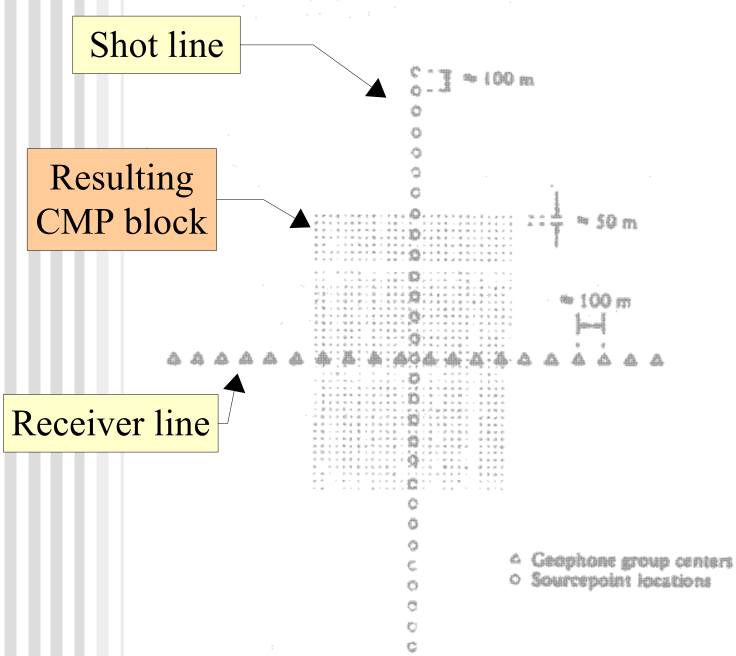
Reflection seismic Method - 3D

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

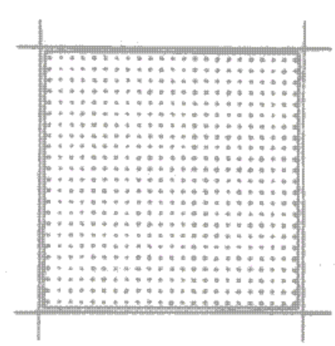
- Reading:
  - Sheriff and Geldart, Chapter 12

Land 3-D acquisition

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



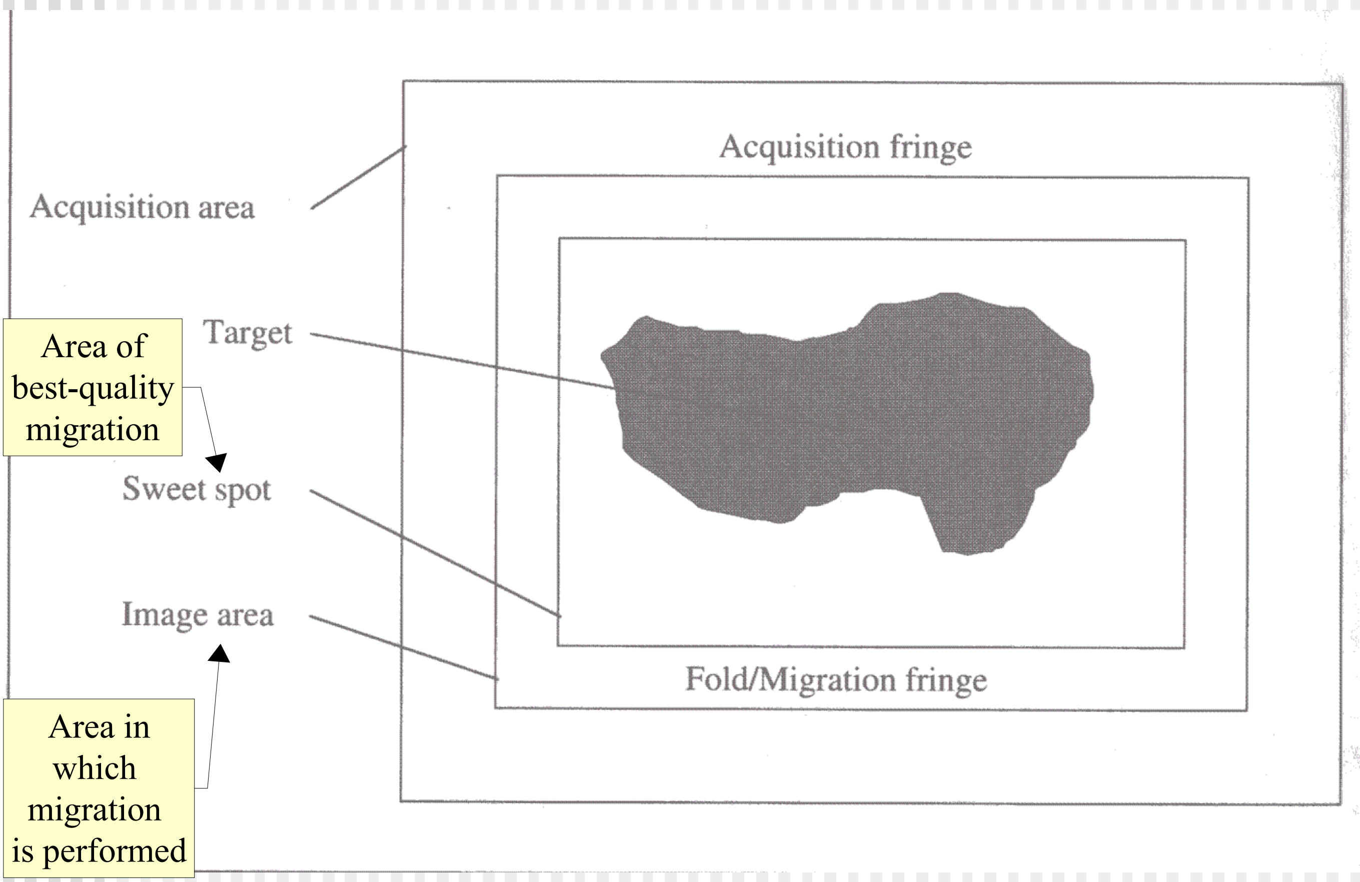
Land patch acquisition



Loop (sources and geophones around the perimeter)

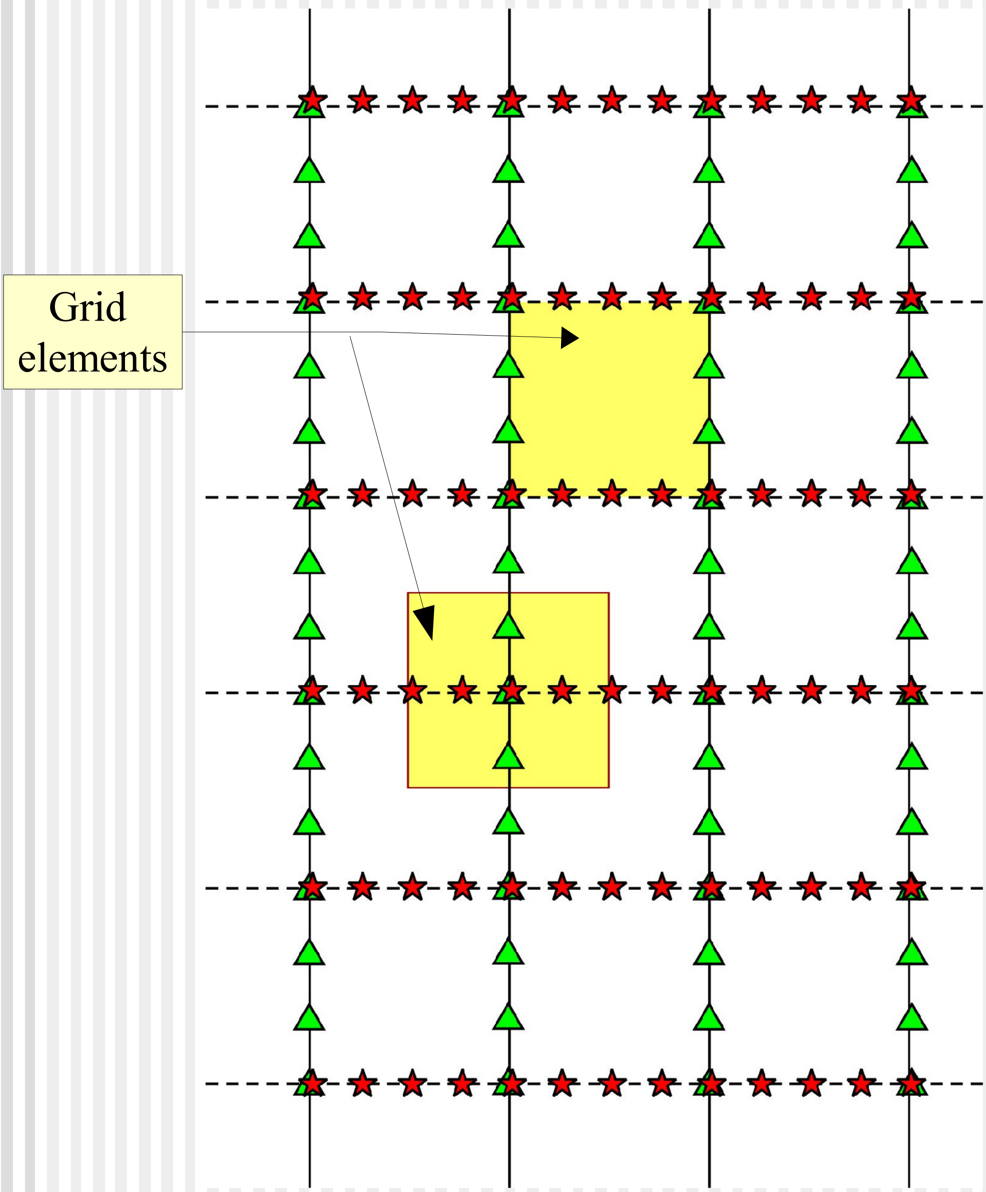
Acquisition fringe

- In order to ensure uniform coverage of the target area after migration, data must be acquired across a broader area:



