Carbonate Reservoir Delineation from Seismic Data – Examples of Crosswell Seismic*

By
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* Adapted from oral presentation at the 2006 AAPG International Conference and Exhibition, Perth, Australia, November 5-8, 2006. See companion article, "Crosswell Seismic in Carbonate Reservoirs – High-Resolution Reservoir Delineation," Search and Discovery Article #40307 (2008).

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Abstract

Crosswell seismic tomography provides better reservoir resolution than surface data; therefore there should be value added in reservoir delineation. Examples of crosswell seismic data from two fields illustrate the resolution and some potential applications of this type of data: (1) defining greater geologic detail between wells (heterogeneity of reservoir), (2) recognizing laterally continuous zones for improved development (well positioning, completions, injection), and (3) input for reservoir models (layering and assigning porosity).

In the first example, the producing formation is limestone with minor dolomite and shale. 3D seismic and down hole log data suggest lateral discontinuities, but details are ambiguous due to the poor resolution. Crosswell data defines the nature of some of the reservoir discontinuity, in that clinoforms which are imaged can potentially isolate reservoir compartments. A comparison with outcrop facies geometries provides some sense of the reservoir facies to be expected between wells.

The second example is a diagenetically complex cyclic shelf dolomite. Variations in amplitude on the crosswell data are the most striking lateral features, and nearly every positive-amplitude event coincides with a significant increase in velocity on sonic logs. Both the seismic and log data respond to the same diagenetic overprint and its resulting petrophysical characteristics; therefore log-derived facies relate to the crosswell data better than core lithofacies. Comparing crosswell data with geostatistical porosity models and with analogous outcrops to further analyze the potential imaging of lateral porosity variation suggests lateral changes in porosity are being imaged at the scale of tens of meters.

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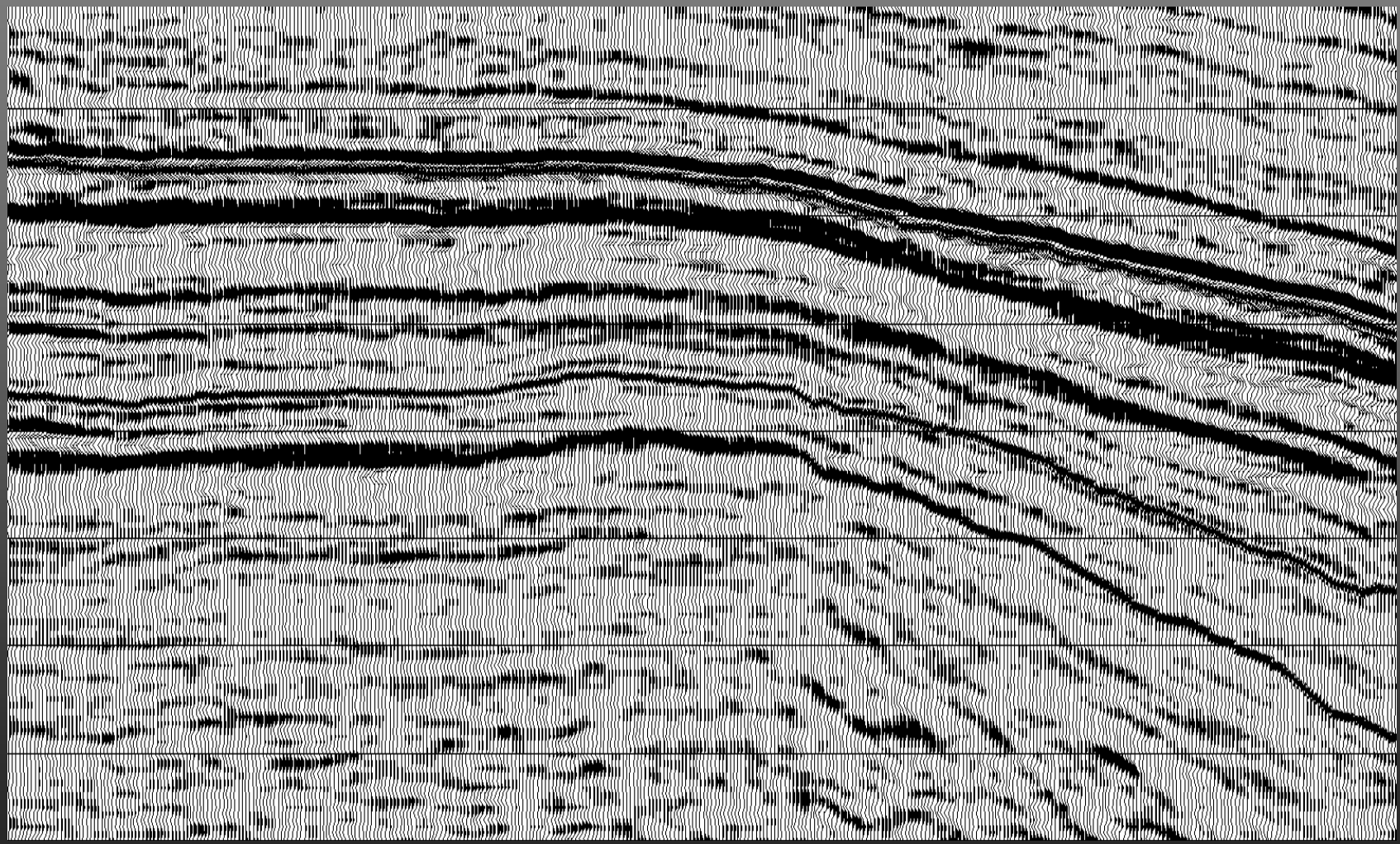
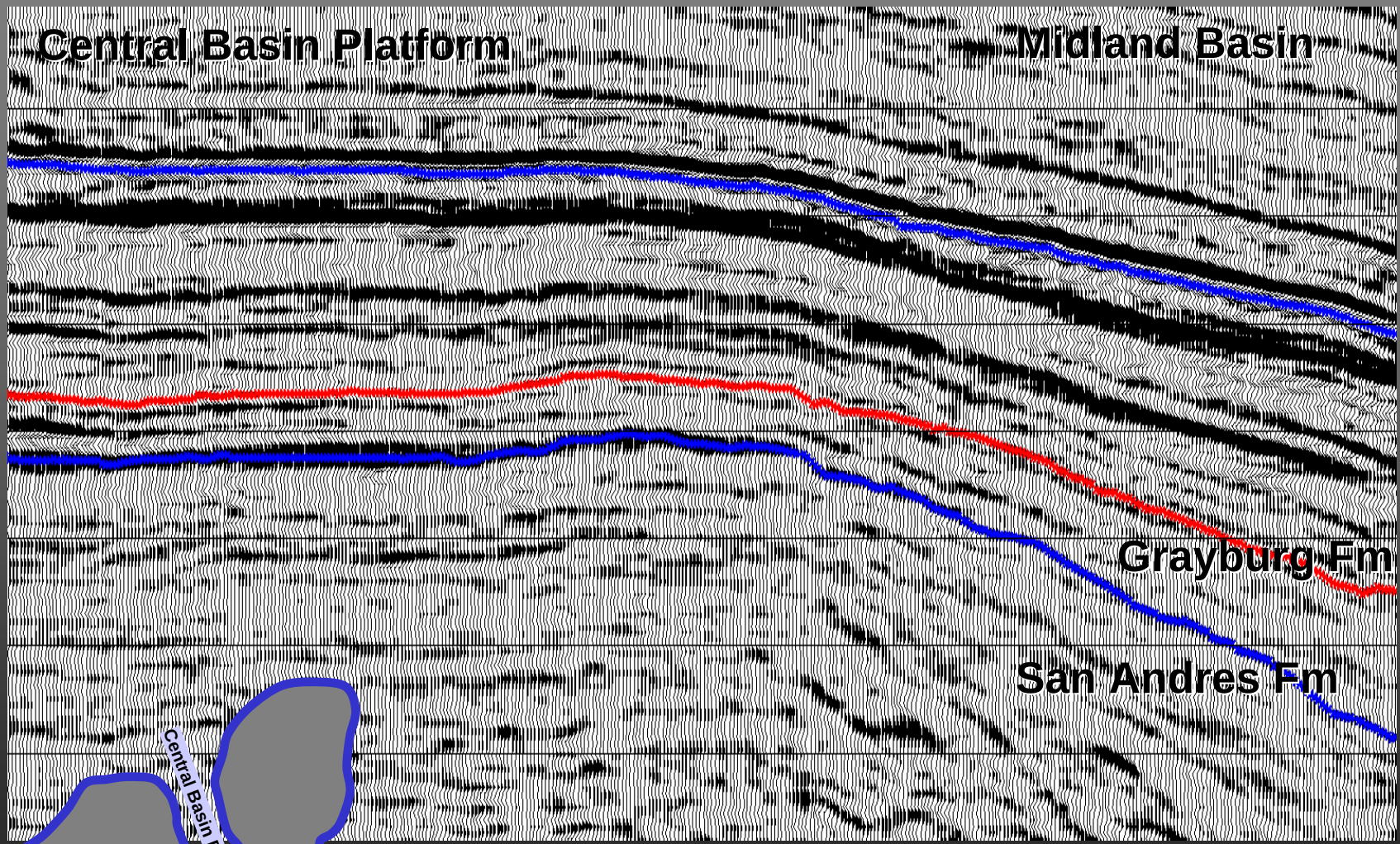
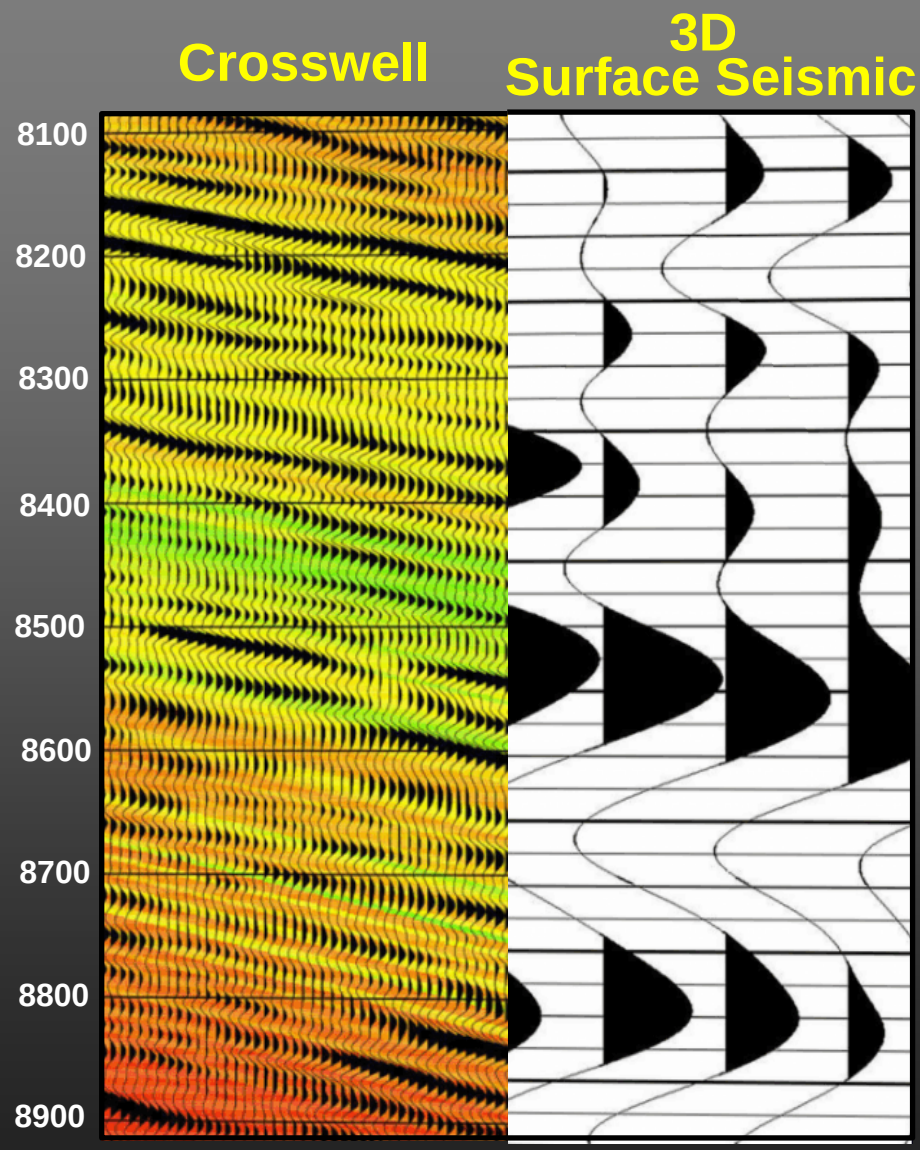
SURFACE 3D SEISMIC



