Structural Controls on the Geomorphology of Brodie Mountain

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INTRODUCTION AND GEOLOGIC SETTING

The Taconic Mountains of western New England are dominated by a series of largely parallel, north-northeast trending ridges and valleys. Our study investigated the structural and lithological controls on the topography and geomorphology. The study area is located on the northern end of Brodie Mountain in Berkshire County, Massachusetts. The area is bounded by Routes 7 and 43 south of Williamstown, Massachusetts, with a total relief of 460 meters (Fig. 1).

Exposed rocks on Brodie Mountain, as mapped by Ratcliffe and others (1993), include units of the Stockbridge, Walloomsac, and Nassau Formations. The Stockbridge Formation (Early Cambrian to Early Ordovician in age) is a series of calcitic and dolomitic marbles representing continental shelf sedimentation. The Nassau Formation, Late Protorozoic to Early Cambrian in age and equivalent to the Greylock Schist mapped by Abeyta and Steffen (this volume), is partly coeval with the Stockbridge Formation but was deposited on the continental slope and rise (Ratcliffe and others, 1993)). The Walloomsac Formation (Middle Ordovician) is mineralogically similar to the Nassau Formation, but is distinguished from it by its dark grey or black color and the common occurrence of graphite. It was probably derived by erosion of accretionary wedge sediments (Karabinos, personal communication).

METHODS

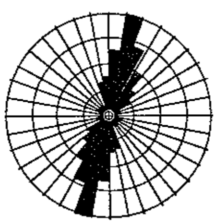
Two weeks of field work consisted of a series of traverses across the field area. Our traverses focused on stream drainages and logging roads to maximize outcrop density. To determine our location, we used USGS topographic maps and altimeters. Measurements of stream orientation were taken from the topographic maps. Streams were divided into 125 meter increments and the orientations of all the increments were plotted on rose diagrams.

RESULTS

The Nassau and Walloomsac Formations alternate on the eastern slope of Brodie Mountain. The Nassau Formation is thick near the summit and on the western slope of the mountain. In outcrop we observed small scale interlayering of the Nassau and Walloomsac Formations. The Stockbridge Formation structurally underlies the Nassau Formation on both the east and west sides of Brodie Mountain.

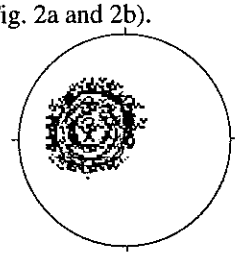
The small scale structures we observed included sets of imbricate faults as well as rotated quartz boudins which, as kinematic indicators, display a top to the west sense of shear.

Foliation measurements were quite consistent throughout the area, striking 017° and dipping 27° to the southeast on average with a standard deviation of 6° on the strike (Fig. 2a and 2b).



N=120

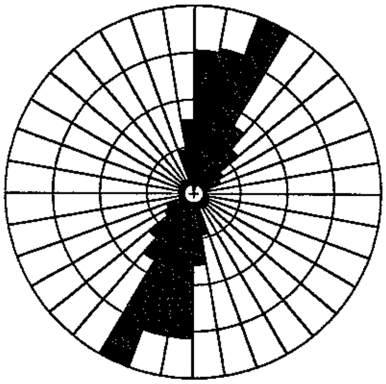
Figure 2a. Rose diagram of strike of foliations. Largest petal is 22%.



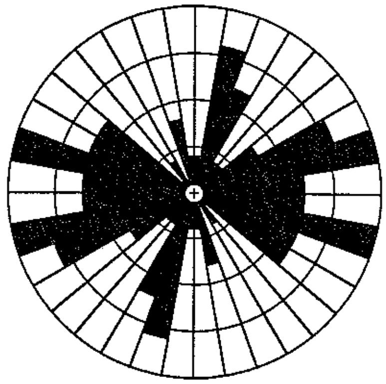
N=120

Figure 2b. Kamb contour diagram of poles to foliations. Contour interval = 2.0 sigma.

