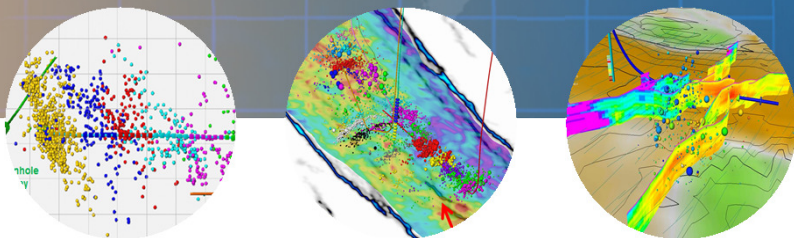


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URS COP 324A 6MH

9 September 2013

Steve Reese
Microseismic Services Engineer

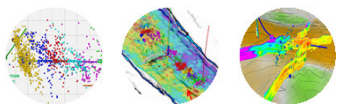


Microseismic Services
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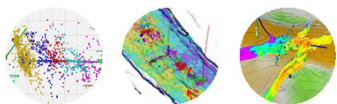
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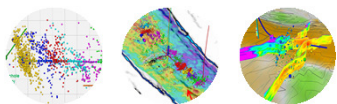
Evaluation Objectives

- Evaluation of fracture geometry
- Stimulated volume of each treatment stage
- Discussion of fracture containment and height growth
- Use of seismic moment as a tool to confirm results



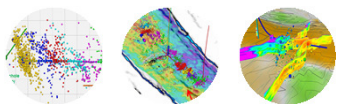
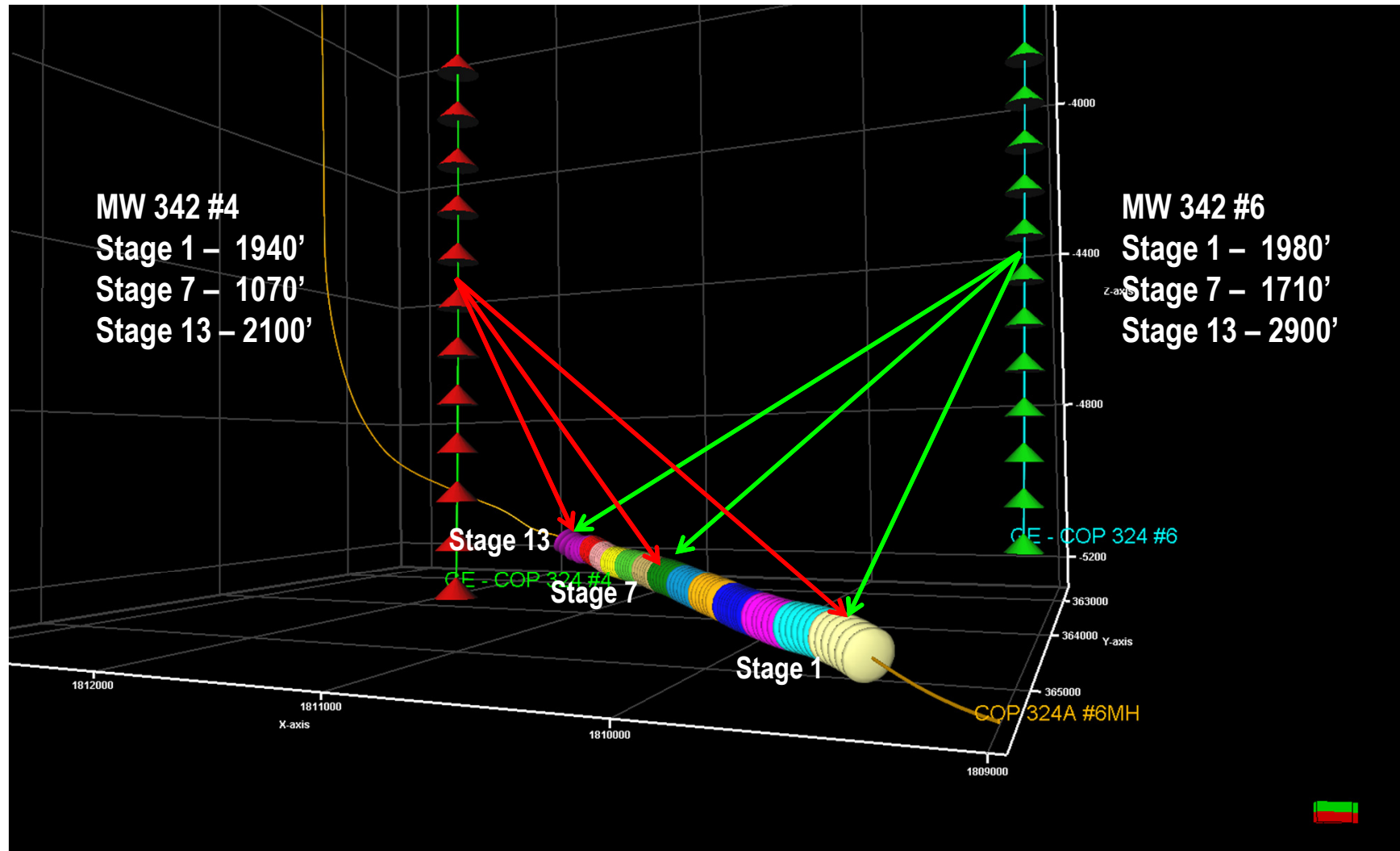
Job Overview

- COP 324A 6HM
 - Marcellus Completion
 - 13 Stages
 - 286 ft Stage Spacing & 60 Perforations/Stage
 - 607,700 gals of clean fluid and 600,500 lbs of proppant per stage
- Dual monitor VSI 12 monitoring array
 - Co-location of events



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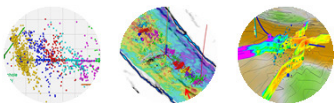
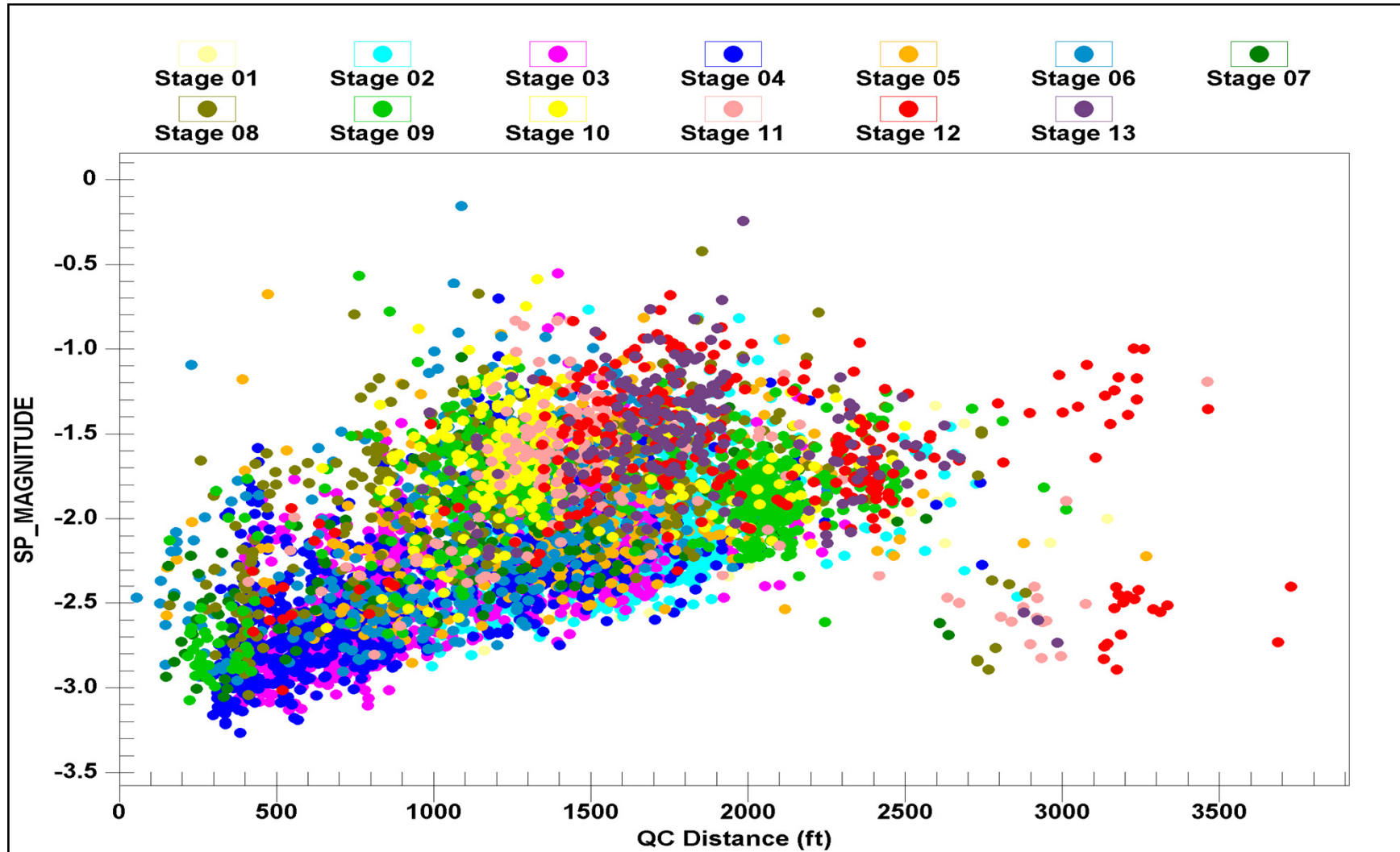
Monitoring Layout and Distances



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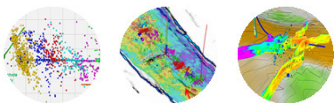
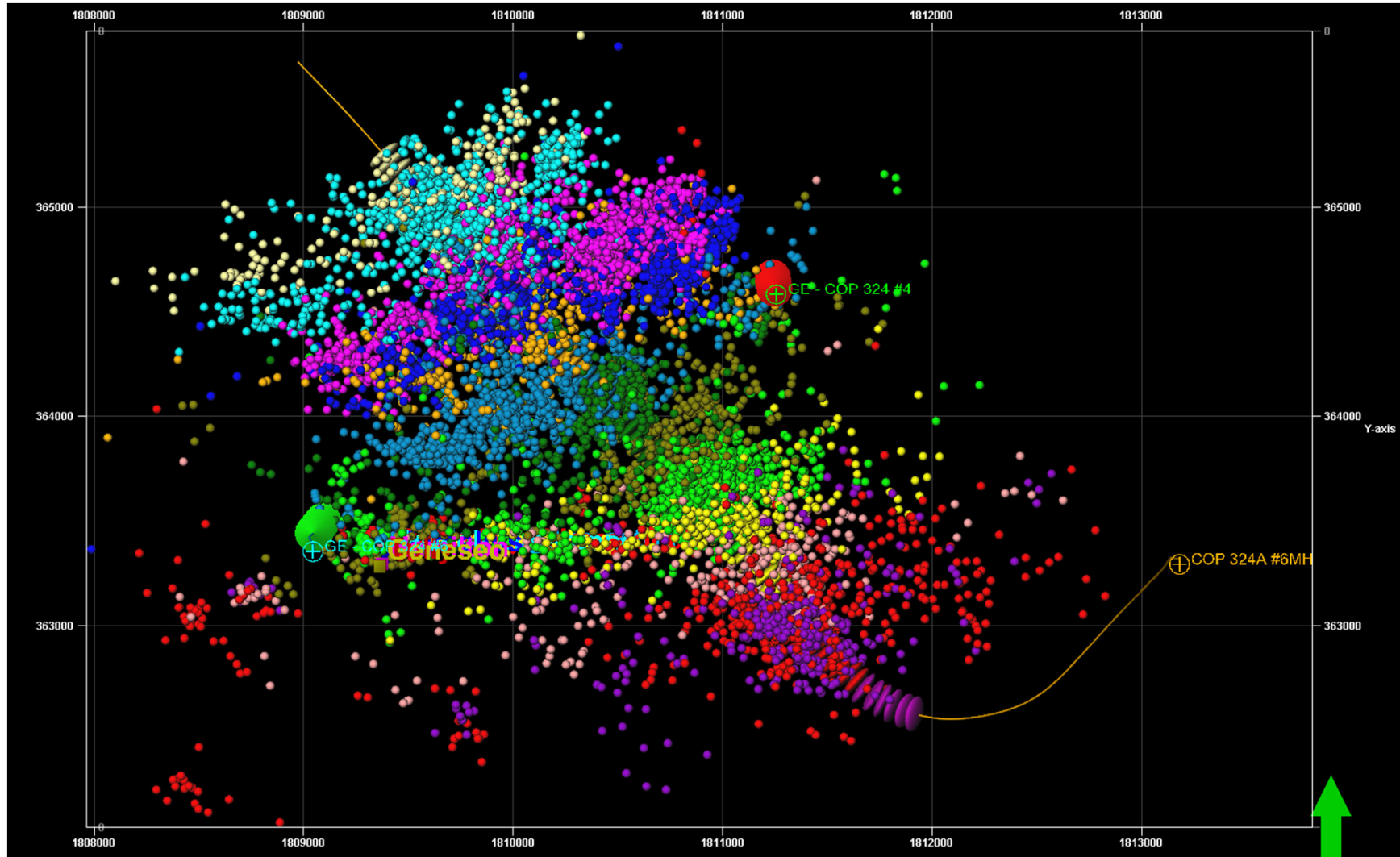
Magnitude vs. Distance



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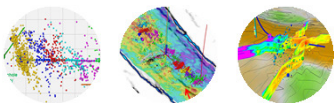
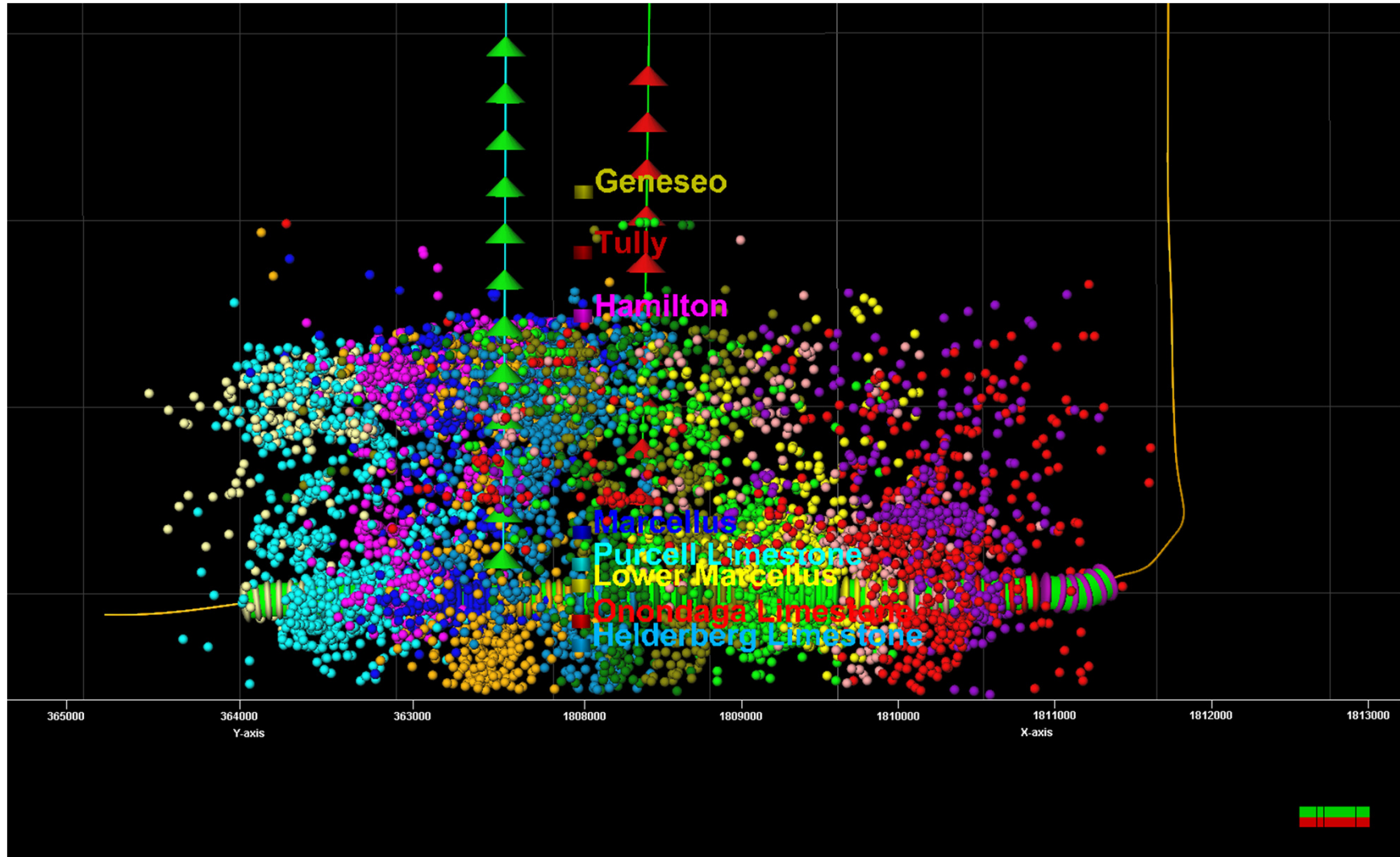
Map View, All Events



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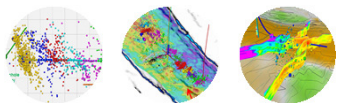
Depth View, All Events



