Bedrock Control on Surficial Deposits and Groundwater Issues in Part of the Knox Mountain Granite: NE Vermont

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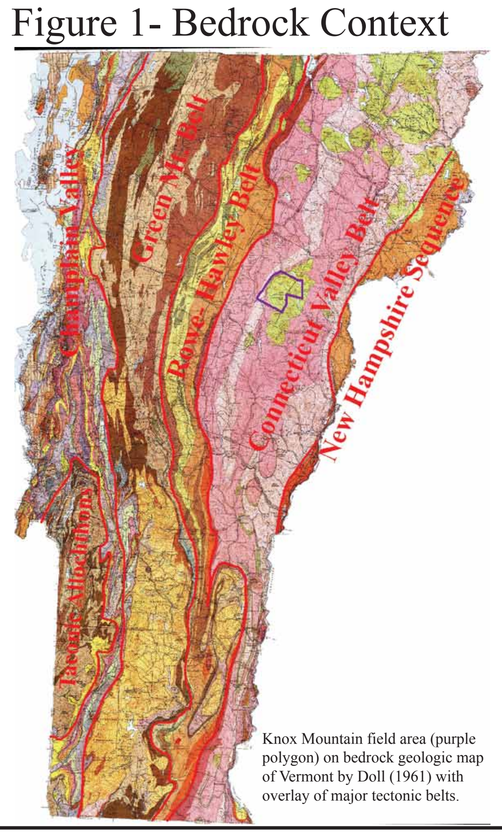
Abstract

During the 2008 field season, bedrock and surficial geologic maps were constructed of parts of the towns of Marshfield and Peacham to serve as a basic framework for understanding elevated U levels in groundwater from bedrock wells in this area. The SE 75% of this region is underlain by the M. Devonian Knox Mt. granite pluton that intruded the Late Silurian-Early Devonian metasedimentary rocks of the Gile Mt and Waits River fms. in the NW 25%. The dominant surficial deposits are tills, ranging from dense, fine-sandy silt matrix till in the NW to a variety of looser, sand-matrix tills in the granite portions. During the course of this project, it was apparent that bedrock structures exerted strong control on the thickness and distribution of surficial deposits. These thick surficial deposits may form localized areas of higher well yields.

We focused on the following associations between bedrock structure and surficial deposit distribution and/or thickness: 1) The paleochannel of Naismith Brook, currently buried by >80 meters of sediments (sandy till at surface with stratified sand and gravel at depth), follows the western intrusive contact of the Knox Mt. granite. 2) Thick (>30m) surficial deposits in the Winooski River valley bottom from Plainfield to Marshfield villages roughly follow the granite contact. 3) Complexes of moraine ridges are found in glacially-scoured rock basins down ice (south of) granite hills whose shapes are controlled by major fracture sets. 4) Major E-W trending valleys in the granite parallel to an E-W fracture set 5) The granite hills deflected ice-flow from about 165° in the metasediments in the NW of the field area to 170 - 200° in the bottom of the Winooski valley and in the granite.

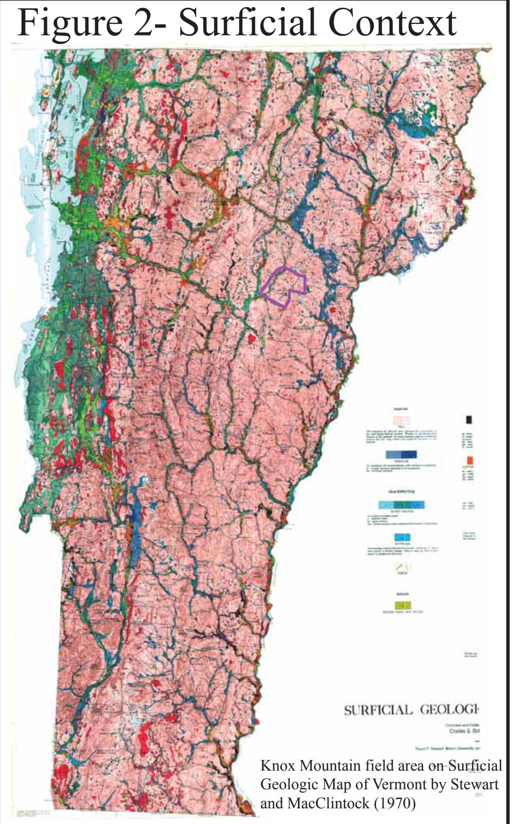
The bedrock- surficial associations have implications for groundwater quantity and quality issues. The thick surficial deposits in the granite contact zone near Naismith Brook are potential zones of higher well yields due to buried stratified sand and gravel aquifers. With respect to groundwater quality, there are numerous public and domestic bedrock wells with elevated abundances of U in the Knox Mt granite. A collaborative study by Gleason (2007) with the Vt Geological Survey tested 19 additional bedrock wells in the field area and found that 2 of 19 wells had elevated gross alpha (>15 pci/l) and that 3 of 19 had elevated U (>20 ppb).

Figure 1- Bedrock Context



Knox Mountain field area (purple polygon) on bedrock geologic map of Vermont by Doll (1961) with overlay of major tectonic belts.

