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B5: Geology of the Lower Ellis River Valley and Rumford Whitecap Mountain, Andover and Rumford, Maine

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GEOLOGY OF THE LOWER ELLIS RIVER VALLEY AND RUMFORD WHITECAP MOUNTAIN, ANDOVER AND RUMFORD, MAINE

By

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INTRODUCTION

Purpose

The East Andover quadrangle was selected for surficial mapping during the 2016 field season as part of the Maine Geological Survey's STATEMAP program. The area was coarsely cataloged by Stone (1899) and Leavitt and Perkins (1935), but the surficial geology had not been officially mapped at a scale finer than the state level of 1:500,000 (Thompson and Borns, 1985), and thus became a priority for the Survey. Bedrock geology of the area was mapped at the 1:62,500 scale (Rumford quadrangle) by Moench and Hildreth (1976). The recent surficial mapping efforts (Locke and others, 2017; Weddle and others, 2017) provided a reminder of how much the area has to offer the visiting geologist, with everything from pegmatites and a rich mining history to eskers and stream terraces. This field trip will provide participants with the opportunity to view a subsample of the geologic features in the East Andover quadrangle and to consider their formative processes. Figure 1 offers an overview of the trip route with stop locations. We will begin in the southeast part of the quadrangle, work our way up the Ellis River Valley, then loop back down to the central portion of the quadrangle to end the day at Rumford Whitecap Mountain.

Physiography Overview

On a broad scale, the East Andover quadrangle lies within the Central Highlands of New England, which contains a wide range of topography and the highest peaks in the region (Denny, 1982). Hanson and Caldwell (1989) focused in on Maine and refined Denny's classification, but this did not significantly change the description of the East Andover area, which was placed in the Central Maine Highlands. This geomorphic region is comprised of several mountain ranges, including the Mahoosuc Range and Blue Mountains, which lie to the west/southwest and north/northeast of the quadrangle, respectively. The foothills of these ranges and lesser peaks make up the topography within the quadrangle and to the south/southeast. Many locals simply refer to this region as the Western Maine Mountains. Tributaries that eventually form the West Branch of the Ellis River flow from the Dunn Notch and Sawyer Notch areas to the west and northwest of the quadrangle. Tributaries of the East Branch of the Ellis River make their way from the Black Brook Notch, Little Ellis Pond, and Ellis (a.k.a Roxbury) Pond areas to join the West Branch just south of Andover village. The area to the north and northeast of this confluence is a relatively large and flat basin formed in the Mooselookmeguntic Pluton. Hanson and Caldwell (1989) attributed broad lowlands that occur within the Central Maine Highlands to underlying plutonic rocks, which are (in most cases) less resistant to weathering and glacial erosion than surrounding metamorphic rocks. The Ellis River flows south from the basin, entering a deep valley that is bounded by Plumbago Mountain and Mount Dimmock to the west and Rumford Whitecap Mountain to the east, eventually reaching the Androscoggin River at Rumford Point.

BEDROCK GEOLOGY

The bedrock in the East Andover quadrangle comprises layered clastic sedimentary rock of Devonian and Silurian age that was later altered by metamorphism to develop aluminous schists, granofels, and calcareous units. These units include the biotite granofels of the Devonian Hildreths Formation; the quartzose biotite granofels, biotite schist, and pale calc-silicate rocks of the Madrid Formation; the rusty-weathering graphitic schist and sulfidic granofels of the Smalls Falls Formation; the cyclically-bedded muscovite-rich schist and granofels of the Perry Mountain Formation; and the lead-gray irregularly-interbedded mica schist and quartzose biotite granofels of the Rangeley Formation (Moench and Hildreth, 1976). These units have experienced at least three distinct metamorphic and deformational events (Guidotti, 1970; Guidotti, 1989), the first two associated with regional folding and faulting

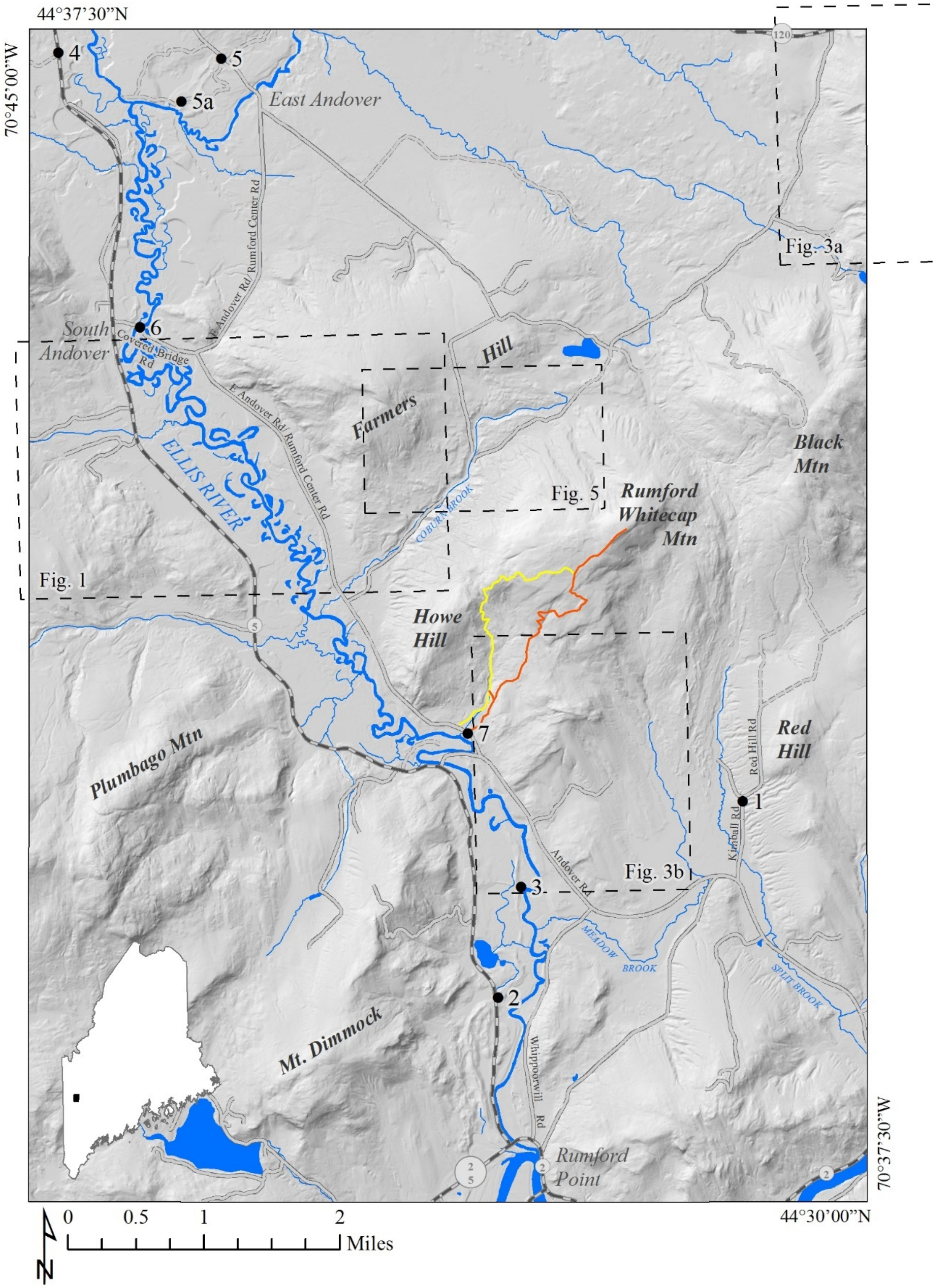

Figure 1. East Andover quadrangle location map. Trip stop locations are labeled with dots and bold numbers. Rumford Whitecap Mountain hiking trails are marked with yellow and red lines. Locations of areas shown in guide figures, but are not stops on this trip, are outlined with dashed boxes and labeled with figure numbers. Cartography by Amber Whittaker.

