Geology and Water:
The Framework of Southern Utah

Iron County Historical Society Meeting

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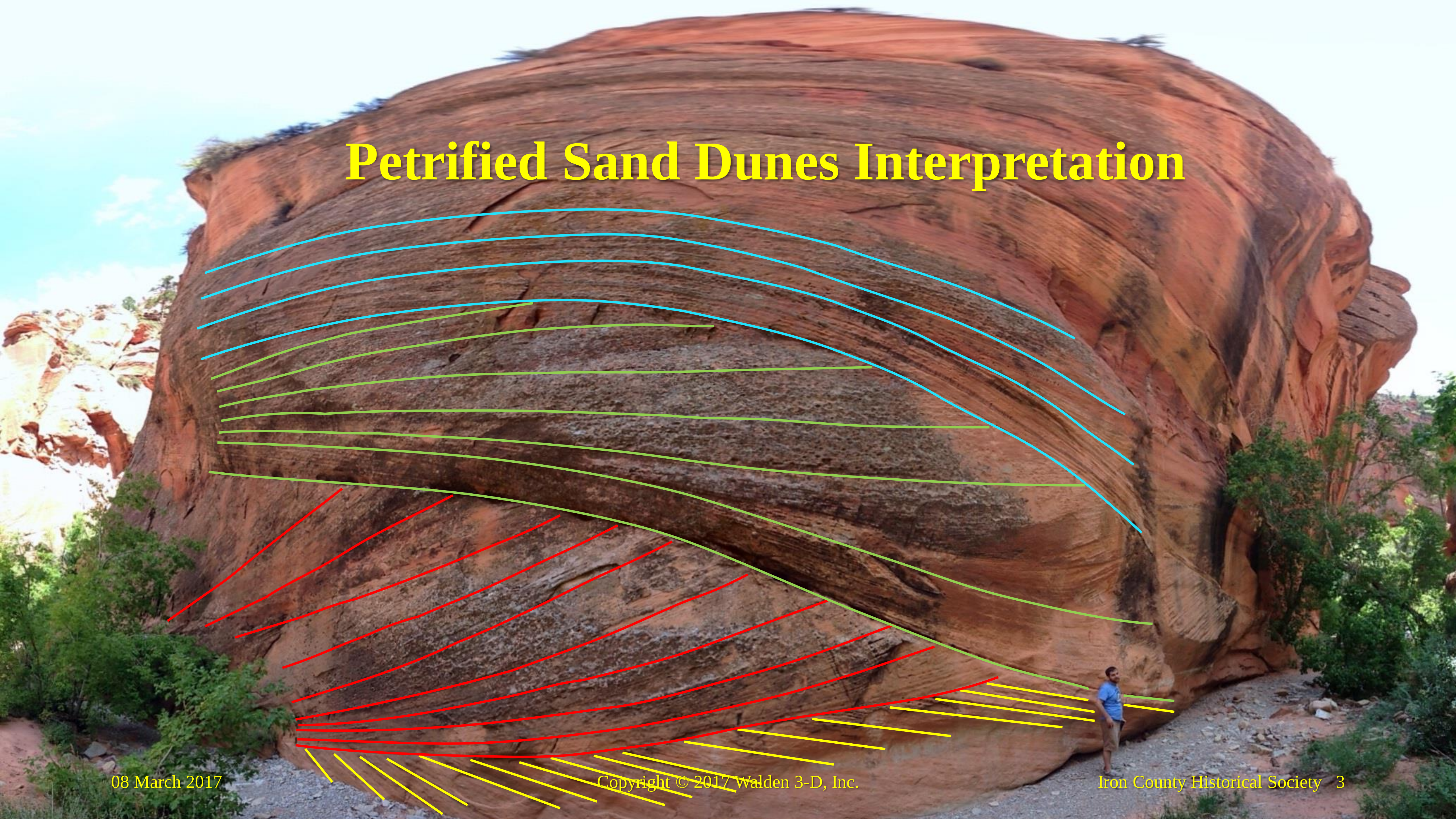
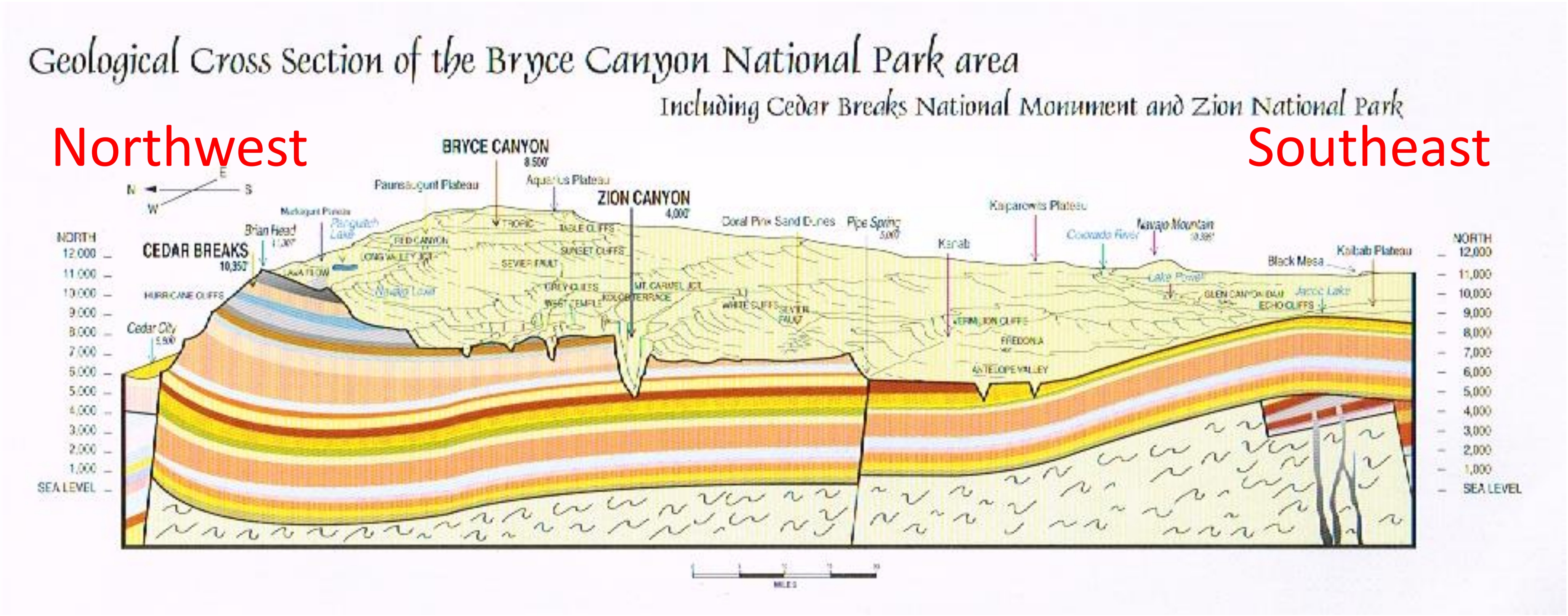
Southern Utah is Geological Heaven