Figure 2- Surficial Context



Knox Mountain field area on Surficial Geologic Map of Vermont by Stewart and MacClintock (1970)

Figure 3- Bedrock Geologic Map

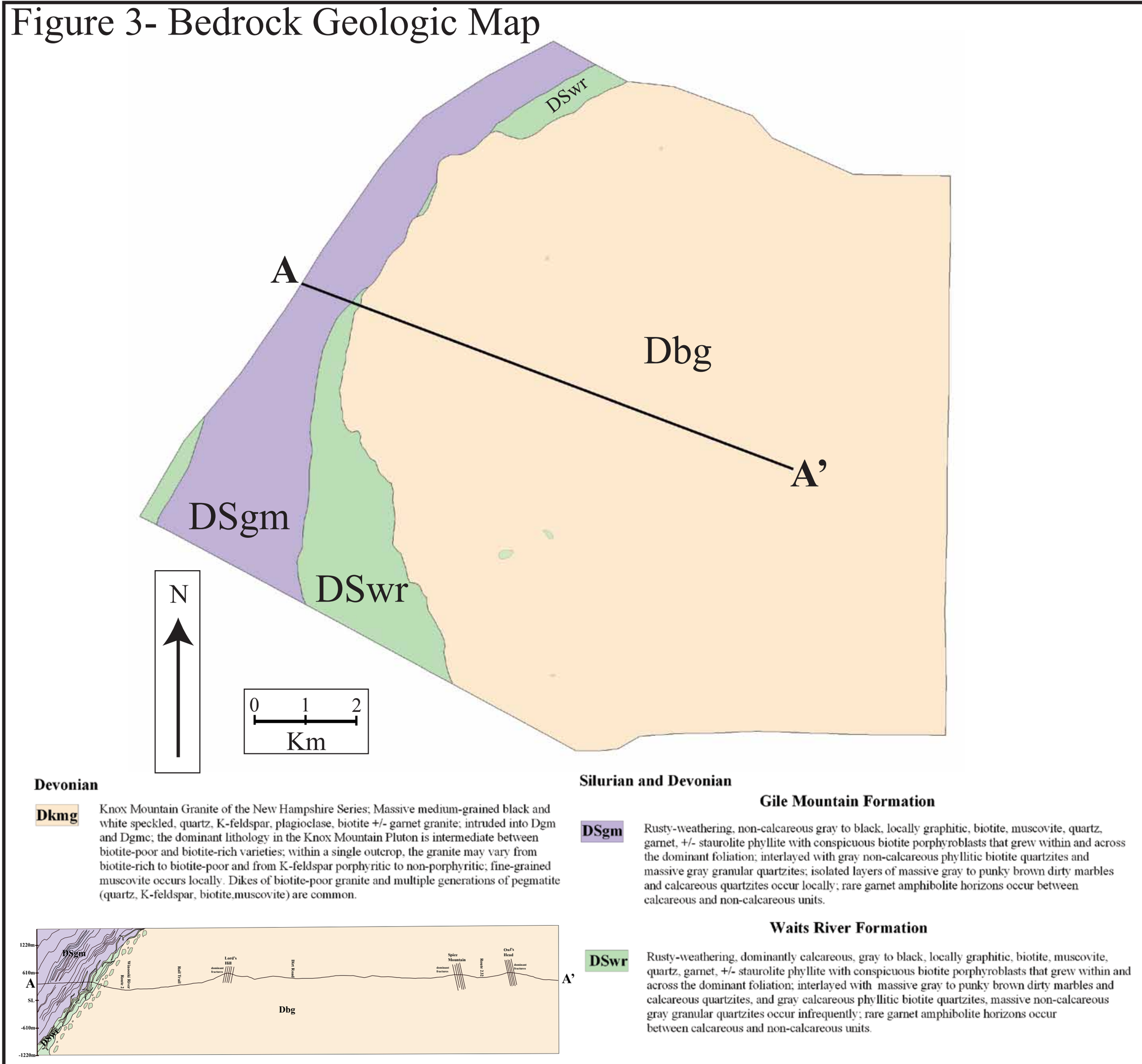
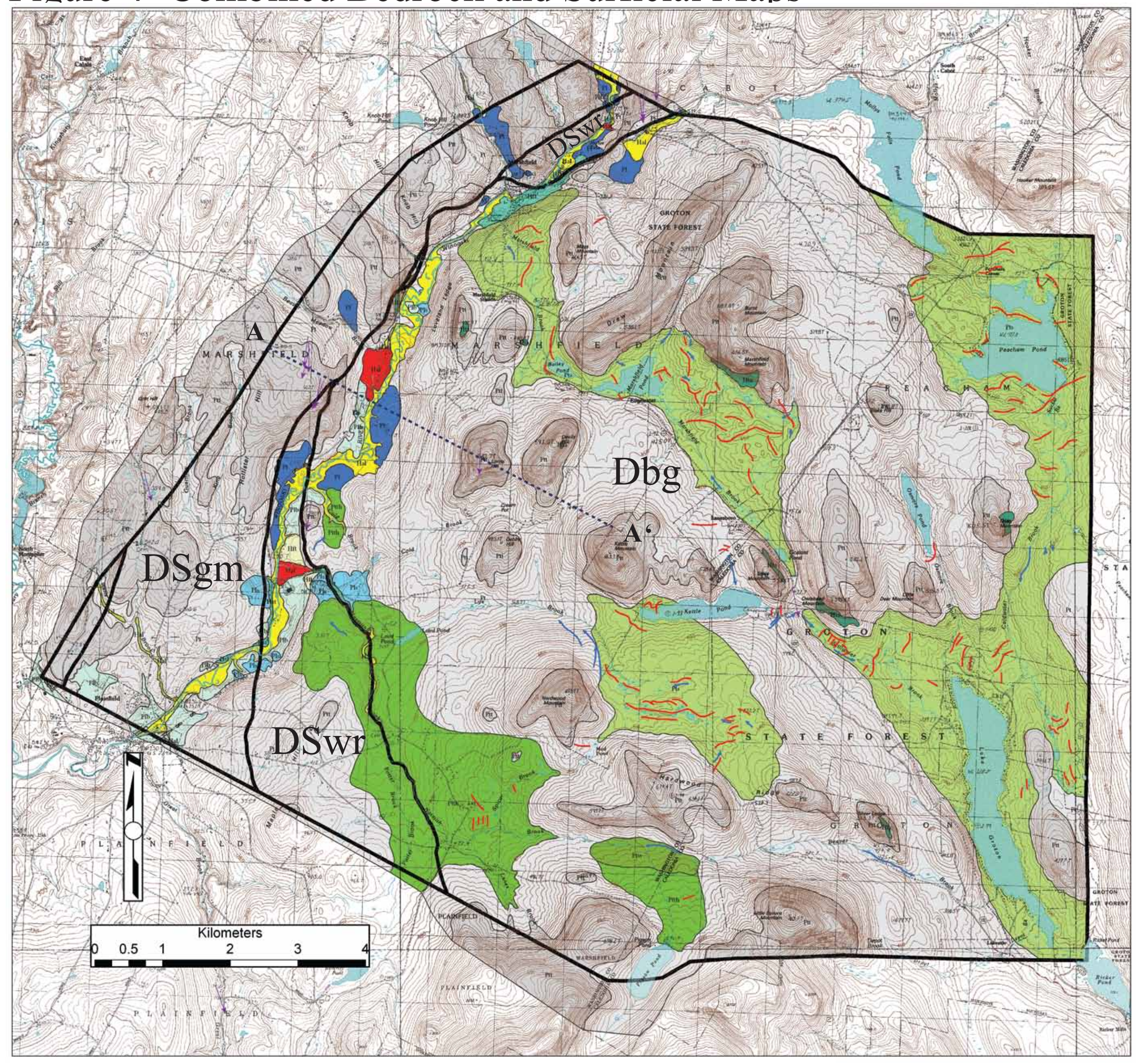
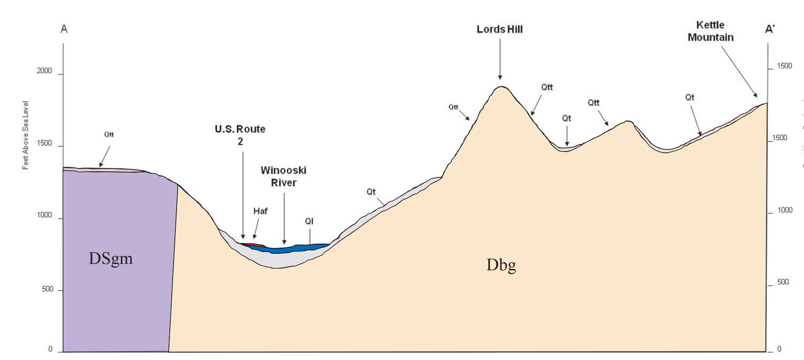


