A Comparison of Brittle and Ductile Basement-Deformation Models Through Study of the Basement-Cover Relationship on the Blue Ridge Near Arcadia, Virginia

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Introduction: The Blue Ridge is a five to ten mile wide anticlinorium running from Georgia to Maryland. It is characterized by a core of Middle Proterozoic gneissic basement rocks flanked to the NW and SE by younger, late Proterozoic and Early Paleozoic sedimentary and volcanic units. Emplacement of the Blue Ridge occurred during the Alleghanian orogeny of the late Paleozoic by means of NW-directed thrust faulting. Near Arcadia, Virginia, the Cambrian sedimentary Unicoi and Harpers units lie on the NW flank of the Blue Ridge in unconformable contact with the basement complex. The Unicoi is locally between a few hundred to a thousand feet thick (Spencer, 1968) and contains shales, some interbedded with sandstones, as well as arkoses, pebbly quartzites, welded tuffs, metabasaltic dikes and sills (or flows?) and a basement-derived conglomerate. The highest pebbly quartzite in the Unicoi is defined as the border between it and the Harpers unit (Bloomer and Werner, 1955), which consists of shales and pearly quartzites. The only mapping and geologic interpretation of the area was done by E.W. Spencer in 1968 as part of mapping the Arnold Valley Quadrangle. That report does not cover the basement-cover relationship in detail.

My project is an interpretation of the basement-cover relationship on the Blue Ridge near Arcadia with the aim of better understanding the basement's deformational style. Two models are proposed. In the first, the basement and cover fold together as ductile units. In the second, the basement deforms brittlely and the cover drapes into folds over it. The basement's lithology supports brittle rather than ductile deformation; it is a crystalline rock without any potential slip surfaces such as bedding planes that would allow ductile deformation such as folding to occur under stress. By studying the basement-cover relationship in detail I am attempting to determine if the basement deformed brittlely as its lithology implies it did.

Field Observations: My field research consisted of mapping basement-cover contact features and measuring attitudes of beds, cleavages, and folds. Figure 1 shows these features. Basement-cover contacts are labeled 1-6, the first two of which are visible and the other four inferred. Two types of penetrative (slaty) cleavage are prominent in shales: a cleavage running parallel to the bedding plane and one cutting it obliquely. The former is presumably a feature of vertical compression. The latter presumably represents axial planar cleavage from folding. Exposures that reveal an axial planar cleavage/bedding relationship and exposures where stratigraphic up can be inferred from sedimentary features are marked C, D, E, etc. Folds are overturned to the northwest and have wavelengths ranging in size from a meter to ten meters.

Interpretation: Five of the basement-sediment contacts indicate some kind of fold relationship. The sixth, on the Appalachian Trail, is of too poor a quality to serve as anything other than a control point. Figure 2 exhibits the features of these contacts as a schematic diagram. The western basement exposure in Figure 2 combines Contacts 1 and 2, and the eastern basement exposure combines Contacts 3, 4, and 5. The contacts were combined because they are from the same basement belts and have similar features.

One of these features clearly supports the ductile basement model. On the western contact (see Fig.2), the cleavage in the adjoining sedimentary rock is axial planar as would be expected from folding.

Several features, however, serve to weaken the ductile model. First, the cleavage in the cover rocks on the eastern contact (see Fig.2) is not axial planar as would be expected had folding occurred there. Second, there is no axial planar cleavage in the western basement exposure (see Fig.2); if the basement was ductile enough to be folded, why wasn't it ductile enough to be cleaved? Third, there is no basal conglomerate adjacent the western basement; a depositional contact should remain so throughout folding. The conglomerate is too thick (1ft.) and too coherent to be pinched out during folding.

Note that this model involves a dextral strike-slip motion in the basement and cover to accommodate the orientation of the beds, cleavage, and basement-cover contact at Area One. There, these features strike E-W, a position that is not compatible with the highly regular regional Appalachian sense of NW directed tectonic transport. A further degree of NW transport of the rocks marked "G" (see Fig. 3) than at "H" would pull the intervening rocks into their E-W striking position. This strike-slip motion could easily arise from the irregular contact between the compressing North American and European/African continents, which caused some areas to thrust further than others. This dextral strike-slip motion does not affect the strength of this model in any way; it only makes the map clearer to interpret.

