

# **PS Data Mining, 3-D Views and Characterization of Fractures, Faults and Migration Paths in the Western Canadian Sedimentary Basin\***

**Jean-Yves D. Chatellier<sup>1</sup>, Michael Chatellier<sup>2</sup>, and Anne Hargreaves<sup>3</sup>**

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<sup>1</sup>Talisman Energy Inc., Calgary, AB, Canada ([Jchatellier@talisman-energy.com](mailto:Jchatellier@talisman-energy.com))

<sup>2</sup>Tecto Sedi Integrated Inc., Calgary, AB, Canada

<sup>3</sup>Canadian Stratigraphic Services (2000) Ltd., Calgary, AB, Canada

## **Abstract**

Data mining and 3D visualization are ideally suited to unravel the hidden details of mature basins; such tools allow many disciplines to be used to construct an improved structural and dynamic picture of a basin. Fractures, faults and migration paths of the Western Canadian Sedimentary Basin will be examined using a series of techniques and methods involving various types of data from different disciplines. The uncertainty related to each parameter used will be addressed and will be overcome by the sheer volume of data available.

The examples presented are essentially from data that are commonly neglected by the oil industry. Cuttings observations that make little sense at first glance can give incredible information on type of tectonic activity, nature of fluid migrations and their relative timing - information will include grain angularity and abnormal red colors planes crossing formations. Three-dimensional views of large amount of data are incredibly powerful when dealing with information from many formations. The chosen examples include drilling problems, abnormal gas compositions as well as unusually high porosity or net-to-gross values, the latter needing normalization per formation to be optimally utilized.

Fractures, faults and migration paths have yet to be better understood at a basin and at more local scales. The mature Western Canadian Basin has a remaining rosy future under oil and gas prices as high as today's. Finding new resources will most likely require innovative thinking and the use of extremely large data sets in a multidisciplinary and cross-formational approach.

### **Acknowledgements**

The authors would like to thank all of the companies that supported this Tecto Sedi Integrated Inc. Fracture Project; these include Talisman Energy, Devon Canada, Encana, CNRL and Calpine Canada. The authors would also like to thank Canadian Stratigraphic Services (2000) Ltd for providing the needed cutting descriptions and allowing to published some of the results.

### **References**

Chatellier, J-Y., and M. Chatellier, 2006, Data Mining and Exploratory Statistics to Visualize Fractures and Migration Paths in the WCBS, CSPG Annual convention, Calgary, AB, Canada.

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Richards, B.C., J.E. Barclay, D. Bryan, A. Hartling, C.M. Henderson, and R.C. Hinds, 1994, Carboniferous strata of the Western Canada Sedimentary Basin, *in* Geological Atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetsen (comp.), Canadian Society of Petroleum Geologists and Alberta Research Council, Special Report 4, p. 221–250.

# Data Mining, 3-D Views and Characterization of Fractures, Faults and Migration Paths

In the Western Canadian Sedimentary Basin  
Using data from public domain



## Abstract

**Data mining** and **3D visualization** are ideally suited to unravel the hidden details of mature basins; such tools allow many disciplines to be used to construct an improved structural and dynamic picture of a basin. Fractures, faults and migration paths of the Western Canadian Sedimentary Basin will be examined using a **series of techniques and methods** involving various types of data from different disciplines. The uncertainty related to each parameter used will be addressed and will be overcome by the sheer volume of data available.

The examples presented are essentially from **data** that is **commonly neglected by the oil industry**. Cuttings observations that make little sense at first glance can give incredible information on type of tectonic activity, nature of fluid migrations and their relative timing – information will include grain angularity and abnormal red colors planes crossing formations. Three-dimensional views of large amount of data are incredibly powerful when dealing with information from many formations. The chosen examples include drilling problems, abnormal gas compositions as well as unusually high porosity or net-to-gross values, the latter needing normalization per formation to be optimally utilized.

Fractures, faults and migration paths have yet to be better understood at a basin and at more local scales. The **mature Western Canadian Basin** has a **remaining rosy future** under oil and gas prices as high as today's. Finding new resources will most likely require **innovative thinking** and the use of extremely large data sets in a **multidisciplinary** and **cross-formational** approaches.

## Keywords

Anomaly approach

Cross-formational approach

Multidisciplinary

3-D exploratory statistics

4-D integration

**Jean-Yves Chatellier**

Talisman Energy Inc. Calgary

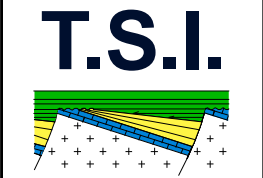
**Michael Chatellier**

Tecto Sedi Integrated Inc. Calgary\*

**Anne Hargreaves**

Canadian Stratigraphic Services (2000) Ltd, Calgary

- Anomaly approach
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# Anomaly Approach Using Core and Cutting Data

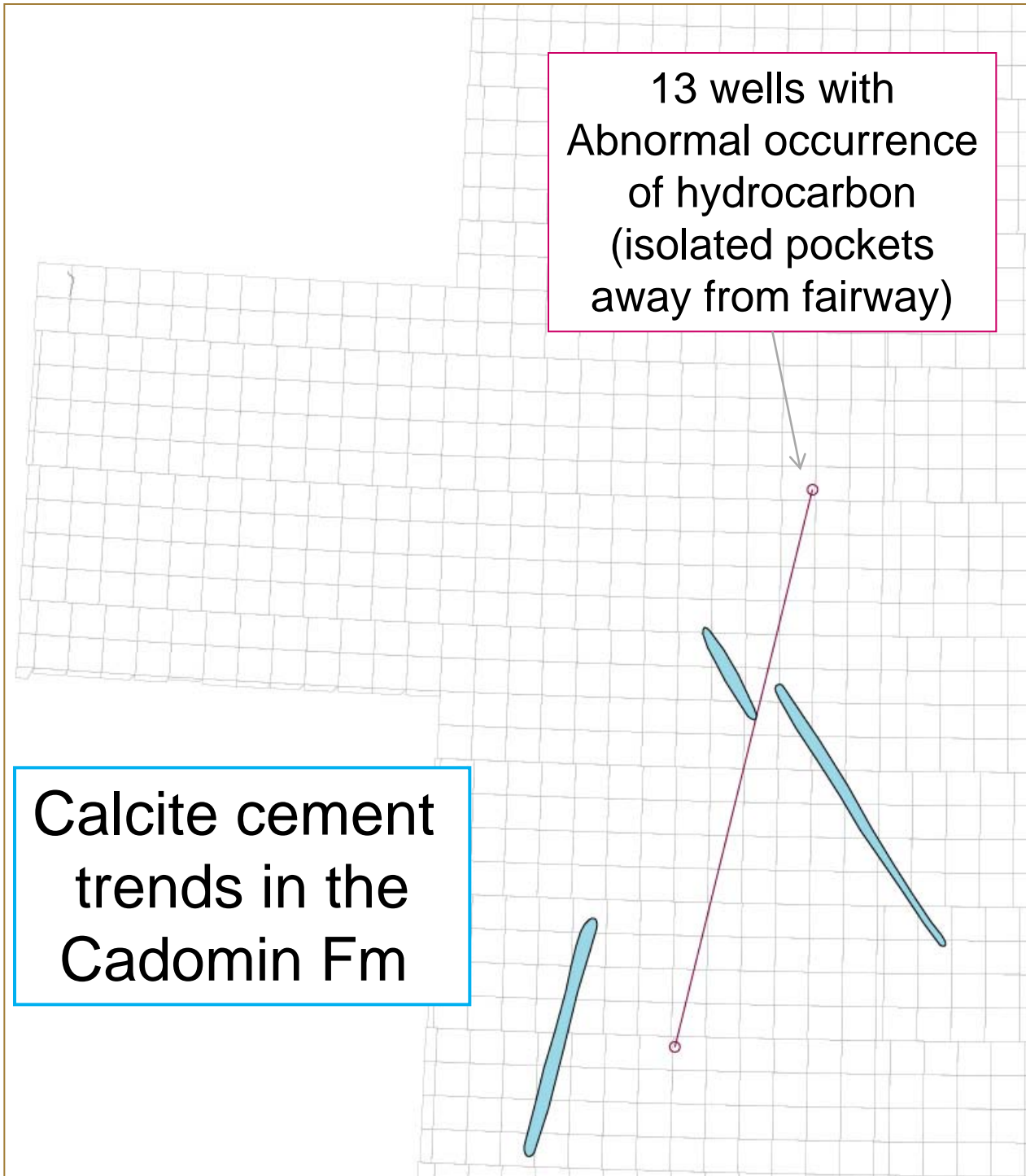
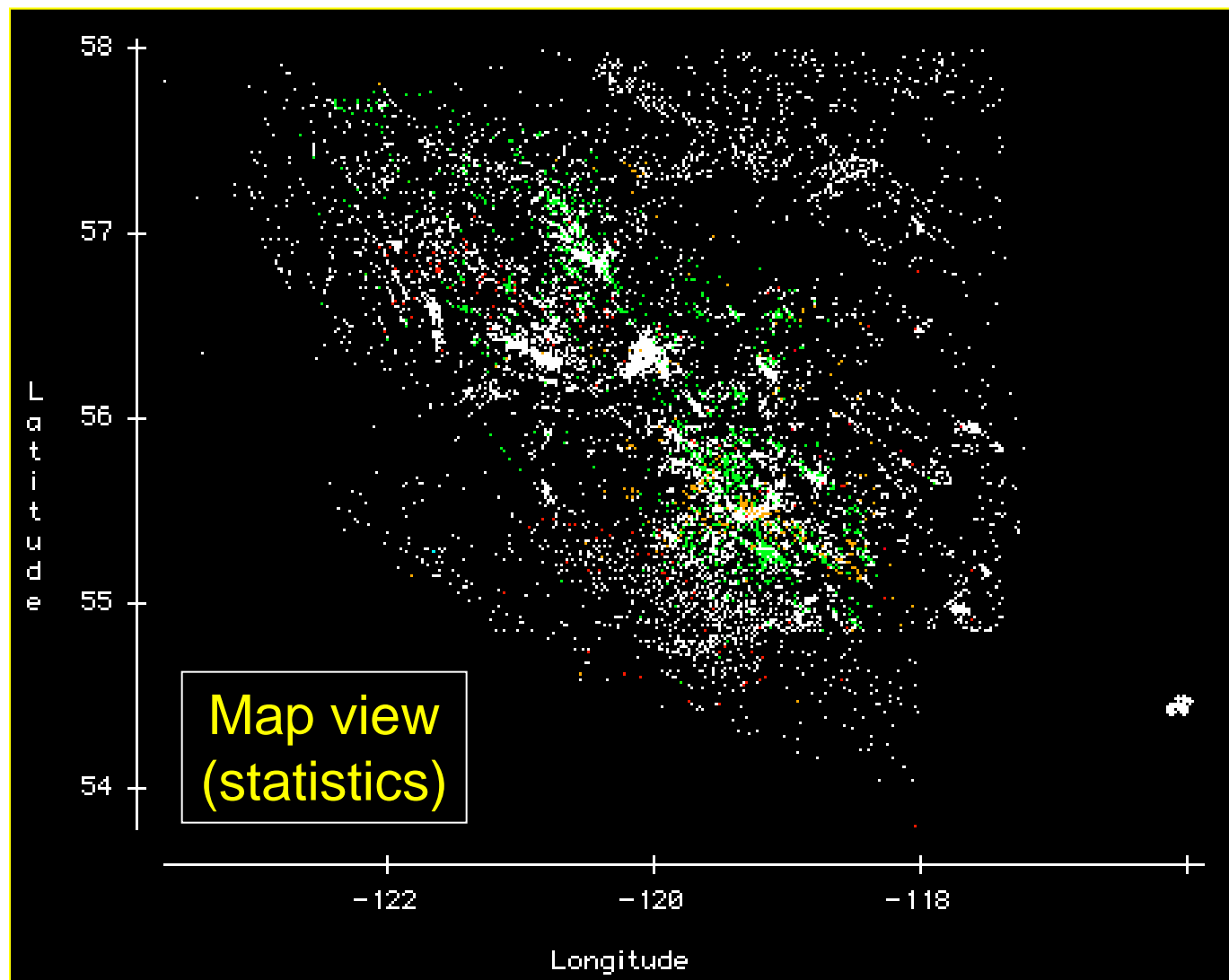
## Diagenetic features

A very large quantity of cuttings description is available for Western Canada (see map on the left for coverage in the Peace River Area).

Pervasive calcite cementation is commonly associated with fluid flow along major fault system.

The map to the right shows calcite cement linear trends affecting the sediments from the Cadomin Fm.

