What’s underfoot in the Finger Lakes Region ?

Our Earth has looked very different over the past 4.5 billion years since it coalesced into a slightly oblong sphere and began to cool. It is currently covered by approximately seven major and more than a dozen minor rocky plates of crust that float on a sea of molten magma at about 1300-2400 ºF [ca. 700-1300 ºC]. Convection currents in the magma move the plates around or add to existing plates at so-called spreading zones, such as the east African rift valley or along the mid-Atlantic ridge that spreads inexorably about an inch [2.5cm] per year pushing the New World and the Old World apart. Some of the plates are composed of denser material and form the thinner oceanic plates of the sea floors. Other, thicker, so-called continental plates are composed of lighter material and bob higher on the magma than do the seafloor plates. If the tectonic vagueries of magmatic convection currents cause one of each type of plate to be pushed against the other, the seafloor plate is typically subducted beneath the continental plate and melts back into the molten magma. The continental plate rides up over it. As you can imagine, this is a slow process involving tremendous forces. The stick-and-slip friction produces a line of earthquakes parallel to the zone of subduction. It also causes the edge of the continental plate to buckle up and magma from the melting subducted plate often makes its way to the surface through a line of conical volcanos about 150 miles (240 km) inland from the subduction zone. Well known examples are the line of volcanoes in the Cascade Mountain Range of the Northwestern US, and the Andes Mountains along the west coast of South America.

The Finger Lakes Region at 42.520º N latitude and -76.723º W longitude is part of a continental plate, the North American plate. These coordinates pinpoint a second growth woods in Schuyler County between the two largest Finger Lakes, Seneca and Cayuga, and are the coordinates of my house, which seems as good a benchmark as any other for these essays. However, in thinking about the deep history of our region, it is important to remember that this piece of land did not always have this location on the surface of the Earth. And most important for our natural history, just because we sit on a lighter continental plate does not mean that this land was always above water. We know that for more than one hundred million years of its history the Finger Lakes Region was covered by oceans in which layer upon layer of sediment was deposited, either minerals, degraded skeletons of marine invertebrate animals, or soils eroded from mountains to the east. These strata were all laid down horizontally and compressed into stone, either harder or softer. Sometime during the Late Paleozoic Era, the bedrock became tilted down to the south exposing the edges of each stratum that run along west-to-east slices across our region. The oldest ones are exposed in the north at Lake Ontario and they get progressively younger as you travel south through our region to the southern tier of counties at the Pennsylvania border. The Pleistocene glaciers of the past million or so years then modified the exposed edges of the strata by gouging a bit of rock here and adding a bit of rock there to complete the current topography we see. Although you can find much older individual rocks scattered on the surface, as we will discuss in a later section, we'll dig into our story beginning at the oldest outcrop of bedrock in the Finger Lakes Region, the Queenston red shale from the Late Ordovician Period.

460 million years ago - Ordovician mountain building and a visitor from outer space

By the Mid Ordovician, the continents had been floating for many billennia, being added to and subducted, colliding and separating. Around 460 Ma, the principal continental masses were again dispersed around the globe. The North American plate was part of a larger mass called Laurentia that straddled the Equator with the Finger Lakes Region in the southern hemisphere around 25º S latitude. Thus, our climate may have been tropical with a seasonal change in length of daylight of about 4 hours. Most of the continent was submerged under the Iapetus Ocean, which separated Laurentia from a more southeasterly mass of small continental plates, Avalonia and Baltica, which we will run into later, literally, and the large southerly mass of plates called Gondwana (Africa, Madagascar, India, Australia, South America, and Antarctica), which sat over the south pole.

The Laurentian plate was being pushed to the east and the oceanic plate under the Iapetus Ocean was being pushed west. They collided and the edge of the continental crust was subducted beneath the oceanic crust raising a line of volcanoes that stretched in an arc from what would become New England south to Georgia. The oceanic plate kept moving and rode up over the edge of the continent, raising an island chain of mountains called the Taconic Mountains as high as the Himalayas. This period of mountain building, the so-called Taconic Orogeny 475-450 Ma, was the first of three orogenies, the Taconic, the Acadian, and the Alleghenian, that we will see contributing terrane to our current Appalachian Mountains. If these Taconic mountains were as high as the Himalayas, where are they now? What goes up must come down, we learn in grade school, expressing the unstated fact that gravity is more than a good idea, it's a Law. The rocks of mountains eventually wear away and move downhill as boulders, pebbles, and dust under the force of gravity aided by water and wind. Sequential orogenies repeatedly built mountains in the northeastern region of the North American plate. They didn't leave much elevation in eastern New York, but they eroded and washed prodigious amounts of sediment into the seas to their west to become the strata we see exposed in the landscape of The Finger Lakes Region today.

In the Late Ordovician Period the Iapetus Ocean was closing along the eastern shore of the North American plate. The island arc had raised the Taconic Mountains that were eroding down and filling the ocean basin to the west with sediment. This sediment flowed off the mountains as a giant delta that extended the length of the island arc from New England through the Mid-Atlantic states depositing the reddish muds and sandy sediments that would become the Queenston shale, siltstone and sandstone. Geologists call such deposits a clastic wedge. They are clastic because they form as an amalgamation of finer sediment worn from pre-existing rocks, in this case the Taconic mountains. Wedge refers to the cross-sectional shape of the deposit. Heavier, larger, typically sandier, bits of sediment fall out sooner and build a thicker deposit close to the source rock, whereas the finer siltier or muddier sediments are carried farther away from shore producing the thinner apex of the wedge. Such clastic wedges accompanied erosion from each of the three orogenies. Strata from the Taconic Orogeny extend from the eastern edge of New York and can be found as far west as Lake Huron, Western Ohio, and Kentucky. In the Finger Lakes Region, these relatively soft shales and sandstones of the Queenston Delta are exposed as the narrow, roughly 25 mi [16km] wide, Ontario Lowlands extending west to east along the southern border of Lake Ontario. They are not particularly fossiliferous in our area, but east and west of us, these and underlying Ordovician strata are full of fossils of marine invertebrate organisms, such as brachiopods, corals, clams, and trilobites, that lived in the warm, shallow, tropical ocean.

One other bit of Finger Lakes natural history from the Ordovician Period is, regrettably, not visible at the surface. It is a large meteor crater, one of only about 180 known examples of Earth being struck by a galactic visitor. The Bear Swamp Crater in Cayuga County is over 2 mi [3.5 km] in diameter and over 980’ [300 m] deep from the floor to the rim, which is about twice as large as the Barringer Meteor Crater on the desert surface near Winslow, Arizona. Unfortunately, the Bear Swamp Crater is 4000’ [1220 m] underground. It was discovered in 2010 by a geophysicist working for an energy company performing seismic surveys to find strata that might contain deposits of oil or gas. The circular structure complete with a central rebound peak showed up serendipitously in one of the surveys. Two bore holes drilled subsequently recovered grains of shocked quartz, indicative of a meteor impact, as well as material confirming that the top of the crater had deformed the older Queenston red shale and sandstone of the Upper Ordovician Period, and that the crater was overlain by undeformed strata of the younger Lower Silurian Medina Formation. While it would be interesting to explore the crater on the surface, it is still exciting to stand at a spot [42º 43.187’ N, 76º 16.637’ W] near Bear Swamp State Forest and contemplate a fireball sizzling through the atmosphere, vaporizing the shallow sea, and exploding as it hit the muddy bottom around 444 million years ago.

440 million years ago – Niagara escarpment and Silurian salty seas

Between the upper Ordovician Queenston sediment and the lowest Silurian layer, the Medina sandstone, there is what geologists call a disconformity. These simply represent gaps in the temporal sequence of layers. They could exist because the “missing” layers were laid down, but were eroded before the next evident layer was deposited, or they occur in places where sediment was deposited over submerged land, then oceans receded leaving the land high and dry for several millennia and no new sediments were deposited, then it was submerged again and sedimentation resumed leaving a temporal gap in the sequence of strata. We don’t know in this case. Nevertheless, sediment continued to wash into the Appalachian Basin from the east for about 20 million years and consolidated into several hundred feet of layers varying in hardness from relatively soft shales to harder sandstones ultimately to a very hard dolomite capstone. The lowest Silurian layer, the red to grey Medina sandstone, is exposed at the southern edge of the Ontario Lowlands in only a thin band no more than a few miles wide at most extending in New York from the Niagara River east through the Village of Medina in Orleans Co. from which it gets its name to just past Rochester. The outcrop runs parallel to and a few miles south of NYS Route 104 and is largely unnoteworthy as a feature of the bedrock. I mention it here, however, because at the very end of this chapter on geology we will return to Medina sandstone cobbles as a building material for homes, schools, churches, etc. that achieved high “folk art” status in the mid-19th century and is absolutely diagnostic of Finger Lakes Regional construction.

Overlying the Medina Group are several layers of softer and harder material culminating in the middle Silurian Lockport dolostone about 425 Ma. Dolostone is a hard calcium carbonate rock like limestone, $CaCO_3$, but some of the calcium has been substituted by magnesium, $Ca Mg (CO_3)_2$, making it slightly harder and even more erosion resistant than limestone. The Lockport is about 20’ [6m] thick and, depending on the location, caps about 180’ [55m] of much softer sandstones and shales that are eroded beneath it. Thus, the Lockport Formation forms an erosion resistant high cliff called the Niagara escarpment that overlooks the Ontario Lowlands. The escarpment is extensive, stretching to the west through Ontario Canada, Lake Huron, the Upper Peninsula in Michigan and down through Wisconsin and even into Illinois on the west side of Lake Michigan. The Lockport Formation extends east in New York from the Niagara River through the eponymous Town of Lockport (Niagara Co.), Rochester, the Finger Lakes Region, and finally tapers out in Herkimer Co, just east of Utica (Oneida Co.). In the eastern part of New York, the escarpment is not very tall, but in the west it is significantly higher, rising 250’ - 1,000’ [75 - 300 m] above the surrounding lowlands. Although the scarp is very erosion resistant, several rivers have pierced it on their way to Lake Ontario. The most notable, of course, is the Niagara River at the falls which have a drop over the Lockport Formation of about 175’ [53m]. The Genesee River also cuts through the Lockport Formation and two other erosion resistant layers in the City of

Rochester (Monroe Co.). At the so-called High Falls, the river drops about 95' [29m] over the dolostone capstone layer. Further down the gorge the river's drop is controlled by two dams. The Middle Falls, once dropping over several limestone strata in the mid Silurian Clinton Group, is now just a hydroelectric dam. Finally, in the Lower Gorge, the hard Medina sandstone is reinforced with another dam to regulate the flow of the Lower Falls which drop about 110' [33.5] in a cascade down to the Queenston shale and the level of Lake Ontario.

Above the Lockport Formation

Xx this section is incomplete

In the eastern part of New York, the seas were deep and sported a rich fauna, including large, now extinct, relatives of arachnids called sea scorpions, or eurypterids. In fact, the New York state fossil is *Eurypterus remipes,* a fearsome armored swimming predator that grew to over 4' [1.3m] long.

430 Ma Silurian Salty Seas

In contrast to the deeper seas of eastern New York, the Finger Lakes Region was covered by shallow seas that evaporated, flooded again, evaporated, flooded, etc. for thousands, perhaps millions, of years. The accumulated evaporation left large deposits of marine salts, mostly halite (sodium chloride, NaCl), anhydrite (calcium sulfate, $CaSO_4$) and gypsum (hydrated anhydrite, $CaSO_4 \cdot H_2O$), interspersed with sediments that became shale and limestone. Five halite strata are recognized in New York with a combined thickness of about 1000' [300m] extending across about 8500 square miles [2.2M hectares] of Central and Western New York, including the Finger Lakes Region. This salt deposit was aptly, if unimaginatively, named the Salina Formation by the pre-eminent geologist of his era, James Dana (born in Utica NY, 1813), who had first studied the formation at salt springs exposed on the surface in the Finger Lakes counties of Onondaga and Cayuga. This vast salt deposit extends from the Finger Lakes Region west through southern Ontario, Canada, to Michigan, and south through western Pennsylvania and eastern Ohio to West Virginia.

Even though the evaporating oceanic salts must have been laid down in horizontal strata, our Silurian salt layers, and the overlying Devonian shale and limestone layers bearing fossils that will be discussed in a later section, became tilted down to the south on average about 60' per mile [9m/km]. In the northern part of the

Finger Lakes Region, the topmost salt layer is at or very near the surface, forming an intermittent line of outcrops 12 - 20 miles [7.5 – 12.5 km] wide that parallels the shore of Lake Ontario, but removed by about 30 miles [48 km] to the south. At the New York-Pennsylvania border, 65 miles [100 km] farther south, the topmost salt stratum is about 4000' [935 m] deep due to the dip of the layers.

Salt City

The Onoñda'gega' [Onondaga] people had a settlement at the south end of the lake called Ganentaha, now Onondaga Lake, where the city of Syracuse is currently located. They were aware of the salt springs in the marshes around the lake margin, but traditionally didn't use them. The people preserved meat and fish by smoking rather than salting. French Jesuit missionaries working among the Onoñda'gega' people in the 1640s and 1650s commented on the salt springs in their reflections (journals), remarking that some springs were saline while 80 or 100 paces away another spring was fresh water. Père Simon Le Moyne S.J., for whom LeMoyne College near Syracuse is named, noted in his diary in 1654 about the Onoñda'gega' people, "They say it [the spring] is inhabited by a demon who makes it fetid", but he also remarked that from the brine he had "…made salt as natural as sea salt and carried a quantity of it to Québec". Significant salt production, however, didn't really pick up for more than 100 years until American settlers moved into Central New York after the Revolutionary War.

