Self-Guided Geologic Tour of the Virginia Wood area in the Middlesex Fells Reservation

Prepared by Jack Ridge, Professor, Dept. of Earth and Climate Sciences at Tufts University, Medford, MA

Some general information before starting a tour in the Middlesex Fells:

Tours in the Crystal Spring and Virginia Wood area have been broken into two parts (north and south of Pond Street). You can do the whole tour in one day, but it is a lot of hiking (~4 twisting miles, ~6 km) and a lot to comprehend in one dose. It's recommended that you do parts of the tour in order: Crystal Spring and then Virginia Wood. Both tours begin at the same spot. Each tour and its stops are marked on the geologic maps. PLEASE FOLLOW the maps as you go. ***It will be handy to have a sense of direction from the sun, remembering that at noon the sun is due South, in the morning it is to the southeast, and by late afternoon it is to the southwest.***

2. At many times of the year and on weekends, parking areas fill, especially along Pond Street, so start early.

3. The tours require hiking over some steep and rocky trails, so plan ahead. It is recommended that you have sturdy hiking or trail shoes. I don't recommend sandals or heeled shoes.

4. Make sure you have enough food and water with you. In the Fells, there is nowhere to get water and the spring water is NOT drinkable.

5. In compliance with DCR rules, please stay on official marked trails as indicated on DCR maps. This is also a way of avoiding poison ivy and ticks. In making the geologic map, special permission was obtained from the DCR to go off the trails. See the DCR's official Middlesex Fells Reservation Trail Map (last updated in March 2020). This map accurately shows trails, except where they have been refurbished, and it has the numbered intersection designations indicated in the guide. The DCR map is online at: https://www.mass.gov/doc/middlesex-fells-reservation-trail-map/download and it is sometimes available at kiosks at Fells parking areas.

6. In wet or winter weather, some rock surfaces are slippery. DO NOT venture out onto frozen ponds and reservoirs. The ice may be too thin to support your weight and it is unpredictable!

7. Do not collect rocks on the tour or deface outcrops by writing on them. It is against DCR regulations. Please remove your own trash and follow other DCR rules. Leave no trace!

Some Fundamental Geology to Get Started:

1. The self-guided tours of the Fells focus primarily on **bedrock geology**. This is a characterization of the solid rock that occurs beneath our feet as viewed from above. Exposures of the **bedrock** surface are called **outcrops**. Loose rock debris (or **float**), sediment, and soils on top of the bedrock comprise the **surficial geology**.

2. **Rocks** are naturally occurring solids made of minerals and non-mineral materials. **Minerals** are naturally-occurring, inorganic, crystalline solids that have a specific chemical formula and unique properties that allow us to tell them apart. A **crystalline material** is one in which atoms have a repeated regular pattern (i.e., crystals or crystal structure). Minerals have names in addition to their chemical formulas. For example, sodium chloride (NaCl), which is the main ingredient of table salt, is known as the mineral **halite**, while silicon dioxide (SiO_2) is **quartz**. The most common mineral at Earth's surface is **feldspar**, an aluminosilicate containing sodium, potassium, and calcium. Non-mineral materials in rocks include organically-produced materials and **natural glass**, which is non-crystalline.

3. Rocks are divided into three main types:

Igneous rocks – rocks formed by the solidification of molten rock, or **magma**. Magmas can invade older rock units in the subsurface and then crystallize to form **intrusions** or **intrusive igneous rocks**, which may later be exposed by erosion at Earth's surface. Magma can also escape to Earth's surface before hardening to form **extrusive** or **volcanic igneous rocks**. Examples of these are **lava flows** or magma explosively ejected into the air that later settles to produce **pyroclastic rocks**.

Sedimentary rocks – rocks formed by the accumulation or deposition of particles produced by the breakdown and erosion of older rocks. This often happens in oceans and lakes or on river flood plains. Sedimentary rocks also include the accumulation of organically-produced sediment, such as clam shells and coral reefs (limestone) and plant material (coal), or chemical precipitates such as salt beds. **Fossils** occur in sedimentary rocks.

Metamorphic rocks – rocks resulting from exposure of existing rocks to increased temperatures or pressures that change the mineral composition and arrangement of mineral grains. We say these rocks are **metamorphosed**.

4. Solid materials (rocks and minerals) have been in existence on Earth for at least 4 billion years. This time in Earth's history defines the expanse of **geologic time**. Geologic time (**geologic time scale**) is subdivided based on past events represented by changes preserved in the rock record. Radiometric dating techniques are then used to place precise numerical ages on rock units and time unit boundaries. A geologic time scale can be found at: https://www.geosociety.org/documents/gsa/timescale/timescl.pdf.

