GSNH Promoting Geological Science & Education

Geological Society of New Hampshire

2013 Summer Field Trip

Bedrock and Surficial Geology of the Lakes Region of Central New Hampshire

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Introduction

The geology of the Lakes Region of New Hampshire encompasses a wide range of geologic processes including; deformation and igneous intrusion during continental collision in the Devonian Period, the development of igneous volcanic complexes during the continental breakup in the Mesozoic Era, and the deposition of glacial deposits during the most recent episode of glaciation in the Quaternary Period. The 2013 Geologic Society of New Hampshire Summer Field Trip will highlight various aspects of each of these major periods of geologic history by incorporating field trip stops and discussions of both the bedrock and surficial geology of the Lakes Region of Central New Hampshire. Bedrock Field Trip Stops will focus on the development of the Mesozoic Belknap Range Intrusive Complex and the older "country" rock. Field Trip Stops highlighting the surficial geology of the Lakes Region will include discussions regarding the transition from Glacial Lake New Durham to present-day Lake Winnipesaukee, descriptions of small-scale glaciolacustrine deposits laid down in ice-dammed glacial lakes, ice-contact deposits, glacial outwash settings, and post-glacial fan construction.

This Field Trip will include seven stops in Alton, Gilford, and Laconia, New Hampshire (Figure 1). The "Base Camp" for the Field Trip will be the Ellacoya State Park in Gilford. Everyone participating in the Field Trip will meet at Ellacoya at 8:00 AM in order to drop off family members who will be staying at the beach for the day and to combine into as few cars as possible. The Field Trip Stops have been organized so that we can return to Ellacoya State Park for lunch at the end of the day.

Our thanks to Dr. Wally Bothner for his pre-field trip visit with us to the Belknap Mountain Complex and his sharing of valuable insights into the geology. The descriptions of many of the bedrock

Field Trip Stops relied heavily on those presented in Wally's and Henry Gaudette's 1971 NEIGC Field Trip Guide. Tusen takk!

Background of Bedrock Geology

Lake Winnipesaukee is surrounded by four igneous/volcanic complexes that developed in the Mesozoic Era during the breakup of the Pangaea supercontinent, including (from oldest to youngest): the Red Hill Complex (199 to 187 Ma), the Belknap Mountain Complex (169 to 159 Ma), the Ossipee Mountain Complex (122 Ma), and the Merrymeeting Mountain Complex (117 to 115 Ma) (Lyons, et. al., 1997) (Figure 2). Although each of these Complexes has a unique geologic history, the Field Trip today will concentrate on the geology of the Belknap Mountain Complex.

Reviews of the geology of the Belknap Complex are provided by Modell (1936), Quinn (1941), Bother (1971), Loiselle (1978), and Long (2005). These reports show that the Complex is comprised of igneous rocks ranging from gabbro to biotite granite (Figure 3). Moat volcanics are exposed locally within the Complex.

Geochemical and isotopic studies of the Complex suggest that various magmas that comprise the Complex formed through fractional crystallization and/or assimilation or reaction with older crust (Bothner and Gaudette, 1971 and Loiselle, 1975). Cross-cutting relationships, compositional trends of the rocks, and radiometric dates suggest the following overall sequence of instruction: Gilford gabbro, Endicott (brecciated) diorite (Stop 5), Ames monzodiorite, Gilmanton Augite Monzodiorite, Belknap Syenite, Sawyer Quartz Syenite, Lake Quartz syenite, Albany Porphyritic Quartz Syenite, Conway Granite (Stop 5), Rowes Vent Agglomerate, and Trap Syenite Breccia (Bothner and Gaudette, 1971). Ring dikes within the Complex are comprised of porphyritic quartz syenite (Stop 2), Conway Granite, monzodiorite, and syenite.

The rocks of the Belknap Mountain Complex intrude into the Devonian Meredith Porphyritic Granite (Kinsman Granodiorite) and the Winnipesaukee Tonalite (formerly quartz diorite), and the Silurian Perry Mountain and upper and lower Members of the Rangeley Formation (Bothner and Gaudette, 1971, Lyons, et al., 1997, and Long, 2005). The Meredith Porphyritic Granite and the Winnipesaukee Tonalite are part of the New Hampshire Plutonic Series. These igneous rocks were intruded into the Silurian country rock during and after regional deformation, respectively.

