LARAMIDE-AGE STRUCTURE, GEOCHEMISTRY AND ORIGIN OF UNAWEEP CANYON IN NORTHERN UNCOMPAHGRE PLATEAU, COLORADO

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Regional and Geologic Maps

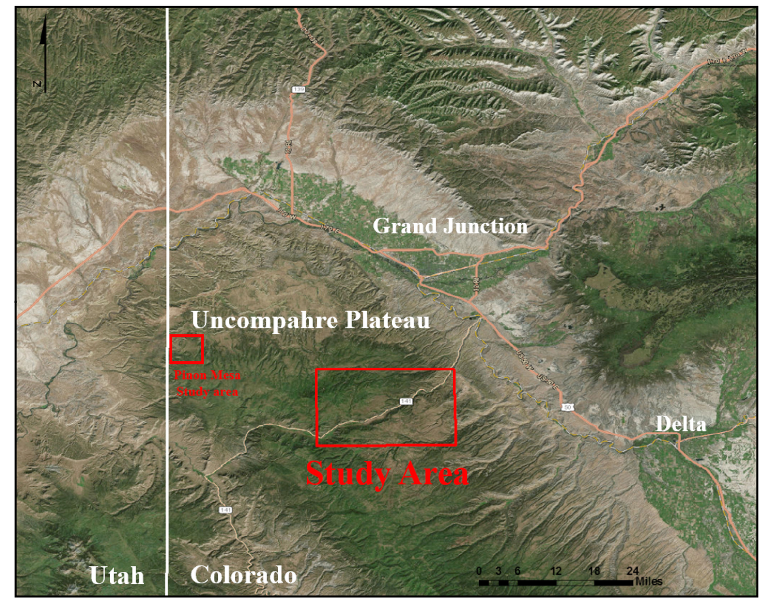

Figure 1. Regional map of central western Colorado

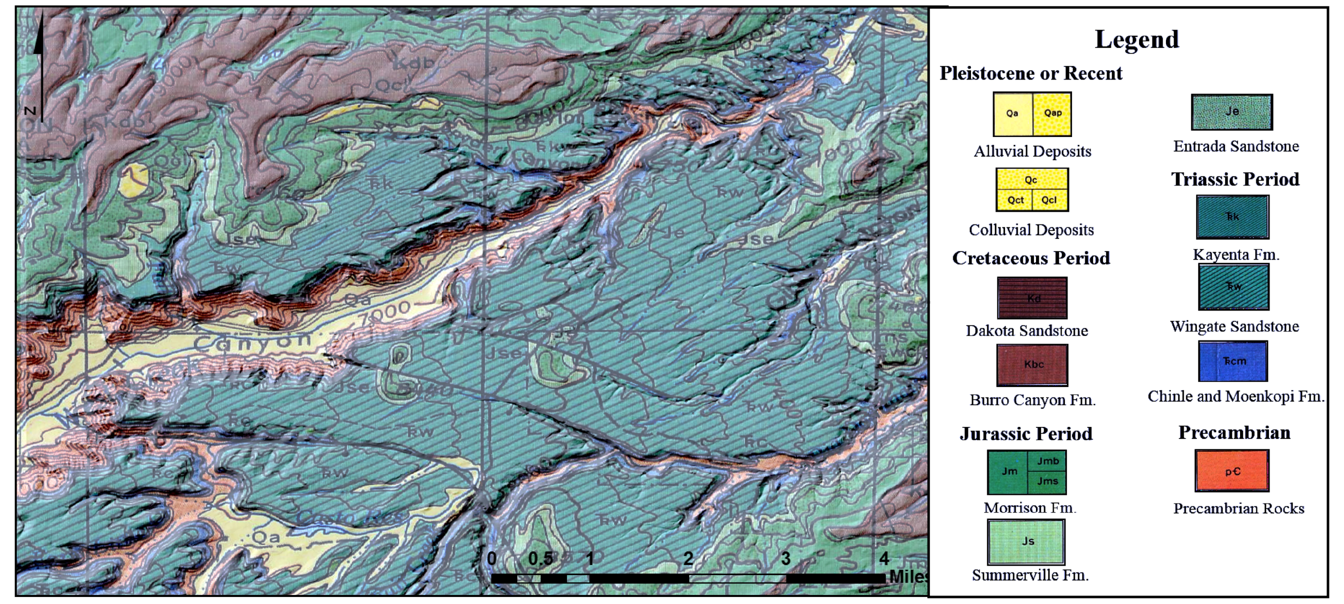

Figure 2. Geologic map of the study area (USGS I-360-1) overlaid onto study area region using ArcGIS.

