Natural Fractures in the Barnett Shale in the Delaware Basin, Pecos Co. West Texas: Comparison with the Barnett Shale in the Fort Worth Basin*

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Abstract

This study describes several sets of natural fractures in a Barnett Shale core from Pecos County, including partly open fractures, fractures associated with chert layers, and early deformed fractures. These are compared with fractures previously described in the Barnett Shale in the Fort Worth Basin. The steep, narrow, calcite-sealed fractures that are present in many Barnett cores in the Fort Worth Basin are important because of their likely tendency to reactivate during hydraulic fracture treatments. In the core studied here from the Delaware Basin there are many different fracture types, including open fractures with cement bridges. The importance of natural fractures for completions in the Delaware Basin is therefore different from that in the Fort Worth Basin.

The range of fracture types is also of potential use in documenting chemical and mechanical processes that were operative during basin development. Early, sediment-filled fractures that were folded during compaction are present. Later fractures contain quartz and dolomite sealing cements. Fluid inclusions and fracture sealing cement patterns can provide information on temperature, pressure and composition of fluids at the time of fracturing. For example, fibrous, bedding-parallel quartz veins contain petroleum inclusions with gas bubbles, indicating this fracture set must have developed under conditions of hydrocarbon cracking, and is probably due to overpressuring.

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Thanks to Pioneer Natural Resources

Outline

- Introduction
  - Opening-mode fracture importance
  - Previous findings, Fort Worth Basin
- Fractures in the Delaware Basin
  - Characterization
  - Origin and timing
  - Present day in-situ stress
- Conclusions

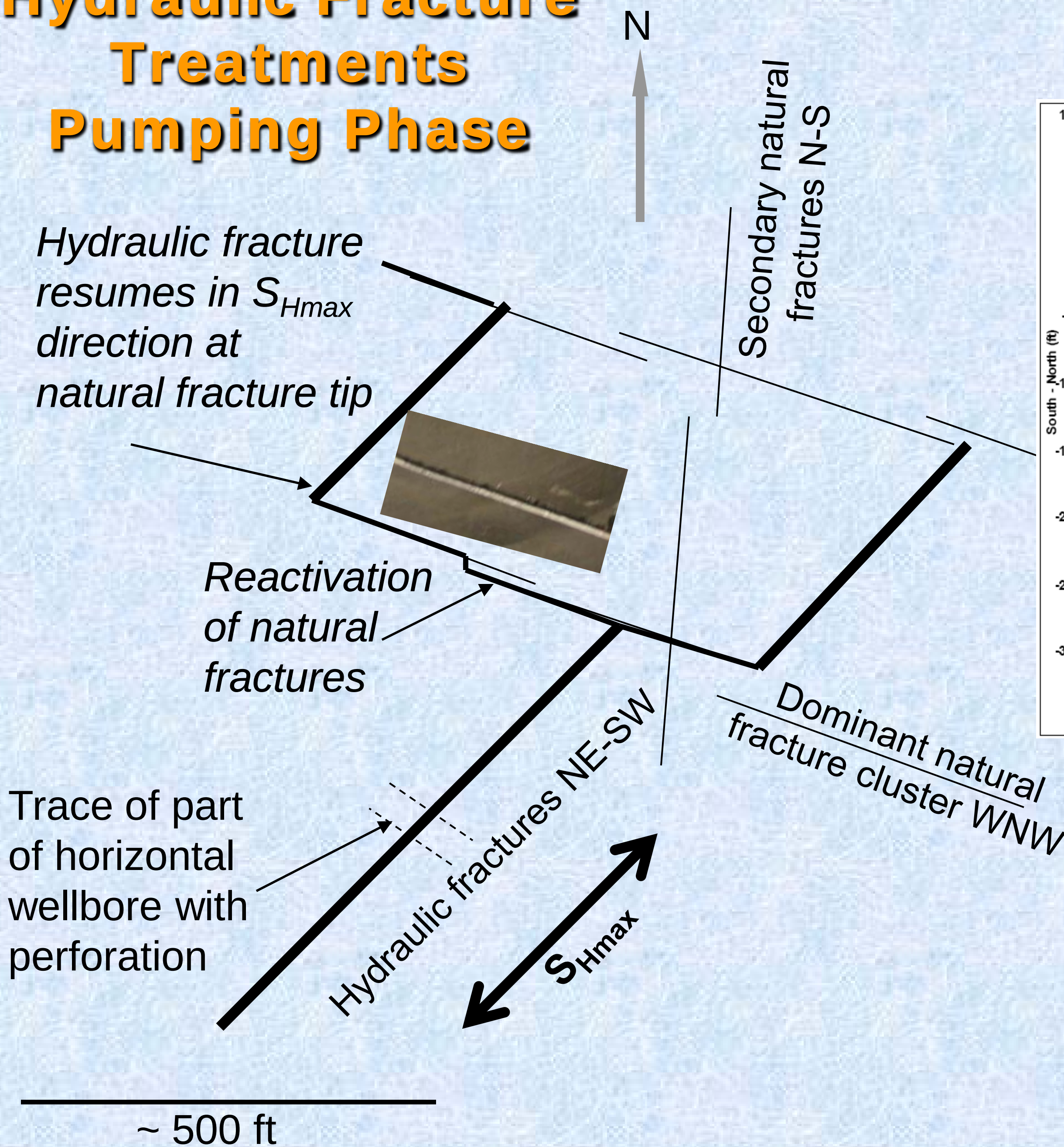
Natural Fracture Relevance for Shale-Gas Plays

- Several scenarios:
  - open, enhance permeability, advantageous;
  - open and detrimental to well completion;
  - sealed but affect hydraulic fracture propagation (positive or negative effect);
  - sealed and have no effect on completion methods or production;
  - absent or sufficiently low in intensity to be irrelevant.

