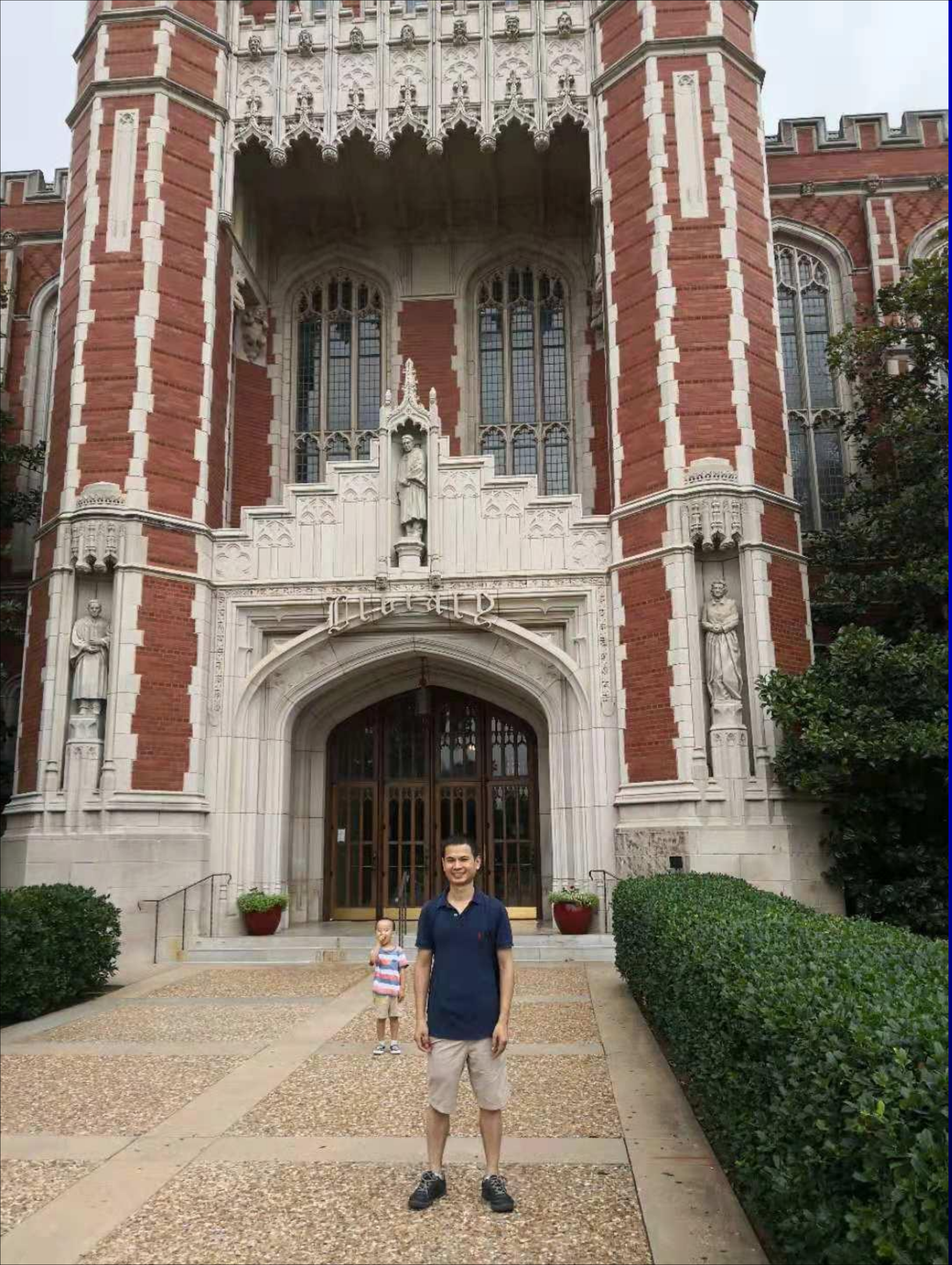
ConocoPhillips
SCHOOL OF GEOLOGY & GEOPHYSICS
The University of Oklahoma

中国石油大学(北京)
CHINA UNIVERSITY OF PETROLEUM

Lecture 1: Introduction

Dr. Zonghu Liao



Dr. Zonghu Liao

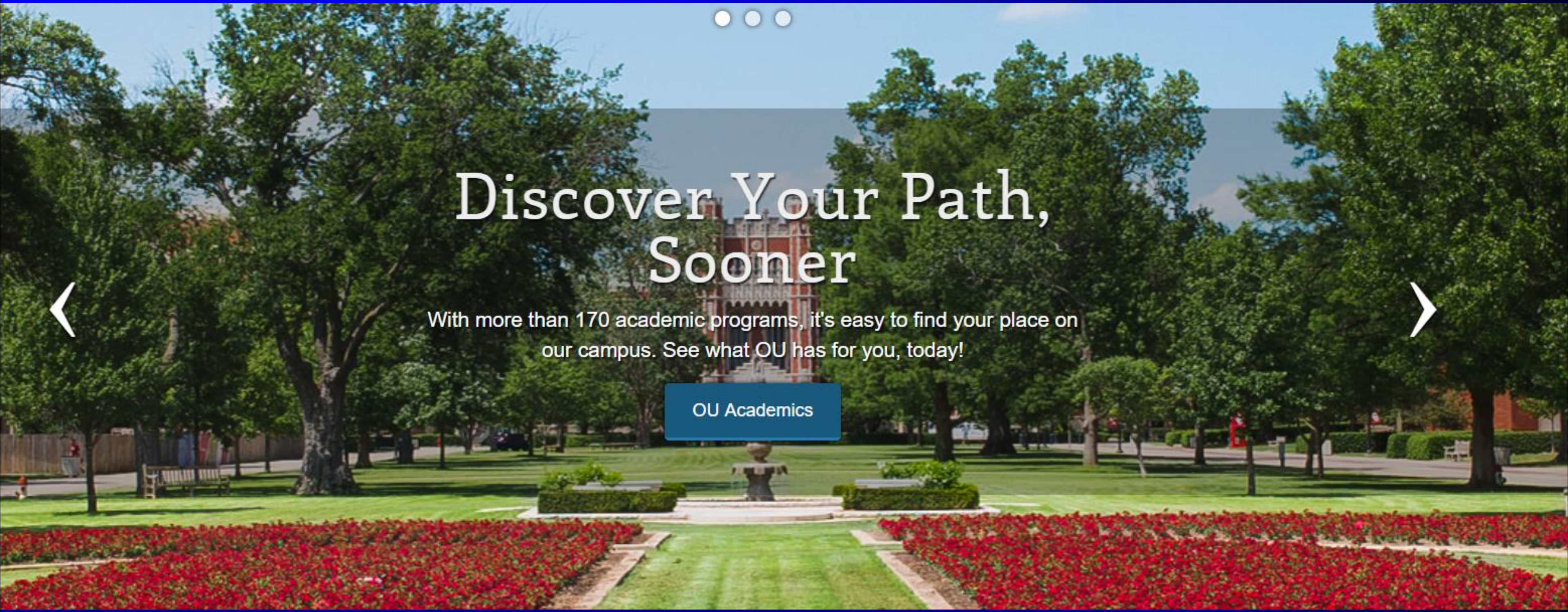
- Fuzhou University
- 2008, BS

- University of Oklahoma
- 2010, 2012 MSs

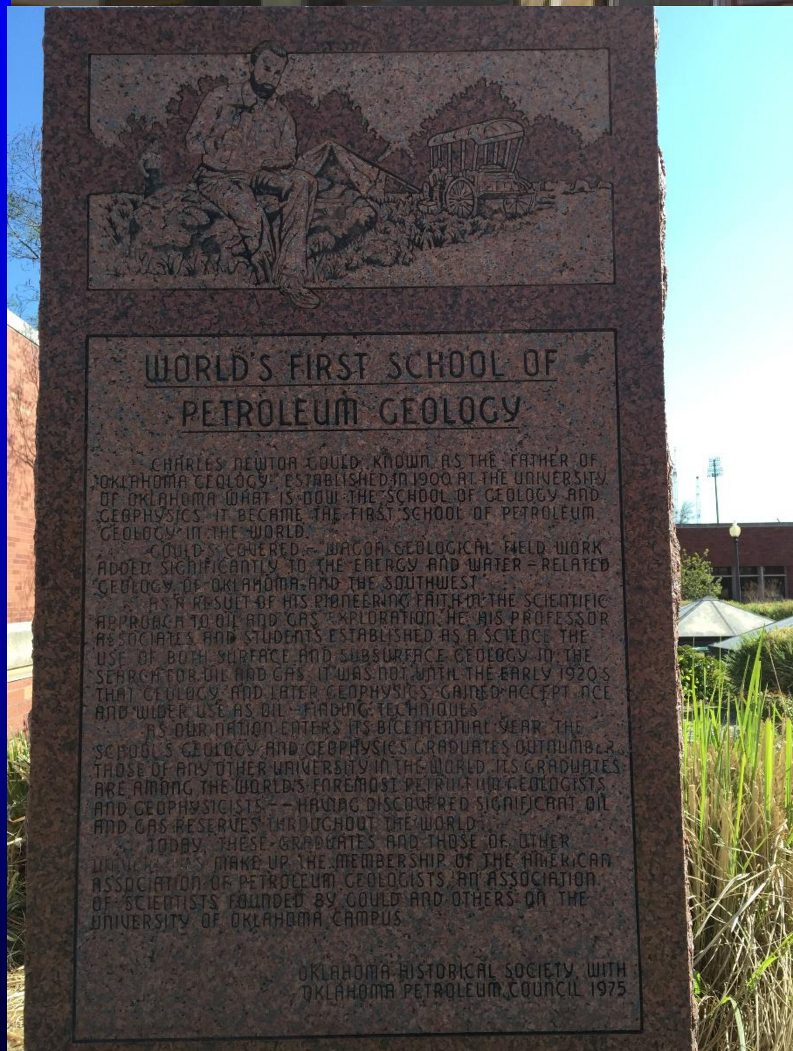
- University of Oklahoma
- 2013, PhD

- China University of Petroleum
- 2014- Associate Professor

University of Oklahoma, School of Geology and Geophysics



The world's first school of petroleum geology, since 1900


WORLD'S FIRST SCHOOL OF
PETROLEUM GEOLOGY
CHARLES NEWTON GOULD, KNOWN AS THE "FATHER OF OKLAHOMA GEOLOGY", ESTABLISHED IN 1900 AT THE UNIVERSITY OF OKLAHOMA WHAT IS NOW THE SCHOOL OF GEOLOGY AND GEOPHYSICS. IT BECAME THE FIRST SCHOOL OF PETROLEUM GEOLOGY IN THE WORLD.
GOULD'S COVERED - WAGON GEOLOGICAL FIELD WORK ADDED SIGNIFICANTLY TO THE ENERGY AND WATER - RELATED GEOLOGY OF OKLAHOMA AND THE SOUTHWEST.
AS A RESULT OF HIS PIONEERING FAITH IN THE SCIENTIFIC APPROACH TO OIL AND GAS EXPLORATION, HE, HIS PROFESSOR ASSOCIATES, AND STUDENTS ESTABLISHED AS A SCIENCE THE USE OF BOTH SURFACE AND SUBSURFACE GEOLOGY IN THE SEARCH FOR OIL AND GAS. IT WAS NOT UNTIL THE EARLY 1920'S THAT GEOLOGY, AND LATER GEOPHYSICS, GAINED ACCEPTANCE AND WIDER USE AS OIL - FINDING TECHNIQUES.
AS OUR NATION ENTERS ITS BICENTENNIAL YEAR, THE SCHOOL'S GEOLOGY AND GEOPHYSICS GRADUATES OUTNUMBER THOSE OF ANY OTHER UNIVERSITY IN THE WORLD. ITS GRADUATES ARE AMONG THE WORLD'S FOREMOST GEOLOGISTS AND GEOPHYSICISTS - - HAVING DISCOVERED SIGNIFICANT OIL AND GAS RESERVES THROUGHOUT THE WORLD.
TODAY, THESE GRADUATES AND THOSE OF OTHER MAKE UP THE MEMBERSHIP OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, AN ASSOCIATION OF SCIENTISTS FOUNDED BY GOULD AND OTHERS ON THE UNIVERSITY OF OKLAHOMA CAMPUS.
OKLAHOMA HISTORICAL SOCIETY, WITH
OKLAHOMA PETROLEUM COUNCIL 1975

My research interests: Structures, earthquake

➤ Submission deadline:

5 December 2016

https://mc.manuscriptcentral.com/interpretation

A joint publication of SEG and AAPG

Interpretation®

A journal of subsurface characterization

Society of Exploration Geophysicists — The international society of applied geophysics

AAPG

Fault damage zones

Fault damage zones are complex bodies that developed along major faults, and include a multitude of faults, fractures, breccia bodies, secondary mineralization, alteration zones, and gouge. The mechanical and hydrologic properties of damage zones play a central role in basin analysis, earthquake activity, ore deposits, geothermal sites, and migration and trapping of hydrocarbons. Further, understanding the structure and geomechanical properties of damage zones is critical for production through horizontal boreholes and successful hydrofracturing of unconventional deposits. For this issue, we invite investigations of all aspects of fault damage zones including seismic interpretation, field observations, laboratory experiments, theoretical models, numerical simulations, and case studies of exploration and production of reservoirs. We also welcome analyses related to mining development, and natural and induced earthquakes.