Structural Summary

A series of 109 structural data points were recorded in the eastern Unaweep Canyon study area. Measurements at locations (Figure 5) verified WNW-ESE striking, left-lateral oblique-slip faults that cross-cut Unaweep Canyon. Based on slickenside striations along these faults, the structures have left-lateral strike-slip and both normal and reverse-dip slip. This data was compiled and analyzed using FaultKin (Allmendinger, 2016), transferred into stereonet diagrams, which revealed strain consistent with Laramide-age tectonic forces (Diagram 1). The tensional strain direction suggests that Unaweep Canyon originally formed as a series of down-to-the SE normal fault structures. The NE-SW striking Unaweep Canyon normal faults formed as transtensional bends between the cross-canyon controlling WNW-ESE striking faults (Figure 4).These major controlling faults include the Nancy Hanks Gulch, Taylor Gulch, Rocky Pitch Gulch – Big Dominguez, and North Gill Creek fault zones (Figure 5). These faults are the eastward continuation of similar WNW-ESE striking, left-lateral oblique-slip faults found in the Pinon Mesa area, just northwest of Unaweep Canyon, for example the Dry Creek Gulch Fault. Country rocks adjacent to these faults are highly silicified and affected by synkinematic, epithermal mineralization (Diagram 2). The sequence begins with synkinematic fluorite-amethyst-calcite-hematite-goethite, and barite, followed by post-kinematic Cu-carbonates, and small concentrations of sulfides. Mineralized flumes are located along left-lateral oblique-slip faults (Figure 4). Multiple types of brecciation have been observed along faults suggesting they formed by a combination of high fluid pressures and tectonic comminution in zones of transtensional faulting (Figure 7).

Structural Analysis

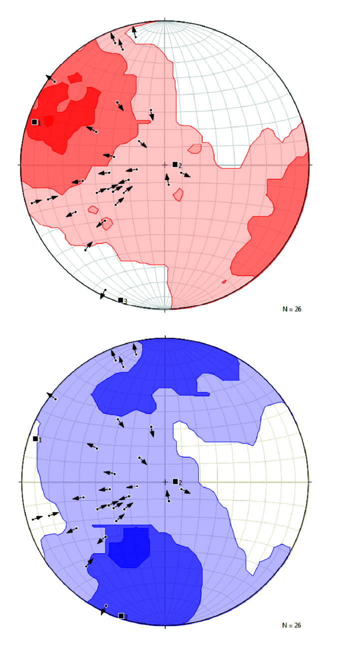

Diagram 1. Red steronet represents NW-SE extensional strain, blue steronet represents NE-SW compressional strain.

Pictures of Study Area

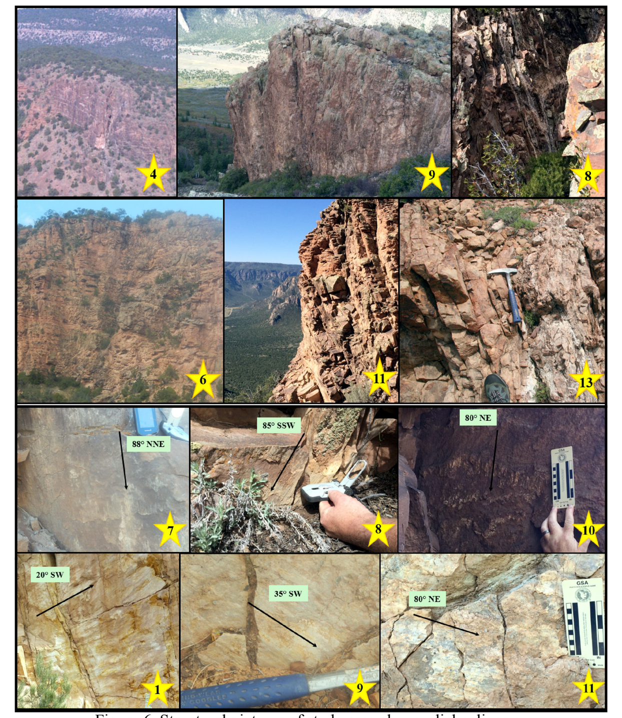

Figure 6. Structural pictures of study area above, slickenlines on bottom, with location numbers in gold stars corresponding to Figure 5.