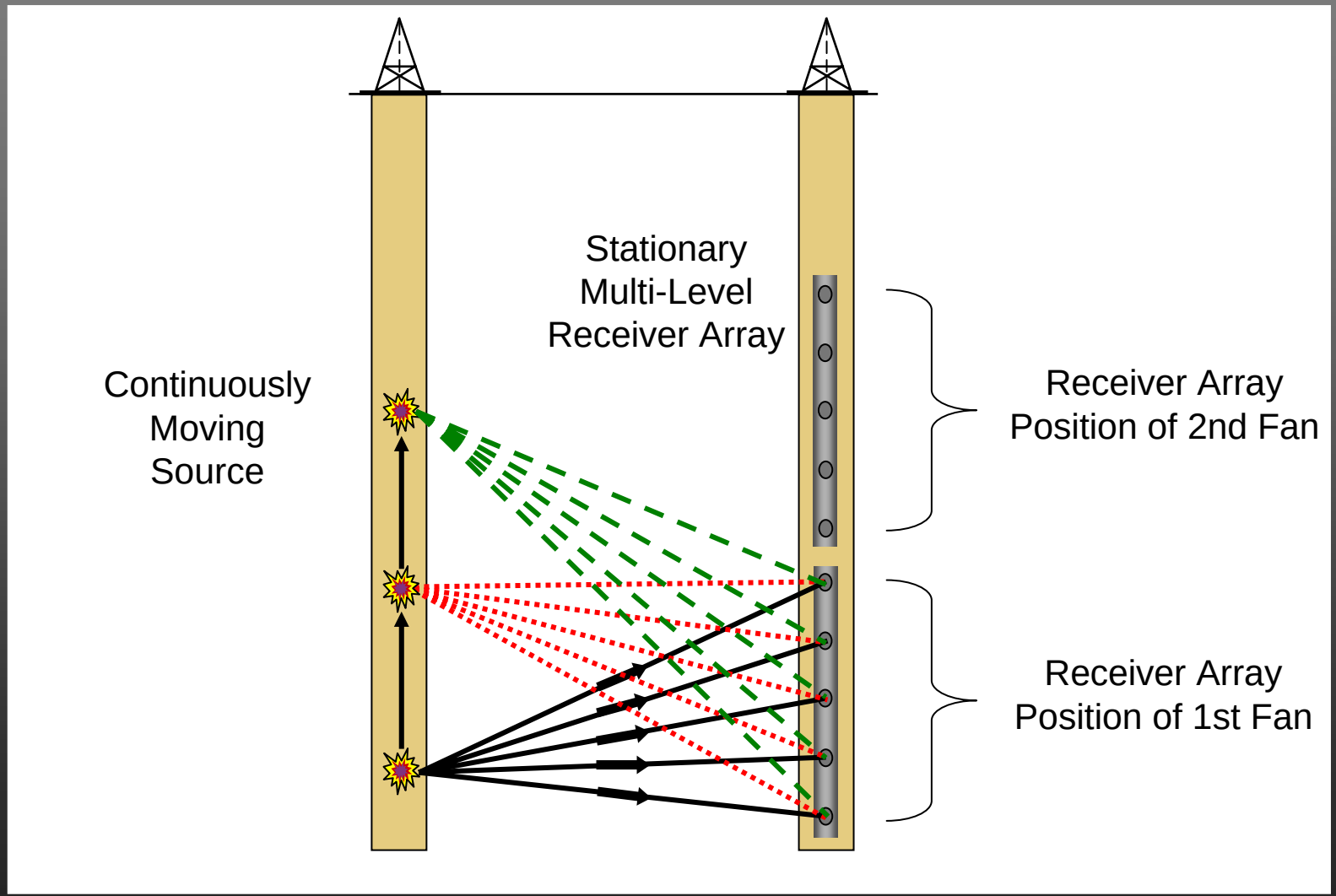
SURFACE 3D SEISMIC



DATA RESOLUTION



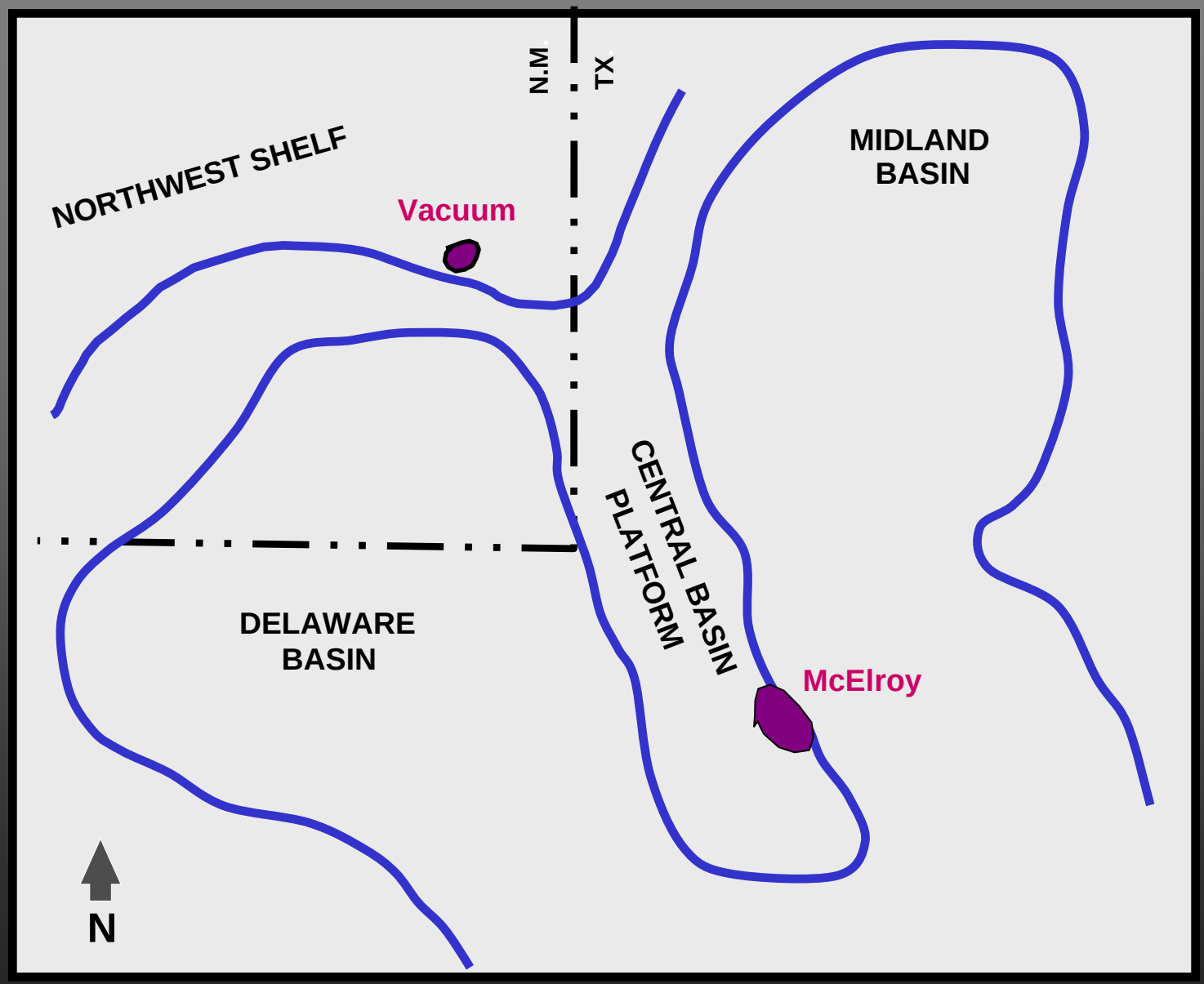
DATA ACQUISITION



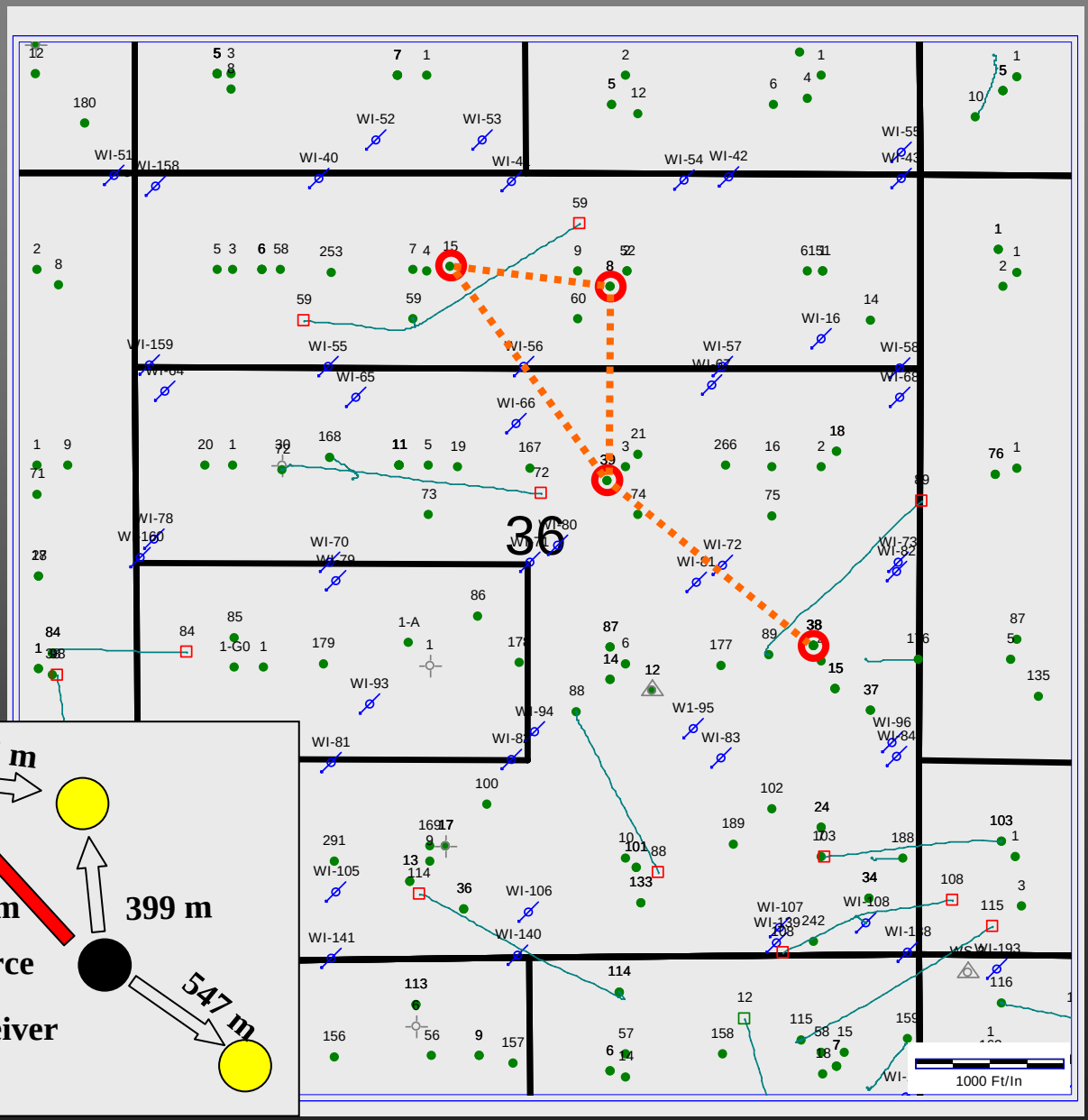
CROSSWELL SEISMIC APPLICATIONS

- *Reservoir Characterization*
  - *Detailed stratigraphy and structure*
  - *Precise tie to logs and cores*
  - *Facies inference*
  - *Static properties*
- *Reservoir Monitoring*
  - *Time-lapse monitoring*
  - *Dynamic properties*
- *Surface Seismic Calibration / Alternative*
  - *Velocity/anisotropy determination*
  - *Shoot below surface problems*

