New Water Opportunities, Shirts Canyon

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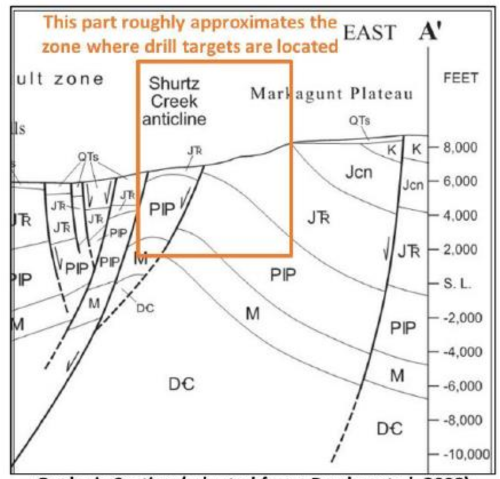
Introduction

The 30 November 2023 Willowstick report (Project No. 23565) identifies 4 potential drilling sites: A & D on BLM land, B on John G. Middleton Living Trust Land, and C on Shurtz Canyon Ranch LLC (Location D in text on page 15 of the report). This report did not consider results from the Dynamic Measurement Lightning Analysis. Proposed wells A, C, and D are within the Lightning Analysis area. The fourth proposed well, B, is just outside of the Lightning study area.

Figure 10 from the report (copied as Figure 1) shows the drill targets are on top of the “Schurtz Creek Anticline.” Since water flows downhill, without a hydrostatic pressure driving force, the top of an anticline is not a good water exploration target area. Also, the faults to the west of the anticline could be interpreted as a flower structure on top of the orange strike-slip fault from lightning analysis.

This note proposes Willowstick be contracted to do one or more additional studies in the area, based on the geologic framework defined by the Lightning Analysis project. Any geologic project needs to start with a tectonic framework for the area of study. Also addressed in this note are Andy McCrea’s comments about strike-slip faults in the Southern Utah (see Figure 2).



Geologic Section (adapted from Rowley et al, 2008)

Figure 1. Shirts Canyon Anticline

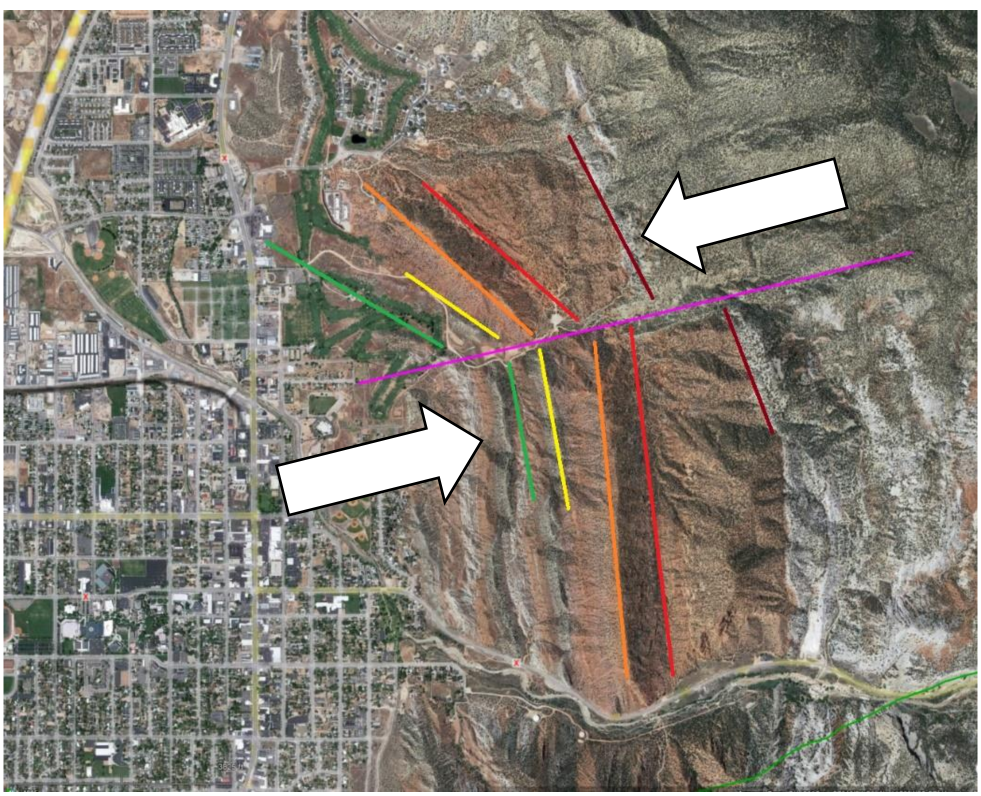


Figure 2. Strike-Slip Fault by the Cedar Golf Course mapped from air photo.

Claron Formation

One of the prominent geological formations in Southern Utah is the Claron Formation. This is the formation is famous for outcropping at Cedar Breaks National Monument and Bryce Canyon National Park. The Claron Formation consists of massive quantities of lakebed sediments deposited over 20 million years, from about 60 to 40 million years ago (see Figure 3).

During this time meandering streams and a large system of shallow but expansive lakes and associated deltas covered several thousand square miles of the now northwest Colorado and southwest Utah and Wyoming. The Cretaceous Seaway had already retreated to the east and south. The meandering stream and lake sediments later lithified into the up-to-700-foot-thick Pink Member of the locally Eocene-aged Claron Formation. Again, the Claron outcrops at Bryce Canyon, Strawberry Point, Cascade Falls, Cedar Breaks National Monument, near Kanarraville, the red hill past the first uplifted fractured quartz-monzonite north of and west on Highway 56 (where the name Claron was first applied), and at Pinto, Utah.