The editors of *Interpretation* (http://www.seg.org/interpretation) invite papers on the topic **Fault damage zones** for publication in a November 2017 special section to supplement the journal's regular technical papers on various subject areas.

Papers will be published online as soon as they are accepted, edited, and composed. The issue is scheduled to be printed in November 2017.

We are seeking submissions on related topics including:

- structure and mechanical models and simulations of fault damage zones
- damage zones effects on reservoir properties
- characterization of damage zones in the field and subsurface
- the impact of damage zone to the petroleum production
- case studies

Interpretation, copublished by SEG and AAPG, aims to advance the practice of subsurface interpretation.

The submissions will be processed according to the following timeline:

Submission deadline:

5 December 2016

Publication of issue:

November 2017

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Assistant editor

Interpretation is the best journal jointed by SEG and AAPG

Course Objectives

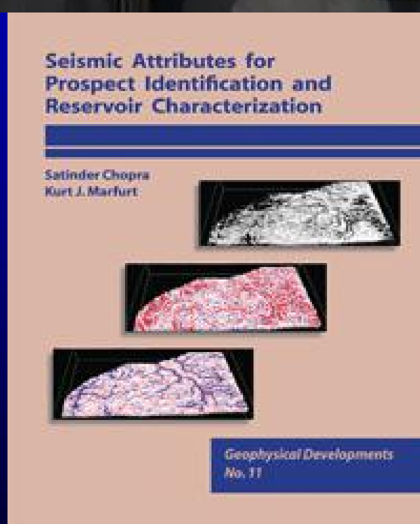
After completing this course you will be able to:

- Generate good quality time-structure maps
- Generate good quality fault-plane images
- Effectively use color
- Effectively use 3D visualization
- Identify noise and artifacts due to seismic acquisition and processing
- Evaluate the quality of interpreted sections and maps
- Predict attributes that may enhance features of geologic interest
- Generate images that can be used in
  - Seismic geomorphology
  - Fracture delineation
  - Reservoir characterization

Course Outline (Lecture)

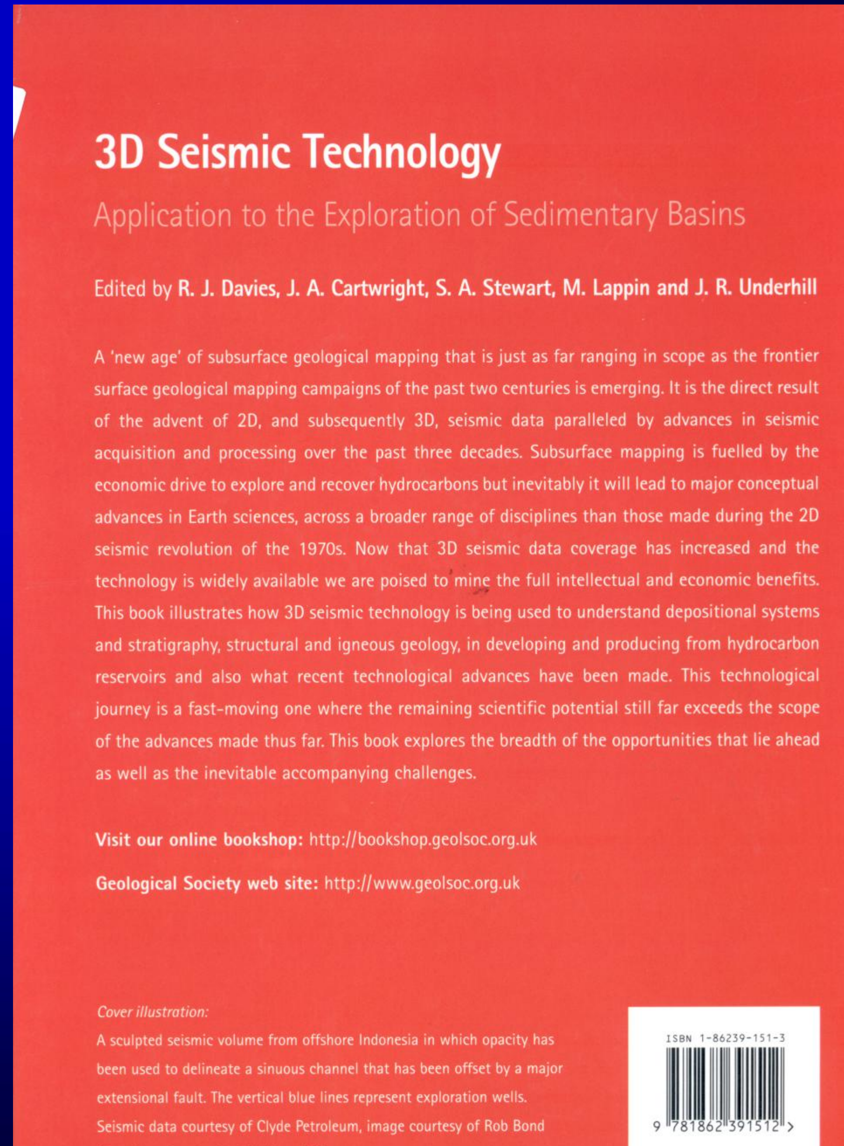
Introduction
The Seismic Experiment
Spectral content and limits to vertical resolution
Color display and 3D visualization
Complex Trace Attributes
Horizon and Formation Attributes
Interpreting a structurally complex section
Geometric Attributes
Structure-Oriented Filtering and Image Enhancement
Spectral Decomposition
Attribute Expression of Geology
Impact of Velocities on Seismic Interpretation
Impact of Migration on Seismic Interpretation
Attribute Illumination of Fractures

Text Book



Title: Seismic Attributes for Prospect ID and Reservoir Characterization
Authors: Satinder Chopra and Kurt J. Marfurt
ISBN: 1560801417
Publisher: SEG/EAGE
Pubication date: 2007-07-07
Price: US$139.00 Member Price: US$89.00 Student

Recommended Book
Excellent case studies and workflows!



3D Seismic Technology

Application to the Exploration of Sedimentary Basins

Edited by **R. J. Davies, J. A. Cartwright, S. A. Stewart, M. Lappin and J. R. Underhill**

A 'new age' of subsurface geological mapping that is just as far ranging in scope as the frontier surface geological mapping campaigns of the past two centuries is emerging. It is the direct result of the advent of 2D, and subsequently 3D, seismic data paralleled by advances in seismic acquisition and processing over the past three decades. Subsurface mapping is fuelled by the economic drive to explore and recover hydrocarbons but inevitably it will lead to major conceptual advances in Earth sciences, across a broader range of disciplines than those made during the 2D seismic revolution of the 1970s. Now that 3D seismic data coverage has increased and the technology is widely available we are poised to mine the full intellectual and economic benefits. This book illustrates how 3D seismic technology is being used to understand depositional systems and stratigraphy, structural and igneous geology, in developing and producing from hydrocarbon reservoirs and also what recent technological advances have been made. This technological journey is a fast-moving one where the remaining scientific potential still far exceeds the scope of the advances made thus far. This book explores the breadth of the opportunities that lie ahead as well as the inevitable accompanying challenges.

Visit our online bookshop: http://bookshop.geolsoc.org.uk

Geological Society web site: http://www.geolsoc.org.uk

Cover illustration:

A sculpted seismic volume from offshore Indonesia in which opacity has been used to delineate a sinuous channel that has been offset by a major extensional fault. The vertical blue lines represent exploration wells. Seismic data courtesy of Clyde Petroleum, image courtesy of Rob Bond (Paradigm Geophysical, Woking, UK)

ISBN 1-86239-151-3
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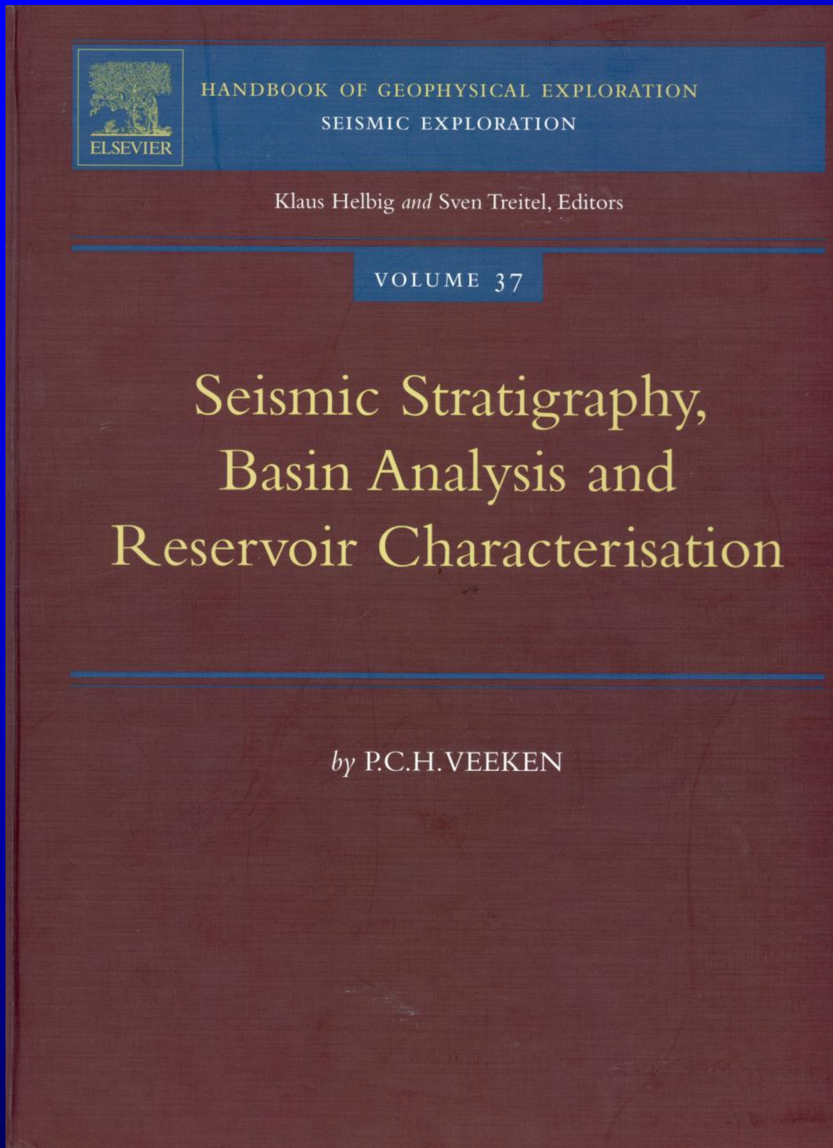


