Overpressure in Shale Gas – When Geochemistry and Engineering Data Meet and Agree*

Jean-Yves Chatellier[1], Kevin Ferworn[2], Nabila Lazreg Larsen[1], Steve Ko[3], Pawel Flek[1], Marianne Molgat[1], and Irene Anderson[1]

Search and Discovery Article #40767 (2011)
Posted June 30, 2011

*Adapted from oral presentation at AAPG Annual Convention and Exhibition, Houston, Texas, USA, April 10-13, 2011

[1]Talisman Energy Inc, Calgary, AB, Canada (jchatellier@talisman-energy.com)
[2]Geomark, Houston, TX
[3]Talisman Energy Inc, Pittsburg, PA

Abstract

A multidisciplinary study has shed a new light on the process of overpressure in shale gas reservoirs. The work consisted of the integration of a large geochemical data set with hydraulic frac and reservoir pressure data from the same wells. Results from this integrated approach suggest that distinct pressure domains exist and that their specific depths and attributes can be easily determined. Whereas various geochemical analyses give conflicting results at first glance, our study shows consistency in the results especially when engineering data is involved in the analysis.

Diverging gas composition results are obtained when using varying sampling techniques. Geochemical compositions from gas chromatography differ from either geochemical compositions measured from isojars (cuttings) or from isotubes (free gas), the latter exhibiting the highest methane content. In stark contrast, both ethane and propane carbon isotopes give matching and consistent values at similar depths despite the sampling differences.

Three geochemical domains can be defined by their characteristic depth trends in ethane and propane carbon isotopes.

1. A shallow domain is characterized by normally increasing isotope values (less negative) with depth.
2. An intermediate domain is characterized by a reverse isotopic compositional trend.
3. A deeper trend is again normal; however, the values are much more negative than in the shallow domain; note that this deeper trend is much more linear when dealing with ethane isotopes.

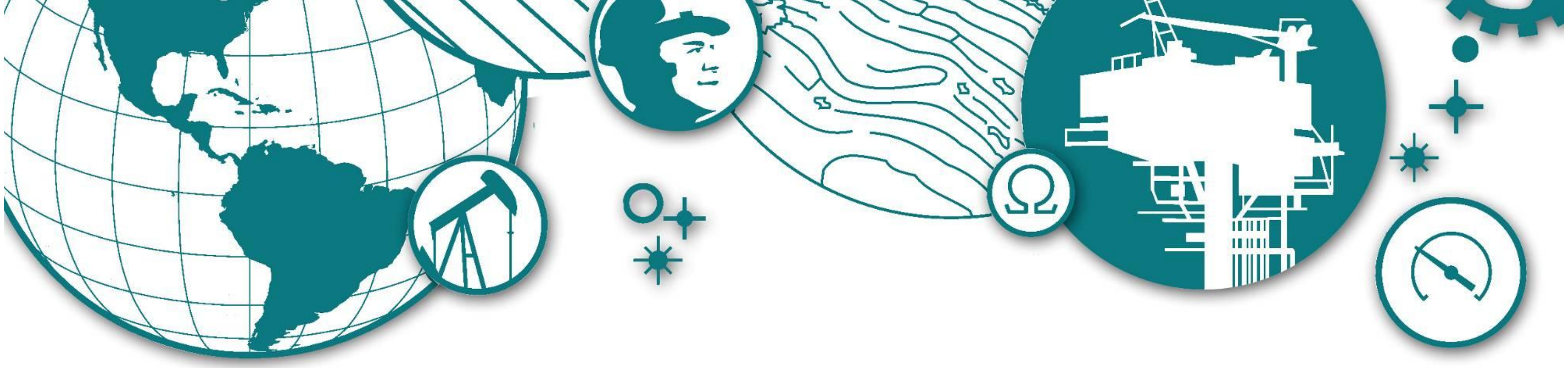
Using the geochemistry results as a starting point, frac gradients and reservoir pressure gradients are examined and re-analyzed. This

integration revealed the existence of at least two pressure domains: a normally pressured domain and an overpressured one. The traditional way of calculating a pressure gradient (reservoir or frac) is simply dividing the pressure value by the depth. Our data sets, however, indicate that individual gradients could be derived for each well or each area and that their intersection with the normal frac gradient is where geochemistry indicates the onset of overpressure.

Overpressured systems can thus be estimated by geochemistry, using any of the following parameters, either independently or in combination:

- Gas composition
- Gas carbon isotope signatures
- Rock-Eval data (Tmax).

Each of these tools has its inherent strengths and limitations as do the various methods of collecting data, all of which are reviewed.



Overpressure in Shale Gas

when Geochemistry and Engineering Data Meet and Agree

TALISMAN ENERGY

Geomark Research Inc.

Overpressure in Shale Gas

when Geochemistry and Engineering Data Meet and Agree

Jean-Yves Chatellier	Geologist	Talisman, Calgary,
Pawel Flek	Geologist	Talisman, Calgary
Marianne Molgat	Geologist	Talisman, Calgary
Nabila Lazreg Larsen	Completion engineer	Talisman, Houston, USA
Steve Ko	Completion engineer	Talisman, Pittsburgh, USA
Irene Anderson	Reservoir Engineer	Talisman, Calgary
Kevin Ferworn	Geochemist	Geomark Research , USA

Talk outline

- **Geochemistry**

Tmax	RockEval
Vitrinite (Ro)	Microscopy
Gas composition	Isotubes and Geojars
Isotope composition	Isotubes and Geojars

- **Frac Gradient**
- **Reservoir Pressures**
- **Overpressure links all of the above**

Geochemistry

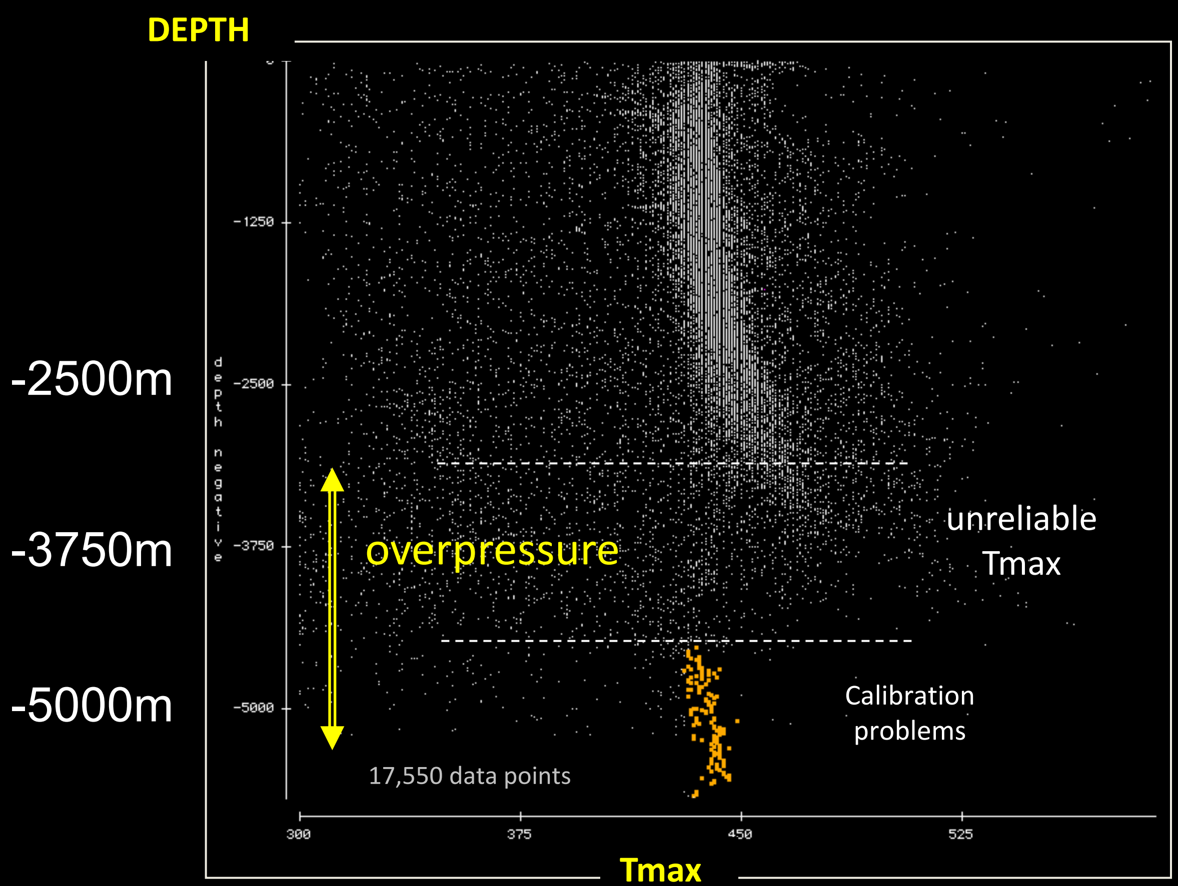
Examples from Alberta

Tmax	Rock-Eval
Vitrinite (Ro)	Microscopy
Gas composition	Isotubes and Geojars
Isotope composition	Isotubes and Geojars

