An Examination of Length Shortening at Various Scales: Applications to a Cross Section of the Central Appalachians, Virginia

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INTRODUCTION:

This study examines four different scales of length shortening in the Great Valley Province of the Central Appalachians. Prior cross section analyses by Kulander and Dean 1988 and Bartholomew 1987, of the Central Appalachians in Virginia have resulted in estimates of length shortening at a macroscopic scale. These studies are limited in their accuracy since different scales of shortening are not accounted for in large-scale cross section work. Assumptions necessary to balancing a section are problematic in application to the Central Appalachian.

The different scales of shortening were part of a 10 kilometer cross-section that was constructed for this study. The line of section was defined by Buffalo Creek which runs from the northwest to the southeast, across the trend of deformation. The field area lies southwest of Lexington and Buena Vista, Virginia. Field data was confined to surface data, for a lack of drill and seismic work done in the area.

The deformation in the area is Alleghenian in age (Pennsylvanian). The trend of deformation is northeast to southwest, perpendicular to Buffalo Creek. Faulting in the area is characterized by imbricate thrusts dipping to the southeast, and trending northeast to southwest great distances along deformation. Two of these faults are the Staunton Pulaski Thrust (SPT) and the North Mountain Thrust (NMT). These two thrusts define the two thrust sheets central to my area. The footwall of the SPT is the Massanutten Blue Ridge sheet while the hangwall of the SPT defines the Pulaski Thrust sheet. The amount of displacement has been calculated along these thrust is as follows, 20 km along the SPT, and 72 km displacement of the Pulaski Thrust sheet. (Kulander and Dean, 1988). While Bartholomew's (1987) calculations predict 110 km displacement of the Pulaski Thrust sheet.

Structure is characterized by large décollement, and thrust sheets of anticlines and synclines. The system of thrusting has been studied extensively by Kulander and Dean (1986). They classify three thrust sheets, 1) the Pulaski, 2) the Massanutten Blue Ridge (MBR), and 3) the Waynesboro sheet. The Waynesboro sheet is in the décollement zone and is in the area of study only at depth. The MBR sheet makes up the northwest section of the study area as the hangwall of the SPT. The Pulaski Sheet has been displaced the greatest distance and is defined as the hangwall of the SPT. This sheet makes up the southeast section of the study area. (see figure 1)

ANALYSIS:

Shortening was studied at four scales, 1.) along a 10 km cross section, 2.) across a 300 m outcrop, 3.) at the scale of 10 cm wavelength small folds and 4.) microscopically, on the hangwall and footwall of the Staunton Pulaski Thrust (SPT).

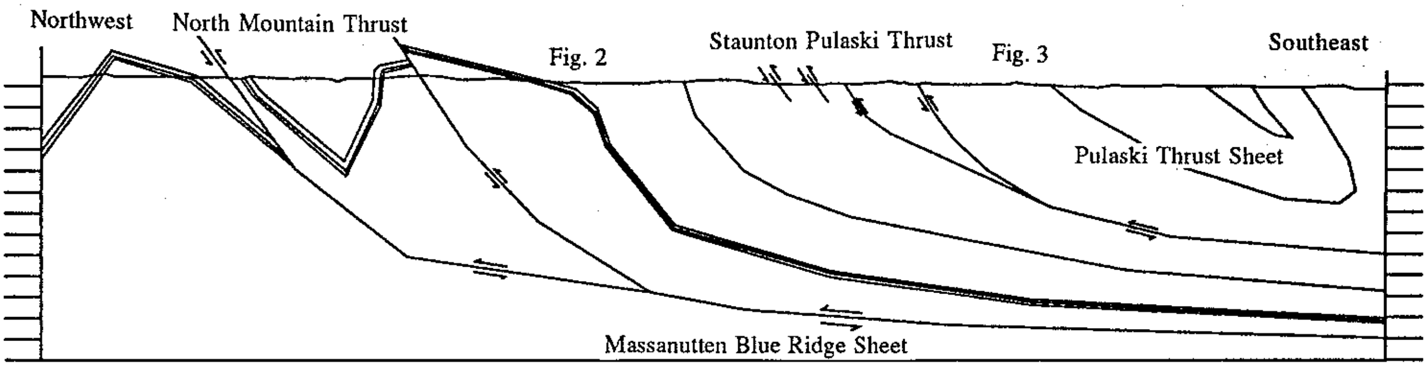

Figure 1. Cross Section along Buffalo Creek. Lincolnshire and New Market limestones are the set of closely spaced units. Study locations are indicated above. The Pulaski sheet is the hangwall of the Staunton Pulaski Thrust while the Massanutten Blue Ridge Sheet is defined as the footwall. The Waynesboro sheet is 15,000 feet below the surface and is not visible in this figure. Shortening = 48%
Scale is distorted due to publication.
N52W No vertical exaggeration. 1:24000 Increments are 1000 feet