Yet another excellent book Veeken (2007) $145

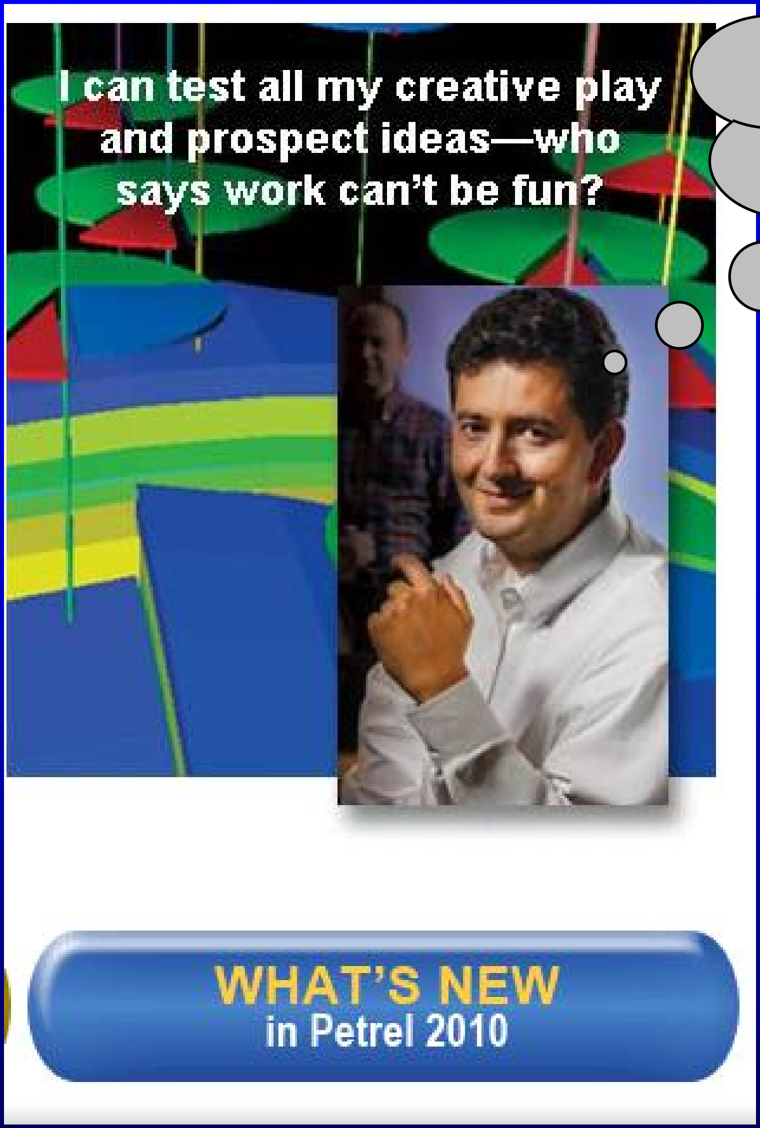
- Good general overview of processing
- Heavier emphasis on reservoir characterization and basin analysis!

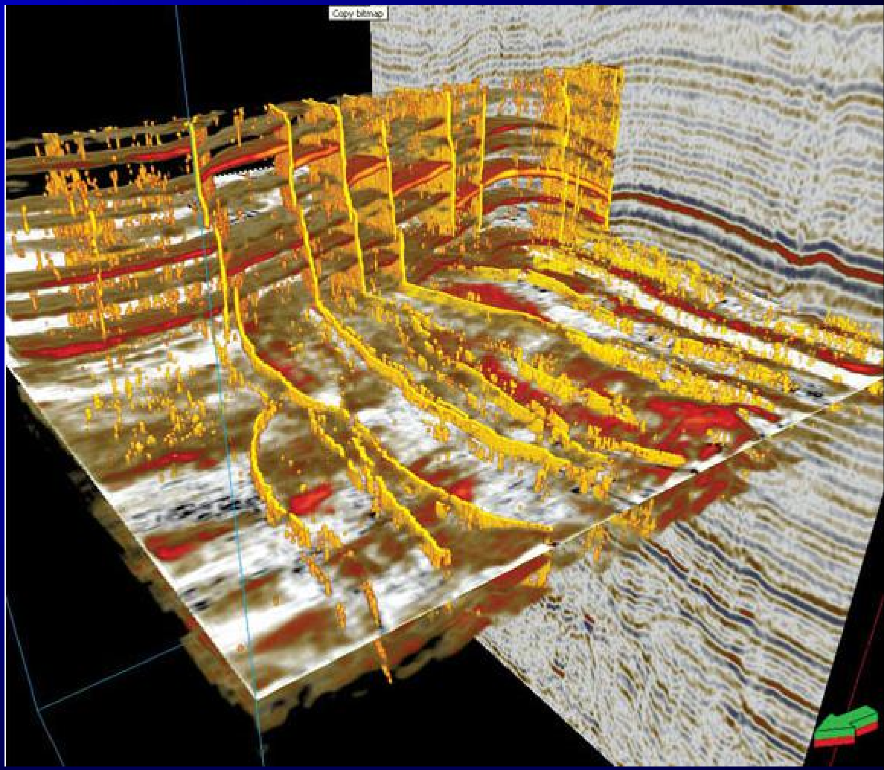
Course Outline (Labs)

Data Loading – what is SEGY and QC-ing your data
3D visualization
Interpreting faults and generating fault planes
Interpreting horizons
Generating horizon slices
Generating attributes
Generating a map
Time/depth conversion (if I can find an appropriate data set)

You can have as much fun as happy as me if you learn Petrel 2010…

Software





Risk Analysis
(How E&P companies evaluate drilling opportunities)

1. Political risk (e.g. Somalia, Sudan, Myanmar are high risk, Louisiana and Norway are low risk)
2. Taxation risk (e.g. Kuwait is very high risk, Norway moderate)
3. Transportation risk (e.g. Oil from offshore Greenland is high, oil from Oklahoma is low)
4. Technical risks
   - Drilling risks: pressures, temperatures, seal integrity, hydraulic fracture response
   - Production risks: Corrosion, heavy oil, disposal costs, …
   - Geological risk: Hydrocarbon volumes, depths and products

Two major objectives in mapping hydrocarbons

1. Exploration: Location of previously untapped hydrocarbons

2. Development (Production, Exploitation): efficient delineation and extraction of those hydrocarbons

Seven components of hydrocarbon accumulation

1. Source rock
2. Migration pathway
3. Reservoir
4. Trap
5. Seal
6. Timing
7. Product

1. Source Rock

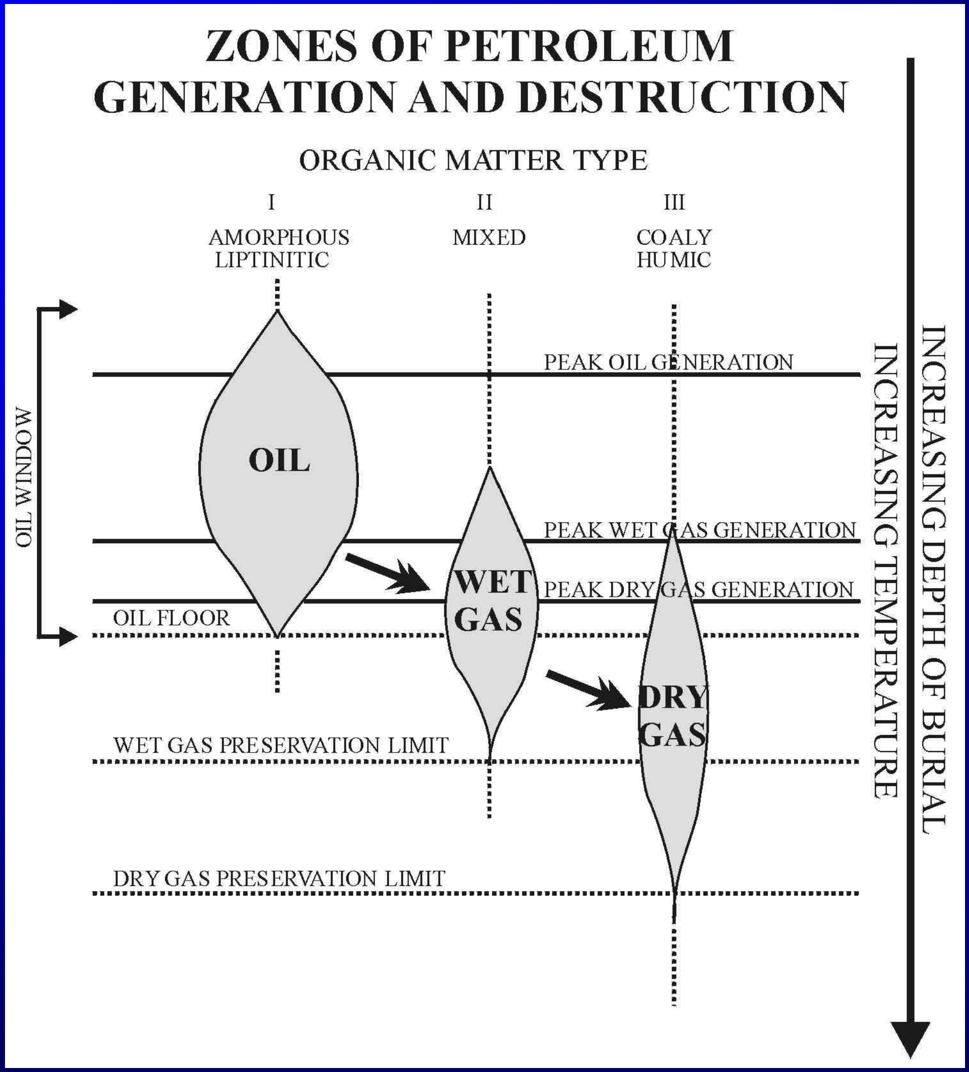
- ***What is it?***

  An organic rich rock, usually shale but sometimes limestone, which contains enough of that material to generate economic hydrocarbons and has been subjected to the proper temperature and pressure conditions to expulse those hydrocarbons.

- ***How does seismic help?***

  Minimal - Seismic cannot identify source rocks but may be used to determine if a known source rock is deep enough to generate hydrocarbons over a large enough area to produce economic amounts

(courtesy Chuck Blumentritt)



Hydrocarbon generation window.

(Lines and Newkirk, 2004)

2. Migration Pathway

- ***What is it?***

  A connection between the area in which a source rock expulses hydrocarbons and the trap in which they are found.

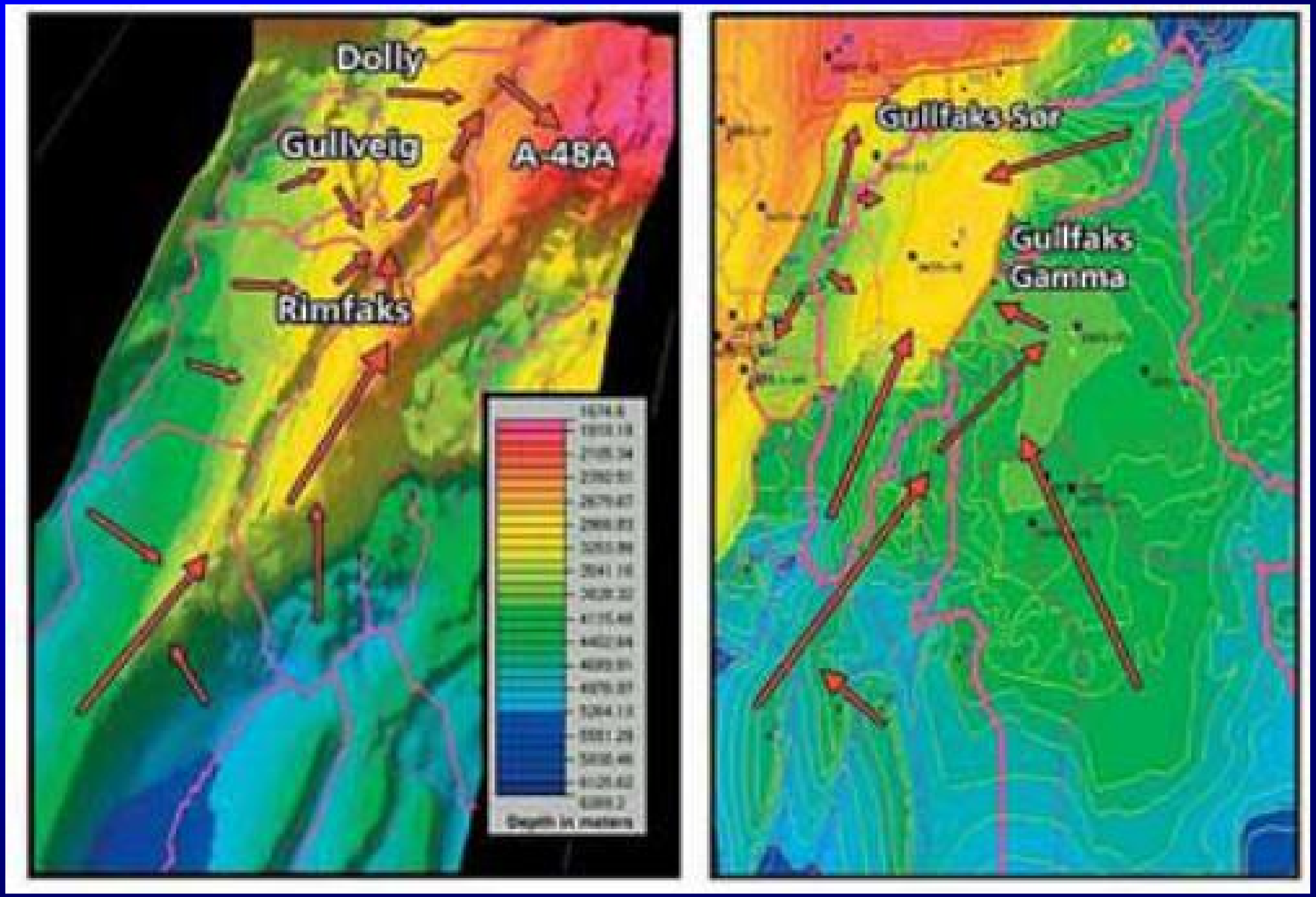
- ***How does seismic help?***

  Minimal-Seismic data may be used to determine what barriers there are between the area in which hydrocarbons are generated and the trap. Seismic data cannot indicate if such a pathway has been used or how efficiently.

