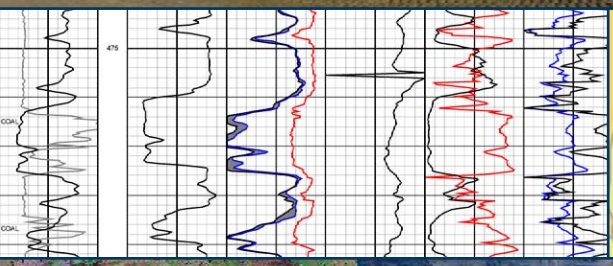
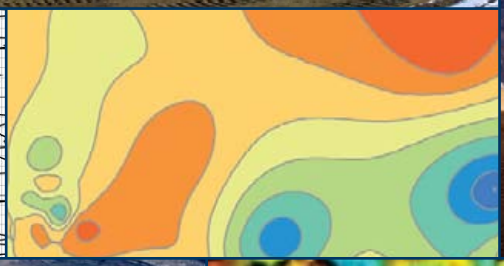
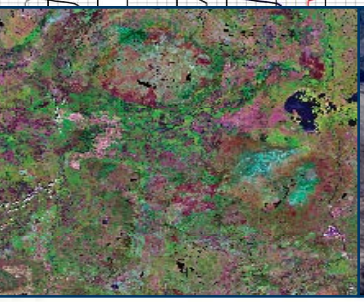
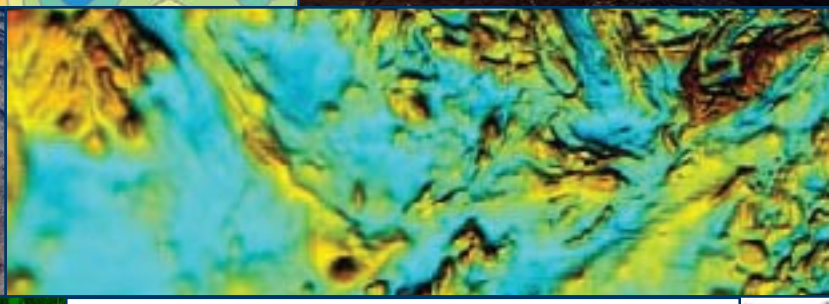
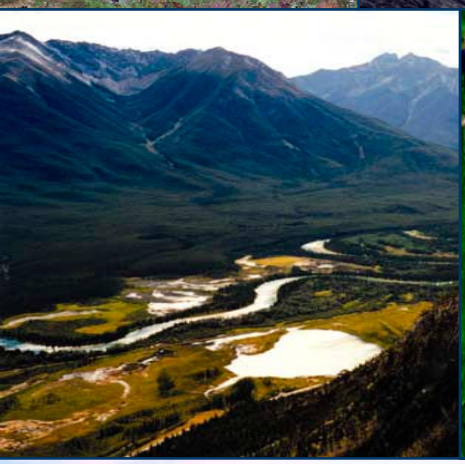
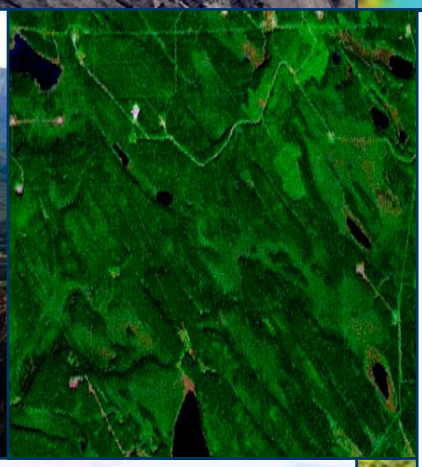
Stress Analysis - Central Alberta

Tertiary, Cretaceous, Jurassic and Triassic Reservoirs



The Hunt for Permeability

Stress • Tectonics • Hydrodynamics • Petrophysics

A Joint Venture, Multi-Client Study by
Rakhit Petroleum Consulting and BJ Services.