CASE STUDIES



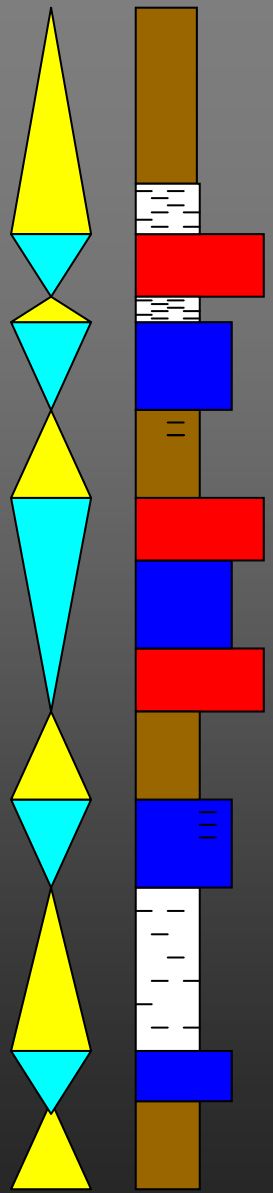
DATA ACQUISITION IN VACUUM



Key Well With Core

AFTER MARTIN ET AL, 2002

GENERALIZED STRATIGRAPHY



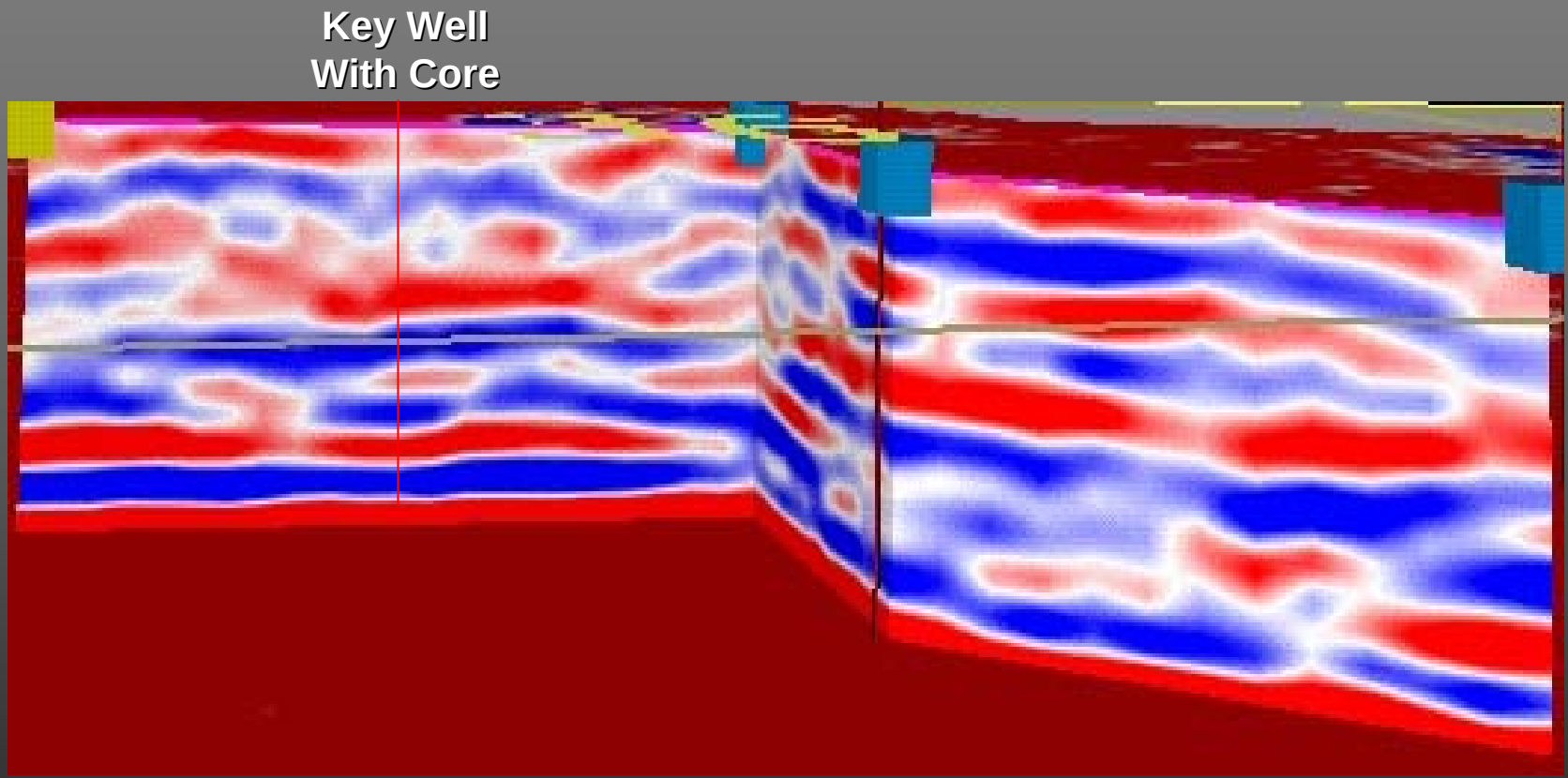
not to scale

Wolfcamp Limestone with Dolomite Stringers and Shale Zones

- MUDSTONE
- SHALE
- PACKSTONE
- GRAINSTONE

AFTER MARTIN ET AL, 2002

SURFACE 3D SEISMIC



Poor Resolution of Reservoir Discontinuity

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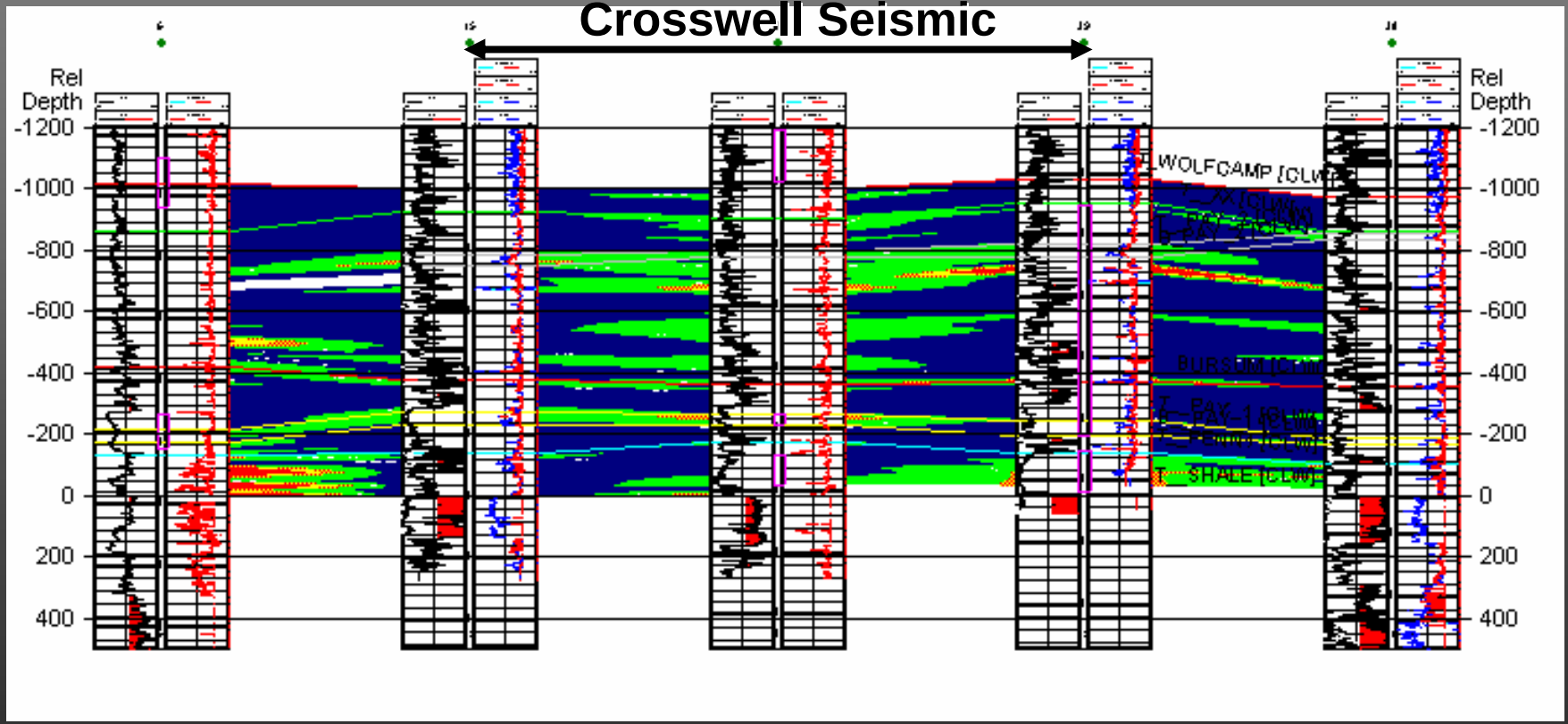
POROSITY DISTRIBUTION