Tmax problem with depth

Alberta

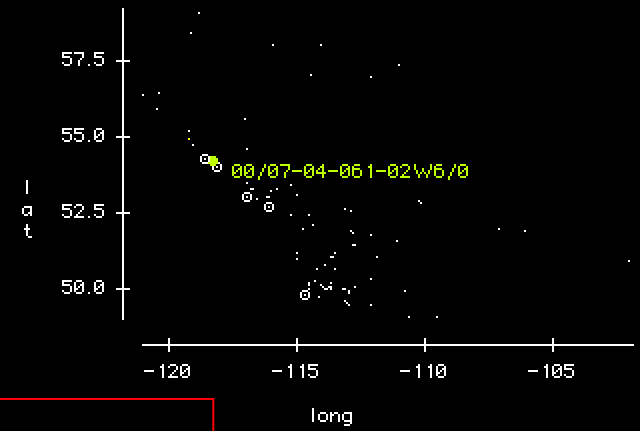
Data set

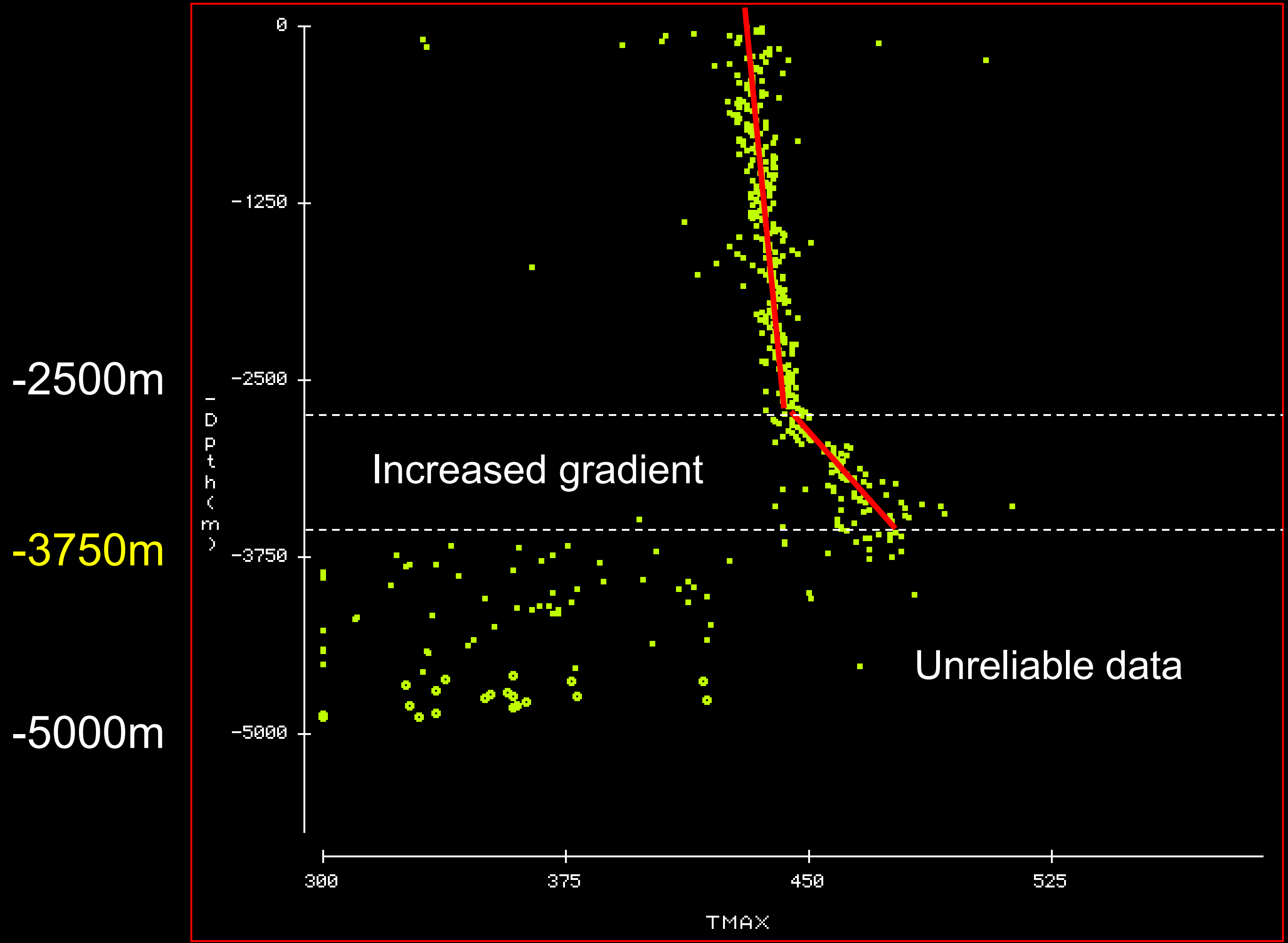


Gas compositions
&
Isotopes
are incredibly
valuable

17,550 data points

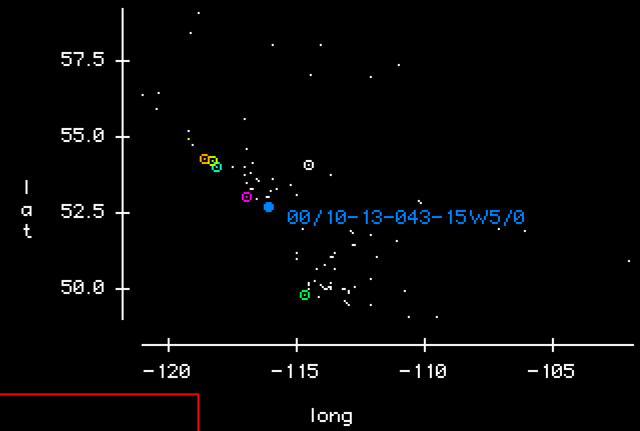
Alberta
07-04-061-02W6

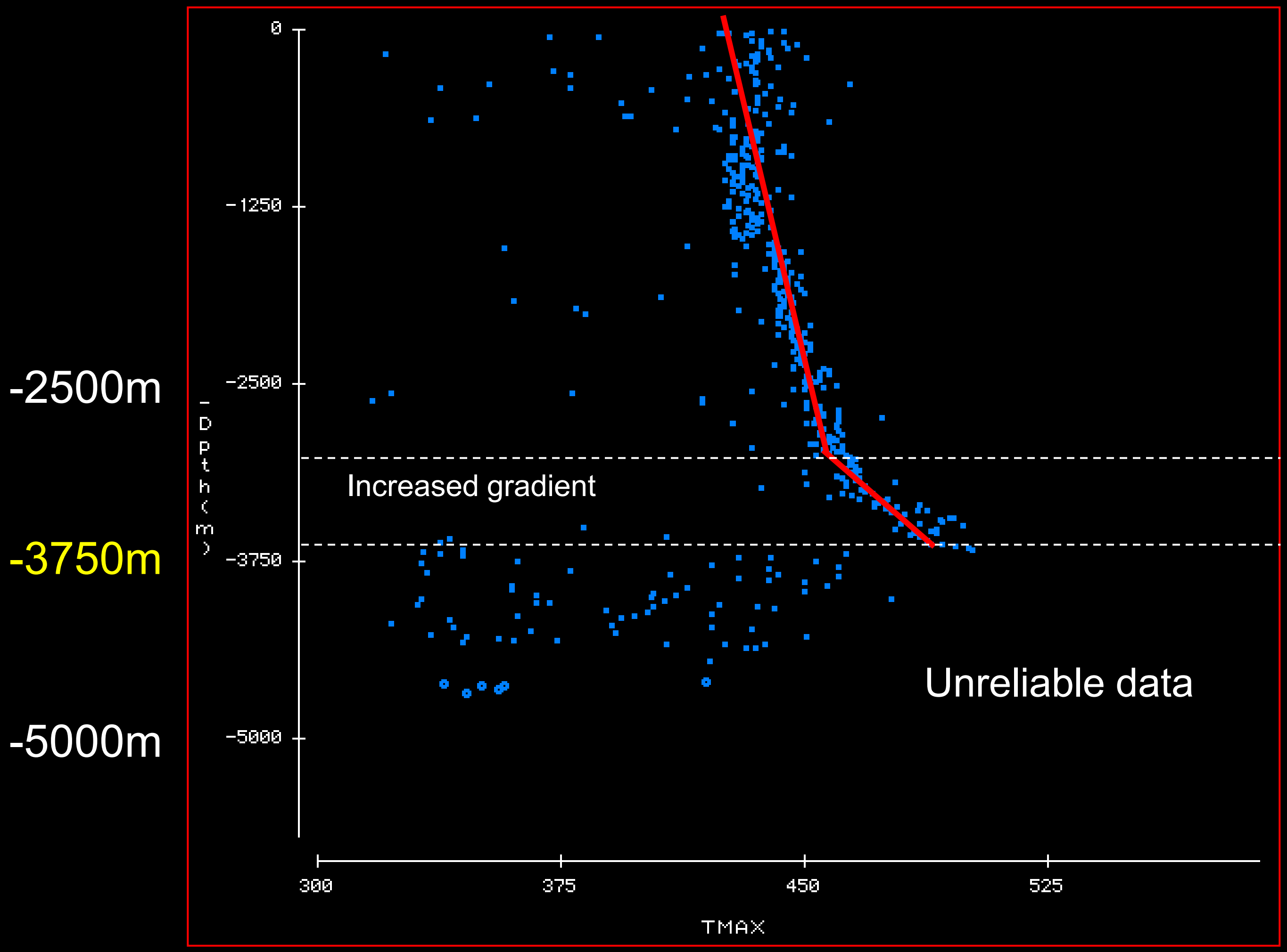




TALISMAN ENERGY

Alberta
10-13-043-15W5



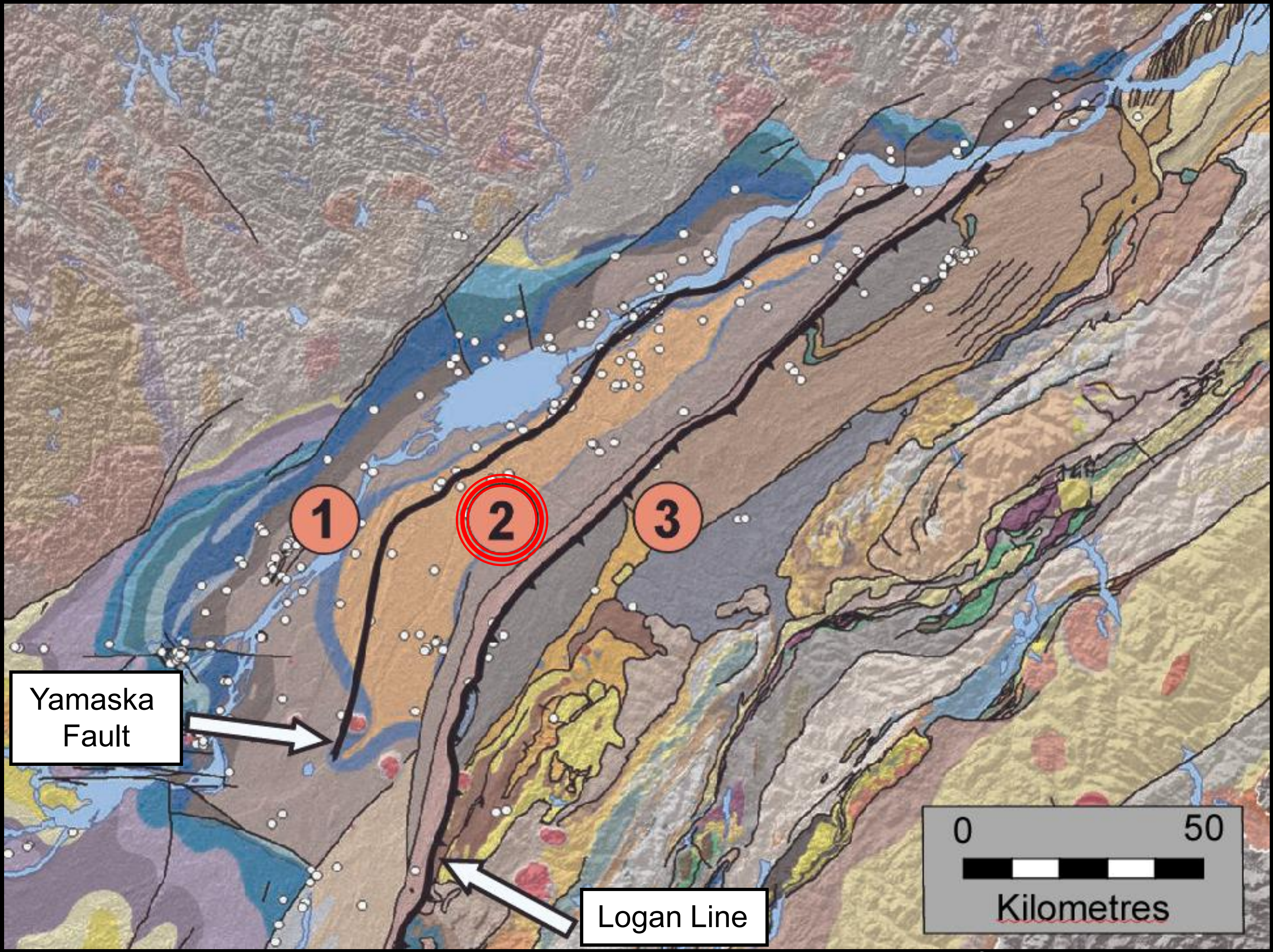


Geochemistry

Examples from Quebec

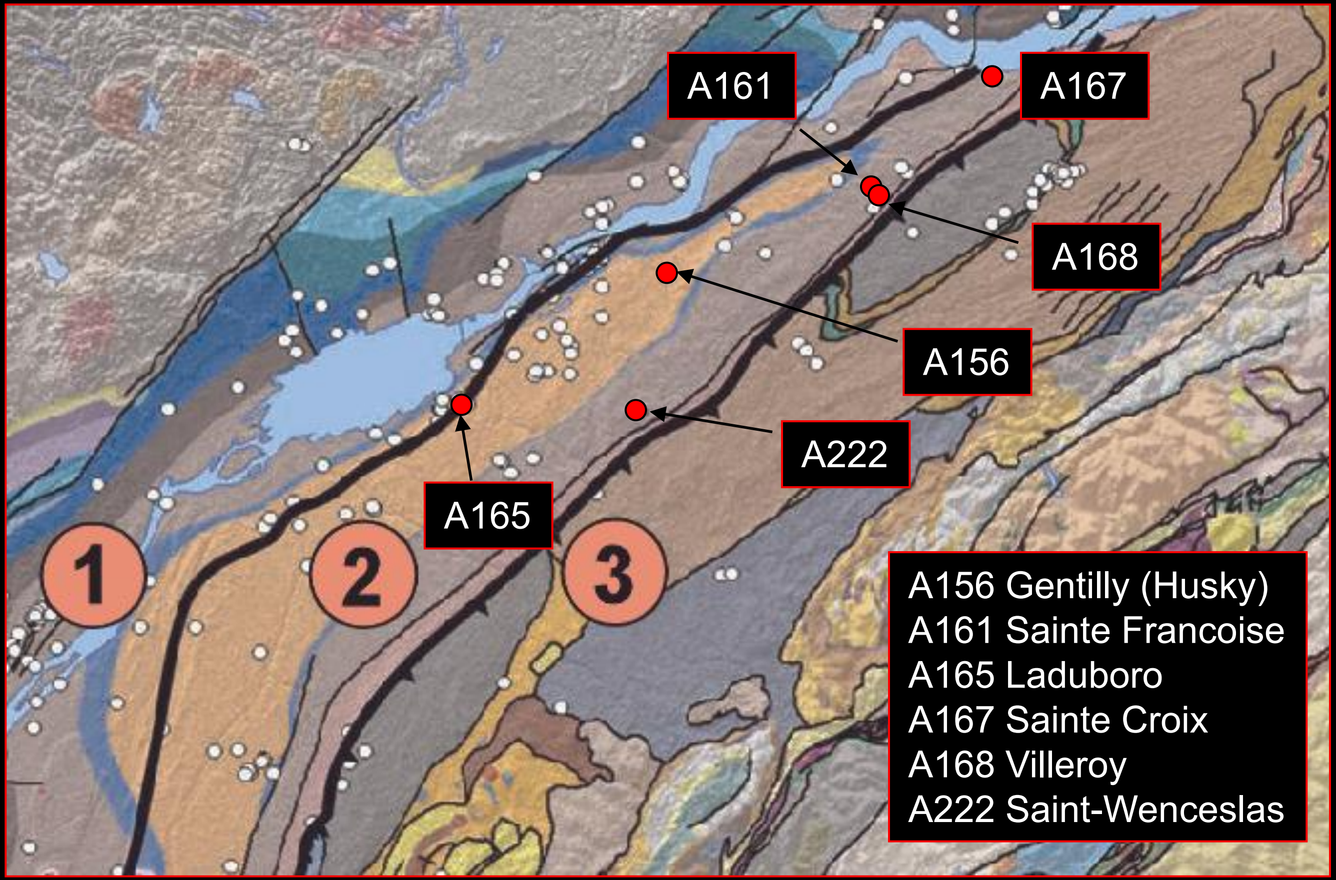
Tmax	Rock-Eval
Vitrinite (Ro)	Microscopy
Gas composition	Isotubes and Geojars
Isotope composition	Isotubes and Geojars

Wells with geochemistry



Adapted from R. Theriault, 2008

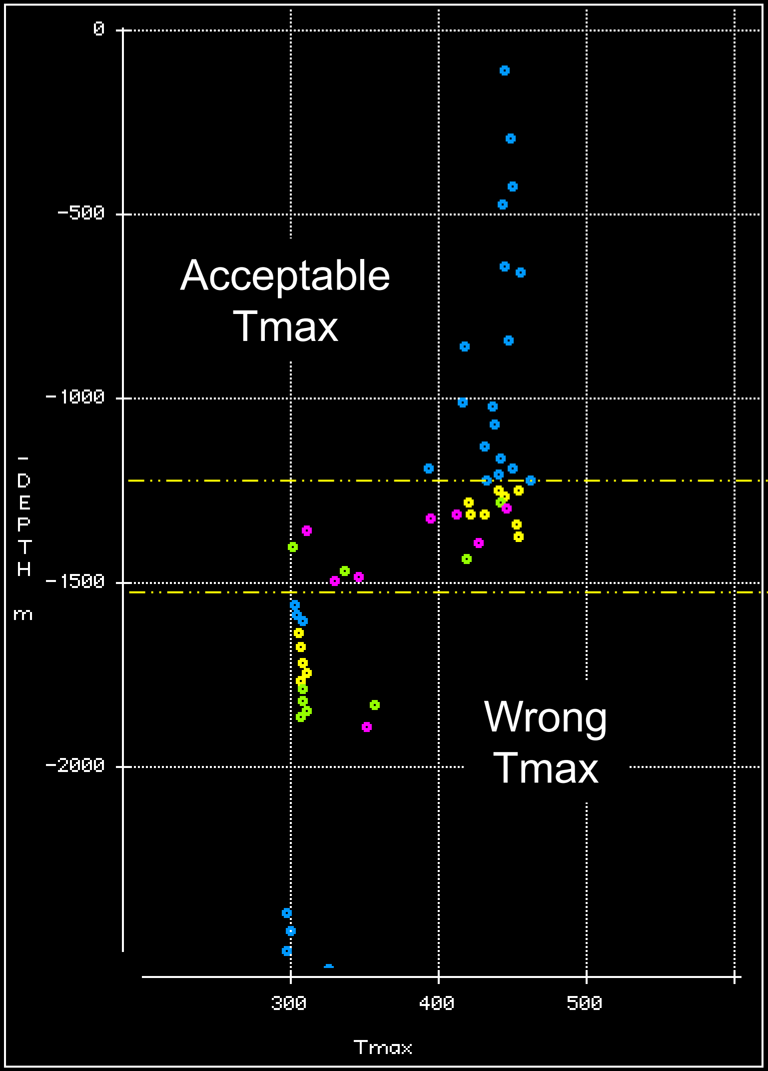
Selected wells for Tmax and Ro trends



Map from Robert Theriault

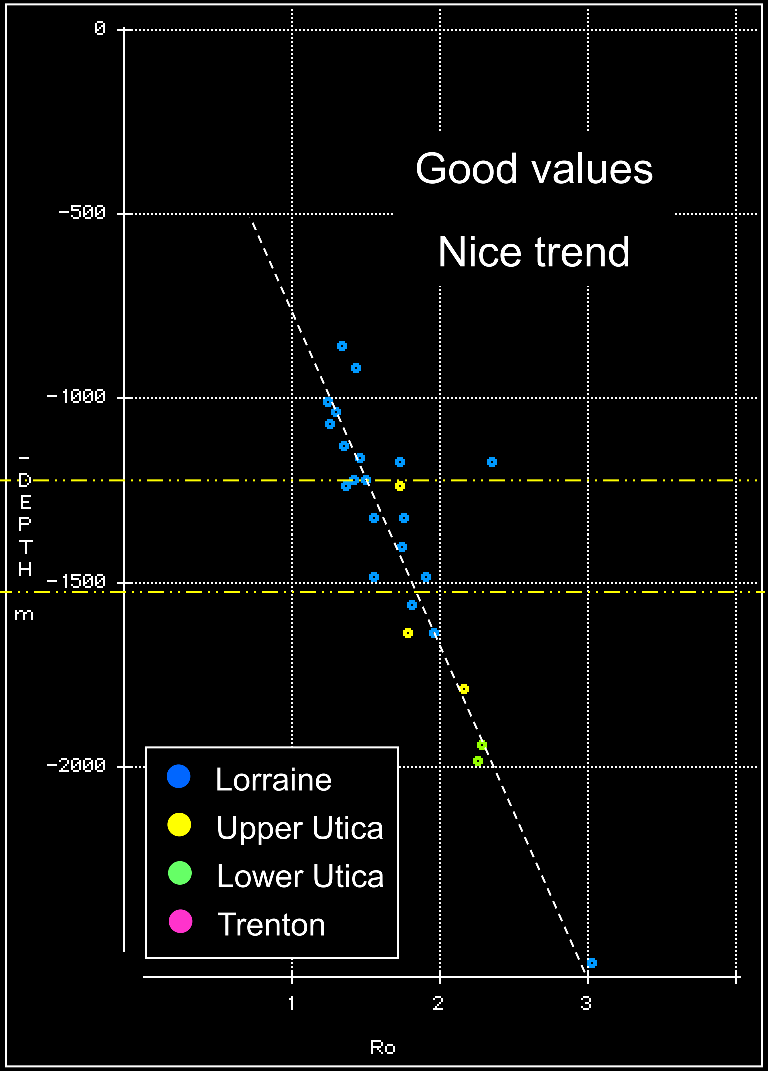
Depth (m)

Tmax



Depth (m)

Vitrinite



Geochemistry

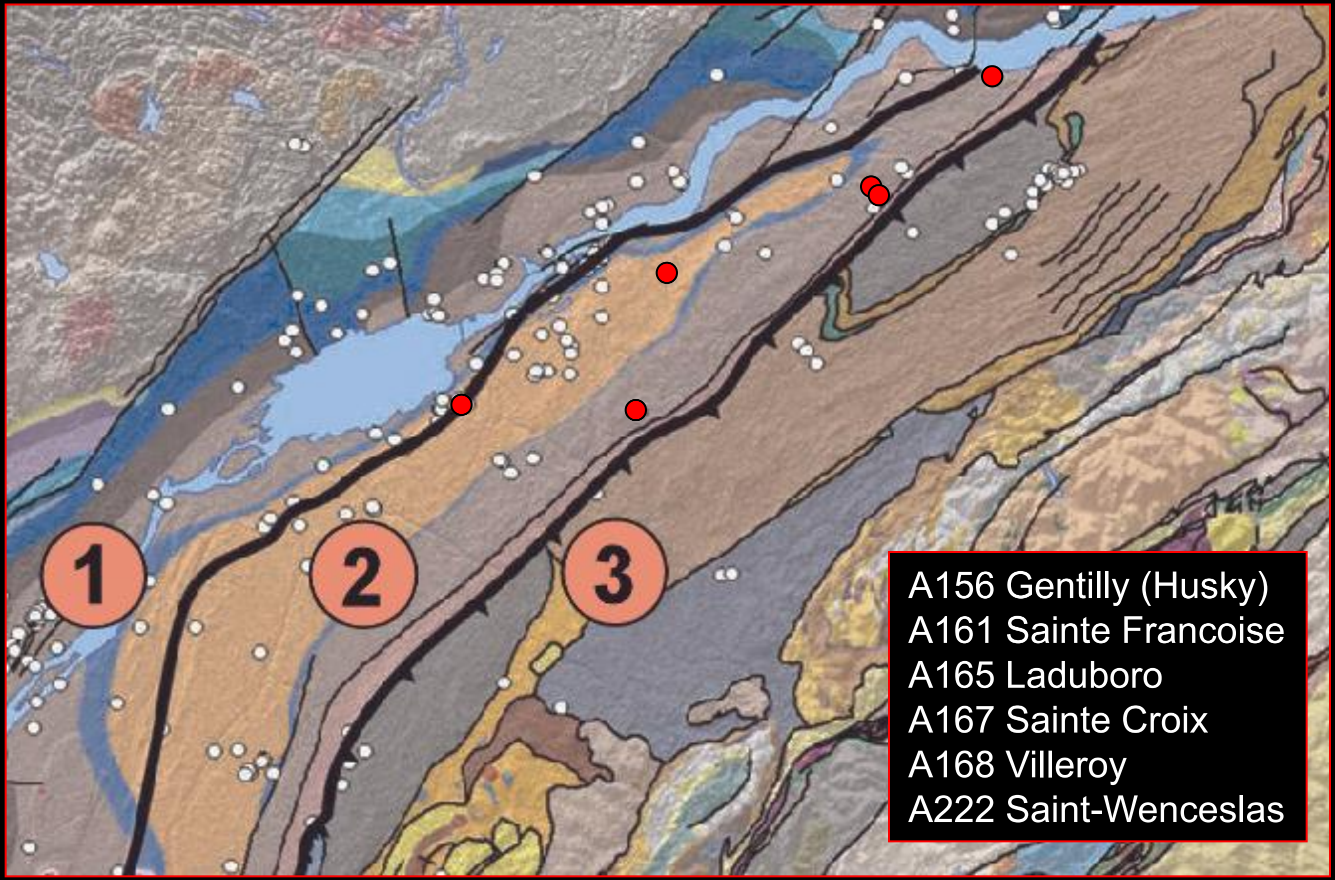
Examples from Quebec

Tmax	Rock-Eval
Vitrinite (Ro)	Microscopy
Gas composition	Isotubes and Geojars
Isotope composition	Isotubes and Geojars

