Integration of Structural Analysis, EMI and GPR Surveys, and Hydrogeology in the Plainfield Quadrangle, Central Vermont II

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Abstract

The Plainfield 7.5' Quadrangle lies on the western side of the Connecticut Valley Trough (CVT), a post-Taconian (Ordovician) extensional basin that was filled in with Silurian-Devonian sedimentary and volcanic rocks. The basin was deformed and metamorphosed during the Devonian Acadian Orogeny, and later intruded by post-orogenic granitoids of the New Hampshire Plutonic Series (NHPS). From oldest to youngest, the rocks in the field area consist of Devonian-aged granitic gneisses, interbedded pelitic (Gile Mt. Fm), semi-pelitic (Waits River Fm) and phyllitic quartzites (Gile Mt. Fm), and biotite granites (NHPS). The Waits River Fm is further divisible into members with thick (DSwt) and thin (DSwt1) marbles, respectively. The degree of metamorphism ranges from biotite- staurolite grade.

We observed two distinct sets of topographic lineaments: the first set follows the dominant bedding-parallel cleavage (S1) that is pervasive in all metasedimentary lithologies. The second set follows fractures that are orthogonal to the dominant foliation (S1). Whereas both lineament sets are clearly expressed in the Waits River Fm, lineaments in the Gile Mt. Fm are dominantly E-W.

Because previous Electromagnetic Induction (EMI) surveys in an adjacent quadrangle showed a strong connection between brittle and ductile structures and groundwater flow, we conducted detailed (1:4000) EMI in specific areas of the Waits River Fm. These surveys demonstrated a strong correlation between lineaments and electrical conductivity (EC). High EC values occurred at outcrops, suggesting the fractures may be groundwater pathways. Since the Waits River and Gile Mt. fms have average well yields that range from 16- 23 GPM in this area, we want to further assess the role that lithology, lineaments, and bedrock structures play in domestic well productivity.

Our ongoing research seeks to: A) Analyze the relationship of well yields to both lineament sets, B) create detailed cross-sections to assess whether fold geometry affects well yields, C) construct a 3D conceptual model for the bedrock hydrogeology of this portion of the CVT.

Figure 1- Bedrock Geologic Map and Cross Section

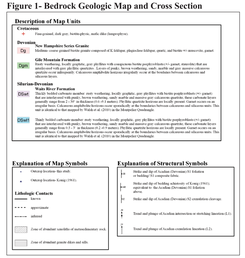
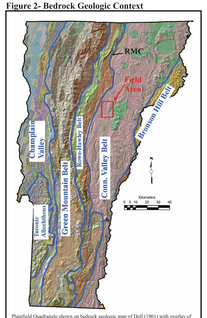


Figure 2- Bedrock Geologic Context



Plainfield Quadrangle shown on bedrock geologic map of Doll (1961) with overlay of lineaments/ axes.

Figure 1- continued

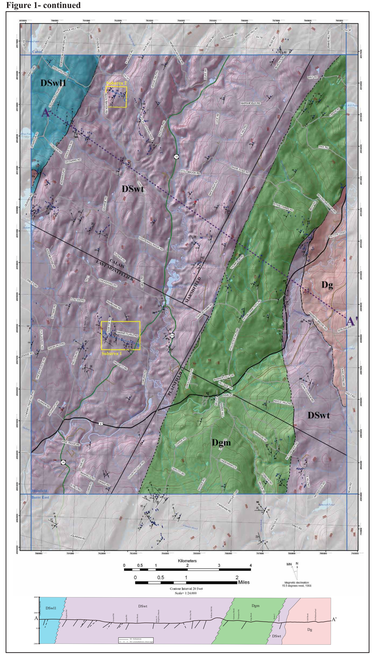
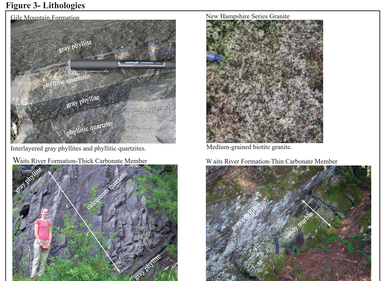


Figure 3- Lithologies



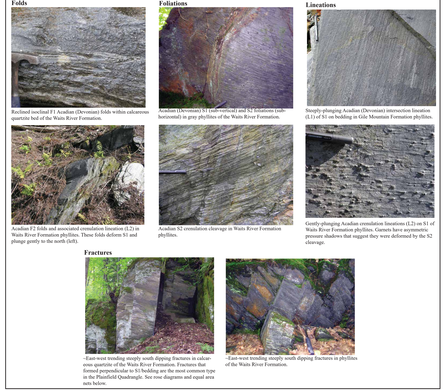
Interlayered gray phyllites and phyllitic quartzites.

