

Self-Guided Geologic Tour of the Skyline Trail in the Middlesex Fells Reservation (Part 1)

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:

1. The tour of the Skyline Trail has been broken into seven parts. You should not try to do the whole tour in one day (~7 miles or 11 km). It is a lot of hiking and a lot to comprehend in one dose. It's recommended that you do parts of the tour in order, moving counterclockwise around the park. Each tour and its stops are marked on the geologic maps with each part. 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 at Bellevue Pond, 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 (SiO₂) 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/>.

Skyline Trail in the Middlesex Fells Reservation version: January 10, 2024

Part 1: From Bellevue Pond across Pine and Little Pine Hills to Red Cross Path

Total distance: 1 mile (1.6 km) to last stop of tour + 0.7 miles (1.1 km) return hike = 1.7 miles (2.7 km)

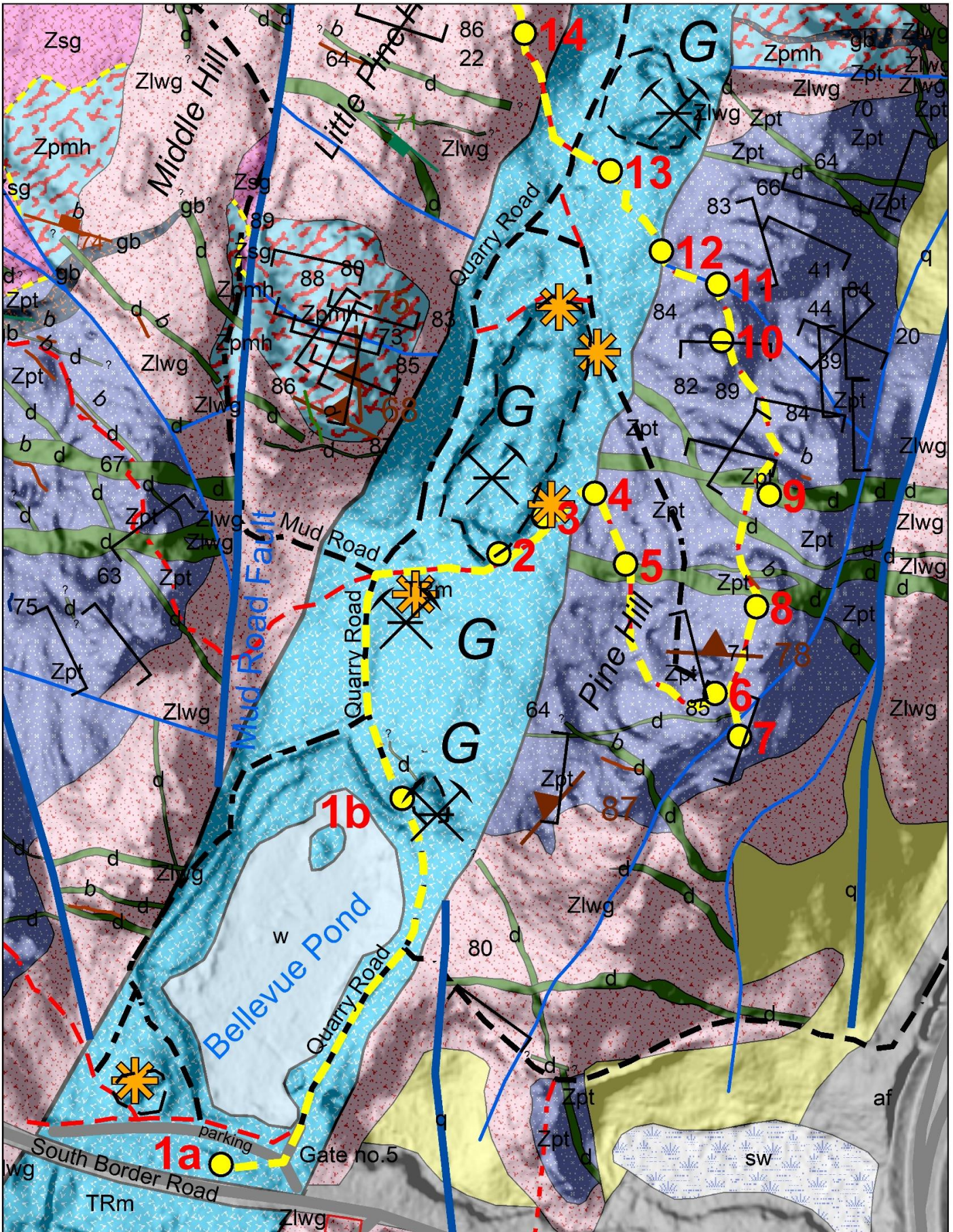
Prepared by Jack Ridge, Professor, Dept. of Earth and Climate Sciences, Tufts University



Starting point: Bellevue Pond parking lot (DCR gate no. 5) on South Border Road at southern end of Pine Hill in Medford (**Stop 1a on Map SKY-1A**). Follow the trail on the geologic maps as you go. Stops on the tour are yellow circles with red numbers. In the guide, trail junction numbers are given that are on the official DCR trail map and marked with signs in the park. Follow the white trail markers in the field and dashed yellow path on the maps. Having a hand lens or magnifying glass can be helpful. Have fun!! I hope you enjoy it!