TALISMAN ENERGY

Selected wells for Tmax and Ro trends

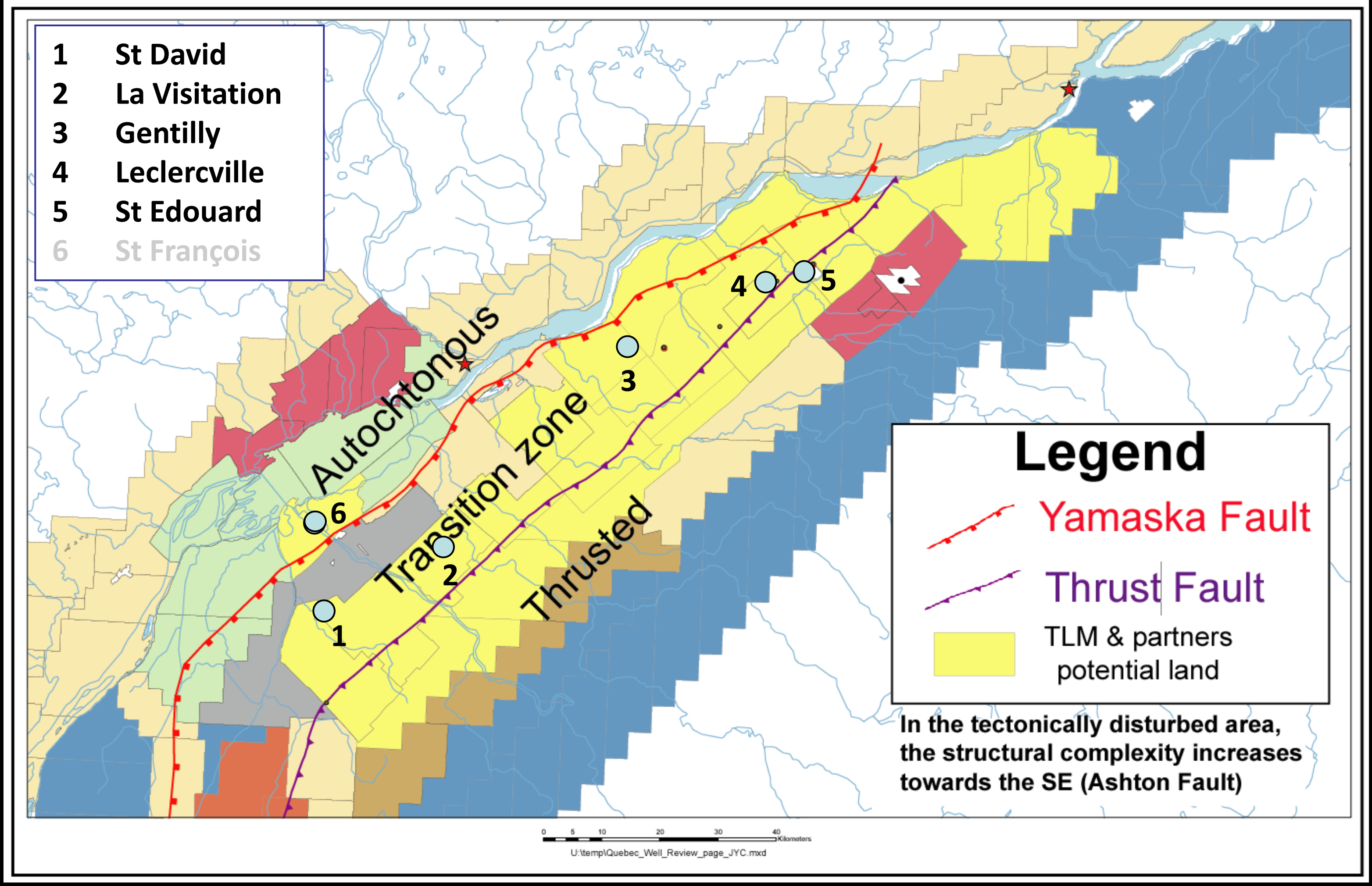
What we have seen before



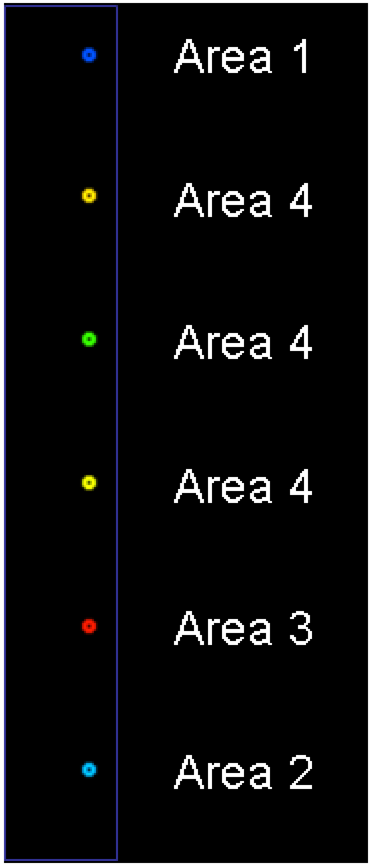
Map from Robert Theriault

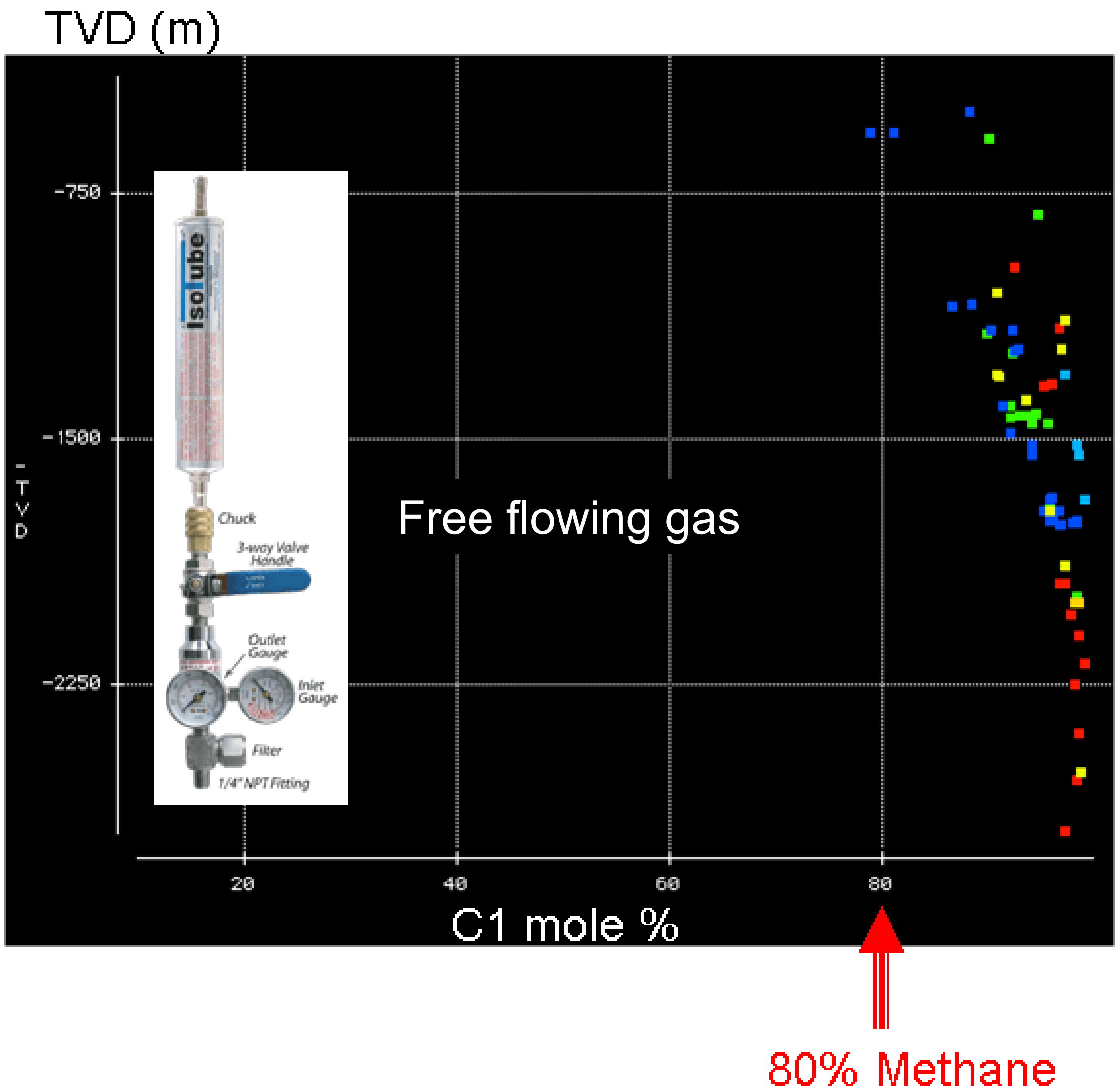
Data from the Geological Survey of Canada

