Hawthorne 3-D Seismic GIS Interpretation

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**3D Seismic Addendum to Statement of Work for
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Executive Summary

A collaborative effort by the Great Basin Center for Geothermal Energy at the University of Nevada, Reno, and Optim Inc. of Reno has interpreted a 3d seismic data set recorded by the U.S. Navy Geothermal Programs Office (GPO) at the Hawthorne Army Depot, Nevada. The 3d GIS interpretation is encoded within an OpendTect database, which will be delivered on DVD to the GPO. Louie will also provide training to GPO staff in examination of the OpendTect database and the export of isochron maps. We interpret a map of the time-elevation of the major fault and its associated splays and basin-ward step faults. The range-front fault is the deepest, and its isochron map provides essentially a map of "economic basement" under the prospect area. There are three faults that are the most readily picked through vertical sections. The fault reflections show an uncertainty in the time-depth that we can interpret for them of 50 to 200 ms, due to the over-migrated appearance of Dawson's prestack time-migrated data set. The three faults we interpreted do appear as gradients in the geophysical potential-field maps. Potential drill targets and areas of development are defined within data volume by the intersections of the fault surfaces with the tracked, strong stratigraphic reflections. Target volumes for drilling and development are defined by the intersections of the faults and bright-spot stratigraphy, and their uncertainty bounds. There are a few such intersections present within the 3d volume, and their locations are coded within the OpendTect database. Target location and depth accuracy can only be improved through comprehensive prestack depth migration after SeisOpt® @3D™ velocity determination from the raw field data.

Background and Delivery of Results

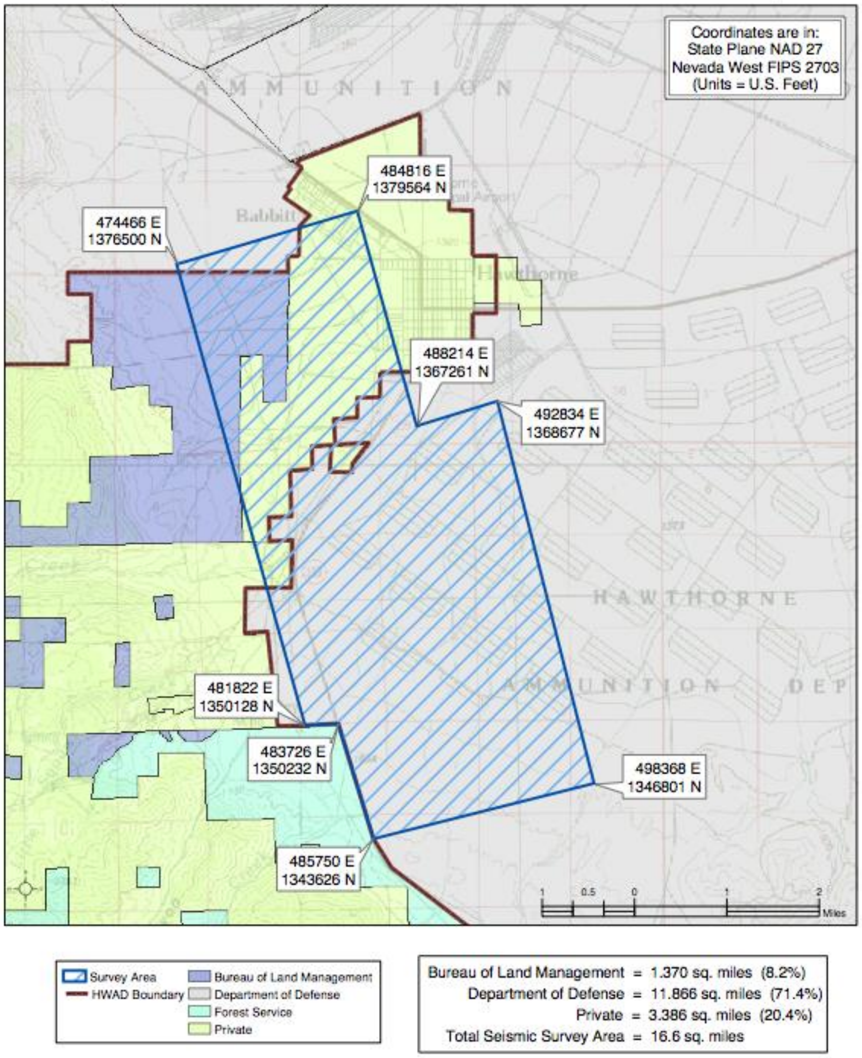
A collaborative effort by the Great Basin Center for Geothermal Energy at the University of Nevada, Reno, and Optim Inc. of Reno has interpreted a large, 3d seismic GIS data set recorded in 2005 by the U.S. Navy Geothermal Programs Office at the Hawthorne Army Depot, Nevada. The seismic acquisition and processing contractor was Dawson Geophysical Co. These data have been processed to prestack time migration stage (PSTM), but were not previously interpreted. We have interpreted these data, focusing on Dawson's data-volume product labeled "Pre-Stack Migration (Filtered)," and created structural maps.

The Dawson PSTM-processed 3d migrated data volume was imported into a 3d seismic interpretation software package, to locate structures that may be relevant to geothermal exploration and development. The OpendTect interpretation software package from dGB group (available from opendtect.org) was used for all 3d seismic interpretation activities. OpendTect software is open-source, so the interpretive software, which runs on any Windows PC, accompanies the interpreted GIS database. All data and interpretations are provided in digital format as part of the OpendTect GIS database, which will be delivered on a data DVD. The seismic survey has been interpreted for stratigraphic horizons and structures that can be used later by the GPO to create a comprehensive 3d geologic and tectonic model.

