The application of seismic derived rock properties in predicting Duvernay Induced Fractures

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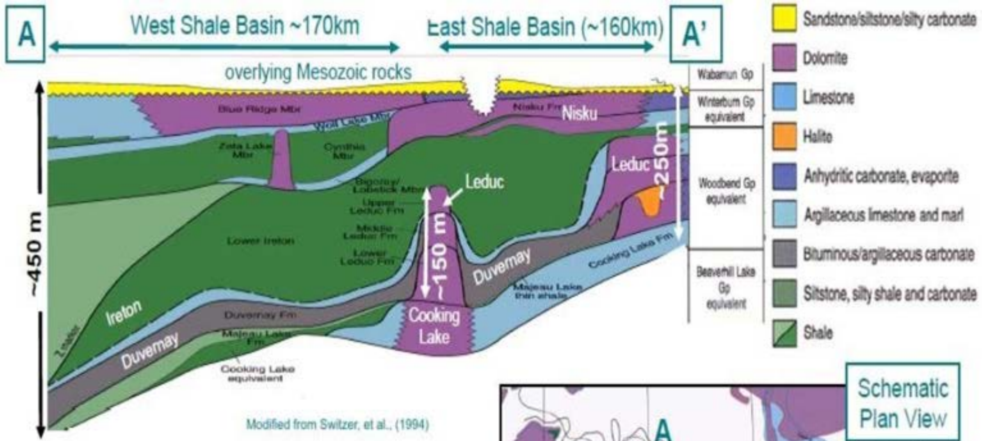
Introduction

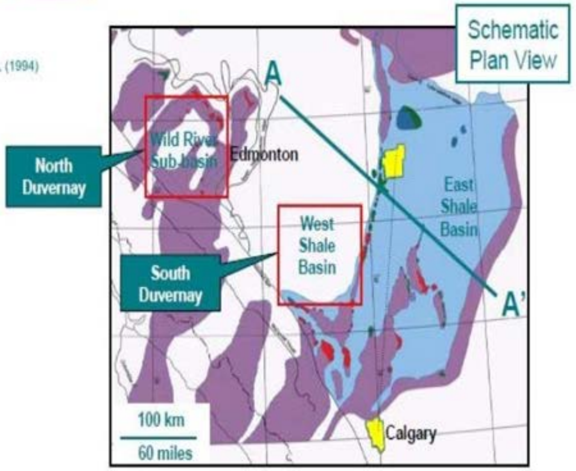
- Overview of Duvernay Geology
  - Regional Framework
  - Modern Analogue
  - Core work
  - Theoretical Rock properties
- Current development practices
  - Horizontal drilling, microseismic results
- Seismic inversion analysis
  - Simultaneous inversion
  - Derivation of rock properties
- Uses and applications
  - Implications of reservoir characteristics
  - Future work

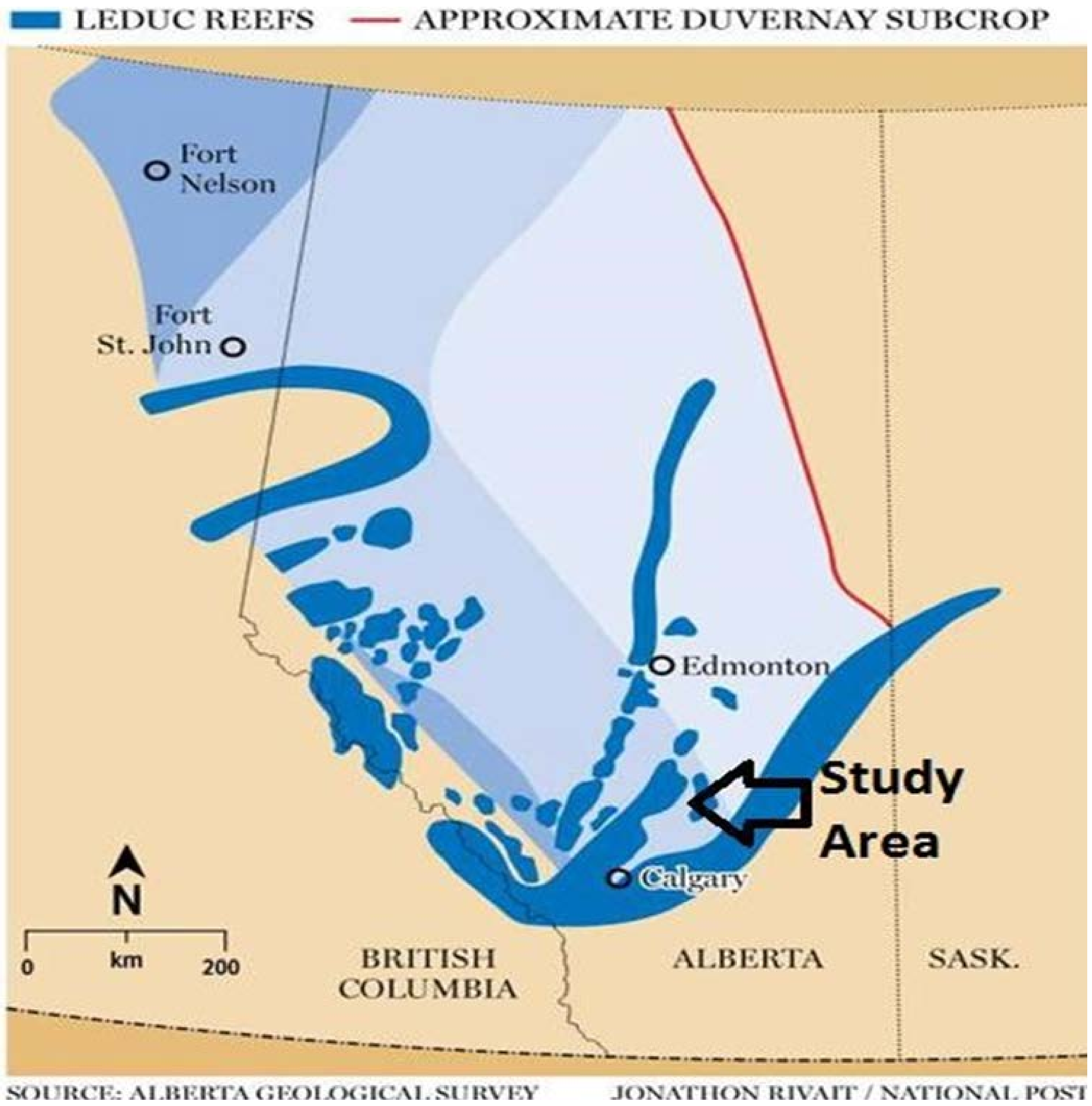
Duvernay Formation mature oil window

Duvernay Formation Depositional Environment



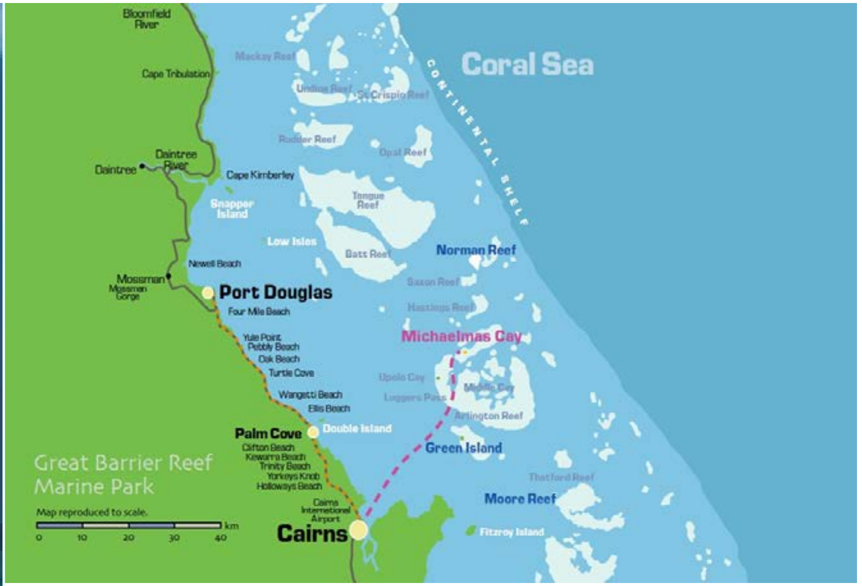
- Both North Duvernay (Wild River) and South Duvernay (West Shale Basin) were centered in areas adjacent to reef development
- Reefs created restricted basin conditions, where organic productivity was high resulting in thick, high TOC shale deposits





Great Barrier Reef, modern analogue to the Leduc / Duvernay

Duvernay /Leduc modern analogue



Kaybob area, core analysis of rock properties.