Petrified Sand Dunes at a smaller scale

Petrified Sand Dunes Interpretation

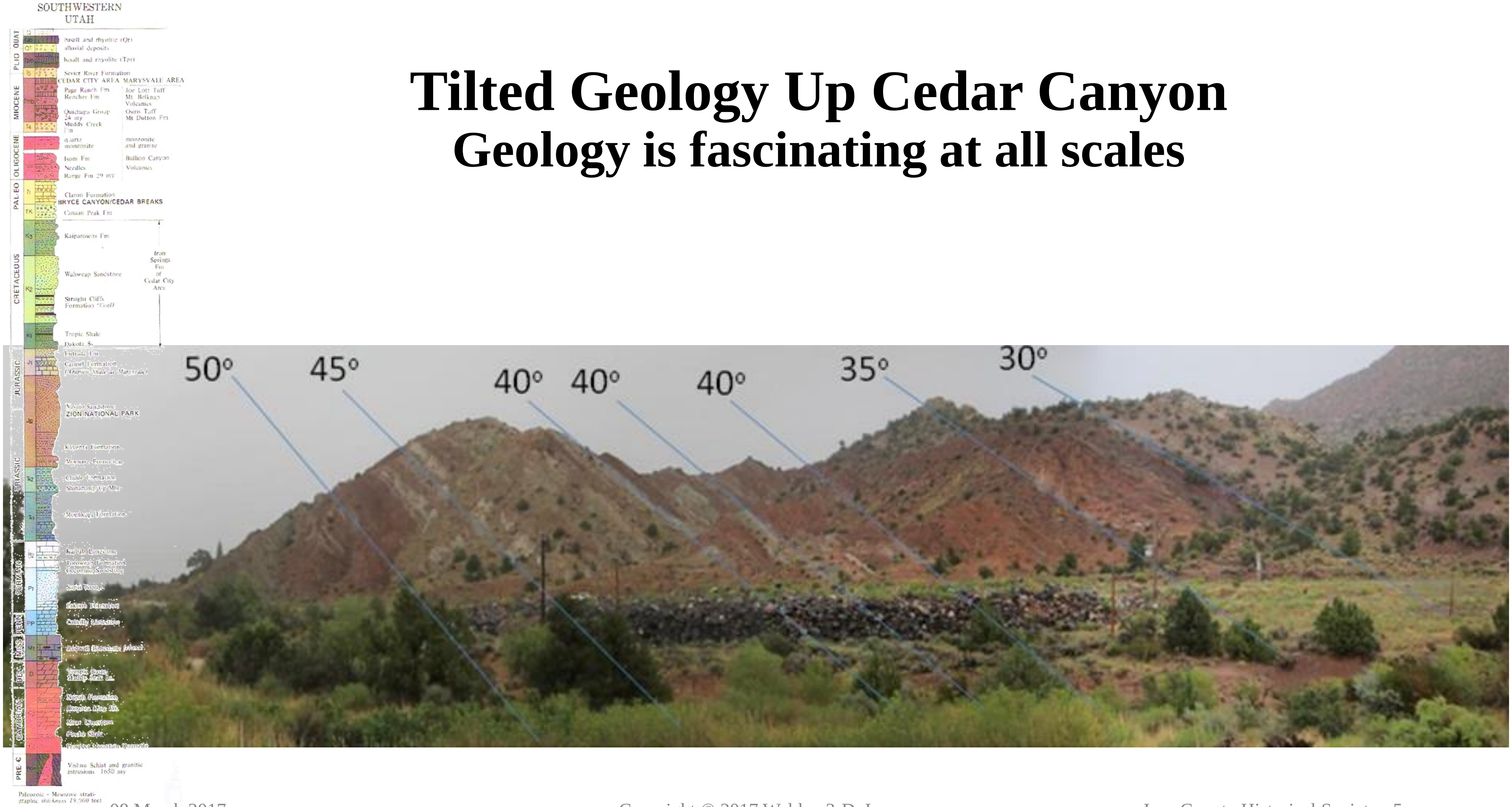


NW to SE Geologic Cross-Section of Southern Utah
at a larger scale

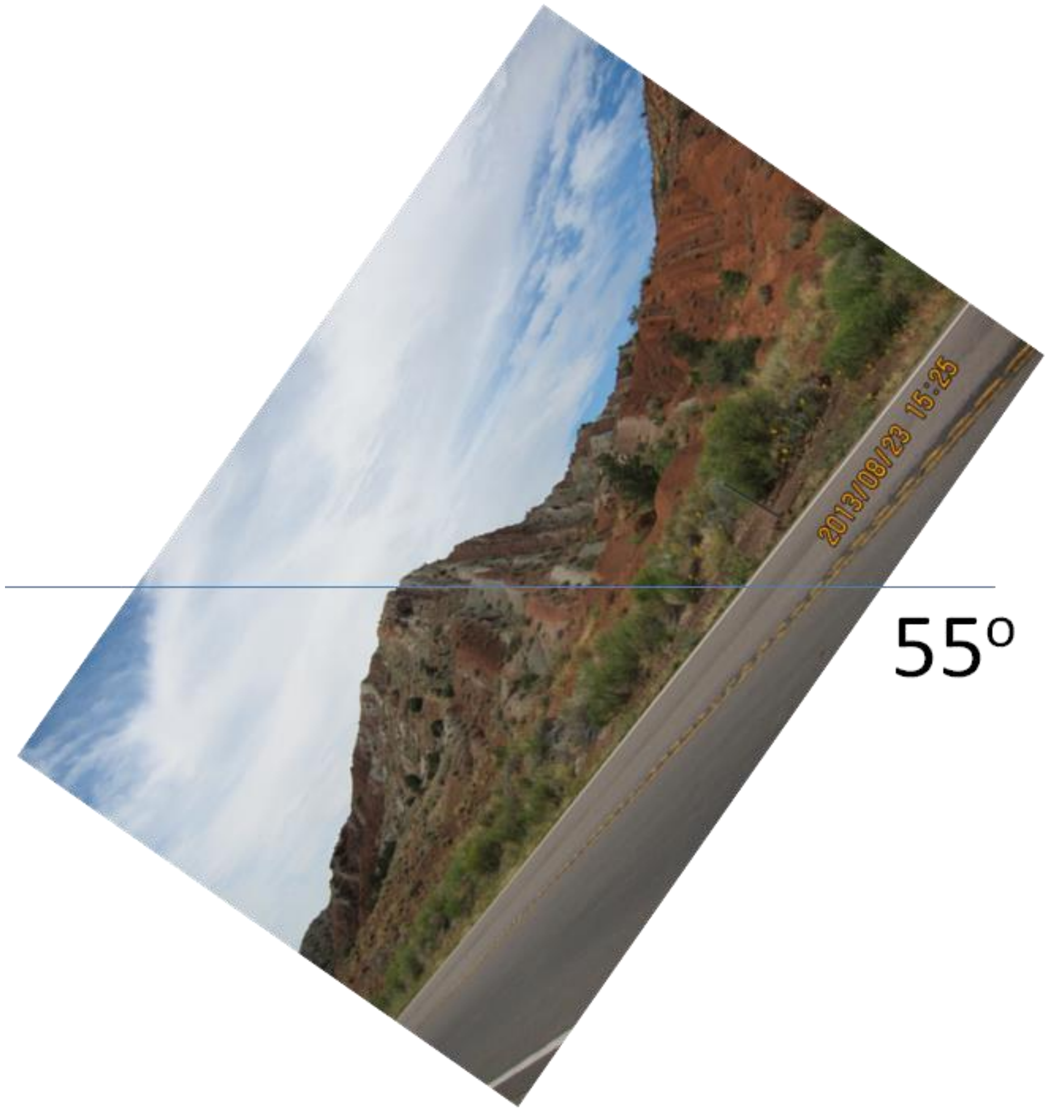


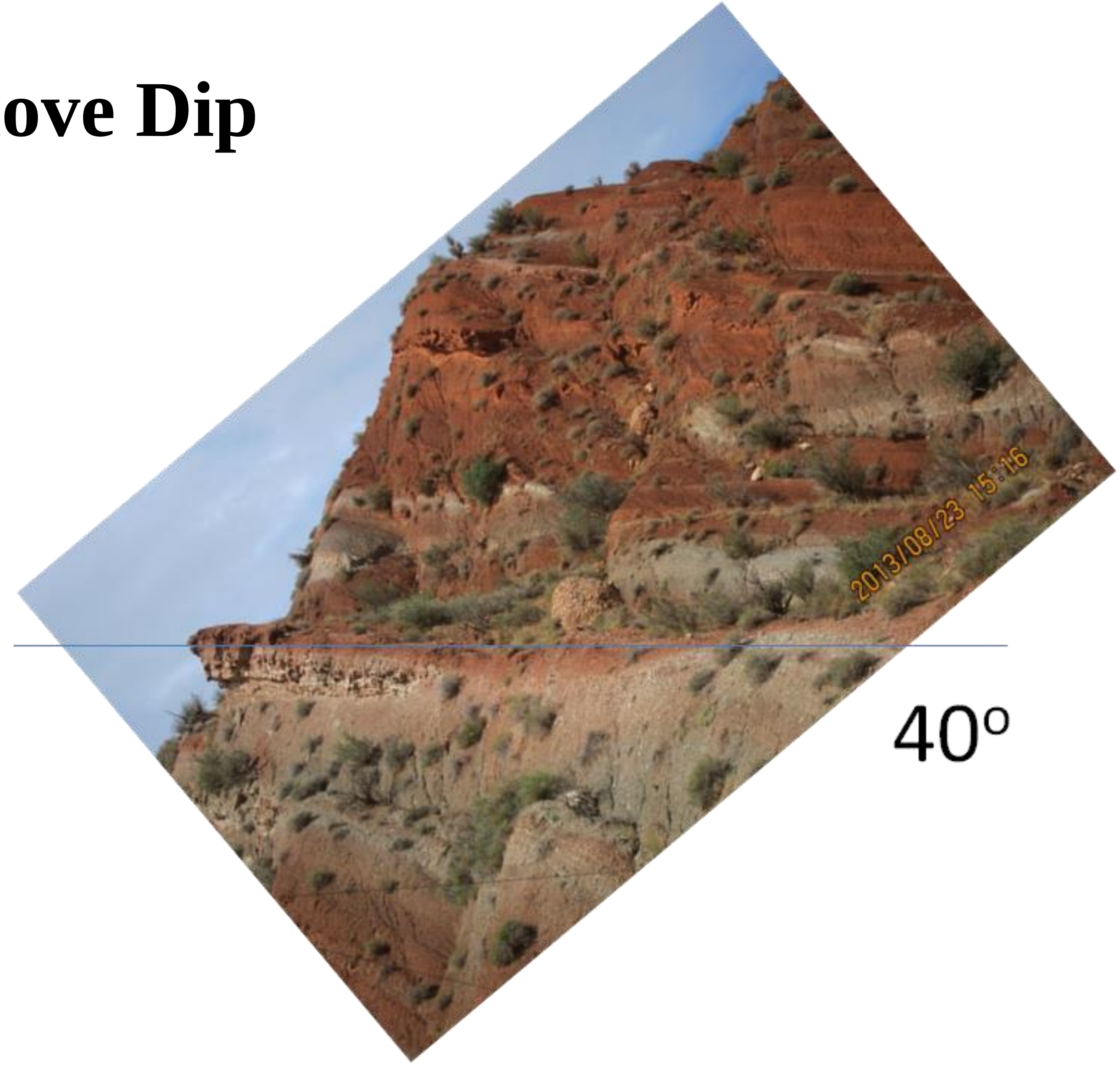
Tilted Geology Up Cedar Canyon

Geology is fascinating at all scales



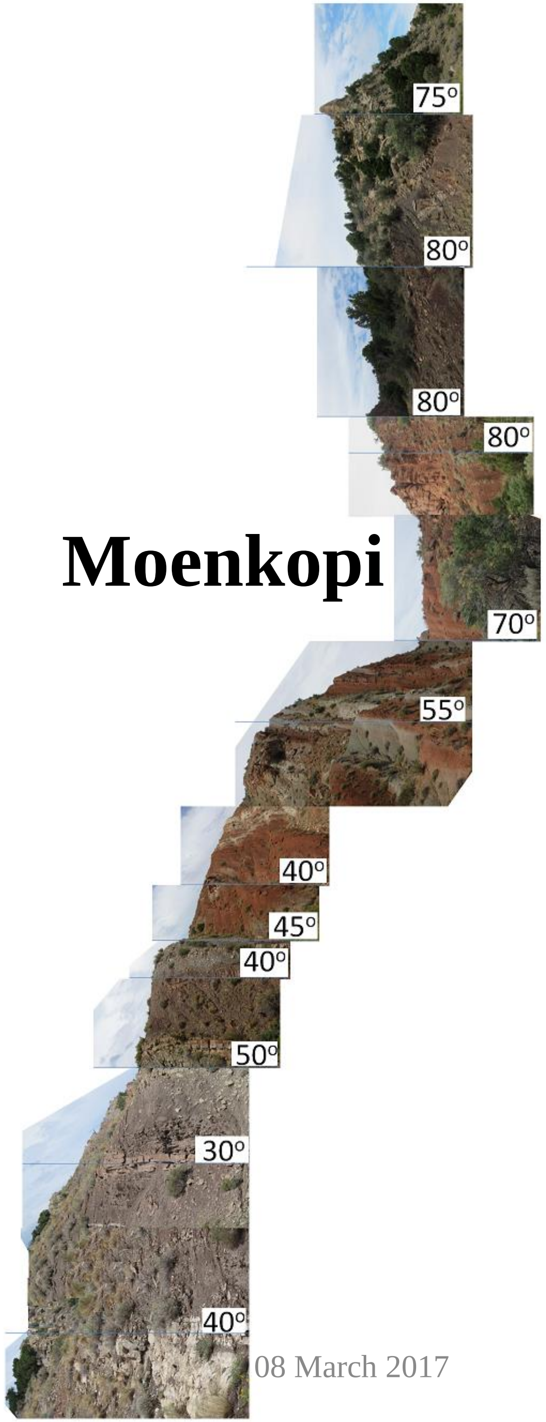
Rotating Photos to Remove Dip



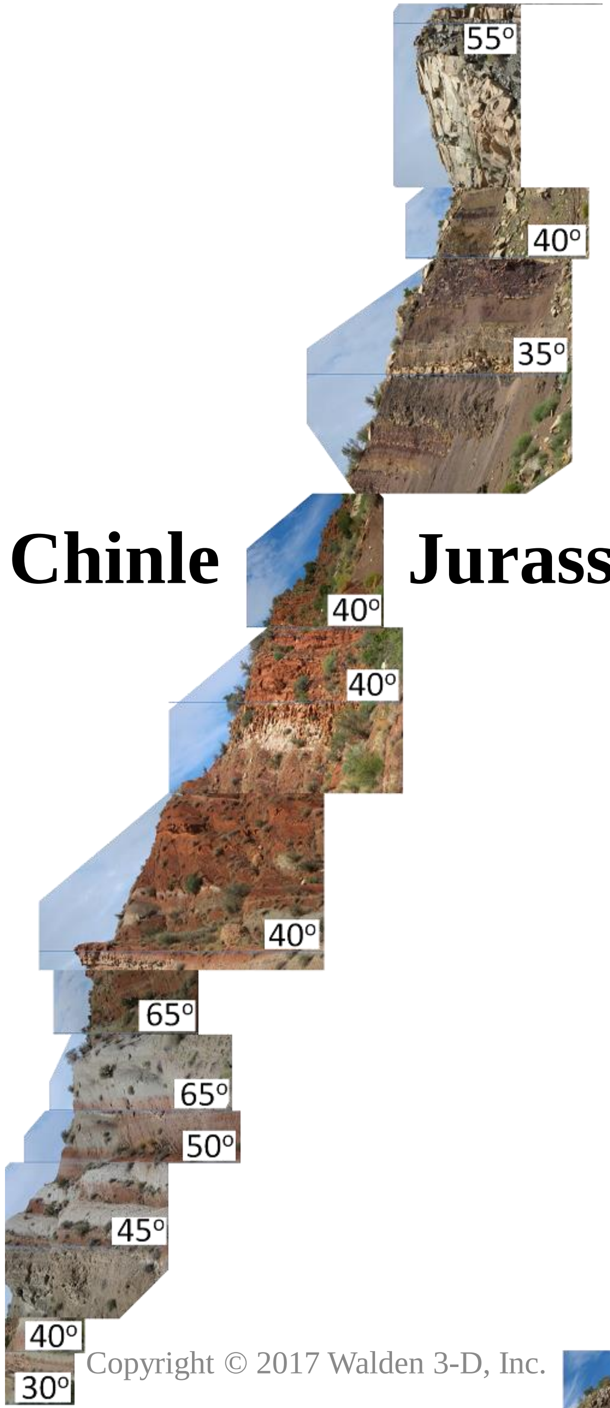


Rotated Type Outcrop Sections

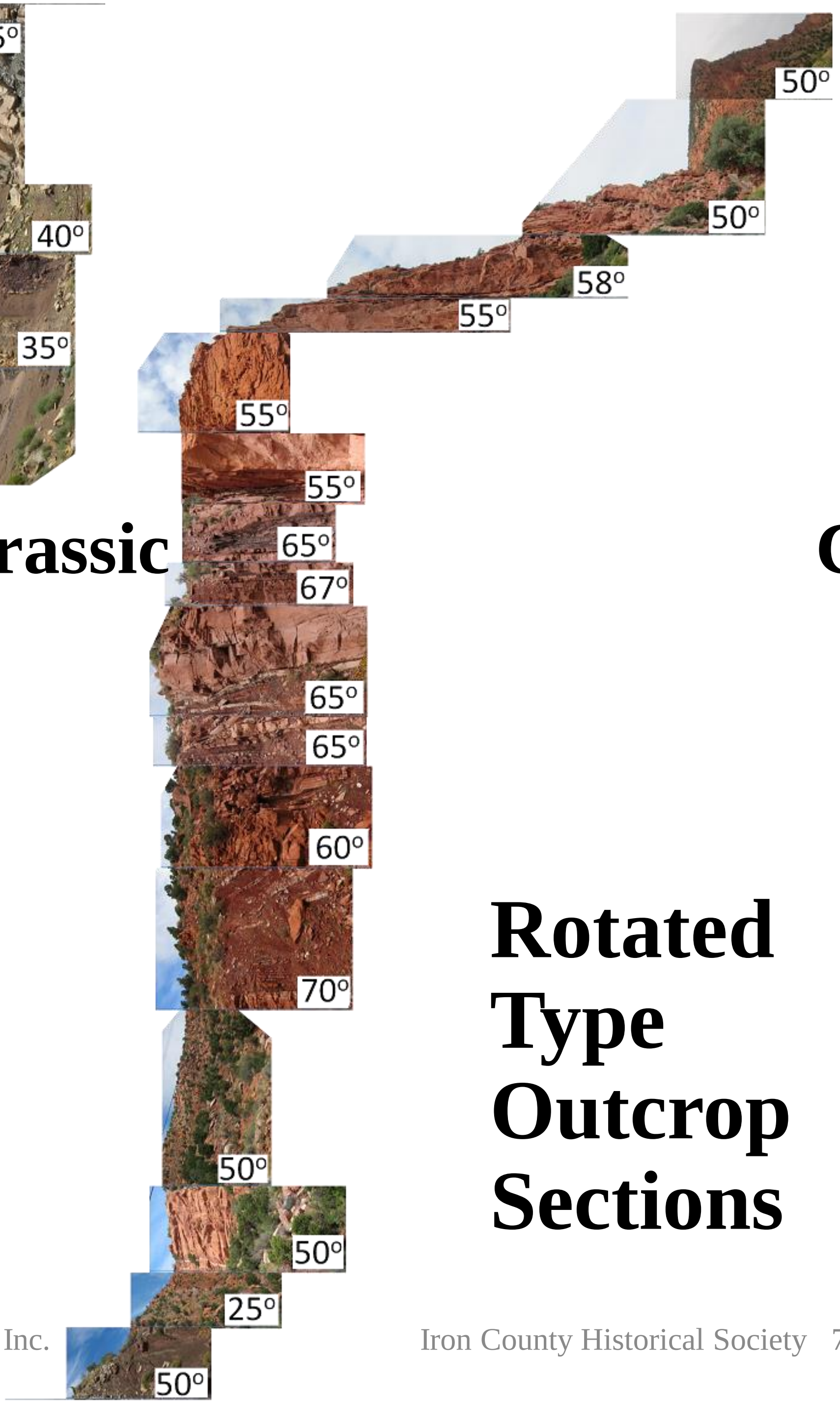
Moenkopi



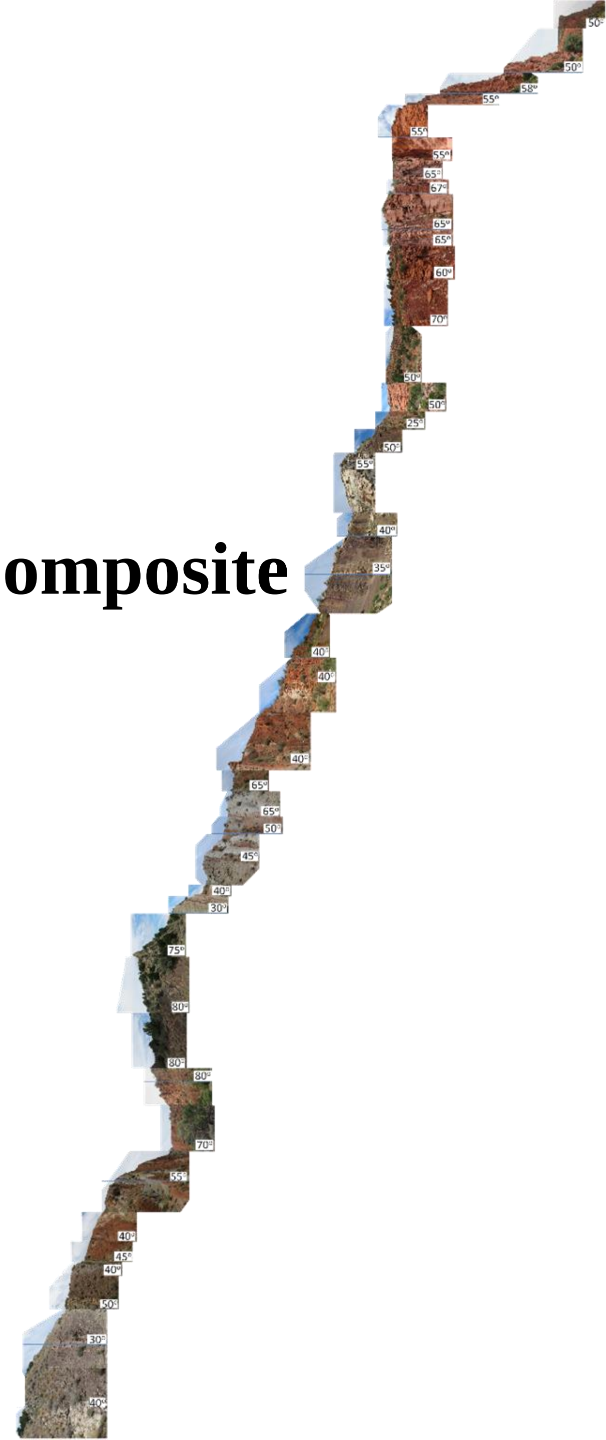
Chinle



Jurassic

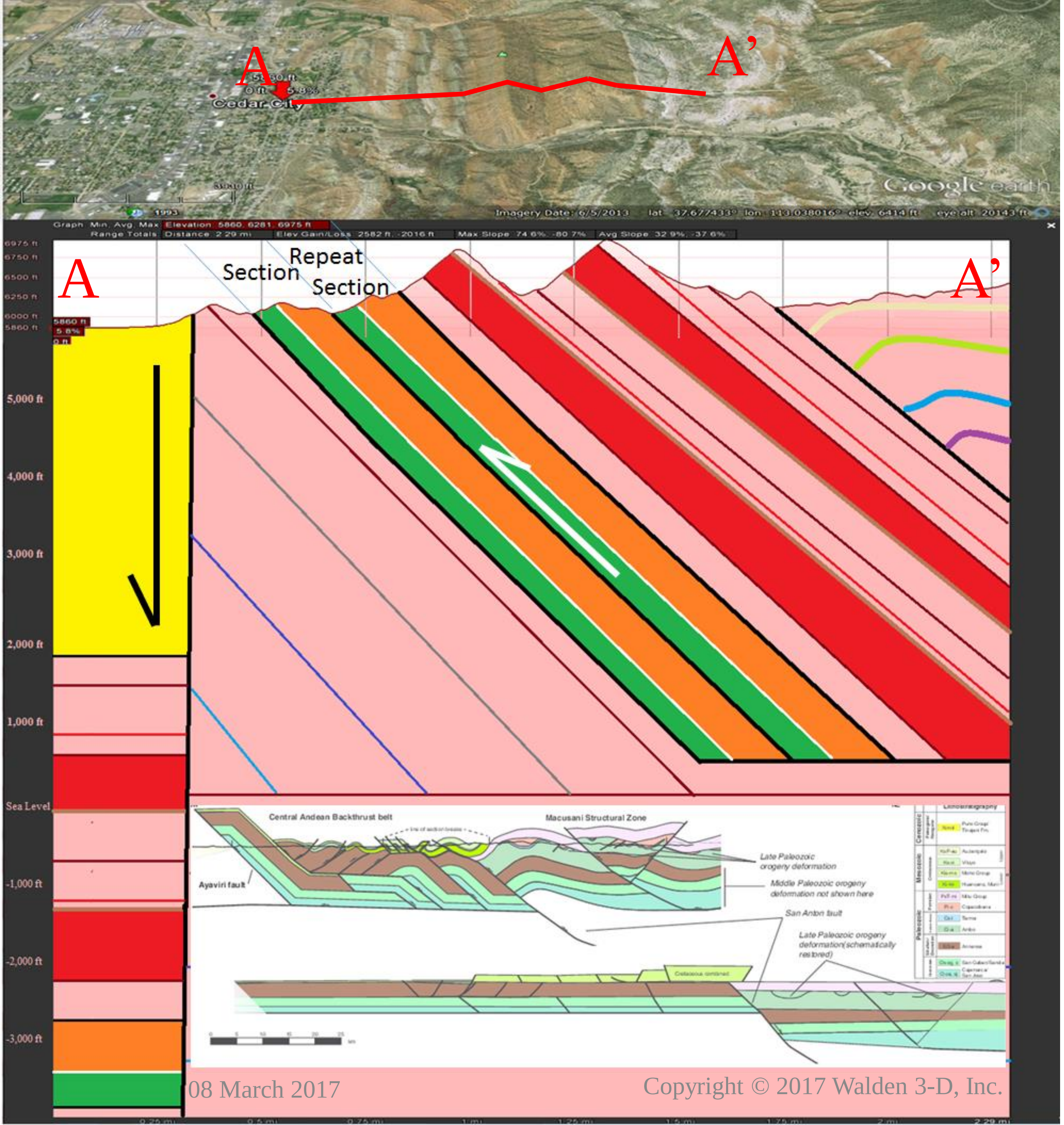


Composite



Cedar's Red Hill

excellent example of backthrust



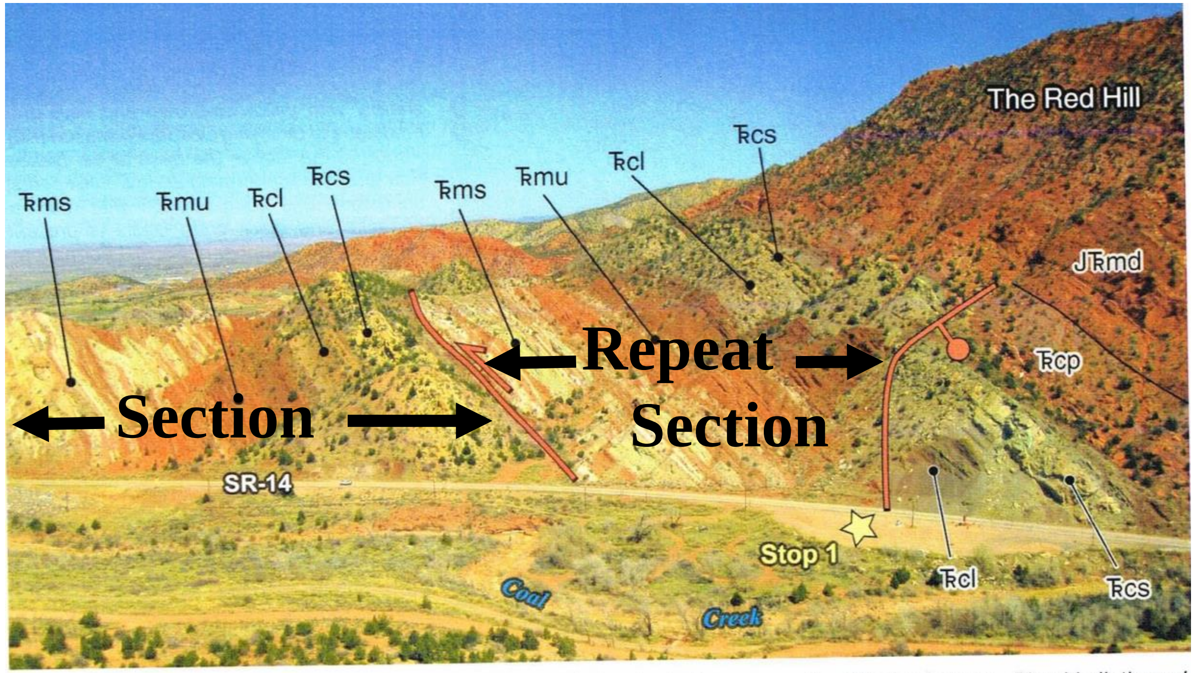
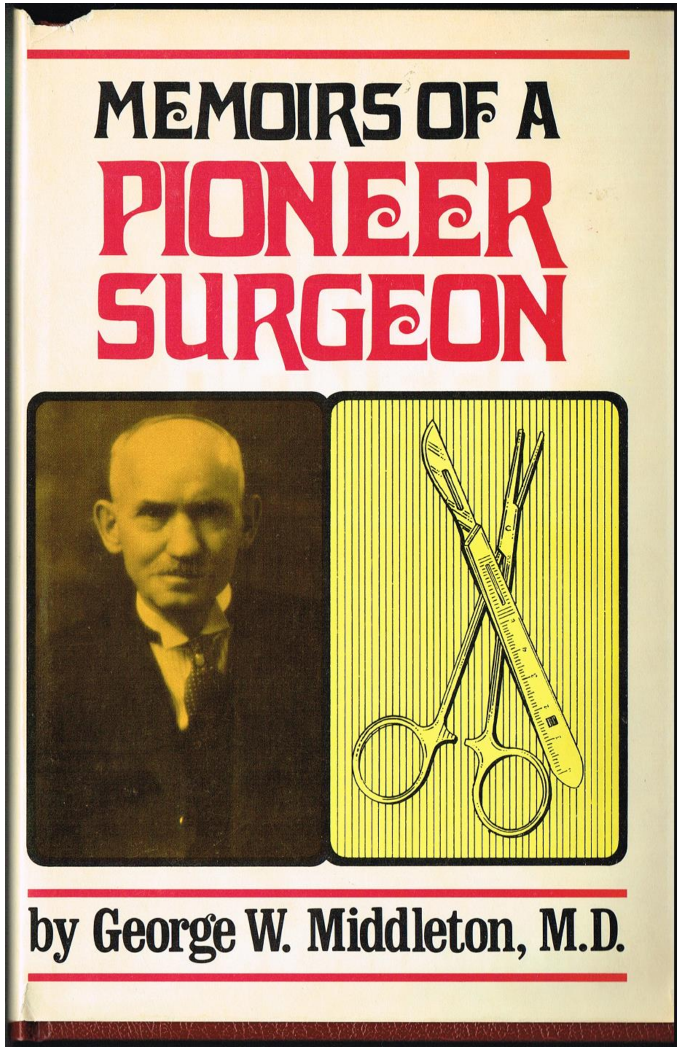
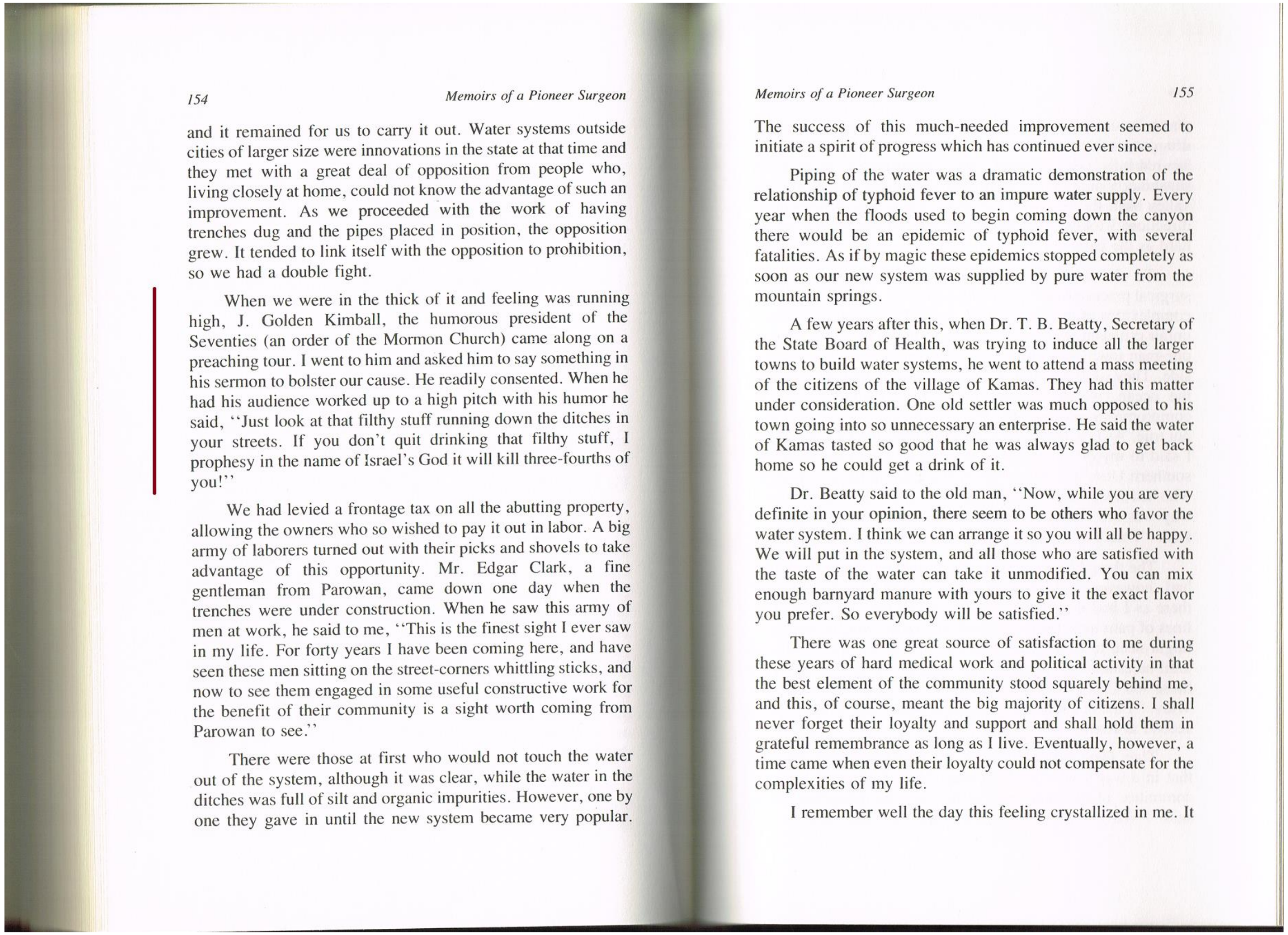


Figure 2. North-directed view of east-dipping Triassic and Jurassic strata near mouth of Cedar Canyon. Shnabkaib through Shinarump strata are repeated along a thrust fault. Bar and ball on downthrown side of normal fault. Ŧms =Shnabkaib Member of the Moenkopi Formation, Ŧmu =upper red member of the Moenkopi Formation, Ŧcl =lower member of the Chinle Formation, Ŧcs =Shinarump Conglomerate Member of the Chinle Formation, Ŧcp =Petrified Forest Member of the Chinle Formation, JŦcs =Dinosaur Canyon Member of the Moenave Formation. Photo courtesy of Tyler Knudsen.

MacLean, J.S., Biek, R.F., and Huntoon, J.E., editors

Historical Water Issue in Cedar City





and it remained for us to carry it out. Water systems outside cities of larger size were innovations in the state at that time and they met with a great deal of opposition from people who, living closely at home, could not know the advantage of such an improvement. As we proceeded with the work of having trenches dug and the pipes placed in position, the opposition grew. It tended to link itself with the opposition to prohibition, so we had a double fight.

When we were in the thick of it and feeling was running high, J. Golden Kimball, the humorous president of the Seventies (an order of the Mormon Church) came along on a preaching tour. I went to him and asked him to say something in his sermon to bolster our cause. He readily consented. When he had his audience worked up to a high pitch with his humor he said, "Just look at that filthy stuff running down the ditches in your streets. If you don't quit drinking that filthy stuff, I prophesy in the name of Israel's God it will kill three-fourths of you!"

We had levied a frontage tax on all the abutting property, allowing the owners who so wished to pay it out in labor. A big army of laborers turned out with their picks and shovels to take advantage of this opportunity. Mr. Edgar Clark, a fine gentleman from Parowan, came down one day when the trenches were under construction. When he saw this army of men at work, he said to me, "This is the finest sight I ever saw in my life. For forty years I have been coming here, and have seen these men sitting on the street-corners whittling sticks, and now to see them engaged in some useful constructive work for the benefit of their community is a sight worth coming from Parowan to see."

There were those at first who would not touch the water out of the system, although it was clear, while the water in the ditches was full of silt and organic impurities. However, one by one they gave in until the new system became very popular.

The success of this much-needed improvement seemed to initiate a spirit of progress which has continued ever since.

Piping of the water was a dramatic demonstration of the relationship of typhoid fever to an impure water supply. Every year when the floods used to begin coming down the canyon there would be an epidemic of typhoid fever, with several fatalities. As if by magic these epidemics stopped completely as soon as our new system was supplied by pure water from the mountain springs.

A few years after this, when Dr. T. B. Beatty, Secretary of the State Board of Health, was trying to induce all the larger towns to build water systems, he went to attend a mass meeting of the citizens of the village of Kamas. They had this matter under consideration. One old settler was much opposed to his town going into so unnecessary an enterprise. He said the water of Kamas tasted so good that he was always glad to get back home so he could get a drink of it.

Dr. Beatty said to the old man, "Now, while you are very definite in your opinion, there seem to be others who favor the water system. I think we can arrange it so you will all be happy. We will put in the system, and all those who are satisfied with the taste of the water can take it unmodified. You can mix enough barnyard manure with yours to give it the exact flavor you prefer. So everybody will be satisfied."

There was one great source of satisfaction to me during these years of hard medical work and political activity in that the best element of the community stood squarely behind me, and this, of course, meant the big majority of citizens. I shall never forget their loyalty and support and shall hold them in grateful remembrance as long as I live. Eventually, however, a time came when even their loyalty could not compensate for the complexities of my life.

I remember well the day this feeling crystallized in me. It

Iron County Today

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Utah state engineer discusses Groundwater Management Plan

BY ASHLEY LANGSTON
Reporter

IRON COUNTY – In 2012, a Groundwater Management Plan was released for the Beryl/Enterprise area that aims to reduce the amount of water being pulled from the ground each year and balance that amount with the amount of water returning to the ground.

This will be done by "regulating" water rights, or prohibiting their owners from drawing water from the ground. The plan will be implemented over the next 115 years, reducing which water rights may be used in stages, beginning with the most recently issued. Now, Cedar Valley water owners could face a similar challenge.

State Engineer Kent Jones visited Cedar City Jan. 7 for a meeting with water rights owners and interested citizens to discuss the likely institution of a Groundwater Management Plan for Cedar Valley and ask for the public's help in verifying the information he has on existing water rights.

Before Jones fielded questions, employees from the Utah Division of Water Rights presented on water policy, Groundwater Management Plans, and the current situation in the Cedar Valley.

Deputy State Engineer Boyd Clayton said before the state engineer can institute a Groundwater Management Plan there must be significant scientific research, more public meetings, and the ability for the public to comment in writing. He said a plan for the Cedar Valley has not been decided yet.

However, because of the way the state law is written, water rights are "first in time, first in right," meaning if a GMP is instituted, water rights issued more recently may have to be cut back. He said if that happens, the owners don't actually lose their right, but are unable to draw water from the aquifer unless at some future time enough water is available to make those rights useable.

"This isn't a time to panic," he

For more information visit www.waterrights.utah.gov Submit written comments to waterrights@utah.gov or Utah Division of Water Rights 646 N. Main St. P.O. Box 506 Cedar City, Utah 84721-0506

SEE WATER | 9

WATER

Continued from page 1

said, adding that while the state engineer is directed by law to give priority to the earliest water rights, he may consider voluntary arrangements and entities and individuals in the area are encouraged to work together, participate in discussions, and try to find solutions.

Assistant State Engineer James Greer said the Cedar Valley Aquifer is being depleted about 28,000 acre-feet per year, which is 4,000 to 8,000 acre-feet more, per year, than is recharged on average. However, water rights exist for between 50,000 and 76,000 acre-feet, and those rights need to be reduced to "safe yield," or the 20,000 to 24,000 acre-feet that is believed to go back into the aquifer in an average year.

When asked what water right years were in danger of being "regulated," or cut, Greer said unfortunately the list of existing water rights has inaccuracies, so they don't know that at this point. However, he asked owners of water rights to visit the Division of Water Rights website and look at the list of rights to make sure their information is accurate. The list can be found at www.waterrights.utah.gov under the Law/Agreements tab, Groundwater Management Plans, Cedar Valley (Iron County), and Priority Listing.

Jones also said because certain areas are seeing greater declines in water levels than other parts of the valley, the GMP may take that into consideration and cut back rights based on both region and priority date.

While many questions were fielded and comments were heard during the meeting, Jones also asked anyone with comments to submit them by Feb. 12 to waterrights@utah.gov or Utah Division of Water Rights, 646 N. Main St., P.O. Box 506, Cedar City, Utah 84721-0506.

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Much of the data presented dated back to the 1930s and 1940s, and Jones was asked whether the goal was to bring water levels back up to that point. He said while an increased water table would be nice, "we're just looking to do what needs to be done to stabilize" and stop from depleting the aquifer further. He said in the areas with the most depletion, the water table has dropped up to 90 feet and subsidence has actually decreased the storage capacity of the aquifer.

It was brought up by a member of the Coal Creek Irrigation Company that the company and the Central Iron County Water Conservancy District are working to develop aquifer recharge basins and capture much of the water that evaporates in the Quichapa Lake area, and Paul Cozzens, a Cedar City Council member and water conservancy district board member, said Cedar City has seen some success with small recharge efforts. He asked if any resources, such as funds or engineering work, were available from the state to help the valley with further efforts.

Jones said his office did not have any such resources available, but that there may be some options through sister agencies such as the Drinking Water Board. Paul Monroe, Central Iron County Water Conservancy District executive director, said the district has been working on efforts to build gravel pits to trap excess water from Coal Creek during high runoff years and allow it to percolate into the aquifer rather than evaporating.

This project has been in the works for at least four years, and the district has been working with the Utah National Guard. However, state funding is not available and the project has been pushed back another year, for possible completion in 2018. Monroe said some board members are eager to speed up the project and may push to do something sooner without the help of federal or state funds.

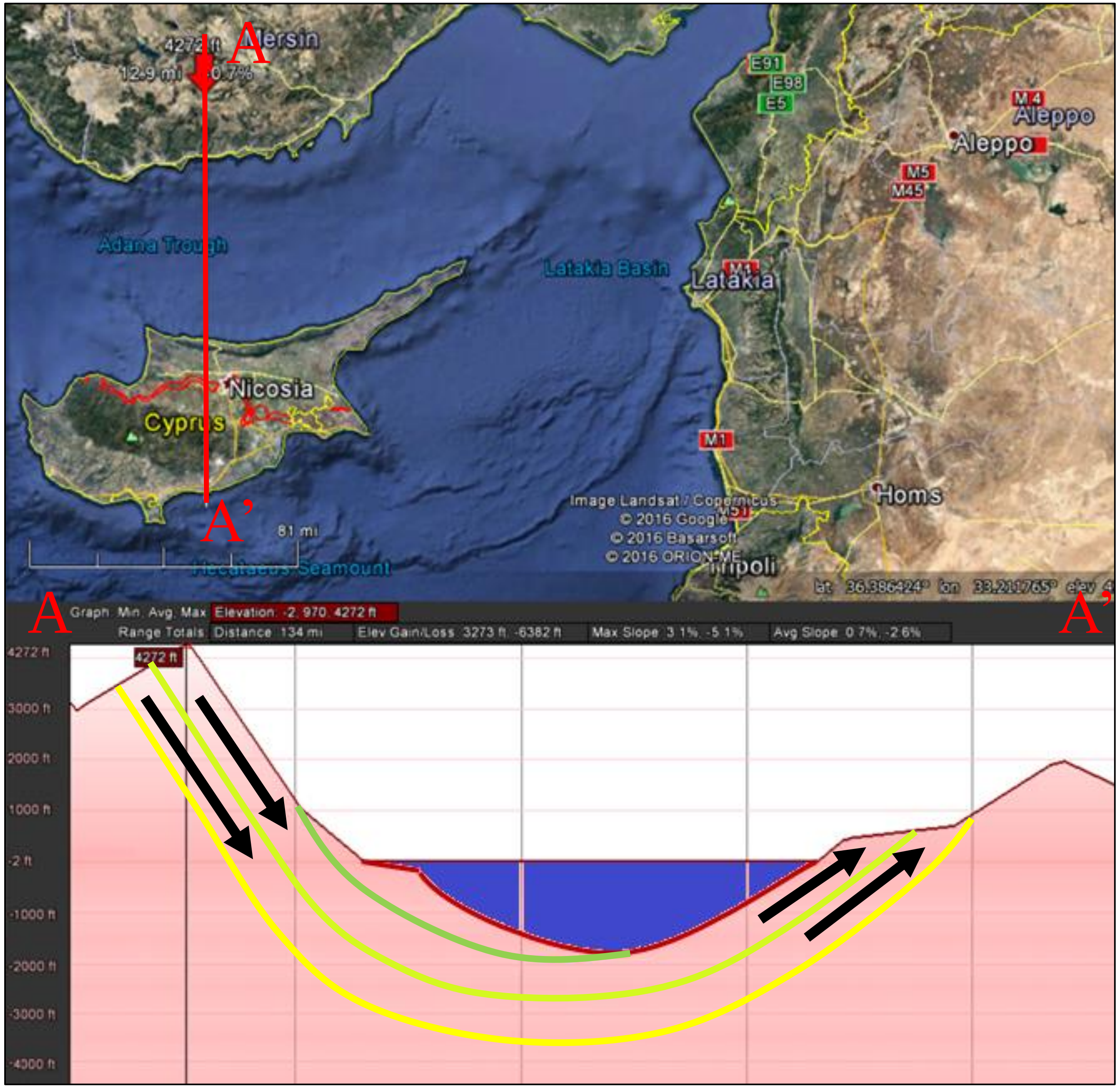
The CICWCD board has been working hard to find ways to import water to the valley, in addition to conserving and better utilizing Coal Creek water. It applied for water rights in valleys northwest of Cedar City in 2006, and in 2014, was granted those water rights. However, it has been involved in a legal battle since. Monroe said if those

court cases are resolved in the district's favor, being able to import that water will certainly work in the favor of water rights owners who face regulation under a Groundwater Management Plan.