Strong lateral velocity variations, typical of fault-bounded alluvial basins, have prevented Dawson's prestack time migration (PSTM) from properly imaging reflection geometry. This problem leaves reflections with a concave-upward "over-migrated" appearance. The concave-upward spreading of the reflections produced considerable uncertainty in the interpretation, since the true location of the reflector could be anywhere along the concave-upward trajectory. Only comprehensive prestack depth migration (PSDM) after SeisOpt® @3D™ velocity determination on the raw field data would be able to place the reflections into their proper geometries and locations.

This report shows a few example vertical and horizontal sections through the seismic data volume, along with 3d representations of the interpreted fault surfaces and tracked stratigraphic horizons. The 3d GIS interpretation is encoded within the OpendTect database and all interpreted surfaces are easily exportable to simple ascii format. Louie will deliver the database on DVD to the GPO. He will also provide training to GPO and contractor staff in examination of the OpendTect database and the export of isochron maps for the interpreted features. Although this is the final written technical report for this project, the project is not completed until the training and exports have been provided.

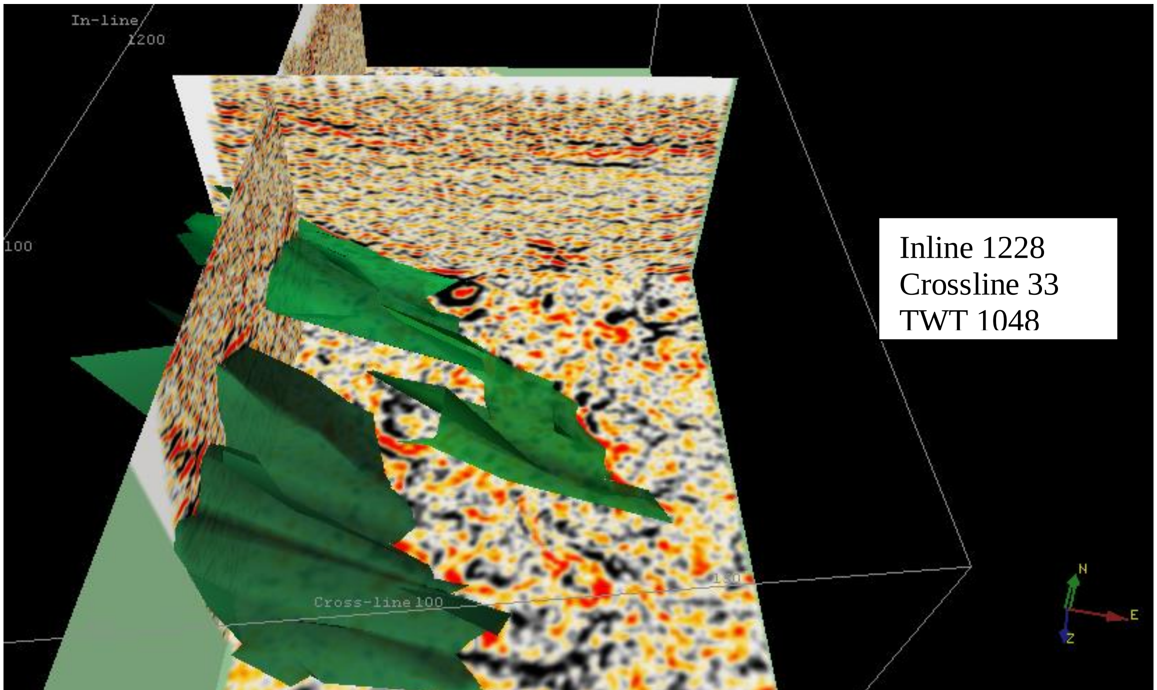
Hawthorne Area 3D Seismic Survey

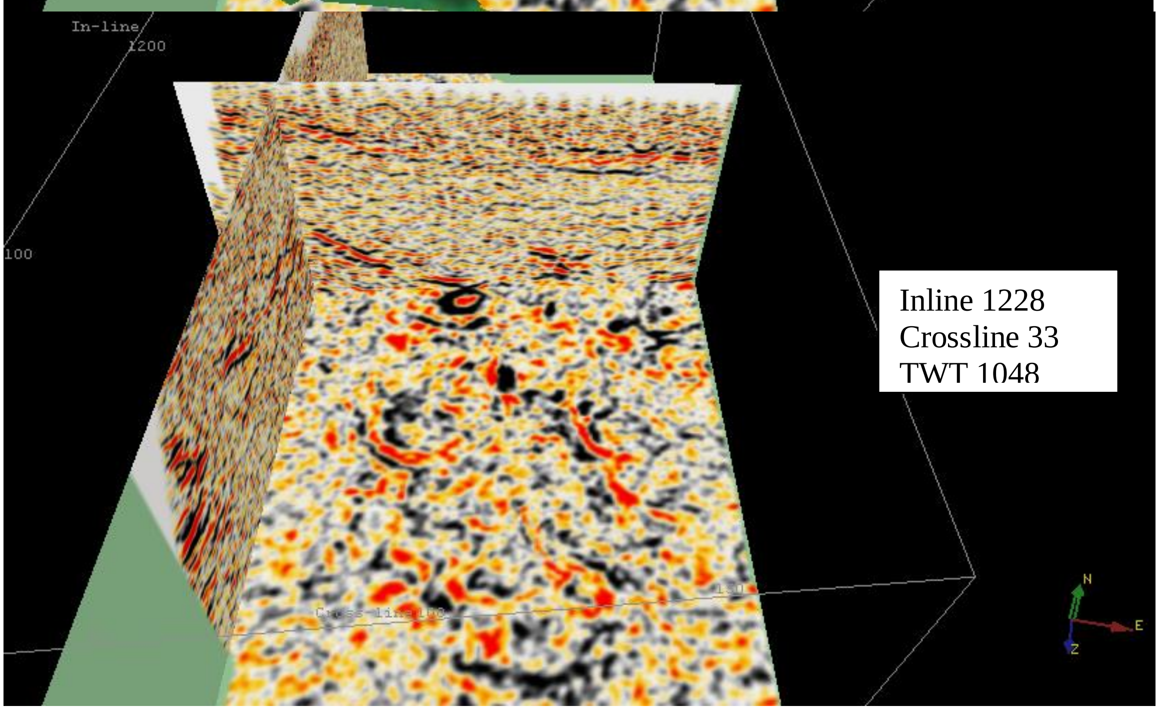


OpendTect V3.2.2b was used to track the visible range-front faults and basin strata.

Fault Interpretations

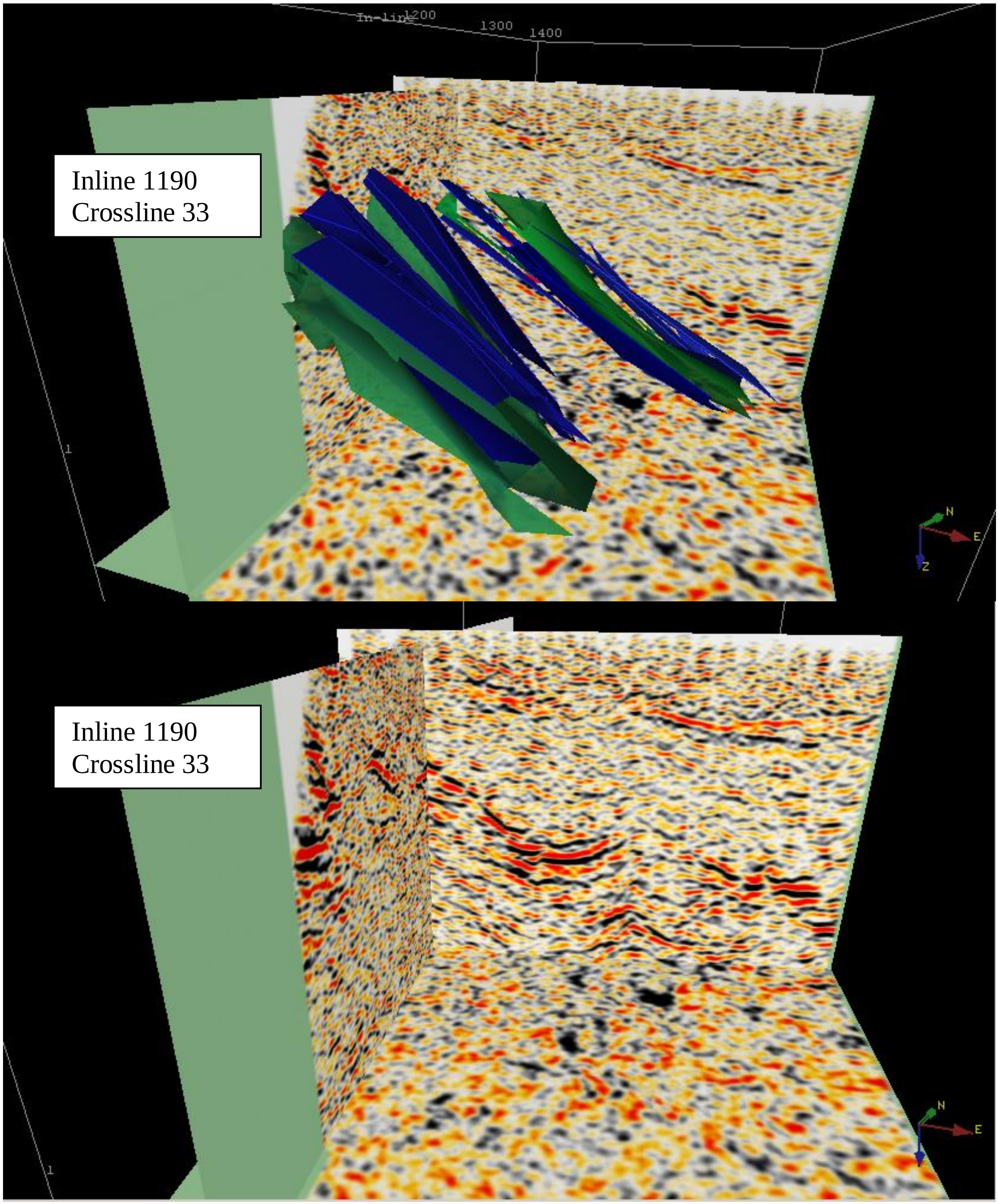
Based on studies of similar geothermal systems in the western Great Basin, it is reasonable to assume that there may be a major fault representing the main geological structure that controls the convective up flow of geothermal fluids beneath the prospect. We interpret (below) a map of the time-elevation of the major fault and its associated splays and basin-ward step faults. The range-front fault is the deepest, and its isochron map provides essentially a map of "economic basement" under the prospect area, and could be used in future efforts to develop a numerical model of the resource for production and reservoir management.





