Trip A-1

THE SALT OF THE EARTH AND THE SOUL OF THE SILURIAN SEA - THE UPPER SILURIAN SYRACUSE FORMATION AND ADJACENT FORMATIONS IN CENTRAL NEW YORK

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INTRODUCTION

The Syracuse Formation occurs within the Upper Silurian Salina Group in the northern Appalachian Basin. Considerable attention has been paid to this formation in the past based on the occurrence of economic quantities of rock salt (halite) and gypsum, which are of significant importance to the historical and economic development of the region. In addition to rock salt and gypsum, the Upper Silurian rocks of central New York State contain a wide variety of interesting and important geological characteristics. While considerable attention has been paid to the occurrence and distribution of halite and gypsum, less attention has been paid to the sedimentary petrology, geochemistry, and paleontology of the Syracuse Formation. The same is generally true for the underlying Vernon Formation and the overlying Camillus Formation. A significant reason for this may be the general softness/lack of resistance of the various lithologies to the processes of mechanical and chemical weathering, coupled with relatively low relief topography in the central New York outcrop belt, which collectively result in limited numbers of (and quality of) rock outcrops available for study. During recent field work, the author has noted that a significant number of the outcrops previously described in the published scientific literature are currently covered or are otherwise inaccessible due to weathering, subsequent land development activities, or other property ownership or management considerations. Luckily, we can supplement the relative scarcity of accessible rock outcrops by examining rock cores through these formations collected from the subsurface. The New York State Museum/Geological Survey maintains (and makes available for study) a collection of rock cores and well drill cuttings from across the state. Rock cores and drill cuttings are typically obtained by the State Museum from oil and gas exploration and development, salt solution mining, or construction project activities.

The goal of this field trip is to provide participants with an opportunity to visit a few of the more accessible outcrops remaining in central New York State to provide a general introduction to the lithological and paleontological characteristics of these fascinating formations. The locations of stops are shown in Figure 1. We will also stop at Cargill's Cayuga Salt Mine, a currently active salt mine located near Lansing, New York, to receive a presentation from the mine's manager (Mr. Shawn Wilzynski) and his staff regarding the mine's geology and operations. Cargill's presentation will be at the surface and we will not be visiting subsurface portion of the mine during this field trip. We are very grateful to Cargill, Mr. Wilzynski, and his team for their willingness to welcome us to their facility, provide us with a presentation on their operations, and show us some rock samples from their mine. Cargill's assistance to our group will contribute significantly to the continuing professional education of current and future professional geologists in New York State.

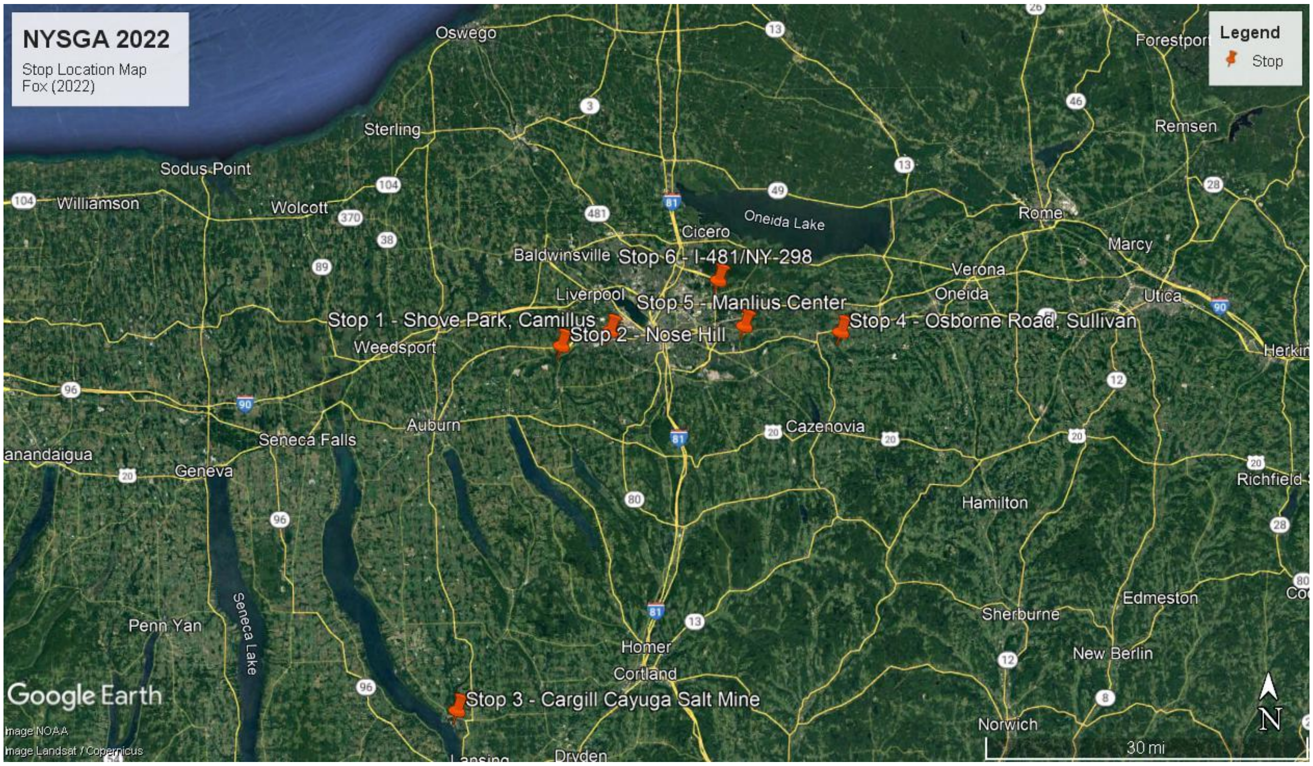

Figure 1. *Google Earth Pro map showing the locations and designations of stops for this field trip.*

GEOLOGIC SETTING

Late Silurian sedimentology and stratigraphy in upstate New York have been studied previously by Alling (1928), Leutze (1955, 1956, 1960, 1964), Fisher (1957), Rickard (1969, 1975), Treesh (1973), Ciurca (1973), Belak (1980), Brett et al. (1990), Ciurca and Hamell (1994), Vrazo et al. (2016), Mayer (2019), and others. The Syracuse Formation and adjacent stratigraphic units were deposited during late Silurian time (Pridoli Epoch) in the northern portion of the Appalachian Basin (Rickard, 1975). The Pridoli Epoch is estimated to have occurred from approximately 419 to 423 ±3 million years before present (Cohen et al., 2013). Figure 2 shows an interpretation of North American paleogeography for 425 million years before present (The Paleontology Portal, 2022). Note the position of central/upstate New York at a paleolatitude somewhere in the range of approximately 25-30° south latitude, placing the study area within Southern Hemisphere subtropical dry belt, a climate belt that is climatologically conducive to the precipitation of evaporite minerals (Sonnenfeld, 1984).

