[PS]Relative Timings of Structures and Mesozoic–Cenozoic Intrusions in the Sand Springs Range, Nevada*

Sean Czarnecki[1], Jacob Jarvis[1], and Joseph I. Satterfield[1]

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[1]Angelo State University, San Angelo, TX, USA (sczarnecki@angelo.edu)

Abstract

The Sand Springs Range (SSR) in western Nevada exposes Mesozoic–Cenozoic structures of the eastern Sierra Nevada, Luning-Fencemaker Thrust Belt, Basin and Range province, and Walker Lane. Recent 1:8000-scale geologic mapping in the northern Sand Springs Range reveals key cross-cutting relations between structures and diverse Triassic–Tertiary igneous rocks. The northern SSR was previously mapped by Page (1964), Willden and Speed (1974), and Satterfield (2005). Our recent mapping includes: locating contacts with GPS and satellite imagery, constructing a grid of tied cross-sections, and sampling and distinguishing seven different igneous map units. Schlumberger's Petrel software will be used construct a three-dimensional model from the geologic map and cross-section grid. Mapping provides four key timing constraints. First, Sierran (D1) axial-planar cleavage (S1) deforms Triassic quartz porphyry intrusions. Second, Cretaceous granitoid units cross-cut S1 and D1 folds and postdate movement on low-angle faults. Third, a basaltic extrusive previously mapped as Jurassic must be Tertiary because it overlaps Cretaceous granite and is interstratified with Tertiary ash flow tuff. Fourth, Tertiary and Cretaceous sills that locally terminate at a low-angle fault actually post-date faulting: they thicken upward below the fault, only terminate below the fault, and rare Tertiary dikes of the same composition cross-cut the fault. The low angle fault provided a barrier to magma ascent. Cross-cutting relations described are significant because they can be subtle, they overturn previously published sequences of events, and they constrain regional deformation timing. This project was supported by a SW AAPG research grant.

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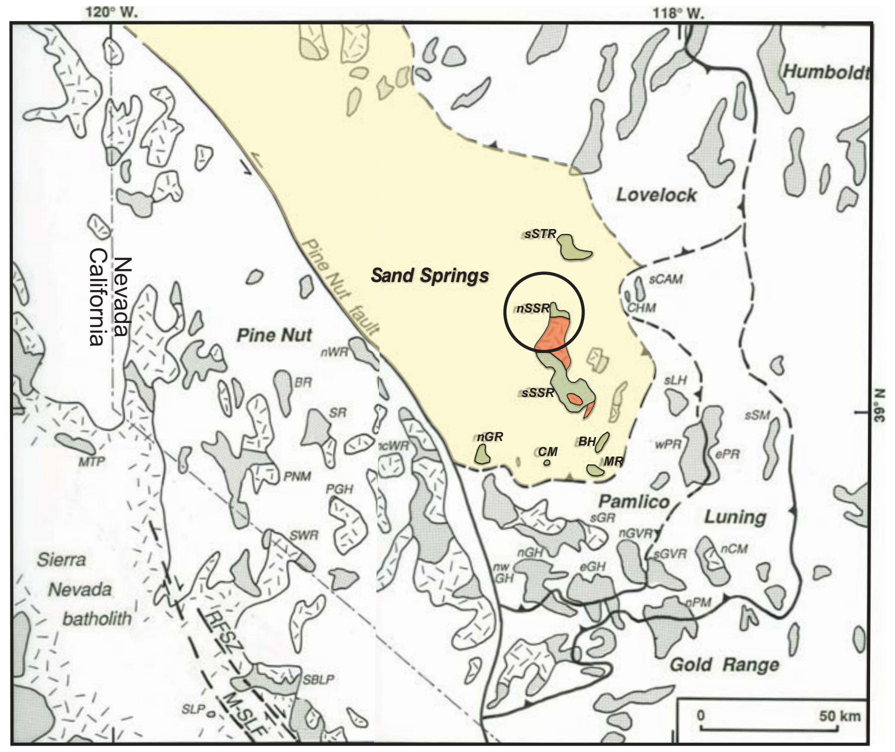
Sean Czarnecki, Jacob Jarvis, and Joseph Satterfield, Department of Physics and Geosciences, Angelo State University

