# PS Three-Dimensional Organization of Low Angle Fault Planes and Fractures in Alberta - A View of Problems in Wells, Sweet-Spots and Migration Paths*

**Jean-Yves D. Chatellier[1] and Michael Chatellier[2]**

Search and Discovery Article #40977 (2012)**
Posted July 16, 2012

*Adapted from poster presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012


[1]Talisman Energy Inc., Calgary, AB, Canada (jchatellier@talisman-energy.com)
[2]Tecto Sedi Integrated Inc., Calgary, AB, Canada

## Abstract

Multidisciplinary 3D integration can unravel structural elements not described before and can explain various types of unexplained anomalies. The present paper is essentially based on the large amount of public domain data available for the Western Canadian Sedimentary Basin; this includes drilling problems, production anomalies, and abnormal gas occurrences as well as more typical geological data such as cuttings and core descriptions or wireline log data.

Commonly, anomalies aligned on a map are interpreted as linked to subvertical faults or fracture systems. On the other hand, apparently random anomalies remain unexplained as they cannot be linked to any other anomaly or structural feature. Three-dimensional exploration statistical tools can reveal the existence of planar relationships between these individual instances. Many low angle structural planes with less than one degree angle connect many interesting features that can be understood in the structural context of the areas involved.

A 3D study of the southern part of the Peace River Area reveal two main planes connecting many large hydrocarbon producers, these two planes account for 56% of the hydrocarbon production covering a very large acreage (after filtering the very deep Devonian that were too rare and too scattered).

Drilling data is too commonly neglected in a structural analysis; it can be used with some caution because many problems can have been caused by operator mistakes or by consequences of previously solved problems (e.g. too high mud-weight following a gas kick inducing a loss circulation problem). The sheer amount of data available from drilling compensates for this kind of uncertainty. One example from West

Central Alberta will show that some 40 planes connecting drilling problems coherently plot on a Schmidt diagram with great circles at 90 degrees from each other.

One example of abnormal porosity spikes delivers a near perfect low angle plane that is totally in line with today's compressional stress regime orientation. Other examples will show the use of gas composition anomalies such as $H_2S$ and a case of abnormal red stain in cuttings that shed new light on the structural history of the Peace River area. Combining data of different kinds brings down the uncertainty linked to the proposed planar relationships.

# Three-Dimensional Organization of Low Angle Fault Planes and Fractures in Alberta

## A view of Problems in Wells, Sweet-Spots and Migration Paths

Using only Alberta released data – cut-off date Dec 31st 2003

## Abstract


**Multidisciplinary 3-D integration** can unravel structural elements not described before and can explain various types of unexplained anomalies. The present paper is essentially based on the large amount of **public domain data** available for the Western Canadian Sedimentary Basin; this includes drilling problems, production anomalies, abnormal gas occurrences as well as more typical geological data such as cuttings and core descriptions.

Commonly, anomalies aligned on a map are interpreted as linked to subvertical faults or fracture systems. On the other hand, apparently random anomalies remain unexplained as they cannot be linked to any other anomaly or structural feature. **Three-dimensional exploration statistical tools** can reveal the existence of planar relationships between these individual instances. **Low angle structural planes** commonly with less than one degree angle connect many interesting features that can be understood in the structural context of the areas involved.

A local 3-D study within the **Peace River Area** reveals two main planes connecting **many large hydrocarbon producers**, these two planes account for 56% of the hydrocarbon production covering a very large acreage (after filtering the very deep Devonian that were too rare and too scattered).

**Drilling data** is too commonly neglected in a structural analysis, it can be used with some caution because many problems can have been caused by operator mistakes or by consequences of previously solved problems (e.g. too high mud-weight following a gas kick inducing a loss circulation problem). The sheer **amount of data** available from drilling compensates for this kind of uncertainty. One example from **West Central Alberta** will show that some 40 planes connecting drilling problems coherently plot on a Schmidt diagram with a direct link to great circles at 90 degrees from each other.

Other examples will show the use of **gas composition anomalies** such as **$H_2S$**. Combining data of different kind brings down the uncertainty linked to the proposed planar relationships.


## Keywords


- Cross-formational approach
- Anomaly approach
- 3-D exploratory statistics
- Big hydrocarbon producers



**Jean-Yves Chatellier ***
Tecto Sedi Integrated Inc. Calgary
jchatellier@shaw.ca

**Michael Chatellier**
Tecto Sedi Integrated Inc. Calgary



**Acknowledgments:**

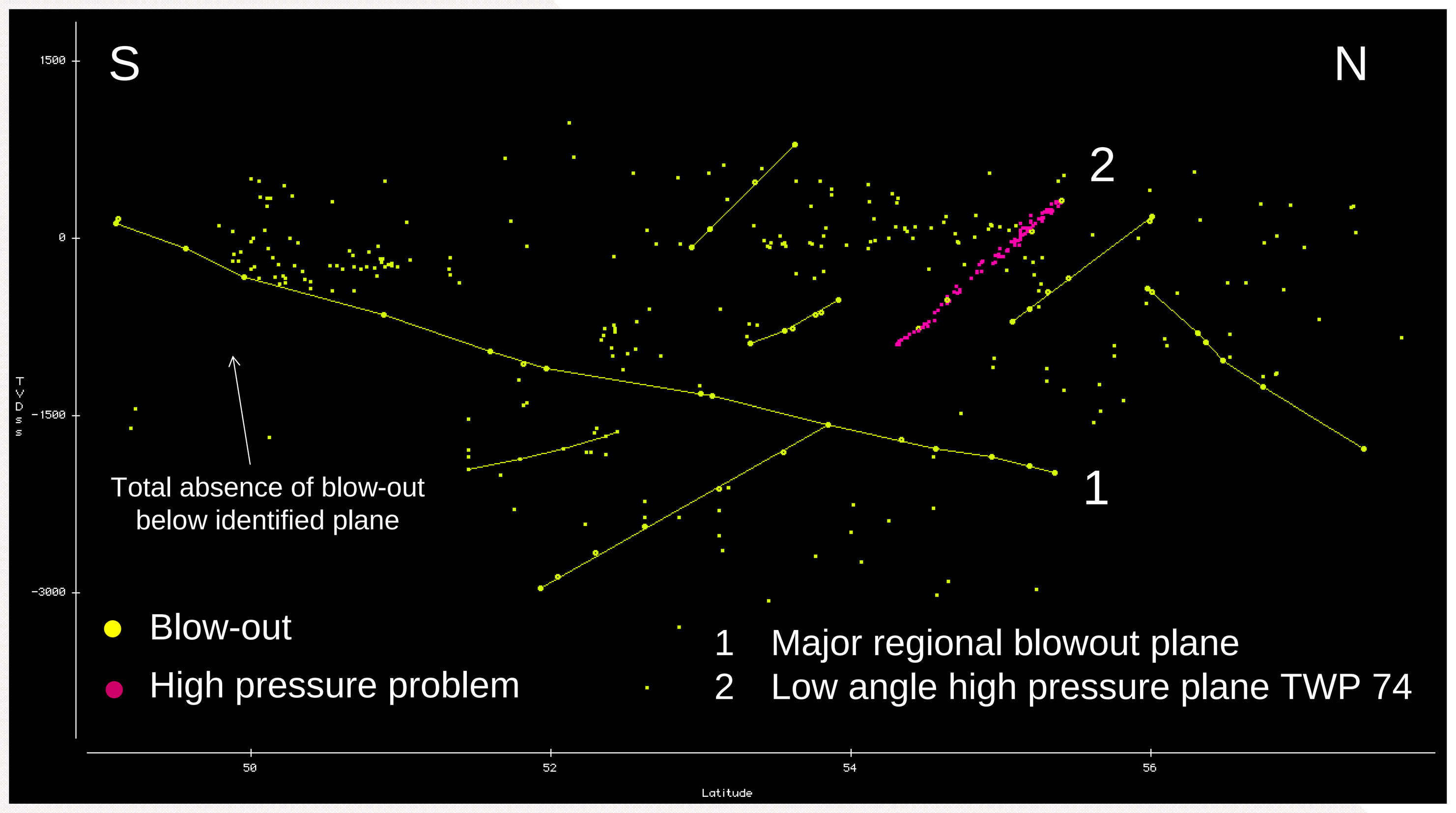
Thanks to Talisman Energy Inc. for permission to present the material from this poster



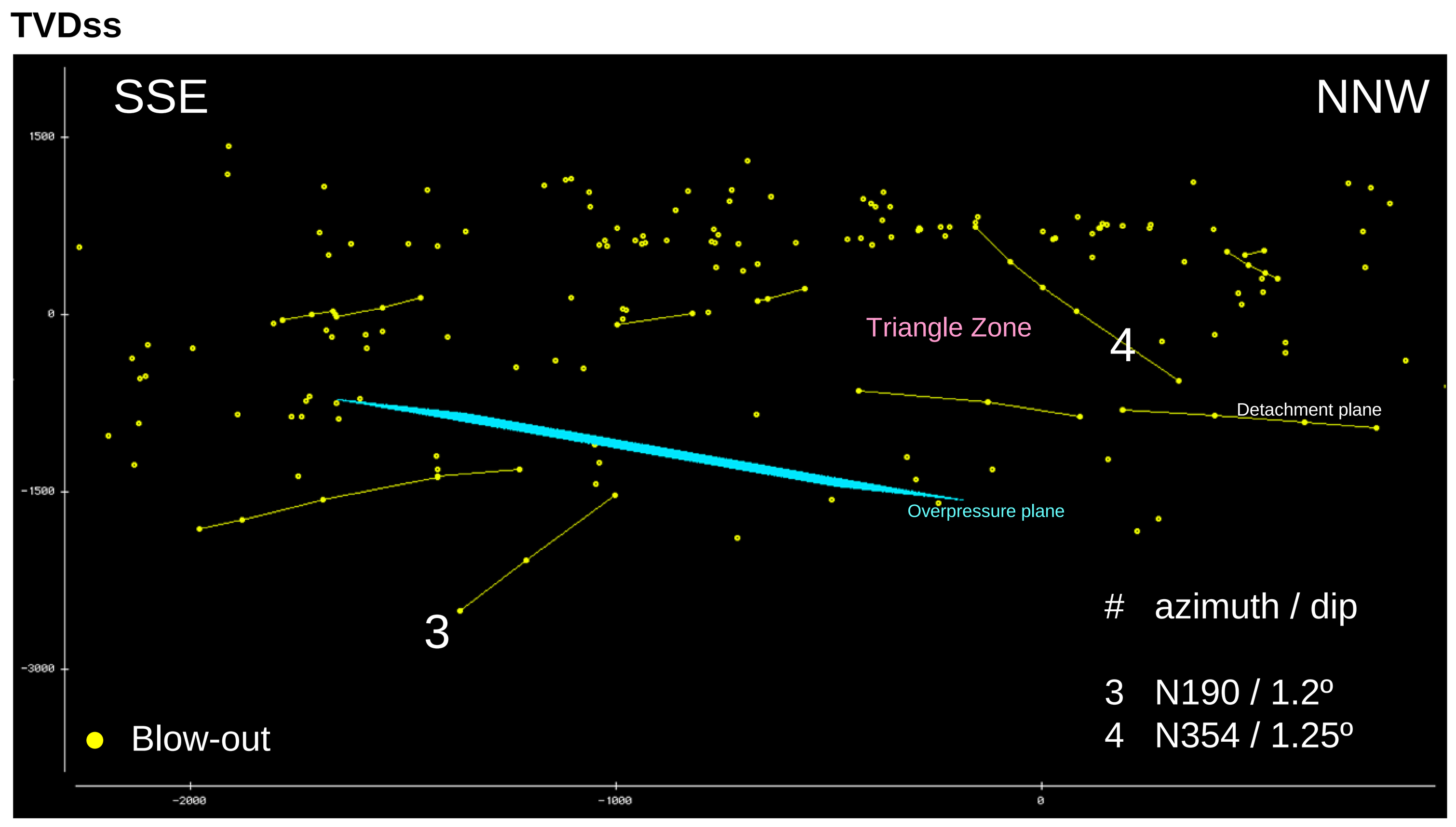
* Presently with Talisman Energy Inc.

