Midwest Geological Sequestration Consortium

General Overview of IBDP Microseismicity

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Schlumberger Carbon Services
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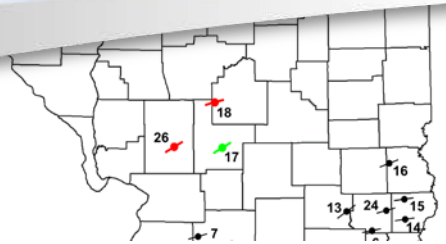
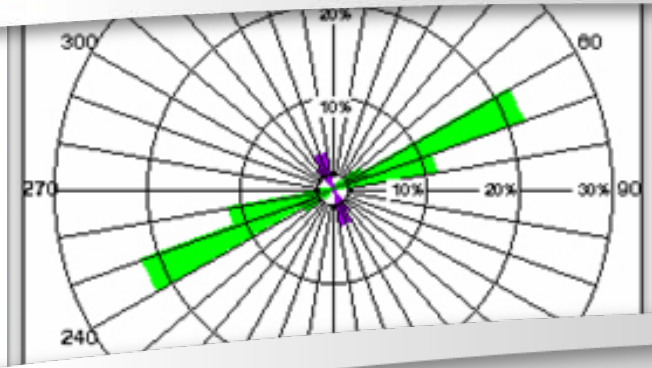
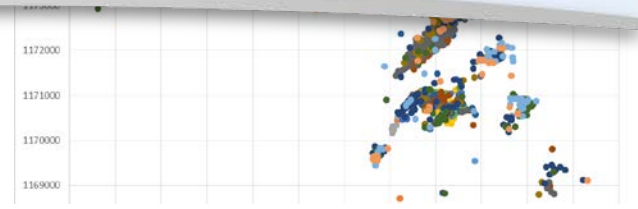
William Graham Payne, Geologist







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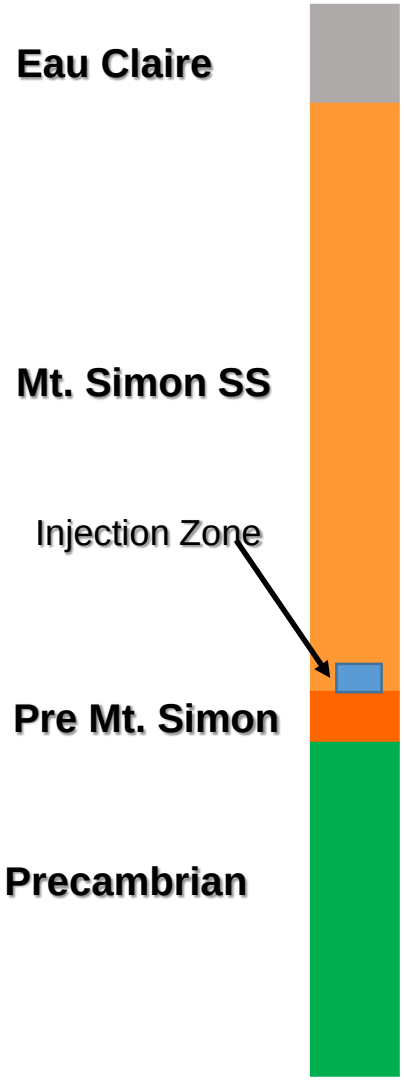
This is a general overview of the IBDP microseismicity showing some of its characteristics.

This site/project is one with a very low increase in formation pressure associated with injection, mainly because of the formation characteristics.

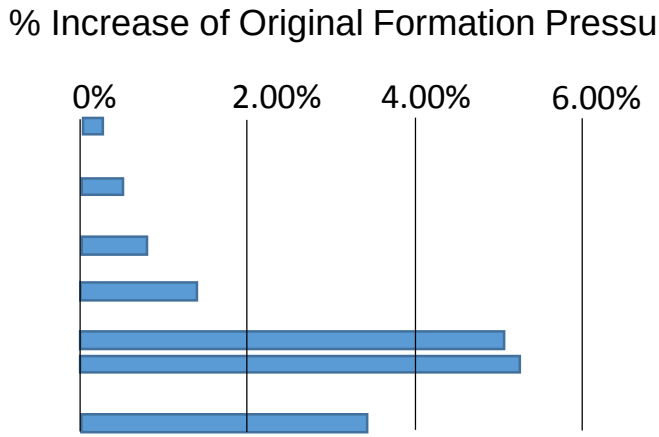
Will present:

Stratified pressure response
Stress directions
Monitoring arrays
Microseismicity development through time

Map View of IBDP wells

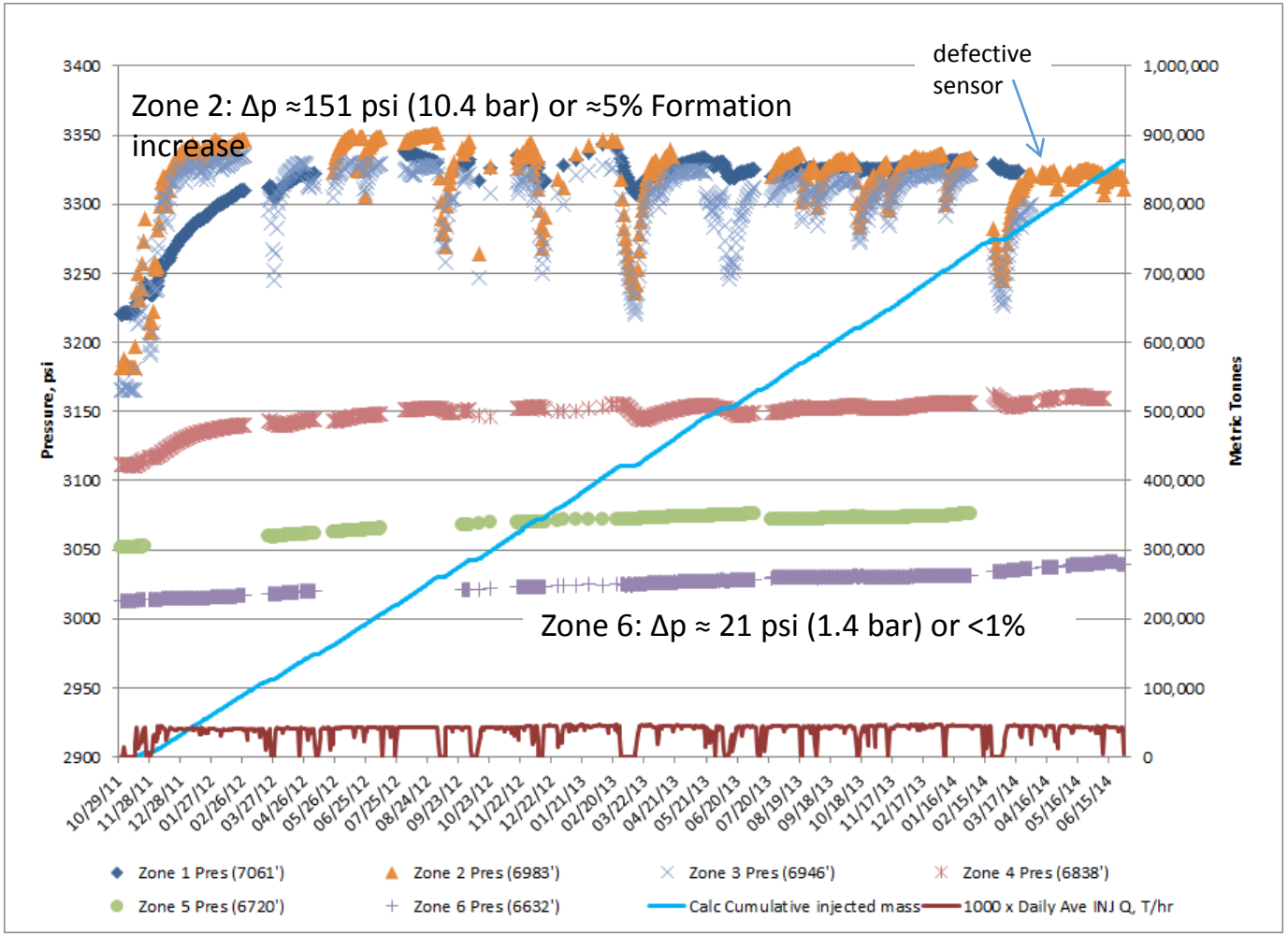


Formation pressure readings in VW1
900 feet from Injection borehole @ 1.5 yrs



Down hole Injection pressure @ CCS1
14% increase above original
formation pressure

VW1 - Verification Well Pressure Monitoring Data (update to 7/1/14)



Cumulative:
863,577 tonnes

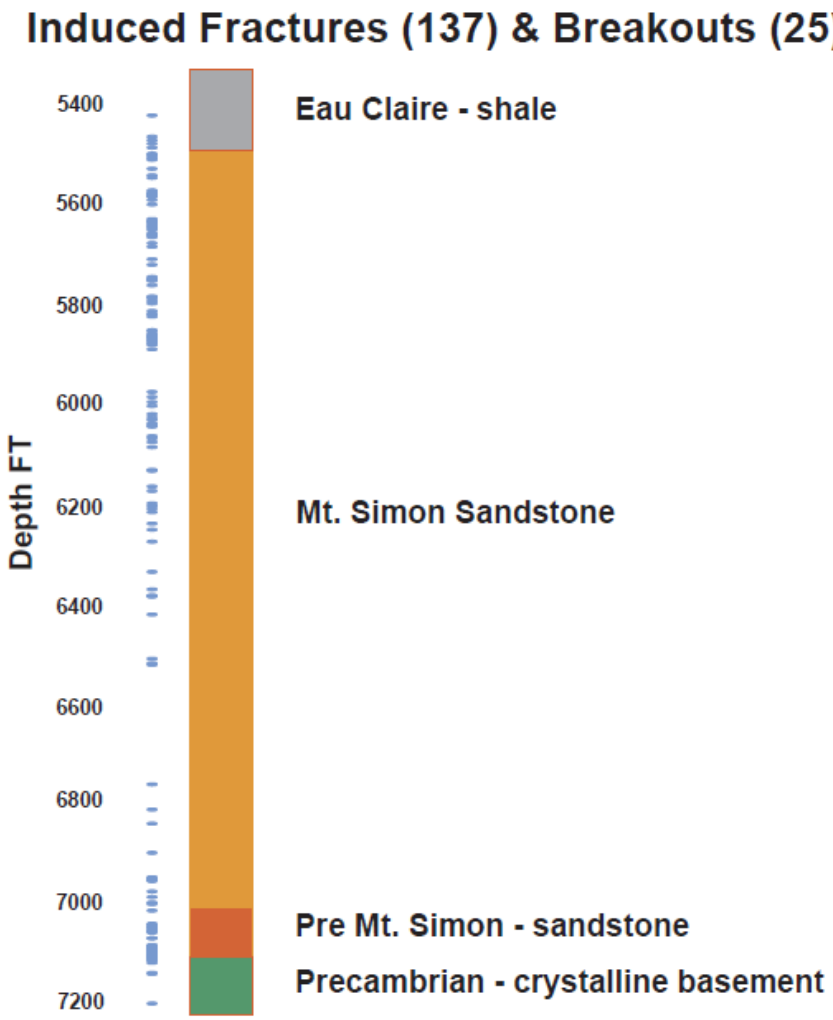
from Schlumberger Carbon Services

∆ P max at VW1 = 5% over original formation pressures

At about 65% of fracture pressures of Mt. Simon

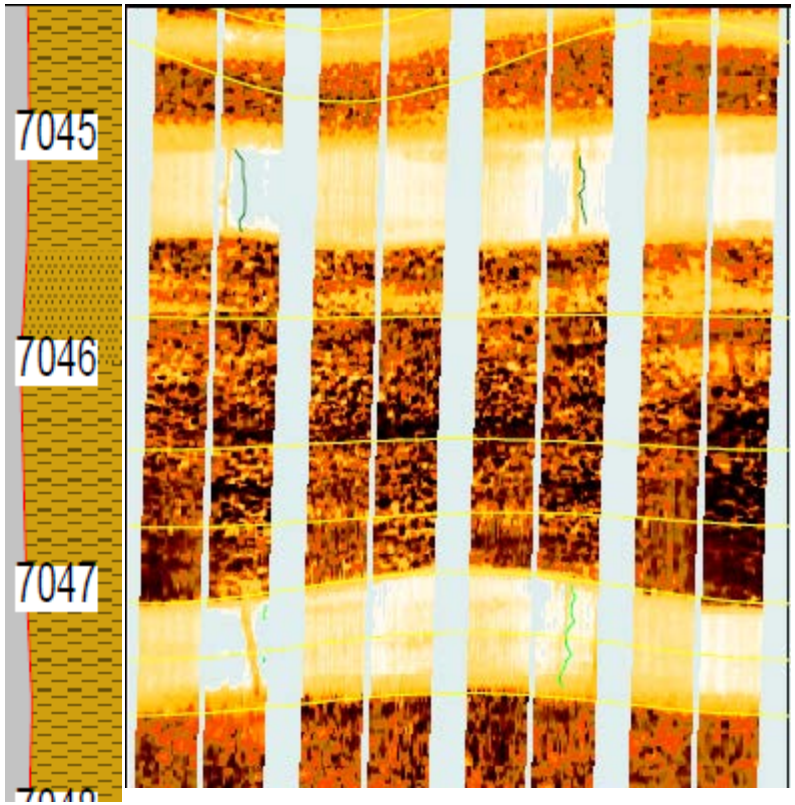
Pressures are stratified

Formation Microimager



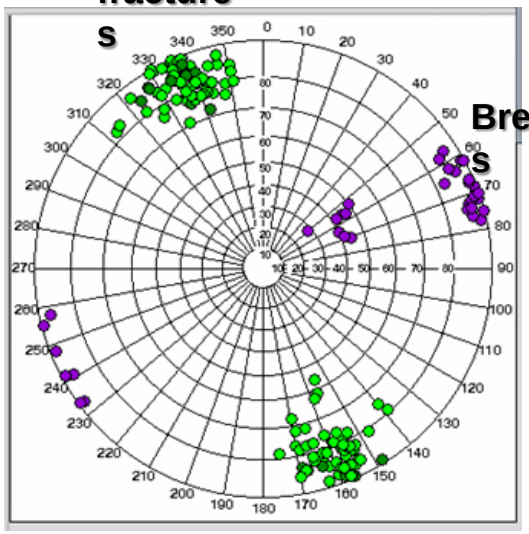
Joe Magdits – Log Analyst @ Schlumberger

Pre Mt. Simon – Induced Fractures
In fine grained stiffer layers

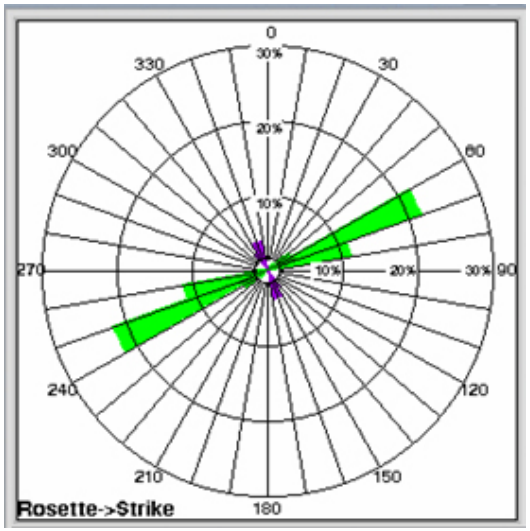


Mt. Simon, Pre Mt. Simon and part of Precambrian basement
Fullbore Formation Microimager

Induced fractures



Breakouts



Maximum horizontal stress direction based on induced fractures and breakouts.