The Appalachian Basin is a foreland basin and consists of an elongate depression in crystalline basement which contains a large volume of predominantly sedimentary stratified rocks. It extends from upstate New York to central Alabama and extends east to west from the west flank of the Blue Ridge Mountains to the crest of the Findlay and Cincinnati arches and the Nashville Dome. It encompasses an area of approximately 207,000 square miles, including all of West Virginia and parts of New York, New Jersey, Pennsylvania, Ohio, Maryland, Virginia, Kentucky, Tennessee, North Carolina, Georgia, and Alabama (Colton, 1961).

The stratified rocks that occupy the basin constitute a wedge-shaped mass whose axis of greatest thickness lies close to and parallel to the east edge of the basin. The maximum thickness of stratified rocks preserved in any one part of the basin today is between 35,000 and 40,000 feet. The volume of the sedimentary rocks is approximately 510,000 cubic miles (Colton, 1961). Sedimentary sequences within the basin are grossly wedge shaped and are thickest along the eastern margin of the basin and thinnest along the western margin.

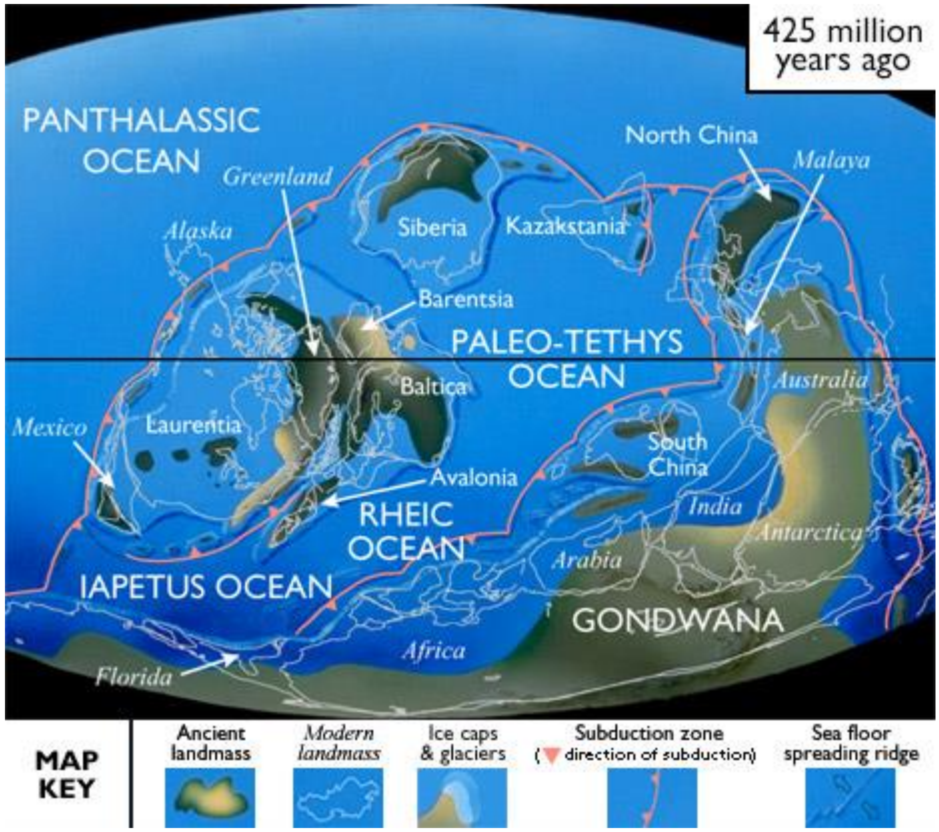

Figure 2. *Interpretation of Late Silurian paleogeography for 425 million years before present (The Paleontology Portal, 2022).*

Major tectonic events that influenced the development of the Appalachian Basin include the Taconian (Ordovician-Silurian), Acadian (Devonian), and Alleghanian (Pennsylvanian) orogenies. These tectonic events were accompanied by the accumulation of large volumes of detrital, siliciclastic sediments in a variety of depositional environments including fluvial, deltaic, beach, shallow shelf, slope, and basin margin settings. Intervening periods of relatively quiet tectonic conditions and corresponding low levels of detrital influx are marked by sequences of carbonate and evaporite sediments that accumulated over widespread areas of the northern Appalachian Basin in a wide variety of depositional environments including supratidal, sabkha, lagoonal, peritidal, shelf, slope, and basin margin settings. The carbonate and evaporite lithologies encountered within the Syracuse Formation record a period of carbonate and evaporite deposition during low periods of detrital influx from the Taconic Mountains to the east.

LITHOSTRATIGRAPHY

The Salina Group occurs within the larger Silurian-Devonian carbonate sequence. Salt-bearing units within the Salina Group occur in the north-central and northwestern parts of the basin, while a thick wedge of fine- to coarse-grained siliciclastic deposits occurs in the northeastern part of the basin (Colton, 1961). The Syracuse Formation and adjacent formations contain all three major types of sedimentary basin fill: siliciclastic, carbonate, and evaporite deposition. Carbonate rock terminology used in this manuscript is consistent with Dunham (1962), Sibley and Gregg (1987), and Mazullo (1992). Evaporite rock terminology is consistent with Sonnenfeld (1984) and Warren (2016). Detrital/siliciclastic rock terminology is consistent with Folk (1954).

Figure 3 presents a generalized stratigraphic column for the Syracuse Formation and adjacent formations based on work performed by Leutze (1955) as a graduate student at Syracuse University. In addition to a very thorough field program in locating and describing outcrops, Leutze clarified the confusing stratigraphic nomenclature previously applied to Salina Group rocks and redefined the Syracuse Formation based on a systematic inspection and evaluation of lithological and paleontological characteristics of the formations.