# High pressure and blow-out low angle planes

**North-South projection of all blow out problems in wells**



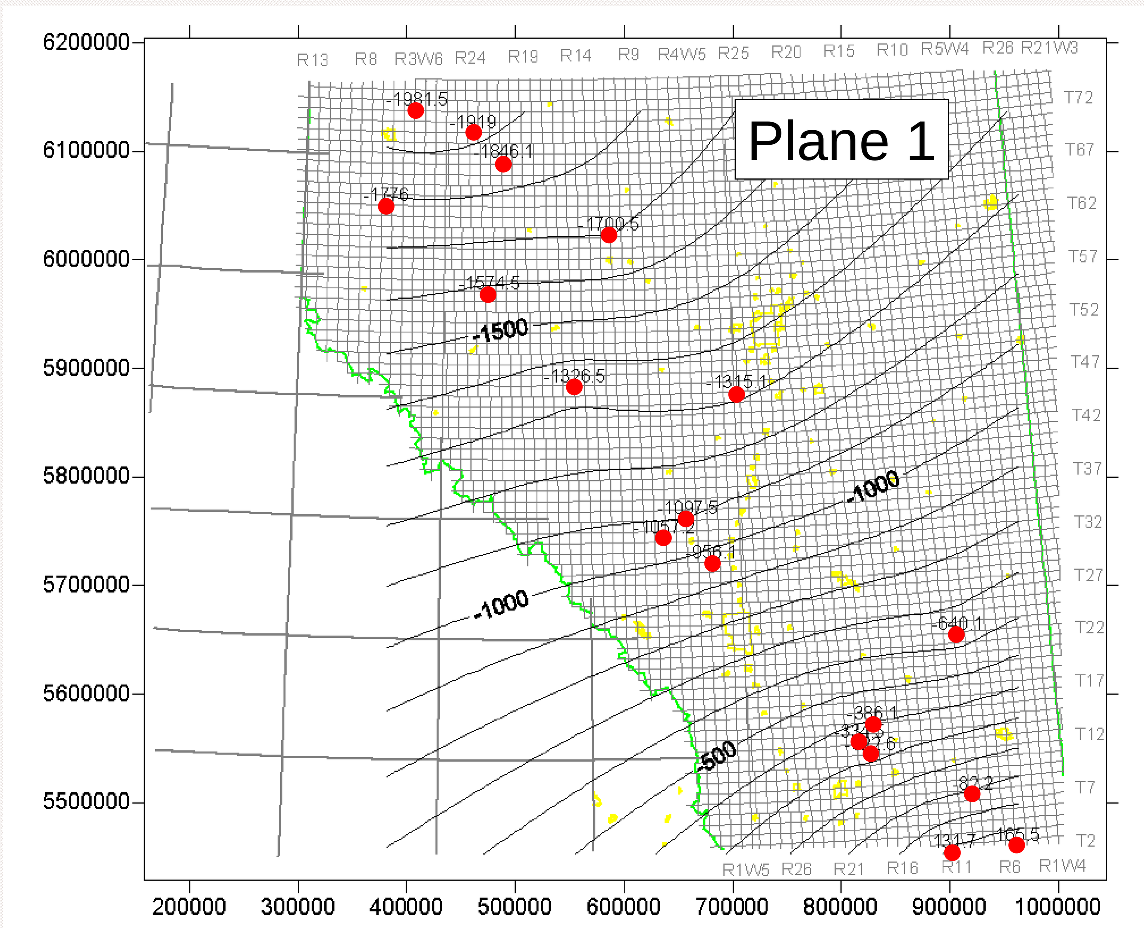

**Zoomed and rotated projection of blow out problems in wells**



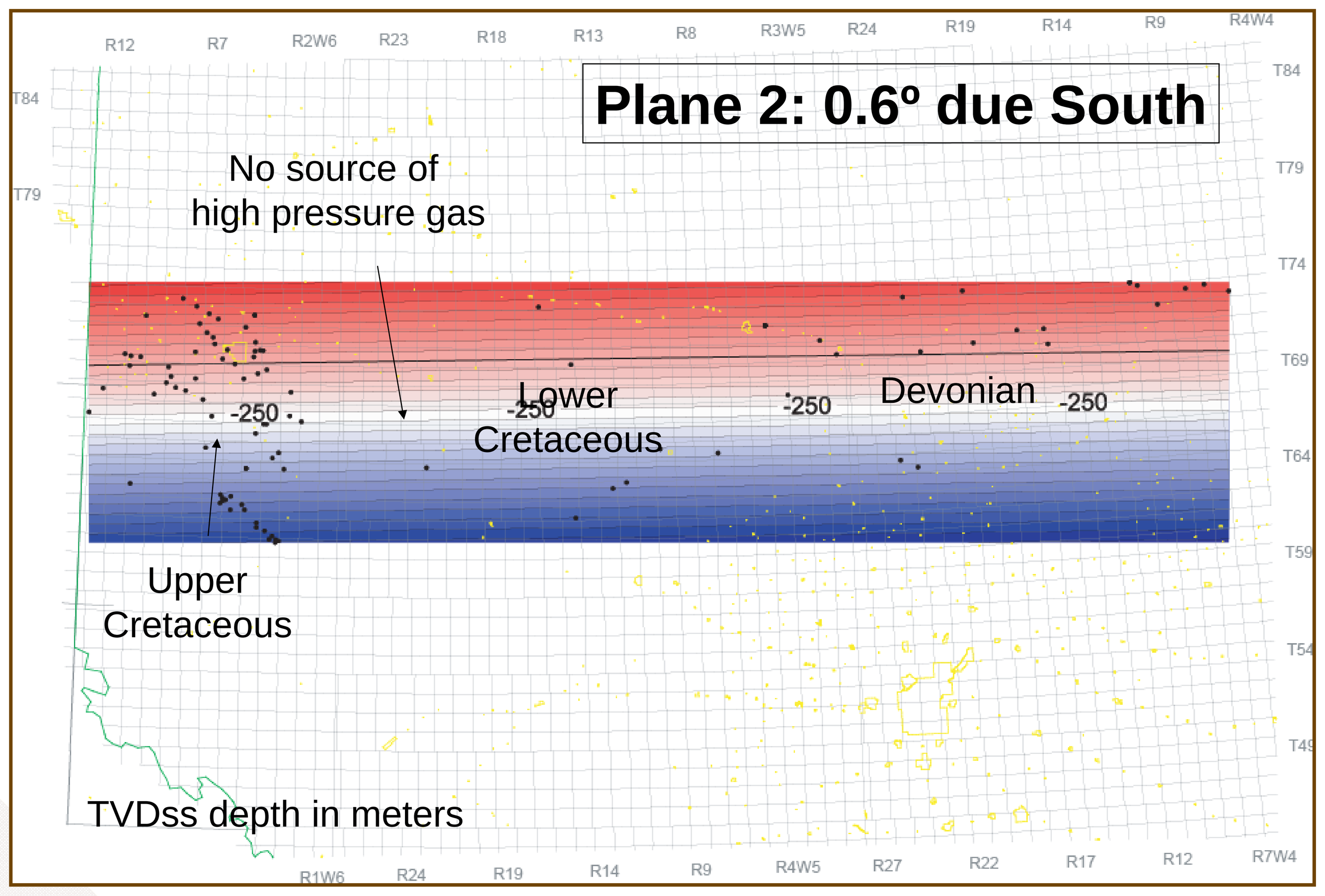

**3-D Projection**

Blow-outs aligned on planes

**Major regional blowout plane**

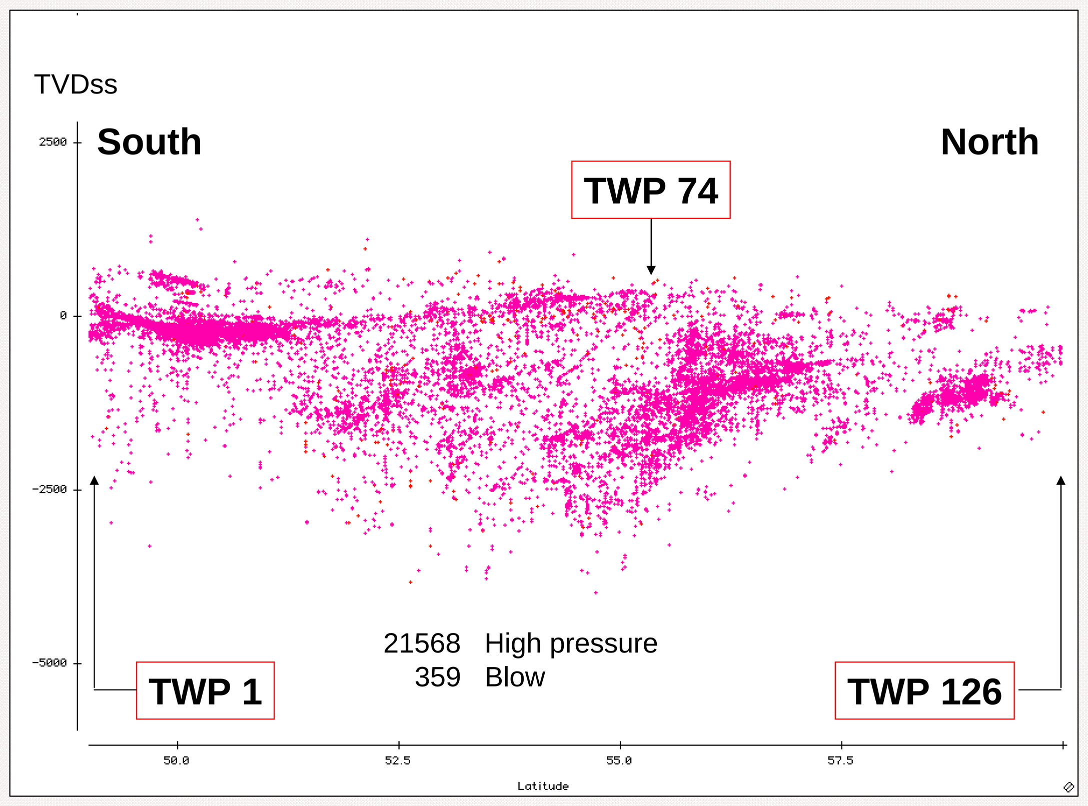



**Map of low angle high pressure plane TWP 74**

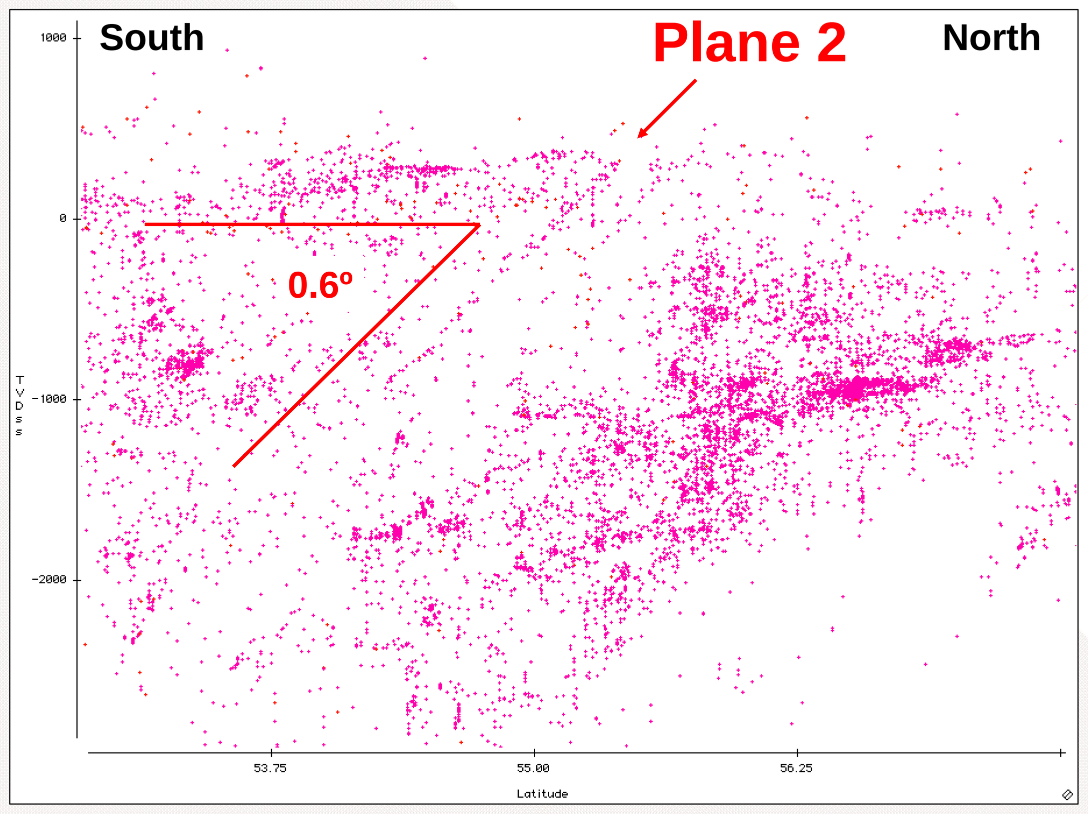



Maps of two major very low angle near N-S planes

**All high pressure problems in wells**
**Perfect North-South Projection**




**Zoomed projection of all high pressure problems**




Extremely well defined very low angle N-S plane

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T.S.I.
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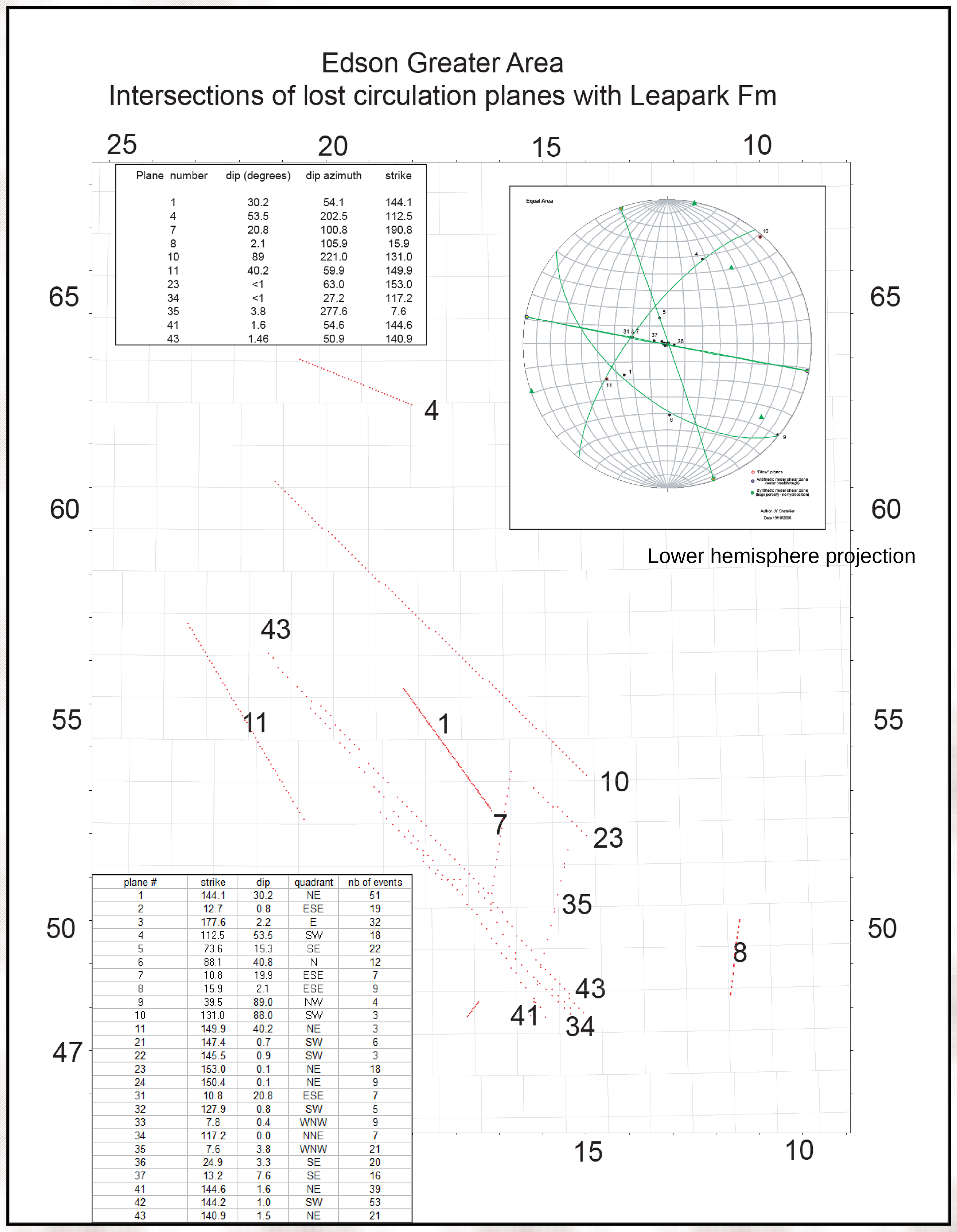
# Planar alignments of lost circulation events

Edson Greater Area
Intersections of lost circulation planes with Leapark Fm




| Plane number | dip (degrees) | dip azimuth | strike |
|---|---|---|---|
| 1 | 30.2 | 54.1 | 144.1 |
| 4 | 53.5 | 202.5 | 112.5 |
| 7 | 20.8 | 100.8 | 190.8 |
| 8 | 2.1 | 105.9 | 15.9 |