In 1751, Sir William Johnson paid ₤350 to the Onoñda'gega' Chiefs for the land surrounding lake up to a distance of two miles away. Johnson was aware of the salt springs, but there is no record whether he ever produced salt there. He tried to represent himself as an agent of the British Crown purchasing the land to prevent the French from building a fort there but was never repaid for his expenses and the land was willed upon his death in 1774 to his son. After the Revolutionary War, the State of New York passed the Confiscation Act in 1779 and seized lands from prominent British loyalists, including Johnson's son, Sir John Johnson. By then the Onoñda'gega' people had been using the springs for many years, and "improvement" of the lands was discussed in the Continental Congress. It was not until 1788, however, that Col. Comfort Tyler, who had served in the Continental Army around the fort at West Point, NY, travelled to the springs just east of the entrance of Onondaga Creek and set up a salt production facility by boiling saline spring water in kettles to evaporate the water and produce the salt. Later that year in September, as part of the Treaty of Fort Schuyler (formerly Ft. Stanwix), the Onoñda'gega' Nation transferred the rights to salt production around the lake margin up to one mile away and the industry began to take off. The land was called the Onondaga Salt Spring Reservation and in 1797 was acquired by New York state as a public works, lest the salt production fall into the hands of a private monopoly. The state began to regulate production by leasing 10 acre [4 Ha] plots, requiring production of at least 10 bushels per annum, fixed the price maximum at 60 cents per bushel, and initially taxed the production at 4 cents per bushel. The boiling method pioneered by Tyler, Asa Danforth, James Geddes, and other settlers that followed requires the input of energy to evaporate the water from the brine, but the forests surrounding the lake were thick and firewood was plentiful. In 1821-1822 a new method was introduced from the Massachusetts sea coast, namely solar evaporation in large shallow wooden vats. This process basically recapitulates Silurian methodology, and has been done by hand for centuries in coastal Brittany, France, to produce sea salt, such as *Fleur de sel*, or in Essex County, England, to produce the larger flaked Maldon sea salt. In this process, sea water is captured in large flat areas and the water allowed to evaporate naturally under the sun. Simple. This concentrates the salt which begins to form crystals on the surface of the remaining water. The slush is raked by hand to avoid clumping and to speed drying. The process is slow and risky, because a sudden rainstorm can ruin a day's work. The boiling process is faster, more controlled, and works in the dark, although the crystals are not as large due to the constant agitation. Isn't sodium chloride just sodium chloride? Yes, but for certain culinary applications, the longer a crystal lingers on the tongue the more flavor it imparts to the dish. Thus, large flaked Maldon salt is not the salt to throw into the pasta water. It is best appreciated as a finishing salt at the table.

The settlement at the south end of the lake grew with the industry. Syracuse, a.k.a. Salt City, was incorporated in 1825. At the height of boiling operations in 1862 over 17,000 kettles each holding between 50-150 gallons of brine were in use. The wood required by the boiling method was initially plentiful, but with growth of the salt industry several hundred cords of wood per day were required to keep the fires burning, and the surrounding forests had been cut down. By the 1870s, anthracite coal dust, considered a waste product from mining operations in northern Pennsylvania, was shipped in by rail and became the new fuel for the kettles. In the late 1850s the solar salt method produced only about one seventh of the boiling method, but it continued to expand and eventually overtook the boiling method around 1864. The Civil War was good for the Syracuse salt industry. Blockades of southern seaports and the Mississippi River prevented imports of salt from reaching the eastern US, and salt works in Michigan tapping into the same Silurian layers were not yet sufficiently developed. The evaporation method continued to expand and in 1900 there were in operation over 43,000 wooden evaporating pans 3 inches deep totaling almost 275 acres [110 Ha] of evaporating pans. The pans were called covers, because each one could be covered by a rolling roof. Between May and early November, the pans were covered at night and left open in during the day. When a summer rainstorm appeared imminent, an alarm bell was rung and hundreds of men, women and even children rushed to the pans and rolled the covers out to protect the brine from dilution. Reports of the day tell that the entire acreage could be covered in only a few minutes! I do not know whether they held public covering drills, analogous to our timed fire drills today.

To increase the amount of brine that could be evaporated, the next technical development, termed solution mining, was to drill wells down to the deeper salt layers, pump fresh water from the lake into the bore hole to dissolve the layers and pump brine up to the surface for evaporation. Neither the salt manufacturers nor geologists of the day fully understood the underlying geology of the region. They assumed that the brine in the springs must be dissolving rock salt immediately below the surface, but the bore holes did not reveal any shallow salt stratum. We now know such strata exist, as described above, but the springs themselves result from water flowing in an aquifer from the south through subterranean gravel that was deposited by the Pleistocene glaciers. Some channels may be closer to salt strata providing briny water, and in other channels the ground water remains fresh. This accounts for the early Jesuit reports of springs separated by only 100 paces being fresh or saline. Eventually, a bore hole encountered a 70' [21m] thick rock salt bed in 1878 in Wyoming County, just to the west of the Finger Lakes. The salt was at a depth of 1279' [390m] and by 1881 solution mining production of brine had begun in western NY. The discovery of the thick layer of rock salt was a boon to the industry, but the idea of pumping water down into a hole to dissolve the crystalized salt, then pumping the brine back up and driving the water off to reconstitute the salt crystals did seem a bit inefficient. Why not just make the hole wider and send men down into the ground to dig the salt?

Three years later, that's what William Foster did when he founded the Empire Salt Company as the first company to mine dry rock salt, which launched the era of underground salt mining in the Finger Lakes Region. The next year the name of the company was changed to Retsof, which is Foster spelled backwards, and the Retsof Mining Company near Piffard in Livingston Co. became the largest rock salt producer in the United States for over a century. This type of mining is called "room and pillar", in which the hard rock salt strata underground are excavated by explosives with the rubble moved to underground crushers. The smaller salt chunks are moved to the entrance shaft and raised by elevator to the surface where they are further crushed and filtered. The size of the rooms depends on the thickness of the strata, but are typically 8' – 40' [2.5 - 12m] tall and extend roughly horizontally through the salt stratum. At its peak, before its collapse and flooding in 1994, the Retsof mine was the largest salt mine in the United States. It had connected three separate mine shafts and had an underground extent the size of Manhattan Island. To avoid collapses, pillars of the rock salt are left unmined and span the distance from floor to ceiling. The size of the pillars and spacing among the rooms depends on a variety of parameters, including the height of the rooms being excavated and the mass and composition of the material overlying the room. At the Cayuga Rock Salt mine 2400' [732m] below the city of Lansing in Tompkins Co., an 8' [2.5m] tall room would be spanned by square pillars roughly 9' x 9' [2.7 x 2.7m] separated by 32' [10m] to allow the proper safety factor.

Solution mining and room and pillar mining grew to be dominant industries in New York with most of the salt used in the United States during the 19th and early 20th century coming from the Finger Lakes Region.

Xx needs data
Peak in boiling 1862 17,000 kettles
Bushel set at 56 lbs

Although the salt industry is still important in New York and in the Northeast US, it is not as extensive as it once was. Today salt mining in New York is primarily in the rock salt business with room and pillar operations. Once there were many producers, but now there are only two: the Cayuga Rock Salt Mine operated by Cargill in Tompkins Co, which has operated continuously since 1921, and the Hampton Corners Mine operated by American Rock Salt in Livingston Co, which opened in 1998. At 2400' [731m] deep, the Cayuga mine is the deepest in North America. The rooms underlay Cayuga Lake and extend seven miles north from the shaft entrance at the town of Lansing. Although the salt stratum obviously spreads beyond the lakebed, Cargill restricts its operation there so that it needs to negotiate mineral rights with only one landowner, the State of New York. The Hampton Corners Mine opened in 1998 and was the first new salt mine in the United States in 40 years. After the collapse and flooding of the Retsof mine in 1994, the salt was still there and over 200 skilled mine workers, engineers, etc. still lived in the area. Thus, American Rock Salt Co. was formed, and four years later began operation 10 miles [6.3km] from the former Retsof site. It is now the largest salt mine in the United States with capacity to produce 18,000 tons of salt per day.

Solution mining operations have also declined from their heyday. Cargill and US Salt still have operations in Schuyler Co. around the south western tip of Seneca Lake at Watkins Glen, and Morton Salt and Texas Brine Corporation have solution mines at several sites in Wyoming Co. With the emergence of "foodie" culture, there have sprung up several artisanal solution mining operations that produce salt the Silurian way, by solar evaporation. One of them is Seneca Salt Company, which produces a nice culinary flake salt.

Road salt – boon and bane

New York gets a moderate amount of snow each winter, with more in the Finger Lakes Region than downstate due to lake effect snowfall from Lake Ontario, as will be discussed in a subsequent chapter. This icy precipitation can make driving treacherous. As we have seen, however, rock salt for road use is mined in abundance under the

Finger Lakes and the cost of transport to spread it on our roads is cheap due to proximity. Thus, to keep its over 44,000 lane-miles of road safe for winter driving, New York leads the United States with application of over one million tons of road salt in an average winter. That's 23 tons per lane-mile. That's a lot of salt, or perhaps a "Lot's wife" of salt. It is largely effective at de-icing the roads. Sodium chloride dissolves very well in water and lowers the freezing point below 32 ºF [0 ºC] depending on the concentration of salt and the temperature. But when the temperature is below about 10 ºF [-12 ºC] salt becomes ineffective at lowering the freezing point of water, and ice crystals will form. That's ok for most of our winters, as the mean low temperature for Ithaca (Tompkins Co.) in our coldest month, February, is 15.3 ºF [-9.3 ºC].

This prodigious amount of salt builds up on the sides of roads and splashes up on vegetation until the spring rains come to wash it into the roadside soil and the water table and ultimately into the Finger Lakes themselves. This last turn in the 430 million year-long cycle of life together for the sodium and chloride atoms to return to the sea is not without effect on many other organisms in our region and in the Finger Lakes themselves. One of the effects seen earliest in the season is roadside mortality of herbivores, especially woodchucks, *Marmota monax* [Sciuridae]. Like all animals, these rodents need sodium and potassium. These elements are vital for nerve cells to conduct an electrical signal from one cell to the next, whether that occurs during thinking or in contraction of a muscle. Plants, on the other hand, lack nervous systems and contain very low concentrations of sodium. Thus, herbivorous animals eat a diet that is low in sodium, as anyone who visits their cardiologist or dietician is aware. For proper function of their nervous systems, however, many herbivores augment their plant diet by seeking natural sources of salt, e.g., salt springs or salt outcrops, called salt licks because of the behavior that herbivores exhibit there, etc. Farmers put out salt blocks for their free-range cattle. Hunters put out salt blocks to attract deer, although this is practice is illegal in New York. But herbivores do not read the law statutes and will seek out salt wherever it is exposed. Woodchucks that have been hibernating all winter break hibernation in late spring and are very sodium deprived. The roadside accumulation of rock salt is a Godsend. Unfortunately, that's to whom many woodchucks are sent. Whether too many woodchucks wander from the shoulder into a lane or drivers swerve to hit them, the desire for salt coupled with poor eyesight outweighs their caution, and woodchucks are killed by the thousands. I am not aware of any data on the numbers of small mammals killed by traffic, as neither the state DOT nor DEC collects such data. There are, however, days in the late spring when I may see two or three new road killed woodchucks on a 12 mile [19 km] drive on NYS Route 96 in Tompkins County from Trumansburg into Ithaca. Multiplied by all the primary and secondary roads in the Finger Lakes Region, this is an unfortunate cost of road salt usage. The state does keep track of calls to remove carcasses of white-tailed deer, *Odocoileus virginiana* [Cervidae], killed on the road. March exceeds all other months, with does outnumbering bucks by far. Although deer may browse through the winter, they certainly do not get the 8–12 lb

[17-22 kg] of greenery needed to sustain their weight. And does need more sodium than do bucks at that time, because in March they are typically eating for two or three, themselves and the developing twin fawns they often carry. Thus, they also go to the roadsides to feed on accumulated rock salt.

The salt spray from roads also exacts a toll on some plants, particularly conifers. Annual plants pass the winter as seeds, and most woody plants drop their leaves to avoid losing too much water in the dry winter air when they are protected by their dead bark. Most conifers, e.g., pines, spruce, fir, junipers, etc., on the other hand, have evolved to keep their needle-like leaves through the winter and continue performing photosynthesis, albeit at a slower rate due to the colder temperatures. To avoid significant water loss, the needles have a thick waxy coating among other adaptations. These are effective and allow conifers to be the dominant trees in the boreal forests that experience the harshest wintery conditions. But the waxy coating is no match for salt spray. Eastern red cedar, *Juniperus virginiana*, is an exception in being very salt-tolerant and drought hardy. But other conifers, especially white pine, *Pinus strobus,* and red pine, *P. resinosa*, as well as spruce, *Picea* spp., are very susceptible to damage from salt spray. Needles on the side facing the road first are coated with salt which dehydrates the needles and then eventually kills the cells of the needle turning it brown. The concentration of sodium inside white pine needles from damaged trees at the roadside is about 75 times higher than normal and is three times higher than in needles on trees just 20’ [6m] from the road. By 40’ [12m] from the roadside there is little evidence of increased salinity.

