Structural and glacial controls on the orientations of tributary streams in the Berry Hill Area

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Introduction

The Ordovician Taconian Orogeny (480-460Ma) deformed the passive margin sediments and underlying basement rocks of ancient North America. In our study area (Fig. 1), the Stockbridge Formation represents former carbonate shelf sediments and the Nassau Formation the slope-rise sediments (Friedman, 1979). Also found is the Walloomsac Formation, a graphitic phyllite derived from sediments shed from the overriding plate during subduction. The Nassau Formation was thrust westward as much as 100 km (Stanley and Ratcliffe, 1985; Karabinos, 1988) over the Stockbridge marble.

The Taconic Range was also affected by the latest Wisconsinan glaciation with ice uncovering the area approximately 15,000-14,000 years ago (DeSimone and LaFleur, 1985). Our study investigated both bedrock and glacial controls on stream course development in the Pittsfield State Forest between Berry Pond and Potter Mountain Road in Hancock, Lanesborough, and Pittsfield, Massachusetts. To determine the predominant control on the pathways of tributary streams, we measured the orientations of joints and foliation in bedrock, and determined ice flow direction and till deposition zones across the area. In addition, we hope to test hypotheses for the locations and orientations of major ridges and valleys in the region.

Goals

1) To determine controls on tributary stream orientations, possibilities include bedrock, glaciers, and till gradient.
2) To develop a structural explanation for the orientations and locations of major ridges and valleys in the area.

Methods

In the field, we measured joints, cleavage, fold axes, lineations, glacial striations, and mapped lithological units. In the lab, we measured rock drumlin orientations to determine ice flow direction. Stream orientations were measured in two ways. First, a coarse measurement was made from the tops of the streams to the point below which there is no outcrop and streams are presumed to meander through till. This lower elevation ranged from 320m to 380m. Second, a more detailed measurement was made along the steep upper portions of the western streams above a significant break in slope located at approximately 450m which is interpreted as a thick till-thin till boundary.

Data

Throughout our study area, foliation strikes 020°-040° and dips 20°-50° to the southeast with little variation. Joints occur in two major groups (Fig. 2). One set strikes between 010° and 040° and dips steeply to the west with uncommon eastward dips. The other set is less prominent and strikes between 110° and 130° with steep dips to the north and south. On the west side of the study area the northeast-southwest joints dip exclusively to the west, whereas on the east side a few eastward dips are observed. There is considerably more scatter in the joints on the east side than on the west side. Also, on the east side there is a higher ratio of southeast-northwest to northeast-southwest joints than in the west. On average, both joint sets strike about 10 degrees more to the north in the eastern streams than in the western streams.

Streams have very similar orientations on both the east and west sides of the ridge (Fig. 3). On the east side streams flow in bedrock along most of their length and are often in deep, steep-sided valleys. Orientations are quite consistent until the streams reach the valley bottom and most segments are oriented between 130° and 150°. In the west we made both coarse and detailed measurements of stream orientations. Orientations determined by both methods were similar, although there was less scatter in the measurement of the upper portions of the streams. Using the detailed measurements, orientations were most common between 290° and 320° whereas for the coarse measurement orientations peaked between 300° and 320°.

Through measurement of rock drumlins and glacial striations, we found ice flow in our area was between 120° and 140°. Two sets of striations each indicated a 120° regional thick ice flow direction.

Interpretations

Our three data sets--joint orientations, ice flow direction, and stream orientations--overlap significantly. To determine whether the orientations of stream courses were influenced more by bedrock or glaciers and till, we focused on the geomorphology and till cover of our streams.

In the upper portions of the western streams, which are not covered by till, stream orientations match the strikes of the southeast-northwest joints, both showing peaks around 300°. Because the stream valleys do not cut through till, past glaciation is presumed to have little influence on their orientations. The matching sets of joint data and stream orientations suggest that in the steep upper portions of western streams joint orientation is the dominant factor controling stream orientation. The orientations of the streams remain constant once they enter thick till and match ice flow direction; based on topography and ice flow direction, the regional till gradient at the time of recession is estimated at about 300°. In their lower portions, stream courses on the west side may have followed the regional till gradient as they were formed, but the evidence is inconclusive.

