Microseismicity monitoring at the Decatur, IL, CO_2 sequestration demonstration site

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Acknowledgements

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  - Stephen Hickman, Art McGarr, Rob Skoumal, Ezer Patlan (USGS)
  - Scott McDonald (ADM)
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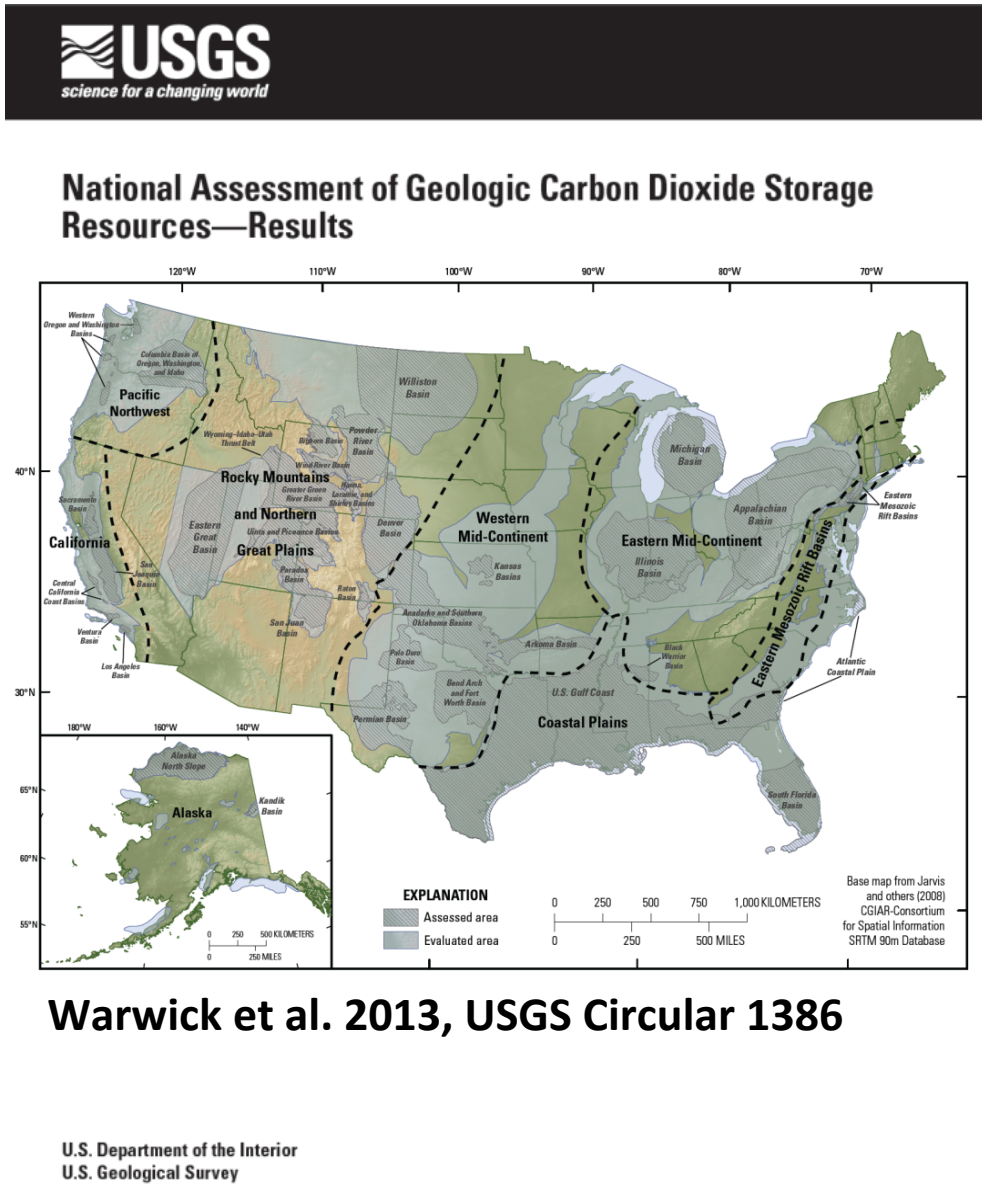
Outline

- Background on CO_2 sequestration U.S.G.S. resource assessment
- Potential California sites and site types for CO_2 sequestration
- Decatur CO_2 sequestration demonstration project:
  - Background
  - Seismic monitoring
  - Reservoir behavior
- Outlook and induced seismicity mitigation strategies

Motivation

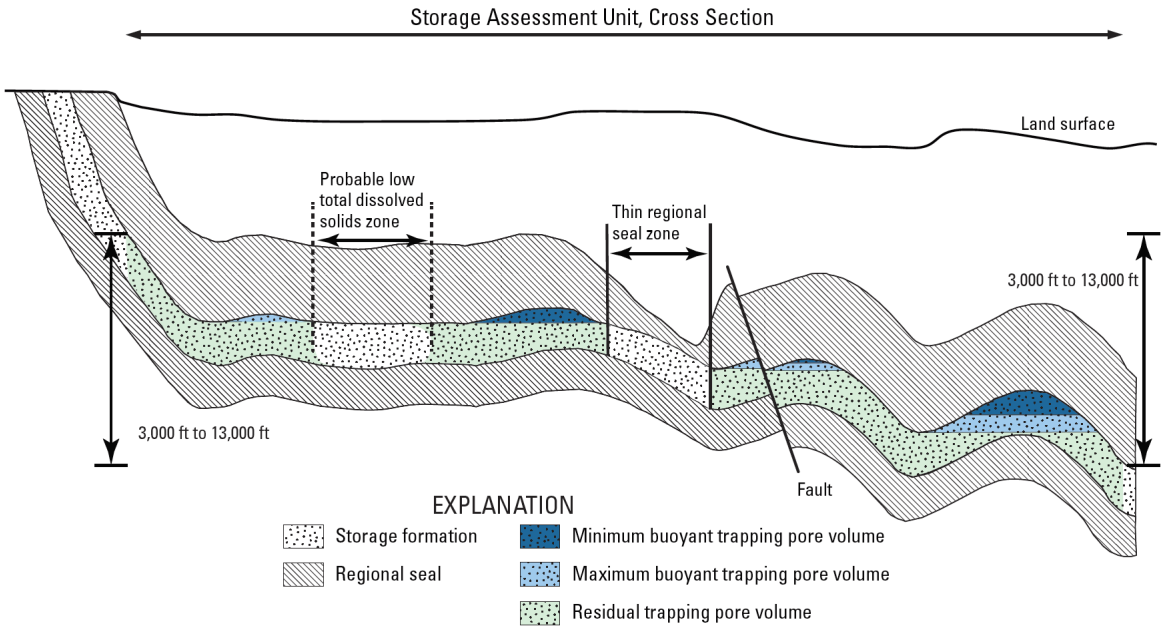
- Estimated storage capacity of more than 500 times the 2011 annual U.S. energy-related CO_2 emissions of 5.5 Gt
- Vast majority of storage capacity (>98%) is in undisturbed saline formations.
- In California several regional basins and formations are potential candidates for CO_2 sequestration
- Induced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



Warwick et al. 2013, USGS Circular 1386

Storage types

- Two general types of storage:
  - Buoyant
  - Residual (classification by reservoir permeability)
- Third type of storage: Known recovery replacement storage (KRR): Replace volume of extracted hydrocarbons
- Large majority of storage type is residual (class 2: 1mD to 1D)