Objectives:

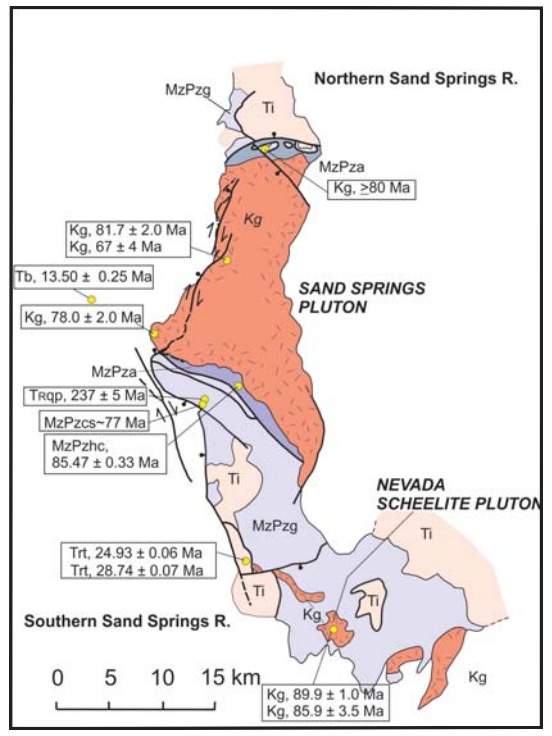
- To create a detailed geologic map at a 1:8000 scale.
- To document slip on map area faults.
- To document the orientations of map-scale folds.
- To construct a tied grid of cross sections to model the subsurface in the future.
- To revise the currently accepted sequence of events based on field findings.

Methods:

- Completed field mapping over a two week period.
- Extrapolated mapped contacts using satellite imagery.
- Measured orientation of planes using a Brunton compass.
- Used measured surface data to create tied cross section grid.
- Constructed stereonets to show deformation phases.
- Analyzed thin sections to complete rock descriptions.

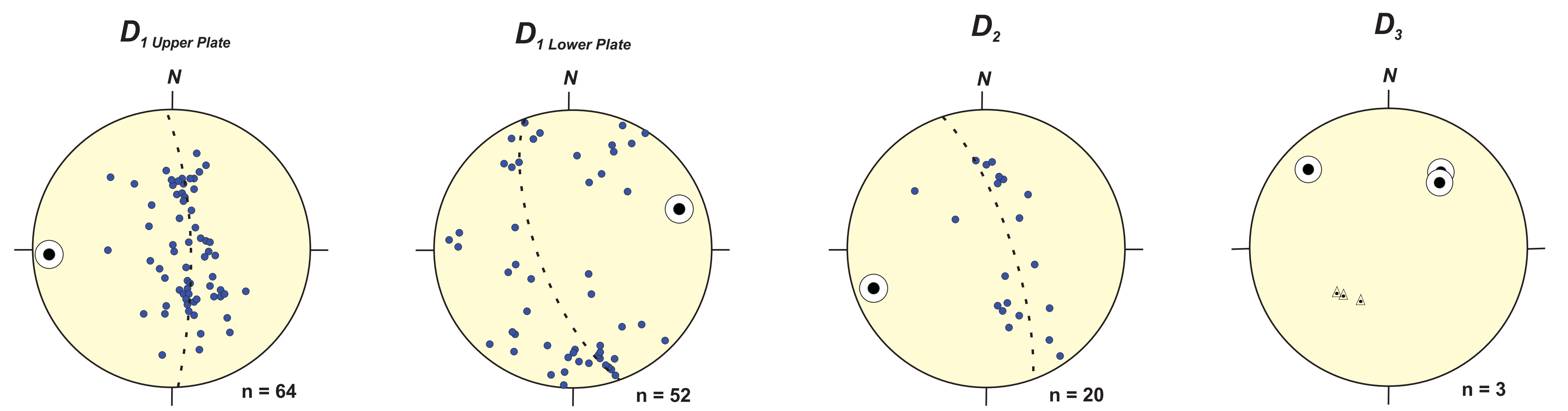


Regional Map showing the location of the northern Sand Springs Range (nSSR) within the Sand Springs Assemblage of the Luning-Fencemaker Fold and Thrust Belt in western Nevada.



