BUILDING STONES OF SCHENECTADY, NEW YORK

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Introduction

The building stones of downtown Schenectady contain some of the best examples of rock types and medium- and small-scale geologic features that the general public can readily view. Within easy walking or driving distance are high-quality rocks of many types, some of them carefully polished and beautifully displayed. There are buildings made with igneous, sedimentary, and metamorphic rocks that include oxide-rich gabbro, porphyritic granite, crossbedded sandstone, fossiliferous limestone, marble, gneiss, and partially melted migmatite. During this half-day trip, we will tour the downtown area to view the most interesting building stones, to see what minerals, fossils and other features they contain, to infer the geologic processes that formed them.

The aim of this trip is to help people to learn more about geology, just by spending a few hours in downtown Schenectady (Figure 1). Anyone who is interested in geology can observe rock types and features on his own, without a guide, and without traveling miles on rural roads, bushwacking through woods and swamps, or stopping next to busy highways. Those who examine urban building stones can sharpen their powers of observation and learn to recognize a wide variety of rock types, minerals, features, and fossils. BRING HAND LENSES!

Each block of building stone, or each panel of facing stone, is one small window into the past. However, there are some important things to remember when looking at building stones. First, remember that all of the rocks you are looking at came from somewhere else. The geologic history that they record within them happened in another place. Second, many buildings contain rocks of several types, so as to juxtapose geologic events from different places and different times. No matter how closely adjacent stones may seem to match one another, we can not, in a strict sense, prove that they were ever connected in their original positions. However, it is a reasonable assumption that similar stones from the same building came from the same formation or body of rock, and possibly came from the same quarry. While the overall arrangement of the stones in a building has no geological meaning, we can gain knowledge about the original rock as the sum of observations made on individual stones.

Building Stones as Geological Materials

Of the numerous varieties of rocks that exist, only a small number are prized as building material. Depending on use, building stone is selected for some combination of strength, ease of working, proximity to the building site, beauty, weather resistance, and availability. These properties depend on many factors, including mineralogy (Table 1), grain size, textures, and overall structure.

Clay-rich sedimentary rocks such as shale and siltstone tend to break up quickly when exposed to the weather, and so tend to make poor building materials. The reason is that clays swell when wet, and shrink when they dry. The constant flexing of the rock causes cracks to form, which speeds up disintegration. Although sandstones (Figure 2) are made of grains of quartz and other weather-resistant minerals, the grains are held together by some kind of intergranular "cement". Some sandstones have clay cement, which causes the sandstones to decompose relatively rapidly like shale and siltstone. Calcite and dolomite are also common cements and are resistant to the effects of wetting and drying, but they are relatively water soluble. As a result, calcite-cemented sandstones tend to weather away grain by grain as the cement dissolves over the years. Quartz is the most weather-resistant of common cements. Quartz-cemented sandstones commonly form prominent ridges and cliffs due to their weather resistance, and can last centuries on a

In Garver, J.I., and Smith, J.A. (editors), Field Trips for the 67th annual meeting of the New York State Geological Association, Union College, Schenectady NY, 1995, p. 275-291.

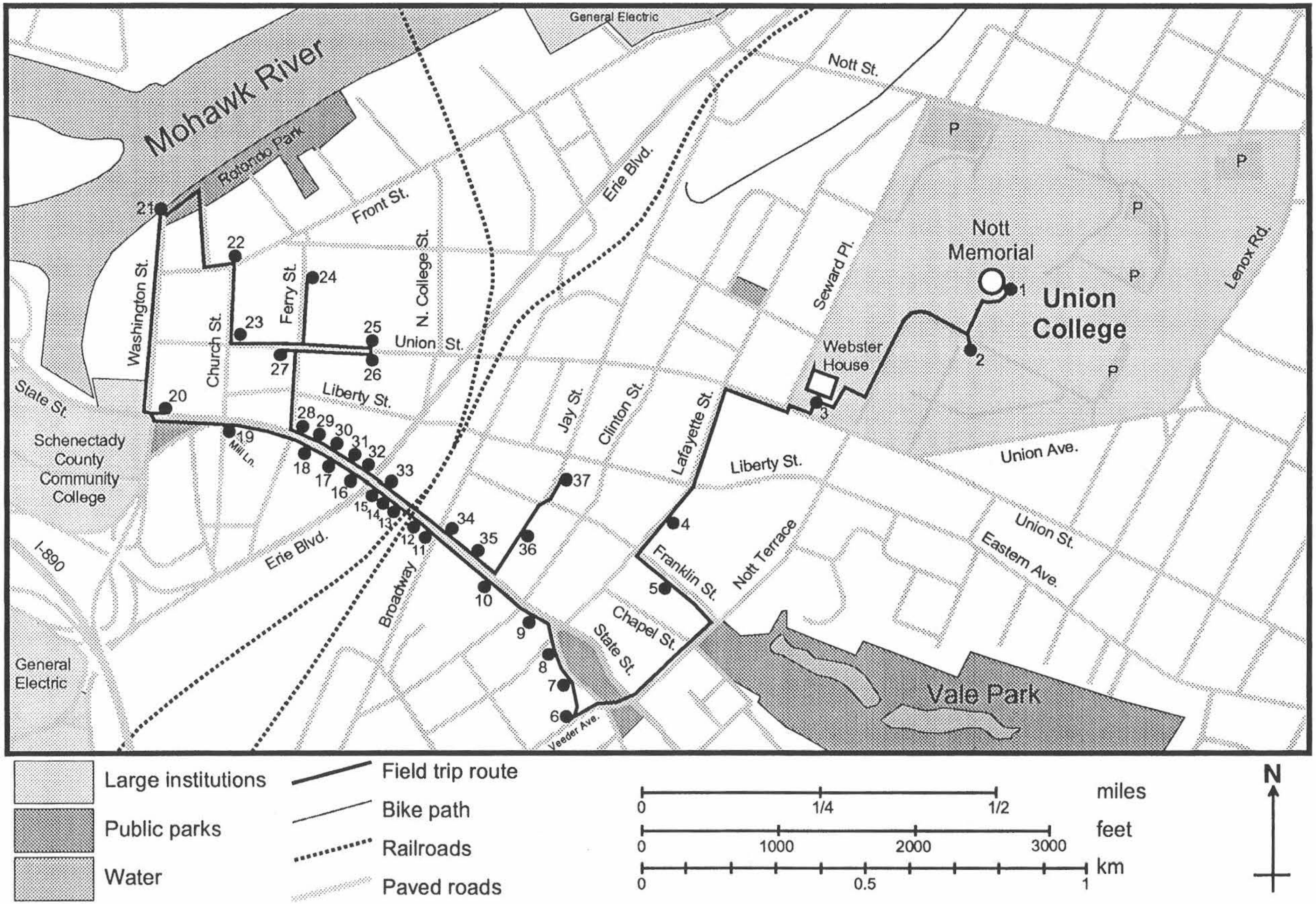


Figure 1. Street map of downtown Schenectady, showing trip route and numbered stops.

building face with little change. Limestones, although they are mostly made of calcite and other relatively soluble minerals, are commonly used for building stone since they are easily worked, aesthetically attractive, and tend to weather evenly. Limestone also commonly contains numerous fossils (Figure 3) and interesting sedimentary features (Figure 4) that can be interpreted in terms of the environment and processes of deposition. Sedimentary rocks are composed largely of minerals that are intrinsically colorless, such as quartz, feldspars, and calcite. The variety of colors one finds in sedimentary rocks usually depends on small quantities of coloring agents that coat or contaminate the mineral grains that make up most of the rock (Figure 5). Like paint on a house, it commonly takes very little pigment coating the grains to color them.

Table 1. Common minerals seen on this trip.

