Structural controls on stream geomorphology in the Savage Hill area, Northern Berkshire County, Massachusetts

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Introduction

During the Taconian Orogeny, (470-450 Ma) west-directed thrusting emplaced slope and rise deposits of the Greylock Schist over shallow water deposits of the Stockbridge Formation and flysch of the Walloomsac Formation. Northeast trending ridges and valleys in the area are oriented parallel to the regional flow direction of the major streams. Our study focuses on the effects structural features in the bedrock have on local stream geomorphology.

Geologic Setting

The study area is located in the 7.5' by 15' Cheshire Quadrangle in the Taconic-Berkshire zone (Zen and others., 1983), and includes several north-south trending ridges and valleys. The elevation ranges from 300 to 630 meters. The exposed lithologies include units of the Late Precambrian to Cambrian Greylock Schist, the Cambrian to Ordovician Stockbridge and the Ordovician Walloomsac Formations. The Greylock Schist is a dark greenish-gray ilmenite, chloritoid, quartz, muscovite schist containing some albite granofels. It originated as argillaceous deposits on the continental slope and rise of ancient North America (Ratcliffe and others, 1993). The members of the Stockbridge Formation that we see in our area are light, blue, gray, weathered calcite and dolomitic marbles representing continental shelf deposits (Ratcliffe and others, 1993). The Walloomsac Formation is a dull gray weathered, black to sooty-gray, carbonaceous, biotite, muscovite, plagioclase, quartz schist. It contains a calcitic schistose marble member and originated as a syn-orogenic flysch.

During the Taconian Orogeny, Laurentia collided with the Shelburne Falls arc. During collision the slope and rise deposits were thrust westward over the shelf deposits and the Walloomsac Formation. A prominent and consistent northeast trending, easterly dipping foliation is parallel to lithologic contacts and to the regional trend of valleys and ridges.

Methods

Data were collected over eleven days. Traverses were concentrated along streams and valleys where outcrop was relatively abundant. We took measurements on foliations, joints, lineations and fold axes. Stream trend direction was obtained using 7.5' by 15' quadrangles. The trend was measured in 5 millimeter increments on the map which corresponds to a distance of 125 meters in the field. Stream data were divided into two groups, an upper and lower. These groups were separated by the break in slope created by lithologic differences between the marble and the schist. We entered all our data into a Excel database which we used to create our figures.

Data

We observed that the lithologies of the valleys were different than that of the ridges (Figure 1). The Stockbridge Formation, consisting of both calcitic and dolomitic members is found in the valley floors. It is not present above 400 meters. The Walloomsac Formation was found on both the east and west slopes of ridges above 400 meters. With one exception, we found Greylock Schist on top of every prominent ridge in our area at elevations above 420 meters.

The foliations we measured throughout our area were consistent and showed little scatter (Figure 2a and 2b). The prominent foliation strikes 026° and dips 40° southeast. There were some foliations found in the eastern part of our study area which strike 200° and dip 70° northwest. These made up less then 5% of our data set. The marbles in our area showed compositional layering parallel to the regional foliation (Figure 3). Although there are several distinct groups of fold axes orientations, the dominant set trends 025° and plunges 10° to the northeast (Figure 4). The folds we measured indicate top to the west sense of

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Thrusting. NNE-SSW striking and east-dipping belts of marble coincide with the major valleys flanking the Greylock massif as well as numerous minor valleys on the massif, even at higher elevations (approximately 800 m). The fault-bounded marble slivers formed when Taconic sequence rocks overrode the carbonate shelf rocks and large portions of the foot-wall became accreted to the hanging-wall. The present location of these slivers between thrust sheets of the Taconic sequence rocks indicates that the imbricate faults were active during westward transport along the basal sole thrust. The carbonate slivers were carried into their present positions along the imbricate splays which separated Taconic sequence rocks. The marked contrast in resistance to chemical weathering and erosion between the schist and the thin marble layers present on the Greylock massif explains the long, narrow, deeply incised valleys.

