Structural Geology of the Allegheny Front near Chimney Rocks Park, Hollidaysburg, PA

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Introduction

Chimney Rocks Municipal Park, Hollidaysburg, PA is located in the Valley and Ridge structural province of the Appalachian Mountain belt and only a short distance from the Allegheny Structural Front. The Allegheny Structural Front separates the Valley and Ridge province from the Appalachian Plateau province and is located approximately 6 miles to the west of Chimney Rocks Park (Figures 1 and 2). The stratigraphy across the regions is fairly consistent: Precambrian crystalline basement below Lower Paleozoic carbonate platform deposits which grade into Upper Paleozoic siliclastic basin deposits. Deformation of the region took place during the Late Paleozoic Alleghenian Orogeny. However, structural geology and deformation styles present in the rocks are dramatically different on either side of the Allegheny Structural Front. Many scenic overlooks at Chimney Rocks Park are west-facing giving spectacular views of the physiographic expression of the Allegheny Front. The following summarizes the structural styles found in the Appalachian Plateau, the Valley and Ridge, and the Allegheny Front with particular attention paid to those features visible at Chimney Rocks Municipal Park.

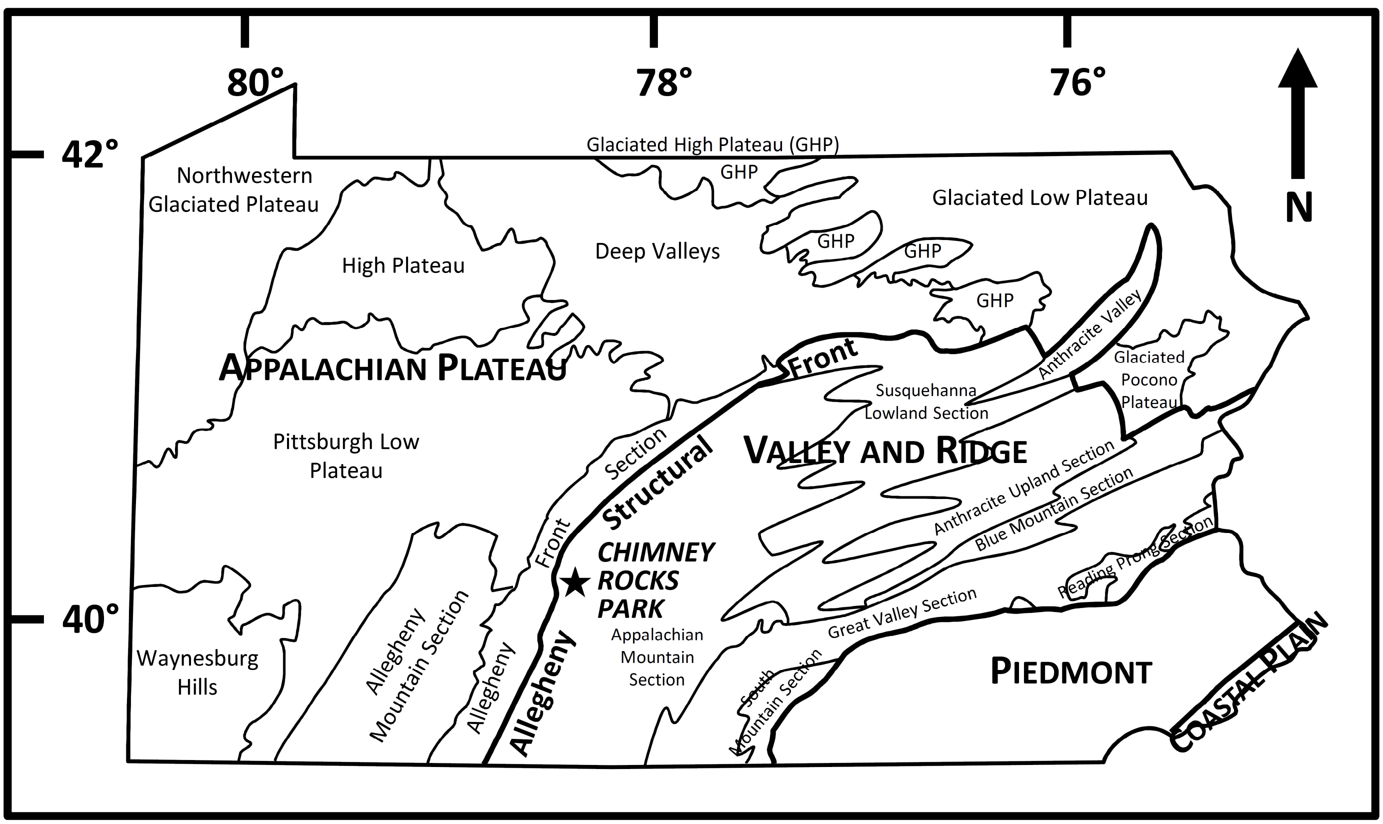

Figure 1. Generalized physiographic/structural provinces of Pennsylvania (Berg et al., 1980). *Note:* Chimney Rocks Municipal Park is shown by the star near the center of the map.