Hydrothermal model

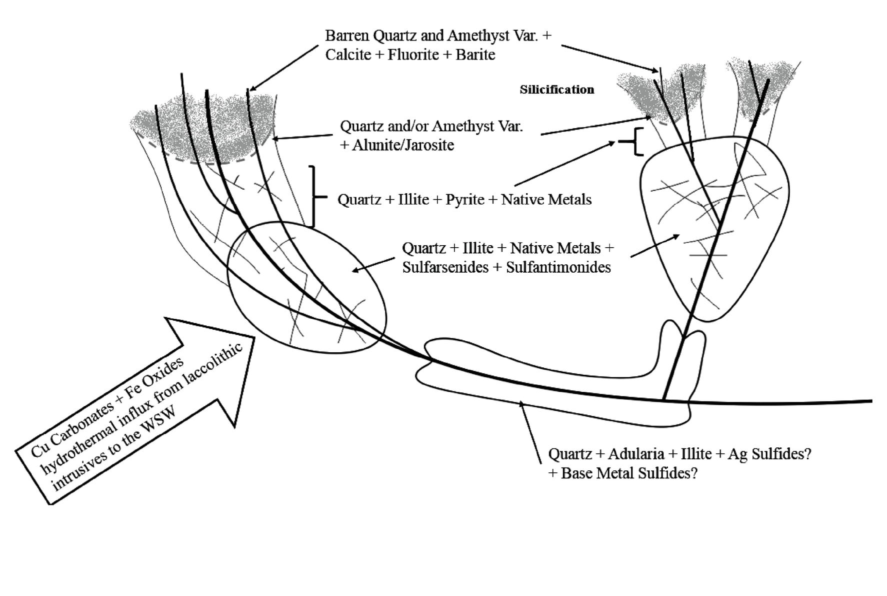

Diagram 2. Structural and mineralogical model of hydrothermal systems observed in the northern Uncompahgre Plateau, CO; based on geochemical observations and comparable models published by Fisher and Julilland, 1986.

Geochemical Data

Concentration in ppm (Logarithmic scale)

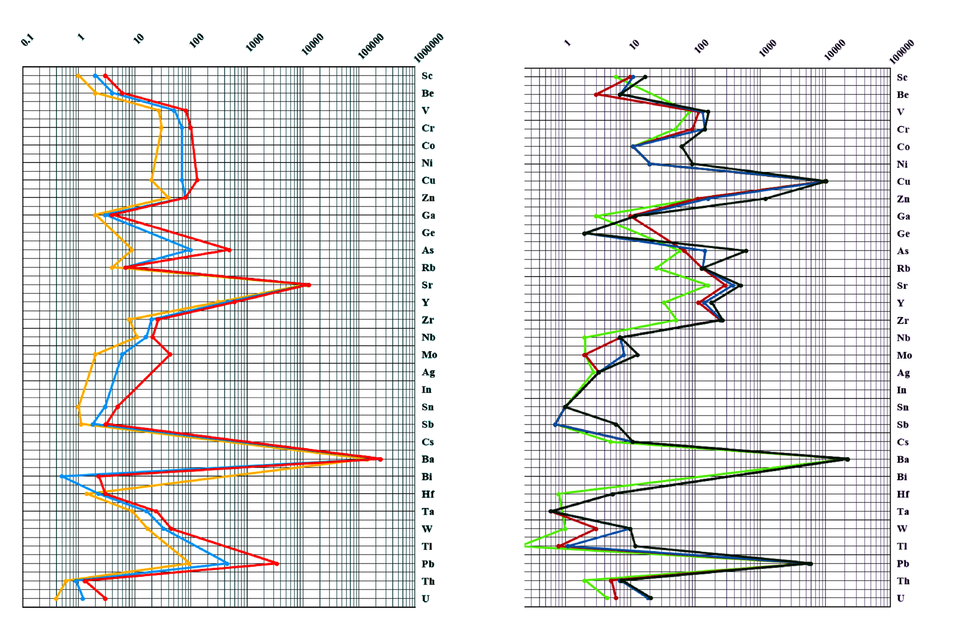

Diagram 3. Elemental geochemical signatures of samples taken from seven locations on the northern Uncompahgre Plateau. This data is preliminary, further sampling is required for a more in depth analysis. Locations can be referenced by color to Diagram 4 legend. Data processed by Actlabs, Canada.

Normalized REE Plot

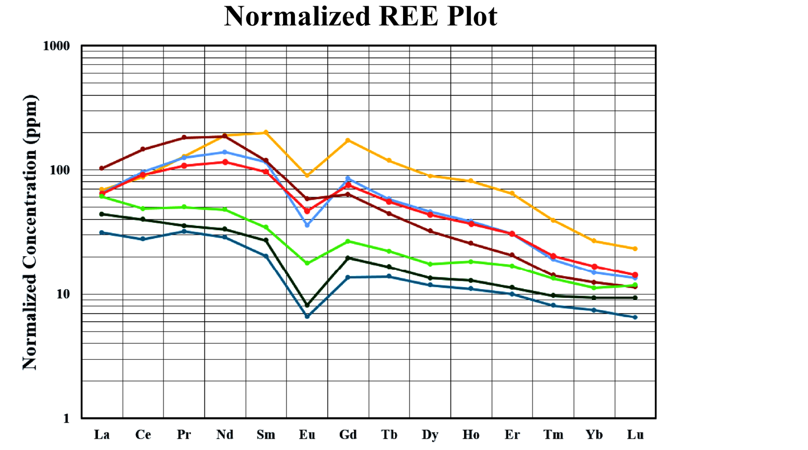

Diagram 4. Chondrite normalized plot of REE signatures, samples correspond to gold stars in Figure 5, Locations correlate by color with Diagram 3.

