IDENTIFYING SEISMIC RISK IN THE APPALACHIAN BASIN GEOTHERMAL PLAY FAIRWAY ANALYSIS PROJECT USING POTENTIAL FIELDS, SEISMICITY, AND THE WORLD STRESS MAP

Frank Horowitz
Cornell University
3 November 2015

The information, data, or work presented herein was funded in part by the Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy, under Award Number DE-EE0006726.

The GPFA-AB Team

- Project Partners
  - Cornell University: **Terry Jordan (PI)**, Frank Horowitz, Jery Stedinger, Jefferson Tester, Erin Camp, Calvin Whealton, Jared Smith
  - Southern Methodist University: **Maria Richards (Lead)**, Cathy Chickering Pace, Matt Hornbach, Zachary Frone, Christine Ferguson, Rahmi Bolat, Maria Beatrice Magnani
  - West Virginia University: **Brian Anderson (Lead)**, Kelydra Welcker, Xiaoning He

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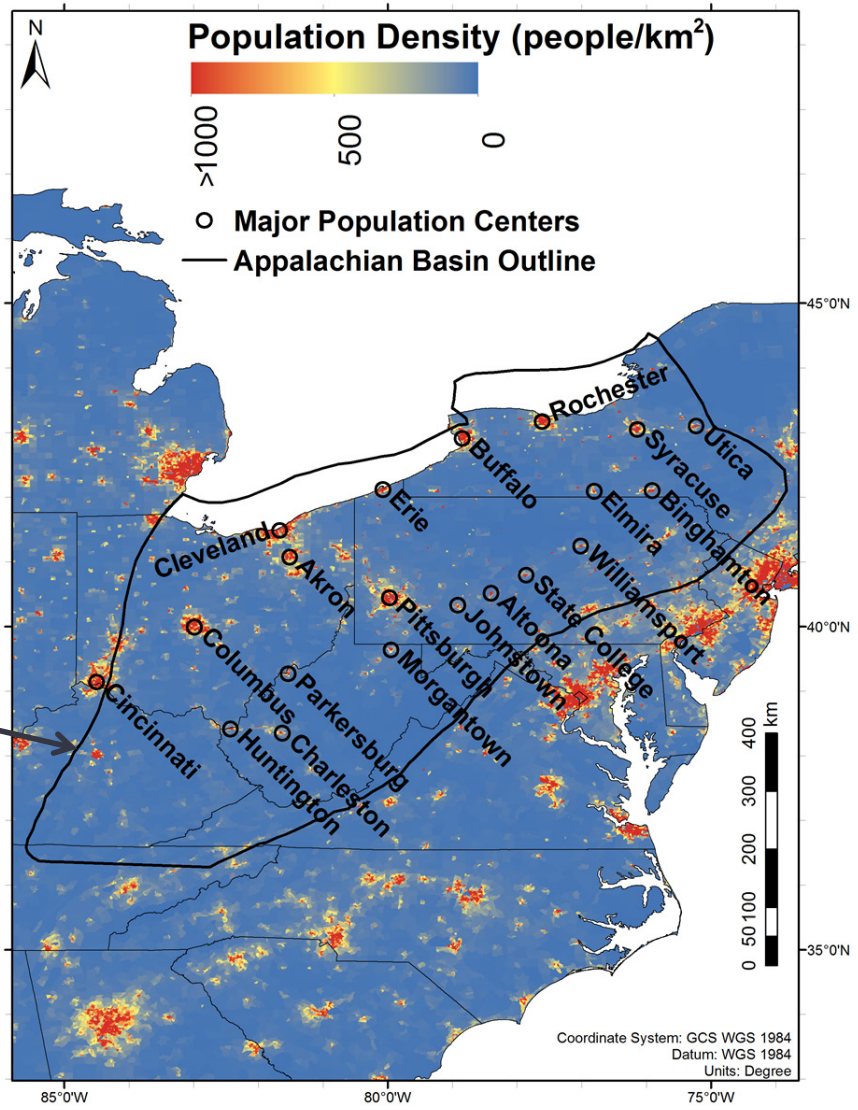
Play Fairway Analysis Area

Potential users of low-temperature geothermal resource found widely

Appalachian sedimentary basin



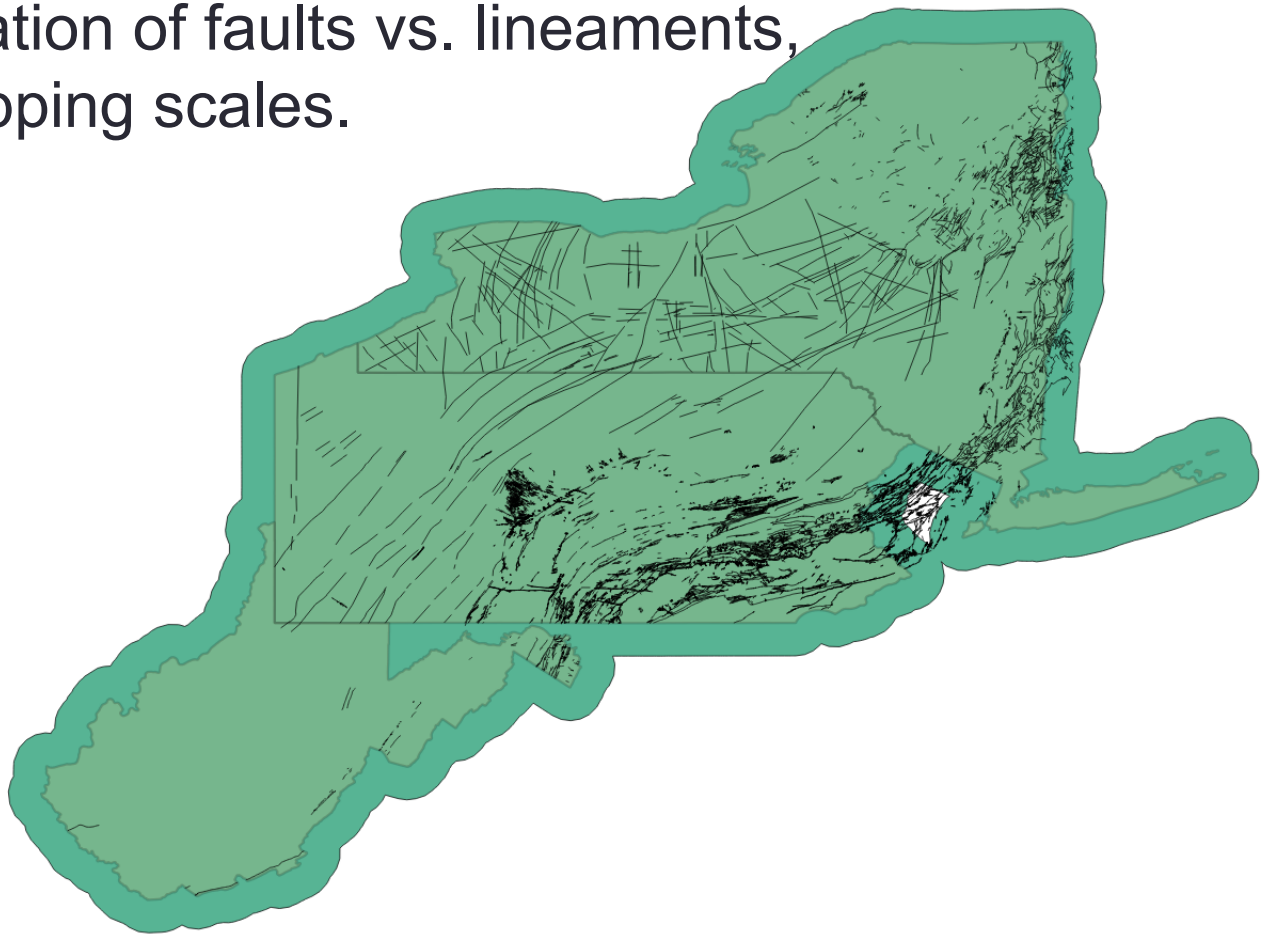
Focus area:
New York
Pennsylvania
West Virginia

Why Seismic Hazards Here?