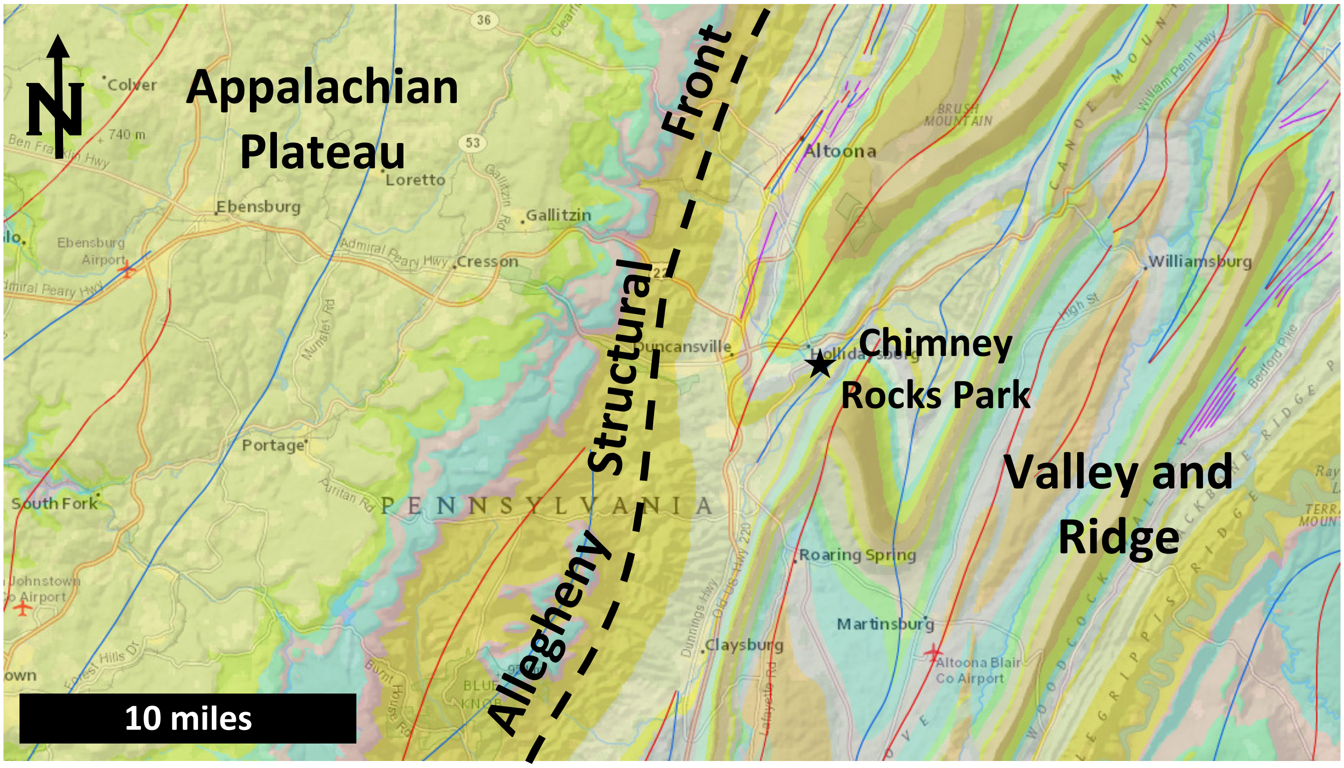

Figure 2. Geologic map of the Chimney Rocks vicinity obtained from the Pennsylvania Geologic Data Explorer (PA-GEODE): Pennsylvania Geologic Survey Interactive Map. Solid colors indicate different geologic units. General structural geology can be inferred by the blue (synclines) and red (anticlines) lines on the map.

Appalachian Plateau

The Appalachian Plateau is the westernmost province of the Appalachian mountain belt and stretches from Alabama to New York. The plateau province comprises almost entirely sedimentary rocks in gentle folds with large wavelengths and amplitudes that decrease to the northwest (see Figures 3 and 4). The Appalachian Plateau is characterized by broad, low, open folds with dips ranging from 20° to less than 5° (Harper, 1989; Beardsley et al., 1999). Wavelengths of the folds range from 5 to 20 miles and the structural relief can be a few hundred to greater than 3,500 feet. Fold axes are generally arcuate and remain parallel to sub-parallel to the arcuate trend of the Appalachian mountain range seen in central Pennsylvania. Folds generally trend northeast to southwest and plunge 1° to 2° to the northeast (Iranpanah and Wonsettler, 1989). Overall the plateau is characterized by generally level surface with some rolling hills, which are at an altitude great enough to permit erosion of deep valleys by streams.

The general stratigraphy is Cambrian through Pennsylvanian sedimentary units deposited on a metamorphic Precambrian basement. Most models of the plateau show anticlines and synclines extending down to a décollement surface (or detachment fault) within salts of the Silurian Salina Group. The Appalachian plateau is often cited as the type example of broad zone, layer-parallel shortening, with subordinate splay faults in the hanging wall of the detachment sheet (Gwinn, 1964; Rodgers, 1964; Scanlin and Engelder, 2003). Layers of rock above the décollement are referred to as the Appalachian

