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Monitoring a Passive Seismic Network at Neal Hot Springs Geothermal Plant

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Abstract

The Neal Hot Springs Project, currently under construction, will produce 23 MW of geothermal electric power once online. The project is located near Vale, Oregon (approx. 90 miles northwest of Boise) and consists of about 9.6 square miles of land, which is leased by U.S. Geothermal Inc. During construction the Geosciences department at Boise State University set up a network of 11 passive seismic stations in the area to monitor seismic activity. The goal is to obtain a large collection of seismic data during construction and testing, and to continue seismic monitoring during production. The data will be used to determine natural seismic activity, if any, in the area, seismic activity directly related to testing and production, and to determine the effects of fluid flow in the subsurface. These data sets may also be useful in targeting future geothermal reservoirs within the project area.

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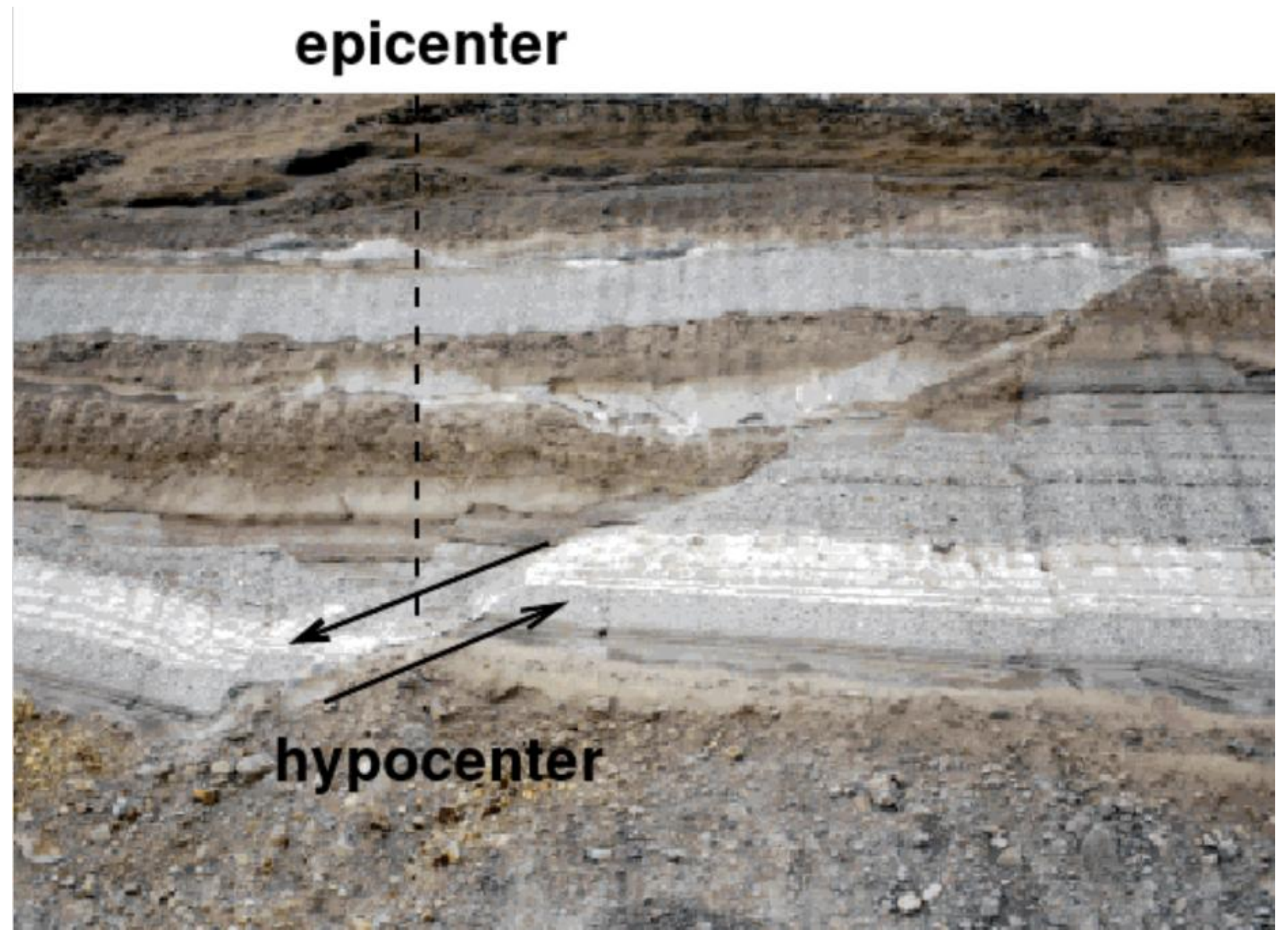
Dan Shaltry and Kasper van Wijk - Boise State University

Abstract: The Neal Hot Springs Project, currently under construction, will produce 23MW of geothermal electric power once online. The project is located near Vale Oregon (approx. 90 mile Northwest of Boise) and consists of about 9.6 square miles of land which is leased by U.S. Geothermal Inc. In May 2011 students and faculty of the BSU Geophysics Field Camp set up a network of 11 passive seismic stations in the area to monitor seismic activity. The goal is to obtain a large collection of seismic data during construction and testing, and to continue seismic monitoring during production. The data sets will be used to establish a datum of natural seismicity, if any in the area, to identify seismic activity directly related to testing and production, and to determine the effects of fluid flow in the subsurface. These data sets may also be useful in locating future geothermal targets within the project area.

I. Earthquakes Introduction

- Earthquakes result when displacement of a rock volume occurs along a fault in the subsurface of the Earth.
- The figure to the right shows a normal fault in which the rock units on the upper left (hanging wall) have slipped with respect to the rock units on the lower right (foot wall).
- If this were in the subsurface the initial point of failure would be the hypocenter, and its projection onto the surface would be the epicenter.