The footwall of the Staunton Pulaski Thrust is the focus of three of the scales of magnitude examined. The three scales examined are 1.) cross section, (see figure 1), 2.) outcrop scale (see figure 2) and 3.) microscopic-dissolution. The units in this area are bluish Ordovician limestones and shales, and display classic brittle-ductile bed deformation relationships in the form of cleavage refraction.

The cross section was constructed based on field data assuming kink fold geometries. Line length balancing methods were used in estimating shortening at cross section scale. These methods assumed uniform bed thickness and uniaxial strain, even though these assumptions are problematic considering the extensive evidence for penetrative deformation. Restoration of the section allowed the evaluation of the percentage shortening in two Ordovician units, the Lincolnshire and New Market limestones (see figure 1). At the scale of the 10 km cross section the shortening was examined in the footwall of the SPT. Restoring the cross section indicated 48% shortening in these units across the cross section. The limitation of this examination of only two units requires examination at a smaller scale.

The second scale was a 300 meter outcrop. This outcrop of Ordovician Edinburg limestone, overlies the Lincolnshire and New Market limestones. Shortening on this scale is small enough that it does not appear in the calculations of the first scale in kilometers. Field methods entailed laying a measuring tape along the outcrop and taking detailed notes and sketches. A cross section was drafted of the outcrop using kink fold geometry construction (see diagram 2). Retrodeformation of faults and folding indicated 54% shortening in this unit. The intensely deformed outcrop (figure 2) lies on the southeast limb of a large anticline. A comparison of the style and intensity of deformation between this outcrop and where it lies in the large section (diagram 1) indicates that shortening at a magnitude of meters is not considered in calculations of shortening in kilometers.