Figure 4- Combined Bedrock and Surficial Maps





Legend

Description of Map Units

Unit	Description
f	Artificial Fill. Artificially emplaced earth along rail beds, road beds, embankments and low lying areas. There is extensive fill along the interstate and along road approaches to the interstate.
gf	Graded or Filled. Areas of extensive grading and/or filling, commonly associated with buildings, parking lots, or roads.

HOLOCENE DEPOSITS

Unit	Description
Haf	Alluvial Fan Deposits. Pebble gravel, cobble gravel, boulder gravel, and pebbly sand deposited at the mouths of tributary streams to the Winooski River. Commonly less than 5 meters in thickness.
Hal	Alluvium. Silt, sand, pebble gravel, cobble gravel, and boulder gravel deposited by modern streams. Deposits include stream channel and bar deposits and finer-grained floodplain deposits. Minor wetland deposits are common. Thickness is highly variable with the deposits along the smaller streams typically less than 3 meters thick. Thicknesses in the Winooski River floodplain are greater. Permeability usually intermediate to low. Can be good aquifer if sufficiently thick but of limited aerial extent. These areas are typically flooded yearly or every few years.
Hft	Fan-Terrace Deposits. Pebble and cobble gravel and pebbly sand deposited on top of lake bottom deposits of glacial Lake Winooski subsequent to drainage of the lake. The gravel and sand are commonly less than 3 meters thick. Found near the mouths of present day tributaries to the Winooski.
Hst	Stream Terrace Deposits. Silt, sand, pebble gravel, cobble gravel, and boulder gravel deposited on terraces above the modern floodplains of streams. Deposits of mappable size are limited to the Winooski River valley. Generally less than 5 meters thick. Variable permeability but usually intermediate. Fair to good aquifer. The terrace surfaces are rarely flooded, if at all. However, these deposits are highly erodible and are quite susceptible to stream erosion and slope failure.
Hta	Talus Deposits. Accumulations of angular to subangular boulders at the bases of prominent cliffs.

