Microseismicity at the Decatur, IL, CO_2 sequestration demonstration Site

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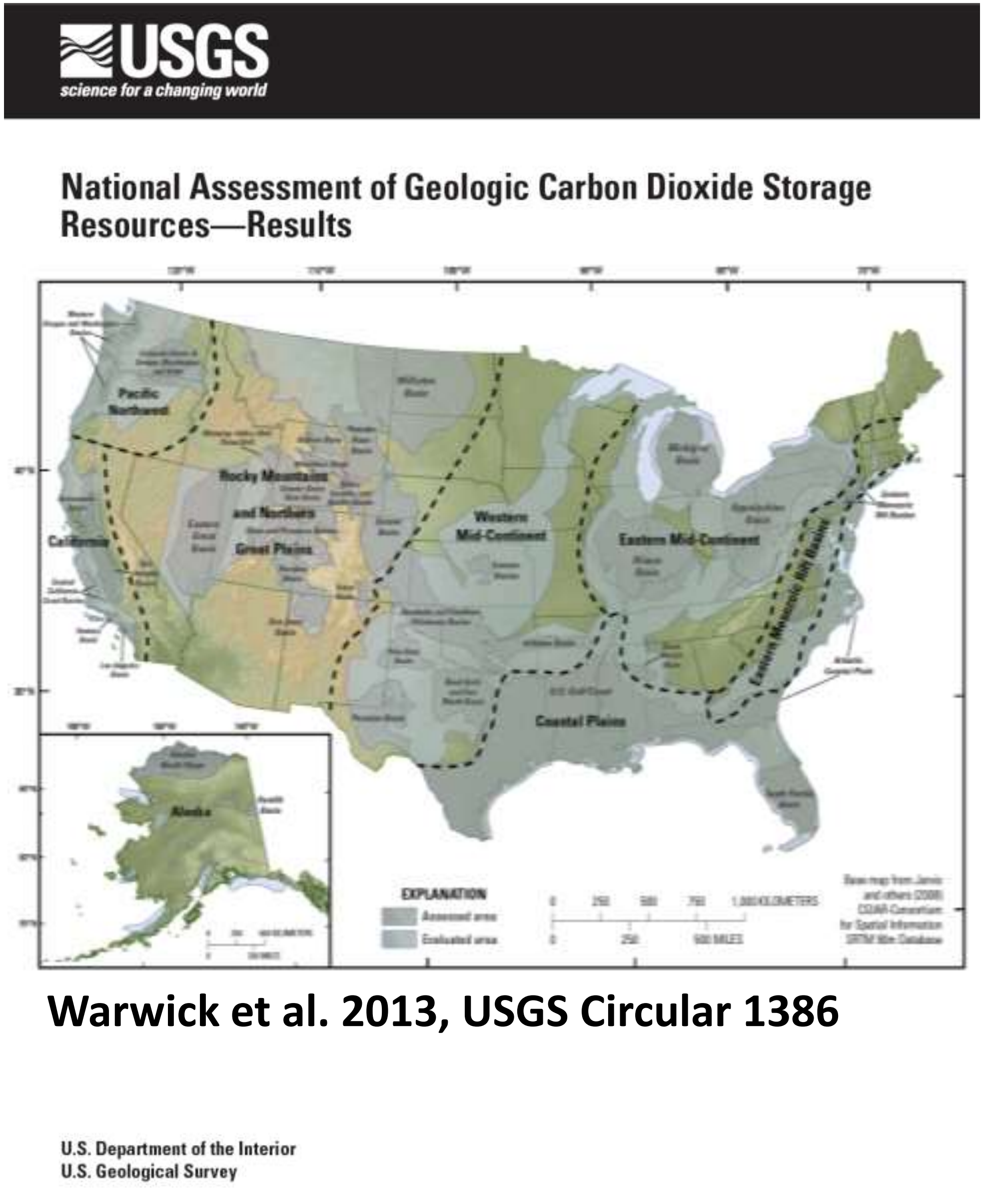
Motivation

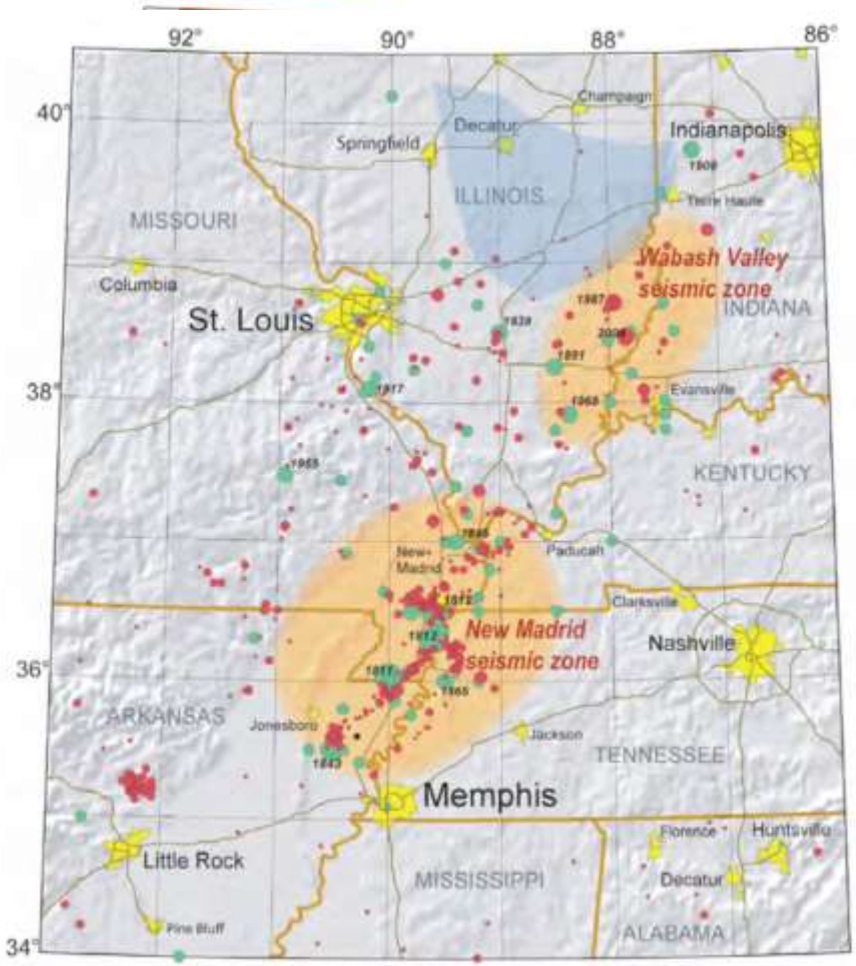
- Estimated storage capacity of more than 500 times the 2011 annual U.S. energy-related CO_2 emissions of 5.5 Gt
- Vast majority of storage capacity (>98%) is in undisturbed saline formations.
- Induced seismicity concerns:
  - Breaching of confining layer(s) creating seal
  - Direct seismic risk to nearby infrastructure and communities?