Those interested in viewing the list of water rights or learning more about studies that have been done in the Cedar Valley or the information that was presented at the GMP meeting are encouraged to visit www.waterrights.utah.gov.

Cedar Still has Water Problems:

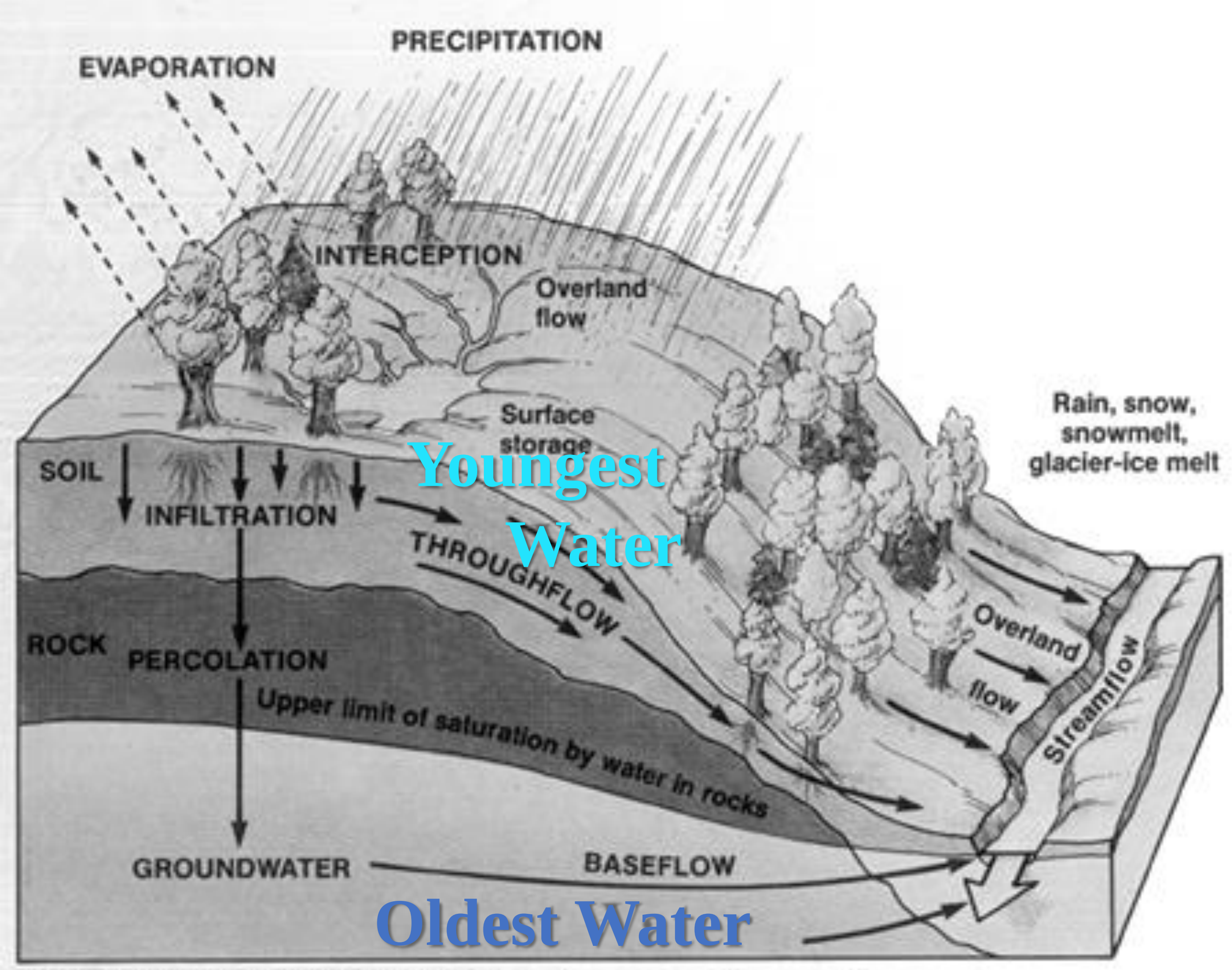
- "regulating" water rights is going to be beginning with the most recently issued water rights;
- State Engineer, Kent Jones, visited Cedar City in Jan 2016 to meet water rights owners & interested citizens;
- there will be more public meetings;
- existing water rights: 50,000 - 76,000 acre-feet (regulators show 34-52% error in known water rights);
- Stating the list of existing water rights has inaccuracies;
- the CICWCD has been working hard to find ways to import water to the valley (not including tapping resources within the Cedar Valley Drainage Basin).



1977 Mobil Oil Project

- This example relates to fluid flow in Southern Utah.
- The Taurus Mountains in Turkey provide a water source, which travels in rock layers and siphons back up into Cyprus.
- This drives hydrocarbons and expels them from the system.
- It also heats water, and creates the basis for hydrothermal alteration which relates to the ancient mines found on Cyprus.

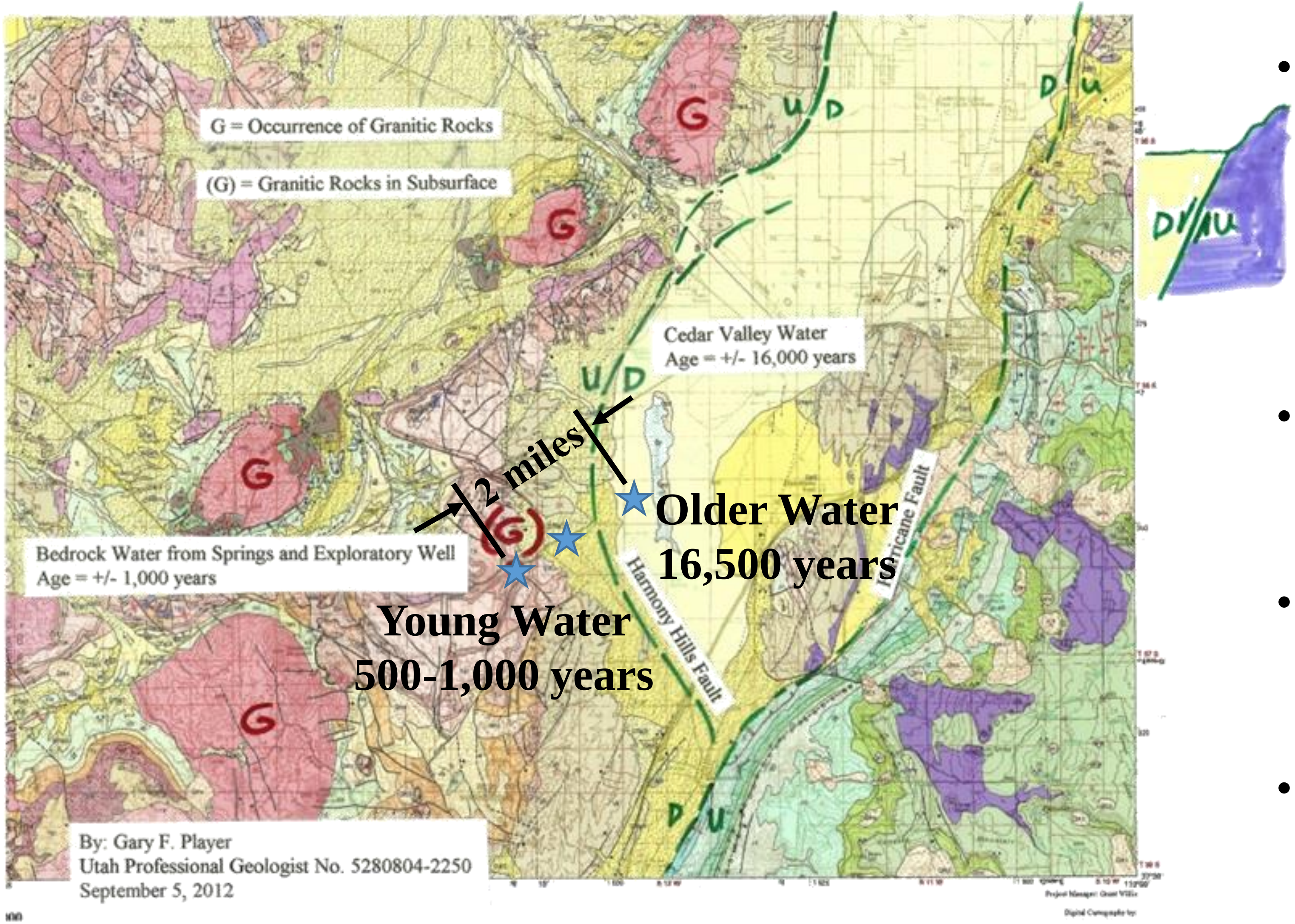
Throughflow, Baseflow, and the Age of Water



http://snobear.colorado.edu/Markw/geog5321_webpage_04.html

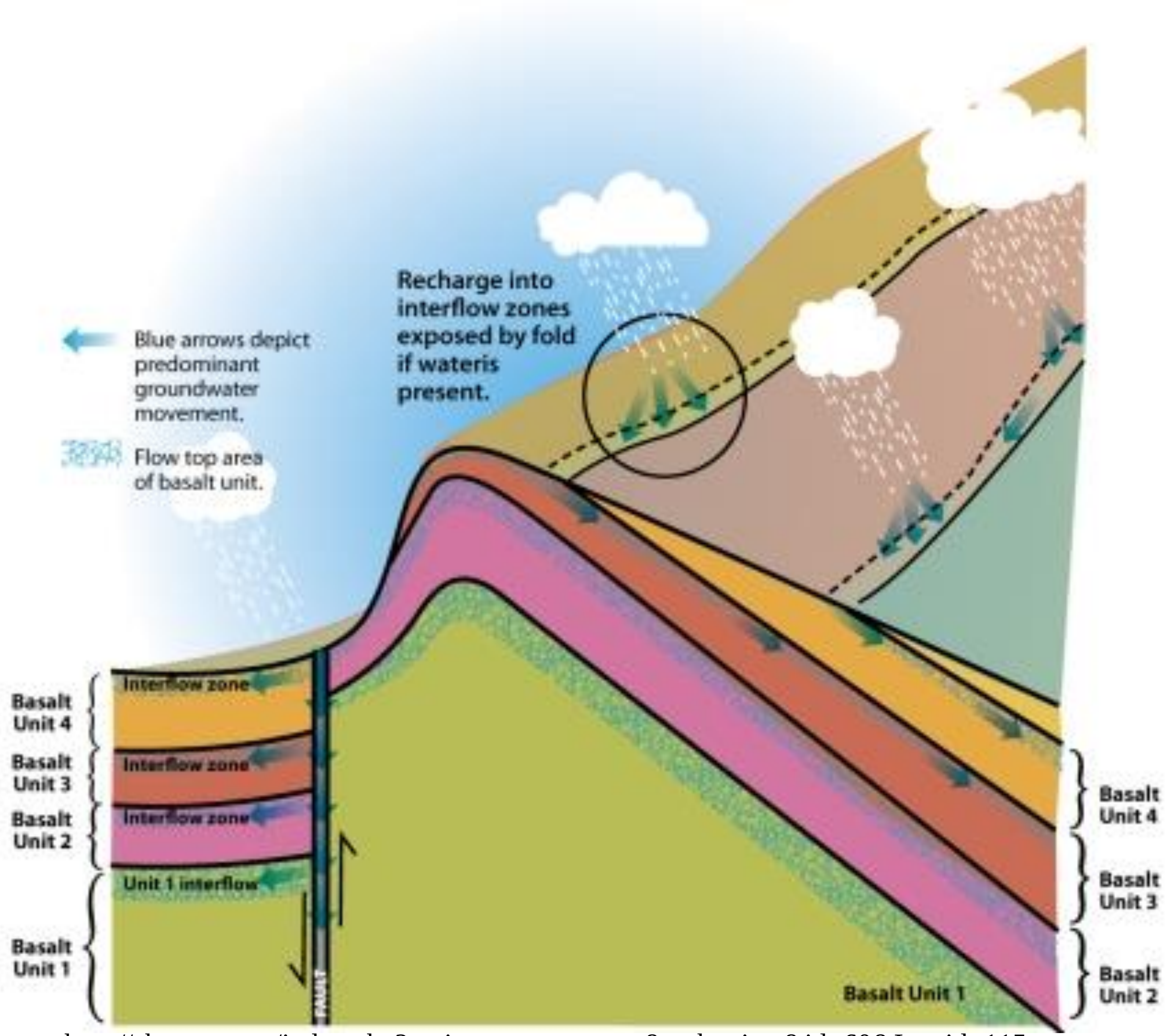
- Coal Creek is the principal source of recharge to the Cedar Valley basin-fill aquifer (Thomas & Taylor, 1946; Bjorklund & others, 1978) .
- Consolidated-rock aquifers are an important secondary component of the Cedar Valley drainage basin's ground water system, but are currently of relatively minor importance for water supply (J. Mason, U.S. Geological Survey) .

Geologic Age shows Geologic Separation
between the west hills and the Cedar Valley Fill Aquifer



- Baseflow from Cedar Mountain to the center of Cedar Valley must bypass east dipping beds, and the Hurricane Fault, which is connected to porous Jurassic Navajo sands 5,000-8,000 feet down the Hurricane Fault plane.
- Although Lake Bonneville did not reach Cedar Valley, the ancient Quichapa Lake was larger in this wetter time.
- The USGS says water in the valley is older because it flows a longer path from the bedrocks to the east and to the west.
- It seems too coincidental age dating shows this is the exactly same age as the much wetter Lake Bonneville time.

In Cedar Valley, like below, there are barriers to Baseflow from the mountains to the east into the valley in the west

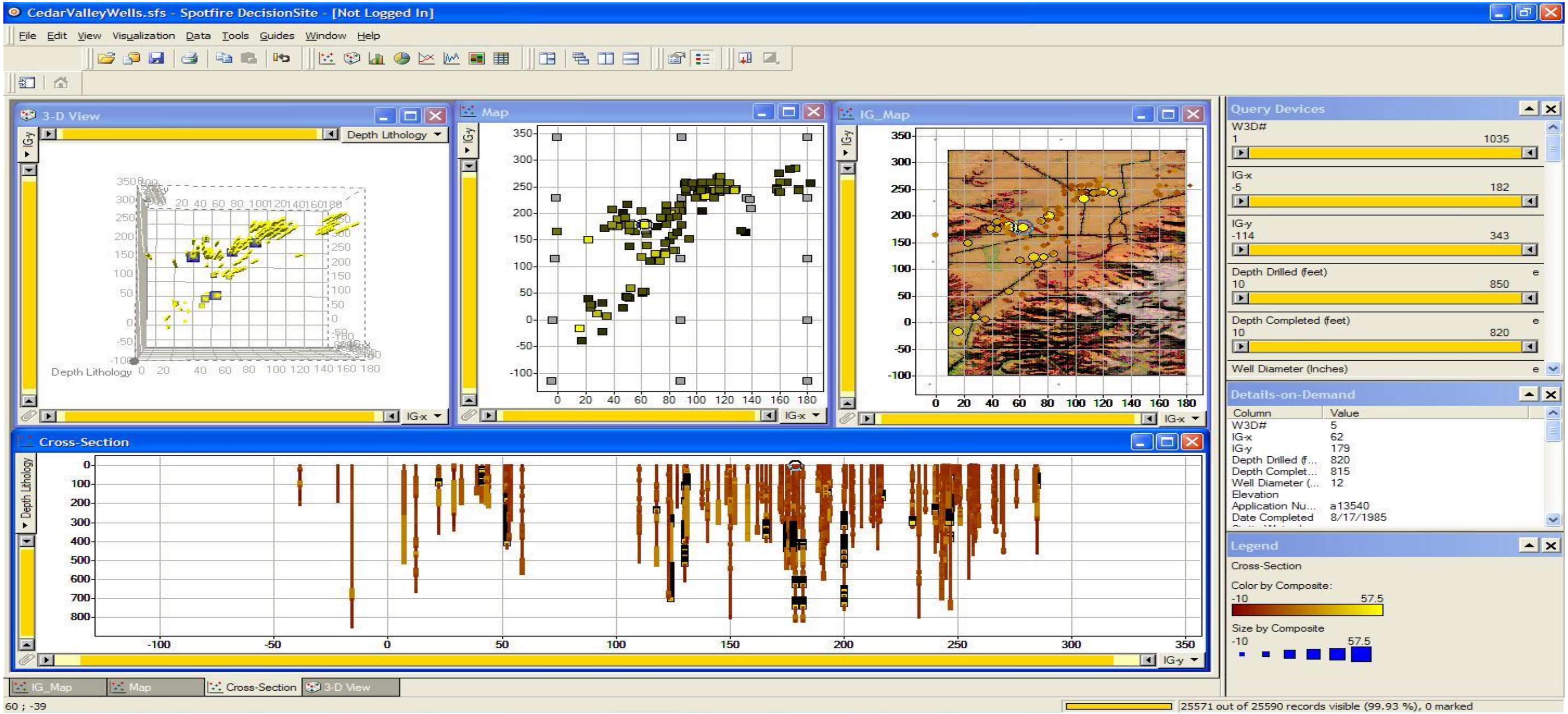


http://cbgwma.org/index.php?option=com_content&task=view&id=60&Itemid=115

- Bedrock dips to the east;

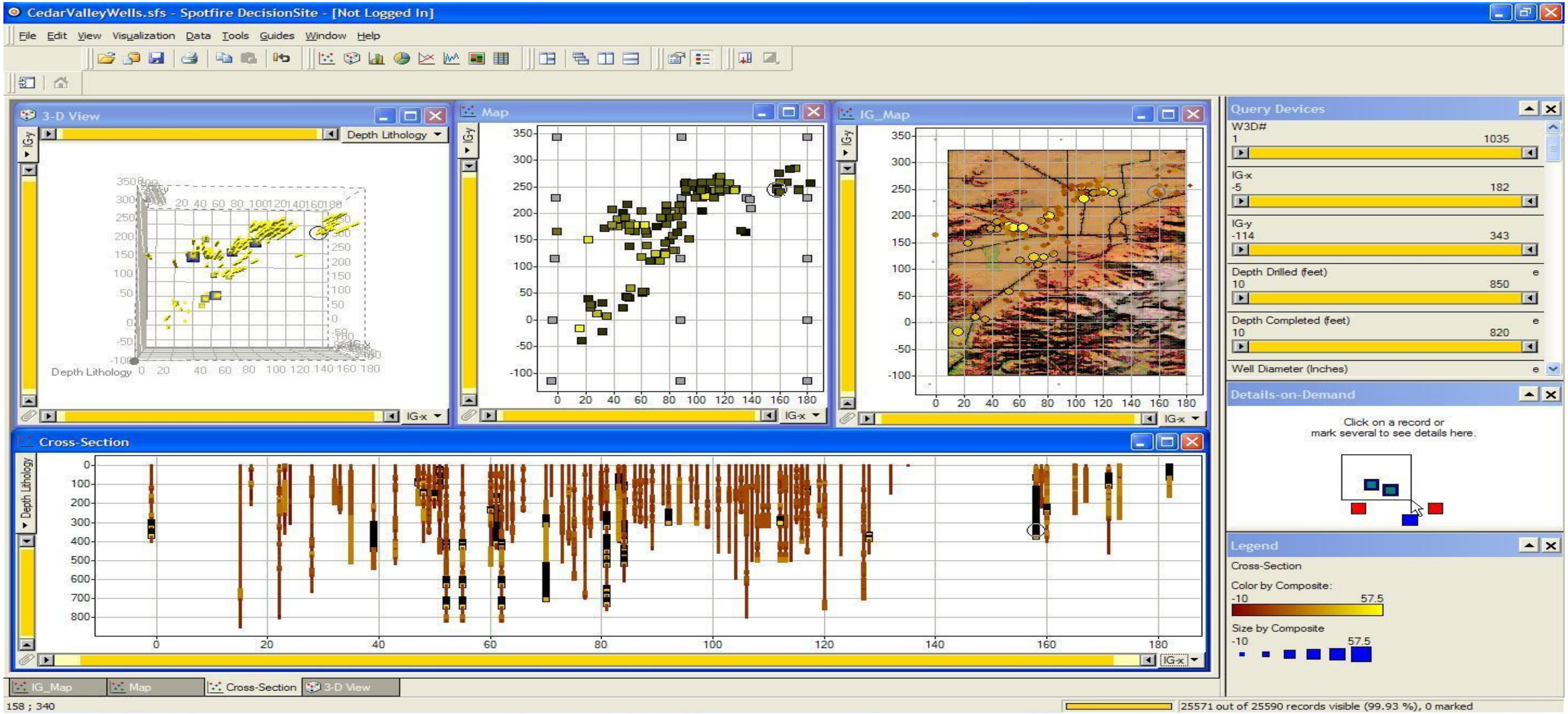
- Faults bounding the valley disrupt baseflow, especially into the Cedar Valley basin fill aquifer, which is isolated by clays and is very shallow.

Few wells in Cedar Valley are deeper than 800 feet



North-to-South cross-section through the Cedar Valley Aquifer, Roice Nelson, 19 Sep 2005.

Details show somewhat isolated shallow aquifers bounded by layers of clay, isolating Lake Bonneville age water



West-to-East cross-section through the Cedar Valley Aquifer, Roice Nelson, 19 Sep 2005.