Barnett Shale, Fort Worth Basin

- Steeply dipping
- Right- and left-stepping examples
- Sealed with calcite

Hydraulic Fracture Treatments Pumping Phase



Microseismic monitoring

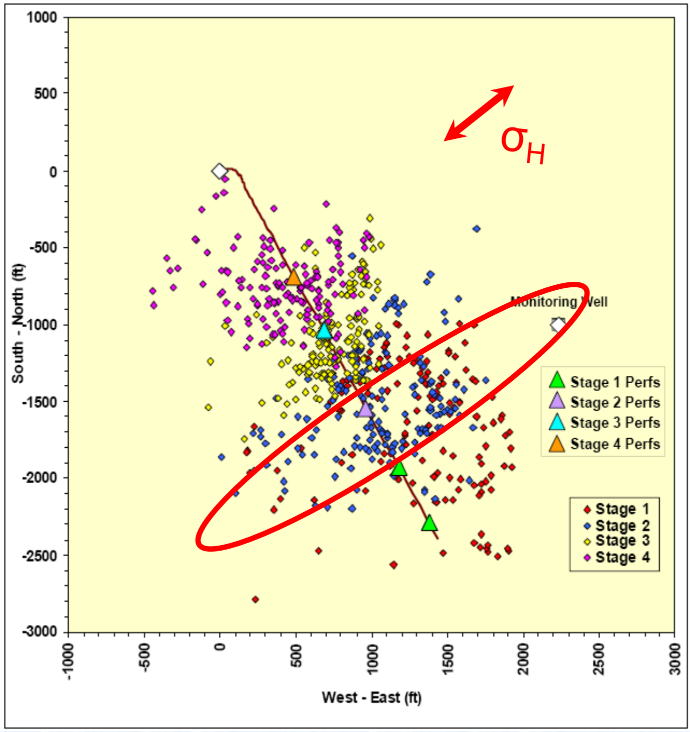


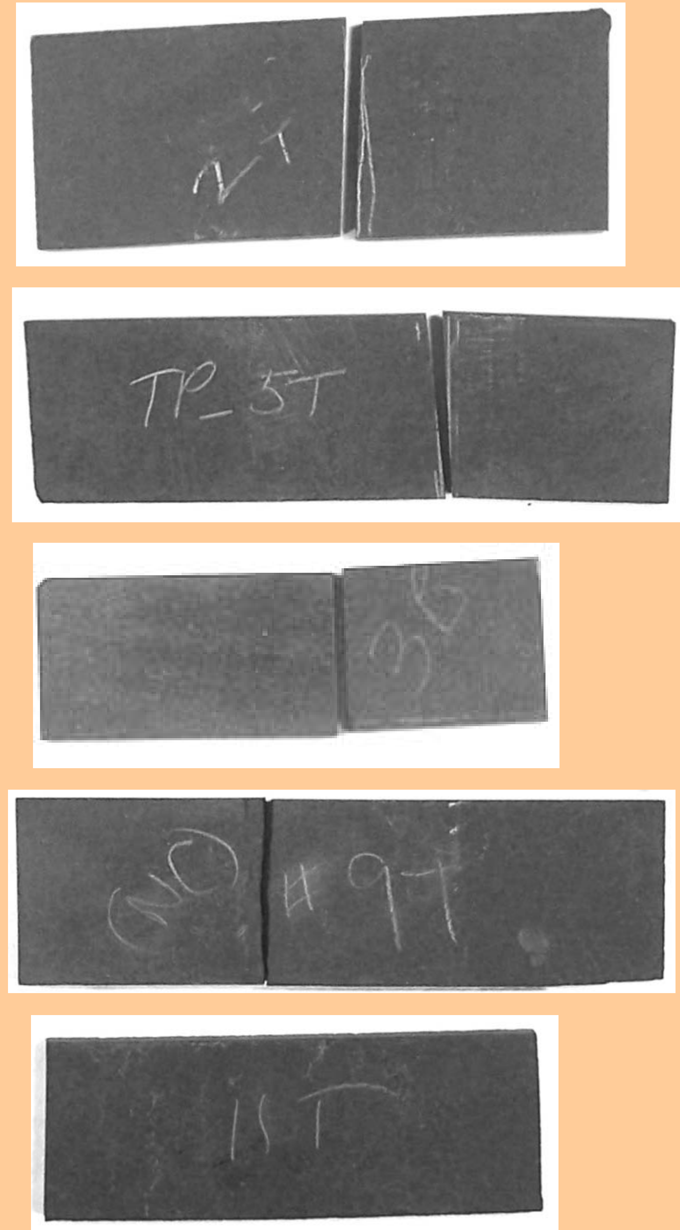
Figure from Waters et al., 2006, SPE 103202

Tensile Testing

Results

- Failure along fracture, EVEN THOUGH THESE ARE SEALED
- Specimens with natural fractures are half as strong as those without

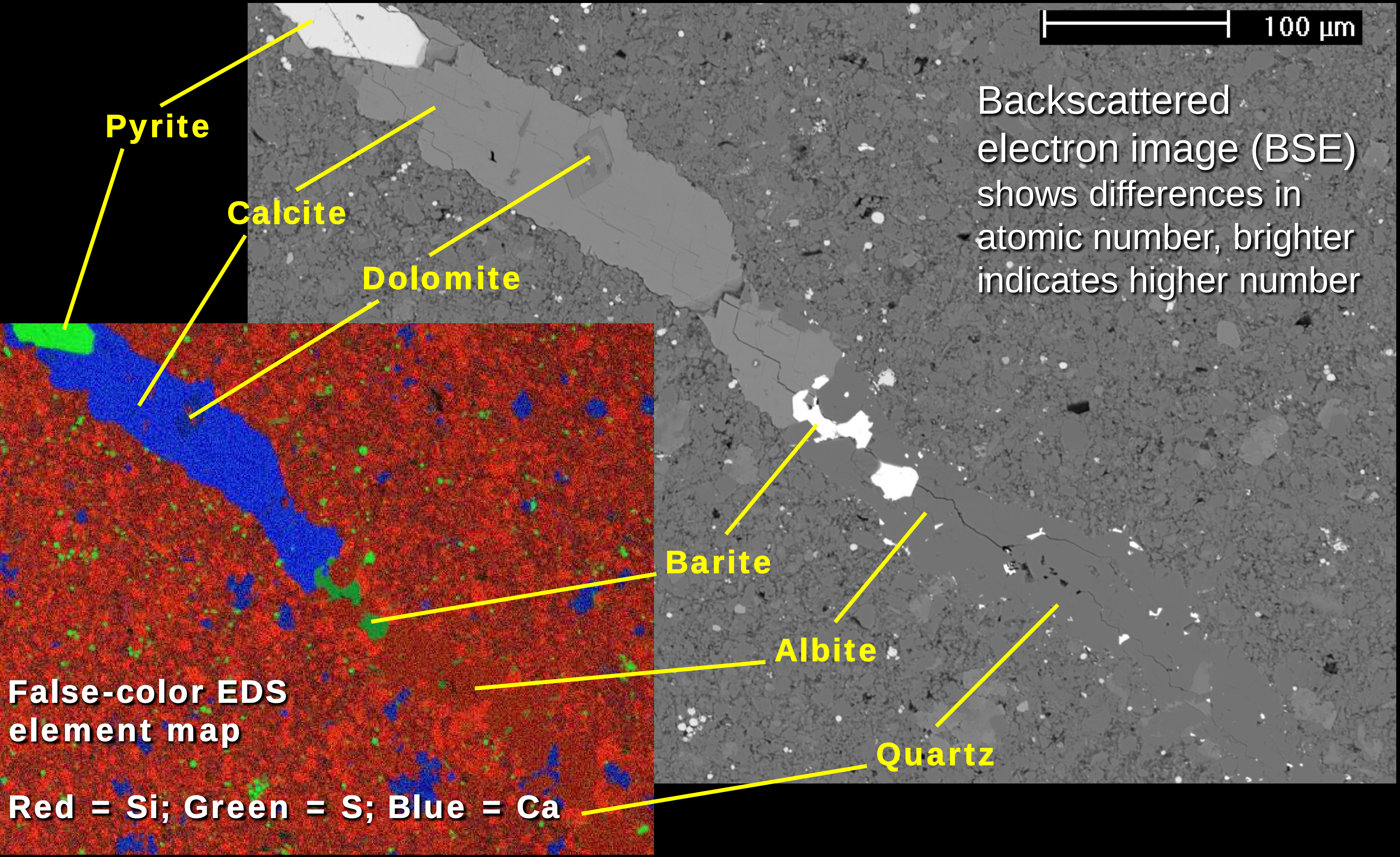
Post-test specimens



Specimen	Rupture (kpsi)
With natural fracture	
2T	2.45
5T	3.86
3B	3.29
No natural fracture	
9T	6.15
11T	6.41

