[AV]Monitoring Steam-Induced Geomechanical Deformation Using Microseismicity and Tiltmeters*

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Abstract

Optimizing steam injections is an important factor in enhanced recovery in heavy oil reservoirs, as well as other EOR injections. Steam injection results in significant geomechanical changes, including pore pressures, thermal stresses and expansion, and significant constitutive property changes. These changes result in deformation that can be used to track the steam migration. Surface uplift associated with the steam movement can be used to image the underground strains associated with the injection. The presence of microearthquake or microseisms can also be used to infer that fracture movement and resulting permeability enhancements play a role in steam movement. Together the surface and seismic deformations can be used to assess the geomechanical state of the rockmass and potentially validate the results of a reservoir flow simulator linked with a geomechanical model.

Here a case study is presented demonstrating the use of microseismicity and surface movements recorded during the warm-up steam injection in a SAGD well pair. Microseismic sensors were placed in an abandoned vertical well slightly offset from the SAGD wells, and a surface tiltmeter array was also installed. Tiltmeter data was inverted for the reservoir strain associated with the steam injection and compared with the microseismic data. The relative timing of the surface and seismic deformations were also examined to assess the significance of induced fracturing as a mechanism for steam migration. The computed reservoir strain was also used to calculate induced stress changes and to predict the geomechanical shear failure state. The associated estimated regions of shear failure were compared with the microseismic event hypocenters.

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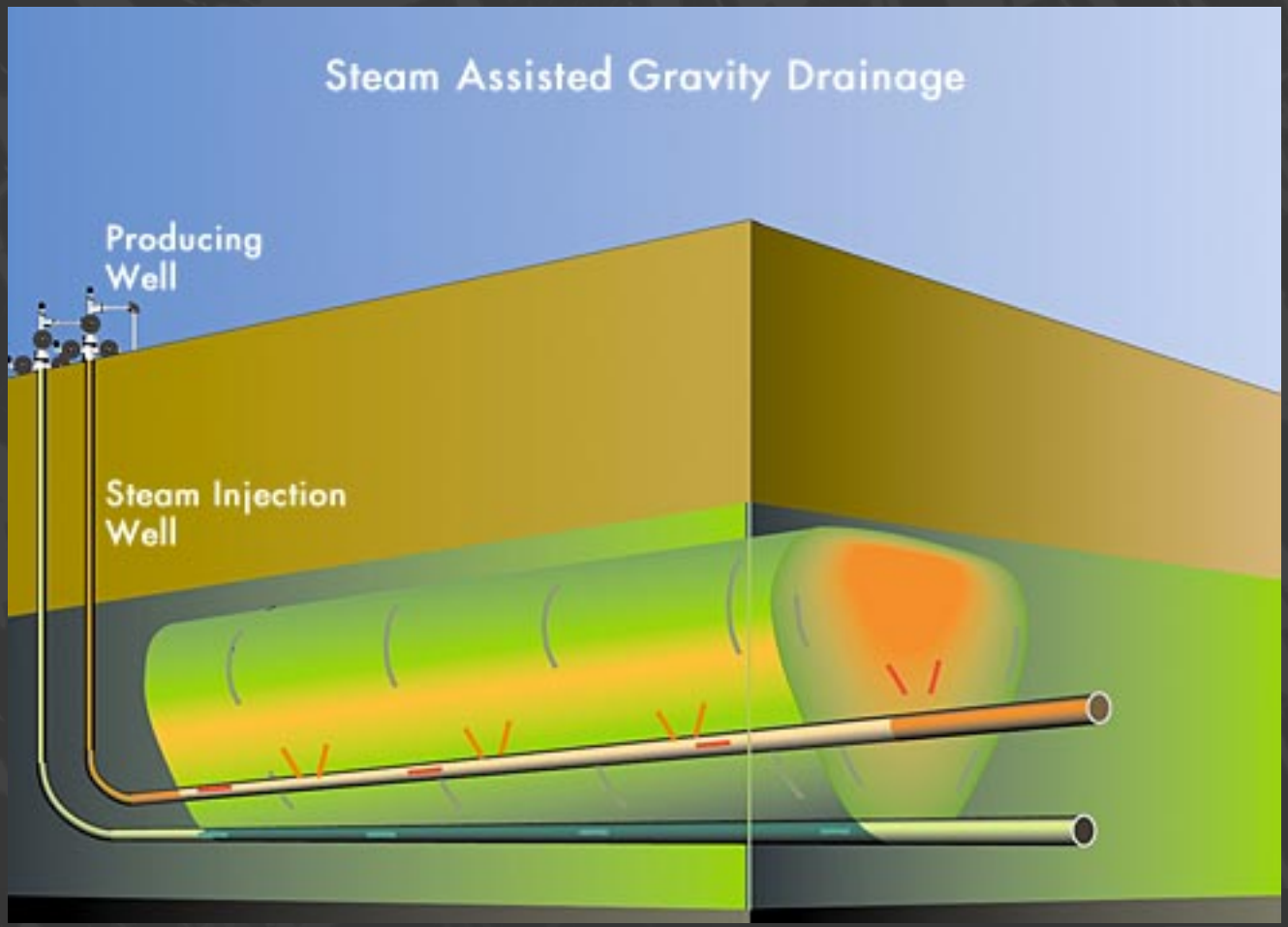
Steam Assisted Gravity Drainage (SAGD)