Mineral	Formula
Silicates	
Quartz	SiO_2
K-feldspar	$KAlSi_3O_8$
Albite	$NaAlSi_3O_8$
Plagioclase	$(Na,Ca)Al(Si,Al)_3O_8$
Biotite	$K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$
Phlogopite	$KMg_3AlSi_3O_{10}(OH)_2$
Muscovite	$KAl_2AlSi_3O_{10}(OH)_2$
Talc	$(Mg,Fe)_3Si_4O_{10}(OH)_2$
Serpentine	$(Mg,Fe)_2Si_2O_5(OH)_4$
Garnet	$Fe_3Al_2Si_3O_{12}$
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
Diopside	$CaMgSi_2O_6$
Clinopyroxene	$Ca(Mg,Fe)Si_2O_6$
Orthopyroxene	$(Mg,Fe)_2Si_2O_6$
Olivine	$(Mg,Fe)_2SiO_4$
Sphene (titanite)	$CaTiSiO_5$
Tourmaline	$(Na,Ca)(Mg,Fe,Al)_6Al_3Si_6O_8(BO_3)_3(OH)_4$
Carbonates	
Calcite	$CaCO_3$
Dolomite	$CaMg(CO_3)_2$
Oxides	
Magnetite	Fe_3O_4
Hematite	Fe_2O_3
Ilmenite	$FeTiO_3$
Rutile	TiO_2
Sulfides	
Pyrite	FeS_2
Native elements	
Graphite	C

Igneous rocks are generally thought of as being hard and strong. However, most are not suitable for use as building stone. Volcanic rocks are usually too porous, fragmented, or brittle. Plutonic igneous rocks (Figure 6) are hard and strong, but not all of these are suitable for building stone either. Plutonic igneous rock is very hard and difficult and expensive to work. Igneous rock that is used for building stone must therefore have special aesthetic qualities to justify the extra difficulty and expense. Many igneous rocks also contain substantial quantities of easily weathered minerals such as pyrite, olivine, and orthopyroxene. Although, the weathering of these minerals usually does not reduce the strength of the rock, the iron and manganese weathered from these minerals can discolor the stone and other parts of the building.

Metamorphic rocks (Figure 7) are derived from igneous or sedimentary protoliths by the action of heat, pressure, and deformation. The wide variety of possible protoliths, and the wide range of conditions under which metamorphism can occur, result in a similarly wide range of metamorphic rock types, colors, and textures. The common metamorphic building stones are slate, marble, gneiss, and *verd antique*. Slate, a fine-grained low-grade metamorphic rock derived from shale, splits easily along its foliation and so is used for roofs and paving for floors and walkways. Marble is metamorphosed limestone. Fossils rarely survive metamorphism, but marble can have large crystals of calcite and a variety of metamorphic minerals including tremolite, diopside, tourmaline, phlogopite, sphene, and graphite. Gneiss is most commonly derived from a felsic igneous rock such as granite or granodiorite, or their volcanic equivalents rhyolite or dacite. Gneisses are composed of feldspar, quartz, and dark iron- and magnesium-rich minerals such as biotite. Gneisses, however, tend to be layered and folded as a result of deformation during metamorphism. Some gneisses have undergone partial melting, so some parts look like gneiss, and other parts have an igneous appearance. These "mixed rocks" are called migmatites.

REFERENCES

Moore, R.C., Lalicker, C.G. and Fischer, A.G., 1952, Invertebrate Fossils: McGraw Hill Book Company, Inc., New York, 766 p.

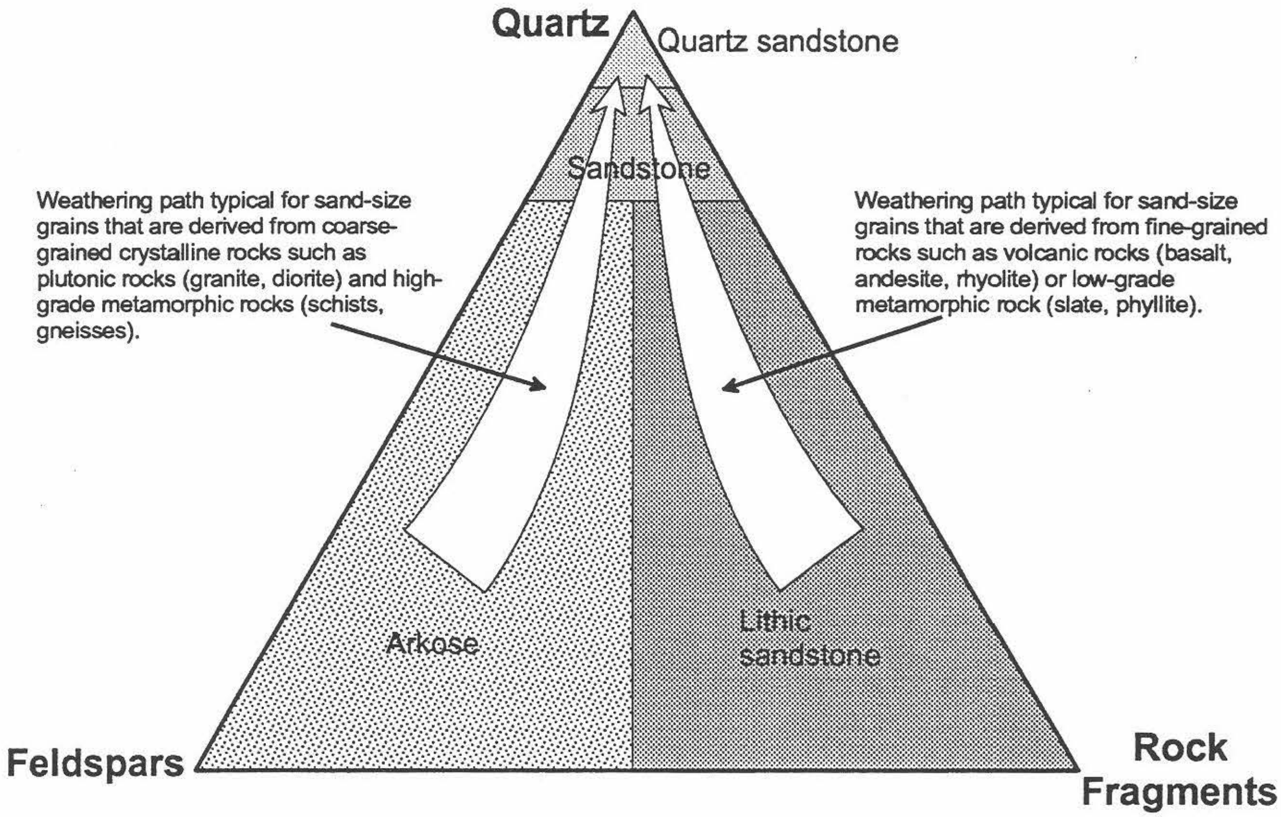


Figure 2. Classification scheme for sandstones. Sandstones have grains that are mostly in the range of 1/16 to 2 mm. Sandstones that were deposited close to their source tend to have unstable grains such as feldspars (usually white or pink) and rock fragments (usually black). With time and transport distance, quartz (glassy clear) eventually dominates.

BUILDING STONES OF SCHENECTADY, NEW YORK

TRIP LOG

Start Assemble at the east side of the Nott Memorial on the Union College Campus

Stop 1 Nott Memorial. Note the various building materials that comprise this structure, from foundation to roof. The foundation appears to be made of gray granodiorite. The abundant wall stones are gray lithic sandstone (Figure 2) that may be Devonian in age, from the Catskill Delta, or Ordovician, from the Schenectady Formation. The columns are of pink granite and gray granodiorite. The light-colored cross bedded quartz sandstone on the steps is probably the Beriea sandstone from Ohio.

Stop 2 Memorial Chapel. This building, constructed after World War I, has been here long enough to demonstrate the effects of weathering on rock. The columns in front of the building are made of calcite marble. Notice that the surfaces of the marble facing the building are smooth with sharp edges. The surfaces facing away from the building are rougher and the edges more rounded, a result of chemical and mechanical weathering on the side exposed to the elements. The steps are gray granitic rock, made of quartz, biotite, and feldspar.

