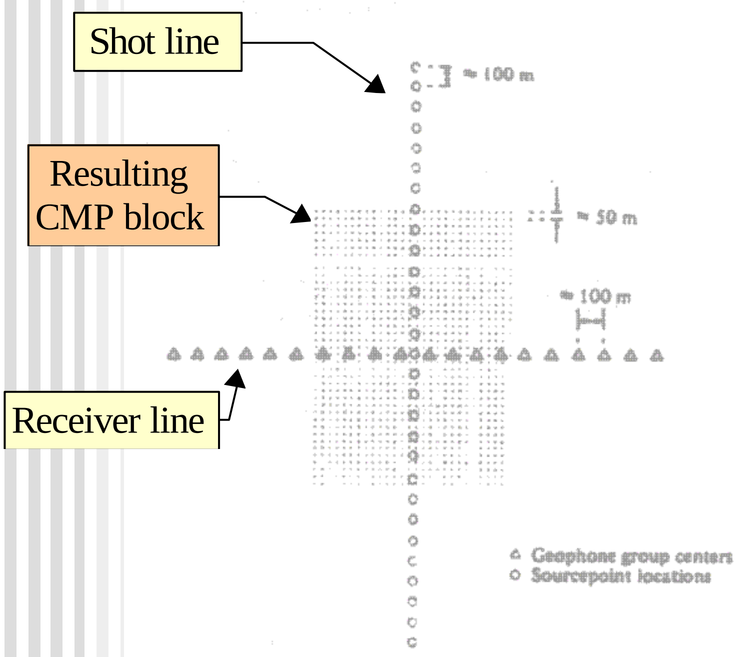
Reflection seismic method - 3D

- 3-D acquisition
- 3-D binning
- Land
- Marine
- 3-D data processing and display

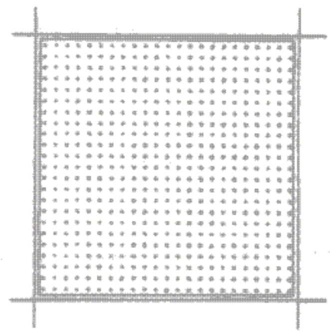
- Reading:
  - Sheriff and Geldart, Chapter 12

Land 3-D acquisition

- Key considerations in 3D work:
  - Cost – minimize the number of source points
  - Offset-azimuth uniformity
  - Uniformity and fidelity
  - Control of the *acquisition footprint*
- For comparable data quality, 3-D work usually requires about ½ of the fold necessary in 2-D



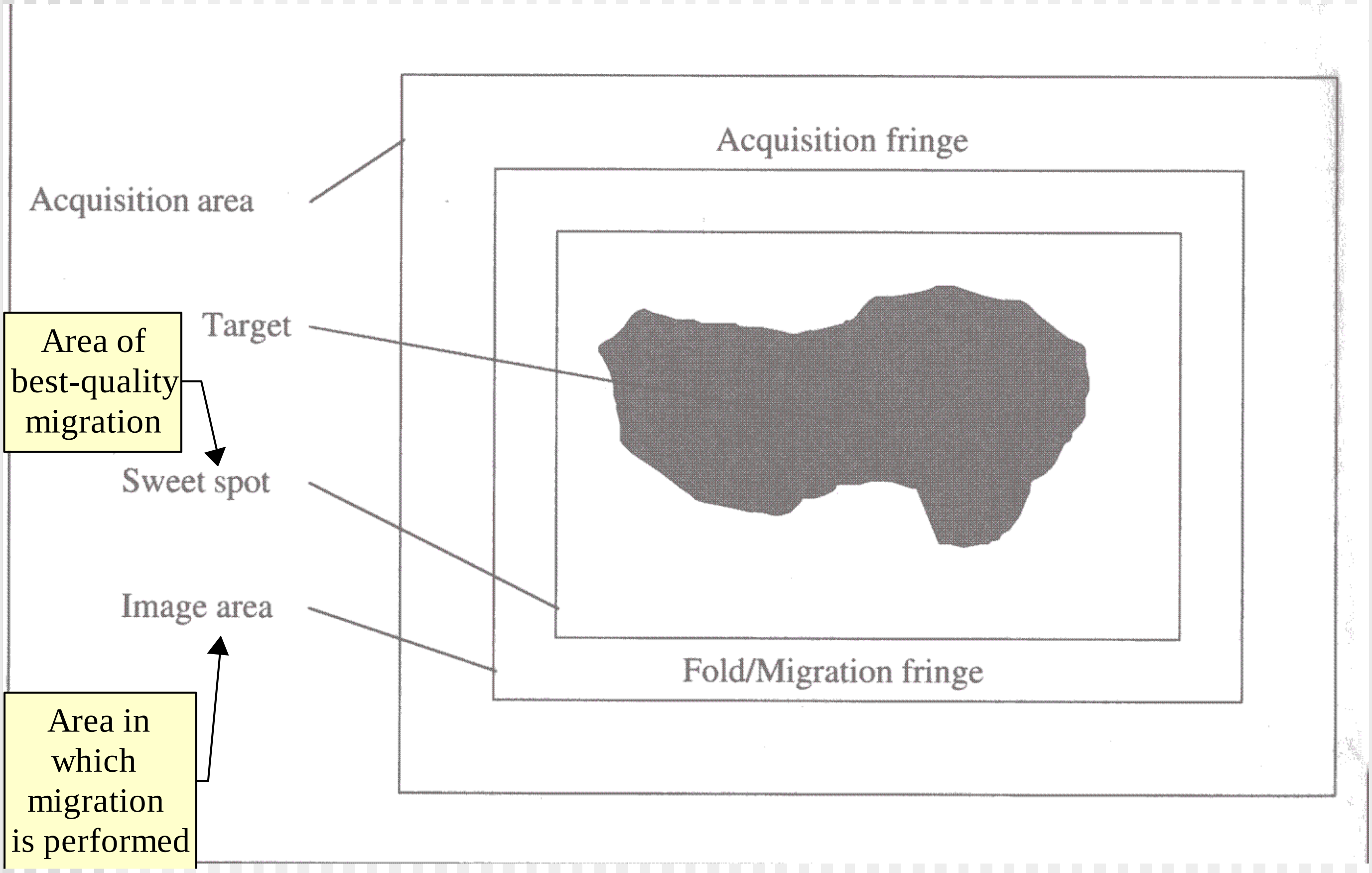
Land patch acquisition



Loop
(sources and geophones around the perimeter)