| 10 | 89 | 221.0 | 131.0 |
| 11 | 40.2 | 59.9 | 149.9 |
| 23 | <1 | 63.0 | 153.0 |
| 34 | <1 | 27.2 | 117.2 |
| 35 | 3.8 | 277.6 | 7.6 |
| 41 | 1.6 | 54.6 | 144.6 |
| 43 | 1.46 | 50.9 | 140.9 |

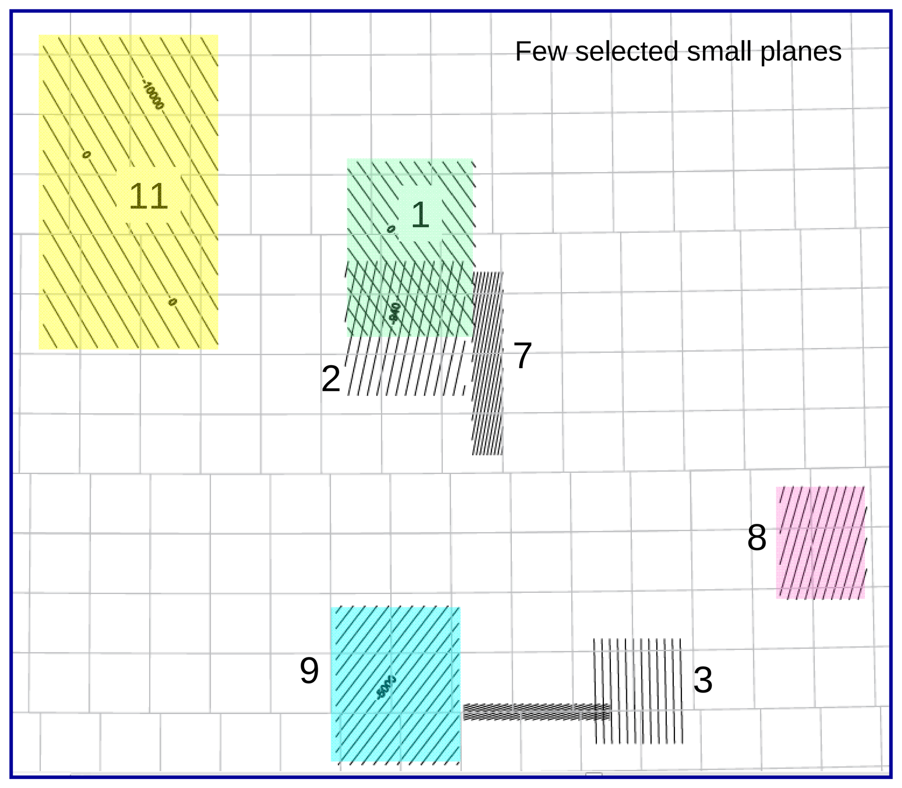
| plane # | strike | dip | quadrant | nb of events |
|---|---|---|---|---|
| 1 | 144.1 | 30.2 | NE | 51 |
| 2 | 12.7 | 0.8 | ESE | 19 |
| 3 | 177.6 | 2.2 | E | 32 |
| 4 | 112.5 | 53.5 | SW | 18 |
| 5 | 73.6 | 15.3 | SE | 22 |
| 6 | 88.1 | 40.8 | N | 12 |
| 7 | 10.8 | 19.9 | ESE | 7 |
| 8 | 15.9 | 2.1 | ESE | 9 |
| 9 | 39.5 | 89.0 | NW | 4 |
| 10 | 131.0 | 88.0 | SW | 3 |
| 11 | 149.9 | 40.2 | NE | 3 |
| 21 | 147.4 | 0.7 | SW | 6 |
| 22 | 145.5 | 0.9 | SW | 3 |
| 23 | 153.0 | 0.1 | NE | 18 |
| 24 | 150.4 | 0.1 | NE | 9 |
| 31 | 10.8 | 20.8 | ESE | 7 |
| 32 | 127.9 | 0.8 | SW | 5 |
| 33 | 7.8 | 0.4 | WNW | 9 |
| 34 | 117.2 | 0.0 | NNE | 7 |
| 35 | 7.6 | 3.8 | WNW | 21 |
| 36 | 24.9 | 3.3 | SE | 20 |
| 37 | 13.2 | 7.6 | SE | 16 |
| 41 | 144.6 | 1.6 | NE | 39 |
| 42 | 144.2 | 1.0 | SW | 53 |
| 43 | 140.9 | 1.5 | NE | 21 |

Graphical summary of
Intersections of lost circulation
Planes with the top of the
Upper Cretaceous Leapark Formation