Discontinuous Pay Zones and Questionable Correlation

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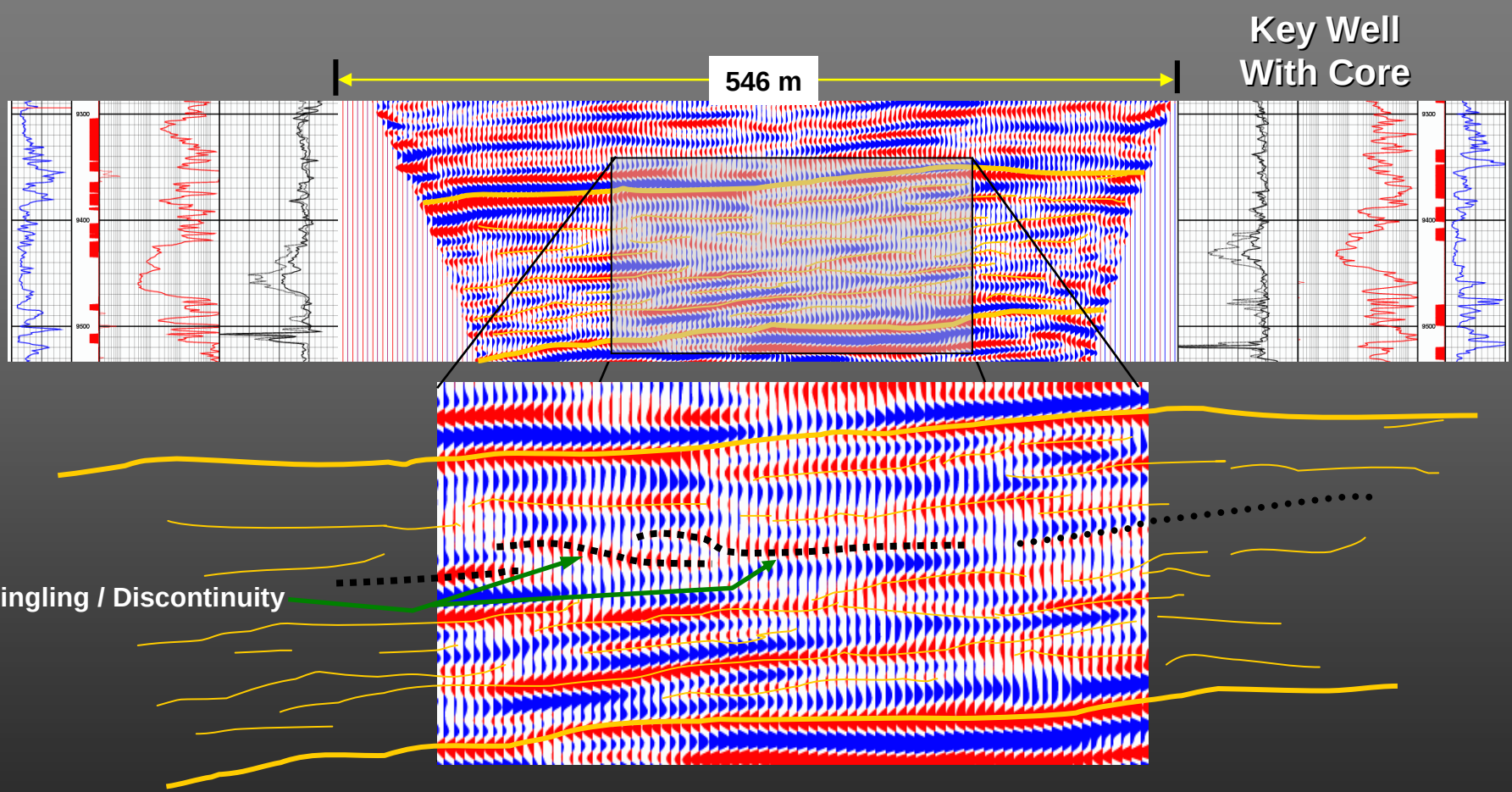
HIGH RESOLUTION FEATURES



Zones May Be Isolated by Clinoforms

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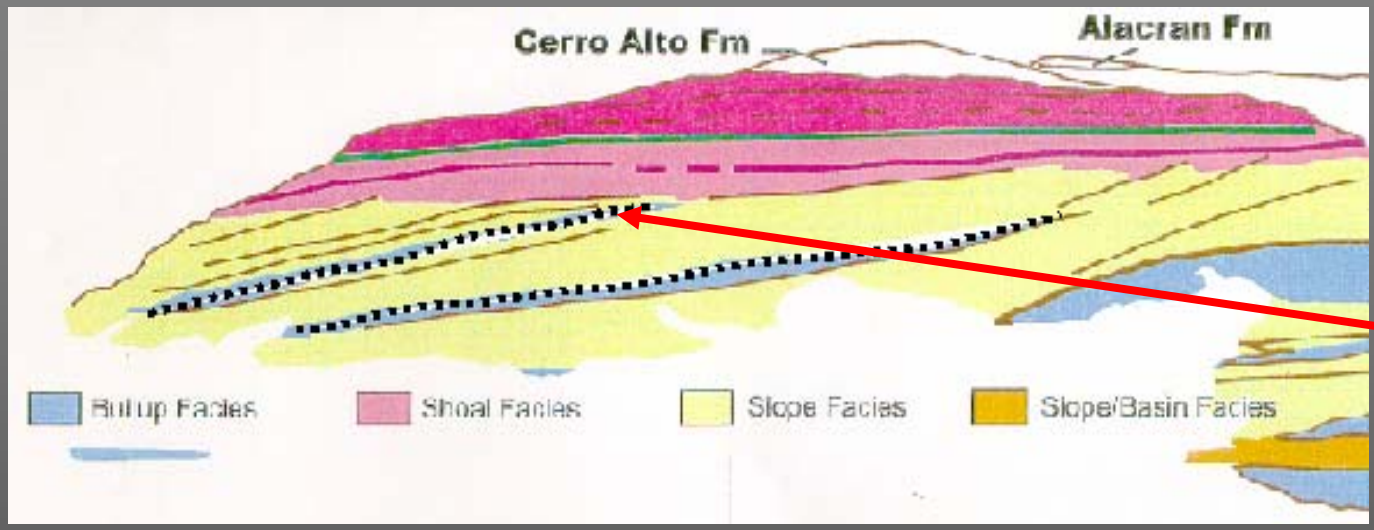
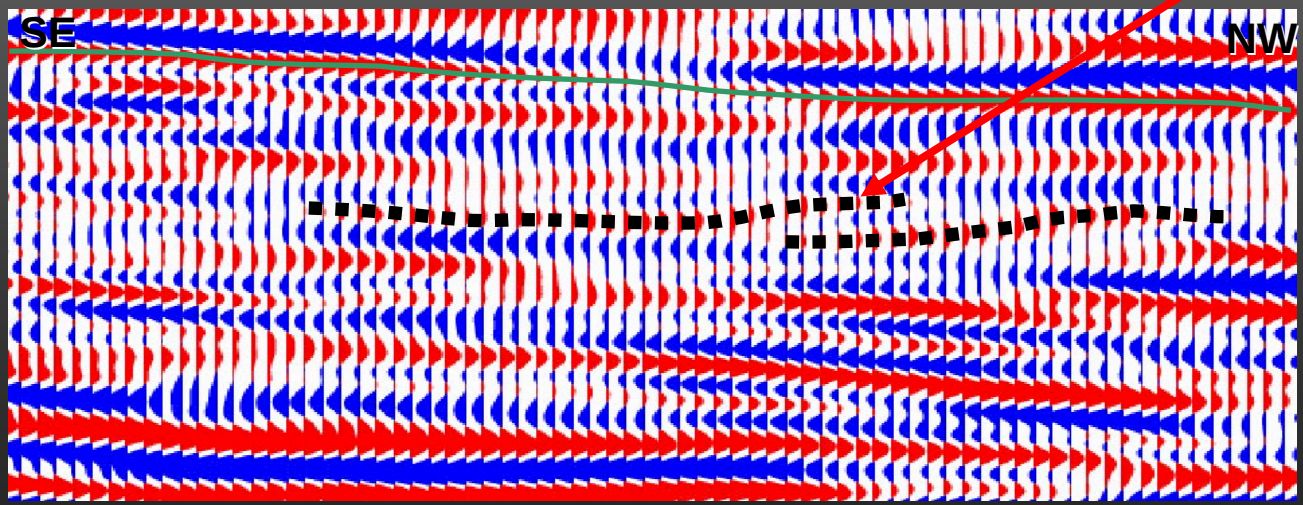
OUTCROP-SCALE RESOLUTION



Clinoforms believed to represent similar environments

Approximately 200 m



~ 55 m

Key Well With Core

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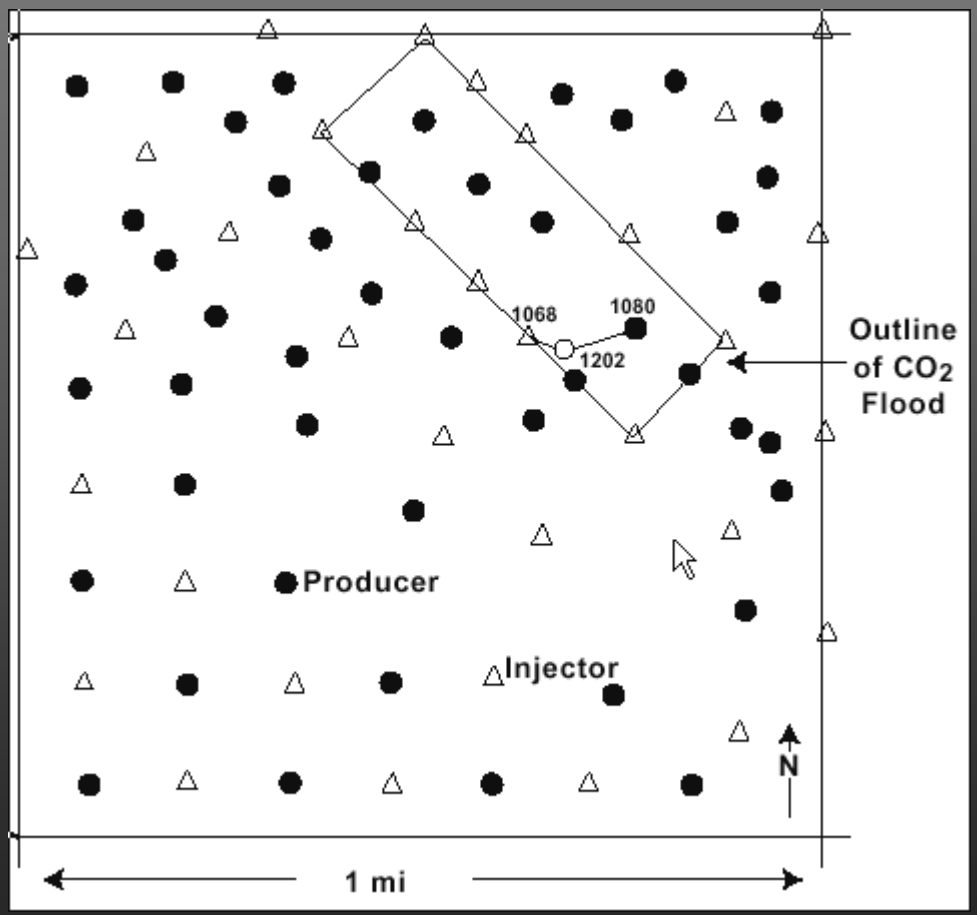
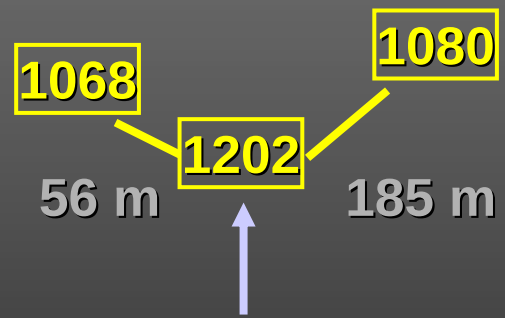
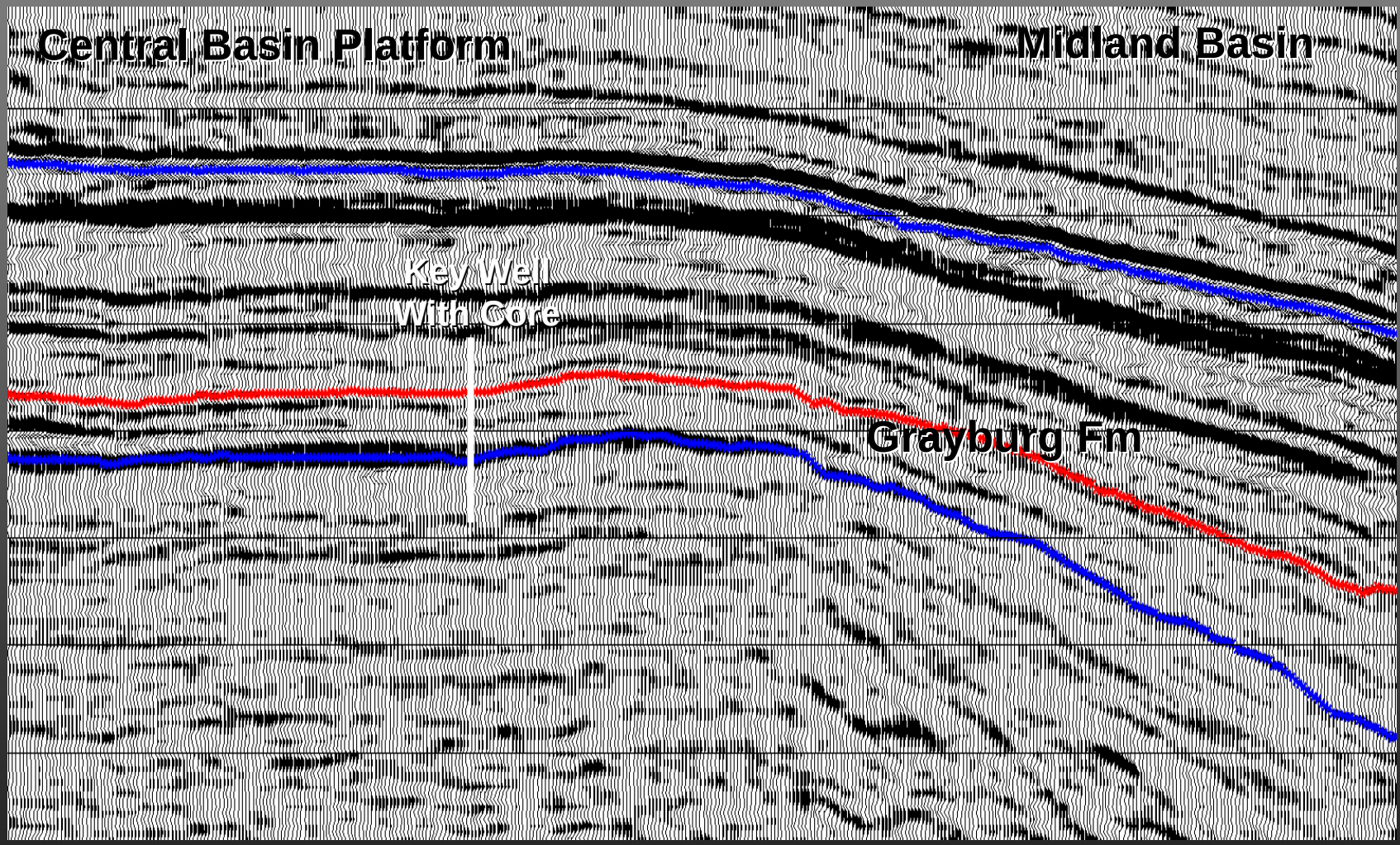
DATA ACQUISITION IN MCELROY