5. On a geologic map, bedrock is classified into units known as **formations**, characterized by rock types and age. Formations have proper names from a place where they are well exposed or first defined. Sometimes, single formations are split into a sequence of mappable units called **members**. The boundaries between geologic units are known as **contacts**. On geologic maps, formations and members are given their own colors and patterns so they can be distinguished from each other. They also have abbreviations that consist of a capital letter for the unit's geologic time period (when it was formed) and lower-case letters that abbreviate for the unit's name. For example, "Zsg" = the Late Proterozoic (Z) Spot Pond Granodiorite (sg). Time period abbreviations in the Fells are Z (Late Proterozoic), P (Pennsylvanian), and Q (Quaternary). If a rock unit does not have a known age or formal name, only lower-case letters are used as an abbreviation. (For example: "d" stands for dolerite). Also shown on maps of the Fells are areas where the geology is concealed by human-made deposits, defined as **artificial fill** (af).

6. On the geologic maps in this guide, geographic north is shown with an arrow. **Compass directions** are given in the guide as degrees W or E of either N or S. For example, N50°E is 50 degrees east of north.

7. **Geologic symbols** on the maps are used to convey information; for example, on the maps here, the blue lines are faults. Symbols at stops on the tour are explained, but a complete description of all rock units and a listing of symbols on the map are given in map explanations at: https://sites.tufts.edu/fellsgeology/

8. The maps in the guide present detailed mapping of the Fells and introduce new formation names. It is an ongoing research project. Things will likely change with more field work and age determinations. Updates of the bedrock map, its explanation, and associated surficial geologic map and tours will be posted as they occur. We welcome feedback at: https://sites.tufts.edu/fellsgeology/.

Virginia Wood (Crystal Spring) and Spot Pond Historic Trails in the Middlesex Fells Reservation version: January 14, 2024

Part 2: Virginia Wood and South of Ravine Road

Tufts UNIVERSITY

(Total distance: about 2 miles (~3 km) round trip.)

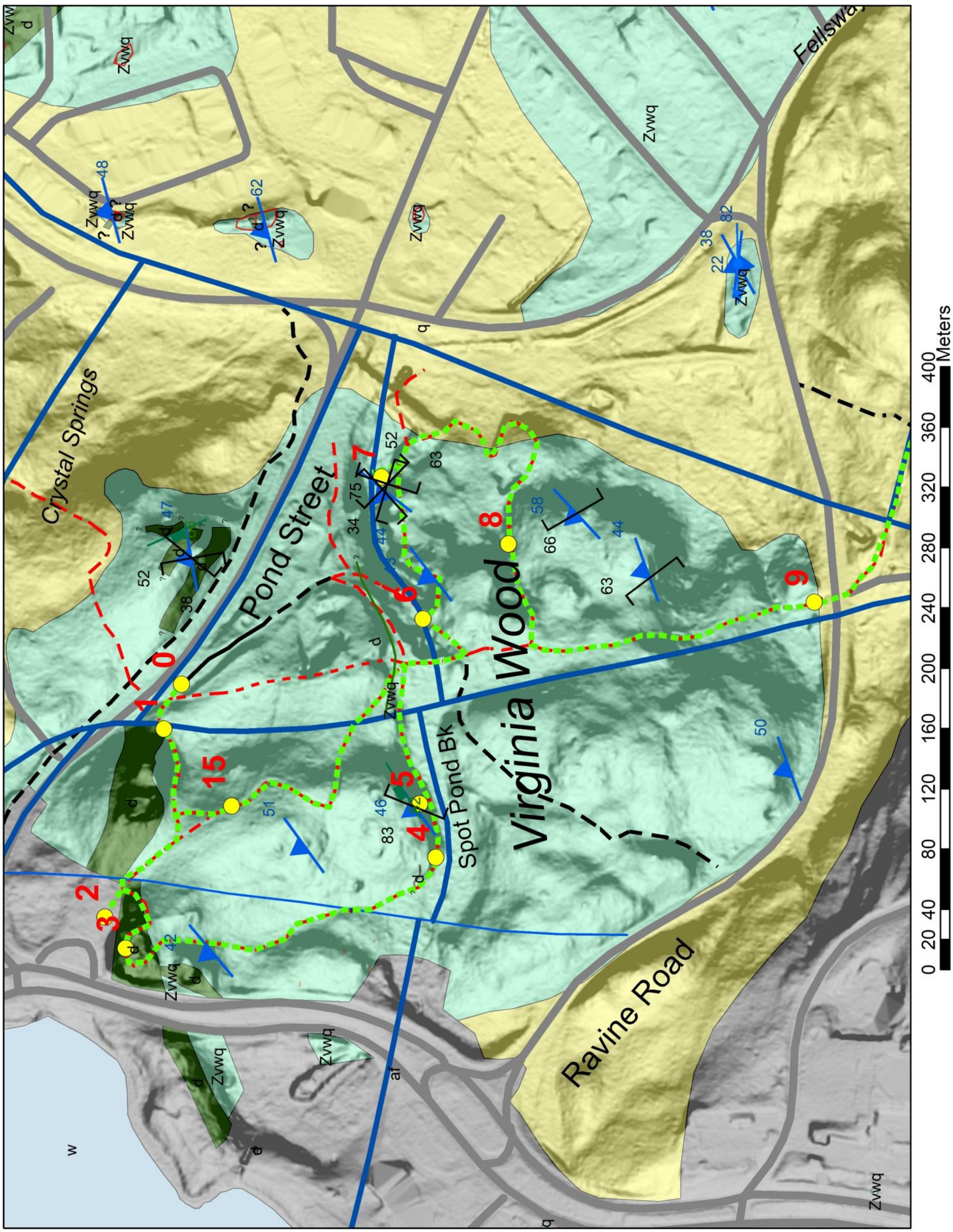
Prepared by Jack Ridge, Professor, Dept. of Earth and Climate Sciences, Tufts University

