Surficial Geology of the Barre East 7.5 Minute Quadrangle, Vermont

Vermont Geological Survey Open File Report VG2018-1

George Springston
Norwich University
Department of Earth and Environmental Sciences
Northfield, VT 05663

Published by: Vermont Geological Survey, Marjorie H. Gale, State Geologist, Department of Environmental Conservation Agency of Natural Resources 1 National Life Drive, Davis 2 Montpelier, VT 05620-3902
http://www.anr.state.vt.us/dec/geo/vgs.htm

Research supported by the Vermont Geological Survey, Dept. of Environmental Conservation,VTANR. This geologic map was supported by the U. S. Geological Survey, National Cooperative Geologic Mapping Program, under assistance Award No.GC17AC00162, 2017. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

On the cover: View looking southeast from the Strong property in northern Orange toward the Knox Mountains.

Table of Contents

Executive Summary

The purpose of this project was to conduct 1:24,000 scale mapping of the surficial geology of the Barre East 7.5 minute quadrangle.

Bedrock outcrops are abundant in large portions of the study area. In addition to the bedrock outcrops visited as part of this and other geologic mapping projects, Plate 1 also shows points where interpretation of lidar topographic data can be used to infer shallow bedrock. These were an aid to construction of the depth to bedrock map (Plate 3).

Glacial till is the most widespread surficial material in the study area. It is generally dense to very dense, unsorted to very poorly sorted, fine-sandy-silt to silt matrix till.

Striations and grooves in bedrock indicated that ice motion directions ranged from 130 to 200°, with the most abundant orientations around 160° and with lesser maxima at 140° and 180°. Where cross-cutting relationships can be observed, the more southerly striations are younger than the southeasterly ones. Crag and tail landforms visible on the lidar-derived topography show similar orientations.

Although no extensive moraines were identified, several small, approximately east-west ridges of sandy till in the Orange Brook valley to the south of Dix Reservoir may be moraines.

Ice-contact sand and gravel deposits are scattered along the western edge of the Knox Mountains in the eastern part of the study area. They consist of unsorted to poorly-sorted sand, gravel, and silt deposited in contact with glacial ice. These include several short esker segments formed in subglacial meltwater stream courses. Most are of limited extent, although the one being excavated at the Orange Town Pit is of moderate size. The deposits in the northeastern part of the study area near the Plainfield/Orange town line appear to have been deposited in proglacial lake of limited extent as glacial ice impeded northward drainage.

Meltwater channels are scattered throughout the northern and eastern portions of the study area. Some occupy cols in east-west ridges and appear to have been formed by south-flowing meltwater while the glacial ice margin stood at the ridge. Others occur on hill slopes and appear to have formed at or perhaps under ice margins as the ice downwasted off of the hillsides.

Stratigraphic sections showing dense till over lake deposits over lodgement till have been identified in the Great Brook watershed in the northeastern portion of the study area and in the Jail Branch valley in the western portion of the study area. These deposits suggest a late Wisconsinan ice readvance into the valley bottoms.

A prominent spillway located northwest of Millstone Hill at about 1171 feet (357 meters) may have been cut by meltwater impounded by the lobe of readvancing ice as it pushed in from the Stevens Branch valley to the west.

A delta located south of the Jail Branch in the southwestern portion of the study area appears to have formed after the final retreat of the ice and records the approximate level of glacial Lake Winooski. Stephen Wright (personal communication, 2013) determined a topset-foreset elevation of approximately 938 feet (286 meters).

Introduction

General Geology

The surficial materials in the region are dominantly of glacial origin and were deposited in the late Pleistocene while the area was covered by the Laurentide ice sheet and during and shortly after the retreat of that ice. Typical of most of New England, the upland areas are covered by till that varies considerably in thickness, composition, and texture. Glacial boulders are common, with numerous granite erratics found to the south and south-southeast of the granite bodies. Bedrock exposures are abundant at the higher elevations and occur at scattered locations in the valley bottoms. Till in the stream valleys may be overlain by a variety of ice-contact sediments deposited during ice retreat. The valley bottoms are underlain by thick glacio-lacustrine deposits. The modern valley bottoms are also the locus of Holocene alluvial fan deposition, fluvial activity, and the accumulation areas for colluvium.

The quadrangle is primarily underlain by the Silurian-Devonian Waits River and the Devonian Gile Mountain Formations along with the Devonian Barre Granite in the southwestern portion of the area and part of the Devonian Knox Mountain pluton in the east (Figure 2, after Ratcliffe et al., 2011).

The Barre East quadrangle is located in the Vermont Piedmont physiographic province (Stewart and MacClintock, 1969). The terrain is generally rolling (Figures 3 and 4), with the steep east faces of the Kittredge Hills standing as exceptions. All streams in the quadrangle drain ultimately into the Winooski River. The stream network is shown in Figure 2. Typical views of the landscape are shown in Figures 3 through 6.

Prior Work

Bedrock mapping at a scale of 1:62,500 was undertaken by Murthy (1957).

Reconnaissance 1:62,500 surficial geologic mapping of the study area was included in the 1:250,000 compilation of Doll (1970). This reconnaissance mapping is shown in Figure 7. A comparison with Plate 1 will show substantial modifications.

