Economic Geology of the Central Hudson Valley, New York

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INTRODUCTION

This trip provides an overview of the Portland cement and aggregate mining industry, past and present, in the central Hudson Valley. We will visit the Holcim US Catskill Quarry, as well as the Colarusso and Holcim US quarries on Becraft Mountain in the Town of Greenport, Columbia County. We will review the classic Tristates and Helderberg stratigraphy, see how geologic principles are applied, examine complex structural settings and see how various professions—e.g. geologist, mining engineer, chemist—work together to make viable products in as efficient, economical and environmentally friendly a manner as possible.

HISTORY OF PORTLAND CEMENT MANUFACTURE IN NEW YORK

Portland cement replaced natural cement starting in the late 1800's, primarily due to the commercial availability of rotary kilns capable of producing large amounts of cementitious material at a relatively low cost. A number of Portland cement manufacturing plants sprang up in the Hudson Valley due to: (1) the proximity to the large metropolitan New York City and other regional markets; (2) the presence of thick, fault-repeated sections of fairly high calcium carbonate limestones; (3) the abundance of clays, shales and argillaceous limestone; and (4) the presence of the Hudson River that served as an efficient transportation route to end users of the cement.

As late as the early 1950's there were at least nine cement plants in eastern New York, including: (1) at Catskill on the east side of U.S. Route 9W, operated variously by Lone Star, North American Cement and Marquette (the cement plant is currently operated by Holcim US—formerly St. Lawrence Cement and Independent Cement—and also contains an aggregate plant operated by Peckham Materials); (2) at Cementon on the east side of U.S. Route 9W, the "Alpha" Plant operated by the Lehigh Portland Cement Company (still used by Lehigh Northeast Cement to grind imported clinker and distribute cement); (3) at Cementon on the east side of U.S. Route 9W, the "Alsen" Plant operated by the Lehigh Portland Cement Company (closed in the early 1980's); (4) at East Kingston, the Hudson Cement Company plant (closed in 1982); (5) at Hudson, on the north side of N.Y.S. Route 23B, the Lone Star plant (closed in the mid-1960's); (6) at Greenport, on the west side of U.S. Route 9, the Universal Atlas Cement plant (the cement plant closed in 1976 but the quarry is still worked for aggregate); (7) at Ravena, on the east side of U.S. Route 9W, the Atlantic Cement plant (still active as a cement plant operated by Lafarge and an aggregate plant operated by Callanan Industries); (8) at Howes Cave on the west side of Sagendorf Corners Road, the North American Cement plant (the cement plant closed in 1976 but Lehigh Northeast Cement maintains cement storage silos and Cobleskill Stone operates a state-of-the-art aggregate plant); and (9) at Glens Falls on the south side of Warren Street, the Glens Falls Cement plant (still active and operated by Lehigh Northeast Cement).

Most of the cement plants once active in eastern New York have shut down, victims of outdated equipment, changing economic forces and environmental activism.

AGGREGATE MINING IN NEW YORK

There are approximately 2083 permitted and approximately 2384 reclaimed commercial mines in New York. More than 99 percent of these mines are or were aggregate mines supplying the sand, gravel, stone, clay and topsoil used to build, repair and maintain the infrastructure that is one of the foundations of the economy. In 2007, New York State's aggregate mining, blacktop production, concrete production and cement mining was responsible for:

- Direct sales of \$3.3 to \$3.5 billion

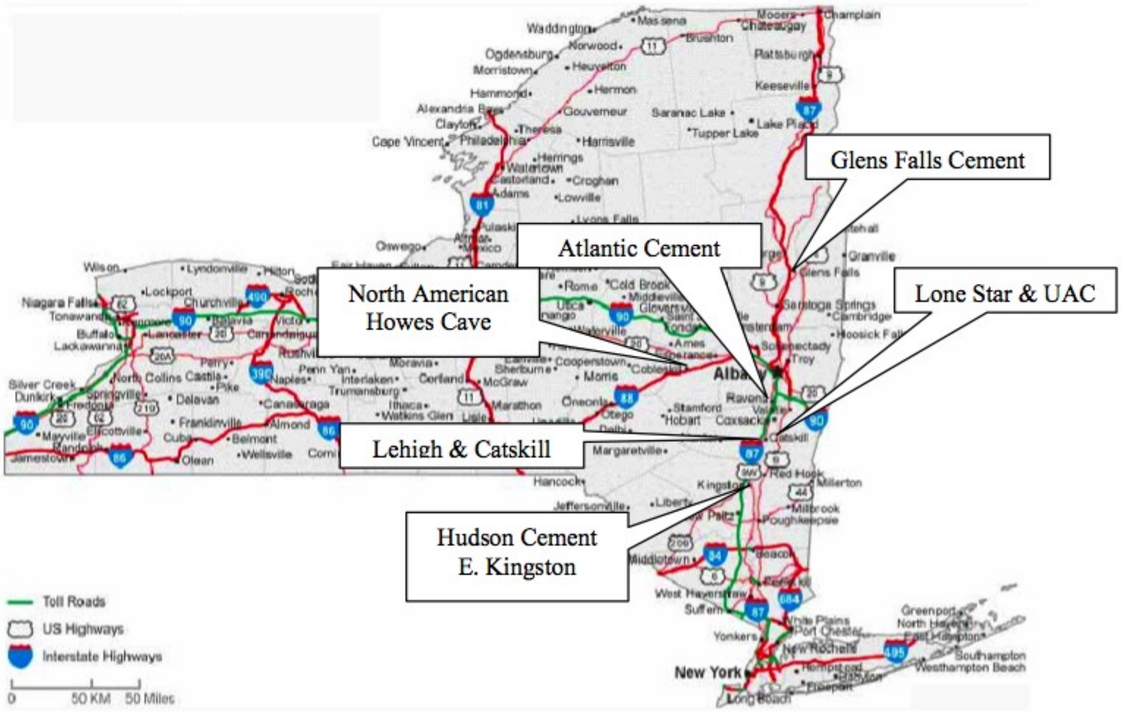

Figure 1. Locations of Cement Plants in Eastern New York in the 1950's.

- Employee wages of $1.2 to $1.3 billion
- Employment of 28,000 to 30,000 people in all parts of the state (average salary of all employees was approximately $48,000, slightly above the median salary for New York industry)
- Direct payment of $87 to $101 million in sales tax, personal income tax, fuel tax, corporate franchise tax, and Mined Land Reclamation permitting fees.

The mining industry has a tremendous economic impact on New York State but is far from secure. Local governments frequently pass restrictive zoning, without proper consideration of the availability of mining resources, which prevents or severely limits mining. Environmental regulation is being enacted at an ever increasing rate - merely familiarizing oneself with the new regulations is a full-time job. Existing mines are inevitably being depleted and, alarmingly, not being replaced equally by new mines. Local shortages of construction materials have resulted in increased costs (hauling aggregate 20 miles roughly doubles the cost) to end users and increased transportation distances, with all the related impacts associated with heavy truck traffic. Since 2001, the number of mines in New York has decreased and the percentage of the mines' permitted area that has been worked has increased dramatically. Downstate New York is particularly had hit by local shortages of concrete sand. This product typically sells for about $8 per ton in upstate New York but sells for about $25 per ton downstate. The increased costs are the result of shortages and increased transportation costs as the material must be hauled in from as far away as southern New Jersey, Canada, the Capital District, the Adirondacks and Central New York.

BACKGROUND

The geologic units being worked in the sites visited today are part of the Devonian Tristates and Helderberg Groups. These units represent deposition in a repeated sequence of increasingly deeper oceans. These transgressive sequences resulted in significantly different depositional environments that exhibit different physical and chemical characteristics that dictate the stone's use as cement or aggregate stone. Purer (higher calcium carbonate) limestones are better suited for use as cement stone and have limited uses as aggregate. Siliceous (lower calcium carbonate) limestones are better suited for use as aggregate, particularly the high friction aggregate used to provide traction on road surfaces (see Figure 7).

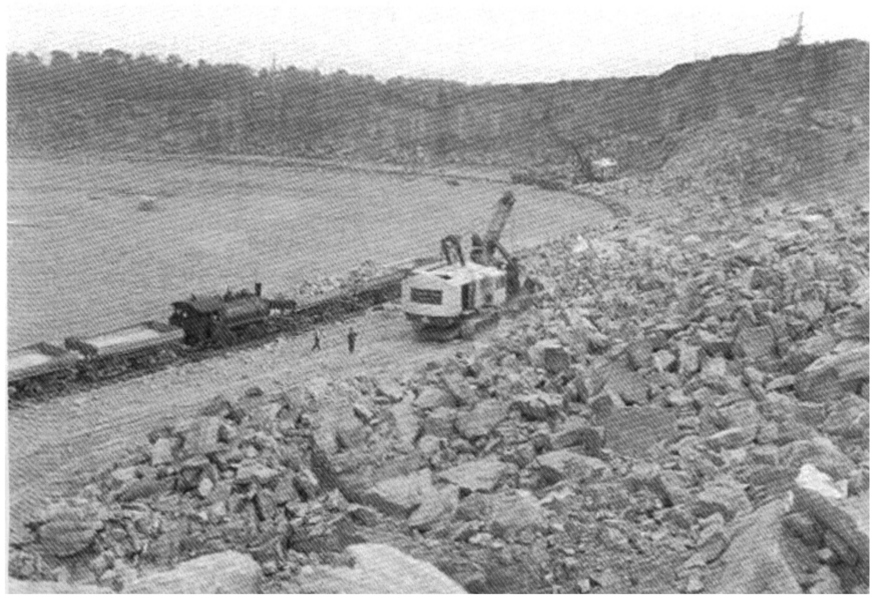

Figure 2. Electric shovel loading rail cars on the floor of the Universal Atlas Greenport Quarry in 1936.

