[AV]Use of Microseismic in Monitoring Hydraulic Fractures in the Bakken Formation, North Dakota, USA*

Gary Forrest[1], Tom Olsen[1], Aleksey Kazantsev[1], Ernest Gomez[1], Tim Dombrowski[1], and Wayne Rowe[2]

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[1]Schlumberger Data and Consulting Services, Greenwood Village, CO (egomez@denver.oilfield.slb.com)
[2]Schlumberger Water Management Services, Denver, CO

Abstract

The Mississippian-Devonian Bakken Formation is a relatively tight mixed carbonate – clastics sequence in the Williston Basin of North Dakota. Although production can exceed 1000 BOPD, hydraulic fracturing is necessary to induce economic production. Until recently a great degree of uncertainty has existed regarding how the Bakken behaves during fracturing. In late 2007 seven (7) operators along with Schlumberger created a consortium that used the best available technologies to optimize understanding of certain geologic, drilling, and completion principles that affect production. As part of this, three (3) horizontal wells (each 4000 feet in length) were drilled in an east-west direction, 1500 feet apart into the Middle Bakken Member. An array of 15 triaxial geophones, with 100 feet between each sensor set, was placed into the middle lateral (Nesson State 42X-36) to monitor the microseismic activity during the hydraulic fracturing of the two (2) outside wells. Different hydraulic fracturing methods were tried in each of the wells, ranging from a single treatment in the northern lateral (Nesson State 41X-36) to a six (6) staged treatment with swell packers in the southern lateral (Nesson State 44X-36). The microseismic events were integrated with the geologic understanding of the area, radioactive and chemical tracers, and reservoir simulation to develop a robust interpretation of effectiveness of the hydraulic fracture treatments.

Reference

LeFever, Julie, 2005, Oil production from the Bakken Formation: A short history: North Dakota Geological Survey newsletter, v. 32, no. 1, p. 5-10.

Microseismic Monitoring of Hydraulic Fractures: Bakken Formation, North Dakota

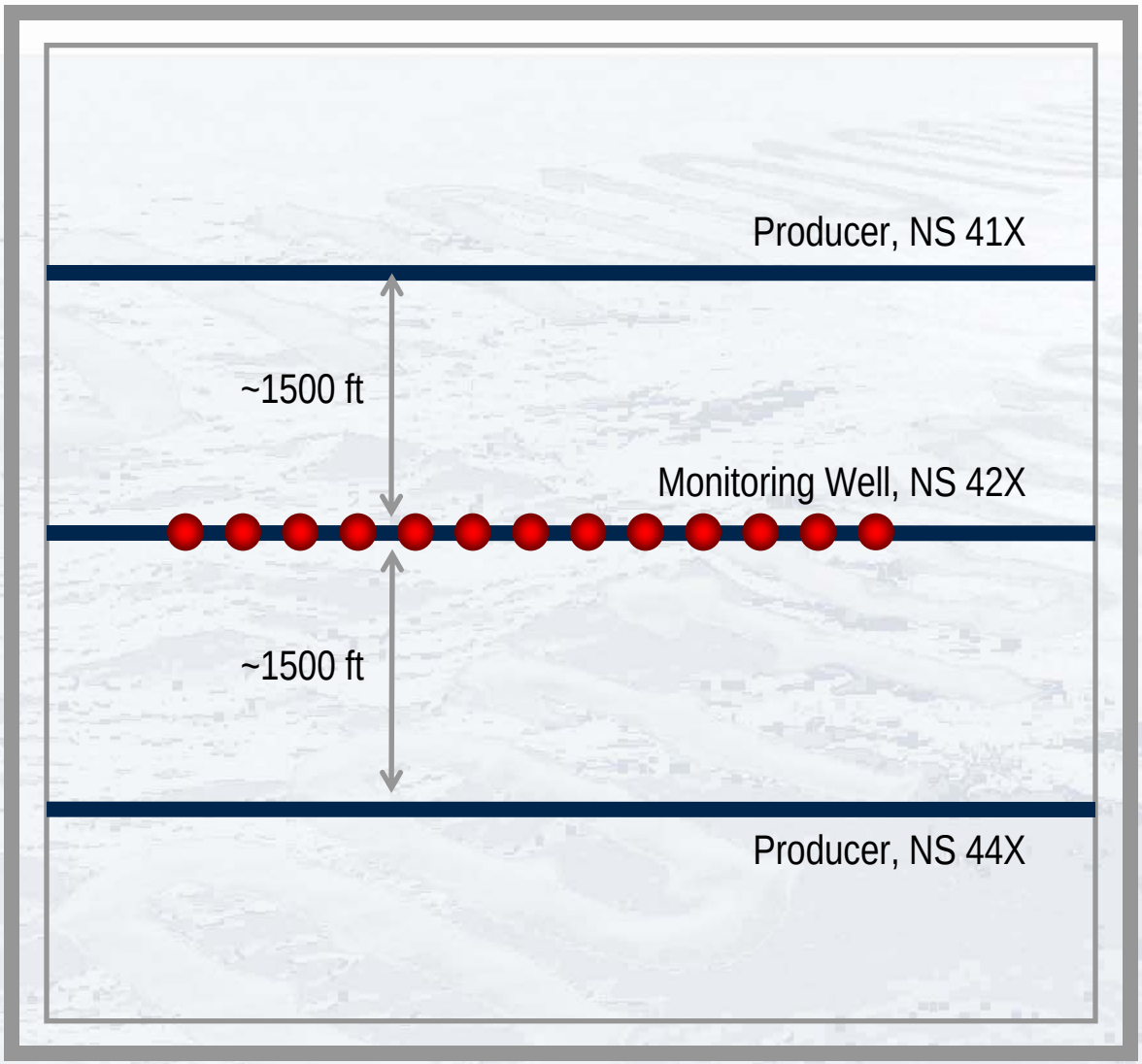
Gary Forrest, Tom Olsen, Aleksey Kazantsev, Ernest Gomez, Tim Dombrowski, Wayne Rowe, Alex Perakis

Schlumberger Data and Consulting Services, Denver

Denver AAPG, June 9, 2009

Schlumberger

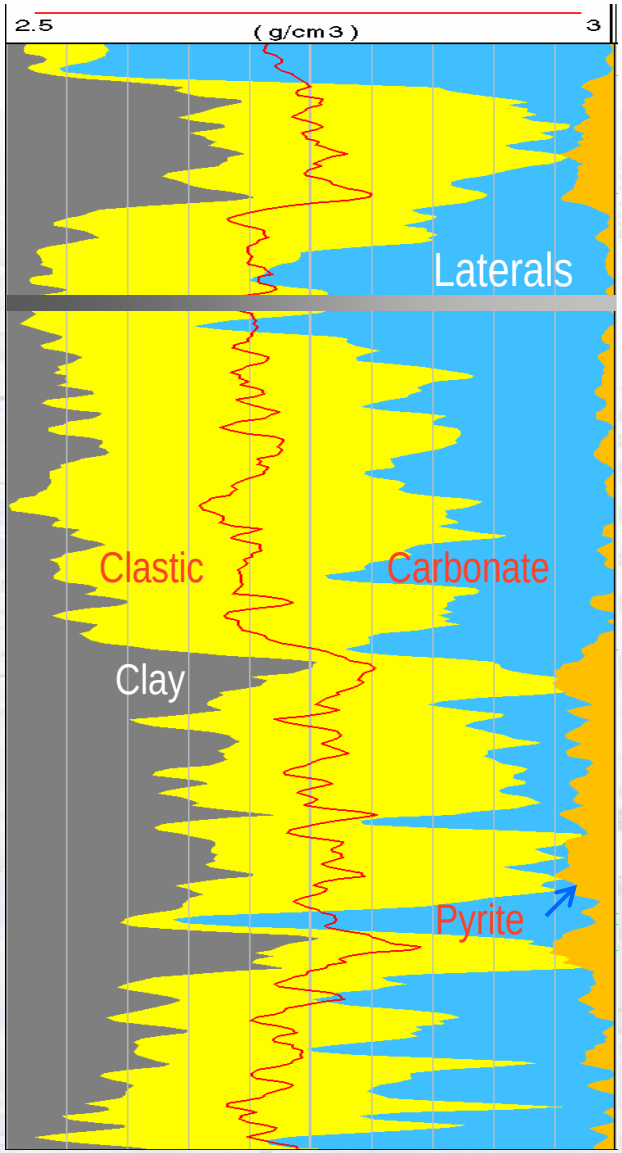
Research Concept



- Drill three wells with single 4000 ft. laterals.
- Use the most advanced technology available.
- Design to support microseismic monitoring from the middle lateral.


