Whose fault is it? A kinematic analysis of high angle faults adjacent to the eastern Snake River Plain near Arco, ID

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1. Abstract

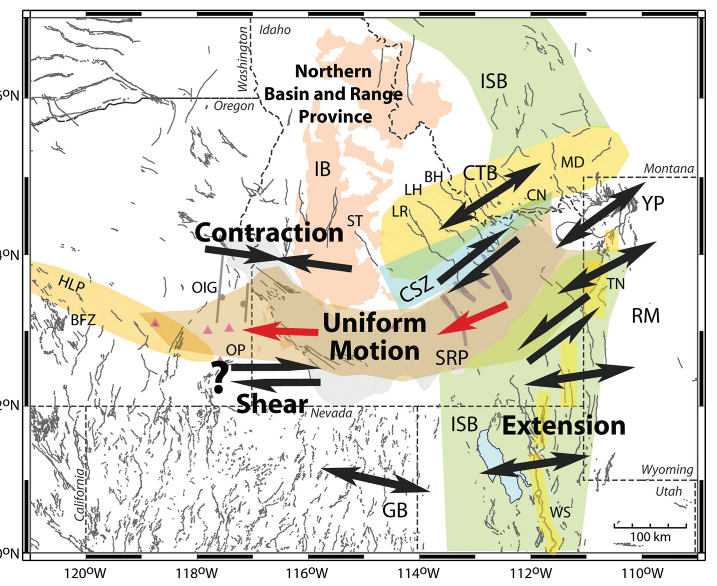
The Eastern Snake River Plain (ESRP) is a northeast-trending volcanic province formed during the North American plate's migration over the stationary Yellowstone hotspot. The Idaho National Laboratory (INL) is located in the west-central portion of the ESRP and overlies one of the most productive aquifers in the United States. The U.S. Geological Survey has collected borehole information at the INL in order to investigate the subsurface stratigraphy of the ESRP and characterize the ESRP aquifer with respect to the migration of radioactive and chemical wastes. The majority of the ESRP aquifer flows through basalt. However, the basalts thin near the northern margin of the ESRP, and groundwater is in contact with underlying rhyolites that have been tectonically tilted and faulted in a manner that may significantly affect the hydrogeology of the aquifer system.

This Idaho State University research, done in cooperation with the USGS, examines patterns of faulting in the Arco Hills as a basis for inferring the subsurface architecture of the adjacent ESRP, which is covered by Quaternary basalt. In addition to the predominantly northwest-striking normal faults that accommodate Basin and Range extension northwest of the Snake River Plain, small-offset, northeast-striking, steeply-dipping faults also occur near the margin of the ESRP. At a regional scale, GPS data suggest an active dextral component of slip along a similarly northeast-trending shear zone between the Basin and Range and Snake River Plain near the Centennial Mountains ~120 km to the northeast. To evaluate the hypothesis that these small faults could be the expression of a similar dextral component of displacement during an earlier phase of development of the Snake River Plain, we conducted a field-based kinematic analysis of small faults northeast of Arco, Idaho. Collectively, these faults record nearly pure dip-slip offset and a northwest-southeast extension direction that is slightly oblique to the ~55° northeast trend of the ESRP. Our preliminary interpretation of these faults is that 1) they result from crustal flexure adjacent to the margin of the ESRP; or 2) they formed as a result of a gradual, along-strike decrease in slip of the Lost River fault toward the ESRP.