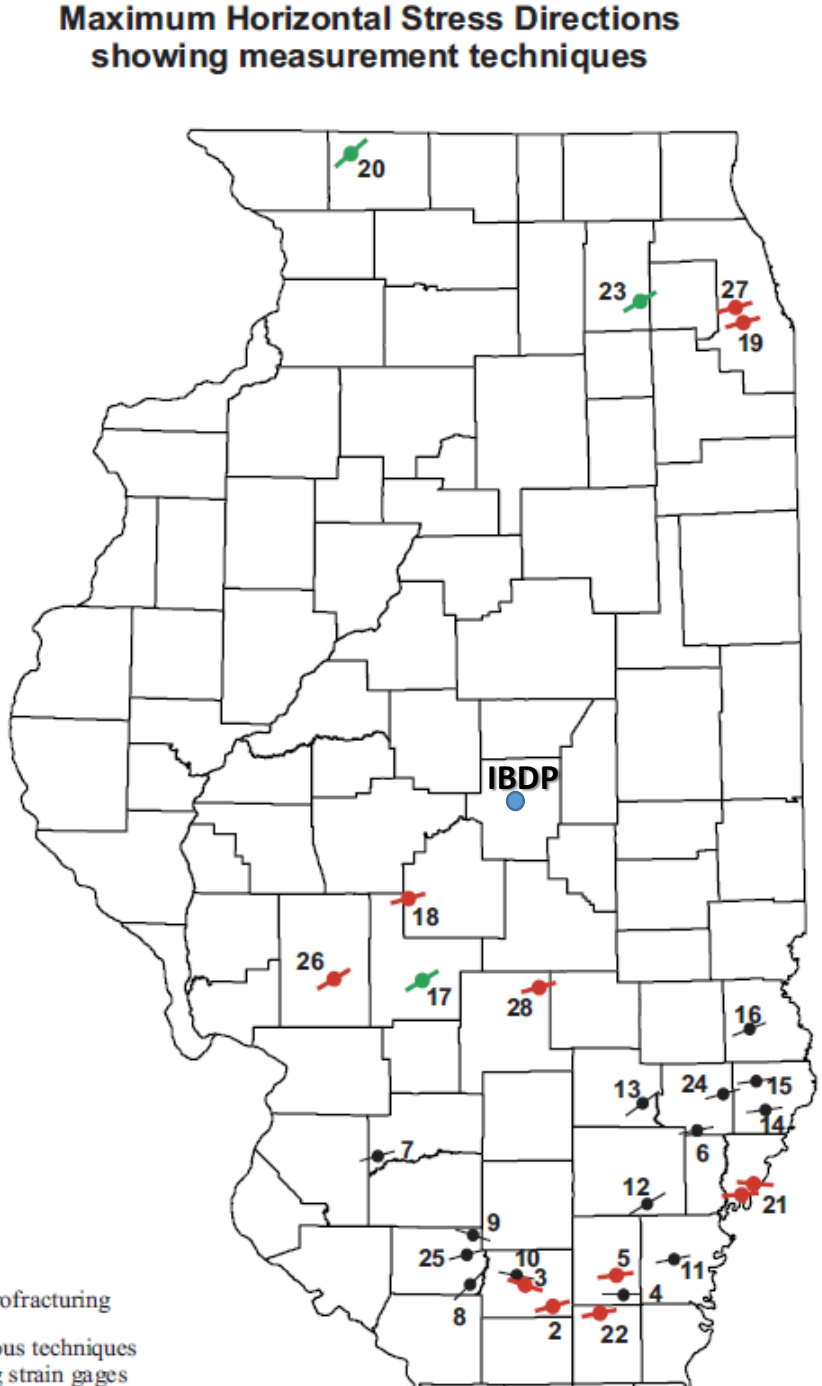
Joe Magdits – Log Analyst @ Schlumberger

Maximum Horizontal Stress Direction

Green – Hydrofracturing

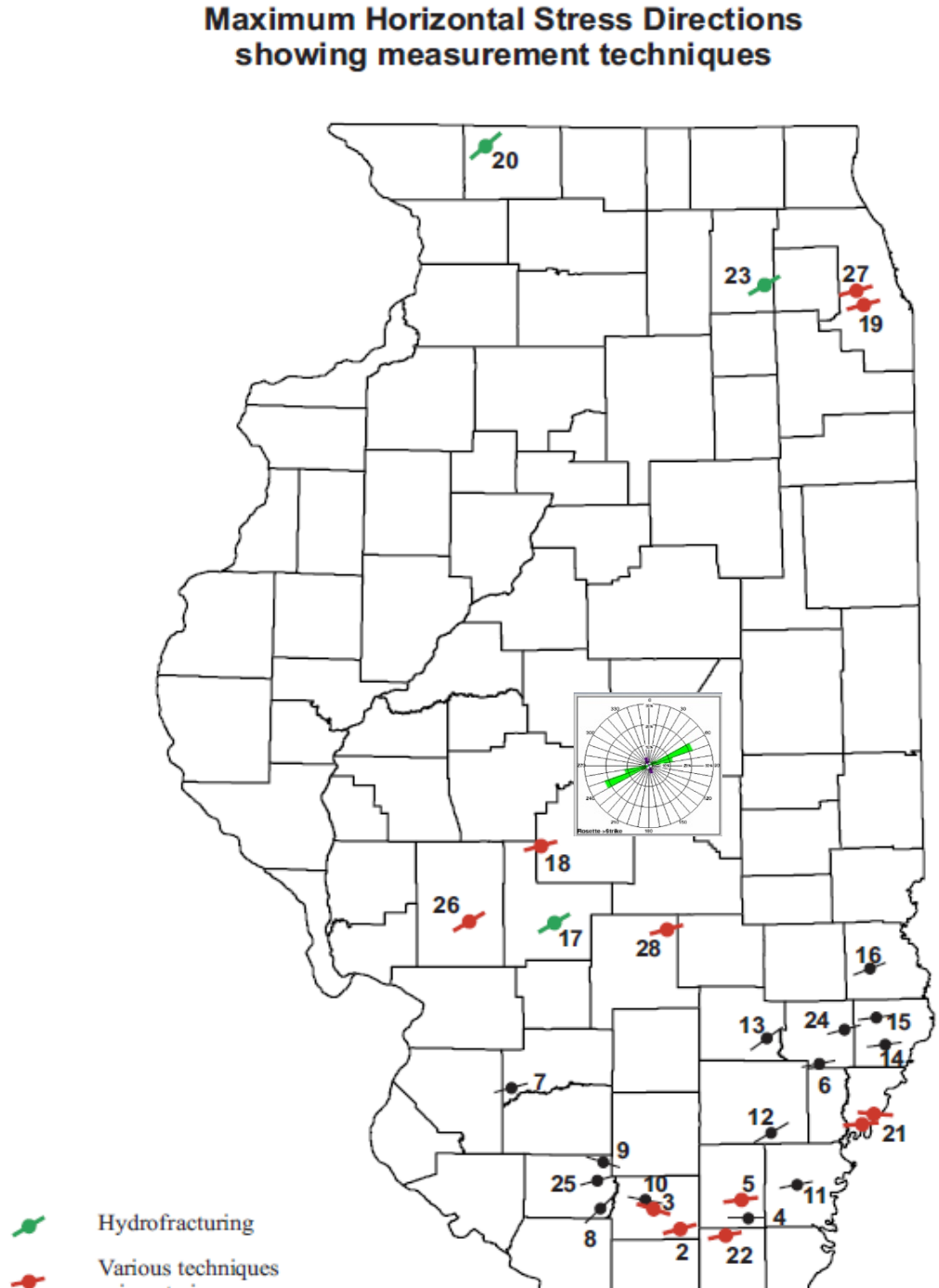
Red – strain gages

Black – break out



Bauer & Nelson 2014, Compilation of In Situ Stress Measurements in Illinois, Unpublished Manuscripts, Illinois State Geological Survey.

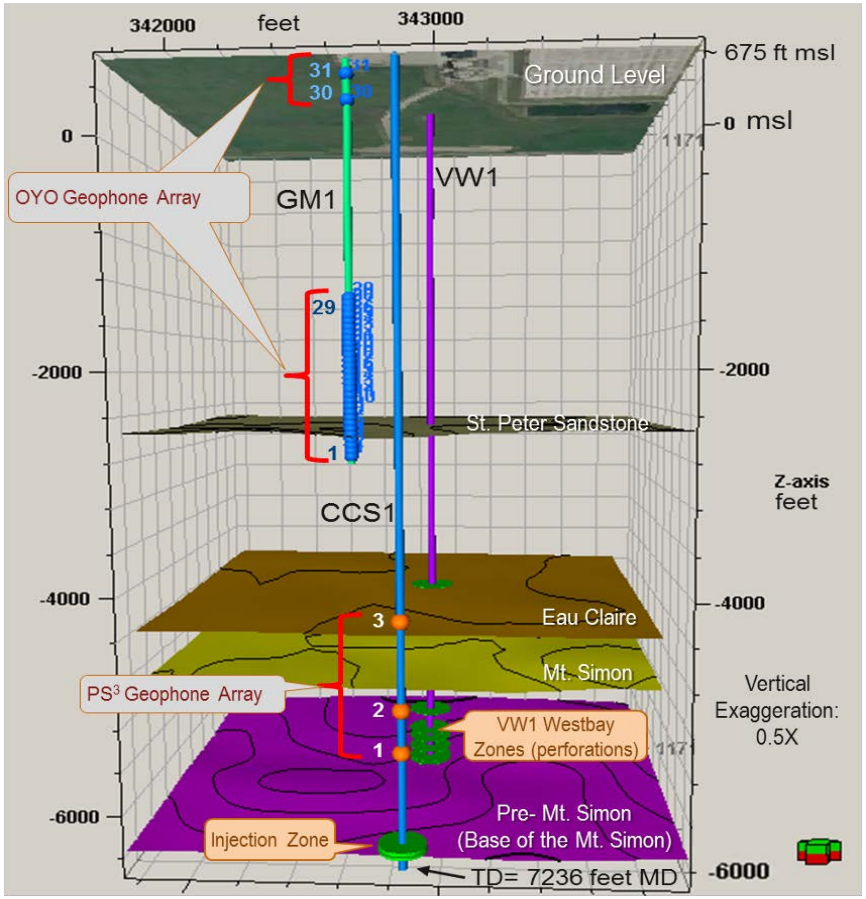
Maximum Horizontal Stress Direction



Bauer & Nelson 2014, Compilation of In Situ Stress Measurements in Illinois, Unpublished Manuscripts, Illinois State Geological Survey.

IBDP Well configuration and geophones

Oblique View looking north



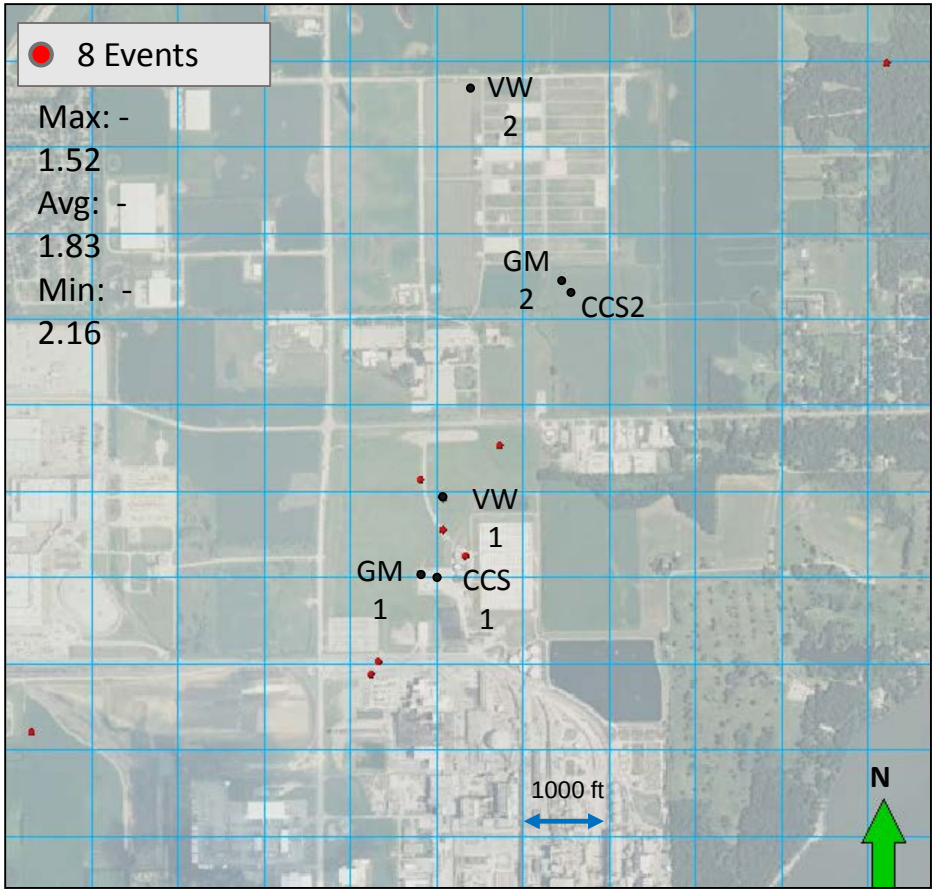
SMC 1850 10 Hz

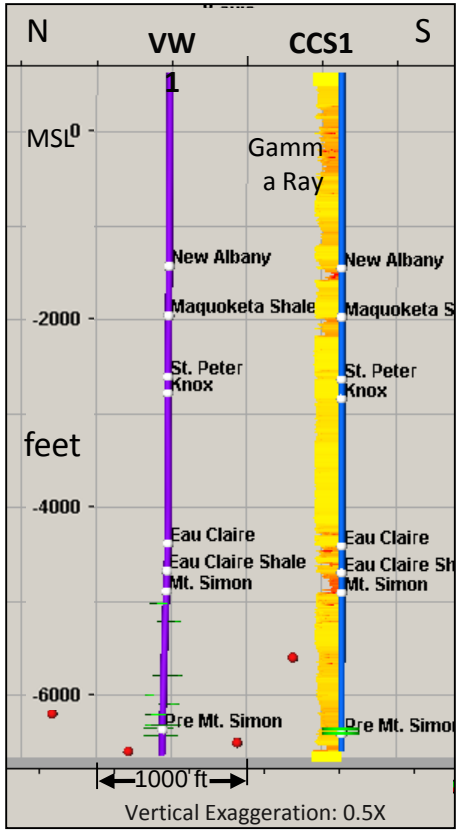
Omni 2400 15 Hz

Valerie Smith
Schlumberger Carbon Services

Local Microseismic Events: Pre-Injection

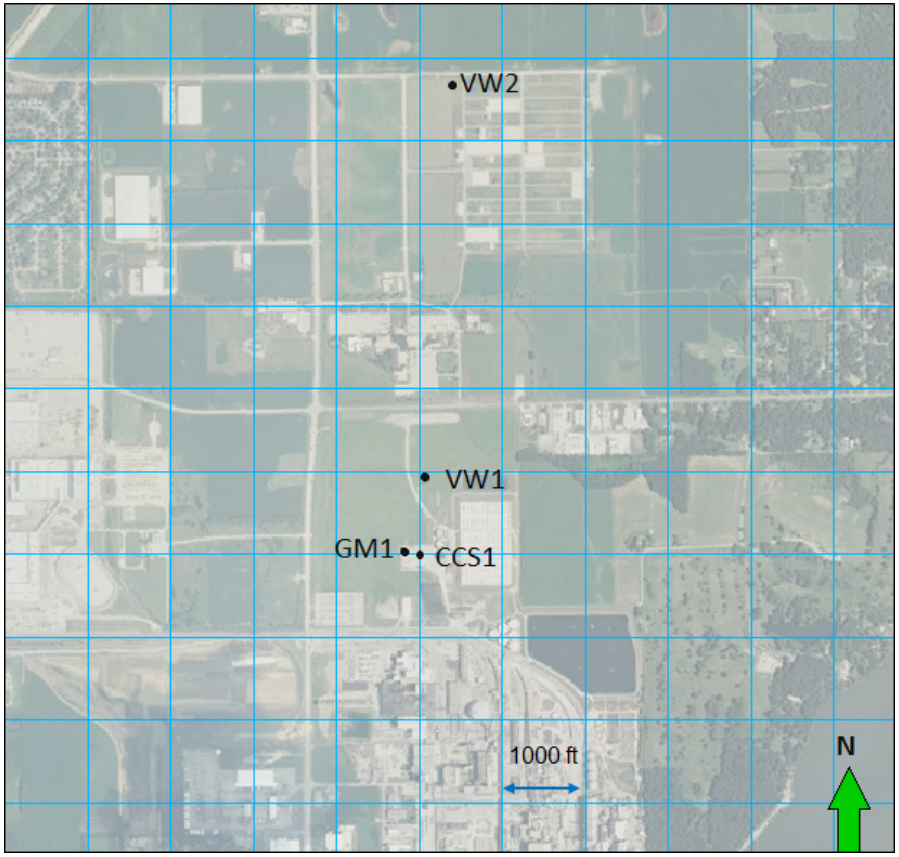
(May 1, 2010 to Nov. 15, 2011)