Courtesy EnCana

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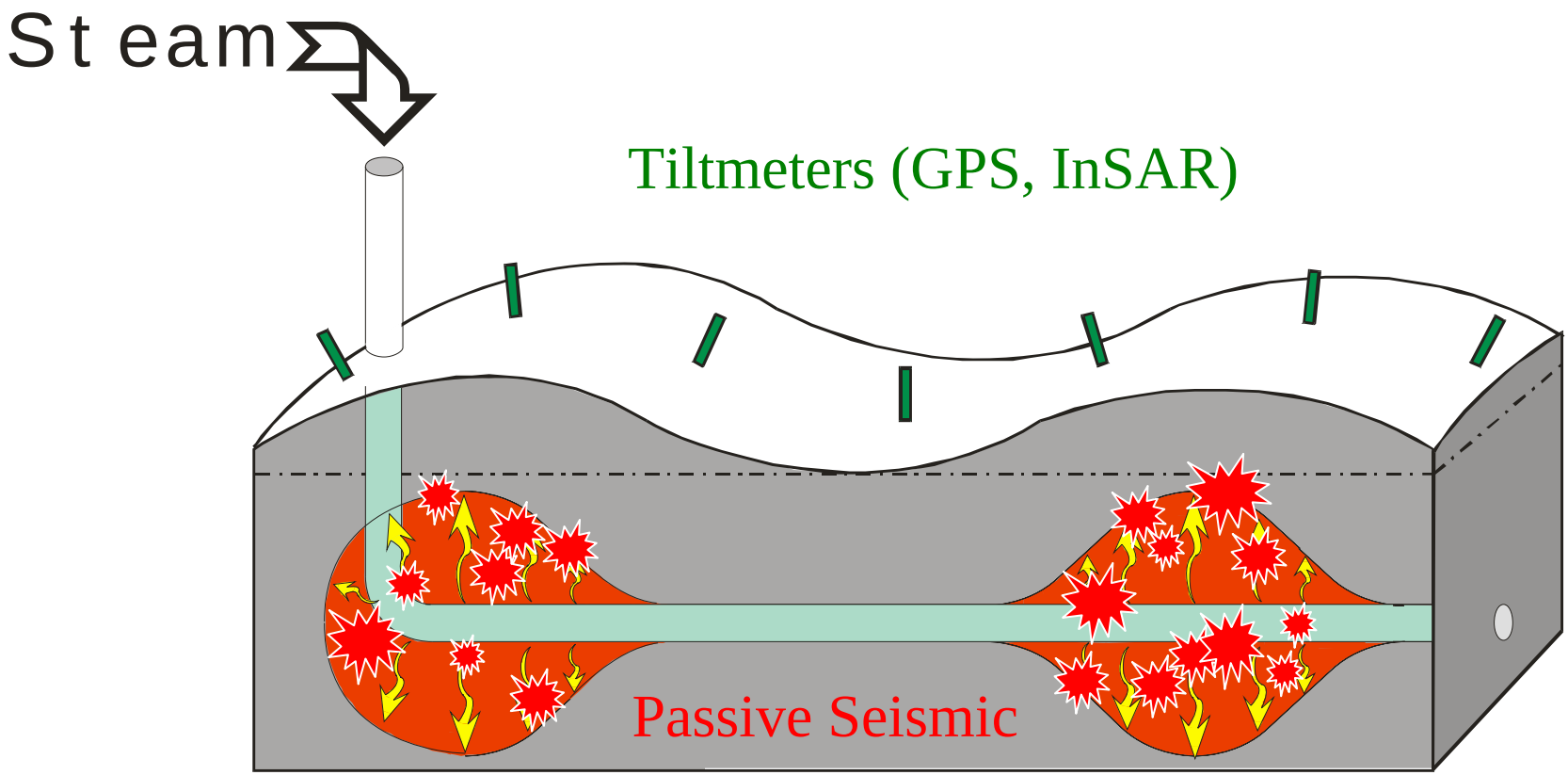
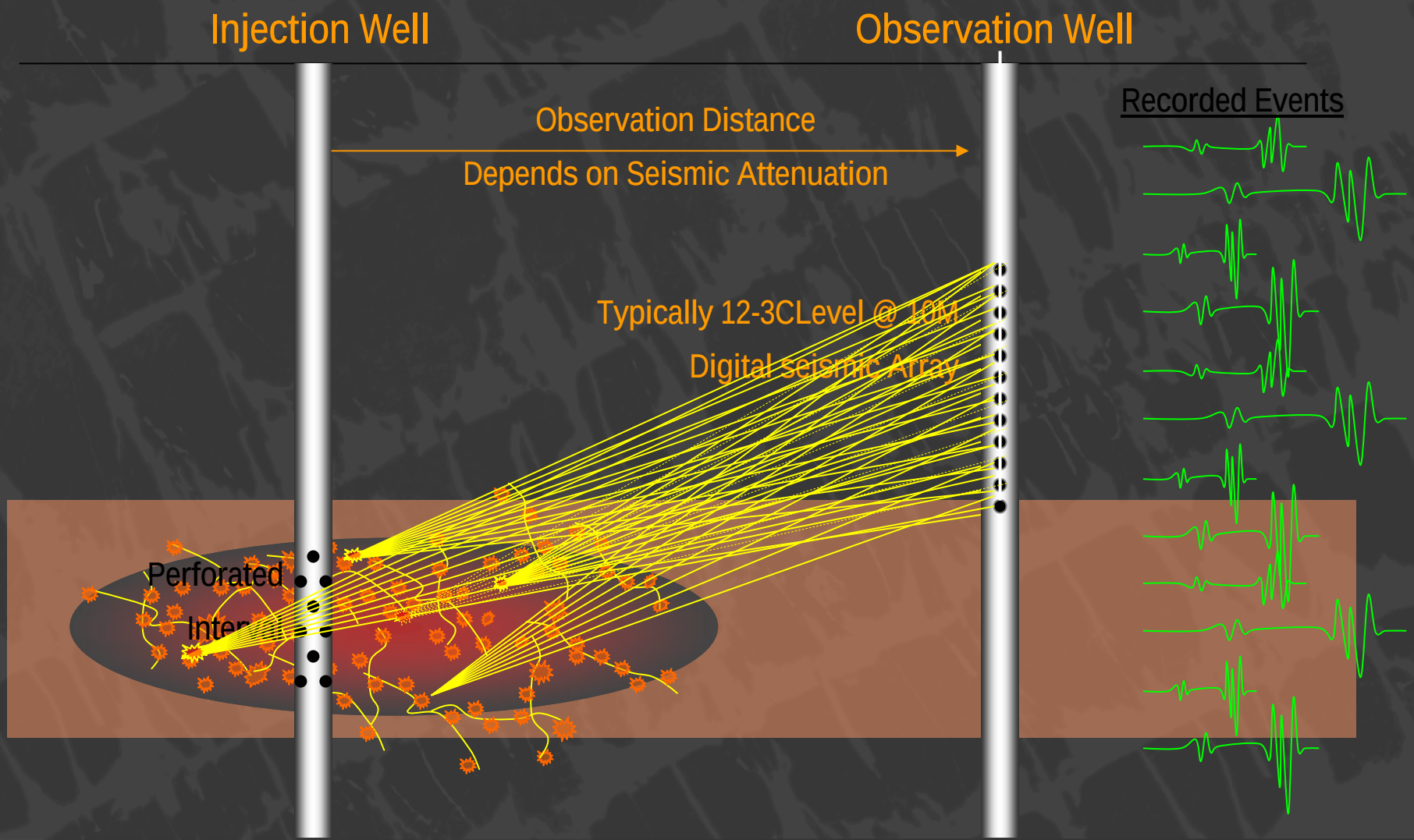
Monitoring Deformation



Principal of Microseismic Mapping



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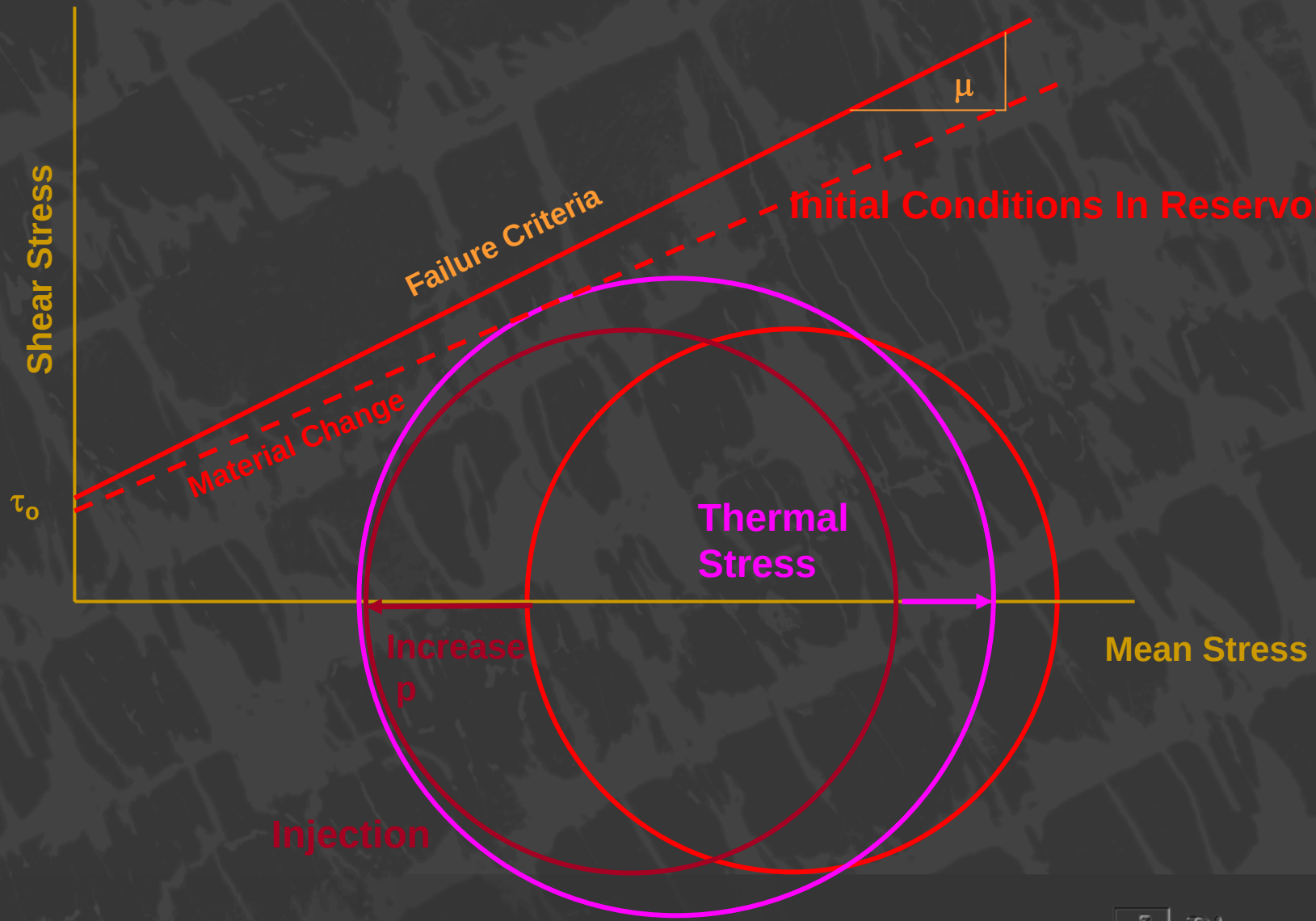
Steam-Injection Induced Shear Failure