Once the snow finally melts and spring rains come, the salt washes into the roadside soil and ultimately makes its way through the watershed to the Finger Lakes. The crusty grey/white stuff is out of sight and out of mind until the next winter, but its effects on our natural history continue. Normal marine plants, such as “sea weeds”, have evolved to tolerate typical concentrations of salt around 3.5%, and estuarine plants have as well. The latter are inundated by salty high tide twice a day. Seaside plants subjected to a lot of salty ocean spray have also evolved to do well in such habitats. But with few exceptions, our native terrestrial and aquatic plants in the Finger Lakes Region did not evolve with heavy concentrations of sodium chloride. The few exceptions are plants directly associated with the salt springs, such as slender glasswort, *Salicornia depressa* [Amaranthaceae]. It is only recorded in New York from Onondaga Co. and from maritime habitats on the Long Island coast.

Some other native plants that have not evolved around saline environments are also somewhat salt tolerant. This physiology is often associated with an evolutionary history of tolerance to drought. We lose water by exhalation of respiratory water, the “breath” you see exhaled in winter, but we lose much more by sweating, which also loses salt. Plants, on the other hand, don’t sweat, but do lose water through their stomata during gas exchange as we do. Thus, as they become dehydrated their internal concentration of salts increases. Several of our plants that are drought tolerant are also adventitiously salt tolerant, such as staghorn sumac, *Rhus typhina* [Anacardiaceae], which is very drought tolerant and also tolerant of salty spay and soil. It flourishes alongside roads throughout New York. Hackberry, *Celtis occidentalis* [Cannabaceae] is a tree that is also drought tolerant and tolerant to salt spray and moderately tolerant of salty soil. It has an unusual distribution in New York, being found in counties along the Hudson River and along the shore of Lake Ontario extending into the Finger Lakes Region.

Roadside invaders

Although areas around salt springs were long the only saline habitats in the post-glacial Finger Lakes Region, during the 20th century roadside habitats have become increasingly salty as winter auto travel became more common. Such habitats have now become welcoming corridors for invasive plants that are halophilic (salt loving), or at least very tolerant of salt. Some notable examples are narrow-leaved cattail (*Typha angustifolia*), common reeds (*Phragmites australis*), and daylilies (*Hemerocalis fulva*), and we’ll give them each a closer look.

Narrow-leaved cattails

The 30 or so species of cattails [Typhaceae] are familiar in marshy, wetland habitats around the world where they emerge from shallower water and grow three to six feet tall [1-2 m] and are easily recognized by their fuzzy, brown, sausage-shaped inflorescence borne on a spike – the cat’s tail - surrounded by about a dozen long, slender, green leaves. The plants can propagate sexually by wind-borne pollen, but they can also spread vegetatively by rhizomes that develop laterally in the soggy soil and send up new daughter shoots called ramets. The most widespread native species in the US is the broad-leaved cattail, *Typha latifolia*, which grows across North America from Alaska to Maine and south to Central America. It likely evolved in Eurasia and spread across the Bering Land Bridge into North America. Pollen assigned to the genus *Typha* is present in sediment cores from Alaska across the US dated to the time of the last glacial maximum. As the glaciers receded, cattails moved northward as soil developed in the proglacial lakes. In the Finger Lakes Region, *Typha* sp. has been recorded in sediment cores at various dates since the glacial retreat: Belmont Bog in Alleghany Co around 4500 y.b.p., Thus, even though the broad-leaved cattail, *T. latifolia*, came from another continent, it has been with us a long time, and we consider it native to our region.

In the early 1800s, however, another species, the narrow-leaved cattail, *Typha angustifolia*, made landfall in New York from Europe. It is easily differentiated by its narrower leaves, 4–15 mm, versus 10-29 mm for *T. latifolia*, and also the separation within the “cat’s tail”. The top part, comprising the male flowers, is separated from the lower sausage of female flowers by a gap of bare stem that can be a half inch up to 4 inches long [1.2-10 cm]. But be careful with identification in late summer. After the male flowers have bloomed, they deteriorate and fall from the stem leaving only the female flower sausage. Look closely and notice that the texture of the spike where the male flowers formerly attached is rough and slightly yellow, but the gap region is smooth and greenish. Back to our invasion. In an 1807 Flora of Plandome, Long Island, NY, only the native *T. latifolia* was recorded. But by 1819, *T. angustifolia* was catalogued in the vicinity of New York City by the polymath John Torrey (born in New York City in 1796), who went on to be a founding member of the New York Academy of Science, the National Academy of Sciences, and the American Association for the Advancement of Science. This date is the earliest I can find for the narrow-leaved cattail in the US. The invader likely arrived in the New World in soil ballast that was unloaded at the port of New York as new cargo was loaded into a ship’s hold for the return voyage to Europe. Soil that was dug for ballast near marshy European ports could easily have contained fragments of rhizomes, or even seeds that can remain dormant in the soil seed bank for many decades. Subsequently, they began to grow after the soil was off-loaded dockside in the New World. By 1894, the narrow-leaved cattail was reported in the Finger Lakes Region in Onondaga Co. and Seneca Co. The Erie Canal that linked New York City up the Hudson River and across the northern ends of Finger Lakes to Lake Erie above Niagara Falls had been completed in 1825. Thus, it was just a matter of time before wetland plants from the New York City harbor area would make their way inland. The New York Flora Atlas additionally records this species from the Finger Lakes counties of Cayuga, Monroe, Tompkins and Wayne. I have also seen it growing in Schuyler Co., in roadside ditches and in a marshy area in my woods. But the narrow-leaved cattail is a more insidious invader than just hitchhiking along the waterways to become a dominant presence in many of our marshes and roadside drainages. It has several adaptations that enable it to get along with *T. latifolia*, and indeed do better than native plants in some waterways. Most relevant to this essay, narrow-leaved cattails are more salt tolerant than broad-leaved cattails in most life stages, but they have other advantages as we shall soon see.

Salty roadside ditches present a challenge to many plants, as described above, but narrow-leaved cattails can do well there as the plant has about twice the salt tolerance of the native broad-leaved plants. The native can obviously do well in roadside drainages, but if push comes to salty shove, the higher tolerance will win out. The seeds of both species can germinate at similar salt concentrations and withstand long exposures to salty conditions. In controlled experiments with step-wise increases of salinity, the leaves of the broad-leaved cattail dried and curled at a salinity of 1%, whereas at 2%, the leaves of the narrow-leaved cattail had reduced growth, but were still green and vigorous. The scenario suggested above that the invasive narrow-leaved cattail was dug for ballast from brackish marshes near European ports could account for its naturally higher tolerance to salty water.

The narrow-leaved cattail also tolerates deeper water than its congener, the native cattail. The broad-leaved plants grow from moist land about 20 cm [7.75''] above the water level to water depths of about 80 cm [31.5"] with a natural abundance around 50-60 cm [19.5'' – 23.5"] depth. On the other hand, the invasive narrow-leaved cattails can also grow in moist soil above the water level but will tolerate deeper water out to about 120 cm [47.25''] deep, also with a natural abundance around 50-60 cm depth. There is no evidence that the two species displace each other. Thus, establishment seems to be "first come, first rooted". However, the extended range into deeper water means that the narrow-leaved plants can still invade into a pond or waterway that already has an established population of the native species closer to the bank.

Finally, the narrow-leaved cattail is allelopathic, which means that it doesn't play well with others. You may be familiar with this phenomenon from black walnut trees, *Juglans nigra* [Juglandaceae], which produce a phenolic chemical compound called juglone in all parts of the tree, especially buds, nut shells, and roots. Juglone is toxic to some plants and can inhibit their growth. Thus, a walnut tree reduces competition for nutrients under its canopy by leaching juglone into the soil. For decades, botanists doubted that any aquatic plants could be allelopathic because any toxic compound would surely be diluted too much in that watery habitat. This turns out not to be the case. Narrow-leaved cattails secrete from their roots several water soluble chemicals derived from phenol, but with much more complicated names, such as *o*-hydroxy cinnamic acid. The inhibitory effects have been tested against river bulrushes, *Bolboschoenus* (= Scirpus) *fluviatus*, a common native wetland plant in the sedge family [Cyperaceae] that also reproduces vegetatively by ramets growing from rhizomes. When plants of the two species are grown experimentally together *au natural* or in soil treated with activated charcoal mixed in to absorb any chemical compound secreted by either plant, there are dramatic differences in growth. In treated soil where chemicals from the cattail are blocked from reaching the bulrush, it develops twice the biomass, longer leaves, and 35% more ramets over several weeks than when the two plants are grown together in untreated soil in which cattail secretions freely diffuse and inhibit the bulrush. Moreover, when grown in the treated soil with the bulrush, the cattail had a 25% reduction in leaf length and ramet number, indicating that when the soil was treated such that the cattail could not inhibit the bulrush, the bulrush out competed the cattail for nutrients. Unfortunately for the bulrush, wetland soils do not have activated charcoal to absorb the so-called allelochemicals of the invader. Thus, the invader can dominate at least one native competitor, and perhaps others, as it moves into new habitats. But the narrow-leaved cattail's allelopathy may have a good side. A trio of the toxic compounds released from its roots have also been shown to reduce the growth of cyanobacteria. They were formerly called blue-green algae, because of their color and they are photosynthetic like algae, but we now know that they are bacteria rather than plants. The cyanobacteria *Microcystis* spp. and *Anabaena* spp. often have explosive population growth leading to "algal blooms" that can be toxic to aquatic organisms by depleting the water of dissolved oxygen and even blocking light from penetrating much below the surface. Their inhibition by narrow-leaved cattail's allelochemicals perhaps benefits the cattail in some way, but the toxic compounds are effective at low concentration and are currently being investigated as a low-cost, natural method to combat algal blooms.

Common Reeds

Common reeds, *Phragmites australis* [Poaceae], present a more complex example of an invasive plant aided by our use of road salt. It is often referred to as a cryptic invasive plant, but you may ask what is cryptic about a stout perennial grass that can grow to 12' [4m] tall. It is common across the US and has existed in wetlands as a member of marsh and fen communities for centuries, indeed millennia. The Anasazi people who lived in the Southwestern US from about 200 B.C.E. to 1500 C.E. used reeds for making many artifacts, such as floor mats, flutes, woven baskets, etc. In our region, people of the Haudenosaunee Confederacy also used the hollow stems, or culms, of native reeds for flutes. Reeds propagate well by vegetative growth, i.e., by spread of roots, rhizomes, and stolons, and also through windborne seeds. But in the late 1700s or early 1800s a different genotype of this species was introduced from Europe, again likely in soil ballast that was unloaded at some Atlantic seaport. Botanical records from herbarium specimens collected before 1910 reveal that the European genotype, referred to as genotype M or *Phragmites australis* subspecies *australis*, was restricted to plants collected from coastal Connecticut, New Jersey and Maryland.

During the early 1900s as automobile traffic and use of road salt increased, this genotype began to spread through New England. After 1960 it was widespread across the United States and into eastern Canada. In New York, it is recorded from eight counties in the Finger Lakes Region plus others that border Lake Erie and Lake Ontario. It is found in roadside ditches, along waterways, and in marshy areas, such as the Montezuma National Wildlife Refuge in Seneca County at the north end of Cayuga Lake. One of the biological attributes of the M genotype of the reed is that it is more salt tolerant than other genotypes. Laboratory tests have shown that it tolerates salinities twice as concentrated as those that kill several native genotypes of the reed. Not only does it tolerate such salty water, but it actually grows better. Thus, the common reed has been part of communities in the US for millennia, but an invasive genotype that loves salt has been able to become the dominant type of reed in the northern Finger Lakes Region by taking advantage of our spreading of 420 million year old salt into our waterways.

Daylilies *Hemerocallis fulva*

When I moved to the Finger Lakes Region from Tucson, Arizona over 30 years ago, this was the farthest east I had lived in the United States. I was very comfortable with plant communities in the Midwest, tall grass prairie, eastern deciduous forest, Ozark glades, etc. I had grown familiar with plants and their rhythms in the Sonoran Desert living there for three years. But I was not deeply familiar with communities in the East. Some of the players were familiar, but some plants and animals were new to me. Because of the long history of colonization by Europeans, I didn't know if a new plant or bug I learned "belonged" here. Was it native to the Finger Lakes Region, or was it brought by colonists, either inadvertently, like the two previous examples of salt tolerant plants? Or had colonists brought it on purpose? Early colonists had certainly brought plants they considered useful for their "kitchen gardens". And in the mid-1800s Acclimatization (or Acclimation) Societies had sprung up across North America and Europe beginning in France dedicated to introducing non-native species, especially birds, to new ranges. One of the most famous stories, which turns out to be apocryphal, is of the supposed desire by Manhattan socialite Eugene Schieffelin to release in New York all the birds cited in the works of William Shakespeare. True, Schieffelin was a member of one of the oldest families in Manhattan and did indeed serve as the Chairman of the American Acclimatization Society based in New York City. In 1890 -1891 the Society released 100 common starlings, *Sturnus vulgaris* [Sturnidae] in Central Park. But starlings and many other species of birds not mentioned by The Bard of Avon had been released for decades by regional societies across the country. The literary reference seems to have been added to Schieffelin's story some 40 years after his death as an embellishment by Edwin Way Teale, the natural history writer, perhaps to highlight the general "… lack of wisdom of introducing foreign species of wildlife without careful consideration."

