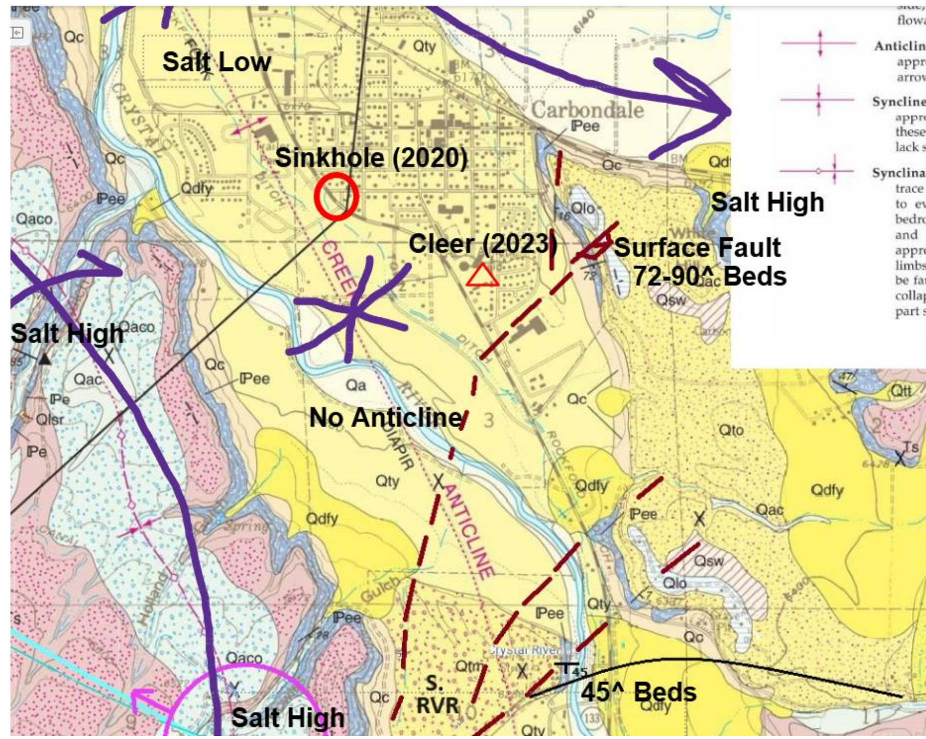
# Subsurface and seismic interpretations of Carbondale and the surrounding Roaring Fork valley




Modified from https://ngmdb.usgs.gov/Prodesc/proddesc_94638.htm Quad Link

6/17/2020 sinkhole on Hwy 133: "Crews filled, tamped down, capped, and paved the sinkhole, which measured 15 feet in diameter by 12 feet deep. Filling the sinkhole required 125 tons of road base material, delivered with 10 truckloads. Once the sinkhole was repaired and repaved, northbound CO 133 was restored to the roadway at approximately 3:30pm and CDOT ended the short detour nearby."

https://www.bing.com/search?pglt=43&q=sopris+sun+carbondale+colorado+6%2F17%2F2020&cvid=fce623c3b3f145d880a1ba072da3afbc&gs_lcrp=EgZjaHJvbWUyBggAEEUYOTIGCAEQABhAMgYIAhAAGEAyBggDEAAYQDIGCAQQABhAMgYIBRAAGEDSAQgzNzAzajBqMagCALACAA&FORM=ANNTA1&PC=U531

Don Marlin notes: Sinkhole in 2020 inspired a review of additional surface, subsurface, and seismic control that could modify the subsurface interpretation. Reference links are embedded in all pages of report.

# Don Marlin prior background:

**Certified Geophysicist #41**

**(AAPG)**

**Certified Professional Geologist #7696**

**(AIPG)**

**Professional Geoscientist #91**

**(LBOPG)**

**B.S. & M.S. Geology, LSU**

**(Publications on seismic, salt, and subsurface available on request)**

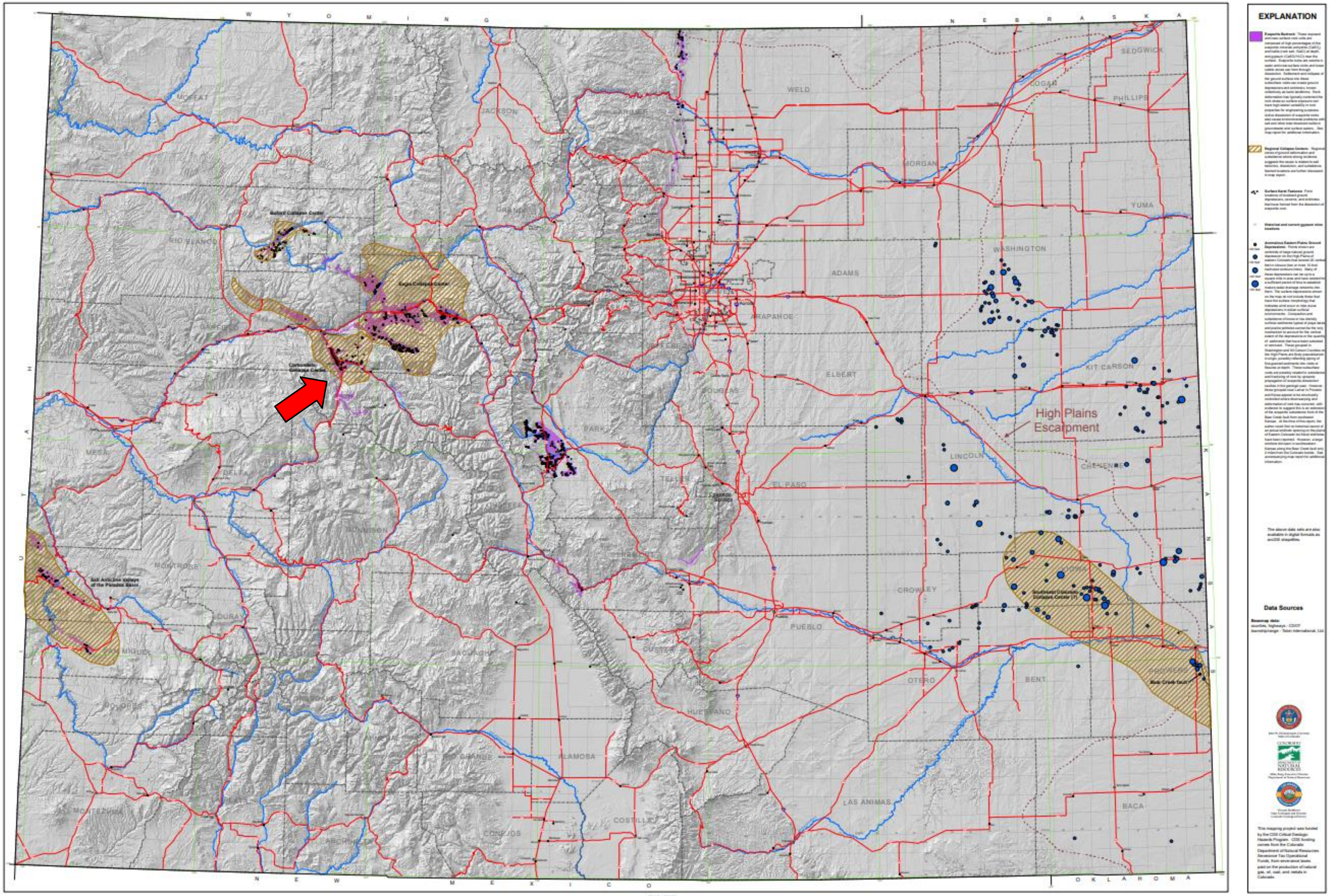
Don Marlin notes: Now retired.

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

Reference: https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/

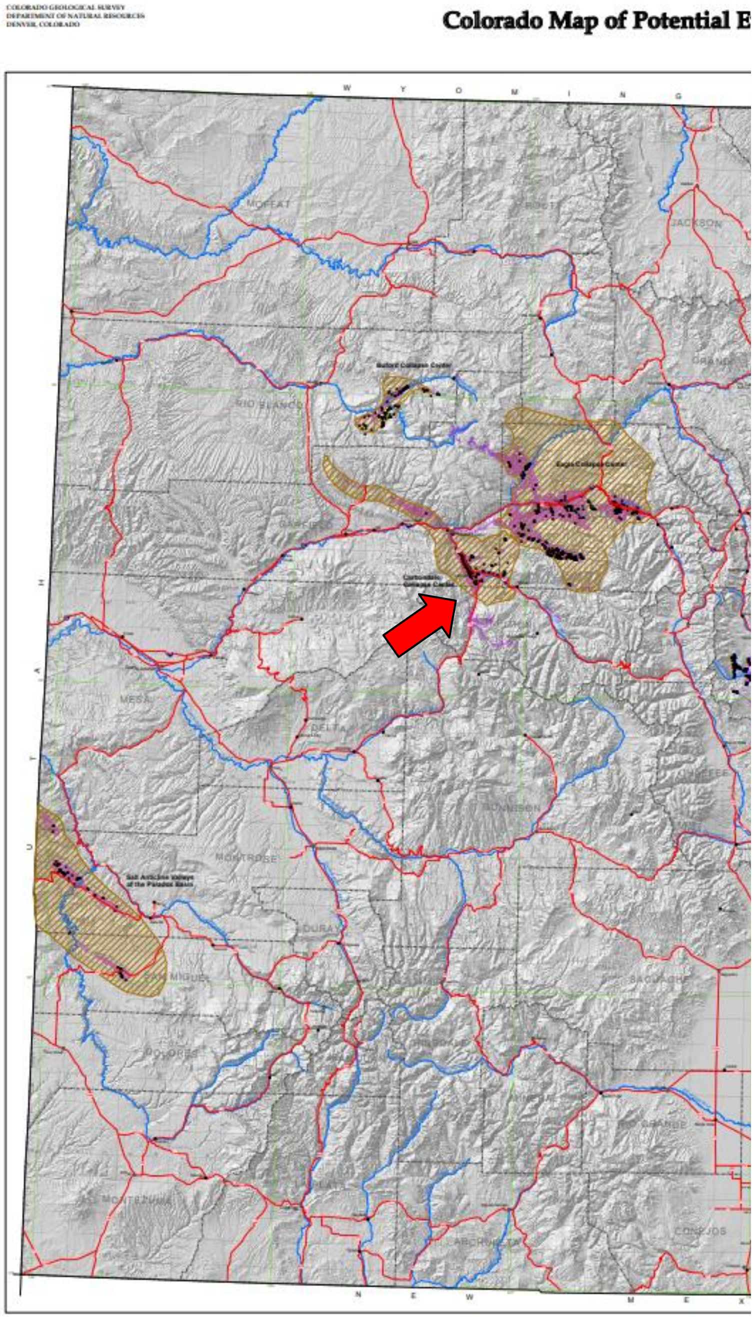
# Colorado Map of Potential Evaporite Dissolution and Evaporite Karst Subsidence Hazards

By Jonathan L. White




Don Marlin notes: Location of project relative to White 2012 Karst hazard map

**Modified from https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/**



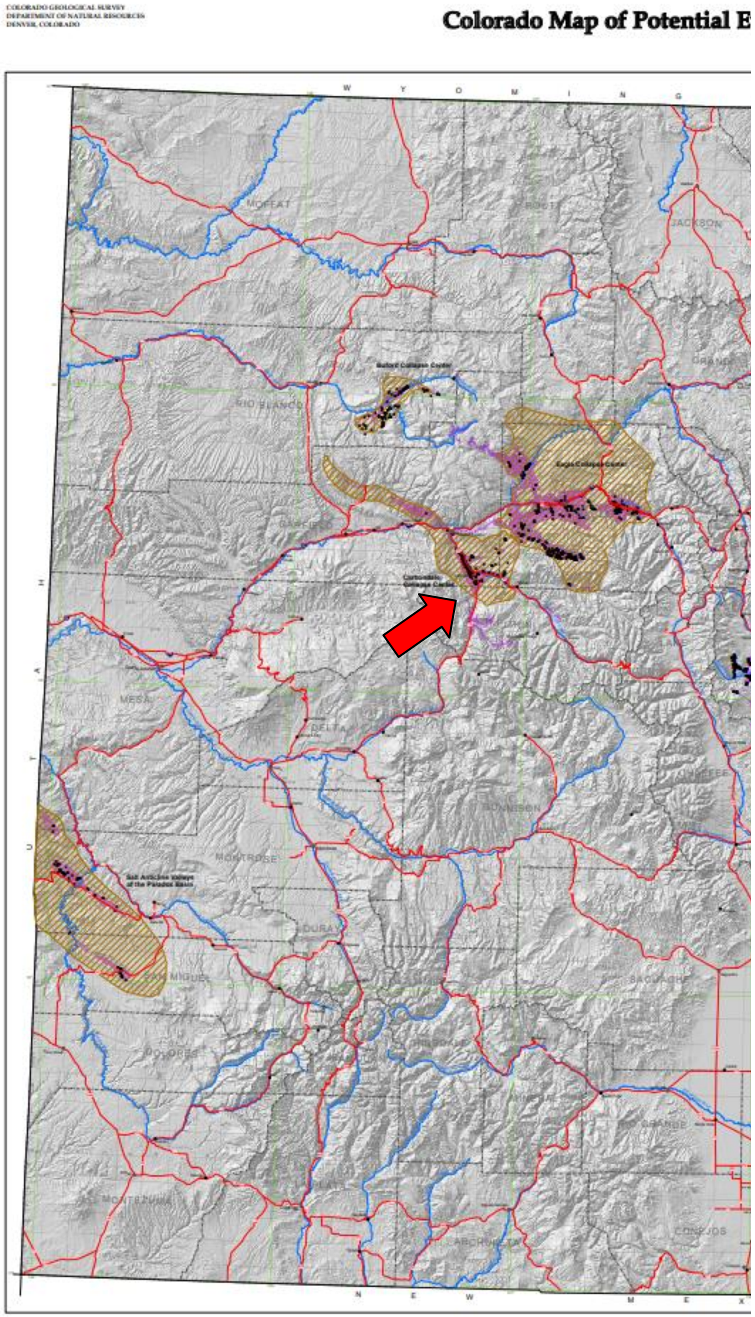

**Modified from https://coloradogeologicalsurvey.org/wp-content/uploads/RT-0061890-i0-8137-2366-3-366-0-1.pdf**

| | | | meters | |
|---|---|---|---|---|
| Cenozoic | Pliocene or Miocene | Sedimentary units | 0-250 | Conglomerate, sandstone, and siltstone |
| Cenozoic | Q - Miocene | Volcanic units | 0-400 | Mostly basaltic flows and minor silicic flows and ash-flow tuffs |
| Cenozoic | Eocene and Paleocene | Uinta, Green River, and Wasatch Formations | 0-3,300 | Uinta Fm.: ss., slst., and calcareous mdst. Green River Fm.: oil sh., calcareous mdst., ss., and slst. Wasatch Fm.: clyst., mdst., slst., ss., and cgl. |
| Cretaceous | Upper Cretaceous | Mesaverde Grp. | 1,450 | Williams Fork Fm. : ss., slst., mdst., sh.,coal, and clinker. Iles Fm.: ss., sh., and slst.; Rollins Ss. Mbr. at top; Cozzette Ss. Mbr. in lower part; Corcoran Sandstone Mbr. at base |
| Cretaceous | Upper Cretaceous | Mancos Shale | 1,400 | Upper mbr.: dark-gray, locally bentonitic, carbonaceous sh.; ss. beds near top, calcareous sh. at base; Niobrara Mbr.: shaly ls.; ls. beds in lower part; lower mbr: gray, very pale gray-weathering, calcareous sh., and dark gray sh., silty sh., calcareous ss., slts., and ls. |
| Cretaceous | L. Cret. | Dakota Ss. | 50-70 | Very pale gray ss., minor carbonaceous shale |
| Upper Jurassic | | Morrison Fm. | 75-150 | Greenish-gray to grayish-red slts., clyst., white ss., and gray ls. near base |
| M. Jurassic | | Entrada Ss. | 20-30 | Gray to pale orangish-gray cross-bedded ss. |
| Upper Triassic | | Chinle Fm. | 20-90 | Pale to reddish-brown calcareous slts., silty ss., and ls. pebble conglomerate |
| L. Trias., L. Perm. | | State Bridge Fm. | 0-1,500 | Pale red, grayish-red, and reddish-brown slts. and minor ss. |
| L. Permian | | Maroon Formation | 1,150-4,900 | Schoolhouse Mbr.; gray sandstone. Main body: grayish-red and reddish-brown arkosic, ss., conglomeratic ss., and mudstone. Lower mbr.; grayish-red and reddish-brown ss.,slts., mdst., white ss., and a few beds of ls., silty ls., gypsum, and anhydrite |
| Middle Pennsylvanian | | Eagle Valley Formation | 100-1,000 | Ss., slts., ls., and silty ls. in various shades of gray; some red, brown, and orange beds; a few beds of gypsum and anhydrite |
| Middle Pennsylvanian | | Eagle Valley Evaporite | un-known | Pale gray to white gypsum, anhydrite, halite, and gray, partly gypsiferous slts., sh., ss., and fossliferous ls. |
| M. and L. Pennsylvanian | | Belden Fm. | 50-250 | Medium-gray to black and dark brown carbonaceous sh. and gray fossliferous ls. |
| Mississippian | | Leadville Ls. | 45-60 | Bluish gray, coarse- to fine-grained ls. and dol. |
| Upper Devonian | | Chaffee Group | 60-70 | Dolomitic ss., dol., ls., gray fossiliferous ls., ss., and dol. sh. |
| L. Ordovician | | Manitou Fm. | 40 | Dol., ls. cgl., calcareous sh.,ss., and ls. |
| Upper Cambrian | | Dotsero Fm. | 20-30 | Thinly bedded dol., dolomitic ss., dolomitic sh., dolomitic cgl., and algal ls. |
| Upper Cambrian | | Sawatch Quartzite | 65-165 | White to yellowish-gray, quartzite; beds of brown sandy dol. in upper part; local arkosic quartz pebble cgl. near base |
| Proterozoic Rocks | | | | Gneissic granitic rocks, sillimanite mica gneiss, amphibolite, and felsic gneiss |

Figure 3. Generalized stratigraphic relations in west-central Colorado. Adapted from Tweto and Lovering (1977), Johnson et al. (1990), Kirkham et al. (1997a), Scott and Shroba (1997), Bryant et al. (1998), Lidke (1998, 2002), Scott et al. (1999), Shroba and Scott (1997, 2001), Scott et al. (2001), and Scott et al. (2002).