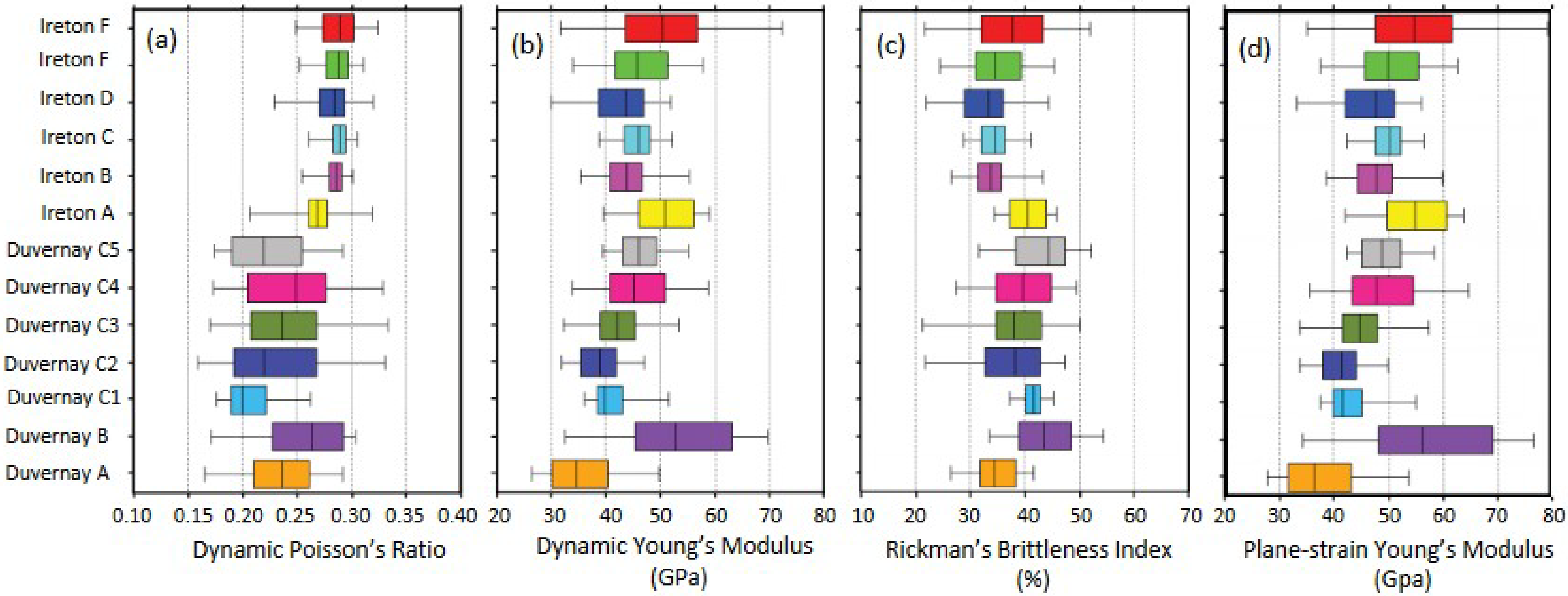
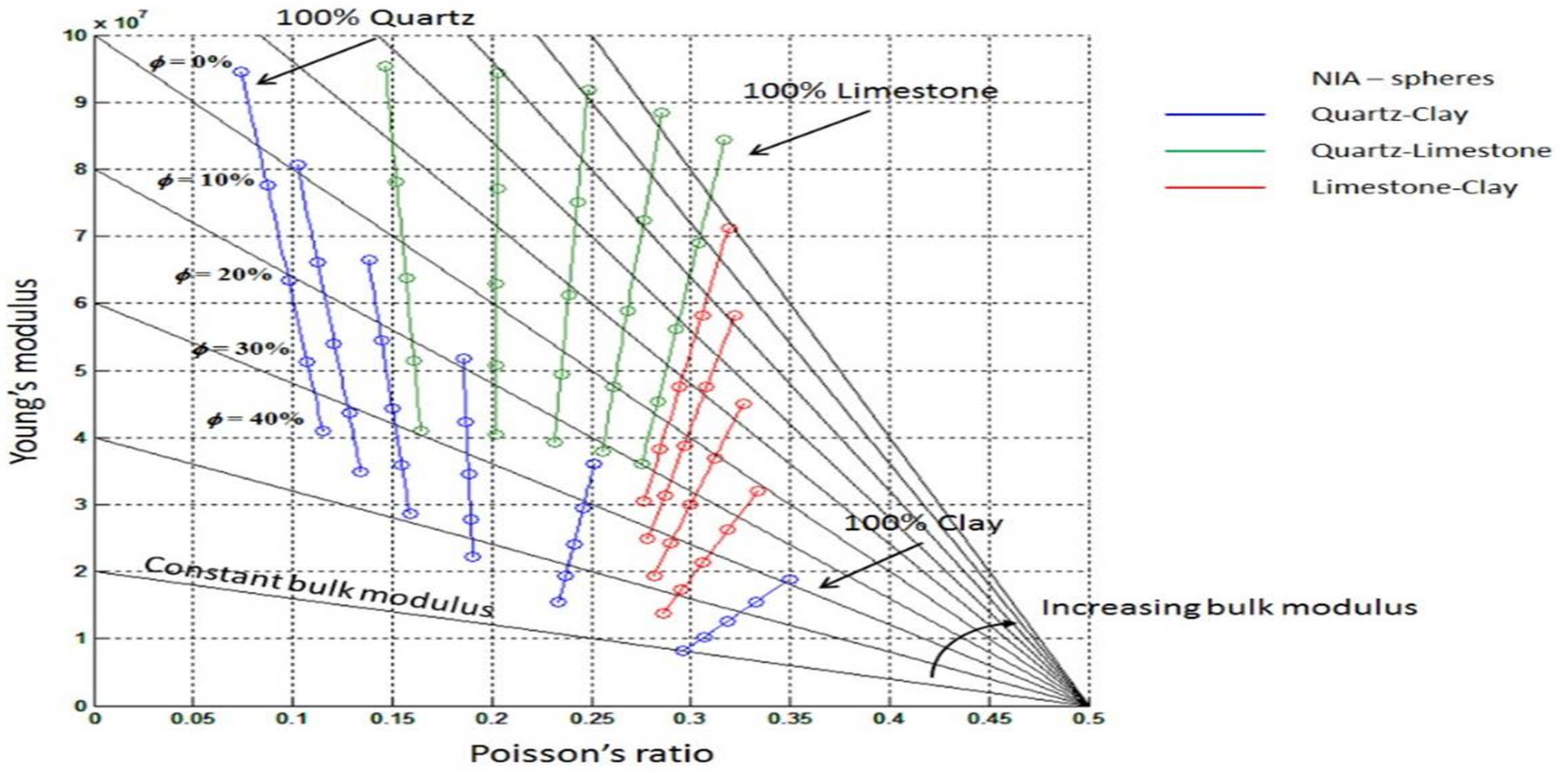


Figure 1. Mechanical properties calculated based on sonic logs for 26 wells for the Duvernay and Ireton formations: (a) dynamic Poisson's ratio, (b) dynamic Young's Modulus, (c) Rickman's brittleness Index, and (d) plane-strain Young's modulus.

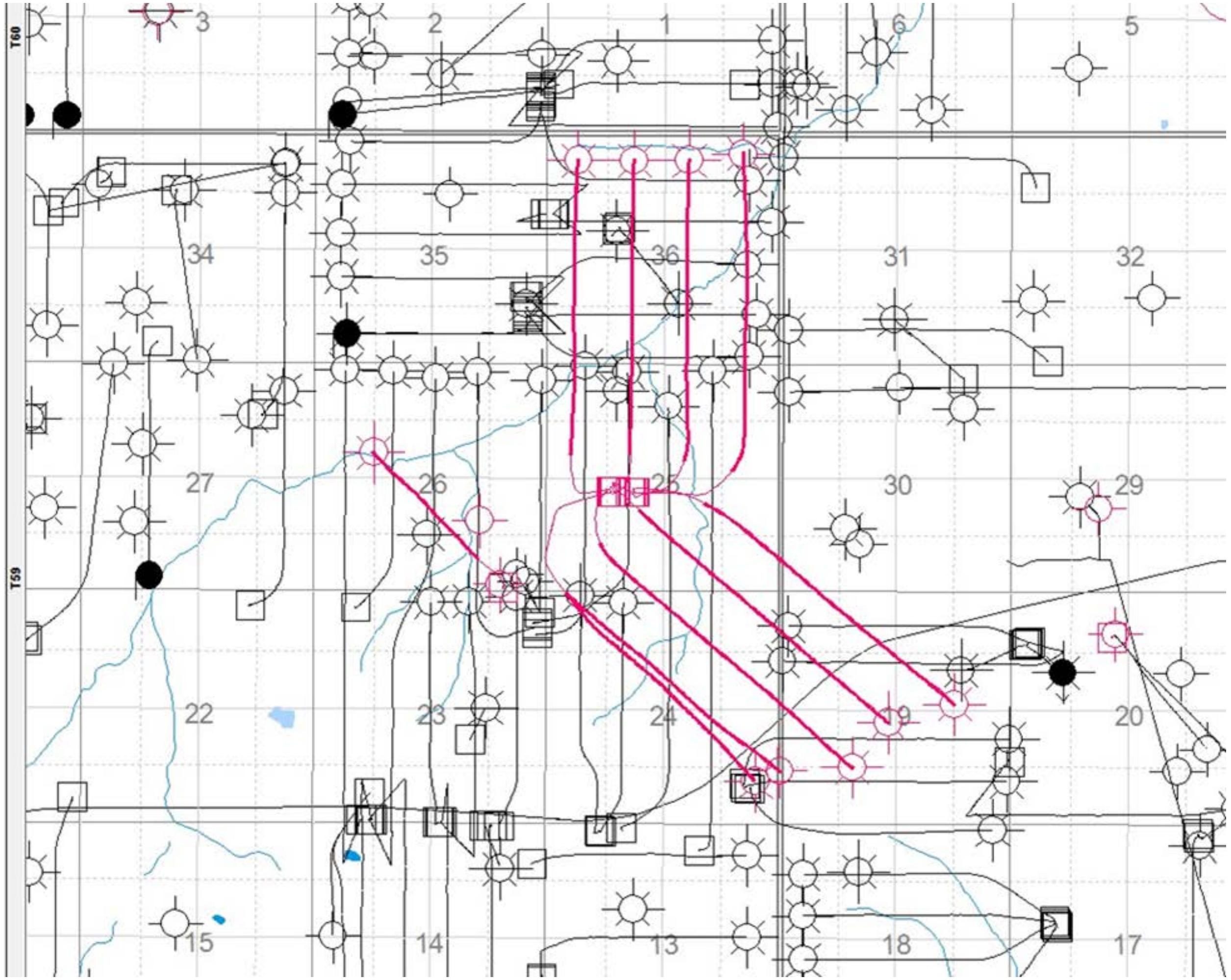
Amy D. Fox, Mehrdad Soltanzadeh Canadian Discovery Ltd.