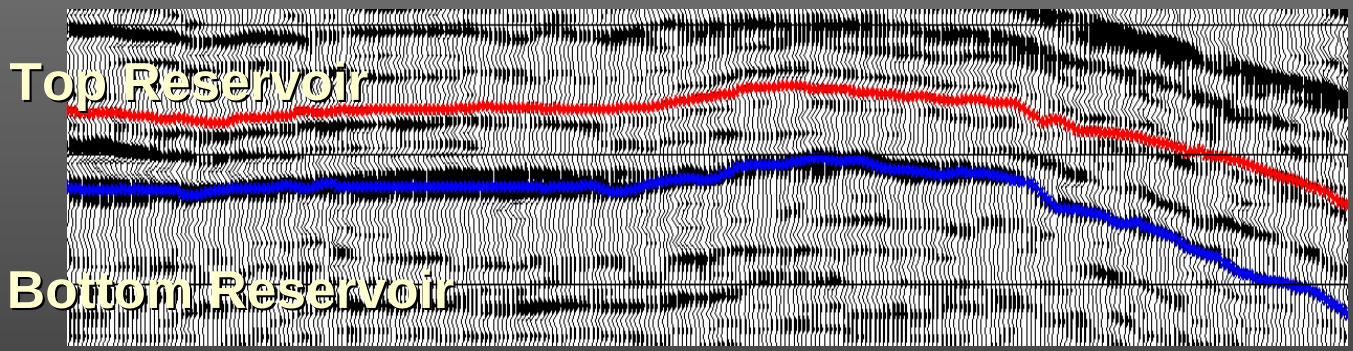


AFTER TUCKER ET AL, 1998

SURFACE 3D SEISMIC

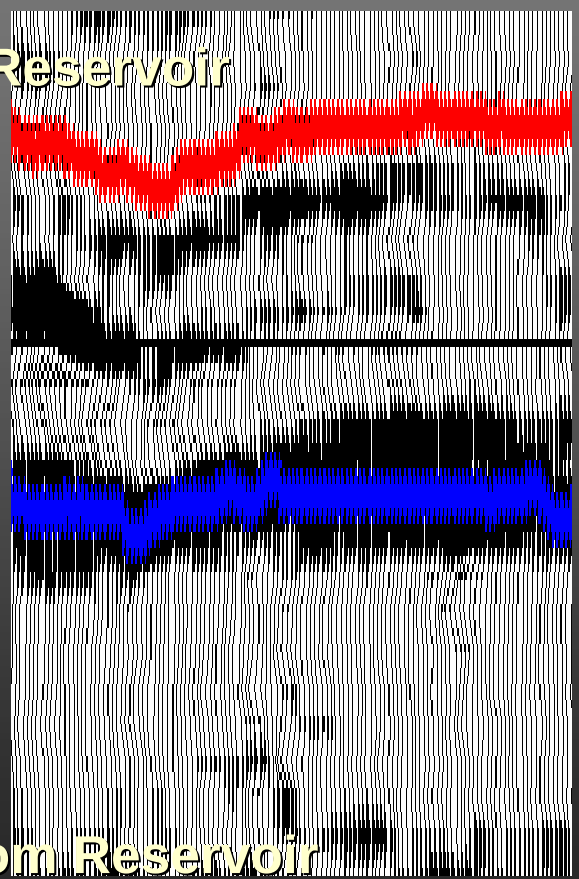


SURFACE 3D SEISMIC
RESERVOIR INTERVAL



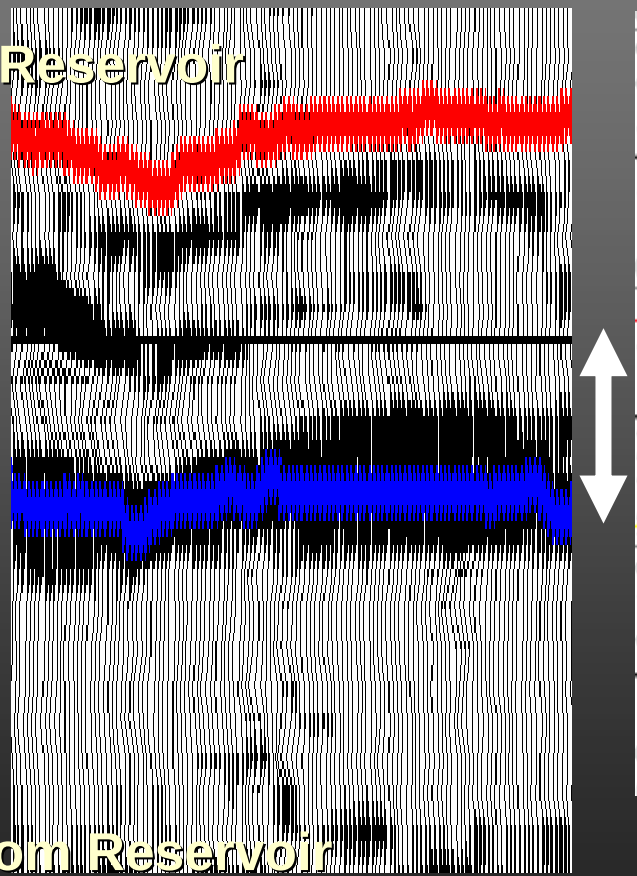
Grayburg Fm

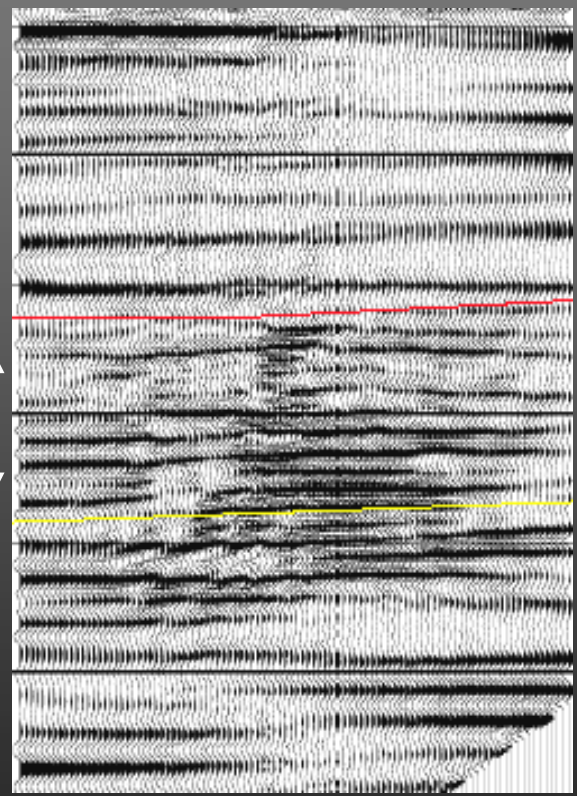
SURFACE 3D SEISMIC
RESERVOIR INTERVAL EXPANDED



Main Pay Zone = 24 m

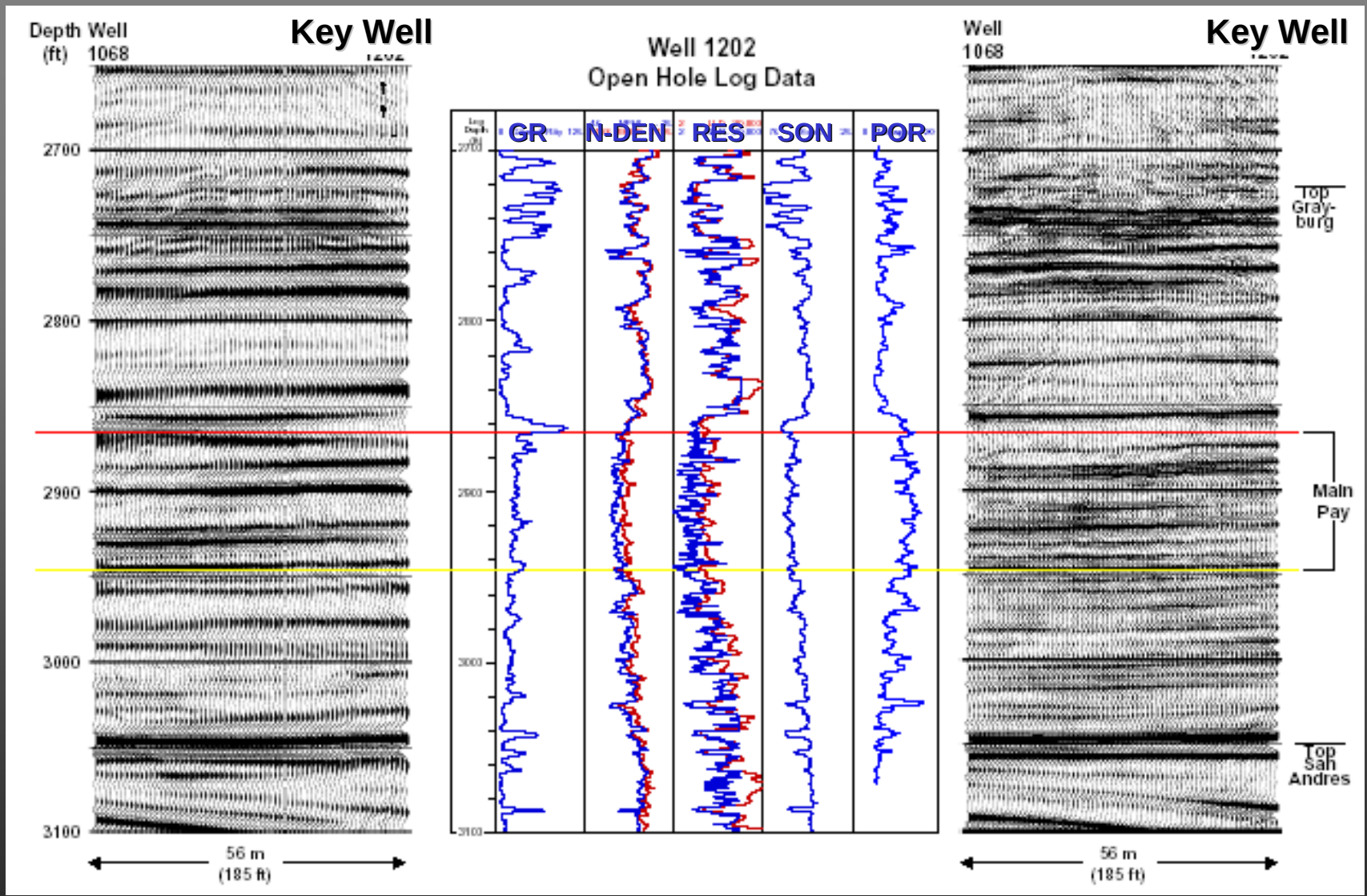
COMPARISON OF SURFACE 3D AND CROSSWELL SEISMIC