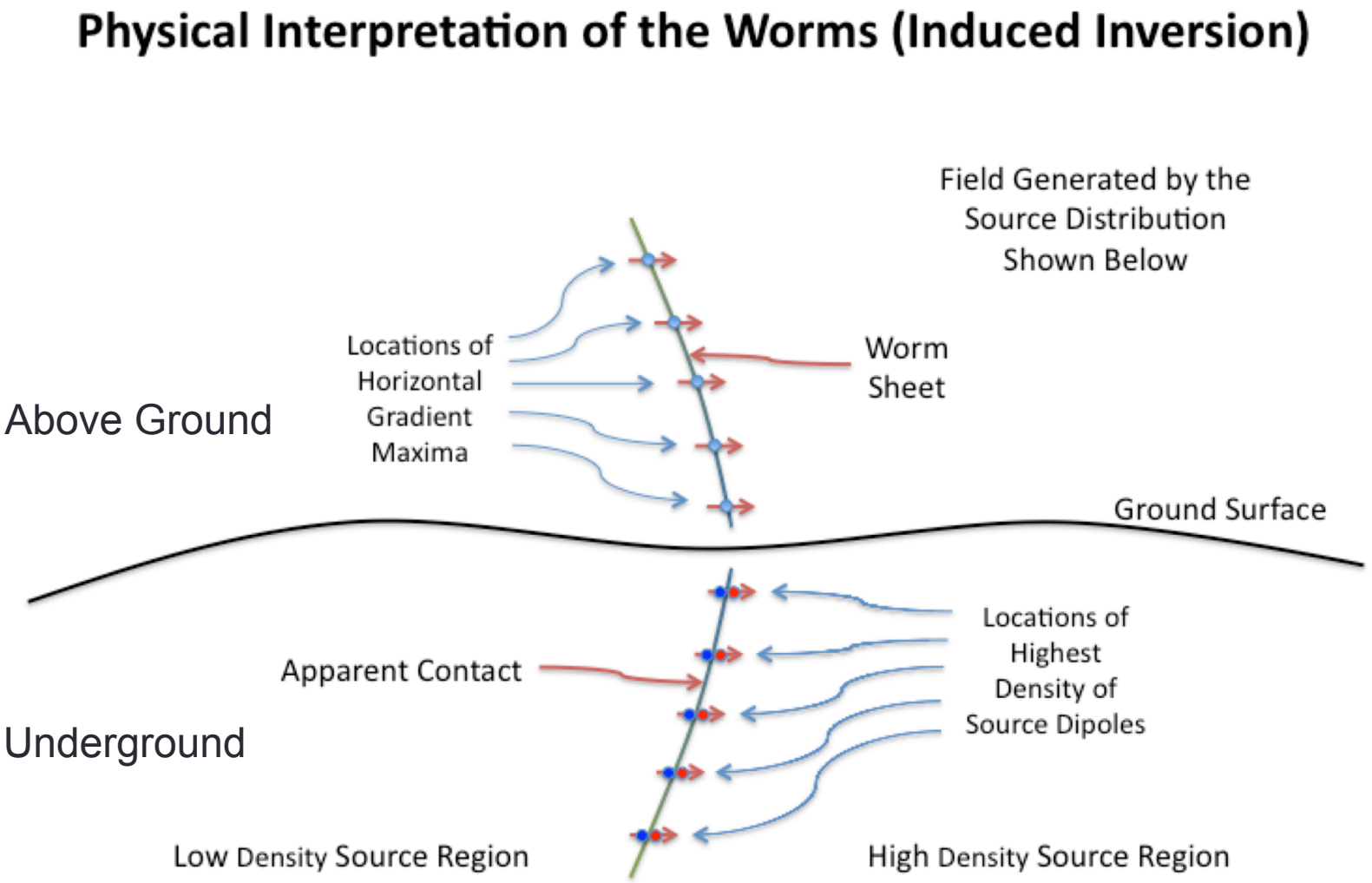
- For most geothermal exploration, finding faults is a *good* thing
  - Because it tends to locate either slip or dilation-induced permeability tendency, or to identify structural controls on flow systems
- In our region, we felt a strong issue would be a potentially detrimental effect on geothermal projects' "social license to operate"
- Seismicity has adversely affected geothermal projects in at least:
  - Basel, Switzerland
  - The Geysers, California
  - Landau, Germany
  - And those are only off the top of my head from the last decade or so…
- So we set out to identify potential locations at risk of induced seismicity to caution users of our "Geothermal Play Fairways"

Pre-existing “Fault” Maps

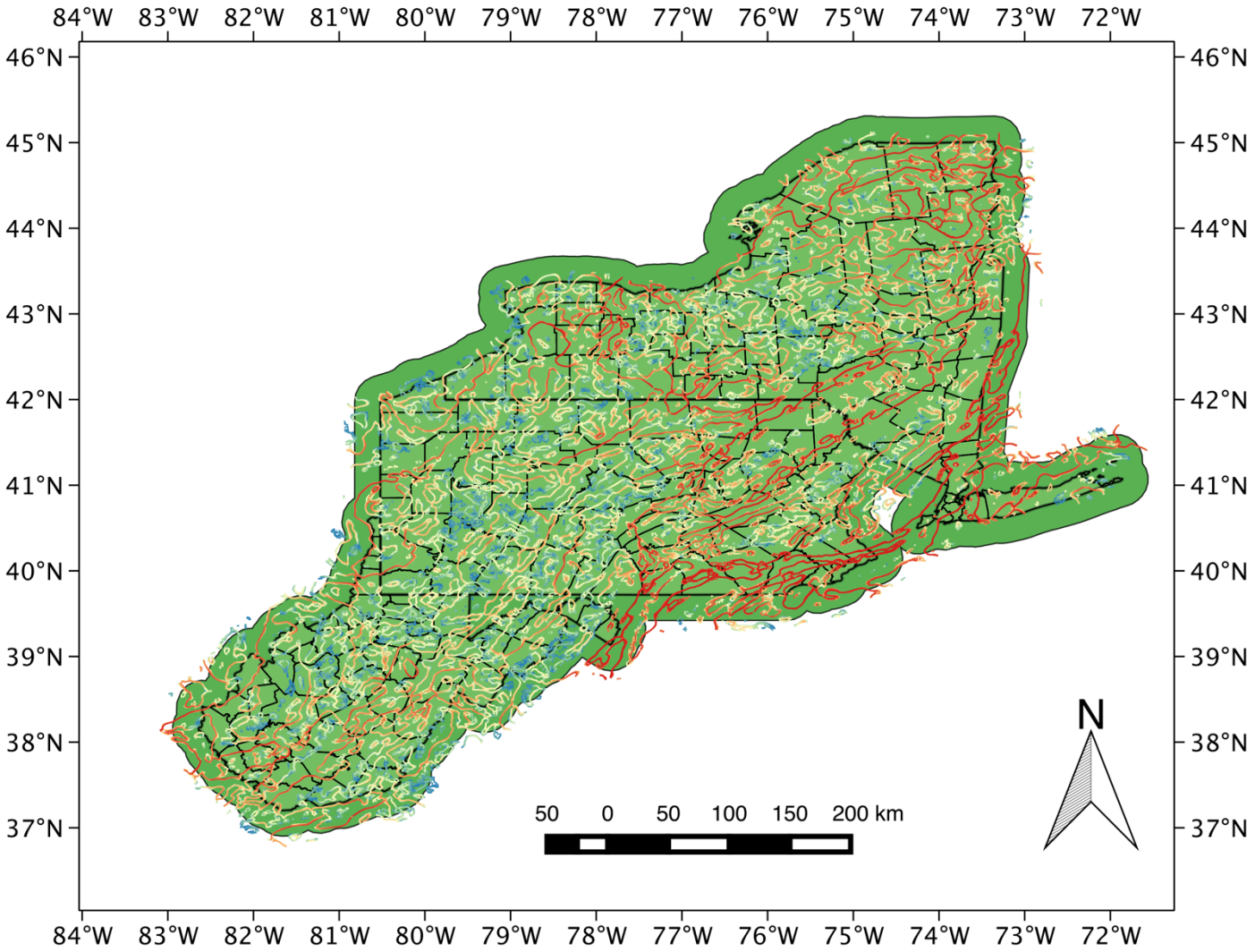
Do not share the GPFA-AB boundaries or scale.
Leads to problems of uneven coverage,
varying interpretation of faults vs. lineaments,
and different mapping scales.