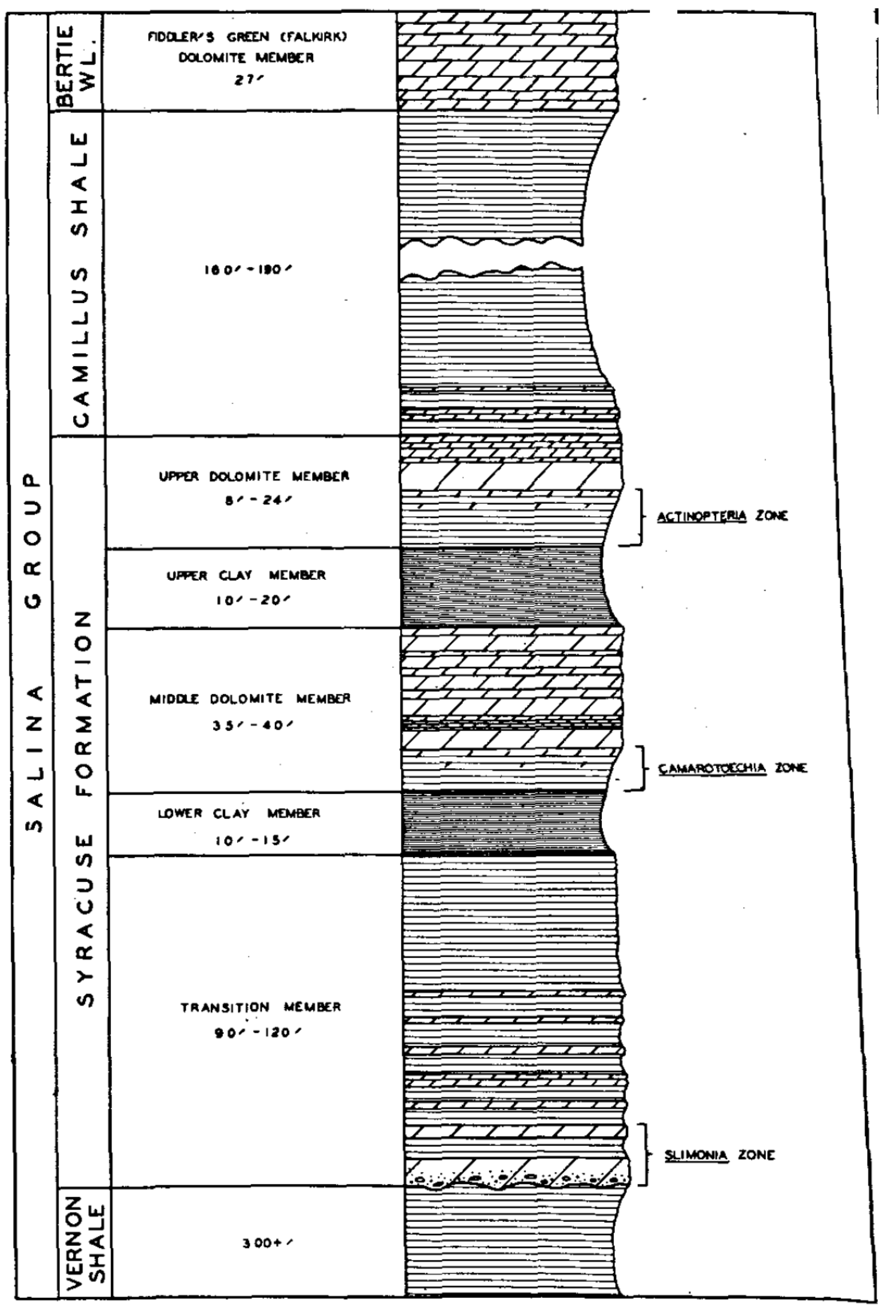

Figure 3. *Generalized stratigraphic column of the Syracuse Formation and adjacent formations in central New York State from Leutze (1956) showing range of thicknesses encountered for the various formations and*

members. Note the disconformable contact between the Syracuse and Vernon formations and the conformable contact between the Syracuse and the Camillus formations. The Slimonia faunal zone was subsequently renamed the Waeringopterus zone in Leutze (1964).

Salt (halite) has not been found to date at Syracuse Formation outcrops, but it is present in significant thicknesses (hundreds of feet) to the south in more basinal settings. Rickard (1969) performed an extensive regional correlation study of the Salina Group in New York, Pennsylvania, Ohio, and Ontario supplemented by a significant amount of subsurface data from oil and gas wells and salt mines and wells. Rickard's work clarified Salina Group stratigraphic relationships across the region and facilitated additional study of the Salina Group. Figure 4 presents an idealized stratigraphic section showing the correlations between surface outcrop units and subsurface units.

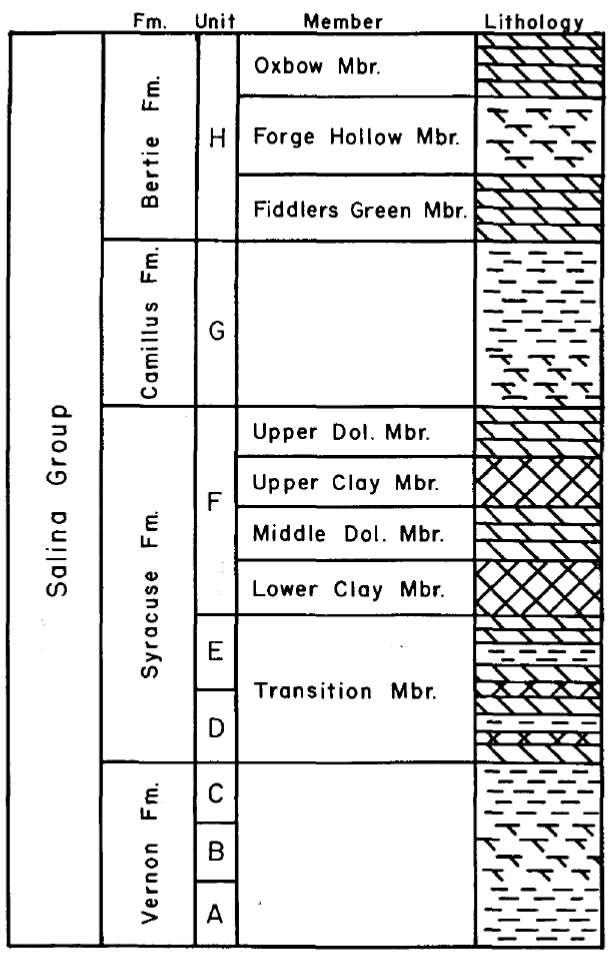

Figure 4. *Idealized stratigraphic section from Treesh and Friedman (1974) showing nomenclature, subdivisions, and correlations between Salina Group surface formations/members from Leutze (1955) and subsurface mapping units from Rickard (1969) listed in the column entitled "Unit".*

The following are brief descriptions of the lithological units at the stops on this trip, based largely on the defining work of Leutze (1955 and 1959). See the section of this manuscript entitled "Field Guide and Road

Log" for figures showing photographs of the various formations and members. Additional information can be obtained from these and other references cited at the end of this manuscript.