In the east we see significantly different topography than in the west. There is no obvious slope break and and streams flow dominantly over bedrock. In the southeast quadrant Daniels, Churchill, and Lulu Brooks show remarkable similarity in orientation and geomorphology (Fig. 1). All three follow nearly identical courses from the ridge crest to the valley bottom, and each flows through a deep, well defined V-shaped valley. The till cover in these streams is minimal. The size of the valleys suggests that they are preglacial and were scoured by active ice as the glaciers advanced. We believe that as the ice retreated stagnant ice was left in these valleys prohibiting deposition of thick till. What caused these valleys to form before the Wisconsinan glaciation is problematic but the similarities of joint and stream orientation in the east suggests that the bedrock may have played a significant role.

Glaciation was not a control on the location and orientation of the ridge and the prominent valley to the east. The orientation of the ridge running through our study area takes a sharp turn north of Berry Pond and turns again just south of Potter Mountain Road, trending 010° in the north and south and 040° in our area. The northeast trend is consistant with the orientations of the cleavage and the prominent northeast-southwest striking joint set we observed, and suggests that the valley adjacent to the ridge may have formed along lines of preexisting structural weakness. On the east side of our area at the base of the ridge we have mapped a thrust fault dipping east, bringing Stockbridge Formation over Nassau Formation (Fig. 1, some contacts taken from Zen et al., 1983). This fault is interpreted as a splay on a sole thrust above which Nassau Formation lies on top of Walloomsac and Stockbridge Formations. The Stockbridge Formation was brought over the Nassau Formation as part of a large sliver plucked from a footwall ramp. The more easily eroded marble lying on top of more resistant phyllite may have caused the formation of the major valley to the east as it was exposed and preferentially eroded.

Conclusions

Both glaciers and bedrock influence the orientations of streams in Pittsfield State Forest. The dominant factor depends on slope angle, till deposition, and preglacial landforms. We conclude that the orientations of the regional till gradient and southeast-northwest striking joint sets were similar and the two acted together as streams formed, resulting in courses which are consistent through much of their lengths. The prominent valley east of the area is probably the result of bedrock erosion along lines of structural and lithologic weakness.

Works Cited

DeSimone, D.J. and LaFleur, R.G., 1985, Glacial geology and history of the Northern Hudson Basin, New York and Vermont: New York State Geological Association, Guidebook to Field Trips, 82-116.

Friedman, G.M., 1979, Sedimentary environments and their products: shelf, slope, and rise of proto-Atlantic (Iapetus) ocean, Cambrian and Ordovician periods, eastern New York state, in Friedman, G.M., ed. 71st New England Intercollegiate Geologic Conference, Guidebook for fieldtrips, p. 47-86.

Karabinos, Paul, 1988, Heat transfer and fault geometry in the Taconian thrust belt, western New England: Geological Society of America, Special Paper 222, 35-45.

Stanley, R.S., and Ratcliffe, N.M., 1985, Tectonic synthesis of the Taconian orogeny in western New England: Geological Society of America Bulletin, v. 96, p. 1227-1250.

Zen, E-An, ed., Goldsmith, Richard, Ratcliffe, N.M., Robinson, Peter, and Stanley, R.S., compilers, 1983, Bedrock geologic map of Massachusetts: U.S. Geological Survey and the Commonwealth of Massachusetts, Department of Public Works, and Sinnot, J.A., State Geologist.

