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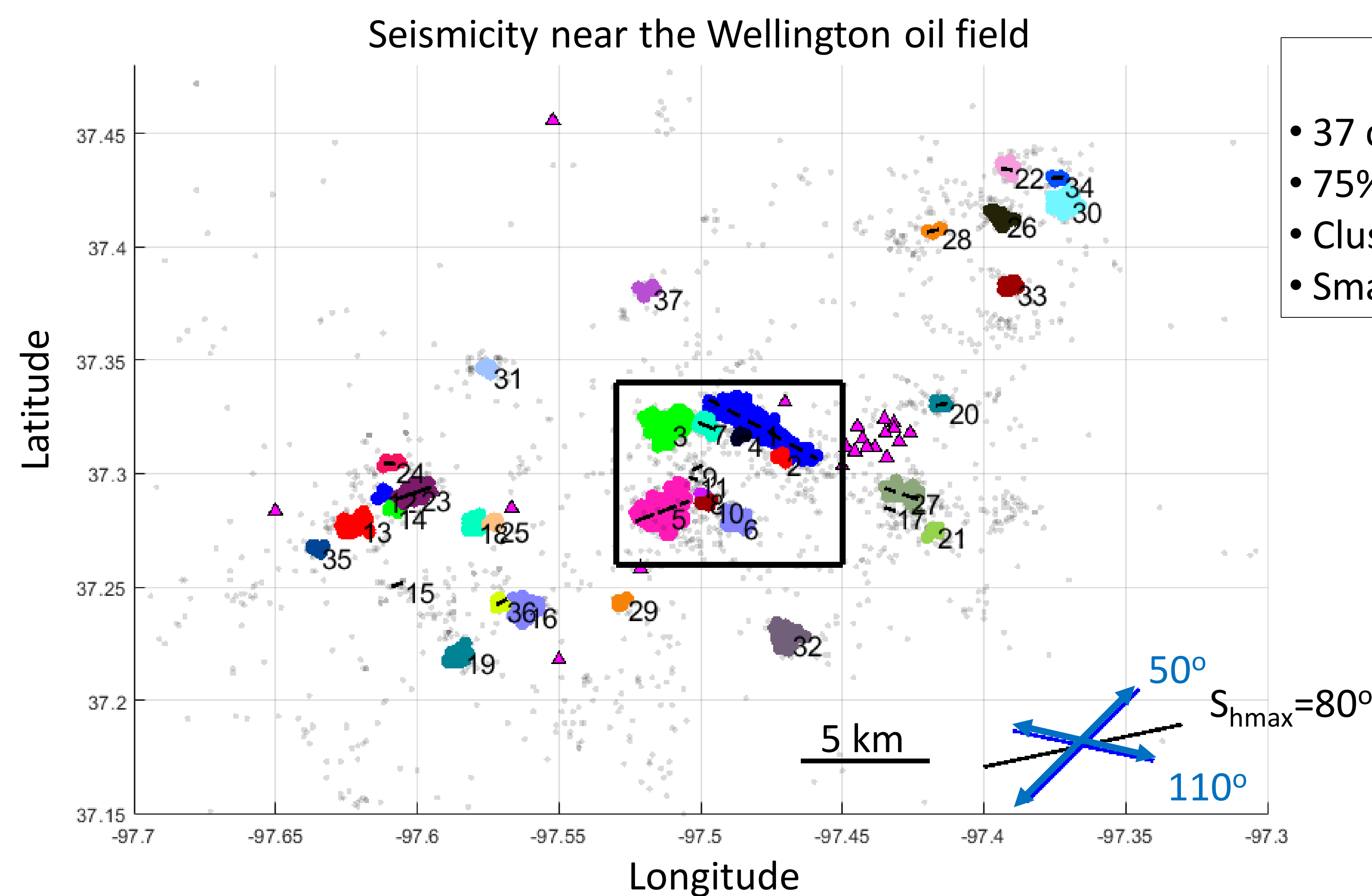
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Abstract:

The Kansas Geological Survey conducted a CO₂ Enhanced Oil Recovery Project at Wellington oil field in Sumner County Kansas, USA, in 2016. This project led to the installation of 18 seismic monitoring stations in and around the field in order to monitor seismicity before, during, and after a 22,000 ton injection of CO₂ in the Mississippian carbonate reservoir. While no earthquakes from the enhanced oil recovery project were detected, the monitoring array was used to track a marked increase in seismicity that began in 2015 in southern Kansas. The increase in seismicity has been tied to increases in waste water injections into the Arbuckle carbonate saline aquifer which sits directly above the granitic basement. From 2016 to 2018 over 3,000 local earthquakes ranging from magnitude 0.4 to 3.6 at depths of 1 to 12 km were located within Sumner County. Analysis of these earthquakes has identified previously unknown faults. Furthermore, earthquake locations show a northward progression from 2016 to 2018 that is likely caused by a change in regional pore pressure. The lessons learned in monitoring for seismicity near the EOR site will be applied to a new potential CO₂ sequestration site in western Kansas where a network of eight seismometers was installed in April of 2019. This site is expected to have very little background seismicity, although some local earthquakes have already been recorded.

Findings from Wellington Network Operation



Local seismicity near the Wellington oil field. Earthquakes are occurring on previously unknown faults in the shallow basement. The small faults are oriented optimally for failure.

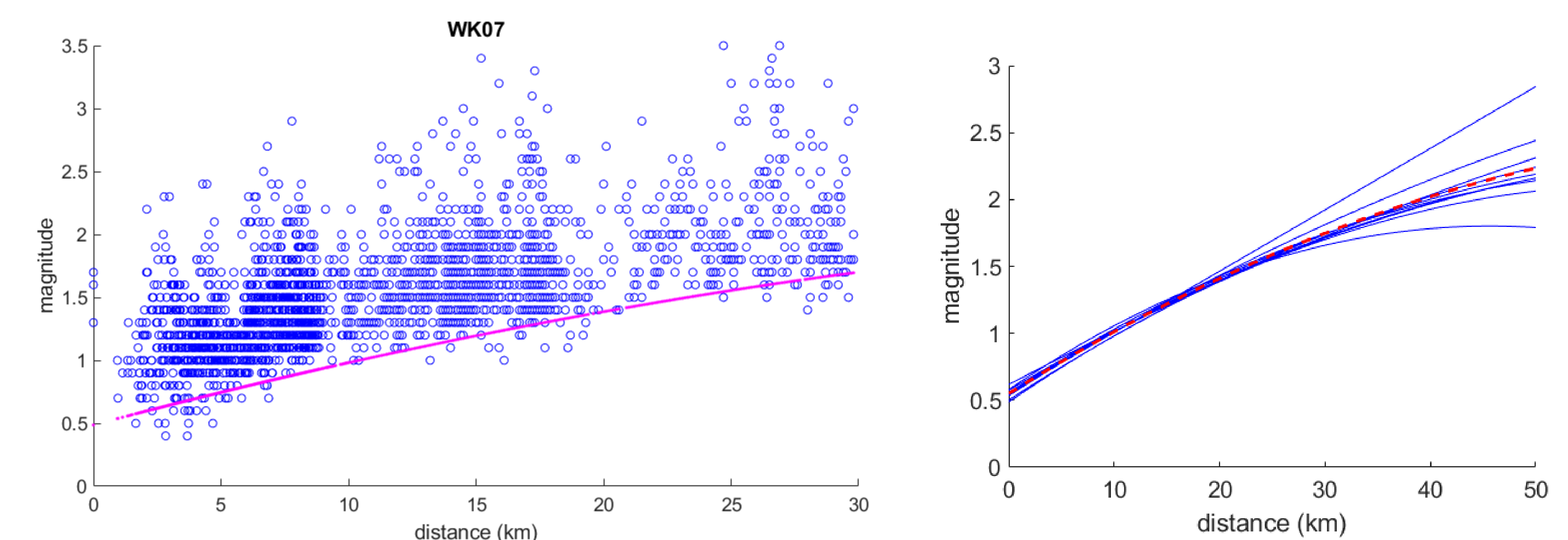
Previous Results

- 37 clusters of earthquakes identified
- 75% of earthquakes occur in a cluster
- Clusters delineate faults 1-8 km long
- Smaller faults optimally oriented fail

Can stations be placed near oil and gas extraction sites and still be capable of detecting earthquakes near M1?

