Structural Analysis of Eagle Rock Gap
Botetourt County Virginia

Paul D. Bowyer
College of Wooster
Wooster Ohio, 44691

Introduction

Eagle Rock gap is a water gap formed by the James River in Botetourt county, west-central Virginia. It is located on the eastern margin of the Valley and Ridge Province of the Appalachians. Immediately to the east is the Great Valley of Virginia. The gap consists of two ridges which are held up by sub-vertical ridge forming Silurian sandstones. The ridges are laterally extensive for approximately 5km on both sides of the gap. The gap exposes Upper Ordovician through Lower Devonian strata, exposed units are: Martinsburg shale, Tuscarora quartzite, Rose Hill sandstone/shale, Keefer sandstone, Eagle Rock sandstone (a new name used for Upper Silurian units), Tonoloway limestone, and Oriskany sandstone. This sequence in exposed for 800m along the gap, which is oriented nearly perpendicular to strike. All deformation at Eagle Rock is attributed to the Alleghanian orogeny (Fig. 1).

The primary structure of the gap consists of a large NW dipping fault (refered to in this study as the Eagle Rock fault) which duplicates the section. This fault is on the limb of a large third-order SE verging syncline. This structure is in a region where principal stress was from the SE, thus most major faults would be expected to dip SE.

Eagle Rock is located near the western edge of the Pulaski thrust sheet. The Pulaski is a series of complex Alleghanian thrusts with a minimum total displacement on the order of 100km. The thrust originates southeast of Eagle Rock and propagates upward from depth on a series of decollements and ramps. Uncertainty surrounds the exact relation of the thrust to Eagle Rock, however it is agreed that Eagle Rock is a marginal feature of it.

The purpose of the study is to present a geometric model to explain the evolution of the Eagle Rock structure, with emphasis on the NW dipping Eagle Rock fault which duplicates the Silurian strata.

Previous Models

Several differing models have been presented to explain the Eagle Rock structure. This in itself illustrates the elusiveness of the structures origin. Foremost among the differences in previous descriptions is the displacement sense of the Eagle Rock fault. This fault has been interpreted as both a normal and reverse fault.

McGuire (1970) mapped Eagle Rock as a foot wall block of the Pulaski thrust. In this model, the Eagle Rock fault is formed early in the deformation by a slumping mechanism with normal fault displacement. The structure was then rotated toward the NW by branches of the Pulaski thrust. This rotation resulted in the sigmoidal folding and rotated the Eagle Rock fault to it current NW dipping orientation (Fig. 2).

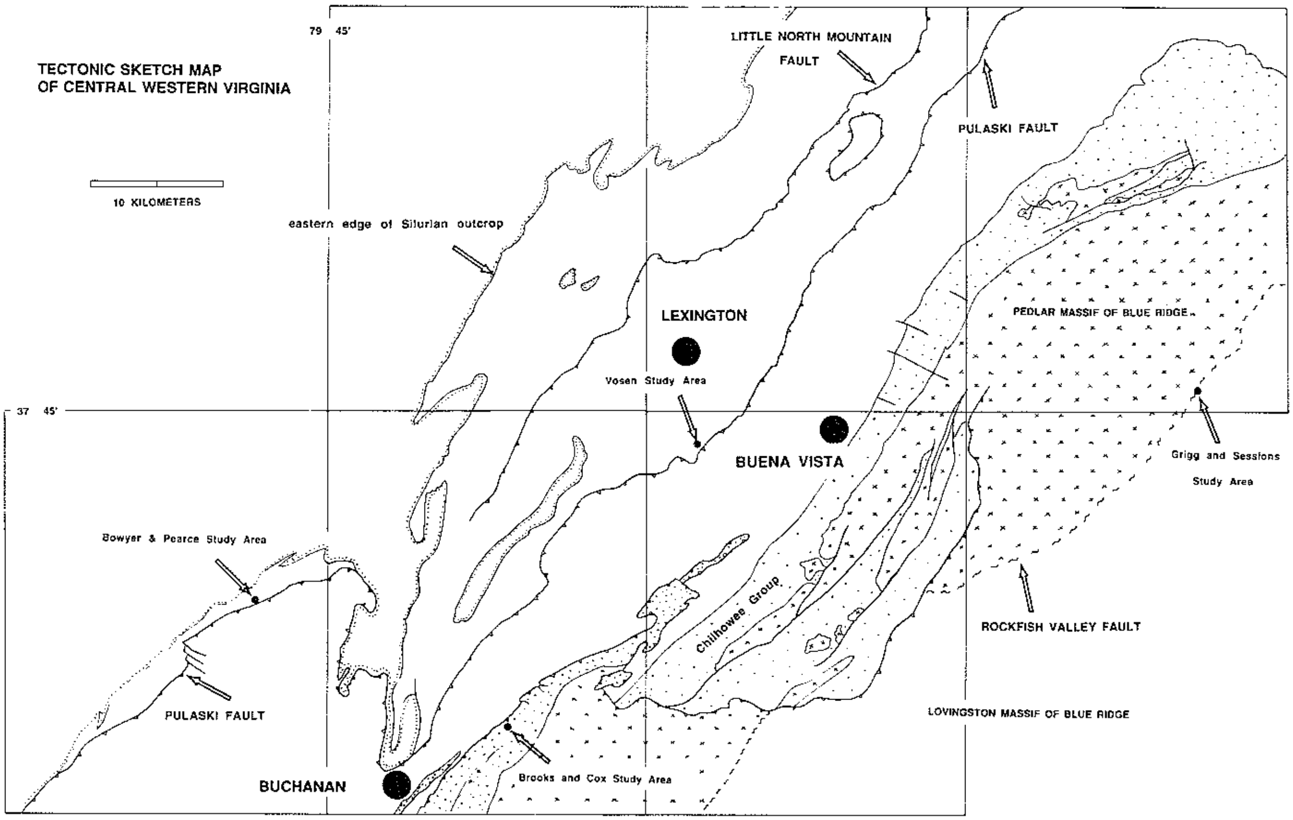
Bartholomew (1982) suggests a similar geometry. In this model the major branch of the Pulaski thrust is shown as running under the gap, thus placing the structure on the hanging wall. As in the earlier interpretation, the Eagle Rock is believed to be a normal fault (Fig. 3.).

