Extracting Formation Properties from Hydraulically Induced Microseisms, Seismic Attributes, and Impedance Inversion*

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Conclusions

- Tectonics influence curvature attribute and induced fracture system orientations
- Hydraulic fractures correlate to anticlinal 3D shapes
- Low-density and low-impedance rock is highly fracture-prone
- Lamé parameters delineate the extent of fracture systems into gas-bearing zones and evaluate stimulation effectiveness
- Formation contact zones can act as relatively impermeable barriers or as weakness planes for propagating fracture systems
- The correlation of microseisms with surface seismic inversion and curvature attributes can be used for improved stimulation plans

Selected References

Aibaidula, A., and G. McMechan, 2009, Inversion and interpretation of a 3D seismic data set from the Ouachita Mountains, Oklahoma: Geophysics, v. 74/2, p. B37-B45.

Pollastro, R.M., D.M. Jarvie, R.J. Hill, and C.W. Adams, 2007, Geologic framework of the Mississippian Barnett Shale, Barnett-Paleozoic total petroleum system, Bend Arch-Fort Worth Basin, Texas: AAPG Bulletin, v. 91/4, p. 405-436.

Roberts, A., 2001, Curvature attributes and their application to 3D interpreted horizons: First Break, v. 19/2, p. 85-100.

American Association of Petroleum Geologists
Geosciences Technology Workshop
Golden, CO

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Overview

I. Introduction
- Objectives
- Significance of Project

II. Geologic Background
- Geologic History

III. Theoretical Background
- Hydraulic Stimulation and Microseismicity
- Curvature from 3D Seismic Data Volumes
- Seismic Inversion

IV. Surface Seismic Analysis
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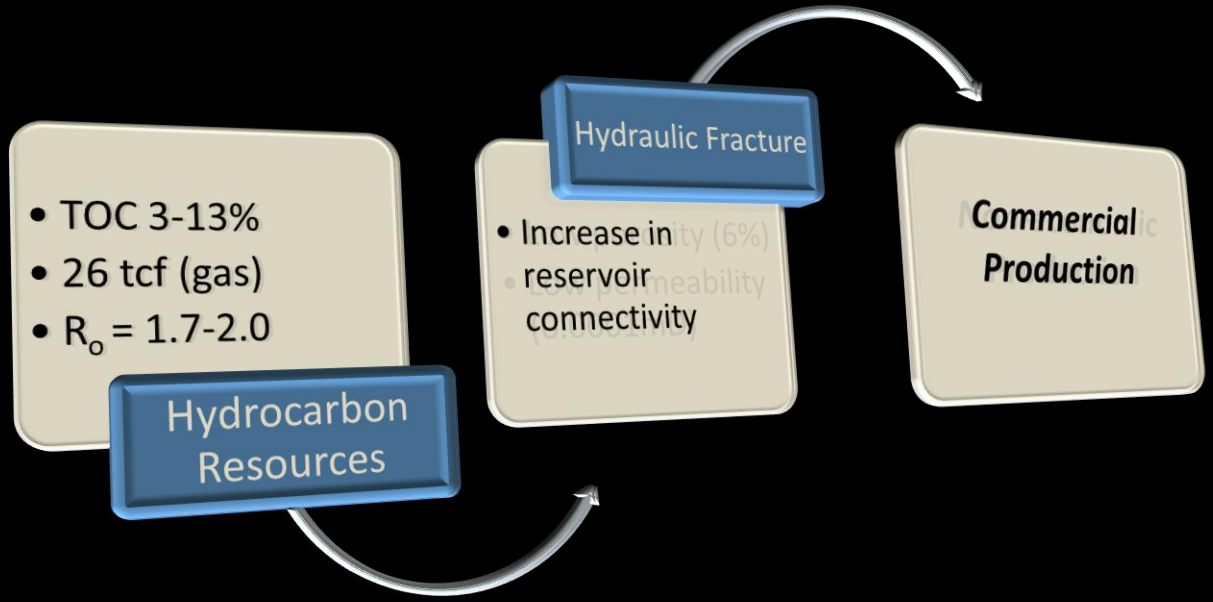
Introduction

Objectives

- **Characterize zones of fracture network propagation during hydraulic stimulation using:**
  - Recorded microseisms
  - Volumetric curvature attribute
  - Inversion volumes
- **Define characteristics of fracture-prone zones from mapped microseism clusters for fracture network characterization**

Significance of Project



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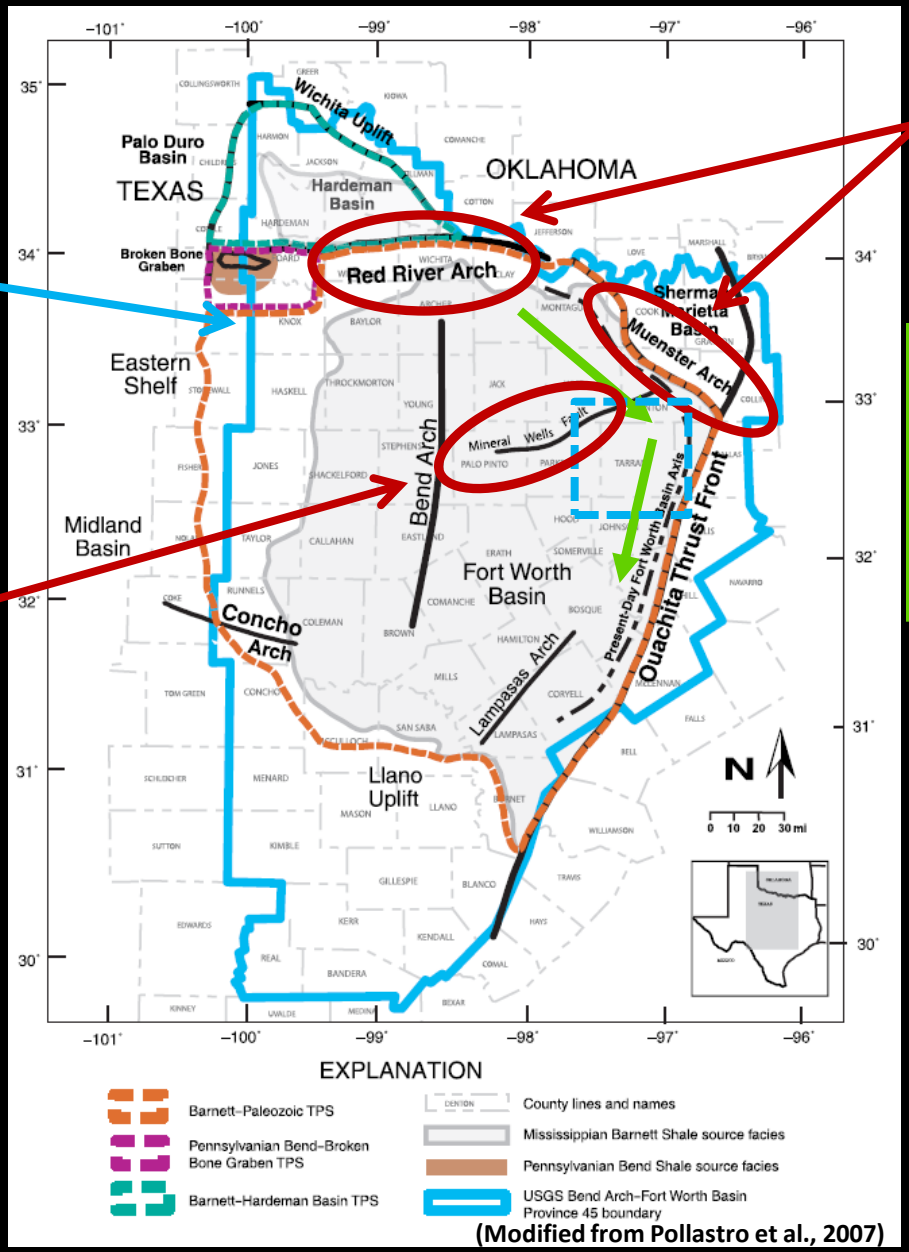
Geologic Background

Geologic History

Fort Worth Basin formed during the Late Paleozoic Ouachita Orogeny, a major tectonic event of thrust-fold deformation.

The Mineral Wells fault has a NE-SW trend and has been proposed to be a basement fault periodically reactivated during the Late Paleozoic.



(Modified from Pollastro et al., 2007)

Basement uplifts formed by reactivated basement faults during Ouachita compression.

The basin deepens towards the north and its axis roughly parallels the Muenster arch, then bends southwards to parallel the Ouachita structural front.

