A GRAVITY SURVEY AND STRUCTURAL MODEL OF THE BLUE RIDGE FRONT NEAR BUENA VISTA, VIRGINIA

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Introduction

The area of study is in the Central Appalachians near Buena Vista, Virginia along the Blue Ridge front. The Blue Ridge anticlinorium has a basement core of Precambrian crystalline rocks flanked on the northwest and southeast by younger sedimentary rocks. The basal sedimentary unit, the Chilhowee group, lies nonconformably on the northwestern side of the Blue Ridge basement complex. The sediments are unmetamorphosed, and the basement metamorphism is Grenville in age. The entire region was affected by the late Paleozoic Alleghanian Orogeny, which transported the Blue Ridge from the southeast on a series of thrust faults.

The area studied lies on a line between and roughly perpendicular to the Pulaski and Blue Ridge thrust faults. A gravity survey was taken along this line in preparation for subsurface modeling of a portion of the contact between the Blue Ridge and Valley and Ridge geologic provinces. The question this survey intended to explore is whether or not the Blue Ridge front in the Buena Vista area is bound by a shallow thrust fault as is found further south. The line of the survey begins in the Unicoi member of the Chilhowee group, and extends across the remainder of the Chilhowee group and into the Cambrian Shady and Rome formations, which are in the Valley and Ridge province. Computer modeling based on the gravity anomaly across the area has allowed an interpretation of the subsurface structure of the units involved.

Field Methods

Given the densities of the units involved and the relatively small scale of the survey, the predicted anomaly was on the order of 5 to 10 milliGals, which is a significant, but not extremely large anomaly. Station elevations and locations read from topographic maps are too rough to provide reasonable gravity values when working with an anomaly of this magnitude. Because elevation corrections can be 5 - 10 mGals, very accurate elevations were needed. Surveying each station location using transit surveying techniques was therefore a necessary step in conducting our gravity survey. The survey line started on the Blue Ridge front between Paxton Peak and Little Pinnacle and extended northwest for a map distance of approximately 3.5 km to the southern part of Buena Vista. (see figure 1) An electronic total field station which combines a theodolite with an infrared distance measuring system able to measure and record station locations with a precision of 0.001 m was used to conduct the survey. A base station was established to start the line and stations were then surveyed at approximately 100 yard intervals. Foliage and other obstacles, however, were numerous. The instrument had to be moved as often as every other station. A survey team usually consisted of one or two people setting up, shooting, and transporting the theodolite, one person setting up the back shot prism pole, and one setting up the prism pole for the next shot. Each station was carefully numbered with a flag so that it could be reoccupied for a back shot or a gravity reading. The data from each field day were downloaded into a Macintosh Quadra 700 computer.

Sixty-three stations were surveyed of which 47 were used as gravity stations. Limited visibility made the additional stations necessary. Stations were chosen for gravity measurement in the flattest possibleareas to minimize very close terrain effects. The stations are located on easily accessible roads.

Gravity measurements were taken using a LaCoste and Romberg Model G gravimeter. Relevant data including station number, date, time, and gravity reading were recorded in a field notebook. Recording the time of measurement was important because it was later needed for the drift correction.

The instrument readings have a drift over time that is caused by tidal forces and relaxation of the zero-length spring within the gravimeter. The drift must eventually be corrected out of any gravity survey, so it was necessary to create gravity loops. A base station was established and reoccupied after taking about 10 - 12 measurements at other stations or after about 2 hours, which allows the assumption that the drift is linear. The last two stations of a loop were also reoccupied before starting a new one, thus allowing a check for accuracy. New base stations were established when travel time became too long.

Data Reduction

A series of corrections must be applied to gravity data before the values can be used to determine any anomaly that may be present. Microsoft Excel was used in this study to calculate the necessary reductions. To begin data reduction all readings had to be corrected for instrument drift. The linear drift between two readings of a single station was determined and subtracted from all gravity values measured during that time interval, thus distributing the drift evenly over time. The readings were then calibrated using the calibration curve specific to the gravimeter that was used in order to transfer them into the standard gravity unit of milliGals. All data were equalized in by adding or subtracting the difference in mGals from an arbitrarily chosen base station. This canonical data set was used for further analysis.