RAKHIT
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integrated geosciences

Stress Analysis - Central Alberta

Introduction

Canadian Discovery Ltd. is pleased to present this intriguing, joint-venture geotechnical study, conducted by Rakhit Petroleum Consulting and BJ Services. The study has compiled the largest frac pressure database in the world. This database has been used to estimate the minimum principal horizontal stress from instantaneous fracture closure pressure data. This field measured data is then compared to passive boundary stress conditions calculated through the modification of the Biot equation by adding terms for temperature, pressure, fluid phase/density and overburden removal. Further integration of potential field data, geothermal gradient mapping, basement tectonics, paleogeography and digital elevation models has created a robust study with applications for geoscientists and engineers.

Why Study Stress?

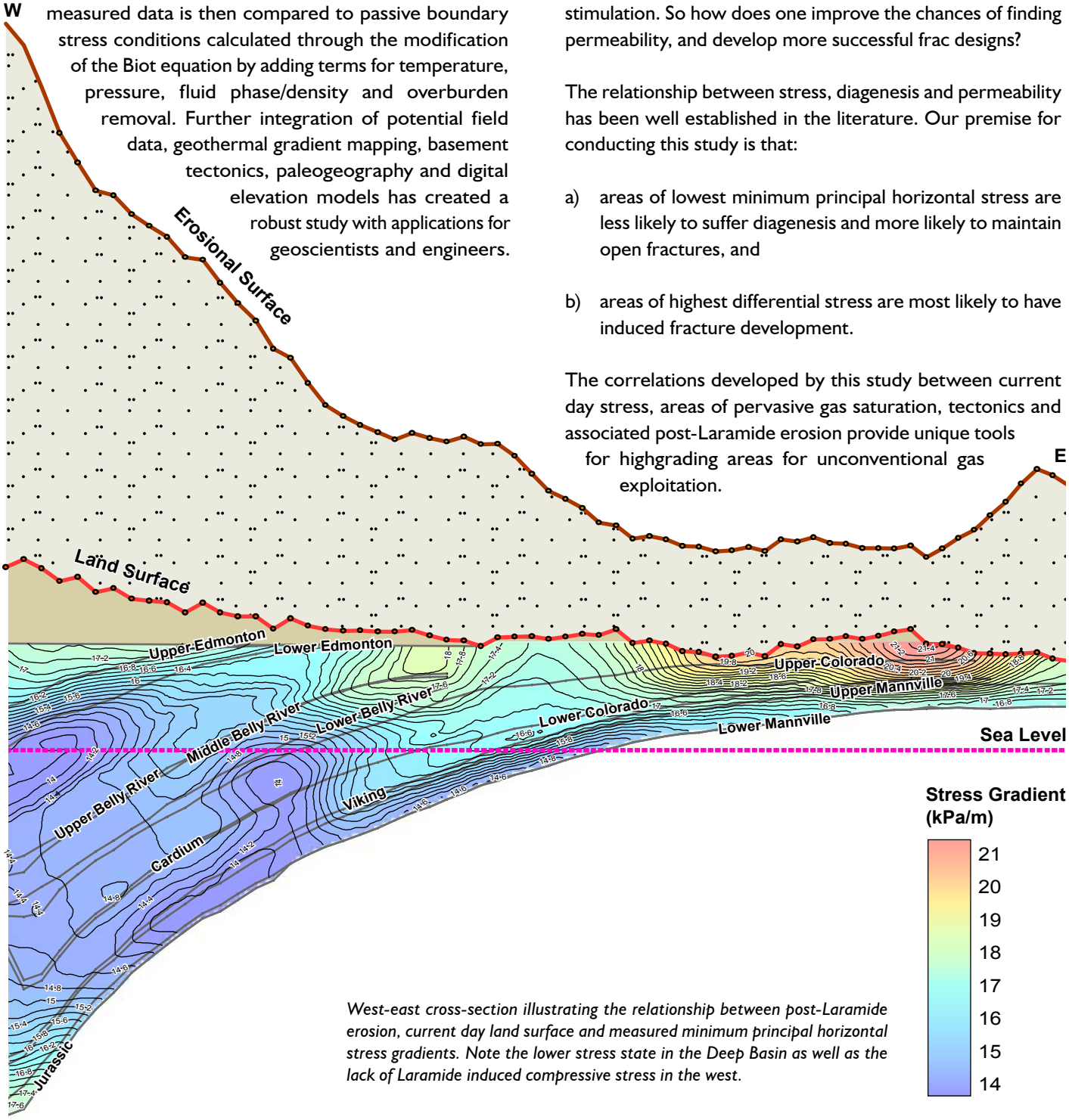
Unconventional gas trapped in microdarcy sands, organic rich shales and coalbeds represents a potential resource well in excess of all the Western Canada Sedimentary Basin's (WCSB) conventional gas. Exploration for this resource is best described as a hunt for permeability, where economic exploitation relies heavily on the design and execution of well completion and stimulation. So how does one improve the chances of finding permeability, and develop more successful frac designs?