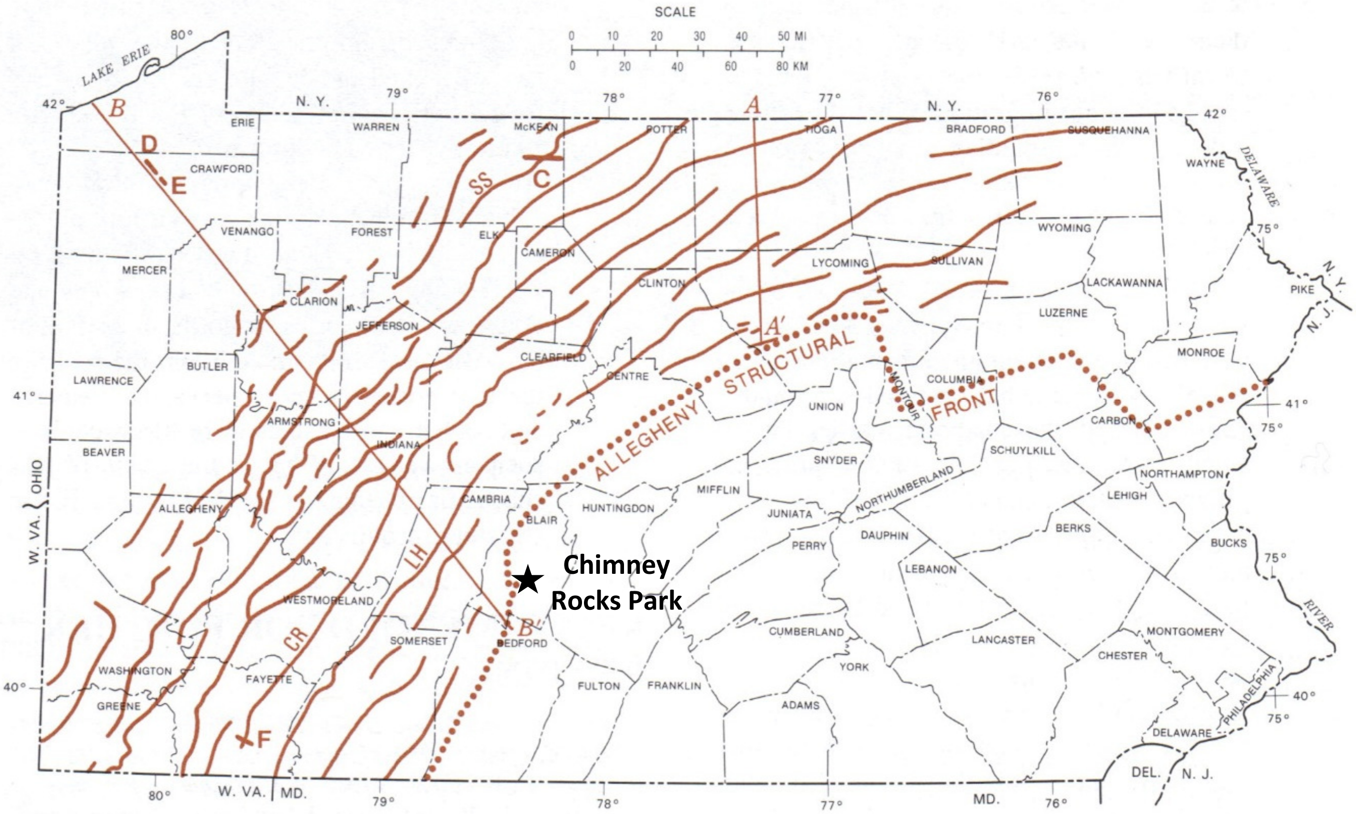

Figure 3. Generalized location of surface anticlines in the Appalachian Plateau province. The cross-section line for Figure 4 is seen above as B-B'. Modified after Figure 20-1 from Beardsley, Campbell, and Shaw (1999).