Theoretical calculation of rock properties

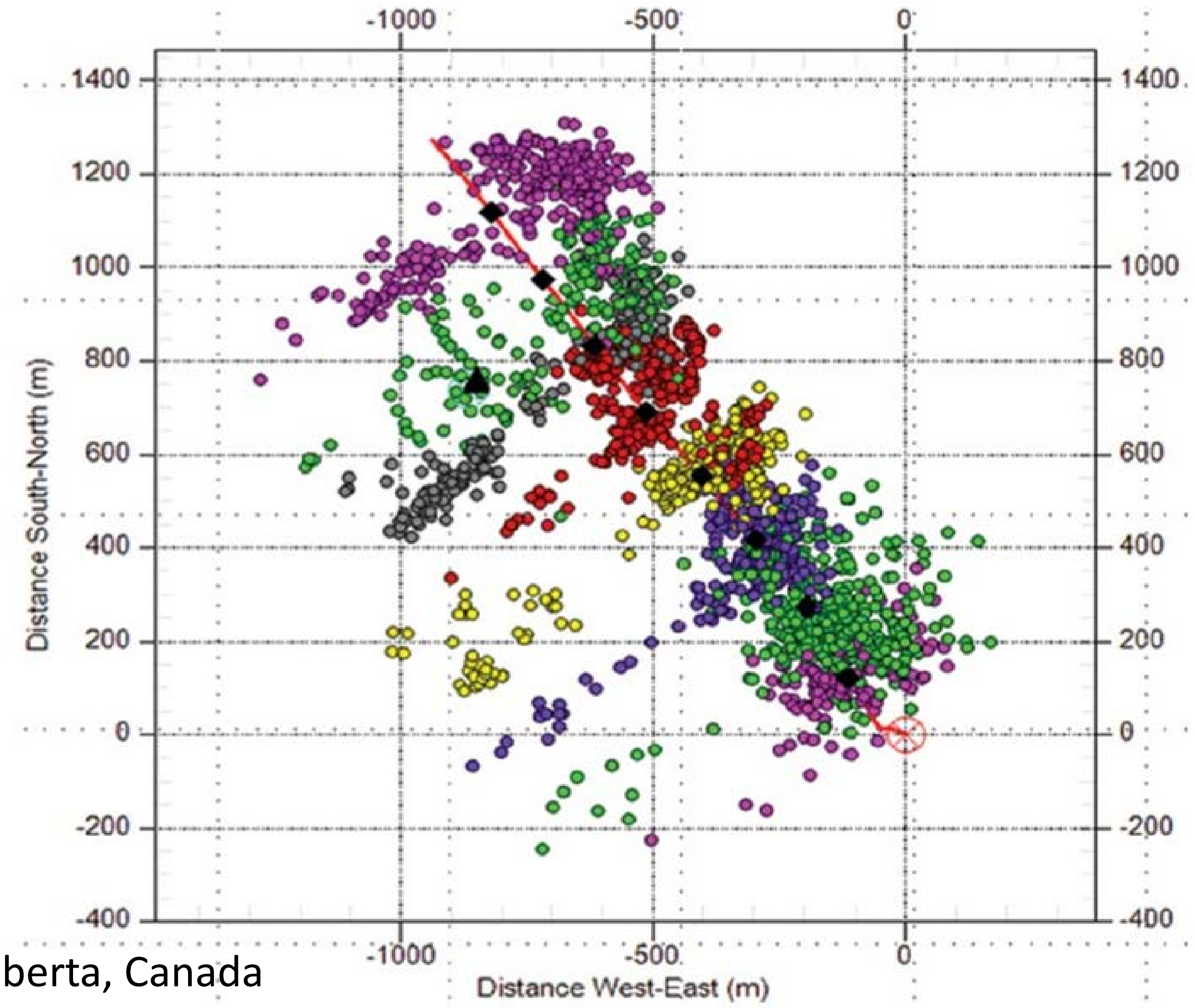


Cho Et al, GeoConvention 2014 FOCUS

Duvernay Horizontal plan, Kaybob/Bigstone



Alberta Example, Montney shale , Microseismic recorded



Shawn C. Maxwell
Schlumberger, Calgary, Alberta, Canada

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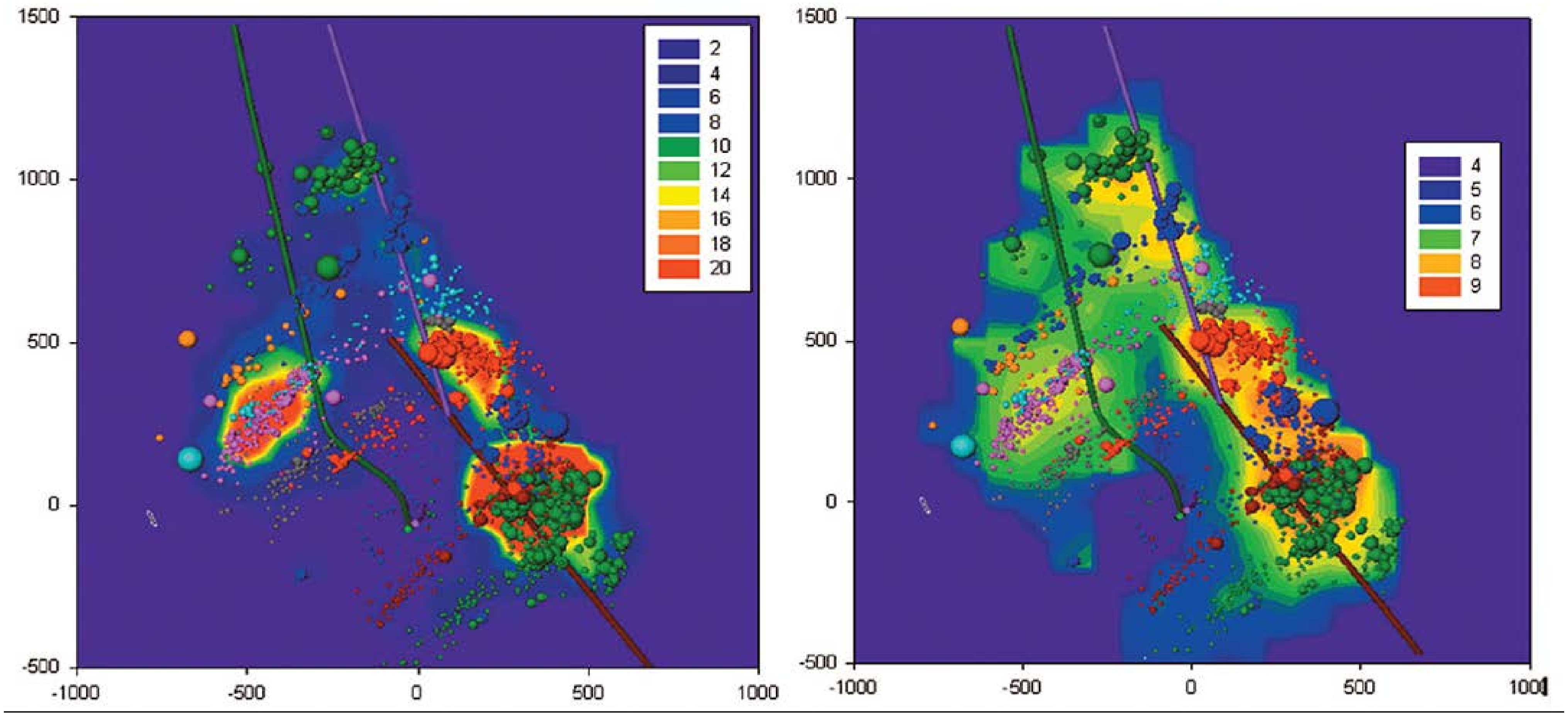
Variations in microseismic activity in the Montney Shale



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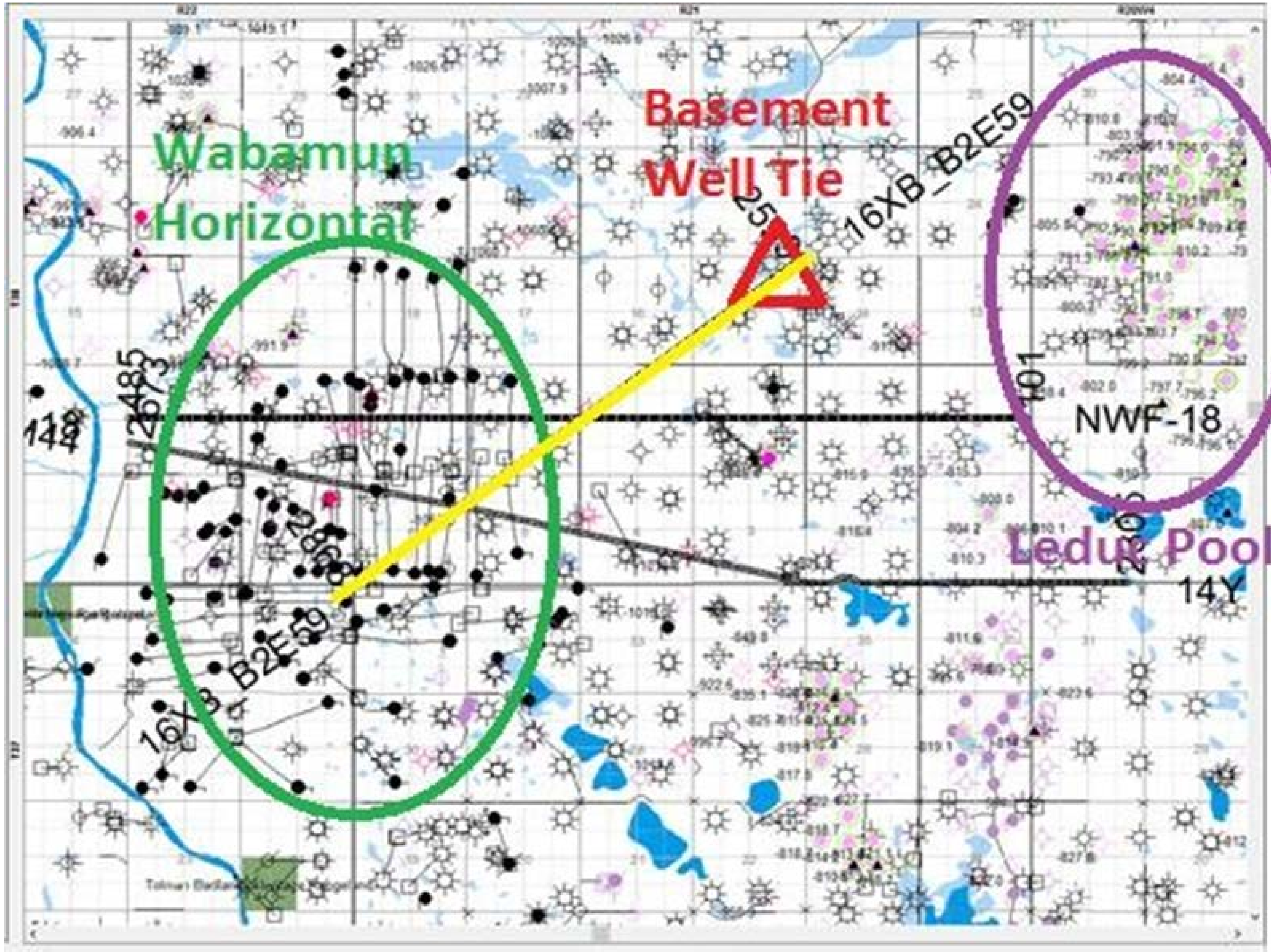
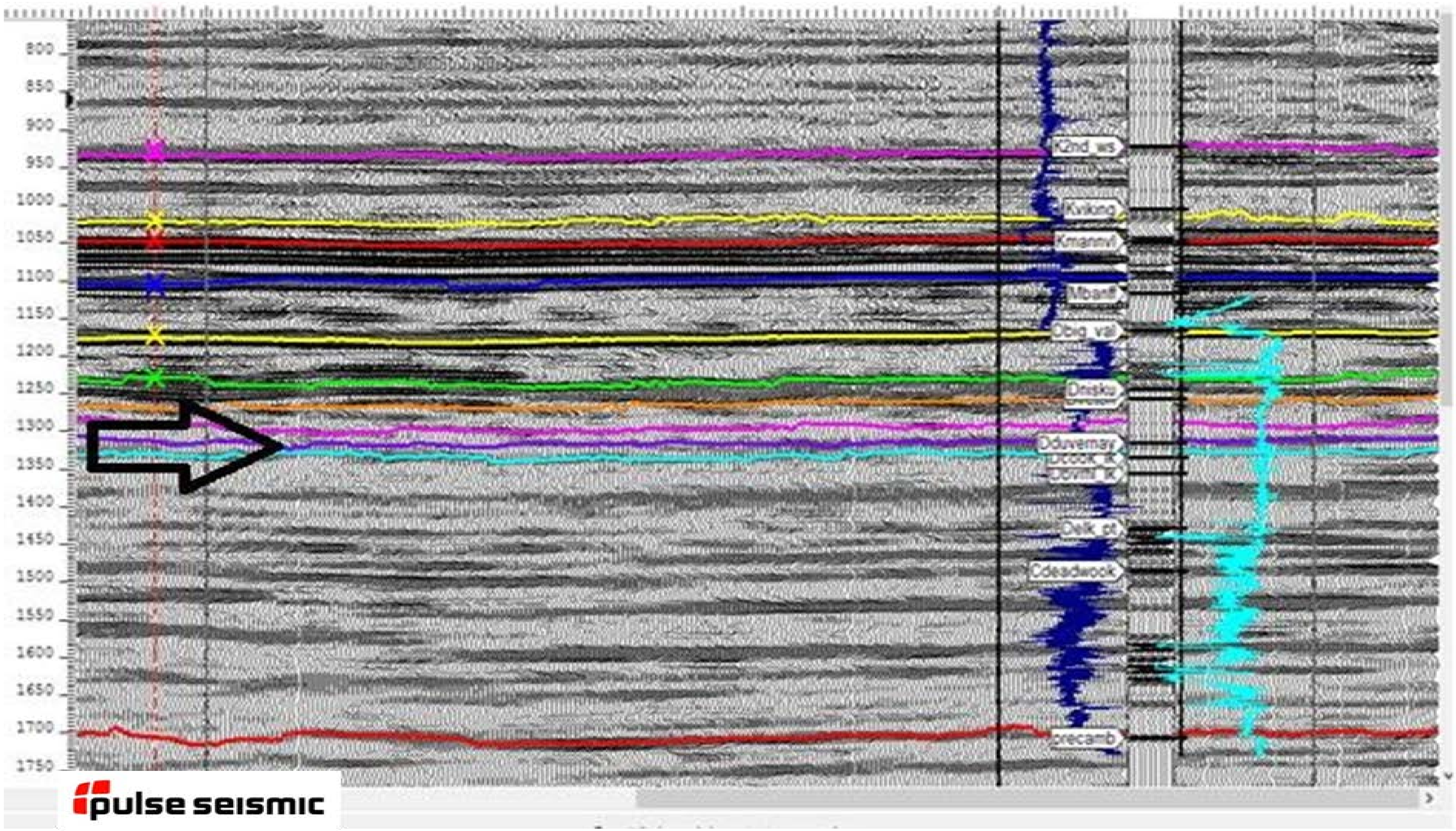
Study area, East – Central Alberta



