Exhibit C

September 10, 2016 Penneco Response to NOD Letter

PENNECO

Notice of Deficiency Response

Penneco Environmental Solutions, LLC

Underground Injection Control Program
Class IID Injection Well Permit Application

Sedat #3A

PENNECO
YOUR ENERGY EXPLORATION PARTNER

September 10, 2016

Mr. Mark Nelson, Hydrologist
United States Environmental Protection Agency
Region III
1060 Chapline Street
Wheeling, West Virginia 26003

RE: Notice of Deficiency; Penneco Environmental Solutions, LLC
Underground Injection Control (UIC) Program
Class IID Injection Well Permit Application Sedat #3A

Dear Mr. Nelson,

Penneco Environmental Solutions, LLC is responding to the Notice of Deficiency dated July 8, 2016 for UIC facility ID PAS2D701BALL, for a proposed injection well for the disposal of E&P wastes. We have addressed the items listed in Attachment 1 of the NOD below and are enclosing revised application attachments as needed.

Item 1. Application Page

We field checked the latitude and longitude of the Sedat #3 A and found the location corresponds to the location shown on the AOR maps.

Item 2. Area of Review

The topographic map of the AOR has been revised to expand the radius from ¼ mile to ½ mile from the injection well. Two (2) printed copies of the revised map are enclosed. A list of landowners and their address are included with the maps along with water well depths where known. Attachment A, Area of Review Methods, was revised to account for the change in radius from ¼ mile to ½ mile. The additional wells within the enlarged radius were added to the well table in Attachment G.

Item 3. Attachment E-USDWs

We have expanded the Attachment E narrative giving more detail on USDWs in the AOR. See the revised enclosed Attachment E.

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Delmont, PA 15626-0300
Ph: (724) 468-8232
Fax: (724) 468-8230
Email: penneco@penneco.com
Web: Penneco.com

We are only listing two USWDs as being in the AOR. Pennsylvania Geological Survey Water Resource Reports #35 (Allegheny County) list three (3) and Report # 37 (Westmoreland County) list two (2) additional aquifers. The Allegheny County aquifers are the Monongahela Group, Conemaugh Group, and the Allegheny Group. In the AOR there are only two (2) the Conemaugh Group and the Allegheny Group. The surface rocks are predominately of the Conemaugh Group which is roughly 400 to 500 feet thick in the AOR. The Allegheny Group ranges from 200 to 300 feet in thickness and is around 450 feet deep in the AOR and in general any water found below 500 feet in depth is of poor quality (Report #37). The Worthington Sandstone, the lower sandstone unit of the Allegheny Group contains highly concentrated brine where the unit lies below drainage and any formations below the Worthington are not suitable as freshwater aquifers because of either low permeability or contain water high in salt content (page 61 report #35).

Report #37 (Westmoreland County) which covers a geographical area outside the Sedat AOR list an additional two aquifers, the Pottsville Group and the Mauch Chunk formation. The Pottsville lies at a depth of around 900 to 950' in western Westmoreland County and Report #37 on page 42 states that "the rocks of the Pocono Group are generally buried more than 500 feet deep, or more than 100 feet below the level of major streams. Wells drilled into these rocks usually encounter salt water". The Pocono Group is made up of three sandstones, the Homewood sandstone, Upper Connoquenessing sandstone and the Lower Connoquenessing sandstone. The drillers' names for these sands was First Salt sand, Second Salt sand and Maxton also sometimes referred to as the Third Salt sand. The Salt sands were drilled for the brine and the Maxton sand for gas, according to the Topographic and Geologic Atlas of Pennsylvania No. 36 Freeport Quadrangle. The Mauch Chunk is absent in the AOR due to either non deposition or erosion, according to Atlas of Pennsylvania No. 36 Freeport (15") Quadrangle, page 59.

A note about Driller's log reports of water shows on well records. These reports are unreliable and highly inaccurate; the water shows are neither measured for quantity nor sampled for quality analysis. The flow volume is estimated by site, and the quality is just a guess, in addition the water in the bore hole is commingled with waters from any zones left open to the bore hole at the time of sampling. The report of fresh water reported at 1,700 feet was a notational error according to Penneco which illustrates another type of widespread reporting error.

The majority of the conventional wells drilled in Western Pennsylvania were/are drilled by cable tool rigs or rotary air rigs and not logged until after the surface, coal and water strings are run and cemented and the well reaches total depth. Some wells do have a gamma ray log to surface but no electric logs are available.

Item 4, 5, 6, 7, and 8. Attachment G - Geologic Data

Items 4, 5, 6, 7 and 8 were addressed by revising Attachment G. Item 4 pertained to a typographical error for a permit number, the correct permit number is now shown in the table. Item 5 asked for additional information on the methodology used to determine the frac gradient. HFRAC provides additional information on the frac gradient in supplement 5 at the end of their original report. We have replaced pages 29 through 35 of the HFRAC report with new full size copies to take care of Item 6. Item 7 asked for justification of the use of 1.8mD for the permeability of the injection zone. HFRAC expands on why this value was chosen in supplement 7 which can be found at the end of their report. To address Item 8 the geological narrative has been revised so that it now includes an additional structure map contoured on top of the Murrysville Sand, and an additional three (3) cross sections across the AOR showing no sand displacement.

Four seismic maps from the USGS Earthquake Hazards Program were added to the end of Attachment G. Map 1 shows historic seismic activity in Pennsylvania, showing there has been no activity in the AOR. Maps 2, 3 and 4 show the probability of natural or induced seismic activity in different formats. All three show low probability of any activity in the AOR.

Item 9. Attachment H - Operating Data

Attachment H was revised to provide more detail as to the source of the injection fluid, which is E&P waste, produced water and flow back fluids. Note that Penneco Environmental Solutions, LLC is applying for a commercial license.

Item 10. Attachment P - Monitoring Program

Attachment P was revised to provide additional information on the monitoring program for both the injection well and the Sedat #1 monitoring well.

Should you need clarification on any other items, please do not hesitate to contact us.

Sincerely,

PENNECO ENVIRONMENTAL SOLUTIONS, LLC

D. Marc Jacobs, Jr.
Senior Vice President

PENN-000018

Attachment A
Area of Review Methods
Sedat #3A Injection Well

Area of Review Methods:

The size of the area of review was determined by a fixed radius of one quarter mile as required by permit application but expanded to a fixed radius of one half mile at request of permit reviewer. Maps with a one quarter mile, one half mile and one mile radius were prepared. A topographic map extending one (1) mile beyond the well site was prepared by Fox and Fox, Inc. with assistance from Penneco Environmental Solutions, LLC. Maps detailing the area of review are in Attachment B. Research was conducted by:

1) Survey by Fox and Fox, Inc. registered professional surveyors
2) Conversation with surface landowners by Fox and Fox, representatives of Penneco Environmental Solutions LLC.
3) Review of Tax Parcel Maps from the county assessment office.
4) Research of Pennsylvania Bureau of Oil and Gas Management's well records
5) Research of Pennsylvania Geological Survey publications covering the area of review
6) Research of USGS publications covering the area of review.
7) Master Thesis (Two) From West Virginia University
8) Series of reservoir test by HFrac Consulting Services.

Using the results from the above research, along with topographic and tax maps displaying surface features such as buildings, and streams, maps of the AOR were prepared for and included in Attachment B.

The same research used to map the area of review was used to provide data on the geology of the injection zone and the confining formations described in Attachment G.

As part of larger study to assess its lease acreage in the area of the Sedat lease Penneco ran a series of reservoir tests using HFrac Consulting Services to determine the character of the Murrysville reservoir and the results are included in Attachment H.

Attachment E

USDWs for Sedat #3A Injection Well

The Sedat #3A AOR is located in the Pittsburgh Low Plateau Section of the Appalachian Plateau physiographic province (refer to map at the end of this attachment). Underlying rock types are shale, siltstone, sandstone, limestone and coal. Aquifers in the AOR are mainly sandstones of the Conemaugh Group and the Allegheny Group. The Pottsville Group and the Mauch Chunk Formation, identified as USDWs in some areas of Pennsylvania lie at too great a depth to serve as aquifers in the AOR or are absent due to non deposition or erosion as is the case for the Mauch Chunk. See the table on the following pages listing USDWs in Pennsylvania. The thickness of the section from the Conemaugh Group through the Allegheny Group runs in the range of 800 feet depending on surface elevation. A review of the well records shows water production as deep as 1,700 feet. However reports of water production by the driller on their driller's logs are highly unreliable, the quantity and quality of the water is not measured by instrument. The quantity is estimated by site and the water quality which is often measured by taste, is a commingled sample from all formations open to the bore hole at the time of sampling. Additionally, Pennsylvania Geological Survey Water Resource Reports #35 and #37 state water quality is extremely poor beyond 500 feet in depth because of moderate to high mineralization of the waters (high dissolved solids and brine).

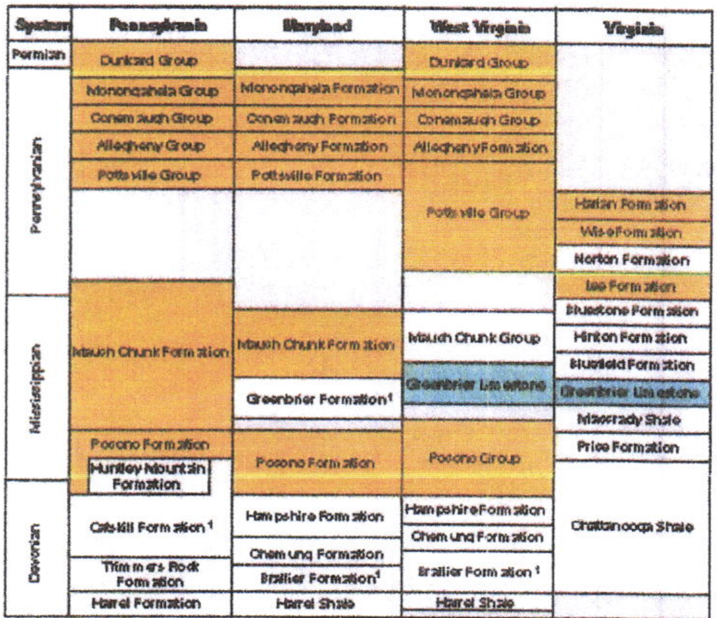
Description of USDWs in AOR

Rock members of the Conemaugh Group predominate at the surface in the AOR: see the section of the geologic map of Pennsylvania at the end of the attachment. The Casselman and Glenshaw Formations make up the Conemaugh Group, and consist of shale, red shale, sandstone and coals.

The Allegheny Group consists of shale, sandstone, thin beds of limestone and coals. The Freeport Formation, Kittanning Formation, Vanport Limestone, and Clarion Formation make up the Allegheny Group.

9-6-2016

Figure 89. The principal aquifers in the Appalachian …aus Province in Segment 11 are sandstones in the g… gic units shown in yellow and limestone shown in …ue. Where fractured, rocks of the Greenbrier, the Catskill, and the Brallier Formations locally yield water. The gray areas represent missing rocks.



[1] Locally water-yielding

Modified from:

…tchen, D.G., and others, 1985a, Correlation of stratigraphic units of North America (COSUNA) Project, southern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

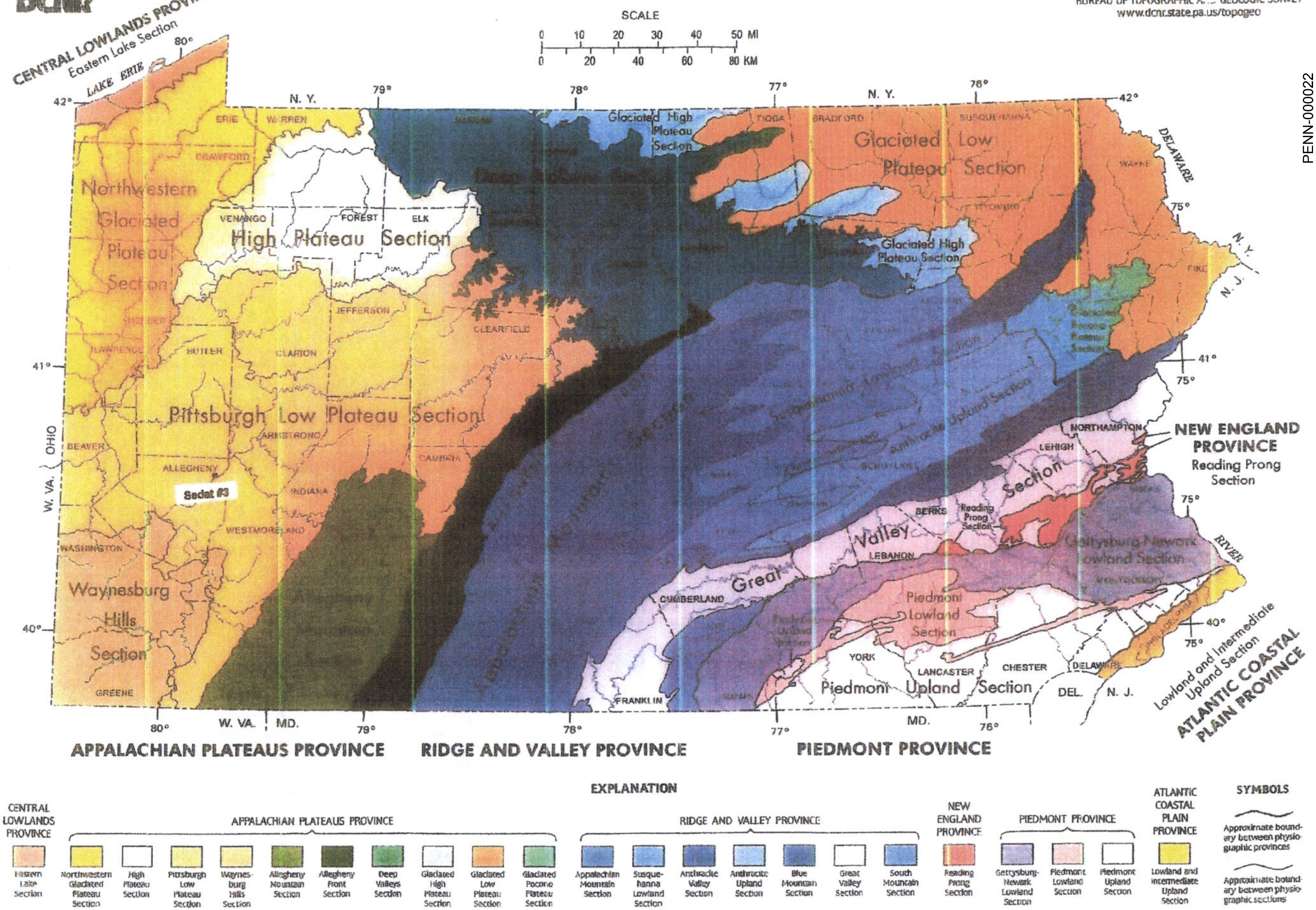
______1985b, Correlation of stratigraphic units of North America (COSUNA) Project, northern Appalachian region: American Association of Petroleum Geologists, 1 sheet.

MAP 13

DCNR

PHYSIOGRAPHIC PROVINC" OF PENNSYLVANIA

COMMONWEALTH OF PENNSYLVANIA
DEPARTME... RESOURCES
CONSERVATION AND N...
BUREAU OF TOPOGRAPHIC A... GEOLOGIC SURVEY
www.dcnr.state.pa.us/topogeo



Compiled by W. D. Sevon. Fourth Edition, 2000.

PENN-000022

Attachment G*
Geological Data on Injection and Confining Zones
SEDAT #3A Injection Well

Geological Data for Sedat #3A Injection Well

The Sedat #3A injection well will be a repurposed depleted natural gas well located in the Renton Gas Field in Plum Borough, Allegheny County, Pennsylvania. The injection well will target the Murrysville Sand as the injection zone which is water saturated and located very near the axis of the Duquesne-Fairmount syncline, see the copy of a section of Pittsburgh Region Structure Contour Map (Map 1) included with this attachment. Also included is a Geologic Map of the western part of Allegheny County, PA (Map 2). The immediate area around the well has been strip mined for coal (Pittsburgh Seam) and mined by underground methods for coal (Upper Freeport Seam); see the Area of Review map in Attachment B.

There are 15 wells within the 1/2 mile Area of Review (ARO) that penetrate the Murrysville sand, the state permit numbers for the wells are:

Permit #	Permit #	Permit #	
003-21287	003-21210	003-22200	003-21223
003-21222	003-21644	003-21238	003-21438
003-21228	003-00674	003-21964	003-21317
003-21225	003-20903	003-21868	

All the wells were cased and cemented through the Murrysville, well 003-00674 was plugged, the well records can be found in Attachment B. The Sedat #1A permit # 003-21210 will be converted to an observation well by perforating the cemented casing string at the depth of the Murrysville.

The Murrysville Sand is approximately 128' thick, and lies at a depth of 1,822' to 1,950' in the Sedat #3A AOR. The well had an original TD of 4,309' and was plugged back to 1,940' to just below the injection zone. See Attachment M Construction Details for well schematic and cement data. Fluid will be injected into a 40' section of the Murrysville Sand through a 4" injection string set on a packer at approximately 1,890' in 7" casing perforated with 41 holes from 1896' to 1936'. The confining zones are the Riddlesburg Shale (Sunbury Equivalent) which overlays the Murrysville with the Riceville-Oswayo Shale lying underneath as the lower confining zone.

The upper confining zone lying directly on top of the Murrysville is the Riddlesburg Shale. The Riddlesburg is a dark gray to greenish and grayish black laminated shale and siltstone with occasional sandstone and limestone beds. The Riddlesburg is between 80 to 90 feet thick in the Sedat #3A AOR; see the Riddlesburg Isopach map, Map 3 at the end of Attachment G.

The Murrysville is a greenish-yellow to gray sandstone with occasional conglomeratic lenses, with high porosity and permeability. Because of the Murrysville's thickness, high porosity and permeability the formation serves as a gas storage reservoir to the south of the Sedat. All most all the wells in the AOR including the Sedat #3A were drilled and cased through the Murrysville without running a porosity logs, see the well records in Attachment B. There are two wells for which porosity logs are available that show the average density porosity through the Murrysville Sand to average around 24%, which agrees with published reports of porosity values in the Murrysville. Refer to the log sections and location map at the end of this attachment for wells permit # 129-24721, and well permit #129-25581. Both wells where saturated with brine and did not produce gas.

Penneco conducted several tests to determine the reservoir characteristics of the Murrysville on its leases with the results included at the end of Attachment H. The test provided a breakdown pressure, the pressure needed to initiate a fracture, as 3,115 psi, ISP is estimated as 1,114 psi, with a fracture gradient of 1.23 psi. The reservoir pressure is 232 psi, with an estimated closure pressure of 553 psi. See the supplement to the HFrac report labeled Item 5 for more detail on the methodology used to determine the fracture gradient.

Formation permeability for the Murrysville was reported by Melissa Sager (Petrologic Study of the Murrysville sandstone in SW PA, 2007) as generally high throughout the formation, with a range of 0.005 to 1,000 millidarcies with an average of around 100 millidarcies. The permeability of the Murrysville in the Sedat #3A is estimated to be 1.8 mD and was determined from a series of tests to determine the reservoir characteristics of the Murrysville sand on Penneco leases conducted by HFrac Consulting Services, LLC, see the supplement to the HFrac report labeled Item 7 at the end of this attachment for additional detail. This value falls within the lower range of Sager's study.

The Riceville-Oswayo Shale lying directly beneath the Murrysville serves as the lower confining zone. The Riceville-Oswayo is about 30 feet thick in the AOR; see Map 4, Isopach map of the Oswayo Shale. The Riceville-Oswayo formation consists of dark gray to medium gray shale and siltstones.

Structurally the AOR has a series of northeast-southwest trending anticlines and synclines with the Sedat #3A well lying along the axis of the Duquesne-Fairmount syncline refer to Map 1. While there are some deep seated basement faults associated with the Rome Trough, review of Map 1, Map 2 and an additional structure map contoured on the top of the Murrysville Sand and additional cross sections across the AOR supports the idea that there are no apparent faults at shallower depths in the AOR. The Murrysville structure map along with additional cross sections across the AOR are from McDaniel's Subsurface Stratigraphy and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA.

Review of Pennsylvania Geologic Publication, Atlas No. 36, Geology of the Freeport Quad (the Sedat #3A is in the SW corner of the quad) states on page 23 "displacement faults where not seen in any outcrop. Inquiry among mine operators indicate practically the same thing". Penneco Environmental Solutions, LLC had a related company that at one time mined in the AOR and a search of its records supports the statement found in Atlas No. 36.

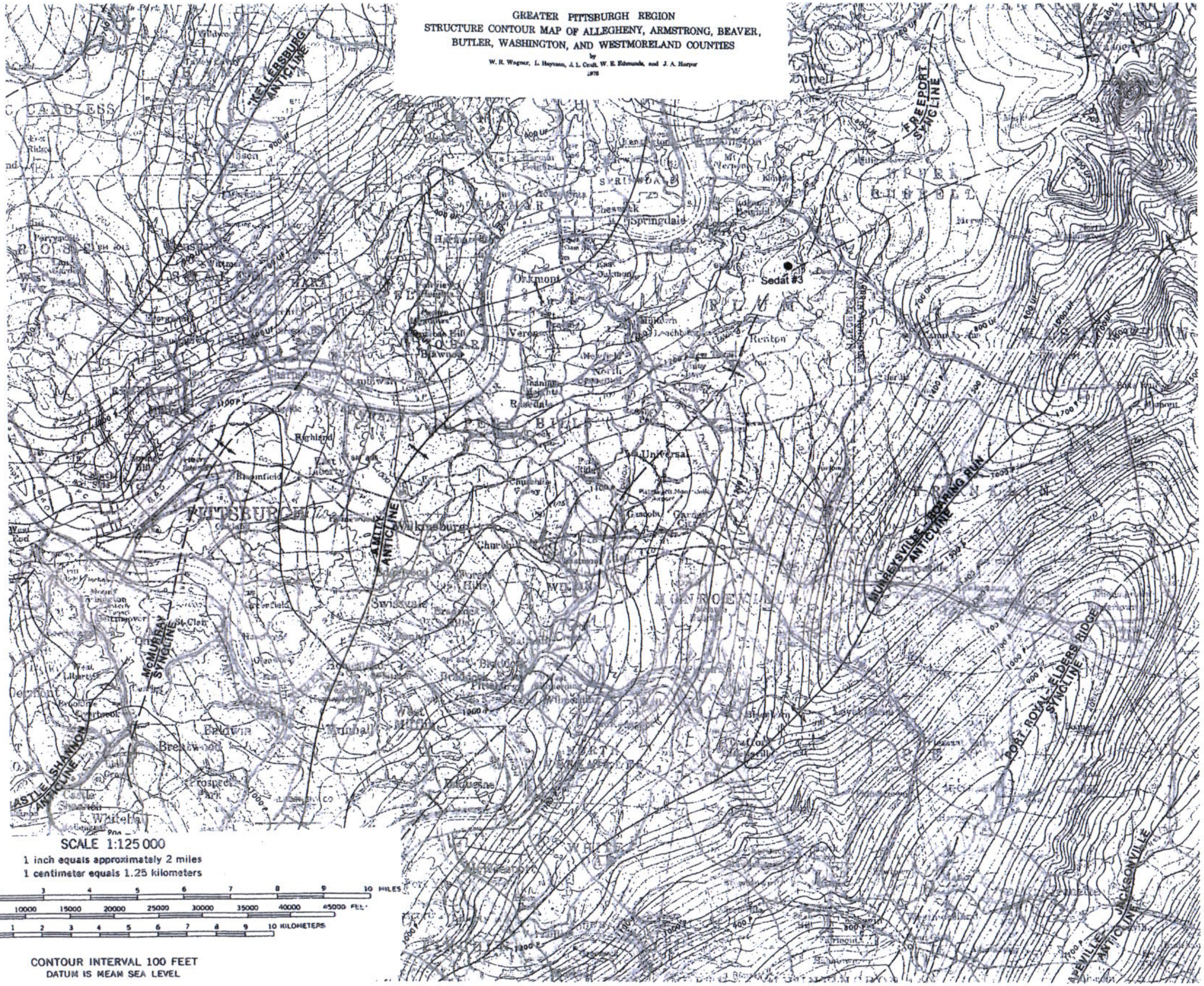
The U.S.G.S rates the probability of seismic activity in SW Pennsylvania with sufficient intensity to cause damage as low. A series of four earthquake maps from the U.S.G.S earthquake hazards program website are found at the end of this attachment.

Earthquake Map 1 shows the historical locations of earthquakes in Pennsylvania and nearby areas. Earthquake Map 2 shows the entire US color code to show the chance of a seismic event occurring from lowest to highest. Map 1 shows no seismic events are shown to have occurred in SW PA, and Map 2 shows the AOR lies in an area with the second lowest hazard level.

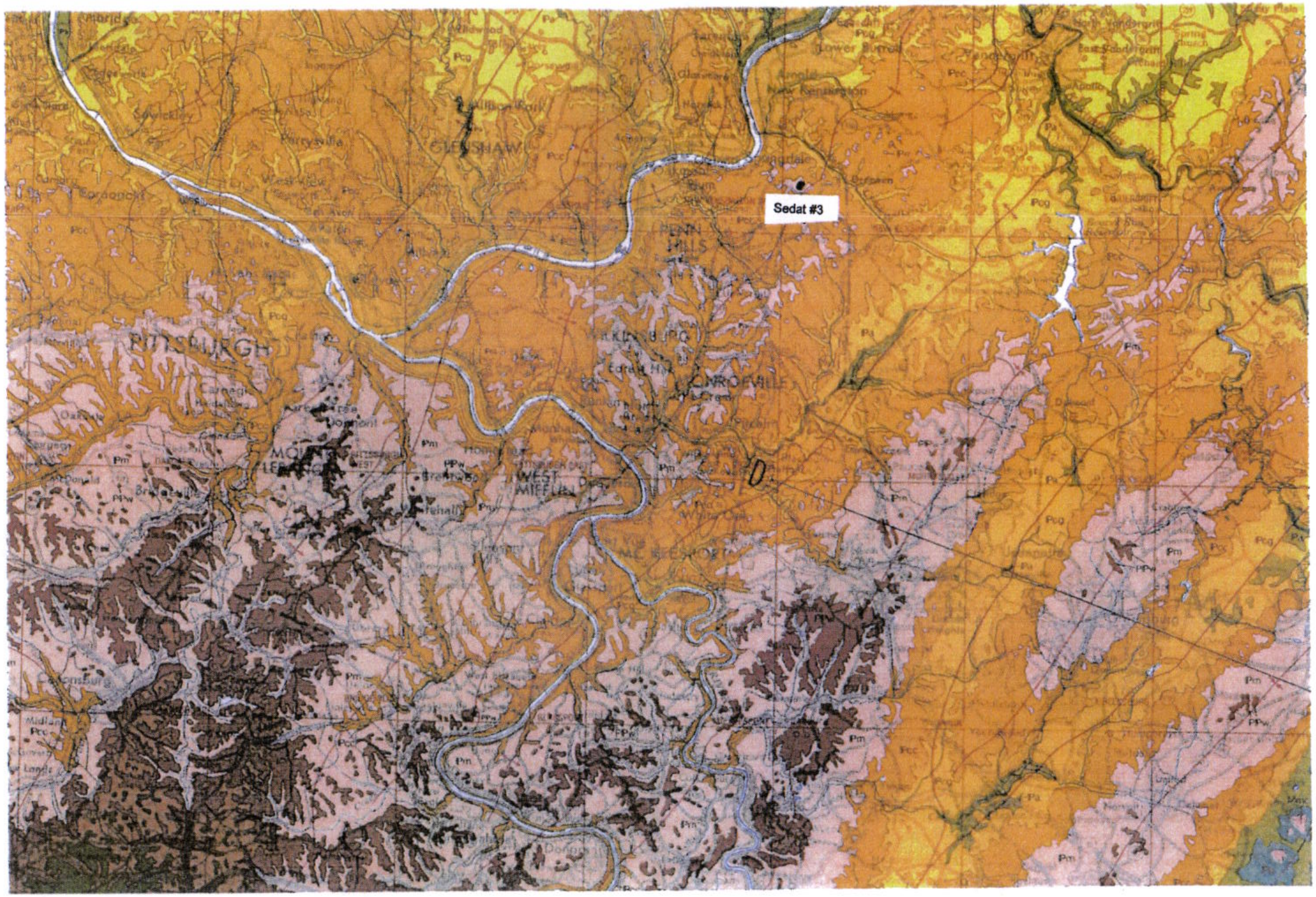
Earthquake Maps 3 and 4 are from U.S.G.S. open file report 2016 One Year Seismic Hazard Forecast for the Central and Eastern United States from Induced and Natural Earthquakes OFR-2016-1035. Map 3 shows there is a small chance (one percent) that ground shaking greater then IV on the Modified Mercalli Scale will occur. Map 4 indicates the change of damage in the NE from natural or induced seismic activity to be 1% to 2%.

Penneco also contends that the maximum injection pressure is sufficiently below the pressure needed to initiate a fracture or reactive any unknown faults. The injection rate is also not of a sufficient volume to open or extend any fractures or reactive any unknown faults in the area, see the HFRAC report.

Map 1


GREATER PITTSBURGH REGION
STRUCTURE CONTOUR MAP OF ALLEGHENY, ARMSTRONG, BEAVER, BUTLER, WASHINGTON, AND WESTMORELAND COUNTIES
by
W. R. Wagner, L. Heyman, J. L. Craft, W. E. Edmunds, and J. A. Harper
KELLERSBURG ANTICLINE
FREEPORT SYNCLINE
Sedat #3
AMITY ANTICLINE
MURRYSVILLE - ROARING RUN ANTICLINE
PORT ROYAL - ELDERS RIDGE SYNCLINE
JACKSONVILLE ANTICLINE
McMURRAY SYNCLINE
CASTLE SHANNON ANTICLINE
PITTSBURGH
Springdale
Oakmont
Renton
Wilkinsburg
Swissvale
Baldwin
Brentwood
West Mifflin
Duquesne
Whitehall
Universal
SCALE 1:125 000
1 inch equals approximately 2 miles
1 centimeter equals 1.25 kilometers
MILES
FEET
KILOMETERS
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

Map 2
From Pa Geologic Map
1980



SCALE 1:250,000

5 0 5 10 15 Miles

5 0 5 10 15 20 25 Kilometers

5000 0 5000 10000 15000 20000 25000 Yards

ONE INCH EQUALS APPROXIMATELY FOUR MILES

SUPERIOR WELL SERVICES

SUPERIOR
Black Lick, Pa.
Mercer, Pa.
Wooster, Ohio
Charleston, W Va

GAMMA RAY
NEUTRON
DENSITY
DUAL INDUC

CPNY PENNECO OIL COMPANY
WELL MARONDA HOMES #1 (PM-
FIELD MURRYSVILLE QUADRANG
CO. WESTMORELAND ST PA

COMPANY PENNECO OIL COMPANY
WELL MARONDA HOMES #1 (PM-594)
FIELD MURRYSVILLE QUADRANGLE
COUNTY WESTMORELAND STAT

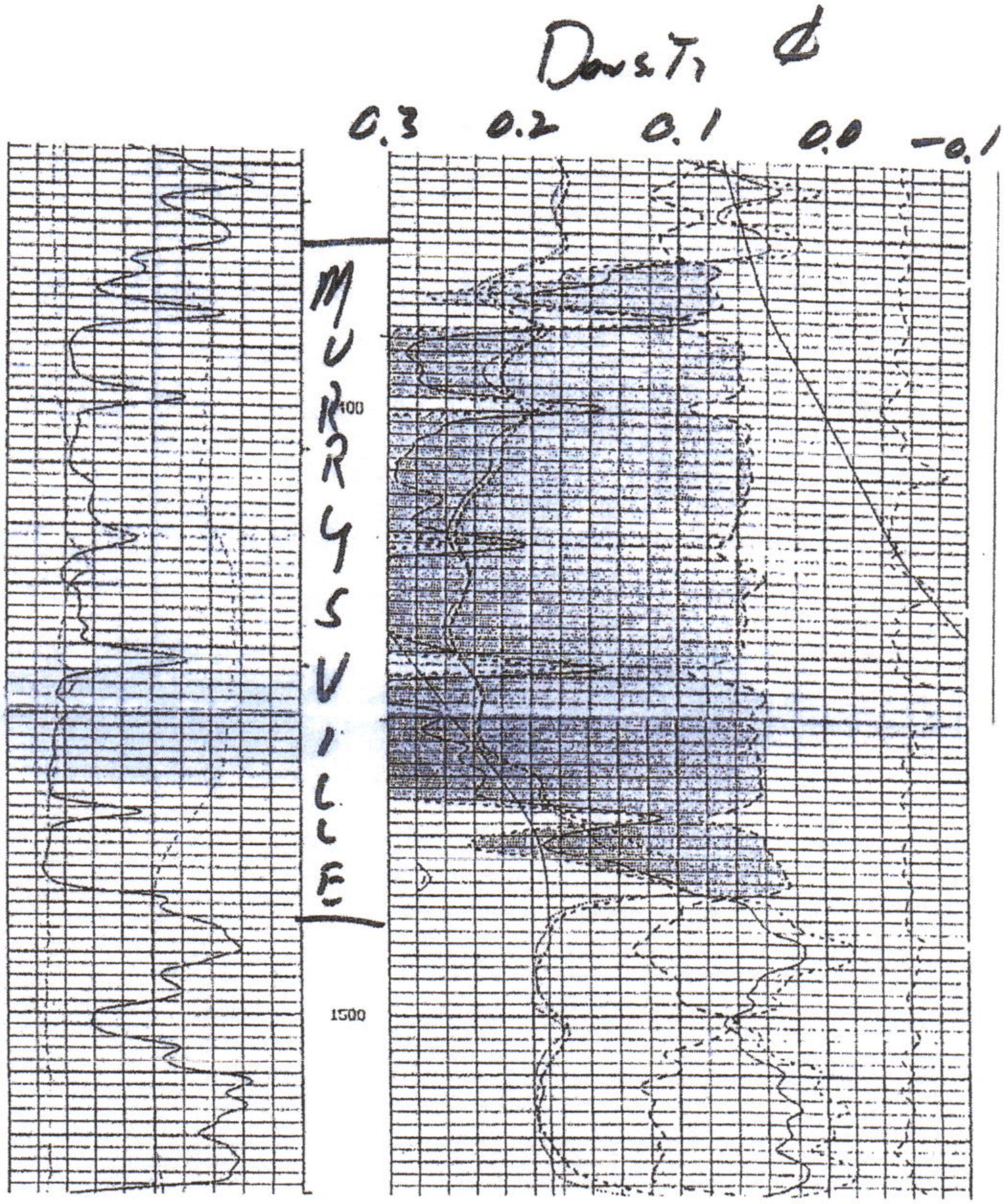
LOCATION
PERMIT#37-129-24721
0' WEST LONG:79°37'58.2"
0' SOUTH LAT:40°29'24.5"

OT

SEC.______ TWP. WASHINGTONE ,______

PERMANENT DATUM GROUND LEVEL ELEV. 1120 FT. EL
LOG MEASURED FROM TOP OF 7" ABOVE PERMANENT DATUM
DRILLING MEASURED FROM K.B.

DATE	06-14-02		
RUN NO.	ONE		
DEPTH-DRILLER	3550 FT.		
DEPTH-LOGGER	3537 FT.		
BTM. LOG INTER.			
TOP LOG INTER.	0 FT.		
CASING-DRILLER	1280 FT.		
CASING-LOGGER	1280 FT.		
BIT SIZE	6.25 IN.		
FLUID TYPE	AIR/GAS		
DENS. : VISC.	N/A		
PH : FLUID LOSS	N/A		
SOURCE OF SAMPLE	N/A		
RM @ MEAS. TEMP.	N/A		
RMF @ MEAS. TEMP.	N/A		
RMC @ MEAS. TEMP.	N/A		
SOURCE: RMF/RMC	N/A		
RM @ BHT	N/A		
TIME SINCE CIRC.	N/A		
MAX. REC. TEMP.	N/A		
EQUIP.: LOCATION	0058/BLKLCK		
RECORDED BY	JERRY MOORE		
WITNESSED BY	MR. JACOBS		


Density Ø
0.3 0.2 0.1 0.0 -0.1
MURRYSVILLE
1400
1500

LDT

Schlumberger

DOMINION EXPLORATION & PRODUCTION, INC.