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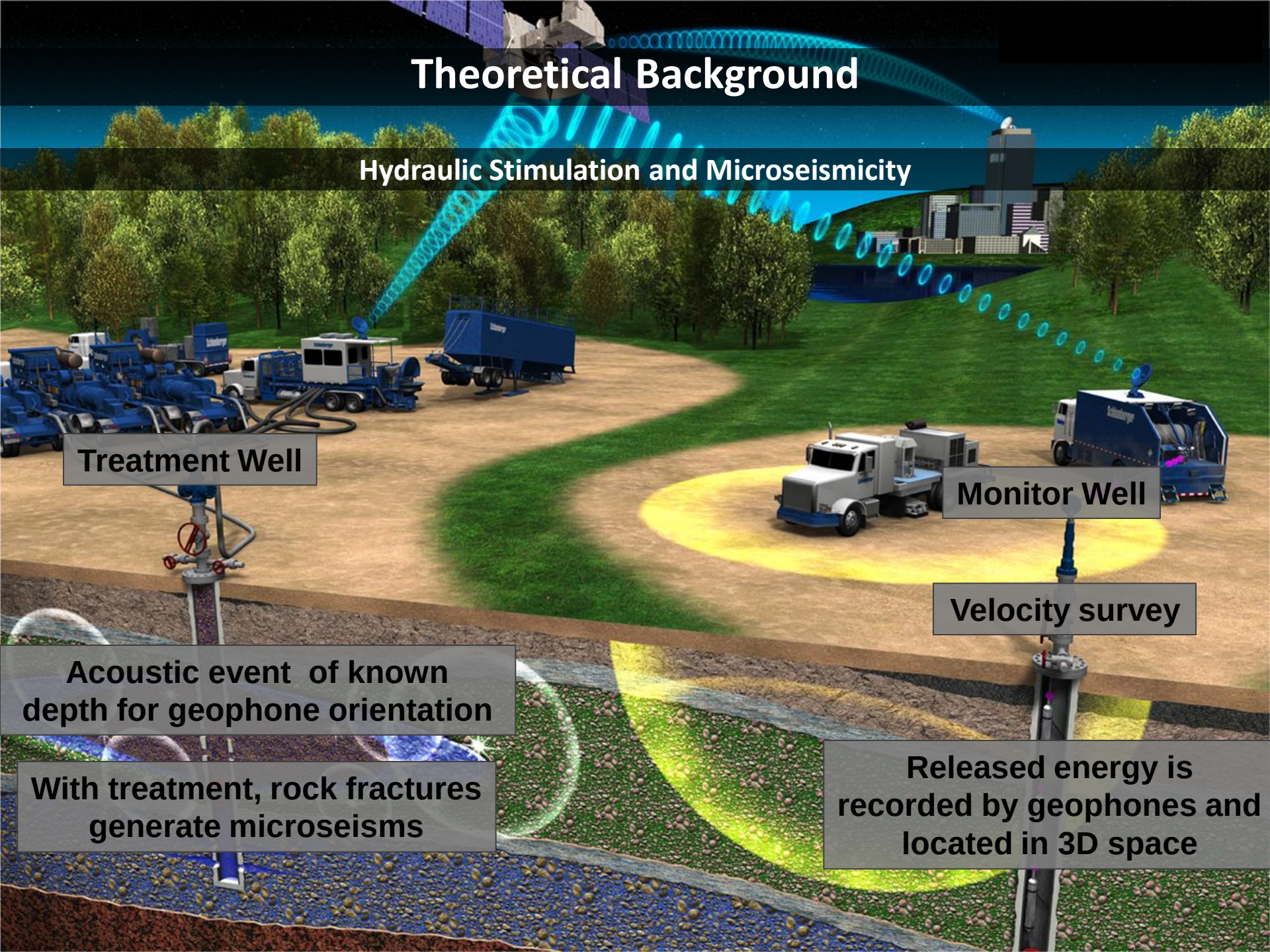
VII. Moving Forward

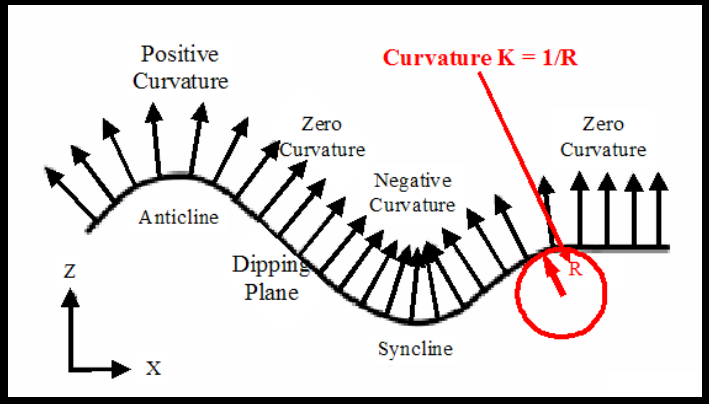
Theoretical Background

Hydraulic Stimulation and Microseismicity

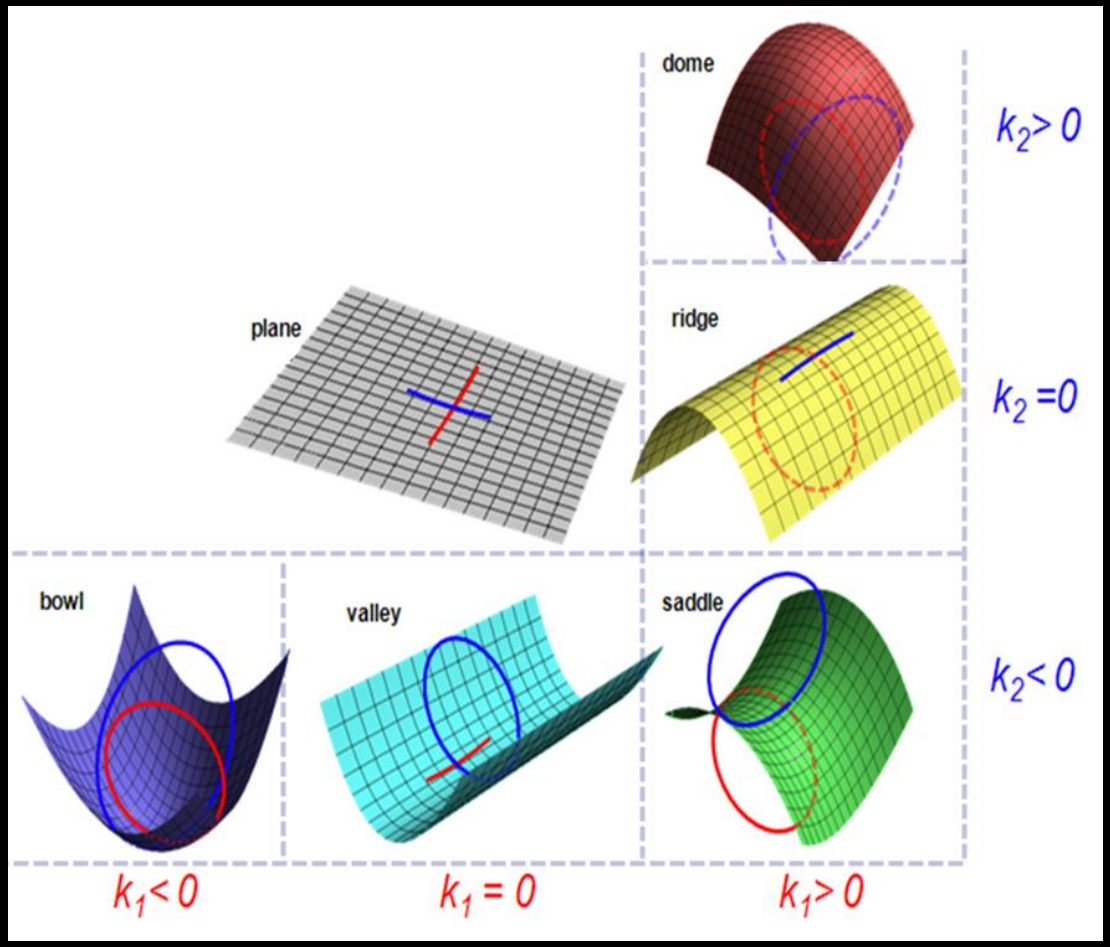


Theoretical Background

Curvature from 3D Seismic Data Volumes



Two-dimensional curvature, where by convention, positive curvature is concave downward, and negative curvature is concave upward (from Roberts, 2001).