Microseismic Services
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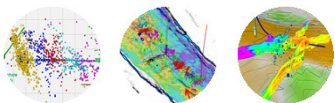
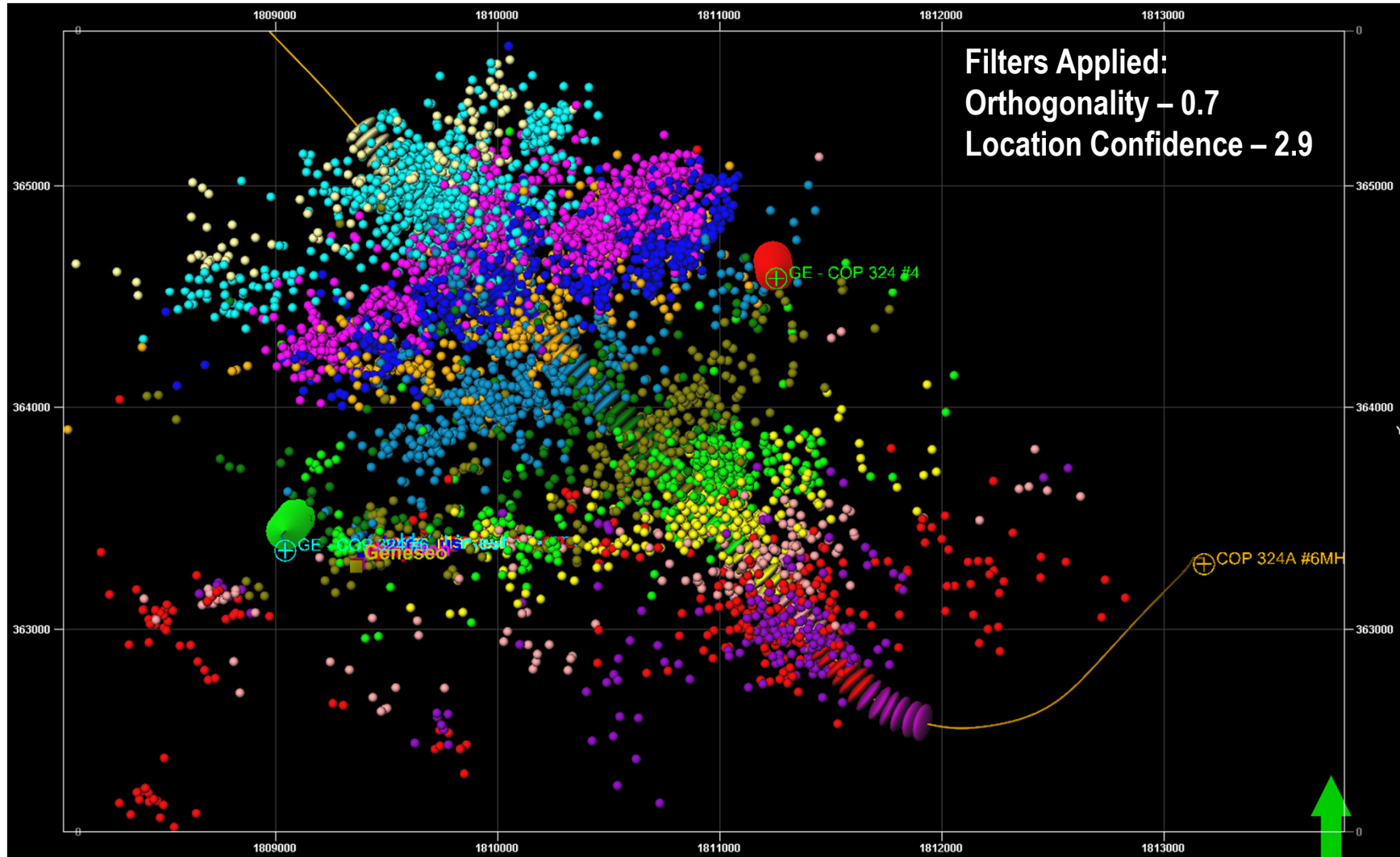
Microseismic Dimensions Summary



Microseismic Services
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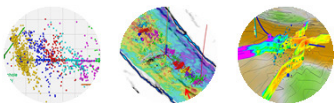
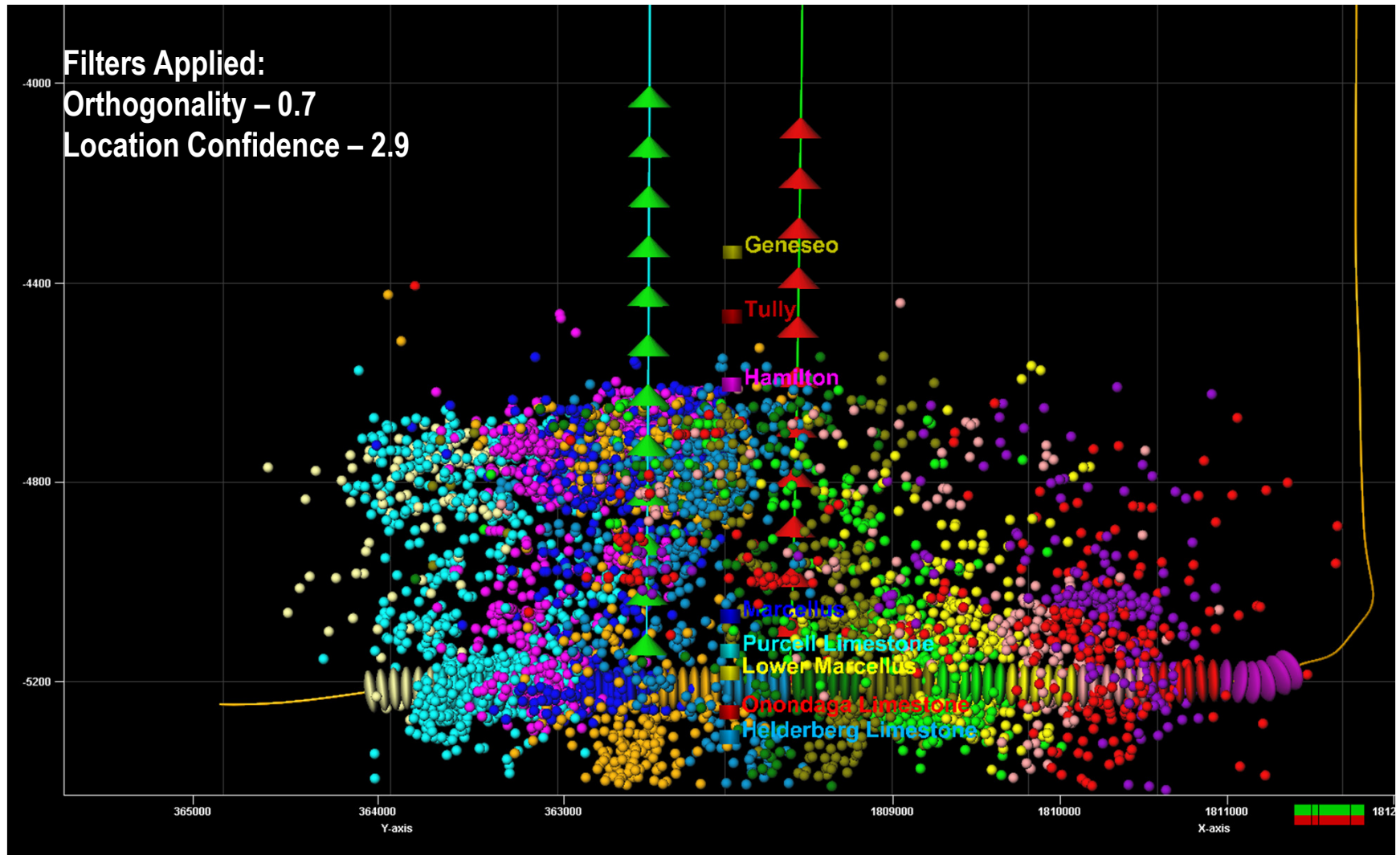
Map View, All Events, QC Filters Applied



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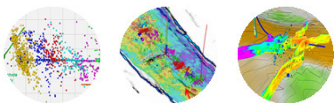
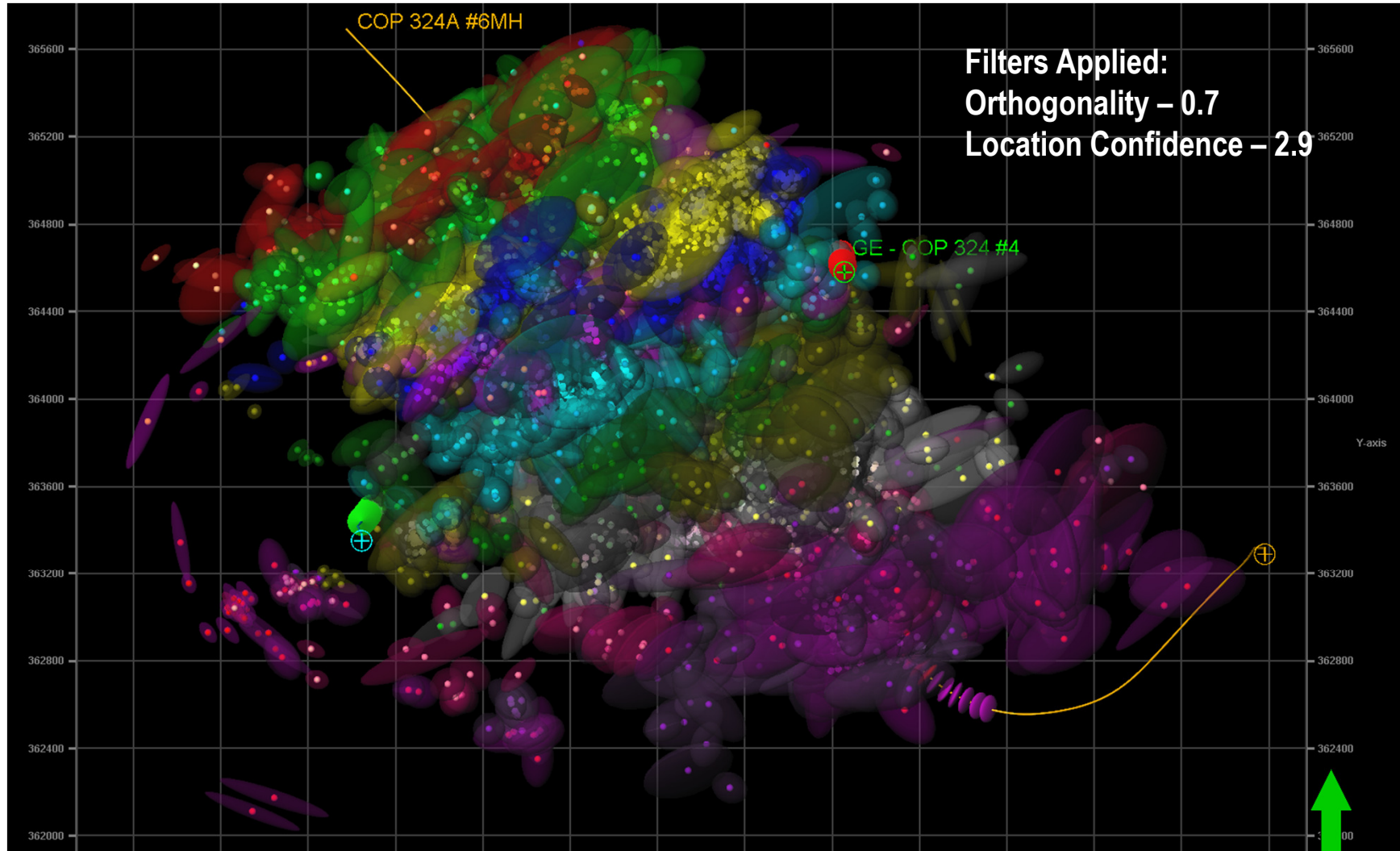
Depth View, All Events, QC Filters Applied



Microseismic Services
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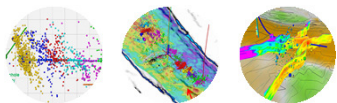
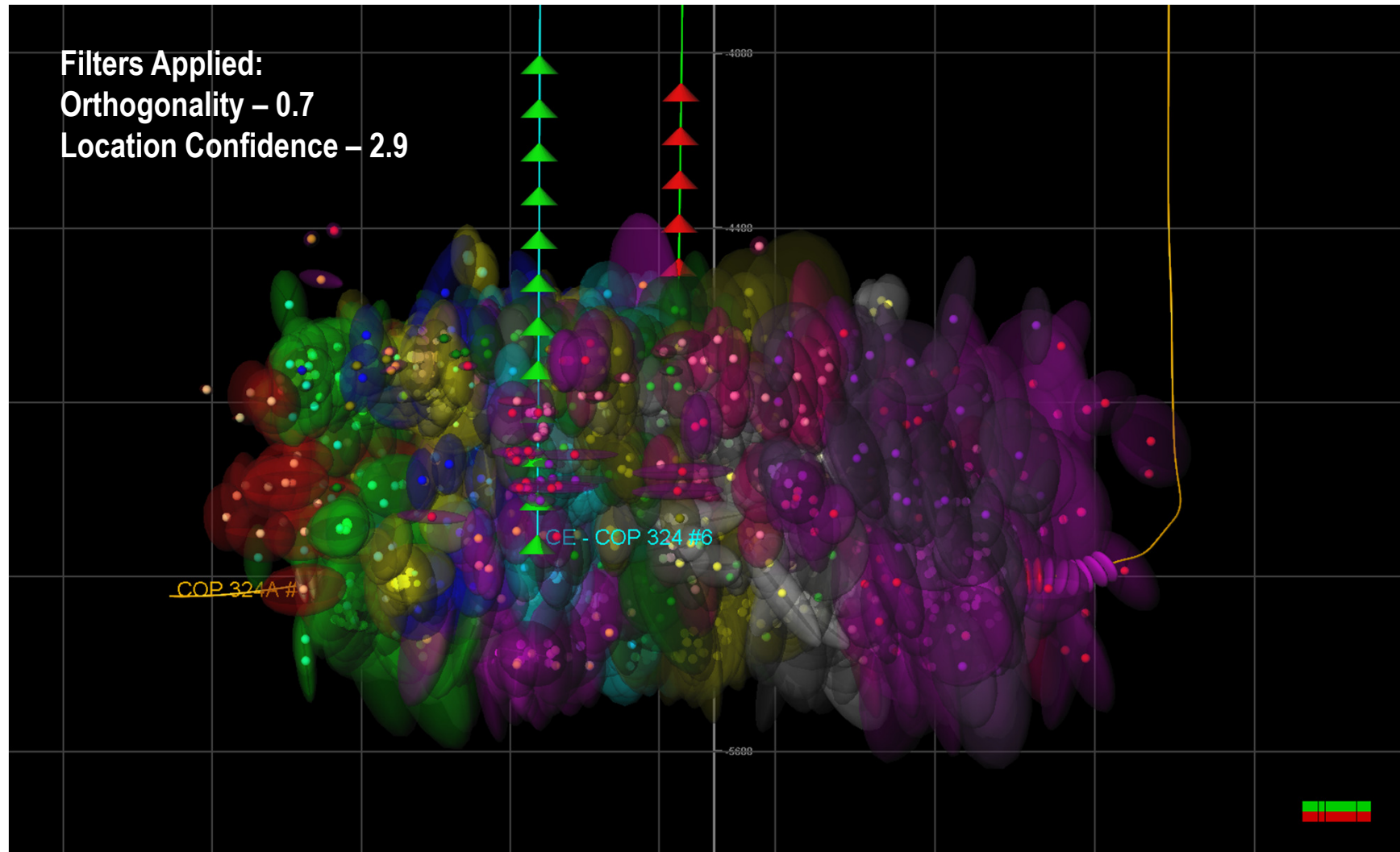
Map View, Uncertainties, QC Filters Applied



Microseismic Services
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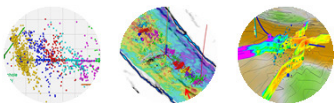
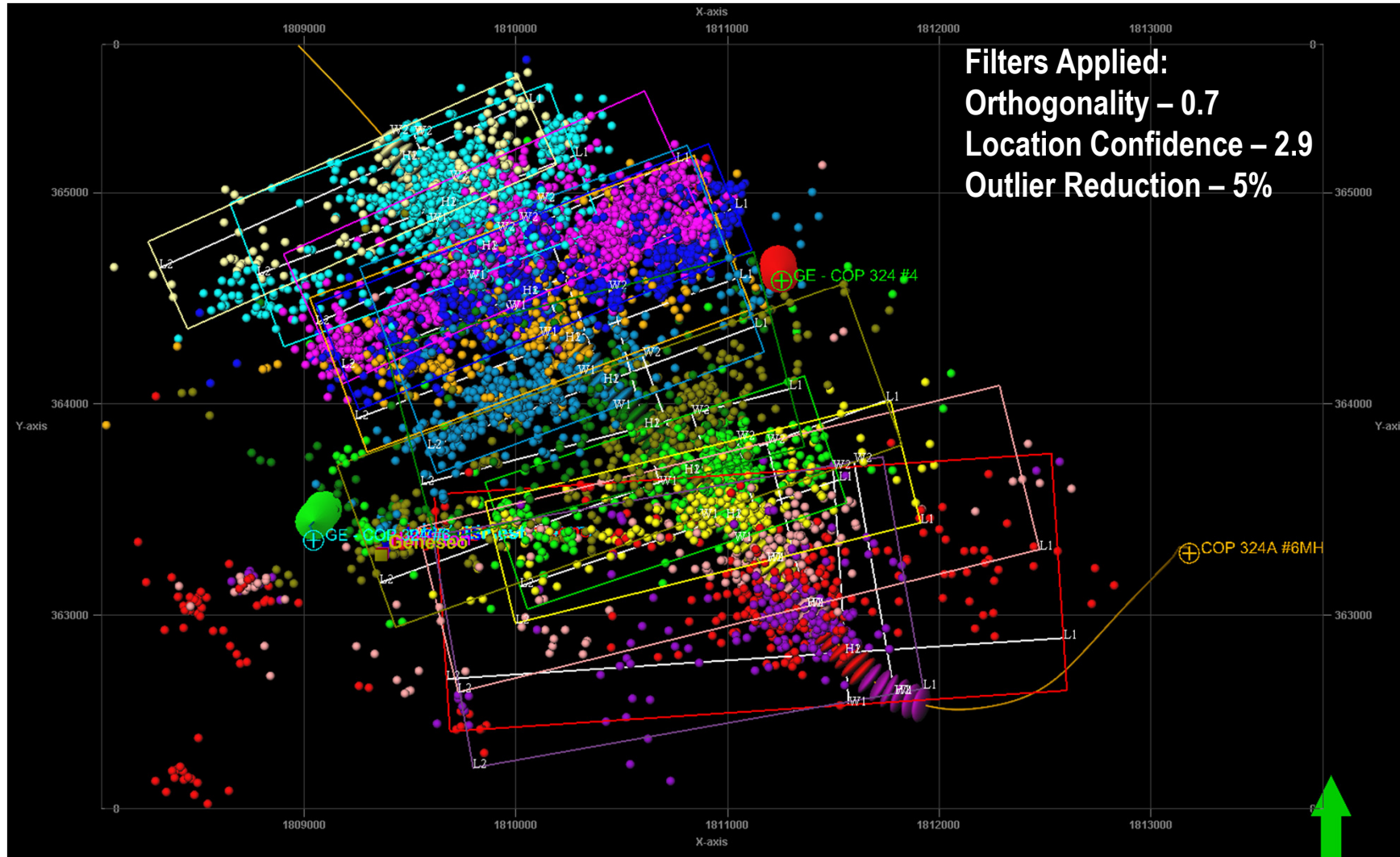
Depth View, Uncertainties, QC Filters Applied