Medium-grained biotite granite.

Calcareous quartzite layer (~12' thick (3.7 m)) in rusty weathering gray phyllite.

Sandy marble layer (~2' thick (0.6 m)) in rusty weathering gray phyllite.

Figure 4- Ductile and Brittle Structures



Reclined (recline) F1 Acadian (Devonian) folds within calcareous quartzite bed of the Waits River Formation.

Acadian (Devonian) S1 (bedding-parallel) and S2 foliations (sub-horizontal) in gray phyllites of the Waits River Formation.

Steeply-plunging Acadian (Devonian) intersection lineation (L1) of S1 on bedding in Gile Mountain Formation phyllites.

Acadian F2 folds and associated crenulation lineation (L2) in Waits River Formation phyllites. These folds deform S1 and plunge gently to the north (left).

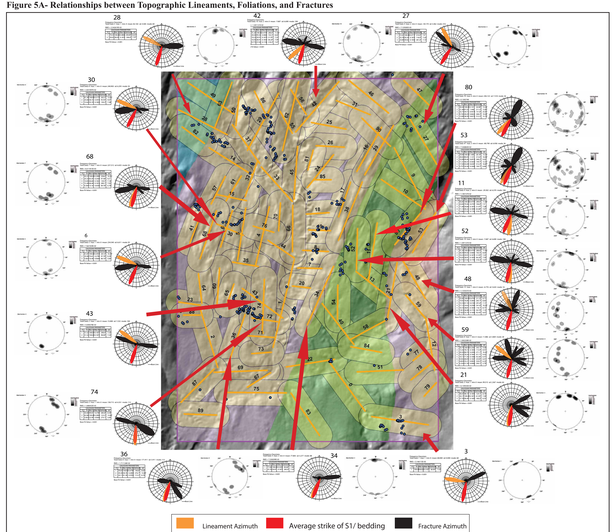
Acadian S2 crenulation cleavage in Waits River Formation phyllites.

Gently plunging Acadian crenulation lineations (L2) on S1 of Waits River Formation phyllites. Garnets have asymmetric pressure shadows that suggest they were deformed by the S2 cleavage.

-East-west trending steeply south dipping fractures in calcareous quartzite of the Waits River Formation. Fractures that formed perpendicular to S1-bedding are the most common type in the Plainfield Quadrangle. See rose diagrams and equal area nets below.

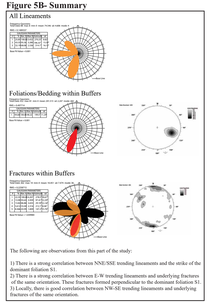
-East-west trending steeply south dipping fractures in phyllites of the Waits River Formation.

Figure 5A- Relationships between Topographic Lineaments, Foliations, and Fractures



Bedrock geologic map of the Plainfield Quadrangle with overlays of topographic lineaments (orange lines), 500 meter buffers on each lineament (light yellow), and field stations/outcrops (blue dots) that fell within these buffers. For each lineament buffer, the ductile and brittle structural data were collected for all field stations that fell within; these data were plotted using Dave Software (Salvini et al., 2000) on frequency azimuth rose plots and equal area nets. By comparing these diagrams against each lineament azimuth, we sought to establish which lineaments were controlled by underlying bedrock structures. See the summary in Figure 5B for our major observations.

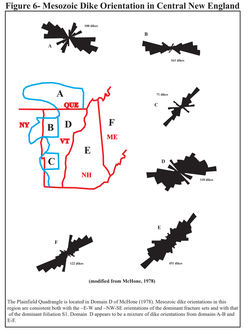
Figure 5B- Summary



The following are observations from this part of the study:

1) There is a strong correlation between NNE/SSE trending lineaments and the strike of the dominant foliation S1.
2) There is a strong correlation between E-W trending lineaments and underlying fractures of the same orientation. These fractures formed perpendicular to the dominant foliation S1.
3) Locally, there is good correlation between NW-SE trending lineaments and underlying fractures of the same orientation.

Figure 6- Mesozoic Dike Orientation in Central New England



(modified from McHone, 1978)

The Plainfield Quadrangle is located in Domain D of McHone (1978). Mesozoic dike orientations in this region are consistent both with the ~E-W and ~NW-SE orientations of the dominant fracture sets and with that of the dominant foliation S1. Domain D appears to be a mixture of dike orientations from domains A-B and E-F.