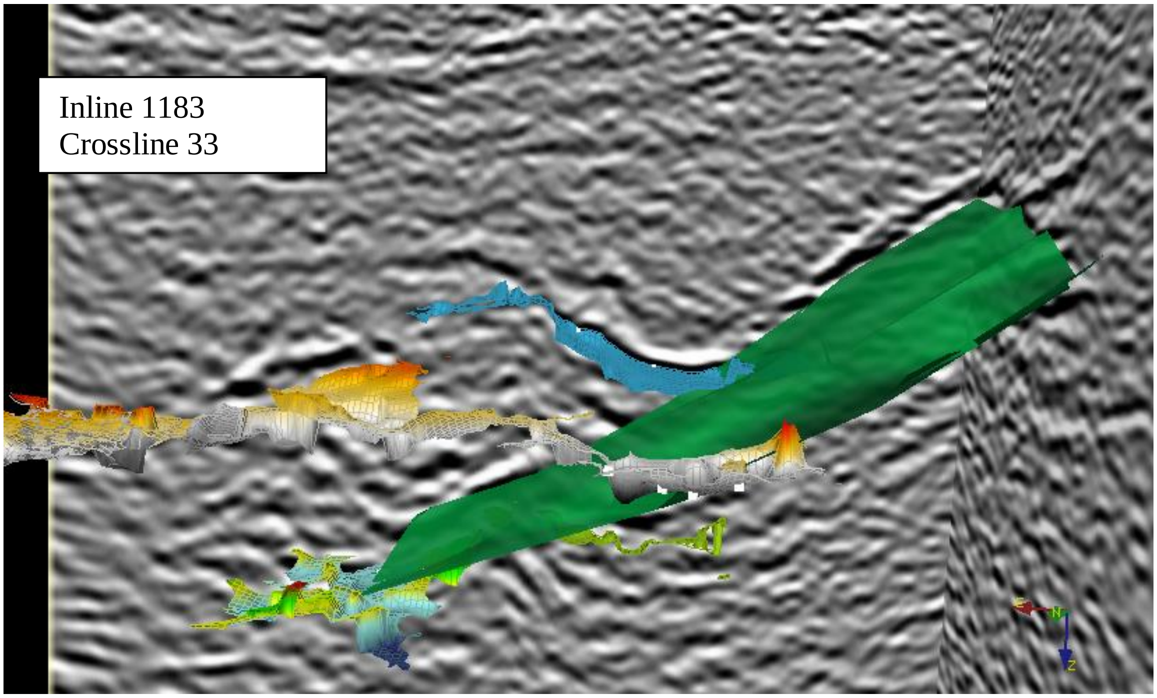
There are three faults in green that are the most readily picked through vertical sections. These begin at an inline of 1011 and can be followed well through inline 1248. They have eastward dip, and the reflections enter the volume at a minimum TWT of approximately 400 ms. As seen in the image, they follow the fault strike displayed in the time section.

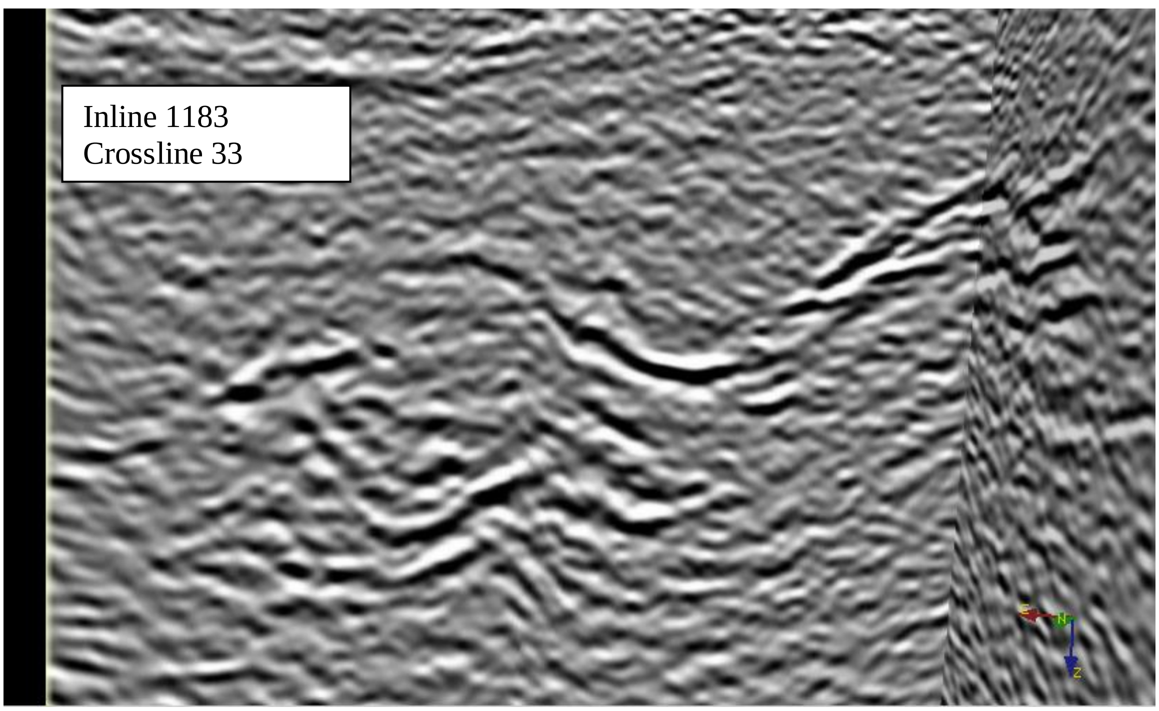
The time-slice above clearly shows the arcs and bulls-eyes of the “over-migrated” appearance of the prestack time-migrated result. It is the over-migrated appearance of the reflections in this Dawson PSTM product that 1) made accurate interpretation difficult, and yielded large uncertainties in the GIS mapping of the fault structures; and 2) allows the suggestion that reprocessing for prestack depth migration (PSDM) will likely improve structural resolution, drastically.