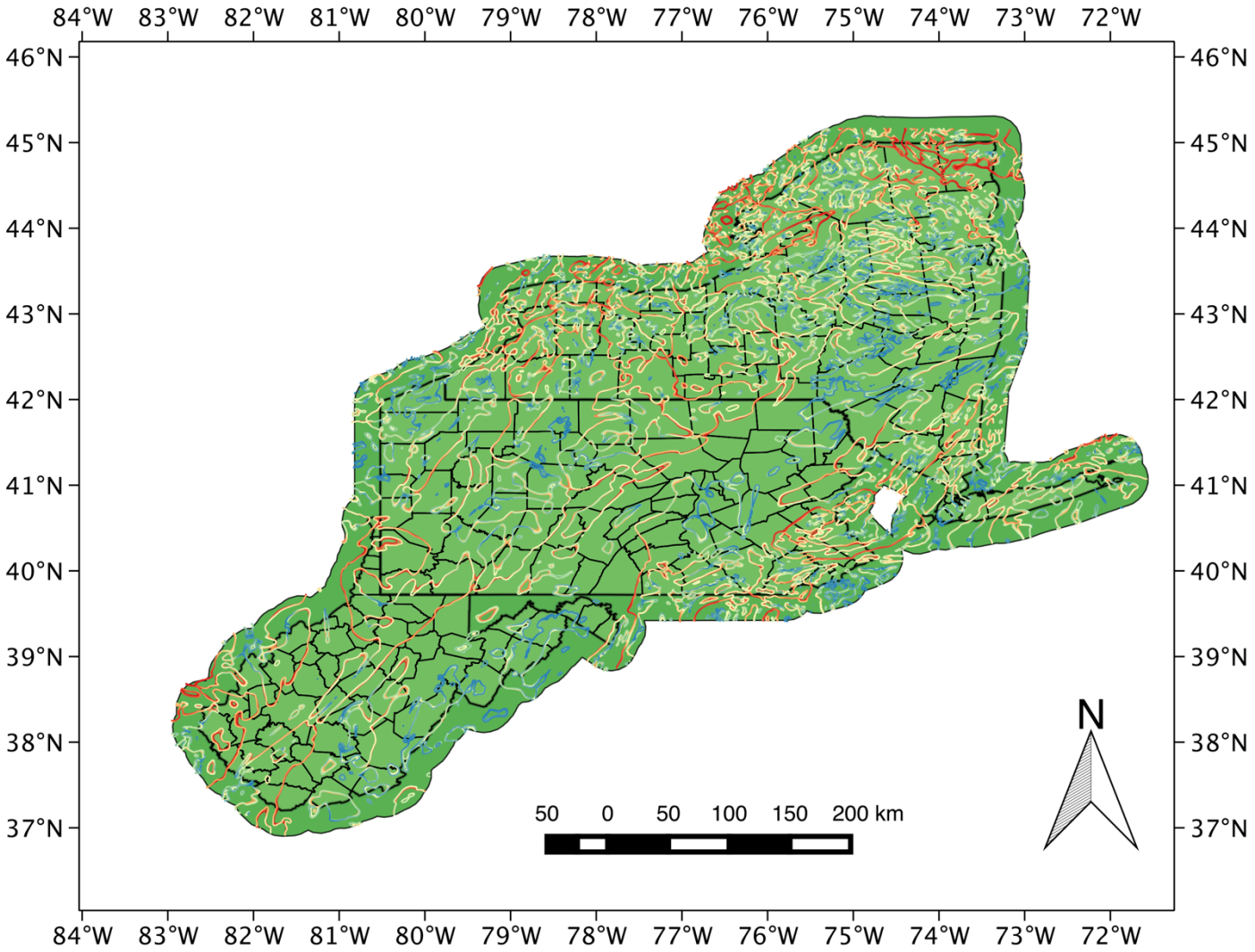
Poisson Wavelet Multi-Scale Edge Analysis of Potential Fields ("Worms") in One Slide