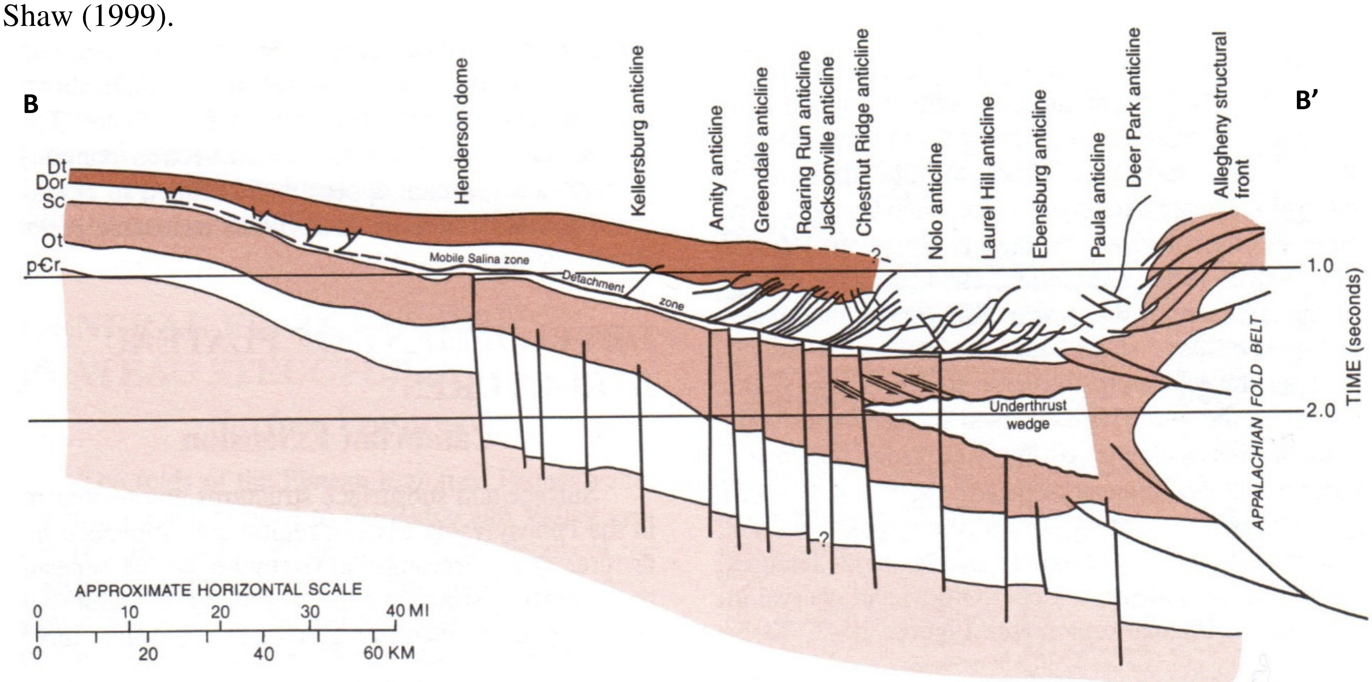

Figure 4. Regional cross section based on seismic data from Erie County to Blair County. Note the contrast of Figure 3 and 4 to the structural style seen in Figures 5 and 6. Modified after Figure 20-4 from Beardsley, Campbell, and Shaw (1999).

Plateau detachment sheet and were folded above the décollement by a variety of mechanisms. Seismic data collected above the décollement supports the presence of imbricated thrusts of splay faults that exhibit fault-propagation folds, fault-bend folds, and kink banding morphology (Scanlin and Engelder, 2003; Gillespie et al., 2015). These imbrications are observed to cut the Lower/Middle Devonian units, which are composed of carbonates (Tully, Onondaga, and Helderberg limestones) and interbedded clastics (Marcellus shale and Oriskany sandstone).

Proximity to the Allegheny Structural Front and variation of thickness of the salt (Salina Group) detachment appears to control the variation of subsurface structural style and structural relief (Wiltschko and Chapple, 1977). Detachment and translation occurred during the Pennsylvanian-Permian Alleghenian Orogeny. Mount (2014) estimated the shortening necessary to create observed structural is approximately 1-2%. However, Scanlin and Engelder (2003) note that movement along the salt décollement alone is insufficient to account for the fold amplitude in the Bedford-Pittsburgh region and that additional mechanisms are required for full anticlinal growth. It is postulated that some salt doming