2. Purpose

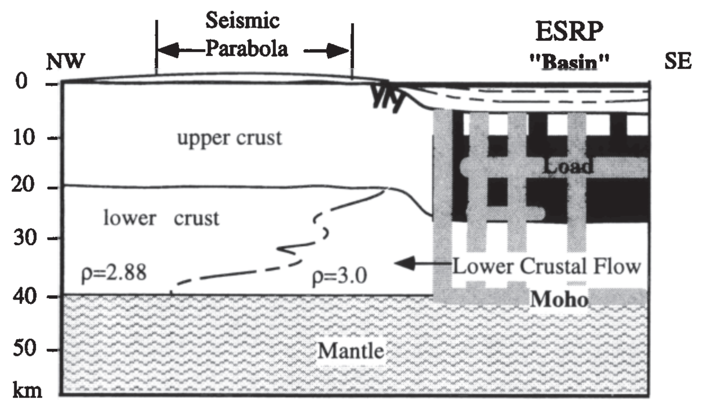
1.) Understand the origin of young faults found around the ESRP
2.) Interpret the subsurface architecture of the ESRP SE of the Arco Hills

3. Hypotheses



Payne et al. (2012)

Current GPS observations suggest that the Basin and Range province north of the ESRP is actively extending, but the ESRP moves as one rigid block. This suggests a component of right-lateral strike-slip displacement occurs between the two domains (Payne et al., 2012). NE-striking faults were hypothesized to accommodate dextral strike-slip displacement associated with the Centennial Shear Zone (CSZ; Payne et al., 2012).



McQuarrie and Rodgers (1998)

NE-striking faults near the margins of the ESRP were previously hypothesized to represent crustal flexure outboard of the downwarped ESRP (Rodgers et al., 2002).

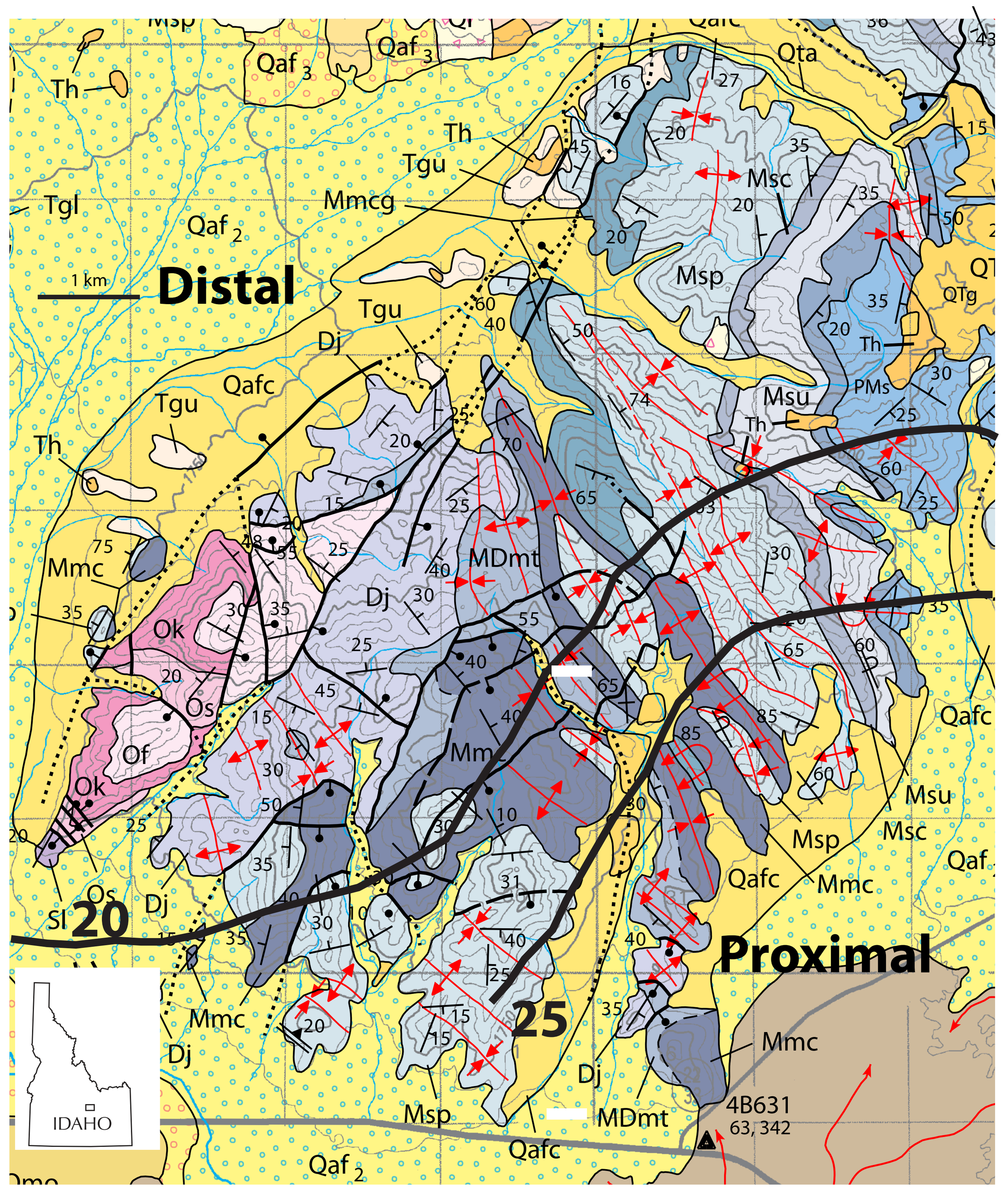
1.) We hypothesize that the NE-striking faults represent transient oblique-slip faults related to the differential extension between the ESRP and the northern Basin and Range province
2.) We hypothesize that small scale faults constrain the regional strain adjacent to the ESRP

