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DEPARTMENT OF ENVIRONMENTAL PROTECTION

Oil and Gas Management

Review of April 2016 Lawrence County Seismic Events

February 17, 2017

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Tom Wolf, Governor

Patrick McDonnell, Acting Secretary

Introductions

Patrick McDonnell, Acting Secretary, Department of Environmental Protection

Seth Pelepko, Chief, Division of Well Plugging and Subsurface Activities, Bureau of Oil and Gas Planning and Program Management

Harry Wise, Licensed Professional Geologist, Subsurface Activities Section, Bureau of Oil and Gas Planning and Program Management

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Agenda

1. Summary of Lawrence County Seismic Events
2. Seismic Overview
   - Induced seismicity
   - Seismic monitoring networks
   - Reporting of seismic events
3. Lawrence County Seismic Event Details
   - Timing
   - Oil and gas activity
   - Geology
4. DEP Recommendations
5. Questions

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Summary of Events

- **Timing:** Several low-magnitude earthquakes occurred in Lawrence County during the morning hours of April 25, 2016.

- **Locations:** Mahoning, North Beaver, and Union Townships, just west of New Castle.

- **Magnitude:** 1.8 - 2.3 on the Richter Scale. Since the seismic events were recorded and felt only by seismometers, they're considered "microseismic."

- **DEP Analysis:** These events correlated with operator activity.

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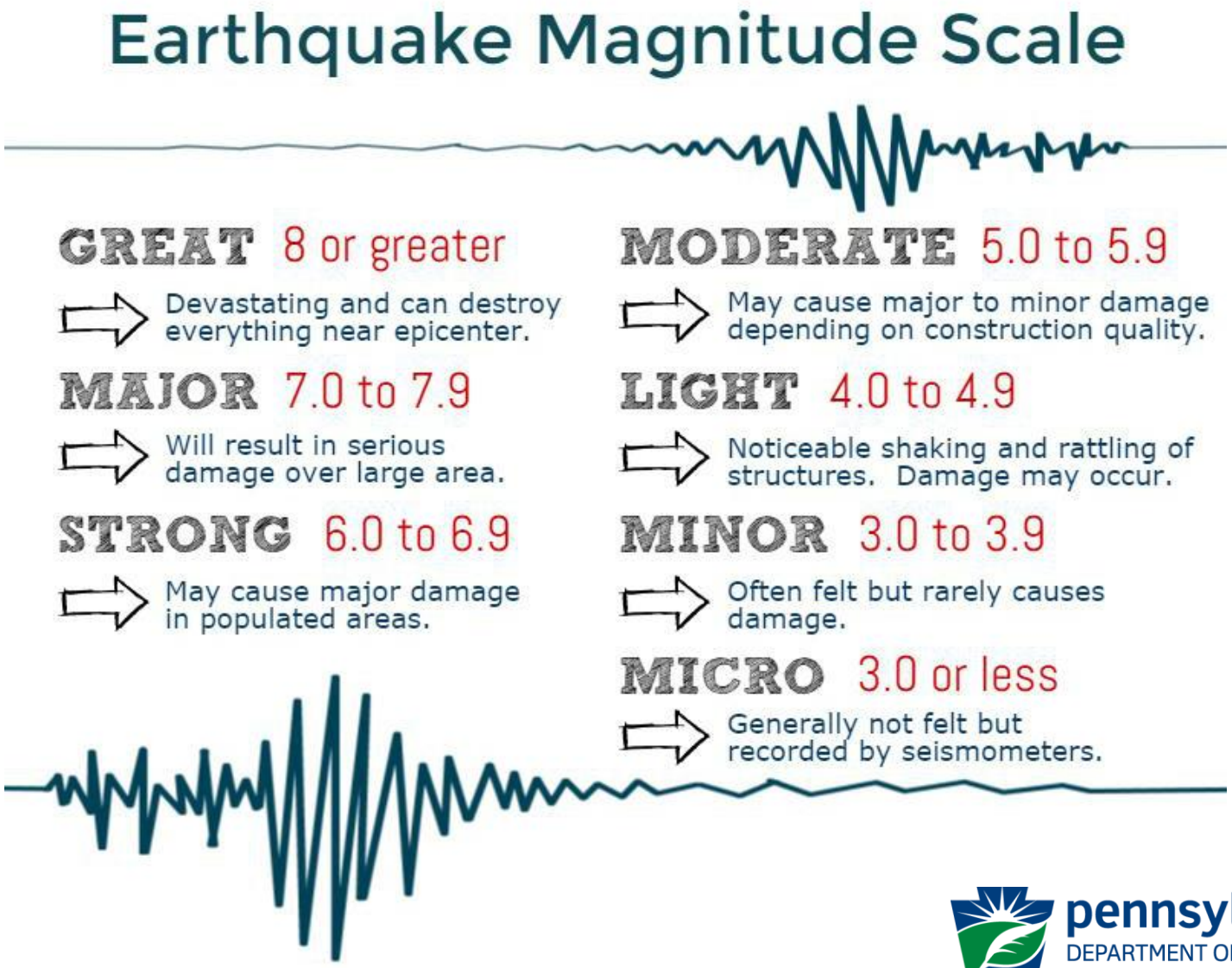
Seismic Overview