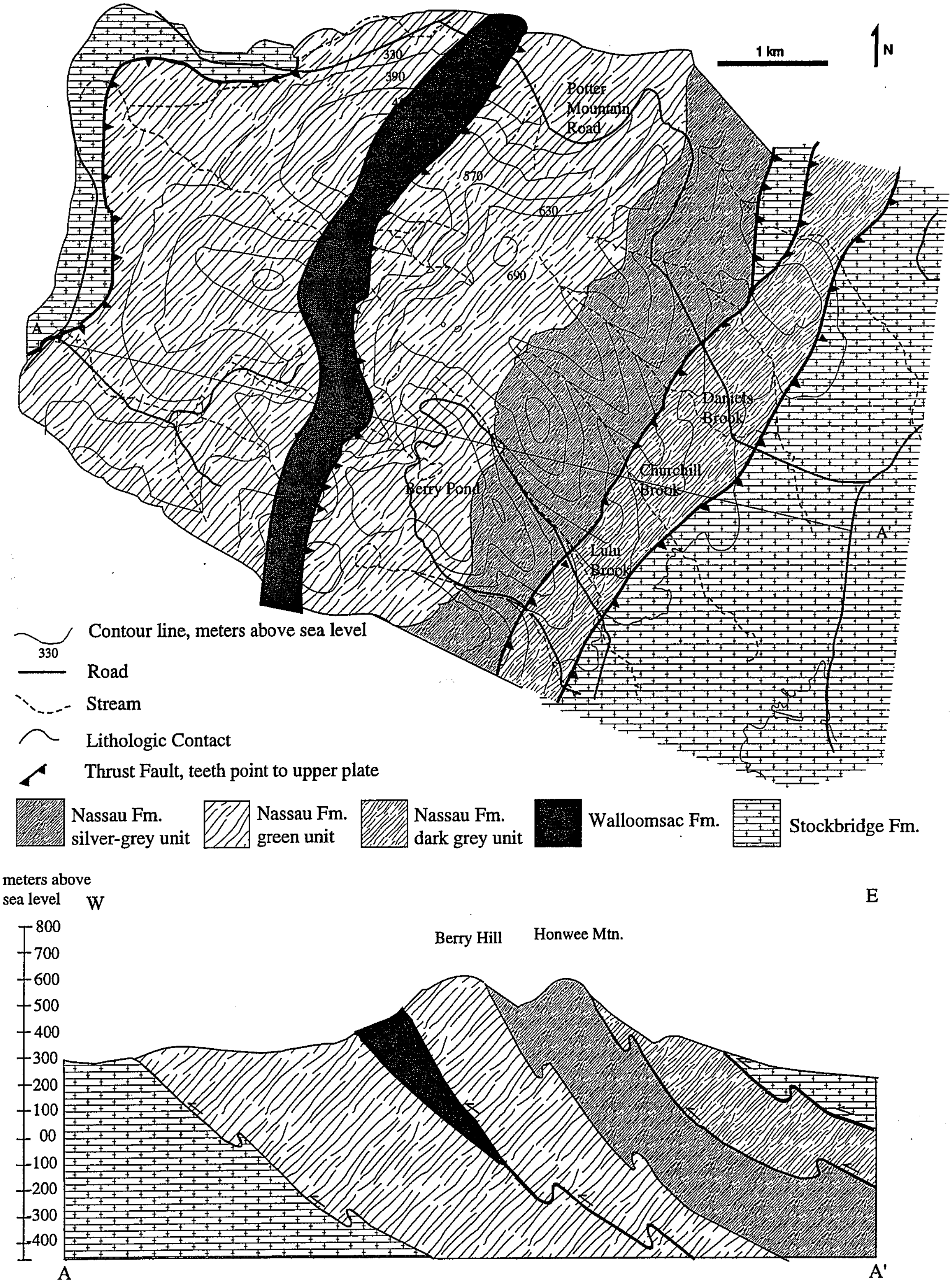

Figure 1. Geologic map and cross section of Berry Hill area.