From Gale and Holder (2008)

SEM Imaging of Fractures



Barnett Fort Worth Basin
Natural Fracture Relevance

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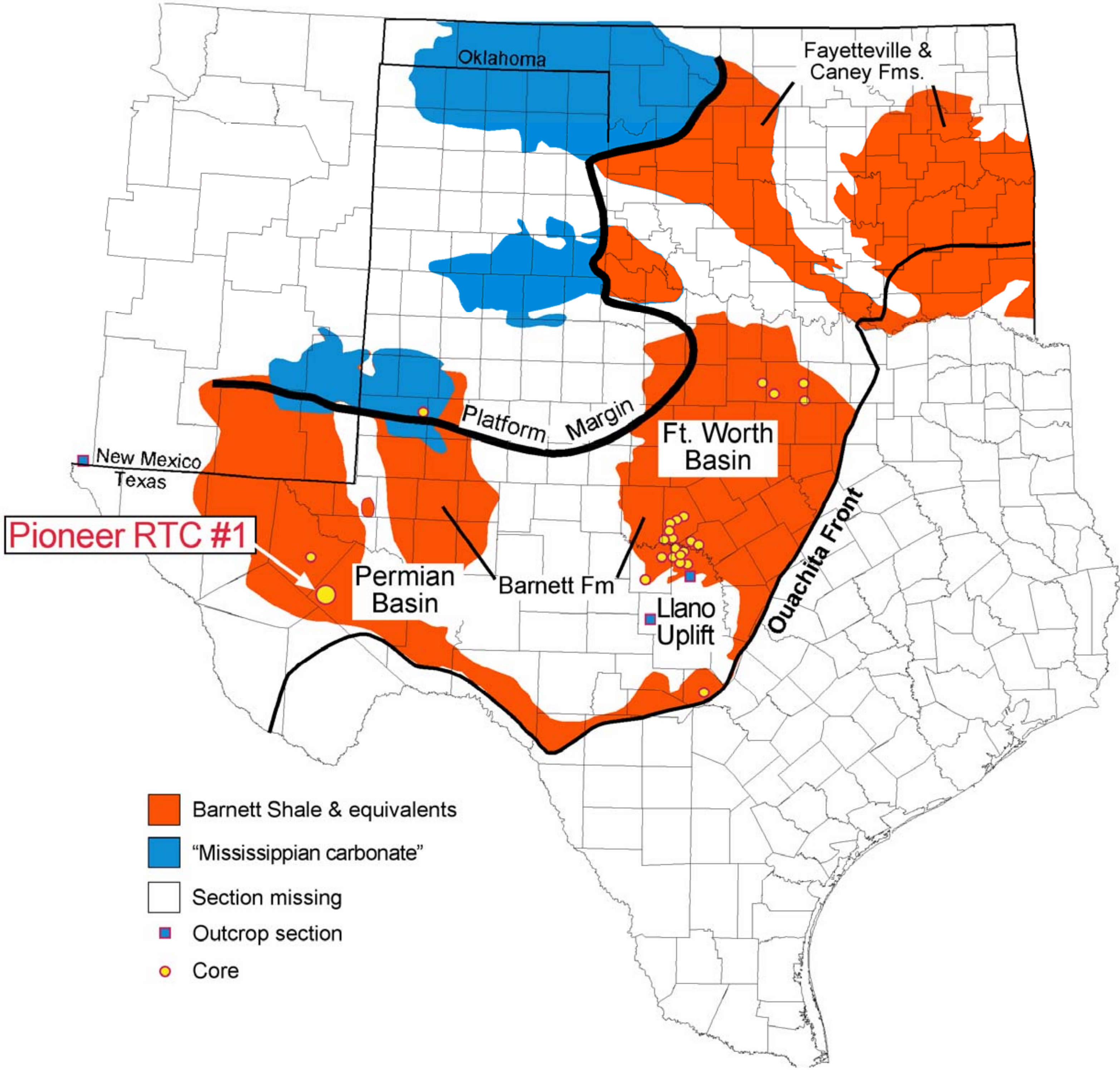
Delaware Basin Study