(courtesy Chuck Blumentritt)

Oil Migration Pathways

(present-day top Middle Jurassic Brent Group level)



around the Rimfaks-Gullveig

around the Gullfaks South

http://www.statoil.com/STATOILCOM/technology

3. Reservoir

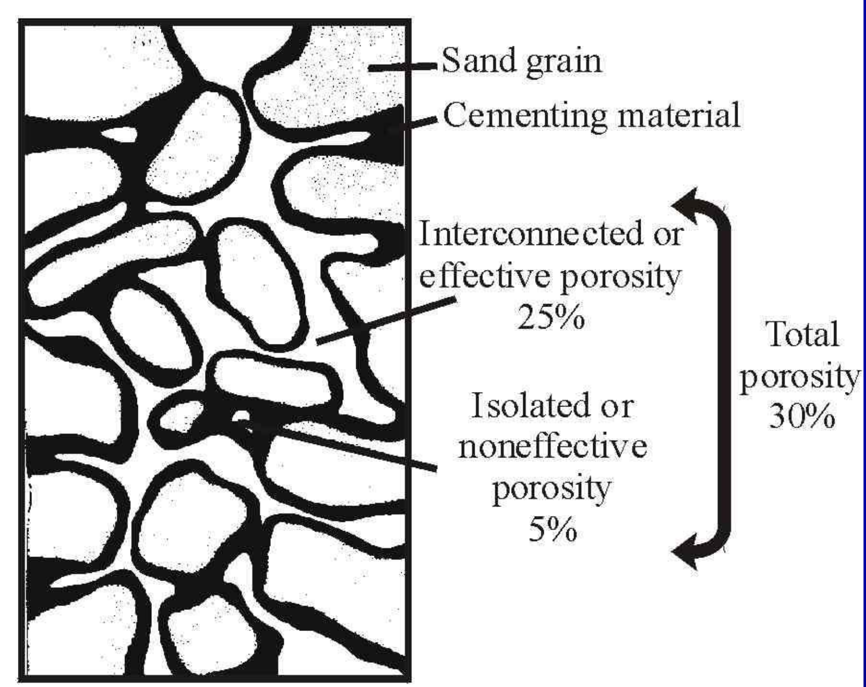
- ***What is it?***

  A rock, usually a sandstone, limestone, or dolomite, with sufficient porosity (holes) and permeability (connections between the holes) to contain hydrocarbons for storage but allow them to be extracted.

- ***How does seismic help?***

  Moderate - Seismic amplitude variations may indicate changes in porosity or changes from a non-porous type of rock to a porous type. Seismic data does not give any indication of permeability. Evolving uses to predict natural fractures, present-day stress field, and shale gas 'fracability'.

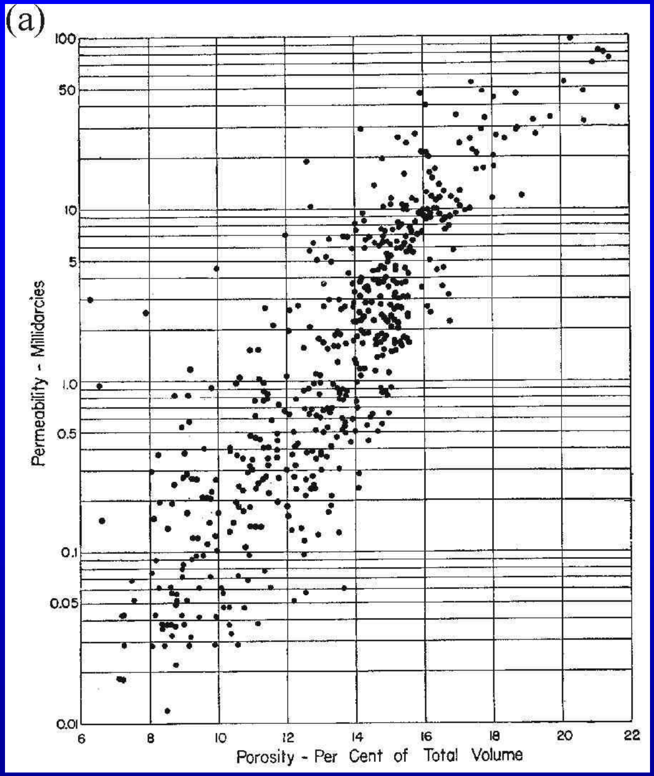
(courtesy Chuck Blumentritt)



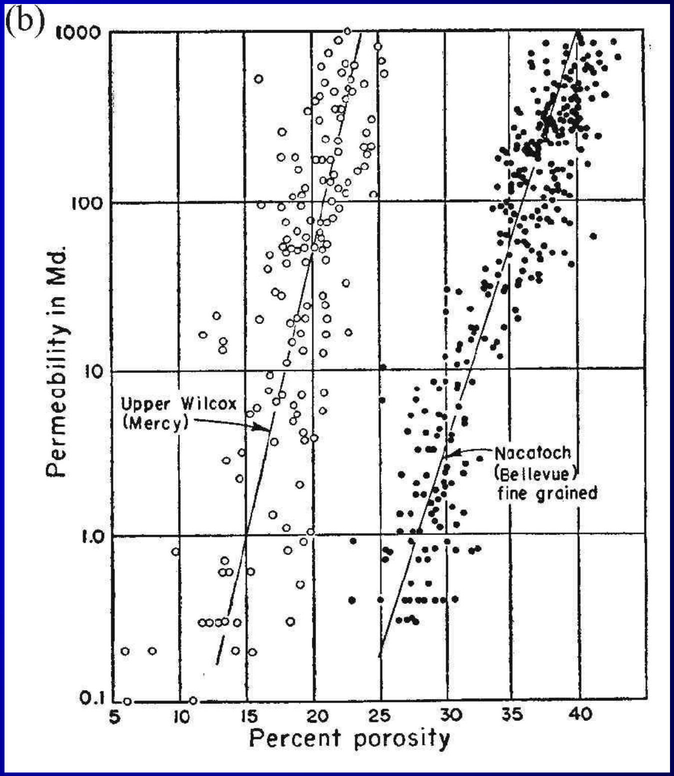
Effective, noneffective and total porosity in a rock matrix.

(Lines and Newkirk, 2004)

Relationship between porosity and permeability



Bradford sandstone, Pennsylvania



Upper Wilcox sandstone, Texas (left) and the Nacatoch sandstone, Louisiana.

(Lines and Newkirk, 2004)

4. Trap

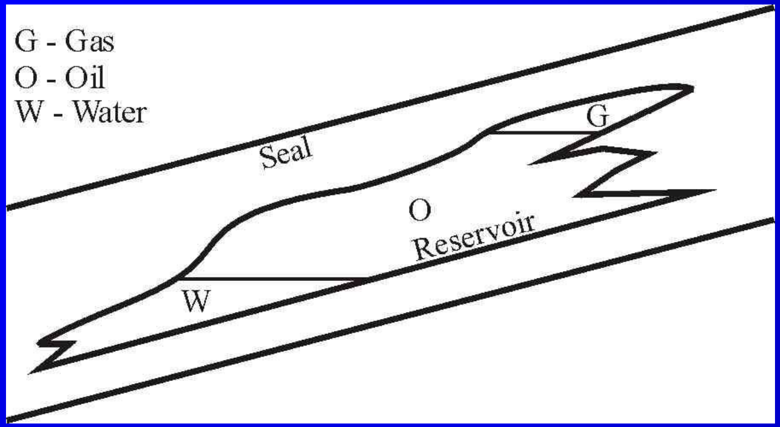
- ***What is it?***

  A configuration of geologic formations and/or faults which is favorable to stopping the upward or lateral flow of hydrocarbons due to pressure.

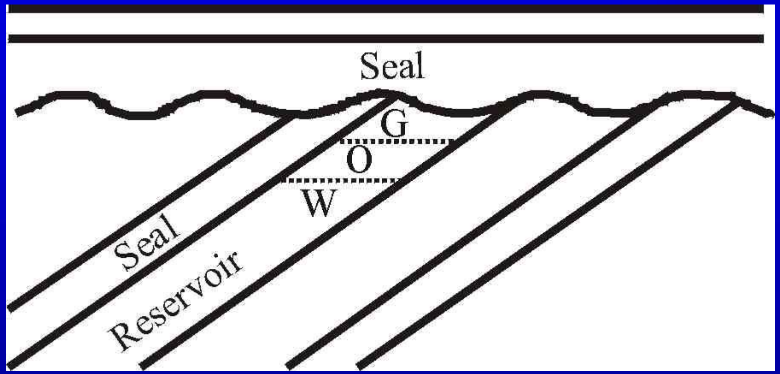
- ***How does seismic help?***

  Major - Mapping horizons is the primary function of seismic interpretation and is what it is best suited for. Seismic data is very effective at defining structure, delineating faults, and showing relationships between wells. *If this part of the interpretation is not done properly, then the rest of the work will not produce any useful results!*

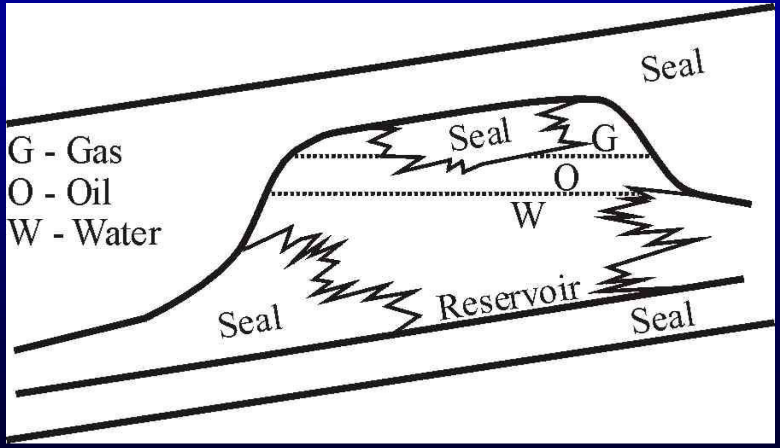
(courtesy Chuck Blumentritt)



A pinch-out is a common type of stratigraphic trap.