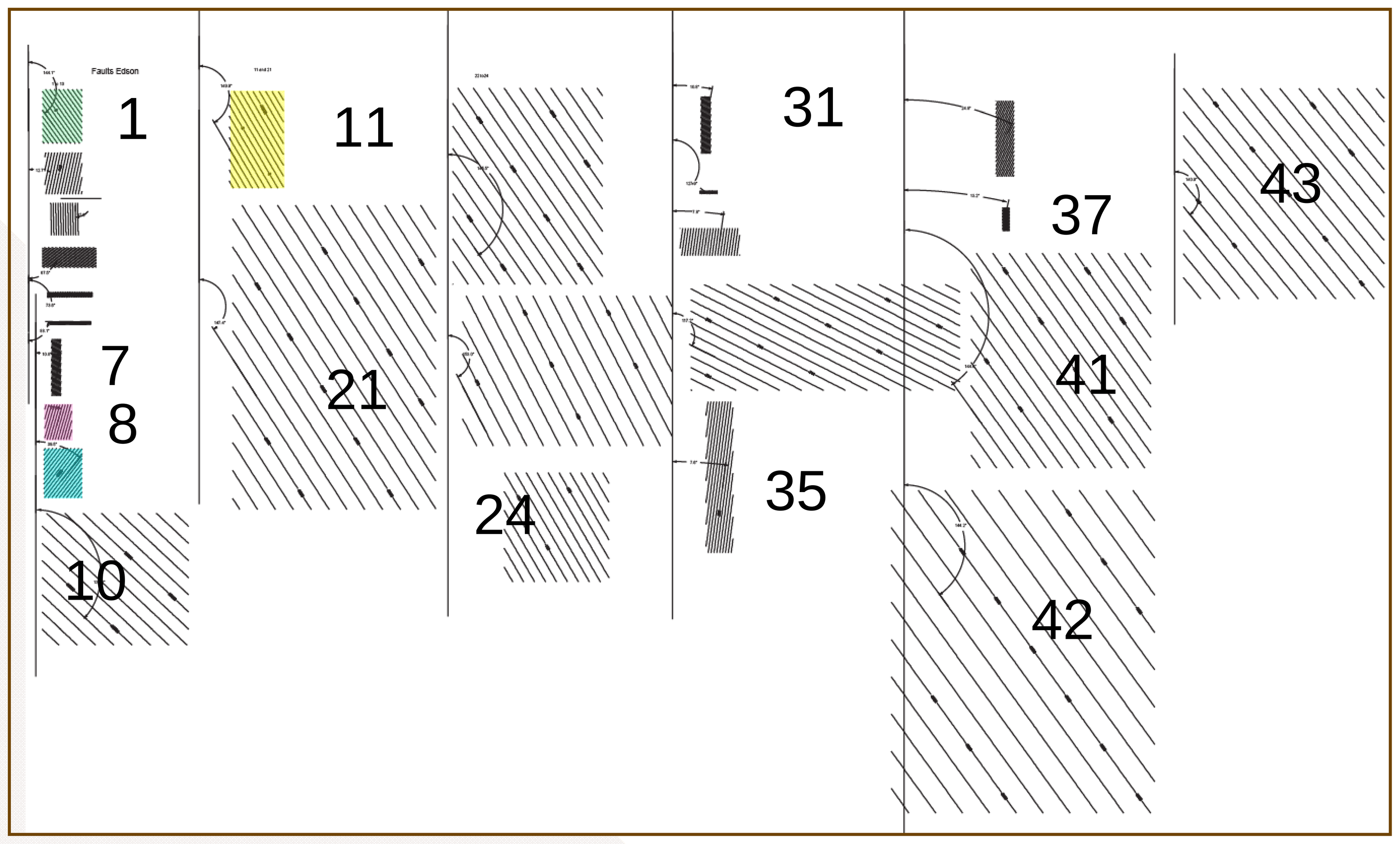
Note that only for vertical
planes (e.g. plane 10) the map
will be the same when dealing
with other formations

The aim of the map is to
give a feel for where to expect
problems and to give the direction
of the intersections

**Geographic position of some planes**



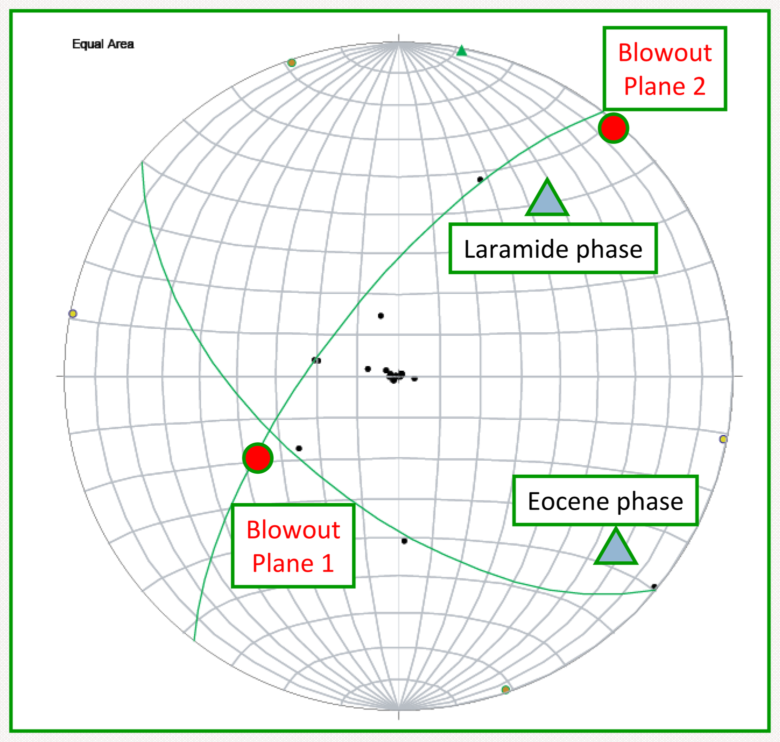

**Dimension of all interpreted lost circulation planes**



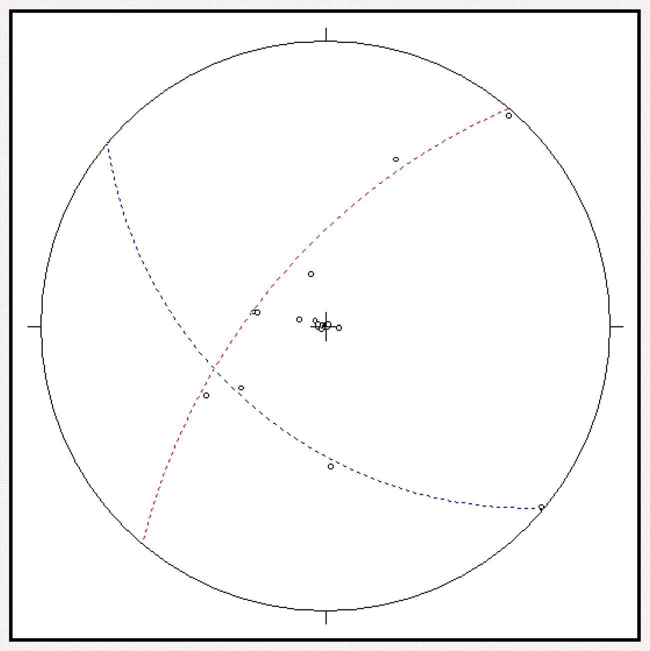

Three stereoplot views of all of the lost circulation
and blow out planes.

Why are the two great circles at 90º to each other?

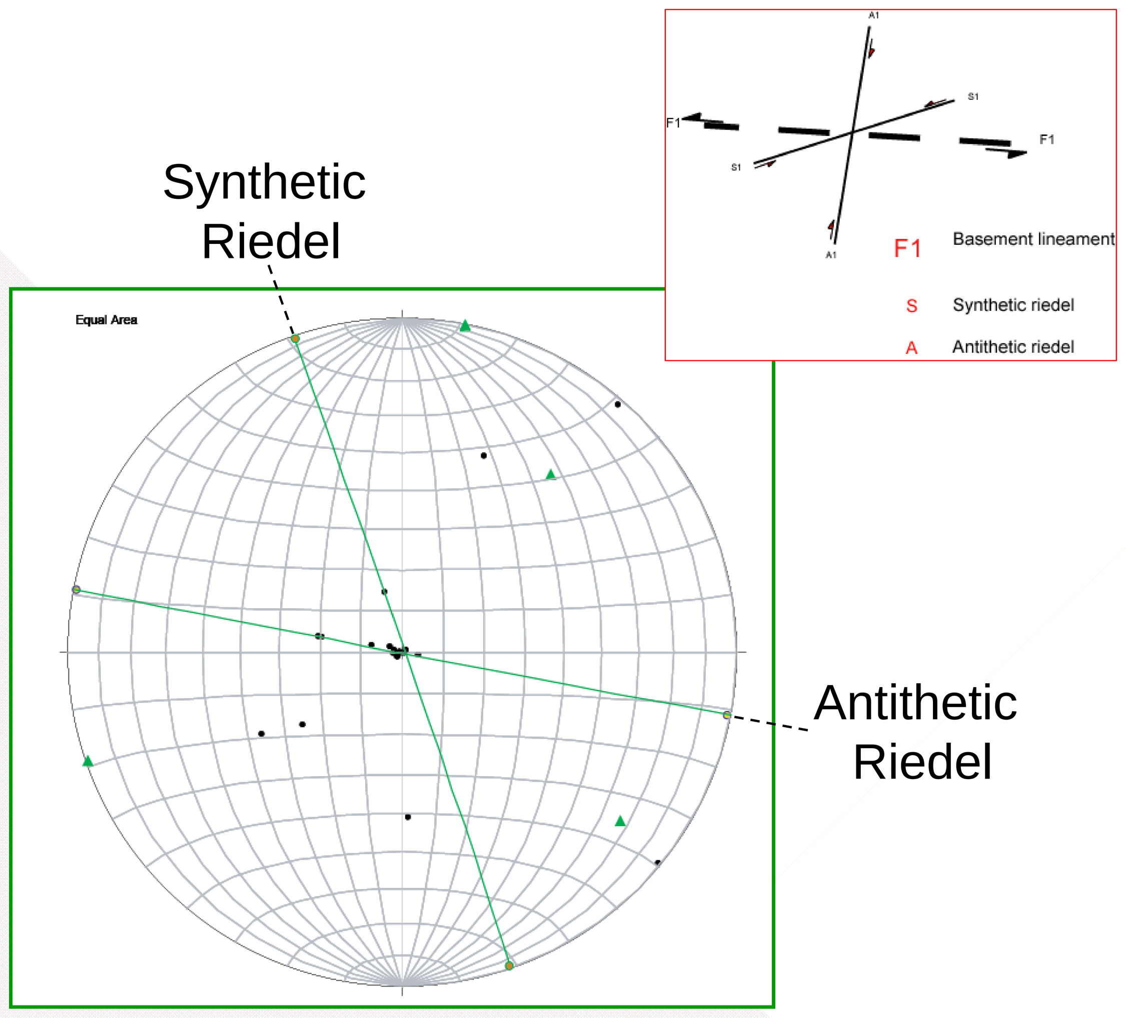
The planes not on the two great circles are aligned
with the main regional riedel shear
directions known in the area