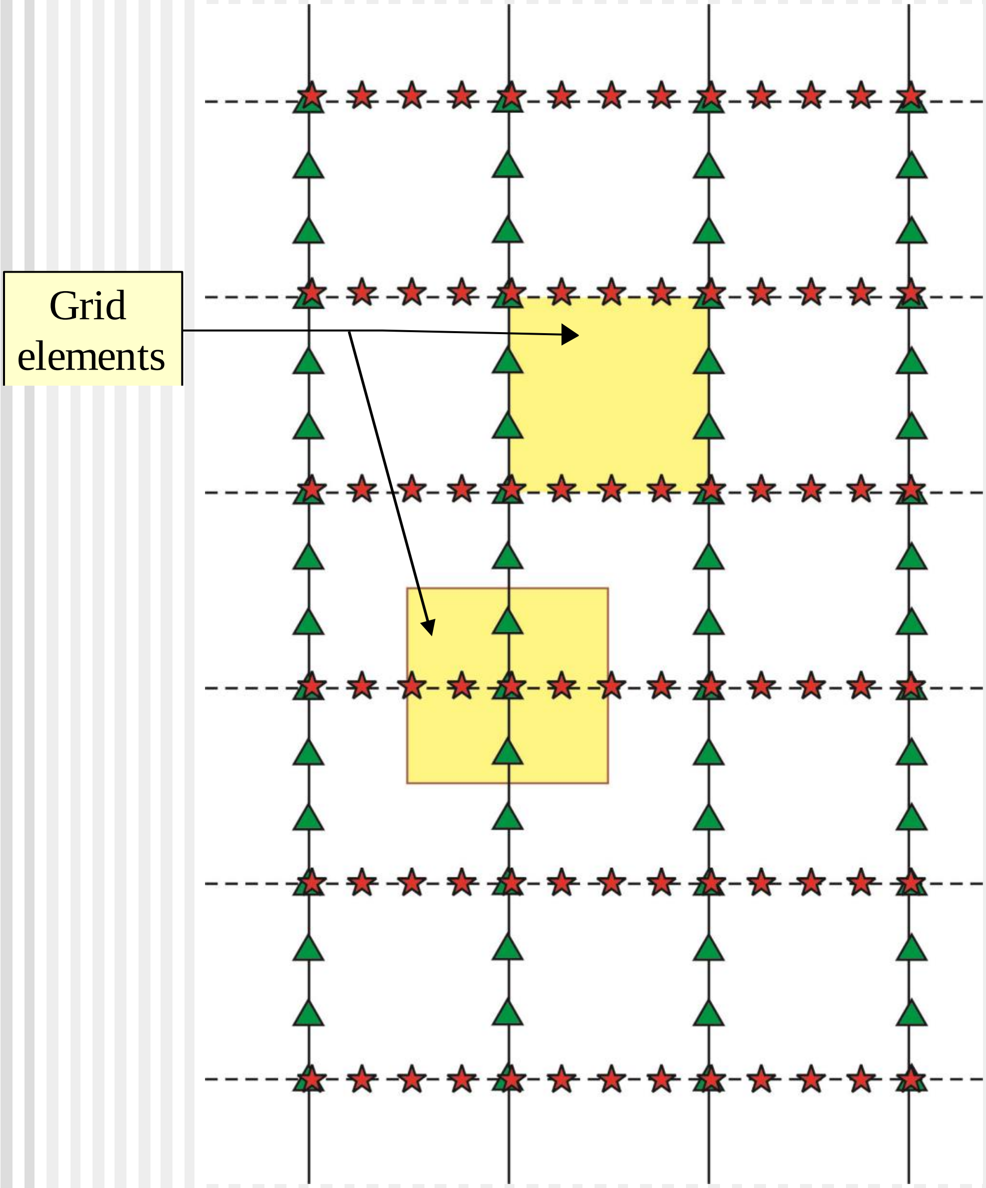
Acquisition fringe

- When planning a reflection survey, and particularly 3D, it is important to ensure that the resulting dataset can be processed to produce adequate coverage of the desired target
- In order to ensure uniform coverage of the target area after migration, data must be acquired across an area expanded by two "fringes":



