Did Dextral Offset or Shortening occur first? A Question within the Sheep Springs Wash in the Calico Fault System, Southern California

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Abstract:

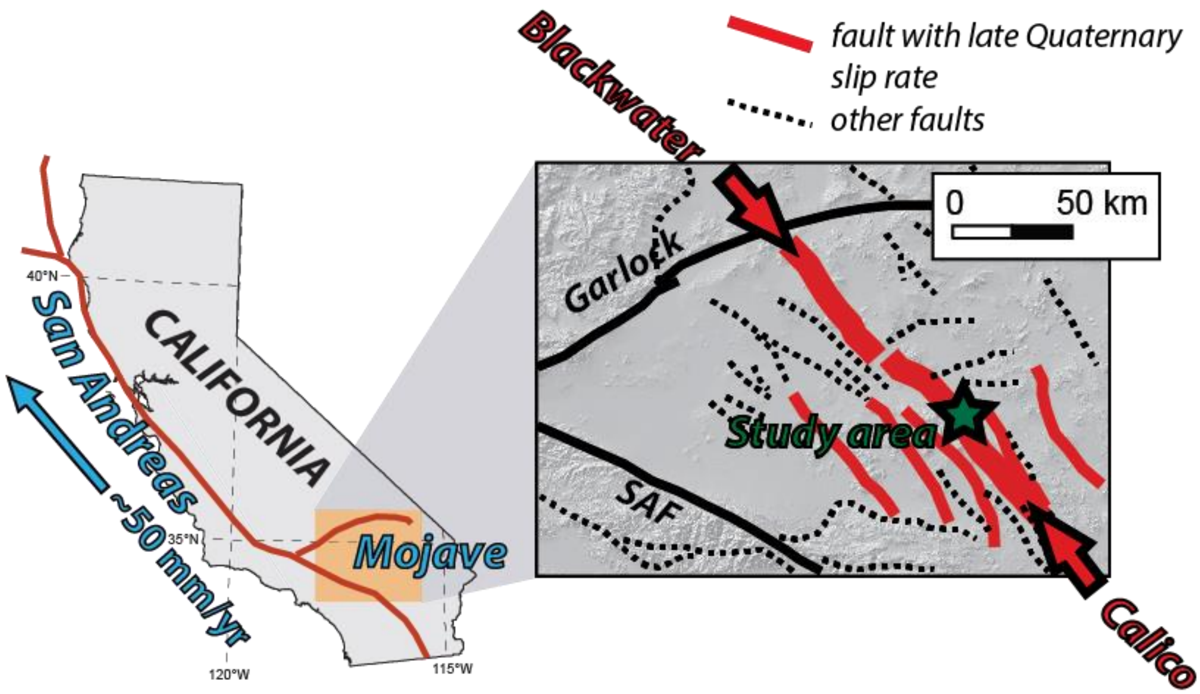
The Calico Fault is a right lateral strike slip fault located in the Mojave Desert of southern California and is part of the Eastern California Shear Zone or ECSZ. The area that was mapped is considered to be the Sheep Springs Wash area within the Mojave Desert. The question that was asked during the mapping project is: Did dextral offset or shortening occur first? This is a good question to ask because there is a big history of extension in the Mojave Desert throughout geologic time. The results from mapping the geology of the area is that shortening came first before dextral offset. The reason that shortening precedes dextral offset is that there was an angular unconformity that was found in the Pickhandle Lacustrine unit which is Miocene in age. The Lacustrine units were deposited horizontally above the volcanic unit. This angular unconformity shows that the crust was compressed instead of dextral offset occurring. Deformation was also seen on both sides of the Calico Fault in the Miocene units. Certain alluvial fans were also truncated by topographic rises as well as seen in the field which proves deformation occurred in the area. The Pipkin Basalt was sheared away on the sides of the slopes and it was not found on top of the anticline because it was eroded away over time.