II. P and S Waves: Locating Earthquakes

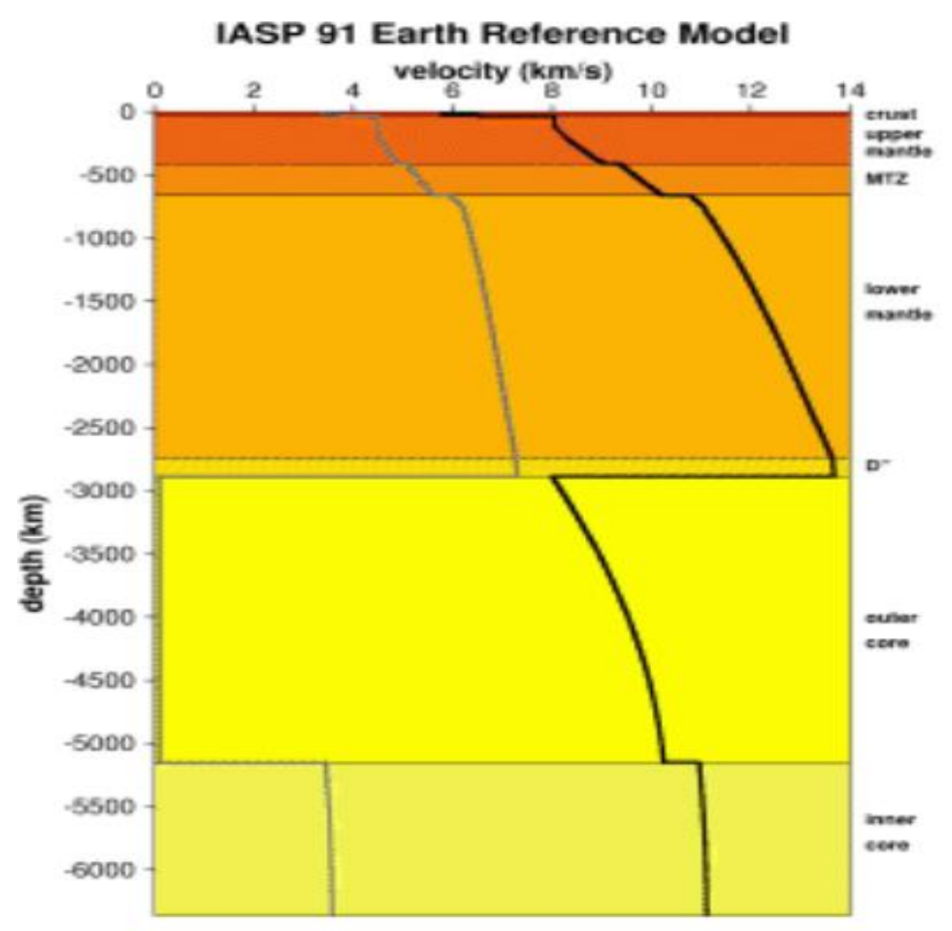


Figure 1: Image from http://civilengineergroup.com

- Earthquakes release energy in the form of waves. P-waves (primary/ pressure) , and S-waves (secondary / shear) waves radiate outward from the hypocenter
- P-waves travel faster than S-waves through the earth, so P-waves are the first to arrive at a seismometer.
- Waves travel at different velocities depending on the type of rock they are travelling through.
- The Earth Reference Model, left, shows average P- and S-wave velocities through known portions of the Earth; inner & outer core, lower mantle, Mantle Transition Zone (MTZ), upper mantle, and crust.