Quebec, Talisman wells

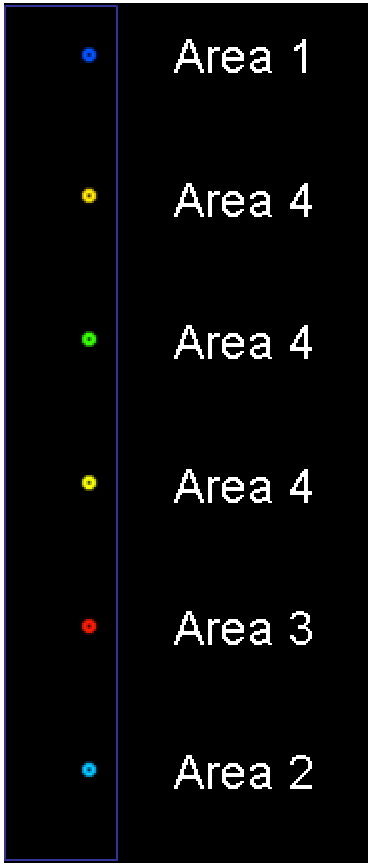


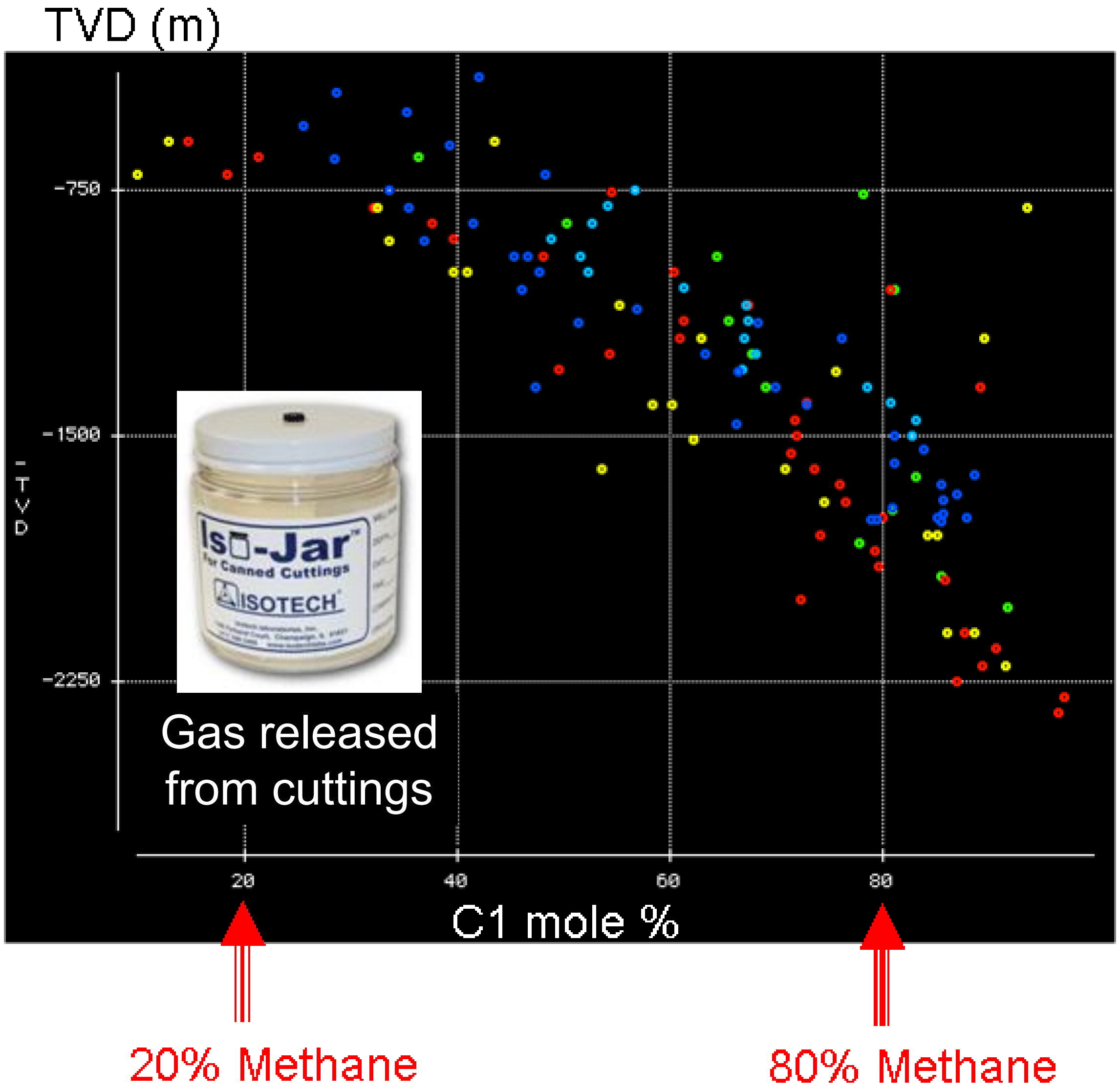
Isotubes Recent Talisman Wells





Geojars Recent Talisman Wells

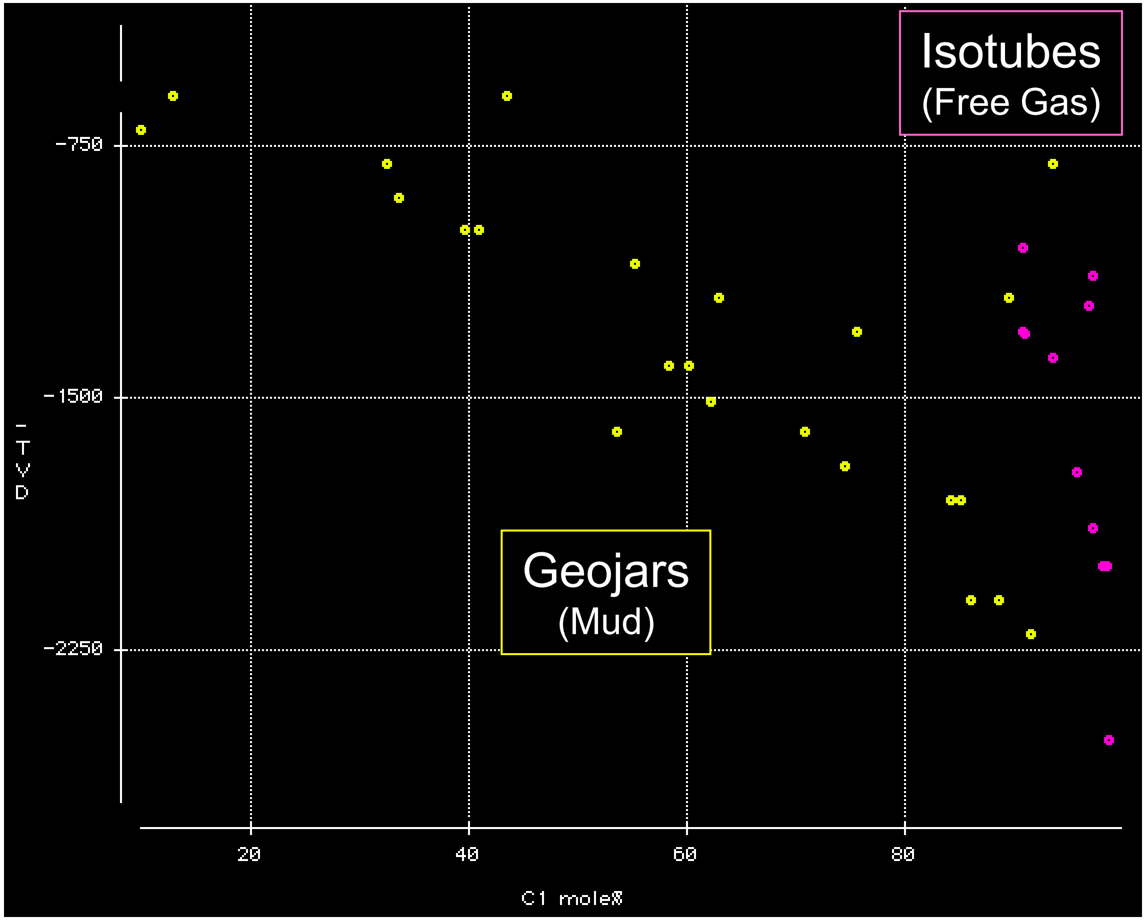




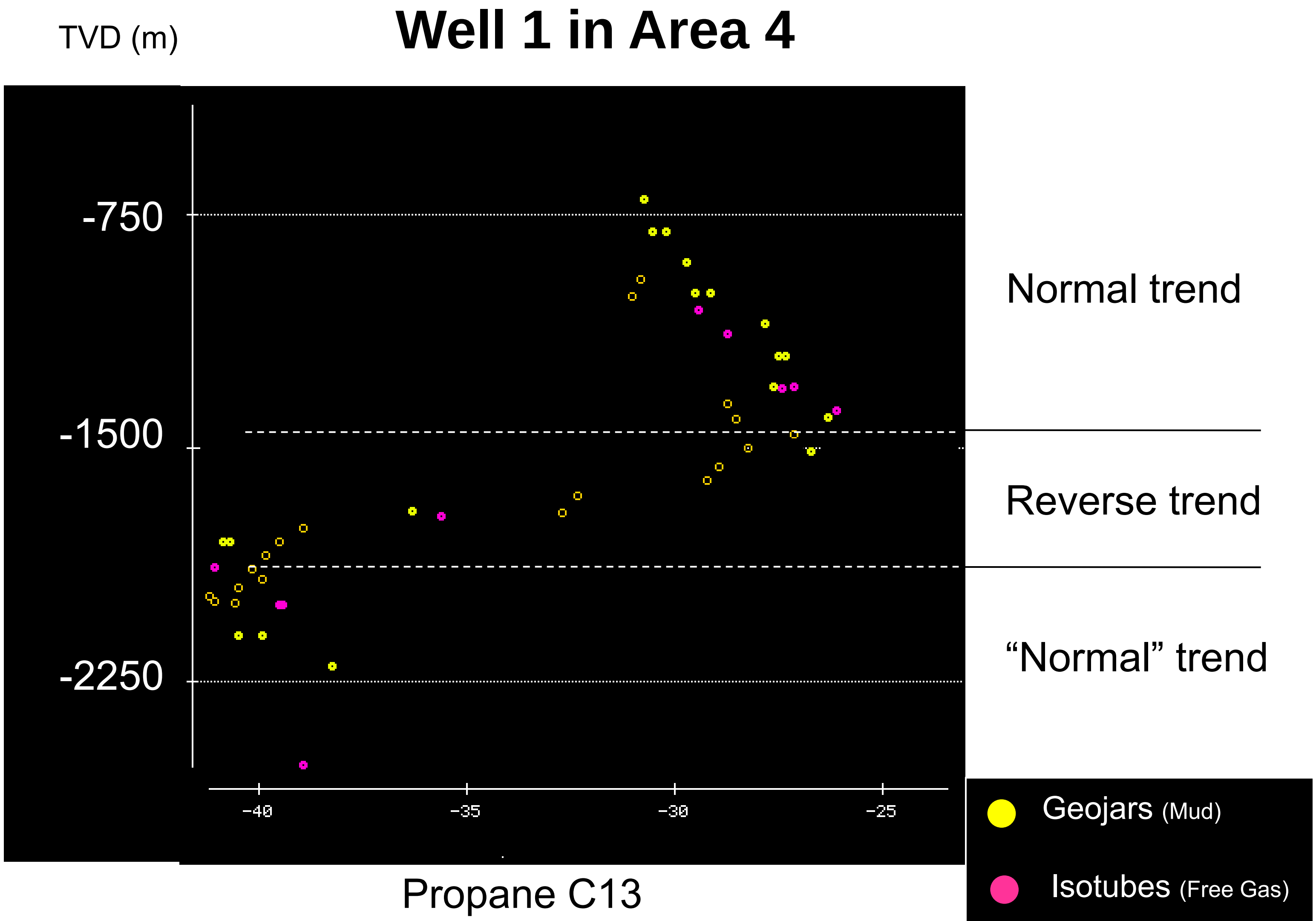
Big difference in gas composition
between isotubes and geojars

TVD (m)