PLEISTOCENE DEPOSITS

Unit	Description
Pl	Lake Deposits, Undifferentiated. Fine grained varved or thinly laminated deposits of silt and silty clay and well sorted, laminated very fine to medium sand, accumulated in glacial Lake Winooski. Thickness typically increases from less than a meter on the valley side to 10 or more meters in the valley bottom. Poorly drained and with poor aquifer potential. Prone to stream bank failures and headward erosion of the slopes.
Plb	Lake Silt and Silty Clay. Fine grained varved or thinly laminated deposits of silt and silty clay accumulated in the deeper portions of glacial Lake Winooski lake basins. Thickness typically increases from less than a meter on the valley side to 10 or more meters in the valley bottom. Poorly drained and with poor aquifer potential. Prone to stream bank failures and headward erosion of the slopes.
Pls	Lake Sand. Well to moderately sorted, laminated very fine to medium sand deposited in shallow waters or on shorelines of glacial Lake Winooski. Of variable thickness; commonly ranging from less than 1 meter to greater than 10 meters in thickness. Prone to gullying and stream bank erosion. Found on higher parts of terraces in the Winooski River valley. Moderately good aquifer if thick, poor if thin.
Pt	Till. Extremely poorly sorted diamict with abundant angular to subangular clasts. Matrix is typically dominated by silt or silty fine sand. Clasts range in size up to large boulders. Surface boulders are commmonly abundant. Deposits are typically unstratified. Thickness generally greater than 3 meters but rock outcrops may be common. Generally low permeability and poor aquifer potential.
Pts	Sandy till. Extremely poorly sorted diamict with abundant angular to subangular clasts. Matrix is typically dominated by fine sand. Clasts range in size up to large boulders. Deposits are typically unstratified, although minor lenses of stratified sand and gravel are found. Thicknesses appear to range from about 3 to 10 meters. Topography is commonly hummocky and moraine ridges are common. Surface boulders are very aboundant, with many large blocks on the moraine crests. Permeability may be low to moderate and these deposits probably have limited aquifer potential.
Ptt	Thin till. Similar to till described above, but thickness generally less than 2 to 3 meters with rock outcrops abundant. Surface boulders or erratics are common. Occurs on moderate to steep hill and mountain slopes and summit areas. Generally low to moderate permeability. Generally poor aquifer potential.
Ptth	Thick till. Similar to the sandy till described above, but of anomalous thickness (exceeding 30 meters in places) and overlying a variety of bedded sands, gravels and silts. Found in the Naismith Brook valley in the west-central part of the project area. Generally low to moderate permeability in the till but the stratified deposits below may have higher permeability and may have better aquifer potential.
Ptw	Washed Till. Similar to the tills described above, but with an extremely bouldery surface with little matrix left between the boulders. Found in the saddle between Nasmith Brook and Beaver Brook, north of Pigeon Pond. This may be the result of winnowing of the fines out from between the boulders by glacial meltwater.

Explanation of Symbols

- Bedrock outcrops
- Striation
- Moraine ridge - Ridge of till interpreted to have formed in marginal zone of glacier
- Outwash channel
- Field Stations
- Wells
- Project area boundary
- Line of cross-section

Figure 5- Moraine Complexes

Introduction

Topographic grain in the highlands underlain by the Knox Mountain Granite is dramatically distinct from that of the surrounding metamorphic rocks. This change in topographic form is closely related to the fashion in which glacial erosion has exploited pre-existing fractures in the granite.

Moraine Complexes

Extensive moraine complexes were discovered in the areas south of Kettle Pond, southeast of Kettle Pond in the Stillwater Brook valley and extending southward along the shores of Lake Groton, around Peacham Pond, and south of Drew and Marshfield Mountains. The moraines are composed of sandy till, often with abundant surface boulders.

Moraine Type

The authors are not aware that similar moraine complexes have ever been described before in Vermont. However, these do appear to be similar to clusters of closely-spaced clusters of moraines that have been described in northwestern and north-central Maine in lowlands underlain by plutonic rocks. Caldwell and others (1985) describe these as follows: "The moraines are 4 to 20 m in height and are generally less than 2 km in length. Numerous boulders, up to 5 m or more in diameter, characterize the surface of the moraines."

They also describe similar moraines in areas to the east that are underlain by the Greenville plutonic belt and consider these to be similar to Rogen moraines. These are shown on the Surficial Geologic Map of Maine as ribbed moraine. Based on a recent review of the characteristics of ribbed moraines (Dunlop and Clark, 2006) the moraines discovered in the study area appear to generally fit their characteristics.

Glacially Scoured Topography

Slopes in the Knox Mountains show a north-south asymmetry with east-west oriented bedrock hills flanked by relatively gentle slopes to the north and steep slopes to the south, with topographic basins scoured in the valley floors and subsequently partially filled with thick sandy till with morainal topography. This asymmetry is illustrated in the topographic profiles shown in Figures 5C and 5D.

References

Caldwell, D.W., Hanson, L.S., and Thompson, W.B., 1985. Styles of deglaciation in central Maine: *In* Borns, H.W., Jr., Lasalle, Pierre, and Thompson, W.B., *eds.*, Late Pleistocene history of northeastern New England and adjacent Quebec: Geological Society of America Special Paper 197, pp. 45 58.

Dunlop, Paul, and Clark, C.D., 2006, the morphological characteristics of ribbed moraine: Quaternary Science Reviews: v. 25, p. 1668 - 1691.

Figure 5A

Figure 5A- A dump of abundant granite boulders on one of the moraine tops in the Marshfield Pond Moraine Complex.

Figure 5B

Figure 5B- A bouldery moraine on the shore of Peacham Pond.

Figure 5C

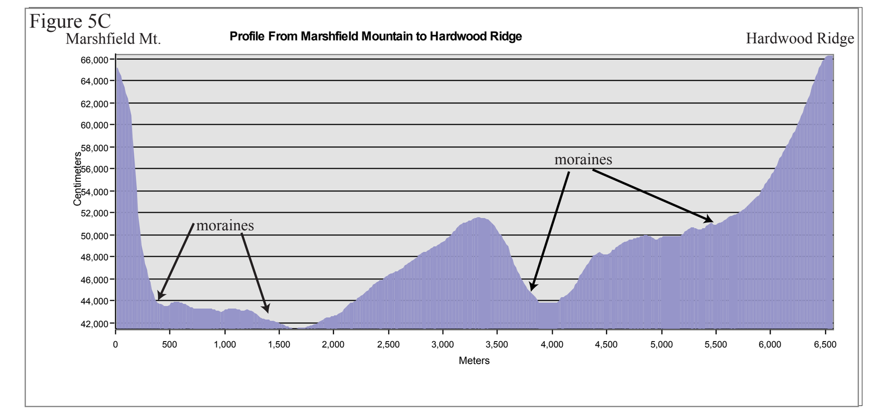


Figure 5C- Topographic profile showing (from north to south) the steep south face of Marshfield Mountain, the extensive Marshfield Pond Moraine Complex, and the relatively gently sloping north face of the bedrock ridge east of Kettle Mountain, the steep south face of this ridge, the Kettle Pond Moraine Complex, and the relatively gentle north slope of Hardwood Ridge. Note that the Kettle Pond Moraine Complex consists of two groups of moraines: those in the bottom of the valley (including moraine dams at both the west and east ends of the pond), and the more extensive group of moraines on the plateau south of the pond.