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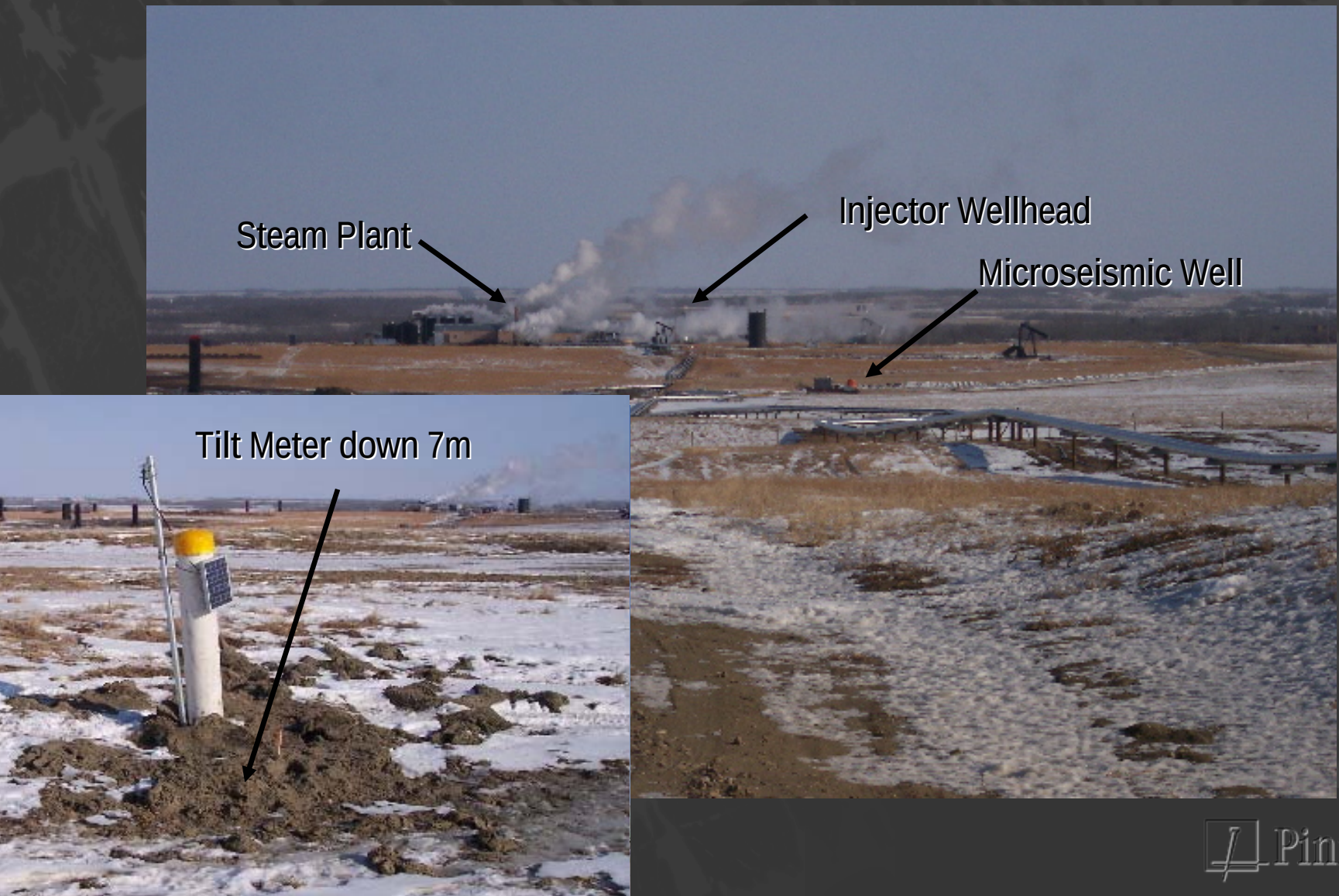
SAGD Injection