Most recently Spencer (1989) described Eagle Rock as a backthrust structure. This requires that the Eagle Rock is a reverse fault. Spencer suggests that a backthrust developed on the Pulaski when it encountered resistance to its NW movement (Fig. 4).

Data

This study is based on data and observations collected in the gap, as well as reference to the previous descriptions, reference to other described occurrences of foreland dipping faults, and with reference to the local geologic map (McGuire, 1970).

Folds analyzed at Eagle Rock consist of the large synclinal hinge in the Keefer and several smaller folds in the Rose Hill. A number of small sigmoidal kink folds in the more shaly layers of the Rose Hill are interpreted as early formed features, forming in sub-horizontal beds. Axial surfaces of these folds strike


TECTONIC SKETCH MAP
OF CENTRAL WESTERN VIRGINIA
10 KILOMETERS
79 45'
37 45'
LITTLE NORTH MOUNTAIN FAULT
PULASKI FAULT
eastern edge of Silurian outcrop
LEXINGTON
Vosen Study Area
BUENA VISTA
PEDLAR MASSIF OF BLUE RIDGE
Grigg and Sessions Study Area
Bowyer & Pearce Study Area
Chilhowee Group
ROCKFISH VALLEY FAULT
PULASKI FAULT
LOVINGSTON MASSIF OF BLUE RIDGE
Brooks and Cox Study Area
BUCHANAN

E.W. Spencer

sub-parallel to bedding and dip 40°SE to bedding when bedding is restored to horizontal. In addition, the NW limbs of these folds dip more steeply than do the SE limbs when restored to horizontal.

The large synclinal hinge in the Keefer has an axial surface orientation of N85°E/36°SE. This hinge is the only measurable large fold in the gap (the upper portions of the gap contain hinge areas but cannot be easily reached). The orientation of this fold fits a NW or SE stress direction but the exact mechanism for this folding is not available from the data. In addition, the data does not show if this large folding predated the Eagle Rock and cross cutting faults.

Analysis of faults at Eagle Rock show three distinct fault types in addition to the major Eagle Rock fault. These are wedge faults, faults perpendicular to bedding, and cross cutting faults.

Wedge faults are common in the Tuscarora and Keefer units. These faults strike sub-parallel to bedding, average strike of these faults as well as bedding is N55°E. Angles to bedding average between 10° to 30°. These faults result in small-scale duplication of beds, displacement ranges from a few centimeters to as much as a meter. Total layer parallel shortening produced by this mechanism in the gap is estimated to be 5%. These faults are interpreted as early formed layer parallel features developed when bedding was sub-horizontal.