Figure 5D

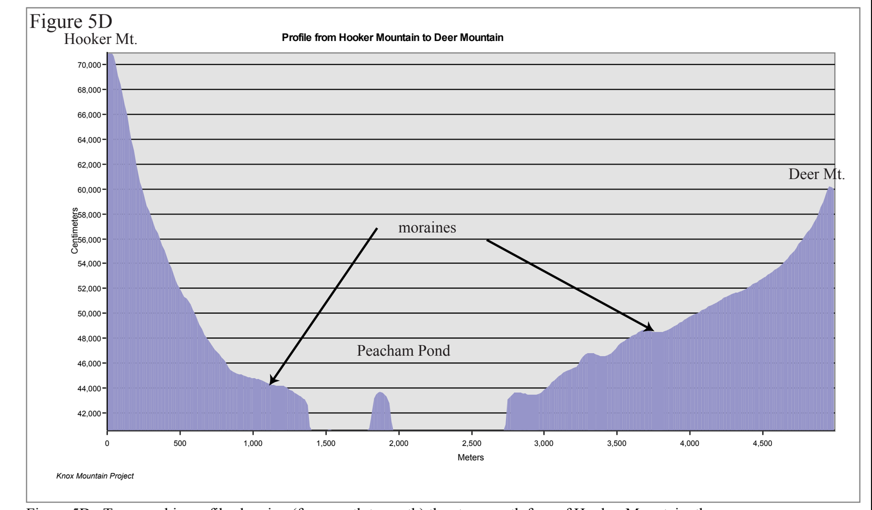


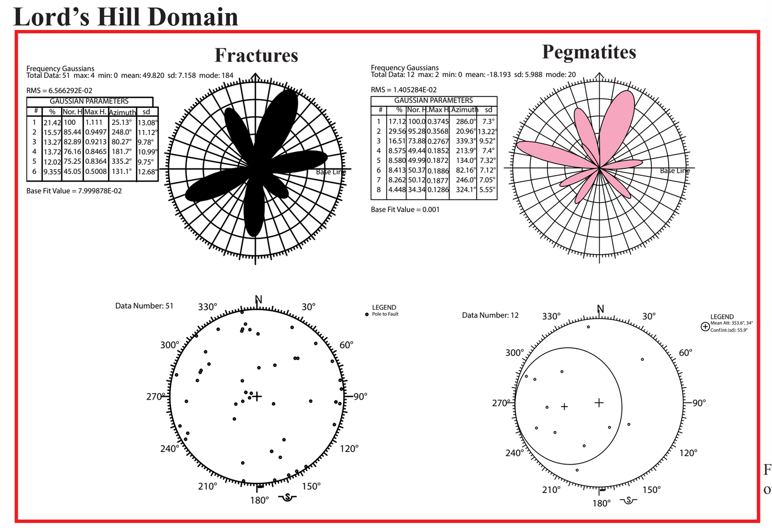
Figure 5D- Topographic profile showing (from north to south) the steep south face of Hooker Mountain, the moraine complex in the Peacham Pond basin, and the relatively gentle north slope of Deer Mountain (AKA Big Deer Mountain).

Figure 6- Bedrock Control of Moraine Complexes

Figure 6D

Figure 6D- View from Owl's Head looking to the west along Kettle Pond. This ~east-west trending valley is parallel to a dominant fracture trend in the Lord's Hill domain shown below.

Lord's Hill Domain



Lord's Hill Domain, Fractures — GAUSSIAN PARAMETERS

#	%	Nor. H	Max H.	Azimuth	sd
1	21.42	100	1.111	25.13°	13.08°
2	15.57	85.44	0.9497	248.0°	11.12°
3	13.27	82.89	0.9213	80.27°	9.78°
4	13.72	76.16	0.8465	181.7°	10.99°
5	12.02	75.25	0.8364	335.2°	9.75°
6	9.355	45.05	0.5008	131.1°	12.68°

Lord's Hill Domain, Pegmatites — GAUSSIAN PARAMETERS

#	%	Nor. H	Max H	Azimuth	sd
1	17.12	100.0	0.3745	286.0°	7.3°
2	29.56	95.28	0.3568	20.96°	13.22°
3	16.51	73.88	0.2767	339.3°	9.52°
4	8.575	49.44	0.1852	213.9°	7.4°
5	8.580	49.99	0.1872	134.0°	7.32°
6	8.413	50.37	0.1886	82.16°	7.12°
7	8.262	50.12	0.1877	246.0°	7.05°
8	4.448	34.34	0.1286	324.1°	5.55°