Gravity Worms for the Region

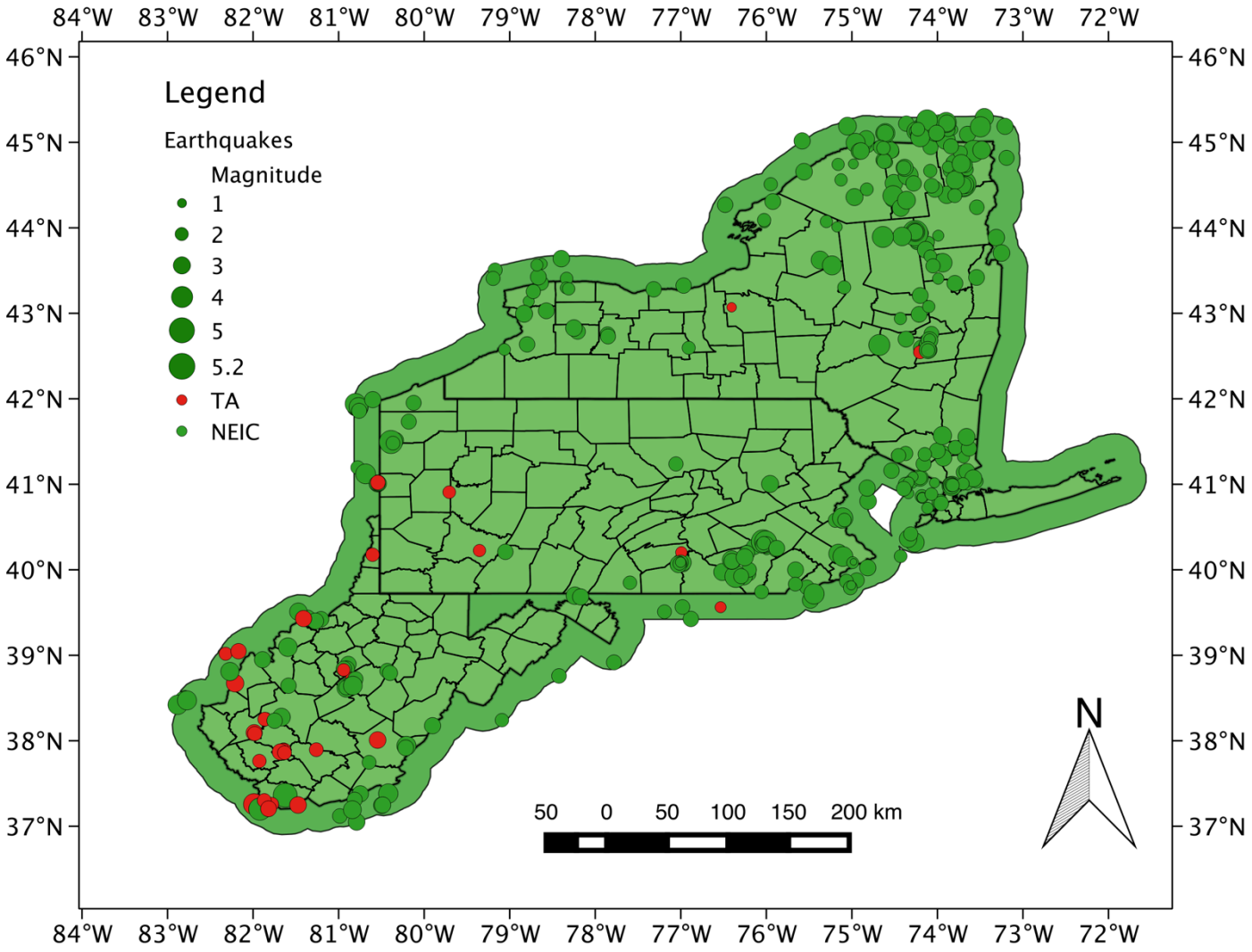


Magnetic Worms for the Region



Earthquakes

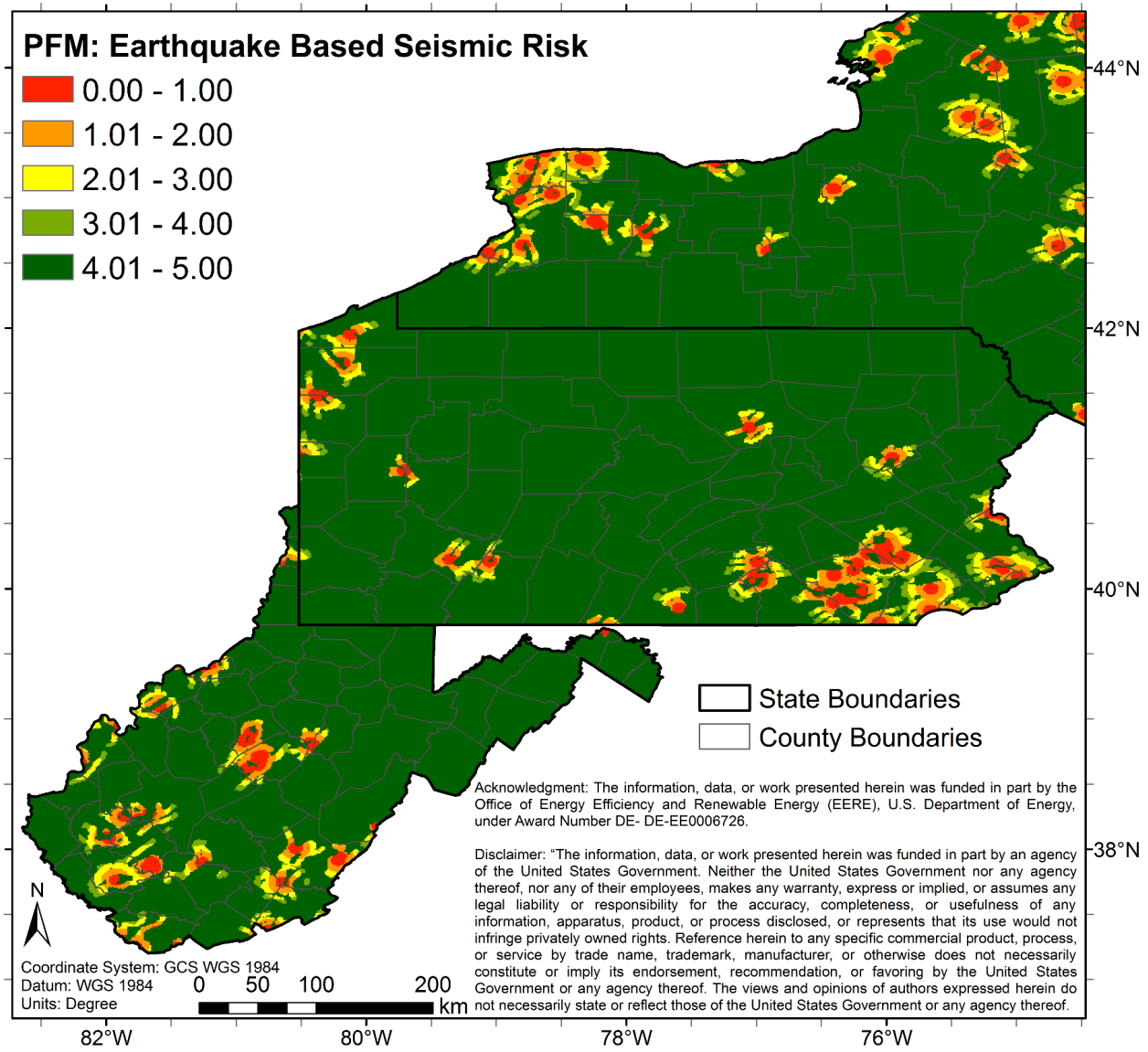
Events from the NEIC (green) and Earthscope's TA (red) occurred between 1/1/1965 and 31/5/2015. An approximate time of day based decontamination procedure was used to remove mine/quarry blasts from the TA events which could have also removed a bit less than half of the real TA EQs.



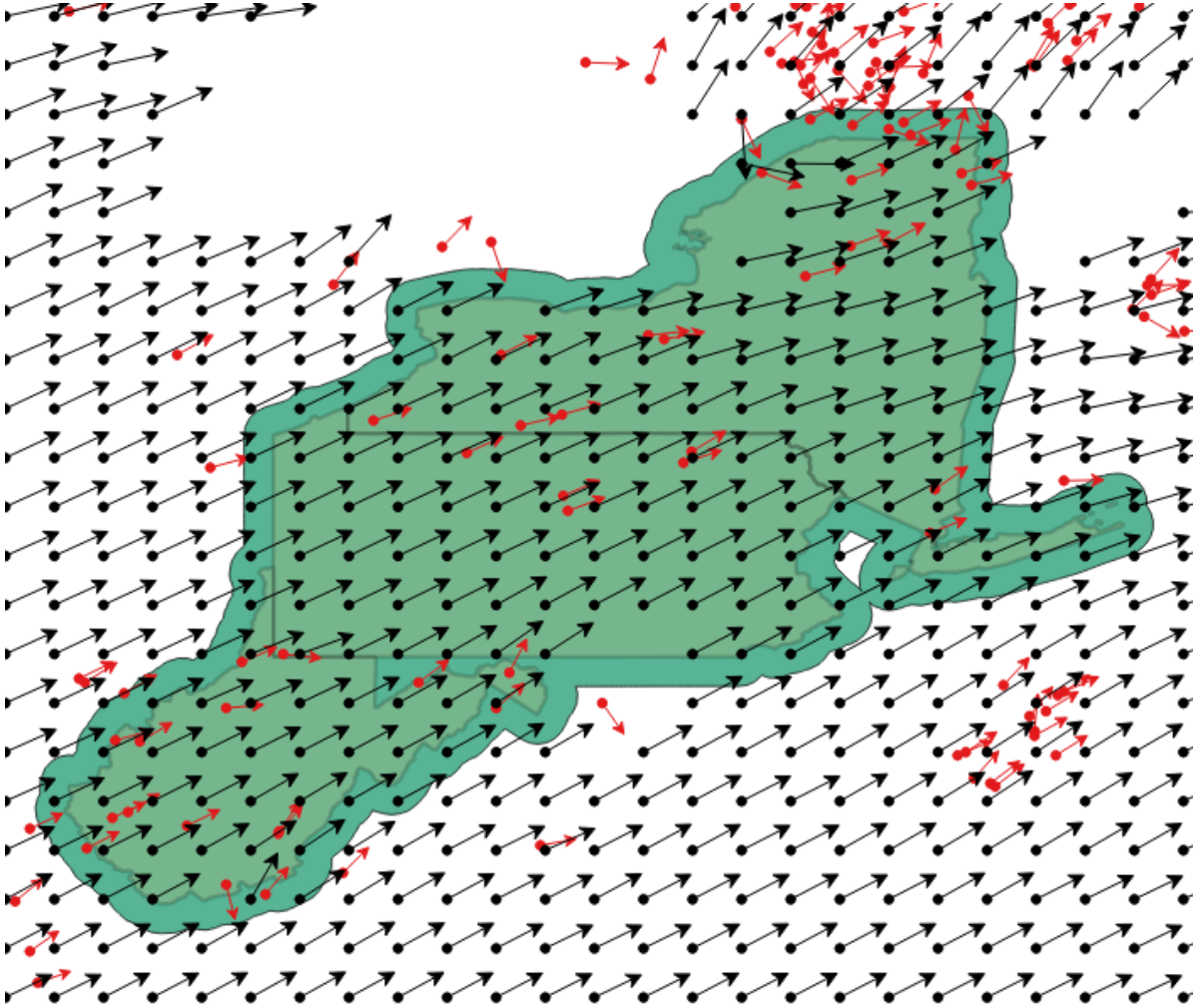
Two Techniques for Identifying Risky Structures