9330 wells with cores and core plugs



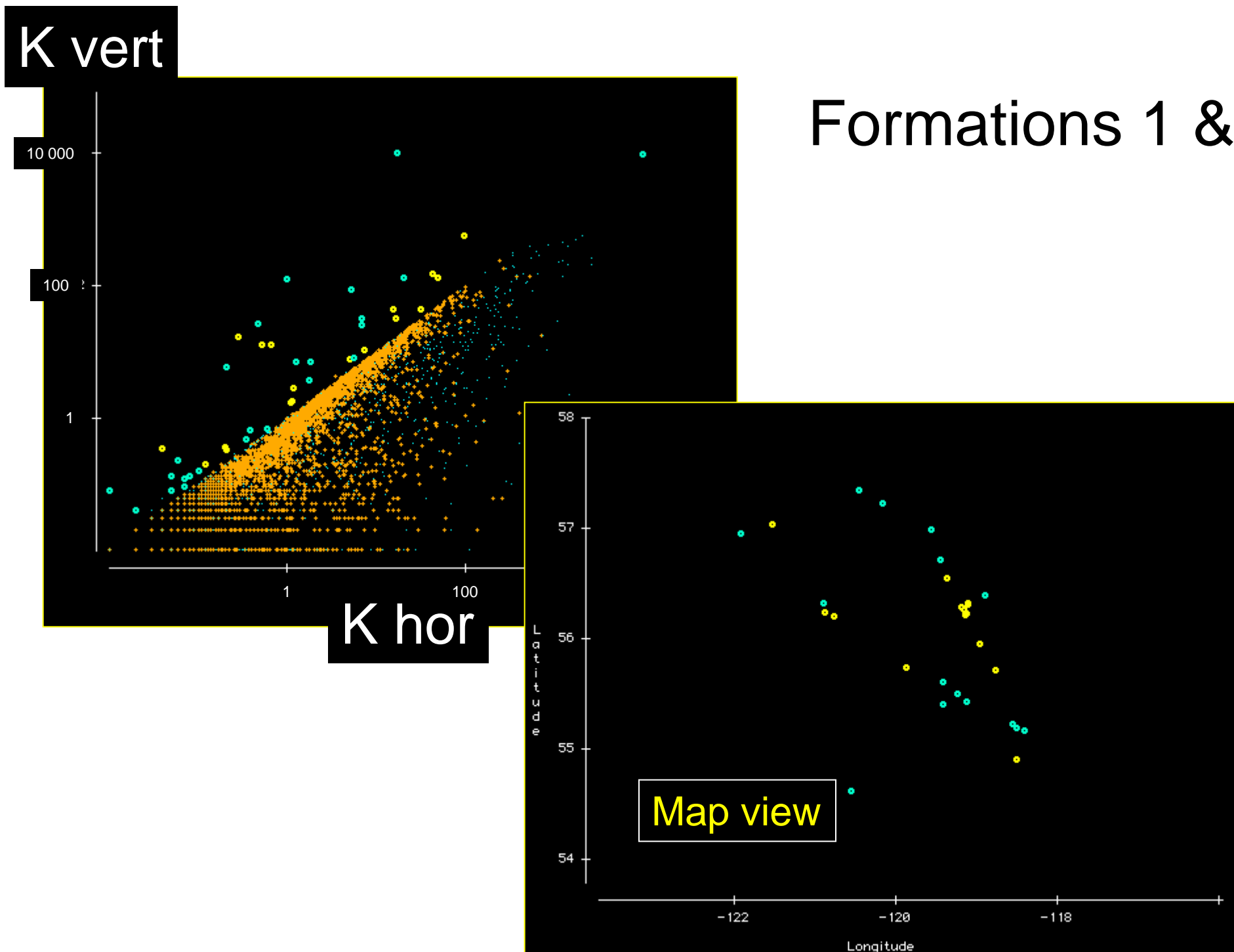
Note the North 9 degree alignments

## Cross-formation petrophysics data

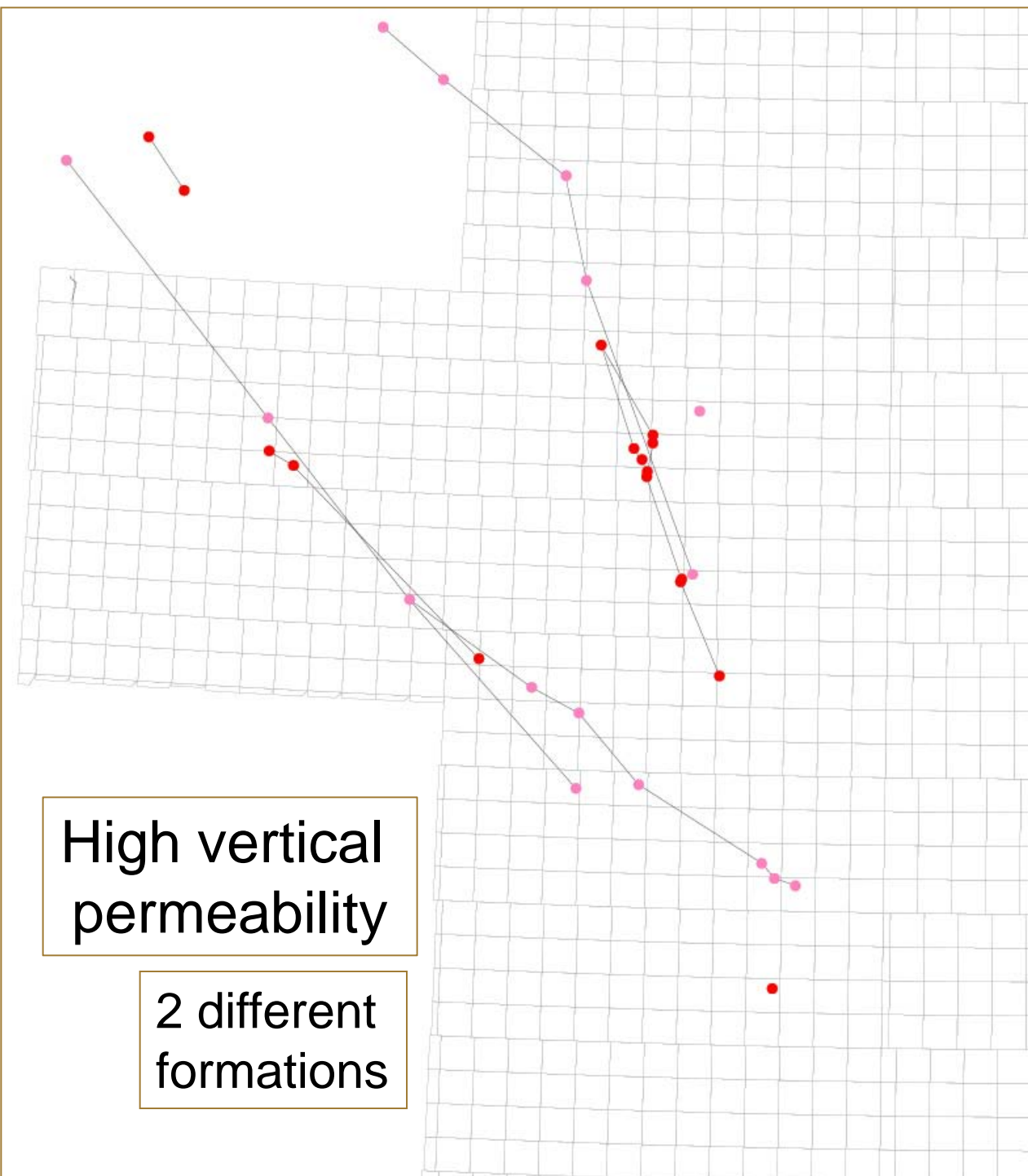
Core plugs are usually taken in unfractured zone  
Data from core plugs will thus not represent faithfully units with fractures

Vertical permeability  
>  
Horizontal permeability

Identifying and mapping wells where  $K_v > K_h$  delineates fracture and fault zones