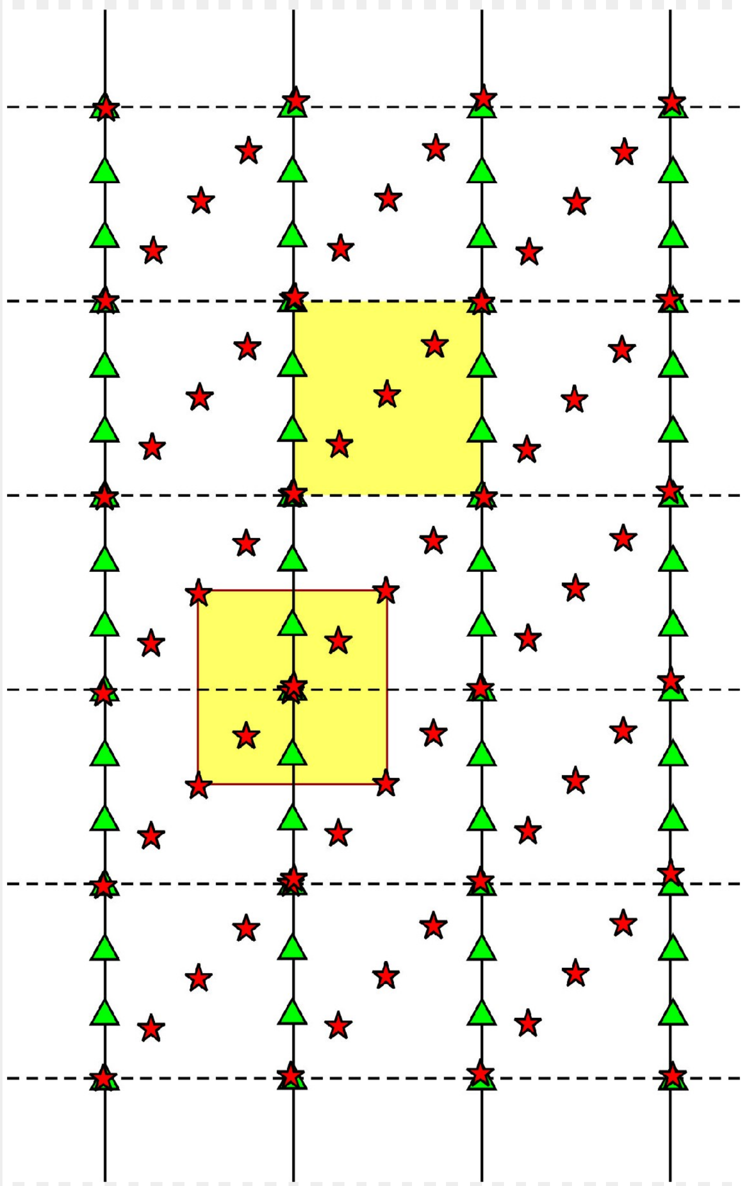
Land acquisition patterns *Orthogonal*

- Simple, but non-uniform azimuthal coverage



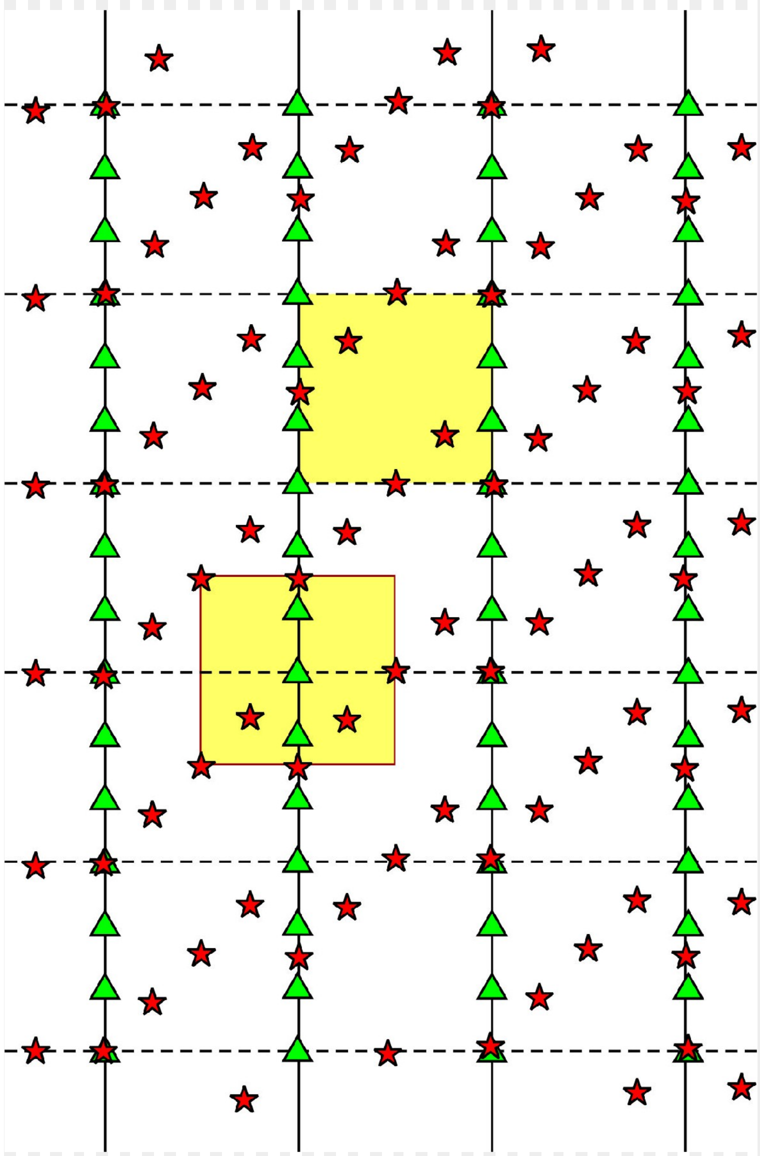
Land acquisition patterns *Diagonal*

- Most popular, better uniformity of azimuthal coverage



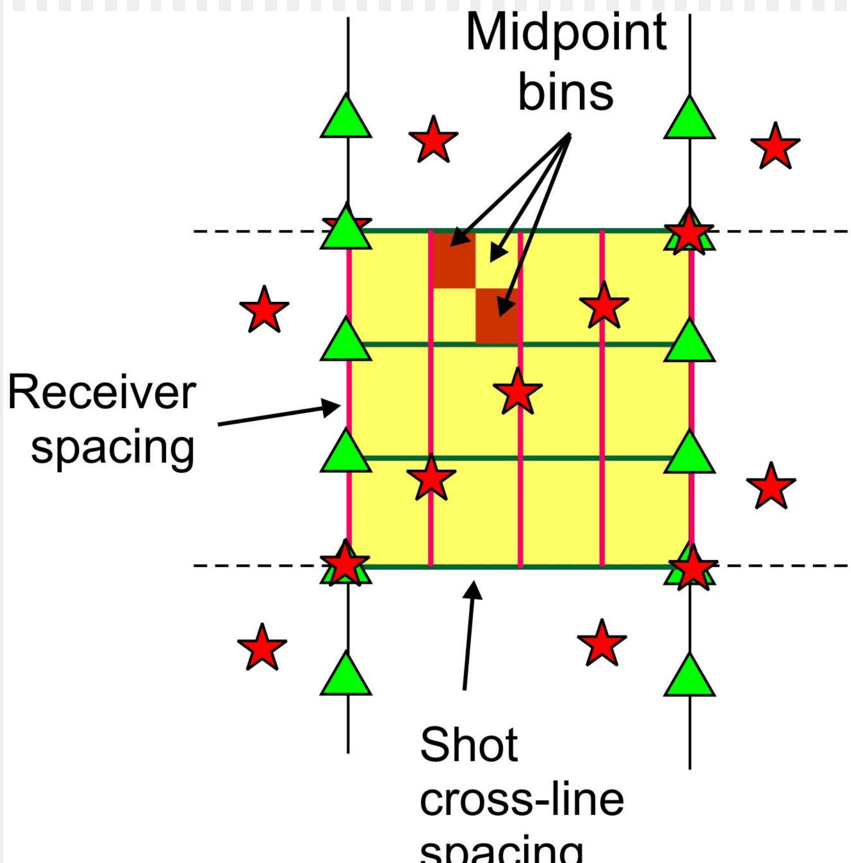
Land acquisition patterns *Staggered*

- Best uniformity of azimuths, but more difficult to implement



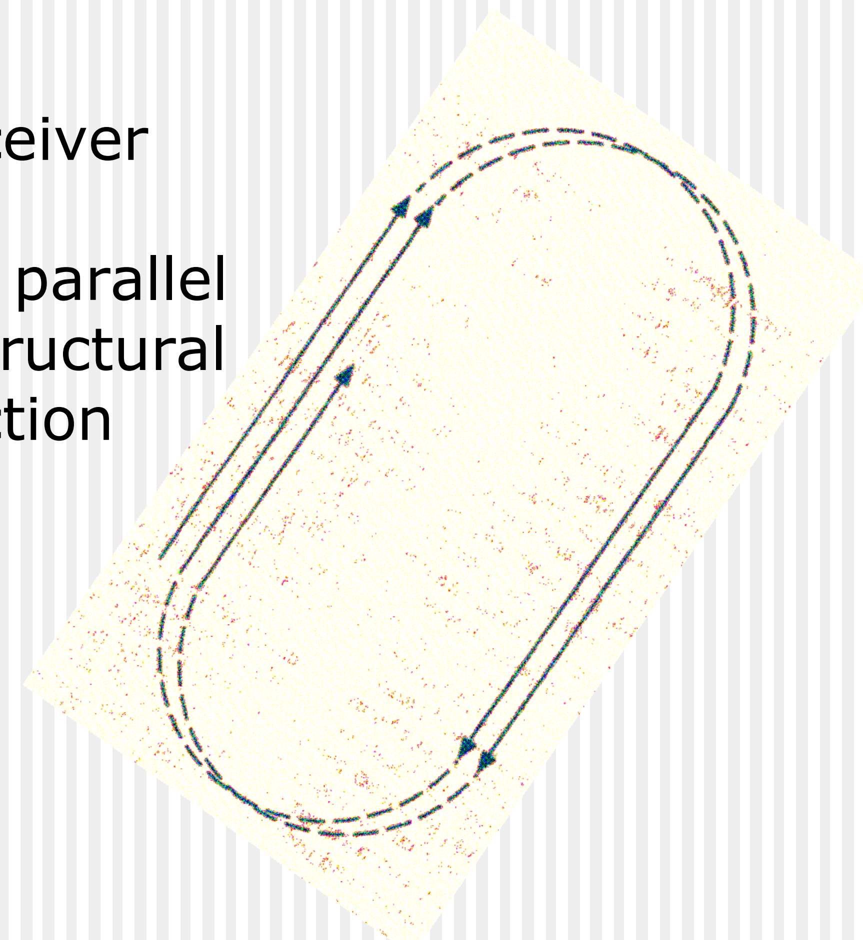