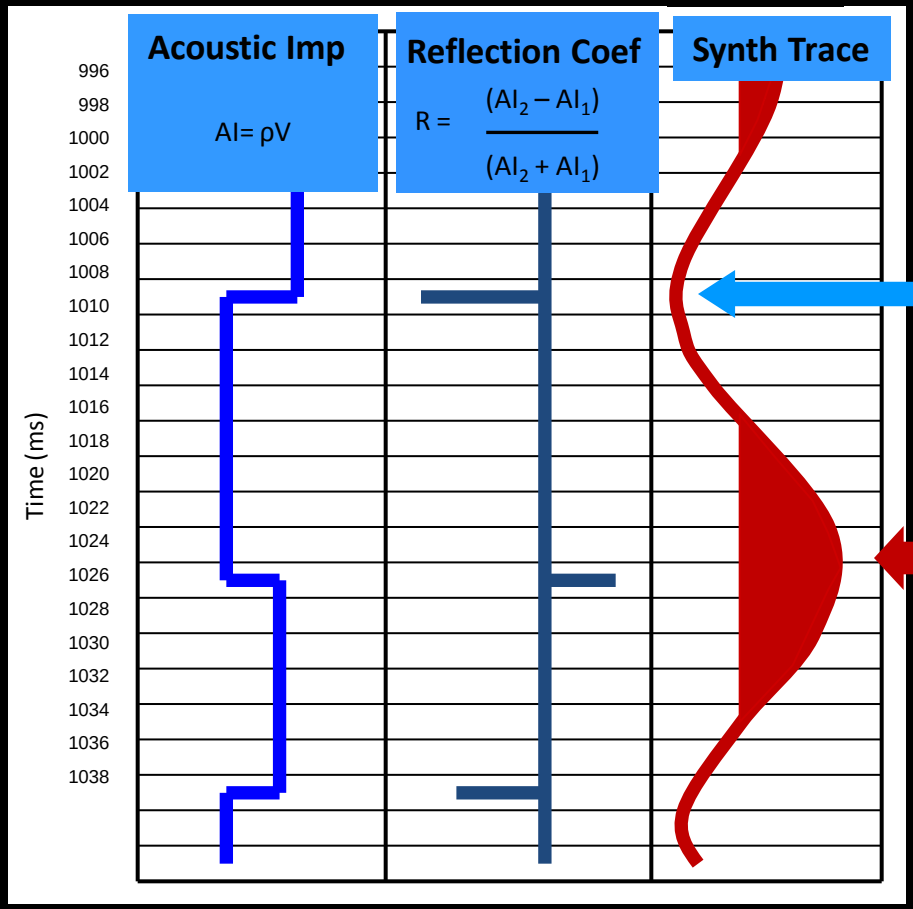
Three-dimensional quadratic shapes of most-positive and most-negative principal curvatures (k_1 and k_2) (modified from Mai, 2010).

Theoretical Background

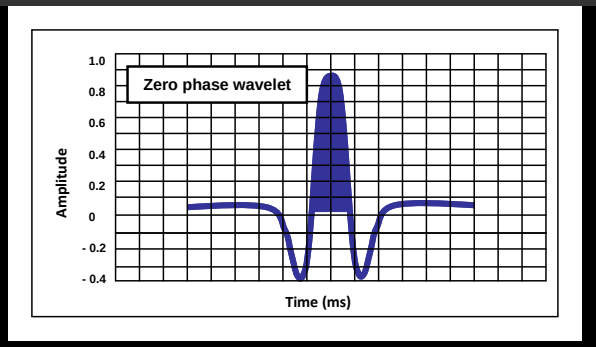
Seismic Inversion

Core

Forward Modeling



Inverse Modeling



Decreasing Impedance
=
Negative Reflectivity
=
Trough

Increasing Impedance
=
Positive Reflectivity
=
Peak

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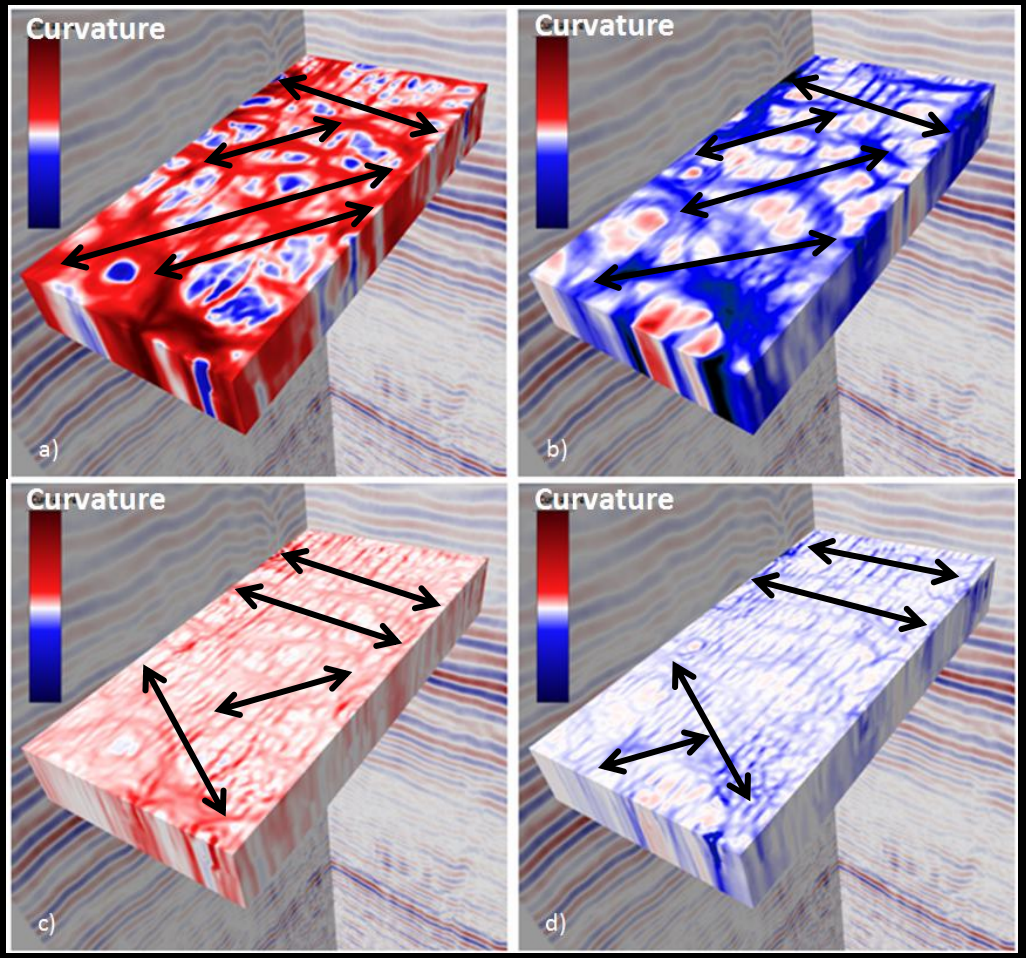
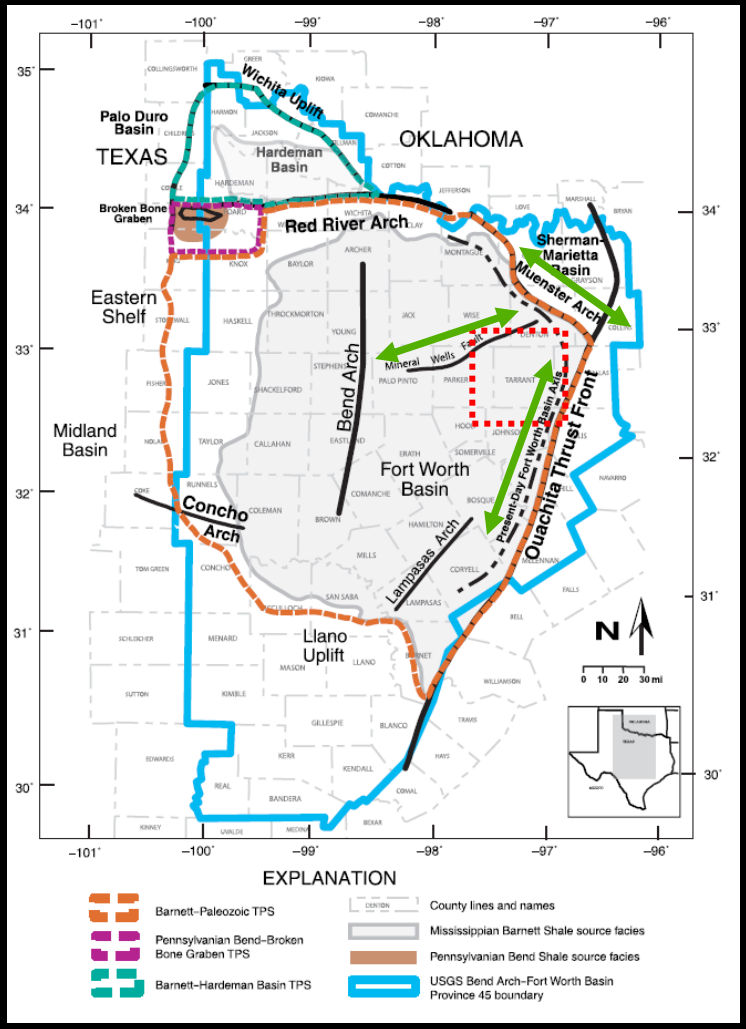
Surface Seismic Analysis