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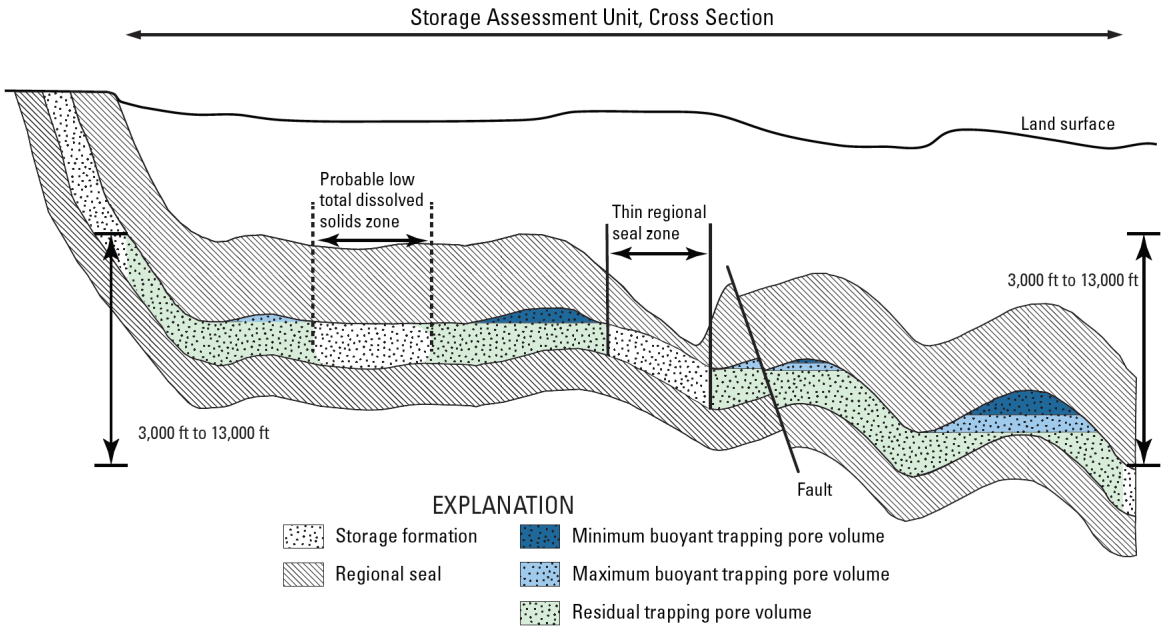
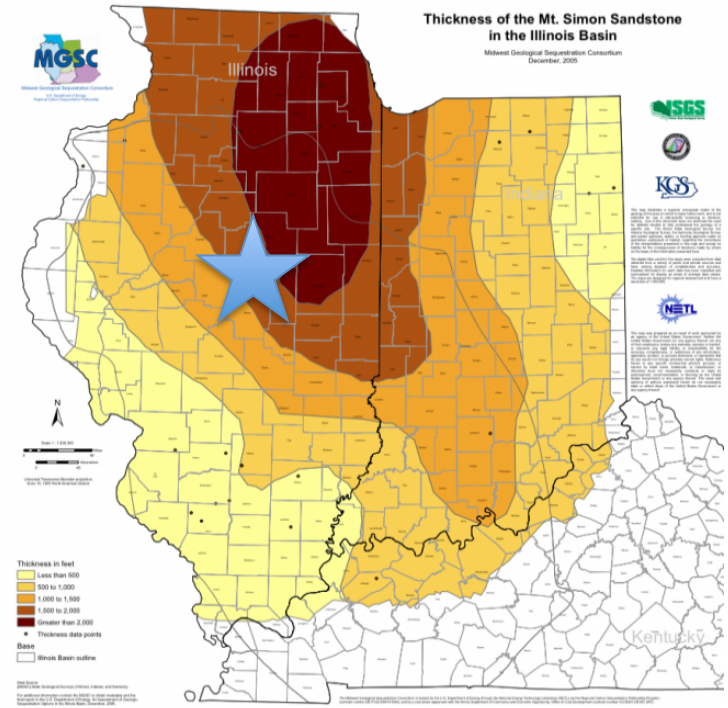


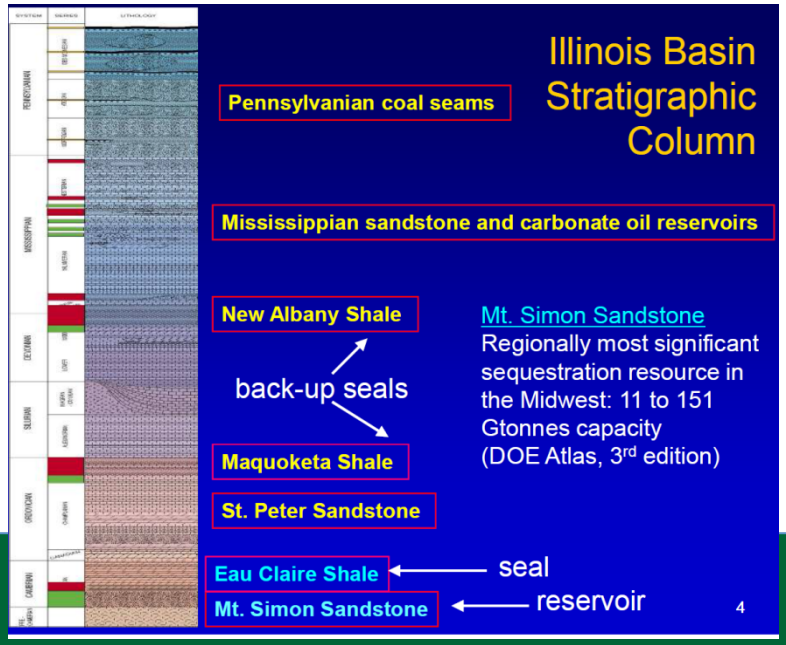
Basin Name	KRR (Mt)	Buoyant (Mt)	Residual (Mt)
LA	13	81	3,500
Sacramento	49	80	29,000
San Joaquin	25	270	48,000
Ventura	32	93	5,700

Background on Decatur CCS project

- Goal is to evaluate feasibility of geologic CO_2 sequestration in regionally extensive Mt Simon Sandstone (undisturbed saline formation – class 2 residual type).
- Injection of 1000 tons/day sc-CO_2 at Archer-Daniels-Midland (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.
- Funding for the project comes from DOE and industry collaborators: ADM and Schlumberger Carbon Services

