Structural deformation across the southwest Mina deflection, California-Nevada: Field studies in the Huntoon Springs area.

Eliya R. Hogan
Advisor: Jeff Lee
Introduction and purpose of study:

The Mina deflection defines a major structural right step within the NW-trending dextral eastern California shear zone (ECSZ)-Walker Lane belt (WLB) system. A mechanism of strain transfer to the WLB from the ECSZ, this poorly studied region is characterized by ENE-trending normal and sinistral faults. Various models have been proposed to explain the specific kinematic processes of strain transfer across the Mina deflection. While Oldow et al. [1] proposed that in the past the Mina deflection predominately transferred strain through extension within a right structural step in ECSZ-WLB system, Oldow et al. [2] suggested that present day strain is accommodated through both extension and translation. Alternatively, Wesnousky [3] argued that rotating crustal blocks within the major ECSZ-WLB dextral shear system during the Pleistocene accounts for the presence of sinistral and normal faults within the Mina deflection. Lee et al. [4] proposed that strain is in part transferred from the White Mountains at rates of 0.4-0.8 mm/yr into the Mina deflection. In addition to these hypotheses, Jones et al. [5] indicated that the Mina deflection should also manifest evidence of a ~3 Ma westward shift of the BRP, due to the same increased GPE responsible for Sierra Nevada uplift. I propose to complete geologic mapping, structural, and geochronological studies within the Mina deflection to test the hypotheses of Oldow et al. [1, 2], Wesnousky [3], Lee et al. [4], and Jones et al. [5] regarding the styles and timing of deformation in the Mina deflection.

Background:

Trending subparallel to the San Andreas fault, the ~800 km long and 65-80-km wide WLB-ECSZ accommodates ~25% of Pacific-North American plate motion [e.g. 6, 7] (Fig. 1A). This deformation zone is defined by NW-striking dextral faults and NE-striking connecting normal faults superimposed on N-NW-striking normal faults of the western BRP (Fig. 1B). The Mina deflection defines an ~60 km-long structural right-step within the WLB-ECSZ and, in contrast to most faults in the WLB-ECSZ, is dominated by of NNE-striking sinistral faults [e.g. 3, 8, 9] (Fig. 1A).
For some time, deformation within the WLB-ECSZ was solely attributed to relative plate motion between the Pacific and North American plates [e.g. 11]. More recently, new geophysical and geological data indicate that deformation is driven by external and internal driving forces, a combination of Pacific-American plate motion and increased gravitational potential energy (GPE), respectively [e.g. 11].

High-angle faults in the Mina deflection are suggested to have accommodated fault slip between dextral faults in the northern ECSZ and dextral faults in the central WLB [1]. Oldow et al. [1] suggested that approximately 45 km of missing expected displacement in the Mina deflection was previously accommodated during the mid Miocene to Pliocene along the low-angle detachment fault of the Silver Peak-Lone Mountain system, east of the MD. Hence, the Mina deflection is proposed to be a transfer zone of strain from the northern ECSZ to the WLB, via extension within the dextral ECSZ-WLB system [1] (Fig. 3A). Recent GPS studies performed in the central WLB, however, indicated that the Mina deflection includes small tectonic blocks that vary in directions of motion [12]. Thus, Oldow [2] suggested that present day strain is manifested through both translation and extension. Specifically, the eastern flank of the Sierra Nevada is characterized by extension-dominated transtension, while regions further west are characterized by strike-slip-dominated transtension, and then by pure extension. The NW-trending kinematic boundary between the extension-dominated and strike-slip-dominated regions is proposed to pass through the central part of the Mina deflection [3] (Fig. 4).
In contrast to Oldow et al.’s [1] initial model of strain transfer, Wesnousky [3] argued that strain is now transferred through steeply dipping sinistral faults that bound rotating crustal blocks within a large right-lateral system of the WLB. Major basins within the WLB may be evidence of this structural regime, and are thus predicted to form at opposite ends and on opposite sides of every sinistral fault (Fig. 3B).