JACOB SNYDER UNIT #3 (WPA06512)
HEMPFIELD TWP
WESTMORELAND PENNSYLVANIA

COUNTY: WESTMORELAND
Field: HEMPFIELD TWP
Location: LATITUDE: 40-15-34.2700
Well: JACOB SNYDER UNIT #3 (WP
Company: DOMINION EXPLORATION & P

LITHO DENSITY
COMPENSATED NEUTRON / GR
ARRAY INDUCTION / TEMPERATURE

LOCATION		Elev.:	
LATITUDE: 40-15-34.2700			K.B.
LONGITUDE: 79-40-1.3600			G.L. 1080 ft
11711' S & 105' W OF NE CORNER			D.F.
Permanent Datum:	GROUND LEVEL	Elev.:	1080 ft
Log Measured From:	KB	8.0 ft	above Perm. Datum
Drilling Measured From:	KB		

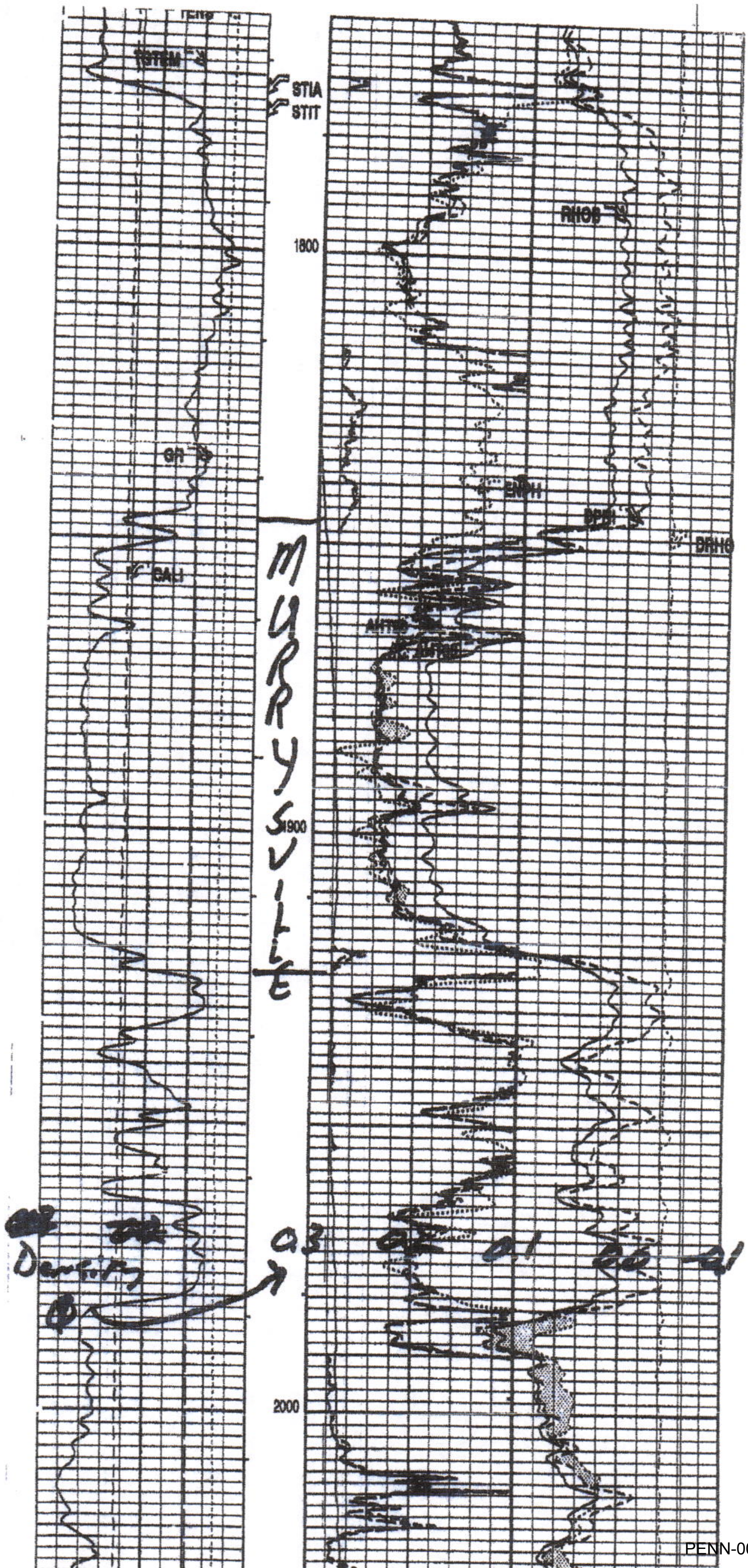
API Serial No	MAP SECTION:	TOWNSHIP:	QUAD:
37-129-25581-00	8	HEMPFIELD	IRWIN

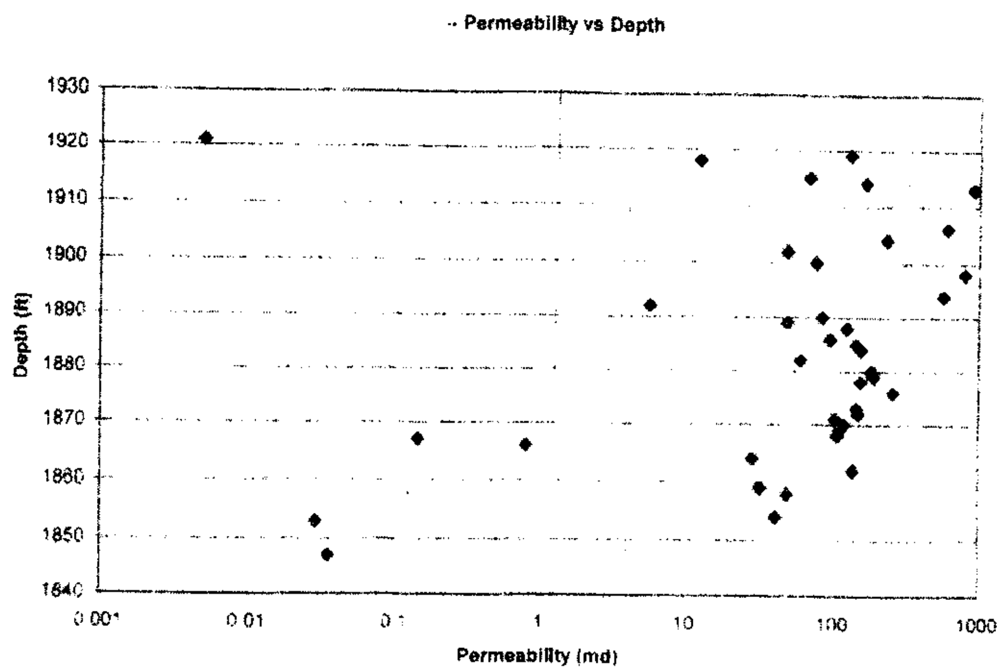
Logging Date	31-Aug-2005	
Run Number	1	
Depth Driller	2130 ft	
Schlumberger Depth	2135 ft	
Bottom Log Interval	2127 ft	
Top Log Interval	0 ft	
Casing Driller Size @ Depth	9.625 in @ 354 ft	@
Casing Schlumberger	398 ft	
Bit Size	8.875 in	
Type Fluid in Hole	AIR / GAS / PRODUCED FLUIDS	
MUD Density / Viscosity	0 lbm/gal	
Fluid Loss / PH		
Source Of Sample		
RM @ Measured Temperature	@	@
RMF @ Measured Temperature	@	@
RMC @ Measured Temperature	@	@
Source RMF / RMC		
RM @ MRT / RMF @ MRT	@ 70 / @ 70	@ / @
Maximum Recorded Temperatures	70 degF	
Circulation Stopped / Time		
Logger On Bottom / Time	31-Aug-2005 / 18:40	
Unit Number / Location	3069 / BRADFORD	
Recorded By	TIM LYON, MIKE KORNACKI	
Witnessed By	NATE ZIMMERMAN, MELISSA THARP	

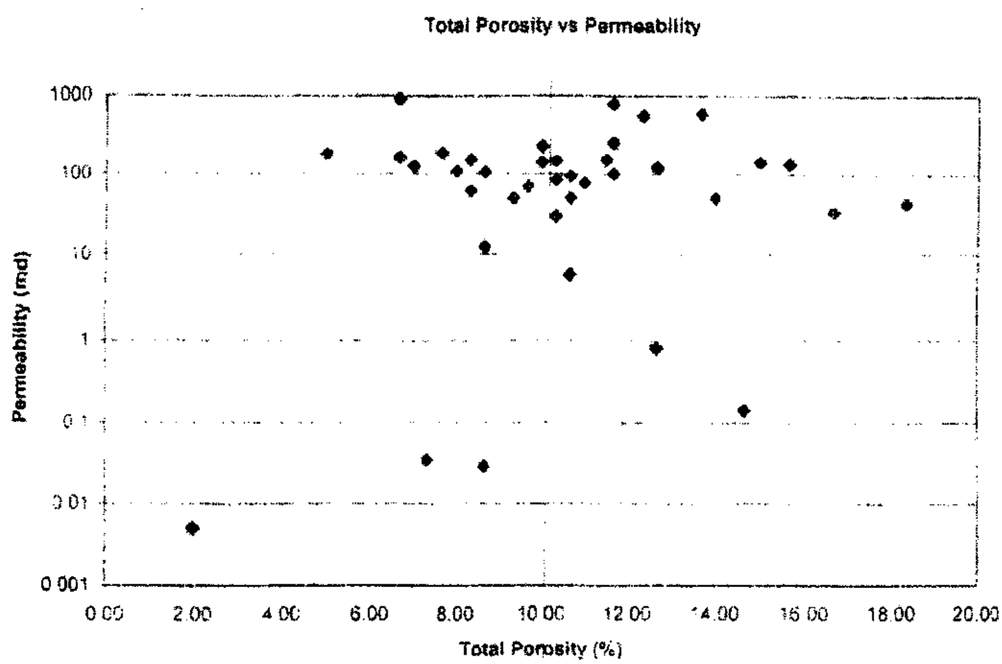
	Run 1	Run 2	Run 3	Run 4

Logging Date		
Run Number		
Depth Driller		
Schlumberger Depth		
Bottom Log Interval		
Top Log Interval		
Casing Driller Size @ Depth	@	@
Casing Schlumberger		
Bit Size		
Type Fluid in Hole		
MUD Density / Viscosity		
Fluid Loss / PH		
Source Of Sample		
RM @ Measured Temperature	@	@
RMF @ Measured Temperature	@	@
RMC @ Measured Temperature	@	@
Source RMF / RMC		
RM @ MRT / RMF @ MRT	@ / @	@ / @
Maximum Recorded Temperatures		
Circulation Stopped / Time		
Logger On Bottom / Time		
Unit Number / Location		
Recorded By		
Witnessed By		

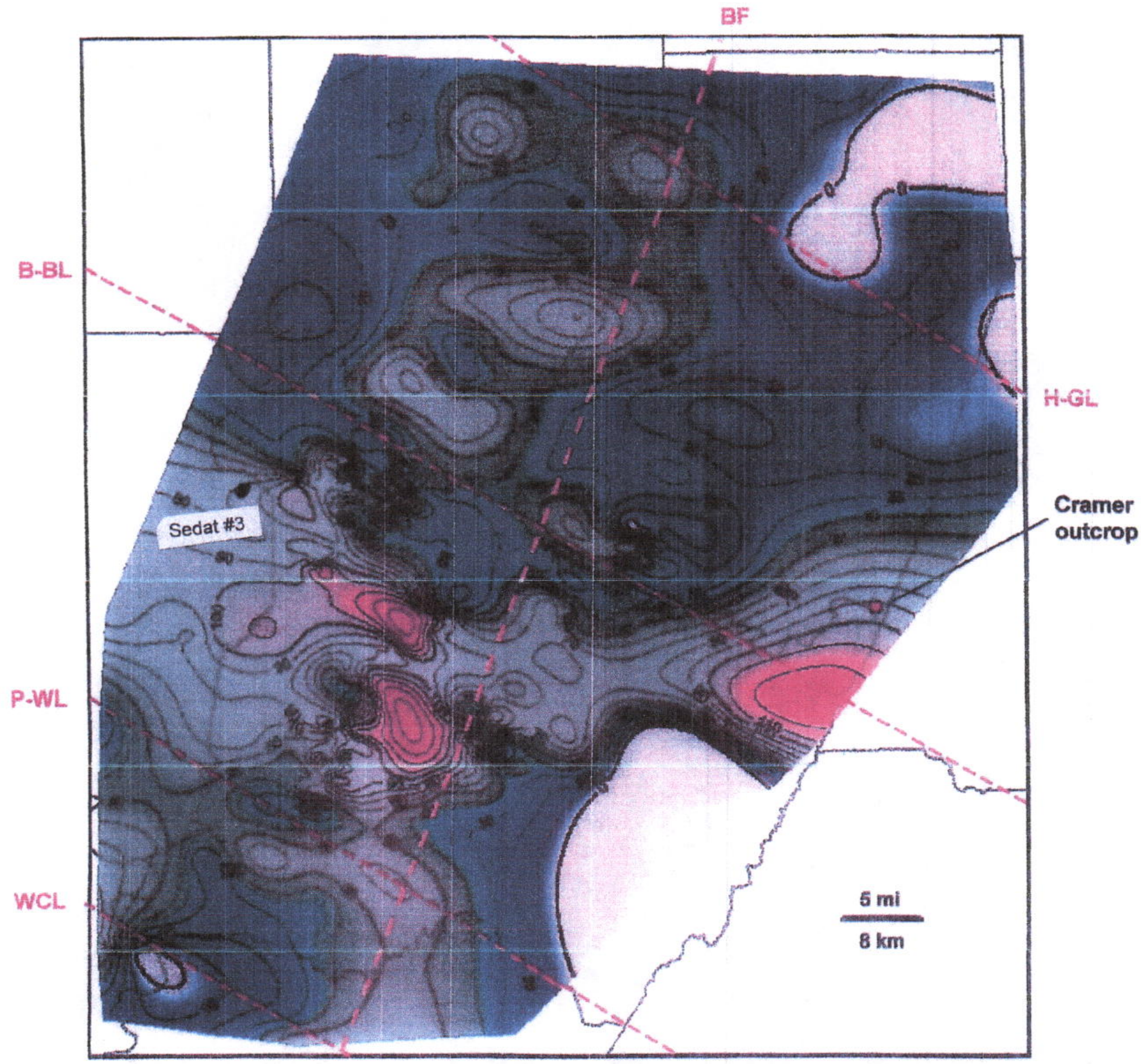
Jacob Snyder Unit #3
129-25581



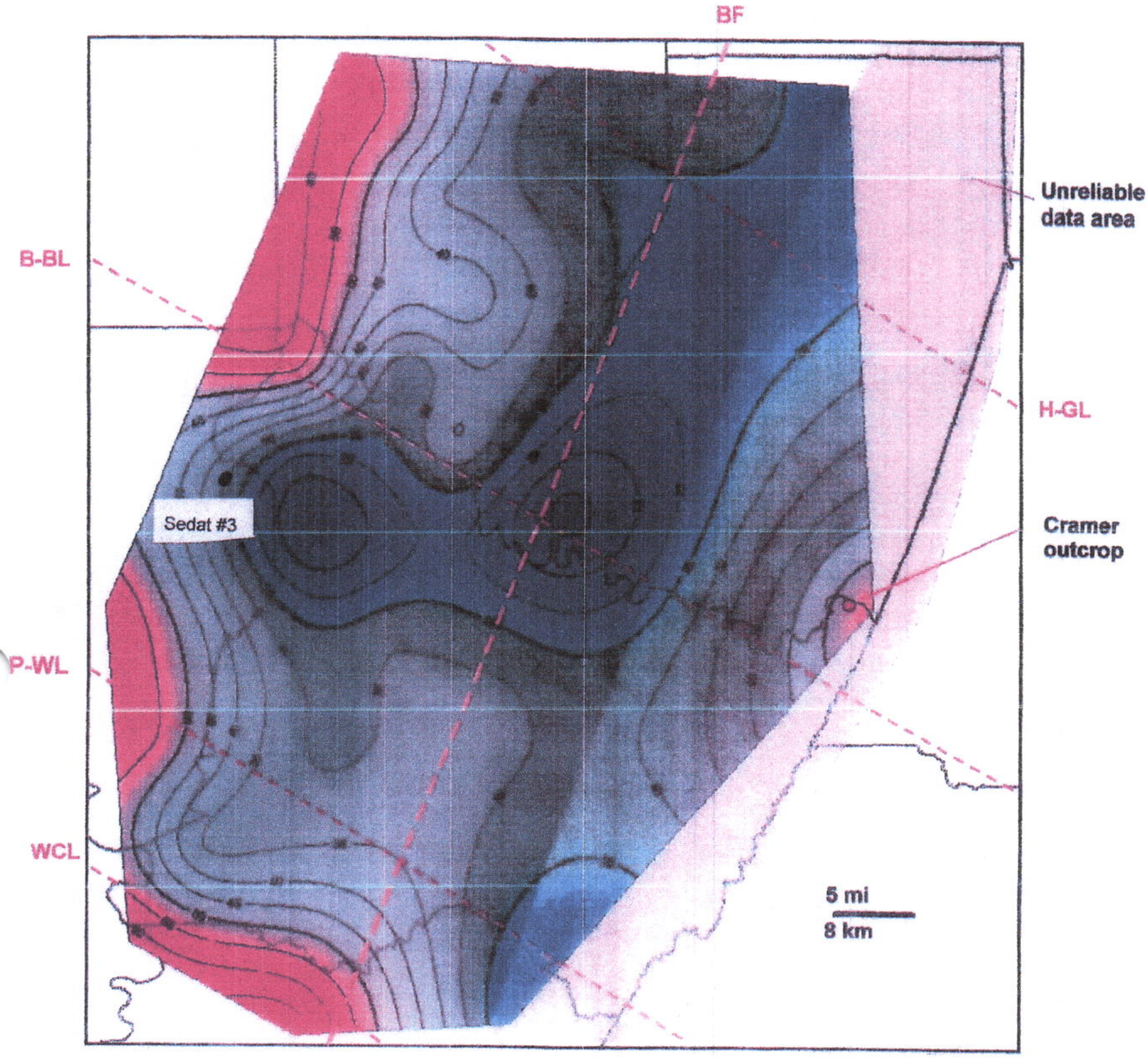




Sage, Melissa, 2007. Petrologic study of Murrysville sandstone in SW PA

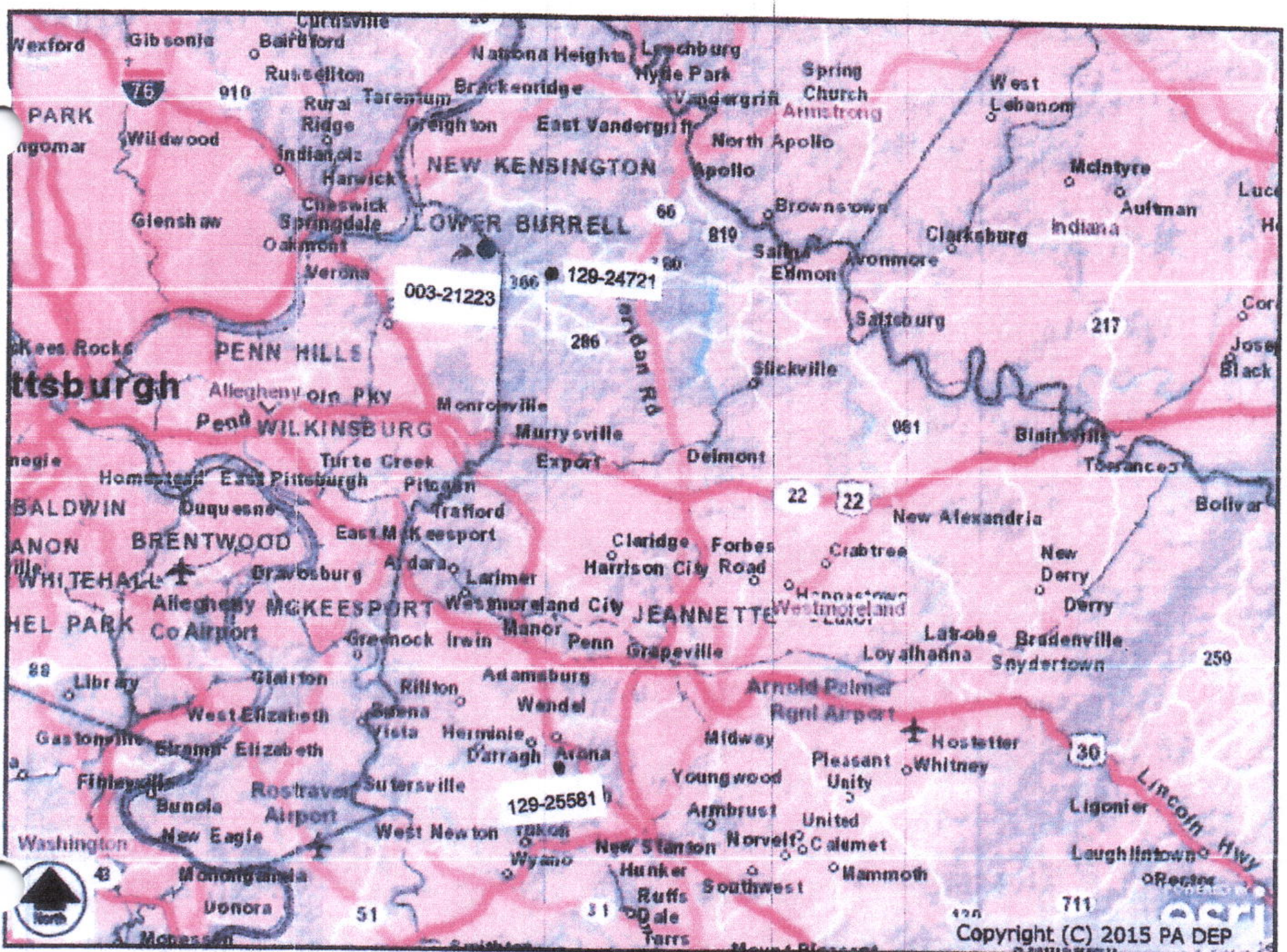


Map 3. Riddlesburg Shale Isopach Map
McDaniel, Bret, 2006. Subsurface Stratigraphy and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA



Map 4. Riceville-Oswayo Shale Isopach Map

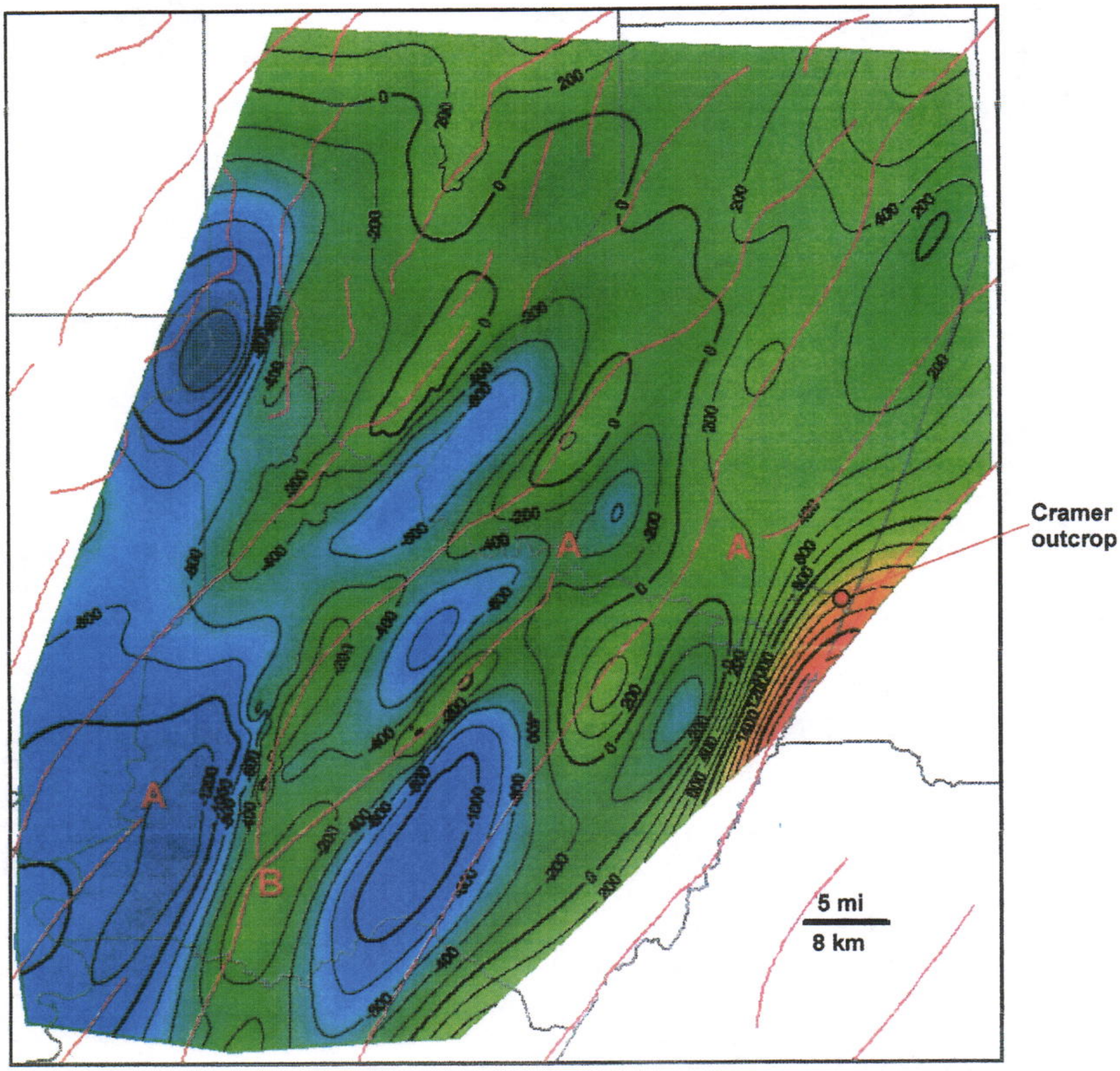
McDaniel, Bret, 2006. Subsurface Stratigraphy and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA.



10 Miles

Legend

Unconventional Wells	Conventional Wells	County Boundaries



Map 5. Structure Map on Top of Murrysville Sand
McDaniel, Bret, 2006, Subsurface Stratigraphic and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA

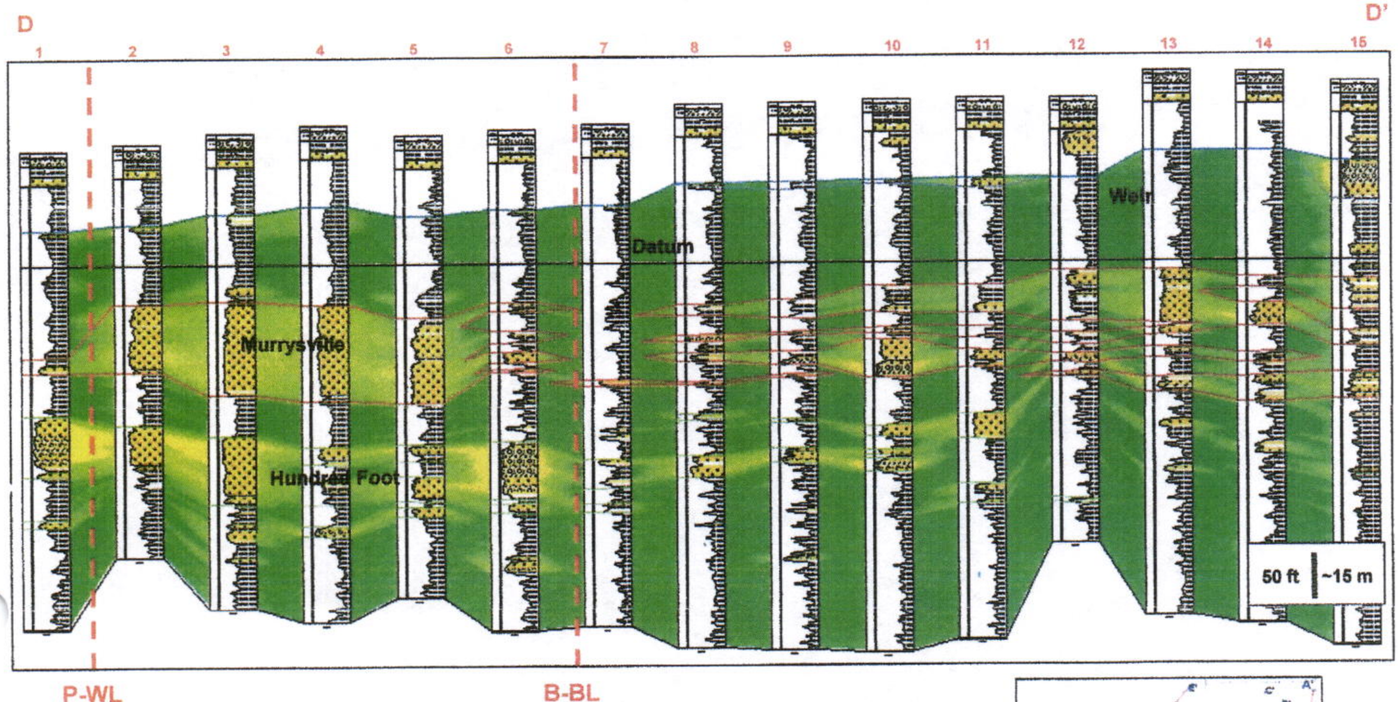
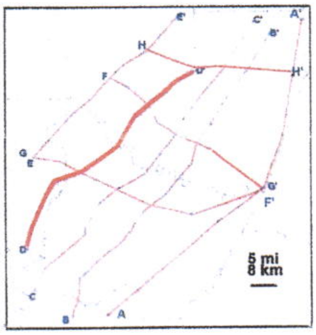


Figure 34. Cross section along D-D'. The most dramatic thinning occurs along this line as the Murrysville crosses the Blairsville-Broadtop Lineament (B-BL). Also evident is that there are two thick sequences of Murrysville, one thick and blocky in the southwest and another that lies to the northeast. It is unclear how this northeastern Murrysville relates to the blocky section to the south. One hypothesis may be that the north Murrysville may be nearshore deposits deposited north and south of the main channel the or perhaps these sandstones are abandoned delta lobes. The Weir is thin since it is far to the west of its depositional trend. The Hundred Foot becomes thick to the south, and it is here where the barrier bar sequence is best developed. See Figure 19 for the location of each numbered well.



Cross Section D-D'

McDaniel, Bret, 2006, Subsurface Stratigraphic and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA

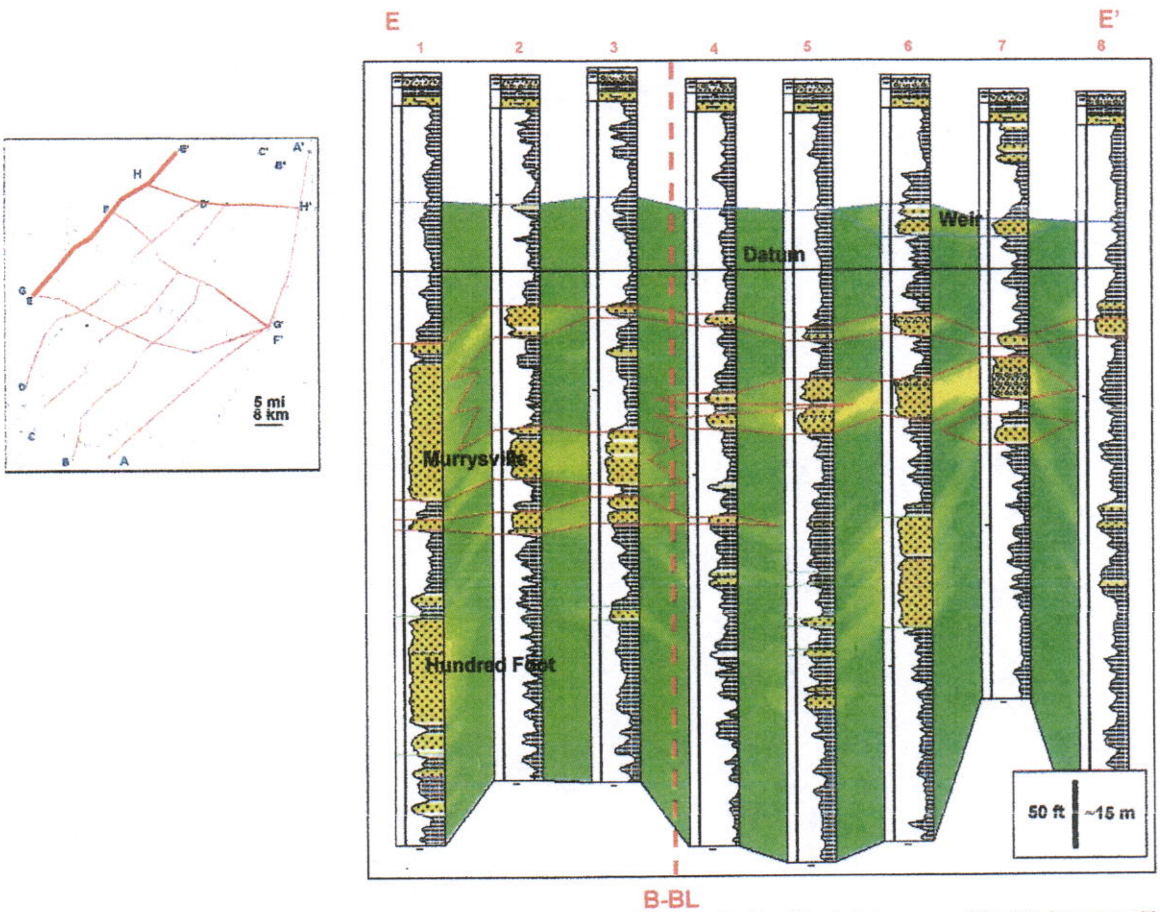
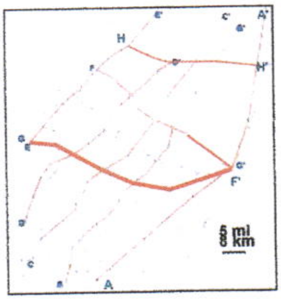


Figure 35. Cross-section along E-E'. This is the most erratic section in terms of correlative sand units. The data becomes difficult to interpret within this section, but there is still some evidence that the Blairsville-Broadtop Lineament (B-BL) may have had some influence on deposition of the Murrysville. The Weir sandstone is nearly gone this far west, with only a few intermittent sandstones. See Figure 19 for the location of each numbered well.

Cross Section E-E"

McDaniel, Bret, 2006, Subsurface Stratigraphic and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA



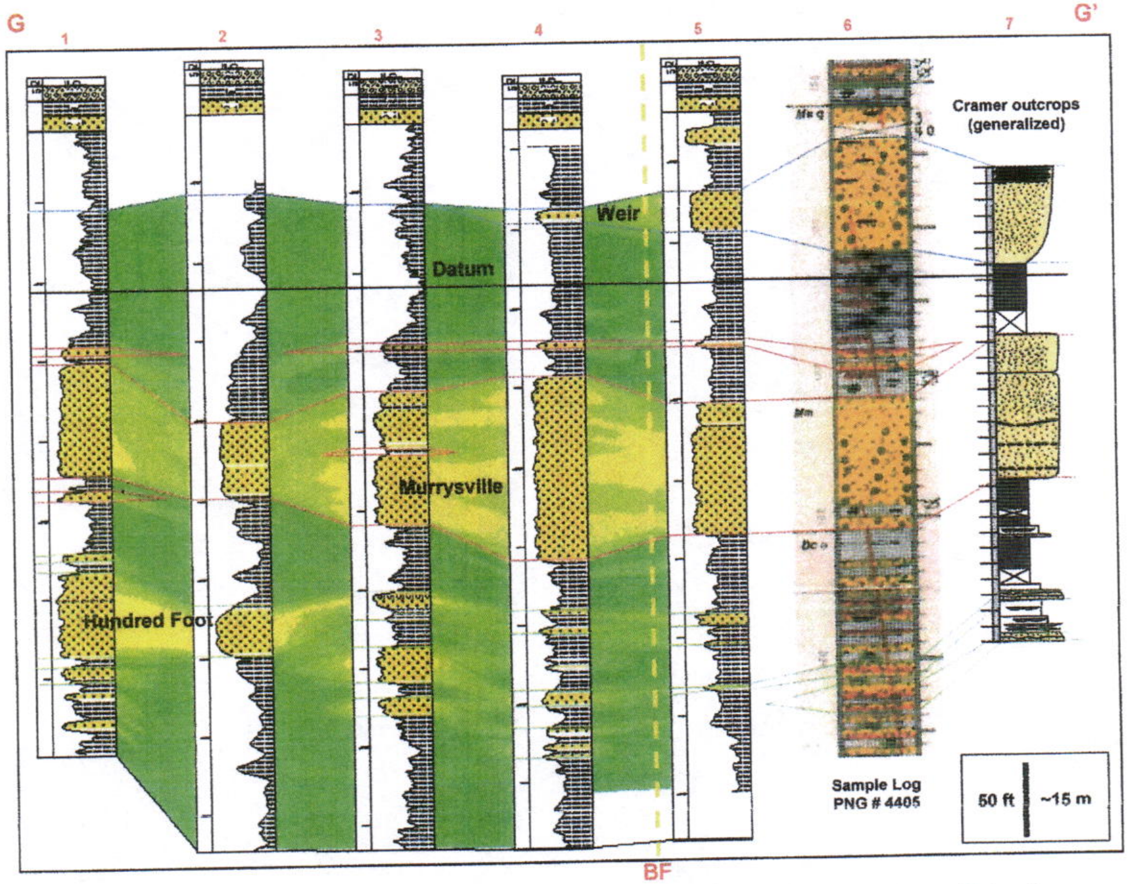


Figure 37. Cross section along G-G' section. This section attempts to tie the well log section to the outcrop data along the major Murrysville trend. Three things are evident from the section. (1)The Weir dramatically thins to the west across the proposed basement fault. (2)The Murrysville displays a thickened section to the west of the basement fault. (3)The Hundred Foot thins eastward as it reaches the basement fault. See Figure 19 for the location of each numbered well.

Cross Section G-G'

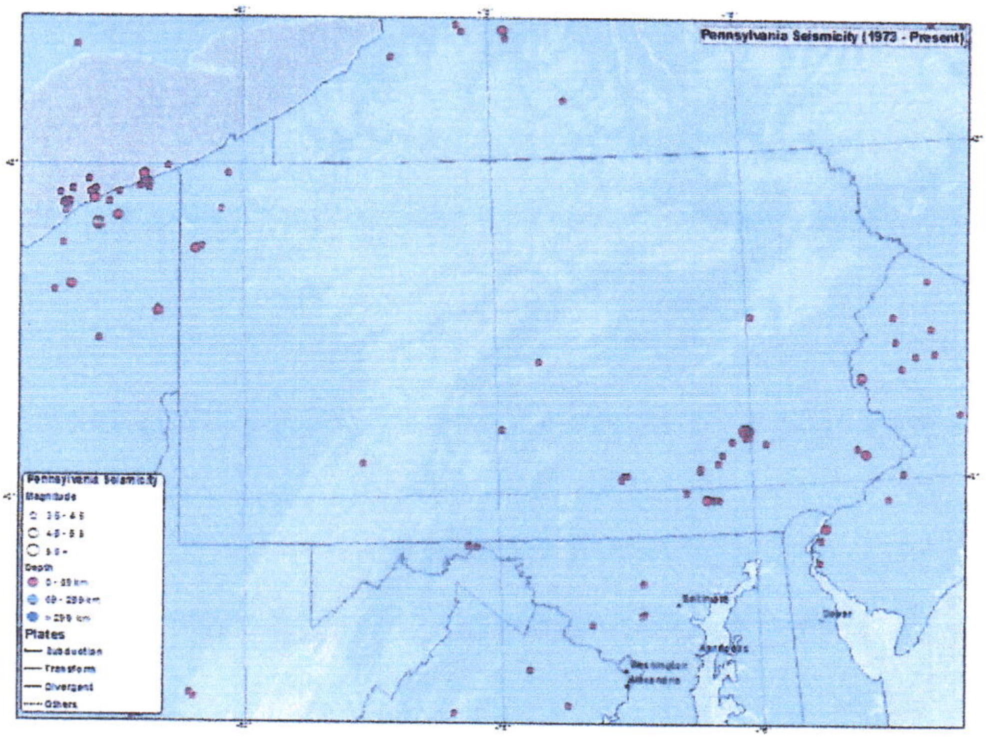
McDaniel, Bret, 2006, Subsurface Stratigraphic and Depositional Controls on Late Devonian-Early Mississippian Sediments in SW PA