Stop 3 Webster House, southwest corner of Union College campus. This building was once the library for the City of Schenectady. The steps and foundation are made of muscovite granite with at least one inclusion of foliated muscovite granite. The sides of the steps are made of a fossil hash limestone, composed of broken pieces of shells, crinoids, and bryozoans. The kinds of fossils and the relatively uniform grain size suggest that they were deposited in a shallow marine environment by relatively uniform currents. The columns on the front of the building are pink granite similar to that quarried on Deer Isle, Maine. The granite has a "rapakivi" texture, which consists of pink microcline phenocrysts with rims of white albite. Rapakivi is a Finnish name meaning approximately "mud rock", after the crystal-bearing soil that commonly develops on rapakivi granite. Other minerals include black biotite and quartz.

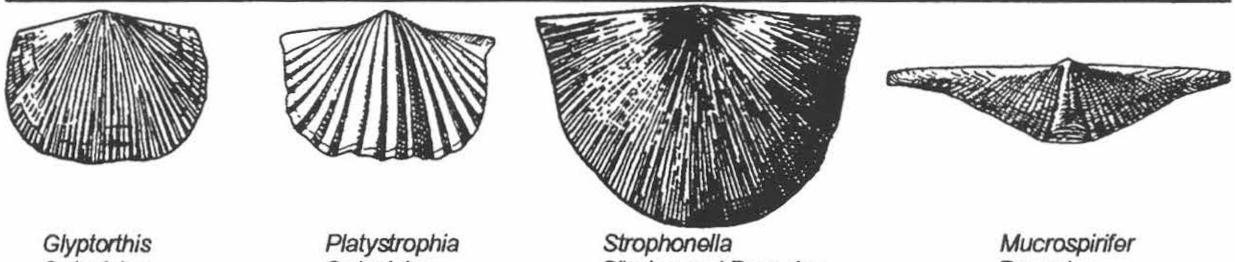
Stop 4 600 Liberty Street (on the Lafayette Street side between Liberty and Franklin Streets). This building has decorative facing stones of muscovite quartzite. This is a metamorphic rock composed mostly of quartz, and with some muscovite, tourmaline, and pyrite. Rocks similar to these are found in the Adirondacks and in New England. The original rock, or protolith, was most likely a quartz-rich sandstone or quartz conglomerate that contained some clay, iron sulfide, and probably organic matter. During metamorphism, under the influence of heat and pressure, the quartz grains in the sand recrystallized into quartzite, while the clays and associated sulfides were transformed into layers composed of muscovite, tourmaline, and pyrite.

Thanks to the varying placement of the stones, one can observe the layers from the side and also face-on. Most of the stones have been placed with the layering horizontal, so that you see contrasting layers that are relatively rich in quartz or in muscovite. Some stones are oriented with the layering vertical and parallel to the building face, so that the stones look sparkly and the long, black tourmaline crystals are easily visible on the surface.

Some of the quartzite is colored pinkish red by weathering pyrite, which leaves cube-shaped cavities behind. One can still see pyrite cubes in some of the stones. Into other cavities, quartz crystals have grown and their prismatic shapes are visible. On the southernmost section of quartzite facing, quartz veins can be seen, some containing quartz boudins – strong quartz layers around which other, weaker rock has deformed.

Stop 5 600 Franklin Street. This one-story modern building has a facade of sandstone that is stunningly fossiliferous. Probably from a Paleozoic shoreline environment, where rich shell beds lay near a sandy beach, this rock is full of fossils. Look for large and whole brachiopods, pelecypods, and gastropods (up to 6 cm across). Note that many of the blocks are darker (browner or redder) and more porous near their periphery. This "weathering rind" probably formed along joint surfaces through which ground water flowed. The ground water gradually dissolved away some calcite, making the rock porous with abundant fossil molds. The joints also broke the rock into slabs, which were later subdivided into blocks for building.

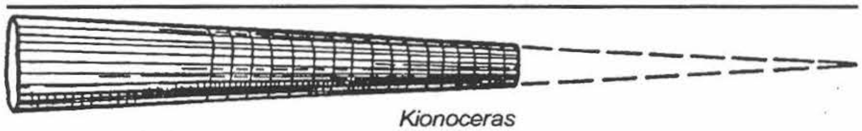
Brachiopods



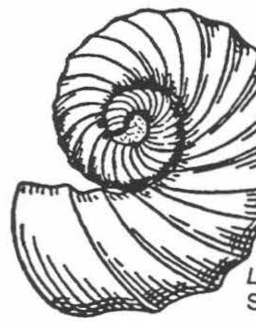
Glyptorthis Ordovician | *Platystrophia* Ordovician | *Strophonella* Silurian and Devonian | *Mucrospirifer* Devonian

Brachiopods are bivalves that usually have calcareous shells. They are characterized by bilaterial symmetry of each valve, but the two valves are typically dissimilar in size and shape.

Cephalopods



Kionoceras
Silurian



Lechtricoceras
Silurian

The cephalopods include squids, octopi, and the Nautilus. Most fossil cephalopods have calcareous, chambered cells that were either straight or coiled. The coiled varieties are symmetrical about a plane that is perpendicular to the coil axis.

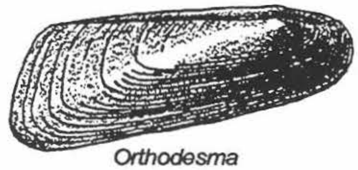
Figure 3. Examples of the kinds of fossils that can be found in building stones in downtown Schenectady. Most of these fossils occur in limestone, but some can be found in some unusual calcareous sandstone (adapted from Moore et al., 1952, reproduced with permission from McGraw-Hill book Company, Inc.). All examples are approximately life-size unless otherwise indicated.

Gastropods

Lecanospira
Ordovician

Snails and related organisms having shells that usually coil along a particular axis, rather than symmetrically about a plane.

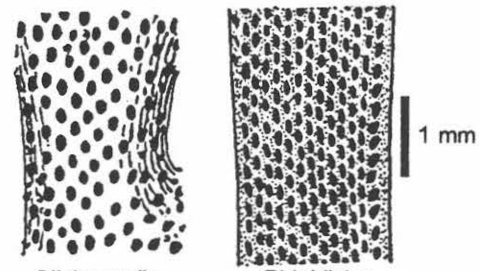
Pelecepods



Orthodesma
Ordovician

Pelecypods include the common modern bivalves, mussels, and clams. The two valves are usually very similar or identical (mirror images), but each shell is not bilaterially symmetical.

Bryozoans

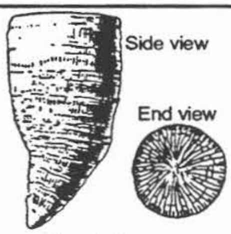


Stictoporella
Ordovician

Rhinidictya
Ordovician

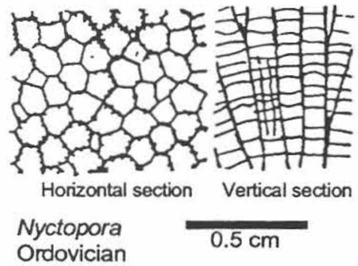
Small leaf-like or branching forms with many small pores, in which these colonial bryozoan polyp organisms lived.

Corals



Streptelasma
Ordovician

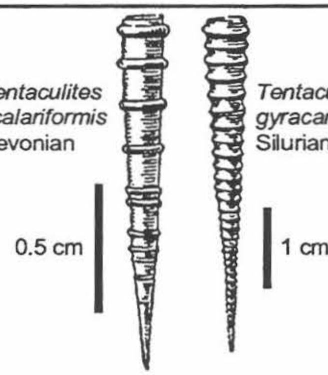
Rugose corals are cone-shaped and have a solitary coral polyp. Radial ribs decorate the inside of the cone.