CMP binning in 3D

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



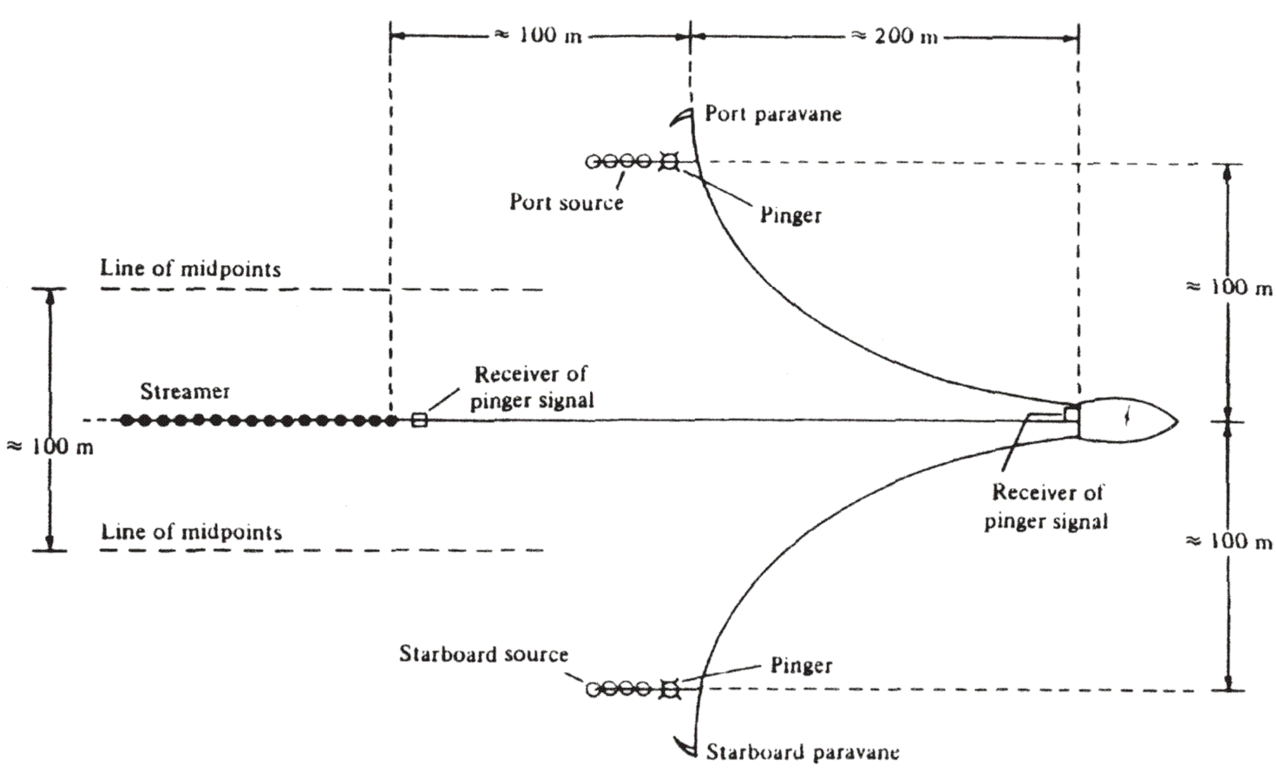
Marine 3-D acquisition

- 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?).



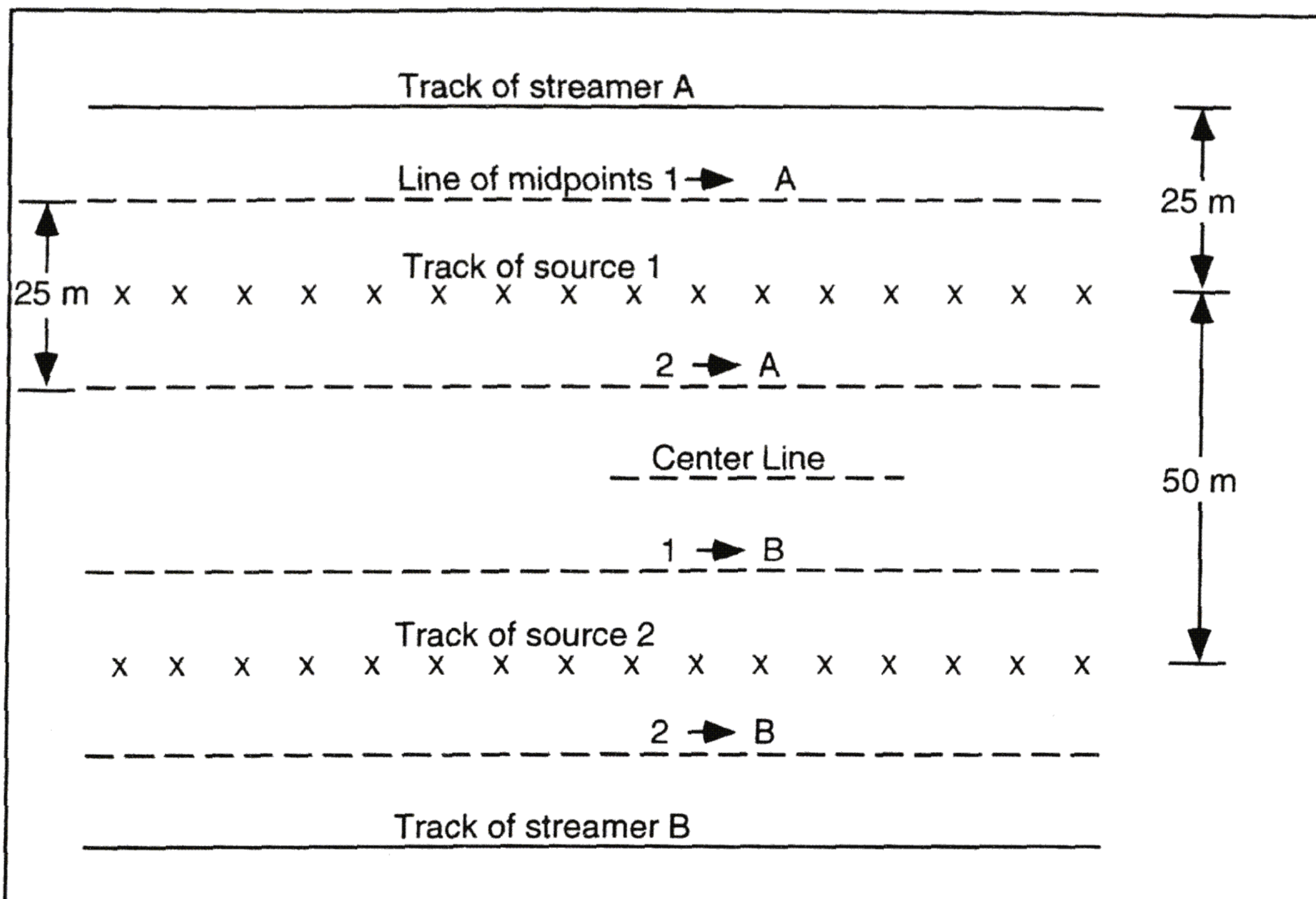
Marine 3-D acquisition

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



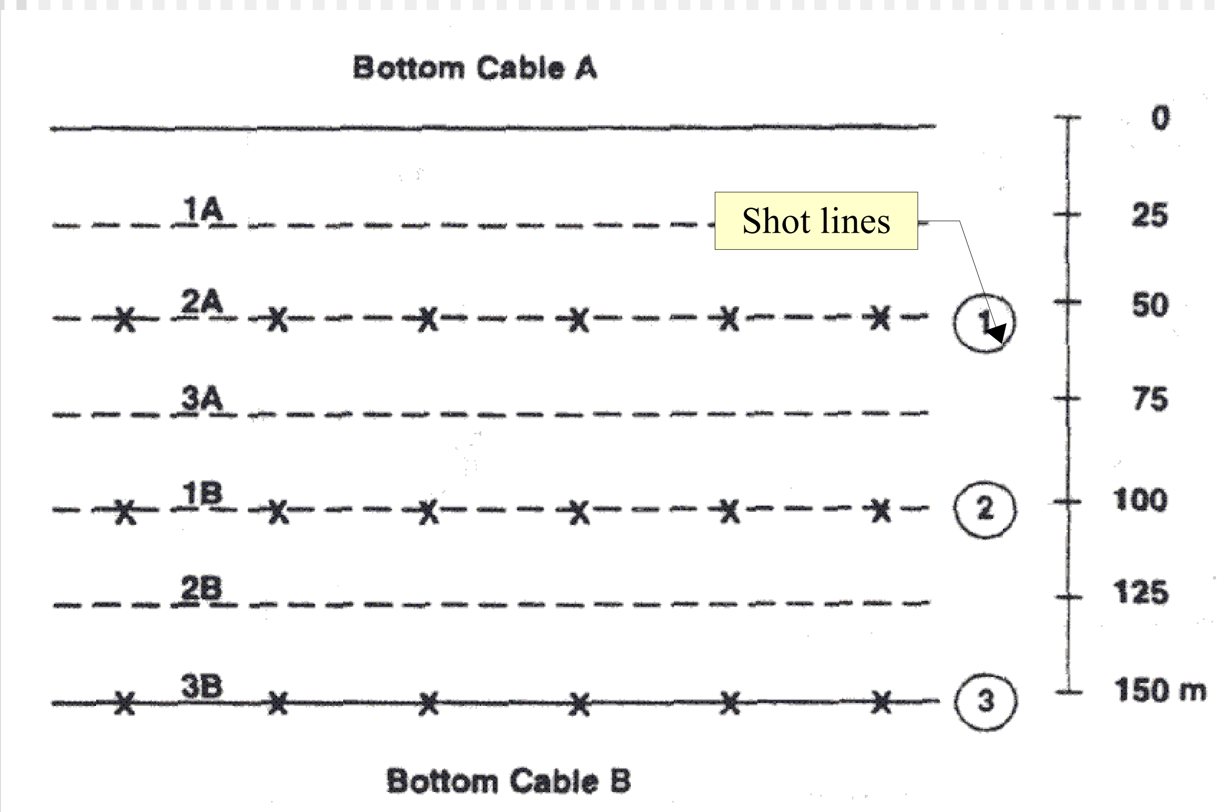
Marine 3-D acquisition

- Typical geometry with two source arrays and two streamers:



Marine swath shooting

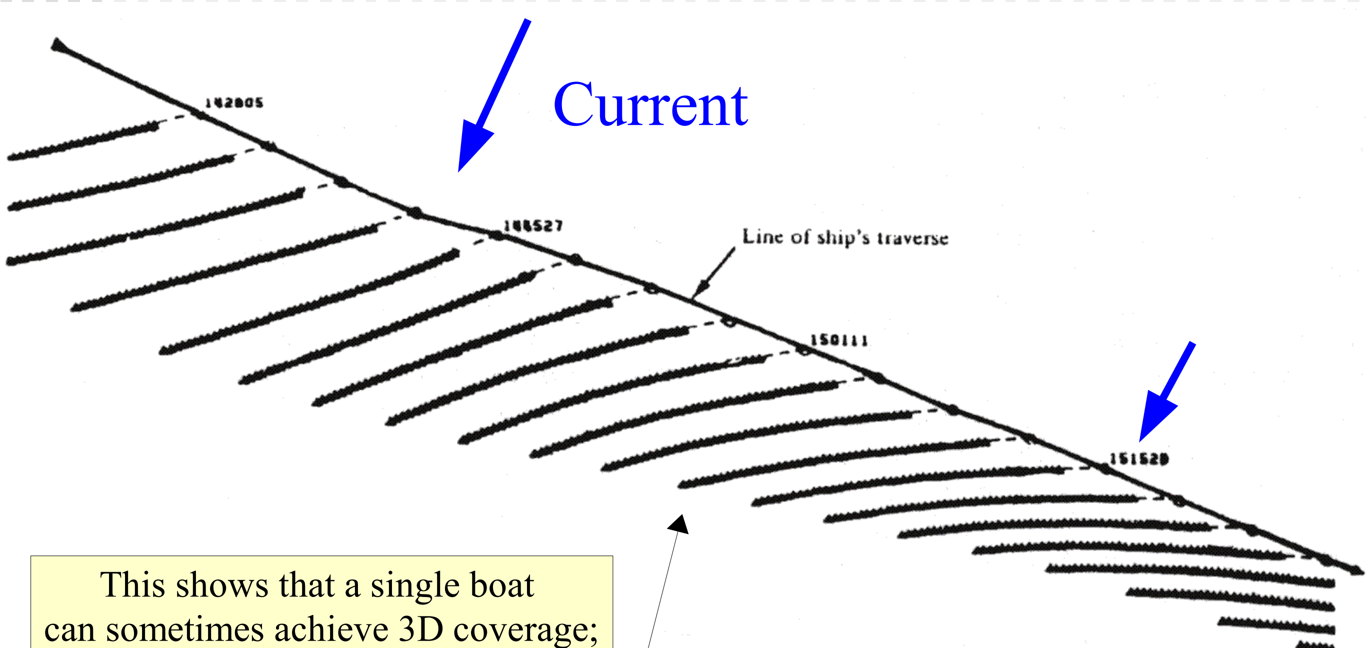
- In shallow water where streamers cannot be towed, bottom hydrophone cables can be deployed in *swaths*.
- A source boat will move along, across, or zigzag between the cables to cover 3D volume.



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

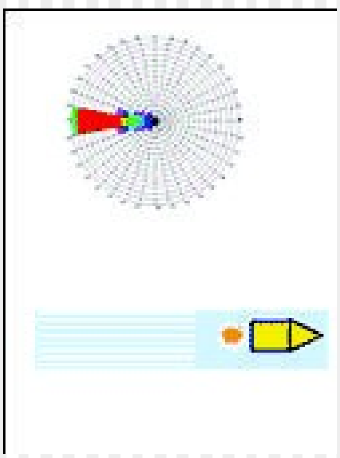
- GPS and radio trilateration of the ship (to ~10-m accuracy)
  - Sometimes anchored *pingers* are also used to locate the survey within an area.
- *Pingers* (tuned acoustic pulse devices) are used to trilaterate the mutual positions of the ship, sources, and streamers.
- Feathering direction is controlled 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

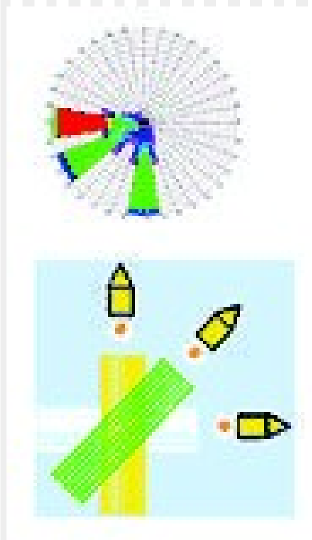
WesternGeco *Magellan*
6 steered streamers

"Coil shooting"
(WesternGeco)

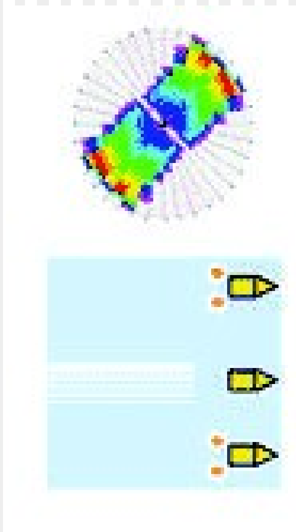
Azimuth marine recording



Single-azimuth



Multi-azimuth (MAZ)



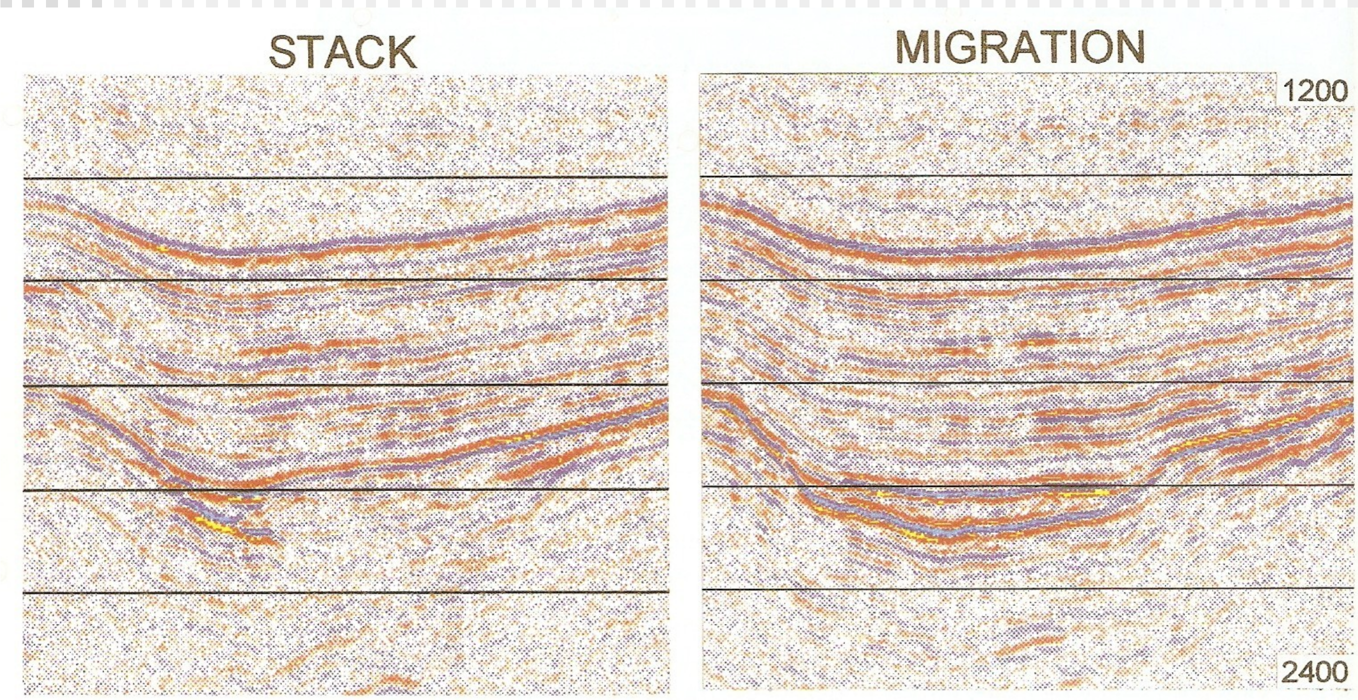
Wide-azimuth (WAZ)

MAZ+WAZ = RAZ

"Rich-azimuth"