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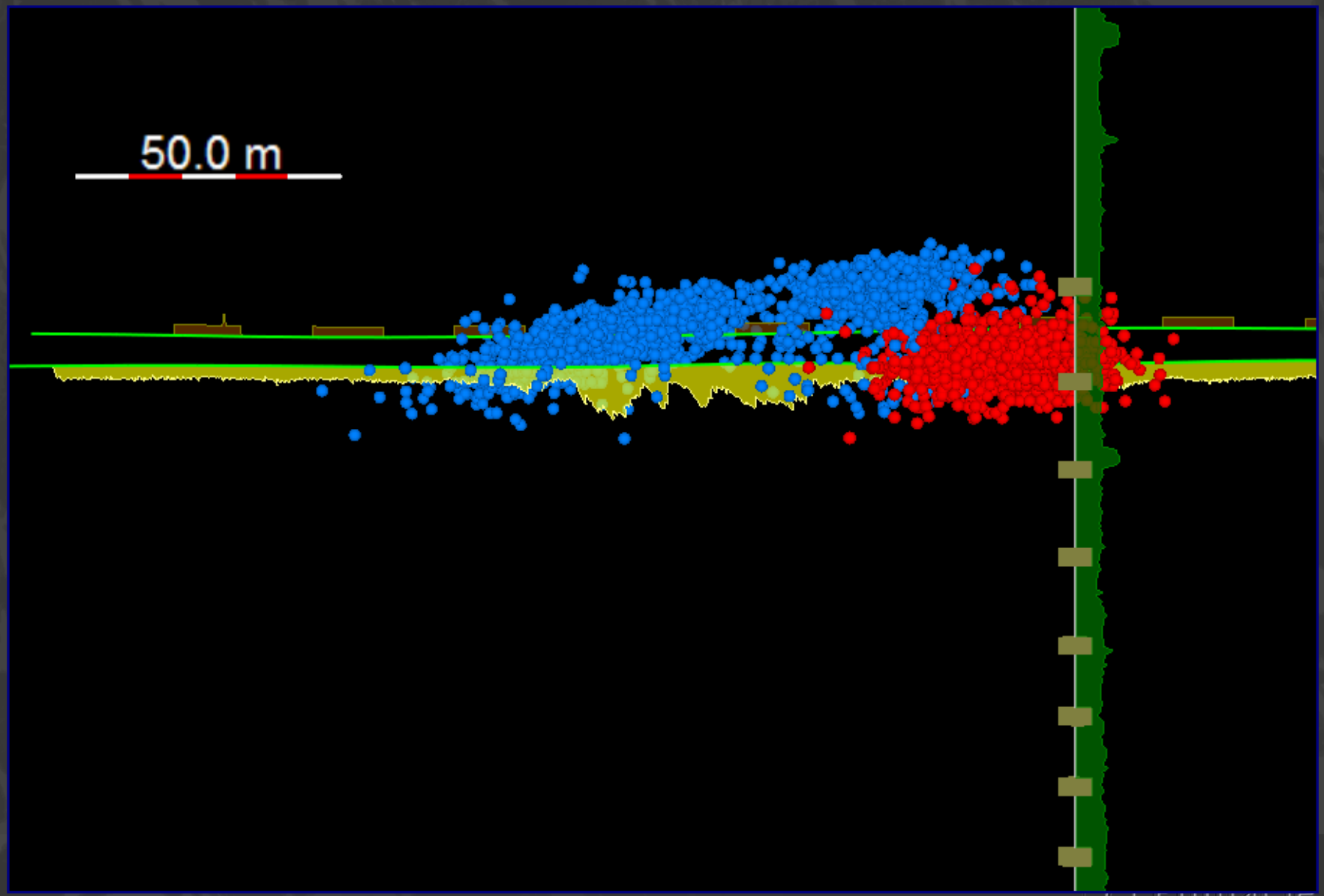
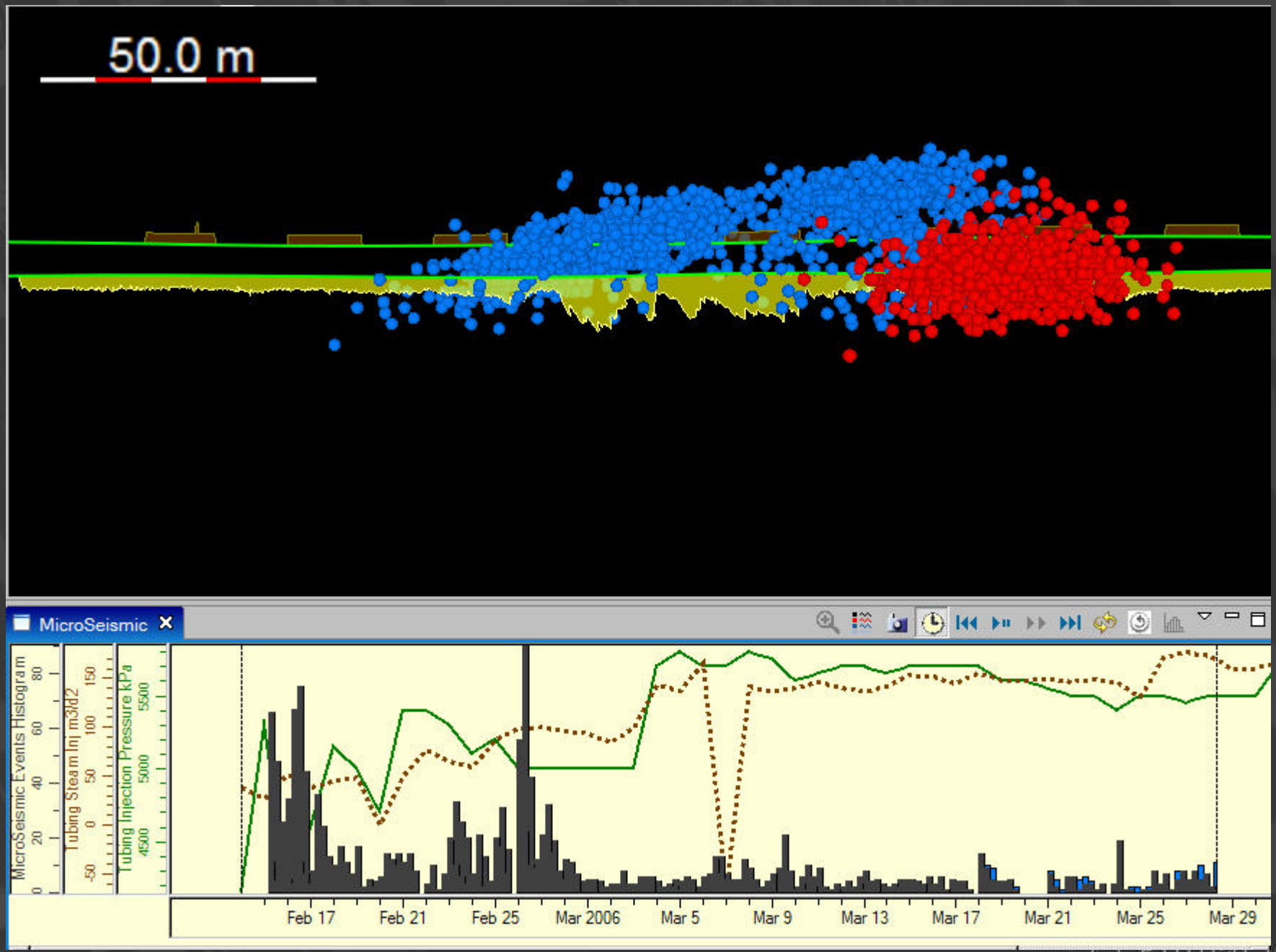
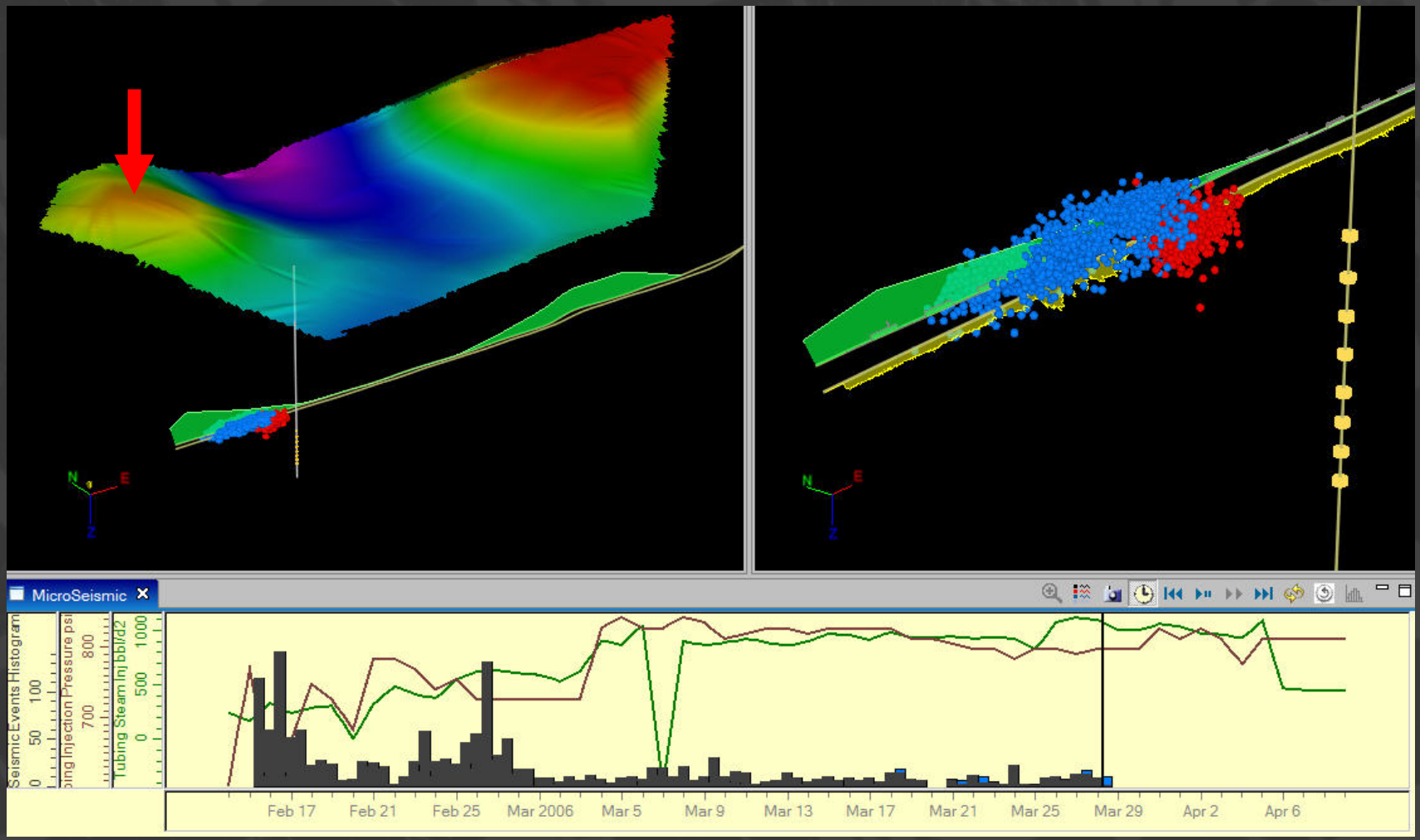
Microseismic Image of SAGD