4. Methods

We conducted a quantitative analysis of high angle faults in the Arco Hills, focusing on the Mississippian Scott Peak Formation. The photo at the top left shows our method for fault measurement (rake). The photo on the right illustrates an example of an offset marker bed that displays normal displacement.

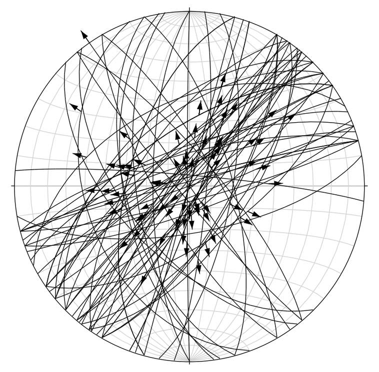
We inputted our data into the program FaultKin, which utilizes small-scale faults to determine the regional kinematics of faulting (Marrett and Allmendinger, 1990). We sought to test whether young faults adjacent to the ESRP record oblique, rather than normal, slip.

5. Geologic Map



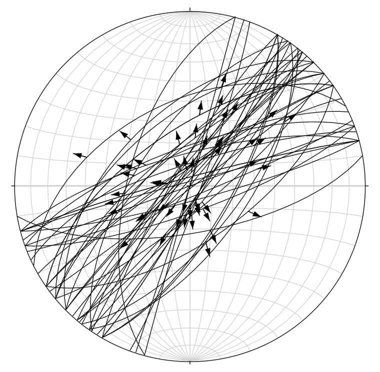
Geologic map of the southern Arco Hills, modified from Skipp et al. (2009). Black contour lines are the contours by McQuarrie and Rodgers (1998) that illustrate the downwarp of the ESRP. Fault data was divided in half along the 20 degree contour.

6. Results - Data

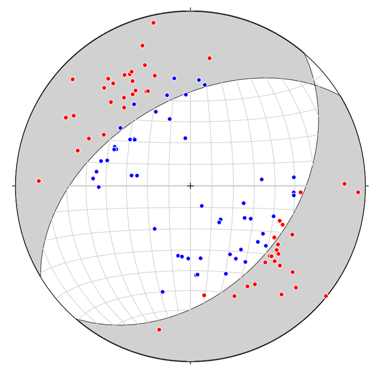


(n = 70)

We found a bimodal distribution of faults in the study area: NE-striking and NW-striking. Elsewhere at the northern margin of the ESRP, Zentner (1989) documented that NE-striking faults cross-cut NW-striking faults. NW-striking faults are well-known to be related to Basin and Range extension. For the present study, we thus excluded NW-striking faults and only analyzed the NE-striking faults in the Arco Hills because this set is of most interest to the regional deformation around the ESRP.