The Water Available from Wells is defined by the Potentiometric Surface

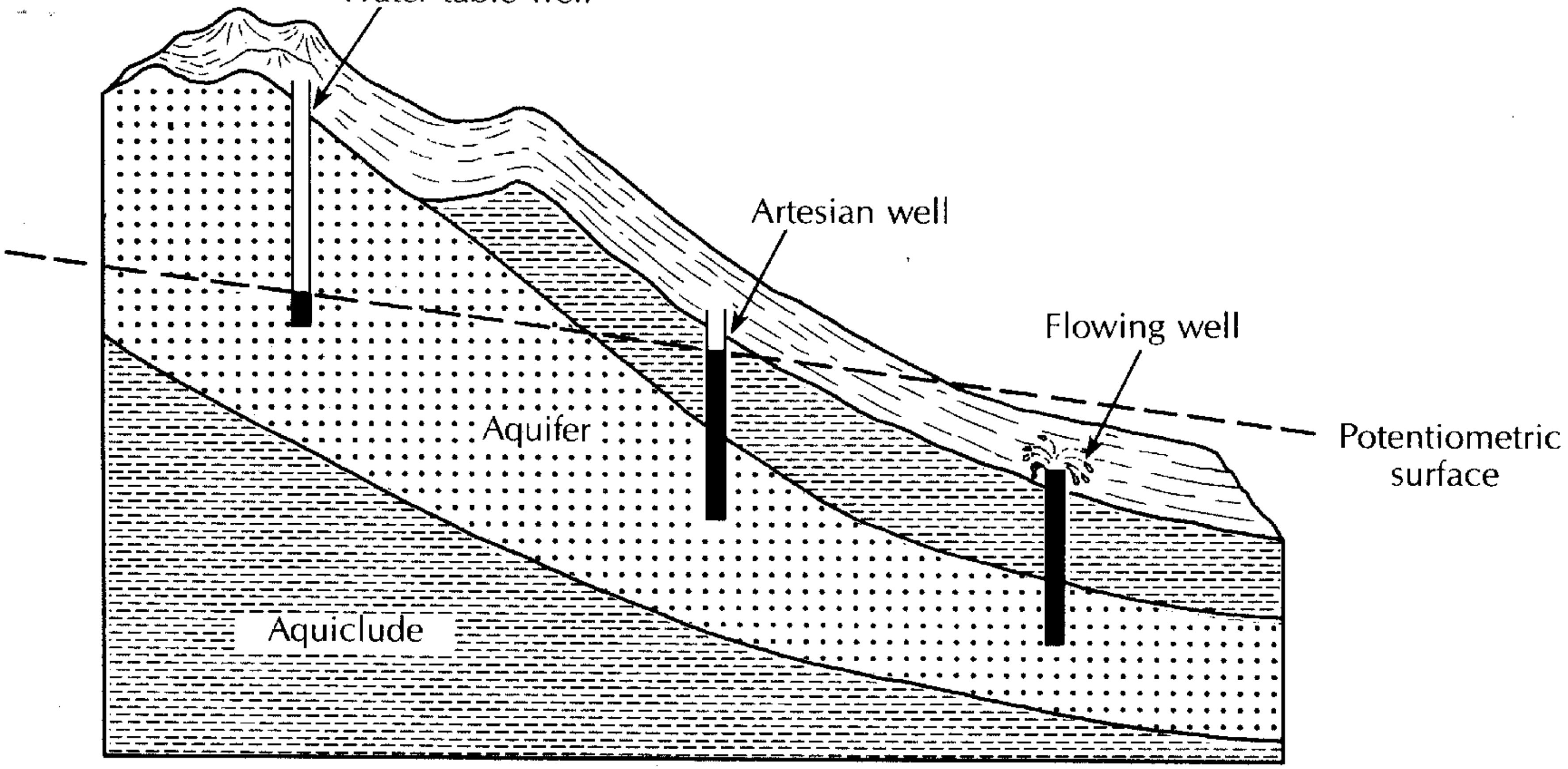


FIGURE 4.21 Artesian and flowing well in confined aquifer.

http://www.ce.utexas.edu/prof/maidment/tmpaper/spring98/landrum/map.htm

Cedar Valley Basin Fill Aquifer Potentiometric Surface

Oct 2009 | Mar 2010 | Residual Sep 1939-Oct 2009

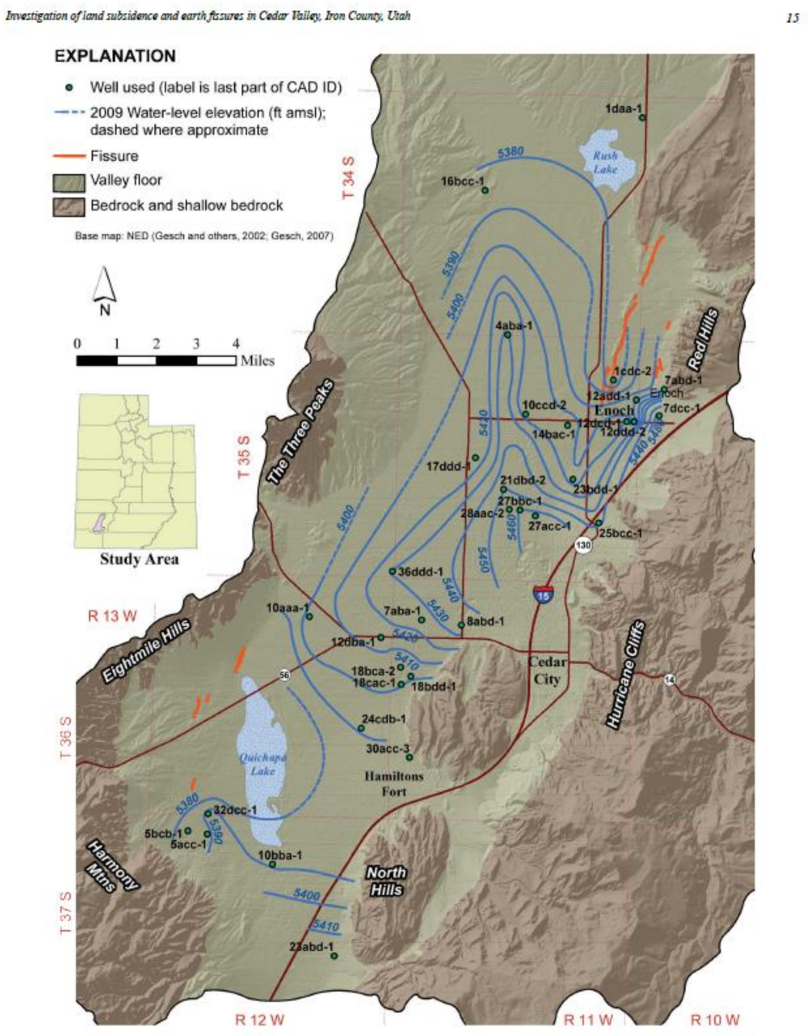


Figure 7. Cedar Valley potentiometric surface during October 2009. Well details and water-level measurements are listed in table 5.

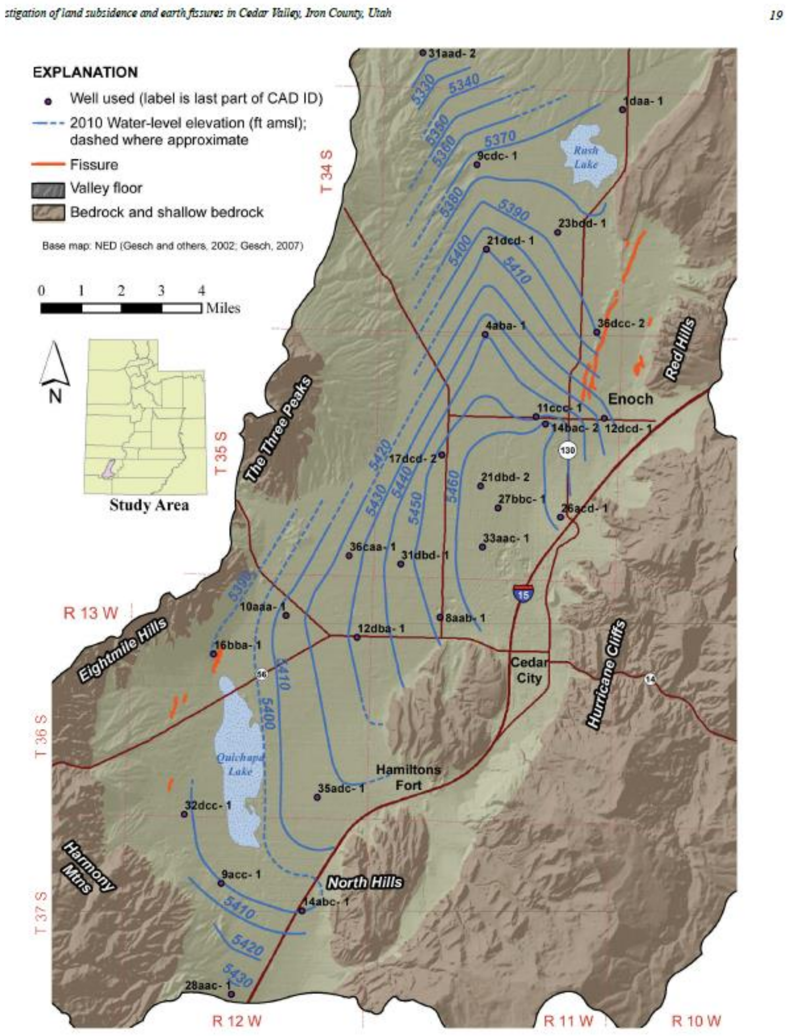


Figure 8. Cedar Valley potentiometric surface during March 2010 from NWIS data (U.S. Geological Survey, 2010). Wells are listed in table 6.

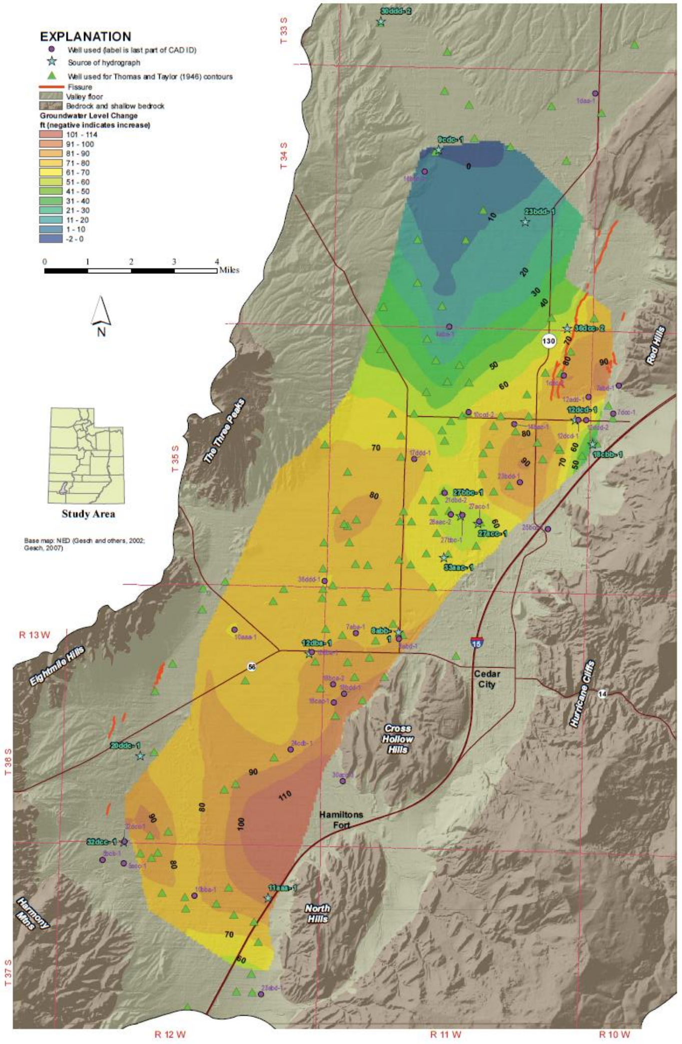
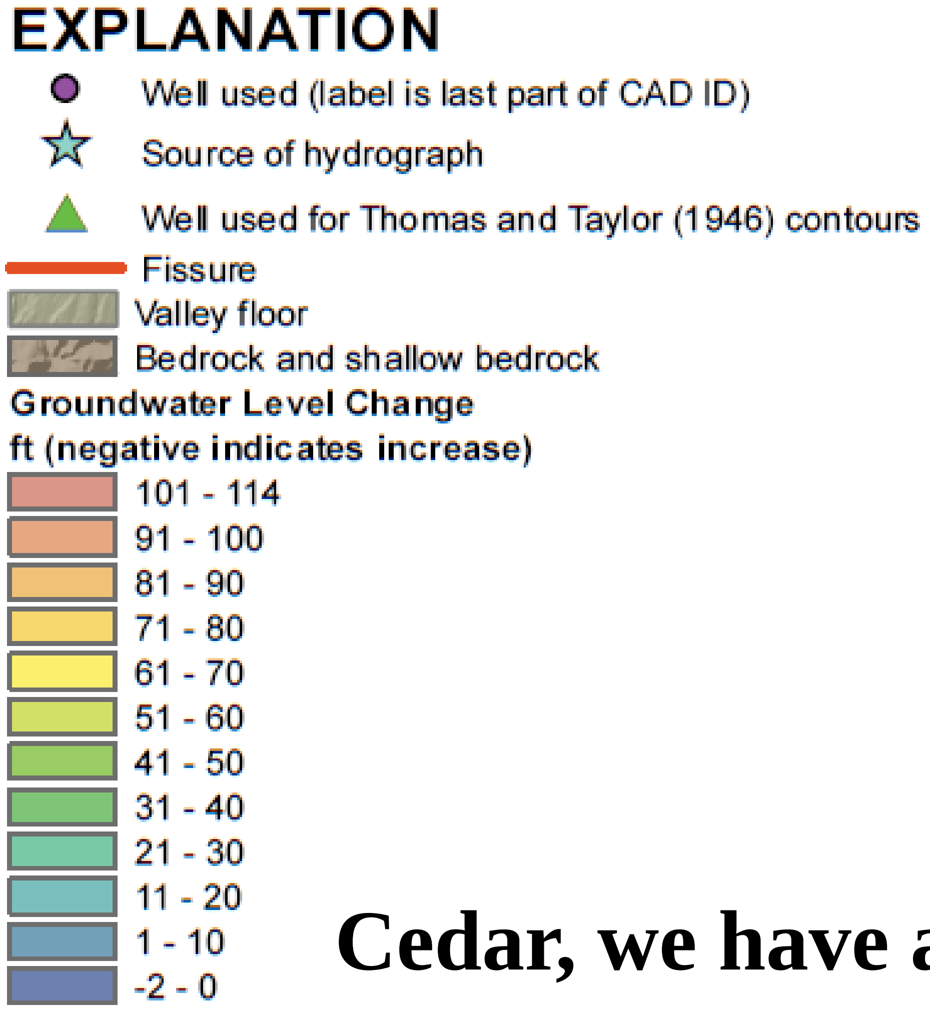
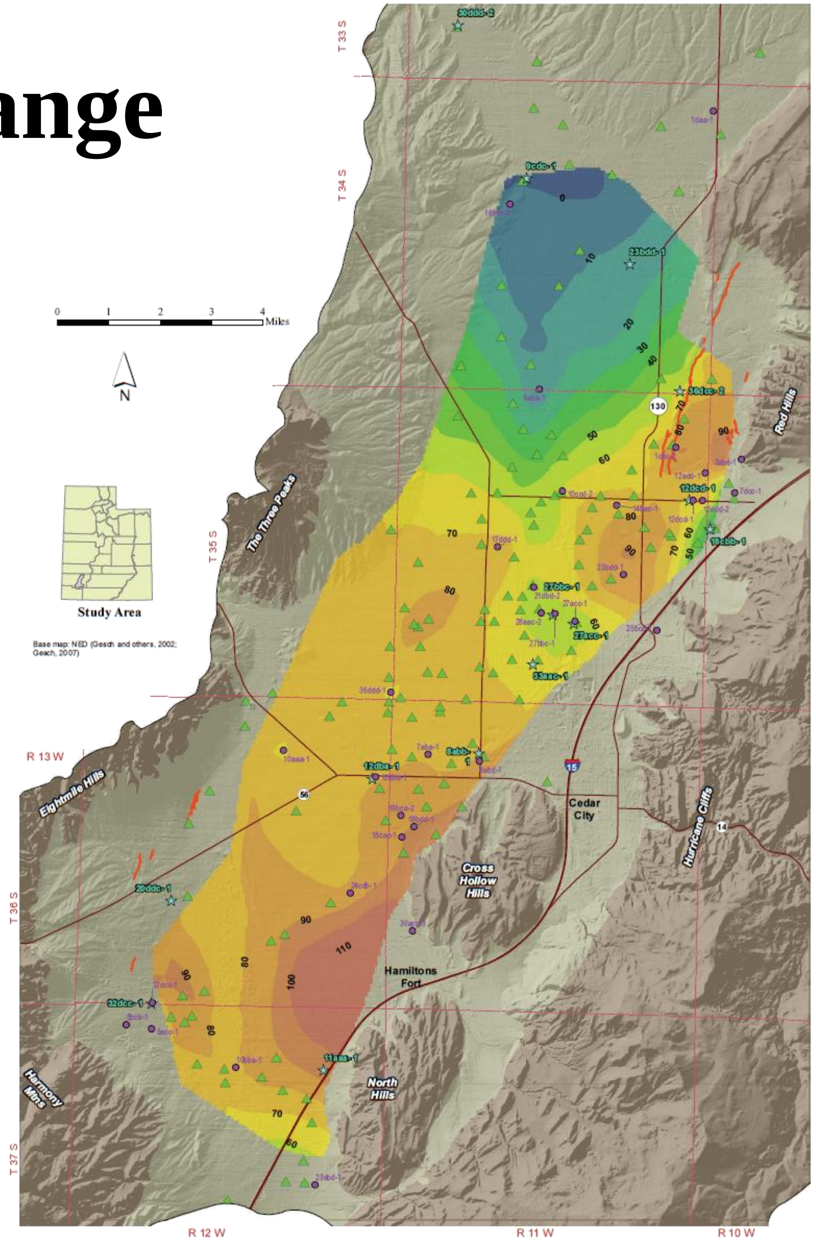


Figure 18. Change in potentiometric surface from September 1939 (Thomas and Taylor 1946) to October 2009 (this study). Thomas and Taylor (1946) did not provide well identification with their well locations. Hydrographs from selected NWIS (U.S. Geological Survey, 2010) wells (stars) are shown on figure 17.

Investigation of land subsidence and earth fissures in Cedar Valley, Iron County, Utah, Tyler Knudsen, Paul Inkenbrandt, William Lund, Mike Lowe, & Steve Bowman, 2014

Zoom on the 1939-2009 residual change in the Potentiometric Surface





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Cedar, we have a problem!

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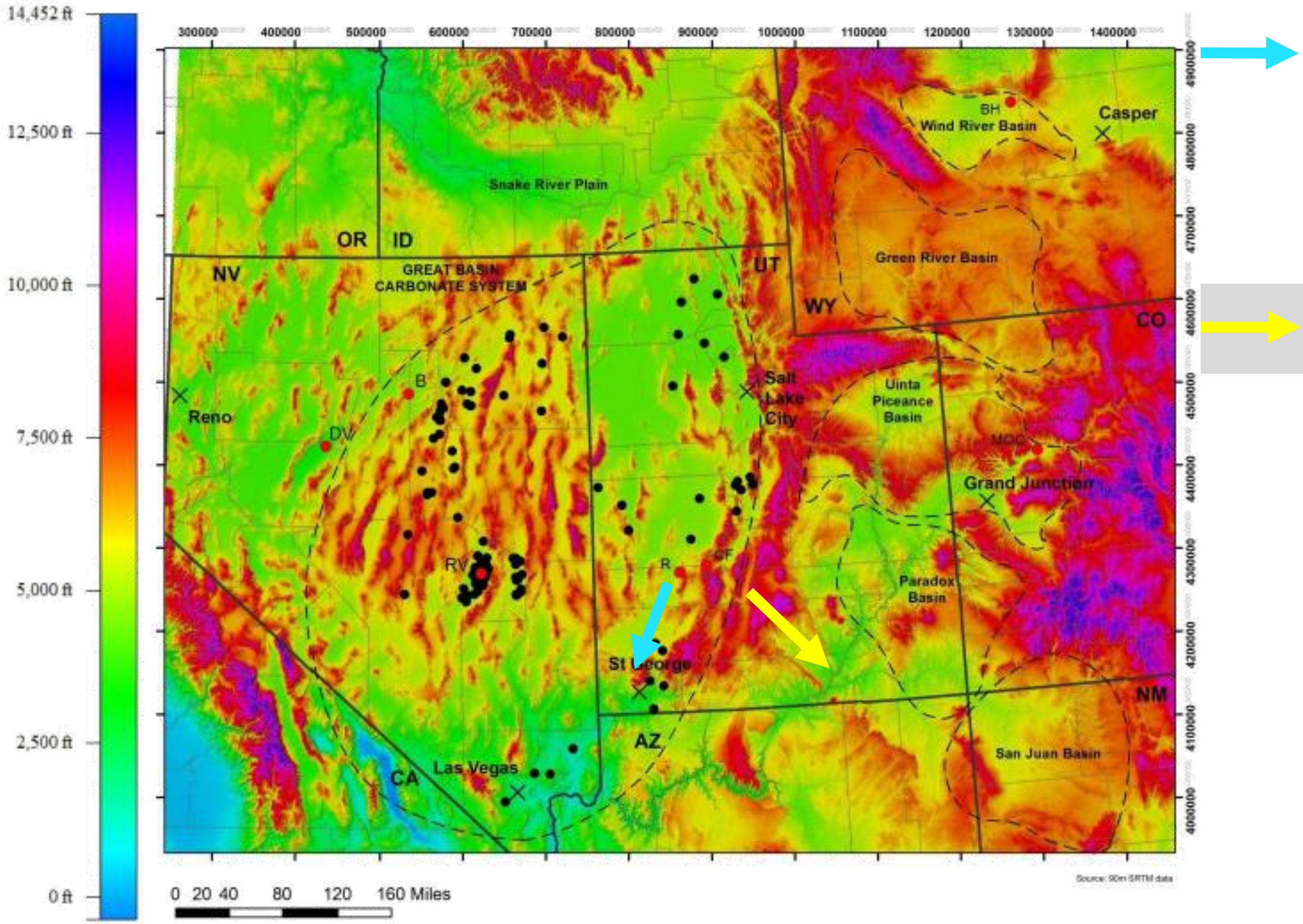
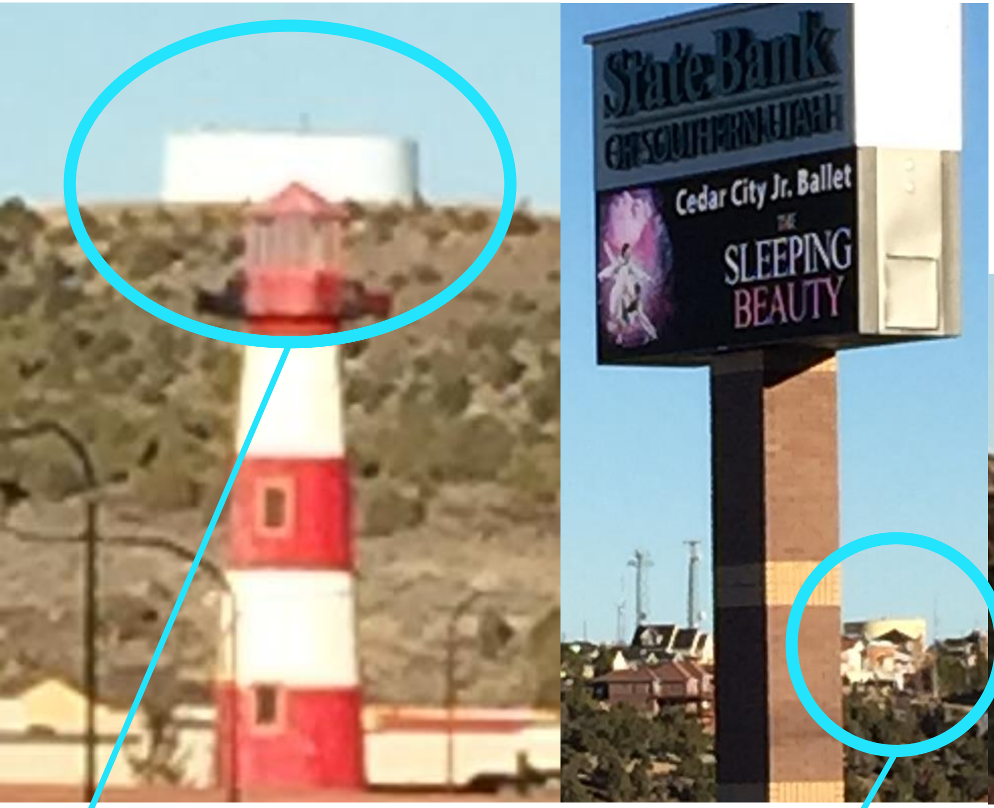
Looking at the Bigger Picture



- There is significant baseflow discharge from The Great Basin (e.g. Cedar City at 5,000 feet) to the south (e.g. St. George at 3,000 feet).
- There is equal or larger baseflow discharge from The Great Basin (e.g. Cedar Valley) to the southeast (e.g. The Grand Canyon).
- This discharge is much deeper than 800 feet, with water running below the isolated Cedar Valley Fill Aquifer.

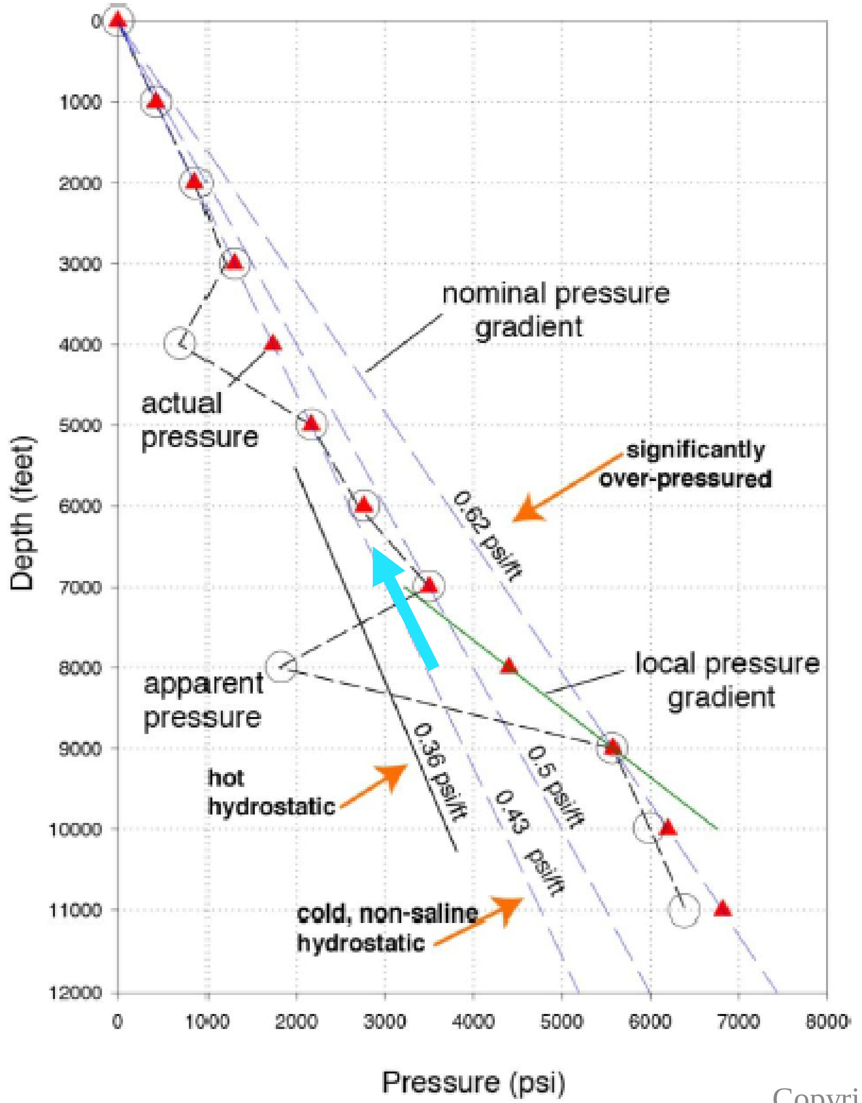
Water Tanks in Cedar City demonstrate hydrostatic pressure

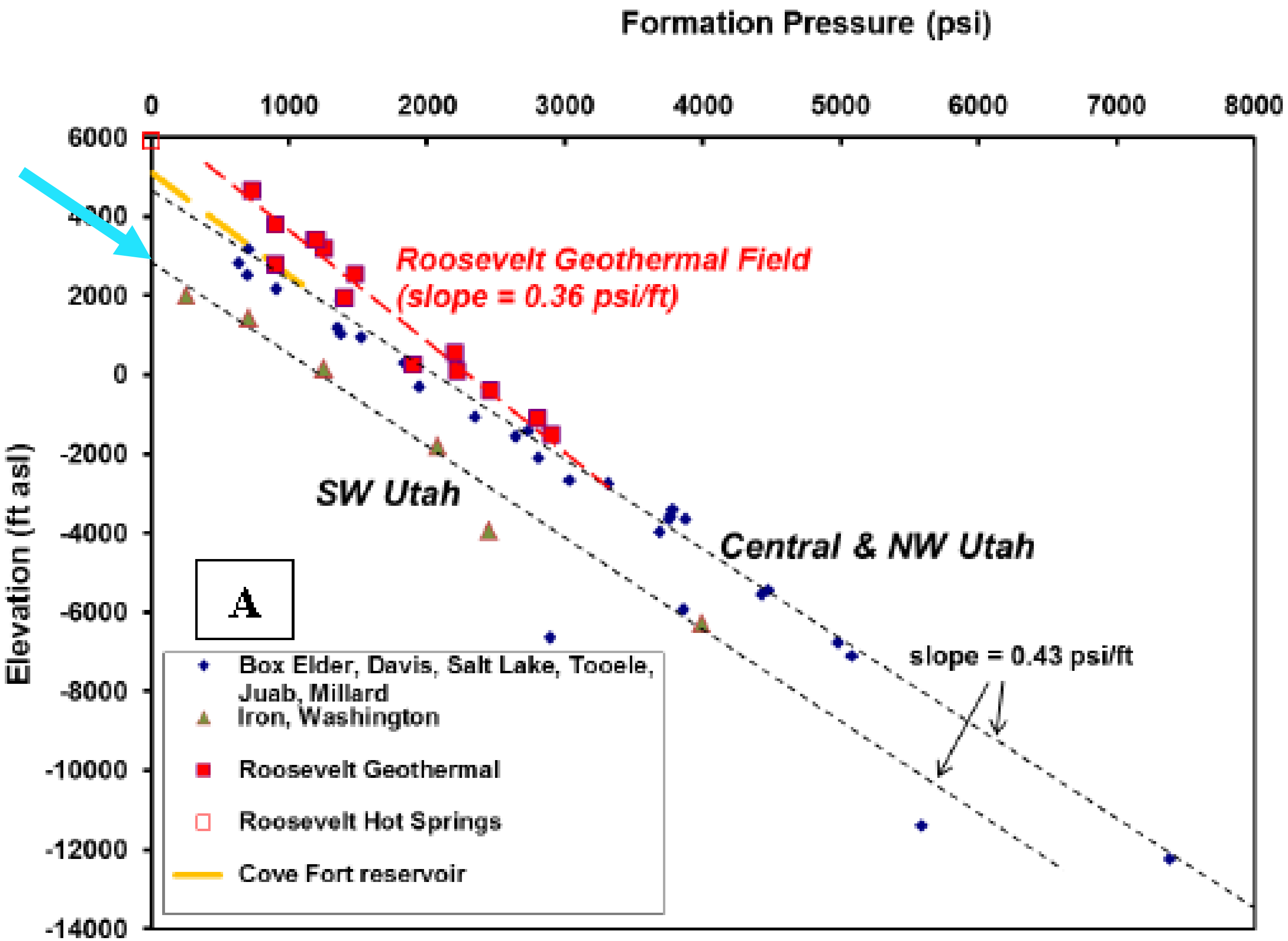


- Stacking water increases density 1 pound per square inch every 2.31 feet, by the equation p=density (water 1 g/cm^2)*gravity (9.7 m/s^2)*depth (or height).