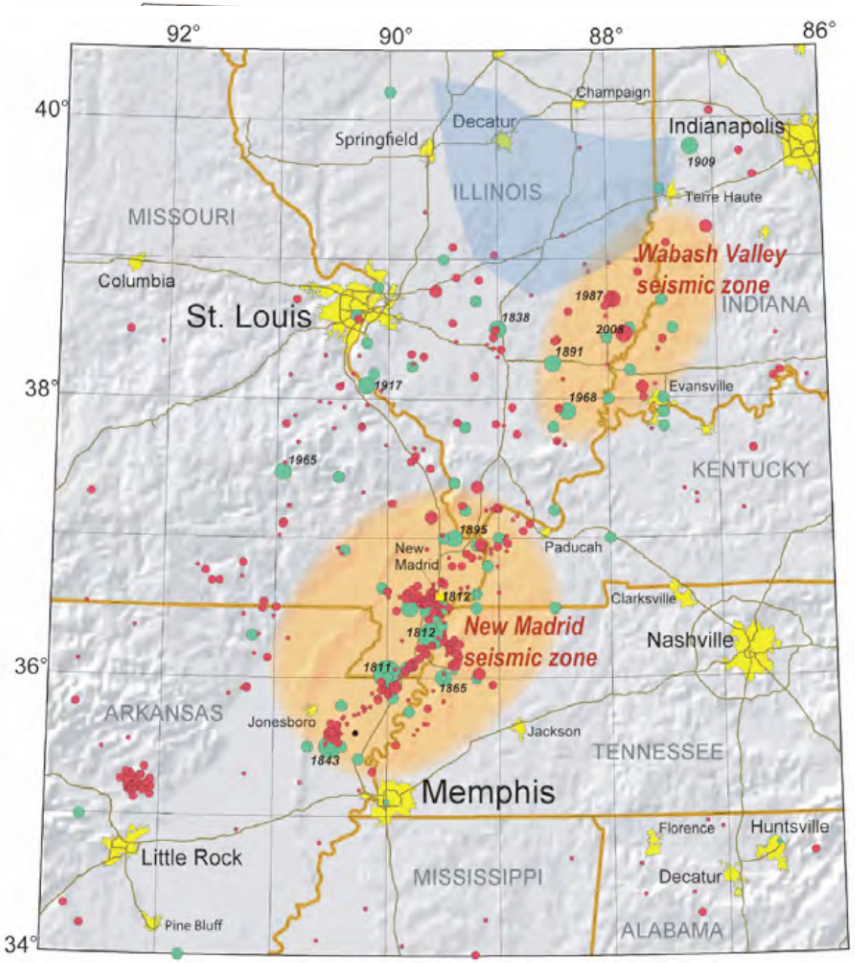


Finley et al. 2012



Background on Decatur CCS project

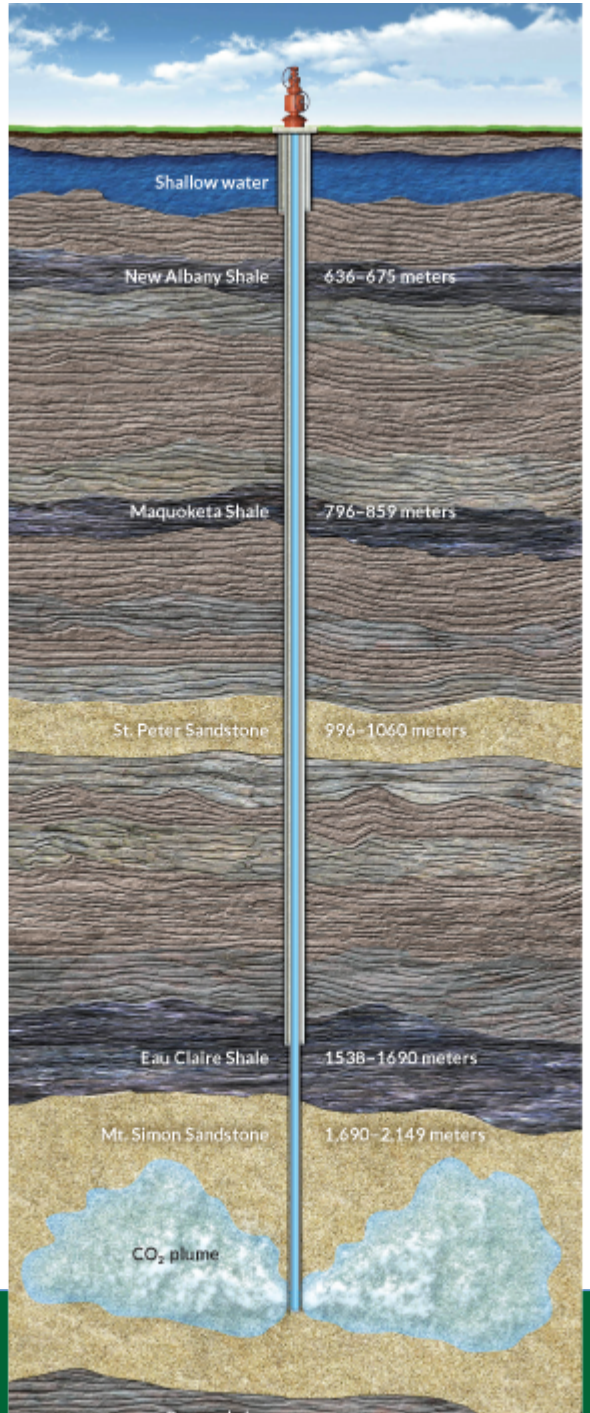
- The Illinois basin is the probable site of large-scale CO_2 injection in the future.
- Several sites of potential industrial scale sequestration have been explored (Decatur, FutureGen 2.0)
- Basin-wide implementation of CO2 sequestration may significantly increase pre pressures in the Mt Simon sandstone:
  - Cause for concern owing to unknown location/extent of basement faults
  - Proximity to historically seismically active zones (Wabash Valley)



Zoback and Gorelick, 2012

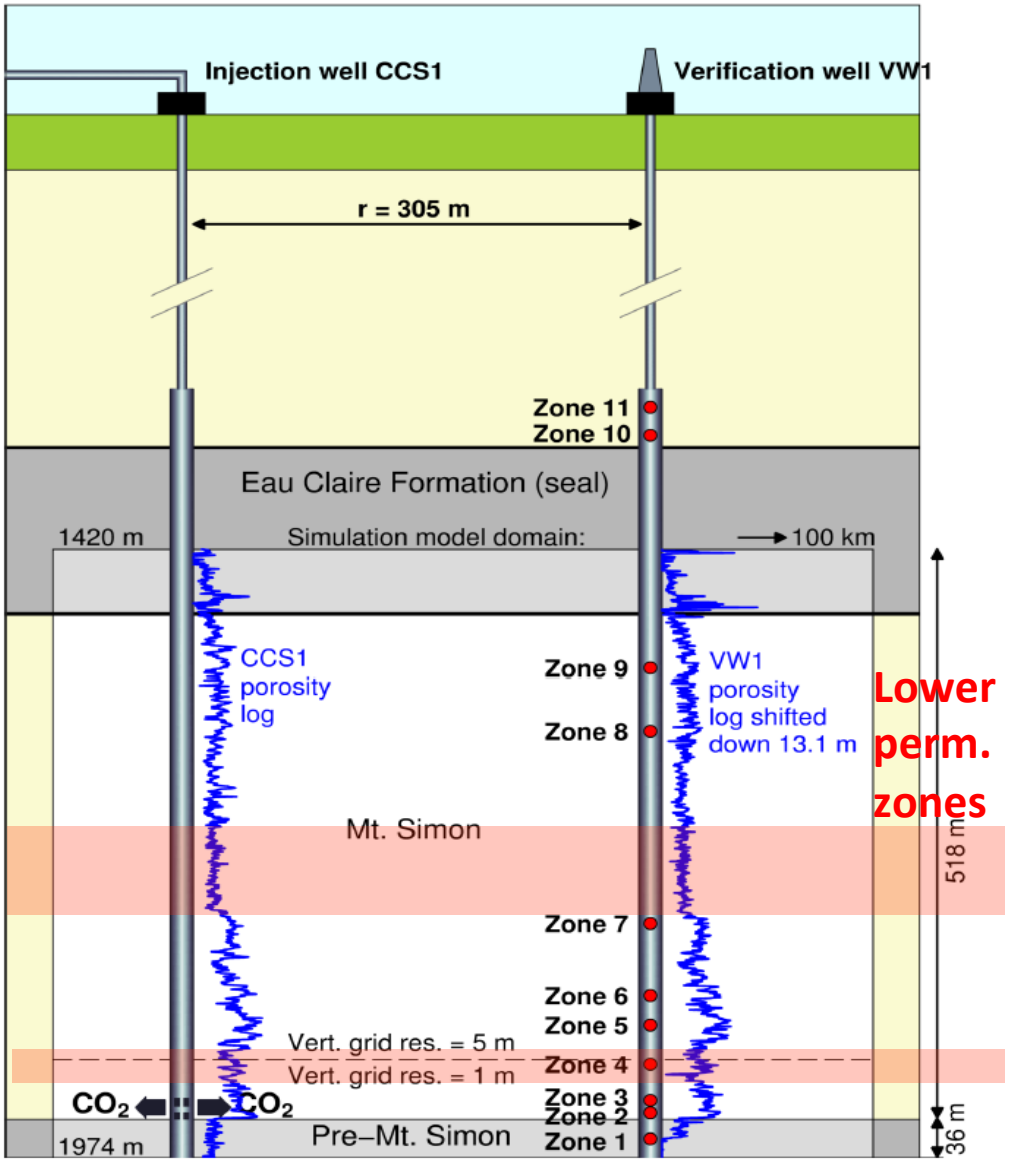
Decatur, Illinois, CO_2 sequestration site

- Deep Wells injecting into porous formations, Mt Simon sandstone
- Inject large volumes for years:
  - 1M tons over three years in first phase
  - 3M tons a year in second phase
- Only project in the US
- No felt earthquakes to date



