The Compass: Earth Science Journal of Sigma Gamma Epsilon

Volume 90 | Issue 1 Article 2

9-19-2019

Orientation of Paleostress of Raplee Ridge Anticline

Loren Randall Holyoak
Southern Utah University, loren.randallmht@gmail.com

John S. MacLean
Southern Utah University, johnmaclean@suu.edu

On the Outcrop

Orientation of Paleostress of Raplee Ridge Anticline

Loren Randall Holyoak and **John S. Maclean**
Department of Physical Sciences
Southern Utah University
351 W University Blvd
Cedar City, UT 84720 USA
loren.randallmht@gmail.com
johnmaclean@suu.edu

LOCATION

During the Laramide Orogeny several major folds were formed in Southern Utah, one of those being the Raplee Ridge anticline (fig. 1). Raplee Ridge is approximately eight miles from Mexican Hat, Utah (fig. 2). The San Juan River cuts through the anticline, exposing the Honaker Trail Formation's beds of shale and limestone with chert nodules. Accompanying the mountain-scale ductile deformation of the Raplee Ridge anticline are decimeter-scale brittle conjugate fractures in the limestone's chert nodules. The objective of this study is to compare the orientation of paleostress that formed the Raplee Ridge anticline with the conjugate fractures within the chert nodules to see if the two different styles of deformation could have occurred during the same orogeny.

Figure 1. Raplee Ridge anticline.

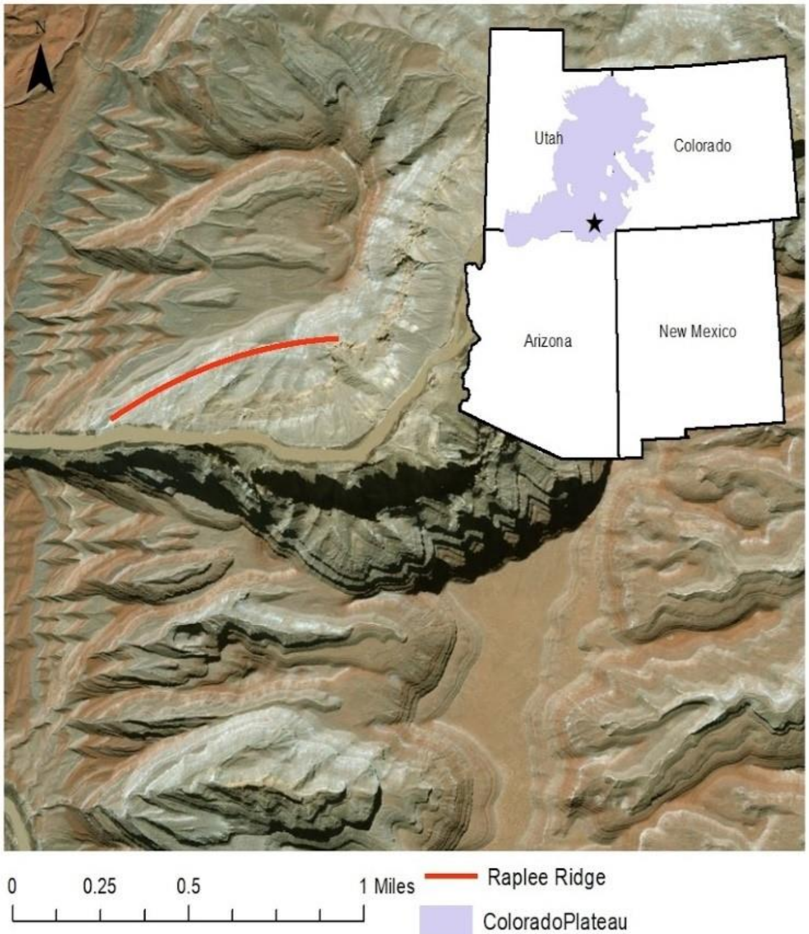

Figure 2. Map of research area.