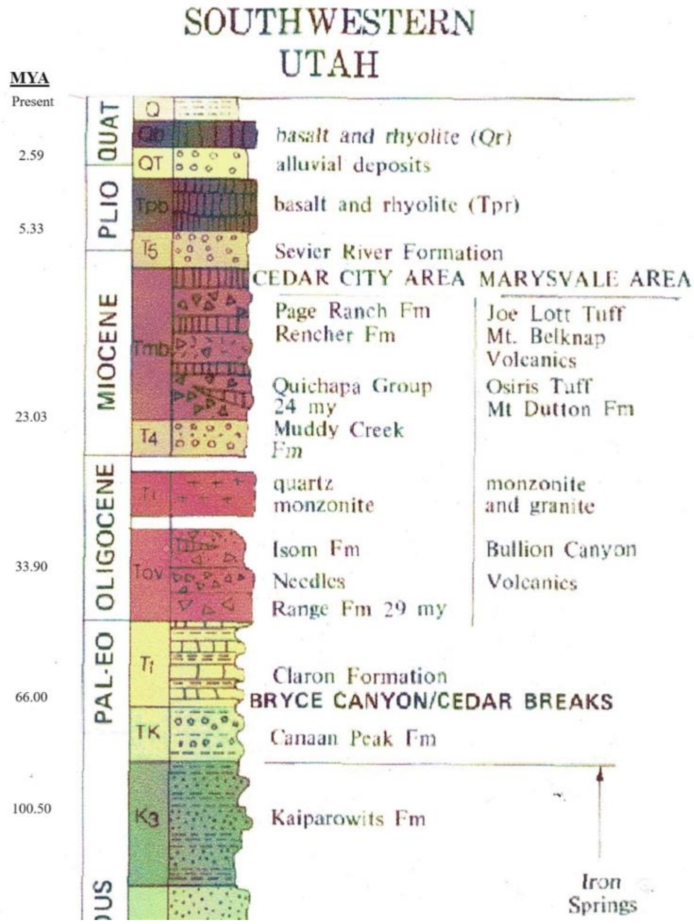


Figure 3. Last 100 million years of geology in SW Utah.

These wide-spread pink lake-bed outcrops, now on both sides of the Hurricane Fault, were originally all at the top of the mountains created by the Laramide Orogeny and the Sevier Orogeny. The area between the Sierra Nevada's and Cedar Mountain reversed from compression to extensional tectonics about 17 million years ago, in the early Miocene. While the San Andreas Fault began to form in the mid-Cenozoic Geologic Era, about 30 million years ago, the first documented portion of the southern San Andreas was 22-13 million years ago. The San Andreas converted compression from the Pacific Plate and related plates against the North American Plate into the extension, forming the Great Basin. Extension resulted in the Hurricane and related fault system, which range from Calgary to Mexico City. In the Cedar City area, there is about 0.2 mm per year movement on the Hurricane Fault. This is 0.00787402 inches per year, which over 17 million years could be up to 11,154 feet of drop of Claron outcrops from one side of the Hurricane Fault to the other. The fault throw at Cedar City is about 5,000 feet, which is the largest drop along the eastern edge of the Great Basin.

Compression

For 100 million years before expansion of the Great Basin began, the area was under compression. This is well documented with overthrust oil and gas fields in Central and Northern Utah. It is less well known the north-south mountains in Nevada are largely overthrusts, and not horst and graben mountains, as was taught at the University of Utah in the 1960's and 1970's.

Compression causes rock layers to fold, and if the compression is enough, to fold over and to become an overthrust. A very nice example of these folds is the folding of Cretaceous layers of rock exposed by the Fiddler's Canyon incised valley, just to the north of Cedar City. This compression is not consistent along the horizontal axes of folds for more than a few miles. Since some areas along the main axis of the fold receive more pressure from the compression than others, they will move more. This additional movement is offset by strike-slip faults. These are very hard to recognize and to interpret. However, in a basin that was under compression during most of its creation, strike-slip faults are much more common than is generally recognized.

Figure 4 shows compression on the North American plate from 175 million years ago to 30 million years ago. The strike-slip movement of Baja British Columbia and Chugach Terrane northward about 2,000 miles along the Baja B.C. Fault was only recently recognized. These diagrams do not begin to illustrate all the other compression resulting east-west strike-slip faults.

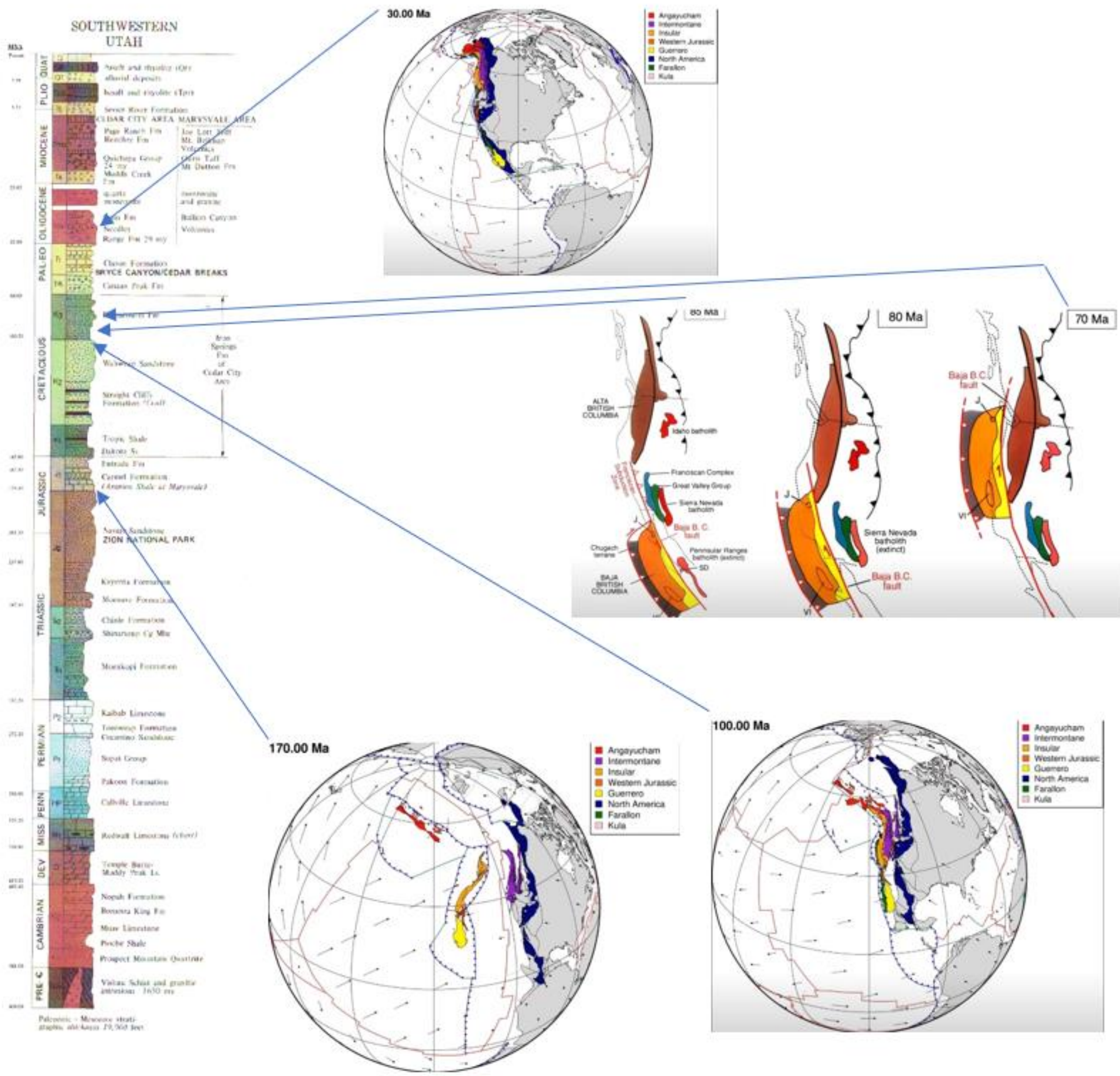


Figure 4. Compression of North America: Pacific Plate against the North American Plate (https://www.youtube.com/watch?v=I9Xk1O17dzg, Nick Zentner)

We know this compression associated with the mountain building of both the Laramide Orogeny, and the Sevier Orogeny was the source of major tectonic changes in Southern Utah. These implications are evident on topographic maps, such as Figure 5.