Pegmatite dikes are common in the pre-Mesozoic rocks. In addition, the country rocks and the units within the Belknap Mountain Complex have been intruded by Mesozoic mafic dikes. Both types of dikes occur at Stop 1 of this Field Trip.

Background of Surficial Geology

The surficial geology of the Lakes Region largely reflects deposition related to the most recent period of continental glaciation (which ended approximately 14,000 years ago), and to a lesser extent, post-glacial deposition along streams and rivers. The advance and retreat of the glacial ice resulted in the deposition of an assortment of surficial deposits and the formation of a variety of landforms. Early descriptions of the surficial geology of the Lakes Region are found in J.W. Goldthwaite's *The Geology of New Hampshire (1925)* and R.P. Goldthwaite's *Surficial Geology of the Wolfeboro-Winnipesaukee Area, New Hampshire (1968).*

Once the ice margin retreated north of a bedrock threshold (approximate elevation of 520 feet) in New Durham, New Hampshire, an ice-dammed lake was formed (discussed by Goldthwait, 1925, but named Glacial Lake New Durham by Goldsmith, 1994). Glacial Lake New Durham drained a large portion of the present-day Winnipesaukee Basin until the ice margin receded north of Belknap Point in

Gilford, New Hampshire. At the same time that Glacial Lake New Durham was draining southward, smaller ice-dammed glacial lakes filled the north-facing valleys on the northern and western sides of the Belknap Range. The glacial lakes on the north side of the Belknap Mountains drained westward along the ice-margin towards the greater Merrimack River drainage system. Once the ice damming Glacial Lake New Durham receded north of Belknap Point, the entire Winnipesaukee Basin could drain westward, as it does today. This event would have caused a dramatic increase in meltwater volumes draining along the ice margin and through the area of Laconia.

The drainage of Glacial Lake New Durham marked a transition in the nature of deposition from ice-marginal glaciofluvial/glaciolacustrine settings to glaciofluvial/outwash settings. The flat outwash plain that includes the Laconia Airport along Route 11 in Gilford was the first outwash deposit laid down in front of the ice margin after this transition. A sequence of segmented eskers north of the Airport trace the receding glacier front within the outwash deposits.

Field Trip Log:

0.0 miles Start (Figure 1):

Ellacoya State Park:

> Access from Portsmouth: Spaulding Turnpike (Route 16) to Route 11 West. Second exit off Alton Rotary, continue on Route 11 West. Drive approximately 12.3 miles on Route 11 to Park on right.
>
> Access from Concord: I-93 North to Exit 20. East on US-3/NH-11 6.3 miles to a right turn onto Laconia-Gilford Bypass. Continue 5.5 miles to end of Bypass. Turn left, staying on Route 11 East. Continue 4.6 miles to Park on left.

Directions to Stop 1:

0.1 (0.1 miles)	Turn south onto Route 11 East;
6.6 (6.5 miles)	Turn into Scenic View parking lot on right.

Stop 1: Scenic View Area (Figure 1)

Beware of cars on Route 11 (tourists and locals going 55+ mph) and falling rock! Please stay between the outcrop and the guardrails along Route 11…but beware of unstable rock on face of outcrop. The proverbial "between a rock and a hard place"!

The Scenic View provides a view of the northern end of Alton Bay, which is located in the southeastern portion of Lake Winnipesaukee. The Ossipee Mountain Complex is visible in the distance on the eastern shore of Lake Winnipesaukee. The Merrymeeting Mountain Complex is just visible above the hills on the east side of Alton Bay. The southern end of Rattlesnake Island and several very small islands south of Rattlesnake Island mark the offshore location of a subporphyritic quartz syenite "outer ring dike" (Bothner and Gaudette, 1971 and Long, 2005) (Figure 1).

