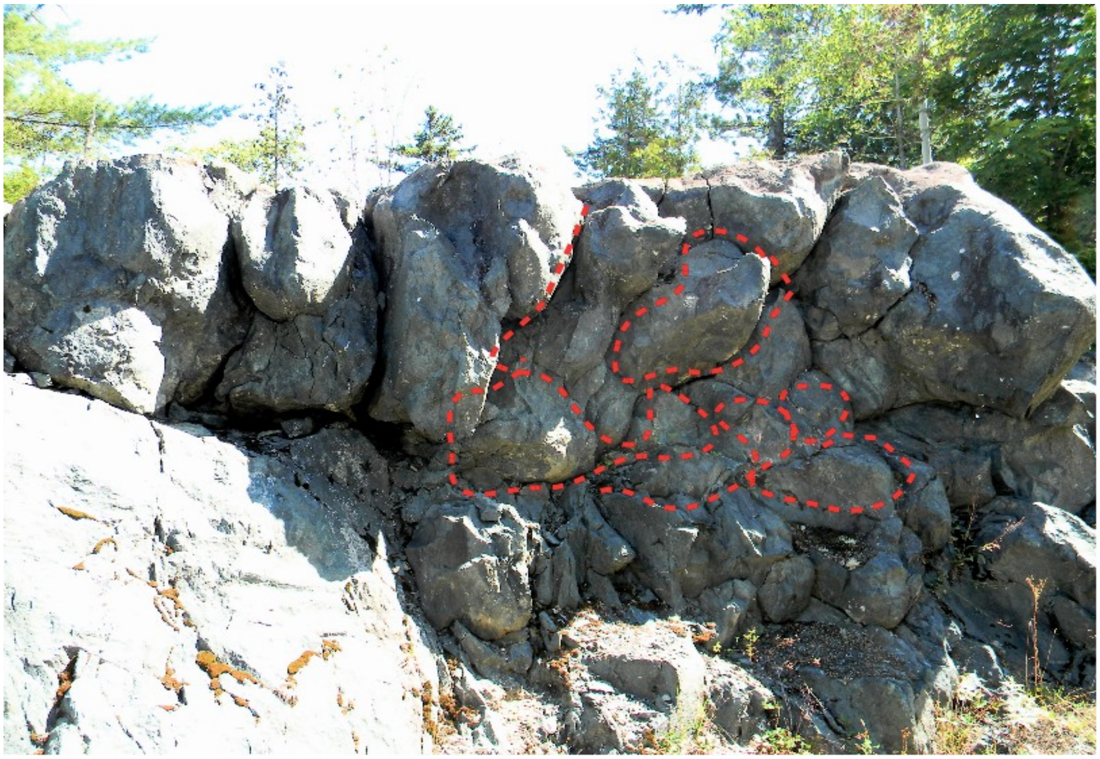
Mary, Margaret, and I went to Clayton, New York in August. Our trip went along our favorite route via Coburn Gore into Quebec to Montreal, then up the St. Lawrence River to Gananoque (almost) and then across the Thousand Islands Bridge into Clayton. The trip has a great mixture of wilderness, farmland, and urban areas. The vistas that reflect the varied geology help make the long trip enjoyable. I can think of much to write about the geology but I will just limit myself to a few locations. I got motivated to write about the geology because of the successful landing of the Curiosity Rover on Mars. This rover's primary mission is to observe and explore the geology of Mars. Our trip fortunately was quicker and required no parachutes or sky cranes. However, the basic method of looking at the rocks to read their story is the same.

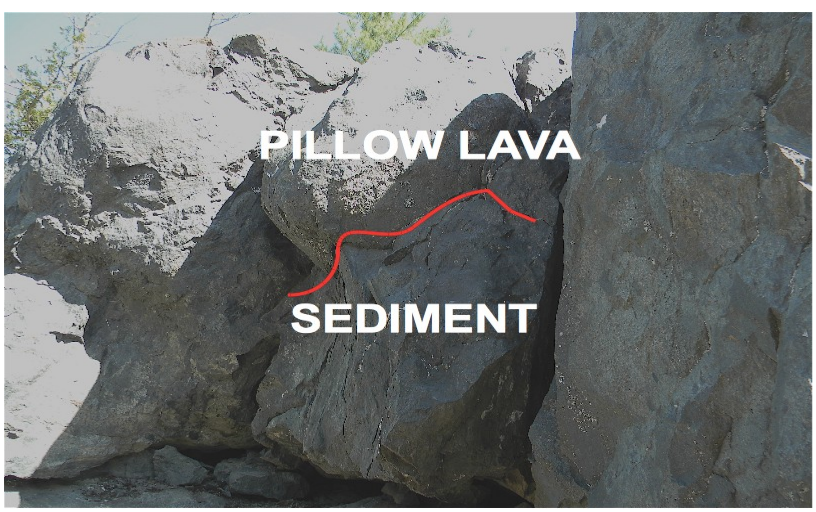
Rocks store information about their history, much of which can be learned by simple observation. This is an aspect of geology that I like, nothing more than observation is needed to start the analysis. I imagine that most people who drive by an outcropping probably notice two things if they look- color and texture. Light rocks, dark rocks, and highly colored rocks come to mind. Texture is another feature that only takes a second to register- rough, smooth, striped, blocky are easily distinguished. I am going to now take you to a rounded black rock, a smooth gray striped rock, and a rough shiny black to gray rock that we passed along the way.