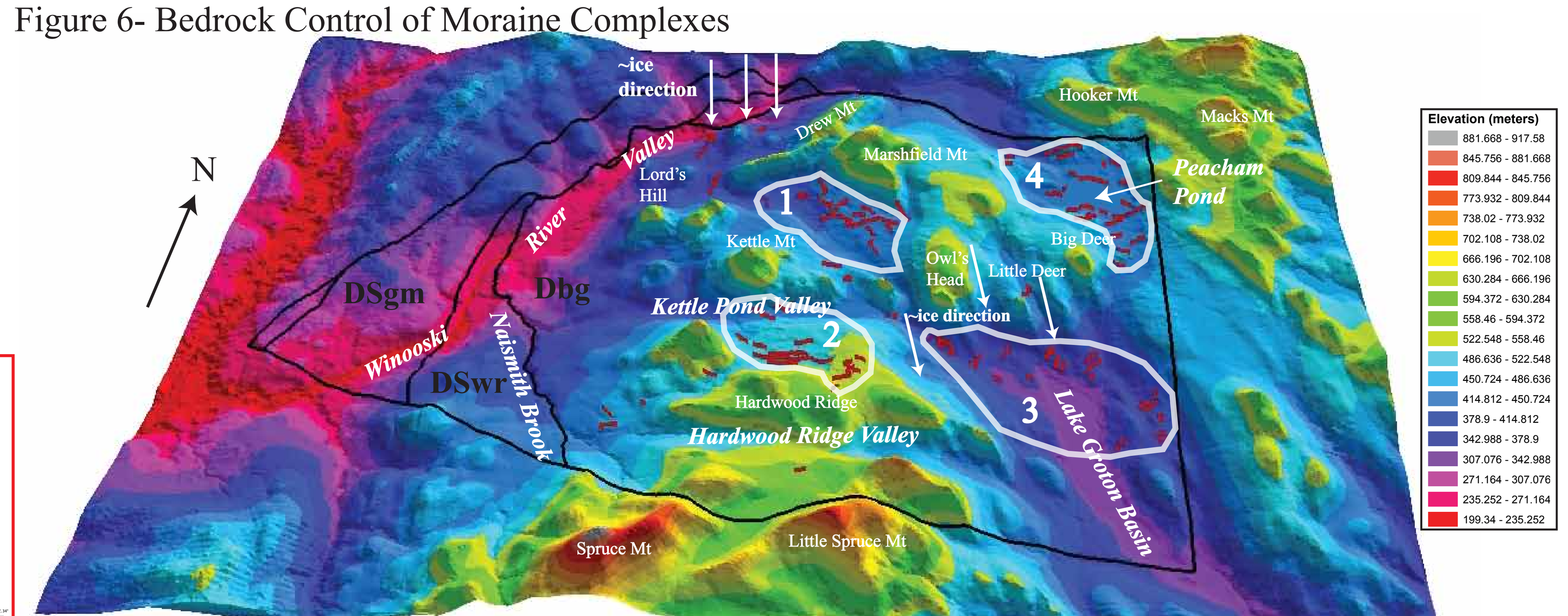


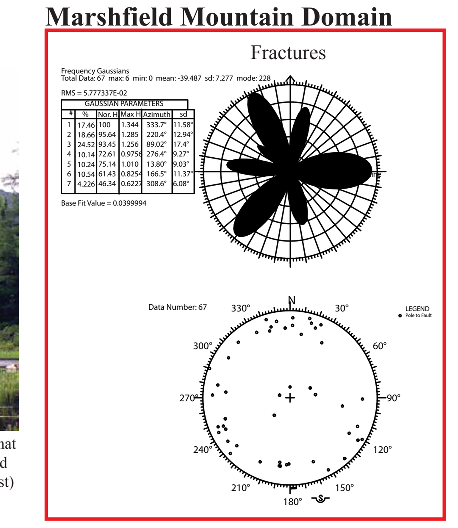
Figure 6A

Figure 6A- TIN with 3X exaggeration that has overlays of bedrock geology (black lines), moraine ridges (red lines), and moraine complexes (white polygons). The fracture control for each moraine is shown in surrounding figures. Fracture domains are geographic and are based on Charnock et al. (2009).

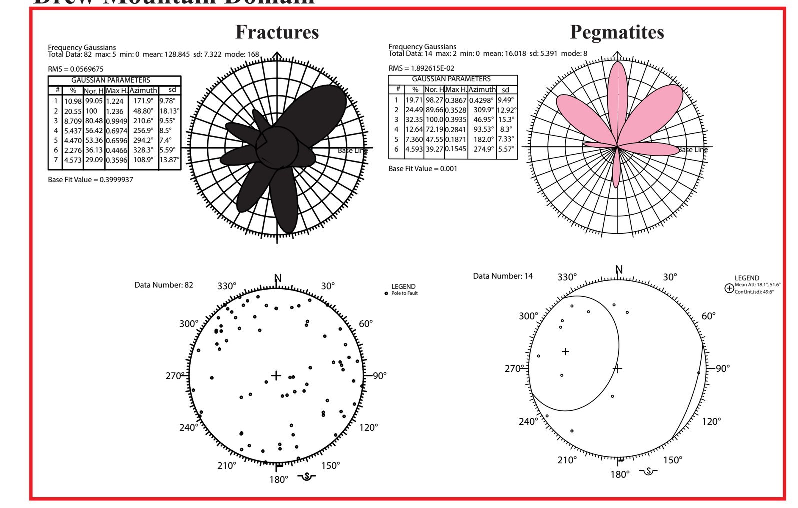
Figure 6B

Figure 6B- East-west striking face (south side) of Marshfield Mountain that is controlled by a dominant east-west trending fracture set (see Marshfield Mountain domain data). The strike of Drew Mountain (directly to the west) is constrained by north-northeast trending fractures (see Drew Mountain domain data).