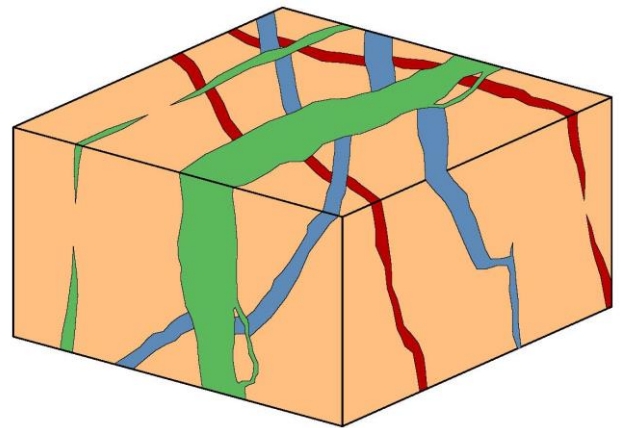
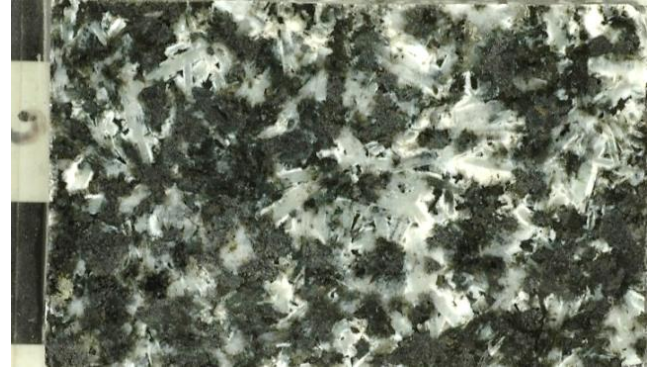
This trip focuses on Neoproterozoic volcanic rocks from the Pine Hill to Middle Hill area and intrusive igneous rocks of the Lawrence Woods Granophyre and Spot Pond Granodiorite. The Neoproterozoic Era was 1000 to 541 Ma (million years ago). You see some younger (Paleozoic, 541-252 Ma) dolerite dikes and the Medford Dike from the Triassic Period (238 Ma). The trip will also point out some glacial features from the last ice age.

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.



0 15 30 60 90 120 150 180 210 240 270 300 Meters

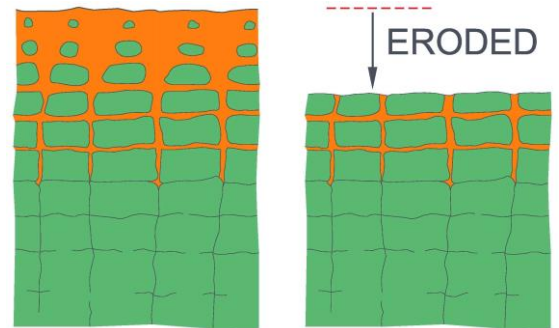
STOP 1a: On the strip of land between the parking lot and South Border Road are boulder-like outcrops (image to right) of the Medford Dike (T_{Rm}). The dike is gabbro, which is a coarse-grained igneous rock composed of mostly mafic minerals. An igneous rock is formed from cooling of molten rock or magma, coarse-grained means it has easily visible mineral grains, and mafic means dark-colored. Below on the right is a slab of gabbro cut with a rock saw to expose a non-weathered surface. Look for mineral grains in the gabbro outcrops. Most of the mafic minerals are pyroxene, and most of the light-colored minerals are plagioclase feldspar. The gabbro is an intrusion in the form of a dike, which is a body of magma that forced open a fracture and then cooled. Dikes generally have a slab-like shape when viewed in cross section (see block diagram below). However, most dikes change thickness, have irregular sides, and sometimes make bends, or pinch out to a point. **Something to remember regarding relative ages of rock units: intrusions, dikes included, are younger than the rocks they intrude. Where dikes cross, the younger dike always crosscuts (or splits) the older dike.** The block diagram shows 3 ages of dikes with different colors and demonstrates cross-cutting relationships. The red dikes are the oldest and the green dikes are the youngest. The Medford Dike formed at great depth back in the Triassic (T_{Rm}) Period (238 Ma), just after the first dinosaurs roamed the land surface. (Note: Ma = mega-annum or millions of years ago.) The age for this rock unit was determined by analysis of uranium and lead isotope ratios on zircon crystals separated from the rock. For more on how rock ages are determined: [RockAges](#). The dike is now exposed at the land surface after erosion removed many kilometers of rock above. At Bellevue Pond, the dike is about 120 m wide, trends NNE to SSW on the map, and gets thinner to the north where it ends near Wrights Pond. The Medford Dike can be traced southward to Lawrence Memorial Hospital, Governors Avenue, the CVS Pharmacy parking lot on High Street, across the Mystic River to the Tufts campus, and into Somerville, where it is exposed at Powder House Square. The Medford Dike easily weathers and erodes (see Stop 2). As a result, it forms the valley of Bellevue Pond.



Head north on Quarry Rd. (from east end of parking lot) to the Skyline Trail. You will see more gabbro outcrops in the road and near the wall at the northeast corner of Bellevue Pond (Stop 1b on Map SKY-1A). Head east (right) on the Skyline Trail at junction D6-2 north of the pond opposite where Mud Road descends from the west.

STOP 2: North of the trail is one of the abandoned quarries in the Medford Dike (T_{Rm}). Gabbro was quarried beginning in the early 1800's for building stone, monuments, and hitching posts that can still be found in downtown Medford. The quarry wall shows deep weathering, which is the natural chemical and physical breakdown of rock exposed to surface conditions such as atmospheric pressures and temperatures, water, oxygen, and acids in rain and soils. Weathering of the gabbro occurred along fractures, which isolated, round non-weathered boulders called corestones (diagram to right, isolated green blocks).

Between the corestones is a crumbly material called grus (orange on diagram), the product of the granular disintegration of the rock where mineral grains separate from each other. Both grus and corestones were partly eroded, especially during glaciation. Erosion is the removal of weathered material. The orange, star-like symbols on the map indicate areas where evidence of preglacial weathering (grus and corestones) in the gabbro is exposed.



STOP 3: Just beyond the view into the quarry, and before the trail makes a bend to the right (south), is a flat-topped ledge of gabbro along the north (left) side of the trail (image to right). The flat surface, which was created by glacial erosion (abrasion) during the last ice age or glaciation, truncates corestones and weathered fractures. During the last ice age this area was covered by as much as 1500 m of glacial ice that slid across the area from about 35-17 ka (kilo-annum or 1000s of years ago). The truncation of corestones shows that the rock was weathered prior to glacial erosion. If the light is right, you may see faintly preserved glacial grooves trending S20°E (parallel to hammer on image). The grooves were visible in 2021, but they may soon disappear as the partly weathered rock surface erodes along the trail. Look for crumbly weathered gabbro in the area.