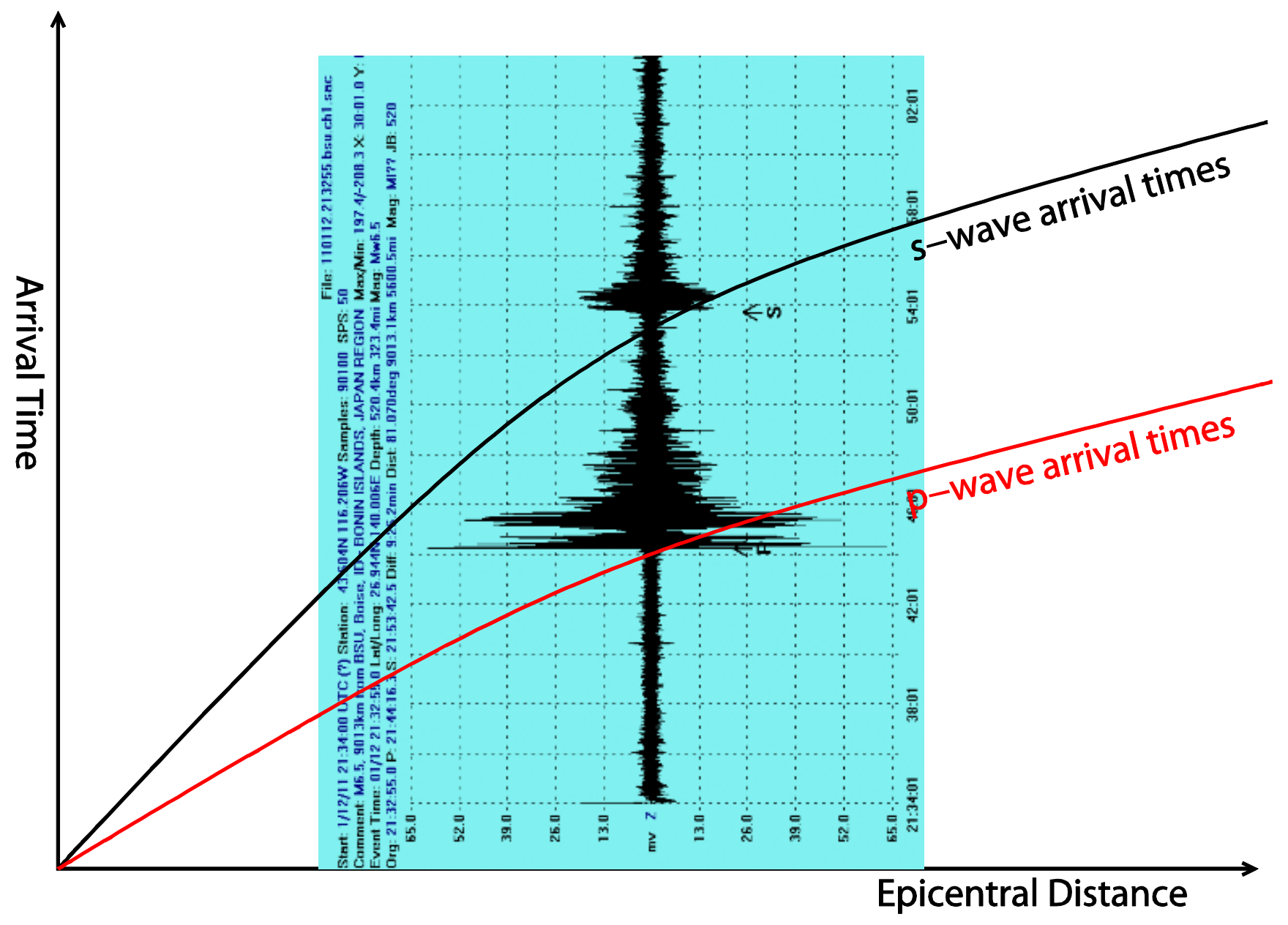


Figure 2: Earthquake recorded at BSU fitted to the travel time vs. distance graph.

- Having measured P and S-wave arrival times, the epicentral distance can be found by fitting the seismic graph to the theoretical arrival time curves.
- Notice the 'P' and 'S' arrows on the graph indicating when each wave arrived.

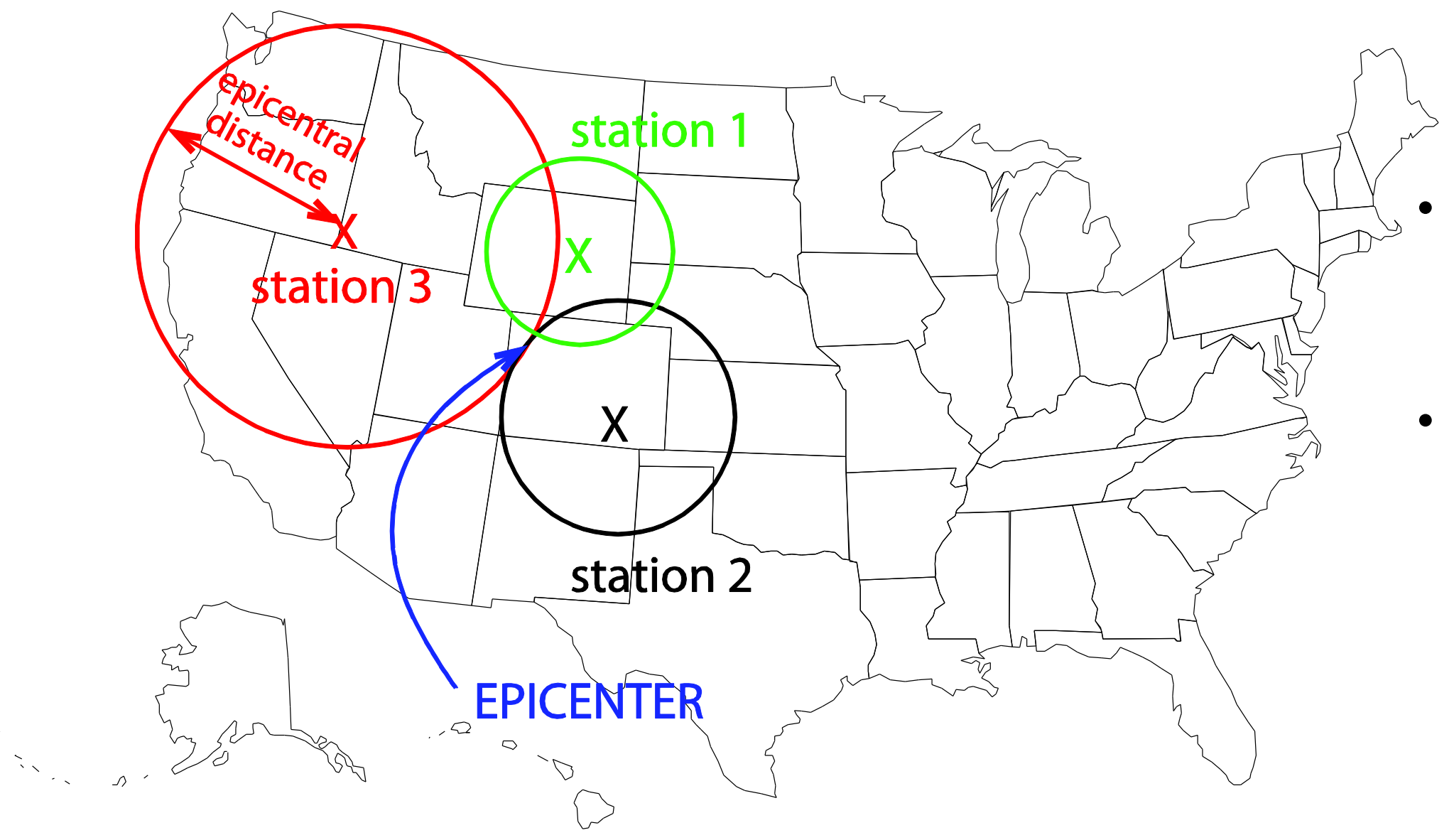


Figure 3: The epicentral distance is proportional to the time between the EQ and the wave's arrival at each seismometer station.

- The location of an earthquake epicenter can be found with three or more seismic stations.
- The point where all epicentral distances meet is the epicenter.

