Self-Guided Geologic Tour of the Skyline Trail in the Middlesex Fells Reservation (Part 7)

Prepared by Jack Ridge, Emeritus Prof., Dept. of Earth and Climate Sciences, 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. 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 spring water in the Fells 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 very 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** or **exposures**. Loose rock debris (or **float**), sediment, and soils on top of the bedrock make up 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 **natural glass**, which is non-crystalline and organically-produced materials.

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 about 4.5 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 their rock types and age. Formations are sometimes assembled into **groups** that have a well constrained age range or association with each other. Formations and groups have proper names from a place where they are well exposed or first defined. Sometimes, single formations are split into 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/or 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), TR (Triassic), 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 dikes). 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, 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 have changed periodically, and this will continue with more field work and precise age determinations. Updates of the bedrock map, its explanation, and associated surficial geologic map and tours will be posted as changes occur. We welcome feedback at: https://sites.tufts.edu/fellsgeology/.

Skyline Trail in the Middlesex Fells Reservation version: May 27, 2025

Part 7: South Reservoir Outlet to Bellevue Pond via Middle Hill

Total distance: 2.6 miles (4.19 km) round trip.

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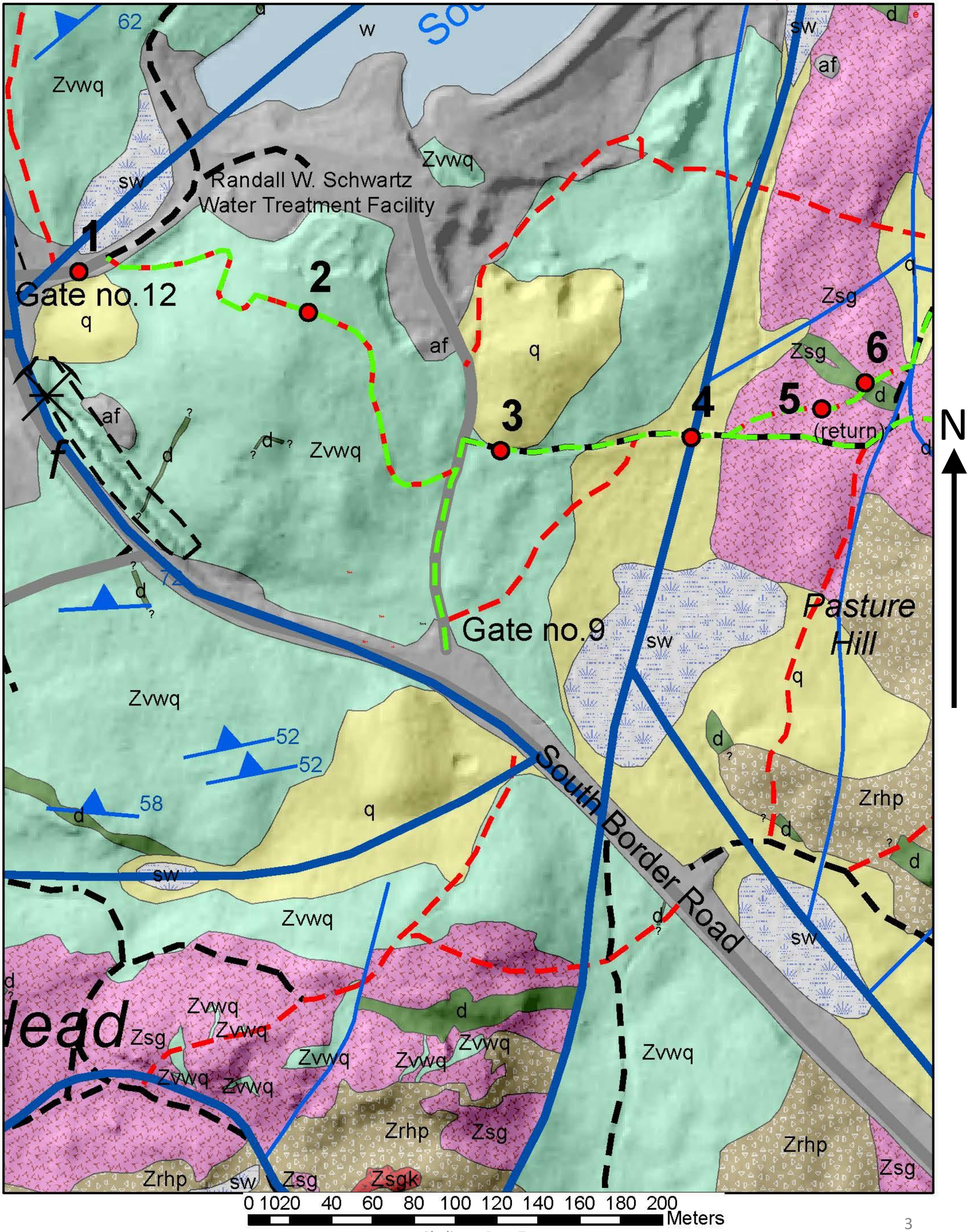
Starting point: Parking area at DCR Gate no. 9 on South Border Road in Medford. This is a large parking area at a dirt road leading to the west end of the South Reservoir Dam (not the access road to the Randall W. Schwartz Water Treatment Facility, which is further west). Follow the trail on the geologic maps as you go. Stops on the tour are shown with red circles and black numbers. Follow the white trail markers in the field and the green dashed path on the maps. In the guide, trail junction numbers are given that appear on the official DCR trail map and are marked with signs in the field. Part 7 begins with Stop 1 on Map SKY-7A.

To get to the first stop on the tour: **Follow Map SKY-7A**. Head north from the parking area on the road at DCR Gate no. 9. At junction B5-8 at the Skyline Trail, head west (left) and follow the trail across the top of the hill to the driveway entrance to the Randall W. Schwartz Water Treatment Facility, which serves the Winchester Reservoirs (DCR Gate no. 12). Follow the driveway east (left) to South Border Road at the south end of the pond or swamp. Having a hand lens or magnifying glass can be helpful. Hope you enjoy the geology! Have fun!!



62
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Zvwq
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Randall W. Schwartz
Water Treatment Facility
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Gate no.12
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2
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Zsg
Zsg
6
5
(return)
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3
d
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72
Gate no.9
sw
Pasture
Hill
Zvwq
52
52
58
d
q
sw
South Border Road
Zrhp
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Meters

Part 7 focuses on the Neoproterozoic Westboro Formation, Spot Pond Granodiorite, Rams Head Porphyry, Lawrence Woods Granophyre, and Lynn Volcanic Complex. The Neoproterozoic Era was 1000 – 541 million years ago. You will also see younger dolerite dikes, faults, and some glacial features.

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.

STOP 1: (also Stop 18 of Part 6): At the south end of the pond is a large Winchester Granite (Zwg) boulder (image below to left). This is a true glacial erratic that was carried at least 0.5 km by the last glacier from areas of granite to the north (see Parts 4-6 of the Tour). What makes it an erratic and not just a glacially-transported boulder is that it now rests on a different rock type, the Westboro Formation (Zvwq). Behind the boulder is a small boulder-covered hill (not the larger bedrock hill in the background), which is a remnant of an end moraine deposited by the last glacier as it receded. An end moraine is a deposit in the form of a pile of sediment left at the edge of a glacier. The moraine may have once blocked the valley, but it was cut away by glacial meltwater flowing south from the glacier as it receded northward. Beneath the southwest arm of South Reservoir and continuing beneath the outlet pond and dam visible to the northeast is a major N-S trending fault (line on image below to right). The rock in this valley is heavily fractured along the fault, which allowed more glacial erosion in this area during the last glaciation. Since the fault crosses beneath the dam, it is important to mention that the fault has not been active for 100's of millions of years.
From here, backtrack on the Skyline Trail east from the driveway to the top of the hill.

