Gravity Profiling for Structural Interpretation of the Blue Ridge Front Buena Vista, Virginia

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Introduction

The purpose of this study was to describe the subsurface structure of the Blue Ridge Front in Central Virginia. Gravity data collected in this area was the primary means of interpretation, and it was constrained by the use of surface geology maps. Emphasis was placed on depth to major detachment, the shape of the detachment, and the possible existence of a diabase body.

Our study area was located near and in the town of Buena Vista, Virginia (Figure 1). Data was collected from surveyed stations near the east bank of the Maury River and continuing into the Blue Ridge on Pedlar Gap Run south of the town. Cambrian formations outcrop along this section beginning in the Unicoi and continue stratigraphically upsection to the Rome. Line length is 3.3 kilometers.

Methods

Pedlar Gap Run was selected as the study area because of its easy access and its favorable orientation to the local structure (Figure 1). To maintain a 0.1 mGal accuracy in the data, the area was surveyed to determine precise elevations and locations for gravimeter stations. A modern total station surveying system provided excellent precision for our inexperienced surveying crew, and increased surveying efficiency along the winding road. Readings were taken using a Lacoste and Romberg gravimeter.

Analysis of the data was done on a Macintosh computer at the College of Wooster. Most standard data corrections were processed quickly on a spreadsheet. Terrain corrections for gravimeter stations were done using the technique described by Hammer (1939). Final corrected data was entered into a modeling program. A two dimensional profile was generated using Grav 2D for Macintosh computers.

Discussion

Regional Geology

The study area crosses sections of the Blue Ridge and Great Valley of the Central Appalachians. These major divisions are characterized by distinct morphology reflecting the lithology and structure of the region's bedrock. The Blue Ridge is a northeast-plunging anticlinorium and contains the highest peaks in the region. The Blue Ridge contains a core of Grenville age gneisses overlain by a cover of late Precambrian and Paleozoic metasedimentary and metavolcanic rocks (Spencer, 1992).

The Great Valley lies between the Blue Ridge on the east and the Valley and Ridge on the west and is structurally part of the Valley and Ridge. It differs only in lithology and topography. The easily weathered Cambrian and Ordovician carbonates and shales create the low relief of the Great Valley.

The Great Valley-Valley and Ridge represents the foreland of the Appalachian orogen. Thick Cambrian to Pennsylvanian sedimentary strata were deformed together during the terminal Paleozoic Alleghanian orogeny, but show virtually no metamorphism. The structure of this region is a fold and thrust province (Spencer, 1992)

Regional Structure

The Alleghanian orogeny was the final of the three orogenic events to affect the Central and Southern Appalachians. The major structures of the study area were produced during this event. Structural features include thrust propagated folds, imbricate thrusts and ramp anticlines, as well as small scale deformational features. The Central Appalachians are typified by thrust propagated folds in the Great Valley-Valley and Ridge and Plateau areas. These folds are characterized by narrow anticlines and broad synclines and significant layer parallel shortening.

Imbricate thrusts in the Valley and Ridge are parallel to bedding in the weak rocks and inclined 20-50° in more competent rocks across bedding (Hatcher and others, 1989). Thrust faults are the primary structure of the area and occur throughout the Blue Ridge, Great Valley, and Valley and Ridge.

Geology of Gravity Line

In the Blue Ridge, the gravity line begins in the siliciclastic, ridge-forming units of the Cambrian Chilhowee Group. The lowest unit, the Unicoi (100-200m), is primary greywacke with beds of pebbly arkose and quartzite and volcanic rocks. The Unicoi Formation is nonconformable with the Pedlar Formation beneath, but is conformably overlain by the Harpers formation. The Harpers Formation (300-500m) is a transitional lithology between mixed lithologies of the Unicoi and the pure quartzite of the Erwin Formation. The Harpers is conformable with underlying and overlying formations. The Erwin Formation (125-200m) is a pure quartzite about 600 feet thick. The formation is 99% pure quartz grains with the only exceptions being areas close to the contacts (Bick, 1960). Erwin is conformable with the underlying Harpers and may be conformable with the Shady Formation overlying.