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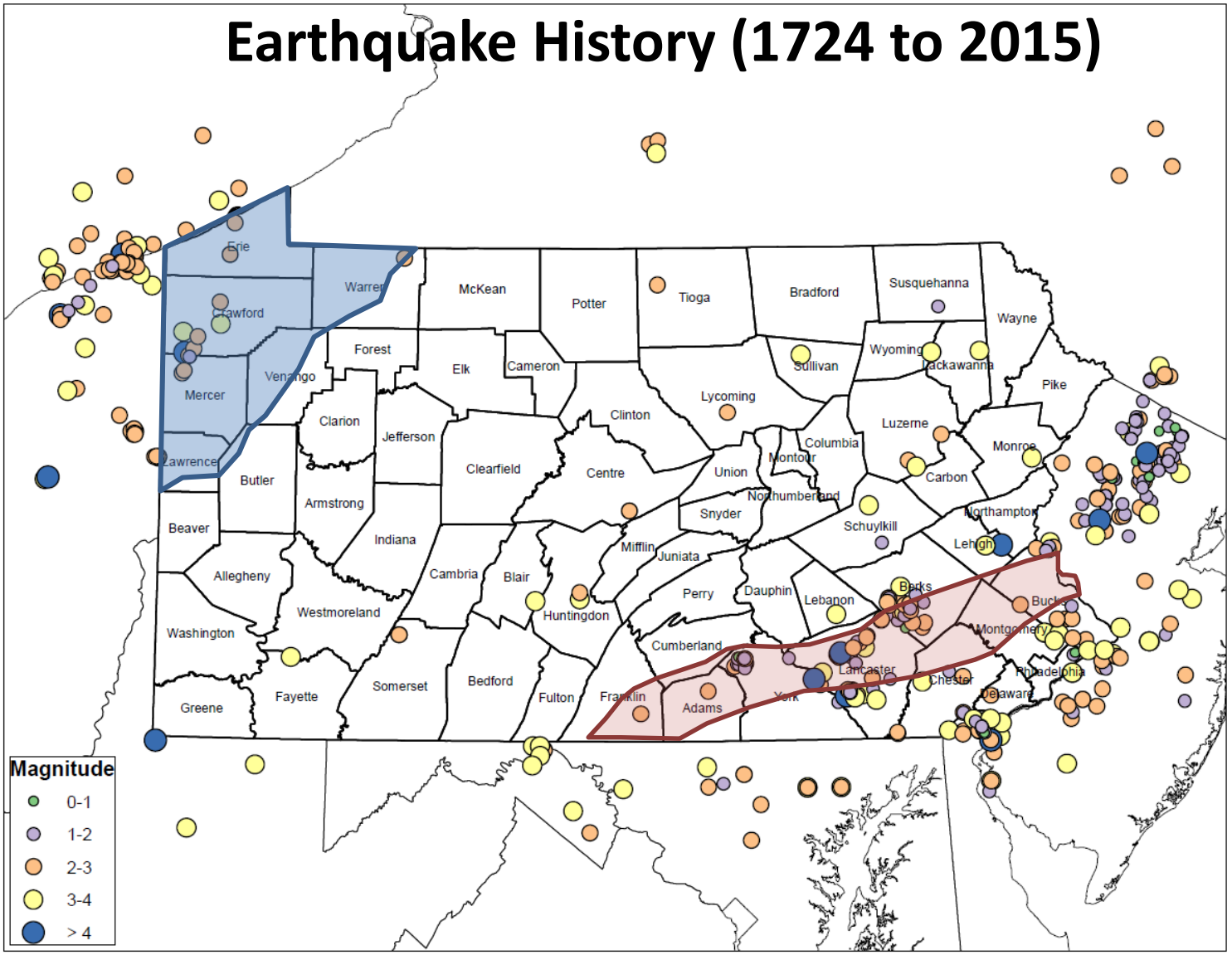
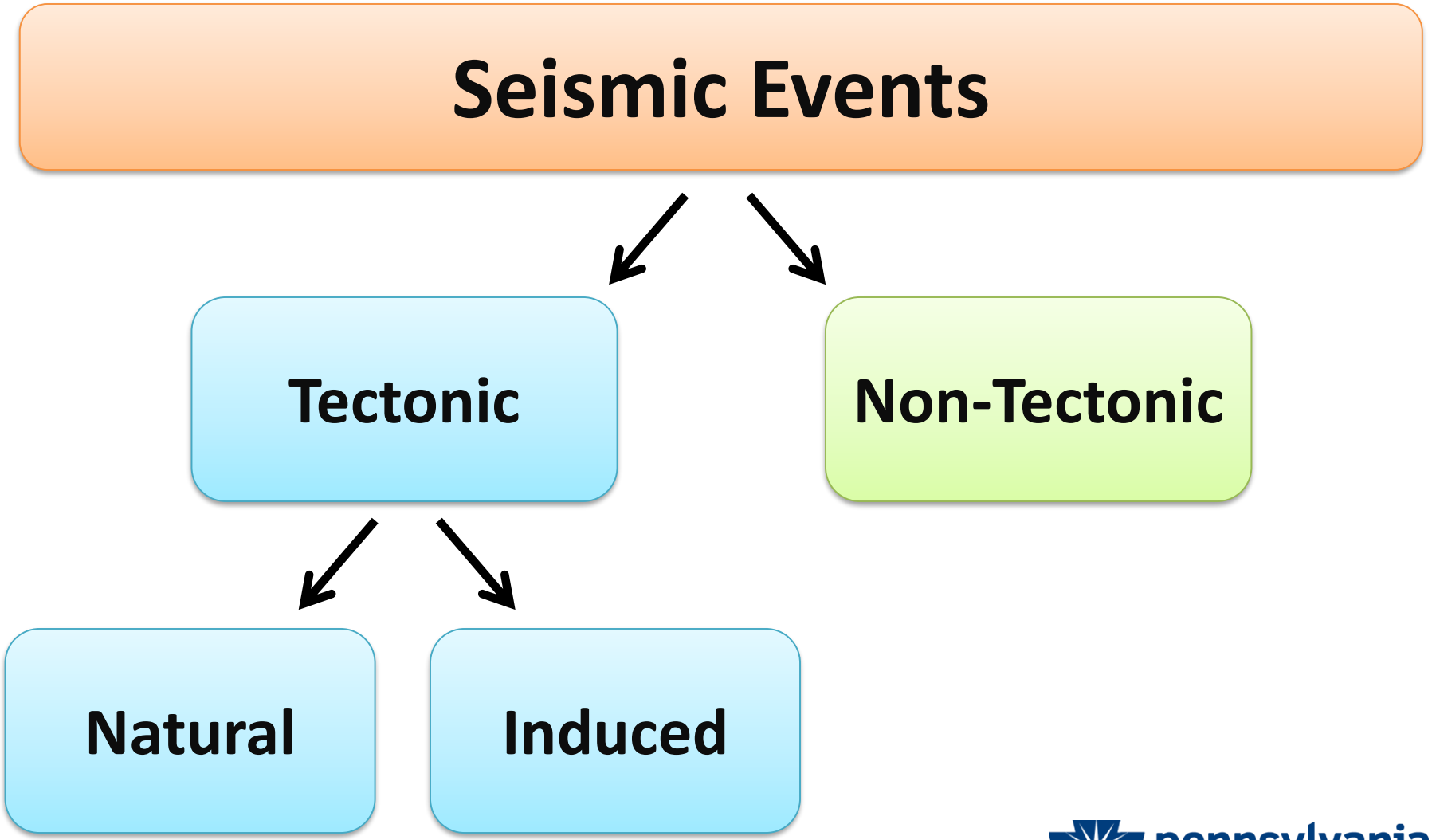
Seismic Overview