Large scale synthetic tie, highlighting the zone of interest



Prestack modeling and inversion

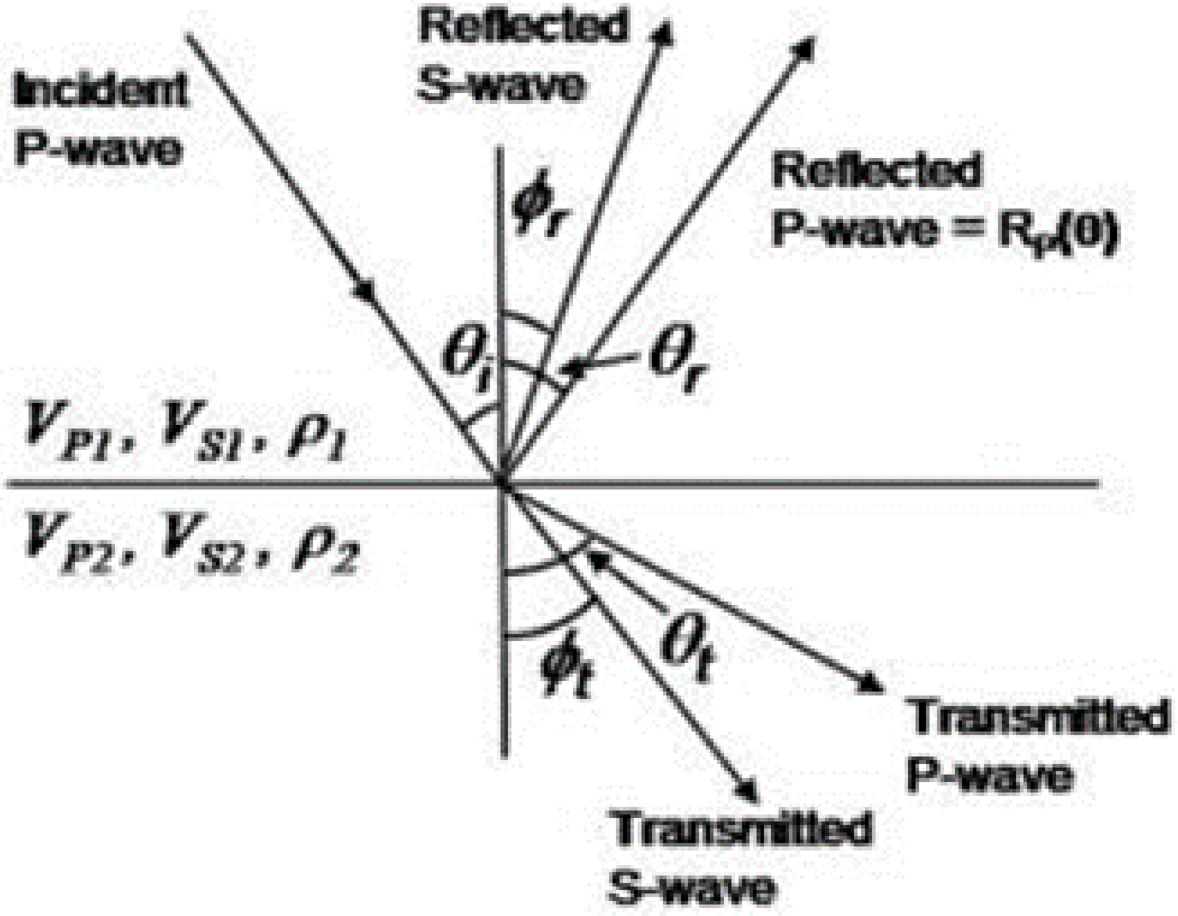
We start with Fatti's version of the Aki-Richards' equation. This models reflection amplitude as a function of incident angle:

$$R_{PP}(\theta) = c_1 R_P + c_2 R_S + c_3 R_D$$

where:

$$c_1 = 1 + \tan^2\theta$$
$$c_2 = -8\gamma^2 \sin^2\theta$$
$$c_3 = -\frac{1}{2}\tan^2\theta + 2\gamma^2 \sin^2\theta$$
$$\gamma = \frac{V_S}{V_P}$$

$$R_P = \frac{1}{2}\left[\frac{\Delta V_P}{V_P} + \frac{\Delta\rho}{\rho}\right]$$
$$R_S = \frac{1}{2}\left[\frac{\Delta V_S}{V_S} + \frac{\Delta\rho}{\rho}\right]$$
$$R_D = \frac{\Delta\rho}{\rho}.$$



Reflection PP calculation

From the Fatti's version of the Aki-Richards' equation:

$$R_{PP}(\theta) = c_1 R_P + c_2 R_S + c_3 R_D$$

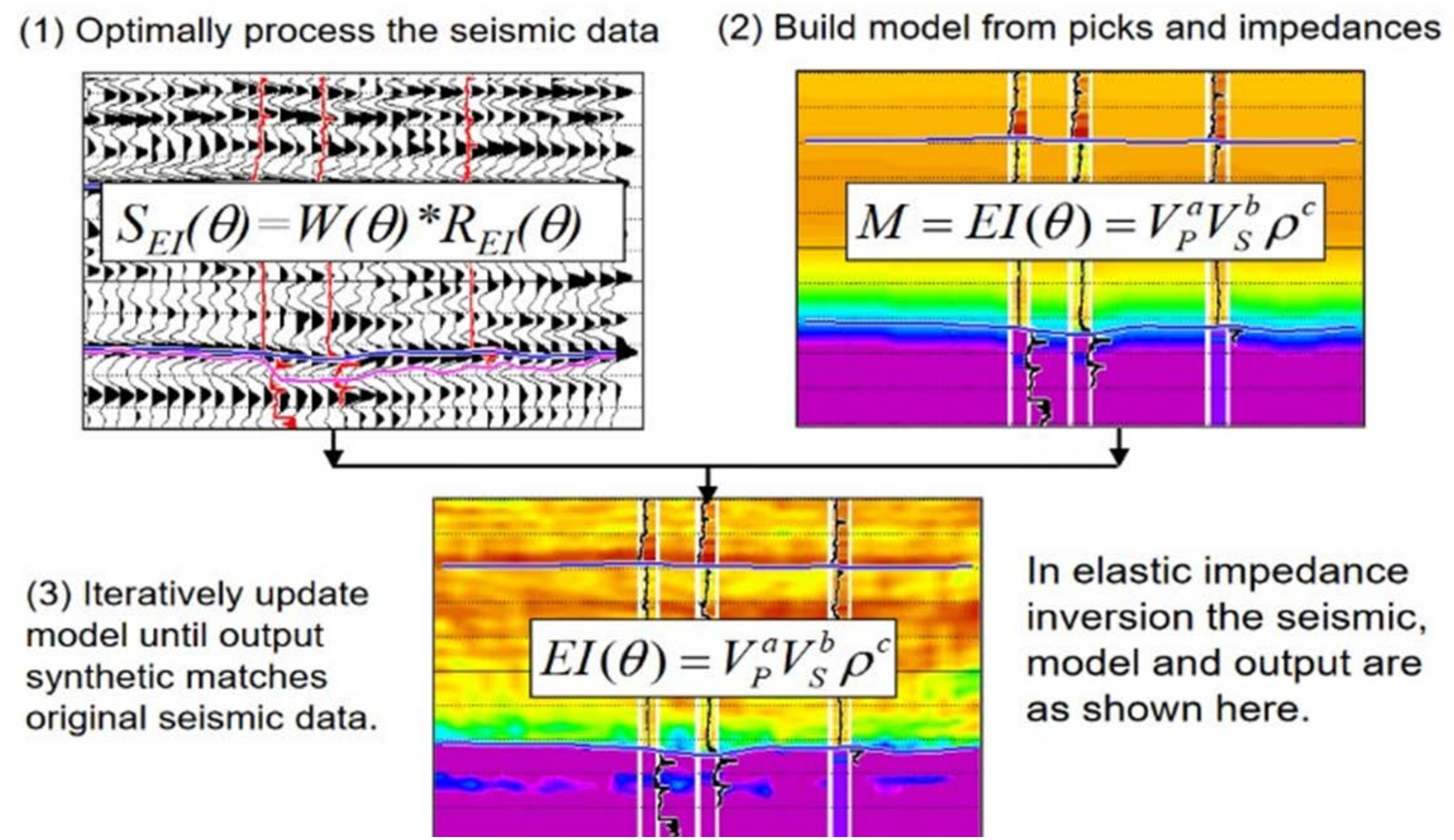
Where,

$$c_1 = 1 + \tan^2\theta, \qquad c_2 = -8\gamma^2\sin^2\theta, \qquad c_3 = -\frac{1}{2}\tan^2\theta + 2\gamma^2\sin^2\theta$$

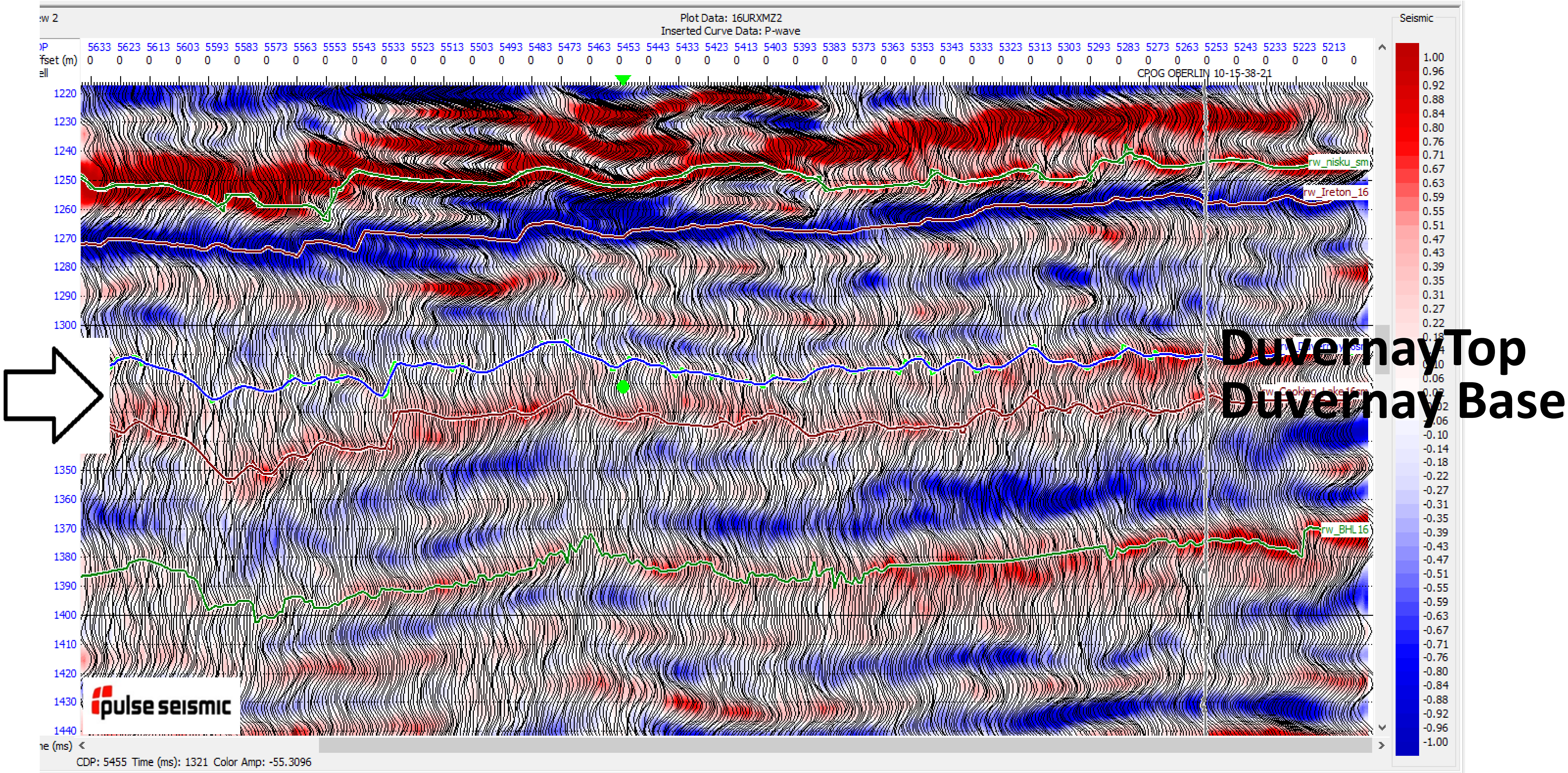
$$R_P = \frac{1}{2}\left[\frac{\Delta\rho}{\rho} + \frac{\Delta V_P}{V_P}\right], \qquad R_S = \frac{1}{2}\left[\frac{\Delta\rho}{\rho} + \frac{\Delta V_S}{V_S}\right], \qquad R_D = \frac{\Delta\rho}{\rho}$$