In the Great Valley, Cambrian and Ordovician carbonates and shales create low topography. In the study area, the Shady Formation does not outcrop but is assumed present. It is conformable with the Erwin below and Rome above. The Shady (300-500m) is composed of medium grained dolomite. The Rome Formation (300-500m) is an interlayered sequence of shale, sandstone, limestone, and dolomite. It is conformable with the Erwin below and Elbrook above. The gravity line ends in the Rome Formation. The Elbrook Formation (300-700m) is included in our model at depth. It consists of mostly dolomite with some limestone. It is conformable with the Rome Formation below (Bick, 1960). The configuration of these units at the surface can be seen in the model (Figure 2). The formations' positions and locations are constrained by maps of surface geology (Figure 1).

Structural Geology of Gravity Line

The Cambrian Erwin Formation is a resistant quartzite and forms the first sharp topography on the northwest side of the Blue Ridge. The gravity line on Pedlar Gap Run follows a valley between the Erwin peaks and crosses the structural grain virtually perpendicularly.

The sequence from the Unicoi Formation through to the Elbrook Formation dips generally uniformly at about 45° toward the northwest. There are no outcropping faults to interrupt this sequence. Some beds show small scale folds, but these features do not disrupt the regional configuration.

The Blue Ridge in this area is a thrusted anticlinorium underlain by the Staunton-Pulaski thrust fault that outcrops 5 miles northwest of the study area. A minor fault separates the Rome and Elbrook Formations to the south of the line, but diminishes close to the town and likely does not outcrop. The importance of this study is that it allows calculation of the detachment depth below the Blue Ridge.

Geophysical Attributes of Structures and Formations

The gravity profile measured at this location contains an anomaly of greater than six mGals. Gravity values are greatest in the Blue Ridge where gravimeter stations are located on the Unicoi Formation. The values decrease westward above the Erwin Formation with the lowest value measured in the middle of the formation. Values increase again moving west, away from the Erwin and moving out into the Great Valley onto Shady and Rome Formations. The model shown in Figure 2 represents a hypothetical structural situation that seems to fit the observed data set fairly well. The gravity low is caused exclusively by the low density of the Erwin Formation.

The depth of the major detachment was determined by the reasonable assumption of distance to outcrop versus typical thrust fault angle. The effect of the fault depth causes the calculated gravity to raise and lower with the fault for all gravity stations. It was therefore easy to find the best fit for the data and fault location.

It is reasonable to assume that the thrust fault at depth was subject to the same deformational folding as other regional features. To incorporate this into the model meant that the smallest differences between calculated and observed gravity data could be corrected for by deforming the otherwise horizontal fault.

The existence of a diabase sill to the west of our line and diabase dikes in the Blue Ridge provides evidence of plutonic activity in the study area. Diabase is the most dense rock used in the model, and it provided a means of increasing the gravity values under stations where the thick formations could not provide enough variation to fit the curve of observed values.

Conclusions

The working model provides evidence for (a) a gravity low caused by the low density Erwin Formation, (b) a major detachment at a depth of 3.25 kilometers, and (c) the likely existence of a diabase body in the volume of rock covered by the gravity line. As with all hypothetical gravity models, specific uncertainties contribute to the possibility of error in the model. For one, density values for nearly all formations have a given a range rather than a specific value. Significant variation from the values used would cause considerable change in the calculated gravity curve but would be legitimate considering the possible range.

Even with the use of geologic maps for surface constraints, the geophysically deduced structure at depth is not unique or unambiguous. Seismic data and/or drill data would be extremely useful in constraining the model further, but they are not available.