Studies performed at the northern tip of the ECSZ indicate that strain from the White Mountains is transferred across Queen Valley into the Mina deflection [4]. Lee et al. [4] used kinematic data to suggest that an average of 0.4-0.8 mm of strain per year may be transferred into the Mina deflection. Nagorsen et al. [9] documented strain rates of 0.7-0.8 mm/yr in the western Mina deflection. Should similar strain rates be documented in other portions of the Mina deflection then it may be concluded that strain is also being
transferred into the Mina deflection from sources other than from the White Mountains, or that the White Mountains transfer a greater amount of strain than initially thought.

In addition to recognizing that external factors such as plate interaction may greatly affect strain kinematics, internal forces may have also affected strain initiation and transfer among faults in the ECSZ-WLB. Jones et al. [5] postulated that at ~5 Ma the western margin of the BRP crossed through the Mina Deflection in southern WLB. At ~3 Ma, replacement of the Sierra Nevada lithosphere by buoyant asthenosphere increased regional GPE, initiated uplift, and increased normal and strike-slip deformation within ~50 km of the Sierra Nevada. A predicted outcome of this event was the westward jump of the western BRP to the present-day eastern flank of the Sierra Nevada. An additional consequence of the Jones et al. [5] hypothesis is that the western portion of the Mina deflection should reflect ~3 Ma deformation, while the eastern part of the Mina deflection should reflect ~5 Ma deformation (Fig. 4).

**Methods and logistics:**

To test the hypotheses of Oldow [2], Wesnousky [3], Lee et al. [4], and Jones et al. [5], I will conduct new geologic mapping, structural, kinematic, and geochronology studies within a region that straddles the predicted the ~5 Ma western edge of the BRP and the
boundary between the strike-slip dominated transtension eastern Mina deflection and extension-dominated transtension western Mina deflection. Fault type, orientation, slip history, and displacement magnitude will be documented by mapping at 1:12,000 scale over a period of three months in the Huntoon Spring region, which straddles the California-Nevada state line.

The excellent exposure of layered stratigraphy, faults, and geomorphic markers (e.g. linear features such as channelized basalt flows and cinder deposits, and basalt ridges, and cinder cones) in the Mina deflection will aid in determining fault orientation, kinematics, magnitude of displacement, and, along with geochronology, fault slip rates. Units exposed in the Huntoon Spring area that may be used to determine fault offset magnitudes include: 1) Oligocene to Miocene rhyolite, andesite, and basalt lavas; 2) Miocene latite and andesite lava; 3) Pliocene potassium-rich andesitic basalt lava and cinder cones; and 4) Quaternary sedimentary deposits [e.g. 6, 9, 13, 14]. Fault striations on exposed fault planes and offset linear markers will provide constraints on the kinematics of fault slip. Abundant volcanic units that were deposited pre-, syn-, and post-fault slip provide dateable markers by which the timing of faulting and fault slip rates may be derived. Volcanic rock samples will be dated using $^{40}$Ar/$^{39}$Ar on whole rock groundmass, biotite, hornblende, and sanidine in order to place temporal bounds on faulting. $^{40}$Ar/$^{39}$Ar analyses will be completed in the USGS $^{40}$Ar/$^{39}$Ar laboratory in Menlo Park in collaboration with Dr Andrew Calvert, a colleague of Dr Jeff Lee.

**Anticipated Results:**

Previous studies in the western Mina deflection provide preliminary field and structural data toward testing the proposed kinematic models. Field and structural data indicate that deformation in the Mina deflection is dominated by normal and sinistral strike-slip faults [e.g. 4, 9, 12]. A detailed study in the Adobe Hills, western Mina deflection, by Nagorsen et al. [9] suggested that the southwestern Mina Deflection records ~3 Ma sinistral-dominated extension, characterized by 2165 m of sinistral offset, and up to ~100 m of vertical offset. These data offer preliminary support for Jones’ et al. [5] hypothesis that a temporal boundary separating ~3 Ma and ~5 Ma deformational structures cuts across the
Mina deflection. The results of Nagorsen et al.’s [9] studies also suggest that Oldow’s [2] prediction that a transtensional boundary lies between the east and west MD may not be correct. Supporting data for the model proposed by Wesnousky [3], however, was not found.