STOP 4: Climbing the west side of Pine Hill, you'll cross the contact between the Medford Dike (T_{Rm}) to the west (below) and the Lynn Volcanic Complex (Zpt) to the east (above). In this case, the volcanic rock is felsite, a name for any fine-grained, light-colored, igneous rock. The contact, which angles downslope to the south (image to right, view up trail), is south of the trail just before the trail bends sharply to the right. The trail steepens as it heads onto volcanic rock that is more resistant to erosion. We'll learn more about the Lynn Volcanic Complex at the top of Pine Hill.

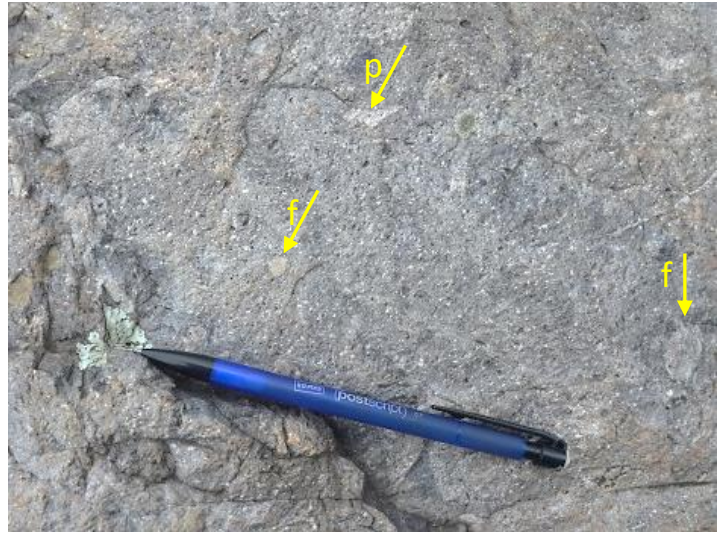


STOP 5: After the trail bends south (right), an E-W trending dolerite dike (d) cuts through the Lynn Volcanic Complex (Zpt) and crosses the trail. The dike is about 6-8 m wide at this location (image below to left shows the north contact of the dike and adjacent volcanic rock), and we will cross over it again at the top of Pine Hill. Dolerite is a mafic igneous rock compositionally like gabbro (Stop 1), but with sand-sized mineral grains. This is considered an intermediate grain size between coarse and fine grains. A fine-grained rock of this composition is called basalt. The lower right image (scale in cm) is a piece of dolerite cut on a rock saw, to expose a smooth, non-weathered surface. The dark, faintly purplish-green to dark green mineral grains are pyroxene and the small, light gray, blade-like mineral grains are plagioclase. Pyroxene is the mafic mineral in the rock, and it is more abundant than plagioclase. In some places the pyroxene is partly altered to dark green chlorite and amphibole. When this rock weathers, oxidation of iron forms a rusty surface. The dike shown here heads downslope, where it is crosscut by the Medford Dike. On Map 1A and throughout the Fells, dolerite dikes are common, and we know they have several different ages by the way they crosscut each other.

Continue to the top of Pine Hill and Wrights Tower.



STOP 6: At the right side of the stairway leading into Wrights Tower are outcrops of the Lynn Volcanic Complex (Zpt), which weathers to light gray. The whole top of Pine Hill is made of this unit, except for some dolerite dikes (d). The felsite here is pyroclastic, meaning it was ejected into the atmosphere during a volcanic eruption, and fell through the air to pile up on the land surface. Pyroclastic rocks have four components: 1) fine glass particles or ash; 2) molten blobs or solid blocks of glassy lava, which when bubbly are pumice; 3) crystals that had started to form in the magma prior to the eruption; and 4) pieces of rock ripped up by the erupting magma called lithic fragments. Lithic fragments can be volcanic rocks from earlier eruptions during the same period of volcanism, or they can be fragments from any older rock unit encountered by the erupting magma in the subsurface. Pyroclastic rocks made of ash with any of the other three components are known as tuff, which is what occurs here on Pine Hill. In the closeup view at the steps to the tower (image above), you can see plagioclase crystals (tiny white specks), scattered lithic fragments (f, occasional round to angular clasts) that are mostly volcanic, but also include metasandstone (more on the metasandstone later), and pumice fragments (p, pinched light gray splotches). This is where a hand lens or magnifying glass can be helpful.



STOP 7: Adjacent to Wrights Tower is an opening onto a rock bench where there is a spectacular view of the Boston skyline (top panorama below). Boston is lower than the Fells because it is underlain by more easily eroded sedimentary rocks. Looking east across Rt. 93, you can see North Medford. Looking southeast, you can see the ocean and the Mystic Tobin Bridge, and to the south is downtown Boston. Further west in the foreground is Tufts University (lower panorama below), and just west of the Back Bay skyline on the horizon is the Blue Hills in Randolph. The images were collected in October 2013.

Continue north on the trail to the far end of the open area (dirt parking lot) opposite Wrights Tower.



STOP 8: Crossing the trail on a low hillcrest is a large dolerite dike (d) seen earlier (Stop 5) that cuts through the Lynn Volcanic Complex (Zpt). The dike looks like two separate dikes because it has a large, elongate inclusion of gray tuff in it. The dike looks like two separate dikes because it has a large, elongate inclusion of gray tuff in it. The surface of the dike is smoother and has a rustier color than the more fractured felsite. The image on the right, looking north on the trail, indicates the position of the volcanic rock (v) in the dike (d). The block of volcanic rock represents an inclusion or xenolith, which is a piece of pre-existing rock that broke off into the magma and got trapped when the dike crystallized. Something to remember when determining the relative ages of rock units: ***Inclusions are always older than the surrounding igneous rock.*** Before continuing, look for the geodetic survey markers (bronze plates) mounted in the dike (see inset to right above) and on the trail. These markers are used for surveying changes in sea level and land surface elevation with millimeter resolution.