Well 1 in Area 4

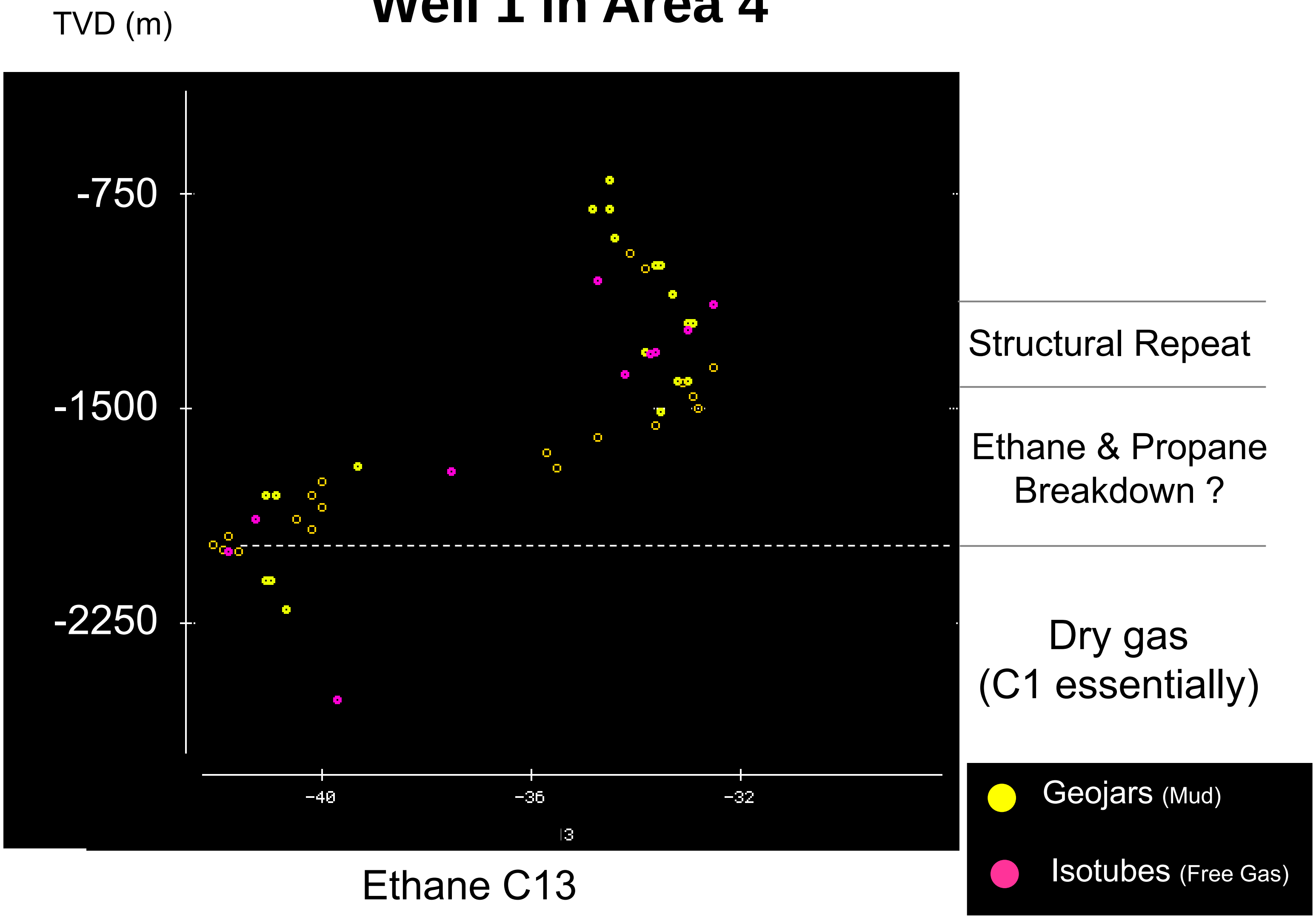


Propane isotope

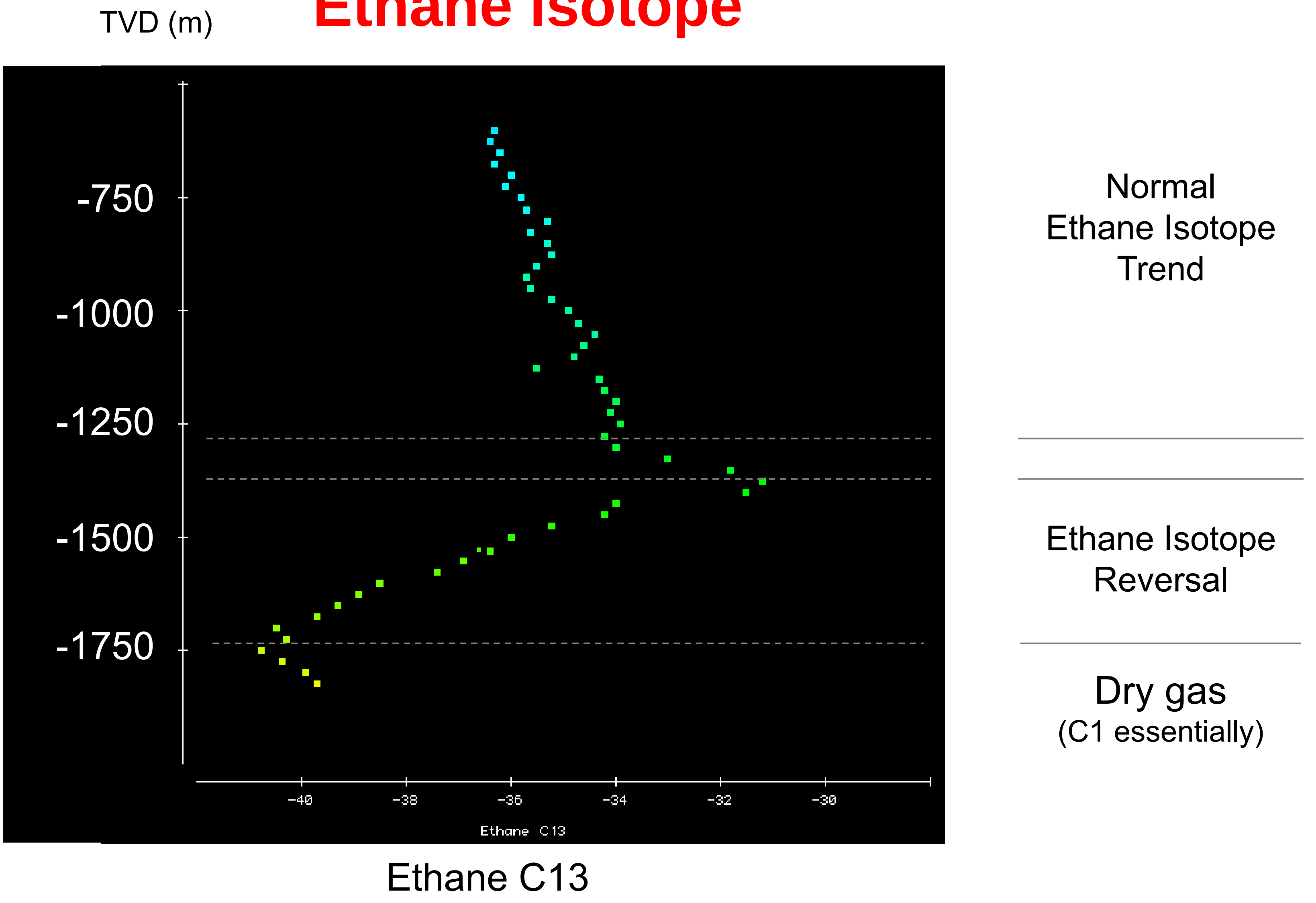


Ethane isotope

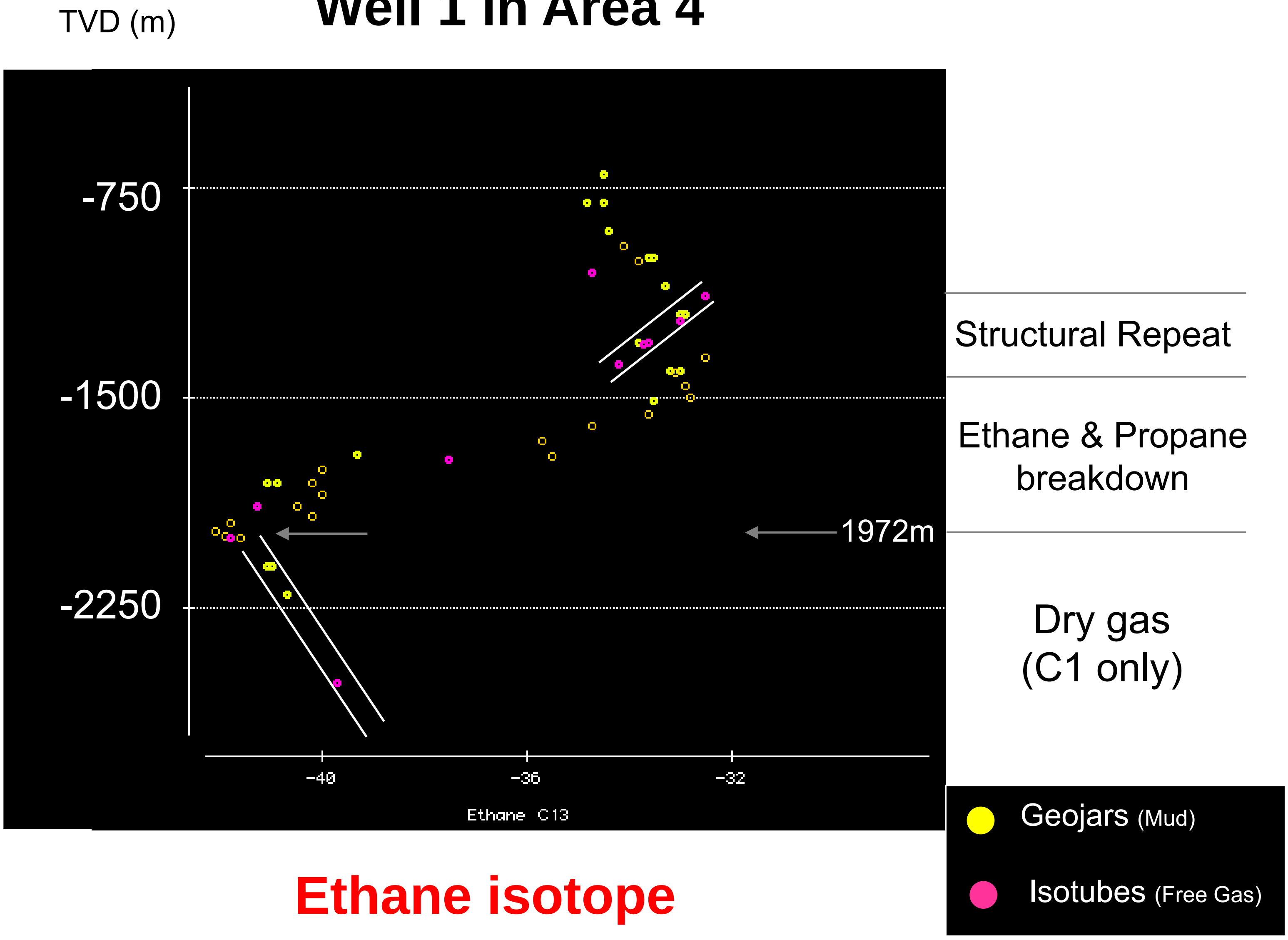
Well 1 in Area 4



Ethane isotope



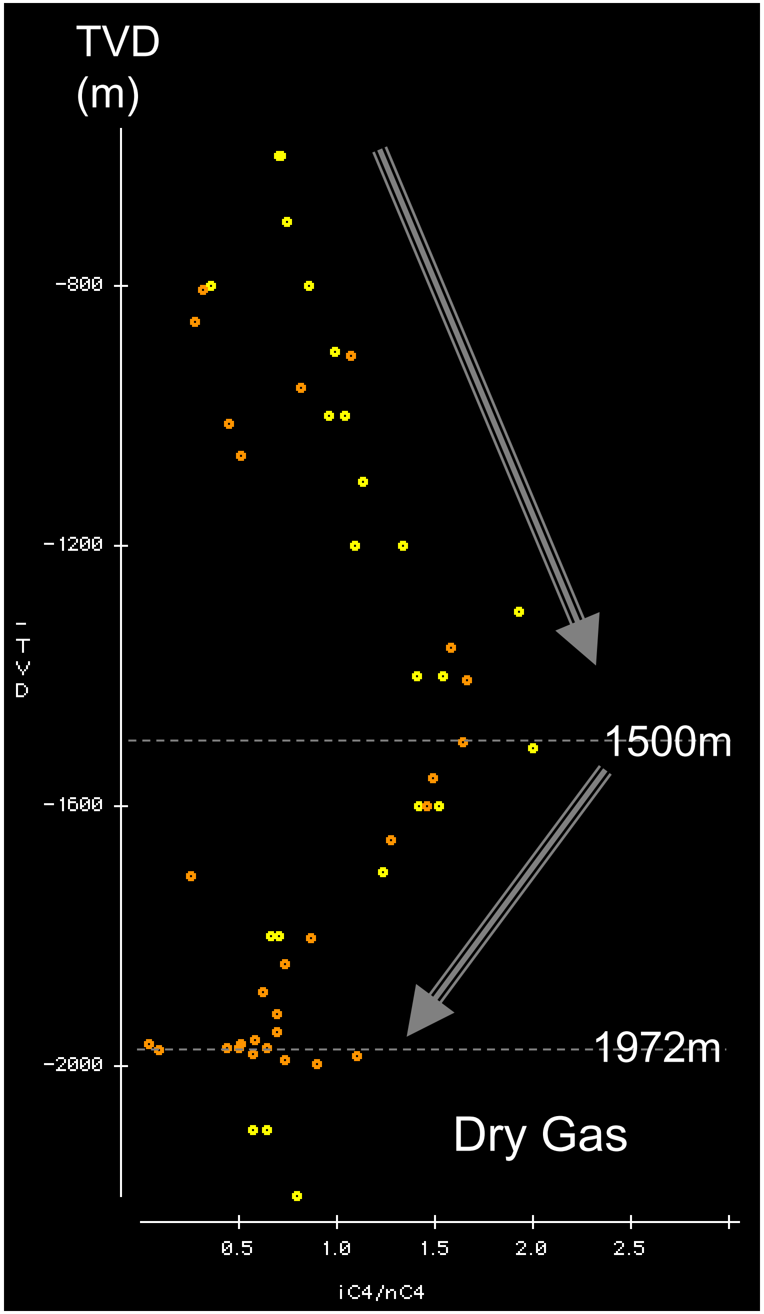
Well 1 in Area 4



Ethane isotope

IsoButane/nButane

from geojars



Area 4 Well 1
Area 4 Well 3

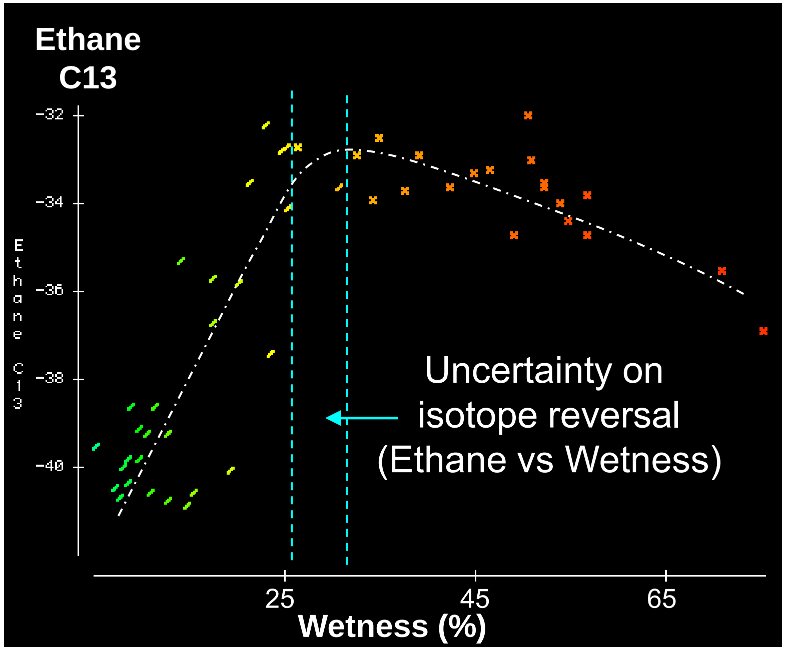
Normal trend

Ethane and propane
secondary cracking ?

Dry Gas

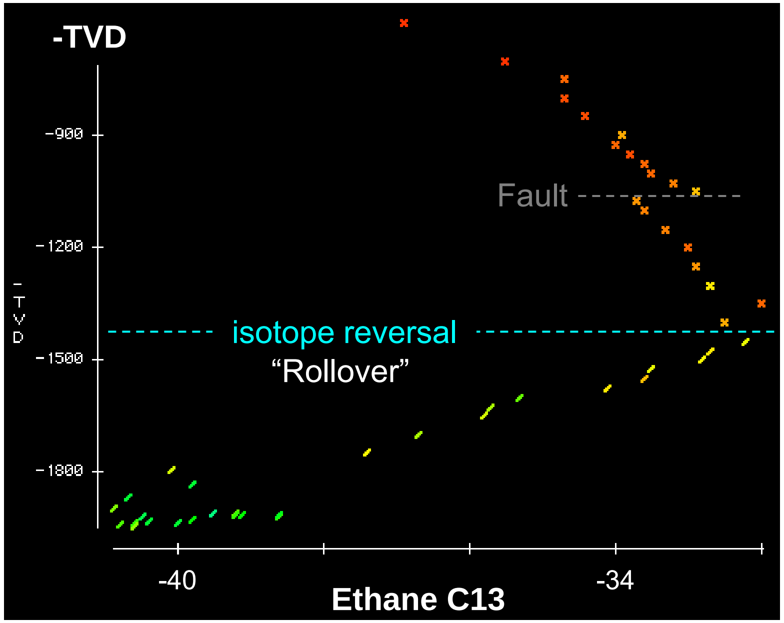
Expressions of Isotope Rollover

Traditional Display



Wetness = C2+ / C1+

Geological Display (depth)



Colors tied to wetness from green (dryer) to red (wetter)

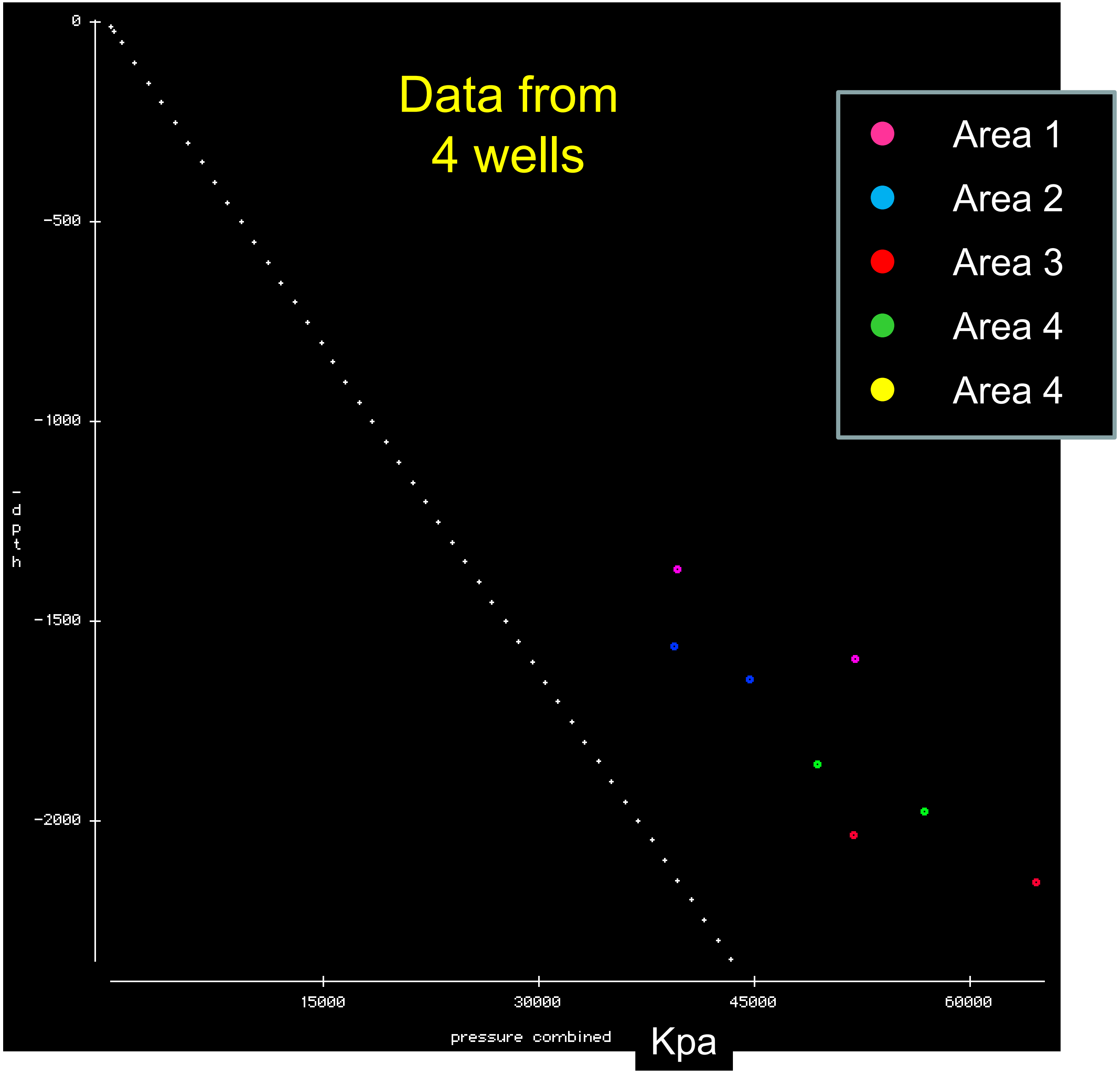
Analogy to phase envelope

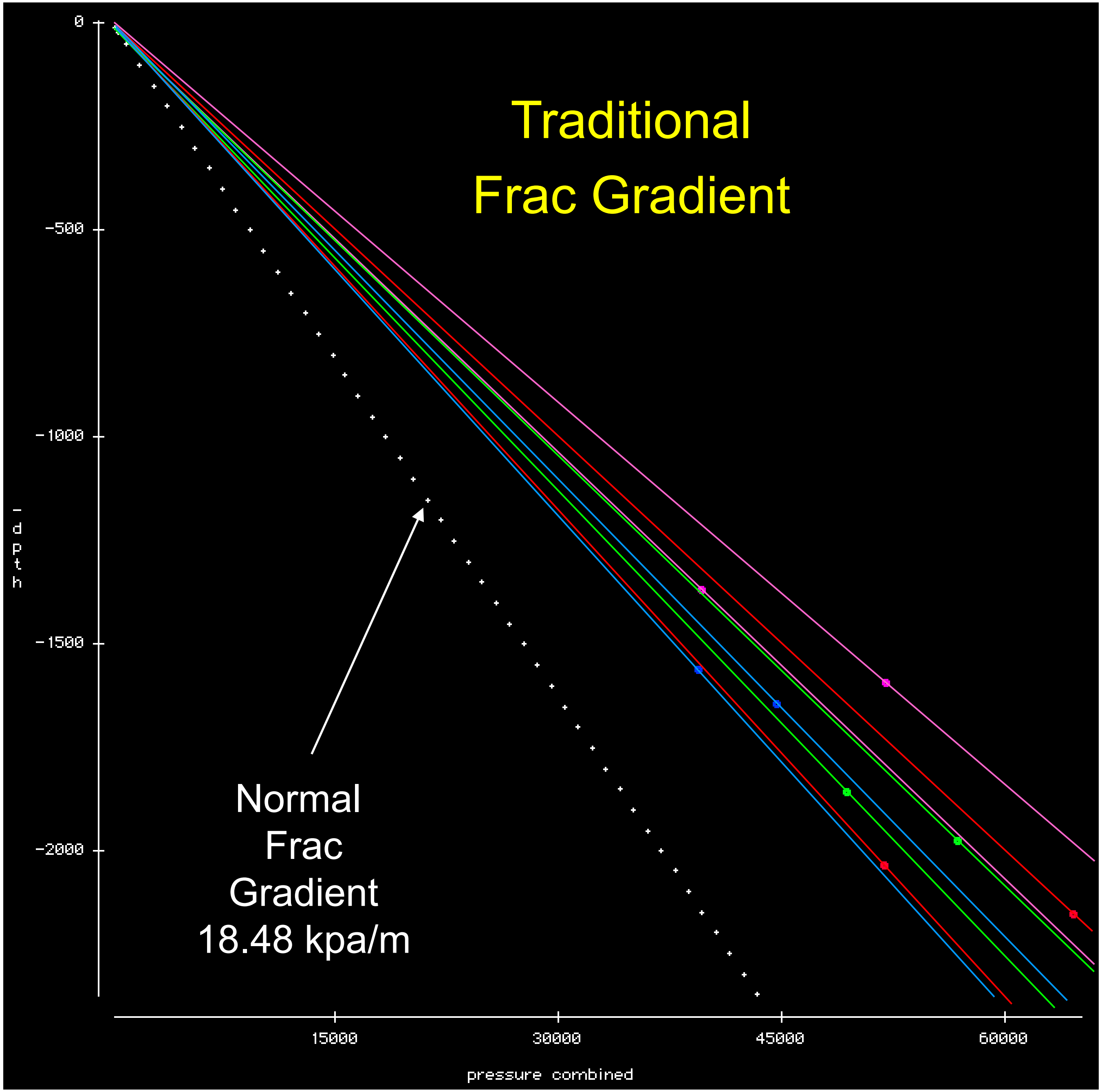
Frac Gradients

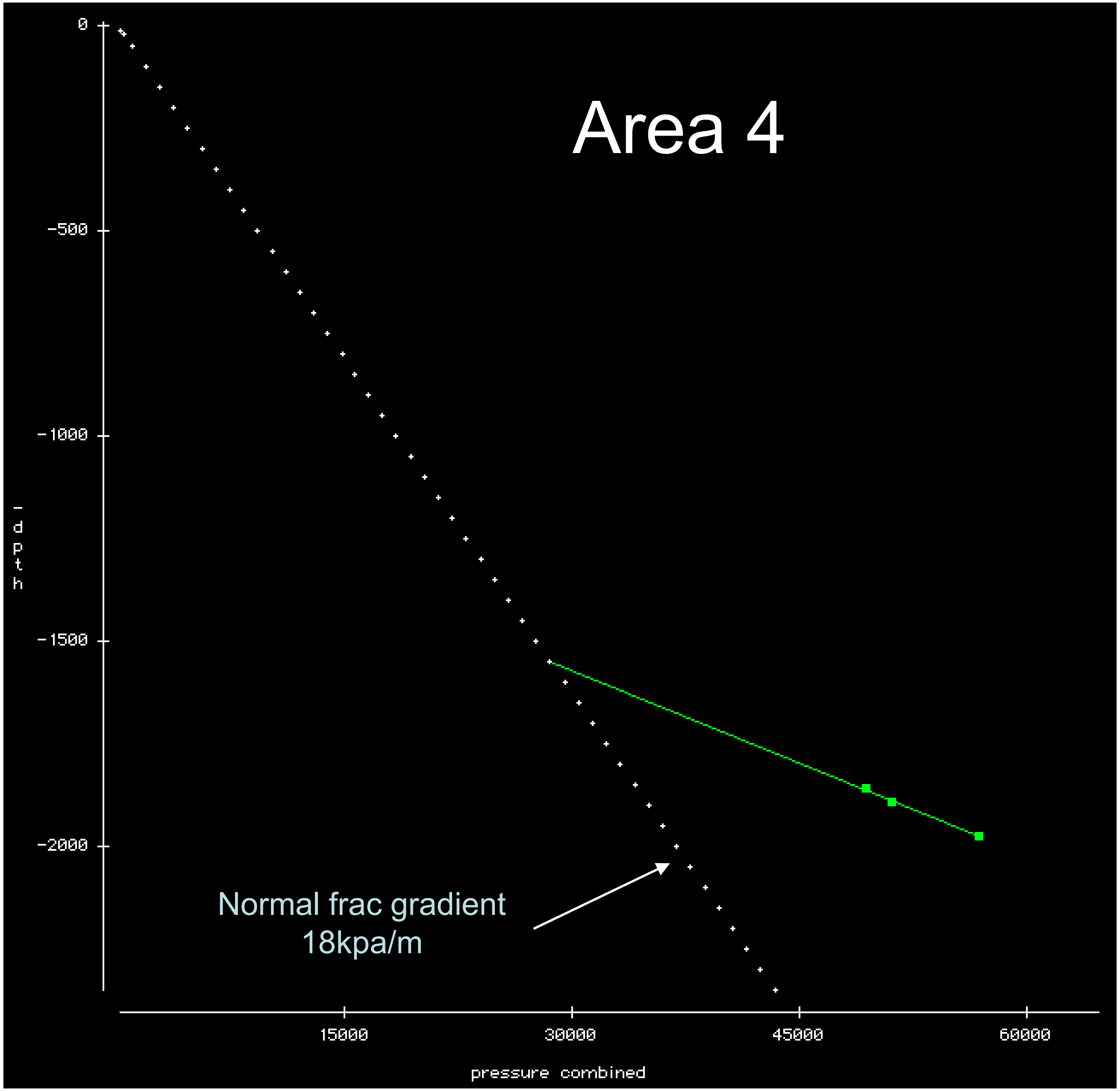
- Data from fracs in vertical wells
- All of the ISIP data are