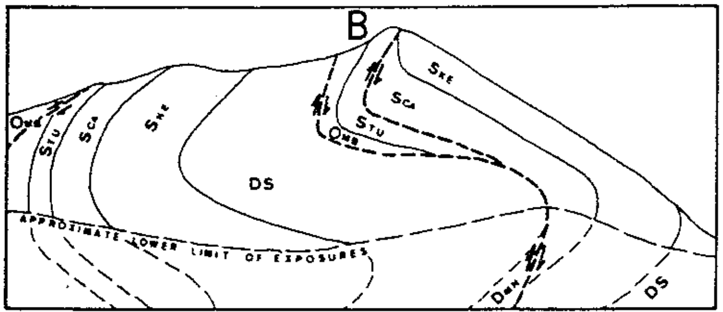

Fig. 2 Schematic section through Eagle Rock gap by McGuire (1970).

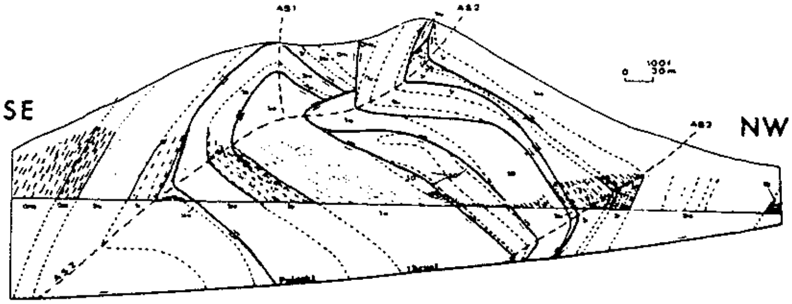

Fig. 3 Schematic section through Eagle Rock by Bartholomew (1982).

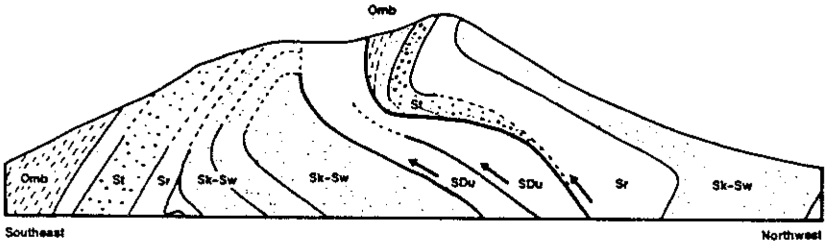

Fig. 4 Cross Section through Eagle Rock gap Showing backthrust geometry (Spencer, 1989).

FIGURE 1.

