The Duvernay Formation-the application of structure and simultaneous inversion for reservoir characterization and induced seismicity

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Motivation

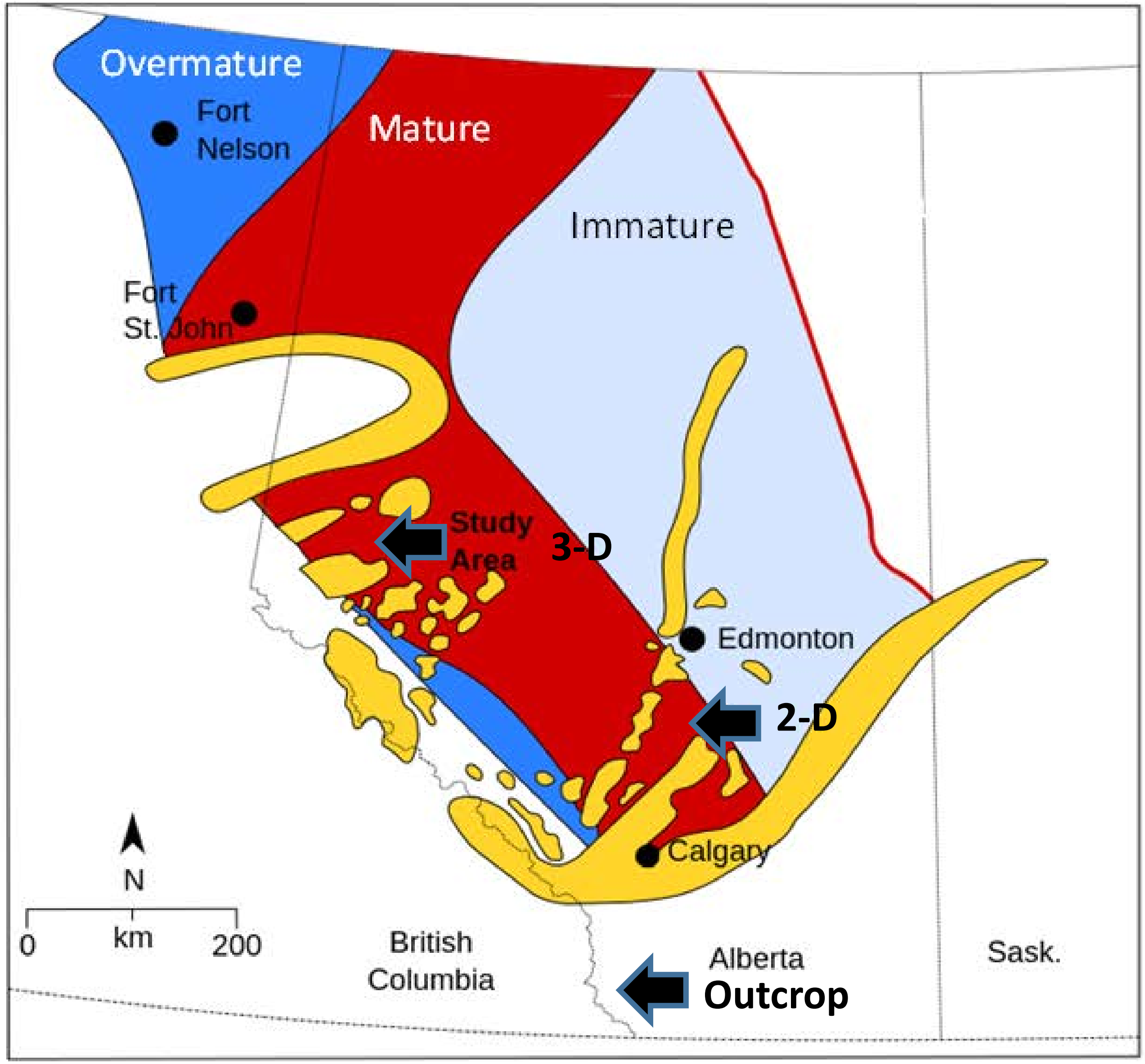
We have a 3-D, 3-C data set; we have mapped structural and stratigraphic features, and calculated key seismic attributes

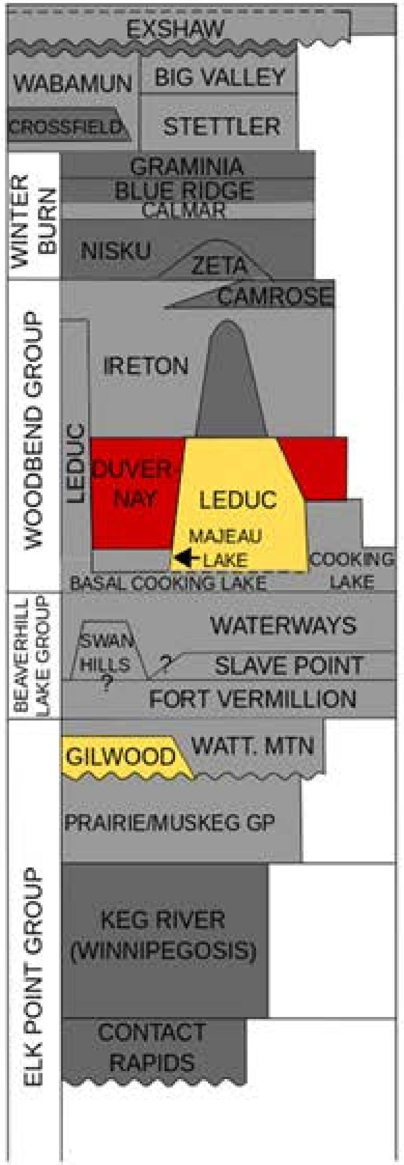
This approach will be useful in optimizing drilling programs, and identify potential drilling hazards

Introduction

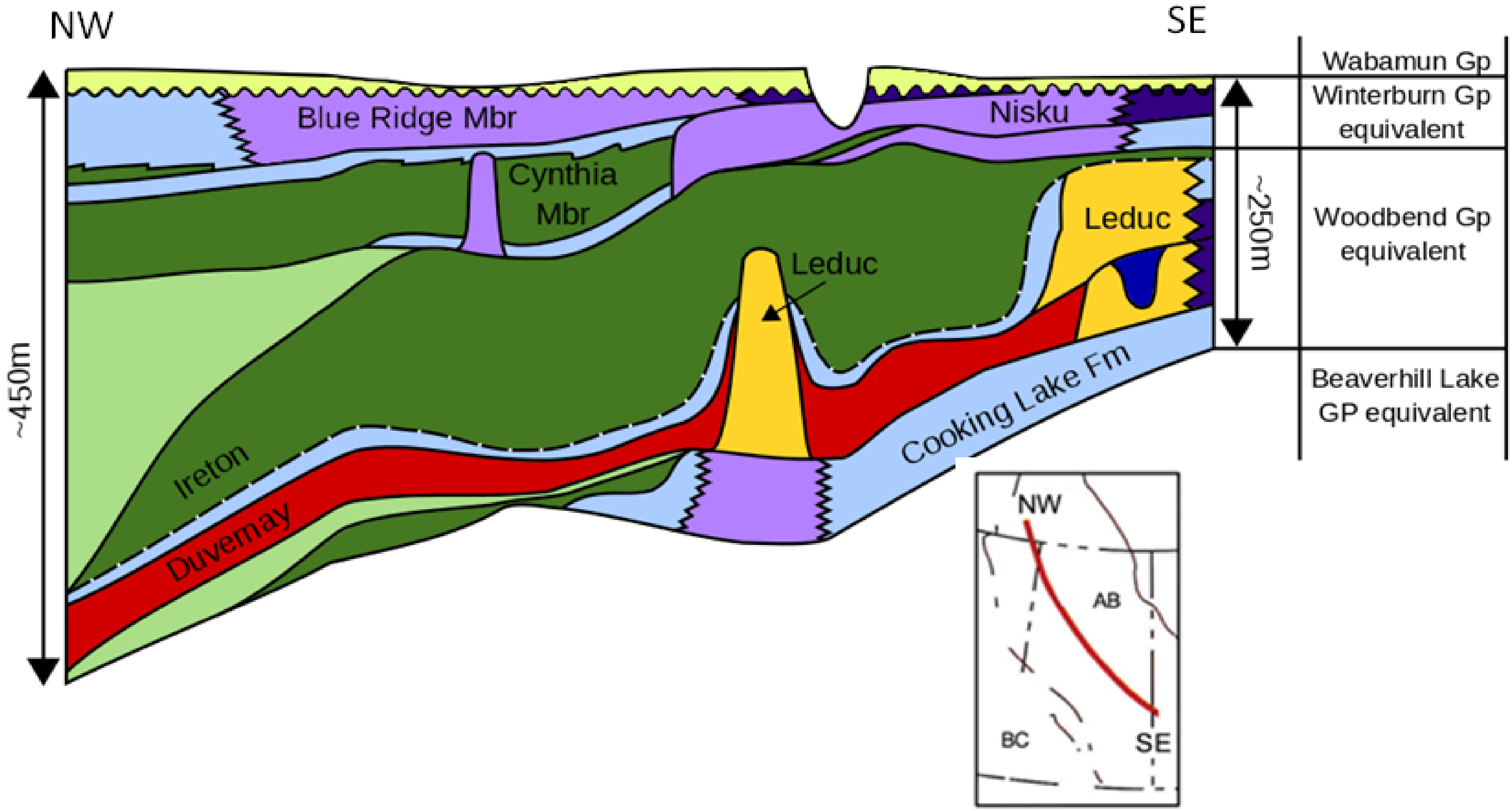
- 1 Overview of Duvernay Geology
  - a. Regional Framework
  - b. Modern Analogue
  - c. modern outcrop
  - c. Core work
  - e. Theoretical Rock properties
- 2 Current development practices
- 3 General workflow
  - a. Structural interpretation
  - b. derivation of rock properties with inversion
- 4 Conclusions and results
  - Implications of reservoir characteristics
- 5 Future Work
  - Implications of reservoir characteristics

