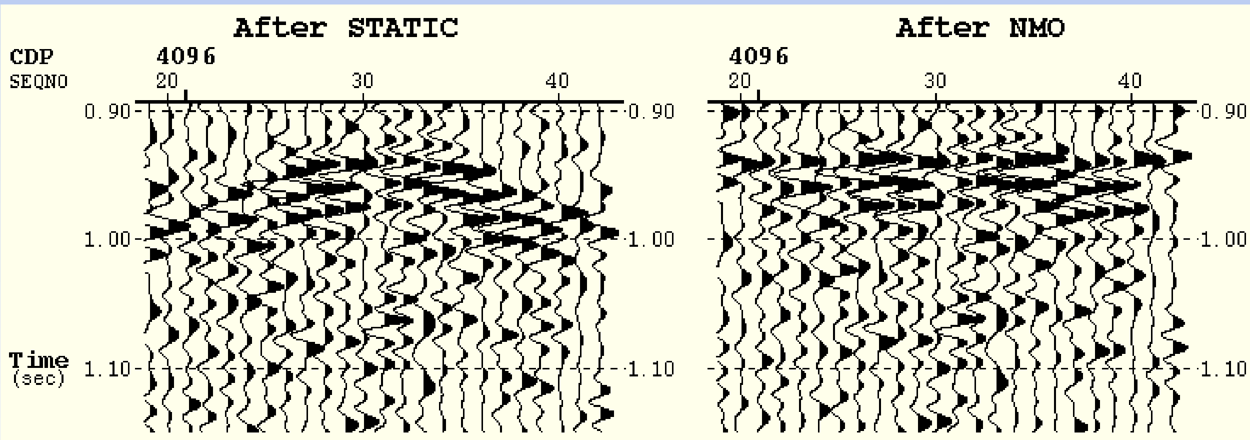
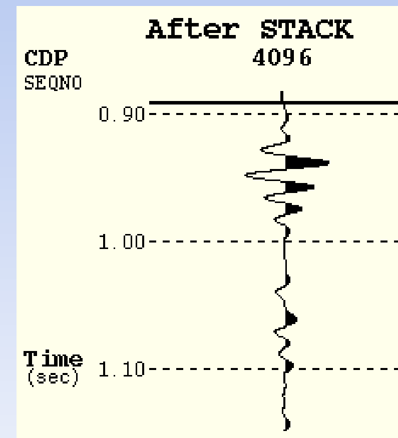
Normal Moveout Correction and Stack

Uncorrected CDP gather **Corrected CDP gather** **Stacked seismic trace**





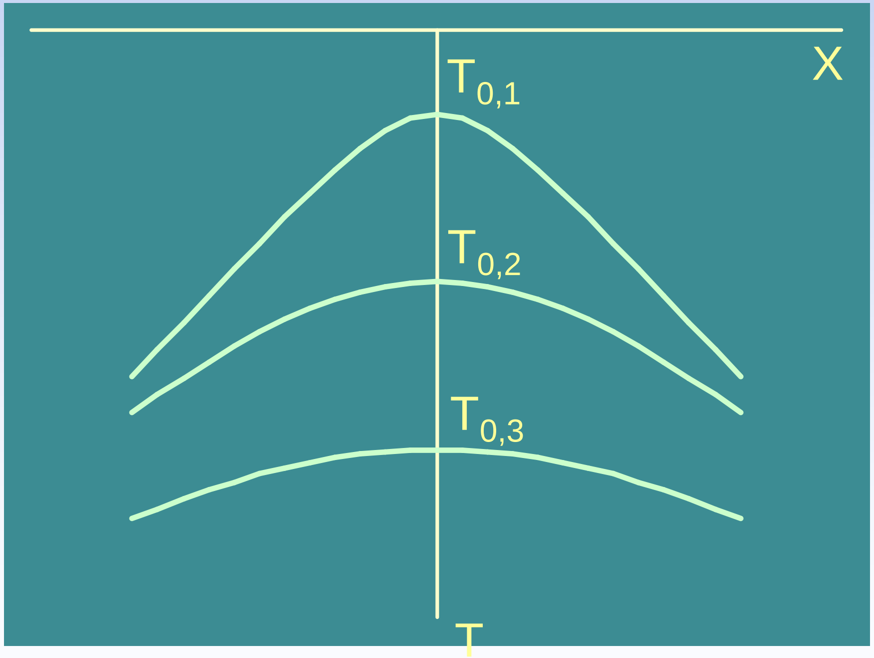
Stacking improves signal to noise by √n, where n is the fold