Legend

- Pinon Mesa lower Adit
- Pinon Mesa upper Adit
- Pinion Mesa Quarry 14
- North Nancy Hanks lower mine
- North Nancy Hanks upper mine
- South Nancy Hanks lower mine
- South Nancy Hanks upper mine 2

Structures of the Northern Uncompahgre Plateau

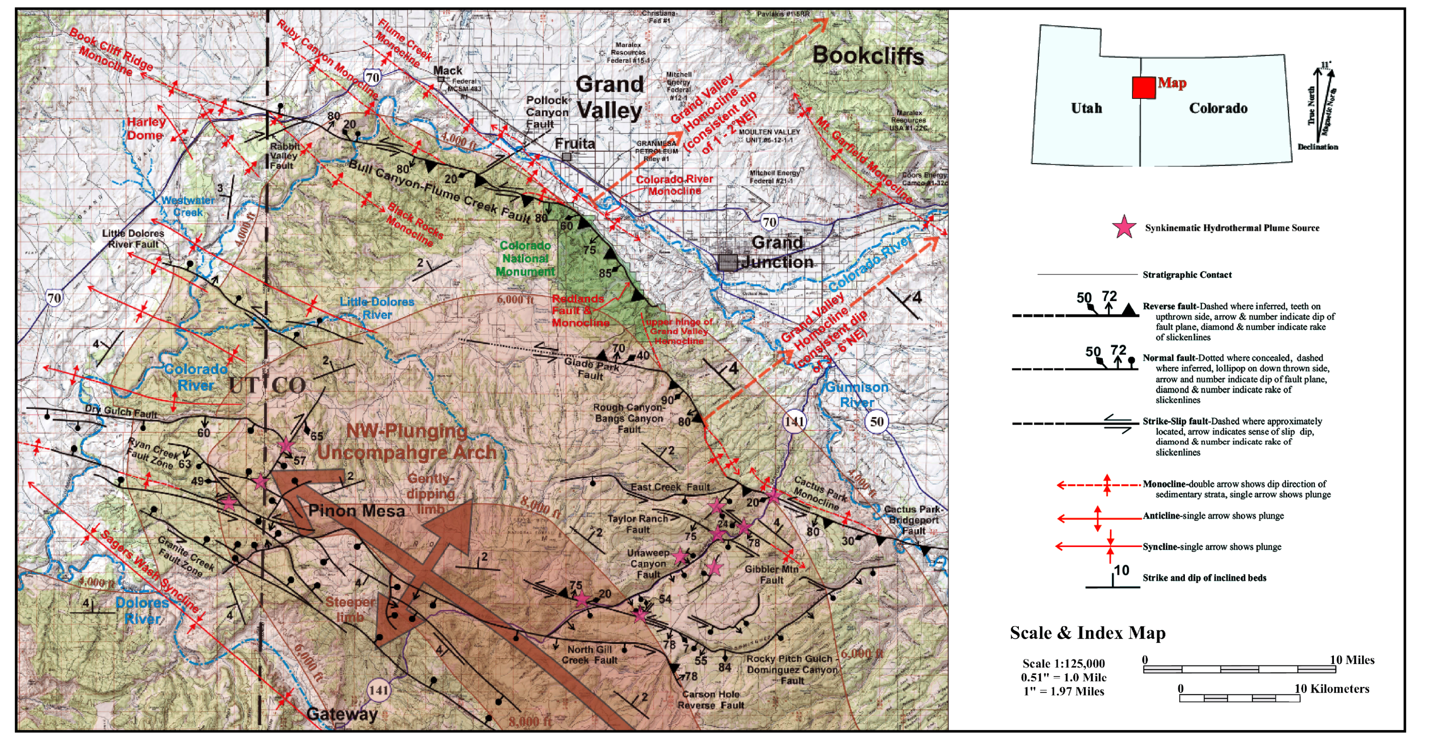

Figure 3. Structural map of the northern Uncompahgre Plateau, CO. Provided by Livaccari et al., 2016.