These equations form the basis to estimate the PP and PS reflect derived from sonic, shear and density logs.

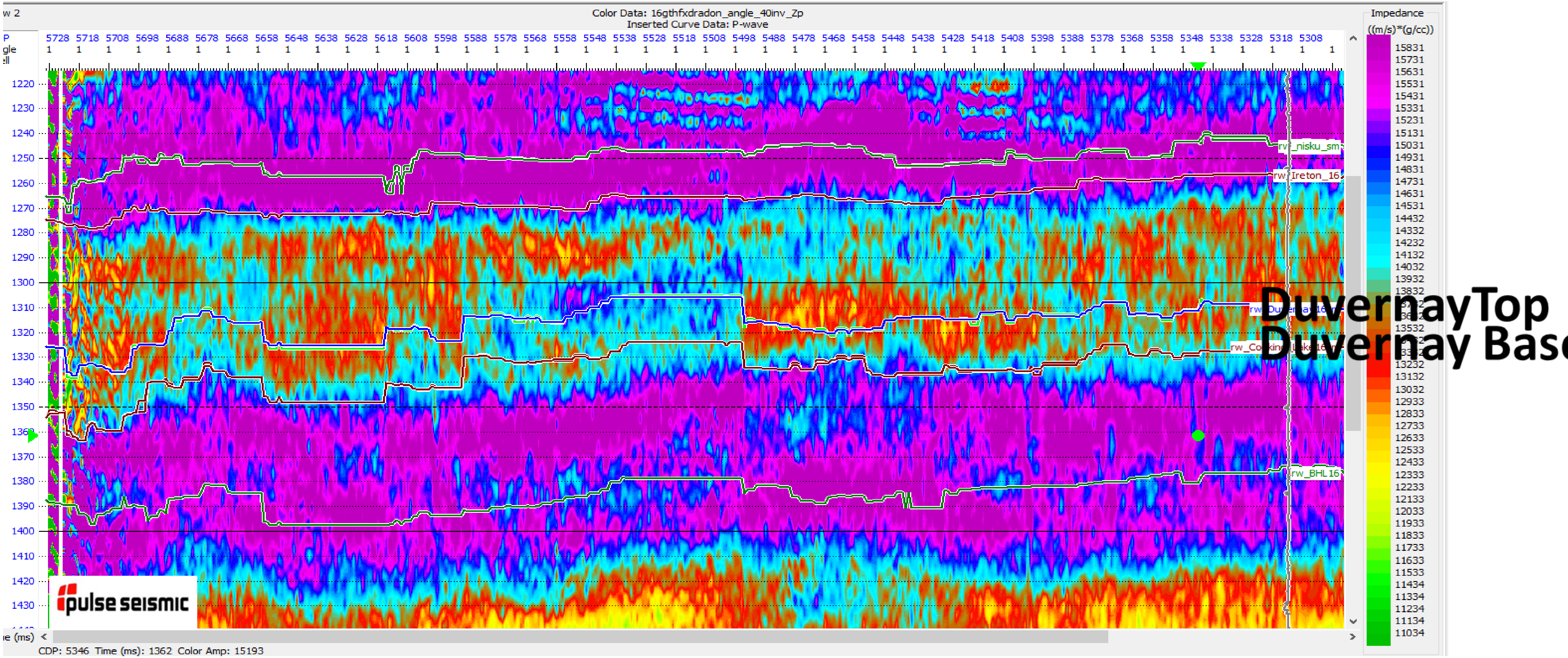
P, S, and density inversion workflow



Stack data


Plot Data: 16URXMZ2
Inserted Curve Data: P-wave
Seismic
CPOG OBERLIN 10-15-38-21
rw_nisku_sm
rw_Ireton_16
rw_BHL16
DuvernayTop
Duvernay Base
pulse seismic
CDP: 5455 Time (ms): 1321 Color Amp: -55.3096

Prestack Inversion, PP reflectivity



Youngs Modulus and Poisson Ratio Calculation from inversion

Related equations are defined as follows:

$$\text{Possion's Ratio: } PR = \frac{0.5 * \left(\frac{Vp}{Vs}\right)^2 - 1}{\left(\frac{Vp}{Vs}\right)^2 - 1}; \text{ Closure Stress Ratio: } CSR = \frac{\text{PR}}{1 - \text{PR}}$$

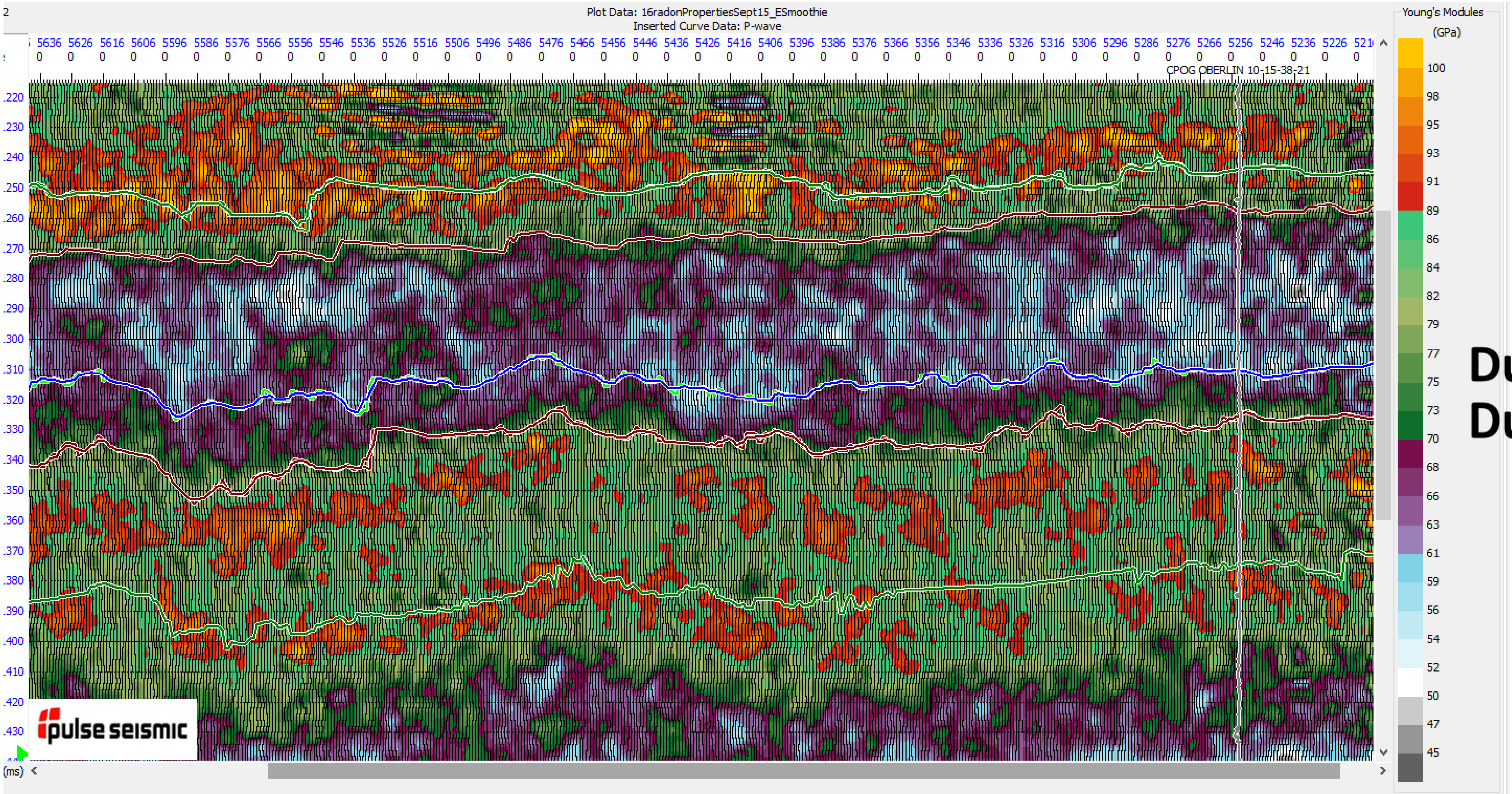
$$\text{Young's Modulus: E} = \frac{2 * Z_s^2 * (1 + \text{PR})}{Density}; \ \rho\text{E} = 2 * Z_s^2 * (1 + \text{PR})$$

$$Brittleness : BRI = 100 * \left(w * \frac{(PR_{max} - PR)}{PR_{max} - PR_{min}} + (1 - w) * \frac{(E - E_{min})}{E_{max} - E_{min}}\right)$$