Camillus Formation

The Camillus Formation in central New York consists predominantly of light olive gray (5Y 6/1) to greenish gray (5GY 6/1 to 7/1) massive, dolomitic, detrital mudstone. The term mudstone is used rather than shale due to a general lack of fissility at the outcrops visited. The contact with the underlying Syracuse Formation is gradational, and the lower portion of the Camillus Formation typically contains laminated to medium-bedded argillaceous dolostones that are lithologically consistent with the dolostones of the Upper Dolomite Member of the Syracuse Formation (see below). Gypsiferous shale has been reported in the lower portion of the Camillus Formation, particularly west of Syracuse. The base of the Camillus Formation is defined by the lowest occurrence of Camillus-type mudstone.

Syracuse Formation

Upper Dolomite Member

The Upper Dolomite Member consists predominantly of brownish gray (5YR 4/1) to pale yellowish brown (10YR 6/2), laminated, argillaceous dolostone that is typically very fine-grained with non-planar anhedral dolomite texture. The general lack of recognizable carbonate grains (allochems) during petrographic examination suggests original deposition as aphanitic to very-fine grained carbonate mud/matrix, which is consistent with deposition as an evaporitic carbonate unit (Warren, 2016). The lowermost beds contain a zone of bivalve-dominated fauna originally designated by Leutze (1956) as the *Cornellites* zone and later designated by Leutze (1956) as the *Actinoptereia* zone. This member also contains interesting beds of dolostone with spherical- to egg-shaped vug-like porosity that has been described by Leutze (1955) as "vermicular rock" (see Figure 36).

Upper Clay Member

The Upper Clay Member consists predominantly of very light gray (N8) gypsum breccia and medium gray (N5) to dark gray (N3) dolomitized detrital mudstone. These deposits have been interpreted by Leutze (1959) as marking the former horizons of more soluble evaporite beds.

Middle Dolomite Member

The Middle Dolomite Member is generally similar to the Upper Dolomite Member and consists predominantly of yellowish brown (10YR 5/2) to brownish gray (5YR 4/1), laminated, argillaceous dolostone that is typically very fine-grained with non-planar anhedral dolomite texture. The lowermost beds contain a zone of brachiopod-dominated fauna designated by Leutze (1956) as the *Camarotoechia* zone. This member also locally contains a "vermicular rock" zone that is several feet thick and is generally similar to the "vermicular rock" zone in the Upper Dolomite Member, although the voids are typically smaller in size in the Middle Dolomite Member.

Lower Clay Member

The Lower Clay Member is lithologically very similar to the Upper Clay Member and consists predominantly of very light gray (N8) gypsum breccia and medium gray (N5) to dark gray (N3) dolomitized detrital mudstone.

Transition Member

The Transition Member consists predominantly of medium gray (N5) to dusky green (5G 3/2) dolomitic, detrital mudstone that is locally gypsiferous. The lower half of the Transition Member typically contains medium gray (N5) to dark yellowish brown (10YR 4/2), laminated to medium-bedded argillaceous dolostone beds that are similar to dolostone beds in stratigraphically higher members of the formation and which often contain mud cracks. The lowest dolostone bed, the base of which is an unconformable contact with the underlying Vernon Formation, is sandy and often contains pebble-sized clasts of shale/detrital mudstone and localized concentrations of an iron oxyhydroxide mineral. The lowermost two dolostone beds constitute a eurypterid fragment-dominated faunal zone originally designated by Leutze (1955) as the *Slimonia* zone. Leutze (1964) subsequently re-designated this zone as the *Waeringopterus* zone.

Vernon Formation

The Vernon Formation consists predominantly of moderate red (5R 5/4), massive to irregularly stratified, detrital mudstone/shale. It typically contains 5 to 15 percent sub-angular to angular quartz silt and is locally dolomitic and gypsiferous. Certain intervals of the formation in central New York (particularly uppermost beds and the middle portion of the formation) are often pale green (5G 7/2) and occasionally contain mud cracks. There is also a relatively rare medium gray (N5) mudstone/shale at the type locality that is located adjacent to the green facies, and reports of marine fauna in the Vernon Formation at the type locality occur in this gray facies (Fisher, 1957).

PALEONTOLOGY

The Syracuse Formation was deposited during semiarid to arid climatic conditions in and near a restricted marine basin as demonstrated by significant occurrences of primary and secondary evaporite lithologies (Alling, 1928; Leutze, 1959; Rickard, 1969; Treesh, 1973). Given favorable bathymetric profiles, restricted marginal marine basins in semiarid or arid climates typically develop an antiestuarine water flow regime, where normal salinity ocean water flows into the restricted basin at the surface to compensate for water losses due to evaporation and outflow of bottom brines. Surface waters in these restricted marginal marine basins can occasionally contain very high levels of organic productivity (Sonnenfeld, 1984; Warren, 2016).

Overall, Salina Group macrofossils are typically sparse, diversity is relatively low, and preservation of calcareous remains is typically poor. However, some macrofossils are locally to regionally common and are well preserved, particularly in the faunal zones of the Syracuse Formation. The macrofossils found in the Syracuse Formation are typically associated with normal marine salinity conditions, thereby demonstrating the occurrence of relatively normal marine salinity conditions at least temporarily during deposition of parts of the Syracuse Formation. Illustrations of the more common macrofossils from several of the references cited are provided below.

Camillus Formation

As mentioned above, all rocks between the Vernon Formation and the Bertie Formation were previously designated as "Camillus" by early investigators (Swartz et al., 1942). Most reports of fossils occurring in the Camillus Formation are from these early investigations and occur in rocks that are currently defined as the Syracuse Formation. Leutze (1964) stated that no significant fossils have been reported from the Camillus Formation. The author's observations during field work performed to date are consistent with Leutze (1964).