within the Salinas Group has contributed to folding (Wiltschko and Chapple, 1977). Evidence appears to suggest that the evolution of the Appalachian Plateau folds are a complex intermingling of mechanisms including: décollement slip and buckling; hanging wall thrusts, imbrications, and wedging; kink banding; salt doming; pervasive layer-parallel shortening; and footwall faulting in basement rocks.

Valley and Ridge

The term Valley and Ridge refers to the structural province while the Ridge and Valley refers to the physiographic province (Faill and Nickelsen, 1999). Since this discussion focuses on the structural geology of the region, Valley and Ridge be used exclusively. The Valley and Ridge province consists of a series of the fold-thrust belts west of the core of the ancestral Appalachian Mountains. It is considered a classic example of a folded and faulted foreland mountain system (i.e., fold-thrust belt) (Faill and Nickelsen, 1999). Folding is pervasive throughout the Valley and Ridge with folds of all sizes, from first order (wavelength > 10 miles) to fifth order (hand-sample size) (Nickelsen, 1963). In general, the folds have planar limbs and narrow noses with respect to the fold wavelength. Ridges represent the stronger ridge-forming rock, where the valleys represent the weaker, more easily erodible valley-forming rocks. Topographic expression is mainly due to the strength of the rocks present, therefore not all valleys are synclines (i.e., there are synclinal valleys as well as anticlinal valleys).