1 a. Duvernay Formation mature oil window

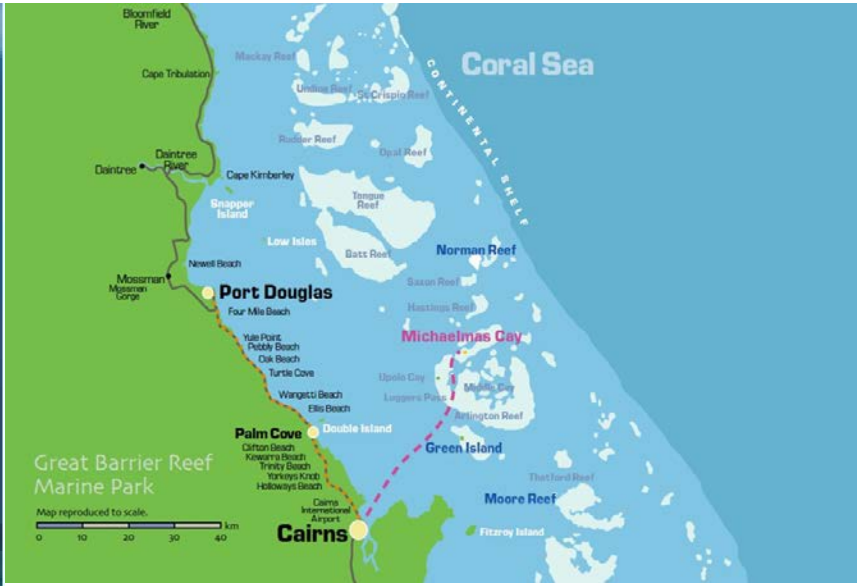




1 a.Devonian Cross Section, the Duvernay shown in red



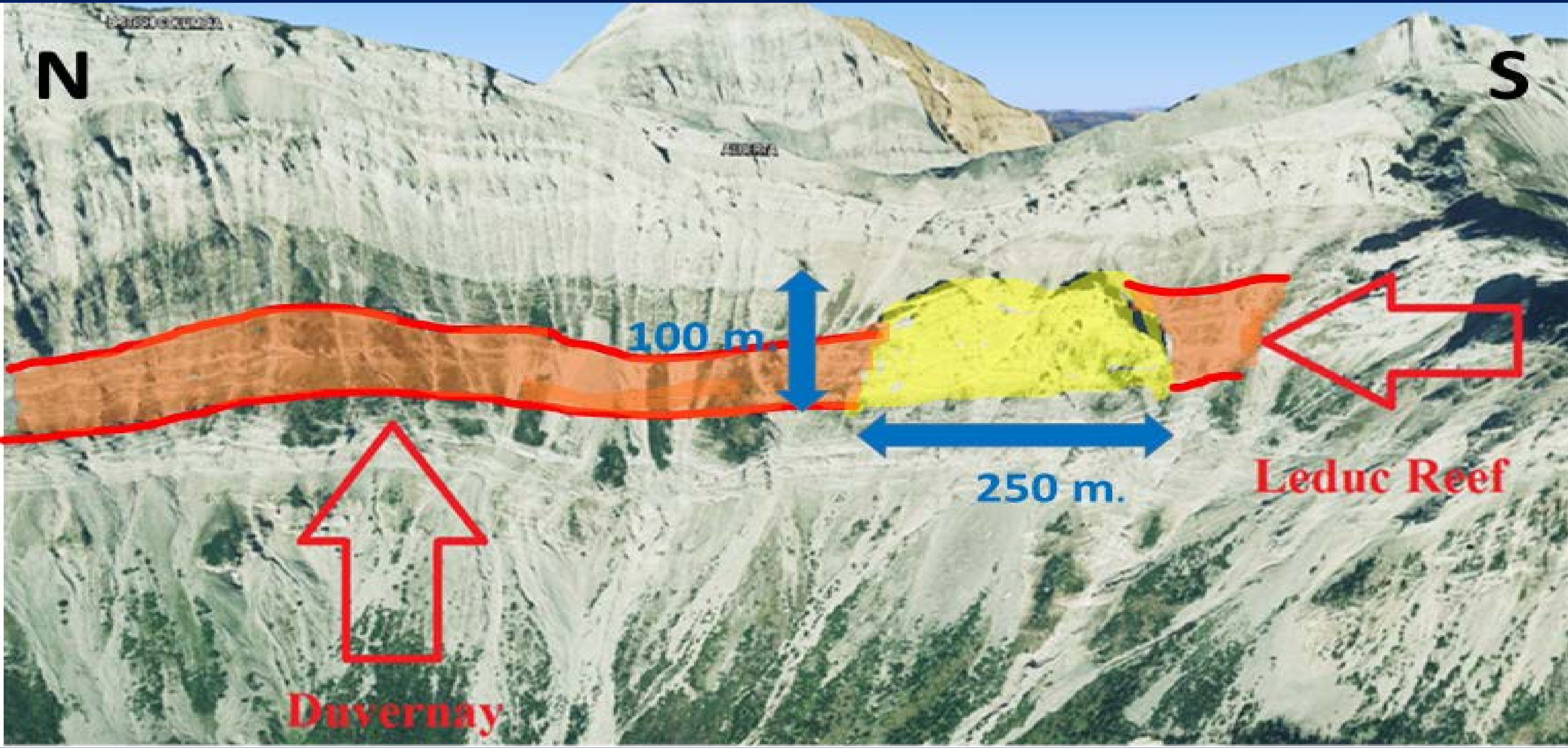
1 b. Duvernay /Leduc modern analogue



1 b. Duvernay /Leduc modern analogue

1 c. Duvernay Outcrop

1 c. Duvernay outcrop



1 d. Core work: Kaybob area rock properties, Duvernay

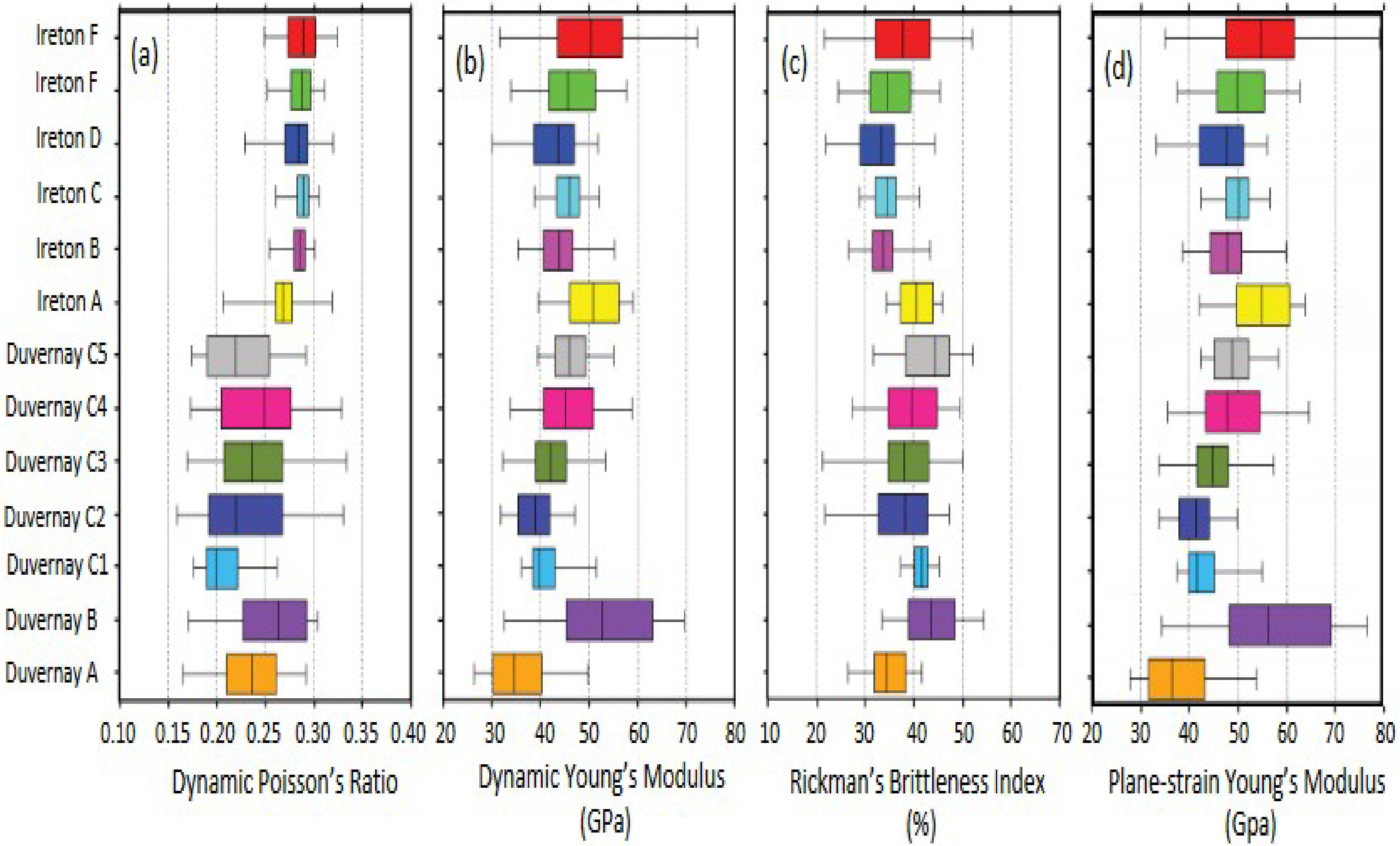


Figure 1. Mechanical properties calculated based on sonic logs for 26 wells for the Duvernay and Ireton formations: (a) dynamic Poisson's ratio, (b) dynamic Young's Modulus, (c) Rickman's brittleness Index, and (d) plane-strain Young's modulus.

Amy D. Fox, Mehrdad Soltanzadeh
Canadian Discovery Ltd.

1 d. Youngs Modulus Posson / Ratio Calculation from Vp, Vs, ρ

Related equations are defined as follows:

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

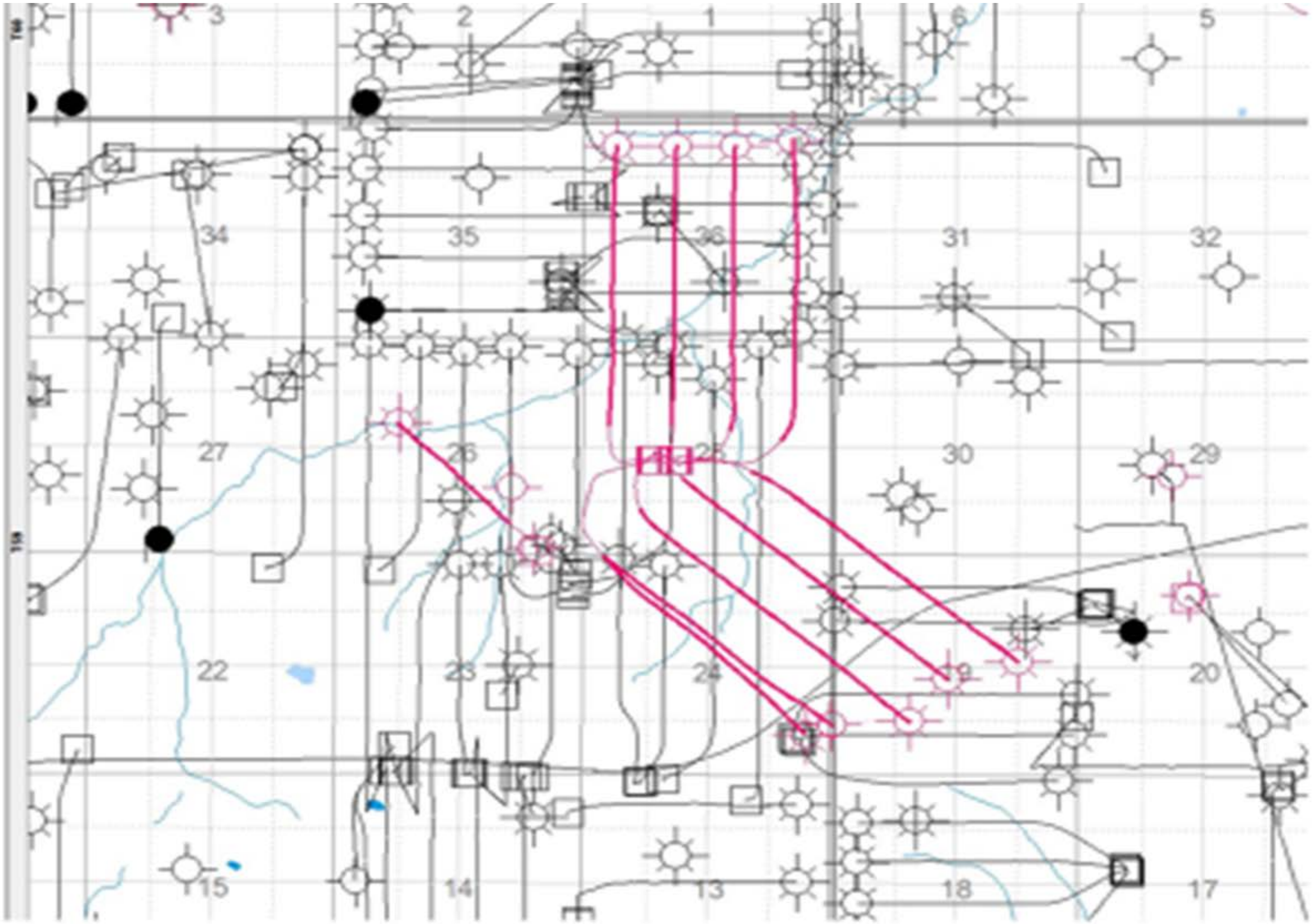
$$\text{Young's Modulus: } \text{E} = \frac{2 * Z_s^2 * (1 + \text{PR})}{Density}; \ \rho\text{E} = 2 * Z_s^2 * (1 + \text{PR})$$