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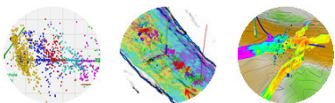
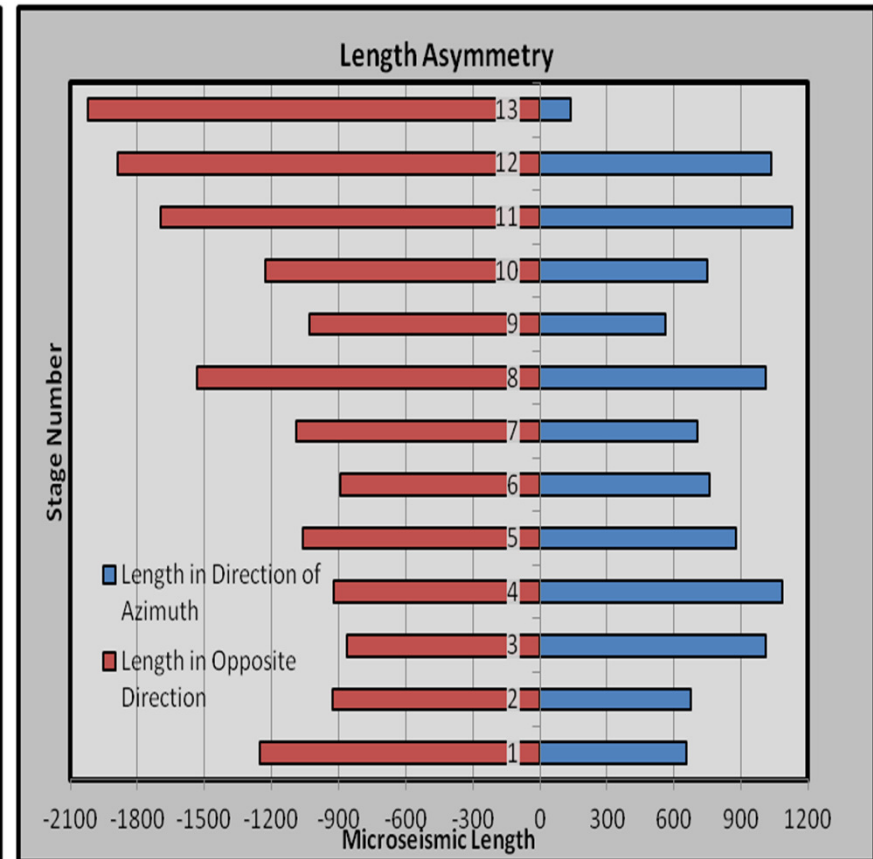
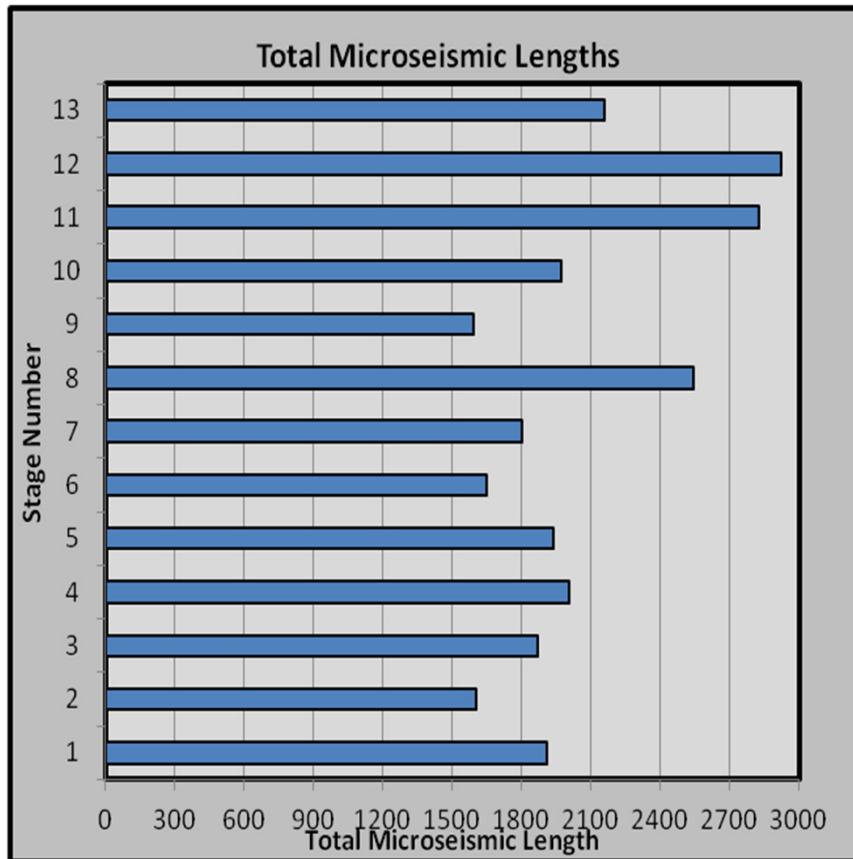
Microseismic Dimensions



Microseismic Services
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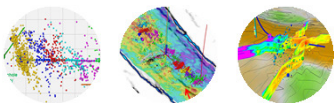
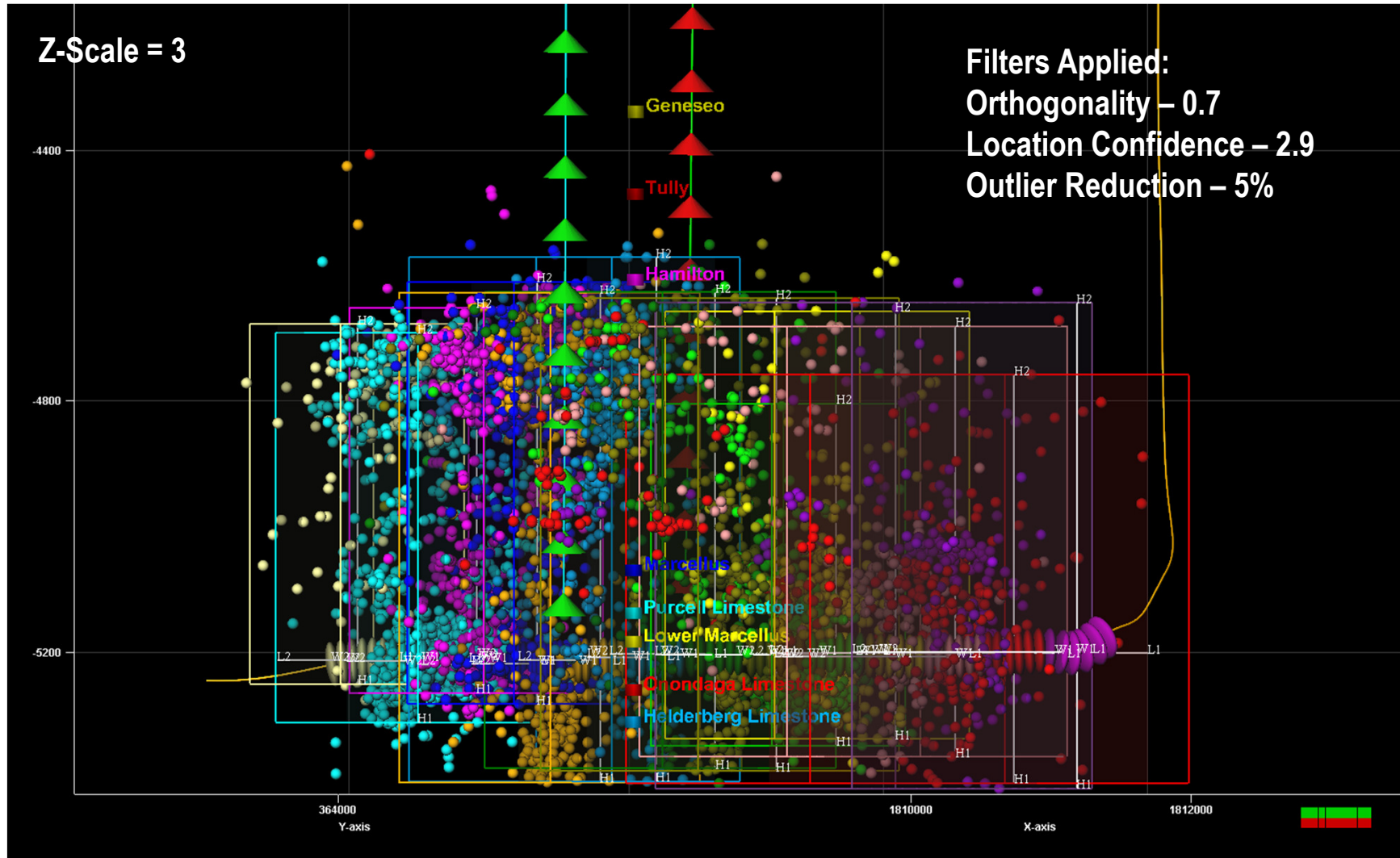
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Microseismic Length Summary



Microseismic Services
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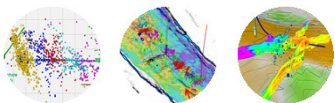
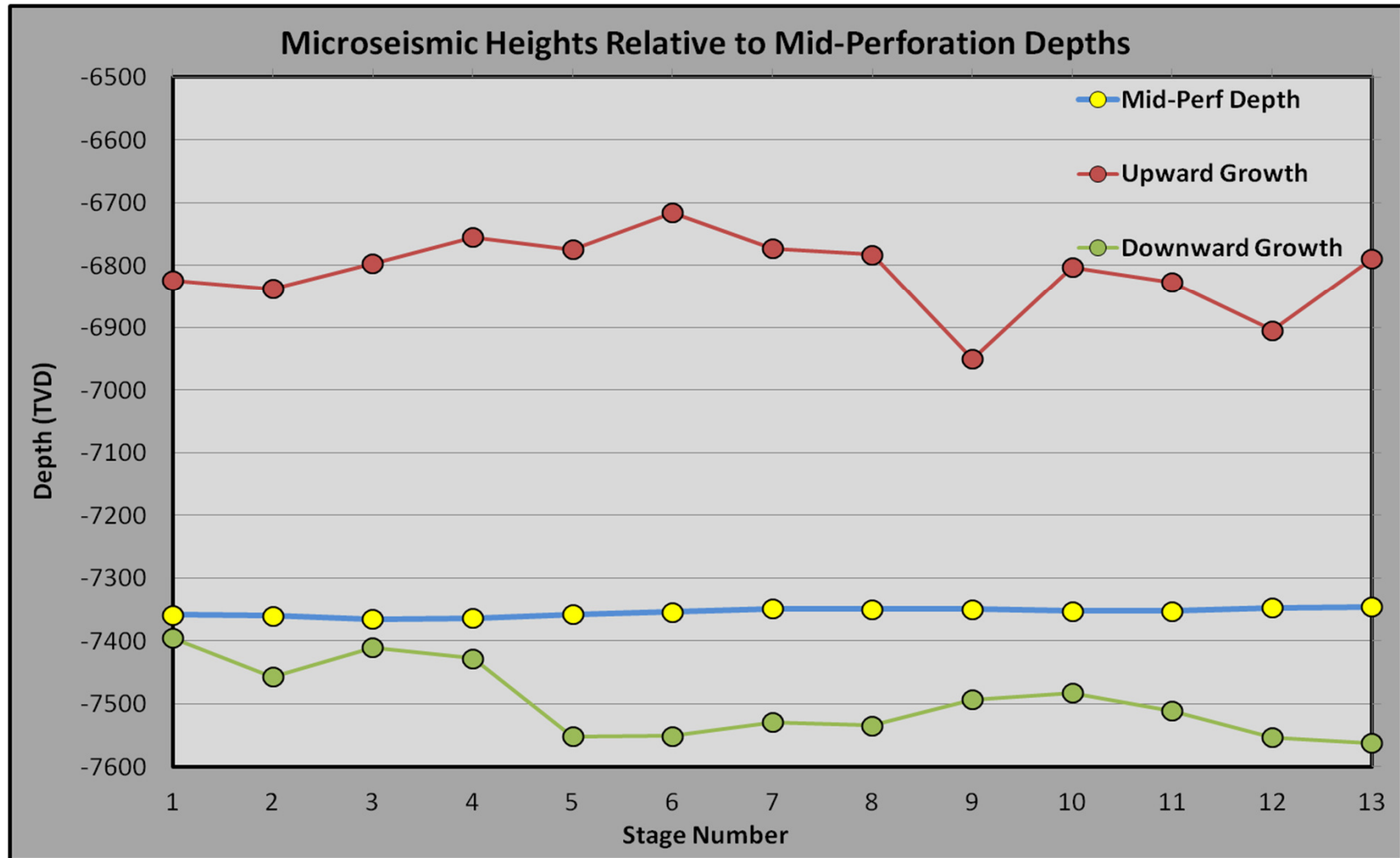
Microseismic Dimensions



Microseismic Services
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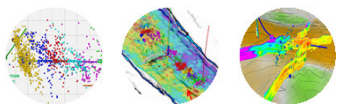
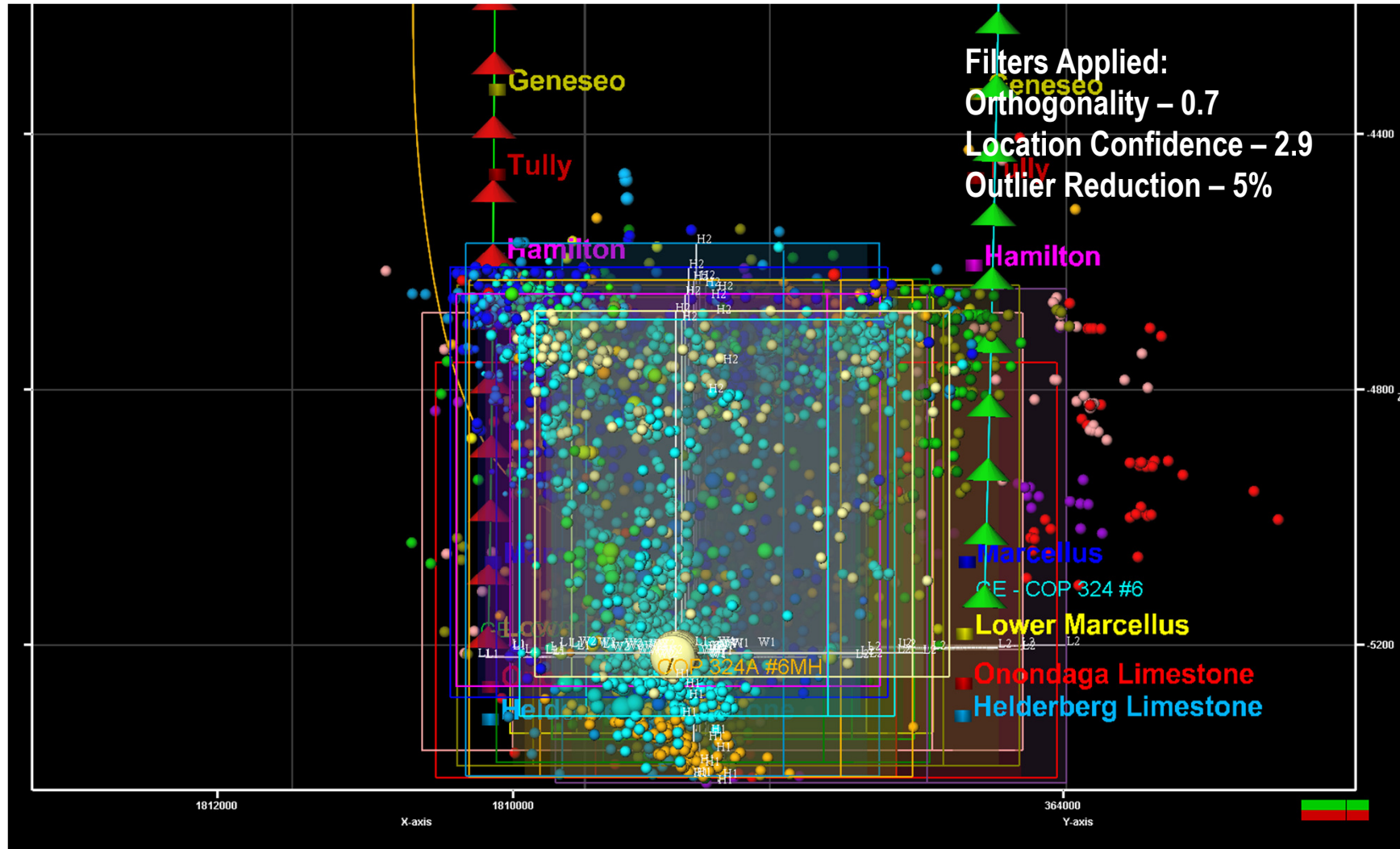
Microseismic Height Summary



Microseismic Services
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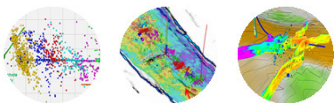
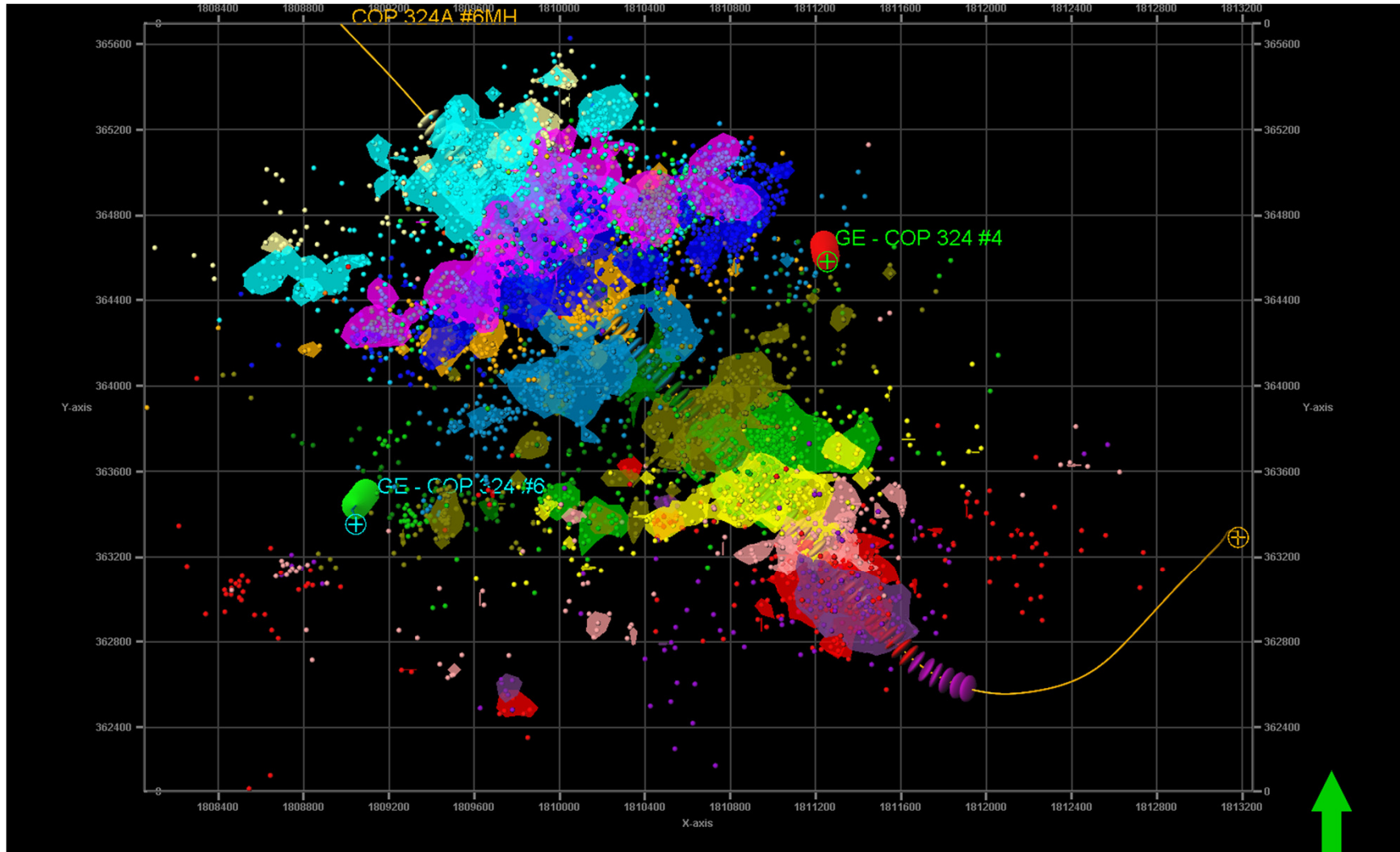
Microseismic Dimensions