Syracuse Formation

Leutze (1955, 1956, 1959, 1964) reports that three faunal zones typically occur within the Syracuse Formation where fossils are most common and best preserved (Figure 3). These faunal zones are relatively thin (generally 1-4 feet in thickness) and interestingly occur stratigraphically above and in close proximity to the unconformity between the Vernon and Syracuse Formations (the *Wareingopterous* zone) and the Lower Clay and Upper Clay members (i.e., the *Camarotoechia* and *Actinoptera* zones, respectively), which may be the remnants of formerly thick evaporite deposits. Fossils also occur locally in some dolostone or shale beds between these zones, but fauna most typically occurs in one or more of these three faunal zones.

The following illustrations with genus and species identifications show some of the more common macrofossils collected from the Syracuse Formation by Leutze (1955). Other less common fauna that occur are not listed/shown below. Taxonomic level terminology revisions at the order level or higher since Leutze's work have been incorporated into this manuscript; however, no attempt has been made to evaluate for potential revisions at the genus or species levels (i.e., genus and species designations listed below are as listed in Leutze's work from the 1950s and 1960s).

Phylum Brachiopoda

Class Rhynchonellata

Figure 5. *Camarotechia cf. litchfieldensis (2X); internal cast of an adult pedicle valve. Middle Dolomite member.*

Figure 6. *Camarotechia cf. litchfieldensis (2X); internal cast of a small brachial valve. Middle Dolomite member.*

Phylum Mollusca

Class Bivalvia

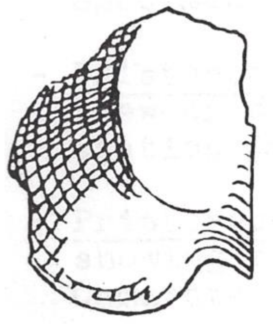

Figure 7. *Cornellites sp. (1X); fragmentary cast of left valve. Upper Dolomite member.*

Figure 8. *Ctenodonta cf. saliensis (1X); cast of left valve. Middle Dolomite member.*

Figure 9. *Rhytimia cf. buffaloensis (1X); cast of left valve. Middle Dolomite member.*

Figure 10. *Cleidophorus ? sp. (1X); cast of left valve. Middle Dolomite member.*

Class Gastropoda

***Figure 11**. Loxonema ? bertiense (2X); composite sketch of several specimens. Middle Dolomite member.*

Figure 12. *Holopea ? sp. (10X); dolomite replacement of original shell material; external shell partly broken away shows columella. Middle Dolomite member.*

Class Cephalopoda

Figure 13. *Pristoceras cf. timidum (2X); side view of conch showing color bands. Middle Dolomite member.*

Figure 14. *Pristoceras cf. timidum (1X); a septum, showing the siphuncle. Middle Dolomite member.*

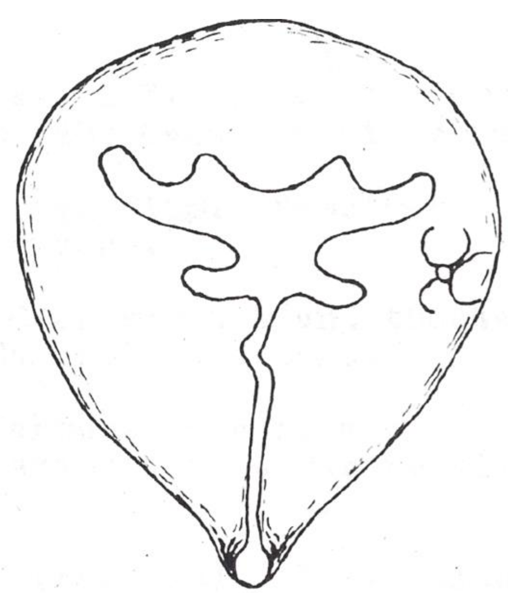

Figure 15. *Pristoceras cf. timidum (3X); cast of an aperture with an ophiuroid (a brittle star, Phylum Echinodermata) attached to the left side. Middle Dolomite member.*

Figure 16. *Pristoceras cf. timidum* (1X); side view of a cast of the living chamber and part of the conch. Middle Dolomite member.

Phylum Arthropoda

Order Eurypterida

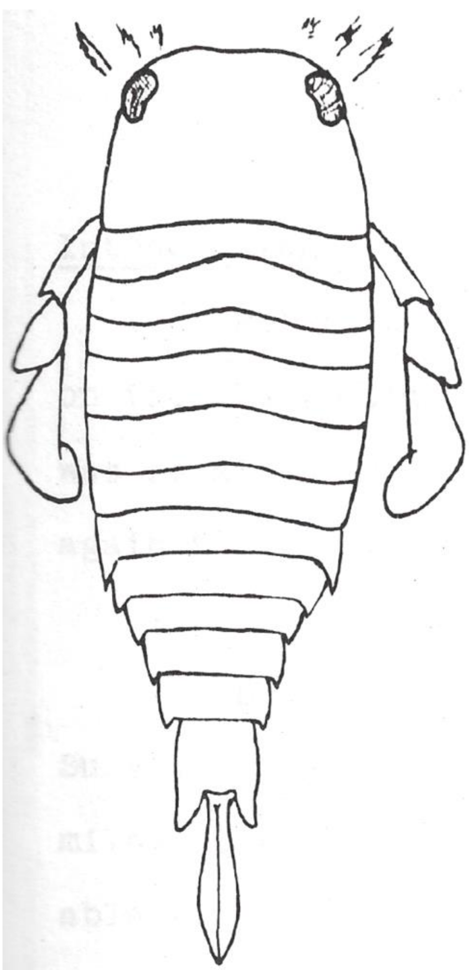

Figure 17. *Waeringopterus apfeli (1X); a composite sketch of specimens. Transition member.*

Figure 18. *Waeringopterus apfeli (2X); mold of right compound eye showing delicate cross hatching. Transition member.*

Class Ostracoda

Figure 19. *Leperditia cf. scalaris (1X); mold of right valve. Middle Dolomite member.*

Phyllum Hemichordata

Subclass Graptolithina

Figure 20. *Medusaegraptus graminiformis (1X); cast of rhabdosome covered with a carbonaceous film. Middle Dolomite member.*

Vernon Formation

The Vernon Formation is generally unfossiliferous with the exception of some isolated beds that generally occur near the middle of the formation (Fisher, 1957). As with the Syracuse Formation, the fauna in the Vernon Formation is marine. Fisher (1957) and Leutze (1960 and 1964) indicate that fauna reported in the Vernon Formation includes bivalves, cephalopods, gastropods, brachiopods, the remains of jawless, armored fishes (Phylum Chordata, Class Pteraspidomorphi, Order Cyathasporida), clawed eurypterids (Family

Pterygotidae), and a siphonophore (Phylum Cnidaria, Class Hydrozoa). Overall, the fauna in the Vernon and Syracuse formations appear to be generally similar.