Nesson State 41X
Nesson State 42X
Nesson State 44X

Bakken Stratigraphy



Lodgepole

Upper Bakken

Middle Bakken

Bakken

Lower Bakken

Three Forks

Anoxic Marine

Marginal Marine Offshore Complex

Anoxic Marine

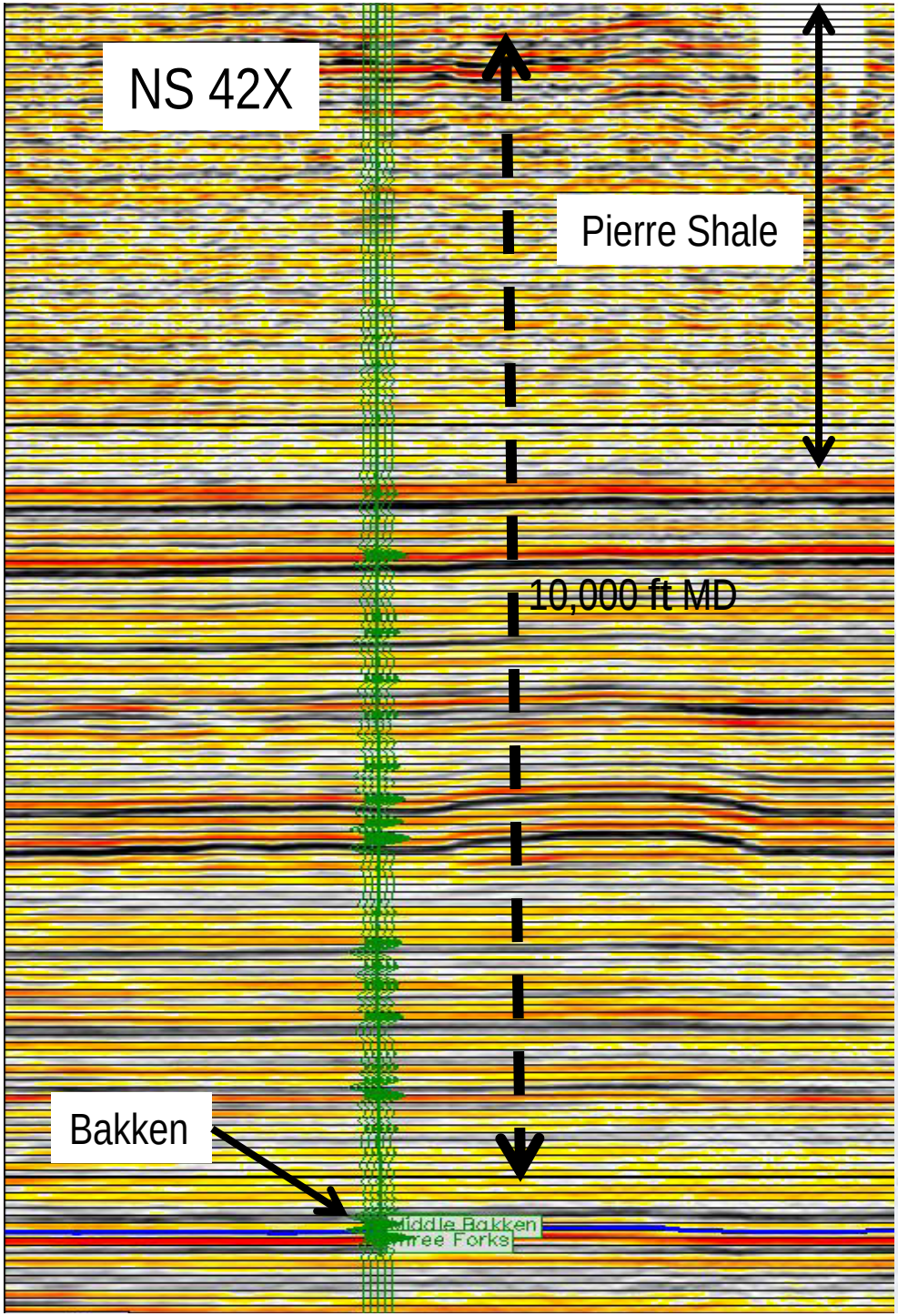
Mississippian

Devonian

(LeFever, 2005)

Three Additional Seismic Systems Installed and Monitored Separately

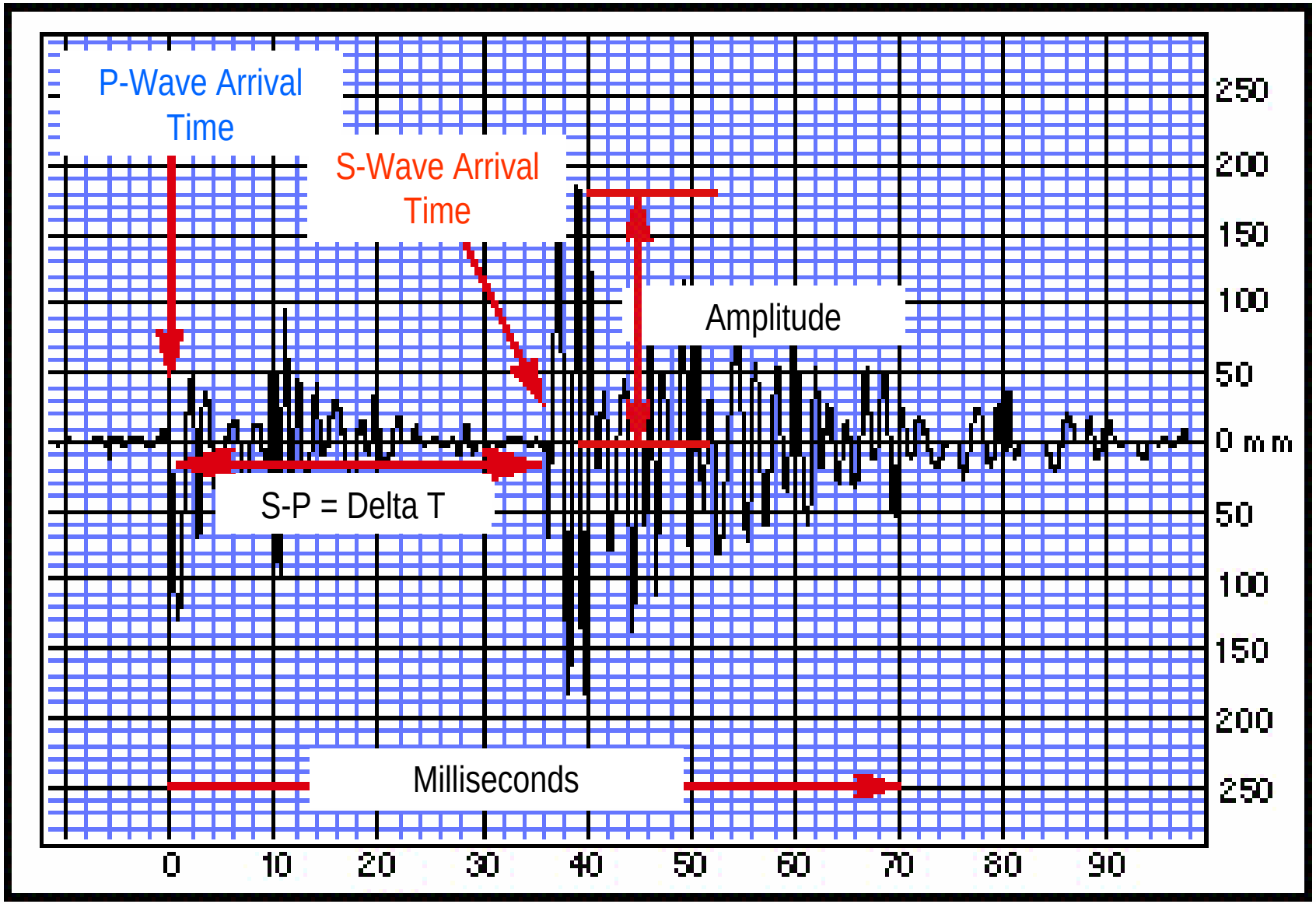
- Department of Energy (DOE) System: 3 bore holes, each with 3 sets of triaxial sensors grouted every 500 feet; maximum depth ~1500 feet
- Terrascience: 18 bore holes with triaxial sensors grouted at ~300 feet
- Microseismic, Inc: 24,000 single component geophones planted on the surface



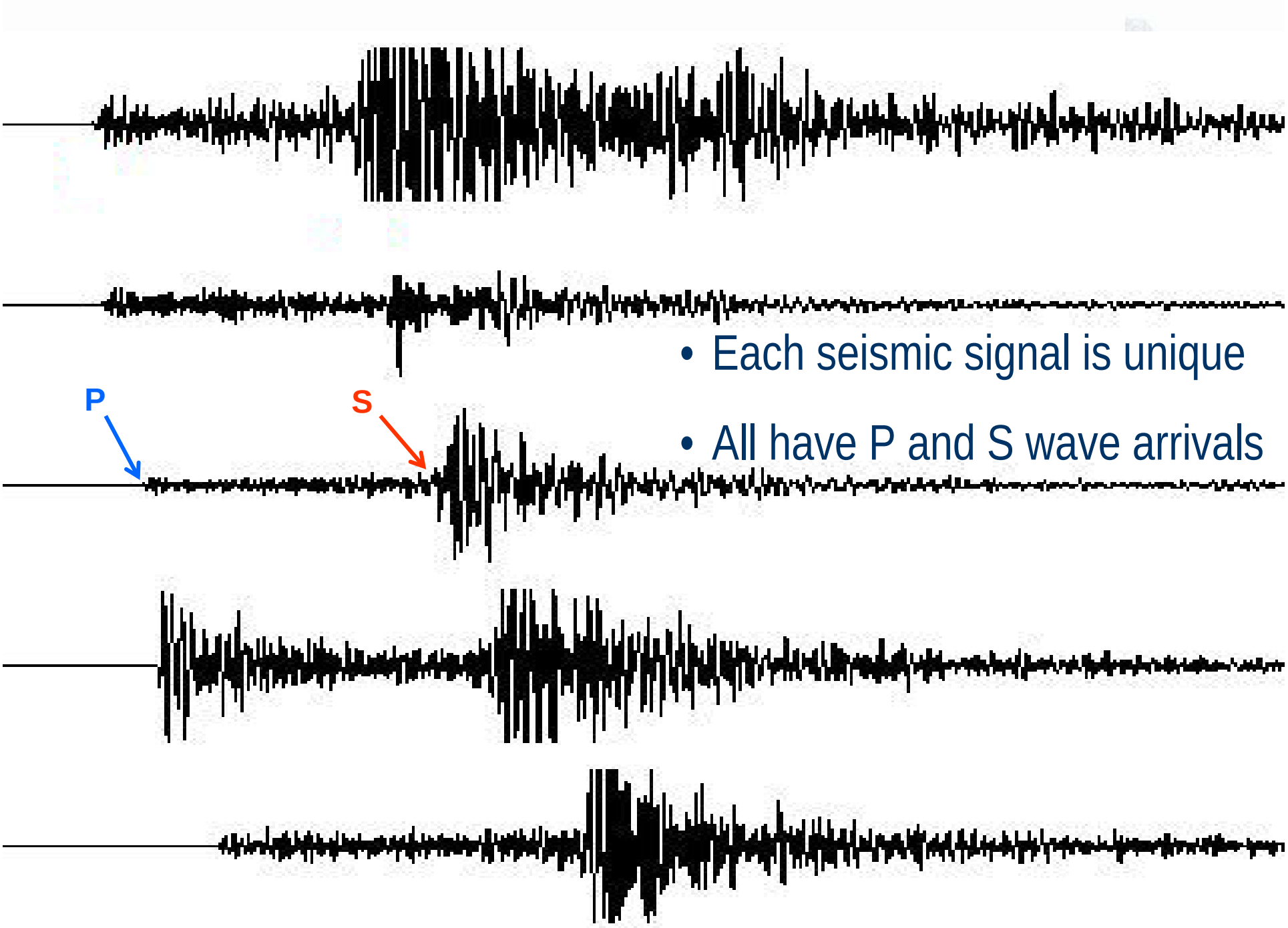
- Severe signal attenuation was a problem for the DOE and Terrascience.
- They did not detect any seismic events, despite the quality and sensitivity of their instruments and deep installations.