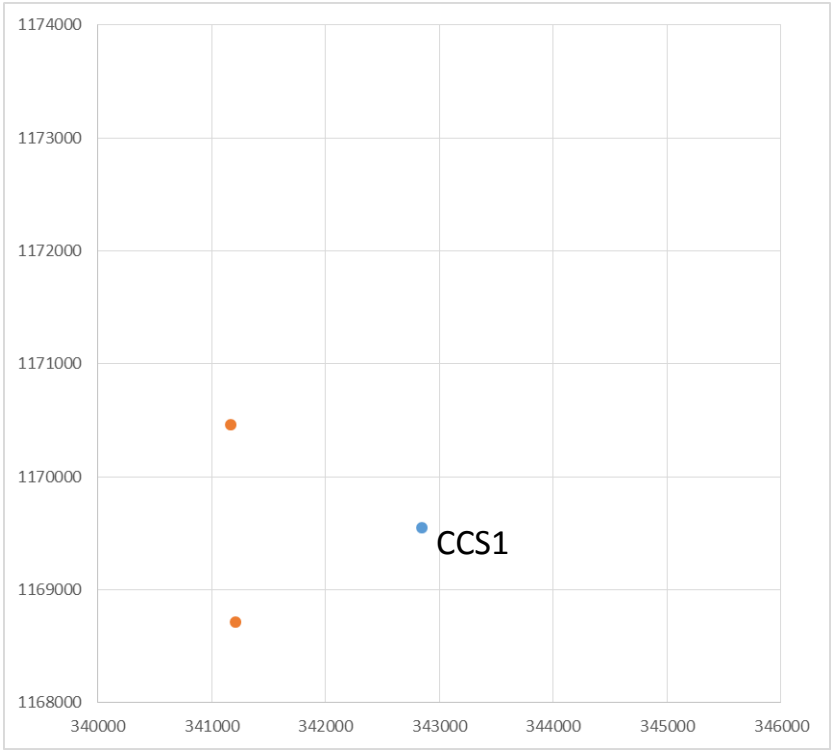
Valerie Smith
Schlumberger Carbon Services

Additional Geophones in VW2 near end of 2013



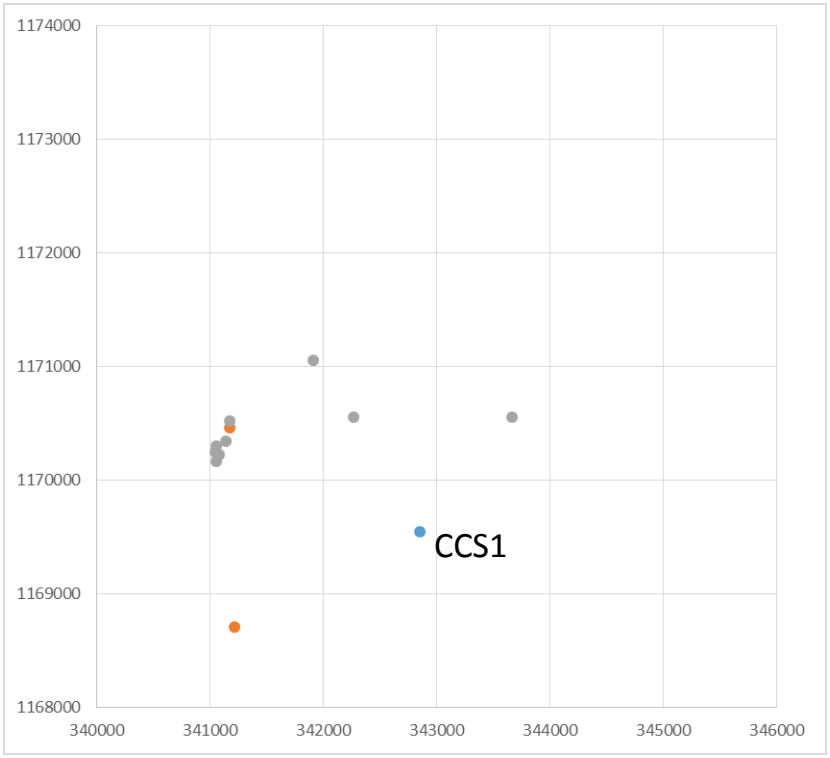
Five Omni 2400 15 Hz
200 ft apart down to 6,950 ft