$$\text{Brinell Hardness Number : BHN} = 75.156 * \text{E} + 18.21$$

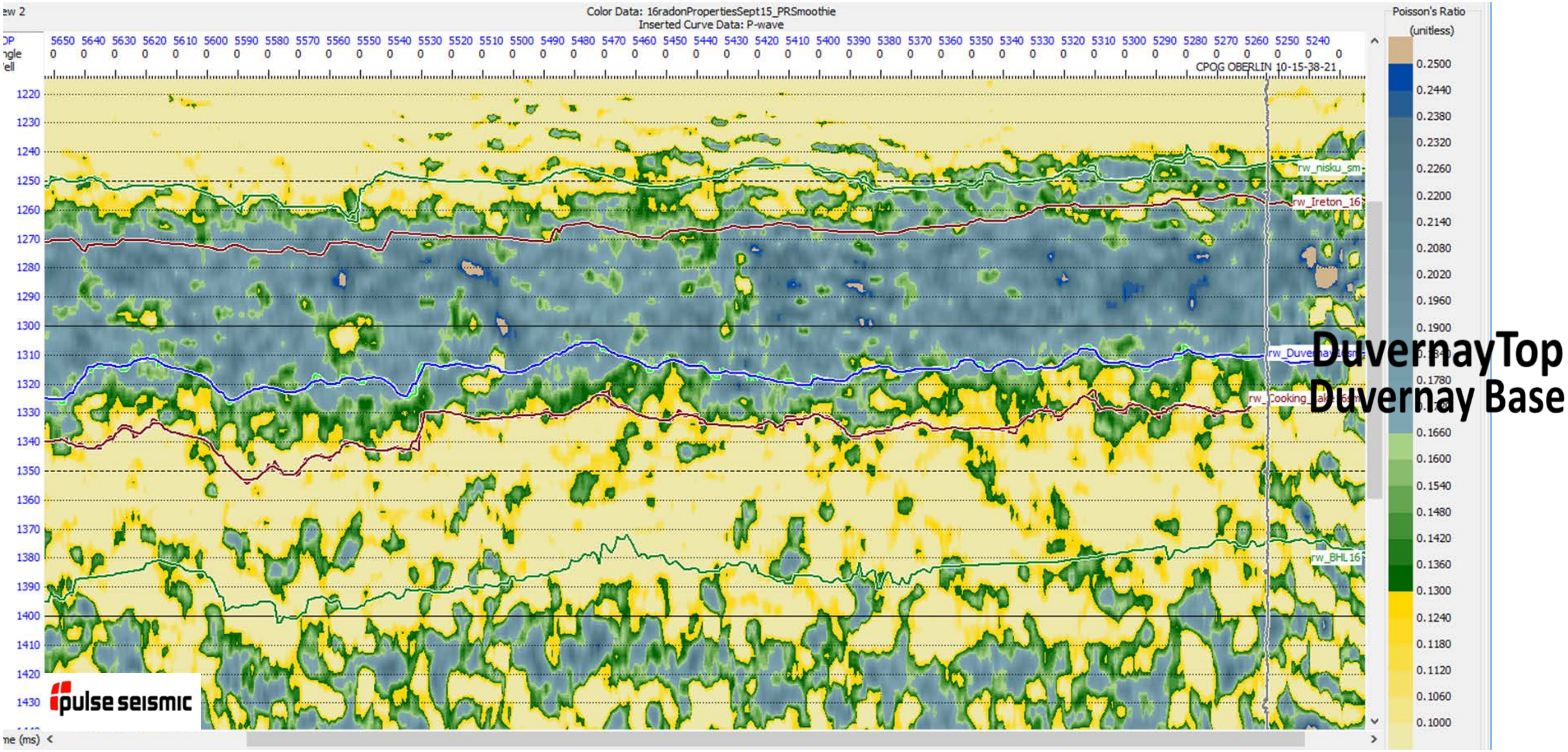
The default impedance unit used in the equation is (m/s)*(kg/m3);
Default velocity unit is (m/s); Default density unit is (kg/m3).
Input values in other units will be converted automatically.

Young's Modulus derived from inversion



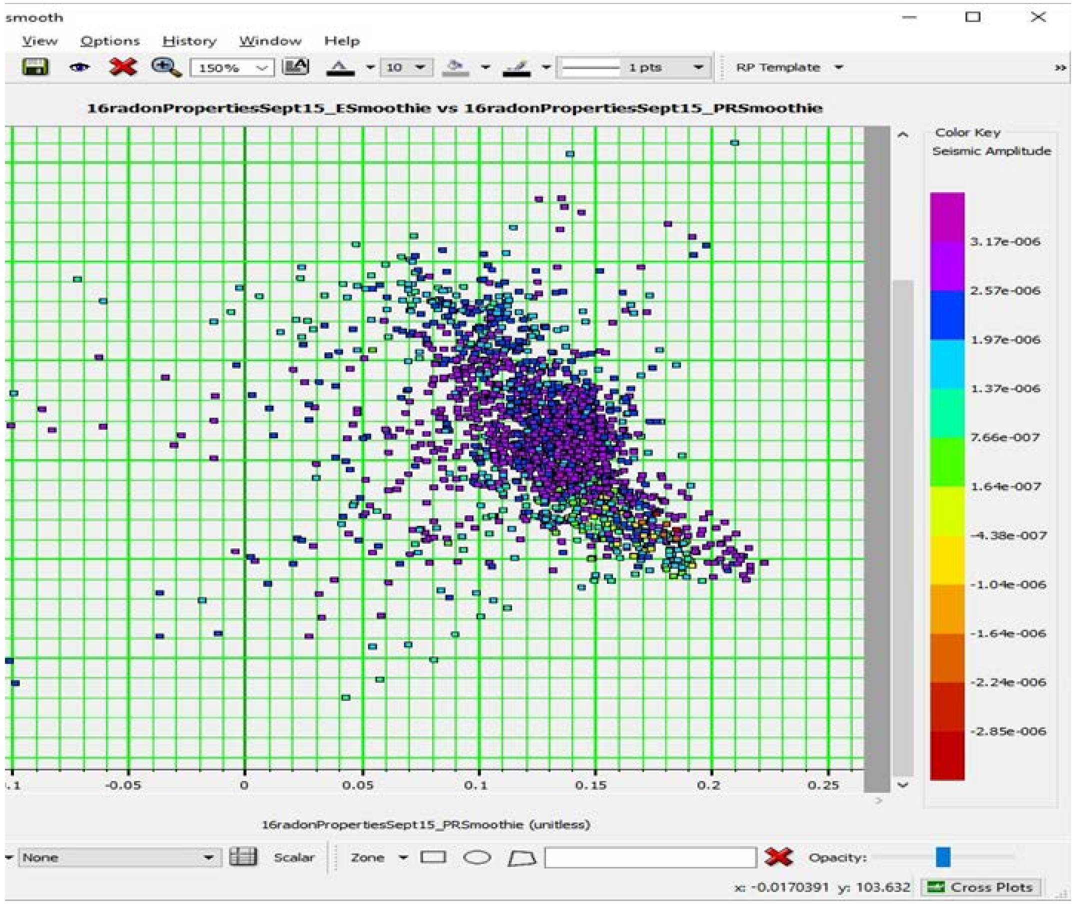
DuvernayTop
Duvernay Bas

Poisson's Ratio derived from prestack inversion



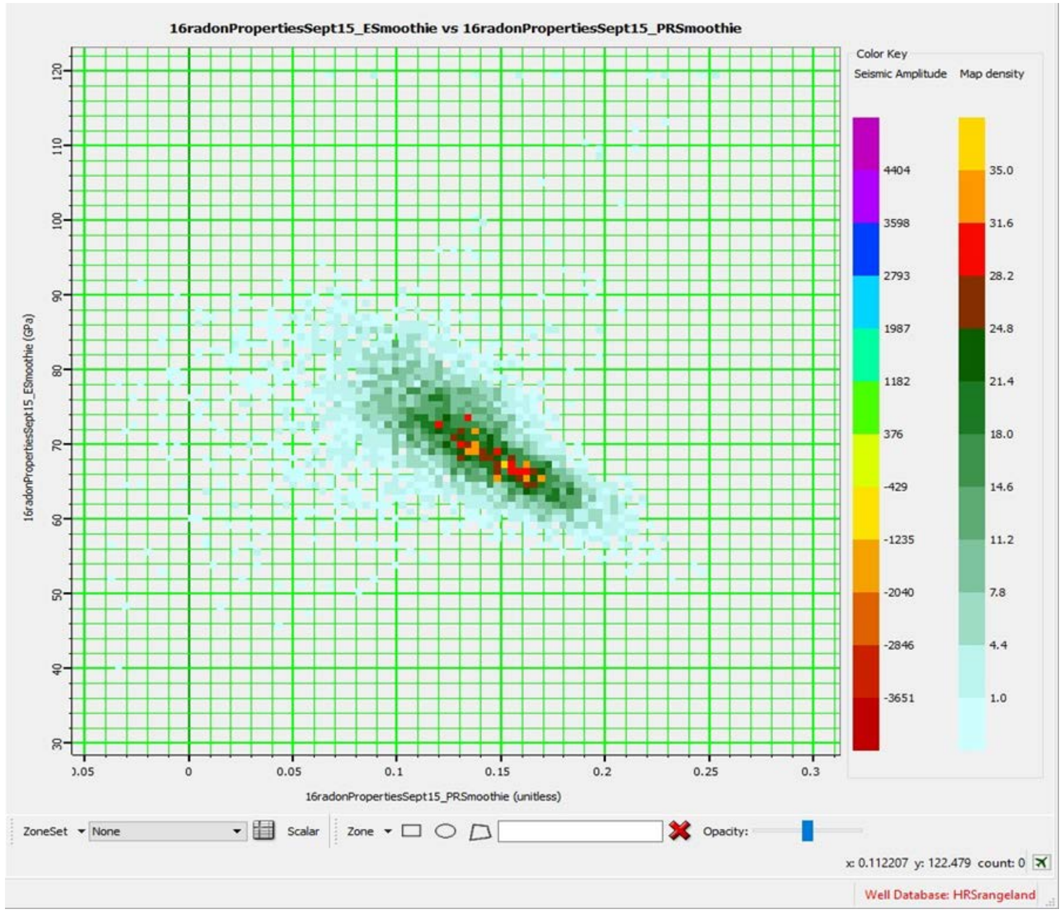
Cross Plot of Poisson Ratio Vs Young's Modulus, Duvernay interval