Stop 1 is located beyond the extent of the main body of the Belknap Mountain Complex (Figure 1). The large outcrop just to the north of the parking lot (on the west side of Route 11) is comprised dominantly of Winnipesaukee Tonalite and subordinate Meredith Porphyritic Granite. These country rocks are intruded by granite and pegmatite veins and dikes and Mesozoic rhyolite, quartz syenite, and diabase dikes (Bothner and Gaudette, 1971). The rhyolite and quartz syenite dikes are covered with wire mesh to help prevent injuries from rock falls.

The southern of the two covered dikes is a pink to gray laminated rhyolite. Quartz grains occur within the fine lamellae along the contact of the dike with the country rock. Broken and rotated K-feldspar clasts and mylonite attest to the cataclastic nature of the contact between the dike and country rock. This N35E trending, 50SE dipping dike could potentially be related to the intrusion of the Conway Granite into the core of the Complex or to the Conway Granite ring dike.

The northern covered dike is a vertically dipping, 20-foot-wide quartz syenite. A thin chill margin occurs along the contact with the country rock and quartz and feldspar phenocrysts can be observed in fresh outcrop.

Directions to Stop 2:

	Reverse direction and proceed on Route 11 West. BEWARE of cars approaching at high speeds. If traffic is too busy, we will take Route 11 East to next road on left and turn around.
8.5 (1.9) miles	Pull off in breakdown lane on right (east) side of Route 11. Last car in line should turn on emergency flashers (Thanks).

Stop 2: Albany Porphyritic Quartz Syenite Ring Dike (Figure 1)

A pink, Albany porphyritic quartz syenite dike is exposed on both sides of Route11. This northwest trending, southeast dipping dike comprises a portion of the Albany Quartz Syenite ring dike that encircles the southern portion of the Belknap Mountain Complex.

K-feldspar phenocrysts occur within an aphanitic chill margin matrix near the contact with the country rock, whereas the core of the dike is equigranular. Zoning within the K-feldspar phenocrysts is sometimes visible in hand sample.

The up to two-meter wide contact between the Winnipesaukee Tonalite and the ring dike exhibits evidence of shearing and grain reduction (mylonitization) that occurred just prior to the intrusion of the dike. This cataclysmic deformation is particularly evident on the lower side of the dike on the east side of the road.

A number of diabase, granitic, and pegmatite dikes intrude the Winnipesaukee Tonalite at this Stop.

Directions to Stop 3:

	Continue on Route 11 West;
9.6 (1.1) miles	Turn left onto Route 11A;
13.9 (4.3) miles	Turn left into main entrance of Gunstock Mountain Resort;
14.3 (0.4) miles	Turn right into Campground (through gate);

14.7 (0.4) miles Park on side of road.

Stop 3: Belknap Syenite and "Rotten Rock" (Figure 1)

Stop 3 incorporates an exposure of "rotten rock" that has developed within the Belknap Syenite and, if planned blasting does not prevent access, a fresh exposure of Belknap Syenite in a quarry with overlying rotten rock.

The Belknap Syenite occurs within the western portion of the Belknap Mountain Complex in two separate areas. This light gray rock is comprised of orthoclase and plagioclase feldspar with minor amounts of hornblende and quartz (Long, 2005). The composition of this rock is similar to the Moat Volcanics. Geochemical evidence suggests that there is a comagmatic relationship (fractional crystallization) between the Belknap Syenite, the Sawyer Quartz Syenite, the Albany Quartz Syenite, and Conway Granite (Bothner and Gaudette, 1971 and Loiselle, 1978).

The unconsolidated material at Stop 3 consists of a layer of glacial till overlying deeply weathered syenite or "rotten rock". Rotten rock localities are relatively uncommon in New Hampshire. In 1938, J.W. Goldthwaite and F.C. Kruger inventoried "weathered rock" around the state and found only 46 localities, one of them being a short distance south of Stop 3. This particular exposure is in the ice shadow of Mt. Rowe, the northernmost highpoint of the Belknap Complex, so perhaps pre-glacial age weathered rock was shielded from deep glacial erosion. However, others have speculated that the kaolinization of the feldspars may be rapid enough that the "rotten rock" could have developed since the recession of the Wisconsinan glacier.

Directions to Stop 3B:

Continue northeast on Area Road (through gate);

15.2 (0.5) miles Pull off on side of road just before Route 11A and Gunstock Mountain Resort sign.