Looking back to the south from the center of the dike (image to right, at lower 'd' on previous image) you can see faintly preserved glacial grooves (parallel to rock hammer). The grooves indicate the flow direction (S30°E) of glacial ice as it slid across the rock surface during the last ice age. This is similar to the ice flow direction seen earlier at Stop 3, and elsewhere in the Fells.



Continue about 50 m to a small valley.

STOP 9: The valley (image to right, view east up valley) is underlain by a dolerite dike (d). The dike is exposed further east and west on the sides of Pine Hill, but in the trail area it is covered by soil and loose rocks. The dike was less resistant to erosion than the surrounding volcanic rocks, probably due to fractures, and was eroded by glacial activity to form a small valley.



Continue another 75 m to a small knob.



STOP 10: The small knob (image to left) is composed of tuff in the Lynn Volcanic Complex (Zpt). This is a great place to see the small, white plagioclase crystals (tiny white flecks) in the tuff, and if you look carefully, you may see a few lithic fragments. The black bracket-like symbols (J) on the map indicate the orientation of fractures, which are also called joints. The tic marks (small bars) on the symbol indicate the direction in which the joint plane dips into the ground, and nearby numbers indicate the degrees of the dip away from horizontal (84°). The joints here are almost vertical. **Continue 25 m to another small valley.**

STOP 11: The small valley (image to right, view northeast) is the location of a minor fault. Faults are cracks, or a series of cracks (fault zone), where rocks on opposite sides have moved relative to each other, which is also known as fault displacement. Fracturing of rock along a fault allows erosion to more easily create a valley. Sometimes, one of the hardest things to determine in the field is the direction of displacement along a fault because they are eroded. Faults like this often represent places where magmas intruded to form dikes, like at Stops 5, 8, and 9. Faults have a pattern to them, often running in parallel sets, as do the dolerite dikes.

Continue across the fault and start to descend westward into the valley below.



STOP 12: As the trail descends Pine Hill (image on right, view back up the trail to east), it again, like at Stop 4, crosses the contact of the Lynn Volcanic Complex (Zpt) and the Medford Dike (T_{Rm}). The line on the image (right) shows the position of the contact, and the letters label outcrops of the Medford Dike and Lynn Volcanic Complex. Note that the volcanic rocks form an upland because of their hardness and resistance to weathering, while the gabbro forms a valley. To the southwest (looking downhill), you can also see the road in the valley below leading up to Wrights Tower.

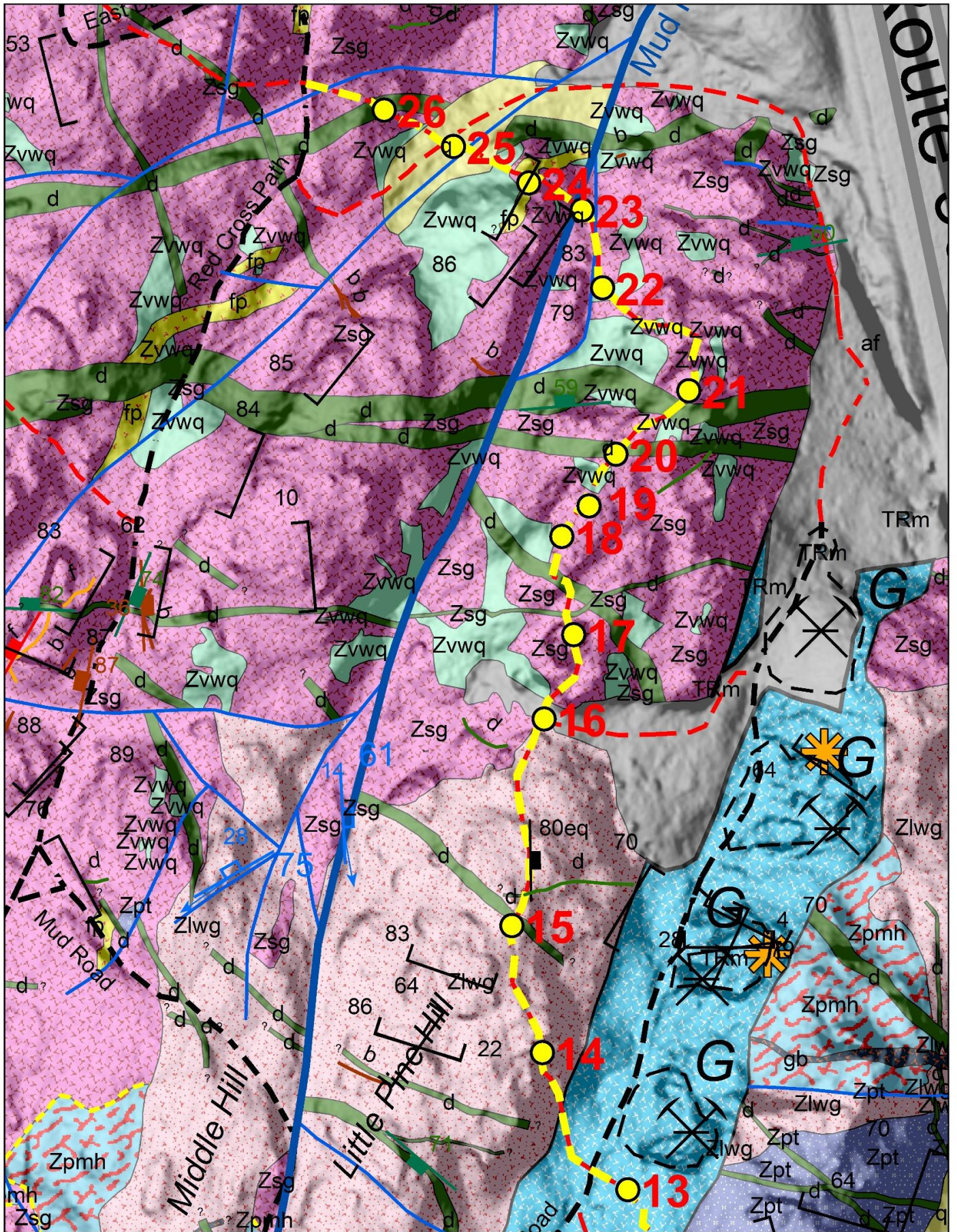
Head downhill into the lowland.