**Don Marlin notes: Stratigraphy between highlighted intervals eroded away in study area.**

Modified from https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/




Don Marlin notes: Stratigraphy between highlighted intervals eroded away in study area.

meters

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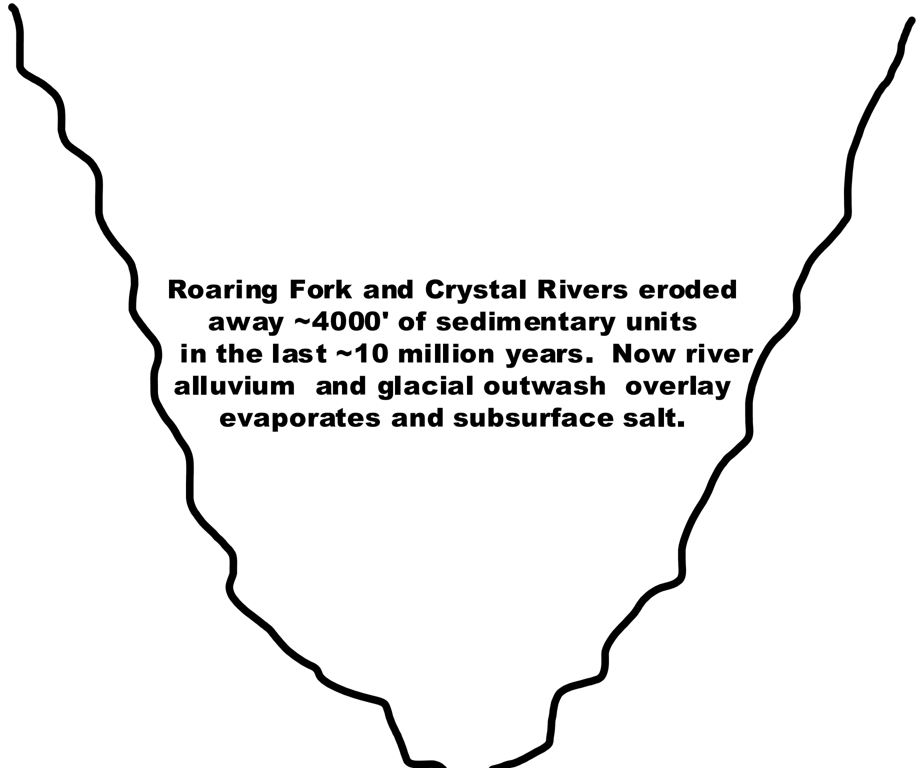


| | | | |
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| | Sawatch Quartzite | 65-165 | White to yellowish-gray, quartzite; beds of brown sandy dol. in upper part; local arkosic quartz pebble cgl. near base |
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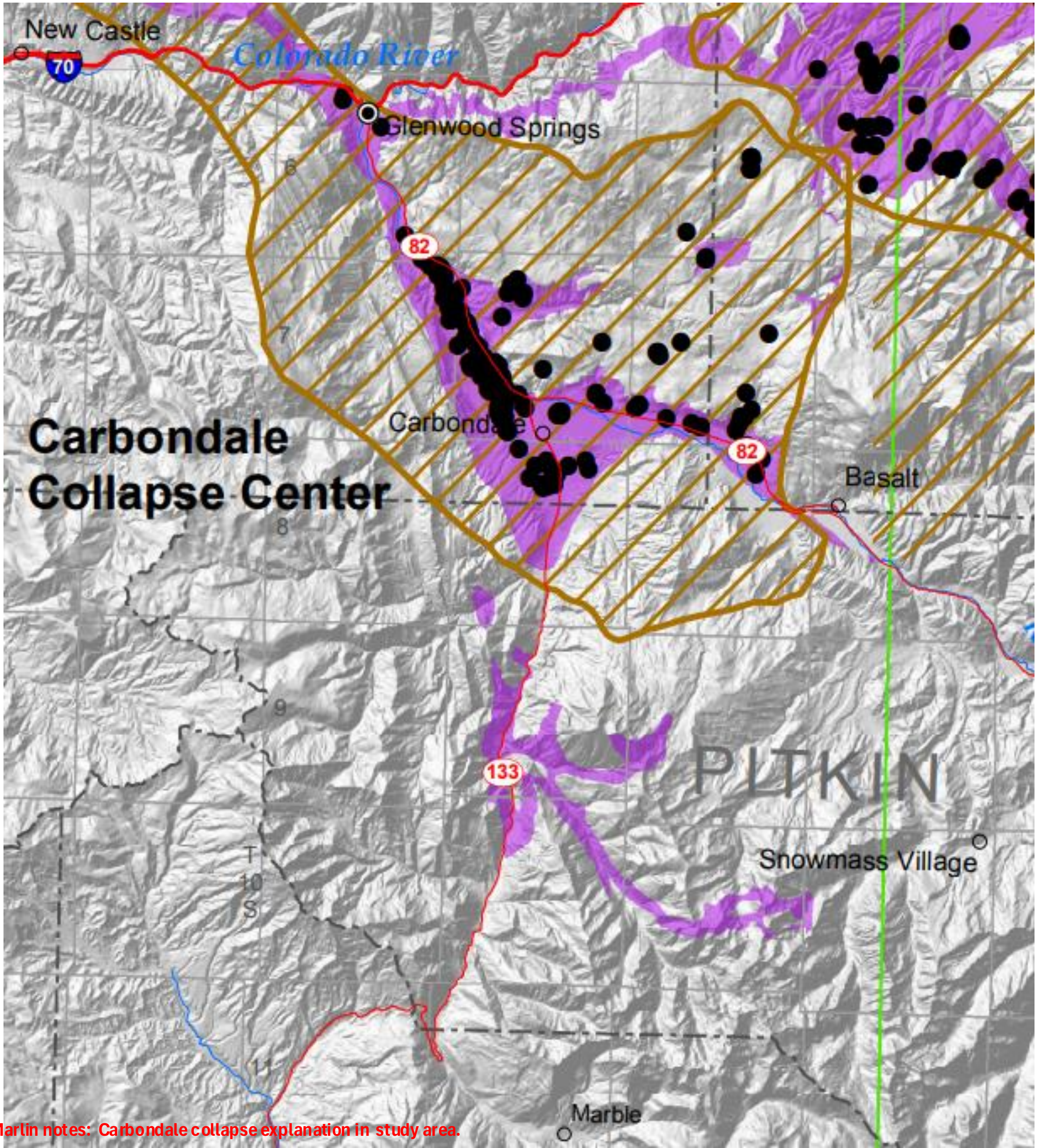
Figure 3. Generalized stratigraphic relations in west-central Colorado. Adapted from Tweto and Lovering (1977), Johnson et al. (1990), Kirkham et al. (1997a), Scott and Shroba (1997), Bryant et al. (1998), Lidke (1998, 2002), Scott et al. (1999), Shroba and Scott (1997, 2001), Scott et al. (2001), and Scott et al. (2002).

# Colorado Map of Potential Evaporite Dissolution and Evaporite Karst Subsidence Hazards

By Jonathan L. White




## EXPLANATION

**Evaporite Bedrock:** These exposed and near-surface rock units are composed of high percentages of the evaporite minerals anhydrite ($CaSO_4$) and halite (rock salt - NaCl) at depth, and gypsum ($CaSO_4 {}^* H_2O$) near the surface. Evaporite rocks are soluble in water and near-surface voids and loose rubble zones can form through dissolution. Settlement and collapse of the ground surface into these subsurface voids can create ground depressions and sinkholes, known collectively as karst landforms. Rock deformation has typically contorted the rock strata so surface exposure can have high lateral variability in rock properties for engineering purposes. Active dissolution of evaporite rocks also cause environmental problems with salt and other total dissolved solids in groundwater and surface waters. See map report for additional information.

**Regional Collapse Centers:** Regional zones of ground deformation and subsidence where strong evidence suggests the cause is related to salt tectonics, dissolution, and subsidence. Named locations are further discussed in map report.

**Modified from Jonathan White 2012: https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/**

Don Marlin notes: Carbondale collapse explanation in study area.

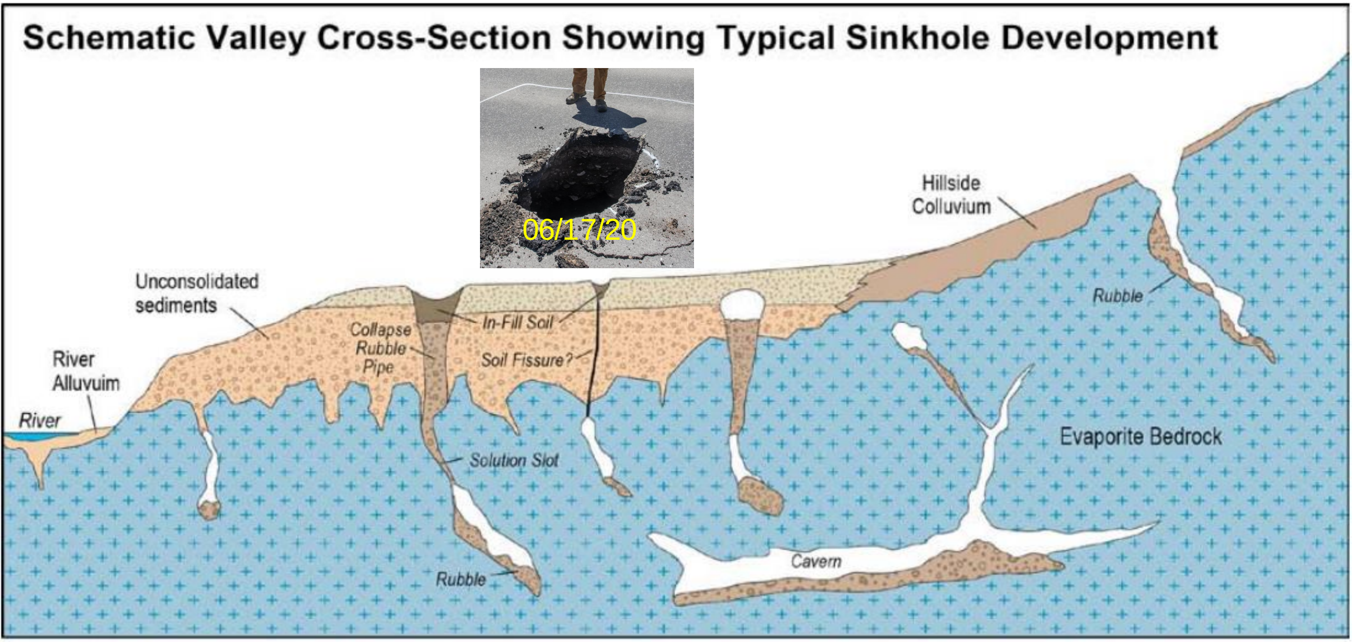



**Figure 4.** Illustration of typical karst and stages of sinkhole development. Sinkholes form by the upward progression of cavern roof collapse that reaches the surface. Small sinkholes can also occur by piping of fine grained sediments into solution slots.

**Colorado Map of Potential Evaporite Dissolution and Evaporite Karst Subsidence Hazards**

by
Jonathan L. White

Colorado Geological Survey
Department of Natural Resources
Denver, Colorado
2012

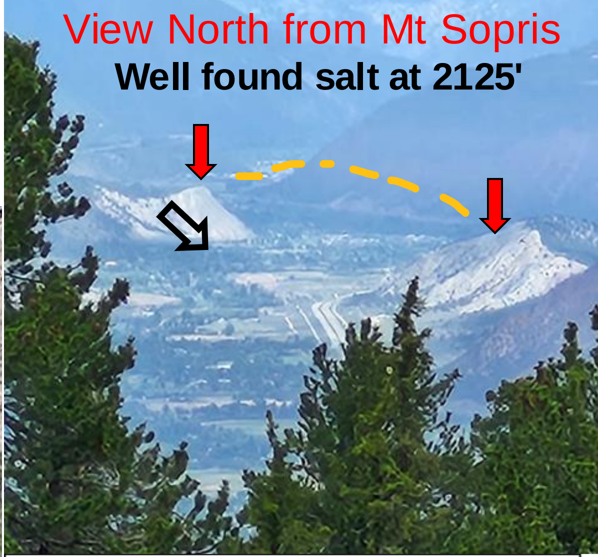

**Figure 3.** Several sinkholes pockmark a mid-Pleistocene glacio-fluvial terrace in the Roaring Fork Valley near Carbondale in Garfield County.

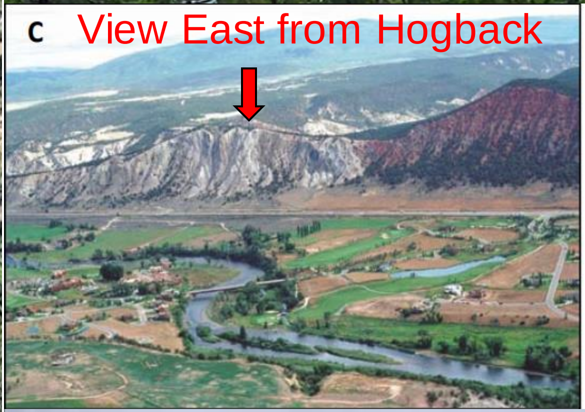
**Figure 10.** Large sinkhole opened in 2005 at golf course club grounds at Ironbridge Development. Two golf carts inside the structure were lost down the throat of the sinkhole. View is to the northwest, down the Roaring Fork River valley towards Glenwood Springs. Red cliffs are the Maroon Formation. For scale, note person in white hardhat standing in the snow.

**Modified from https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/ Photos from OF-12-02 Report**

Don Marlin notes: Visual summary and schematic of hazards in the study area since Holocene-Pliocene unconsolidated sediments lie directly on Late Pennsylvanian evaporative bedrock in the valley.