STOP 2: About 20 m after the highest point of the hill is a good area to see the rock types of the Westboro Formation (Zvwq). This unit is made of argillite and metasandstone (image to right). Argillite (dark gray) is hardened lightly metamorphosed mudstone, while metasandstone (white) is metamorphosed sandstone. Here, the metasandstone is almost entirely quartz. The metamorphism was caused by compression and shearing of the rock formation by mountain building processes resulting from plate tectonics. Because it affected a large region, we call this regional metamorphism. This area was lightly metamorphosed but it was still intense enough to obscure much of the original bedding in the rock. The original mudstone and sandstone represent an ancient continental shelf environment. Analysis of radioactive elements in zircon sand grains in the metasandstone indicates that it cannot be older than about 910 Ma (mega-annum or millions of years ago), placing it in the Neoproterozoic Era. Zircon (zirconium silicate) is a mineral that has trace amounts of radioactive uranium from the time it was originally crystallized in an igneous rock. The uranium is lost only by radioactive decay to lead. This allows us to calculate the age of the zircon grains. The zircon grains have various ages from the many different igneous rocks that were eroded to produce the sand, meaning that the grains are older than the sandstone. Therefore, the youngest zircon grains give the maximum (oldest possible) age of the Westboro. The Westboro can also not be younger than about 609 Ma, the age of the oldest igneous unit (Spot Pond Granodiorite) that intrudes it. For more on how ages are determined for rocks see: RockAges. **Continue east on the Skyline Trail back to junction B5-8. Head north (left) on the road for about 15 m to the continuation of the trail and head east (right).**

STOP 3: Shortly after re-entering the trail, there is a large, glacially-transported boulder (image to right) of the Westboro Formation (Zvwq) south of the trail (right). The boulder is unusual because the Westboro Formation has many fractures that usually prevent the survival of large boulders during glacial transport. You can see fractures on the side of the boulder and small pieces that have broken off it. This boulder is not technically a glacial erratic because it was not removed from the Westboro's outcrop area.

Continue on the trail into the valley ahead.

STOP 4: In the base of the valley is the stream outlet from the large dam at the south end of South Reservoir. This valley is the location of a major N-S trending fault that runs down the east side of South Reservoir. A fault is nothing more than a fracture along which both sides have moved relative to each other. Along this fault, the west side has moved south relative to the east side, which is a common pattern on N-S trending faults in the Fells. The fault places the Westboro Formation (Zvwq) on the west (near) side next to the Spot Pond Granodiorite (Zsg) on the east (far) side. Since the fault crosses beneath the dam, it is again important to mention it has not been active for 100's of millions of years.

After reaching the east (far) side of the valley, continue uphill and follow the trail as it branches northeast (left) at junction B5-9 and joins the Reservoir Trail (orange markers).

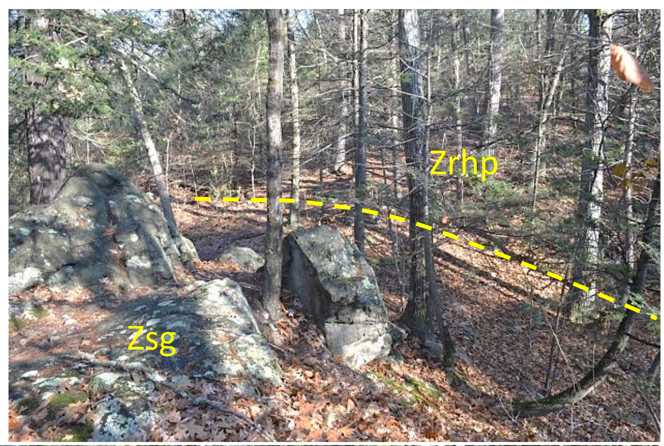
STOP 5: The first rock outcrop encountered on the east side of the valley (image below to left) is some glacially smoothed Spot Pond Granodiorite (Zsg), which is the coarsest igneous rock unit in the Fells and has an age of about 609 Ma. For more on how ages are determined for rocks see: RockAges. On the far side of the granodiorite is a dolerite dike (d). Dolerite dikes will be discussed at Stop 6. The granodiorite is an intrusion, which is magma that forced its way into older rocks and then crystallized. Here, the intrusion is a pluton, which is a large, irregularly-shaped body of igneous rock. ***Intrusions are always younger than the rocks they intrude***. For more on how plutons form see: Plutons. Granodiorite is a coarse-grained igneous rock in which quartz makes up 20-60% of the light minerals and two types of feldspar make up the rest. In granodiorite, plagioclase feldspar dominates over alkali feldspar. The composition of the Spot Pond unit varies somewhat from place to place, and small samples can be misleading. In the image (below to right), the tannish grains are alkali feldspar, the white grains are plagioclase, and the light gray areas are quartz. The mafic (dark) mineral areas are biotite (black) mica that was altered to chlorite (dark green color). On weathered surfaces, the quartz grains stick up from the surface because they are more resistant to weathering and erosion than feldspar.

Continue uphill on the trail. Stop 6 is about 25 m beyond Stop 5 at the crest of the hill.

Stop 6: At this stop the Spot Pond Granodiorite (Zsg) is intruded by a dolerite dike (d) that crosses the trail (image below on left). A dike is a type of intrusion in which magma forced its way into a crack or fracture, separating the sides of the fracture and then crystallizing. Over short distances, dikes can have the form of planar slabs, but they can also bend and pinch out to nothing. Remember: ***Intrusions, dikes included, are always younger than the rocks they intrude*.** Dolerite is a mafic (dark-colored) igneous rock with sand-sized mineral grains. This is considered intermediate between coarse- and fine-grained. A fine-grained mafic rock of this composition is basalt, and coarse-grained is gabbro. On the image of this rock cut on a rock saw (image below on right), the dark faintly purplish-gray and green mineral grains are pyroxene, which has been partly altered to chlorite and amphibole, and the small light gray mineral grains are plagioclase, which are hard to see in this example. Pyroxene is the main mafic mineral in the rock, and it dominates over plagioclase. When this rock weathers, oxidation of iron in the mafic minerals can form a rusty surface. Dikes like this are common in the Fells and throughout the Boston area.

Continue the tour on Map SKY-7B. Proceed to the next junction (C5-12) at an unnamed road and head north (left). Immediately after a small fault valley at junction C5-1, head east (right) up a steep slope, where the Skyline Trail departs from the other trails and roads.