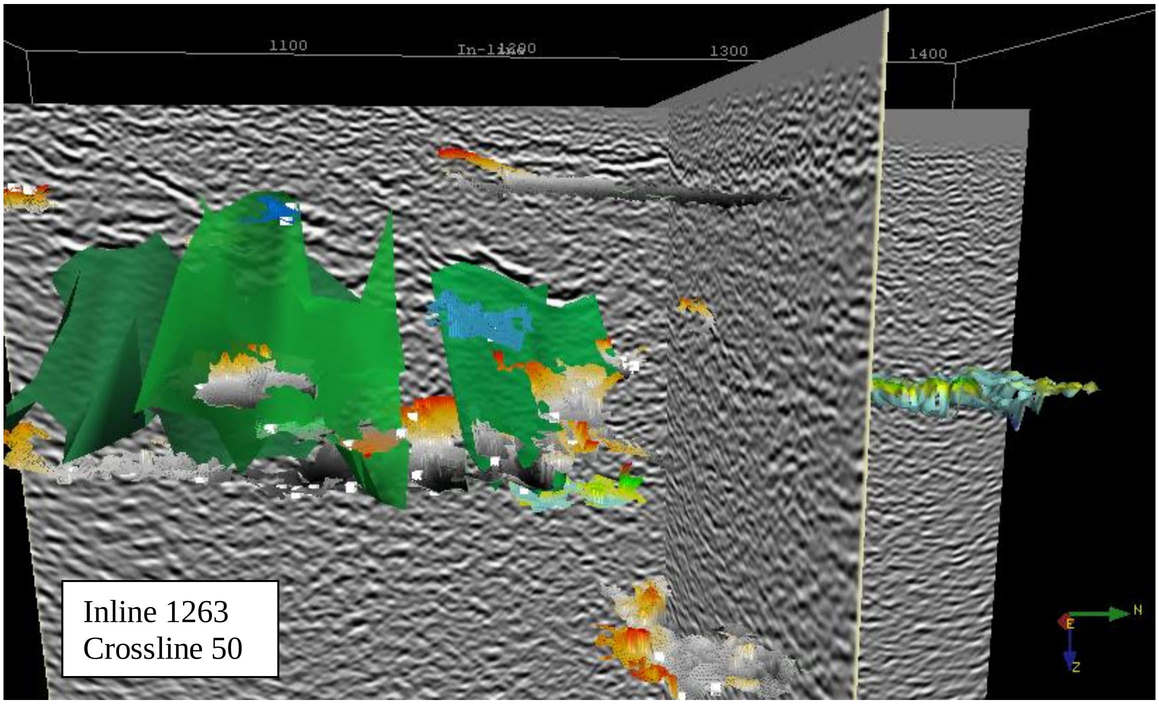


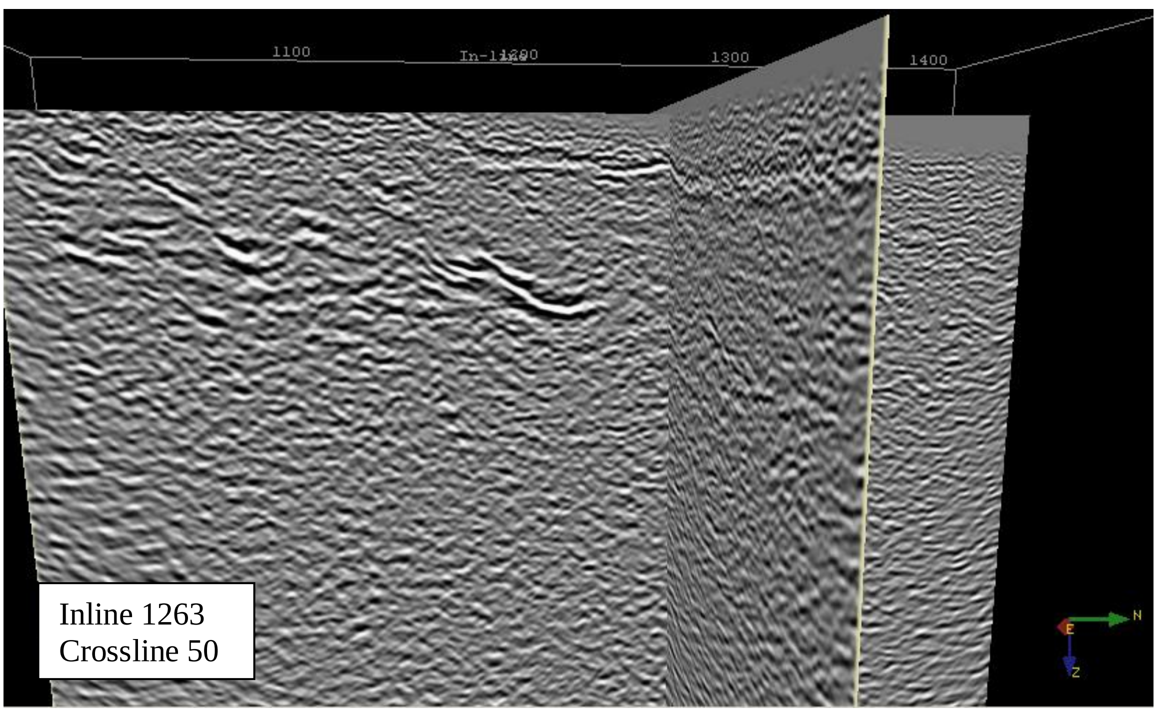
The fault reflections, though easily picked, show an uncertainty in the time-depth that we can interpret for them of at least 50 and up to 200 milliseconds in many areas, due to the over-migrated appearance of the PSTM data set.