1. Worms near recorded events
2. Worm orientation in regional stress field

All Worms Within 20 km of EQs

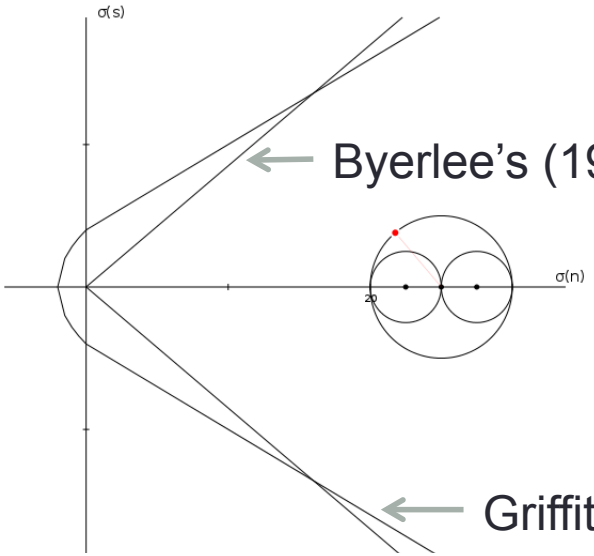


World Stress Map



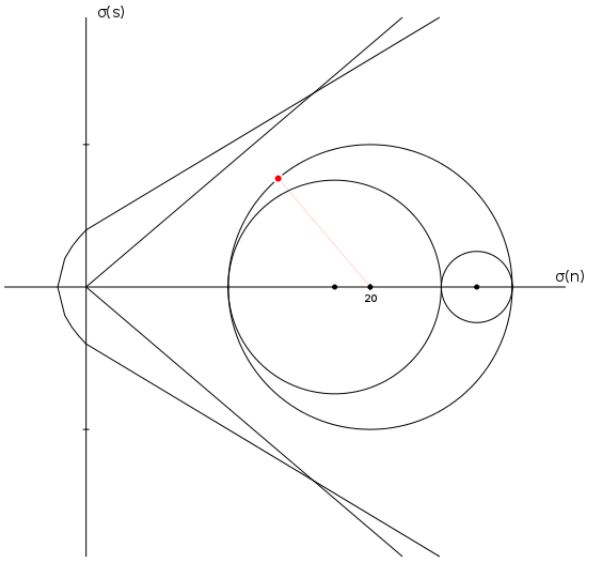
From Heidbach et al. 2010.