This trip focuses on the Neoproterozoic metasedimentary rocks of the Westboro Formation and the Lynn Volcanic Complex (Boojum Rock Tuff) as well as younger dolerite dikes and glacial deposits. The Neoproterozoic Era was 1000-541 million years ago. This tour will also point out some major faults and discuss the geology's importance to the historic development of the area.

Starting point: Parking Area at Gate no. 42 on the section of Pond Street heading east away from Spot Pond (see Map VW-1, Stop 0). Note: Alternate parking is at Stop 2 on Woodland Road. Head west from the west end of the Pond Street parking area on the Virginia Wood Trail (red trail markers). This trail is included with the Crystal Springs Trail on the DCR trail map. Follow the trail on the geologic maps as you go. On the geologic maps, stops on the tour are marked by yellow circles with red numbers. Follow the red and yellow trail markers in the field and dashed lime green path on the maps. Some parts of the tour will follow the yellow trail markers of the Spot Pond Historic Trail. Trail junction numbers are given that are on the DCR trail map and are marked with signs in the park. It is helpful to have a hand lens or magnifying glass. Hope you enjoy the geology! Have fun!!

NOTE: Polished rock images are cut rock slabs photographed under water. Scale bars are in centimeters. In pictures of rock surfaces there is often a camera lens cap, pencil, or rock hammer for scale.

Map VW-1


N
Crystal Springs
Pond Street
Virginia Wood
Spot Pond Bk
Ravine Road
Fellsway
Zvwq
Meters
0 20 40 80 120 160 200 240 280 320 360 400

To make this a looping tour that does not frequently repeat itself, the guide will take advantage of segments of both the Virginia Wood Trail (red trail markers) and the Spot Pond Historic Trail (yellow markers). Note that the Virginia Wood Trail may be marked as the Crystal Spring Trail on new trail markers in the park.

STOP 1: A short distance out of the parking lot (stop 0) you will see a steep hill to the west that is a wide, E-W trending dolerite dike (image below left in early spring). A dike is an intrusion of magma that filled a fracture. Dolerite is an igneous rock of intermediate grain size made of mafic (dark-colored) minerals and plagioclase feldspar. Dolerite dikes are common across the Fells. Usually, dolerite dikes contain the mafic minerals pyroxene and magnetite. Pyroxene may be partly altered to chlorite and amphibole, both of which make the rock green. The high iron content of the rock gives it a dark color on fresh surfaces, as is easily seen on the cut rock sample (image below right) while outcrop surfaces tend to be rusty due to oxidation of iron. The faintly purple grains below are pyroxene that are partly altered to chlorite and amphibole (both green). Gray grains are plagioclase. The dolerite here is highly fractured because of two different faults that displace it. A major E-W fault occurs on the north (far) side of the dike along Pond Street, and a major N-S fault cuts it off on its east end at the parking lot, displacing segments of the dike almost 500 m. Its other half is north of here on Saddleback Hill. Continue up the trail past the south side of the dike where you will see a plaque mounted on the side of the dike dedicated to Virginia Tudor, for whom Virginia Wood is named.

Continue uphill past the dike on the Historic Trail. At junction F3-1, continue straight ahead, following the Spot Pond Historic Trail (yellow markers) to the parking area on Woodland Road near its intersection with Pond Street.

STOP 2: The trail crosses a gap in the dolerite dike where it is displaced by a small N-S trending fault. You will notice that the west end of the dike segment from Stop 1 is highly fractured. Along the parking lot, the north side of a displaced dike segment (image below) has beautiful glacial grooves and striations from the south-southeast flow of the last glacier trying to make its way over the dike. The flow was deflected to the east and then up and over the dike. **From the parking area, head back to the Spot Pond Brook Historic Trail and then follow it west (right) to the top of the dike above the parking lot.**

STOP 3: At the top of the hill is an exposure of the relatively coarse-grained interior of the dike. The rock surface has a salt-and-pepper appearance with visible crystals up to 2 mm in length. The dike here is not as heavily fractured as the dike segment to the east at Stop 1. From the top of the hill, be on the look out for faint glacial grooves oriented at about S31°E. These grooves give a better measure of regional ice flow than the striations at Stop 2 because ice flow was deflected sharply east along the north face of the dike segment. Through the trees, there is a view of Spot Pond to the west.