- The pressure in our water faucet is tied to the height the water tank is above us.
- Less than normal hydrostatic pressure means there is a leak in the water system.

Iron County and the Entire Southern Great Basin
have lower than normal hydrostatic pressure

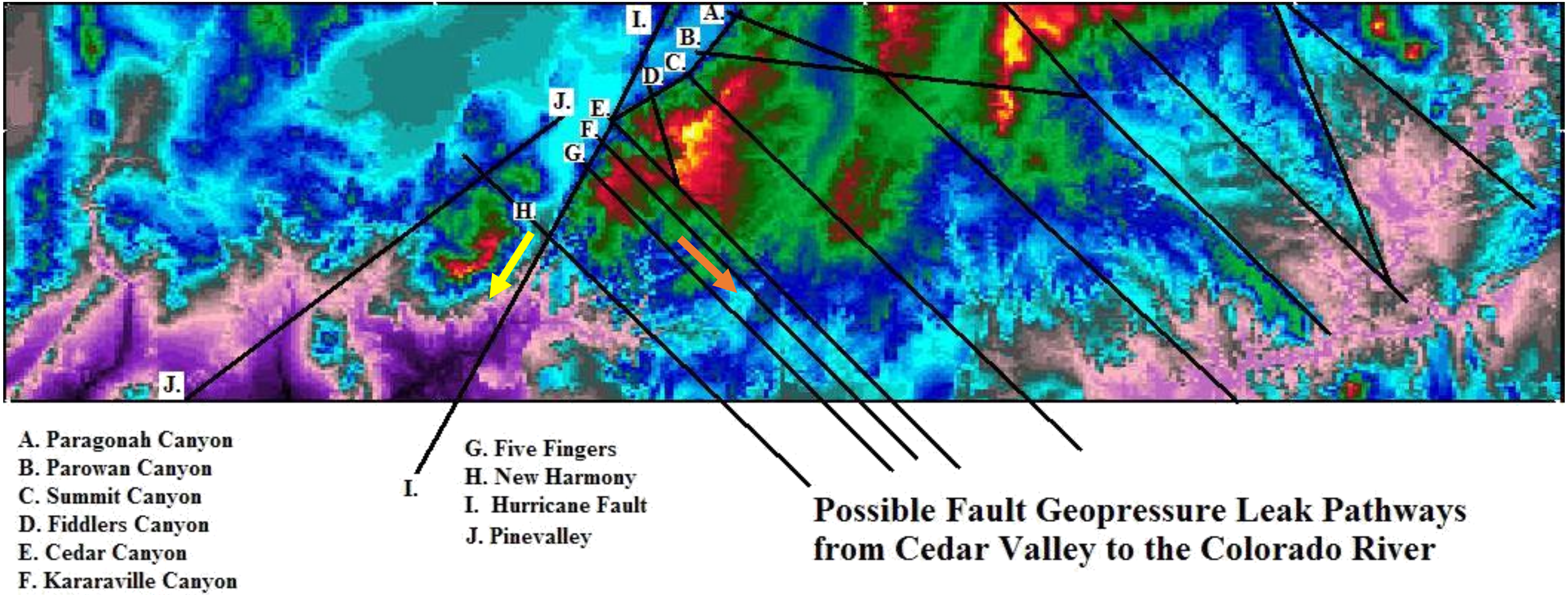




Formation Pressure as a Potential Indicator of High Stratigraphic Permeability
Rick Allis , Utah Geological Survey

There is a leak in the water system

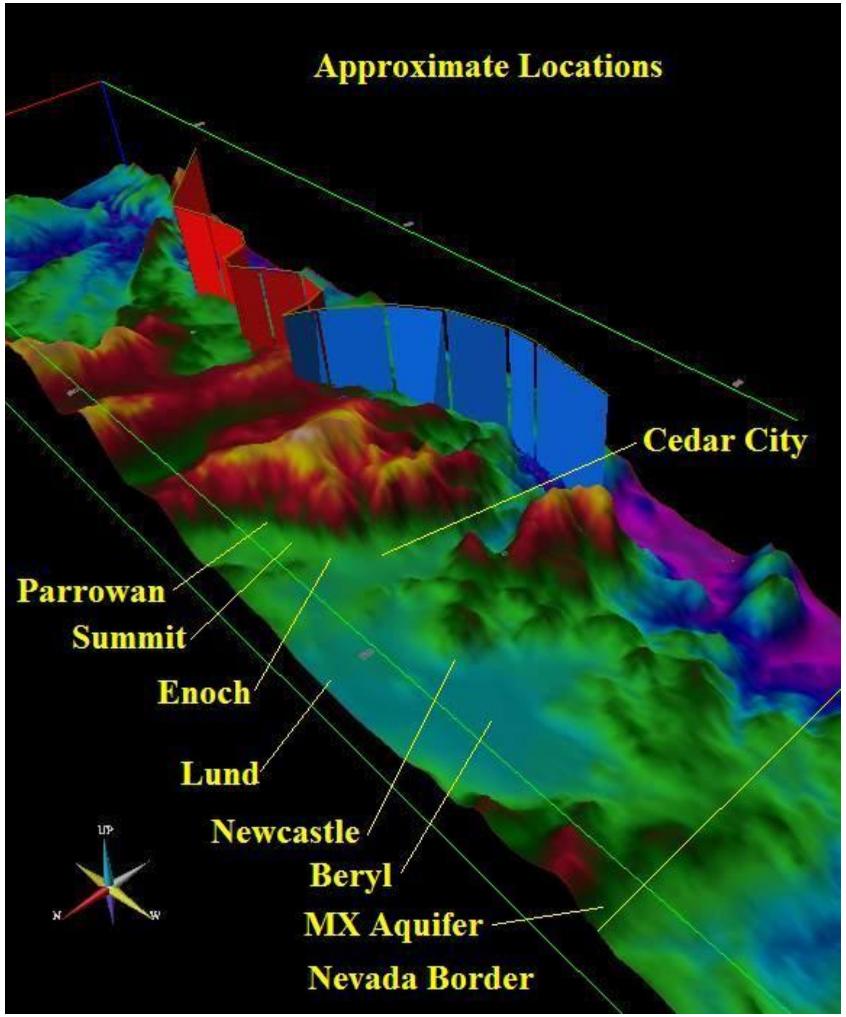
Large Fracture Systems Drain Downhill and to the Grand Canyon Lowering Hydrostatic Pressure in the Southern Great Basin



This discharge is not accounted for in the existing USGS aquifer models for Cedar Valley.

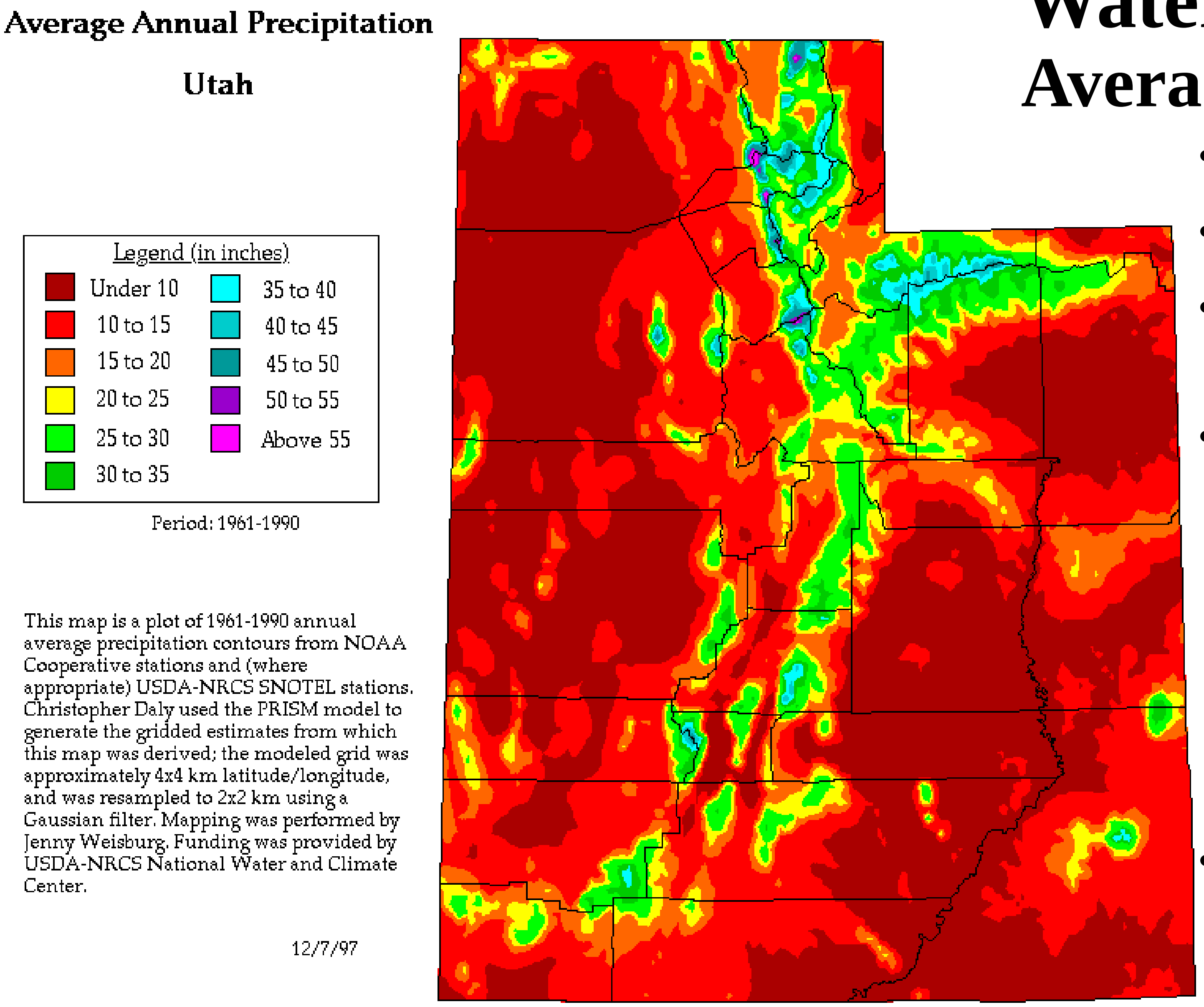
Merging Geology, Water, and Economics

Map provided to Eldon Schmutz of the CICWCD, just before the CICWCD filed for West Desert Water in 2006

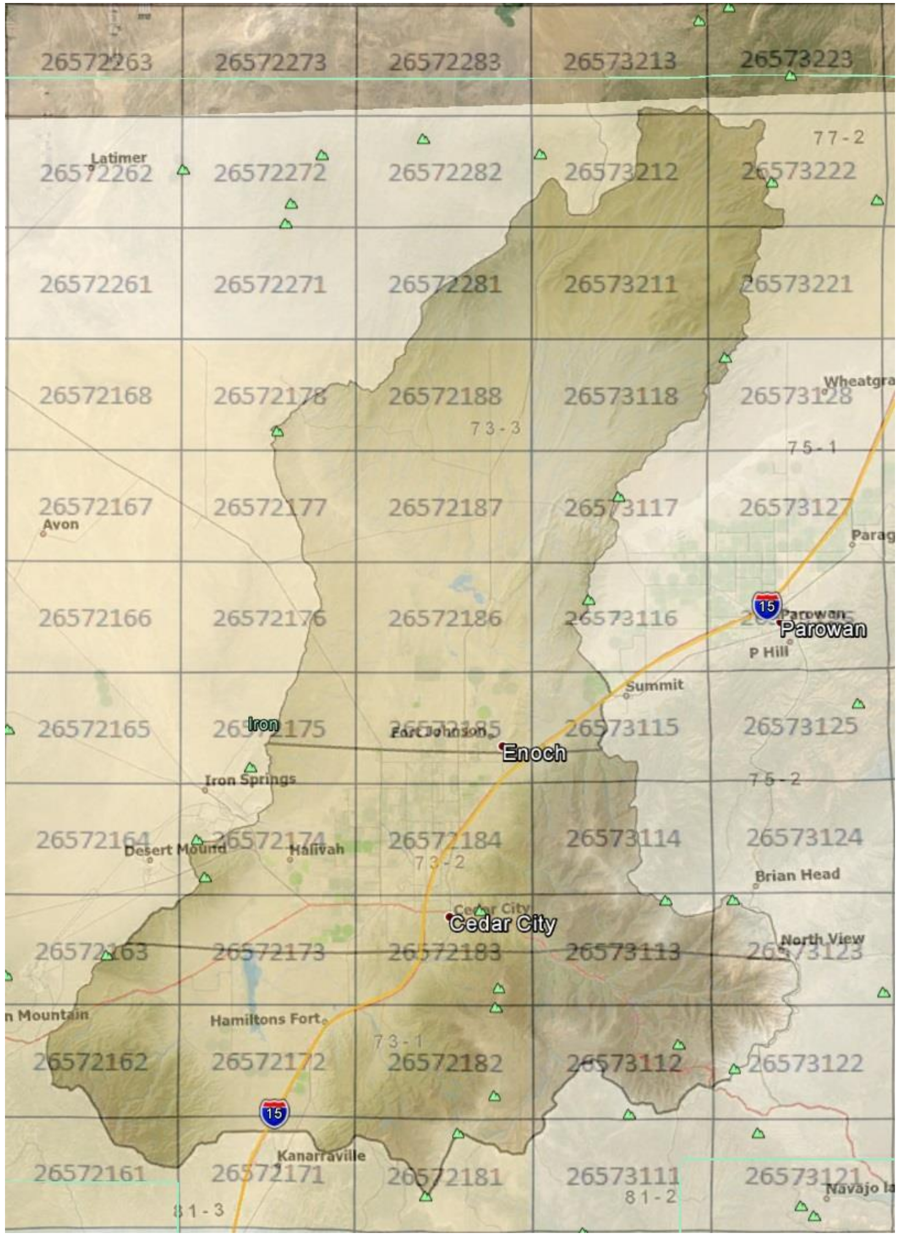


- Lake Powell Pipeline cost of $1 billion over 50 years, including $20,000 per acre foot + cost to pump water up the Black Ridge 3,400+ feet to Cedar Valley was rejected by voters.
- Pine Valley Pipeline cost of $150+ million over 10 years, with water at $9,259 per acre foot, will be another tough political fight.
- Untested bedrock aquifers to the east and to the west of Cedar Valley can be tested for $500,000; or less than $500 per acre foot.

Water System Recharge
Average Annual Precipitation

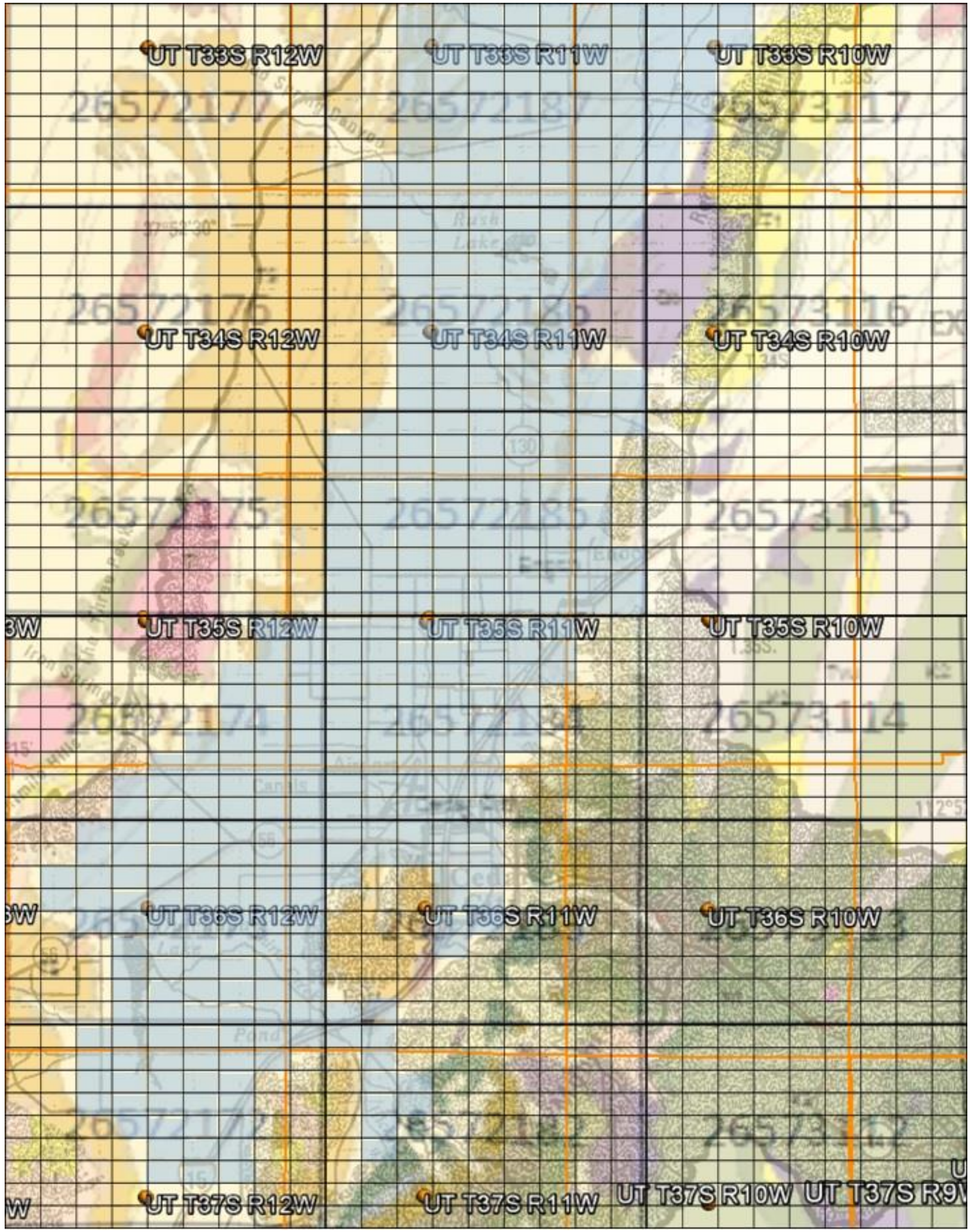


- 1 foot in the valley annually
- 3 feet in the mountains annually
- A good well produces 800 to 3,200 acre-feet of water per year.
- With no drawdown, and a 10% infiltration rate this implies
  - In the valley 12.5 sq mi surface area needed to produce 800 ac-ft , and 50 sq mi needed to produce 3,200 ac-ft; and
  - In the mountain 3.2 sq mi needed to produce 800 ac-ft and 16.3 sq mi needed to produce 3,200 ac-ft in the mountains.
- Hydrology models do not show enough of the annual precipitation discharge escaping the Southern Great Basin and Cedar Valley going downhill and through large transform faults.



Cedar Valley Drainage Basin

- Water for Cedar Valley is available from anyplace in the Cedar Valley Drainage Basin.
- There are consolidated rocks on either side of the Cedar Valley Aquifer, within the Cedar Valley Drainage Basin, which hold tremendous volumes of water:
  - On the west are fractured quartz monzonite rocks, which have excellent water production in New Harmony;
  - On the east are 20-30% porosity Cretaceous rocks, which have excellent water production at Brian Head.
- These aquifers are semi-isolated from the Cedar Valley Fill Aquifer by faults and clays.



The Cedar Valley Aquifer Extent

- The Cedar Valley Aquifer is shown by the blue colored squares on this map.
- Each colored square is about ~0.36 square miles in size. There are 421 cells covering the Cedar Valley Aquifer, or 152 sq. miles.
- This is ~97,000 acres, with an average of 12 inches of precipitation per year, implying an average of 10,000 acre-feet of recharge in the aquifer per year with a 10% infiltration rate.

More water is discharged than recharged in Cedar Valley

Table 3. Transient groundwater model budget from Brooks and Mason (2005), representing the model approximated budget for the year 2000.

		Cubic Feet/Day	Acre-ft/Year
RECHARGE	Irrigation and precipitation on irrigated lands, including seepage from Coal Creek	2,330,000	19,500
	Winter precipitation on all areas	700,000	5900
	Subsurface Inflow		
	Parowan Valley[1]	370,000	3100
	North consolidated rock	160,000	1400
	Southeast consolidated rock	36,000	300
	East consolidated rock	84,000	700
	Southwest consolidated rock	190,000	1600
	West consolidated rock	120,000	1000
	Inflow from south of area	9500	80
	Total recharge (rounded)	4,000,000	33,500
DISCHARGE	Wells	4,080,000	34,200
	Evapotranspiration	530,000	4500
	Springs	150,000	1300
	Outflow to other areas	320,000	2700
	Total discharge	5,100,000	42,700
	Water removed from storage[2]	1,100,000	9100

[1]Includes 1100 acre-feet per year recharge from consolidated rock.
[2]Valley-wide water-level declines from March 2000 to March 2001 indicate a removal of water from storage (discharge exceeding recharge).

Loss of at least 9,100 acre-feet/year

This and other hydrology models are like and as valid as the financial proforma's of a new business.

Exploration water wells, instead of customers, validate the model.

Investigation of land subsidence and earth fissures in Cedar Valley, Iron County, Utah, Tyler Knudsen, Paul Inkenbrandt, William Lund, Mike Lowe, and Steve Bowman, 2014, page 14.

How do Geoscientists see under the ground?

- Line 711 was my first assignment in Mobil Field Operations in February 1978 (it was cold, saw bear tracks).
- When I learned of Bengt Nelson's first winter (1856-1857) at Iron Springs.
- Figures to right from Line 704.

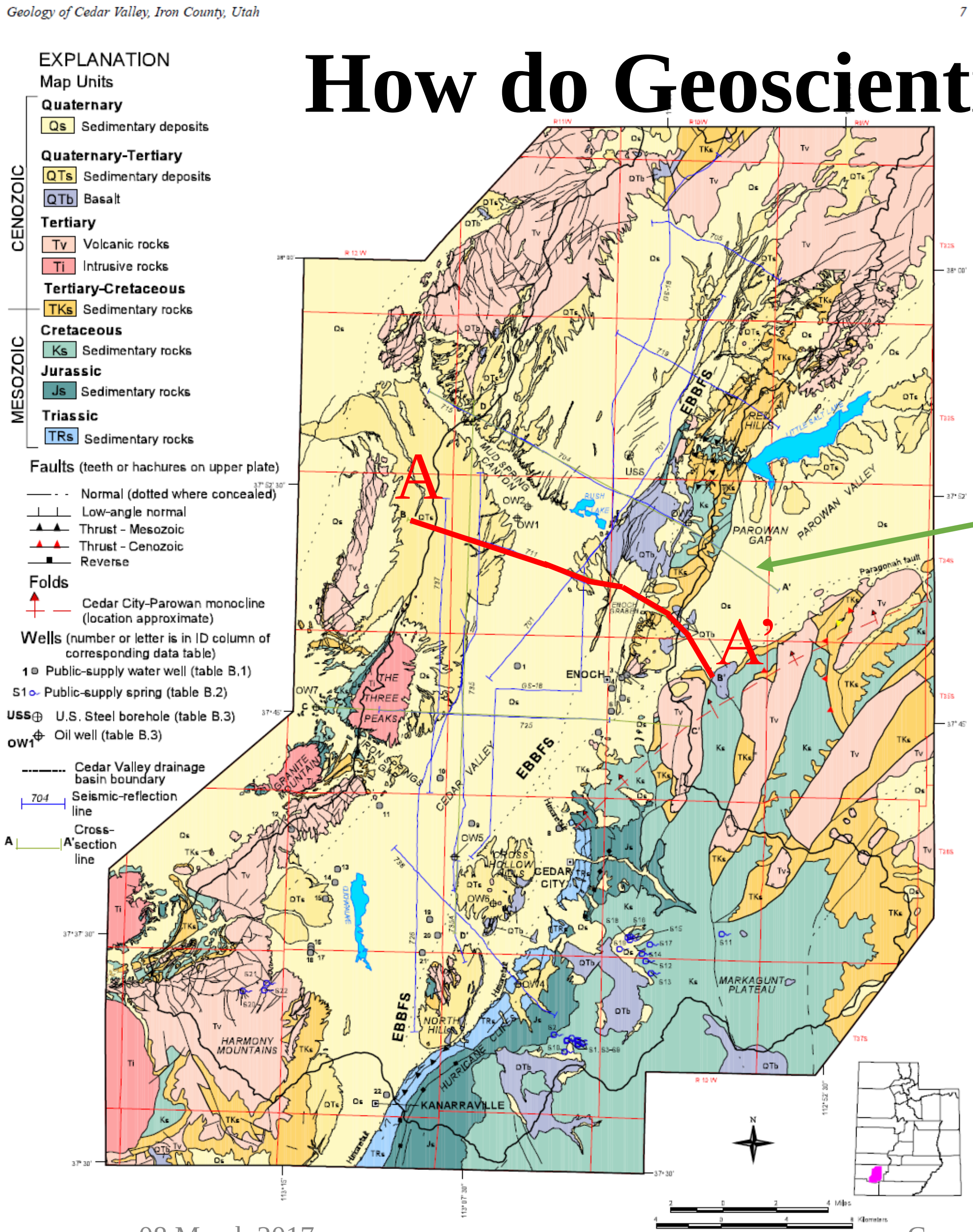


Figure 6. Simplified geologic map of Cedar Valley drainage basin and adjacent areas. EBBFS is eastern basin-bounding fault system. See figure 5 for stratigraphic column, and appendix A for correlation of map units with those on plates 1 and 2.