Curvature Attribute

Most Positive Principal Curvature
k1

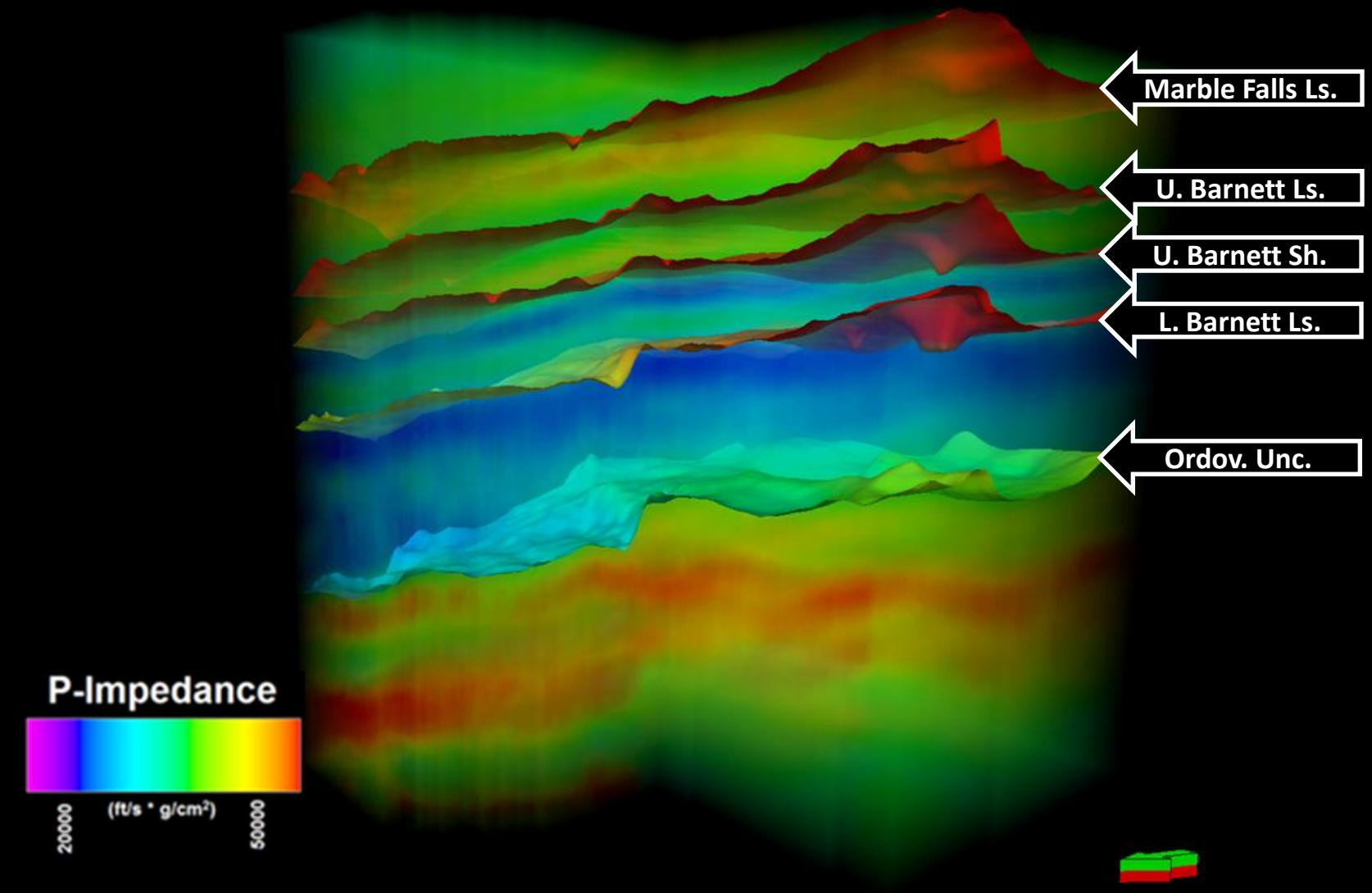
Most Negative Principal Curvature
k2





Surface Seismic Analysis

Seismic Inversion



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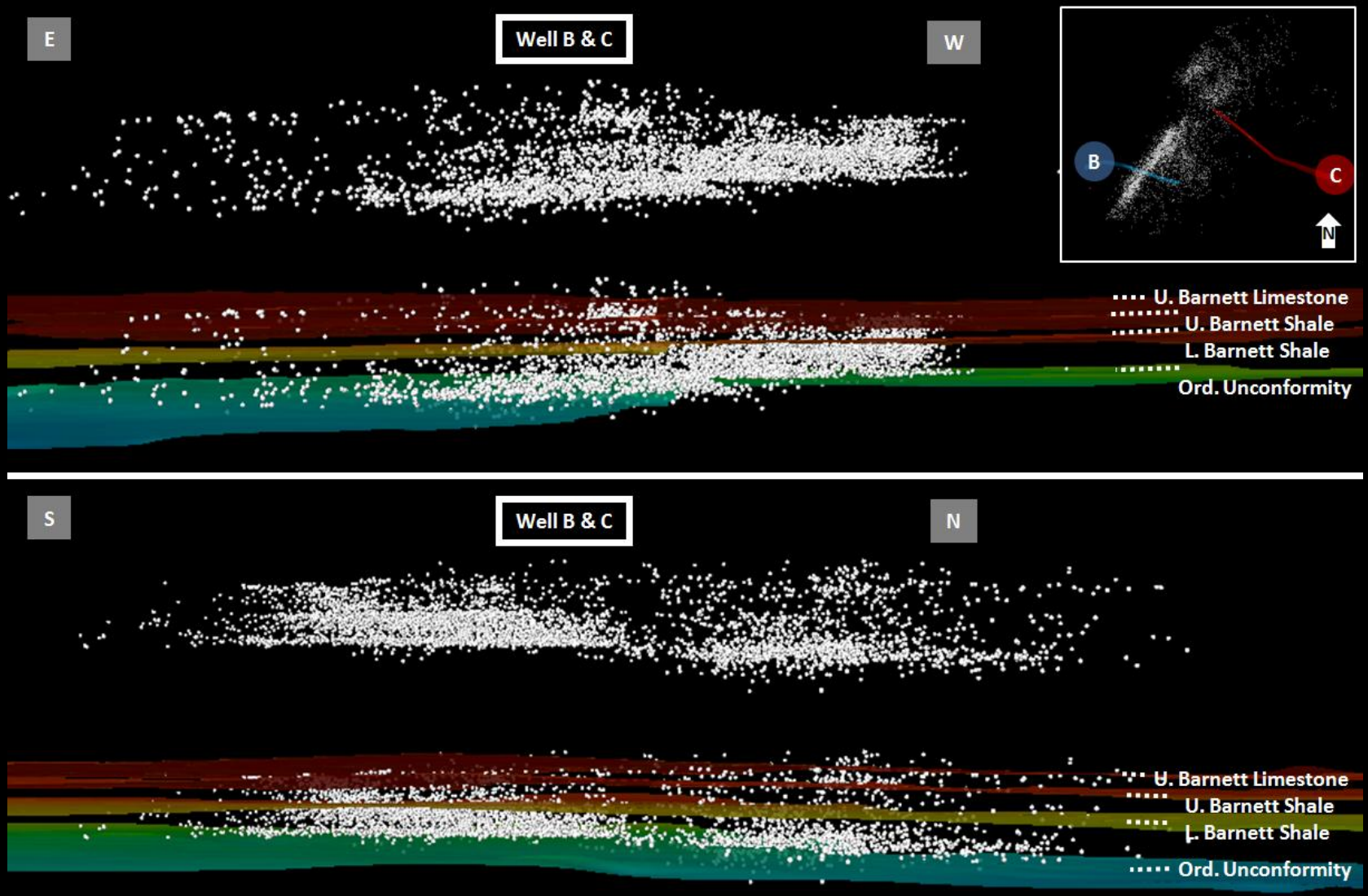
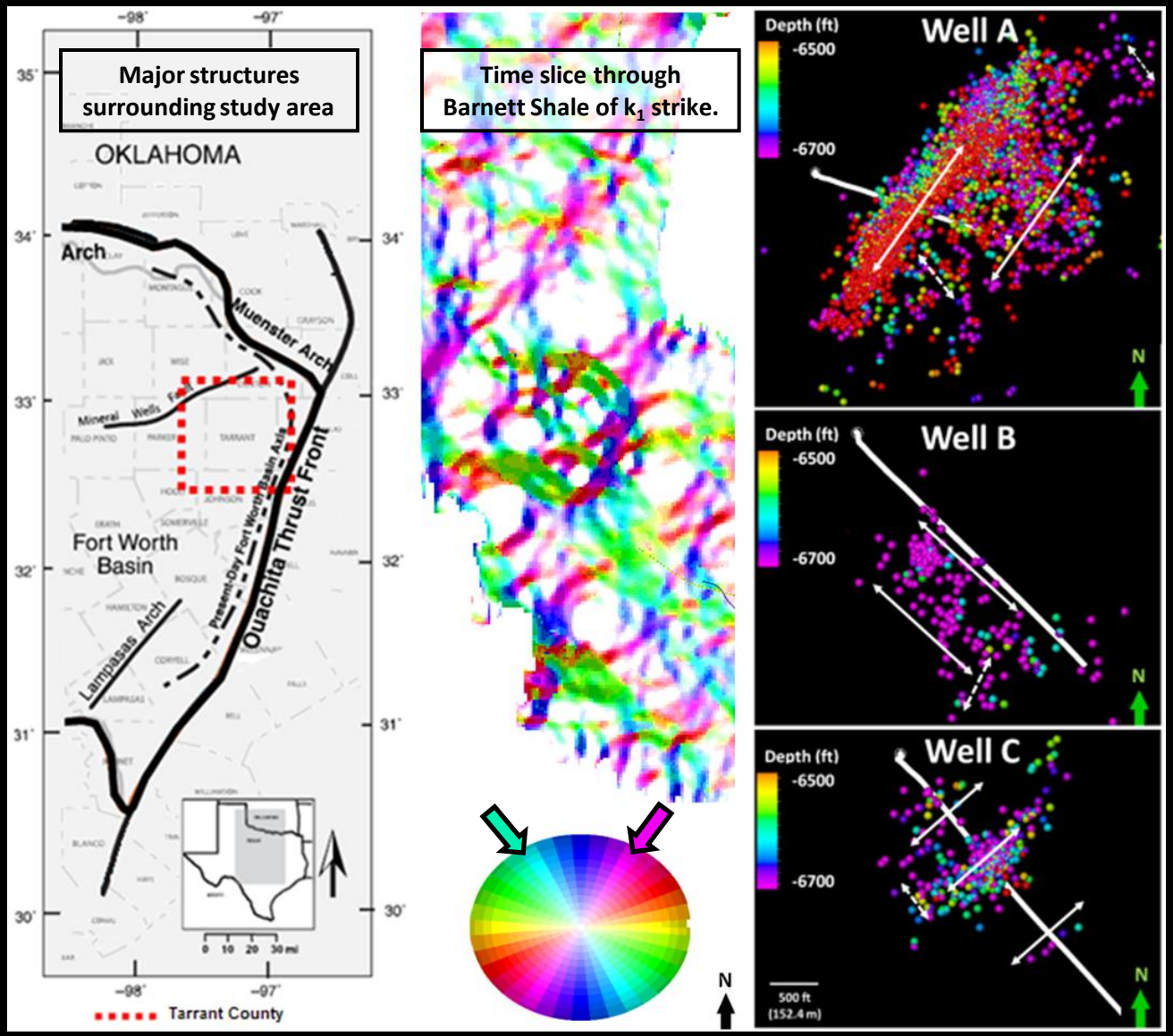
Microseismic Analysis