Map of the Sand Springs Range showing location and age of samples dated. Figure courtesy of Joseph Satterfield.

Stereonets Illustrating the Orientation of Structures Related to Deformation Events

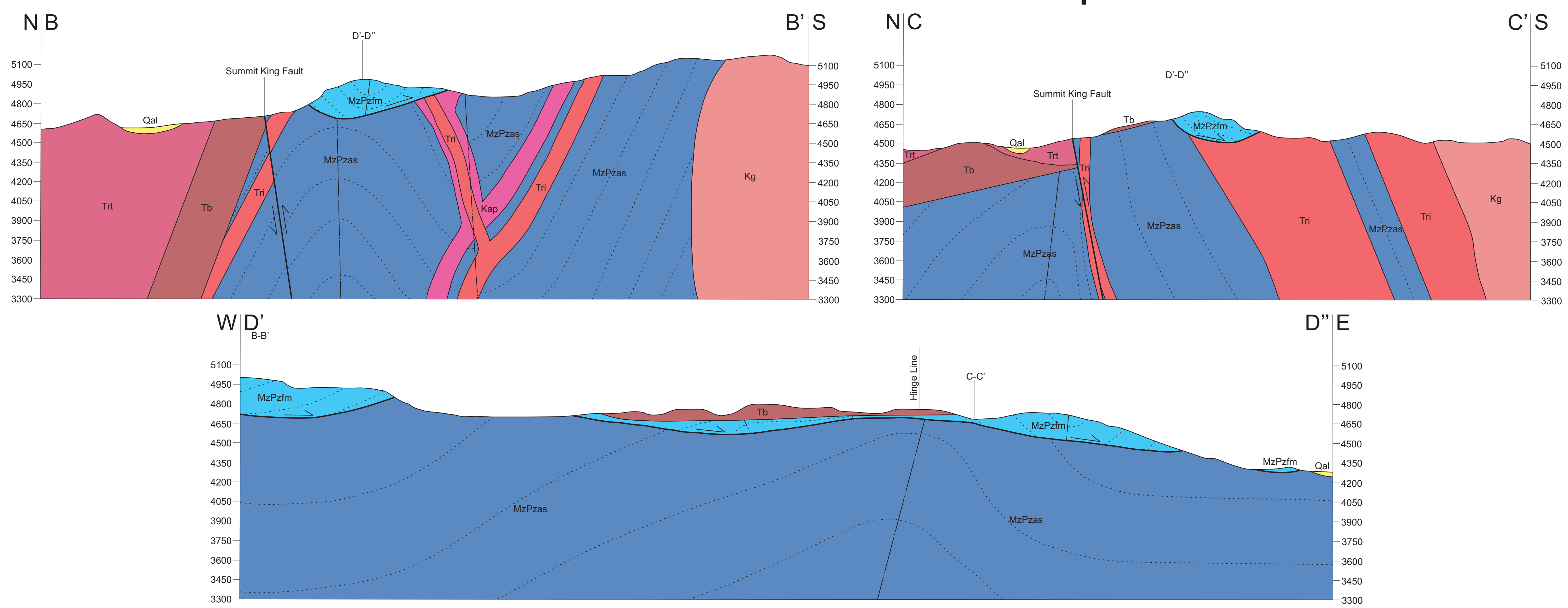


D_1 deformation created the metamorphic foliations of the MzPzfm, MzPzas, and MzPzqs. The D_1 stereonets show the difference in orientation of the foliations within the MzPzfm (upper plate) and the MzPzas and MzPzqs (lower plate). The D_2 steronet shows the orientation of folds created by the second stage of deformation which have axial planes trending NE-SW. The D_3 stereonet shows the orientation of broad folds which have axial planes generally trending NW-SE. D_3 data courtesy of Joseph Satterfield.