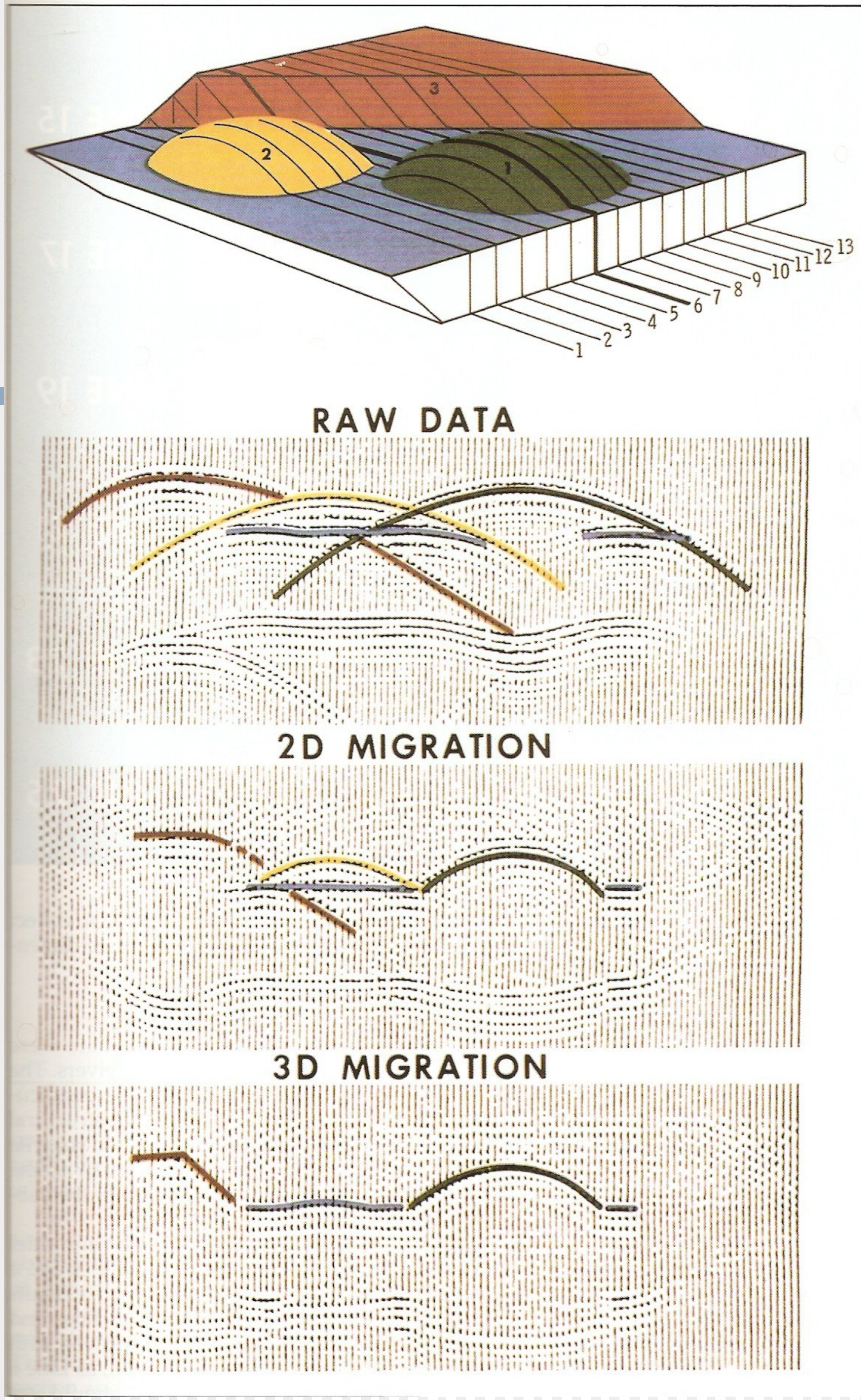
3D Imaging

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



Example of striking improvement from 3D migration

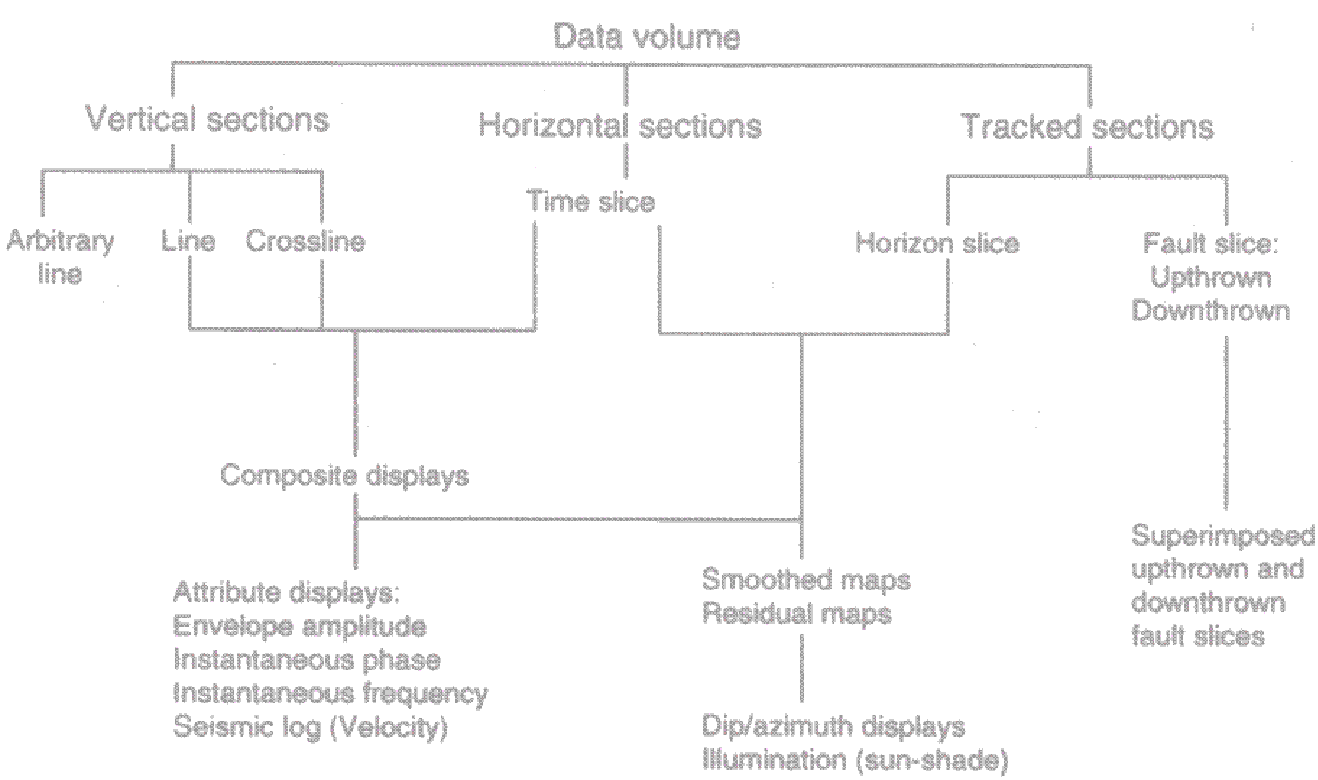
(South Australia, Santos Ltd.)



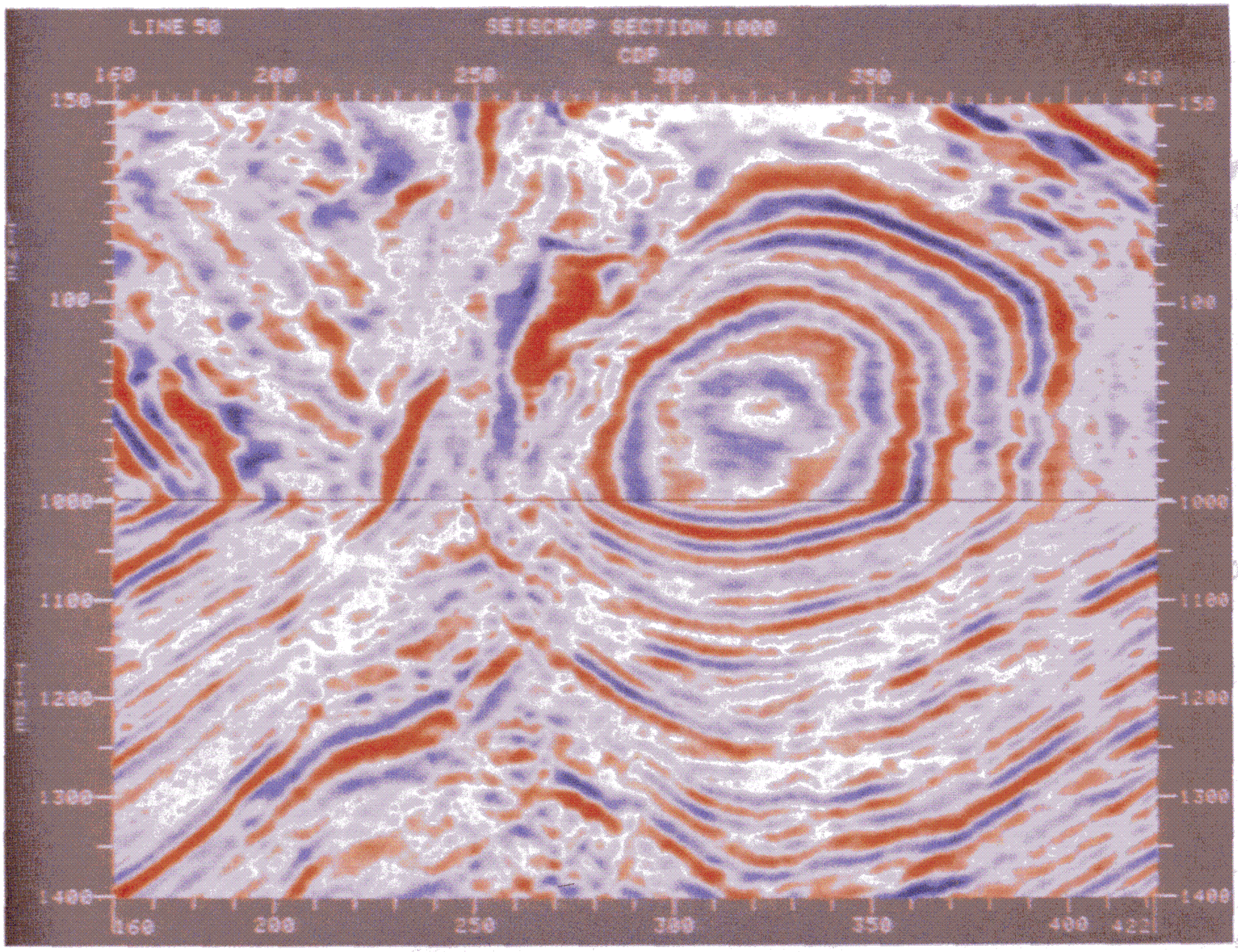
- Comparative effects of 2D and 3D migration (French, 1974)