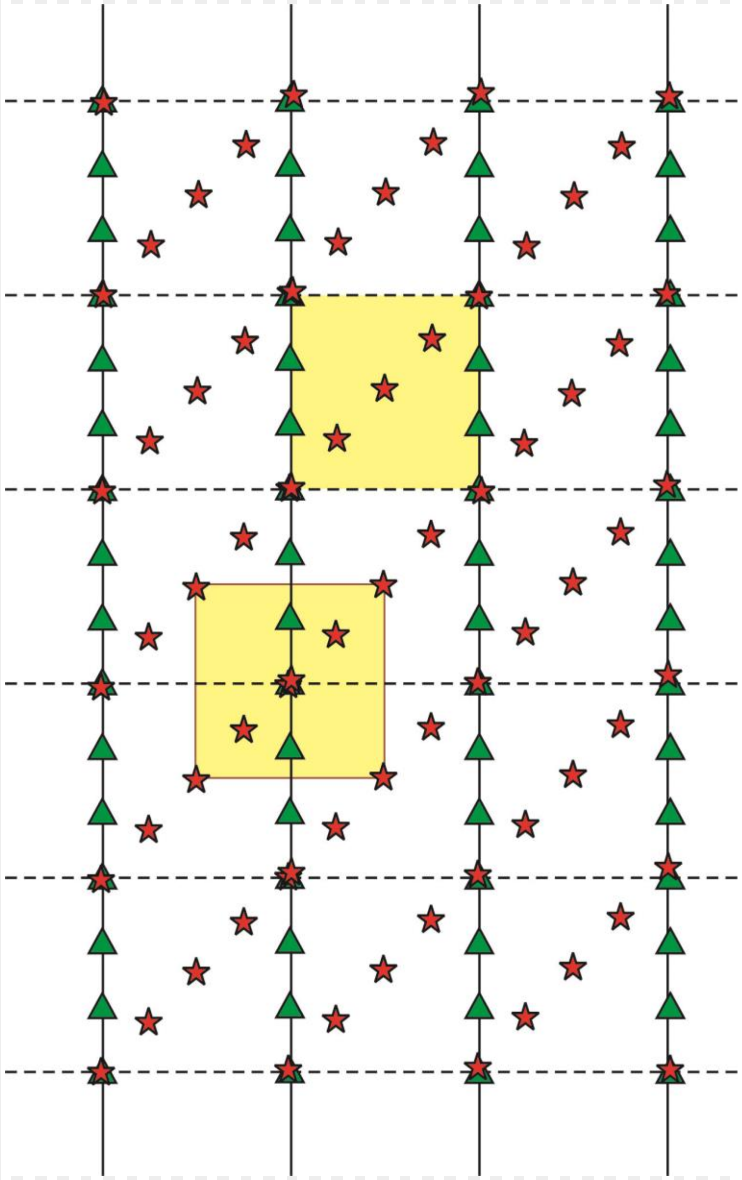
Land acquisition patterns
Orthogonal

- Simple, but non-uniform azimuthal coverage



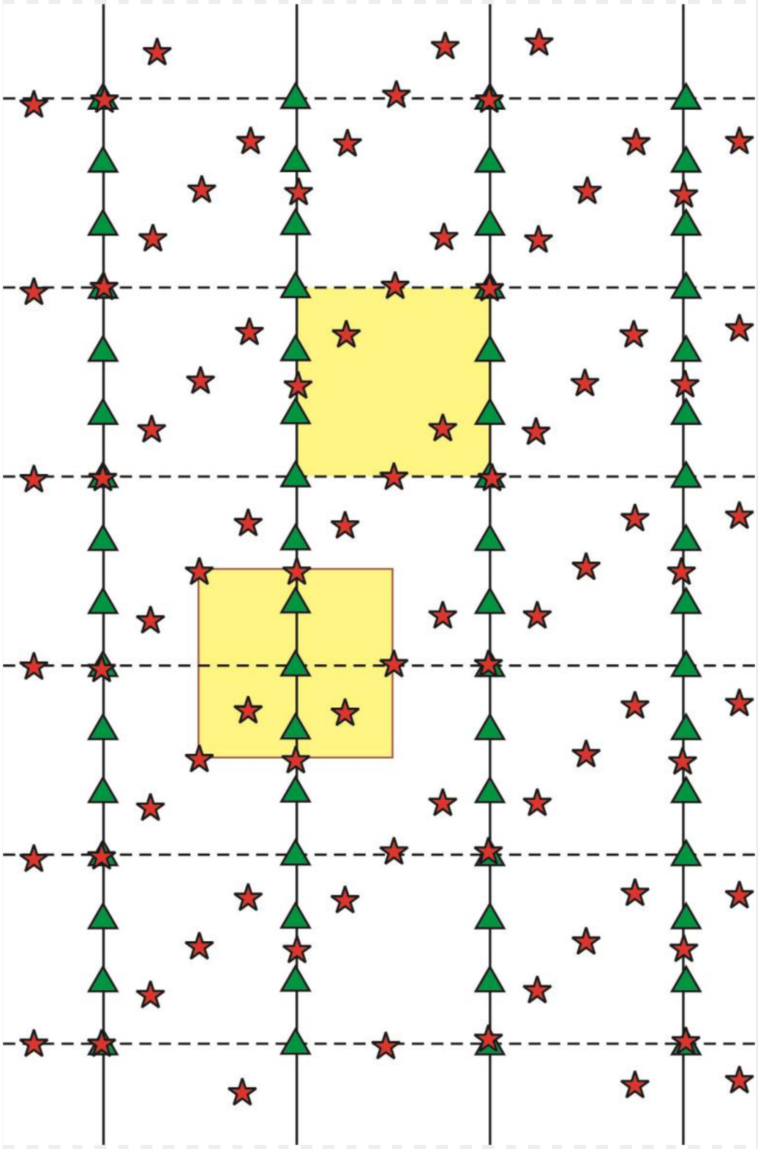
Land acquisition patterns
Diagonal

- Most popular, better uniformity of azimuthal coverage



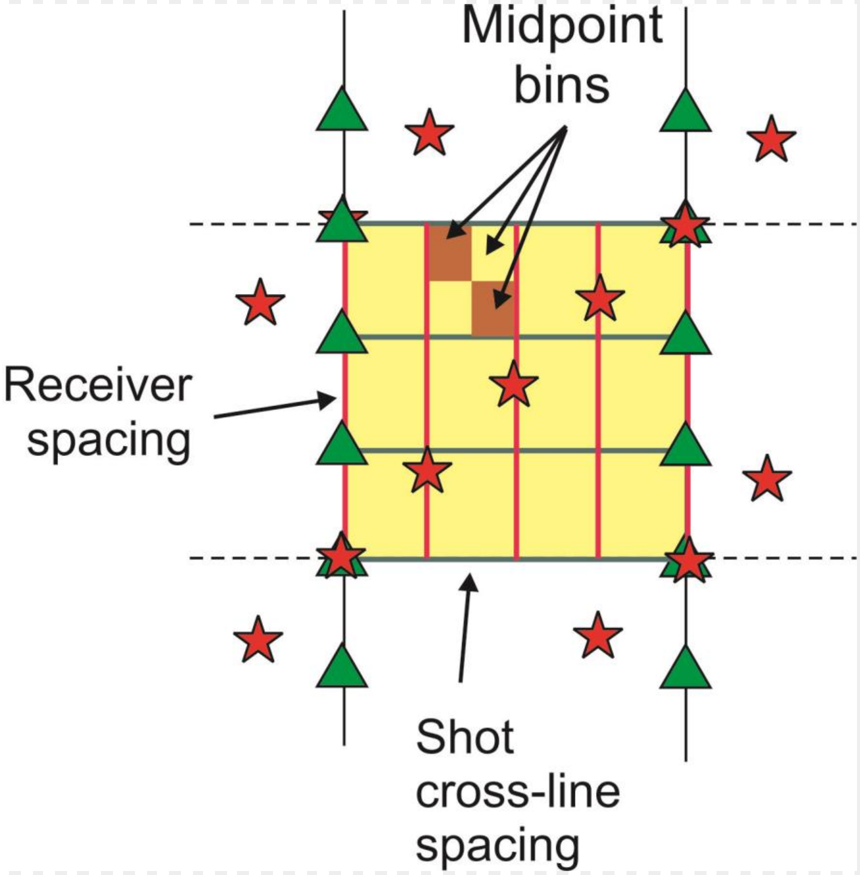
Land acquisition patterns
Staggered diagonal

- Best uniformity of azimuths, but more difficult to implement



CMP binning in 3D

- For all patterns, binning of the elementary grid cell is the same
- Controlled by ½ receiver (in-line) and source (cross-line) spacings



Calculating CMP fold in 3D

- In 2D, the nominal CMP fold (expected number of records with midpoints within a given CMP bin) is given by the formula that you should remember:

$$\text{CMP\_fold} = \frac{N_{ch}}{2k}$$

where N_{ch} is the number of channels recording each shot, and k is the number of geophone spacings per shot spacing

- **How to calculate the fold in 3D?**
- The answer is by basically the same formula, only you need to understand its meaning like this:

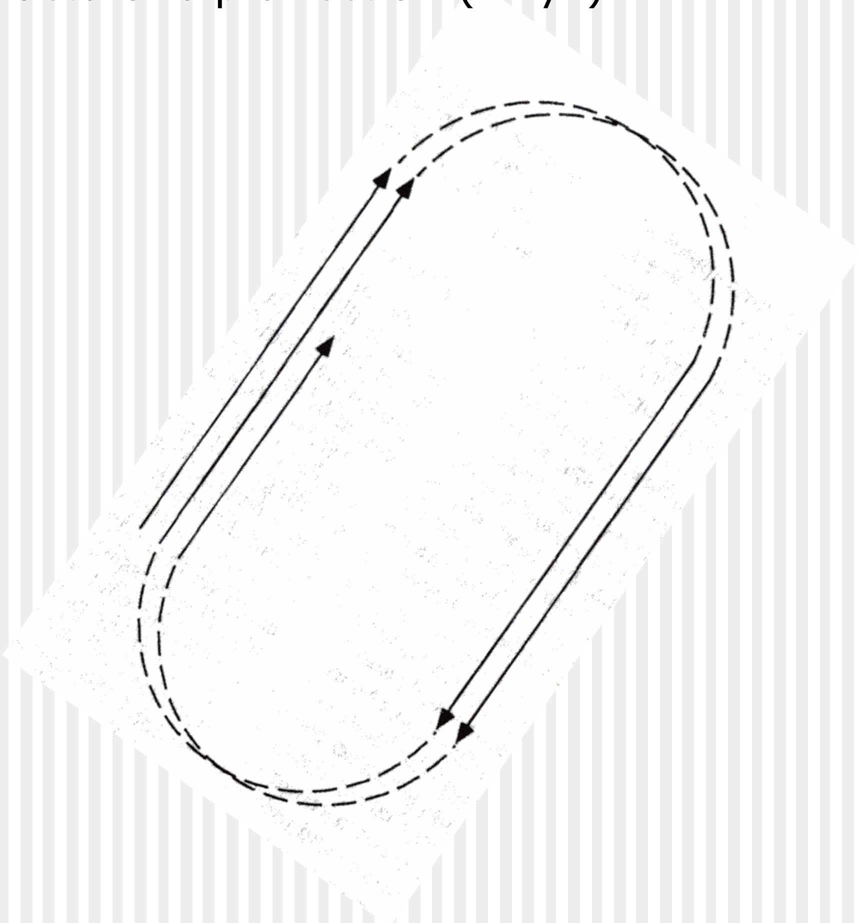
$$\text{CMP\_fold} = \frac{N_{\text{records}}}{N_{\text{CMP\_bins}}} = \frac{N_{ch} \times N_{\text{shots}}}{N_{\text{CMP\_bins}}}$$

where N_{shots} and $N_{\text{CMP\_bins}}$ are the "nominal" number of shots and CMP bins within the whole survey or its representative block shown by yellow in the preceding slides. Note that for 2D: $N_{\text{CMP\_bins}} / N_{\text{shots}} = 2k$ (there are two CMPs per receiver spacing and k receivers per shot spacing)

- For 3D, the representative block is shown by yellow in the preceding slides, and you can easily count the N_{shots} and $N_{\text{CMP\_bins}}$ within it.

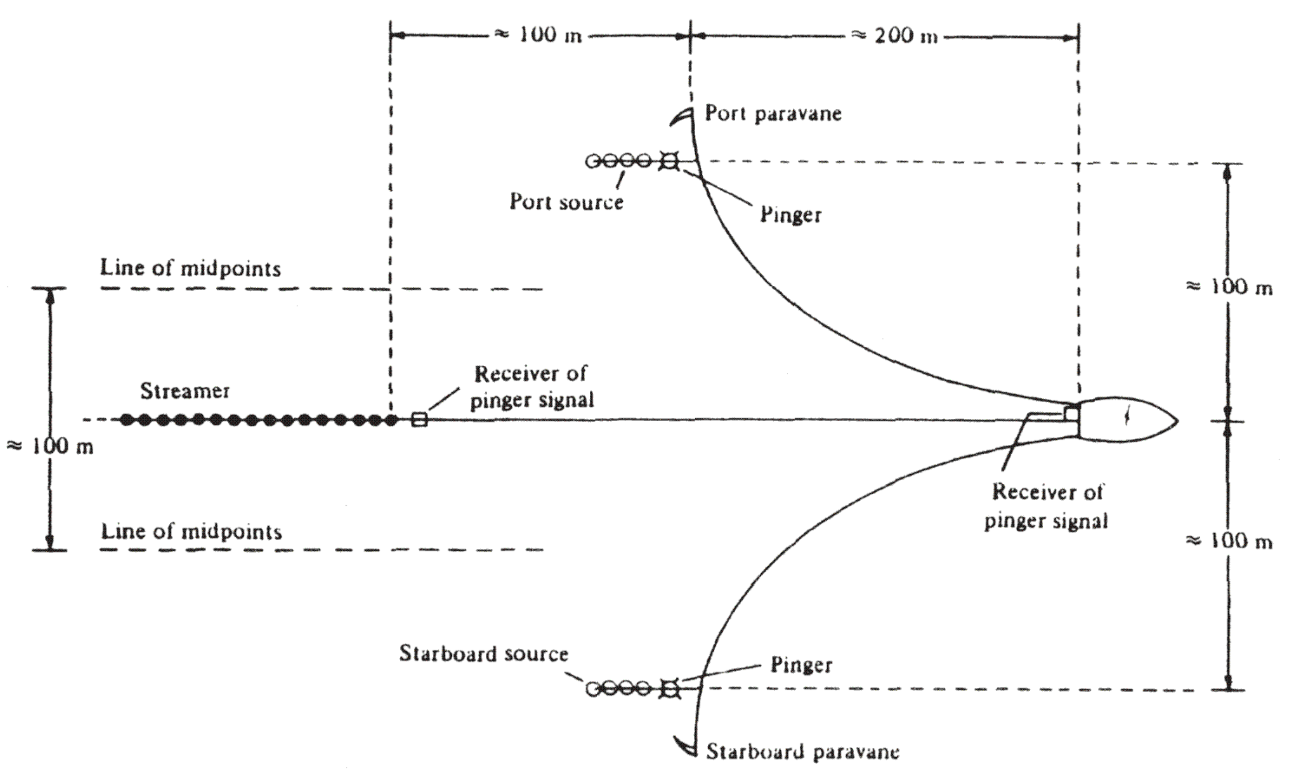
Marine 3-D acquisition

- Marine 3-D data are generally acquired using a boat towing a hydrophone array (*streamer*) and an array of air guns.
- The boat traverses the area back and forth:
- Shot/receiver lines are oriented parallel to the structural dip direction (why?).