I knew about the intentional release of non-native birds, such as the starling, the pigeon, the house sparrow, etc. for a variety of reasons, but I wondered about the daylilies I saw. In the Finger Lakes Region they were planted in peoples' yards as I had seen growing up in Missouri. But here, I also saw them growing well in drainage ditches, roadside verges, and even spreading into sunny woodland ecotones. It turns out that they are also not native to North America, but they have travelled much farther than narrow-leaved cattails and M genotype common reeds to get to that same drainage ditch. The common or tawny daylily (or day lily), *Hemerocallis fulva,* is in fact not a true lily. Hence, I will use the combined spelling, as we do with dragonflies, butterflies, etc., which are not true flies like house space flies are. Recent molecular studies have indicated that the daylily is a member of the Asphodelaceae, a Gondwanan lineage with genera in South America, southern Africa, and Australasia, and is more closely related to succulent plants, such as *Aloe* spp, than to true lilies [Liliaceae].

The tawny daylily's journey to the Finger Lakes Region began in the North Chinese Plain and is recorded in song before 500 B.C.E. during the Chou Dynasty (1122 – 255 B.C.E.) The flower buds are digestible and nutritious for humans,

xx how?? Needs data

But don't let your cat near them as they can have toxic effects. Eating just a few leaves can release an as yet, unidentified, water-soluble toxin that causes lethal kidney failure. Thus, even the water in a vase of cut daylilies is dangerous to your cat. Daylilies are safe for humans, however, and also for other mammals that have been tested, including horses, rabbits, rats, mice, deer (unfortunately for gardeners) and dogs. The latter may get an upset stomach, but the symptoms pass when the dog vomits. No kidney failure.

The roots can be used medicinally as an analgesic, a diuretic, and various other remedies depending upon the concoction, and were first illustrated in a Materia Medica from the Sung Dynasty around 1059 C.E. The route from central China to Europe is unclear. The silk road overland trade route that operated from about 300 B.C.E. until it was closed by the Ottoman Empire in 1453 has been suggested. Also, a route that began in Central Asia and then transferred to Indian, Arab, Phoenician (note this term), and other seafaring folk could have brought the daylily to Venice. A similar route was taken by lapis lazuli from Afghanistan to be ground into the pigment ultramarine (Latin for beyond the sea) that was so prized by Medieval and Renaissance artists for coloring the robes of Jesus and Mary.

By the 16th Century the tawny daylily was in Europe. Daylilies had been listed in several herbals in the mid-1500s and were often referred to with Latin names and descriptions. Unfortunately, the Latin nomenclature for plants was not yet standardized. So, unless there was an illustration or very precise description, it is not clear what organism was really being referred to or whether the author had ever even laid eyes on it. In 1576 in Antwerp, Belgium, Mathias de l'Obel (Latinized to Lobelius in the practice Linnaeus would also follow 200 years later) published his *Natural History of Plants*. It contained a woodcut unambiguously figuring the tawny daylily. His description is spot-on for what we recognize today in the roadside ditches. The flowers are yellow-red and borne on a round stem, 18' or more in height [45 cm], surrounded by numerous long slender leaves arising from a perennial rhizome at or just below ground level. The rhizome produces fleshy tuberous storage roots. The flowers are pollinated by insects, and the seed capsules are roughly triangular. The woodcut reveals that the stem bifurcates near the tip. Along each side five or six flowers will develop, but only one per day. They transform from bud to fully open in about 5 hours and remain in bloom for less than one day before senescing. Hence the common name, daylily. In the woodcut, the plant is referred to by the pre-Linnean name of Liriosphodelus phoenicius (recall that one possible route to Europe involved Phoenician trading vessels). It was not until 1753 with the publication of *Species Plantarum* by Carolus Linnaeus [born Carl von Linné] that plant names were codified. We call them Latin names, although, as in the case of the tawny daylily, *Hemerocallis fulva*, Linneaus occasionally used Greek roots. *Hemer* is Greek for day. (Hemera was Goddess of the Day.) *Kalli* refers to beauty, and *fulva* means reddish-yellow or tawny. Thus, the reddish-yellow daytime beauty. And indeed, it is. As I write this passage in early-July the roadsides in the Finger Lakes Region are aflame mile after mile with tawny daylilies.

Twenty years later, in 1596, the tawny daylily was recorded in England. When precisely it got to colonial North America is unclear. The colony of Williamsburg, Virginia established in 1632, kept detailed records of the plants grown there and reports the tawny daylily, but does not mention the first year. The earliest record I can find for the daylily in New York is from Adriaen Van Der Donck, a Dutch lawyer who arrived from The Netherlands in 1641 or 1642, to serve as a sheriff/prosecutor in the independent estate of Rensselaerswijk near current Albany in the Dutch colony of New Netherlands. In 1646, he was granted a parcel of 24,000 acres [97 km^2] on the mainland north of Manhattan Island and began developing his own estate. As a landed young gentleman of means, he was accorded the honorific title of young lord, which in 17th century Dutch was jong + heer, and his estate was referred to as the Jongkheers Land. We now refer to the city that occupies that land as Yonkers. Van Der Donck was very interested in the indigenous culture and became conversant in the language of the Mahican and the Mohawk peoples. In his writings about native plants, he lists and differentiates the red (*Hemerocallis fulva*) and the yellow (*H. flava*) daylilies. Thus, the flowers must have been here and perhaps somewhat naturalized by then.

Both species were common in records of gardens throughout the colonies in the 1700s. But their escape into our roadsides and woodlands seems to have begun in earnest in the second decade of the 1800s. The first record of naturalization I have seen is in Thomas Nuttall's Genera of North American Plants and a Catalogue of Species to the year 1812 (published in 1818).

"Naturalized in moist meadows around Philadelphia, and also in secluded situations on the banks of the Schuylkill… I have introduced it into American Flora to make its future progress which is already such as easily to impose upon a stranger for an indigenous plant."

Xx This section is incomplete

With that, we will leave the Silurian Period and its lasting effects in the Finger Lakes Region and move on to the bedrock of the Devonian Period, which is the exposed bedrock from the New York State Thruway south to the Pennsylvania border.

419 - 358 Ma – Fluctuating Devonian seashores teaming with life … or not

As many frustrated gardeners in our area know, one does not need to dig very deep to strike layers of rock. Millions of years' of layers of rock. Most of the rock exposed in, or directly underlying, the landscape of about one third of New York State, including the Finger Lakes Region, was laid down as marine sediments over roughly 60 million years during the Devonian Period. Indeed, the strata of New York are arguably the most complete, undisturbed assemblage of well exposed layers of this Period anywhere in the world. Tectonic currents had moved the North American Plate a bit southward since the Silurian Period, and by 400 Ma the Finger Lakes Region was about 25º S latitude. Many of the other continental plates were also clustered further south. Most of the North American plate was covered from the south by the Kaskaskia Sea, a warm tropical sea that extended from the current east coast westward across what are now the Great Plains to Nevada, which was elevated just enough to be slightly above sea level. The Rocky Mountains would not be raised for another 300 million years during the Laramide Orogeny about 80-70 Ma.

Acadian orogeny 400-380 Ma and formation of the Catskill Delta

In the Middle to Late Devonian Period, beginning roughly 390 Ma, the North American plate collided with the smaller continental plate of Avalonia/Baltica. This plate had broken up leaving terrane in northern Europe, and the Avalonian plate added crust to the North American plate along the Canadian Maritime provinces and New England down to Connecticut. Neither continental plate was as easily subducted as is an oceanic plate, thus their collision caused compression that raised the Acadian Mountains. The collision lasted millions of years through the end of the Devonian, 358 Ma, and into the Mississippian Period.

On the western flanks of the Acadian Mountains, the rocks flowed downhill through rivers to the Kaskaskia shoreline and eventually formed the Catskill Delta, a great alluvial fan extending across eastern New York and Pennsylvania. Sediments coming off the mountains were deposited in horizontal layer after horizontal layer, thicker in the east and tapering off in the west forming a typical clastic wedge as described above for the Ordovician Queenston red shale. This process persisted over

30 million years in the Finger Lakes Region as the mountains, once as high and peaked as the Andes, became the low hills of today.

Closer examination of the sediments reveals a lot about the position of the shoreline to the east, and the environment of the seas covering the so-called Appalachian Basin of the Finger Lakes Region, Western New York, and Pennsylvania. The size of eroded material from the mountains determines how far out into the sea the sediment is carried by river currents before it falls from the water column, settles on the bottom, and begins its long transformation into layers of sedimentary rock. Heavier sand grains and gravels fall out quickly, close to shore, whereas finer silt and mud particles are carried farther out to sea before they settle. Thus, the grain size of the Devonian sedimentary layers at one road cut or gorge wall indicates something about how far that location was from the delta over millions of years of that rock column's history. One might think that the shoreline of the alluvial fan of a delta only goes one way, i.e., it extends farther from the source of sediments as the river deposits more and more sediment. Taughannock Falls State Park, on the west side of Cayuga Lake about 9 miles north of Ithaca in Tompkins Co. includes the spectacular 215' (65m) high Taughannock Falls. Taughannock Creek which flows over the falls and into the lake has carved its gorge through layers of shale and siltstone depositing the material about one mile away at the edge of the lake to produce an alluvial fan that extends roughly 250m from the shore. This deposition and extension of the shoreline only goes in one direction here because the lake level is relatively constant. However, global sea levels can rise and fall depending upon how much water is tied up in glaciers and polar ice caps. Currently, we are experiencing a warming climate, shrinking glaciers and the subsequent rise of sea levels. Shorelines are receding. But if we drifted into a new ice age, glaciers would grow, sea level would lower, and shorelines would extend farther out onto the continental shelf with little change in the rate of erosion or sediment deposition, but the size of the grains settling out at a particular location would become coarser.

The depth of the sea can also affect the type of sediments that solidify into rock. Warm shallow seas bathed in minerals and nutrients freshly eroded from the mountains are conducive to marine life, especially invertebrate animals, such as corals that sequester calcium carbonate ($CaCO_3$) to build their domiciles, a.k.a. reefs, as well as other more mobile creatures that use the material to build protective shells that they carry with them. As these creatures die or the reefs are abraded, the calcareous shells and reef bits rain down on the sea floor and eventually become limestone. Mud with dissolved organic material that gets washed off the mountain is degraded by decomposing microorganisms and becomes shale, brown or grey, and typically fine grained. But if the muddy sediment falls into a deeper basin that lacks oxygen, many fewer microbes can live there and degrade it. The sediments contain what biologists and geologists call DOC, dissolved organic carbon. These high carbon sediments deposited in anoxic environments become black shales. They often also contain golden flecks of iron pyrite, fool's gold, which is chemically iron and sulfur (FeS_2). At shallower depths the iron is oxidized to limonite ($FeO – nH_2O$), which is basically rust with a variable number (n) of water molecules attached. Animals that fossilize in the black shales often have a gold-colored sheen from the pyrite. Back in the 1970s, paleontologists realized that the iron pyrite was dense enough to show up in x-ray images allowing investigation of the soft internal anatomy of animals that typically does not fossilize. The thin layer of pyrite outlined many internal structures in incredible detail. Beecher's Trilobite Bed in Upper Ordovician dark shale, the Frankfort Formation, in Rome, NY, Oneida Co, just east of Syracuse, is famous for its golden trilobites in the genus *Triarthrus*.

With the foregoing paragraphs laying the groundwork, what Catskill Delta strata can we see in the Finger Lakes Region? Remember from the Silurian salt chapter that the sedimentary layers covering central New York tilt down to the south. Thus, rock layers are seen on edge running roughly from east to west with older layers in the north at Lake Ontario and younger and younger strata exposed as one travels south through the Finger Lakes Southern Tier to the Pennsylvania border.

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Most rock sequences the Finger Lakes Region are missing Early Devonian strata and progress directly from a layer of Late Silurian dolostone of the of the Salina Group, to the Middle Devonian Onondaga Formation of the Helderberg Group, in what is referred to as a disconformity as discussed previously.

Xx discuss laws of superposition? Niels Steensen [1638-1686], anglicized to Nicolas Steno, was a Danish anatomist and geologist who in 1669 published the first treatise to express that fossils were the remains of once living animals

Basic rules of sedimentary geology - layers begin horizontal, upper are older, can be matched across valleys

Nevertheless, generally the lowest Devonian stratum in the Finger Lakes Region is the limestone of the Onondaga formation, which dates to the boundary between the Early and Middle Devonian, about 393 Ma. It is exposed in band roughly 10 to 30 miles wide that runs from the Hudson River Valley in the east, westward across the state to Lake Erie and on through southern Ontario, Canada, over to Lake Huron. Across upstate New York the band parallels the southern shore of Lake Ontario and crops out primarily just south of the NYS Thruway. During the Devonian, the tropical seas were clear and teaming with life. Extensive reef systems were built in the shallow waters offshore of the continental plates and provided homes for communities of many creatures. Today reefs occupy less than 1% of the sea floor, but are home to about 25% of the marine biodiversity. It was likely similar in the Devonian. Reefs were and are built by a variety of organisms including some of the simplest. Thus, it is all the more amazing that their structures are some of the few non-human constructions that are visible from space. The animals that make coral reefs are kin to jellyfish and are polyps that look like small goblets attached at the base with tentacles sticking up, instead of the inverted bowl shape with tentacles hanging down like jellies have. The polyps have a gut cavity with only one opening. Food is stabbed by stinging cells on the tentacles, just like jellies use, then it is moved to the gut to be digested and the waste products go back out through the same hole. This method works, but is not terribly efficient, or appetizing from our point of view. Slightly more advanced organisms evolved the flow through gut – in one hole and out the other - and all other animals, including us, kept it. Each polyp concentrates calcium carbonate from the water and secretes it as a small rocky cup from which the polyp extends its tentacles to feed when it is not frightened. Hundreds of thousands or even millions of the polyps can build something massive, such as the Great Barrier Reef. But most coral polyps also have another source of food. Each polyp has single-celled organisms living in its tissue that are capable of photosynthesis to produce sugar from sunlight and water and carbon. These single-celled symbionts get a place to live within the polyp, and the polyp gets some free carbs. However, the photosynthetic lodgers need sunlight, which restricts most corals to live in clear, shallow water rather than abyssal depths.