TECTONIC SETTING

The evolution of the Farallon Plate controlled much of the structural geology of western North America. Pangea began to break apart about 200 million years ago (Brunsvik, *et al*., 2015, and references therein). A passive margin formed on the eastern part of North America, and terranes carried by the subducting Farallon Plate were accreted onto the western margin of the craton. During the late Mesozoic a subduction zone formed on the west coast of North America where the oceanic Farallon Plate subducted beneath the continental crust of the North American Plate (fig. 3).

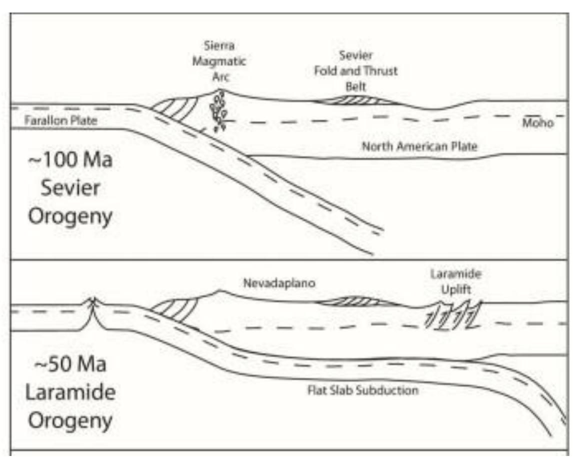

Figure 3. Early evolution of the Farallon Plate. The Sevier Orogeny caused by subduction of the Farallon plate at a normal angle and the Laramide Orogeny caused by flat slab subduction (modified from Brunsvik, *et al*., 2015).

The first major terrane accretion dates back to approximately 160 Ma (Sigloch, 2013). The plate originally subducted at a typical subduction angle (45°). This is evident due to the thin-skinned style of deformation characterized by the Sevier Orogeny in the Western United States (Myatt, *et al*., 2009). The Sevier Orogeny began approximately 130 million years ago and ended at about 60 million years ago. Due to this typical subduction, fold and thrust belts are present in the western states (DeCelles, 2004).

At about 80 million years ago the subduction angle began to change from a typical angle to flat slab subduction creating the Laramide Orogeny (fig. 3). There are several different mechanisms that contributed to this change in subduction angle, including increased buoyancy of the subducted plate, increased slab suction force, and increased plate velocity (Stevenson and Turner, 1977).

As the angle of subduction changed, the deformation changed from thin-skinned to thick-skinned. Thick-skinned deformation involves basement cored uplift, meaning that the faults displace basement rock and its overlying sedimentary layers (Goldstrand and Mullet, 1995). An example of deformation caused by the Laramide Orogeny is the Monument upwarp. The Monument upwarp is a broad dome that has a north-south length of approximately 110 miles and a width of 40 to 60 miles. The Monument upward is modified by a number of smaller anticlines and synclines such as the Raplee anticline.

SITE DESCRIPTION

Raplee Ridge is made up of the Paradox Formation, Honaker Trail Formation, Rico Formation, Halgaito Tongue, and the Cedar Mesa Sandstone (fig. 4).