that imparted foliation with overall near-vertical dip and northeasterly strike, and the third likely associated with the emplacement of several plutonic bodies that are aligned in a northwesterly direction, perpendicular to the regional structures. The northern third of the quadrangle is dominated by the Devonian-age Mooselookmeguntic Pluton, which is a composite igneous complex dominated by two-mica granite with smaller amounts of granodiorite, tonalite, and quartz diorite (Moench and Hildreth, 1976; Tomascak and others, 2005). The string of mountains that cross from west to east in the center of the quadrangle (Plumbago, Rumford Whitecap, and Black Mountains) are characterized by igneous rocks. Plumbago Mountain consists of mafic to ultramafic metamorphosed intrusive igneous rocks cut by beryl-bearing and rare-mineral pegmatite dikes that host the Newry Mines. Rumford Whitecap Mountain, the final stop on this field trip, is named after the white granitic pegmatite and aplite exposed at the top. Black Mountain, although predominantly metasedimentary, is intruded by several pegmatite dikes, some of which have been quarried. Jurassic/Triassic basaltic dikes are scattered throughout the quadrangle and cut all units.

Several economic mineral deposits have been worked in the pegmatites of the East Andover quadrangle. Pegmatites in Maine have been prospected for gem minerals like tourmaline as well as materials used in the manufacture of war equipment such as: sheet and flake mica for use in heat-resistant windows or in capacitors for its dielectric properties; feldspar for use as a flux in ceramic and glass production; beryl for creating beryllium-metal alloys; lithium-bearing minerals such as lepidolite or spodumene for use in ceramics, glass, and metal alloys; and cesium-bearing minerals like pollucite for use as a getter in vacuum tubes (cesium is liquid at room temperature and easily combines with gases like oxygen). In the early 1900s, the most well-known quarries at the Newry Mines on Plumbago Mountain in the western part of the quadrangle produced gem-quality mineral specimens, as well as high-quality feldspar and spodumene with mica and beryl byproducts (Cameron and others, 1954; King, 2000). Dunton Quarry (part of the Newry Mines) yielded gem-quality colored tourmalines in the 1970s. The area is occasionally open for collecting (Thompson, 2013). Colored tourmaline and purple lepidolite were found at Black Mountain in the late 1800s, although there are few reports of gem-quality specimens. In the early 1900s, the quarry was worked for scrap mica, beryl, potash and soda feldspar, and spodumene. Mining ended sometime before 1950 (Cameron and others, 1954; King, 2000). Five pegmatites at the Red Hill quarries in the eastern part of the quadrangle were explored for beryl in the late 1940s (Shainin, 1949).

The pegmatite at Rumford Whitecap was explored for beryl and feldspar based on the success of the deposits at Plumbago and Black Mountains. In 1961, the Whitecap Mountain Syndicate drilled two exploration holes at the summit with a combined length of 994 feet under the direction of Moyd (1961). Moyd's report indicates that the exploration cores were retained by the mining consultant Robert W. Bridgeman, and that the boreholes were marked with brass-sheathed pipes. Neither the cores nor the borehole locations could be found by MGS staff during preparation for this field trip. Core logs are available in the 1961 report. The cores were sampled by Moench and Zartman for whole-rock rubidium-strontium dating (Moench and Zartman, 1976). Moyd observed that the Rumford Whitecap pegmatite was not concentrically zoned and lacked any of the rare pegmatite minerals that were sought at the time, such as beryl or colored tourmaline; it was also determined that the deposit could not be economically mined for feldspar. The body is primarily granitic pegmatite and aplite, rhythmically layered, with blocks of the surrounding metasedimentary rocks and granite included in the main mass. Mineralogically, the pegmatite contains large crystals of quartz, feldspar, and muscovite, with accessory black tourmaline and garnet. Feldspar in the pegmatite is 40% potassium feldspar and 60% sodium-rich plagioclase (Moyd, 1961).

SURFICIAL GEOLOGY

Previous Observations and Research

Stone (1899) made his way up the Ellis River Valley in the late 1800s as part of his efforts to catalog the glacial deposits of Maine, and even though he was often without accurate maps, his observations were very insightful. He noted the broad Andover basin containing "sedimentary plains of gravel, sand, and silt" and the steep-sided U-shaped valley that leaves the basin at South Andover. Stone also described "a plain of well-rounded glacial gravel" in the valley from South Andover to Rumford Point, with a "plexus of reticulated ridges inclosing kettleholes and a lakelet" near Rumford Point. He argued that glacial processes must be responsible for these deposits since the modern Ellis River was "so gentle that it is impossible to accept such coarse, well-rounded matter as ordinary stream wash." The possibility of a glacial lake was also mentioned due to the presence of clay in some areas of the valley. Stone presented an elaborate argument for an ice dam in the Androscoggin River Valley near Rumford that would have created a proglacial lake extending up the Ellis River Valley to Andover, and in the Barkers Brook Valley to the south of the Androscoggin River, with a spillway elevation of about 730 feet in North Woodstock (Bryant Pond quadrangle). Thompson (2008) did find evidence for a proglacial lake in the Barkers Brook and Androscoggin River Valleys, naming it Glacial Lake Hanover during mapping of the Bryant Pond quadrangle (directly south of the East Andover quadrangle).

The ice or debris dam near Rumford must have persisted for some time to allow a continuous lake to form from the Androscoggin Valley up to Andover as described by Stone (1899), and other theories were put forth by subsequent researchers. Leavitt and Perkins (1935) visited the Ellis River Valley during their efforts to catalog the quality of Maine's glacial deposits for use in road construction. Many of their observations were comparable to Stone's with some additions. They noted that the Andover basin, with "an unknown thickness of sand" must have formed in granitic bedrock, similar to other inter-mountain basins in New England. A lake was hypothesized to exist in the upper portion of the valley, including the Andover basin, with an ice or debris dam blocking the Ellis River Valley between Plumbago Mountain and Howe Hill (the western arm of Rumford Whitecap Mountain). Lastly, kame terraces were observed to line the valley, which in the context of their publication refers to a wide variety of stratified sediments.

From 1963 to 1965, Maine Department of Transportation (MDOT) geologist Maurice Fournier cataloged aggregate sources in the Rumford region. Most deposits were mapped from pre-existing borrow pits and their geologic origins were loosely categorized in several MDOT soils reports (e.g. Baker, 1967). Fournier wrote a short synopsis of his thoughts on the geology of the Ellis River Valley, building on the ideas of Leavitt and Perkins: "…damming of the glacial waters probably occurred at a construction [*sic*] within the valley between Howe Hill and the northerly end of Mt. Dimmock. This allowed the glacial meltwater to rise until another channel developed. Apparently the Ellis River once traversed a more easterly course from North Rumford and flowed into the Androscoggin River about five miles downstream from where it now terminates at Rumford Point." It is interesting that neither Stone (1899) nor Leavitt and Perkins (1935) mentioned Meadow Brook and Split Brook, which now occupy the valley Fournier described. Both Meadow and Split Brook are underfit for this valley, and it is certainly possible that the Ellis River, or even the Androscoggin River, once took this path. However, this valley likely existed prior to glaciation instead of being carved out by glacial meltwaters due to its size and traverse through metamorphic bedrock.

Aquifer mapping field work for the East Andover quadrangle was completed in 1989 (Nichols and others, 1995), although the physical maps for the area have been updated over the years. Seismic profiling was a part of this field work and revealed bedrock depths of approximately 288 feet (88 meters) in the central portion of the valley between Howe Hill and Plumbago Mountain, providing further evidence of the glacially carved valley. Data from this mapping was compiled into a surficial materials map, which has also been updated over the years and as a result of the most recent mapping efforts. More detailed aquifer information will be presented in the hydrogeology section of this guide.