Introduction:

The Calico Fault is a right lateral or dextral strike-slip fault within the Mojave Desert in southern California. The area that was mapped was called the Sheep Springs Wash and is in the southern portion of the Calico Fault System. The hypothesis that was questioned was: did shortening occur first or did dextral onset within the Calico Fault System. The idea of dextral offset is that two areas are displaced from each other, by a certain amount of distance, such as a stream channel along a fault or an alluvial fan that is offset. This is a good hypothesis to question because there is a big history of extension present in the Mojave Desert. If shortening occurred first before dextral offset, then there would be an angular unconformity within the field area because this feature is a telltale sign of shortening occurring in that area. If dextral offset took place instead of shortening, then there would be offset features within the mapping area.

The geologic setting of this field area is that there are quaternary deposits throughout the field area with some volcanic units interbedded within the quaternary units. According to the paper by Glazner et al, 2000, the northern portion of the Rodman Mountains make up a large extent of the map area. According to the paper by Ganev et al, 2010, the Calico Blackwater fault system is the longest within the Mojave part of the eastern California shear zone (ECSZ). The ECSZ is a system of dextral faults that splay off from the San Andreas Fault across the Mojave Desert to the Sierra Nevada Mountains.

According to the paper by Dokka and Travis, 1990, there was a period of large extension during the Miocene in the west and central areas of the Mojave Desert due to some detachment faults. There are also kilometer scale structural relationships that are also outlined in this paper which were used to figure out the movement during the late Cenozoic. According to the paper by Bartley et al, 1990, there have been reverse faults that have occurred with Miocene rocks in most of the Mojave block of crust. The structures that were observed trend east to west which indicates north south narrowing within the map area. A regional map showing the location of the study area is below.



Methodology:

When in the Mojave Desert to map part of the Calico Fault and surrounding area, a small area of the entire fault system known as the Sheep Springs Wash was mapped. The mapping was completed during the days of March 9th to March 11th, 2016. The tools that were used during the mapping were a Brunton pocket transit compass to measure strike and dip of bedding as well as a shovel to dig pits to look at the underlying soil to help determine geologic units within the map area. LiDAR aerial photos were given out as the base to draw the geologic units on top of to create the geologic map. This geologic field map was then digitized in ArcMap to create the final geologic map for the field area of the Calico fault system. Careful field notes were also taken to create unit descriptions for the geologic units present in the map area. The field data was classified according to the classification system outlined in the book by Bull, 1991. A geologic cross section was also constructed by hand and the transect was drawn from west to east along the mapping area and is shown in Appendix A along with the stratigraphic column. According to the paper by Frankel and Dolan, 2007, alluvial fans are recorders of tectonic movement within the area as well as climactic events. LiDAR can also be used effectively to map quaternary units in this part of the country as outlined by the paper by Frankel and Dolan, 2007. The next section talks about the geology of the field site that was visited during the days of March 9th -11th, 2016.

Geology of Field Area:

The creation of the Calico Fault first began with the extension of the basin and range providence and the movement of California northward during the last 30 million years. According to the paper by Glazner et al, 2000, the Calico Fault is younger than 23 million years old because of the correlation of strata in the surrounding field areas. The San Andreas Fault is rotating counterclockwise and the principal stress sigma 1 is perpendicular to the fault and is undergoing extension. The shearing began around 30 million years ago. The western US tectonic videos show clearly how this part of the country evolved over time as California moved northward and the basin and range providence was created.

In the Sheep Springs Wash part of the Calico system, there are multiple units that include igneous and quaternary units. The following table shows the units that were observed while mapping and their descriptions. The ages are courtesy of the paper by Oskin et al, 2007.

Unit	Morphology	Surface	Soil	Age
Q_{aw}- Quaternary Alluvial Wash	Active wash, sediment actively transported	Very prominent bar and swale topography, fine grained sand to mud.	Fine grained soil since this is an active transport area.	15.3 ka
Q_4	Flood plain, bar and swale topography	Bar and Swale Topography present.	Light tan color	
Q_{2b}	Pipkin Basalt is observed in this unit.	No remnant topography, well developed pavement.	Reddish Av horizon	
Q_{2a}	Ridge and Ravine topography	Rubification and overturned clasts	Reddish soil profile as seen in pit 2	
Q_1	Pipkin basalt is observed in this unit. Rubification present, high degree of varnish.	No preserved surface	A_v horizon is 8-12 cm observed in pit 1	