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

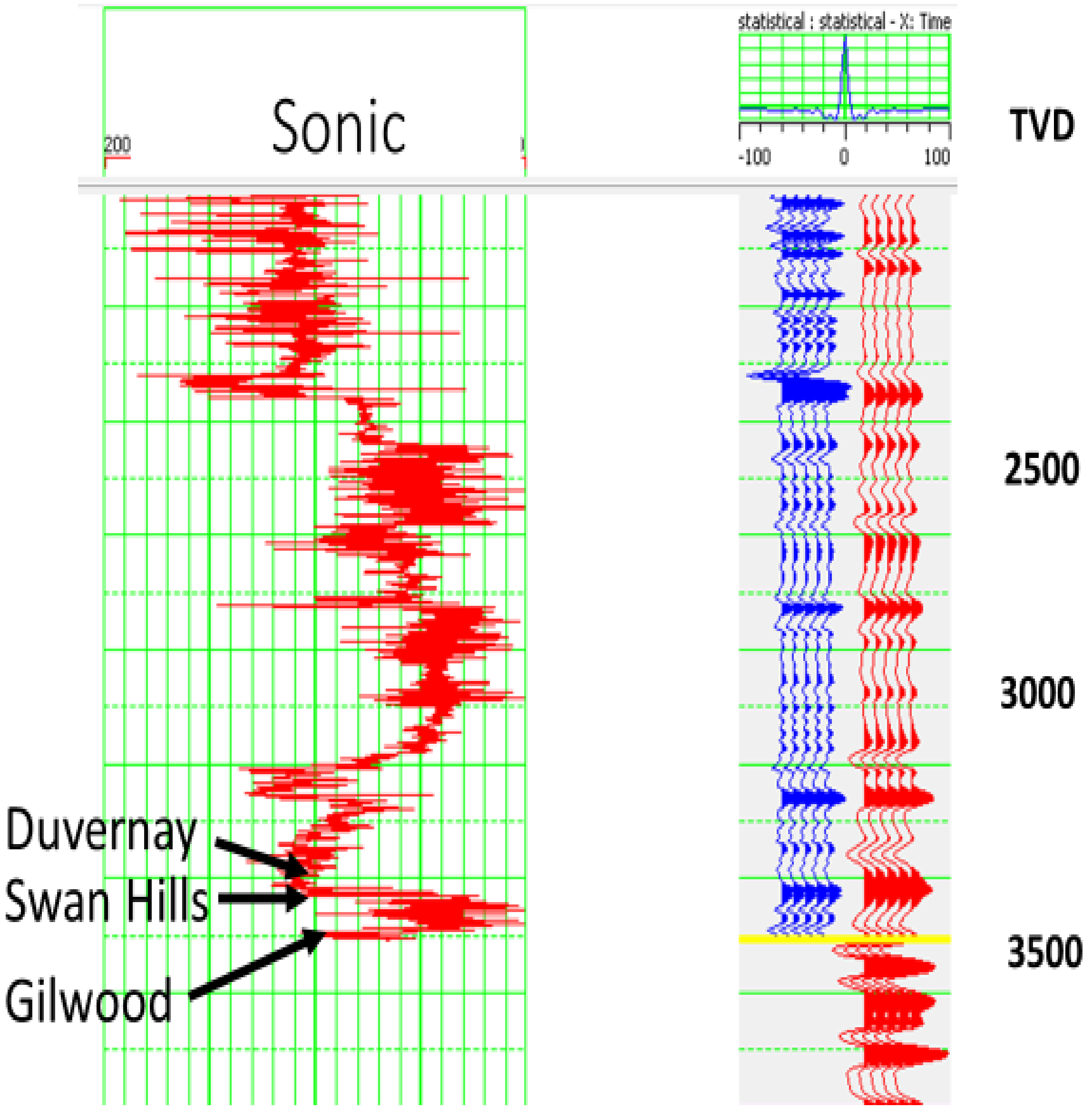
$$\text{Brinell Hardness Number : BHN} = 75.156 * \text{E} + 18.21$$

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.

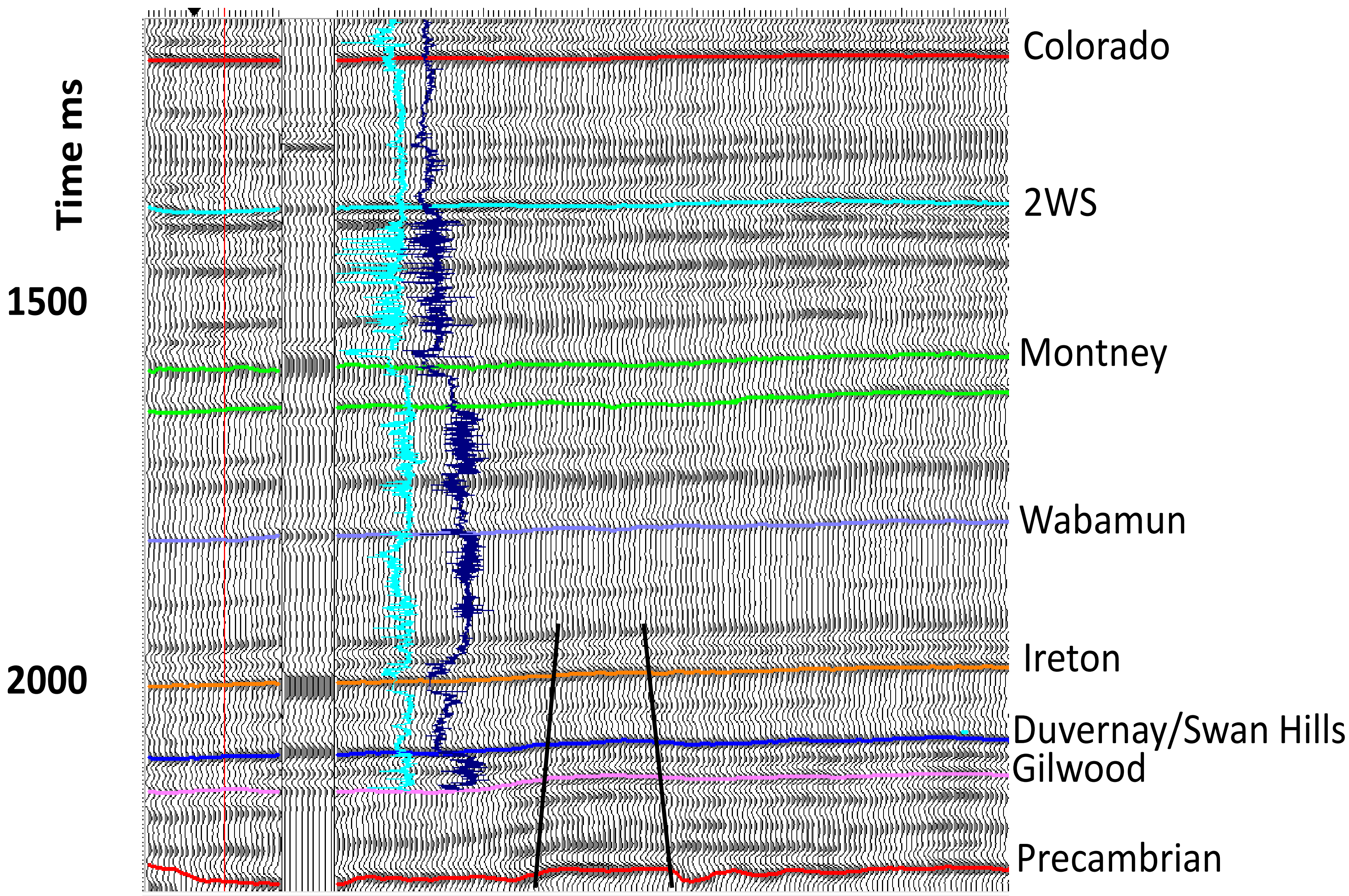
Duvernay Development practices



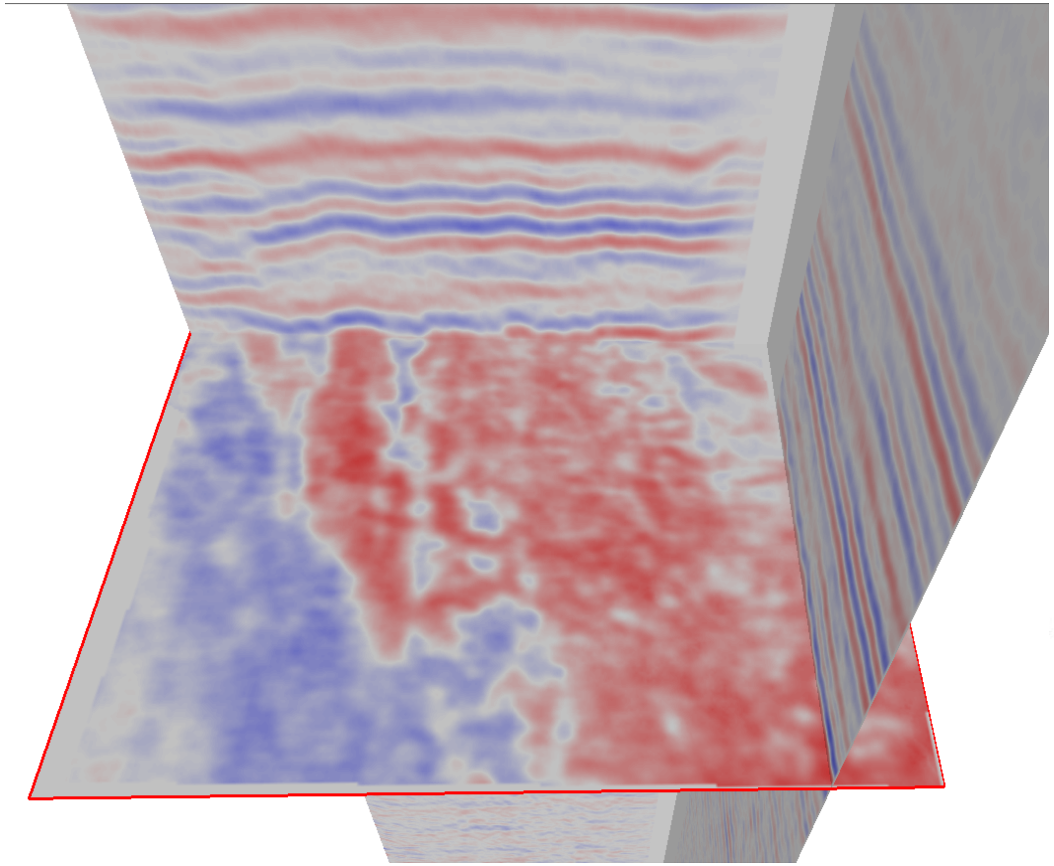
Synthetic seismogram tie



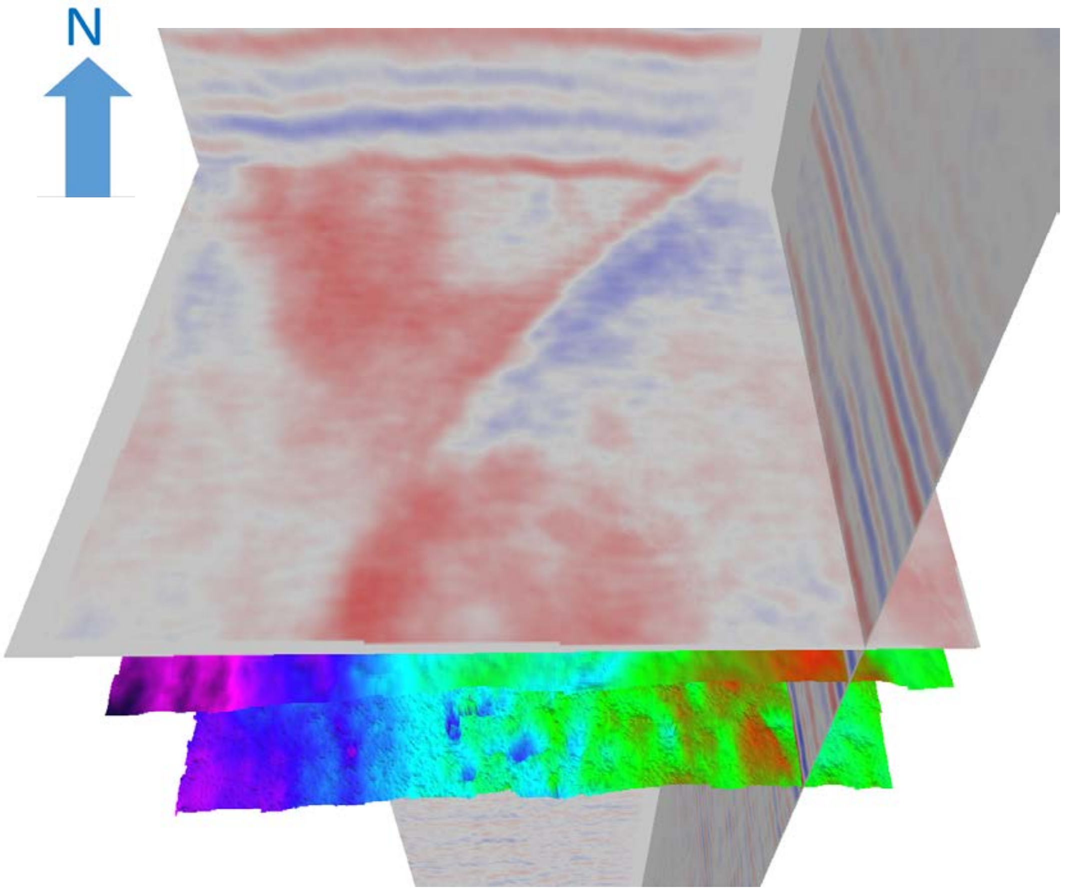
3 a. Large scale seismic data with sonic tie