In the more recent decades, research in the Western Maine Mountains and nearby White Mountains of New Hampshire has focused on the manner and timing of regional deglaciation. Geologists have long debated the state of the Laurentide Ice Sheet during its retreat from the state: Was it actively flowing or stagnant? Stone (1899) believed that the ice was active due to his observations of moraines in the Upper Androscoggin Valley. Leavitt and Perkins (1935) thought that the ice sheet thinned to stagnant tongues within the mountain valleys. Koteff and Pessel (1981) put forth the idea of systematic stagnation zone retreat, in which portions of the ice margin were stagnant. (Borns (1989) and Thompson (2001) can be referenced for a more detailed summary of this debate.) Thompson (2001) mentions the East Andover quadrangle in his account of deglaciation in western Maine, citing striation observations from lower elevations to the southwest of Plumbago Mountain that show a localized change in ice flow direction. Striations, gouges, and streamlined topography throughout the quadrangle are generally oriented to the southeast, averaging about 150°. In the area described by Thompson, ice flow shifts to the south/southwest, indicating that there may have been an active ice tongue flowing towards the Stony Brook drainage in the Puzzle Mountain quadrangle to the west. In areas that lack abundant moraines such as the Western Maine Mountains, the direction of ice retreat may also be tracked by the location of meltwater channels (Thompson, 2001) and sediments deposited by glacial meltwater (morphosequences) (Koteff and Pessl, 1981). Basal radiocarbon ages from ponds in western Maine indicate that the East Andover quandrangle was deglaciated between 13,200 and 12,300 radiocarbon years BP (Borns and others, 2004). New work on cosmogenic dating of glacially transported boulders has the potential to further improve the deglacial chronology of the region (Bromley and others, 2015), but similar research has not yet been conducted in the East Andover quadrangle or in the immediately surrounding areas.

Overview of Landforms and Sediments

The landforms and associated sediments of the Ellis River valley can be subdivided into erosional and depositional categories. LiDAR topographic data for the region became available towards the end of the mapping process in spring of 2017, and has been useful in delineating landforms. On the broadest scale, the most noticeable erosional feature is the valley itself, which exhibits the classic steep sides of a glacially formed U-shaped trough in many reaches (Figure 2). Views of the valley shape are possible from portions of the hike up Rumford Whitecap Mountain during this trip (Stop 7).

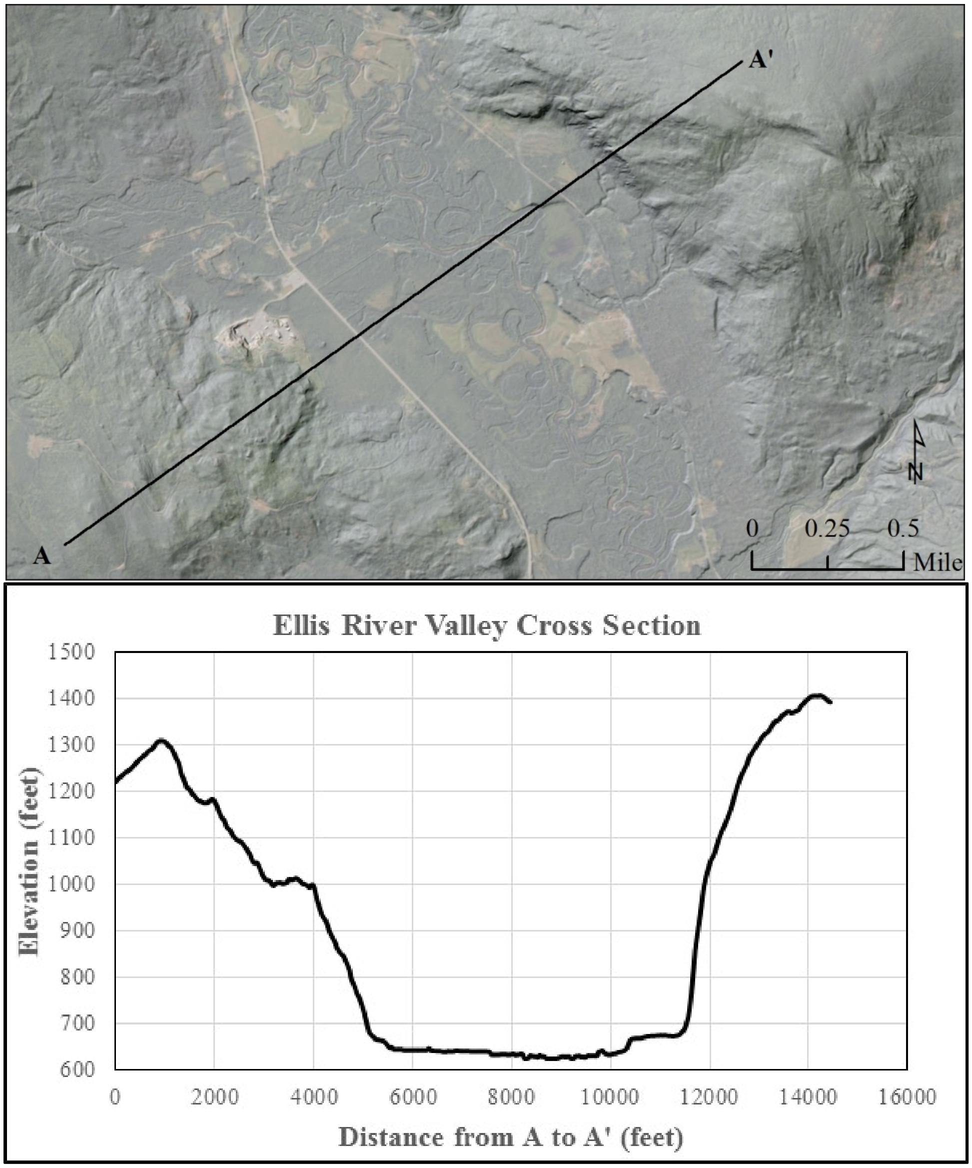

Figure 2. The top image shows LiDAR hillshade imagery over aerial photography for a section of the Ellis River Valley between the eastern edge of Little Puzzle Mountain (Puzzle Mountain quadrangle) and Farmers Hill. The graph shows a topographic cross section through the valley (extracted from the 2-meter LiDAR DEM) illustrating the steep sides of a U-shaped valley. Depth to bedrock in this section of the valley approaches an additional 200 feet (61 meters) below the valley floor (Locke and others, 2017).

Rôche moutonées are classic erosional landforms, created by glacial abrasion on the up-ice side of a bedrock obstruction and plucking on the down-ice side, forming an asymmetrical hill. North Twin Mountain is the best example of a rôche moutonée in the area, but lies just to the east in the Rumford quadrangle (Figure 3a). Fortunately, North Twin Mountain will be visible from the summit of Rumford Whitecap Mountain during Stop 7. LiDAR hillshade imagery also reveals areas of glacially streamlined topography in great detail (Figure 3b).