3-D Seismic Transect

Seismic Signal

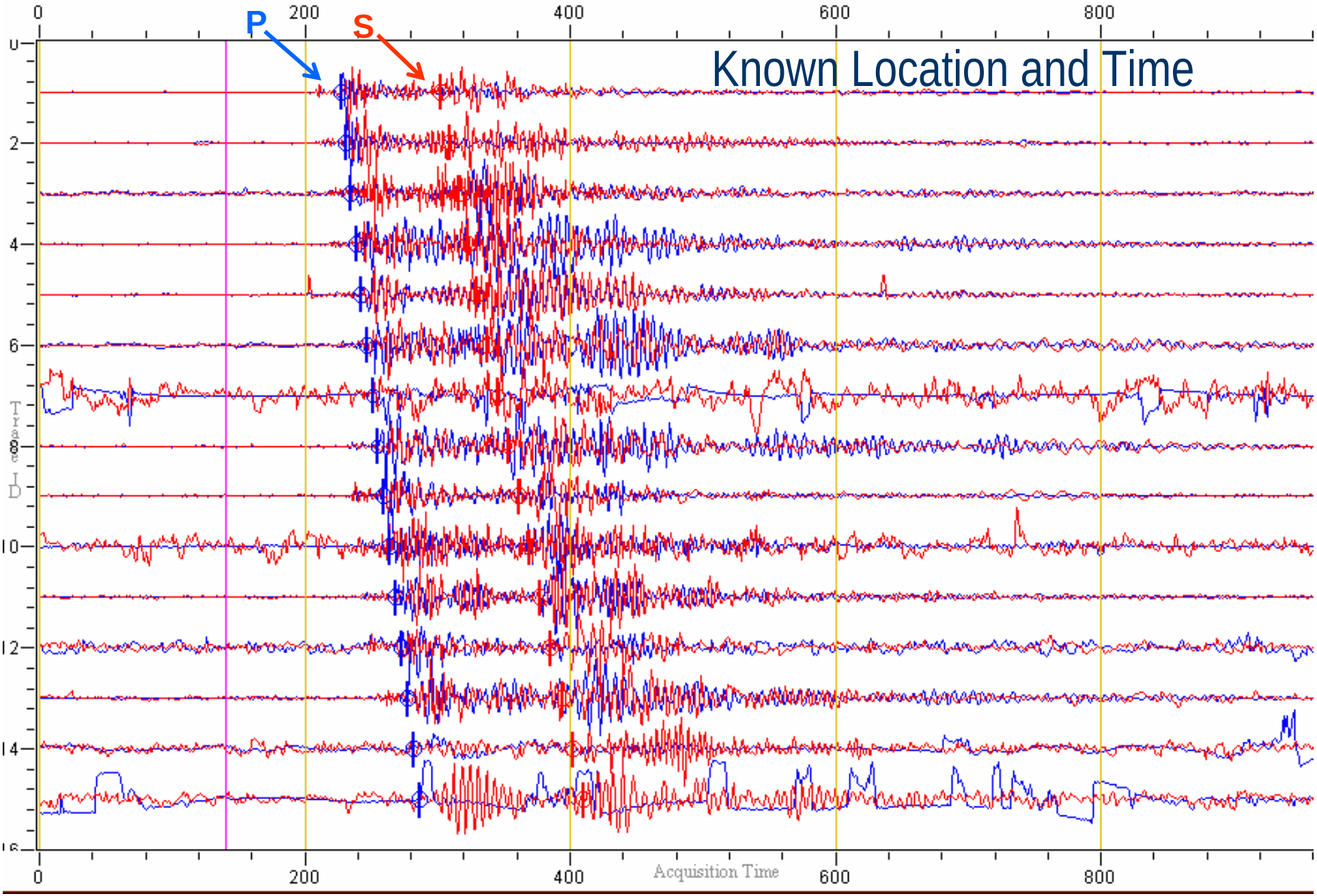


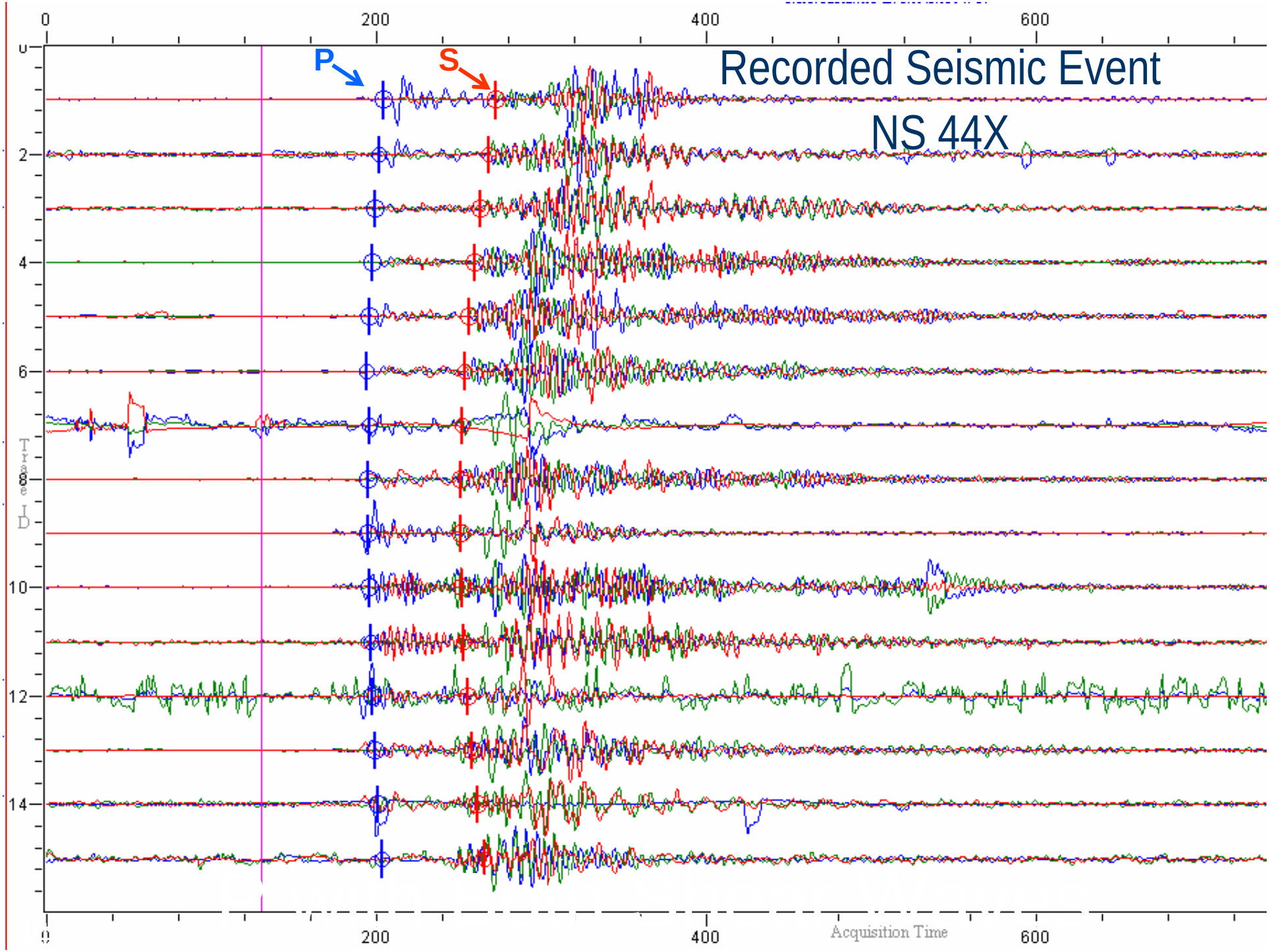
From Geology Labs Online, University of California