Xx

These coral animals, such as tabulate and rugose corals, produced vast reefs that were also contributed to by calcareous sponges, such as stromatoporids, and even some cyanobacteria, photosynthetic bacteria that are still important members of reef communities. Reefs provided the framework for attachment of other invertebrate animals that also had hard shells, such as crinoids, mollusks, and brachiopods.

As millions of these organisms died, their skeletons, some whole, but most broken and abraded, became the calcium carbonate that accumulated and was eventually compressed into the hard layers of the Onondaga limestone. It’s erosion resistant layer forms another escarpment that parallels the Niagara escarpment, some 25 miles to the North. In some layers the composition is also dolostone, which includes the infusion of magnesium into the calcium carbonate as mentioned above in the Silurian Lockport Formation. The outcrops of Onondaga Limestone extend across the north ends of the Finger Lakes, and in the central Finger Lakes Region the Onondaga layer is about 25m (80’) thick. It can be seen in a line of quarries from Jamesville Quarry southwest of Syracuse in Onondaga Co., in the east, through Seneca Stone Quarry, south of Seneca Falls in Seneca Co, to Oaks Corners Quarry run by Hanson Aggregates in Ontario Co. in the west. The strata of these quarries were all deposited in the Appalachian Basin and recorded what was occurring about 392 Ma. Near the top of the Onondaga Limestone layers in the Seneca Stone quarry there are several thin black strata of bentonite clay over a thickness of about 2'. This is the Tioga Ash layer which has been dated around 390 Ma. The collision of Avalonia with the North American plate raised the Acadian Mountains and produced volcanos that spewed ash from time to time. In the Middle Devonian, the Finger Lakes Region was south of the equator and the ash was blown westward by the southern trade winds across what has become Eastern North America. By examining the grain size of the ash – remember that larger grains fall out closer to the source - the volcanos that produced the Tioga Ash are likely to have been in what is now eastern Virginia.

At several local sites the Onondaga Limestone has been quarried for dimension stone, i.e., slabs cut to precise measure, rather than crushed stone, which was used for significant 19th century constructions. The Hall of Languages (1871), the first building of Syracuse University and which initially housed the entire university, is faced with Onondaga Limestone quarried on the Onoñda'gega' Nation Territory south of the city. McGraw Hall (1873), one of the first four buildings on the Cornell University campus housed the original Geology Department and is trimmed with the stone from a now abandoned quarry south of Union Springs, Cayuga Co. The Genesee County courthouse (1841), a wonderful three-story Greek revival structure in Batavia has a façade of stone quarried on Consider Warner's farm in the nearby Town of LeRoy. Downstate, the stone was used for the Brooklyn Bridge that crosses the East River from Manhattan Island to Brooklyn (begun 1869). Massive blocks of Onondaga Limestone from quarries in Kingston, Ulster Co., provide the 60,000 ton cable anchorages underwater. Kingston is east of the Finger Lakes Region located right at the Hudson River on which the stone could be floated to the construction site. Granite is used for the bridge construction above the water line because limestone does not weather as well. Although this decision was made in the 19th century, it was prescient as the tremendous deluge of acid rain falling in the Northeast US during the 1970s would have eaten away at the $CaCO_3$ limestone. Field geologists typically carry a vial of vinegar (acetic acid, CH_3COOH) in their kit to put a few drops onto stone suspected of being limestone. The chemical reaction breaks down the limestone's calcium carbonate into calcium acetate, plus water, plus carbon dioxide gas, which fizzes away [$CaCO_3 + 2CH_3COOH = Ca(C_2H_3O_2)_2 + H_2O + CO_2$] Don't be too disappointed if you have a specimen that you think is limestone, but doesn't fizz. Dolostone looks similar, but the magnesium retards the evolution of CO_2 bubbles.

The Onondaga Limestone and dolostone are harder than the overlying Marcellus shale. As the softer shale erodes, the limestone remains, forming an escarpment across the northern tips of the Finger Lakes that separates the Ontario Lowlands to the north from the Appalachian Plateau to the south. In several places, however, streams have cut through the overlying layers, but have been hung up on the Onondaga and produce an east-west series of waterfalls, not unlike the series of falls and rapids in rivers coming off the Piedmont to the Coastal Plain in the Eastern and Southeastern US. The most spectacular along the Onondaga escarpment is Chittenango Falls in the eastern Finger Lakes Region. It drops about 50 m (167') in several stages in Chittenango State Park, Madison Co., about 13 km (20 mi) east of Syracuse. Farther to the west, Honeoye Falls in Monroe Co. make a more modest descent over the escarpment. And just to the west of the Finger Lakes Region, in Genesee Co. several creeks cascade over the escarpment. Tonawanda Creek about 8 km (12 mi) west of Batavia drops 6 m (20') in a meandering curtain as Indian Falls, and Oatka Creek in LeRoy drops about 2m (6') along a 50m (165') long exposed ledge.

The Village of Seneca Falls in Seneca Co. at the northwest corner of Cayuga Lake is on the escarpment, but is perhaps a bit of a misnomer. There are no falls. Once upon a time there was a stretch of vigorous rapids with the Seneca River dropping about 15m (50') in elevation over the course of a mile. Considering the rapids unnavigable, early settlers created three man-made dams to harness the water power and a prosperous settlement known as Mynderse Mills evolved. The three dams created the only falls in the area. In 1817 the Seneca-Cayuga canal was built to bypass the falls and it provides to this day a navigable link between the two largest Finger Lakes, Seneca and Cayuga. In 1828 the canal was joined to the newly completed Erie Canal that provided a shipping lane from New York City up the Hudson River to Albany and westward across to the Great Lakes above Niagara Falls at Buffalo. The settlement grew even more, and in 1831 incorporated as the Village of Seneca Falls. But in August 1915 the splash pool below the third of the "Seneca Falls" was dammed up and in two days' time the falls were submerged to become Van Cleef Lake. The Seneca Falls exist now only in the village name.

The Onondaga limestone is overlain by about 10 million years of shales that eroded as muds through the Catskill Delta. As sea levels rose and fell, the Finger Lakes Region was further out in a deeper basin or nearer to the delta in shore. The muds layered into shales and mudstones that fluctuated between fine grained and coarser. These shales are named for local areas beginning with Marcellus continuing up through higher layers named after other local places, such as Skaneateles, Ludlowville, etc., Together they make up what is called the Hamilton Group. Because of the tilt of the strata, these shales are exposed in gorges, road cuts and quarries from the Onondaga escarpment extending south into the Finger Lakes Region. They were deposited in shallower seas and are full of fossil remains of over 100 species of invertebrate animals.

Xx perhaps discuss after the joints

I’ll only discuss one of the layers of the Hamilton Group, the Marcellus Shale because it has been in the news quite a bit in the past 20 years. The mid-Devonian formation was named by the NY State Geologist James Hall in 1863 from an outcrop in the Town of Marcellus, southwest pf Syracuse in Onondaga Co.

Across the middle of the Finger Lakes Region, at the top of the Hamilton Group, about 384 Ma, is another layer of stronger limestone xx to xx thick, called the Tully Limestone, named for the Onondaga Co. town south of Syracuse where the strata are exposed at the surface. There are many smaller cataracts that flow over the Tully throughout the Finger Lakes Region, but there are also a couple of spectacular drops. One of the prettiest is Carpenter’s Falls north of New Hope in Cayuga Co. Bear Swamp Creek flows over a 3m (10’) thick slab and plunges about 23m (75’) as the creek makes its way into Skaneateles Lake from the west. The underlying Moscow shale has been eroded away beneath and in back of the slab creating a spectacular natural grotto. A better place to see a larger expanse of the Tully Limestone is in the bed of Taughannock Creek as it flows from the falls eastward into Cayuga Lake. The creek has eroded the overlying shales of the Genesee Group and the harder sandstone of the younger Sherburne Formation to leave the creek bed of the more resistant Tully Limestone exposed for about a mile below the falls. At the entrance to Taughannock Falls State Park the creek makes a couple of small cataracts over the edge of the Tully and you can walk on it all the way up to the splash pool of the Taughannock falls.

Xx incomplete
Portage escarpment
Ithaca falls 150’, Buttermilk falls, Cascadilla falls
western and northern boundary of Appalachian plateau

Late Devonian (372 Ma) extinctions

The Periods of Earth’s history recorded in the geologic column of rocks are not based on any standard timing, but were determined by changes in rock type and fossil assemblages that differed, often abruptly, from one stratum to the next. William Smith, a British surveyor and self-taught geologist in the early 1800s, noted the variety of rock type and fossil assemblages, and how the changes from stratum to stratum corresponded as he worked around England surveying for construction of canals. In 1815 he produced the first geologic map of surface exposures for Britain. It was an astounding accomplishment. It dared to expose the idea that the order of the rocks beneath our feet and the fossils they contain were conserved not just locally, but regionally, and by extension, perhaps even globally. Geologists began to study the strata more closely. Adam Sedgwick, an English priest and another self-taught geologist, and Roderick Murchison, a Scottish geologist, explored north central Wales, which exposed the lowest strata in Britain to contain any fossils. The Welsh people refer to their land as Cymru, but the Romans had Latinized the name to Cambria. Thus, in 1835 Sedgwick and Murchison proposed that the lowest fossil bearing strata be called the Cambrian series (539 - 485 Ma). One of the characteristic denizens of that assemblage is the trilobite *Paradoxides davidis*, which grew up to 50 cm [20"] long. It is also present in Cambrian strata in coastal Newfoundland, having been brought there with the Avalonian terrane as it smacked into North America at the beginning of the Acadian Orogeny around 400-380 Ma. Murchison also studied the exposures of southern Wales, which were higher in the rock column than the Cambrian strata. They contained a very different group of fossils and in 1839 he named those strata the Silurian system, after a Celtic tribe, the Silures, who had lived in southern Wales.

He and Sedgwick also worked farther south in England in Devonshire and described strata that were different from the underlying marine Silurian layers, but also differed from the overlying Carboniferous strata that were loaded with plant fossils. Some of the layers were limestone from abraded reefs. Sedgwick and Murchison collected some fossils, but also relied on specimens collected by Lt. William Lonsdale, a geologist, who had collected and amassed a huge record of fossils in the strata in Devon County, including coral fossils, such as *Favosites* sp., as well as crinoids, brachiopods, molluscs, etc. This was a completely different community than found in the underlying Silurian or overlying Carboniferous, and in 1840 Sedgwick and Murchison argued that it should be named the Devonian, after Devon County. The argument was countered by a couple of other geologists and for several years there raged "The Great Devonian Controversy" whether these strata were simply different layers of the older Silurian Series. After several years and evidence collected from similar strata in Europe, Murchison and Sedgwick's view eventually prevailed and the distinct layers above the Silurian, were named the Devonian. In 1843, James Hall (1811 – 1898), the newly appointed New York State Geologist described the boundaries of Devonian strata across New York State with some of the best exposures occurring in gorges of the Finger Lakes Region. He went on to publish a 13 volume series *The Palaeontology of New York* (1847–1894) that became the definitive work on the stratigraphy of the Silurian and Devonian Period deposits in Eastern North America.

In many cases the boundaries between strata were and are relatively easy to determine because the assemblage of fossils is completely and abruptly different. This is not simply due to local events, such as the advance and retreat of the Catskill Delta shoreline that regularly made the Finger Lakes Region occupy a shallower sea or a deeper water portion of the Appalachian Basin. Such local changes in depositional environments would lead to changes in the creatures living in those waters, and thus their fossils, but the changes would be relatively gradual, as we discussed above. In contrast, the changes in the strata that mark the ends of the geologic Periods are drastic and, as it turns out, global. These represent significant extinction events. There have been five major ones and many people recognize that we are experiencing, indeed we are causing, a sixth global extinction event now due to the alarming disappearance of many groups of organisms. The previous five, in mostly reverse order, occurred at the following stratigraphic boundaries.

The most recent, and best known, extinction event marked the boundary between the end of the Mesozoic Era and the beginning of the Tertiary Era, more commonly referred to now as the Cretaceous-Paleogene boundary, or K-Pg boundary, at 65 Ma. It is well known in popular culture as it marks the extinction of the non-winged dinosaurs, which was followed by the rise of mammals, as well as the winged dinosaurs, a.k.a. the birds. It also marks the extinction of many marine groups, including some cephalopod molluscs called ammonites, which had an even longer evolutionary run than the dinosaurs. This event coincides with the collision of a massive meteorite into the Yucatan Peninsula of Mexico, which has been implicated as causing drastic climate changes that upset terrestrial and marine ecosystems.