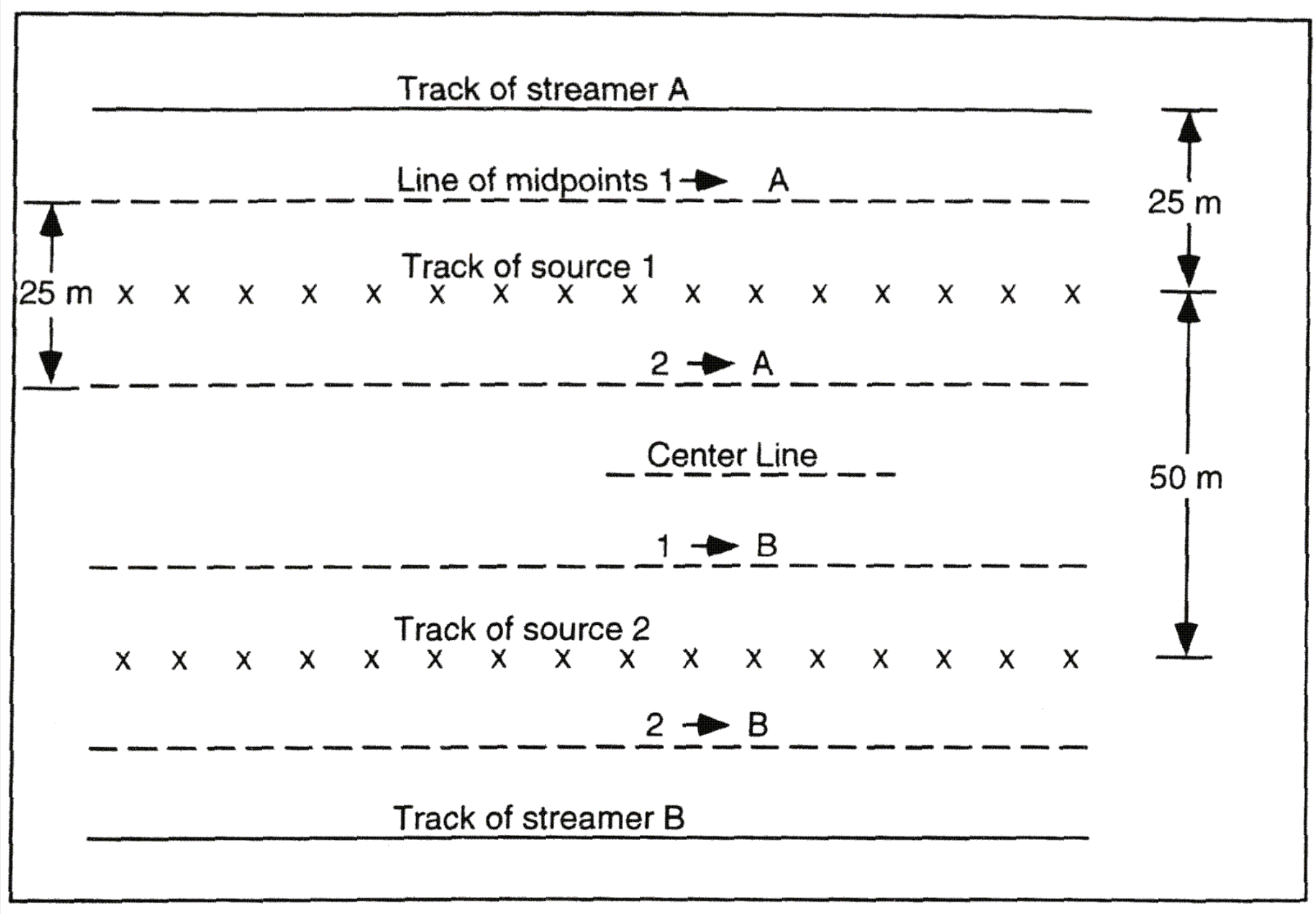
Marine 3-D acquisition

- To save on the costs, several (up to 6) parallel streamers can be towed by one ship
- Or, two source arrays firing in an alternating order can create two lines of midpoints in one pass of the boat:



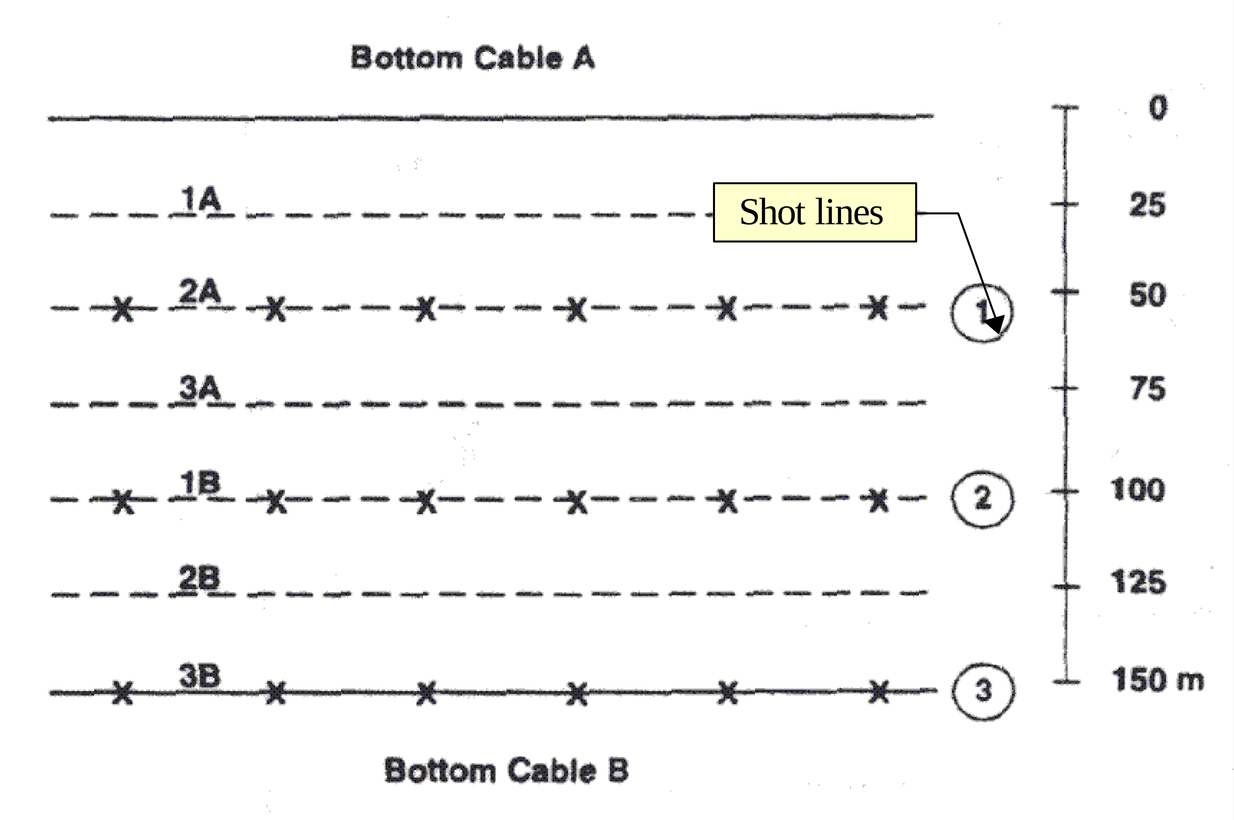
Marine 3-D acquisition

- Typical geometry with two source arrays and two streamers:



Marine swath shooting

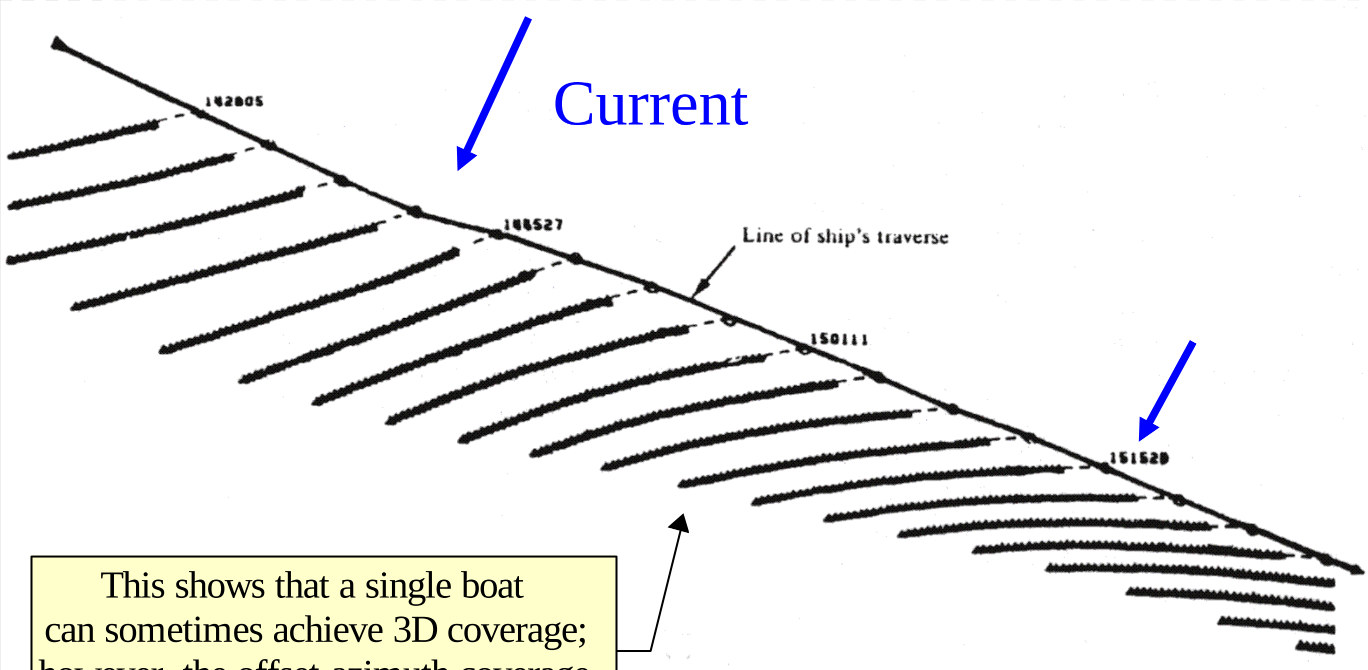
- In shallow water where streamers cannot be towed, bottom hydrophone cables can be deployed in *swaths*
- A source boat will move along, across, or zigzag between the cables to cover 3D volume



Note that this particular pattern gives good in-line but poor offset-azimuthal coverage

Streamer feathering

- Due to cross-current, the streamers and sources often deviate away from the track.
  - This shifts the actual reflection midpoints and creates uneven fold.
- Therefore, *accurate positioning* of all components is critical.



This shows that a single boat can sometimes achieve 3D coverage; however, the offset-azimuth coverage here is not great (e.g., unreversed)

Streamer/Airgun array Positioning

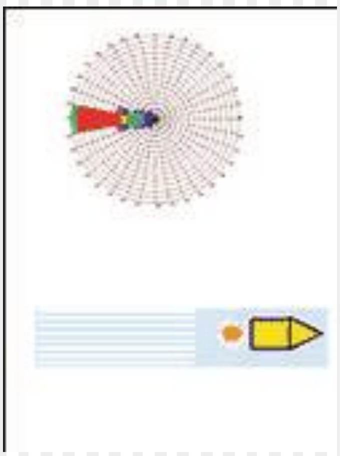
- GPS and radio trilateration of the ship (to ~10-m accuracy)
  - Sometimes anchored *pingers* are also used to locate the survey within an area.
- *Pingers* (tuned acoustic pulse devices) are used to trilaterate the mutual positions of the ship, sources, and streamers.
- Feathering direction is controlled with compasses installed in the streamer.
- This results in *great redundancy* of navigation data.
  - This redundancy is utilized in data reduction using the ideas of the Generalized Inverse...
- Recent development – accurate steering of the streamer (“Q Marine” technology)

Precise steering allows collecting "full-azimuth" marine data

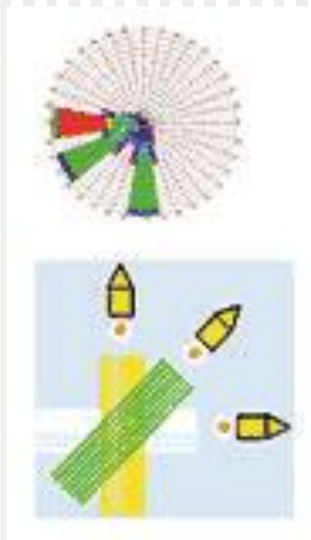
WesternGeco *Magellan*
6 steered streamers

"Coil shooting"
(WesternGeco)

Azimuth marine recording



Single-azimuth



Multi-azimuth
(MAZ)

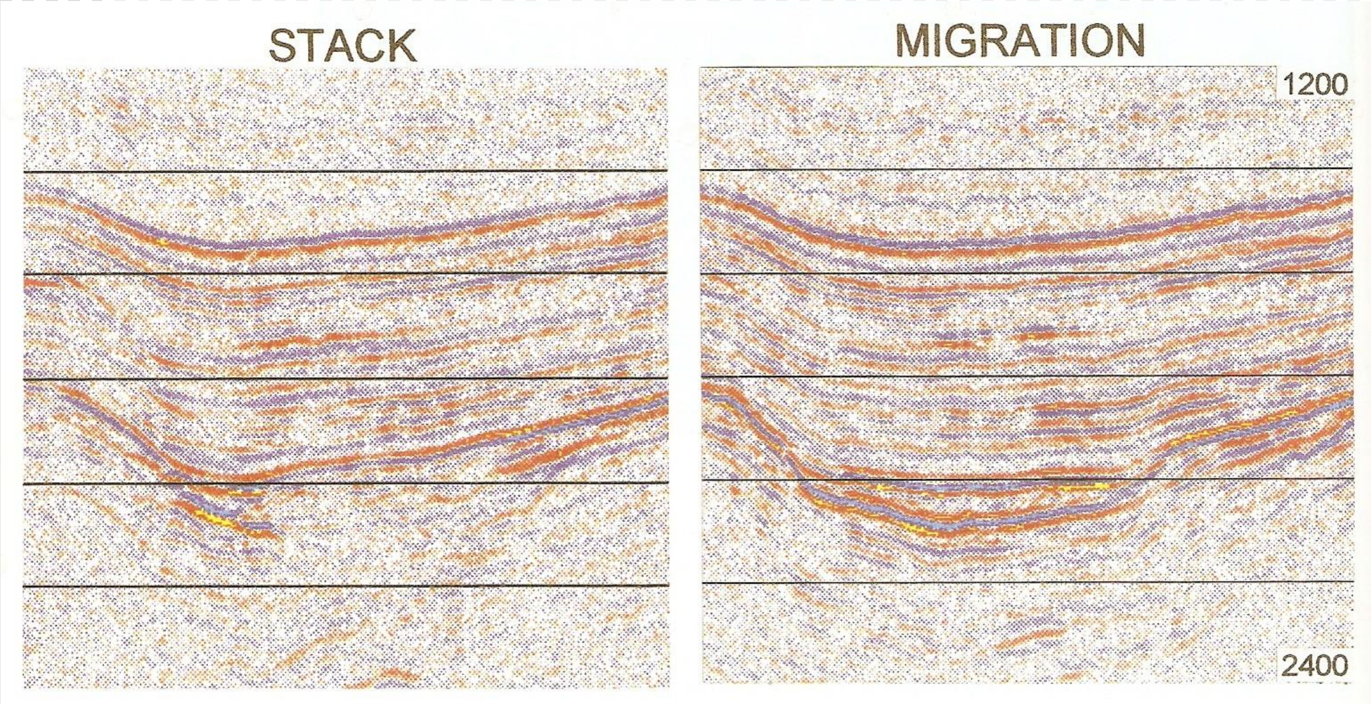
Wide-azimuth
(WAZ)

MAZ+WAZ = RAZ

"Rich-azimuth"