Warwick et al. 2013, USGS Circular 1386

Background on Decatur CCS project

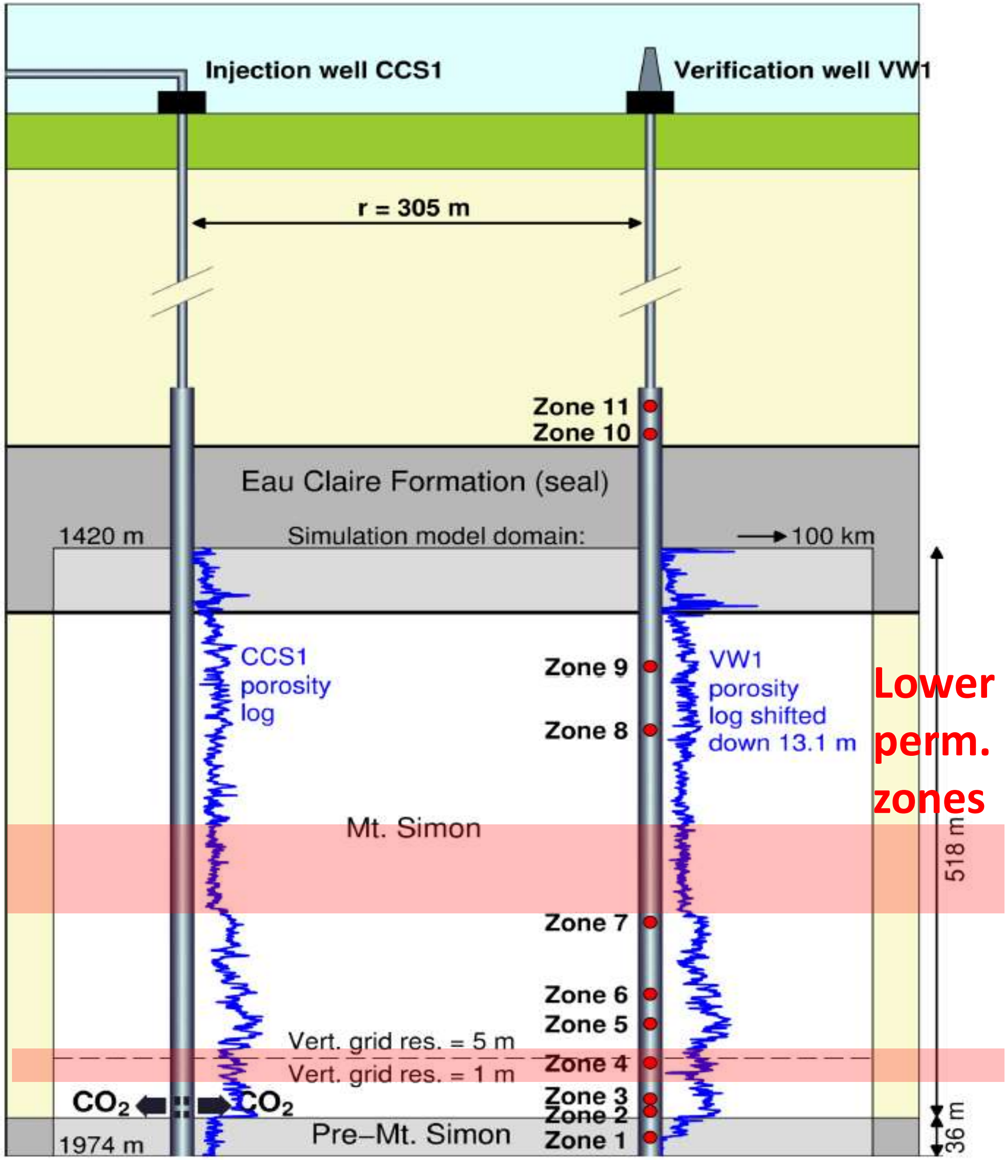
- The Illinois basin is the probable site of large-scale CO_2 injection in the future.
- Goal is to evaluate feasibility of geologic CO_2 sequestration in regionally extensive Mt Simon Sandstone (undisturbed saline formation).
- Injection of 1000 tons/day sc-CO_2 at ADM ethanol production plant into Mt Simon Sandstone at 2.1 km depth, resting directly on top of pre-Cambrian basement. Injection started in November 2011 and finished in November of 2014, after injecting 1MT of sc-CO_2.