From the top of the hill, head south, following the yellow trail markers between two ridges of the Westboro Formation (Zvwq). Continue south to Spot Pond Brook.

STOP 4: Spot Pond Brook follows a major E-W trending fault. At the brook, the trail heads east (left) to where you will see the first good outcrops of the Westboro Formation (Zvwq, image below left). The rock along the fault is highly fractured and iron-stained (rusty) in many places. There are also intersecting fracture sets resulting from shearing during both metamorphism and fault movement. The Westboro Formation is composed of interlayered light gray metasandstone, which is metamorphosed quartz sandstone, and dark to light gray argillite and slate (image below right), which are metamorphosed, muddy sedimentary rock called shale. The argillite and slate are compositionally the same but slate displays cleavage while argillite does not. The cleavage will show up as closely spaced, shiny break planes, though here it is poorly developed. This unit went through what is called regional metamorphism, where compression and deformation of the rock happened over a large area due to tectonic forces. The metamorphism here is relatively light, since we can still determine the original rock types and often see traces of original bedding. The minerals in this rock unit are relatively unchanged as compared to many other areas of New England, where rocks were metamorphosed at greater depths and at higher pressures.

Continue for 50 m along Spot Pond Brook.

STOP 5: In a slight cove in the rock face there is a distinct, light gray layer in the Westboro Formation (Zvwq, image to right). This layer was folded and has many fractures cutting across it. Microscopic analysis of this unit shows that it is almost entirely quartz silt and fine sand surrounded by tremolite. Tremolite is a metamorphic calcium-magnesium silicate mineral formed from minerals that originally had a high calcium and magnesium content and were low in iron. It gives the rock a creamy white color. The original rock likely contained dolomite (calcium-magnesium carbonate) and perhaps was sand and mud cemented by dolomite, likely on a continental shelf environment.

Continue to follow the brook to junction F3-2, where there is a dark gray outcrop of argillite at the foot of a bridge over Spot Pond Brook. Follow the red and yellow trail makers across the bridge and on the far side turn east (left) down the historic trail.

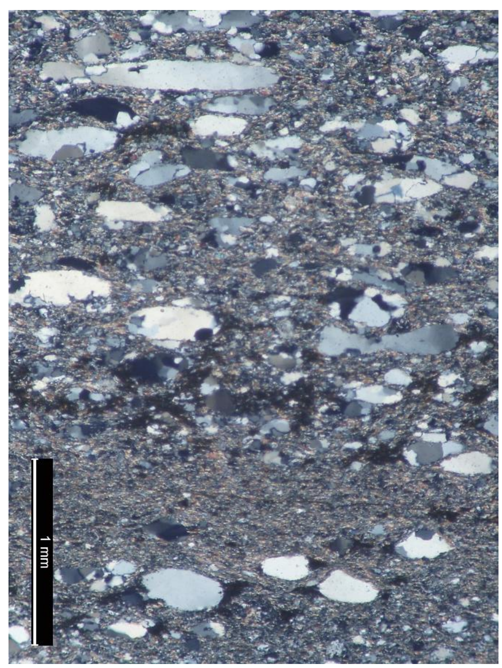
STOP 6: A short ways down the trail is a good view back to the west (upstream) of the waterfall under the bridge (image to right). This image was taken in April 2020 after heavy rains, when the brook was really flowing due to water being released from Spot Pond. A second bridge further downstream is shown in the next image below. There are a few clues along the historic trail to the industry that established itself here. It is well worth reading ***The Lost Mill Village of Middlesex Fells*** (2017, Heath, D.L. and Simcox, A.C.: History Press, Charleston, S.C., 127 p.) for the full story. See also the historical trail guide for the area: ***A Trail Guide for Virginia Wood and Haywardville in Middlesex Fells*** (2021, Alison C. Simcox and Douglas Heath: A&D Books, South Orange, NJ, 19 p.). The industrial history will not be repeated here but it is worth mentioning the geology that sparked industrial activity. All the E-W valleys running through this area occur along faults that fractured the rocks and allowed both preglacial and glacial erosion to occur. These steep valleys are critical because they allowed the passage of water eastward from Spot Pond to the lowland in Melrose and Malden. The water's drop in elevation provided the waterpower for early industry. Without the faults, there would be no water outlet to the east from Spot Pond, and the water would have escaped to the south through the Wrights Pond area instead of over the steep upland here.

In addition to the scenery, there are several exposures of the Westboro Formation (Zvwq) in this area that show evidence of the deformation and regional metamorphism experienced by the unit (images below). The rock has cleavage planes and intersecting low angle fractures that in some cases mimic bedding in sedimentary rocks. These exposures continue down beyond the second bridge.