STOP 13: In the lowland just before Quarry Road is a view north or to the right (image to right taken in fall) into an abandoned quarry in the Medford Dike (T_{Rm}). The quarry wall here shows beautiful corestones and weathered seams with grus. This quarry can be observed along Quarry Road, but if you choose to enter it, make sure you have poison ivy protection.

From Stop 13, follow the tour on Map SKY-1B. Cross Quarry Road at junction D6-1 and continue west (straight ahead) on the trail uphill to the top of Little Pine Hill.

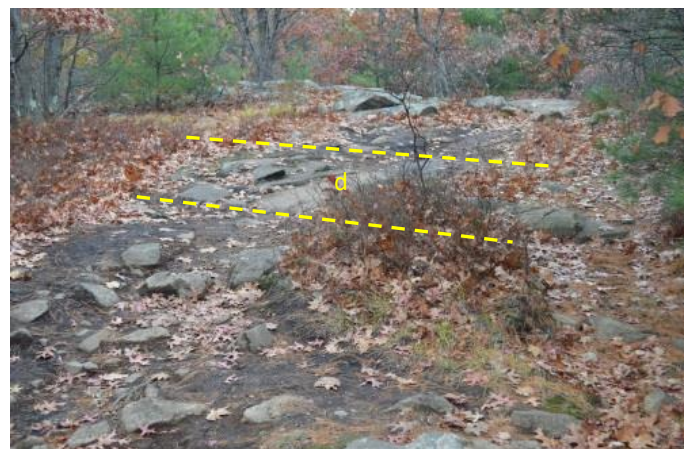
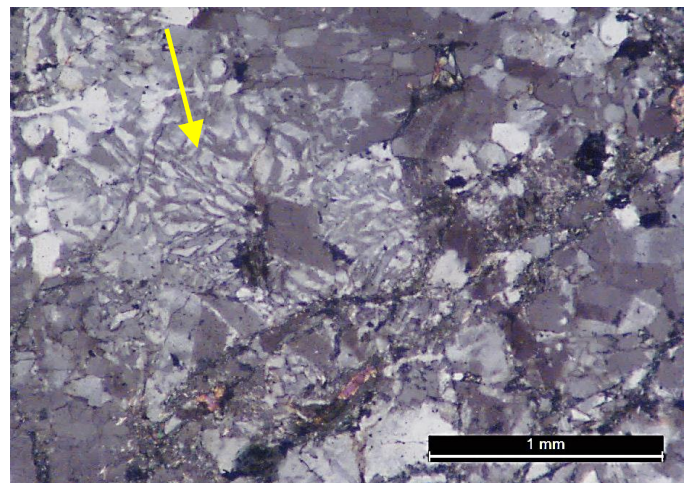
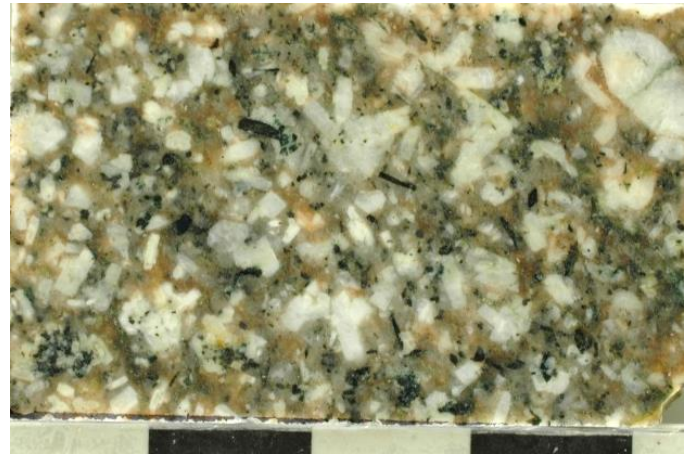




0 15 30 60 90 120 150 180 210 240 270 300 Meters

STOP 14: The steep slope of Little Pine Hill crosses from the Medford Dike (T_{Rm}) into the Lawrence Woods Granophyre (Zlwg, field image to right). The exact contact of these two units is concealed by rock debris and soil. The granophyre occurs across much of the southern Fells, from the Wrights Pond area and North Medford to Medford High School. A cut rock surface (image to right below) shows the details of this porphyritic rock formation, which has a uranium-lead age of 596 Ma (mega-annum or millions of years old). [For more on how rock ages are determined: RockAges](#). A granophyre is an igneous rock of granitic composition that has a granophyric texture. Porphyritic means a rock has minerals with two different grain sizes (porphyry), one coarse set forming phenocrysts (here, the white mineral, which is plagioclase), and finer minerals that make up the surrounding ground mass (pinkish orange to gray areas). A granite is a coarse-grained igneous rock with its light-colored minerals composed of 20-60% quartz and two different feldspars, plagioclase and alkali feldspar, that are about equal in abundance. Because the magma did not cool slow enough, the alkali feldspar did not have a chance to fully crystallize as isolated crystals. Instead, it formed rapidly at the same time as quartz, creating a situation where the two minerals are microscopically intergrown as the granophyric texture mentioned above (striped areas in microscope view below to right at arrow). Granophyric alkali feldspar and quartz are responsible for the pinkish-orange to gray color you see in the rock. Here, almost the whole ground mass (fine part) of the rock is granophyric. The rock also has a mafic (dark) mineral that appears as small rods, which is an amphibole called hornblende (see cut rock image). It is difficult to see all this in an outcrop in the field (top right image), especially because of lichens growing on the rock surface (light green patches). The plagioclase phenocrysts and the granophyric texture get finer as you approach the contacts with other rock formations. We call this finer-grained area, where the edge of the magma lost heat more rapidly, the "chill zone" or chilled margin. The whole middle section of Little Pine Hill is in a granophyric chill zone, and we may be looking at the chilled roof of an ancient magma chamber. In general, when an intrusion covers a wide area (unlike a dike) we call it a pluton. In this case, the overall fine grain size of the ground mass indicates that the rock cooled rather quickly. The magma chamber was likely near the surface, acting as a feeder for volcanic eruptions. We call this a subvolcanic pluton. At this point, a working hypothesis is that the granophyre may be associated with eruptions that produced the Lynn Volcanic Complex (Stops 6 and 10). [For more on how plutons form: Plutons](#).