Young's Modulus



Poisson's Ratio

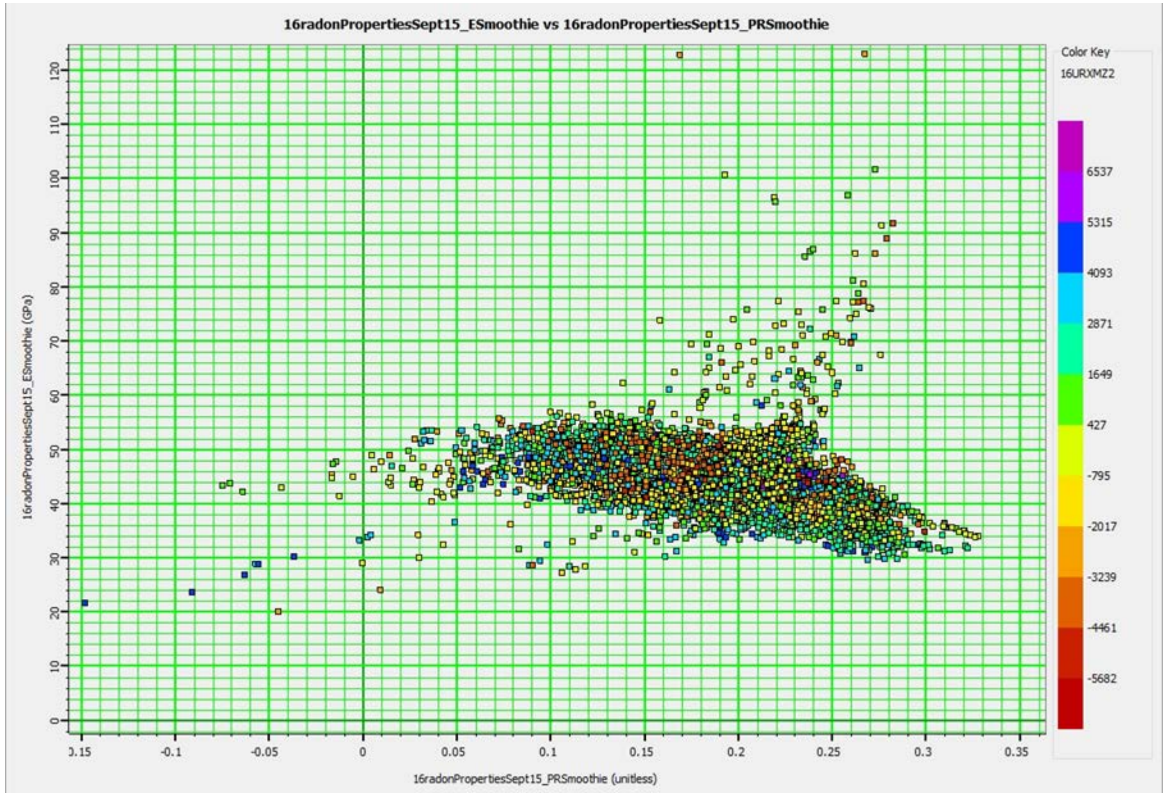
Young's Modulus



Poisson's Ratio

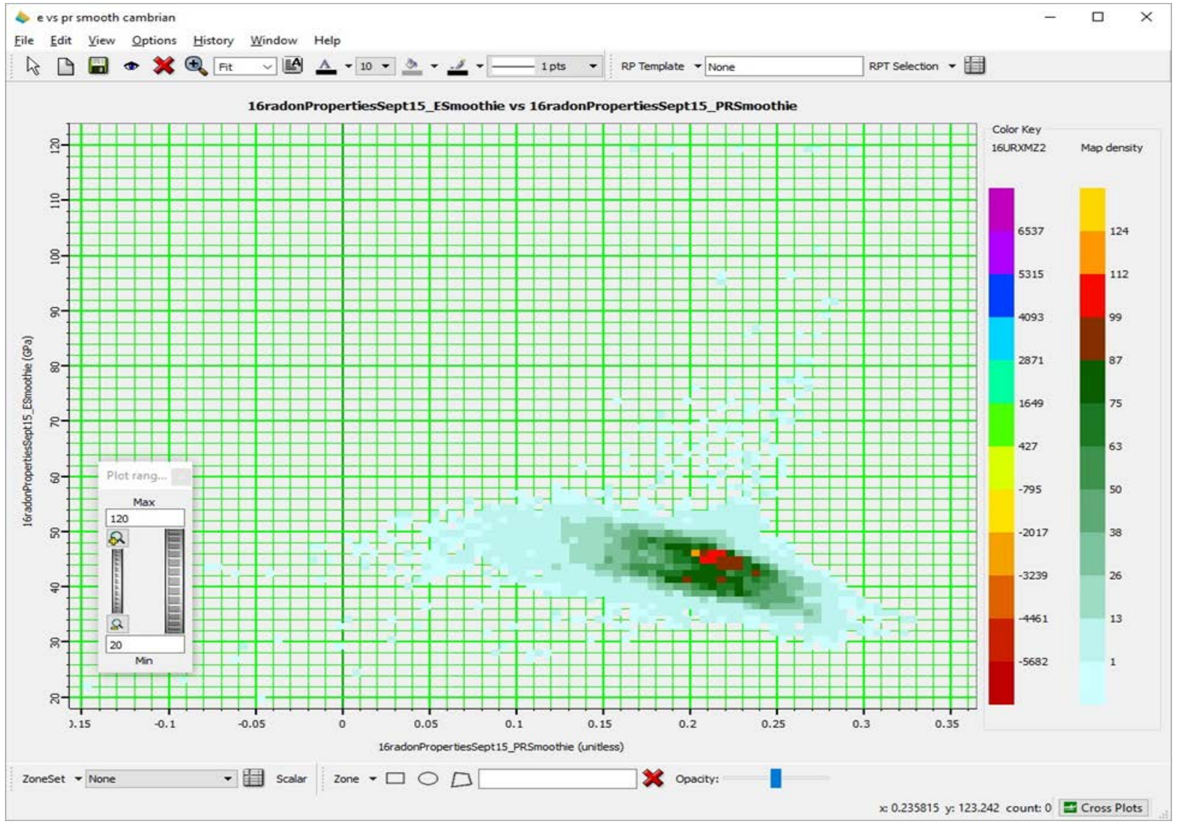
Cross Plot, Poisson Ratio Vs. Young's Modulus, Cambrian

Young's Modulus



Poisson's Ratio

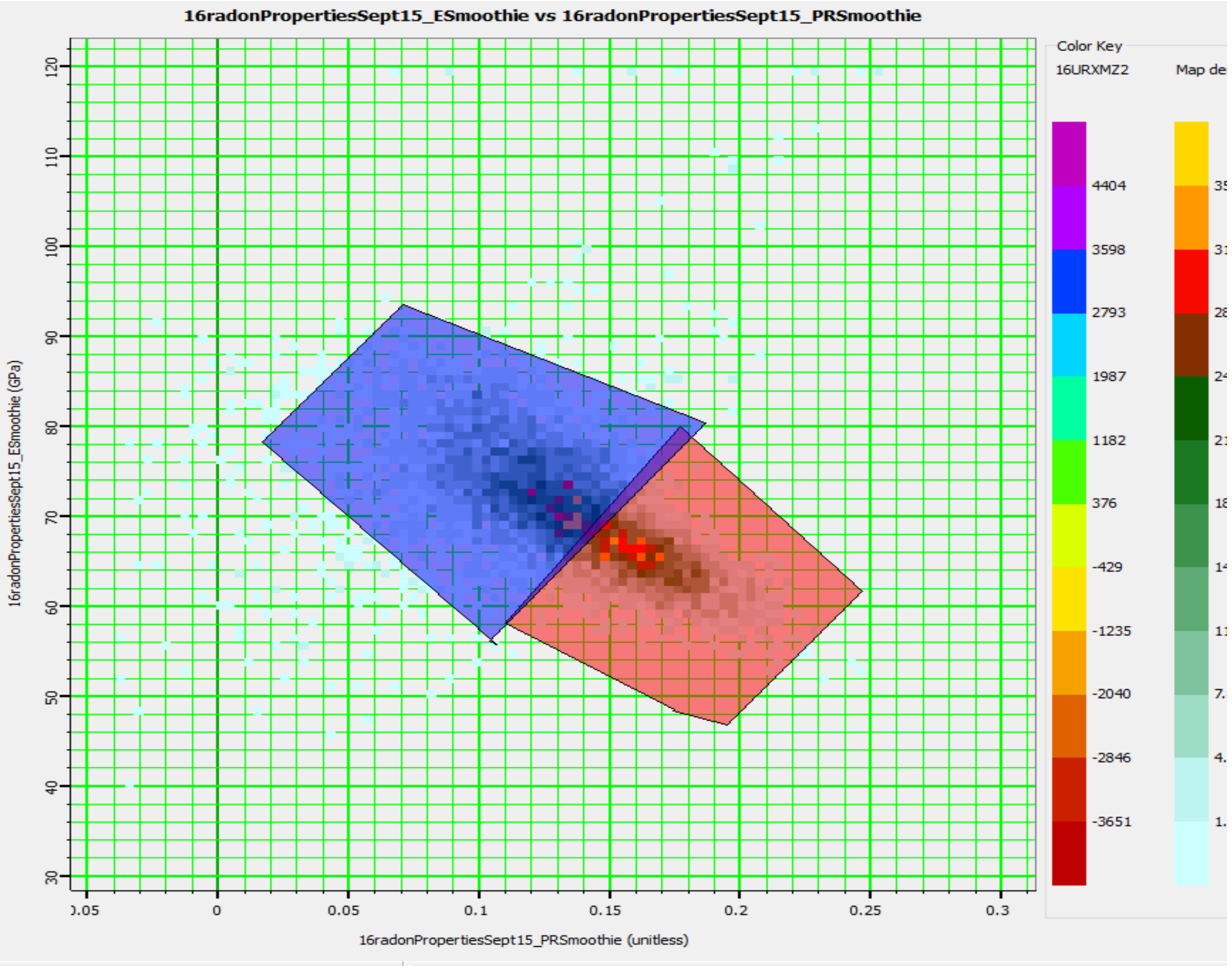
Young's Modulus



Poisson's Ratio

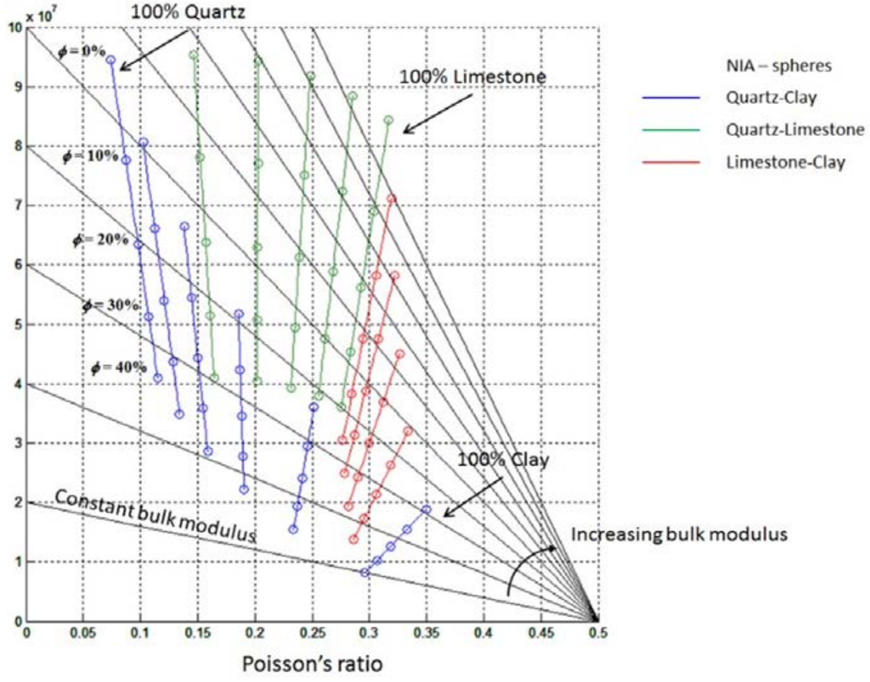
Derived and theorecical rock properties, Duvernay Formation