Triassic Rift area shaded in red. Glaciated area of NW PA shaded in blue.

USGS and DCNR (2015, 2003)

Induced Seismicity



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Induced Seismicity

Research on causes of induced seismicity is an evolving science.

Preliminary contributing factors identified at this point:

- Stress/Strain – Brittle Rock Fracture
- Increase or change in pressure regimes proximal to active faults.
- Fault plane orientation
- Separation of crystalline “basement” rock and area of concern

All of these contributing factors can be identified at the Lawrence County event.

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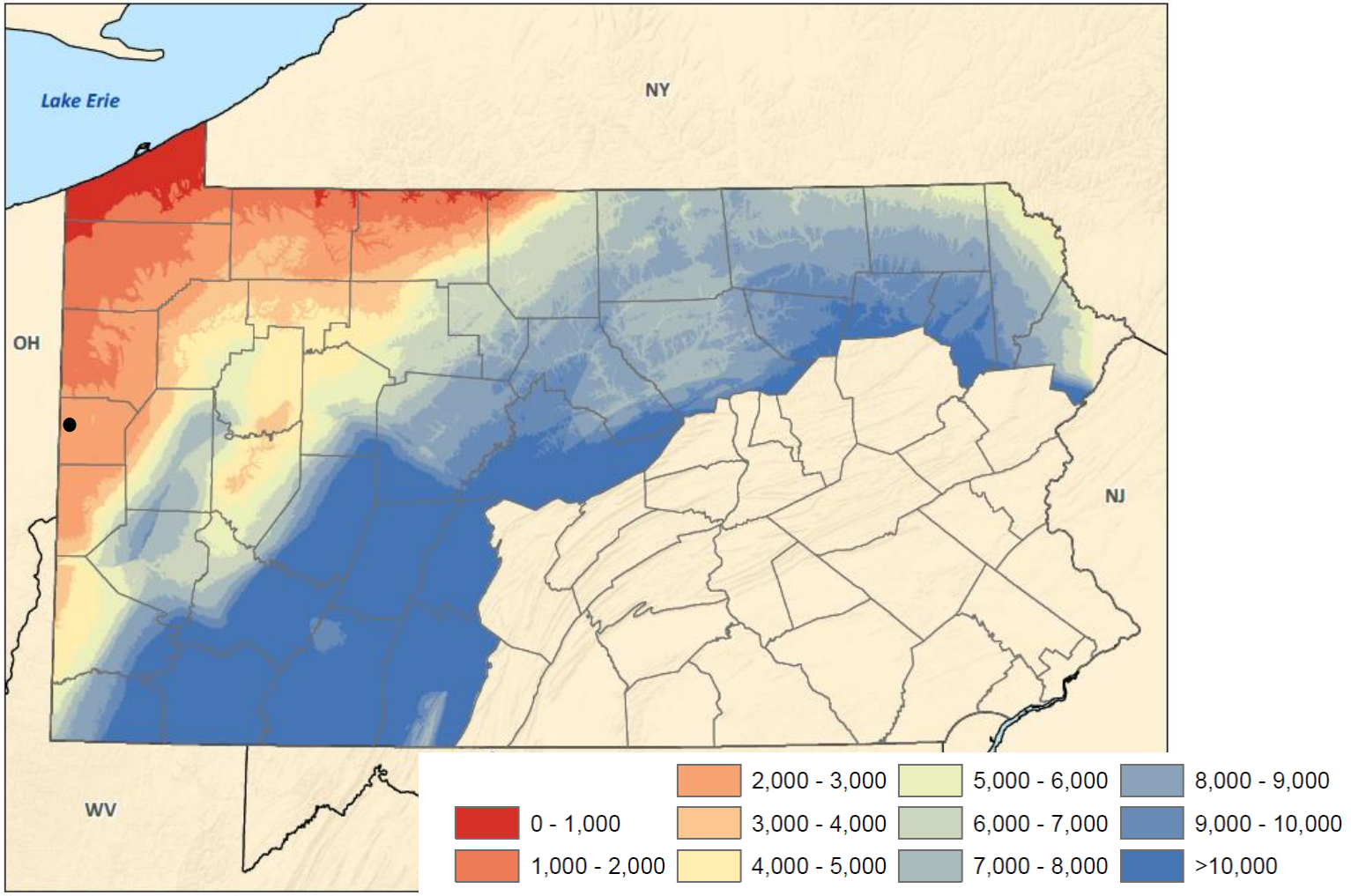
Induced Seismicity