Age of the Westboro Formation: The Westboro Formation is the oldest rock formation in the Fells and the only one that shows significant regional metamorphism. The Westboro Formation is named for exposures in Westboro, Massachusetts, where it is exposed along the Mass Pike. Maximum ages for the Westboro Formation have been determined by measuring uranium and lead isotope ratios in zircon grains in metasandstone. Zircon is a zirconium silicate mineral. The zircon crystals were originally deposited as sand grains that were derived from the erosion of older igneous rocks. The youngest ages from zircon crystals are at about 910 Ma (million years ago), so this is the oldest possible (maximum) age for the unit. In the eastern Fells, igneous units that intrude the Westboro, and volcanic units that rest on unconformities on the Westboro, all date from 609-595 Ma and are much younger. In this case the unconformities are erosion surfaces that represent a gap in the rock record and were overlain by sedimentary or volcanic rocks. In the western Fells, the Nanepashemet Formation rests on an unconformity on the Westboro Formation but the Nanepashemet is also intruded by the Winchester Granite, which is 609 Ma, and the Nanepashemet is not regionally metamorphosed. Given the extent of the Westboro's metamorphism and the length of time likely involved for this to happen prior to formation of the Nanepashemet, the Westboro is probably much older than 609 Ma.
For more on how rock ages are determined see: RockAges.
For more on unconformities see: Unconformities.

Proceed to the bottom of the Spot Pond Brook gorge. Near the bottom of the gorge, you will find a short, unmarked trail that makes its way over to the stream. At this spot is a great view of the stream valley (image below on upper left, view up valley to west). You are at the upstream end of an old mill pond.

STOP 7: This valley has a fault that runs right down the center of the valley and displaces rock units exposed on opposite sides. Exposed on the south (near) side of the valley is very hard, stretched metasandstone (image below on lower left). This rock is easily recognized by its very flat fractures that break the rock up into blocks. Quartz grains in this rock are severely flattened and stretched (microscope image below on right), as well as lined up parallel to the discontinuous layering seen in the outcrop. Some of the quartz grains have started to recrystallize into separate, smaller quartz crystals giving them a patchy appearance. The quartz grains are surrounded by very fine, elongate grains of tremolite that are must abundant in the creamy white streaks seen on the outcrop. Darker areas in the rock have chlorite.



From the brook, head back to the trail. The trail winds around in the lowland at the bottom of Spot Pond Brook through a series of foundation ruins from the factory buildings and mill ponds that were once here. As the trail starts to head west again (back upslope) it arrives at a steep slope, or escarpment, marking the very eroded eastern side of a fault. The eroded escarpment is composed of the Westboro Formation (Zvwq).

STOP 8: The steep escarpment, or sudden break in slope (image to right), is the badly eroded west side of a N-S trending fault zone marking the eastern edge of the Fells from here to further south in Malden. (See Part 2 of the Rock Circuit Tour.) A fault zone is a zone of small branching faults that make up an area of displacement instead of a single fault plane. The fault zone continues north past Crystal Springs, paralleling the Lynn Fells Parkway into Melrose. Areas just to the east in the lowland are underlain by the Westboro Formation and there is considerable displacement along the N-S trending fault zone. The fault zone is approximately located on the map along the edge of the Fells because it lies beneath a cover of glacial deposits in the valley. Without rock exposures in the valley, where glacial sediment is thick, it is difficult to precisely map the fault.

Follow the historic trail up the escarpment and back to the Virginia Wood Trail at junction F3-4. Head south (left) following the red markers to Ravine Road. At the base of a small escarpment to the west (right) that parallels the trail is the major N-S trending fault discussed at Stop 1.