References

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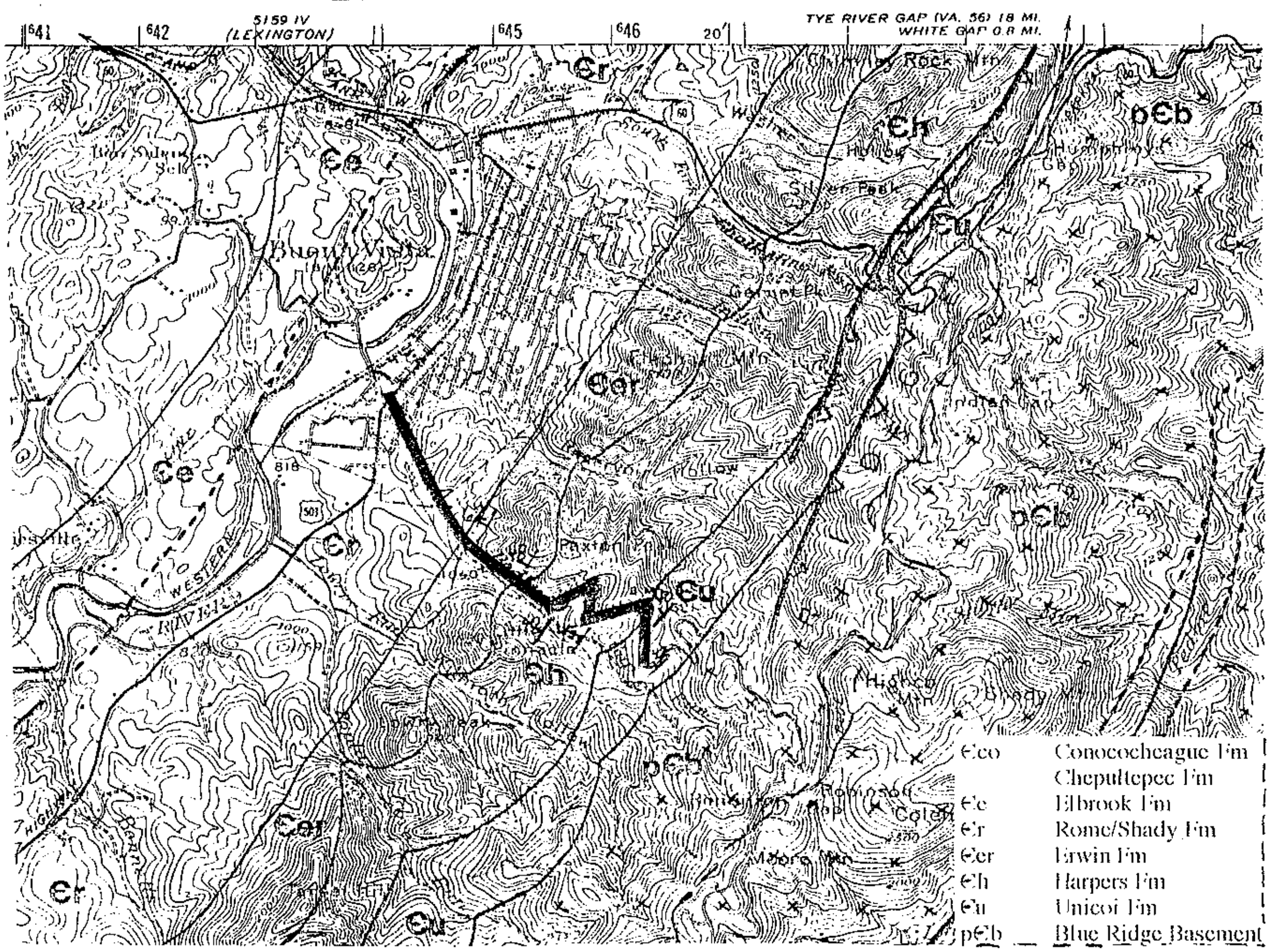

Figure 1: Geologic map of the study area showing the location of the gravity profile (heavy line) and structural data (after Spencer, unpublished).