A small number of faults are present in the Keefer and Tuscarora which are perpendicular to bedding. These faults are exposed as planar surfaces oriented perpendicular to bedding with well developed slickenlines. Exposures range from a few square centimeters to square meters in area. The slickenlines of the surfaces consistently trend parallel to bedding dip, both in steeply and more shallow dipping beds. These are also believed to be early formed features, resulting from early layer parallel compression in sub-horizontal bedding.

Two sets of cross cutting faults are present throughout the gap and strike sub-parallel to bedding. These faults have a uniform steep dip averaging 70° both to the NW and SE. The NW dipping faults are somewhat more numerous and have greater average displacements. Displacement is dominantly reverse and ranges from nearly no perceived movement to as much as meter. Reverse displacement is seen as clear displacements of beds, however, this is only seen on a limited number of the NW dipping faults and cannot be seen in the SE dipping set. These faults cut across small-scale folds and do not appear to be folded themselves. The exposed lengths however, is not not sufficient to conclude that larger-scale folding has not affected them. Average exposed lengths are one to five meters. The dihedral angle between these two sets is approximately 40°. It is tempting to conclude that these faults represent a conjugate set, however, the reverse motion of the NW dipping faults is opposite that in a conjugate geometry. It is therefore inconclusive from the data whether or not these faults are related. Regardless of this, the dominate NW dipping faults are believed to be the most important mesoscopic features in the gap. Because these faults show reverse displacement and are in roughly the same orientation as the Eagle Rock fault, it is possible that the Eagle Rock is reverse as well. This idea was first put forward by Spencer (1989). Although there is no conclusive evidence which links these small reverse faults to the Eagle Rock, it must be noted that this is the only available observation within the gap which may indicate the regional motion sense of the Eagle Rock fault.

The Eagle Rock fault is visible only as a complexly fractured zone in the Tuscarora quartzite. No direct data on this fault can be measured, however within the large-scale structure of the gap and the geologic quadrangle (McGuire, 1970), it can be inferred that this fault strikes sub-parallel to bedding and dips approximately 60° to the NW. A number of small fault surfaces in the Tuscarora at the fault zone were measured. These show a wide range of orientations, with the most numerous surfaces trending sub-parallel to bedding strike. This would suggest that there has been some degree of strike-slip motion on the Eagle Rock. This, however, is unconfirmed or supported by any other available data. If there is a component of strike-slip motion on this fault, it is interpreted as limited in magnitude relative to the dip-slip displacement. This is supported by the small-scale of these fault surfaces, and analysis of bedding, fault, and fold data from both sides of the Eagle Rock fault which shows little to no change in orientation across it. Unlike the smaller cross cutting faults, the Eagle Rock fault is shown by other authors to be folded near the top of the ridge.

Interpretation

At road level in the gap, no conclusive or compelling evidence exists which shows relevance to the structures origin. The set of NW dipping reverse faults are believed to be late stage features, forming after the Eagle Rock fault. Based on regional information from McGuire's mapping, Eagle Rock is interpreted as a forward-dipping duplex which forms an antiformal stack. This model constrains the Eagle Rock fault to be a folded thrust with a present-day apparent normal fault displacement. This geometry is similar to a model described by Diegel (1986) in Tennessee.

References cited

Bartholomew, M. J., Schultz, A. P., Henika, W. S., and Garthright, T. M., II, 1982, Geology of the Blue Ridge and Valley and Ridge at the junction of the central and southern Appalachians, in Lyttle, P. T., ed., Central Appalachian Geology: American Geological Institute, p. 143-146.

Diegel, F. A., 1986, Topograpical constraints on imbricate thrust networks, examples from the Mountain City window, Tennessee, U.S.A.: Journal of Structural Geology, v. 8, No. 3/4, p. 269-279.

McGuire, O. S., 1970, Geology of the Eagle Rock, Storm, Oriskany, and Salisbury quadrangles, Virginia: Virginia Department of Mines, Minerals and Energy, Division of Mineral Resources, 39 p.

Spencer, E. W., 1989, Valley and Ridge and Blue Ridge Traverse, Central Virginia, Field Trip Guide Book T157, 69 p.