Folds are the most noticeable features in this province; however, the most fundamental tectonic element is the system of southeast dipping thrust faults that rise through the stratigraphic column. Strata have been forced westward by tectonic collision where they have been folded and forced over massive thrust faults. Many thrusts are blind, flat-ramp-flat thrusts that do not break the surface. Faulting is abundant throughout the Valley and Ridge. Most faults present are thrust faults, there are some strike slip systems, and extensional faulting is rare (Faill and Nickelsen, 1999). The Valley and Ridge fold-thrust belt sits above a basal décollement located in the Cambrian strata of the Waynesboro formation, a carbonate shelf sequence. The thrusts rise from the flat floor décollement in the Lower Cambrian Waynesville formation at approximately 10 km depth and are responsible for the numerous fault bend folds throughout the province. The majority of exposed rocks are sedimentary Ordovician, Silurian, Devonian, and Mississippian units. There is little metamorphism and virtually no igneous intrusions. All of the structures within this province are considered to have been created during the Alleghenian orogeny (rather than the Grenville, Taconic, or Acadian orogenies).

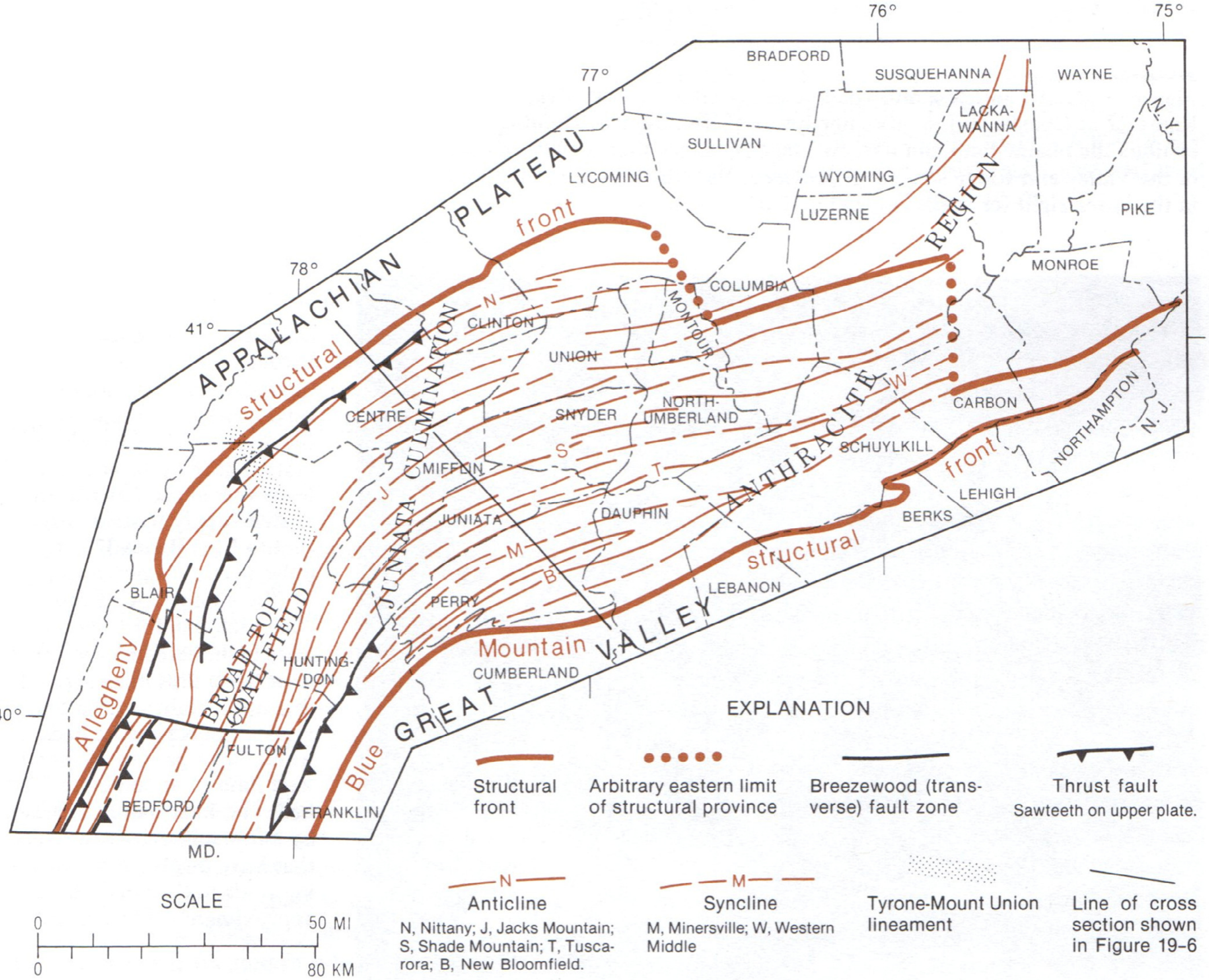

Figure 5. Generalized location of fold axial traces and major thrust fault systems across the Valley and Ridge province. The cross-section line for Figure 4 is seen above as the black solid line near the center of the map. Modified after Figure 19-3 from Faill and Nickelsen (1999).

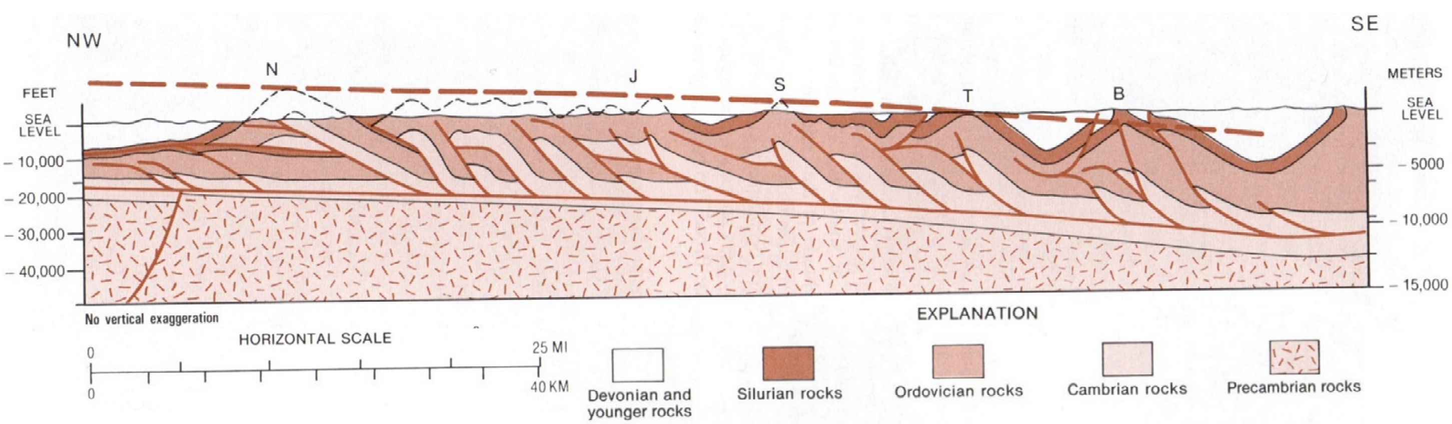