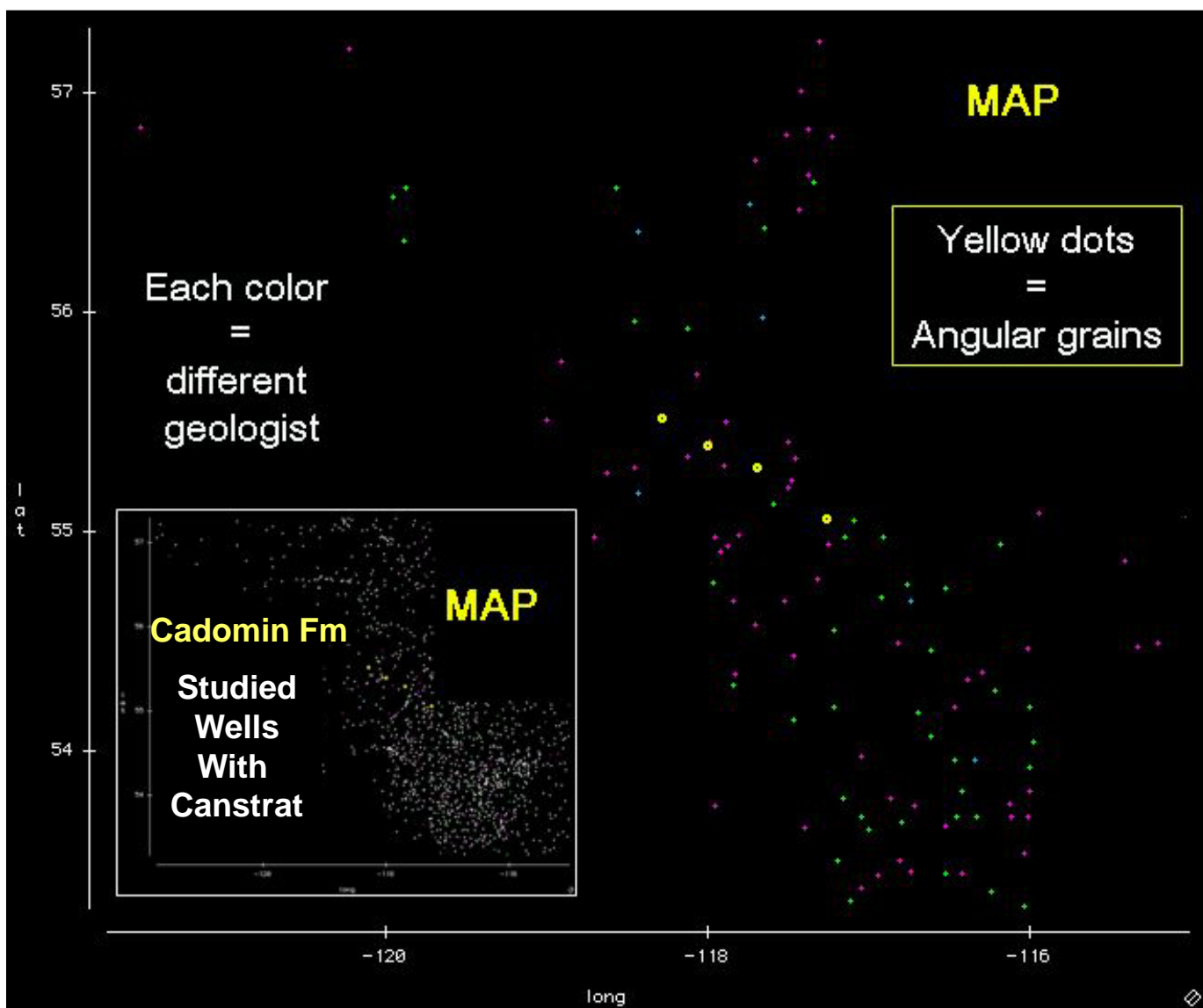


Formations 1 & 2



## Abnormal geomechanical data

Fault activity post sandstone cementation

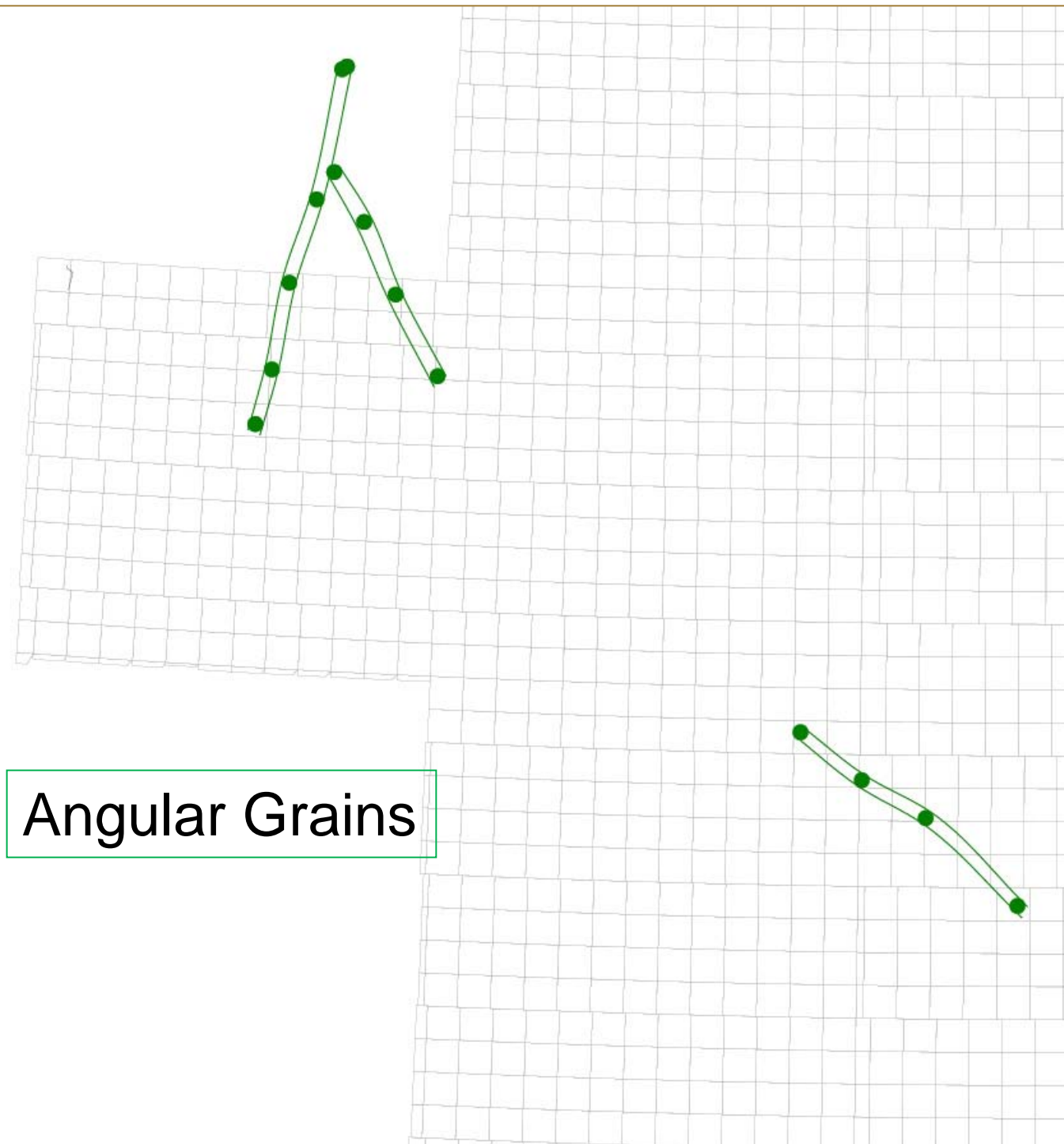


Cadomin Fm  
Angular grains are indicative of shearing post lithification of the Cadomin sediments

Large amount of angular grains have been identified in 4 wells out of 112 described by 3 geologists

For one geologist it was his 39th well in this formation and that area

These 4 wells are perfectly aligned with The Rycroft Fault published by the GSC further to NW (Richards 1994)



Note the North 9 degree alignments

# The Power of Combining Data Sets

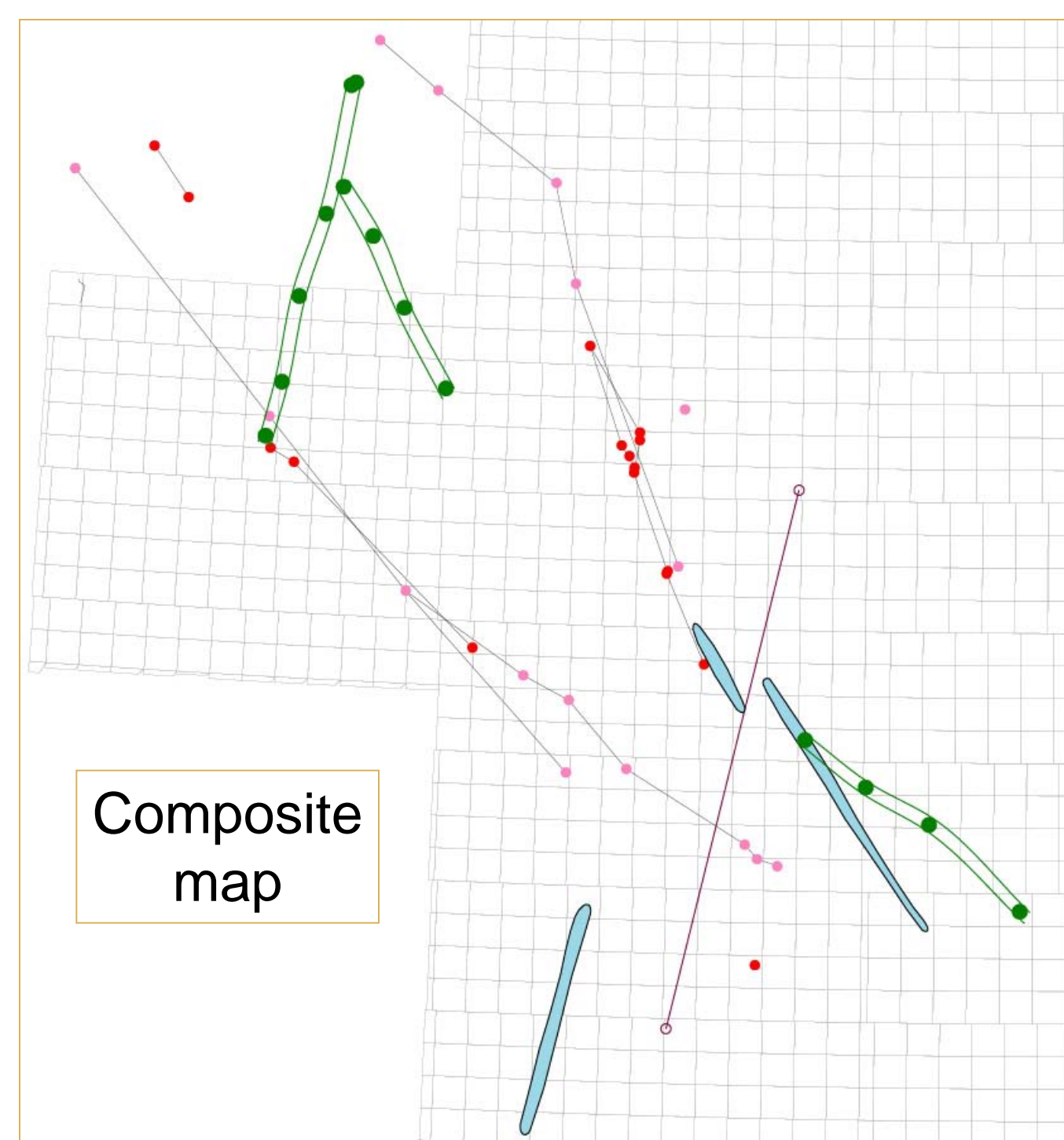
## Combining data sets can give interesting patterns

The **North 9 Degree trend** is outlined by three different sets of observations:

- Pervasive calcite cement
- Hydrocarbon trend
- Angular grains in Cadomin Fm

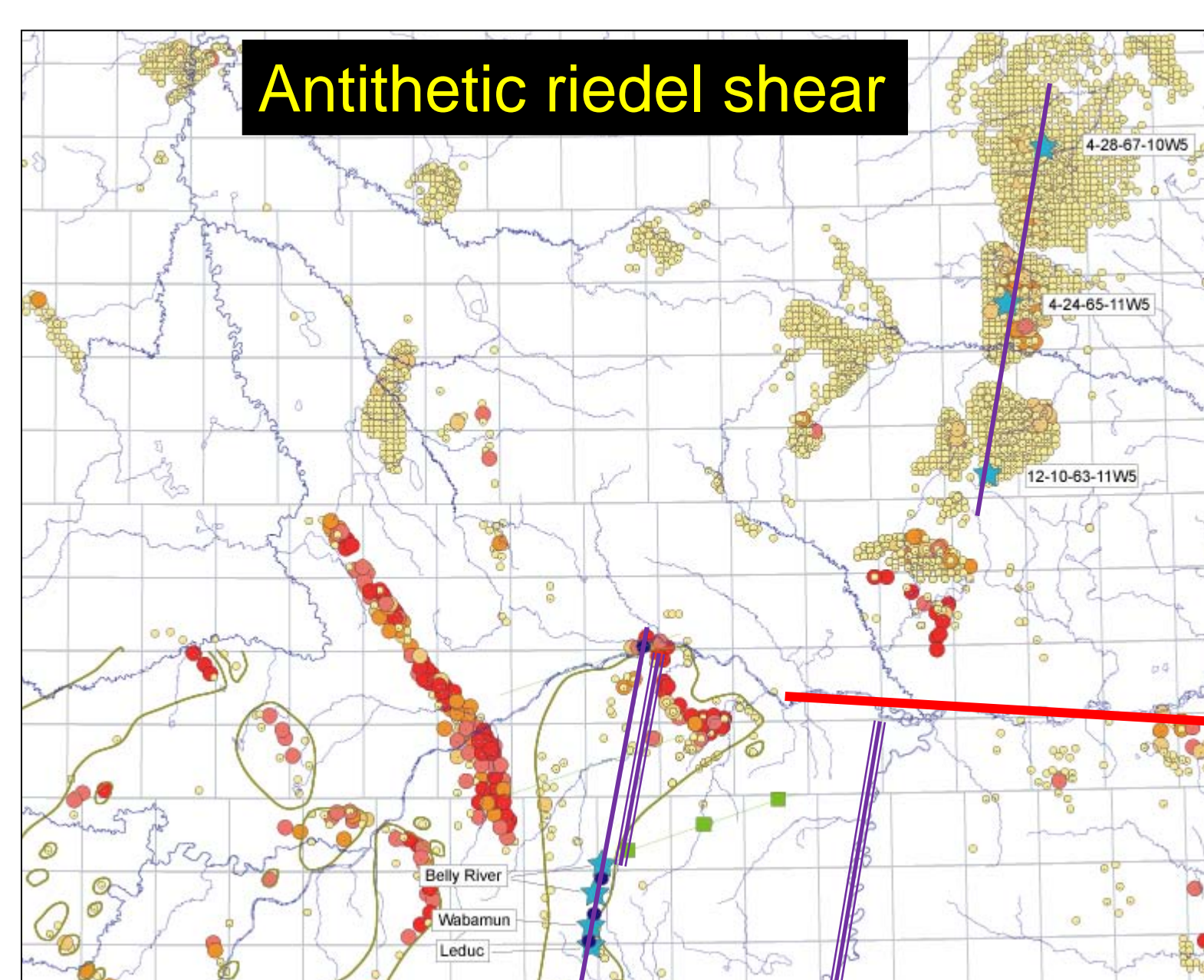
**Cross-Formation** analysis strengthens and validates interpretations

Large scale and **multidisciplinary** studies deliver new horizons for exploration



Note: a North 9 degree trend was first recognized in the Banff Fm (Chatellier, 1992 & 2004)