Introduction

The Uncompahgre Plateau (Figure 1) is a NWSE striking asymmetrical anticlinal Laramide uplift bounded on the west by the Uncompahgre fault, a reactivated Permian/Pennsylvanian reverse fault originating in the Ancestral Rocky Mountain orogenic period (Baars, 1981). The eastern boundary (Figure 3) consists of multiple WNW-ESE striking, left-lateral oblique-slip faults which splay into transpressive bends along multiple NW-SE striking monoclines and reverse faults (Livaccari et al., 2016). Stratigraphically the area has a significant angular unconformity between the Triassic, Jurassic and Cretaceous sediments and the underlying Precambrian igneous intrusive bodies and metamorphic facies. The sediments overlying the angular unconformity begin with the Triassic Chinle Formation and continue upsection through the lower Cretaceous Burro Canyon and Dakota Formations (Figure 2). Classification of the Mesozoic, Paleozoic, and Precambrian facies is thoroughly addressed by J.E Case (1991), as is much of the structural mapping of the northwestern portion of the Uncompahgre Plateau. Laramide orogenic stresses provided the impetus for the reactivation of the Permian/Pennsylvanian fractures, introducing plastic deformation of Jurassic sediments as evidenced by the Cactus Park and Redlands reverse fault, and were responsible for the brittle deformation of Jurassic sediments along the eastern portion of the Uncompahgre uplift (Livicarri, 2007). Finally, Laramide tectonic extensional stresses acting upon the transpressional faulted central northern Uncompaghre Plateau, formed the Unaweep Canyon Fault as a series of down-to-the SE normal fault structures (Figure 4), supporting the previous hypothesis of the modern canyon forming due to incision in the late Cenozoic by the ancestral Gunnison and/or Colorado (Hood et al., 2014).

Unaweep Fault

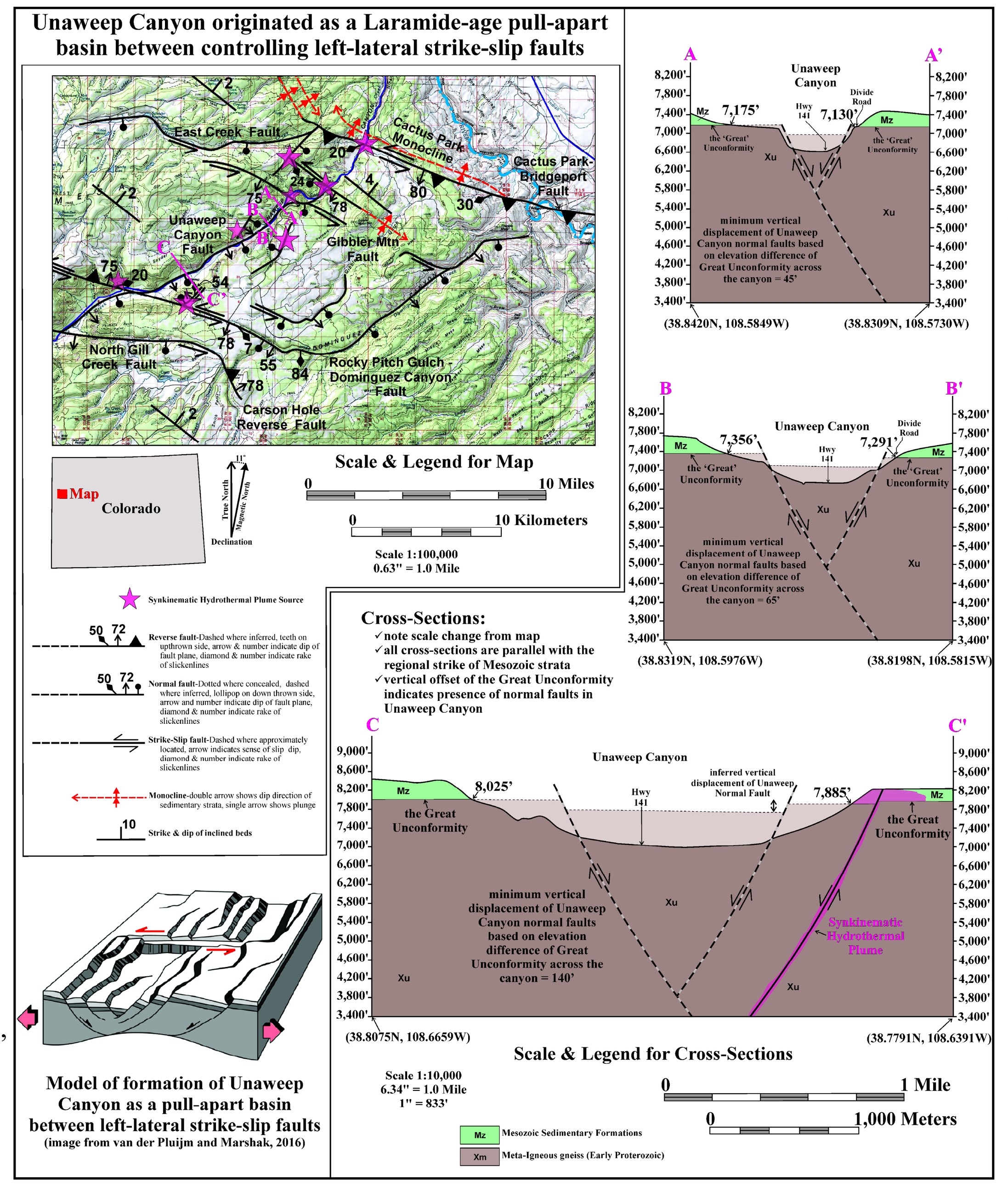

Figure 4. Structural map and cross-sections of the Unaweep Fault in eastern Unaweep Canyon, northern Uncompahgre Plateau, CO.