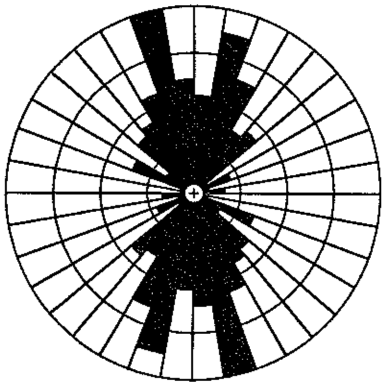
We observed distinct joint patterns on the east and west flanks of Brodie Mountain. On the eastern slope the average strike of the prominent joint set was 085° and a minor joint set was present with an average strike of



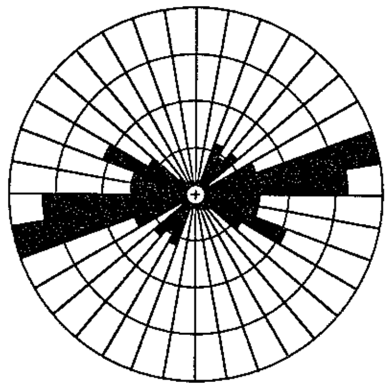
N = 173 Maximum Percentage = 22.0 Vector Mean = 17
Figure 2: Rose diagram showing the strike of the dominant foliation.



N = 42 Maximum Percentage = 11.2 Vector Mean = 78
Figure 3: Rose diagram showing the strike of all joint measurements taken in the field.



N = 161 Maximum Percentage = 14 Vector Mean = 358
Figure 4: Rose diagram showing the trend of streams with a slope < 10%.



N = 81 Maximum Percentage = 21 Vector Mean = 83
Figure 5: Rose diagram showing the trend of streams with a slope ≥ 10%.