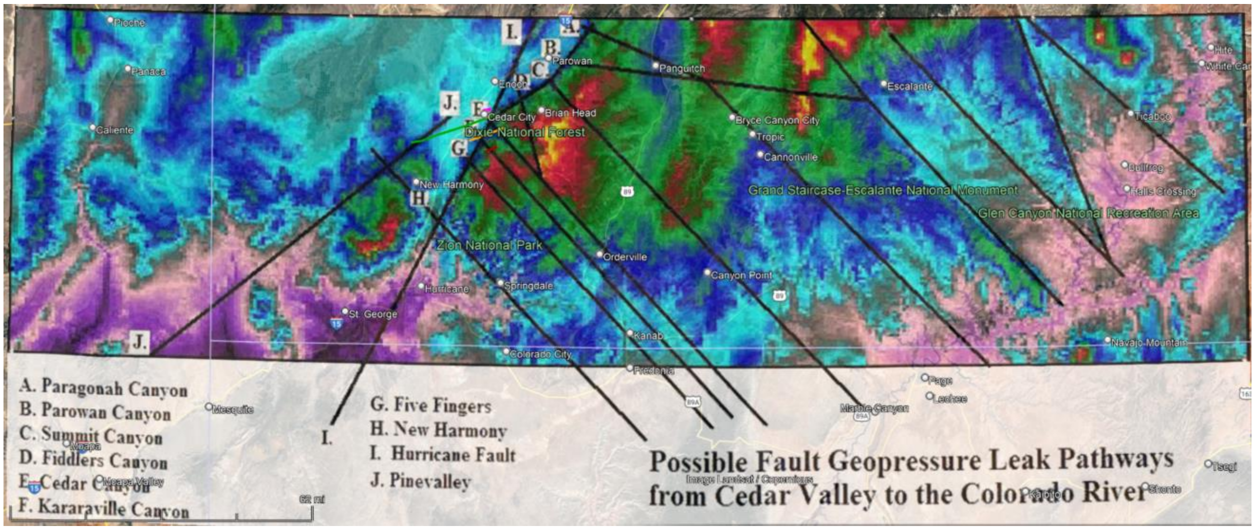


Figure 5. Large tectonic derived faults both along and parallel to and the Hurricane Fault appear to be the driving forces and framework for creation of canyons in southwestern Utah. This image was created to illustrate how these large regional faults could be leakage point, explaining why the Southern Great Basin has lower than normal hydrostatic pressure. Water is moving out of the basin along these fault lines to the Colorado River in the Grand Canyon.

Shirts Canyon and Harmony Hills Lightning Analysis

The Lightning Analysis prepared for and shared with Cedar City by Willowstick, identified three previously unrecognized strike-slip faults. The 20 July 2022 report, "Cedar Vally Water Initial Interpretation" was placed on-line for review by the Central Iron County Water Conservancy District at dynamicmeasurement.com/220720_CICWCD/220719_DML_Interpretation_Cedar_Valley_CICWCD.pdf. Figure 6 shows depth-slices through both the Harmony Hills and the Shirts Canyon SPOT[sm] Lightning Analyses.

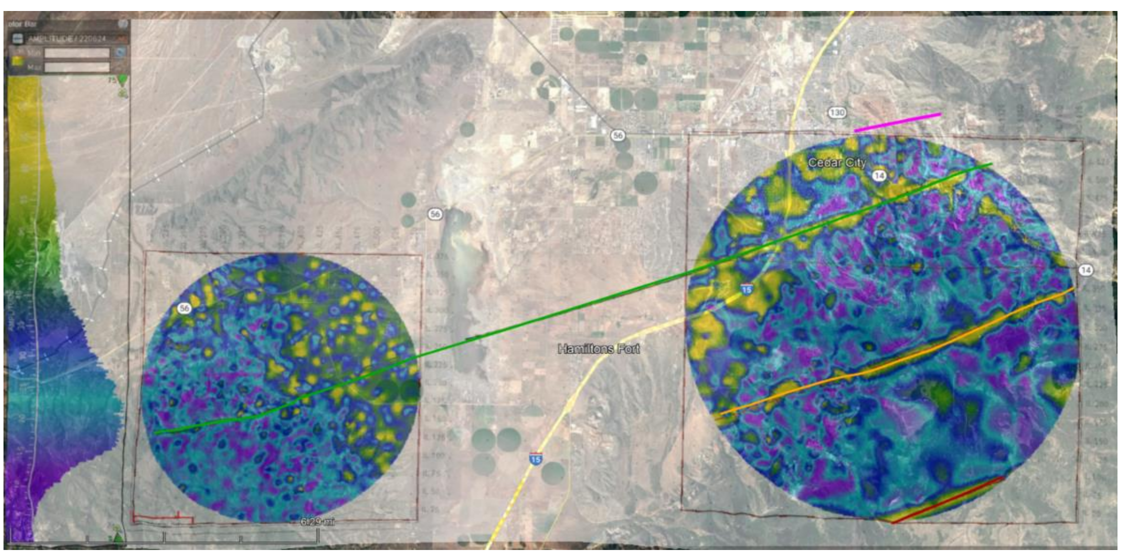


Figure 6. Depth-Slices through the Harmony Hills & Shirts Canyon lightning derived Symmetry Volumes, with interpretation of 3 strike-slip faults and the fourth Cedar Golf Course strike-slip fault.

Strike-Slip Faults

There are several examples of thrust faulting in the Cedar City area, as shown in Figure 7. Whenever you have this much thrusting along this long of a fold axis, with different amounts of thrusting at each outcrop, there will be strike-slip faults between the areas of consistent compression or thrusting. The amount of movement along these thrust faults will vary as a function of the amount of compression and movement along the strike-slip faults. Four different outcrop examples are shown: (1) the Cedar Canyon Back Thrust (A-A' and A-A'-A''); (2) the Spring Canyon Thrust (B'-B); and (3) the Taylor Creek Thrust (C-C'); and (4) the Cedar Golf Course Thrust (in map view).