Lower hemisphere projection



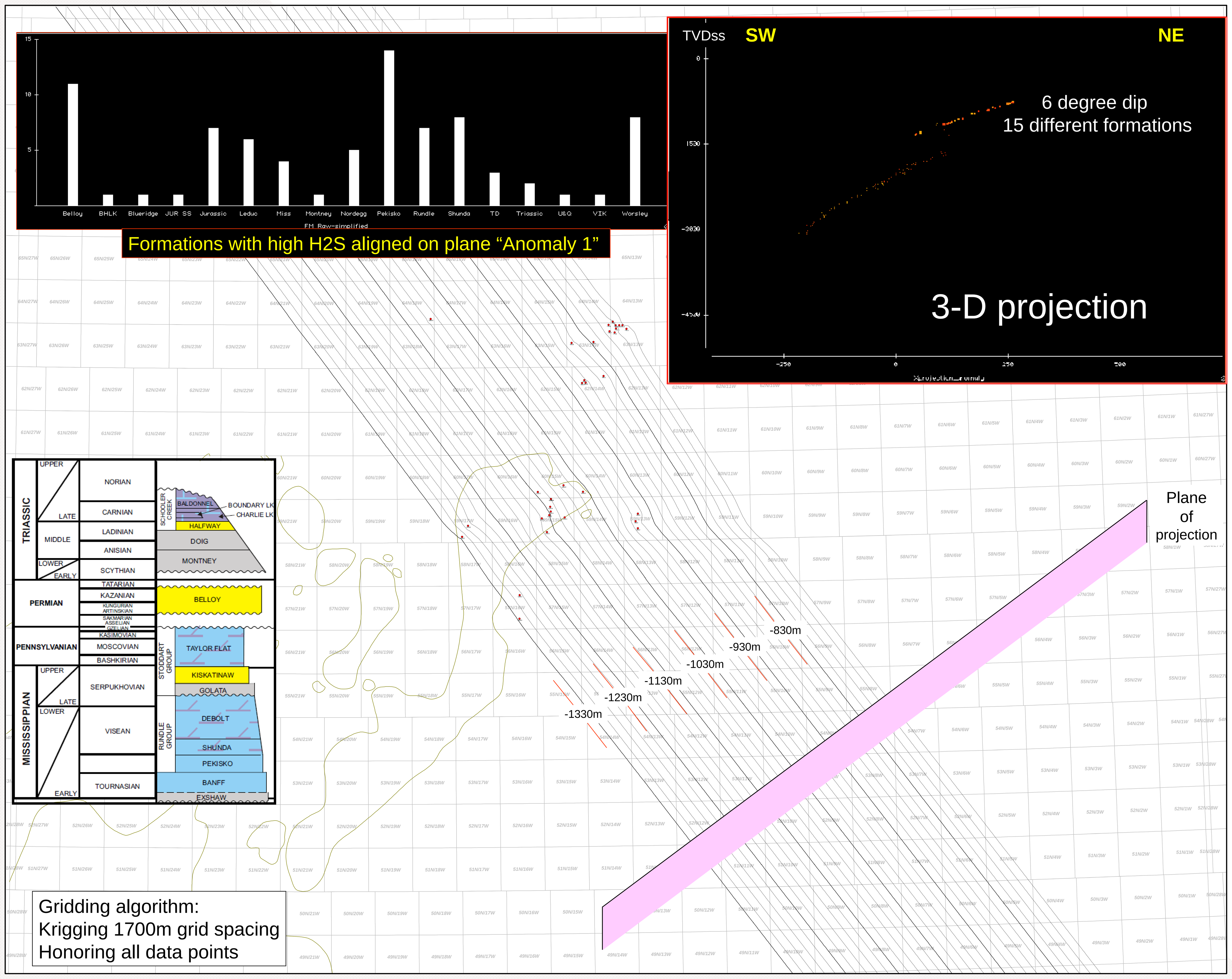
Lower hemisphere projection

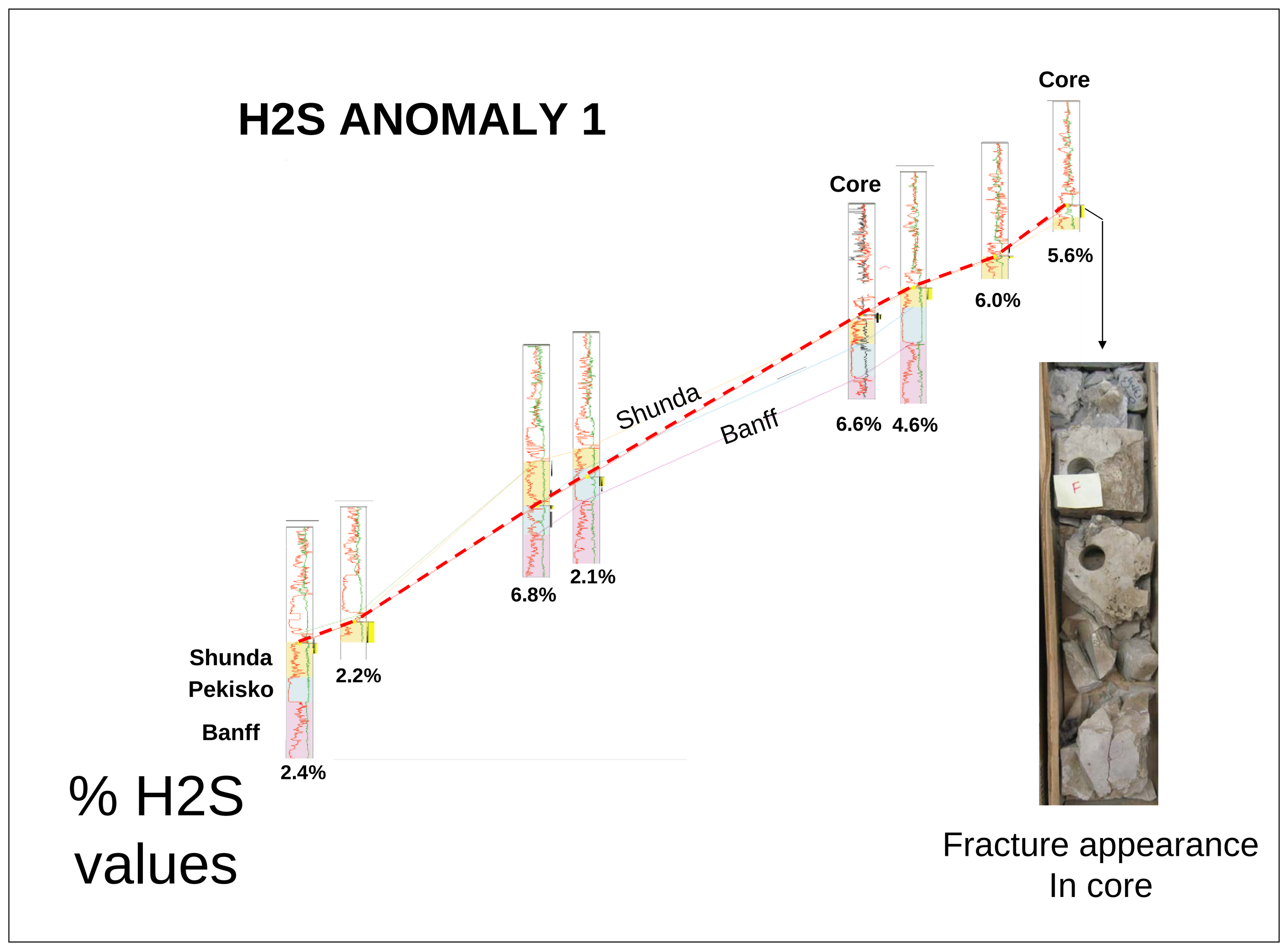


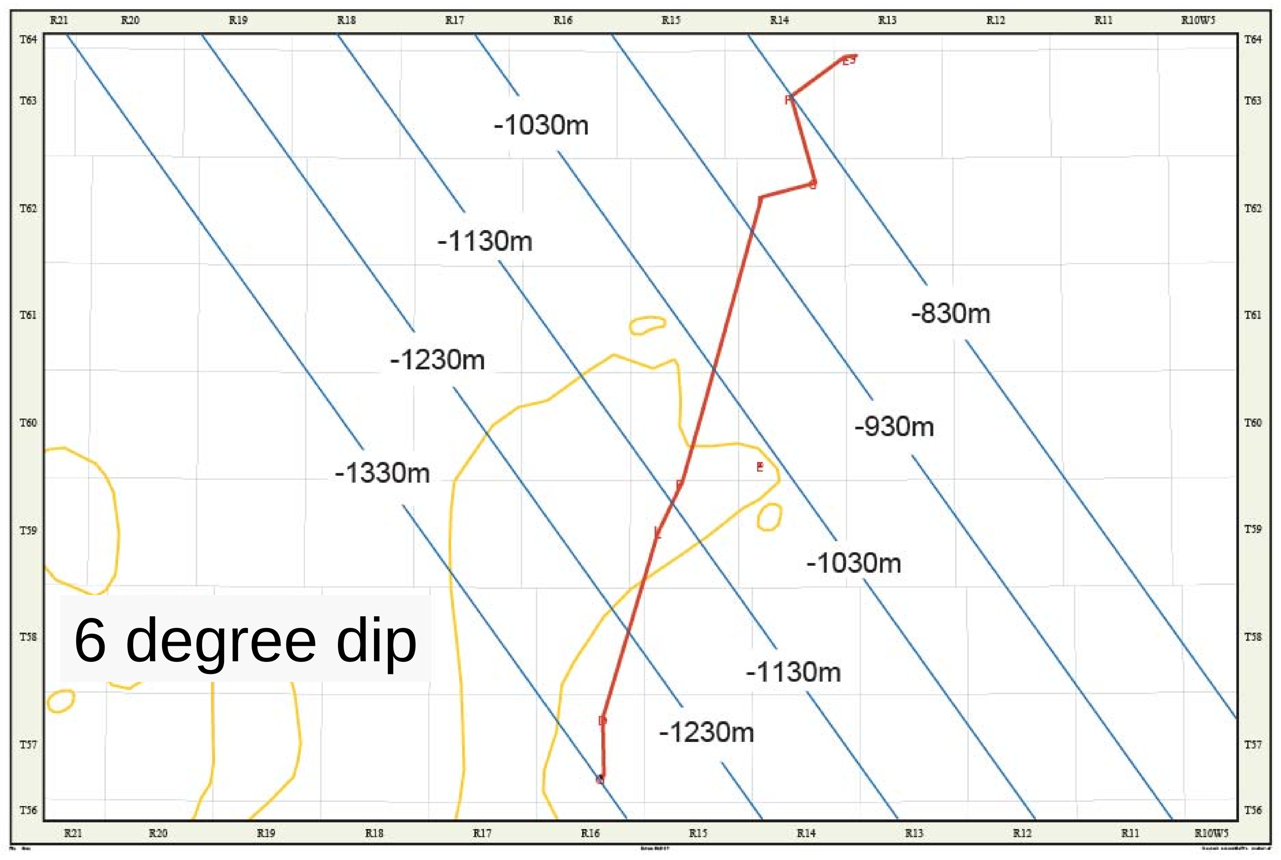

Lower hemisphere projection

# H2S Anomalies aligned on low angle planes

## Example 1



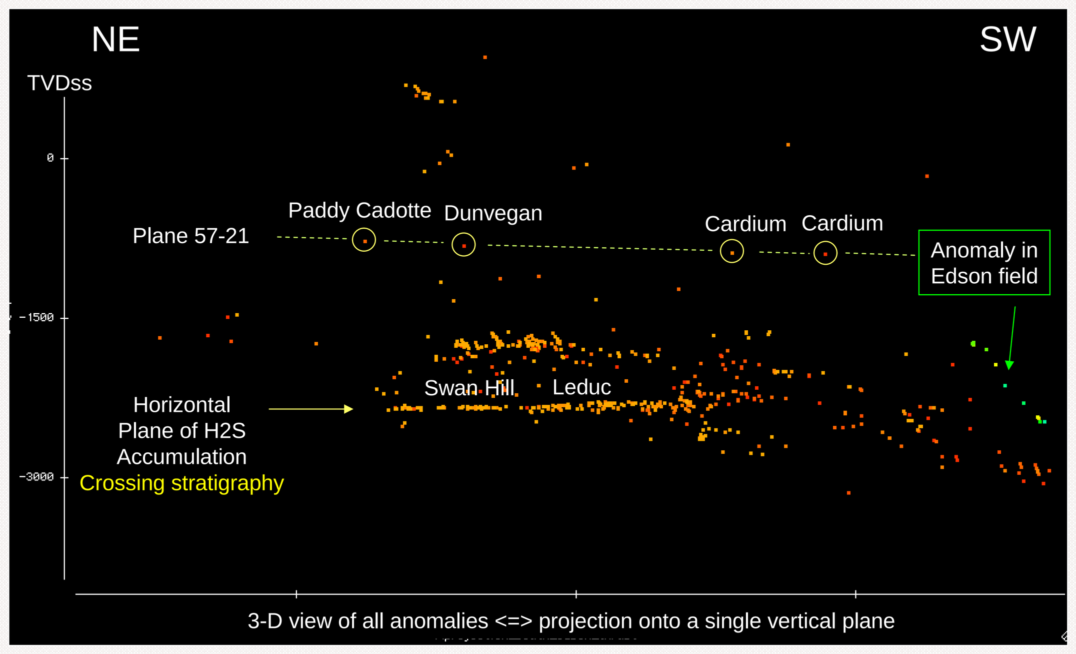




Simplified map for cross-section above

## Example 2

H2S Subhorizontal fault planes

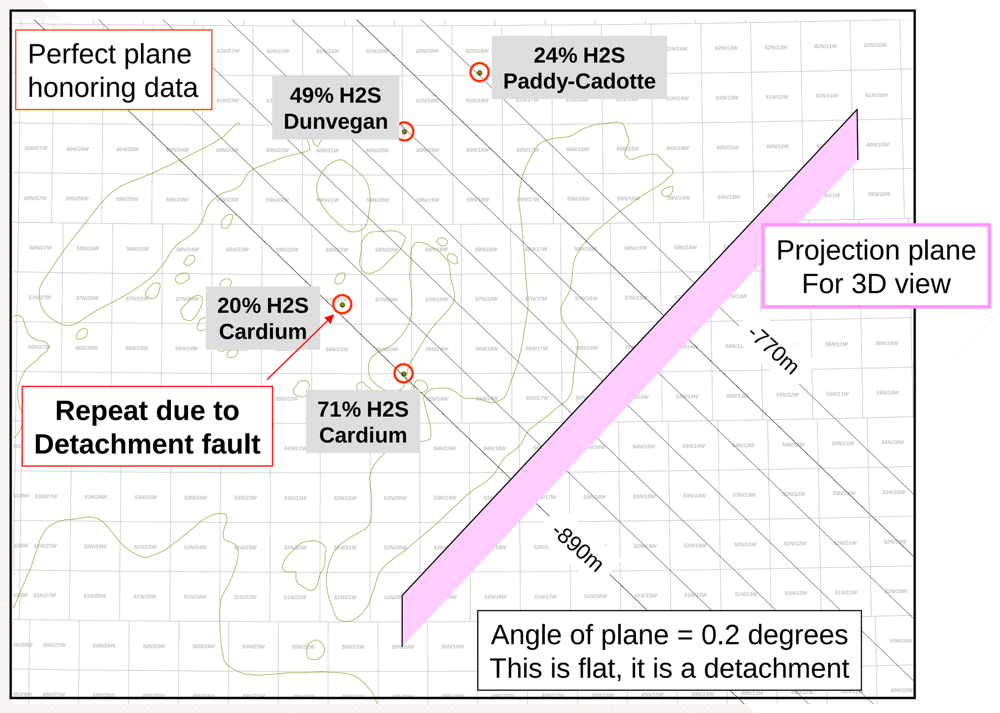



Note the very horizontal distribution of H2S crossing stratigraphy from the Swan Hill of Kaybob to the Leduc of Pine Creek