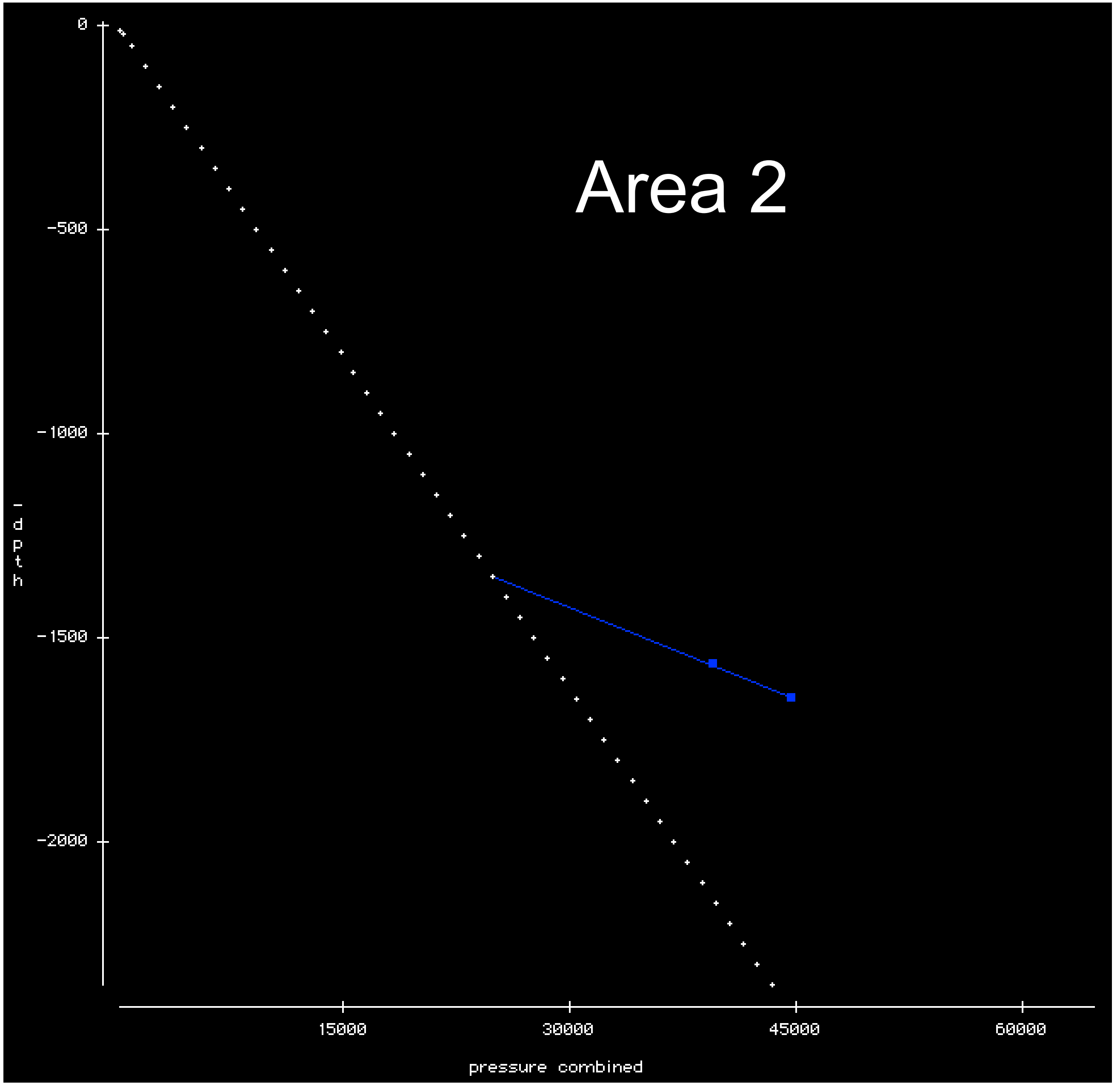
  from interpretation of one single completion engineer

ISIP = Instantaneous Shut-In Pressure in Kpa

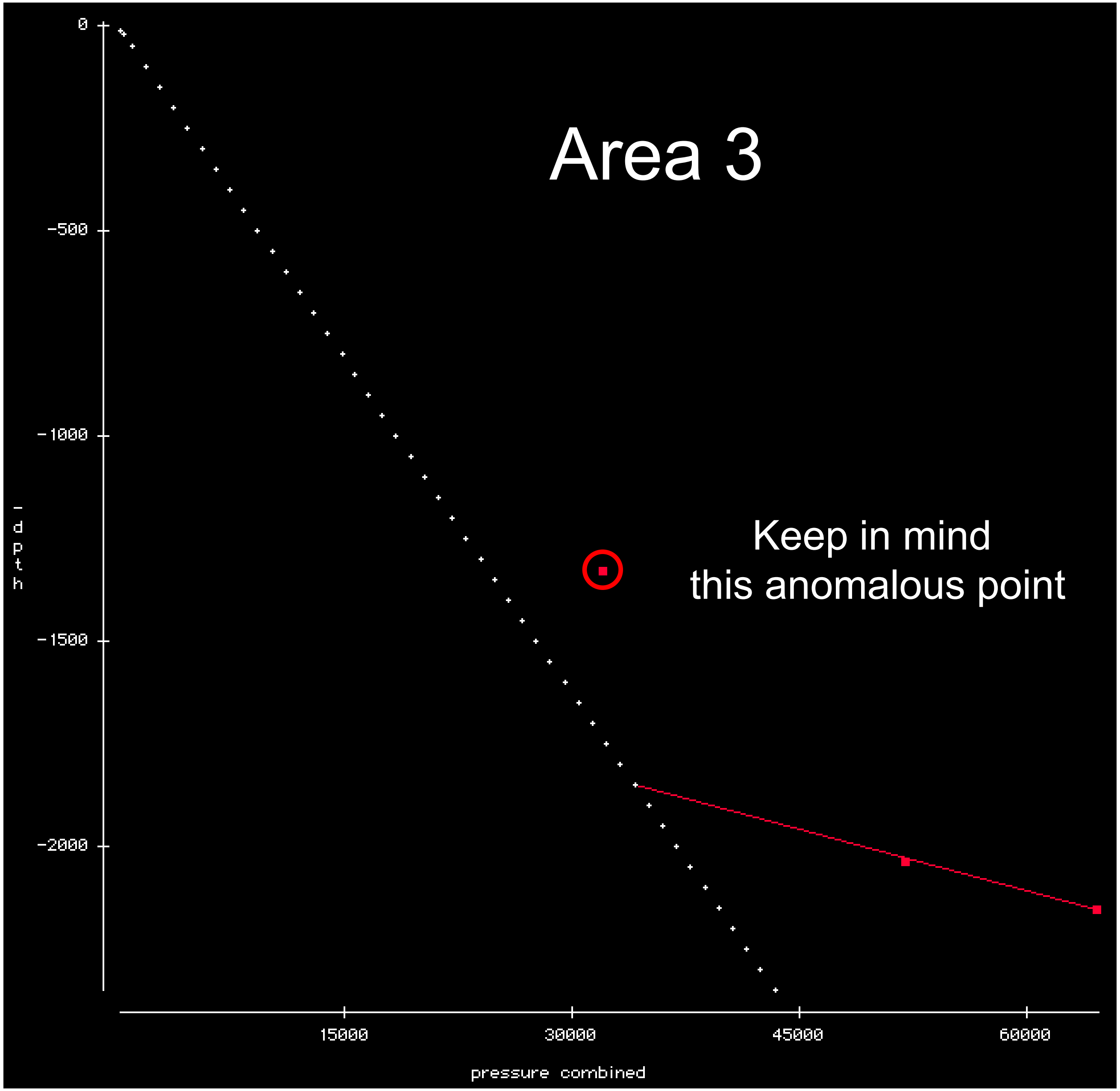

Data from
4 wells
Area 1
Area 2
Area 3
Area 4
Area 4
0
-500
-1000
-1500
-2000
-dpth
15000
30000
45000
60000
pressure combined
Kpa

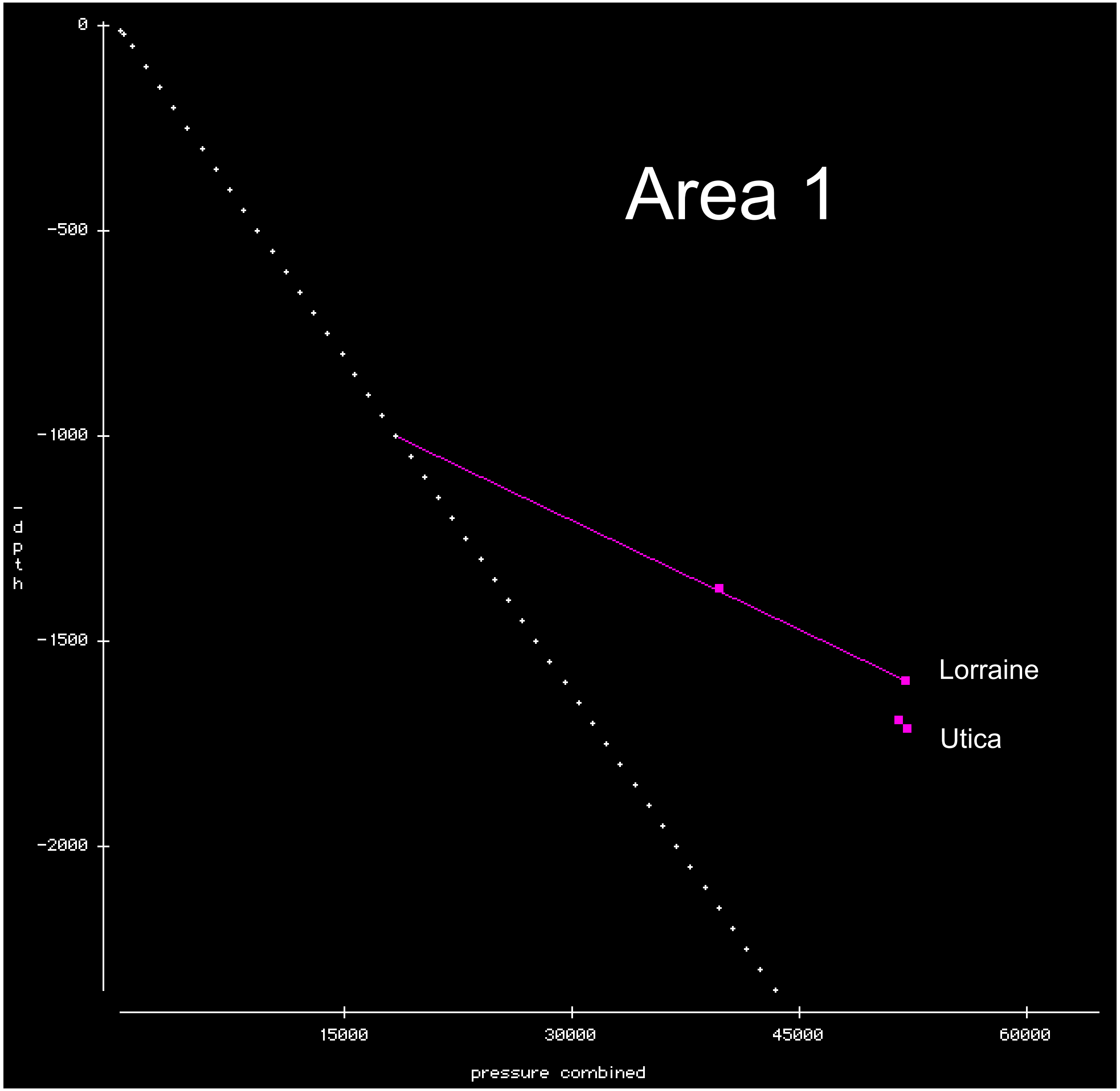

Traditional
Frac Gradient
Normal
Frac
Gradient
18.48 kpa/m
0
-500
-1000
-1500
-2000
- d p t h
15000
30000
45000
60000
pressure combined


Area 4
0
-500
-1000
-1500
-2000
-depth
15000
30000
45000
60000
pressure combined
Normal frac gradient
18kpa/m

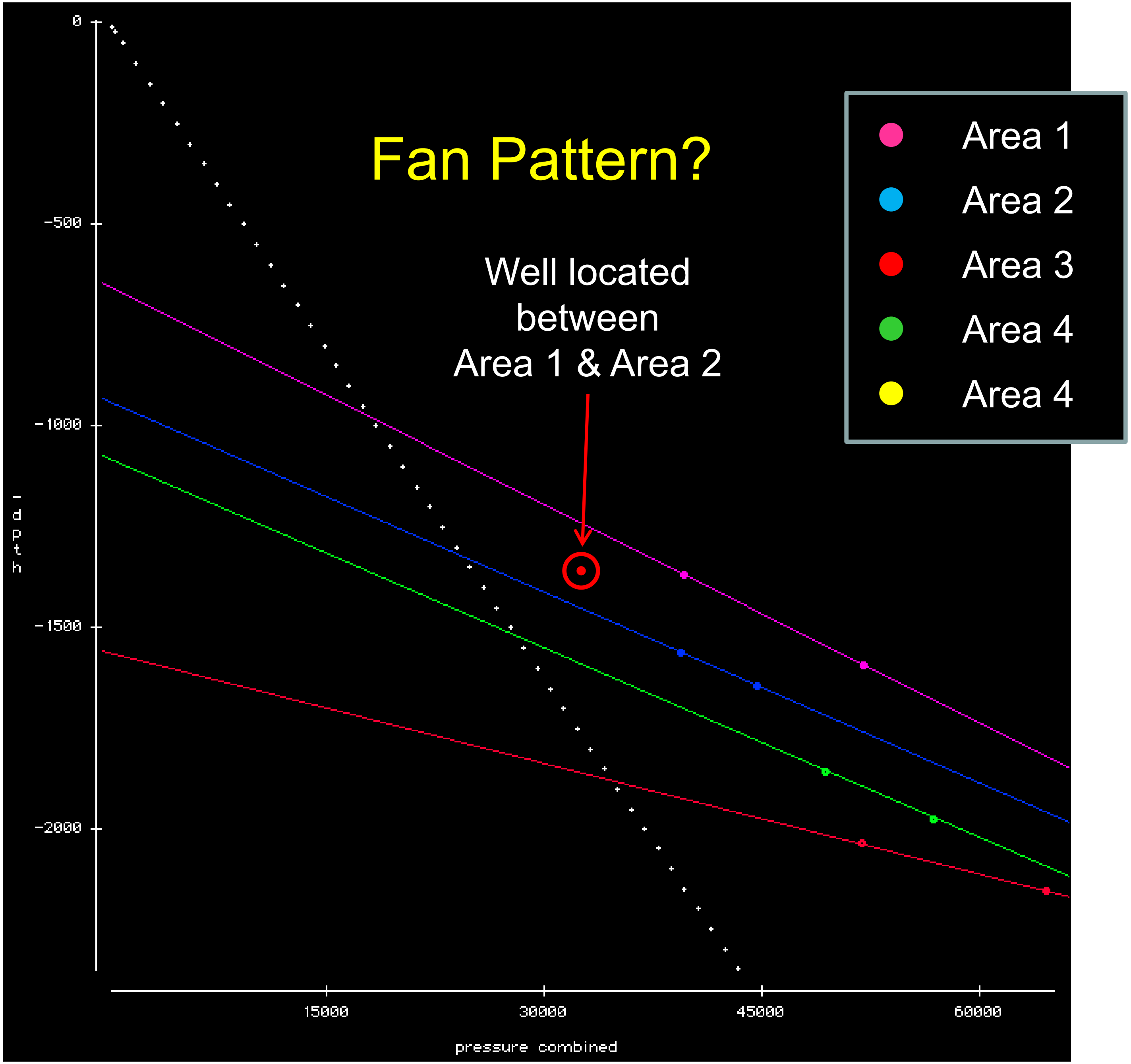


Area 2
0
-500
-1000
-1500
-2000
depth
15000
30000
45000
60000
pressure combined


Area 3
Keep in mind
this anomalous point
0
-500
-1000
-1500
-2000
-dpth
15000
30000
45000
60000
pressure combined