III. Neal Hot Springs

The map below shows the positions of each seismometer station and the basic geological structure of the Neal Project area. "The hot springs are in a region of complex and intersecting fault trends associated with two major extensional events, the Oregon-Idaho Graben and the Western Snake River Plain. The intersection of these two fault systems, coupled with high geothermal gradients from thin continental crust produce pathways for surface water and deep geothermal water interactions at Neal Hot Springs. New geologic mapping, geochemistry and several boreholes in the area suggest a steeply dipping 60^0 normal fault dips to the southwest to form a half-Graben basin. This basin-bounding fault serves as the primary conduit for deep water circulation" (Colwell,2012).

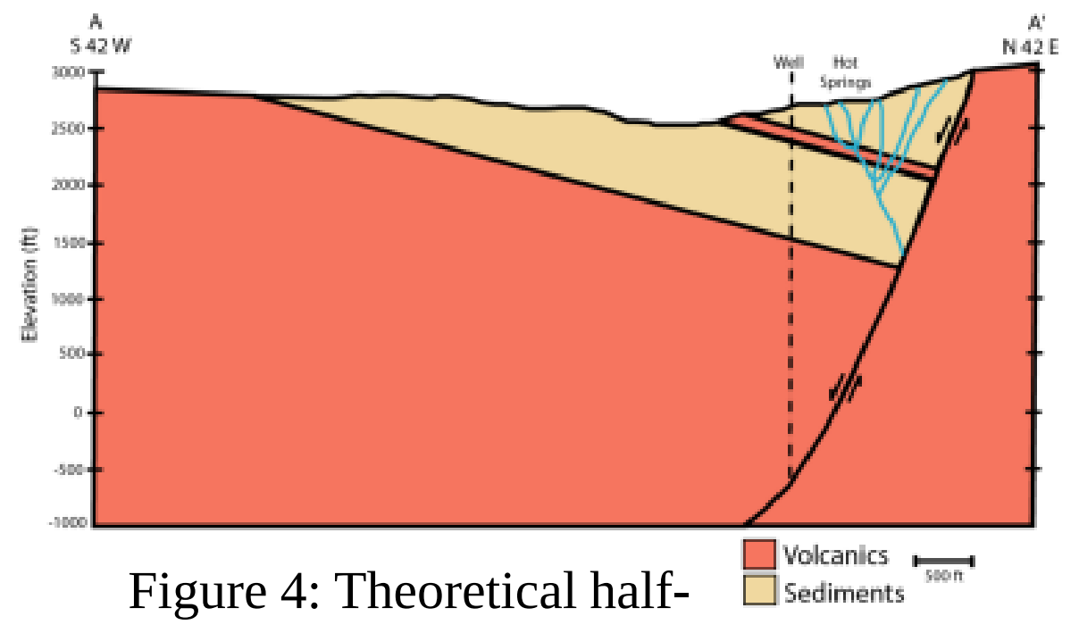


Figure 4: Theoretical half-Graben formation at Neal.