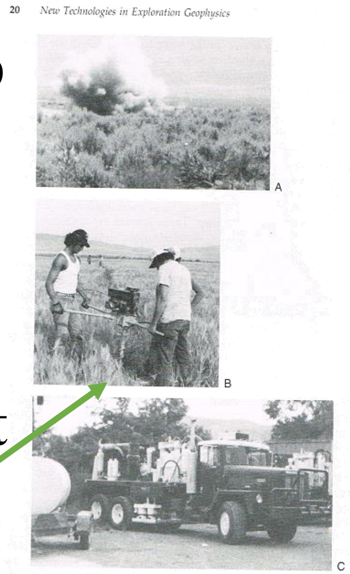
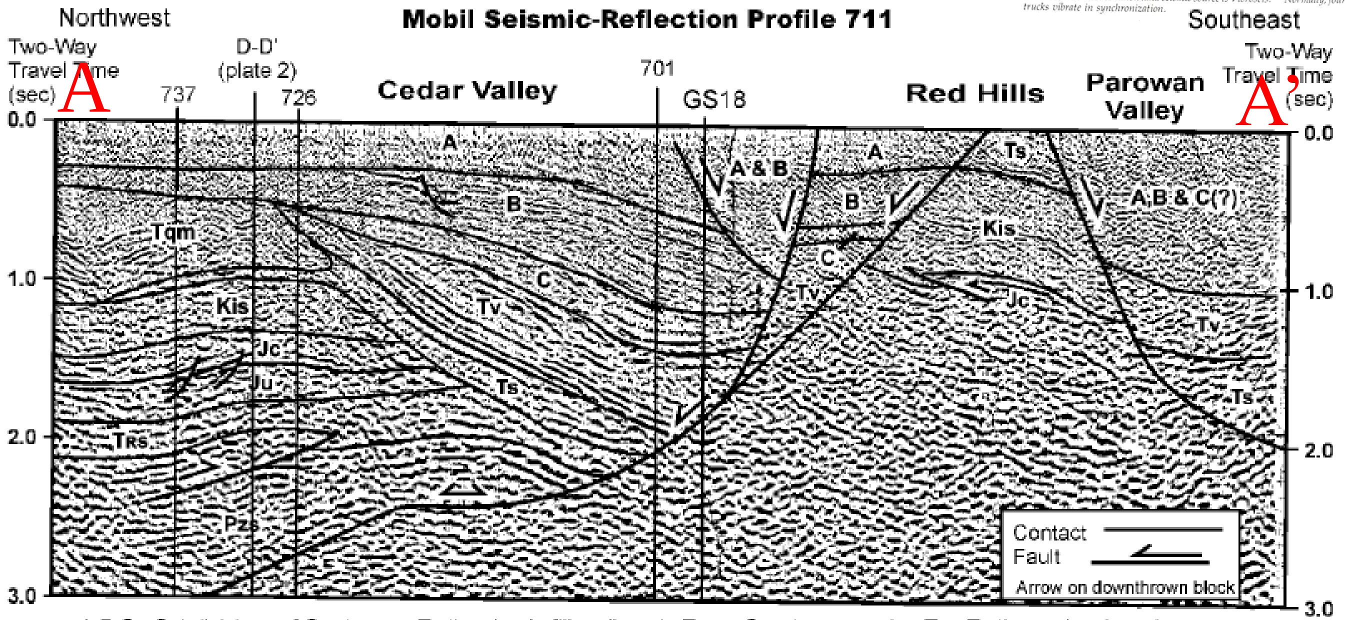
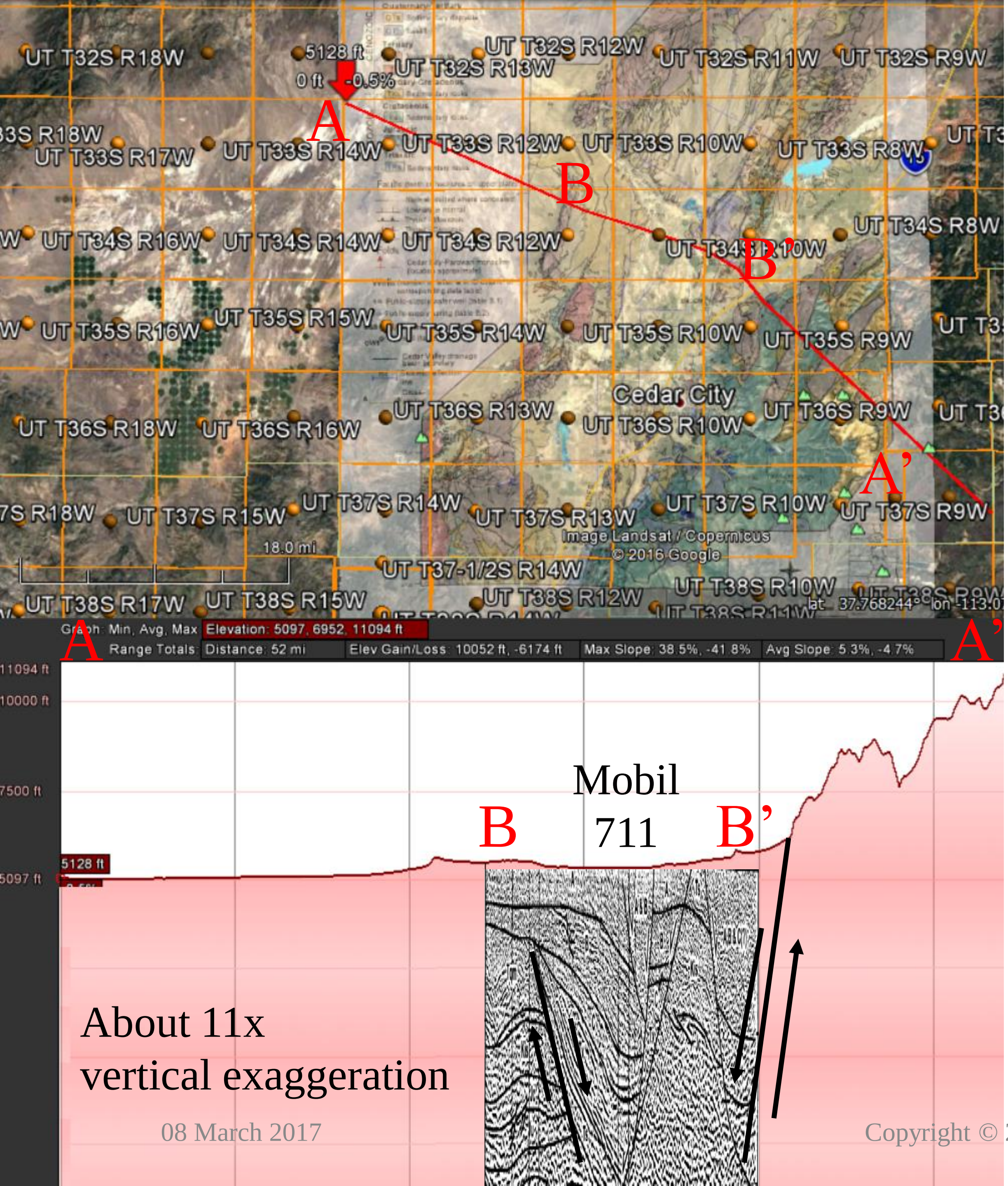


Figure 1-5. Typical land crew operations in southwestern Utah. (A) Surface shooting using ten 5-lb sacks of explosives on a primachord string. The environmental damage is temporary, but overshooting, like overgrazing, can cause long-term problems. (B) Shallow hole shooting of, say, 10 lbs of dynamite per shotpoint is better in agricultural areas. (C) The most common land seismic source is Vibroseis.™ Normally, four of these trucks vibrate in synchronization.



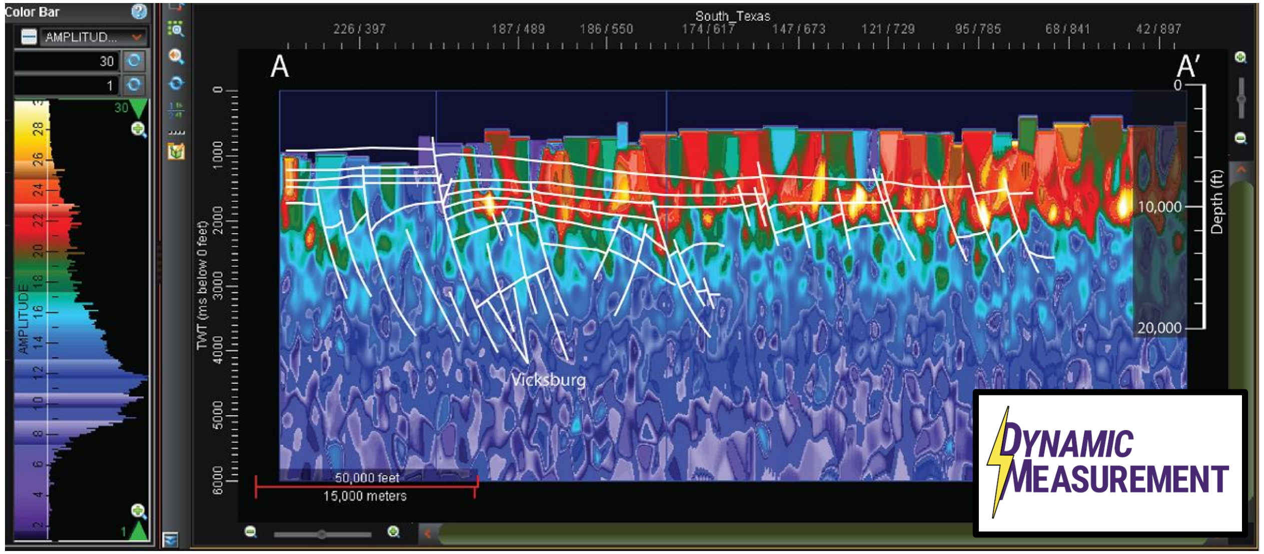
A,B,C - Subdivisions of Quaternary-Tertiary basin-fill sediment; Tqm - Quartz monzonite; Tv - Tertiary volcanic rocks; Ts - Tertiary sedimentary rocks; Kis - Iron Springs Formation; Jc - Carmel Formation; Ju - Navajo Sandstone, Kayenta, and Moenave Formations, undifferentiated; TRs - Triassic sedimentary rocks; Pzs - Paleozoic sedimentary rocks.



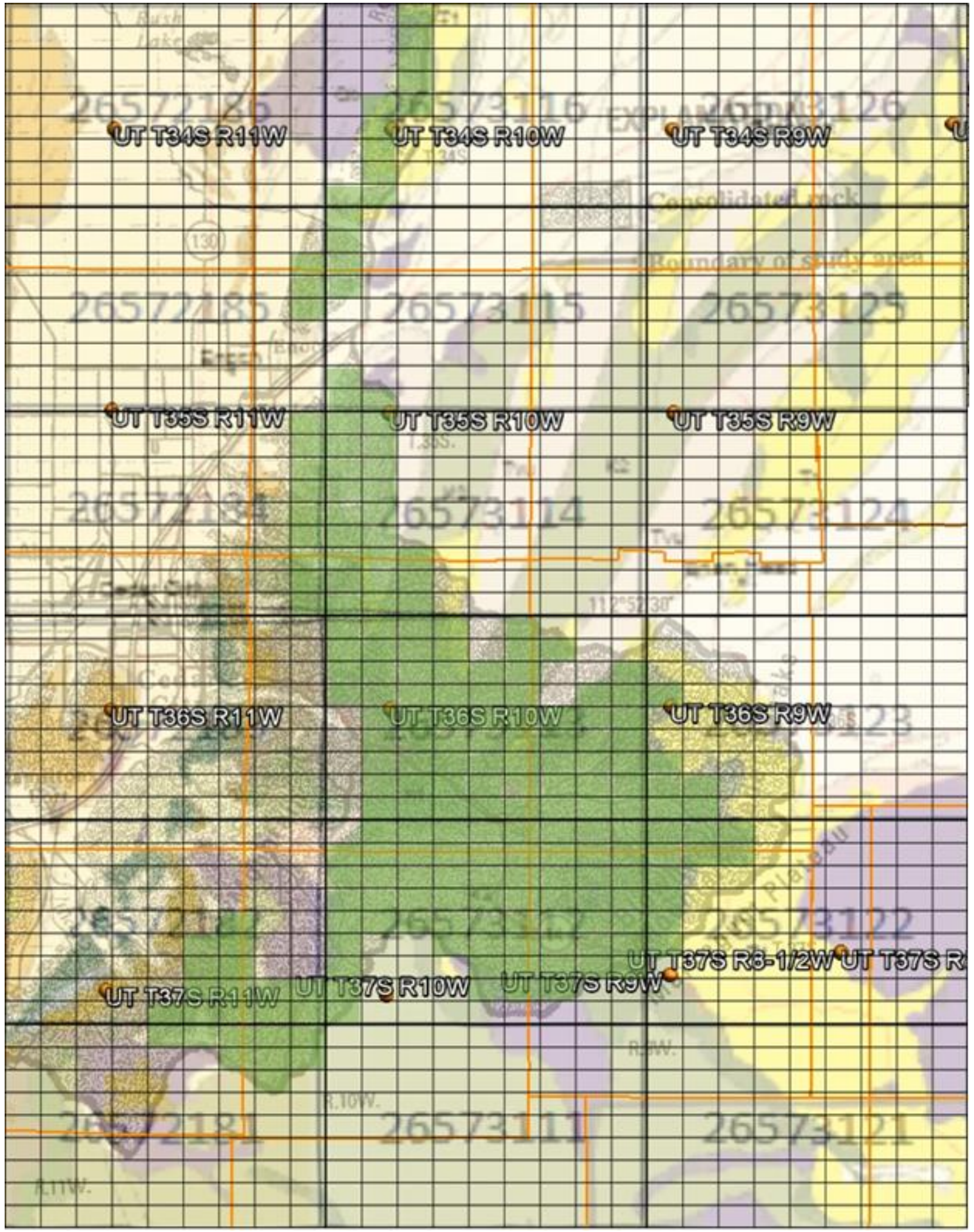
Mobil Line 711 cross-section

Other ways to see underground include:

- Electrical Methods
  - Resistivity, Magneto-tellurics, Self-Potential, etc.
- Potential Fields & Seismic
  - Gravity, Magnetics & Earthquake, Refraction, Reflection
- Satellite: (Thermal Reflectance, Elevation, etc.)
- Lightning: (Resistivity & Attribute Maps & Volumes)



Untapped Cretaceous Aquifer
above the repeated road repairs in Cedar Canyon
(note most significant flow is on east facing outcrops, because beds dip east)



The Cretaceous Aquifer Extent

- The Cretaceous Aquifer is shown by the green colored squares on this map.
- Each colored square is about ~0.36 square miles in size. There are 213 cells covering the Cretaceous Aquifer, or 77 square miles.
- This is ~50,000 acres, with an average of 36 inches of precipitation per year, implying an average of 15,000 acre-feet of recharge in the aquifer per year with an infiltration rate of 10%.

Cretaceous Age Straight Cliffs to Dakota Sandstone up Cedar Canyon

This is where landslides regularly happen

Straight Cliffs Formation over Dakota Formation, north of Highway 14 at Mile 8, east of Cedar City.

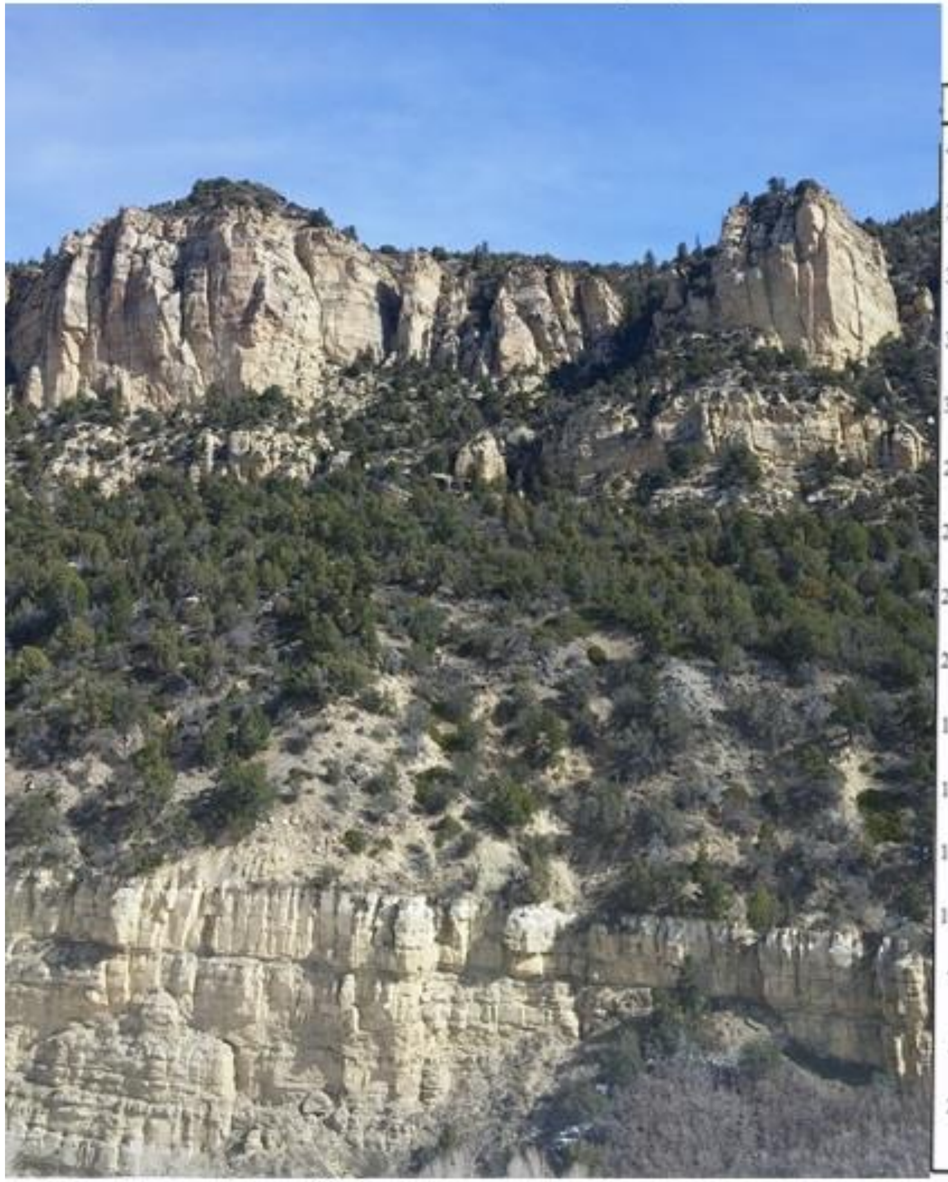


Photo by Gary F. Player, Utah Professional Geologist 5280804-2250, March 14, 2015

Utah Geological Association Publication 30 - Pacific Section
American Association of Petroleum Geologists Publication GB78
345

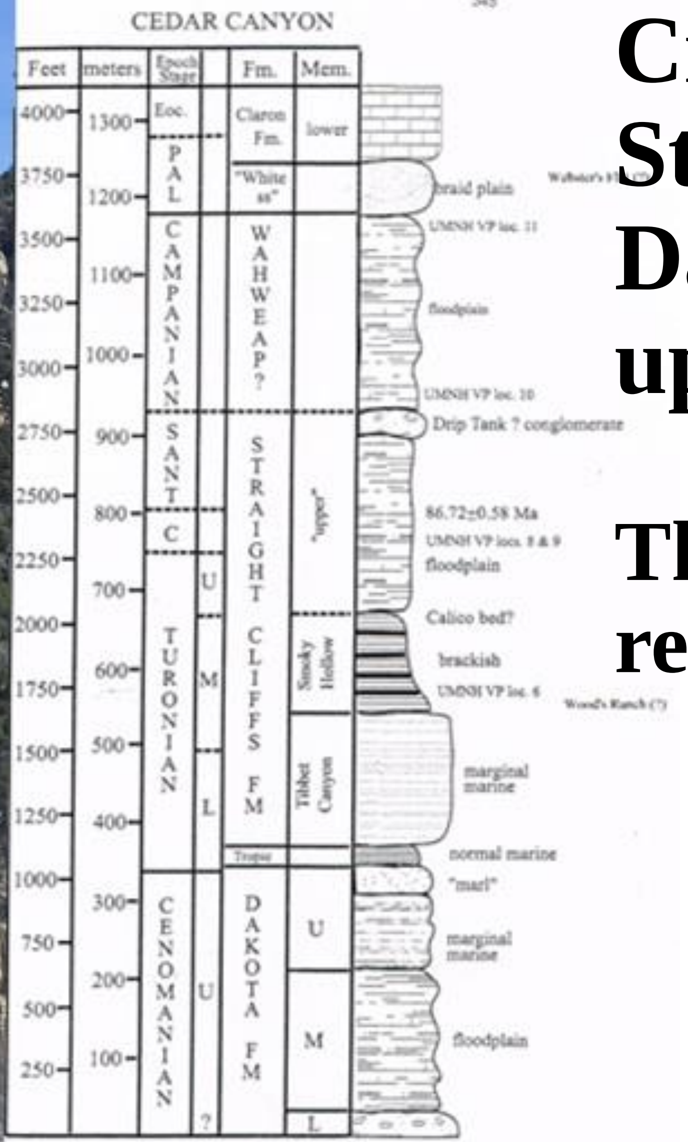
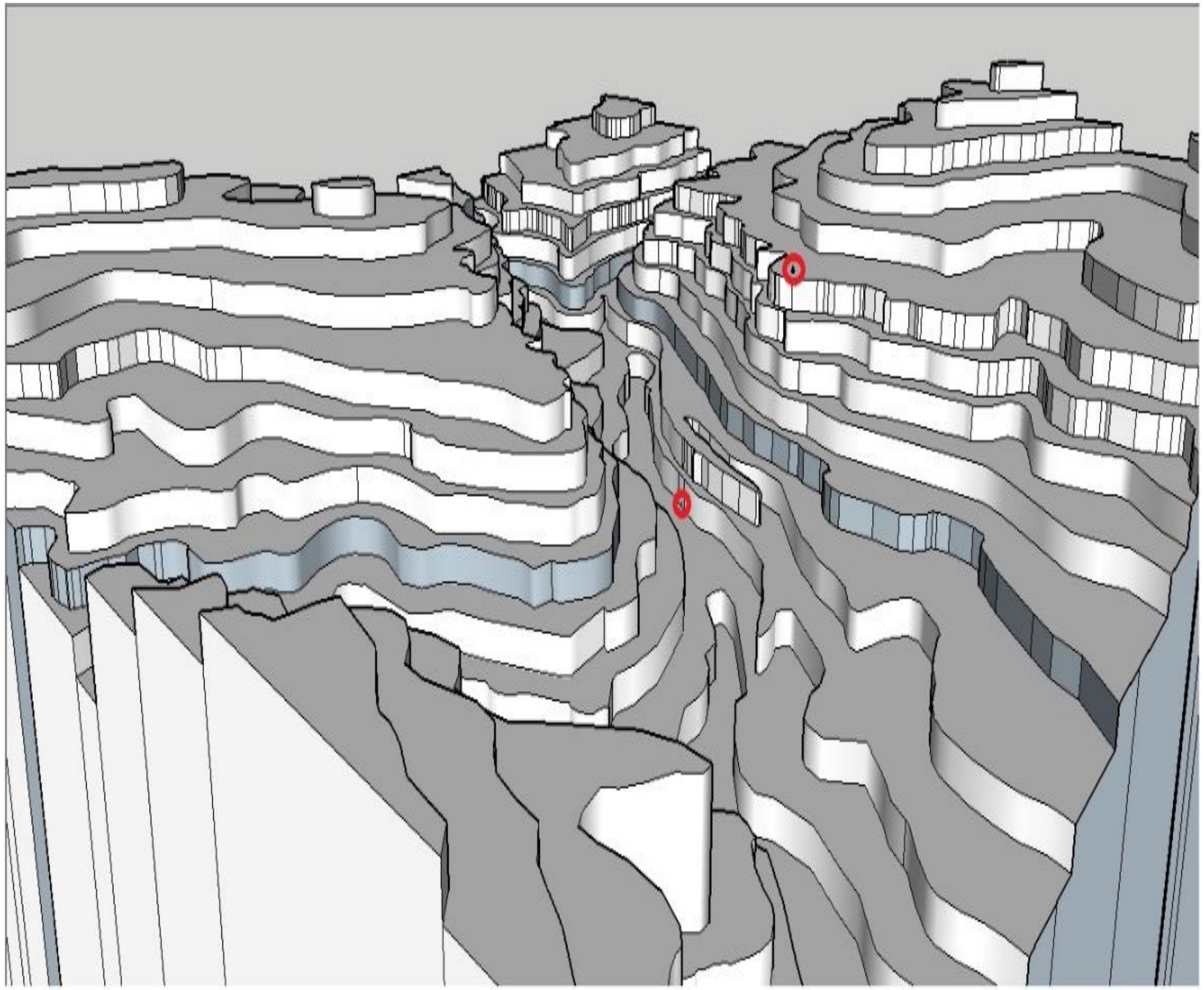
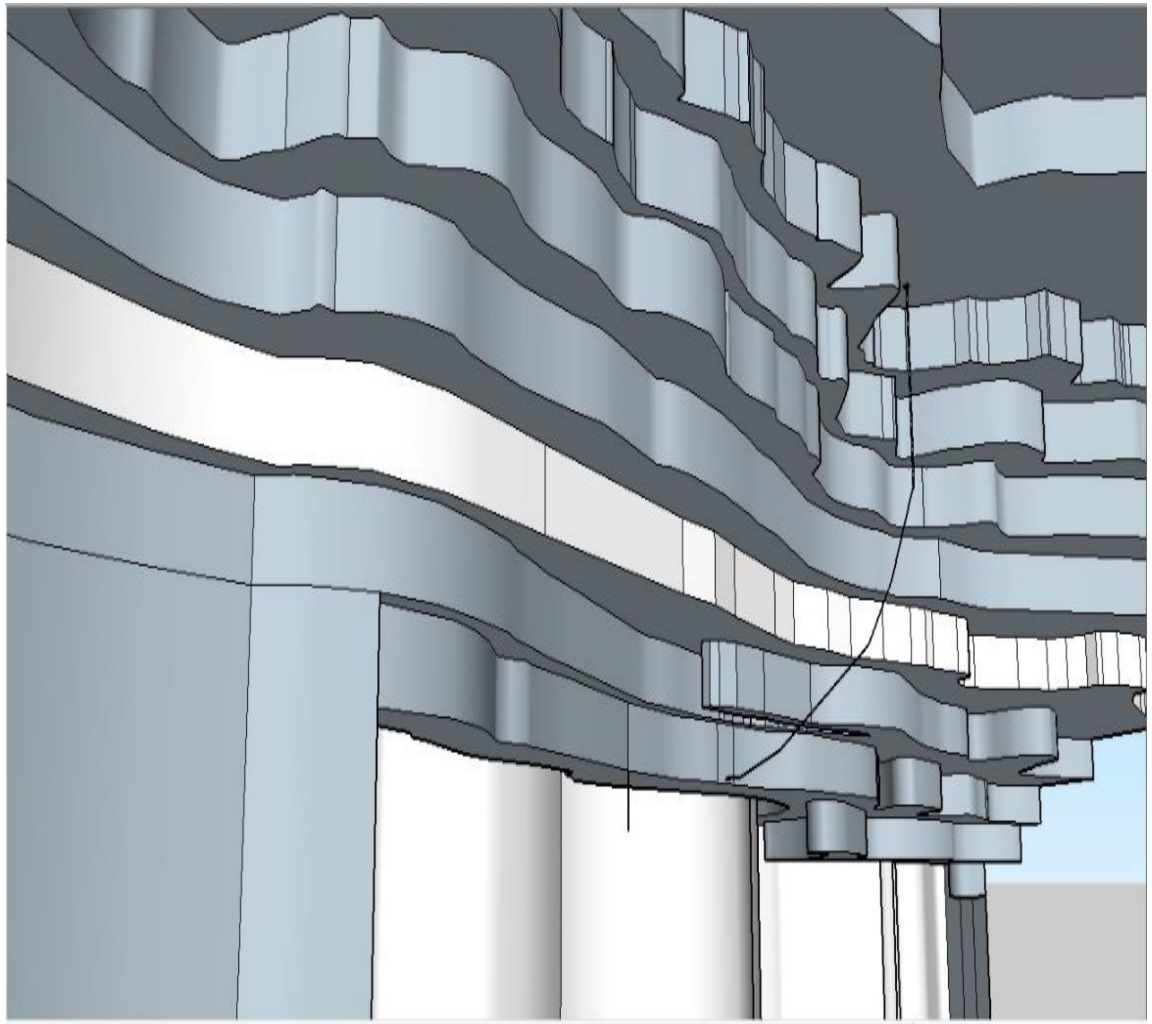