50.0 m
MicroSeismic
MicroSeismic Events Histogram
Tubing Steam Inj m3/d2
Tubing Injection Pressure kPa
Feb 17
Feb 21
Feb 25
Mar 2006
Mar 5
Mar 9
Mar 13
Mar 17
Mar 21
Mar 25
Mar 29

Integrated Strain-Microseismic



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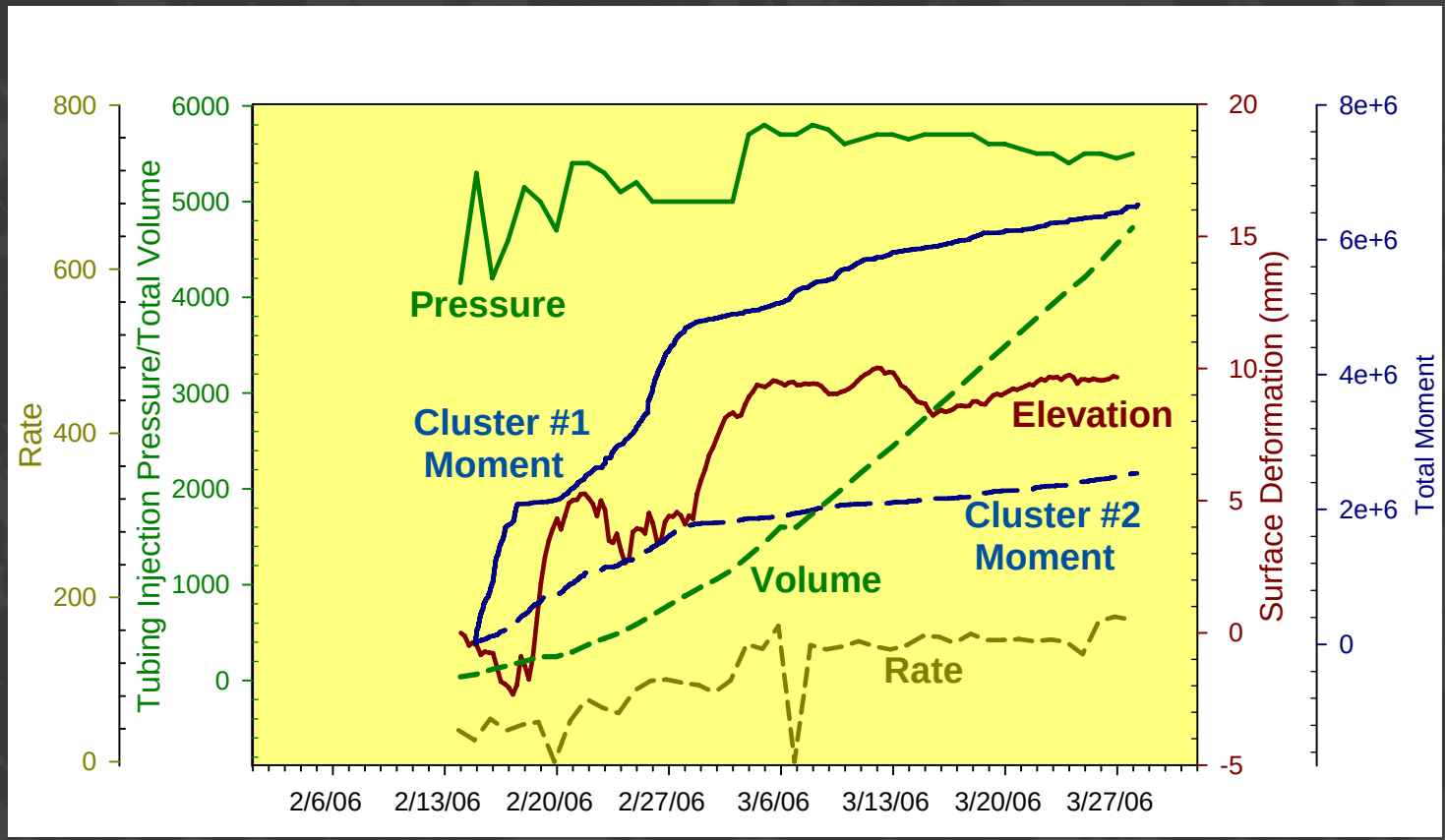
Geomechanical Deformation



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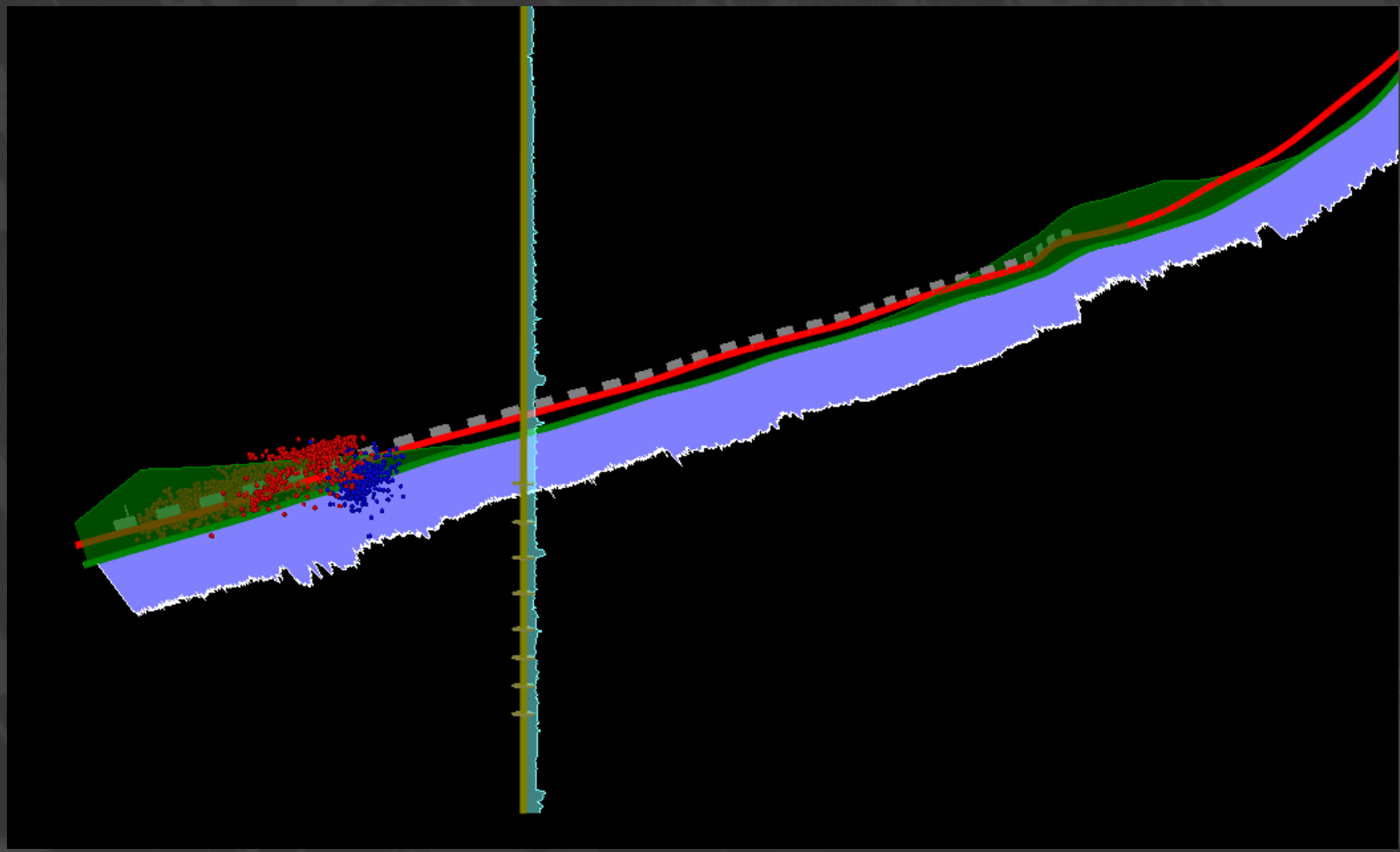
Reservoir Heterogeneity