These geologic units have been subject to tectonic activity as part of the Acadian and Alleghenian Orogenies. At Catskill, the folding and related thrust faulting is severe. The eastern part of the quarry is characterized by repeat sections of Kalkberg-Coeymans-Manlius. The central part of the quarry is characterized by repeat sections of New Scotland-Kalkberg. The southern and western parts of the quarry are characterized by repeat sections of Port Ewen-Alsen-Becraft. Relatively undisturbed sequences of the Esopus Shale outcrops in the area west of the quarry.

The combination of physical and chemical variations in the various beds and the presence of folds and faults every 100 feet in any direction results in the Catskill Quarry's reputation as a geologist's dreamland and a mining engineer's nightmare. At the Holcim US Catskill Quarry, seven or eight imbricate sheets have been identified beginning with the outstanding work done by George Chadwick in the 1940's, and culminating with massive mapping and core drilling projects in 1985 and 2004 by Holcim and the authors.

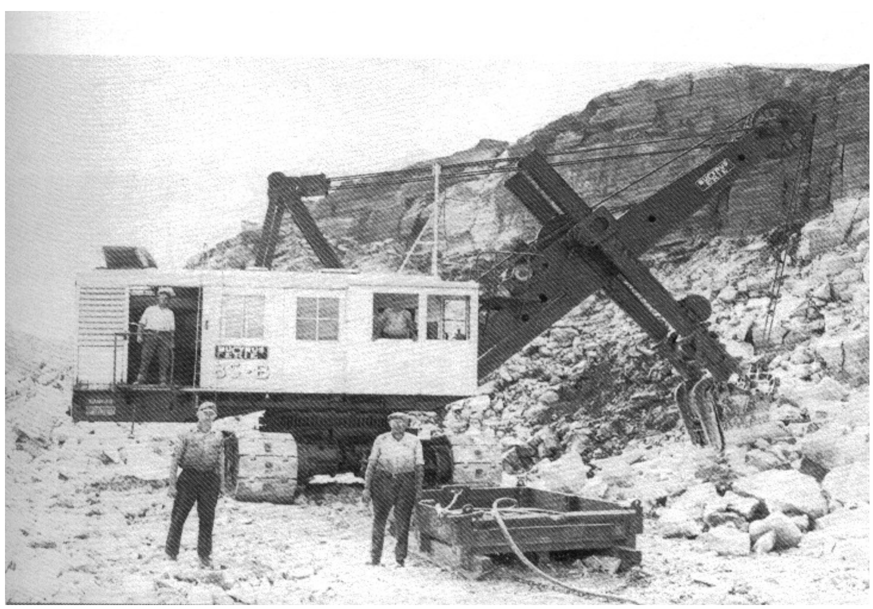

Figure 3. Electric shovel and operators at Universal Atlas Greenport Quarry in 1938.

The same geologic formations being worked at Catskill are present at the Colarusso and Holcim US's Greenport Quarries. These quarries are located on Becraft Mountain, an outlier of Lower Devonian limestones and shales that was thrust west and over the Taconic Orogeny jumbled up Ordovician shales, siltstones and sandstones.

Mount Ida, located a few miles to the northeast of Becraft Mountain, is the only other significant outlier of Devonian limestone in Columbia County.

Mining on Becraft Mountain has been ongoing since 1675. Cut stone for foundations and buildings gave way to small lime kiln operations which in turn gave way to Portland cement mining and manufacture. Cement mining was done in 1901 by Knickerbocker Cement and the Hudson Portland Cement Company. By 1930, these operations were being run by Lone Star Cement and Universal Atlas Cement. Lone Star operated a cement plant to the northeast and a quarry on the northeast side of Becraft Mountain until the mid-1960's. Universal Atlas was bought out by U.S. Steel but continued to operate a cement plant on U.S. Route 9 west of and a quarry on the northwest and center of Becraft Mountain.

Until the 1950's, Universal Atlas operated rail cars on an ever shifting series of rail lines to move stone from the quarry to the plant. The rail cars were loaded by electric shovels and hundreds of workers were employed handling electrical cable and moving the rail lines as the quarry faces advanced (see Figures 2 to 6).

Figure 4. Moving railroad track at Universal Atlas Greenport Quarry in 1937.