The relationship between stress, diagenesis and permeability has been well established in the literature. Our premise for conducting this study is that:

a) areas of lowest minimum principal horizontal stress are less likely to suffer diagenesis and more likely to maintain open fractures, and

b) areas of highest differential stress are most likely to have induced fracture development.

The correlations developed by this study between current day stress, areas of pervasive gas saturation, tectonics and associated post-Laramide erosion provide unique tools for highgrading areas for unconventional gas exploitation.



West-east cross-section illustrating the relationship between post-Laramide erosion, current day land surface and measured minimum principal horizontal stress gradients. Note the lower stress state in the Deep Basin as well as the lack of Laramide induced compressive stress in the west.

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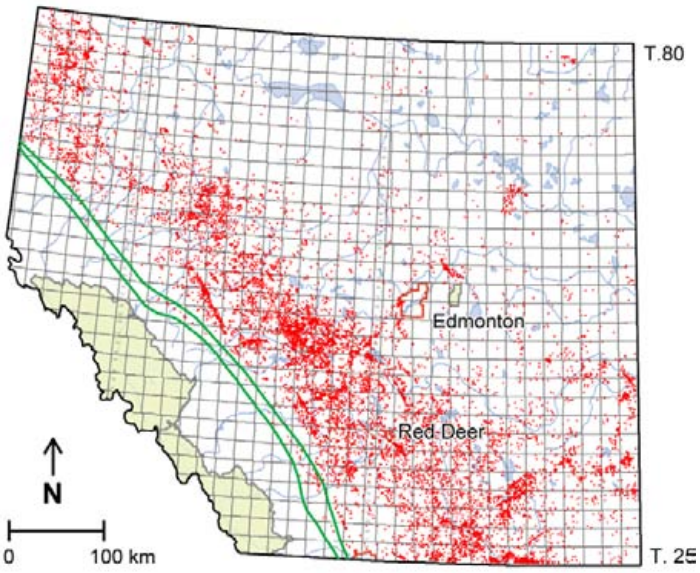
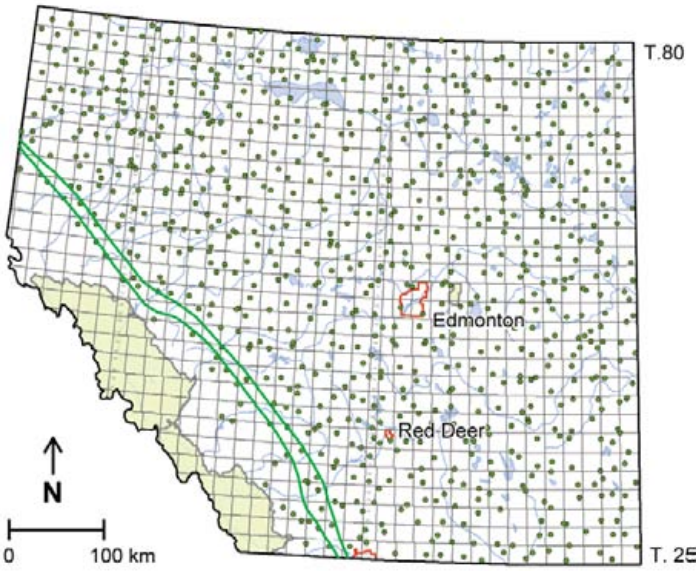
The Study