The first outcropping we will observe is along Route 27, not far from the Dead River and north of Eustis, Maine. These rocks are unusual in that they are very black in color and have a bulbous lumpy look to them. This shape is very odd, at least in this region where the rocks tend to be more substantial and massive in outline. Looking more closely at the rocks it is hard to pick out any distinctive minerals, ignoring the white stuff filling in some cracks. If we try to trace around the bulging pieces of rock we are unable to draw a straight line or connect any blobs together in the same plane. In some places, a different kind of black rock wraps around the bulging bits. Just what are we looking at?

This outcropping is composed of pillow lavas that were formed by an underwater eruption. The water quickly cooled the lava as it flowed, thus making the rounded shapes. Think of hot taffy being dropped into ice water. Here I drew red lines around some pillows.



When newly formed, the lava ran across older flows and the lava pushed down into mud. At nearly the same time, the space between flows was filled with mud (the second dark rock). Here is a closer look at a larger pillow pushing into the former mud.



The water must have been deep because I didn't see much evidence of bubbles in the lava. Water pressure at depth keeps gases from escaping the lava, just like the cap on a soda bottle. The lava pillows got pulled by gravity so they became spread out from side to side. These pillows have their long sides going up and down, almost, so they must have been tilted sometime after they were deposited. Now we know a bit of very ancient history. Once there was an ocean or sea here with an underwater volcano that erupted to form the pillow lavas. The lava and mud surrounding the lava were tilted and raised above sea-level, perhaps all during the same geological event. The sea where the lava flowed is now long gone. The rocks look pretty much like they did when first formed, so other that being tilted upright, they have not be subjected to enough heat and pressure to change their outward appearance. A considerable amount of action and motion has happened here over very long time periods. These easily overlooked and somewhat ugly black rocks have an interesting story to tell.

A bit further north along Route 27 is Sarampus Falls. Not a long drop, a meter or so, but there is a large inviting pool below the falls. Also, a conveniently located Maine DOT picnic area, one of the few such picnic stops that are left along our state highways. This pleasant situation makes it a safe and enjoyable place to stop and look at the geology. If you have read Kenneth Roberts' novel about Benedict Arnold's march to Quebec, Arundel, then you will remember the disaster that struck the troops at Sarampus Falls.

Ledges are exposed at the falls and also along the inside edge of the sharp corner in the highway. Be careful looking at this roadside outcropping, the verge is narrow, there is no visibility and the trucks barrel through quite rapidly. Even from the distance you can see that these rocks are different from the other outcropping of black lava.

Here the rocks are gray instead of black. The gray is actually more of a very coarse salt and pepper texture with white (feldspar and quartz) and black (biotite) minerals. A closer inspection shows that the white and black specks make up wispy layers. Notice the larger white mineral aggregate and how the dark layer wraps around it and even looks like they may have been twisted up together like a jelly roll. Here I drew some yellow lines to follow the dark layers.

These rocks have been through a lot heat and pressure to look like this. The rocks were heated to nearly melting temperatures, this allowed the minerals to separate and then there was some amount of shear to form the layering perhaps. Because these rocks have been subjected to high pressure and temperature they must be much older than the black lavas seen just a short distance away. Or perhaps some major geological event, like a fault, brought these rocks together.