Gravity increases toward the poles and decreases with rising elevation, therefore latititude and elevation adjustments were made. The 1967 geodetic reference system formula, which involves the latitude in radians and constants dependent on the flattening and rate of rotation of the earth, was used to calculate the latitude corrections. The corrections for changes in elevation were made based on the rate of gravity decrease with elevation of 0..3068 mGal/m.

The excess mass between sea level and the station elevation must be accounted for with the Bouguer correction. The first step is a simple Bouguer correction which assumes the excess mass consists of an infinite slab of uniform thickness and density. The relief of the area was significant because it crossed the Blue Ridge front, therefore terrain corrections also had to be made for each station as the second part of the Bouguer correction. The Hammer method was used to determine the terrain corrections. Nine of the forty-seven gravity stations were actually corrected and the remaining station corrections were interpolated from these values.

Results

The end result of the gravity reductions is a gravity profile that indicates any anomalies due to the densities, thicknesses, and extent of the rock units alone. The resultant gravity profile for the survey line is shown in figure 2. The observed anomaly has a magnitude of about 6.5 mGals. A gravity high appears on the southeast end of the line and decreases fairly constantly to a low that begins 1.5 km into the line. The gravity low stays constant for 1 km. The profile then shows a steady gravity increase at the northwest end of the line up to about one half of the magnitude of the gravity high.

Interpretations

The issue in question is whether or not the Chilhowee group is truncated by a thrust fault near the contact between the Blue Ridge and Valley and Ridge provinces in the Buena Vista area. There is compelling evidence in the gravity anomaly which supports the conclusion of a truncating thrust fault at depth underlying the area, but not for one that surfaces at the base of the Blue Ridge.

In order to support this conclusion a subsurface model was created using the modeling program Grav2D. (see figure 3) Contacts were based on Spencer, 1993. (see figure 1) Unit densities were taken from Wilson, and unit thicknesses were obtained from lectures and materials received while in Virginia. This is a preliminary model. Additional work is in progress on this and other possible models.

The gravity anomaly dictates that there must be a low density unit with its mass concentrated beneath the gravity low. The lowest density unit is the Antietam sandstone and quartzite member of the Chilhowee group. The profile also indicates a very high density unit beneath the gravity high. Although there are no outcrops of the dense Catoctin unit in the immediate area, the unit does exist in the region. When it appears, it is the basal unit in contact with the basement instead of the Unicoi, thus it is reasonable to assume that it is present at depth between the basement complex and the Unicoi. The northwest end of the profile suggests a unit with a density between those of the Antietam and Catoctin units. The Shady and Rome formations follow the Chilhowee group in the stratigraphic sequence and they are of intermediate density. Although the Shady formation does not crop out in the Buena Vista area, it is possible that it is concealed beneath thick colluvial and alluvial deposits. Subsequent models will have to be adjusted for a better fit on the northwestern end, but the important question can be answered with this preliminary model.

The proposed model indicates the presence of a detachment fault at a depth of about 1.5 km with the Rome and Elbrook formations underlying it as they do south of the study area under the Pulaski thrust fault. The beds are truncated by the fault and have experienced fault drag which has caused them to fold into an anticlinal structure. This fault drag is what allows the mass of the Antietam unit to be concentrated beneath the observed gravity low. The increase in gravity to the northwest indicates that the Antietam does not extend westward into the valley.