n	10	75	150
√n	3	9	12

Normal moveout (NMO) correction decreases with increasing time

Several horizontal reflectors

Uncorrected CDP gather



Moveout relationship

$$T^2 = T_0^2 + X^2/V^2$$

Larger velocity = less moveout

Greater TWT = less moveout

Can stack more easily in hard rock (or deeper in sed basins) with less accurate velocity estimates.

Velocity analysis most critical and difficult in top 0.5 s (also lower fold)

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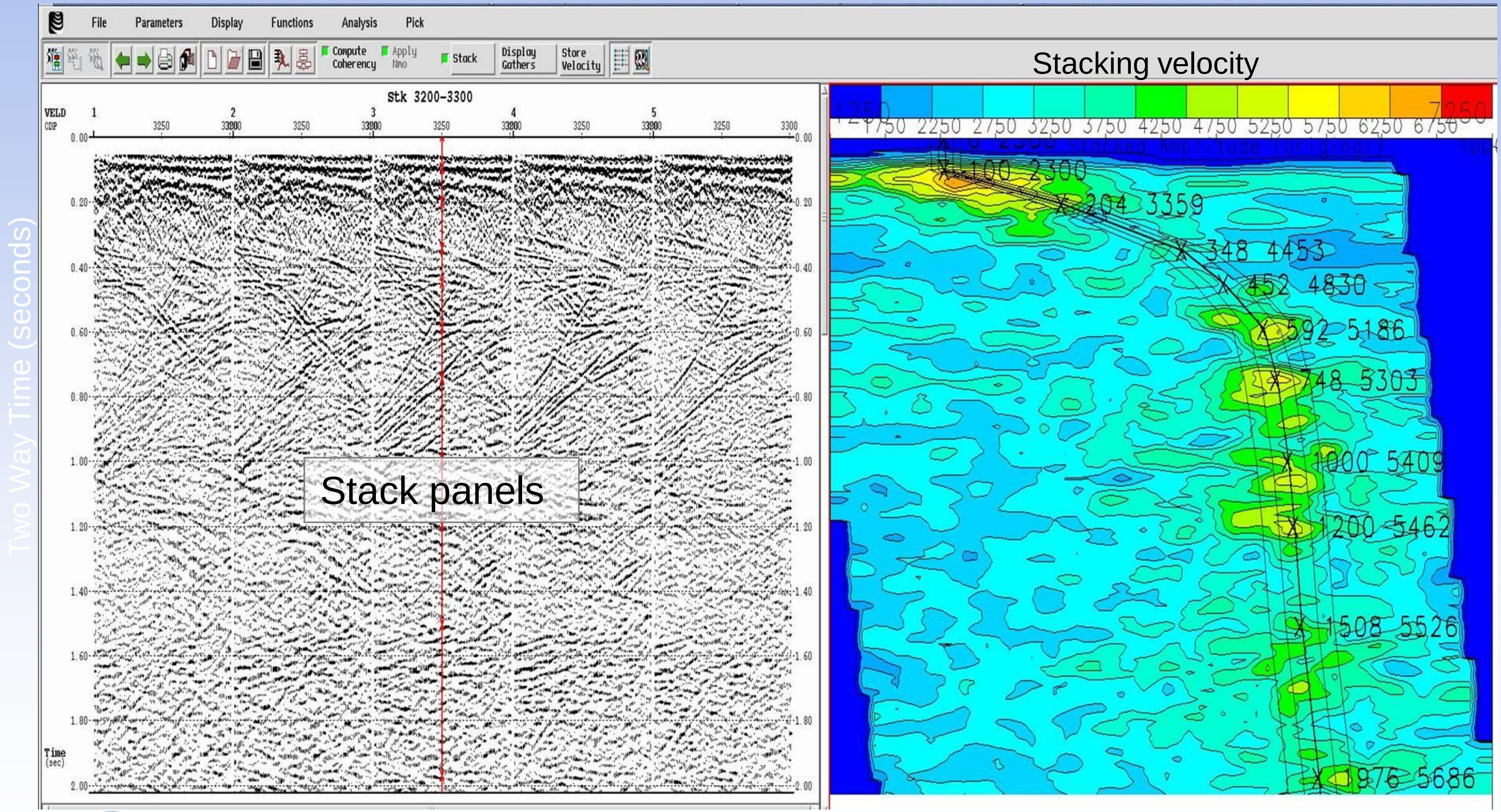
Post-DMO Velocity Analysis