The surficial deposits in the Great Brook watershed in the northeastern portion of the study area were mapped by Springston and Barg (2002). A detailed study of landslides in the Great Brook watershed was undertaken by Springston and Thomas (2014). Exposures of lacustrine sand overlain by till along Jail Branch were interpreted by Larsen and his students (Larsen, 1972) as having formed during ice advance, with lake sand deposited in a pro-glacial lake and the till representing the SE advance of Late Wisconsinan ice. Along the Honey Brook tributary there are several large landslides (ranging up to 190 feet high). These are cut into thick sections of outwash and glaciolacustrine deposits overlain by thick lodgement till (Dunn and others, 2015). The lacustrine deposits in Jail Branch could have been deposited in an arm of a Late Wisconsinan proglacial lake, in Glacial Lake Winooski, or in a small proglacial lake that formed during ice readvance by an ice margin that sealed the Jail Branch valley from draining north into Stevens Branch and the larger Winooski drainage basin. Such a lake could have formed during initial ice advance or during retreat. Exposures along the northern parts of Great Brook show interlayered lacustrine debris flow and turbidity flow deposits that are overlain by thick, dense till. Evidence is building of a late Wisconsinan ice readvance (Middlesex Readvance of Larsen, 1999). Work by Wright (Wright, 2015 and Wright and others, 2015) suggests that following ice margin retreat northward to at least the northern fringes of the Winooski River valley, there was a substantial readvance that involved ice flowing eastward and southward in the valley bottoms. By this model, the thick upper till deposit that is observed in the Jail Branch, Honey Brook and northern Great Brook valleys would have been deposited during this readvance.

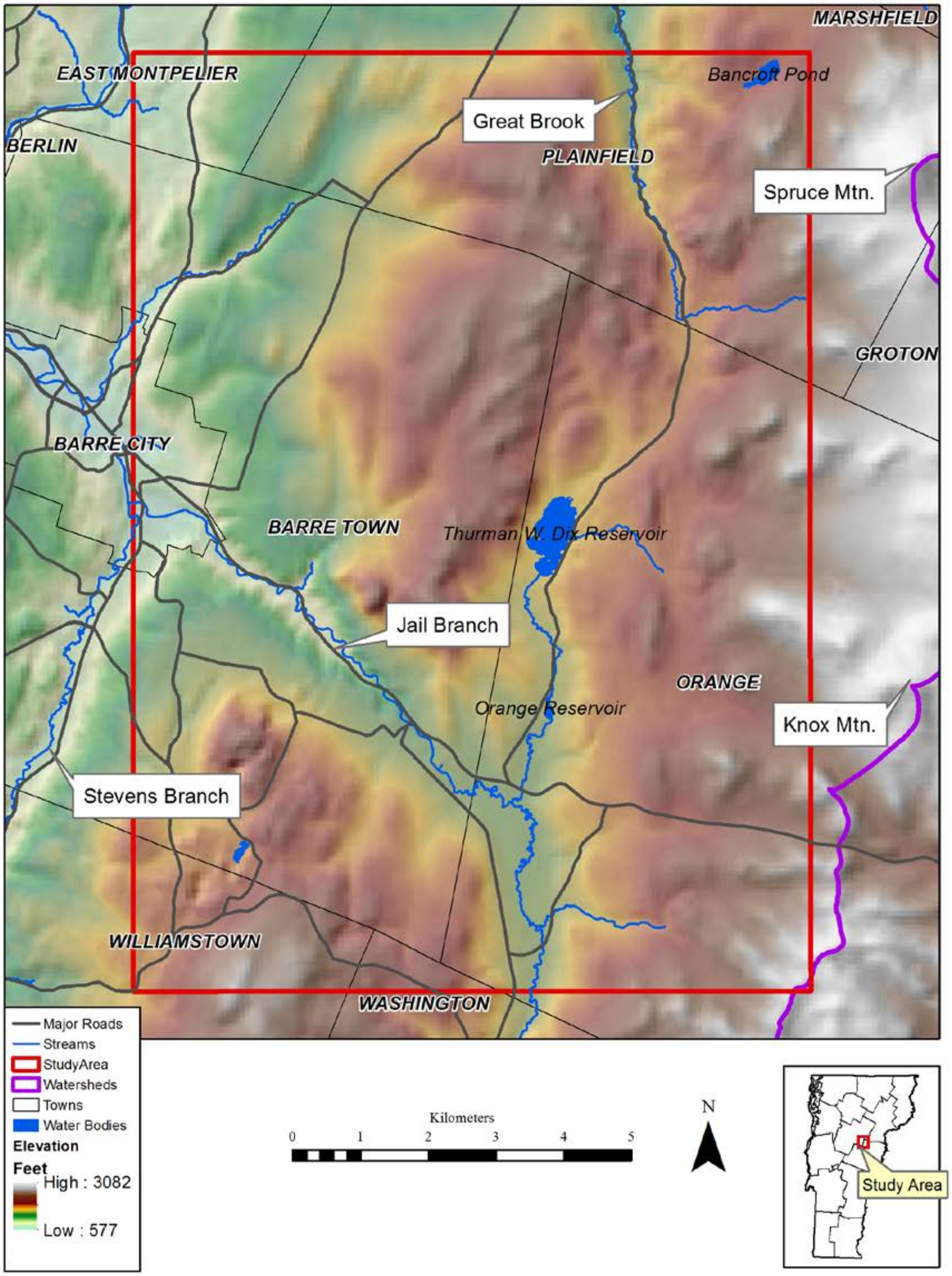

Figure 1. Location map.