Figure 5. Comparison of Upper Cretaceous and lower Tertiary stratigraphy in Cedar and Parowan Canyons. The Parowan section is hung on the contact between the Claron and Grand Castle Formations. UGA Pub. 30

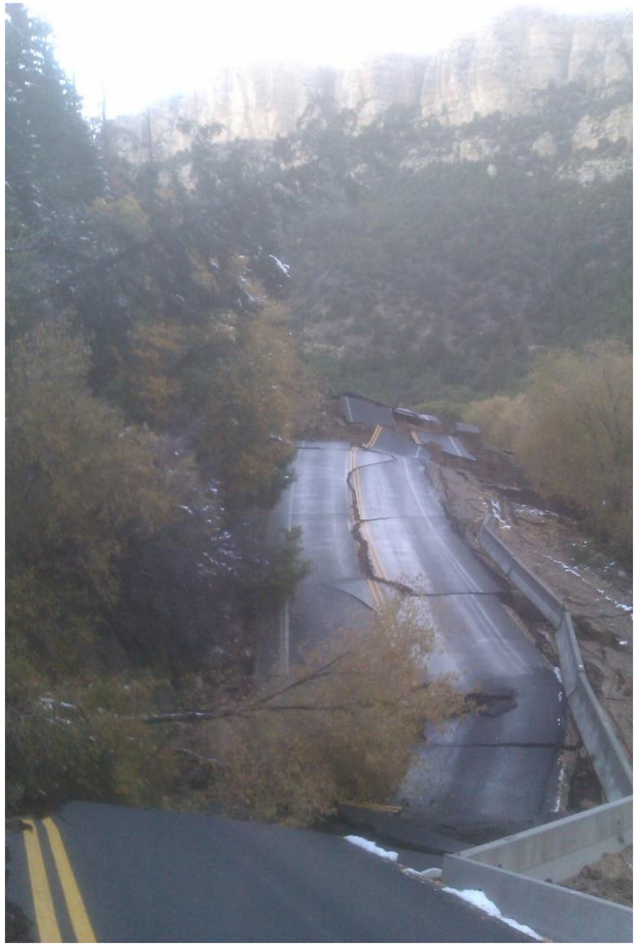
Deviated Hole from Straight Cliffs to Dakota Sandstone which, with turbines in the well, could also be a new source of energy

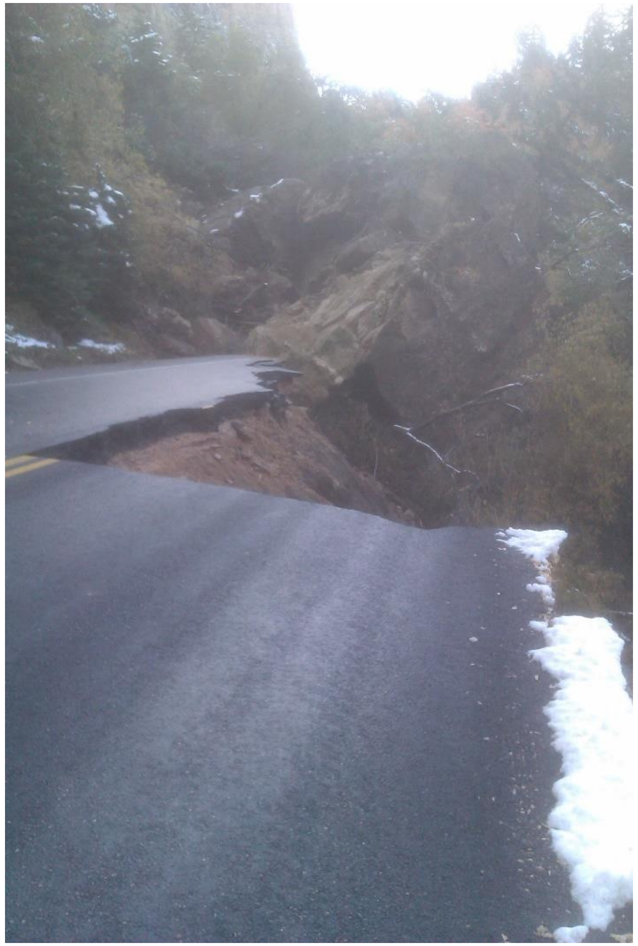




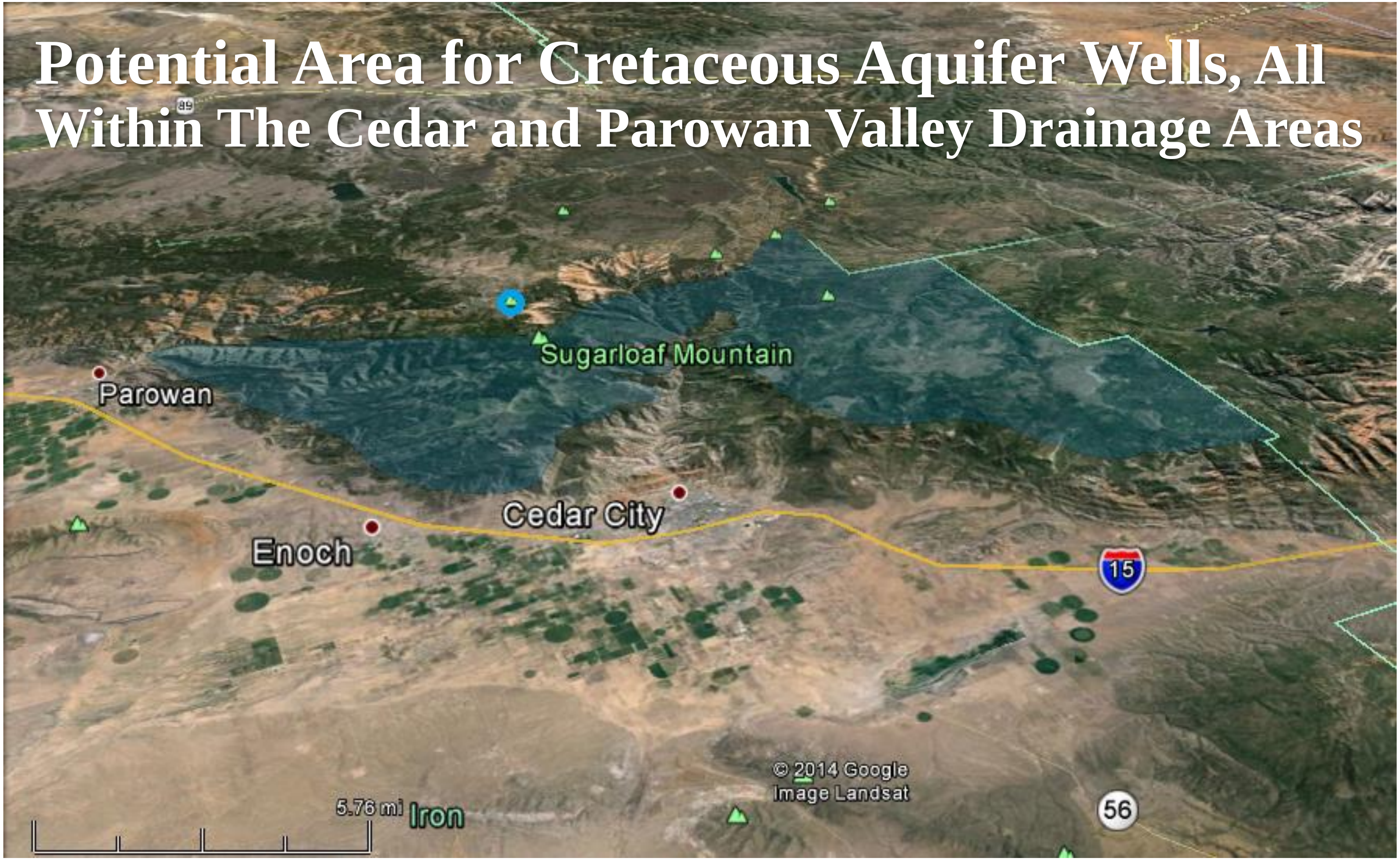
What is the cost to repair the road?

Compared to the cost of drilling a deviated hole
and draining the water out of the cliffs to prevent landslides?





Potential Area for Cretaceous Aquifer Wells, All Within The Cedar and Parowan Valley Drainage Areas

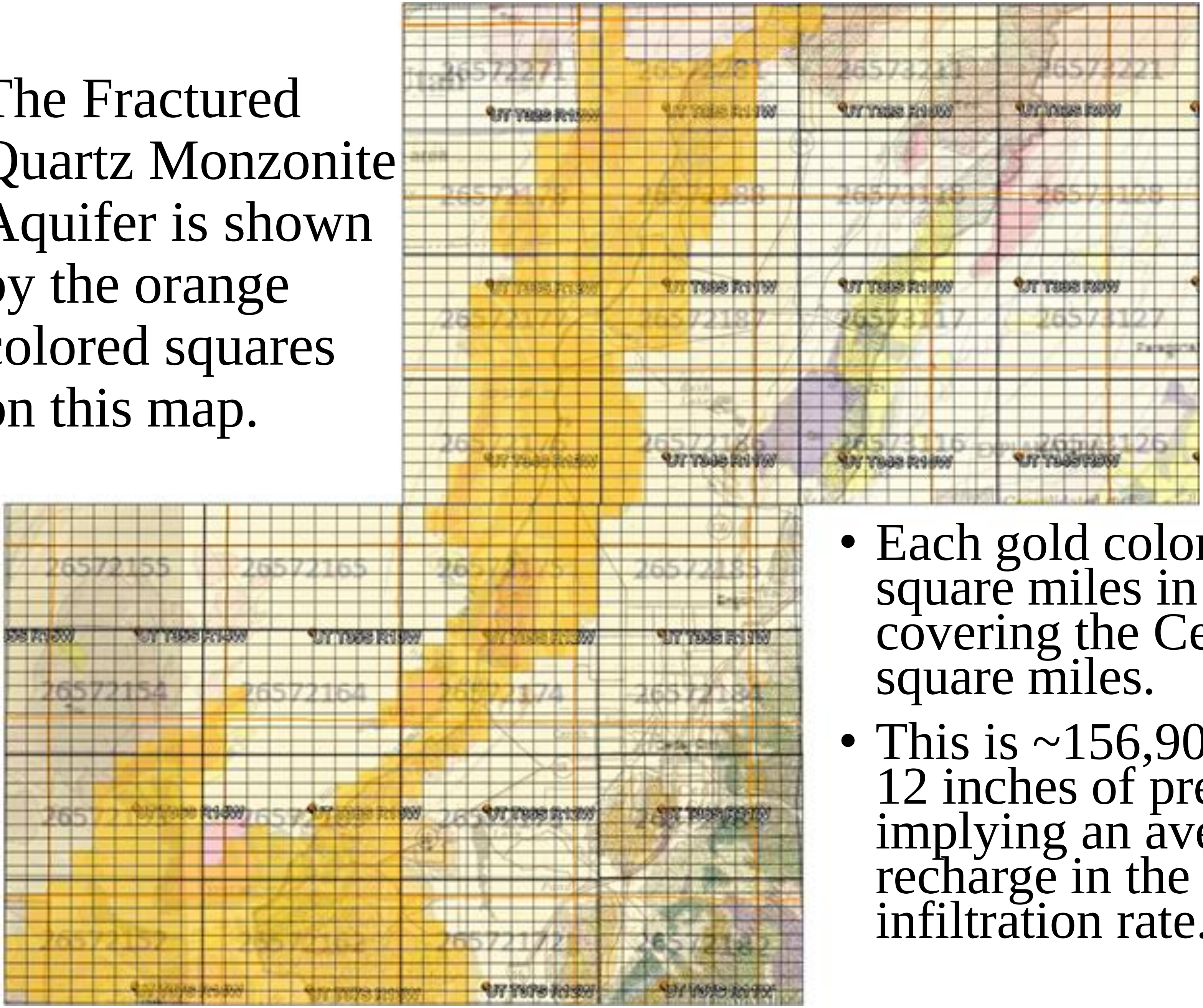


Untapped Fractured Quartz Monzonite Aquifer
Photograph of water in Blowout Pit at Iron Mountain

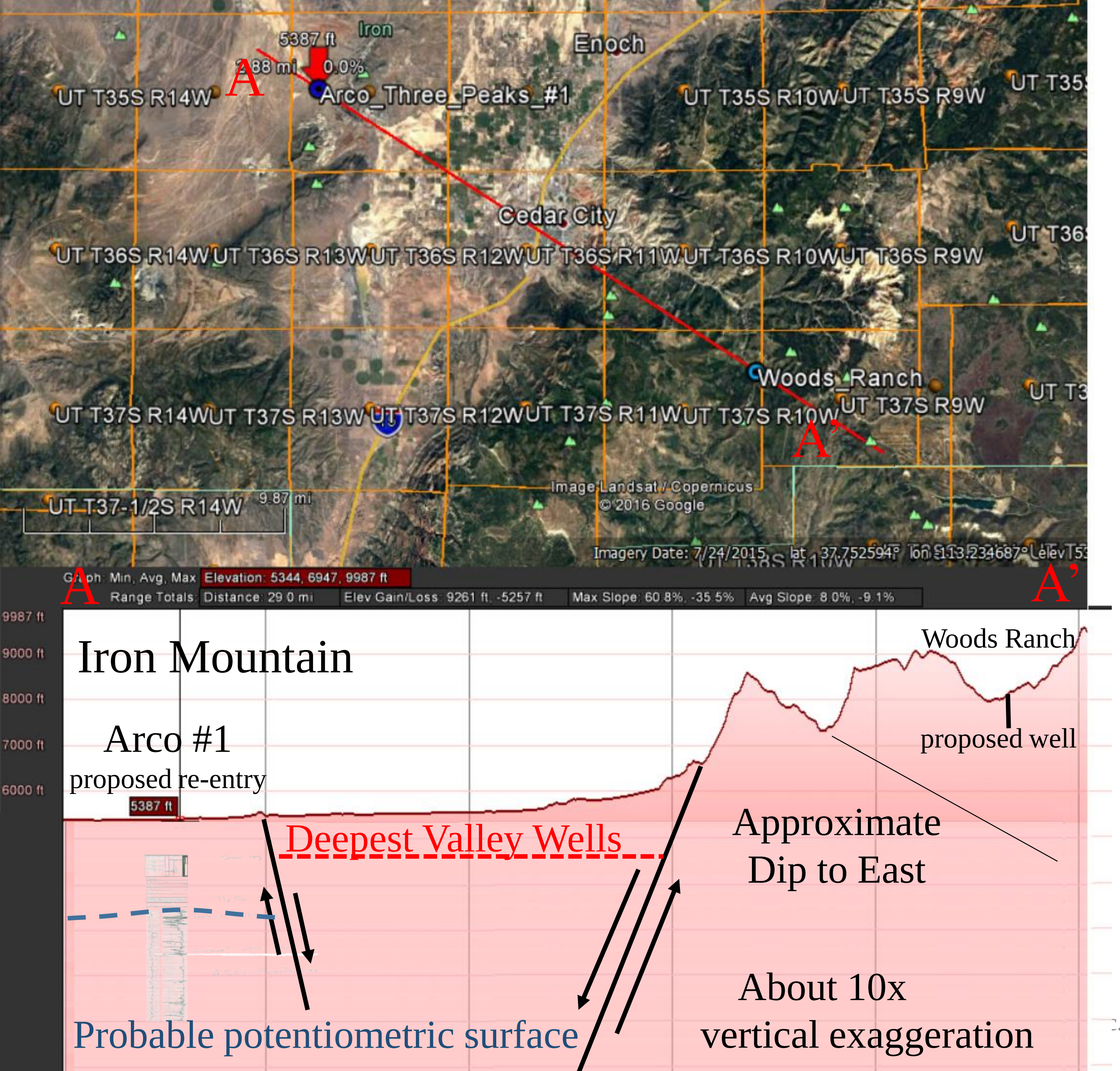
Photograph by Gary Player

Fractured Quartz Monzonite Aquifer Extent

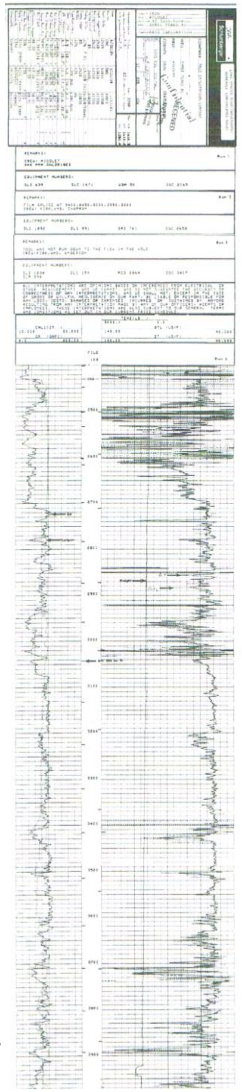
The Fractured Quartz Monzonite Aquifer is shown by the orange colored squares on this map.



- Each gold colored square is about ~0.36 square miles in size. There are 681 cells covering the Cedar Drainage Basin, or 245 square miles.
- This is ~156,900 acres, with an average of 12 inches of precipitation per year, implying an average of 15,700 acre-feet of recharge in the aquifer per year at a10% infiltration rate.



Arco #1 – Woods Ranch cross-section



- An opportunity to test the Fractured Quartz Monzonite Aquifer is to reopen this well.

Top Qm = 2,322’
Fractured: 2,500’-2,615’

Fractured: 2,960’-3,050’

- The proposed test in the Cretaceous rocks is at Woods Ranch or Sheepherder’s Cabin.

Transferring Water Rights
either up the mountain or to the west solves over allocation issues!

Potential Development of Bedrock Aquifers in Nearby Mountain Areas

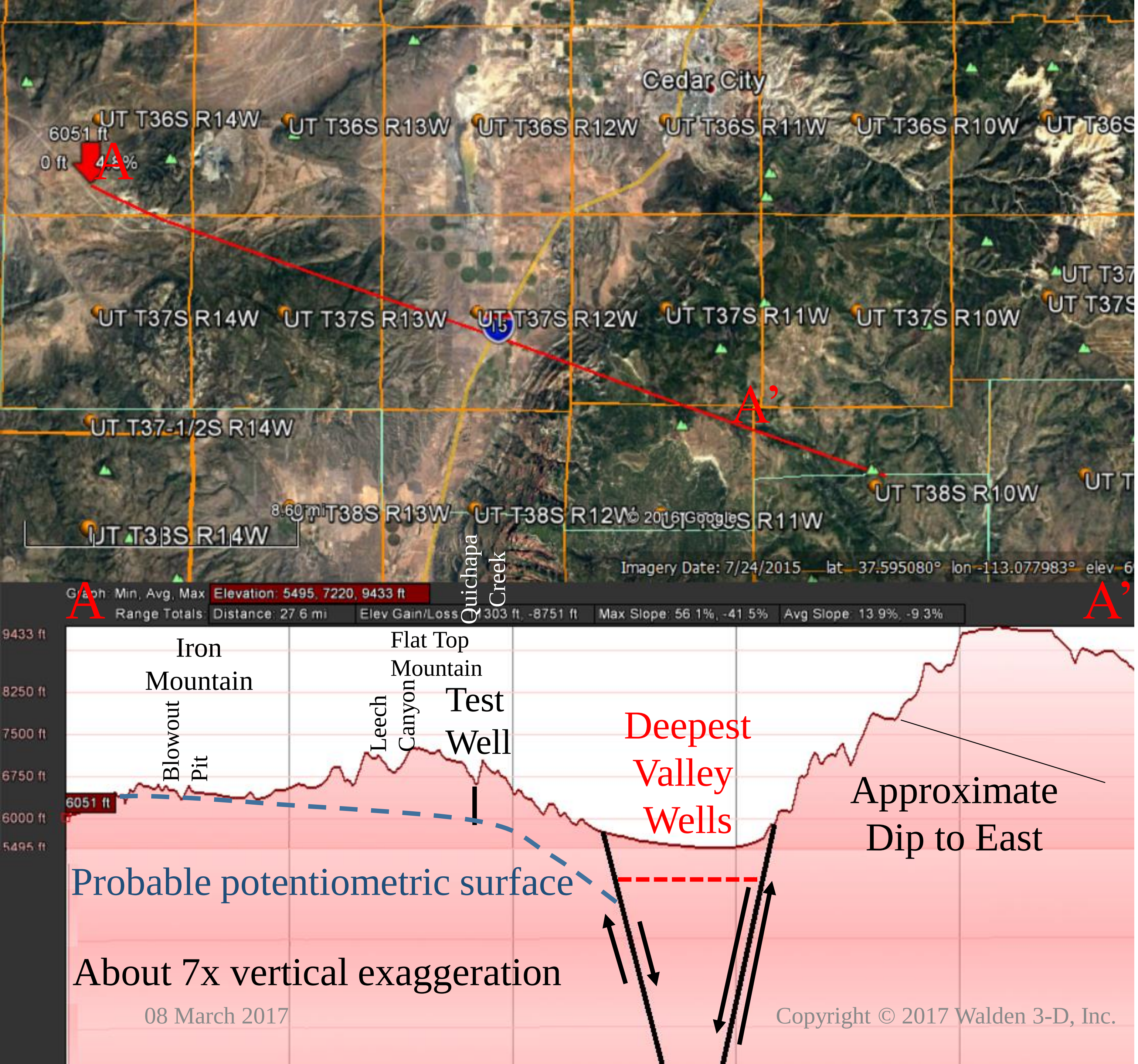
27. *Exploration of bedrock aquifers in the mountains of Iron County could result in the identification of more renewable water than is currently pumped ("over drafted") from the sand and gravel aquifers under Cedar Valley. Average annual precipitation records show that water production from the bedrock aquifers in the mountainous areas of the county can be sustained without damaging existing flows from the springs and creeks now tapped for use. [Gary Player]*
28. *Is there a possibility that the State would consider appropriating new water rights if it was found that water contained in bedrock aquifers does not contribute to the valley aquifer? [Cedar City]*

The State Engineer wants to encourage new groundwater development so long as it does not take away water from existing users. Mr. Player's exploration proposals and his previous reports to Cedar City have been reviewed and compared with findings from other hydrogeologic studies. Two regions have been proposed for exploration: the mountains west of Cedar City and the mountains east of Cedar City. At this time, the State Engineer believes the western mountain bedrock aquifers are hydrologically connected to the valley aquifer and water in the eastern mountain bedrock discharges to Coal Creek or flows southeast and to the Virgin River. Since each of these sources is considered to be fully appropriated, further development would cause impairment to other water rights. To alleviate overdrafts in the basin water rights would need to be purchased and transferred to these locations prior to diverting from these sources.