(Below) Example of detected magnitude vs distance for a station in the Wellington earthquake Monitoring Network. The magenta line is an estimate of the minimum detectable magnitude at a given distance.

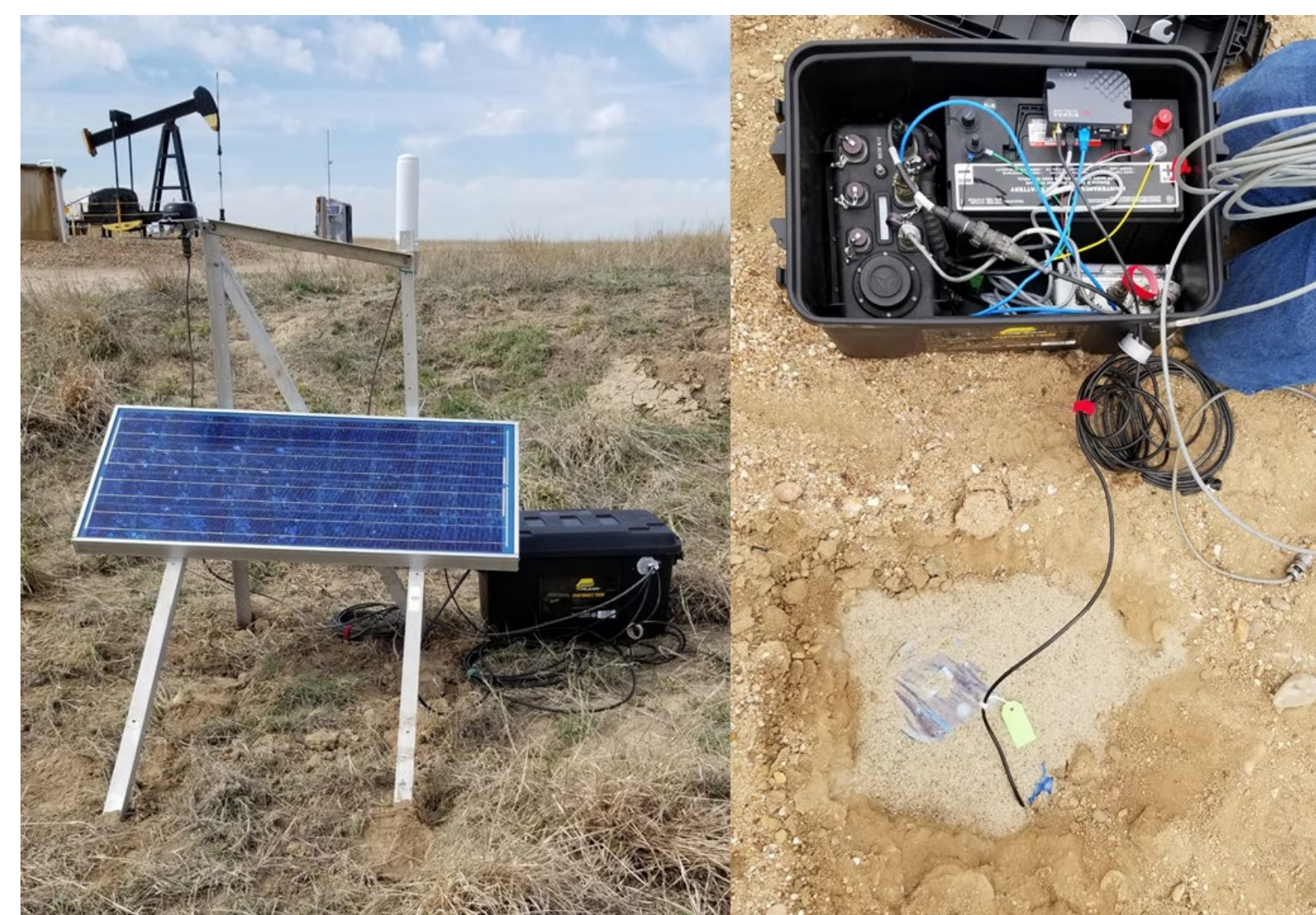
(Below) Plot of estimates of minimum detectable magnitudes at a given distance from all stations within the Wellington Monitoring Network. The dashed line shows the average, used in the analysis.