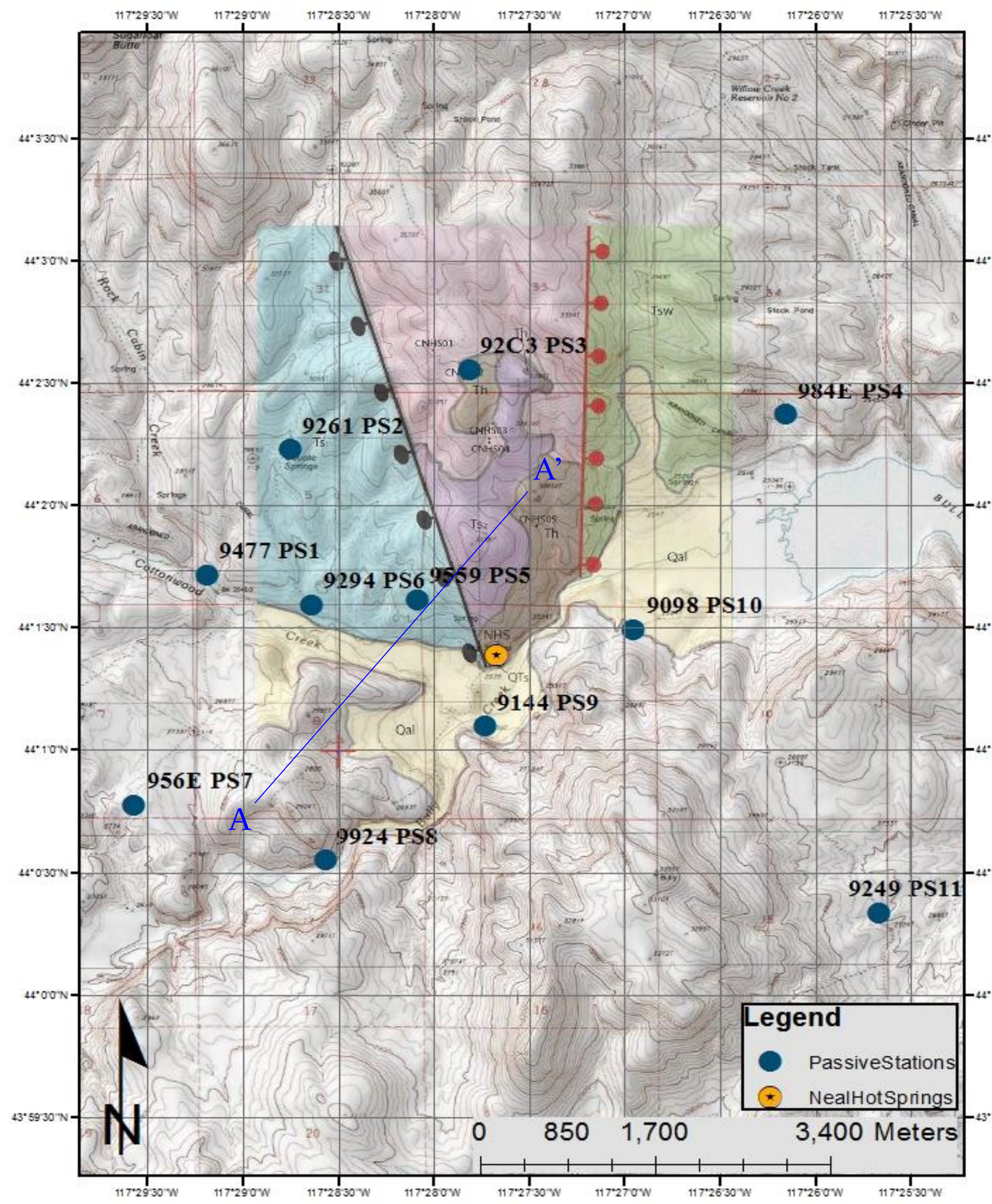
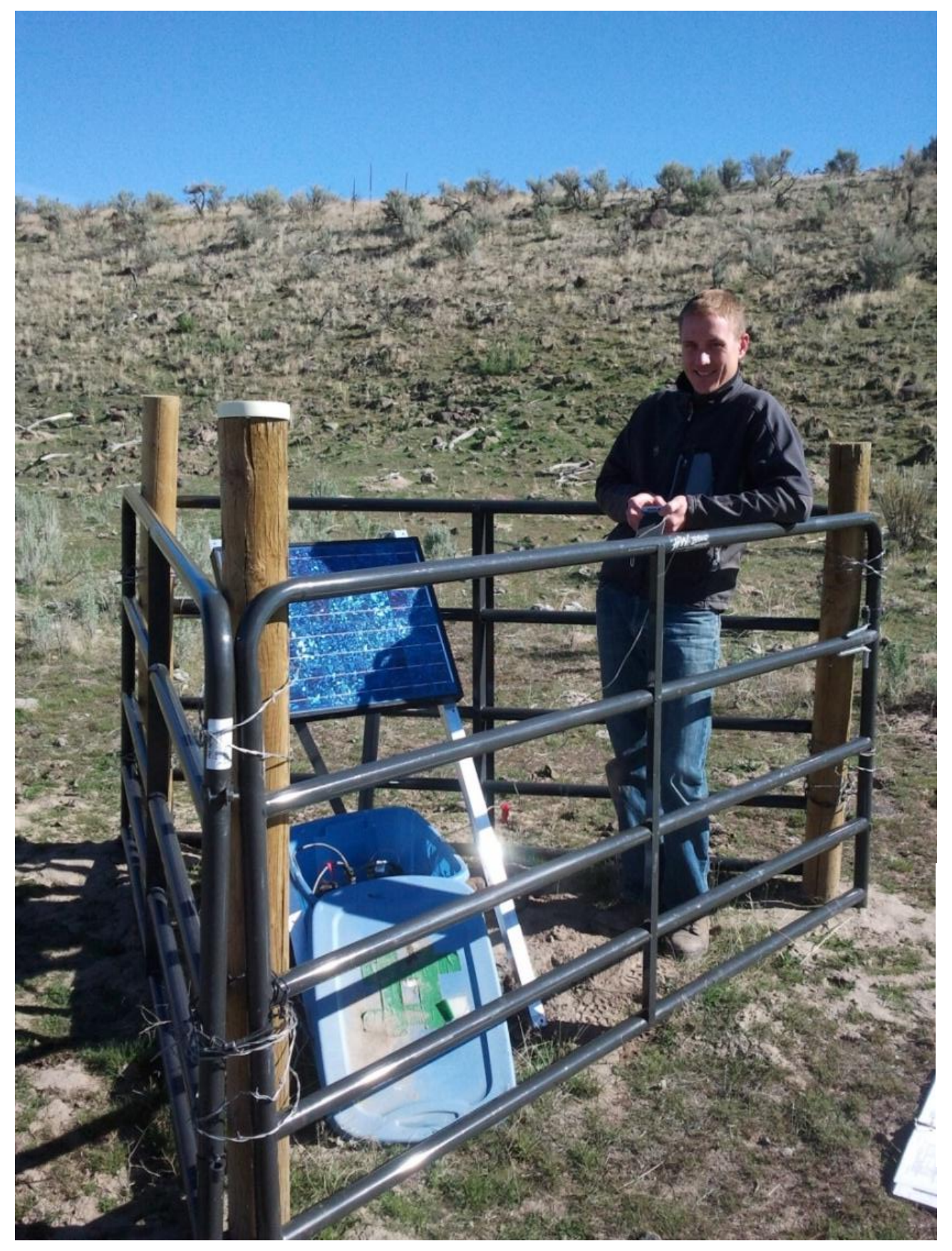


Figure 5: Map showing station locations and geology of the study site (Colwell, 2012).



- Each station requires 5 essential components
- Most important is a GPS clock, all stations must agree what time it is!
- The sensor "feels" the seismic waves in 3 directions (up, down, & side to side) as they arrive .
- The Data Acquisition System records data from the clock and the sensor onto flash drives.
- A solar panel and battery powers the system.
- The fence keeps the cows out.