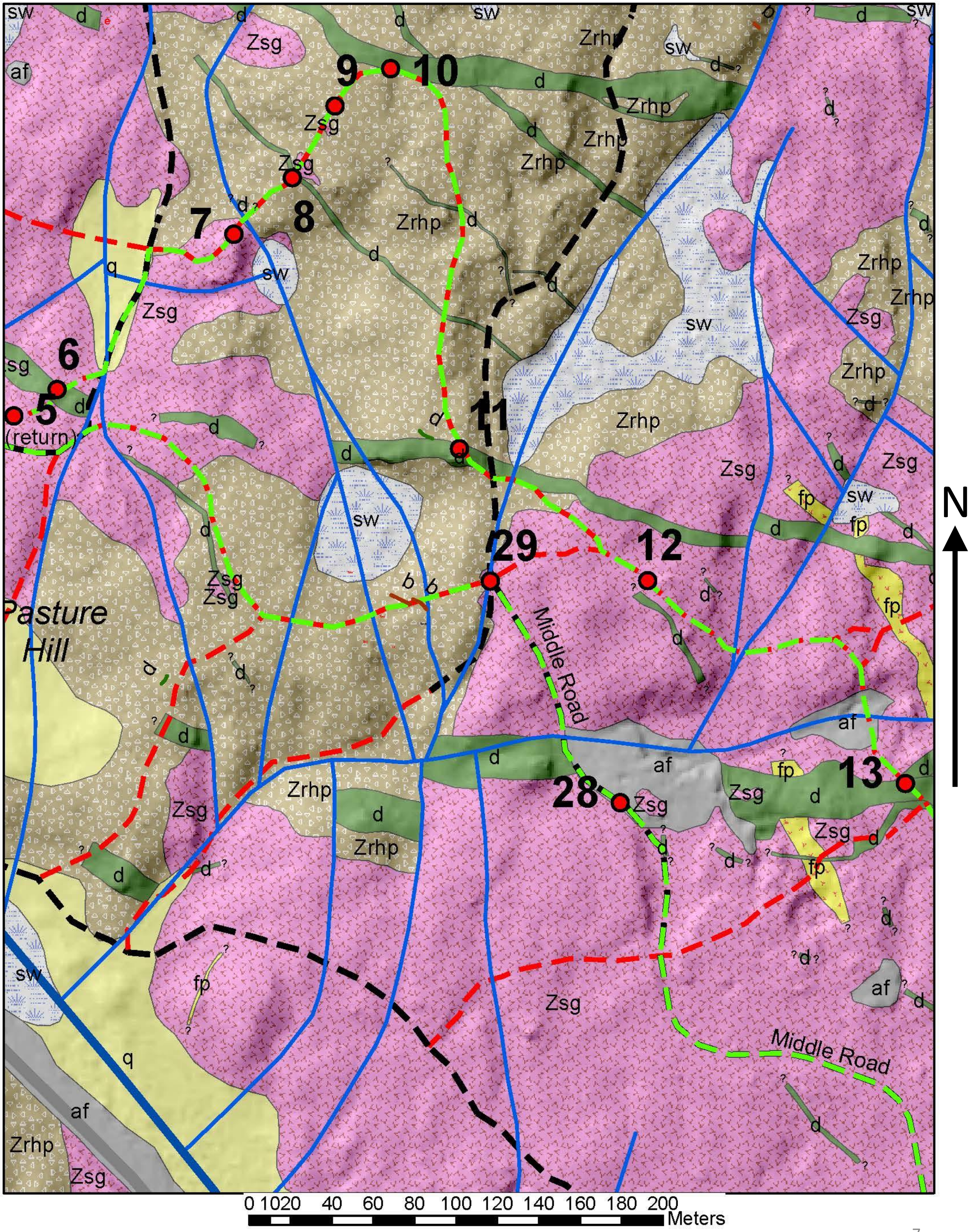
STOP 7: At the top of the knob, which is made of Spot Pond Granodiorite (Zsg), you have a view east across a small ravine that follows a minor fault (image to right). Note the abundant fractures in the granodiorite and how crumbly it is adjacent to the fault. The fault continues south (to right), where it runs down the axis of a wetland. Across the fault is the Rams Head Porphyry (Zrhp). You will notice this unit by its speckled appearance (You'll learn more about this unit at Stop 9).



Continue east (straight ahead) across the ravine and fault.

STOP 8: Part way up the slope is a dolerite dike (d) cutting across the trail (image to right). Look for the contacts of the dike with the Rams Head Porphyry (Zrhp), especially on the west (downslope) side of the dike. The dike can be distinguished by its finer grain size and smoother surface relative to the porphyry. It has a few large plagioclase feldspar crystals and some gas bubbles, or vesicles, that show up as holes in the rock.

(cont. Stop 8 after map on next page)


Pasture Hill
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Middle Road
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Zsg
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af
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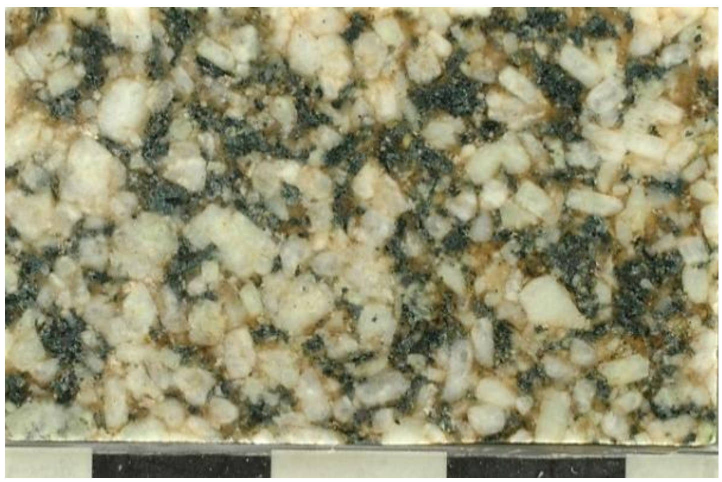
29

STOP 8 (cont.): The top of the dike also has faint glacial grooves that are oriented S10°E (image to right, parallel to hammer), which are best seen when the rock surface is wet. This is a more southerly direction than most striations and grooves in the Fells. Glacial ice flow was deflected southward as it slid across this slope. As you continue north (uphill) from the dike are inclusions of the Spot Pond Granodiorite (Zsg) in the Rams Head Porphyry (Zrhp), but they are subtle features. An inclusion, or xenolith, is a piece of pre-existing rock that broke off into magma and later got trapped when the magma crystallized. ***Inclusions are always older than the surrounding igneous rock.*** This establishes the Rams Head Porphyry as being younger than the Spot Pond Granodiorite. **Continue uphill on the trail.**

STOP 9: Above the dike and just beyond an inclusion of the Spot Pond Granodiorite (Zsg) near the crest of the hill is an exposure of the Rams Head Porphyry (Zrhp) in the trail, which is easily recognized by its speckled appearance and abundant veins (image below to left). Like the Spot Pond Granodiorite, the Rams Head is a pluton. For more on how plutons form see: Plutons. This unit is porphyritic quartz diorite that intruded the Spot Pond Granodiorite (Zsg). Quartz diorite porphyry is a coarse-grained igneous rock in which less than 20% of the light-colored minerals are quartz, less than 10% are alkali feldspar and the rest are plagioclase. Diorite tends to also have a higher mafic (dark) mineral content than granites. Porphyry is a rock that has minerals with two distinct grain sizes. In this case, the large crystals, or phenocrysts, are white plagioclase, while the quartz and alkali feldspar are smaller grains that make up the ground mass between the phenocrysts. Chlorite is the dominant mafic mineral, formed by alteration of biotite (black) mica and amphibole. Mafic mineral abundance in this unit varies, and the alkali feldspar content can creep above 10%, but rarely and only slightly. In the image of the porphyry cut on a saw (below to right), the rectangular white crystals are plagioclase, while the smaller orange-brown areas are the quartz and alkali feldspar ground mass. There is a higher percentage of mafic minerals than ground mass. The Rams Head has an age of about 596 Ma. For more on how ages are determined for rocks see: RockAges. **Follow the trail to the top of the hill.**



STOP 10: Where the trail takes a bend to the south (right) it temporarily follows the path of a 10 m-wide dolerite dike (d). From where the trail crosses the dike (image to right), there is a view 15-20 m to the west (left) of the dike where it forms a small knob, which looks like the back of a whale. As the trail continues past the step, it follows the dike and then bends to the south (right) across outcrops of the Rams Head Porphyry (Zrhp). **Over the next 200 m, the trail descends benches in the porphyry and crosses over two dikes, the second of which is well exposed in the trail. The first dike is thinner and a challenge to see along the trail.**

STOP 11: Just before Middle Road (Mountain Bike Loop), the trail descends across a large E-W trending dolerite dike (d). The image to the right is a view south (ahead) approaching the dike before dropping down to the road (there is no junction number here).