The main components of the study include:

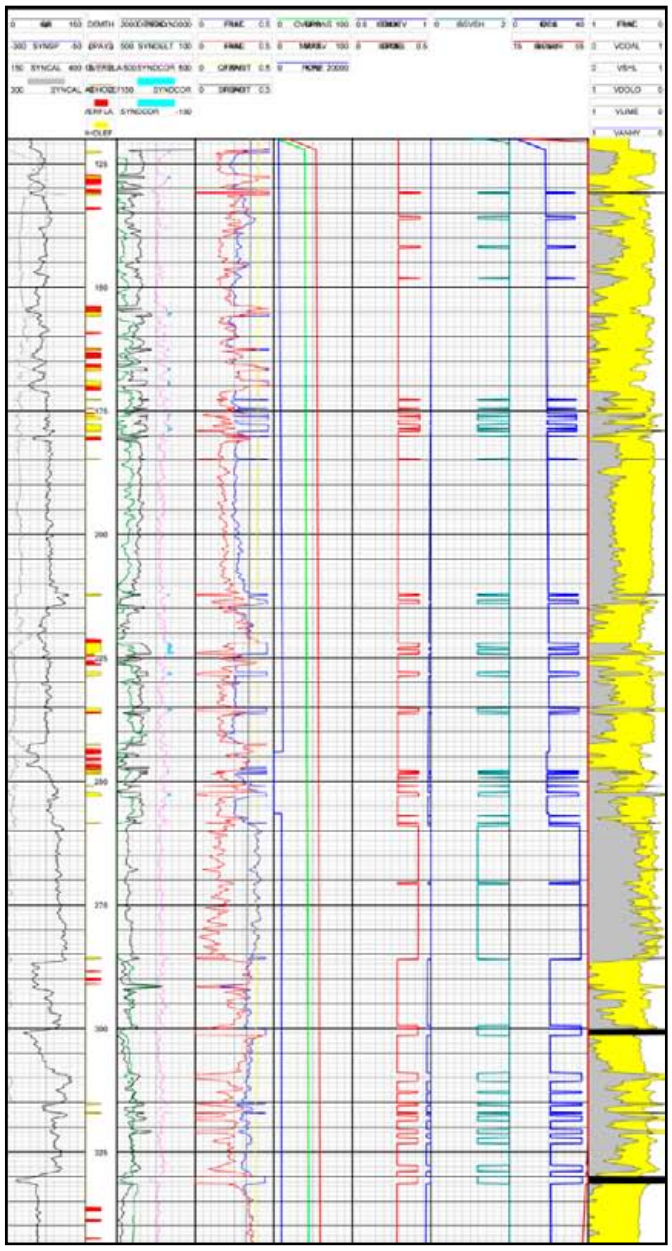
- Minimum principal horizontal stress (S_h) and stress gradient maps for 15 geological units from the Triassic to the Tertiary
- Calculated passive boundary stress (S_v, S_{hpb}) and effective stress ratio (ESR) maps for 15 geological units
- Overburden removal estimation from sandstone compaction curves
- Investigation of the geological controls that may cause variances in stress state such as pore pressure, temperature, basement tectonics, reef trends and subcrop edges



Stress Analysis study area map showing BJ and client frac data distribution.



Stress Analysis study area map showing petrophysical wells.



One of over 700 interpreted well logs including sand/shale, pore pressure, S_v, S_{hpb}, ESR and compaction curves.

Data

1. BJ Services instantaneous fracture closure pressure data (15,098 tests)
2. High graded leak-off test data (3,152 tests)
3. Client donated frac pressure data (395 tests)
4. Petrophysical control well data with compaction curves, pressure profiles, S_v, S_{hpb}, and ESR calculations

Digital well data provided in Microsoft Excel format.

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Deliverables

This comprehensive study includes over 150 maps, provided in both PMF (ArcReader) and PDF (Adobe Acrobat). ArcGIS and ESRI Shape files are also available, allowing full integration with G&G project workflow.