Main Pay Zone
= 24 m

CROSSWELL SEISMIC AND LOGS



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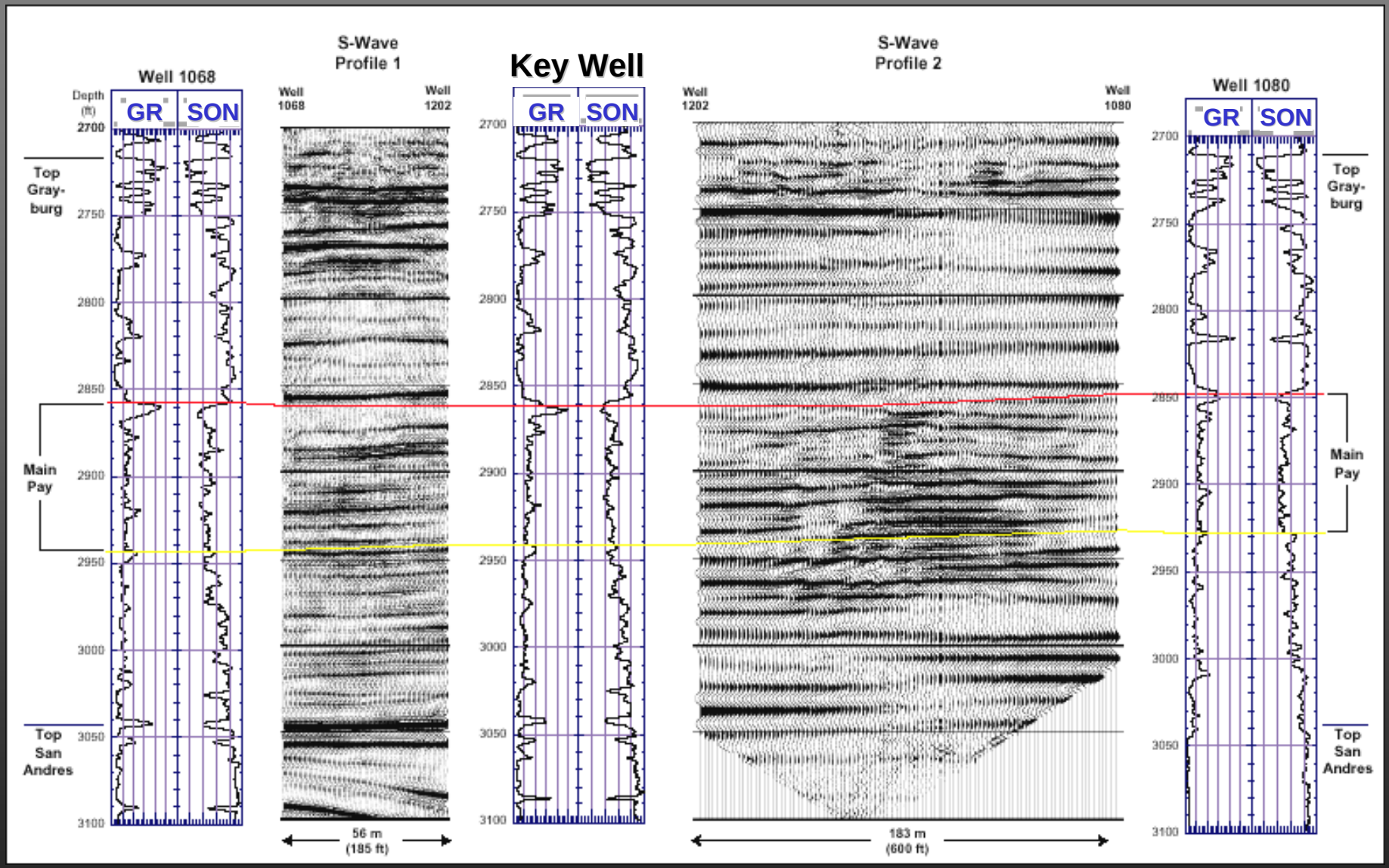
Reflectors = Increases in Sonic, Resistivity, and Bulk Density, also Decreases on Neutron from High to Low Porosity (or Gypsum)

INTERWELL VARIATION



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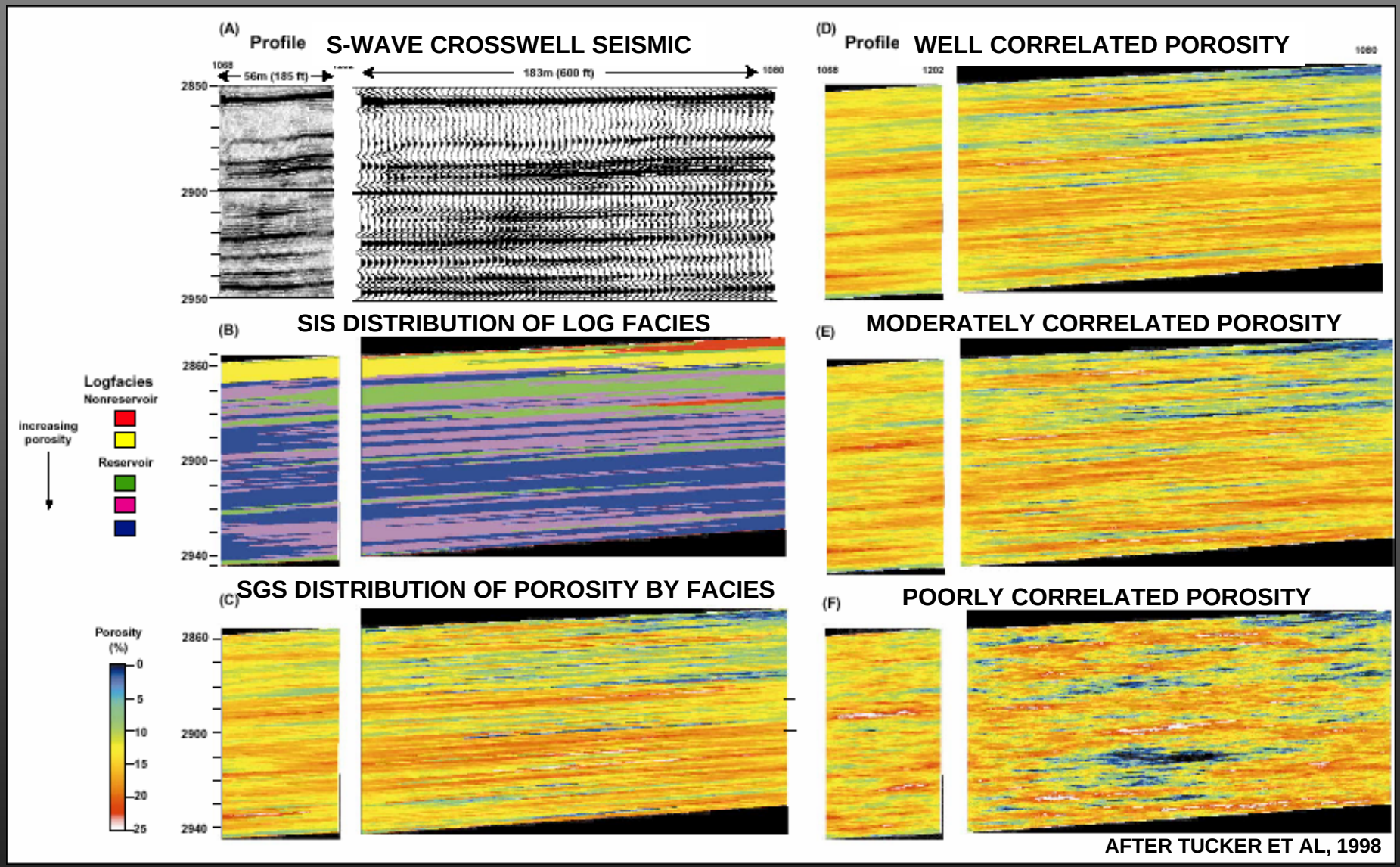
Reflectors, Along With GR and Sonic Log, Suggest Interwell Variation

LATERAL RESOLUTION

VALUE IN LAYERING AND ASSIGNING POROSITY TO MODEL



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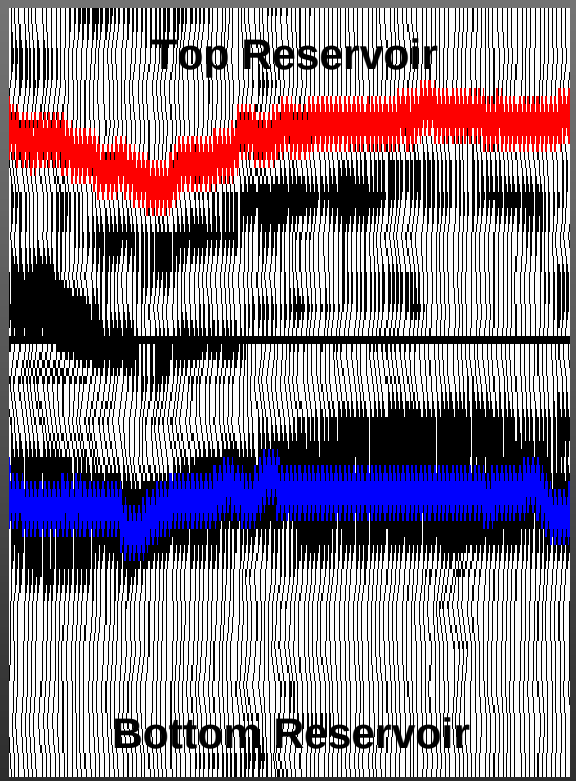
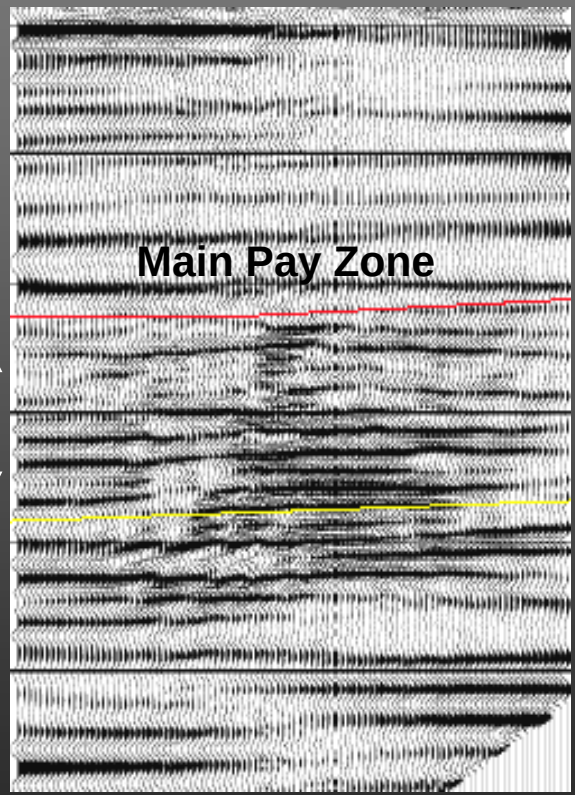
Images Resolve Lateral Changes in Porosity <56 m but >15 m