Qc- Quaternary Conglomerate	Very angular, some very rounded.	Brecciated near the Calico Fault		
Mpv-Miocene Pickhandle Volcanic	Grey vesicular basalt that varies in size.			
MpL-Miocene Pickhandle Lacustrine		Fine Grained with sandstone interbedded		
MpC-Miocene Pickhandle Clastic	Sandstone with layers of tuff.			
Mzc-Celine Monzonite	Biotite Quartz Monzonite			
Pipkin Basalt	Vesicular Basalt, visible to the naked eye.			388.9 ka

The following photo was taken on March 10th, 2016 at 10:57 am and shows a syncline on the right side of the outcrop inside the black square according to the photo taken by Kelner ,G, 2016

Image 1: This image shows the syncline on the left side of the mapping area. The black box indicates the area of study within the photograph.

The following photo shows fault gouge that was observed on both sides of the Calico Fault. This is important because it shows that the fault was in between the two fault gouge deposits and observed in the field area taken by Kelner, G ,2016.

Image 2: This image shows fault gouge that was found on the left side of the mapping area.

Image 3: This image shows an anticline in the eastern portion of the map area.

The following photo shows a portion of the alluvial wash portion of the map.

Image 4: This image shows a portion of the alluvial wash unit within the mapping area. Taken March 9th 2016 at 7:35 PM.

The next image shows the beginning of an area where the Pipkin Basalt clasts are present.

Image 5: This image shows a portion of an outcrop where the Pipkin basalt clasts are present. Taken on March 10th 2016 at 2:27 PM.

All of the images noted above are noted on the geologic map in Appendix A and annotated with a *.

Silver Bell Fault:

According to the paper by Glazner et al, 2000, the Silver Bell Fault is a dip slip fault and terminates into the Calico Fault. The units surrounding the fault are Tertiary strata. The lower member is a volcanic unit that is andesite at the bottom and grades up to basalt at the top of the unit. The andesitic layer is about 900 meters thick and consists of conglomerate and tuff breccia. The basalt layer on top is 1000 feet thick and is made up of basalt flows. The upper clastic unit overtops the basalt flows and is 400 meters thick. A large cinder cone is the source of the basalt clasts and they have been dated to be around 7-800,000 years old.

According to the paper by Oskin et al, 2007, the Calico-Blackwater fault system is the longest set of active dextral faults in the Mojave Desert. There are some quaternary features that are offset in the northern Rodman Mountains by the Calico Fault that are studied in the Oskin et al, 2007 paper. According to the paper by Glazner et al, 2000, several areas in the east part of the Mojave block show structures that indicate that shortening was covered by Miocene extension that happened earlier. A geologic map of the field area is in Appendix A. The stratigraphic column as well as the cross section are also located here. The stratigraphic column shows the correlation between units while the cross section shows how area looks at depth.

Calico Fault:

According to the paper by Glazner et al, 2000, the Calico Fault occupies the largest amount of right lateral slip in the Mojave Block of crust. The Calico Fault goes through the middle of the mapping area lengthwise and is a right lateral strike-slip fault. Fault gouge was observed along both sides of this fault as seen in image 2 above. The Calico fault is also connected with the Silver Bell Fault which is seen on the geologic map in the appendix of this document.

Rodman Hills Thrust Fault:

According to the paper by Oskin et al, 2007, the blind thrust fault is in the northwestern part of the map area. No measurements were taken at this location. The average dip of faults in this area of California are about 50 degrees. Calculations were performed using the equations from the paper by Thompson et al, 2002. One of the equations was $S = \frac{\vartheta}{\sin\delta + m\cos\delta}$ which calculated the dip slip rate. The calculations are to calculate the dip slip rate for areas with a 25 and 50 degree slope. The slip rate for the 25 degree slope was -19.982 meters per event and the slip rate for the 50 degree slope was -12.943 meters per event. The topographic profile of the Rodman Thrust Fault is below.