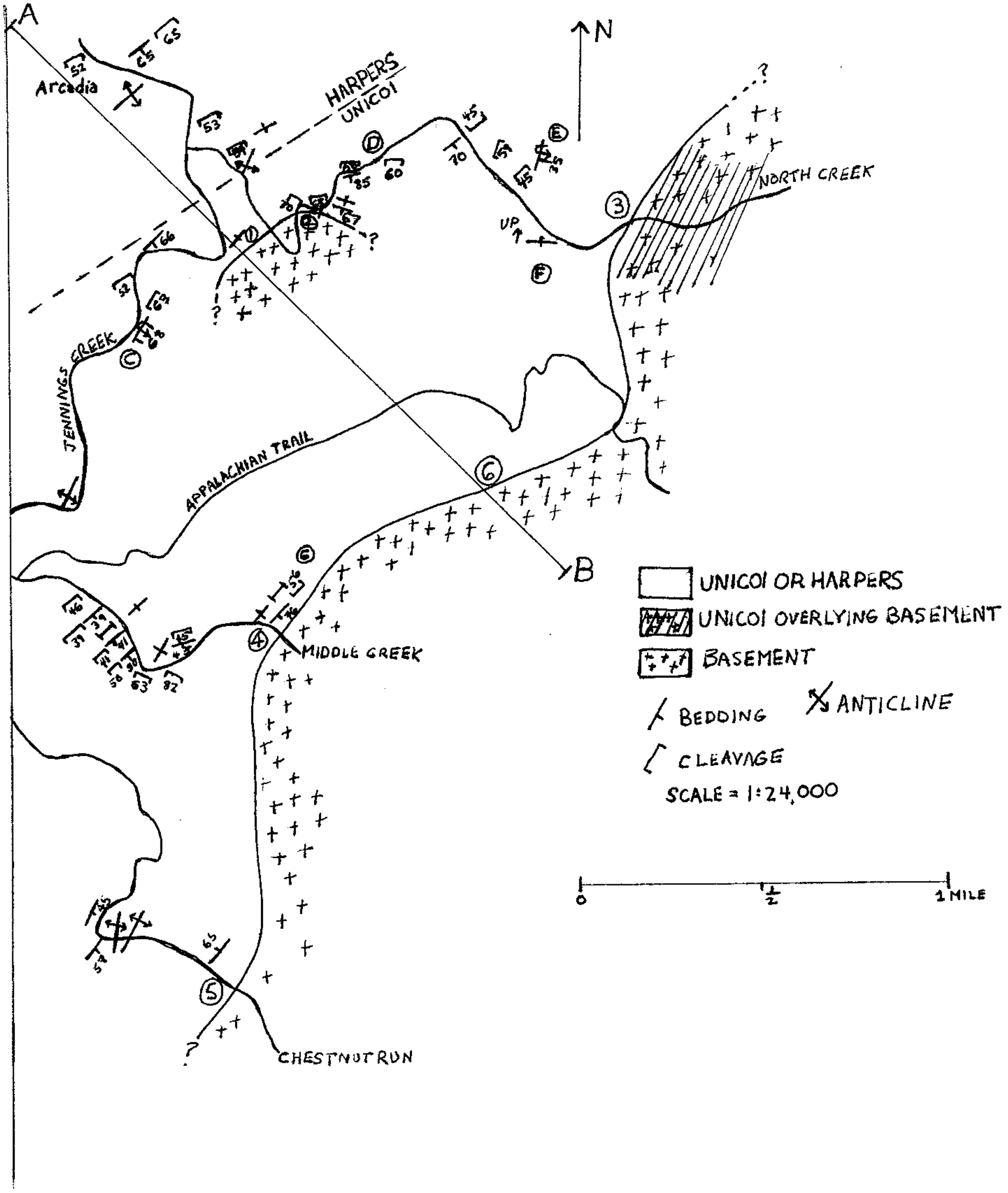
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FIGURE 2.