References

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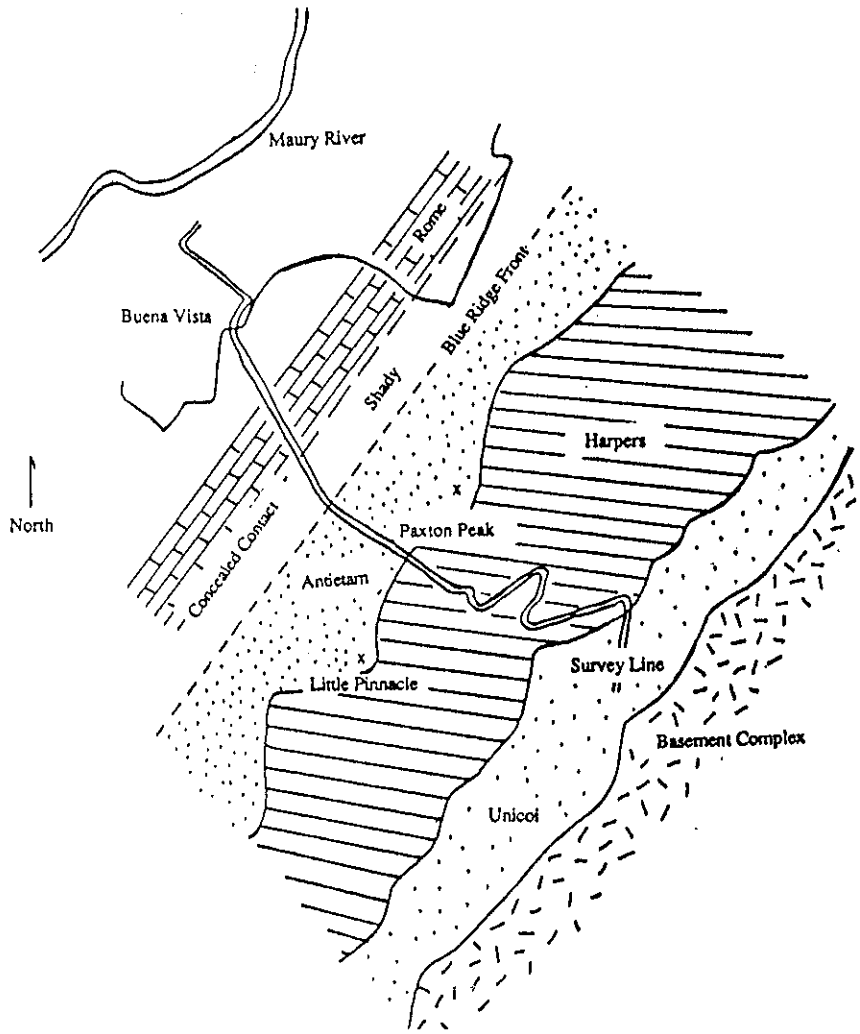

Figure 1 Map view of study area. Spencer 1993.