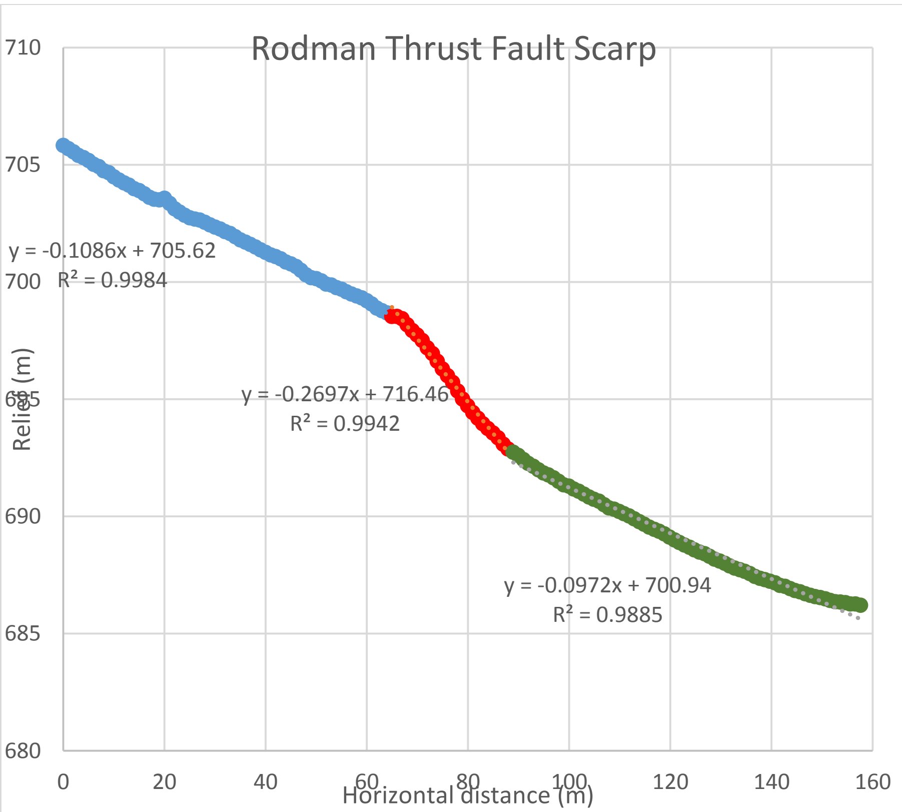


Chart 1: This chart shows the slope profile for the Rodman thrust fault.

Discussion:

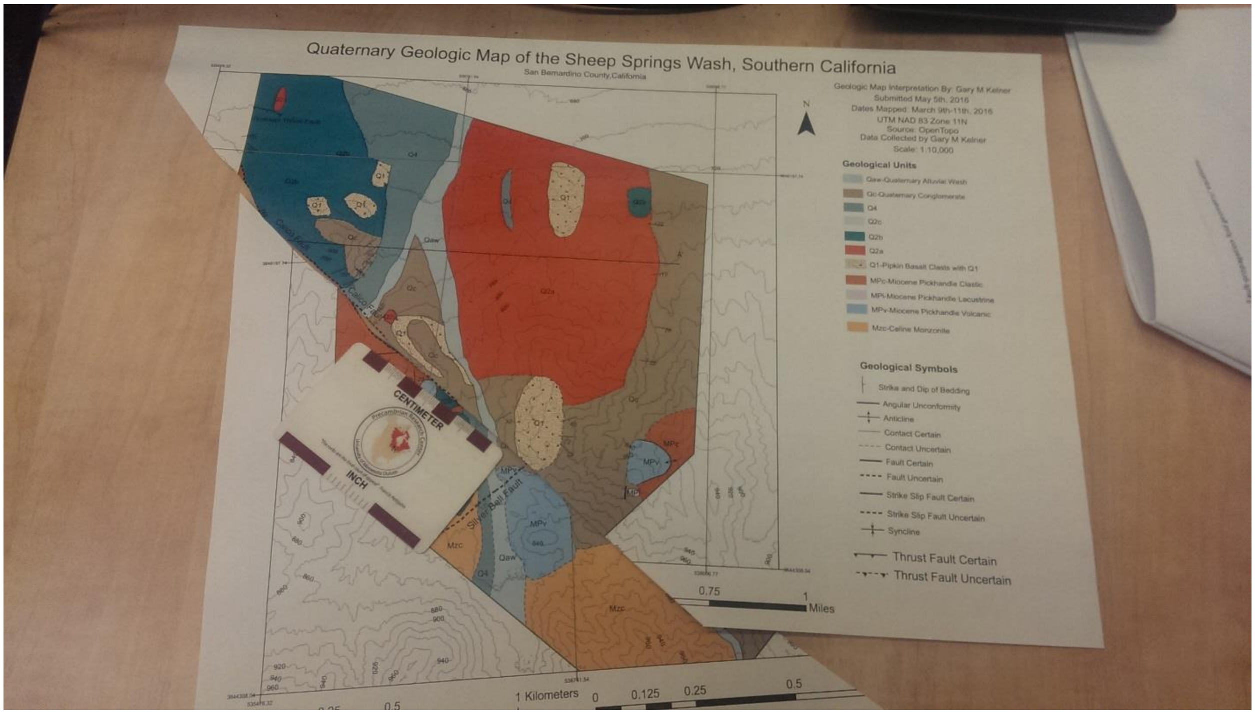
The Calico Fault system has some different structural features within it and the surrounding Mojave Desert. I believe that shortening occurred first before dextral offset. I believe this because there was an angular unconformity that was found which was in the Pickhandle Lacustrine units which are of Miocene age.