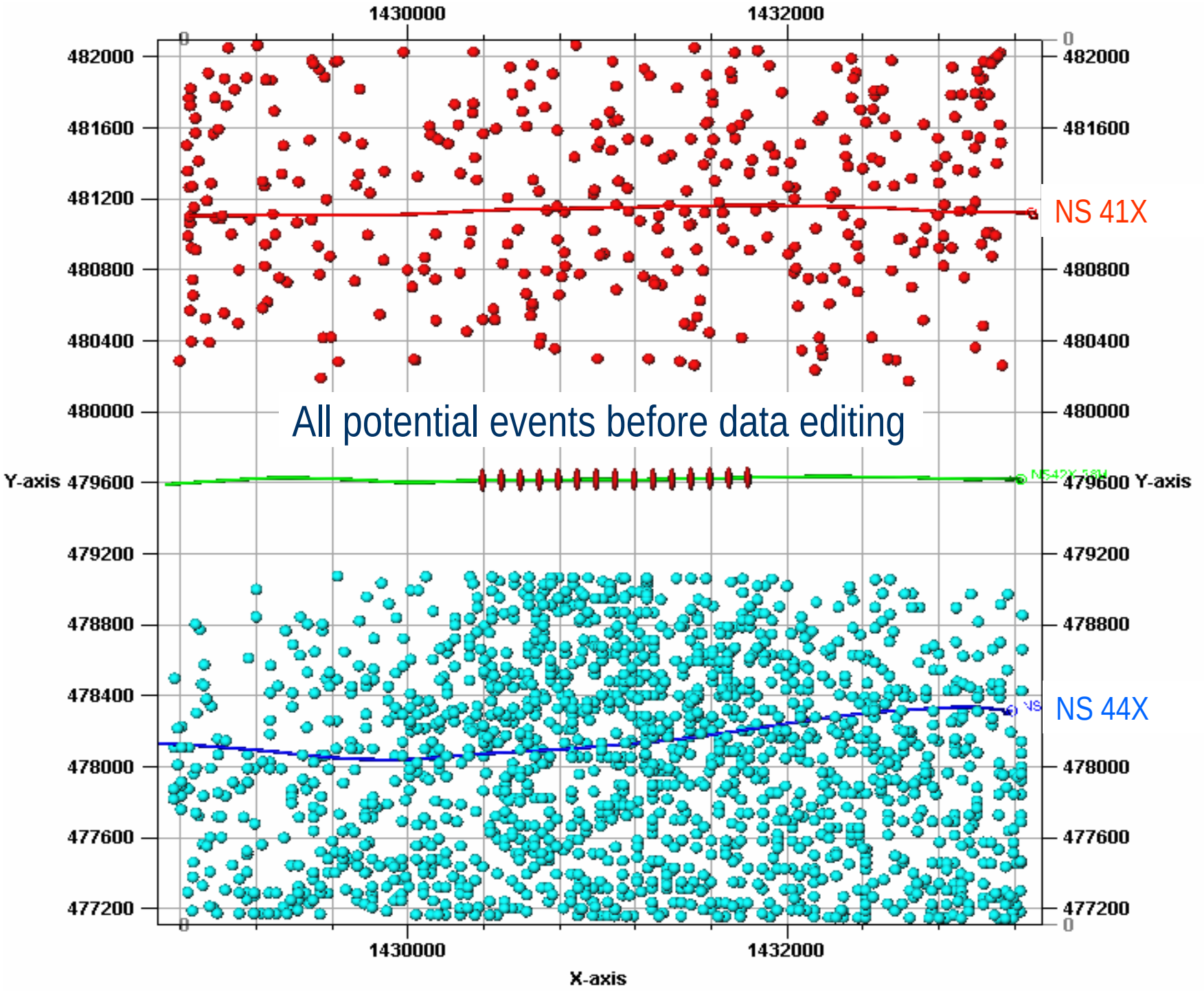


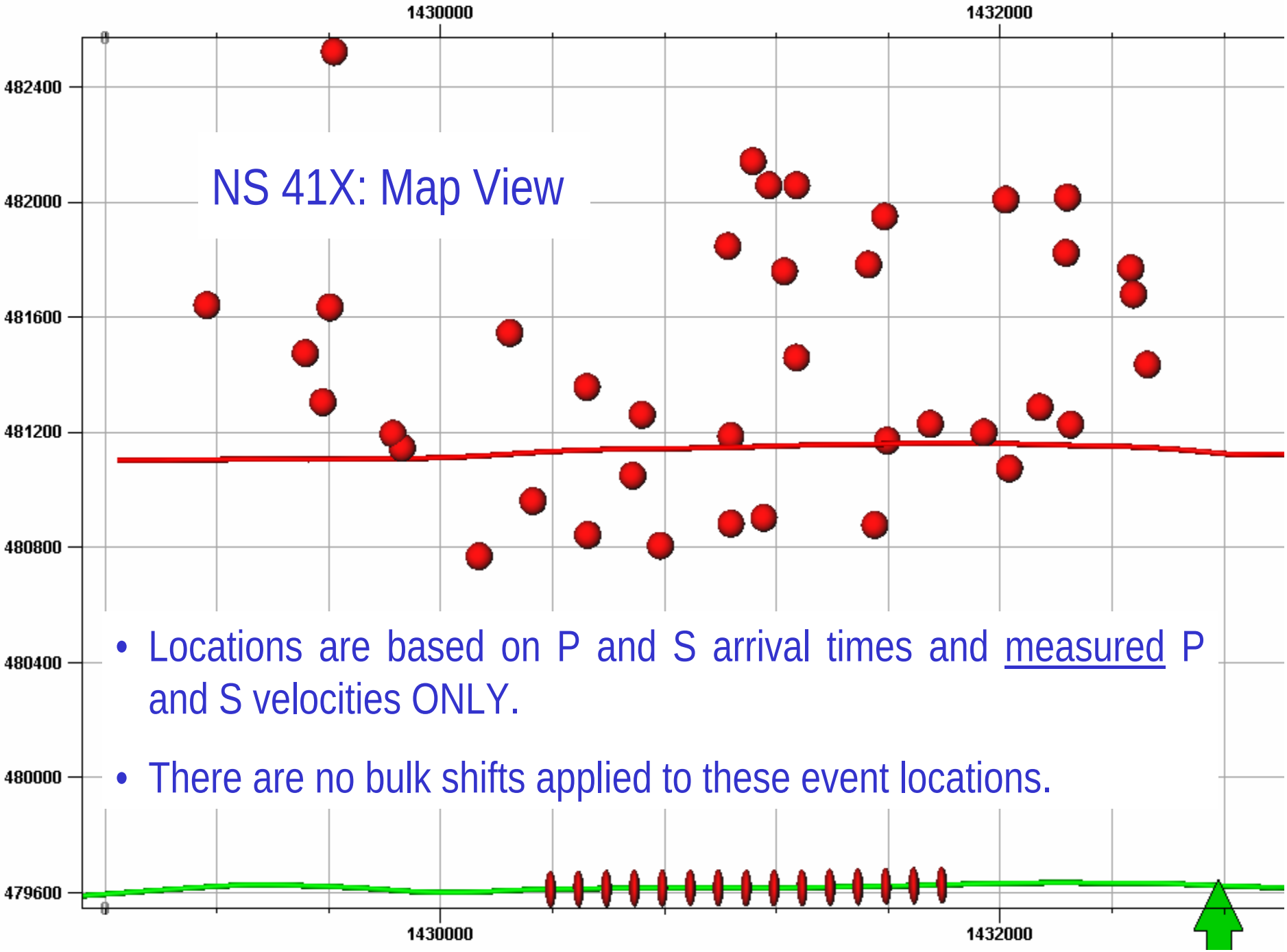
- Each seismic signal is unique
- All have P and S wave arrivals