3D data displays

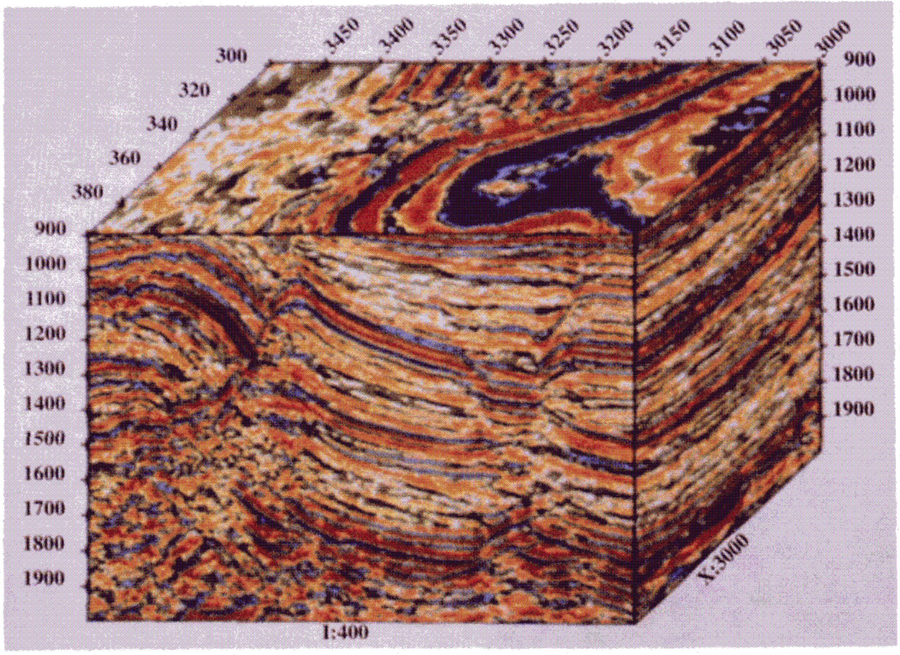
- A variety of geometrical types
- Attributes (amplitudes, their gradients, phases, acoustic impedance, porosity, directions, statistics)
- Colour (continuous or discontinuous palettes to highlight gradational character or contrasts)
- Interactive analysis using workstations



3D displays (Sheriff and Geldart, plate 7)



(a)



(b)

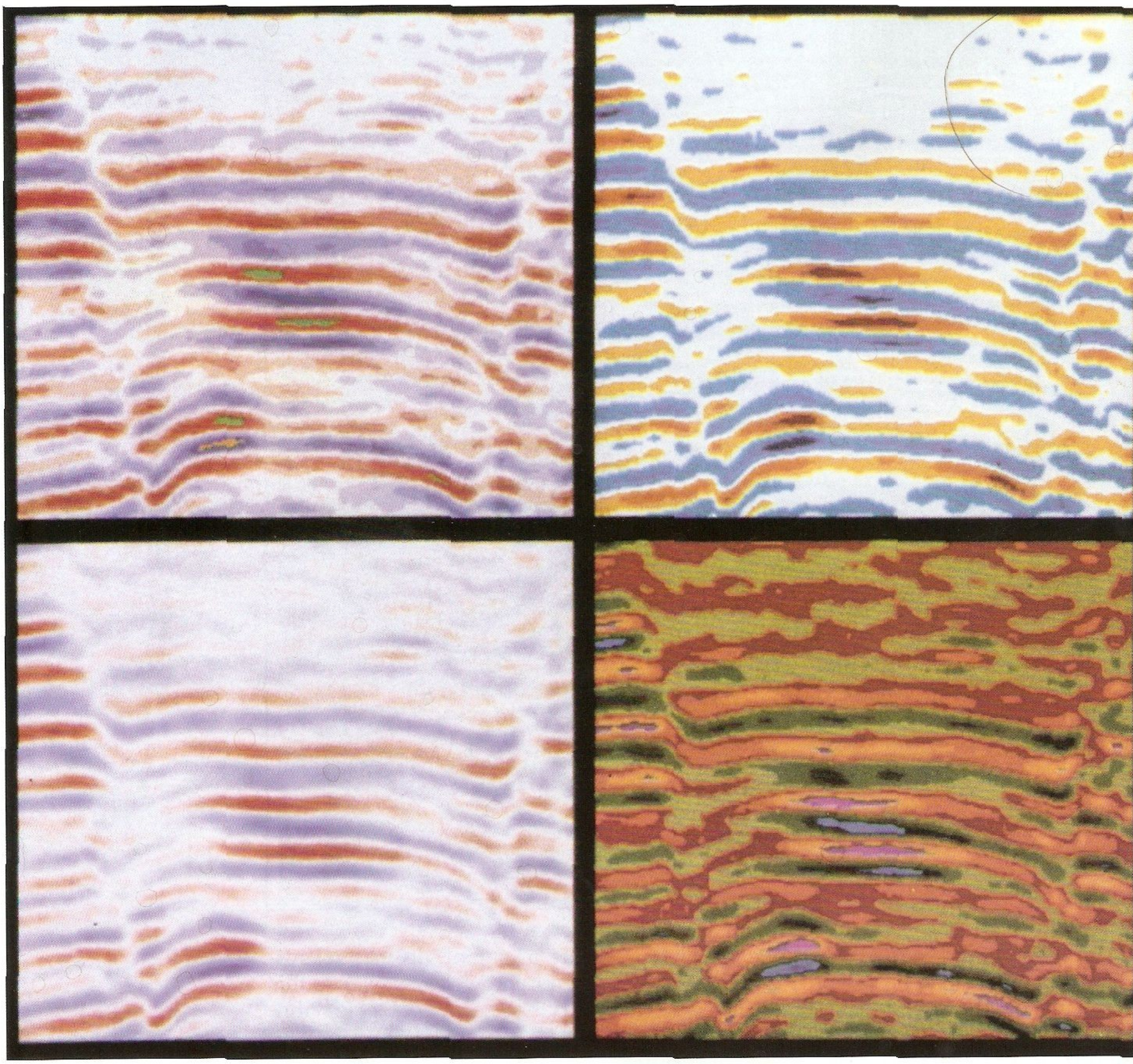
Use of colour

- 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 exist
  - Gradational (aid viewing smooth variations of amplitudes)
  - Contrasting (visually enhancing variations)

Use of colour

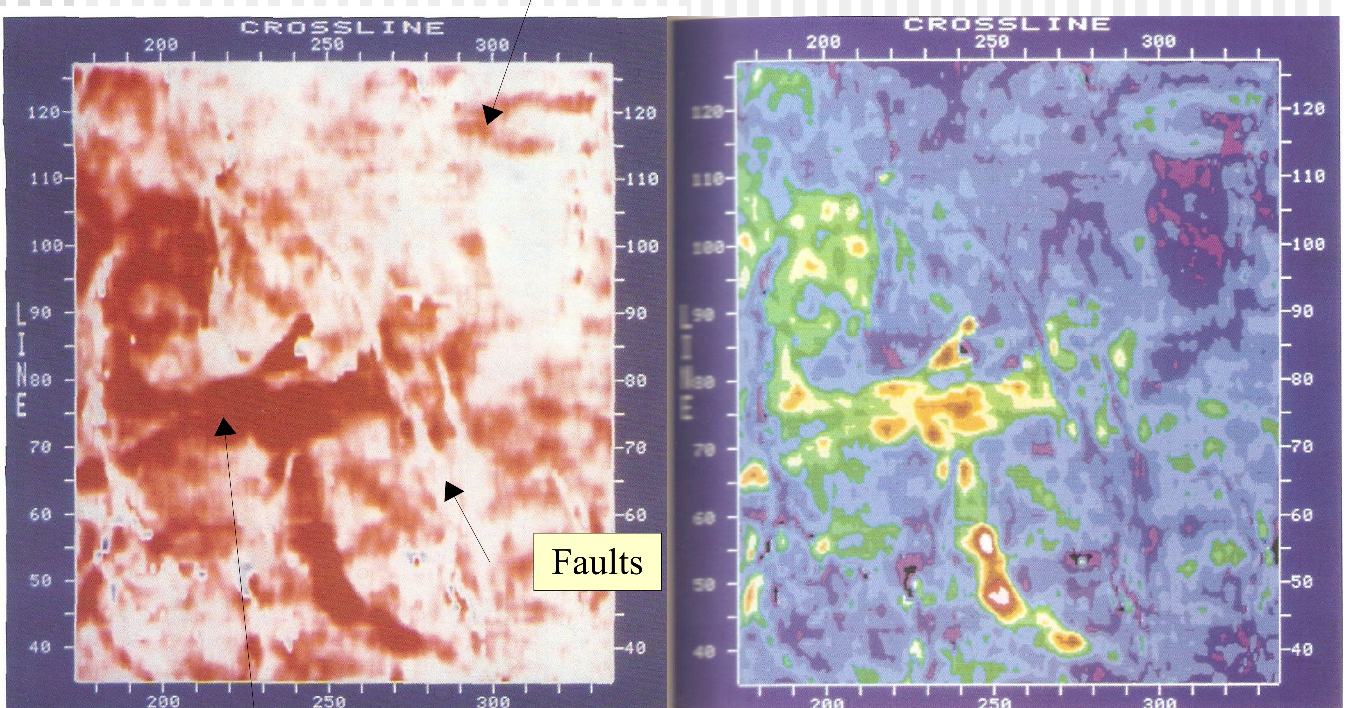
The same line shown in different color schemes