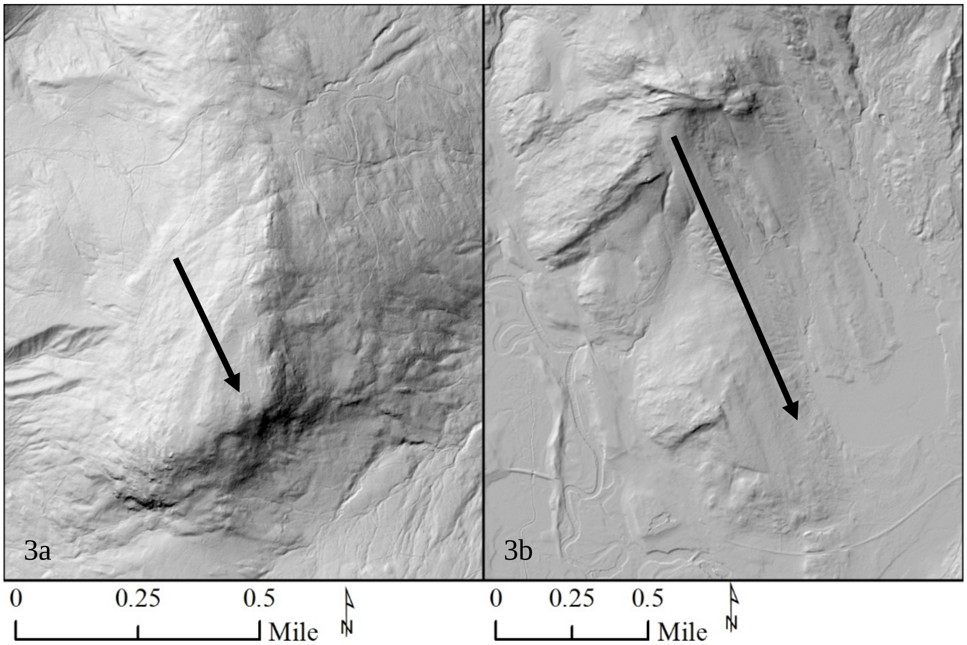

Figure 3a and 3b. LiDAR hillshade of North Twin mountain (just off the northeast corner of the quadrangle) is shown on the left (3a). The north/northwest side is gently sloping, while the southeast side is steep from glacial plucking. LiDAR hillshade imagery of glacially streamlined topography in the south-central portion of the quadrangle is shown on the right (3b). Arrows indicate approximate ice flow direction.

There are many examples of micro-erosional features in the quadrangle such as glacial striations, grooves, and crescentic gouges. Many of these features will be visible on the hike up Rumford Whitecap Mountain at Stop 7 (Figure 4).

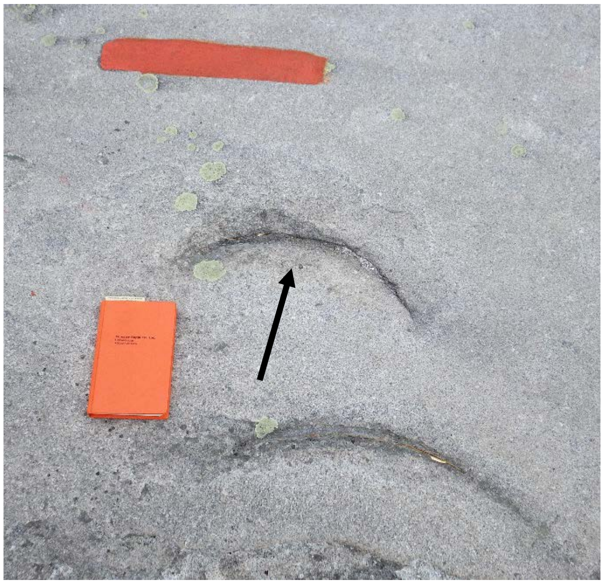

Figure 4. Crescentic gouges along the Rumford Whitecap Mountain red trail. Rock or boulders lodged in the ice were forced against the underlying bedrock, chipping pieces from the bedrock to create the gouges. These gouges are usually concave in the up-ice direction, so the ice was flowing from the bottom to the top of the photo in this example. Photo: Lindsay Spigel.

Meltwater channels and stream terraces round out the major erosional landforms in the quadrangle, transitioning from late glacial to modern stream processes. LiDAR topographic imagery has made it easier to pick out meltwater channel routes, especially in forested areas. Channels formed by glacial meltwater can be distinguished from sub-aerial streams because these channels often have irregular locations and paths, and are commonly occupied by underfit modern streams. A good meltwater channel example in the East Andover quadrangle is the channel currently occupied by the headwaters of Coburn Brook (Figure 5). The channel is quite deep for the size of the modern stream, especially in the uppermost reach where it is about 50 feet (20 meters) deep. It is unlikely that modern flow in this section of Coburn Brook would be enough to carve this channel. The ice margin was likely in this location long enough for a marginal channel to develop in the saddle between Rumford Whitecap Mountain and Farmers Hill.

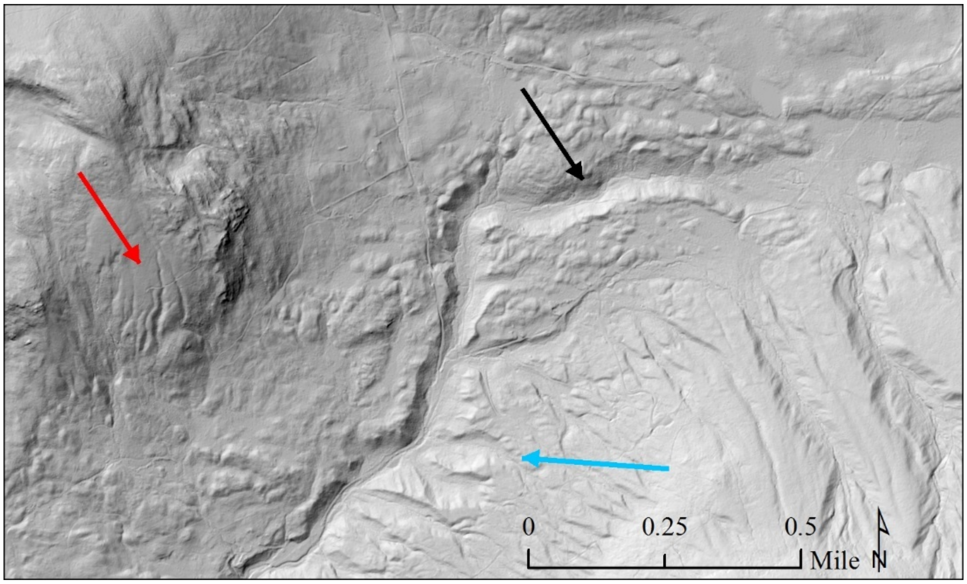

Figure 5. LiDAR hillshade imagery of the Coburn Brook meltwater channel (black arrow). Flow was right (northeast) to left (southwest). Note the small, irregular channels that end abruptly in the left-center of the image (red arrow) – it is possible that these are small meltwater channels. Contrast these to the more orderly channels in the southeast corner of the photo (blue arrow) that most likely formed by sub-aerial processes in late-glacial to early Holocene times, before thick vegetation cover became established.

During late-glacial and early post-glacial times, the young Ellis River responded to changes in base level and began to incise through glaciofluvial and glaciolacustrine deposits, terracing the valley over time (Figure 6). The modern channel continues to slowly meander across the valley floor, leaving many well-preserved oxbow channels – each a snapshot of the river at that point in time. See the Stop 4 Road Log for additional imagery.

Depositional features in the East Andover quadrangle include glacial till, glaciofluvial/lacustrine deposits, quaternary alluvial fans, and eolian deposits. Till in the quadrangle is usually stony with a sandy matrix, but deposits have not been analyzed in any detail beyond basic unit mapping. Esker deposits, kettles, and other miscellaneous ice-contact sand and gravels near the confluence of the modern Ellis and Androscoggin Rivers could be considered a “head of outwash” area (Thompson, 2001), indicating that the ice margin was paused in that area long enough for the materials to accumulate. (See Stop 2 Road Log for more landform descriptions.) There is a similar area further up the valley in South Andover, indicating another possible pause during retreat. There may have been more similar evidence in the valley between these areas that has subsequently been altered or covered by other processes and deposits. Overall, the depositional features also point towards a southeast to northwest ice retreat.