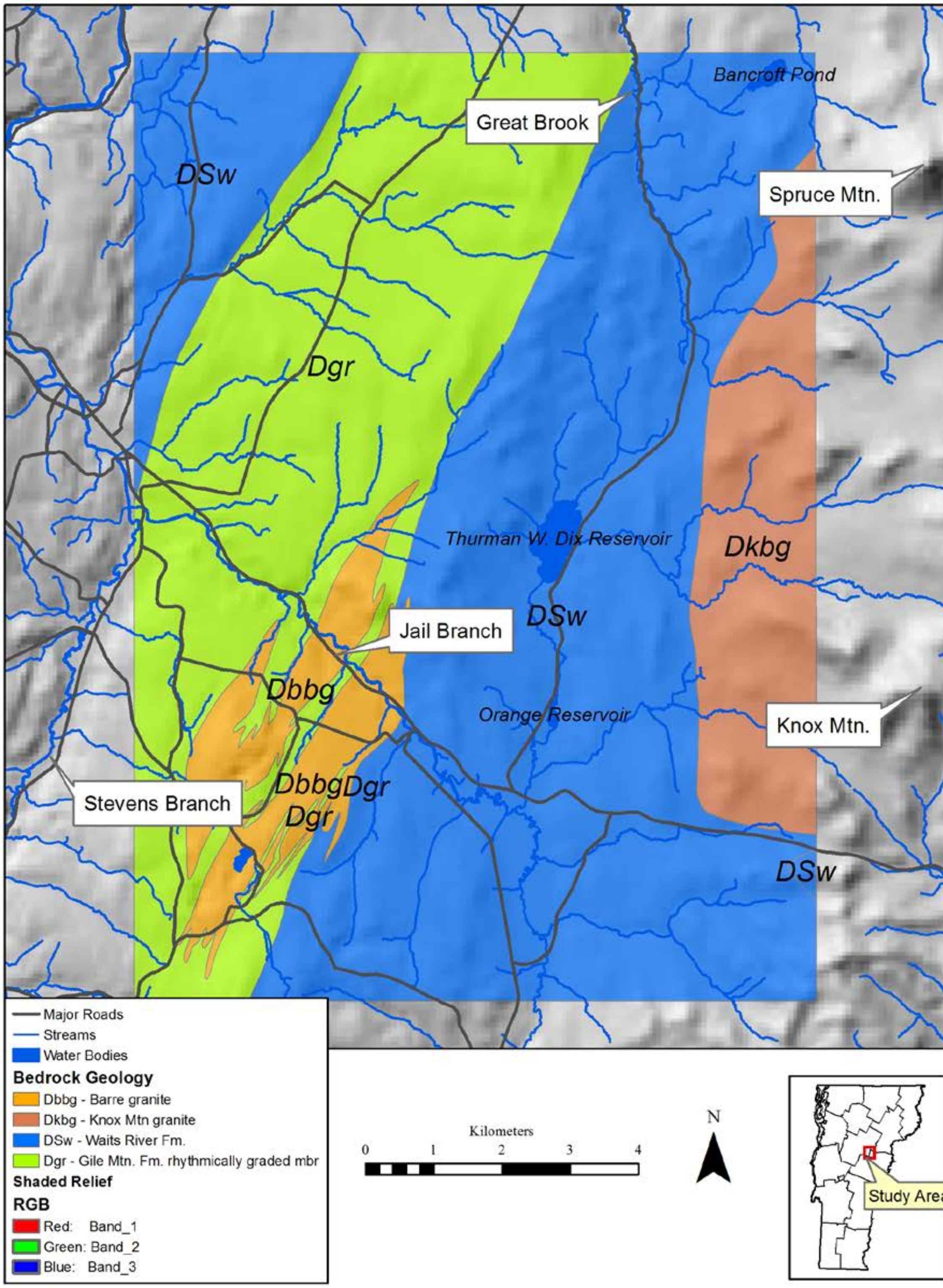

Figure 2. Bedrock geology (after Ratcliffe and others, 2011).

Figure 3. View looking south toward Barre City from hills east of Route 14.

Figure 4. View looking north across the Jail Branch valley of Cobble Hill. Taken from grout piles on Millstone Hill.

Figure 5. View looking west across the Stevens Branch valley toward the Green Mountains and Mount Hunger. Taken from hilltop east of Route 14.

Figure 6. View looking northeast across central part of study area toward Spruce Mountain. Taken from grout piles on Millstone Hill.