Dec 2011



Each Division in X & Y
= 1,000 Ft or
≈ 300 m

Jan 2012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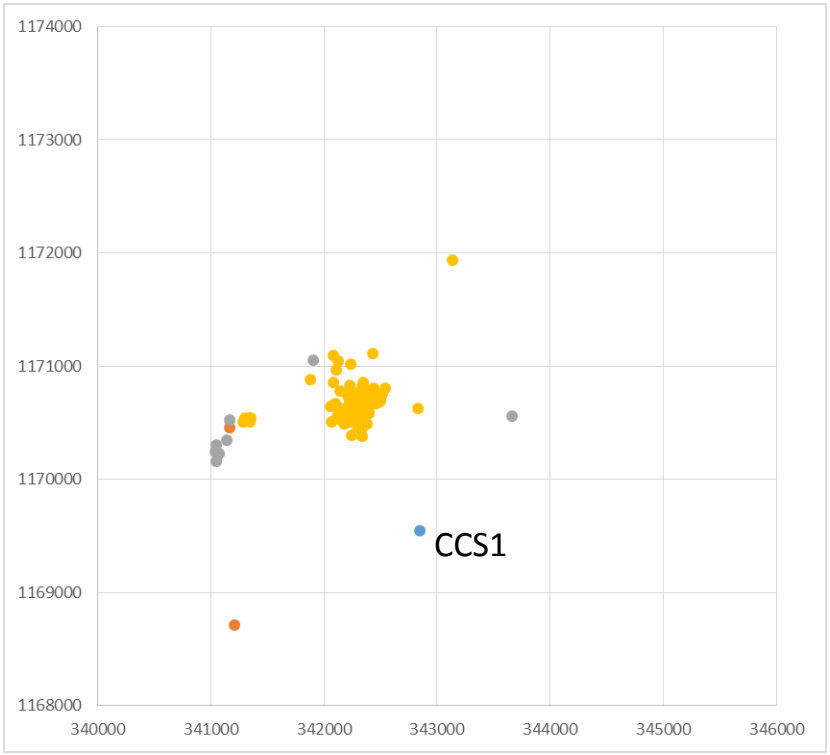
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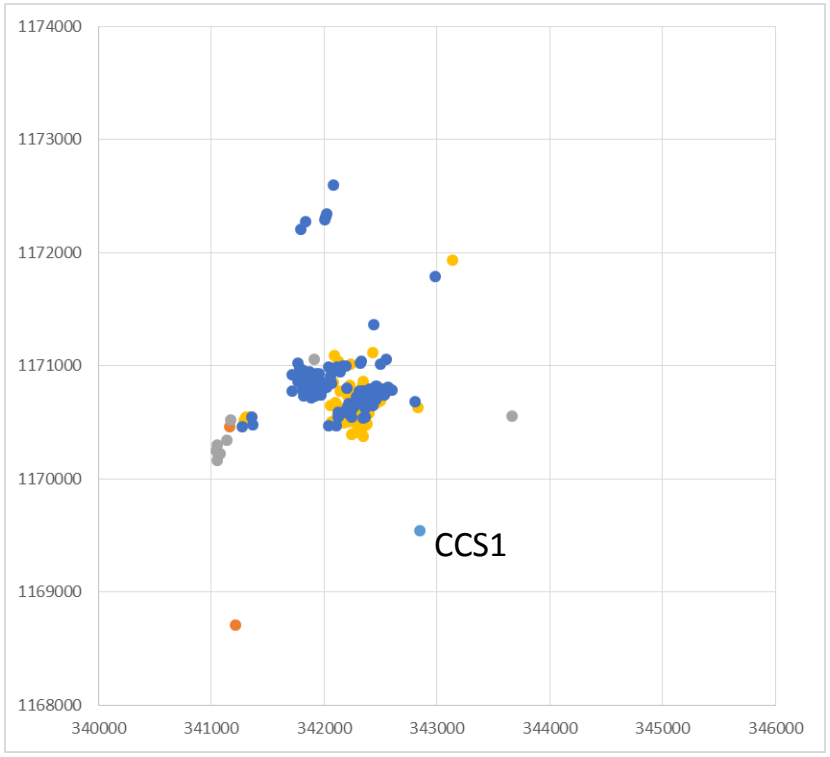
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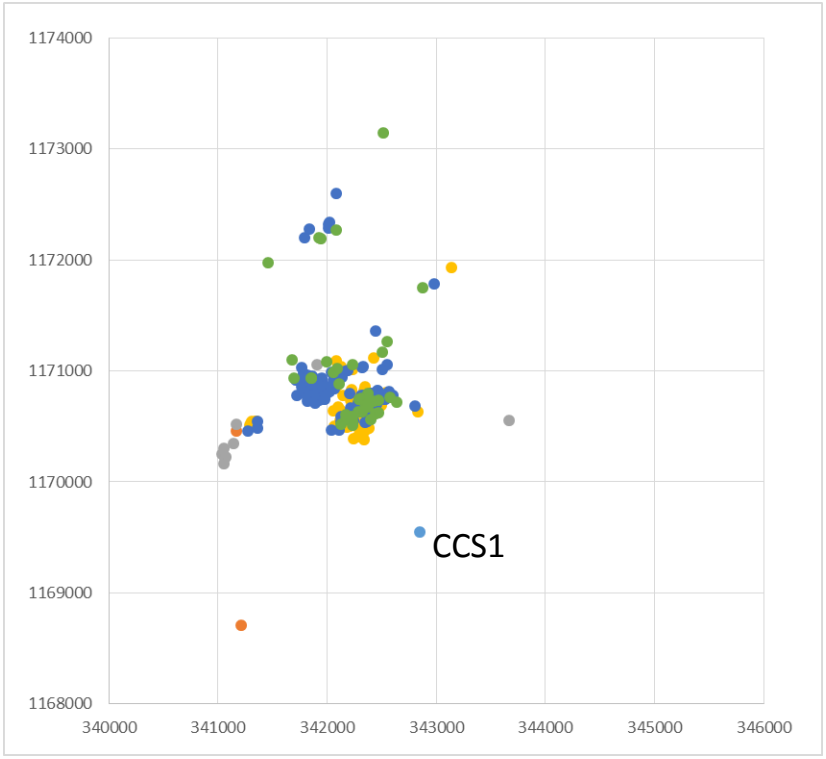
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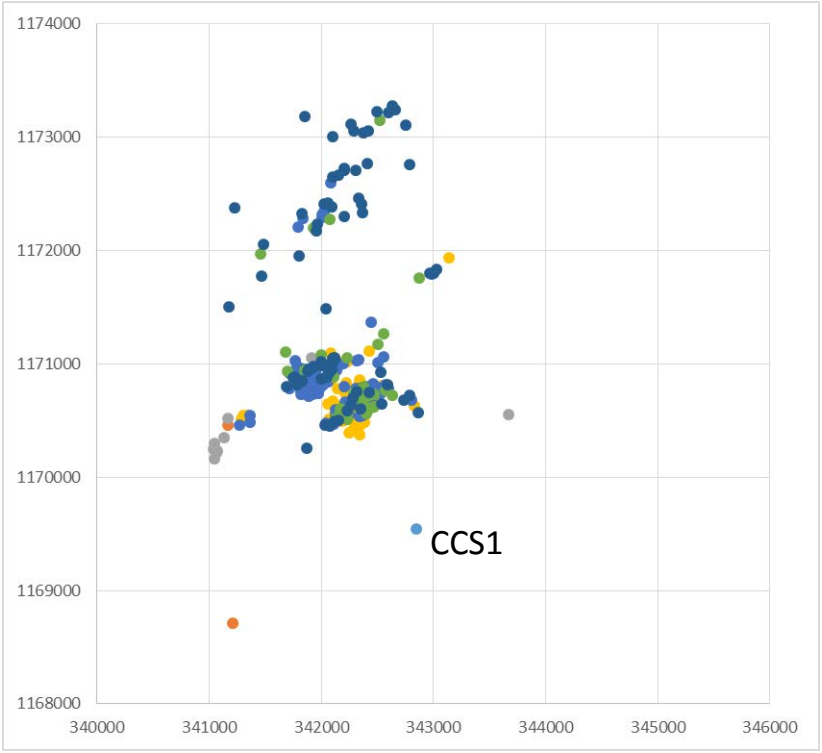
May 2012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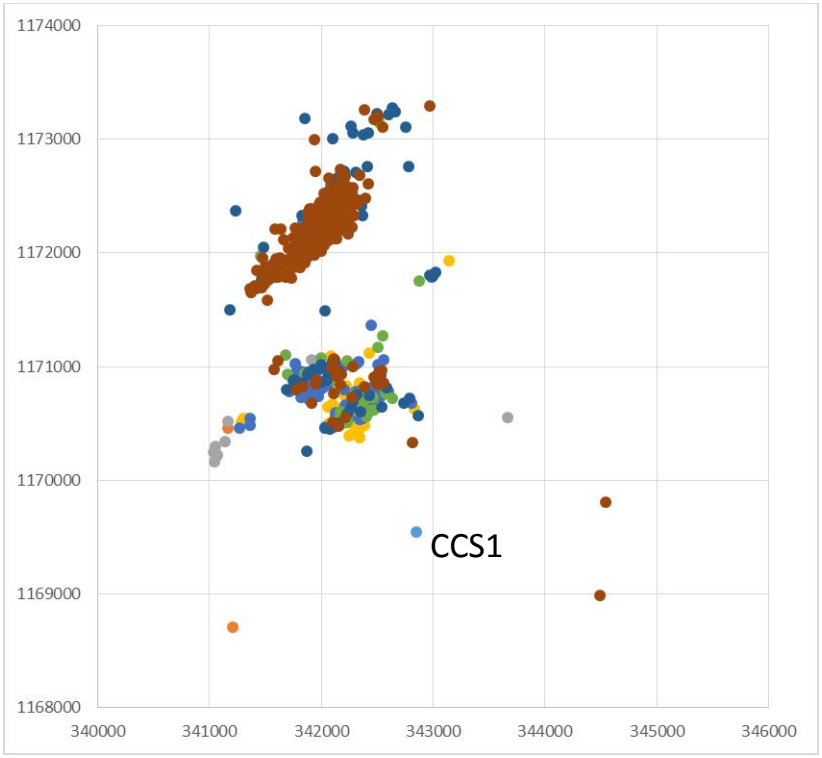
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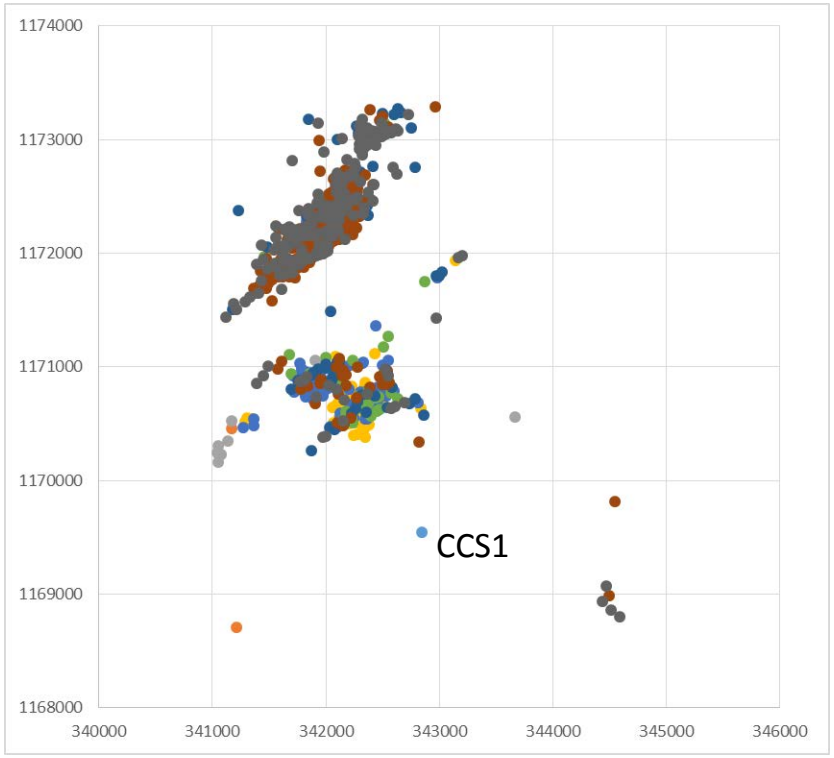
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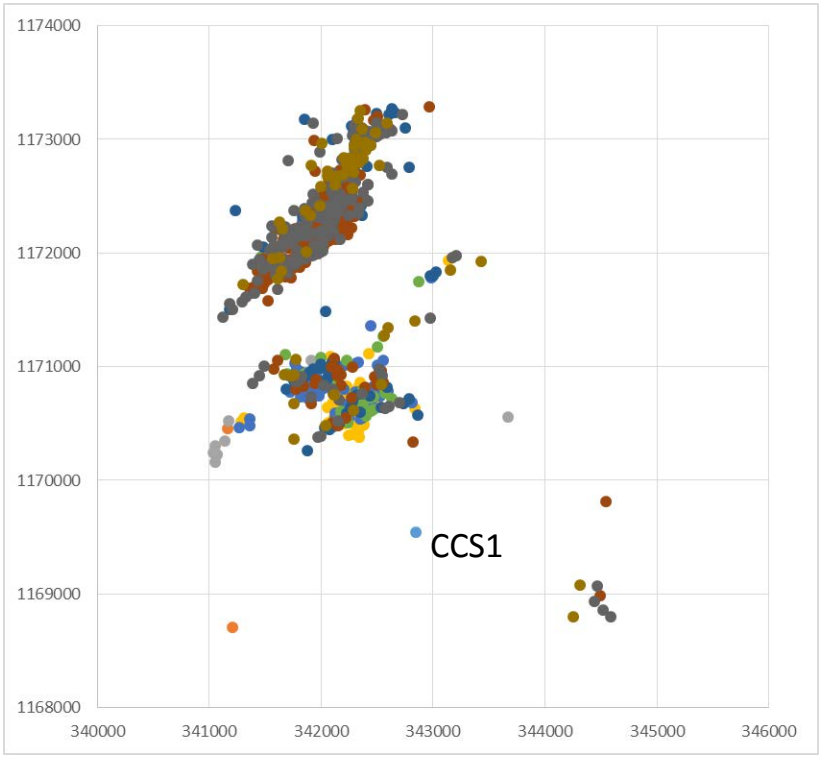
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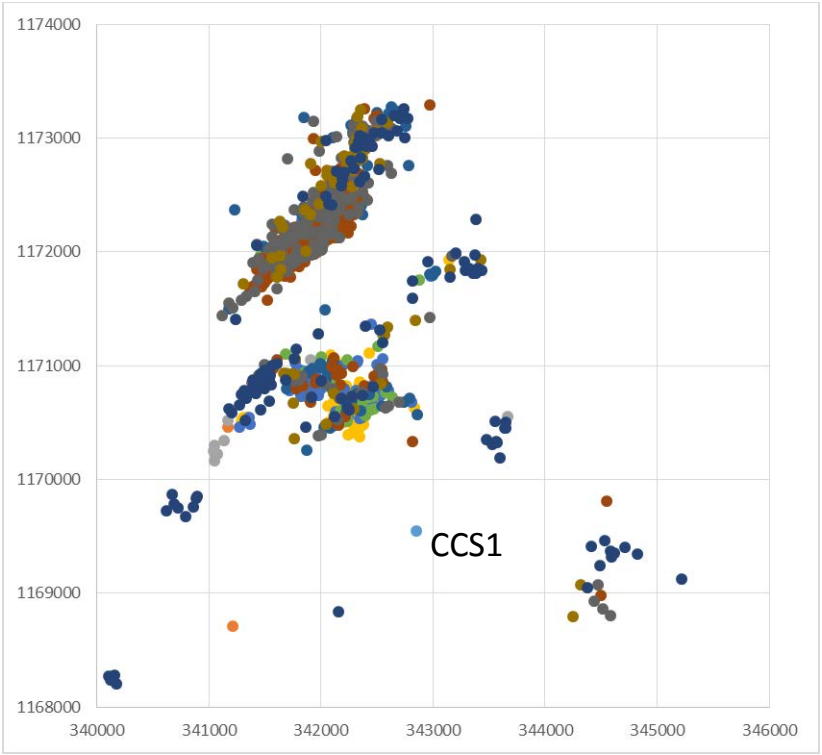
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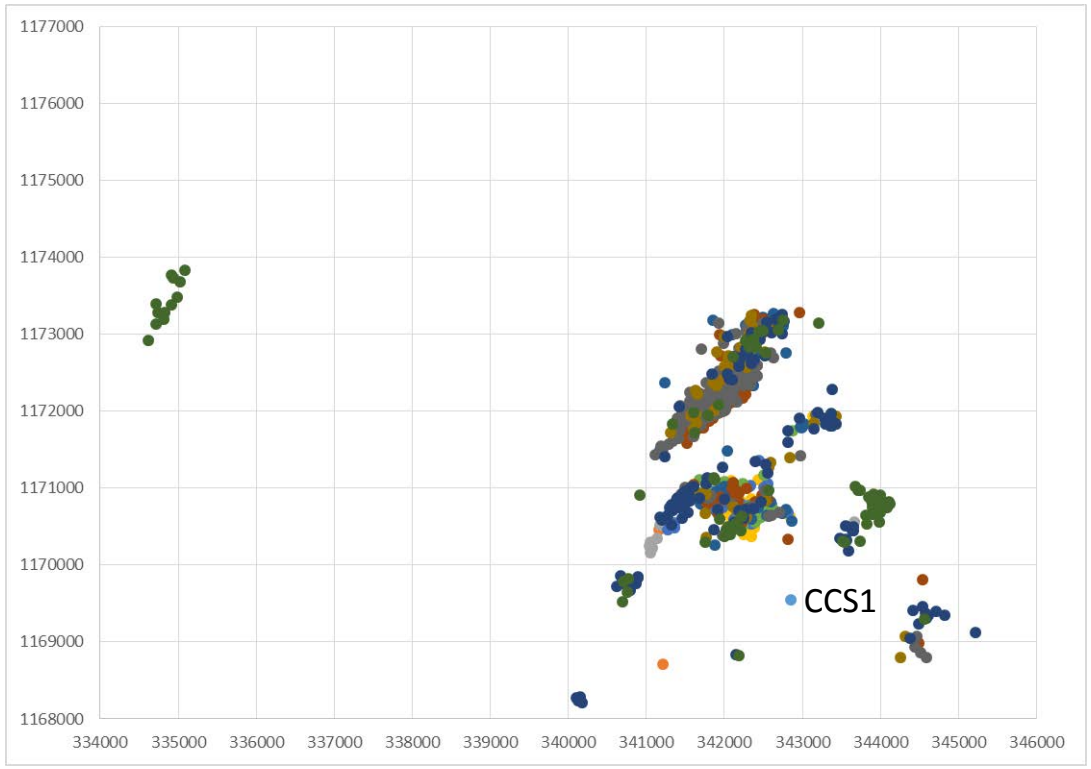
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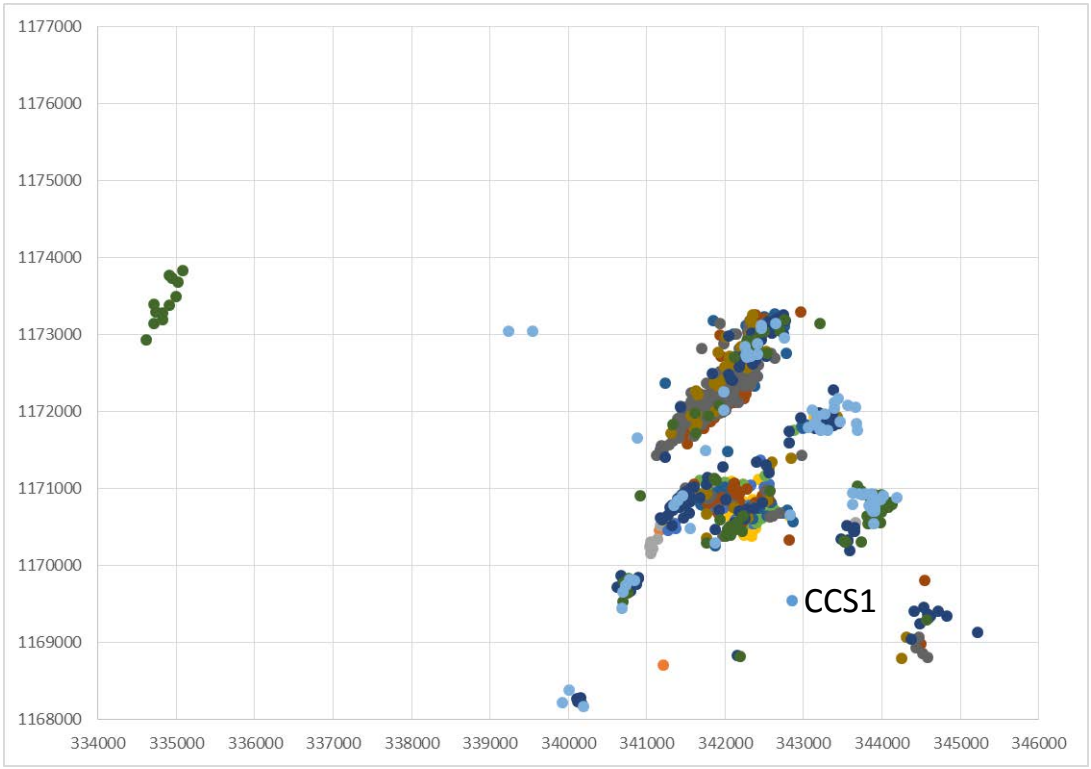
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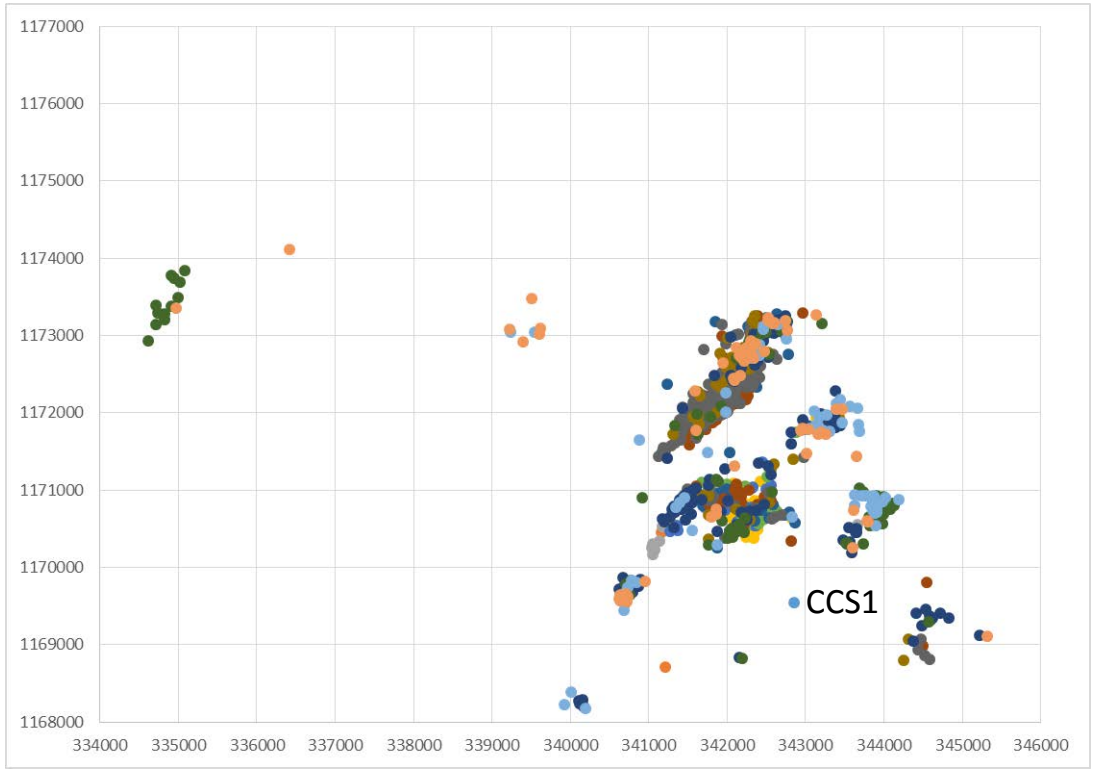
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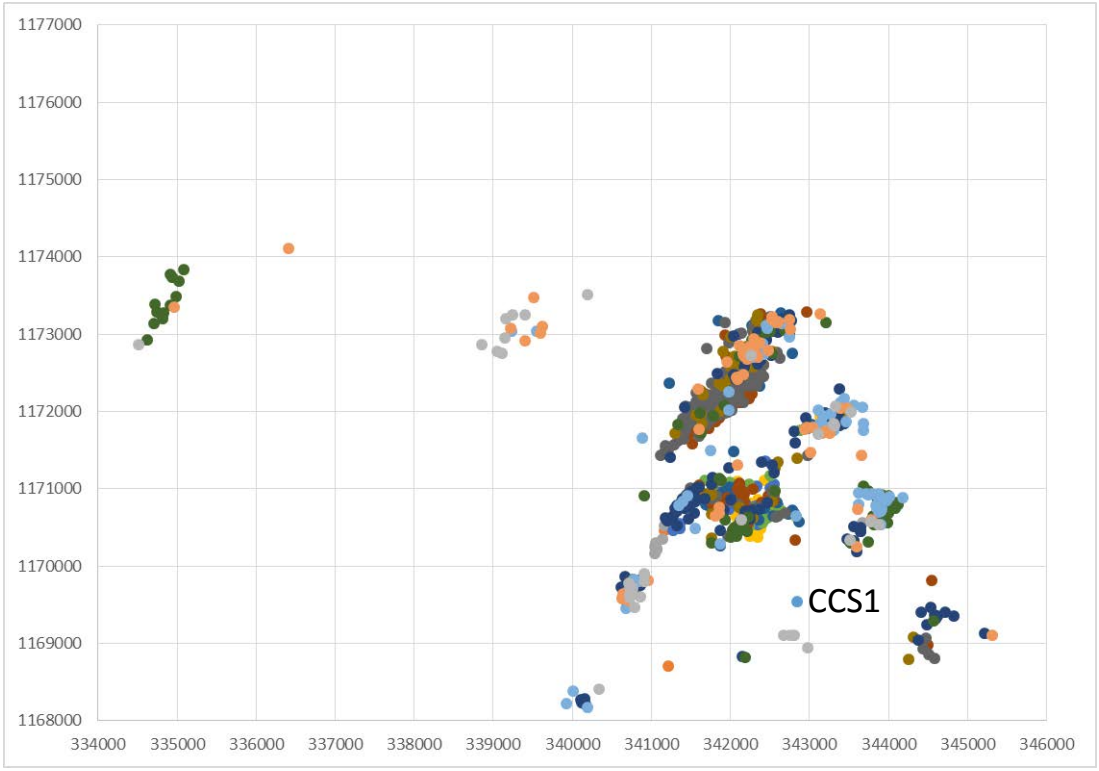
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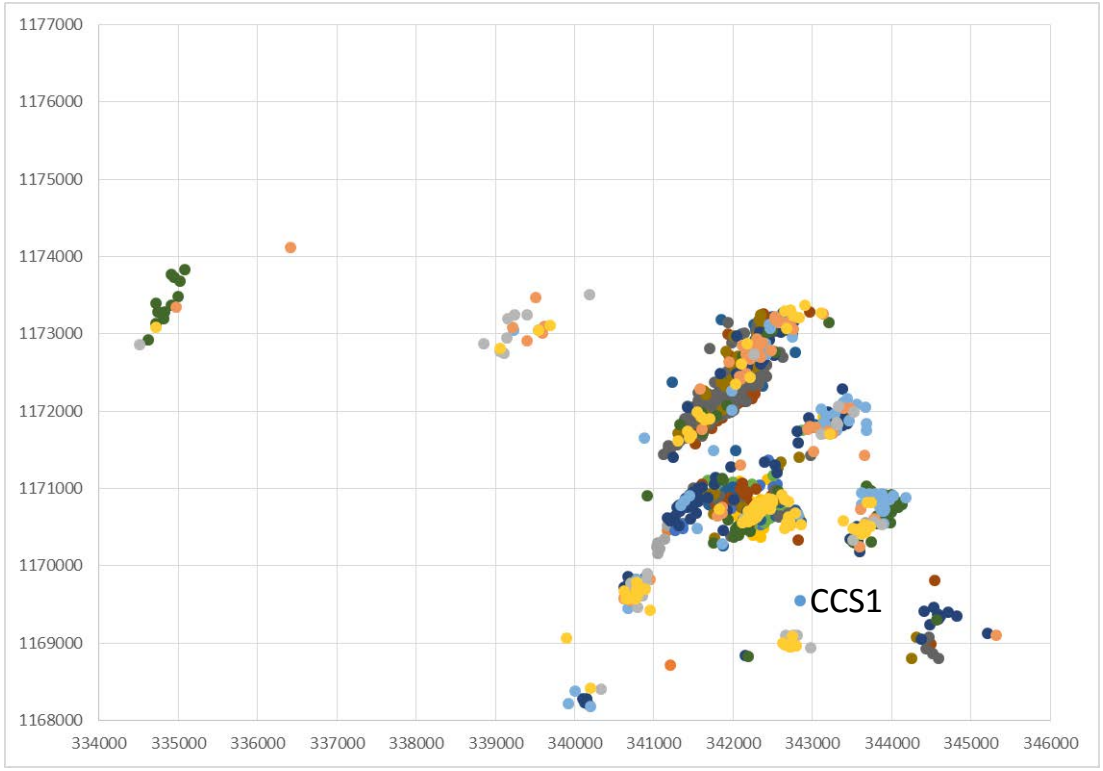
Feb 2013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Why did Cluster 1 form at about 1,800 feet (550 m) from CCS1 first before Cluster 2 at an average of 1,160 feet (350 m) from CCS1?

Estimates are that Cluster 1 Δ pressures were about 50 psi (3.5 bars) or 0.35 MPa at the time of first formation.