View to the east of the eastern klippe. At least five light-colored Tri sills can be seen approaching but ultimately terminating just below the thrust (thick black line) at the base of the cliff-forming MzPzfm. Photo courtesy of Joseph Satterfield.

View to the northeast of the eastern klippe showing a light-colored Tri sill cutting across the thrust (black line, dashed where approximately located) at the base of the cliff-forming MzPzfm. Photo courtesy of Joseph Satterfield.

Cross Sections of the Eastern Half of the Map Area

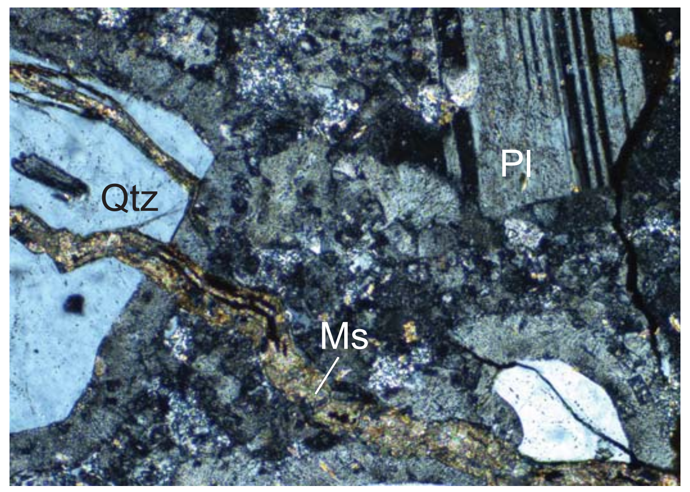


Scale 1:4000

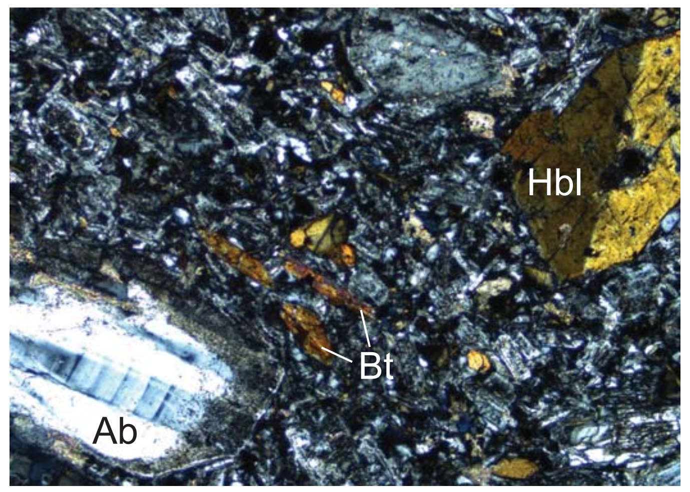
Eastern half of a tied grid of cross sections at the same scale as the geologic map. B-B' and C-C' are views to the east and show the D2 folding of the thrust faults and of the D1 metamorphic foliation of MzPzfm and MzPzas. These sections also show that the sills intruded along foliation planes, that Kap pooled at the central klippe thrust fault, and the separation of the Summit King Fault and how it cross-cuts the youngest units in the map area (Tb and Trt). D'-D'' is a view to the north showing the broader D3 folds of the thrust faults and of the D1 metamorphic foliation of MzPzfm and MzPzas. No vertical exaggeration.

Jacob Jarvis and Sean Czarnecki at the end of the final day of field work, August 20, 2015. Photo courtesy of Joseph Satterfield.