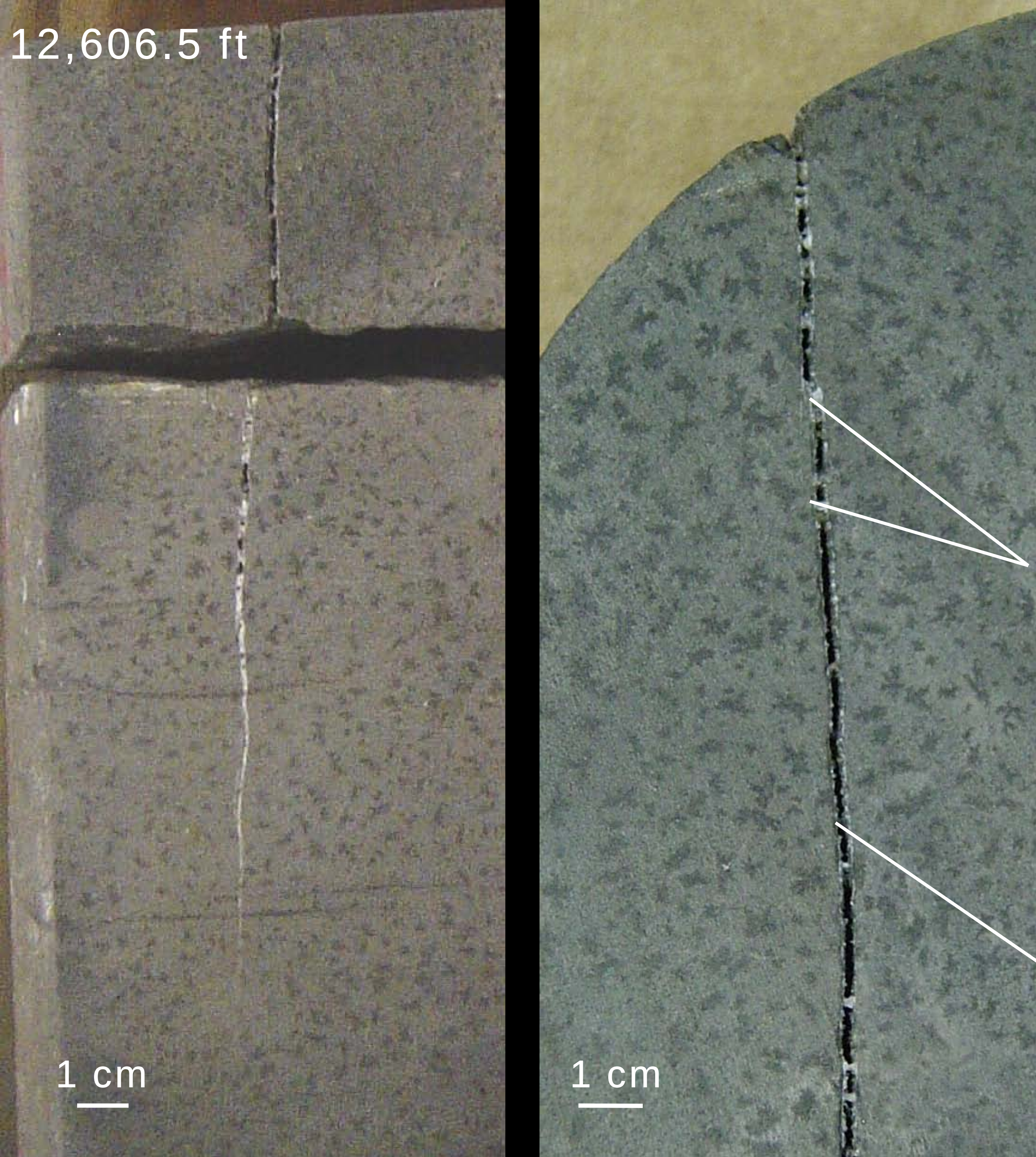
Barnett Shale

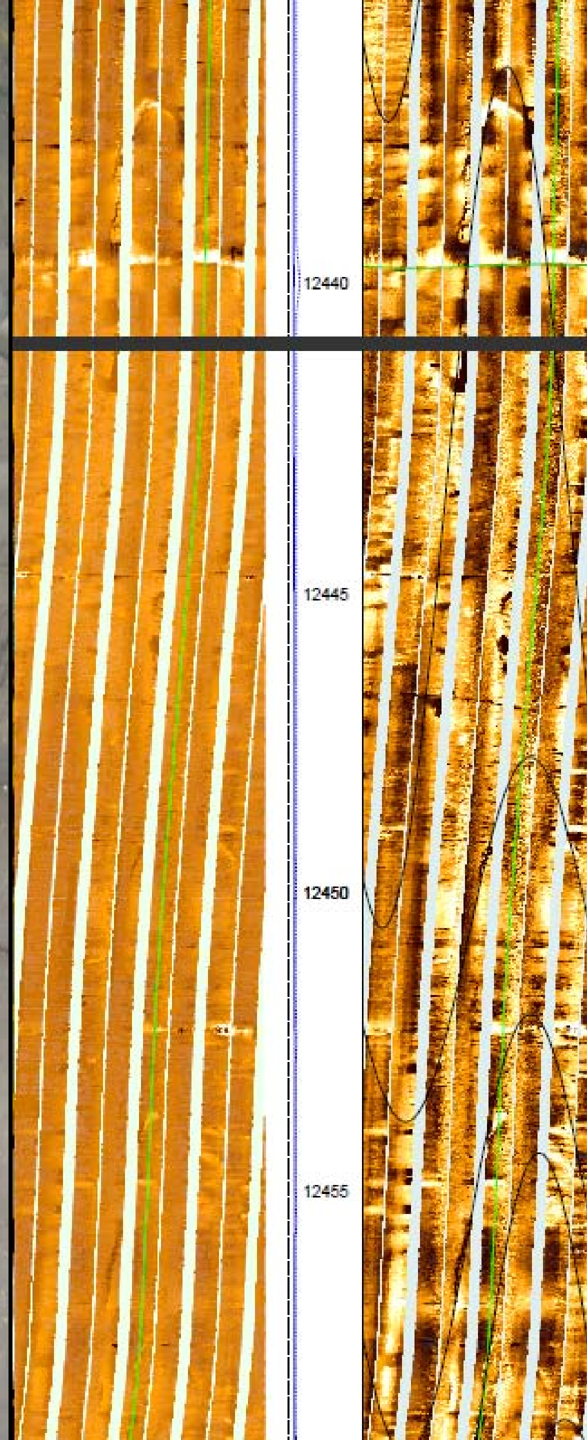
Map courtesy Steve Ruppel

DISTRIBUTION OF EARLY MISSISSIPPIAN DEPOSITS



Open Fracture Barnett Shale, Delaware Basin

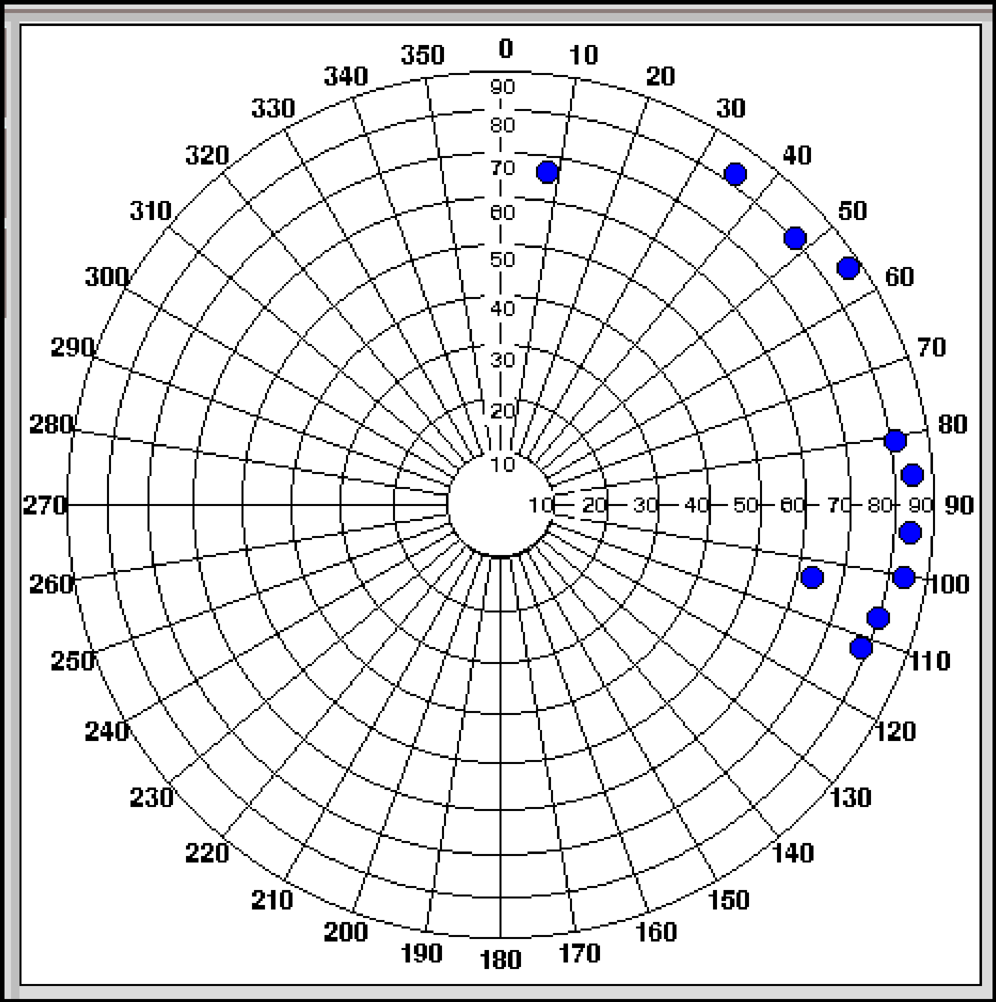