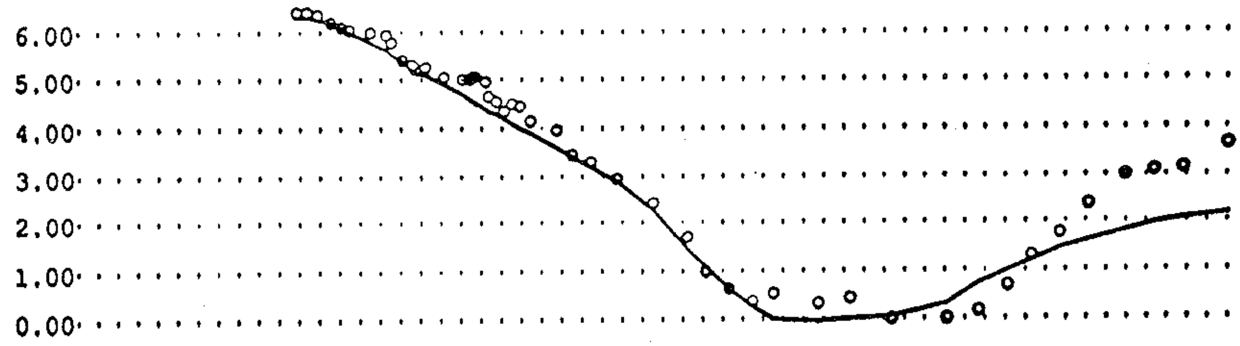

Figure 2 Gravity anomaly

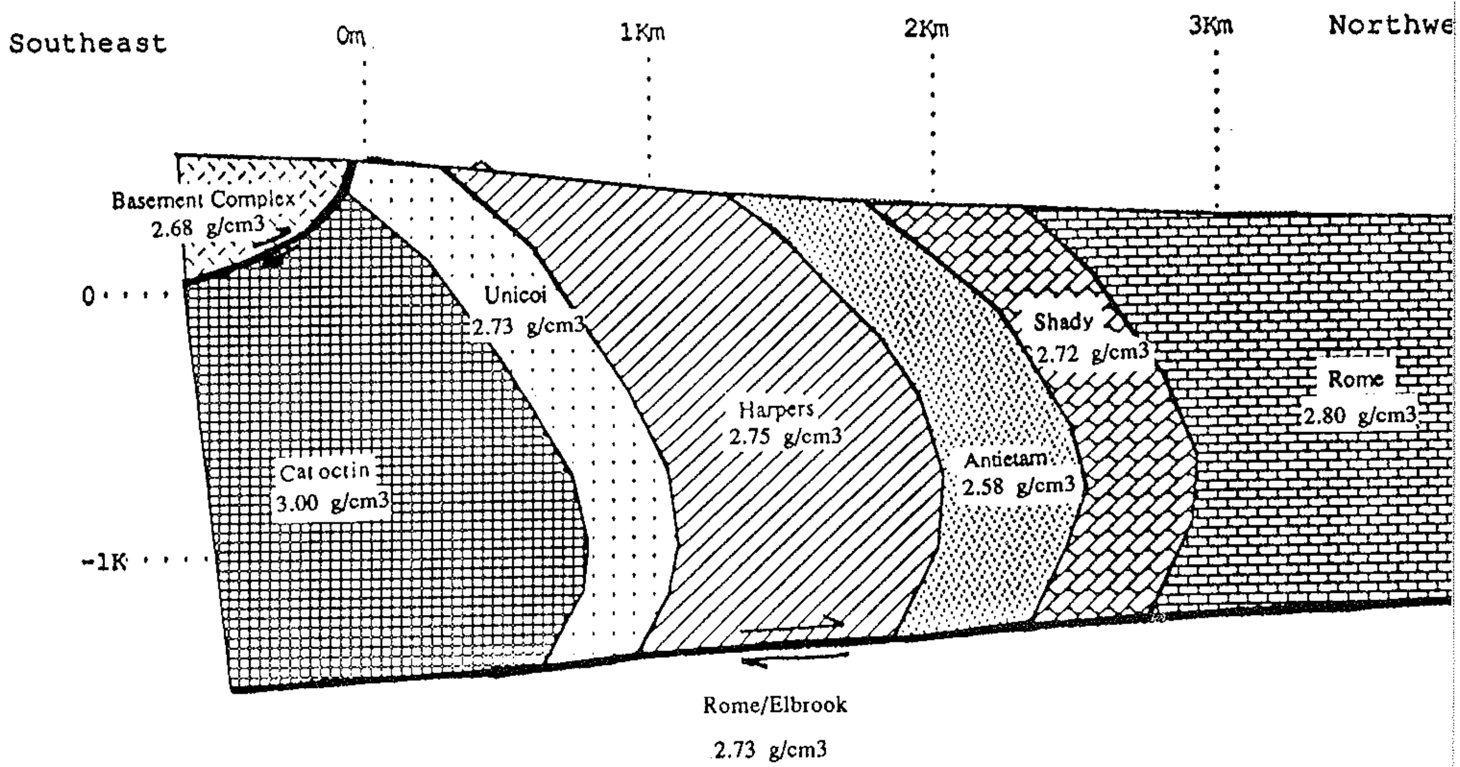

Figure 3 Structural model