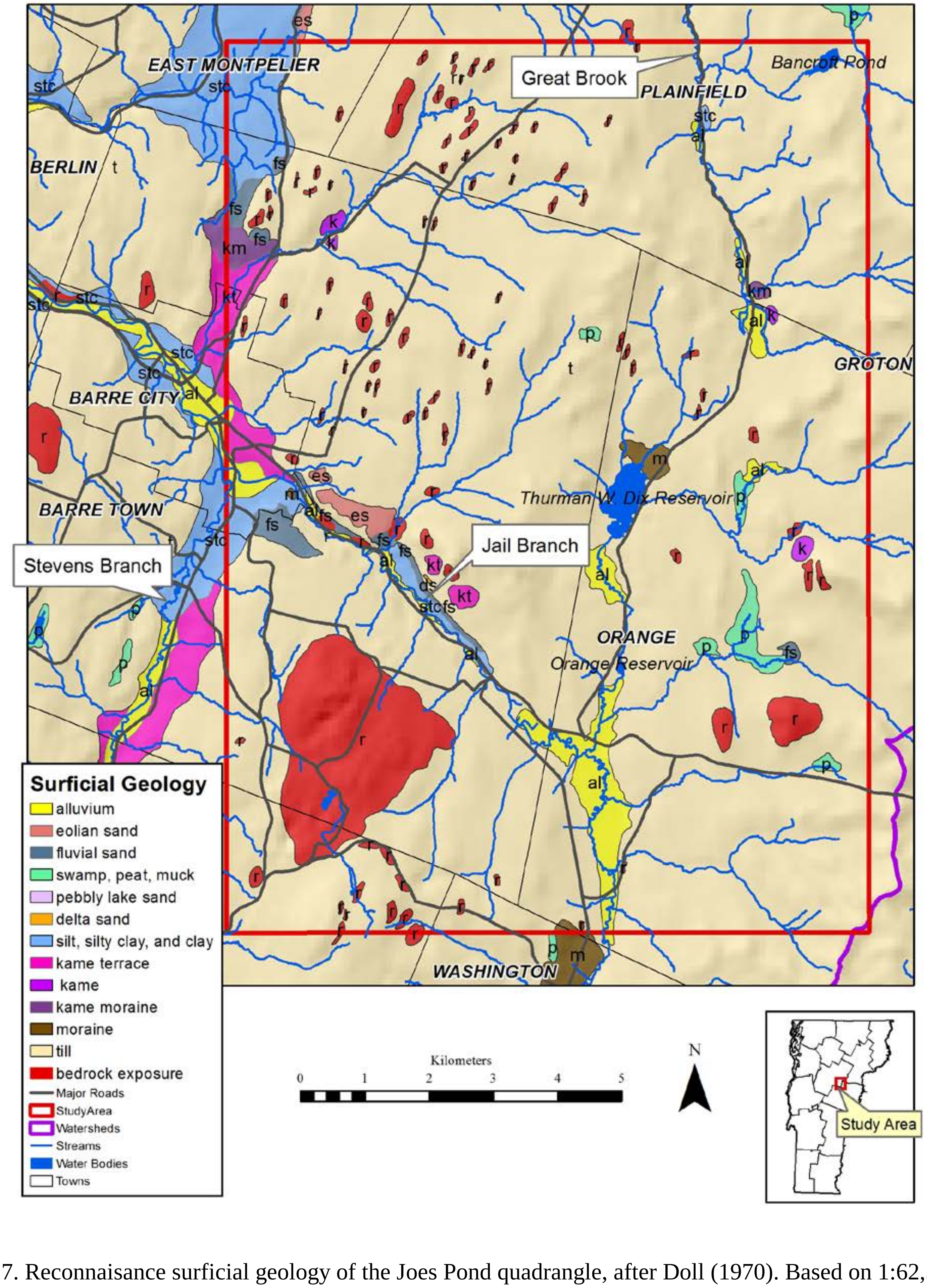

Figure 7. Reconnaisance surficial geology of the Joes Pond quadrangle, after Doll (1970). Based on 1:62,500 mapping by David P. Stewart. The present study has resulted in substantial modifications (see Plate 1).

Methods

Field work involved visits to 607 exposures of surficial deposits and 127 bedrock outcrops. The locations of approximately 92 bedrock outcrops were obtained from. Additional surficial geologic information was obtained by analysis of 596 water well logs. The logs were derived from databases managed by the Drinking Water and Groundwater Protection Division of the Vermont Department of Environmental Conservation. The water well locations are shown on Plate 1. As many of the older wells have uncertain locations, only wells with verified locations are used in this analysis. Newer wells with driller-reported GPS locations or E911 addresses are assumed to be close to the correct locations. Additional boring logs were obtained from the Vermont Agency of Transportation and from State records of hazardous waste sites. Descriptions of sand and gravel resources were obtained from Highway Materials Studies undertaken by the Vermont Agency of Transportation. All of the above are also shown on Plate 1.

Surficial Geology

Ice-movement Indicators

Striations and grooves in bedrock indicated that ice motion directions ranged from 130 to 200°, with the most abundant orientations around 160° and with lesser maxima at 140° and 180° (Figure 8). Where cross-cutting relationships can be observed, the more southerly striations are younger than the southeasterly ones.

The pattern of cross-cutting striations in the study area is similar to that seen in the Woodbury quadrangle to the north (Springston and others, 2015) and in the St. Johnsbury quadrangle to the northeast (Springston and Haselton, 1999). This relationship has been seen at many other sites in the region and Wright (2015) has interpreted this to suggest an earlier regional ice flow trending roughly 160° with a later more southerly re-orientation of flow.

A few roche moutoneés seen on the granite knobs in the Barre town Forest and crag and tail landforms visible on the lidar-derived topography show similar orientations (Figure 9)

.