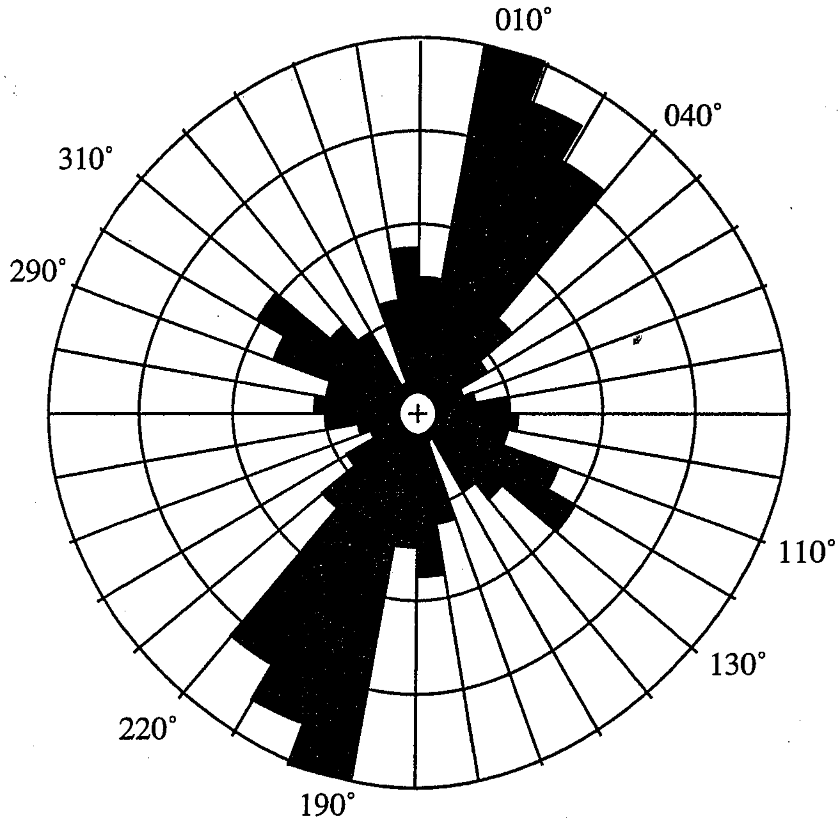

Figure 2. Bidirectional rose plot of joint orientations.

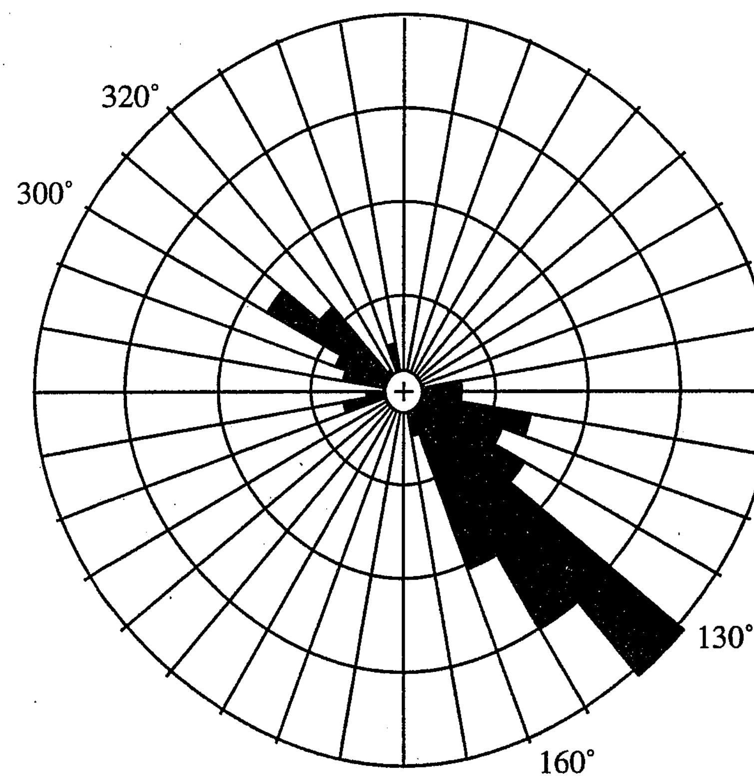

Figure 3. Unidirectional rose plot of stream orientations in 125m segments.