Comparison of Different Methods of Strain Analysis Within the Tamaqua Syncline, Central Pennsylvania

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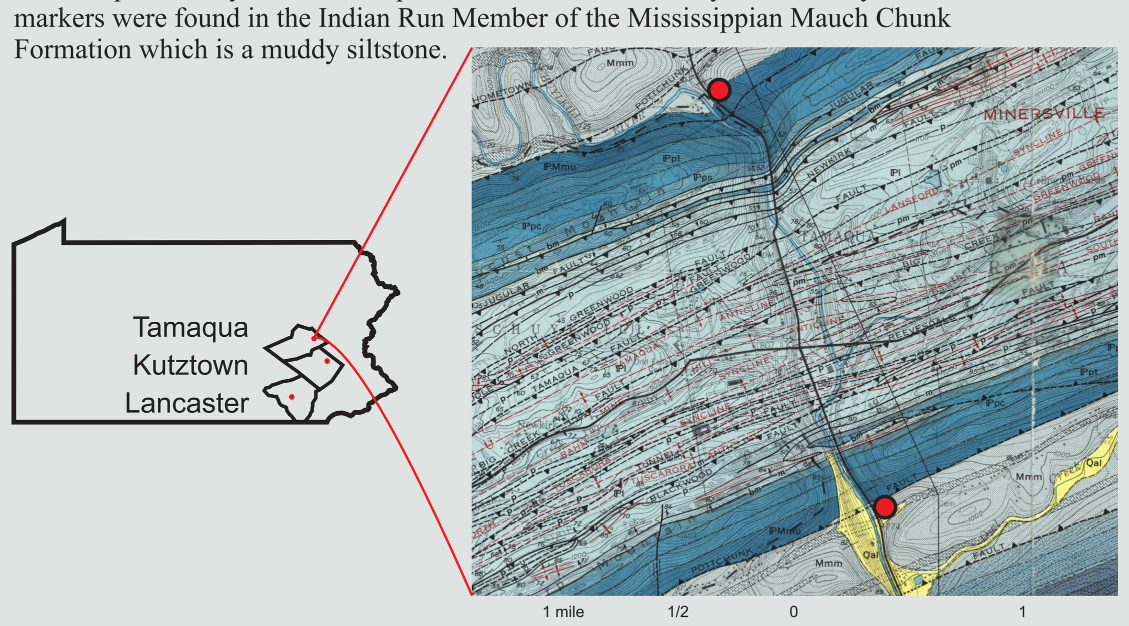
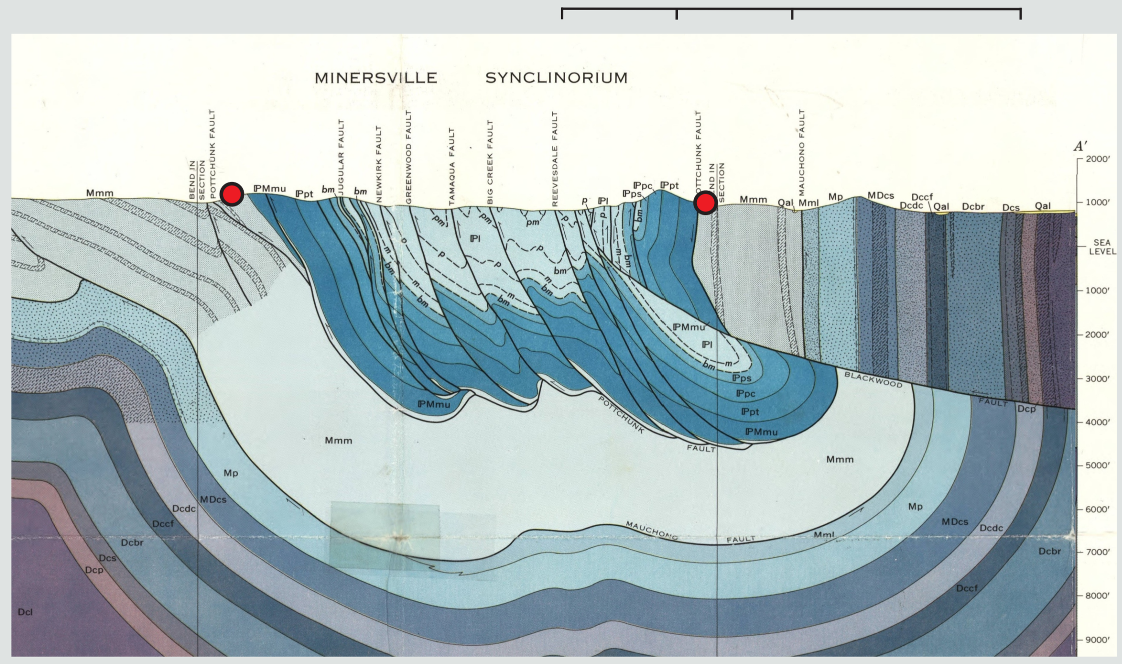
Abstract:

The Indian Run Member of the Mississippian Mauch Chunk Formation crops out on the north and south limbs of the Tamaqua Syncline on Route 309 outside of Tamaqua, Pennsylvania. The sandstone and mudstone redbeds preserve strained mud cracks, raindrop impressions, and mud rip-up clasts, as well as outcrop-scale thrust faults and cleavage, each providing an independent measure of strain direction and /or magnitude. We determined the principle direction and magnitude of strain using different methods to evaluate the consistency of results revealed by using various features and techniques, and to identify discrepancies in shortening direction or strain magnitude that might indicate multiple phases in the Alleghanian Orogeny. The fold axis of the Tamaqua Syncline trends 73° giving a shortening azimuth of 163°. Map-scale thrust faults strike 67°, perpendicular to a shortening direction of 157°, and slickenlines on outcrop-scale, low-displacement (1-3m) thrust faults indicate a shortening direction of 155°. Cleavage formed before significant folding occurred, and its orientation is consistent with a shortening direction of 159°. The direction of shortening derived from elliptical strained raindrop impressions is 161°. Fry center-to-center method on a bedding surface containing hundreds of strained raindrop impressions provided an ellipticity (R) of 1.6. Calculations of ellipticity based on measurements from 40 individual raindrop impressions also yielded an average R of 1.6 with values ranging from 1.2 to 2.0 and a standard deviation of 0.17. Individual raindrops in the Mauch Chunk Formation vary in ellipticity, possibly indicating that some impressions were not initially circular, but the average ellipticity of a large population gives R similar to that derived by the Fry method. Post-deformation clustering of initially distributed mud crack trends yields a shortening direction of 160°. The various methods and deformed features used in this study reveal very similar shortening directions, between 155° to 163°, and R values of 1.6, indicating that only one phase of Alleghanian deformation was responsible for producing these features in the Tamaqua Syncline. Using different methods on different strain markers also verifies that these methods, in this locality, yield compatible results.

Local Geology:

The research area lies on the north and south limbs of the Tamaqua Syncline, outside of Tamaqua, Pennsylvania. Tamaqua is located in eastern Schyulkill County. Strain markers were found in the Indian Run Member of the Mississippian Mauch Chunk Formation which is a muddy siltstone.





Mud Crack Strain Analysis:

Outcrops with exposed mud cracks were found next to a rail trail that runs along the east side of Route 309 south of Tamaqua, PA. The bedding here is vertical and stratigraphic up faces north. The process of finding strain using mud cracks is described below.

- Record the length and orientation with respect to horizontal of each mud crack
- Find the original trend of the mud cracks (when sediment was horizontal) by rotating and converting the measured angles to azimuth from 1-180
- Translate the orientations so that they are angles measured from perpendicular to shortening ($0 \pm \pi/2$)
- Double the angles for a $0 \pm \pi$ scale
- Shift the angles to a $0 - 2\pi$ scale and convert to radians
- Now that each mud crack angle is in radians, it represents a vector
- Split all vectors into x and y components, add all x and all y respectively, then put back into a single vector, the magnitude of which is the **r** needed for the chart below (**|r|/n**)
- The **n** value is the total number of data points
- **|r|/n** is the formula used to find a range of possible strain ratios depending on the number of data points

Mud Cracks:

Both exposures of mud cracks were found on the vertically dipping south limb of the Tamaqua Syncline and are shown at the same scale in the photographs.

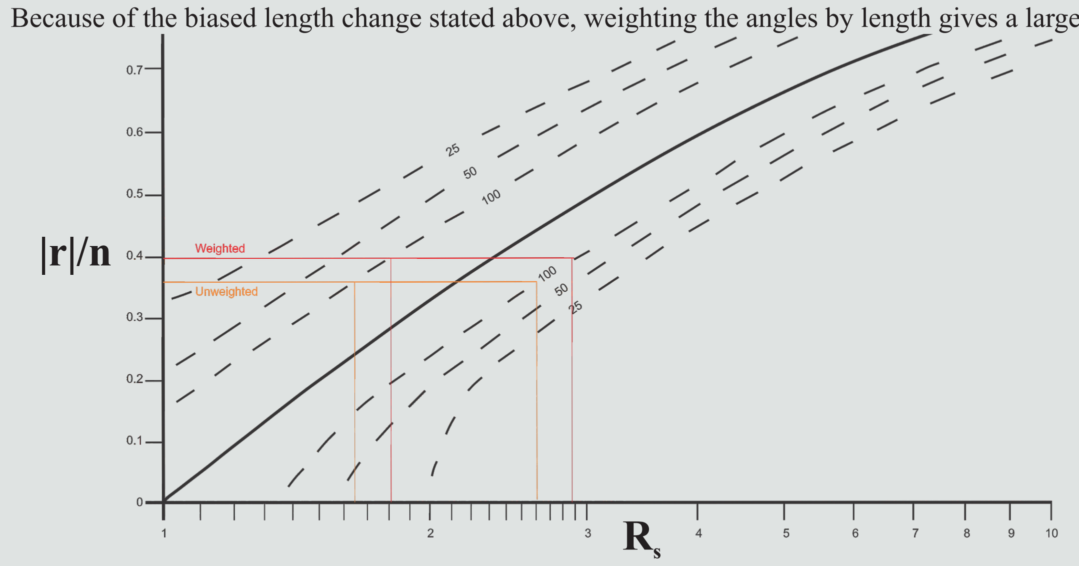
Finding the Strain Ratio:

A range of R values is given from **|r|/n** in the chart below.

- For the data, **|r|/n**=0.36, with **n**=109
- This gives a strain ratio range of 1.6-2.6

When linear features are strained, those features parallel to the direction of shortening will become shorter and those perpendicular to the direction of shortening will not change in length. Would weighting the data by length give a more accurate strain ratio? Could Sanderson's (1977) method be expanded upon to include the measured lengths of each mud crack?

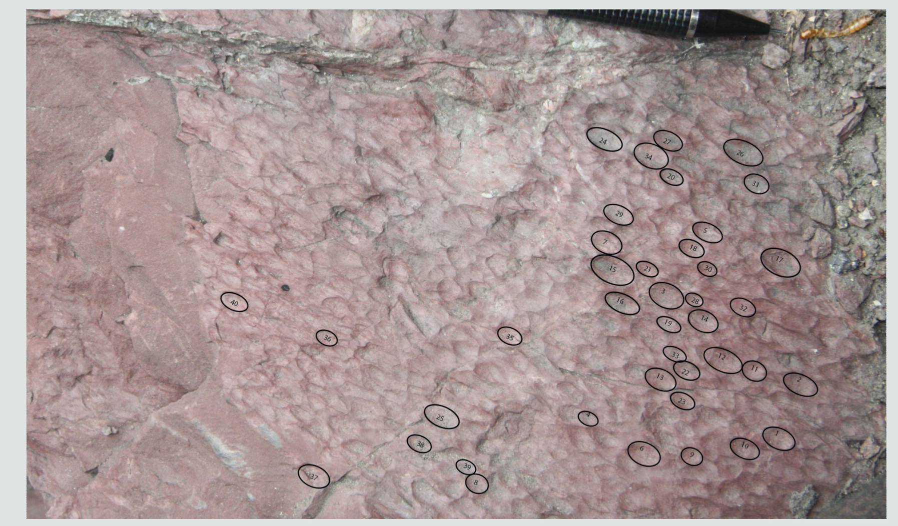
- Sanderson assumed that each vector had a magnitude of 1 and **n** was the number of data points, so **n** is equal to the total length of all data points
- By factoring in the length of each mud crack, **n** becomes the total length of all mud cracks (**|r|/n**=0.40)
- In the expanded method, the range is shifted higher (1.8-2.9)
- Because of the biased length change stated above, weighting the angles by length gives a larger strain ratio



Raindrop Impressions: Ellipse Method

A small outcrop containing raindrop impressions was found on the north limb of the syncline and provided a reliable marker with which to calculate strain.

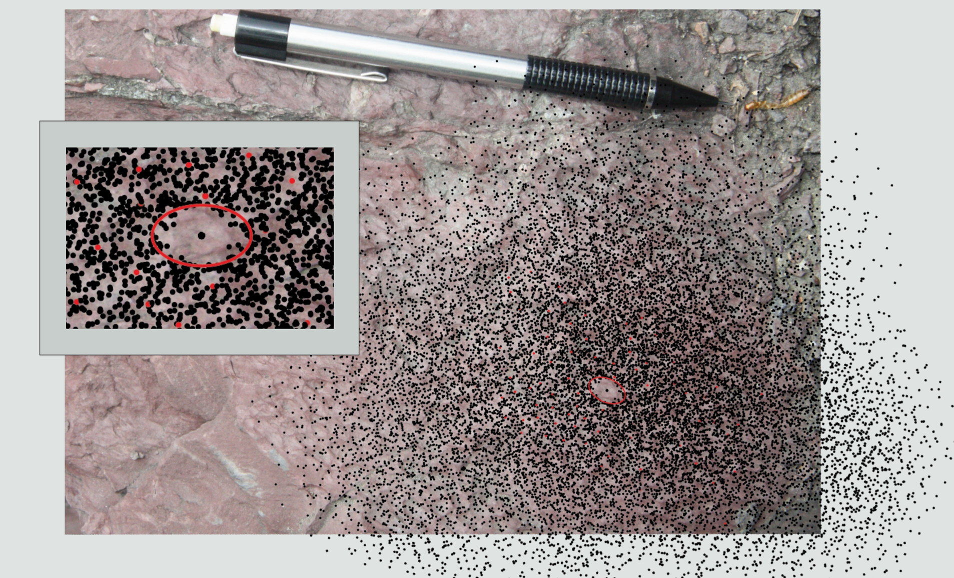
- Photograph was rotated so that the major axis of the ellipses were horizontal
- Not every raindrop is a perfect circle at formation, so many were identified to give an average over a large sample
- Ellipses were drawn over 40 individual raindrops: major and minor axis lengths were recorded
- Strain ratio was calculated for each raindrop giving an average ellipticity of 1.6
- Values ranged from 1.25 to 1.99 with a standard deviation of 0.17