Patterson Network Design

Objectives

- Monitor baseline local seismicity near Patterson and Hartland fields in Kearny Co., Kansas
- Design a network that can detect small magnitude ($M_w > 1$), local (10-20 km distance) events
- Utilize access rights already provided to oil and gas operations (noisy environments)
- Installed network of eight seismic stations April 22-23, 2019

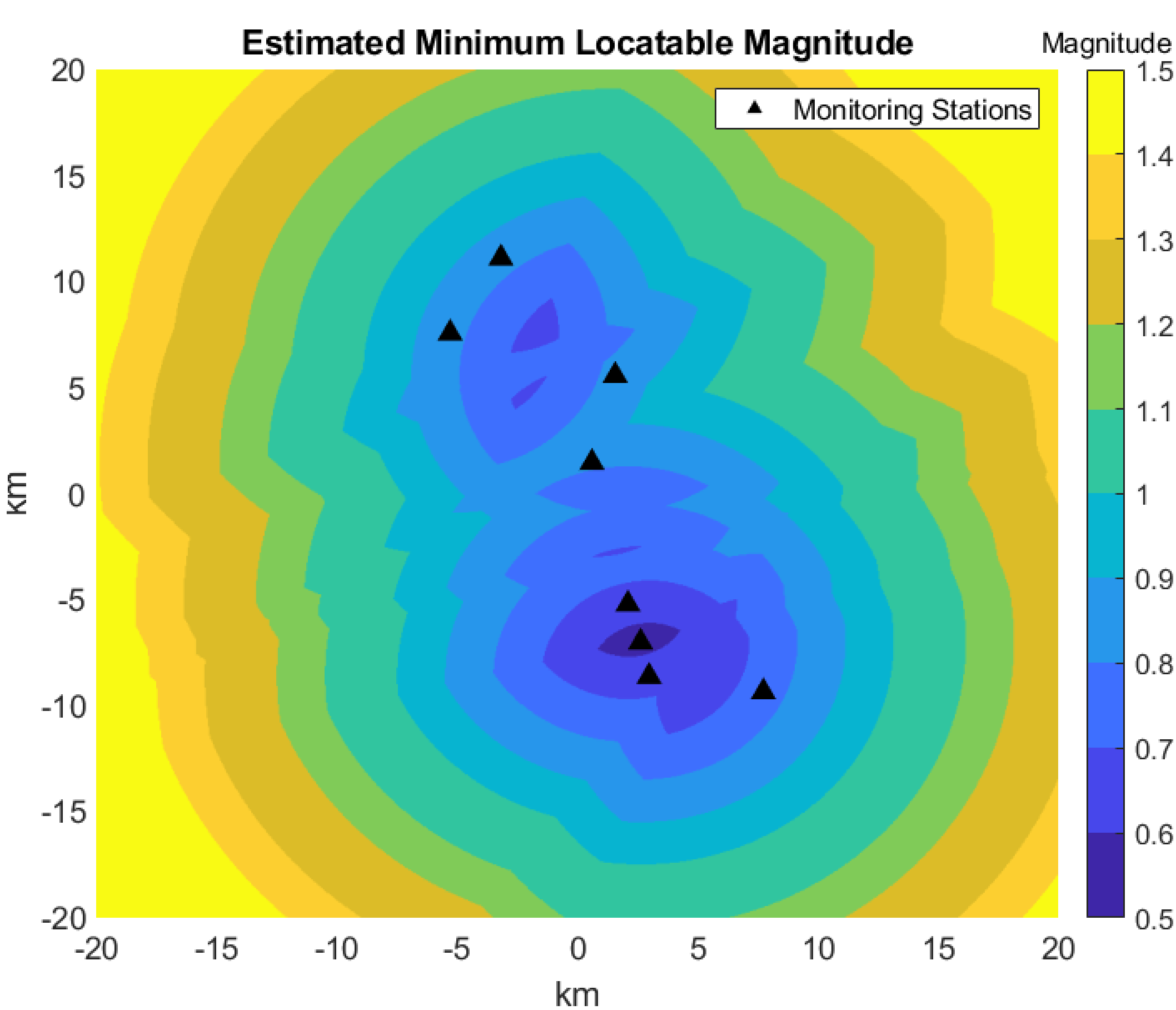
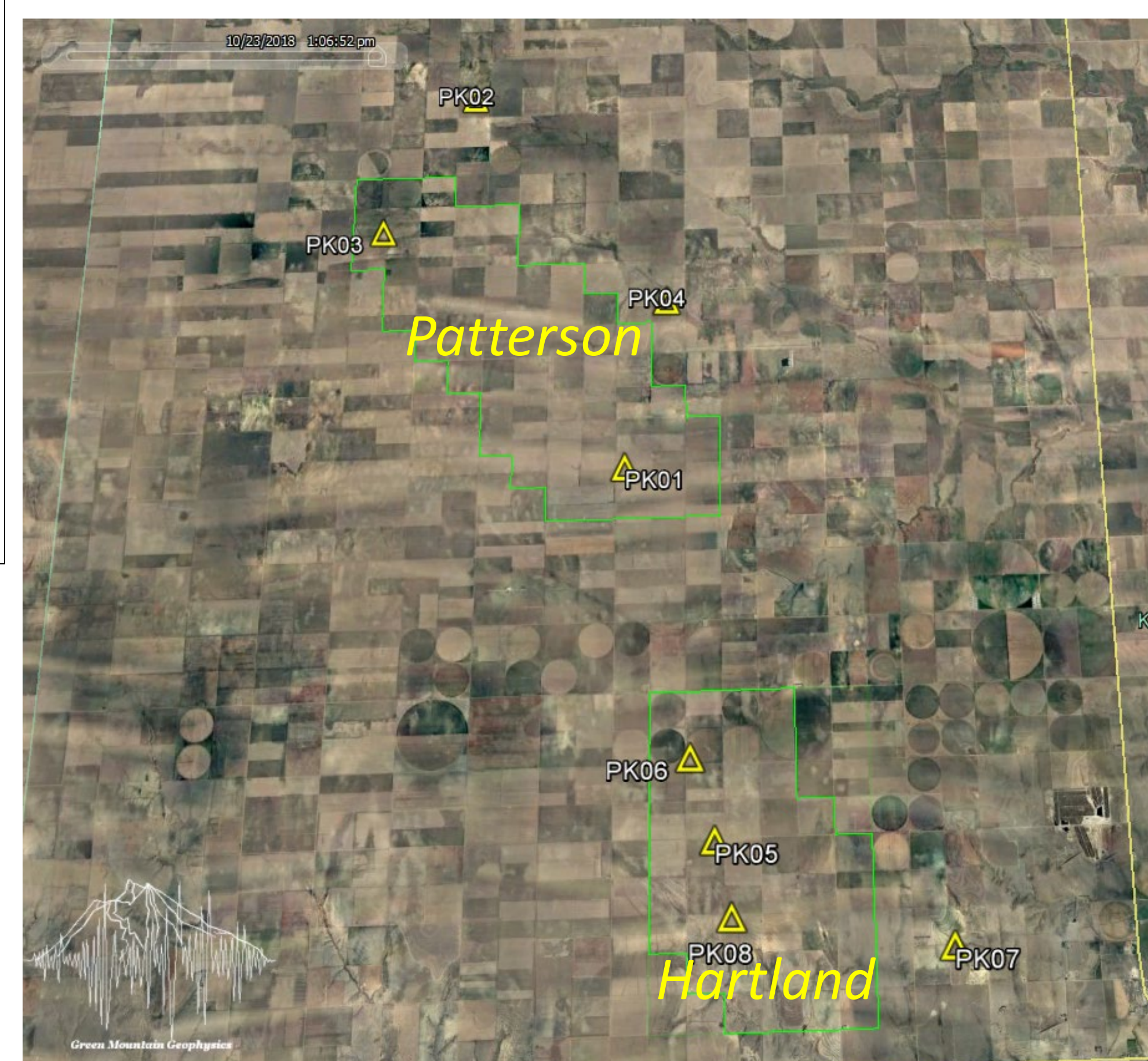


(Right) Seismic station locations PK1 through PK8 (yellow triangles) shown with the outlines of 3D seismic surveys (green outlines).