**Projection and map view of a shallow H2S very low angle plane**

Slope = 100 meters in 35 km
0.2 degree dip

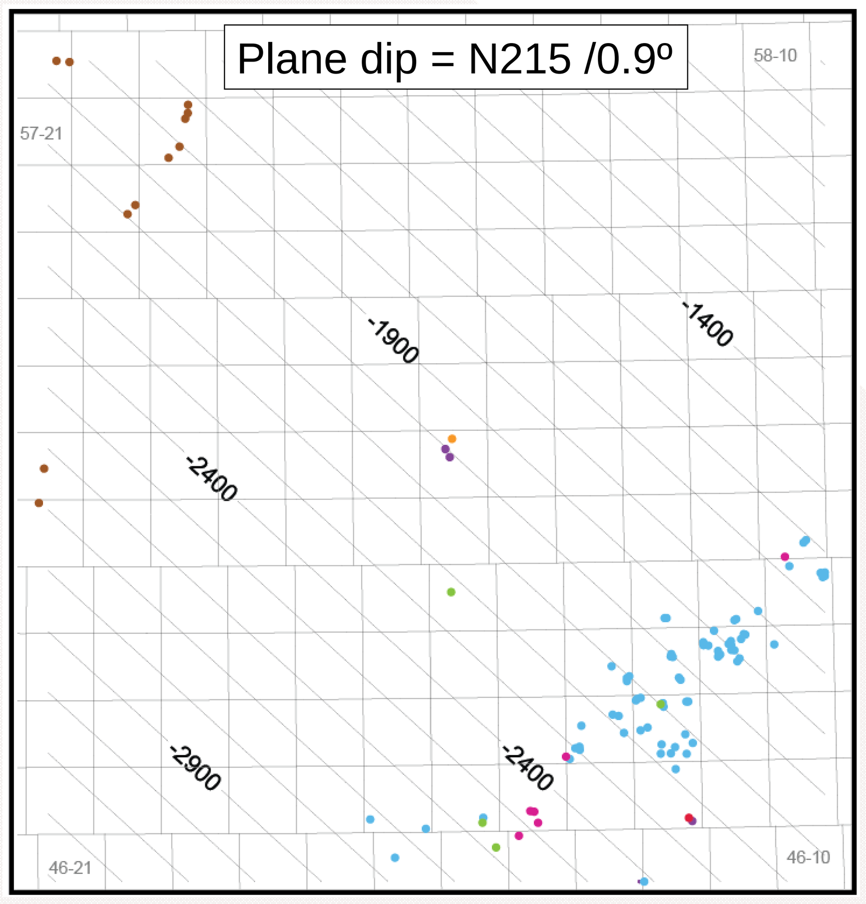
H2S low angle plane




Note that the direction of the plane of projection is the direction of today stress

# Low Angle Hydrocarbon Migration

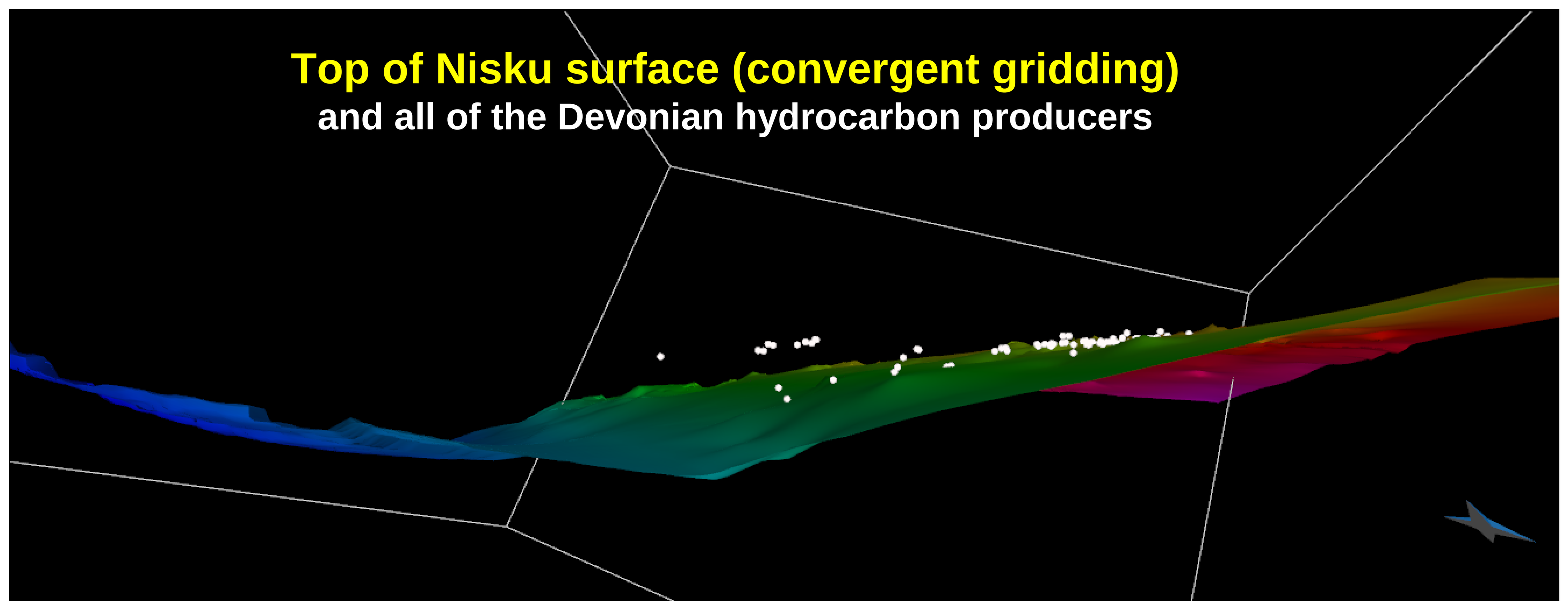
## in West Central Alberta




Hydrocarbon producing pools

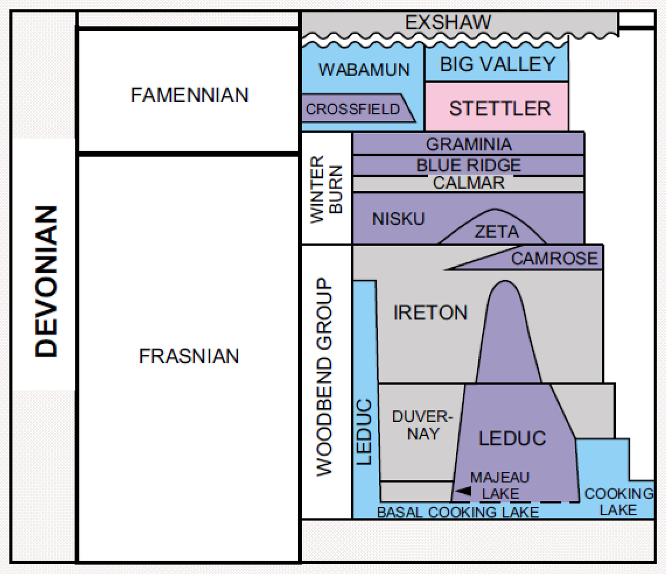
- Wabamun Fm
- Winterburn Gp
- Blueridge Mbr
- Nisku Fm
- Cynthia Mbr
- Wolf Lake Mbr
- Zeta Lake Mbr