Zoback and Gorelick, 2012

Background on Decatur & CCS

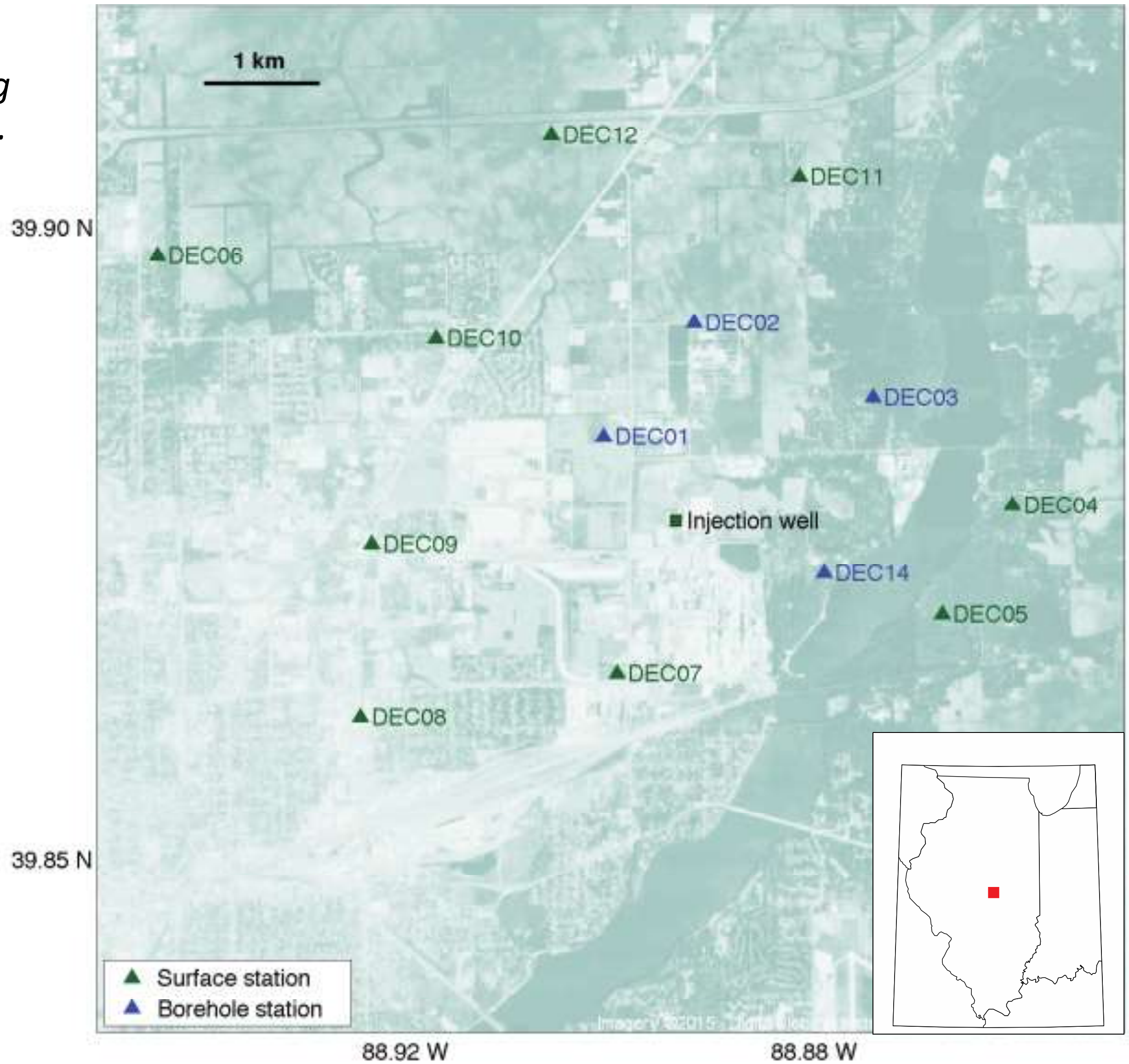
- Injection occurs right over crystalline basement into the lower Mt. Simon
- Extensive evidence of heterogeneous permeability structure (vertically, horizontally)
- Similar physics as wastewater injection sites except: buoyancy, compressibility, and mobility of sc-CO_2
- Same concerns: pore pressure change, mass added, poro-elastic strain changes
- Better opportunity to learn about physical mechanisms governing induced seismicity:
  - Seismic monitoring
  - In-situ stress analyses
  - THM models of injection & deformation



Strandli et al., 2014

Seismic network

- 3 borehole stations: 2 Hz, 3-component geophone *(Hasting Microseismic S10g-2.0, flat vel. response > 2Hz*)
- 3-component force-balance accelerometers (*Kinemetrics EpiSensor FBA ES-T*, DC to 200Hz, ±2g full scale) at all 12 stations.
- 3-component broadband (*Trillium Compact 120*, flat vel. response 120s to 100Hz) at 9 surface-only stations
- Start: July 2013
- 12 stations online since Sept 2013
- 4th borehole station became operational in December 2014



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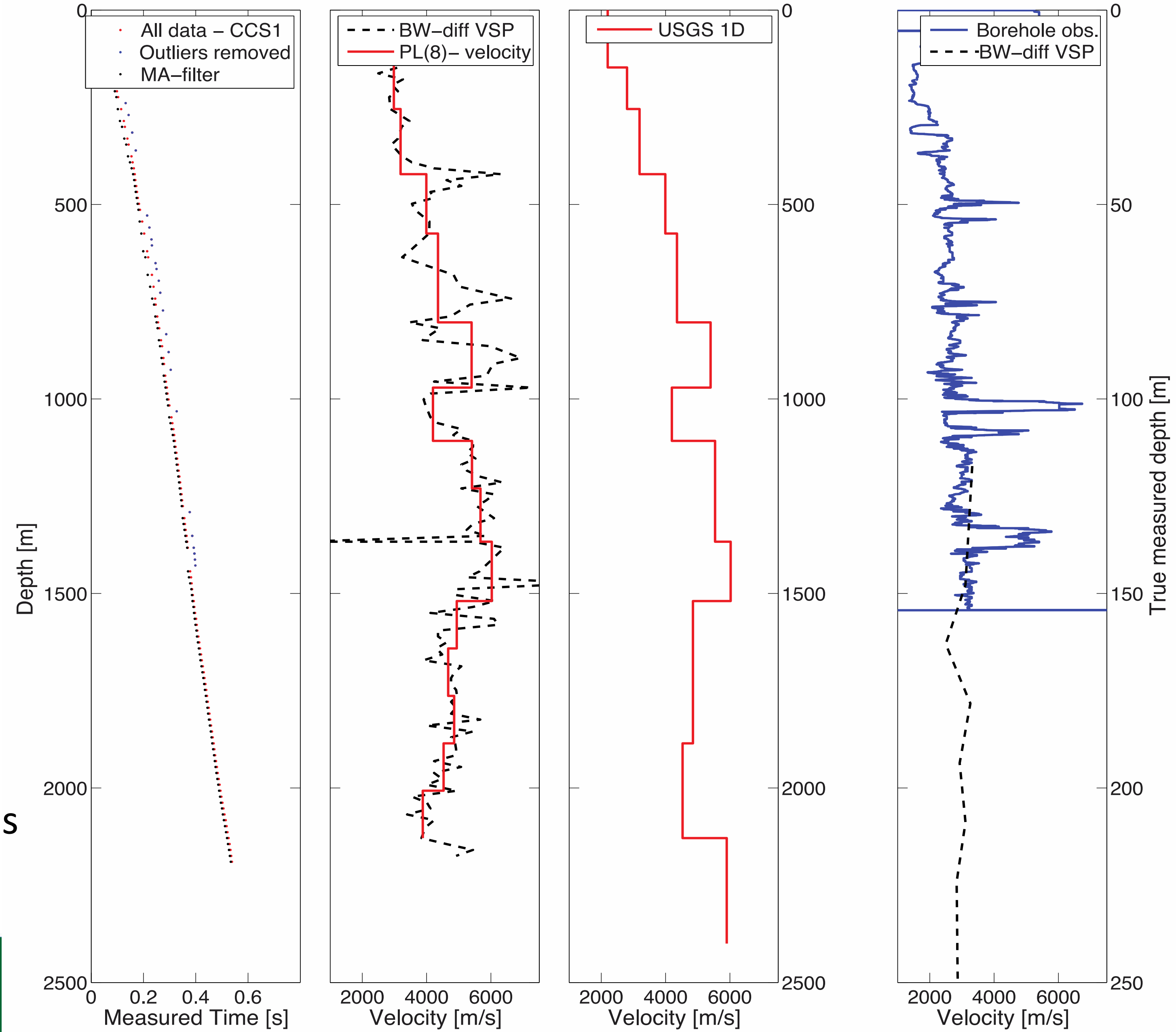
Velocity model