Figure 6. Cross-section of the central Valley and Ridge province showing the classic fold-thrust belt deformation style. Modified after Figure 19-6 from Faill and Nickelsen (1999)

Allegheny Structural Front

The Allegheny Structural Front is a major topographic escarpment which marks the transition from the Valley and Ridge structural province to the east and the Appalachian Plateau province to the west. The Front is a 1-2 km zone where within the subsurface there is a major step-up along the basal décollement. The décollement, or detachment fault, separates the relatively undisturbed strata below from the deformed strata above. The décollement facilitates much of the translational motion associated with deformation as well as acting as a nucleation surface for many of the thrust/splay fault that deform the overlying strata. At the Allegheny Front the basal décollement, below the folded strata, rises up some 2,600 m from the Cambrian Waynesboro formation in the Valley and Ridge into the Silurian Salina Group in the Appalachian Plateau (Faill, 1993) (see Figure 7). The abrupt change in décollement depth may be the result of diminishing force influence on the rocks from the Alleghenian Orogen. However, the greater influence appears to be the deep southeast dipping reverse fault displacement of the basement (~700 m of displacement) on which appears to initiate imbrication of overlying thrust faults (Scanlin and Engelder, 2003). Basement faults are thought to be at 7 to 8 km of depth. This displacement appears to act a "speed bump" for the westward motion of the Valley and Ridge fold thrust belt during the Alleghenian Orogeny.