(n = 50)



Stereonet of great circles with hanging wall slip direction (arrows) for the NE-striking faults of the Arco Hills.

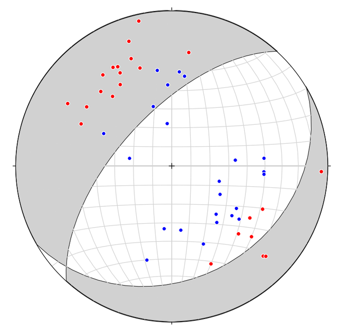
Fault plane solution, shortening-axes (blue) and extension-axes (red) of the NE-striking faults of the Arco Hills.

1.) Numerous small displacement magnitude NE-striking faults surround the margin of the ESRP
2.) These collectively record nearly exclusively dip-slip
3.) They dip both NW and SE

7. Results - Spatial Pattern

In order to determine if the brittle deformation within the Arco Hills varies spatially, we divided fault data points in half (Geologic Map). Fault data was separated along the 20 degree fold plunge contour by McQuarrie and Rodgers (1998).

Distal Faults

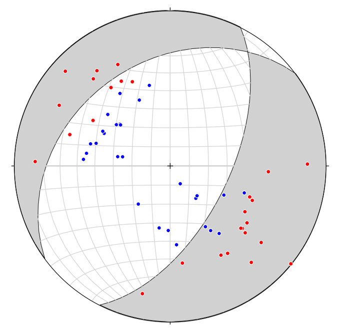


(n = 23)

Fault	Strike	Dip	Trend	Plunge	Slip Sense	A-R rake
1.	059.5	28.6	132.5	27.5	NR	-074.9
2.	222.5	62.5	030.5	61.4	TL	081.9

P-axis: 114.4, 71.4; T-axis: 318.5, 17.1

Proximal Faults

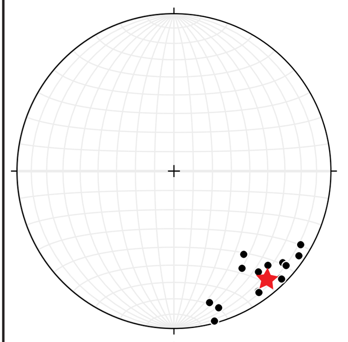


(n = 27)

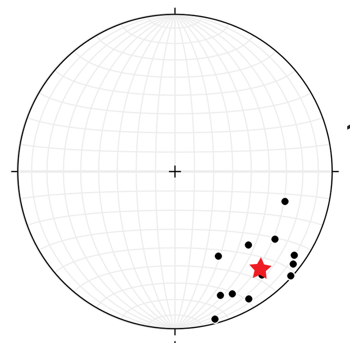
Fault	Strike	Dip	Trend	Plunge	Slip Sense	A-R rake
1.	233.6	33.5	063.3	30.6	NR	-067.1
2.	026.7	59.4	143.6	56.5	TL	075.5

P-axis: 262.5, 71.7; T-axis: 127.2, 13.3

NW Dip

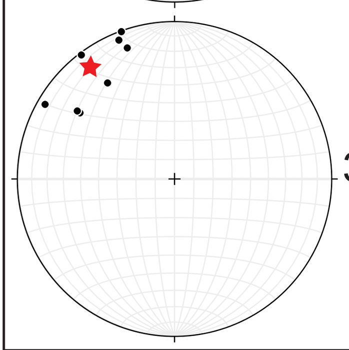


121, 12
(n=15)

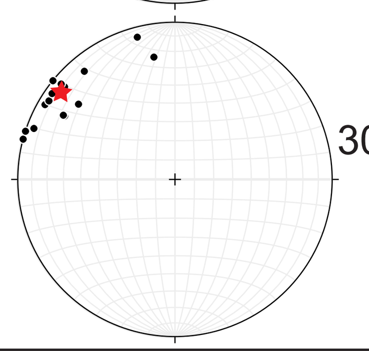


139.5, 18
(n=12)