Nyctopora
Ordovician

Tabulate corals are layered or plate-shaped and are made up of numerous small cells. The cells were where the many little colonial polyps lived.

Tentaculites

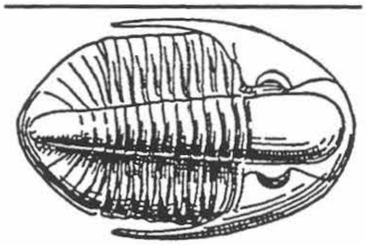


Tentaculites scalariformis
Devonian

Tentaculites gyracanthus
Silurian

Tentaculites is a variety of invertebrate of uncertain zoological affinity. Shells are typically chitin mineralized with calcium phosphate.

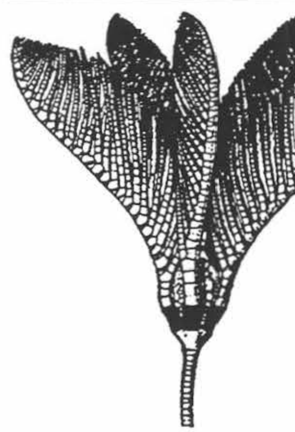
Trilobites



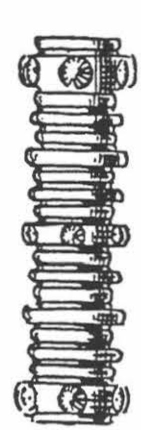
Bathyurus
Ordovician

Trilobites were arthropods whose closest modern relative may be the horseshoe crab. Though extinct since the Permian, trilobites dominated the community of mobile bottom-dwelling organisms in the Paleozoic seas. The mineralized chitinous exoskeletons commonly appear as thin, black plates in rock.

Crinoids



Ptilocrinus
Modern



Close-up of crinoid stalk

Close-up of crinoid segments

Crinoids are delicate, flower-like organisms that consist of a segmented stalk, a plate-covered body, and numerous segmented tentacles. The segments are made of calcite and usually become disarticulated during decomposition of the soft parts of the organism. Most crinoid fossils are disarticulated disk segments.

Stop 6 Schenectady County Office Building, Veeder Avenue and State Street. The facade of this modern building contains three types of building stone. At the Veeder Avenue entrance, the steps and low enclosing wall are made of coarse, gray granite which contains white plagioclase, pink K-feldspar, hornblende, and gray quartz.

The red facing stone around the Veeder Avenue entrance is an oxidized granite. The oxidized iron, as hematite, gives it a red color. Look closely at the quartz to see its bluish cast, an effect that is commonly produced by the presence of sub-microscopic rutile crystals that scatter blue light. The presence of blue quartz suggests a special temperature history for the rock. Titanium, in the original magma, was included as a minor dissolved impurity in quartz as it crystallized. If the pluton had cooled relatively quickly, over tens of thousands of years, titanium would have remained dissolved in the quartz. However, this pluton either cooled much more slowly, or the pluton was reheated to moderate temperatures and slowly cooled long after the pluton was solid. Over this long time at moderate temperatures (~400°C), titanium dissolved in the quartz nucleated and grew as tiny rutile crystals.

The retaining wall and the low walls parallel to Veeder Avenue and enclosing the Albany Street entrance are made of gray diorite (Figure 6), a plutonic igneous rock that contains much less quartz and K-feldspar than granite, and more sodium- and calcium-rich plagioclase. This diorite contains fine-grained xenoliths, which look like dark blobs. They may be "auto-inclusions", inclusions of finer-grained (more rapidly cooled) portions of the same magma, which was later fractured and mixed with adjacent magma.

Stop 7 County Courthouse, Albany Street. The walls next to the sidewalk are biotite granite. The dark, sparkly flecks are the mica biotite, which are the next most abundant mineral after feldspar and quartz. The steps of the Courthouse are muscovite granite, which is similar to the biotite granite but it also has shiny flakes of colorless muscovite.

The columns and pediments of the Courthouse are made of limestone. First, look at the middle pediment on the left as you face the Courthouse. Notice the layers in this rock. In the lower half of this pediment, the layers are slanted; in the upper half, the layers are horizontal. The slanted layers are called cross-beds. Inspection of the rock with a hand lens shows that it is made largely of small fossil fragments. Many of the fossil fragments are rounded, suggesting abrasion during transport in water. The fact that most of the particles are of similar size suggests deposition by relatively even currents water. These observations might lead us to interpret that this rock originated as deposits in tidal channels or deltas on a carbonate bank, such as might be found in the present day Bahamas.

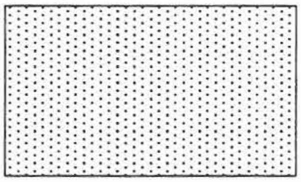
Stop 8 St. Joseph's Church, Albany Street. This brick church has four types of building stone. The lowest foundation stone is a gray-green sandstone. Notice the pattern of closely spaced horizontal lines made by cutting tools on many of the block surfaces. Notice, too, that some of the blocks have another, less regular pattern of horizontal lines or grooves, thicker than the tool-cut pattern. These are "plane beds", horizontal layers made when sand is deposited in fast-moving streams or currents. These may be Devonian sandstones from the Catskill Delta.

Capping the lower foundation stone is a lighter-colored fossiliferous limestone that contains bryozoans. The steps of the church are made of coarse-grained, gray, biotite granite. Atop the stones that flank the steps are blocks of fossil hash limestone.

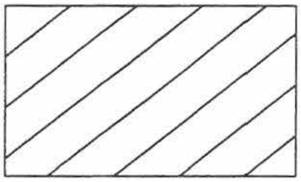
Stop 9 504 State Street. The large panels of facing stone that cover the entryway are made of marble. Look for panels that contain large and dramatic folds that are highlighted by gray patches and layers in the white rock. The black specks and gray areas are graphite, formed by the metamorphism of organic matter that was present in the original limestone. The sparkly mineral is the brown mica, phlogopite, a magnesium-rich biotite. The elongate, colorless to light brown crystals in the marble are the mineral actinolite, an amphibole similar to hornblende. Its presence indicates that high temperatures were reached during metamorphism.

Outside the entryway, note the foundation stones composed of fossil hash limestone. Notice that this limestone is coarser – the fossil fragments are larger – than in fossil hash limestones at previous stops. Notice, too, the shapes of the fragments. Many of them are rounded, indicating that the fragments have been abraded during transport.

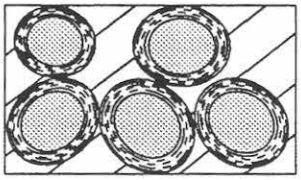
Around the corner on Clinton Street, look at the blocks of limestone and the orientations of the layers within them. Notice that some blocks contain slanted cross-beds. In one block, a flat-



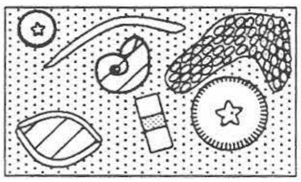
Carbonate mud. Fine-grained calcite with crystals too small to see, even with a hand lens, starts as muddy material. The rock made from carbonate mud is fine-grained and usually colored in shades of gray. The carbonate mud is produced by certain kinds of algae, from abrasion of larger calcite fossils, and from inorganic precipitation.



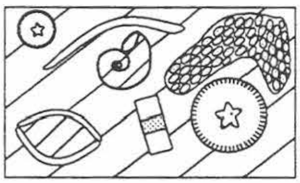
Crystalline calcite cement. Void space, such as the space between fossil grains, can be filled in by calcite crystals that are precipitated from groundwater circulating through the rock. Nice calcite crystals can sometimes be seen in some cavities that were not completely filled in.