Stop 3b (Option if extra time is available): Trap Syenite Breccia (Figure 1)

Small outcrops of trap syenite breccia are located along the north side of the road and in the stream bed of Poorfarm Brook in the area of the bridge on Route 11A. This rock is comprised of fine-grained glassy trachytic matrix with clasts of Belknap Syenite (Bothner and Gaudette, 1971). This small igneous intrusion was likely a volcanic vent through which trachytic magma intruded and incorporated the host rock (Belknap Syenite).

Directions to Stop 4: (If we skip Stop 3B, we will reverse direction and drive back through the campground.)

15.5 (0.8 miles) Turn left onto Route 11A;

18.2 (2.7 miles) Turn right onto Route 11B; (at 18.7 miles, we cross a stream cut into basal till); (at 19.3 miles, you get a good view across the post-glacial alluvial fan).

19.8 (1.6 miles) Turn right onto Route 11 East;

22.7 (2.9 miles) Turn left onto Ellacoya State Park entrance road for Lunch and Stop 4!

Stop 4: LUNCH on the Ellacoya State Park Delta Surface

Ellacoya State Park is on a constructional delta built into Lake Winnipesaukee by Poorfarm Brook. The present-day elevation of Lake Winnipesaukee is 504 feet, controlled by a spillway in Lakeport (part of Laconia). Prior to the construction of dams and dredging of the Weirs Channel, the elevation may have been somewhat different, but likely within a few feet of its present elevation. Approximately 100 feet above Ellacoya and to the west, remnants of a former delta constructed into Glacial Lake New Durham lie stranded against the steep slope Figure 2 (Tinkham and Brooks, 2004). Between Ellacoya and Gunstock Recreation Area, Poorfarm Brook has degraded through exposures of basal till up to 80 feet thick, providing large volumes of material for the delta. Offshore from Ellacoya, the very shallow gently dipping surface of the lake bottom drops off suddenly, providing a glimpse of the most distal foreset beds of the delta.

Directions to Stop 5:

0.0 (0.0 miles) Reset Odometers!

0.1 (0.1 miles) Turn right onto Route 11 West;

0.9 (0.8 miles) Turn left into parking lot for Lockes Hill (overflow parking in Scenic View on right side of Route 11).

Stop 5: Endicott Brecciated Diorite and Lockes Hill Drift Deposit (Figures 1 and 2)

Endicott Brecciated Diorite

Outcrop locations are on the west side of Route 11 to the north of the parking lots. This location is along the edge of the mapped limit of the Endicott Brecciated Diorite. The outcrops are comprised of dark gray diorite, occasional Winnipesaukee Tonalite, Perry Mountain Formation (?), and Conway Granite. Cross-cutting relationships suggest there were several episodes of Conway Granite intrusion into the other rocks.

The intrusion of the granite into the other rocks has resulted in the development of angular to sub-rounded blocks of the other three rocks types. In places, the contact between the granite and the other rock types is sharp with no signs of alteration. In other locations, blocks of diorite, tonalite, and Littleton Formation have convolute to serrated edges, have been highly altered, and/or appear as whips or ghosts within the granite. K-felspar phenocrysts have developed within some of the diorite blocks as a result of the reaction with the granite.

Lockes Hill Drift Deposit

During the latest stage of Glacial Lake New Durham, the receding ice margin exposed a gap just south of Lockes Hill at an elevation of 780-800 feet. That low spot in the ridge allowed water from Glacial Lake Gilford to drain into Glacial Lake New Durham, falling approximately 160 feet in just over one-half mile. The remnants of a debris fan may be present at an elevation of 620-640 feet, but it appears to have been a small fan that was either covered by Route 11 or used for fill during its construction. Meltwater from Glacial Lake Gilford would have been sediment-starved, as it was spilling from the deepest part of the Glacial Lake. It appears that only a thin drift cover would have been available to erode, so any fan deposited would likely be very small.

However, during reconnaissance of the area to search for the debris fan it was noted that a semi-linear ridge trends steeply down the eastern slope of Lockes Hill, just north of the former spillway. The higher points of the ridge have an esker-type form and some test pits show well-rounded pebbles to cobbles, suggesting the feature may be of sub-glacial or englacial origin. The old pit at the base of the feature appears to be in poorly-sorted ablation till. The highest elevation of the drift ridge appears to grade to the temporary spillway south of Lockes Hill.

