May 30, 2015: Technical Summary of Work Performed and Major Findings for the Geology of the Woodbury Quadrangle, Vermont

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Summary of Work Performed 2014-2015

This year's STATEMAP projects focused on creating surficial and bedrock geologic maps and databases in order to provide Vermonters with information they need for aquifer identification, understanding groundwater resources, and protecting public health and safety. Traditional bedrock and surficial geologic maps were produced and will be used as the foundation to address current issues of water supply and radioactivity in groundwater in Vermont. Integration of surficial and bedrock geologic data broadens the view for evaluating any geologic issue. The VGS involves communities at the grassroots level and addresses issues specific to town and state needs, particularly groundwater and both physical and geochemical hazards. Companion studies with Vermont universities and students allow us to leverage our basic geologic mapping and provide towns with significant groundwater data, hazard information, and land use resources.

Surficial mapping was conducted to provide complete geologic information at 1:24,000 for the Towns of Calais and Woodbury on the Woodbury Quadrangle in north-central Vermont (Figure 1). The maps will serve as a base for town planning, gravel resources, water resources and protection. Surficial mapping was conducted by George Springston from Norwich University, Ethan Thomas (intern) and Jonathan Kim (VGS). Bedrock geologic mapping was conducted by Jonathan Kim and Marjorie Gale (VGS), George Springston, G. Christopher Koteas, and Christopher Defelice (Norwich University) and student intern Nicole Saitta. Koteas and Defelice, while not formally part of this Statemap bedrock project, contributed lithological and structural data to our effort. Maps were completed and digitized during the spring of 2015.

Till samples were collected from exposures in the Woodbury area. Geochemical analyses were completed by Activation Laboratories in Canada. XRD of the mineralogy of the samples is being conducted by Dr. Peter Ryan and students at Middlebury College. Till chemistry and mineralogy is of interest in terms of any contribution to surface and groundwater quality, soil formation, and understanding the geographic distribution of specific elements such as calcium in parent soil materials.

Project 1: Bedrock Geologic Map of the Southern Two-Thirds of the Woodbury Quadrangle, Vermont, Washington County, Vermont by Jonathan Kim, Marjorie Gale, George Springston, G. Christopher Koteas, Christopher Defelice, and Nicole Saitta

In Vermont, the Richardson Memorial Contact (RMC) separates Pre-Silurian metamorphic rocks of the Rowe-Hawley Belt (west) from those of Siluro-Devonian age in the Connecticut Valley Trough (east). Richardson (1919) called this boundary the "Cambrian-Ordovician Erosional Unconformity/ Contact" and Currier and Jahns (1941) noted that it was marked by quartz pebble conglomerates and fossiliferous marbles (Shaw Mt. Fm). The Ordovician Taconian Orogeny deformed and metamorphosed the west side of the RMC, but the Acadian Orogeny affected rocks on both sides.

The RMC is interpreted as an unconformity throughout the southern half of Vermont (Ratcliffe et al., 2011). However, in central Vermont, Westerman (1987) proposed that the RMC was an Acadian (Devonian) fault, the Dog River Fault Zone (DRFZ). Walsh et al. (2010) argued that the RMC unconformity and DRFZ were not always coincident. The RMC is located in the northwestern one-third of the Woodbury Quadrangle, where it bounds Cambro-Ordovician metasedimentary rocks of the Moretown Formation to the west from those of the Shaw Mountain, Northfield, and Waits River formations, which are of Silurian-Devonian age, to the east.

The Connecticut Valley Trough in the Woodbury Quadrangle is generally comprised by calcareous conglomeratic quartzites of the Shaw Mountain Formation; gray phyllites of the Northfield Formation; interbedded gray phyllites and sandy (impure) marbles of the Waits River Formation; and biotite granites of the New Hampshire Series. The Rowe- Hawley Belt consists primarily of interbedded grayish-green phyllites and phyllitic quartzites of the Moretown Formation.

<u>Summary of Significant Findings</u>

- In the Montpelier and Barre West Quadrangles, Walsh et al. (2010) was able to divide the Waits River Formation into two members based on the thickness of sandy marble/ calcareous quartzite layers that are interlayered with rusty weathering gray phyllite. The western member (DSwl1) is composed of carbonate layers that range from 0.5 – 3' in thickness whereas those in the eastern member (DSwt) vary from 2-30' in thickness. Kim and Rukznis (2011) were also able to map these two Waits River members in the Plainfield Quadrangle. We were able to extend the same belts of "thick" and "thin" marbles northward from the Plainfield Quadrangle into the Woodbury Quadrangle. We will evaluate whether the marble thickness plays a role in bedrock well yields.
- In the Woodbury and Plainfield quadrangles, the consistent vergence of shallowly north-plunging, asymmetric, F_4 fold trains over tens of square kilometers indicates that a major syncline is located east of the Woodbury Quadrangle and likely corresponds to the Townsend-Brownington Syncline of Doll (1961).