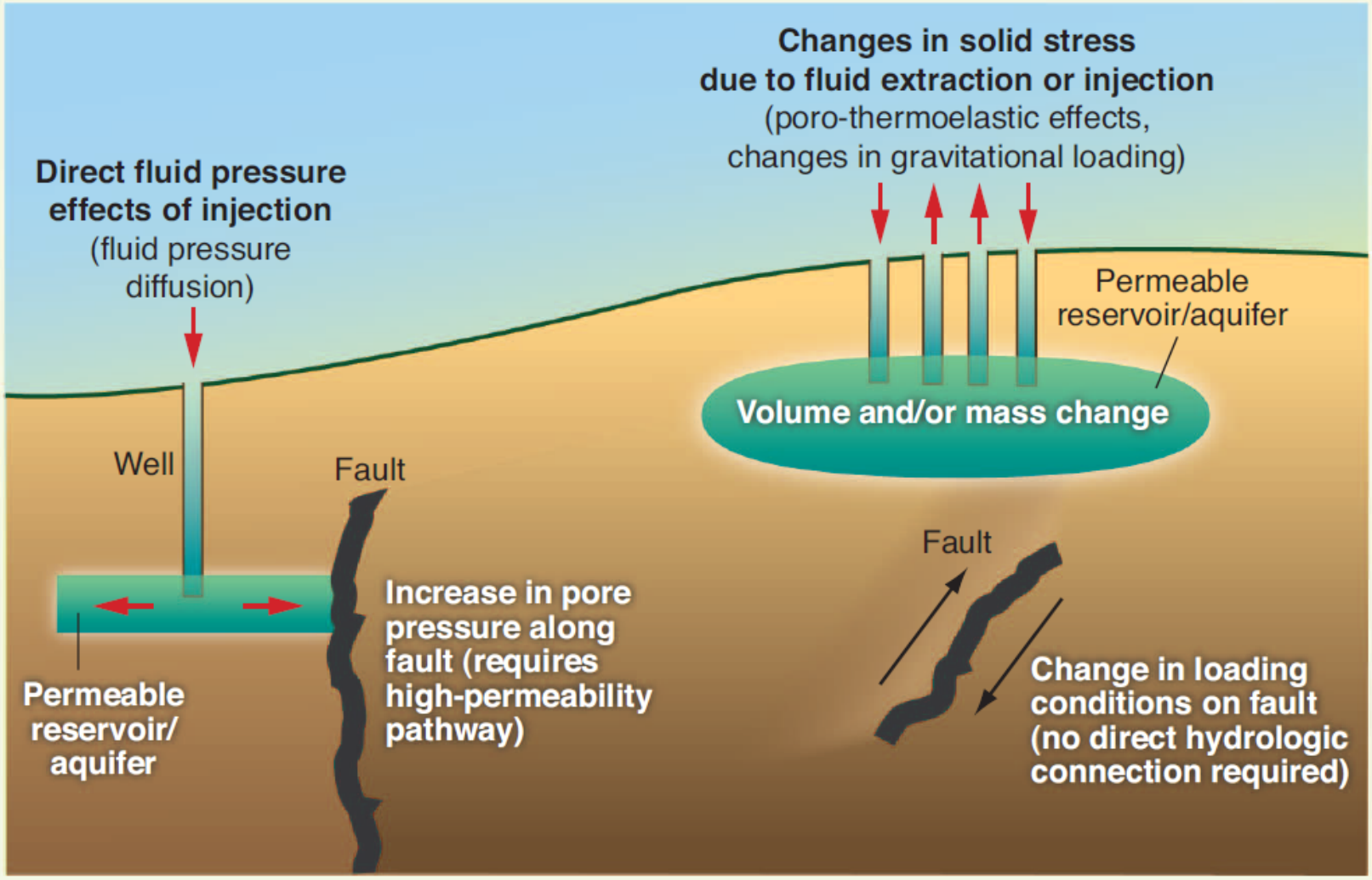
Background on Decatur & CCS

- 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

Physical processes at play



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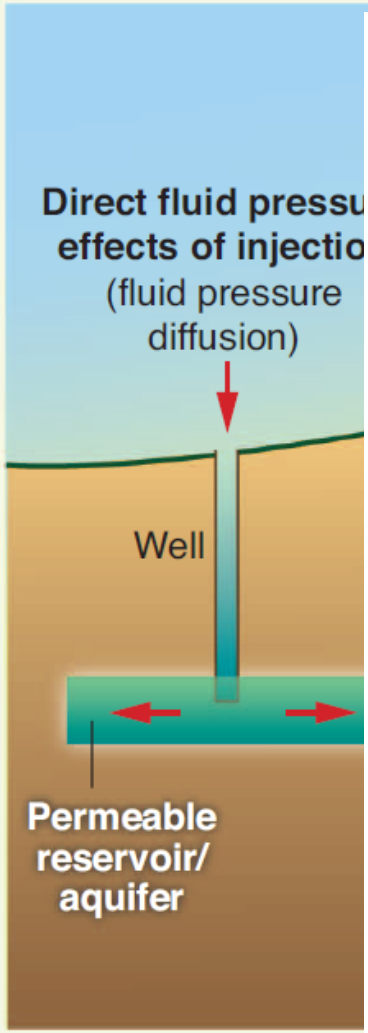
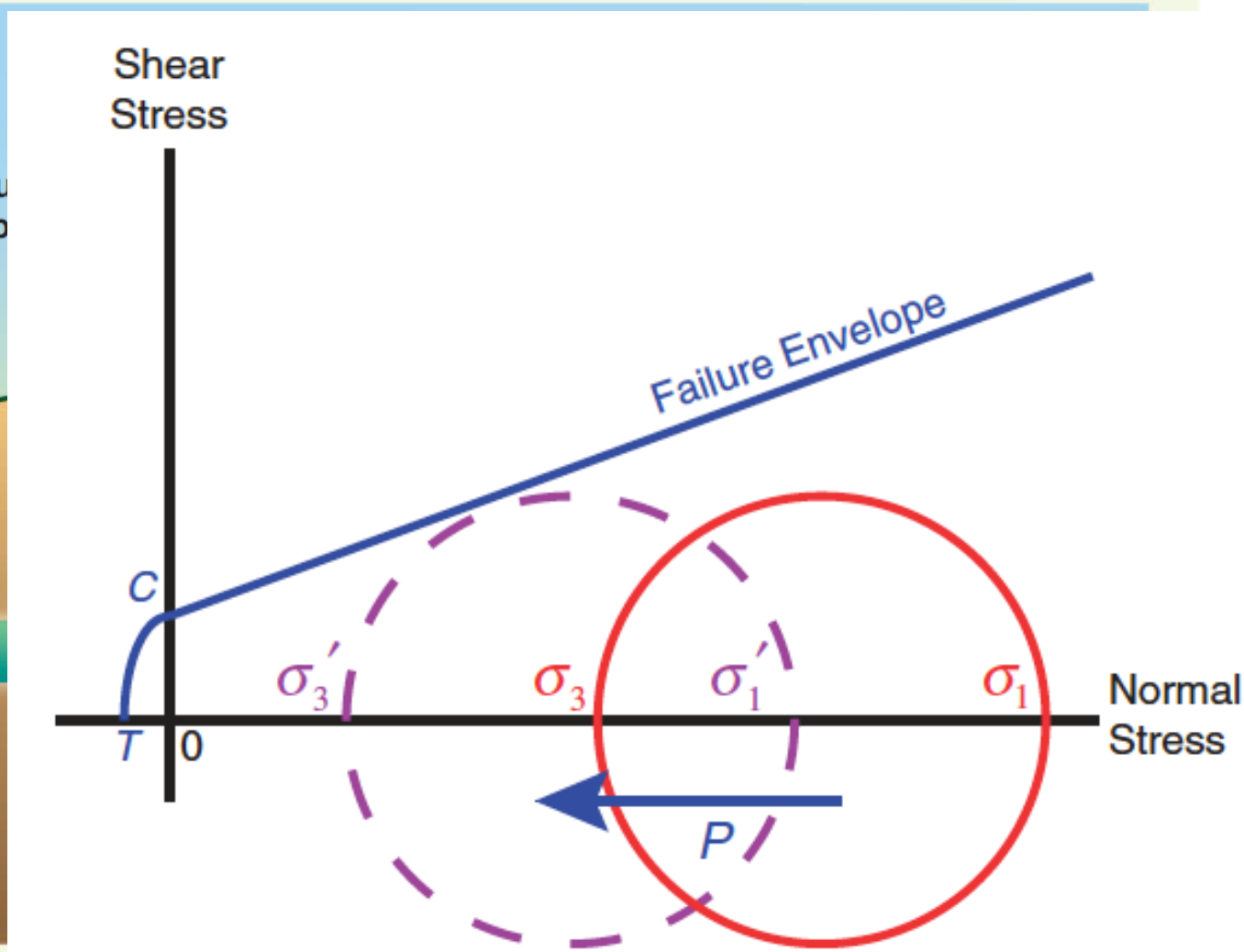
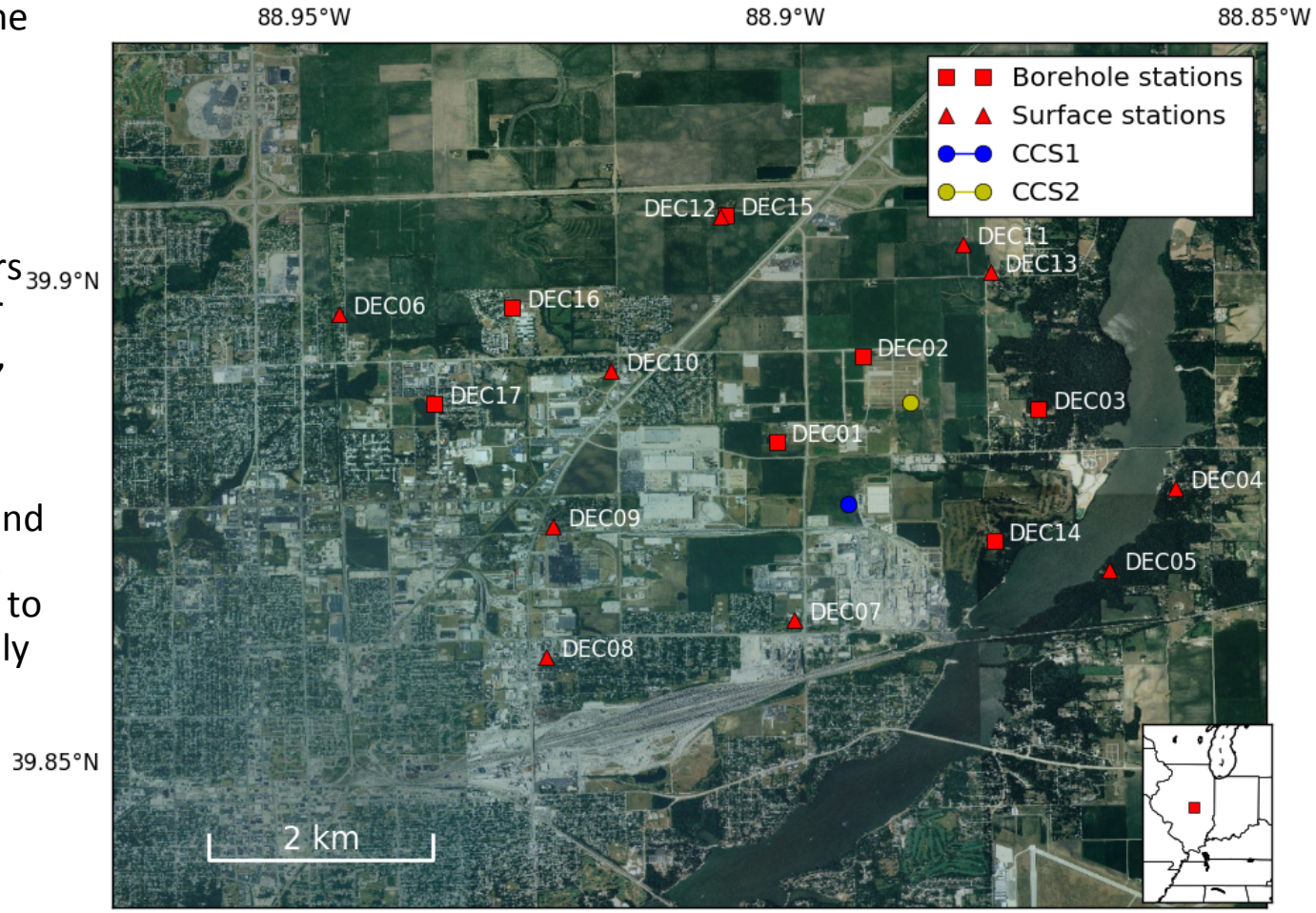