Microseismic Services
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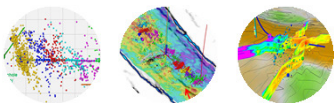
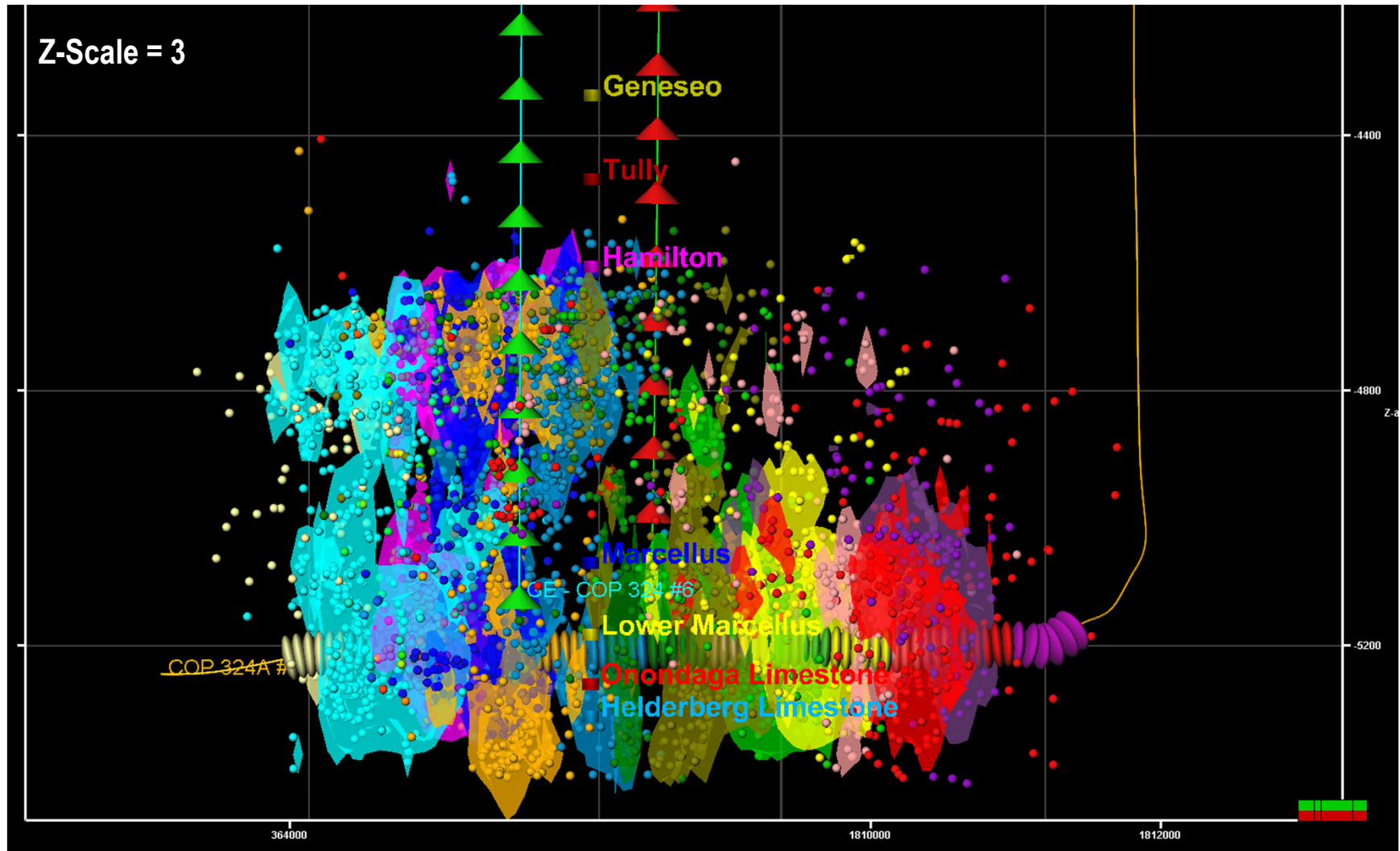
Microseismic Volume



Microseismic Services
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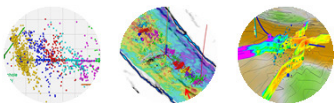
Microseismic Volume



Microseismic Services
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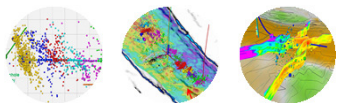
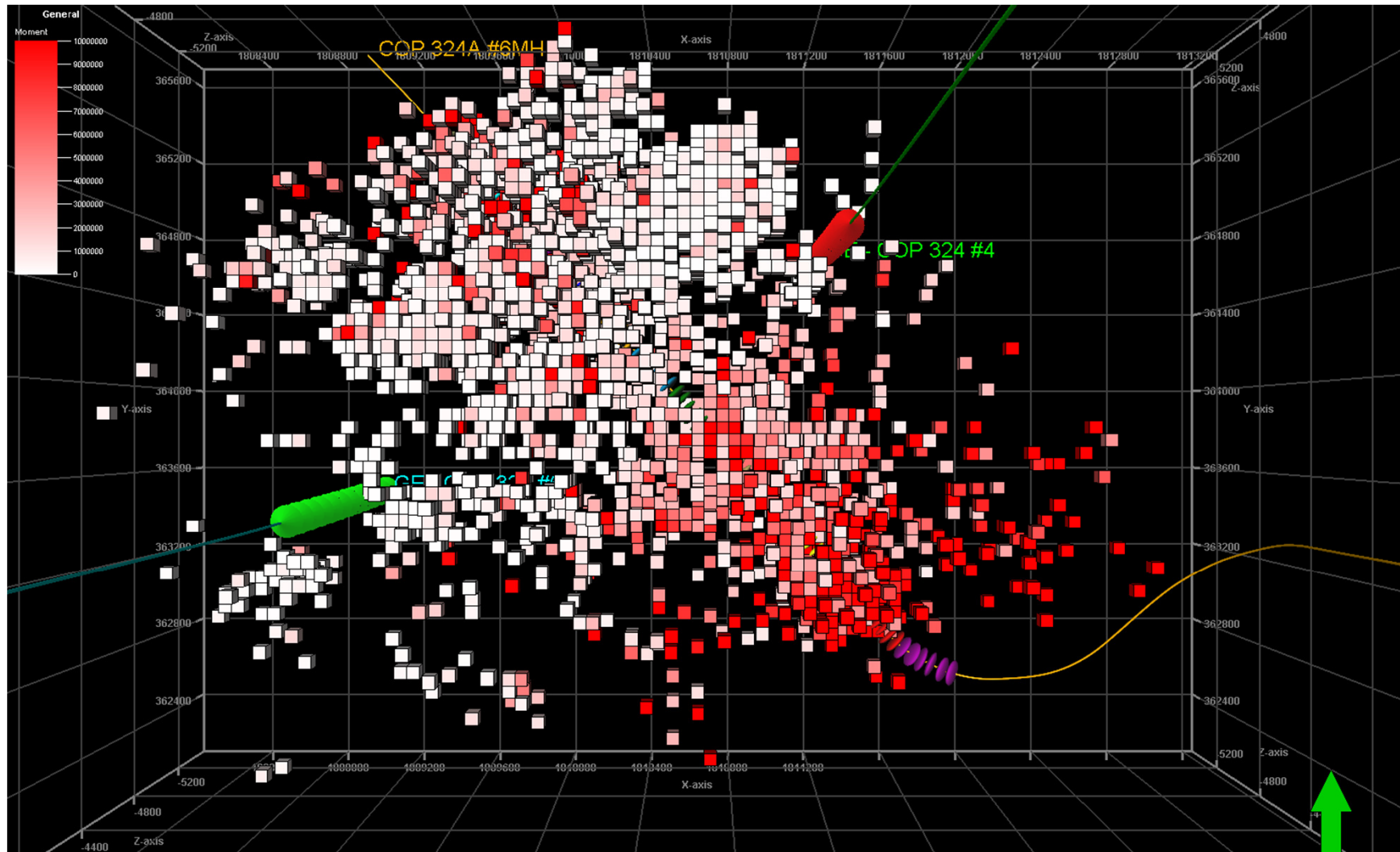
Seismic Moment Evaluation



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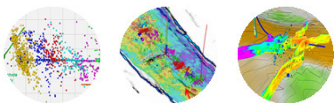
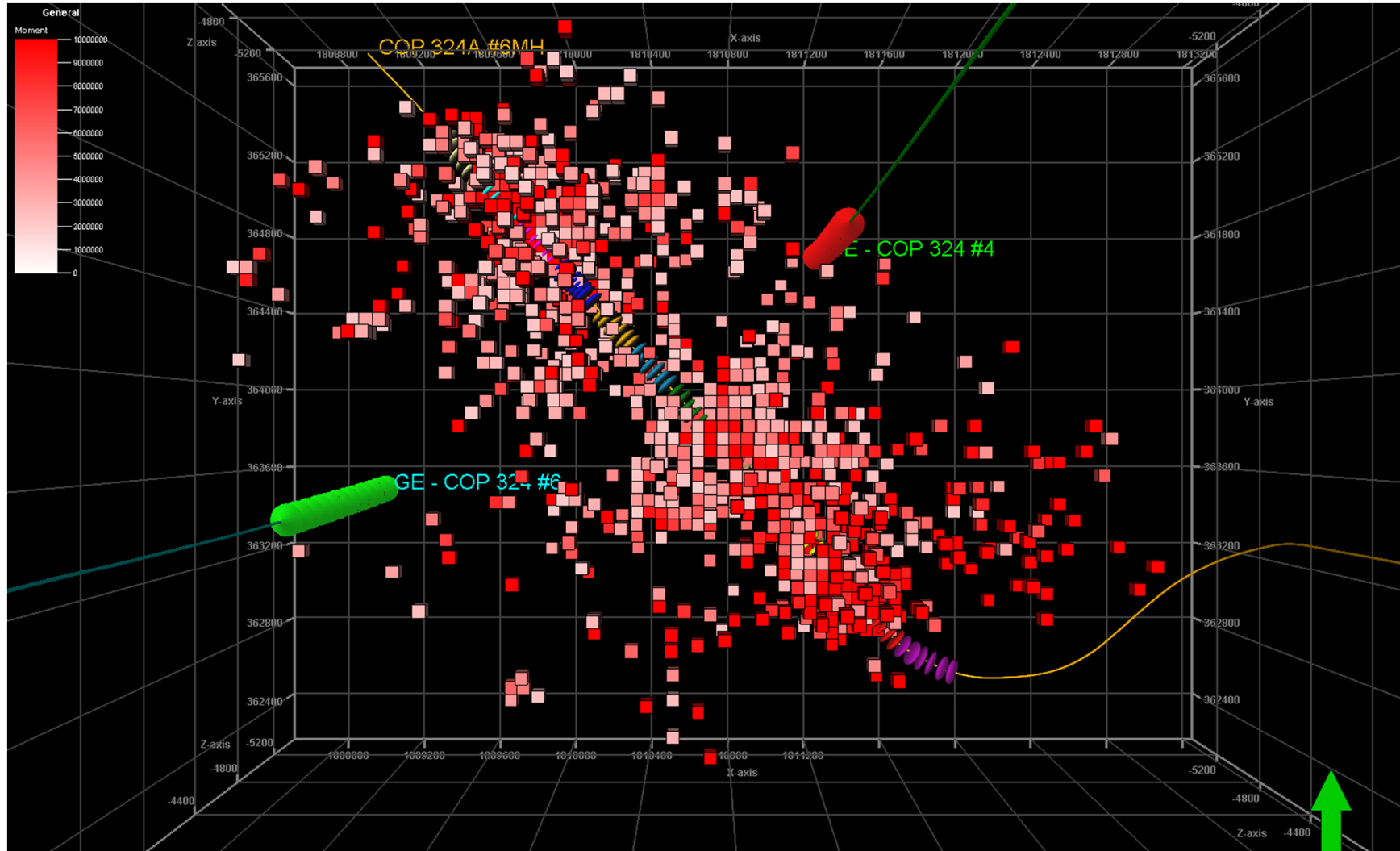
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Pillar Grid of Seismic Moment



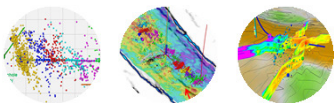
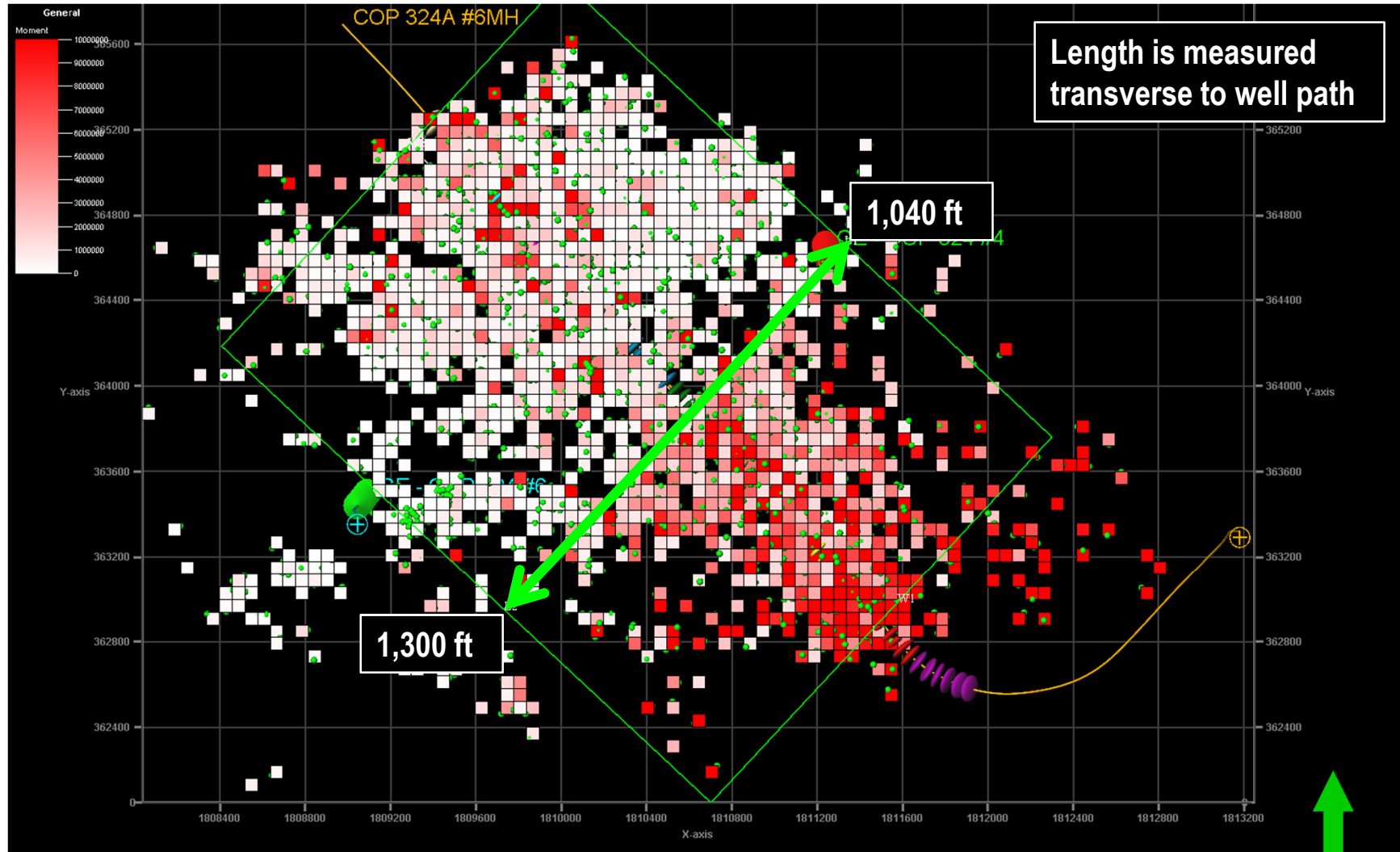
Microseismic Services
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Pillar Grid of Seismic Moment, Filtered



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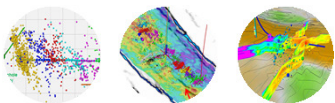
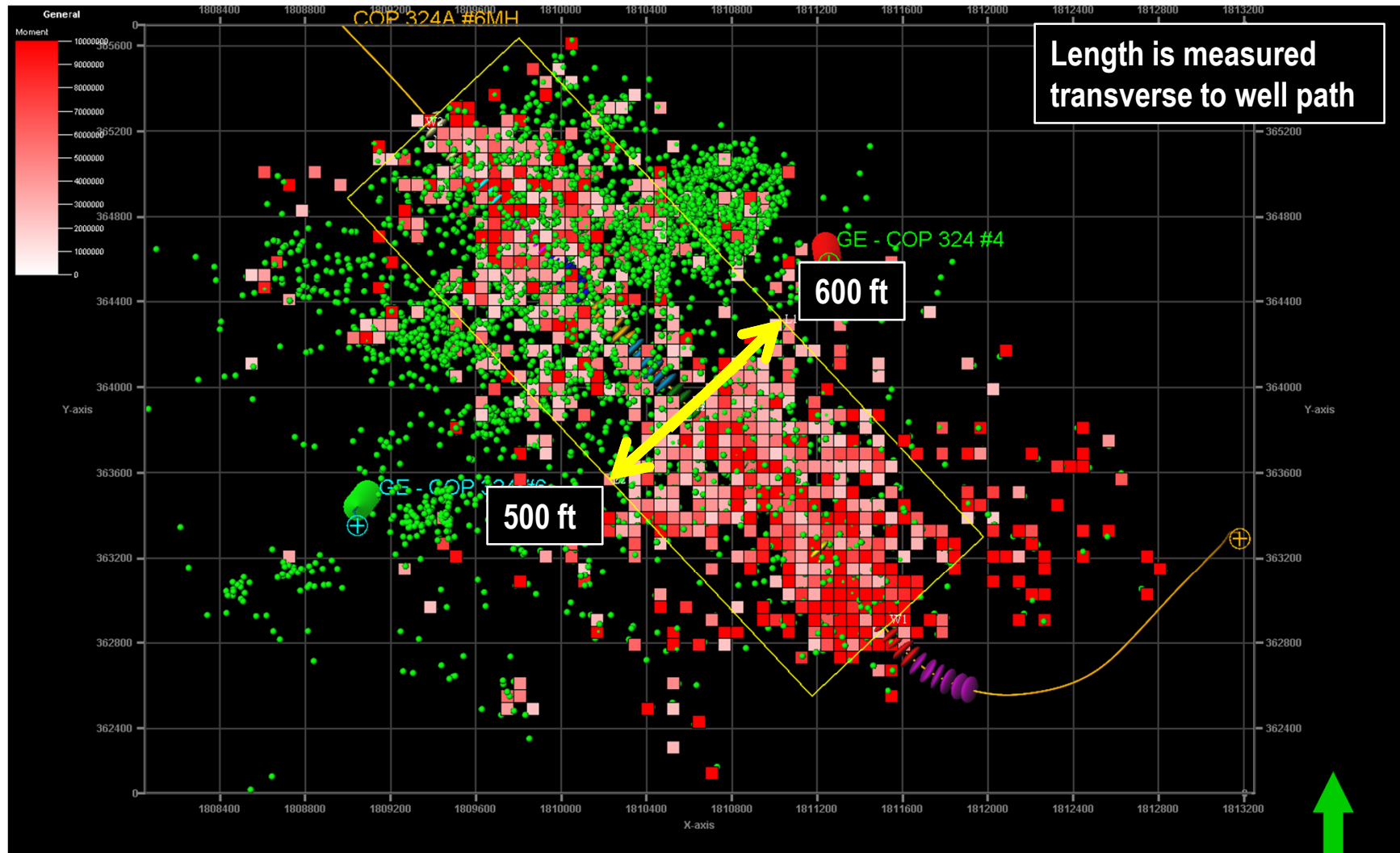
Average Maximum Extent of Microseismic Activity