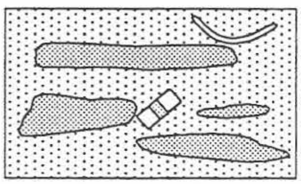
Oolites. An oolite starts out life as a seed grain (a bit of fossil, quartz sand, fish bone). The seed grain is rolled by tidal currents in an area with carbonate mud. The fine mud grains stick to the seed grain to form a layer. When the tide turns, the oolite rolls the other way and another layer is build up. Eventually the oolite becomes too large to roll. Oolites are therefore ovoid grains composed of a central seed surrounded by thin layers of fine-grained carbonate mud. Oolites are typically 1 mm in diameter.



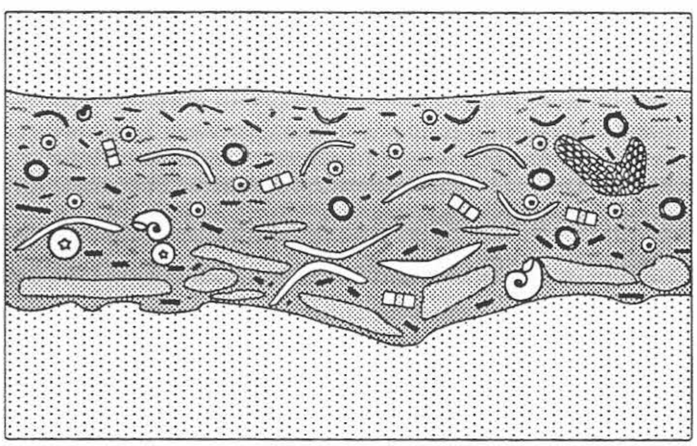
Here is an example of fossils embedded in carbonate mud. The fossils shown here include crinoid fragments (doughnuts), a bryozoan (celled structure), a gastropod (snail), and some brachiopods (arc-shaped bivalve shell fragments). The void spaces inside the paired bivalve shell and the gastropod have been filled by crystalline calcite cement.



In this example, the fossils are the same as above, but have been cemented together by coarse-grained calcite cement that was precipitated from groundwater.



Rip-up clasts. During storms or other heavy wave action in near-shore environments, pieces of local carbonate rock can be torn up and deposited elsewhere. In this example, carbonate rock clasts have been mixed with and deposited in a matrix of fossils and carbonate mud.



Graded bed of coarse-grained fossil-bearing limestone. Graded beds are those that vary systematically in grain size from bottom to top. Graded beds in limestones typically represent storm deposits that were formed in shallow offshore water or in a nearshore or lagoon environment. The beds are made of coarse-grained carbonate materials that were transported and deposited in an environment different from where they formed. The bottoms of graded beds are usually irregular, as a result of erosion of the sediments by the storm waves and currents. As the currents slowed, large rip-up clasts and big fossils were deposited first, followed by particles of smaller and smaller size. The example here shows a graded bed between two layers of carbonate mud. This example is typical of storm surge deposits in a lagoon environment in which carbonate mud is usually deposited.

Figure 4. Examples of typical limestone compositions and textures.

lying fossiliferous layer truncates, or cuts off, the cross-beds in a lower layer. This sedimentary feature is typical of channel fills – channels that have cut into underlying layers that are then filled in with sediment.

Stop 10 Key Bank, 436 State St. The foundation stones on the outside of this building are made of rapakivi granite. Look closely and you will see large crystals of feldspar, much larger than the other crystals in the rock. These large crystals are called phenocrysts, and they crystallized from the slowly-cooling magma. Later, more rapid cooling caused crystallization of the smaller crystals that make up the matrix to the phenocrysts.

Stop 11 340 State Street. The facing stone on this building is made of a granitic migmatite that contains the minerals K-feldspar, quartz, plagioclase, and biotite. This rock is composed of two parts: a metamorphic component and an igneous component that are closely associated. The metamorphic component is a layered gneiss that is separated into blocks by dikes and other small bodies of unlayered granite and granitic pegmatite. The gneiss has the same mineralogy as the granite, and it contains fine-grained dark inclusions that look like igneous xenoliths. This evidence suggests that the gneiss was once a granite, was then metamorphosed to form the gneiss, and metamorphism reached high enough temperatures so that the rock partially melted (~800°C). Deformation while the rock was partly liquid caused segregation of the liquid into fractures, which became the granite and pegmatite dikes when they crystallized during cooling.

Stop 12 332 State St. The base of this building is made of a fine-grained biotite granite, over which is a fossil hash limestone.

Stop 13 TrustCo Bank, 320 State St. This building has columns of pink biotite granite and slabs of polished red granite. The latter is particularly interesting. It contains large, gray to white plagioclase crystals that contain concentric layers within them having slightly different appearance. The layers formed as the crystals grew while suspended in the granite liquid. Some of the pink K-feldspar crystals have rims of white albite, which is the rapakivi texture described above. The zoning and rapakivi textures indicate physical changes in the magma during growth of these crystals, changes that may have included temperature, pressure, water content, or the chemical composition of the liquid during mixing with other magma or during crystallization of the liquid.

Stop 14 Rudnick's, 308 State St. This storefront is faced with a granitic gneiss: a metamorphosed light-pink or tan granite. If you look carefully, you will see that the rock has a weak foliation that is defined by the parallel orientation of elongated crystals, including feldspar augen (Figure 7). Augen formed during deformation from pre-existing large crystals in the granite protolith.

Stop 15 Fleet Bank, 306 State Street. Although the source of this rock is unknown, it looks just like the Whiteface Mountain facies of anorthosite from the high peaks region of the Adirondacks. Anorthosite is an igneous rock composed mostly of dark- to light-gray plagioclase with small quantities of black pyroxene and perhaps a few other minerals. Undeformed Adirondack anorthosite contains large dark-gray plagioclase crystals up to 30 cm long, and commonly 10 cm long. The dark color is caused by dust-sized ilmenite that formed in the plagioclase during cooling. When the original anorthosite was deformed, the edges of the gray plagioclase, and sometimes whole crystals, recrystallized into smaller light-gray or white plagioclase crystals that are free of ilmenite dust. In some of the less deformed parts of this rock you can see nice, big dark-gray igneous plagioclase crystals, and interlocking plagioclase and pyroxene crystals that have the original igneous texture. If you look closely at the dark-gray plagioclase crystals, you may see the blue iridescence that this variety of plagioclase is famous for.

Stop 16 Olender Furniture, 260 State Street. The front of this building is made of polished muscovite-biotite granite. The interesting thing about this rock is that, if you look closely with a hand lens, you will see occasional dull pinkish-tan crystals up to 2 mm long. These are crystals of allanite, a member of the epidote family that is extremely rich in rare earth elements and the radioactive elements uranium and thorium. Over geologic time, the uranium and thorium cause sufficient radiation damage to the allanite crystal lattice to destroy it. The result is a glass that weathers easily to the pink material you see. Fresh allanite is dark brown and shiny. This granite is