Marshfield Mountain Domain



Drew Mountain Domain



Drew Mountain Domain, Fractures — GAUSSIAN PARAMETERS

#	%	Nor. H	Max H.	Azimuth	sd
1	10.98	99.05	1.224	171.9°	9.78°
2	20.55	100	1.236	48.80°	18.13°
3	8.709	80.48	0.9949	210.6°	9.55°
4	5.437	56.42	0.6974	256.9°	8.5°
5	4.470	53.36	0.6596	294.2°	7.4°
6	2.276	36.13	0.4466	328.3°	5.59°
7	4.573	29.09	0.3596	108.9°	13.87°

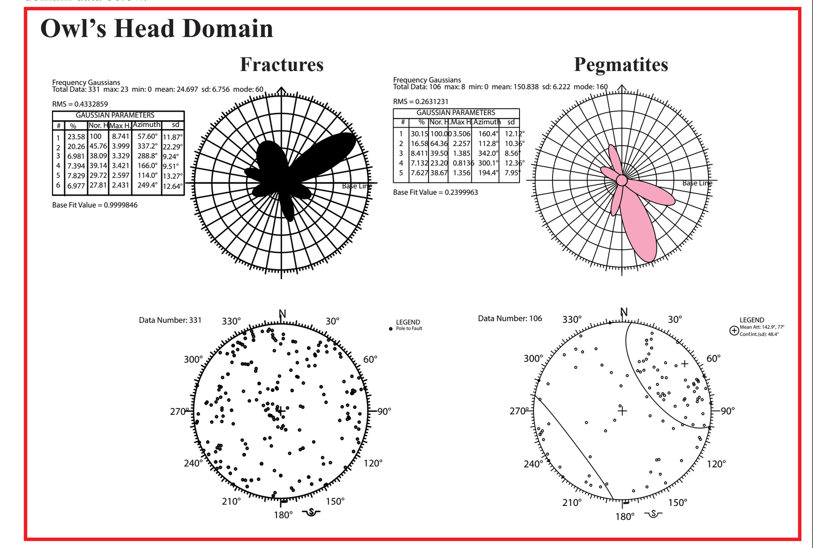
Drew Mountain Domain, Pegmatites — GAUSSIAN PARAMETERS

#	%	Nor. H	Max H.	Azimuth	sd
1	19.71	98.27	0.3867	0.4298°	9.49°
2	24.49	89.66	0.3528	309.9°	12.92°
3	32.35	100.0	0.3935	46.95°	15.3°
4	12.64	72.19	0.2841	93.53°	8.3°
5	7.360	47.55	0.1871	182.0°	7.33°
6	4.593	39.27	0.1545	274.9°	5.57°

Figure 6C

Figure 6C-View to the south-southeast into the Lake Groton basin from the top of Little Deer Mt. The strike of this basin is parallel both to dominant fracture and pegmatite trends and to the ice direction based on striations.See Owl's Head domain data below.

Owl's Head Domain



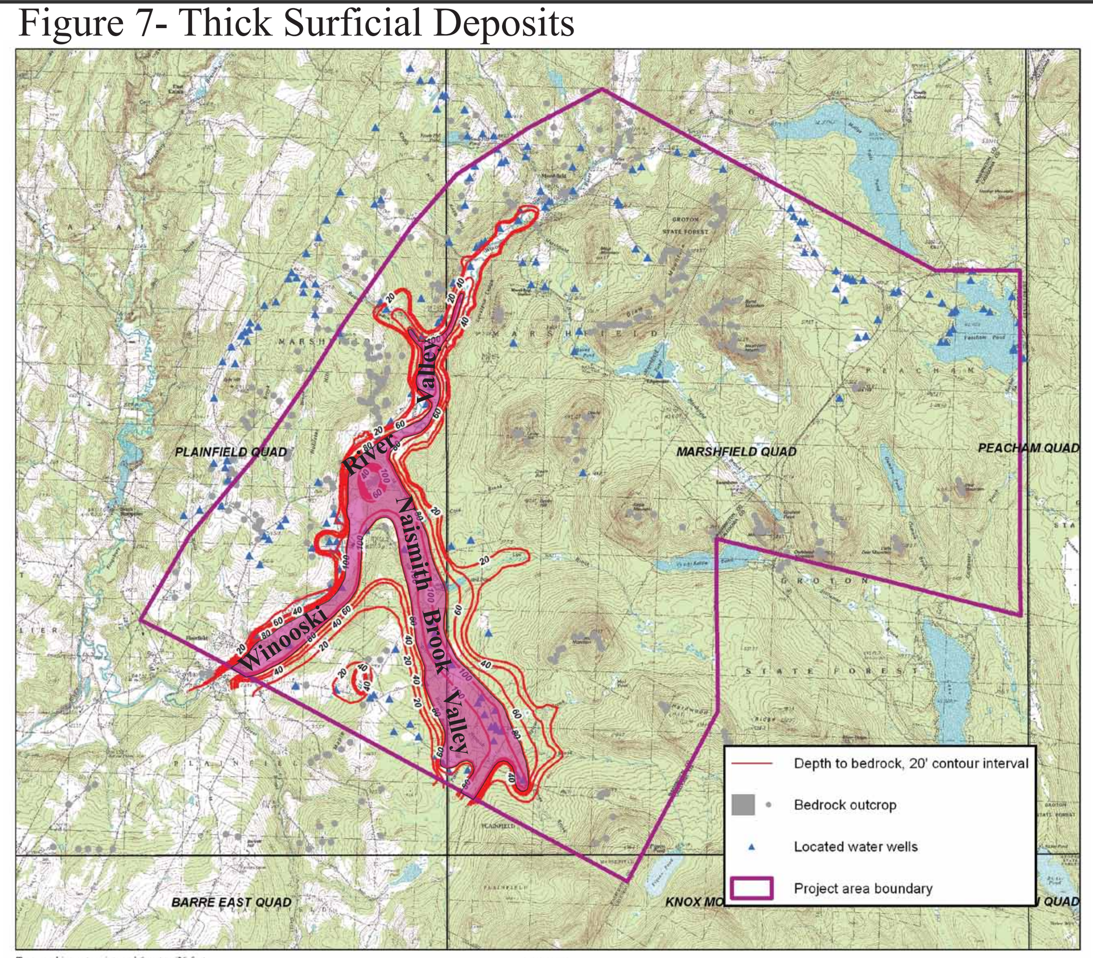
Owl's Head Domain, Fractures — GAUSSIAN PARAMETERS