Microseismic Interpretation



Microseismic Analysis

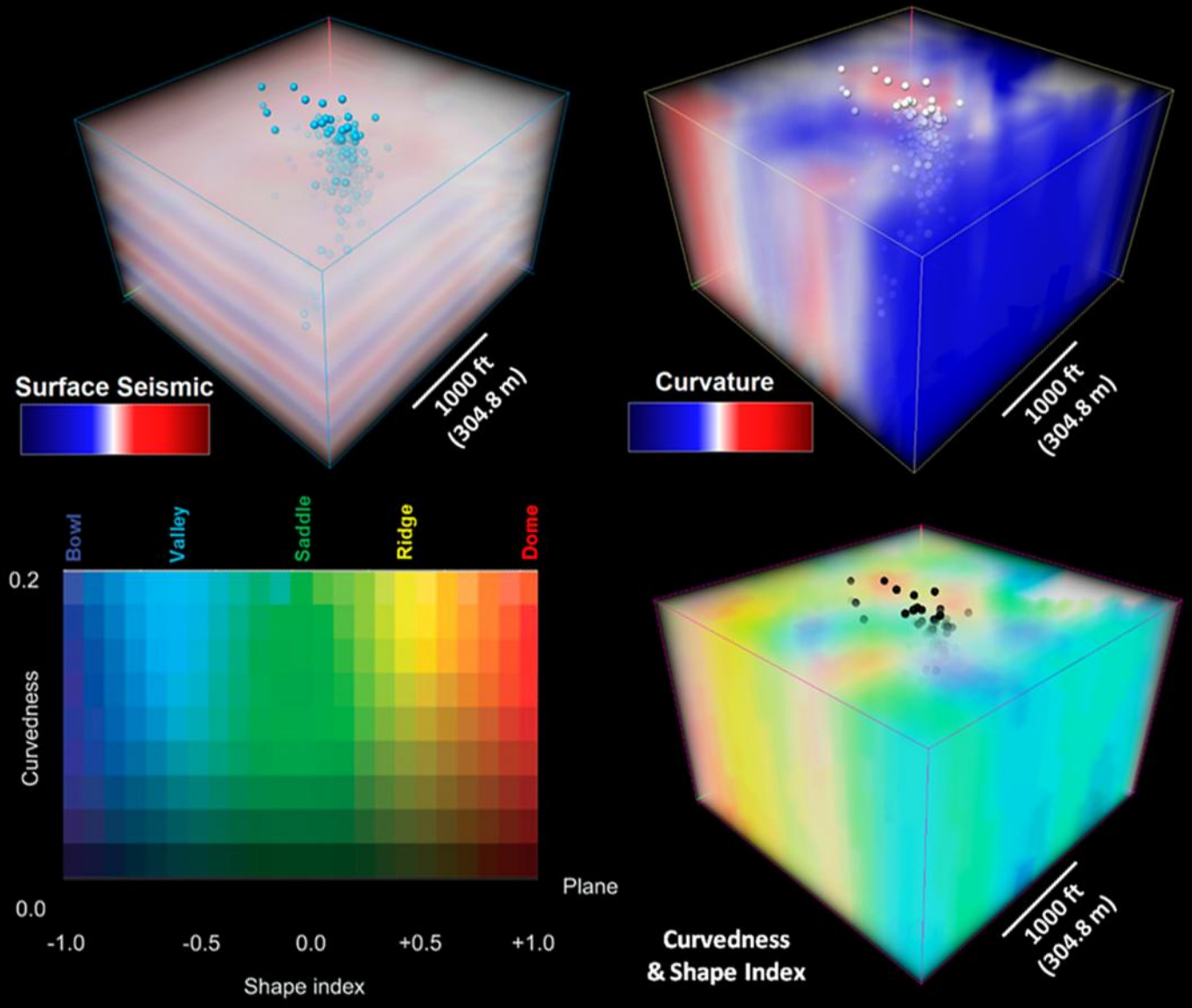
Microseismic and Volumetric Curvature



(Modified from Pollastro et al, 2007)