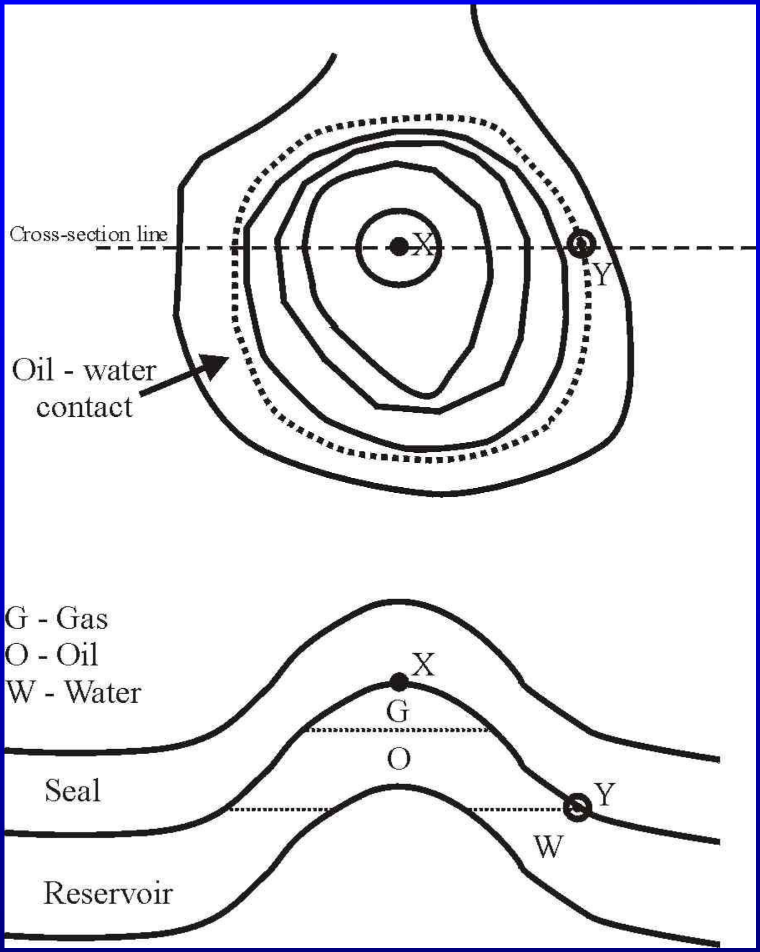


An unconformity traps hydrocarbons with an impermeable seal directly above the unconformity.



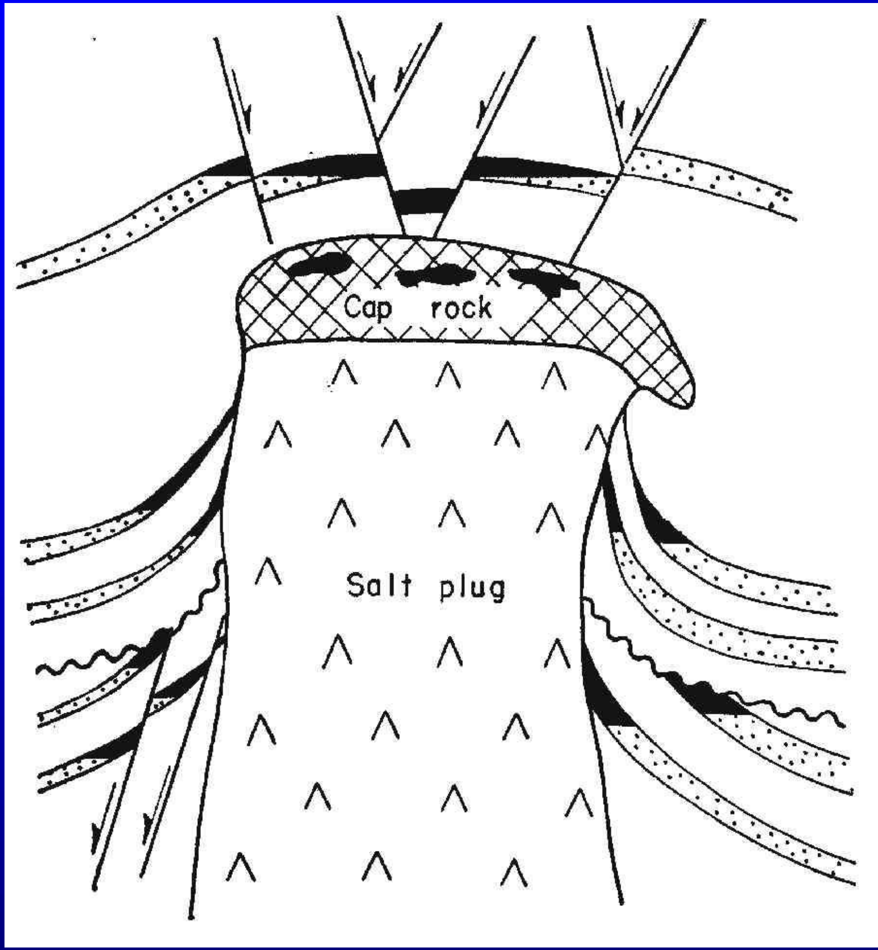
Reef exploration is widespread in the Western Canada Sedimentary Basin

(Lines and Newkirk, 2004)



Structural trap caused by folding of the strata.

(Lines and Newkirk, 2004)



Stratigraphic and structural traps associated with a salt dome

(Lines and Newkirk, 2004)

5. Seal

- ***What is it?***

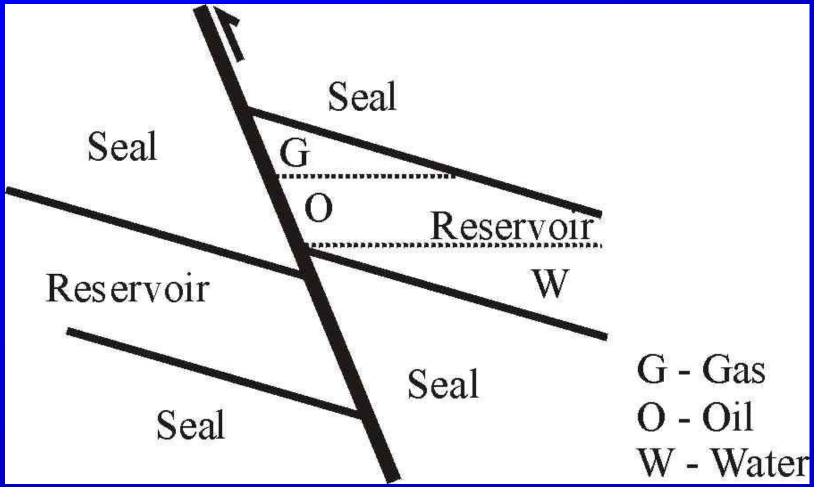
  A layer of non-porous and/or impermeable rock which prevents the upward or lateral flow of hydrocarbons from the trap. It is the structural or stratigraphic configuration of the seal that forms the trap. Some workers consider the top and lateral seals separately.

- ***How does seismic help?***

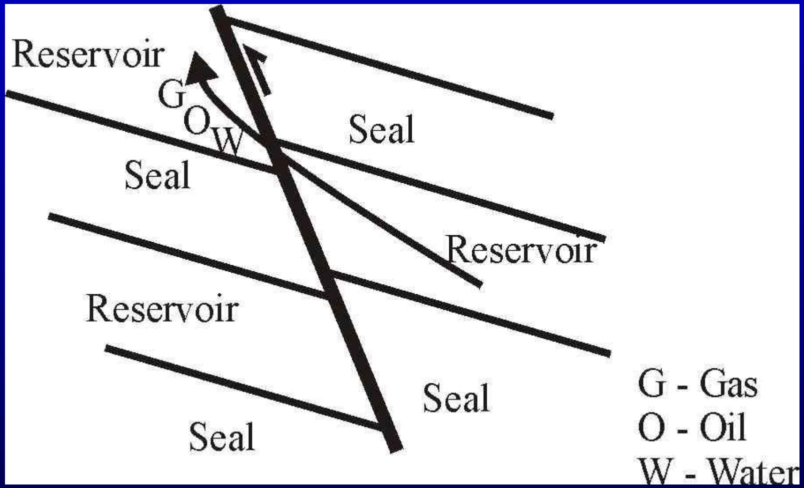
  Minimal - Seismic data generally cannot be used to determine if a particular rock layer or trapping configuration will provide a seal or not. It can only be used to identify the configuration of a likely seal as identified in a well. Note that the properties of the rock layer may change so that it is no longer a seal and prospective location.

(courtesy Chuck Blumentritt)

Examples of a faulted trap



With a good seal.



Without a seal. The gas, oil and water are able to migrate out of the faulted region.

(Lines and Newkirk, 2004)

6. Timing of Events

- ***What is it?***

  Each of the previous five events must occur in a specific sequence to create a hydrocarbon accumulation. For instance, if the trap does not form before the oil migrates, then it will not trap any hydrocarbons

- ***How does seismic help?***

  Major - Evaluation of changes in the thicknesses between horizons can be used to determine when events occurred. A thin area between two horizons indicates that the lower horizon had a structure on it at the time the upper horizon was deposited.

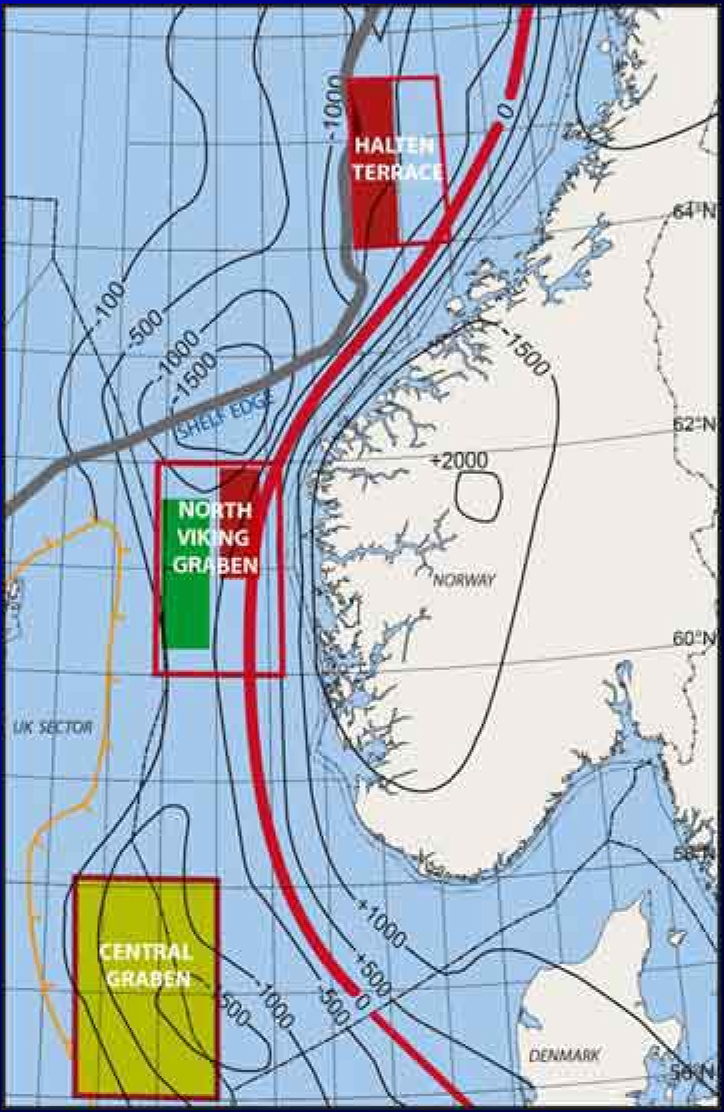
(courtesy Chuck Blumentritt)

Breached seals in the North Sea

red areas – more than 50 per cent of the overpressured Jurassic (rotated fault block) traps have leaked;

yellow area – 30 to 50 per cent have breached seals;

green area – less than 30% have experienced seal failure.



http://www.statoil.com/STATOILCOM/technology

7. Product

- ***What is it?***

  Oil, gas, condensate, or water in the reservoir

- ***How does seismic help?***

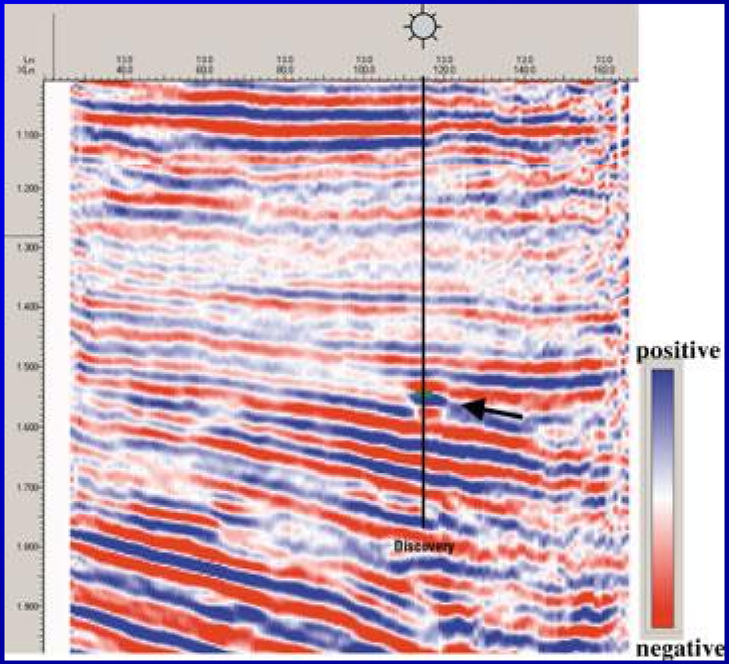
  Moderate for Gas - Lateral variations in amplitudes may be indicative of gas in the trap. It does not indicate whether it is an economic accumulation or not. Amplitude anomalies may also indicate migration pathways, changes in rock properties, changes in rock type, and many other things.