**Significance of research:**

Results obtained from this research will be crucial in testing models that predict how intracontinental deformation within the western US Cordillera responded to external (plate motions) and internal forces (gravitational potential energy). Data obtained from my field research in the southern Mina deflection will be crucial to complete testing the models proposed by Oldow [2], Wesnousky [3], Lee et al. [4], and Jones et al. [5], and will either verify or contradict the hypotheses that: 1) strain transferred from the ECSZ into WLB is characterized by differing zones of transtension in the Mina deflection [3]; 2) strain is predominately transferred along sinistral faults within a dextral system; 3) strain in the Mina deflection is largely transferred from the White Mountains at rates of 0.4-0.8 mm/yr; and 4) the Mina deflection will manifest structural evidence that the Sierra Nevada uplifted at ~3 Ma. Ultimately, the data I propose to collect will contribute to our understanding of how the western edge of the North American continent responded to opposing plate motions, increased GPE, and varied strain regimes.
REFERENCES


13. Gilbert, C. M. (1968). Structural and volcanic history of Mono Basin, California-
14. Petronis, M. S. (2009). Late Miocene to Pliocene vertical-axis rotation attending
development of the Silver Peak-Lone Mountain displacement transfer zone, west-

Schedule:

**June 2011- September 2011:**
Field work in the Huntoon Spring area, Mina Deflection

**Fall Quarter, 2011:**
Map and structural data compilation
Cut billets for thin section analyses
Separate minerals for $^{40}$Ar/$^{39}$Ar geochronology

**Winter Quarter, 2011/12:**
Continue compiling map
Thin section analysis

**Spring Quarter, 2012:**
Write thesis
**Budget:**

<table>
<thead>
<tr>
<th>Budget item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4x4 truck rental</td>
<td>$3500</td>
</tr>
<tr>
<td>Gas</td>
<td>$1275</td>
</tr>
<tr>
<td>Field Assistant transportation</td>
<td>$828</td>
</tr>
<tr>
<td>Lodging</td>
<td>$718</td>
</tr>
<tr>
<td>Food</td>
<td>$2000</td>
</tr>
<tr>
<td>Total</td>
<td>$8321</td>
</tr>
</tbody>
</table>

**Budget justification:**

Rental of a 4x4 truck is necessary to access the field area. Truck rental will take place through Enterprise, which charges ~$3500 for a 90 day period. Roundtrip mileage from Ellensburg, WA to the field area is 1,020 miles. An average of 10 miles of driving in the field is estimated per day, and 12 trips to Bishop, CA (~120 miles roundtrip from the field area) will be necessary to restock supplies. Thus, total mileage is estimated to be at approximately 3,600 miles. Assuming the truck achieves an average of ~10 miles per gallon of gas, ~300 gallons of gas is estimated for use during this project. At an average of $5.00 per gallon, the cost of gas is predicted to be at least $1,275. While in the field, assistants will change every 3 weeks. This entails three exchanges during the course of 12 weeks, and will require that a rental vehicle be used for transportation to and from the field area for each exchange. At a rate of $15/day at $0.09/mile, an assumed rental period of three days/exchange, and an assumed gas cost of $300/exchange, the total cost for three exchanges sums to ~$828. The cost for two people to stay one night at the WRMS is $58. Thus, 11 uses of the WRMS will cost $638. When combined with average costs required to camp en route from WA to CA, lodging expenses sum to ~$760. In total, anticipated costs for this research will be ~$8,321.