(Left) Patterson field seismic station installation of a Sercel L-22 Short Period seismometer

(Right) Expected detection threshold of ~M0.8 near the injection wells, with magnitude of completeness of ~M1.5 for Kearny County (stations black triangles)

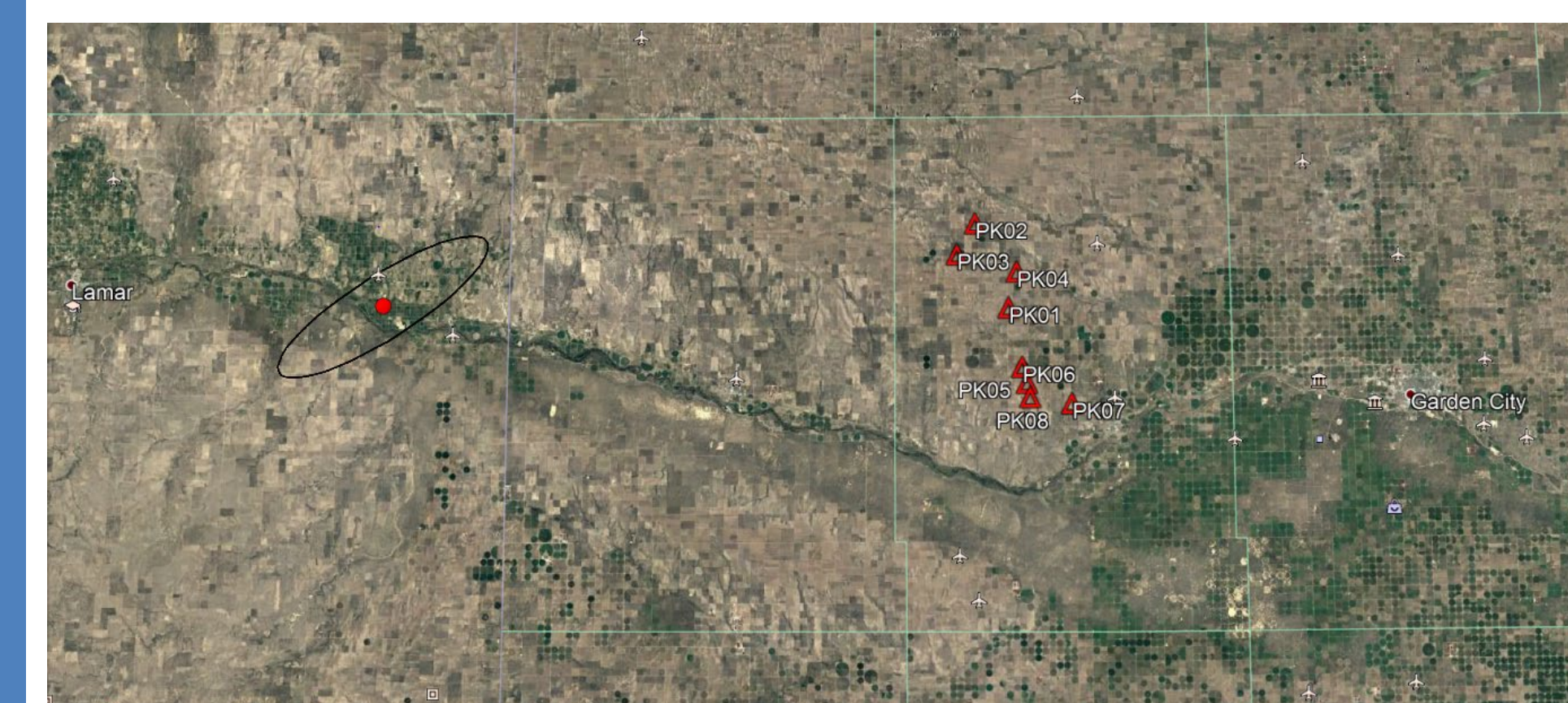
(Left) Blocked velocity model from Longwood well las data