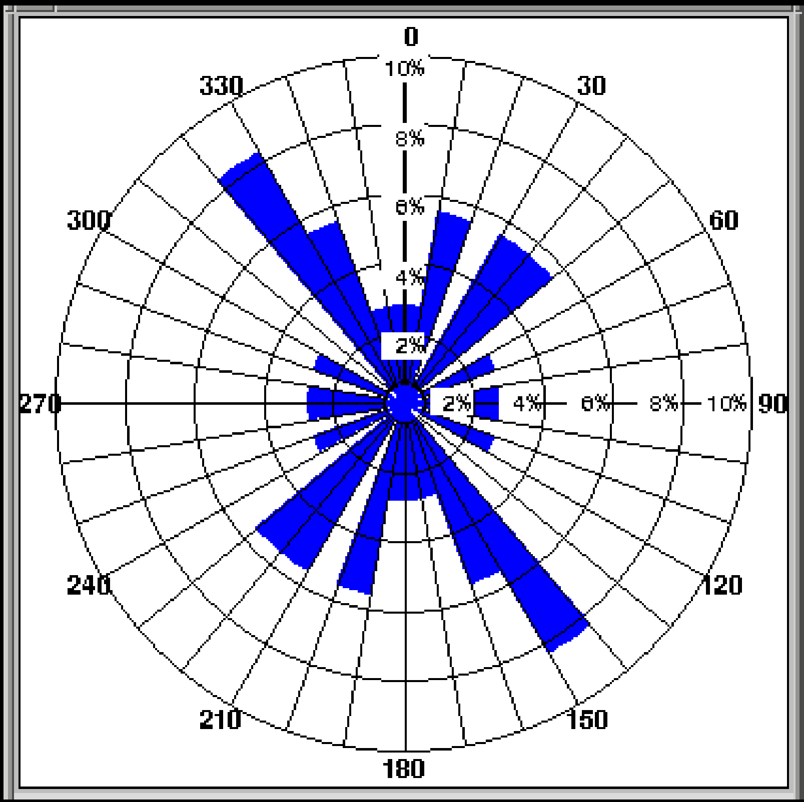
Partly Open Fracture

- Had been picked as induced fracture on image log (black)
- Note fully sealed tip
- Trend is NE-SW, dipping to SE
- Here natural and induced fractures are sub-parallel