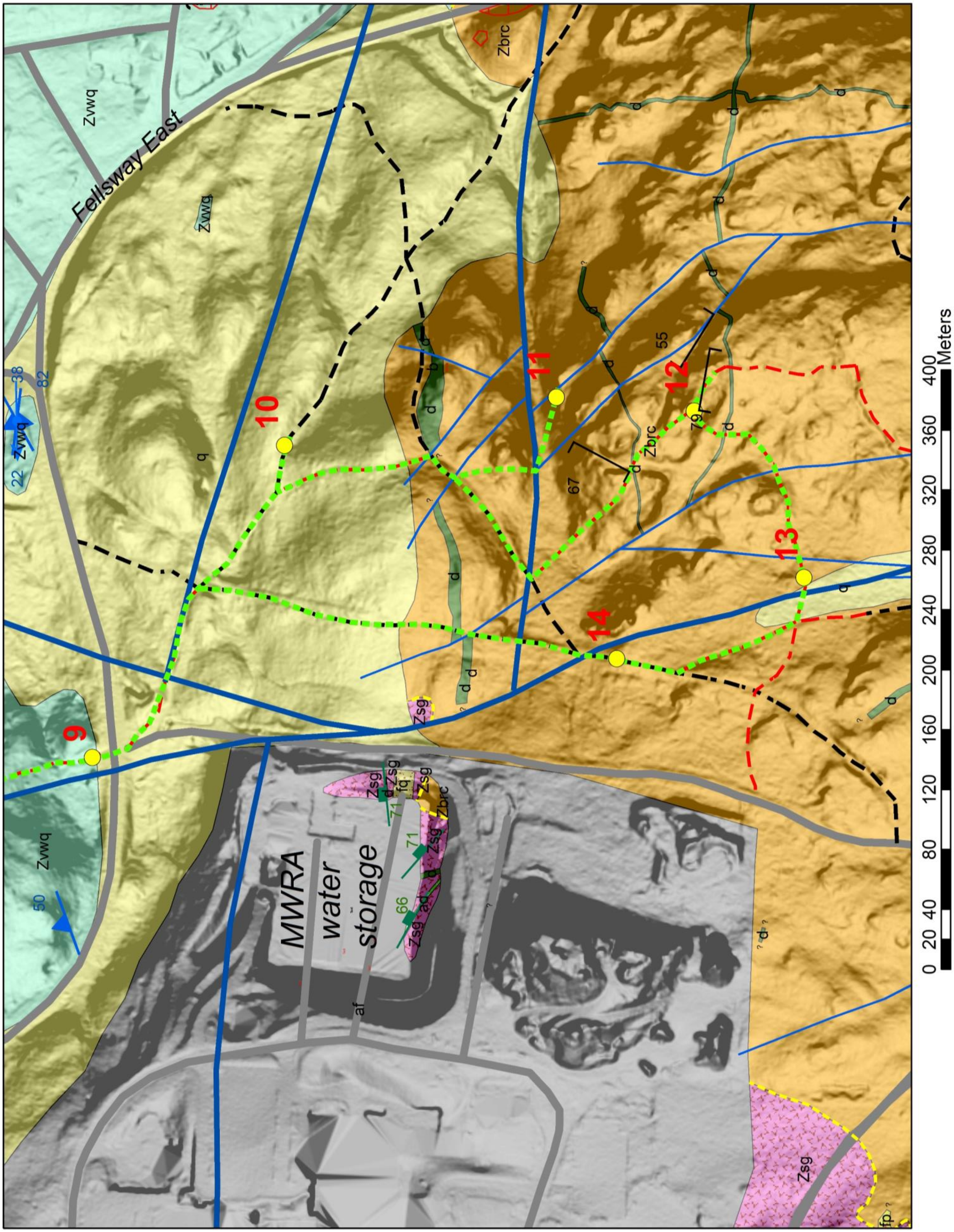
STOP 9: Before arriving at Ravine Road is a stream valley. This valley carries far less water than Spot Pond Brook and is usually dry. The threshold (divide) between this valley and Spot Pond is relatively high, meaning that Spot Pond cannot overflow here. Water has also not been artificially diverted from Spot Pond to this valley as it has at Spot Pond Brook. Some water comes from Spot Pond, but only by slow groundwater seepage along bedrock fractures associated with a major E-W trending fault in this valley. The exact position of the fault in this valley is not precisely known because it is covered by thick glacial sediment. It likely lies beneath the thick glacial deposits on the south (far) side of Ravine Road as shown on Map VW-2. The main hypothesis right now is that the fault separates the Westboro Formation (Zvwq) to the north from the Boojum Rock Tuff (Zbrc) and coarse igneous rock of the Spot Pond Granodiorite (Zsg) to the south. The volcanic rocks and granodiorite are exposed in the woods east of Pipeline Road and were exposed during excavation in 2013 for the MWRA water storage facility west of Pipeline Road (see exposures shown on map VW-2).

Continue the Tour on Map VW-2

After crossing the stream valley and carefully crossing Ravine Road (traffic is heavy!) at Gate no. 39 to Pipeline Road, you will see the new MWRA water storage facility on the hill to the southwest (above to right). Take Pine Grove Path (red trail markers) east (left) through a wooded area. Pine Grove Path crosses Melrose Path at junction F3-7. Stay on Pine Grove Path past Melrose Path.