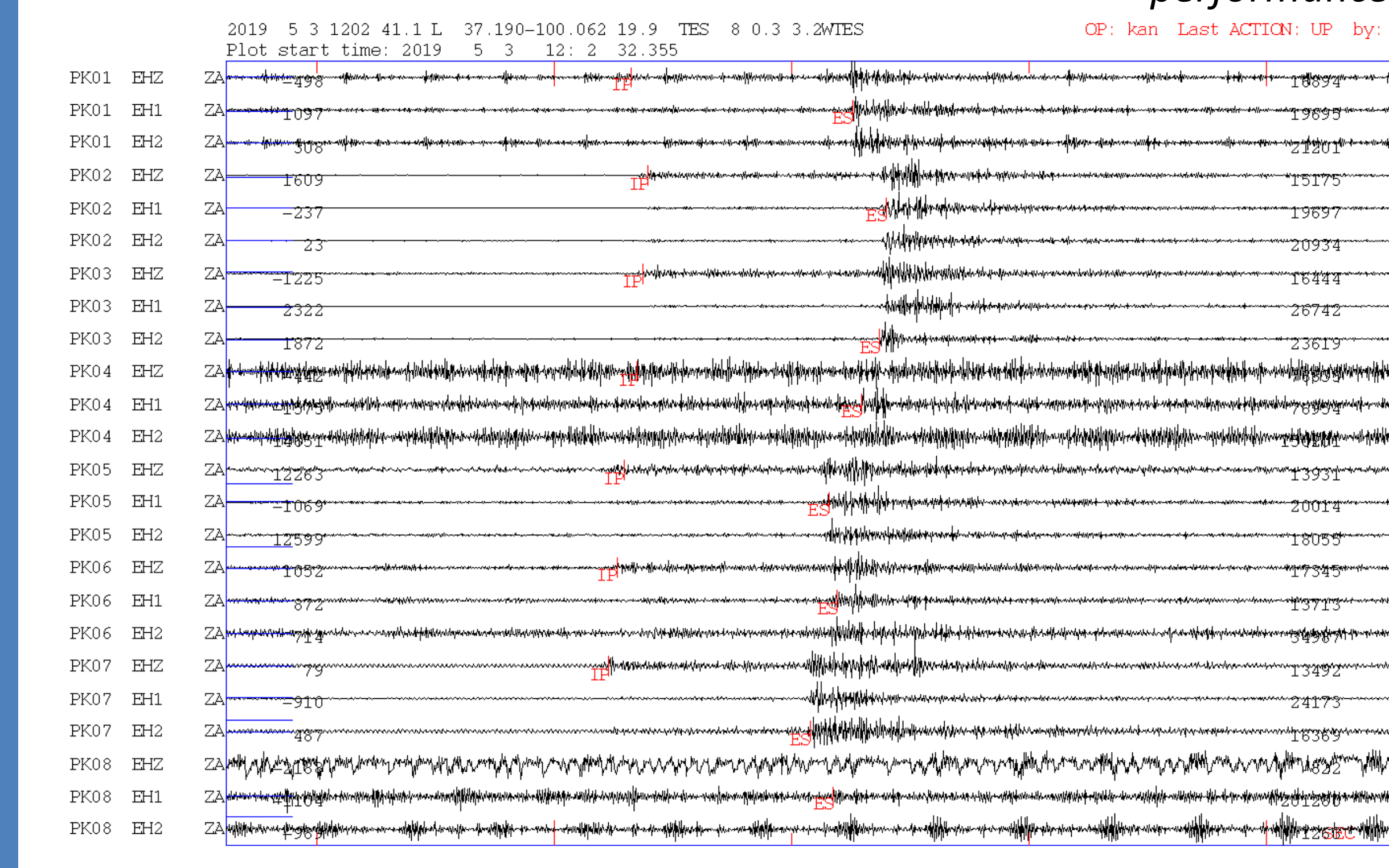
Patterson Network Results

Results

- No local earthquakes detected May - October 2019
- 24 distant earthquakes located as confirmation of successful network operation and verified by USGS



Seismic network (triangles) and located earthquakes (circles). A subset of detected regional earthquakes is analyzed every month for verification of network performance.



(Above) Waveforms from a 3.2 magnitude May 3 regional earthquake with P- and S-wave picks shown (red marks) on vertical (EHZ) and horizontal (EH1 & EH2) channels.

References

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Impacts

- Sites with significant background noise are expected near oil and gas operations. Benefits of using existing access rights should be weighed against the noise of the sites
- Small earthquakes can still be detected using these noisy sites
- Two stations will need to be moved in the future to create a more sensitive network

Acknowledgements

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