Separation of “Basement” Rock and Utica Shale (in feet)



Black dot is the well pad location.

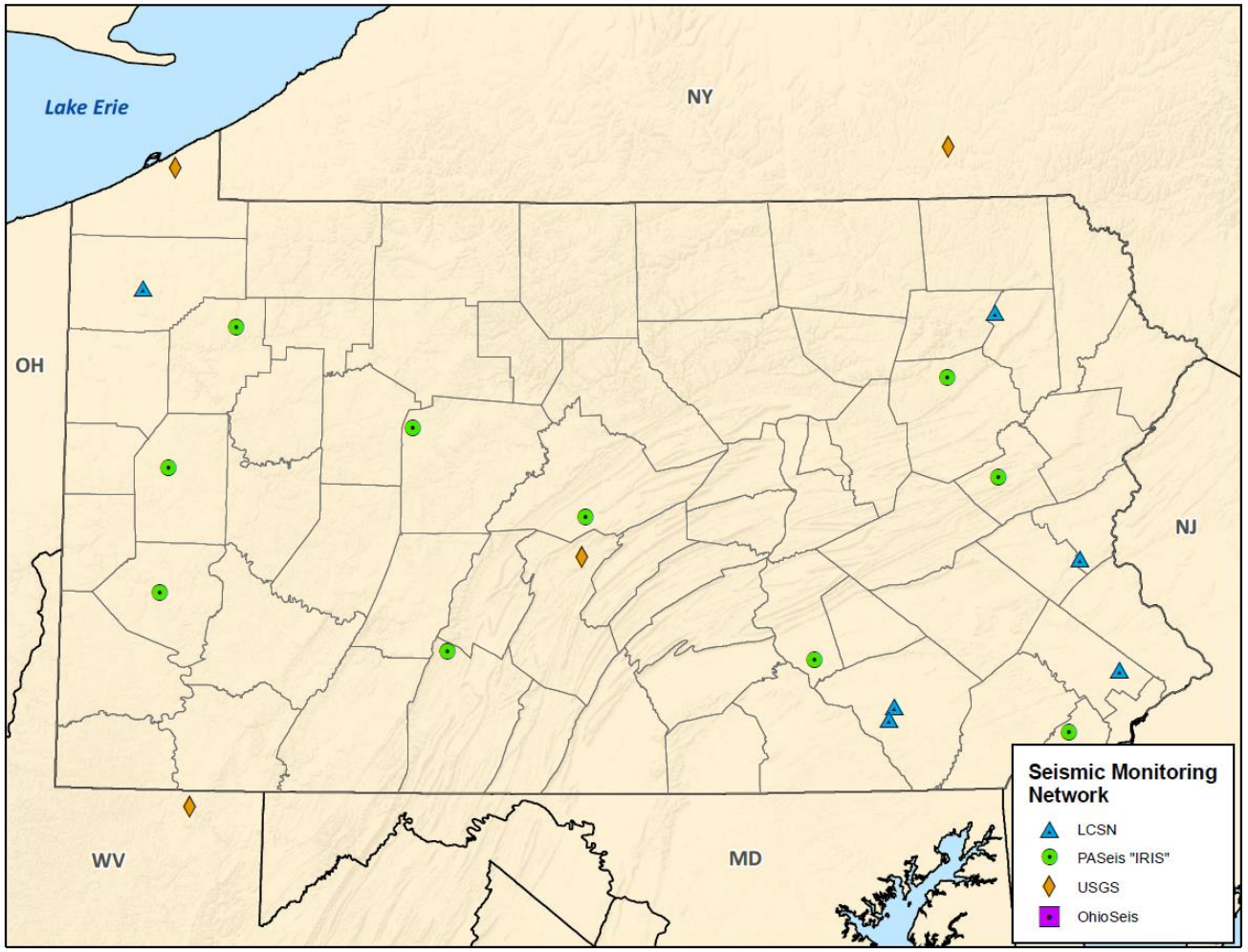
PA Seismic Monitoring Networks

Several research organizations operate seismometers in Pennsylvania:

- Pennsylvania State Seismic Network (PASeis) – Collaboration with DEP and PA Department of Conservation and Natural Resources
- Lamont-Doherty Cooperative Seismographic Network (LCSN) based at Columbia University
- U.S. Geological Survey's Advanced National Seismic System