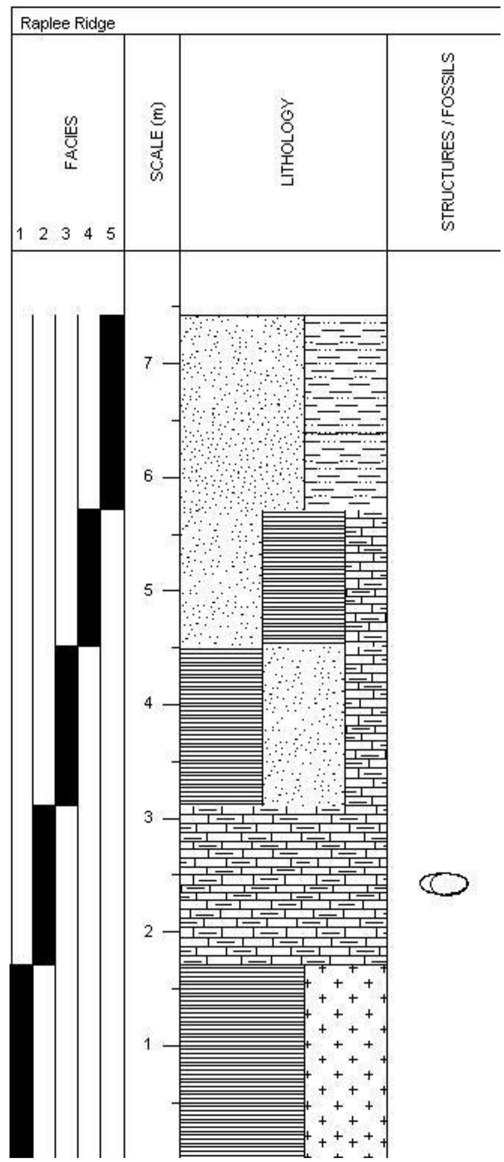

Figure 4. Stratigraphic column of Raplee Ridge. Facies 1: Paradox Formation-salt and shale. Facies 2: Honaker Trail Formation – limestone. Facies 3: Rico Formation – shale, sandstone and limestone. Facies 4: Halgaito Tongue – sandstone, shale and limestone. Facies 5: Cedar Mesa Sandstone – sandstone and siltstone (modified from Mynatt, *et al.*, 2009).

The Paradox Formation is composed mainly of cyclically deposited beds of salt, anhydrite, carbonate rocks, and black shale (Huffman and Condon, 1993). The Rico Formation is composed of thick, red, slope-forming shale layers that are separated by erosionally resistant layers of sandstone and limestone. The Halgaito Tongue consists of red to brown fine-grained silty sandstones and shales and some thin beds of unfossiliferous limestone. The Cedar Mesa Sandstone is a cross-laminated yellow to grey fine-grained sandstone with interbedded red to brown siltstone and sandstone (Mullens, 1960). The formation of interest of this study is the Honaker Trail Formation. This formation consists of dark grey limestone with black chert nodules. It was deposited during the Pennsylvanian Period when the majority of Utah was covered in a warm shallow sea. The chert nodules in the Honaker Trail Formation were on average 30 centimeters in length and 10 centimeters in width (fig. 5). The entire set of stratigraphy is folded in the Raplee Ridge anticline (fig. 6), and the chert nodules are extremely fractured (fig. 7).

Figure 5. Representative chert nodule in the Honaker Trail Formation.

Figure 6. Entire set of stratigraphy folded in the Raplee Ridge anticline.

Figure 7. Conjugate fractures in a chert nodule.

SITE SIGNIFICANCE

The area of study is approximately 8 river miles upstream from Mexican Hat, Utah. A group of geology students traveled to the area by rafting the San Juan River from Sand Island near Bluff, Utah (fig. 8 & 9). The goal of the field trip was to determine whether the origin of stress that caused the anticline had the same orientation as the stress that caused the chert nodule's fractures. Students measured the orientations of fractures in the chert nodules and bedding planes from the anticline's base to close to its nose. Bedding planes and at least three chert nodules were measured approximately every ten meters. The data points were plotted on stereo nets using Rick Allmendinger's program Stereonet 9 (Allmendinger 2006-2016).

Figure 8. Four of the 12 individuals that participated in this research trip.

Figure 9. Campsite at the research area.

The bedding planes on the western limb of the anticline have consistent orientations of approximately 310,20 (fig. 10). The stereo nets of the chert nodule factures show two sets of conjugate nearly vertical fractures (fig. 11). The first fracture set ranges in strike from 260° to 240°, and the second fracture set ranges from 350° to 030°. The majority of the data are contained in these two groups with only a few outliers.

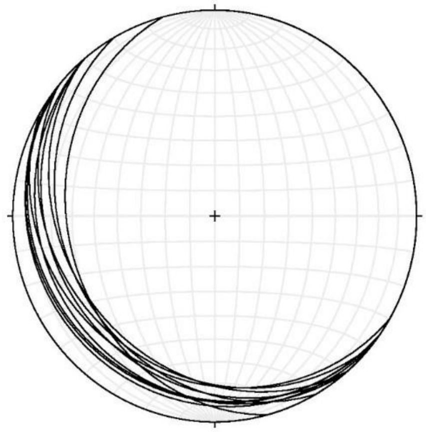

Figure 10. Orientation of bedding planes. Average 310,20. N=22.