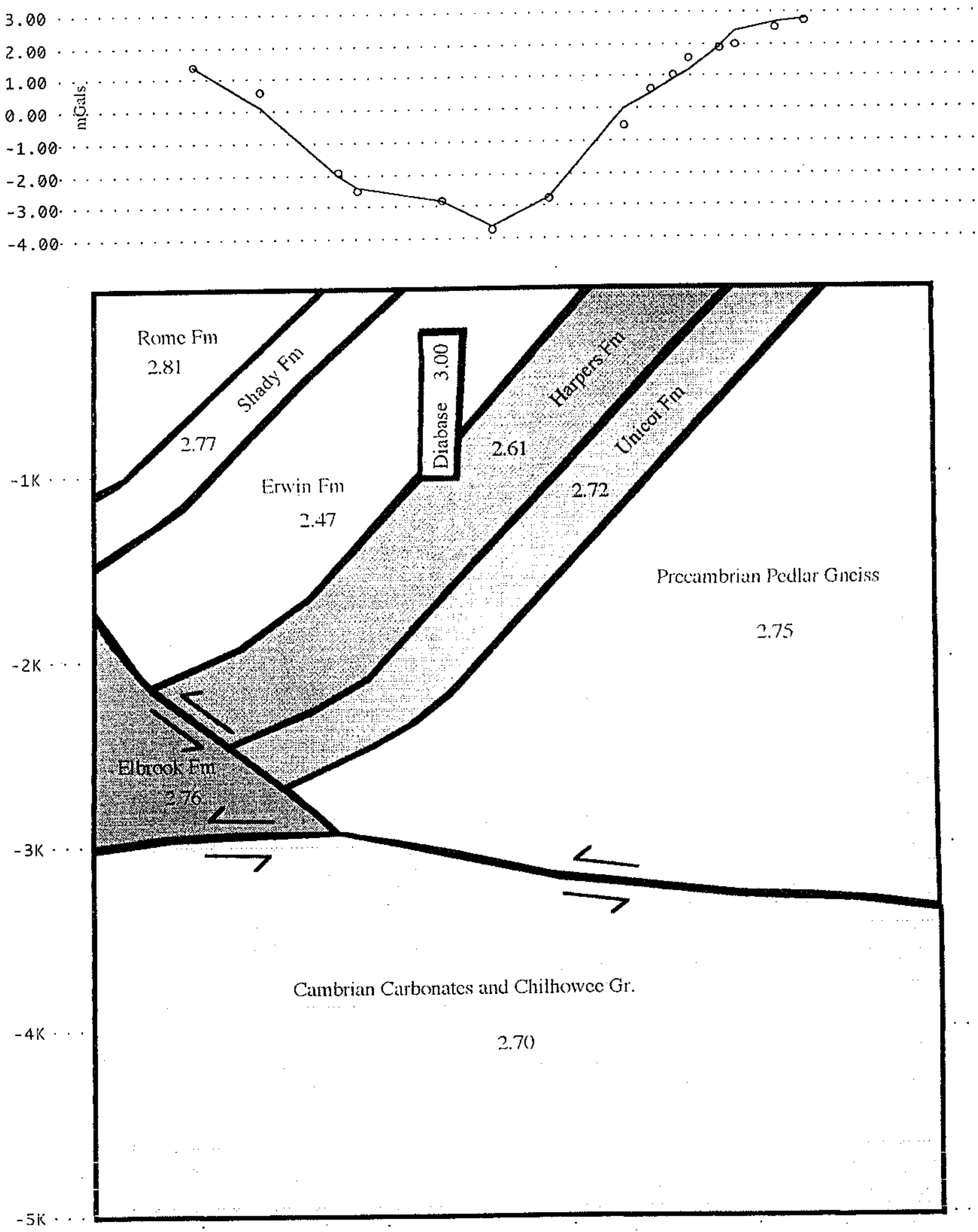

Figure 2: Structural cross section of the study area based on gravity data. Formation names are shown with the densities used in the model. In the graph above the cross section, open circles represent the measured and terrain corrected gravity values. The solid line is the calculated curve derived from the geologic cross section. Model depth is 5 km.