Several points to consider:

- If this feature is of ice-contact origin, what mechanism allows it to concentrate material on the steep, southeastern face of a hill?
- Is the feature related to the large head difference (about 70 psi) between Glacial Lakes Gilford and New Durham?
- Could the feature be the erosional remnant of a much larger fan?

Directions to Stop 6:

	Continue on Route 11 West;
3.0 (2.1 miles)	Turn right on Route 11-B North;
4.3 (1.3 miles)	Turn left on Kimball Road, approx. 100 feet before the Route 11-C intersection;
4.9 (0.6 miles)	Take sharp right and continue on Kimball Road;
5.1 (0.2 miles)	Park on shoulder before intersecting with Route 11-C.

Stop 6 – Segmented Eskers at Head of Outwash (Figure 2)

Stop 6 is located north of the Laconia Airport and within an area of outwash and ice-contact deposits. The remnants of a north-south trending esker can be found along the eastern edge of Kimball Road and a small segment of an esker is still in place on the north side of Route 11-C (watch for traffic!). At least six of these small esker segments exist in the small valley to the north feeding into the outwash deposit. In some cases, small outwash fans can be seen grading into the outwash deposits at the down-ice end of these small eskers. Abundant scabby wetlands and areas of ablation till suggest stagnant ice blocks filled much of the valley and outwash was deposited within and around those ice blocks.

Directions to Stop 7:

	Proceed to end of Kimball Road; Turn left onto Route 11-C and proceed southwest.
6.3 (1.2 miles)	Pass Lily Pond on the right, a large kettle hole at the distal end of the outwash plain;
6.5 (0.2 miles)	Turn right at the lights onto Route 11 West;
6.8 (0.3 miles)	Take a left, continuing on Route 11 West (By-pass);
10.5 (3.7 miles)	Take Route 107 exit off By-pass (second exit);
10.8 (0.3 miles)	Turn left on Route 107 South (Province Road);
11.0 (0.2 miles)	Turn left into the entrance of Gilbert Block and Stone Sand Pit (across from the store).

Stop 7 Delta Grading to Spillway at 680-700 feet (Figure 2)

Stop 7 offers a good exposure of a delta built out into an ice-dammed lake in the valley of Durkee Brook. Meltwater from Glacial Lake Gilford was directed through the Saltmarsh Pond Spillways (900 to 920 feet, and later 860 to 880 feet) to Jewett Brook and then westward along the ice margin. The glaciofluvial deposits along the ice margin eventually graded to the glacial lake in the Durkee Brook Valley, whose elevation was controlled by a temporary spillway to the west at an elevation of 680 to 700 feet. Coarser (sand to pebble) topset beds overlie the steeply-dipping and finer (fine to coarse sand) foreset beds. At the base of the distal foreset beds, gently-dipping bottomset beds may be visible.

Return Trip to Ellacoya State Park

11.2 (0.2 miles)	Turn right out of Gilbert Block (north on Route 107) and immediately turn right and enter the Route 11 Laconia By-pass;
15.5 (4.3) miles	Turn left at end of bypass (at lights). Stay on Route 11 East.
20.2 (4.7) miles	Ellacoya State Park will be on your left.

(If you are not returning to Ellacoya, you can take Route 11 West to I-93.)