From A. Brown, AAPG Memoir 42, 2004

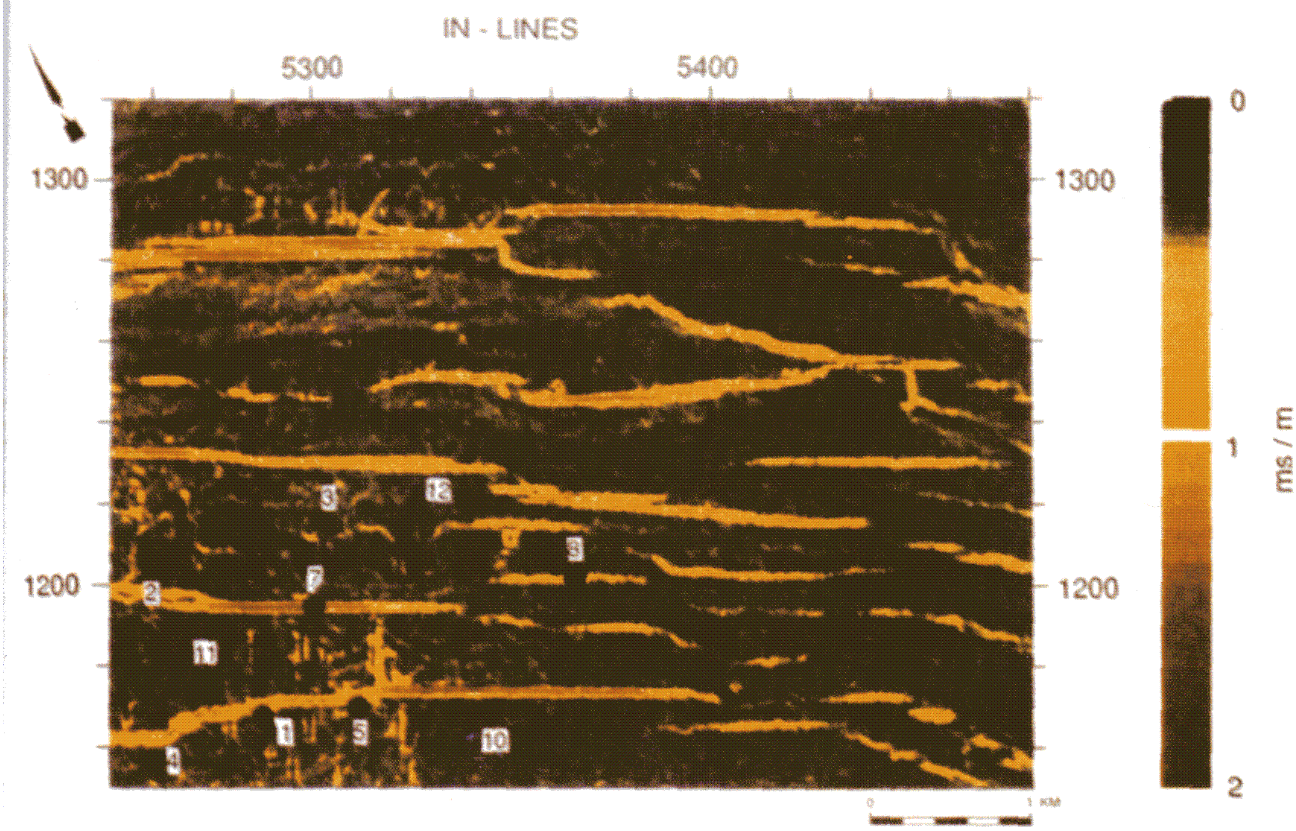
Use (and abuse) of colour

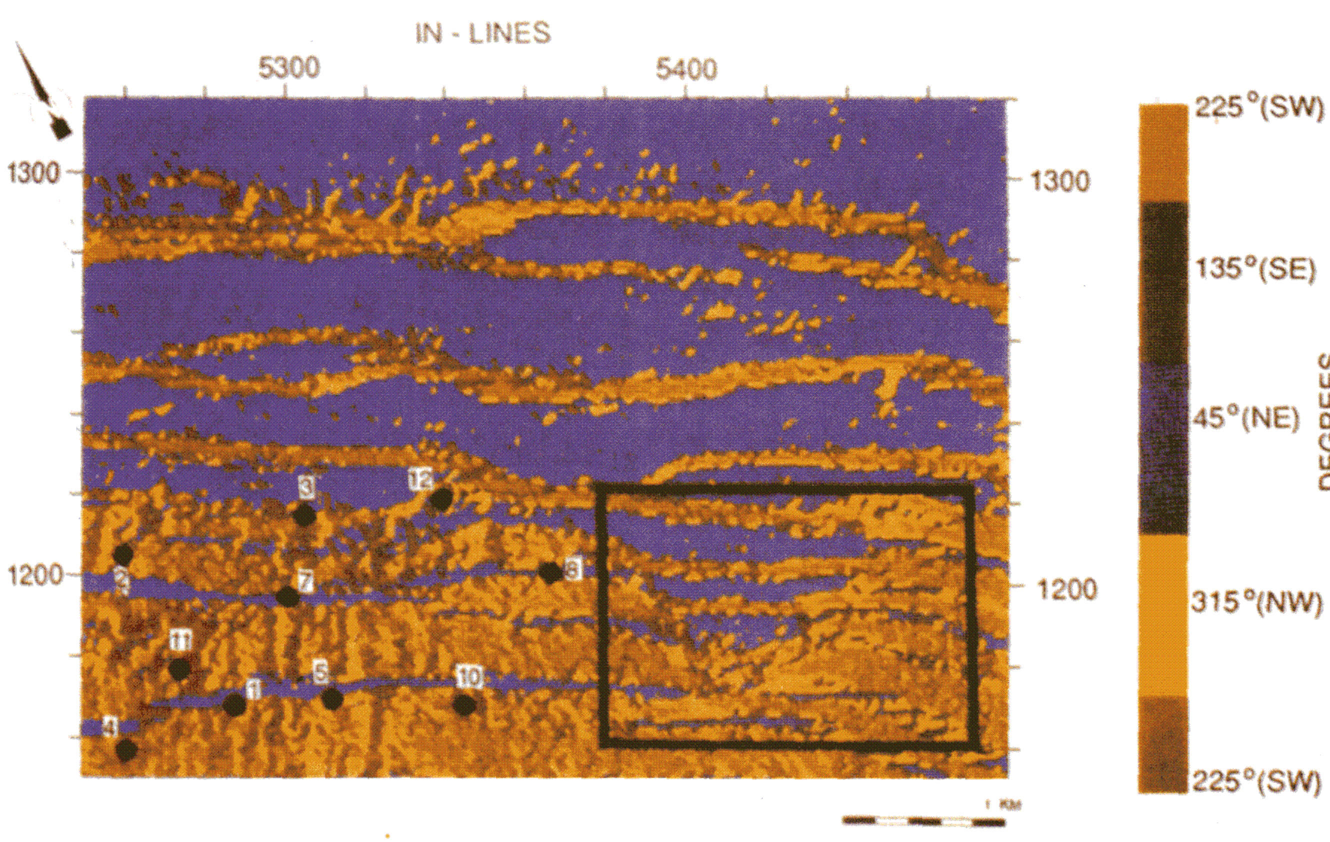
- High-contrast colour scheme (on the right) emphasizes details of amplitude variations complicates observation of the channel system



From A. Brown, AAPG Memoir 42, 2004

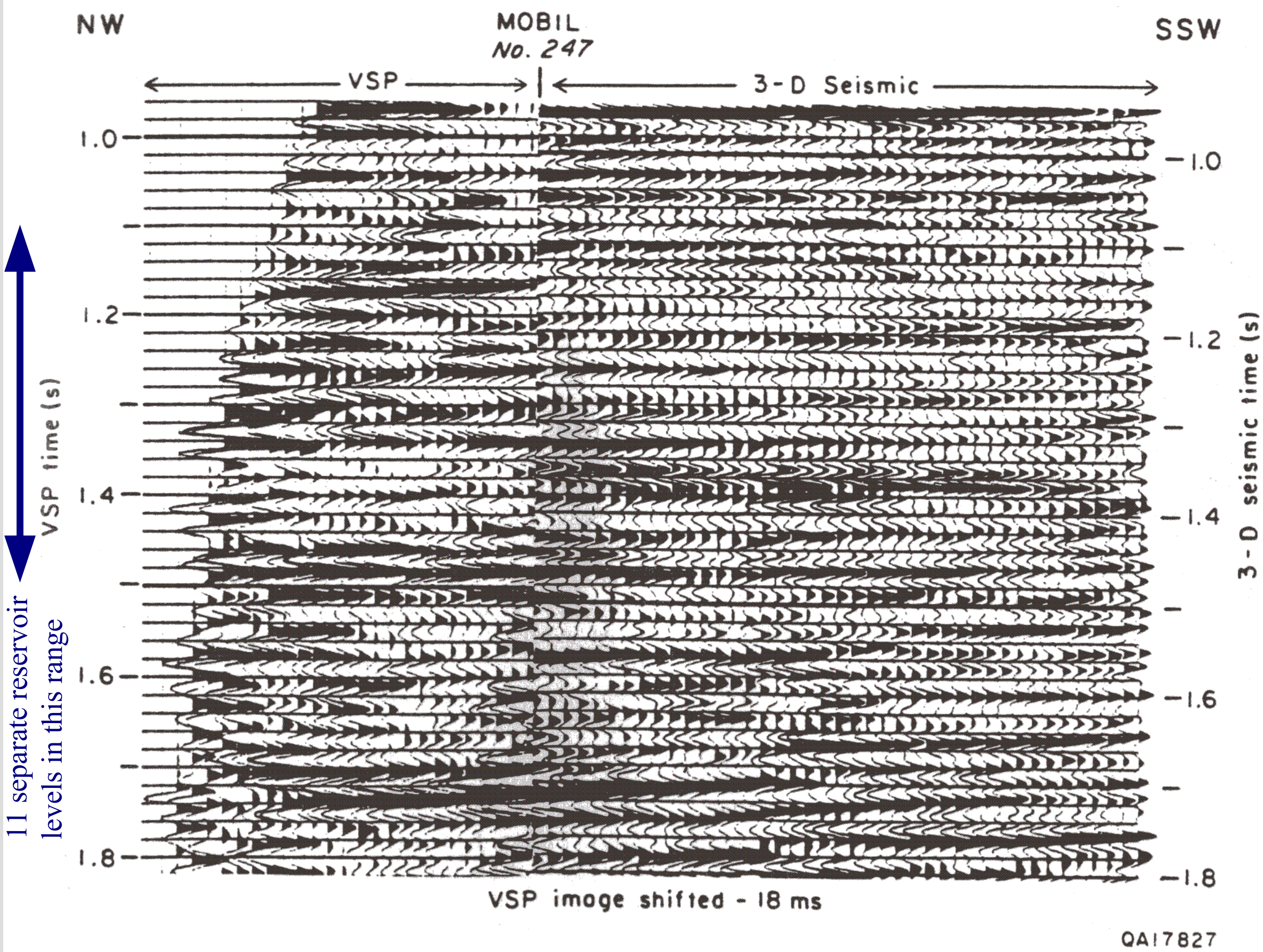
Directional attributes (Sheriff and Geldart, plate 6)