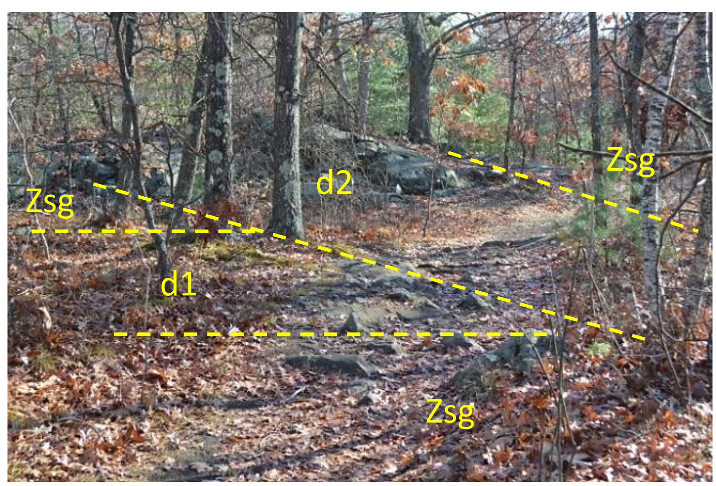
Cross Middle Road and continue uphill from the road where the Skyline Trail joins the Cross Fells Trail (blue markers) at junction C5-15.

STOP 12: After Middle Road, the trail crosses over a small area of the Rams Head Porphyry (Zrhp) before crossing its contact with the Spot Pond Granodiorite (Zsg) and then arriving at junction C5-15. The contact of these units is not well exposed. Beyond junction C5-15, the Skyline Trail traverses an area of glacially streamlined granodiorite (image to right). The northern ends of these outcrops form steep heads with tails that taper to the south formed by heavy abrasion of sliding glacial ice. Note the coarser grain size of the granodiorite as compared to the Rams Head Porphyry and look for the raised quartz grains. Quartz is more resistant to weathering and erosion than feldspar and therefore tends to stick up above the eroded rock surface.

The trail continues across a small fault valley and then a second hill made of granodiorite.

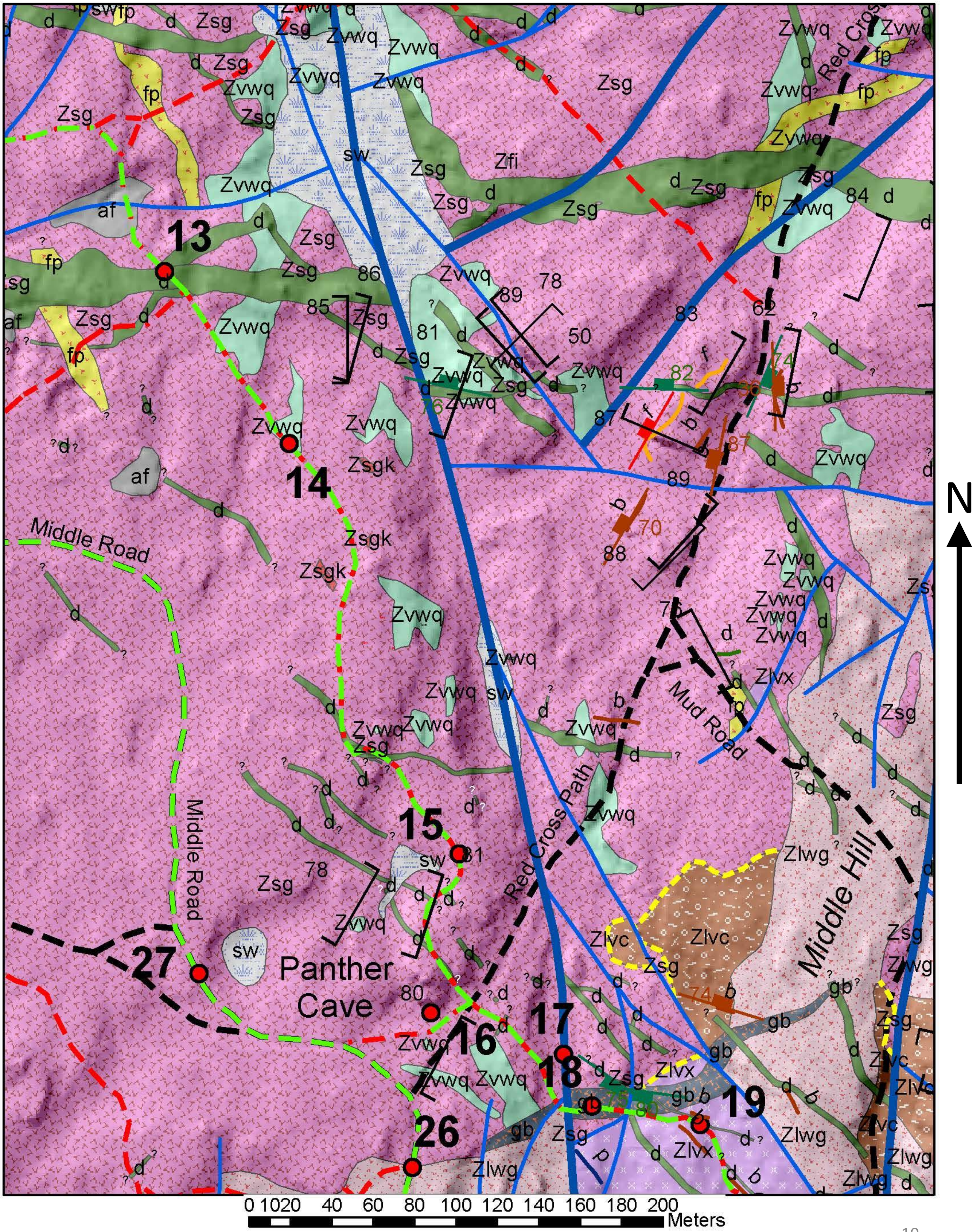
Continue the tour on Map SKY-7C. At trail junction C5-16, head south (right), leaving the Cross Fells Trail behind. Note: this junction is a triangle. Just beyond the junction, the Skyline Trail crosses an E-W trending fault valley, which is filled with artificial rock waste (af on map) from an old quarry area to the west.

STOP 13: About 30 m south of (beyond) the fault valley at junction C5-24, the trail crosses the intersection of two dolerite dikes (d) (image to right, view south) that cut through the Spot Pond Granodiorite (Zsg). The trail surface sits mostly on the larger E-W trending dike (d2 on image), which crosscuts the older and smaller NE-SW trending dike (d1). The older dike shows a greater amount of alteration and has many more fractures and veins.