GPS Clock

Seismic Sensor

Data Acquisition System

IV. Data Processing

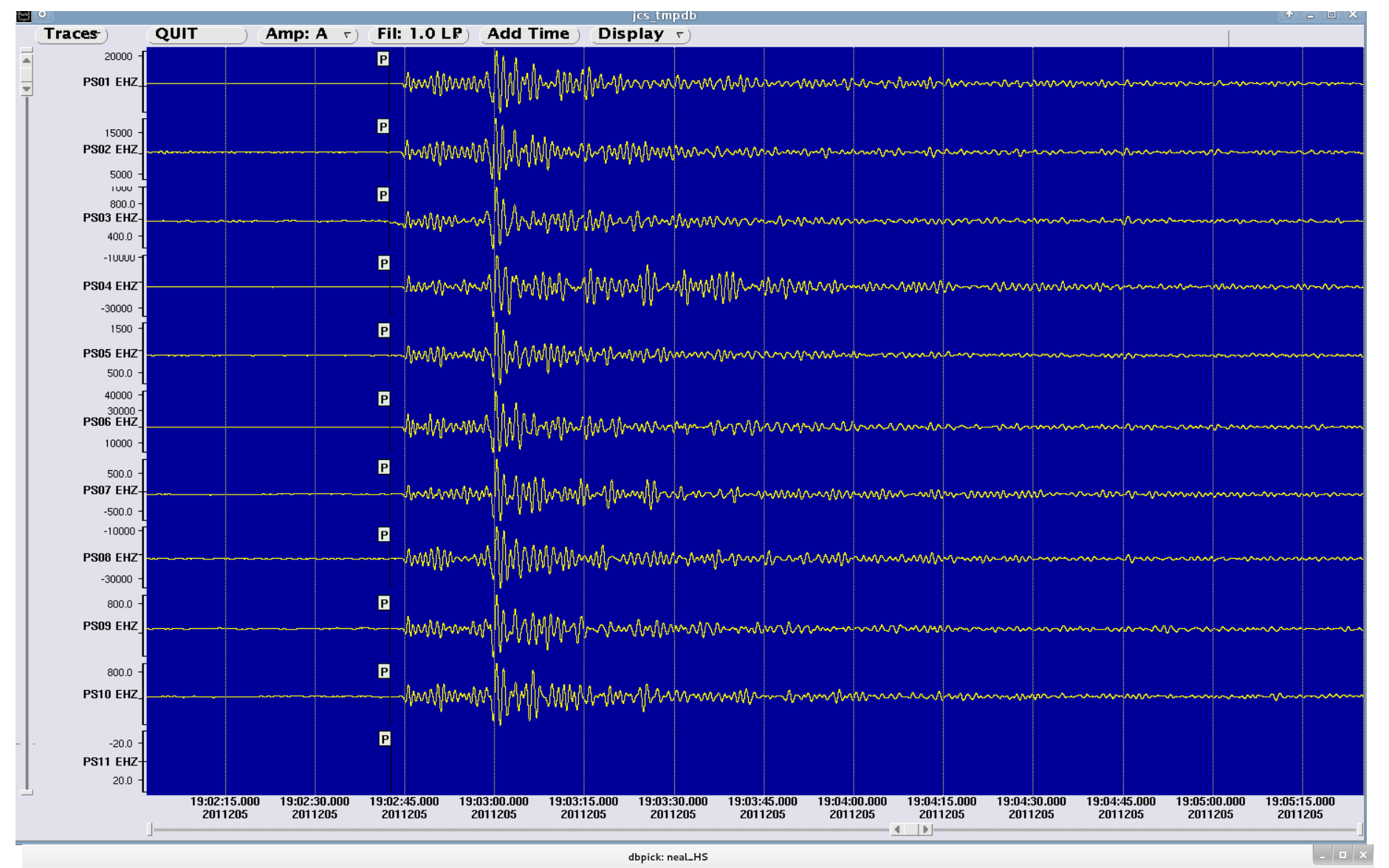
All global events of magnitude >= 5

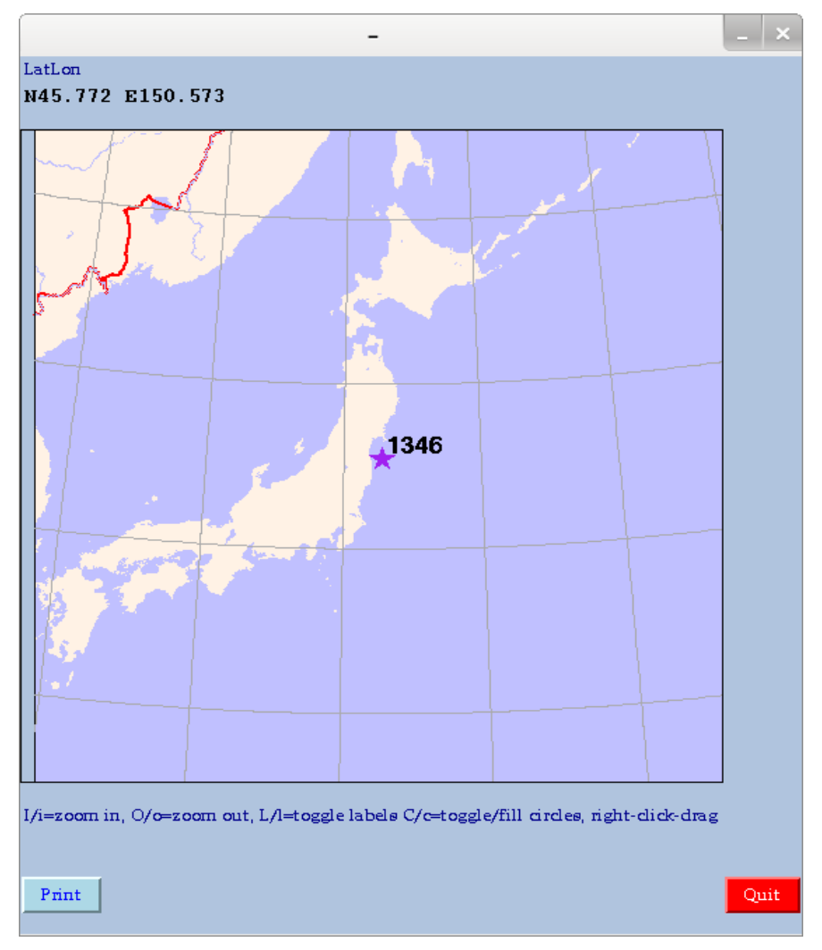
Box coordinates: 51N, 33S, -106E, -128W, events of magnitude >= 3