STOP 15: A little ways (~25 m) after arriving on the flat top of Little Pine Hill, the trail crosses two E-W trending dolerite dikes (d) cutting through the Lawrence Wood Granophyre (Zlwg). The larger dike (image to right) is easy to spot, but the second is narrower and not as easily seen. Both dikes have a smoother surface than the granophyre.



Continue to the north end of the hill where it descends into a valley that bisects Little Pine Hill and crosses the trail.

STOP 16: At the very bottom of the slope, on the last step descending into the valley (image to right, view back up trail to south), is the VERY inconspicuous contact of the Lawrence Woods Granophyre (Zlwg) and the Spot Pond Granodiorite (Zsg). The valley bottom here is covered by artificial fill, which is rock waste piled into the valley during the construction of Rt. 93. It also conceals part of the Medford Dike (T_{Rm}) along Quarry Road to the east. The fill makes it difficult to determine whether this small valley has a fault or not.



Continue north on the trail climbing a steep slope.

STOP 17: On the steep slope is Spot Pond Granodiorite (Zsg), which is a pluton that has a uranium-lead age of 609 Ma. [For more on how rock ages are determined and how plutons form: RockAges and Plutons.](#) On the knob on the west side of the trail (image on right, yellow arrow) is a good place to see the texture of the granodiorite, the coarsest igneous rock unit in the Fells. The lumpy surface has been compared to the sole of hobnailed boots, which have metal studs in them to create a tread. Granodiorite is a coarse-grained igneous rock in which the light-colored minerals are composed of 20-60% quartz and two feldspars, with plagioclase being more abundant than alkali feldspar. This gives the rock a gray, rather than pink, appearance. The composition of the Spot Pond varies somewhat from place to place, and small samples can be misleading. On a cut rock surface (image to right) alkali feldspar is pinkish-orange, plagioclase is creamy white, and quartz is light gray. On weathered surfaces, the quartz grains are more resistant to weathering than feldspar and the quartz grains give the rock its hobnailed surface. Mafic minerals are biotite (black) mica that is altered to chlorite (greenish-gray). On the trail, you may also see fine-grained, dark gray areas in the granodiorite (foreground of trail image above right), which are inclusions of the Westboro Formation (Zvwq, too small to show on the map). This rock formation is made partly of metasandstone, which is metamorphosed sandstone that is here rich in quartz. However, it also includes layers of dark gray argillite, which is hardened, lightly metamorphosed siltstone and shale. Baking of argillite inclusions in magma, much like firing pottery in a kiln, produces a hard, brittle rock called hornfels. As the trail steeply descends the north side of the small knob shown on the image above, look for dolerite dikes (d) at the base of the slope.



After crossing a small valley at junction D5-6, the trail rises onto a smooth hill of granodiorite.

STOP 18: On the smooth slope the trail angles upward across a smooth bare slope (image below on left) on the Spot Pond Granodiorite (Zsg). Smooth surfaces like this are common on the granodiorite and are formed by glacial erosion. At the very bottom of the slope, is a contact with a large inclusion of the Westboro Formation (Zvwq) in the granodiorite. The inclusion is gray hornfels and is large enough to show on the map. On the flat top of the hill, you may also notice some linear cracks filled with fine-grained rock that is more resistant to erosion than the surrounding granodiorite (image below to right). These are quartz veins that may be derived from the melting of metasandstone in the Westboro Formation (Zvwq).

Continue up the slope to where the trail levels off.



STOP 19: On the flat top of Little Pine Hill, you will find two areas (1 and 2 on image to right, view to northeast) with small inclusions of the Westboro Formation (Zvwq) in the Spot Pond Granodiorite (Zsg). At the first location, the rock is very smooth and polished with glacial striations that record the flow of glacial ice at S28°E. This area also has a peculiar pistachio-green color, which is the mineral epidote. Epidote commonly forms because of chemical alteration of igneous rocks by later reheating events in the presence of hot (hydrothermal) groundwater, which is called hydrothermal alteration. The second area is a cluster of small inclusions that appear to have been a metasandstone block that broke apart. In both places, the metasandstone inclusions look like they were coming apart in the magma, not just physically breaking apart into smaller pieces, but melting, mixing, and chemically reacting with the granodiorite magma. This is a process known as assimilation.



Continue on the trail for another 20 m or so.

STOP 20: The trail crosses two dolerite dikes (d, image to right shows south (near) side of first dike). See if you can find the north (far) sides of the dikes exposed on the trail.

Follow the trail to the north end of the hill. About 5 m before reaching the northern summit of Little Pine Hill there will be a step in the trail.