**The Roaring Fork has a subsurface salt structure that has pushed up the Eagle Valley evaporites. River downcutting and freshwater dissolution creates complex recumbent folds near CRMS along Edgerton Creek And Hwy 108 (Thompson Creek Road).**



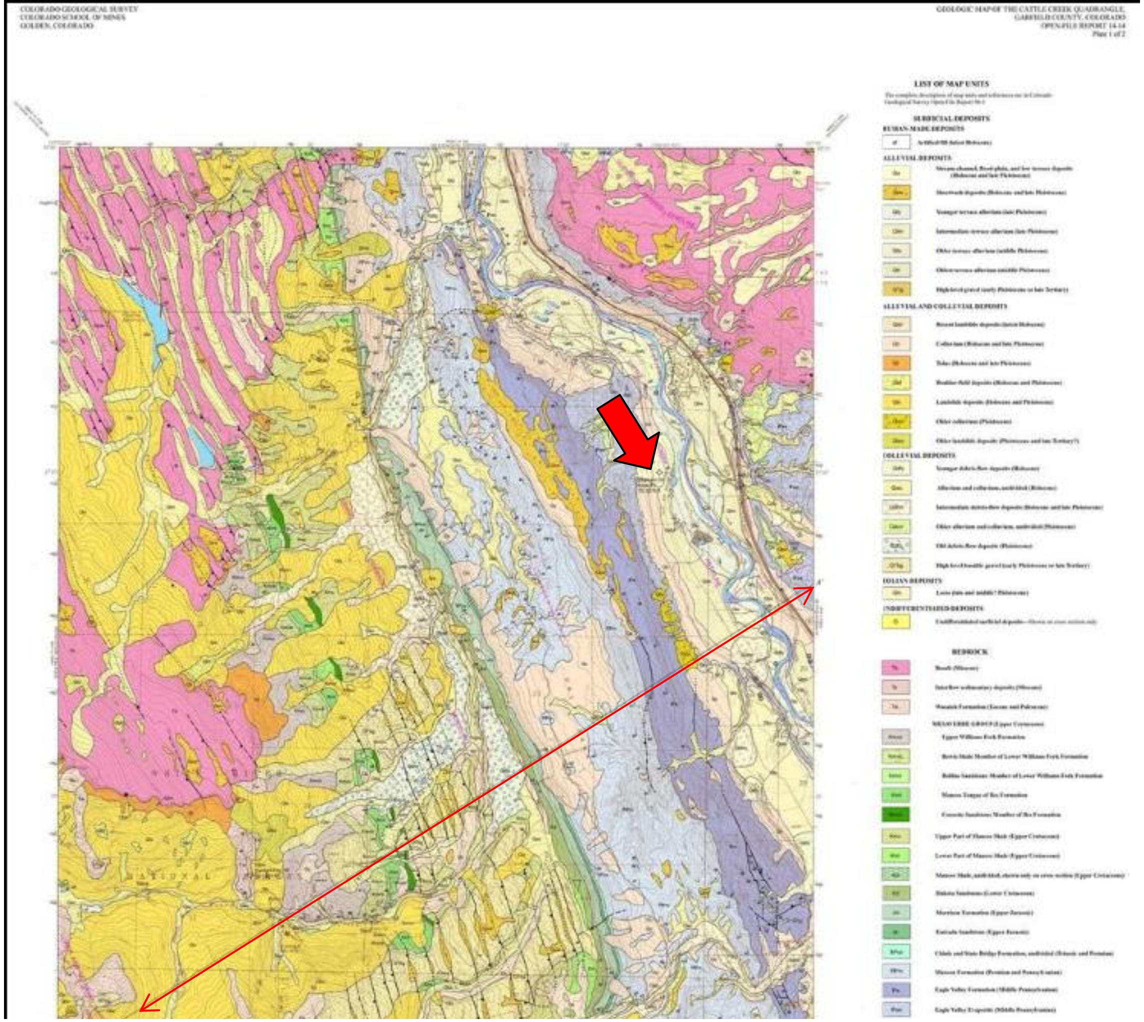


"In the subsurface near Cattle Creek Station (the Rose well), the evaporite is gray to brown anhydrite interbedded with light-colored siltstone and sandstone and a few dark shale beds to a depth of 2,125 feet. Below this level halite is the principal rock. No halite is present at the surface anywhere in the area." Mallory, W.W., 1971, The Eagle Valley Evaporite, northwest Colorado: A regional synthesis: U.S. Geological Survey Bulletin 1311-E, 37 p.
https://pubs.usgs.gov/bul/1311e/report.pdf report.pdf (usgs.gov)

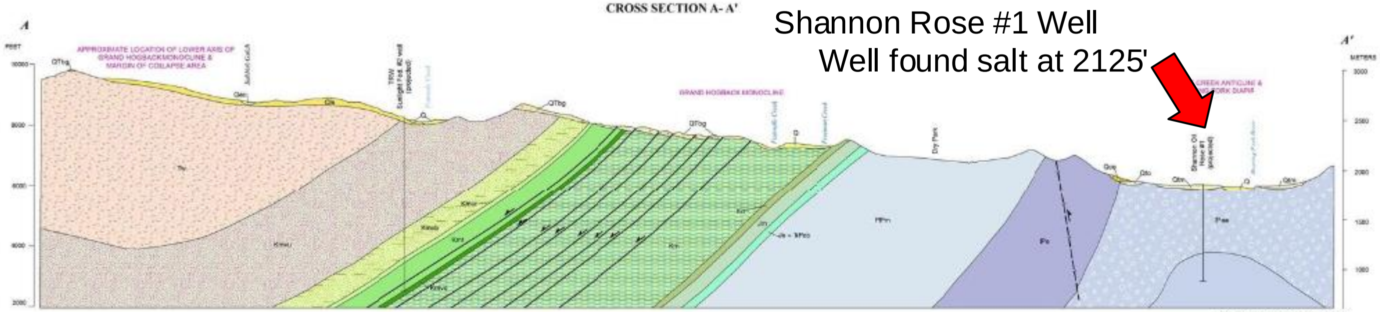
Don Marlin notes: Pictures taken in 2024 illustrate the instability of evaporite outcrops and how they intrude into surrounding topography from mobilized salt rising to the surface and confirmed by 1960 well control.

**2014 Kirkham et.al. (Cattle Creek Quad)**

**Modified fromhttps://ngmdb.usgs.gov/Prodesc/proddesc_101352.htm**




CROSS SECTION A- A'



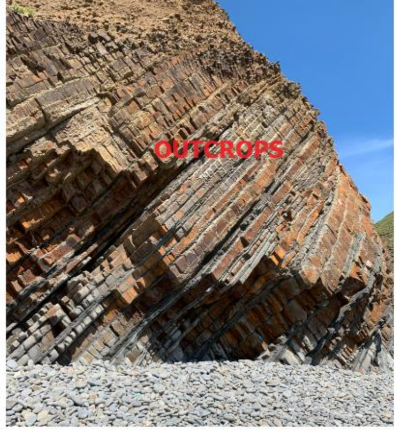

CATTLE CREEK QUADRANGLE GEOLOGIC MAP, GARFIELD COUNTY, COLORADO

By Robert M. Kirkham, Randall K. Streufert, H. Thomas Hemborg, and Peter L. Stelling

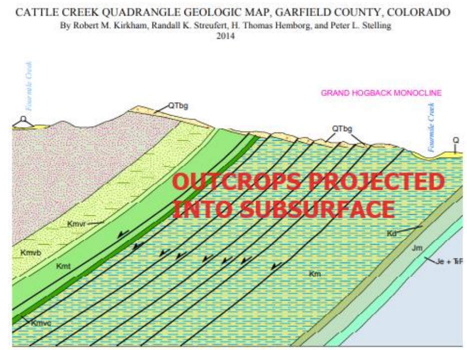
2014

Don Marlin notes: The 2014 quad and section are accurate. Well projected to section.

# FUNDAMENTAL TOOLS OF SUBSURFACE MAPPING




1) Outcropping bed orientation is projecting into the ground

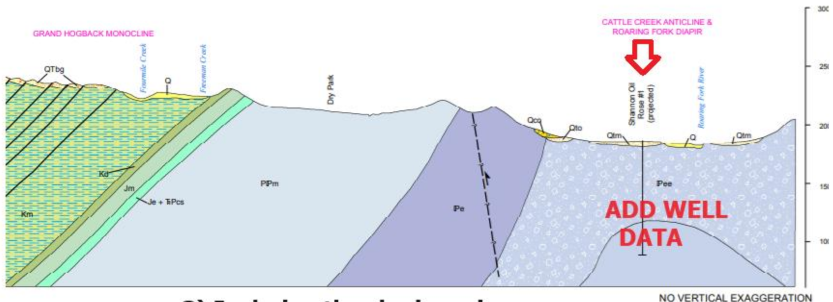



2) Project the outcrops into the subsurface and draw a cross section

## OUTCROPs

## SURFACE PROJECTION

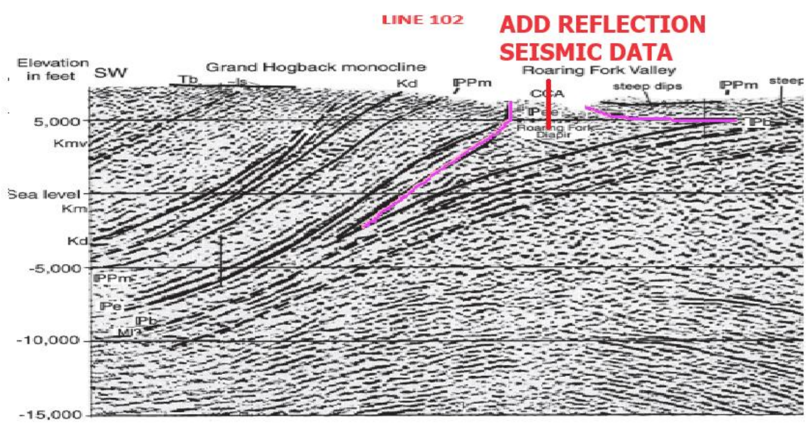
**Modified from https://ngmdb.usgs.gov/Prodesc/proddesc_101352.htm**




3) Include other beds and any well information that may have subsurface data

## WELL TIES

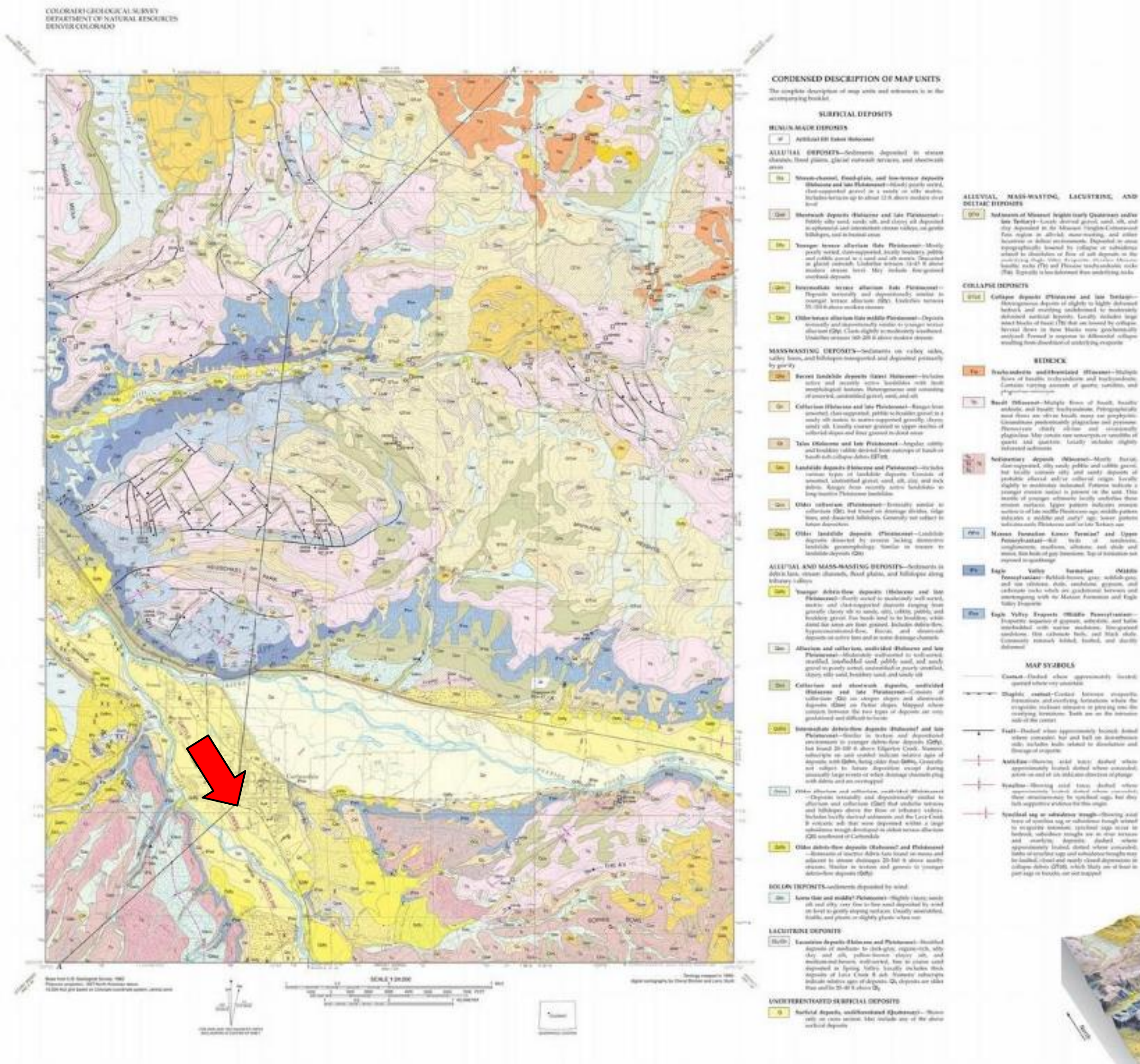
**Modified from https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central**

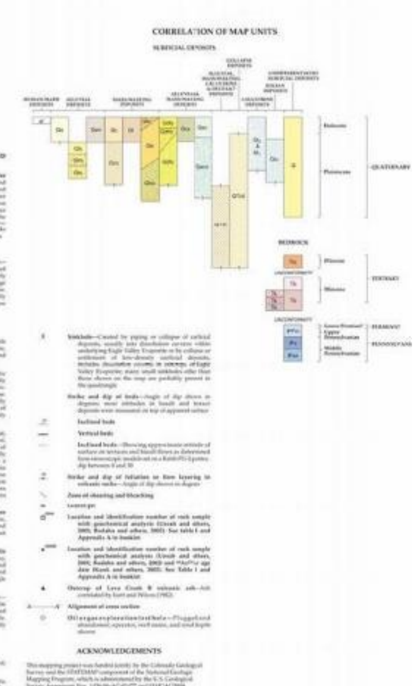



4) Integrate two-dimensional reflection seismic to revise steps 1-3 and fill in missing information for more accuracy.

## SEISMIC

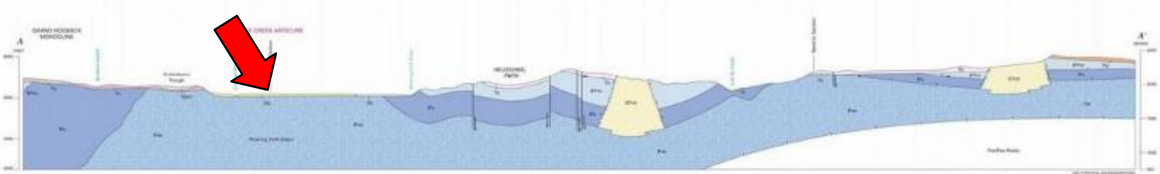
Don Marlin notes: Commonly seismic is not integrated into quad maps.




**SEISMIC AND SUBSURFACE WELL CONTROL MODIFY THIS CROSS SECTION TO SHOW NEAR SURFACE FAULTING AND SALT NOT ONLY EVAPORITES**

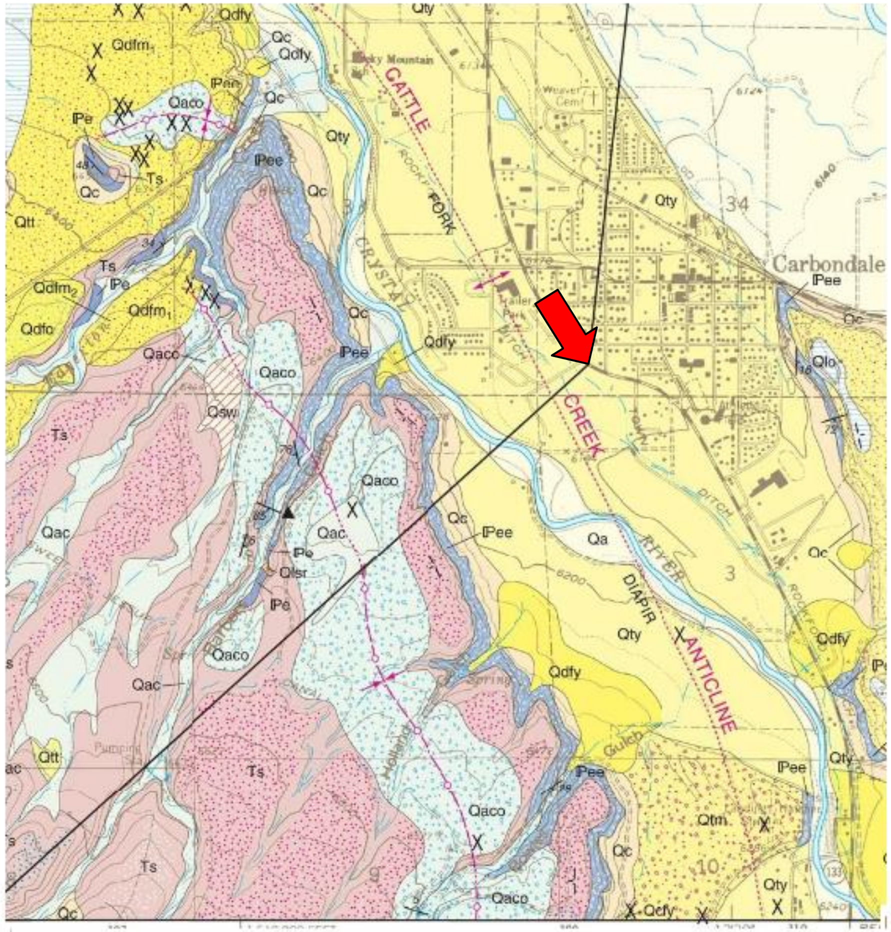
**Link: https://ngmdb.usgs.gov/Prodesc/proddesc_94638.htm**

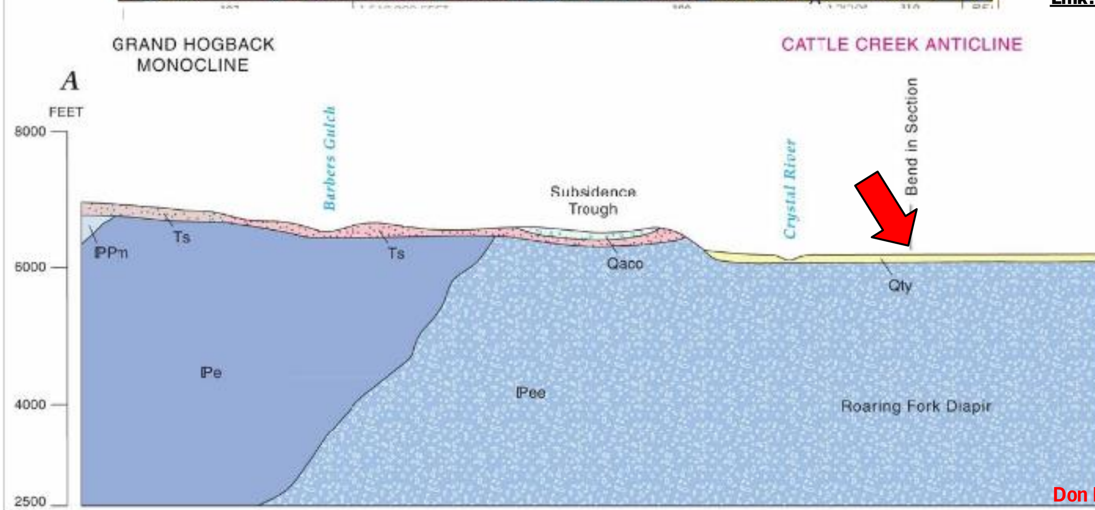


GEOLOGIC MAP OF THE CARBONDALE QUADRANGLE, GARFIELD COUNTY, COLORADO

By Robert M. Kirkham and Beth L. Widmann
2008

Don Marlin notes: The 2008 quad should be modified.... not solely used for future exploratory drilling .