Structures of Pinon Mesa

Structures of Eastern Unaweep Canyon

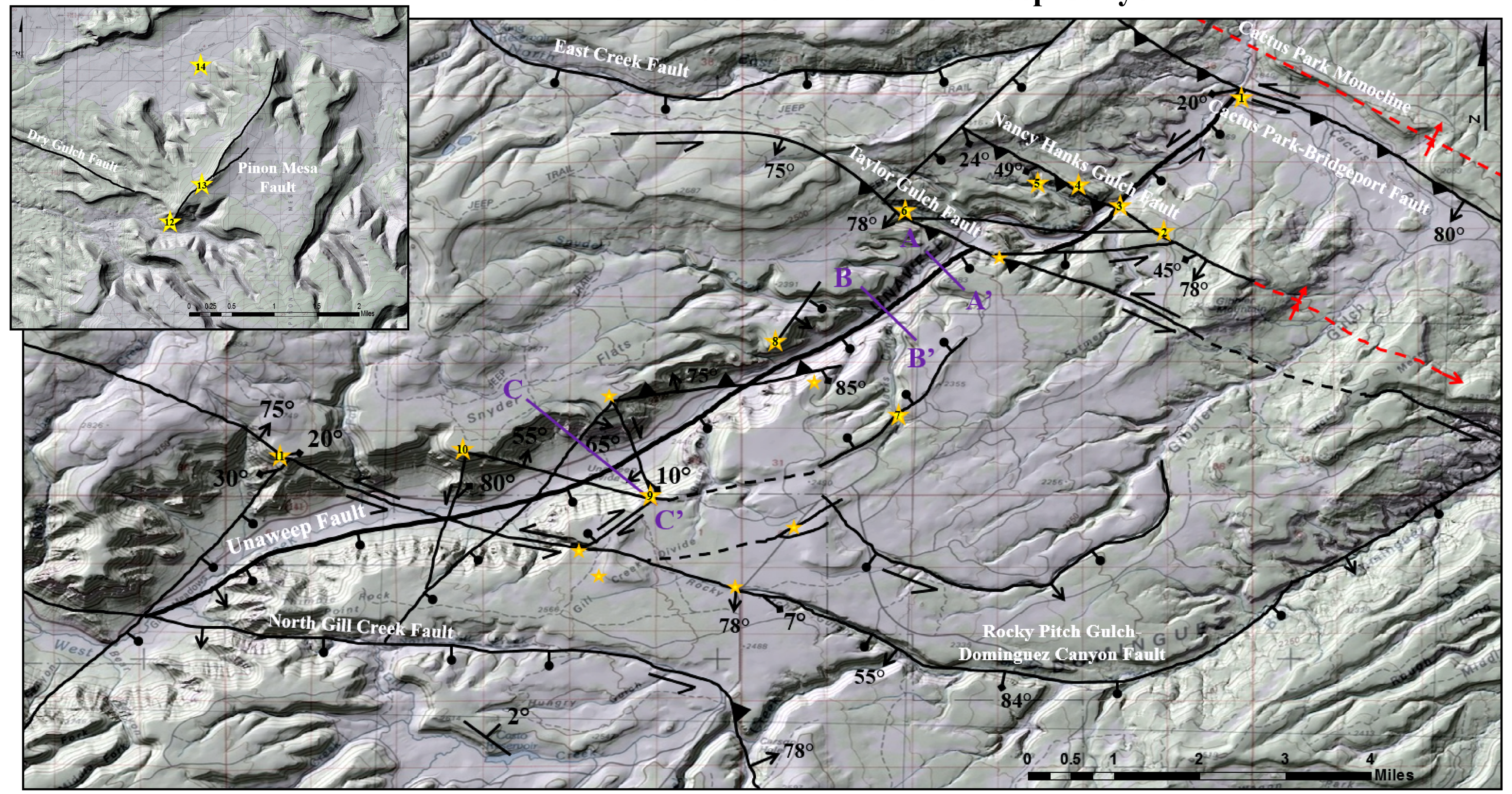

Figure 5. Structural map of eastern Unaweep Canyon. Symbols and structural features can be referenced to the legend in Figure 4. Gold stars with numbers represent locations which correspond to pictures and/or sample locations in Figure 6 and Figure 7. Gold stars without numbers represent locations where data was sampled from similiar outcrops and landforms to numbered gold stars.