STOP 21: At the step is a partly-assimilated Westboro Formation (Zvwq) hornfels inclusion in the Spot Pond Granodiorite (Zsg). The inclusion (image to right, pencil for scale at arrow) has a color like a dolerite dike, but it is surrounded by the granodiorite and doesn't have the same shape as a dike. It also contains abundant quartz grains that are not found in dolerite. Behind the knob on the east (right) side of the metasandstone are some more inclusions that appear as streaks in the granodiorite where the metasandstone has been assimilated. About 7-8 m before (south of) the metasandstone step at Stop 21 is a metamorphic rock boulder with dark mineral banding, unlike any rock unit in the Fells. This rock was glacially-transported from north of the Fells and is a glacial erratic, which is a glacially-transported rock that is resting on a different rock formation than the one in which it formed.



Head west (left) down the steep northern end of Little Pine Hill and past junction D5-5.

STOP 22: After junction D5-5 the trail crosses an inclusion of metasandstone in the Spot Pond Granodiorite (Zsg), left side of trail, just before descending into the head of a small valley (image below on left looking south). On the far (west) side of this small valley is a knob of Spot Pond Granodiorite (arrow). The valley is a small fault that splits away from a major fault (see Stop 23) that is on the far (west) side of the small granodiorite knob (see Map SKY-1B). We know these valleys represent faults because there are different rock types next to each other on opposite sides of the valleys. The valleys also displace dolerite dikes and Westboro inclusions in the granodiorite. The small valley is filled with rock rubble and glacial boulders.

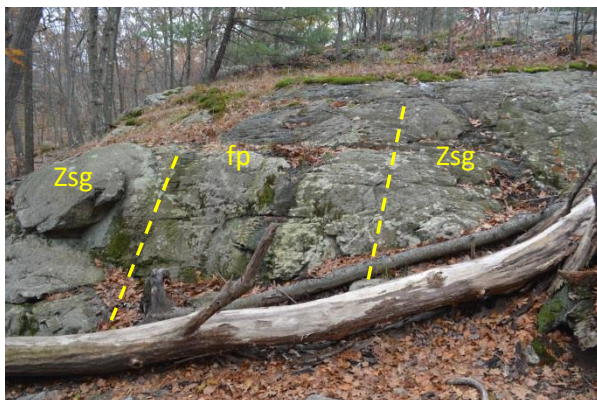
Speaking of boulders!! – If you move further down the trail another 20 m and look northeast (opposite the small knob to the south) in the distance, you will see one of the largest glacially-transported boulders in the Fells (at arrow, image below right). This Spot Pond Granodiorite (Zsg) boulder is more than 5 m on its long axis. You will likely see a trail leading over to the boulder. Boulders of this size are unusual because the rocks in the Fells are so fractured that boulders usually break out of the bedrock as smaller chunks, or they fall apart during transport. Technically, this is not a glacial erratic because it is not sitting on a different rock type than the one in which it formed. It is still impressive!



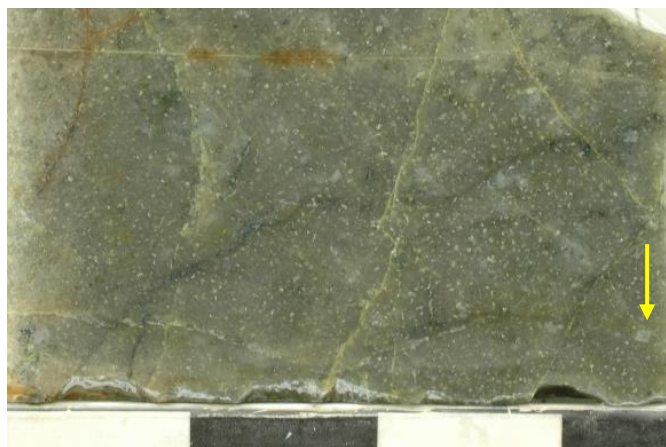
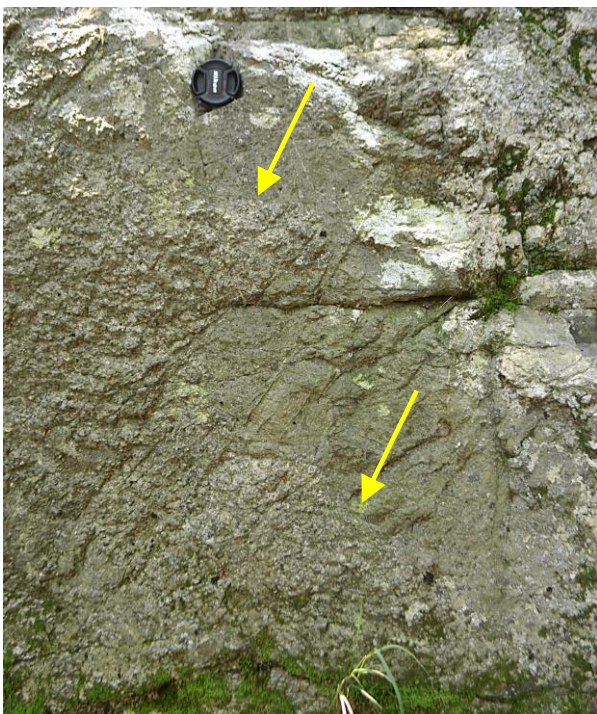
STOP 23: Moving downslope past the small granodiorite knob, the trail arrives at another small valley. Looking south (left), this is the path of a major fault in the Fells called the Mud Road Fault (image to right, line shows approximate location). A steep ledge occurs on the west (far) side of the fault, and on the east (left) is the small granodiorite knob from Stop 22 (left side of image to right). The small knob is essentially an island between two faults where the fault to the east is a small branch that split away from the larger Mud Road Fault. The Mud Road Fault is NNW-SSE trending, runs southward from here through several wetlands, and separates Middle and Little Pine Hills before it is crosscut by the Medford Dike (i.e., older than the dike). You may notice on **Map SKY-1B** that some dolerite dikes (d) to the south are cut off by the fault, while others seem to cross it unscathed. What does this potentially tell you about the relative ages of the dikes and faults?