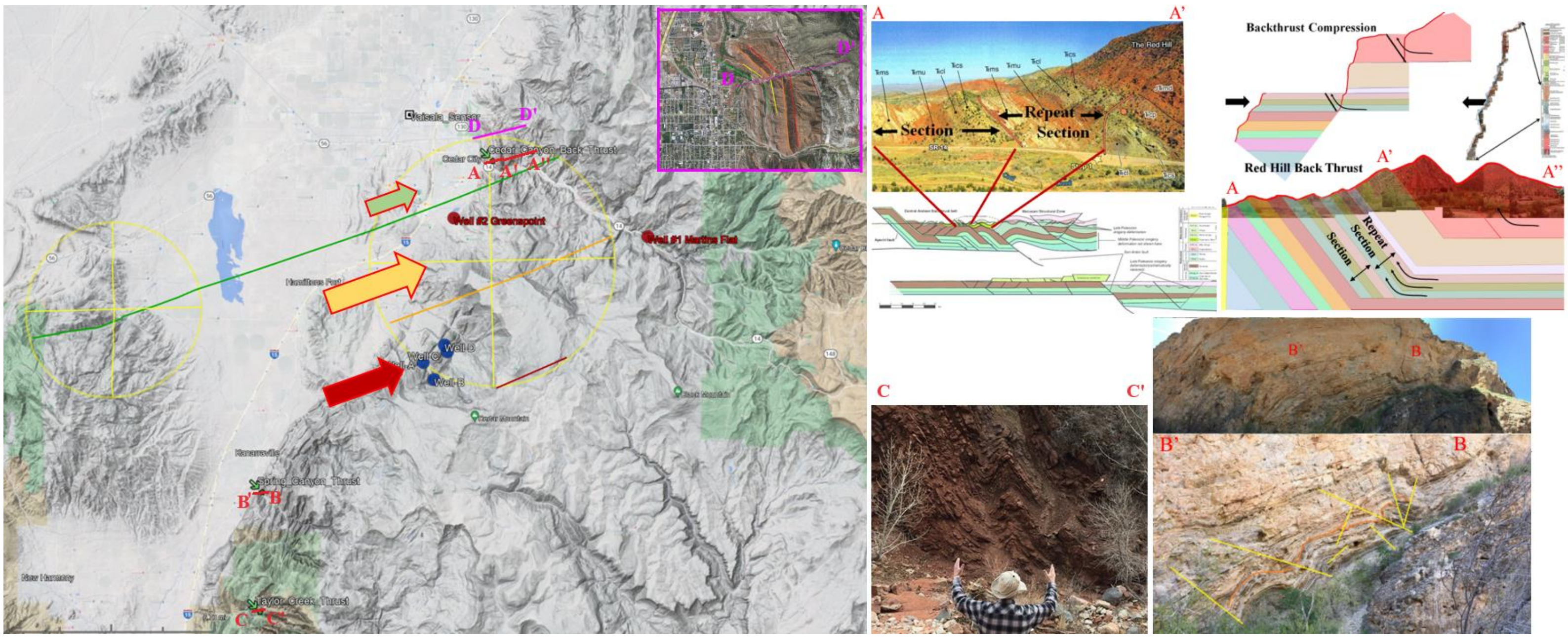


Figure 7. Thrust Outcrops in canyons cutting the Hurricane Fault Outcrop. A-A' and A-A'-A'' are an outcrop photo and an outcrop diagram showing the Back Thrust at the mouth of Cedar Canyon. B-B' shows an overall and a close-up photo of thrusting in Spring Canyon at the south end of Kanarraville. The C-C' thrust example is along the Taylor Creek hike inside the Kolob portion of Zion National Park. The D-D' thrust example from satellite view at the Cedar City Golf Course. In addition, the location of the well at Greenspoint and the well at Martin's Flat are shown, along with Proposed Wells A, B, C, and D in Shirts Canyon. Lastly, the location of Vaisala's lightning sensor at the Cedar City Airport is shown.

Interpretation Factors

In two of Dynamic's first regional lightning analysis projects, we found there can be feedback between Vaisala sensors. In the spirit of full disclosure, we shared this information with Willowstick, who became concerned with the viability of our data. This noise train resulted in a line of shallow noise along the line connecting lightning sensors in both North Dakota and South Texas. The noise in these two examples looks somewhat like the anomalous data interpreted as strike-slip faults in the Shirts Canyon lightning analysis.

However, The Vaisala sensor in Cedar Valley is north of the study area, and orthogonal to the strike-slip fault interpretations. The more we have looked at this data, the more it shows the results represent geological anomalies. The strike-slip fault interpretation is the best interpretation fitting the data. The only interpreted strike-slip lineament impacting the new proposed well locations is the Orange Lineament, approximately through the center of the Shirts Canyon SPOT^{sm}. This spatial relationship highlighted in Figure 8.