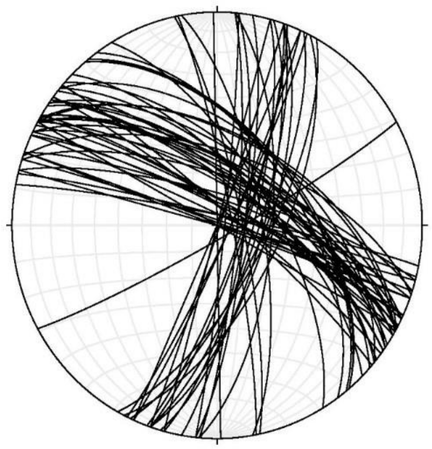

Figure 11. Orientations of the chert nodule fractures. N=70.

The orientations of the chert nodule factures show conjugate pairs. By bisecting the acute angle of these fractures, a paleostress analysis allows a determination of the direction of the stress that caused the fractures. According to the analysis the direction of stress that caused the factures is approximately 040.

To calculate the maximum compression of the fold the assumption is made that the other limb of the anticline has approximately the same strike of the limb that was measured and is dipping in the opposite direction. Therefore, the orientation of the maximum compression is 90° from the hinge line (310°) which is 040. The paleostress of both the asymmetrical anticline and the chert nodule fractures have the same orientation. It is reasonable to assume that the asymmetrical anticline and the conjugate fractures were both formed during the Laramide Orogeny.

The geology exposed in the Raplee Ridge anticline offers a wonderful opportunity to use a paleostress analysis to compare two styles of deformation. The two different styles of deformation present are the ductile deformation of the anticline and the brittle deformation of the chert nodule fractures. The orientations of the fractures and the bedding planes show that the orientation of maximum compression is the same for both styles of deformation, suggesting that both were formed during the same tectonic event, the Laramide Orogeny.

REFERENCES

Brunsvik, B., Gale, C., Cope, M., Petersen, J., and Zdanowski, S., 2015. Field and petrographic analysis of the Indian Peak-Caliente caldera complex at Condor and English Canyons in eastern Nevada. *The Compass*, v. 87, no. 4, p. 121-141.

DeCelles, P.G., *et al.*, 1995. Thrust timing, growth of structural culminations, and synorogenic sedimentation in the type Sevier orogenic belt, western United States. *Geology,* v. 23, no. 8, p. 699. Doi:10.1130/0091-7613(1995)023<0699:ttgose>2.3.co:2.

Huffman, A.C., Jr., and Condon, S.M., 1993. Stratigraphy, structure, and paleogeography of Pennsylvanian and Permian rocks, San Juan Basin and adjacent areas, Utah, Colorado, Arizona, and New Mexico. *Evolution of Sedimentary Basins-San Juan Basin*, U.S. Geological Survey Bulletin 1808, p. 019-043.

Goldstrand, P.M. and Mullett, D.J., 1995. The Paleocene Grand Castle Formation-a new formation on the Markagunt Plateau of southwestern Utah, *Geologic Studies*, p. 61-77.

Mullens, T.E., 1960. Geology of the Clay Hills area San Juan County, Utah. *U.S. Geological Survey Bulletin 1087H*, p. 259-336.

Mynatt, I., et al., 2009. Fracture initiation, development, and reactivation in folded sedimentary rocks at Raplee Ridge, Utah. *Journal of Structural Geology*, v. 31, no. 10, p. 1100-1113.

Sigloch, K., and Mihalynuk, M., 2013. Intra-oceanic subduction shaped the assembly of Cordilleran North America. *Nature*, v. 496, no. 7443, p. 50-56.

Stevenson, D.J. and Turner, S.J., 1977. Angle of subduction. *Nature*, v. 270, p. 334-336.