STOP 24: About 25-30 m after crossing the Mud Road Fault, the trail turns west (left) around the end of a knob, which is the steep north end of Middle Hill. Crossing the trail is a very irregular porphyritic rhyolite dike (fp) that cuts through the Spot Pond Granodiorite (Zsg, image to right, south or left side of trail). Hopefully, the log will still be there). The contacts are subtle, hard to see, and very irregular (image below right, at arrows, left or east side of dike when facing south). The contacts are not sharp or flat, like the dolerite dike contacts visited earlier, but instead seem to bleed into the surrounding granodiorite. The dike has many closely-spaced fractures that run horizontally across the rock face. Granodiorite appears to have been partly assimilated by the dike.



What is rhyolite? Rhyolite (image below) is a fine-grained igneous rock with the same chemical composition as granite. Rhyolite is a type of felsite, which is a generic name for any light-colored, fine-grained, igneous rock. The dike here may have a composition more like granodiorite, in which case, it would technically be called dacite instead of rhyolite. A chemical analysis would be needed to determine this. It is essentially formed from a granitic magma that cooled too quickly for coarse crystals to develop. There are several rhyolite dikes in the Spot Pond Granodiorite in this area that have a light gray to light reddish-gray color. The dike is porphyritic, but phenocrysts are difficult to see in the field. On the image below, the arrow points out a tiny, light gray plagioclase phenocryst. The phenocrysts tend to blend into the light gray ground mass of the rock.



The trail descends into another valley where it crosses an old dirt road.

STOP 25: There is another fault here, but not one that bisects the Fells. In case you are starting to get worried, none of the faults in the Fells are active. Here, in the floor of the valley, the bedrock surface and fault are concealed by glacial sediment from the most recent geologic period in Earth's history, called the Quaternary (last 2.6 million years). Since the map is intended to show the bedrock geology, areas where Quaternary deposits of any type cover the bedrock, so that the rock types cannot be confidently mapped, are shown with a yellow color (q) but not subdivided as to the type of surficial deposit. There is a surficial geologic map on the web site that shows a classification of these deposits.

Continue west climbing out of the valley.

STOP 26: A short distance from the dirt road, the trail crosses an E-W trending dolerite dike (d) before reaching Red Cross Path. The trail cuts across the dike (image to right).



From Stop 26, continue west on the trail about 40 m to Red Cross Path at junction C5-21. This is the starting point of Part 2 of the Skyline Trail tour.

END OF PART 1

To return to the parking lot at Bellevue Pond:

At junction C5-21, take Red Cross Path south (left). In about 200 m you will reach junction C5-25. Continue another 150-200 m on Red Cross Path to Mud Road (junction C6-4), which has a triangular trail junction. At junction C6-4, take Mud Road southeast (left) across the top of Middle Hill. When you reach the valley on the other side of the hill, the road runs to the south (right) down a steep-sided valley with the Mud Road Fault, which we saw at Stop 23, between Middle and Little Pine Hills. Note that the road here is often wet and muddy. In the winter, it forms a sea of ice because water in wetlands to the north seeps along the fault and then discharges at the road, which is lower than the wetlands. The often-wet conditions here are why it's called Mud Road. The road will bring you to Quarry Road (junction D6-2), where you started the tour on the Skyline Trail. Head south (right) on Quarry Road to the Bellevue Pond parking area.

Alternative:

If you feel more adventurous, you can start Part 2 of the tour (Red Cross Path to Sheepfold), which ends north of here at Sheepfold.

When done as a standalone tour, parking for Part 2 is at Sheepfold and you should walk south to junction C5-21 on Red Cross Path to start the tour, which will take you back to Sheepfold.

If you add Part 2 to Part 1, starting at Red Cross Path from the end of Part 1, you will have to walk back to Bellevue Pond from Sheepfold, which is about 1.5 miles (2.5 km) along easily traveled dirt roads. However, combining two tours can make for a long hike.

Here is a listing of all the rock units and features you have seen on the first segment of the Skyline Trail. For which units listed below can you determine relative ages?

dolerite dikes (d)
porphyritic rhyolite dike (fp)
Lawrence Woods Granophyre (Zlwg)
Lynn Volcanic Complex (Zpt)
Medford Dike (gabbro, (T_{Rm})
Mud Road Fault
Spot Pond Granodiorite (Zsg)
Westboro Formation (Zvwq) – as inclusions

Here is a list of the features and vocabulary for Part 1 of the Skyline Trail tour:

Vocabulary:

minerals:

quartz
plagioclase feldspar
alkali feldspar
pyroxene
amphibole – hornblende
biotite mica
chlorite
epidote

coarse-grained vs. fine-grained
mafic rocks and minerals

magma, magma chamber – molten rock

subsurface igneous rocks:

basalt (as dikes)
dolerite (also sometimes called diabase)
felsite (light-colored, fine-grain igneous rock)
gabbro
granodiorite
granophyre
porphyry, porphyritic
(phenocrysts + finer ground mass)
rhyolite (as dikes)
intrusion
dike, crosscutting dikes
pluton - [For more on how plutons form: Plutons.](#)
subvolcanic
inclusion (xenolith)
chill zone or chilled margin
assimilation

volcanic (surface, extrusive) igneous rocks:

lava – flow of extruded magma
pyroclastic rocks – ejected into atmosphere
tuff = volcanic ash (glass shards) ± (pumice, crystals, lithic fragments)

sedimentary rocks:

sandstone, siltstone, shale

metamorphic rocks:

metasandstone - metamorphosed sandstone
argillite – hardened shale/siltstone
hornfels – baked clay-bearing rocks
hydrothermal alteration

time abbreviations:

Ma = mega-annum

ka = kilo-annum

radiometric dating - [For more on how rock ages are determined: RockAges.](#)

contacts – boundaries between geologic units
sharp vs. diffuse contacts

fracture planes or joints

fault, fault displacement

weathering – surface degradation of rocks

erosion – removal of weathered rock debris

corestones and grus

glaciation or ice age

glacial striations and grooves

glacial erratic – glacial boulder, unlike bedrock