The big extinction before that occurred during the Mesozoic Era at the boundary between the Triassic and the Jurassic Periods around 201 Ma. About 50 % of marine invertebrate species were wiped out. Roughly 80% of terrestrial quadrupeds also went extinct.

Xx 50 % marine inverts, 80% of terrestrial quadrupeds. 22% fams 80%spp

Before that was “The Big One”. It marks the border between the end of the Paleozoic Era and the start of the Mesozoic Era, or more commonly referred to as the Permian-Triassic extinction event, at 250 Ma. More than 80% of marine taxa went extinct. Some estimates are as high as 95%. No more trilobites, which had evolved roughly 20,000 species and had been among the dominant arthropods of the Paleozoic Era. The sea scorpions, or eurypterids, also went extinct then. Many types of coral, such as tabulate and rugose corals that had built the massive reefs during the Devonian also went extinct, and many millennia would pass before reefs began to be developed again.

Xx went extinct in the Dev?

Number four in this hit parade is the oldest of the mass extinction events in the fossil record and occurred in the Late Ordovician Period about 445 Ma, just around the Ordovician-Silurian boundary. It was the second most devastating of the “Big Five” with

50-60% of genera of marine creatures going extinct. Terrestrial ecosystems were not very well developed yet, so these numbers represent 50%-60% of all genera, perhaps as much as 84% of all species of creatures large enough and hard enough to be recognized in the fossil record. Trilobites were hit especially hard, losing over 70% of genera. They never really recovered the diversity they had achieved, even though they made it almost another 200 million years, and in our Devonian shales we have representatives of several genera, *Dipleura*, *Greenops*, and *Eldredgeops* (formerly Phacops). The trilobites finally went extinct when the Permo-Triassic event ended their run.

There is one more extinction event included in the "Big Five", number two in temporal order from oldest until now. It occurred in the Late Devonian, just before the Carboniferous boundary, about 365 Ma, and is evident in strata around the Finger Lakes Region. In addition to marine ecosystems, by this time complex terrestrial tropical forests had developed significantly. In the Town of Gilboa, Schoharie Co. about 63 km [100 mi] to the east of the Finger Lakes are the remains of the oldest fossil forest, which dates to about 385 Ma. The Gilboa forest had a canopy at least 8 m tall composed of trees resembling tree ferns and was up on the land above the Catskill Delta. About 20 million years before the extinction event, the forest became buried in sediment associated with a rise in sea level that moved the shoreline even farther to the east. The terrestrial ecosystems that did experience the extinction event lost about 45% of their plant species, but the devastation was even greater for marine ecosystems as we shall soon see. At 365 Ma in the Late Devonian, the Finger Lakes Region was still in the Appalachian Basin with shallower seas in the east closer to the delta shoreline and with deepening seas to the west.

Late Devonian strata are exposed in the southwest part of the state in an outcrop belt that starts at Lake Erie, extends east through Wyoming Co. and then turns southeast being exposed in Livingston Co. before heading south through Steuben Co. New York and into Pennsylvania south of Corning, NY. Several exposures in Wiscoy ?? xx, Big Creek near Hornell and road cuts at Cameron in Steuben Co., NY, and also in Tioga in Tioga Co., PA, just across the state line show evidence from fossils (and lack thereof) of the extinction event. The extinction was actually a one-two punch separated by about a million years around 372 Ma. This is the border between the Upper Frasnian Stage and the Lower Famennian Stage, which is the last Stage of the Devonian Period before the Carboniferous Period. Below this border the strata are composed of shale and silt and are loaded with fossils of creatures that built the extensive Devonian reefs, such as tabulate and rugose corals, stromatoporid sponges, atrypid and strophomenid brachiopods, and a variety of crinoids. Above the border is about 4 m [13'] of dark shale and an abrupt change in fossil composition. The coral reef builders are gone. Many types of brachiopods also went extinct or were severely diminished in diversity.

Estimates of the effects on marine biotic diversity are that roughly 70-80% of species and 20-25% of families went extinct at the Frasnian-Famennian border. This was not just in the Finger Lakes, although the Devonian strata exposed here are particularly illustrative. These losses occurred around the world. In other areas, placoderms, which were among the earliest of jawed fishes, also went extinct. They were not particularly abundant in the fossil record in New York, but they had been a dominant inhabitant of Devonian seas for around 80 million years, and then they were gone.

After the change in rock type, fossils of a different fauna begin to appear. Above the Devonian there are scant few deposits of Carboniferous strata. There are a few square miles literally on the Pennsylvania border. There are many deposits in Pennsylvania. The lower, or older (358 – 323 Ma), Carboniferous strata are termed in North America as Mississippian and are primarily marine limestone deposits. The upper, or younger (323-299 Ma), Carboniferous strata are termed in North America as Pennsylvanian after that state. They contain the remains of amphibians and giant insects that roamed the swampy terrestrial forests composed of large spore bearing trees called lycopods, and an understory of ferns and horsetails. Many of these forests became fossilized and were compressed into the coal beds that powered the industrial revolution in the US.

In the Middle to Late Devonian Period, roughly 370 Ma, the North American plate collided with the smaller continental plate Avalonia. It had been travelling with another small continental plate, Baltica, since the Late Ordovician. This plate had broken up leaving terrane in northern Europe, and the Avalonian plate added crust to the North American plate along the Canadian maritime provinces and New England down to Connecticut. Neither continental plate was as easily subducted as is an oceanic plate, thus their collision caused compression that raised mountains, in this case the Acadian Mountains. The collision lasted many millions of years through the end of the Devonian, 358 Ma, into the Mississippian Period. In addition to raising mountains, the compression also broadly raised land over hundreds of miles of the North American plate, such that sedimentary layers that had previously been deposited horizontally were raised up closer to the contact zone, and tilted down away from the contact zone.

Mesozoic modification of Devonian strata

After the Devonian sediments were deposited, we know very little about what happened in the Finger Lakes Region until the glacial extremes of the Pleistocene Epoch came to an end around 15,000 years ago. There are no sediments younger than the Upper (late) Devonian about 358 Ma. There may not have been any further marine incursions, and there is no record of marine sediments or of terrestrial flora or fauna for that matter.

During the subsequent Carboniferous Period was the Finger Lakes Region covered by steamy tropical swampland teaming with dragonflies sporting meter wide wingspans as were prevalent just across the border in Pennsylvania? Did dinosaurs roam across central New York during the Mesozoic Era? Any traces of communities that had existed were erased by erosional forces and finally scrubbed clean by the relentless cycles of advance and retreat of ice age glaciers, as we will discuss in a subsequent section.

Nevertheless, there are several literal lines of evidence of geologic activity in the Finger Lakes Region between 358 Ma and the last ice age. The first lines are the linear cracks resulting from collisions of drifting continents. During the Devonian Period the Finger Lakes Region was south of the equator, but now it's not, so our continental plate must have been moving northward across the surface of the globe. It was also slowly rotating counterclockwise. The other continents were also moving. At the start of the Permian Period, about 300 Ma, the Finger Lakes Region was about 5º S latitude, and all the continents were joining to form a supercontinent. This concept was pieced together in an amazing scientific *tour de force* by Alfred Wegener (1880 – 1930), a German geophysicist, who in 1915 assembled geographic, geological, glacial, paleomagnetic and paleontological evidence that the current continents had been together in one supercontinent that he named Pangea, from the Greek *pan* for entire and *Gaia* for Mother Earth. Although his ideas were initially controversial and received with skepticism, even ridicule – "how preposterous to suggest that massive continents should actually move over the globe" – we now know that he got it right and Wegener is considered the father of the theory of continental drift. Pangea would stay together until about 180 Ma when the mid-Atlantic spreading zone between two oceanic plates began to push North America and Europe apart, and the great southern land mass called Gondwana began to break up into South America, Africa + Madagascar, India, Antarctica, and Australia.

Although the continents travelled together for millennia, their initial contact was not simply a gentle docking. Around 320-280 Ma, the northwest corner of Africa (as part of the supercontinent Gondwana) slammed into the North American continent all along the Eastern Seaboard during the Alleghanian Orogeny, the last in the series of three Paleozoic Era mountain building episodes in the eastern US. We can see direct evidence of this collision in the Finger Lakes Region. First, the Devonian sedimentary strata, whether limestone, shale, sandstone, etc. had been laid down horizontally. The collision then slightly tilted by ?? Acadian Orogeny in the Late Devonian. The creatures that were buried in vast numbers within the strata had decayed producing large amounts of methane gas trapped among the layers.

Xx comment on prevalence in black shales such as Marcellus, Geneseo, etc

When the collision occurred, the bedrock was stressed and compressed gasses forced their way upward. The pressure caused parallel joints to fracture vertically through the strata that were aligned parallel to the stress field and perpendicular to the direction of the force of the collision with Africa. These joints are readily visible on the surface of exposed strata in stream beds and walls in many of the gorges that feed into the Finger Lakes, e.g., in Tompkins Co. in Taughannock Creek that flows eastward into Cayuga Lake about 9 miles north of Ithaca. Since the collision, the continent has rotated about 20º counterclockwise. These joints are referred to as the J1 joint set and are now oriented around 75º - 80º east of north running from ENE to WSW.

"Fast" forward about 30 million years to around 270 Ma and the plates were still jostling against each other, dancing a continental do-si-do as they moved northward and each rotating counterclockwise driven by its own magmatic convection currents. The Finger Lakes Region was about 10º north of the Equator when northwestern Africa and eastern North America again pushed violently against each other. This time their relative positions had shifted through about 90º of counterclockwise rotation. Again, the pressure caused a set of joints, the J2 set, to break through the Devonian sedimentary strata, but this second set is almost perpendicular to the older J1 set of joints. The J2 current orientation is roughly 10º – 20º west of North, and run from NNW to SSE. The combined pattern of the two joint sets produces a checkerboard grid across the sediments, and weakening due to joints contributes to the rectilinear erosion patterns seen in some of the exposed strata. Great rectangular slabs often fall from gorge walls down onto the creek beds which themselves are criss-crossed by a jointing pattern so regular that it looks to be the unfinished work of some prehistoric stone mason.

Xx add bit about Marcellus Shale here or above

As thin as 5' feet thick across northern half of the Finger Lakes Region where it is exposed. In the south, at the New York – Pennsylvania border however, because of the tilt of the strata the base is farther underground, roughly 4500', and because it was deposited closer to the Catskill Delta the layer is thicker, between 150' and 200' thick.

Magma in the Finger Lakes

Between the breakup of Pangea about 200 Ma and the ice age, there are more lines of evidence of goings on in the Finger Lakes Region during the Mesozoic Era. Unfortunately, they shed no light on the question of dinosaurs. These literal lines are dikes of igneous rock that intruded vertically through the Devonian strata and are composed of minerals in a family generally called peridotite. The type of peridotite occurring in our dikes contains mica and crystalized inclusions whose composition indicates that they originated at relatively shallow levels in the Earth's mantle, about 90-150 km deep. This type of peridotite is called kimberlite, named after Kimberley, South Africa, where such formations became famous, as we shall soon see.

Dikes represent molten magma that forced its way upward, splitting the overlying rock, and subsequently cooled and crystalized. Unlike the western United States which has a long history of volcanic activity, and hence igneous rocks that all start as magma, the eastern US has almost no igneous rocks. Surface rocks are mostly sedimentary, except for the metamorphic heated, squeezed and folded rocks of the Appalachian and Allegheny Mountain chains. But at some time during its northwestward continental drift, central New York passed over a magmatic hotspot strong enough to intrude over 80 kimberlite dikes into our Devonian sedimentary layers, one of the densest arrays of dikes in northeastern North America. They range in width from a centimeter wide to over 3 meters wide for a dike in Williams Creek, Tompkins Co., and most are located around Ithaca in Tompkins Co. and around Syracuse in Onondaga Co. Using radiometric dating methods, primarily uranium – lead and potassium – argon (for a description of radiometric dating see the section on carbon 14 dating of pollen in the forest chapter), the dikes in the Syracuse area were intruded around 125 Ma, and dikes in the Ithaca area of two different mineral compositions were intruded earlier around 146 Ma and again around 120 Ma. The dikes run roughly N-S and push up primarily through the J2 joints that had broken through the Devonian strata some 200 million years earlier. In molten magma, crystals of its constituent minerals have random orientations. But as the magma cools, iron bearing minerals, such as magnetite, begin to develop polarity, i.e., a dipole with positive and negative ends, which aligns with the Earth's magnetic field, like tiny compass needles or a bunch of iron filings under the influence of a refrigerator magnet. As the temperature cools below the Curie Point, about 570 ºC [1060 ºF] for magnetite, this alignment becomes fixed. This so-called magnetic remanence is then a permanent feature of the rock unless it is subsequently re-heated above its Curie point by volcanism or metamorphism or lightning strike, etc. and the crystal orientations become more random. Volcanic lava that is cooling today in Hawai'i, or Iceland, or Sicily, or Indonesia will have magnetic remanence that points toward the magnetic north pole as we know it today. But the magnetic north pole has not always been in the same position relative to the True North Pole around which the Earth rotates. It has wandered quite a bit residing at temperate latitudes and even below. Nor have the continents always been in the same position relative to the North Pole. Thus, the magnetic remanence of the 120 – 146 Ma kimberlite dikes in our area has a dipole, but the north-south axis does not align with the current north-south orientation of the Earth's magnetic field. Given the position and orientation of the North American continent at that time, the Finger Lakes area Kimberlite dikes indicate a paleomagnetic "north" pole located at about 58 ºN and 200 ºE that would place it roughly in Bristol Bay at the top of the Alaskan Peninsula.