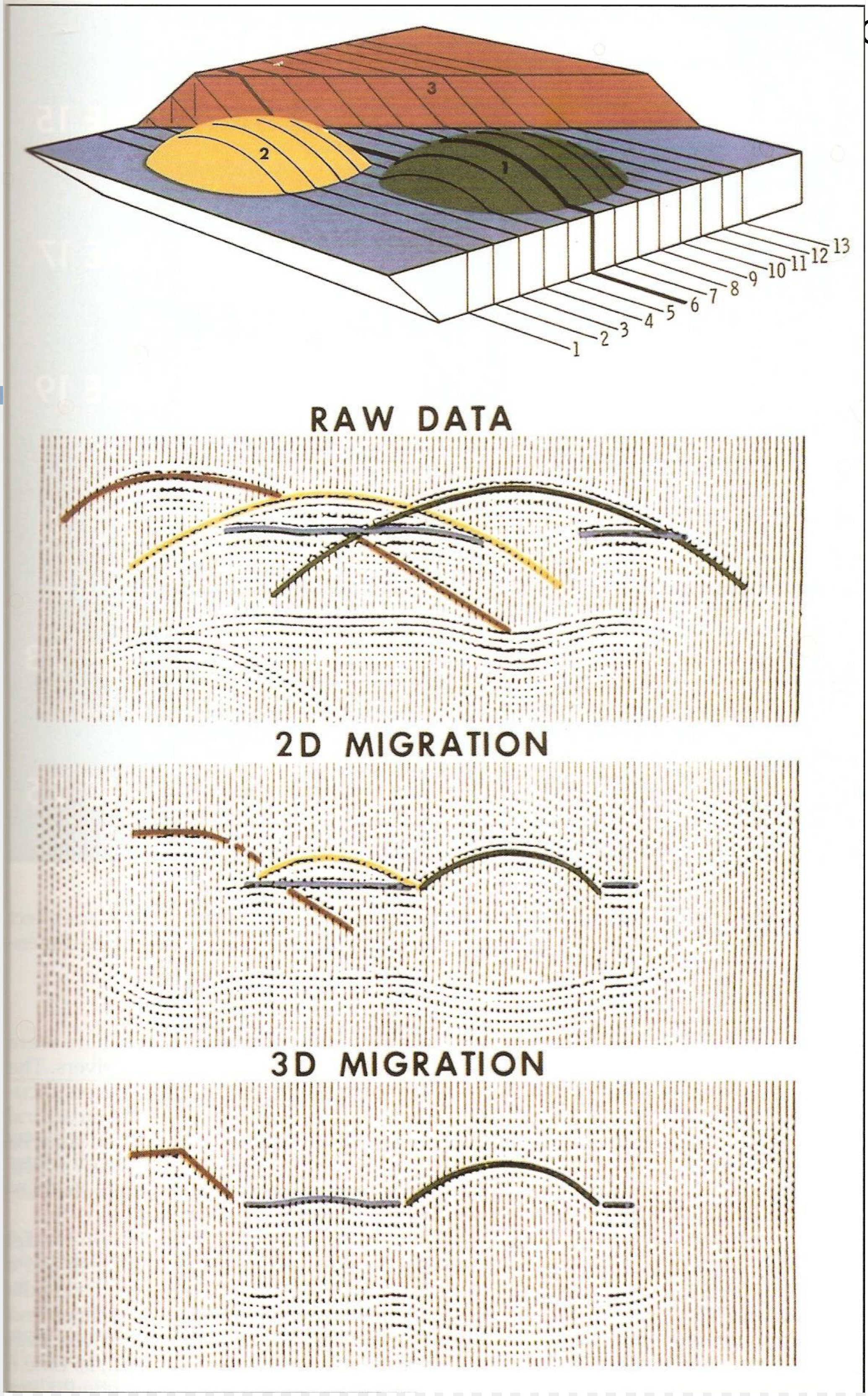
3D Imaging

- 3D acquisition provides adequate data for accurate 3D imaging of the subsurface



Example of image improvement from 3D migration

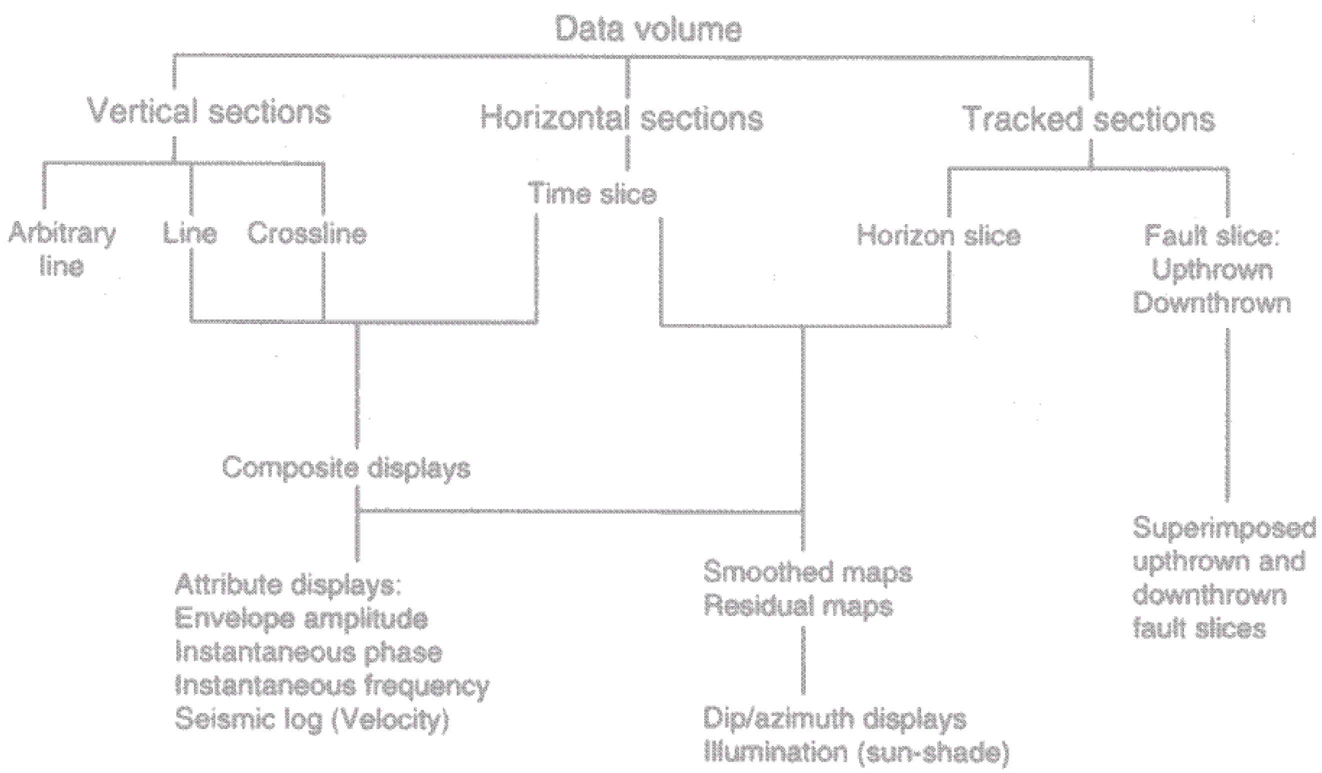
(South Australia, Santos Ltd.)