#	%	Nor. H	Max H.	Azimuth	sd
1	23.58	100	8.741	57.60°	11.87°
2	20.26	45.76	3.999	337.2°	22.29°
3	6.981	38.09	3.329	288.8°	9.24°
4	7.394	39.14	3.421	166.0°	9.51°
5	7.829	29.72	2.597	114.0°	13.27°
6	6.977	27.81	2.431	249.4°	12.64°

Owl's Head Domain, Pegmatites — GAUSSIAN PARAMETERS

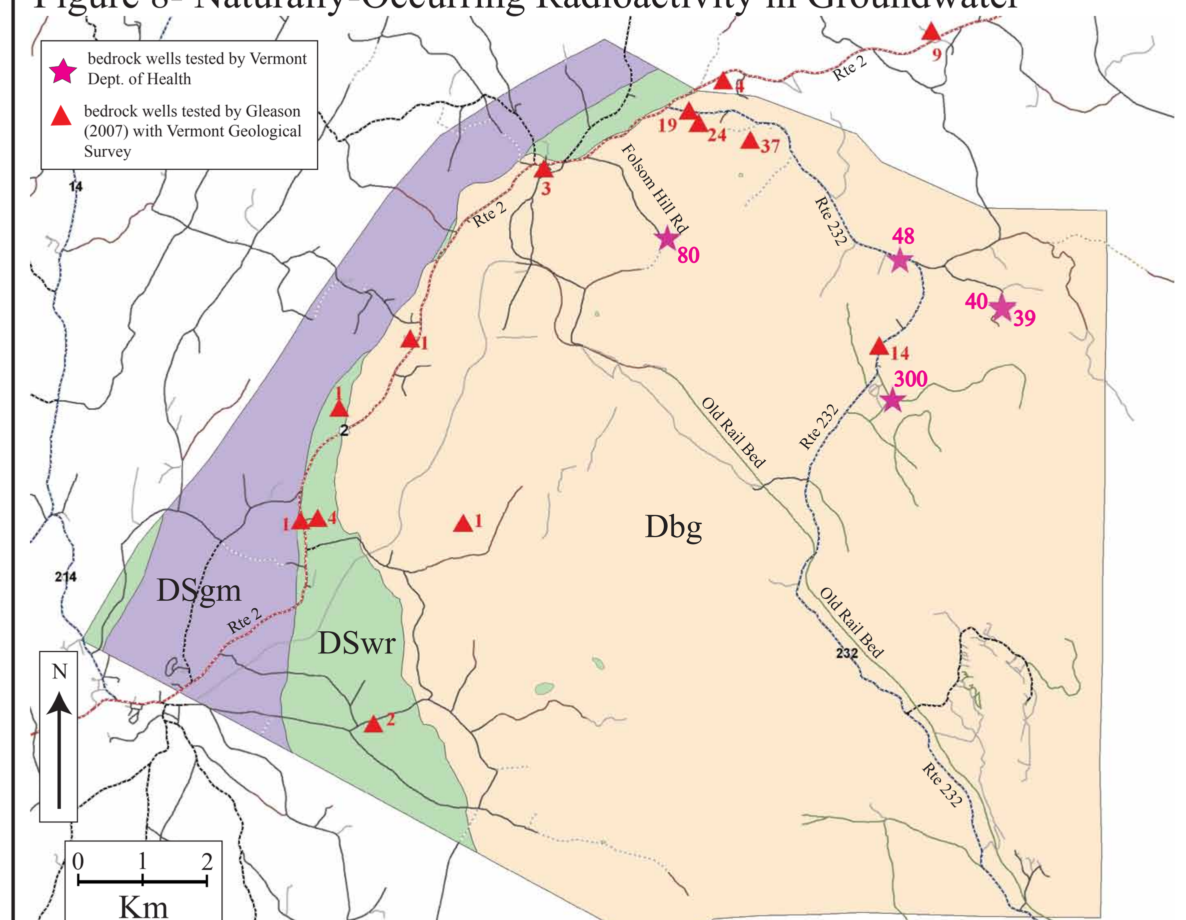
#	%	Nor. H	Max H	Azimuth	sd
1	30.15	100.00	3.506	160.4°	12.12°
2	16.58	64.36	2.257	112.8°	10.36°
3	8.411	39.50	1.385	342.0°	8.56°
4	7.132	23.20	0.8136	300.1°	12.36°
5	7.627	38.67	1.356	194.4°	7.95°

Figure 7- Thick Surficial Deposits



Thick surficial deposits are found in the Winooski River and Naismith Brook valleys. Areas with >80' of overburden are shaded in purple. The Naismith Brook valley and the northern half of the Winnoski River valley follow the western margin of the Knox Mountain granite exactly.

Figure 8- Naturally-Occurring Radioactivity in Groundwater



Magenta stars and red triangles are bedrock wells tested by the Vermont Dept. of Health (VDH) and by Gleason (2007)(with the Vermont Geological Survey), respectively. Groundwater from each well was analyzed for radionuclides (Uranium and Gross Alpha). Uranium concentations in parts per billion (ppb) are shown next to each well location. The VDH standard for Uranium is 20 ppb. In this field area, the only wells with elevated radionuclides were from the granite (Dbg).