## 3-D views of a mega migration low angle plane

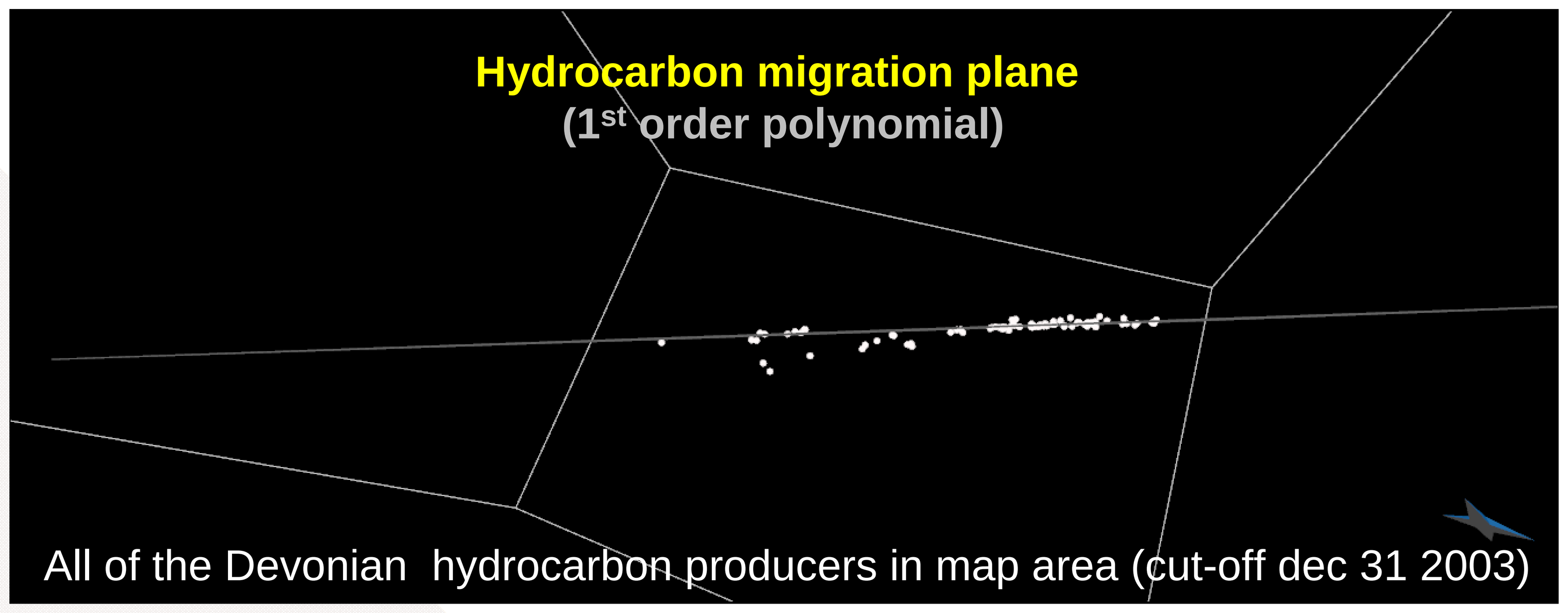



View optimized for Top Nisku

Simplified stratigraphic chart

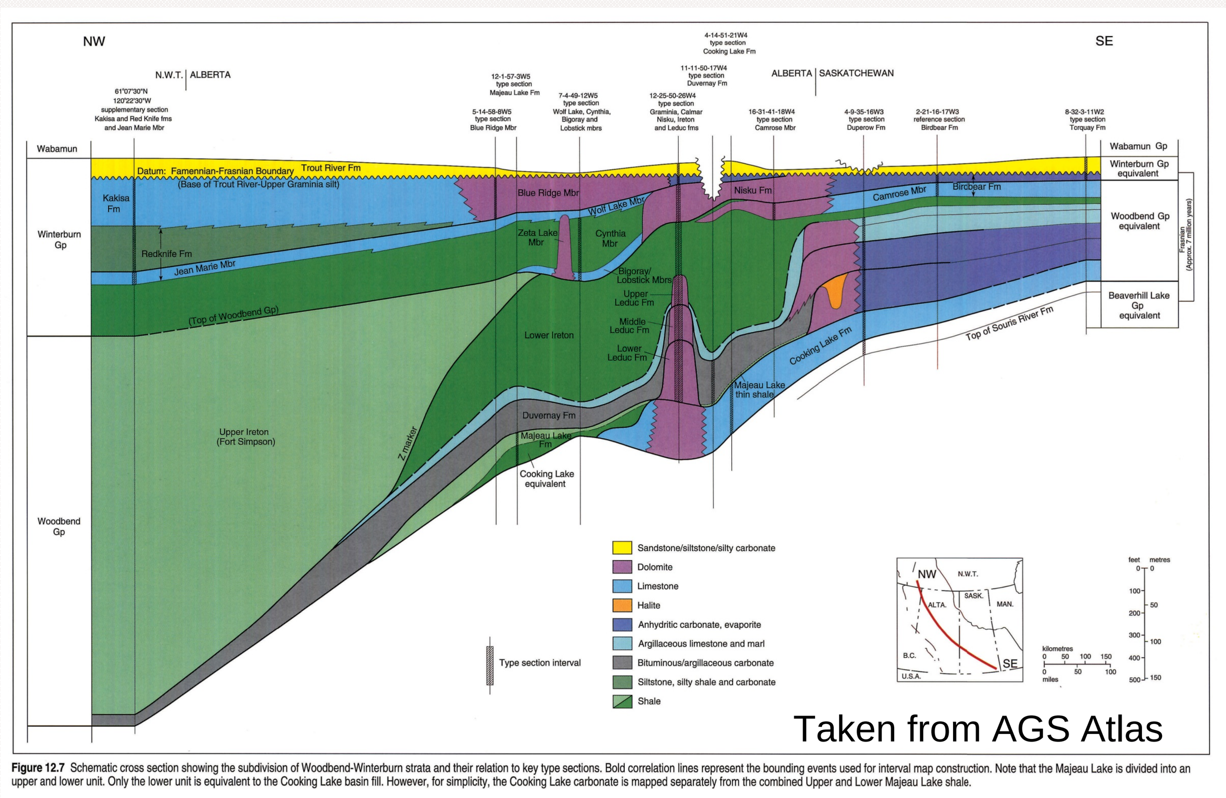


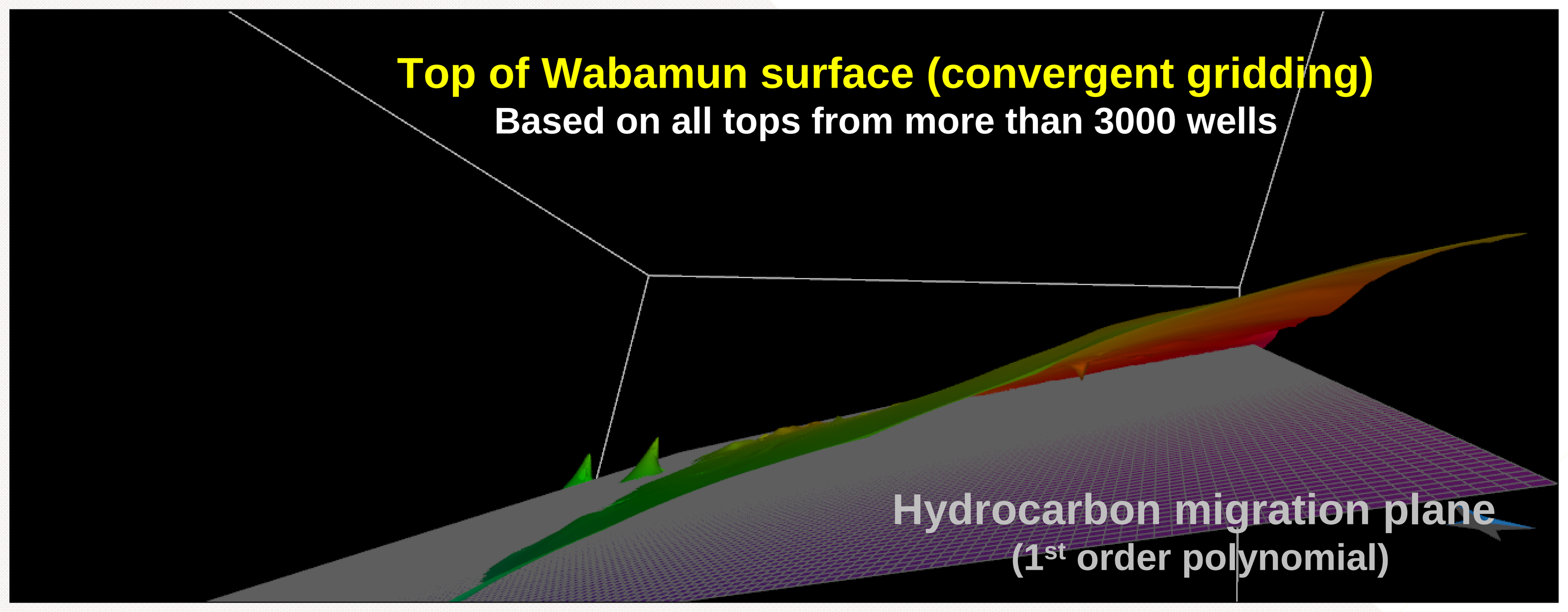

A very large majority of Devonian hydrocarbon pools is aligned on one preferential low angle plane dipping 0.9º to the SW (North 215º)




View optimized for planar oil pools alignment

Schematic cross-section of some Devonian strata




View optimized for multi-layer display

Depths are at top producing intervals, not at the depth of the production perforations

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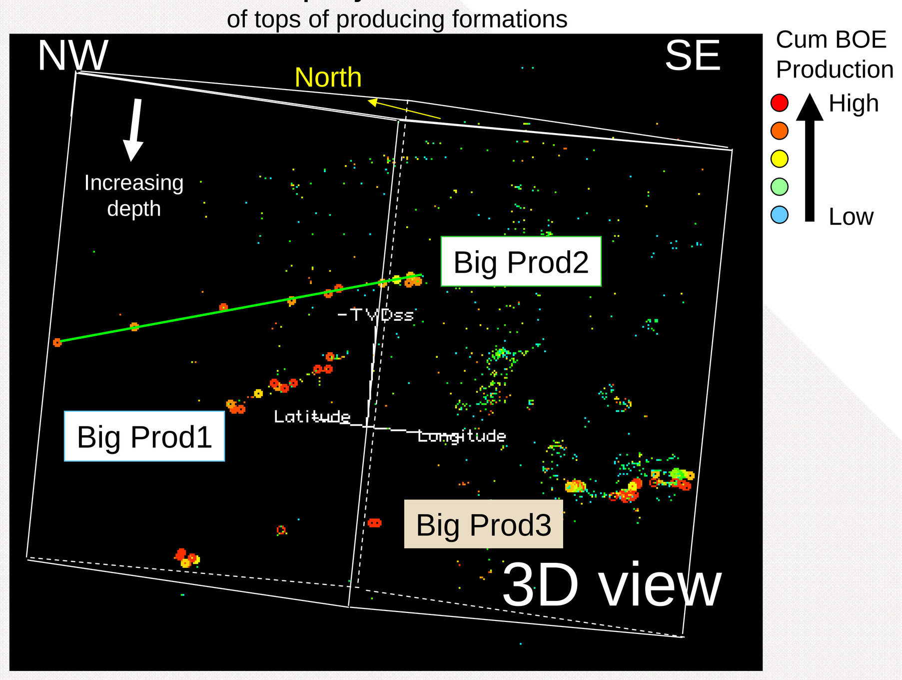
# Hydrocarbon Migration along Low Angle Planes