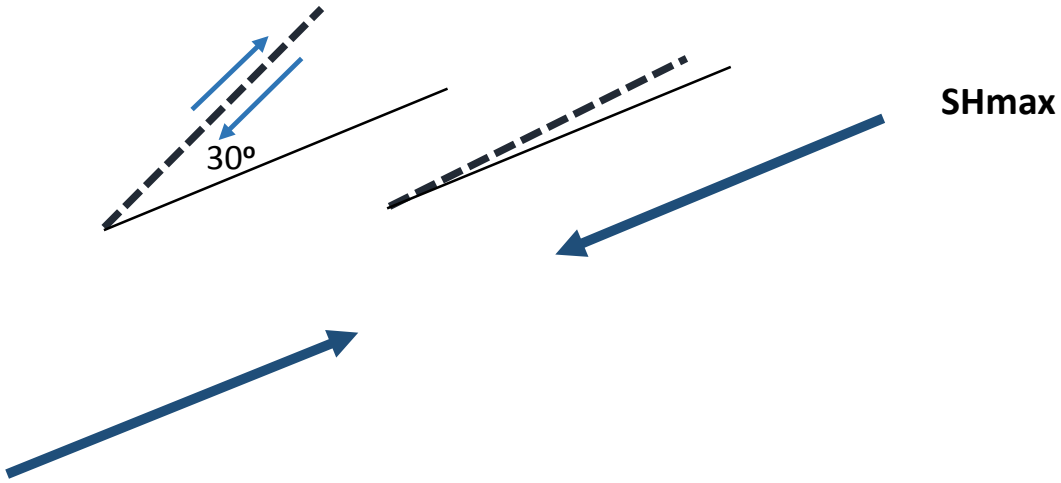
Pre-existing fractures close to 30 degrees from the maximum horizontal stress direction are optimally oriented in the direction expected for strike-slip movements (King, 1994).

From hydraulic fracturing, microearthquakes are triggered along pre-existing natural fractures that are favorably oriented for slip (Pearson 1981; Rutledge and Phillips 2003; and Shapiro et al., 2006).

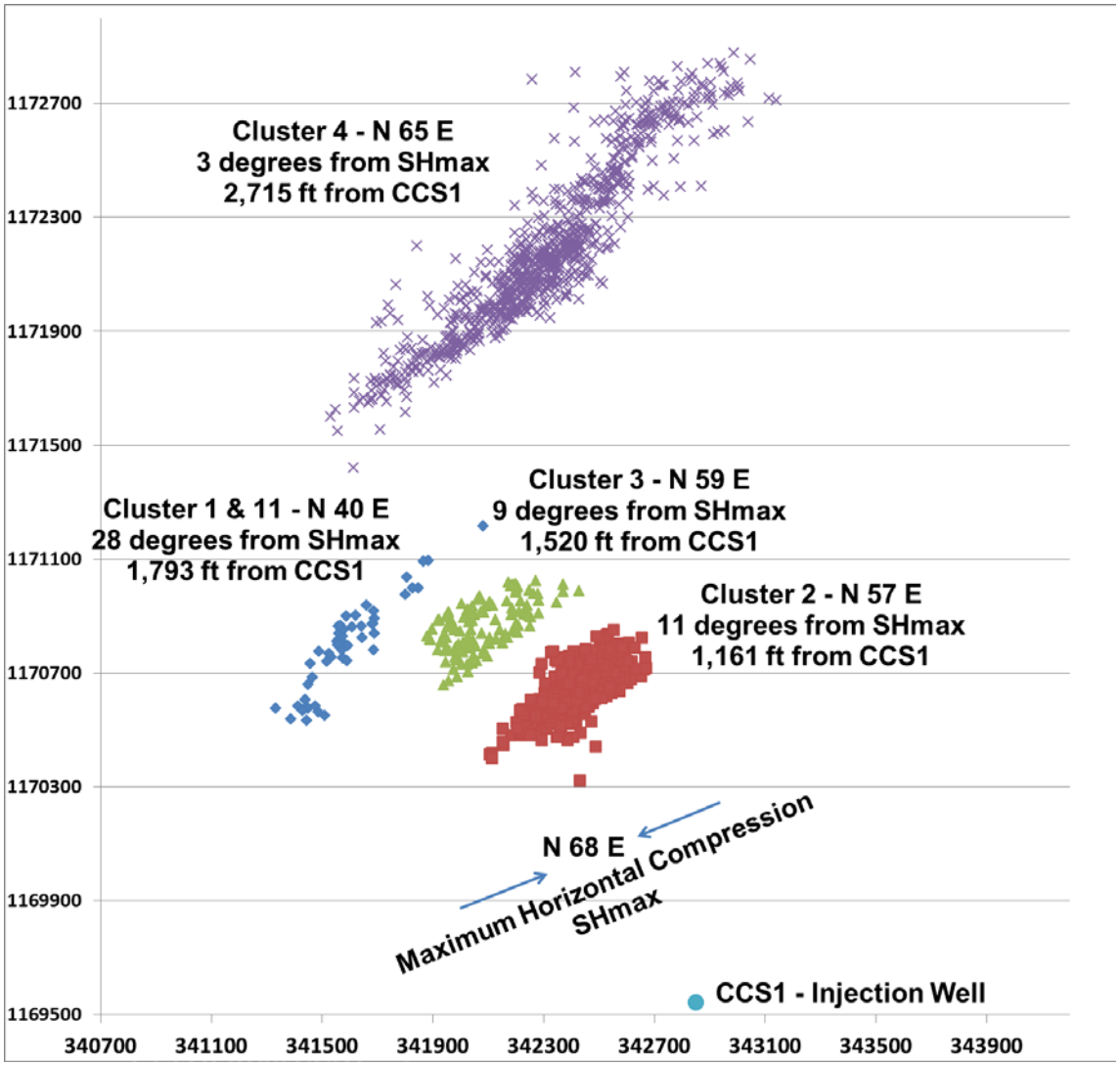
Baig et al., (2012) found for hydraulic fracturing of some wells that events tended to fall along two main trends, the early events follow a trend roughly 30 degrees from SHmax and the later events follow a lineation approximately parallel to SHmax.

Yang et al., (2013) found similar trends for hydraulic fracturing in the Bakken formation where detected microseismic events from many stages trend ~30 degrees from the direction of SHmax.

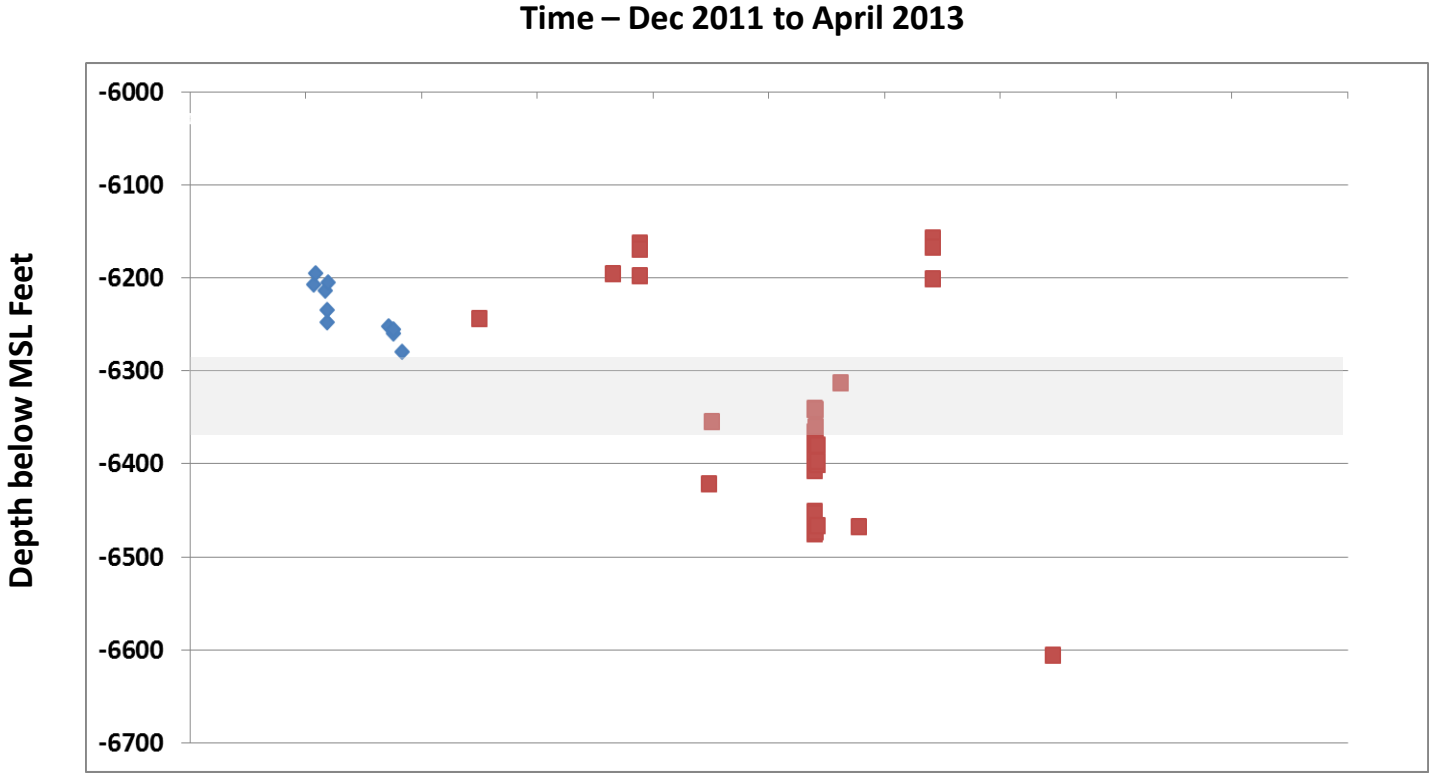
Optimally oriented to slip: strike-slip



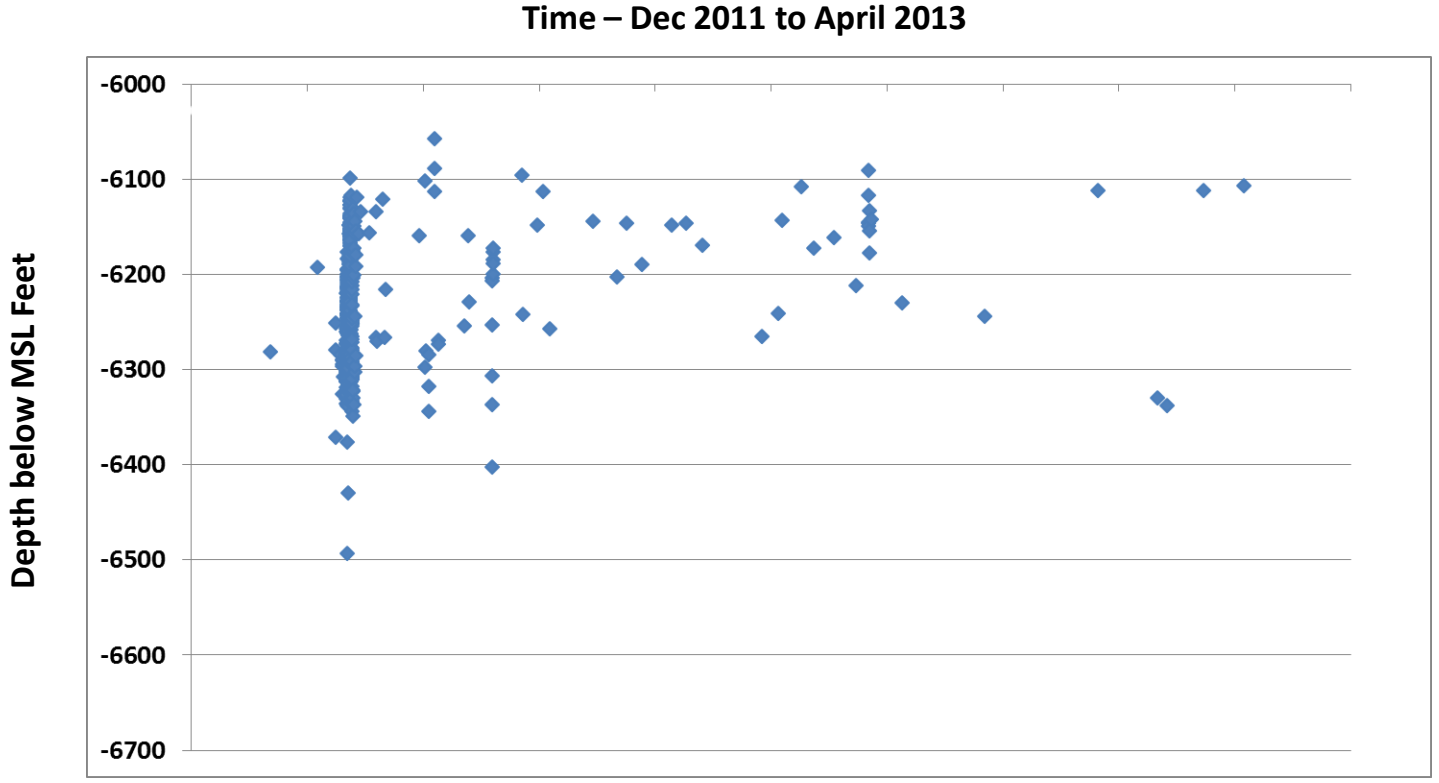
Each Division in X & Y
= 400 Feet or
≈ 120 m