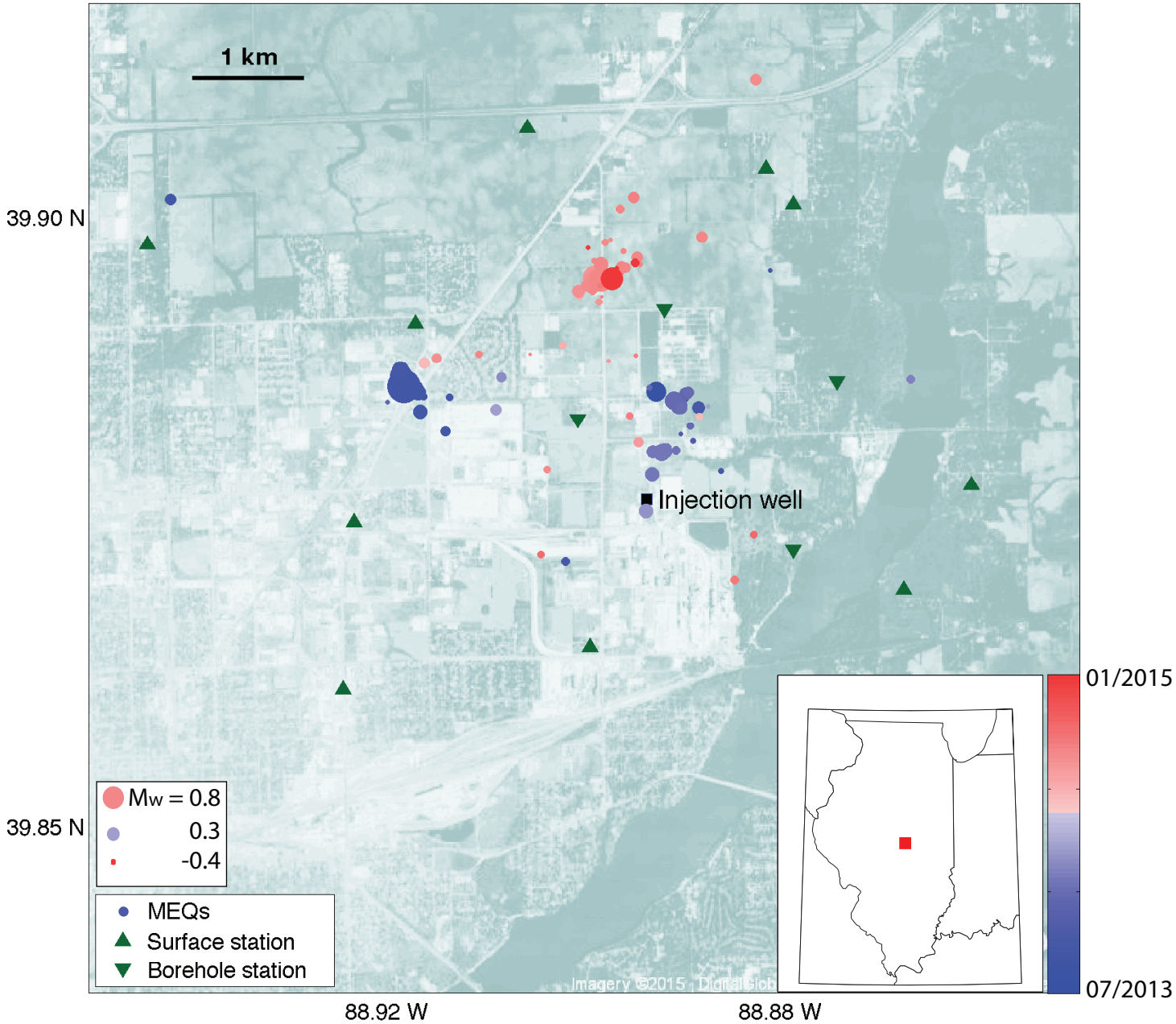
science for a changing world

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 15 stations.
- 3-component broadband (*Trillium Compact 120*, flat vel. response 120s to 100Hz) at 9 surface-only stations
- Start: July 2013
- Currently 15 stations installed (7 borehole)
- All data available at IRIS



Catalog locations



USGS
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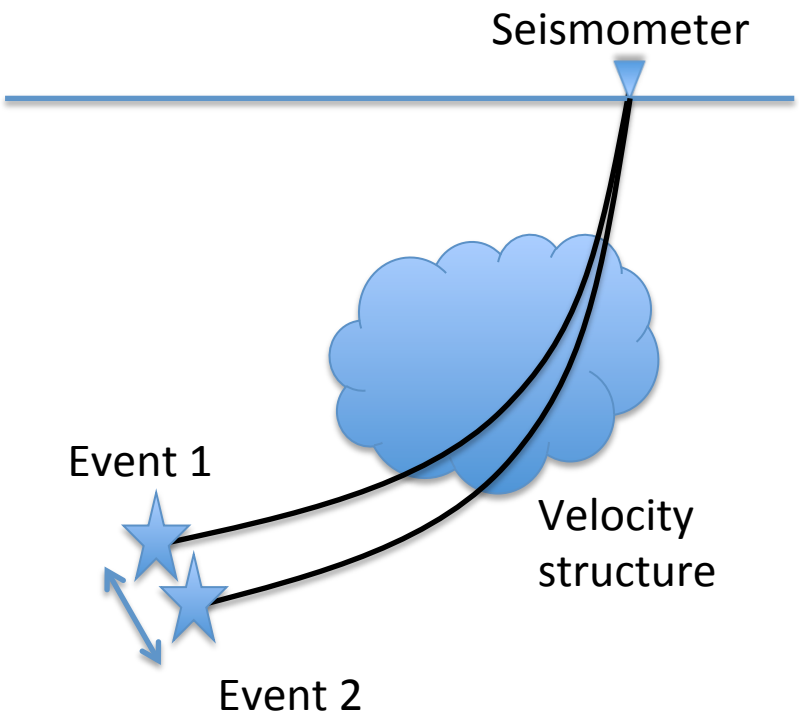
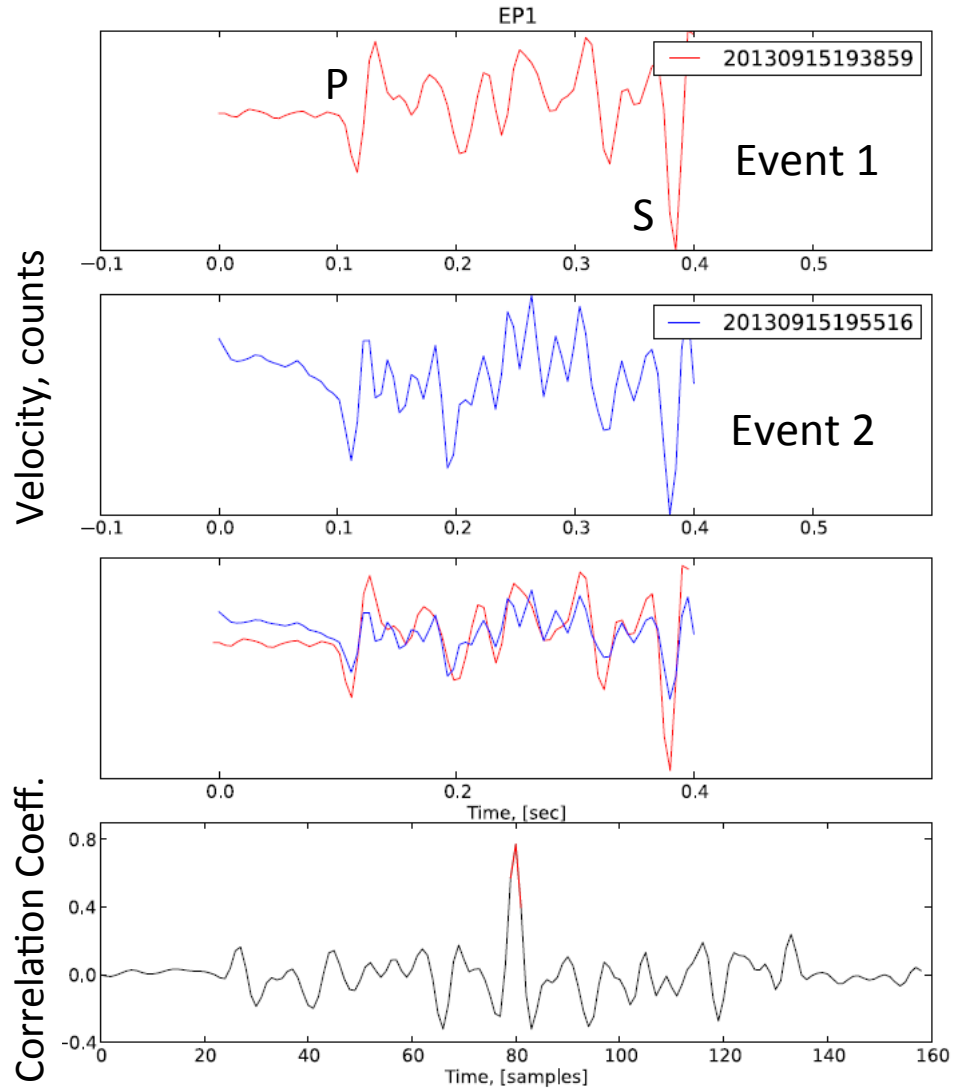
Double-difference relocation