Microseismic Services
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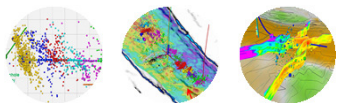
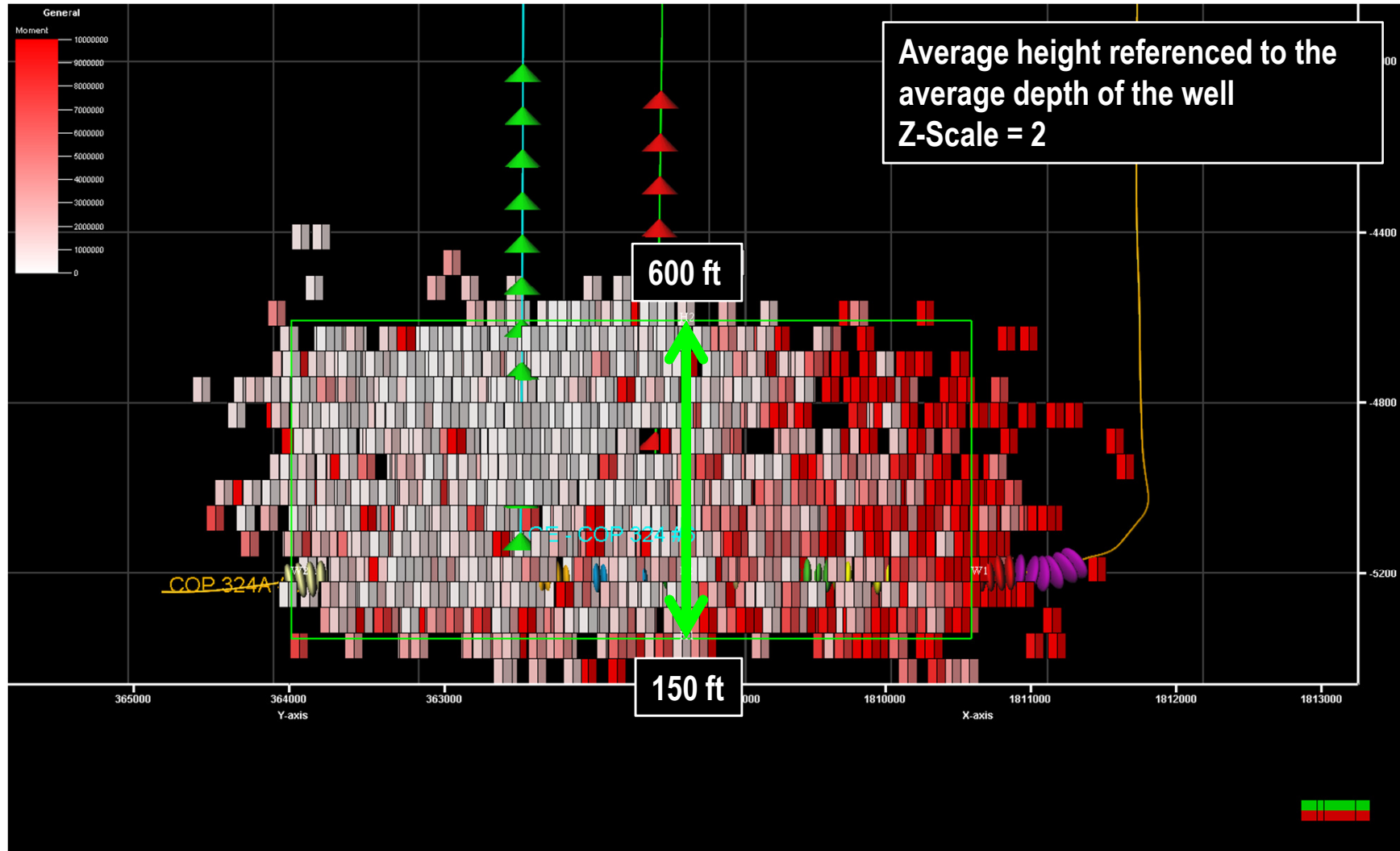
Average Extent of High Deformation



Microseismic Services
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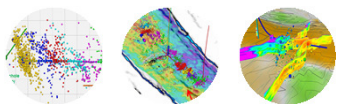
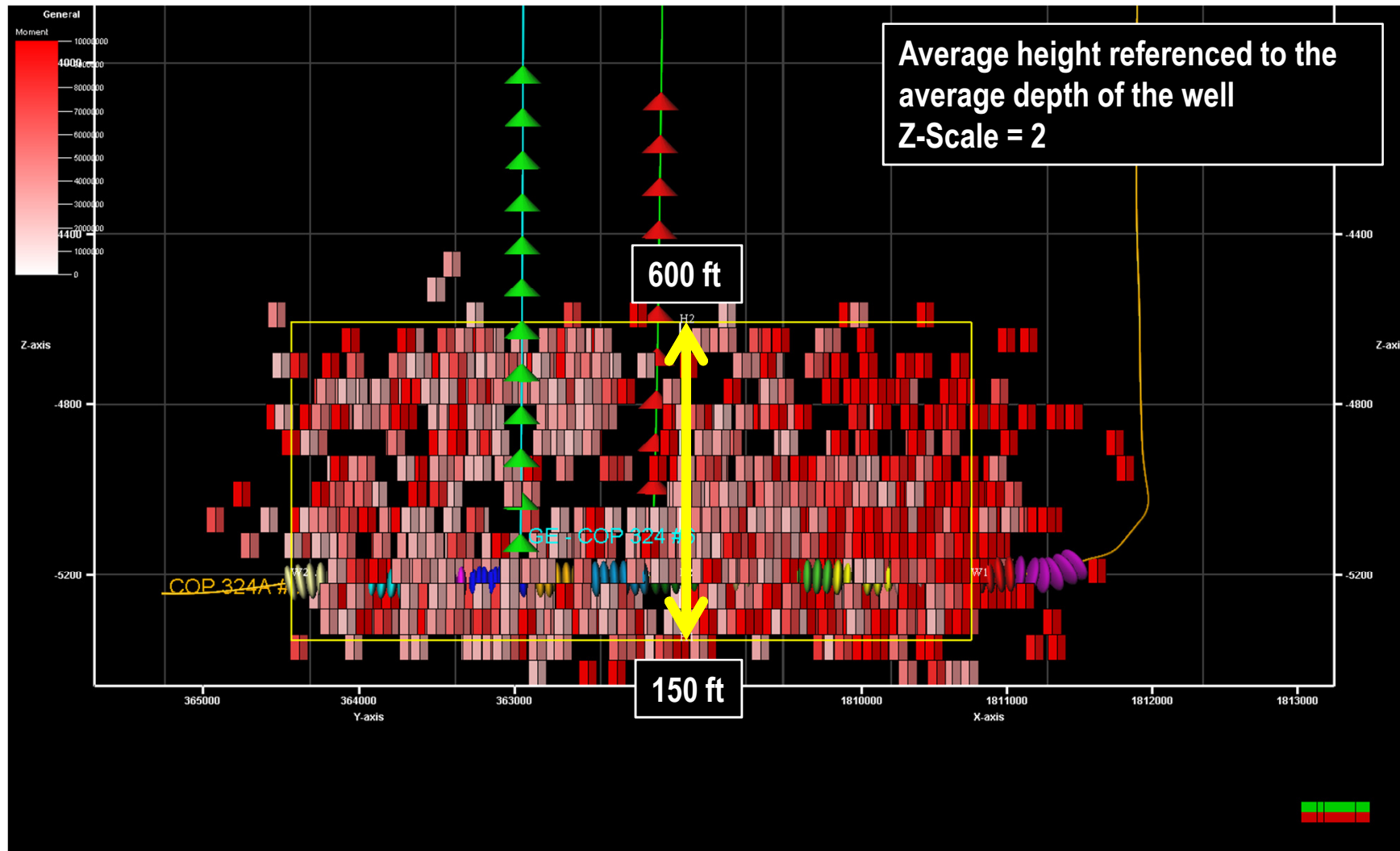
Average Maximum Extent of Microseismic Activity



Microseismic Services
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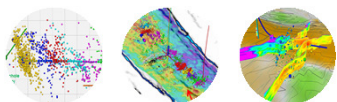
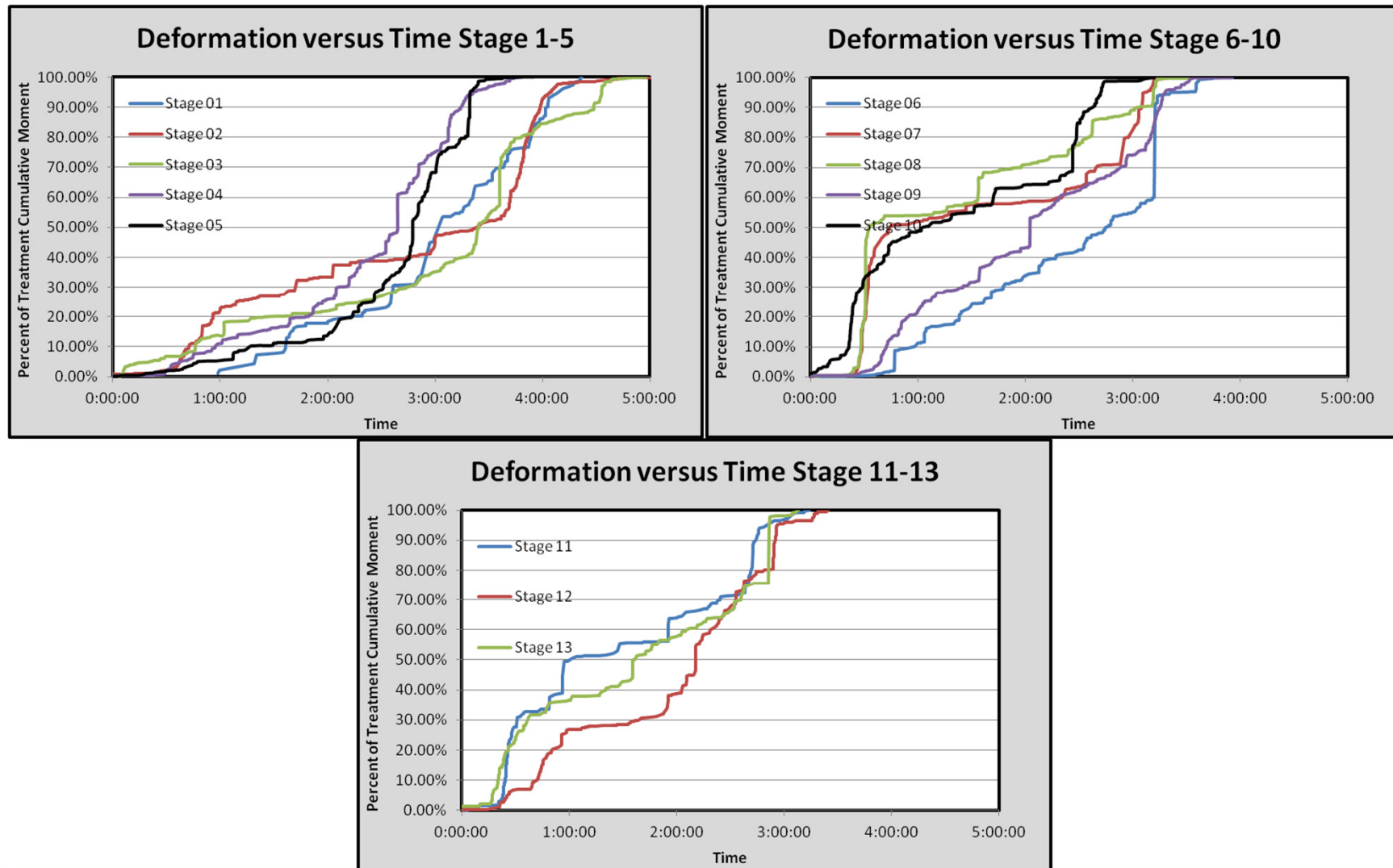
Average Extent of Highest Deformation



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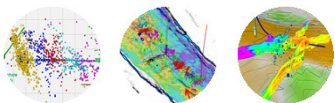
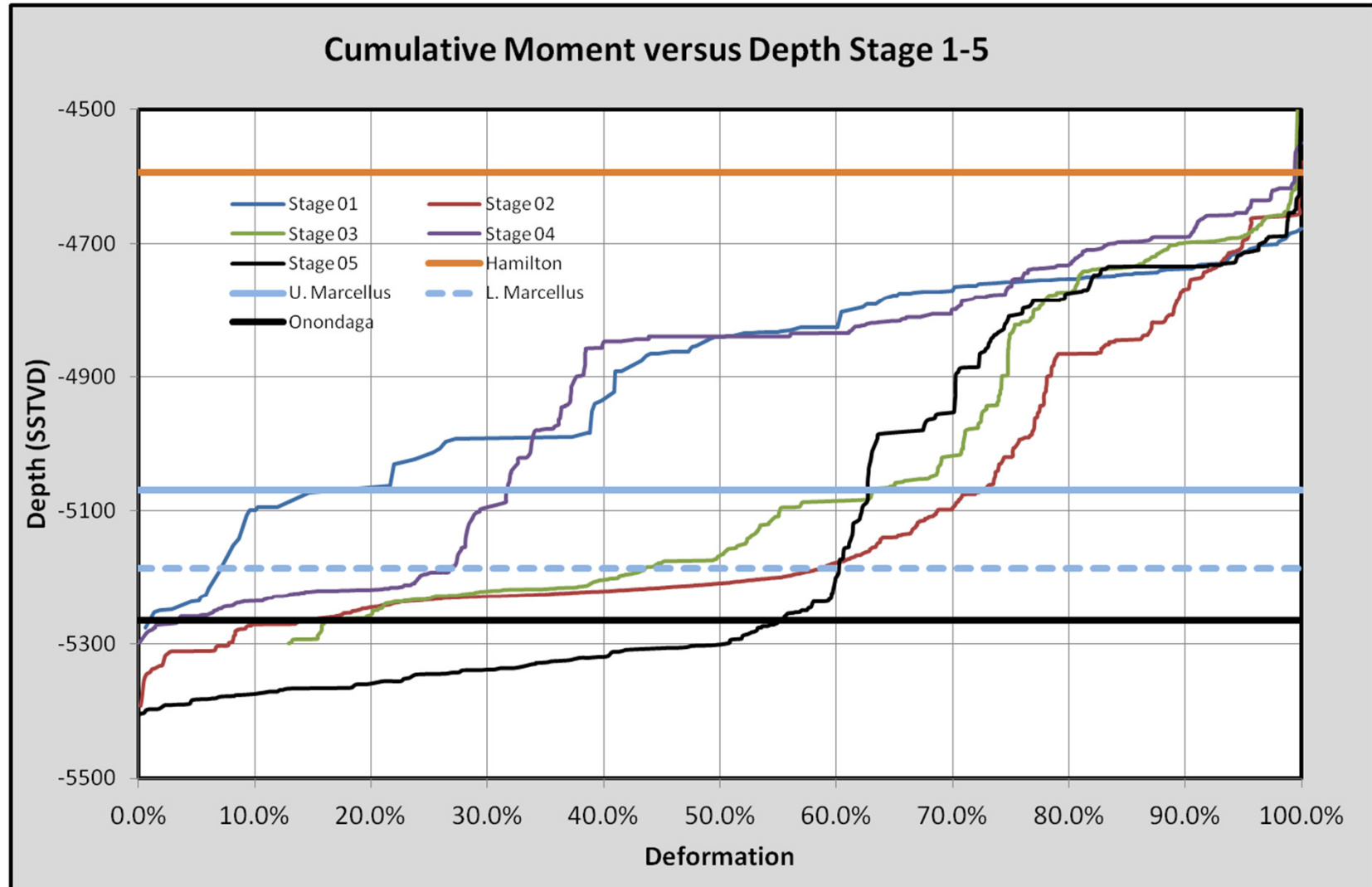
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Deformation versus Time



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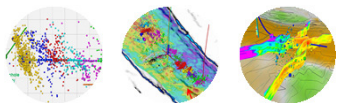
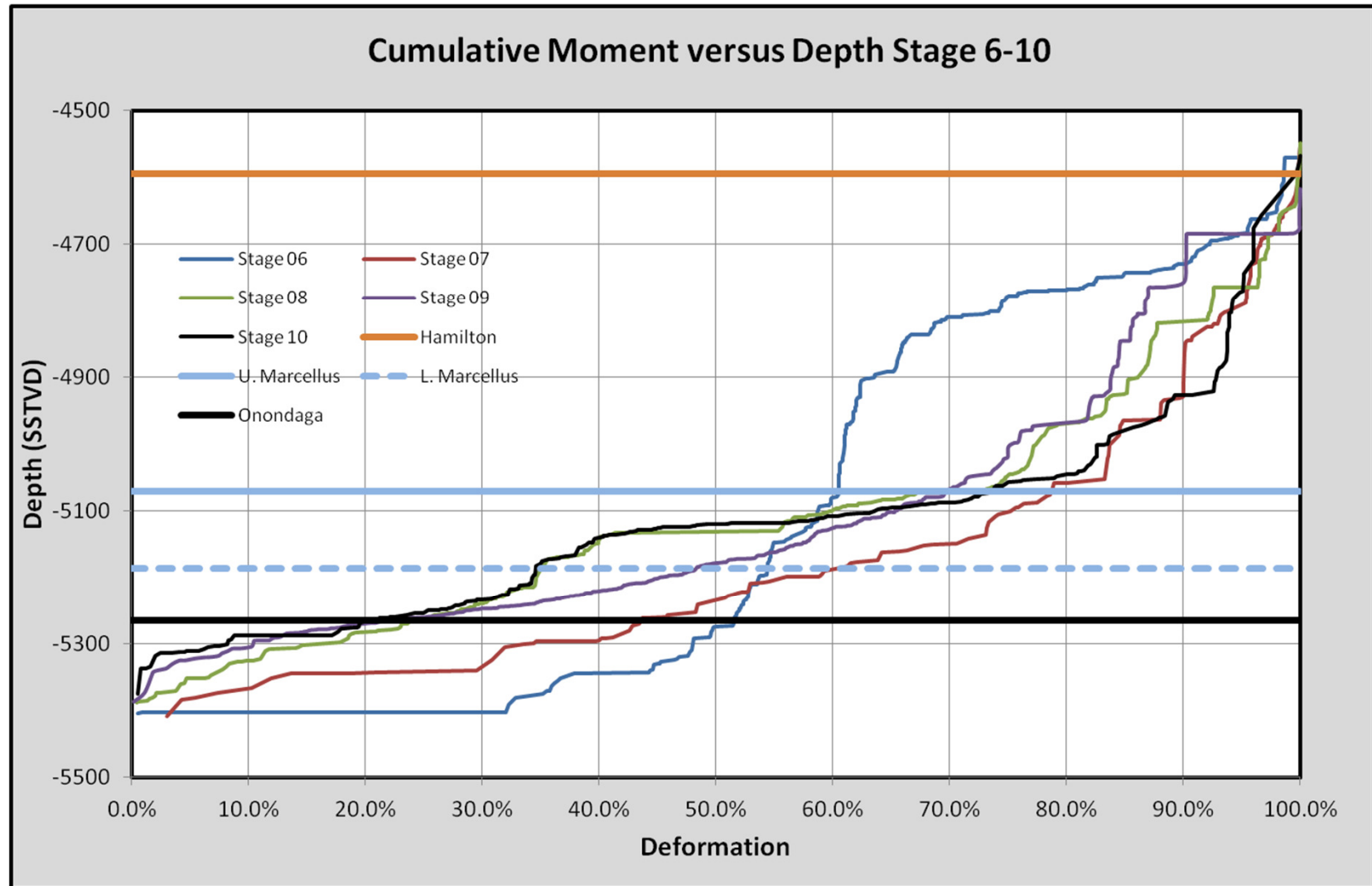
Cumulative Moment versus Depth Stage 1-5