The Allegheny Front marks the boundary of two distinct structural styles. It is useful to compare figure 3 to figure 5 to see the decrease in density of fold axes present in the different provinces. Figures 4 and 6 offer an opportunity to contrast the subsurface structure of the provinces. The Plateau has less shortening, but less mechanically strong stratigraphic sequences (e.g., salt doming accommodating large scale folds). In contrast, the Valley and Ridge has much more shortening, but stronger lithologies. The amount of shortening seen in the Valley and Ridge is an order of magnitude greater than that of the Plateau (Faill, 1993). One of the fundamental changes observed on either side of the Front is the significant decrease in faulting observed at the surface in going from the Valley and Ridge to the Appalachian Plateau. The Front is also defined as the eastern continental divide; where on the east side all water flows to the Atlantic, all water on the west side flows to the Gulf of Mexico.

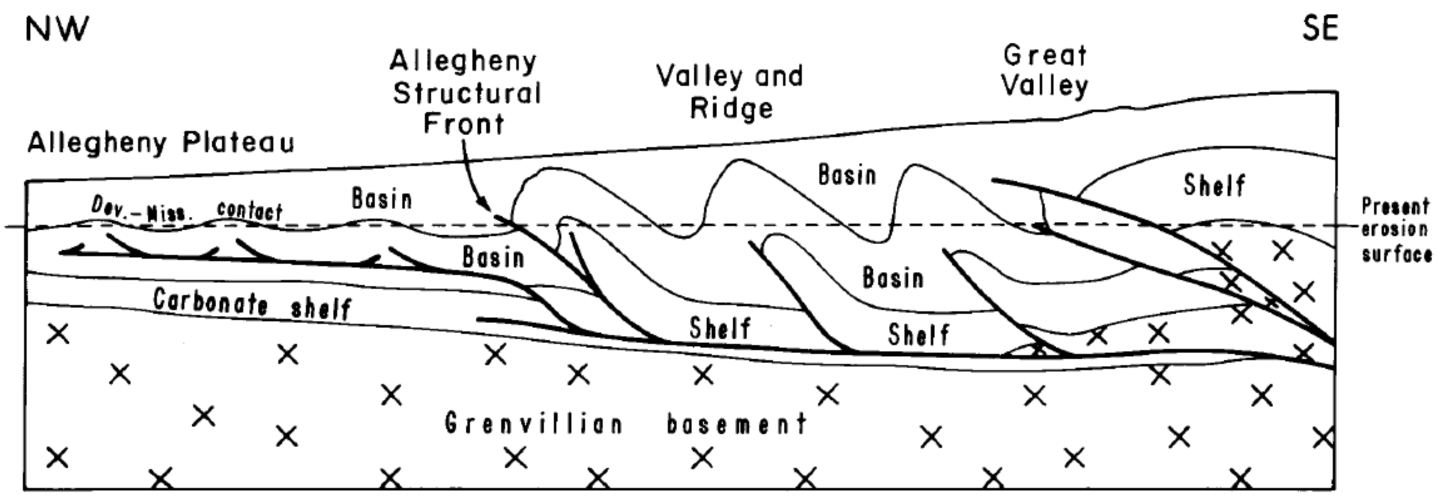

Figure 7. Cross section of the Alleghenian décollement in Pennsylvania, rising from within the crust in the southeast, entering and paralleling the carbonate shelf deposits under the Valley and Ridge Province, and ramping up to the Silurian level under the Allegheny Plateau. Vertical exaggeration ~3X (Figure and caption from Figure 18 in Faill (1993).

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