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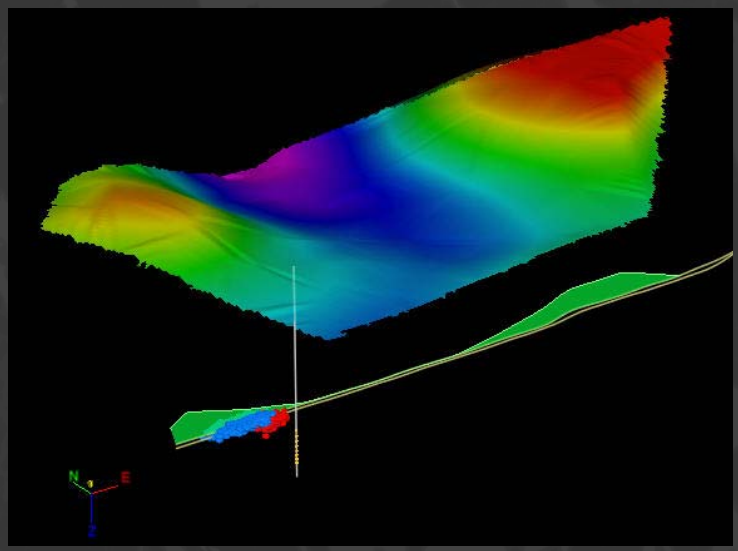
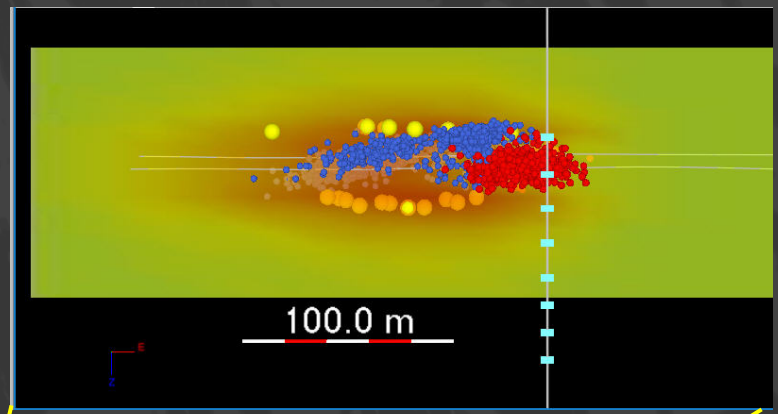
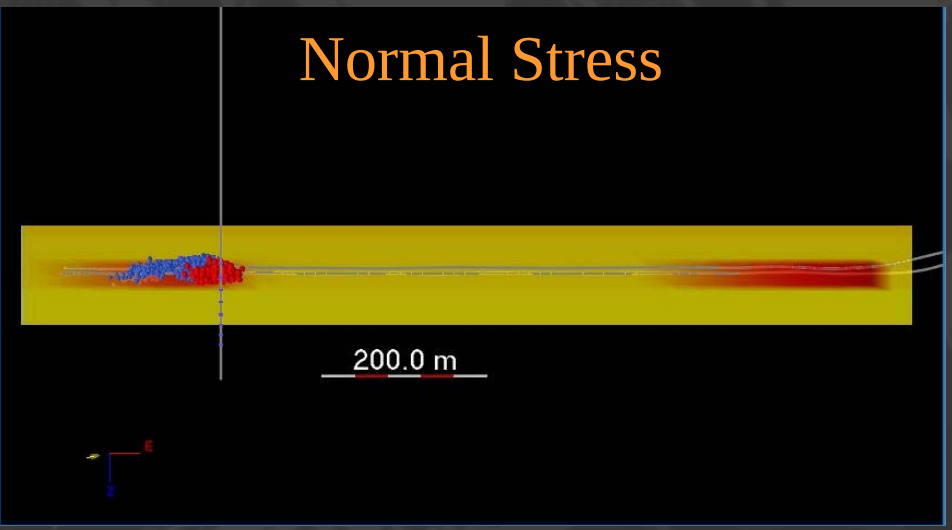
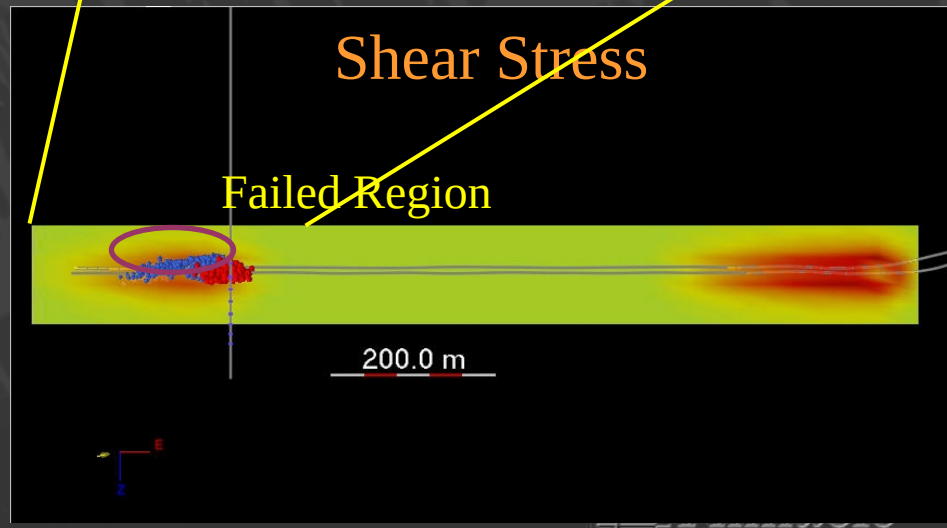
Computed Stress Changes