The Silver Bell Fault truncates into the Calico Fault in the southern portion of the mapping area. The notion is that the units that encompass the area around the fault are tertiary in origin.

The deposition of the Miocene units came before the Quaternary was deposited in the map area. The Celine Monzonite is the main igneous unit within the map area and is towards the bottom of the map.

An angular unconformity indicates that shortening occurred first because tectonic loading was occurring during some earthquakes in this area of California. The shortening occurred due to the fold because of the conglomerate unit was deformed. Deformation was observed on both sides of the Calico Fault and is observed in the Miocene units. Alluvial fans around the area were also truncated by a topographic rise which suggests that shortening occurred first before dextral offset. The Lacustrine unit was deposited horizontally above the volcanic which was located on the eastern side of the map area.

The slip rate along the Calico fault using the Pipkin Basalt as a measure for offset, I came up with a value of 0.64 mm/yr. I took the measurement of 4.5cm between the alluvial wash channels which converts to 0.45 kilometers or 450 meters on my map scale. I then took that value multiplied by 1000 and then divided by the age of the Pipkin Basalt of 700,000 years to get 0.64 mm per year. I performed another trial with my map cut along the Calico Fault. I then slid the smaller piece of the map to line up the other alluvial wash channel and then measured the distance. I measured a distance of 7 centimeters which converts to 0.7 kilometers or 700 meters of dextral offset. When using the age of the Pipkin Basalt of 700,000 years, I get a rate of 1millimeter per year. There had to be some loss due to the compression that was also taking place in this area. I believe that there would be more shortening than what Oskin et al,2007 stated because there would have been more slip saved up to create more shortening. An image of the map offset is below.



Conclusion:

The Calico Fault System is a very complex but interesting part of the Mojave Desert in southern California. Shortening occurred first before dextral offset due to the unconformity in the Miocene Lacustrine units. There is a big history of extension in the Mojave Desert which makes the question of shortening verses dextral offset an important one to answer in this field area. When shortening takes place, unconformities are seen in the field area as opposed to offset features which would signify dextral offset. This area is a very important region to study because it can tell us whether dextral offset or shortening occurred first in this area of the Mojave Desert.

Acknowledgements:

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Kelner, G.M. Photos within the map area. Taken by GoPro Hero. March 9th-11th, 2016

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Appendix A:

Quaternary Geologic Map of Sheep Springs Wash, Southern California

Cross-Section of field area

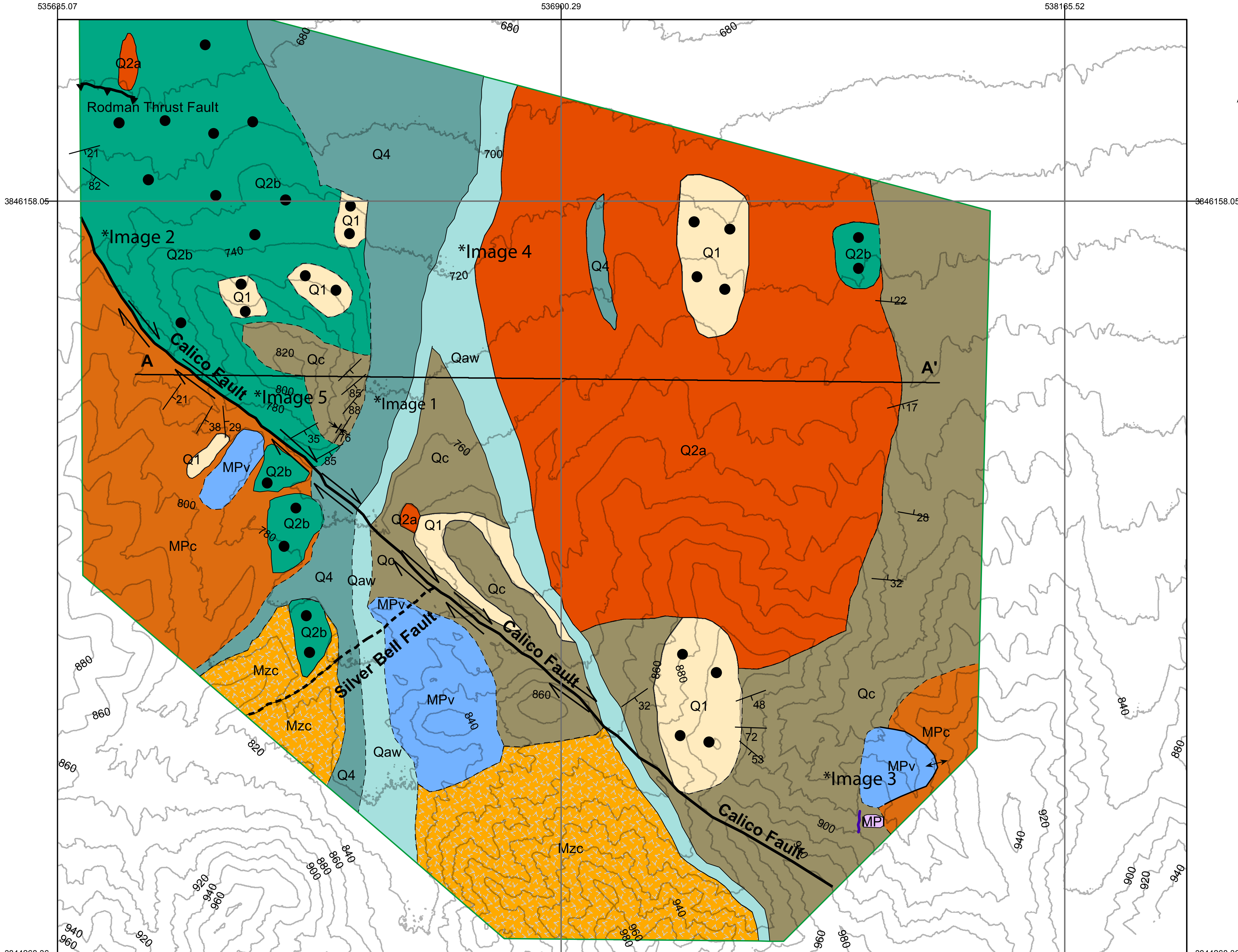
Stratigraphic Column of units within field area

The geologic map, cross section as well as stratigraphic column are located here.

Cenozoic Geology Map of the Sheep Springs Wash, Southern California

San Bernardino County,California

Geologic Map Interpretation By: Gary M Kelner
Submitted May 5th, 2016
Dates Mapped: March 9th-11th, 2016
UTM NAD 83 Zone 11N
Source: OpenTopo
Data Collected by Gary M Kelner
Scale: 1:10,000