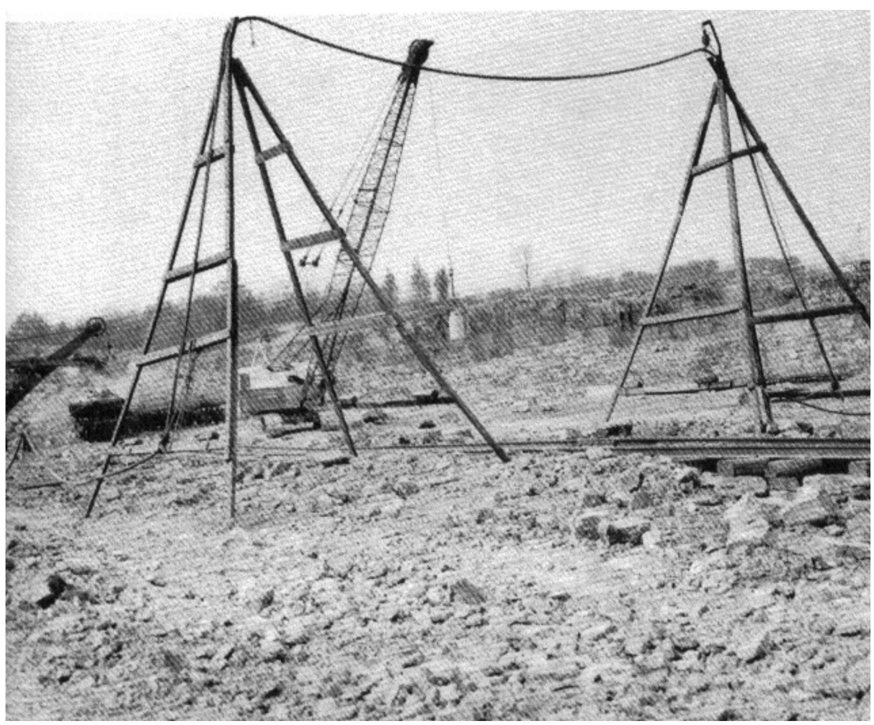

Figure 5. Electric cables and drop ball in Universal Atlas Greenport Quarry in 1953. The drop ball was state-of-the-art equipment at the time, replacing the "blast agent monkeys" whose responsibility it had been to hand drill holes in several pieces of shot rock too big to be put into the crusher, load these holes with sticks of dynamite, light the sticks of dynamite and run like crazy.

ROAD LOG AND STOP DESCRIPTIONS

Meet at the parking lot of the Home Depot in Catskill near Exit 23 of the Thruway at 9:30 am. To get to the Home Depot, take the N.Y.S. Thruway to Exit 21 (Catskill/Cairo/N.Y.S. Route

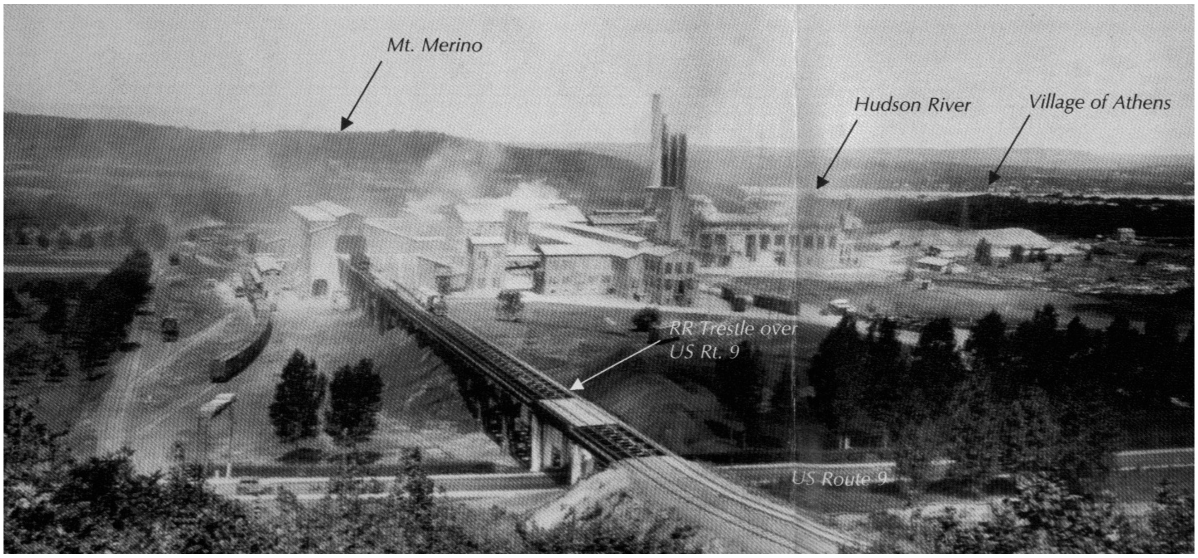

Figure 6. Cement plant on the west side of U.S. Route 9 in Greenport in 1925. Note the trestle bridge over the highway that brought stone to the plant by rail.