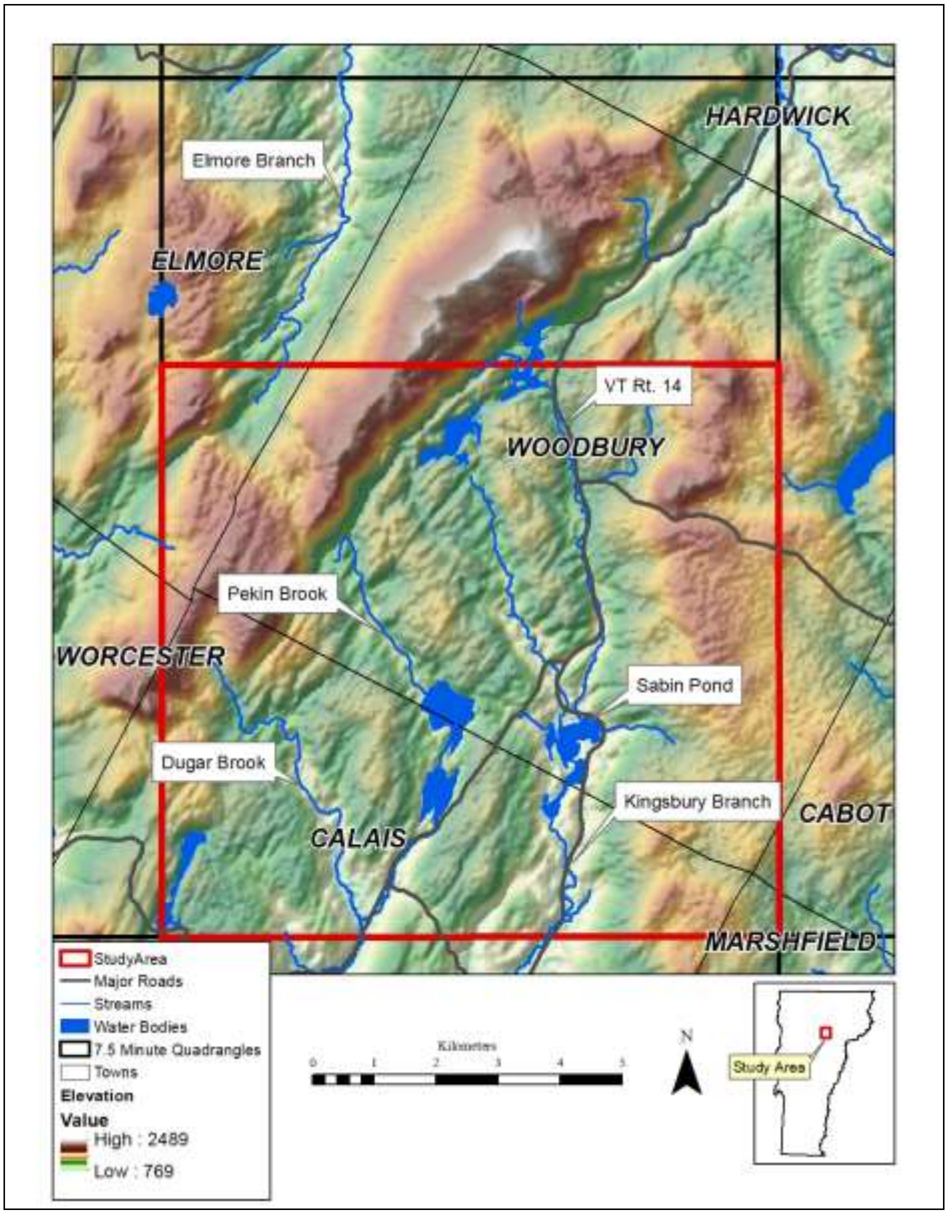

Figure 1. Location map.