Need to correct for the effect of dip on moveout using Dip Moveout (DMO)



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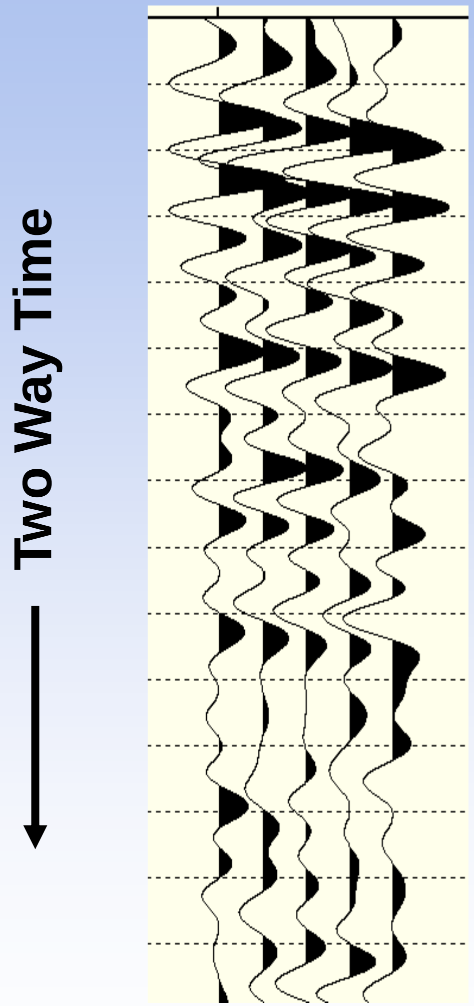
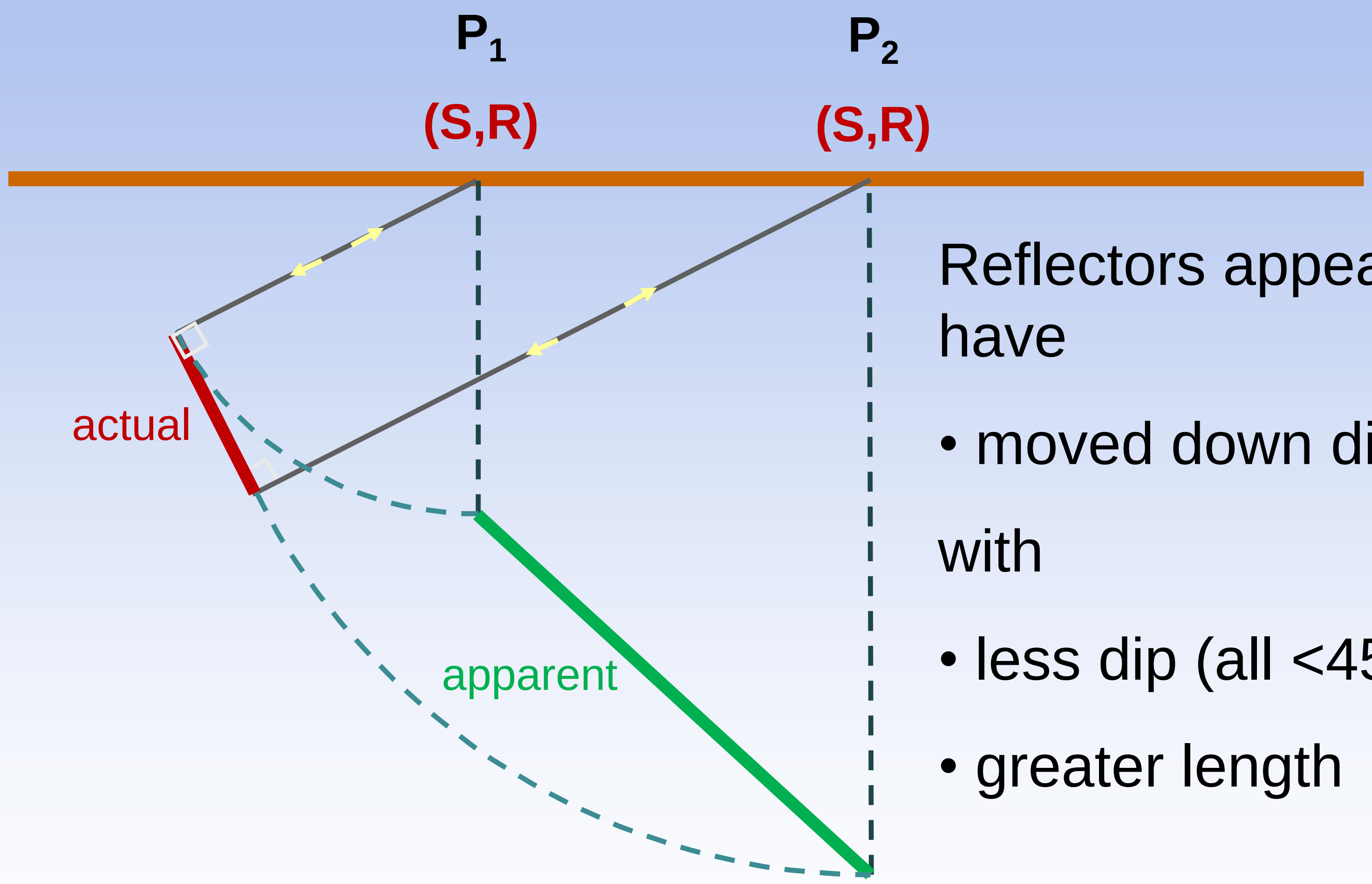
Seismic Section – Set of Stacked Traces