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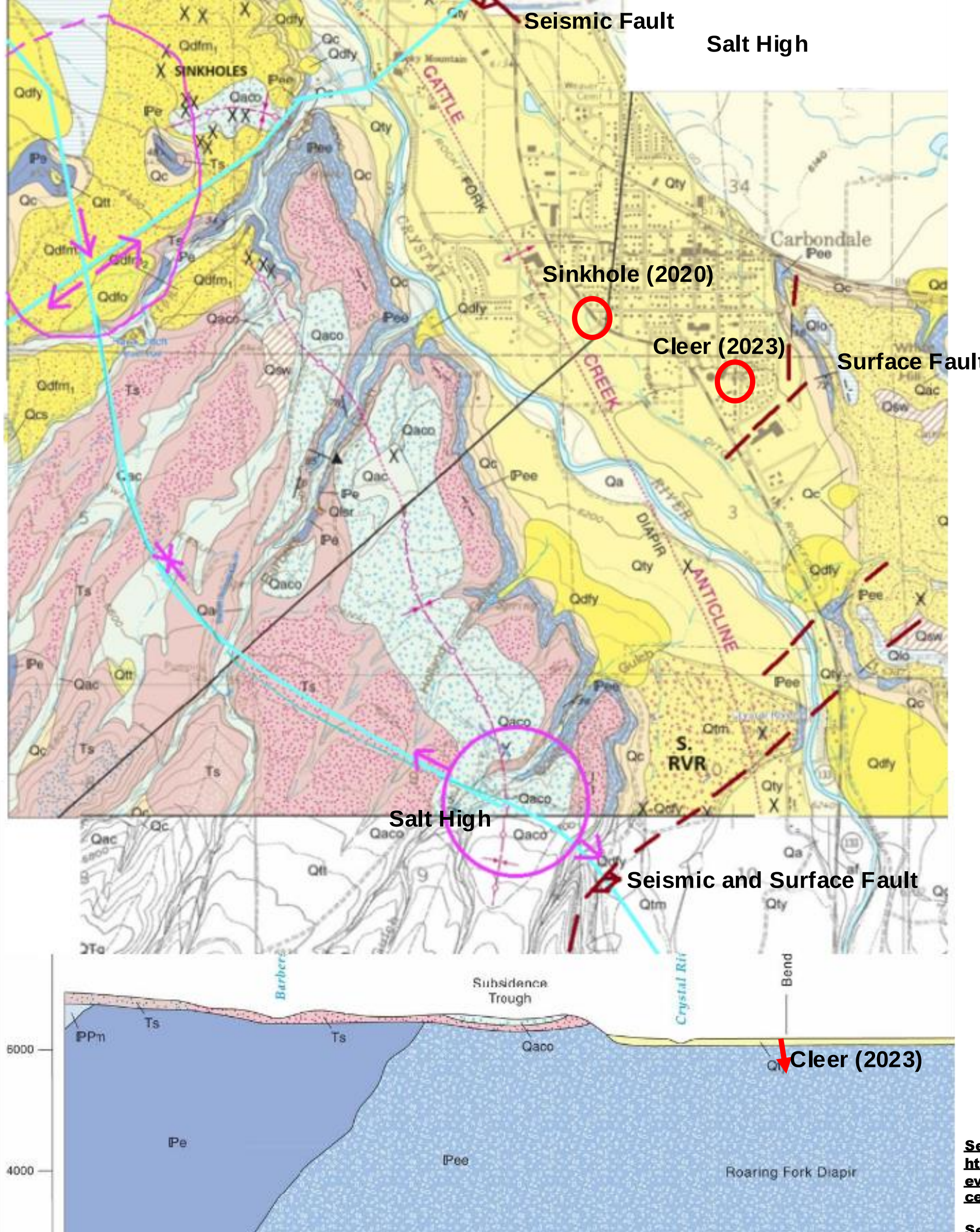
Don Marlin notes: Zoomed in area of modification in this report.




**Upper quad modified fromhttps://ngmdb.usgs.gov/Prodesc/proddesc_94638.htm**

**Lower quad modified from https://ngmdb.usgs.gov/Prodesc/proddesc_41291.htm**

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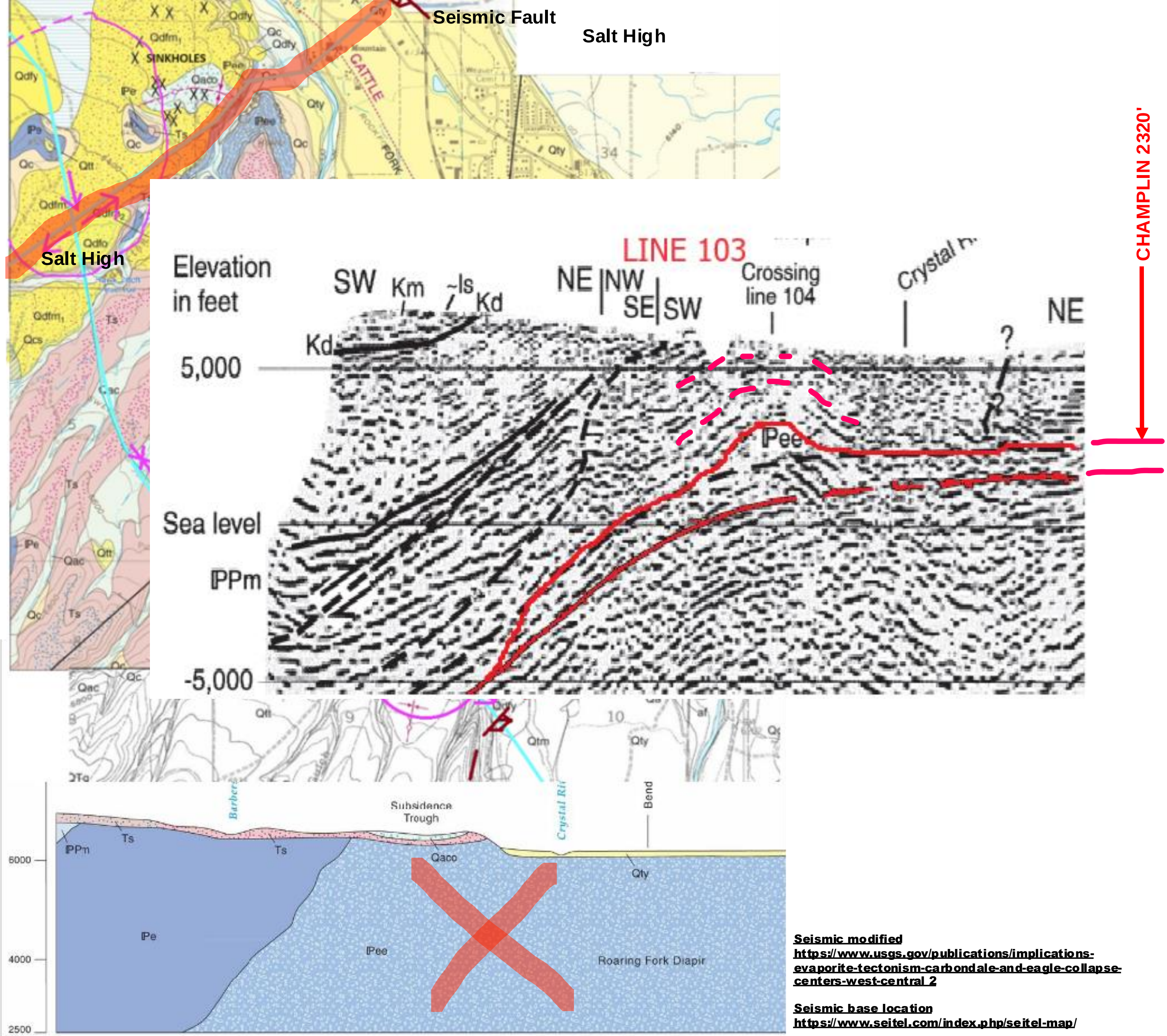
**Seismic modified https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location https://www.seitel.com/index.php/seitel-map/**

Don Marlin notes: Notable additions highlighted on 2008 quad and section.

Don Marlin notes: Quad map approximate position of depth processed Line 103 from Perry (2002) approximating the location of reflectors that are interpreted to be a salt structure under Crystal River Ranch with surface features, a salt synclinal axis under the Crystal River, questionable subsurface faulting near the town center, and a rise of possible salt which may tie to lost circulation below 1700' and inferred to be salt below 2320' TD in 1962 Champlin well 1 mile East off this line position.




**Upper quad modified fromhttps://ngmdb.usgs.gov/Prodesc/proddesc_94638.htm**

**Lower quad modified from https://ngmdb.usgs.gov/Prodesc/proddesc_41291.htm**

**Seismic modified https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central_2**

**Seismic base location https://www.seitel.com/index.php/seitel-map/**

Don Marlin notes: Oriented line approximate position of depth processed Line 103 from Perry (2002) approximating the location of reflectors that are interpreted to be a salt structure under Crystal River Ranch with surface features, a salt synclinal axis under the Crystal River, questionable subsurface faulting near the town center, and a rise of possible salt which may tie to lost circulation below 1700' and inferred to be salt below 2320' TD in 1962 Champlin well 1 mile East off this line position.

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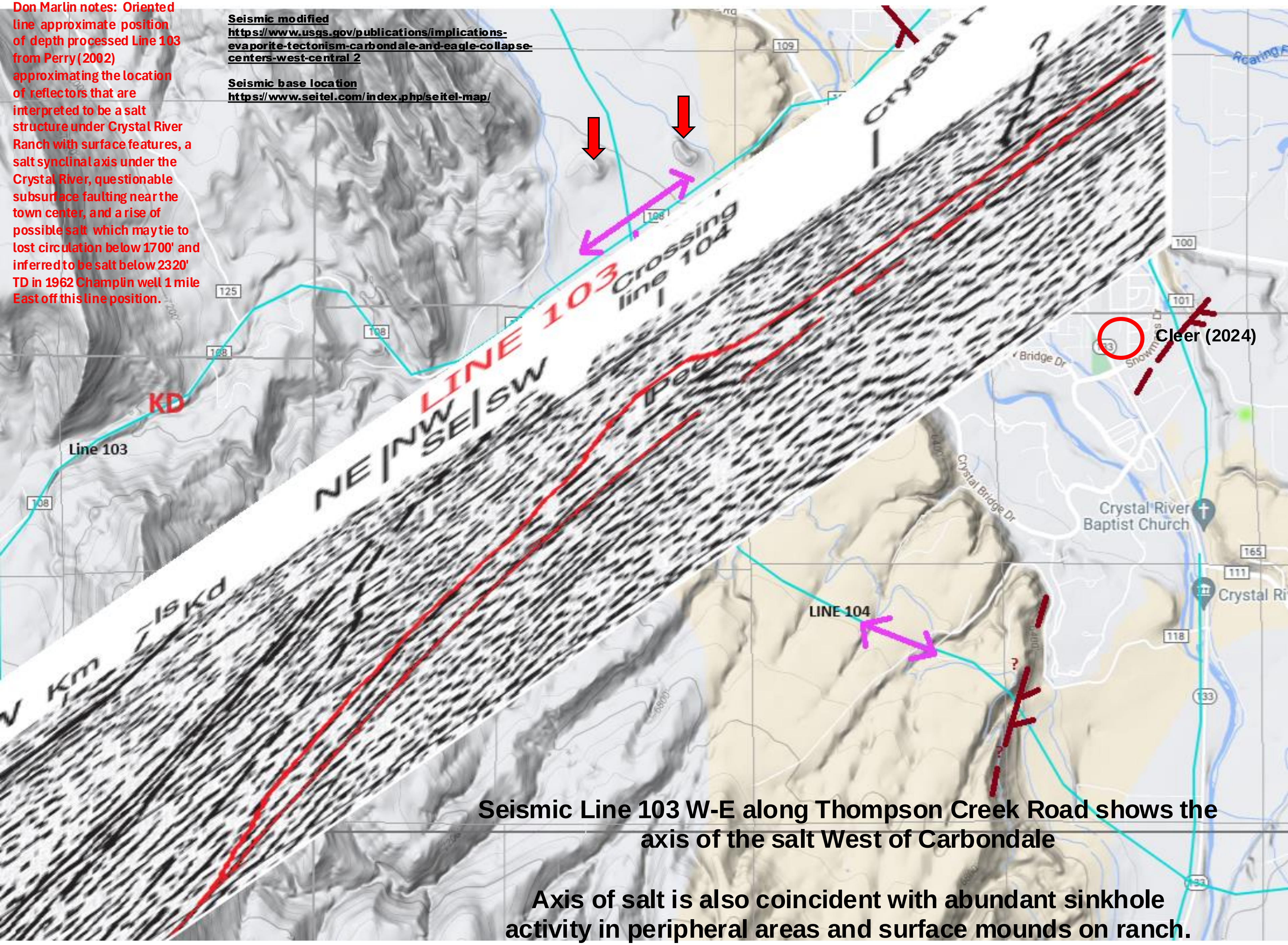
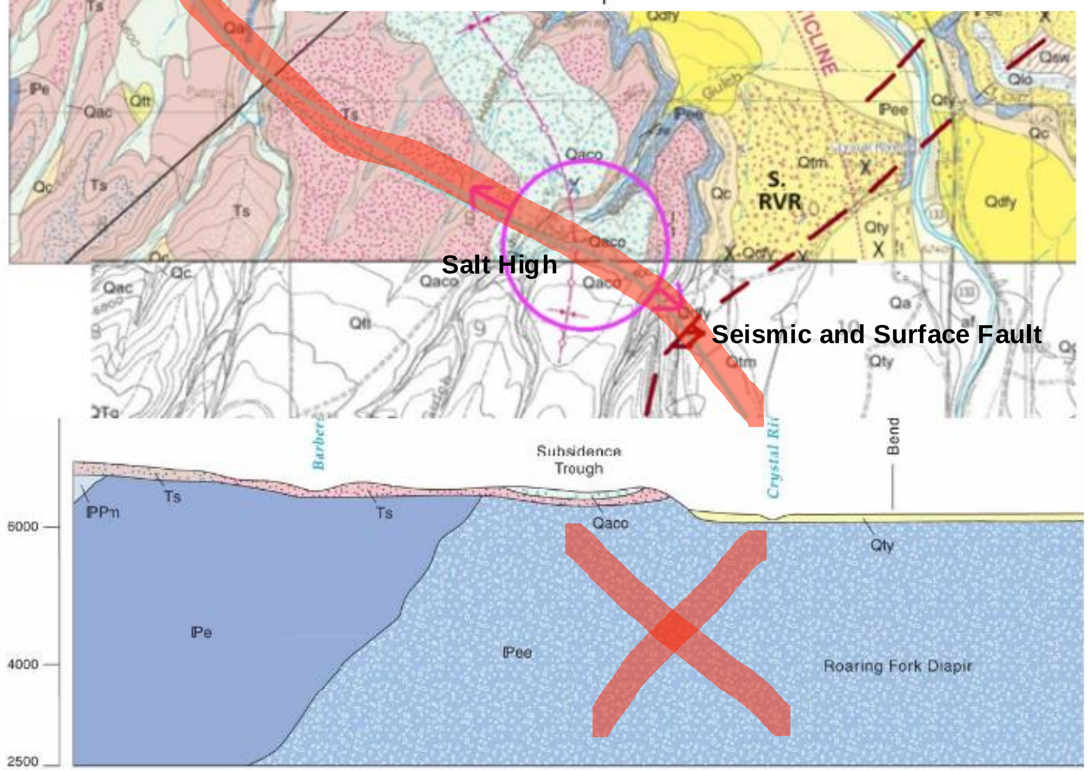
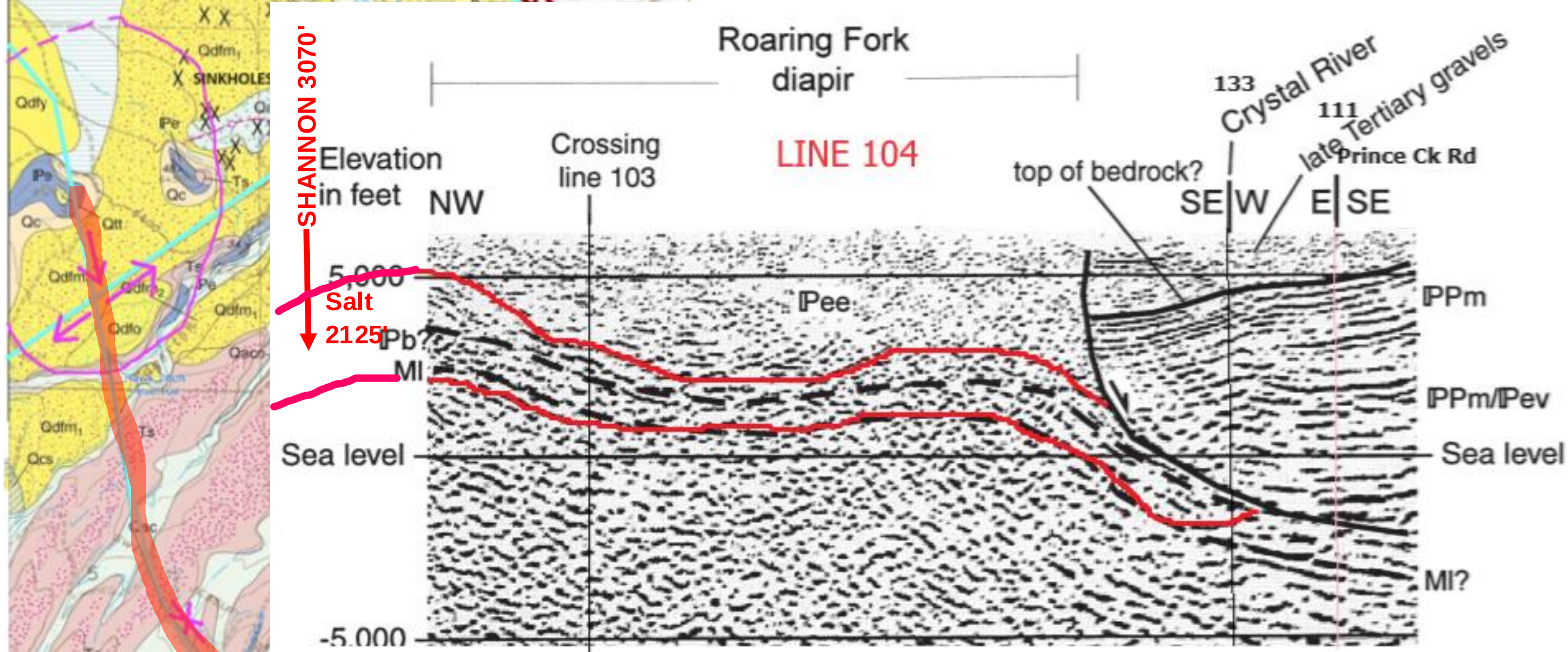