Beyond the dikes, Stop 14 is 40 m beyond a steep slope that descends the south side of the younger dike at Stop 13 (straight ahead).

Map SKY-7C


13
14
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Middle Road
Middle Road
Panther Cave
Red Cross Path
Red Cross
Mud Road
Middle Hill
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0 10 20 40 60 80 100 120 140 160 180 200
Meters

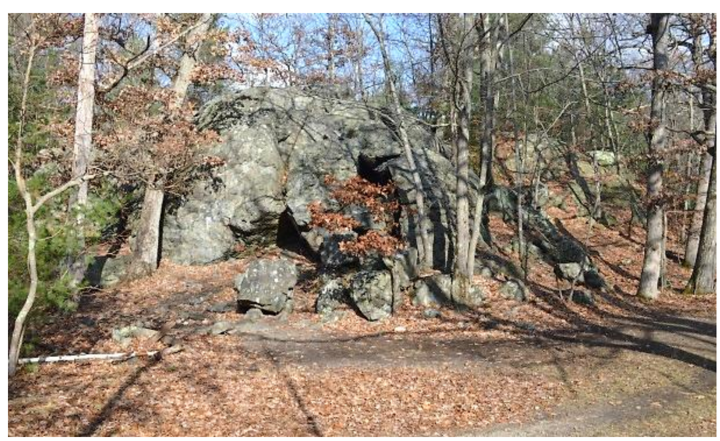
STOP 14: On the east (left) side of the trail is a terrific example of an inclusion (image to right) in the Spot Pond Granodiorite (Zsg). An inclusion or xenolith is a piece of pre-existing rock that broke off into magma and got trapped when the magma crystallized. ***Inclusions are always older than the surrounding igneous rock.*** The inclusion is from the Westboro Formation (Zvwq) and is made of thin layers of white metasandstone in rusty-gray argillite. Metasandstone is metamorphosed sandstone and argillite is hardened, lightly metamorphosed mudstone. The metamorphism was not intense enough to wipe out the original layering or sedimentary bedding. The inclusion was metamorphosed by the deformation of Earth's crust over a large area (regional metamorphism) before being heated to a high temperature (contact metamorphism) when it broke off into the granodiorite magma. Contact metamorphism caused many of the minerals in the inclusion to recrystallize at high temperature, making the rock extremely hard. This is especially true of clay minerals in the argillite, which were baked as if they were being fired in a kiln to make pottery. The resulting hard and brittle rock is called hornfels. The rusty gray color you see here is common in argillite hornfels inclusions in the granodiorite.

Continue south on the trail.

STOP 15: Over the next 200 m, the trail crosses the glacially streamlined topography of the Spot Pond Granodiorite (Zsg) before passing a depression to the west (right). Depressions like this are not uncommon in the granodiorite and may be the result of erosion of dike intersections or intersecting, closely-spaced fractures, although neither of these mechanisms is obvious from the rock exposures surrounding this depression. The depressions were most likely excavated during glaciation, perhaps because the area was more weathered than other areas of the granodiorite. At this point, the mechanisms that generated the depressions remain a mystery. The depressions are also the sites of vernal pools (vernal meaning spring), or temporary ponds. In the spring, the vernal pools fill with water from rain and snowmelt, which seep into the ground and then through the subsurface to the pool. During the summer, the pools dry out due to evaporation and seepage (infiltration), when the water table is low.

Continue south on the trail a short distance and descend a steep slope to Red Cross Path and junction C6-3. Follow Red Cross Path to the west (right) for 50 m to Panther Cave.

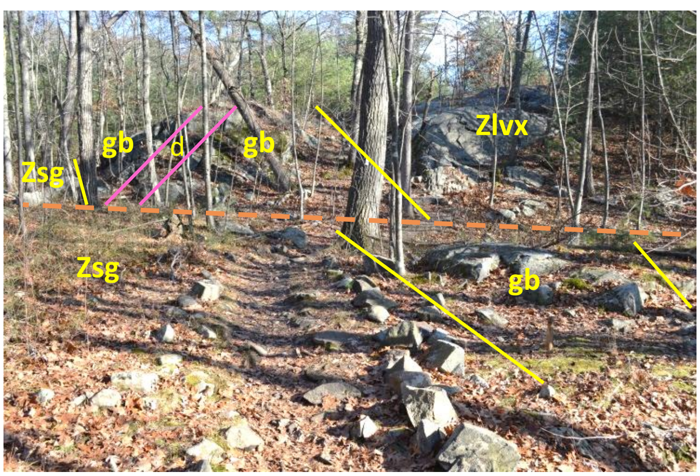
STOP 16: Panther Cave (image to right) is not really a cave, but rather large granodiorite boulders piled on top of each other at the southern end of the Spot Pond Granodiorite (Zsg) upland. The boulders were deposited here by the southward movement of glacial ice during the last glaciation.

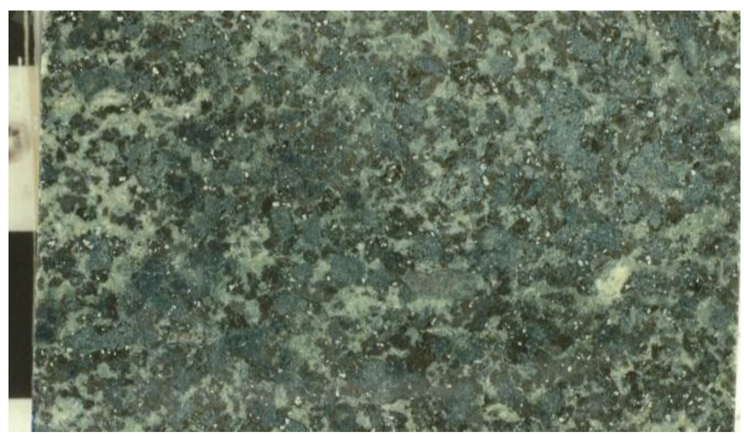


After visiting the "cave", return to the Skyline Trail and continue south (right). The trail descends into a valley.

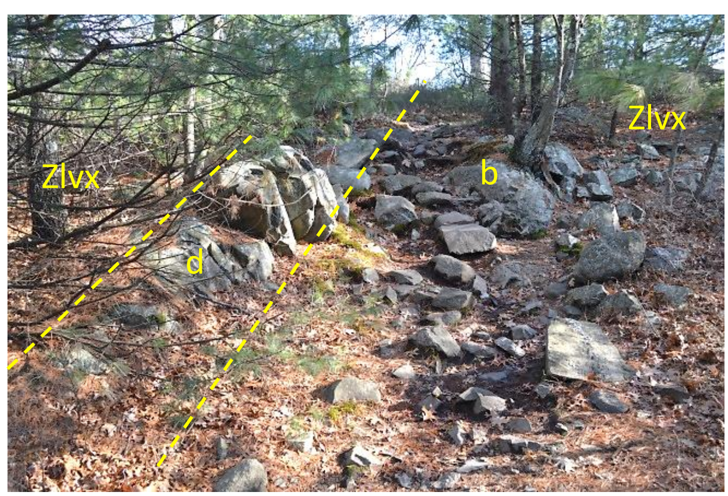
STOP 17: The valley is occupied by a major fault zone (image to right shows trace, view south or ahead on the trail). At this location, the fault brings the Lawrence Woods Granophyre (Zlwg) on the west (right) side in contact with the Spot Pond Granodiorite (Zsg) and Lynn Volcanic Complex (Zlvx) on the east (left) side. You'll learn about the granophyre and volcanic rocks at upcoming stops. Rocks along the fault are heavily fractured. Displacement does not appear to be extreme, with the west side moving to the south and upwards relative to the east side. This fault can be traced northward through Middle Reservoir and into Winchester. We will see this fault again later in the tour near Bellevue Pond where it is crosscut by the Medford Dike (T_Rm).
Continue on the trail until you reach a footbridge.