Microseismic Analysis

Microseismic and Volumetric Curvature



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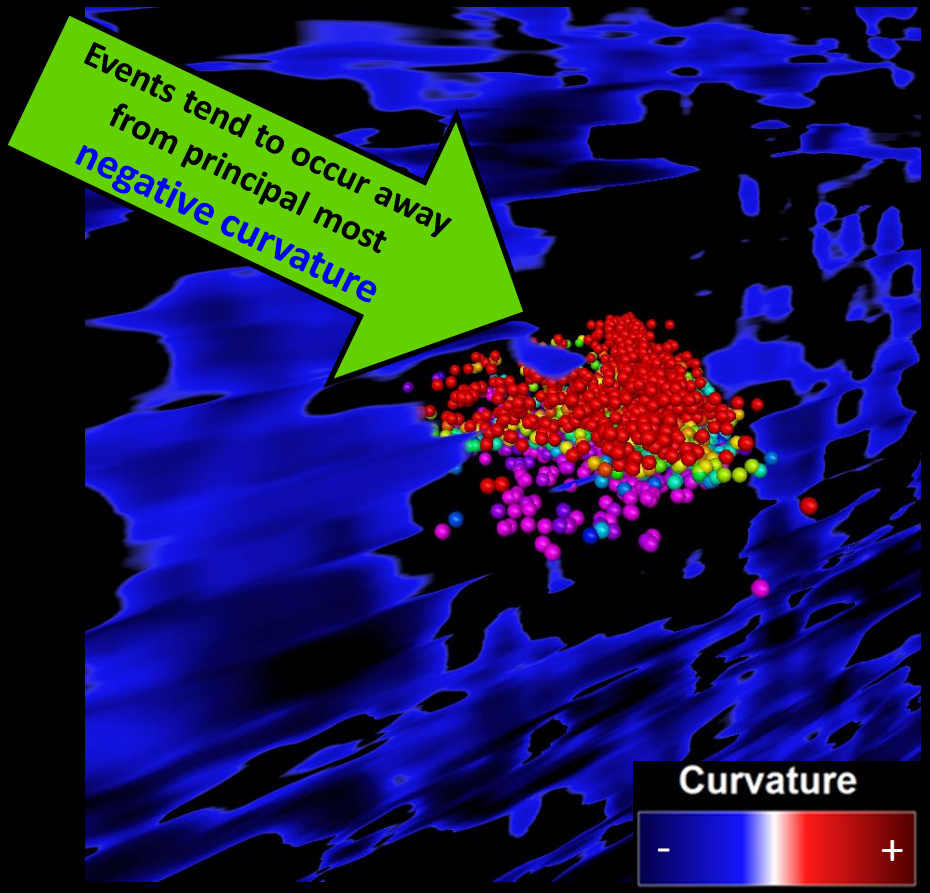
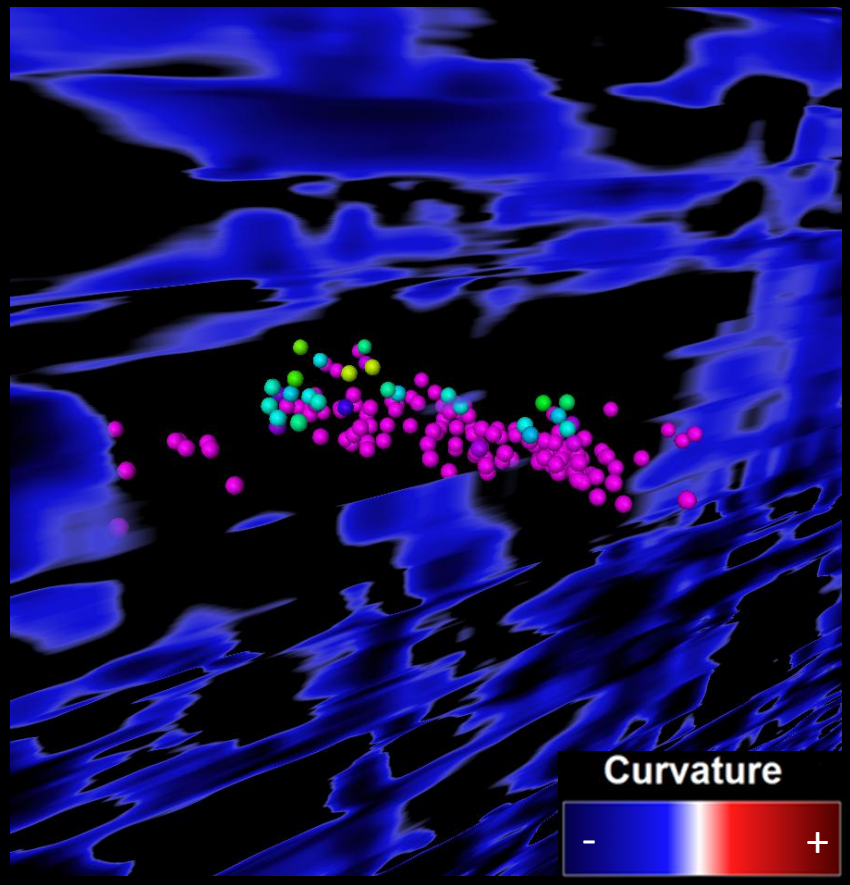
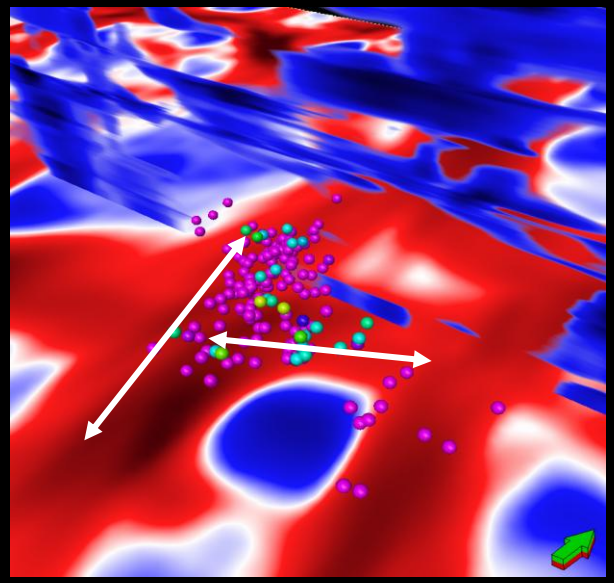
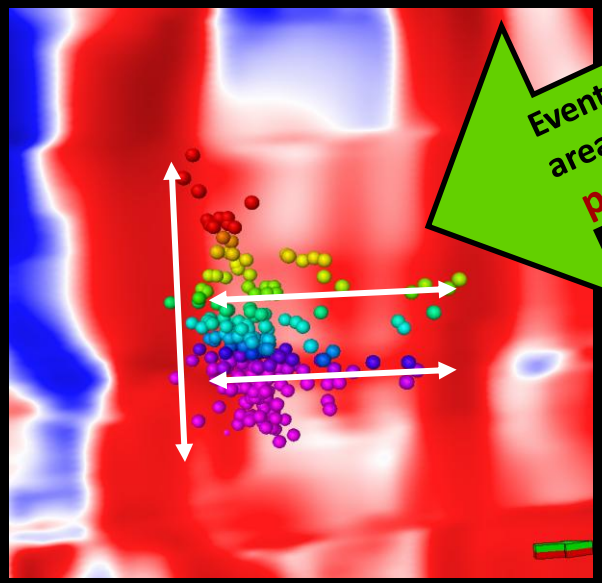