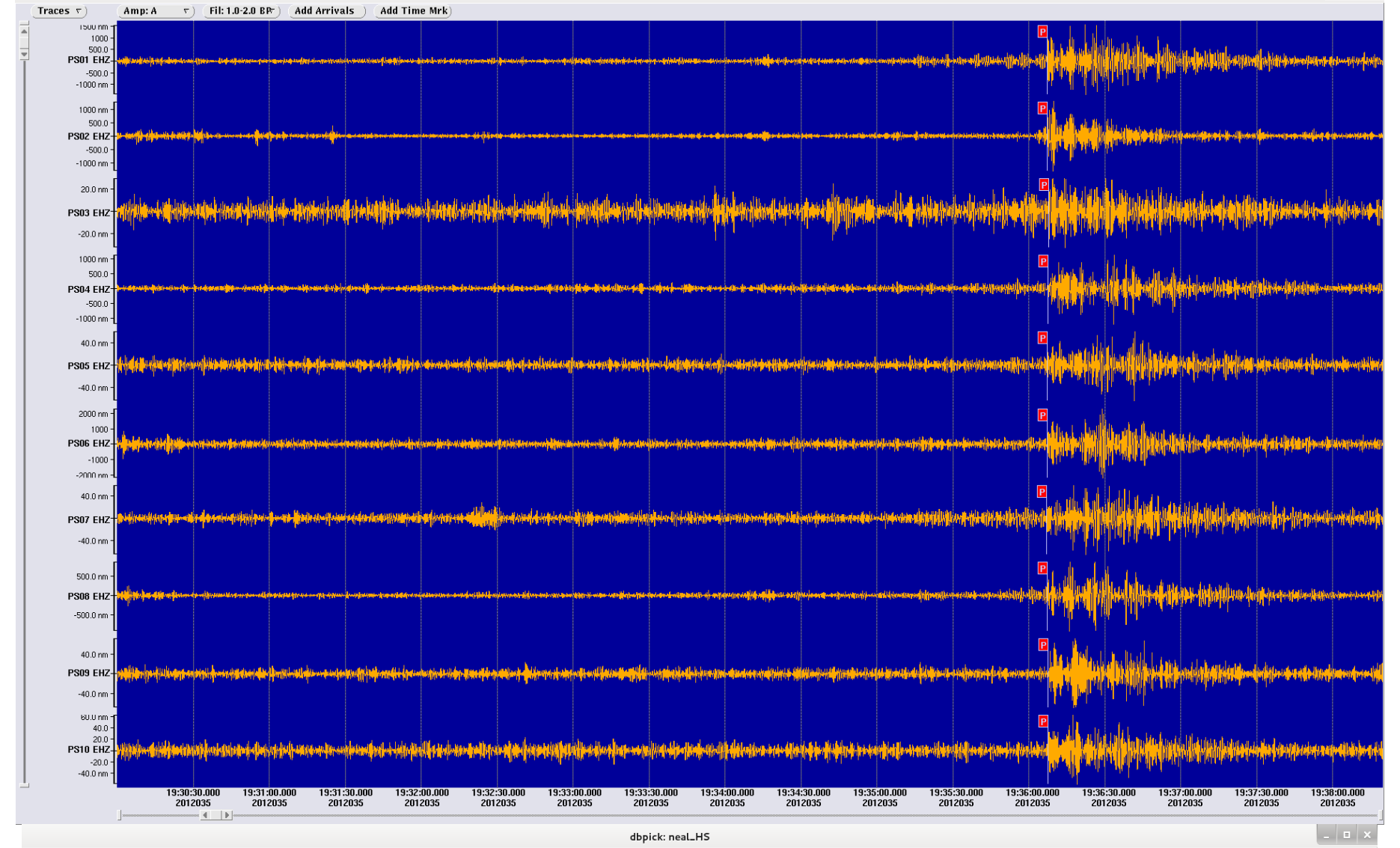
Box coordinates: 48N, 42S, -111E, -120W, events of magnitude >= 1

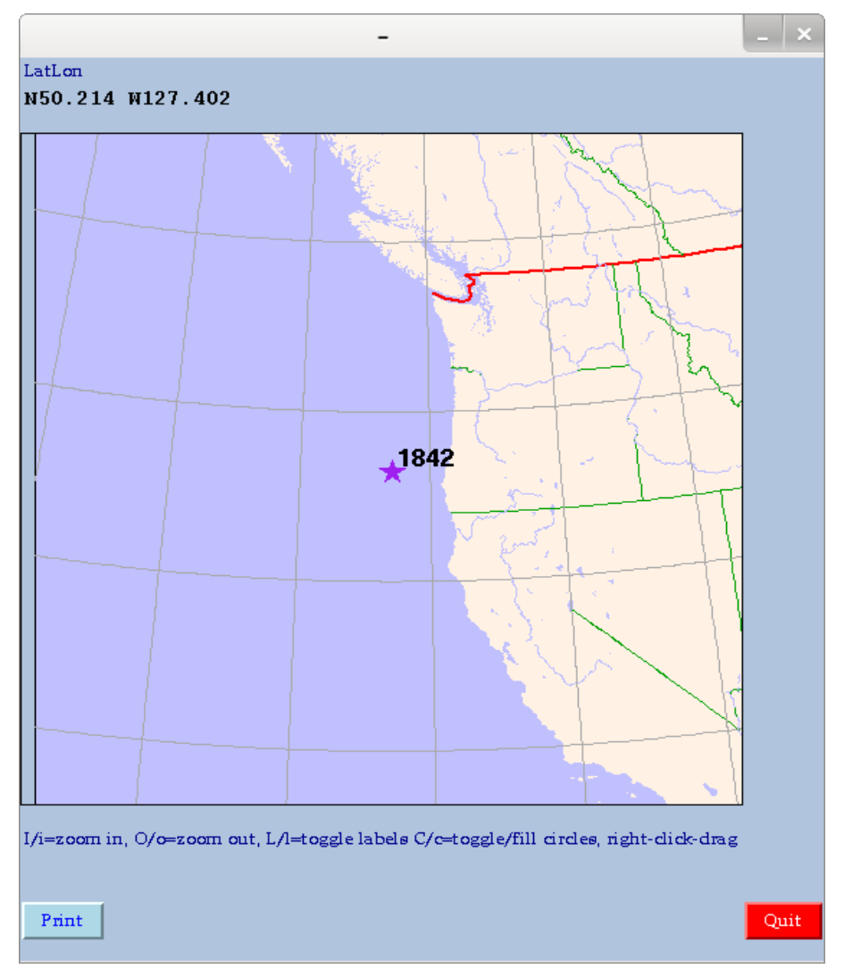
All data that we gather must be processed and sent to IRIS's (Incorporated Research Institutions for Seismology) database in Washington, according to their formatting requirements. Once we have done that we use IRIS's Seismiquery tool to generate a data file of seismic events within the three areas shown above (global, regional, then local). We use this file to generate markers in our data so we can filter out events not associated with the Neal area.