Chair plot through Precambrian and Swan Hills

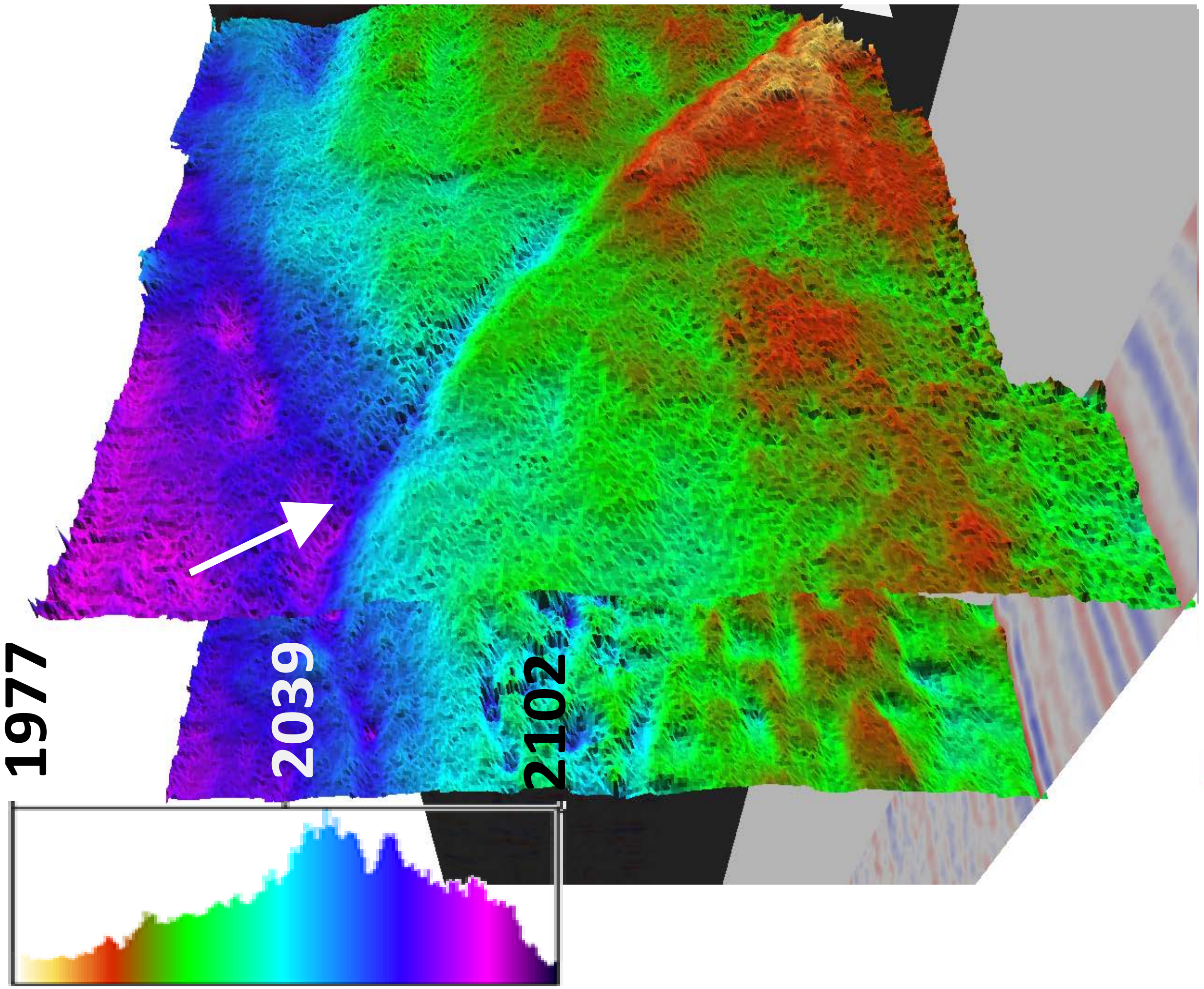


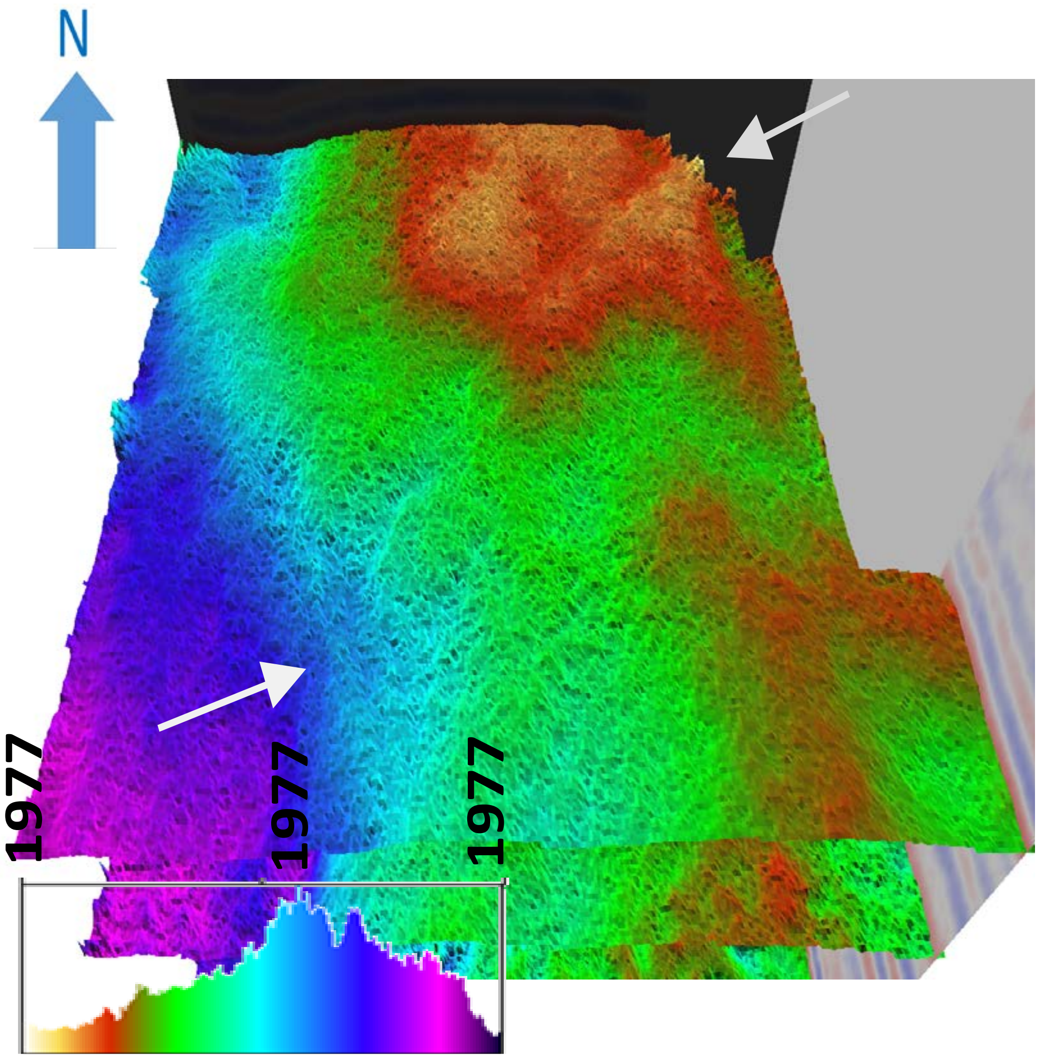
(a)



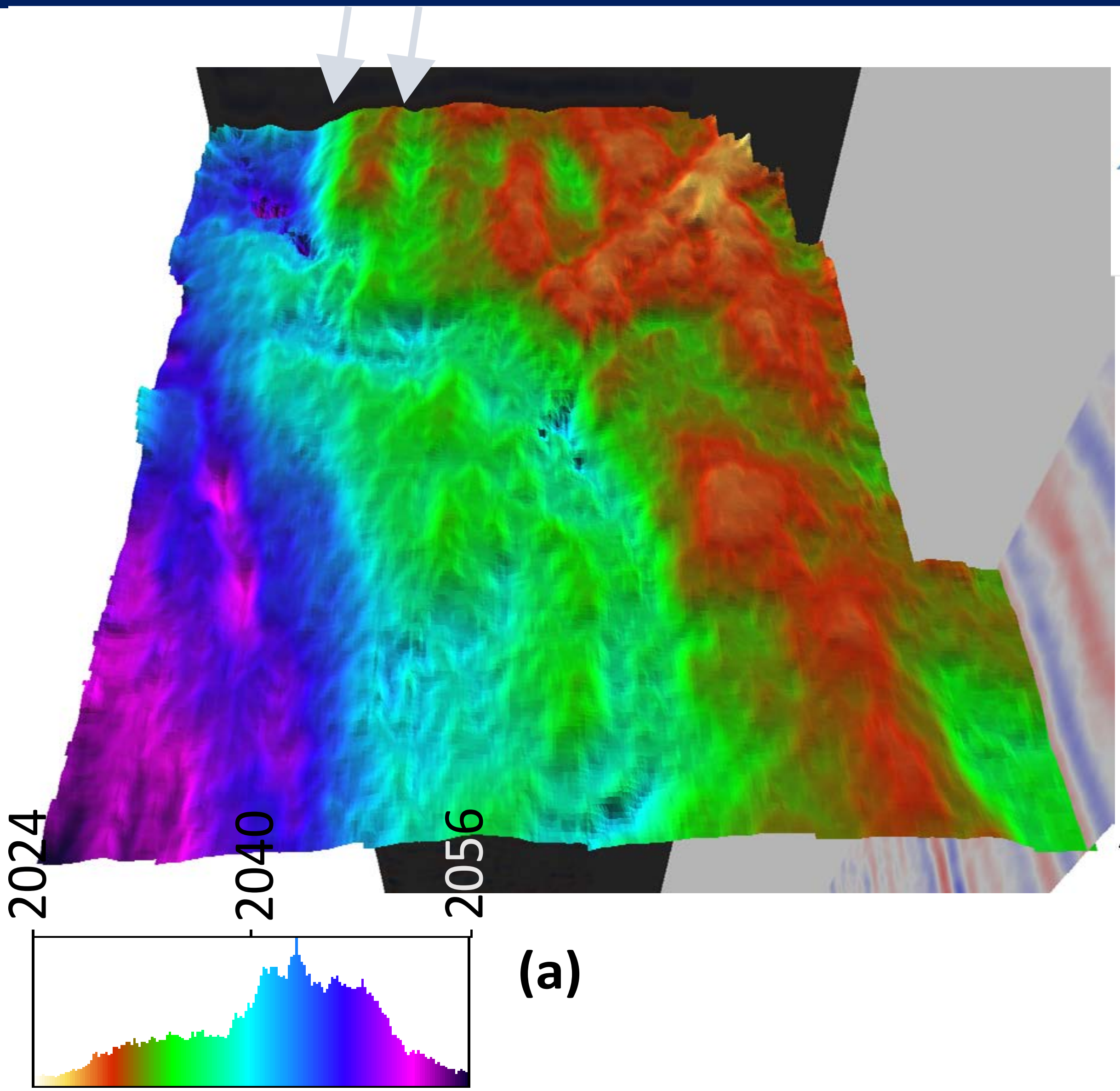
(b)