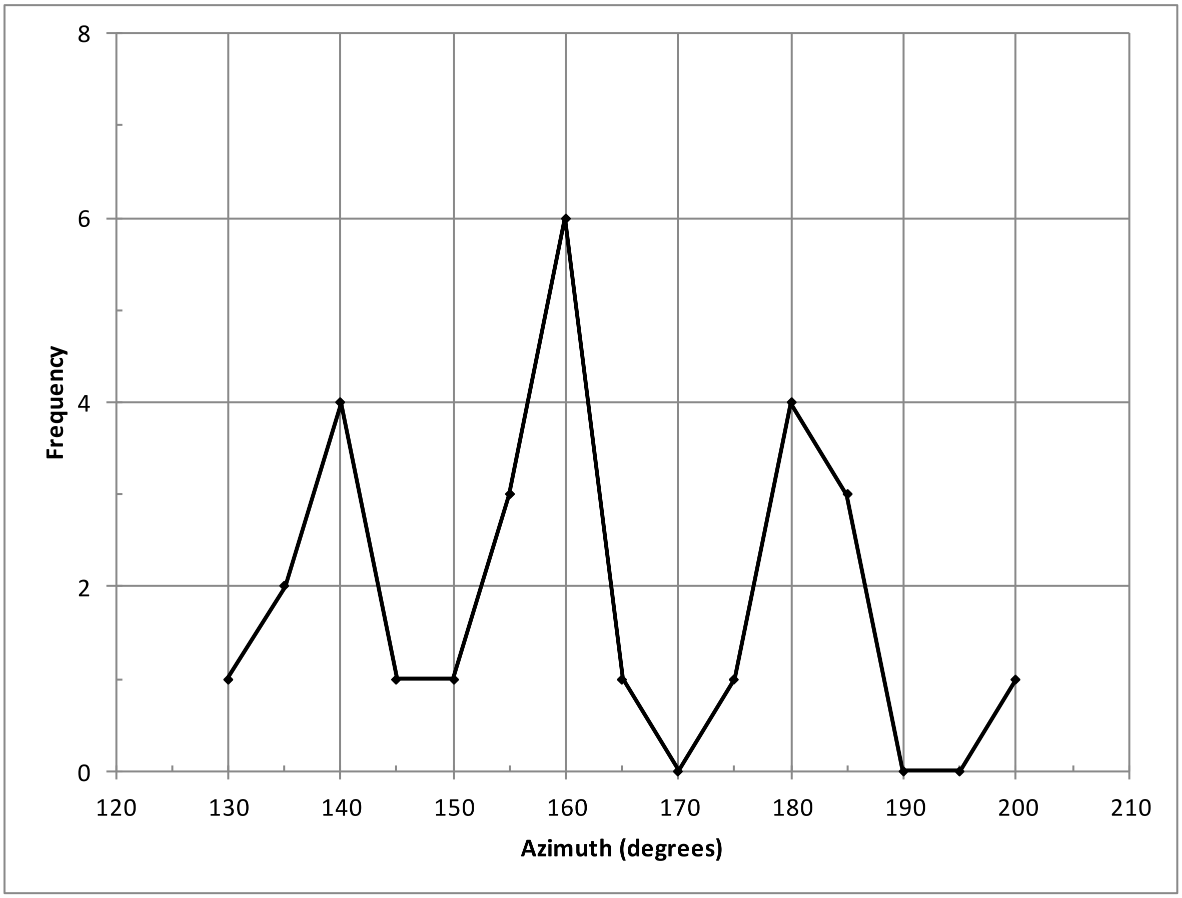

Figure 8. Azimuth frequency histogram of glacial striations and grooves in the Barre East quadrangle. Binned at 5° intervals, n = 28.

Figure 9. Looking east at roche moutonée on Millstone Hill, Barre Town. Glacial ice movement from left to right.

Glacial Boulders

Glacially transported granitic boulders are widespread throughout the eastern third study area. These were derived from the Knox Mountain pluton and indicate generally southward ice movement. Some are erratic boulders in that they now rest on different bedrock types, but most have come to rest within the area of the Knox Mountain pluton or adjacent areas of abundant granite dikes and sills. A few of the larger ones are shown on Plate 1 and an example is shown in Figure 10).

Figure 10. Large granite erratic in woods east of Dix Reservoir. Site 343.

Meltwater Channels

Meltwater channels are scattered throughout the northern and eastern portions of the study area and are shown on Plate 1. Some occupy cols in east-west ridges and appear to have been formed by south-flowing meltwater while the glacial ice margin stood at the ridge. An example from the ridge east of Gallup Hill in the north-central part of the quadrangle is shown in Figure 11. Others occur on hill slopes and appear to have formed at or perhaps under ice margins as the ice downwasted off of the hillsides. These are abundant in the eastern section of the quadrangle on the flanks of the mountains of the Knox Mountain pluton.

A prominent spillway located northwest of Millstone Hill at about 1171 feet (357 meters) may have been cut by meltwater impounded by a lobe of readvancing glacial ice as it pushed in from the Stevens Branch valley to the west (see below).

Figure 11. Meltwater channel in southern Plainfield, looking south. Site 265. east of Lower Road.

Stratigraphy

Pleistocene Deposits

Although the Pleistocene Epoch ranges from about 11,700 years before present back to about 2.58 million years (Cohen and others, 2017), all of the glacial deposits in the study area are believed to belong to the last stage of the Pleistocene, the Wisconsinan Glacial Stage, which extends from about 71,000 to 11,700 years before present.