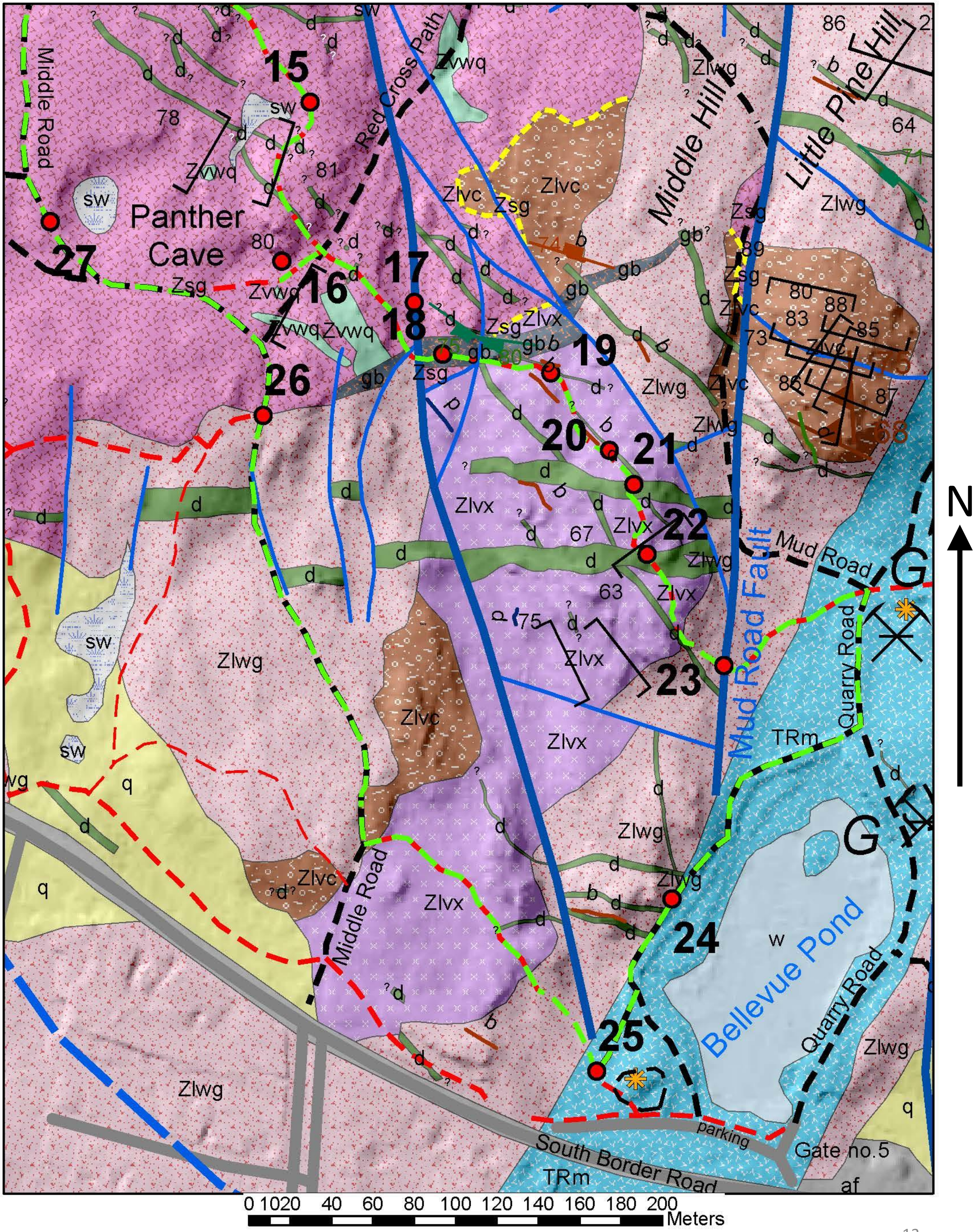
STOP 18: At the east (far) end of the footbridge that crosses the stream and fault valley (image below on left) is a gabbro dike (gb) cutting through the Lynn Volcanic Complex (Zlvx) and Spot Pond Granodiorite (Zsg). ***Like other intrusions, dikes are always younger than the rocks they intrude.*** Gabbro is a coarse-grained igneous rock composed of mostly mafic minerals. Coarse-grained means mineral grains are easily visible without magnification and mafic means dark-colored (image below on right). Look for mineral grains in the gabbro outcrop in the foreground (see image below on left). Most of the mafic minerals are pyroxene that was altered to amphibole and chlorite and the light-colored minerals are altered plagioclase. The gabbro is like the dolerite dikes in the area, but it is coarser and more altered. The situation here is complicated by two factors: 1) the gabbro dike is offset by the major fault seen at the last stop as well as a minor fault running along the base of the steep slope ahead on the trail (dashed orange line, image below to left), and 2) the gabbro is crosscut by a younger and smaller dolerite dike (d, pink lines on image).





Continue on the trail up the stairs and around a bend to the south (right).
STOP 19: Just before the trail reaches the top of Middle Hill (image on right), the small dolerite dike (d) that cut through the gabbro dike (gb) at the last stop also cuts through the Lynn Volcanic Complex (Zlvx) and parallels the east (left) side of the trail. Paralleling the dolerite dike and on the west (right) side of the trail are small (15-20 cm-wide) basalt dikes (b on image). Basalt dikes are finer-grained versions of the dolerite dike. The dolerite and basalt dikes appear to have intruded at the same time, but the thinner basalt dikes cooled faster, producing a finer grain size.
Continue the tour on Map SKY-7D.




Middle Road
Panther Cave
Red Cross Path
Middle Hill
Little Pine Hill
Mud Road Fault
Mud Road
Quarry Road
Bellevue Pond
South Border Road
parking
Gate no.5
N
15
16
17
18
19
20
21
22
23
24
25
26
27
Zvwq
Zlvc
Zsg
Zlwg
Zlvx
TRm
sw
gb
q
w
af
0 10 20 40 60 80 100 120 140 160 180 200
Meters

Continue on the trail to the top of Middle Hill.

STOP 20: At the top of the hill is a good exposure (image to right) of the dolerite dike (d) from Stop 19 cutting through the gray-weathering, highly fractured, crystal tuff in the Wakefield Formation of the Lynn Volcanic Complex (Zlvx). The volcanic rock here is a type of felsite, a name for any light-colored fine-grained igneous rock. The felsite here is crystal tuff. Tuff is an extrusive (erupted at Earth's surface) volcanic rock made of volcanic ash (fine glass particles) and other components, which can include: 1) chunks of molten or solid blobs of lava, which when bubbly are called pumice; 2) crystals that started to form in the magma prior to the eruption; and 3) pieces of rock ripped up by the exploding magma called lithic fragments. Lithic fragments can be volcanic rocks from earlier eruptions during the same period of volcanism, or they can be fragments ripped up from any older rock unit encountered by the erupting magma in the subsurface. The crystals in the tuff on Middle Hill appear as tiny white specks in the rock (arrows on image to right of cut rock). Lithic fragments are present, but very sparse. Note how fractured the volcanic rock is in this area because it is near some major faults.