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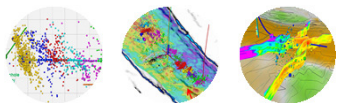
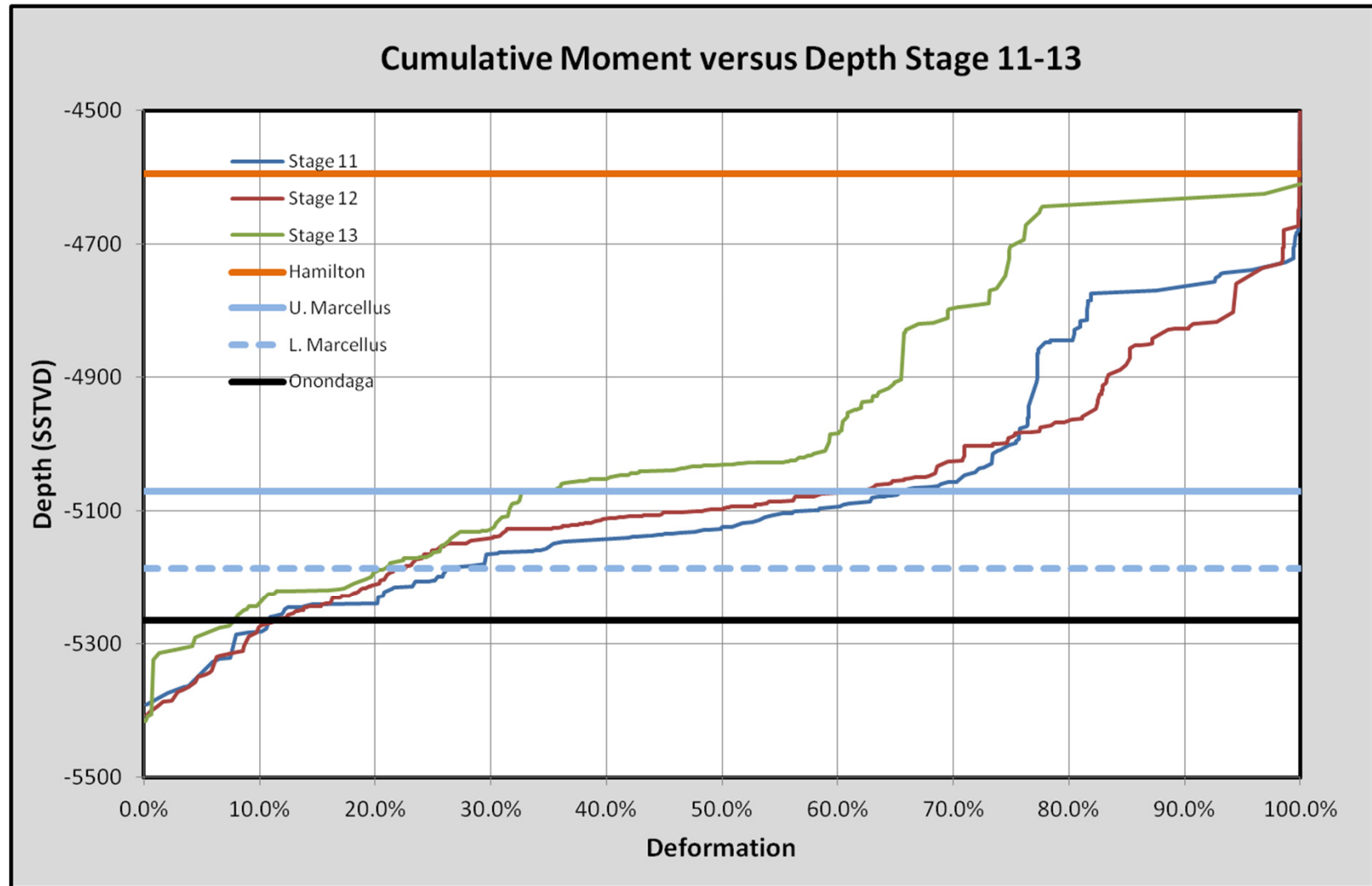
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Cumulative Moment versus Depth Stage 6-10

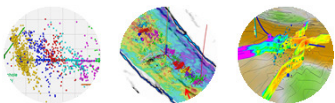


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Cumulative Moment versus Depth Stage 11-13



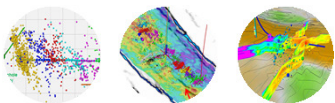
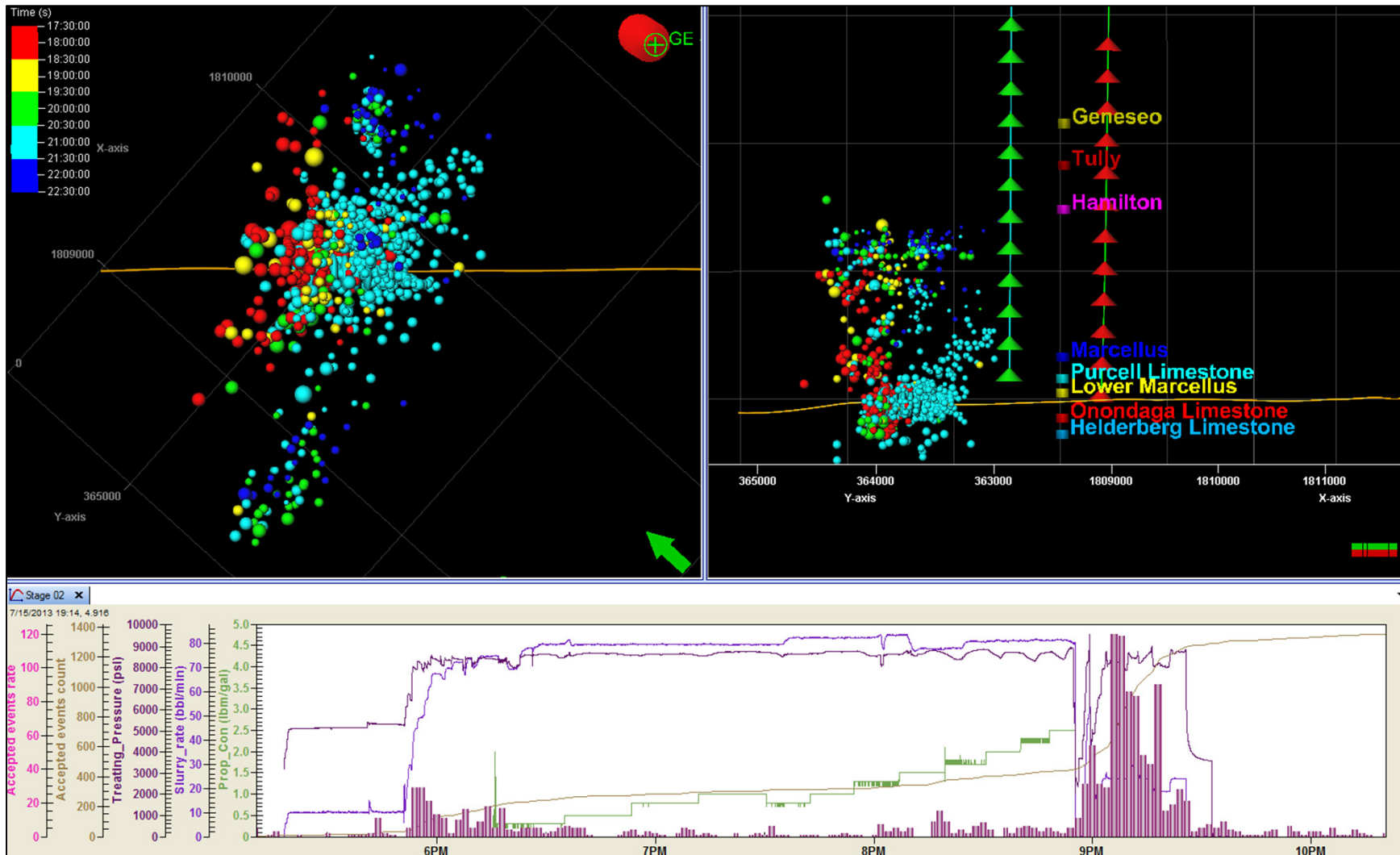
Time Dependent Behavior



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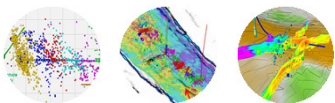
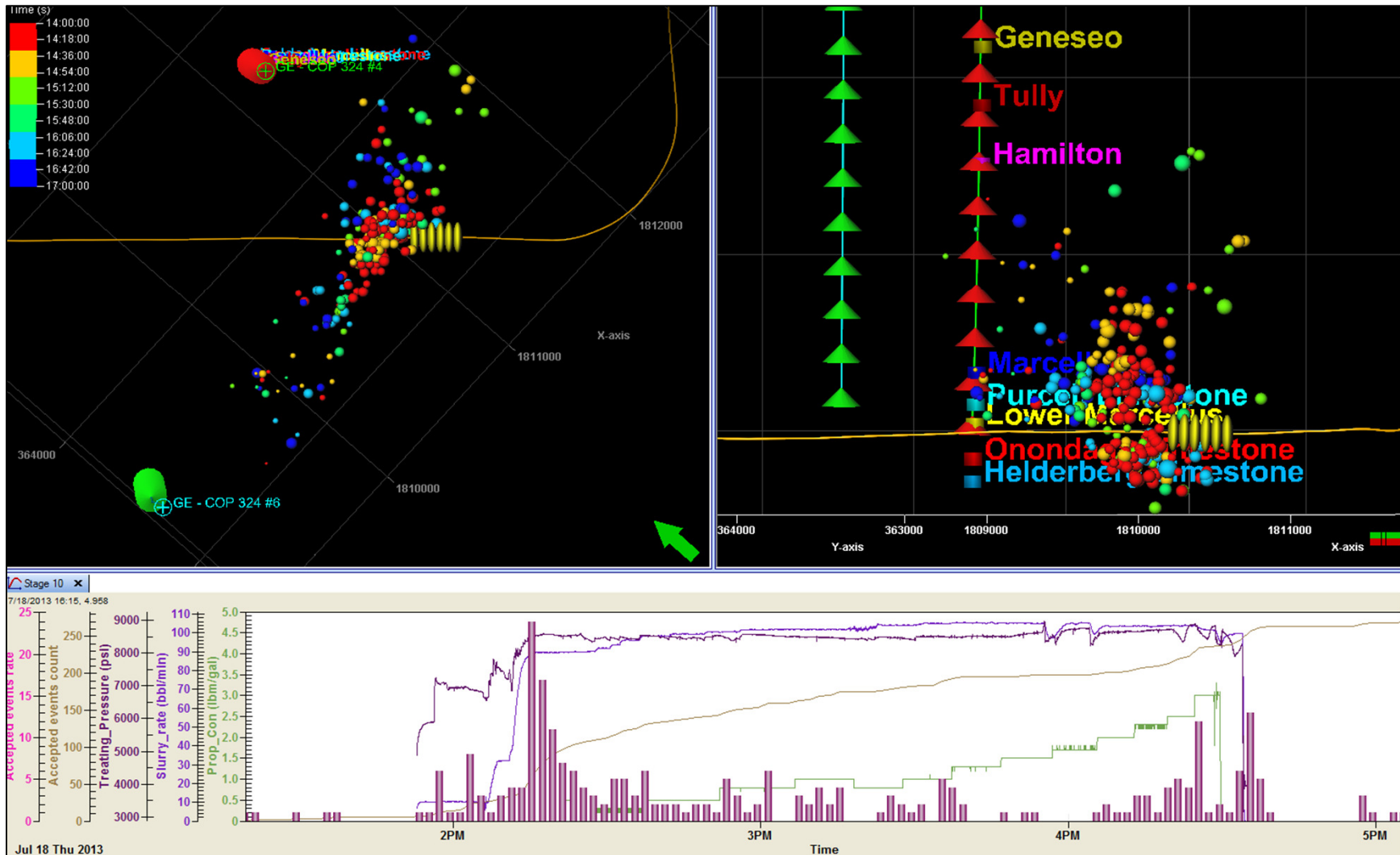
Time Dependent Behavior – Stage 2



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Time Dependent Behavior – Stage 10

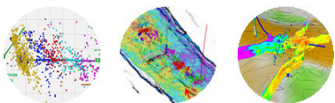


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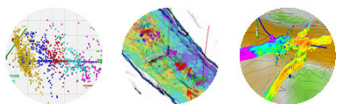
Conclusions

- Seismic moment based length calculation of 1,100 feet
 - Length estimate is less than 50% of the estimates obtained from the event locations
- Microseismic activity in the Hamilton increases when there is good containment against downward growth by the Onondaga
 - There is no corresponding increase in the observed fracture length in the Marcellus
- No observed trends between cumulative moment values and key treatment parameters

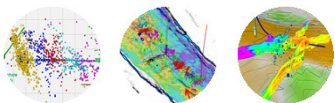
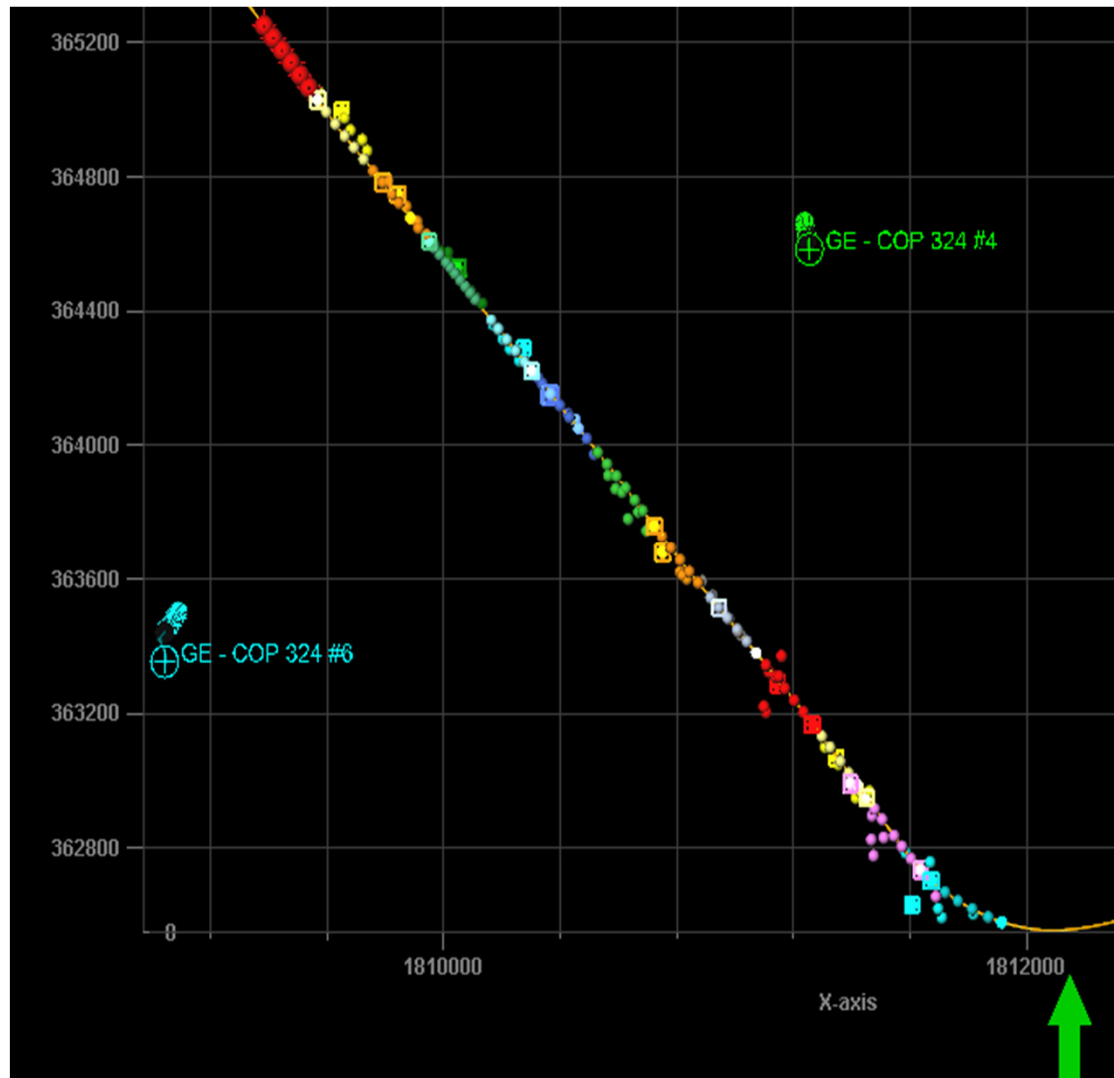


Recommendations

- A reduction in total fluid volume and modified proppant scheduling might be considered
- Initial wellhead pressure can be used to estimate induced stresses effecting fracture geometry