High-precision relative locations



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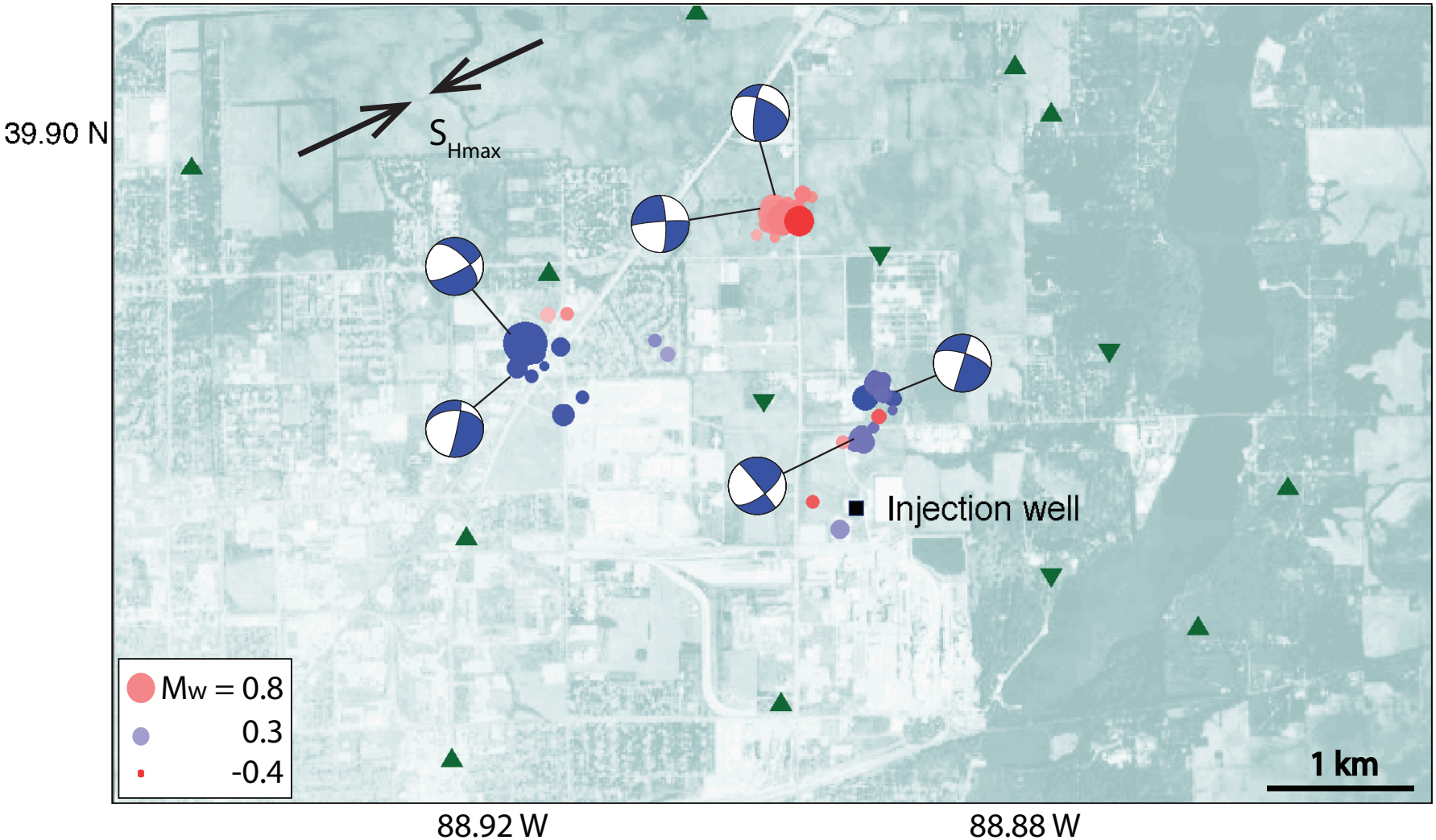
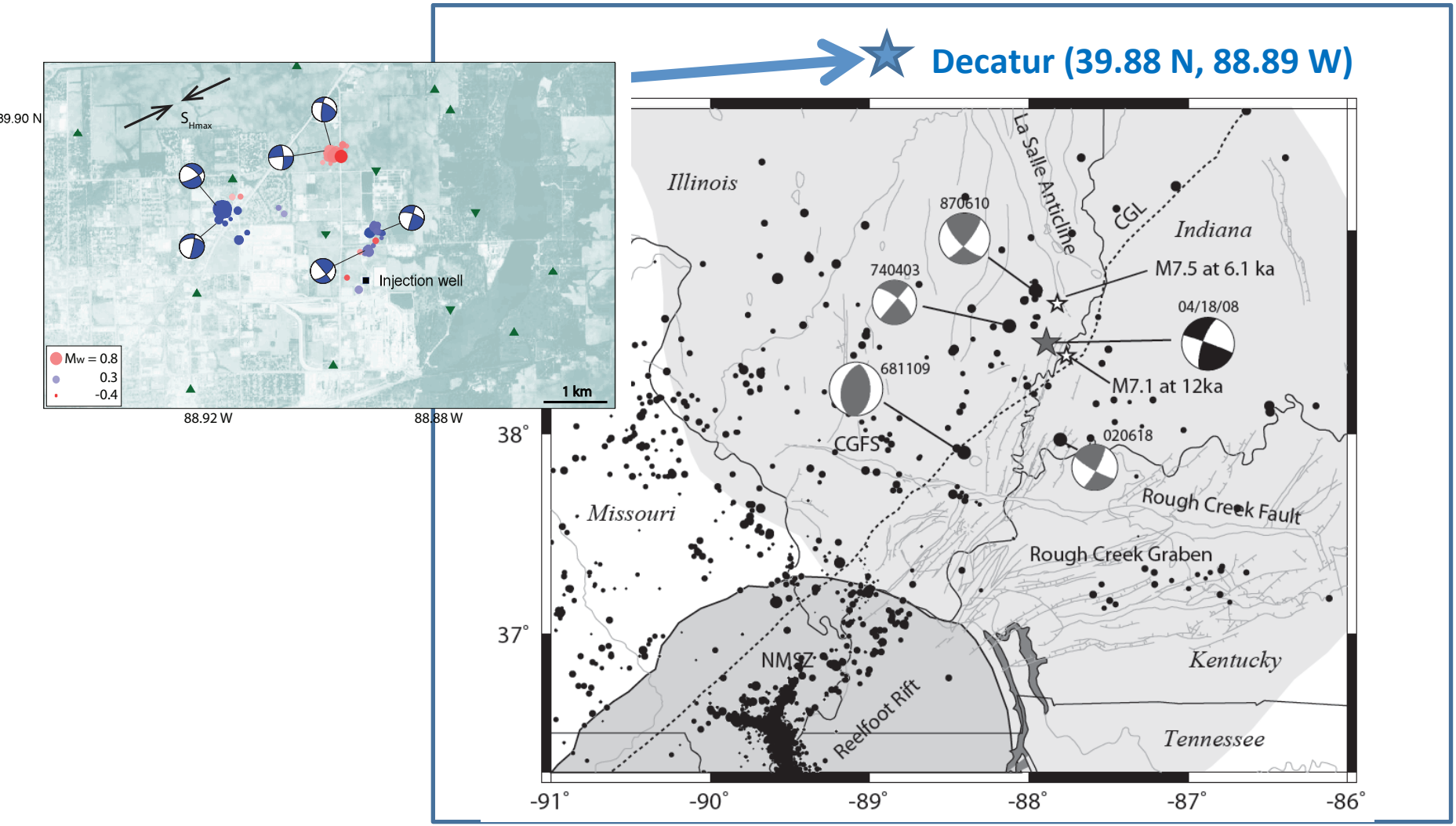