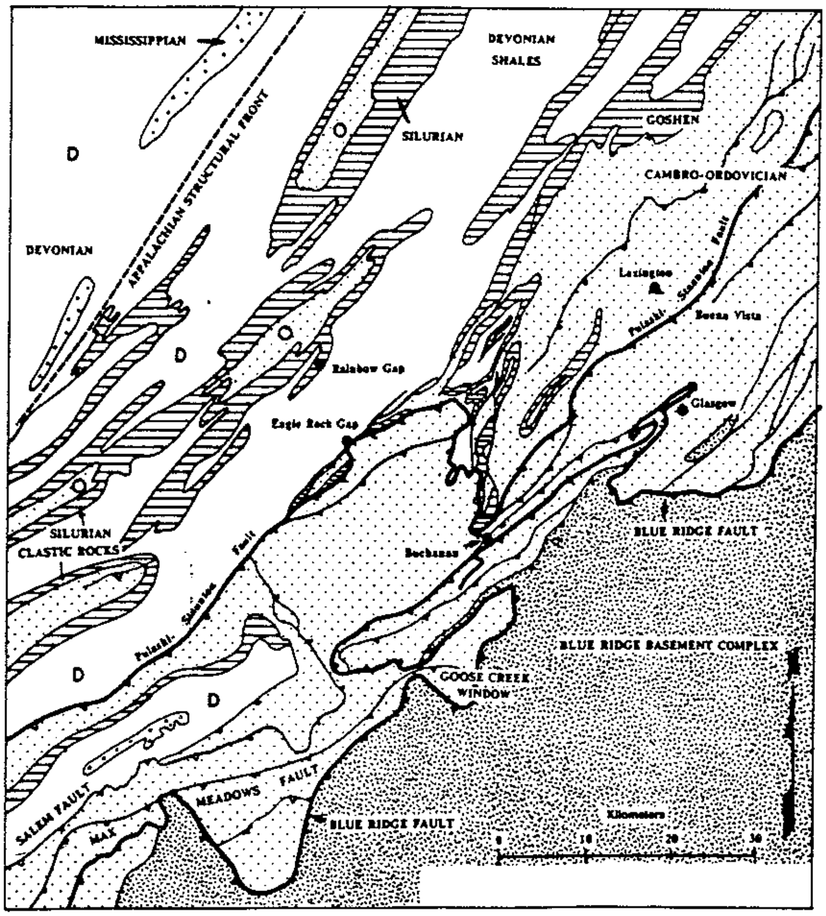


Fig. 1 Regional map showing relation of Pulaski thrust to Eagle Rock gap (after Spencer, 1989).

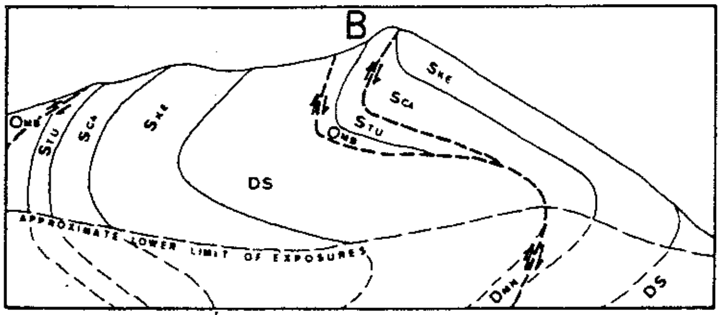


Fig. 2 Schematic section through Eagle Rock gap
by McGuire (1970).

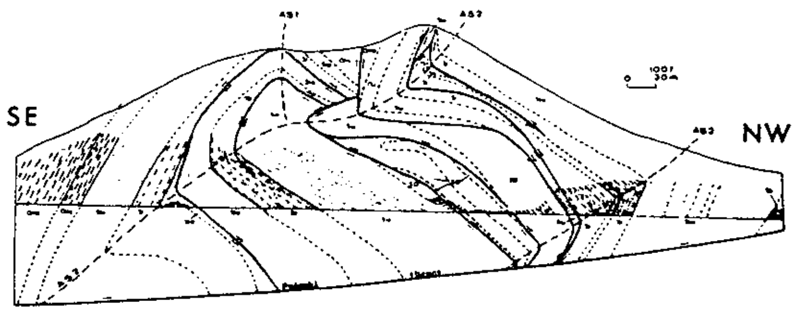


Fig. 3 Schematic section through Eagle Rock by
Bartholomew (1982).

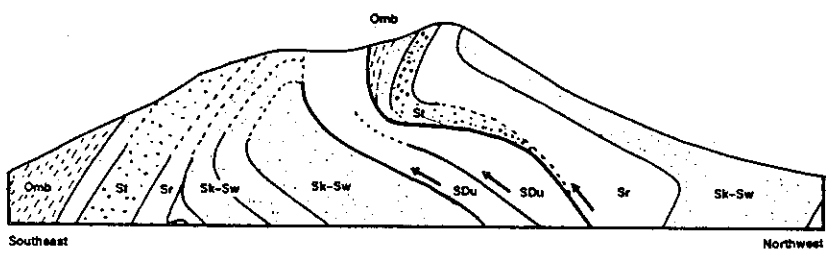


Fig. 4 Cross Section through Eagle Rock gap
Showing backthrust geometry (Spencer, 1989).