The head of outwash deposits may have blocked drainage of the Ellis River Valley at the southern end, but there was another outlet through the Meadow Brook and Split Brook Valleys as was suggested by Fournier. Any ponded water in this area would not have been very deep, unless this outlet was blocked where it meets the Androscoggin Valley as well, making it part of Glacial Lake Hanover. As the ice retreated up the valley, various glaciolacustrine and glaciofluvial deposits were laid down, filling the valley with sediments as meltwater flowed from the margin and the surrounding hills. Ponded areas likely filled with sediments, eventually becoming outwash plains. The highest elevation sediments in the valley (usually along the margins) slope from just over 700 feet (213 meters) in the northern portion to about 650 feet (198 meters) in the southern portion, but this slope is not continuous, with breaks at South Andover and Howe Hill, again indicating possible pauses in ice retreat. Good exposures of glaciofluvial and glaciolacustrine sediments in the valley are not common, as many gravel pits in the area are no longer active. Figure 7 shows an example from a fresh exposure that has since been closed. LiDAR imagery has also revealed braided channel patterns on some of these higher surfaces (see Road Log for Stop 5.)

Figure 6. Photo of subtle terraces on the west side of the Ellis River Valley near Stop 3. A black arrow points to the most obvious terrace. Photo is looking roughly northwest. Ryan Gordon for scale. Photo: Lindsay Spigel.

Figure 7. Outwash sand and gravel from an exposure in the northern portion of the Ellis River Valley. The photo was taken facing west. Dipping beds in the center of the photo indicate water flow to the south. Scale bar increments are inches on right, centimeters on left. Photo: Lindsay Spigel.

As ice or till dams dissipated, meltwater streams and eventually modern streams began to flow freely and modify the valley deposits. Wind likely reworked these sediments, too, creating small eolian deposits. Streams draining the barren, freshly deglaciated landscape eroded glacial deposits from the uplands. When these steep mountain streams met the relatively flat Ellis River Valley floor, they lost energy and their ability to transport sediments, depositing these sediments to form alluvial fans. Many alluvial fans in the area are easy to pick out since they are preferable for farming, the cultivated fields popping out from the mostly forested landscape. Fans tend to have finer sediments that were winnowed from the hillside (much preferred over stony till), but are not as threatened by flooding since they are slightly above the main valley floor (Figure 8). (See also Road Log for Stop 1.)

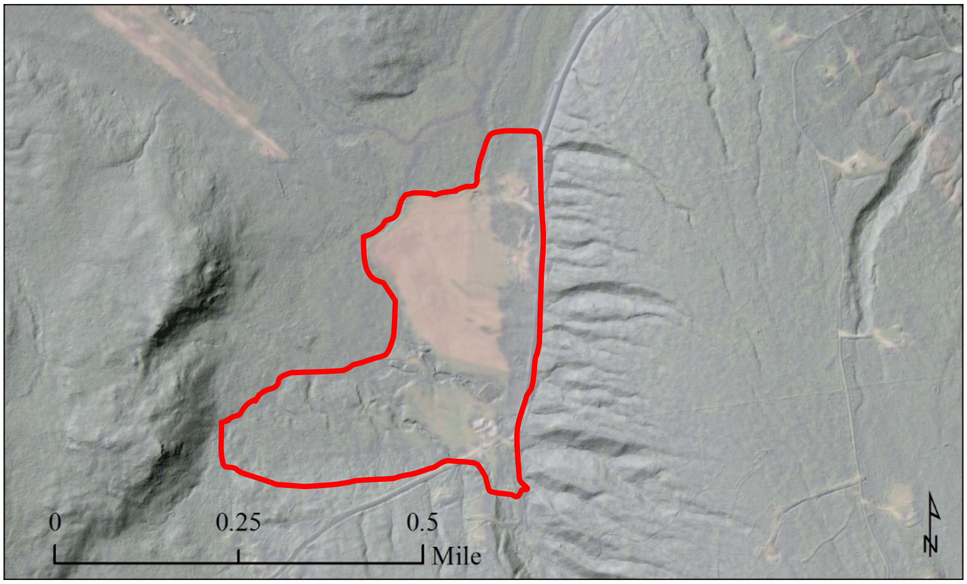

Figure 8. LiDAR hillshade and aerial imagery of an alluvial fan (roughly outlined in red) in the southeast portion of the quadrangle. The fan is preferable for farming and thus is easy to identify in the otherwise forested landscape. The many channels that fed the fan are also visible.

HYDROGEOLOGY

Water Resources in the Lower Ellis River Valley

The Lower Ellis River Valley is rich in groundwater and surface water resources. The mean annual precipitation in the watershed is 44 inches. The Ellis River itself is gauged by the USGS at a point in South Andover (USGS gauge 01054300), where the annual mean discharge is 300 cubic feet per second from a watershed area of 130 square miles. Monthly mean flows range from 103 cubic feet per second in September to 880 cubic feet per second in April.

Surficial materials that fill much of the valley are saturated with fresh water and make good aquifers, that is, the saturated sediments are transmissive enough to yield groundwater to a properly constructed well at a rate greater than 10 gallons per minute. The Maine Geological Survey maps most of the valley bottoms in the East Andover quadrangle as significant sand and gravel aquifer, including the entire Ellis River Valley, plus the valley bottoms in the Split Brook and Meadow Brook watersheds (Foster and others, 2016). High-yielding aquifers are mapped on both sides of the Ellis River along most of its length from the confluence of the East and West Branches in Andover down to the Androscoggin River. High-yielding aquifers are defined as those where saturated surficial deposits have the potential to yield greater than 50 gallons per minute to a properly constructed well.

The bed of the Ellis River is very sandy and is likely well connected to the aquifers below and on both sides, so that the surface water and groundwater in the valley can be viewed as a single resource. The Ellis River likely receives net groundwater inputs along most of its length, which increase its discharge in addition to tributary inputs of surface water. On top of the net gain to the river from groundwater, groundwater and surface water probably exchange frequently in both directions in what is called hyporheic exchange, the bi-directional exchange of water through the shallow riverbed and riverbank sediments.

Although farmers may withdraw surface water from the Ellis River and tributaries from time-to-time for irrigation, and residents throughout the valley use springs, bedrock wells, and dug wells for domestic uses, there are no especially large withdrawals of groundwater in the valley, except for the Rumford Water District (see below).

Milligan Farm Esker

The esker system that runs roughly parallel to the Ellis River consists of thick sand and gravel deposits (see Stops 2 and 3). The section of esker that is utilized for its water resources is about two miles north of where the Ellis River flows into the Androscoggin, and is called the Milligan Farm esker after the family that owned and farmed the surrounding land. Here the esker ridge runs almost due north-south along the western bank of the river. The ridge is approximately 250 feet wide, and 20 to 30 feet higher than the land to the west, which is mostly river terrace and wetland. The Ellis River has eroded into the esker sediments at several locations where meander bends arch westward, and has cut entirely through the esker to the north (See Stop 3, Figure 14). Exposed sediment near the crest of the esker shows medium to coarse sand and rounded gravel and cobbles (Figure 9). At locations near the southern end of the esker, similar rounded gravel and cobbles can be seen in the river bed and bank where the stream impinges on the steep esker side (Figure 10). In these locations, concentrated spring flow is clearly visible entering the river through the bank close to the water line. Beneath the esker, sand and gravel deposits have been found to at least 90 feet below the ground surface (Locke and others, 2017).

Figure 9. Exposed sediment near the crest of the esker, showing medium to coarse sand, rounded gravel and cobbles. Photo: Ryan P. Gordon.

Rumford Water District Wells

Beginning in 1913, the Mount Zircon Reservoir, managed by the Rumford Water District (RWD), was the primary supply of drinking water for the town of Rumford. When the Safe Drinking Water Act was amended in 1986, the new federal law added additional regulated contaminants and mandated that surface water systems be filtered, among other strengthened drinking water standards. These changes prompted RWD to make improvements in their water supply infrastructure, including a move away from surface reservoirs. A study by the district indicated that the system needed significant improvements, including a new source of groundwater. At that time, RWD operated two wells on the Swift River, installed in 1953 and 1963, but the yield was insufficient, and they were only used when drought or water quality impacted the reservoir (A.E. Hodsdon, 1989a).