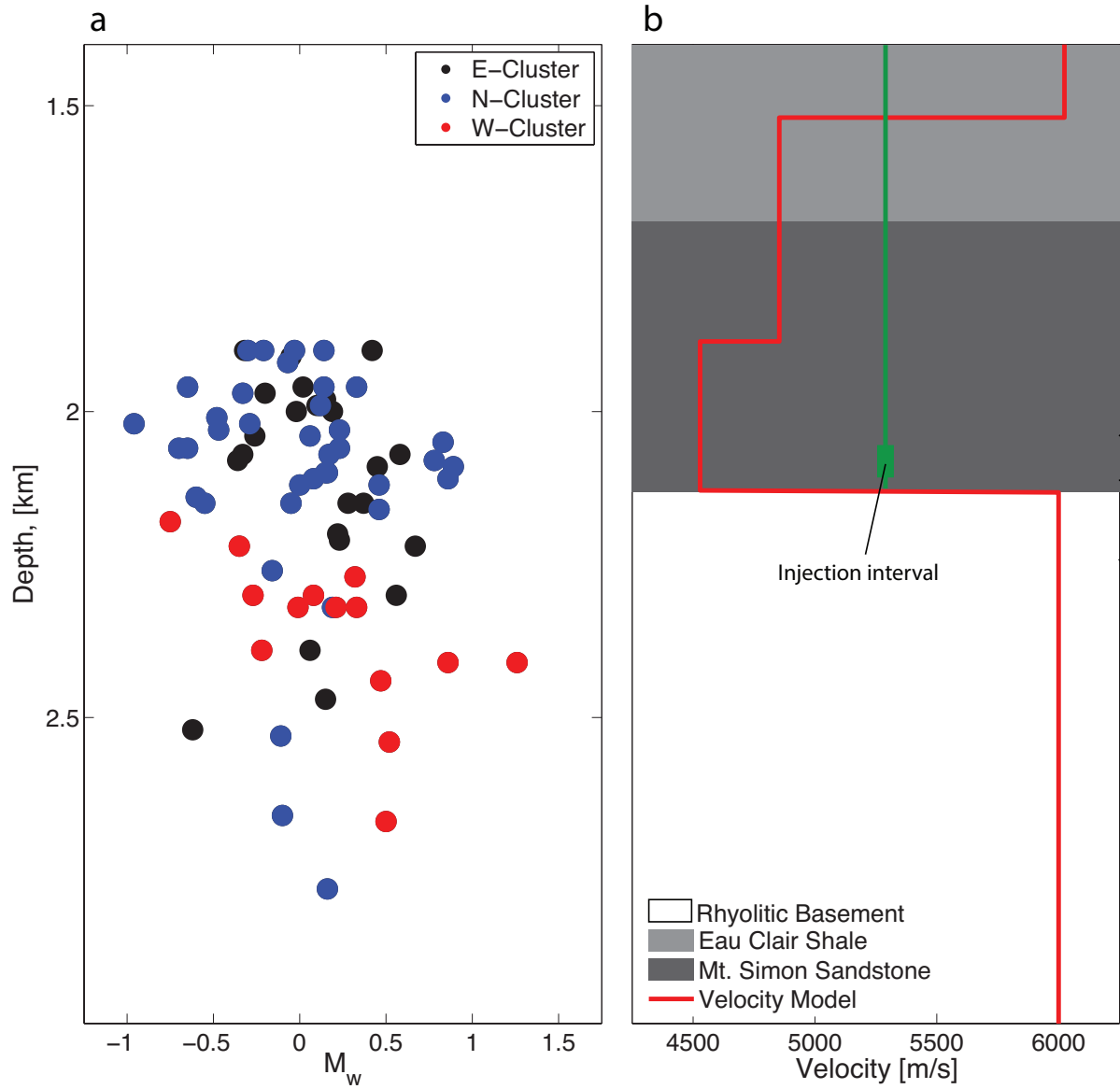
Regional Seismicity



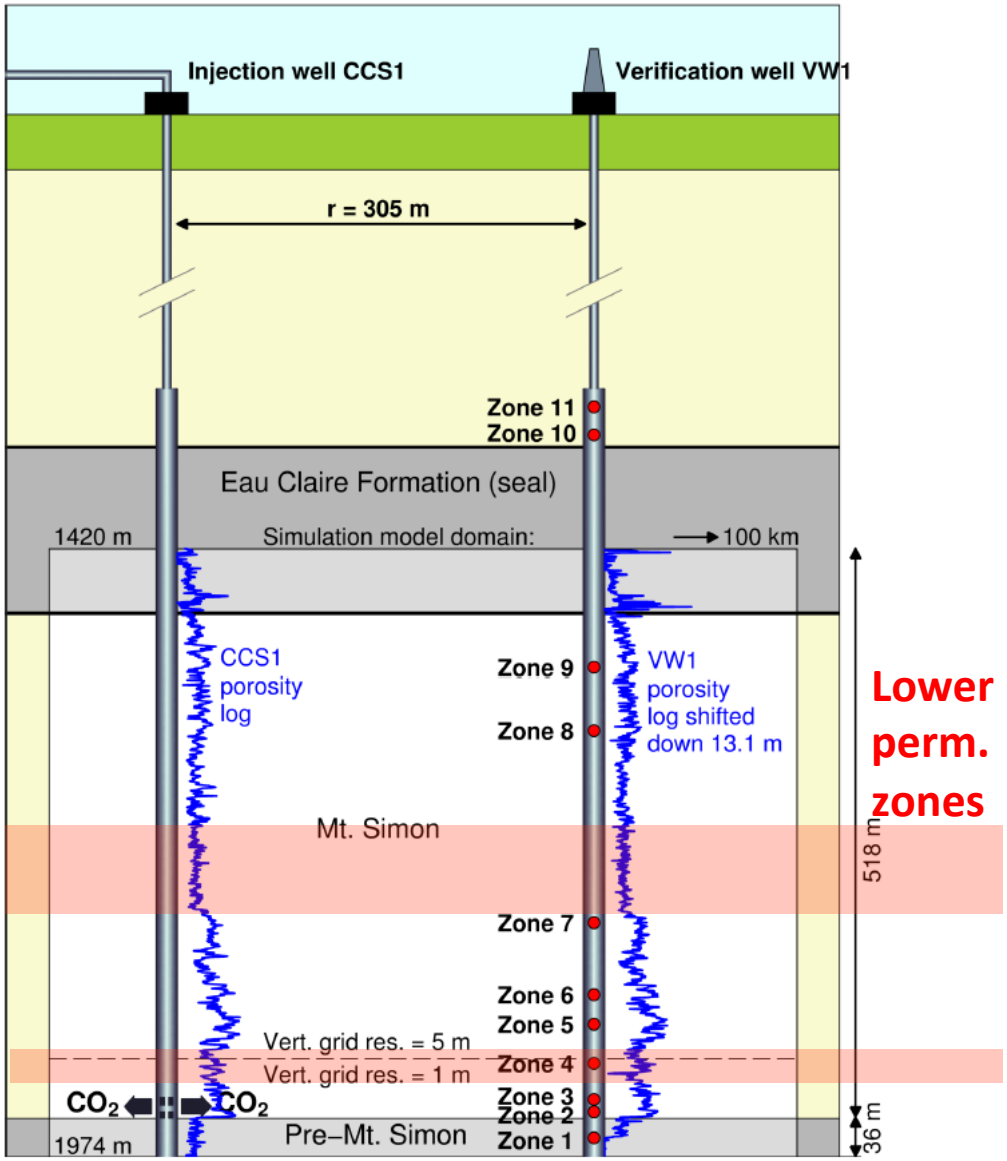
Seismicity in Wabash Valley Fault System and northern NMSZ *(Hamburger et al. 2011)*