  Minimal for Oil - The presence of oil in a reservoir does not significantly affect the amplitudes of the seismic data.

  AVO (amplitude vs. offset) is a more advanced amplitude interpretation process that works well in finding gas in Tertiary basins.

(courtesy Chuck Blumentritt)

Example of a seismic 'bright spot'

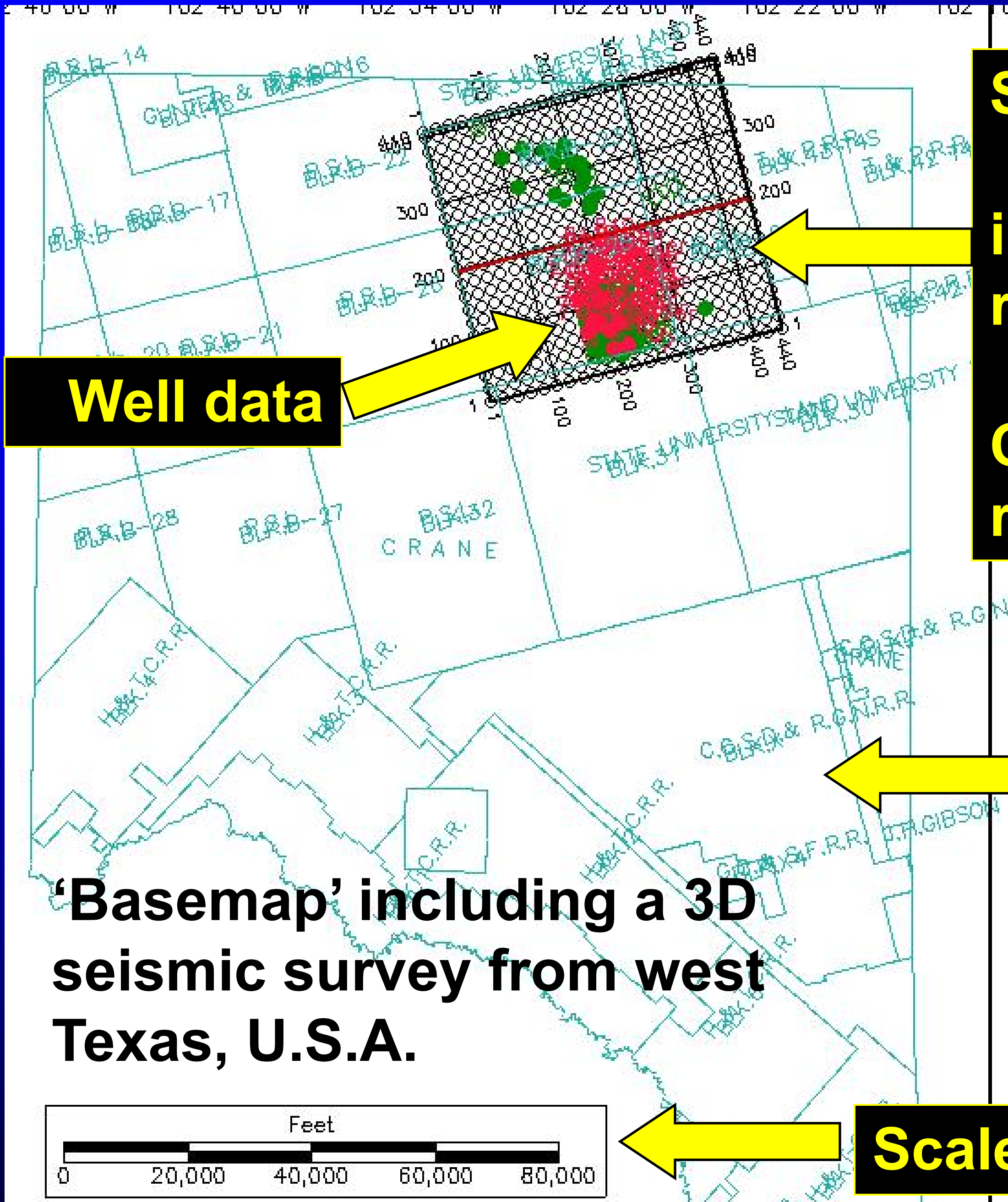


A Frio reservoir in the Gulf Coast. Bright spot pay sand shown by high amplitude at arrow.

(Burnett and Castagna,2003)

http://www.aapg.org/explorer/geophysical_corner/2003/01gpc.cfm

Vocabulary of 3D Seismic Surveys



Survey area:

inlines go N60E
range from 1-440

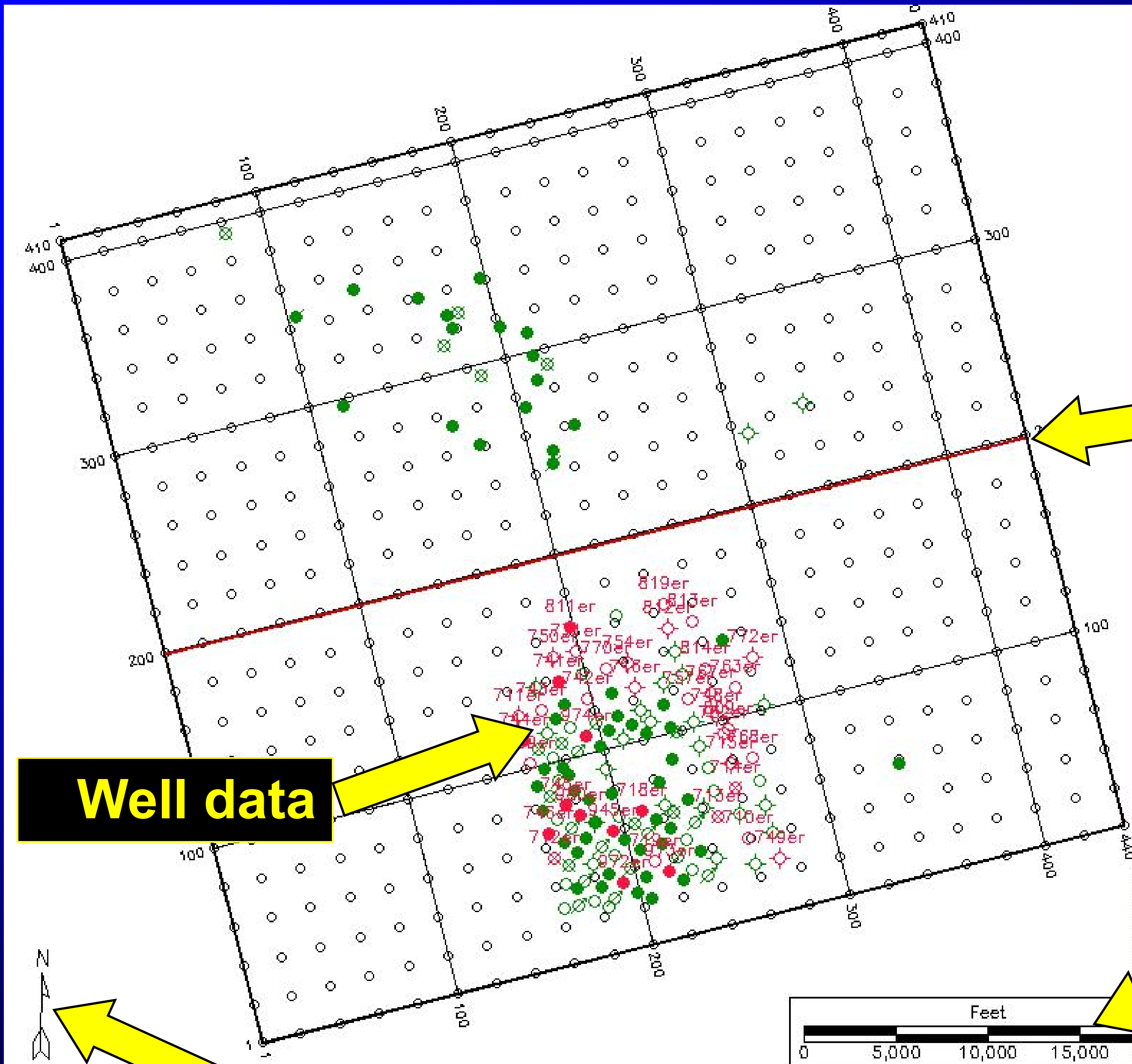
Crosslines go N30W
range from 1-410

Well data

Culture data:
Townships, block
boundaries, etc.

Scale bar

'Basemap' including a 3D seismic survey from west Texas, U.S.A.