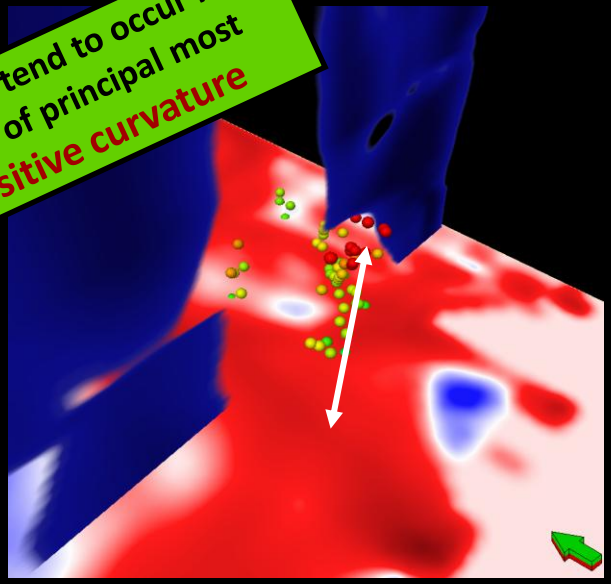


Microseismic Analysis

Microseismic and Volumetric Curvature





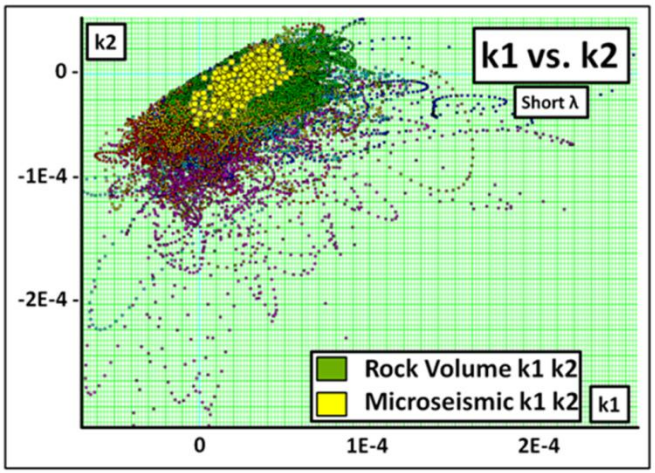


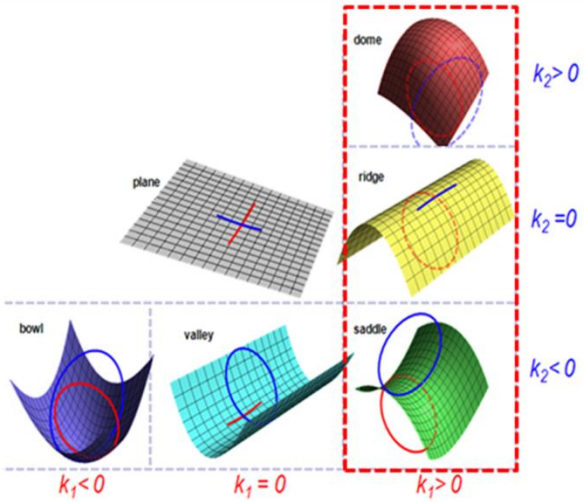
Curvature

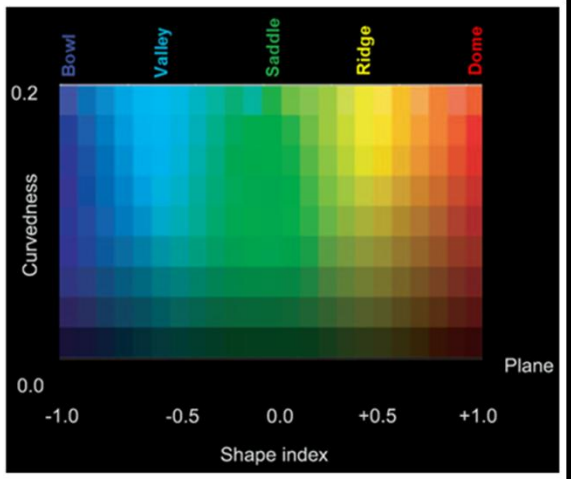
- +

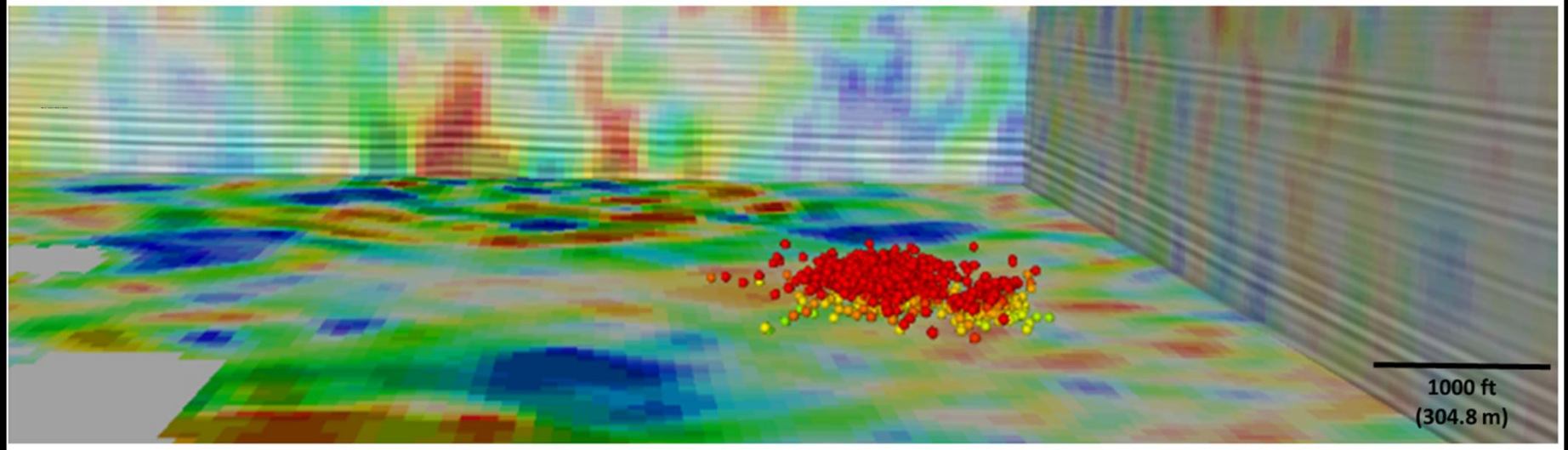
Microseismic Analysis

Microseismic and Volumetric Curvature



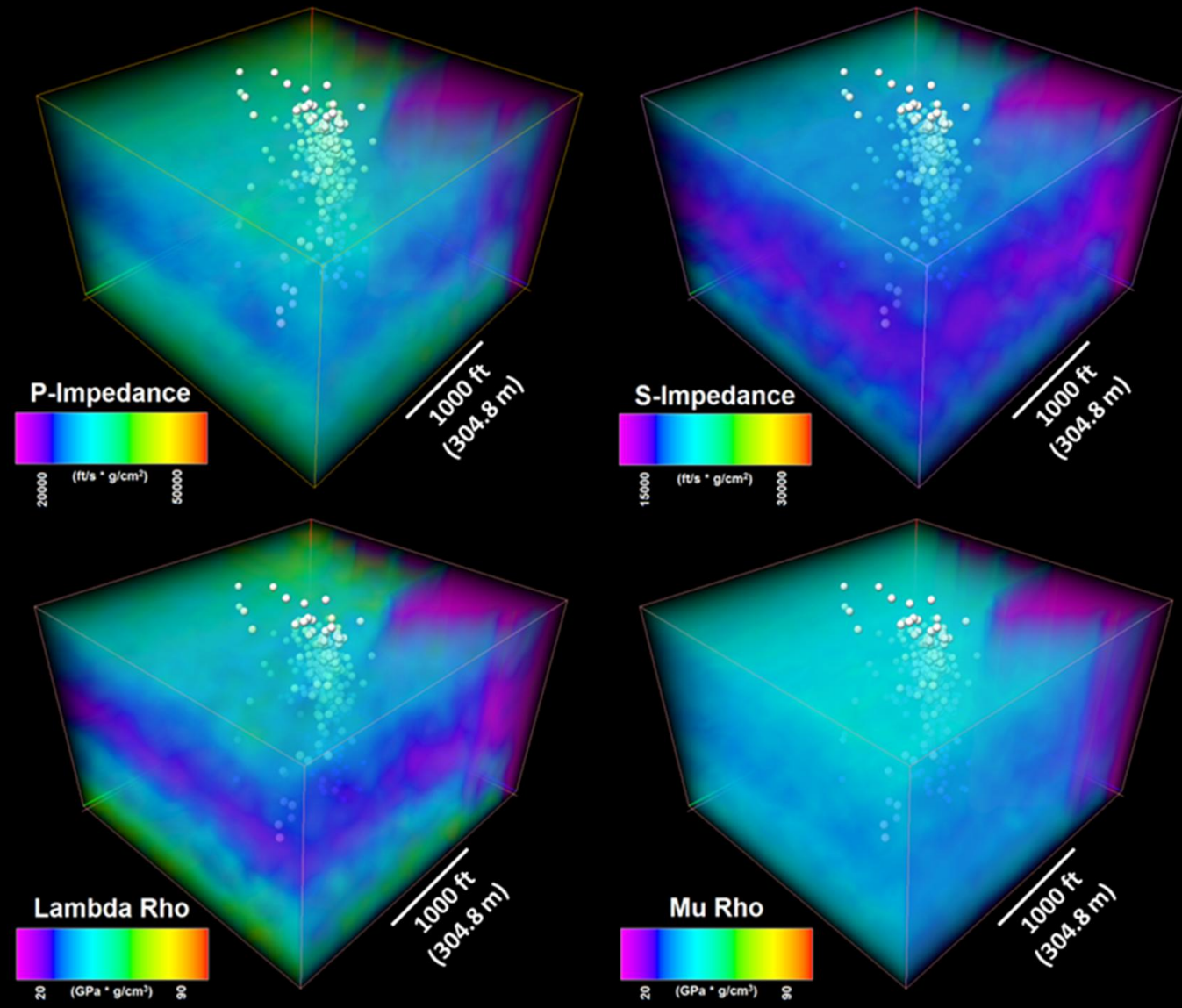






Microseismic Analysis

Microseismic and Seismic Inversion Properties



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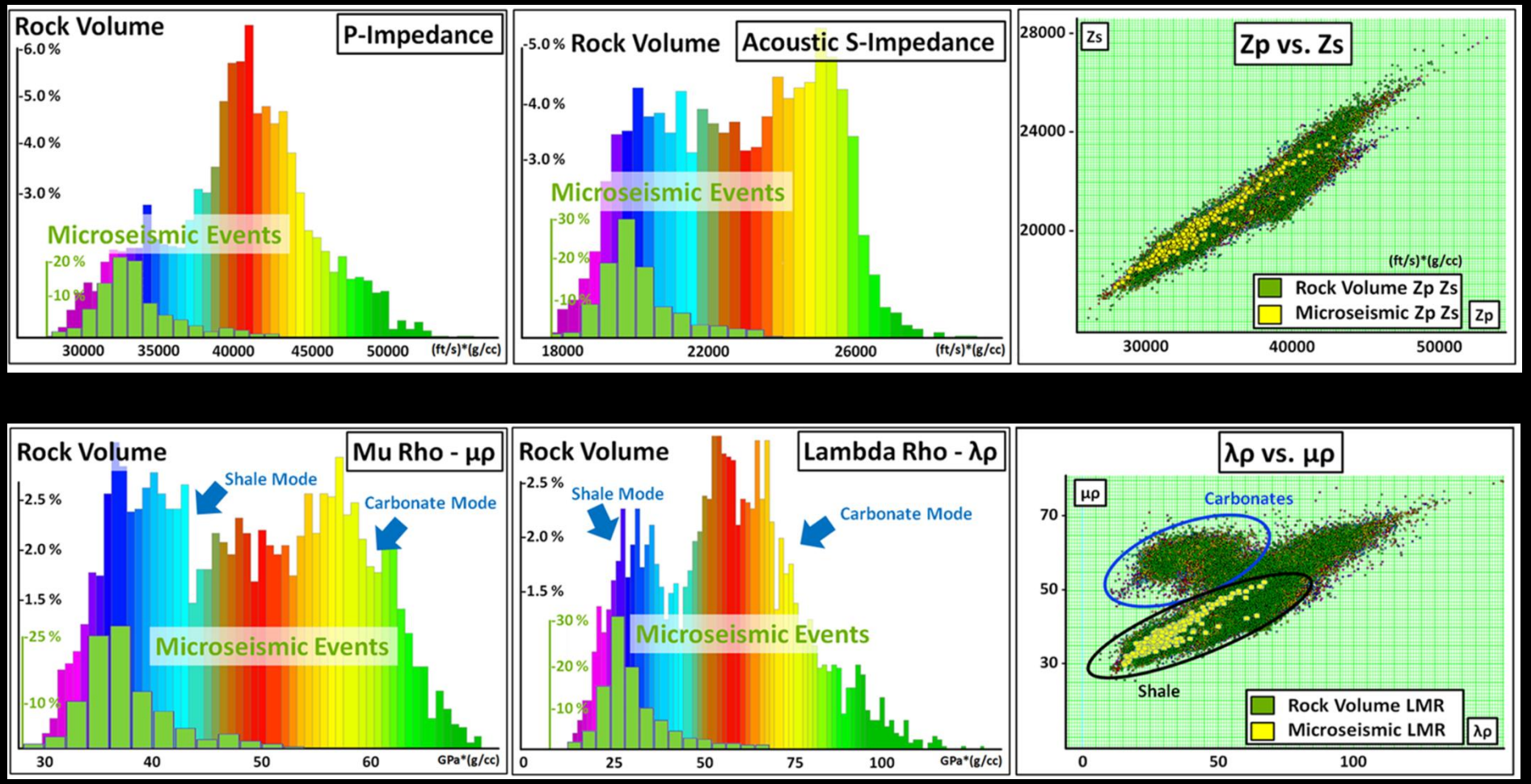