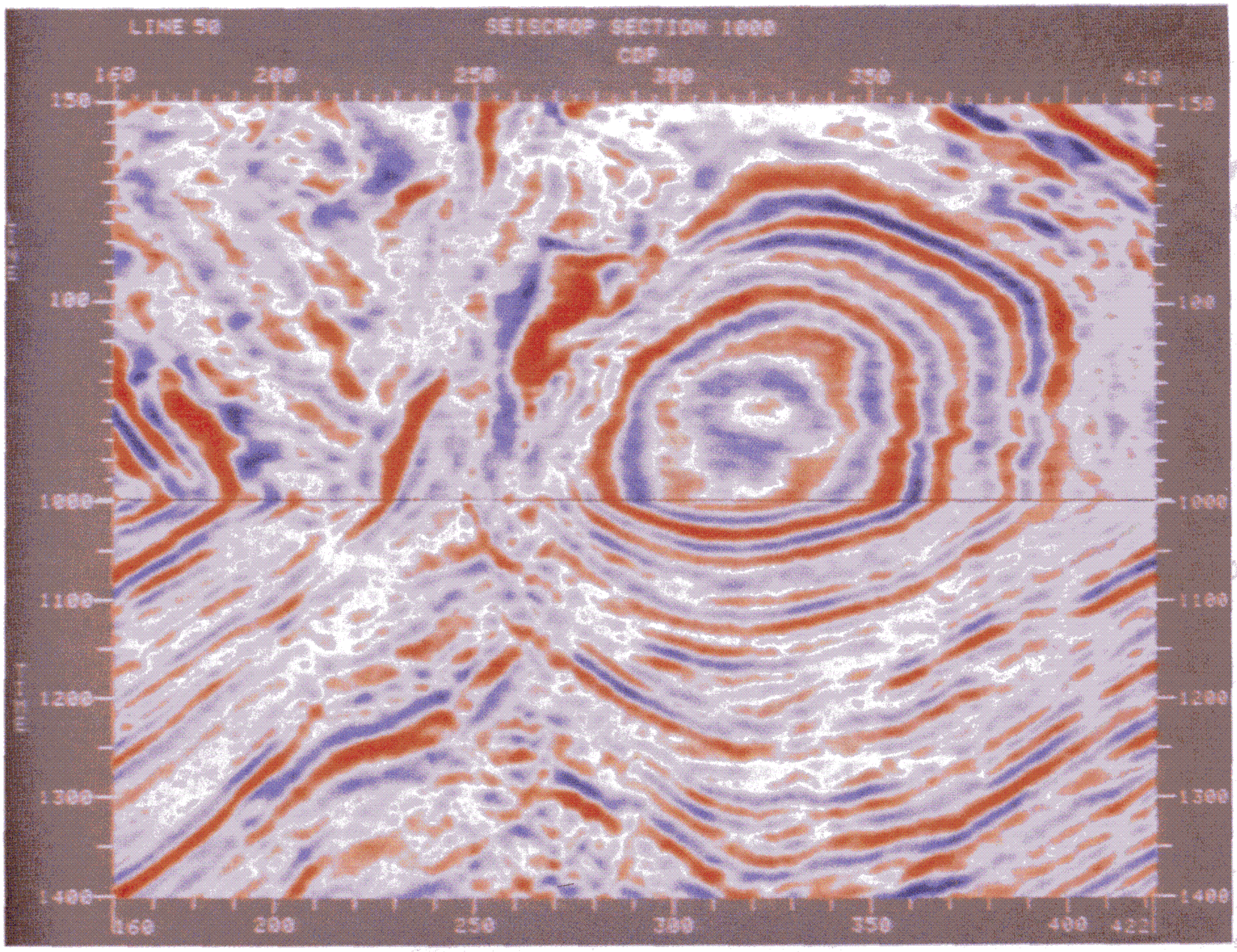
- Comparison of the effects of 2D and 3D migration (French, 1974)

3D data displays

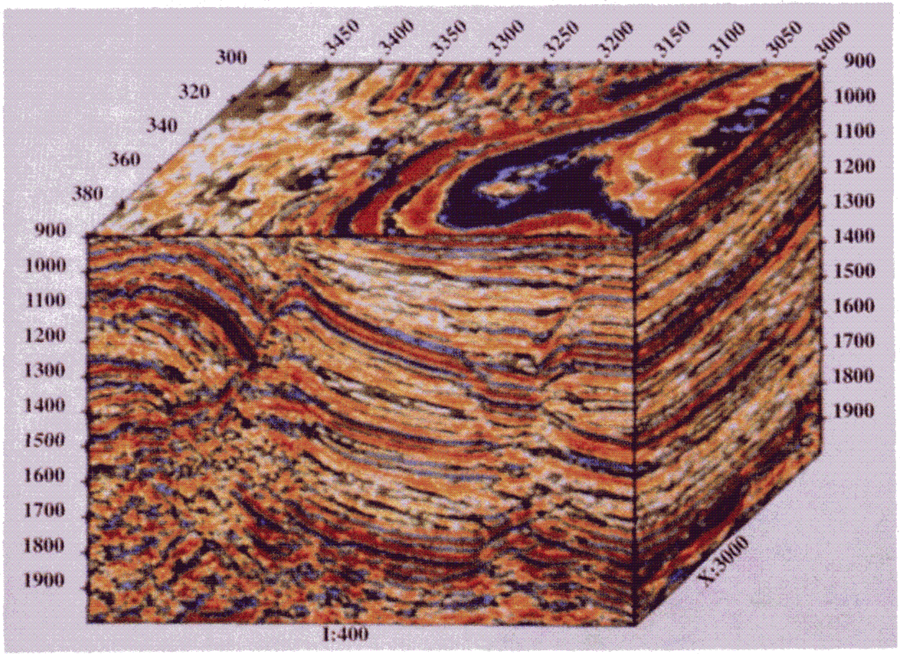
- A variety of geometrical types
- Attributes (amplitudes, their gradients, phases, acoustic impedance, porosity, directions, statistics)
- Colour (continuous or discontinuous palettes to highlight gradational character or contrasts)
- Interactive analysis using workstations



3D displays (Sheriff and Geldart, plate 7)



(a)



(b)

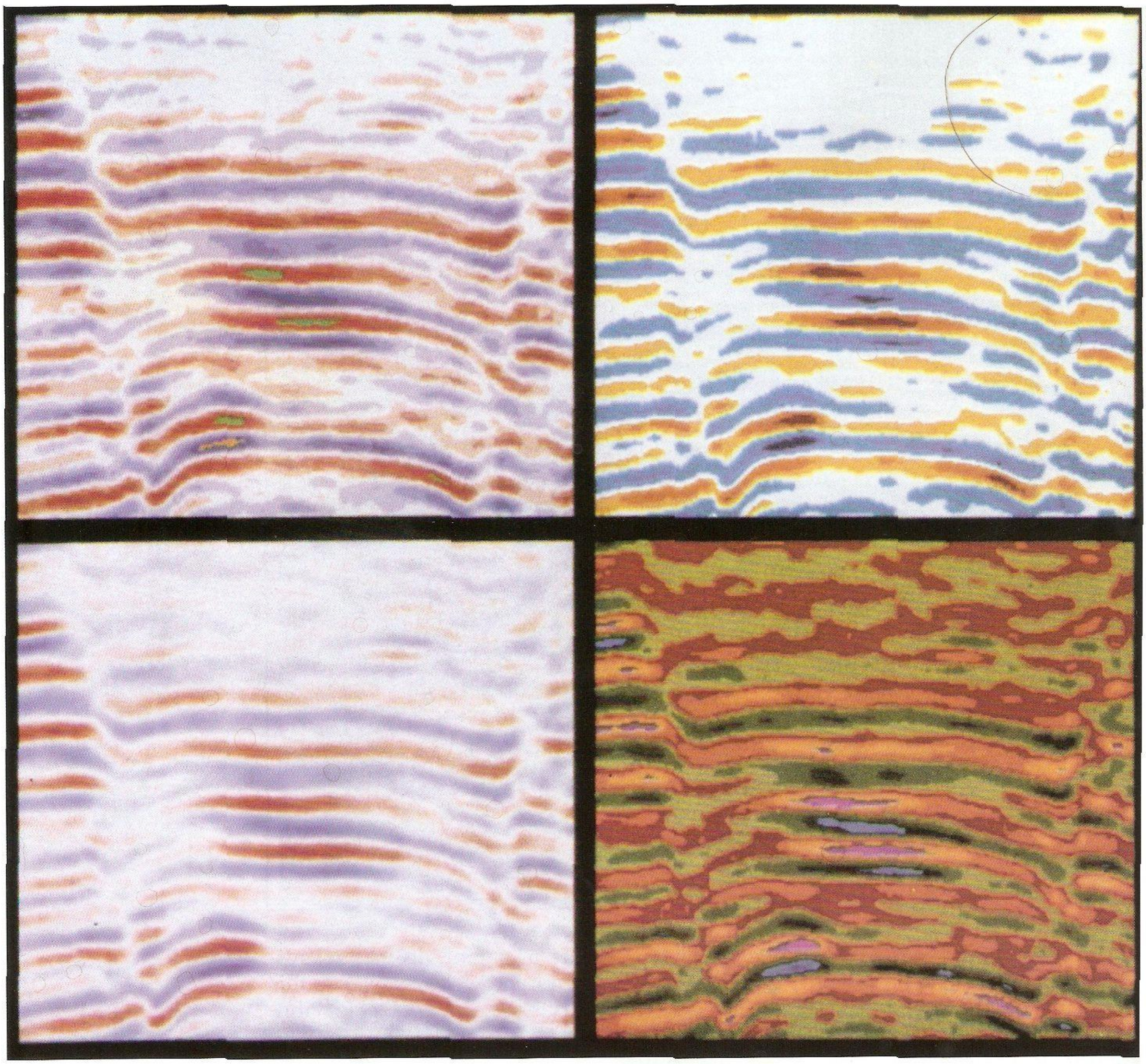
Use of colour

- For a zero-phase reflection from a positive impedance contrast...
  - American convention is POSITIVE amplitude
  - European (and the rest of the world's) convention is NEGATIVE amplitude
- Positive amplitudes are usually painted BLUE in seismic sections
- Negative amplitudes are usually RED