Map VW-2

N


Fellsway East
Zvwq
Zbrc
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MWRA water storage
af
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9
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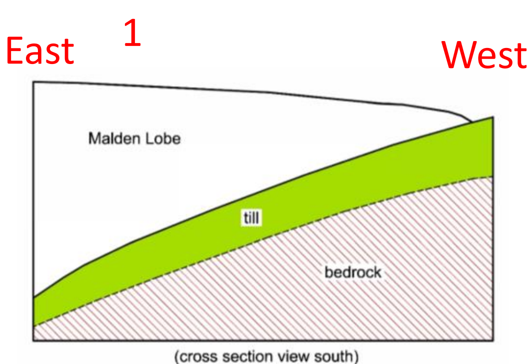
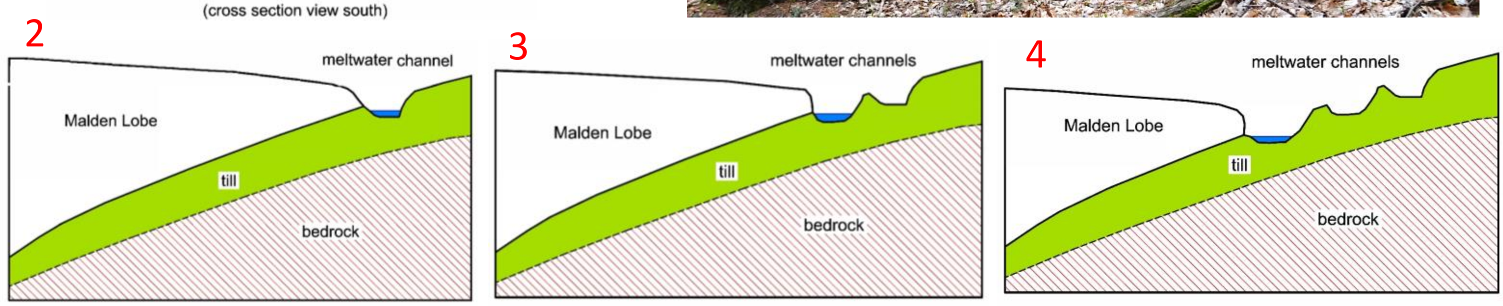
0 20 40 80 120 160 200 240 280 320 360 400 Meters

STOP 10: After crossing Melrose Path, you will see a prominent mound in the woods to the north (left), which is best viewed from late fall to early spring when there are fewer leaves on the trees. This mound runs parallel to Ravine Road and is composed of glacial sediment. Between the mound and Pine Grove Path is a glacial meltwater channel decreasing in elevation from west to east (away from Spot Pond). At junction F3-8, the trail leaves Pine Grove Path and heads up a steep hill to the south. Before ascending the hill, take a short trip (about 50 m) further along Pine Grove Path, which is in a meltwater channel (image below right, view from trail above). There are a series of channels like this separated by mounds of till between Pine Grove Path and Ravine Road. Till is sediment laid down at the base of a glacier. There are no bedrock exposures in this area because the till is very thick. As the last glacier receded about 17,000 yr ago, it formed a large, southward-flowing lobe of ice in the valley of Melrose and Malden to the east. Along the west side of the Malden Lobe, meltwater was escaping from the glacier and from the Spot Pond basin to the west. As this meltwater discharge flowed eastward along the edge of the glacier, it dissected the till, cutting channels and leaving behind linear mounds of till (diagram below showing channels developing in 4 steps in an east-west cross section viewed from the north). Several channels were cut in succession as the margin of the glacier receded eastward and to lower elevations, each time guiding meltwater along the edge of the glacier and cutting a new, lower channel. Landforms of this type are not uncommon in New England but require a thick blanket of till, which is scarce in the Fells.





After viewing the channel, head back to junction F3-8 and ascend the hill up a steep till surface. While ascending the hill you can view the meltwater channel below at the last stop. The hillslope is till covered and has no outcrops until you arrive at the very top. At the first trail junction turn right (southwest) and then, in 20 m at junction F3-9, turn south (left) on a small trail at a bald bedrock knob.

STOP 11: This knob is the first visible outcrop of the Boojum Rock Tuff (Zbrc) in the Lynn Volcanic Complex. This volcanic rock is very hard and usually forms good outcrops. It will be examined more fully at a future stop. Follow the small trail around the west (right) side of the mound and down into a stream valley. This valley is the location of another major E-W trending fault and likely served as a significant glacial meltwater outlet. Follow the trail across the stream and up the south side of the valley. After about 40 m is a good view of the steep valley side and path of the fault below (image to right in early spring). Note the large, angular blocks of rock that have fallen from the heavily fractured south valley wall. This type of deposit is called talus.

From the valley side vantage point, head back to the Virginia Wood Trail (red markers) and head west (left). At junction F4-3, turn left (southeast) up a steep face of the Boojum Rock Tuff (Zbrc). The Virginia Wood Trail ends at junction F4-4, where it links with the Rock Circuit Trail (white trail markers). The precise end of the Virginia Wood Trail is marked on the rock surface.

STOP 12: This stop (junction F4-4) is also Stop 19 on Part 2 of the Rock Circuit Trail tour. Scattered across the top of the bench about 15 m before the end of the Virginia Wood Trail are remnant orange (iron)–stained and polished striation surfaces. The striations are oriented at S55°E and record ice flow deflected eastward as the glacier slid up and around the steep slope (image to right). Across the hilltop striations are oriented S30°E.