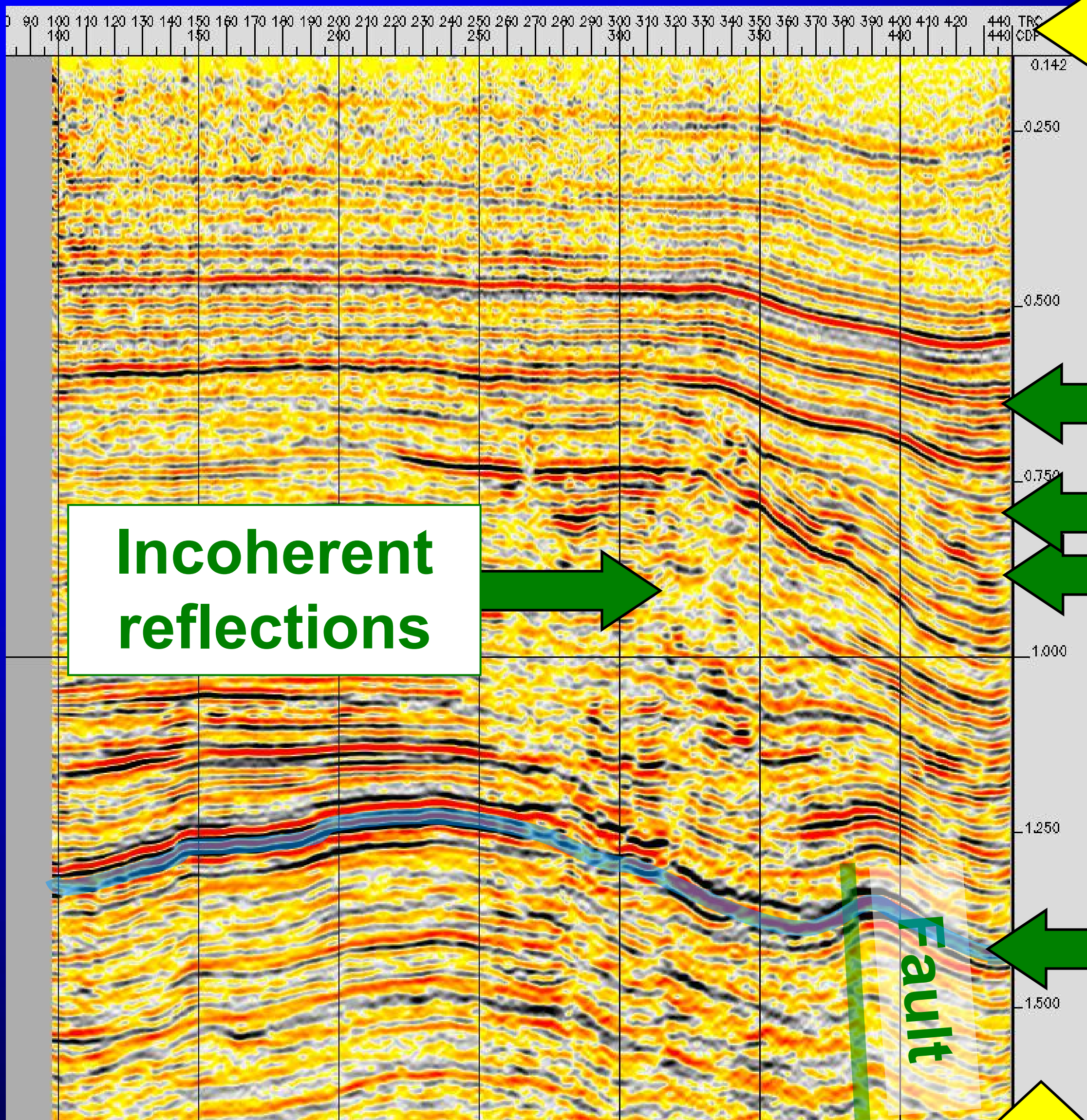


Location of inline 200

Well data

Scale bar

North arrow



Trace and CDP (crossline) indices

Syntectonic deposition

Unconformity

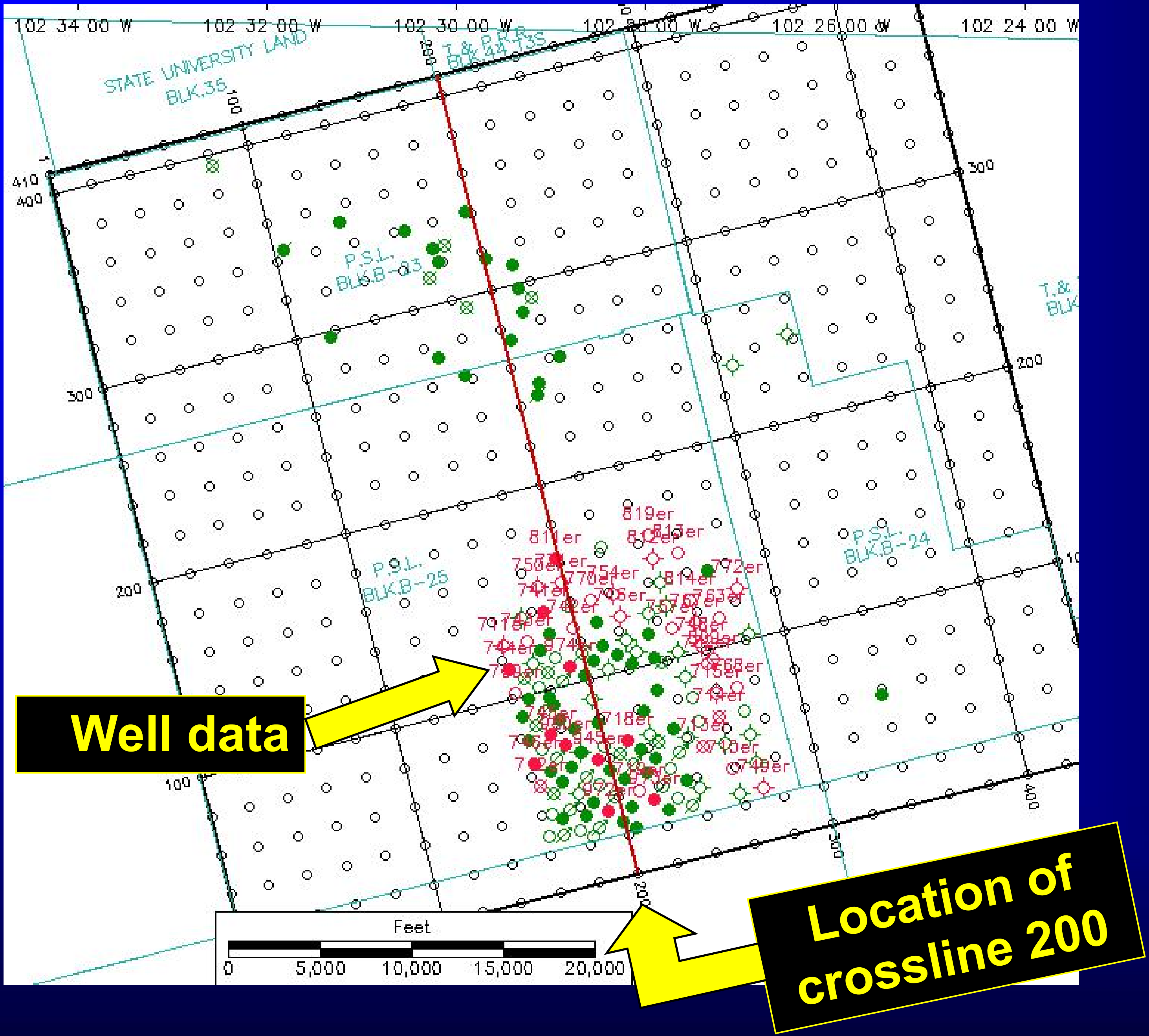
Progradation

Incoherent reflections

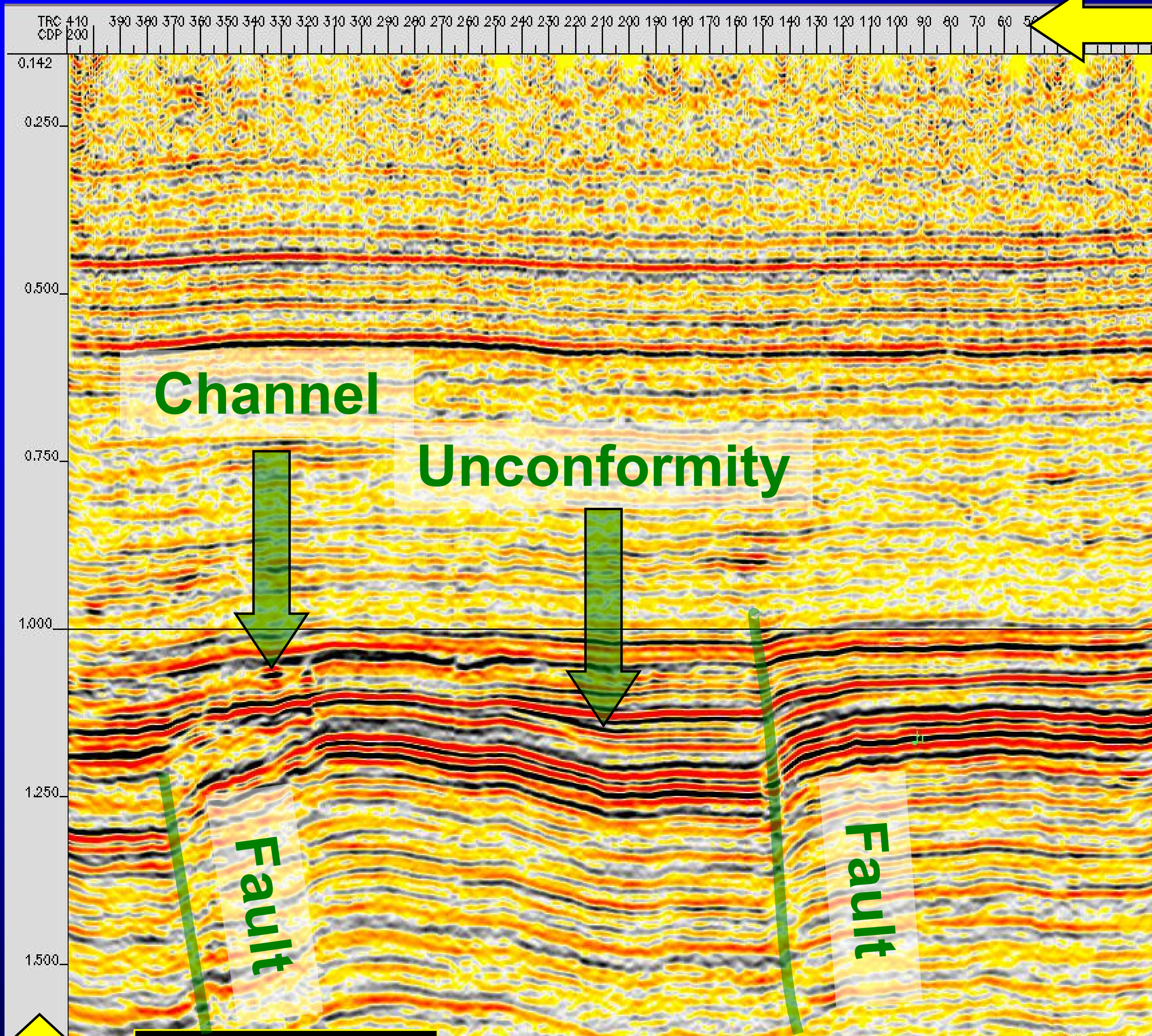
Horizon pick (top Devonian)

Time axis (in s)

inline 200

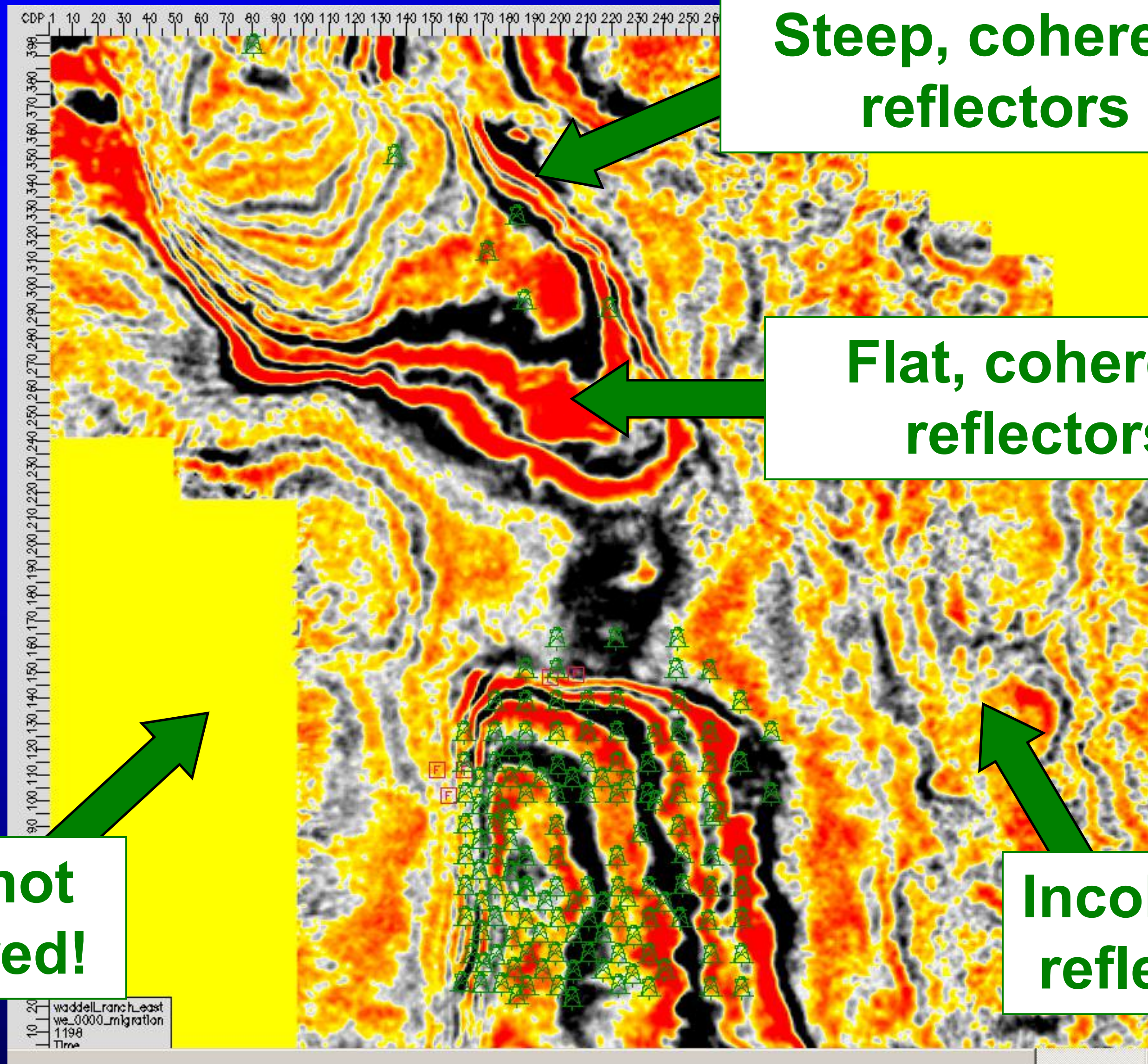

Well data
Location of crossline 200
102 34 00 W
102 32 00 W
102 30 00 W
102 28 00 W
102 26 00 W
102 24 00 W
STATE UNIVERSITY LAND
BLK.35
P.S.L.
BLK.B-23
P.S.L.
BLK.B-25
P.S.L.
BLK.B-24
Feet
0
5,000
10,000
15,000
20,000