The dikes often weather to a lighter color than the surrounding grey shales and limestones. The mineral olivine [$(Mg^{+2}, Fe^{+2})_2 SiO_4$] is a dominant component of the Earth's upper mantle and makes up about 35% of the dike material. It imparts a slightly green cast to the rock, as you might deduce from its name. Nevertheless, the dikes are often difficult to see because most have been overgrown. Many of the dikes originally listed in the older literature of the area have not been seen in decades. Nevertheless, several good examples can still be found. Ironically, one of the easiest dikes to see spans Cascadilla Creek at the southern entrance to the Cornell University campus and intrudes into the Devonian layers underneath Snee Hall, which fittingly houses the administrative offices of the Earth Sciences department. The College Avenue bridge crosses Cascadilla Gorge from "college town" onto the campus. Behind the Cornell welcome sign on the college town end of the bridge is a disused stone stairway that leads down the gorge wall to the creek bed. Watch your step ! Immediately upstream, adjacent to the stairs, the dike is about 1m wide. Bits of mica and other crystalline inclusions sparkling in washed specimens and the lack of stratification allow easy differentiation from the Devonian sedimentary ground rock.

Another relatively easy example to find is exposed around 42.456944º N, -76.525278º W in Williams Creek, which crosses under NY RTE 96 just past Hopkins Place north of Ithaca. About 50m upstream from the road on the north bank of the creek, a majestic old sugar maple more than 1m in diameter hangs on at the precipice of the channel listing just a bit over the creek. Its massive tangle of gnarled roots holds fast to the edge of the 3.5m wide dike that can be recognized by its slightly green-black color and, again, the lack of stratification that is found in the neighboring sedimentary layers of dark gray shale. Under the tree on the left, there is also a vertical vein of white calcite about 3-4mm wide in the dike that has been hypothesized to result from carbonate minerals that came from the surrounding sediments and filled the joint. As you walk from the road to the dike, notice the J1 and J2 joint patterns on the creek bed. A series of small cataracts fall from ascending slabs over their J2 edges that lie perpendicular to the east-west creek bed.

The most picturesque dike to find easily in our area spans Six Mile Creek several hundred meters upstream from the Mulholland Wildflower Preserve in Tompkins Co. at about 42.429267° N, -76.480226° W. The dike is 15-20cm [6'-8'] wide, bears a bit west of north, and rises perpendicular to the creek toward the walking trail. On the upstream side, it is contacted by slabs of bedrock that are protected from erosion by the harder dike. It is exposed on the downstream side, as the softer shale has eroded away. It is easily recognized at low water by the greenish color and, if the day is sunny, the mica and other crystals give it a sparkly appearance lacking in the sedimentary bedrock of our region.

You may have recognized the eponymous name for the dike mineral, kimberlite, as the site of famous South African diamond mines. As the kimberlite magma cools some of the minerals that crystalize out are diamonds. The mines around Kimberley, South Africa have yielded many of the world's largest diamonds since the sites were first discovered on the farm of Johannes Nicholas and Didrik Arnoldus De Beers in 1866. In 1869, the Star of Africa, a diamond larger than 80 carats [0.56 oz] was found that launched a world-wide diamond rush, similar to the California gold rush launched 20 years earlier by the finding of gold nuggets in the creek by John Sutter's Mill near Sacramento. Prospectors travelled to South Africa for several years as more stones were unearthed in nearby mines, and they dug a hole big enough to be seen from space. In 1888, a British geologist determined that the diamonds were borne in peridotite veins that also contained olivine. The news percolated to the US that kimberlite dikes were a source for diamonds, and the composition of the dikes in the Finger Lake Region, though typically narrow, were also composed of kimberlite. There was a flurry of speculation after the turn of the 20th century that conditions might be right for diamonds to be found in the kimberlite dikes here in the Finger Lakes Region. Alas, none has been found...yet.

The Big Chill - Pleistocene glaciation and its results

After the Devonian Period, we really don't know what went on in the Finger Lakes Region other than some Earth shaking effects of jostling among the continental plates, and that our plate later passed over a magmatic hot spot that intruded some diamond-less kimberlite dikes. We do know, however, that the North American plate continued moving northward toward the pole and rotating counterclockwise to the present location of our Finger Lakes benchmark (my house) at a latitude of 42.520º N. While that latitude is not particularly polar, it is no longer tropical either. We know also that the Earth's climate fluctuated and around 2.6 Ma it got much cooler in what is called the Quaternary, or Pleistocene, glaciation. The evidence comes from examinations of the ratio of isotopes of oxygen in dated ice cores and ocean sediments. Each isotope has eight protons, but the heavier oxygen has ten neutrons while the common lighter oxygen has only eight neutrons. During warmer climatic periods, water vapor containing the heavier oxygen isotope moves in the atmosphere farther from the equator toward the poles before it condenses out and adds to the polar ice cap. During colder climatic periods, water with the heavier oxygen isotope condenses out of the atmosphere closer to the equator, and the water that precipitates onto the polar ice caps is relatively enriched in the lighter oxygen isotope. Thus, the ratio $^{18}O/^{16}O$ becomes smaller in the polar ice.

Such climatic cooling also leads to an increase in the thickness and extent of the polar ice caps not just a difference in the isotope ratios. The poles are at a slightly farther distance from the sun than are equatorial lands, and more importantly, polar terrains are at a shallower angle to the sun's rays, thus they are generally cooler and more water vapor condenses there. As the atmosphere gets cooler, more ice accumulates adding mass to the polar ice cap. This pressure from behind and the pull of gravity moves glaciers downhill. But they don't only push ice, they push everything else that is in their way as well. Down to the bedrock. They can even scratch the bedrock in the direction they are moving. Alfred Wegener, mentioned previously as the father of the Theory of Continental Drift, used such directional scraping as some of his lines of evidence that the continents had not always been in their current locations. When he fit the outlines of South America and Africa together, he found that currently disoriented glacial scrapings on each continent became aligned toward a common south pole. Some of the very old literature describes exposed lines of glacial scraping in the Finger Lakes Region, but unfortunately, none of the modern geologists I've spoken with have been able to find any exposures.

Glaciers can sculpt the landscape subtractively as they gouge valleys and smooth the terrain. But they can also have an additive effect where they deposit the rocks or fine mineral dust, called loess, that they push. The spatial extent of a glacier is determined by a balance of the mass of ice added to the more polar, or mountain top, regions, called the accretion zone, versus the mass lost from melting at the face, or terminus, of the glacier, called the ablation zone. This balance is not simply an advance and then a retreat. Or even seasonal, i.e., the glacier advances as more snow is deposited during the winter and then recedes as summer temperatures increase the melting side of the equation. That back and forth certainly can occur, but on a brief time scale relative to stages of glacial advance, when they are really on the move, versus the so-called interglacial stadia, when they are not moving forward.

The most striking landscape effects of the glaciers in our region are the Great Lakes and the subtractive effects of the glacier, the gouging of the valleys of the Finger Lakes themselves. But there are also significant additive effects, such as the thousands of drumlins deposited in the plain between the north ends of the Finger Lakes and Lake Ontario, or the line of glacial rubble of the so-called Valley Heads Moraine extending for miles that blocks the southern ends of the major valleys. We'll begin first with the reveal, i.e., the melting of the ice sheet, then discuss subtraction, and finally conclude with additions to our landscape.

These sections are not completed

Melting produces the pro-glacial lakes, then eventually the Great Lakes

Subtractions are the valleys of the Finger Lakes themselves

Glacial additions to the landscape

On top of the subtractive effects, literally, of the scouring advances of the ice face during the Wisconsin glacial episode, several additive aspects of our landscape were revealed as the glacier retreated for good. In terms of decreasing size these are the moraines, drumlins, and finally individual glacial erratic boulders. As a glacier moves forward it pushes debris of all sizes in front of it. Once the glacier stops advancing and the face retreats through melting, the deposited rocks are called a terminal moraine. With the next advance, the glacier may gouge more rock from the surface and add it to the moraine. It may even push the accumulated mass of the moraine farther down slope. In the 20th and now 21st century many current glaciers are retreating. Back in the 1980s my wife and I visited Athabasca glacier in Jasper National Park, Alberta, Canada. The bare ground in the valley leading up to the ice face was sporadically crossed by lines of rocks 3 to 6 inches high running perpendicular to direction of advance and retreat of the ice face. Each line had a small marker with the year for which that location represented the terminal moraine for that year. It was a startling vision to see that the terminus of that glacial lobe had receded about a mile [1.5 km] in the past century. The stuttering retreat of the glacier in the Finger Lakes Region likely left similar deposits, but as that began roughly 15,000 years ago, re-forestation has obscured all but the larger effects on the topography.

Moraines

The Terminal moraine that marks the maximum extent of the so-called Ontario lobe of the Laurentide Ice Sheet is not very evident in New York. The ice completely covered Central New York, sparing only a bit of southwestern New York, south of Salamanca in Cattaraugus Co. There the Alleghany upland proved enough higher in elevation to stave off being inundated by the glacier’s advance. This unglaciated area, called the Salamanca re-entrant, extends from the Pennsylvania border north to the Allegheny River. There are a few deposits of glacial till evident in road and stream cuts,

Xx Incomplete

A moraine that is a much more prominent feature of the Finger Lakes Region is the Valley Heads moraine. It is a jagged ridge line that runs roughly east to west at the south ends of the Finger Lakes and is composed of rock gouged from the lake valleys.

Xx Again incomplete

Drumlins

Drumlins are classic post-glacial landforms that occur in groups, typically referred to as a drumlin field. You never find only a single drumlin after the glacier has retreated, although we will see shortly that in New York one famous drumlin among the many thousands does have its own name. A drumlin is an elongate, sub-elliptical pile of mixed rock, pebbles, and till deposited underneath the glacier. Unlike moraines, they are only revealed after the glacier's retreat. They have a characteristic shape of a "teardrop" on its side; they rise rather abruptly on the "upglacier" end (north in our area) to heights from 50' -100' (15 - 30 m), then taper down along their length of 0.6 to 1.2 miles [1 - 2 km]. Their width varies from 1300' - 2000' [400 – 600m]. The drumlin field in New York occupies the Ontario Lowlands and extends primarily from the Onondaga Escarpment north to Lake Ontario, and from Niagara and Erie Counties in the west almost 200 miles east to Oswego and Onondaga Counties. It is among the most recognized in the world, and topographic maps or 3D images of the field are often used as exemplars in textbooks of physical geology. Drumlins in any local area typically point their long axis in the same direction, likely the direction of advance and retreat of the glacial lobe in that locale. The mechanisms that produce drumlins are still a matter of debate with some showing evidence of deposition of the accumulated material by meltwater under the glacier, and others perhaps looking more like the melt water sculpted them from a larger previously consolidated pile of material. Digging deeper into the mechanism is beyond the scope of this essay.

Measurements of the orientation of long axis of almost 7000 drumlins across our drumlin field has revealed a clockwise shift as one travels from east to west. In the east, around Syracuse and Oneida Lake, drumlins point to the NW and NNW. In the middle of the field, in Wayne and neighboring counties, they point nearer to due north. And the drumlins west of Rochester tend to point to the NE and ENE. Although their orientation does change, the field is basically oriented north – south and is an impediment to smooth, level east-west traffic. Thus, the NYS Thruway, Interstate 90, that crosses the state from Albany west to Buffalo threads the straightest route south of the main field close to the Onondaga Escarpment such that the construction engineers didn't continually need to cut through drumlins. As you travel that route, note that on the south side you will pass close to more steep hills than on the north side of the road. These are the upglacier ends of the drumlins that road engineers skirted. There are a few that have been quarried, such as…

xx get data

Among the thousands of drumlins spread across the Ontario Lowlands, two have individual names and are tourist attractions in their own rights. The first is actually a small group of drumlins called Chimney Bluffs on the shore of Lake Ontario near the Town of Huron (Wayne Co.) and the other, about 35 mi (55 km) to the SW, is arguably the most famous single drumlin, Hill Cumorah, near the Town of Manchester (Ontario Co.).

The drumlins of Chimney Bluffs are protected in an eponymous New York State Park. As the glacier receded, drumlins were revealed, but many were still under the accumulated meltwater of the proglacial lakes. As the lakes released their water to eventually become the current Lake Ontario, some drumlins remained submerged. However, at the shoreline from around Sodus Bay (Wayne Co.) east to Oswego (Oswego Co.) many drumlins have been partially eroded by wave action to expose their interior composition. Chimney Bluff is about 2 mi (3Km) east of Sodus Bay and is a particularly picturesque array of such partially eroded drumlins.

The most famous single drumlin is in Ontario Co. about 2 mi (1.5 km) north of the town of Manchester on NYS RTE 21. In almost every respect, it is similar, even approaching identical, to the thousands of others in the drumlin field. This particular drumlin, however, has its own name, Hill Cumorah. On the night of September 21-22 in 1827, a 21-year-old treasure hunter and "glass looker", i.e., crystal gazer in our 21st century parlance, named Joseph Smith met with the angel Moroni, who gave him 24 gold plates that had been buried in the drumlin. Smith transcribed the writing on the plates into the Book of Mormon. The legend continues that after Smith finished the transcriptions the plates were reburied or put into to cave in the drumlin. There is currently a Church of Jesus Christ of Latter-day Saints (Mormon) Visitor Center at the drumlin, and every summer from 1937 until the eventual cancellation during the covid pandemic, an elaborate pageant illustrating various stories from the Book of Mormon was staged nightly under the lights atop the drumlin before audiences in the thousands. The plates have yet to be recovered by modern day treasure hunters.