PA Seismic Monitoring Networks

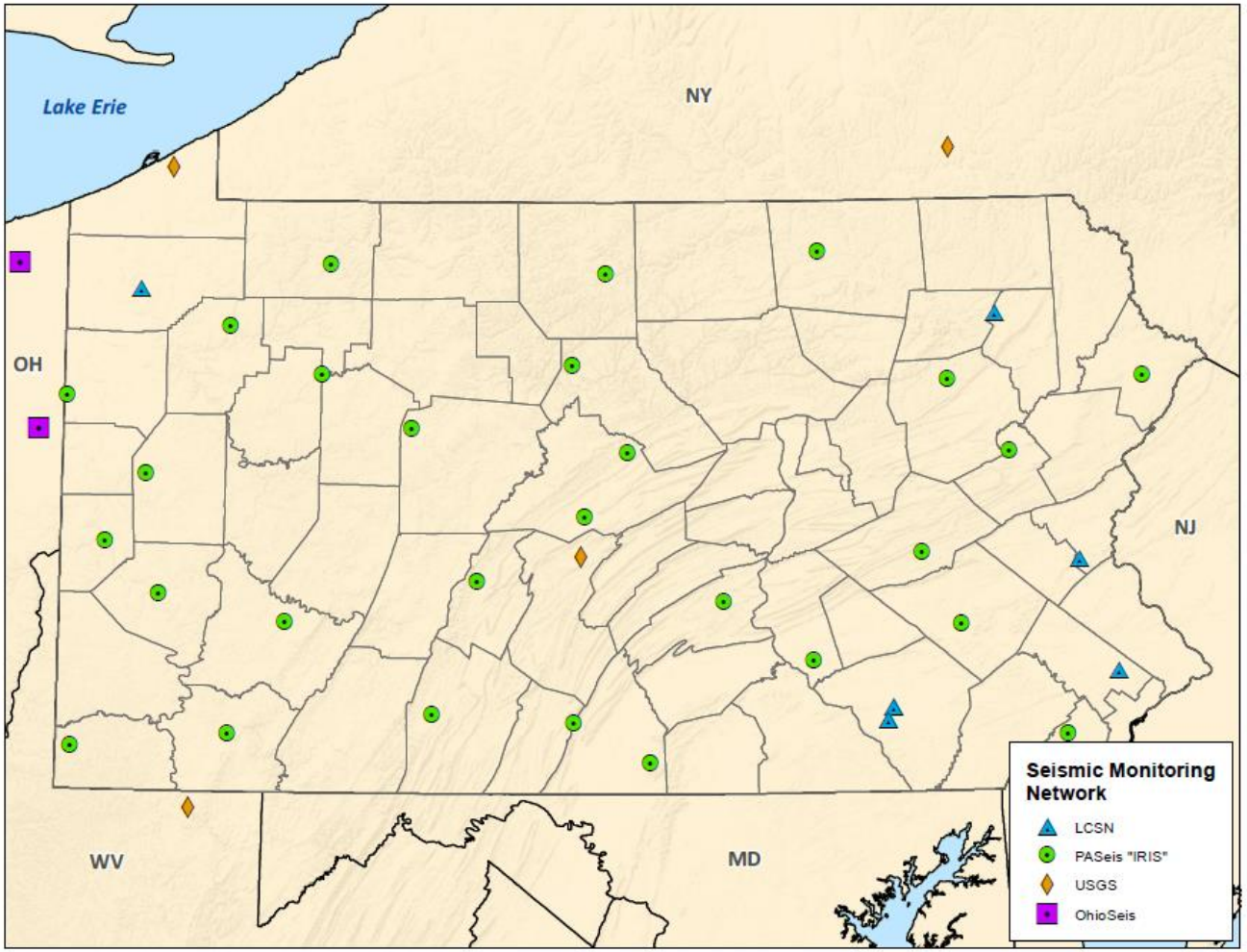
Previous Seismometer Locations (~2010)



USGS and DCNR (2015, 2003)

PA Seismic Monitoring Networks

Current Seismometer Locations (2016)



USGS and DCNR (2015, 2003)

Reporting of Seismic Events

When a Seismic Event Occurs in PA

- PASeis notification
  - PASeis records detectable seismic events and notifies DEP and DCNR.
  - Event is determined to be tectonic or nontectonic.
- DEP action if event is tectonic:
  - Upon PASeis notification of tectonic events, DEP evaluates if there is oil and gas activity (stimulation or hydraulic fracturing) near seismic event epicenter.
    - Spatial/temporal correlation

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Lawrence County Event Details

- DEP completed a technical investigation and concluded the April 25, 2016, seismic events in Mahoning, North Beaver and Union Townships were correlated with operator actions.

- A synopsis of the DEP investigation follows.