**Seismic Line 103 W-E along Thompson Creek Road shows the axis of the salt West of Carbondale**

**Axis of salt is also coincident with abundant sinkhole activity in peripheral areas and surface mounds on ranch.**




**Upper quad modified fromhttps://ngmdb.usgs.gov/Prodesc/proddesc_94638.htm**

**Lower quad modified from https://ngmdb.usgs.gov/Prodesc/proddesc_41291.htm**

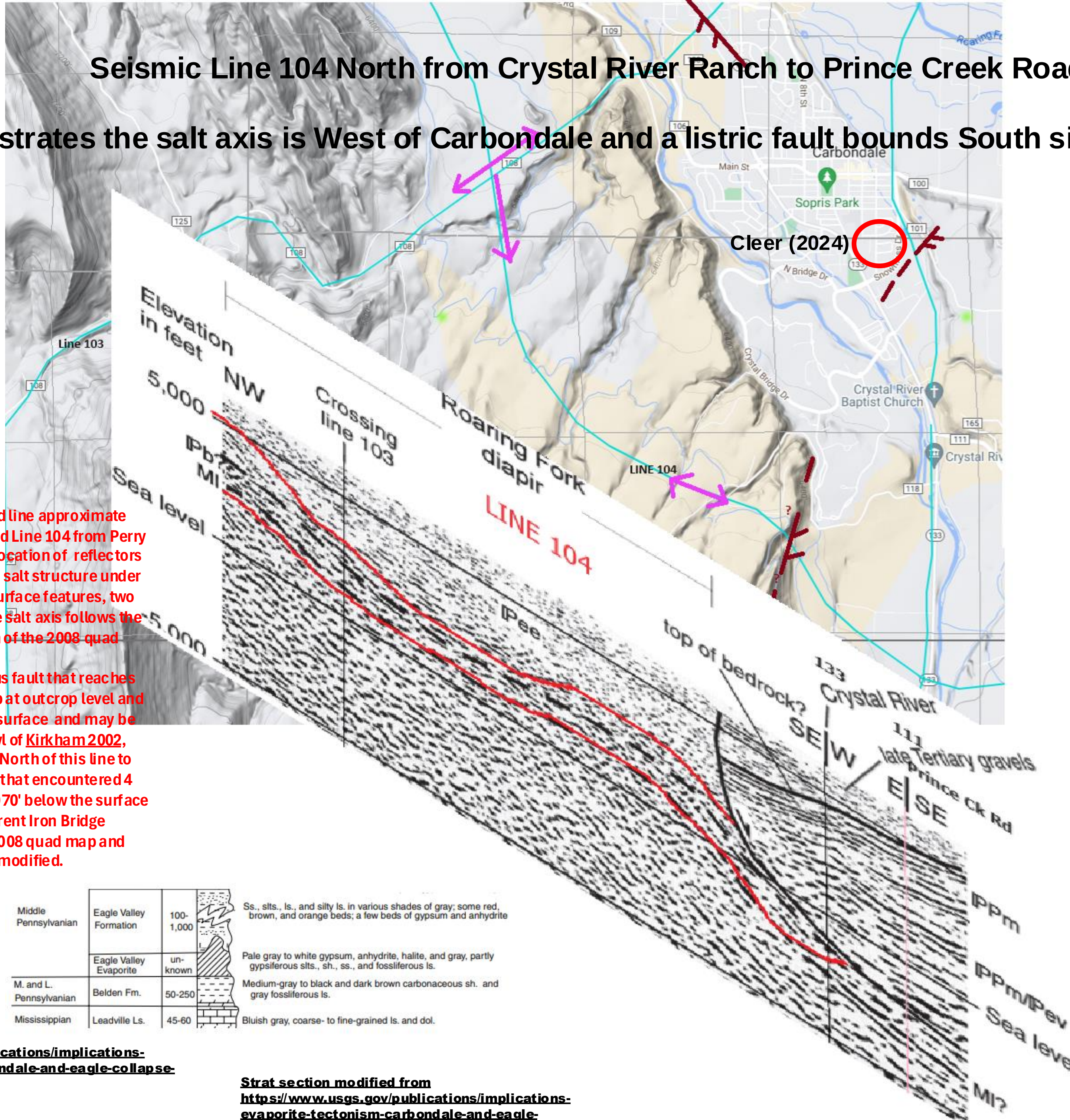
Don Marlin notes: Quad map approximate position of depth processed Line 104 from Perry (2002) approximating the location of reflectors that are interpreted to be a salt structure under Crystal River Ranch with surface features, two salt swells that suggest the salt axis follows the surface subsidence trough of the 2008 quad map, a large listric and possible contemporaneous fault that reaches the surface as a fault scarp at outcrop level and extends 7000' into the subsurface and may be the basis of the Sopris Bowl of Kirkham 2002, and a projection ~4 miles North of this line to the 1960 Shannon Rose #1 that encountered 4 lenses of salt at 2125' to 3070' below the surface at the South end of the current Iron Bridge subdivision. The current 2008 quad map and section is suggested to be modified.

**Seismic modified https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central_2**

**Seismic base location https://www.seitel.com/index.php/seitel-map/**

# Seismic Line 104 North from Crystal River Ranch to Prince Creek Road

# illustrates the salt axis is West of Carbondale and a listric fault bounds South side of town




Don Marlin notes: Oriented line approximate position of depth processed Line 104 from Perry (2002) approximating the location of reflectors that are interpreted to be a salt structure under Crystal River Ranch with surface features, two salt swells that suggest the salt axis follows the surface subsidence trough of the 2008 quad map, a large listric and possible contemporaneous fault that reaches the surface as a fault scarp at outcrop level and extends 7000' into the subsurface and may be the basis of the Sopris Bowl of Kirkham 2002, and a projection ~4 miles North of this line to the 1960 Shannon Rose #1 that encountered 4 lenses of salt at 2125' to 3070' below the surface at the South end of the current Iron Bridge subdivision. The current 2008 quad map and section is suggested to be modified.

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| | Eagle Valley Evaporite | un-known | Pale gray to white gypsum, anhydrite, halite, and gray, partly gypsiferous slts., sh., ss., and fossliferous ls. |
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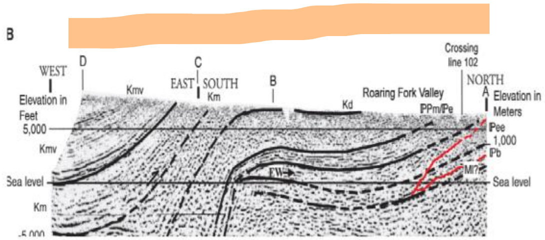
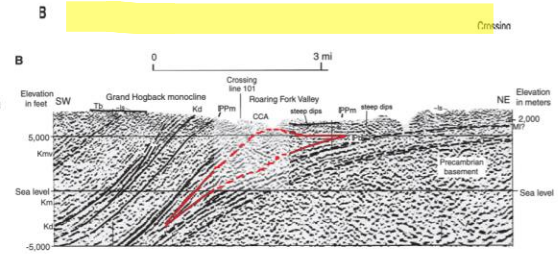
**Seismic modified**
**https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location**
**https://www.seitel.com/index.php/seitel-map/**

**Strat section modified from**
**https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central**



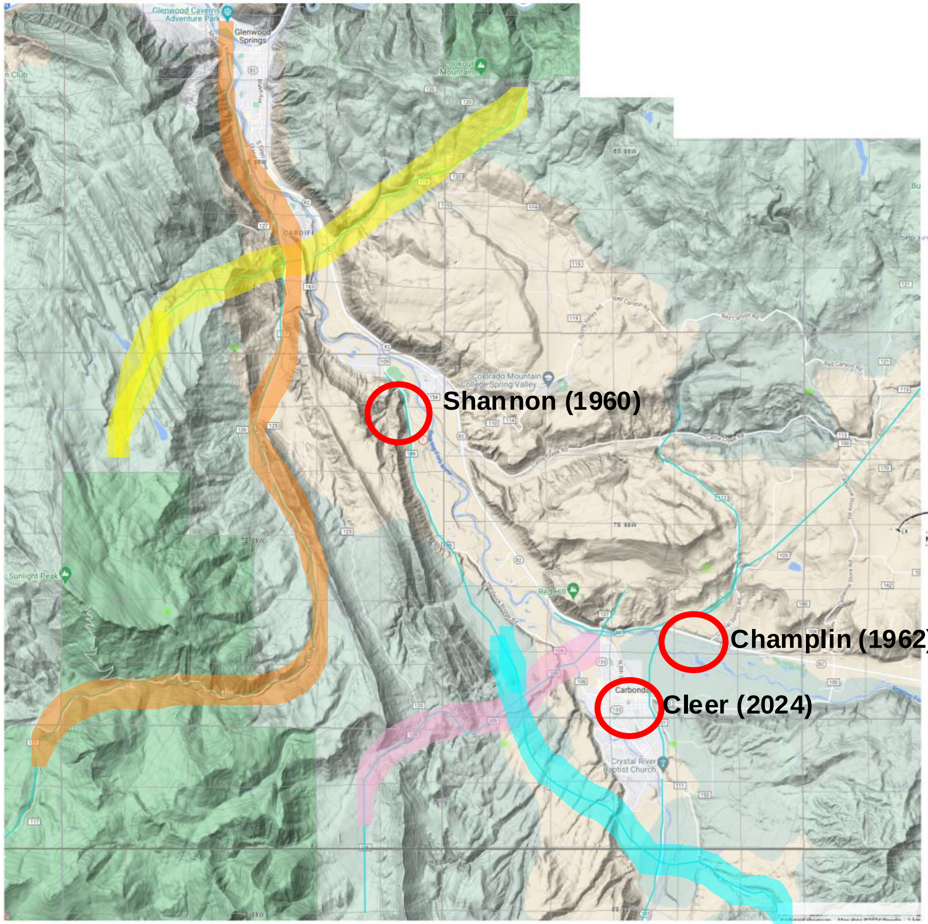




Seismic from Perry etal January 2002 Geological Society of America Special Papers 366:55-72

2024 Basemap (Seitel)

2024 reinterpretation (red)

Don Marlin notes: Seismic basemap position of four depth processed lines from Perry (2002) used for approximating the location of reflectors that are interpreted to be a top and base of salt structure under the Roaring Fork and Crystal River valleys. Approximate positions of key subsurface well control is also shown by circles.



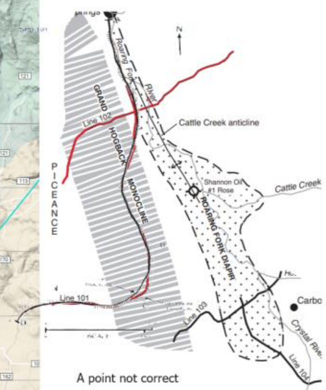
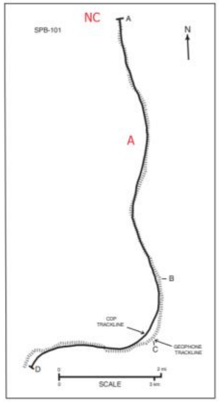
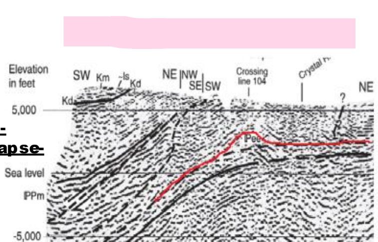
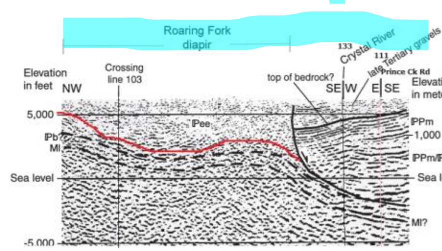




Figure 3. Difference between geophone trackline and CDP trackline. Letters A–D refer to discussions of interpretations of line 101. See Figure 4 for location of seismic line.