In 1988, preliminary reconnaissance by Bradford Caswell noted several locations where the gravel esker is in contact with the adjacent river on property owned by Robert Milligan (Milligan Farm Esker), near where RWD had done limited test drilling in 1961 (A.E. Hodsdon, 1989a). The more southerly area, where rounded gravel was noted in the river bed, was identified as the highest priority site to investigate and to install additional test wells. In 1989, 14 test wells were installed in the esker area, finding as much as 100 feet of coarse sand, gravel, cobbles, and boulders (A.E. Hodsdon, 1989b). Prior to pumping, groundwater flow through the esker was to the south and east. Analysis of a 5-day pump test at 400 gallons per minute determined high transmissivity values of between 300,000 to 400,000 gallons per day per foot, with an average saturated thickness of 50 feet, leading to an estimated hydraulic conductivity of around 900 feet per day (A.E. Hodsdon, 1989b). In 1990, a production well was drilled that provided up to 700 gallons per minute. The well was brought online in 1991, but the well pumped sand and yields soon dropped. It was determined during investigations in 1995 that the well had been improperly constructed and was faulty (A.E. Hodsdon, 1998).

Figure 10. Rounded gravel and cobbles in the river bank, near a flowing spring. Photo: Ryan P. Gordon.

A replacement well was installed in 1997, to the north of the first well, and continues to supply water of excellent quality to the Rumford area today. This well is 95 feet deep with a 20-foot screen, and has a safe yield in excess of 1000 gallons per minute. During the testing of this well, a combined 1700 gallons per minute were pumped from both production wells for two days, which successfully induced recharge from the Ellis River (A.E. Hodsdon, 1998). This pump test demonstrated that a connection between the river and esker aquifer does exist, and that the river can provide water to the wells in addition to the natural recharge and storage of the aquifer.

ACKNOWLEDGEMENTS

Entry to many sites listed here is at the discretion of the landowner. The authors wish to thank the many landowners for granting access to private property and permission to park for the purposes of this trip on September 30, 2017. Thank you to the Mahoosuc Land Trust for hosting us on their trails to Rumford Whitecap Mountain. Thank you to Woody Thompson for providing photos and additional information about the area.

ROAD LOG

MEETING POINT: Saturday, September 30th, 8:30 AM in the Maine DOT Riverside Rest Area on U.S. Route 2 (356262.00 m E, 4923630.71 m N) in Bethel, ME. From the intersection of State Route 35 and U.S. Route 2 in Bethel, head east on U.S. Route 2 towards Rumford; the rest area will be on the right side in about 3.5 miles. We will consolidate vehicles as much as possible and head east to the first stop from here. Those who will not be hiking Whitecap Mountain should share a vehicle so they don't get stuck at the last stop without a ride back to the meeting point. The mileage starts over at each stop to avoid any confusion that might occur from parking and turning around in slightly different areas.

Mileage

0.0	From the Maine DOT Riverside Rest Area, turn right onto U.S. Route 2.
13.3	Turn left onto Andover Road. This road follows the Split Brook Valley. Note the size of the valley in comparison to the size of Split Brook, which we will cross at approximately mile 14.7 (there is a small bridge with sign).
15.3	Turn right onto Kimball Road.
16.3	Drive to the end of Kimball Road (passing the big red barn and farmhouse). Turn around in the small cul-de-sac at the end of Kimball Road and drive back down towards the farmhouse. Park on the side of the road just before reaching the farmhouse.

STOP 1. KIMBALL FARM (3694763.11 m E, 4933470.70 m N).

The Kimball Farm has a very interesting landscape, which can be viewed from Kimball and Red Hill Roads. Please stay on the roads/edge of roads and refer to the LiDAR image below to guide you during the stop (Figure 11). Walk to the north end of Kimball Road or view the area as we turn around at the end of the road. Observe the small ridges to the west. It is possible that there was a small ice tongue flowing down the east side of Rumford Whitecap Mountain, and these ridges are likely very small esker segments that are part of some associated miscellaneous ice-contact deposits. View a till exposure on the east side of Kimball Road, north of the farmhouse. Walk up Red Hill Road and look down into the hillside channels; consider how and when these channels formed. These channels were also viewed during a previous NEIGC trip (Thompson, 1989). At the time, much of this hillside was pasture and the channels were easily viewed from the road and accessed on foot. It was postulated that these channels were glacial meltwater channels. What do you think? Walk south on Kimball Road to the edge of the farm and view the alluvial fan and overall landscape. In 1990, two sediment cores were taken in the fan roughly south of the main barn as part of aquifer mapping in the area. Sediments in the cores varied widely, but generally indicated mixed fluvial sediments (silt to pebble gravel) over possible lacustrine sediments and/or till (Locke and others, 2017).

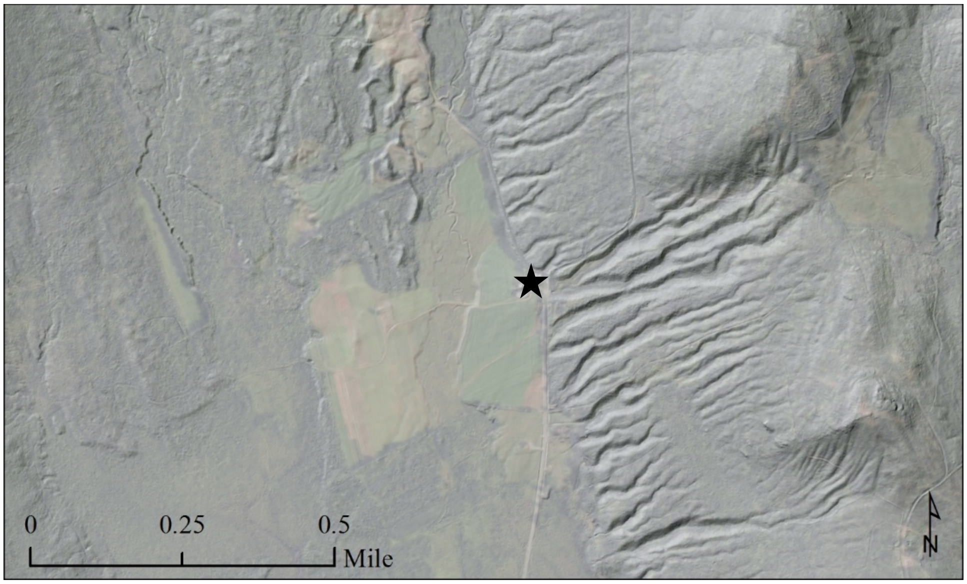

Figure 11. Stop 1 LiDAR hillshade and aerial imagery. Star at approximate parking location.

0.0	From the Kimball Farm House, head south on Kimball Road.
0.6	Turn right onto Andover Road.
1.8	Turn left onto Whippoorwill Road.
3.7	Turn right onto U.S. Route 2.
3.9	Turn right onto Maine Route 5 (Ellis River Road).
5.0	Turn right into gravel pit.

STOP 2. BERNARD PIT (366529.67 m E, 4931204.44 m N).

This gravel pit is located in a portion of the Ellis River esker system (Figure 12). Eskers form at ice margins as sub-glacial meltwater carves conduits up into the base of the ice, releasing sediment from the ice which accumulates over time to build the ridge-like landform. Fluvial transport of materials within the esker system also tend to round and sort the sediments. An excellent synopsis of esker formation can be found in Thompson and Hooke (2016). The pit has not been excavated in a few years, but one can still get an idea of the esker formation. Please do not climb up on the pit face. Observe the cobbles present in the deposit. No provenance studies have been done at this location, but rock types represented in the esker are similar to the bedrock units described to the north and west of this location including: Several different kinds of igneous rocks like granitic pegmatite, granite, granodiorite, or tonalite with included blocks of related igneous rocks that may be from the Mooselookmeguntic Pluton and dominate the deposit; coarse or fine-grained mafic cobbles that may be from the Plumbago mafic or ultramafic intrusions, or from younger basaltic dikes; and smaller amounts of metasedimentary rocks like schist or granofels that match descriptions of the regional bedrock units. Observe the sand on the east side of the pit; consider how this deposit was formed. Figure 13 is an older photo of this section of the pit with a relatively fresh exposure, but note that material has been removed from this area since the photo was taken.