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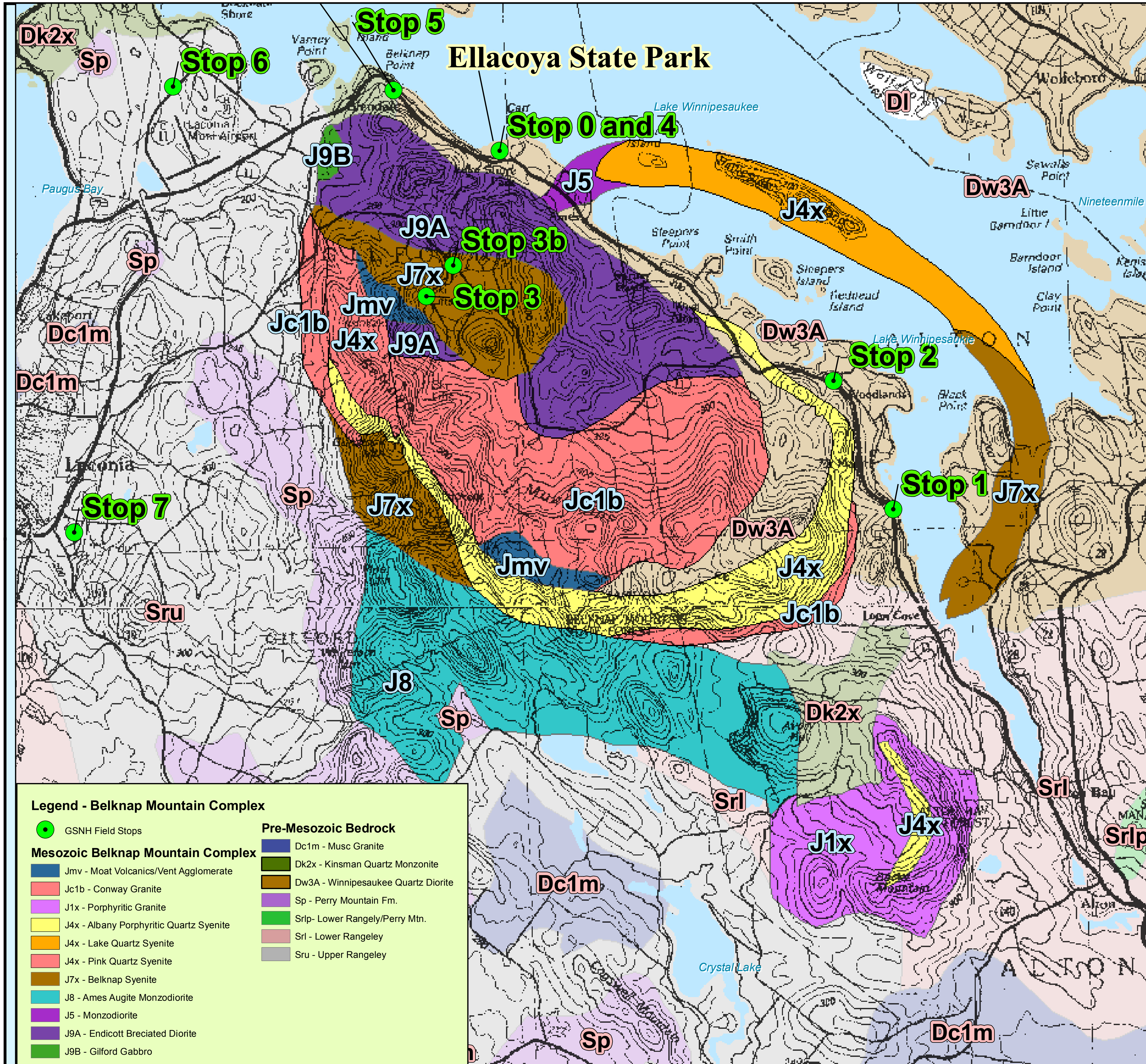
FIGURE 1