- VSP at CCS#1
- Basement P-velocity from acoustic log
- Good match to shallow sonic log in USGS borehole (right panel)
- Initially constant Vp/Vs=1.83
- Caveats: S-velocity varies shallow



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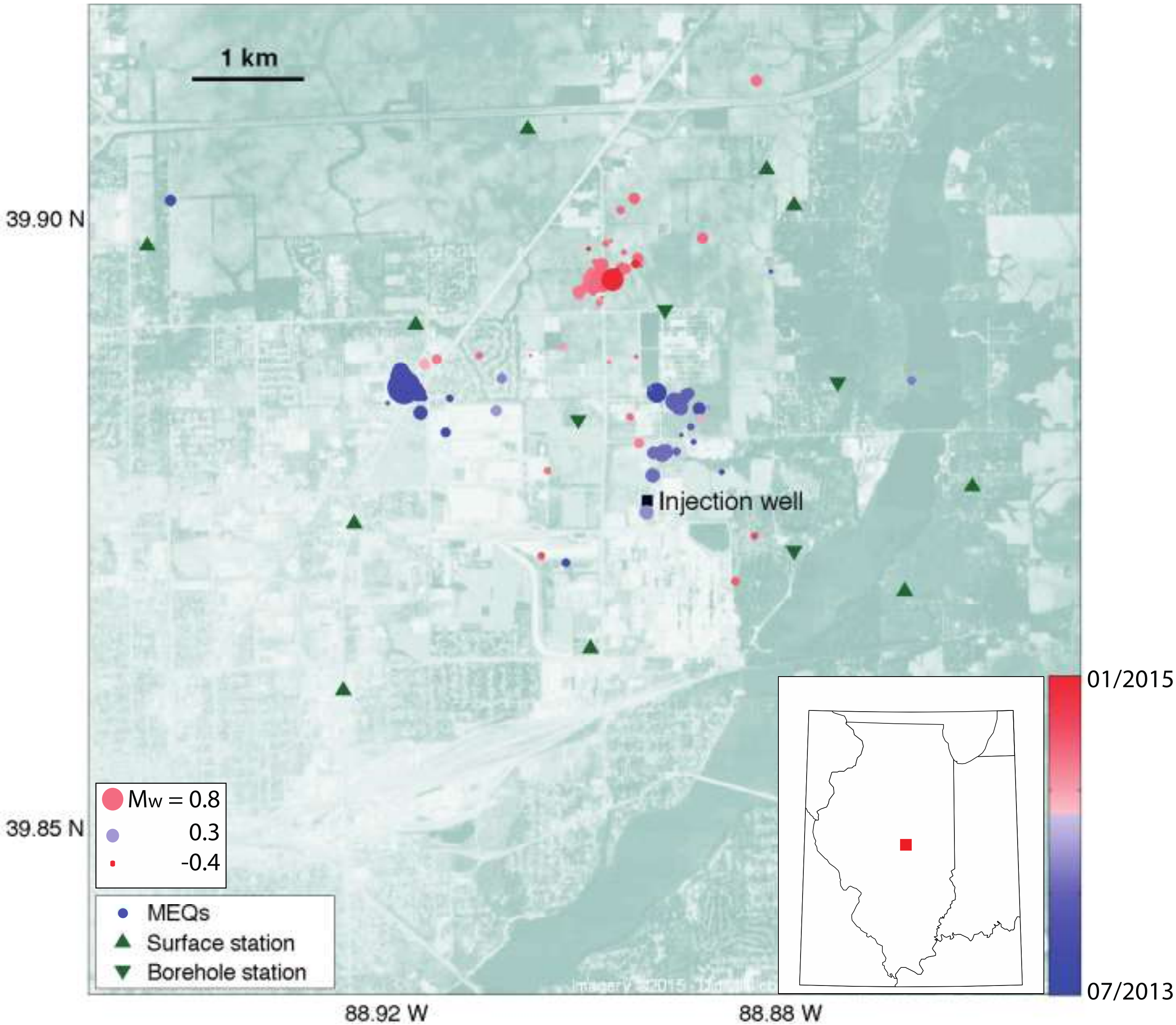
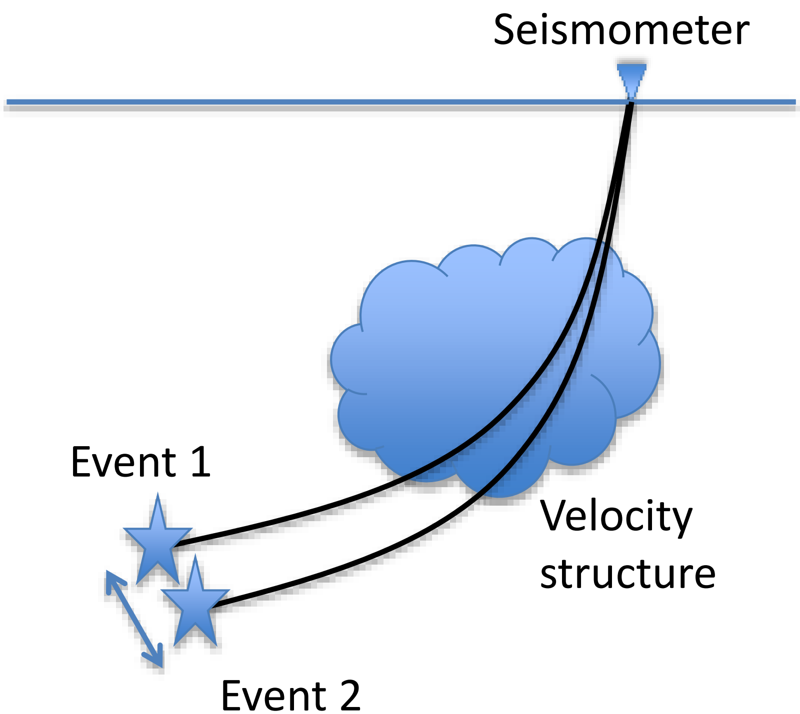
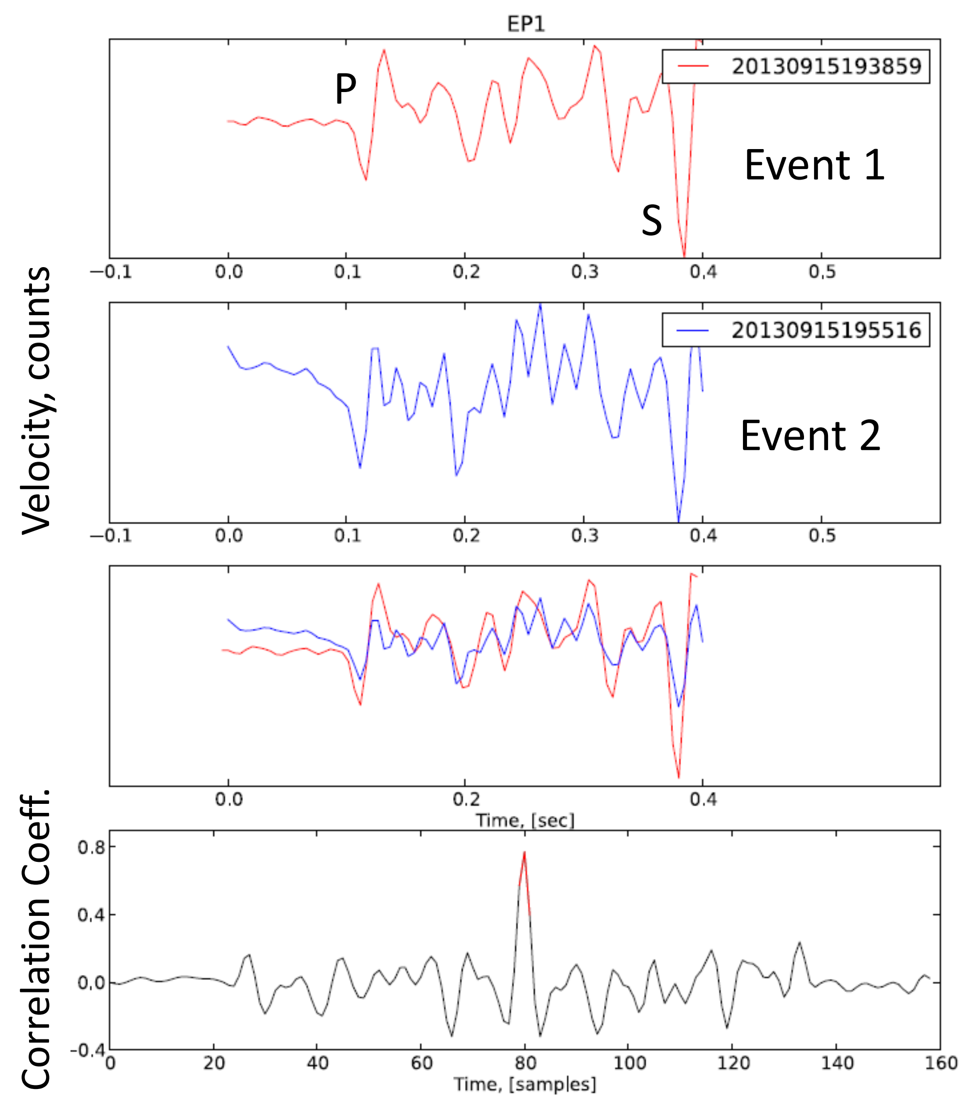
Catalog locations