- Two thick (40-50') bodies of Shaw Mountain Formation calcareous conglomeratic quartzite were mapped in the Woodbury Quadrangle. The relatively undeformed quartz pebbles within these quartzites argues against the Richardson Memorial Contact being coincident with the Dog River Fault Zone at this latitude.
- From west to east in the Woodbury Quadrangle, the S_3 and S_4 foliations bend from north-northeast striking to ~east-west striking as a result of F_5 folds. The northern part of this map marks the appearance of a major F_5 fold zone that deflects all lithologies. We are investigating the influence that this F5 fold zone may have on the distribution of surficial deposits.

Project 2: Surficial Geologic Map of the Southern Two-Thirds of the Woodbury Quadrangle, Vermont, Washington County, Vermont by George Springston, Ethan Thomas, and Jonathan Kim

Surficial mapping was conducted at 1:24,000 scale for the Towns of Calais and Woodbury on the Woodbury Quadrangle in north-central Vermont (Figure 1). Glacial till in the study area is generally dense with a fine-sandy silt to silt matrix, although several exposures of fine-sandy till were encountered. East of the Moretown Formation the till matrix is commonly calcareous, reflecting a local source. Clasts in the till are also predominantly of local origin. Granitic boulders from the Woodbury Granite bodies are widely distributed in the eastern portion of the study area.

Discontinuous ice-contact sand and gravel deposits are common along a glacial drainage route that runs from Valley Lake to South Woodbury and Sabin Pond before emptying into the arm of glacial Lake Winooski that filled the Kingsbury Branch valley (Figure 2). Eskers along the route are evidence that it functioned as a subglacial or englacial drainage route while the area was still ice-covered. This route may also have served as a postglacial drainage route as ice continued to recede to the northeast. Numerous potential kettle holes are visible on the land surface and depressions in several of the lake bottoms may also represent kettle holes.

A second glacial drainage route follows a path parallel to Cranberry Meadow Road through Cranberry Meadow Pond and southward through Forest Lake, Mirror Lake, and North Calais to the arm of glacial Lake Winooski that filled the Pekin Brook and Dugar Brook valleys. Deposits of sand and gravel are very limited along this route, perhaps suggesting that it served as a meltwater route following retreat of the ice margin farther to the northeast.

Ice-contact sand and gravel bodies also fill parts of the valley of the Kingsbury Branch from Greenwood Lake to South Woodbury.

Glacial lake deposits are widespread in the valleys in the south-central and southeastern portions of the study area in the northern arms of glacial Lake Winooski. The shorelines of this Late Pleistocene water body have been tilted by post-glacial isostatic rebound and are accordingly projected using shoreline tilt of 4.7 feet per mile to the N21W from a threshold at Williamstown Gulf (after Larsen, 1987). As projected, these shorelines fall below the upper limits of some of the lacustrine deposits. In particular, the upper surface of a delta identified in this study on the west side of Vt. Rt. 14 and south of Sabin Pond appears to extend up to about 316 meters (1037 feet) while the projected shoreline in the vicinity is only at about 302 to 303 meters (991 to 994 feet). This is consistent with observations made in other parts of the Winooski Valley and suggests that revisions are needed to the direction and magnitude of the tilt. This delta may serve as an important control in the future revision of this critical shoreline projection. An increase in the shoreline elevations at South Woodbury would result in projection of the shoreline far up into the ice-contact deposits. However, it is unclear to what extent this would be realistic. It may be that this valley was blocked from inundation by active or stagnant ice throughout the life of the lake.