Glacial Erratics

Other noteworthy, but less commonly encountered, additions to our landscape made by the glacier are so-called glacial erratics. The vast majority of material deposited by the glacier – the till or drift - is composed of rocks, pebbles, and dust carried from relatively nearby areas within about 50 mi [80km] upglacier. As we have been discussing, this material derives from sedimentary rock, sandstone, limestone, dolostone, etc. The bedrock in the Finger Lakes Region. Thus, the till looks like the surrounding rock, only ground up. But occasionally one finds large boulders, or much more frequently their smaller eroded fragments in streams, composed of igneous or metamorphic rock, such as granite or gneiss. These rocks were left as calling cards upon the glacier's retreat and remind us that the accretion zone that pushes the glacier's face and its accompanying debris is many hundreds or even a thousand miles upglacier. So where did our igneous erratics come from?

One of the prettier erratics, and most easily recognized as an intruder in our somber looking sedimentary geology, is a coarse-grained granite composed of large bits of glassy greyish quartz embedded in a matrix of pink feldspar. These minerals are formed from the most abundant elements in the Earth's crust, oxygen and silicon. Quartz is silicon dioxide [SiO_2], often with tiny amounts of something else that imparts the different colors to various types of quartz. Feldspars are a large family of minerals that make up more than half of the Earth's crust. They too are based on oxygen and silicon, but also contain aluminum, the third most abundant element in the crust, and then a bewildering array of other elements, such as potassium, sodium, calcium, etc. that confer color and structural properties to the various feldspars. Our pink feldspar contains potassium (elemental symbol K from Latin *kalium*) as its extra element and could have a chemical formula of $KAlSi_3O_8$. It is colloquially called K-spar.

The pink granite is eroded from the Canadian Shield, which represents the bedrock of eastern and central Canada and is among the oldest rocks on the planet to be exposed at the surface. It has been a geologically stable part of the crust called a craton that comprises the North American continental plate. The shield is composed of several geologically and chronologically distinct regions called Provinces. (It is Canada, eh?) The Superior Province from which the pink granite originates solidified from hot magma during the Archean Eon, over 2.5 billion years ago. That's with a B. They are old rocks. Our atmosphere did not even contain significant gaseous oxygen yet, as we will discuss in a subsequent chapter. The Superior Province forms the core of the shield and wraps around Hudson Bay extending through Quebec, Ontario, and into Manitoba. The rock is sometimes referred to as the Laurentian pink granite in the quarry and masonry industry with the grain size varying from coarse to fine depending upon the precise source locale. It also underlies the eponymous Lake Superior, and pushes into the US in Minnesota near the Wisconsin border. Indeed, this pink or red granite is the Wisconsin State Rock. The closest exposure of the Superior Province to the Finger Lakes Region is about 300 miles [475 km], but any particular boulder may have travelled much farther.

Another type of granitic glacial erratic (say that three times fast), is a bit younger, about 1.0 - 1.2 billion years old, and traveled a shorter distance. The stone comes from the Grenville Province which borders the Superior Province to the east and southeast and extends into the US as the Adirondack Mountains. The granite is again a mix of quartz and feldspar, but the composition is different with calcium rather than potassium being the extra element [$CaO \cdot Al_2O_3 \cdot 2SiO_2$]. The Adirondack Region is the largest outcrop on Earth of this type of granite, termed anorthosite, and some of it has ended up in our fields and streams after the glacier retreated. The quartz is darker grey to black and the feldspar is whitish. One famous boulder, roughly 9 tons [8200 kg] and 5‘ [1.5m] in diameter, is the Tarr Boulder on the Cornell University campus Arts Quad outside the southwest corner of McGraw Hall, the first home of the Geology Department. The boulder is named in honor of Ralph Stockman Tarr (1864 – 1912), who served for 20 years until his untimely death as a Cornell geologist, early glaciologist in Alaska, and with Admiral Peary in Greenland. Tarr liked to sit outside McGraw Hall to think and enjoy a pipe. In 1915, his students memorialized him and his thinking spot with a glacial erratic from the Adirondacks that was found on the Hart farm a couple miles south of the campus. The boulder has a seat carved out, and it is still a wonderful place to sit and look to the west over the valley of Cayuga Lake and contemplate the power of the glacier and the wondrous landscape it left us in the Finger Lakes Region.

Lake Iroquois and cobblestone architecture

A glacier recedes when the “glacier equation” becomes unbalanced in favor of more melting from the ablation zone near the face than addition of snow to the accumulation zone of the ice field. Where does that melt water go? Depending on the topography, the water simply drains down the glacial valley through the watershed into a terminal lake with no outlet, or through wider and wider waterways into the ocean. This was a problem, however, for the Laurentide Ice Sheet in Central New York. Glacial advance had been held up by the Late Devonian Portage Escarpment, as described above, and the even higher Alleghany Plateau. In pre-glacial times, water in the lake valleys had originally flowed south,

Describe outlet flow in East vs west Finger Lakes?

but the Valley Heads moraine deposited by the ice sheet blocked that passage, and as the ablation zone receded northward, the melt water had nowhere to go. It pooled up across central New York and southern Ontario forming a large so-called proglacial lake named Lake Iroquois. Its southern outline paralleled the southern shore of the current Lake Ontario, but because the water level of the proglacial lake was about 98’ [30m] higher than that of Lake Ontario, Lake Iroquois extended about xx miles [xx km] further inland onto the Ontario Lowland of what is now New York State.

The glaciers had deposited subangular, erratic rocks of various sizes across all land covered by the ice, as described above. Early settlers called them “field stones” and cleared them from their fields and pastures. The lapping of Lake Iroquois waters at the shoreline, however, deposited a ridge of smoother, rounded, “lake-washed” stones that extended from Buffalo in Erie County along the southern shore of the lake eastward through Rochester in Monroe County, to Syracuse in Onondaga County. You might think that as the glacier continued to recede, parallel lines of stones would continue to be deposited ever northward, as described above for the Athabasca Glacier. But this was not the case here. At its highest level, Lake Iroquois had a continual outlet through the Mohawk River valley to the southeast. At some time, however, the lake level became lower than that channel causing melt water to impound and extend the lake further and further north. But water will find a way out of containment and the eventual release of Lake Iroquois was rather sudden. As the melting ice sheet receded and Lake Iroquois extended further north it was contained by an ice dam just north of the Adirondack Uplands. Around 13,350 y.b.p. the dam gave way, and the lake began to empty into the lower St. Lawrence lowlands and down the Hudson Valley out to the North Atlantic. The valley was scoured, producing an alluvial fan on the continental shelf of Hudson River sandy sediment containing the occasional boulders the size of small cars. The force of this flood was tremendous. The flow rate has been estimated at 80,000 – 90,000 m^3 per second, which over a period of 2.5 months dropped the level of Lake Iroquois about 120m to the present Lake Ontario level.

Thus, after the waters receded exposing the Ontario Lowlands, we were left with the drumlin field and subangular field stones strewn across about 10 counties, and a ridge of smaller, smooth, lake-washed, oblong to round stones deposited inland from the edge of the new Lake Ontario. The smaller field stones and the lake-washed stones together are referred to as cobblestones, which the American Geosciences Institute defines as measuring about 3 to 10 inches [60 – 254mm]. They are roughly hand sized. The most abundant ones are comprised of dark red to gray early Silurian Medina sandstone, which comprises the bedrock exposed at the surface along a line parallel to Lake Ontario about 4-8 miles [6–12 km] inland. That formation made a brief appearance at the start of this geology chapter. It is understandable that such rock would be eroded into cobbles by glacial scrubbing and wave action of subsequent proglacial lakes and deposited nearby. But other cobbles deposited in the ridge are derived from more exotic rocks, such as coarse and fine-grained igneous and metamorphic rock, granite, quartzite, gneisses, etc. initially delivered by the glaciers from much farther north.

Members of the Onöndowa’ga:’ (Seneca) Nation lived in the area and used the ridge as a trail to cross the Ontario Lowlands between the new lake shore and the Niagara Escarpment, some 4-5 miles (6-8km) further south. After European settlers moved into the area the trail was widened in 1798 into a stagecoach turnpike that was eventually, and appropriately, called Ridge Road East and Ridge Road West. In 1926 it was designated as U.S. Route 104 that extends from Lewiston at the western border of NY, east through Rochester, further on to Oswego, and ending in Williamstown

(Oswego Co.). In the middle of the 19th century, roughly from 1820 until 1860, the lake-washed stones and similarly sized field stones were used in a characteristic style of cobblestone architecture for homes and public buildings. Between 700 and 1200 such structures are known to have been built in the United States, with earlier ones incorporating more field stones and later ones more lake-washed stones. Over 90% of these cobblestone structures were built within a 65 mile (180km) radius of Rochester NY (Monroe Co.) with only about 70 structures known from other states ranging from Colorado to Vermont. The hand-sized cobblestones were arranged in linear rows, called courses, separated by an inch or so [3cm] of a soft lime or quicklime (calcium oxide, CaO) mortar joint. Larger blocks at the corners of the walls, called quoins, were constructed of dimension stone, often cut from local limestone, dolostone or sandstone. This absolutely iconic Finger Lakes Region construction pattern developed into something of a folk art, with various stone masons adopting particular embellishments to the basic pattern, e.g., mixing round with oblong stones, or alternating contrasting red and grey colors, or opposing oblong stones at an angle in neighboring courses to produce a herringbone pattern. Many of the buildings still stand and are listed on the National Registry of Historic Places by the US National Park Service. The Cobblestone Society has a museum complex in a cluster of cobblestone buildings along Route 104 in the Hamlet of Childs (Orleans Co.).

One of the earliest cobblestone buildings still standing is the Roe Schoolhouse, sometimes called the Watson Schoolhouse, in the Town of Butler (Wayne Co.). It is located on NYS Route 89 at Van Vleck Rd about 1.5 mile [2km] south of Ridge Road (US Route 104). It is a modest, 20' x 28' [6 x 8.5m] one-room structure built around 1820 in the Federal style by Daniel Roe using rougher, irregular field stones that Roe and his family removed from their property. The field stones are from a variety of rock formations, some local bedrock and others are older erratics brought by the glaciers from Canadian bedrock. The quoins are roughly cut from limestone or dolostone, likely from the Clinton Group that overlies the Medina sandstone. The building initially served as an early Methodist meeting place and a one-room schoolhouse until the early1930s when the local schools were consolidated. It is now operated as a Museum by the Butler Historical Society.

A fine example of the middle period of cobblestone construction is the Tolford-Feldman House in the Town of Ridgeway (Orleans Co.) at 2499 Swett Rd, just north of Ridge Road. It is a two-story structure built in 1845 in the Greek Revival style. Courses on the sides of the house are set with irregular field stones. But the front of the house and the tops of the sides underneath the gables are set with smooth, oblong lake washed cobbles of red and grey Medina sandstone in a beautiful herringbone pattern. The Village of Medina, from which the stone is named, is also located in the Town of Ridgeway.

Octagonal houses became a short-lived construction fad after the 1848 publication of Orson Squire Fowler's book "The Octagon House, A home for All". Fowler built his home, pejoratively dubbed Fowler's Folly, in Fishkill (Dutchess Co.) southeast of the Finger Lakes Region. In 1850 James Coolidge was inspired to construct a two-story octagonal house on Main Street in the Village of Madison (Madison Co.). Coolidge designed an even more oddly shaped building a few miles to the west on NY Route 20 in the City of Bouckville that was completed in 1851. It was called the Coolidge Stores building and currently houses the Landmark Tavern. Both the octagonal home and the larger irregular six-sided storehouse are constructed in the Greek Revival style, and use courses of closely size-matched spherical cobbles.

A final unusual cobblestone structure is the Town Hall of the Town of Ulysses in the Village of Trumansburg (Tompkins Co.). The structure is in the Greek Revival style faced with narrow courses of about 3000 field stone cobbles collected in Genoa (Cayuga Co.). The lintels and sills at the windows, and the quoins are cut from Llenroc, a local mid-Devonian sedimentary sand/siltstone quarried by the Finger Lakes Stone Co. of Ithaca. Llenroc application is unusual in that the stone slabs are applied at 90^o to the bedding plane, exposing the original horizontal surface on the vertical walls. The stone is more fragile in this orientation as roots and freeze/thaw weathering can cause sedimentary layers to flake off. Nevertheless, the attractive stone provides a decorative, often fossiliferous, element as a veneer, rather than as structural support. Many buildings on the campus of Cornell University in Ithaca are faced with this stone, especially on the Engineering Quad. Indeed, Llenroc is Cornell spelled backwards. Ironically, because the Llenroc laminae are susceptible to flaking due to penetration by roots, etc. the buildings in this part of the Ivy League university campus are not permitted to be covered with ivy. The Ulysses Town Hall, though constructed in a mid 19^{th} century cobblestone style, is actually relatively new. The original structure was a woodframe and cinderblock building that housed a tractor dealership. Xx x then what??

In 1997-1998, however, the building was expanded and given a cobblestone façade. One of the architects was Mark Inglis of Wayne County, a descendent of a cobblestone mason, and the project was carried out by Paul Briggs, a stone mason from Lansing (Tompkins Co.) with experience in cobblestone restoration.

Xx No summary yet