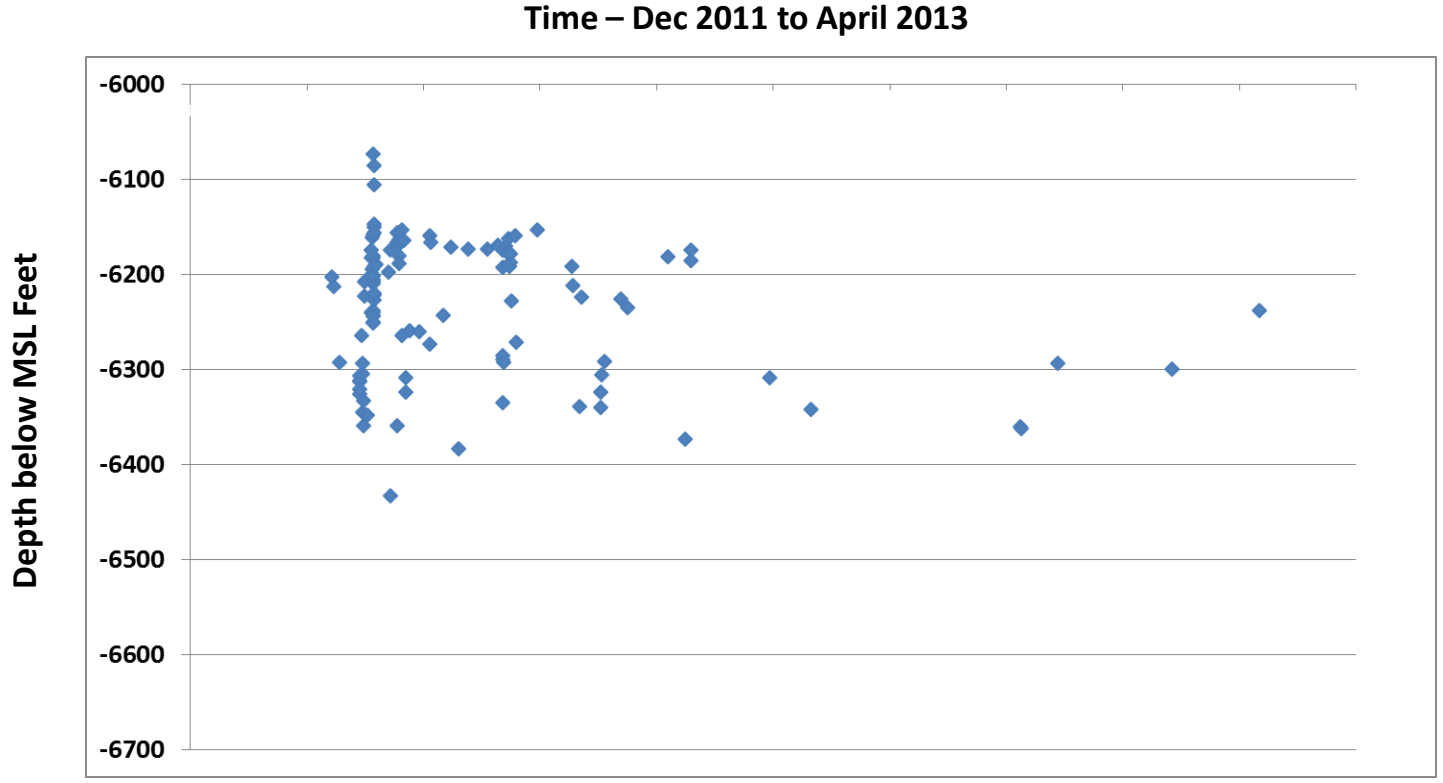
Cluster 1 & 11 development



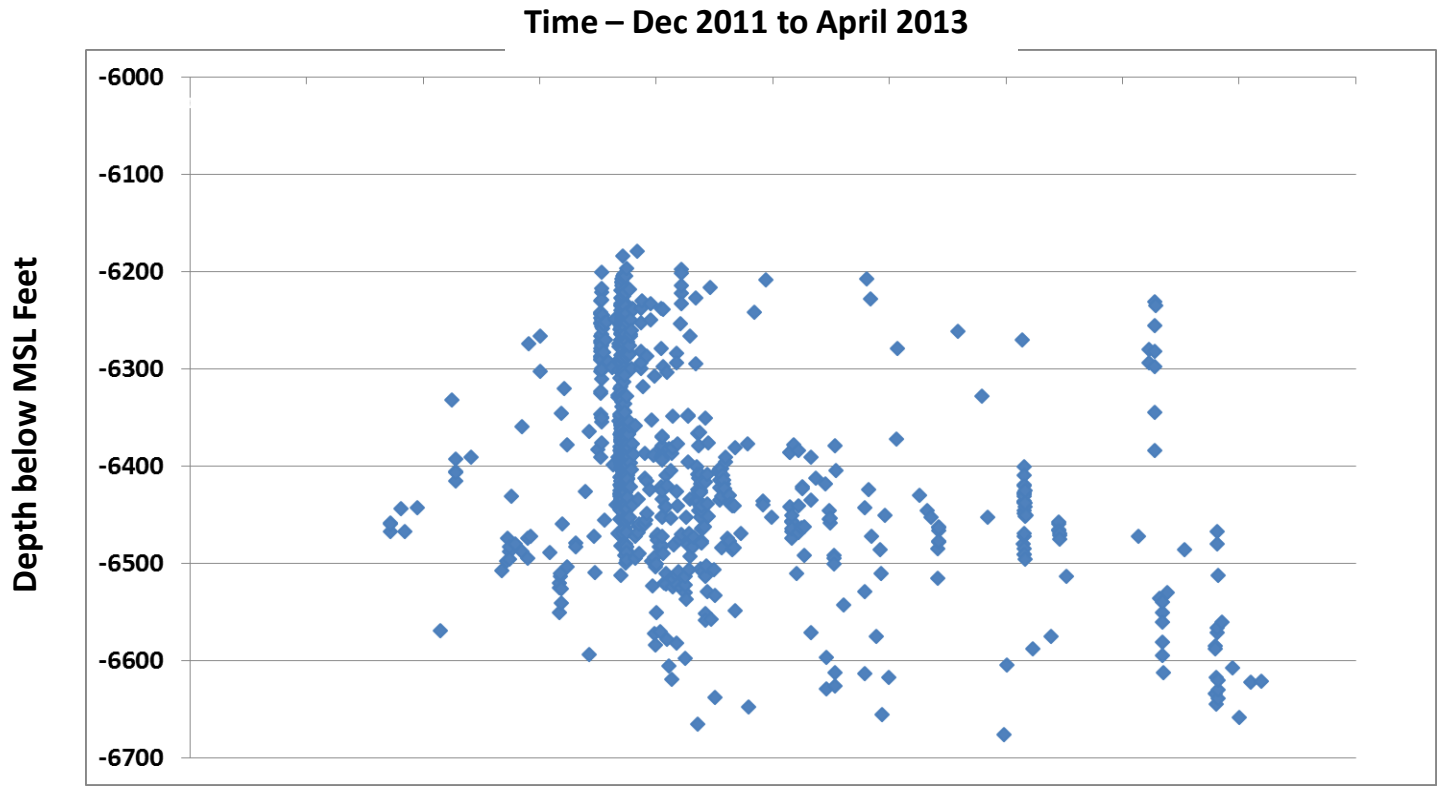
Cluster 2 development



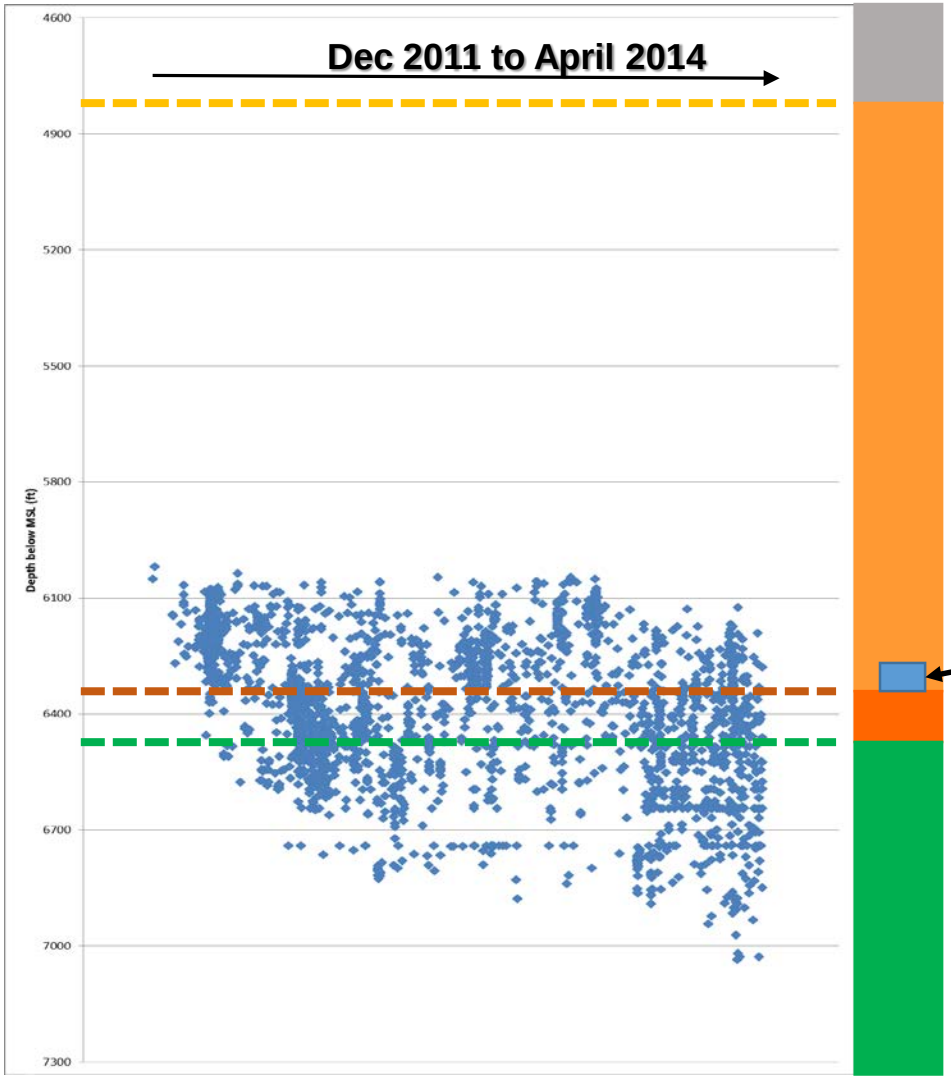
Cluster 3 development



Cluster 4 development



Depth thru Time



Eau Claire – 1st seal

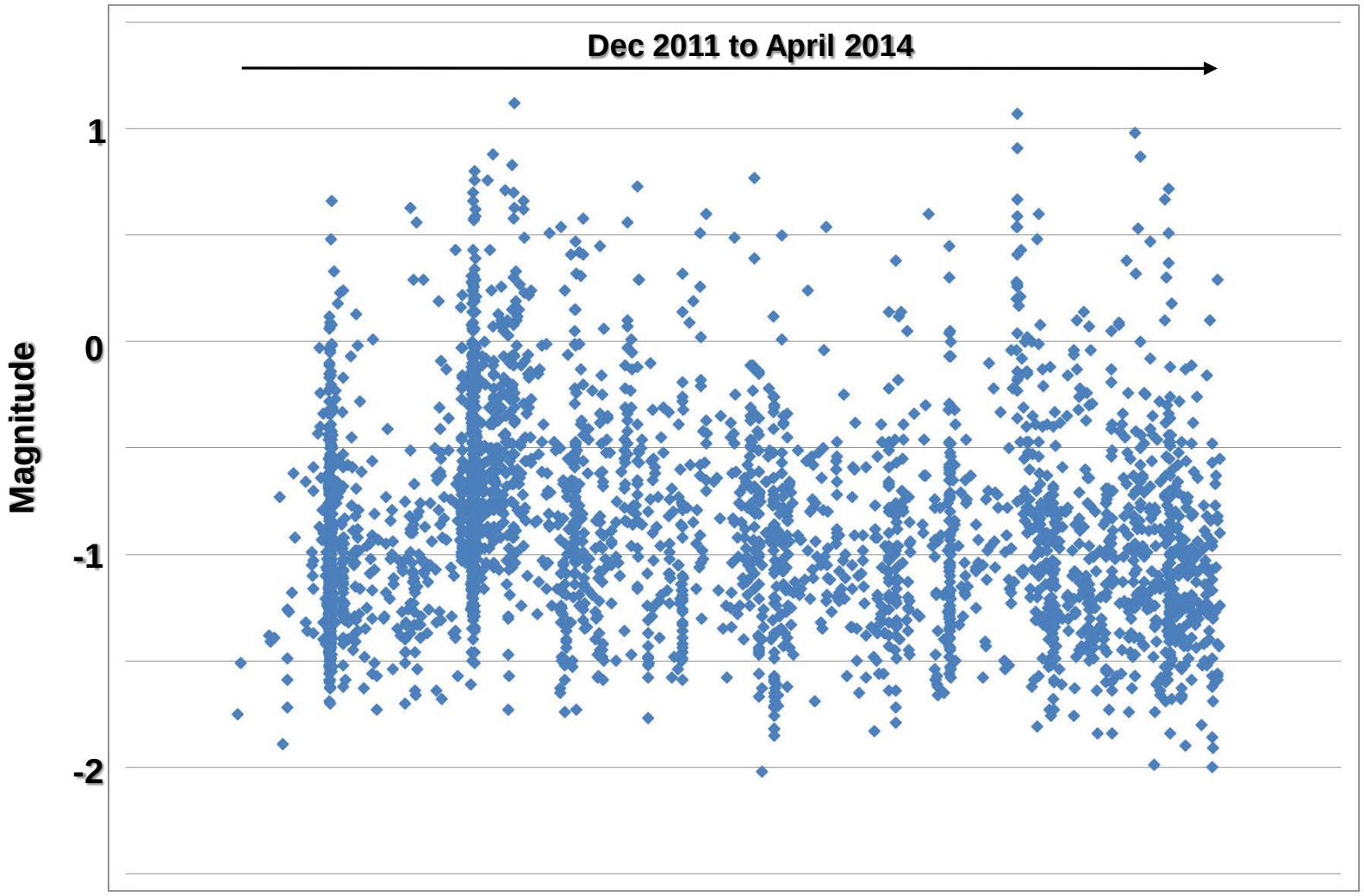
Mt. Simon Sandstone

Injection Zone

Pre Mt. Simon

Precambrian crystalline basement

Vertical depth divisions = 300 feet ≈ 100 meters


Dec 2011 to April 2014
Magnitude
1
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-1
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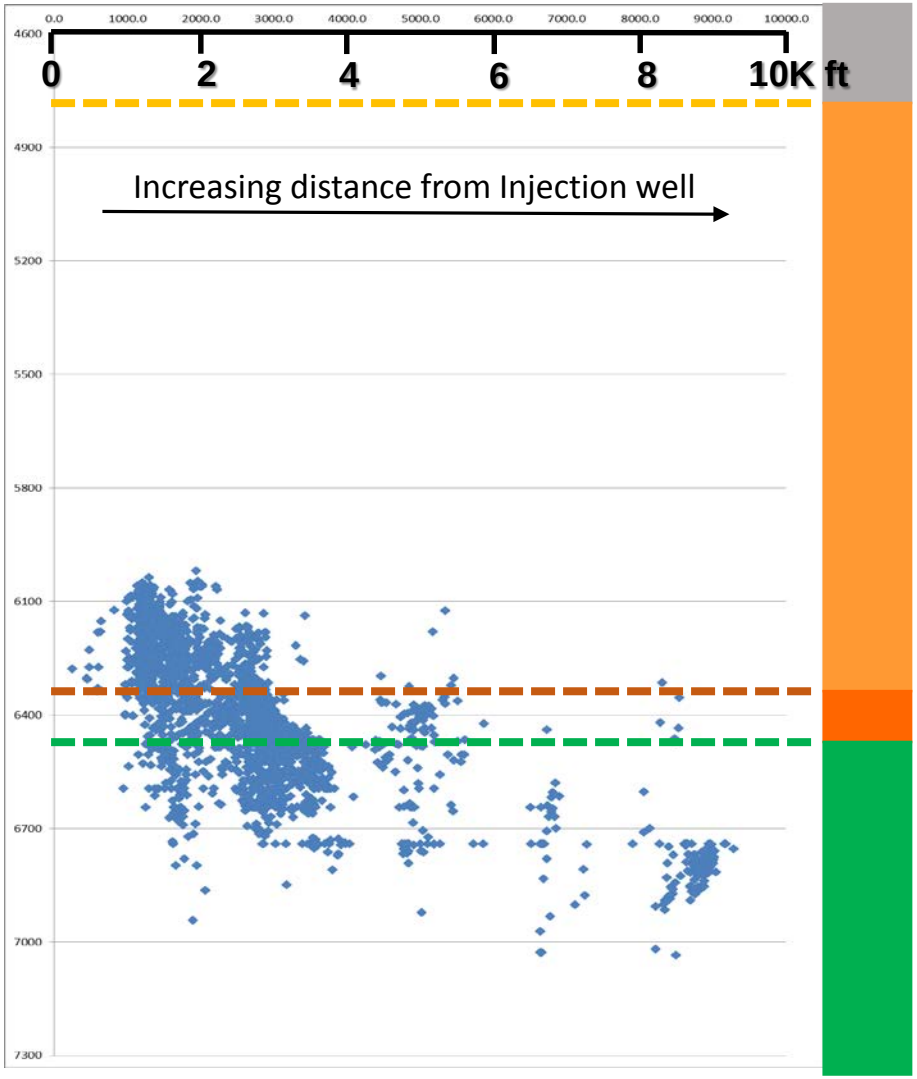
Depth vs Distance from Injection well - CCS1