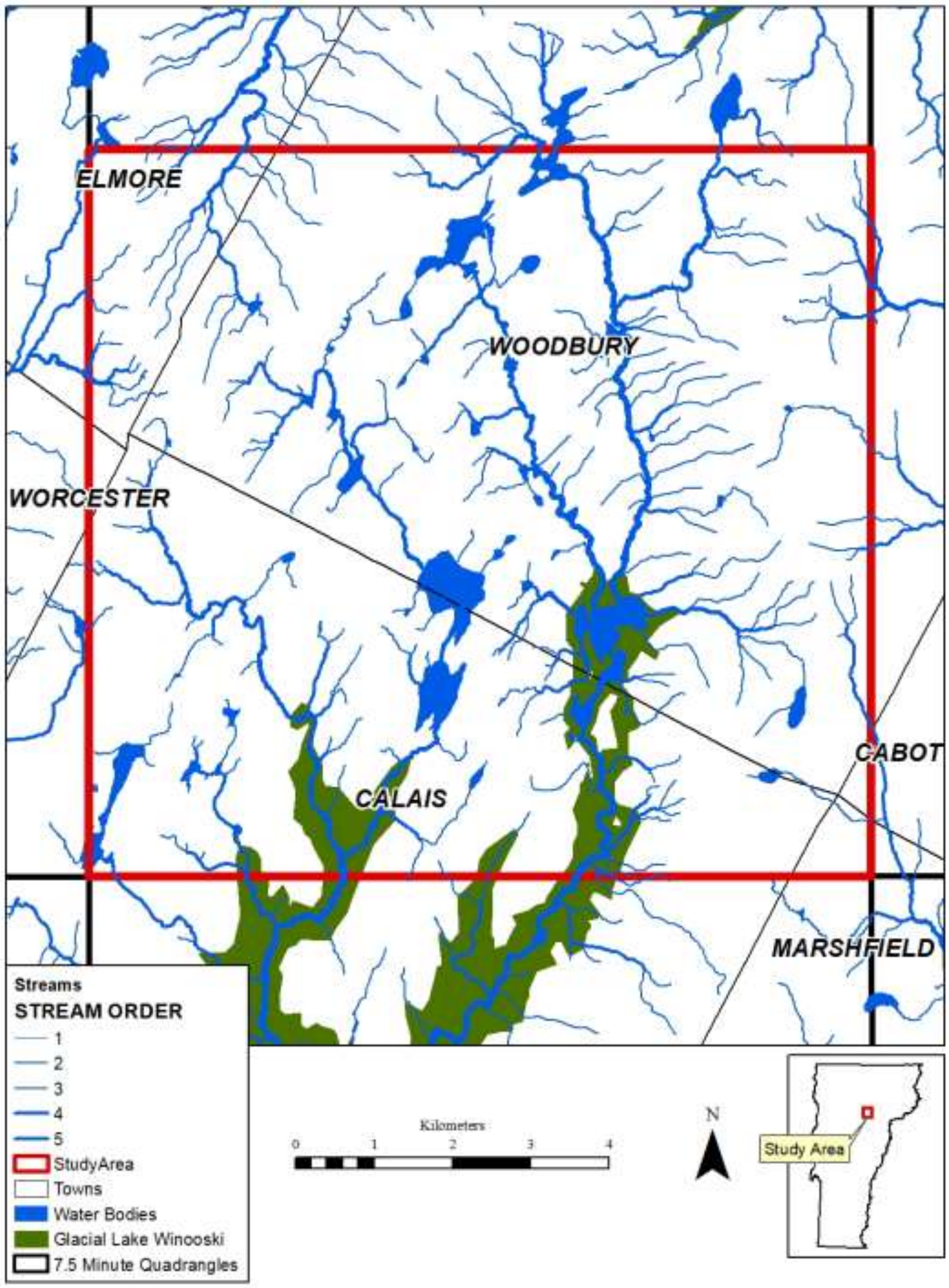

Figure 2. Waterbodies and extent of glacial Lake Winooski. Glacial Lake Winooski shorelines have been tilted by post-glacial isostatic rebound and are accordingly projected using shoreline tilt of 4.7 feet per mile to the N21W from a threshold at Williamstown Gulf (after Larsen, 1987).

The ice-contact deposits at Sabin Pond and South Woodbury were clearly part of a glacial meltwater drainage route that entered glacial Lake Winooski just to the south of Sabin Pond. Thus, the timing of ice retreat to the latitude of South Woodbury may be constrained to sometime within the life of the lake.

Striations and grooves in bedrock indicated that ice motions were predominantly from 140 to 190°, with a range of values from 92° to 198°. Two frequency maxima occur in the azimuth values at about 140 to 145° and from 160 to 185°, with the latter being the dominant one (Figure 3). Cross-cutting relationships are rarely seen, but at station WO872 the 194° striations cross-cut the 164° striations and are thus younger. This relationship has been seen at other sites in the region and might suggest an earlier regional ice flow trending roughly 160° with a later more southerly re-orientation of flow. The most easterly striations are generally quite thin and short, suggesting that they are the result of minor late ice movement.

The distribution of granitic glacial erratics on the surficial geologic map of the study area is additional evidence that glacial ice motion had a strong southward component of motion. The western limit of these granitic boulders is from Woodbury Village southward along a line that passes about 0.5 kilometers west of South Woodbury.