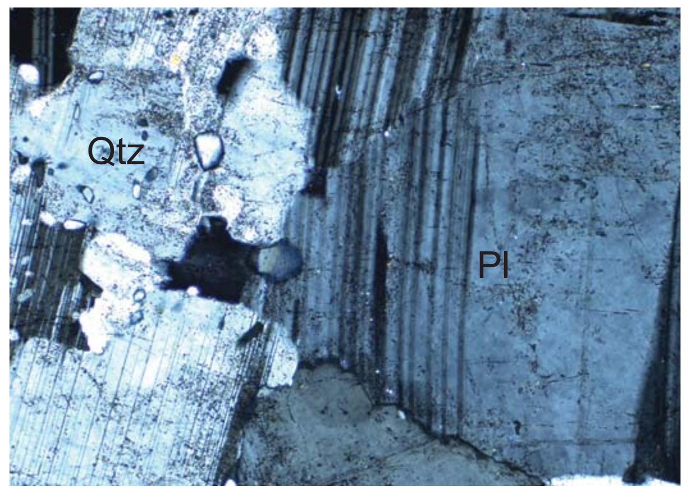
Thin Sections of Igneous Units Critical to Relative Timing of Structures



081015-2 Tri 100X Mostly quartz matrix with larger quartz, plagioclase, and muscovite crystals. The overall aphanitic texture of this rock is an indication of its Tertiary age, which constrains the age of the thrust fault it cross-cuts.



080915-2 Trt 100X The aphanitic quartz and albite matrix of this intrusion are indicative of its Tertiary age which constrains the age of the Summit King Fault which cross-cuts it.



081815-1 Kap 100X The 1-3 mm quartz and plagioclase crystals in this section are indicative of the Cretaceous age of this intrusion which constrains the age of the thrust below which it pools.

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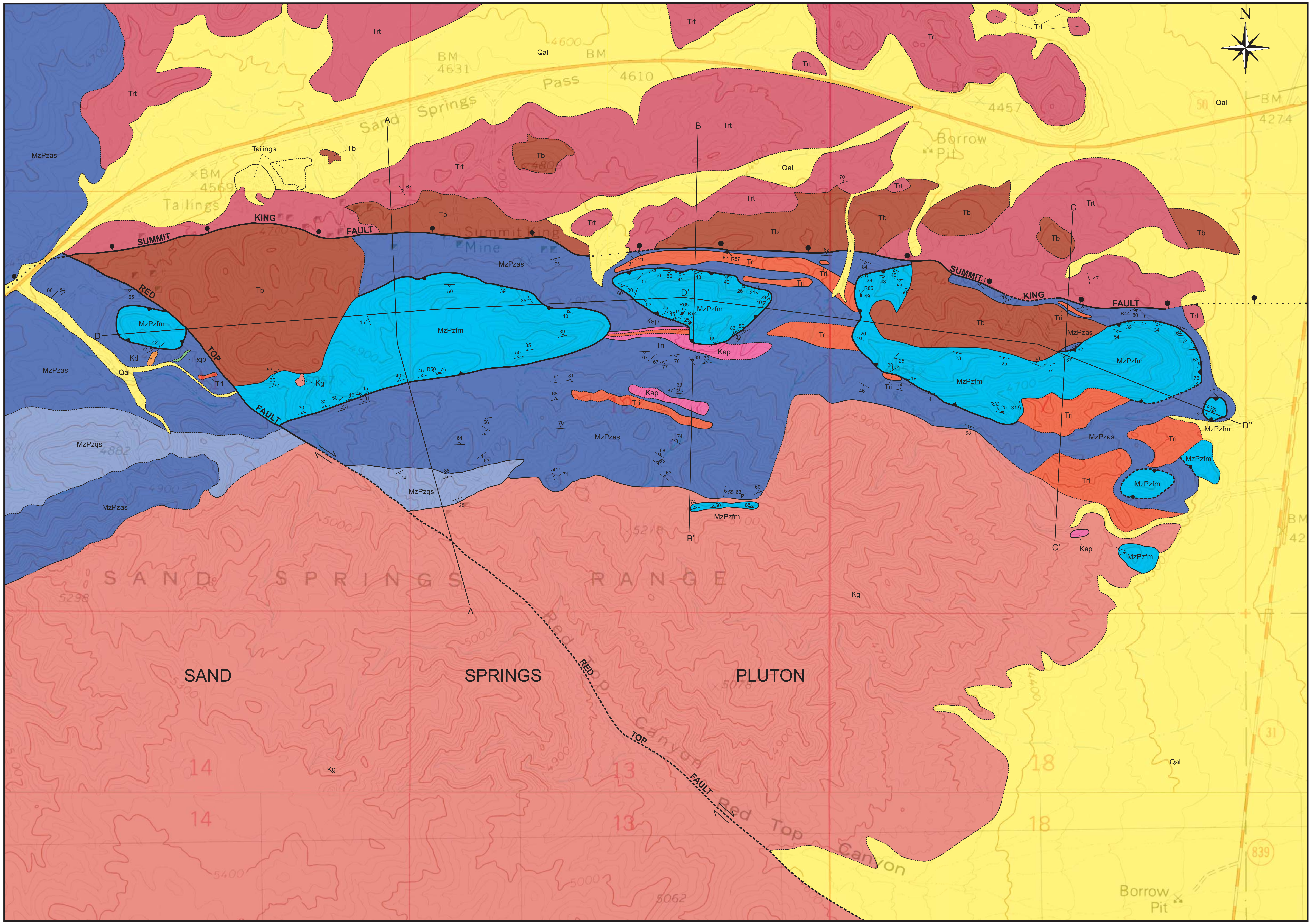
Conclusions:

- Basalt previously mapped as Cretaceous is actually Tertiary, which constrains the age of the high-angle faults which cross-cut it.
- Tertiary sills stop at or cross-cut folded low-angle faults, indicating that the age of these faults is Tertiary or older.
- The pooling of a Cretaceous sill at the central low-angle fault constrains the age of low-angle faults to Cretaceous or older.
- These findings lead to the following revised Sequence of Events interpretation:

1) TRqp plutons intrude protolith of MzPzas.
2) D1 metamorphoses and deforms TRqp and MzPz protoliths into MzPzqs, MzPzas, and MzPzfm metamorphic tectonites. D1 folds formed.
3) Thrust fault transports upper plate above lower plate, creating klippen.
4) D2 folds foliation in MzPzqs, MzPzas, and MzPzfm and the thrust faults in a NE-SW orientation.
5) D3 refolds foliation in MzPz units and the thrust faults in a NW-SE orientation.
6) Kg pluton passively intrudes MzPz units.
7) Kdi and Kap sills intrude MzPzas and MzPzfm primarily along metamorphic foliation. Kap pools at central klippe thrust fault.
8) Tri sills intrude MzPzas, MzPzfm, and Kap primarily along metamorphic foliation and often stop at or cross-cut thrust faults.
9) Tb and Trt deposited atop erosion surface. Tb pools in klippe anticlines.
10) Red Top Fault cross-cuts metamorphic units, thrust faults, Cretaceous intrusions, and Tertiary extrusives.
11) Summit King Fault cross-cuts MzPzas and Tertiary extrusives.

Geologic Map of the Northern Sand Springs Range, Churchill County, Nevada

Sean Czarnecki, Jacob Jarvis, and Joseph Satterfield
Department of Physics and Geosciences, Angelo State University April 2016



LEGEND

Quaternary

- **Qal** — **Quaternary alluvium.** Unconsolidated sand, gravel, and mud in active or recently active stream channels and alluvial fans mapped in relatively flat topographic lows using satellite imagery.

Tertiary

- **Trt** — **Tertiary rhylite tuff.** White rhyolite tuff which weathers gray. Contains 40% quartz and 50% albite mostly ≤ 1 mm but some large (0.5-2.0 cm) subhedral-euhedral crystals, and trace biotite and subhedral hornblende ≤ 2 mm. A highly fractured and friable slope-former which exhibits compaction foliation of 2-40 mm fiamme and is locally hydrothermally altered to a pale green color. Primarily exposed north of Summit King Fault.
- **Tb** — **Tertiary basalt.** Gray basalt which weathers dark brown, and contains 20-30% fishscale 0.5-5.0 mm albite crystals in an aphanitic mafic matrix. Cliff-former which is very resistant. Flow foliation evident locally.
- **Tri** — **Tertiary rhyolite intrusion.** White to cream and tan rhyolite. Contains 90% quartz crystals that are up to 0.35 mm in an aphanitic quartz matrix which also includes trace muscovite and plagioclase. Moderately resistant and slightly friable. Unit presents itself mostly as E-W trending sills or dikes but also as larger masses.