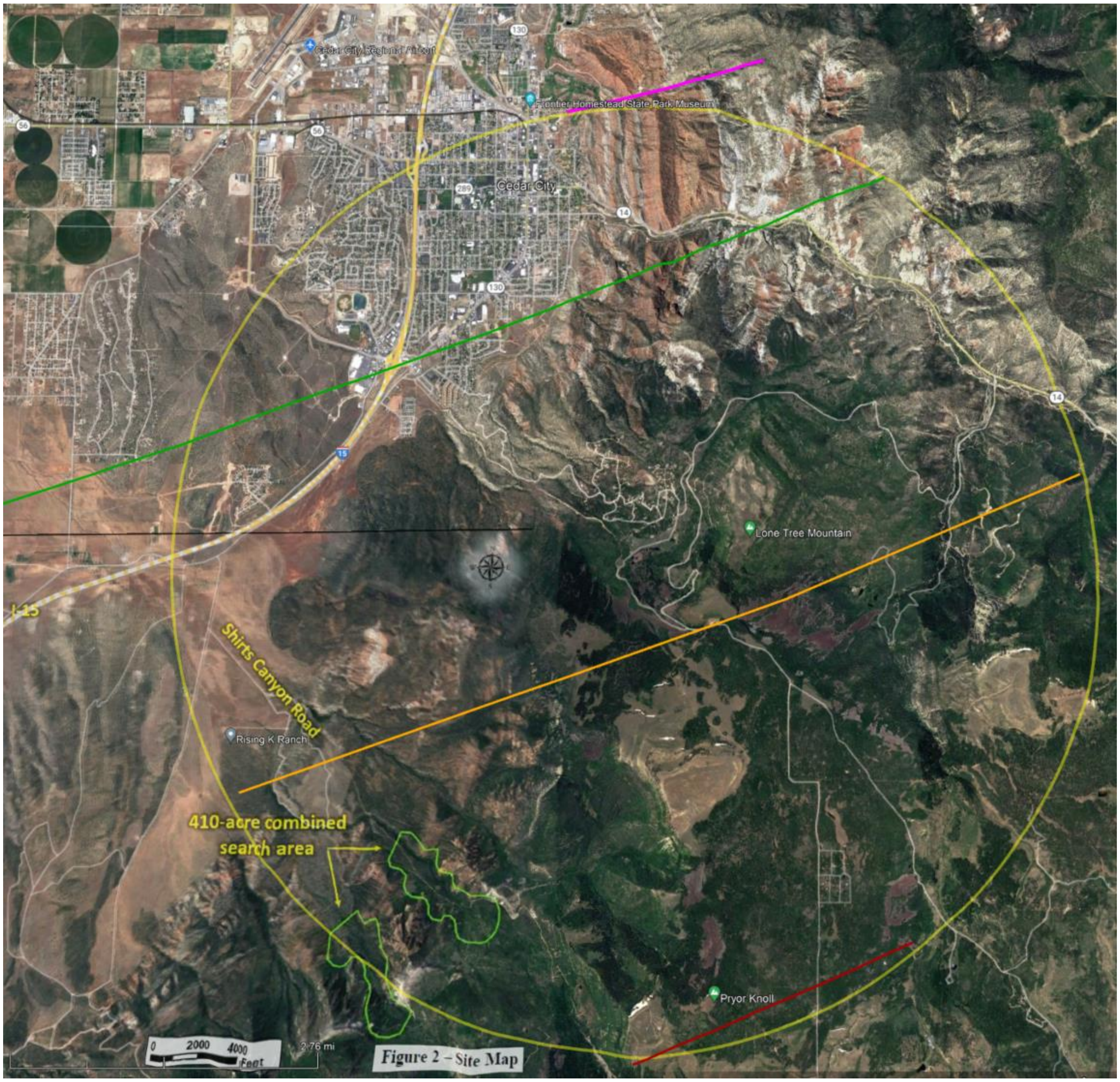


Figure 8. The two new search areas in Shirts Canyon (green outlines) and the location of the orange interpreted strike-slip fault (along with the Cedar Golf Course interpreted strike-slip fault, the Cedar Canyon interpreted strike-slip fault, and the Southern interpreted strike-slip fault.

Location of Willowstick Shirts Canyon Geophysical Investigation

In the initial project Willowstick only did their geophysical investigation where Cedar City owned the property. The logic was, that if they used the geological framework provided by the lightning analysis, it could get landowners excited about potential drilling sites, and raise the price of drilling and of water. This is a political consideration, which is best kept separate from a scientific investigation.

The Shirts Canyon investigation was different, and Willowstick still did not use the Shirts Canyon Lightning Analysis. Two small subbasins associated with the Shirts Canyon Anticline were identified through “a brief desktop study of the area,” including “geology, faulting, lineaments from imagery and LiDAR topography, and available well data.” None of the 4 potential drilling sites are on city property.

Proposed wells A & D are on BLM land, B is on John G. Middleton Living Trust Land, and C is on Shurtz Canyon Ranch LLC (Location D in text on page 15 of Willowstick Report). Figure 9 shows the location of the four proposed wells relative to the orange strike-slip fault interpretation from the Lightning Analysis Project.

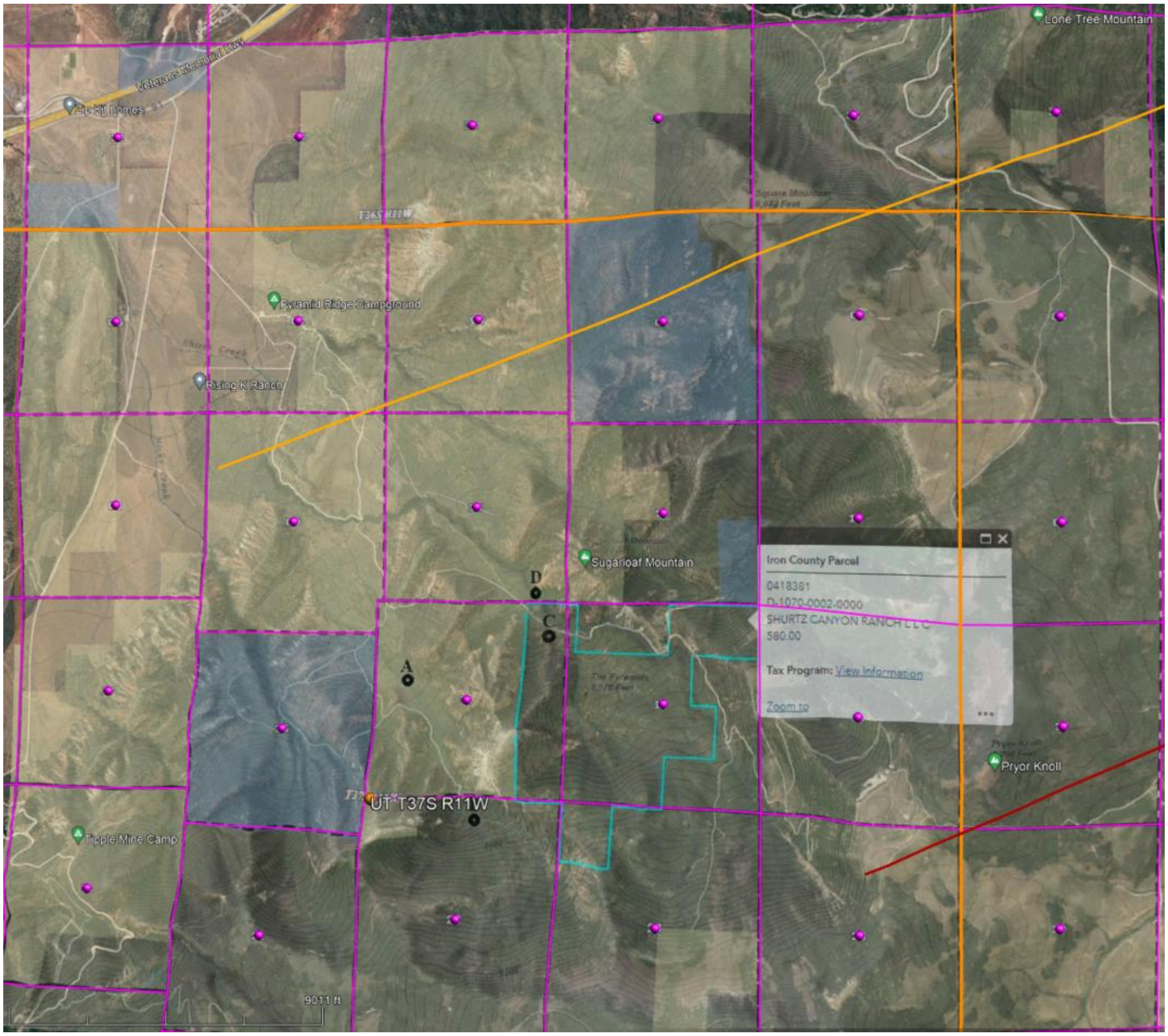
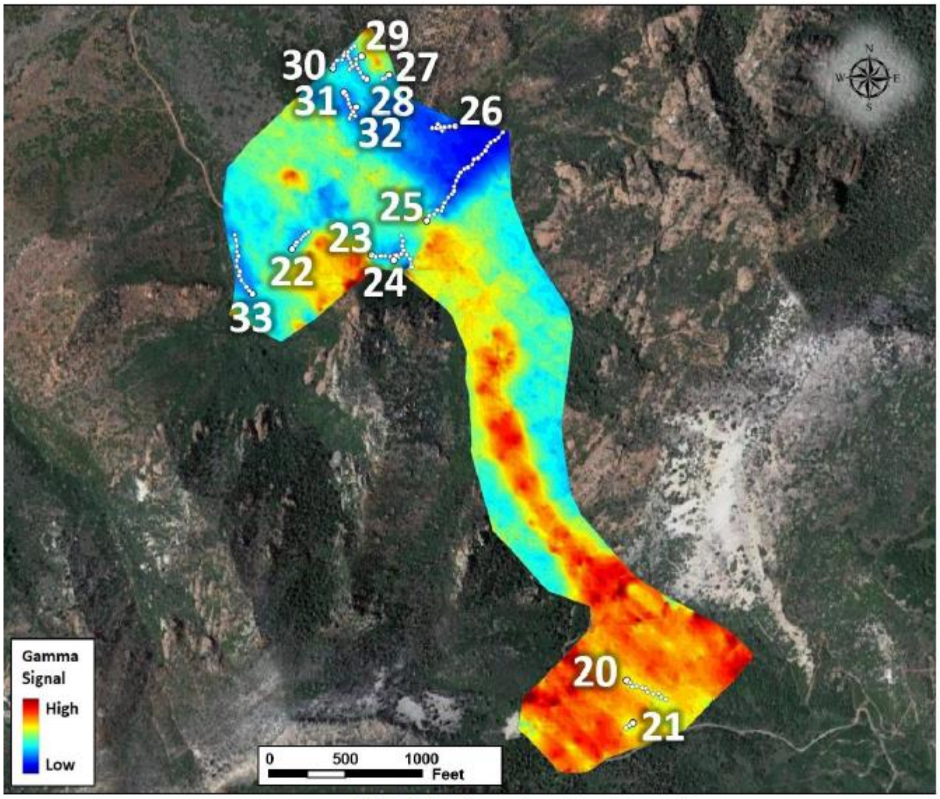