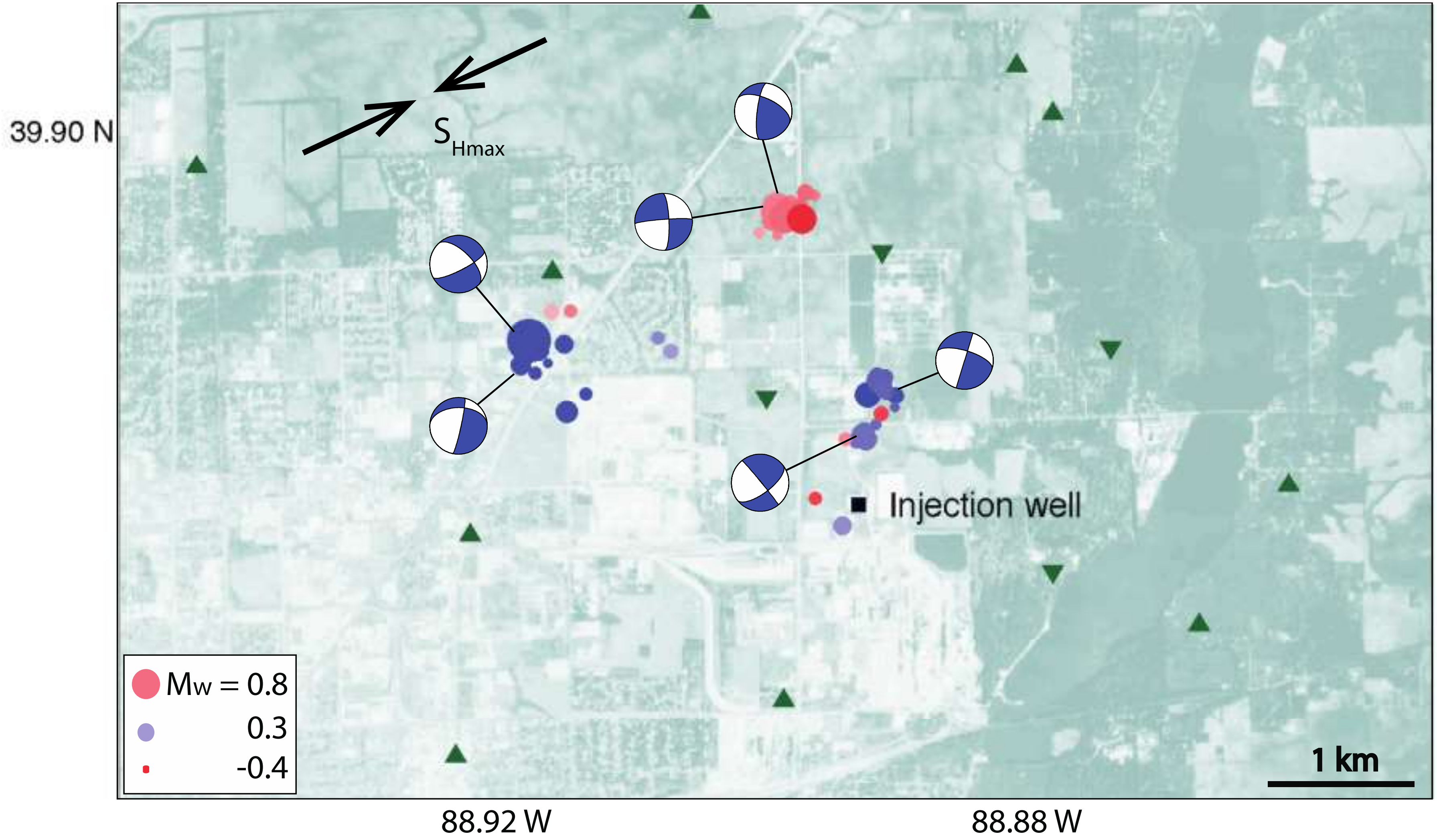
Double-difference relocation



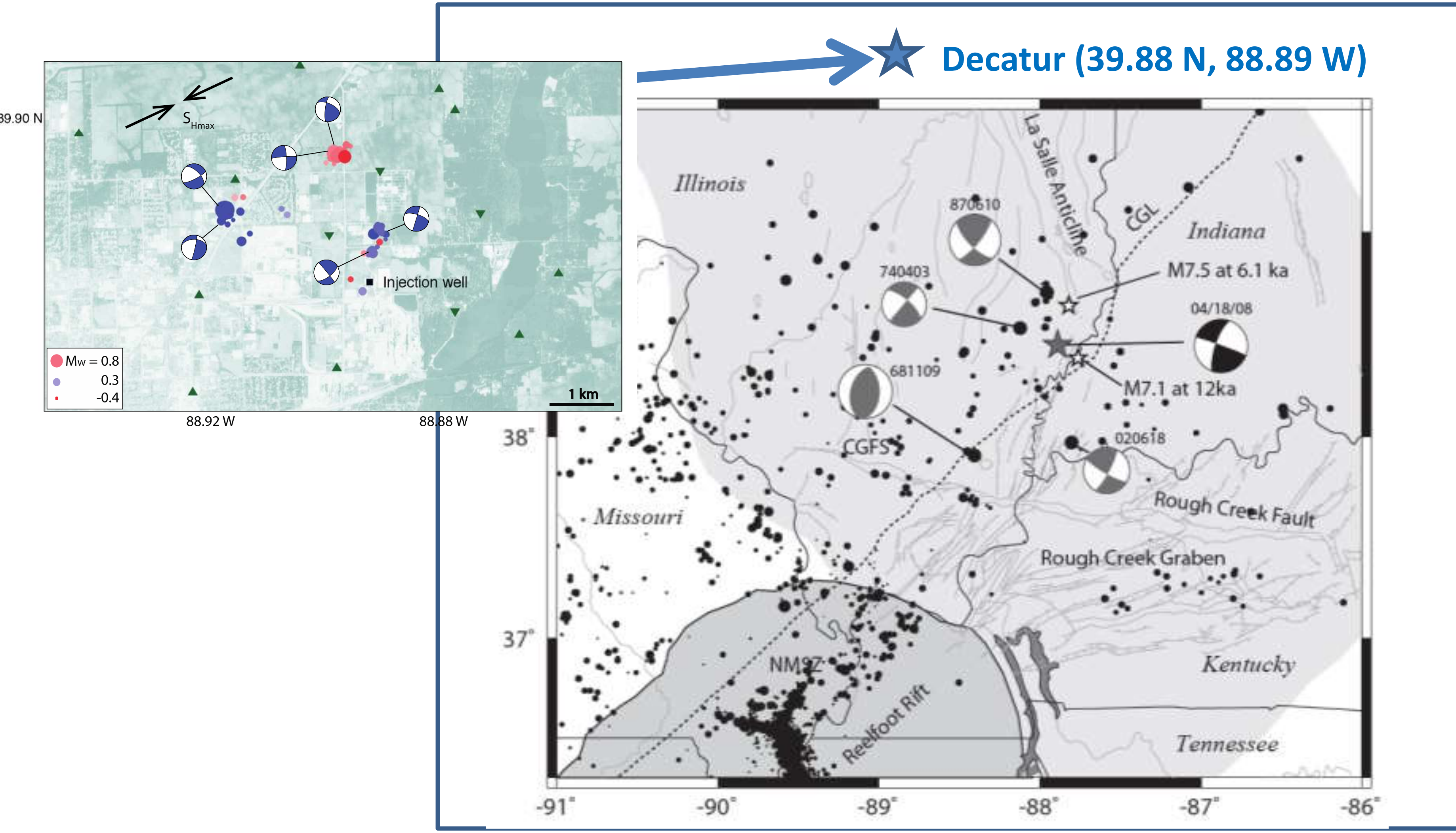


High-precision relative locations

Double-difference locations