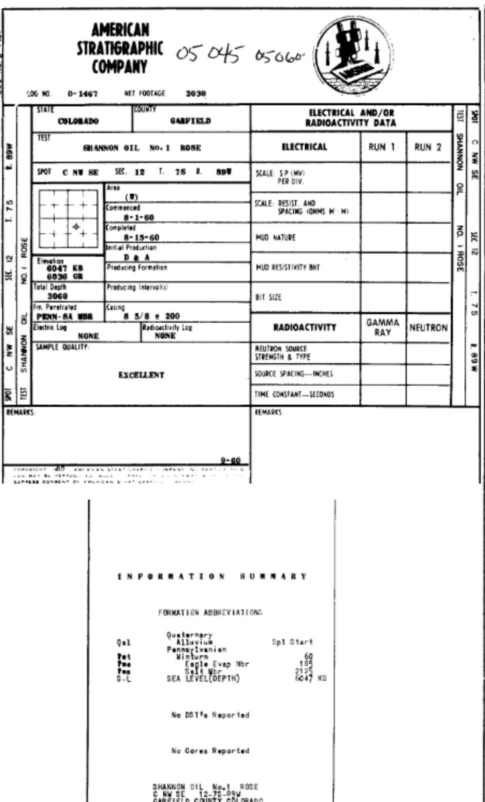



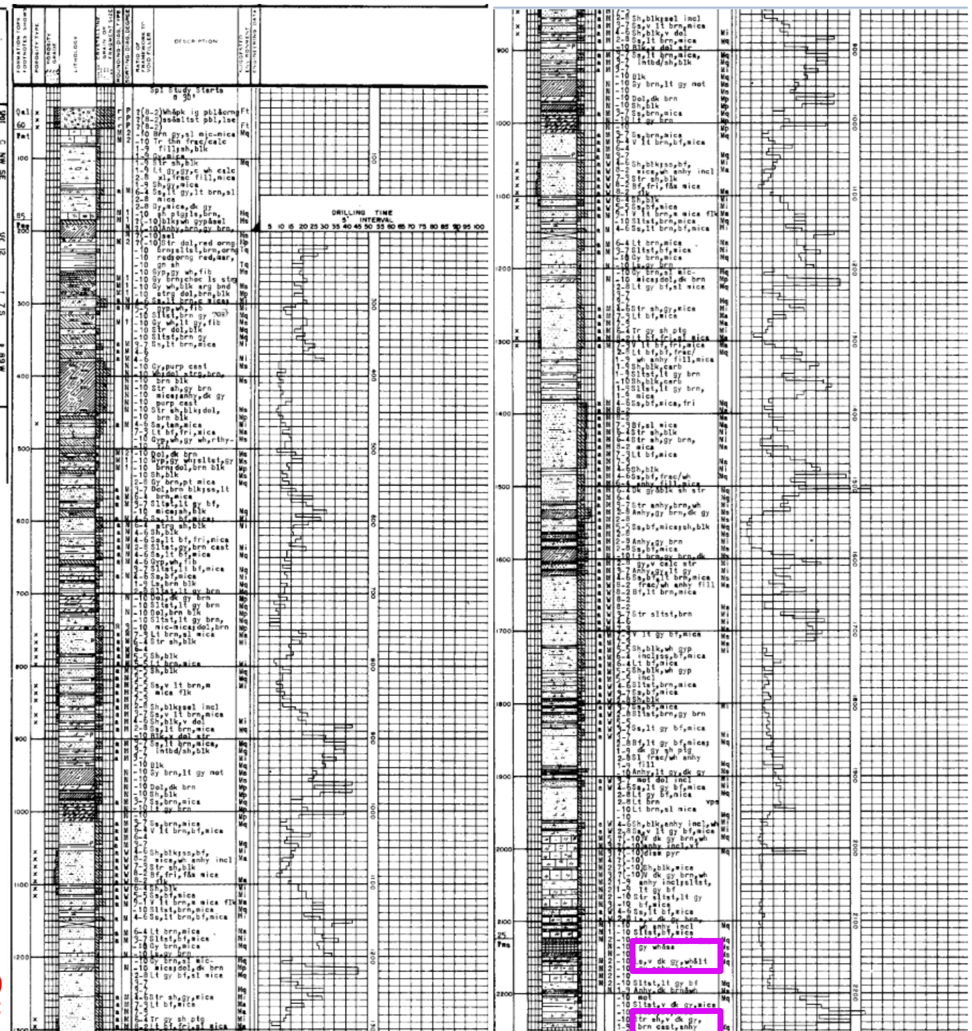

**Seismic modified**
**https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

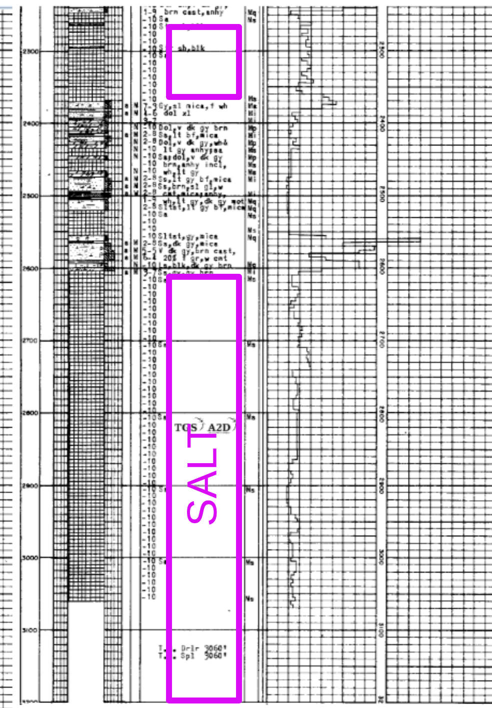
**Seismic base location**
**https://www.seitel.com/index.php/seitel-map/**

# Shannon Rose #1 Sample Log (not published, located in archive file June 2024)

## Grey-white salt from 2125' to 3060' in 4 lenses (935' gross interval)

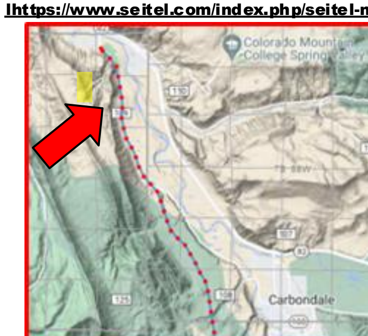


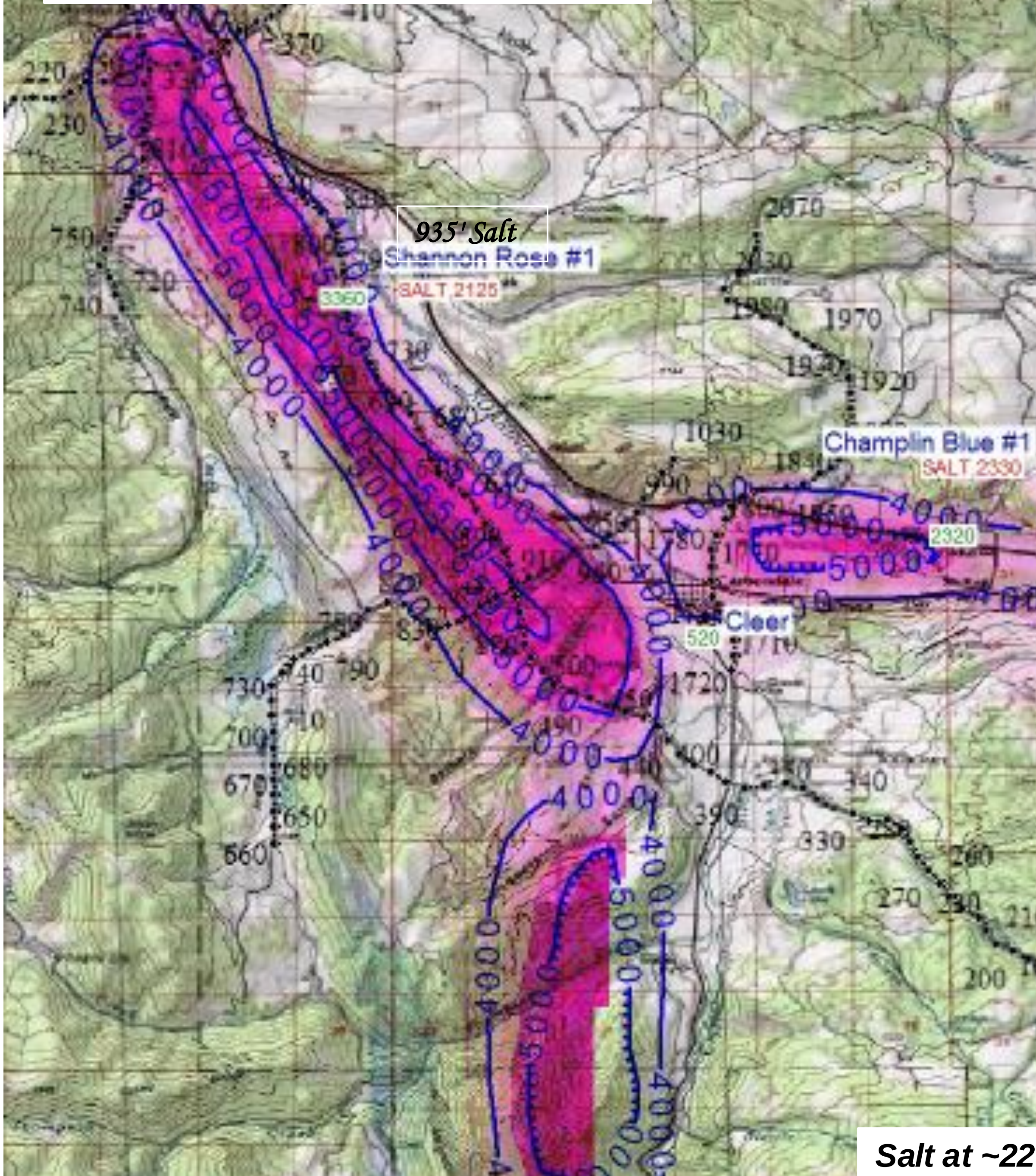



Don Marlin notes: 1960 Shannon Rose #1 sample log located that confirms that salt was encountered in the shallow subsurface at the end of the current Ironbridge subdivision. This well actually ties Line 104 from Perry (2002), but was not mentioned in the publication. Personal communication with Seitel provided that no reflectors are (interpretable) on this line suggesting it is all very near surface salt and evaporites from the end of the publicized line to the well position.

**Seismic base**
**lhttps://www.seitel.com/index.php/seitel-map/**



# Subsurface Top Salt Structure Map



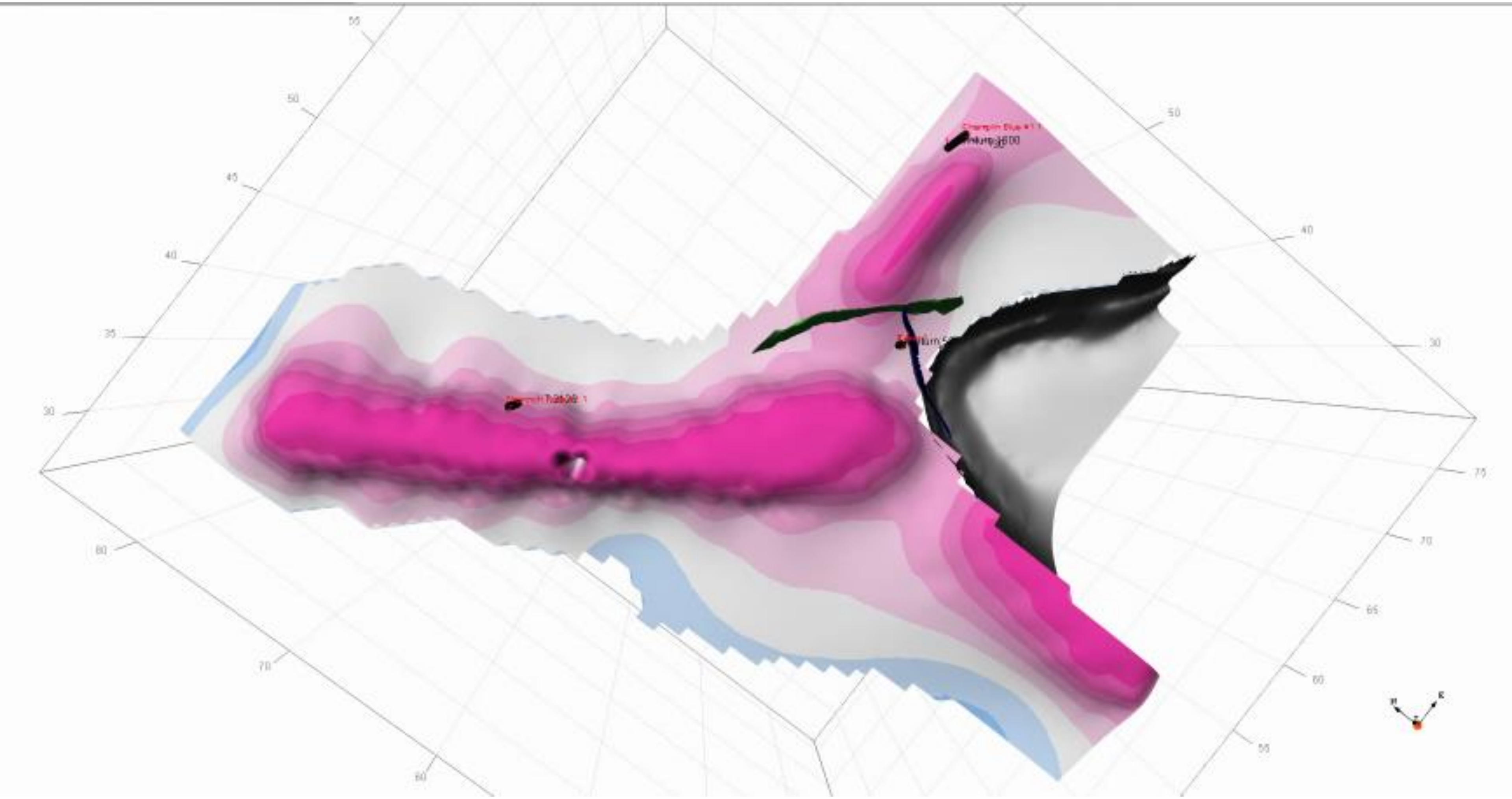

Don Marlin notes: This map was created by manually projecting depths of interpreted top of salt to approximate SP positions and well control and contouring the same in depth above sea level. The map suggests a split of the salt diapir going West of the town of Carbondale and ENE of the town bifurcated by the listric fault-bounded Sopris bowl. The Westerly salt trend underlies the 2008 quadrangle map subsidence trough and trends south merging with the Elk Creek anticline and Grand Hogback bounding the Piceance basin on the East.

**Seismic modified**
**https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location**
**https://www.seitel.com/index.php/seitel-map/**

***Salt at ~2200' under Carbondale***

# Subsurface Top Salt Structure Map



Don Marlin notes: An aerial view of the salt structure and possible interpreted subsurface and surface fault trends and well control as if the overlying layers were stripped away down to the top of salt. This map was created by manually projecting depths of interpreted top of salt to approximate SP positions and well control and contouring the same in depth above sea level. The map suggests a split of the salt diapir going West of the town of Carbondale and ENE of the town bifurcated by the listric fault-bounded Sopris bowl. The Westerly salt trend underlies the 2008 quadrangle map subsidence trough and trends south merging with the Elk Creek anticline and Grand Hogback bounding the Piceance basin on the East.