Bedrock Geology of Belknap Mountain Complex Lakes Region, New Hampshire



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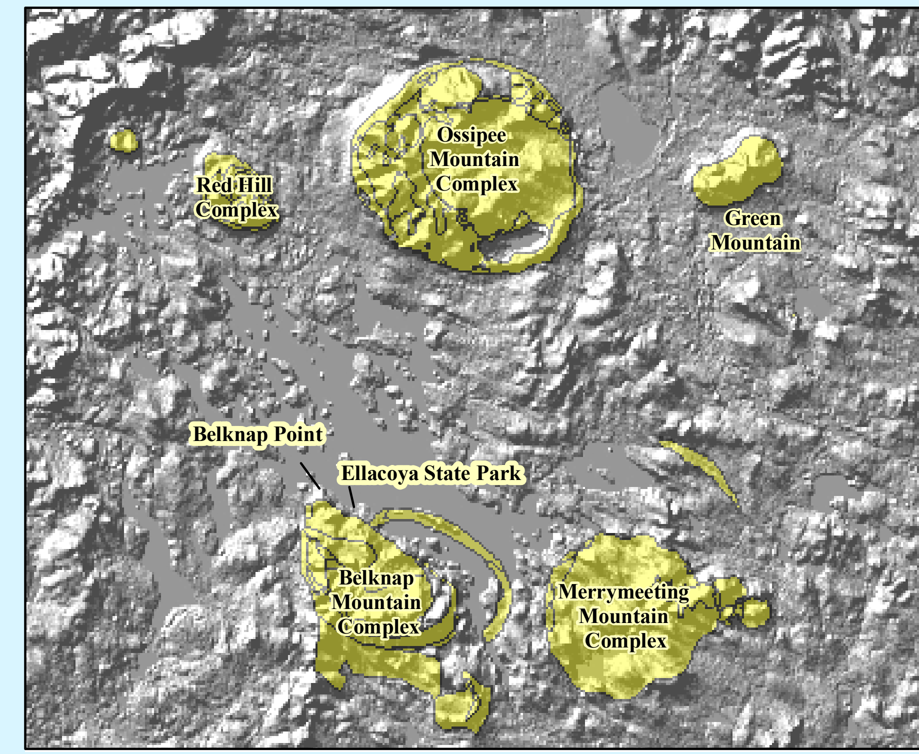

Mesozoic Igneous Complexes in the Lakes Region Overlain on Shaded DEM

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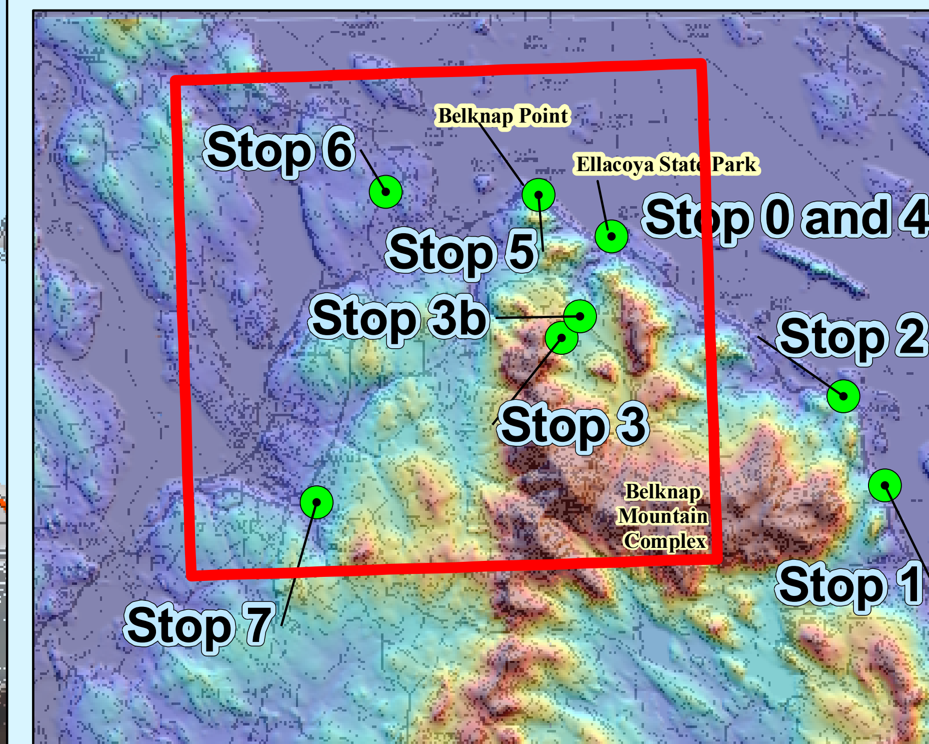
1:72,000

GSNH 2013 Summer Field Trip **FIGURE 1**

FIGURE 2

Surficial Geology
Lakes Region
New Hampshire

1:196,000



Color-Contoured DEM of
Field Trip Area

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1:48,000

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GSNH 2013 Summer Field Trip **FIGURE 2**