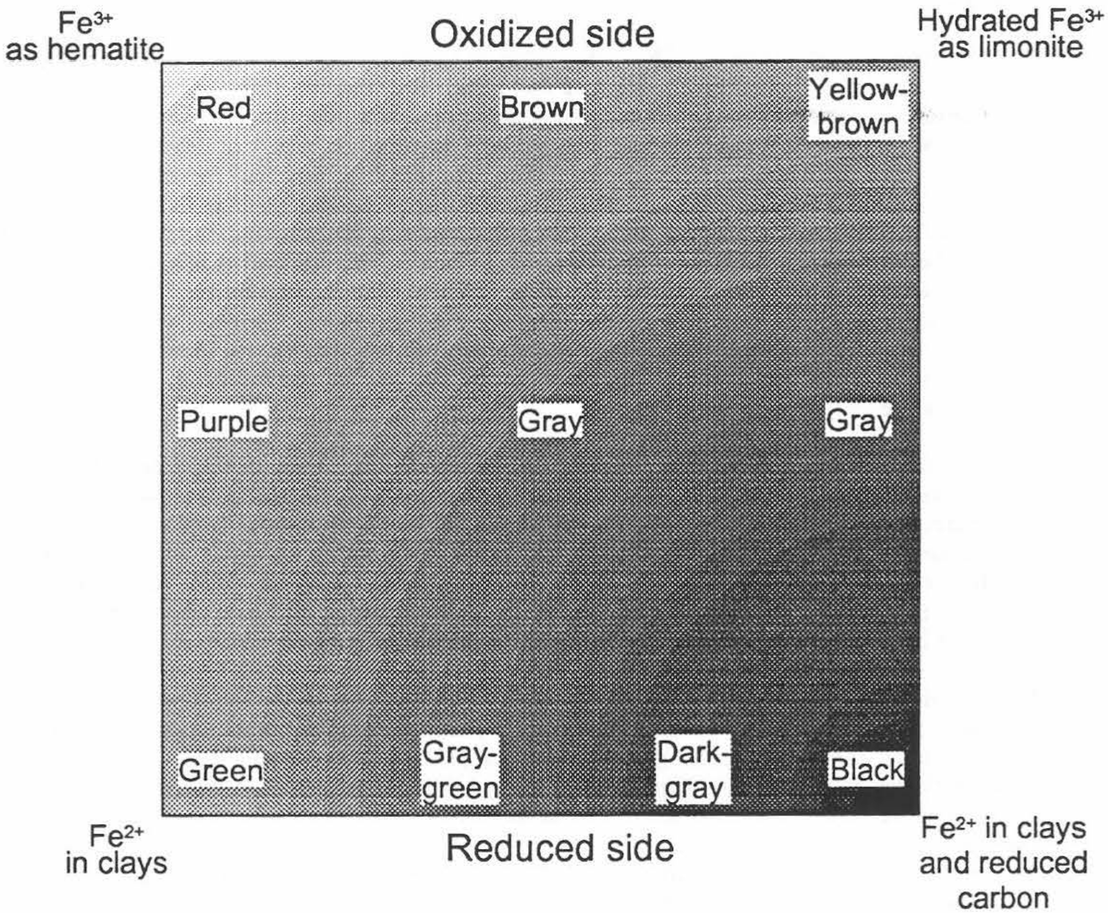


Figure 5. Diagram illustrating the origin of color in many sedimentary rocks. Most minerals in sedimentary rocks are essentially colorless, yet sedimentary rocks have a wide variety of colors. The color of many sedimentary rocks is caused by small quantities of coloring agents that include the forms of iron in the rock and the abundance of reduced carbon. Depending on its oxidation state and the minerals it is in, iron can impart red, yellow-brown, or green colors. Reduced carbon usually imparts a gray to black color. Rocks with little or no iron or reduced carbon are usually light-gray or white.

probably no more radioactive than the other rocks you have seen today, it just has larger (but fewer) crystals that contain these ubiquitous radioactive elements. This rock also contains small xenoliths, or perhaps auto-inclusions, and big, white K-feldspar phenocrysts.

Stop 17 224 State Street. The face of this building is composed of pink biotite granite that contains several xenoliths. Besides these and the zoned feldspars, the most interesting aspect of this rock is that it contains numerous, brownish-red crystals of sphene up to 3 mm long that are shaped like elongated diamonds. The name sphene is derived from the Latin word for wedge, which these pointy crystals resemble. Sphene is useful for radiometric dating, and is one of the second author's favorite minerals.

Stop 18 Fleet Bank, 216 State St. The facing stone of this entryway is composed of an almost black gabbro, an iron- and magnesium-rich rock that is rare as a building stone. The bulk of the rock is composed of dark-gray plagioclase, up to 5 cm long, and black clinopyroxene. These form an interlocking, igneous texture. If you look at a low angle at the highly polished surface, you will see that some patches of crystals are very shiny, like metal. If you look closely at these metallic patches, you will see that there are two different minerals present. One is more shiny and better polished. This is ilmenite which, in large concentrations, is the principle ore mineral of titanium. The other is somewhat duller and more poorly polished. This mineral is magnetite, and its poor polish is caused by its four good cleavage planes. The intersecting cleavages make numerous tiny triangular pits on the surface that are difficult to polish away. Ilmenite and magnetite both crystallized from the magma, are both oxide minerals, and are both natural semiconductors.

This building also has fossil hash limestone and biotite granodiorite. The granodiorite contains phenocrysts of white feldspar.

Stop 19 Curb stone at the intersection of Mill Lane and State St. This rock is a granitic gneiss that has a peculiar texture. Most of the mineral grains are rather small and form closely-spaced layers. The most obvious grains, however, are white feldspars that have angular or broken shapes. This is a particular kind of gneiss known as a mylonite. Mylonites are fault rocks in which fault deformation was by slow ductile flow instead of by brittle fracture. This rock was deformed enough to recrystallize the quartz and micas, but the large, strong feldspars remain intact enough to give an indication of the original grain size of the granite.

Stop 20 YMCA, on the south side facing State St. The lower part of the building is made of highly fossiliferous limestone, in which can be seen bryozoans, crinoids, brachiopods, and gastropods. Some of the stones have layering, both horizontal plane beds and cross beds. These indicate that this rock was deposited in a near shore carbonate bank environment in which currents, possibly driven by the tides, transported and deposited the fossils.

Stop 21 Washington St. at Rotondo Park. The stone wall at this Mohawk River overlook is composed mostly of fine-grained dolomitic limestone. The limestone is made of fine-grained, gray calcite mud (Figure 4), with irregular layers and patches of coarser-grained, brownish dolomite. The dolomite fills ancient worm burrows and bioturbated horizons in the rock.

In addition, the lower part of the wall on the west side contains some blocks of fossil-rich limestone that contain large brachiopods and tabulate coral. There are also some blocks of gray Schenectady Formation lithic sandstone (Figure 2), one of which has exposed flute casts that were formed by the swift turbidity currents that deposited the sandstones.

Stop 22 21 Front St. This house contains an excellent example of a red sandstone. With a hand lens you will be able to see that the rock contains abundant translucent white and pink feldspars in addition to gray glassy quartz and mica. The abundant feldspars mean that this sandstone is classified as an arkose (Figure 2), the grains for which were derived from coarse-grained igneous or metamorphic rocks, and were transported a relatively short distance prior to final sedimentation and lithification into rock. The red color strongly indicates that this sediment was originally deposited on land, which allowed oxidation of the iron to form the red hematite pigment. This rock was probably quarried from Mesozoic red beds in the Connecticut River basin or in the Newark-Delaware basin farther south.