Figure 7- Integrating EMI with Field Mapping at Subarea 1

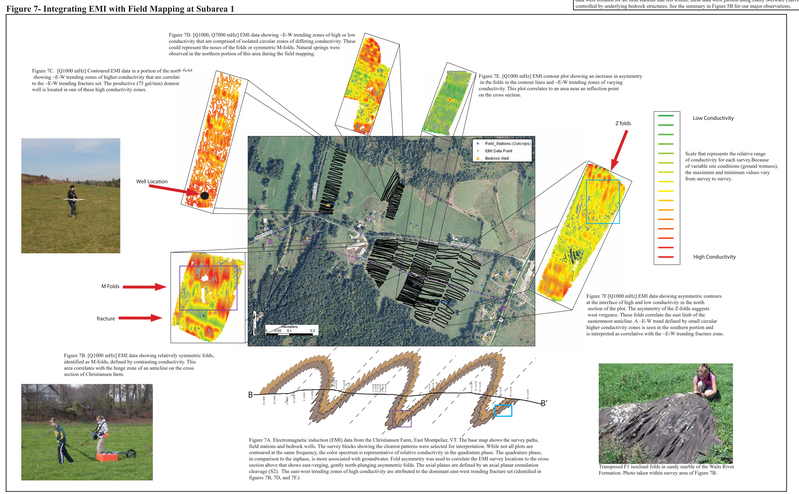
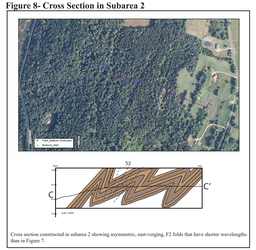
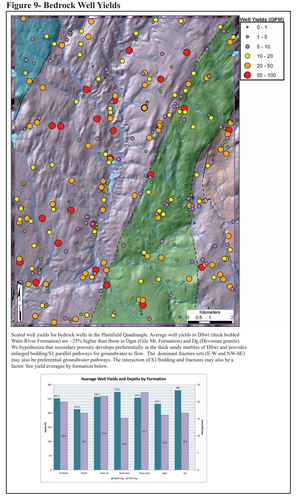


Figure 8- Cross Section in Subarea 2



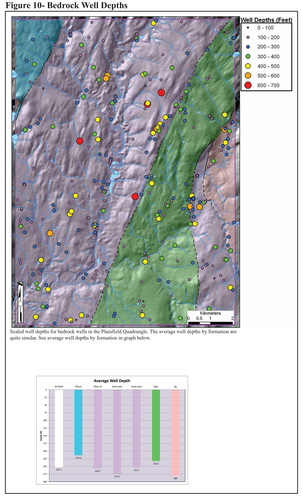
Cross section constructed in subarea 2 showing asymmetric, east-verging, F2 folds that have shorter wavelengths than in Figure 7.

Figure 9- Bedrock Well Yields



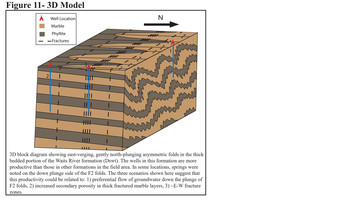
Scaled well yields for bedrock wells in the Plainfield Quadrangle. Average well yields in DSwt (thick bedded Waits River Formation) are ~25% higher than those in Dgm (Gile Mt. Formation) and Dg (Devonian granite). We hypothesize that secondary porosity develops preferentially in the thick sandy marbles of DSwt and provides enlarged bedding/S1 parallel pathways for groundwater to flow. The dominant fracture sets (E-W and NW-SE) may also be preferential groundwater pathways. The intersection of S1-bedding and fractures may also be a factor. See yield averages by formation below.

Figure 10- Bedrock Well Depths



Scaled well depths for bedrock wells in the Plainfield Quadrangle. The average well depths by formation are quite similar. See average well depths by formation in graph below.

Figure 11- 3D Model



3D block diagram showing east-verging, gently north-plunging asymmetric folds in the thick bedded portion of the Waits River formation (Dswt). The wells in this formation are more productive than those in other formations in the field area. In some locations, springs were noted on the down plunge side of the F2 folds. The three scenarios shown here suggest that: this productivity could be related to: 1) preferential flow of groundwater down the plunge of F2 folds, 2) increased secondary porosity in thick fractured marble layers, 3) ~E-W fracture zones.

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References:

Doll, C. (Editor), 1961, Geologic Map of Vermont, scale 1:250,000.

Kim, J. and Ruksznis, A., 2011, Bedrock Geologic Map of the Plainfield Quadrangle, Washington County, Vermont: Vermont Geological Survey Open File Map VG11-3, 2 plates, scale 1:24,000.

McHone, J.G., 1978, Distribution, orientations, and ages of mafic dikes in central New England: Geological Society of America Bulletin, v. 89, p. 1645-1655.

Salvini F., Billi A., Wise D.U. (1999). Strike-slip fault-propagation cleavage in carbonate rocks: the Mattinata fault zone, Southern Apennines, Italy. Journal of Structural Geology. vol. 21, p. 1731-1749 ISSN: 0191-8141.