Good! Help fund a test well!

Wrong! Quartz monzonite aquifers are deeper, 2,200 foot deep at Arco well, than the currently tapped 800 foot deep Cedar Valley Aquifer!

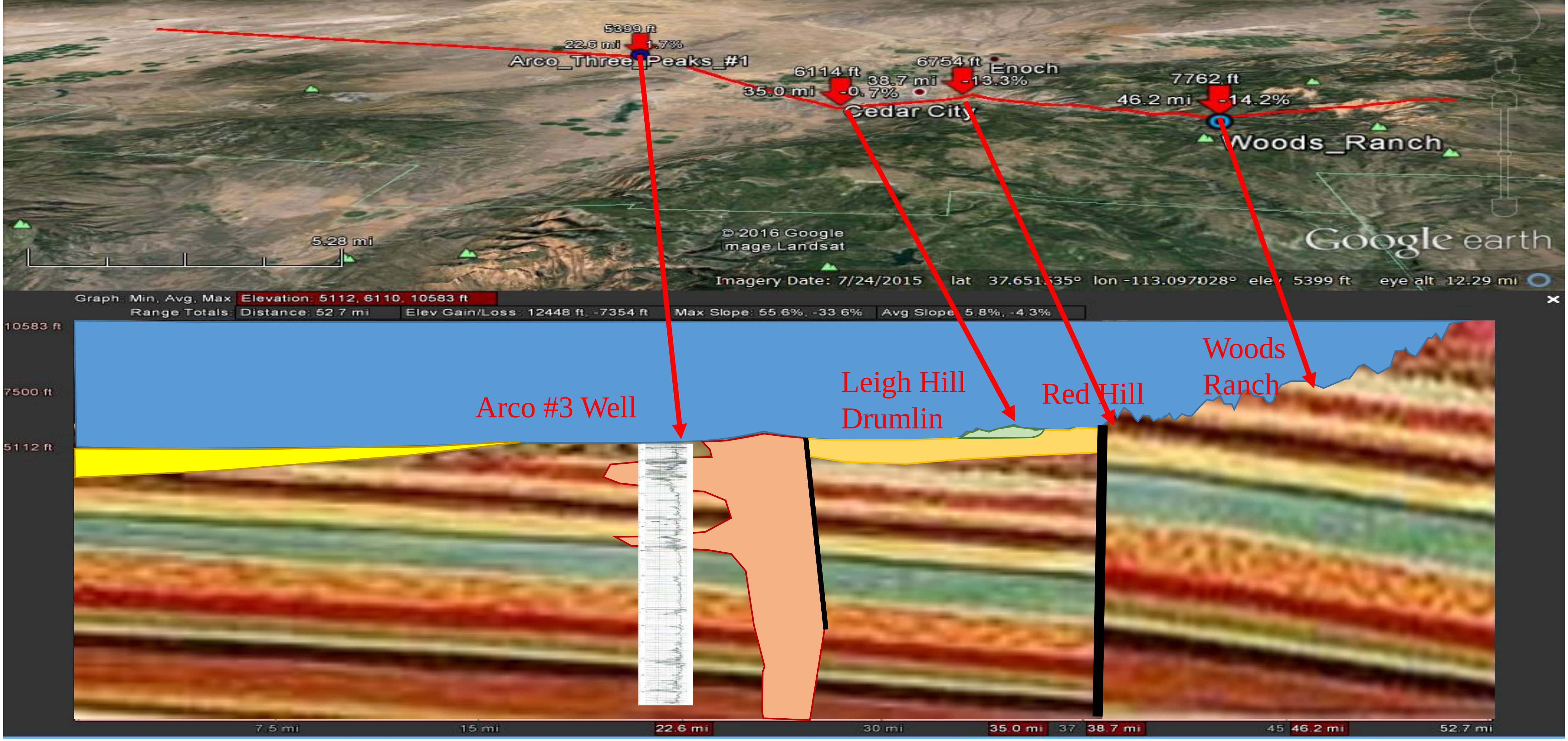
We recommend a $250,000 well at or near Woods Ranch to test the Cretaceous Aquifer. If only 1,000 acre-feet of water are produced, it will have cost $250 per acre foot, and water can be put in Coal Creek.



Blowout Pit Cross-Section

- Dip on bedrock to east drives water falling on Cedar Mountain east.
- Throw of Hurricane Fault allows water to drop down 5,000 feet to the porous Jurassic Sandstone.
- Water filling Blowout Pit tested in Quichapa Creek test well.

Integrating a new Hydrologic Model across Iron County



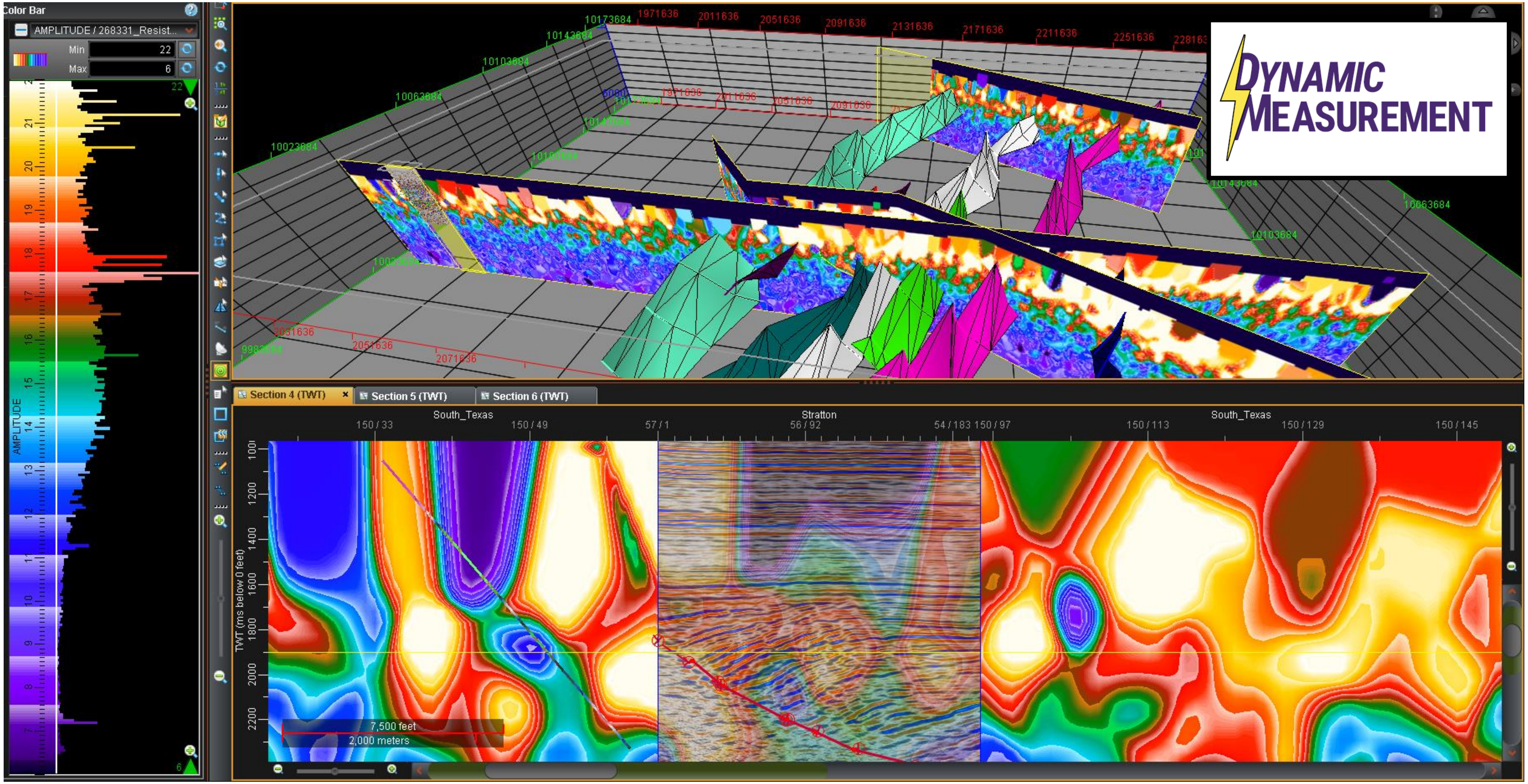
Conclusion of CICWCD Funded Report

The Geology of Cedar Valley, Iron County, Utah, and Its Relation to Ground-Water Conditions
by Hugh A. Hurlow

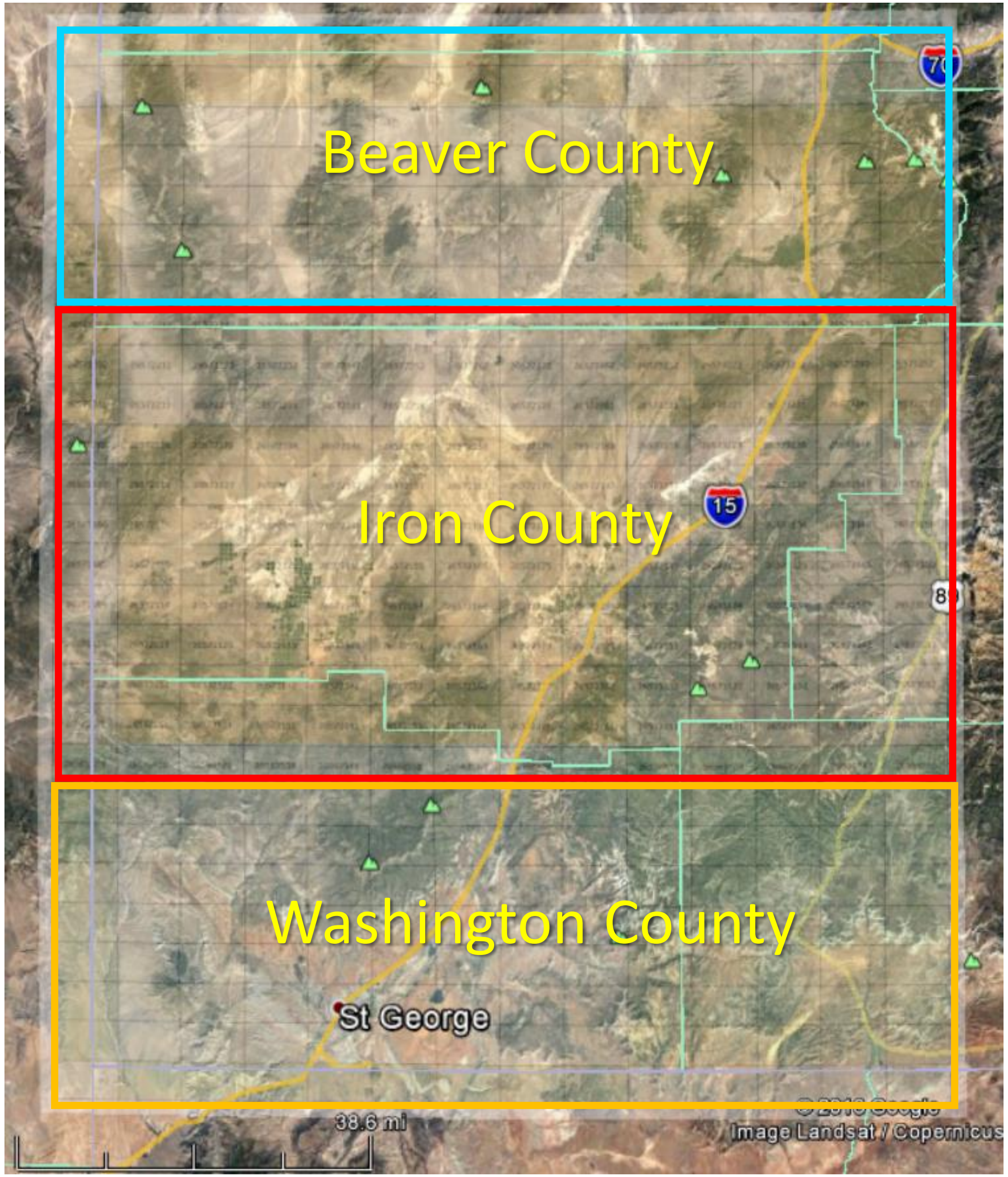
“Most precipitation in the Cedar Valley drainage basin falls on Triassic through Tertiary-age bedrock exposed on the steep cliffs and high plateaus to the southeast. This precipitation either runs off or percolates through bedrock to Coal Creek, which forms the principal source of recharge to the Cedar Valley aquifer as it flows into the valley.

- **Bedrock is important** to the hydrogeology of Cedar Valley, not only because it transmits water to Coal Creek, but also because
    1. it is hydrologically connected to the basin fill across the basin-bounding faults, although the amount of cross-fault flow is probably small, and
    2. **it is a likely target of future water development**.
- Most bedrock units in the study area consist of interlayered sandstone and mudstone, forming heterogeneous potential aquifers of uncertain extent, transmissivity, and chemical quality.
- **The best established and potential bedrock aquifers** in the study area are
    - **fractured Tertiary volcanic rocks and quartz monzonite** exposed in the hills bounding the southwestern, western, and northeastern valley margins, and
    - the Jurassic Navajo **Sandstone in the subsurface east of the valley**.”

A New Geologic Framework from Lightning Analysis
will be built at some point, funded privately or publicly



Lightning Analysis Prices



Beaver	Area	Price	Per Unit
Acres	1,805,485	$232,350	$0.13
Sq.Km.	7,306		$31.80
Sq.Mi.	2,821		$82.36

Iron	Area	Price	Per Unit
Acres	3,093,510	$280,000	$0.09
Sq.Km.	12,519		$22.37
Sq.Mi.	4,834		$57.93

Wash.	Area	Price	Per Unit
Acres	2,102,048	$244,920	$0.12
Sq.Km.	8,507		$28.79
Sq.Mi.	3,284		$74.57

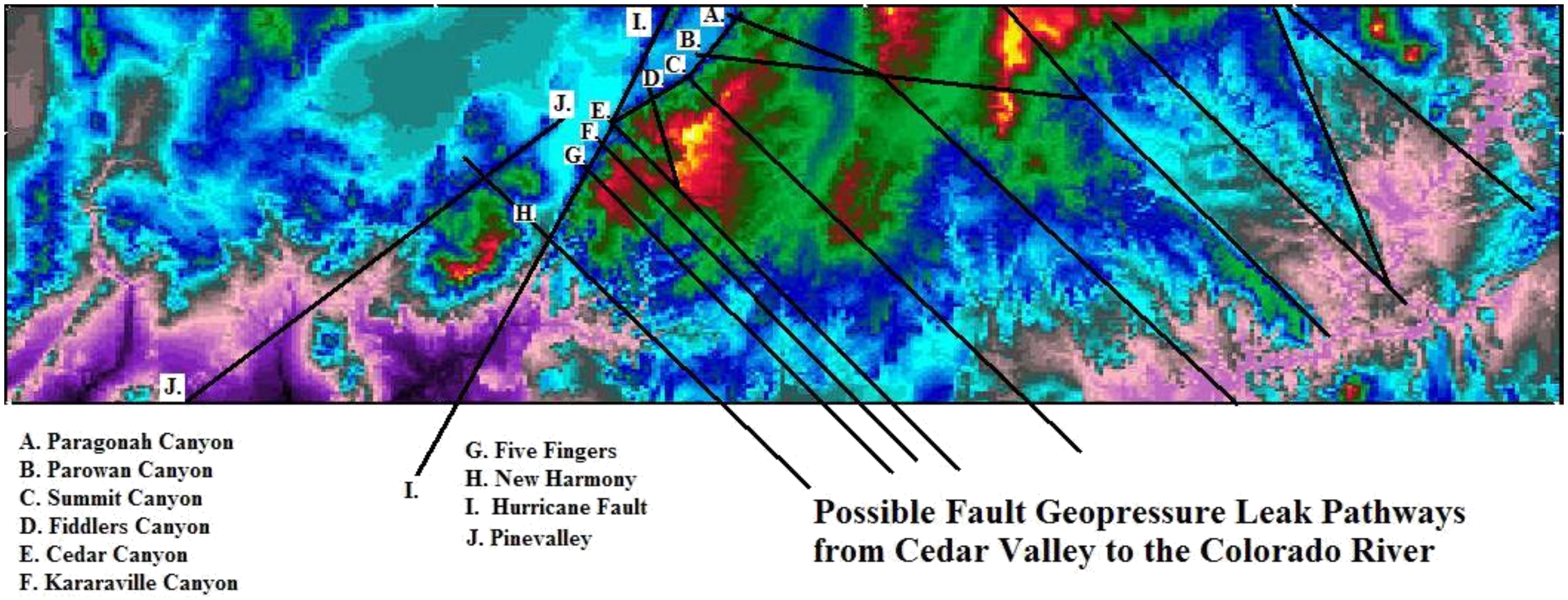
TOTAL	Area	Price	Per Unit
Acres	7,000,614	$371,560	$0.05
Sq.Km.	28,331		$13.12
Sq.Mi.	10,938		$33.97

Summary

- We will never run out of water in Cedar Valley,
  just as the world will never run out of oil.
- Iron County has run out of $1,800 per acre-foot water, and will run out of $3,000 per acre-foot water, just as the world has run out of $5 or $30 per barrel oil.
- **There is a difference between the Cedar Valley Fill Aquifer and the Cedar Valley Drainage Basin**, which difference needs to be leveraged.
- The Cedar Valley Fill Aquifer is being damaged by over production.
- **There are two significant untapped aquifers adjacent to Cedar Valley** which are both included within The Cedar Valley Drainage Basin:
  1. **The Cretaceous Aquifer to the east**; and
  2. **The Quartz Monzonite Aquifer to the west**.
- **Existing over production and over allocation can be solved by transferring water rights out of the Cedar Valley Aquifer to these two adjacent aquifers**.

Science Helps, and history is still hard to do right!

We all present the data available to us, as it is filtered by our world view, including how Geology and Water are the Framework of Southern Utah



Thank You!

This presentation is posted at:

- http://www.walden3d.com/IronCounty/CedarValleyWater/pdf/170307_Geology_and_Water_The_Framework_of_Southern_Utah.pdf

See Also:

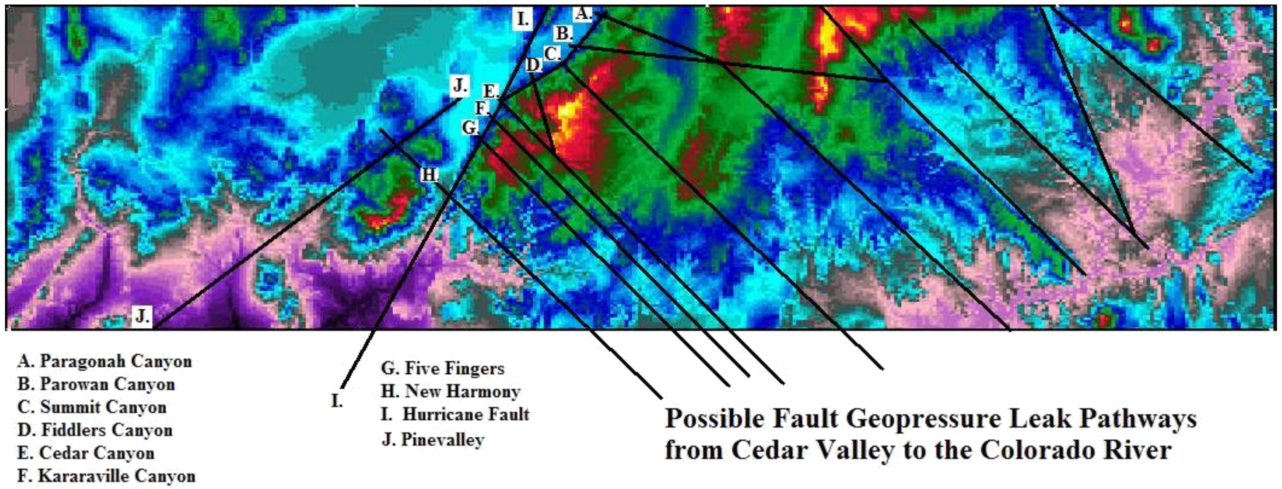
- http://www.walden3d.com/IronCounty
- http://www.walden3d.com/IronCounty/intro
- http://www.walden3d.com/IronCounty/CedarValleyWater/
- http://www.walden3d.com/IronCounty/ig/IronCounty/IC_3_Approaches.html
- http://www.walden3d.com/IronCounty/ig/IronCounty/IC_3_Aquifers.html
- http://www.walden3d.com/IronCounty/ig/IronCounty/IC_CVA.html
- http://www.walden3d.com/IronCounty/ig/IronCounty/IC_KA.html
- http://www.walden3d.com/IronCounty/ig/IronCounty/IC_QMA.html

Abstract - Geology and Water: The Framework of Southern Utah

H. Roice Nelson, Jr., a geophysicist (the University of Utah, 1974), has spent over 45 years working in oil & gas and mineral exploration.

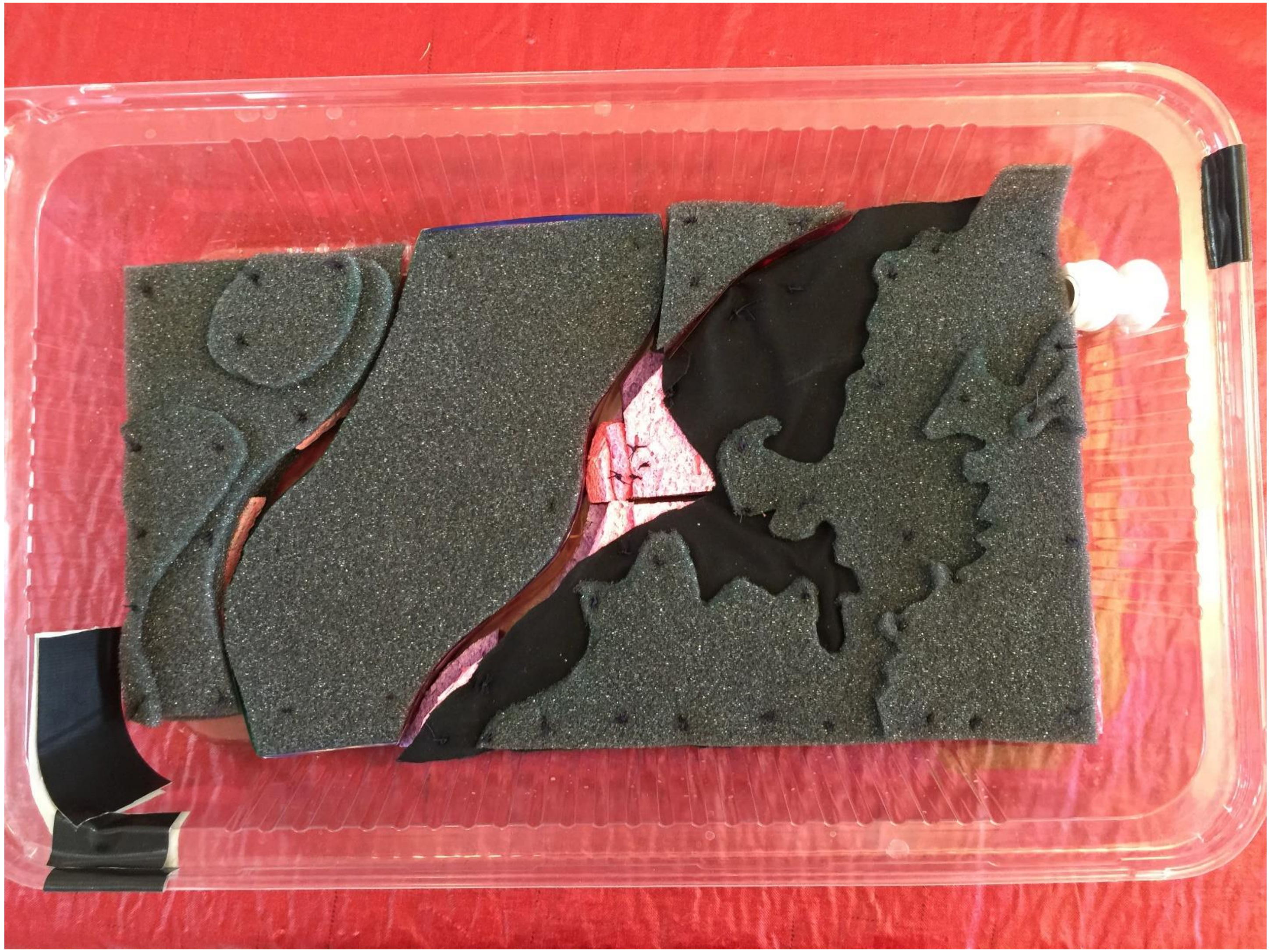
Southern Utah is geologically unique. Built on a foundation of Pre-Cambrian schists and granitic intrusions are layers of shale, limestone, sands, and more shales. Jurassic deserts created the petrified eolian sand dunes we love to examine at Zion and Snows Canyon. Cretaceous age Dakota Sandstone, Tropic Shale, and Straight Cliff sandstones, shales, and coals seen up Cedar and Parowan Canyons underlay the Cedar Breaks and Bryce Canyon Claron Formation. These formations have been pierced by volcanic and granitic intrusions, creating volcanic flows, mineral mining, and fractured-quartz-monzonite aquifer opportunities in this area. This quality and diversity of seismic scale outcrop geology is not found anywhere else on Earth.

Located at the southern end of The Great Basin, the structural geology ranges from horst and graben features, tied to a failed rift, to thrust and back-thrust blocks, and related folding. Transform faults from Cretaceous age spreading centers, shown below, define canyon and aquifer drainage patterns. This is the geologic and water framework Native American, Spanish Explorers, and Mormon Pioneers built their respective societies on. This geological review of Southern Utah focuses on on-going issues with and possible solutions to obtaining the water necessary to sustain Southern Utah population growth.



Map of Model Area

Sponge Model



Sponge Model – Isolated Cedar Valley Aquifer