Jointing. The NNE-SSW striking prominent joint set and crenulation cleavages are closely parallel to the major ridges and valleys and exert an enormous influence on the topographic development of the area. The WNW-ESE striking prominent joint set is approximatley parallel to many of the tributary streams. Many tributary streams are influenced by both joint sets and follow a roughly rectilinear path down the sides of ridges to the major valleys. This pattern is especially pronounced in deeply incised valleys where surficial cover is thin or absent.

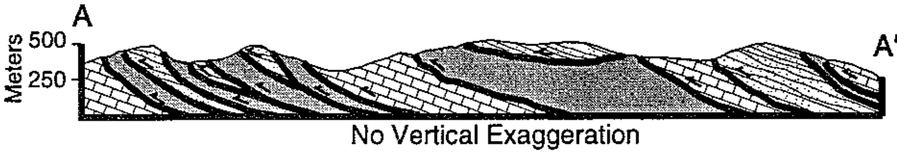
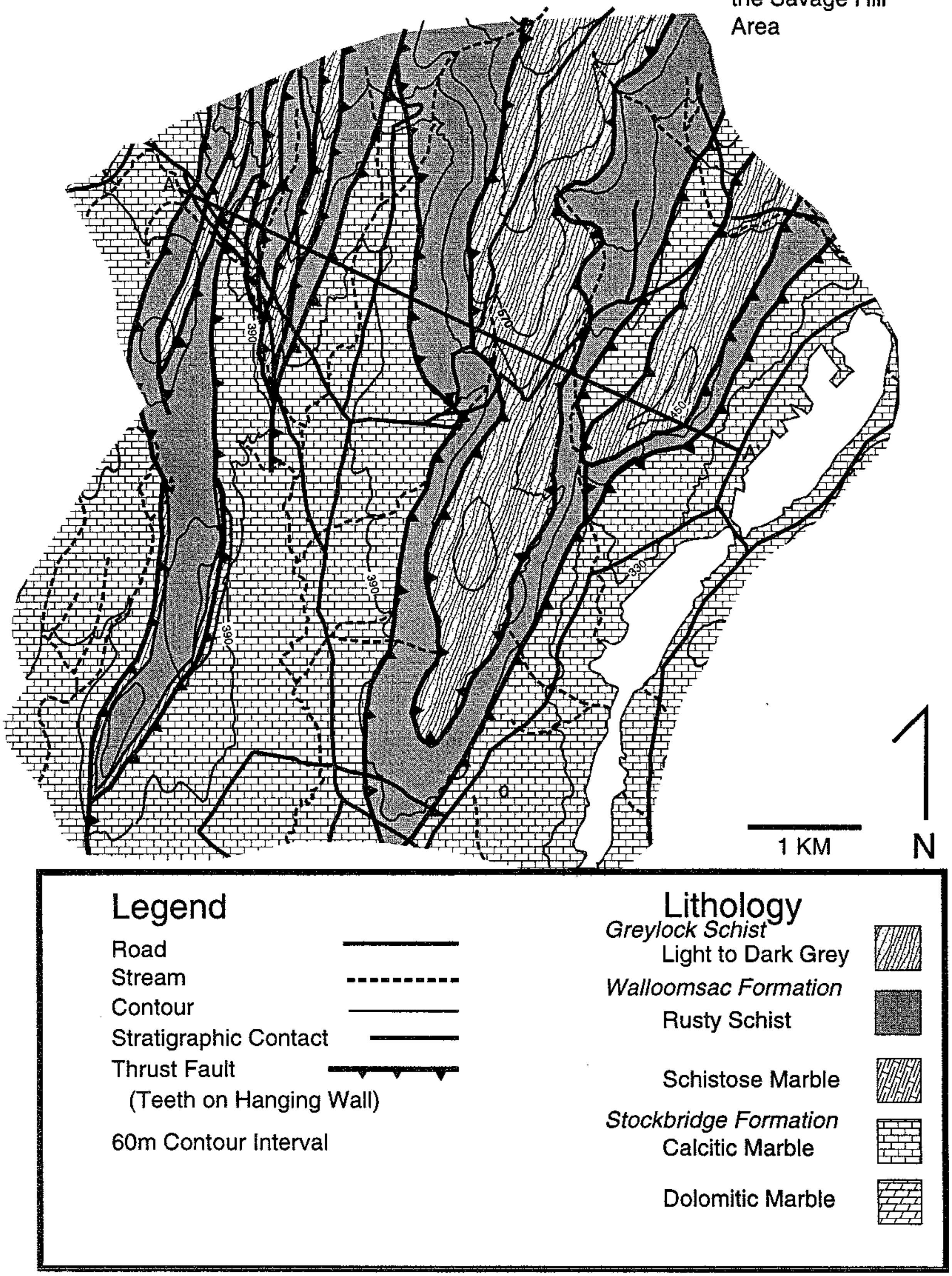


