Relation of Allegheny thrust-faulting to an outcrop of the Edinburg formation: Stoneridge Farm, Lexington, VA

Christina Vosen '92
Carleton College

Background

This study investigates the relation of deformation in an outcrop of the Edinburg formation to the adjacent Pulaski-Staunton fault. The fault is one of the major Allenghenian thrust faults in the Valley and Ridge province of the south central Appalachians. Extending 500 km from Staunton, Virginia to North Carolina, the minimum displacement on the fault is 100-110 km (Bartholomew, 1987). This fault is unusual because it originates below the Rome formation involving allocthonous crystalline basement and has an associated fault breccia. Both of these characteristics indicate a thrust fault of greater magnitude and displacement than most of the faults in this area of the Valley and Ridge province.

Within the Glasgow Quadrangle of Rockbridge County, Virginia, the Pulaski-Staunton fault generally strikes N40°E thrusting the Cambrian Elbrook formation onto the Edinburg formation with a stratigraphic throw of 1500 meters. The Edinburg formation is exposed parallel to the fault's strike and most of the Edinburg formation's deformation in this area has been related to the Pulaski-Staunton fault. One kilometer downstrike from the study area, the fault trace changes from a linear trace bounded by simple deformation in the footwall to a complex zone of folds and subsidiary faults in the footwall side of the fault trace. This structure is interpreted as a wedge of the footwall transported from the edge of a fold ramp (Spencer 1991). Its close proximity to the outcrop may have affected the stress field acting upon the limestone.

The study area is located on Stoneridge Farm 5 miles south of Lexington, Virginia. With the Pulaski-Staunton fault only 100 meters to the southwest, the outcrop of Edinburg limestone lies in the footwall side of the fault. The rock exposure dips north 3-5° exposing folded beds in oblique cross-section. The distinguishing features of the outcrop are steeply dipping fold axii which appear to indicate a stress field contrary to the nearby fault. A series of veins with varying orientations cut and parallel bedding. In some places the bedding is obliterated by a closely-spaced, pervasive fracture and/or pressure solution cleavages. My goal is to determine the sequence of deformational events indicated by the features of this outcrop and compare the indicated stress fields for tectonic deformation to that of the Pulaski-Staunton fault. To analyze the outcrop, I gathered data by two methods. I first measured the major structural features and then mapped a representative area in detail using 2 by 2 meter blocks.

The Stoneridge Farm outcrop is composed of a single rock type identified as the Liberty Hall facies of the Edinburg formation. At this site the Liberty Hall facies is a black limestone uniformly fine-grained and well-lithified interbedded by layers of silty buff-colored limestone. The bedding is locally disrupted and so lacks any distinctive marker beds. The beds are an average thickness of 6 cm varying between 3 and 30 cm. There are no fossils or structures to indicate younging direction.

Description and Explanation of Features (see map)

Examples of synsedimentary deformation are evident throughout the outcrop. The most obvious examples are recumbent isoclinal folds found throughout the outcrop. These folds have an amplitude of 20-40 cm and a wavelength of 4-6 cm. They are confined to single bedding layers and cut tranversely by pressure solution cleavage. The limestone beds are commonly disrupted and the silty interbeds are lensoidal. For this reason, marker beds cannot be traced for more than 6 meters. These characteristics are consistent with the depositional environment of carbonates originating in a foreland basin. Located on the continental margin pre-deformation, the sediments would be slightly unstable leading to synsedimentary deformation.

One distinct set of calcite veins is distinguished by discolored, even silty, calcite and their large size varying from 2-15 cm wide and 6 cm to 1 m long. The structural relationships indicate this episode of veining postdates synsedimentary deformation and precedes any later deformation. The veins either lie perpendicular to bedding along axial planes or occur without regard to any particular orientation except that they cut bedding and are seen in cross-section. The edges of the veins are a rough and typically parallel to each other. The discolored calcite filling is normally laminated parallel to the edges and is composed of coarse crystals with fluid inclusions. The veins often originate near lenses of silty limestone. In many cases, the silty interbeds appear to be 'flowing' into the veins. Small-scale thrust faulting is also seen in conjunction with the veins.

The emplacement of these veins is attributed to dewatering of the sediments. Deposition followed by burial of water-laden sediments beneath a thrust sheet produce high fluid pressures. (Winslow, 1984) Fluid pressures may be further elevated by the migration of fluids from further below the thrust sheet, leading to rapid expulsion of water and mobile silt from the limestone. (Oliver, 1986) The disorganized orientation of calcite crystals and the rough boundary between veins and limestone indicate a rapid deformation, while the size of the veins indicates a major deformational event. The discontinuity of the silty limestone lenses may be due to depletion of these more porous layers by this event. The veins are oriented approximately perpendicular to bedding which is consistent with other examples of clastic-intrusions (Winslow, 1984).