Interpreted Conductive Fractures
Image Log



Stereographic projection – poles to fractures



Strike

High variability of strike, NW-SE dominant

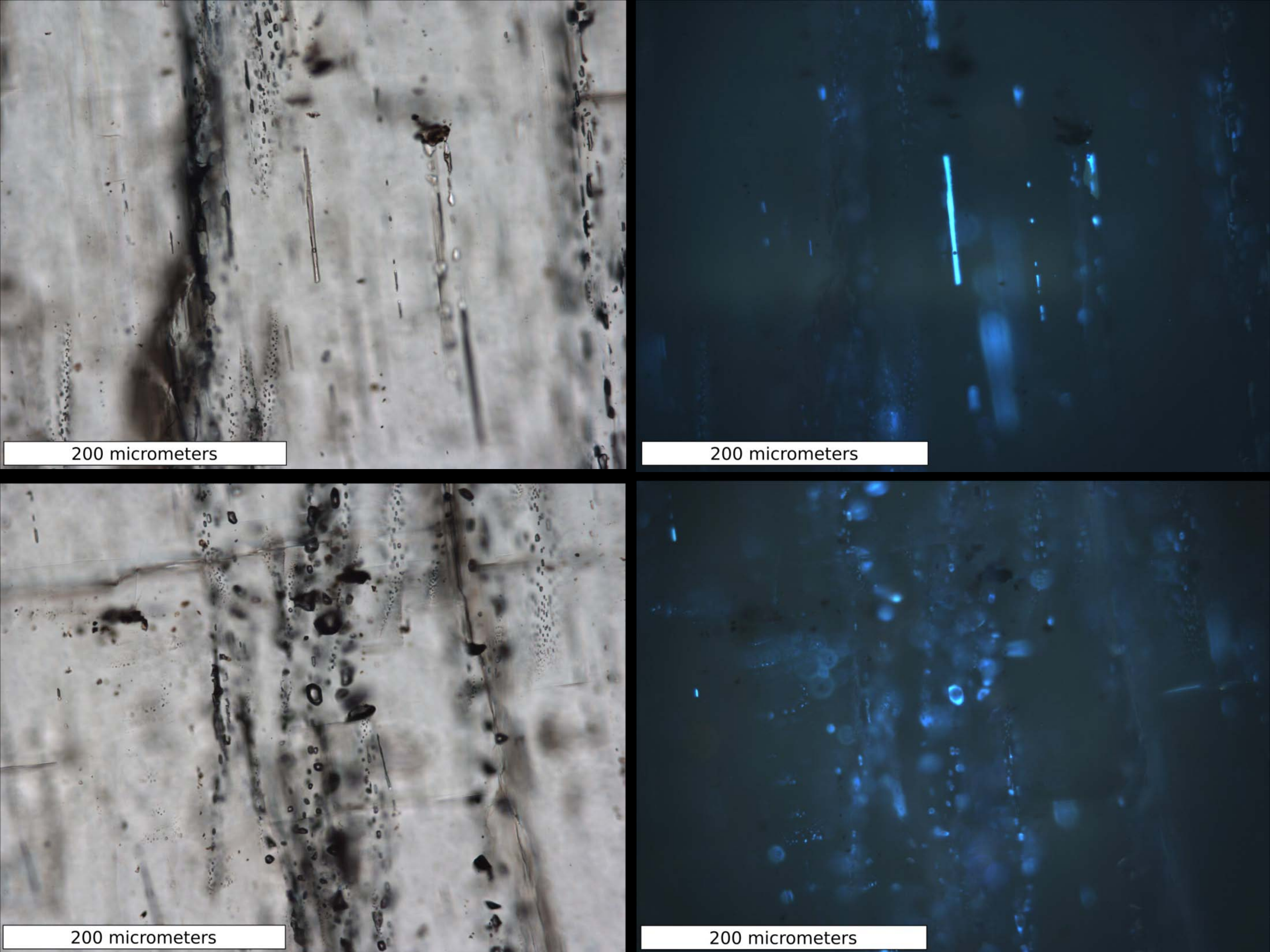
Most steeply dipping to the SW or W

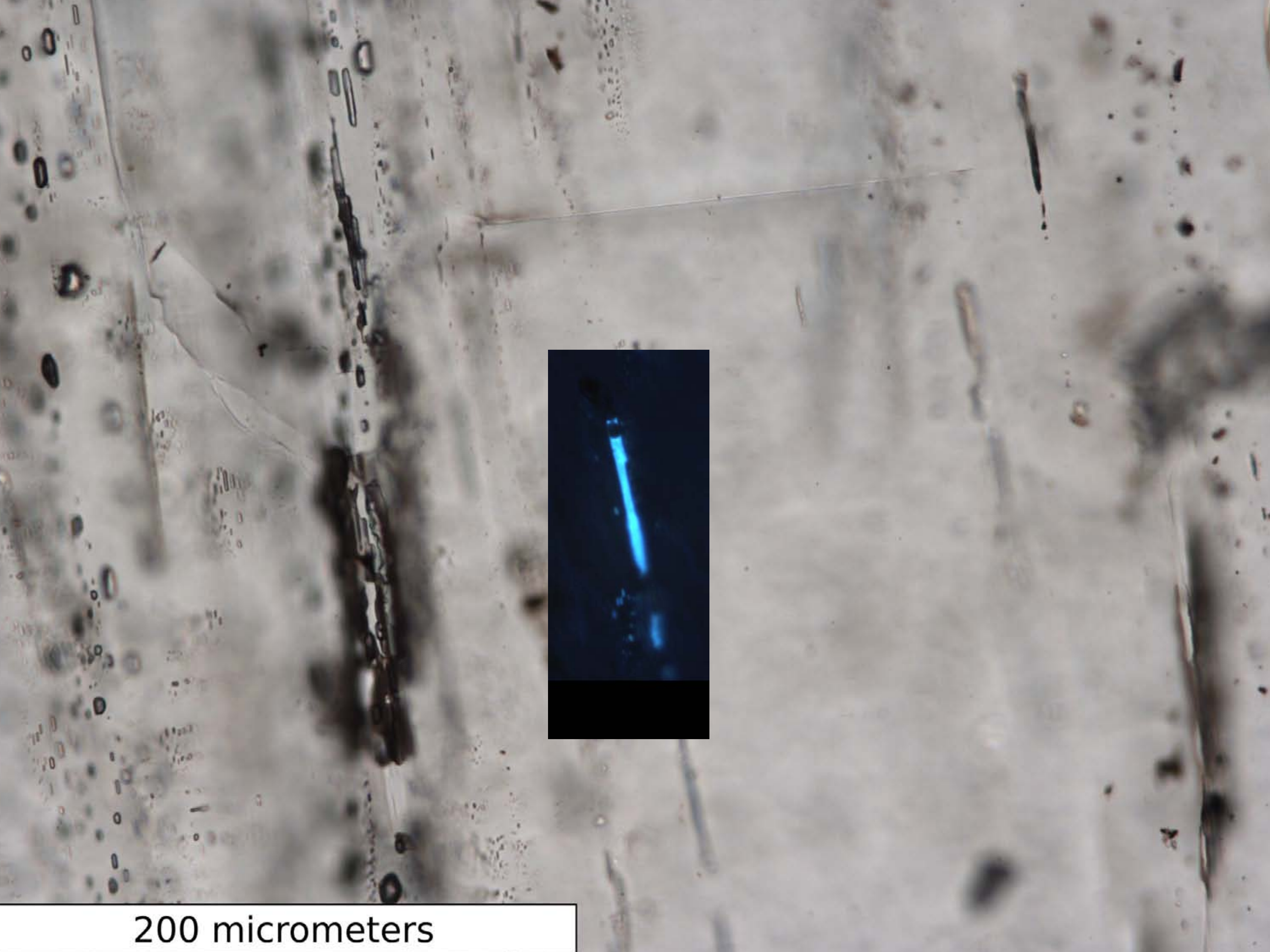
Low angle opening-mode fractures

Fibrous fill

12,374 ft

12,383 ft


200 micrometers
200 micrometers
200 micrometers
200 micrometers


200 micrometers

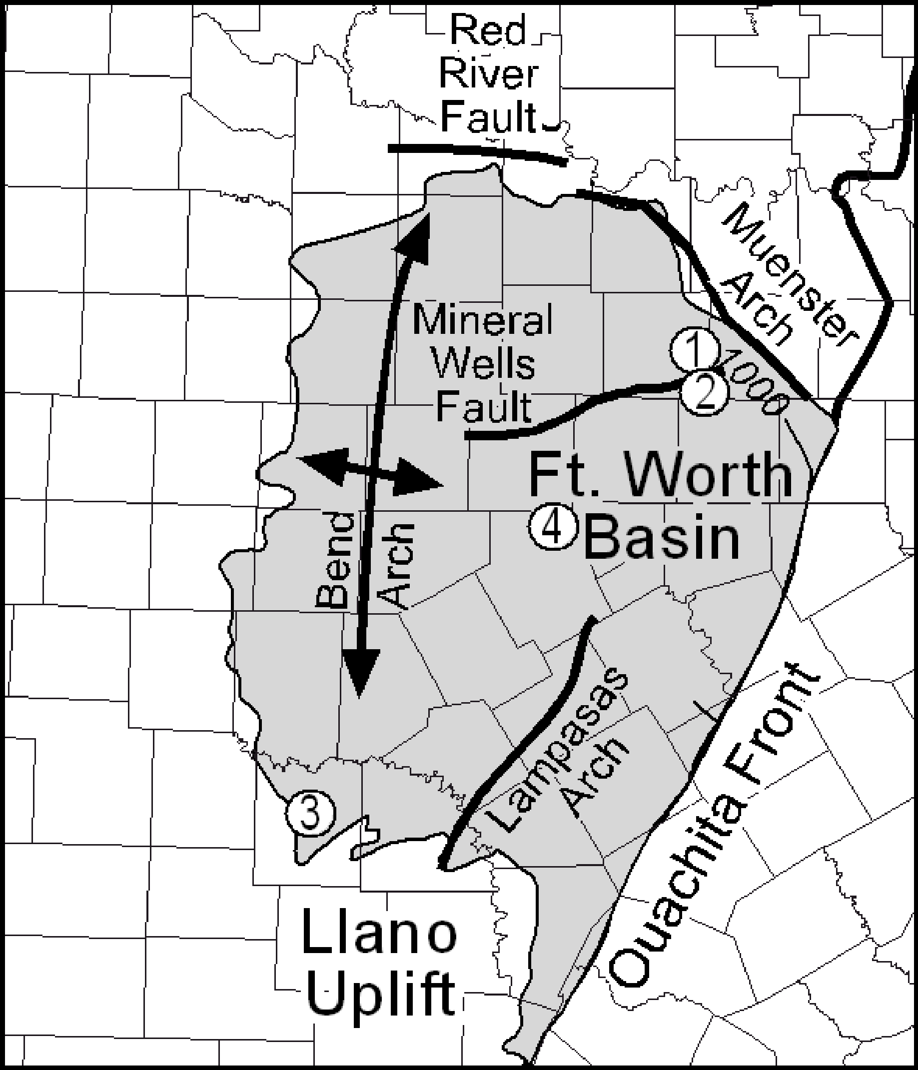
12428.3

12431.4

Early fractures

- Carbonate and quartz cement
- Vertical and horizontal components
- Complex branching
- Tapers down and up
- Vertical component shortened by compaction
- Internal fabric
- Porosity