Figure1: Geologic Map and Cross Section of the Savage Hill Area



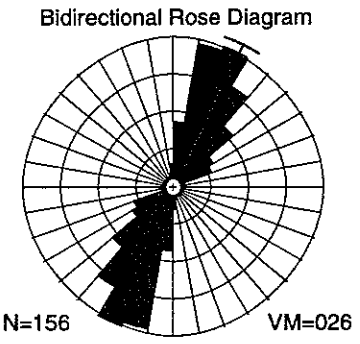


Figure 2a :Strike of Foliation

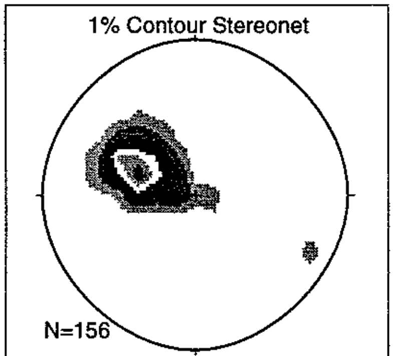


Figure 2b: Poles to Foliation

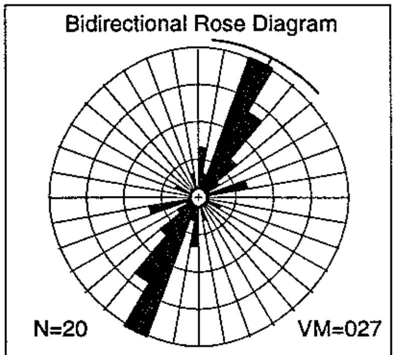


Figure 3: Strike of Bedding

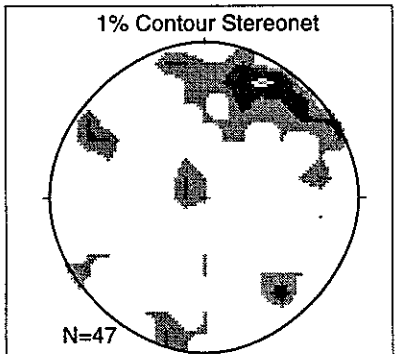


Figure 4: Fold Axes

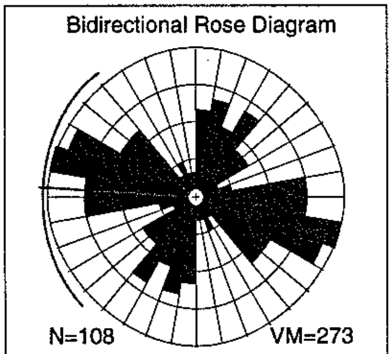


Figure 5: Strike of Joints

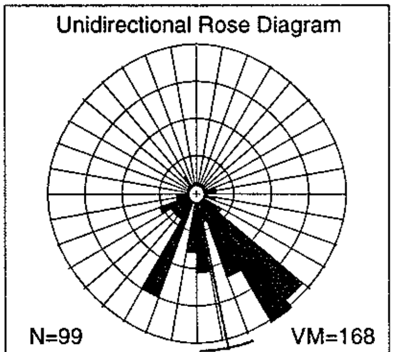


Figure 6a: Upper Elevation Streams

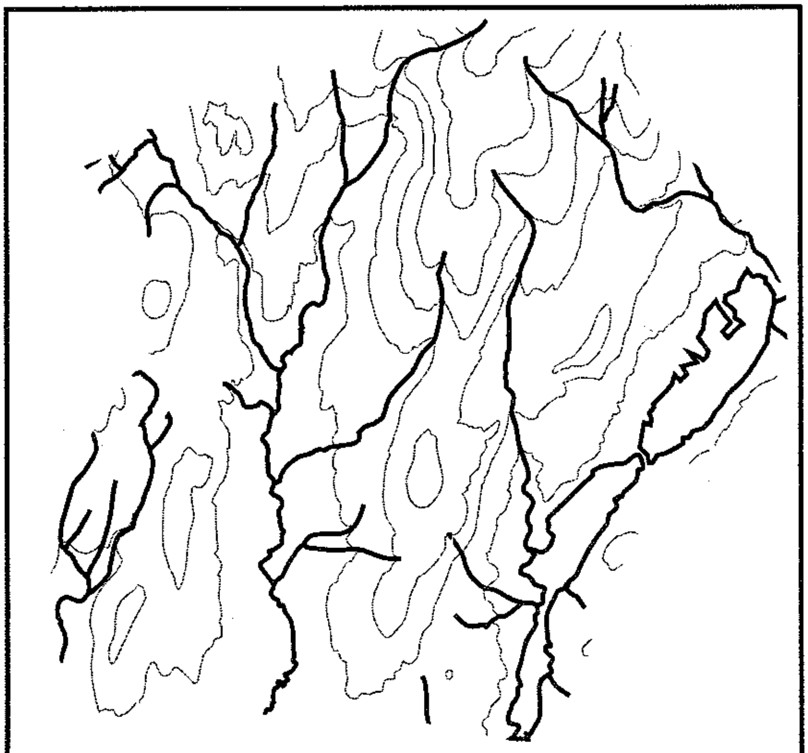


Figure 7: Stream Networks in Savage Hill Area

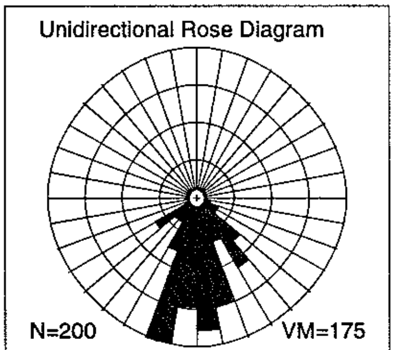


Figure 6b: Lower Elevation Streams

shear. The joints we measured strike in two prominent directions. The most prominent set strikes 110° and the other set strikes 030° (Figure 5). Jointing was easier to recognize and measure in the marble than in the other lithologies. Therefore, our data set may favor jointing orientations present in the marble.

Our upper elevation stream data set, which is a measure of stream orientations above 390 meters, shows a bimodal distribution of 140° and 200° (Figure 6a). The lower elevation stream data set shows one prominent orientation of 190° (Figure 6b). The streams above 390 meters are smaller first and second order streams which flow down the flanks of mountains. The streams below this level are higher order streams which run through the dominant north-south trending valleys (Figure 7).

Interpretations

The two stream data sets we collected, although showing similar mean vectors (within 20°), show that stream flow direction is controlled by different factors at different elevations. In the upper stream data set, the mean vector, which represents the average stream orientation, is 168°. However, there are two distinct groups of stream orientations which are not similar to the average orientation direction. These two orientations of 140° and 200° correspond to the primary and secondary joint sets of 110° and 210° (Figure 5 and 6a). Upper elevation streams can follow either set of joints, however, streams that flow down the western slopes tend to follow the secondary joint set while streams that flow down the eastern slopes tend to follow the primary joint set. Some upper elevation streams also alternate between joint sets and therefore create distinctly sharp bends. Since the trend of the dominant foliation is parallel to that of the secondary jointing it is difficult to determine whether foliation or jointing controls the less dominant stream orientation.