A Comparison of Brittle and Ductile Basement-Deformation Models Through Study of the Basement-Cover Relationship on the Blue Ridge Near Arcadia, Virginia

Derek Brooks
Carleton College

Introduction: The Blue Ridge is a five to ten mile wide anticlinorium running from Georgia to Maryland. It is characterized by a core of Middle Proterozoic gneissic basement rocks flanked to the NW and SE by younger, late Proterozoic and Early Paleozoic sedimentary and volcanic units. Emplacement of the Blue Ridge occurred during the Alleghanian orogeny of the late Paleozoic by means of NW-directed thrust faulting. Near Arcadia, Virginia, the Cambrian sedimentary Unicoi and Harpers units lie on the NW flank of the Blue Ridge in unconformable contact with the basement complex. The Unicoi is locally between a few hundred to a thousand feet thick (Spencer, 1968) and contains shales, some interbedded with sandstones, as well as arkoses, pebbly quartzites, welded tuffs, metabasaltic dikes and sills (or flows?) and a basement-derived conglomerate. The highest pebbly quartzite in the Unicoi is defined as the border between it and the Harpers unit (Bloomer and Werner, 1955), which consists of shales and pearly quartzites. The only mapping and geologic interpretation of the area was done by E.W. Spencer in 1968 as part of mapping the Arnold Valley Quadrangle. That report does not cover the basement-cover relationship in detail.

My project is an interpretation of the basement-cover relationship on the Blue Ridge near Arcadia with the aim of better understanding the basement's deformational style. Two models are proposed. In the first, the basement and cover fold together as ductile units. In the second, the basement deforms brittlely and the cover drapes into folds over it. The basement's lithology supports brittle rather than ductile deformation; it is a crystalline rock without any potential slip surfaces such as bedding planes that would allow ductile deformation such as folding to occur under stress. By studying the basement-cover relationship in detail I am attempting to determine if the basement deformed brittlely as its lithology implies it did.

Field Observations: My field research consisted of mapping basement-cover contact features and measuring attitudes of beds, cleavages, and folds. Figure 1 shows these features. Basement-cover contacts are labeled 1-6, the first two of which are visible and the other four inferred. Two types of penetrative (slaty) cleavage are prominent in shales: a cleavage running parallel to the bedding plane and one cutting it obliquely. The former is presumably a feature of vertical compression. The latter presumably represents axial planar cleavage from folding. Exposures that reveal an axial planar cleavage/bedding relationship and exposures where stratigraphic up can be inferred from sedimentary features are marked C, D, E, etc. Folds are overturned to the northwest and have wavelengths ranging in size from a meter to ten meters.

Interpretation: Five of the basement-sediment contacts indicate some kind of fold relationship. The sixth, on the Appalachian Trail, is of too poor a quality to serve as anything other than a control point. Figure 2 exhibits the features of these contacts as a schematic diagram. The western basement exposure in Figure 2 combines Contacts 1 and 2, and the eastern basement exposure combines Contacts 3, 4, and 5. The contacts were combined because they are from the same basement belts and have similar features.

One of these features clearly supports the ductile basement model. On the western contact (see Fig.2), the cleavage in the adjoining sedimentary rock is axial planar as would be expected from folding.

Several features, however, serve to weaken the ductile model. First, the cleavage in the cover rocks on the eastern contact (see Fig.2) is not axial planar as would be expected had folding occurred there. Second, there is no axial planar cleavage in the western basement exposure (see Fig.2); if the basement was ductile enough to be folded, why wasn't it ductile enough to be cleaved? Third, there is no basal conglomerate adjacent the western basement; a depositional contact should remain so throughout folding. The conglomerate is too thick (1ft.) and too coherent to be pinched out during folding.

Note that this model involves a dextral strike-slip motion in the basement and cover to accommodate the orientation of the beds, cleavage, and basement-cover contact at Area One. There, these features strike E-W, a position that is not compatible with the highly regular regional Appalachian sense of NW directed tectonic transport. A further degree of NW transport of the rocks marked "G" (see Fig. 3) than at "H" would pull the intervening rocks into their E-W striking position. This strike-slip motion could easily arise from the irregular contact between the compressing North American and European/African continents, which caused some areas to thrust further than others. This dextral strike-slip motion does not affect the strength of this model in any way; it only makes the map clearer to interpret.