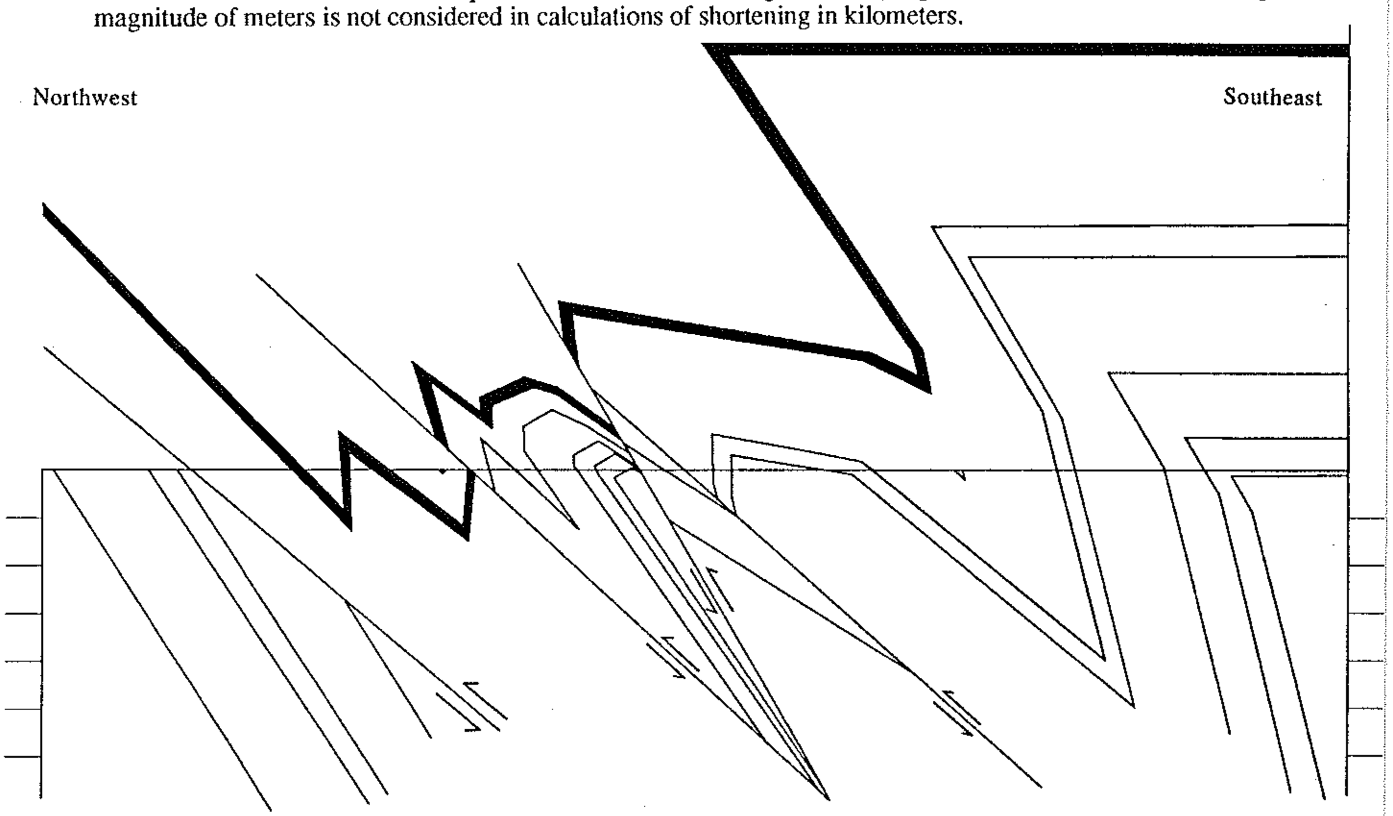

Figure 2. Cross Section of Ordovician Edinburg Limestone along Route. 251. Key bed is shaded black. Shortening= 54% Scale is distorted due to publication.
N55W No vertical exaggeration. 1:480 Increments are 40 feet

The third scale was at a microscopic level and looked at dissolution along cleavage surfaces within three fold hinges. Samples were taken of the Ordovician Edinburg limestone from the outcrop in figure 2, cut to uniform size and dissolved in hydrochloric acid. In the samples one-centimeter thick cleavage planes occurred every 5 cm. Within these five centimeters, six smaller cleavage planes were found with widths of .2 cm. Dissolution of the microlithons indicated 20% clay and silt material in the limestone. A plane of one centimeter thick cleavage was dissolved and revealed that 55% of the material in the cleavage plane was clay and silt. Calculations using these compositions resulted in an approximate shortening of 23%. Calculations for this percentage assumed no dissolution within the microlithon. The presence of the six smaller planes of cleavage confirms that shortening through dissolution did occur within the microlithon. Therefore, the percentage shortening on this scale is only a minimum. Again, shortening at this scale is not considered in calculations in scales of meters or kilometers. Another shortcoming of dissolution calculations is the relocation of the material that is treated as, essentially dissolved mass. These calculations only consider a two dimensional plane of dissolution while in fact, dissolved material remains in the system.

Deformation in the MBR sheet in the hangwall of the SPT was characterized by isolated small scale ductile deformation amidst large thrust bounded structure. The ductile style of deformation indicates great pressures and is evident by the presence of sheath and ptigmatic folds (see figure 3). Because of the ductility of the deformation shortening was examined at a more detailed scale by examining centimeter scale folds of the Cambrian Conococheague limestone. The fourth scale is in the order of magnitude of centimeters on the outcrop. Deformation of units in the hangwall of the SPT are characterized by large anticlines and synclines with isolated intense areas of micro structural deformation in hinges of folds. Photos were taken within 100 m of each other along fold axis in a hinge of an anticline. Twenty five micro units were measured in the photographs and retrodeformed. Shortening calculations indicated average shortening of 67.9 %, with as much as 94.2% and as little as 33.8% shortening occurring in micro units. Samples for thin sections were taken in this area and will be examined with the aim of calculating percentage shortening at a microscopic level.

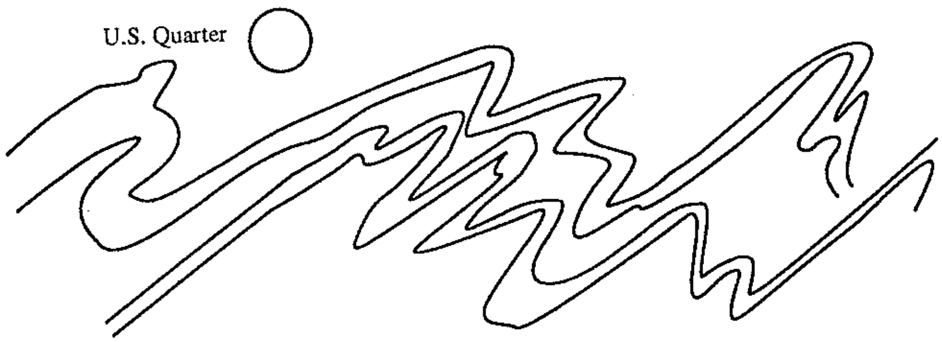

Figure 3. Trace of ductile micro units within a fold hinge in Cambrian Conococheague limestone.