The lower elevation streams have an average orientation of 175°. There is only one dominant orientation, as opposed to two in the upper streams. This dominant orientation of the lower streams is 195°. Therefore, these streams could only be affected by secondary joints. The prominent stream orientation also matches the strike of the regional foliation. As streams move downward into the valleys and reach the marble lithological contact, they are increasingly affected by regional foliation and bedding than by joints.

We believe the bedrock geology of our study area is dominated by imbricate faults. We base this on the following evidence: If the rocks were extensively folded, we would expect to find more variation in the strike and dip of the bedding and foliation. The sense of shear in the small scale folds shows top to the west movement. Although the number of contacts we observed directly was small, every contact showed signs of thrusting. There is no symmetrical pattern to the lithologies we mapped. Even if folding could explain this pattern, we did not see an abundance of complex structures that normally accompany folding. We observed outcrop scale features, such as deformed marble slivers encased in schist, (8 meters) which could have only been transported to their present locations by fault drag. These features show evidence of large displacement on fault surfaces.

Conclusions

- Imbricate thrust faults dominate the structure in the area.
- Streams above 390 meters are influenced by the primary joints, secondary joints and foliation.
- Streams below 390 meters are influenced by foliation and secondary joints.

References Cited

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Mountain geomorphology: An investigation of mountain building mechanisms and their affect on stream orientations

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INTRODUCTION

The orientation of streams that have high gradients are greatly affected by the bedrock that they flow through. They can be affected by both the lithology and structures in the rock such as faults, folds, foliation, and joints.

The purpose of our study was to analyze the geology of an area in the central part of the Berkshire Mountain Range, Massachusetts to examine relationships between regional tectonics and present day geomorphology. This abstract presents two mechanisms for the evolution of the area: thrust slivers and folded thrusting. It also presents correlations between bedrock structures and stream flow orientations.

GEOLOGIC SETTING

Our study area is located south of Williamstown in the Cheshire and North Adams USGS 7.5' by 15' quadrangles. The area is bounded by Route 7 to the west, Rockwell Road on the east, Roaring Brook to the north, and Pratt Hill to the south (Figure 1). This area was mapped previously by Ratcliffe and others (1993).

The geologic units found in the area belong to the Stockbridge and Walloomsac Formations and the Greylock Schist, which is equivalent to the Nassau Formation. The Greylock Schist (Early Cambrian to Late Proterozoic) and Stockbridge Formation (Early Ordovician to Early Cambrian) overlap in age (Ratcliffe, 1993); however, their environments of deposition were different. The Greylock Schist originated from slope and rise deposits while the Stockbridge Formation originated from limestone deposited on the continental shelf of Laurentia. The Walloomsac Formation (Middle Ordovician) is a syn-orogenic flysch formed from sediment shed from advancing thrust sheets during the Taconian Orogeny.

The Greylock Schist in this area is a medium to dark gray schist and the Stockbridge Formation is represented by gray, coarse-grained calcitic marble. The Walloomsac Formation in our area consists of two members: a black, graphitic phyllite and an easily eroded, highly micaceous, sandy calcitic marble.

These units were deformed during the Taconian Orogeny (450-470 Ma). In this event, a magmatic arc collided with the ancient continent of Laurentia. The collision caused the faulting, folding, and metamorphism in western New England.

METHODS

We performed our field work over a two-week period, focusing on streams and ridges where we found the most outcrop. We mapped our stations using topographic maps and an altimeter. We used a protractor to measure the orientations of 0.5 cm sections of the streams on the topographic maps. We sub-divided the stream data based on the average slope of each stream. Those streams with an average slope $< 10\%$ tend to be at low elevations, generally strike north-south, and are usually higher-order streams. The streams with an average slope $\geq 10\%$ tend to lie at higher elevations, generally strike east-west, and are usually first order streams. We plotted this stream data and our structural data (i.e., foliation and joint orientations) on stereonet diagrams for analysis.

DATA

The outcrop patterns in our study area strike essentially north-south. This pattern is especially prevalent in the southwestern corner of the area. The only anomaly in this pattern is around the most prominent ridge "Sugarloaf" (Figure 1). Here the outcrop pattern and location of the contacts that we observed are concentric about the ridge.