Depths

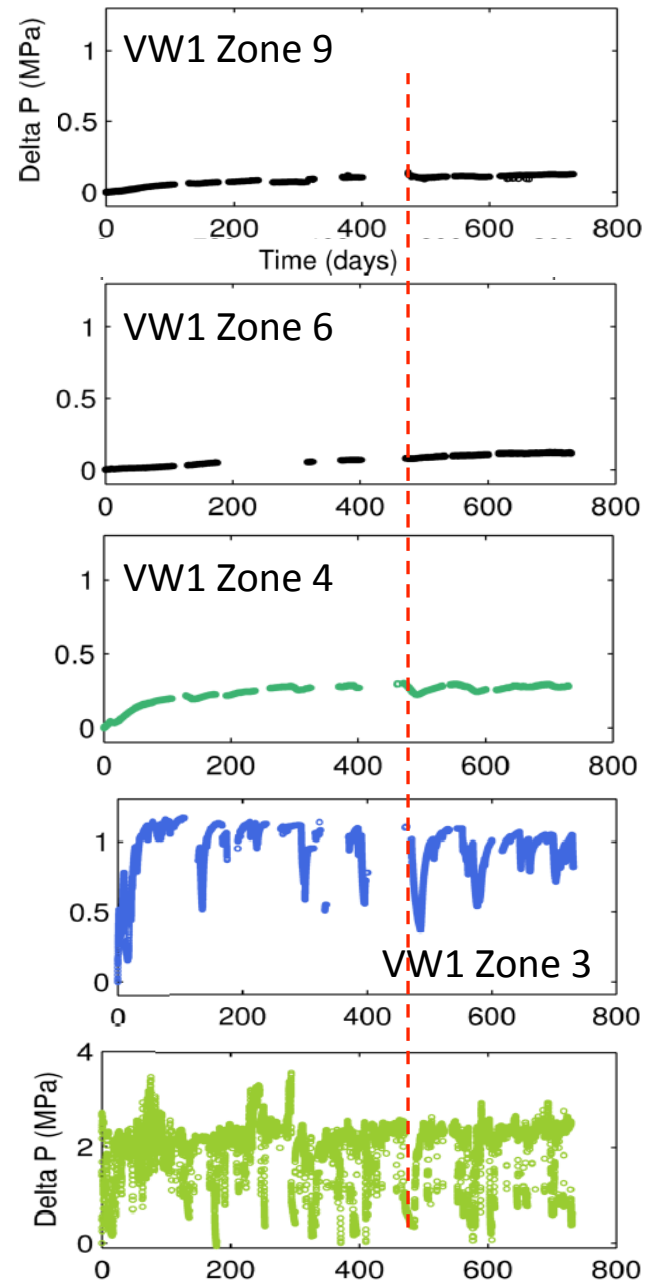
- East cluster near injection well appears slightly shallower, but still in basement
- All events are well below Eau Claire Shale
- Comparison of velocity models with SCS yielded similar results, but no access to S-wave velocity model



Hydrologic stratification of Mt. Simon



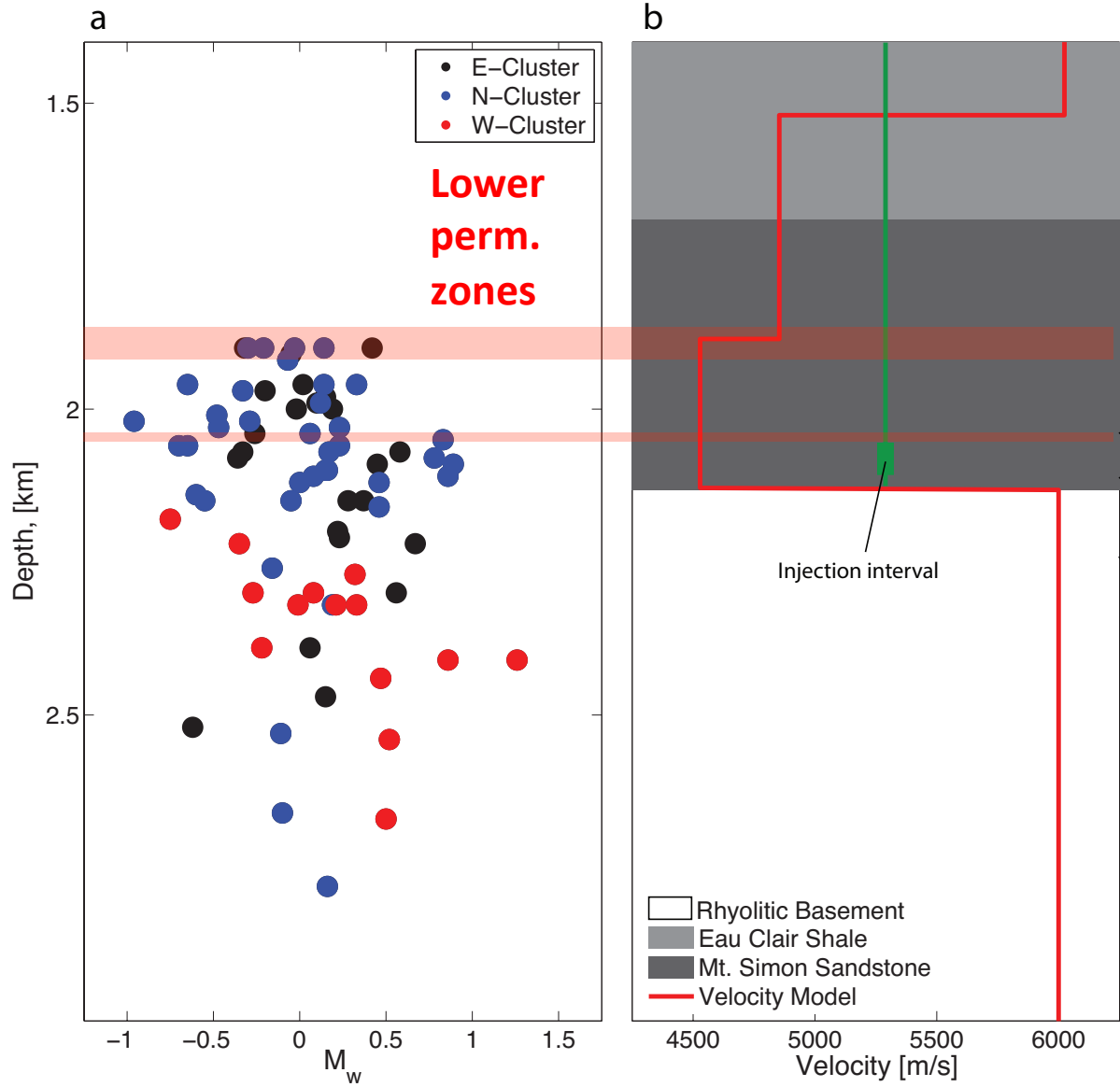
Lower perm. zones



Strandli et al., Energy Procedia, 2013

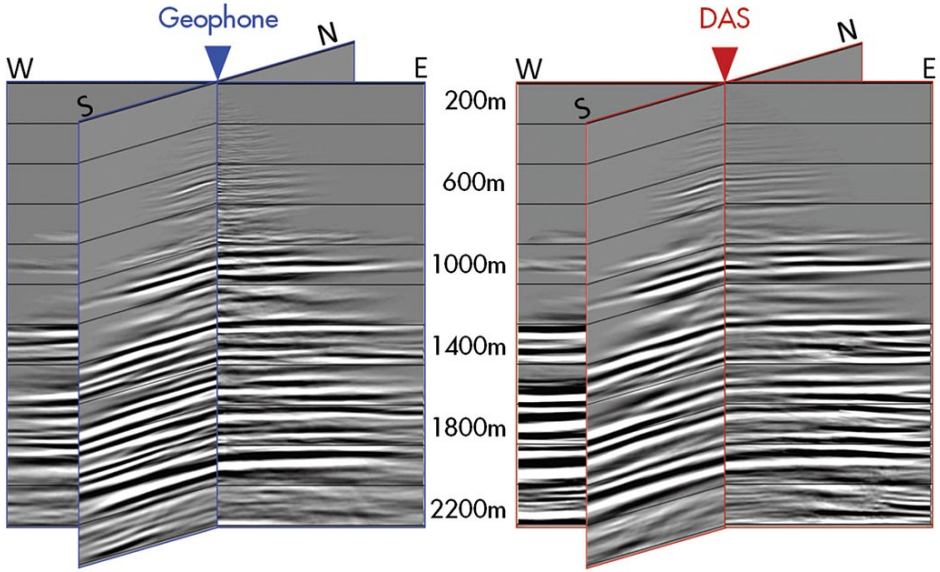
Depths

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



Summary

- 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.
- Many of the same key ingredients to induced seismicity seen across regions of significant wastewater disposal
- The next phase of the Decatur project will test whether the shallow injection serves to insulate the basement from pore pressure changes, thus likely reducing the likelihood of significant felt events in the basement.

Outlook & mitigation strategies

- Dense instrumentation at injection sites and accessible injection/production data are a key ingredient
- Imaging of basement faults impossible with current techniques, MEQs may be our best bet.
- Second phase of project will inject slightly shallower, above the deepest baffle, to test hypothesis of basement isolation