The following illustrations with genus and species identifications show some of the more common macrofossils collected by others from the Vernon Formation as illustrated and described in Fisher (1957) and Flower and Wayland-Smith (1952). Taxonomic level terminology revisions at the order level or higher since the 1950s have been incorporated into this manuscript; however, no attempt has been made to evaluate for potential revisions at the genus or species levels.

Phylum Brachiopoda

Class Lingulata

***Figure 21**. Lingula allingi (2X); note the foramen, the completely enclosed slit-like passage for the opening of the pedicle, slightly apical of the pedicle valve. Also note the prominence of the radially-arranged costellae along the valve margin.*

Phylum Mollusca

Class Gastropoda

***Figure 22.** Poleumita vernonensis (2X); apical view of an immature specimen showing four whorls.*

Class Bivalvia

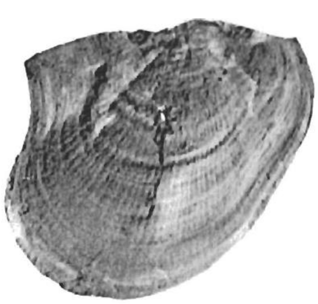

Figure 23. *Pterinia wayland-smithi (2X); mold of left valve; typical cancellate pattern is well shown in this earliest pectinate genus.*

Class Cephalopoda

Figure 24. *Spyroceras sp. (2X); portion of conch showing narrow camerae and moderately-arched septa.*

Phylum Chordata

Class Pteraspidomorphi

Order Cyathasporida

Figure 25. *Vernonaspis leonardi (2X); interior of dorsal plate showing pineal body, branchial impressions, semicircular canals, and impression of brain.*

Figure 26. *Archegonaspis ? sp. (2X); interior of ventral plate, whitened, etched, showing cancellous layer and the interrupted canals of the lateral line system; in the lower left quadrant, the plate is removed completely, showing the external mold of the pattern of the dentin area.*

Phylum Arthropoda

Class Ostracoda

Figure 27. *Leperditia scalaris (3X); mature specimen.*

ACKNOWLEGEMENTS

Sincere gratitude and appreciation are offered to Shawn Wilczynski and the entire team at Cargill for allowing us to visit the Cayuga Salt Mine and for their time and effort in providing us with a very interesting and informative presentation. Thanks also are offered to Brian Slater and Marian Lupulescu of the New York State Museum/Geological Survey, who provided access to and shared their significant knowledge of rock core, drill cuttings, and mineral samples from the phenomenal collections of the New York State Museum, which assisted ongoing research and the development of this field trip. Thanks also to Dave Valentino (SUNY Oswego Department of Atmospheric and Geological Sciences) and Nick DiFrancesco (University at Buffalo Department of Geology) for interesting discussions that initiated and facilitated the development of this field trip and for reviewing the draft manuscript. Thanks also go to Trisha House of SUNY Oswego's Department of Atmospheric and Geological Sciences for administrative and logistical assistance in setting up the field trip, and to SUNY Oswego geology students Alex Robinson and Nathan Drake for assisting their fellow geology students by agreeing to drive the college vans procured for this field trip, and for enhancing the sustainability aspects of this field trip by resulting in a reduced number of vehicles and associated reduction in carbon emissions to the atmosphere.

FIELD GUIDE AND ROAD LOG

General Suggestions: Parking is limited at some stops, so please carpool with others as much as possible. Many of our stops are along active roads, so please remain alert for vehicular traffic at all times. **It is required that you bring and wear a high-visibility fluorescent safety vest at the stops**, and hard hats are recommended as well if you plan to locate yourself beneath or close to rocks that are above you. Please remember to dress for the weather and wear waterproof field boots. Portions of trails can be narrow and slippery, so please watch your step and tread safely. Please bring your own rock hammer and hand lens. Access to some beds at outcrops can be facilitated if you have a camper's shovel to make "stairs" for yourself through talus that occurs at the base of many outcrops. Please stay hydrated and protect yourself from biting insects with whatever means you deem appropriate. In my experience, four very effective techniques (when used together) include wearing pre-treated clothing (e.g., Insect Shield®), tucking your pants into your boots, tucking your shirt into your pants, and tucking your shirt sleeves into your gloves. Guidance for protection from biting insects is available from the Centers for Disease Control here: Avoid bug bites | Travelers' Health | CDC. Please bring your own lunch and non-alcoholic beverages. We will try to stop as a group occasionally for bathroom breaks along the route, as restrooms generally are not available at most of the stops. If you are having any issues during the field trip, please let me know and we'll do our best to assist you.

Meeting Point (Stop 1): Shove Park, Town of Camillus, Onondaga County, New York - Look for and park near a blue Honda Pilot with New York license plate number BEB-5439.

Meeting Point (Stop 1) Coordinates: 43° 2'21.13"N, 76°15'6.91"W

Meeting Date/Time: 24 September 2022/8:30 a.m.

We'll walk together from the meeting point upstream through the woods along Geddes Brook to an outcrop which exposes the upper portion of the Syracuse Formation (Upper Dolomite Member) and the overlying Camillus Formation (mostly covered). The contact between these two formations is gradational and mostly covered at this location, but there is good exposure of the Upper Dolomite Member here. Relatively resistant dolostone beds and less resistant argillaceous dolostones below form a low-relief waterfall near the top of the Upper Dolomite Member.

Figure 28. *View looking southwest at Stop 1 along Geddes Brook at a portion of the Upper Dolomite Member of the Syracuse Formation.*

Distance (miles)

Cumulative Mileage	Point-to-Point	Route Description
0.0	0.0	Meeting Point (Stop 1)
0.2	0.2	Head northeast on Shove Park Dr. toward Slawson Dr.
0.5	0.3	Turn left onto Slawson Dr.
0.6	0.1	Turn right onto Rowena Dr.
3.5	2.9	Turn left onto West Genesee St.
5.7	2.2	Turn left onto NY-174 S/Elm St; safely pull off the road far to the right at the intersection with Forward Road (Stop 2).