## Faults and fracture systems as expressed by production behavior

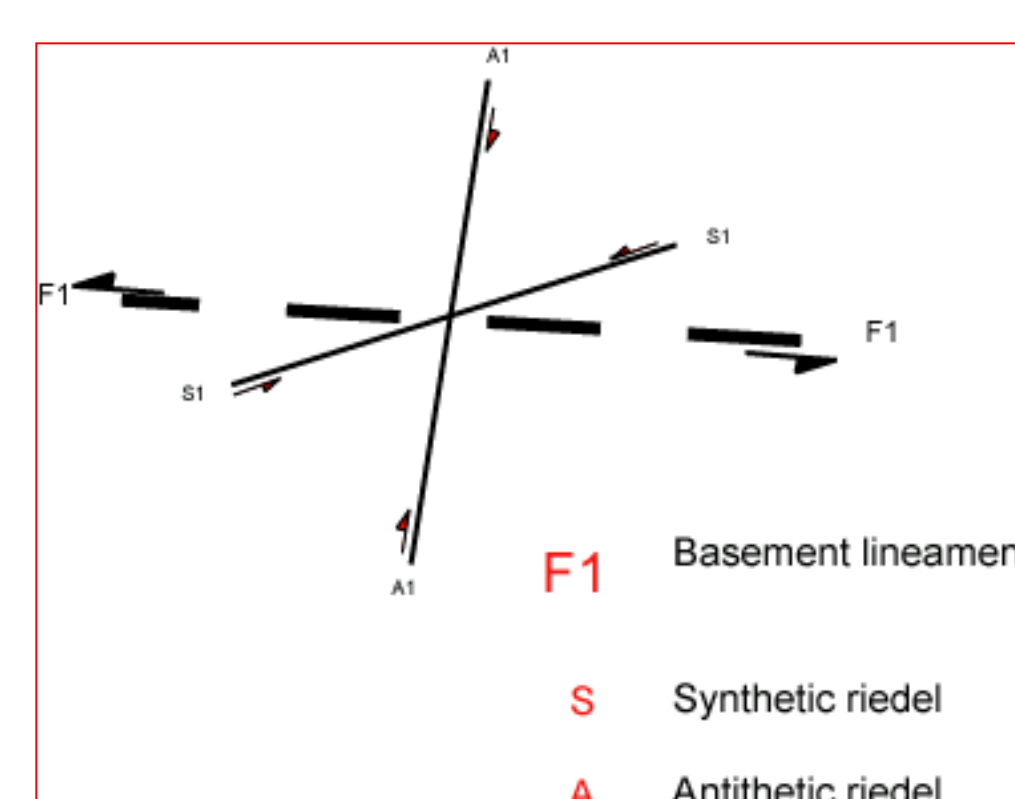


Three sets of lineaments

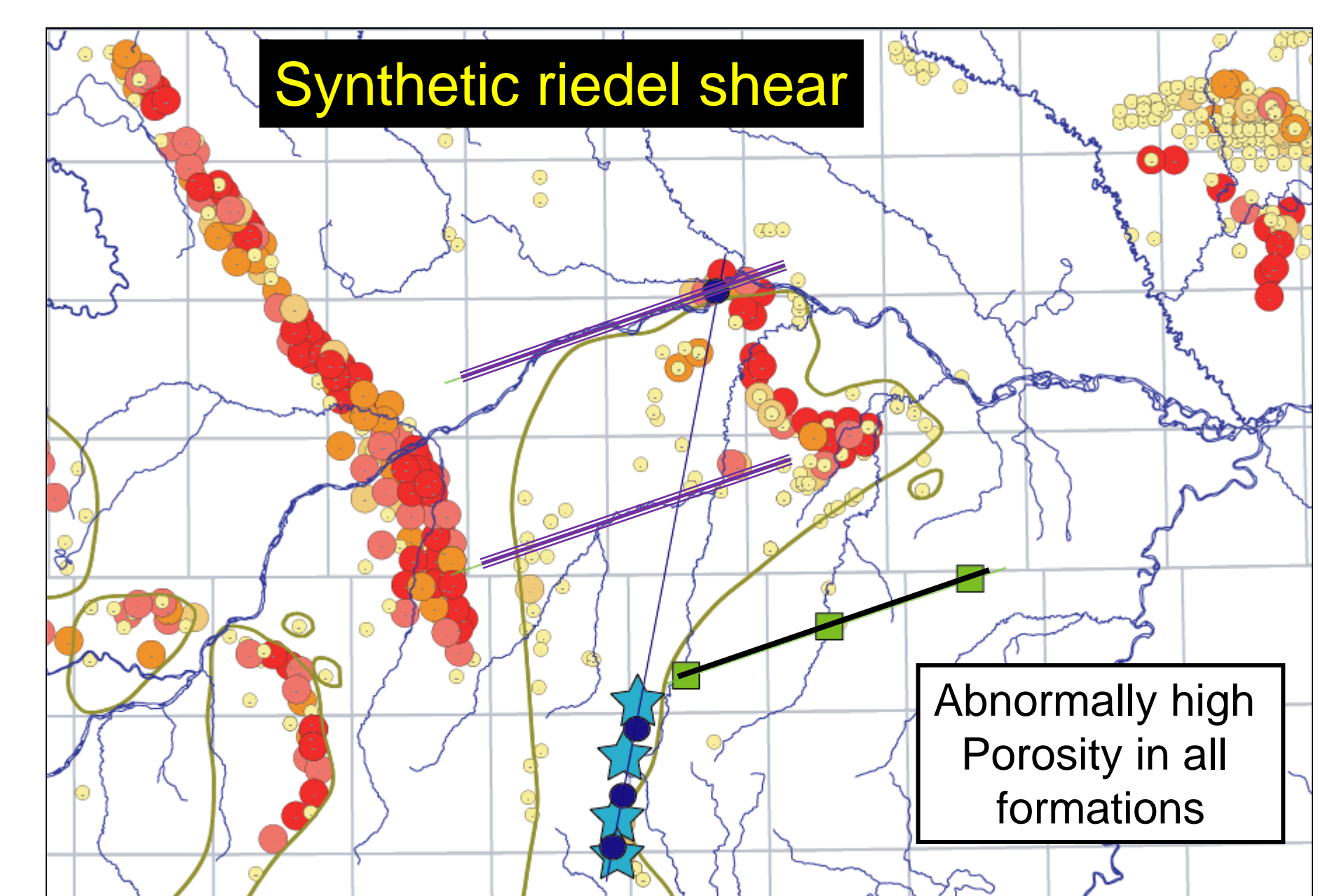
One structural model to explain all three

Major breakthrough in understanding:

- Hydrocarbon distribution
- Production behavior
- Abnormal porosity enhancement
- Linear River patterns

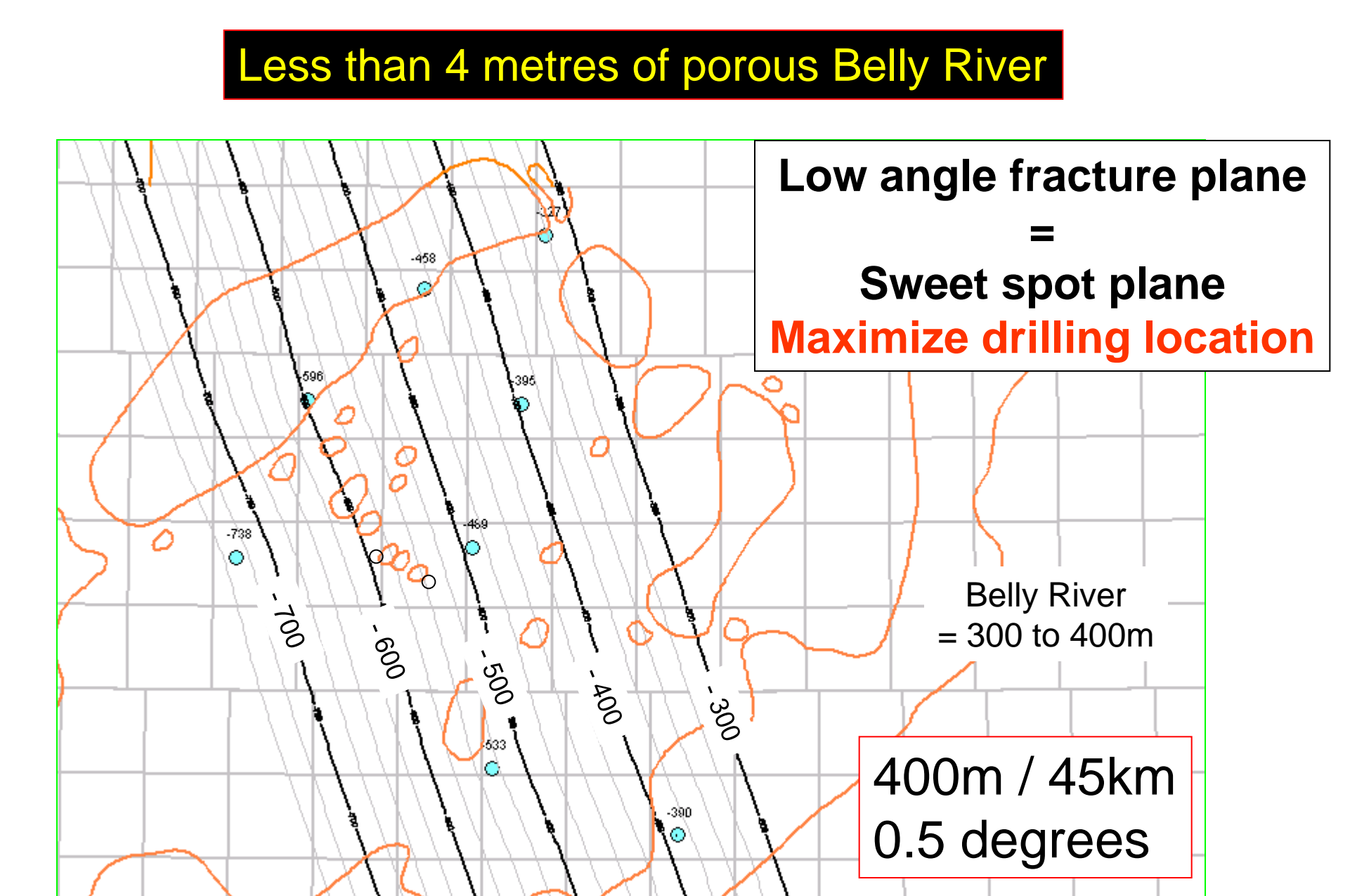


- ★ Extreme water cut (in most cases suddenly)
- Mississippian producers in unexpected locations
- Large porosity enhancement in every formation (fractures)
- Rectilinear river
- Alignment of wells with high water cuts
- Major deep seated fault

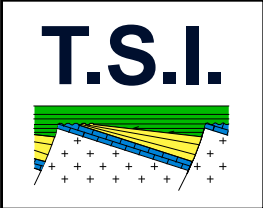


## Fracture planes best expressed in tight areas

- The porous Belly River Sands are only occasionally tight
- 10 wells in the area under study have a maximum of 4m of porous sands (400m gross)
- The porosity steak in 8 of these wells line up perfectly on one plane
- This is a plane characterized by open fractures
- That plane identified in tight zones could be a sweet spot plane in some producing fields

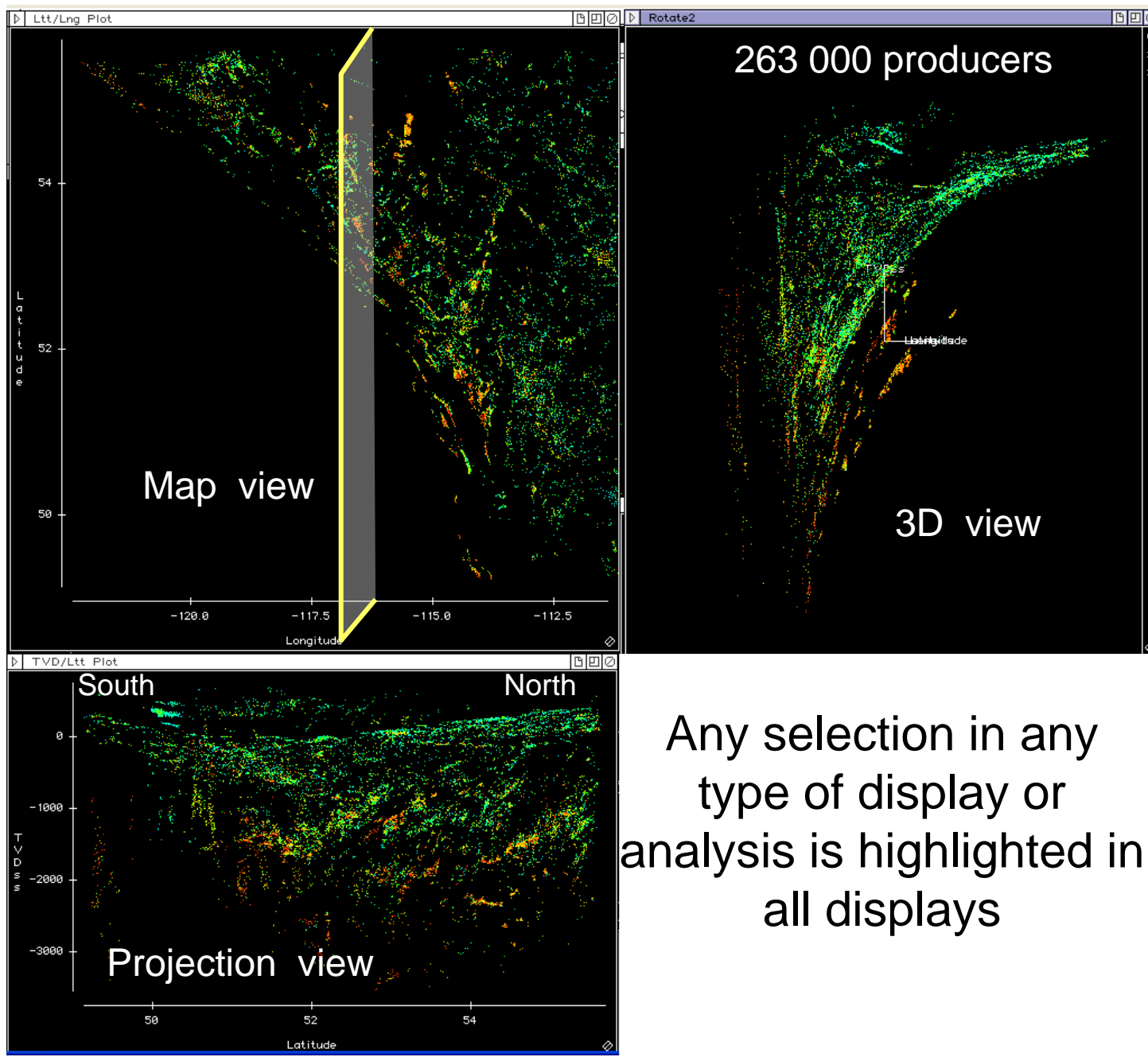


- Anomaly approach
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- 4-D integration