Young's Modulus



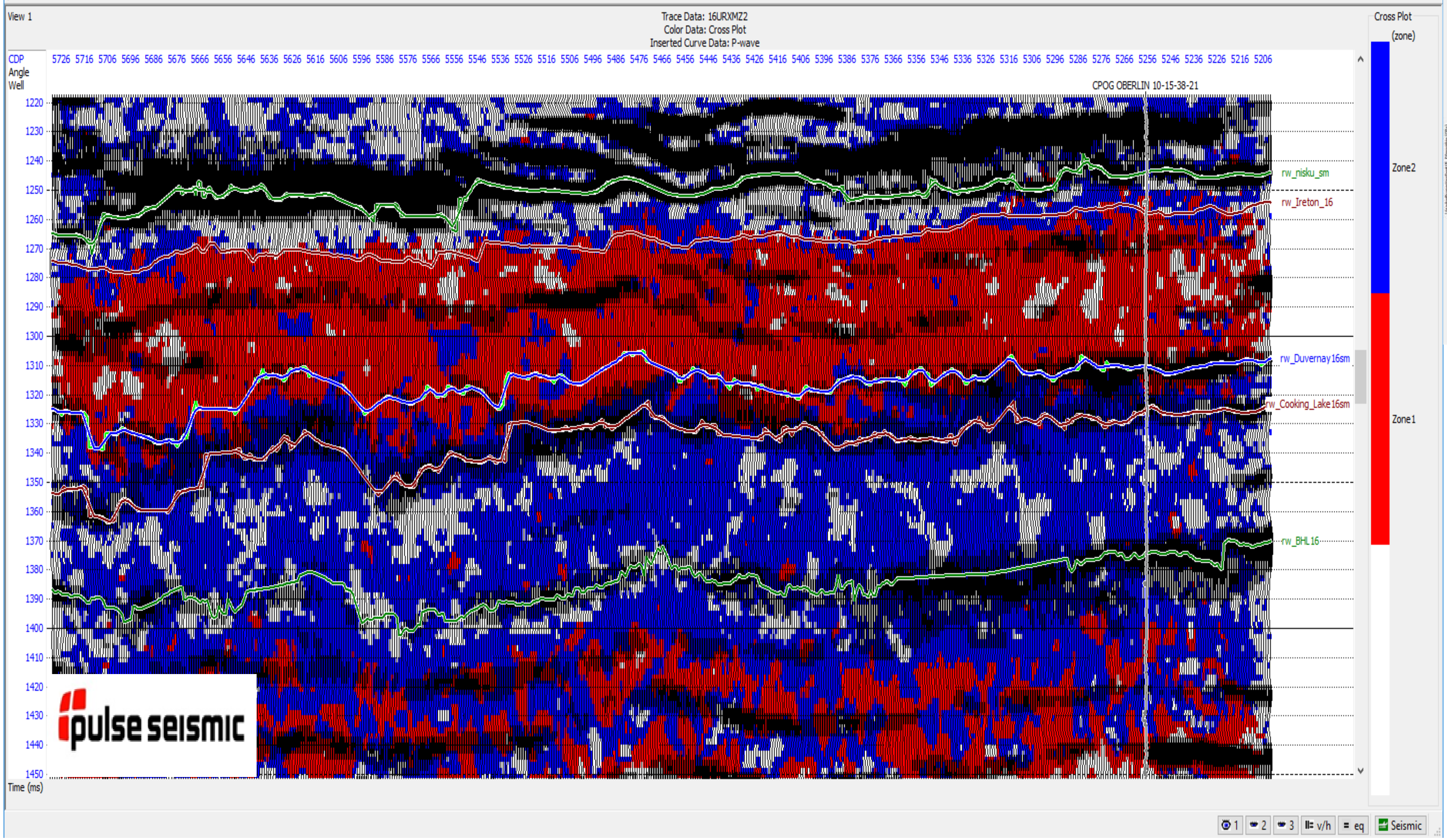
Poisson's Ratio

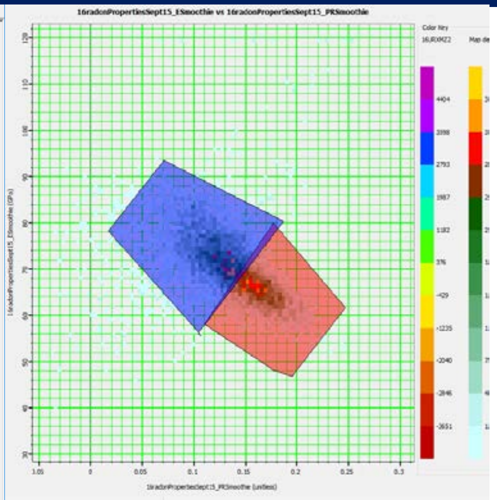
Young's Modulus



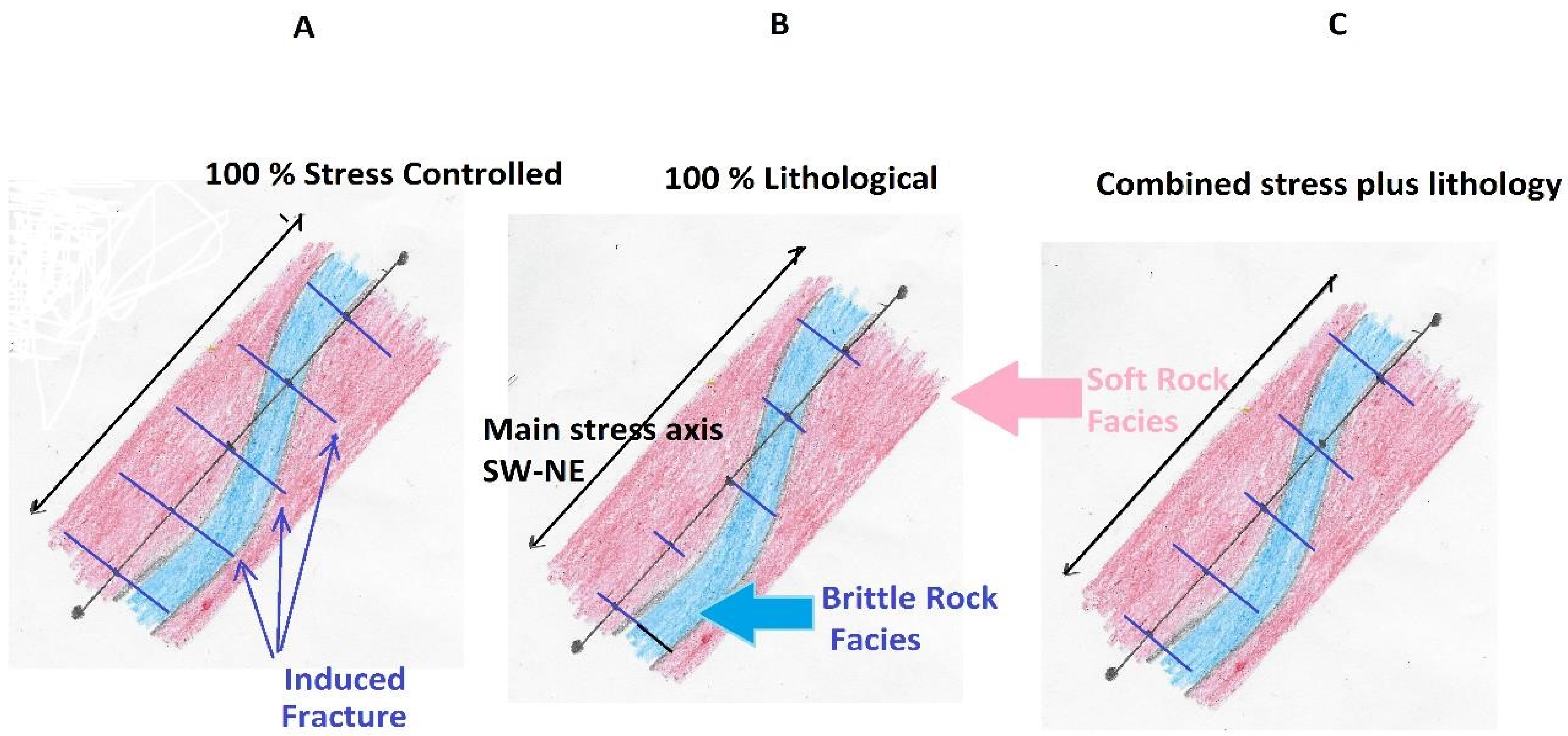
Poisson's Ratio

Blue areas are high brittleness, Red areas are low brittleness

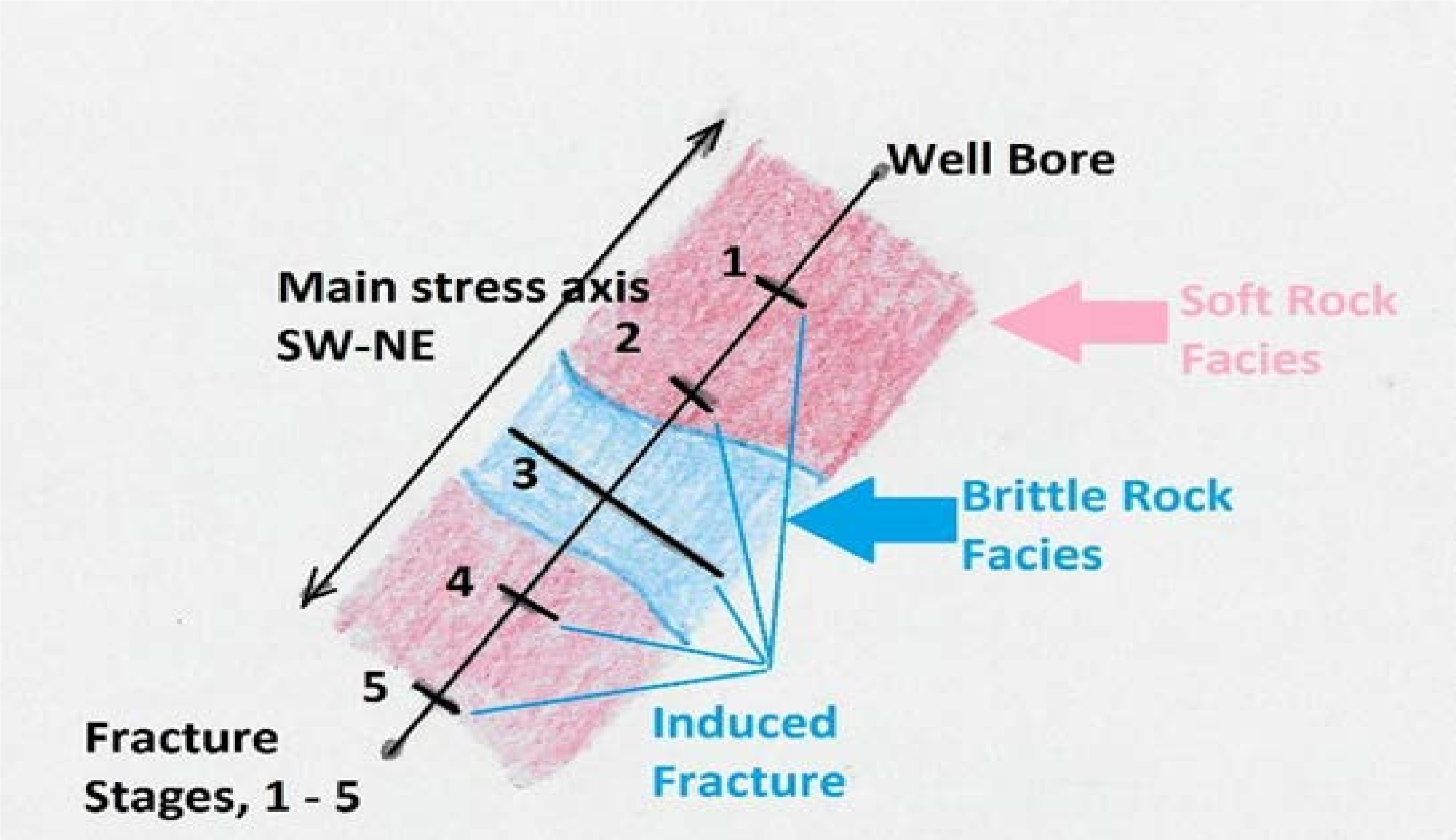




Estimated response to fracture stimulation based on brittleness



Geologicaly defined prediction for induced fractures



Conclusions

- Reservoir attributes can readily be extracted from prestack data
- Wells can be better positioned based on rock parameters
- Reservoir characterization may be able to explain the variable fracture patters and productivity of horizontal wells

Future work

- A 3-D data set has become available in Bigstone, with well control and ongoing microseismic monitoring
- This data set will be analyzed using the same methodology outlined in this presentation, with the incorporation of microseismic data.
- I expect to have results late 2017, or early 2018.

Software

- **TECHNICAL SOFTWARE USED**
- Geoview (HRS), pre and poststack inversion
- Geoscout, Well grid and culture data base, LAS files, production and perforation information
- Seisware, Conventional seismic interpretation
- Vista, prestack data preparation.

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- Dr. Brian Russell, technical advice and consultations
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