The dominant feature of the outcrop is a series of tectonically related folds. The folds vary in form. Some of the folds are gentle, though most are angular and asymmetrical with mashed zones of ductile deformation at their hinges. In folds without disrupted hinges, beds at the hinges show thickening. In some cases folding is disharmonic or the fold changes shape from a gentle to an angular fold following the axial surface. The variance in hinge forms indicates non-cyllindrical folds, while the disharmonic folding can be attributed to synsedimentary deformation. The interiors of a few folds show localized incidences of highly ductile deformation indicating that tectonic folding may be centered around earlier synsedimentary deformation (Lowry, 1957). Evidence for partially lithified sediments can be seen in the ductile movement of beds and silt at the core of some folds, mashed zones near hinges, and bed thickening in hinge zones.

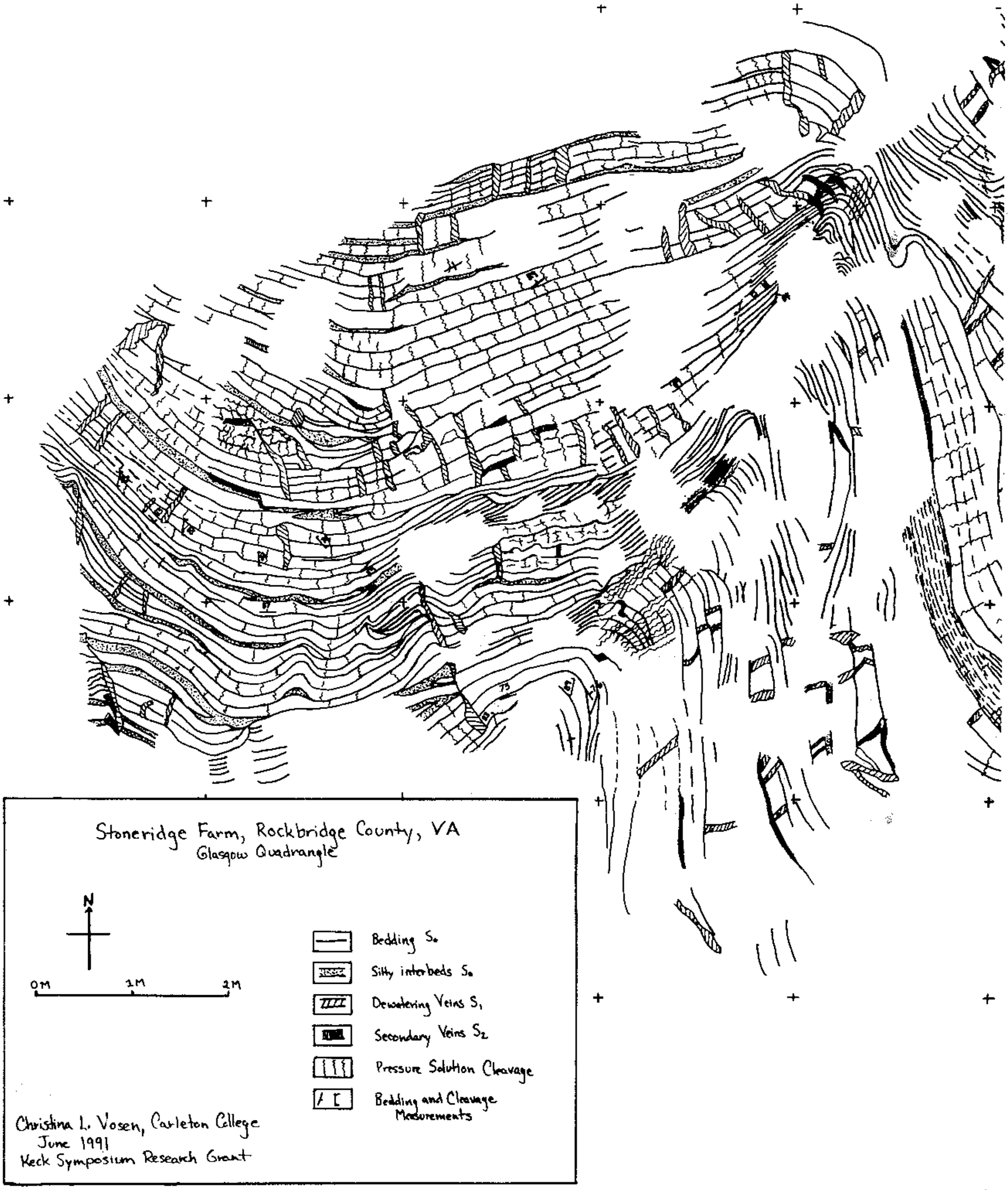
Despite an apparent orientation contrary to the Pulaski-Staunton fault, folding is related to displacement on the Pulaski fault. Stereonet analyses of fold axii indicate noncyllindrical, asymmetrical folds with a variety of orientations. The various orientations, however, fall on a plane striking approximately N10°E very similar to the N40°E strike of the fault. The orientation of fold axii within the fault plane are indicative of discon folds also called drag folds which are formed by friction along the footwall of thrust faults (Suppe 1985). The steep dips of the fold axii may be related to this type of folding, however, structures post-dating folding indicate a later origin.