USGS
science for a changing world

Earthquake Hazards Program

Pennsylvania

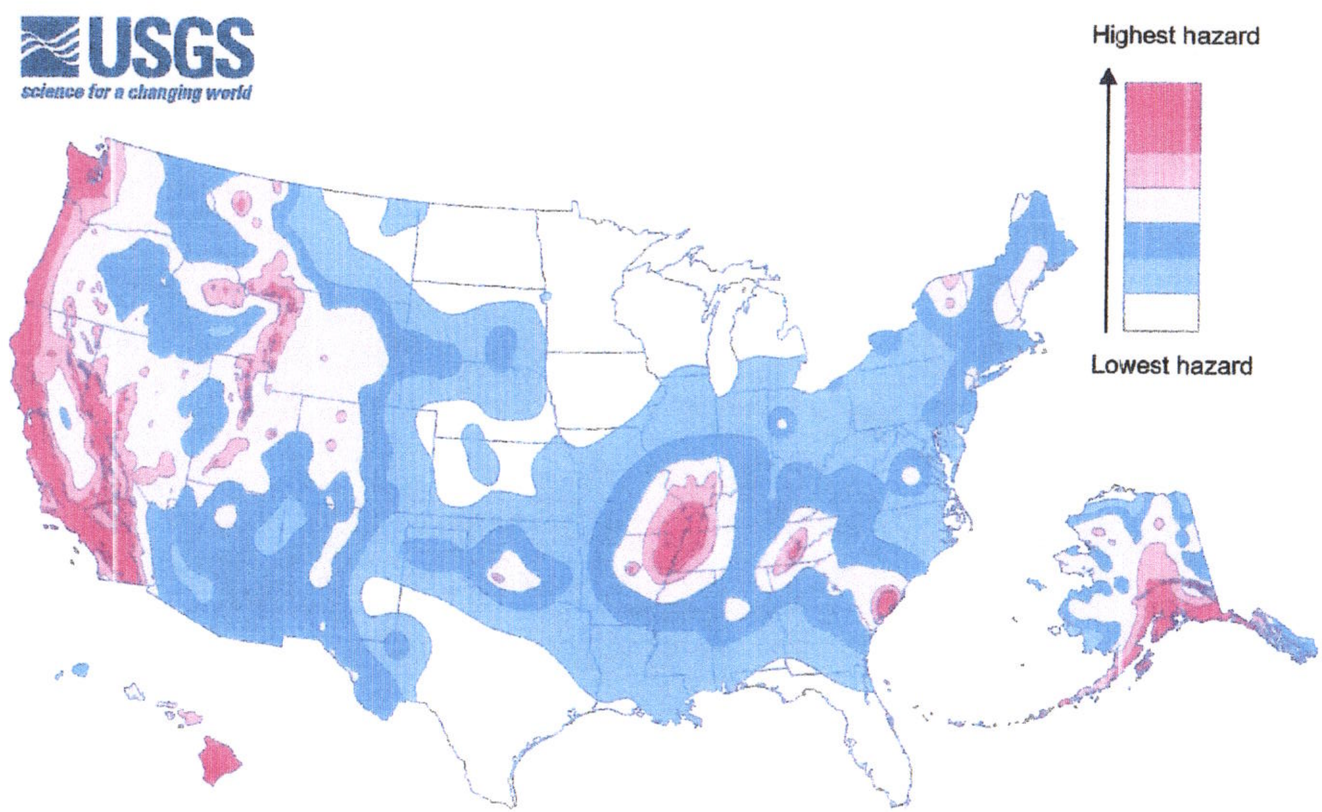
Seismicity Map - 1973 to March 2012



Share this page: Facebook Twitter Google Email

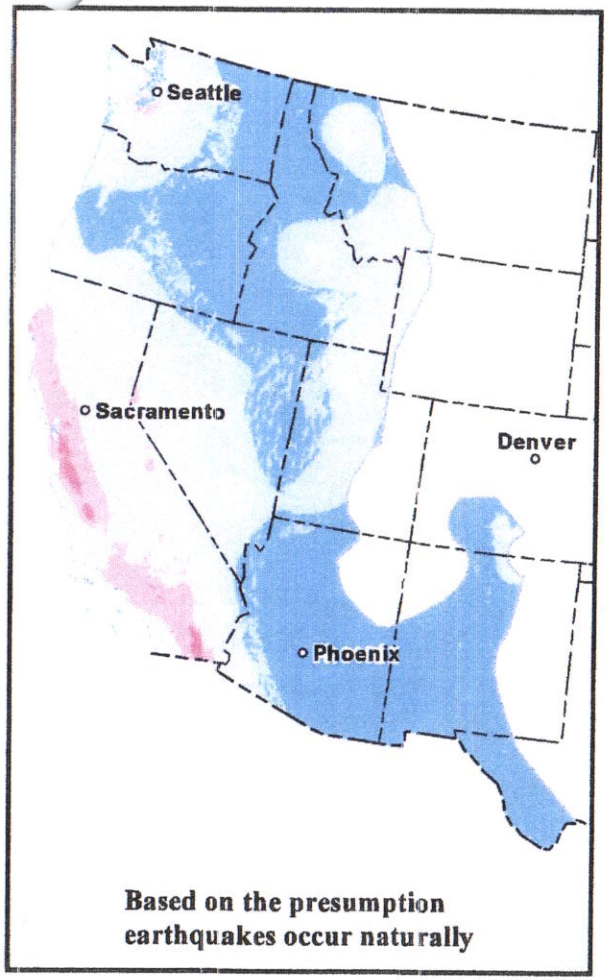
Earthquake Map 1

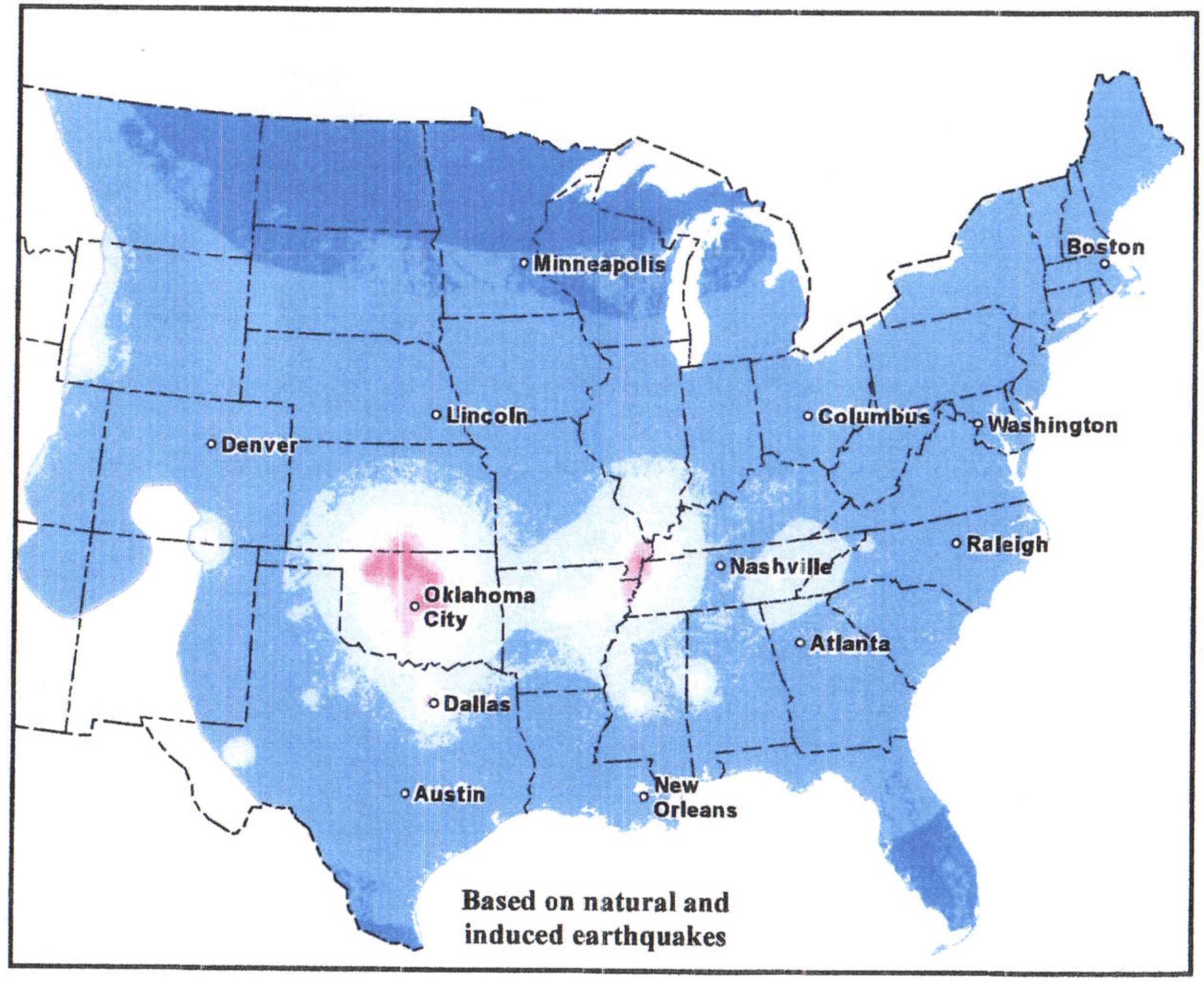
PENN-000040



Earthquake Map 2

JSGS Forecast for Ground Shaking Intensi rom Natural and Induced Earthquakes in





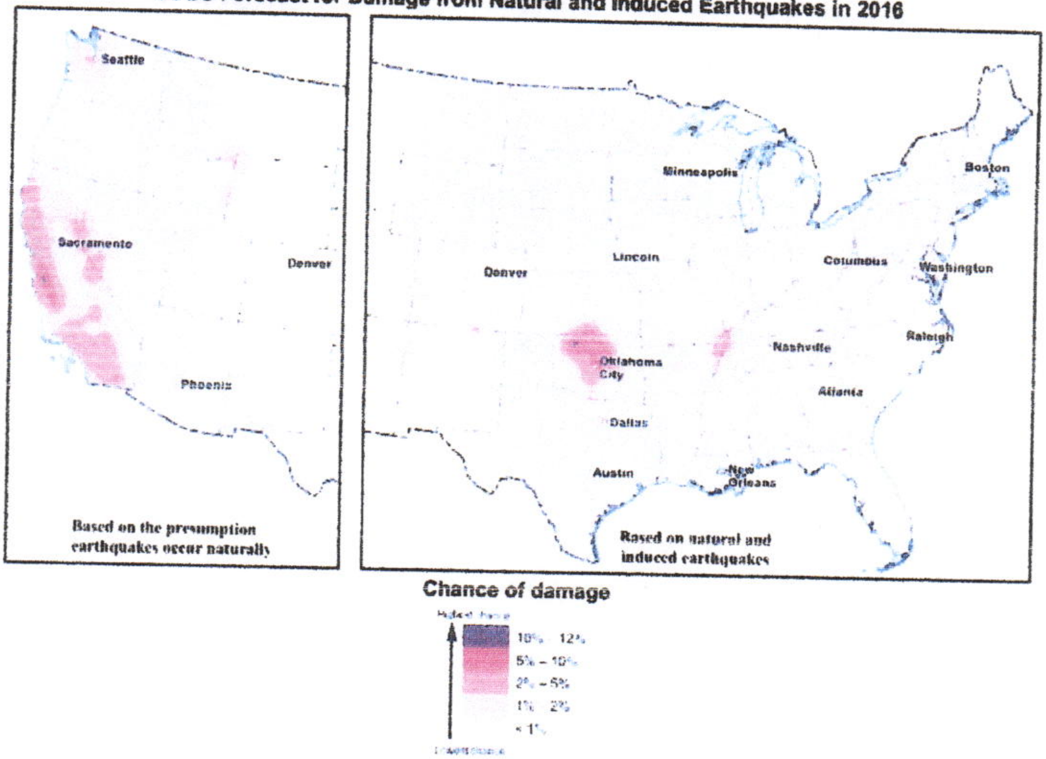
Earthquake Map 3

Modified Mercalli Intensity

VIII+	Shaking severe, heavier damage
VII	Shaking very strong, moderate damage
VI	Shaking strong, felt by all, minor damage
V	Shaking moderate, felt indoors by most, outdoors by many
IV	Shaking light, felt indoors by many, outdoors by few
III	Shaking weak, felt indoors by several

USGS map displaying intensity of potential ground shaking from natural and human-induced earthquakes. There is a small chance (one percent) that ground shaking intensity will occur at this level or higher. There is a greater chance (99 percent) that ground shaking will be lower than what is displayed in these maps.

USGS Forecast for Damage from Natural and Induced Earthquakes in 2016



USGS map displaying potential to experience damage from natural or human-induced earthquakes in 2016. Chances range from less than 1 percent to 12 percent.

USGS map displaying potential to experience damage from a natural or human-induced earthquake in 2016. Chances range from less than one percent to 12 percent.

Six States Face the Highest Hazards

The most significant hazards from induced seismicity are in six states, listed in order from highest to lowest potential hazard: Oklahoma, Kansas, Texas, Colorado, New Mexico and Arkansas. Oklahoma and Texas have the largest populations exposed to induced earthquakes.

"In the past five years, the USGS has documented high shaking and damage in areas of these six states, mostly from induced earthquakes," said Petersen. "Furthermore, the USGS Did You Feel It? website has archived tens of thousands of reports from the public who experienced shaking in those states, including about 1,500 reports of strong shaking or damage."

In developing this new product, USGS scientists identified 21 areas with increased rates of induced seismicity. Induced earthquakes have occurred within small areas of Alabama and Ohio but a recent decrease in induced earthquake activity has resulted in a lower hazard forecast in these states for the next year. In other areas of Alabama and small parts of Mississippi, there has been an increase in activity, and scientists are still investigating whether those events were induced or natural.

People living in areas of higher earthquake hazard should learn how to be prepared for earthquakes, and guidance can be found through FEMA's Ready Campaign.

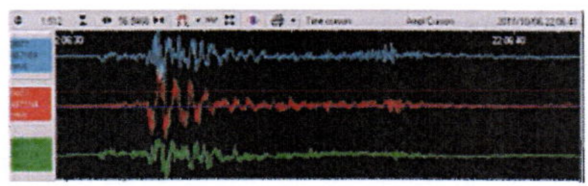
Earthquake Map 4

PennState Extension

Natural Gas

Seismicity in Pennsylvania and the Pennsylvania State Seismic Network

Dr. Andrew Nyblade, Dept. of Geosciences, Penn State, discusses the research on seismic activity as part of a DCNR and DEP monitoring program



www.dcnr.state.pa.us

Time Log:

00:00 Introduction

03:41 Earthquake primer and review of seismicity in PA

14:29 Review of building the PA Seismic network

20:56 Seismicity in PA 2013-2014

35:01 More on building PASEIS

42:54 Lawrence County Earthquakes

47:30 Q & A

Seismicity in Pennsylvania and the Pennsylvania State Seismic Network powerpoint
PDF, 5.5 MB

Recorded Webinar - Seismicity in Pennsylvania and the Pennsylvania State Seismic Network

Seismicity in Pennsylvania and the Pennsylvania State Seismic Network (PASEIS)

Andy Nyblade
Department of Geosciences, Penn State University
May 19, 2016

PennState

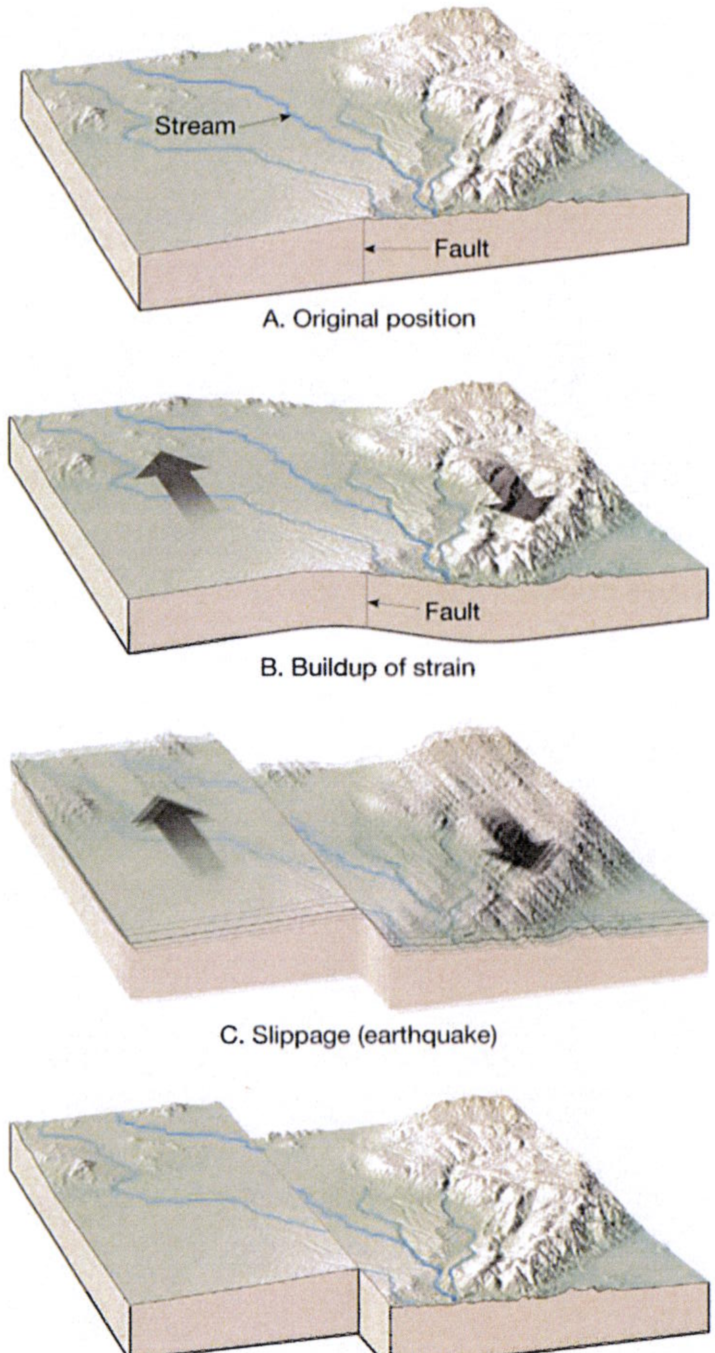
pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Introduction

- Earthquake primer
- Review of seismicity in PA
- Review of seismic networks in PA
- Building the Pennsylvania State Network (PASEIS)
- Seismicity in Pennsylvania 2013-2014
- More on building PASEIS
- April 25, 2016 Lawrence County earthquakes

Deformation of rocks



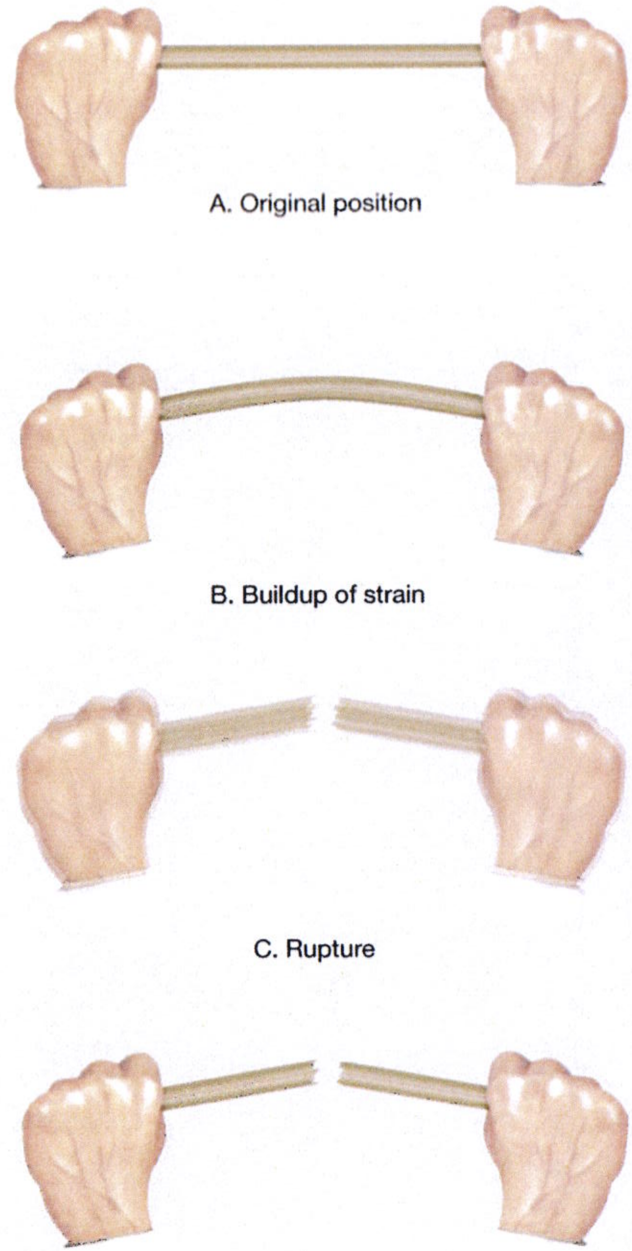
A. Original position

B. Buildup of strain

C. Slippage (earthquake)

D. Strain released

Deformation of a limber stick



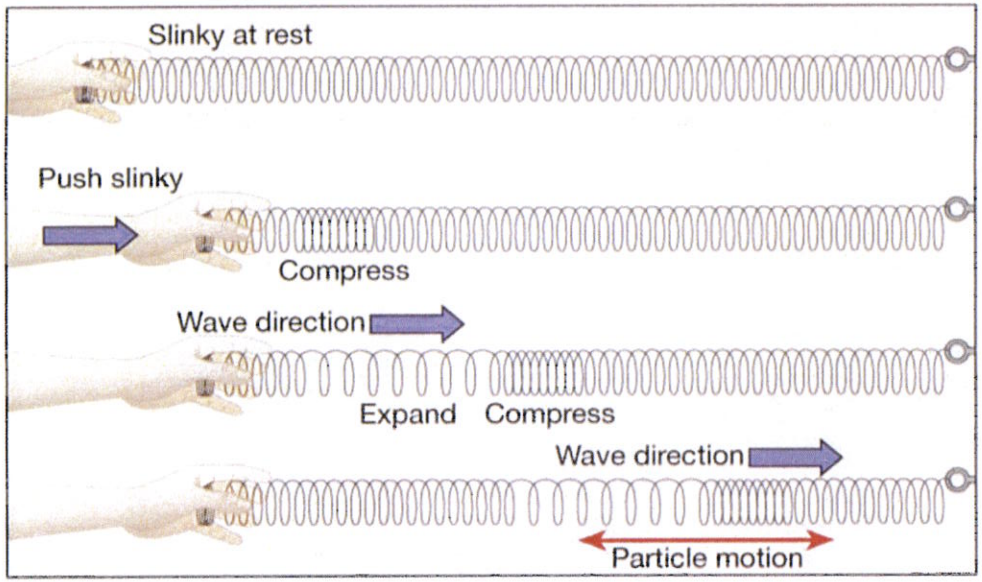
A. Original position

B. Buildup of strain

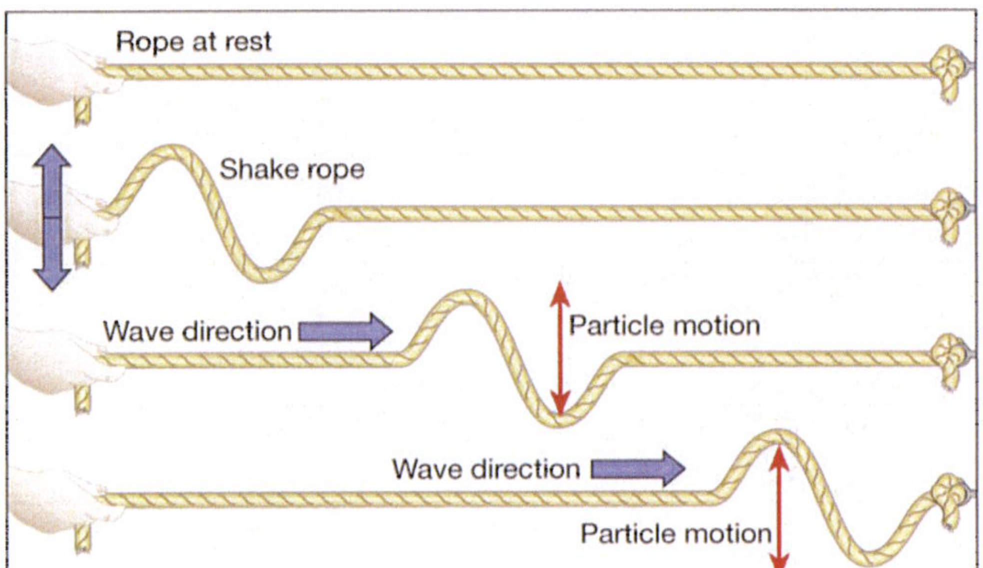
C. Rupture

D. Strain released

Body Waves:

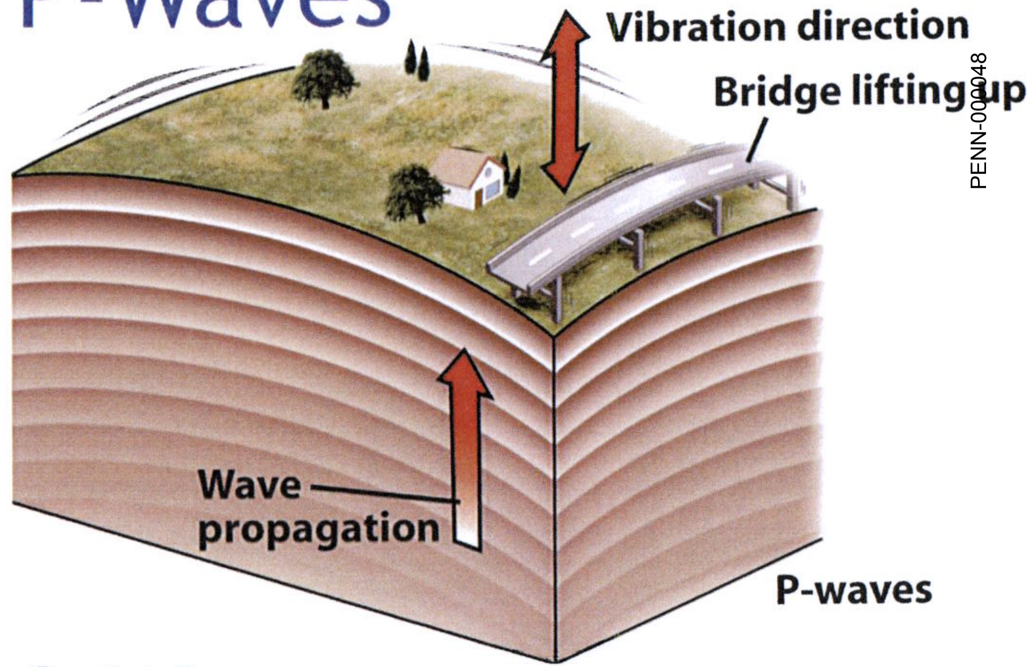


A. P waves generated using a slinky

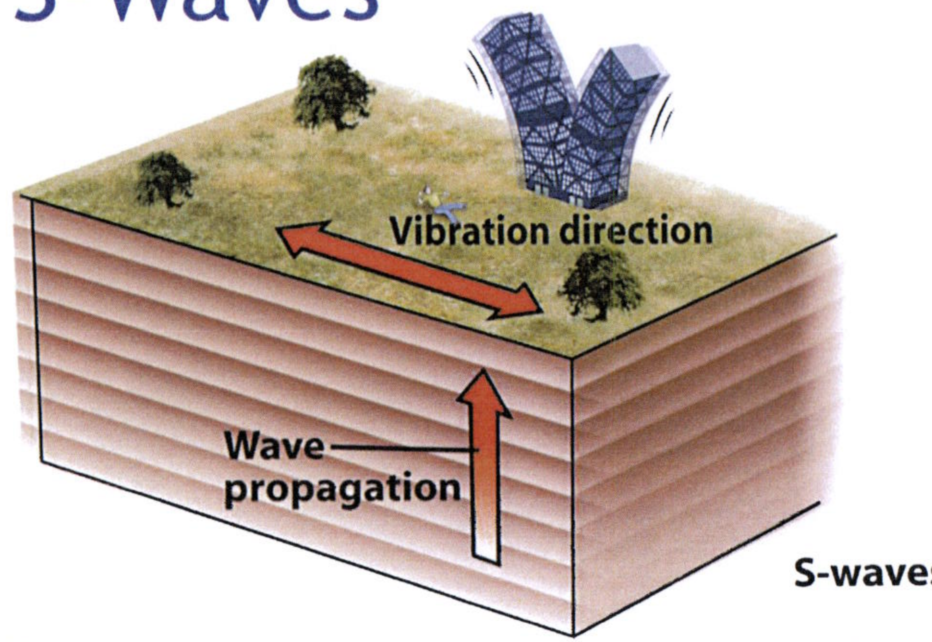


C. S waves generated using a rope

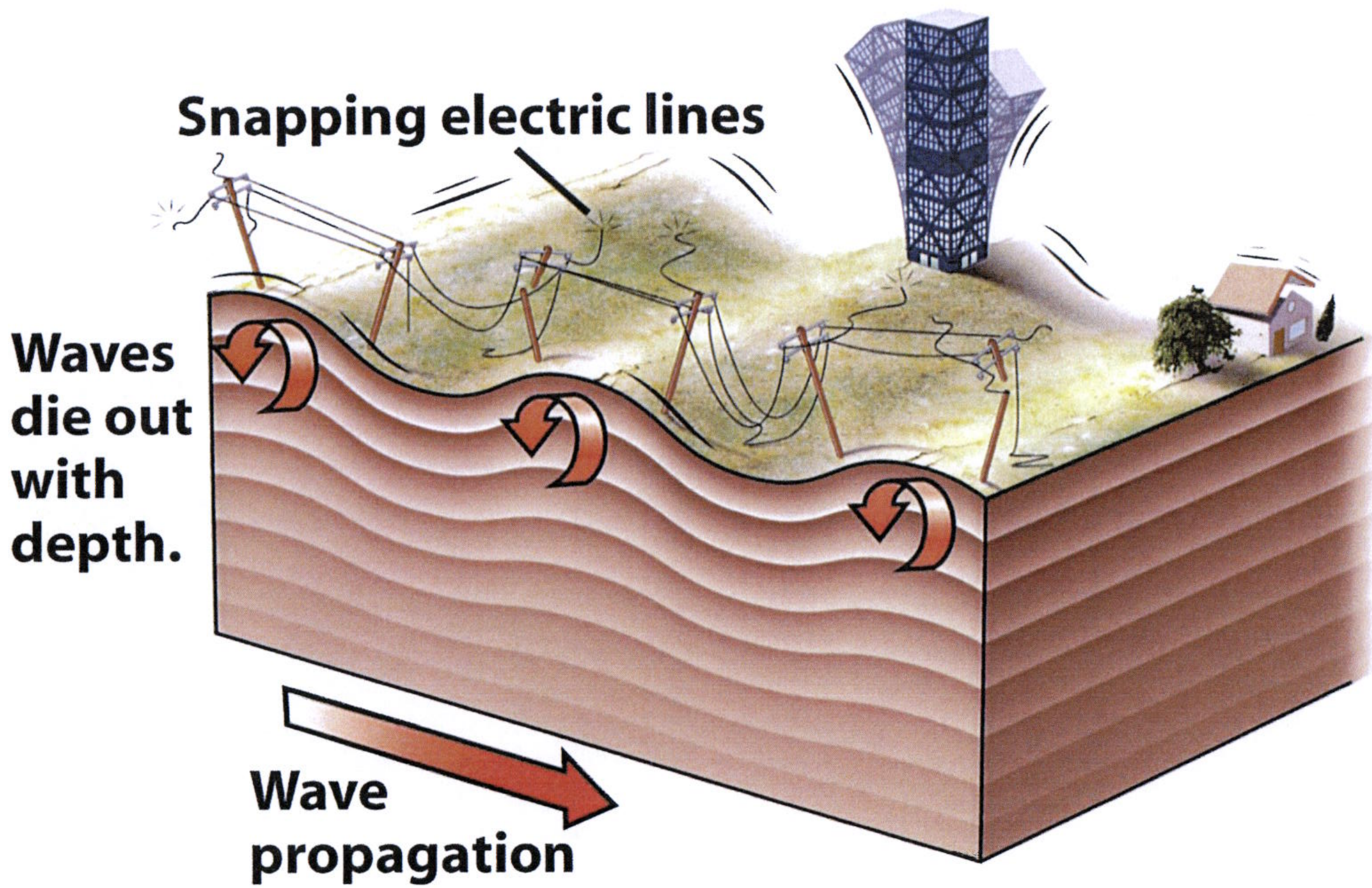
P-Waves



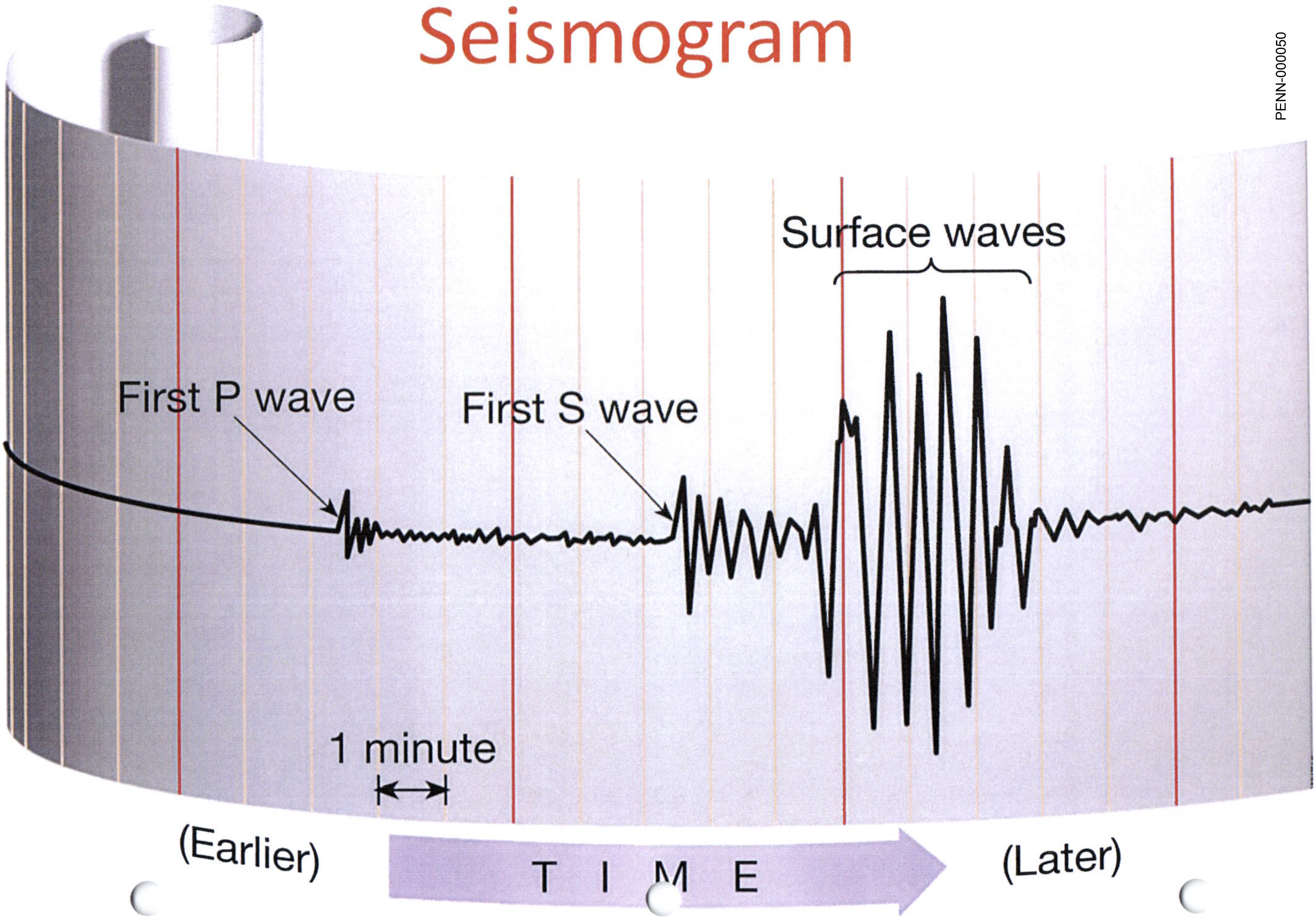
S-Waves



Surface Waves:

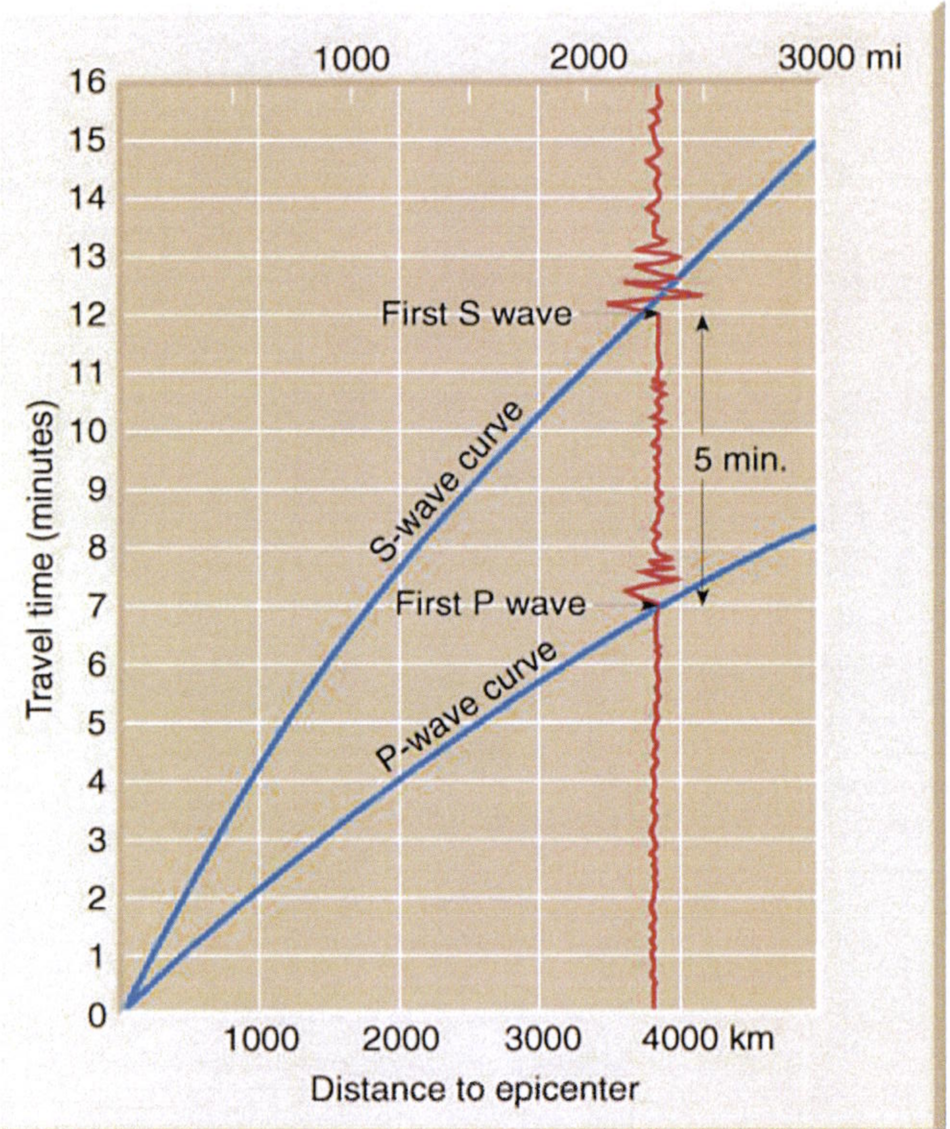


Seismogram



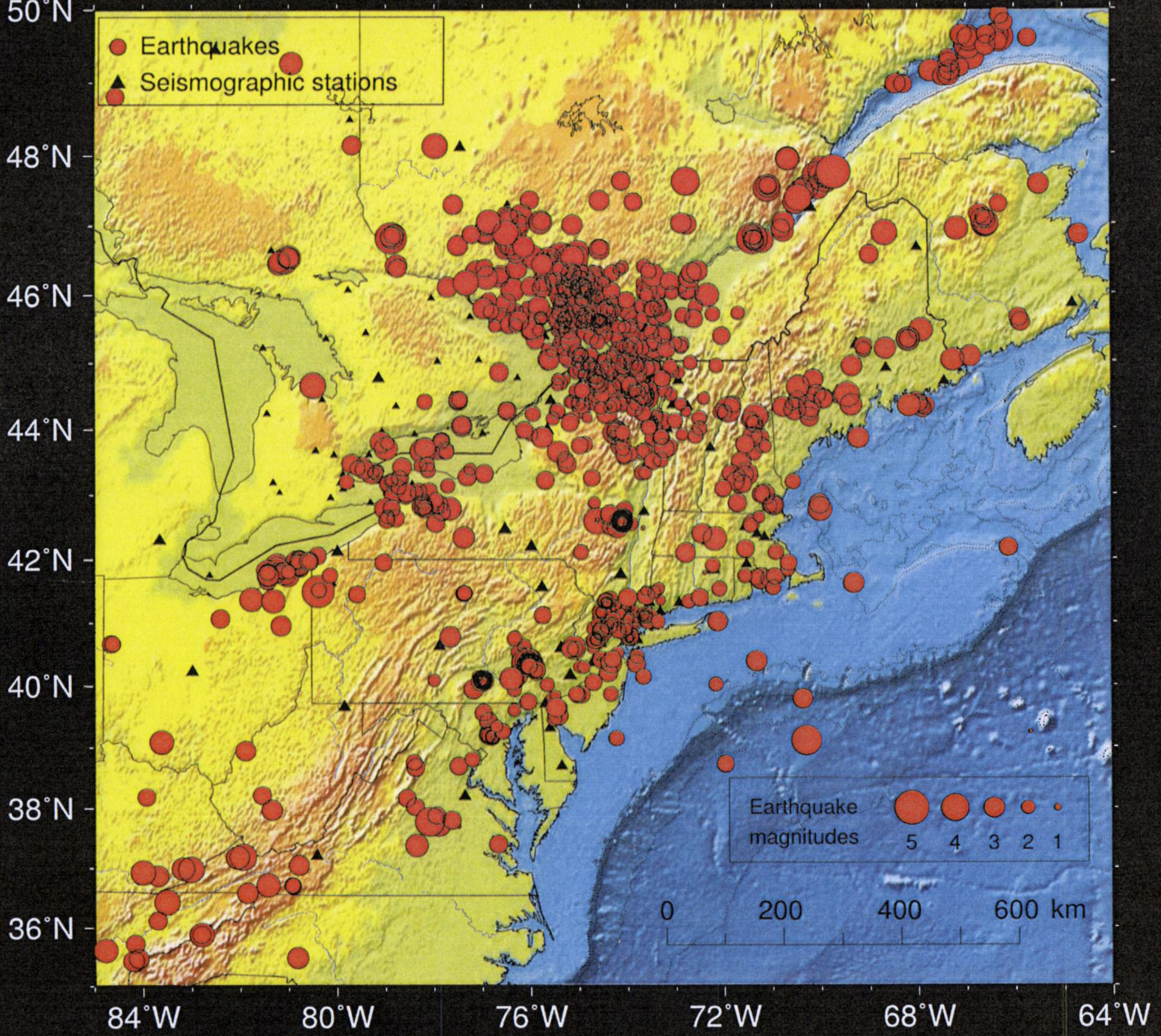
Surface waves
First P wave
First S wave
1 minute
(Earlier)
T I M E
(Later)

Earthquake Location

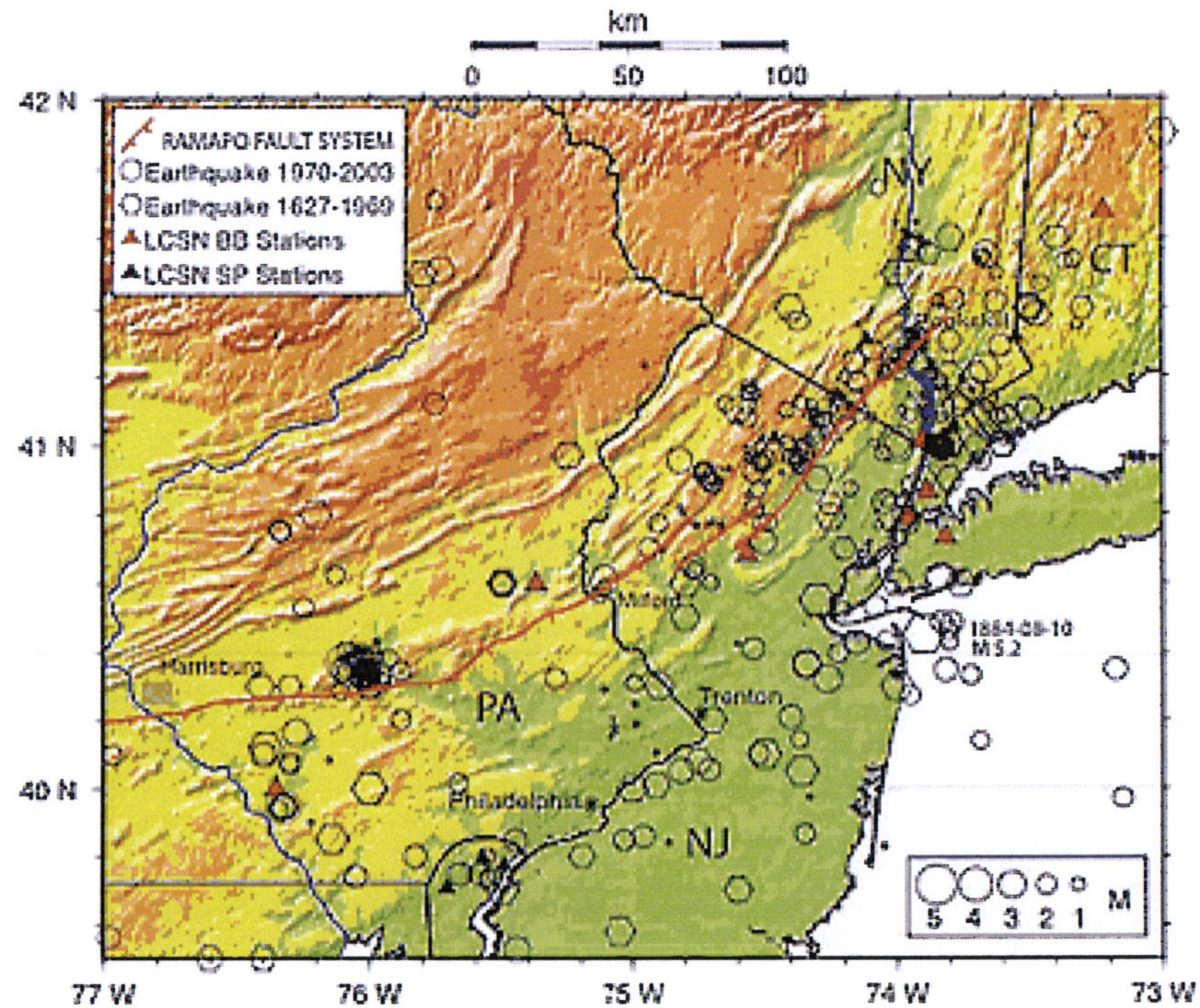


PENN-000051

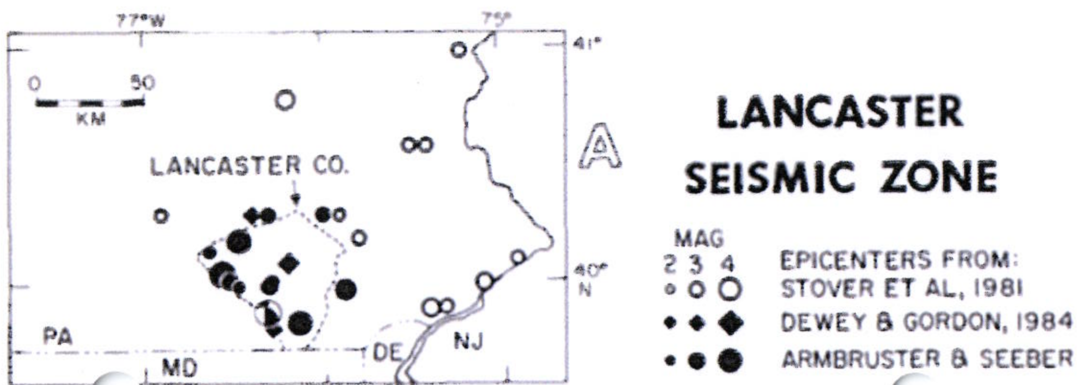
Earthquakes in NE United States and Canada 1990 - 2010



Earthquake locations by the Lamont Cooperative Seismographic Network, US Geological Survey and the Geological Survey of Canada.
June 2010, Won-Young Kim, Lamont-Doherty Earth Observat[hole punch] of Columbia University, <www.ldeo.columbia.edu/LCSN>.