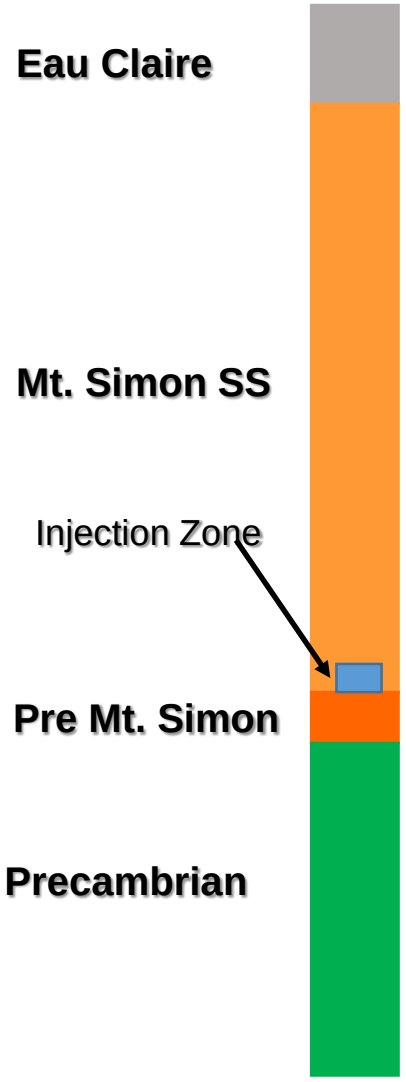
Eau Claire

Mt. Simon Sandstone

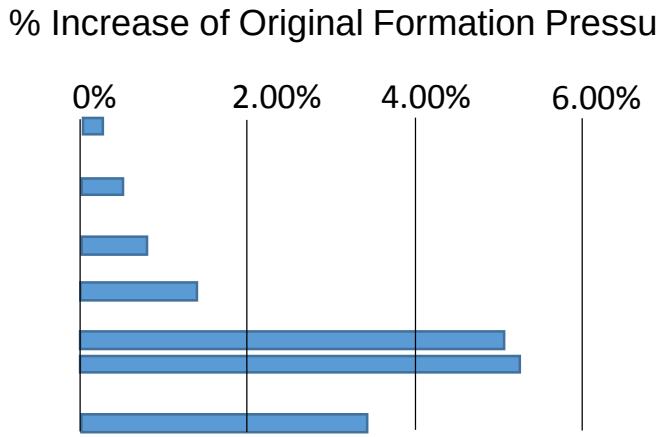
Pre Mt. Simon

Precambrian crystalline basement

Vertical depth divisions = 300 feet ≈ 100 meters

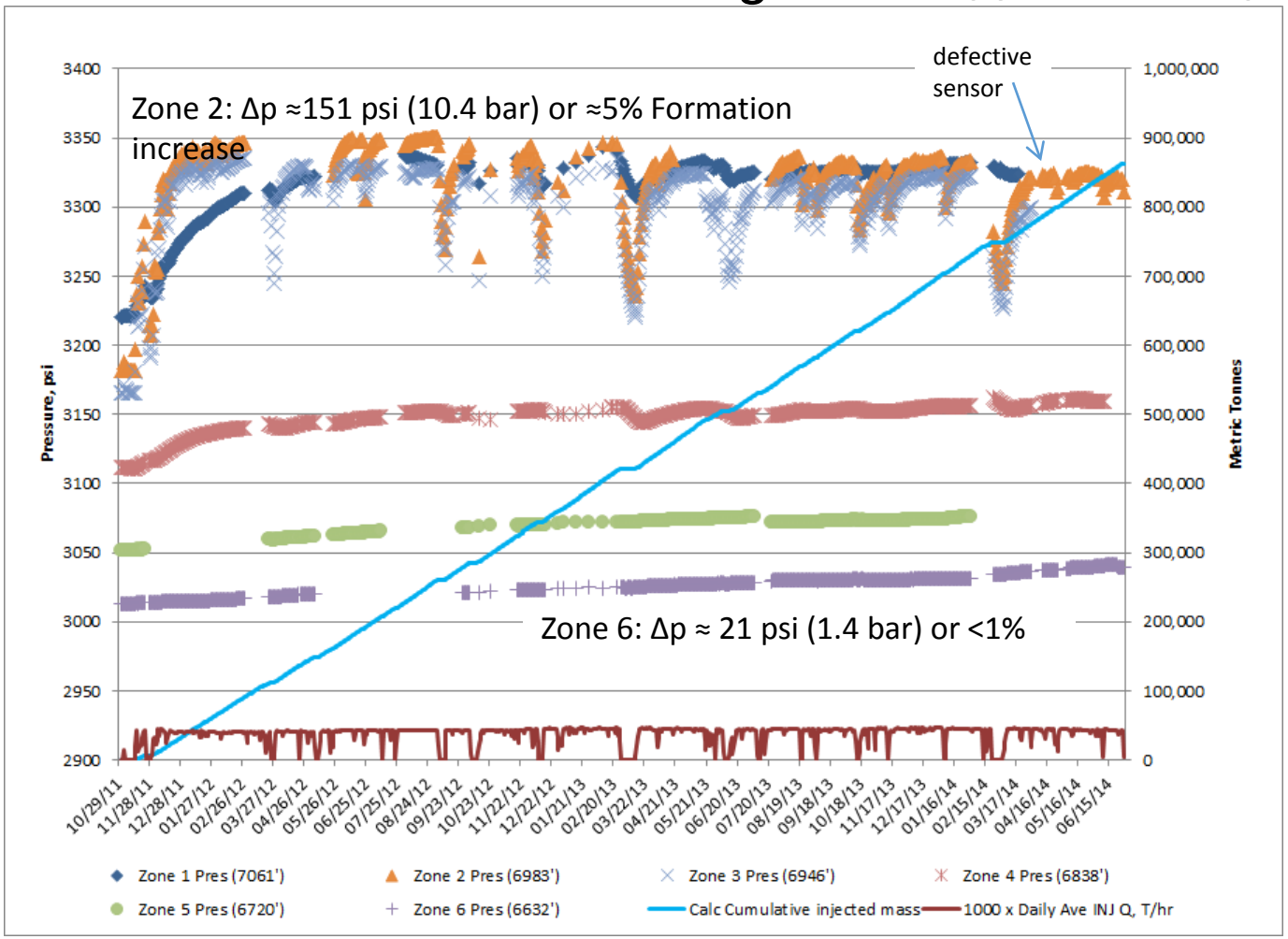


Formation pressure readings 900 feet from Injection borehole @ 1.5 yrs



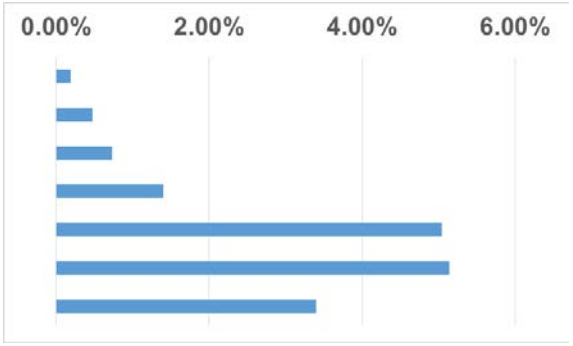
Down hole Injection pressure @ CCS1
14% increase over original formation pressure

Verification Well Monitoring Data (update to 7/1/14)