Swan Hills and Ireton Structure

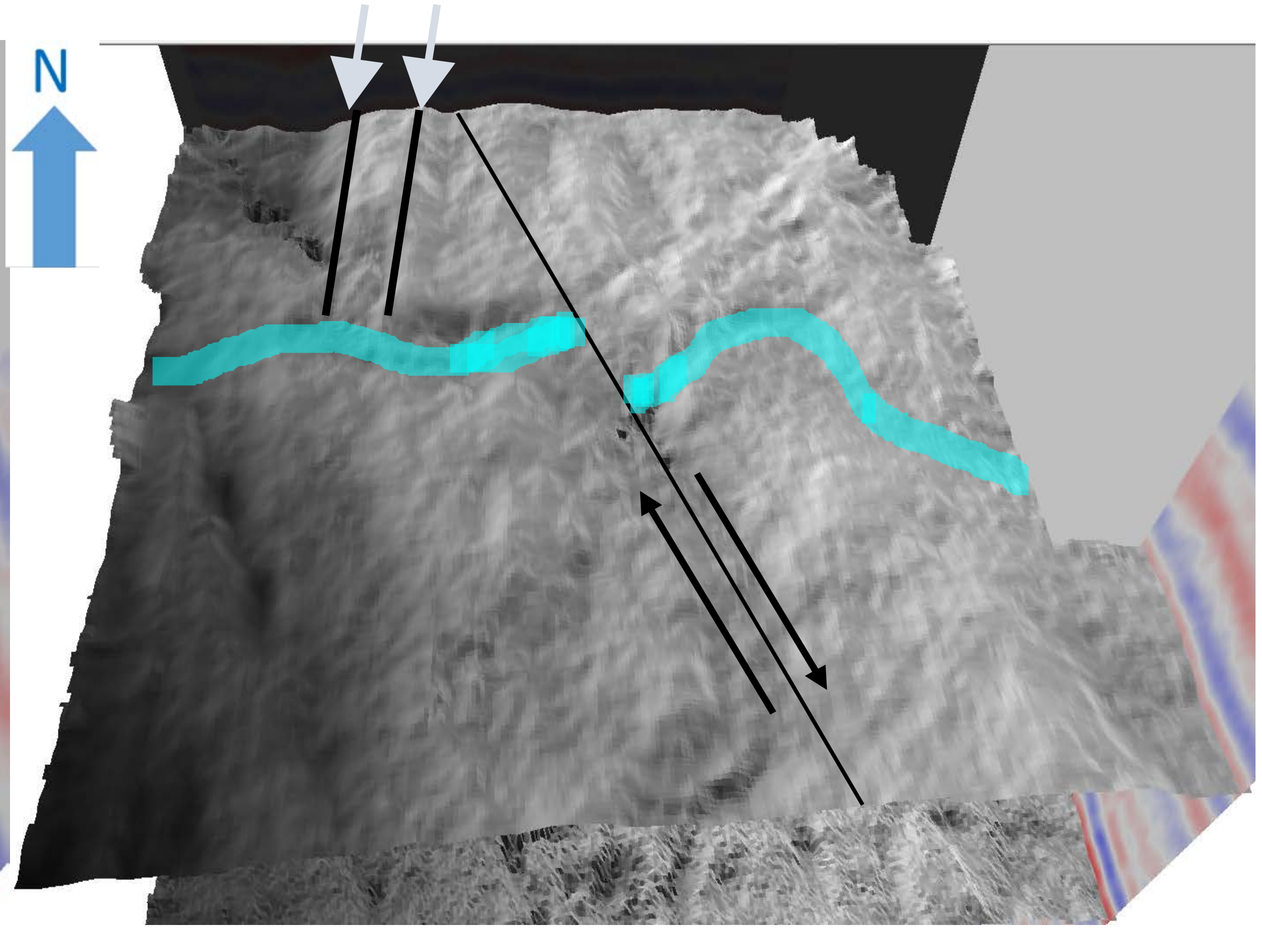




Fault – Time structure, Gilwood



(a)



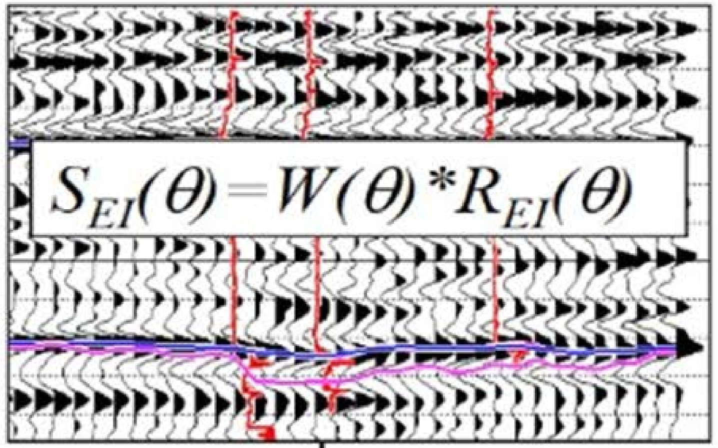
(b)

3 b.General inversion workflow

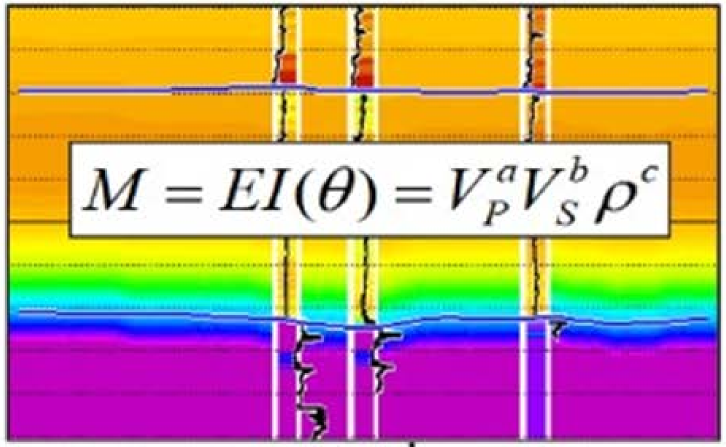
Elastic impedance inversion

HAMPSON-RUSSELL
A CGGVeritas Company

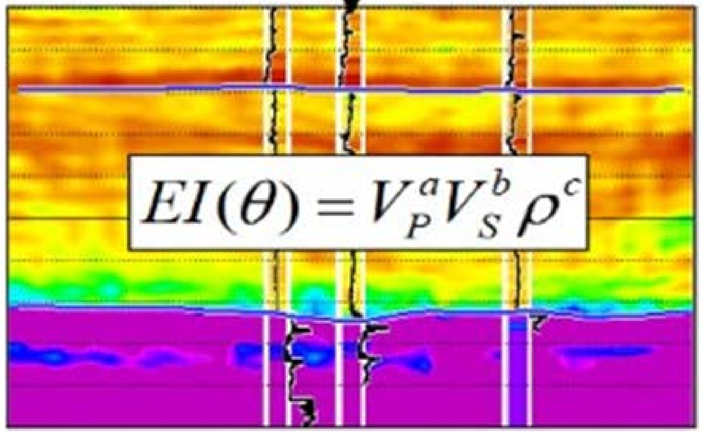
(1) Optimally process the seismic data



(2) Build model from picks and impedances

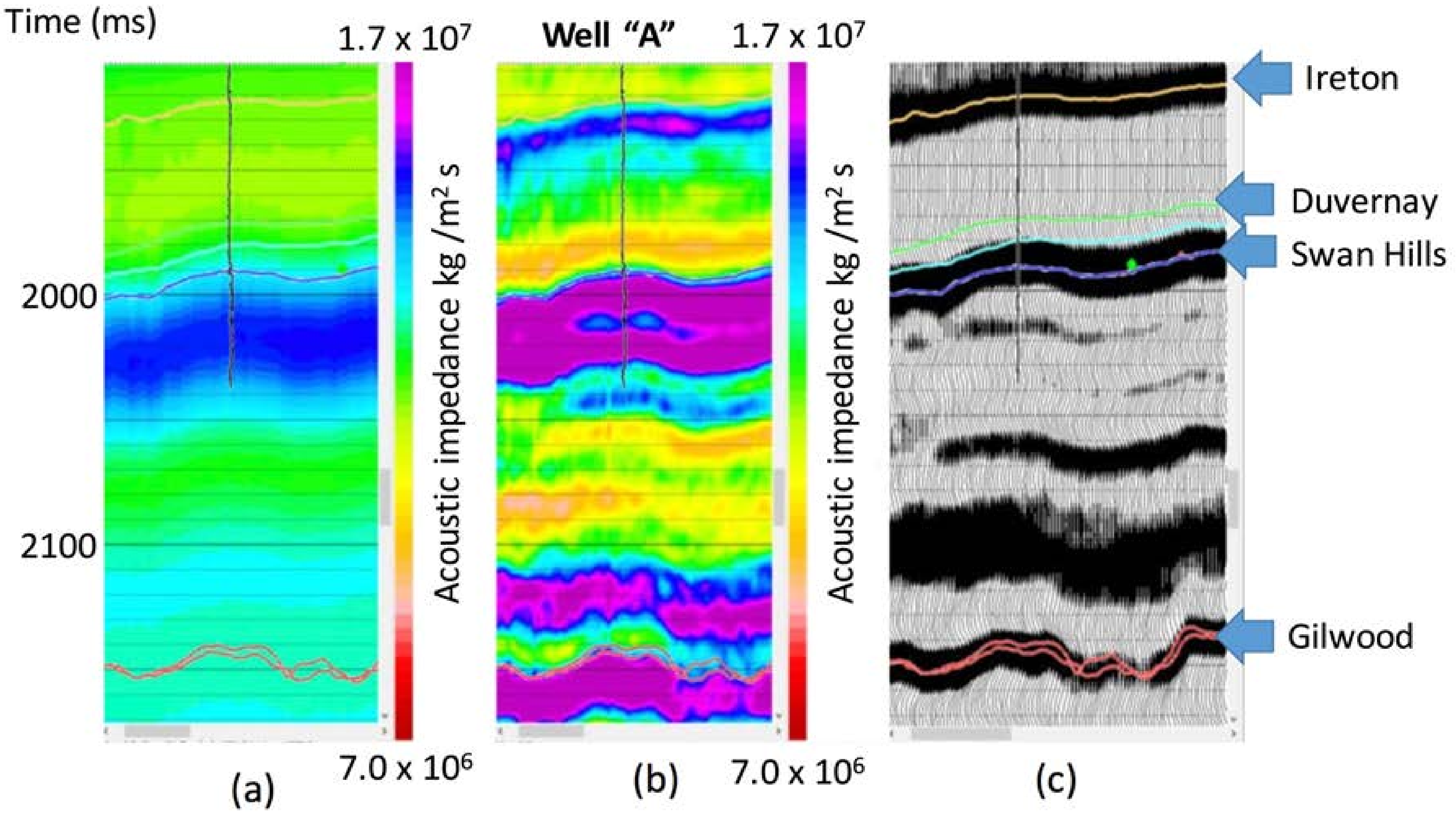


(3) Iteratively update model until output synthetic matches original seismic data.