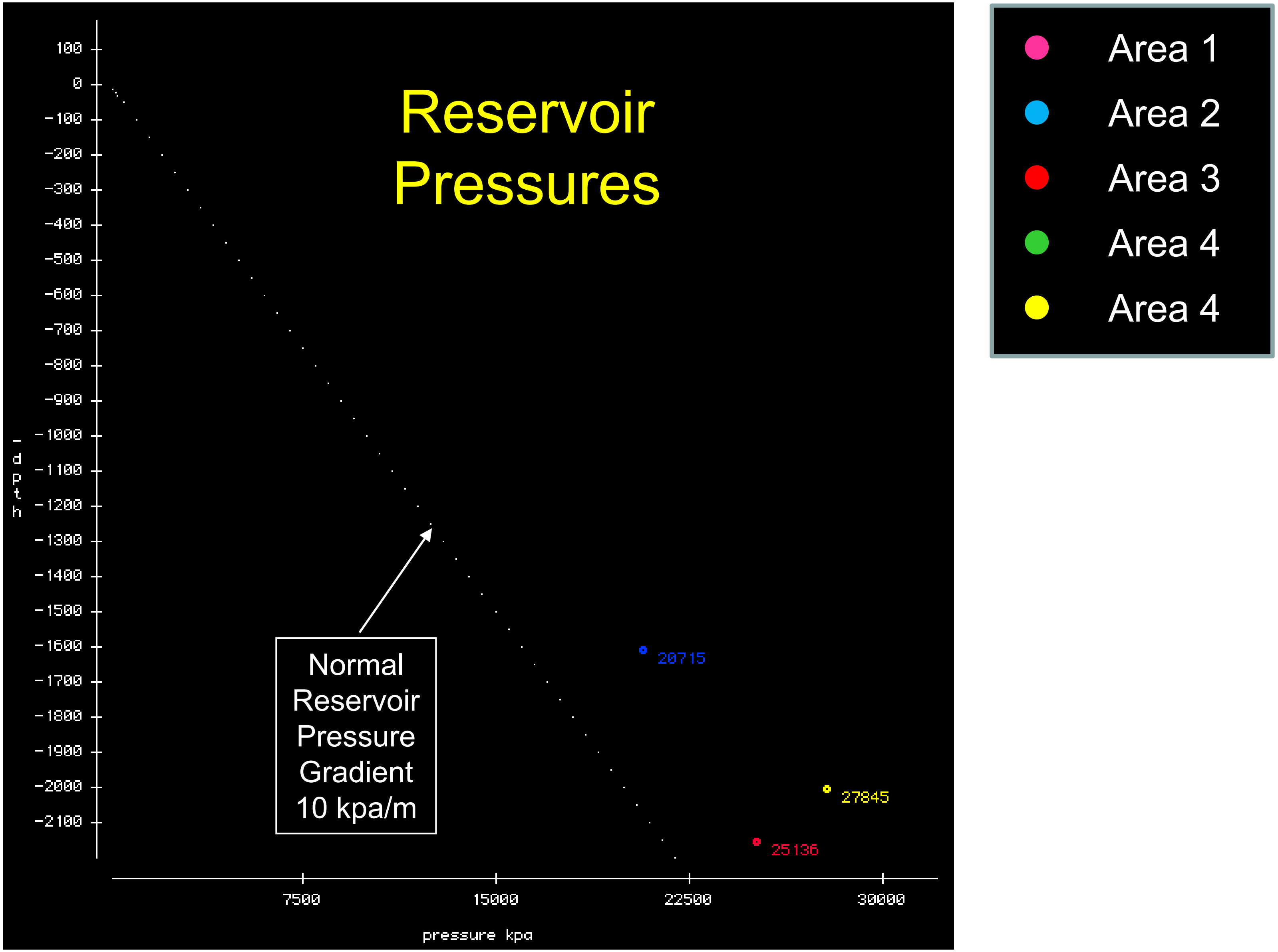
Area 1
0
-500
-1000
-1500
-2000
depth
Lorraine
Utica
15000
30000
45000
60000
pressure combined



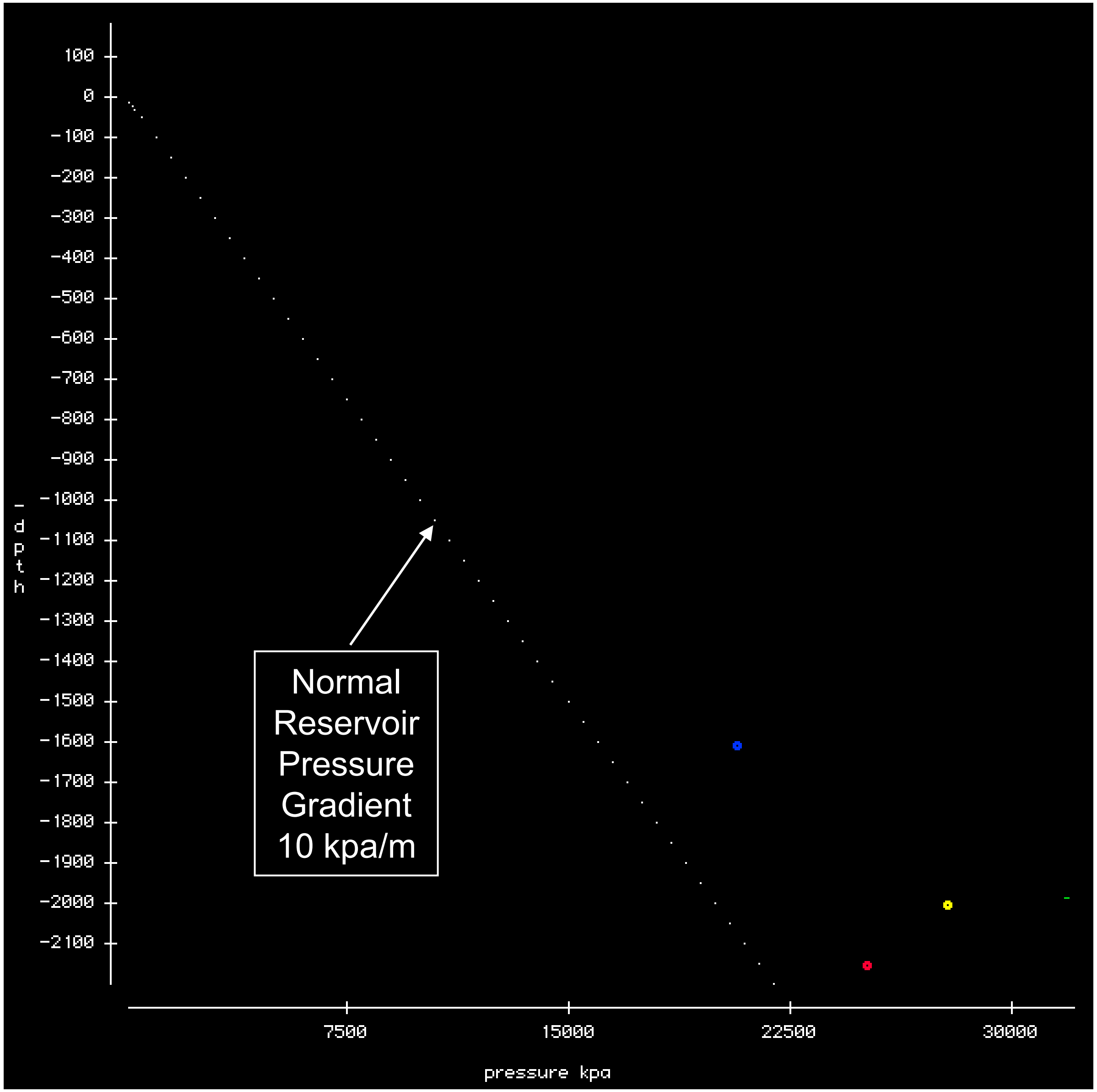
Fan Pattern?
Well located between Area 1 & Area 2
Area 1
Area 2
Area 3
Area 4
Area 4
0
-500
-1000
-1500
-2000
-depth
15000
30000
45000
60000
pressure combined

Reservoir Pressure

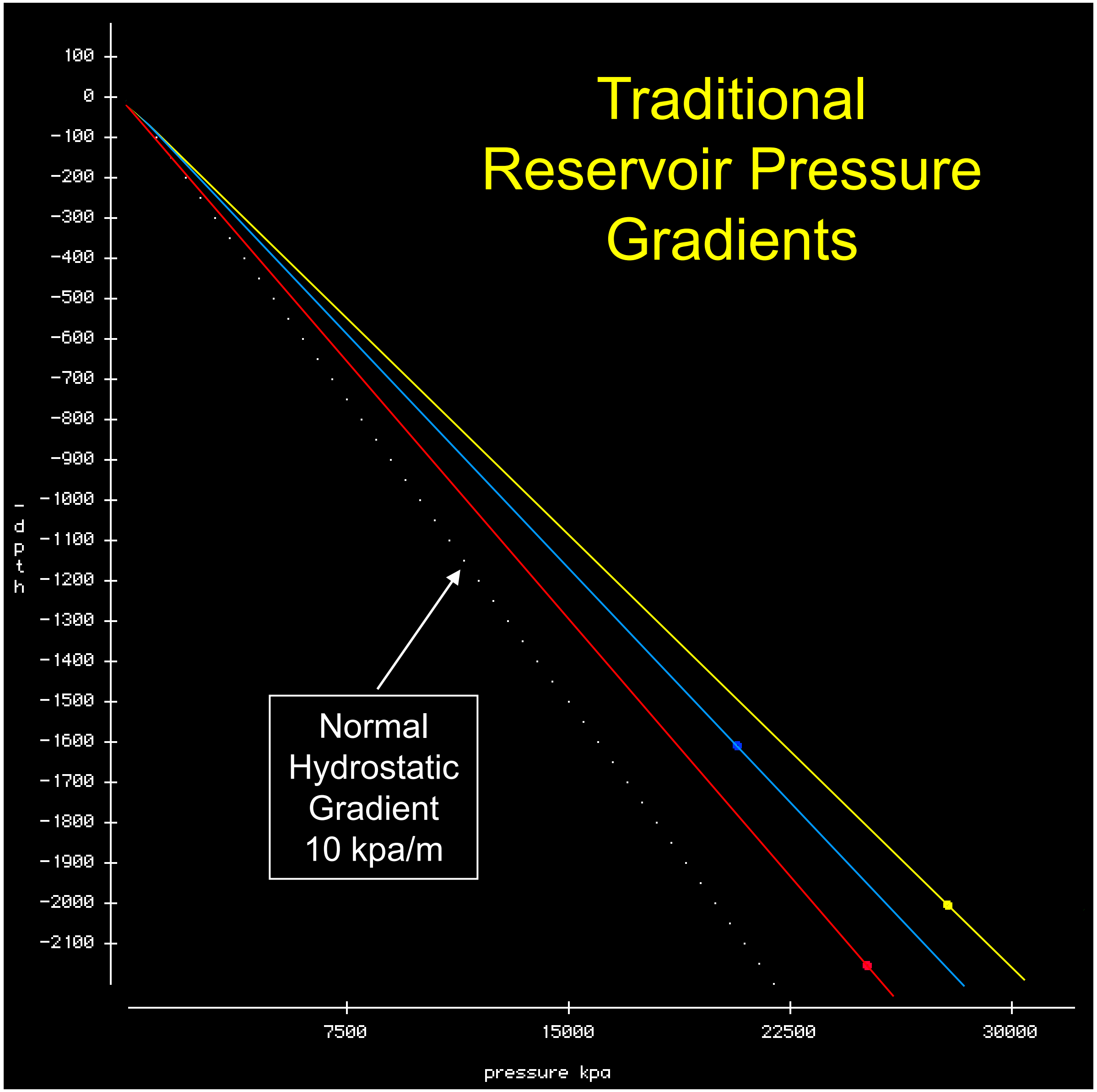
- Data from monitors left for six months downhole in vertical wells
- All of the data from interpretation of one single reservoir engineer

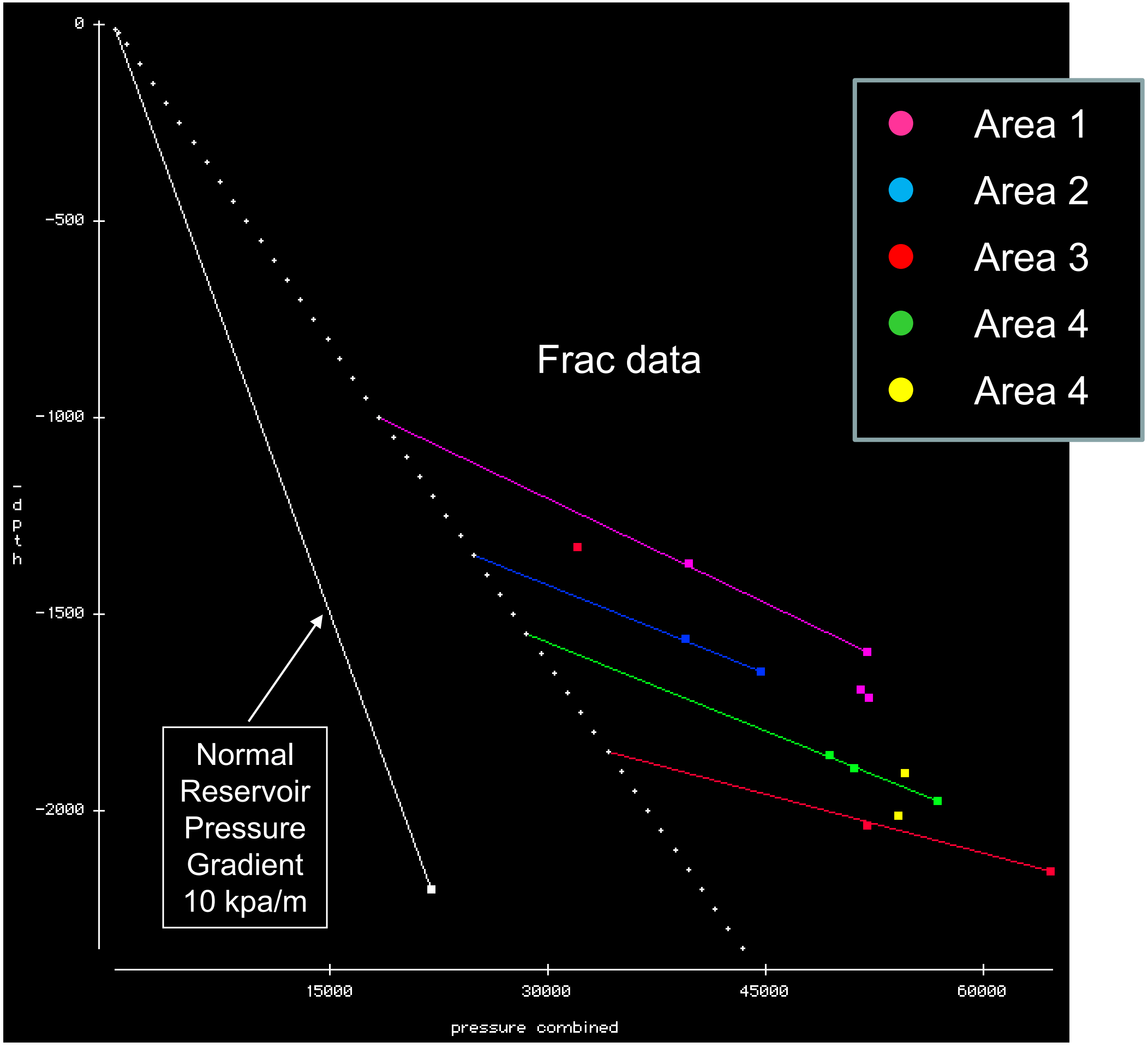


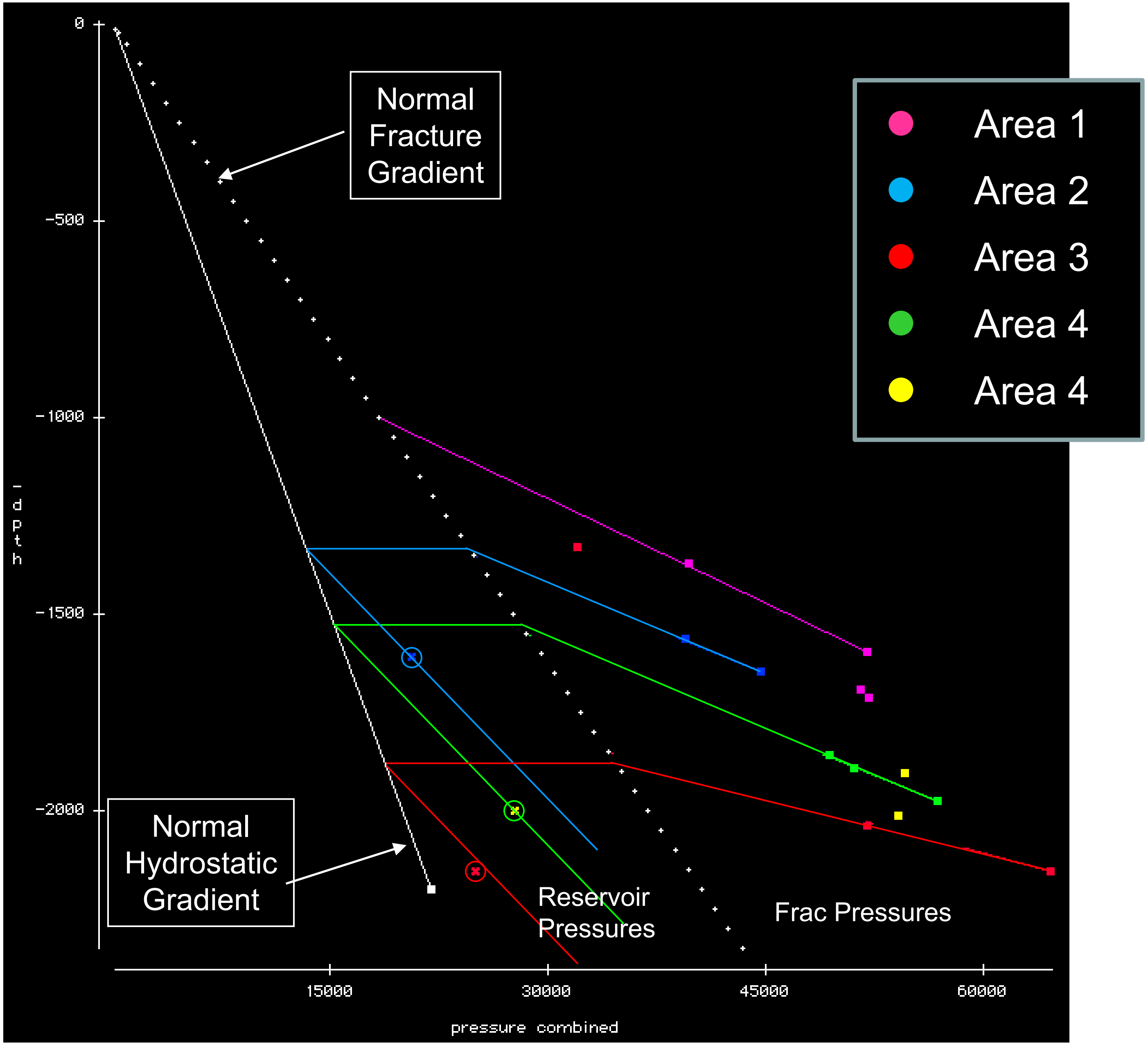
Reservoir Pressures
Normal Reservoir Pressure Gradient 10 kpa/m
20715
27845
25136
pressure kpa
-dpth
Area 1
Area 2
Area 3
Area 4
Area 4