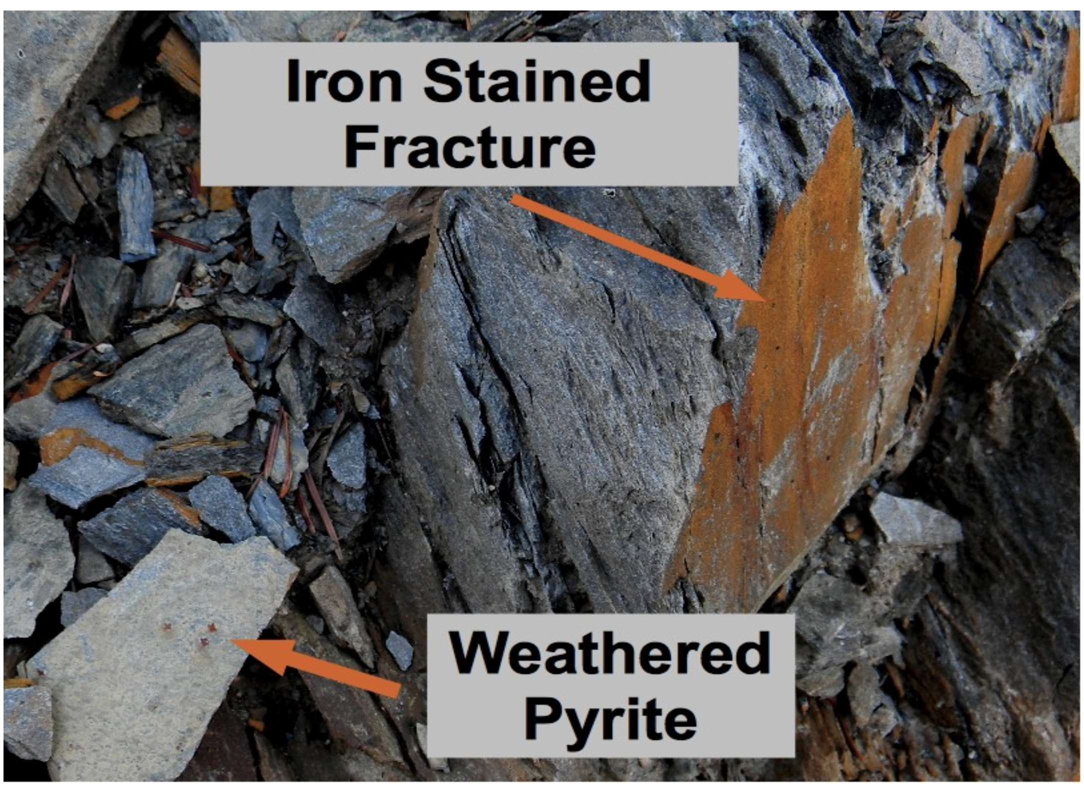
These gray rocks are part of what is called the Chain Lakes Massif. This could have been a micro-continent, an outlying prong of the ancient north American basement such as seen further north and west in Canada, or maybe some unusual geological event metamorphosed some parental volcanic and sedimentary rocks maybe 500 million years ago. These rocks were made from even older volcanic and sedimentary rocks (based on compositions and inclusions of different rock types). They represent an unusual geological association unlike any other exposed for hundreds of miles. The Chain Lakes Massif is something of a geological enigma and quite a few people have tried to explain how it fits into the regional geological history.

The final rock outcropping to be described is to the northwest of the Chain Lakes Massif in Quebec just east of Notre Dame du Bois. Not long after crossing into Canada at Coburn Gore the massif ends somewhere along the road into Woburn, PQ. Woburn lies in a broad flat valley arrayed with trim houses and a lumber mill. You get the feeling of emerging out of the wilderness and entering civilization here. Notre Dame du Bois lies on the road that runs in almost a straight line from Woburn west to Sherbrooke. Straight yes, but up and down over the numerous and rolling hills (mountains). Just before coming into Notre Dame du Bois the road swings sharply over a west facing bluff and there is a picnic area looking out over the village and Mount Megantic to the north (the mountain is worthy of its own post another time). The rocks of interest lie just uphill of the picnic area along the sharp curve.

Depending on the weather at the time, the rocks can appear to be black, but the day we stopped it was sunny and the mica in the rocks made them look silvery, like fish scales. Look at the picture and you can tell easily that this rock is very different from the other two described.

The layering in the rock is more pronounced and regular. The outcropping also has flat surfaces with a rusty orange coating. Looking more closely, you can see that the rock is loaded with tiny flakes of mica, all oriented the same way to make the shiny surface.

The surface has little wrinkles in and not obvious in this picture larger folds several centimeters across. Scattered through the rock are little blocky minerals that look dark red or orange but are actually pyrite. Pyrite, is usually bright yellow, hence its name of fool's gold. The pyrite's surface is dark because it is weathering by reacting with water and gases in the atmosphere and on the surface.



The environment where these rocks formed must have been devoid of oxygen because the iron and sulfur in pyrite are both in a reduced form. The parent of this rock was probably a marine mud laid down in a deep (?) quiet basin where very fine particles could slowly settle to the bottom. No oxygen could get mixed in or was quickly consumed by other minerals. These sediments were buried and then at some point, this sea disappeared. The sediments were heated up and subjected to pressure to make the mica and pyrite crystal form. The pressure caused the mica to be oriented in a parallel manner to give the rock its layered texture. Next the rocks were folded to make the large and small folds perhaps at the same time as the whole region was lifted up in the mountain-building episode. Perhaps when the rocks were lifted up the cracks formed or they could have come later when the rocks were cooler and more brittle. In more recent geological time the rocks became exposed to the surface. Acidic water filtering into the cracks started to dissolve the pyrite to put iron into solution and form sulfuric acid from the sulfur. The newly formed sulfuric acid caused more mineral matter to dissolve and as long as water is available this type of weathering goes on unchecked. This is the same process that causes acid mine drainage. The water has oxygen in it and some of the iron gets oxidized, Oxidized iron is not soluble and settles out of solution as an oxide or hydroxide mineral, maybe even a carbonate mineral, hence the iron staining on the fracture surfaces.

Based on the differences seen in just these three outcrops we know that the Chain Lakes massif was once flanked by undersea volcanoes on one side and a quiet marine basin on the other. Geological forces affected the rocks to tilt, fold, and uplift them but with very different styles of heat and pressure. Even more amazing as we go further up the St. Lawrence River valley the sedimentary rocks have been changed very little and are almost in the same orientation as when they first formed.