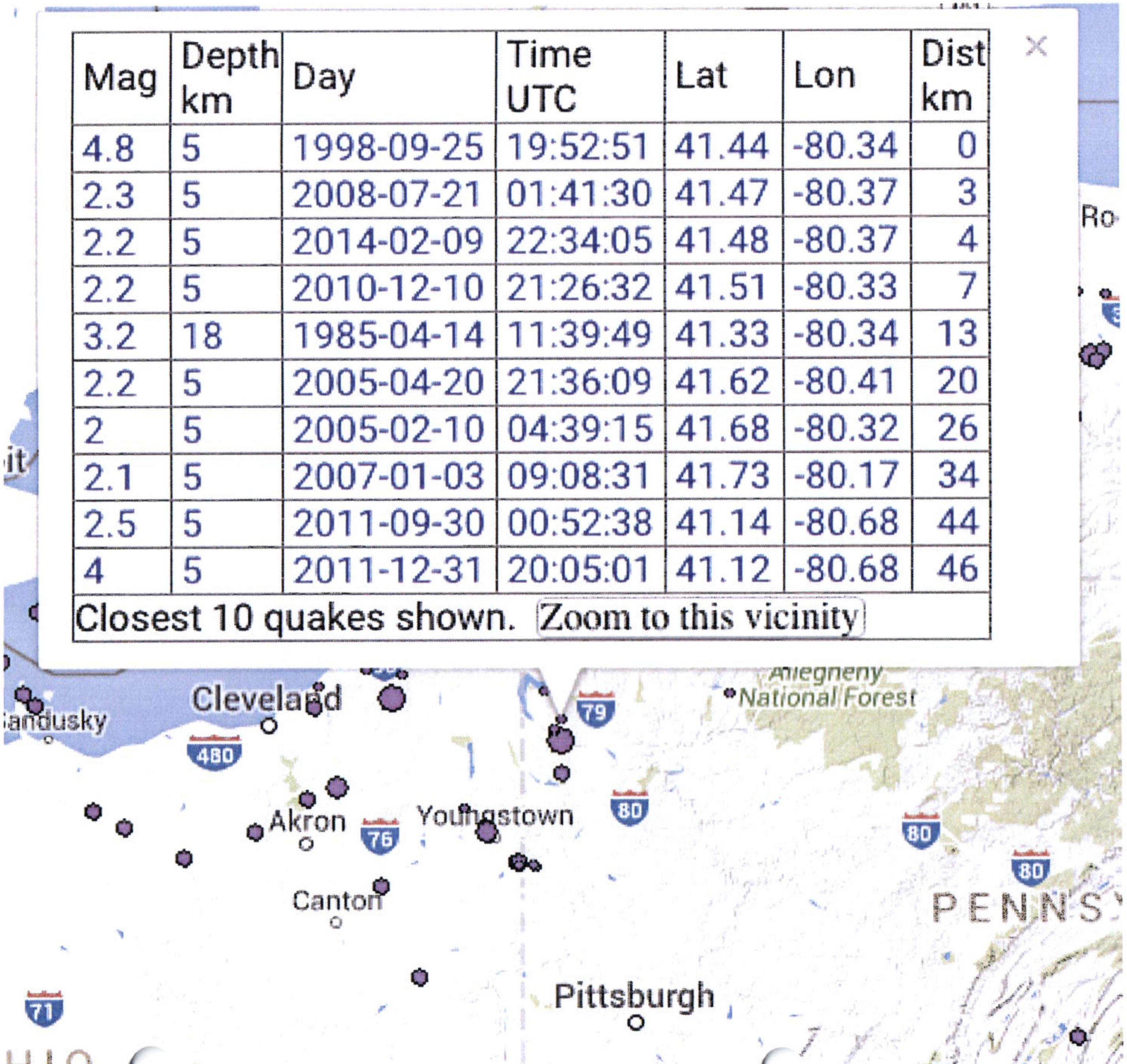
www.earthinstitute.columbia.edu/news/2004/story04-30-04b.html)



Armbruster and Seeber (1987)

PENN-000053

IRIS Earthquake Browser



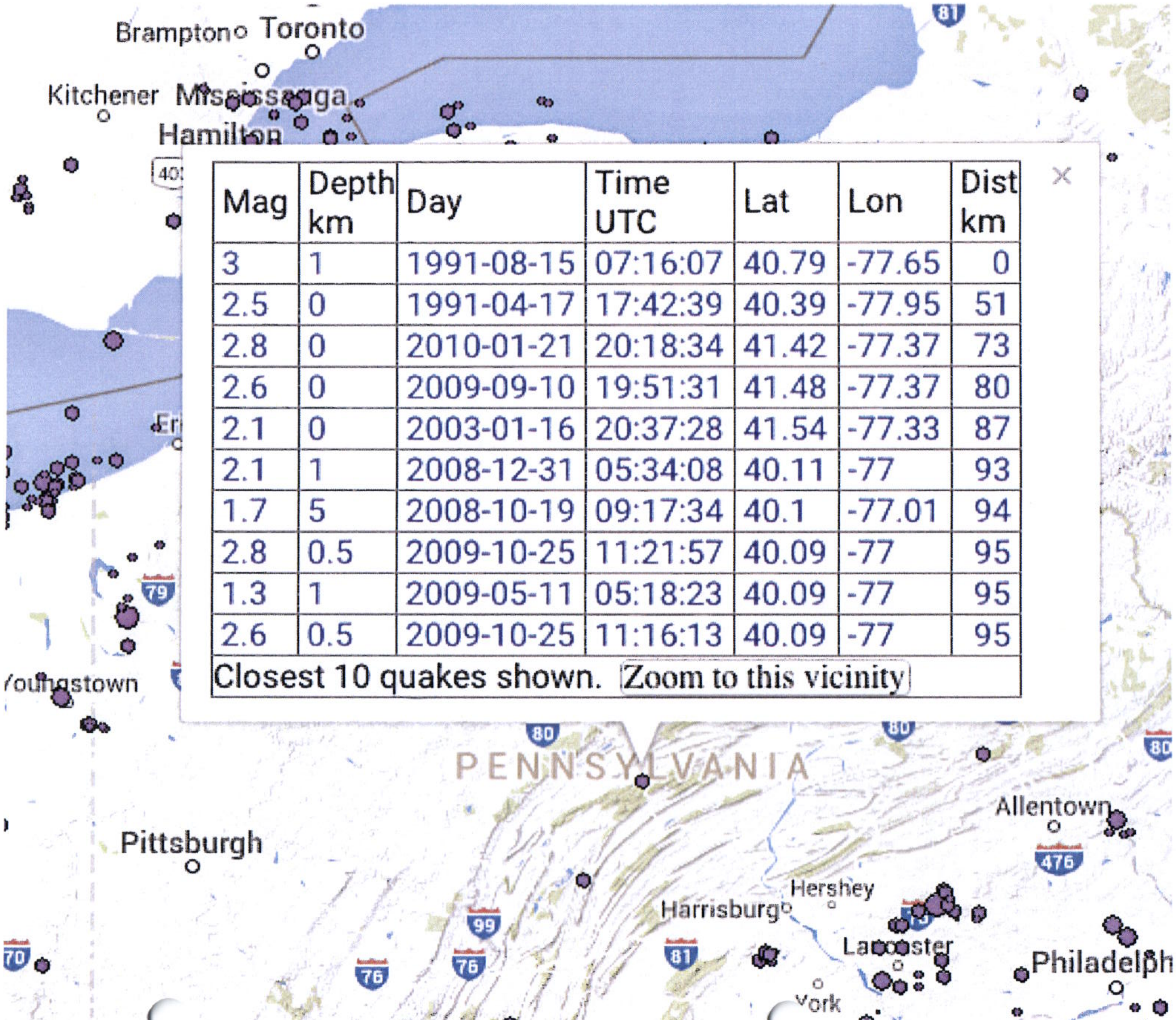
Mag	Depth km	Day	Time UTC	Lat	Lon	Dist km
4.8	5	1998-09-25	19:52:51	41.44	-80.34	0
2.3	5	2008-07-21	01:41:30	41.47	-80.37	3
2.2	5	2014-02-09	22:34:05	41.48	-80.37	4
2.2	5	2010-12-10	21:26:32	41.51	-80.33	7
3.2	18	1985-04-14	11:39:49	41.33	-80.34	13
2.2	5	2005-04-20	21:36:09	41.62	-80.41	20
2	5	2005-02-10	04:39:15	41.68	-80.32	26
2.1	5	2007-01-03	09:08:31	41.73	-80.17	34
2.5	5	2011-09-30	00:52:38	41.14	-80.68	44
4	5	2011-12-31	20:05:01	41.12	-80.68	46

Closest 10 quakes shown. Zoom to this vicinity

IRIS=Incorporated Research Institutions for Seismology (www.iris.edu)

Sept. 25, 1998 Pymatuning, PA earthquake (Mag. 5.2)

IRIS Earthquake Browser



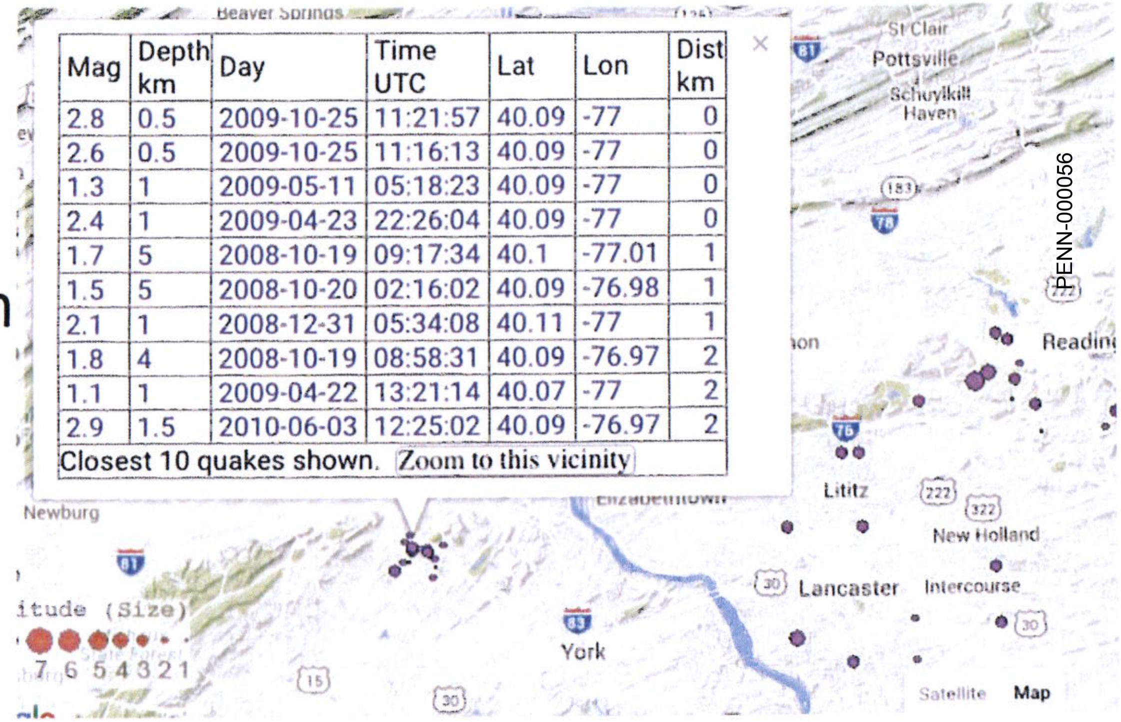
Mag	Depth km	Day	Time UTC	Lat	Lon	Dist km
3	1	1991-08-15	07:16:07	40.79	-77.65	0
2.5	0	1991-04-17	17:42:39	40.39	-77.95	51
2.8	0	2010-01-21	20:18:34	41.42	-77.37	73
2.6	0	2009-09-10	19:51:31	41.48	-77.37	80
2.1	0	2003-01-16	20:37:28	41.54	-77.33	87
2.1	1	2008-12-31	05:34:08	40.11	-77	93
1.7	5	2008-10-19	09:17:34	40.1	-77.01	94
2.8	0.5	2009-10-25	11:21:57	40.09	-77	95
1.3	1	2009-05-11	05:18:23	40.09	-77	95
2.6	0.5	2009-10-25	11:16:13	40.09	-77	95

Closest 10 quakes shown. Zoom to this vicinity

Aug. 15, 1991 Centre Hall earthquake (Mag. 3)

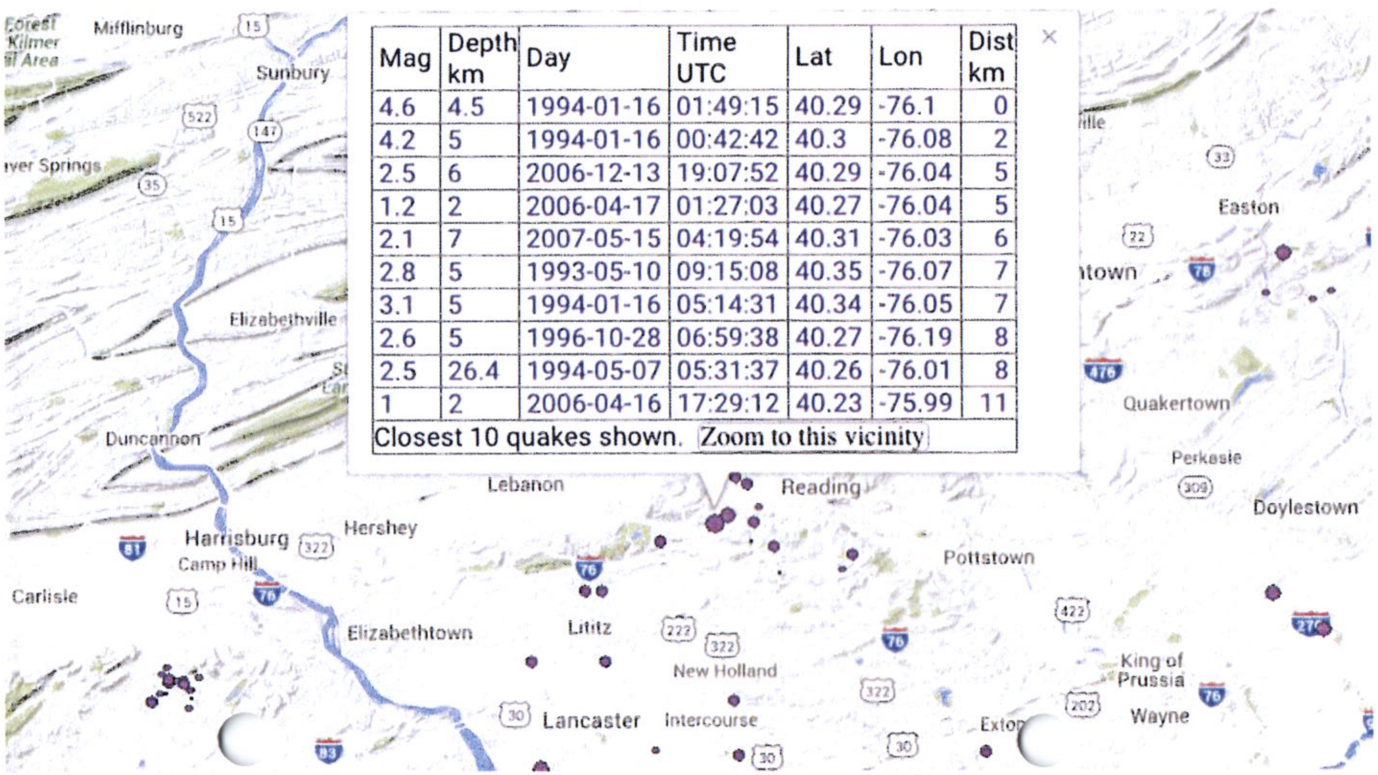
IRIS Earthquake Browser

Dillsburg swarm



Mag	Depth km	Day	Time UTC	Lat	Lon	Dist km
2.8	0.5	2009-10-25	11:21:57	40.09	-77	0
2.6	0.5	2009-10-25	11:16:13	40.09	-77	0
1.3	1	2009-05-11	05:18:23	40.09	-77	0
2.4	1	2009-04-23	22:26:04	40.09	-77	0
1.7	5	2008-10-19	09:17:34	40.1	-77.01	1
1.5	5	2008-10-20	02:16:02	40.09	-76.98	1
2.1	1	2008-12-31	05:34:08	40.11	-77	1
1.8	4	2008-10-19	08:58:31	40.09	-76.97	2
1.1	1	2009-04-22	13:21:14	40.07	-77	2
2.9	1.5	2010-06-03	12:25:02	40.09	-76.97	2

Closest 10 quakes shown. Zoom to this vicinity



Mag	Depth km	Day	Time UTC	Lat	Lon	Dist km
4.6	4.5	1994-01-16	01:49:15	40.29	-76.1	0
4.2	5	1994-01-16	00:42:42	40.3	-76.08	2
2.5	6	2006-12-13	19:07:52	40.29	-76.04	5
1.2	2	2006-04-17	01:27:03	40.27	-76.04	5
2.1	7	2007-05-15	04:19:54	40.31	-76.03	6
2.8	5	1993-05-10	09:15:08	40.35	-76.07	7
3.1	5	1994-01-16	05:14:31	40.34	-76.05	7
2.6	5	1996-10-28	06:59:38	40.27	-76.19	8
2.5	26.4	1994-05-07	05:31:37	40.26	-76.01	8
1	2	2006-04-16	17:29:12	40.23	-75.99	11

Closest 10 quakes shown. Zoom to this vicinity

1994 Wyomissing Hills earthquakes (Mag. 4.0 foreshock and 4.6 mainshock)

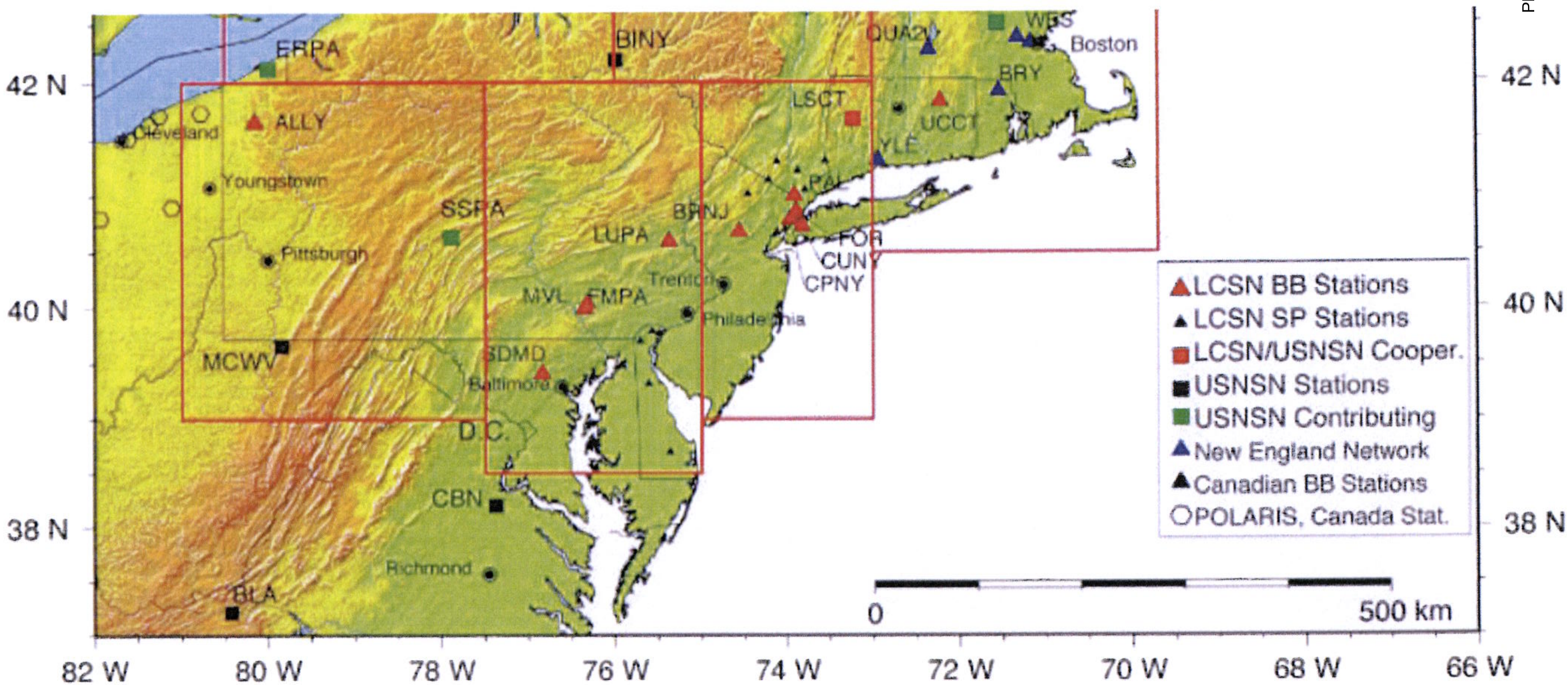
PENN-000056

Permanent Seismic Stations in PA through 2015

3 Networks:

- USGS National Network (2 stations)
- Lamont Doherty Earth Observatory Cooperative Seismic Network (LCSN) (supported as a regional network by the USGS) (6 stations)
- Initial 10 PASEIS stations

USGS and LCSN Stations



PENN-000058

Initial 10 PASEIS stations

PENN-000059

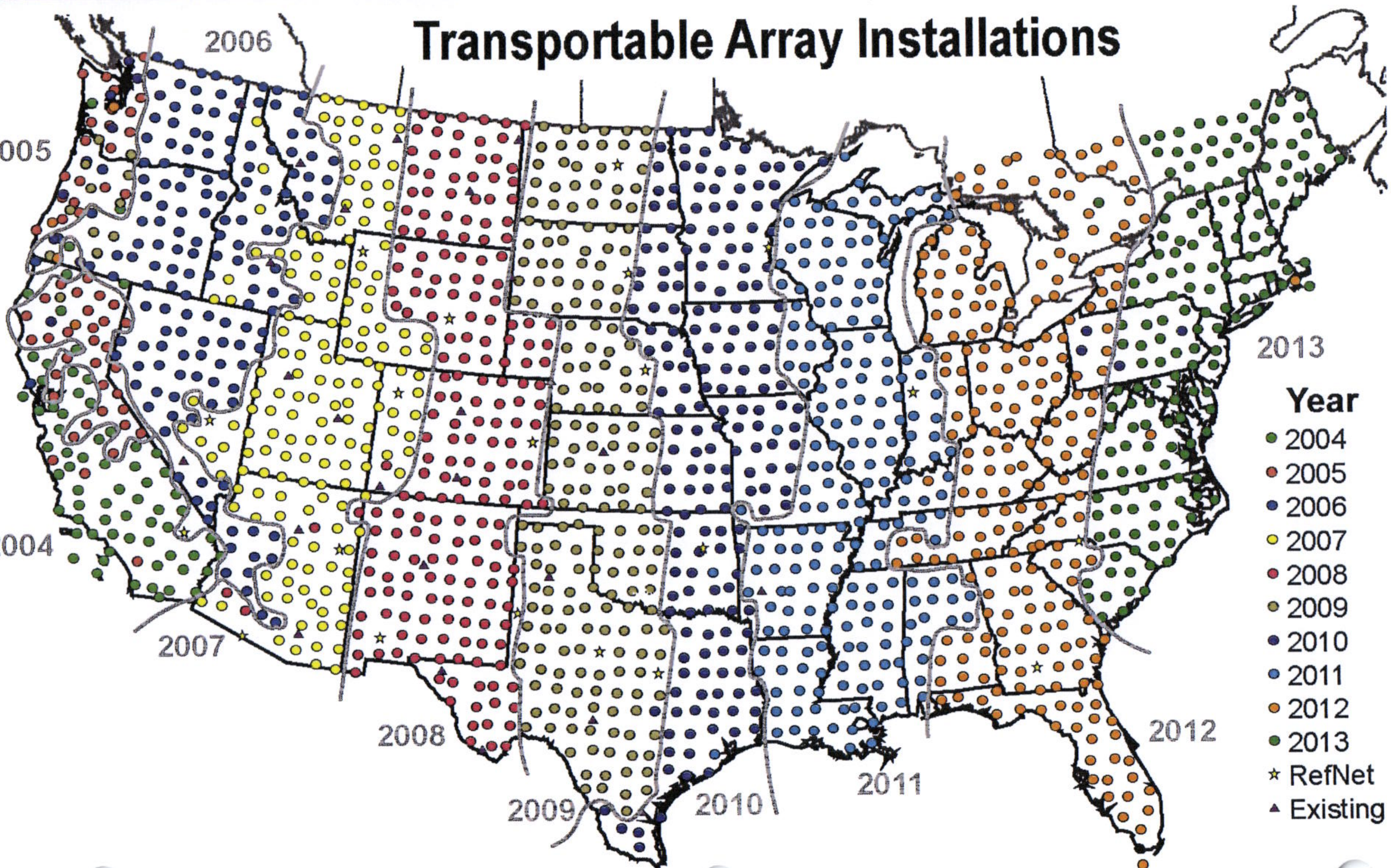
History of building a PA state seismic network

- 2006-2010 Establishment of the first 6 permanent PASEIS stations – DCNR
- 2009 Carbon sequestration technical assessment - DCNR
  - *25 portable seismic stations*
- 2010 Purchase of 4 USArray stations from IRIS – DCNR
- 2013 Earthquake monitoring during USArray - DCNR
  - *Support for temporary network to densify the USArray network, develop seismicity catalog*
- 2015 Expand the 10-station permanent network to 30 stations and provide seismic event information – DCNR and DEP

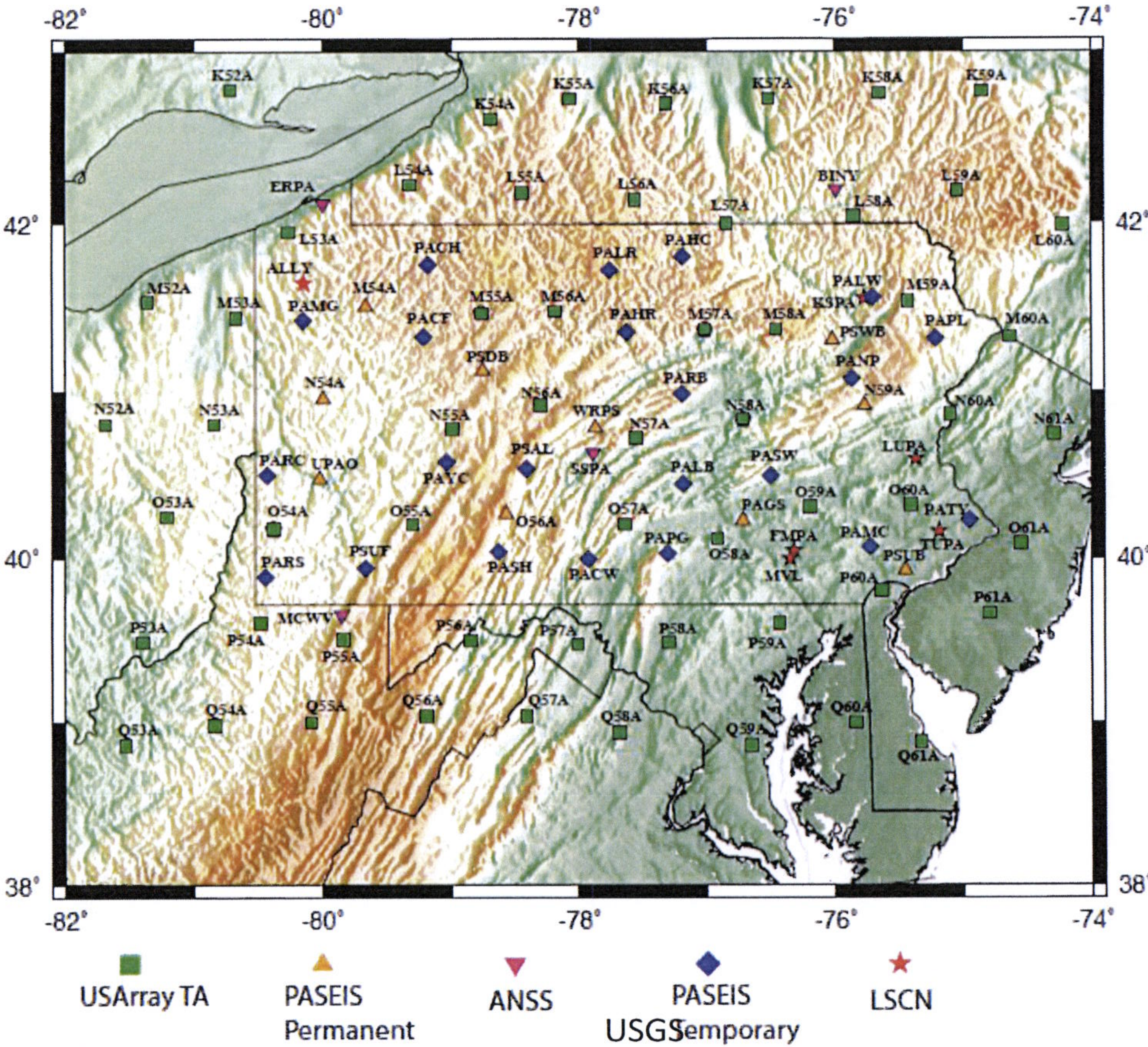
earth scope

USArray

Transportable Array Installations



Stations 2/2013 to 12/2014



- Over 100 3-component high quality (broadband) stations
- Recording continuously
- Sample rates of between 40 and 100 samples per second

PA seismicity 2/2013 to 12/2014 (from Kyle Homman's MS thesis)

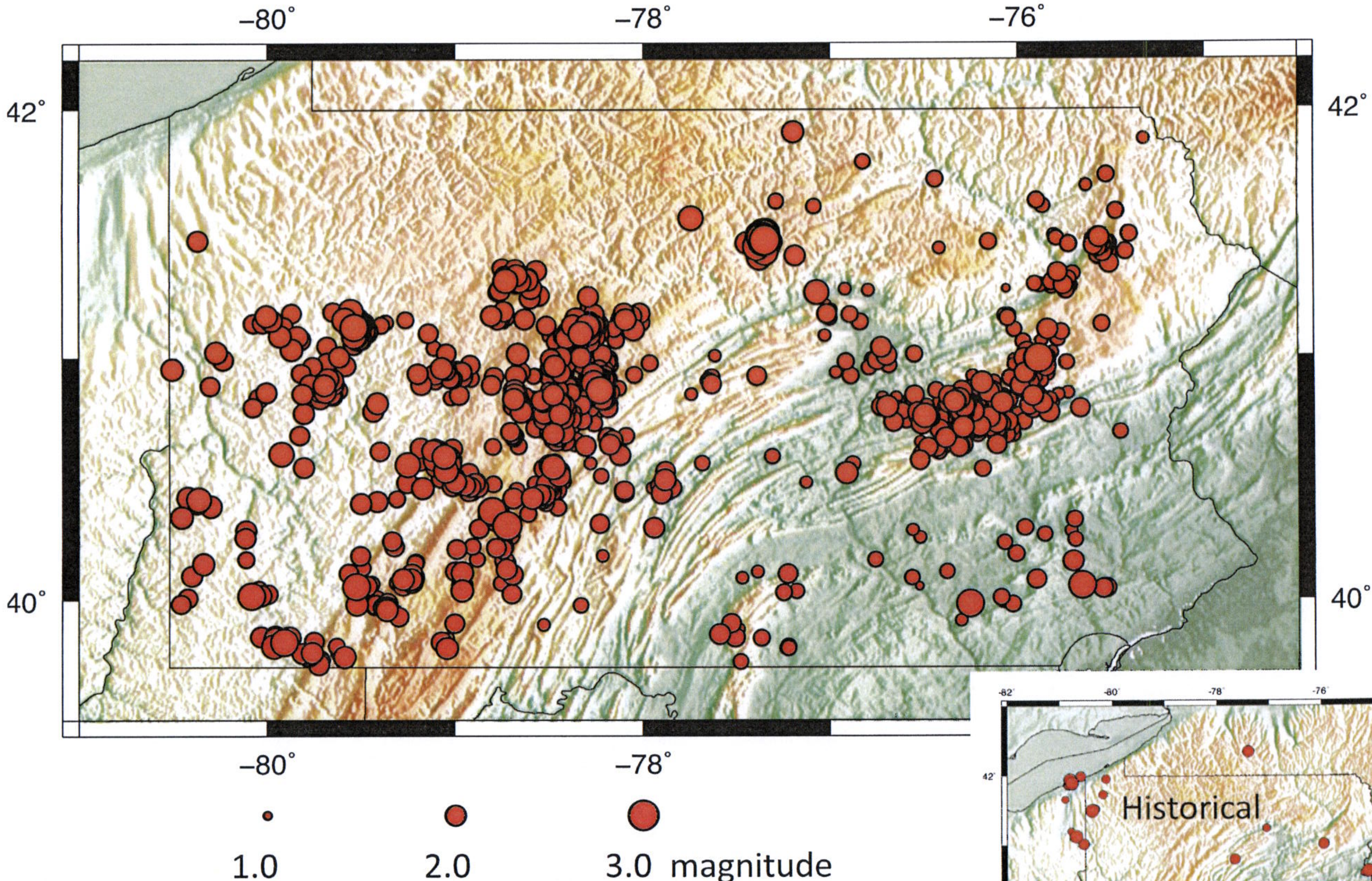
- Average number of stations used for each event: 10
- Minimum number of stations used was 4
- 1568 events with 1355 located in Pennsylvania

Picking and Locating Events

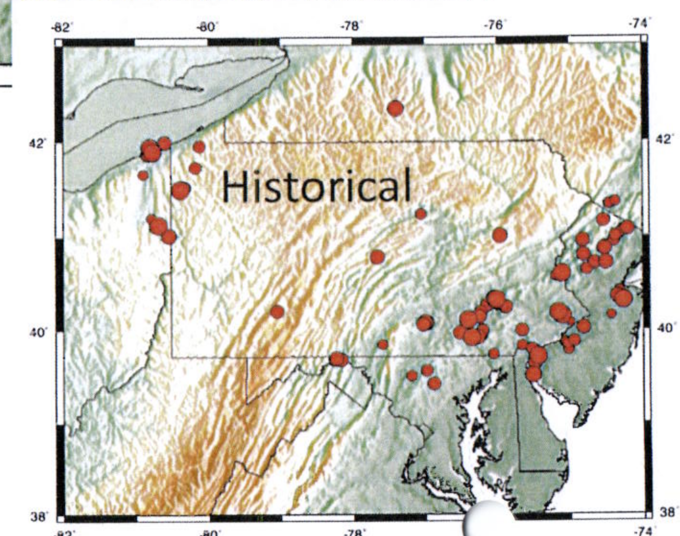
- Used Antelope Software package
- Manually picked arrival times
- Filtered with a 1-5 Hz bandpass filter
- Preliminary locations from Antelope using IASP91 velocity model
- Relocated using HYPOELLIPSE and a velocity model for Pennsylvania
- Magnitudes determined using Richter's method for local magnitude

Layer	P-wave Velocity (km/s)	Depth of Interface (km)	Vp/Vs Ratio
1	6.0	0.0	1.74
2	6.3	10.0	1.74
3	6.6	20.0	1.74
4	6.9	30.0	1.74
5	8.1	37.0	1.74