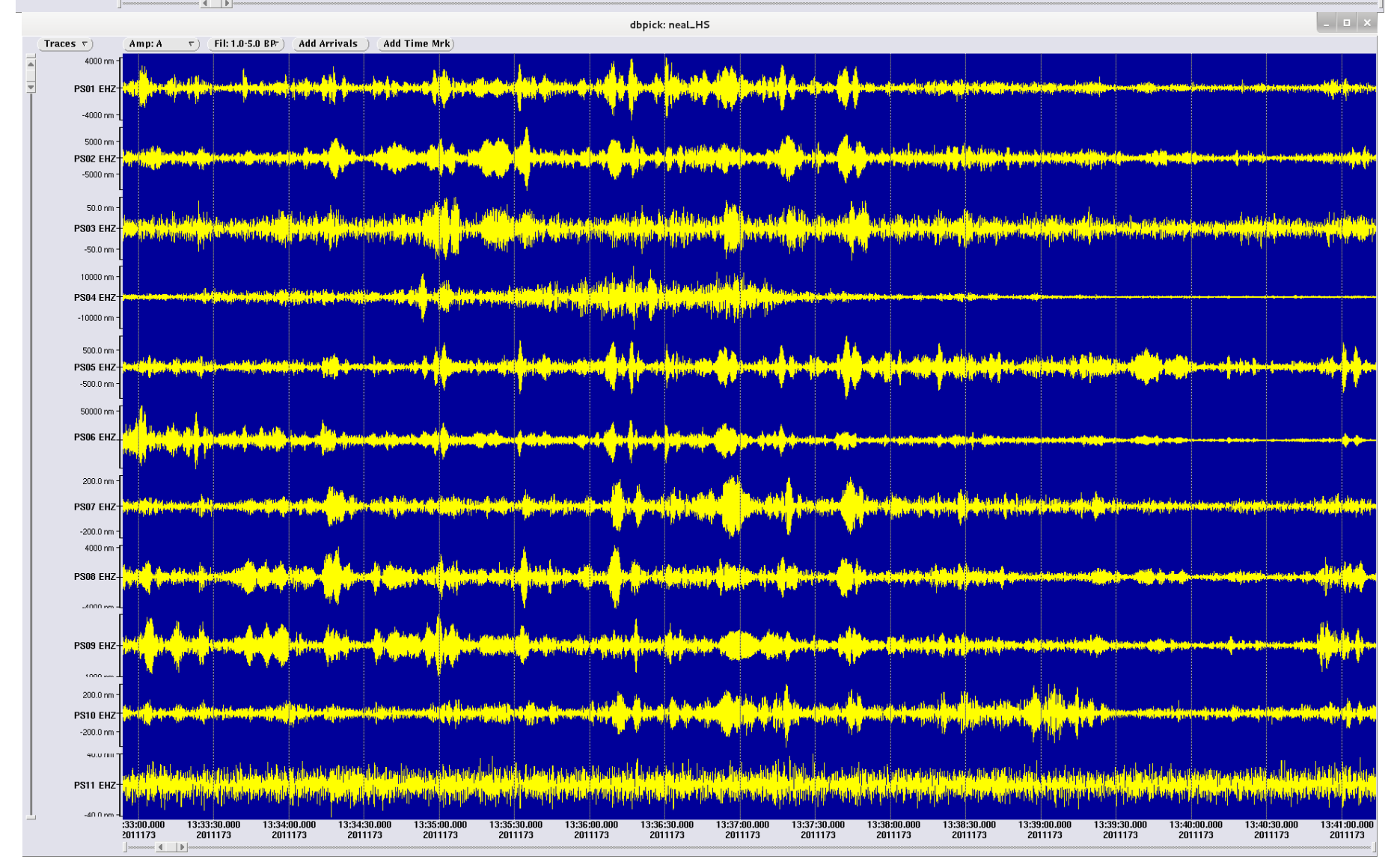
V. Examples From Our Data











The graphs on the left show the amplitude of seismic waves in nano meters (10^{-9}m, y-axis) with respect to time (in seconds, x-axis). Each line or "trace" represents the corresponding seismic station. The locations of these events are indicated on the corresponding maps

- The top graph shows traces from an aftershock of the Honshu Earthquake near Japan. This aftershock took place on June 24, 2011.
- The middle graph shows an earthquake event off the coast of Oregon on Feb. 4, 2012.
- The bottom graph shows wiggles from within the Neal area. We have determined that these events are associated with "noise" from construction and testing. We will continue to monitor the area after production begins, and expect to see events like these associated with fluid movement.

VI. Acknowledgements/References

Colwell, Clinton et al., 2012, Integrated Geophysical Exploration of a Known Geothermal Resource: Neal Hot Springs.

Students & faculty of BSU Geophysics Field Camp, 2011.