Stop 2: Nose Hill, Town of Camillus, Onondaga County, New York

Stop 2 Coordinates: 43°1'10.43"N, 76°20'27.85"W

This stop provides an excellent opportunity to observe stratigraphic units in the upper portion of the Syracuse Formation, including the Upper Clay and Upper Dolomite members. The contact with the base of the overlying Camillus Formation is also exposed. The Middle Dolomite Member of the Syracuse Formation is also present in this outcrop; however, it is mostly covered by talus near the base of the outcrop.

Figure 29. *View looking west at the outcrop exposed at Stop 2, which shows in ascending order the Middle Dolomite Member (largely covered by talus; "MD"), the Upper Clay Member ("UC"), and the Upper Dolomite Member ("UD") of the Syracuse Formation. The overlying Camillus Formation ("CM") is also shown.*

Distance (miles)

Cumulative Mileage	Point-to-Point	Route Description
5.7	1.1	Turn right onto Forward Road
6.8	5.8	Turn left onto NY-321 S
12.6	2.0	Slight right onto Old Seneca Turnpike
14.6	1.0	Turn left onto County Line Rd.
15.6	2.6	Turn right at the first cross street onto US-20 W
18.2	1.4	Turn left onto Town Hall Rd.

19.6	1.3	Turn right onto Melrose Rd.
20.9	1.2	Turn left onto Oakridge Rd
22.1	0.6	Turn right onto E Lake Rd./Owasco Rd.
22.7	0.3	Turn left onto White Bridge Rd.
23.0	1.4	At the traffic circle, take the second exit onto Sand Beach Rd.
24.4	27.2	Turn left onto NY-34 S
51.6	0.7	Continue straight onto NY-34B N
52.3	0.9	Turn left onto Portland Point Rd
53.2	0.0	Turn right into the Cargill Cayuga Salt Mine facility and safely park, being careful not to park in a manner or location that may disrupt traffic flow for any facility vehicles (Stop 3).

Stop 3: Cargill Cayuga Salt Mine, Town of Lansing, Tompkins County, New York

Stop 3 Coordinates: 42°31'57.05"N, 76°31'45.08"W

Cargill Deicing Technology operates this mine, providing customers with deicing technology and road salt that saves lives, enhances commerce, and reduces environmental impact.

In 1915, John Clute organized the Rock Salt Corporation on Portland Point in Lansing. In 1916, a shaft was sunk to -1500 feet, but the salt was of poor quality. By 1918 the mine was still not producing well and was shut down. In 1921, Frank L. Bolton and John W. Shannon bought the mine and further sank the shaft to -2000 feet to a better vein of salt which was 99% pure. The operation was managed by Frank Bolton, and then his wife Lucie when he died. The mine was operated by the Cayuga Rock Salt Company, Inc. until Cargill acquired the mine in 1970 and modernized the mine with new beltlines for salt haulage, ventilation updates, a new shaft, and new diesel-powered equipment. The mine produces approximately 2 million tons of road salt annually that is shipped to more than 1500 locations throughout New York State and the northeastern United States. The mine employs more than 200 full-time employees in operations, maintenance, engineering, finance, management and support positions.

Currently, the mine is advancing north up Cayuga Lake and is approximately one mile past Taughannock Point. The salt is mainly sold in the road deicing market in the Northeast (including New York, Vermont, and Pennsylvania) but is also sold under the Diamond Crystal name as residential deicing salt.

The Cayuga Mine operates under a Mined Land Reclamation Permit issued by the DEC in 1975. Permit renewals were approved in 1985, 1997, 2003, 2007, 2012, 2019 and modifications were approved in 2013, 2015 and 2017. In each case, DEC determined that there would be no significant adverse environmental impact from mining.

In the mid-1990s, Cargill undertook a thorough environmental assessment of the region to verify Cargill's understanding of the geology. This work has served as a critical foundation for the continued evaluation and study of mine stability and operations. Data collected through these continuing studies is regularly evaluated and verified by numerous third-party experts employed by DEC and Cargill.

Figure 30. *Salt-mining operations within Cargill's Cayuga Salt Mine.*

Since 2002, the Cayuga Mine has submitted an annual report on the status of special conditions outlined in the permit. The primary focus is on mine stability, three-year mine plans and water management. DEC utilizes the services of Dr. Vincent Scovazzo, an internationally recognized mine stability expert from the John T. Boyd Company, for mine stability review and participation in the annual on-site visit and inspection of the mine. Over the years, Cargill has relied on several similarly credentialed experts to assist its own mine stability and other technical evaluations. Each year Cargill performs an internal risk review with leaders to evaluate and manage the risks associated with mining.

In addition, the federal Mine Safety & Health Administration (MSHA) oversees mine safety such as adequacy of underground ventilation and emergency access. MSHA inspects the mine every calendar quarter. Each of these inspections typically lasts six to eight weeks.

The mine's manager, Mr. Shawn Wilczynski, and his staff, will provide us with a presentation on the mine's geology and operations. I have requested that they also show us specimens of rock salt and other lithologies from the Syracuse Formation from their mine. The total thickness of the Syracuse Formation at the mine exceeds 800 feet, including a total salt thickness exceeding 400 feet. The mine historically has produced salt from either the F1 unit (No. 4 Salt) or the D unit (No. 6 Salt) of the Syracuse Formation. Stratigraphically, the F1 unit is interpreted to occur within the Lower Clay Member and the D unit is interpreted to occur within the Transition Member of the Syracuse Formation (Figure 3). Cargill is currently mining the D unit (No. 6) salt.

Distance (miles)

Cumulative Mileage	Point-to-Point	Route Description
53.2	0.9	Turn left onto Portland Point Rd.
54.1	1.2	Turn right onto NY-34B S
55.3	10.4	Keep right to continue on NY-34B S/Peruville Rd. (NOTE: we are really heading east on this leg of the trip, so don't be confused by "NY-34B S").
65.7	0.9	Turn left onto School St.
66.6	3.5	Continue onto McLean Rd.