Orientation in Stress Field



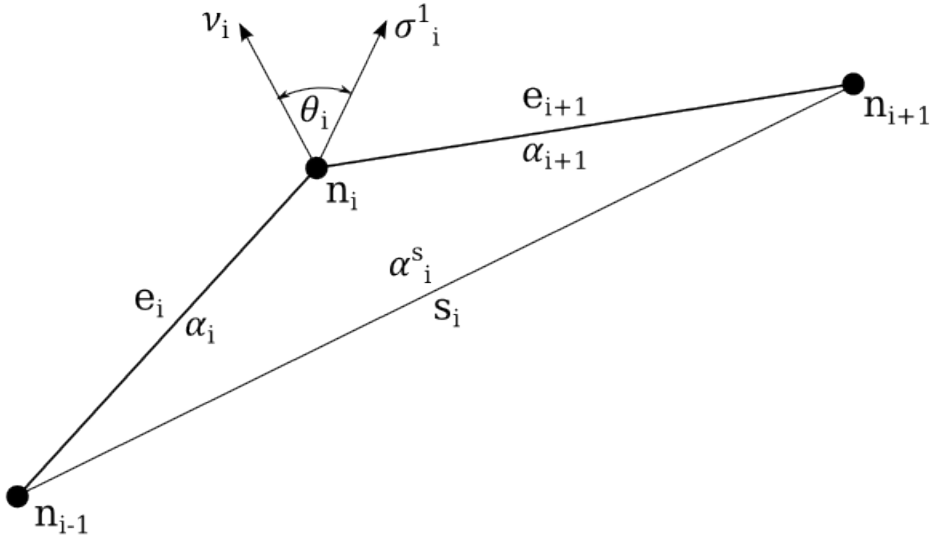
Byerlee's (1978) Law

Griffith-Coulomb Failure

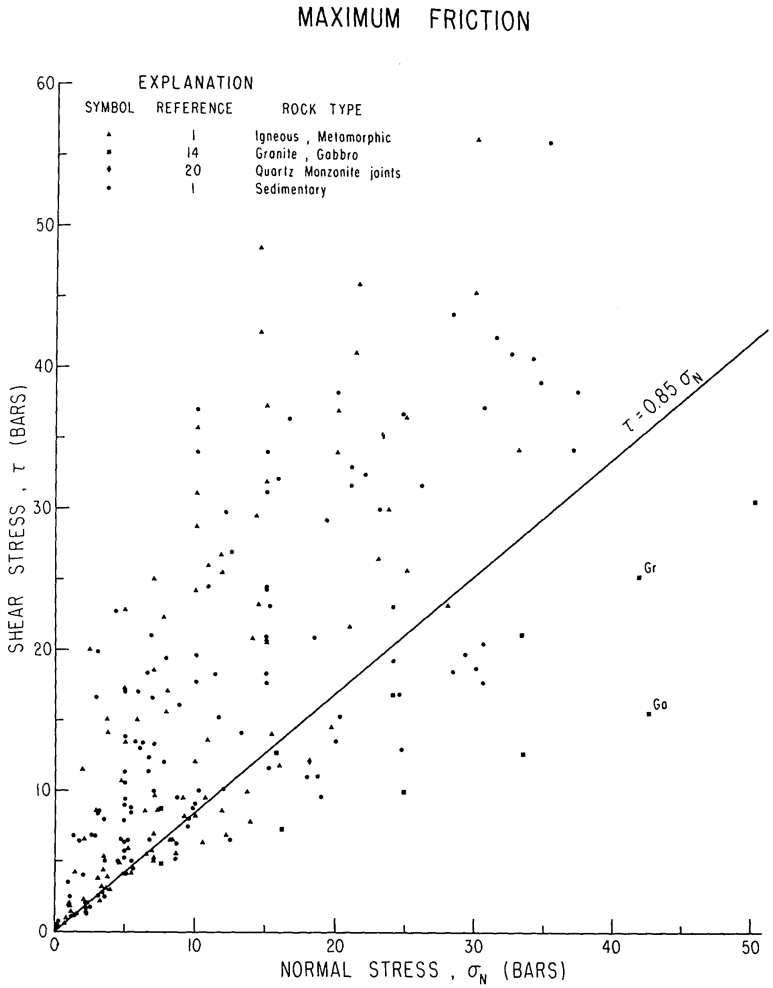


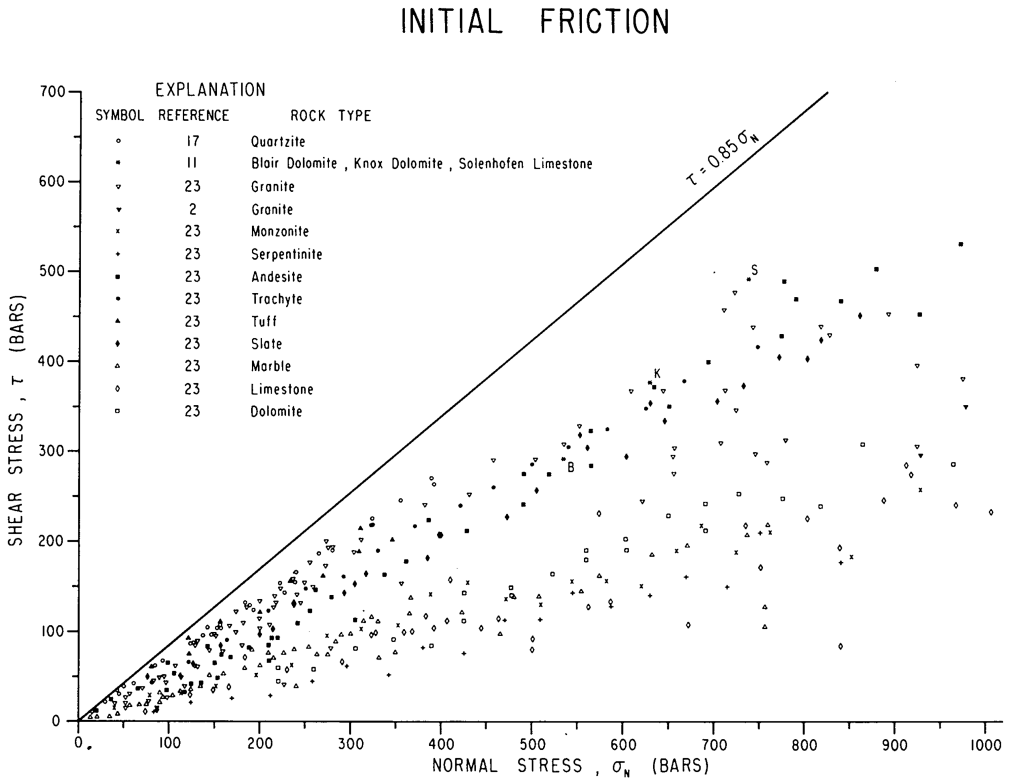
Assume worms are representing vertically dipping structures and σ_3 is horizontal.