Follow the trail for about another 20 m (see Map SKY-7D).

STOP 21: The flat top of Middle Hill has excellent exposures of two 8-12 m wide, E-W-trending dolerite dikes (d) that cut through the crystal tuff (Zlvx). The same two dikes also occur on Pine Hill to the east.

In the first dolerite dike (image to right) are inclusions of the crystal tuff. The dolerite surface is very smooth because of glacial erosion, and you may see faint traces of glacial grooves that are oriented S30°E. The second dolerite dike is at Stop 22.

Follow the trail for another 30 m to the steep edge of the hill.

STOP 22: The second dolerite dike (d) is on the flat top of Middle Hill just before the trail steeply descends into the valley to the east (image to right). The dike cuts through crystal tuff in the Wakefield Formation of the Lynn Volcanic Complex (Zlvx). The flat dolerite surface is smoothed and has glacial grooves that trend S23°E. You can also find inclusions of volcanic rock in this dike. Why are the glacial grooves in a different direction than at Stop 21? Small differences are not uncommon. The base of a glacier has plastic ice that can squirm around irregularities on the rock surface. It is also possible that the striations were formed at slightly different times.

Descend the steep side of Middle Hill and into the flat-floored valley below.

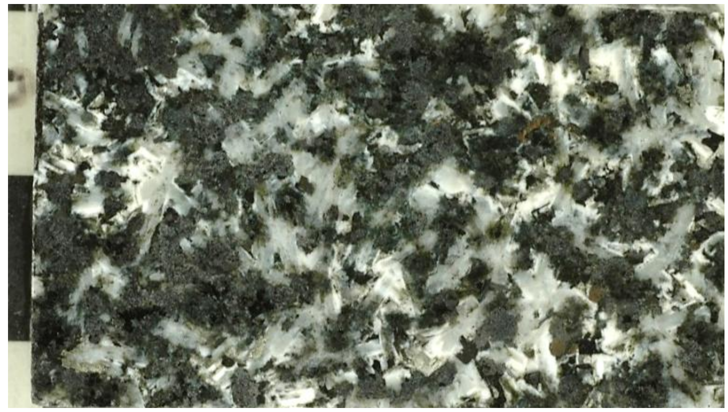
STOP 23: At the base of the steep slope descending Middle Hill, where the trail bends to the left (northeast), is a flat area partially underlain by the east (near) side of the Medford Dike (T_Rm, described in Part 1 of the Skyline tour). **Follow the discussion below on map SKY-7D**. To the north-northeast from Stop 23 and through the woods is the southern end of Little Pine Hill. To the north is Mud Road, which follows the valley between Middle Hill on the west and Little Pine Hill on the east. Along the road is the Mud Road Fault. This is a major N-S trending fault that runs from Stop 23 to the north where it eventually crosses under Rt. 93 (see Part 1 of the Skyline tour for information on this fault and the Medford Dike). The southern extension of the fault runs along the base of the steep slope at this stop on the east side of Middle Hill. It is crosscut and displaced by the Medford Dike (T_Rm) north of Bellevue Pond. A continuation of the fault can be found on the opposite (east) side of the Medford Dike just off the east side of Map SKY-7D.

Continue east (ahead) on the trail to Quarry Road (junction D6-2). From here, the tour leaves the Skyline Trail to return to the parking area where you began. Head south (right) on Quarry Road and then head west (right) on the road at the stone wall at the north end of Bellevue Pond (junction D6-3). Follow this road to the west side of the pond.

STOP 24: On the west side of Bellevue Pond, the road follows a steep slope on the right that is underlain by the Lawrence Woods Granophyre (Zlwg). At about the midway point of the west side of the pond, note the pinkish-gray color of the granophyre and its scattered white crystals. The exact contact with the Medford Dike (T_Rm) is concealed by the road (image below on left). The granophyre occurs across much of the southern Fells, from the Wrights Pond area to Medford High School. Granophyre is a porphyritic igneous rock of granitic composition having a granophyric texture (image below on right). A granophyric texture occurs when two minerals, in this case quartz and alkali feldspar, rapidly grow side-by-side at the same time as microscopic, intergrown, irregular plates. The granophyric texture is the pink area in the image below on the right. (A microscope view of the granophyric texture is in Part 1 of the Skyline tour.) A porphyritic rock has two different grain sizes, the coarser set forming phenocrysts (in this case white plagioclase) and the finer minerals making up the surrounding ground mass (in this case the pink granophyric areas and quartz). Granite is an igneous rock in which the light-colored minerals are 20-60% quartz with the rest being plagioclase and alkali feldspar in about equal abundance. One other mineral occurs in the granophyre here and that is the mafic (dark) mineral that appears sparsely as small rods, which is an amphibole called hornblende. This mineral is partly altered to chlorite. The granophyre is relatively fine-grained in this area near its contact with the crystal tuff (Zlvx). This is the chill zone, or the area near the magma's contact with cooler rocks where the intrusion cooled more rapidly. In general, this rock unit is fine-grained, and it appears to be a near-surface pluton (large, irregularly shaped intrusive body) that may have fed volcanic eruptions. We refer to these plutons as being subvolcanic. For more on how plutons form see: Plutons. It appears that the Lawrence Woods Granophyre is a subvolcanic pluton associated with the Wakefield Formation of the Lynn Volcanic Complex (Zlvx). The Lawrence Woods Granophyre has an age of about 596 Ma. For more on how ages are determined for rocks see: RockAges.

After continuing south (straight ahead on trail) over a small stone bridge, you will come to a fork in the trail at junction C6-9. The fork to the east (left) heads to the Bellevue Pond parking lot and the starting point of Part 1 of the Skyline tour. Take the western (right) fork to the first trail on the west (right). This is Stop 25.

STOP 25: The valley from the north that ends here is the southern extension of the major fault valley that you saw at Stop 17. East (to left) of the trail is a small knob of the Medford Dike (T_Rm) that has a small quarry on its southwest side. You will see many dark gray, rounded boulders of this unit lying about in the woods in this area. ***I don't suggest that you go in the old quarry because it is overgrown with poison ivy.*** There are good outcrops of the Medford Dike at the southern end of the island between the Bellevue Pond parking area and South Border Road. (This is Stop 1 on Part 1 of the Skyline tour. If you go to this parking area, you will have to return to Stop 25 to complete this part of the tour.) Gabbro is a coarse-grained igneous rock composed of mostly mafic minerals. The image above shows a slab of gabbro cut with a rock saw (scale in cm) to expose a non-weathered surface. Most of the mafic minerals are pyroxene, amphibole, and biotite (black) mica, and the light-colored minerals are plagioclase feldspar. The Medford Gabbro is an intrusion in the form of a large dike. Remember: ***Intrusions, dikes included, are always younger than the rocks they intrude.*** This unit formed at great depth back in the Triassic Period, when the earliest dinosaurs roamed the land surface (238 Ma, mega-annum or millions of years ago). The age for this rock unit was determined by analysis of uranium and lead isotope ratios in zircon crystals separated from the rock. For more on how ages are determined for rocks see: RockAges. At Bellevue Pond, the dike is about 100-120 m wide and trends NNE to SSW on the map. The Medford Dike can be traced from the Wrights Pond area, across Rt. 93 and the Fells to Lawrence Memorial Hospital, along Governors Avenue to the CVS Pharmacy parking lot on High Street, across the Mystic River to the Tufts University campus and into Somerville, where it is exposed at Powder House Square. The gabbro tends to weather and erode more easily than other rocks in the Fells. For more on this unit, see Part 1 of the Skyline tour.