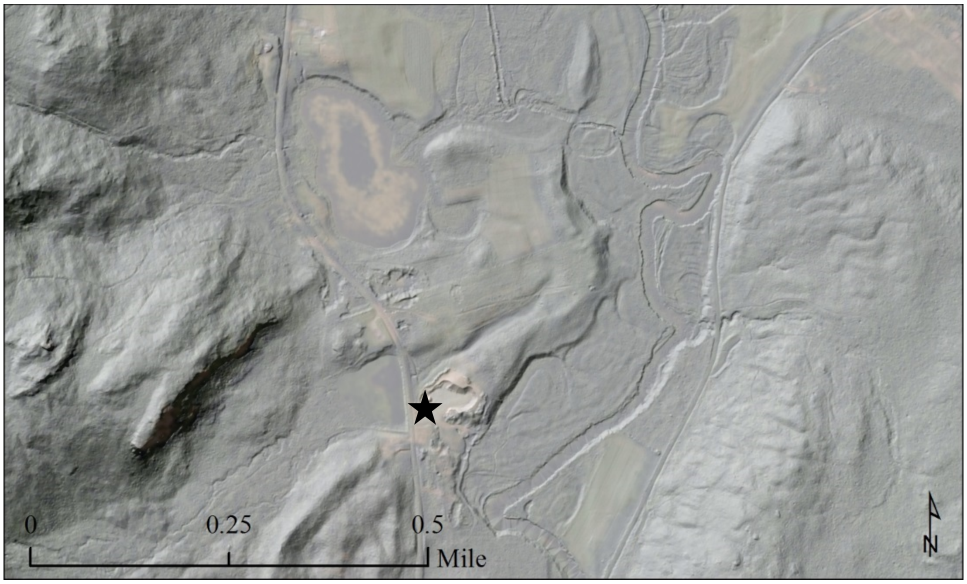

Figure 12. Stop 2 LiDAR hillshade and aerial imagery. Star marks approximate parking location.

Figure 13. Photo of sand in east side of pit, taken on August 21, 2003. Photo courtesy of Woody Thompson.

0.0	From the pit drive, turn right onto Maine Route 5 (Ellis River Road). Pass Davis Pond Kettle on right.
0.9	Turn right on farm road, just past large white barn. Park on either side of the farm road before the gated bridge. Please do not block the gate.

STOP 3. RUMFORD WATER DISTRICT (366829.95 m E, 4932509.98 m N).

Here we will walk into the water district property and over the esker, viewing an exposure of esker sediments and the well pump houses (Figure 14). We will then walk toward the southern end of the esker to see the river bank springs and eroded esker cobbles.

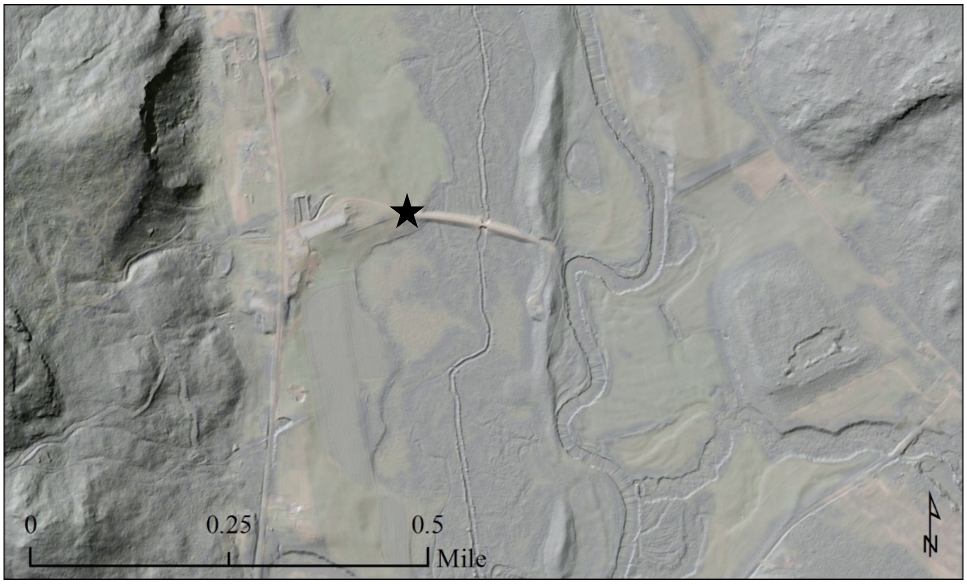

Figure 14. Stop 3 LiDAR hillshade and aerial imagery. Star marks approximate parking location.

0.0 At the intersection of the farm road and Maine Route 5, turn right onto Maine Route 5.
7.7 Turn right into the third entrance to Woodlawn Cemetery. Follow the road to the back of the property where it turns to loop back around and park, staying on road. *Please use caution – some graves are very close to the road so please do not stray from the road tracks!* If the gates are closed, we will have to park along Maine Route 5 and walk to the back of the cemetery.

STOP 4. WOODLAWN CEMETERY (361554.13 m E, 4942498.84 m N).

At this brief stop we will walk down a woods road at the back of the cemetery to view an impressive terrace scarp and large oxbows (Figure 15).

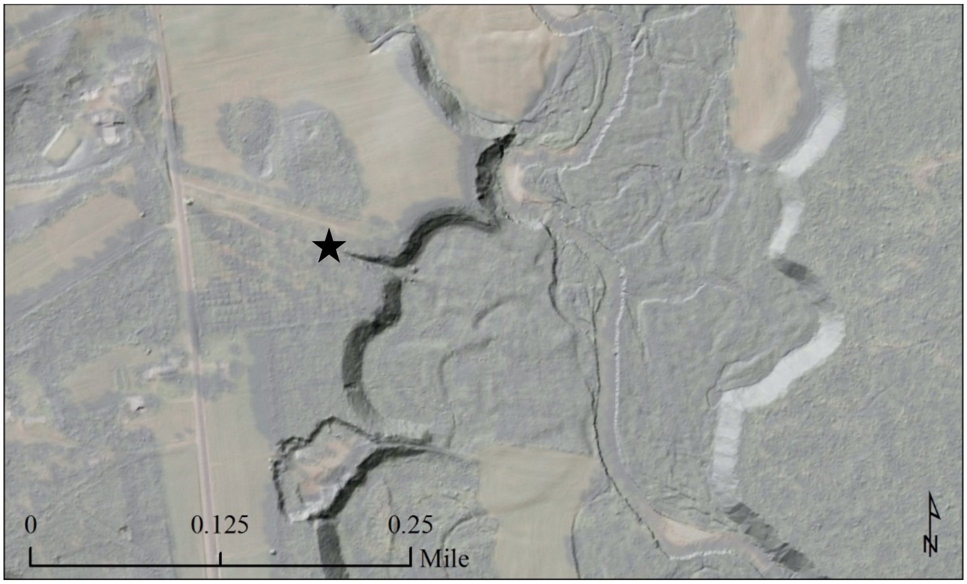

Figure 15. Stop 4 LiDAR hillshade and aerial imagery. The small excavation in this image (bottom left, above the scale bar) is the location of the exposure shown in Figure 7. Star marks approximate parking location.