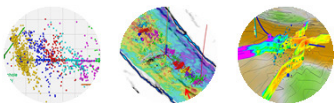
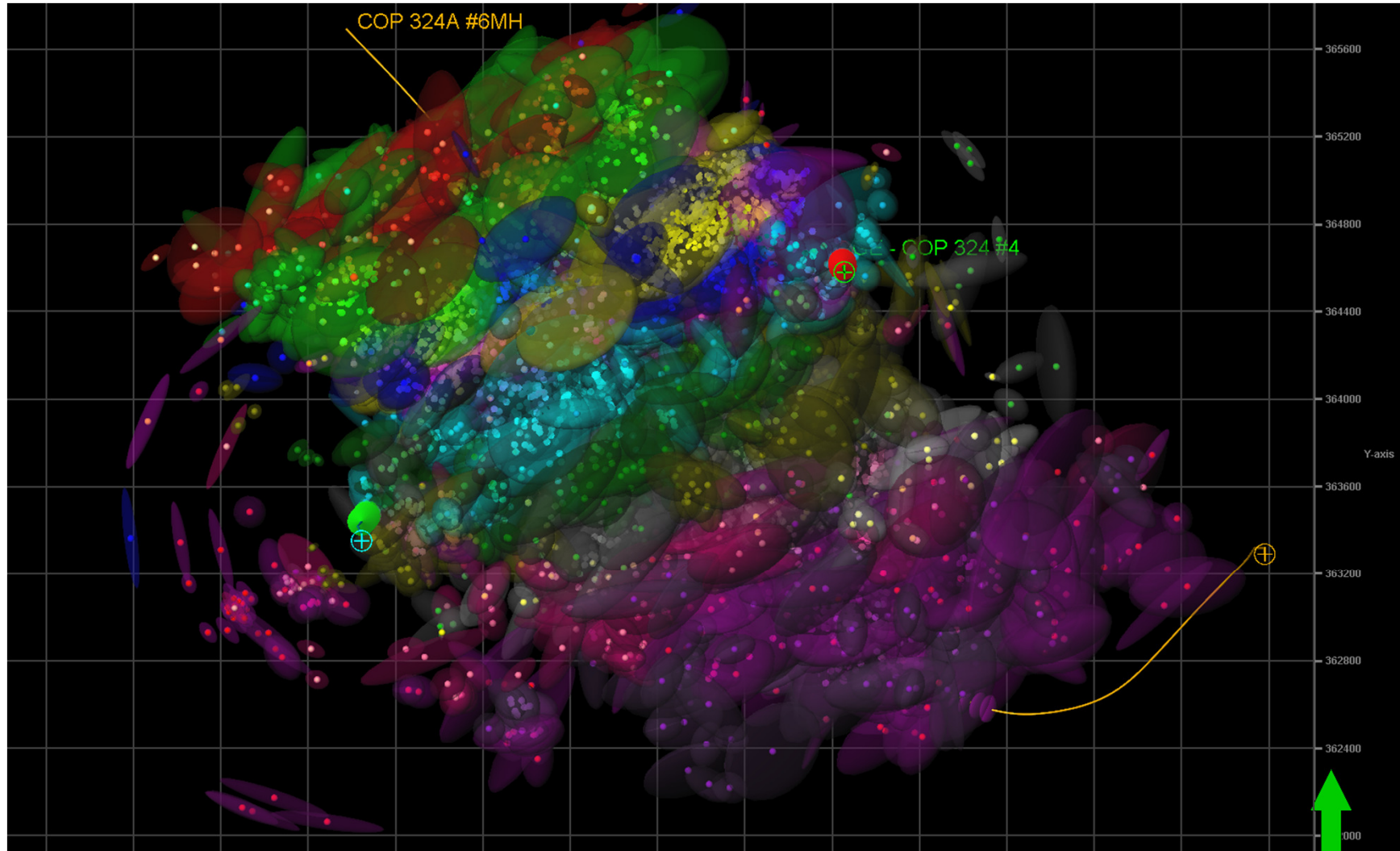


Calibration Shots



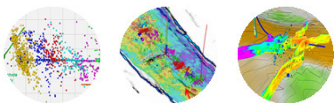
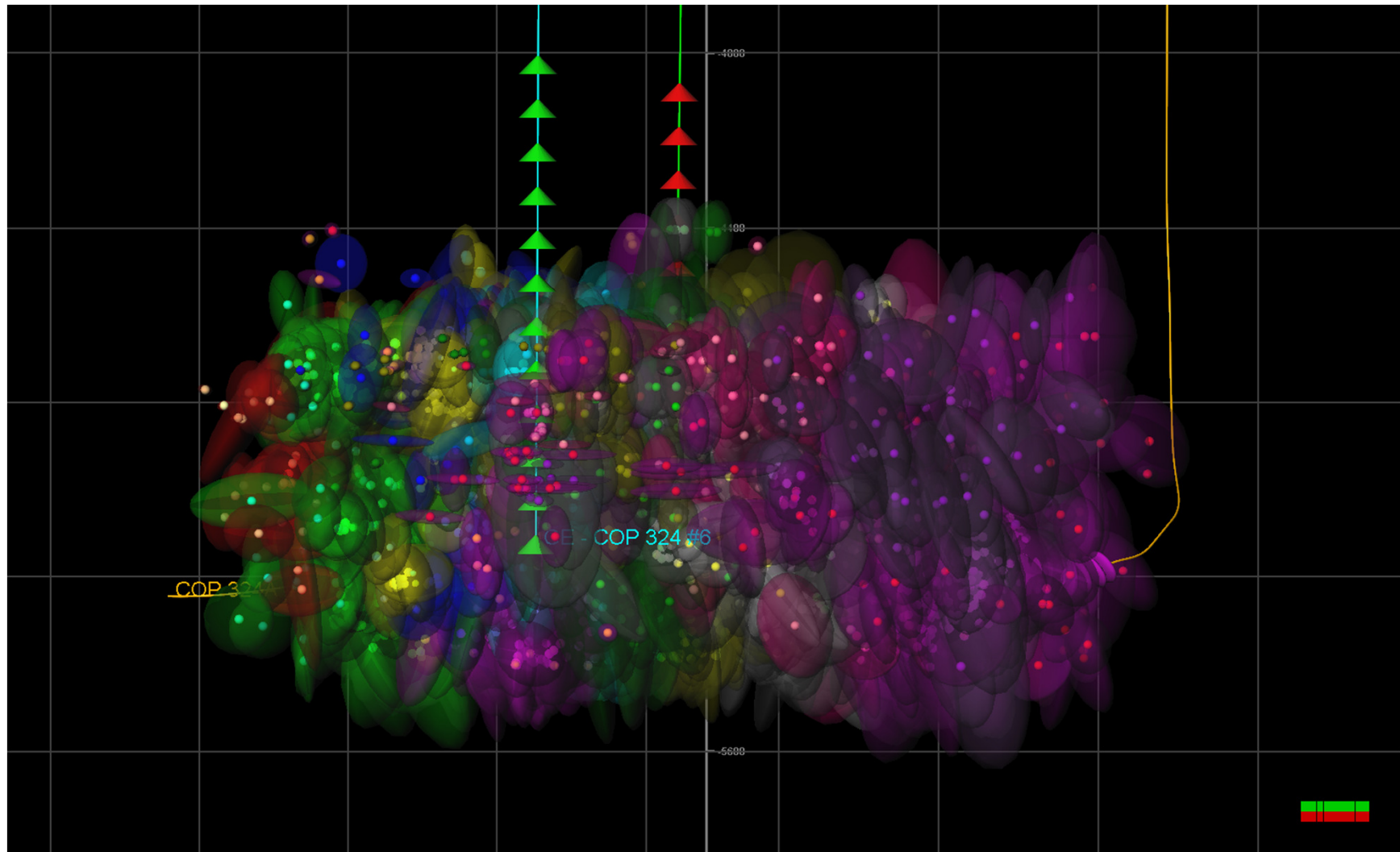
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Uncertainties, Map View, Unfiltered



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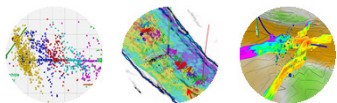
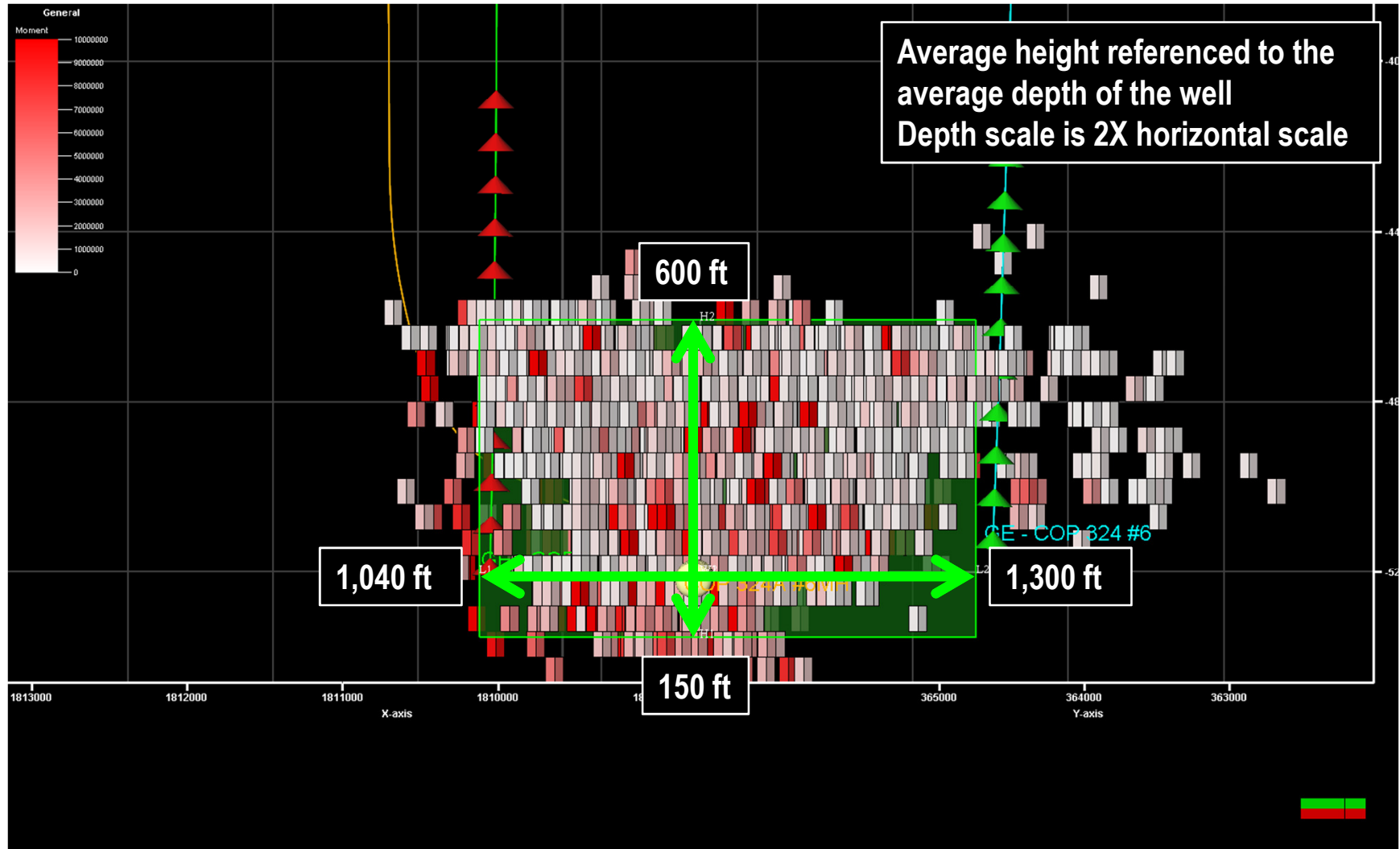
Uncertainties, Depth View, Unfiltered



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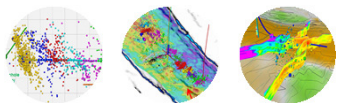
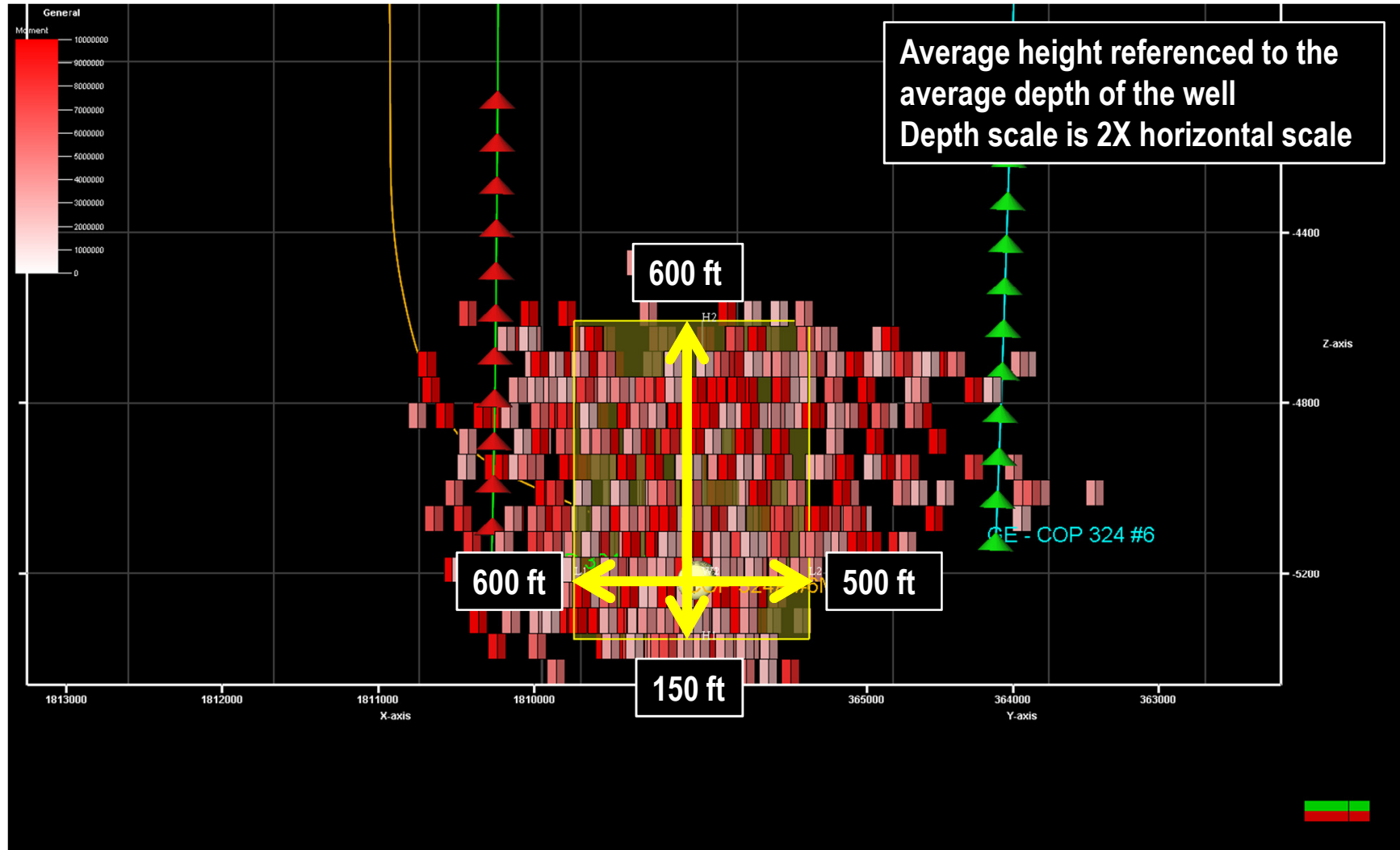
Average Maximum Extent of Microseismic Activity



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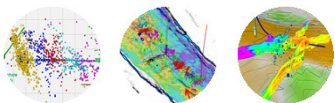
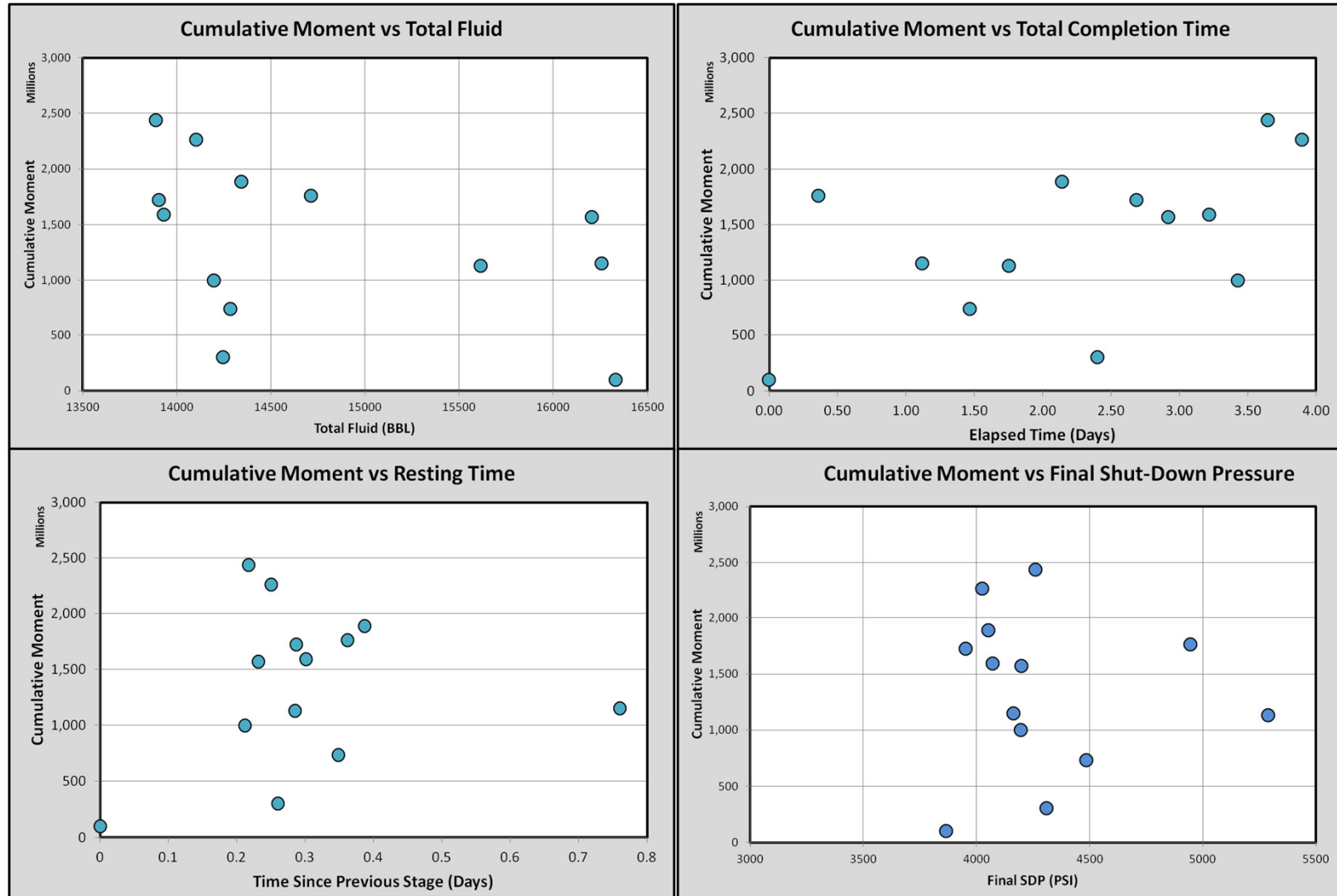
Average Extent of Highest Deformation