Till is very dense to loose, unsorted to very poorly sorted material deposited directly from glacial ice. It contains a wide range of grain sizes, from clay or silt up to large boulders. The matrix is commonly dominated by the silt or sand fraction.

Throughout most of the area the till has a silt to very-fine-sand matrix and is very dense when unweathered (Figure 12). Boulders of the local Knox Mountain Granite are common in the eastern half of the study area and those of the Barre Granite are common in the southwestern portion. The thickness is highly variable, from less than 3 meters to greater than 30 meters. In the northeastern portion of the study area many exposures of till are highly weathered and it appears that there is a large component of the easily-weathered Waits River Formation (Figure 13). In many cases the clasts in these exposures are weathered to “ghosts” that can be easily dug through with a shovel or trowel.

Figure 12. Dense gray silt-till exposed in a gully across a woods road. Site 42, Strong Farm, northern Orange.

Extensive areas of moderately dense to loose, fine- to coarse-sand matrix till are found in the Orange Brook valley in the vicinity of Dix Reservoir and the Lower Orange Reservoir (Figure 14). This till may be derived partly from the Knox Mountain Granite.

The areas mapped as till include small areas of talus (fans or aprons of fallen rock at the bases of cliffs) and colluvium (slope-wash deposits on the lower portions of slopes).

Figure 13. Brown, weathered, fine-sandy till. Site 273 on hilltop on Strong Farm, northern Orange.

Figure 14. Coarse sandy till from an east-west till ridge (possible moraine). Site 325, Barre City Forest, east of Dix Reservoir.

As discussed in Larsen (2001) and 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 (Thompson and other, 2017). Subsequent discoveries of thick dense till over lacustrine sediments at several locations in Washington County support this readvance hypothesis (Dunn and others, 2011; Dunn and others, 2015), Dunn and Morin, 2018).

Several possible moraine ridges underlain by sandy till were identified in the Orange Brook valley to the south of Dix Reservoir. These are shown on Plate 1. Granite boulders are common on the ridges, but they are also widespread on smooth till slopes in the area. Shovel holes and other exposures showed little sign of stratification.

Several areas of ice-contact deposits, including at least three esker segments, are scattered up and down the eastern portion of the quadrangle (Figure 15). These are composed of unsorted to poorly-sorted stratified sand, gravel, and silt deposited in contact with glacial ice. Surface may contain scattered kettle holes formed by melting of buried ice blocks or be a highly complex kame and kettle. Esker ridge composed of ice-contact stratified sand and gravel deposited by glacial meltwater streams in tunnels within or beneath the glacial ice.

Figure 15. Looking east at Town of Orange sand and gravel pit in ice-contact deposits. Site 362, northwest of Hurricane Hill.

A variety of lacustrine deposits have been identified in the study area. Most appear to be associated with glacial Lake Winooski. These range from well-sorted sand, pebbly sand and/or sandy gravel deposited in shoreline, shallow water, or lake bottom environments of a glacial lake to clay, silt, and very fine to fine sand deposited in deeper waters. The finer-grained deposits are commonly laminated and often show clear indications of varves (annual sediment layers).

Figure 16. Bedded sand and gravel exposed in excavation between Hilltop Avenue and Ayers Street, Barre City. A probable lacustrine deposit.

Stratigraphic sections showing a dense upper till over glaciolacustrine deposits over dense lodgement till have been identified in the Great Brook watershed in the northeastern portion of the study area and in the Jail Branch and Honey Brook valleys in the western portion of the study area (Figures 17 and 18). Sections along the Jail Branch and Honey Brook reveal that the upper till is up to 10 meters thick. The glaciolacustrine deposits consist of a wide variety of subaqueous debris flow, turbidity flow, grain flow, and slump deposits (Dunn and others, 2015 and Dunn and Morin, 2018). Dunn and Morin (2018) suggest that the sediments were deposited during the advance of an ice margin eastward into a lake filling the Jail Branch valley. The limits of the readvance till suggest that the ice may have reached only as far east as East Barre.

Stephen Wright (personal communication, 2013) has identified a delta in the western part of the study area. Well-sorted sand and gravel topset and foreset beds are interpreted to have been deposited in glacial Lake Winooski at the mouth of the Jail Branch. This deposit appears to have formed after the final retreat of the ice and records the approximate level of glacial Lake Winooski. Wright (personal communication, 2013) determined a topset-foreset elevation of approximately 938 feet (286 meters).

Figure 17. Exposure of dense silt till in bed of Honey Brook, Barre Town.

Figure 18. Looking west into steep landside-gully complex consisting of lacustrine laminated diamict deposits overlain by readvance till. Lodgement till is exposed in the stream at the base. Honey Brook valley, Barre Town.

Holocene Deposits
The Holocene deposits are described briefly below. These are less than about 12,000 years old. Cohen and others (2017) give 11,700 years before present as the base of the Holocene

Artificial Fill. Artificially-emplaced material along road beds, embankments and in developed areas. Material varies from natural sand, gravel, or till to various artificial waste materials. Thickness varies.