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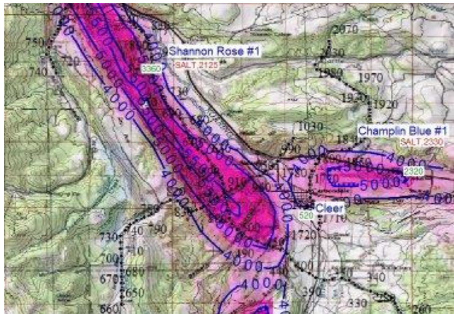
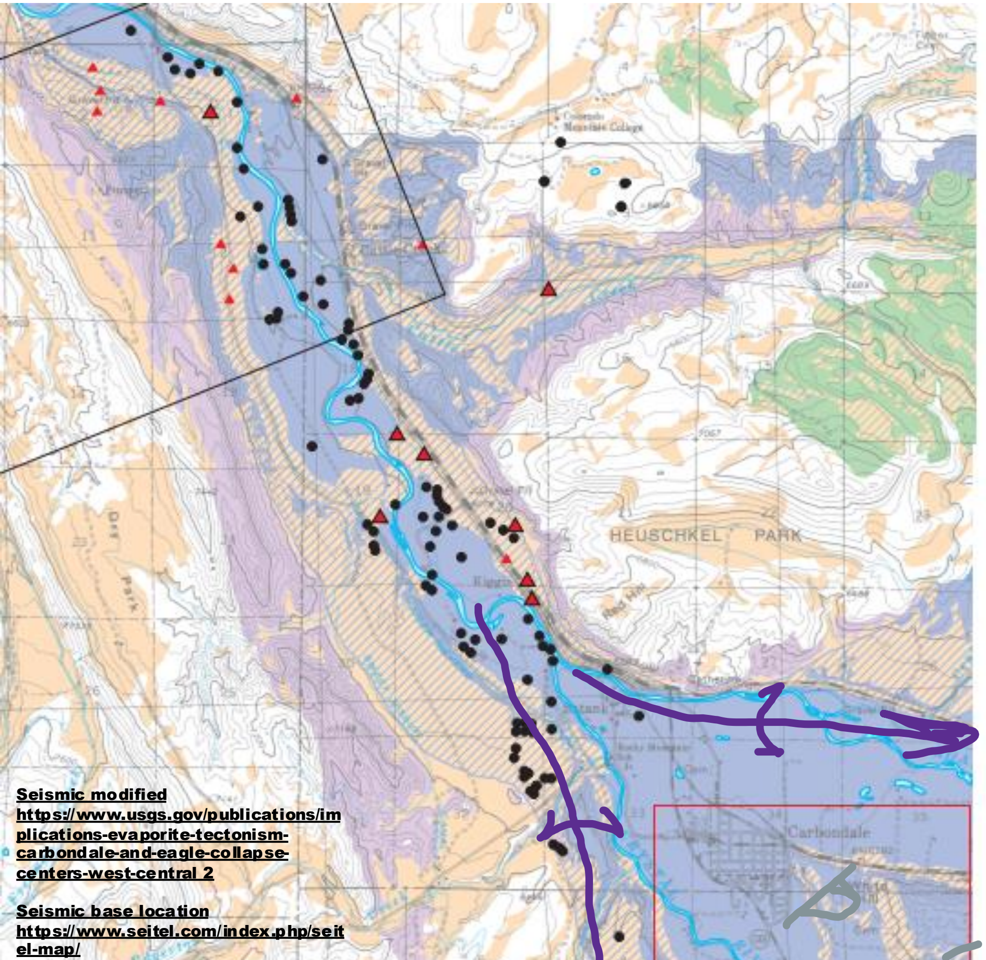
**Seismic base location**
**https://www.seitel.com/index.php/seitel-map/**



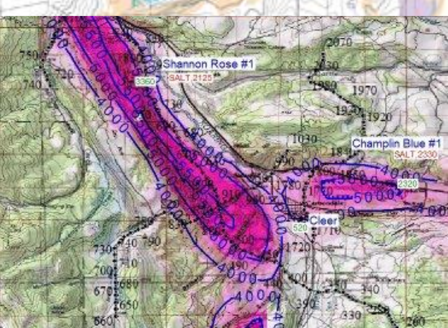
# Valley Sinkholes....Carbondale may be related to contemporaneous / listric faulting and underlying salt

**Karst base modified fromhttps://www.americangeosciences.org/sites/default/files/Environment-colorado4.pdf**




**Seismic modified https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location https://www.seitel.com/index.php/seitel-map/**

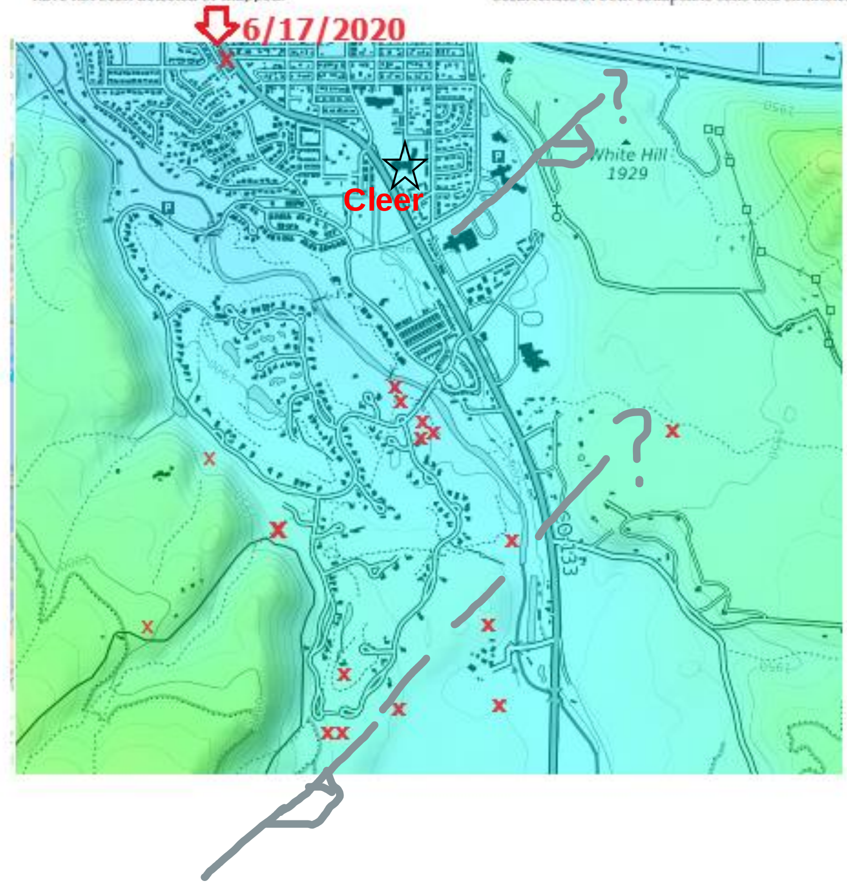



Modified from: Collapsible Soils and Evaporite Karst Hazards Map of the Roaring Fork River Corridor, Garfield, Eagle, and Pitkin Counties, Colorado
Jonathan White, 2002

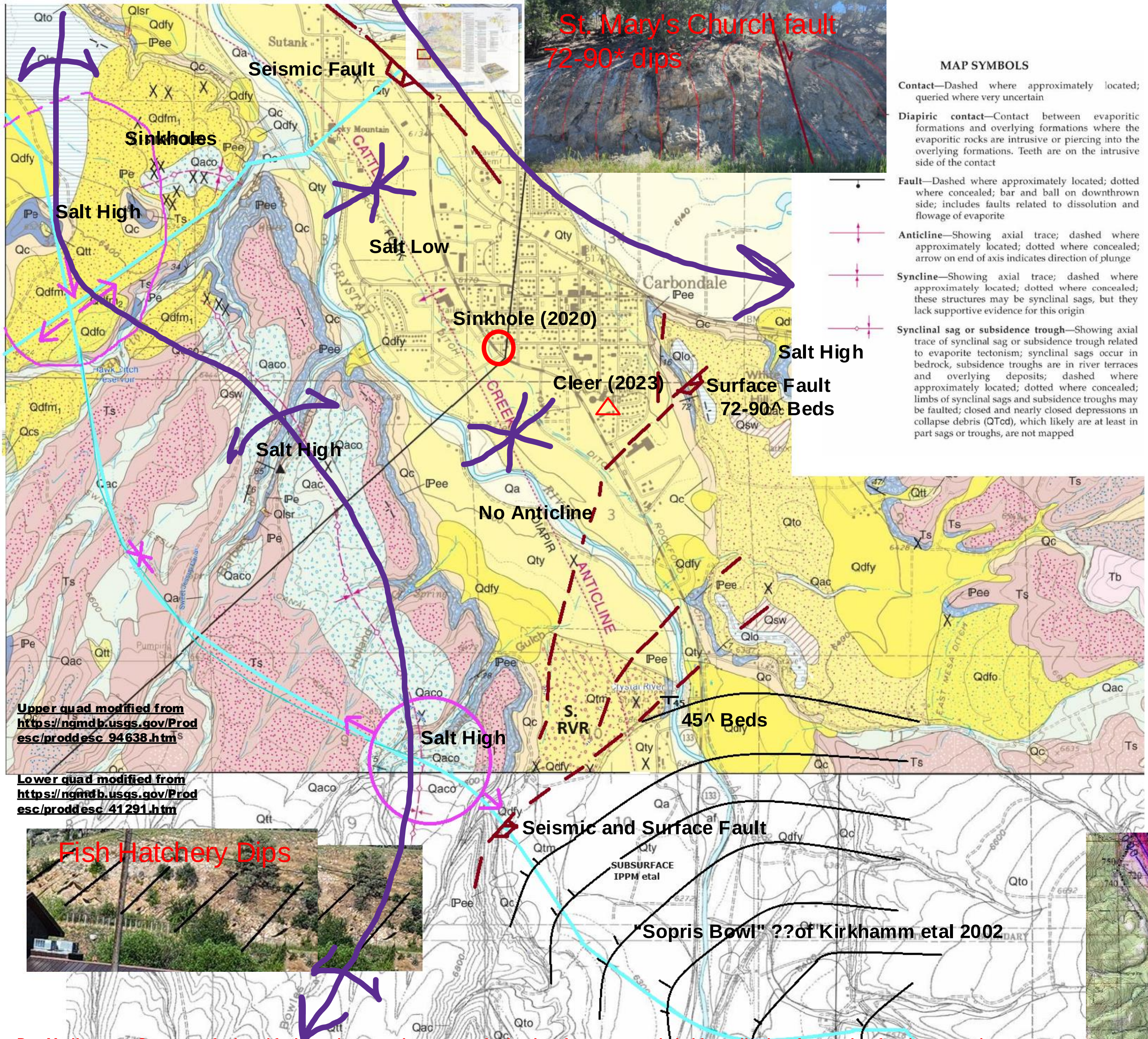
**Sinkholes and subsidence features**— Ground depression areas created either by (1) piping or collapse of surficial deposits into dissolution fissures, voids, or caverns within underlying Eagle Valley Evaporite, (2) downward movement of gravel chimneys into deep bedrock voids, (3) dissolution caverns in outcrops of Eagle Valley Evaporite, or (4) large-scale collapse or settlement of low-density surficial deposits. A black dot denotes small sinkholes or clusters of small sinkholes, and closed, hatured lines denote the larger subsidence areas. Many small sinkholes in addition to those shown are probably present where the Eagle Valley Evaporite is shown, but have not been detected or mapped.

denotes small sinkholes or clusters of small sinkholes, and closed, hatured lines denote the larger subsidence areas. Many small sinkholes in addition to those shown are probably present where the Eagle Valley Evaporite is shown, but have not been detected or mapped.

**Soil-collapse locations**—Historical occurrences of soil settlement, damage to structures, and/or collapsible soils verified by soil testing. These data were compiled by CGS as part of the Statewide Collapsible Soil Study (White and Greenman, in prep.). Red triangles show approximate locations of historical occurrences of collapsible soils or damage to a structure as a result of soil collapse and settlement. A Red triangle with black edging denotes approximate locations of historical occurrences of both collapsible soils and sinkholes.



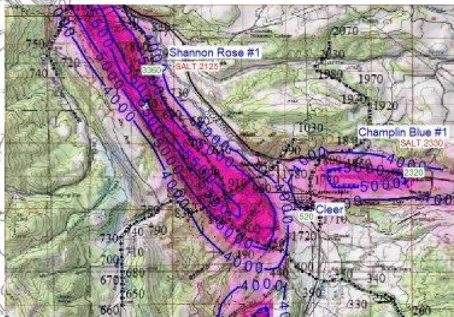

Don Marlin notes: Summary of salt and fault trends versus the new top of salt subsurface map.



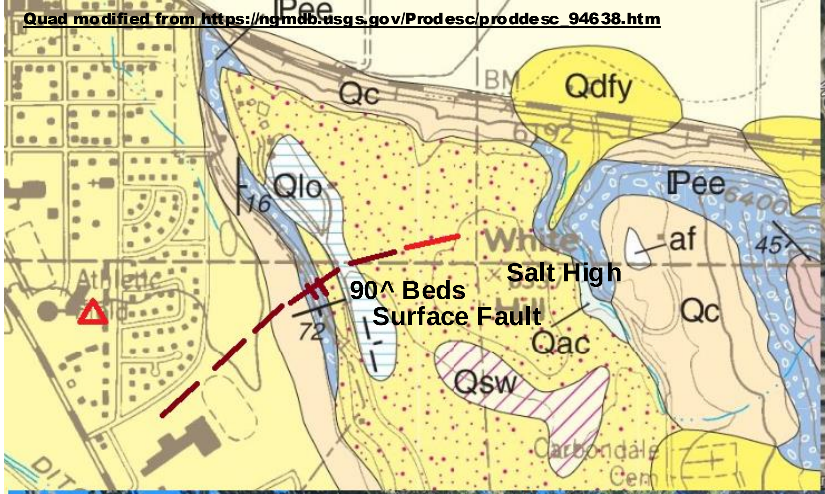

# Quadrangle map modifications From seismic

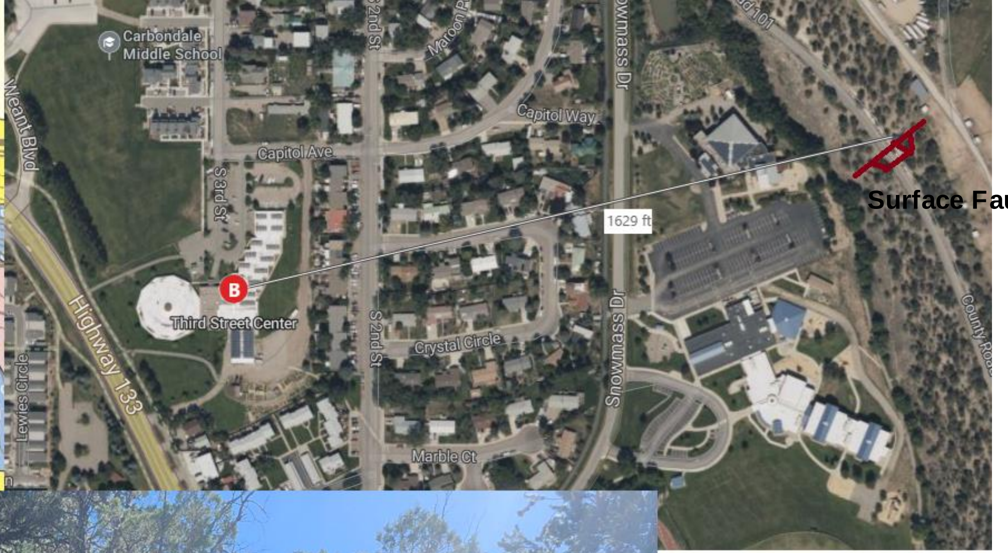
**Seismic modified https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location https://www.seitel.com/index.php/seitel-map/**

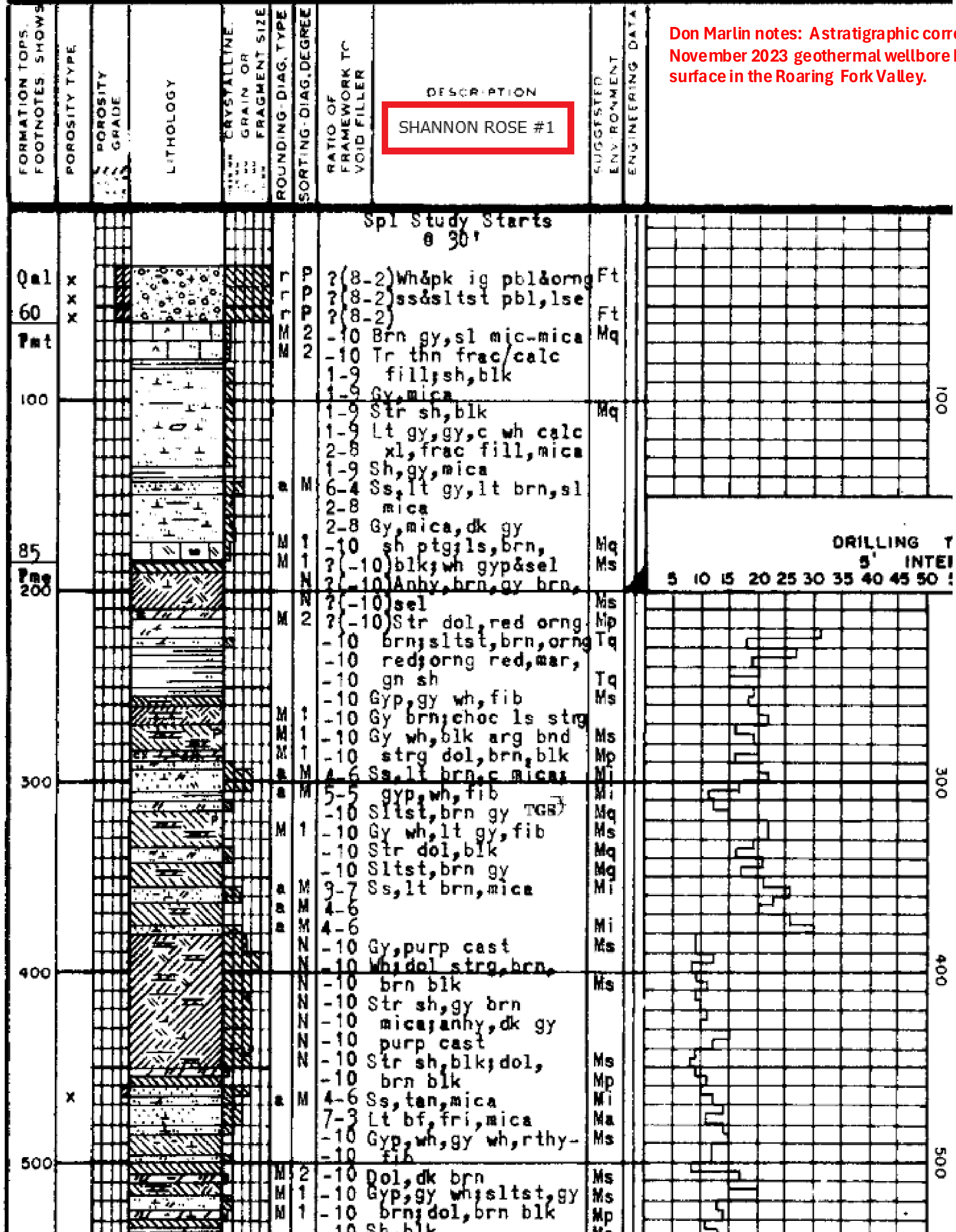



Don Marlin notes: Summary of salt and fault trends versus the new top of salt subsurface map concluded from all subsurface and surface interpretations.