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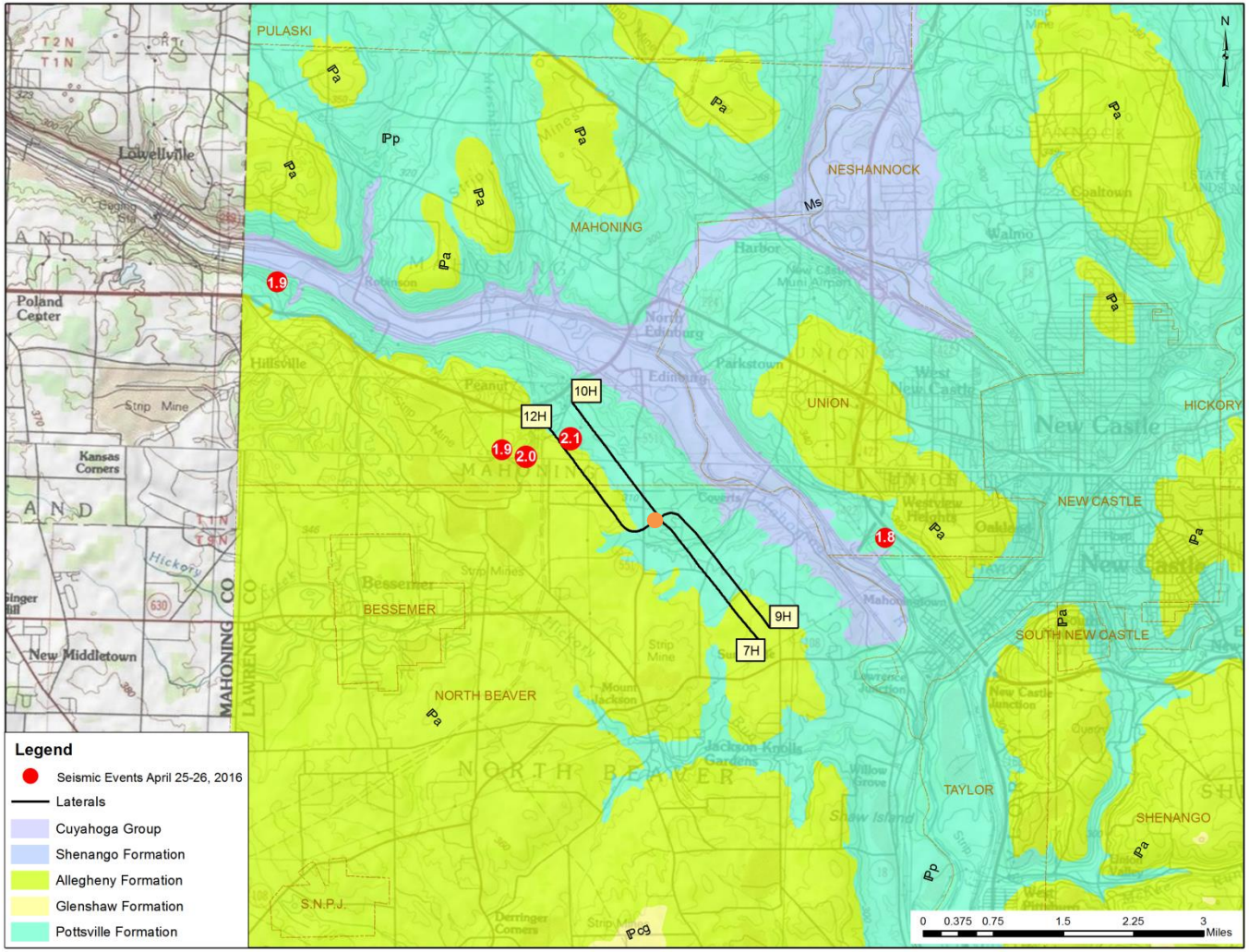
Lawrence County Event Details

Lateral Locations, Epicenters per Lamont Doherty Network, and Geology

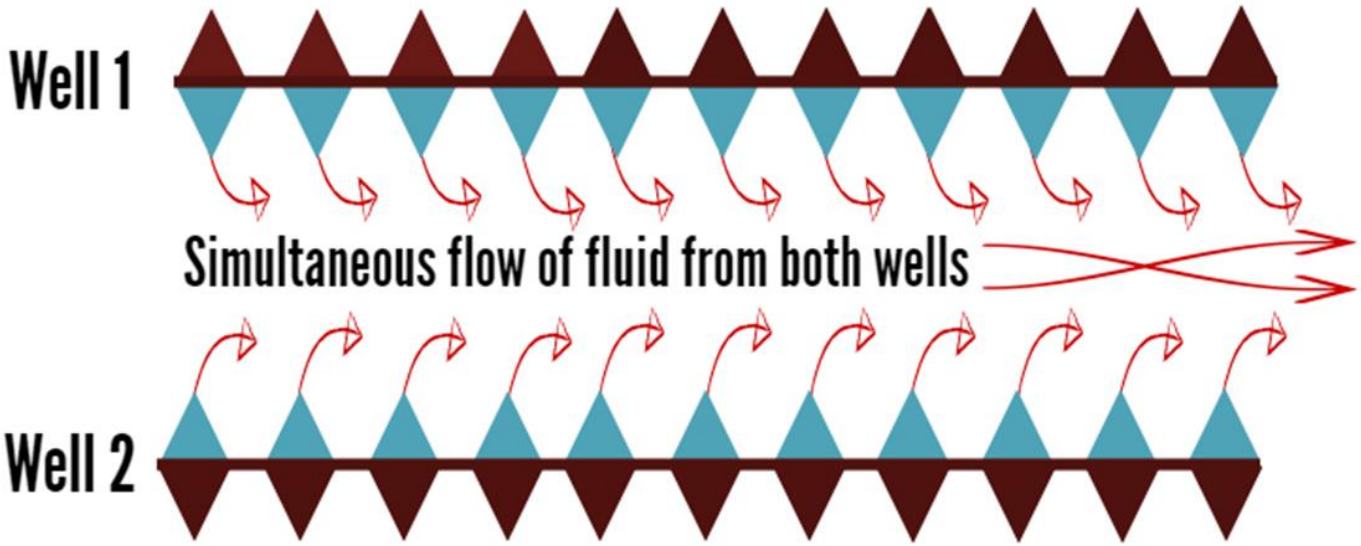


Orange dot is the well pad location.

