ANALYSIS OF SMALL-SCALE LAYER PARALLEL SHORTENING IN THE GREAT VALLEY OF THE CENTRAL APPALACHIANS, VIRGINIA

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Introduction

Previous balanced cross-sections constructed across the Great Valley and Valley and Ridge of Virginia, have depicted deformation on regional scales. This shortening comes in the form of immense thrust sheets that are folded, faulted, and stacked along major detachment horizons. What is not represented in these reconstructions is the magnitude of layer parallel shortening that occurs on a local scale. Second and third order folds, faults, and pressure solution cleavage are prevalent throughout the individual master thrust sheets and are the source of considerable unaccounted shortening. The primary purpose of this study is to examine and describe the subordinate structures formed within the major North Mountain thrust sheet in the Great Valley of Virginia. A balanced cross-section across a portion of the North Mountain thrust sheet was constructed and restored to provide a quantification of the amount of shortening that has taken place. Using a method described by Epard and Groshong (1993), an attempt was made to calculate the depth to the detachment using this detailed profile.

Geologic Setting

The Great Valley is a narrow, topographically low region that lies between the Blue Ridge and the Valley and Ridge and consists of Cambro-Ordovician carbonates and shales. This area of study is located within the zone of transition between the Central and Southern Appalachian structural belts. The transition is seen as a shift in the style of Alleghanian-age (Late Paleozoic) deformation of the sedimentary cover. The dominance of folding, typical of Central Appalachians structure, terminates in this zone, and is accommodated by thrusting, typical of Southern Appalachian structure.

The North Mountain Thrust Sheet

In the region of study, three major and distinct, stacked allochthonous thrust sheets are recognized to have imbricated from a basal detachment. They are the Waynesboro, the Massanutten-Blue Ridge, and the Pulaski-North Mountain thrust sheets (Kulander and Dean, 1988). The Waynesboro is the lowermost thrust sheet in the Great Valley and is not exposed in this region but remains as a blind thrust underlying much of the area to the west. The basal detachment of the Waynesboro is seated in the Lower Cambrian Rome Formation. Development of these thrusts are sequential from east to west

The Massanutten-Blue Ridge thrust sheet is recognized by Kulander and Dean (1988) to be the initial thrust sheet to develop and transport Cambro-Ordovician rocks westward during the Alleghanian episode. Rocks of the Precambrian basement are interpreted to have been transported by this master thrust sheet, forming the Blue Ridge complex. This thrust sheet terminates in the Blue Ridge about 15 km southeast of the study area. The Pulaski-North Mountain thrust is folded by the sequentially youger Massanutten thrust, which has allowed for a continuation of westward displacement of the Cambro-Ordovician rocks. Kulander and Dean (1988) indicate that the movement of the North Mountain thrust sheet decreases from northeast to southwest, while the Pulaski fault displacement increases from northeast to southwest, implying a fault displacement transfer. These two faults link in the subsurface to the east. The structural section was measured between the outcropping North Mountain Fault 2 miles to the northwest, and the outcropping Pulaski thrust 2-3 miles to the southwest.

Stratigraphic Setting

The structural profile measured in this study is dominantly developed in beds of the Edinburg Formation (Middle Ordovician). Spencer and others (1989) described the Edinburg Formation as dark-gray to black limestone interbedded with black, fissile, calcareous shale. The Edinburg Formation represents a shallow, tropical sea deposit; a component of the ancient carbonate bank that formed along the eastern margin of North America prior to the Taconic Orogeny.

Research Methods

Strike and dip measurements of bedding were taken along the Route 251 roadcut (Fig. 1), which parallels Buffalo Creek, just northwest of Lexington. Conveniently, the roadcut runs nearly perpendicular to the regional strike, allowing for minimal distortion in the construction of the cross section. A tape measure was laid down along the road so that precise distances between stations could be recorded. Readings were taken about every fifteen feet or in places where there was a change in the structure. Several samples displaying solution cleavage were collected and analyzed to determine if there is sufficient volume loss to create problems in balancing the cross-section.

The folds clearly displayed chevron geometry, consisting of long planar limbs and narrow fold hinges. Thus, the cross section was constructed by establishing dip domains, and the intersection of these dip domains marked the axes of the folds. Within a couple of the dip domains, the dip of bedding shifts to a steeper or shallower dip, demonstrating that there are kinks in the limbs of the folds. To construct this profile, it was necessary to kink the fold hinges, as well, in order to maintain a consistency of bedding thickness.