23). Note the benign looking outcrops of Becraft Limestone (every cement producer's desire) on the west side of the off-ramp. Stop and pay toll. Go 0.1 miles beyond toll booths to intersection with N.Y.S. Route 23. Go straight across the highway to the Home Depot entrance road. We will assemble on the left (southeast side) of the parking lot. Note the outcrops of New Scotland Argillaceous Limestone on the southeast side of the parking lot.

After assembling at Home Depot, we will drive to our first stop, the Holcim US Catskill Quarry.

Mileage		**Route Description**
0.0	0.0	Return to N.Y.S. Route 23 and turn left, note rip rap drainage stone in roadside ditches and black-top in road, both produced at the Catskill Quarry.
0.3	0.3	Go straight and continue on County Route 23B. The classic Jefferson Heights road cut is on the left on the N.Y.S. Route 23 off ramp.
1.6	1.3	Turn right onto U.S. Route 9W south. Bridge crosses the Catskill Creek. Go straight up the hill underneath the aged railroad trestle.
2.4	0.8	Junction with N.Y.S. Route 385. Veer slightly to the right, staying on Routes 385 and 9W south.
2.7	0.3	Junction with N.Y.S. Route 23A, keep going straight.
3.3	0.6	Turn left, staying on U.S. Route 9W south.
6.6	3.3	Follow Route 9W south to the entrance to the Holcim US Catskill Quarry on the right. Do not go into the Peckham Materials entrance! We will park our cars in the unpaved lot on the left side of the entrance road and car pool for stops in the quarry.

The haul roads, location of quarry faces and various hazards frequently shift in an operating quarry. Therefore, we will drive by convoy to each stop. Please bring your lunches.

STOP 1. Tracey's Landing Quarry. Historically, the quarry operators gave numerical names to their quarries. This practice became difficult at the Catskill Quarry as the property was an amalgamation of at least three different quarries and each company often had the same name on different quarries. Beginning in the early 1990's quarry nomenclature reached an art form under the guidance of Richard Playle and Dave Blasko, mining engineers, Jim Sucke, Murray Craft and Floyd Mower, quarry managers and Paul Griggs, consulting geologist. We became frustrated at trying to use ever-changing landmarks in planning discussions so a systematic nomenclature system based on geologic structure was devised (see Figure 8).

The Tracey's Landing Quarry was named after Bart Tracey, a mining engineer and quarry manager who worked at the quarry in the early 1990's. He had done some of the original chip sampling exploration in this area and was one of the first people to suggest this area as a viable source of cement stone.

Overall, the geologic structure in the Tracey's Landing Quarry is a rolling, doubly-plunging asymmetrical, thrust-faulted syncline. The east limb of the syncline is nearly vertical and continues east down the slope overlooking U.S. Route 9W. The center of the syncline was typically capped by siliceous limestones of the Glenerie and Port Ewen Formations overlying the cement-friendly Alsen Limestone and the cement mother lode, the Becraft Limestone. The west limb of the syncline contains the argillaceous limestones of the New Scotland Formation.

This quarry was worked by removing the argillaceous limestones from the underlying Alsen and Becraft. The "overburden" rock was used by Peckham Materials as high friction aggregate. This quarry served as the main source of cement stone for about 10 years.

STOP 2. Mower's Lake. This quarry is part of the Apple Orchard and was named for Floyd Mower who worked his way up from an equipment operator in 1970 to Quarry Manager in 2003. The quarry serves as a sump for the Apple Orchard which has been a major source of cement stone since the early 1990's.

A series of pumps discharge water from the quarry so that it can be worked dry. The water is used in the cement plant for thermal cooling. Overall, the structure in this area consists of a southward-plunging asymmetrical, heavily faulted syncline-anticline pair.

Unit		Depositional Environment	Thickness at Catskill Quarry	Thickness at Greenport	Primary Use
Onondaga Limestone		Varies	Up to 30'	Up to 50	Aggregate (not used yet)
Tristates Group	Schoharie Calcareous Grit	Deep Ocean	190	90	Fill
	Esopus Shale	Deep Ocean	200	190	Fill
	Glenerie/"Oriskany" Siliceous Limestone	Neritic C	15	10	Aggregate
Helderberg Group	Port Ewen Argillaceous Limestone	Neritic C	25-30	35	Aggregate/Cement
	Alsen Limestone	Neritic B	30		Cement
	Becraft/"Becraft Contact" Limestone	Forereef-Neritic A	65	70	Cement
	New Scotland Siltstone-Argillaceous Limestone	Neritic C	75	70	Aggregate
	Kalkberg Argillaceous Limestone	Neritic B	75	75	Aggregate
	Coeymans Limestone	Reef-Neritic A	17	10	Cement
	Manlius Limestone	Lagoonal-Reef	50	50	Cement
	Rondout Shale/Sandstone/(Silurian)	Lagoonal/Varies	10-30	Up to 10'	Causing Miners' Curses

NOTE: Geologic nomenclature in quotations is based on quarry usage.