Tracked Stratigraphic Horizons



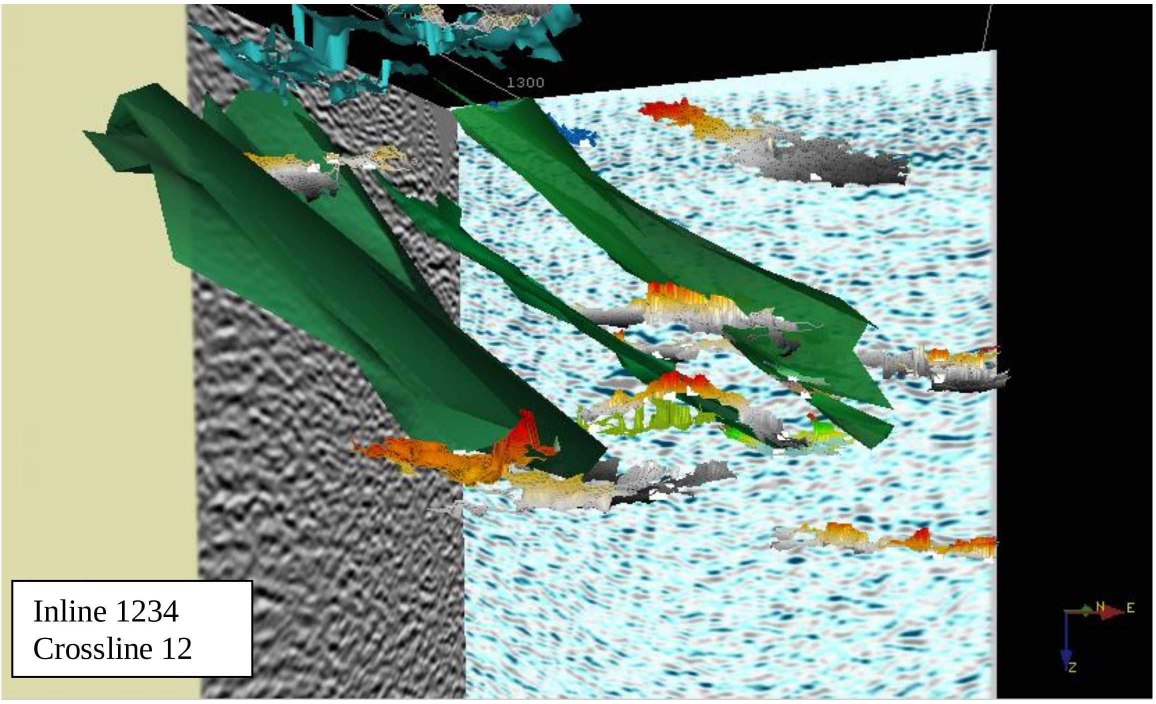


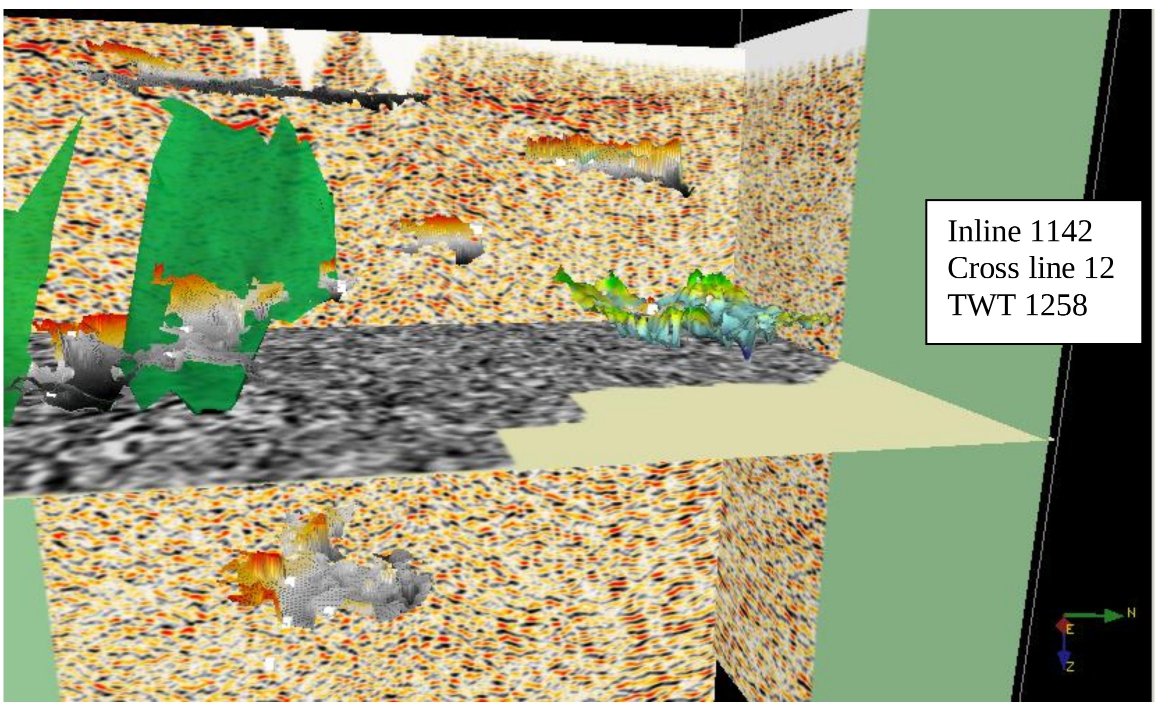




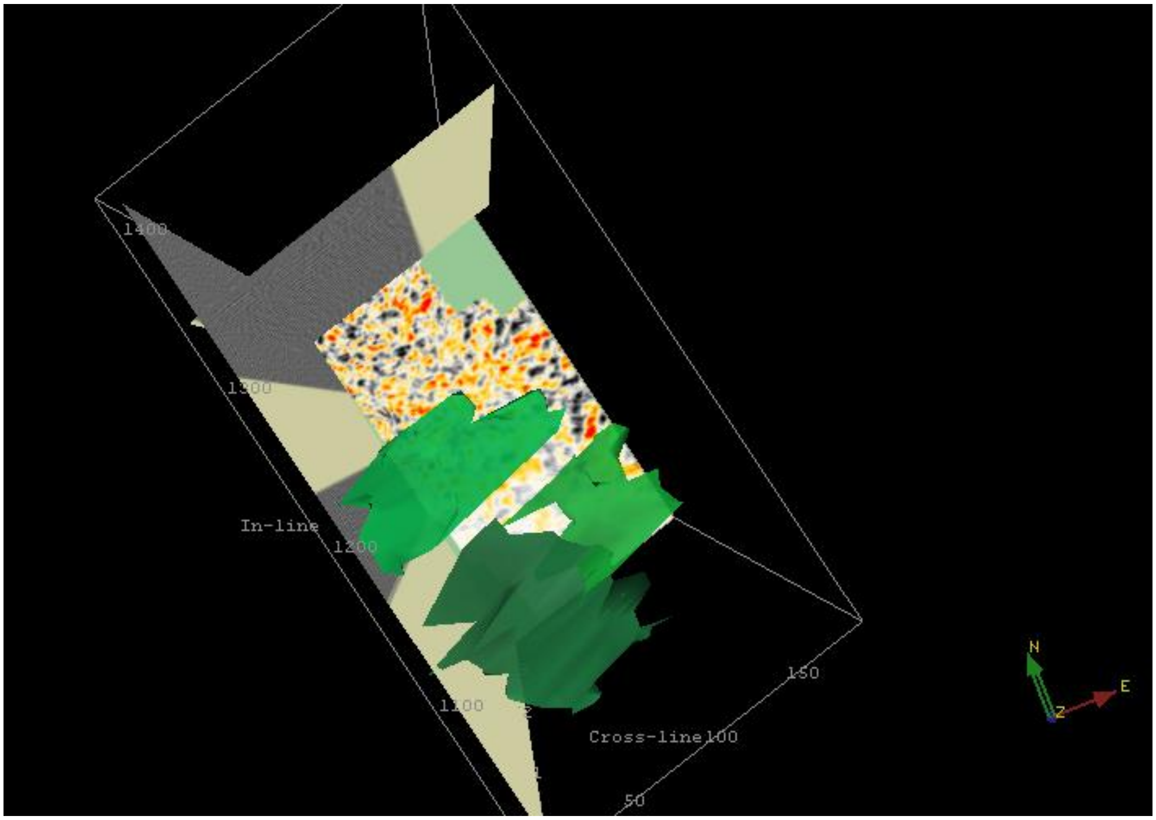
Though some horizons are able to track across the volume, most track only across small sections. There is more tracking confidence within the smaller sections as the horizons display much less variability in time. It is unclear as to whether the tracked strata display vertical offsets due to faulting or whether the program is tracking between two horizons. Despite these uncertainties, it is noted that horizons beginning from seeds located in different points in the volume track the same features.