⇒ Orientation in σ_1 direction and slip tendency is a function of azimuth only



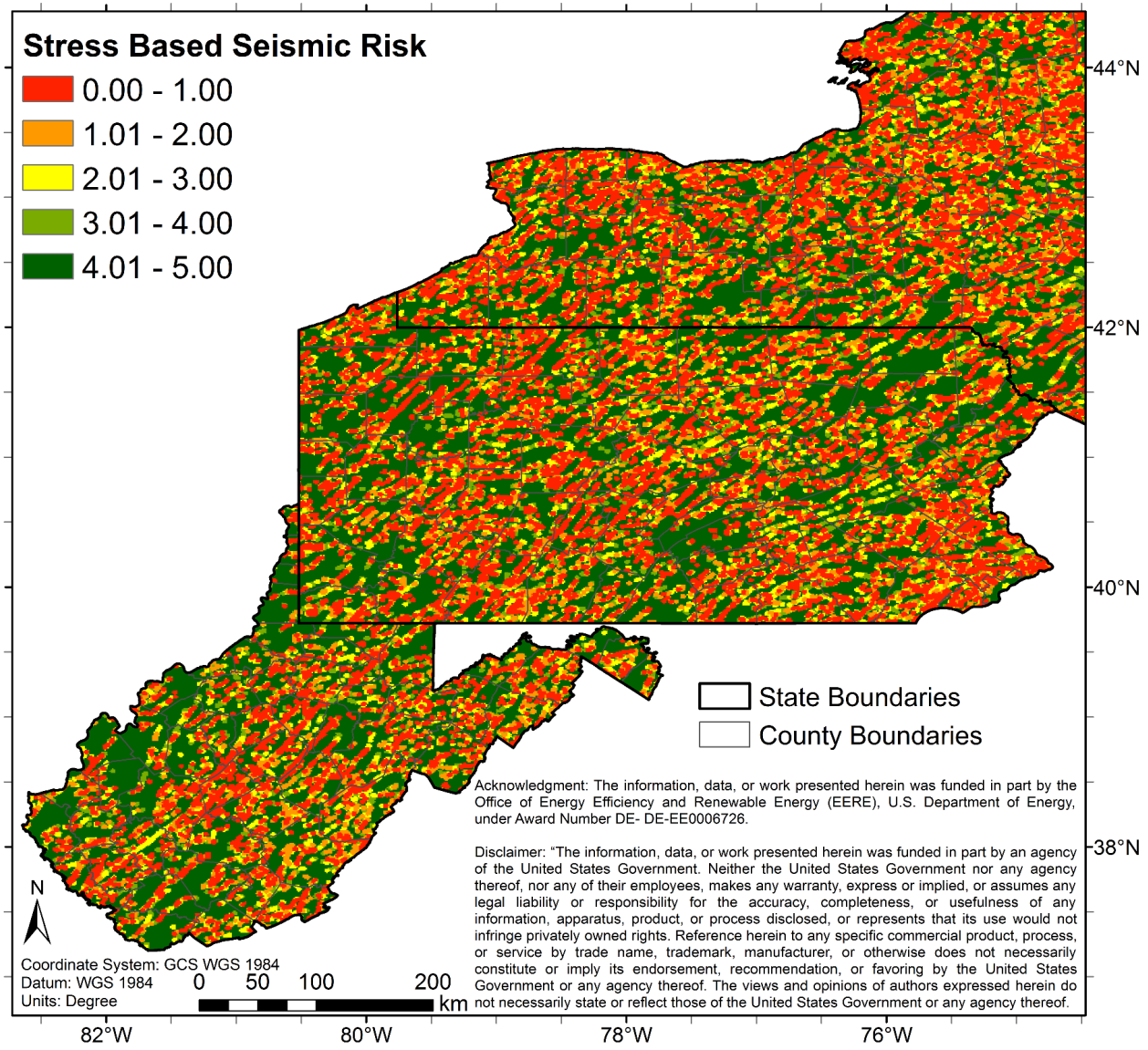
Brief Aside: Byerlee's Law



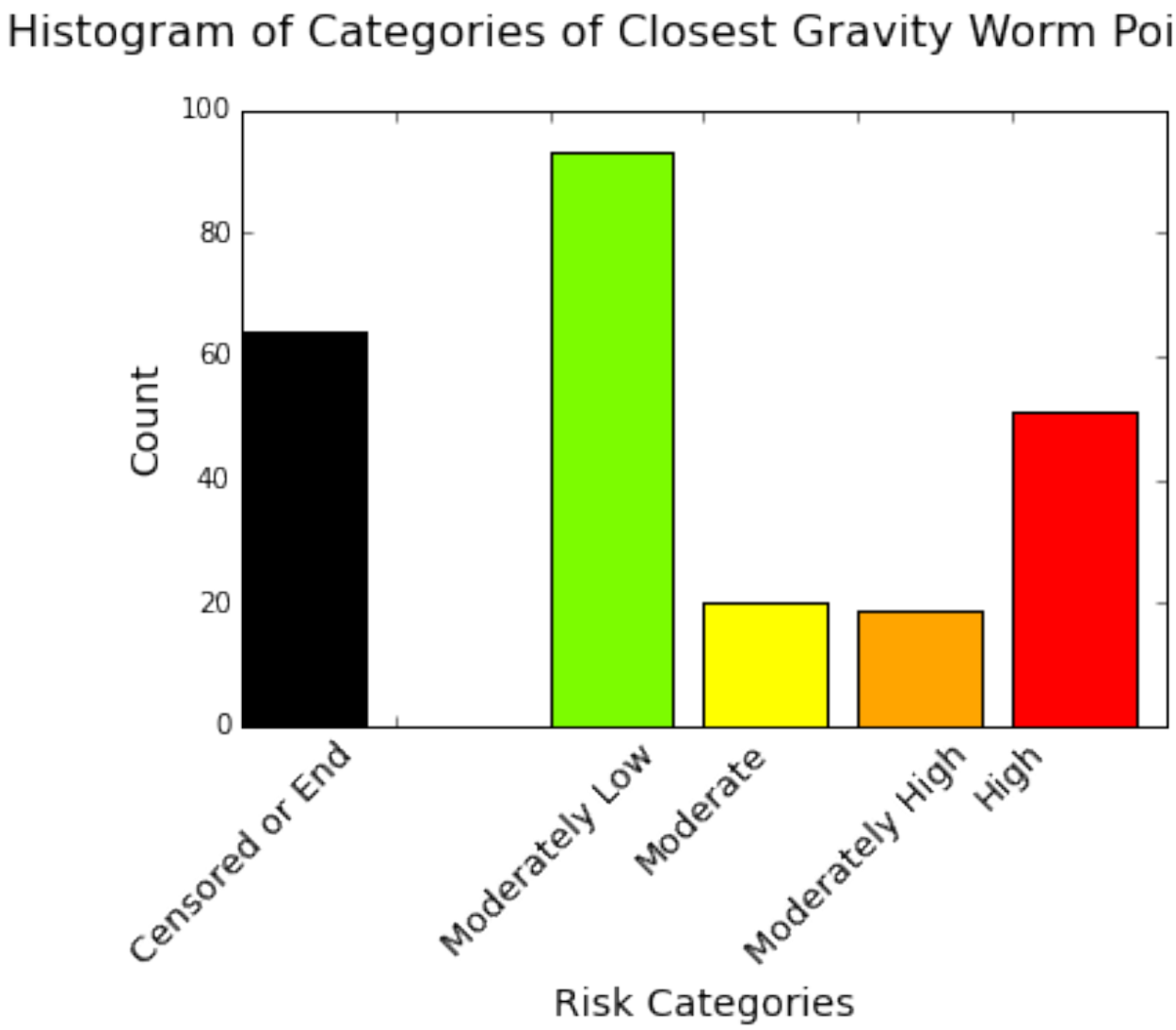


Byerlee (1978)

Worm Segments Oriented for Slip Relative to WSM



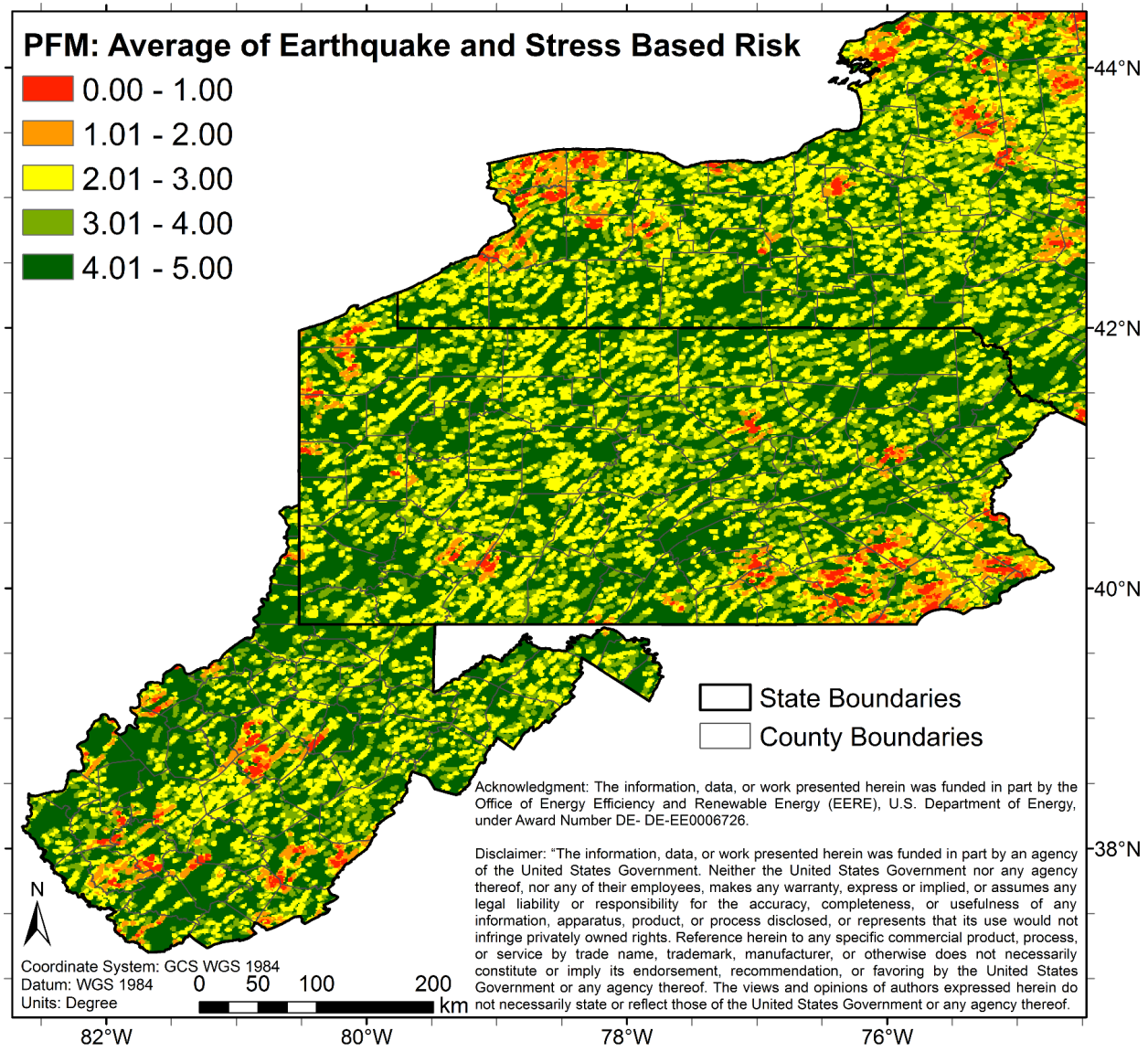
Some Slip Orientation Classification Statistics