Lawrence County Event Details

What is zipper fracturing?

Zipper fracturing is defined as fracturing operations to be carried out concurrently at two horizontal wellbores which are parallel to each other and not very far from each other.



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Lawrence County Event Details

Key Geologic Factors Tied to Seismicity

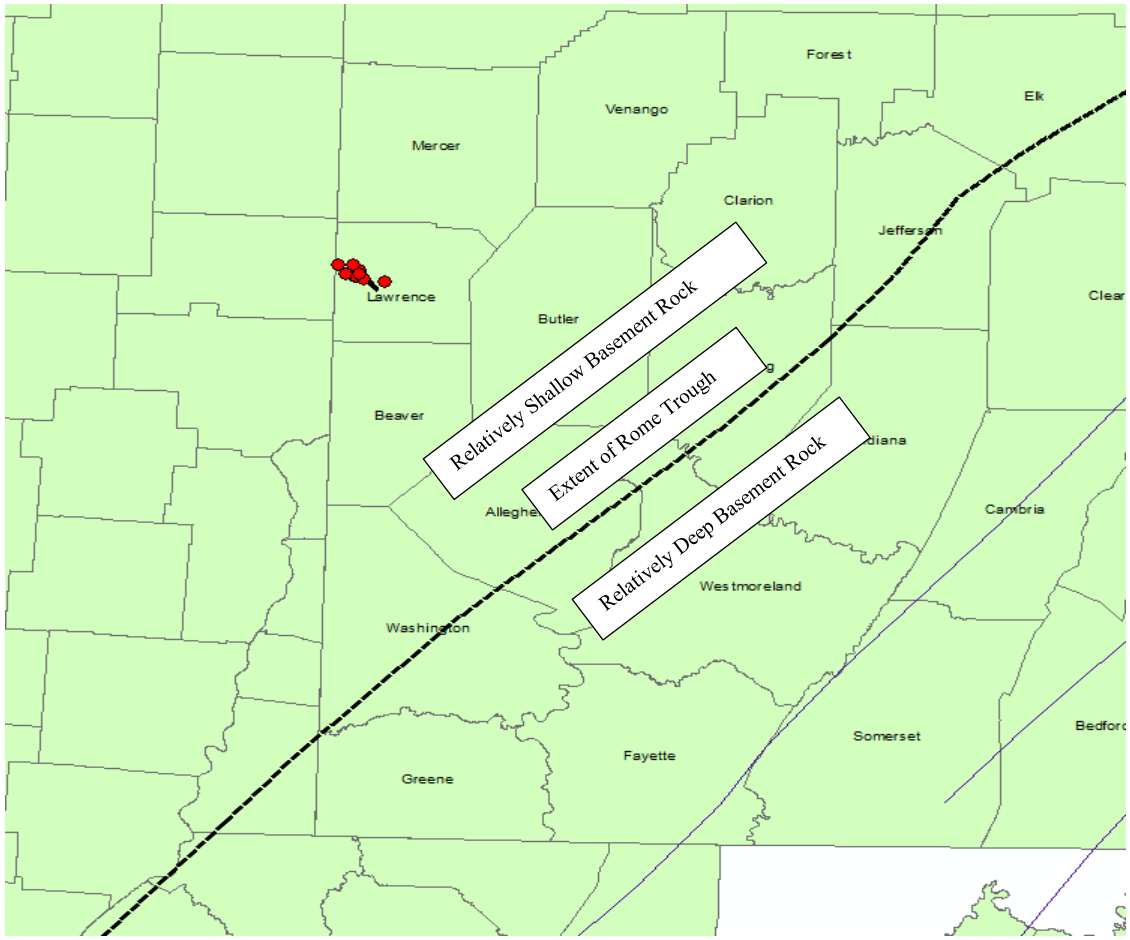
- The Rome Trough structural feature accommodates a deepening of Precambrian crystalline “basement” rocks to the South and East of the well pad and seismic event locations.

- The depth to Precambrian crystalline “basement” rock in the area of the well pad is approximately 9,500 to 10,000 feet.

- Literature proposes that the Blairsville-Broadtop Lineament extends through Lawrence County, but currently the mapped extent ends in Butler County.