Most of the lakes and ponds in the study area can be attributed to one or more of the following: erosion by streams, scour of bedrock by overriding glacial ice, blockage of a valley by glacial

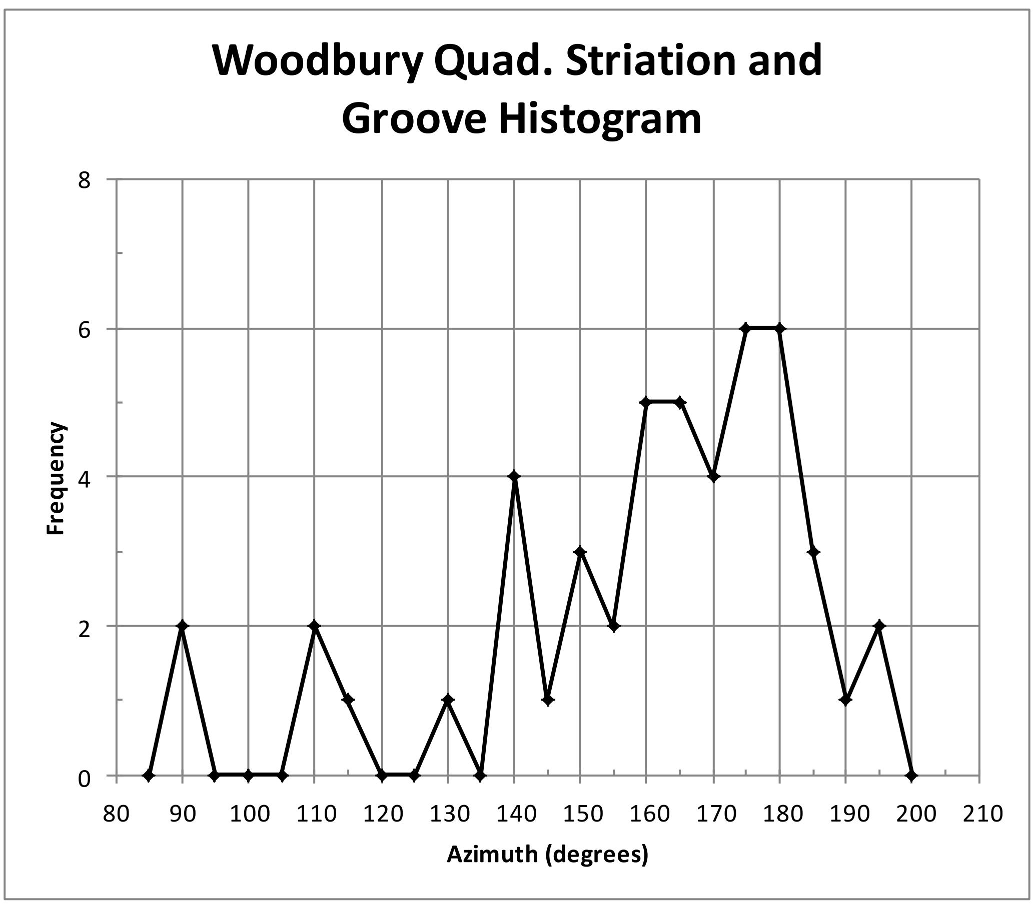

Figure 3. Frequency histogram showing azimuths of glacial striations and grooves in the study

area.

deposits, and melting of stranded ice blocks to form kettle holes. Greenwood Lake is the shallowest of the large lakes and ponds and appears to have originated due to a combination of stream erosion and glacial scour with blockage of drainage to the north or south by glacial deposits. Valley Lake appears to be largely the result of glacial scour with some blockage due to glacial deposits and a possible kettle hole on the northwest side. Forest Lake and Mirror Lake seem to be the results of both glacial scour and melting of stranded ice blocks. Sabin Pond appears to be the result of melting of about five large stranded ice blocks amidst esker and other ice-contact sand and gravel deposits. These deposits are, however, within a deeply-scoured bedrock basin.

The juxtaposition of a string of bedrock depressions running from Greenwood Lake southwestward through Valley Lake and Smith Pond to Curtis Pond with the steep range of hills immediately to the northwest (the southwestward continuation of Woodbury Mountain) may be due to some combination simple differential erosion and enhanced glacial scour down-glacier from resistant bedrock features.

As discussed in Larsen and others 2003), there is substantial evidence in central Vermont for a late Wisconsinan readvance, which appears to correlate with the Bethlehem-Littleton readvance in New Hampshire. More recent discoveries of thick dense till over lacustrine sediments at several locations in Washington County support this interpretation (Dunn and others, 2011; Dunn and others, 2015). No clear evidence of a readvance was found during this study, but dating of peat deposits in kettle holes might help constrain the last retreat of ice from this area.

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