70.1	1.2	Turn left onto Luker Rd.
71.3	2.4	Turn left onto NY-281 N/West Rd.
73.7	0.5	Turn right
74.2	0.7	Follows signs for I-81 N
74.9	19.5	Merge onto 1-81 N
94.4	0.4	Take exit 15 toward US-11/US-20/Lafayette
94.8	0.2	Merge onto US-11 S
95.0	9.8	Turn left onto US-20 E
104.8	4.7	Turn left onto Pompey Center Rd.
109.5	1.3	Turn right onto Enders Rd.
110.8	5.2	Turn right onto NY-173 E
116.0	0.5	Turn right onto Madison St.
116.5	0.7	Continue onto Perryville Rd.
117.2	1.1	Turn left onto Osborne Rd.
118.3	0.0	Safely pull far off the road to the right (Stop 4).

Stop 4: Osborne Road, Town of Sullivan, Madison County, New York

Stop 4 Coordinates: 43° 2'15.24"N, 75°49'51.85"W

The Middle Dolomite Member of the Syracuse Formation is well exposed at this locality, and this locality reportedly is one of the better locations in central New York to find fossils from the *Camarotoechia* zone (Leutze, 1956). The fossils are generally well preserved in gray shale near the base of the Middle Dolomite Member. The fauna is concentrated in the lowermost few feet of the member and fossils become rare higher in the section. Wavy, parallel bedding and lamination, which are locally discontinuous, are commonly observed at this locality.

Figure 31. *View looking east-southeast at a portion of the outcrop at Stop 4 showing the Middle Dolomite Member of the Syracuse Formation. More resistant, wavy-bedded dolostones near the top of the outcrop are gradationally underlain by argillaceous dolostones, which are gradationally underlain by predominantly shale/detrital mudstone. The contact with the underlying Lower Clay Member may be covered by talus near the base of the outcrop.*

Distance (miles)

Cumulative Mileage	Point-to-Point	Route Description
118.3	1.1	Head southwest on Osborne Rd toward Evans Rd.
119.4	0.7	Turn right onto Perryville Rd.
120.1	0.5	Continue onto Madison St.
120.6	3.2	Continue straight onto NY-5 W/West Genesee St.
123.8	4.1	Turn right onto NY-290 W
127.9	0.6	Continue straight, road turns into NY-257 S
128.7	0.0	Carefully cross over and pull off safely on the left (south) side of the road into the gravel parking lot (Stop 5).

Stop 5: Manlius Center, Town of Manlius, Onondaga County, New York

Stop 5 Coordinates: 43° 2'45.38"N, 76° 0'25.21"W

We will walk from the parking lot north along the former railroad bed for approximately one tenth of a mile. The former railroad bed is somewhat overgrown with vegetation, but there are excellent exposures of the Syracuse Formation, particularly on the eastern hillside. Although there is no formal type section designated for the Syracuse Formation and the lowermost member of the formation (the Transition Member) is not exposed here, this large outcrop was cited by Leutze (1959) as an ideal reference section for the Syracuse Formation given its accessibility, relative completeness, and clarity of the stratigraphic section. The exposed portion of the Syracuse Formation at this location is approximately 64 feet thick and the stratigraphic units exposed here include (in ascending order) the Middle Dolomite Member (37 feet thick), the Upper Clay Member (11 feet thick), and the Upper Dolomite Member (16 feet thick). Talus typically obscures much of the Middle Dolomite Member. Access to exposed rock can be facilitated by digging "steps" in the talus using a camping shovel.

Figure 32. *View looking east standing on the former railroad bed at Stop 5 showing an exposure of the upper portion of the Syracuse Formation.*

Figure 33. *Photo showing the upper portion of the Syracuse Formation including (in ascending order) the Middle Dolomite Member (mostly covered by vegetation; "MD"), the Upper Clay Member ("UC"), and the Upper Dolomite Member ("UD").*

Figure 34. *Closer view of the Upper Clay Member showing gray to dark gray dolomitic carbonate mudstone and light-colored gypsum (selenite). Note the presence of wavy, parallel bedding suggesting preservation of*

some primary depositional texture. However, some discontinuous, wavy, non-parallel bedding and brecciated texture is also present, suggesting leaching, dissolution, and recrystallization (secondary evaporite mineralization).

Figure 35. *Closer view showing the Upper Dolomite Member at Stop 5. The thickness of the exposed interval shown in this photograph is approximately 15 feet.*

Figure 36. *Close-up view of "vermicular" dolostone collected from the Upper Dolomite Member at Stop 5.*

Distance (miles)

Cumulative Mileage	Point-to-Point	Route Description
128.7	0.6	Turn right out of the parking area to head north on NY-257 N
129.3	1.7	Turn left onto NY-290 W
131.0	3.3	Turn right onto Fremont Rd.
134.3	1.0	Turn left onto NY-298 W
135.3	0.1	Turn right onto the I-481 S ramp
135.4	0.0	Pull off far to the right and park prior to the curve in the on-ramp (Stop 6).

Stop 6: Intersection of NY Route 298 and I-481, Town of DeWitt, Onondaga County, New York

Stop 6 Coordinates: 43° 6'25.24"N, 76° 3'15.56"W

Our last stop on this trip will be a brief stop at a small exposure of the Vernon Formation. The Vernon Formation in central New York is often moderate red (5R 5/4; see Figure 37); however, certain intervals of the formation (particularly the middle portion in central New York) are often pale green (5G 7/2) as seen at this stop (Figure 38). Given its softness and lack of resistance to weathering, significant outcrops of the Vernon Formation are rare, particularly in areas of relatively low topographic relief.

Figure 37. *Photo showing an exposure of predominantly moderate red Vernon Formation. This outcrop is not visited on this field trip and is shown for information purposes only. Intersection of NY-51 and County Highway 16, Town of Litchfield, Herkimer County, New York.*

Figure 38. *Photo showing an exposure of predominantly pale green Vernon Formation at Stop 6, Town of DeWitt, Onondaga County, New York.*

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ASSESSMENT QUESTIONS FOR CONTINUING PROFESSIONAL EDUCATION CREDIT (FOR NEW YORK-LICENSED PROFESSIONAL GEOLOGISTS)

We will verbally address these questions and discuss the answers in the field at the end of the field trip.

1. During what period of geologic time and approximately how long ago (in millions of years before present) was the Syracuse Formation deposited?
2. True or false: the Syracuse Formation contains siliciclastic, carbonate, and evaporite lithologies.
3. Describe the most predominant color(s) for each of the following formations:
    a. Camillus Formation
    b. Syracuse Formation
    c. Vernon Formation
4. What is the name of the faunal zone contained within the Transition Member of the Syracuse Formation, and what type of animal is the zone named after?
5. What is the approximate annual production of rock salt (in tons) at Cargill's Cayuga Salt mine?