## in Peace River Area

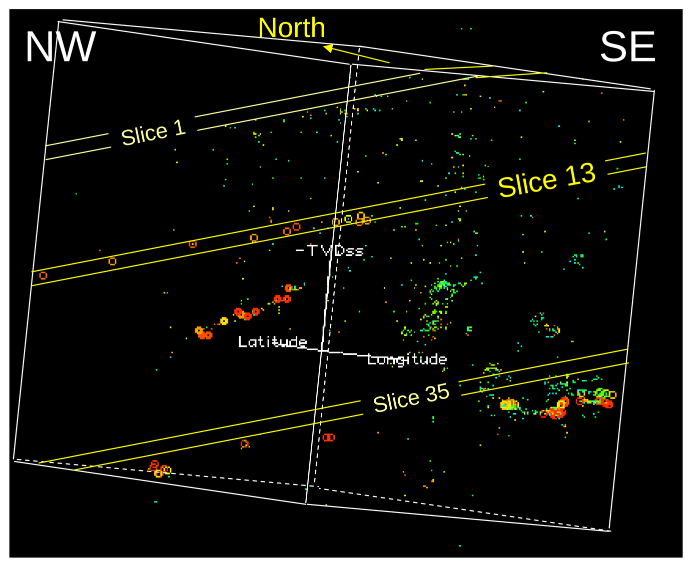
### Planar alignments on 3-D volume

Vertical projection / 3D view
of tops of producing formations




Only accounts for wells that drilled to Wabamun

### Slicing the dice for 3-D statistics

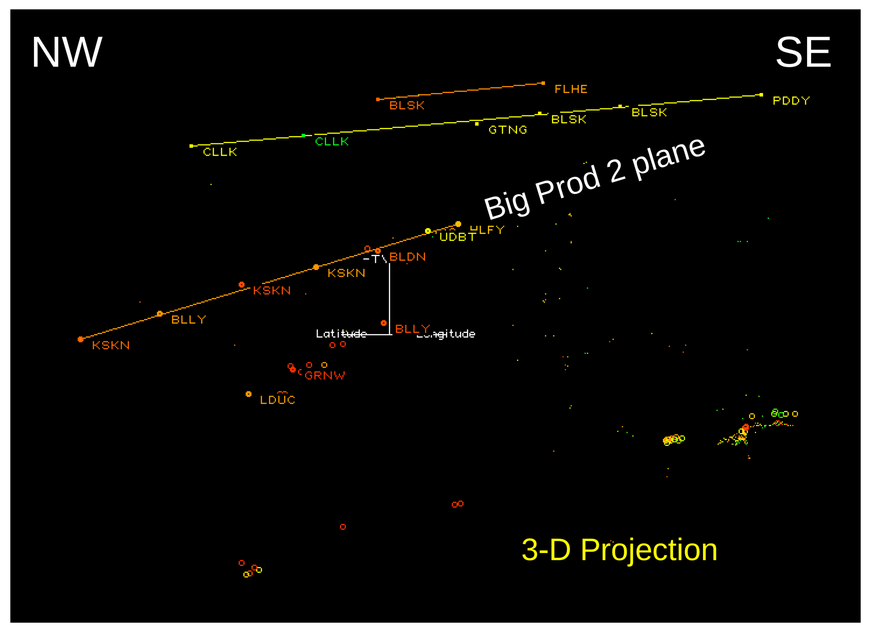



Slice 13
has produced
24.95 % of
the total production
from
slice 1 to slice 35

Slice 13 =1/35th of the
whole rock volume
i.e. 2.85 %

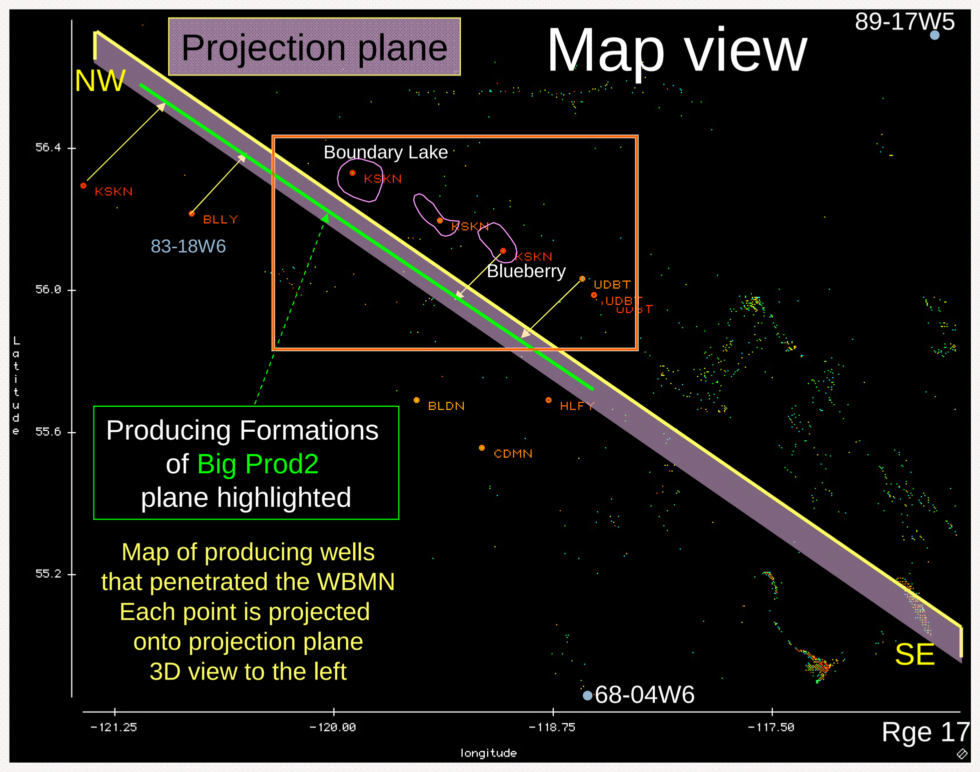
Each slice has the same rock volume

### Planes crossing formations



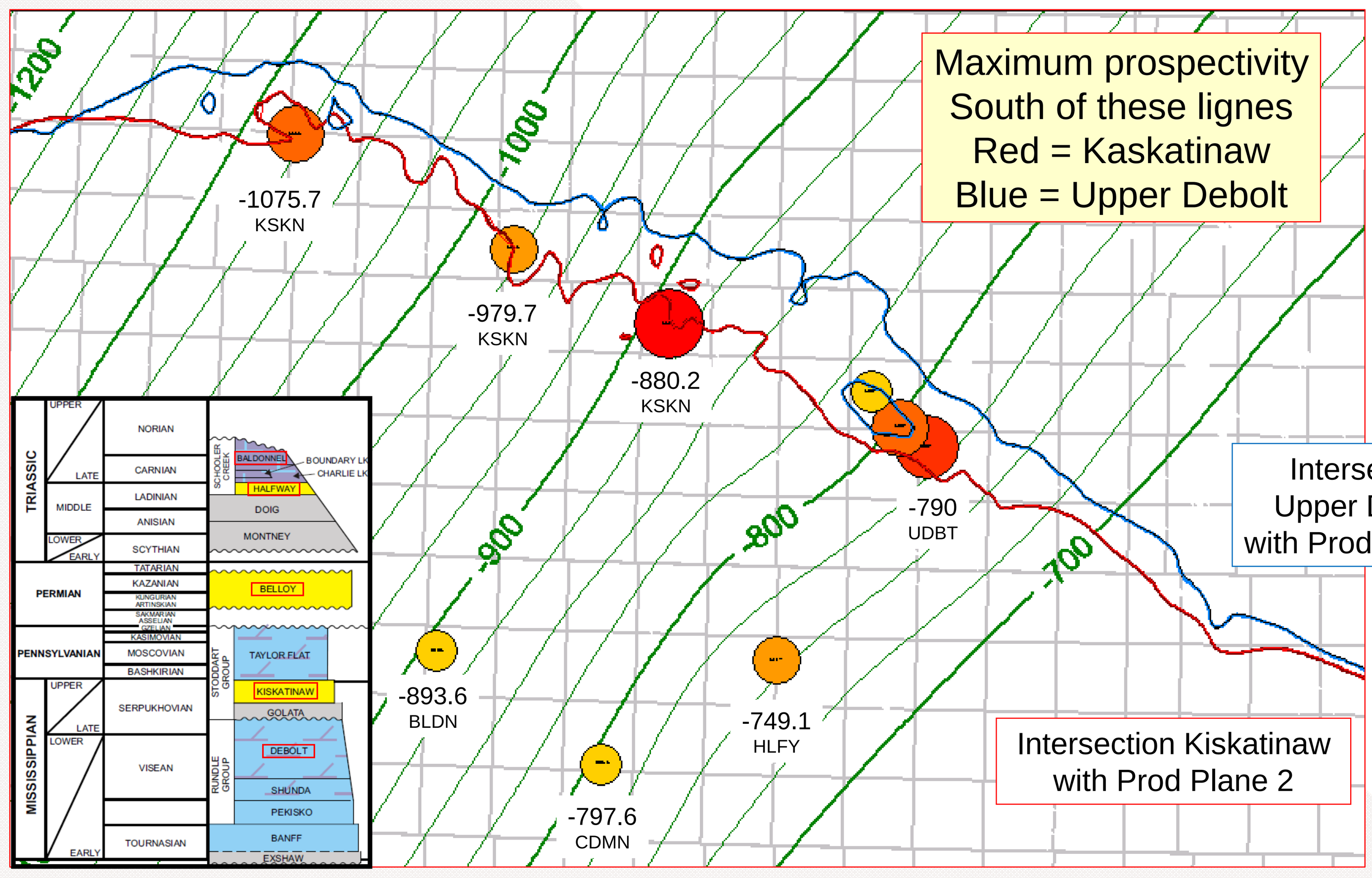

Strat chart for the Big Prod 2 plane as insert in the map below

### Map view of 3-D volume and projection orientation



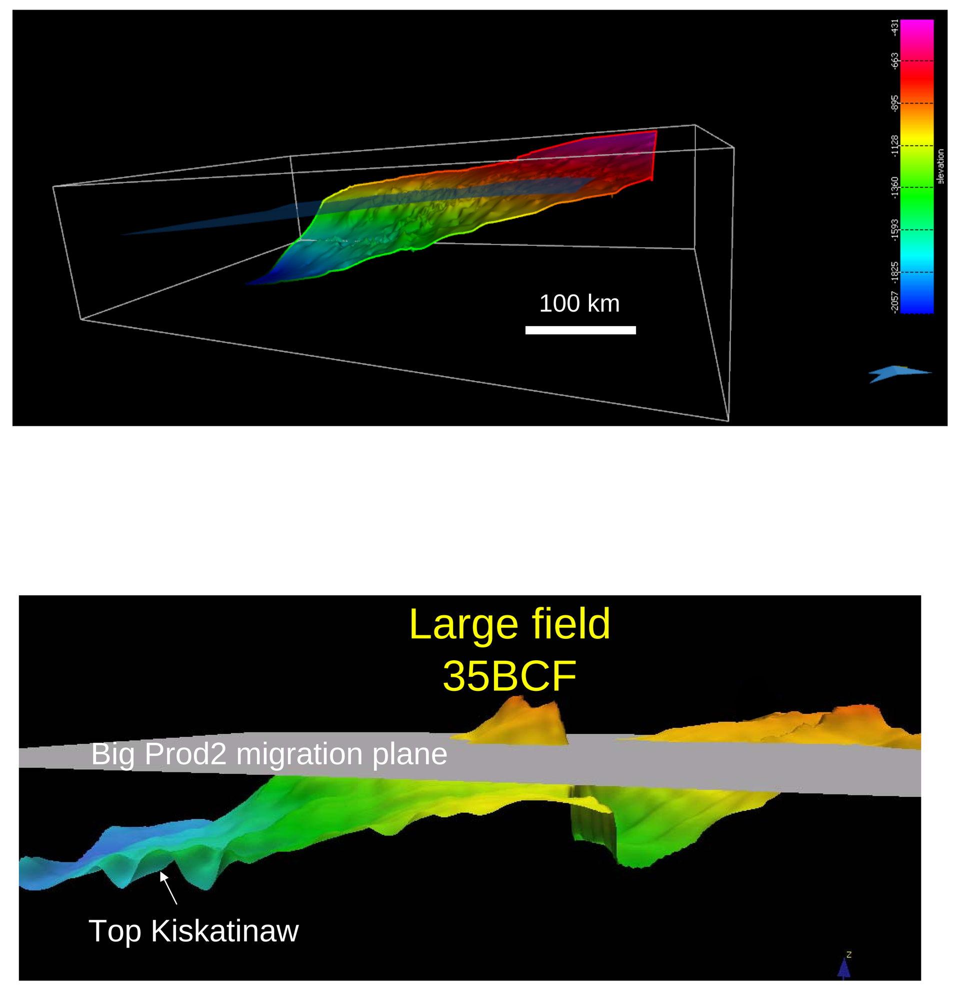

Same projection plane orientation for all 3-D plots and projections

### Contour map of Big Prod 2 Plane and intersections with two formations

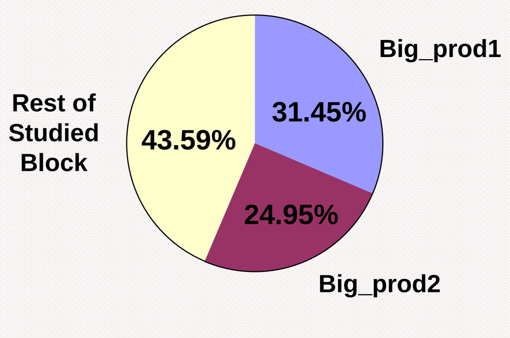



KSKN = Kiskatinaw ; UDBT = Upper Debolt ; HLFY = Halfway ; CDMN = Cadomin ; BLDN = Baldonnel

### 3-D views of Big Prod 2 Plane

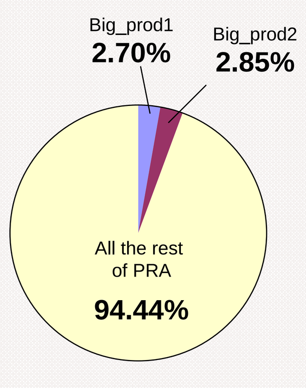



### Cumulative Production




The calculations are restricted to
the rock volume above Big Prod3

### Proportion of rock volume




Big prod 1: 34.8 mm BOE
Big prod 2: 27.6 mm BOE
All others: 48.2 mm BOE

**Pools located on 2 low angle planes account for 56% of the hydrocarbon produced in the selected volume**

## 3-D exploratory statistics clearly indicates that hydrocarbon in the study area is not randomly distributed