Adapted from Katz (1955)



-80°
-78°
-76°
42°
40°
1.0
2.0
3.0 magnitude

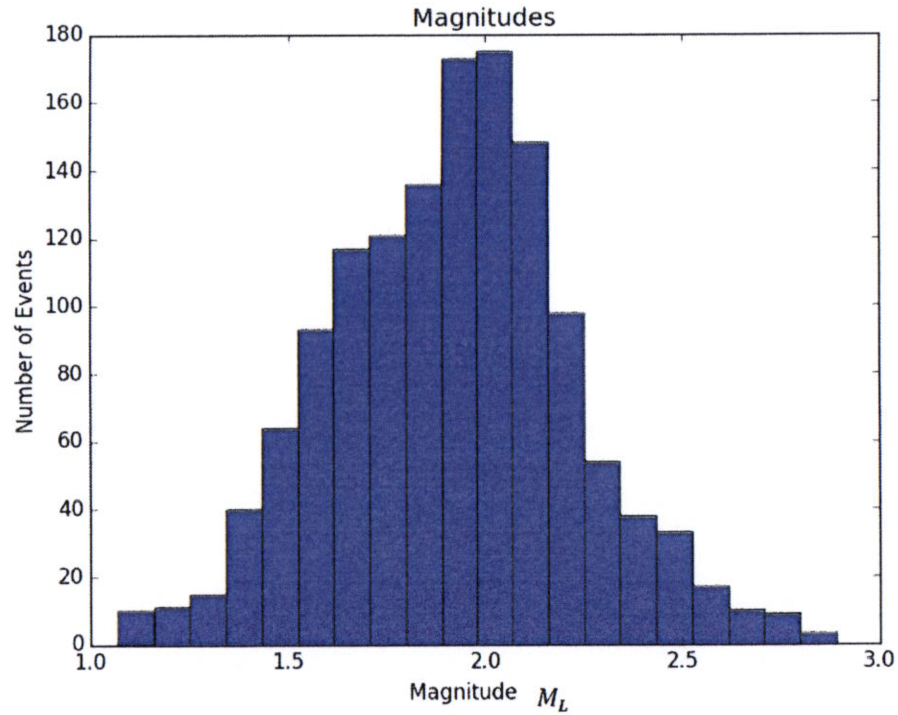


Historical
-82°
-80°
-78°
-76°
-74°
42°
40°
38°

PENN-000065

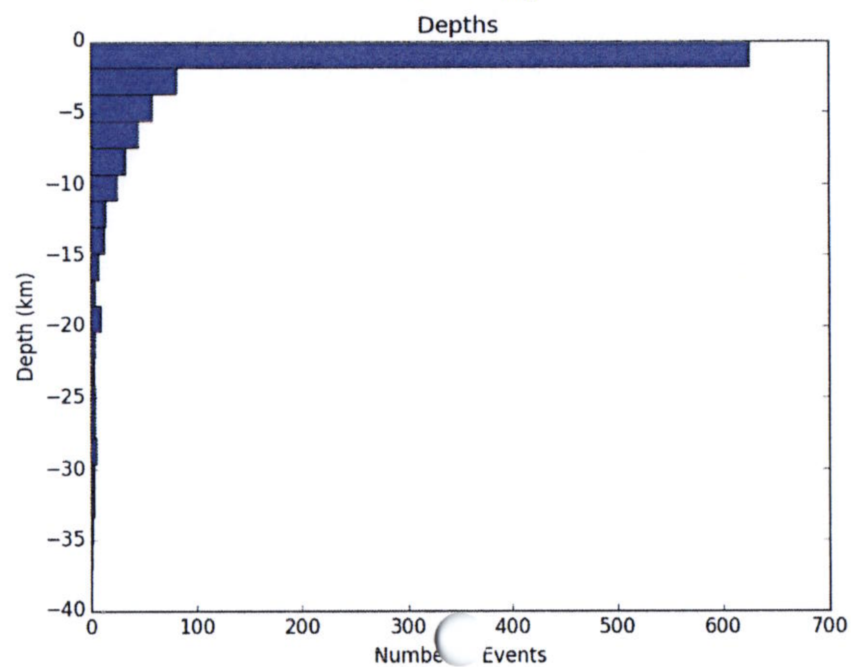
Magnitudes and Depths

- Local magnitudes range from 1.07 to 2.89



Catalog is complete to magnitude 2

- Depths mostly < 1 km

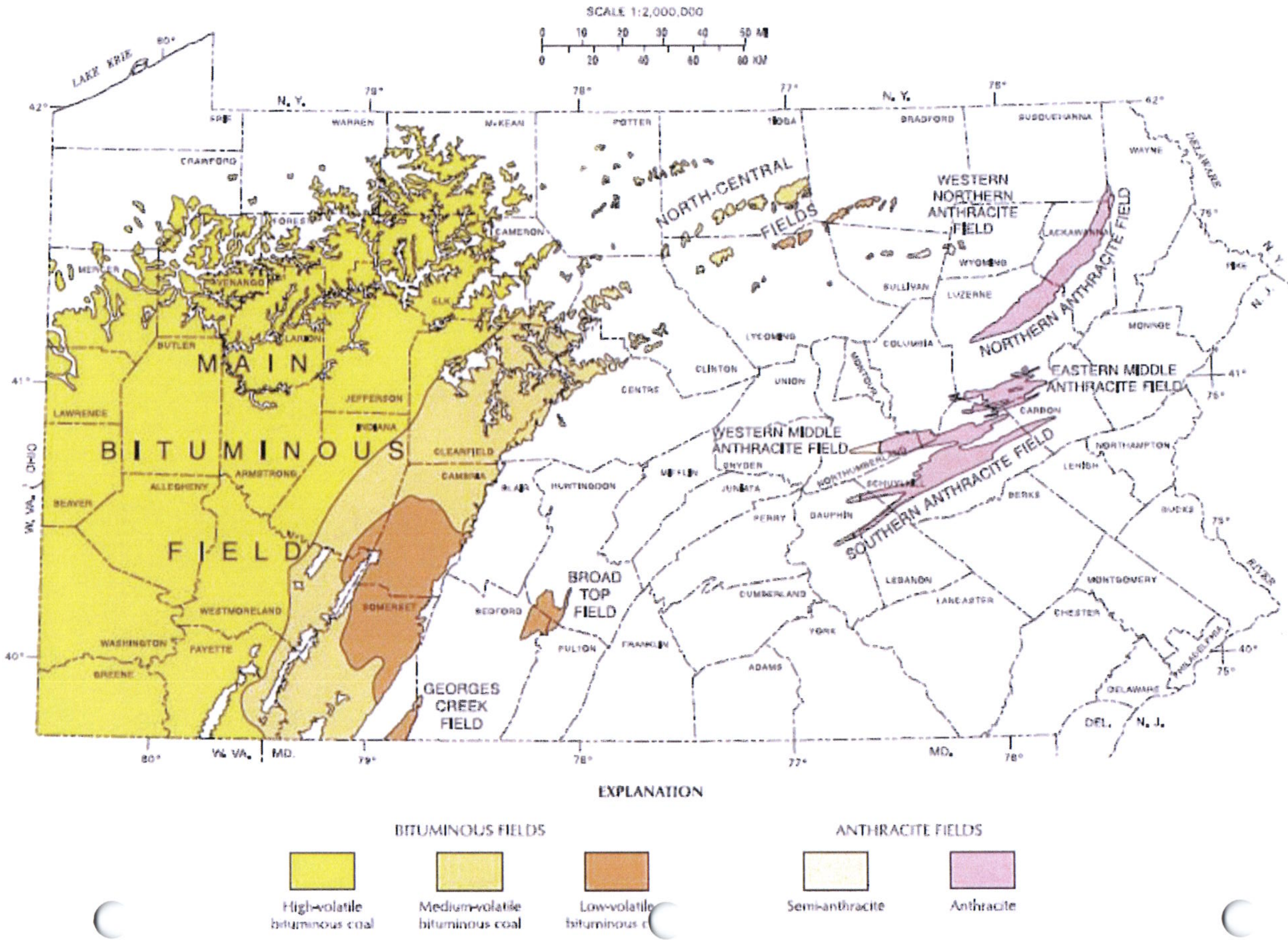


What are the sources of the seismic events?

Several possibilities

- tectonic earthquakes
- mine blasts (quarries, coal mines, other mines)
- induced seismicity from wastewater disposal wells
- induced seismicity from hydraulic fracking

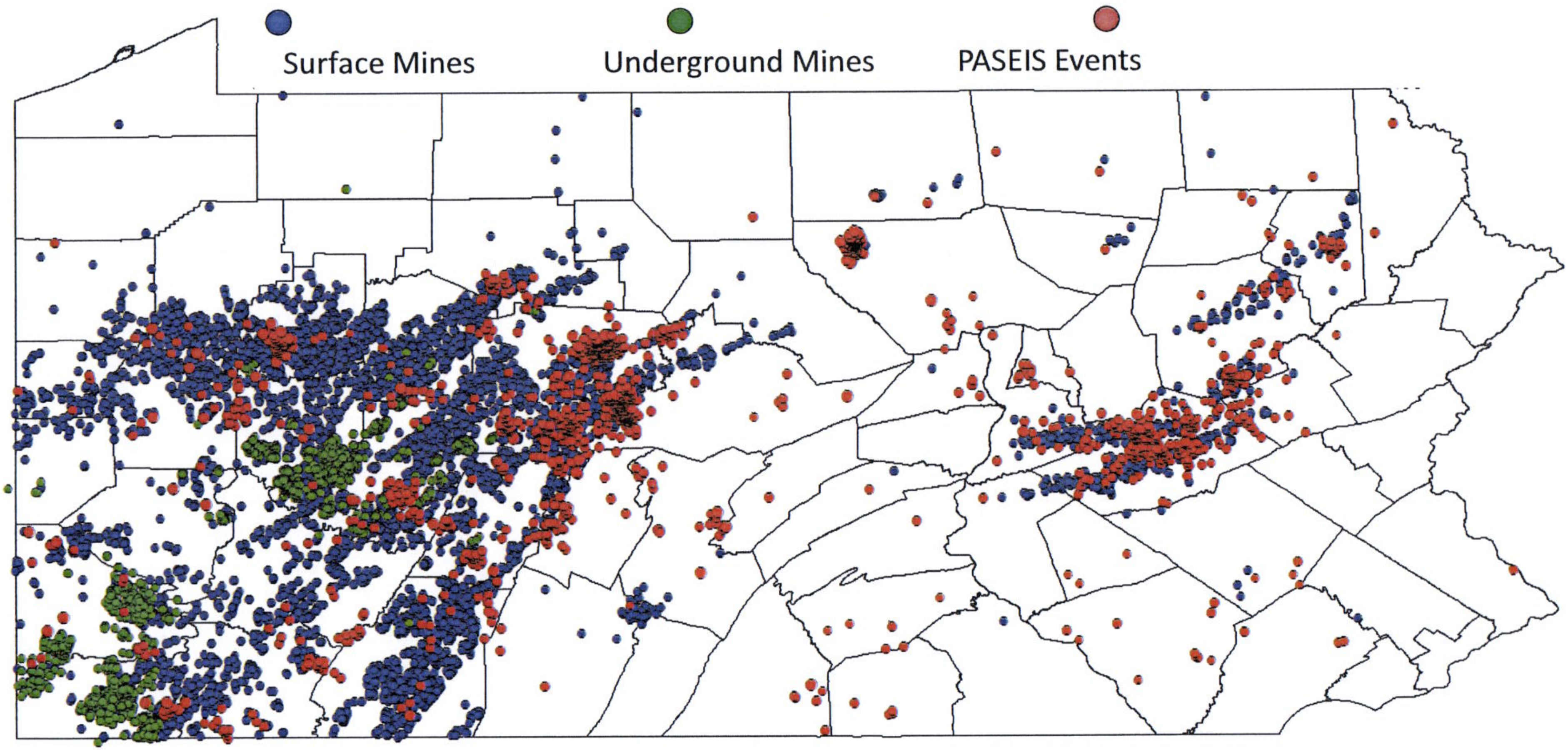
DISTRIBUTION OF PENNSYLVANIA COALS



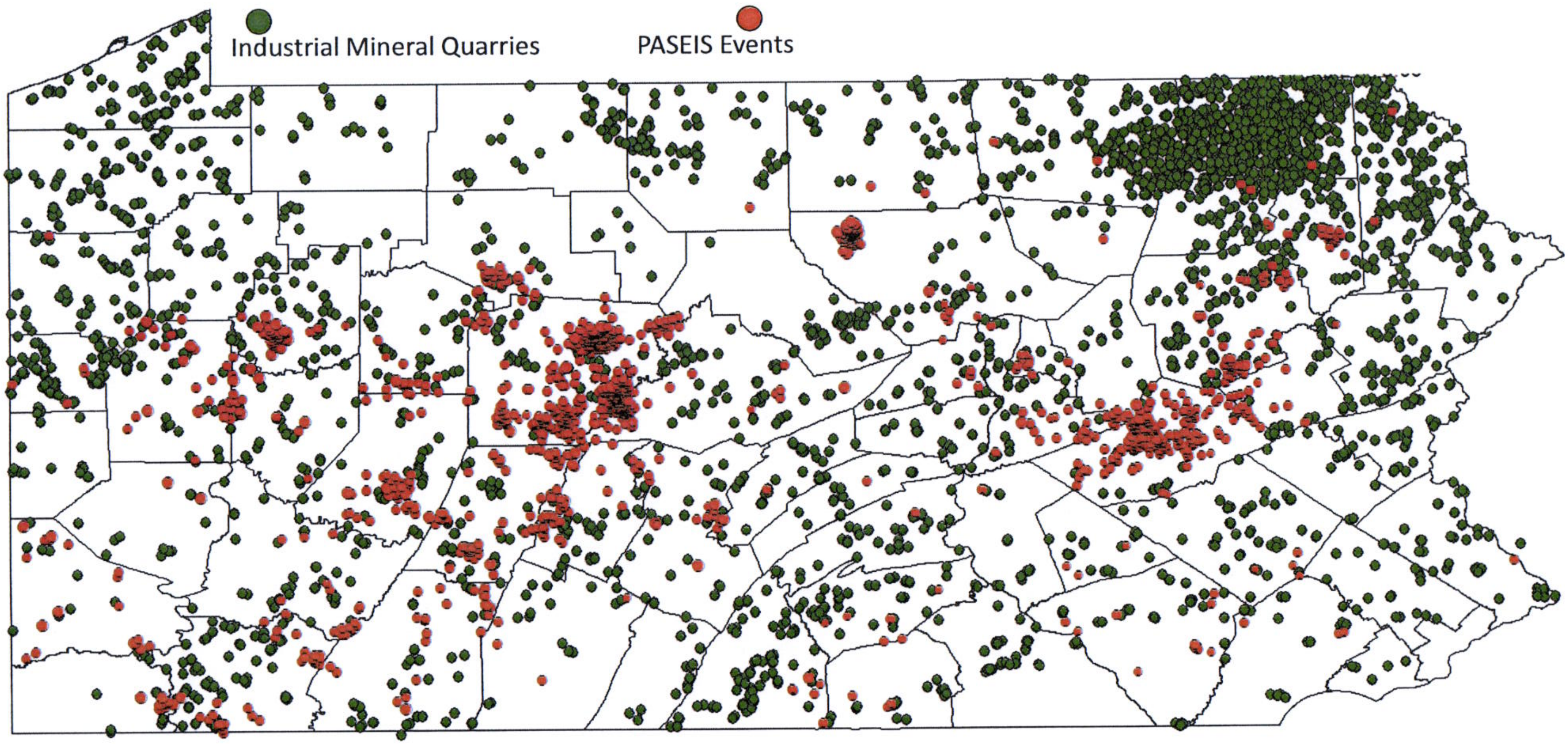
USGS Event Classification for Blasts

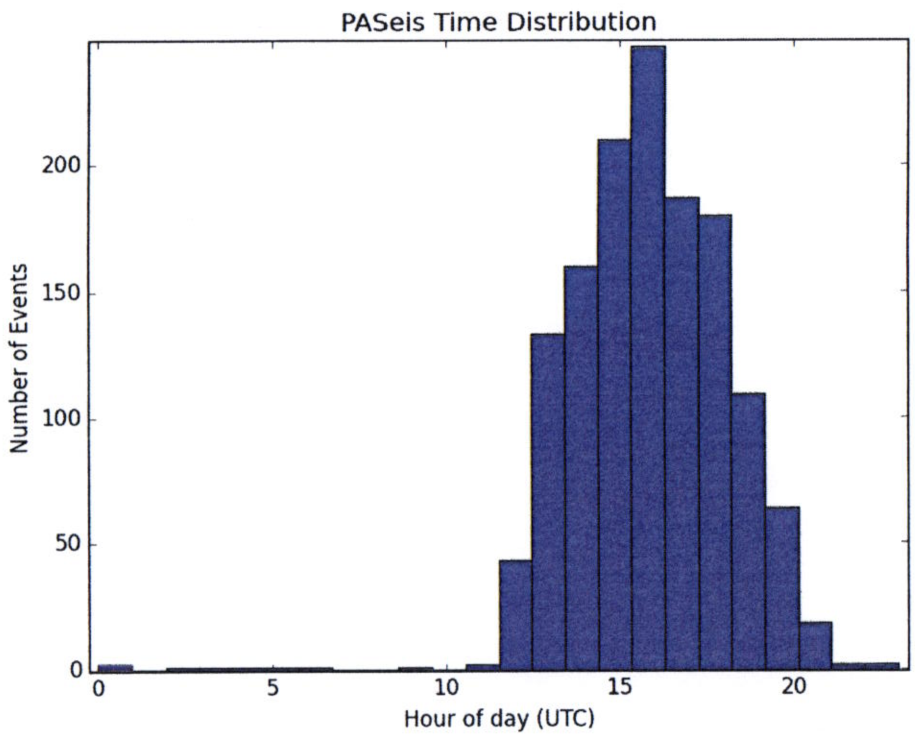
- Time of event (during working hours)
- Location of events relative to mines and quarries (within 5 km)
- Emergent phase arrivals
- Lack of clear S-wave arrivals
- Excessive low-frequency signal
- Presence of a short period surface wave

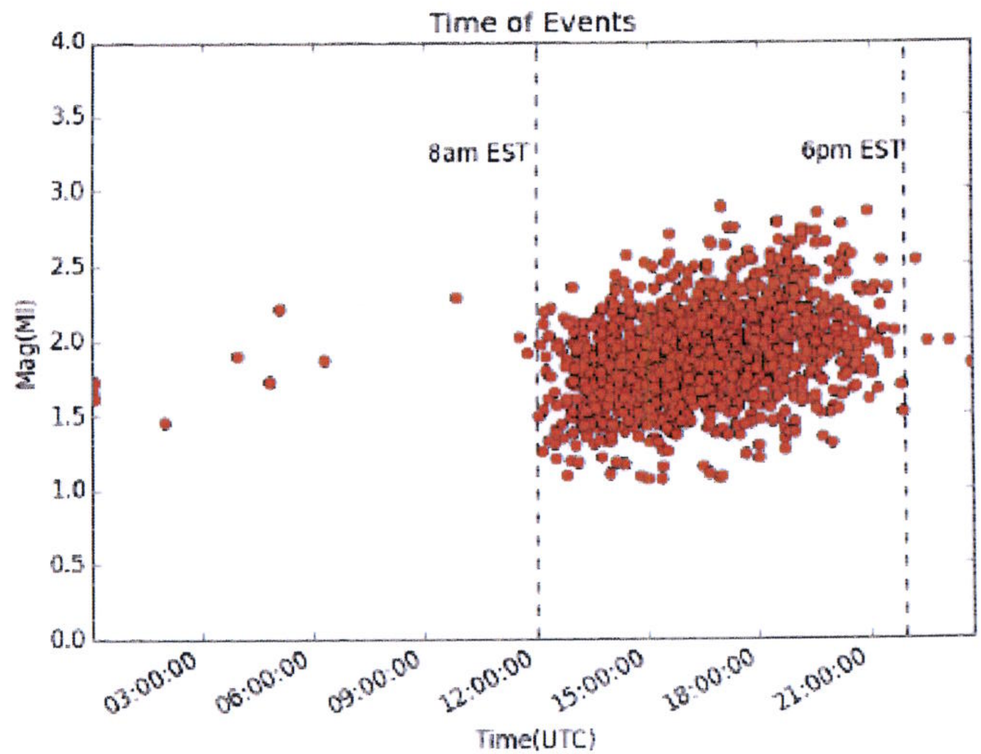
Spatial correlation with coal mines

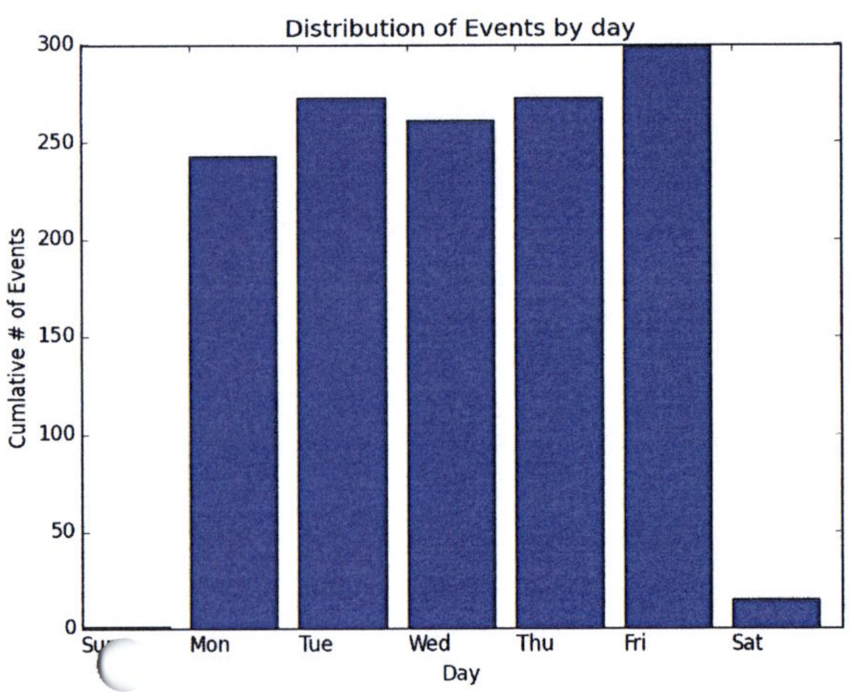


Spatial correlation with other mines

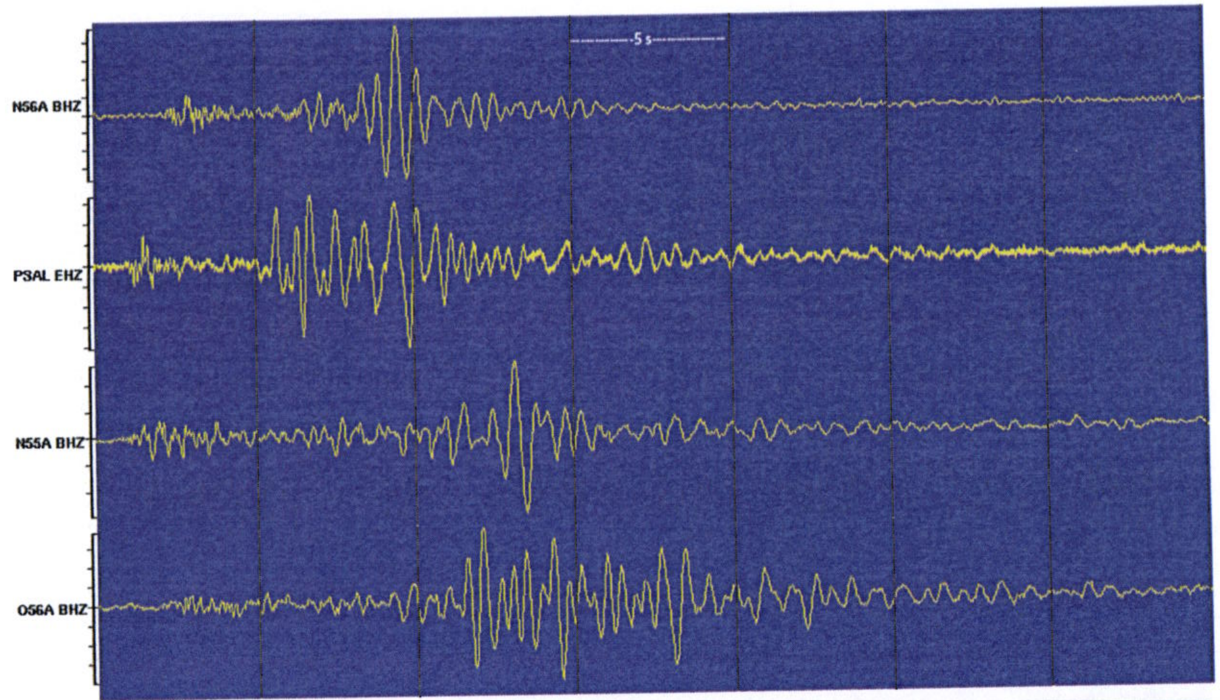








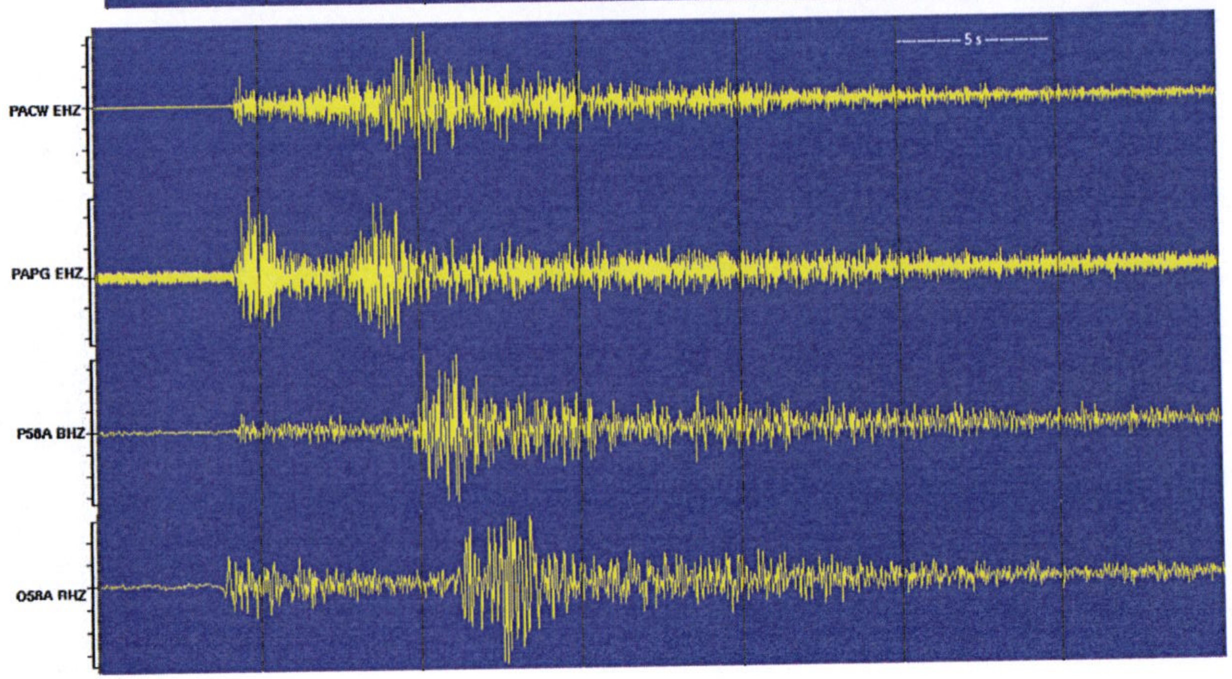
Timing of Events



Blasting event

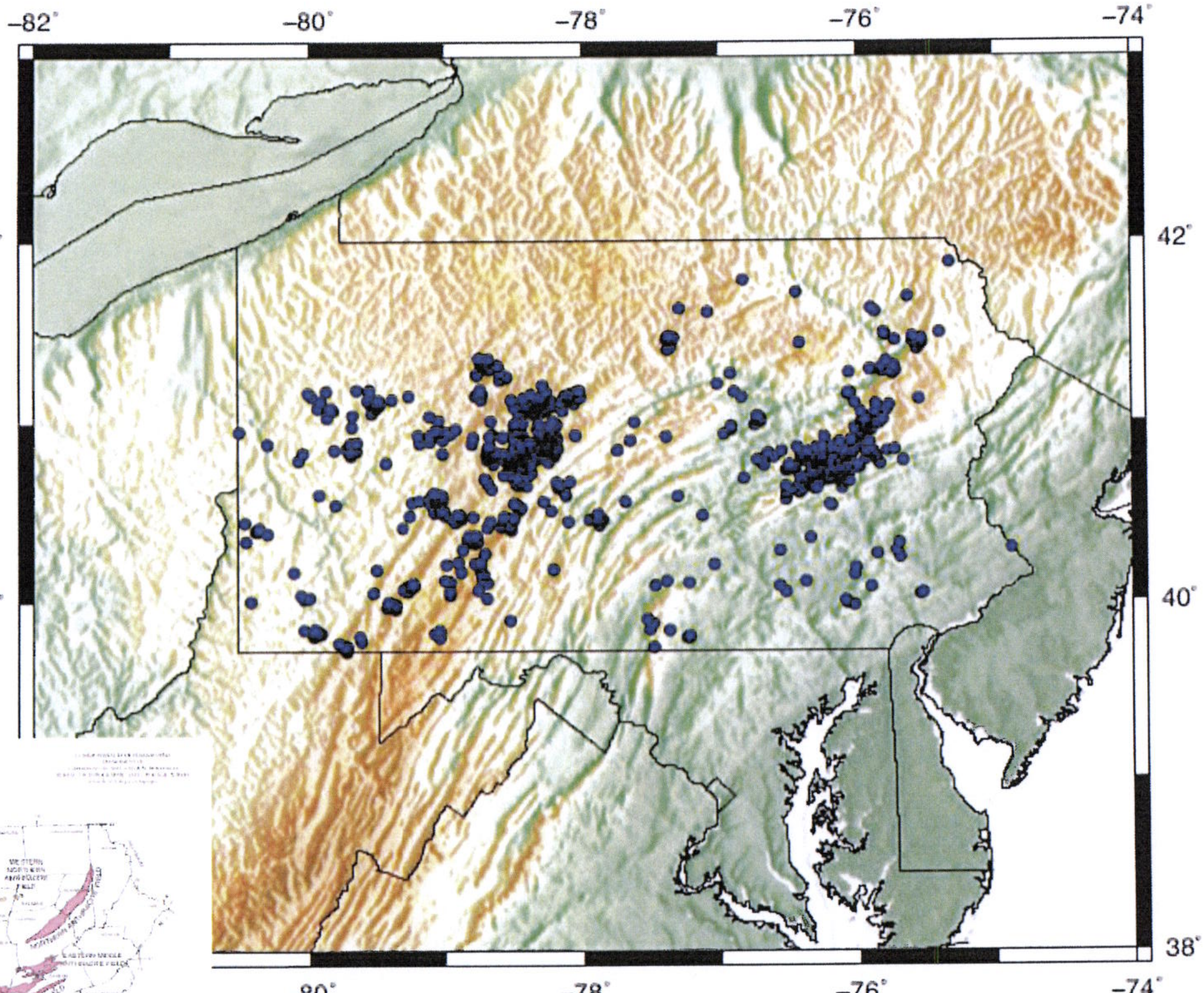
Waveform characteristics

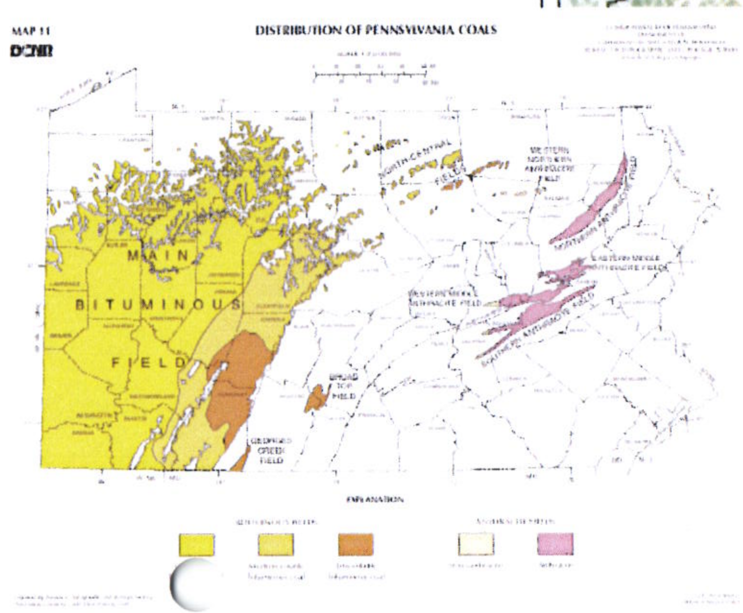
- Emergent phase arrivals
- Lack of clear S-wave arrivals
- Excessive low-frequency signal
- Presence of a short period surface wave



Earthquake

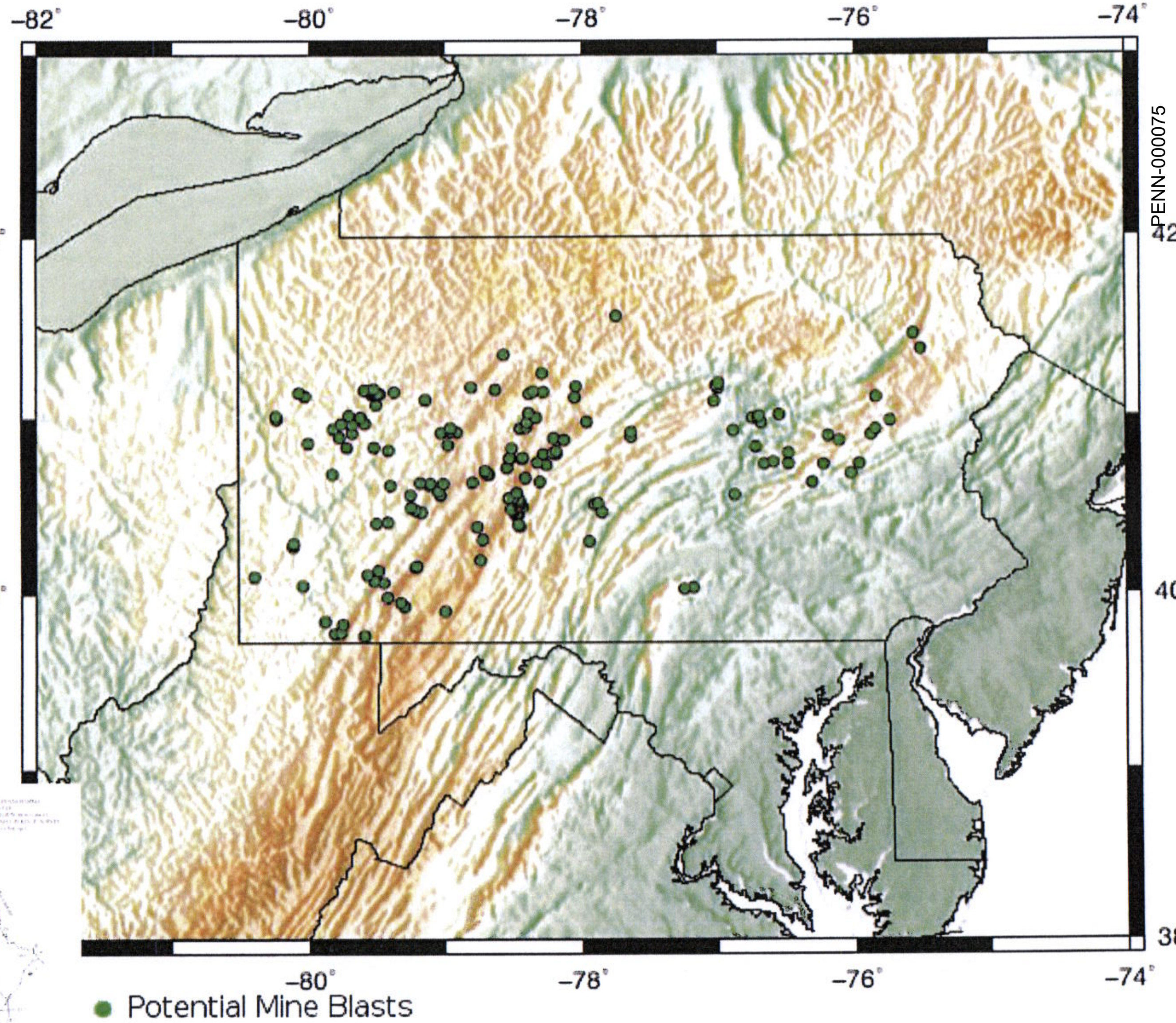
Mine or Quarry Blasts (1117 events)

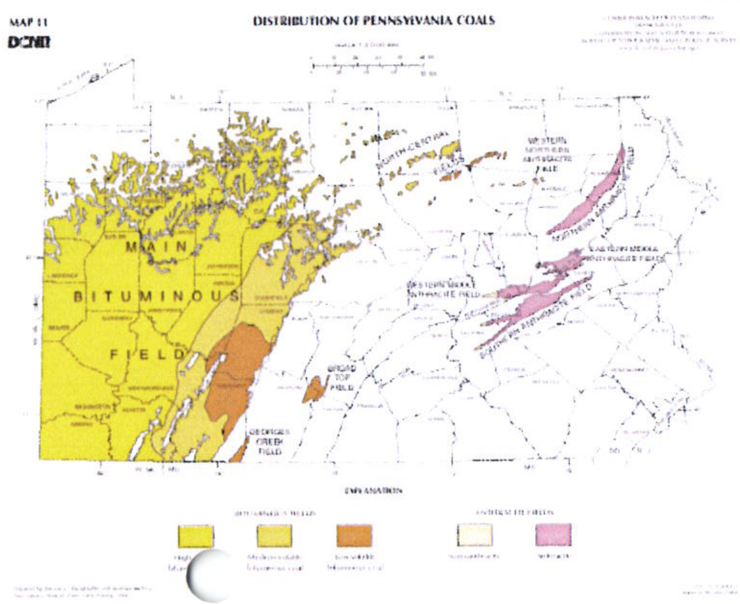




PENN-000074

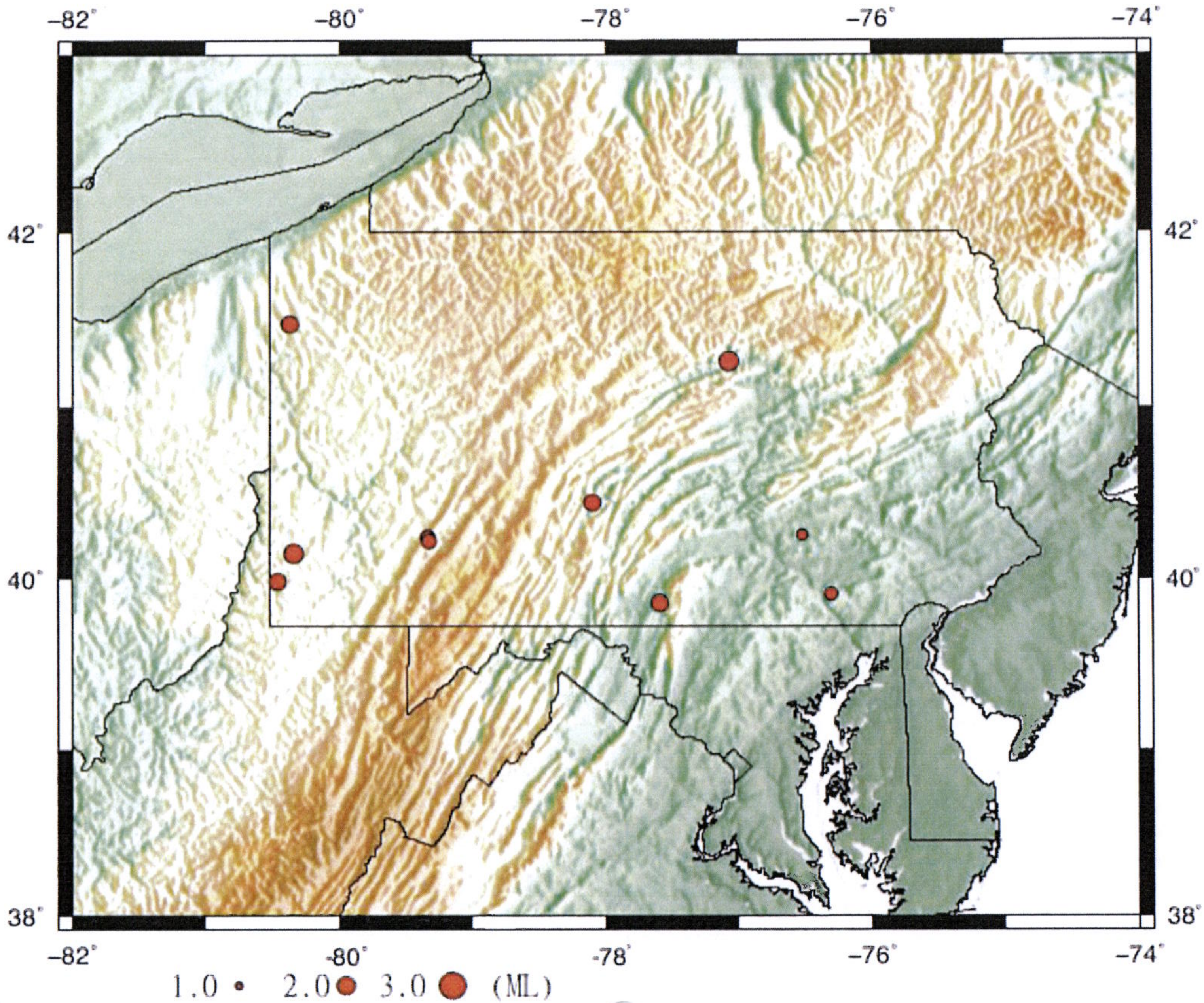
Potential Mine or Quarry Blasts (165 events)





PENN-000075

Non-mining events – 11 of them.