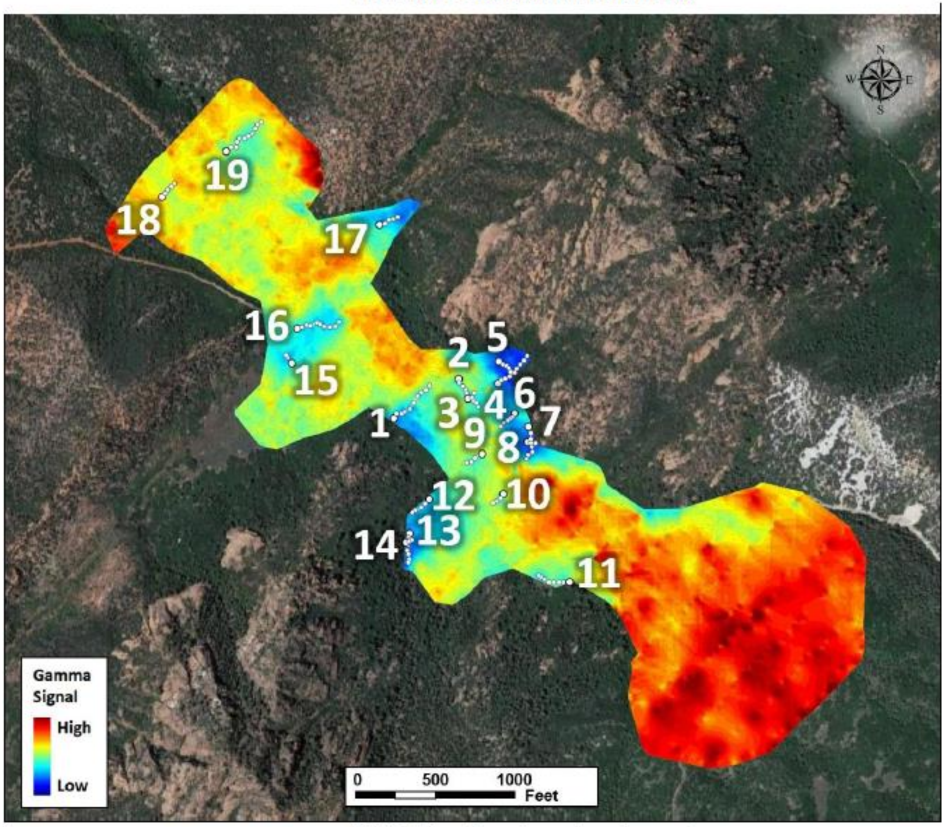
Figure 9. The location of proposed Well A and Well D on BLM Land (tan color); Well C on Shurtz Canyon Ranch LLC (outlined in cyan); and Well D on John G. Middleton Living Trust Land (and outside of the original Lightning Analysis SPOT[sm].

Geophysical Data Results

The MSR Results from Willowstick, and the Apparent Resistivity from Dynamic Measurement match in the same way the initial locations Willowstick developed matched. Figure 10 shows MSR Line locations overlaid on the Gama Signal results. Figure 11 is the MSR results for the four proposed drill targets. Figure 12 shows Apparent Resistivity across the locations. High resistivity (yellows and reds) imply water filled sediments. Figure 13 is a scaled integration of MSR Results and Lightning Apparent Resistivity results. Quoting from the Willowstick report: "In alluvial (valley) drilling, high porosity zones are important to groundwater storage and production. In consolidated bedrock formations, open fracture systems are crucial. Another term for it is fracture networks or high fracture-porosity networks."