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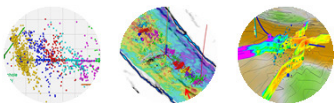
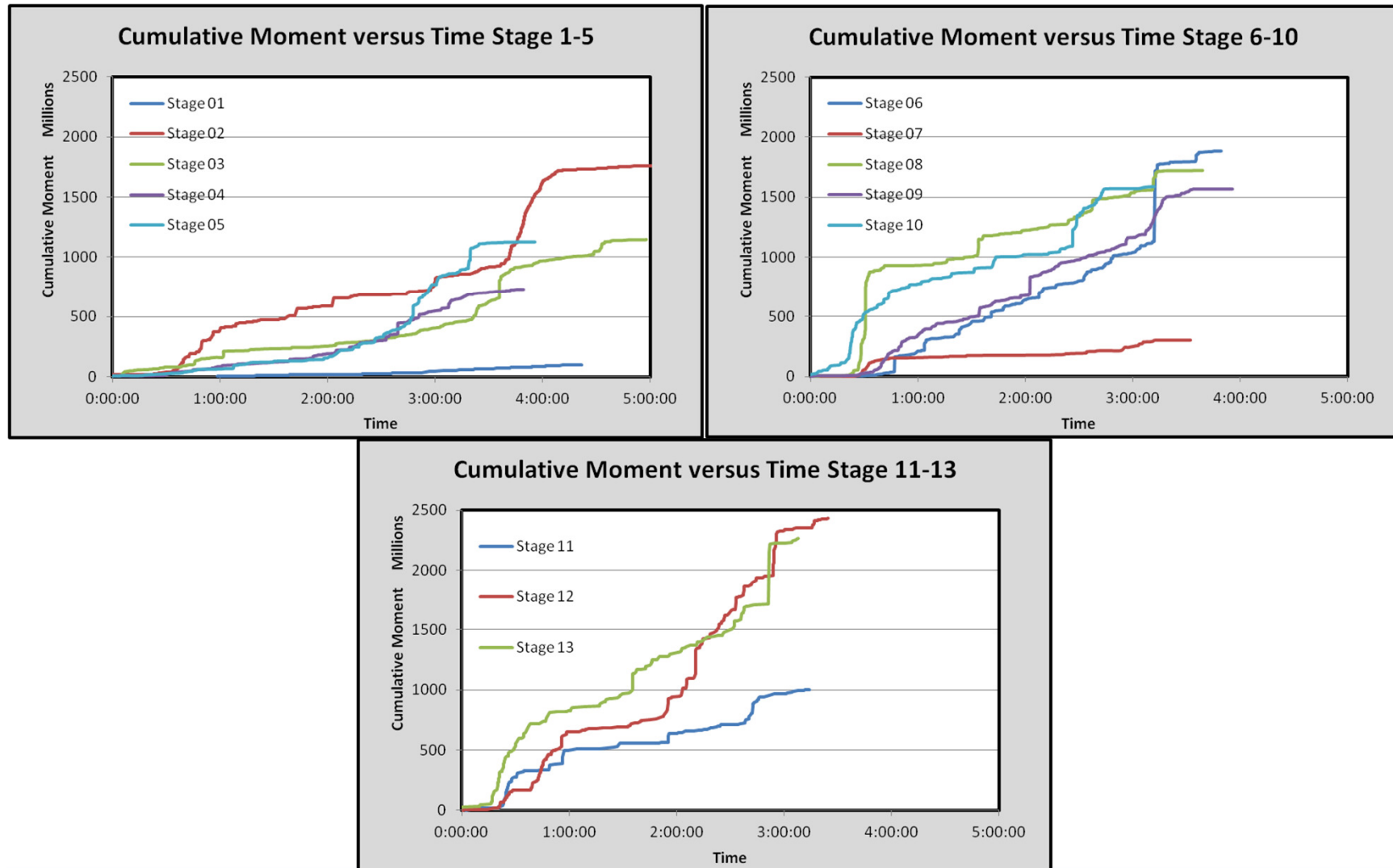
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Cumulative Moment Diagnostic Plots

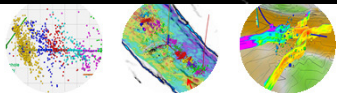
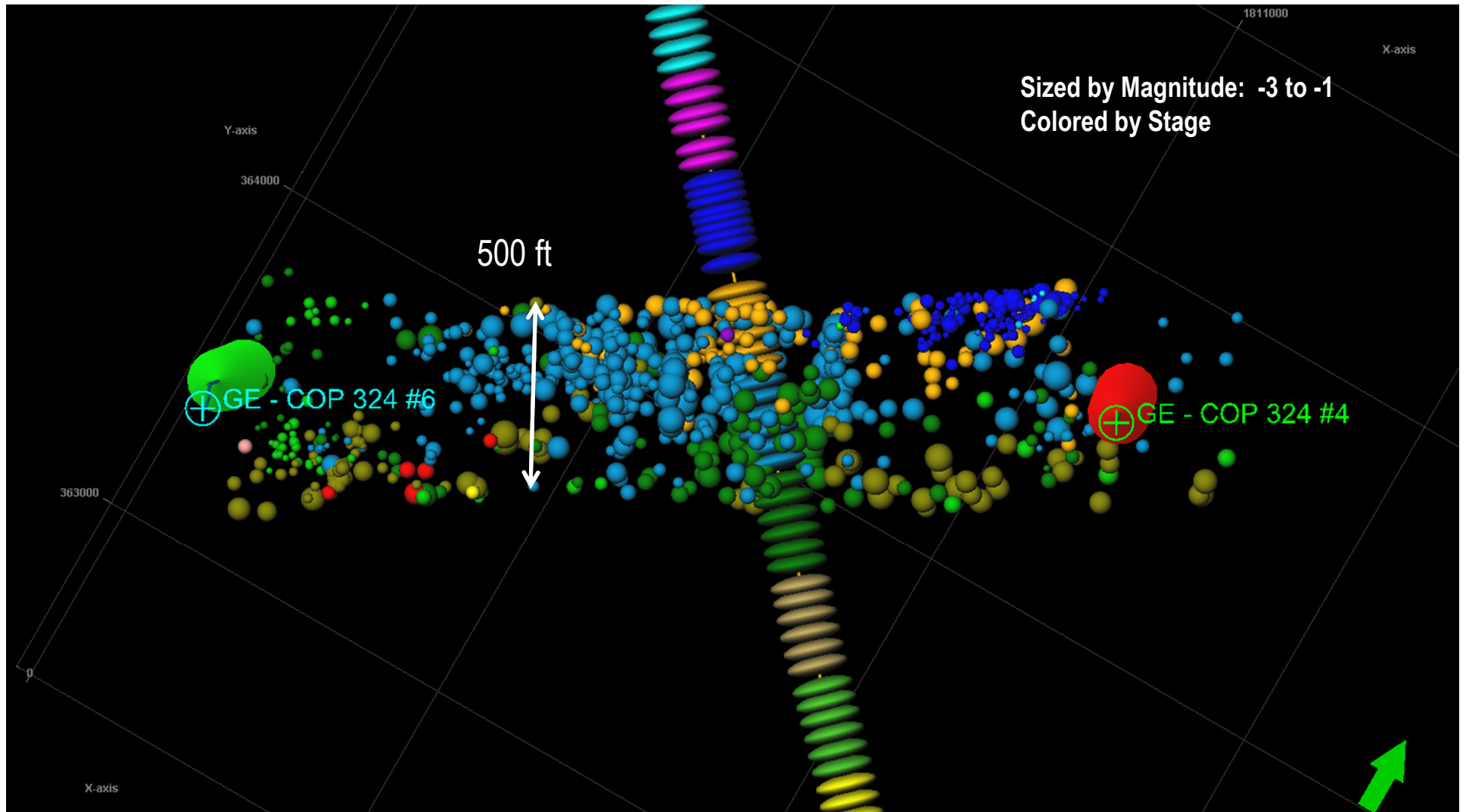


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Cumulative Moment versus Time

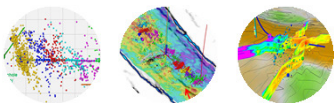
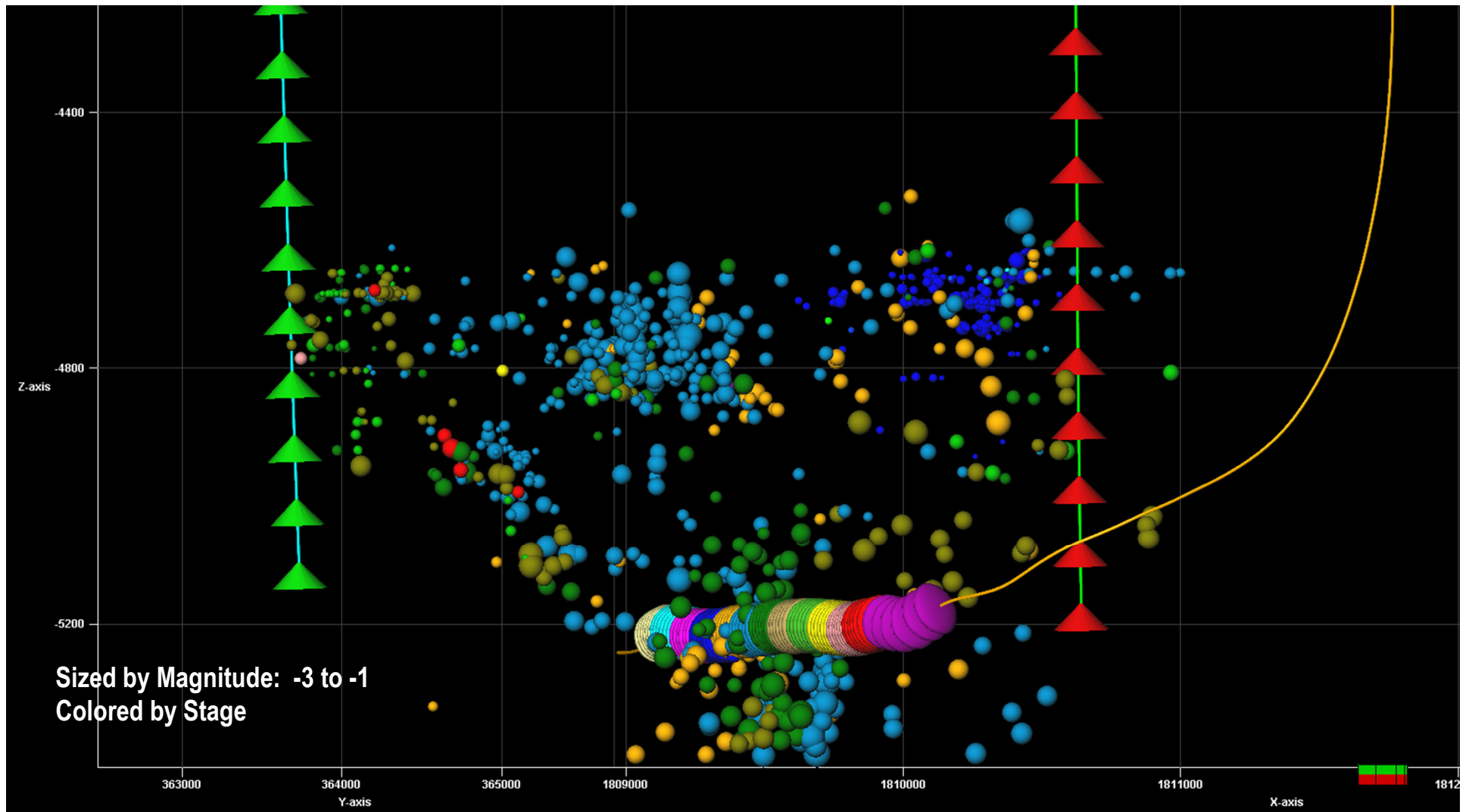


Map View of Cross Section



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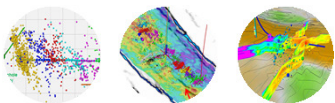
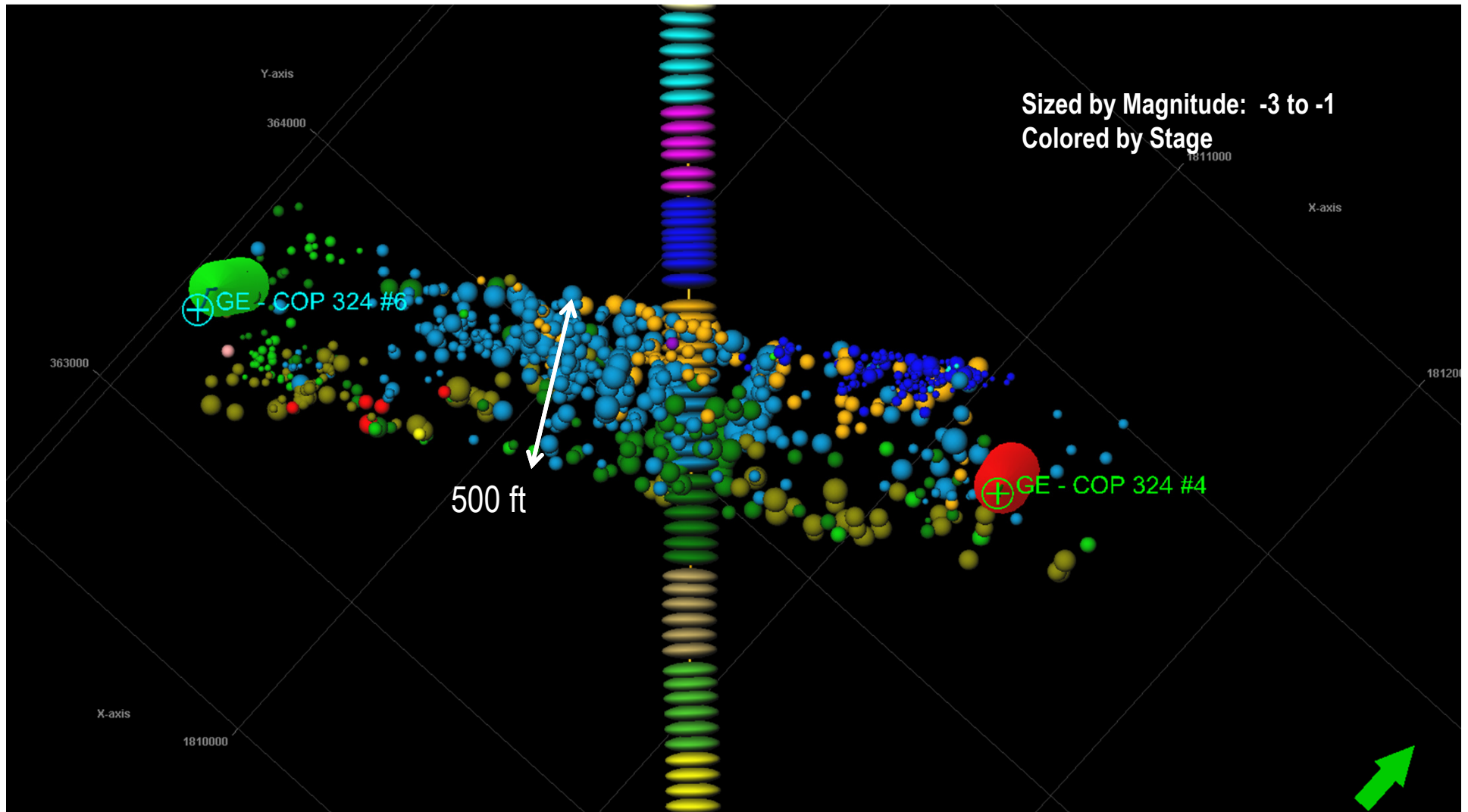
Rotated 90 Degrees “Crosswell View”



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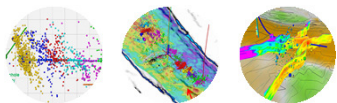
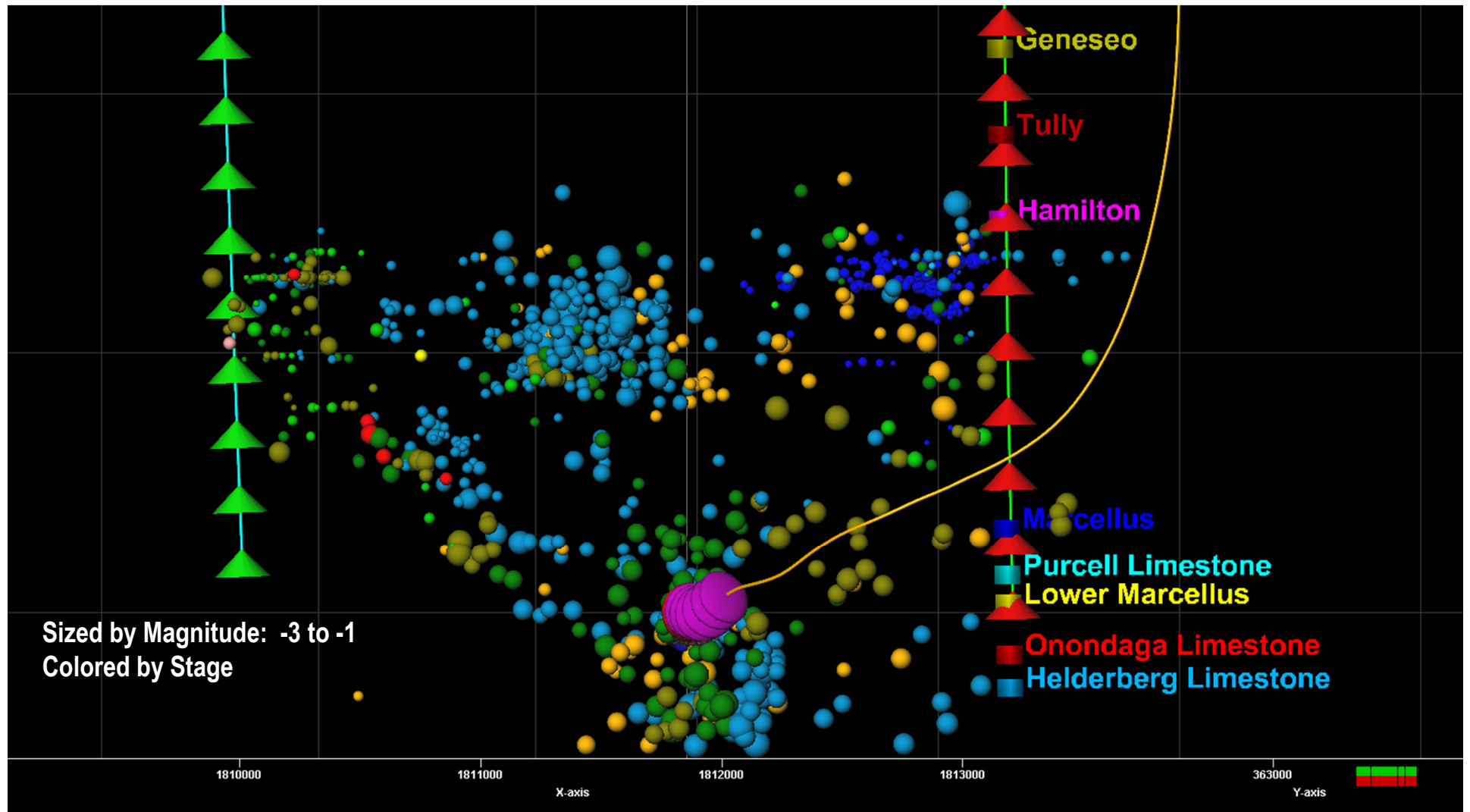
Map View of Cross Section



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Rotated 90 Degrees “Crosswell View”



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