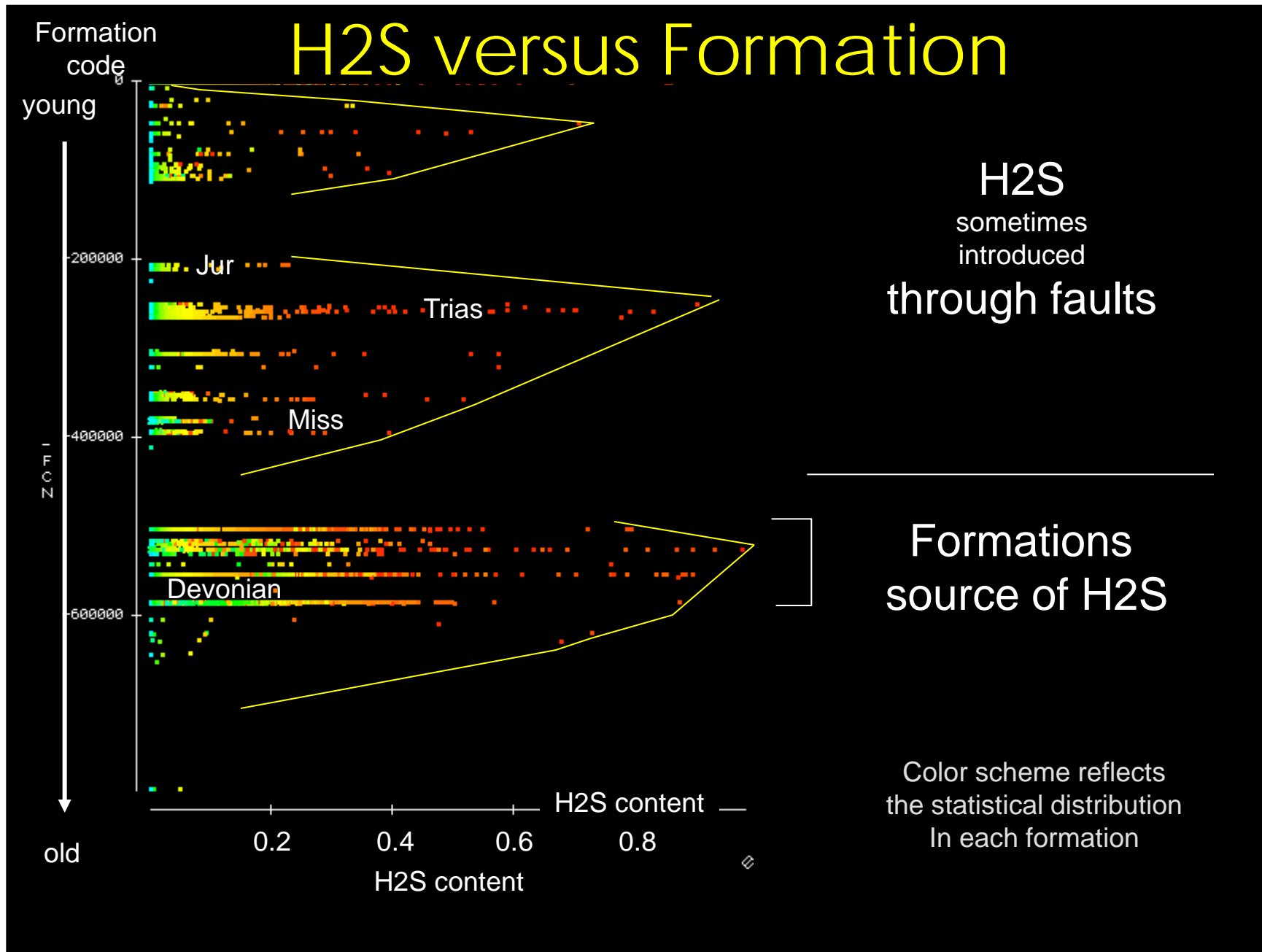
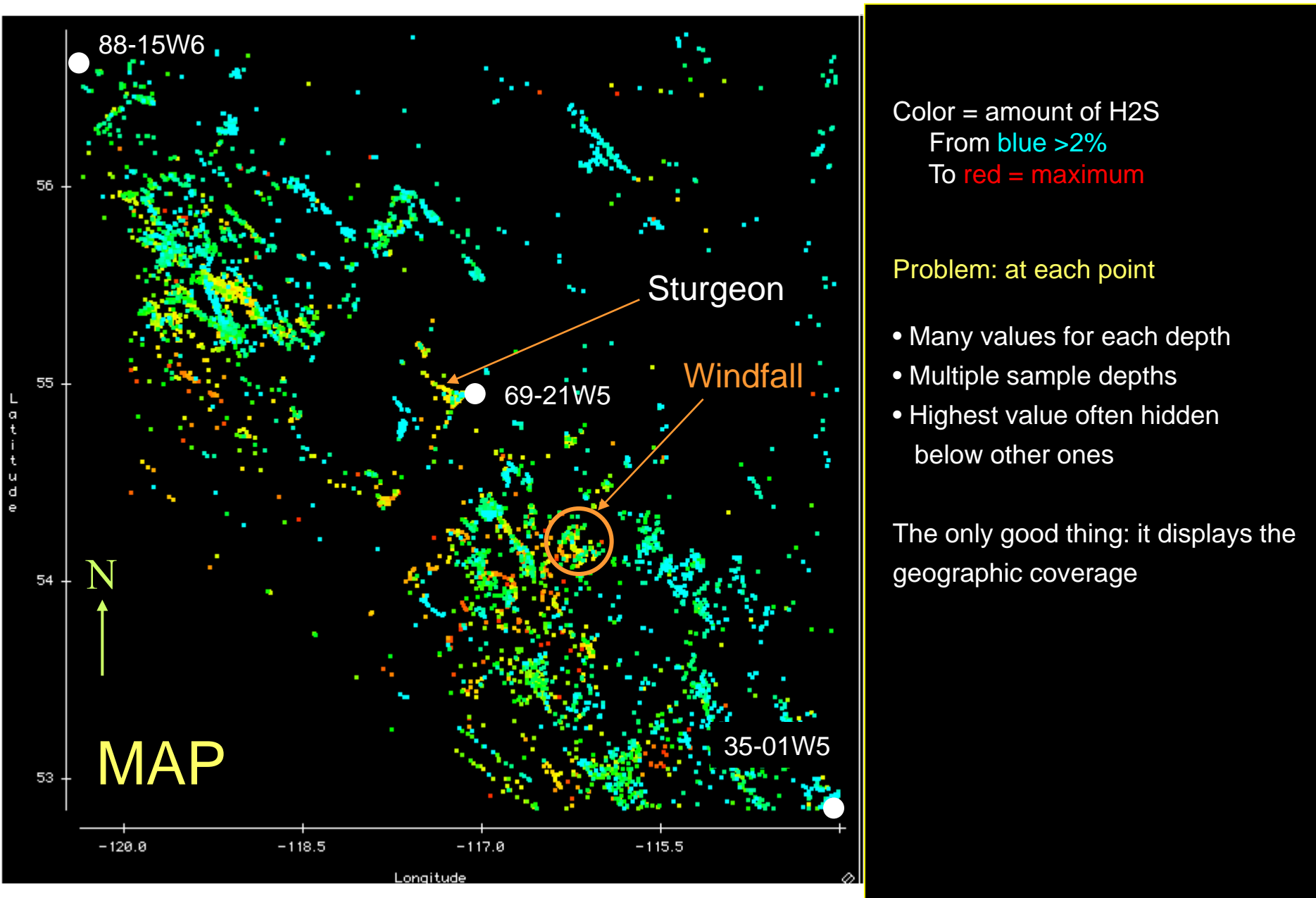
# Fractures and Faults as seen by Gas Composition

## Fault planes and fracture networks defined by H2S anomalies



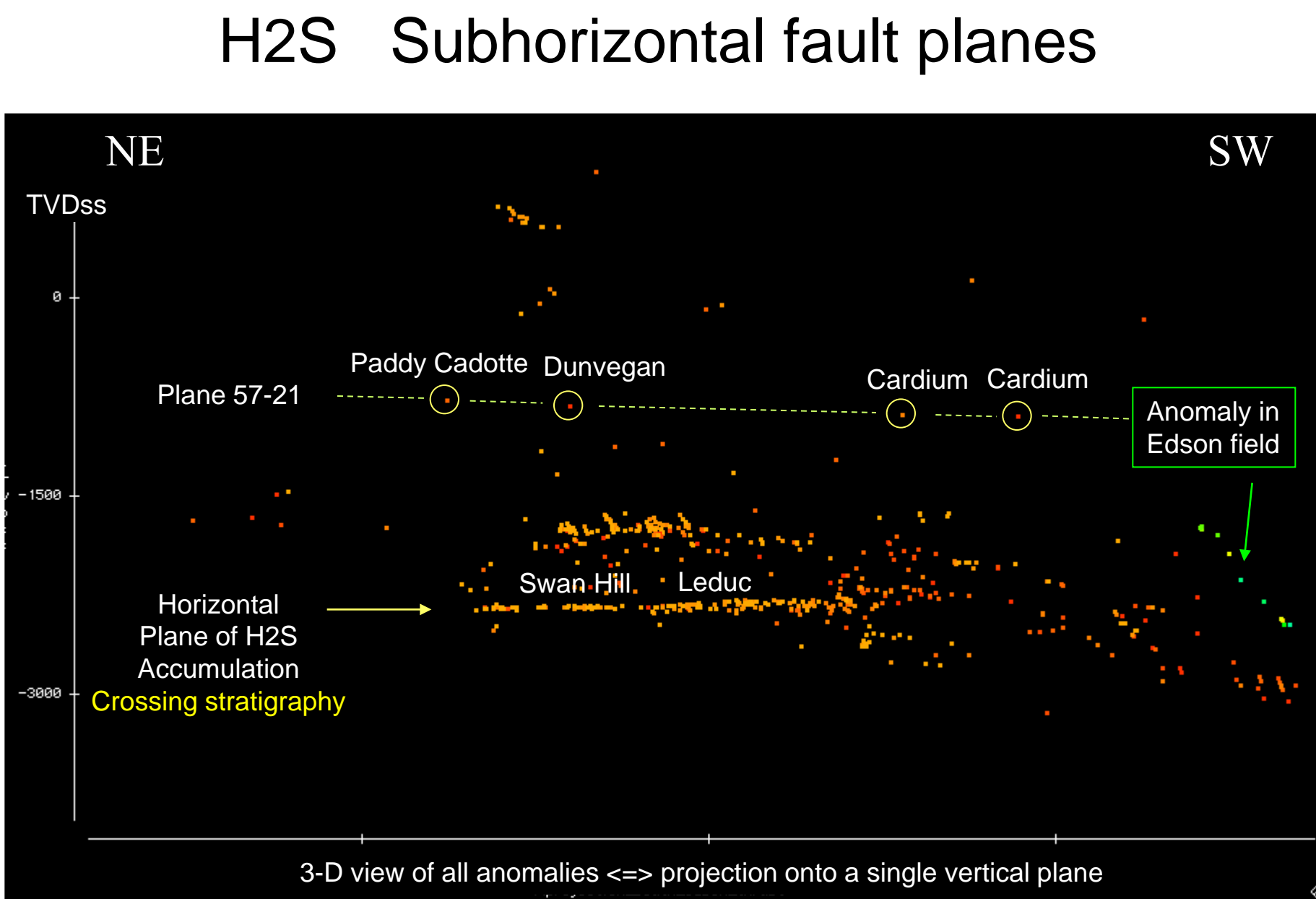
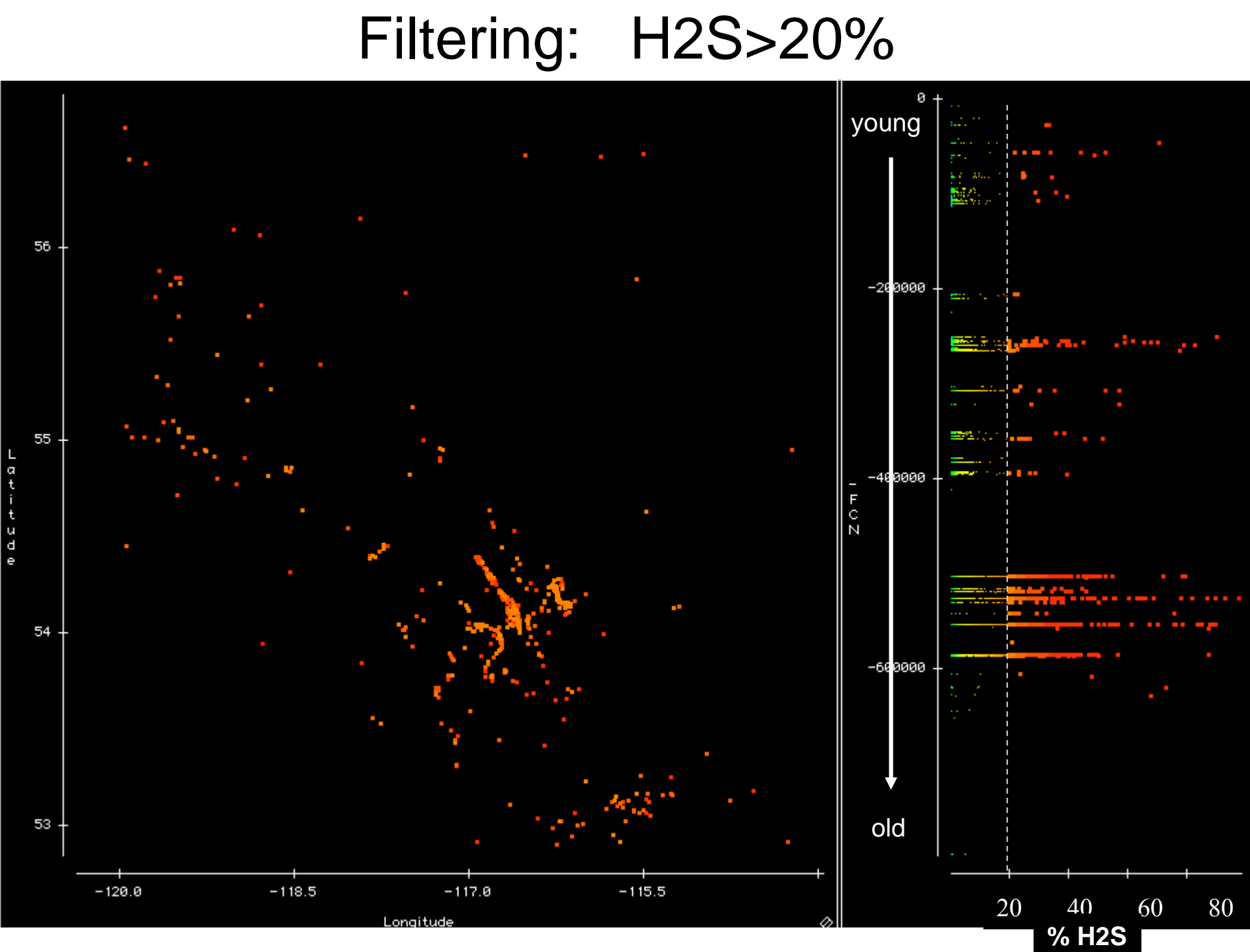
Three different common views generated by a 3-D exploratory statistical software.  
All of the data is plotted in each display