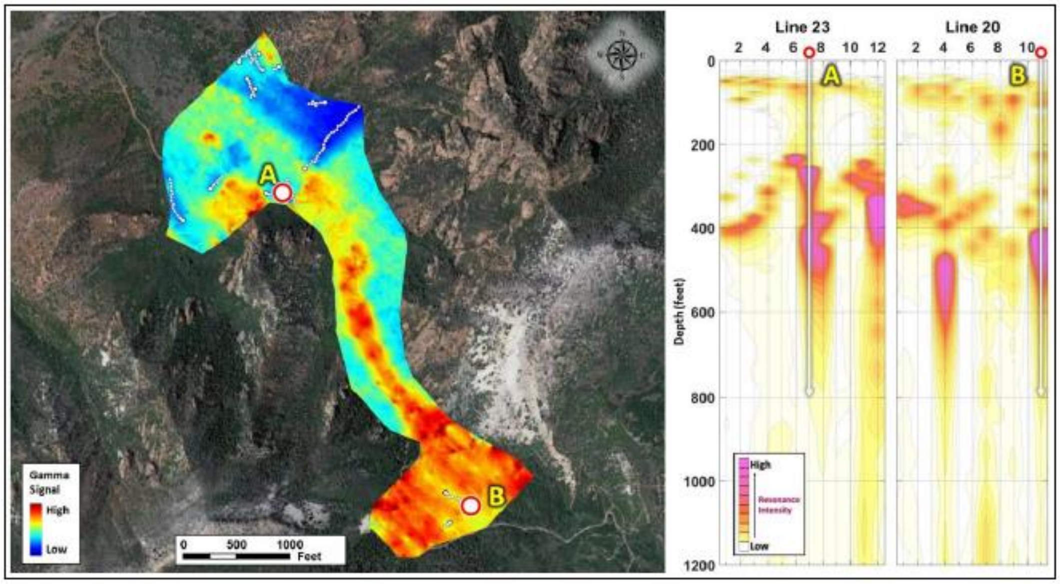


MSR Line Locations (south area)

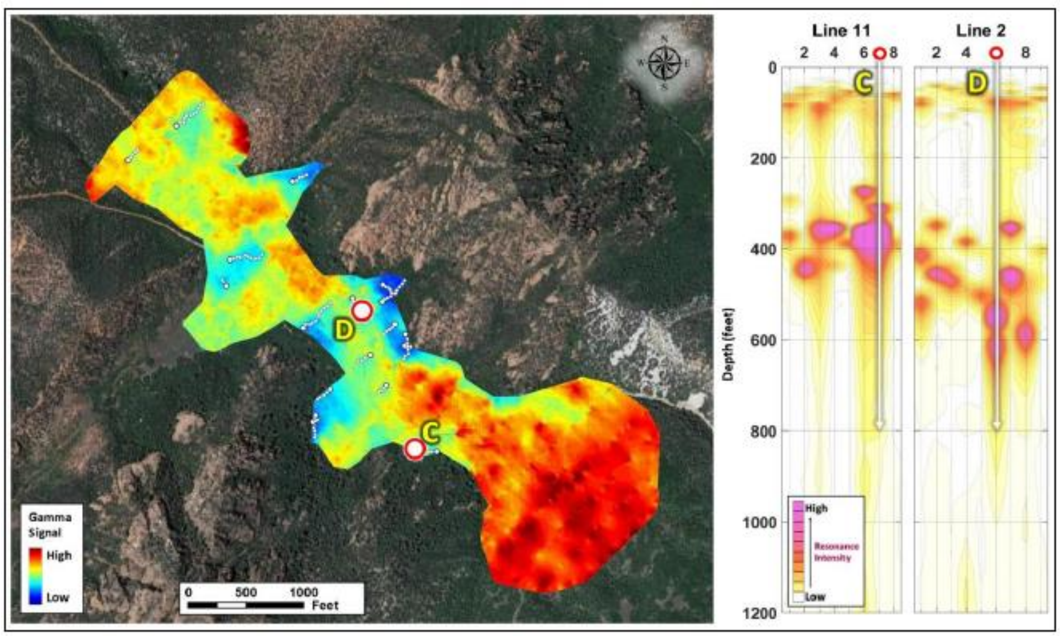


MSR Line Locations (north area)

Figure 10. MSR Line Locations overlaid on Gamma Measurements.



MSR results for drill targets A and B (south area)



MSR results for drill targets C and D (north area)

Figure 11. The MSR results for the four proposed drill targets.

A key assumption behind the strike-slip interpretation of the lightning data results is that the pressures associated with breaking rocks along strike-slip lineaments provides a long-lasting open fracture network. This long-lasting fracture network is full of water, which will control the electrical currents and measurements the lightning analysis is based on. These fracture networks provide a “stream” flow path for water from the mountains to faults along the edge of the valley. The Hurricane Fault, by comparison, is a slow growth fault, and movement does not crack open nor create the same type of long-lasting fracture network strike-slip tectonic faults do. In fact, the lightning data does not show where the Hurricane Fault is along the downthrown block forming of Shirts Canyon.

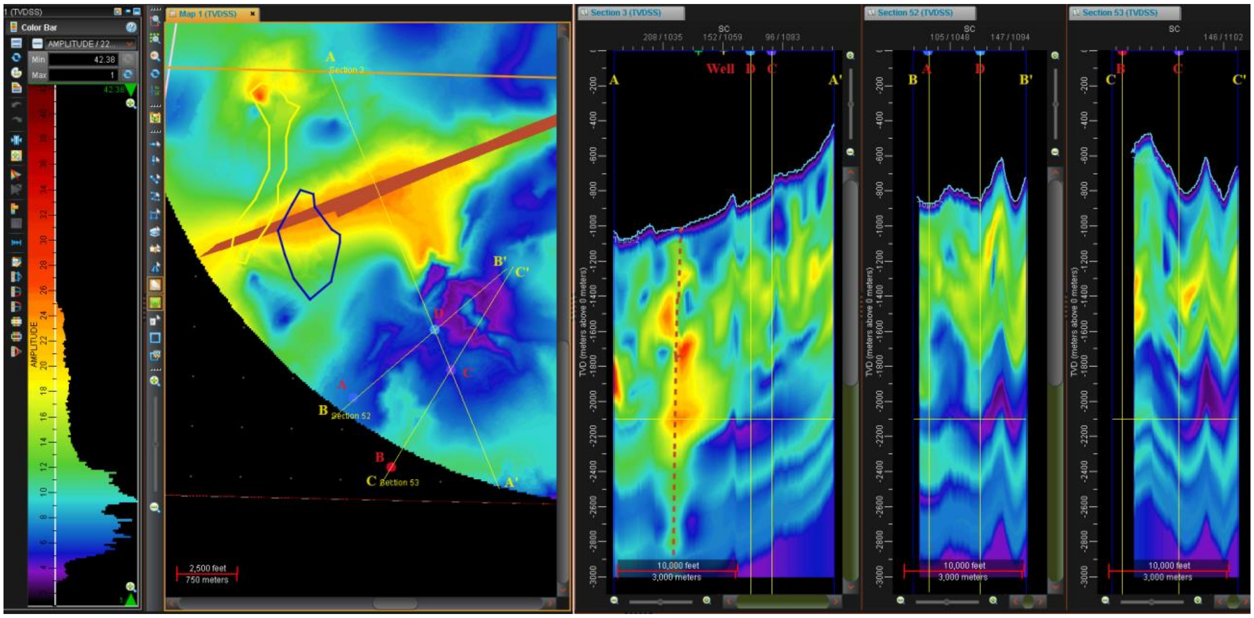


Figure 12. Apparent Resistivity cross-sections across the proposed drilling locations. Note the strongest vertical resistivities (yellow and red colors), along the interpreted orange strike-slip fault, and the fracture network, comes nearest to the surface.