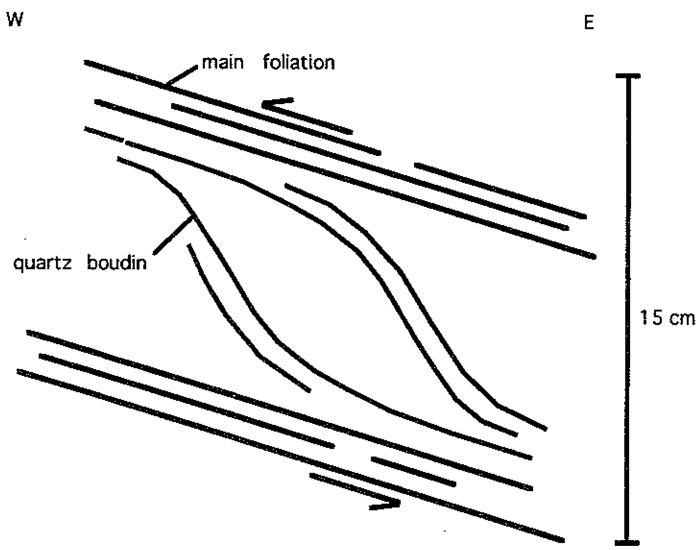
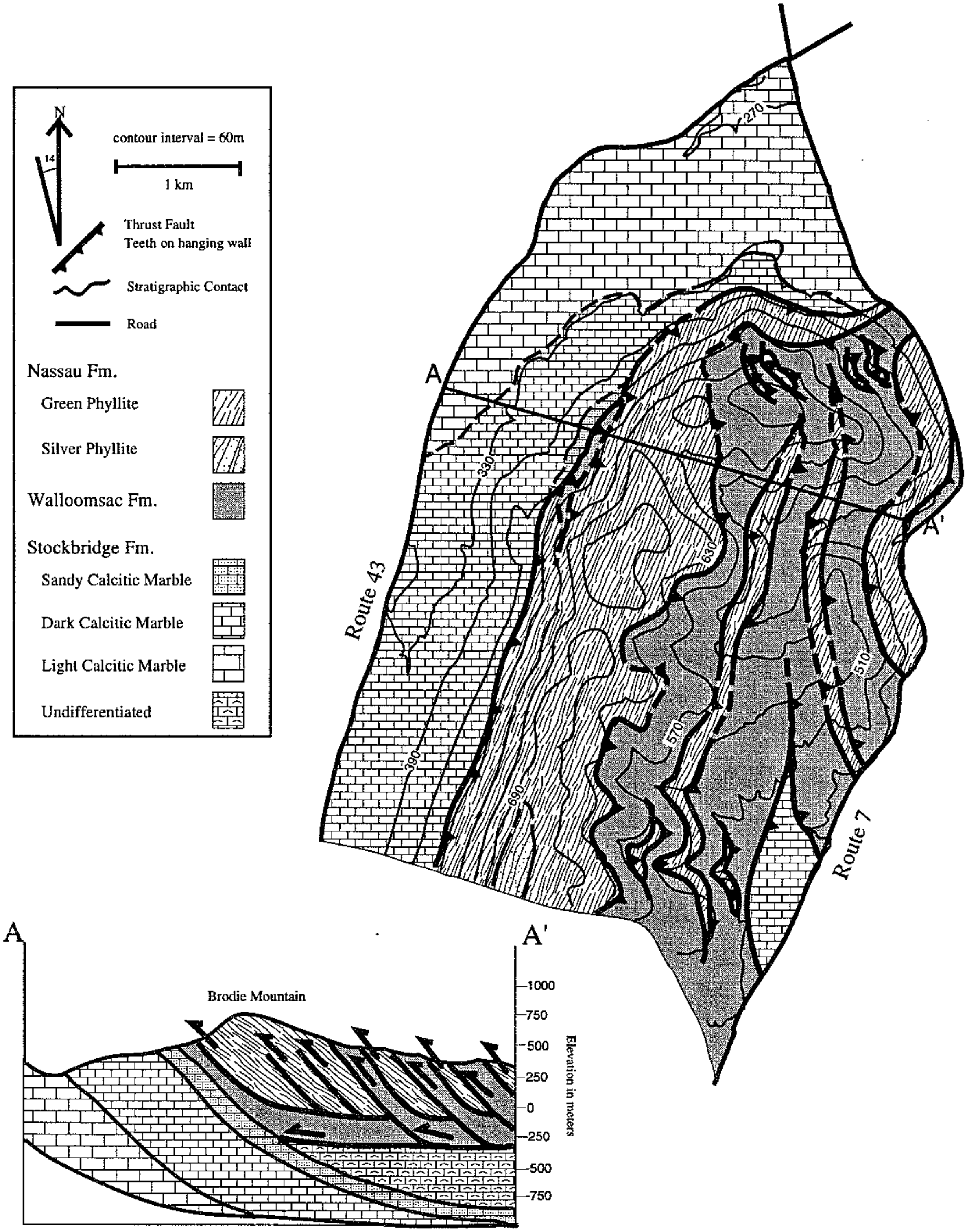


Figure 6: Cross section of a typical quartz bouden sheared in the direction of motion.



Geologic Cross Section A-A'

Figure 1. Geologic map and cross section of Brodie Mtn.

015° (Fig. 3). Joints on the western slope had an average strike of 295° and a dip of 76° to the northwest (Fig. 4). Because the western slope of Brodie Mountain is lacking in data, it is unclear whether the differences are statistically significant.

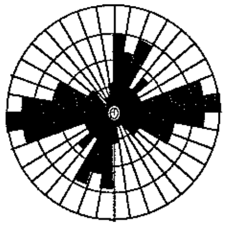

N=58

Figure 3. Rose diagram of joints on the east slope of Brodie Mt. Largest petal is 12%.

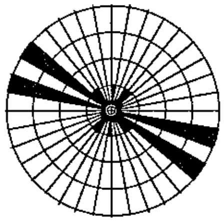

N=12

Figure 4. Rose diagram of joints on the west slope of Brodie Mt. Largest petal is 31%.

The stream orientation data had approximately the same average trend as the average strike of the joints on the eastern and western slopes (Fig. 5 and 6). On the eastern slope of the mountain there are very few streams that follow the second joint set. On the western slope, the streams parallel the measured joint orientation.