But ….

Seismic data are recorded in (two-way travel) time and the traces are displayed vertically with time increasing downwards

Imaging of Dipping Reflectors on Stack Section



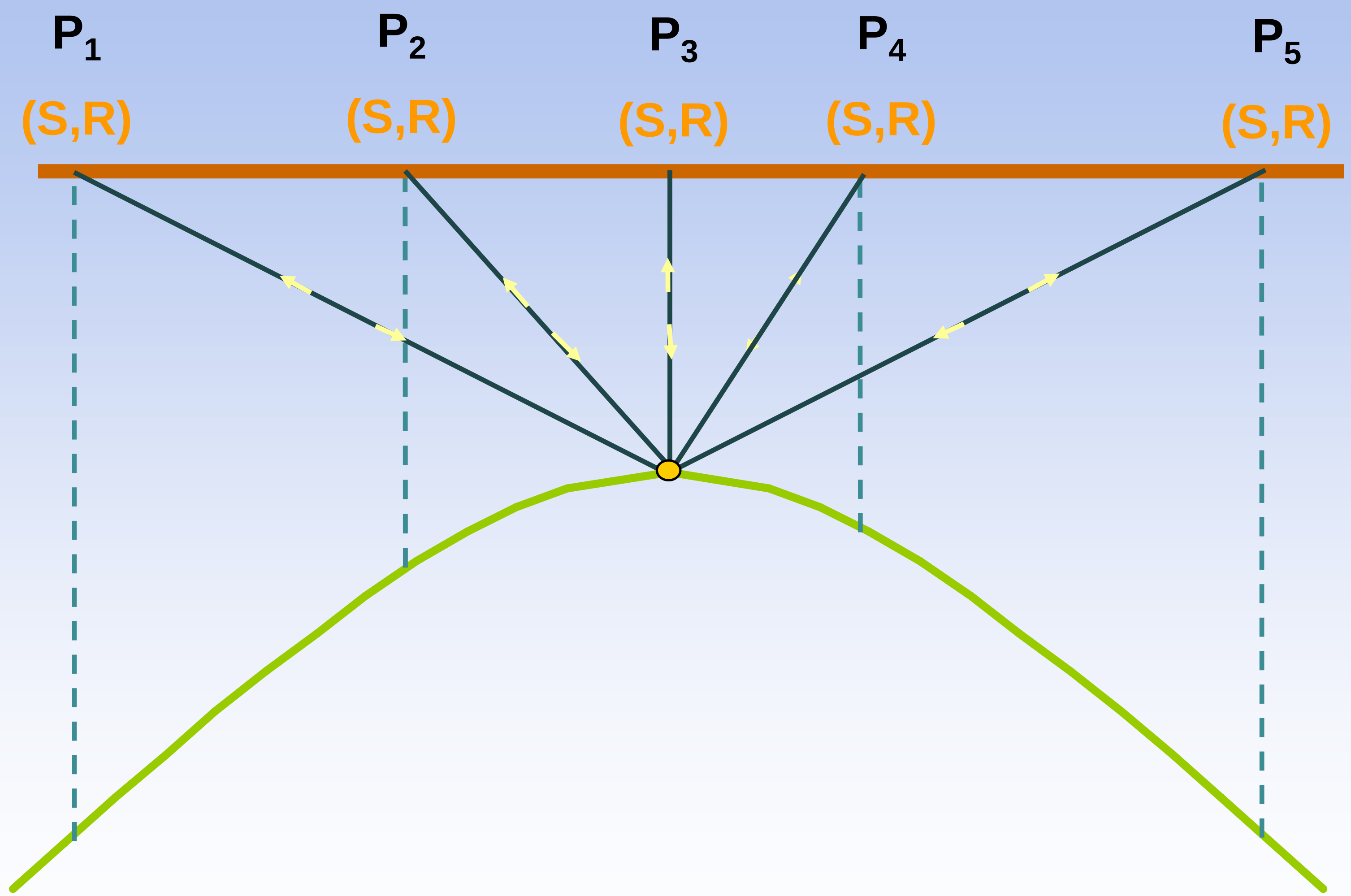
Reflectors appear to have

- moved down dip

with

- less dip (all <45°)
- greater length

Generation of Diffractions



Results of Migration

Migration improves a seismic image by

- moving reflectors to their correct positions
- steepening the dip of dipping reflectors
- collapsing diffractions

Migration can be evaluated by

- appearance of diffractions (curves vs ‘smiles’)
- juxtaposition of reflectors of different dip