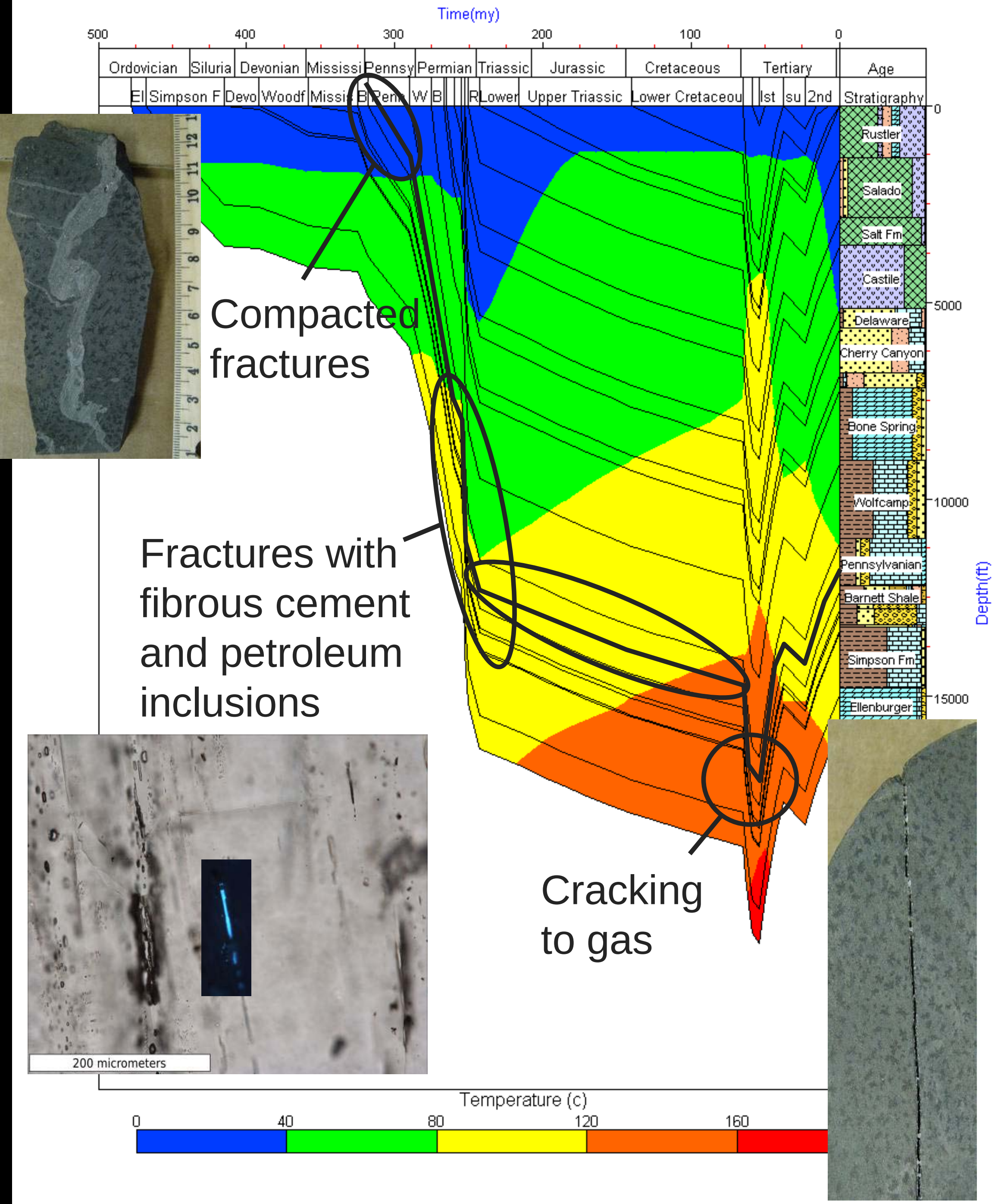
Origin of Opening-Mode Fractures



Map after Montgomery et al. (2005)

- Regional burial plus gas generation
- Differential compaction (local stress)
- Regional, tectonic paleostress
- Local effects of major faults and folds
- Sag features associated with underlying karst
- Stress release during uplift

Fracturing History



Compacted fractures, early carbonate cement, later quartz cement

Smectite to ~95% illite in range 20–200°C, with 17 - 28 wt% release of silica (Van de Kamp, 2008)

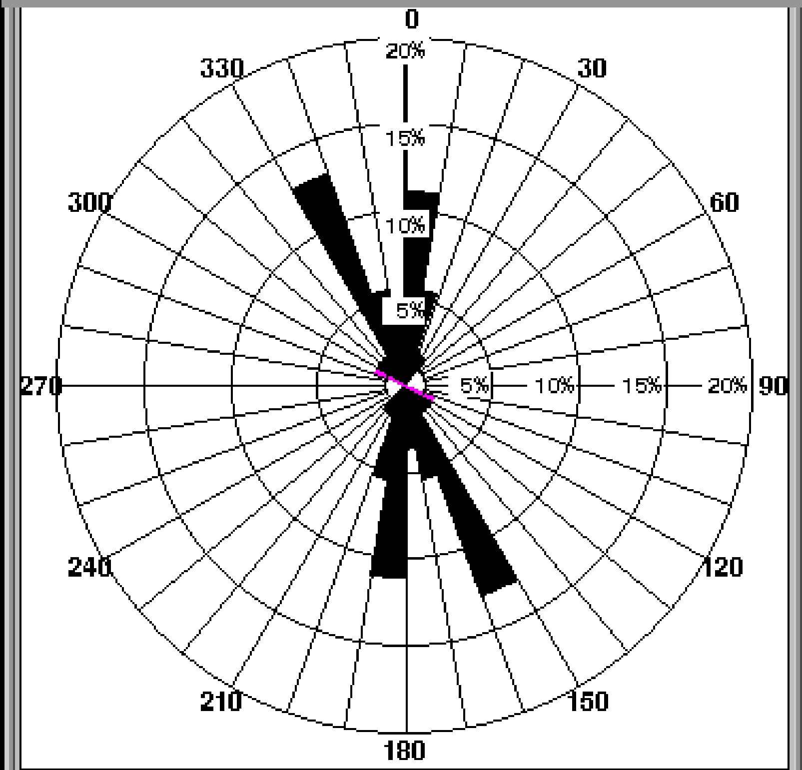
Horizontal and irregular vertical fractures. Fibrous quartz cement, petroleum inclusions: trapped during kerogen to oil cracking, before oil to gas is complete

For type II marine algal kerogen primary cracking between 80 and 180°C.
Secondary cracking to gas at ≈150°C

Quartz bridged and lined planar fractures. Blocky cement – some crack seal in bridges