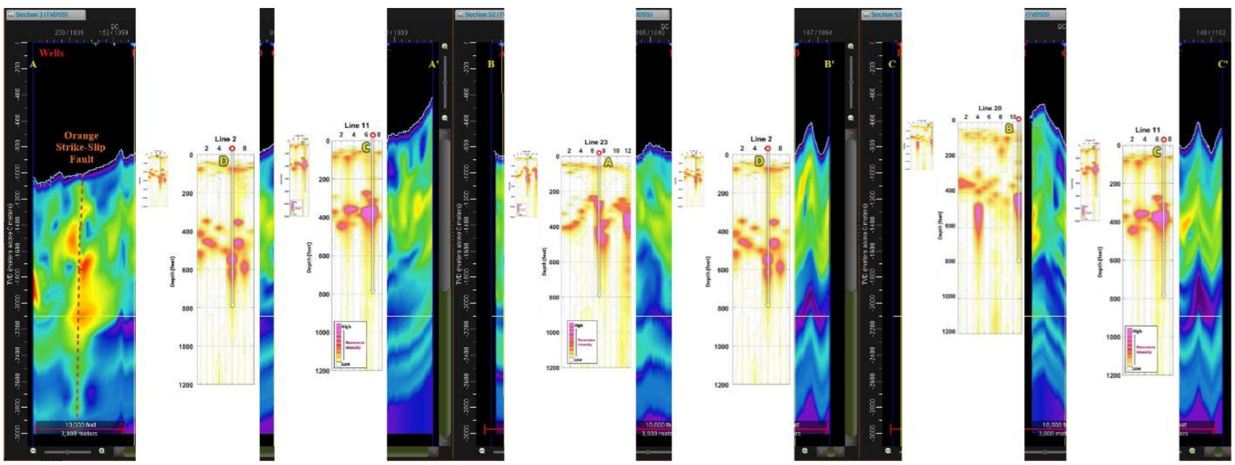


Figure 13. Scaled integration of Lightning Apparent Resistivity Cross-Sections and MSR Cross-Sections. Note the MSR Data is displayed twice, one vertically scaled to math Apparent Resistivity Cross-Sections, and one large enough to be able to see and evaluate the MSR data.

Dynamic Measurement results show, when there is an open fracture network, there are higher resistivities (fresh water increases the resistivity of the rock formations). Lightning analysis provides a much deeper look at geology than MSR or Gamma Ray measurements. The cross-sections confirm shallow fracture networks Willowstick maps. With each well location Willowstick proposed, there is a drop between low resistivity and high resistivity along the cross-section, implying fault planes. These faults are the fracture-networks, which are the basis for the Willowstick proposed locations.

Using the same type of demonstration of lightning analysis results done last time, we can review the lightning analysis results anytime there is interest by someone in the city, or county, or state. This note is not as comprehensive as it could be. Please let us know if there are questions or additional displays which could be useful to Cedar City.

Figure 14, the last example included in this note, shows arbitrary apparent resistivity cross-sections through the proposed wells, and along the orange interpreted strike-slip fault.

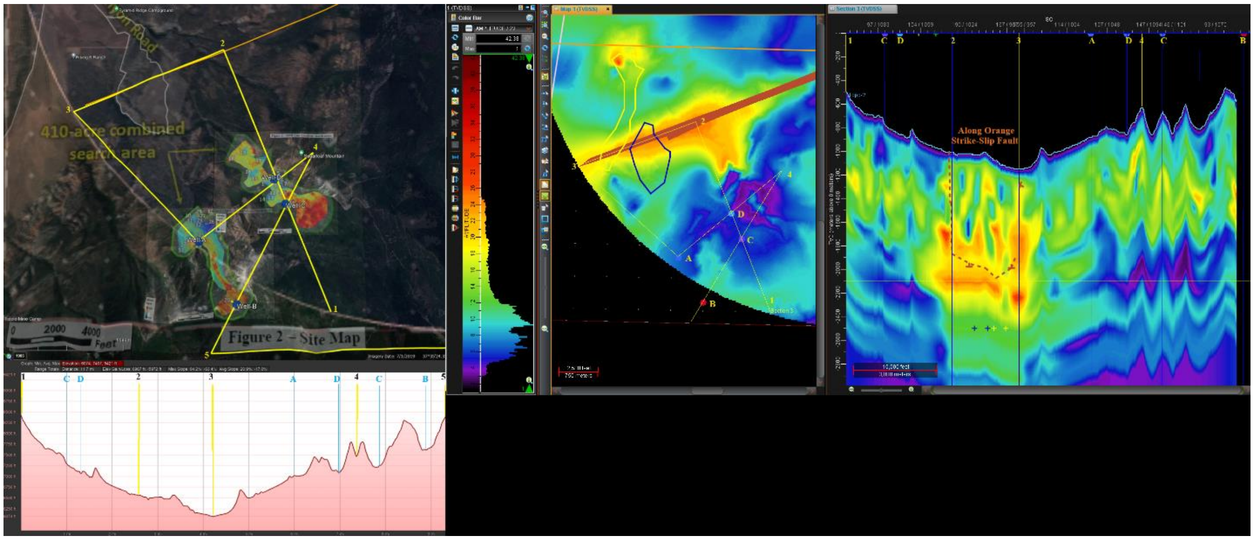


Figure 14. An Arbitrary Apparent Resistivity cross-section starting in the southeast, going through proposed wells C and D to the strike-slip anomaly, then east southeast along the strike-slip anomaly (strong yellows and reds), then back to proposed Well A, proposed Well D, and back southwest through proposed Well C and proposed Well B.

Recommendation

Since Willowstick results have proven out with the well-bore, it makes sense to do one or more additional set of measurements along the interpreted orange strike-slip fault. In the Shirts Canyon area, the strike-slip fault is through BLM land, the same ownership as proposed Well A and proposed Well D. If this strike-slip fault interpretation is correct, wells along this fracture network will be much more successful than the currently proposed wells.