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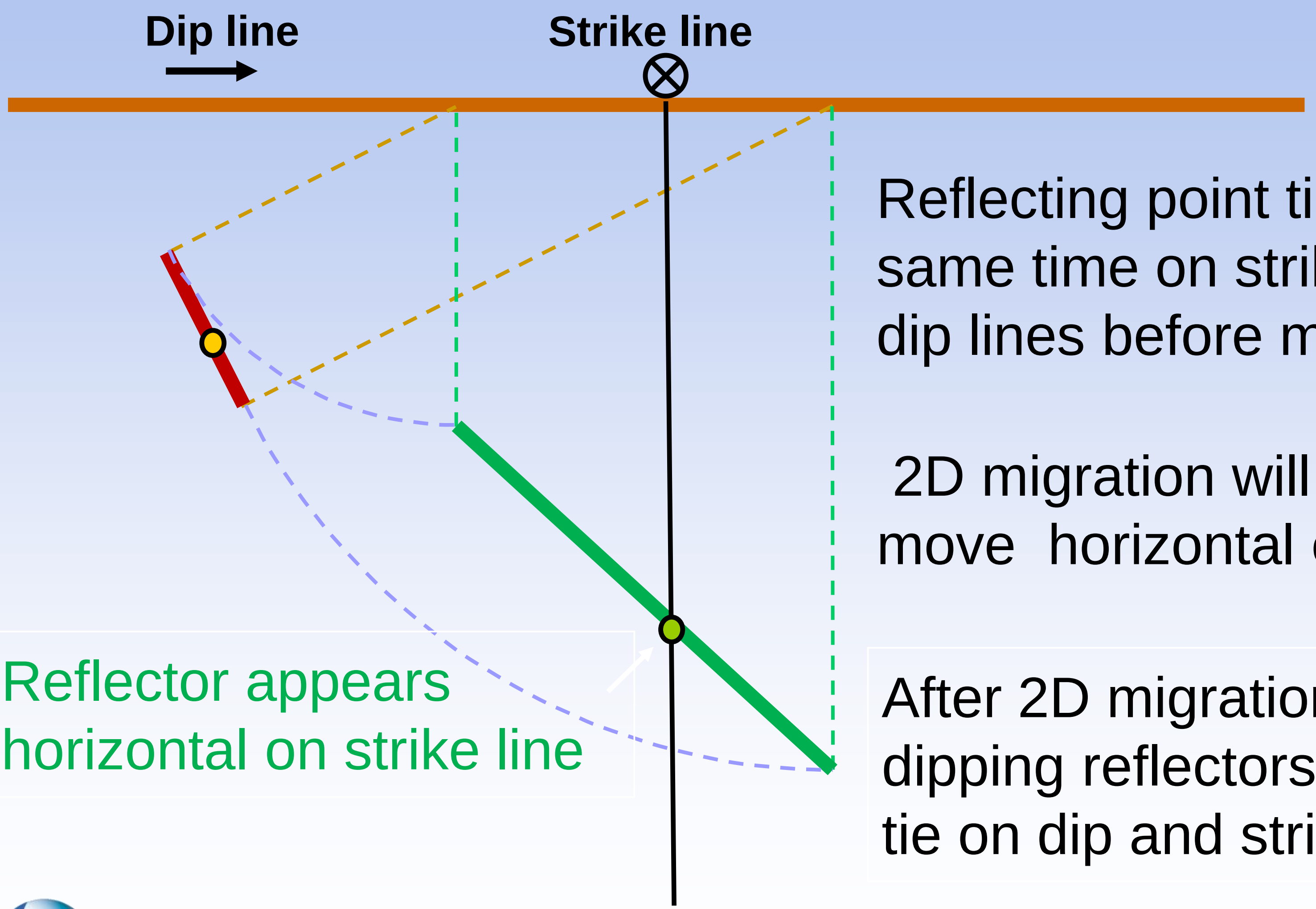
Limitations of 2D Migration