There are a number of limitations that arise when constructing a balanced cross-section in an area of intense deformation. Ideally, the line of section should extend outside the deformed zone in order to establish pin lines for accurate restoration of bedding. However, this condition could not be satisfied in this case. Instead, pin lines for restoration of individual beds were arbitrarily established in the axes of two major folds. An attempt was made to determine the depth to detachment using Epard and Groshong's (1993) excess area method. However, since there are no undeformed locations for pin lines, values calculated to depth of detachment were spurious. Another problem encountered, is that no key beds could be traced throughout the outcrop to verify the accuracy of the constructed cross-section. Observation of numerous outcrops throughout the area confirm the highly folded profile construction.

Interpretation of Data

Chevron folds of high frequency, such as those depicted in the cross section, suggests that these are fault propagation folds. In such structures, each fold is cored by a fault that has imbricated from a basal detachment zone. The tips of such faults must lie below the road level, as only a few very minor faults occur in the section. Folds are oriented with fold hinges plunging S27°W at 11°, and axial surfaces dip at approximately 40°-60° to the southeast. Northwest facing anticline limbs are vertical to overturned at 70°, and southeast facing anticlines dip at 20°-50°.

Construction of the cross-section (Fig. 2) clearly demonstrates significant shortening within this portion of the North Mountain thrust sheet. Restoration of the bedding to its original planar sequence, revealed a 55% layer parallel shortening due to folding alone. Within the tight hinges of two folds, solution cleavage accounted for an additional, local 20% volume reduction. Layer parallel shortening at this scale should be considered when attempting to quantify the extent of Alleghanian-age deformation in the Appalachians.

References

Epard, J., and Groshong, R. H., 1993, Excess Area and Depth to Detachment: AAPG Bulletin, v. 77/8, p. 1291-1302.

Kulander, B. R., and Dean, S. L., 1988, The North Mountain-Pulaski fault system and related thrust sheet structure, p. 107-118. In: Mitra, G. and Wojtal, S. (eds.), Geometries and Mechanisms of Thrusting. The Geological Society of America Special Paper 222.

Spencer, E. W., Bell, D. J., and Kozak, S. J., 1989, Valley and Ridge and Blue Ridge Traverse, Central Virginia, Field Trip Guide Book T157. 28th International Geologic Congress, 69 p.

Figure 1. Index map showing stuctural section (heavy line) along Route 251. Note north-south overturned fold located west of the section; axis passes through Kiger Hill. (Taken from Spencer, 1967)