Large map of Alberta, from township 35 to 88.  
Filter for wells with any H2S>2% occurrence  
The color corresponds to the H2S content



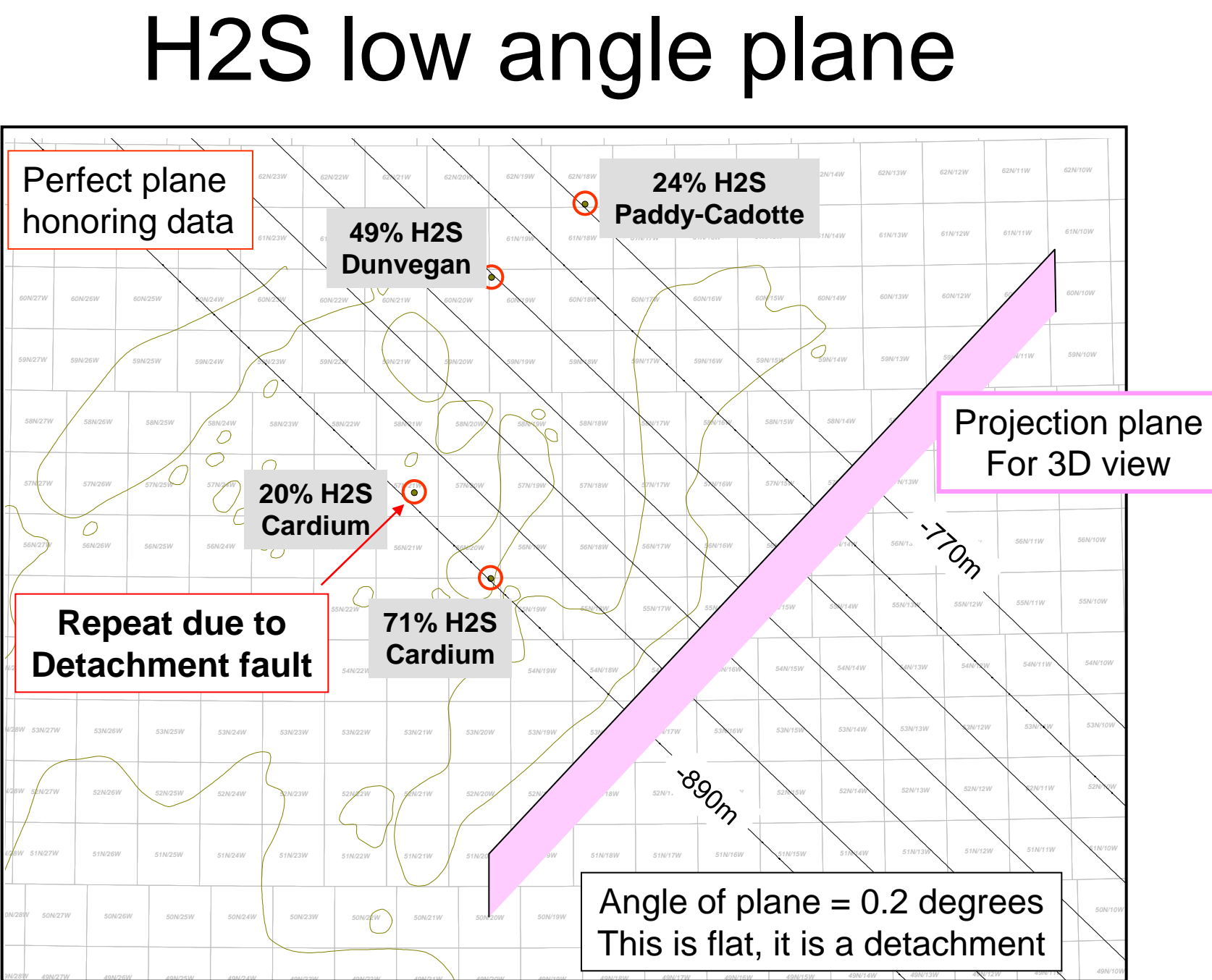
The Devonian and possibly some formations of the Triassic have been generating H2S,  
The other H2S occurrences may result from the migration of gasses via fractures and faults

The same view with values of H2S greater than 20%  
Note some reefs and some linear patterns shown in the H2S map

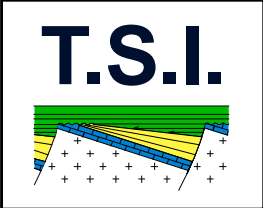


Note the very horizontal distribution of H2S crossing stratigraphy  
From the Swan Hill of Kaybob to the Leduc of Pine Creek

A map view of the shallow H2S very low angle plane  
Slope = 100 meters in 35 km  
Note that the direction of the plane of projection is the direction of today's stress

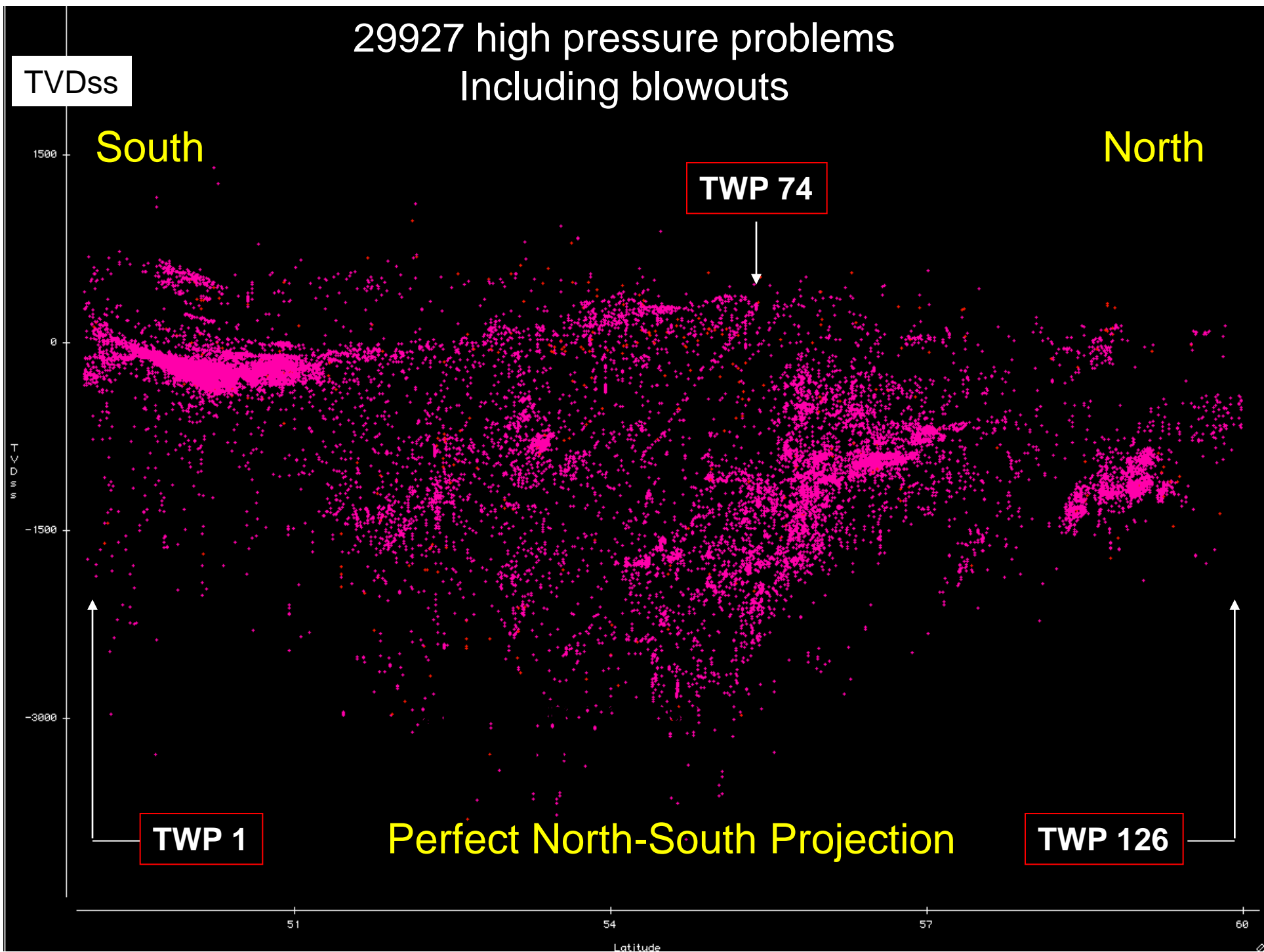


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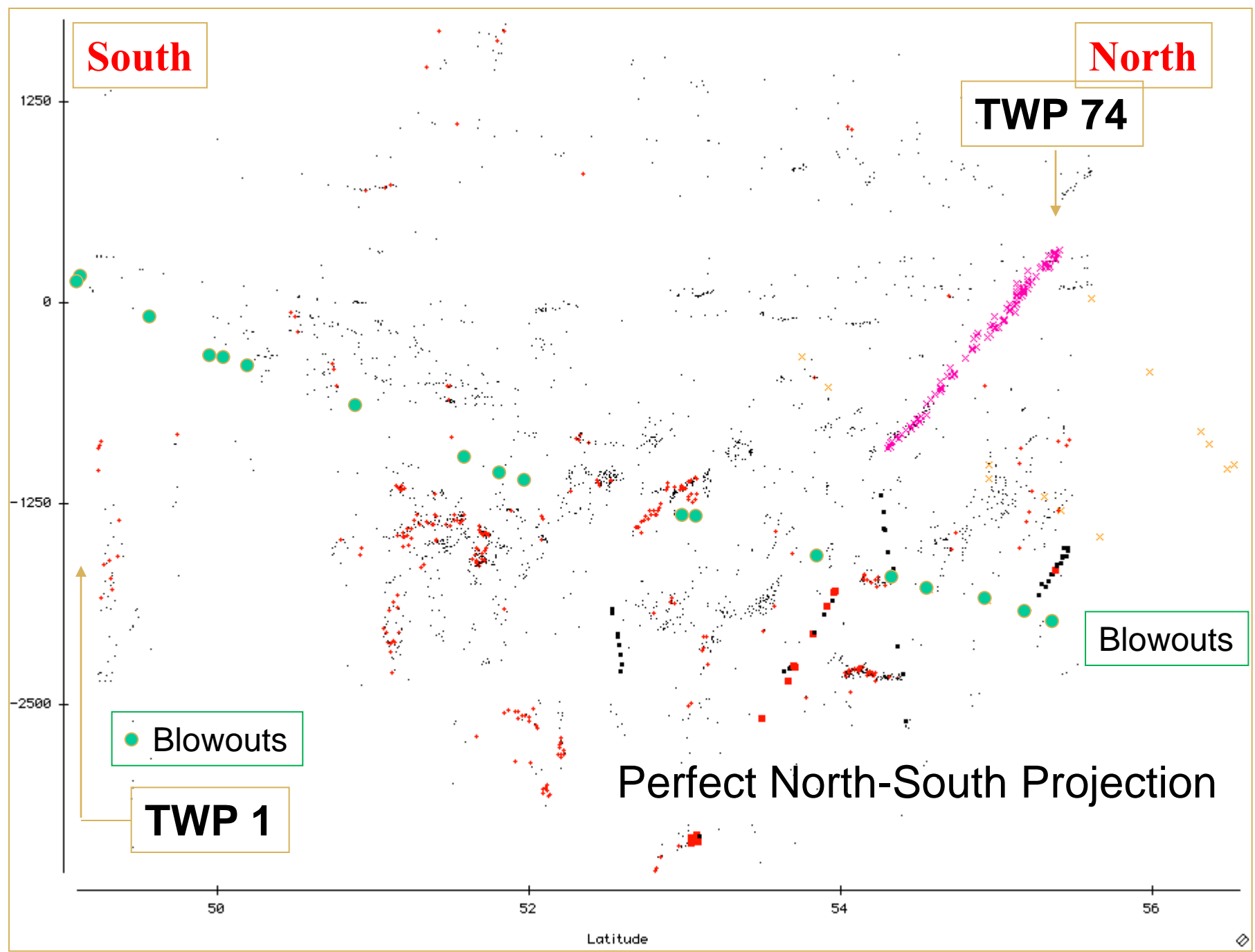
# Abnormal pressures and abnormal porosities