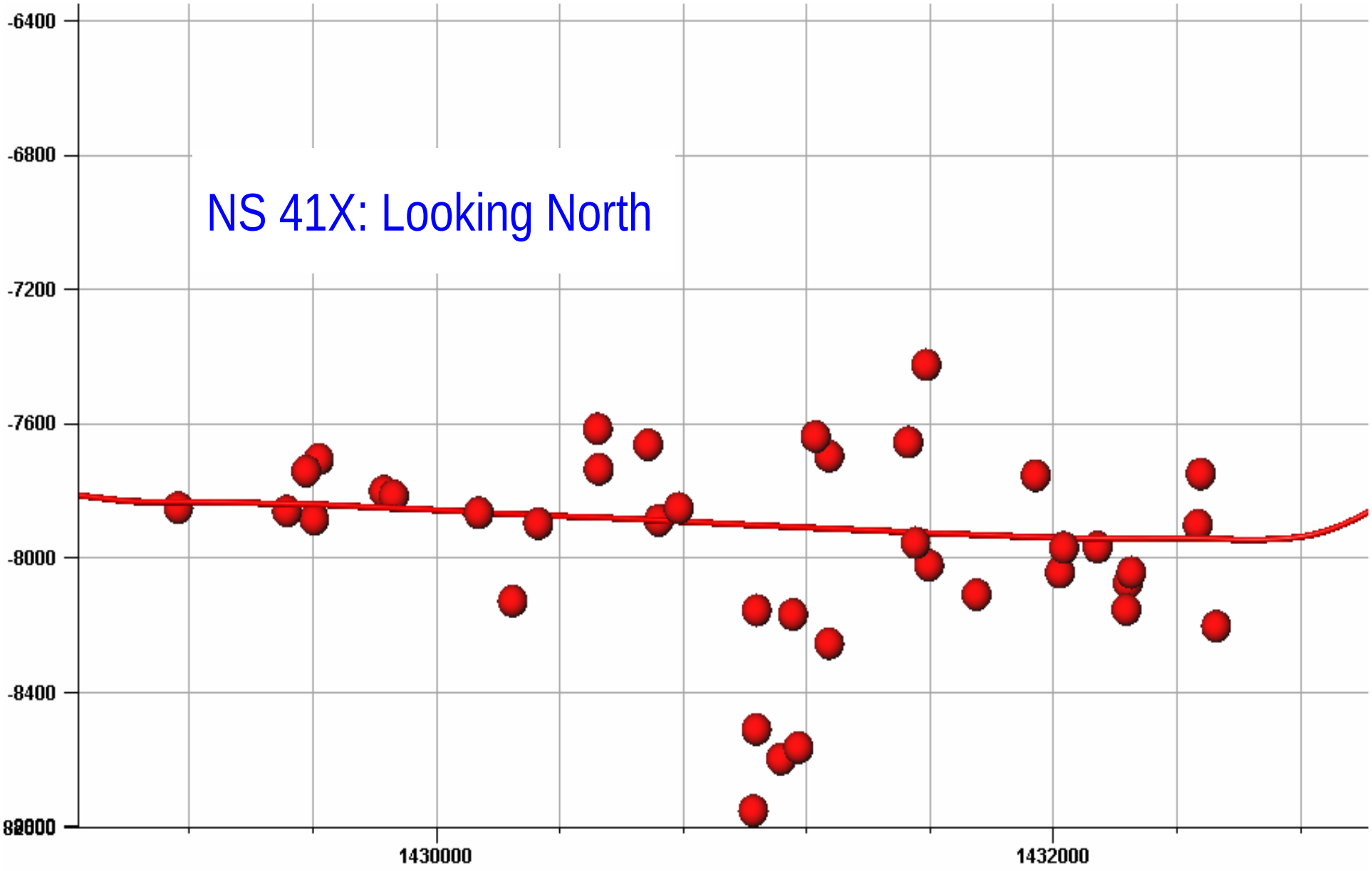
Perf Shot on May 20 at 23:32:17, 2008 GMT



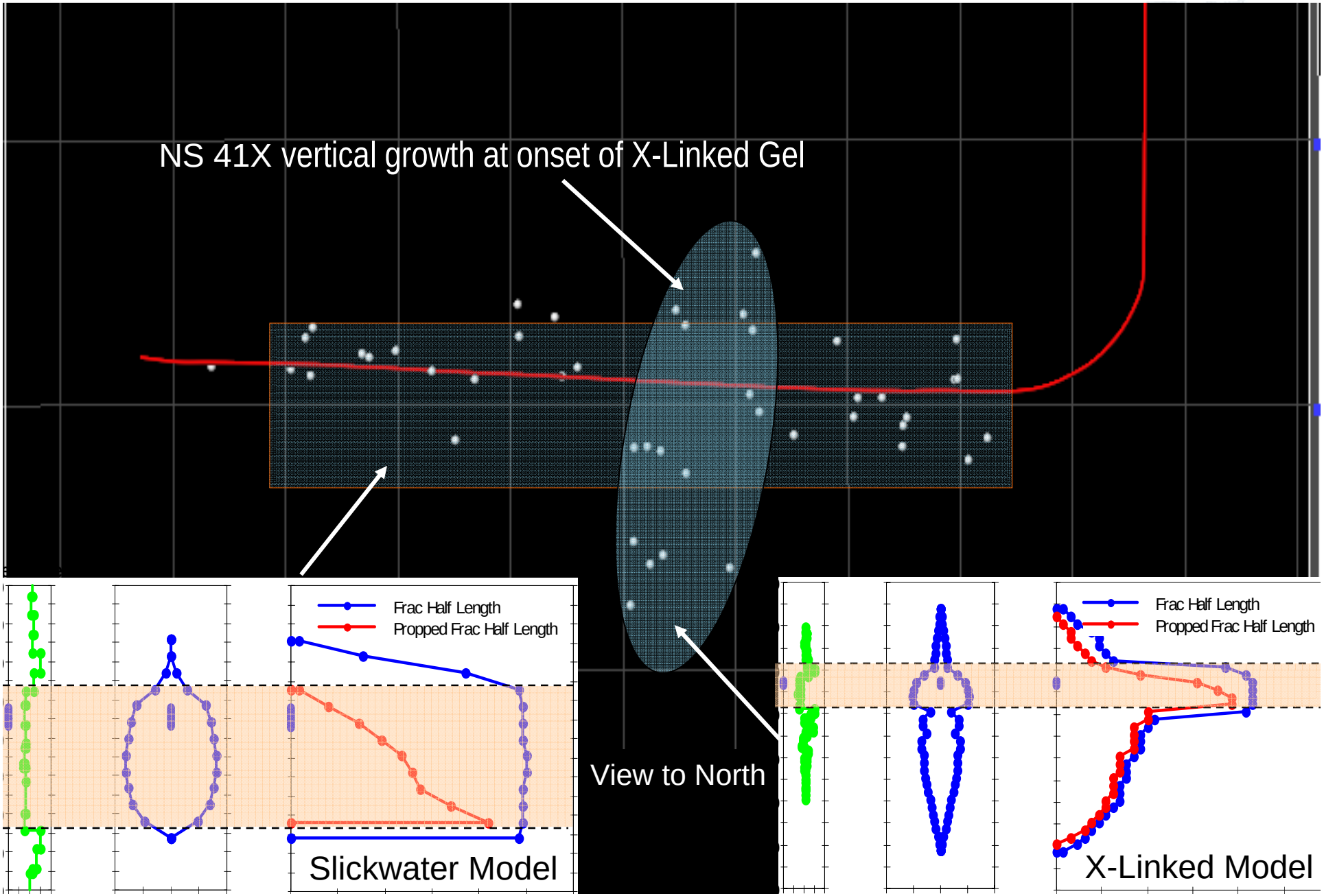

Recorded Seismic Event
NS 44X
P
S
0
200
400
600
2
4
6
8
10
12
14
Trace ID
Acquisition Time

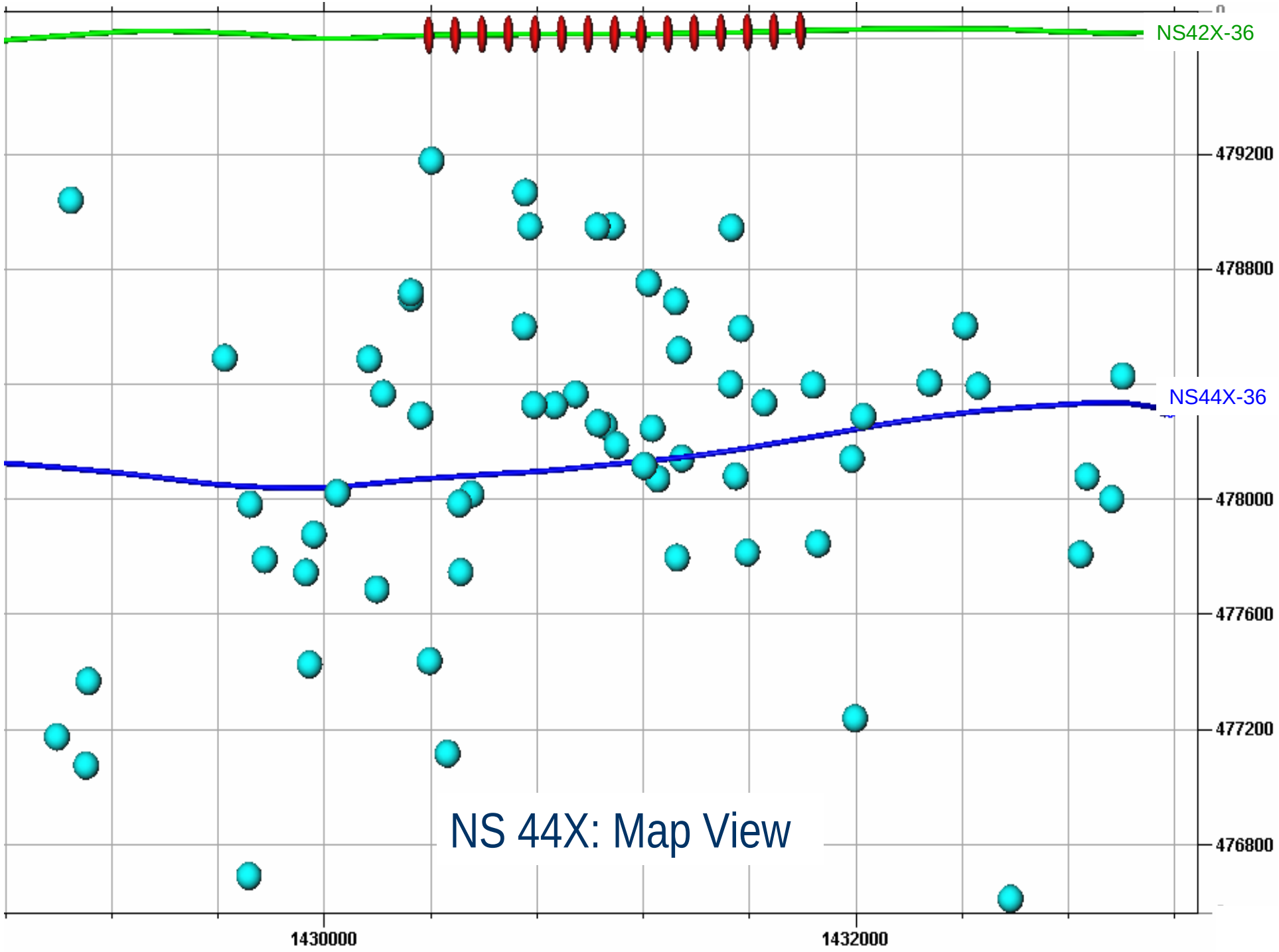

All potential events before data editing
NS 41X
NS 44X
1430000
1432000
482000
481600
481200
480800
480400
480000
479600
479200
478800
478400
478000
477600
477200
Y-axis
X-axis


1430000
1432000
482400
482000
481600
481200
480800
480400
480000
479600
NS 41X: Map View
• Locations are based on P and S arrival times and measured P and S velocities ONLY.
• There are no bulk shifts applied to these event locations.