Brecciation Photos

Brecciation Diagram

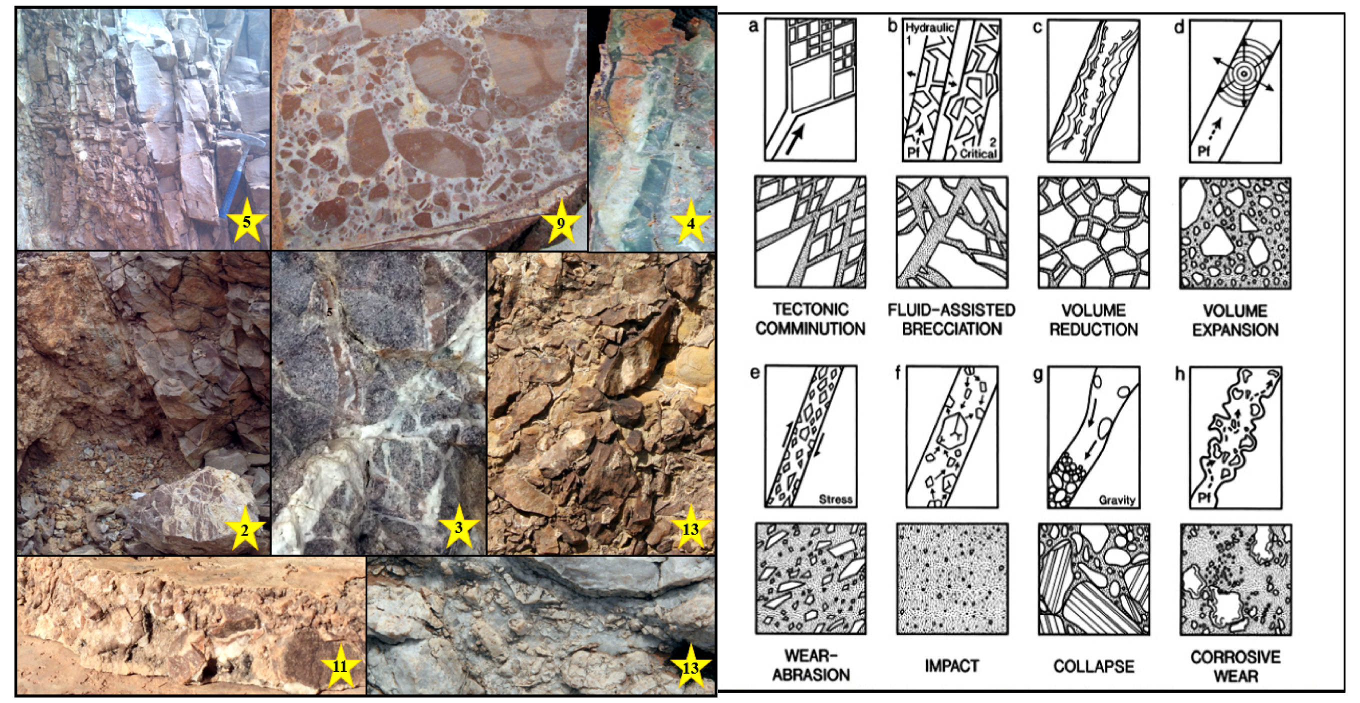

Figure 7. Brecciation samples and outcrops on the Uncompahgre Plateau, with corresonding numbered gold stars to map locations on Figure 5 (left). Schematic illustration (right) with different mechanisms of brecciation in hydrothermal systems and geometric representation (Jebrak, 1997).

Conclusion

Unaweep Canyon originated as a Laramide-age pull-apart basin between the controlling left-lateral strike-slip faults found in Cactus Park, Nancy Hanks Gulch, Taylor Gulch, Rocky Pitch Gulch, and North Gill Creek. The Unaweep Canyon Fault has a displacement of 140 ft. just east of Rocky Pitch Gulch. Prior to this study, there were two major hypotheses for the formation of Unaweep Canyon; Cenozoic incision by the ancestral Gunnison and/or Colorado rivers (Hood et al., 2014), or Permian-age glaciation creating a sediment filled glacial valley exhumed by ancestral river flow (Soreghan et al., 2007). We find the latter to be implausible due to the structural and geochemical data collected. The correlation of cross-canyon faulting extending into the Jurassic sedimentary layers, and the evidences of normal fault kinematics within the eastern Unaweep Canyon proper, restrict the timeframe of the Unaweep Canyon Fault formation to the Mesozoic or Cenozoic period. Radiometric dating would constrain this timframe. Also using Pinon Mesa elemental concentration data as a control group for north and south Nancy Hanks elemental concentration data some differentiation of geochemical signatures on either side should be evident due to influx of sedimentary material from infill. In addition, due to the difference in mechanical competency between Triassic infill and Precambrian crystalline rock, some form of deviation to the strike of the cross canyon faulting would be expected. Based on the structural data, the series of Laramide NE-SW striking normal faults between the controlling WSW-ESE striking left-lateral oblique-slip faults collectively created zones of weakness capitalized by Cenozoic river incision, leading to the formation of the modern Unaweep Canyon.