Lawrence County Event Details

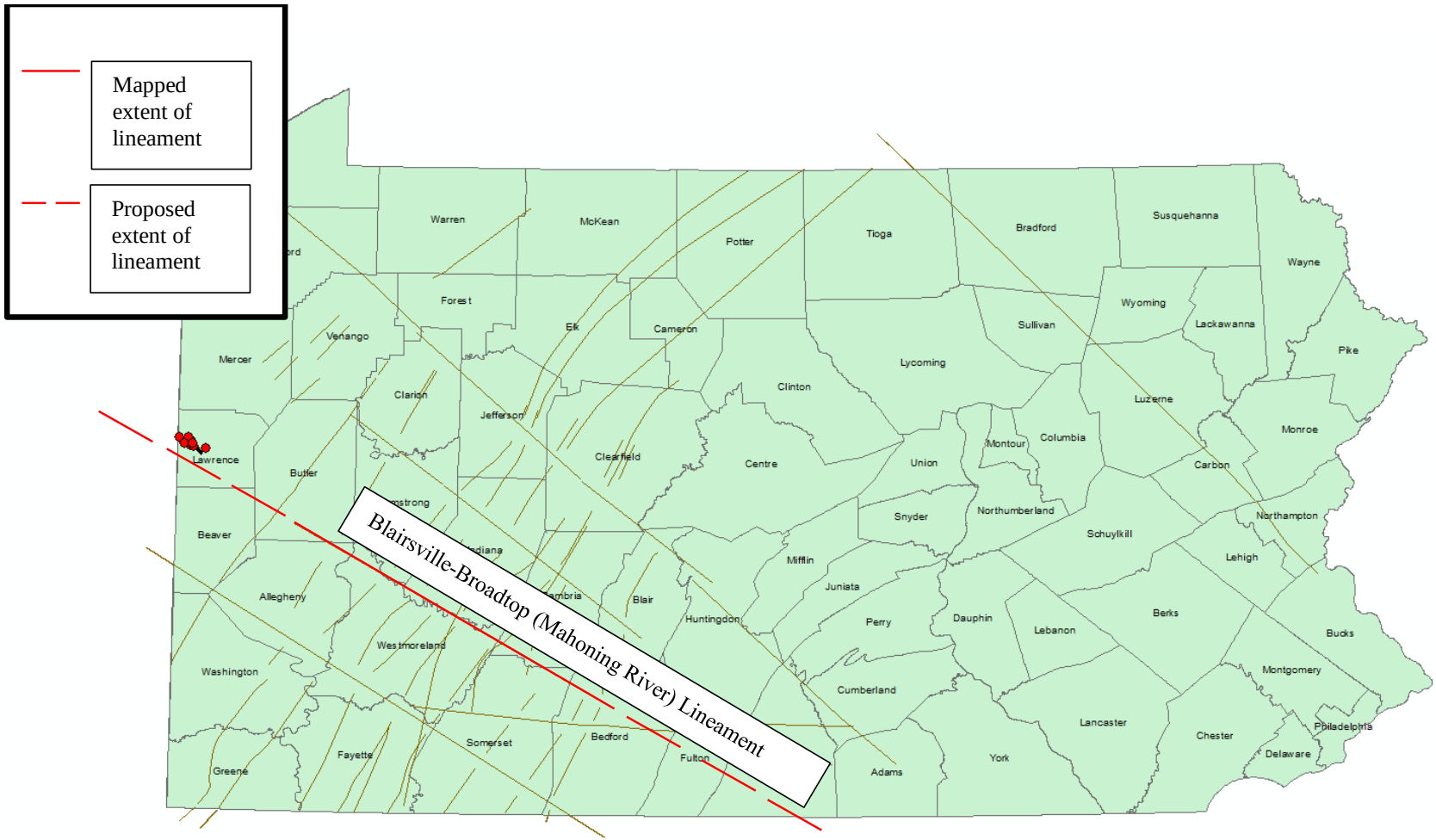
Well site area and regional geologic structure



The Rome Trough is associated with thicken sediments and deepening to crystalline "basement" rock.

Lawrence County Event Details

Seismic event locations with regional geologic structure



DEP Recommendations

Based on the events of April 25, DEP recommended the following for Hilcorp Utica Shale Formation gas wells development in North Beaver, Mahoning and Union Townships:

1. Hilcorp should maintain operation of its own seismic network within these townships.
2. If a seismic event of 1.0 or greater magnitude occurs within a 6-mile distance of any active Hilcorp wellbore path, the company should notify DEP within 10 minutes via email and 1 hour via telephone.
3. If any succession of three (3) 1.5 to 1.9 magnitude “Events” occur within a three consecutive day period and are within a 3-mile radius of the wellbore path, Hilcorp should notify the DEP within 10 minutes via email and 1 hour via telephone.
   - Actions taken for this range of magnitude of tectonic seismic events would include suspension of stimulation operations, and submittal of seismic data and a plan detailing modifications to stimulation operations for DEP to review and make recommendations on within 24 hours.

DEP Recommendations

Recommendations, cont.

4. If a seismic event of 2.0 or greater magnitude occurs within a 3-mile distance of the wellbore path, Hilcorp should notify the DEP within 10 minutes via email and 1 hour via telephone
   - Actions taken include discontinuation of stimulation operations, flowing back the well, and submittal of seismic data and a plan detailing any potential modification to stimulation operations for DEP to review and make recommendations on.
5. Discontinuation of zipper fracturing during any future completions work associated with Hilcorp Utica gas wells in North Beaver, Union, and Mahoning Townships.
6. These terms will apply to any new permits requested by Hilcorp within the referenced townships.
7. On November 16, 2016, a seismic monitoring plan submitted by Hilcorp was approved by DEP implementing the recommendations set forth.

DEP Follow-up

Continued Work:

- DEP will continue to actively discuss research findings relating to induced seismicity with all groups performing research studies to better understand potential triggering mechanisms.
- Based on the development of the study of induced seismicity, begin crafting guidance documents relating to response procedures and operator activities.

DEP Mission

"To protect Pennsylvania's air, land and water from pollution and to provide for the health and safety of its citizens through a cleaner environment. We will work as partners with individuals, organizations, governments, and businesses to prevent pollution and restore our natural resources."

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Oil and Gas Management

Questions?

http://www.dep.pa.gov/About/Regional/NorthwestRegion/Community-Information/Pages/Lawrence-County-Earthquake.aspx