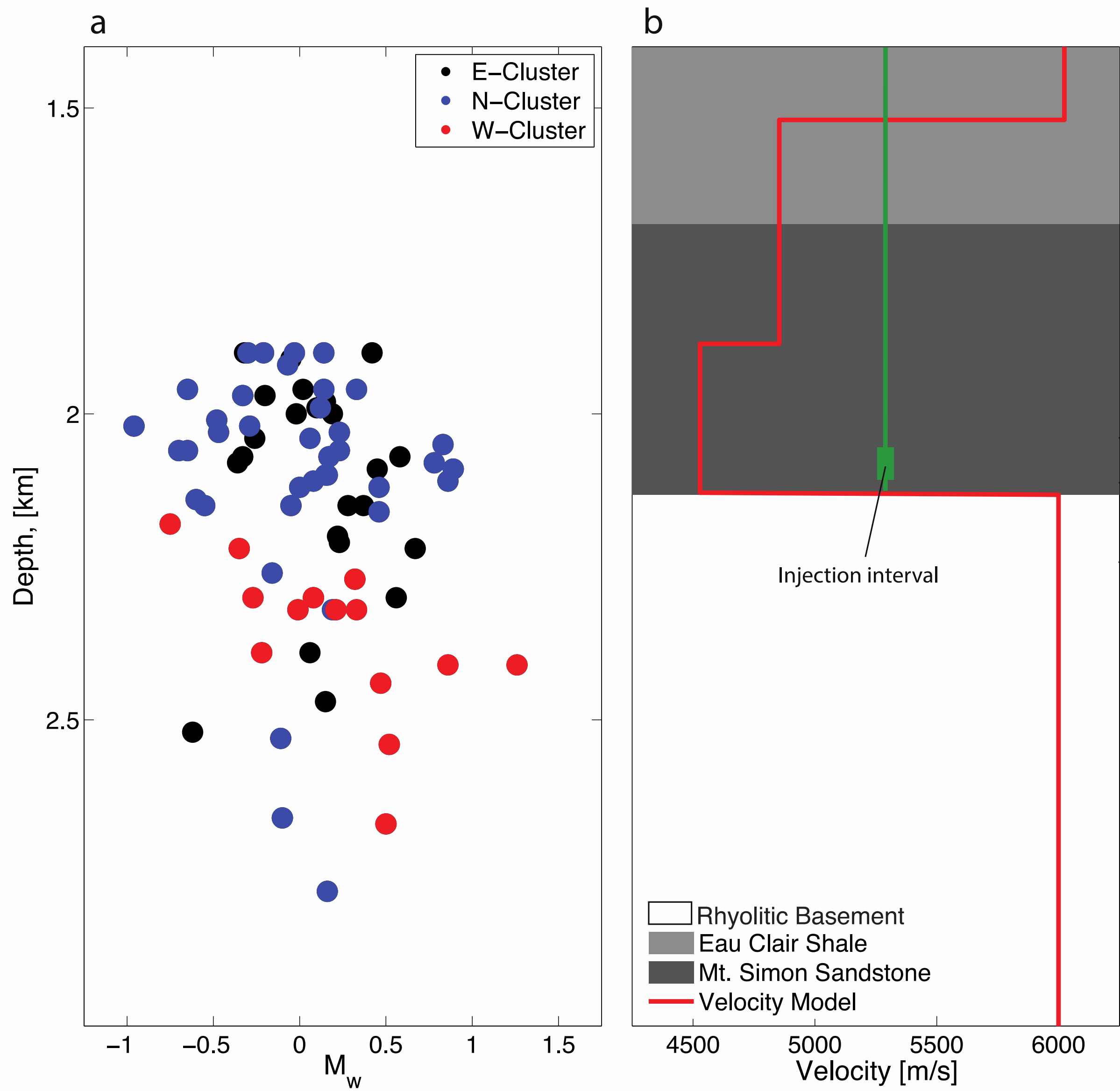
Regional Seismicity



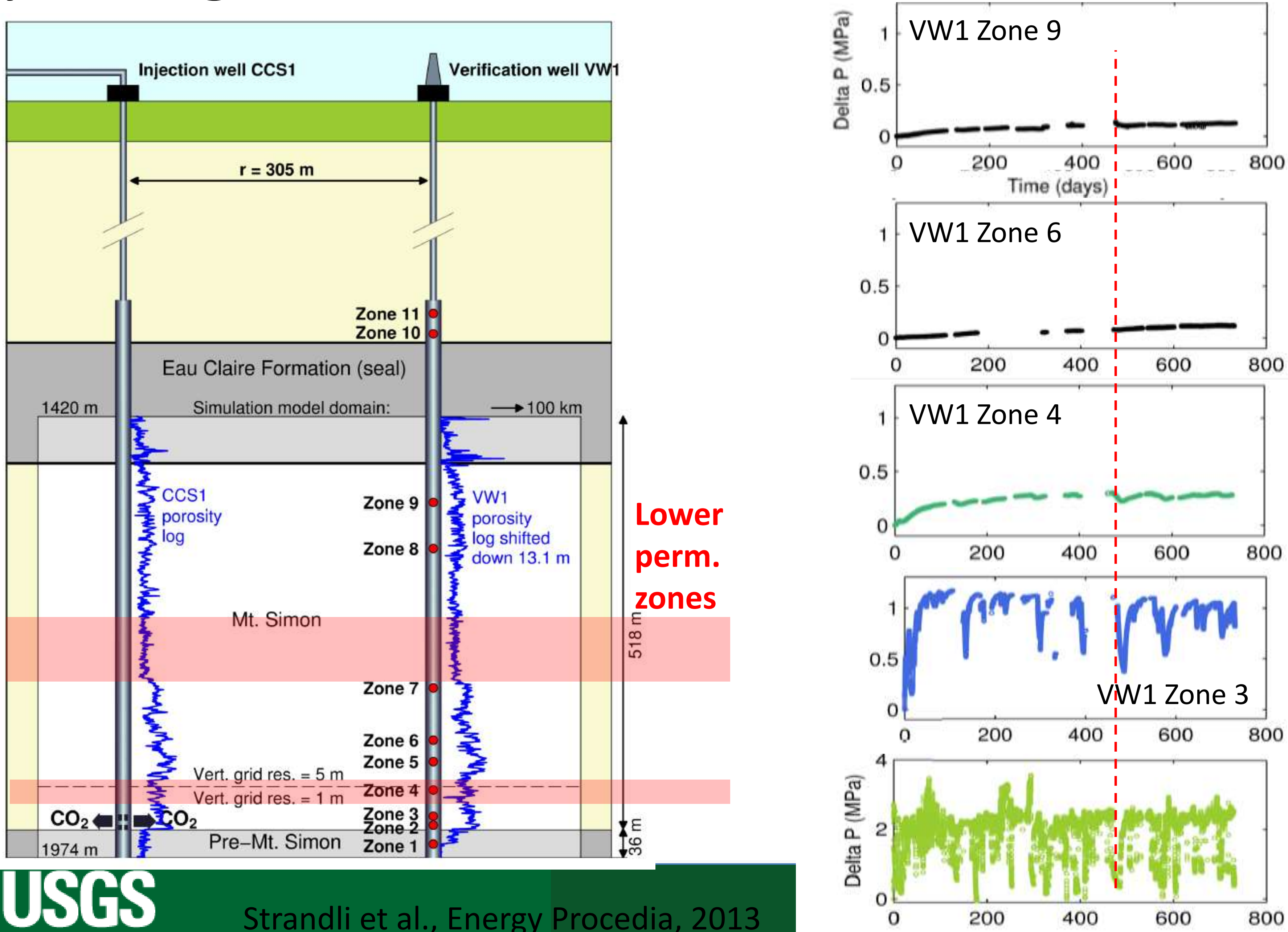
Seismicity in Wabash Valley Fault System and northern NMSZ *(Hamburger et al. 2011)*