Figure 7. Stratigraphy of the Catskill and Greenport Quarries.

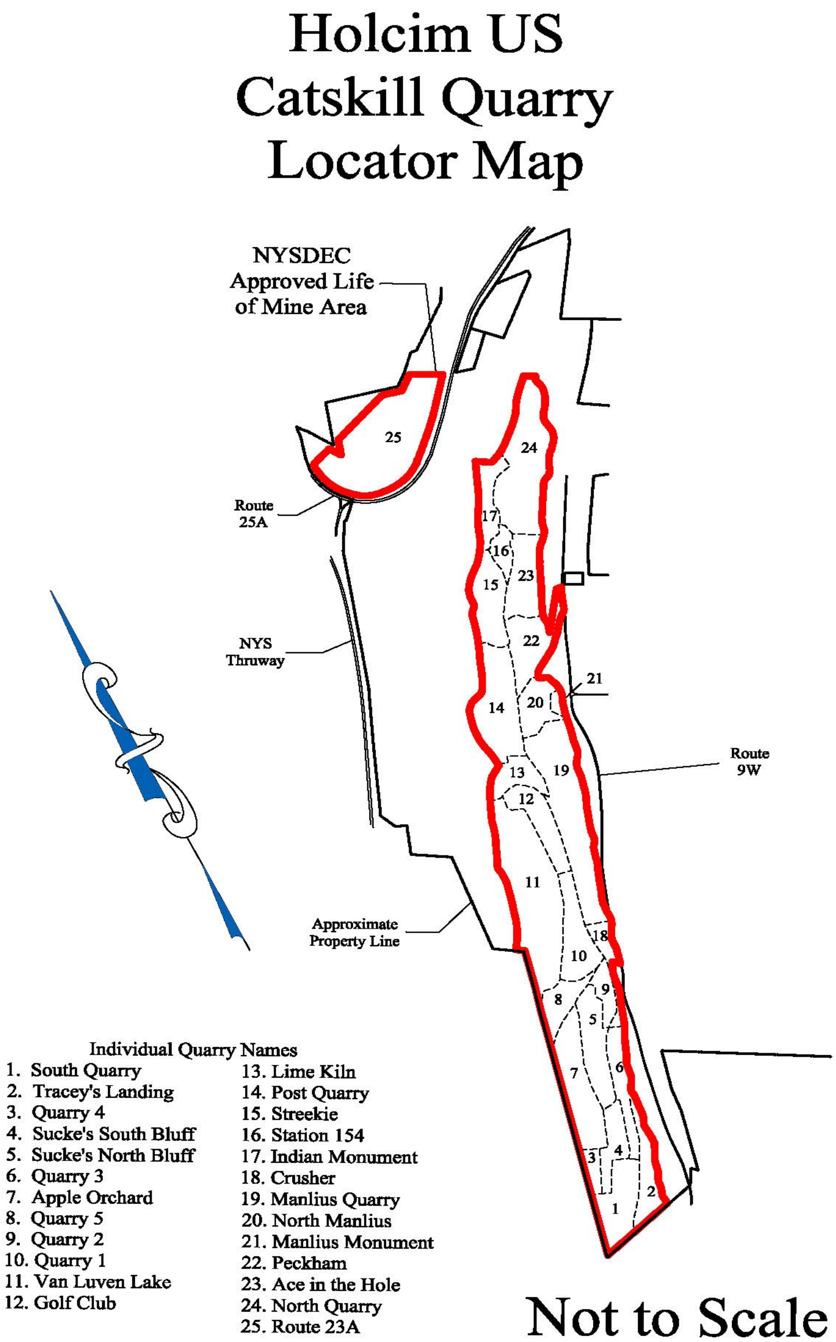

Figure 8. Holcim US Catskill Quarry Locator Map.