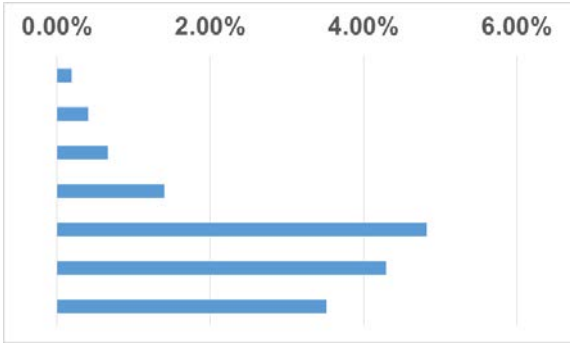


from Schlumberger Carbon Services

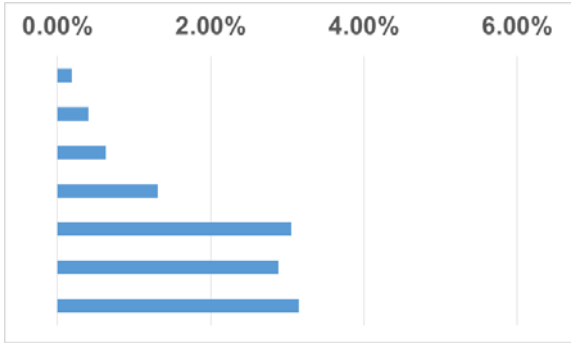
Reaction @ VW1 to Two week shut in



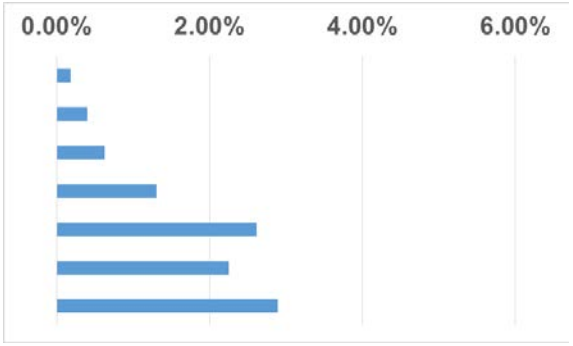
CCS1 Injection @ +14% ΔP



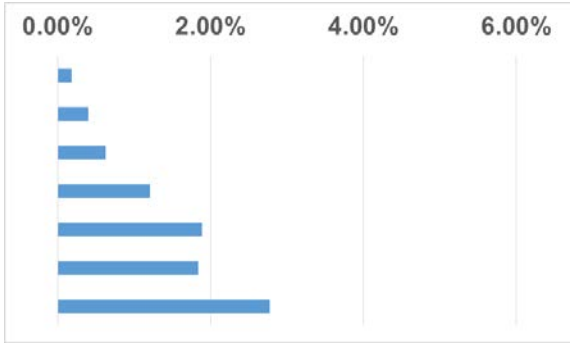
1 day into shut in – CCS1 @ +5.4%



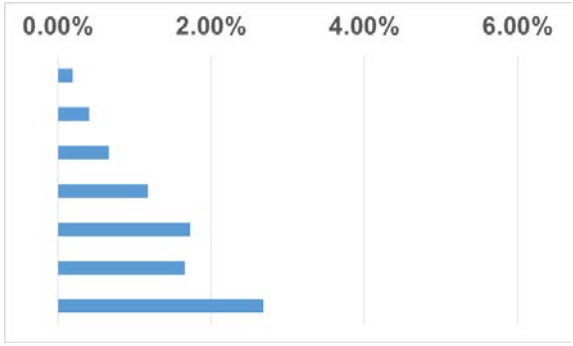
4 days into shut in – CCS1 @ +4.5%



8 days into shut in – CCS1 @ +4.0%

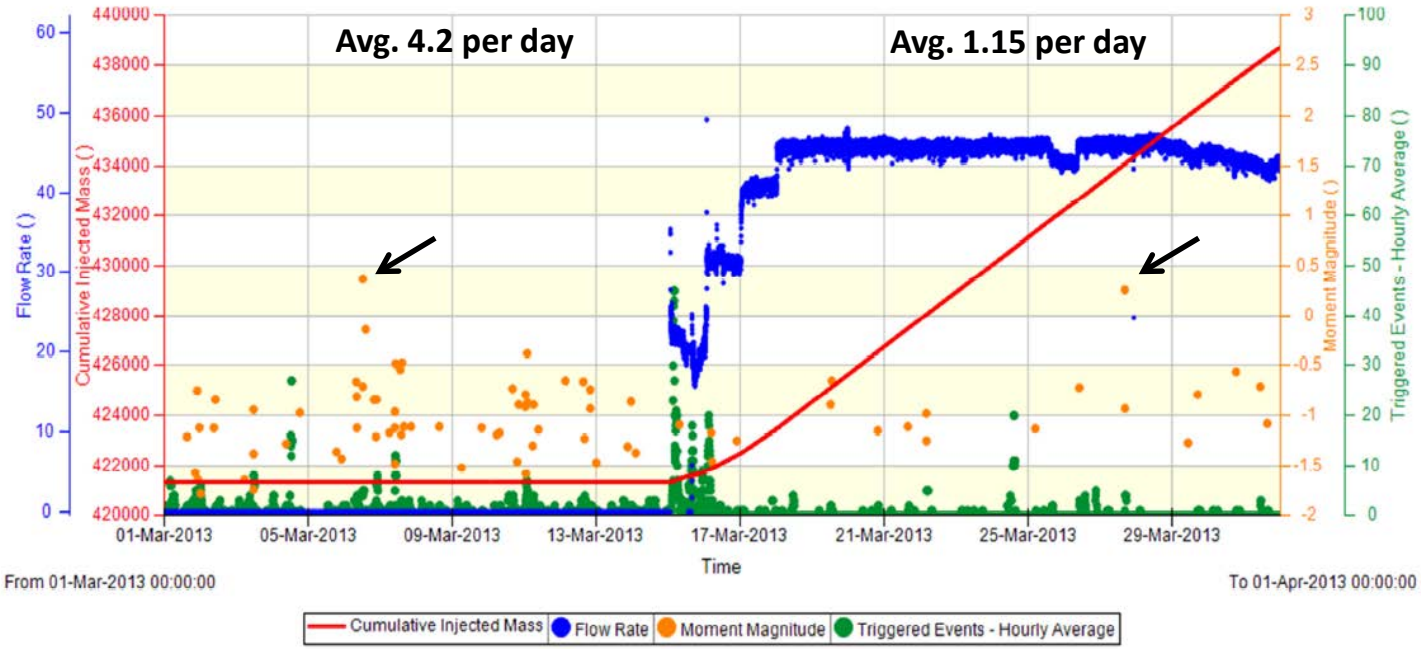


12 days into shut in – CCS1 @ +4.0%

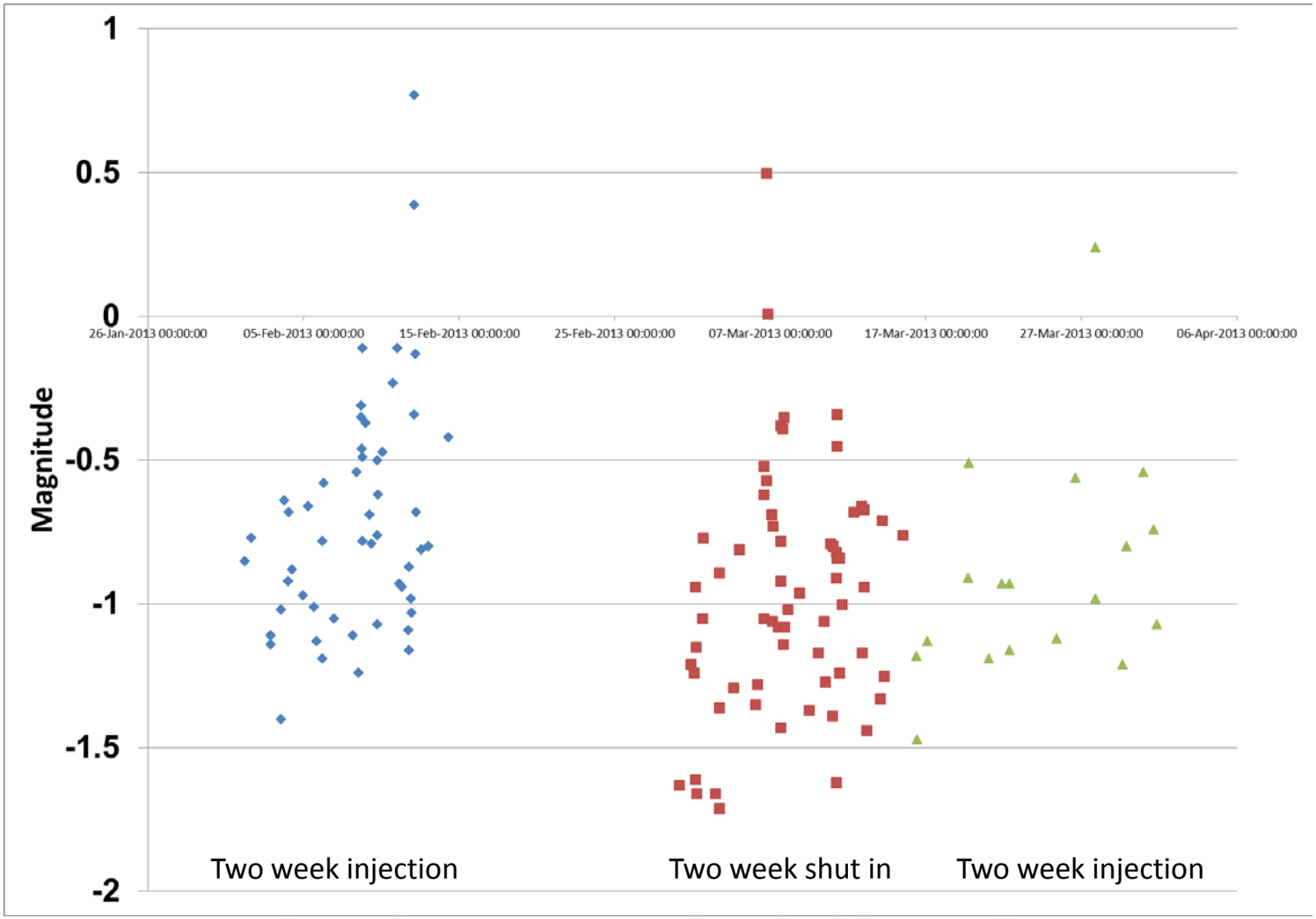


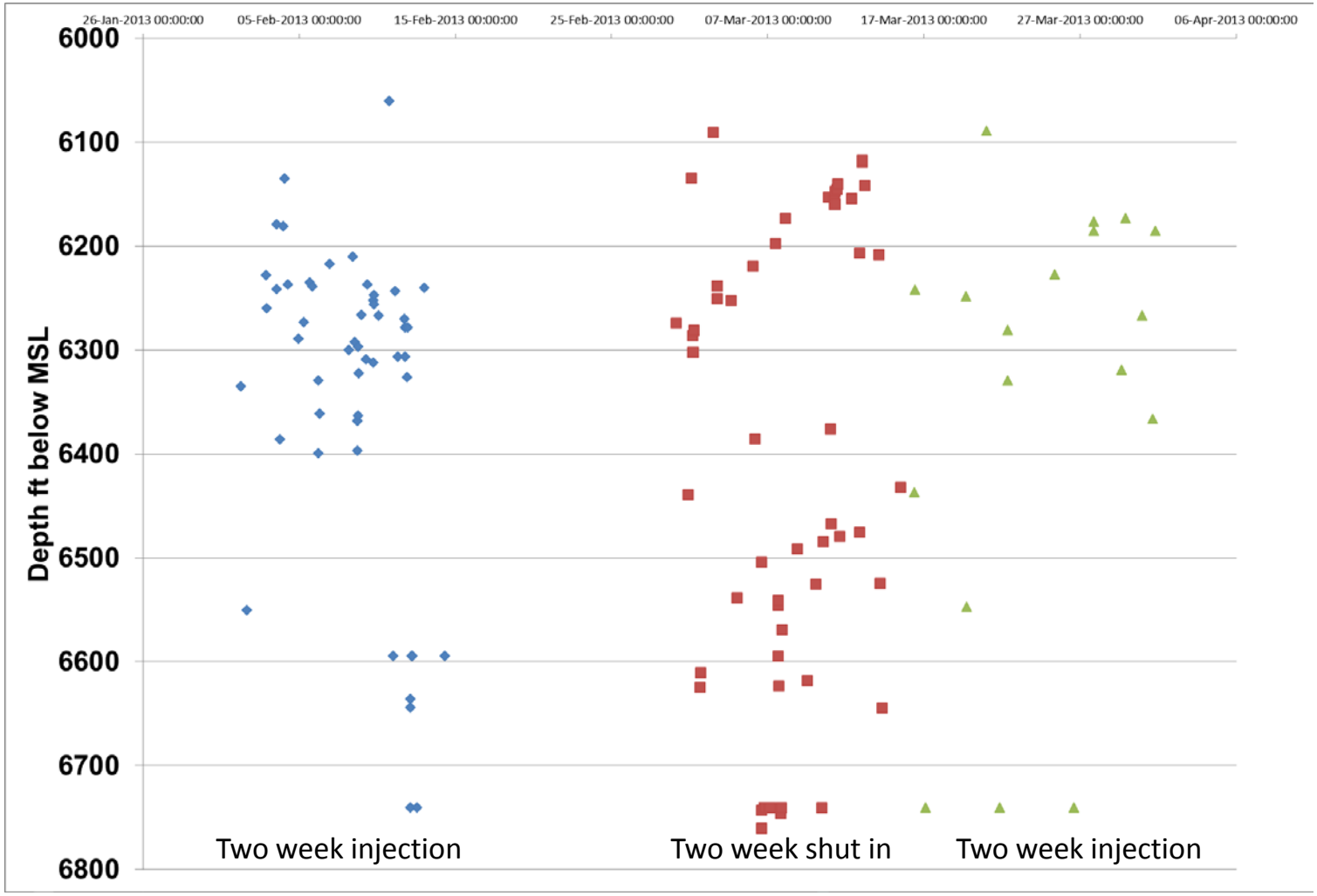
14 days into shut in – CCS1 @ +3.8%

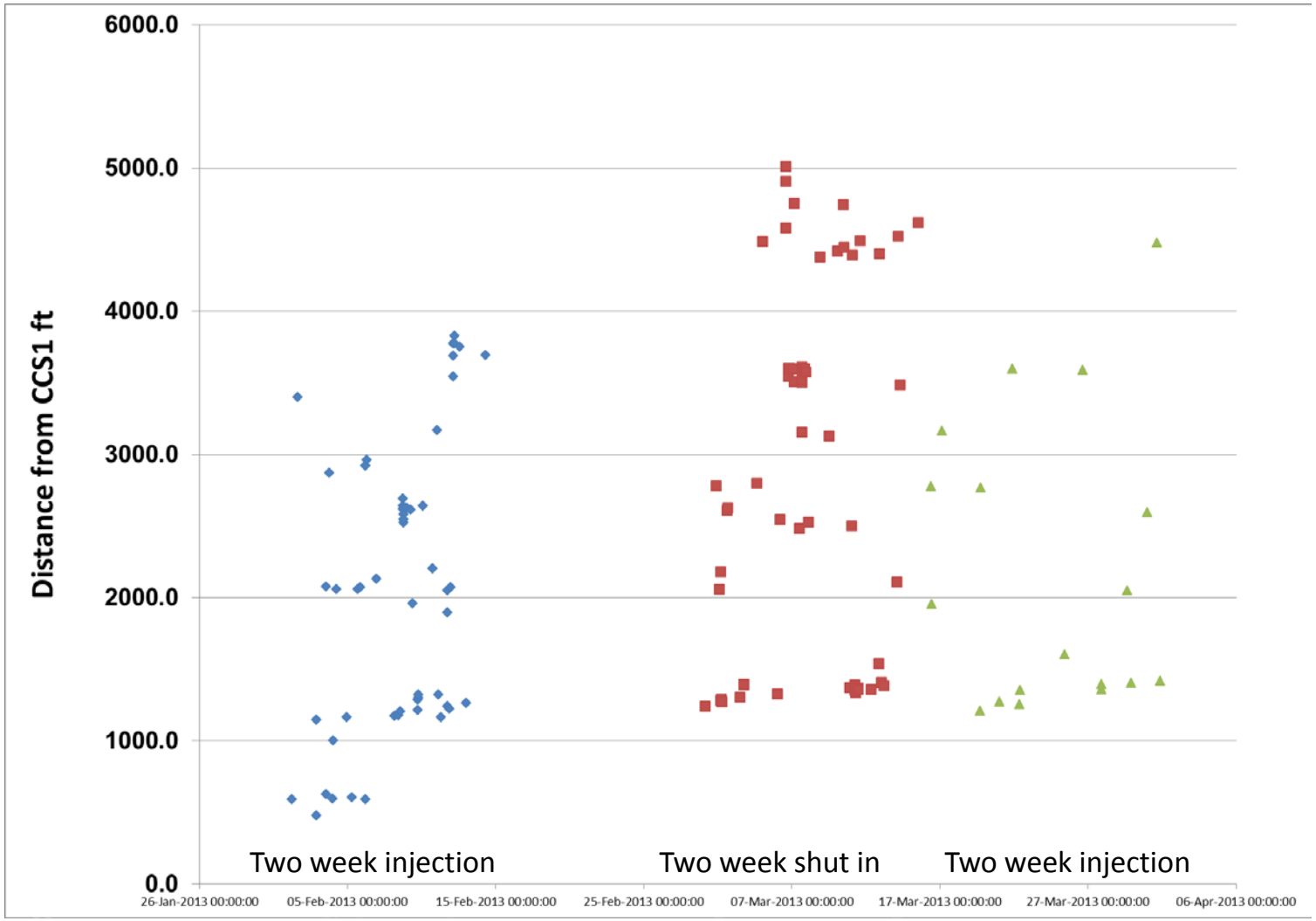
Locatable Events – March 2013



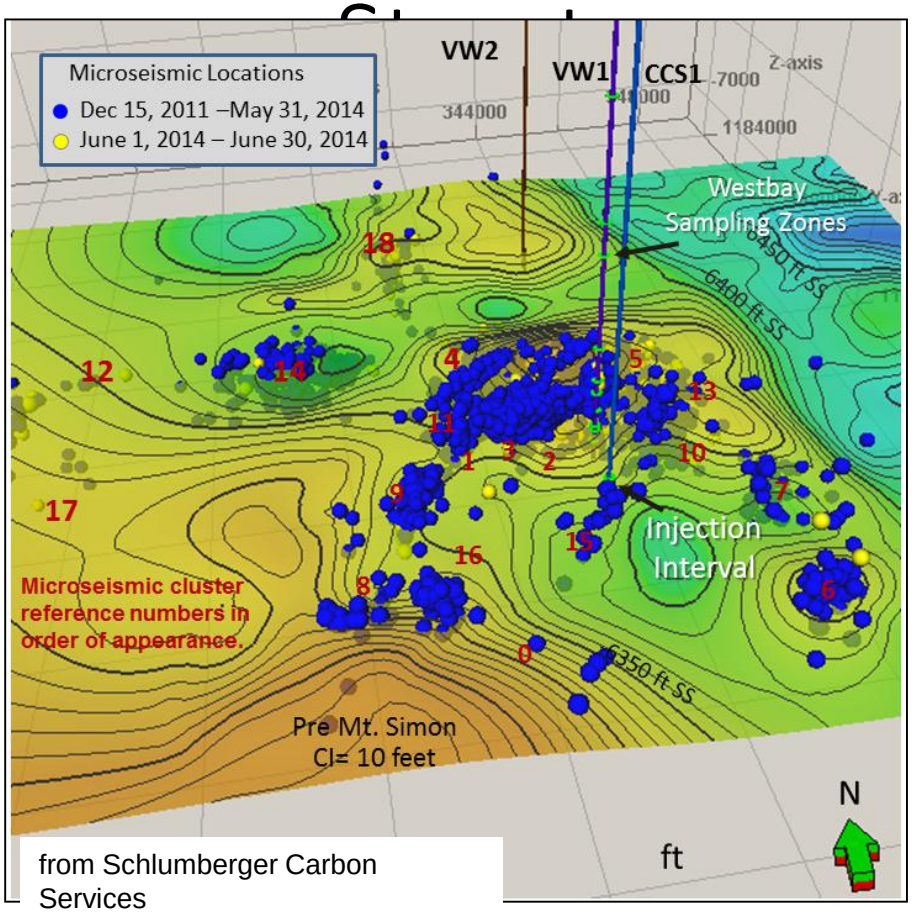
William Graham Payne - SCS


1
0.5
0
-0.5
-1
-1.5
-2
Magnitude
26-Jan-2013 00:00:00
05-Feb-2013 00:00:00
15-Feb-2013 00:00:00
25-Feb-2013 00:00:00
07-Mar-2013 00:00:00
17-Mar-2013 00:00:00
27-Mar-2013 00:00:00
06-Apr-2013 00:00:00
Two week injection
Two week shut in
Two week injection


26-Jan-2013 00:00:00
05-Feb-2013 00:00:00
15-Feb-2013 00:00:00
25-Feb-2013 00:00:00
07-Mar-2013 00:00:00
17-Mar-2013 00:00:00
27-Mar-2013 00:00:00
06-Apr-2013 00:00:00
Depth ft below MSL
6000
6100
6200
6300
6400
6500
6600
6700
6800
Two week injection
Two week shut in
Two week injection

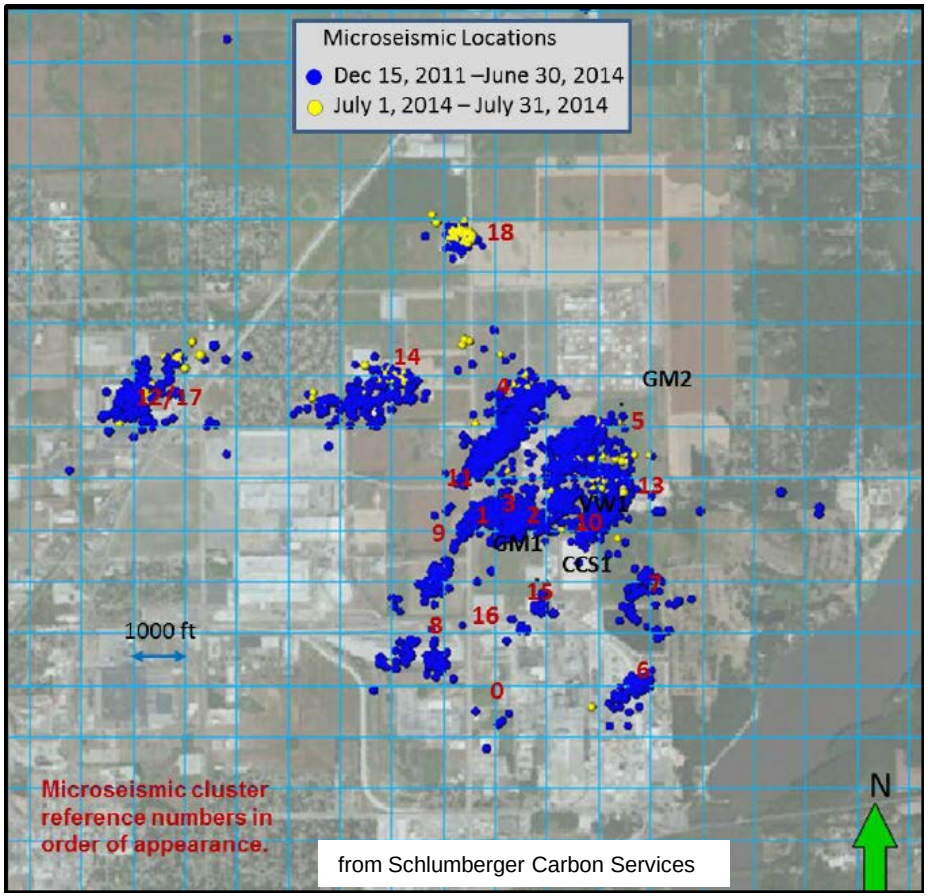

Distance from CCS1 ft
6000.0
5000.0
4000.0
3000.0
2000.0
1000.0
0.0
26-Jan-2013 00:00:00
05-Feb-2013 00:00:00
15-Feb-2013 00:00:00
25-Feb-2013 00:00:00
07-Mar-2013 00:00:00
17-Mar-2013 00:00:00
27-Mar-2013 00:00:00
06-Apr-2013 00:00:00
Two week injection
Two week shut in
Two week injection

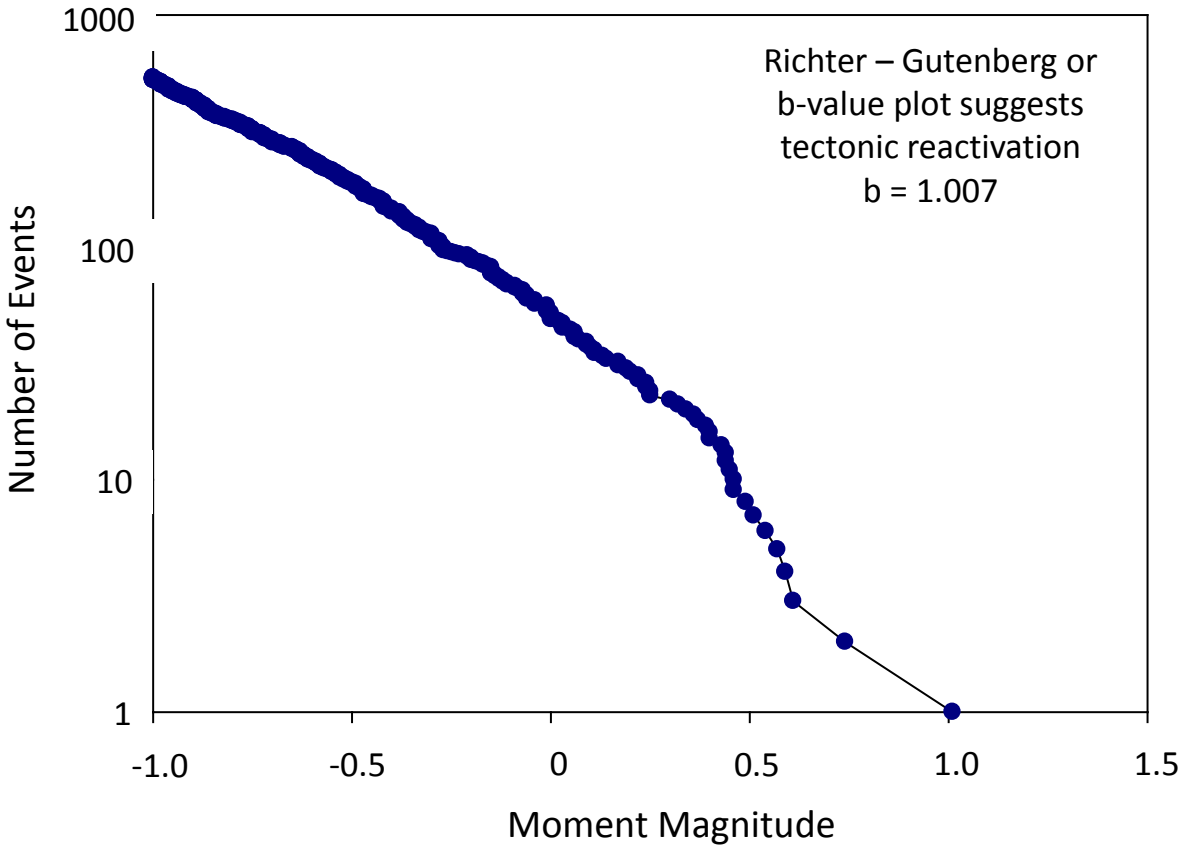
Microseismic Cluster Activity: Relationship to Pre-Mt. Simon



from Schlumberger Carbon Services

Microseismic Cluster Activity:
Cluster Locations in Relation to Surface Features





from Schlumberger Carbon Services

Microseismic Activity: Overview

- Stratified pressures and Max. Δ P of 5% increase for one “layer”
- Pressures far below fracture pressures
- Lower permeability layers near top of injection restrict pressure increases upward, restricting seismic development
- Locations determined using geophone arrays in CCS1, GM1, and VW2
- Form distinct clusters along undetected pre-existing structures
- Distributed between Lower Mt. Simon Sandstone, Pre-Mt. Simon Unit, and Precambrian basement
- Magnitudes range from -2.14 to 1.14 & 94% are less than 0
- Magnitude range does not change much through time
- b values of about 1 indicate reactivation of pre-existing features
- Overall project average of microseismic events is 4 per day

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