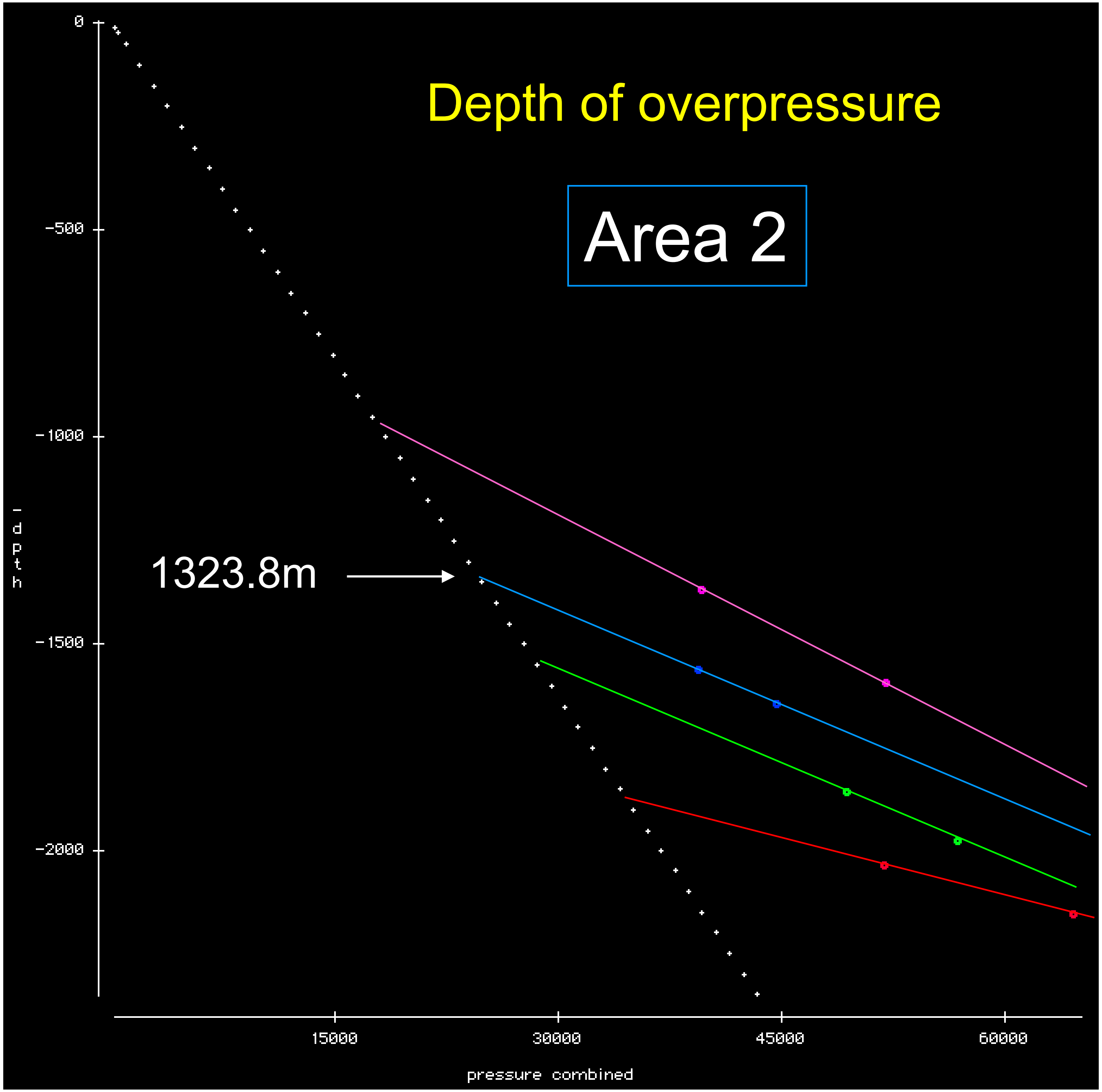
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
-dpth
7500
15000
22500
30000
pressure kpa
Normal Reservoir Pressure Gradient 10 kpa/m


Traditional
Reservoir Pressure
Gradients
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
-1100
-1200
-1300
-1400
-1500
-1600
-1700
-1800
-1900
-2000
-2100
-dpth
Normal
Hydrostatic
Gradient
10 kpa/m
7500
15000
22500
30000
pressure kpa


0
-500
-1000
-1500
-2000
-depth
15000
30000
45000
60000
pressure combined
Frac data
Area 1
Area 2
Area 3
Area 4
Area 4
Normal Reservoir Pressure Gradient 10 kpa/m



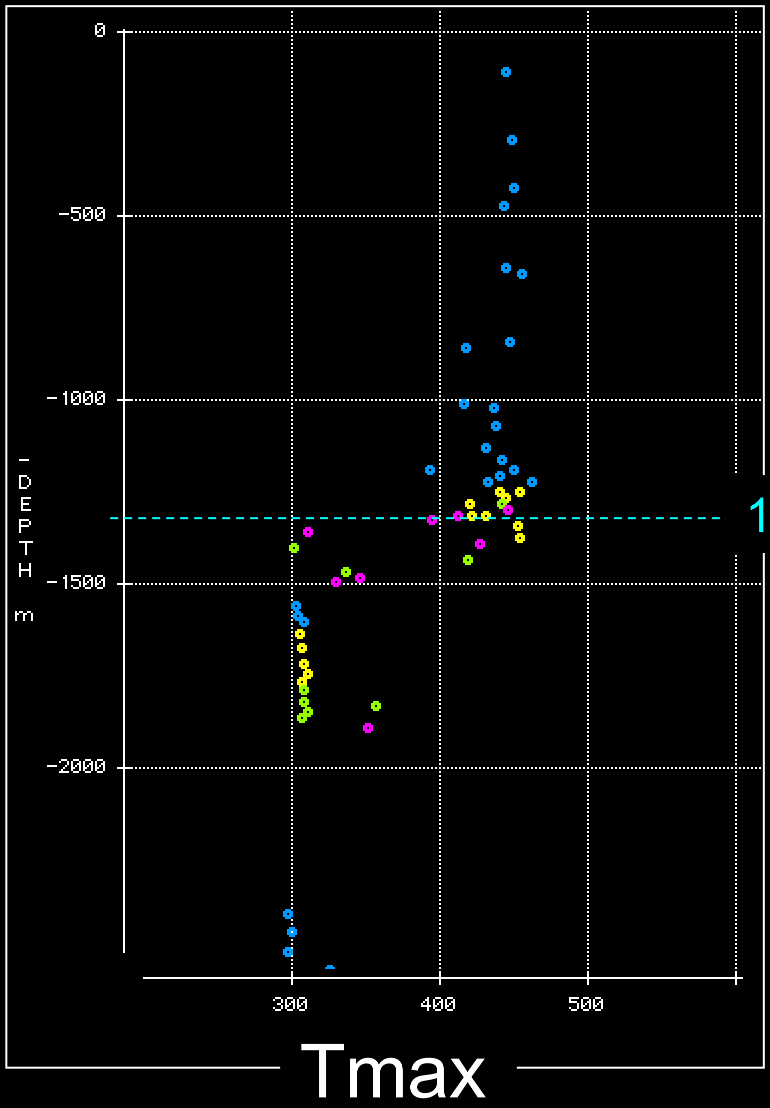
Normal
Fracture
Gradient
Normal
Hydrostatic
Gradient
Reservoir
Pressures
Frac Pressures
Area 1
Area 2
Area 3
Area 4
Area 4
0
-500
-1000
-1500
-2000
-dpth
15000
30000
45000
60000
pressure combined

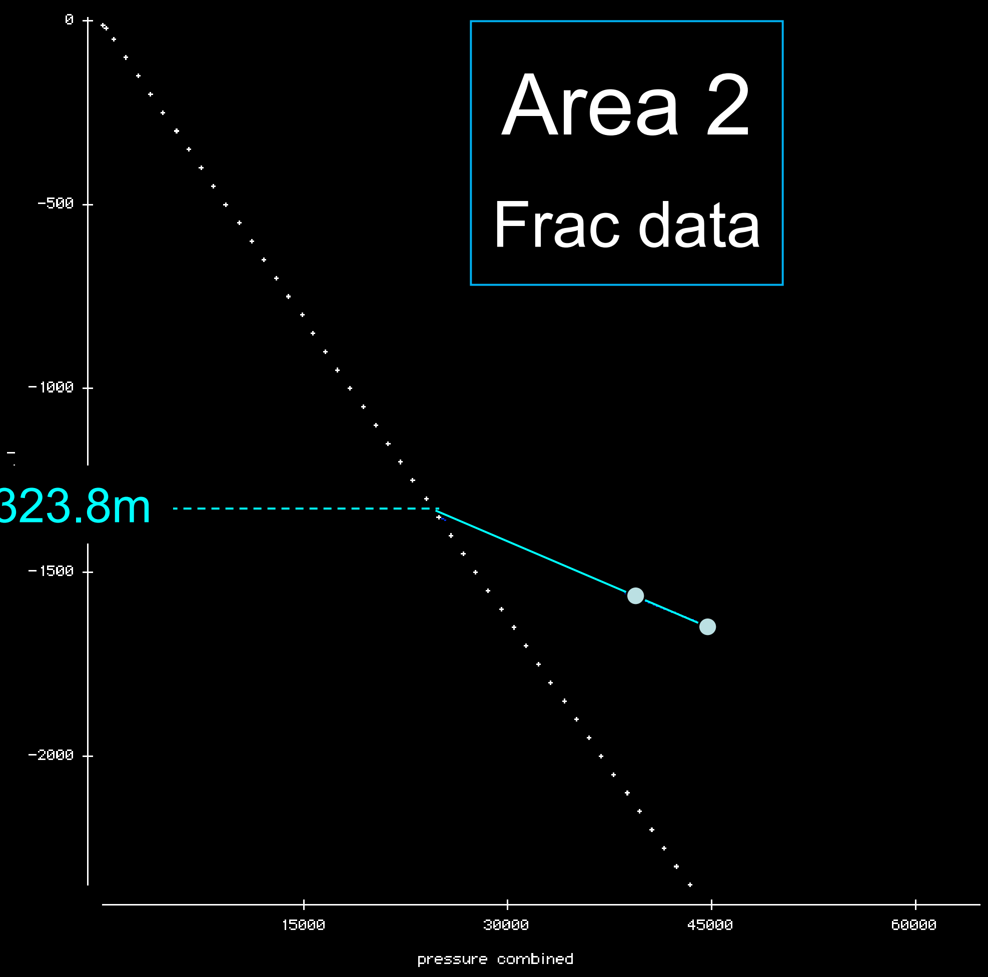


Depth of overpressure
Area 2
1323.8m
0
-500
-1000
-1500
-2000
-depth
15000
30000
45000
60000
pressure combined

TALISMAN ENERGY

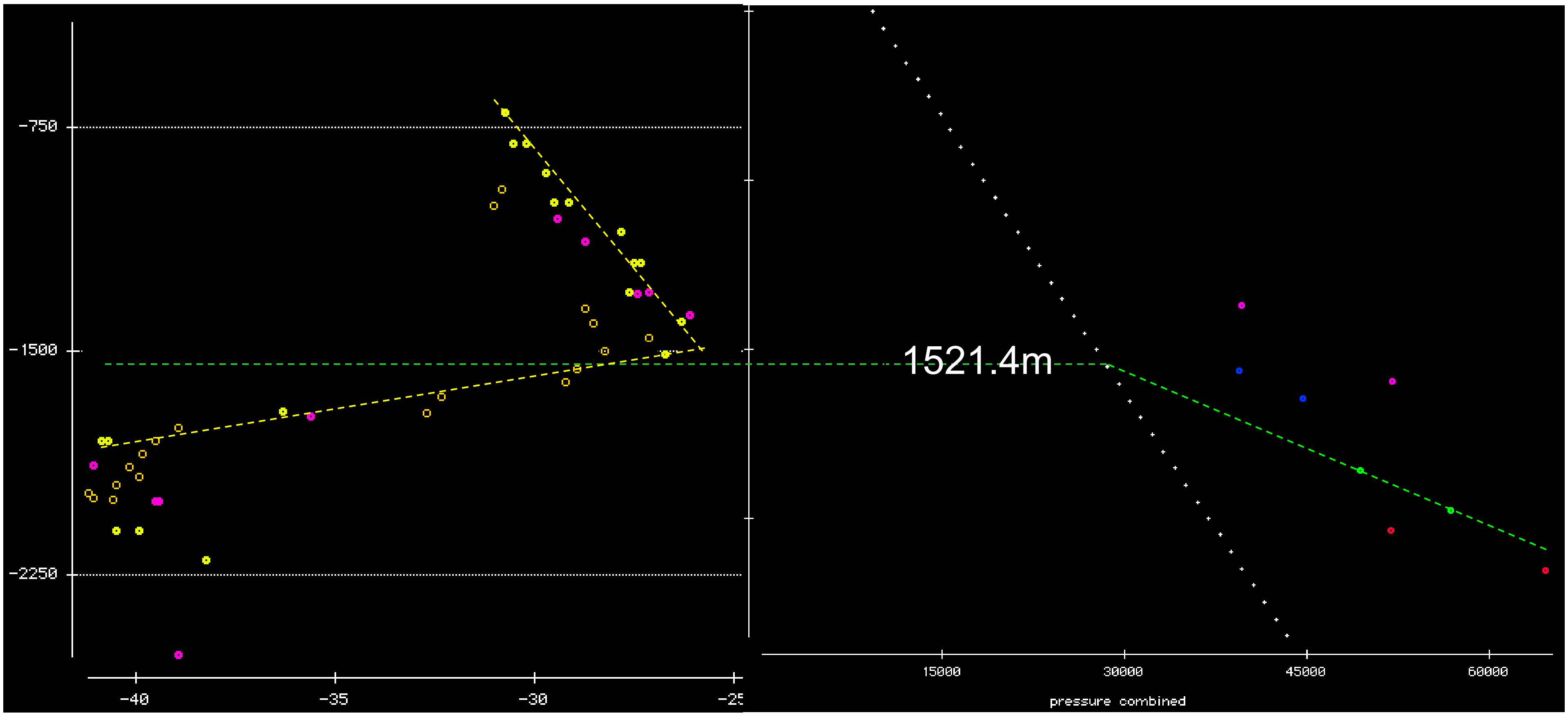
6 other wells from Area 2





Match frac data with isotope reversal

Area 4 Well 1 ← 7km → Area 4 Well 2



Propane isotopes

Frac pressures

Match between overpressure from frac data and the Ethane or Propane Isotope Rollovers

Pressure Conclusions

Two domains can be distinguished:

Normally pressured and overpressured

Two gradients could be used to characterize a zone in one area

Instead of multiple gradients for every hydraulic frac

Frac data should be sufficient to **estimate reservoir pressure**

Usable for resource assessments and mud-weight prediction

In horizontal wells it is recommended to use only the **first frac stage** data

The only frac in virgin rock

Practical / economical Implications

Mud-weight predictions

Casing Strength Prediction

Choosing where to drill and frac

- Overpressured zone
- Dry gas window
- Optimal frac pressure depth