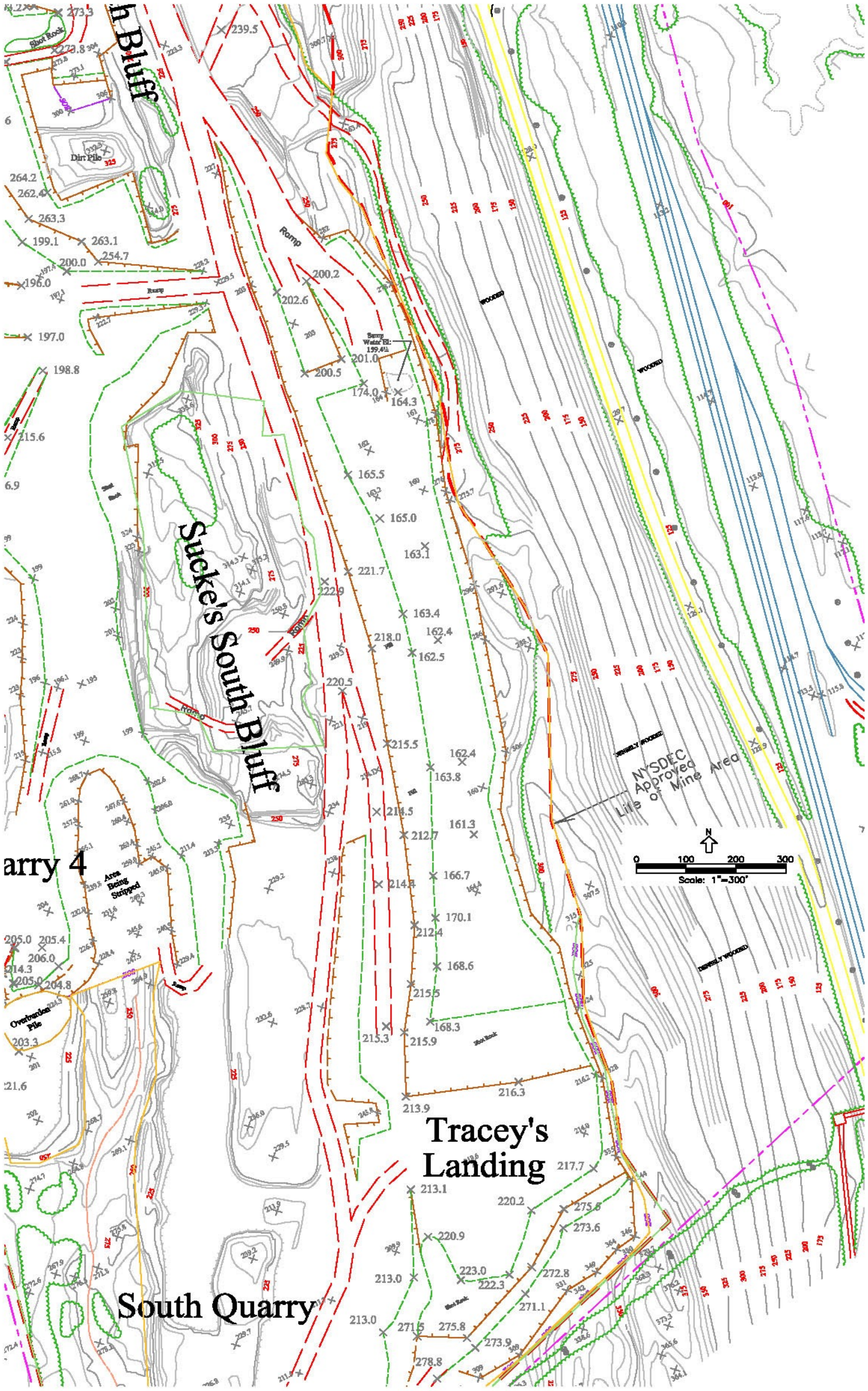

Figure 9. Map of the Tracey's Landing Quarry.

STOP 3. Floyd's Folly. The aforementioned Floyd Mower contributed greatly to the economic viability of this quarry which is in the final developmental stages for full cement stone production. In the 1980's the quarry manager was considering plans for filling this area with overburden rock (this was prior to the involvement of the aggregate producer, Peckham Materials). Floyd, who often operated the bulldozer and was a pretty good amateur geologist, pointed out the presence of near vertical beds of Becraft Limestone in the floor and convinced the powers that be to not cover this area.

STOP 4 Apple Orchard. The Apple Orchard Quarry was developed in the early 1990's and has been a major supplier of cement stone since that time. The cement stone reserves were first evaluated by George Chadwick in the late-1940's but were not mined due to the thickness of overburden rock overlying the fault-repeated thick section of cement stone.