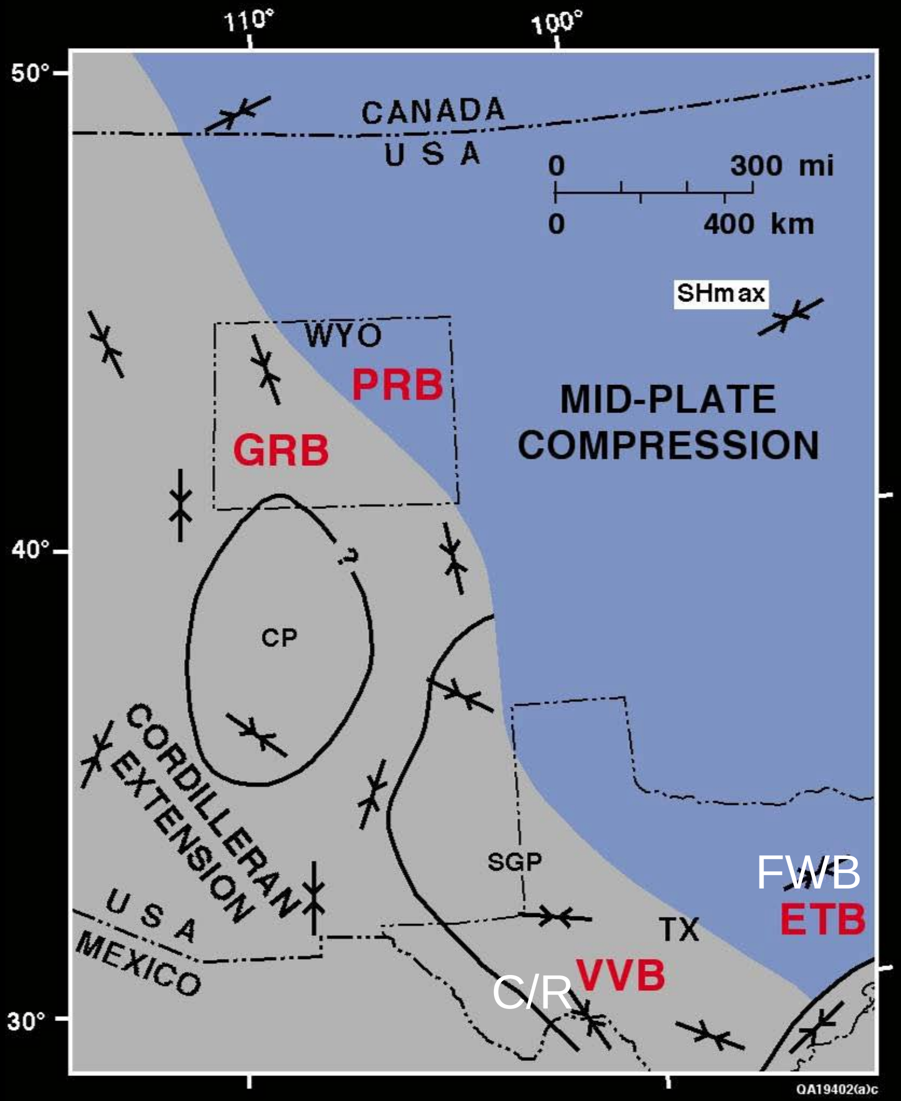
Fracture Orientation - Image Log Data

Strike: Induced fractures and breakouts



Sonic scanner and tiltmeter data give S_{Hmax} as NNE

In Situ Stress



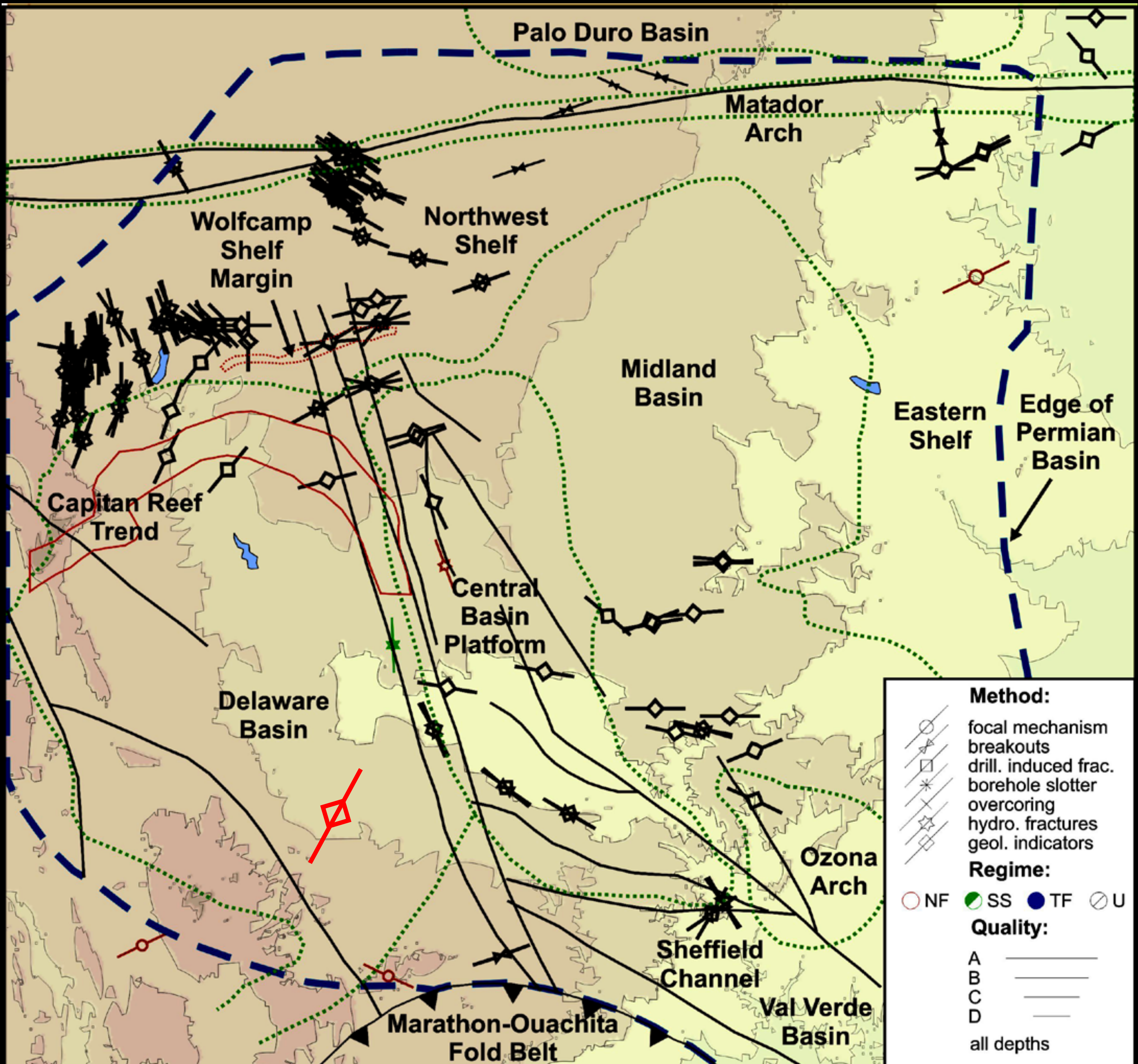
Map modified from Zoback and Zoback (1989) and Laubach et al. (2004)

Present day in situ stress controls hydraulic fracture orientation

Fort Worth Basin
- in Mid-Plate Compression province

West Texas, Permian Basin
- at boundary between Cordilleran Extension and Southern Great Plains (SGP) provinces
- need to carefully establish S_{Hmax}

Tingay, 2006 Present Day Stress Map



Barnett Delaware Basin
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Conclusions

Barnett Shale, Delaware Basin

- Many different natural fracture types
  - Open fractures in core
  - Many other sealed fractures
- Fracture cements may provide key to timing
  - Composition and texture
  - Fluid inclusions
- Natural opening-mode fractures important for completions

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