Intersections of Faults With Stratigraphic Horizons



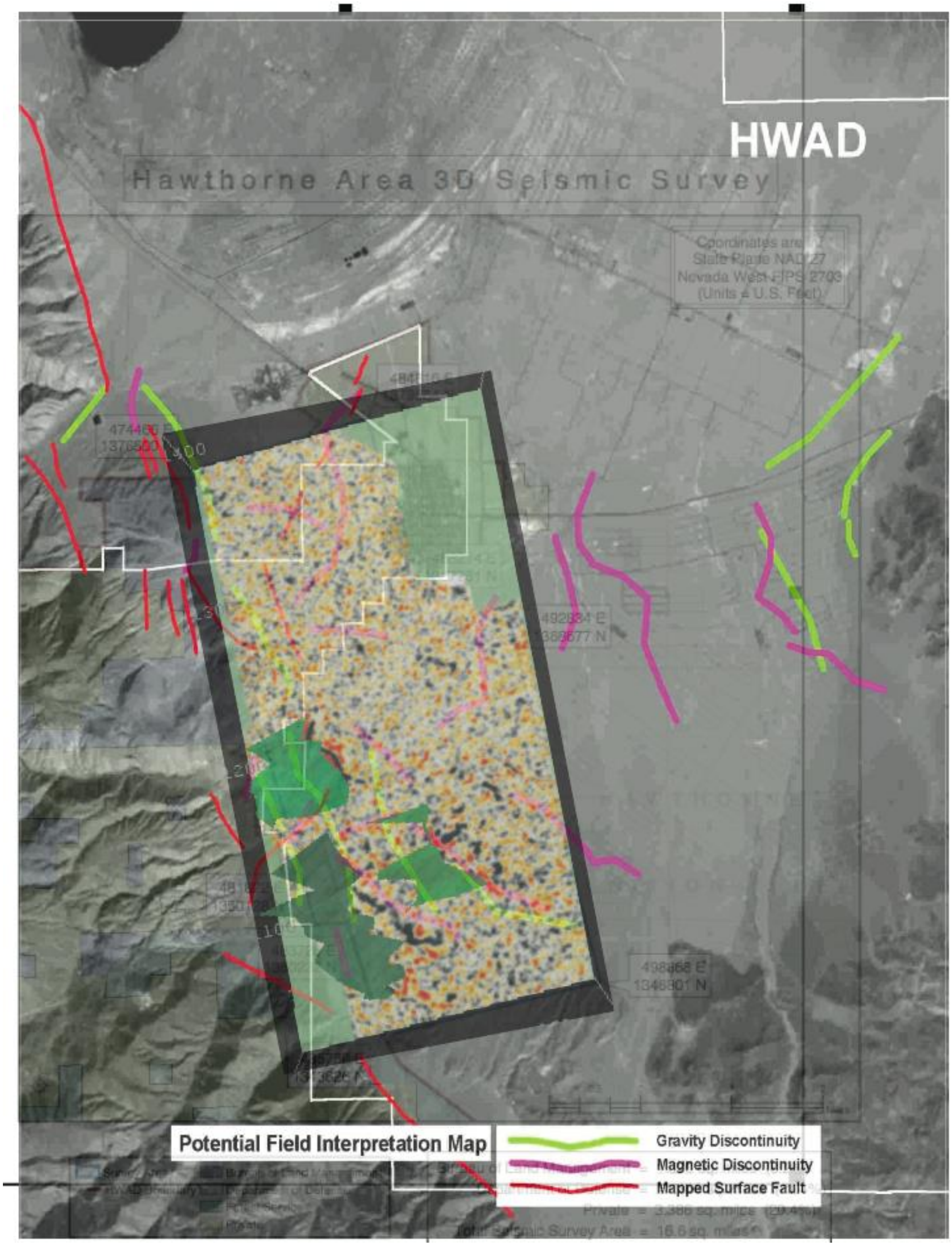


There is coherency in tracked strata in the range of 400-500 ms, which would correspond with the volcanic sediments in the upper basin, and in the range of 1100-1200 ms. With a migration velocity of 8000 ft/s, 1100 ms corresponds to a depth of 4400 ft.



Potential drill targets and areas of development are defined within Dawson's PSTM data volume by the intersections of the fault surfaces with the tracked, strong stratigraphic reflections. Most of these reflections likely represent interfaces between clastic sediment and fractured volcanic flows within the basin pile. At other geothermal prospects in the Great Basin, comprehensive prestack depth migration of specially-designed seismic data sets reveal highly reflective fault surfaces below their intersections with the strong stratigraphic reflections. Such seismically reflective faults are likely to be conduits for hot fluid rising from greater depths, and have recently been successfully developed in Nevada.

In Dawson's Hawthorne PSTM data set, the fault reflections can only be located within certain boundaries, and not all strong stratigraphic reflections were imaged clearly. Thus, the most promising drill targets are not points or lines (where a sharp fault intersects a sharp stratigraphic bright spot), but are volumes. The target volumes are bounded by the fault uncertainty bounds, and by the bright-spot uncertainty bounds. There are a few such intersections present within the 3d volume. Their locations are coded within the OpendTect database.



This image is an overlay of the survey area with previously mapped discontinuities. The spatial fit is not exact but it is apparent that there are matches between the multiple study types. The three faults we interpreted also appear as gradients in the geophysical potential-field maps.

Exporting structure contour maps in time, “isochron” maps, of the imaged structures from the OpendTect database will also allow location of these target volumes. Because the data were processed only to prestack time migration (PSTM) stage, and not to the prestack depth migration stage, vertical two-way travel times to structures and horizons will be accurate. However, not enough is known about the (usually large) spatial variations in rock velocities across the prospect, for any depths computed from travel times to have uncertainties below ±20%. This accuracy can only be improved through comprehensive prestack depth migration (PSDM) after SeisOpt® @3D™ velocity determination on the raw field data.