Reflecting point ties at same time on strike and dip lines before migration

2D migration will not move horizontal events

Reflector appears horizontal on strike line

After 2D migration, dipping reflectors will not tie on dip and strike lines

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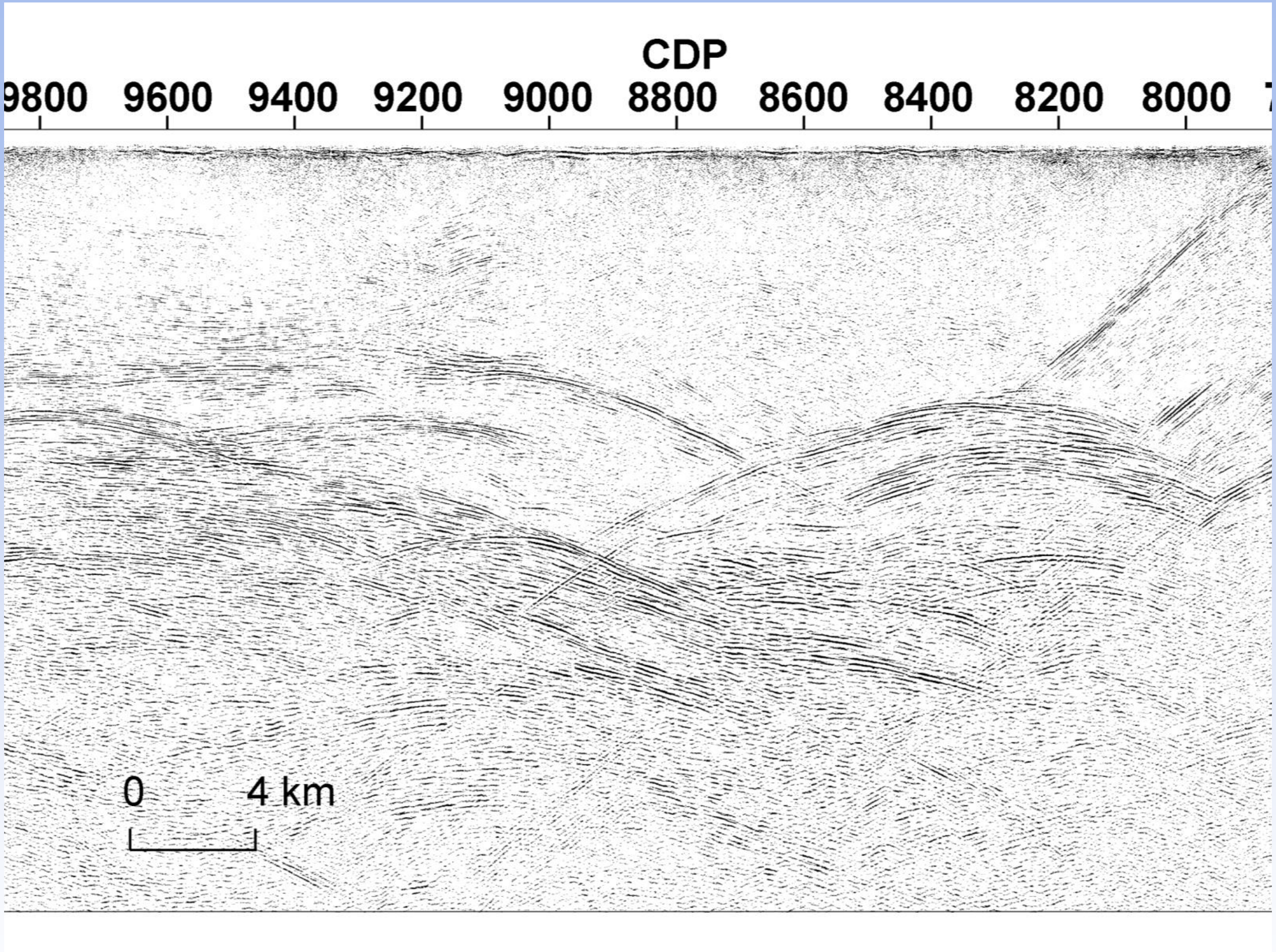
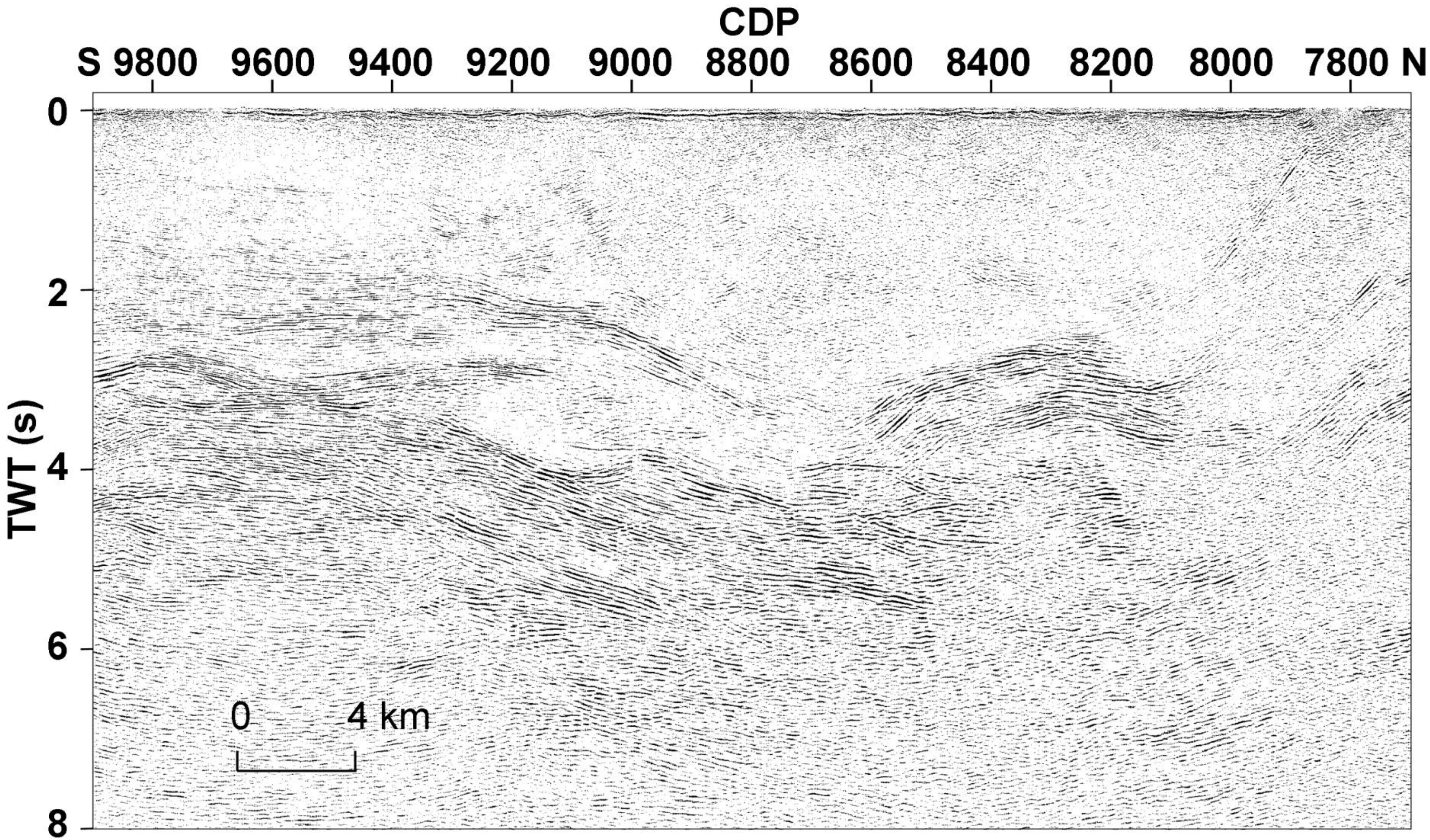


Portion of line CP1 – DMO applied



Portion of line CP1 – after Migration

Caveats for Interpretation

- Faults may be reflective, else identify by terminations
- Angular unconformities may have variable amplitude & polarity
- Dipping reflectors will not be imaged correctly if crossed obliquely
- Dipping reflectors at section ends may not be completely imaged
- 2D migration will not remove out of plane (sideswipe) reflections
- Curved events (migration smiles) at section edges are artefacts
- Seismic section is in two-way time – low velocity layers at top will appear thicker
- Seismic resolution of the order of 50 m in hard rock (to see top and bottom of a layer), better in sedimentary basins

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Conclusions

- 580 km of 75-fold deep crustal seismic reflection data were acquired for the Capricorn, using the CDP continuous profiling method.
- Geoscience Australia processed the data, using commercial industry standard software.
- Key steps included refraction statics and velocity analysis. DMO and migration were essential for imaging steep reflectors.
- High quality seismic sections imaged the crust from the base of regolith to Moho, revealing previously unknown structures in areas of no outcrop.

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