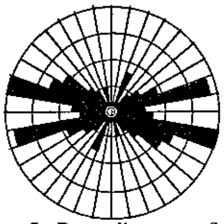

N=80

Figure 5. Rose diagram of east slope drainage on Brodie Mt. Largest petal is 16%.

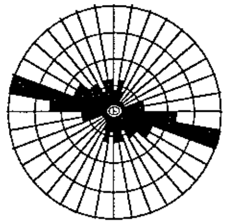

N=52

Figure 6. Rose diagram of west slope drainage on Brodie Mt. Largest petal is 19%.

We also measured stream orientation data for the Route 7 and 43 valleys that border our area. The Route 43 valley has a stream orientation of approximately 013° (Fig. 7). The Route 7 valley has an average drainage direction of 343°. The valleys, which are both underlain by marble, have orientations close to the prominent foliation that we measured on the east slope of Brodie Mountain (Fig. 8).

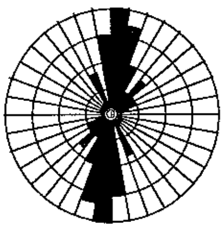

N=61

Figure 7. Rose diagram of Route 43 drainage. Largest petal is 20%.

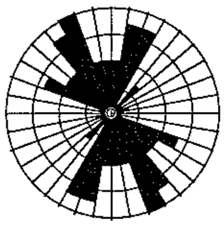

N=42

Figure 8. Rose diagram of Route 7 drainage. Largest petal is 14%.

Crenulation lineation measurements, which mark the intersection of an older and a younger cleavage, were also quite consistent with a few exceptions (Fig. 9). The younger cleavage has approximately the same strike as the older cleavage but dips more steeply.

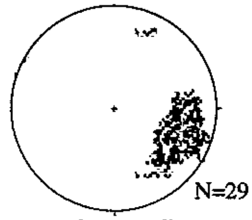


Figure 9. Contour diagram of lineations. Contour interval is 2%/1% area.

INTERPRETATIONS

Our cross-section (Figure 1) shows a duplex model to explain the tectonic evolution of the Brodie Mountain area. The evidence for this interpretation is as follows:

•We believe the small scale structures that we observed on traverses, such as imbricate thrust faulting and small duplexes involving quartz veins, are a small scale reflection of the large scale structural style (J. Leftwich, personal communication).

•The duplex model provides a plausible explanation for the alternating phyllite-marble packages that are seen throughout the Taconic Range and more specicifcally in our area. Existing geologic models for this area invoke a complexly folded thrust sheet in conjunction with erosion to explain not only the alternating marble-phyllite sequence, but also for the alternating sequence of the Nassau and Walloomsac Formations (Ratcliffe and others, 1993). The duplex model implies the stacking of alternate layers of phyllite and marble, allowing the marble to be eroded in a linear fashion, leaving the phyllite to create the ridges. On the other hand, the folded thrust model invokes the emplacement of a slab of phyllite over the marble, not accounting for the linear fashion in which the marble erodes (see Fig. 1 and Cross Section B mapped by Ratcliffe and others, 1993). Also, the small scale structures mentioned above are more consistent with the duplex model than with the folded thrust model.

The similarity between the orientations of the streams and the strike of major joint sets on both the east and west slopes of Brodie above 330 meters suggest that the joints control drainage patterns (refer to Figures 3-6).

Although the western slope may not have enough joint set measurements to be qualatatively compared to the eastern slope, because the stream orientation on the western slope followed the joint set so closely, we feel that perhaps an explanation for the two very different joint sets can be made. Although it is not certain, the lithologies and their sequences could help explain the different joint sets. On the east slope, there is an alternating package of the Nassau and Walloomsac Formations. On the west slope, there is a large mass of Stockbridge Formation butted up against Nassau Formation. Perhaps the joint sets formed differently because the lithologies on the slopes had different amounts of stress applied to them or had stress applied to them at different times.