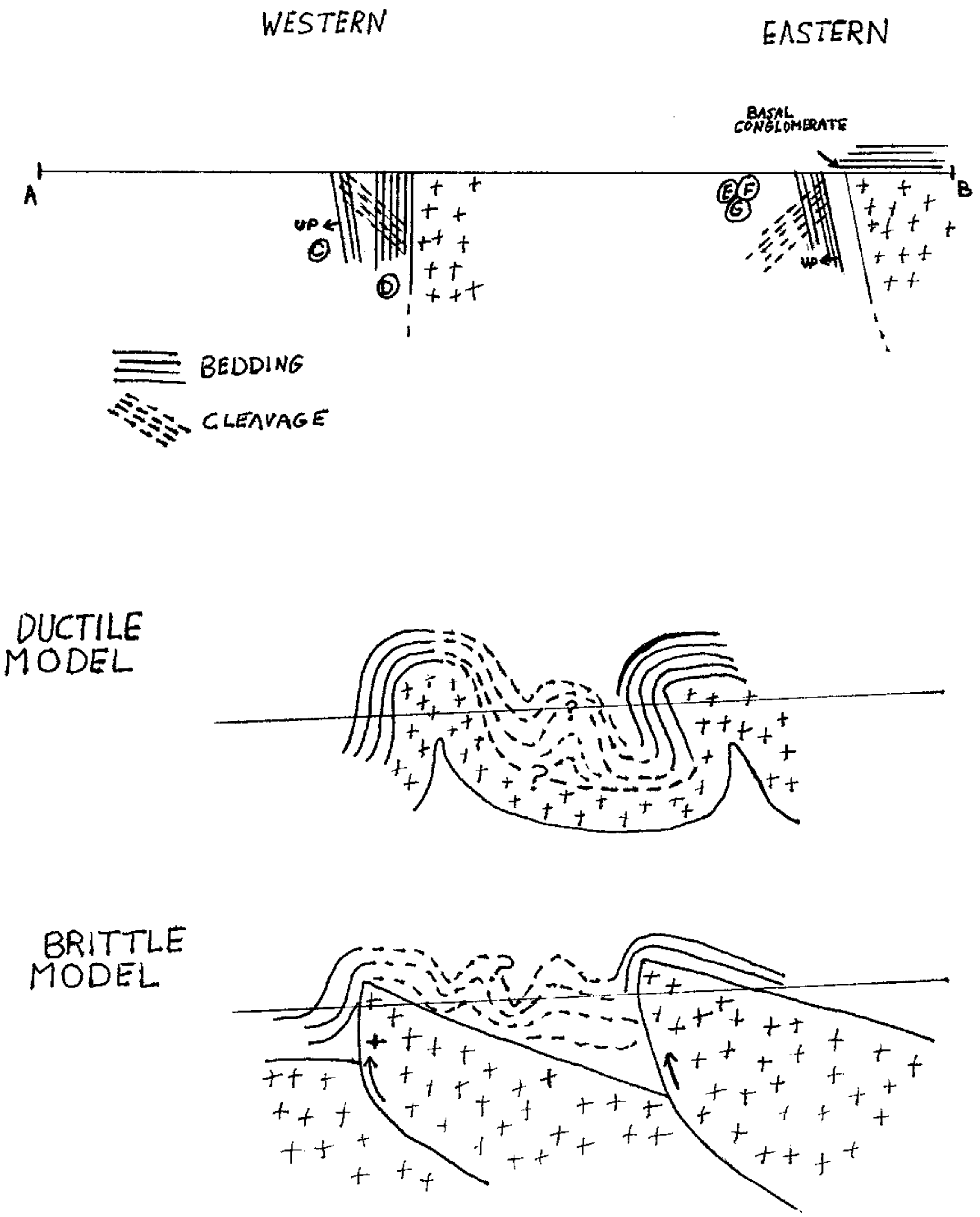
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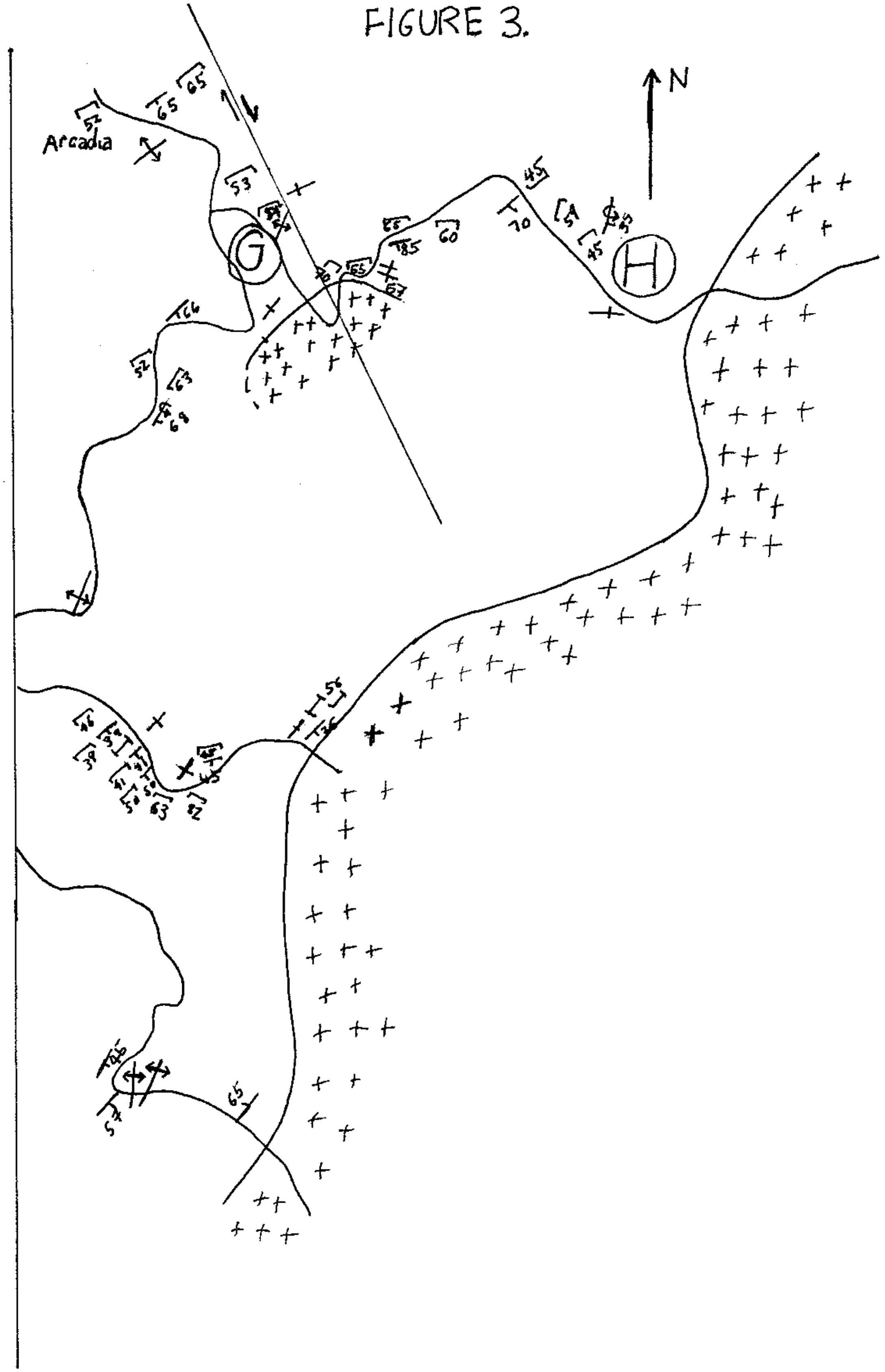
FIGURE 3.