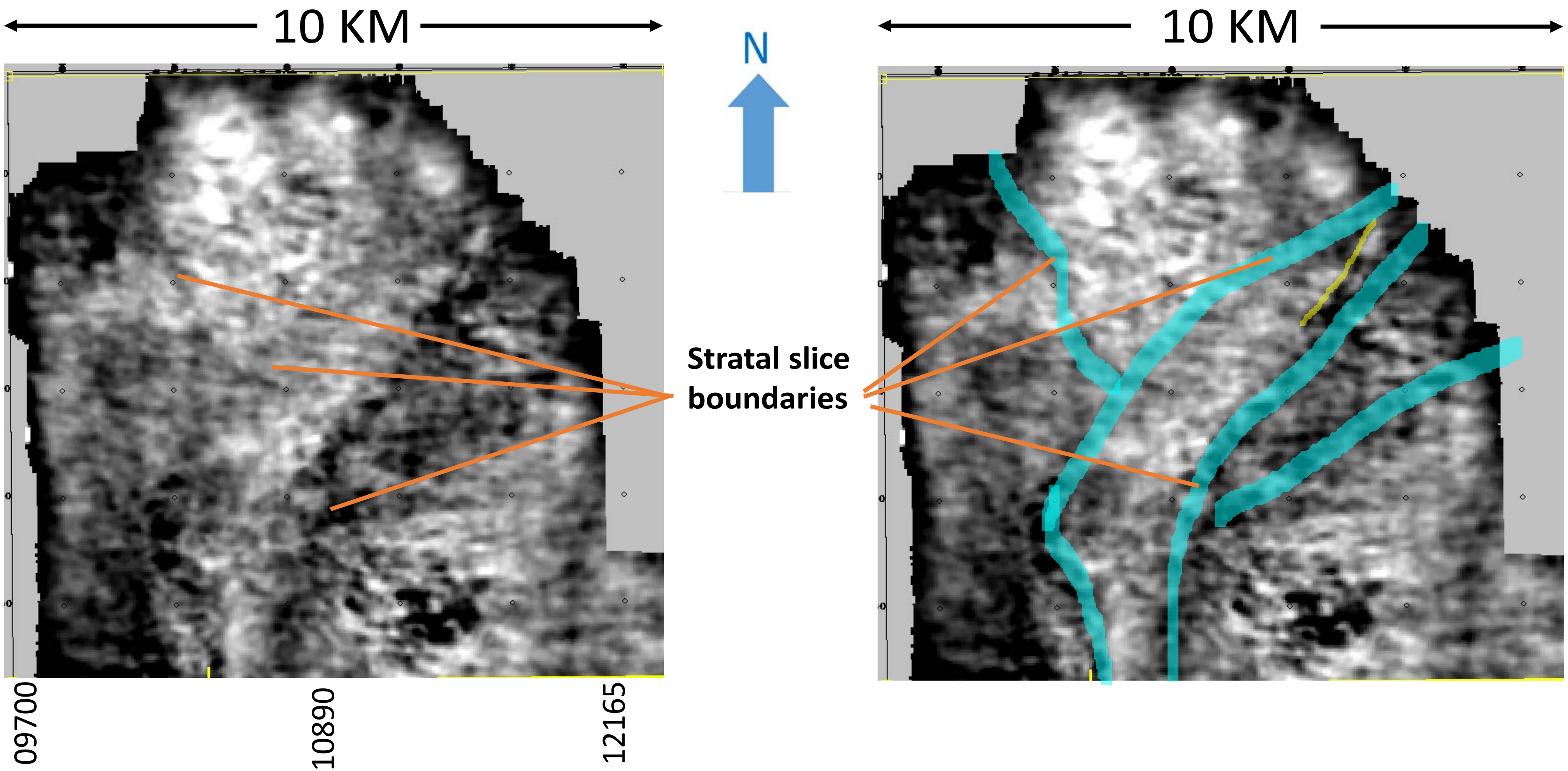


In elastic impedance inversion the seismic, model and output are as shown here.

3 b. Model / post stack inversion / Input data



Stratal slice, post stack inversion



(a) (b)