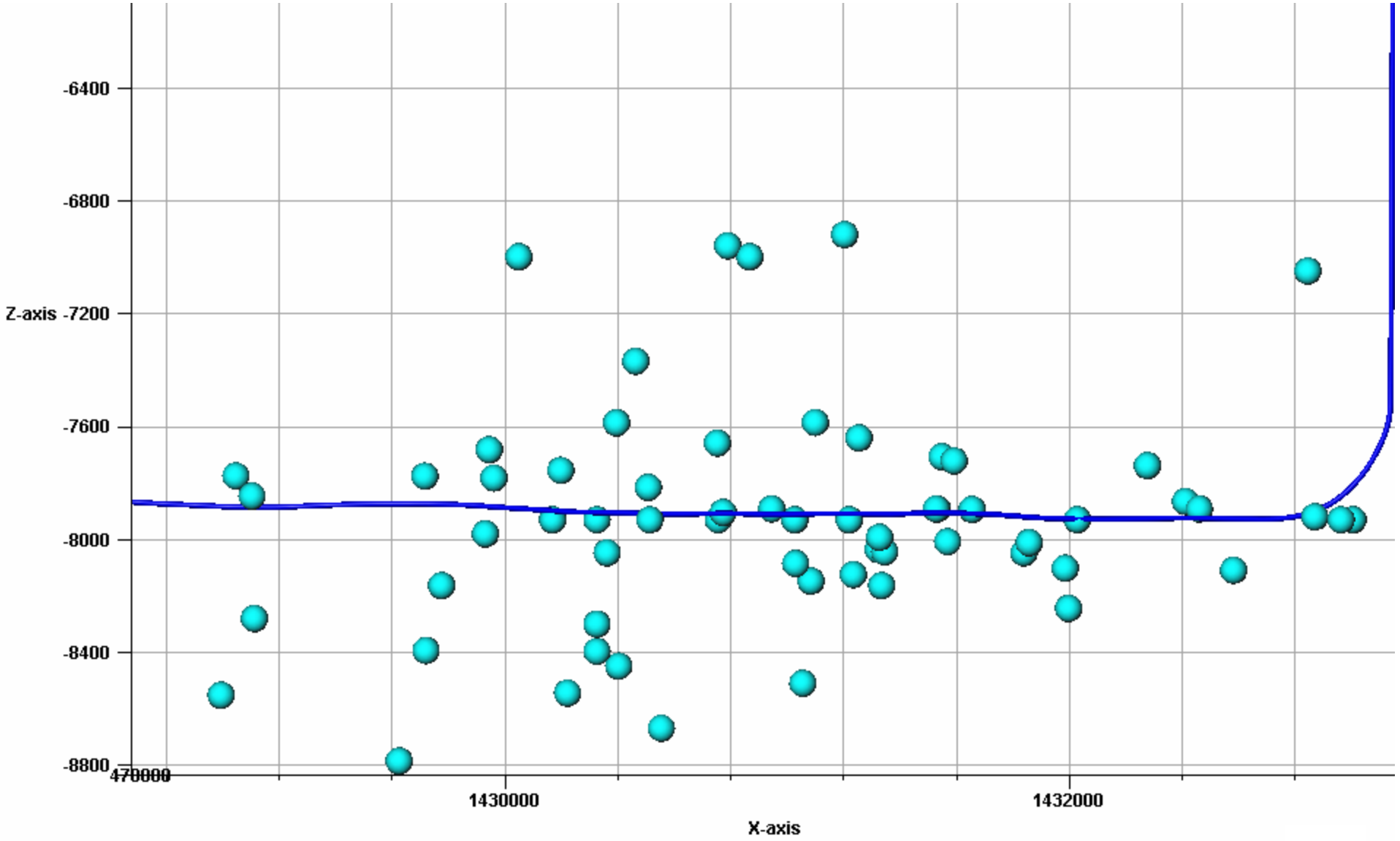

NS 41X: Looking North
-6400
-6800
-7200
-7600
-8000
-8400
1430000
1432000

X-Linked Gel: Height Growth



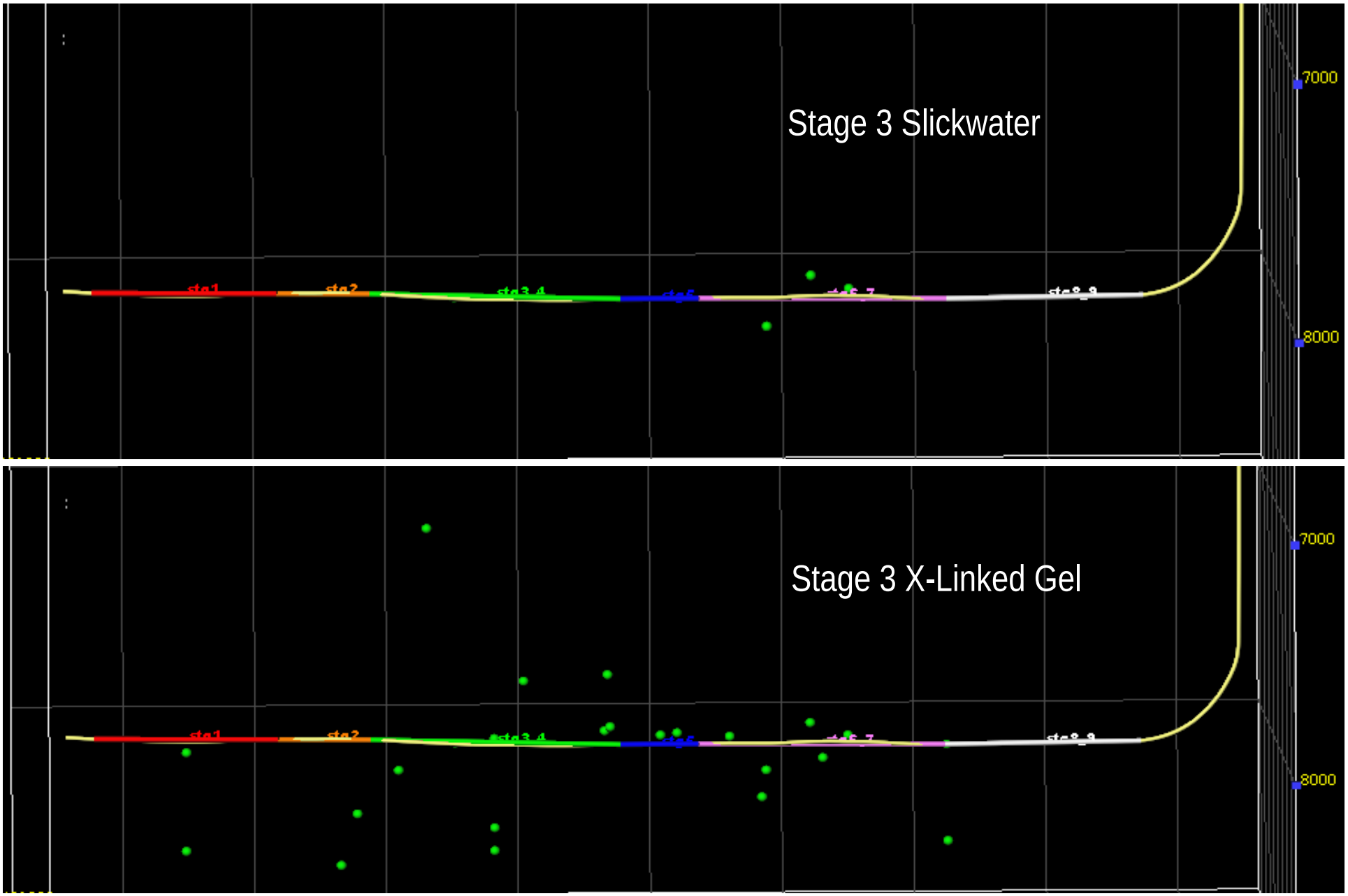


NS 44X: Map View

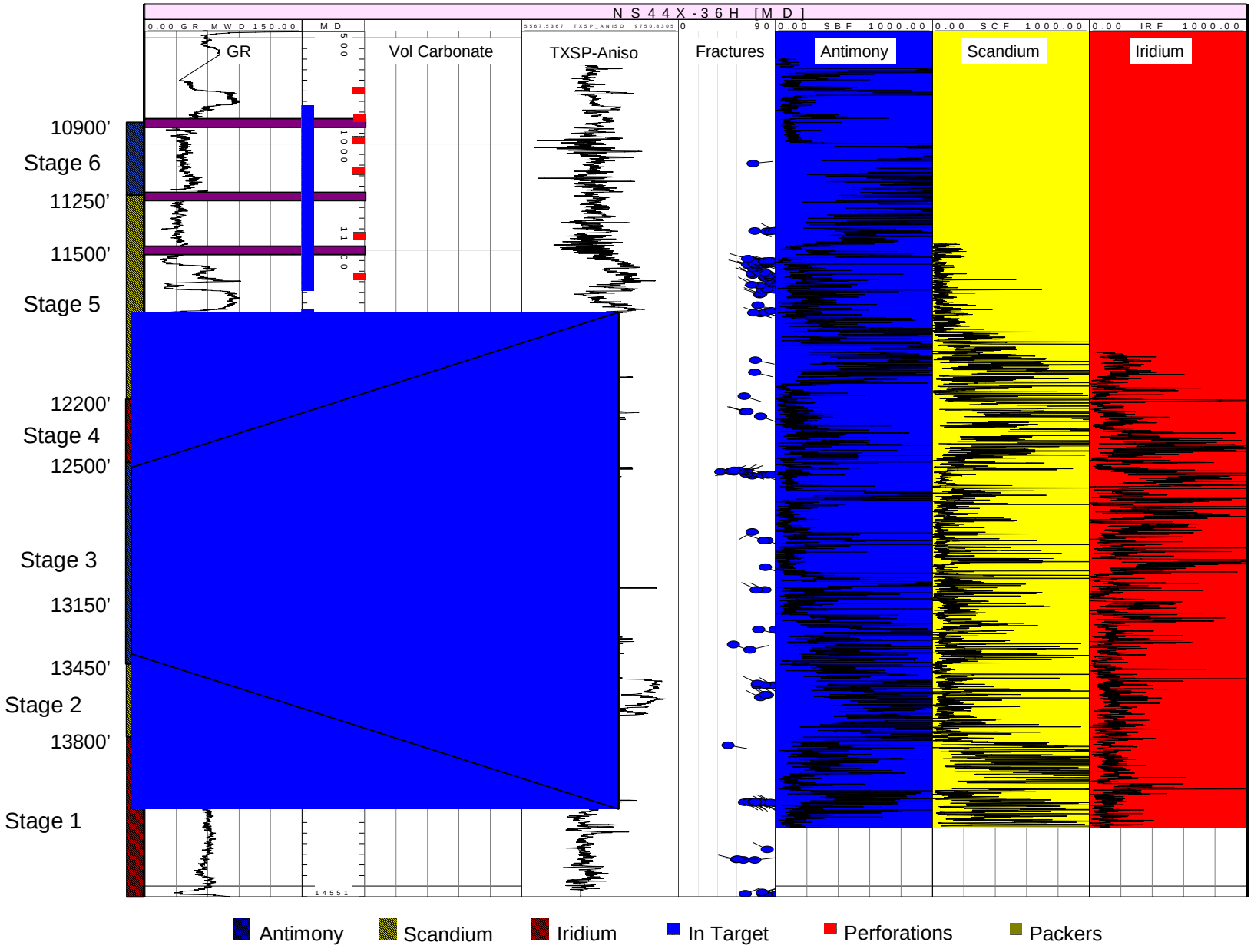


NS 44X: Looking North

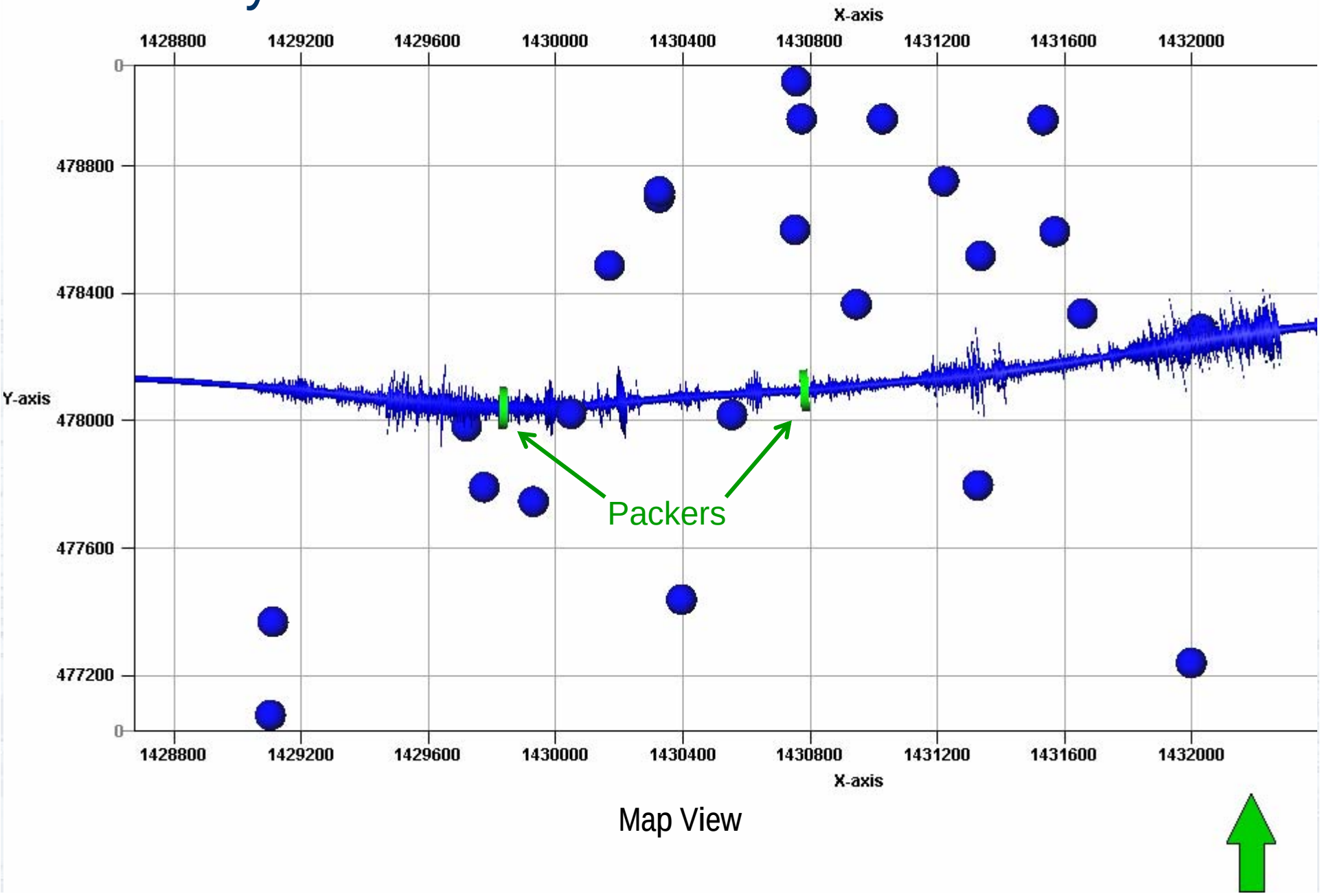
NS 44X Comparison