0.0 At the intersection of the cemetery road and Maine Route 5, turn right.
0.9 Turn right onto Maine Route 120 in Andover Village.
1.7 Stay straight onto East Andover/Rumford Center Road.
2.8 Turn right into gravel pit and park in flat area adjacent to East Andover/Rumford Center Road.

STOP 5. CHADBOURNE PIT (363478.00 m E, 4942388.84 m N).

This gravel pit has not been recently active, but has exposures of coarser glaciofluvial sediments. Consider the sediments along with the imagery in Figure 16. The area includes an unnamed kettle lake (west), evidence of former braidplain (east and southwest), and a small esker remnant (southwest). The braidplain to the east lies at about 705 feet (215 meters) and is oriented northeast to southwest. There is also evidence of braidplain on this higher surface to the northwest in the Andover and Ellis Pond quadrangles - this plain lies at about 702 feet (214 meters) and is oriented northwest to southeast. (We drove over this surface as we passed through Andover Village.) Meltwater was likely diverted around a streamlined hill that runs northwest to southeast just north of the area displayed in Figure 16, and met near the modern confluence of the East and West Branches of the Ellis River. Sediment was still coarse enough to warrant a braided channel system even as the stream began to incise, as there is still remnant braidplain at about 656 feet (200 meters) just south of the kettle lake. The modern floodplain lies at about 636 feet (194 meters), so that's about 69 feet (21 meters) of stream incision since deglaciation. Along with Stops 4 and 5a, we will have experienced the transition of fluvial systems from late-glacial to modern times, all in one corner of the quadrangle.

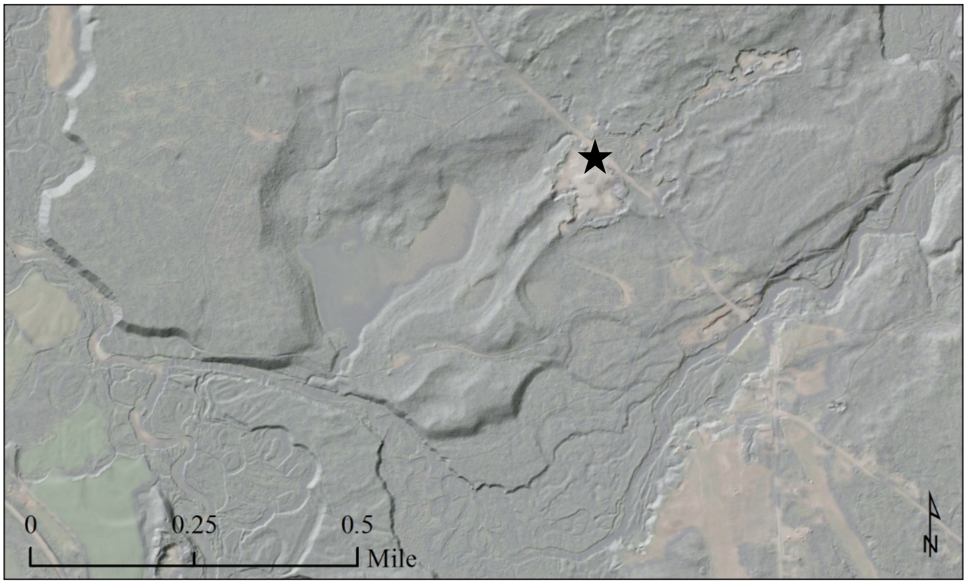

Figure 16. LiDAR hillshade and aerial imagery for Stops 5 and 5A. The gravel pit is in the top center of the image. Esker remnant is next to the 0.25-mile mark on the scalebar. Star marks approximate parking location.

0.0	From parking area in the pit, follow logging road to the southwest corner of pit.
0.7	Turn around in log yard and park on side of road. From the log yard, we will walk down a woods road about ½ mile to:

OPTIONAL STOP 5A. MEETING OF THE WATERS (362999.85 m E, 4941895.23 m N).

Time permitting, we will view an impressive cut bank on the West Branch of the Ellis River just upstream of its confluence with the East Branch (hence the “Meeting of the Waters”). The view is best if you wade across the river here, so bring your rubber boots if you packed them. One can really get a feel for the type and volume of glaciofluvial sediments in this area (Figure 17).

Figure 17. Photo of the cut bank at the “Meeting of the Waters.” Amber Whittaker for scale. Photo: Lindsay Spigel.

0.0	From the gravel pit parking area, turn right onto East Andover/Rumford Center Road.
2.5	Bear right onto Covered Bridge Road.
3.0	Park on side of road. There is a small pull-out just before the bridge that will fit about three cars, but others must park on the side. Do not cross the bridge – the road narrows after the bridge, making it difficult to park. Do not park in the entrance to Covered Bridge Campground on the west side of the bridge.

STOP 6: LUNCH AT LOVEJOY COVERED BRIDGE (362453.80 m E, 4939229.61 m N).

Just upstream of the covered bridge is the USGS continuous gauging station on the Ellis River (station #01054300). This station uses a nitrogen gas bubbler to measure the river stage (height of water). The stage is related to discharge by creating a rating from discharge measurements that are periodically made downstream of the bridge by USGS personnel.

0.0	Turn around in the road and head east on Covered Bridge Road.
0.5	Turn right onto East Andover/Rumford Center Road.
4.1	Parking lot for Rumford Whitecap Preserve. There is only room for about five cars in this lot. Please do not park in the lot if you will not be hiking. Those at the end of the caravan should park on the more open west side of the road *before* reaching the parking lot.

STOP 7: RUMFORD WHITECAP PRESERVE (366236.73 m E, 4934338.15 m N).

A separate handout will be distributed for this stop so hikers don't have to lug their guidebooks along and can move at their own pace. We will hike up the yellow trail, meeting the orange/red trail for the last stretch to the summit, and will descend on the orange/red trail. The hike is about five miles round trip, so bring whatever you think you will need for that distance. Time permitting, we will begin with a visit to some inactive pits just off the yellow trail to the Rumford Whitecap summit. These pits expose a wide variety of materials in a relatively short transect. The group will stay together while viewing these pits and then those that do not wish to hike can depart.

Outcrops of the metasedimentary units that are crossed on this hike – the rusty-weathering graphitic schist of the Smalls Falls Formation on the lower slopes, and the light-colored quartz-rich biotite granofels and quartzite of the Perry Mountain Formation near the tree line – are small and poorly exposed. Look for relatively fresh clasts of the country rock in the surficial deposits (float) at the start of the trail – these angular and friable pieces of rusty-weathering, dark-colored schist obviously did not travel far from their source.

The pegmatite contact nearly coincides with the tree line as you hike up the mountain. The rock is very white due to the abundance of quartz, feldspar, and muscovite – hence the name "Whitecap" – and there is nearly 100% exposure of the rock. The large size of the minerals make them easy to identify. Numerous other igneous features are easily observable – pegmatite dikes cutting fine-grained granite, xenoliths of granite or metasedimentary rock included in the pegmatite, and graphic intergrowths of feldspar and quartz or tourmaline and quartz are common (Marvinney, 2012).

Glacial striations and crescentic marks are easily observed above the tree line, with many examples occurring right along the trail (Figure 4). Glacially transported boulders are also plentiful, but are not erratics since they are of the same rock type as the bedrock in the vicinity (Marvinney, 2012). Rumford Whitecap's summit offers 360° views of the surrounding glaciated landscape – hopefully the weather will be clear so we can take advantage. The remainder of the ascent and descent mostly traverses stony till.

End of trip. To return to the meeting point, head south on East Andover/Rumford Center Road from the Rumford Whitecap Preserve parking lot. Drive 0.2 mi and turn right onto Andover Road (esker ridge follows the left side of the road for a bit). Drive 0.3 mi and turn left onto Maine Route 5/Ellis River Road. Drive 2.9 mi and turn right onto U.S. Route 2. Drive 8.8 miles to Maine DOT Riverside Rest Area on left.

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NOTES