0 0.25 0.5 1 Kilometers

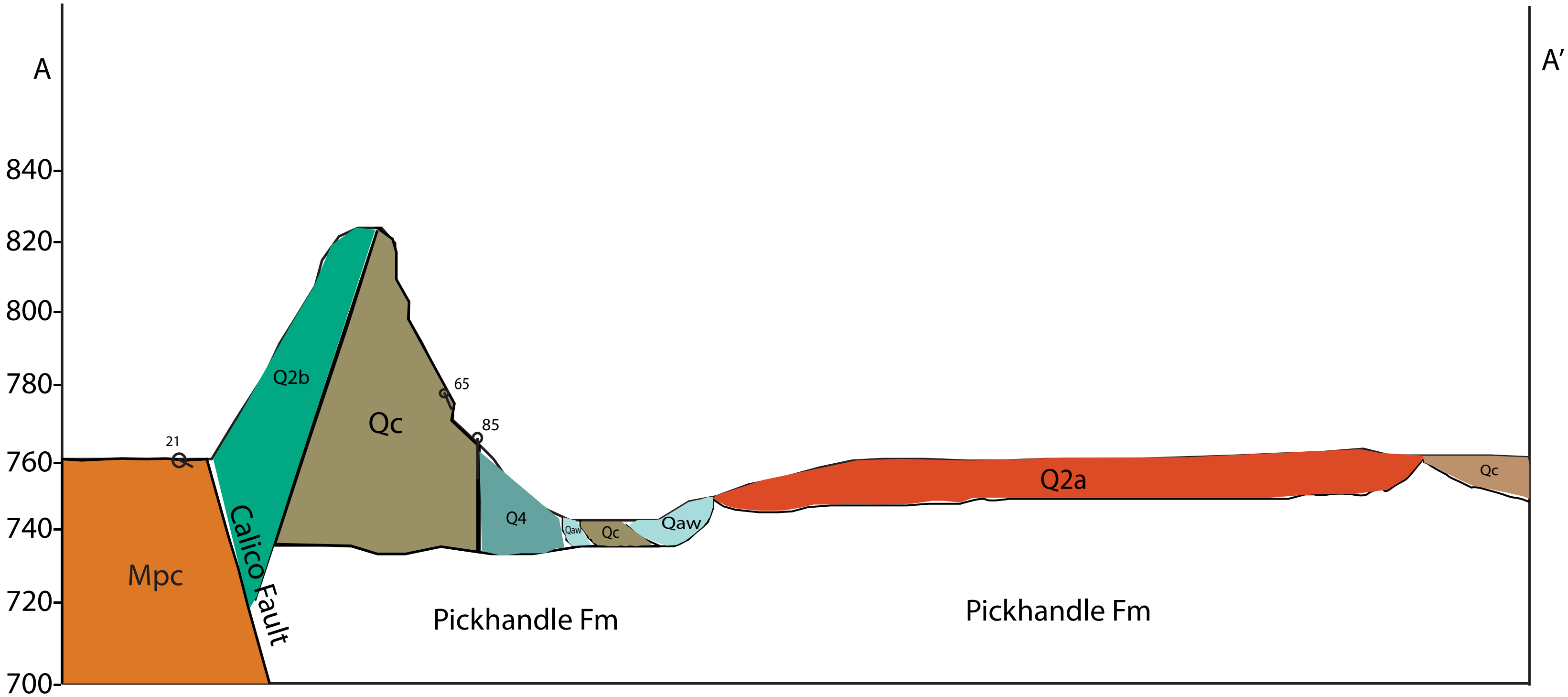
0 0.125 0.25 0.5 0.75 1 Miles

Geological Units

- Qaw-Quaternary Alluvial Wash
- Qc-Quaternary Conglomerate
- Q4
- Q2b
- Q2a
- Q1
- MPc-Miocene Pickhandle Clastic
- MPl-Miocene Pickhandle Lacustrine
- MPv-Miocene Pickhandle Volcanic
- Mzc-Celine Monzonite
- Pipkin Basalt Clasts

Geological Symbols

- **Strike and Dip of Bedding**
- **Angular Unconformity**
- **Anticline**
- **Contact Certain**
- **Contact Uncertain**
- **Fault Certain**
- **Fault Uncertain**
- **Strike Slip Fault Certain**
- **Strike Slip Fault Uncertain**
- **Syncline**
- **Thrust Fault Certain**
- **Thrust Fault Uncertain**



Scale:

2.5 cm=0.25 Km

No Vertical Exaggeration

Cross Section of the Sheep Springs Wash, Southern California

San Bernardino County, California

By: Gary Kelner

9-11 March 2016

Stratigraphic Column of the Sheep Springs Wash, Southern California

By: Gary M Kelner