Preliminary Geochemical Summary

Multiple samples were gathered from seven mineralized zones along fractures in Unaweep Canyon and Pinon Mesa (Fig. 5). The samples were crushed and micro-milled. A whole rock lithogeochemistry analysis was performed using ICP-OES and ICP-MS at ACTLabs, Canada. Elemental analysis data was graphed per element as concentration in ppm (Diagram 3). Of interest was the correlation between elemental signatures related to the elevation and location of the sample sites. Upper Nancy Hanks mine samples retained the same elemental peaks in both the north and south side samples. Though different than the peaks from upper mine samples, the lower Nancy Hanks mine samples also retained peak correlation in both north and south side samples. Pinon Mesa lower and upper samples correlated with lower Nancy Hanks mines. High levels of As, Pb, Mo, and Zn, were used to reference a proper hydrothermal model (Diagram 2), (Fisher et al.,1986). Cu and Sr were anomalously high on Pinon Mesa reflecting the influx of Tertiary intrusive fed hydrothermal mineralization. REE data returned was then chondrite normalized and plotted (McDonough, 1995). The graphed data points indicate the minerals were derived from an intermediate source rock (Diagram 4). Because samples were taken from vein material they reflect the chemical constituents of the source rock. The Precambrian igneous basment in the area of the samples is primarily intermediate composition, and therefore could be the source of this data.

References

Allmendinger, R.W., Cardozo, N., and Fisher, D., 2012, Structural geology algorithms: Vectors and tensors in structural geology: Cambridge University Press, p. 302
Baars, D. L., & Stevenson, G., M., 1981. Tectonic evolution of western Colorado and eastern Utah. NM: New Mexico Geological Society.
Case, J., E., 1991. Geologic map of the northwestern part of the Uncompahgre uplift, Grand County, Utah, and Mesa County, Colorado, with emphasis on Proterozoic rock 1991 0-865-705. US Government Printing Office.
Emmons, W., H., Larsen, E., S., 1923. Geology and Ore Deposits of the Creede District, CO. USGS, Washington GPO, Bulletin 718.
Fisher, D., G., Julilland, J., D., 1986. Mineral deposit types and their characteristics. USDOI, BLM Denver, CO., 3031-1
Hood, W., Aslan, A., & Betton, C., 2014. Aftermath of a stream capture: Cactus Park lake spillover and the origin of East Creek, Uncompahgre Plateau, western Colorado. Geosphere, 447-461.
Jebrak, M., 1997. Hydrothermal breccias in vein-type ore deposits: A review of mechanisms, morphology and size distribution. Elsevier Science B.V., Ore Geology Reviews 12, p. 111–134.
Livaccari, R., Director, 2007, October 27. Laramide-Age Left-Lateral Strike-Slip Deformation Along the Northern Uncompahgre Plateau, Western Colorado. GSA Denver Annual Meeting. Lecture conducted from , Denver Co.
Livaccari, R., Trumbo, A., Feil, M., 2016, Laramide Structure of the Uncompahgre Plateau of western Colorado: GSA Annual Meeting, Denver Colorado, Abstract 347-22.
Mankowski, L., C., Director 2002, July 21. Structural mapping of the Uncompahgre Front near Gateway, Colorado With emphasis on Ancestral Rocky Mountain fabrics. AAPG Hedberg Conference. Lecture conducted from , Vail, Colorado.
Marrett, R.A., and Allmendinger, R.W., 1990, Kinematic analysis of fault-slip data: Journal of Structural Geology, v.12, p. 973-986
McDonough, W., F., and Sun S.,-s., 1995. The Composition of the Earth Chemical Geology, p.g. 223-253
Soreghan, G., Sweet, D., Marra, K., Eble, C., Soreghan, M., Elmore, R., . . . Blum, M. (n.d.). An Exhumed Late Paleozoic Canyon in the Rocky Mountains. J GEOL The Journal of Geology, 473-481.
Thomson, S., N., Soreghan, G., Eccles, T., M., 2012. Elevated Cenozoic geothermal gradients and later post-6 Ma incision of the Uncompahgre Plateau and Unaweep Canyon (western Colorado) revealed by low temperature thermochronology. GSA Rocky Mountain Section - 64th Annual Meeting, GSA Abstracts with Programs, Vol. 44, No. 6, p. 18.

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