SE Dip



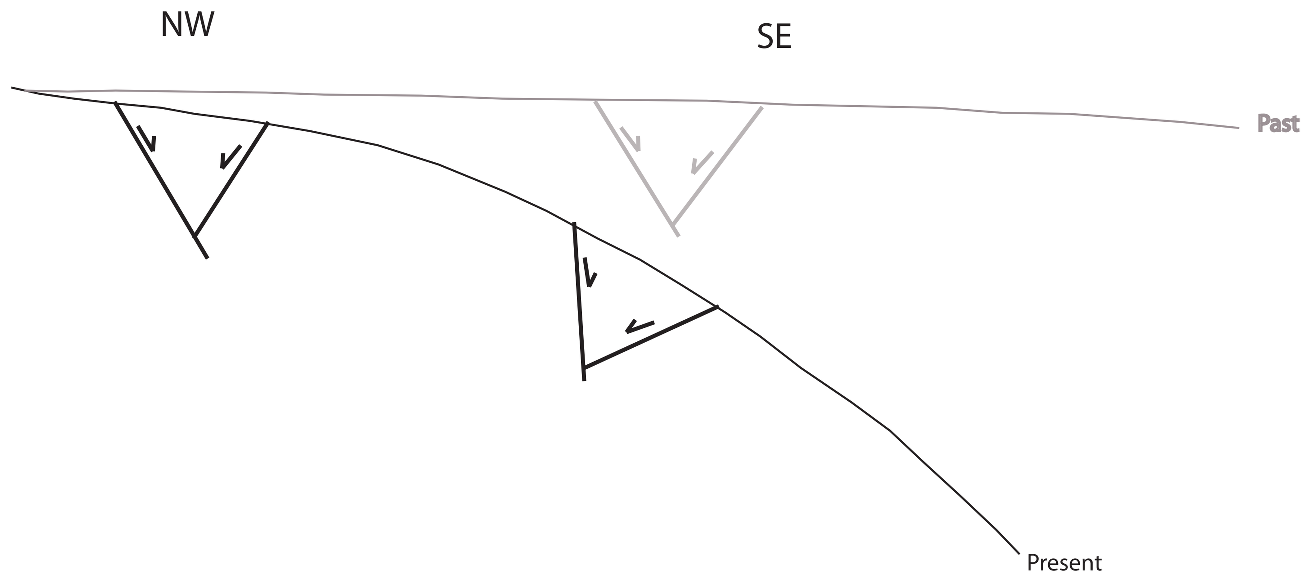
322.4, 13.1
(n=8)



307.6, 9.6
(n=15)

8. Interpretation

1.) We interpret the NE-striking faults to be Neogene normal faults associated with the Yellowstone and Basin and Range provinces
2.) Current GPS observations suggest there must be a component of right-lateral shear between the ESRP and northern Basin and Range province, but no evidence is found for this. Therefore, right-lateral slip must be accommodated along distinct segment boundaries along Basin and Range normal faults
3.) Preliminary work suggests that faults closer to the ESRP (proximal) record a shallowly NW-SE plunging extension direction; faults farther from the ESRP (distal) record a steeply plunging NW-SE extension direction
4.) SE dipping faults steepen toward the ESRP, whereas NW dipping faults shallow toward the ESRP
5.) Faults appear to have been rotated
6.) The change in extension orientation, and fault dip suggests that the faults adjacent to the ESRP were rotated after formation and predate, or occurred early on in the subsidence of the ESRP (figure below)
7.) The NE-striking faults likely formed as a result of early stages of flexure from the emplacement of the midcrustal sill



9. Future Productions

1.) Correlation of a subsurface SR-type rhyolite (Branney et al., 2008) to other subsurface and surface rhyolites
2.) Interpretation of subsurface architecture of the ESRP in relation to the subsurface rhyolite
3.) Age constraints from rhyolites will constrain the rate of subsidence of the ESRP, which will help with the interpretation of the evolution of the subsurface architecture of the ESRP.

10. Acknowledgments

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