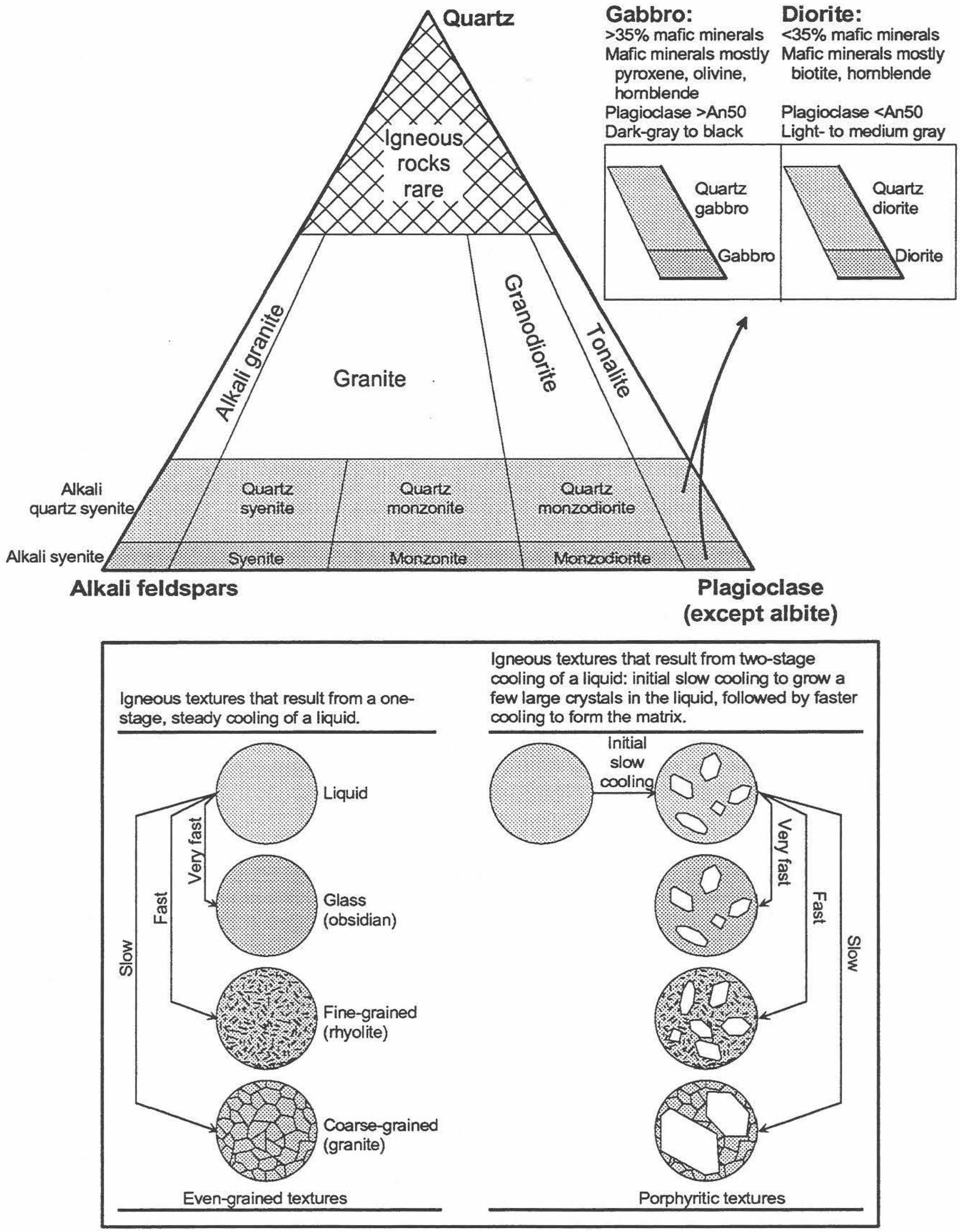


Figure 6. Classification scheme for the common putonic igneous rocks. The alkali feldspars include the Na-feldspar albite, the K-feldspars sanidine, orthoclase, and microcline, and the Na-K-feldspar perthite. The K-feldspars can be pink or white, whereas albite and the plagioclase feldspars are rarely pink and usually white or gray. Anorthosite is a type of gabbro or diorite having >90% plagioclase.

Stop 23 First Reformed Church, at the intersection of Union and Church Streets. This church was originally built in 1862, but was damaged by fire and rebuilt in 1948. The foundation to this church is made of highly fossiliferous limestone that contains abundant bryozoans, brachiopods, tabulate and rugose corals, crinoids, and cephalopods.

The front of the church has steps made of slate, probably from the Taconics in New York or Vermont. The pillars are made of pink granite, containing pink K-feldspar, white albite, clear gray quartz, and black mafic minerals. Several xenoliths can be seen. The coarse-grained red sandstone surrounding the doors is feldspar-rich arkose similar to that at Stop 22. The brown sandstone, which is carved into the forms of corn, grapes, wheat, pine, and oak, is a quartz sandstone in which most of the grains are glassy quartz. In both sandstones the coloring agent is hematite.

The step below the doorway on the east side near the front of the church is a different fossiliferous limestone that contains abundant gastropods up to 4 cm across. This rock also contains thin, black fragments of trilobite shells and sub-spherical ostracods (?).

Stop 24 St. Georges Episcopal Church. In the cemetery next to this church one can see the results of differential weathering. Compare in particular the weathering of marble and red sandstone of stones of similar age.

The stone around the front door is made of fossiliferous limestone that includes beautiful examples of brachiopods, rugose coral, bryozoans, trilobite fragments, crinoids, and fine-grained rip-up clasts that were probably broken up and transported during storms. Some of the rip-up clasts contain thin layers that were probably deposited by algal mats on the floors of quiet lagoons. Most of the church is made of gray sandstone that weathers brown.

Stop 25 First Presbyterian Church, 209 Union St. This building contains red quartz sandstone and blocks of gray sandstone, probably from the Schenectady Formation. The building next door is the Turnbull House. It is made of a red quartz sandstone that has numerous peculiar pockmarks up to 4 mm across. Many of the pockmarks have a rhombic (diamond) shape that is reminiscent of the crystal form of calcite. Calcite was probably the first cement in this rock, which was then followed by a more durable cement such as quartz. When the sandstone blocks were exposed to the weather, the soluble calcite gradually dissolved, and the sand grains which the calcite held in place fell out, leaving the pits.

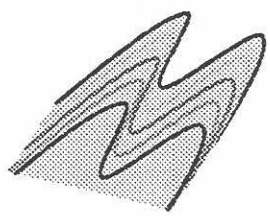
The steps of this building are made of red arkose, in which can be seen numerous black grains which are sand-size grains of the fine-grained metamorphic rocks slate and phyllite. The presence of both feldspars and low-grade metamorphic rock fragments indicates a nearby source area for the sand that was made up of igneous and low-grade metamorphic rock.

Stop 26 220 Union St., Van Antwerp house This old house has a variety of different kinds of slate on its roof. The colors of the slates include black, red, gray, green, and purple (Figure 5). The different shapes, thicknesses, and edge treatments clearly show that the slates had different sources, and were probably periodically replaced to make repairs. The rusty-weathering slates are probably from Pennsylvania, whereas the others are probably from the Taconics in Vermont or New York.

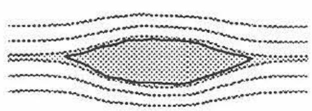
Stop 27 108 Union, the old Schenectady Court House. The steps are made of gray sandstone that has interesting parallel grooves on their sides. These grooves are formed as the plane beds in the sandstone weather out at different rates because of different grain sizes or different cements in alternating layers. The blocks to the sides of the steps are made of fossiliferous limestone that contains tabulate and rugose corals, brachiopods, and other fossils. An excellent tabulate coral can be seen to the left of the steps, and a large cephalopod fragment can be seen just to the right of the steps.

Stop 28 215 State Street. The facing stone beneath the windows is marble. This marble is particularly interesting because it contains stylolites – very wiggly, sub-parallel sets of black lines in the rock. Stylolites form as fractures or other surfaces in the rock, along which water flowed during burial or low-grade metamorphism. The water dissolved some of the calcite, and left the dark insoluble material behind. Dissolution does not form a flat surface, but rather develops interdigitating calcite fingers on either side of the solution surface. This is what makes the stylolites so irregular. The fingers point in the direction of the maximum compressive stress that was acting on the rock during stylolite formation. This building also has muscovite-biotite

Metamorphic grade ↓	Resulting metamorphic rock types			
Very high	Aluminous Gneiss	Quartzite	Marble	Pyroxene gneiss
High	Biotite schist	Quartzite	Marble	Amphibolite
Medium	Muscovite schist	Quartzite	Marble	Epidote amphibolite
Low	Muscovite phyllite	Quartzite	Marble	Chlorite-actinolite schist
Very low	Slate	Quartzite	Marble	Greenstone
Unmetamorphosed Protolith →	**Shale**	**Sandstone**	**Limestone**	**Basalt**



Folds are very common in metamorphic rocks, since most metamorphic rocks have been deformed. Although many protoliths are layered to begin with and remain layered after metamorphism, layering can also form during metamorphism from unlayered protoliths. After severe deformation, inhomogeneities, such as veins, dikes, or pebbles can be smeared out so that they appear to be layers.