Artificial Fill, Mine and Quarry Waste. Extensive piles of granite quarry waste, locally known as “grout piles.” Numerous Barre Granite quarry sites dot the landscape in the southwestern part of the study area. The quarry sites are shown on Plate 1 and an example of a water-filled abandoned quarry is shown in Figure 19. Many of the grout piles are also shown on Plate 1 and a view across the piles is shown in Figure 20.

Alluvium. Silt, sand, and gravel deposited by modern streams. Includes stream channel, bar, and floodplain deposits. Wetland deposits are common within these areas and are not distinguished. Thickness in tributary valleys is typically less than 3 meters, although the depth may be much greater in the valleys of the larger streams.

Alluvial Terrace Deposits. Silt, sand, and gravel deposited on terraces above the modern floodplains of streams. Composed of a variety of channel, bar, and floodplain deposits. Generally less than 5 meters thick.

Alluvial Fan Deposits. Boulder, pebble, and cobble gravel and pebbly sand deposited at sites where steep, stream gradients are sharply reduced. Common at the mouths of steep tributaries where they meet the main stream.

Wetland Deposits. Accumulations of organic matter and/or clastic sediment in low-lying areas. Includes a wide variety of wetland types. Commonly overlying other deposits such as alluvium, lacustrine sediment, or till. Only a few larger deposits are shown.

Colluvium. Fans or aprons of slope-wash sediment that have accumulated at the base of steep slope segments. Thickness is highly variable, although usually less than 3 meters. An accumulation of colluvium against the uphill side of an old stone wall is shown in Figure 21.

Figure 19. Abandoned granite quarry hole in Barre Town Forest on Millstone Hill.

Figure 20. View from grout piles on west side of Church Hill Road, looking west toward distant grout piles and Quarry Hill.

Figure 21. Colluvium built up against uphill side of a stone wall. Site 278 on Strong Farm, northern Orange.

Summary

The purpose of this project was to conduct 1:24,000 scale mapping of the surficial geology of the Barre East 7.5 minute quadrangle. Field work involved visits to 607 exposures of surficial deposits and 127 bedrock outcrops. The locations of approximately 92 bedrock outcrops were obtained from. Additional surficial geologic information was obtained by analysis of 596 water well logs.

Bedrock outcrops are abundant in large portions of the study area. In addition to the bedrock outcrops visited as part of this and other geologic mapping projects, Plate 1 also shows points where interpretation of lidar topographic data can be used to infer shallow bedrock. These were an aid to construction of the depth to bedrock map (Plate 3).

Glacial till is the most widespread surficial material in the study area. It is generally dense to very dense, unsorted to very poorly sorted, fine-sandy-silt to silt matrix till.

Striations and grooves in bedrock indicated that ice motion directions ranged from 130 to 200°, with the most abundant orientations around 160° and with lesser maxima at 140° and 180°. Where cross-cutting relationships can be observed, the more southerly striations are younger than the southeasterly ones. Crag and tail landforms visible on the lidar-derived topography show similar orientations.

Although no extensive moraines were identified, several small, approximately east-west ridges of sandy till in the Orange Brook valley to the south of Dix Reservoir may be moraines.

Ice-contact sand and gravel deposits are scattered along the western edge of the Knox Mountains in the eastern part of the study area. They consist of unsorted to poorly-sorted sand, gravel, and silt deposited in contact with glacial ice. These include several short esker segments formed in subglacial meltwater stream courses. Most are of limited extent, although the one being excavated at the Orange Town Pit is of moderate size. The deposits in the northeastern part of the study area near the Plainfield/Orange town line appear to have been deposited in proglacial lake of limited extent as glacial ice impeded northward drainage.

Meltwater channels are scattered throughout the northern and eastern portions of the study area. Some occupy cols in east-west ridges and appear to have been formed by south-flowing meltwater while the glacial ice margin stood at the ridge. Others occur on hill slopes and appear to have formed at or perhaps under ice margins as the ice downwasted off of the hillsides.

Stratigraphic sections showing dense till over lake deposits over lodgement till have been identified in the Great Brook watershed in the northeastern portion of the study area and in the Jail Branch valley in the western portion of the study area. These deposits suggest a late Wisconsinan ice readvance into the valley bottoms. In the Jail Branch valley the readvance till appears to have reached only as far east as about East Barre.

A prominent spillway located northwest of Millstone Hill at about 1171 feet (357 meters) may have been cut by meltwater impounded by the lobe of readvancing ice as it pushed in from the Stevens Branch valley to the west.

A delta deposit located south of the Jail Branch in the southwestern portion of the study area appears to have formed after the final retreat of the ice and records the approximate level of glacial Lake Winooski. Stephen Wright (personal communication, 2013) determined a topset-foreset elevation of approximately 938 feet (286 meters).

Acknowledgements

Many individuals helped with the project. Thanks to Rick Dunn (Figure 22), my colleague at the Department of Earth and Environmental Sciences, for his efforts to unravel the mysteries of the stratified diamicts in the Great Brook and Honey Brook exposures. Tyler Hermanson undertook an outstanding Senior Research Project on the Honey Brook deposits and contributed substantially to our understanding of their origin. Bram Towbin, Sarah Albert, and Dave Strong kindly shared their deep knowledge of the local terrain.

Finally, many thanks to the landowners who kindly allowed access to their properties.