For each of 15 map units:

- Vertical Principal Stress (S_v) Distribution Map
- Calculated Horizontal Passive Boundary Stress (S_{hpb}) Map
- Calculated Pore Pressure (P_p) Map
- Calculated Effective Stress Ratio (ESR) Map
- Minimum Principal Horizontal Stress (S_h) Distribution Map
- Minimum Principal Stress Gradient Map
- Structure Contour Map (RPCL picks)
- Minimum Principal Stress Distribution Map (frac data by quality code)
- Isotherm Map
- Correlation of Isotherm and Minimum Principal Stress Map

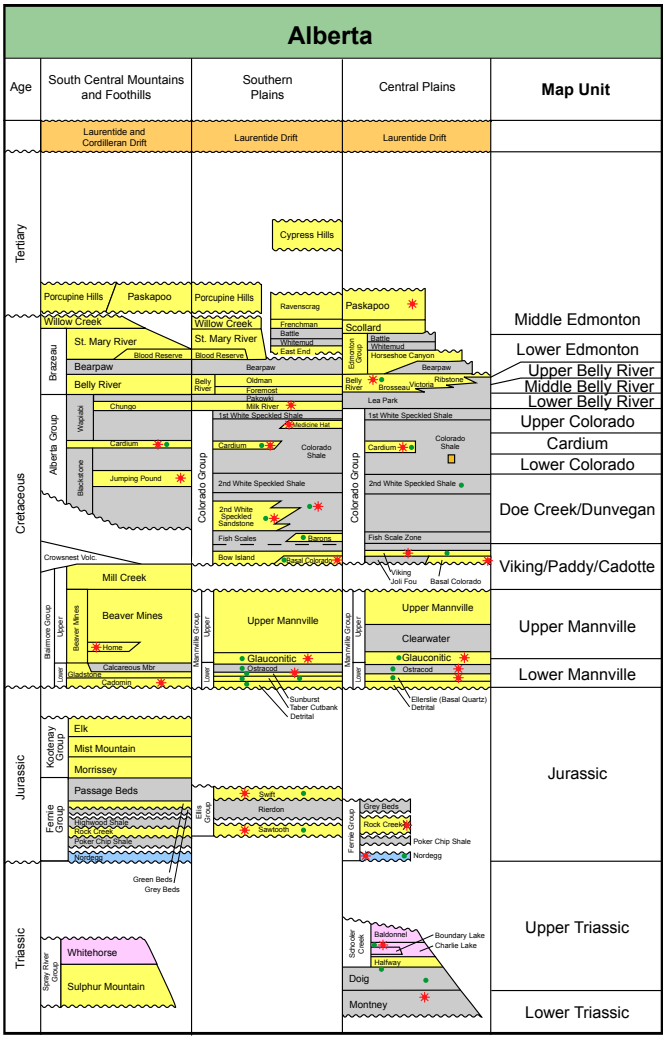
One-of maps:

- Stress Orientation Map
- Fracture Data Distribution Map - Over 700 tests will be tied to interpreted well logs via PMF interface
- Well Data Distribution Map
- Geothermal Gradient Map
- Basement Tectonic Domain Map from Potential Field Data
- Gravity Field (Magnetic Intensity) Map (2)
- Post-Laramide Erosion Map, Calculated from Compaction Curves
- Erosion Estimates from Coal Reflectance (Moisture Content) - for Issler, Bustin, Nurkowski & Study (4)
- Structural Trends Map from Remote Sensing Data
- Published Minimum Principal Stress Gradient Map

In addition to the maps, an in-depth illustrated technical report is provided in hard-copy and PDF format. A web-based interface ensures ease of navigation across the study.

Report to include:

- Introduction, Theory, Methodology, Discussion by Map Unit, Conclusions and Recommendations
- Supporting Graphs (stress versus depth plots, histograms, regressions, sensitivity tests, etc.)
- Technical Illustrations
- Data



Stratigraphic chart showing the 15 map units used for the study.

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