CONCLUSIONS:

1.) At a macroscopic scale (in kilometers), 48% shortening was calculated for the Ordovician Lincolnshire and New Market limestones.
2.) At outcrop scale (in meters) 54% shortening was calculated for the Ordovician Edinburg limestone.
3.) 23% Shortening through dissolution was calculated for the Edinburg limestone.
4.) 67.9% shortening was calculated at a centimeter scale for the Cambrian Conococheague limestone.
5.) Large scale interpretations of percentage shortening within thrust sheets cannot be accurate unless a spectrum of micro to macro structures are analyzed.
6.) Percentage shortening in general will be greater than predicted in the Central Appalachians due to penetration of deformation.
7.) SPT hangwall deformation is characterized by intense isolated micro structure amidst large scale structure.
8.) SPT footwall deformation is characterized by meso and macro scale structures.
9.) Assuming consistent bed thickness is problematic, considering the amount of meso and micro structural deformation and dissolution that has occurred in the units within the study area.

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A Magnetic Survey of Precambrian Greenstones and Cambrian Clastic Sedimentary Rocks of the Chilhowee Group, Blue Ridge Mountains, Virginia.

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INTRODUCTION

The Blue Ridge Mountains extend more than 1000 kilometers from Georgia to Pennsylvania. The location of the magnetic survey conducted in this project is located approximately 10 kilometers east of Lexington, Virginia and is within the Blue Ridge complex. This complex is a northeast plunging anticlinorium containing a core of Grenville-age, high-grade gneisses which are flanked and overlain by a cover of late Precambrian and Paleozoic meta-sediments and meta-volcanics. The purpose of this research project was to determine whether magnetics is a viable tool for mapping on a small scale within the Blue Ridge Complex. Two traverses are compared in this study: (1) a transect from the Lynchburg reservoir area which is underlain by well exposed outcrops of Cotoctin greenstones and (2) a transect from the Beverlytown area which has generally poor exposures.

ROCK UNITS

The primary rock units in the survey area are the Virginia Blue Ridge basement, the Swift Run, the Cotoctin Formation, and the Chilhowee Group, consisting of the Antietam Formation, the Harpers Formation and the Unicoi Formation. The basement rocks of the Virginia Blue Ridge consist of Precambrian granite, hypersthene granodiorite, charnokite and unakite. The Precambrian Swift Run Formation (0-120 m) contains primarily greywackes, sub-greywackes and volcanics. The Cotoctin Formation (0-300 m) consists of greenstone with greywackes, arkoses and tuffs, is Cambrian-Precambrian in age, and is associated with the initial rifting of the ancestral Atlantic Ocean at about 650-600 Ma. The Unicoi Formation, the oldest formation in the Chilhowee Group includes greywacke, sandstone and pebble conglomerate with a few tuffaceous beds. Overlaying the Unicoi is the Harpers Formation (300-500 m) with laminated shales, greywacke and quartzite. The Antietam (125-200 m), the youngest formation of the Chilhowee Group, is a thin-bedded to massive buff and blue-gray to white sandstone and quartzite with a few thin beds of shale (Spencer, 1992). The clastic rocks of the Cotoctin Formation as well as the Chilhowee Group are indicative of clastics associated with rift basins. Also of note is a ductile deformation zone (DDZ) which is a braided zone of mylonite, and cataclasite running perpendicular to the Beverlytown traverse. This zone is approximately 100 yards wide and is highly deformed.

FIELD METHODS

Along with two other colleagues I collected magnetic total-field values with a proton precession magnetometer in three separate areas. The approximate location of our work is between 79°13' and 79° 20' west longitude and 37°35' and 37°42' north latitude. These three areas are: (1) the Oronoco area, (2) the Lynchburg Reservoir area, and (3) the Beverlytown area. A total of 23 traverses were completed over a three week period. Diurnal variation was determined by taking readings of a base station at the beginning and the end of each traverse. The diurnal variation was +/- 0.75 nT/ 15 minutes.

Traverse lengths ranged from approximately 3,000 feet to approximately 20,000 feet with a reading was taken every 100 feet. When a large anomaly was recorded between consecutive stations, reading intervals were changed to 25 feet in order to more completely define the point at which the large anomaly occurred. Culverts, piping, metal guard rails, telephone and power wires were noted and readings within 25 to 50 feet of these disturbing influences were discarded because of the anomalous readings they created.