Augen (German for "eyes"), are formed from preexisting crystals in a metamorphic rock. Deformation smears out the crystal into a lens (eye) shape, with a fine-grained recrystallized mineral rim, and tails that extend both directions from the crystal in the plane of the rock layering..

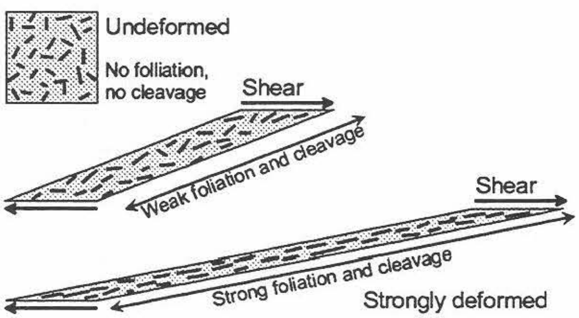


Illustration of how foliation and cleavage develop in a rock. The first block represents an undeformed rock having randomly oriented minerals such as the sheet silicates biotite, muscovite, and chlorite. These minerals are usually plate-shaped and have a good mineral cleavage. Although the minerals have cleavage, the rock initially has no cleavage or foliation. As the rock is deformed by shear (shown here) or flatening, the crystals gradually align themselves parallel to the direction that the rock is being elongated. The parallel arrangement of plate-shaped minerals is the rock foliation. The parallel alignment of the cleavage in these minerals results in a rock having good cleavage also.

Figure 7. The common metamorphic rocks that form at different metamorphic grades from four common protoliths. Metamorphic rock mineralogy and textures can be very complex, and depend on the protolith, which gives the rock its chemical composition, in addition to metamorphic pressure and temperature (grade), degree and type of deformation, and details of the metamorphic history of the rock.

granite facing some portions, and blocks of very fine-grained fossil hash limestone with visible bedding.

Stop 29 225 State St. The facing below the windows of this building is black slate. The surface of the slate is the natural texture that formed when the slate was split along its excellent cleavage. The cleavage of slate is caused by the parallel alignment of muscovite and chlorite, which themselves have an excellent mineral cleavage. The sections of the building between the windows are faced with biotite granite, which contains rare, large feldspar phenocrysts.

Stop 30 Mr. James Salon, 249 State St. The beautiful polished green stone on the outside of this building is a chlorite schist, rare in building stone because it is quite soft and hard to polish. If you look closely, you will see dark red garnets up to 4 mm across in this lovely rock. The most striking thing about this rock is its wavy "grain". The principal grain is a strong foliation of parallel-aligned chlorite crystals. This foliation was developed by deformation during metamorphism (Figure 7). At the time it was formed, this foliation was probably quite planar. The rock was later deformed twice to form two sets of small "crenulation" folds that are similar in size, shape, and appearance to the corrugated paper of a cardboard box. This rock therefore gives clear evidence of three episodes of deformation during metamorphism. Different episodes of deformation probably indicate different episodes of the mountain building event that caused the metamorphism.

Stop 31 Schenectady Federal Savings, 251 State St. This entryway is faced with slabs of spectacular red granitic migmatite. The visible minerals include pink K-feldspar, white plagioclase, glassy-clear gray quartz, and black biotite. As described above, migmatite means "mixed rock" in which some parts appear to be metamorphic rock and others appear to be igneous. The layered portions of this rock are gneisses that have been highly metamorphosed and deformed. The igneous rocks include the entire range from fine grained granite to granitic pegmatite (very coarse-grained). In some places gneissic layers or granitic dikes have been offset by small shear zones (very local and short faults), that formed when the rock was hot, ductile, and probably partly liquid. Some of the granite dikes are obviously intrusive and crosscut layering or other dikes, but some appear to have formed in place by the partial melting of the metamorphic portions. On the polished surface one can see metallic gray and metallic yellow minerals, which are iron oxides and pyrite, respectively.

Stop 32 267 State Street. This building has polished facing stone that looks identical to the dark gabbro at Stop 18, only more fine-grained. The Photo Lab, at 273 State St. has a few small slabs of gray quartz monzonite porphyry (Figure 6) on the lower part of the foundation.

Stop 33 Wall Street, at the intersection of State Street and Erie Boulevard. The lower part of the wall facing Erie Boulevard is composed of fossiliferous limestone. Many of the features that can be seen here are illustrated and explained in Figure 4. Some layers in the rock are composed of very fine-grained carbonate mud that contains few fossils. This may have been deposited in a quiet, possibly hypersaline lagoon environment. The coarse-grained layers that are interbedded with the carbonate mud are made mostly of whole and broken fossils and chunks of rock that look like the carbonate mud. These were probably formed by masses of water that were forced over the beach area into the lagoon during severe storms. The fast-moving, turbulent water carried fossils from the near offshore and beach environments into the lagoon where they were deposited as the currents slowed. In some cases the storm surge currents broke up lithified sediments into smaller stones, which were transported and deposited with the fossils as "rip-up clasts". The storm surge deposits are typically coarse-grained on the bottom and grade to finer-grained on top. Using this rule, you can see that some of the blocks are upside-down from their original orientation. Fossils visible here include gastropods, brachiopods, and corals. Red sandstone and fine-grained fossil hash are also present in this wall.

Stop 34 401 State St. The facing stone on the outside of this building is an almost black diabase, a rock of basaltic composition having a grain size and texture intermediate between that of gabbro and basalt, but having a similar chemical and mineral composition. It is formed in small plutons that cool relatively quickly (in ~1 to 100 years), and in the centers of thick lava flows and lava lakes. This rock contains long, lath-shaped plagioclase crystals that enclose black pyroxenes and metallic iron-titanium oxides. The textures are best seen by looking at a low angle at light reflected off the polished surface.

Stop 35 Center City and CVS, 433 State St. The facing stone here is composed of a "hypersolvus" granite. The granites we have seen previously have had discrete crystals of K-feldspar (pink or white) and plagioclase (usually white in granite, with twinning). This granite has only one feldspar with a composition intermediate between plagioclase and K-feldspar. During cooling, this intermediate feldspar composition became unstable and unmixed into very thin, alternating layers of K-feldspar and plagioclase. The unmixed feldspar is known as perthite. If you look closely with a hand lens you will see the alternating, irregular layers of unmixed plagioclase and K-feldspar in the feldspar crystals. Perthite only forms in slowly cooled rocks. If the rock had cooled quickly, it would still have only a single feldspar.

Stop 36 Jay Street pedestrian mall. Some stores have *verd antique*, green serpentinite, and green to maroon to brown altered serpentinite. The original material for both was probably ultramafic rock, such as a dunite or peridotite, which may have been part of the deep oceanic crust or upper mantle. During metamorphism, the rock was infiltrated by aqueous fluids that turned anhydrous olivine and pyroxene into water-bearing serpentine, talc, and amphiboles, and deposited silica and white calcite. Deformation during metamorphism shattered the rock mass, forming irregular blocks and veins. The altered serpentinite formed when later circulation of oxygen-rich water through the rock caused some of the iron in the silicates to turn to hematite, staining parts of the rock red.

Stop 37 City Hall. This building is among the most splendid in downtown Schenectady, and is a fitting location for the end of the trip. The steps are made out of gray muscovite granite, similar to that found in many other buildings we have seen.

The columns are made of white Vermont marble. These columns show especially well the effects of weathering, similar to that seen on the columns of Memorial Hall on the Union College campus (Stop 2). The side of the columns facing the elements are rather rough and worn-looking. The side of the columns facing the building is contrastingly smooth with sharp edges to the carved flutes. The softness, excellent cleavage, and solubility of calcite in the marble is what makes it so susceptible to weathering.

The historical placards on the front of the building are made of altered serpentinite, similar to that seen along Jay St. at Stop 36.