COMPARISON OF SEISMIC AND OUTCROP

SURFACE SEISMIC

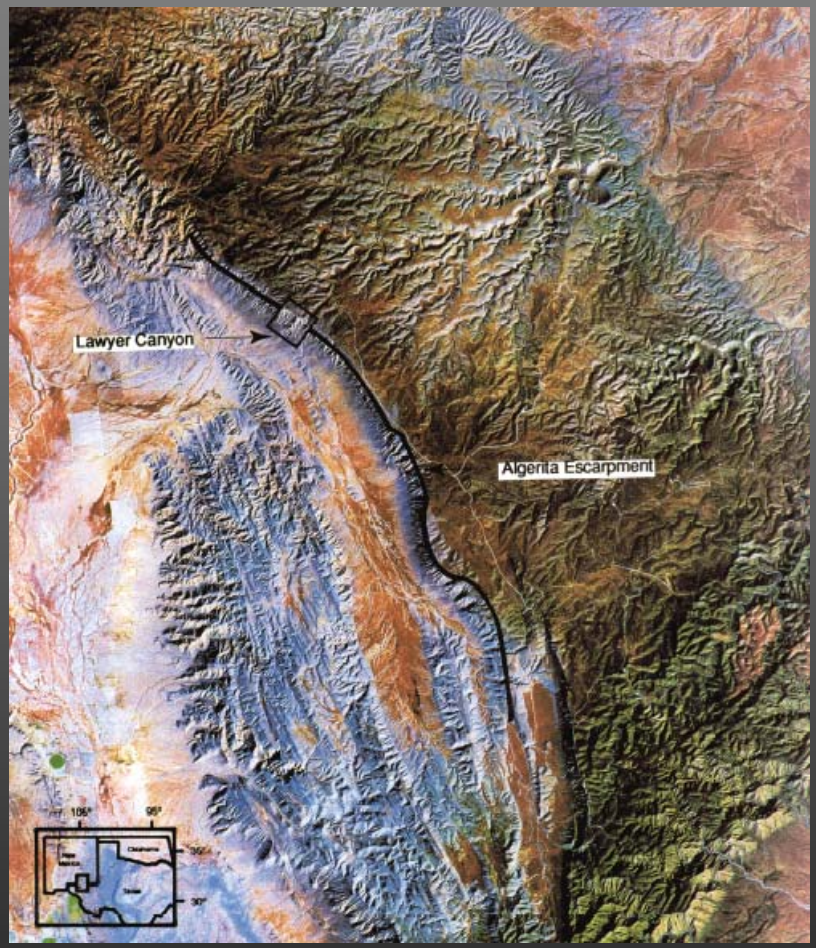


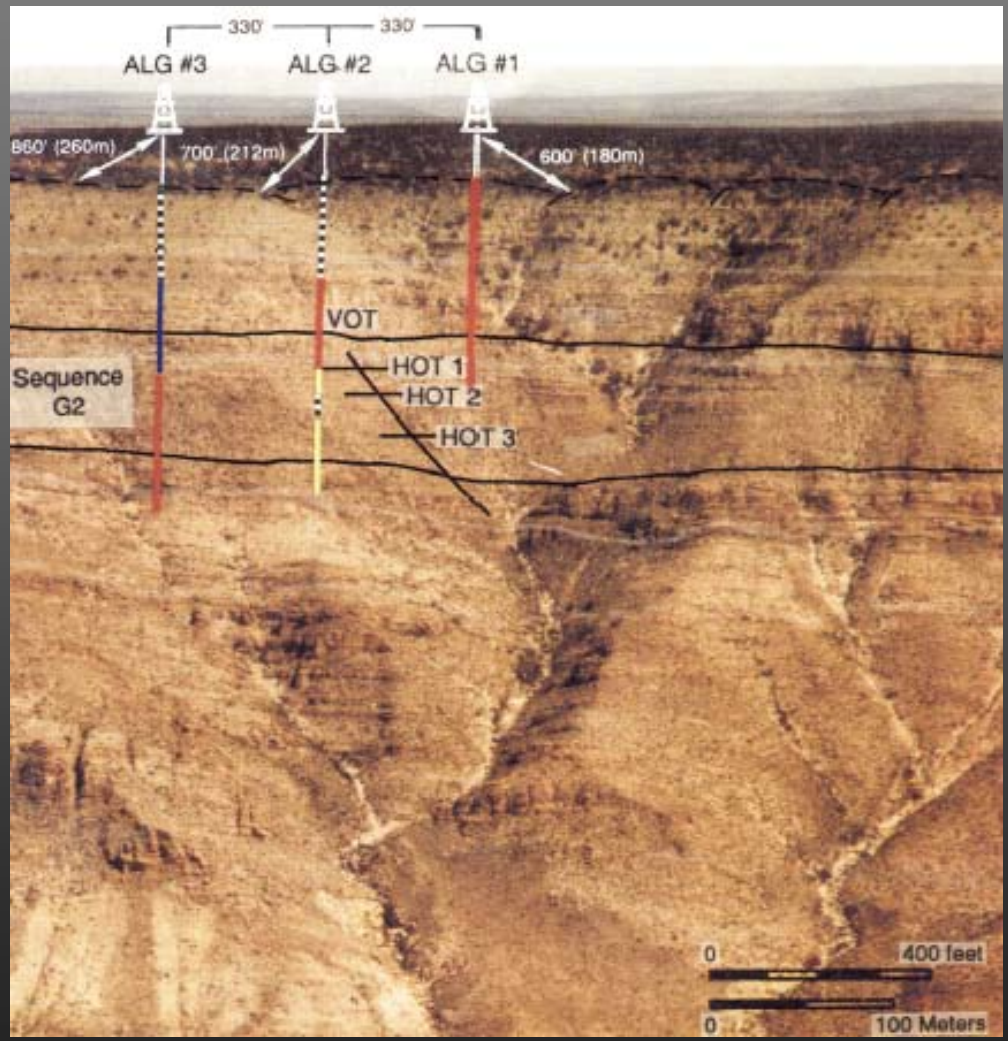
CROSSWELL SEISMIC



OUTCROP ANALOG

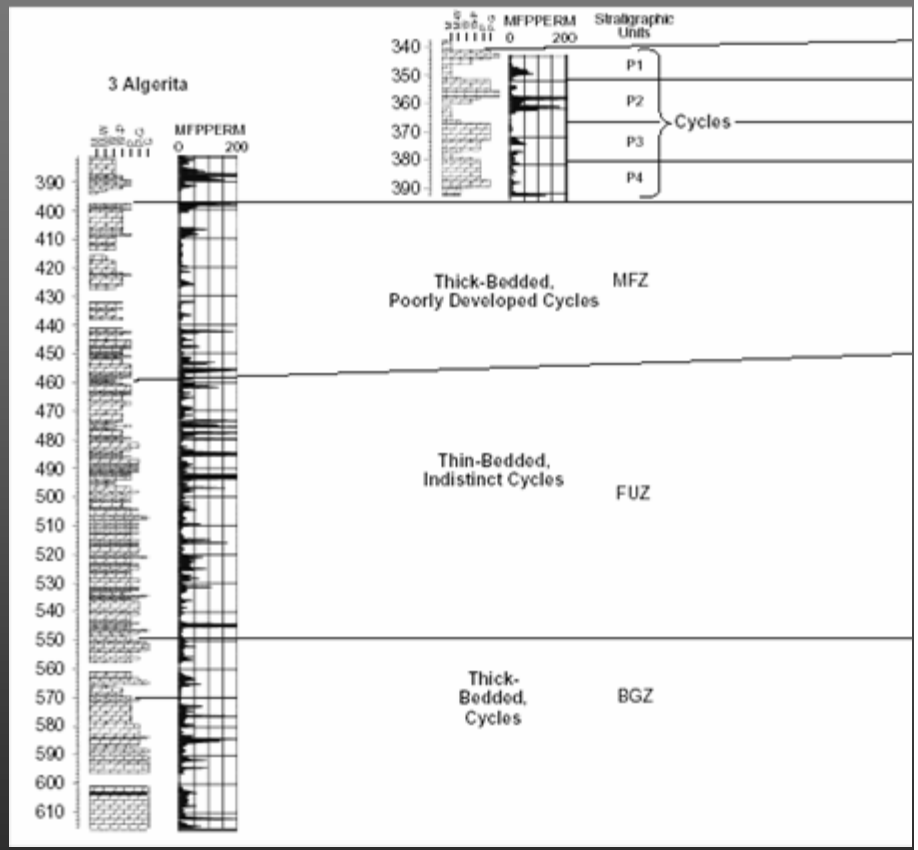
RESERVOIR-SCALE OUTCROP STUDIES

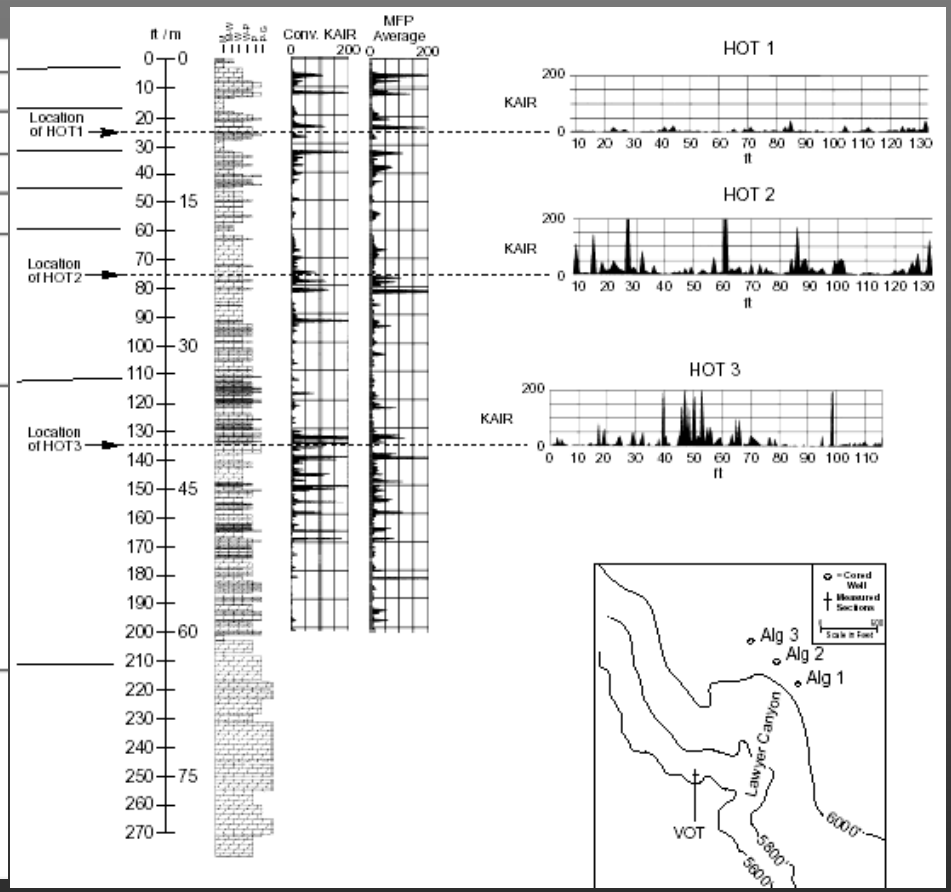




AFTER EISENBERG ET AL, 1994

STRATIGRAPHY, FACIES, AND PERMEABILITY





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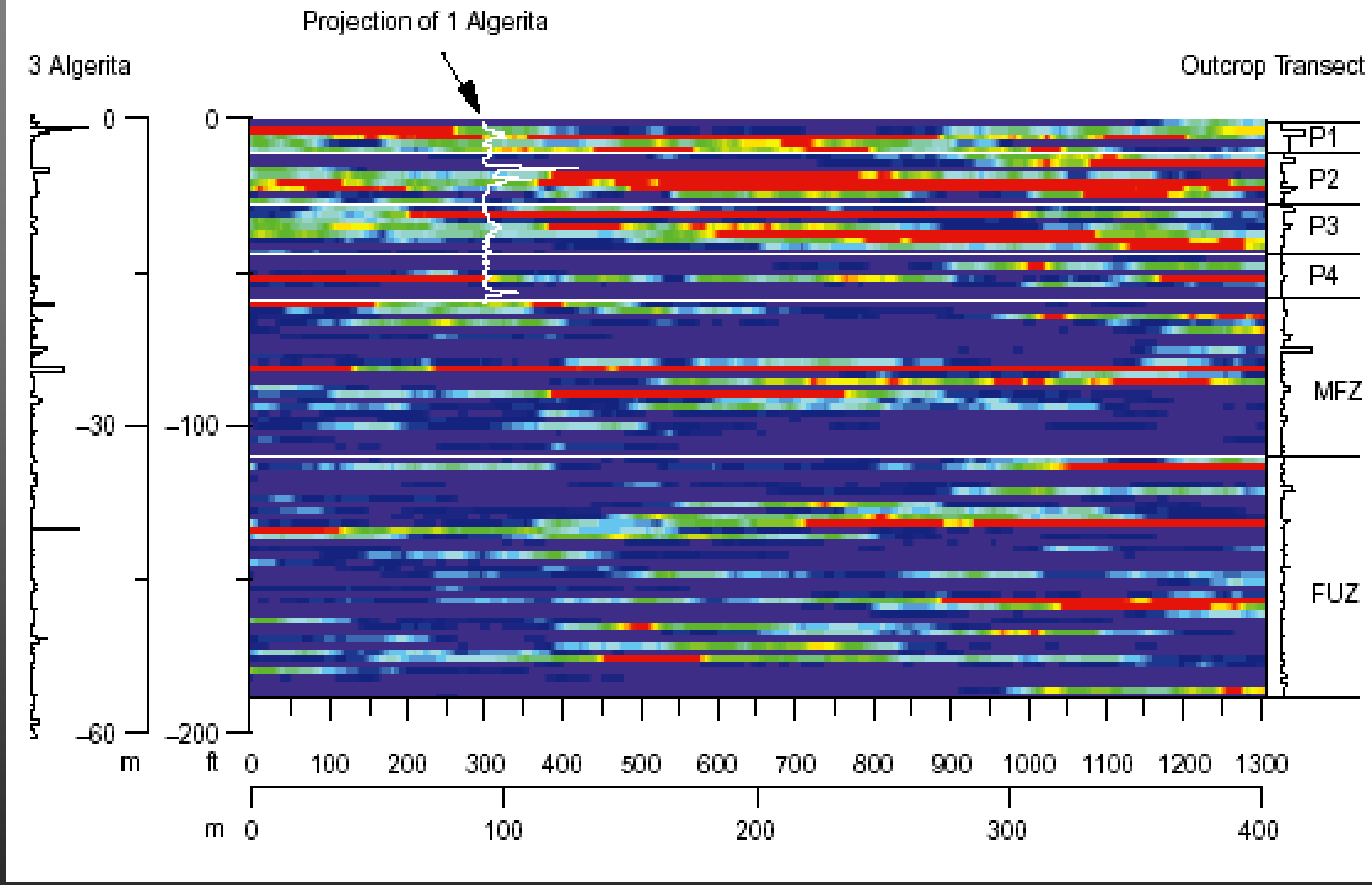
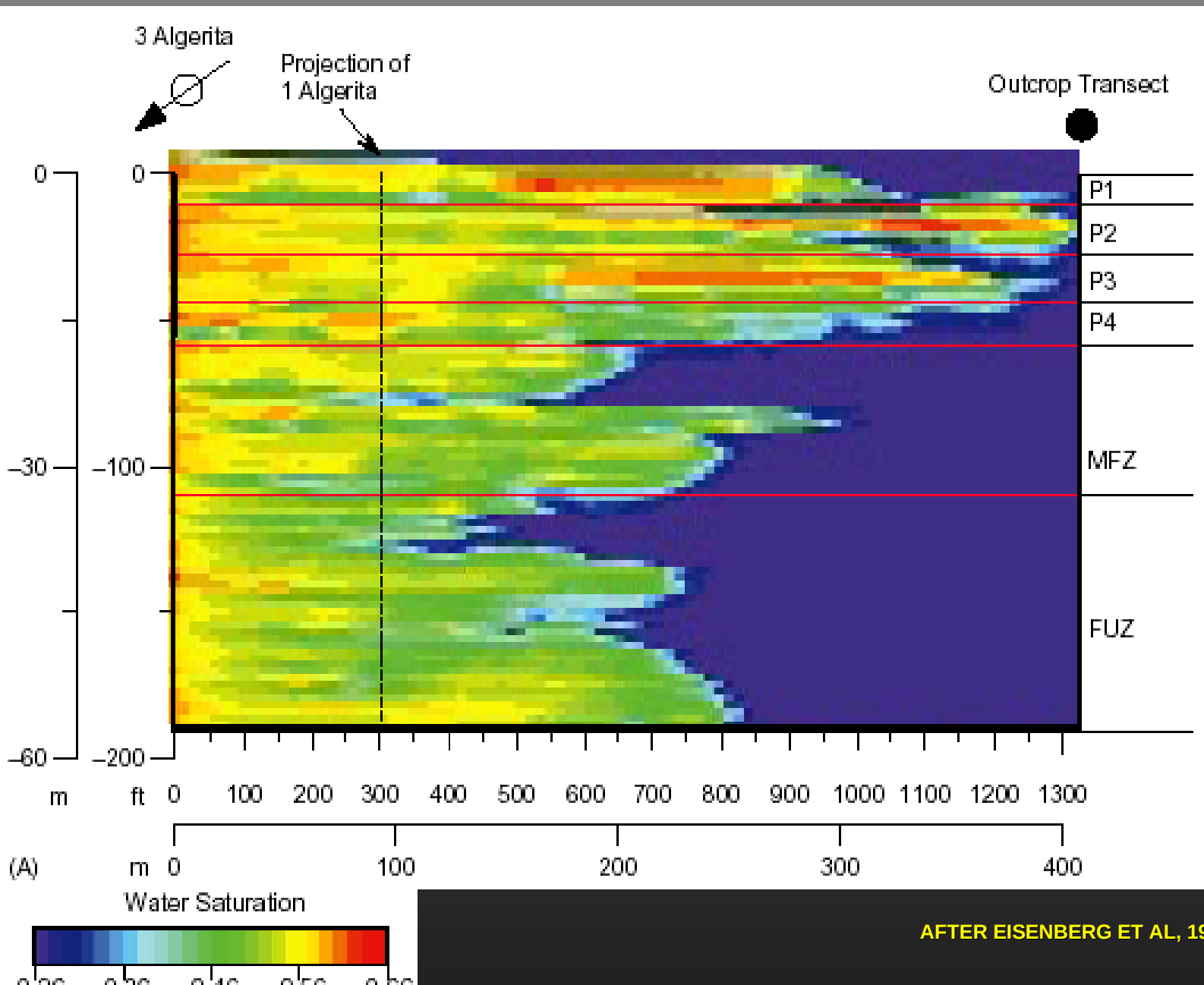
MODELING PERMEABILITY



AFTER EISENBERG ET AL, 1994

MODELING FLUID FLOW