Acoustic Impedance

PP and PS data regristration

W ← 3 km. → E

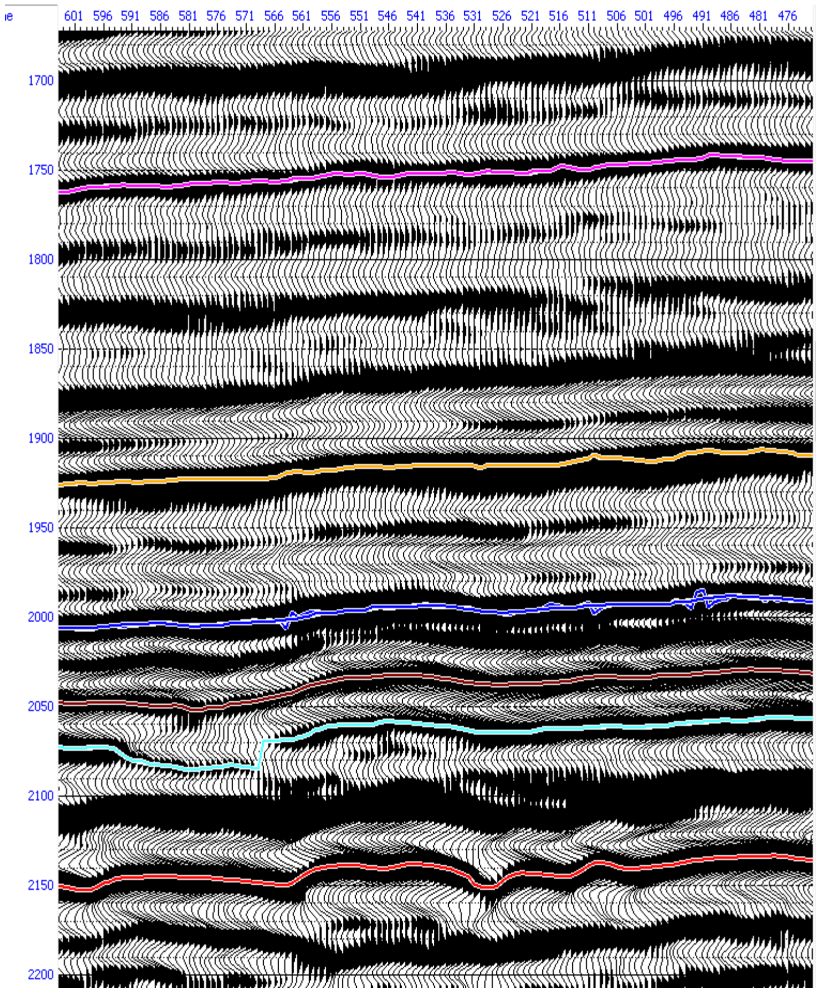
W ← 3 km. → E

1800

1900

2000

2100



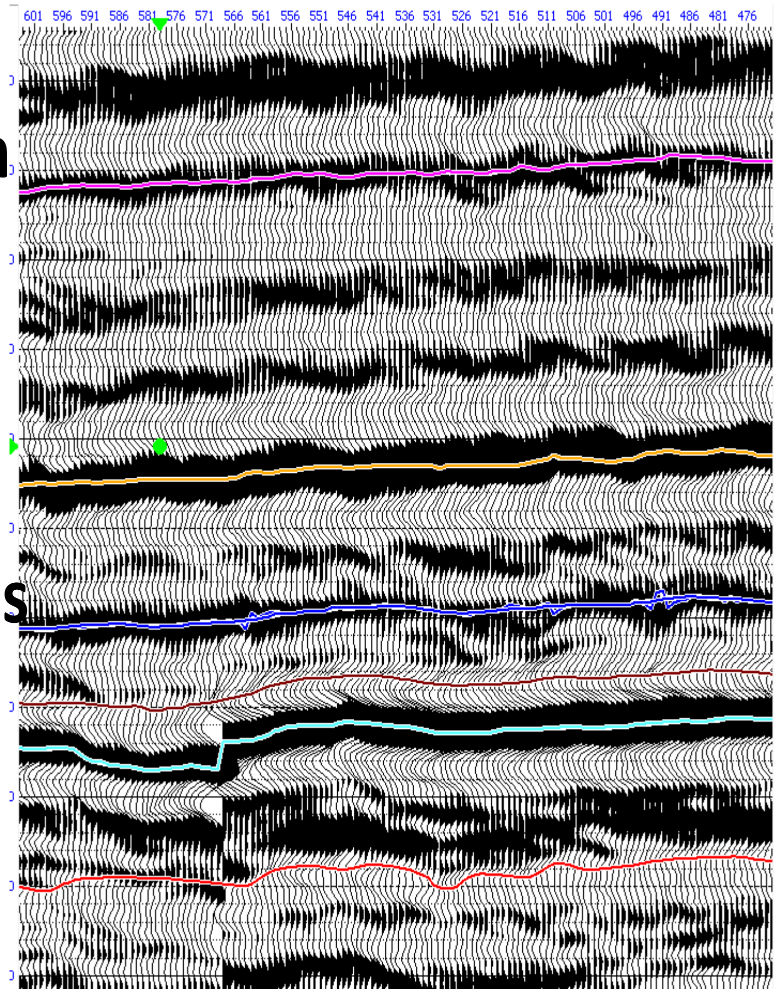
PP seismic section

Wabamun

Ireton

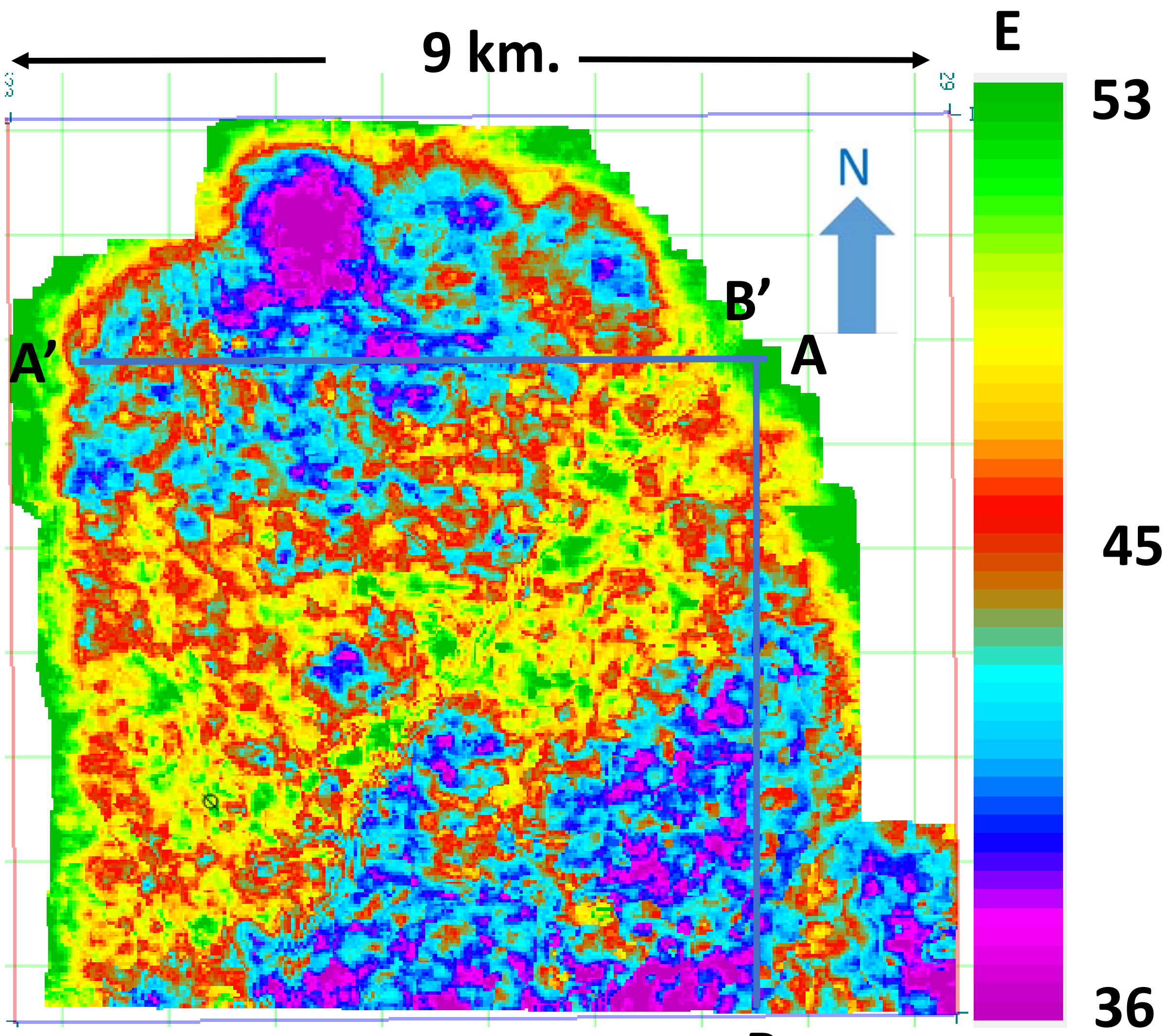
Swan Hills

Gilwood

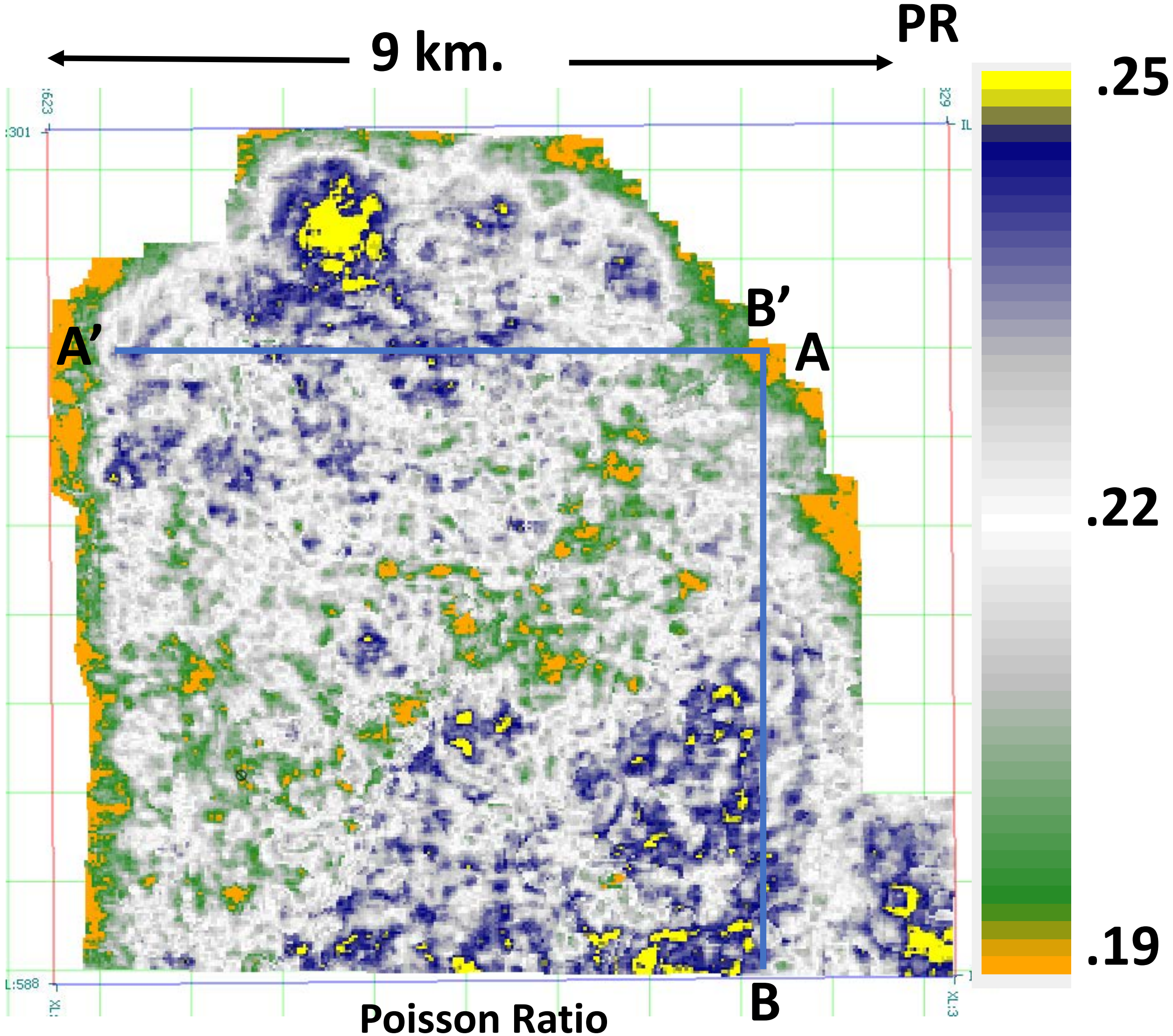


PS seismic section

Duvernay elastic properties

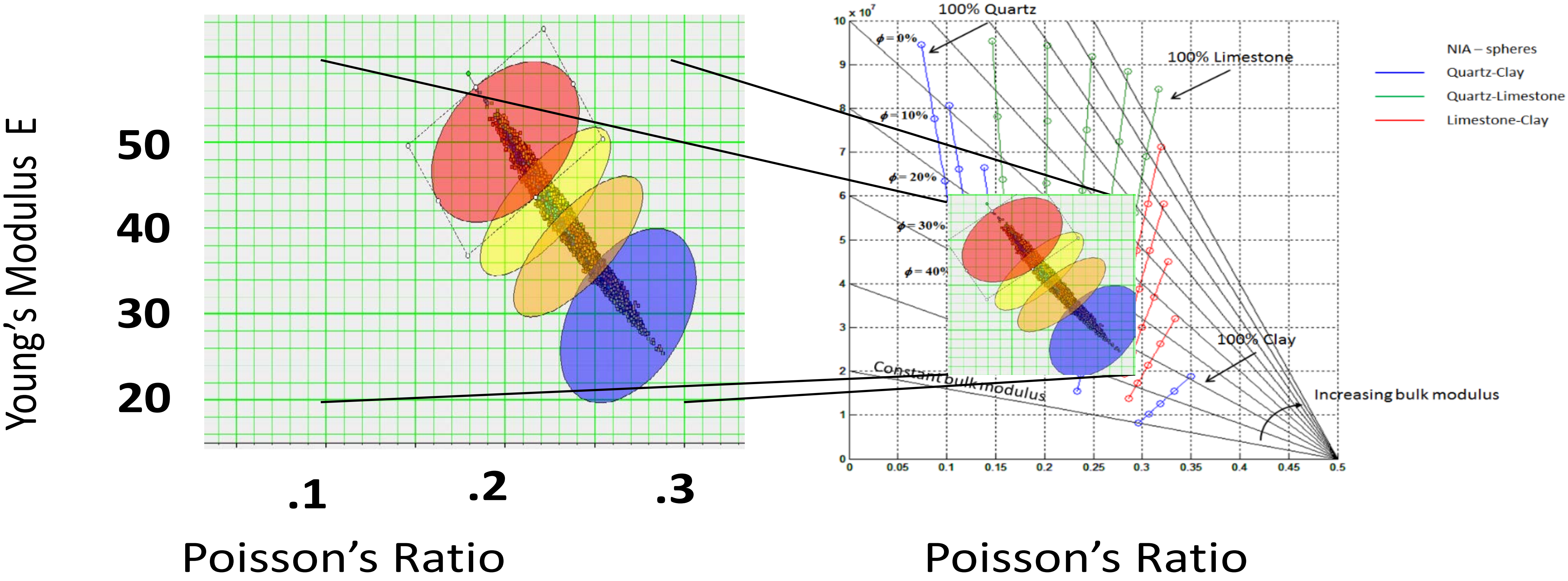


Young's Modulus



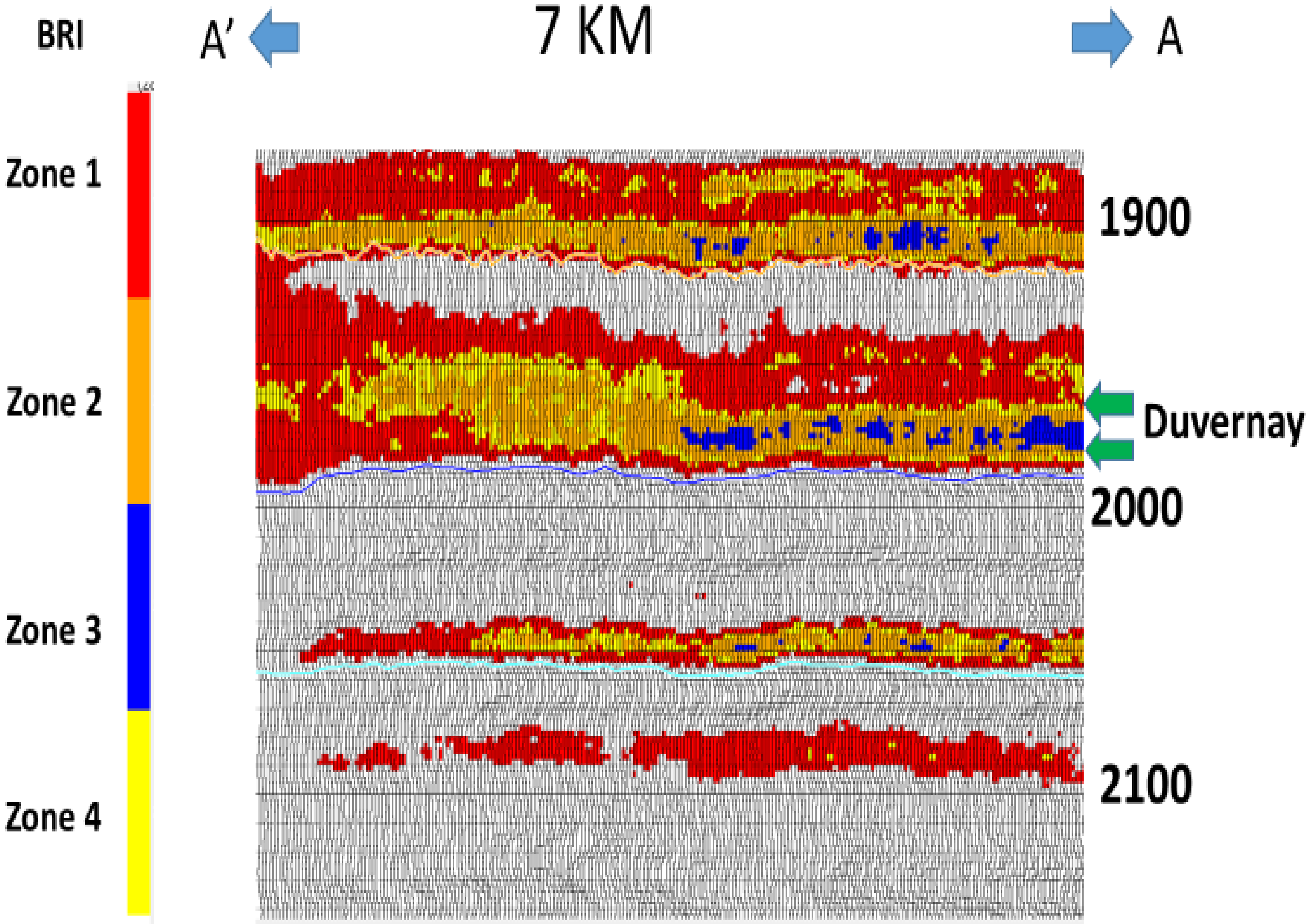
Poisson Ratio

E and PR, derived and theoretical values

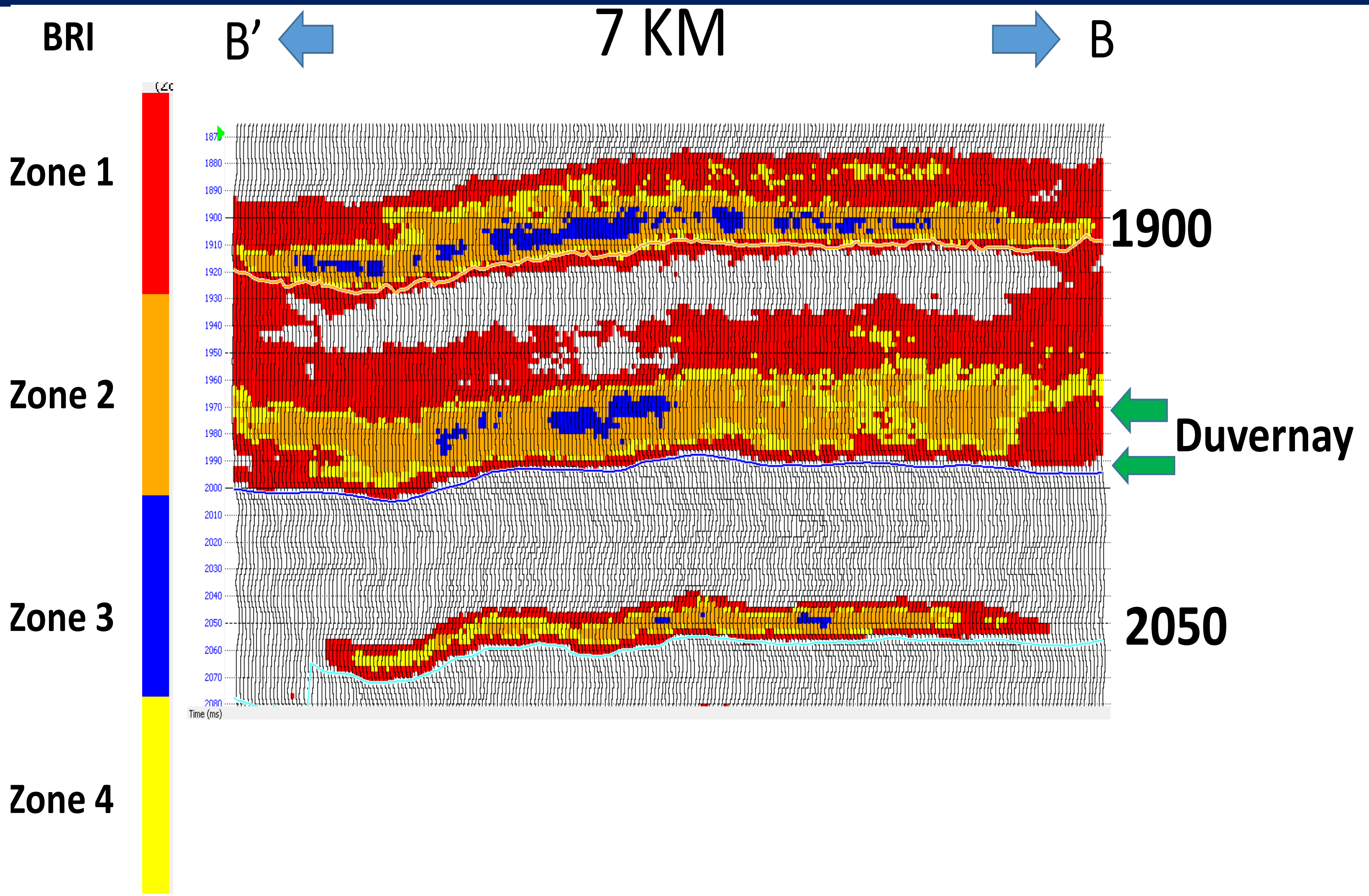


Cho et al. 2005

BRI values

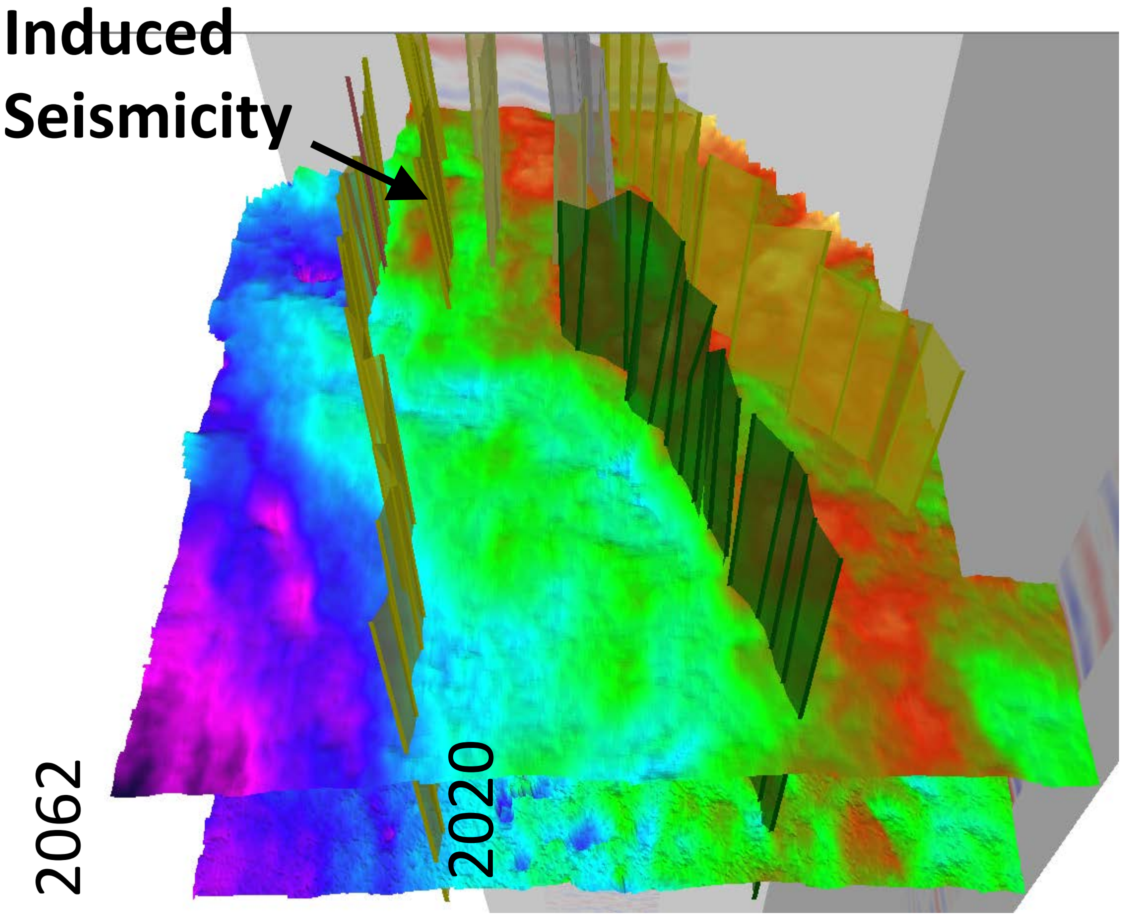


BRI values

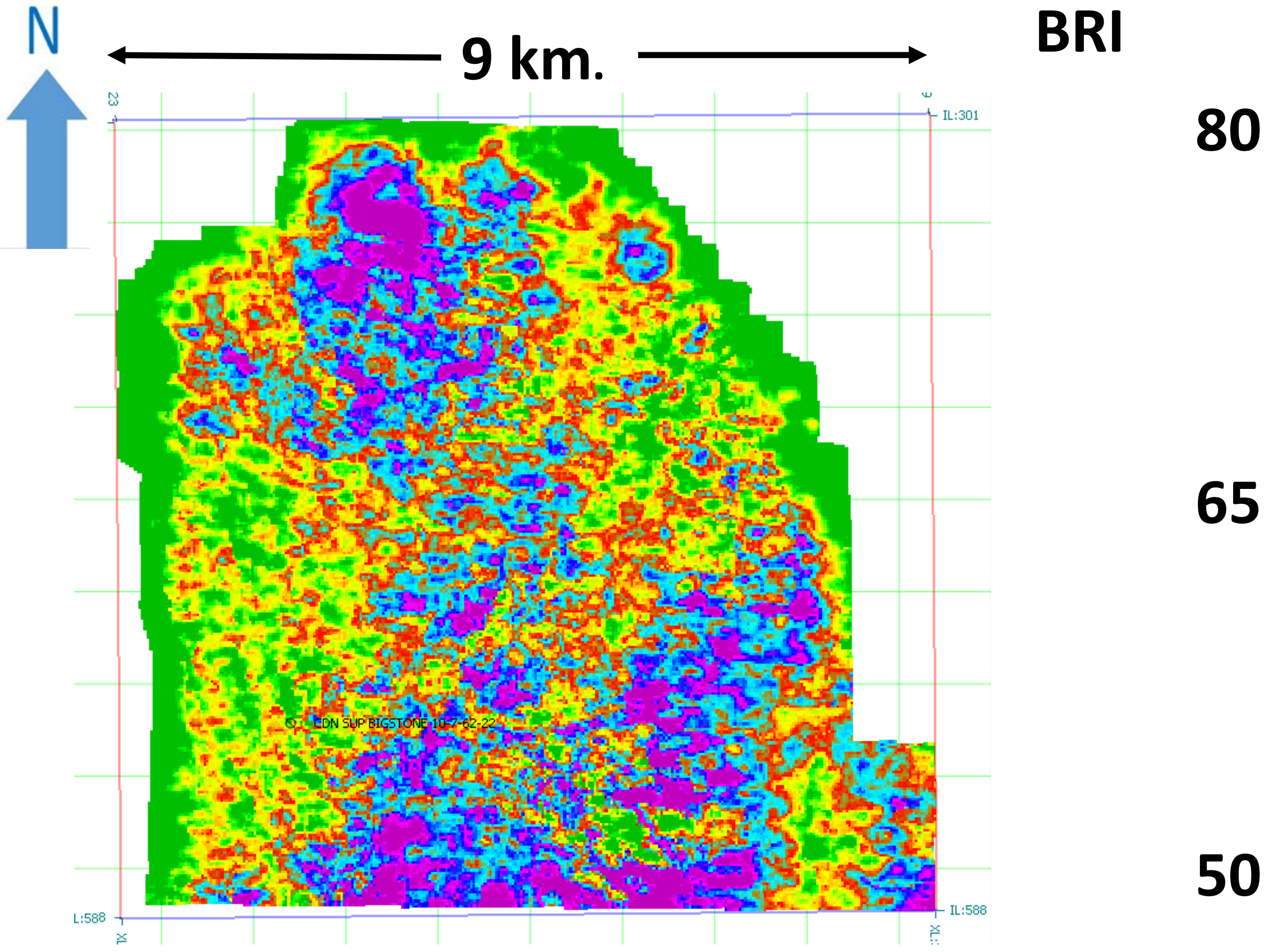


BRI
B'
7 KM
B
Zone 1
Zone 2
Zone 3
Zone 4
1900
Duvernay
2050
Time (ms)

Gilwood Structure and Duvernay formation BRI



(a)



(b)

4. Conclusions

- Reservoir attributes can readily be extracted from prestack data
- Wells can be better positioned based on rock parameters and structure
- Reservoir characterization may be able to explain the variable fracture patters and productivity of horizontal wells
- Fault mapping can determine the potential of induced seismicity, and may explain induced earthquakes occur

5. Future work

- Calibrate microseismic recorded data with the PP PS mapping and reservoir characterization
- Determine which faults are responsible for induced seismicity, and identify potential geohazards.
- Analyze the AVAz response of this data, The induced Duvernay microseismic events are not aligning to the assumed regional gradient , preliminary results indicate the trends are off by 15 degrees.

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.

Acknowledgements

- Dr. Brian Russell, technical advice and consultations
- Staff and students in CREWES, MIC
- Arcus Seismic Solutions for the use of the 3-D, 3-C data.
- Divestco for providing Digital well logs.

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- Questions?