## Pressure problems



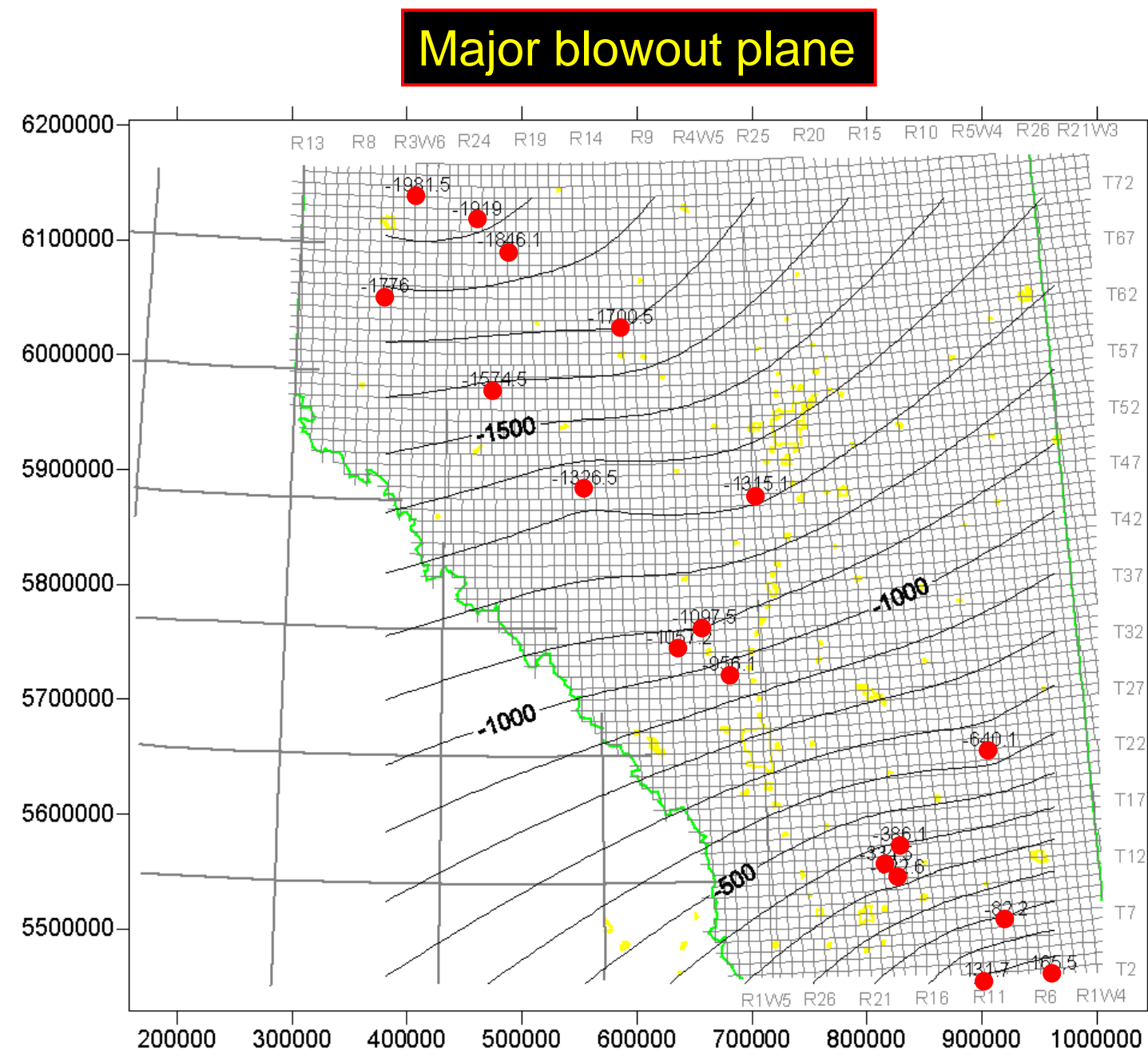
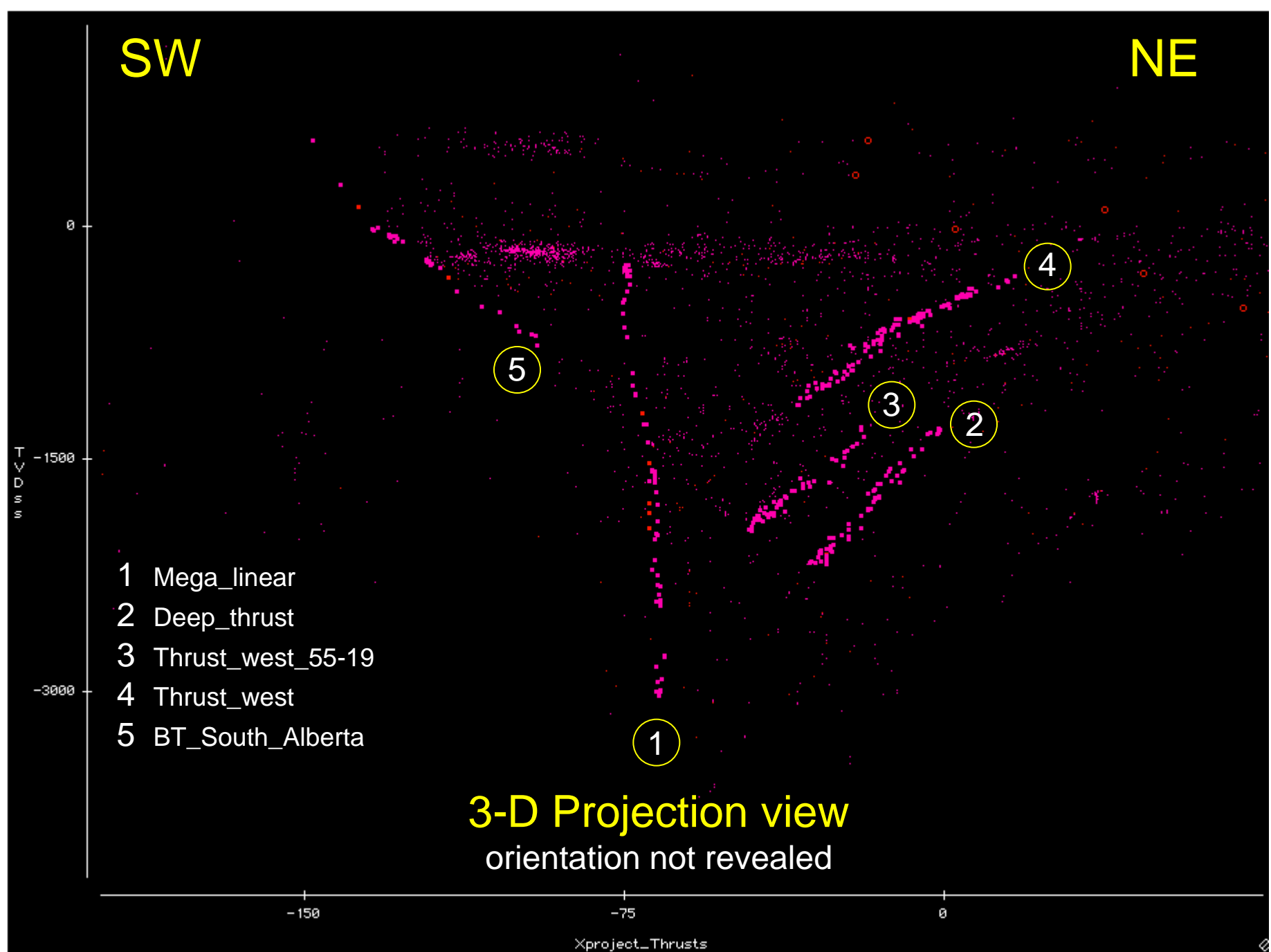
3-D analysis of high pressures and blow-out occurrences reveals the existence of major fault planes and fracture networks

The plane outlined on the projection view to the left is extremely extensive from British Columbia to Saskatchewan; encompasses 101 wells; however large areas on that plane do not exhibit any high pressure; if there is no gas in the area, there is no high pressure problems.



A 3-D analysis of high pressures and blow-out occurrences reveals the existence of major fault planes and fracture networks

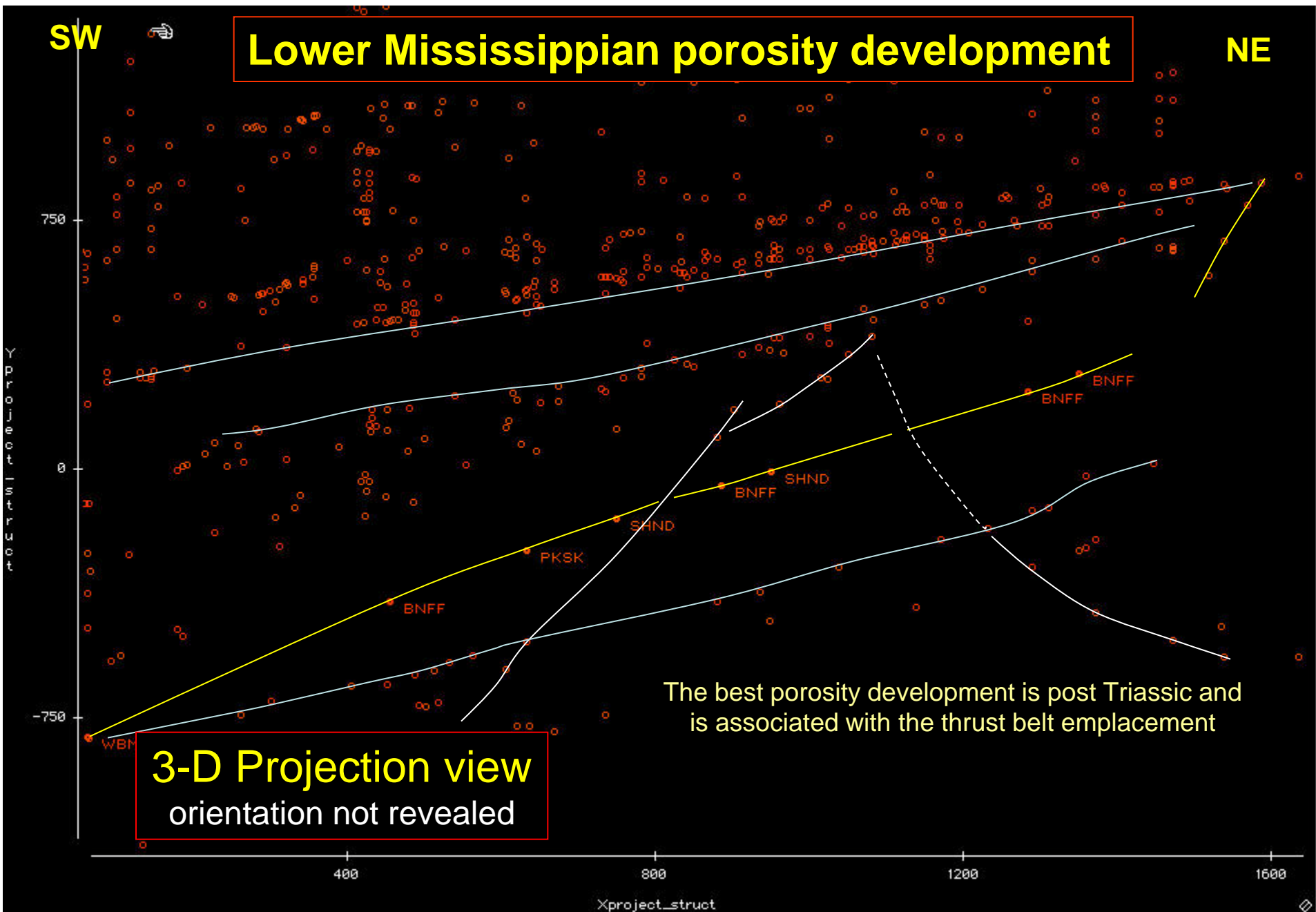
Eighteen blowout occurrences are aligned on a major plane. It is seen on a north south projection (left diagram) and has been mapped across a large area in Alberta (right diagram)