NS 44X, Stage 3: Radioactive Tag

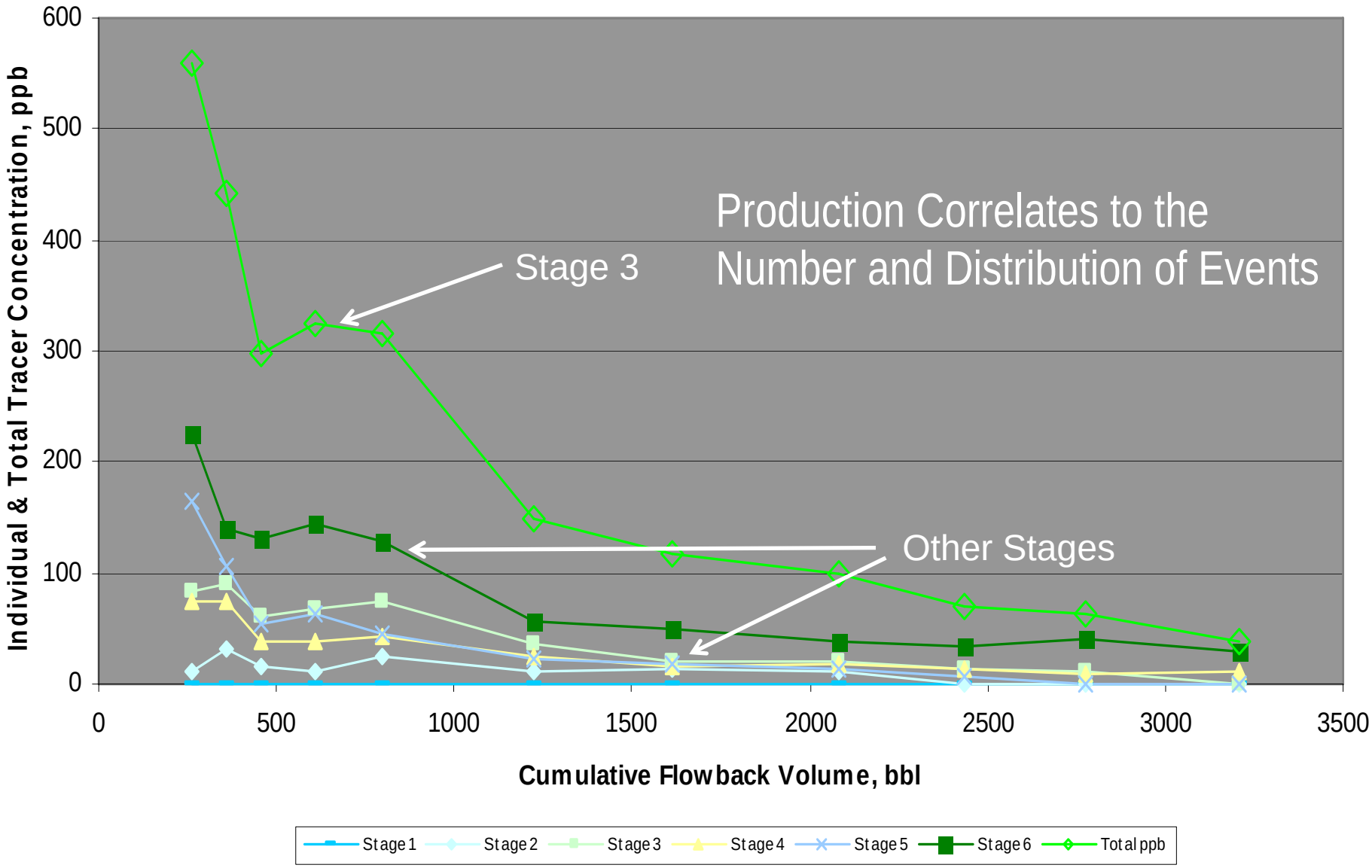


Antimony Tracer

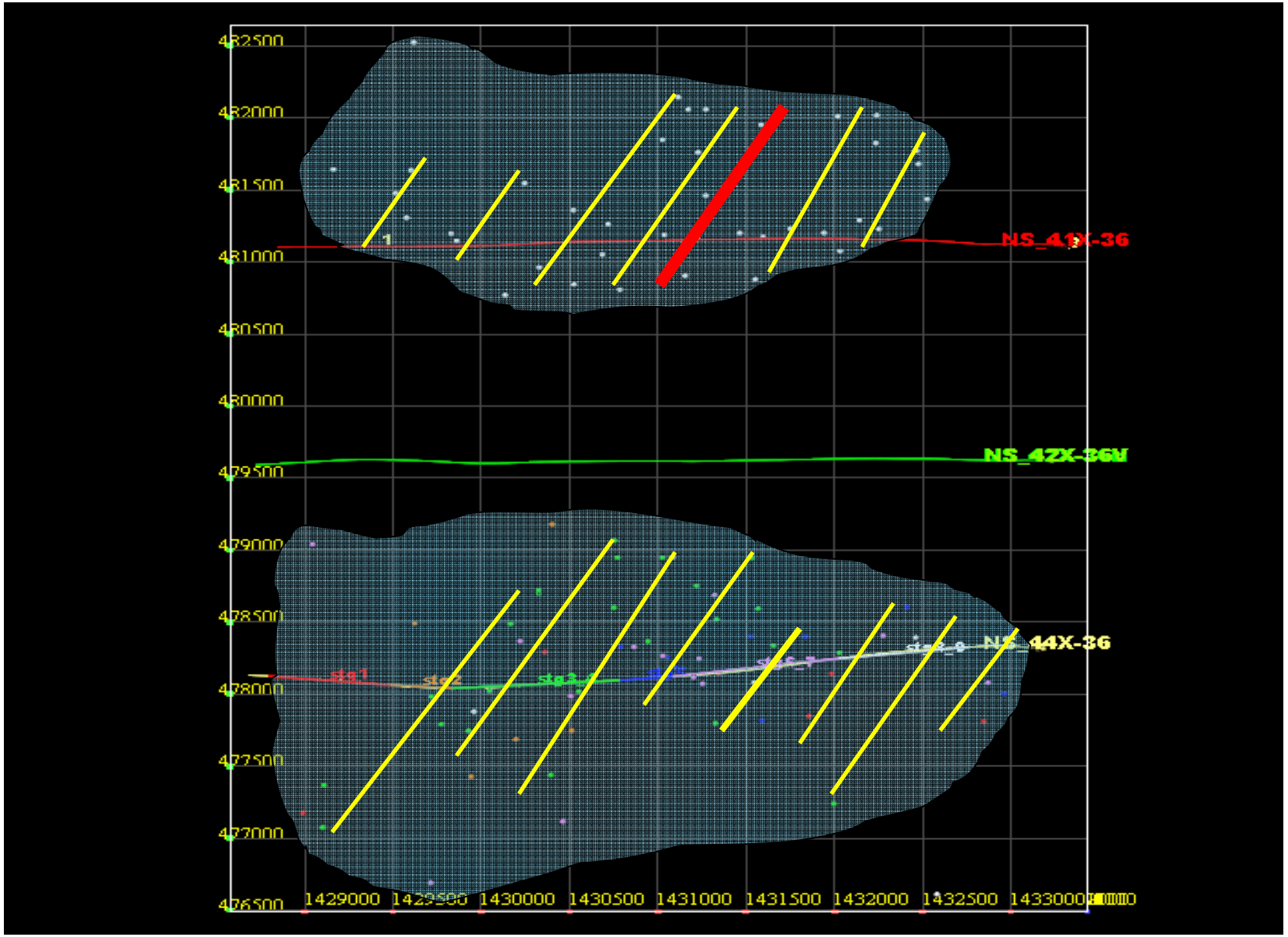


Map View

NS 44X Chemical Tracer Flow Back

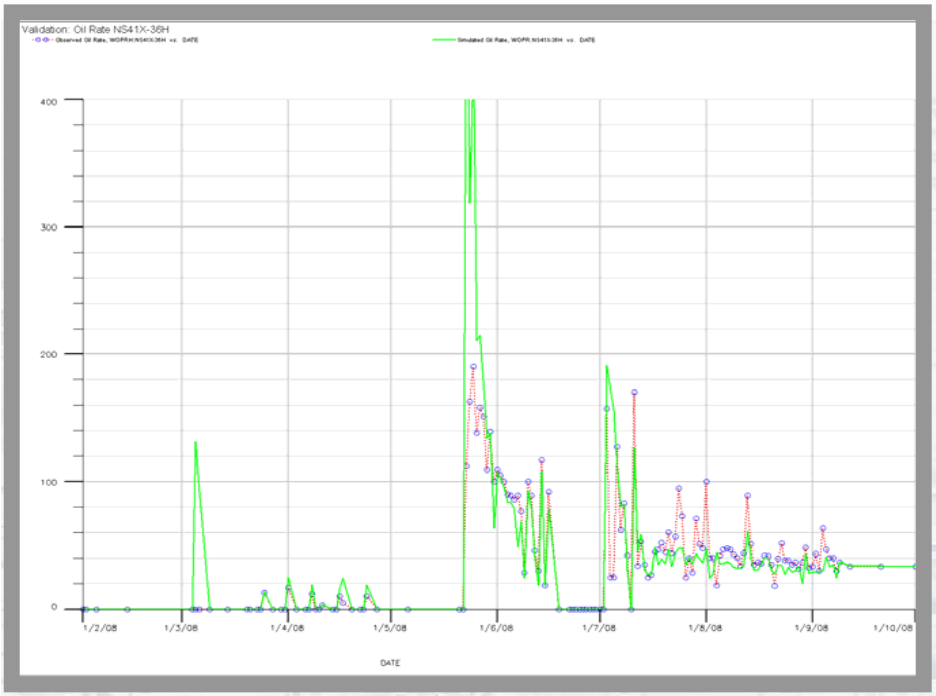


Production Model Fracture Fit

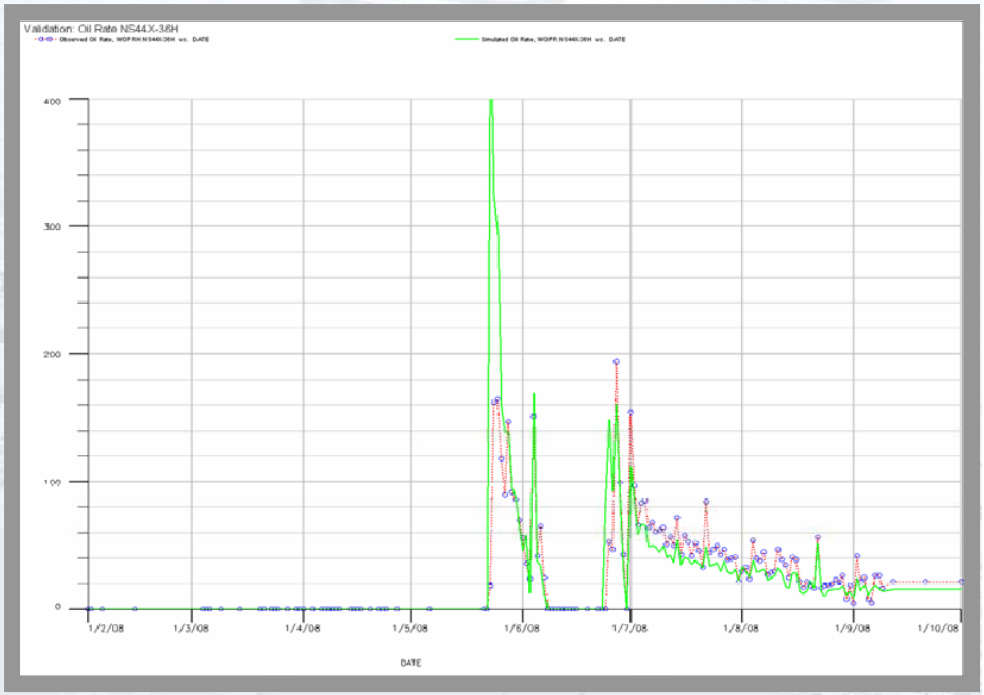


Model Validation: Well Oil Production Rate

NS 41X



NS 44X



Key Observations

- Seismic events show a strong correlation to the changes in frac fluid.
- Production history shows a strong correlation to the number and distribution of seismic events for each stage.
- History match from the seismic based reservoir model was nearly perfect; requiring only a 10% adjustment to permeability for a fit.