The correlation between the orientations of the eastern and western branches of the Green River (routes 7 and 43, respectively) and the overall dominant foliation of both the eastern and western slopes of Brodie Mountain suggests that the dominant foliation and lithologic packaging controls the orientation of the river (refer to Figures 2b and 7-8).

CONCLUSIONS

- •The duplex model is the most viable hypothesis to explain the geologic patterns and geometries in our study area.
- •Jointing influences the orientation of streams flowing off of the mountain ridges.
- •Lithology is the major influence on the orientation of the streams in the large valleys.
- •On a regional scale, the drainage is controlled by large structures: major foliation and lithologies. Locally, on a small scale, joints control the orientation of low order streams.

REFERENCES

Ratcliffe, N.M., Potter, D.B., and Stanley, R.S., 1993, Bedrock Geologic Map of the Williamstown and North Adams Quadrangles, Massachusetts and Vermont, and part of the Chesire Quadrangle, Massachusetts: U.S. Department of the Interior, U.S. Geological Survey.

Structural controls on valley and ridge orientation on the southeastern flank of Mount Greylock, Berkshire County, Massachusetts

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INTRODUCTION

Many of the ridges and valleys in Western Massachusetts and Eastern New York are oriented NNE. Glacial carving did occur during the Pleistocene, but glacial striations and crescentic marks in the region suggest that glaciers moved in from the northwest (330°) rather than the northeast; therefore they cannot be invoked to explain the observed orientation of valleys. The object of our study was to investigate the possible existence of a structural control on valley orientations by determining the relationships between structural and lithologic features, valley orientations, and tributary stream orientations.

GEOLOGIC SETTING

The area of study is the southeastern flank of Mount Greylock in the Cheshire $7^{1}/_{2}$' by 15' Quadrangle. Route 8 and Rockwell Road represent the East and West borders, respectively (Fig. 1). Topographic relief is approximately 670 m, from the Route 8 valley to the highlands occupying the northwest corner of our area.

The bedrock in the area is dominated by units of the Greylock Schist, the Stockbridge Formation, and the Walloomsac Formation. The Stockbridge Formation in the area includes a calcitic and a dolomitic marble with coarse-grained textures and a color ranging from light to dark grey. It was deposited in a shallow offshore environment on the continental shelf during the Cambrian and Ordovician. The Walloomsac Formation, an extremely dark grey, rusty, micaceous and graphitic phyllite with minor marble, may represent syn-orogenic sediment shed from advancing thrust sheets (Ratcliffe and others, 1993). Further offshore on the slope and rise of the continental margin, the Greylock Schist, a grey-green chloritic schist with albite and quartz, was deposited during the Late Proterozoic to Early Cambrian. During the Ordovician Taconian Orogeny, the collision of an arc with ancient North America resulted in westward-directed thrusting and the consequent emplacement of the Greylock Schist above the Stockbridge and Walloomsac Formations.

METHODS

A two-week field study of our area was concentrated along streams, roads, and trails. We located ourselves using topographic maps and altimeters. Lithologic samples were often taken because wet bedrock was difficult to identify in the field. We measured stream orientations from topographic maps in 5 mm increments, and plotted the data on rose diagrams. We plotted the orientations of two major ridges and one line of slope-change within our area, using best-fit lines to follow the topography.[1]

DATA

Dominant cleavage, or foliation, strikes very consistently between 000° and 040° within our area (Fig. 2). Dips range between 15° and 90° to the east, although the vast majority of dips are to the east between 25° and 50° Often, exact dip was difficult to measure because of the undulation in the surface, but even in cases such as these, an overall east dip was not difficult to discern. The trend of local ridges closely matches the foliation strike; the three ridges which we measured trend between 025° and 035° (Fig. 3). While the orientations of lithologic contacts were not measured, the map reveals that they, too, strike NNE (Fig. 1).

Our measured joints formed a maximum between 090° and 120° (Fig. 4). The measured set strikes almost perpendicular to the foliation, indicating that they are tectonic in origin (Leftwich, pers. comm.). While many joints

[1]The two ridges and single line of slope-change will all be referred to as "ridges" from here on.