The rock here is the Boojum Rock Tuff (Zbrc, image below right) in the Lynn Volcanic Complex, which makes up the southeastern corner of the Fells. This is volcanic unit is pyroclastic, meaning it was ejected into the air prior to accumulating upon landing. Pyroclastic units can have 4 components in them: 1) ash, or fine, broken glass shards, that may have still been molten when they landed; 2) crystals which are mineral grains that had started to crystallize in the magma prior to eruption; 3) large pieces of glass and pumice (bubbly glass), which may still have been molten when they landed; and 4) lithic fragments, which are fragments of pre-existing rock, either from prior volcanic eruptions or any older rocks through which the magma passed in the subsurface. The rocks exposed here are welded crystal tuff. Tuff is any pyroclastic rock with ash in it. The term welded refers to the fact that the ash and glass/pumice fragments were at least partly molten (liquid), allowing them to adhere to each other when they landed. The tuff here has abundant crystals, which occur as small (up to 2 mm) white plagioclase feldspar grains that are often broken (image above). This unit is noteworthy among volcanic rock units in the Fells because it lacks quartz crystals and has a very consistent composition over its large outcrop area. In an outcrop, you may see occasional small lithic fragments, but you will not see glassy materials for two reasons: the glassy ash particles are too small to see without a microscope, and glass that remains at high temperatures after it solidifies will slowly convert to a crystalline solid composed of very fine-grained quartz and feldspar. This change of hardened glass to a crystalline material is called devitrification and this material gives the rock its overall greenish-gray color on fresh surfaces. The larger glass and pumice fragments are up to 5 mm and were soft when they landed. As a result, they were flattened under the weight of accumulating material above before they hardened and devitrified. The flattened fragments, best seen in a microscope, blend in with surrounding devitrified ash.

An additional feature at this stop is the pistachio green-colored mineral epidote that coats fracture planes, especially in the last 10 m leading up to the end of the Crystal Springs Trail (image to right). Epidote is a calcium-rich aluminosilicate mineral that commonly forms by precipitation from hydrothermal (hot water) solutions that circulated along fractures. Epidote coated fractures are common across the entire Fells.

From this stop, the tour loops back to Ravine Road by way of the Rock Circuit Trail (white markers). From Stop 12 head west (right from Virginia Wood Trail) on the Rock Circuit Trail down a steep slope into a valley. The trail goes through an area of heavily fractured and faulted rock in the crystal tuff, with deep linear hollows and isolated knobs covered by angular rock debris. The trail continues west, crossing a wood walkway.

STOP 13: Shortly after the wood walkway, there was a tree throw in 2020 (image to right). A tree throw occurs where a tree has toppled and uprooted the soil beneath it. I am uncertain as to how long this feature will last because the dead tree will decay. The pine trees in this forest are very susceptible to wind damage like this because of their height and because the soils here are very wet and do not allow roots to penetrate deeply. Tree throws are an important mechanism behind long term soil erosion in this area, especially on steeper slopes. You will likely see tree throws and evidence of old ones in several places in this forest.

Continuing west, the trail crosses an unmarked trail. Take this unmarked trail northwest (right) to join Melrose Path. Head north (to right) on Melrose Path for about 50 m.

STOP 14: Melrose Path passes a rock exposure in the trail as well as a large, linear outcrop of the Boojum Rock Tuff (Zbrc) in the woods to the east (right) that looks like a whale (image to right). Shortly after this outcrop, Melrose Path goes by another path (unnamed) on the right where the major fault we saw at Stop 11 crosses to the west. On both sides of the fault are exposures of the Boojum Rock Tuff (Zbrc).

Continue north downhill on Melrose Path. In about 100 m, all outcrops disappear as Melrose Path gets steeper and crosses thick glacial sediment. Continue down to Pine Grove Path at junction F3-7. Take Pine Grove Path (red markers) to the west (left) to Pipeline Road and head north (right) across Ravine Road. Follow the trail north to Spot Pond Brook and cross the bridge. On the far side of the bridge follow the red trail markers up the hill to the northwest (up to the left – not straight!). At the top of the hill, the trail turns to the north (right) and will eventually overlook a valley below to the east .

STOP 15: Just before junction F3-1, the trail overlooks a valley and pond (in the spring) to the east (right). A major N-S trending fault runs along the bottom of the slope below and beneath the pond. This fault was also seen between Stops 8 and 9 while walking over to Ravine Road. The N-S trending fault, like others of this orientation across the Fells, crosscuts and displaces the E-W trending faults. This means that the N-S faults are younger than the E-W trending faults. If you look at the geologic maps for this tour and the Crystal Springs Trail north of Pond Street (Part 1), you can see that the N-S trending fault has been traced for a long distance. This fault also displaces large, E-W trending dolerite dikes like the one near the parking area, meaning that the N-S faults are also younger than the dikes.

At junction F3-1, turn east (right) and head downslope to the parking area on Pond Street. You will see the Virginia Tudor plaque and pass Stop 1 from earlier in the tour.

END OF TOUR