Trace (inline) and CDP indices



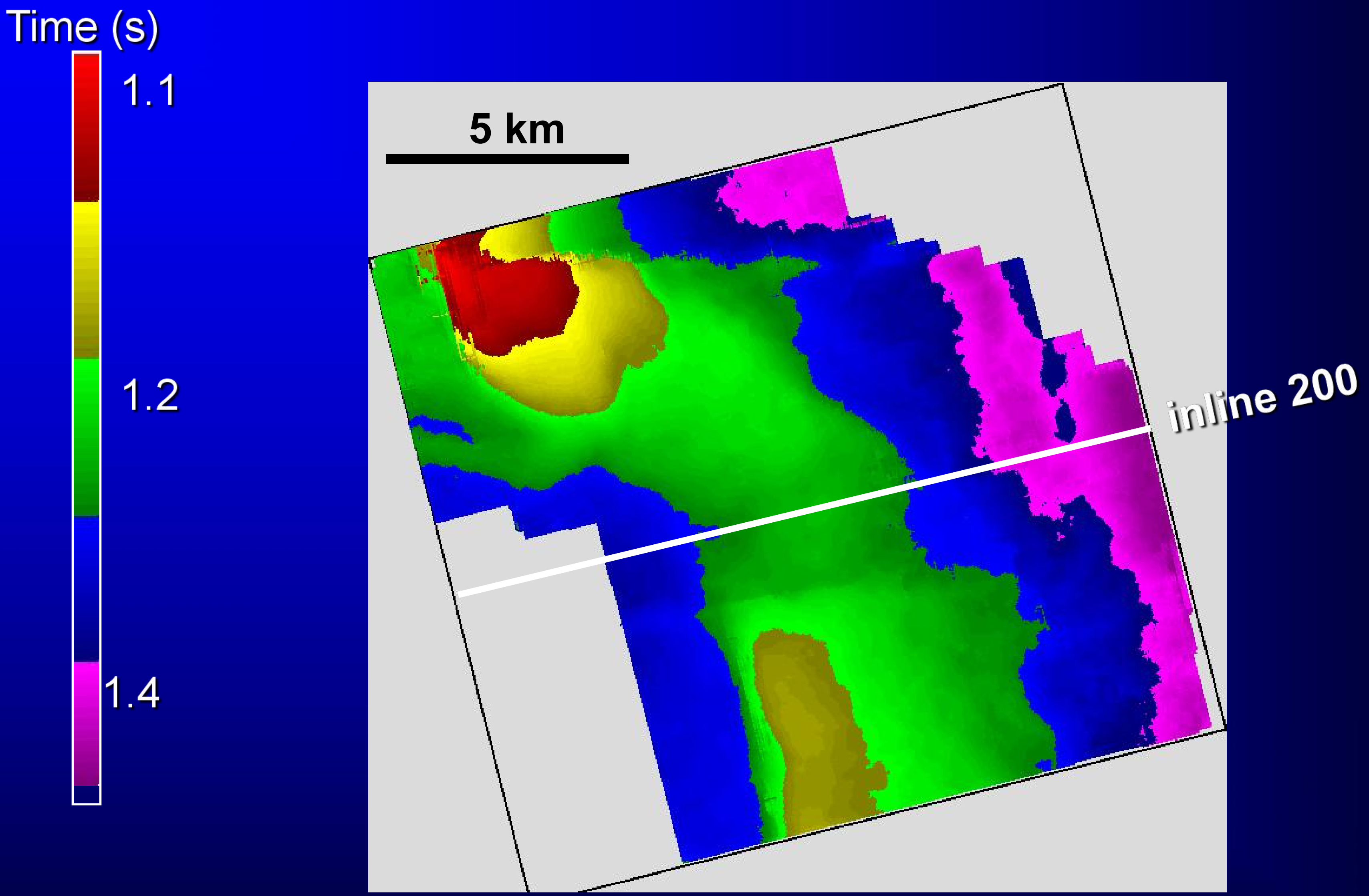
Time axis (in s)

crossline 200



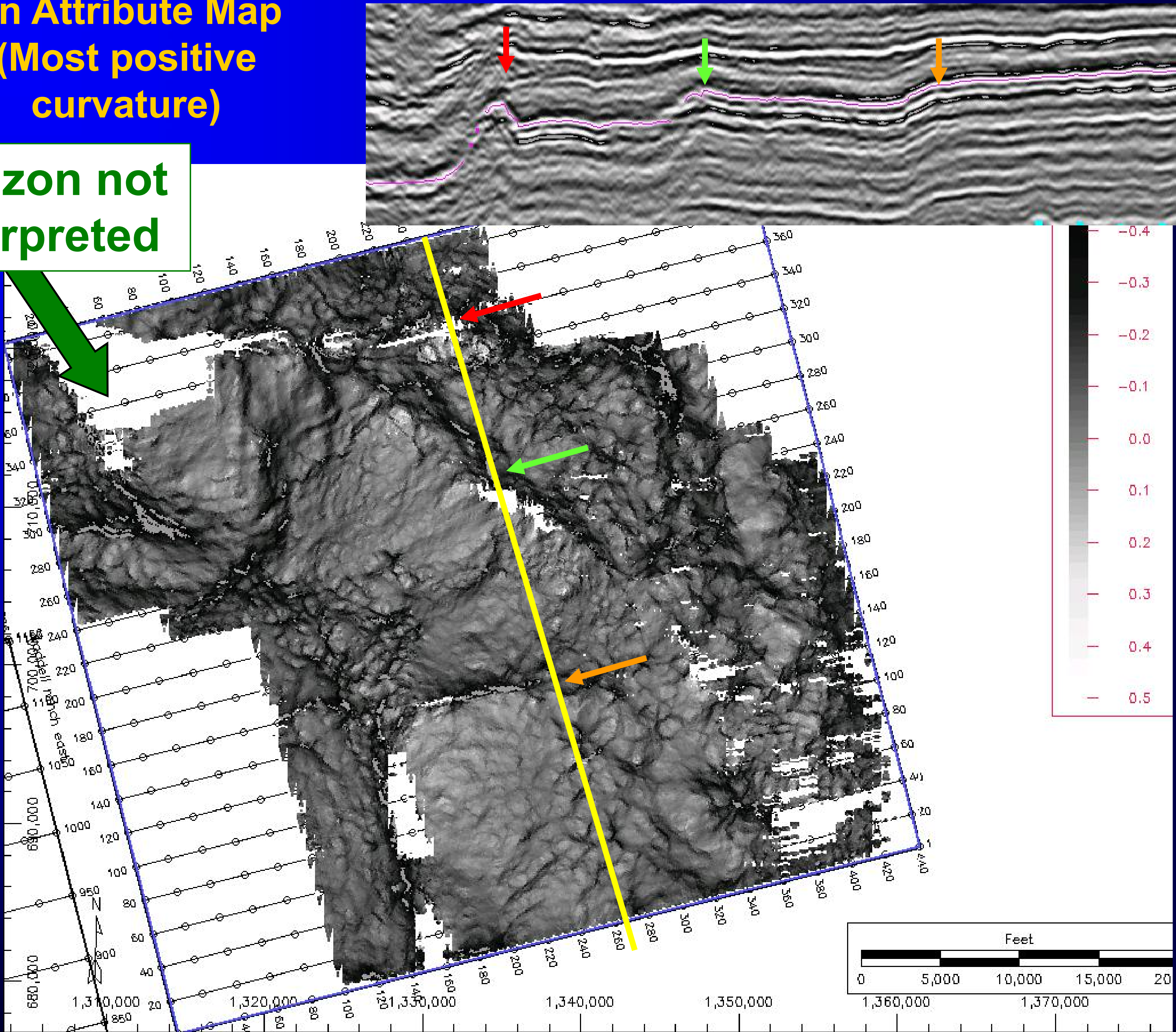
timeslice at t = 1.198 s

A time/structure map (Devonian horizon)

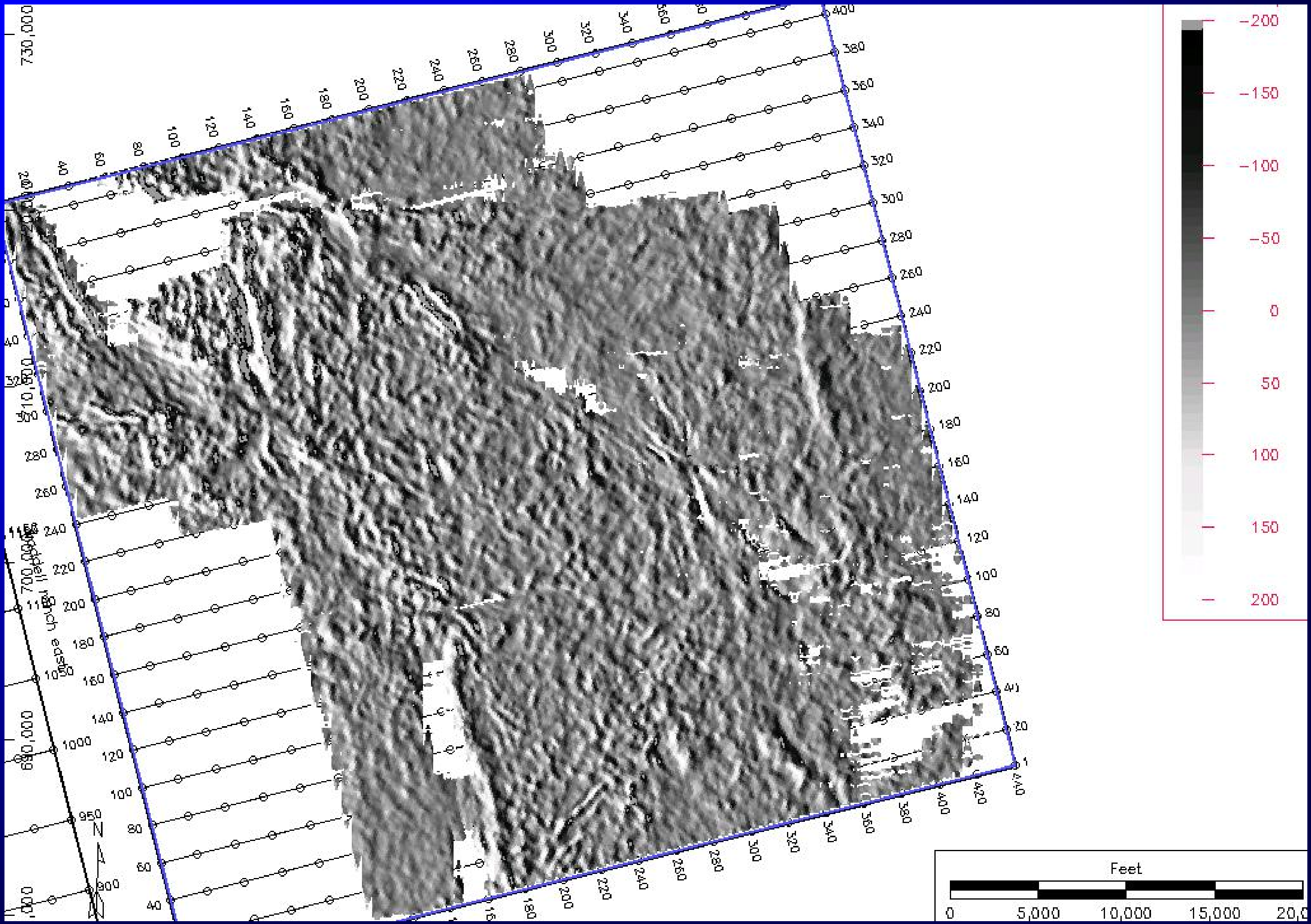


An Attribute Map (Most positive curvature)

Horizon not interpreted



Another attribute map (Inline amplitude gradient)



channels and mass wasting