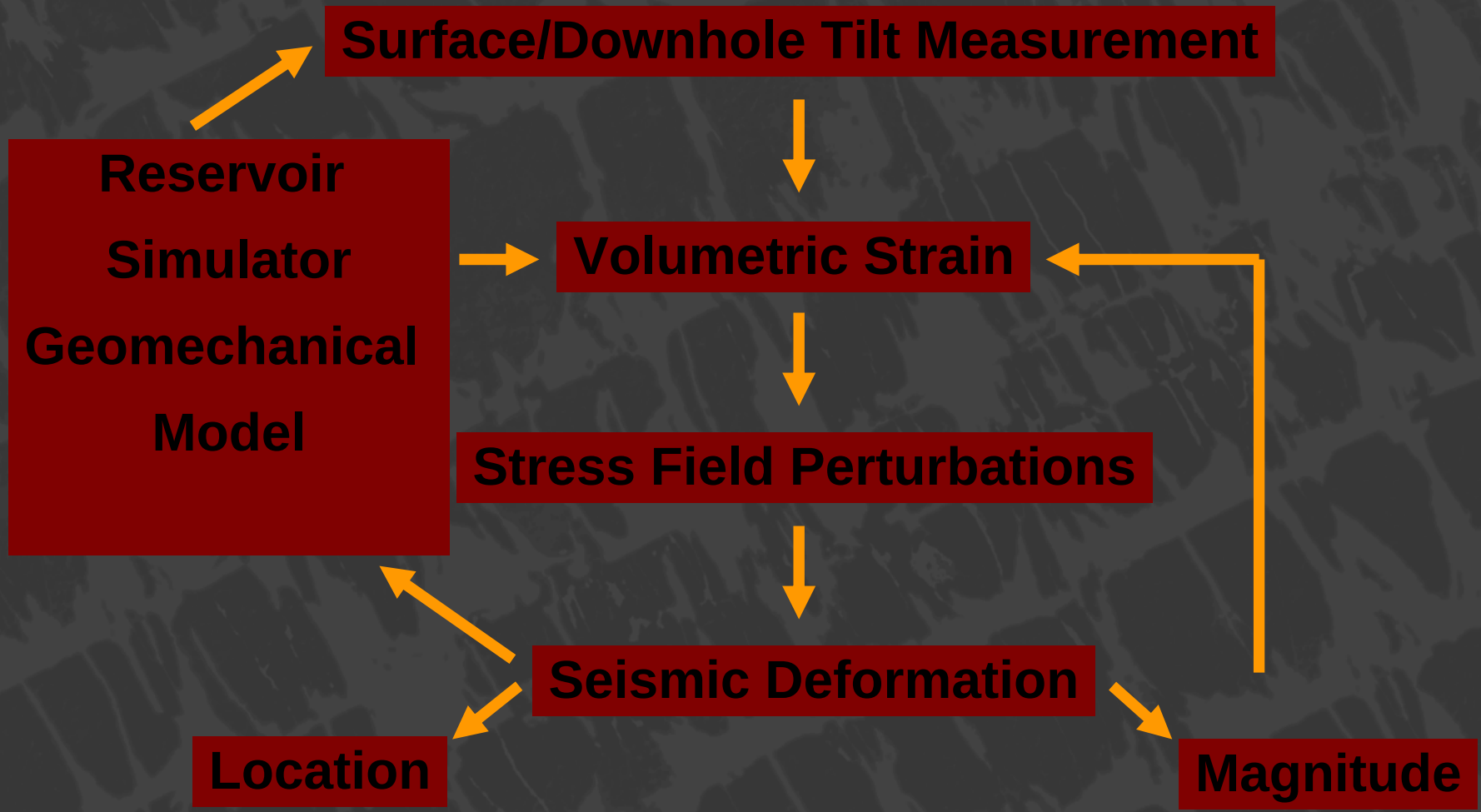






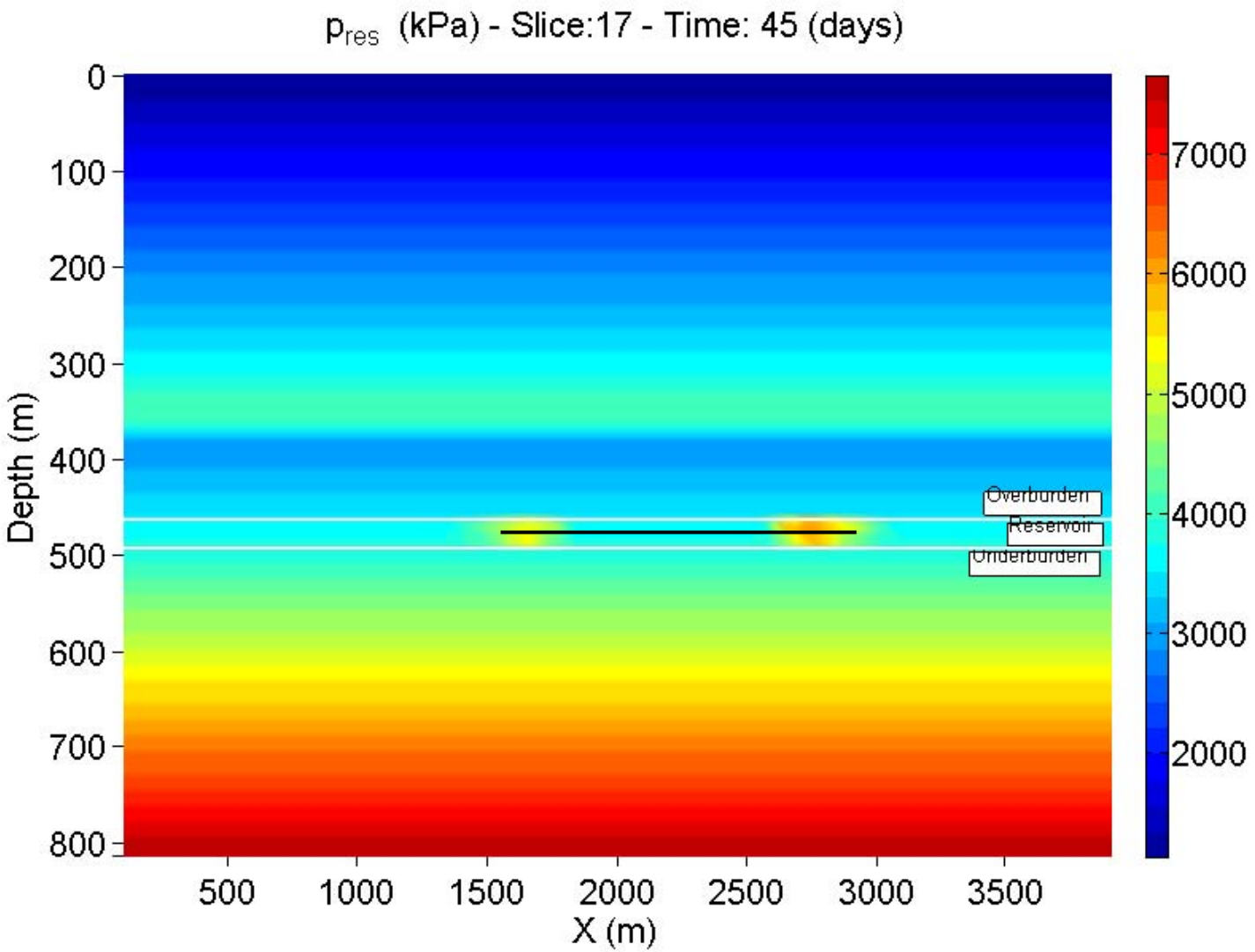


Deformation Calibration : Reservoir Simulation

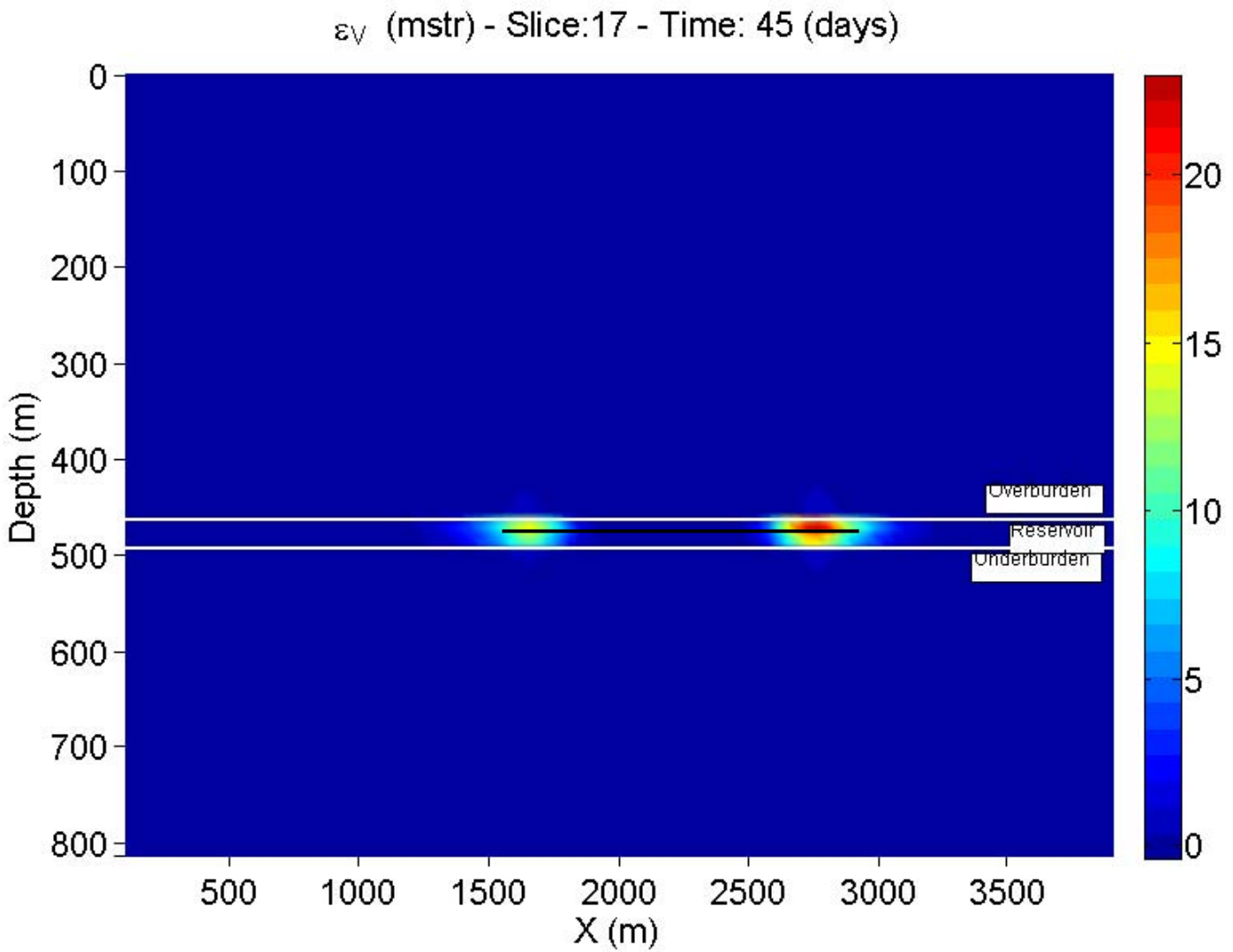


Simulated Reservoir Pressure

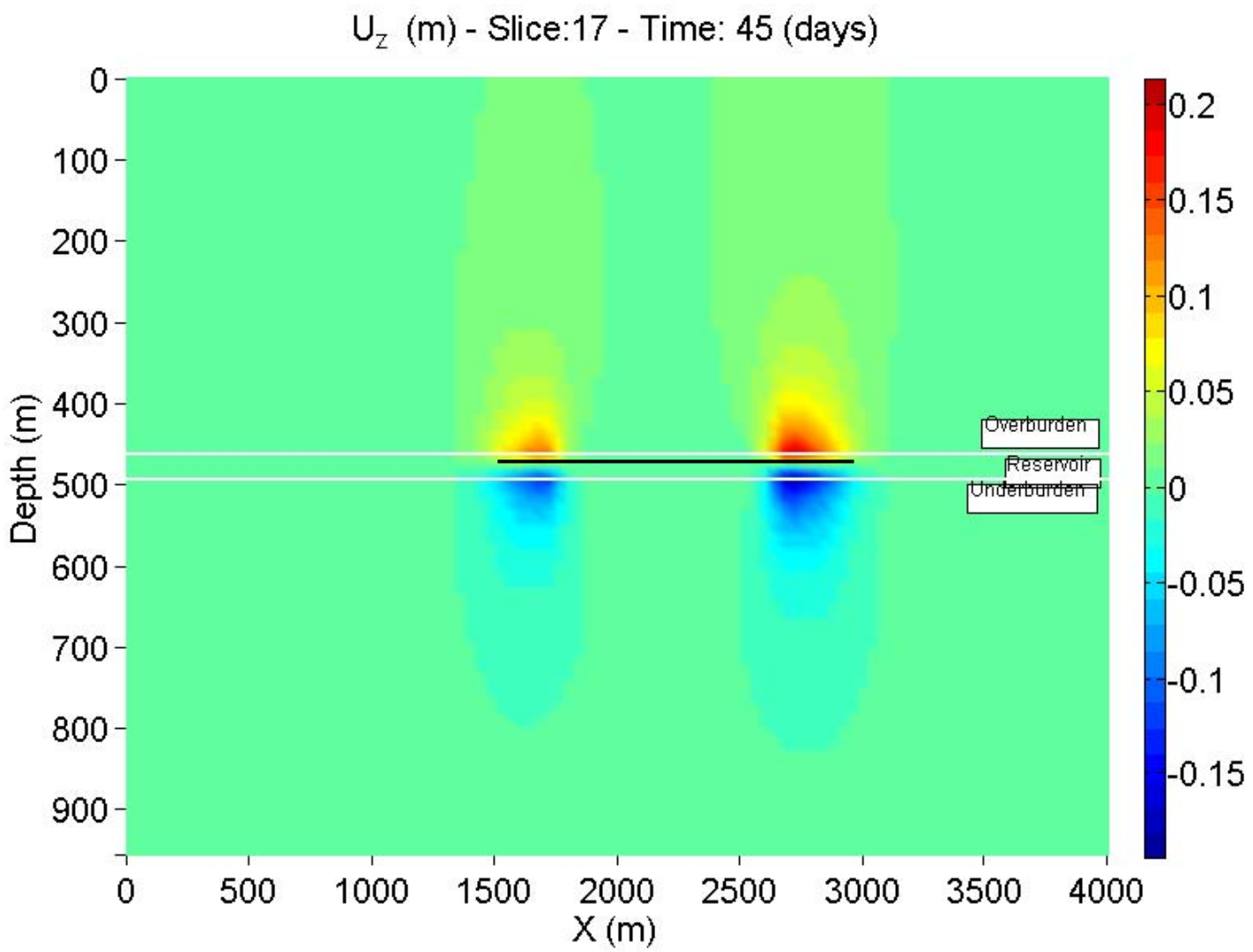
History Match on Injection Pressure/Volume : Strain



Simulated Volumetric Strain



Simulated Uplift



Conclusions

- Integrated passive seismic and reservoir strain can be used to image deformation
- Can be directly used to check conformance and break out
- Integrated data can be used to calibrate a reservoir simulator by matching predicted and observed strains