Raindrop Impressions: Fry Method

The Fry Center-to-Center method for calculating strain was used on the raindrop impressions to compare the results given with the ellipse method.

- The center of each raindrop in an area was marked in the program Adobe Illustrator
- All points were grouped together and the group was copied, just as you would copy all of the centers on an overlay
- The 'overlay' was copied many times, moving a different point to a chosen center each time until all points were used
- An ellipse was drawn over the center following the edge made by the points and its ellipticity was measured to be 1.6

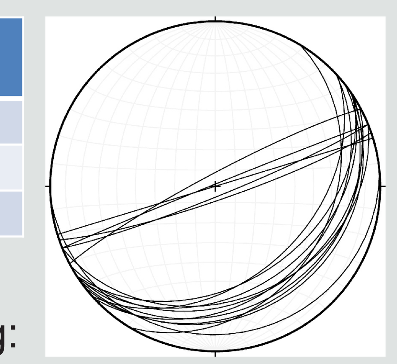


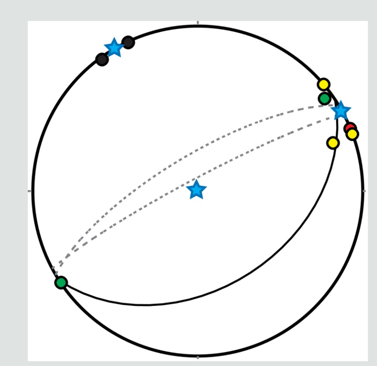
Results:

Source:	Shortening Direction:
Fold Axis:	163°
Thrust Faults:	157°
Fault Slickenlines:	155°
Cleavage:	159°
Raindrop Impressions:	161°
Mud Cracks:	160°

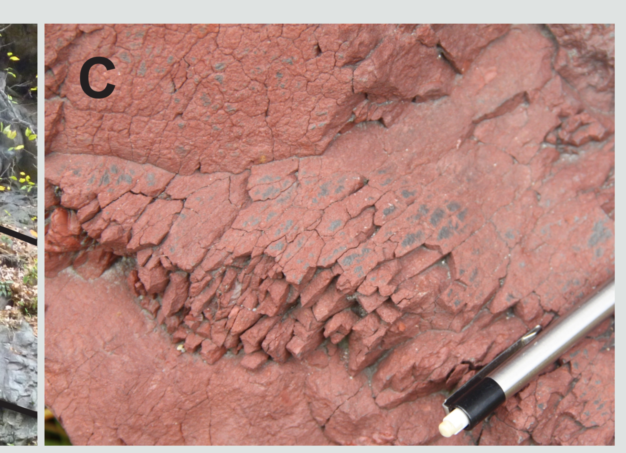
Source:	Strain (R)
Raindrop Ellipse:	1.6
Fry Method:	1.6
Mud Cracks:	1.6-2.6

Bedding:





- Cleavage: grey dashed great circles
- Thrust fault: black great circle (**B**)
- Slickenlines on outcrop-scale thrust faults
- Pencil structures in paleosols (**C**)
- Elongated mud chips (**A**)
- Raindrop impressions
- Principal strain directions inferred from all of these features, showing compatibility



Conclusions:

- The different methods of strain analysis we used to analyze deformation of the rocks in the middle Mauch Chunk of the Tamaqua Syncline produced very similar results.
- Our research confirms that each of the methods used here yields a reliable and compatible estimate of direction and/or magnitude of strain.
- The formations in the Tamaqua Syncline experienced only one phase of Alleghanian deformation.
- Weighting mud cracks by length provides a larger strain ratio, but the characteristic that causes this may be useful as an independent measure of strain direction and / or strain ratio.

If I am not at the poster and you have any questions, here is a picture of me: come find me and I will be happy to answer.

Brandon Stickler is a senior at Kutztown University, will graduate in May 2014 with a B.S. in Geology, and is currently looking for employment.

References:

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