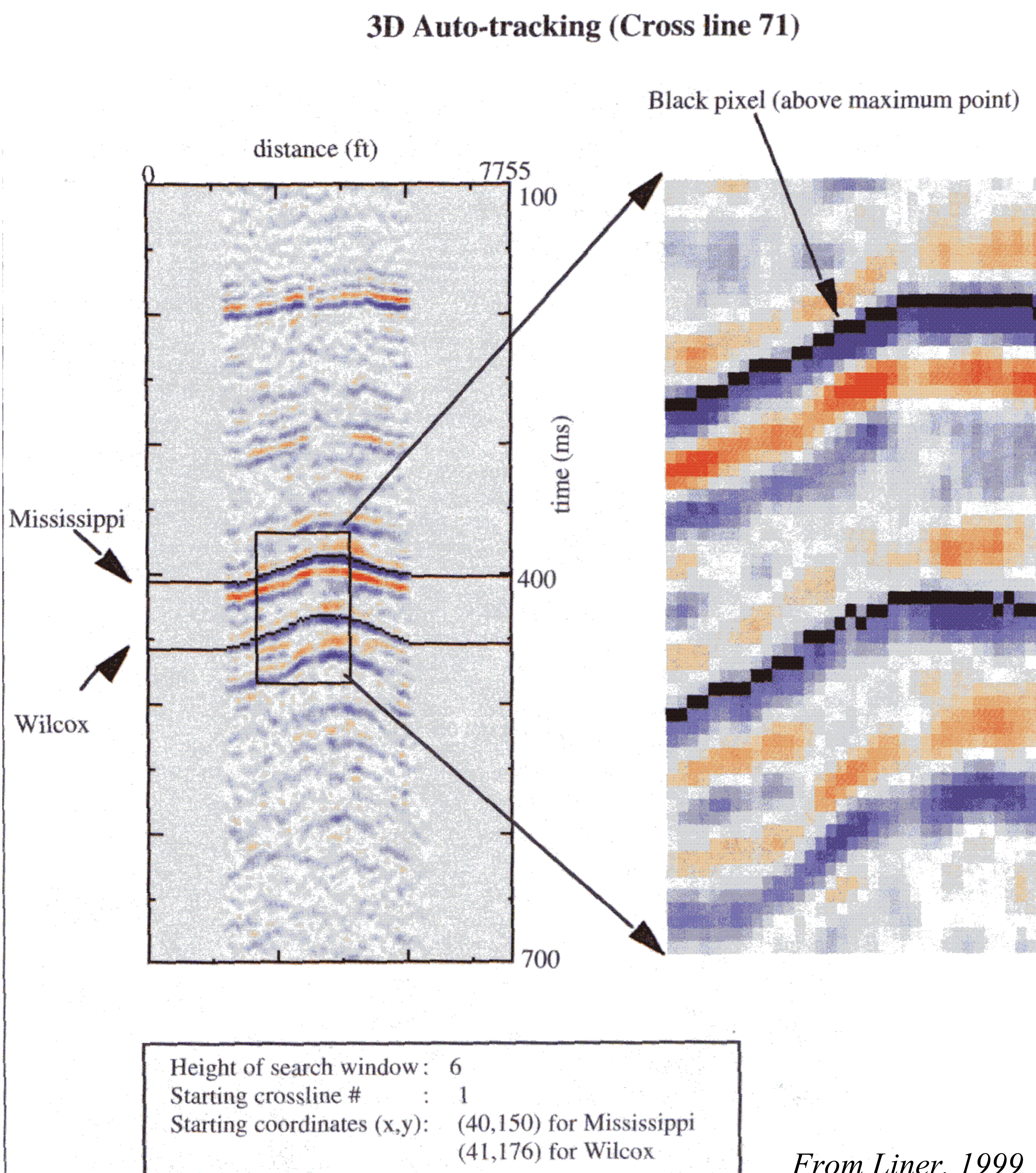


3D horizon tracking

- Manual ("point" or "stream") tracking
  - Good for consistent interpretation
- Automatic
  - Relies on a *zero-phase wavelet* (tracking the maximum amplitude)
  - Preferable for accurate amplitude analysis
- To identify correct reflection events, data are compared to borehole logs, synthetics, and VSPs

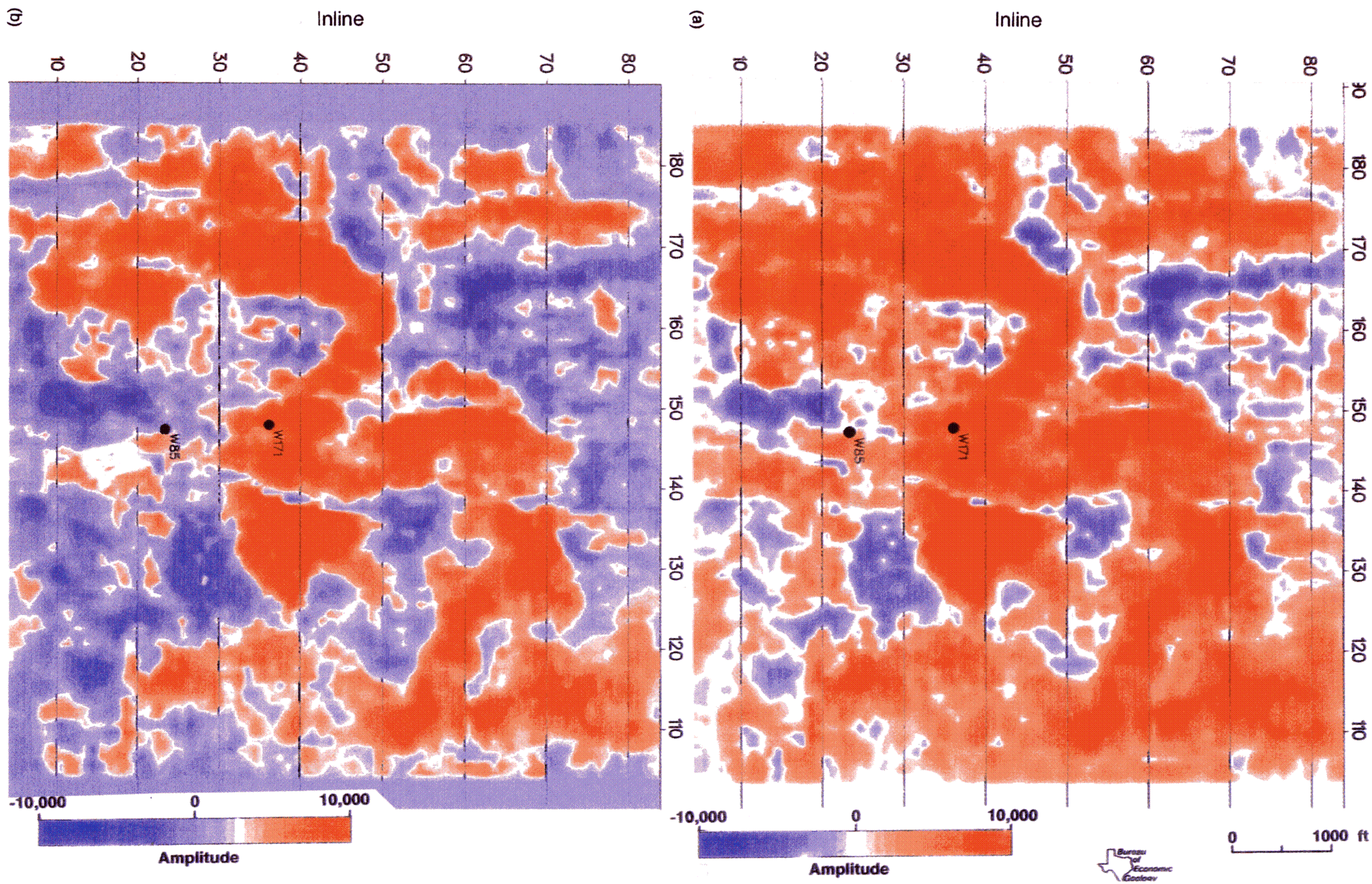


3D horizon autotracking



From Liner, 1999

Horizon slice (Sheriff and Geldart, plate 15)



Horizon slice (Sheriff and Geldart, plate 16)