Don Marlin notes: A surface fault and higher dips in evaporite beds are within 1629' of the 3rd Street Center geothermal well drilled in November 2023 nearer than the hazards shown on the current 2008 quad map.




**Don Marlin notes: A stratigraphic correlation section from the 1960 Shannon Rose #1 wellbore to Cleer November 2023 geothermal wellbore highlights that vertical and lateral heterogeneity exists in the shallow surface in the Roaring Fork Valley.**

CLEER 3RD STREET CENTER #1

| Start | End | Activity | Hrs:Min | From | To | | Comments |
|---|---|---|---|---|---|---|---|
| 16-Nov-23 | | | | | | | setup, warmup, mixed mud |
| 7:37 | 7:40 | | 0:03 | 0 | 10 | | [illegible] |
| 7:40 | 8:09 | | 0:29 | 11 | 20 | | granules, v coarse sand, coarse sand, gravel (pebbler/cobble) (50/35/10/5), angular to subround (lots of mud lost to this region according to driller) |
| 8:09 | 8:32 | | 0:23 | 21 | 30 | | AA, cobble/boulders encountered (~25' was problematic) |
| 8:32 | 9:00 | | 0:28 | 31 | 40 | | [illegible] |
| 9:00 | 9:16 | | 0:16 | 41 | 50 | | AA |
| 9:16 | 9:32 | | 0:16 | 51 | 60 | | AA |
| 9:32 | 9:50 | | 0:18 | 61 | 70 | | AA, more silt, less sandy(40/40/10/10), ~50% limestone (LS) |
| 9:50 | 10:03 | | 0:13 | 71 | 80 | | AA, ~75% LS |
| 10:03 | 10:18 | | 0:15 | 81 | 90 | | AA |
| 10:18 | 10:29 | | 0:11 | 90 | 100 | | AA more gravel, less sand (60/20/10/10), ~50% LS |
| 10:29 | 10:43 | | 0:14 | 101 | 110 | | granules, clay, v. coarse sand to silt (50/30/20) |
| 10:43 | 11:05 | | 0:22 | 111 | 120 | | [illegible] |
| 17-Nov-23 | | | | | | | reseated casing, setup, warmup, mixed mud |
| 8:05 | 8:19 | | 0:14 | 121 | 130 | | pebbles, v. coarse sand to silt (50/50), ~25% LS (reduction in LS fraction may be due to non-LS cuttings settling in hole overnight) |
| 8:19 | 8:27 | | 0:08 | 131 | 140 | | AA |
| 8:27 | 8:33 | | 0:06 | 141 | 150 | | AA |
| 8:33 | 8:38 | | 0:05 | 151 | 160 | | [illegible] |
| 8:38 | 8:45 | | 0:07 | 161 | 170 | | AA |
| 8:45 | 8:50 | | 0:05 | 171 | 180 | | AA |
| 8:50 | 8:56 | | 0:06 | 181 | 190 | | AA |
| 8:56 | 9:01 | | 0:05 | 191 | 200 | | AA |
| 9:01 | 9:09 | | 0:08 | 201 | 210 | | AA |
| 9:09 | 9:14 | | 0:05 | 211 | 220 | | AA |
| 9:14 | 9:23 | | 0:09 | 221 | 230 | | AA |
| 9:23 | 9:30 | | 0:07 | 231 | 240 | | AA |
| 9:30 | 9:34 | | 0:04 | 241 | 250 | | AA |
| 9:34 | 9:38 | | 0:04 | 251 | 260 | | AA |
| 9:38 | 9:45 | | 0:07 | 261 | 270 | | AA |
| 9:45 | 9:51 | | 0:06 | 271 | 280 | | AA |
| 9:51 | 9:57 | | 0:06 | 281 | 290 | | AA |
| 9:57 | 10:01 | | 0:04 | 291 | 300 | | friable black carbonaceous shale/coal and darker grey LS (90/10) |
| 10:01 | 10:07 | | 0:06 | 301 | 310 | | AA |
| 10:07 | 10:11 | | 0:04 | 311 | 320 | | AA (50/50) |
| 10:11 | 10:18 | | 0:07 | 321 | 330 | | AA |
| 10:18 | 10:22 | | 0:04 | 331 | 340 | | AA |
| 10:22 | 10:28 | | 0:06 | 341 | 350 | | AA (loop stuck on way down first try) |
| 10:28 | 10:31 | | 0:03 | 351 | 360 | | AA (bit stuck on way up) |
| 10:31 | 10:37 | | 0:06 | 361 | 370 | | AA |
| 10:37 | 10:45 | | 0:08 | 371 | 380 | | AA |
| 10:45 | 10:52 | | 0:07 | 381 | 390 | | AA |
| 10:52 | 11:00 | | 0:08 | 391 | 400 | | AA (20/80) |
| 11:00 | 11:05 | | 0:05 | 401 | 410 | | AA |
| 11:05 | 11:12 | | 0:07 | 411 | 420 | | AA |
| 11:12 | 11:19 | | 0:07 | 421 | 430 | | AA |
| 11:19 | 11:27 | | 0:08 | 431 | 440 | | AA |
| 11:27 | 11:34 | | 0:07 | 441 | 450 | | AA (10/90) (loop stuck on way down second try) |
| 11:34 | 11:41 | | 0:07 | 451 | 460 | | AA |
| 11:41 | 11:50 | | 0:09 | 461 | 470 | | Dark grey micritic LS (no shale noted) |
| 11:50 | 11:58 | | 0:08 | 471 | 480 | | AA |
| 11:58 | 12:07 | | 0:09 | 481 | 490 | | AA |
| 12:07 | 12:21 | | 0:14 | 491 | 500 | | AA (lighter grey, similar to 150-290') |
| 18-Nov-23 | | | | | | | Repaired mud pump, setup, warmup, mixed mud |
| 11:10 | 11:15 | | 0:05 | 501 | 510 | | AA (some black shale present,may be due to cuttings settling in hole overnight) |

**Sample Log**
**Link: https://gdr.openei.org/submissions/1598**

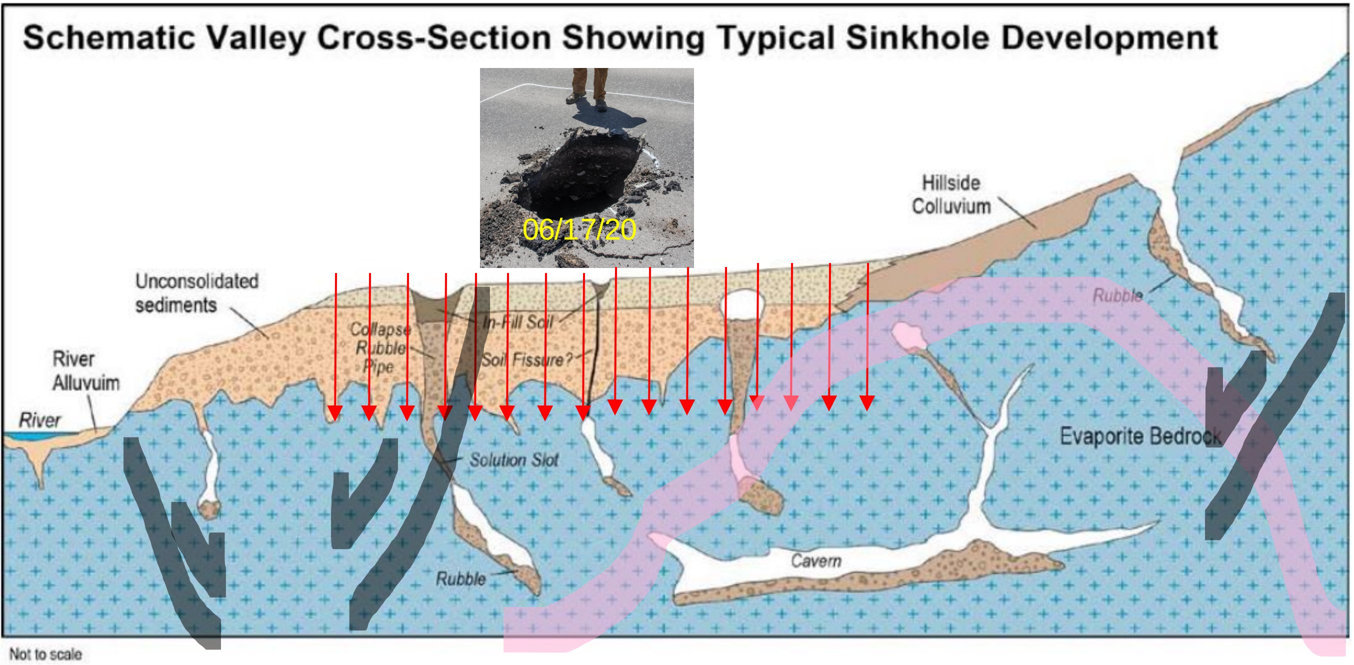



**Figure 4.** Illustration of typical karst and stages of sinkhole development. Sinkholes form by the upward progression of cavern roof collapse that reaches the surface. Small sinkholes can also occur by piping of fine grained sediments into solution slots.

Don Marlin notes: Vertical and lateral heterogeneity could lead to encountering new hazards in the shallow subsurface with dense geothermal drilling. Caution is advised.

**Colorado Map of Potential Evaporite Dissolution and Evaporite Karst Subsidence Hazards**

by
Jonathan L. White

Colorado Geological Survey
Department of Natural Resources
Denver, Colorado
2012


**Figure 3.** Several sinkholes pockmark a mid-Pleistocene glacio-fluvial terrace in the Roaring Fork Valley near Carbondale in Garfield County.

**Modified from https://coloradogeologicalsurvey.org/publications/evaporite-dissolution-karst-subsidence-hazard-map-colorado/ Photos from OF-12-02 Report**

**Figure 10.** Large sinkhole opened in 2005 at golf course club grounds at Ironbridge Development. Two golf carts inside the structure were lost down the throat of the sinkhole. View is to the northwest, down the Roaring Fork River valley towards Glenwood Springs. Red cliffs are the Maroon Formation. For scale, note person in white hardhat standing in the snow.

Don Marlin notes: Vertical and lateral heterogeneity could lead to encountering new hazards in the shallow subsurface with dense geothermal drilling. Caution is advised. Note the drilling and completion hardships encountered in the first wellbore from November 2023.

| | | | | |
|---|---|---|---|---|
| Drilling | 7:54 | Hrs:Min | Drilling 0 - 520' | |

**COMMENTS:** (16NOV) Gravel in the upper 40' of hole caused concern to driller, casing installed after drilling 120' (POOH). Casing consisted of 2x20' 6" dia Cresline HDPE, top ~4.5' were cut after insertion (~35' casing). Casing would not stay seated so drillers packed more hole plug (total 2 bags) and SDFN to allow to set overnight.

(17NOV) Casing reseated with more hole plug (5 addtl bags) and drilling continued without issue to 500'. Drillers experienced difficulty pulling string at 400' and bit was stuck at ~360' for remainder of day - the mud pump had reduced circulation and driller believed cuttings accumulated atop the bit on the way down.

(18NOV) Mud pump repaired and hole redrilled extending an additional 20' (520' total). Initial attempt to install loop failed ~350' due to debris / narrowing in hole. Redrilled hole to 520'. Second attempt got loop to 450', trimmed ~4 feet above ground, ends melted shut, tied to metal stake, and grouted with 20 bags of TG Lite and 10 bags of PowerTEC.

(20NOV) Grout settled to 18' below surface (within casing), drillers backfilled with mudchips, cleaned up, and vacated site.

Summary notes:

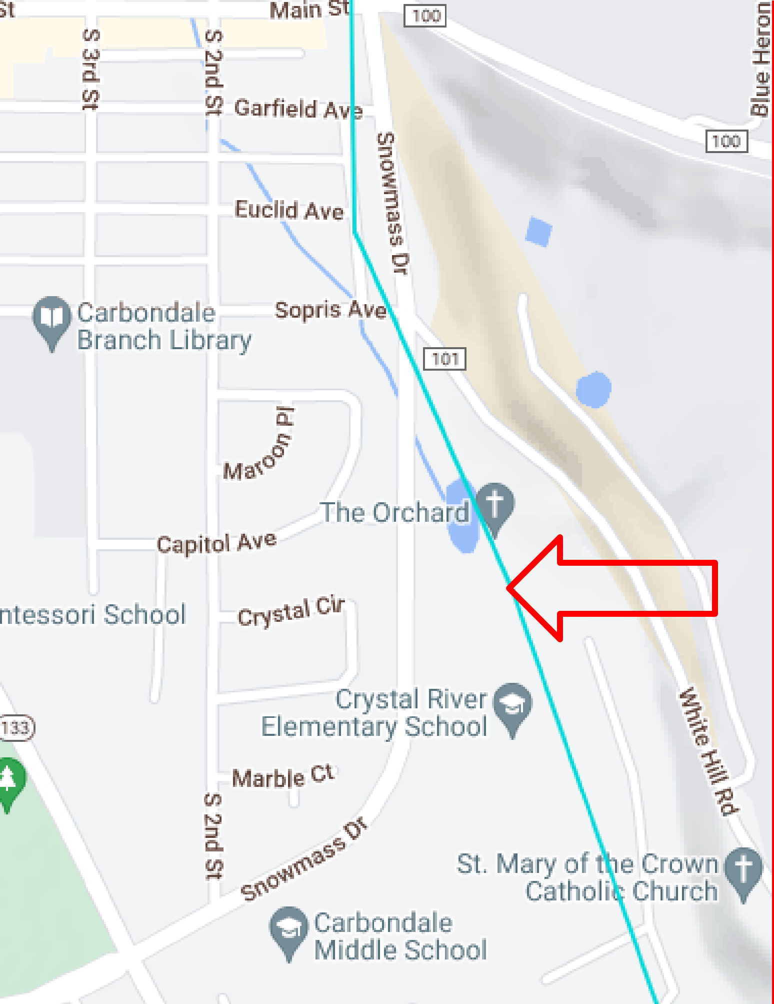
40 to 60' in adjacent areas may require casing due to unstable ground and large hard rock gravels (granite, basalt). This driller widened the hole to 8" down to 40' and installed 2x20' sections of locally sourced 6" dia Cresline HDPE and sealed with 3/8" bentonite hole plug. Production drillers may consider bringing preferred casing/hole plug to site as local supply/variety could be limited.

300' to TD may contain unstable carbonaceous shale lenses in adjacent areas, loop depths may vary within this range although head driller said he is confident 450' loop depth is achievable at scale.

Drilling crew were helpful, hard working, and a pleasure to work with. They spoke highly of their company and were happy with the equipment they were using.

Head driller notes:
Clarity on mud/cutting disposal prior to arriving at site would have been helpful and allowed them to coordinate disposal option prior to arrival. This could cause delays for future exploratory holes depending on local disposal options.

**Drilling Comments Link: https://gdr.openei.org/submissions/1598**





**Seismic modified**
**https://www.usgs.gov/publications/implications-evaporite-tectonism-carbondale-and-eagle-collapse-centers-west-central 2**

**Seismic base location**
**https://www.seitel.com/index.php/seitel-map/**

Don Marlin notes: Additional 2D seismic control through the area of geothermal drilling could aid identifying additional subsurface karst hazards. A 3D survey could additional be a very good tool for high resolution subsurface understanding via a dense source and receiver design.

## SPB-108A (SDL-2144169) SOUTH PICEANCE BASIN

| GENERAL | | SOURCE INFORMATION | |
|---|---|---|---|
| Location: | | Type: | VIBROSEIS |
| Vintage: | 01-JAN-1986 | Interval: | 220 |
| Size: | 16.73 mi | Line Spacing: | |
| Bin Size: | | | |

| PATTERN / DENSITY | | RECEIVER INFORMATION | |
|---|---|---|---|
| # of Channels: | | Array: | |
| Fold: | 30 | Inverval: | 110 |
| Spread: | | Line Spacing: | |
| Patch: | | | |

**$1,500/mile with a 10 mile minimum license**

# Summary

- To present an interpretation based on additional subsurface / seismic since quads do not accurately depict this area as accurately as possible without these tools.

- Faulting that reaches the surface is a better basis for sinkholes than solely salt in town proper area.....but nearby evaporite outcrops and faulting creates further instability risk.

- Instability risk may be diminished by obtaining additional 2D seismic very close to the 3rd street Center area by providing additional subsurface control for drilling.

- Wellbore instability is likely to continue in the project area.

Don Marlin notes: Thank you for your time and consideration in this 2024 interpretation.