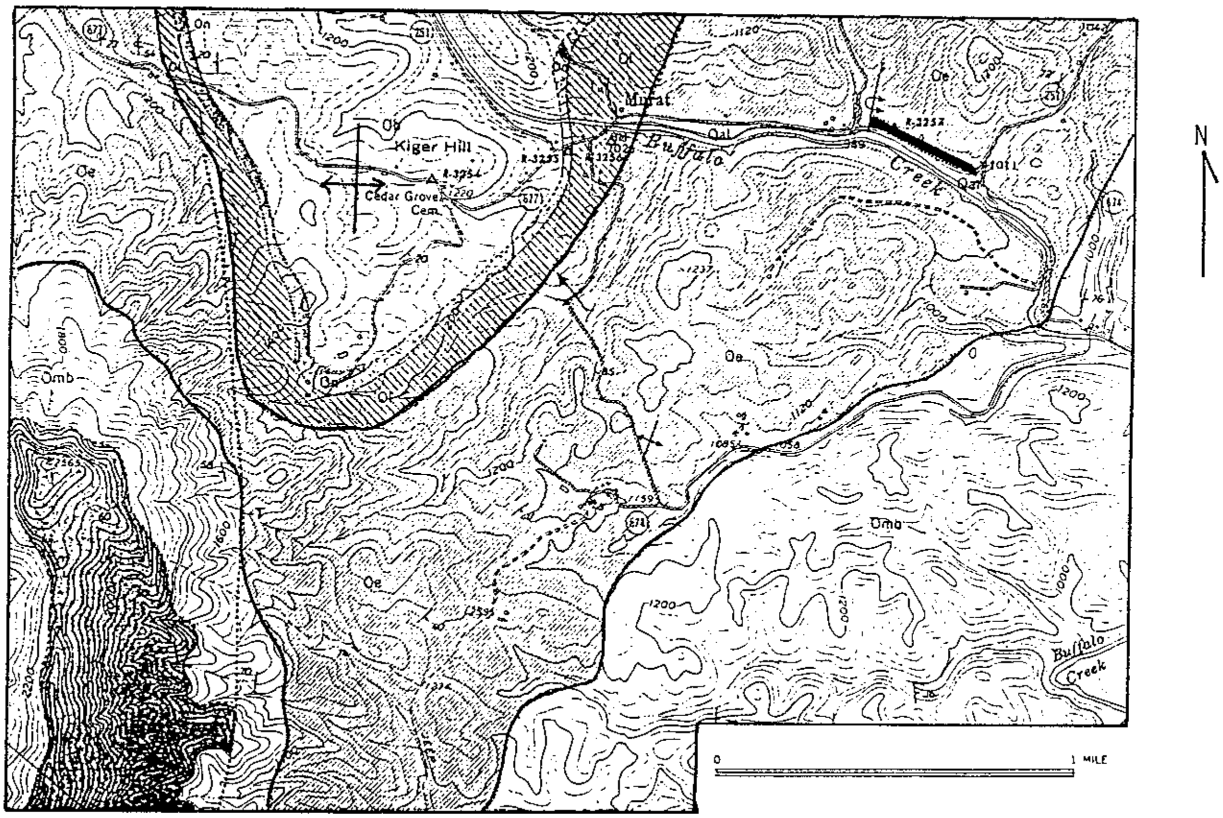

Figure 2. Constructed cross section between stations 1 and 34 along Route 251. Note chevron form of folds and subvertical to overturned northwest facing anticlinal limbs.

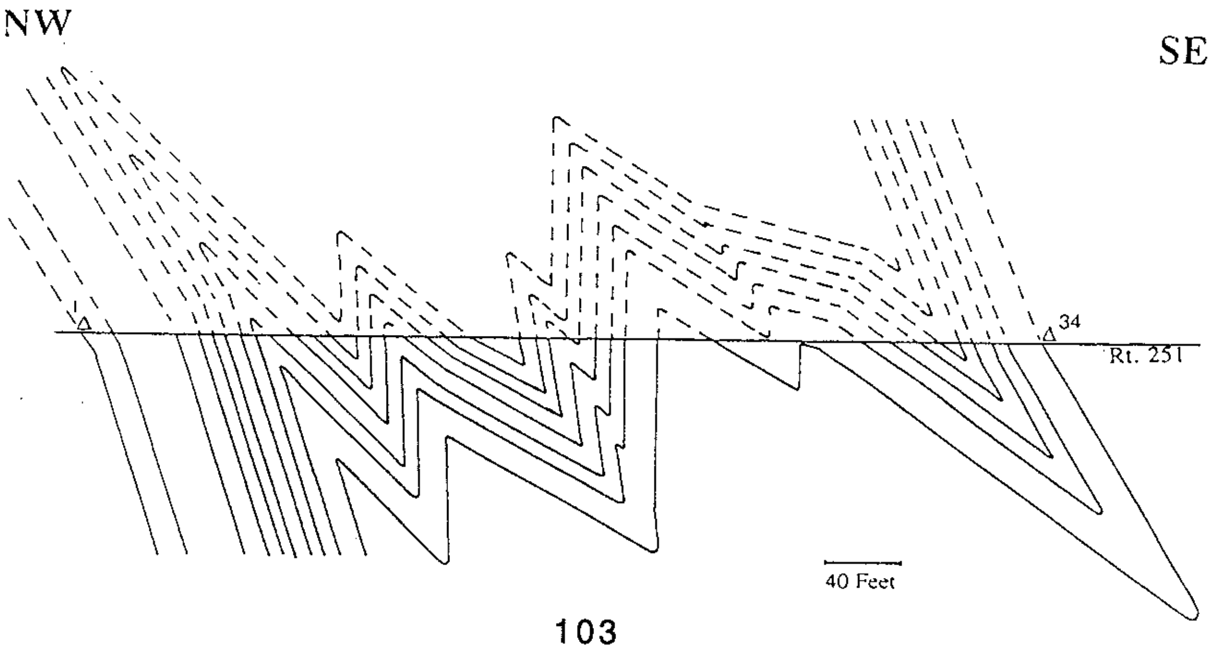

Figure 3. Schmidt lower hemisphere equal area plot of poles to bedding using measurements between stations 1-34. Great circle defines a fold axis plunging S27°W at 11° (shown by open circle at base of great circle).