MISORIENTATION

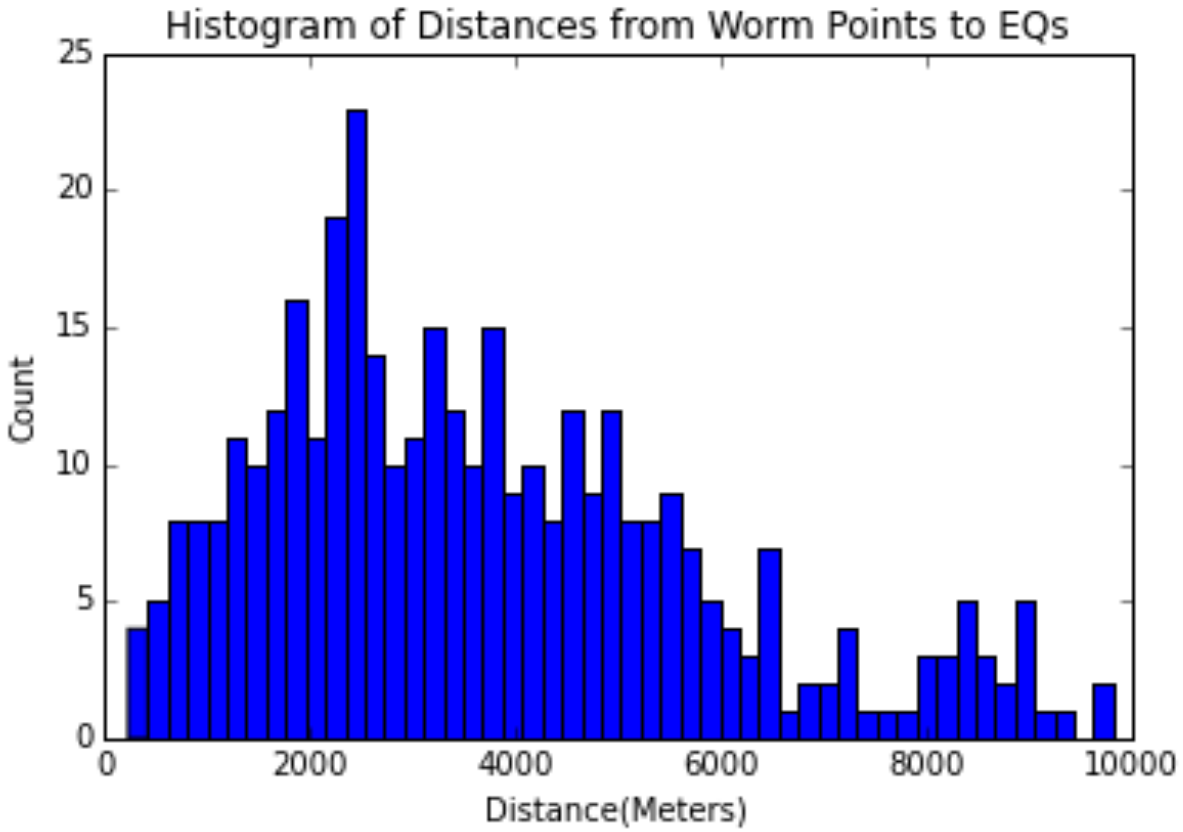
- **0-5°**
- **5-10°**
- **10-15°**
- **>15°**

Averaging Proximity and Orientation Risks



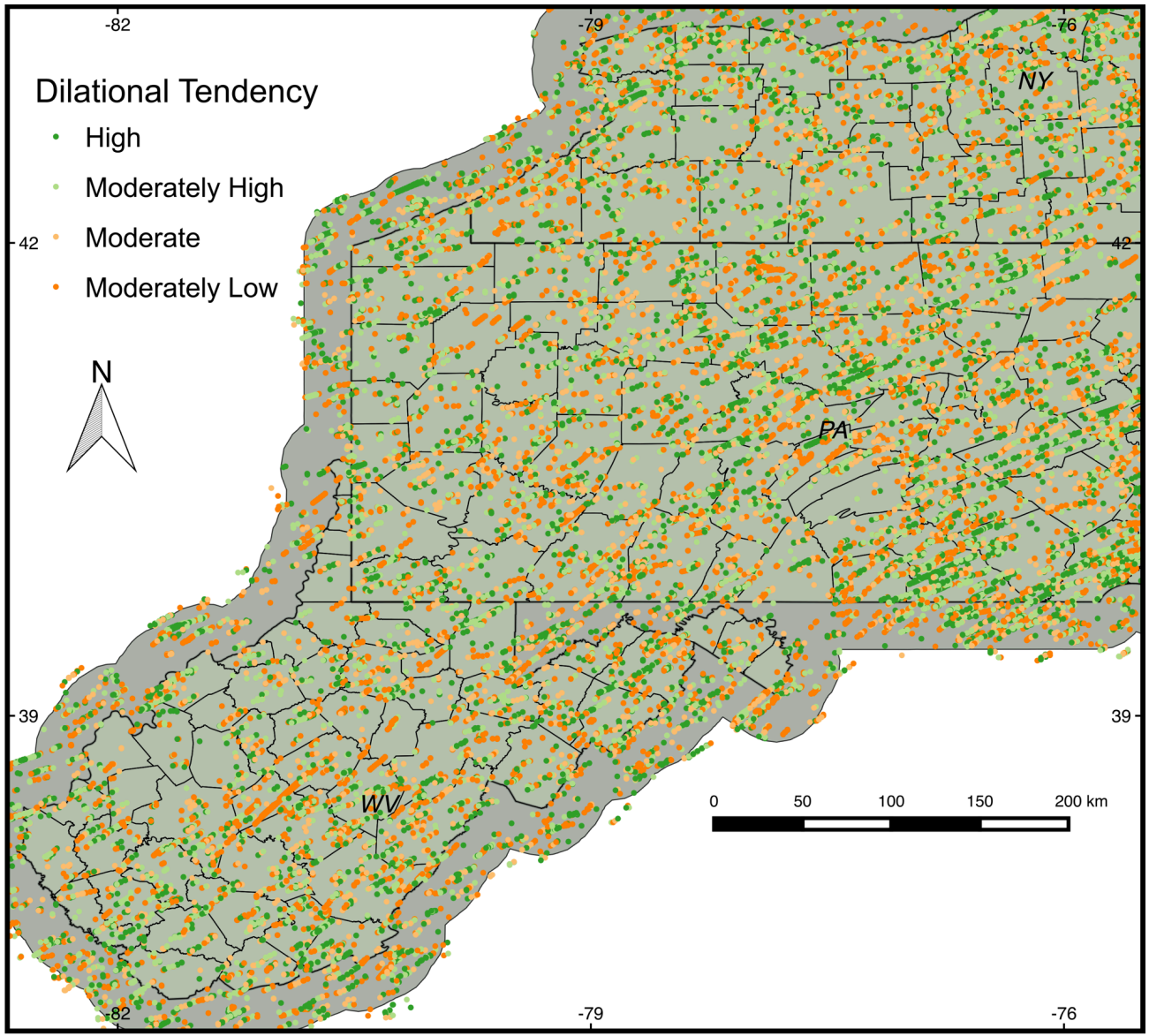
EQ-Worm Proximity Histogram

- From a sister USGS funded project over a different (Adirondack) footprint with Cindy Ebinger and Korin Carpenter (U. Rochester)



Worm Segments Oriented for Dilation Relative to WSM

These identify locations where one might find (mode I) **fracture** permeability for geothermal developments – a *good* thing!



Conclusions

- Some lateral discontinuities detected by worms are active faults
  - Even in intra-plate settings
- Worms nearby to EQs are candidate active faults
- Orientation-in-principal-stress-directions, while a necessary condition for induced seismicity under a Byerlee's Law model, doesn't actually appear to work very well for natural seismicity
  - Possibly due to a **lack of stress magnitude** information
  - Possibly due to that being an **incorrect model** for active faulting/ induced seismicity
- We've found locations where direct use geothermal prospects appear to be at higher risk of induced seismicity than for other locations

Thanks!

- Questions?

- frank.horowitz@cornell.edu