Depths

- East cluster near injection well appears slightly shallower, but still in basement
- All events are well below Eau Claire Shale
- Comparison of velocity models with SCS yielded similar results, but no access to S-wave velocity model



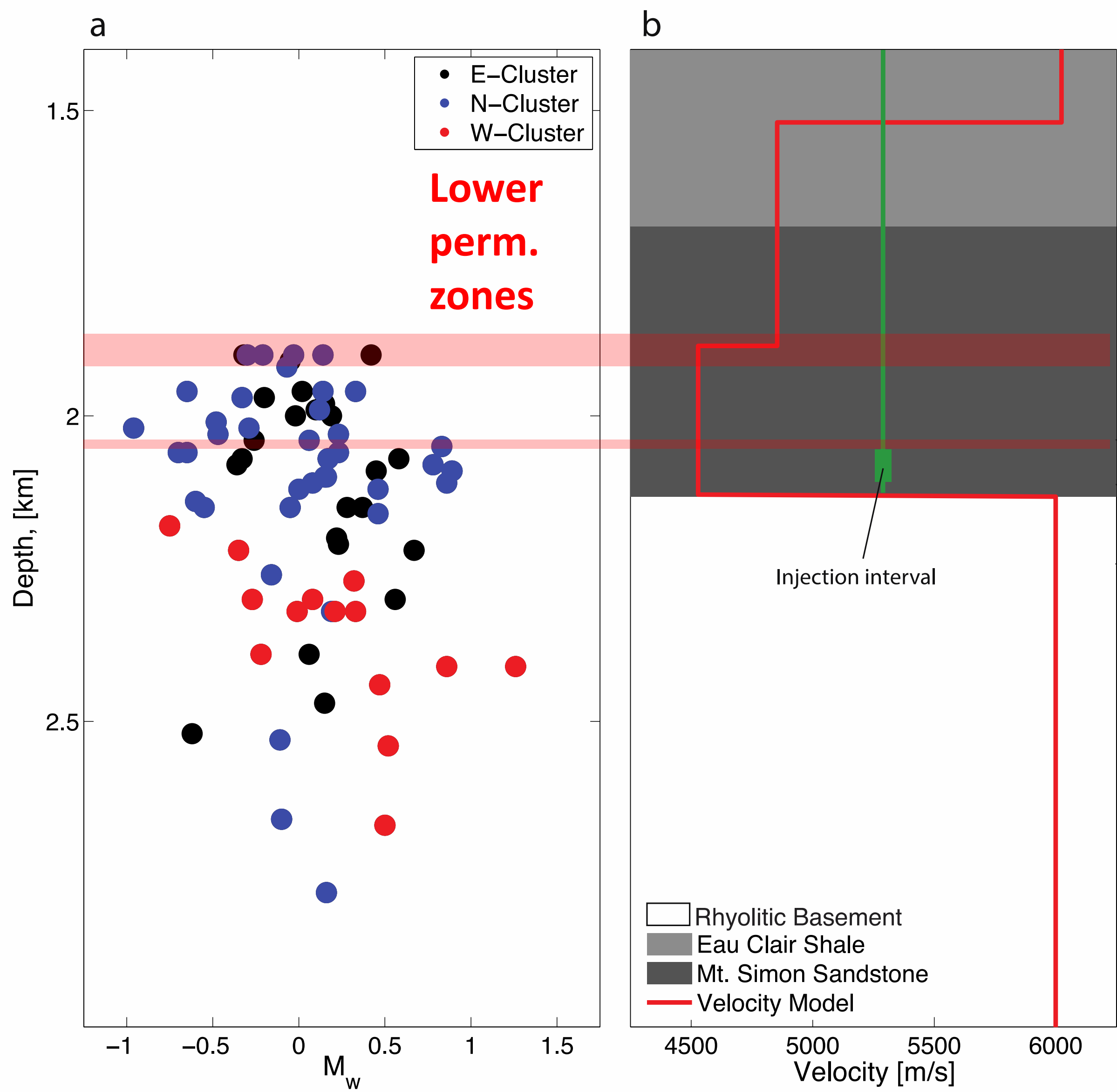
Hydrologic stratification of Mt. Simon



Strandli et al., Energy Procedia, 2013

Depths

- Less seismicity above baffles due to poor pressure communication
- Can these baffles insulated regions from pore pressure changes?



Conclusions

- Seismic events located by this network group into three distinct clusters with moment magnitudes ranging from M_w = -1.1 to 1.2.
- Most of these micro-earthquakes are located in the lower Mt. Simon Sandstone and to a lesser degree in the granitic basement, well below the caprock, and are unlikely to have compromised the integrity of the seal.
- Focal mechanisms and possibly alignments of hypocenters suggest that observed microseismicity is due to reactivation of basement faults/fractures that are well oriented for slip in the current stress field.
- Pore pressure communication through high-permeability zones, likely pre-existing.
- Low permeability hydrologic baffles reduce pressure communication to shallower portions that experience less seismicity.
- Can basal seals insulate basement faults from pore pressure changes? What effects do poro-elastic strains have on the basement?