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It is possible that the latter features of the contacts (missing cleavage, conglomerate) have been distorted in the complex deformational history of the Appalachians and therefore do not necessarily rule out ductile basement behavior. Nevertheless, given the existing data I think the ductile model is unrealistic.

The brittle-basement model proposes basement deformation by thrust faulting to the NW followed by draping of the sedimentary cover over the faulted surface. Accordingly, the western basement contact is not a normal depositional one but rather a fault surface, which explains why the basal conglomerate is missing there; it may easily have ruptured as the basement uplifted underneath it. Another advantage of the brittle basement model is that it explains why there is no axial planar cleavage in the western basement: it was never folded in the first place. For the same reason the cleavages in the adjoining sedimentary rocks need not be axial planar either. Their orientations could have come about by several means: cleavage could have developed from shear stress before downward folding occurred, perhaps during decollement-style thrust faulting when great masses of rocks were sliding over one another. During folding it either retained in its position or rotated, depending on how much slip occurred between the beds and how much confining pressure was applied to the beds.

Conclusions: The Blue Ridge basement rock near Arcadia, Virginia probably deformed in a brittle fashion. The brittle-deformation model can successfully accommodate more of the structural features at the basement-cover contacts than the ductile model. However, although the brittle model does predict the missing conglomerate and the missing cleavage in the basement, part of its success also lies in that it does not predict any specific cleavage orientation in the cover rocks adjoining the basement at all. Some further tests would help in choosing between the two models more clearly. For example, if the basement deformed brittlely then the sense of motion on the western basement's contact surface should show the basement rising up through the cover as a fault rather than slipping past the cover in the opposite direction during folding. Studying the orientation of the basement's mafic fabric might also help-- an orientation parallel to bedding would favor folding and one against bedding would favor faulting.

References Cited

Bloomer, R.O., and Werner, H.J., 1955, Geology of the Blue Ridge Region of Central Virginia: Geol. Soc. America Bull., vol 66, p.579-606.

Spencer, E.W., 1968, Geology of the Natural Bridge, Sugarloaf Mountain, Buchanan, and Arnold Valley Quadrangles, Virginia. Commonwealth of Virginia, Department of Conservation and Economic Development, Report of Investigations 13, Map of Arnold Valley Quadrangle.