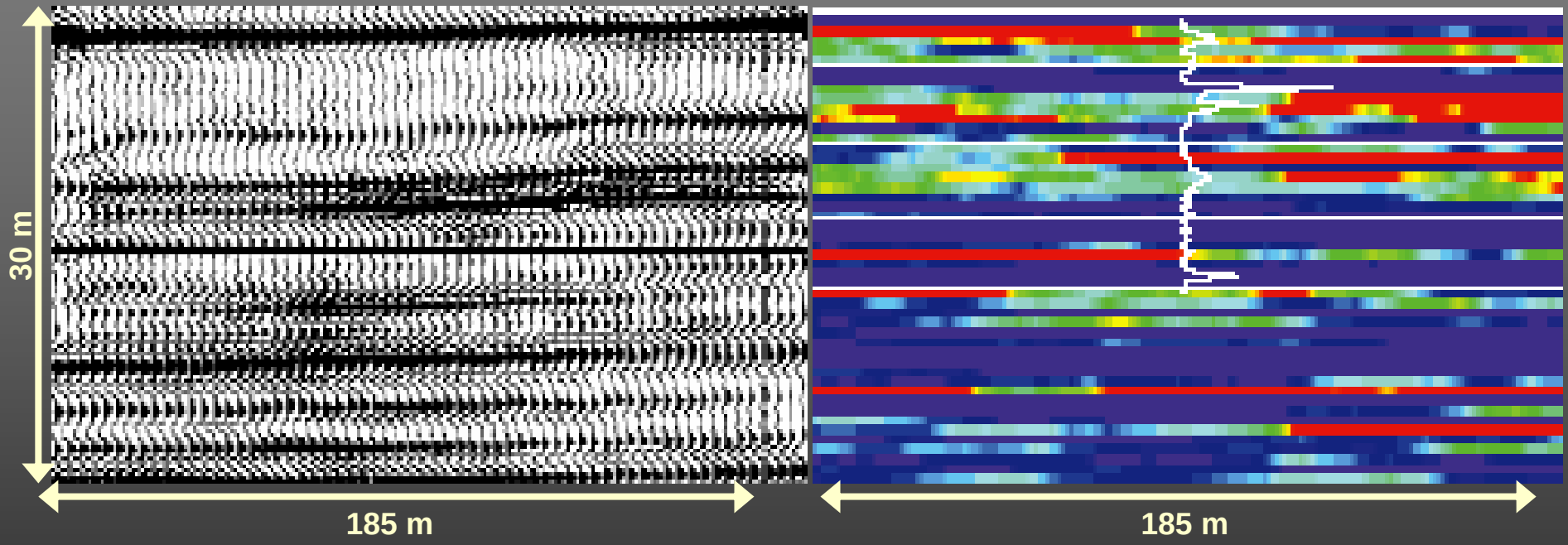


AFTER EISENBERG ET AL, 1994

CROSSWELL RESOLUTION

CROSSWELL SEISMIC

OUTCROP PERMEABILITY



Images Resolve - Small-Scale Cycles

Lateral Changes in Porosity Comparable to Outcrop

CROSSWELL SEISMIC VALUE IN RESERVOIR DELINEATION

- Define greater geologic detail between wells (heterogeneity of reservoir)
- Recognition of laterally continuous zones for improved development (well positioning, completions, injection)
- Input to reservoir models when tied to facies (layering and assigning porosity)

THANK YOU FOR LISTENING!