- Numerous colour schemes are used to enhance perception of variations in the data
  - Gradational (aid viewing smooth variations of amplitudes)
  - Contrasting (visually enhancing variations)

Use of colour

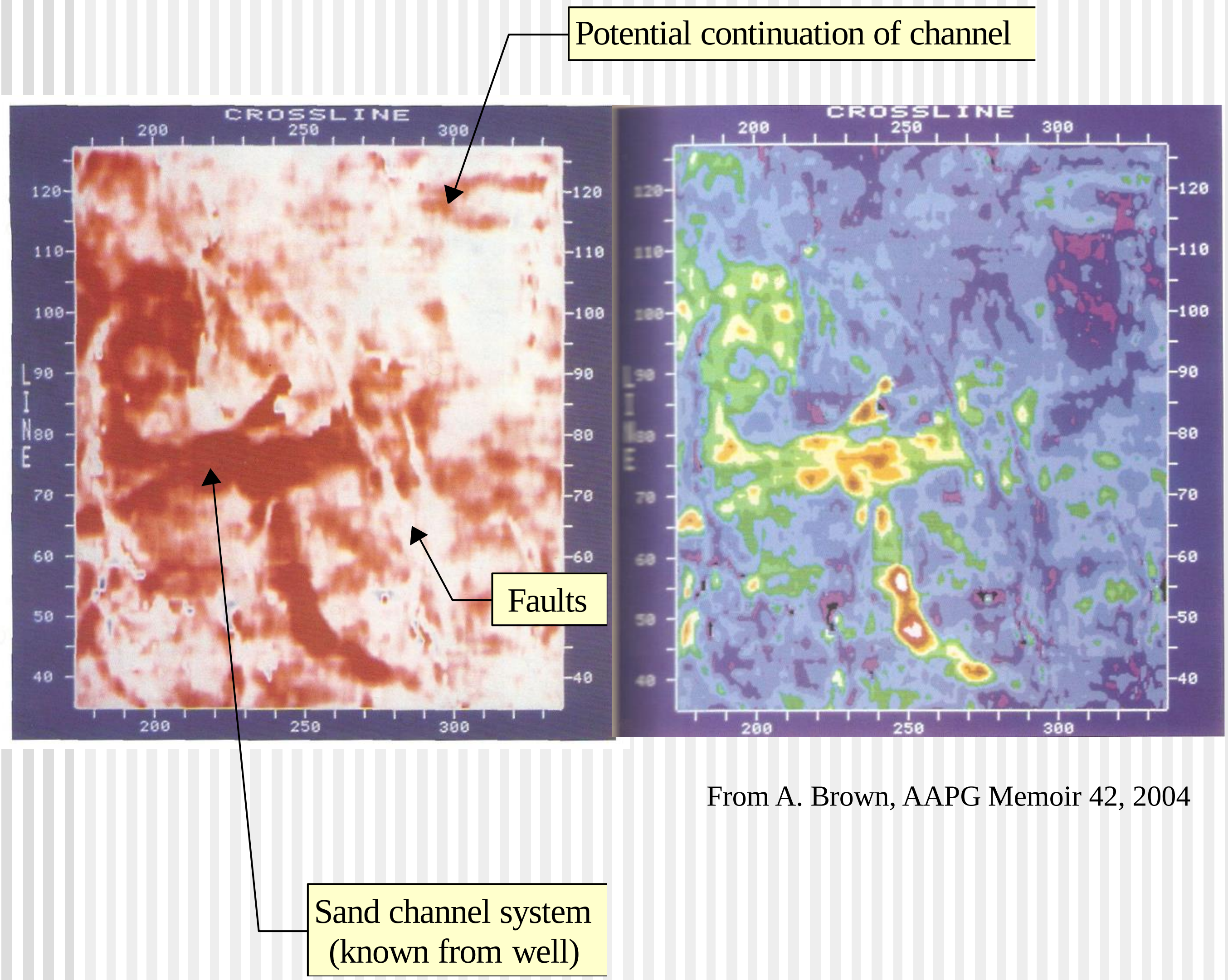
The same seismic line shown in different colour schemes



From A. Brown, AAPG Memoir 42, 2004

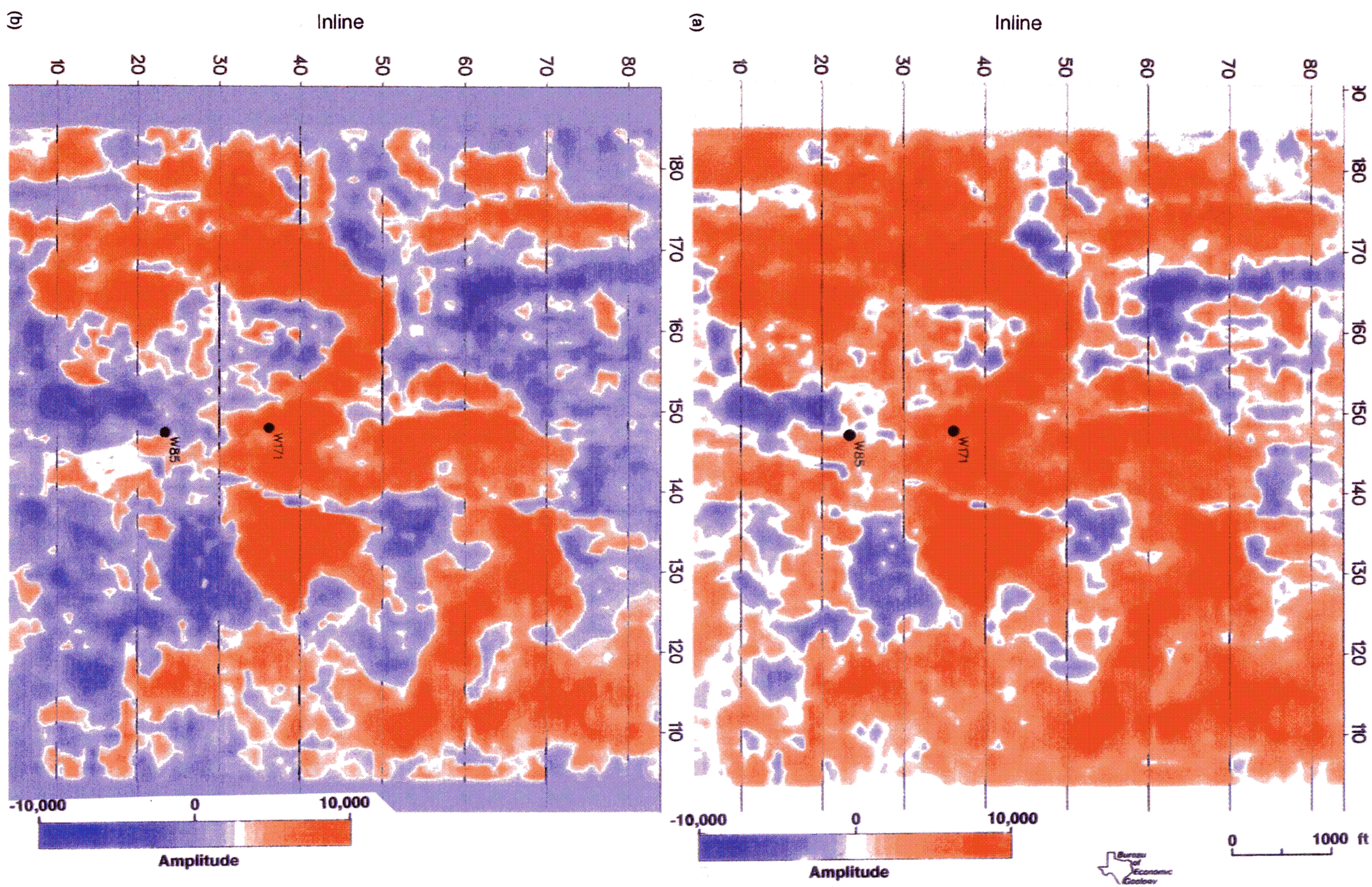
Use (and abuse) of colour

- High-contrast colour scheme (on the right) emphasizes details of amplitude variations but seems to complicate the observation of the channel system



From A. Brown, AAPG Memoir 42, 2004

Horizon slice (Sheriff and Geldart, plate 15)



Horizon slice (Sheriff and Geldart, plate 16)