PENN-000076

What are the sources of the non-mining seismic events?

Several possibilities

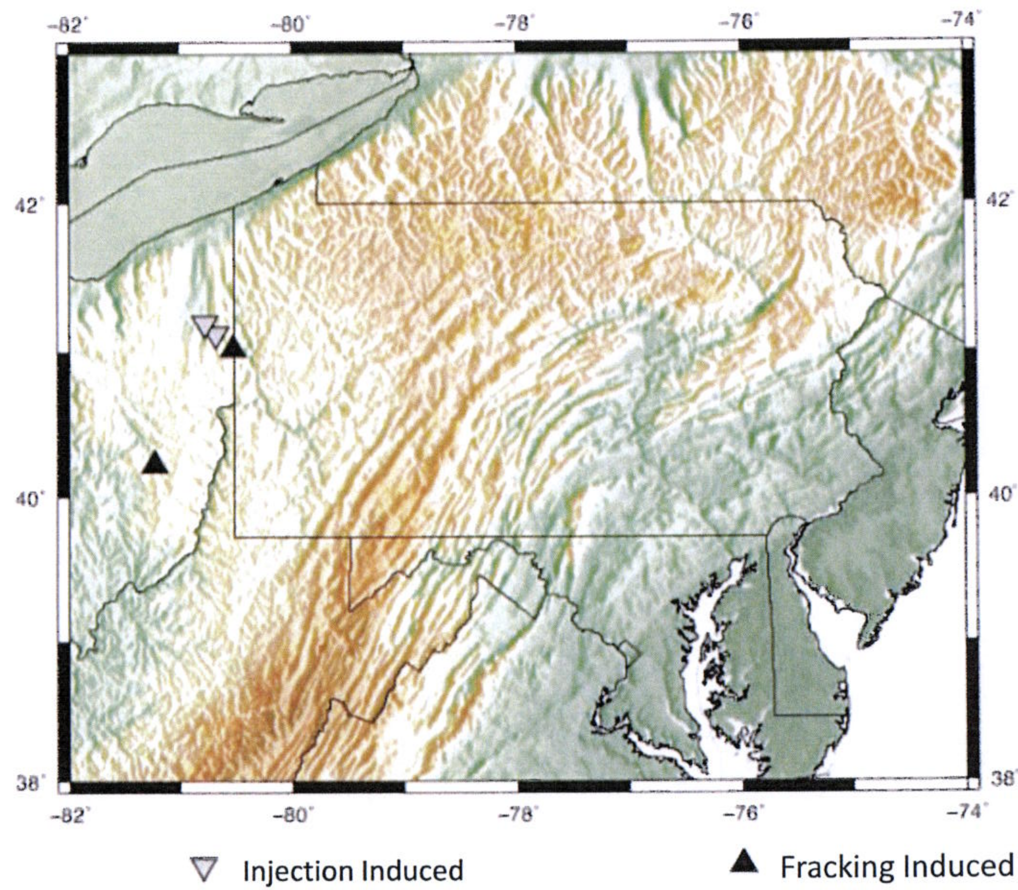
- tectonic earthquakes

-induced seismicity from wastewater disposal wells

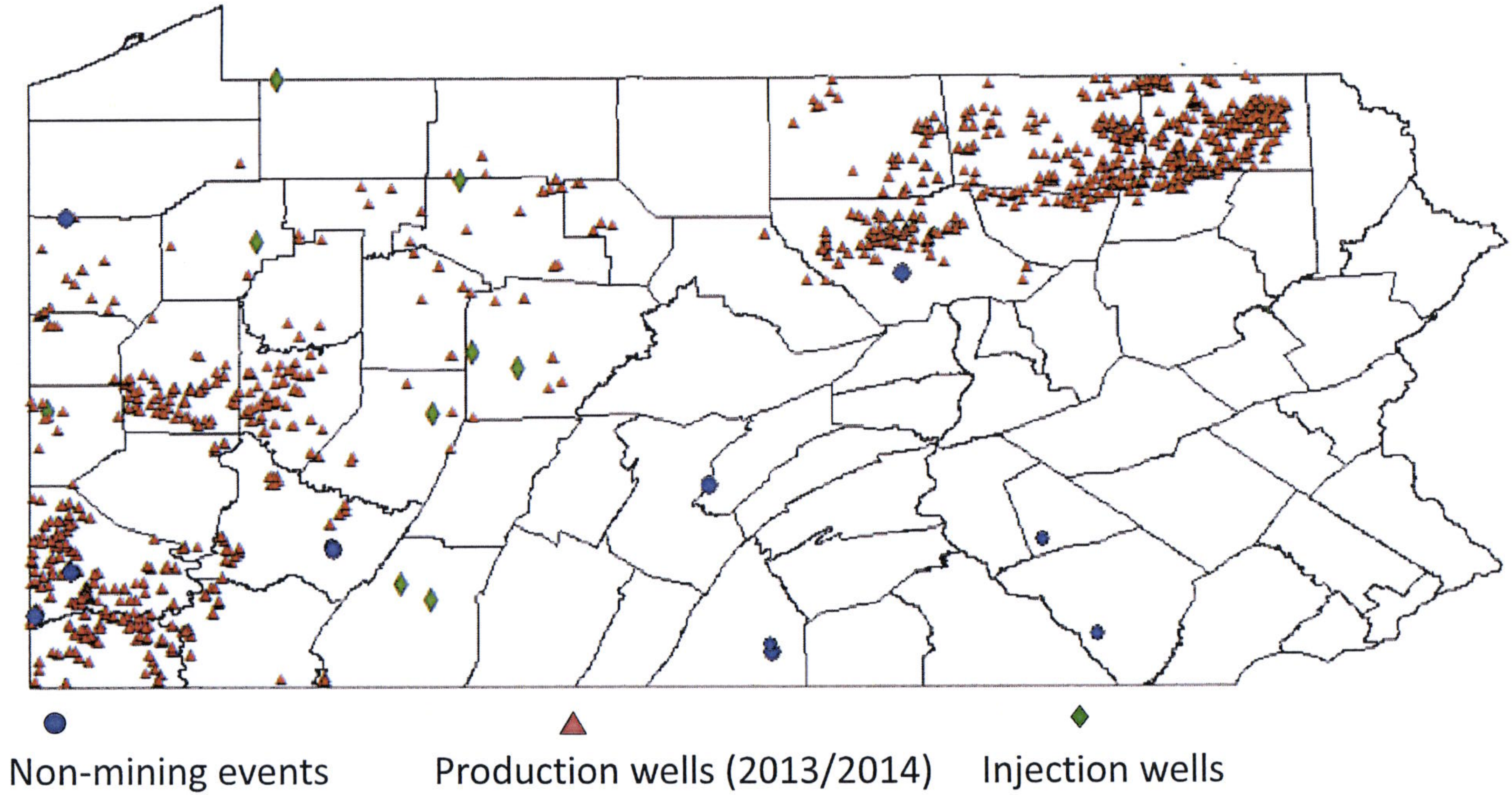
- induced seismicity from hydraulic fracking

Induced Seismicity

- Induced events have occurred in several areas of the US
- Both wastewater injection and hydraulic fracturing can induce seismic activity – events of both kinds in Ohio
- Pennsylvania has both hydraulic fracture wells and wastewater injection wells



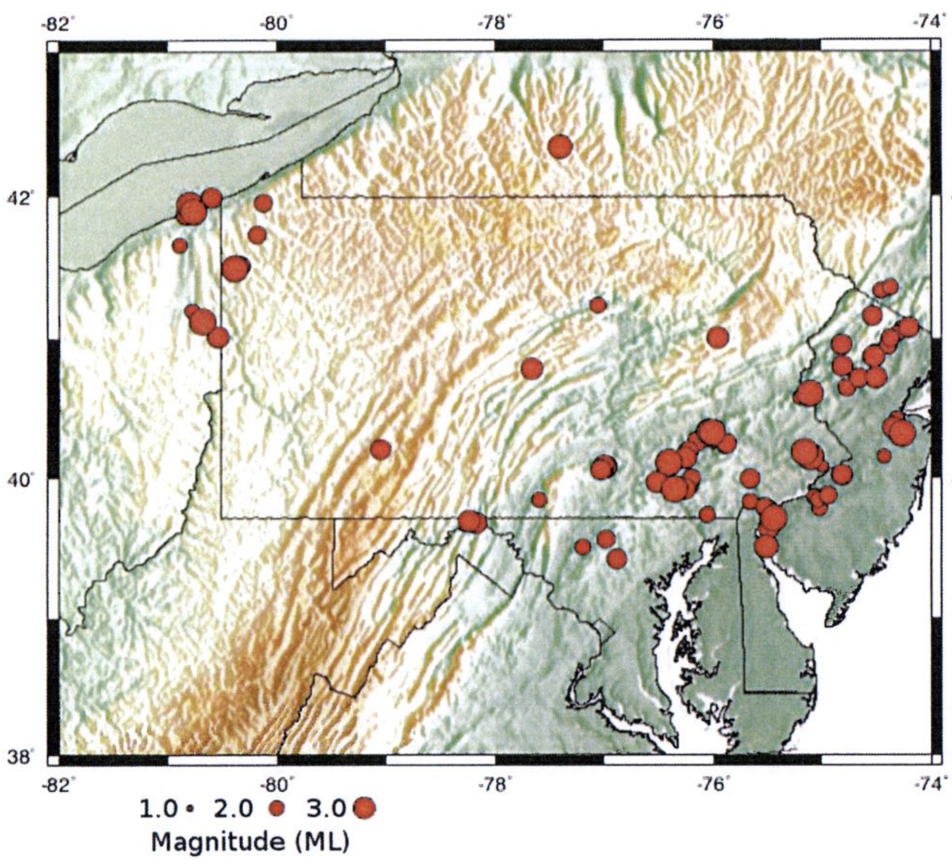
Are there spatial and temporal correlations with well activity?



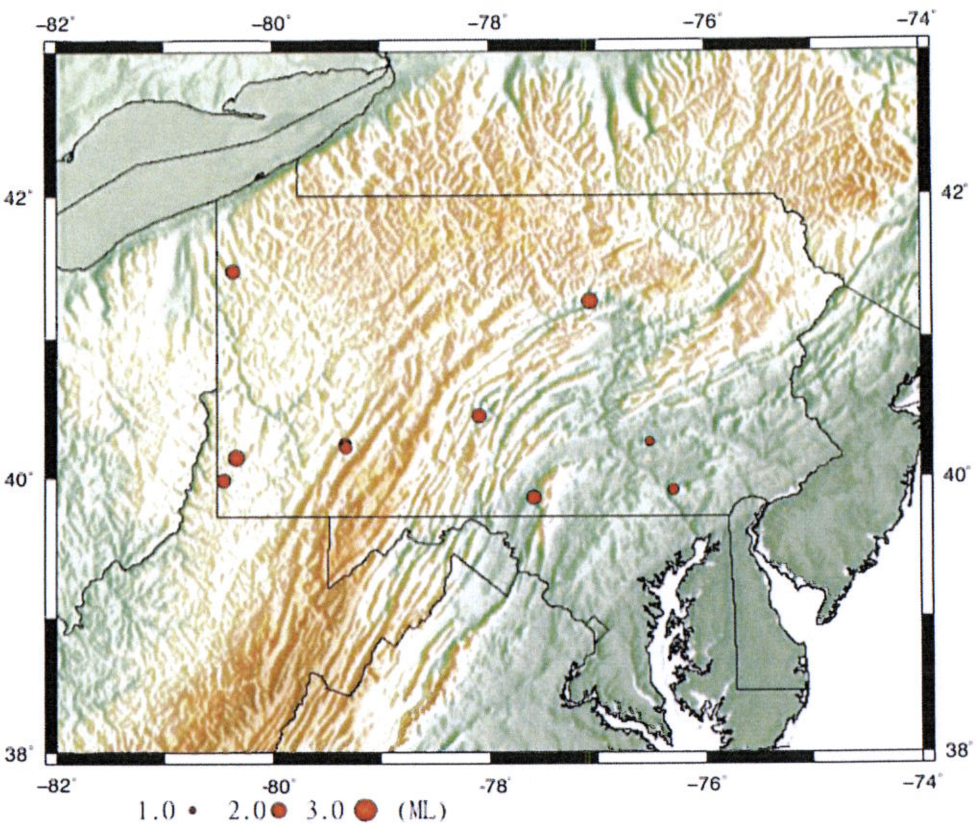
-No correlation has been found with either injection wells or fracked wells

Summary of findings: 1344 mining related events

11 Non-mining events – they are all probably tectonic earthquakes



Historical



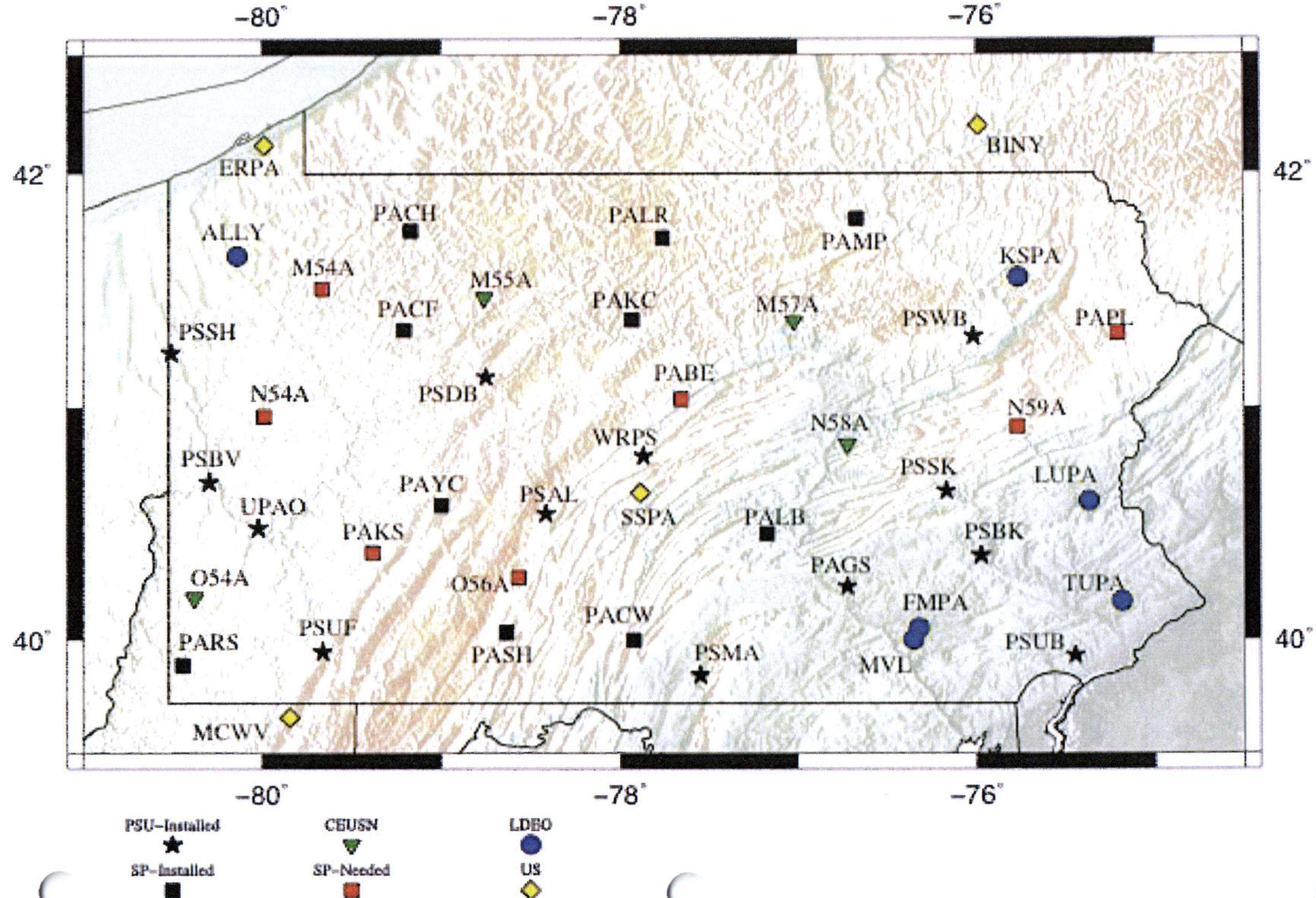
2013-2014

PENN-000080

Expanding the Pennsylvania State Seismic Network

- 30 stations in the PASEIS network by summer 2016
- 6 stations operated by LCSN (LDEO)
- 2 stations operated by the USGS (US)
- 4 stations in the CEUSN network operated by IRIS/USGS

+ several stations in neighboring states



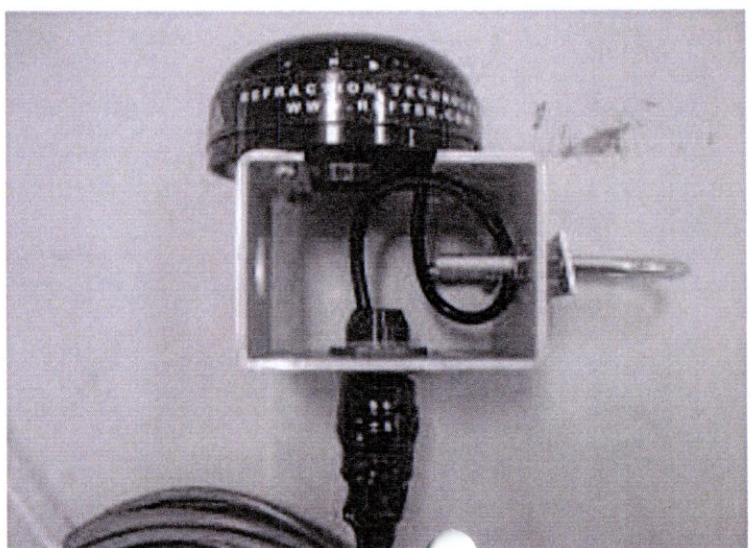
PENN-000081

PASEIS Seismic Equipment

Data logger/Digitizer

3-component ground motion sensor (vertical, north-south, east-west)

GPS clock



What does a PASEIS station look like?

PENN-000083

PASEIS data are openly available from the IRIS Data Management Center (http://ds.iris.edu/mda/_PENN) or (http://ds.iris.edu/mda/PE)

IRIS MDA Usage

IRIS DMC MetaData Aggregator

Legend: R A R P

Virtual network summary (1 time span)

Virtual Network	_PENN :: Pennsylvania State Geological Survey :: _PENN Network Map
Start	2004/04/01 00:00:00
End	2599/12/31 23:59:59

Stations for _PENN virtual network (25 stations) :: Click column title to sort

	Network	Station	Site	Latitude	Longitude	Elevation	Vnet start	Vnet end
A	PE	NCAT	NC A&T Campus	36.078958	-79.771183	243	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PACH	Chapman State Park, Clarendon, PA	41.756660	-79.171430	431	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PAGS	PA Geological Survey, Middletown, PA, USA	40.230000	-76.720000	120	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PAKC	Kettle Creek State Park, Renovo, PA	41.374710	-77.932530	294	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PALB	Little Buffalo State Park, PA, USA	40.458910	-77.167830	145	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PALR	Lyman Run State Park, Galeton, PA	41.725095	-77.760062	537	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PAMP	Mt. Pisgah State Park, Troy, PA	41.805900	-76.668890	348	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PARS	Chapman State Park, Clarendon, PA	39.886320	-80.445220	305	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PASH	Shawnee State Park, Schnellsburg, PA	40.026000	-78.635690	393	2004/01/01 00:00:00	2500/12/30 23:59:59
R A	PE	PSAL	PSU Altoona Campus, PA, USA	40.543700	-78.414500	402	2004/01/01 00:00:00	2500/12/30 23:59:59

Station summary (1 time span)

Network	PE :: Penn State Network :: PE Network Map
Station	PACH :: Chapman State Park, Clarendon, PA :: Penn State Network :: PACH Station Map :: RESP :: SAC PZs :: XML
Latitude	41.756660
Longitude	-79.171430
Elevation	431
Start	2016/03/18 (078) 00:00:00
End	2599/12/31 (365) 23:59:59
Epoch	**2016/03/18 (078) 00:00:00 - 2599/12/31 (365) 23:59:59**
Instrument	Reftek 130 Datalogger
Channels (Hz)	Location --: LOG (0)
Instrument	Nanometrics Trillium Compact/Reftek 130 Datalogger
Channels (Hz)	Location --: HHE (100) R A, HHN (100) R A, HHZ (100) R A, LHE (1), LHN (1), LHZ (1)
MetaData Load	2016/04/15 (106) 14:10:37

Virtual network affiliations:

Name	Description	Primary DC	Secondary DC
_PENN	Pennsylvania State Geological Survey	PENN	IRIS DMC
_REALTIME	Stations collected and served in real time at the DMC	IRIS DMC	IRIS DMC
.UNRESTRICTED	All unrestricted stations, generated via cron	IRIS DMC	IRIS DMC
_US-REGIONAL	US Regional Networks	PSU	IRIS DMC

Real-time data availability (view Station Monitor) ← View some of the data

	Earliest	Latest
R	2016/05/06 (127) 00:00:00	2016/05/18 (139) 00:00:00

Archive data availability - Make a batch request for data (breq_fast) - (data access overview) ← Information on how to request the data

PENN-000085

Station Monitor

Choose a station

Network: PE

Station: WRPS

or choose: List Stations in Network | WRPS - PSU, University Park, PA, USA

Show Station

WRPS - PSU, University Park, PA, USA

Network: PE - Penn State Network
Location: 40.79°N - 77.87°W

Daily Data

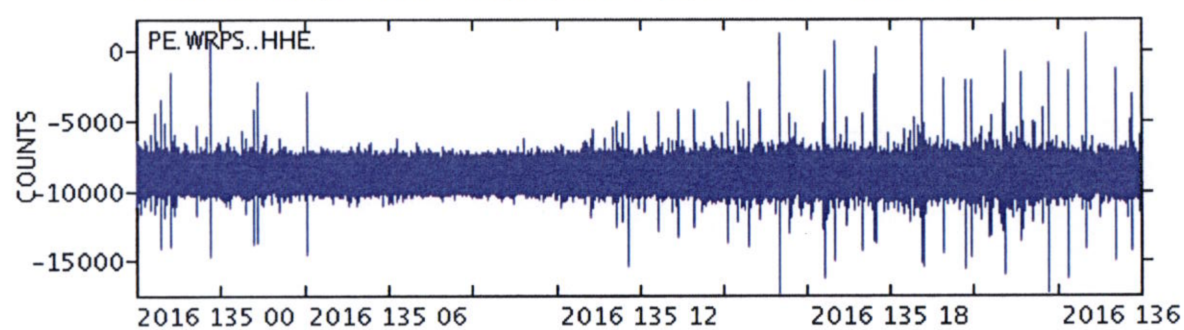
Day: 2016-05-14

Location/Channels: --:HHE/HHN/HHZ

Update

--.HHE

PE_WRPS_??_HHE, 8640001 samples, 100.0 sps, 2016-05-14T00:00:00.000



PASEIS web site – coming soon

- Station information
- Station and event maps
- Instructions on obtaining data
- Seismic event information determined from the 42 stations in PA plus open stations in neighboring states – event location, depth, origin time and magnitude

Minor earthquake measures near city

Posted: Tuesday, April 19, 2016 12:08 am

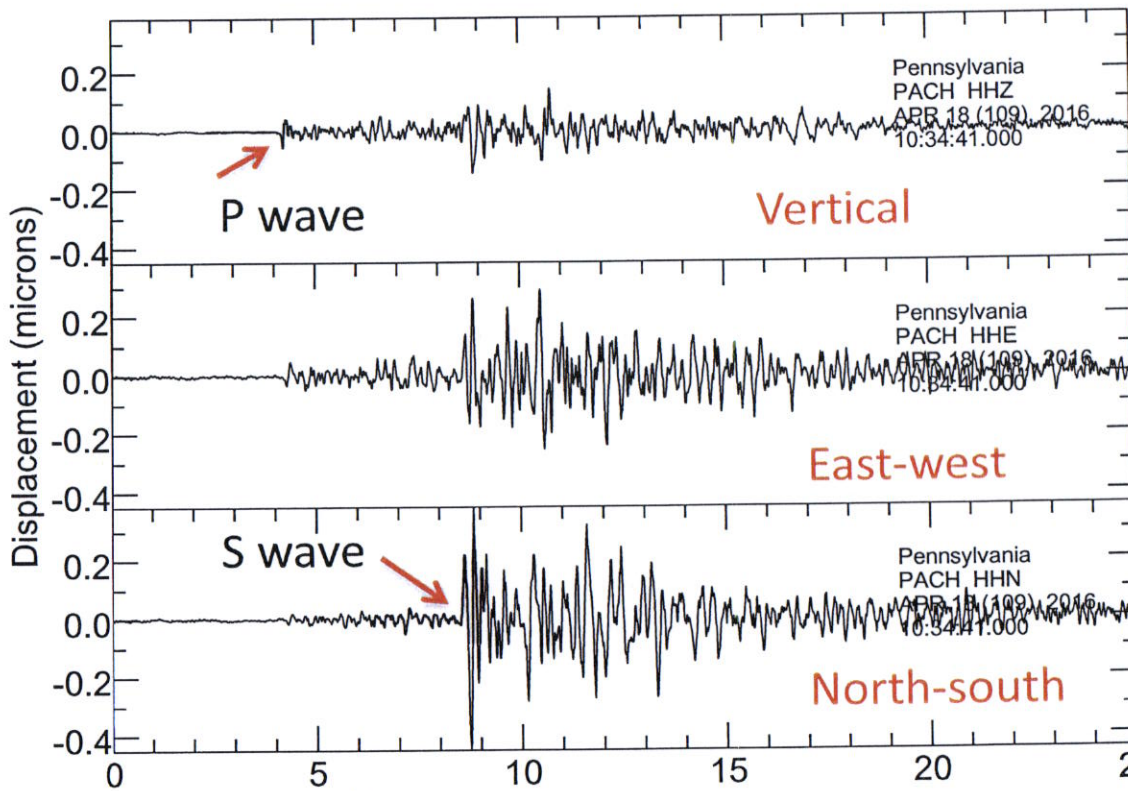
By Stella Ruggiero sruggiero@titusvilleherald.com | 0 comments

A small earthquake, which was likely too weak to be noticed by anyone other than geologists, measured in the Titusville area on Monday, around 6:34 a.m.

The quake was magnitude 2.2, according to AccuWeather meteorologist Jordan Root. He said it was fairly weak on the scale, and not likely felt by many people, or maybe no one at all. As of late Monday afternoon, Root had received no reports of anyone experiencing the quake.

Magnitude 2.2
Time: 2016/04/18 06:34:40 local
Depth 3.3 miles (5.2 km)
Near Titusville, PA

What do the data look like? (Chapman State Park)



1 micron = 0.001 millimeter

Figure courtesy C. Ammon

PENN-000088

State studying link between fracking, Lawrence County earthquakes

By Laura Legere / Pittsburgh Post-Gazette April 29, 2016

Epicenters of Monday's earthquakes in Lawrence County compared with the location of the shale gas well pad that potentially triggered them.

	EARTHQUAKE MAGNITUDE	TIME OCCURRED
A	1.9	12:05:25 AM
B	1.7	4:16:55 AM
C	1.8	5:03:02 AM
D	1.9	10:54:26 AM
E	1.8	10:10:23 PM

Source: Esri, Pennsylvania Department of Environmental Protection, Un[illegible]d States Geological Survey Post-Gazette

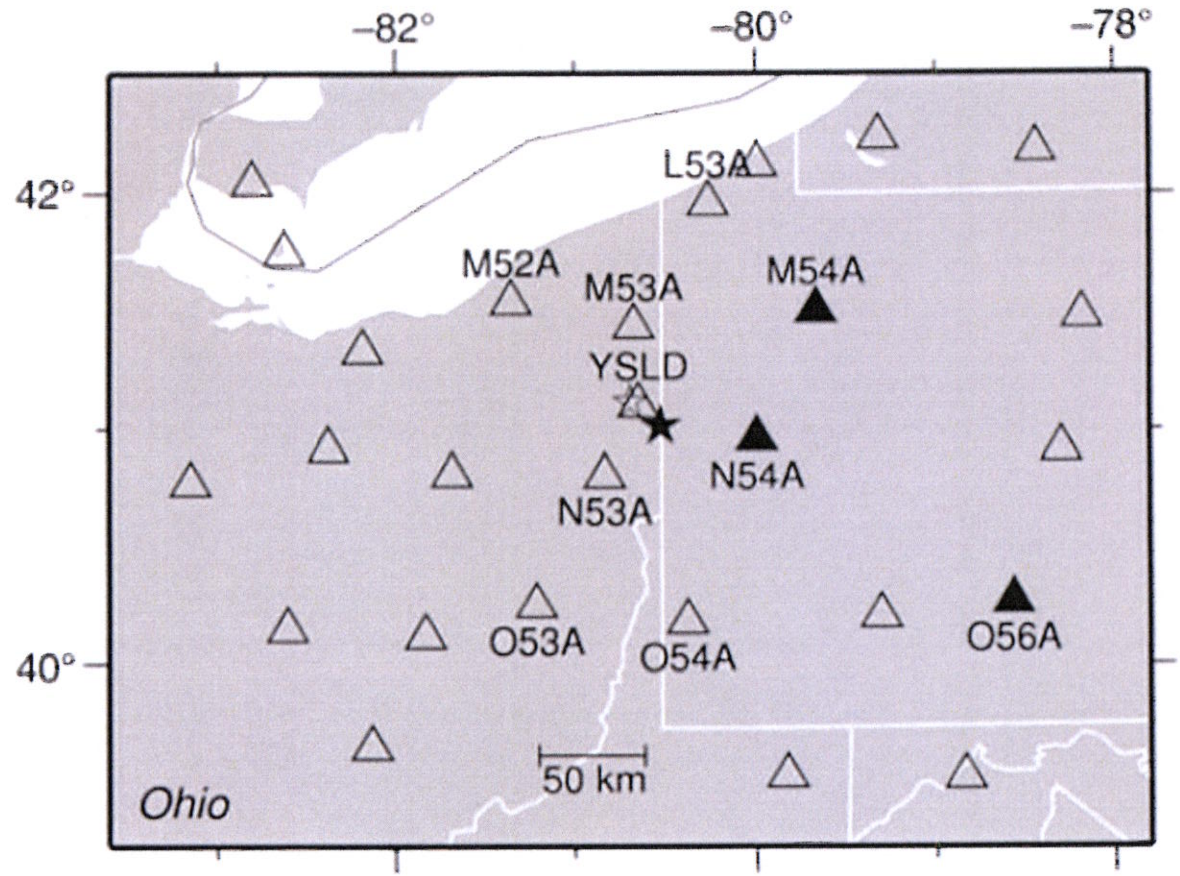
Bulletin of the Seismological Society of America, Vol. 105, No. 1, pp. –, February 2015, doi: 10.1785/0120140168

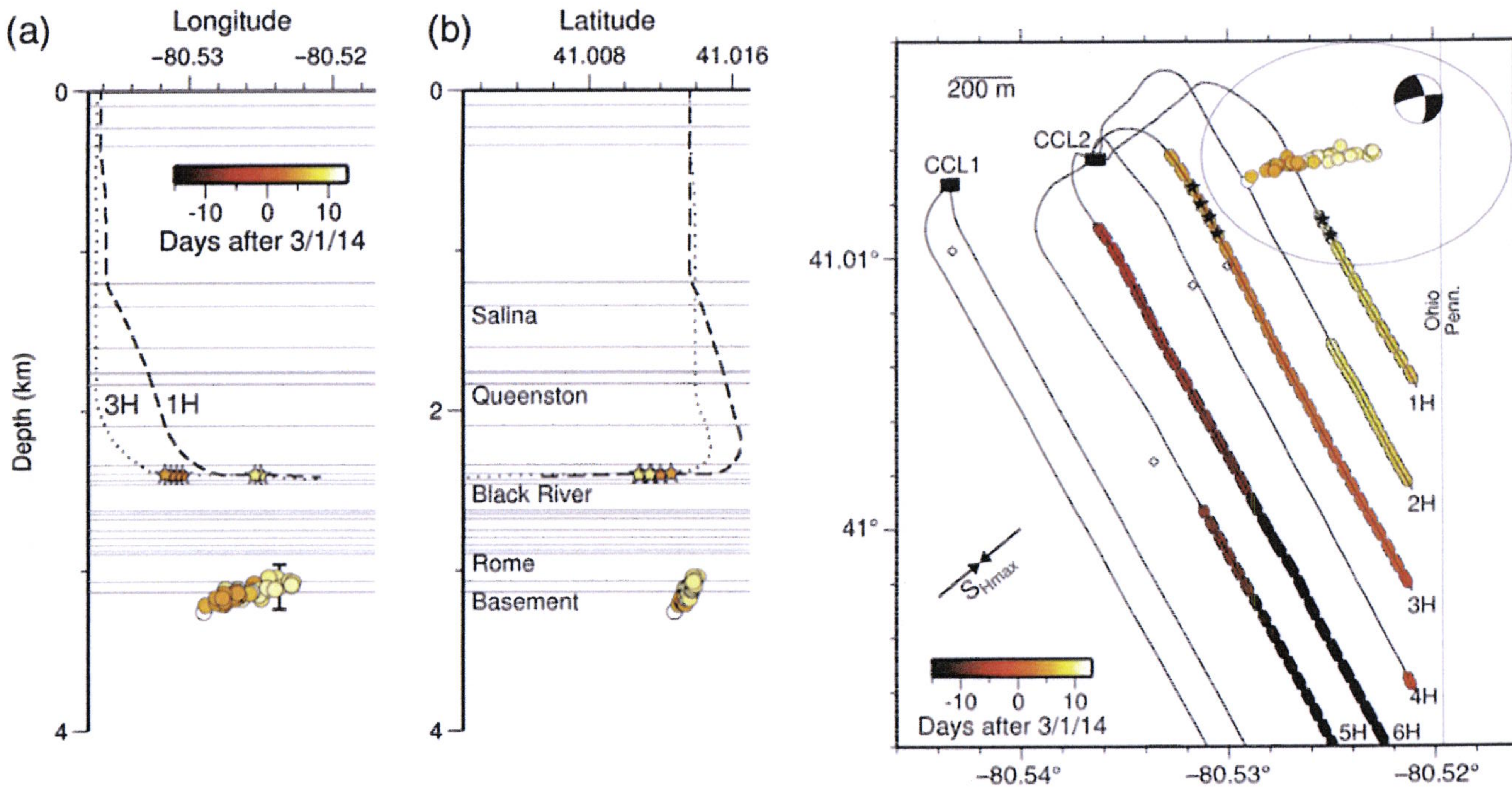
PENN-000090

Earthquakes Induced by Hydraulic Fracturing in Poland Township, Ohio

by Robert J. Skoumal, Michael R. Brudzinski, and Brian S. Currie

- March 4-12, 2014
- 77 events identified
- Magnitudes 1 to 3
- Correlated with fracking of the Utica Shale





PENN-000091

Did a similar thing happen with the Lawrence County earthquakes? Possibly.

-initial analysis of data indicates >30 events with magnitude >1

Initial Performance of PASEIS network

PENN-000092

2014 Poland Township events:

- Initial event detected was magnitude 3

2016 Lawrence County events:

- Initial event detected was magnitude 1.9

PASEIS network is designed for detecting and locating magnitude 2 and larger events.

Thanks to DCNR and DEP for promoting open data access!

pennsylvania
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Thanks to IRIS for providing data archiving and distribution!

IRIS

HFRAC
Consulting Services, LLC

December 7, 2015

Mr. Marc Jacobs, Jr.
Senior Vice President
Penneco
6608 Route 22
Delmont, PA 15626

Re: Sedat #3A (Murrysville) – Reservoir and Fracture Characterization

Dear Marc,

The following summarizes the reservoir and fracture characterization for the Murrysville formation in the Sedat #3A located in Plum Borough, Allegheny County, Pennsylvania.

A series of tests were designed and conducted at the Sedat #3A to gain a better understanding of the reservoir and fracture characteristics of the Murrysville formation which underlies a sizeable portion of Penneco's proximate lease acreage.

The tests were comprised of (1) formation breakdown, (2) DFIT (diagnostic fluid injection test) to determine closure stress, reservoir pressure, and reservoir transmissibility (kH/mu), (3) Step Rate to determine the fracture extension pressure, and (4) Rate Stepdown to determine the near wellbore friction which includes perforation friction and friction caused by near wellbore tortuosity.

Table 1 shows the timeline of the work performed on the Sedat #3A.

Several high level observations from the work performed was that (1) the well goes on vacuum very quickly after injection stops (i.e., pressure goes to zero on the surface) and (2) the surface treating pressures were excessively high given the depth of the well and the closure stress.

On September 1, 2015 a DFIT was pumped to determine the closure stress, reservoir pressure, and reservoir transmissibility (kH/mu). The DFIT was pumped at 4 bpm for 1500 gals. Bottomhole pressure was recorded with a bottomhole gauge set 1910 ft. The results from the DFIT using the Nolte G function gave a bottomhole closure stress of 553 psi which gives a closure stress gradient of 0.29 psi/ft.

330.401.1921
hjacot@hfrac.com
www.hfrac.com

P.O. Box 801 • New Philadelphia, OH 44663

The pressure decline data after closure (ACA) was analyzed with the Nolte FR function to determine reservoir transmissibility. Based on the pressure response it appears that pseudoradial flow was reached. The reservoir transmissibility was 88 mD-ft/cP assuming a reservoir fluid viscosity of 1 cP. The actual results will vary based on the actual reservoir fluid viscosity. The formation capacity (kH) was 88 mD-ft. Assuming a height of 50 ft gives a reservoir permeability of 1.8 mD.

Following the DFIT, an attempt was made on September 29, 2015 to breakdown additional perforations with 500 gals of 15 percent HCL acid and small concentrations of sand pumped in a 20 lb/1000 gal linear gel. The surface pressure was reduced when the acid entered the perforations but quickly increased as low concentration (0.25 lb/gal) of 40/70 sand entered the perforations. The sand was cut and the well flushed.

On October 1, 2015 a Step Rate was pumped to determine the fracture extension pressure. The initial rate was 0.25 bpm and increased to 1.0 bpm in increments of 0.25 bpm. The rate was then increased to 4 bpm in increments of 0.50 bpm. The injection time for each rate was four hours.

The results from the Step Rate gave a fracture extension pressure of 1.70 psi/ft which is abnormally high and cannot be used for formation evaluation. The cause of the excessively high fracture extension pressure was near wellbore friction comprised of perforation friction and friction caused by tortuosity (i.e., a poor connection between the wellbore and the created hydraulic fracture).