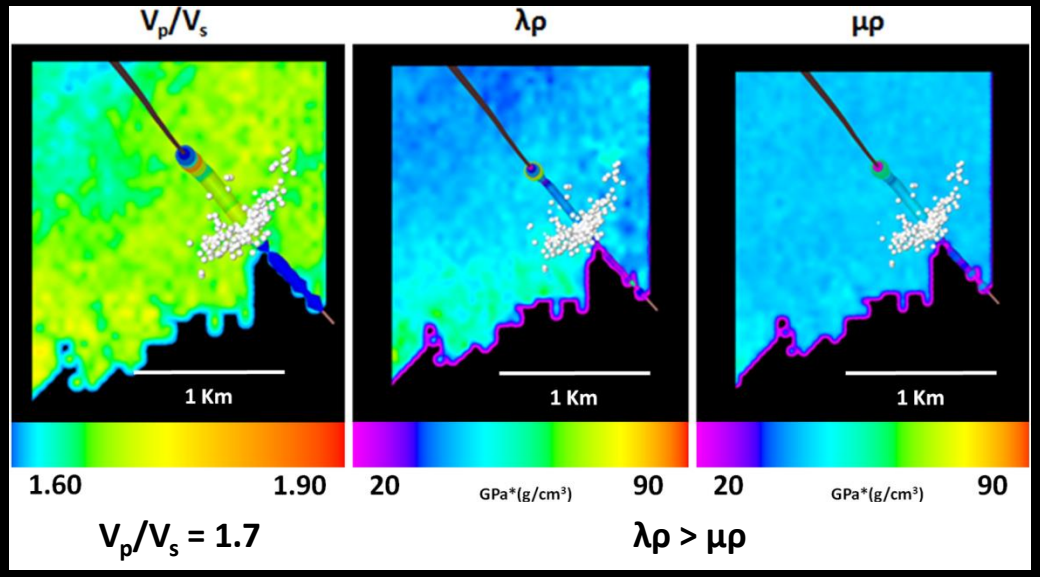


Microseisms occur in a narrow range of impedance values

Microseismic Analysis

Microseismic and Seismic Inversion Properties



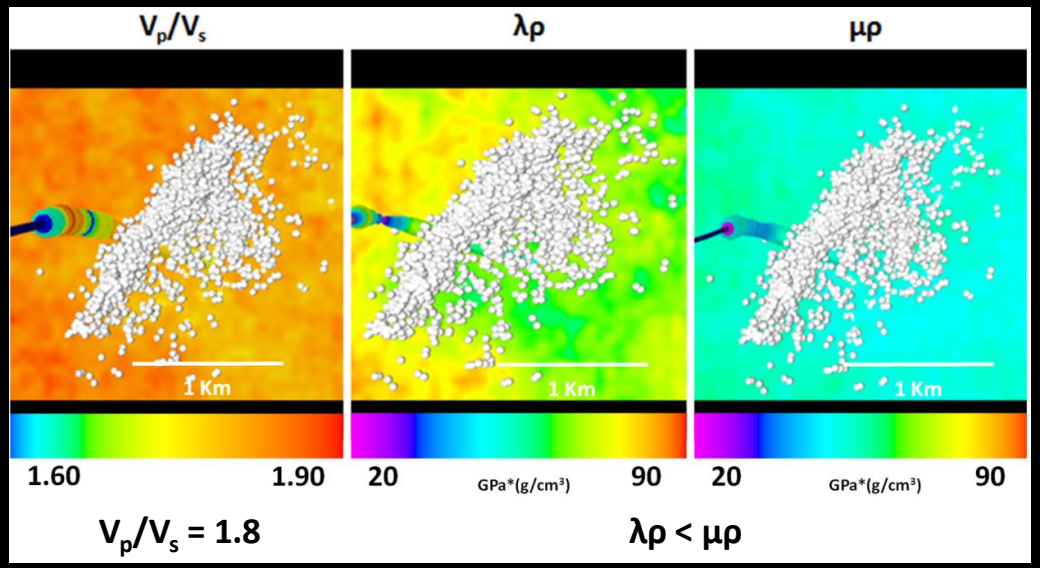
Low Production

Gas saturated shales:

V_p/V_s = 1.7 - 3.0

λρ < μρ

(Goodway et al., 2006; Aibaidula and McMechan, 2009)



High Production

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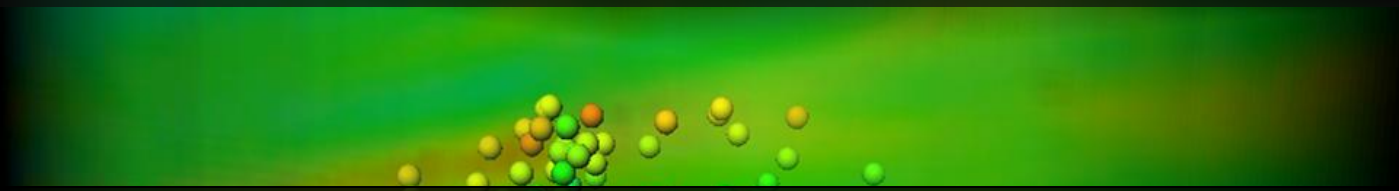
Thank You



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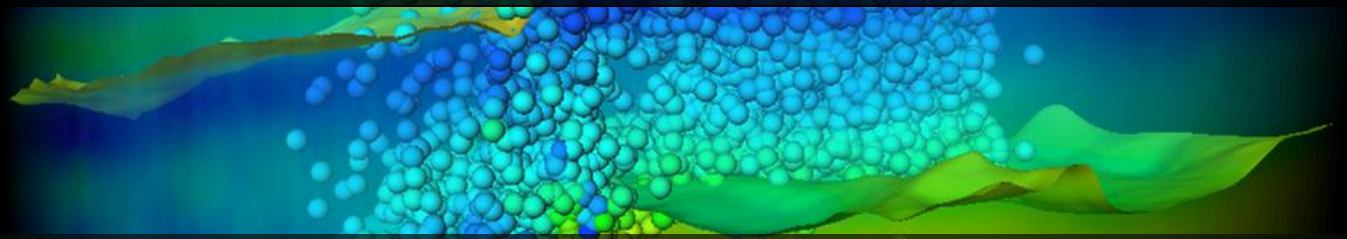

Questions?