Related to the folding is pressure solution cleavage. Axial planar and stylolitic, the cleavage typically lies in the same plane as the dewatering veins and in some cases uses the veins as planes of shortening. Pressure solution appears to have continued after the termination folding as the poles to cleavage are more consistent with one another than are those of folded bedding. The intersections of the cleavage planes also line up with the fold axii on the N10°E plane dipping 70°.

A second episode of veining is also associated with folding. This set of veins can be identified by a pure calcite composition colored cloudy white. The crystalline texture is somewhat finer and the edges are distinct boundaries between the calcite and the limestone. They often lie along bedding planes, but also are found within beds approximately parallel to bedding and at fold hinges. These orientations indicate contemporaneous formation with folding. Pressure solution led to an abundance of calcite in solution which was deposited often at fold hinges. As folding continued, bed-slip calcite veins formed. The pressure solution cleavage is found cross-cutting veining which further substantiates the continuing formation of cleavage after folding.

A second, less-developed pressure solution cleavage plane is evident in rock samples oriented roughly parallel to the outcrop surface and perpendicular to the preceding cleavage planes. A related set of veining is composed of a fine-grained fibrous calcite with fibers oriented parallel to bedding planes. Some beds are stepped indicating extension along bedding where a 12 cm thick bed separated along the dewatering veins. These features mark a changing stress field possibly induced by late stage faulting on the Pulaski fault and can explain the steeply dipping fold axii.

Portions of the outcrop exhibit zones of cleavage domination where almost all indications of bedding disappear and a closely-spaced pressure solution cleavage dominates for several square meters. The orientation of this cleavage is roughly north/south and nearly vertical. The cleavage is finely -spaced approximately 4 cm and the rock between the cleavage partings has a finely-laminated texture which can be interpreted as bedding. Dewatering veins are not evident in these areas. The formation of these zones of cleavage domination is puzzling. The zones may be the result of any event in the history of the outcrop: differences in original deposition i.e. a finely-laminated material reacting to stress differently; cleavage formation in area severely disrupted by synsedimentary deformation; dewatering which aligned minerals later used as pressure solution planes; or distortion from the nonparallel folds and subsequent changing stress field centering strain in these areas (Geisen, 1975).


Stoneridge Farm, Rockbridge County, VA
Glasgow Quadrangle
N
0M
1M
2M
Bedding S0
Silty interbeds S0
Dewatering Veins S1
Secondary Veins S2
Pressure Solution Cleavage
Bedding and Cleavage Measurements
Christina L. Vosen, Carleton College
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Conclusions

Sequence of events

-Original deposition within a foreland basin causes initial synsedimentary deformation evidenced by isoclinal folds and discontinuous beds.

-Deposition is followed by burial of the sediments beneath a thrust sheet. High water-content and elevated fluid pressures due to simple loading and fluid migration from below the thrust sheet, lead to the rapid expulsion of water and highly mobile silt from the limestone interbeds. Dewatering veins result.

-With displacement along the Pulaski-Staunton fault, friction causes drag folding of the partially lithified sediments now on the footwall of the thrust-fault resulting in ductile deformation within folds and noncyllindrical folds with varying fold axii. As folding continued, bed-slip calcite veins began to form. Pressure solution cleavage led to highly mobile calcite which was deposited often at fold hinges. With strain hardening, pressure solution cleavage continues to develop.

-Late stage faulting on the Pulaski fault causes fold axii to dip by as much as 80° either by bringing up a wedge of the footwall or simply through the heavier loading of an additional overlying thrust sheet. The changing stress field is marked with the less-developed pressure solution cleavage and extension parallel to bedding indicated by rare veins and stepping beds.

The final analysis relates the multi-phase deformation of this outcrop, veins, folds, steep axii, entirely to the Pulaski fault except for the initial slumping during deposition. The formation of the dominant cleavage zones is still undetermined. Further thin-section analysis and a larger scale map may be necessary to discover the origin of these zones. Areas adjacent to major faults often undergo several phases of deformation which are difficult to separate. The study of this outcrop is representative of the type of detailed work which is necessary to unravel the sequence of deformational event amidst the myriad of possibilities presented.

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