Cretaceous

- **Kg** — **Cretaceous granite.** White granite which weathers off-white to brown. Phaneritic crystals consisting of 35-45% ~4 mm quartz, 40% ~8 mm plagioclase, 0-16% ~8 mm hornblende, 8-10% ~5 mm biotite, and 1-5% muscovite, which are anhedral to subhedral. Highly resistant and flow foliation present locally. Primarily exposed as the Sand Springs Pluton.
- **Kap** — **Cretaceous aplite.** Grey to dark grey aplite, weathers cream to tan to brown. Minerals consist of ~60% 1-3 mm plagioclase, ~40% 1-3 mm quartz, and trace biotite. Highly resistant and non-friable.This unit is finer grained than other Cretaceous intrusions, and this is presumed to be due to its emplacement as shallow sills or dikes.
- **Kdi** — **Cretaceous diorite.** Grey to black diorite. Porphyritic with a matrix of 100% ~0.5 mm plagioclase (possibly anorthite) crystals. Porphyries are ~6 mm hornblende with some opaques. Highly resistant and non-friable. Unit is present as sills or dikes.

Triassic

- **Trqp** — **Triassic quartz porphyry.** White to cream to light tan quartz porphyry. Weathers grey to black and contains a metallic sheen on some surfaces. Matrix is nearly 100% quartz with ~3 mm quartz porphyries that constitute 5% of the unit with trace feldspar. Contains a penetrative metamorphic foliation, is lightly resistant, and weathers to a moderate slope former.

Mesozoic or Paleozoic

- **MzPzfm** — **Mesozoic or Paleozoic foliated marble.** White and gray foliated marble in which the foliation is defined by thin (1-4 mm), sometimes folded, white bands of thermally altered up to 3.0 mm calcite crystals within a gray matrix of 0.18-0.25 mm calcite crystals. Very firm cliff-former. Thermal alteration due to Cretaceous intrusions, Tertiary intrusions, and related hydrothermal activity locally obliterates foliation. Primarily exposed on klippen.
- **MzPzas** — **Mesozoic or Paleozoic andalusite schist.** Very dark-gray andalusite schist containing distinctive 5% by volume 0.5-1.0 mm andalusite crystals in an aphanitic matrix containing graphite, biotite, and quartz. Abundant graphite is from a carbon-rich shale protolith. Slope former which is highly friable when weathered. Remnant bedding seen locally (most often on west side of map area) and is evidenced by interbedded MzPzqs. Schistosity evidenced by fracturing into thin sheets.
- **MzPzqs** — **Mesozoic or Paleozoic quartz schist.** White to cream to light-brown quartz schist which weathers light-red to brown. Contains 98% 0.35-0.50 mm quartz crystals, and trace muscovite from an inferred quartz sandstone protolith. Slope former which is highly friable when weathered. Remnant bedding seen locally (most often on west side of map area), and schistosity is evidenced by fracturing into thin sheets. Interbedded with MzPzas and locally calcareous. Primarily exposed in distinct beds on western side of map area near Kg contact.

Symbols

- 46 — **Strike and dip of original bedding (S_0)**
- 67 — **Strike and dip of compaction foliation (S_0)**
- 63 — **Strike and dip of metamorphic foliation (S_1)**
- R74 25 — **Strike and dip of fault surface, including rake of slickenlines (S_F)**
- **Contact**
- **Contact approximately located**
- **Strike-slip fault**
- **Strike-slip fault approximately located**
- **High angle fault, ball on downthrown side**
- **High angle fault approximately located, ball on downthrown side**
- **High angle fault covered, ball on downthrown side**
- **Thrust fault, teeth on upper plate**
- **Thrust fault approximately located, teeth on upper plate**

Scale 1:4000

0 — 0.25 — 0.5 — 0.75 — 1 Miles