## Step 1

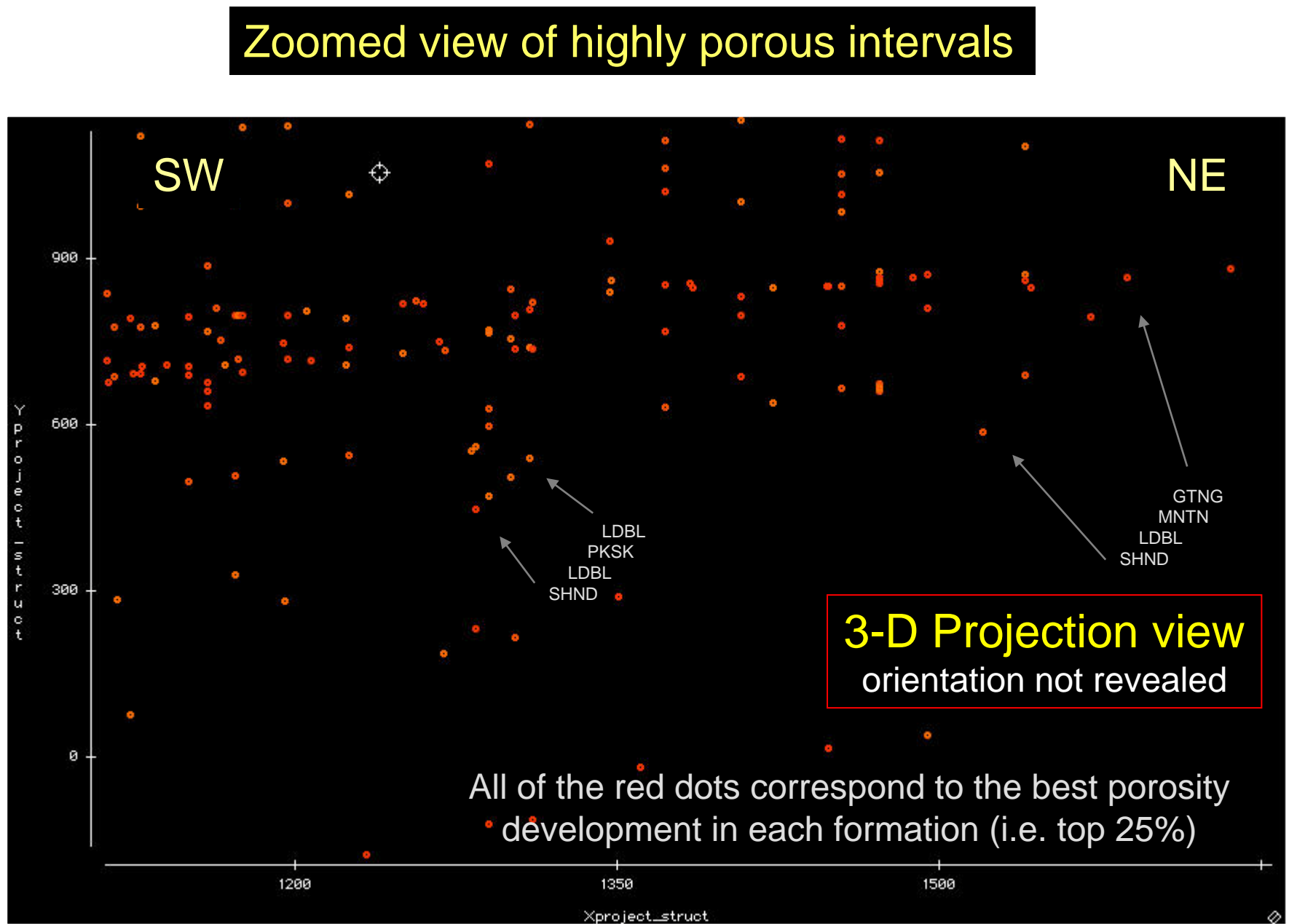
Normalizing porosity thickness to the statistical distribution of each formation

(some formations have natural very high Net-to-Gross whereas other are essentially non-porous)



## Abnormal porosity

All of the data shown corresponds to top 3% most porous



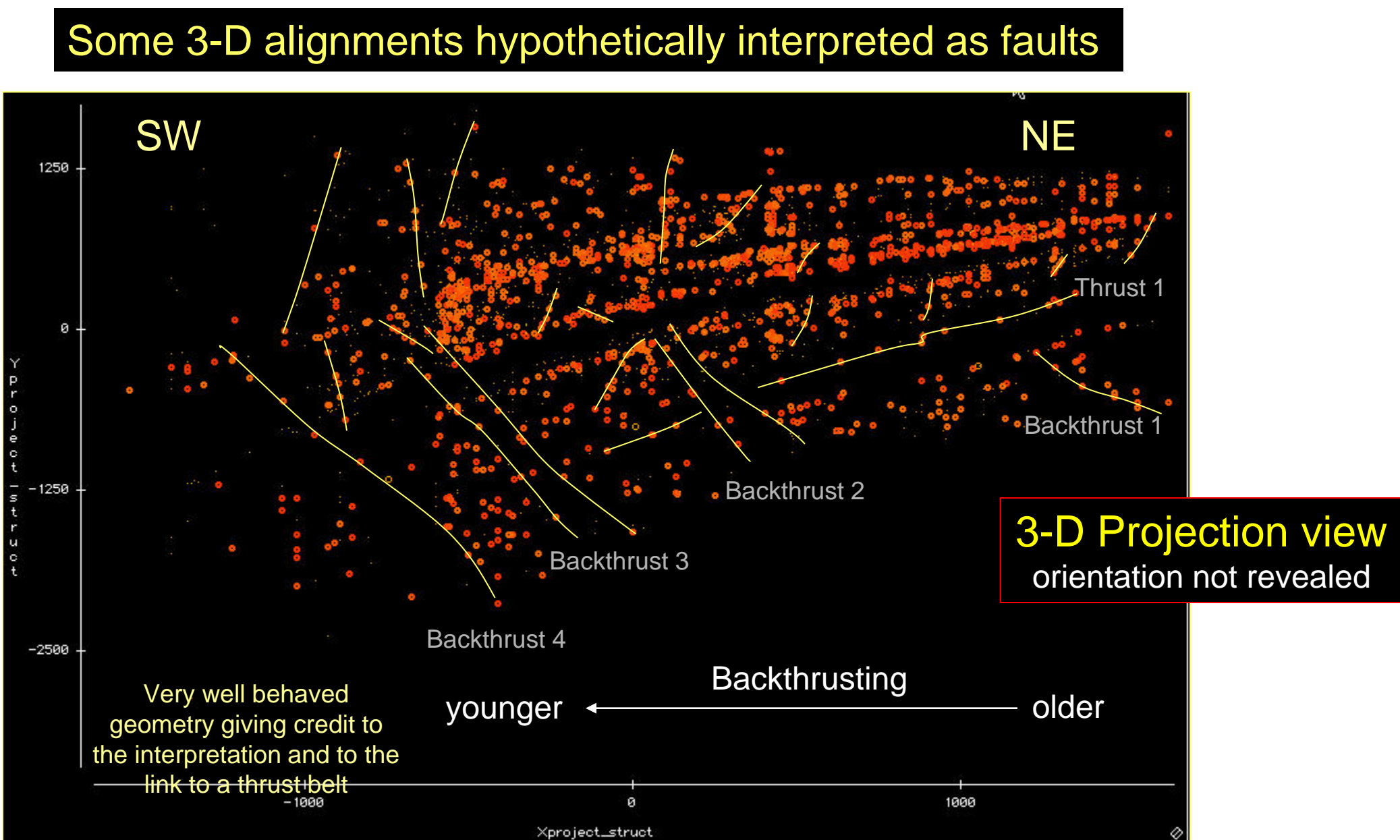
Major fault and fracture planes can be identified and interpreted.

The large amount of wells and of porous units increase the reliability of the interpretation.

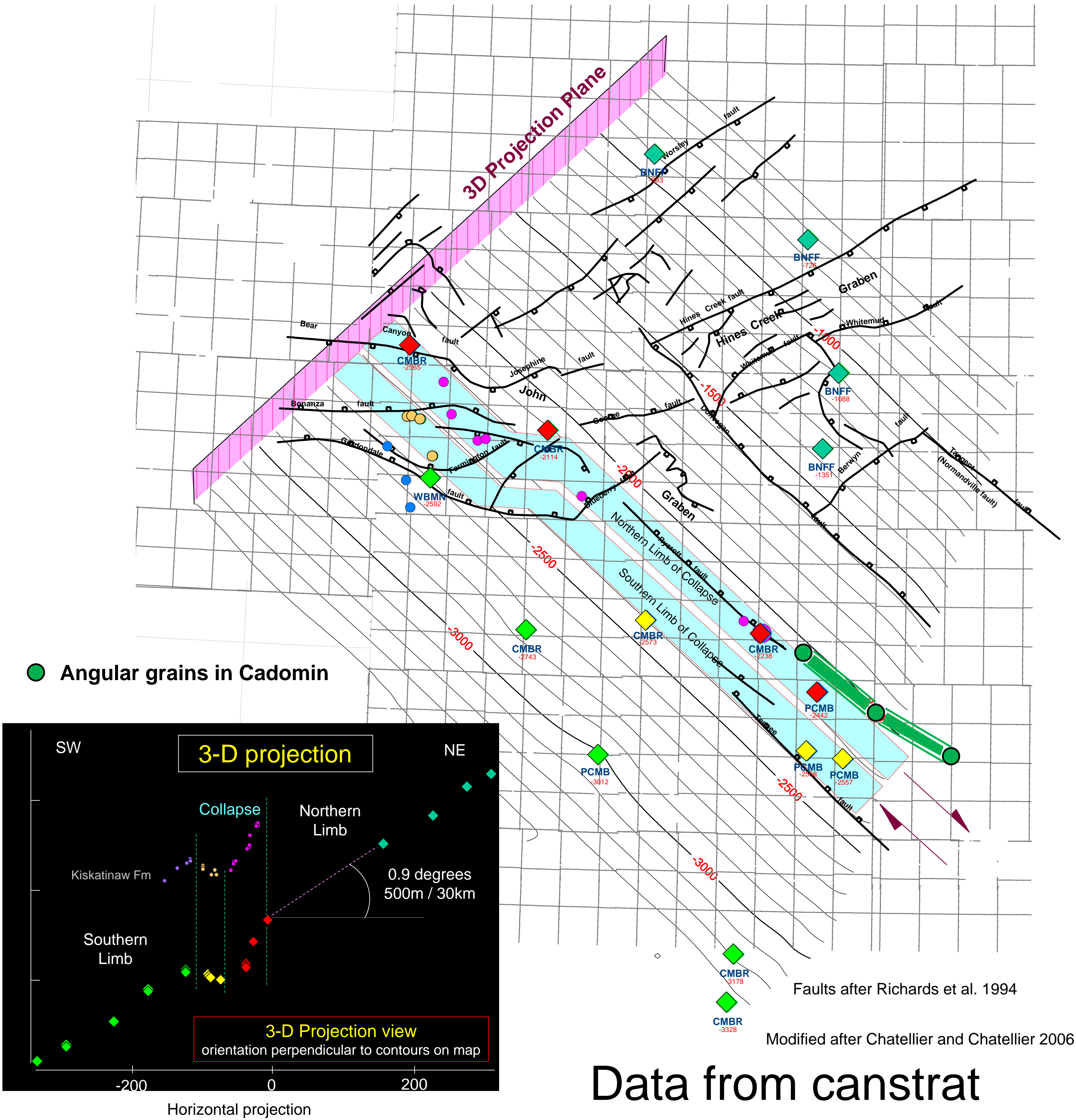
## Step 2

3-D visualization of the most porous class in each of the formation; all formations at the same time

Stepwise introduction of the next classes of highly porous units



# 4-D analysis and timing of migration using cuttings



## Iron rich fluid flow along a fracture network Pattern and timing , a 4-D view

A total of 134 color combinations has been used to described cuttings. Filtering and visualizing some specific red shades of colors has revealed fracture networks that have been the focus of iron-rich water flows.

The light red stains are distributed and aligned in two broken planes exhibiting parallel geometries. The lower fracture plane crosses various stratigraphic units including the Precambrian, Cambrian, Wabamun and Banff. Fractures cross-cutting stratigraphy are best expressed in the Banff formation where the red stain gradually climbs from SW to NE from the lower Banff to the very upper Banff.

Both fracture systems are characterized by a collapse domain interpreted to have taken place after the iron-rich fluid flow.

Integrating with the angular grains Cadomin lineament, we can emit the hypothesis that the collapse may have occurred after Cadomin lithification.

Note: All of the data in this poster is public domain, except for the cuttings data that was provided by Canstrat.

A huge amount of data related to hydrocarbon production is readily available and incredibly valuable but the results are too sensitive to be released.

## Bibliography

Chatellier, J-Y., 1992, Structurally controlled diagenesis of a carbonate ramp (Banff Formation, Alberta, Canada), Sedimentary Geology, Vol. 79, p. 77-90.

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## Conclusions

- 1 • **Anomaly** and **cross-formational** approaches are key to unravel fracture and fault patterns
- 2 • A **multidisciplinary** approach bringing together rock descriptions, petrophysics, fluid types and pressure data is essential
- 3 • **3-D visualization** is vital to understand fractures and faults, especially in foreland basins
- 4 • A **4-D analysis** is the way forward as it can give insight into the sequence of events – a critical mean to validate an interpretation
- 5 • Mature basins and the Western Canadian Basin in particular will give rewards to those who dare to integrate all of the data at hand