Based on the results from the Step Rate another attempt was made to reduce the near wellbore friction with additional acid and higher injection rates. On November 17, 2015 several injections were performed to reduce near wellbore friction. The first injection consisted of 1500 gals 7.5 percent HCl acid and the second injection used 750 gals 15 percent HCl acid. Following the second acid injection the injection rate was 26 bpm and the surface pressure was 2980 psi.

A Stepdown was performed after the second acid injection to quantify the amount of near wellbore friction and break out the perforation friction and friction caused by tortuosity. Perforation friction varies with the flow rate squared and tortuosity varies with the square root of the flow rate. The results from the Stepdown show a total near wellbore friction of 2011 psi at 26 bpm of which 1300 psi is perforation friction and 711 psi is friction caused by tortuosity. The number of open perforations was 5 assuming a discharge coefficient of 0.60.

The perforation efficiency is very low with only 5 out of 41 perforations open.

The ISIP at the end of the last injection was 1446 psi giving a F.G (fracture gradient) of 1.23 psi/ft suggesting a possible horizontal component to the created fracture. The high fracture gradient could also be the result of near to mid-field fracture complexity. As with the other injections the surface pressure quickly fell to zero. This rapid pressure decrease following the rate shutdown is a common response for mid-field fracture complexity (i.e., restriction away from the wellbore).

The results from the tests on the Sedat #3A are shown in **Table 2**.

In summary the Murrysville formation in the Sedat #3A is characterized by low reservoir pressure, 232 psi, low closure stress, 0.29 psi/ft., and higher than anticipated pumping pressures because of complex near or mid-field fracture complexity. Low perforation efficiency also contributed to the higher than expected pumping pressures.

Thank you for the opportunity to work on the Sedat #3A project with Penneco. If you have any questions or comments let me know.

Sincerely,

Henry Jacot
H-Frac Consulting Services, LLC

Table 1 – Timeline

Activity	Date
Perforate	August 7, 2015
Spot Acid and Pull Tubing	August 28, 2015
Break Formation and Pump DFIT	September 1, 2015
Perforation Cleanup	September 29, 2015
Step Rate	October 1, 2015
Perforation Breakdown	November 17, 2015

Table 2 - Results

Parameter	Value
Breakdown Pressure	3115 psi
Bottomhole Closure Stress	553 psi
Closure Stress Gradient	0.29 psi/ft
Surface ISIP	1446 psi
Fracture Gradient	1.23 psi/ft
Reservoir Pressure	232 psi
Reservoir Transmissibility (kH/mu)	88 mD-ft/cP
Formation Capacity (kH)	88 mD-ft
Reservoir Permeability	1.8 mD
Fracture Extension Pressure	N/A

PENNECO

SEDAT #3A

PLUM BOROUGH

ALLEGHENY COUNTY, PA

December 7, 2015

HIFRAC

TEST OBJECTIVES

- ✓ Formation Breakdown Pressure
- ✓ Closure Stress
- ✓ Fracture Gradient (F.G.)
- ✓ Reservoir Pressure
- ✓ Reservoir Transmissibility (kH/mu)
- ~~x Fracture Extension Pressure~~

HIFRAC

PENN-000099

TIME LINE

Activity	Date
Perforate	August 7, 2015
Spot Acid and Pull Tubing	August 28, 2015
Break Formation/Pump DFIT	September 1, 2015
Perforation Cleanup	September 29, 2015
Step Rate	October 1, 2015
Perforation Breakdown	November 17, 2015

HIFRAC

TEST RESULTS

Parameter	Value
Breakdown Pressure	3115 psi
Closure Stress	553 psi
Closure Stress Gradient	0.29 psi/ft
ISIP	1446 psi
Fracture Gradient	1.23 psi/ft
Reservoir Pressure	232 psi
Reservoir Transmissibility (kH/mu)	88 mD-ft/cP
Formation Capacity (kH)	88 mD-ft
Reservoir Permeability	1.8 mD
Fracture Extension Pressure	N/A

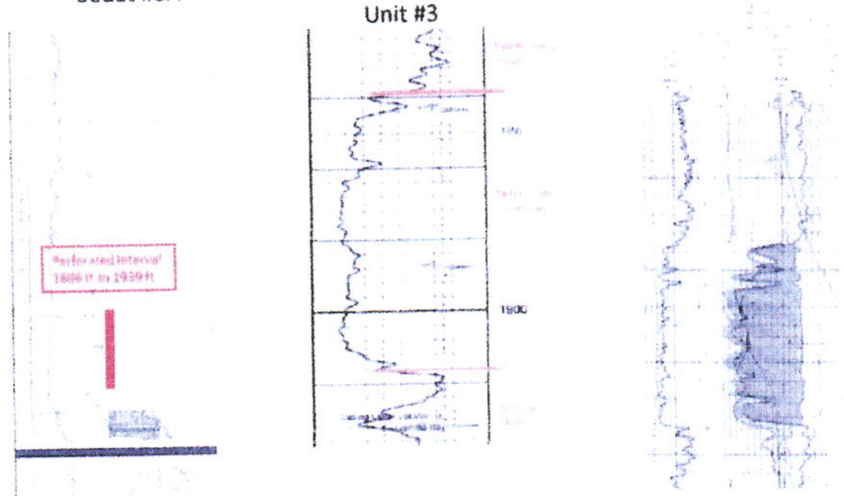
HFRAC

MURRYSVILLE LOGS

Sedat #3A

Snyder Unit #3

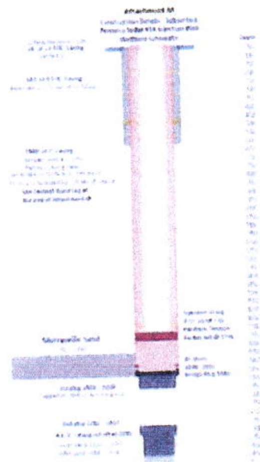
Watt #3



HFRAC

Murrysville type logs.

SEDAT #3A
WELLBORE SCHEMATIC



HIFRAC

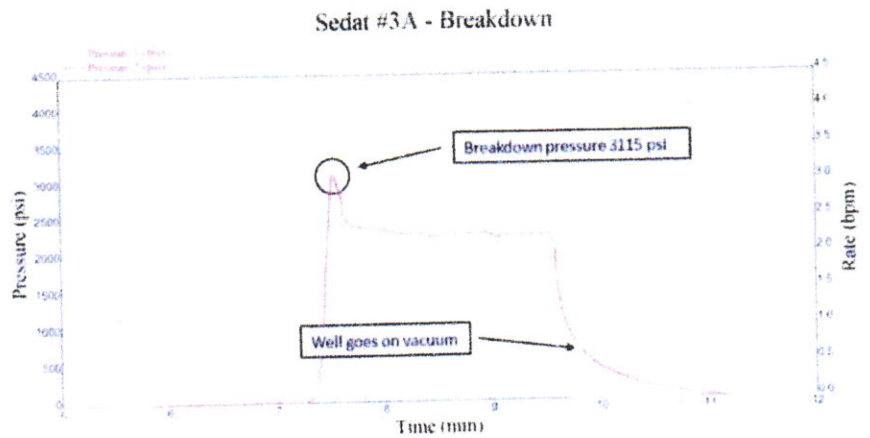
PERFORATION DATA

Description	Value
Entry Hole Diameter	0.58"
Phasing	60 degree
Type	EHC
Charge	25 grams
Depth	1896 ft to 1939 ft
Perforations	41 ea

HIFRAC

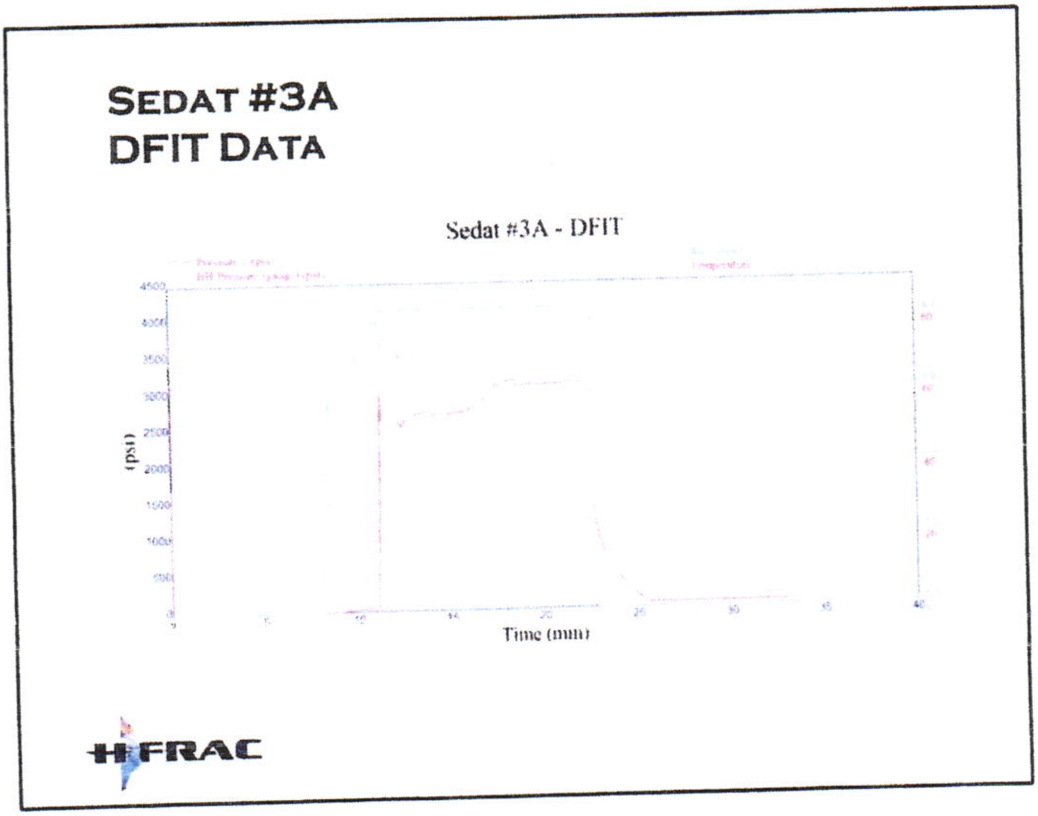
The Sedat #3A was perforated in the Murrysville from 1896 ft to 1939 ft with 41 0.58 in entry hole perforations. Perforation phasing was 60 degrees and the charge was 25 grams.

SEDAT #3A BREAKDOWN



HFRAC

The Murrysville formation in the Sedat #3A was broke down on September 1, 2015. The breakdown pressure was 3115 psi. Following the breakdown the acid was displaced at 4 bpm The well was on vacuum after shutdown with the pressure decreasing to zero in less than two minutes.

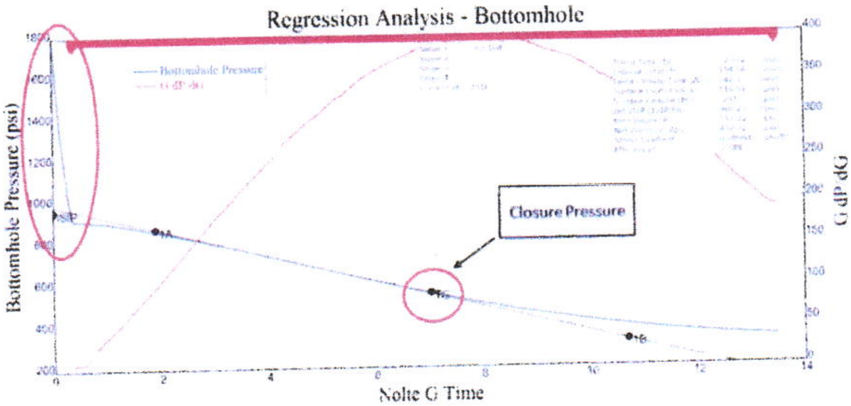


Following the formation breakdown a DFIT (diagnostic fluid injection test) was pumped in the Murrysville to determine closure stress, reservoir pressure, and reservoir transmissibility (kh/mu). Prior to starting the DFIT the whole was loaded with water. After the hole was loaded 1500 gals of water was pumped at 4.1 bpm. The average surface treating pressure was 2902 psi and the average bottomhole treating pressure was 3816 psi.

During the injection the surface pressure increased from 2700 psi to 3100 psi with a constant rate indication some type of restriction.

After the rate went to zero the surface pressure declined rapidly and went to zero. The bottomhole pressure was recorded with a bottomhole pressure gauge at 1910 ft.

SEDAT #3A
NOLTE G FUNCTION



HIFRAC

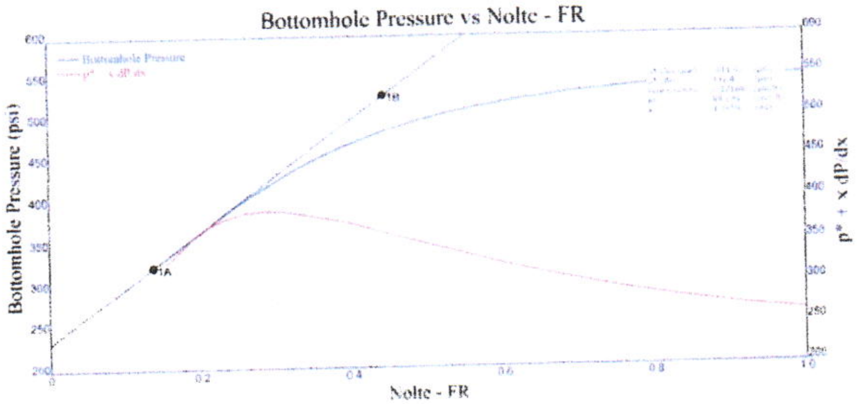
The bottomhole pressure from the DFIT was analyzed with the Nolte G function to determine the closure pressure and closure stress gradient.

Following the injection the pressure declined rapidly. The rapid pressure decline is most likely caused by fracture complexity and low closure stress and not leakoff into the formation.

The estimated bottomhole ISIP is 960 psi resulting in a fracture gradient of 0.50 psi/ft.

Closure occurred at a Nolte G time of 7.2 giving a bottomhole closure of 553 psi. The closure stress gradient is 0.29 psi. The net pressure was 407 psi and the fluid efficiency was 79 percent.

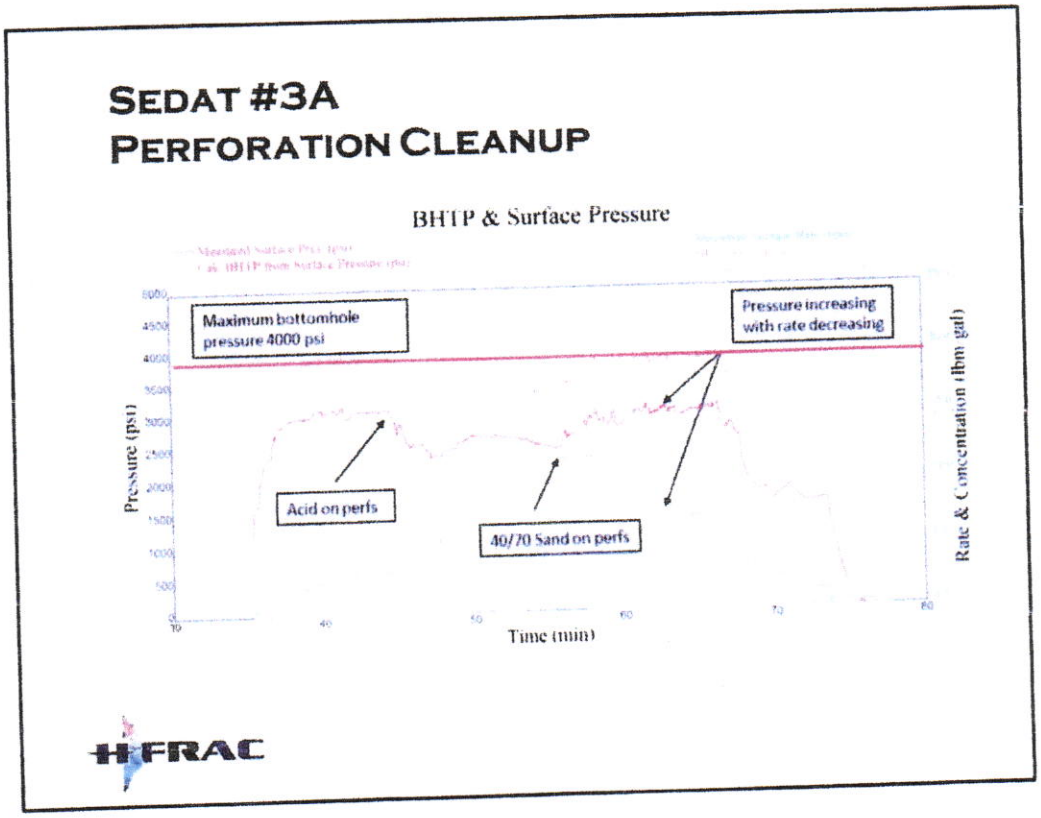
SEDAT #3A
AFTER CLOSURE ANALYSIS



HFRAC

The bottomhole pressure after closure was analyzed using the Nolte FR function. If the late time data reaches pseudoradial flow estimates of reservoir transmissibility (kh/mu) and reservoir pressure can be determined.

The results from the Nolte FR function show that pseudoradial flow was reached. P* was 232 psi. The formation capacity (kH) was 88 mD-ft assuming a reservoir fluid viscosity of 1 cP. Using a formation height of 50 ft the reservoir permeability is 1.8 mD.



On September 29, 2015 an attempt was made to remove excess friction seen on the DFIT. 500 gals of 15% HCL was pumped. A decrease on the surface treating pressure was seen when the acid was on the perforations. The surface pressure decreased and the injection rate was increased to 12 bpm. The surface pressure continued to decrease to 2500 psi.

Low concentration (0.25 lb/gal) of 40/70 sand was pumped in an effort to remove the excess friction. The surface pressure initially decreased with the 40/70 sand on the perforations but increased rapidly to over 3000 psi on the surface. The maximum pressure on the packer was 4000 psi so the injection was decreased to 11 bpm then to 7 bpm.

The calculated bottomhole pressure remained close to 4000 psi and was erratic.

The rate was reduced and the pressure declined to zero in less than two minutes.

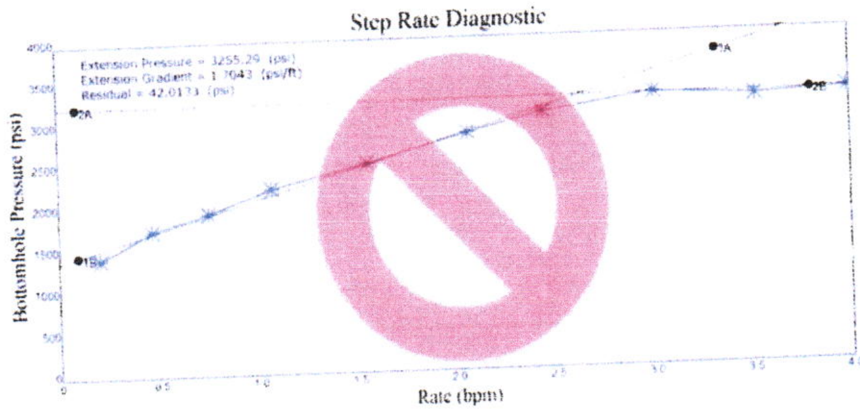
SEDAT #3A
STEP RATE TEST

A Step Rate Test was pumped on October 1, 2015 to determine the fracture extension pressure. The initial rate was 0.25 bpm and increased in 0.25 bpm increments until 1 bpm where it was increased to 4 bpm in 0.5 bpm increments. Injection period for each rate stage was 4 hours.

Following the rate increases the rate was decreased from 4 bpm in 1 bpm increments until the rate reached zero.

Total injected volume was 4292 bbls.

SEDAT #3A
STEP RATE

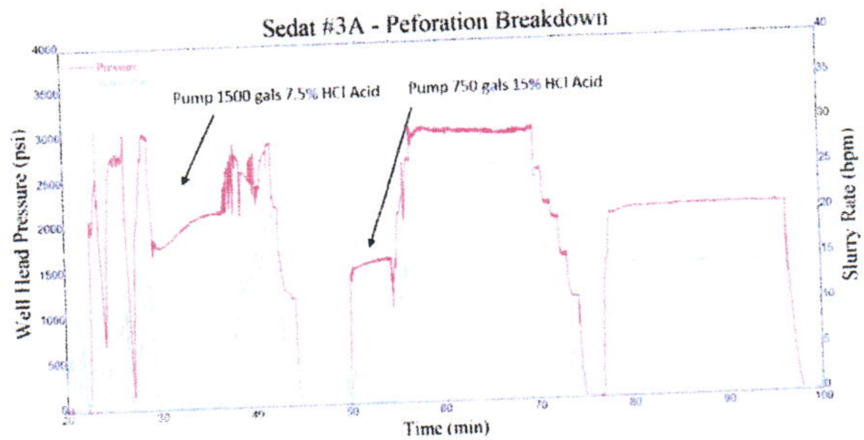


HIFRAC

Analysis of the Step Rate gave a fracture extension pressure of 3255 psi and fracture extension gradient of 1.70 psi/ft. This high of extension pressure gradient is unrealistic and cannot be used.

The high fracture extension pressure gradient is a result of excess near wellbore friction as evidenced by the sudden pressure increase with each rate increase (slide 13).

SEDAT #3A
PERFORATION BREAKDOWN



HIFRAC

On November 17, 2015 additional acid was pumped in an attempt to breakdown additional perforations and remove excess near wellbore friction to establish better communication between the wellbore and created hydraulic fracture.

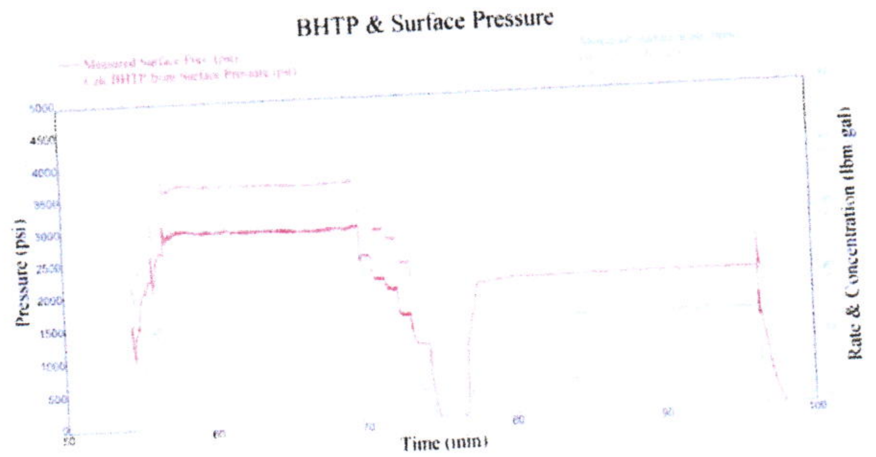
The first acid injection consisted of 1500 gals 7.5% HCl and the second acid injection was 750 gals 15% HCl acid.

Following the acid injections the maximum rate was 26 bpm at an average surface pressure of 2980 psi.

A rate stepdown was performed at the end of the acid breakown. An additional injection was pumped at 15 bpm to establish an ISIP.

The ISIP was 1441 psi.

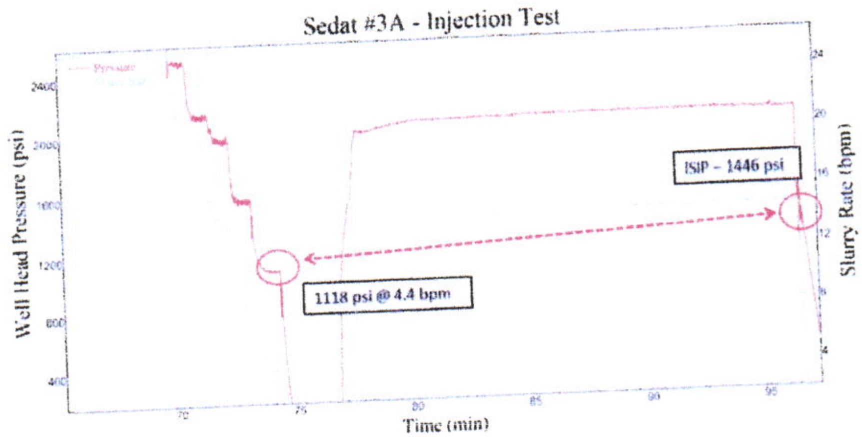
SEDAT #3A
SURFACE & CALC'D BH PRESSURE



HFRAC

This plot shows the calculated bottomhole pressure from the acid breakdown.

SEDAT #3A
INJECTION TEST (ZOOMED)

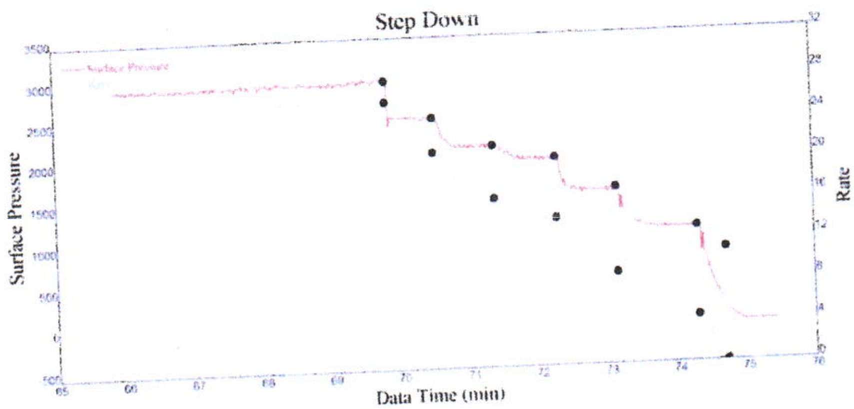


HIFRAC

This plot zooms in on the rate stepdown and final injection. The final rate on the stepdown was 4.4 bpm and the pressure was 1118 psi. The final ISIP was 1446 psi giving a fracture gradient of 1.23 psi/ft

This high of fracture gradient may be caused by either a horizontal fracture or excess fracture complexity.

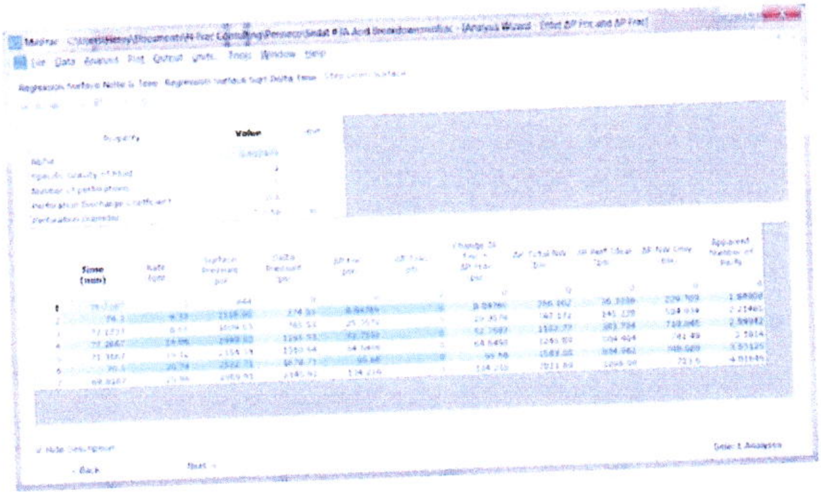
SEDAT #3A
STEPDOWN POINT SELECTION



HIFRAC

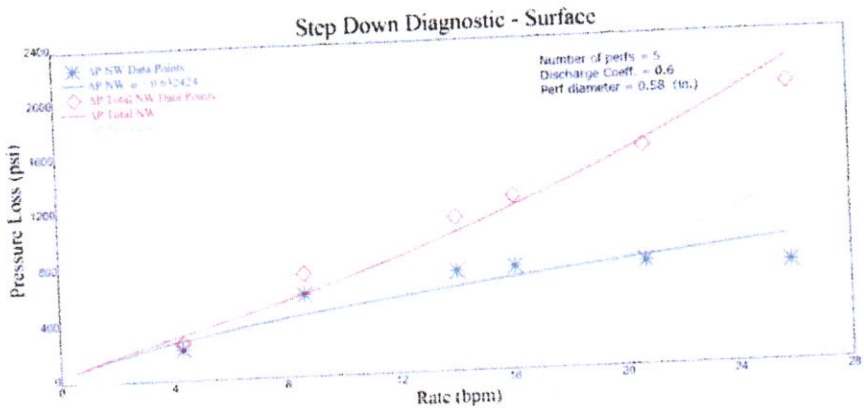
A Stepdown Analysis was conducted to determine the cause of the excess near wellbore friction.

SEDAT #3A
STEPDOWN TABLE



Stepdown Table showing the point selection and friction values.

SEDAT #3A
STEPDOWN ANALYSIS



HIFRAC

The Stepdown Analysis gives a total near wellbore friction of 2011 psi at 26 bpm. Of which 1300 psi is perforation friction and 711 is near wellbore tortuosity. The resulting number of perforations is 5 assuming a discharge coefficient of 0.60.

Sedat #3A
Summary

- A series of injections were pumped on the Sedat #3A to determine closure stress, fracture gradient, reservoir pressure, reservoir transmissibility (permeability), and breakdown pressure.
- During the injection tests excess friction existed either because of limited number of perforations open or near wellbore fracture complexity.
- Attempts were made to reduce the excess friction with acid, higher rates, and low concentrations of 40/70 sand. Acid and higher injection rates removed some of the excess friction but the high excess pressures still existed.
- The rate stepdown analysis showed total near wellbore friction of 2000 psi comprised of 1300 psi of perforation friction and 700 psi of near wellbore tortuosity of fracture complexity.

HIFRAC

Sedat #3A
Summary (cont.)

- The rate stepdown shows only 5 perforations open out of 41 perforations.
- After each injection the pressure quickly fell to zero at the surface because of the low closure stress of the Murrysville.
- The closure stress determined from the DFIT was 553 psi giving a closure stress gradient of 0.29 psi/ft. The Murrysville in the Sedat #3A cannot support a column of water.
- The DFIT reached pseudoradial flow. The After Closure Analysis with the Nolte FR function gave a reservoir transmissibility (kH/mu) of 88 mD-ft/cP assuming a reservoir fluid viscosity of 1 cP. Assuming a height of 50 ft the reservoir permeability is 1.76 mD.

HiFRAC

SEDAT #3A
SUMMARY (CONT.)

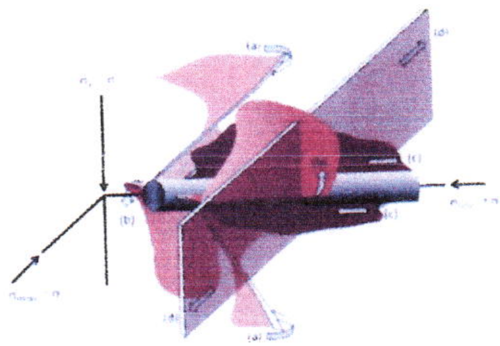
- The ISIP at the end of the last injection was 1446 psi giving a fracture gradient of 1.23 psi/ft suggesting a possible horizontal fracture. The high fracture gradient could also be the result of near or mid-field fracture complexity.

HIFRAC

APPENDIX

HFRAC

COMPLEX FRACTURE PROPAGATION
HORIZONTAL WELLBORE



HiFRAC

AFTER CLOSURE ANALYSIS

- The reservoir transmissiblity (kh/μ) can be calculated by analyzing the pressure decline data after closure; if the late time pressure data reaches pseudo-radial flow.
- Similar to a Horner analysis with the reservoir transmissibility calculated from the slope of the late time data.
- The pressure data when plotted on log-log scale will exhibit a slope of unity when pseudo-radial flow has developed.

HFRAC

Radial Flow Time Function

$$F_R(t,t_c) = \frac{1}{4}\ln\left(1 + \frac{\chi t_c}{t - t_c}\right)$$

where

$\chi = 16/\pi^2$

t_c = time to closure, min

t = time, min

F_R = radial flow function

After Closure Analysis

$$kh / \mu = 251{,}000\left(\frac{V_i}{m_R t_c}\right)$$

where

k = reservoir permeability, mD

h = net pay, ft

μ = reservoir fluid viscosity, cP

V_i = volume injected, bbl

m_R = slope

t_c = time to closure, min

HIFRAC

API Permit #: 37-003-21223
Customer: PENNECO
Lease and Well Name: SEDAT #3A
A.F.E #: N/A

UNIVERSAL WELL SERVICES, INC.

Job Type: MISC. PUMP PTA
Cement Operator: LANCE SHIREY
Date Cemented: 8/28/2015
Drilling Contractor: SERVICE RIG

Cement Slurry Information

No. of Sacks	Cement Blend Composition	Yield (ft^3/sk)	MixWater (gal/sk)	Density (lb/gal)	(bbl) Mix Water	(ft3) Of Slurry	(bbl) Of Slurry
				Totals			

Wellbore Information

	New/Used	Diameter (In)	Weight (lb/ft)	Top (ft)	Bottom (ft)	Collapse/Burst Pressures (psi)
Casing	Used	4 1/2	10.5	SURFACE	1,941	
Previous Casing						
Tubing or Drillpipe	Used	1 1/2	4.6	SURFACE	1,930	
Open Hole						
Open Hole						

Requested TOC (ft)	SURFACE
TVD (ft)	N/A
Displacement Depth (ft)	
Displacement (bbl)	

Pumping Returns

Spacer or Gel Sweep Return Seen At Surface	
Cement Returns Seen at Surface	
Amount of Cement Returns (BBL)	

Cement Slurry Temperature Record (°F)

Cement	Reading 1	Reading 2	Reading 3	Average
Blend 1				
Blend 2				
Blend 3				

Fluid Information

Mix Water Temp (°F)	
Displacement Fluid Type	Brine
Displacement Fluid Temp (°F)	
Displacement Fluid Density (lb/gal)	8.3

Time	Rate (bpm)	Volume (bbl)	Pressure (psi)	Event or Stage Description
12:15				Arrive On Location, Wait for Rig to Run Casing
				Spot Trucks, Hold JSEA,
				Hold Safety Meeting
				Load Lines, Test Lines
13:00	0-2	1	0-25	PUMP WATER
13:02	2	4.8	25	PUMP ACID 7.5%IRON CHEK
13:04	2	4	25	PUMP WATER
13:06				SHUT DOWN PULL TUBING
				FILL 4.5 W/ RIG
15:09-15:27	0-4	6	0-3000	PUMP WATER TO PUSH ACID BACK IN FORMATION
15:27				SHUT DOWN
				RACK UP
16:00				LEAVE LOCATION

Comments:

HFRAC Report – Page 29

Thank You for your Business

UWS Cement Operator Signature: LANCE SHIREY

Customer Representative Signature:

PENN-000126

TREATMENT SUMMARY

Customer Name:	Penneco	DFIT	Date: 9/29/15
Well Name:	Sedat #3A		

PRESSURES IN PSI

BREAKDOWN 2900 TOP PERF MD 1896
AVERAGE 2341 BTM PERF MD 1936
SHUT IN: INSTANT 1251 5-MIN 0 10-MIN na

CLEAN VOLUMES IN GAL

TOP PERF TVD 1896 PAD 70
BTM PERF TVD 1936 DISPL 30
TREATMENT 247 TTL VOL 100

HYDRAULIC HORSEPOWER

USED 671

RATES IN B.P.M.

AVG TREATING 11.7 MAXIMUM 11.9

DESCRIPTION OF JOB DFIT

Time	Rate (bpm)	Slurry Volume (gal)	Pressure (psi)	Description of Stage or Event
8:45	na	na	na	Hold Safety Meeting
9:11	na	na	na	Prime Pumps
9:17	na	na	4752	Pressure Test Lines
9:20	na	na	na	Fix Leak
9:28	na	na	na	Prime Pumps
9:29	na	na	5132	Pressure Test Lines
9:33	0.0	0	0	Load Hole
9:37	0.0	21	45	Pump Pad
9:41	na	na	na	Prime Acid
9:44	0.0	40	68	Pump Acid
9:50	0.1	40	1328	Displace Acid/Pump Pad
10:00	4.0	64	2900	Break Formation
10:05	11.9	107	2700	Establish Rate
10:05	11.9	110	2693	Start Sand @ 0.25 40/70
10:12	11.6	175	2852	Start Sand @ 0.30 40/70
10:12	11.7	193	2885	Cut Sand/Flush
10:22	5.0	273	2640	Establish 5.0 bpm
10:23	3.2	275	2031	Establish 3.0 bpm
10:25	2.4	280	1755	Establish 2.0 bpm
10:26	1.4	284	1624	Establish 1.0 bpm
10:28	0.0	287	1251	Shutdown

Totals

Sand	40/70	9	Sks
Chemicals	Unislick ST-50	5	Gals
	Unigel 5F	175	Lbs
	LEB 10X Breaker	0.4375	Gals
	15% HCL	495	Gals

UNIVERSAL WELL SERVICES, INC.

API Permit #: 3700321223
Customer: PENNECO OIL COMPANY
Lease and Well Name: SEDAT 3A
A.F.E #: N/A

UNIVERSAL WELL SERVICES, INC.

Job Type: DFIT
Cement Operator: JAMES CAMPBELL
Date Cemented: 10/1/2015
Drilling Contractor: N/A

Cement Slurry Information

No. of Sacks	Cement Blend Composition	Yield (ft³/sk)	MixWater (gal/sk)	Density (lb/gal)	(bbl) Mix Water	(ft3) Of Slurry	(bbl) Of Slurry
				Totals			

Wellbore Information

	New/Used	Diameter (in)	Weight (lb/ft)	Top (ft)	Bottom (ft)	Collapse/Burst Pressures (psi)
Casing	USED	4 1/2	10.5	SURFACE	1,930	
Previous Casing						
Tubing or Drillpipe						
Open Hole						
Open Hole						

Requested TOC (ft)	
TVD (ft)	
Displacement Depth (ft)	
Displacement (bbl)	

Pumping Returns

Spacer or Gel Sweep Return Seen At Surface	
Cement Returns Seen at Surface	
Amount of Cement Returns (BBL)	

Cement Slurry Temperature Record (°F)

Cement	Reading 1	Reading 2	Reading 3	Average
Blend 1				
Blend 2				
Blend 3				

Fluid Information

Mix Water Temp (°F)	
Displacement Fluid Type	
Displacement Fluid Temp (°F)	
Displacement Fluid Density (lb/gal)	

Time	Rate (bpm)	Volume (bbl)	Pressure (psi)	Event or Stage Description
0730				ARRIVE ON LOCATION, HOLD JSEA
0745				SPOT TRUCKS, MAKE HOOKUPS, WAIT ON RIG
				HOLD SAFETY MEETING
0927	.1-1	1	0-3300	LOAD LINES, PSI TEST
0932	.3-2	14	0-100	PUMP WATER TO LOAD HOLE
0944	.25	2.7	0-450	PUMP WATER TO START DFIT
0955	0	0	0	SHUTDOWN, RELEASE PRESSURE, UNHOOK
				WELL HEAD FLANGE NEEDS TIGHTENED
1005	.25	60	0-700	PUMP WATER TO START DFIT
1405	.5	120	450-825	RATE CHANGE TO .5 BBL/MIN
1805	.75	180	825-1075	RATE CHANGE TO .75 BBL/MIN
2206	1	240	1075-1330	RATE CHANGE TO 1 BBL/MIN
0205	1.5	360	1330-1770	RATE CHANGE TO 1.5 BBL/MIN
0605	2	480	1770-2004	RATE CHANGE TO 2 BBL/MIN
1005	2.5	600	2004-2162	RATE CHANGE TO 2.5 BBL/MIN
1406	3	720	2162-2400	RATE CHANGE TO 3 BBL/MIN
1806	3.5	840	2300-2600	RATE CHANGE TO 3.5 BBL/MIN
2205	4	512	2450-2500	RATE CHANGE TO 4 BBL/MIN
0011	3	90	2200-2250	RATE CHANGE TO 3 BBL/MIN
0041	2	60	2025-2050	RATE CHANGE TO 2 BBL/MIN
0111	1	30	1400-1450	RATE CHANGE TO 1 BBL/MIN
0141	0	0	1427-0	SHUTDOWN, MONITOR PRESSURE 10 MIN.
0155				RELEASE PRESSURE, UNHOOK
0200				RACKUP
0230				JOB COMPLETE, LEAVE LOCATION

Comments: WELL WENT ON VACUUM WHEN PUMPS WERE SHUT DOWN TO MONITOR THE WELL.