Figure 22. Rick Dunn of the Norwich University Department of Earth and Environmental Sciences, on exposure of dense lodgement till at base of thick section in Honey Brook, Barre Town.

References

Cohen, K.M., Finney, S.C., Gibbard, P.L., and Fan, J.-X.2017, The ICS International Chronostratigraphic Chart: Episodes, v. 36, p. 1990204.

Doll, C.G., ed., 1970, Surficial Geologic Map of Vermont, Vermont Geological Survey, Montpelier, 1:250,000.

Dunn, R.K., and Morin, Joel, 2018, A proglacial ice margin depositional sequence marked by sedimentation in a grounding zone wedge and by remobilization of basin slopes: Geological Society of America, Northeastern Section Abstracts with Programs, v. 50, no. 2, 37-3.

Dunn, R.K., Springston, G.E., Hermanson, T., and Thomas, E., 2015, Interbedded subaqueous debris and turbidity flows; a thick and laterally extensive ice-proximal facies preserved in isolated proglacial basins: Geological Society of America, Northeastern Section Abstracts with Programs, v. 47, no. 3, p. 113.

Dunn, R.K., Springston, G.E., and Wright, S., 2011, Quaternary geology of the central Winooski River watershed with focus on glacial lake history of tributary valleys (Thatcher Brook and Mad River): *in* West, D.P., Jr., *ed.*, Guidebook for Field Trips in Vermont and adjacent New York: New England Intercollegiate Geological Conference, 103rd Annual Meeting, Middlebury College, Middlebury, Vermont, pp. C3-1 to 32.

Murthy, V.R., 1957, Bed rock geology of the East Barre area, Vermont: Vermont Geological Survey Bulletin 10, Montpelier, 121 p. plus 3 plates.

Larsen, F.D., 1972, Glacial history of central Vermont; in Doolan, B.L. and Stanley, R.S., eds., New England Intercollegiate Geological Conference Guidebook, p. 296–316.

Larsen, F.D., 2001, The Middlesex readvance at 11,900 14C years BP (abs.): Geological Society of America, Northeastern Section, Abstracts with Programs, v. 33, no. 1.

Larsen, F.D., Wright, S.F., Springston, G.E., and Dunn, R.K., 2003, Glacial, late-glacial, and postglacial history of central Vermont: Guidebook for the 66th Annual Meeting of the Northeast Friends of the Pleistocene, Montpelier, Vermont, 62p.

Ratcliffe, N.M., Stanley, R.S, Gale, M.H., Thompson, P.J., and Walsh, G.J., 2011, Bedrock Geologic Map of Vermont: USGS Scientific Investigations Map 3184, 3 sheets, scale 1:100,000.

Springston , G.E., and Barg, Lori, 2002, Surficial geology of the Great Brook watershed, central Vermont: Manuscript submitted to the Vermont Geological Survey, Waterbury, 1 color plate, 1:24,000.

Springston, G. and Dunn, R., 2006, Surficial Geologic Map of the Southern Worcester Mountains Watershed, Middlesex and Stowe 7.5 minute quadrangles, Vermont: VGS Open-File Report VG2006-3.

Springston, G.E., and Haselton, G.M., 1999, Surficial geologic map of the eastern portion of the Saint Johnsbury 7.5 x 15 minute quadrangle: Open File Report VG99-8, Vermont Geological Survey, Waterbury, 5 plates, scale 1:25,000.

Springston, G.E., and Kim, J., 2011, Surficial geologic map of the Plainfield quadrangle, Vermont: Vermont Geological Survey Open File Report VG11-2, 1 color plate, 1:24,000.

Springston, G.E., and Kim, J., 2008, Surficial geologic map of the Knox Mountain area, Marshfield and Peacham, Vermont: Vermont Geological Survey Open File Map VG08-4, Waterbury, 2 color plates, scale 1:24,000.
http://www.anr.state.vt.us/DEC/GEO/images/digitalofrs/KnoxMtnSurficialMap.pdf .

Springston, G.E., Thomas, E, and Kim, J, 2015, Surficial Geologic Map of the Southern Two-Thirds of the Woodbury Quadrangle, Vermont, Washington County, Vermont: Vermont Geological Survey Open File Report VG2015-3. Available at
http://dec.vermont.gov/sites/dec/files/geo/OpenFile/WoodburyQuadSurfMap.pdf .

Springston, G.E. and Thomas, E.J., 2014, Landslide hazard analysis of the Great Brook watershed, Plainfield, Vermont: Report prepared for the Central Vermont Regional Planning Commission, Montpelier, Vermont, 34 p., plus 1 plate (1:10,0000). Available at http://centralvtplanning.org/wp-content/uploads/2012/03/GreatBrookLandslideReportFinal03172014.pdf .

Stewart, D.P. and MacClintock, P., 1969, The surficial geology and Pleistocene history of Vermont: Vermont Geological Survey Bulletin 31, Montpelier, Vermont, 251p.

Thompson, W.B., Dorion, C.C., Ridge, J.C., Balco, Greg, Fowler, B.K., and Svendsen, K.M., 2017, Deglaciation and late-glacial climate change in the White Mountains, New Hampshire, USA: Quaternary Research, v. 87, p. 96-120.

Wright, S.F., 2015, Late Wisconsinan ice sheet flow across northern and central Vermont: Quaternary Science Reviews, v. 129, p. 216-228.