After Stop 25, the tour will return you to the parking area on South Border Road at the beginning of Part 7. This part of the tour will quickly move through the Fells and will not identify all the rock units with detailed descriptions. You have already seen them on this tour. Continue northwest (right) from Stop 25 on the small side trail just before South Border Road. It crosses up over a steep slope at the contact of the Wakefield Formation of the Lynn Volcanic Complex (Zlvx and Zlvc) and the Lawrence Woods Granophyre (Zlwg). The granophyre intruded the volcanic rocks, which form the roof of the granophyre pluton. After climbing the slope, the flat area above is crystal tuff, like earlier in this hike, and volcaniclastic conglomerate (Zlvc) in the Lynn Volcanic Complex. This conglomerate is made up of dominantly volcanic rock fragments. Unfortunately, it is difficult to see this in outcrops and usually requires cutting the rocks open on a rock saw.

Continue north to where the trail ends at Middle Road, where there is no trail junction number. Turn north (right) onto Middle Road.

STOP 26: Refer to map SKY-7D and go about 180 m on Middle Road to Stop 26. Middle Road takes you through exposures of the Lawrence Woods Granophyre (Zlwg). The road crosses over dolerite dike segments on the east (right) side that are offset by a small fault and then descends into a small valley. Climb the steep slope on the far side and just beyond the top, where a side trail enters from the west, is the contact between the Lawrence Woods Granophyre (Zlwg) and the Spot Pond Granodiorite (Zsg). These two units have a sharp contact. Look for the contrast between the finer-grained granophyre (south) and the coarse-grained granodiorite (north) in road outcrops.

Continue north (straight ahead) to the fork in the road and stay to the left (west) where Middle Road heads off to the northwest near Panther Cave, which was seen earlier. In a short distance the road will split a second time. Stay to the right (north) at the second split.

Continue the tour on Map SKY-7C.

Continue north on Middle Road beyond the last road split for about 40 m to Stop 27, adjacent to a depression on the east (right).

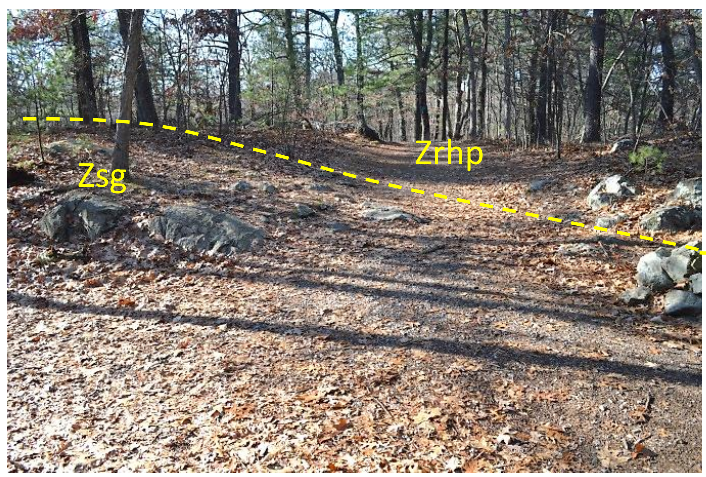
STOP 27: Here is a view to the east (right) of the vernal pool depression in the Spot Pond Granodiorite (Zsg) discussed at Stop 15 (image on right). This is a better view of the depression, and you can see its steep rim.

Continue north (straight ahead) on Middle Rd. for about another 400 m. Continue the tour on Map 7B.

STOP 28: In an area east (to right) of the road, you will find some glacially polished outcrops of the Spot Pond Granodiorite (Zsg) with beautiful glacial striations (image to right). The striations begin at junction C5-23. 40 m beyond the junction on the east (right) side of the road is where the image was taken. The striations bend slightly around the granodiorite knobs but are generally oriented S14°E. The striations can be seen better if the rock surface is wet. Look for the irregular metasandstone inclusions from the Westboro Formation in the outcrop as well. On the west side of the road is an area where glacial sediment was excavated. The fill taken from this area was probably used for road construction in the Fells.

Continue north (straight ahead) on Middle Road and up a hill about 120 m to junction C5-14, where the Cross Fells Trail (blue markers) crosses Middle Road.

STOP 29: At road junction C5-14 (image to right, view to west) is the contact between the Spot Pond Granodiorite (Zsg) and the chill zone of the Rams Head Porphyry (Zrhp). The porphyry has a speckled appearance (see Stop 9).



At junction C5-14, head west (left) on the combined Cross Fells Trail (blue markers) and Mountain Bike Loop (green markers). After crossing the rise in the image to the right you will soon see speckled outcrops of the Rams Head Porphyry (Zrhp) in the road with occasional small basalt and dolerite dikes.

At junction C5-13, the Cross Fells Trail branches off to the southwest (left). Stay on the Mountain Bike Loop to the northwest (right). The Mountain Bike Loop will cross back into the Spot Pond Granodiorite (Zsg) just before it slowly bends to the west (left).

Continue the tour on Map SKY-7A. Stay on the Mountain Bike Loop west. You will pass a trail on the north (right) and then a short distance later on the south (left) at junction B5-10. After merging with the trail from earlier today at junction B5-9, continue downhill and cross the valley at Stop 4. Continue to the access road at junction B5-6 (just past Stop 3). Follow the access road south (left) to the parking area at DCR Gate no. 9 on South Border Road.

END OF PART 7

Here is a listing of all the rock units and features you have seen on Part 7 of the Skyline Trail. See if you can place most of the geologic units and major N-S faults according to their relative ages.

dolerite dikes (d)
gabbro dike (gb)
Lawrence Woods Granophyre (Zlwg)
Wakefield Formation of the Lynn Volcanic Complex (Zlvx and Zlvc)
Medford Gabbro (T_Rm)
N-S faults
Rams Head Porphyry (Zrhp)
Spot Pond Granodiorite (Zsg)
Westboro Formation (Zvwq)

Here is a summary of the features and vocabulary for Part 7 of the Skyline Trail tour:

minerals:
- quartz
- plagioclase feldspar
- alkali feldspar
- mafic rocks and minerals
- pyroxene
- amphibole – hornblende
- biotite mica
- chlorite
- zircon
- pyrite

igneous rock types:
- coarse-grained vs. fine-grained
- dolerite
- gabbro
- felsite
- crystal tuff
- granodiorite
- granophyre, granophyric texture
- porphyry, porphyritic
  - (phenocrysts + ground mass)
- quartz diorite
- magma – molten rock, magma chamber
- intrusion
  - dike
  - pluton - For more on how plutons form see: Plutons.
  - chill zone or chilled margin
  - crosscutting
- inclusion (xenolith)

sedimentary rocks:
- conglomerate and breccia
- volcaniclastic conglomerate
- sandstone
- mudstone (shale and siltstone)

metamorphic rocks:
- regional metamorphism
- argillite
- metasandstone
- contact metamorphism
- hornfels

time abbreviations:
- ka = kilo-annum
- Ma = mega-annum

radiometric dating - For more on how ages are determined for rocks see: RockAges.
zircon crystals
Neoproterozoic Era
contacts

fracture planes or joints
fault, fault displacement

weathering – surface breakdown of rocks
erosion – removal of weathered material
glaciation or ice age
glacial striations and grooves
glacial deposits
end moraine
glacial erratic