"THANK YOU"

Customer Representative Signature:

TREATMENT SUMMARY

Customer Name:	Penneco Oil Co	Acid Breakdown	Date:	11/17/15
Well Name:	Sedat #3A			

PRESSURES IN PSI

BREAKDOWN 3114 TOP PERF MD 1896
AVERAGE 2506 BTM PERF MD 1936
INSTANT 1401 5-MIN 0 10-MIN 0

CLEAN VOLUMES IN GAL

TOP PERF TVD 1896 PAD
BTM PERF TVD 1936 DISPL 1270
TREATMENT 27888 TTL VOL 36750

HYDRAULIC HORSEPOWER

USED 1130

RATES IN B.P.M.

AVG TREATING 18.4 MAXIMUM 26.3

DESCRIPTION OF JOB Slickwater Fracture

Time	Rate (bpm)	Slurry Volume (bbl)	Pressure (psi)	Description of Stage or Event
5:00				Arrive on location, rig up
7:06				Hold Safety Meeting
7:31			4160	Test Lines
7:33				Fix Leak
7:37			4665	Re-Test Lines, Good Test
8:09				Open Well
8:17	2.7	0	1766	Pump Water
8:19				Shutdown, Re-Prime Pump
8:21	2.7			Pump Water
8:23				Shutdown, Replace Hose
8:27				Re-Prime Pump, Inspect Pump
8:52	5	32	2320	Pump Water
8:55	7.2	40	3114	Break Formation
8:57	10.7	55	3058	Pump Tripped Out, Resume Pumping
8:58	14.1	68	3031	Establish Rate
8:59	4.0	75	1815	Pump Acid
9:07	6.4	110	2167	Displace Acid
9:09	14.1	126	2733	Acid to Perfs
9:12	20.1	171	2802	Establish Rate
9:13	16.0	183	2236	Stepdown Rate
9:14	5.1	198	1279	Stepdown Rate
9:15	0.0	203	261	Shut Down
9:21	3.7	204	1401	Pump Water
9:21	4.0	204	1520	Pump Acid
9:25	4.0	239	1385	Displace Acid
9:28	26.0	284	3005	Establish Rate
9:41	20.8	609	2541	Stepdown Rate - 20 BPM
9:41	16.1	620	2164	Stepdown Rate - 15 BPM
9:42	14.2	636	2006	Stepdown Rate - 14 BPM
9:43	8.6	650	1387	Stepdown Rate - 10 BPM
9:45	4.4	656	1117	Stepdown Rate - 5 BPM
9:46	0.0	664	0	Shut Down

Totals

Chemicals	Unigel 5F	0	Lbs
	LEB 10X Breaker	0	Qts
	FRP 121	110	Lbs
Acid	15% HCL	750	Gals
	7.5% HCL	1,500	Gals

UNIVERSAL WELL SERVICES, INC.

CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Sample Number: 07163702

Customer:	Penneco Oil Co., Inc.	**Collection Date:**	07/29/16 13:00
Site:	Gas Well	**Received Date:**	07/29/16 15:43
Monitoring Pt:	DeSimone #3	**Matrix:**	Non Potable Water (NPW)
Source Type:	Discharge	**Collection Method:**	Grab

07163702	Result	Reporting Limit	Method	Analysis Date	Analyst
Specific Gravity	1.1027 grams/ml	grams/ml	ASTM D1429	8/3/16 0:00	33-325
Total Dissolved Solids	140958 mg/L	5 mg/L	SM 2540 C	8/3/16 8:12	PLP
pH	5.78 SU	SU	SM4500 H+B	8/1/16 13:00	EJK

Sample Comments:

pH: The pH result measured @ temperature of 25 deg C pH: The pH was analyzed outside of the 15 minutes holding time.

Ryan C Shafer

Ryan C Shafer, Vice President of Operations

Analyst Reference: 33-325 - G & C Laboratory

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CWM Environmental
11931 State Route 85
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Sample Number: 09150657

Customer:	Penneco Oil Co., Inc.	**Collection Date:**	08/28/15 08:00
Site:	Sedat #3A	**Received Date:**	09/04/15 16:17
Monitoring Pt:	Tank Water	**Matrix:**	Non Potable Water (NPW)
Source Type:	Discharge	**Collection Method:**	Grab

09150657	**Result**	**Reporting Limit**	**Method**	**Analysis Date**	**Analyst**
Specific Gravity	11084 gr/ml	0 gr/ml	ASTM D-1298	9/9/15 0:00	33-325
pH	4.69 SU	SU	SM4500 H+B	9/9/15 13:30	JRD
Total Dissolved Solids	155476 mg/L	5 mg/L	SM 2540 C	9/8/15 16:03	ARB

Sample Comments:

pH: The pH result measured @ temperature of 25 deg C pH: The pH was analyzed outside of the 15 minutes holding time.

Ryan C Shafer

Ryan C Shafer, Vice President of Operations HFRAC Report – Page 34

Analyst Reference: 33-325 - G & C Laboratory

Analyte names in bold are listed under the laboratory's current NELAP scope of accreditation.

Universal Well Services, Inc.
Chemical Technology
13549 S. Mosiertown Road
Meadville, PA
814-373-3107

Laboratory Water Analysis

Sample Information

Company	Penneco
Well Name	Sedat 3a
Sample ID	Frac Water
Formation	
Date Sampled	9/23/2015
Date Analyzed	9/23/2015
Analyst	Bilich

Analysis Results

	Sample 1	Sample 2	
pH	4.90	5.10	
Temperature	74.4	74.3	°F
Specific Gravity	1.110	1.132	
Fluid Density	9.26	9.44	lb/gal
Chlorides (titrated)	100,000	120,000	mg/L
Total Dissolved Solids	159,500	191,400	mg/L
Total Suspended Solids	N/A	N/A	mg/L
Approximate Salt Percentage	14.4	16.9	%
Total Hardness	67,000	70,000	mg/L
Ca Hardness	63,000	60,000	mg/L
Ca^{2+}	25,200	24,000	mg/L
Mg Hardness	4,000	10,000	mg/L
Mg^{2+}	971	2,428	mg/L
Total Iron (titrated)	437	319	mg/L
Sulfates	39	10	mg/L
Hydroxide Alkalinity as $CaCO_3$	0	0	mg/L
Carbonate Alkalinity as $CaCO_3$	0	0	mg/L
Bicarbonate Alkalinity as $CaCO_3$	0	0	mg/L
Total Alkalinity as $CaCO_3$	0	0	mg/L
Tannin/ Lignin	N/A	N/A	mg/L
Barium/ Strontium PS	< 1	< 1	mg/L
Specific Conductance	172,500	193,200	µmhos/cm

HFrac Report Supplement Items 5 and 7

Item 5 Attachment Geologic Data

The Fracture Gradient (F.G.) 1.23 psi/ft was calculated using the ISIP (instantaneous shut-in pressure) of 1446 psi and fluid S.G. of 1.10 psi/ft. The mid-perforation depth was 1917.5 ft (1896 ft – 1939 ft).

$$F.G. = \frac{ISIP + HydrostaticHead}{Depth}$$

$$F.G = \frac{1446 + 913}{1917.5} = 1.23$$

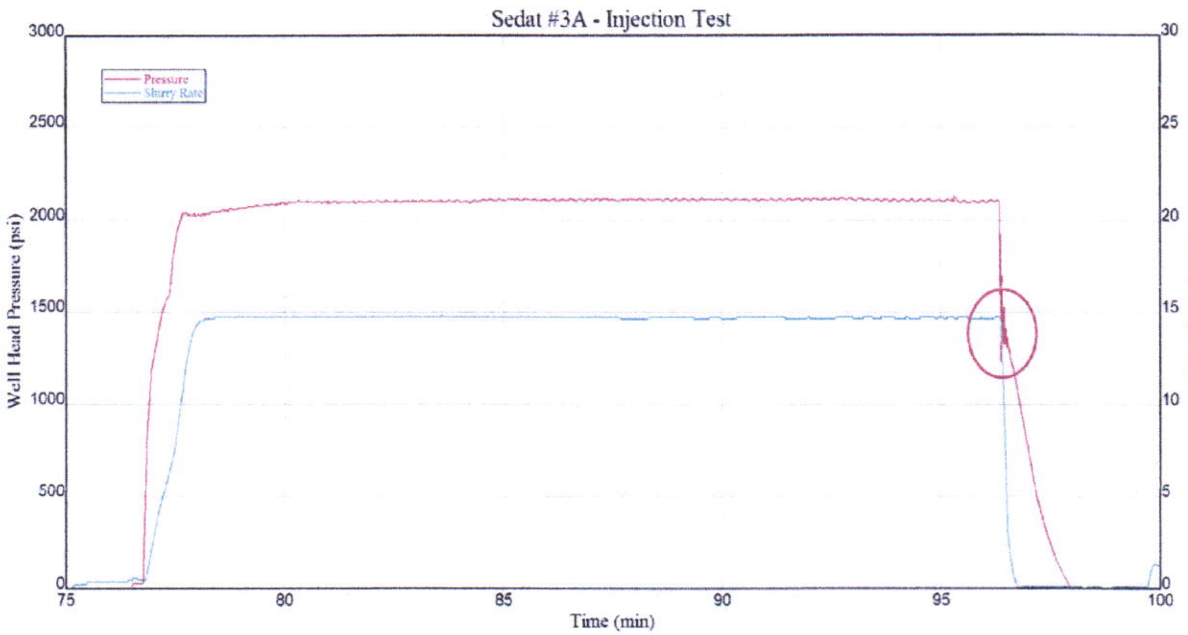


Figure 1 - Sedat 3A Injection Test pumped on November 17, 2015. ISIP 1446 psi.

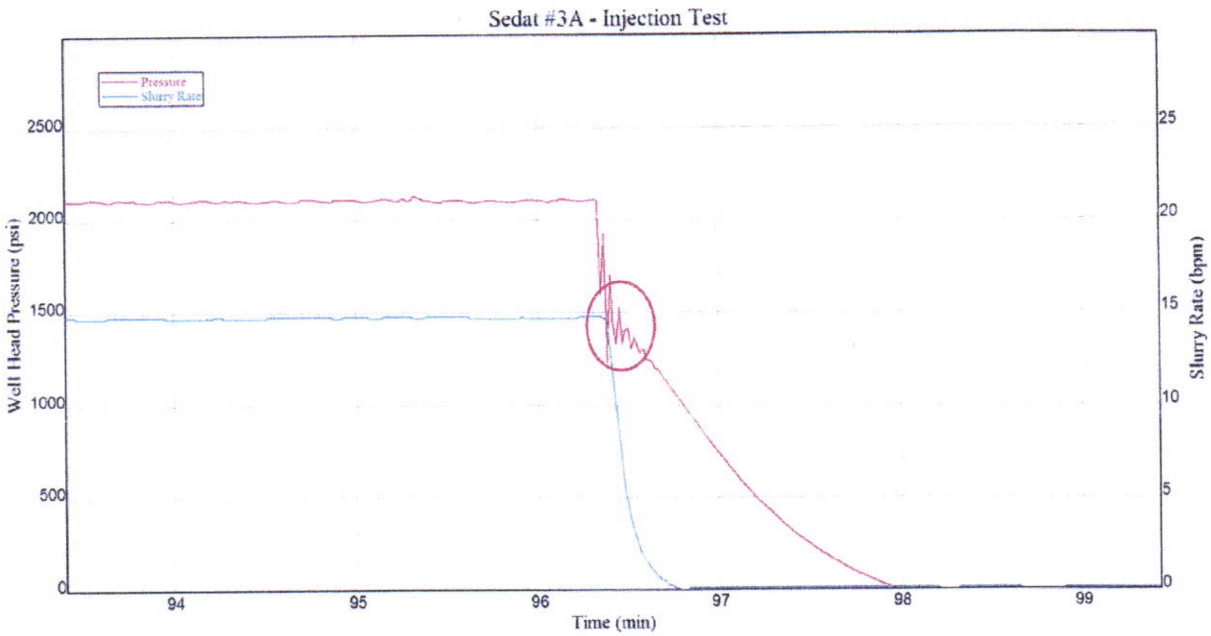


Figure 2 - Sedat #3A Injection Test pumped on November 17, 2015 (zoomed). ISIP 1446 psi

Item 7 Attachment Geologic Data

The reservoir permeability of 1.80 mD was an average permeability using a formation height of 50 ft. Using a reservoir permeability of 1.8 mD and formation height of 50 ft the formation capacity (k/H) was 90 mD/ft.

The bottomhole pressure after closure was analyzed using the Nolte FR function. If the late time data reaches pseudoradial flow estimates of reservoir transmissibility (kh/mu) and reservoir pressure can be determined.

The results from the Nolte FR function show that pseudoradial flow was reached. P* was 232 psi. The formation capacity (kH) was 90 mD-ft assuming a reservoir fluid viscosity of 1 cP. Using a formation height of 50 ft the reservoir permeability is 1.8 mD.

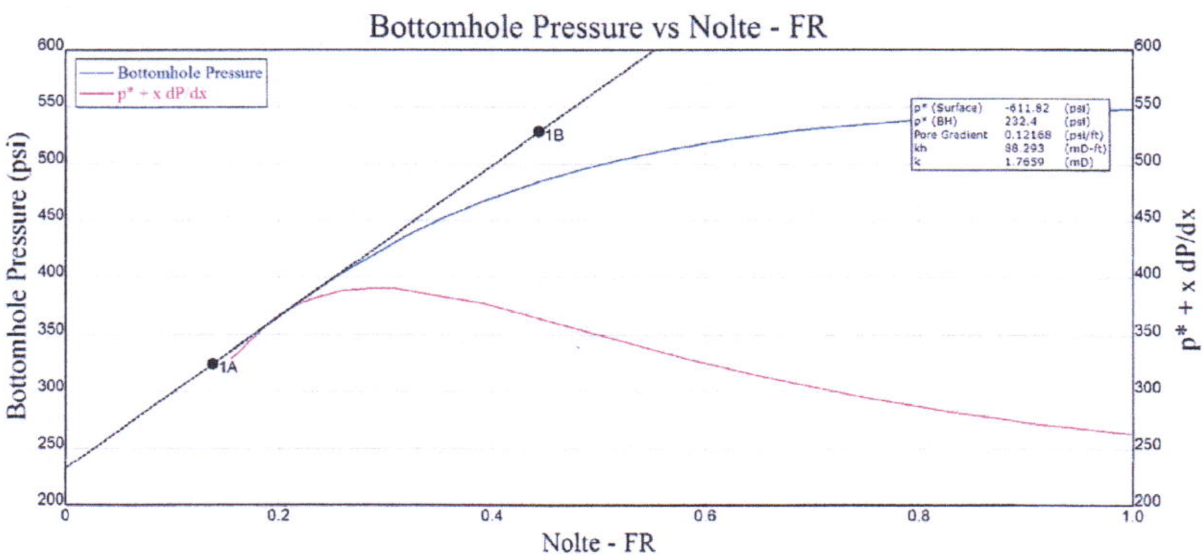


Figure 3 - Sedat #3A After Closure Analysis (ACA)

$$kh / \mu = 251,000\left(\frac{V_i}{m_R t_c}\right)$$

where

k = reservoir permeability, mD

h = net pay, ft

μ=reservoir fluid viscosity, cP

V_i=volume injected, bbl

m_R = slope

t_c = time to closure, min

Attachment H
Operating Data
Sedat #3A Injection Well

Injection Rates and Volumes

1) The proposed average injection rate is 1,800 BBLs of water per day and the maximum rate should be no greater than 2,000 BBLs of water per day or 54,000 BBLs per month.

Injection Pressures

2) Injection pressure is expected to be below 1,420 psi, the calculated maximum injection pressure at the well head, without accounting for any friction through the perforations through the 7" casing and the pipe friction through the 4 ½" injection string. The bottom hole pressure/reservoir pressure as measured with a bottom hole pressure gage is 232 psi.

   The maximum injection pressure of 1,420 psi, was calculated using the formula published in 40 CFR 147.1953, Pm= [(FG – (0.433)(Sg)]D, for a column of water. The fracture gradient of 1.23 from the Reservoir and Characterization study found at the end of Attachment G was used. The Sg used was 1.11, the Sg of the produced brine water used in the formation study and a depth of 1,896' the top perforation in the Sedat #3A. [Pm = (1.23 – 0.433 (1.11))1896]; Pm=1,420#.

Annulus Fluid

3) Fresh water will be in placed in the 4 ½" by 7" annulus, mixed with a chemical such as ALPHA 3207 which acts as a corrosion inhibitor and bacteria growth preventer. One (1) gallon of ALPHA 3207 will be mixed with approximately every 1,000 gallons of fresh water placed in the annulus. The MSD sheet for the chemical mixture ALPHA 3201 listing ingredients and physical data is included in this section. Positive pressure will be maintained on the annulus to monitor mechanical integrity.

Source and Analysis of Injection Fluid

4) The source of the injection fluid will be E&P wastes, produced water from oil and gas wells and flow back fluid from oil and gas well stimulation activities. Penneco Environmental Solutions, LLC will accept fluid generated by other drilling and production companies (filing a commercial application) The geographic area from which fluids will be generated is Western Pennsylvania and possibly a small amount of the fluids may originate in the shale gas fields of North Eastern Pennsylvania. Representative sample analyses from two wells are included with this attachment. Before injection the produced fluid will be analyzed for the parameters required by the permit. The produced fluid and flow back water will be subjected to treatment and passed through a filter to remove

large particles and suspended solids from the fluid before injection. The solids removed will be transported to an appropriate waste disposal site.

8-24-16

Attachment P
Monitoring Program
Sedat #3A Injection Well

Monitoring Program for Sedat #3A Injection Well

The Sedat #3A injection well will be monitored for the well's entire life in compliance with all EPA monitoring guidelines and reporting requirements.

The injection site is located so that the facilities cannot be seen from public roads or public or private properties adjacent to the site. The access road is gated and will be locked when the site is not operating. The injection site and surface facilities will be fenced and lighted at night with the fenced gate locked when the site is not operating.

There will be one (1) monitoring well, identified by its Pennsylvania issued permit number, 003-21210. This is a depleted gas well that will be adapted for use as an observation well and is 1,010' to the south west of the Sedat #3A, see well plat map at end of Attachment. The well has satisfactory spacing and placement to provide adequate sampling area without having to drill a well or wells for the specific propose of sampling. A monitoring string set on a packer immediately above the Murrysville Sand will be installed to isolate the Murrysville injection zone. Penneco will sample, monitor and record quarterly, or more often if required by permit, the fluid level in the Sedat #1 monitoring well, either by slick line or service rig. The company will monitor the pressure at the well head and as well as the 7" – isolation string annulus. The results will be reported as required by permit or according to EPA guidelines. Any change in fluid level or fluid makeup will be investigated as to its cause. Quarterly mechanical integrity testing will also be conducted.

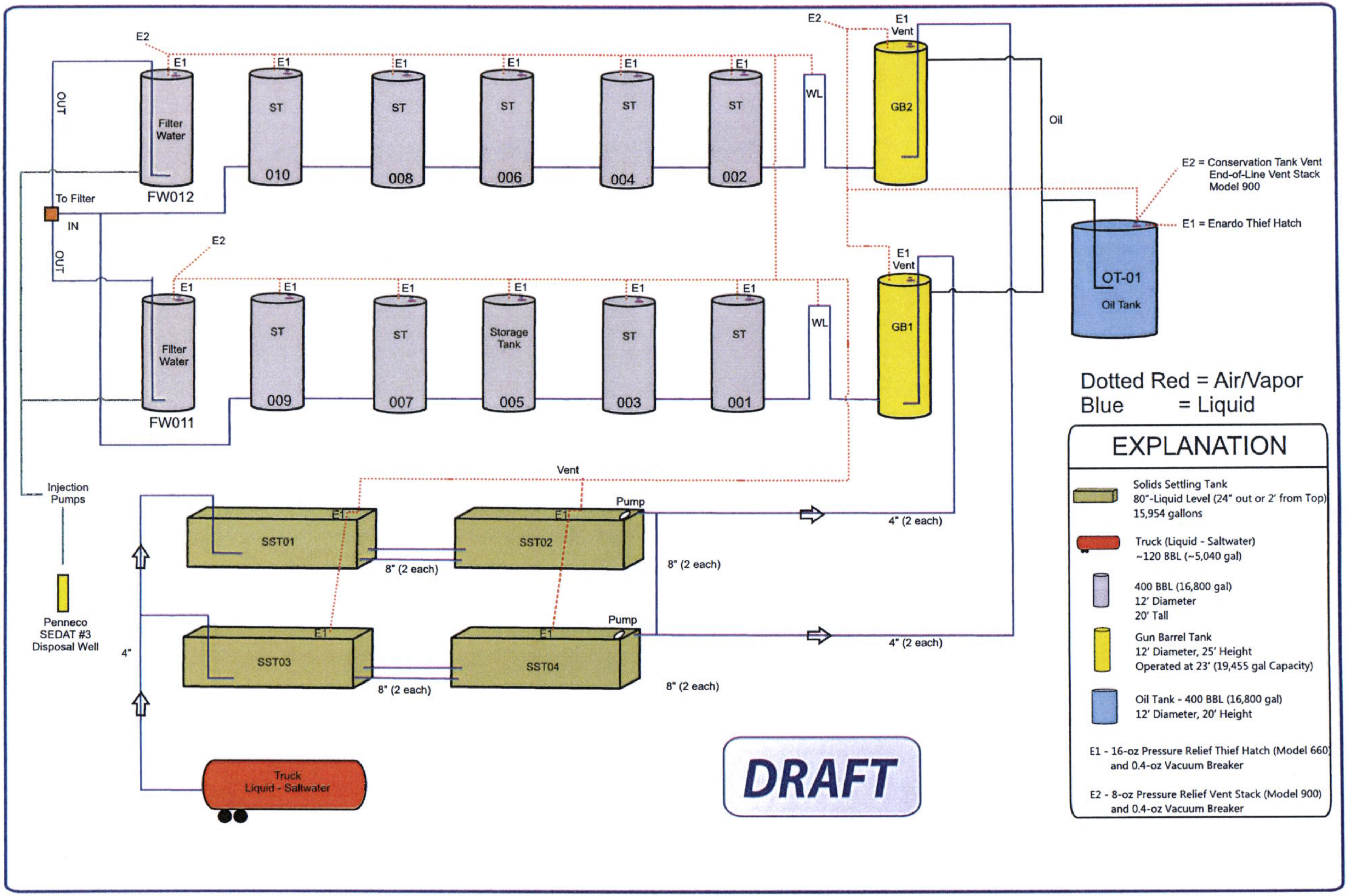
Pressure and rate monitoring will be at the well site (wellhead); both injection pressure and the pressure on the 7" by 4 ½" annulus will be monitored. The company will also conduct quarterly mechanical integrity testing as required by Pennsylvania Oil and Gas regulations. Pressure will be measured by use of a continuously recording pressure gage and the injection rate by a continuously recording flow meter. Results will be reported to the EPA as required by the injection permit or according to EPA guidelines, but not less than annually.

The specific gravity of each truck load will be measured to ensure the specific gravity of the fluid to be injected does not exceed the allowed value.

Injection fluids will be sampled and analyzed quarterly with the sample taken at the injection site (wellhead). The results will be reported as required by the permit or according to EPA guidelines.

The company will also be prepared to conduct any other monitoring or sampling as required by the permit.

9-6-2016



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CLIENT	PROJECT DESCRIPTION	FIGURE 1
Penneco Environmental Solutions LLC	**SEDAT #3 Salt Water Disposal Well Surface Facility**	Process Flow Diagram

PENN-000141

Titanium Environmental Services, LLC
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September 28, 2016

Mr. Marc Jacobs
Penneco Environmental Solutions, LLC
6608 Route 22
Delmont, Pa 15626-2408

RE: Proposal for a Surface Facility for your proposed Sedat #3 SWD

Dear Mr. Jacobs,

Titanium Environmental Services, LLC (TES) is pleased to present the draft drawings and process flow for Penneco Environmental Solutions, LLC (PES) Sedat #3 Salt Water Disposal (SWD) well surface facility. As previously discussed, PES and TES agree that safe and environmentally sound design and operations are paramount to meeting PES's expectations for their operation.

In that vein, TES has proposed a facility that would be acceptable for Resource Conservation and Recovery Act (RCRA) waste operations. TES believes that ultimately the requirements for wells and surface facilities that manage class II waste related to exploration and production will be raised to match those presently applicable to class 1 non-hazardous well and facility operations. Some of these requirements will be very expensive or even impossible to incorporate into existing wells and surface structures. As the cost to construct the well(s) and surface equipment with the safeguards that will be regulatory mandates is not significant, if incorporated with the construction design, we recommend and have incorporated these protective components into our plans.

The entire surface facility will be built atop a multilayered secondary containment system/structure. The facility will begin with a base layer of clay, felt liner, 60 mil High Density Polyethylene (HDPE) liner, and another felt liner, perforated liquid collection pipe system covered by pea gravel, concrete containment floor and walls. The edge of the HDPE liner will be folded up against the containment walls to keep rainwater from entering the system. The liquid collection system piping will be extended from under the containment to allow for inspection or liquid (condensation) removal and as the last mechanical containment to intercept a leak.

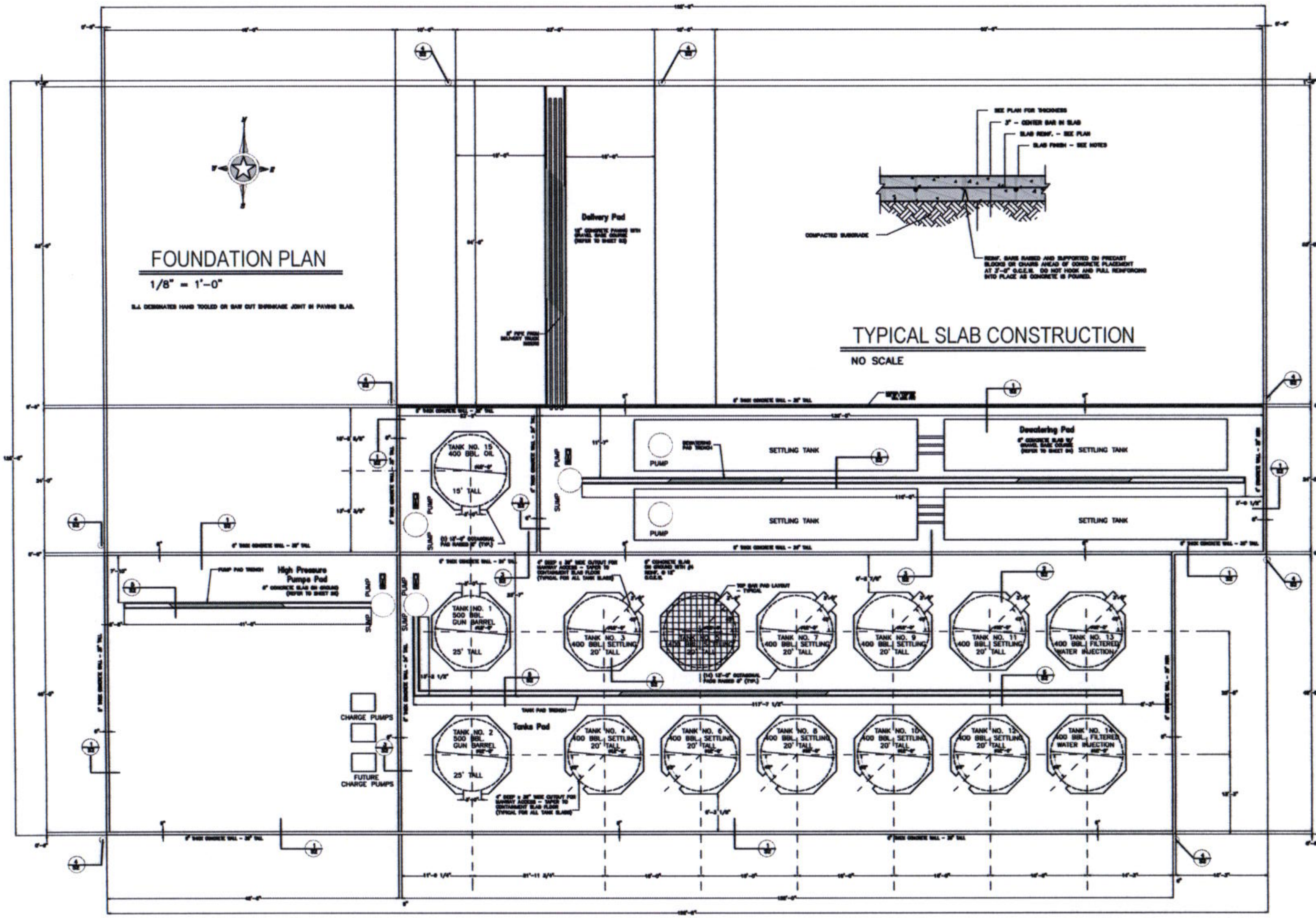
Notice the truck unloading pad is built to prevent rainwater run on and all rainwater or truck leakage will be collected by the truck bay collection system which empties into the solids settling tank containment which can hold all the trucks that could be in the truck bays. All sump pumps automatically empty the sumps without human intervention. If the receiving tanks can't hold the trucks trying to unload (Level transmitters) the system closes all unloading lines until there is sufficient room to continue unloading. Further if there is insufficient room in the storage tanks, the system will not let the transfer pumps move fluid from the receiving/settling tanks to the storage tanks. Thus the unloading valves won't open nor will the transfer pumps transfer fluid into tanks that are already full. The water filtering pumps will transfer filtered water into the pre-injection tanks (Filtered Water) as long as the fluid level in the filtered water tanks does not exceed the upper limit established by the operator. The injection pumps will inject water into the well as long as there is sufficient filtered water to inject and all control parameters for the well are within preset value ranges.

All liquid unloading at the facility will enter tanks that are equipped with internal piping that allows fluids to be introduced under the liquid level in the tanks (submerged loading). Submerged loading is a recognized method of reducing emissions. All liquid transfer systems are connected together by a vent header to vapor balance the exchange between the receiving and transferring tanks. All used filters and tank cleanout solids are collected and disposed of to a permitted facility.

TES suggest Standard Operating Procedures (SOP) and daily facility inspections which would not be addendums to the Permit as they will have to be modified over time and could be "Permit Modifications" if they were addendums. All waste should have an approved profile to be accepted at the facility. All trucks would be unloaded through Mass Flow Meters recording density and volume. Likewise Mass Flow Meters would be used for injection measurement for reporting of density and volume.

Simplicity in design with many passive controls that don't require human attention or maintenance is TES's design goal. The design also reduces the number of incidents/accidents caused by operator error or inattention. Tanks that might fail, can be valved out of operation and bypassed with no effect on the operation. There is one transfer pump (plus one standby), one filter pump (plus one standby), one charge pump (plus one standby) and one injection pump (plus one standby). Three unloading bays and only one or two required. Since the PLC logic instructs the continuous filtration and injection of water, the only operator interaction is changing the filters when required and making sure inbound trucks/loads are approved into the facility and then enabling the specific unloading valve. All sump pumps activate automatically and are freeze protected as is the transfer pump. All containments have a fluid level alarm to detect leaks and have reduced height walls between them that together can contain 110% of any of the tank systems plus a twenty-five year 24 hour rainfall event.

If you have any questions about this letter or any of the drawings or process flow diagram please call TES' Special Projects Manager, Lynn Goldston – 903-235-1477.



GENERAL NOTES

GENERAL:

THE DESIGN PROFESSIONAL WAIVES ANY AND ALL RESPONSIBILITY AND LIABILITY FOR PROBLEMS WHICH ARISE FROM FAILURE TO FOLLOW THESE PLANS, SPECIFICATIONS AND THE DESIGN INTENT THEY CONVEY, OR FOR PROBLEMS WHICH ARISE FROM OTHERS' FAILURE TO OBTAIN AND/OR FOLLOW THE DESIGN PROFESSIONAL'S GUIDANCE WITH RESPECT TO ANY ERRORS, OMISSIONS, INCONSISTENCIES, AMBIGUITIES OR CONFLICTS WHICH ARE ALLEGED.

ALL WORK TO CONFORM TO 2011 OHIO BUILDING CODE, 2011 OHIO MECHANICAL CODE AND 2011 OHIO PLUMBING CODE.

CONTACT PROPER AUTHORITIES TO LOCATE EXISTING UNDERGROUND UTILITIES PRIOR TO EXCAVATION FOR FOOTINGS.

EARTHWORK: ALL EARTHWORK, INCLUDING EXCAVATIONS, FILLS, PROOFROLLING, TESTING, COMPACTION, ETC., TO BE PERFORMED IN ACCORDANCE WITH RECOMMENDATIONS CONTAINED IN THE SOILS REPORT AND/OR THE SPECIFICATIONS. ALL EARTHWORK SHALL BE INSPECTED FOR CONFORMANCE WITH THE SOILS REPORT AND CONTRACT DOCUMENTS.

CONTROLLED COMPACTED FILL: ALL SOFT MATERIAL THAT CANNONT BE COMPACTED AND MATERIAL THAT CANNOT SUPPORT THE REQUIRED THICKNESS OF CONTROLLED COMPACTED FILL AND/OR FOUNDATION LOADS WITHOUT DETRIMENTAL SETTLEMENT, MUST BE REMOVED PRIOR TO PROOFROLLING.

AFTER STRIPPING AND GENERAL EXCAVATIONS, THE ENTIRE BUILDING AREA SHALL BE PROOFROLLED WITH A PNEUMATIC TIRED ROLLER OR EARTHMOVING UNIT HEAVY ENOUGH TO DETECT CAVITIES, SINKHOLES, SOFT SPOTS OR IRREGULARITIES IN THE SUBGRADE. TESTING LABORATORY REPRESENTATIVE TO OBSERVE AND MAKE RECCOMENDATIONS DURING PROOFROLLING OPERATIONS. TRACK MOUNTED EQUIPMENT SUCH AS BULLDOZERS, FRONT END LOADERS, ETC. ARE NOT TO BE USED FOR PROOFROLLING OR SOIL COMPACTION.

AFTER PROOFROLLING AND CORRECTIVE MEASURES AS REQUIRED BY THE TESTING REPRESENTATIVE ARE ACCOMPLISHED, GENERAL FILL SHALL BE PLACED PRIOR TO CONSTRUCTION OF FOUNDATIONS. ALL FILL WITHING 5'-0" BEYOND THE BUILDING LINES SHALL BE CONTROLLED, PLACED AND COMPACTED TO 95% STANDARD PROCTOR DENSITY (ASTM D698). FILL SHALL BE PLACED IN LAYERS OF APPROPRIATE THICKNESSES REQUIRED BY THE NATURE OF THE SOIL OR AS DIRECTED SO THAT THE MATERIAL WILL BE COMPACTED THEROUGHOUT THE ENTIRE LAYER. SPECIAL CARE SHALL BE TAKEN TO ADEQUATELY COMPACT FILL AND BACKFILL IN AREAS EXCAVTED FOR PIPE TRENCHES, FOOTINGS AND FOUNDATION WALLS. ALL FILL SHALL BE SELECT MATERIAL WITH A LIQUID LIMIT LESS THAN 30 AND A PLASTICITY INDEX (PI(NO GREATER THAN 15.

FOUNDATIONS: FOUNDATION WORK HAS BEEN DESIGNED AND ELEVATIONS ESTABLISHED ON THE BASIS OF THE GEOTECHNICAL REPORT WRITTEN FOR THE USE OF THE OWNER, ARCHITECT AND ENGINEER. FOOTINGS HAVE BEEN DESIGNED TO BEAR ON UNDISTURBED RESIDUAL SOILS OR COMPACTED STRUCTURAL FILL CAPABLE OF SAFELY SUPPORTING A NET PRESSURE OF 2,000 PSF. IF FOUNDATION CONDITIONS PROVE UNACCEPTABLE AT ELEVATIONS SHOWN, FOOTINGS SHALL BE CARRIED DEEPER OR OTHER REDESIGN OF FOUNDATIONS WILL BE REQUIRED AT THE DIRECTION OF THE ARCHITECT/ENGINEER.

CONCRETE: MINIMUM 28 DAY CYLINDER STRENGTH OF 3,000 PSI AND MAXIMUM SLUMP OF 4" PRIOR TO ADDITION OF SUPERPLASTICIZERS. REINFORCING STEEL ASTM A615, GRADE 60. LAPS 32 DIAMETER UNLESS NOTED. ALL BARS SECURELY HELD IN ACCURATE POSITION BY SUITABLE ACCESSORIES, TIE BARS, SUPPORT BARS, ETC. EXCEOT AS NOTED OR SPECIFIED. ALL CONCRETE WORK TO COMPLY WITH ACI BUILDING CODE (ACI-318), DETAILING MANUAL (ACI-SP66) AND ACI SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS (ACI-301), STANDARD TOLERANCES FOR CONCRETE CONSTRUCTION AND MATERIALS (ACI-117). HOT WEATHER CONCRETE TO COMPLY WITH ACI-305. COLD WEATHER CONCRETE TO COMPLY WITH ACI-306.1. PROVIDE ADEQUATE BARRIERS TO PROTECT CONCRETE FROM DRYING PREMATURELY.

SLAB ON GROUND: FLOAT FINISH THEN BROOM FINISH EXTERIOR SLABS.

ALL CONCRETE SHALL BE CURED, EITHER BY APPLICATION OF AN APPROVED CURING COMPOUND OR BY WATER CURING FOR 7 DAYS MINIMUM. CURING COMPOUND SHALL BE CLEAR STYRENE ACRYLATE TYPE, 30% SOLIDS CONTENT MINIMUM. SUBMIT MANUFACTURERS LITERATURE MEETING THESE REQUREMENTS FOR APPROVAL. WATER CURING SHALL CONSIST OF PONDING, BURLAP, CONTINUOUS SPRAYING OR COMPLETE POLYETHYLENE COVER. THOROUGHLY SOAK CONCRETE WITH ADDITIONAL WATER PRIOR TO COVERING WITH POLYETHYLENE AND SEAL ALL JOINTS WITH TAPE. REPAIR ANY TEARS AND MAINTAIN A MOIST CURING CONDITION FOR ENTIRE CURING PERIOD.

EMPLOY A TESTING AGENCY. ACCEPTABLE TO THE OWNER, WHO WILL PERFORM INSPECTIONS AND TESTING OF CONCRETE. MAKE ONE SET OF FOUR CONCRETE CYLINDERS FROM EACH 50 CUBIC YARDS WITH A MINIMUM OF ONE SET FROM EACH DAYS OPERATIONS FOR EACH CLASS OF CONCRETE. TEST SPECIMENS SHALL BE MADE IN ACCORDANCE WITH ASTM C31. MAKE ONE SLUMP TEST ON THE CONCRETE AT THE BEGINNING OF THE POUR AND FOR EACH SET OF CYLINDERS TAKEN IN ACCORDANCE WITH ASTM C143. MAKE ONE ENTRAINED ARE TEST WITH EACH SLUMP TEST IN ACCORDANCE WITH ASTM SPECIFICATION FOR ALL AIR-ENTRAINED CONCRETE. CYLINDER SHALL BE TESTED IN ACCORDANCE WITH ASTM C39, TWO CYLINDERS AT 7 DAYS AND TWO AT 28 DAYS OLD. THE TESTING AGENCY SHALL SUBMIT, IN A TIMELY MANNER, THE RESULTS OF THEIR INSPECTIONS AND TESTS TO THE ARCHITECT/ENGINEER FOR REVIEW.

NO CALCIUM CHLORIDE OR ADMIXTURE CONTAINING CHLORIDES SHALL BE USED IN ANY CONCRETE WITHOUT SPECIFIC APPROVAL BY THE ARCHITECT/ENGINEER.

PROVIDE CORNER BARS IN EXTERIOR CORNERS OF GRADE BEAMS AND WALLS, TO MATCH HORIZONTAL REINFORCING.

THOROUGHLY COMPACT ALL SUBGRADE MATERIAL PRIOR TO PLACING CRUSHED STONE. REMOVE ANY LOOSE MATERIAL AND DEBRIS THAT CANNOT BE ADEQUATELY COMPACTED.

REVISIONS

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LONGVIEW, TEXAS 75602
(903)660-1020 FAX (903)668-4199

DRAFT

PROPOSED FOUNDATION PLAN

PENNECO ENVIRONMENTAL SOLUTIONS, LLC

DATE 7/24/16
SCALE AS NOTED
SHEET NO. S1

PENN-000144