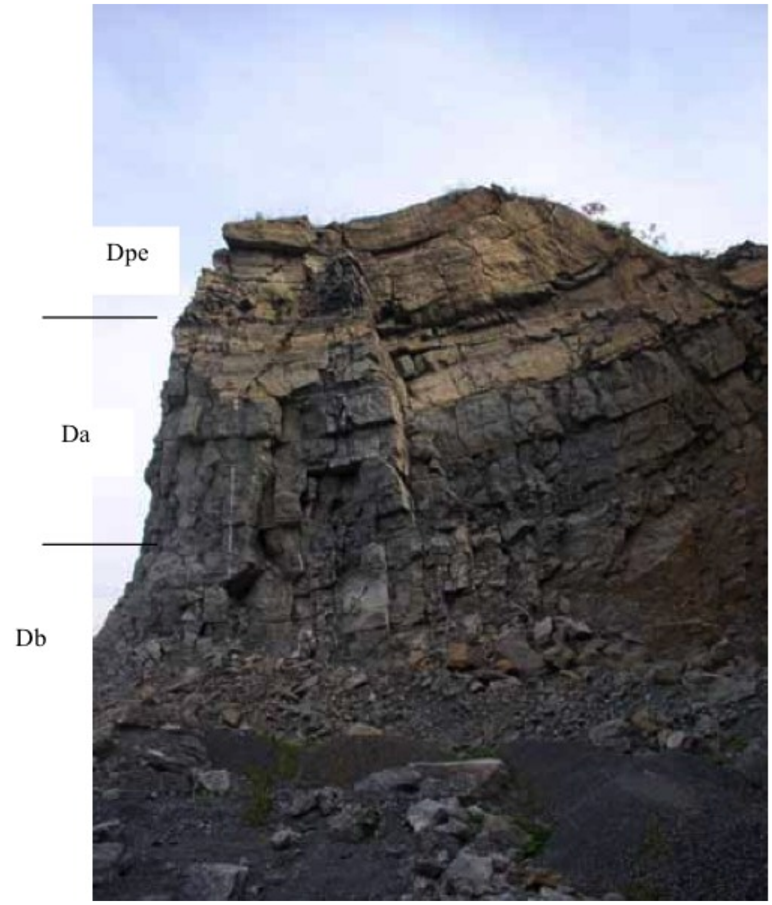

Figure 10. Photo of the north face of the Tracey's Landing Quarry showing the center of the syncline. The dark colored argillaceous limestones of the Port Ewen Formation cap the face. The middle of the face contains the Alsen Limestone and the light–colored stone in the lower third of the face is the Becraft Formation.

In 1988, a geology student named Bill Reinhart worked as an intern at the quarry and researched the prior studies, did some field mapping and made some logical conclusions based on his work. There is an infamous memo in the quarry files from a bemused high level manager that questioned how a geology student could find such a large reserve of cement stone so close to the primary crusher when everyone else had been searching all over the quarry. The answer is, like the quarry geology, fairly complex: (1) the other searchers did not have the requisite geologic expertise; (2) until the authors' involvement at the quarry, geologic investigation had largely been confined to specific areas with little or no formal correlation between individual studies; (3) the task of map making was more time consuming in past days and there were few landmarks that could be used to accurately determine the locations of individual study areas; (4) the text and large scale plans in the geologic reports had gotten separated over the course of the numerous quarry sales and land swaps; and (5) the geology is insanely complex.

The development of the Apple Orchard was a turning point in the history of the quarry. This quarry led to the involvement of Peckham Materials, starting in 1991, to remove the aggregate stone and led to the ultimate geologic investigation and mine planning of the entire quarry.

Overall, the structure in this quarry consists of an asymmetrical, doubly plunging, rolling, highly faulted anticline-syncline pair. The west limb is nearly vertical and the east limb in bounded by the most prominent fault in the quarry, the Sucke's Bluff (or "Sucke's") Fault. This fault has been traced the entire length of the quarry and onto the Lehigh Northeast Cement quarry to the south. The dark colored stone to the left (east) is New Scotland argillaceous limestone and the stone underlying the fault is mainly Alsen and Becraft limestone.

Note in driving to the next stop that the main haul road parallels the path of Sucke's Fault and is mainly underlain by thick repeat sections of aggregate grade rock.

STOP 5. Golf Club. The Golf Club Quarry was last mined more than 50 years ago. At that time, a public road ran through the middle of the quarry. The northward advancing face containing high grade Becraft Limestone at the surface neared the road so the quarry operators started moving in a westerly direction, giving the quarry its distinctive shape. Using much more primitive blasting methods than employed today, they opened up large fractures in the rock that allowed a steady stream of water to flow into the quarry, effectively ending excavation operations at that time.

Overall, this quarry is part of the east limb of a faulted, fairly symmetrical syncline bounded on the east by Sucke's Fault.

STOP 6. Streekie Lake. The Streekie Lake Quarry is a current and future major source of cement stone. Named for a prior owner and its tendency to hold water during periods of wet weather, the quarry structure consists of the west limb of a faulted anticline and a complexly faulted anticline-syncline pair. In general, the top of the face contains Port Ewen siliceous limestone that is removed for use as aggregate overlying repeated sections of Alsen and Becraft limestone to great depth.

The hydrogeology in this area is interesting. The upland areas to the west are underlain by till-

Figure 11. Photo of the north face of Mower's Lake showing the complex folding and thrust-faulting typical of this quarry. The dark colored rock at the upper right of the face is from the lowest part of the New Scotland Formation. It occurs in a sheet that has been thrusted over a complex mélange of Port Ewen-Alsen-Becraft.

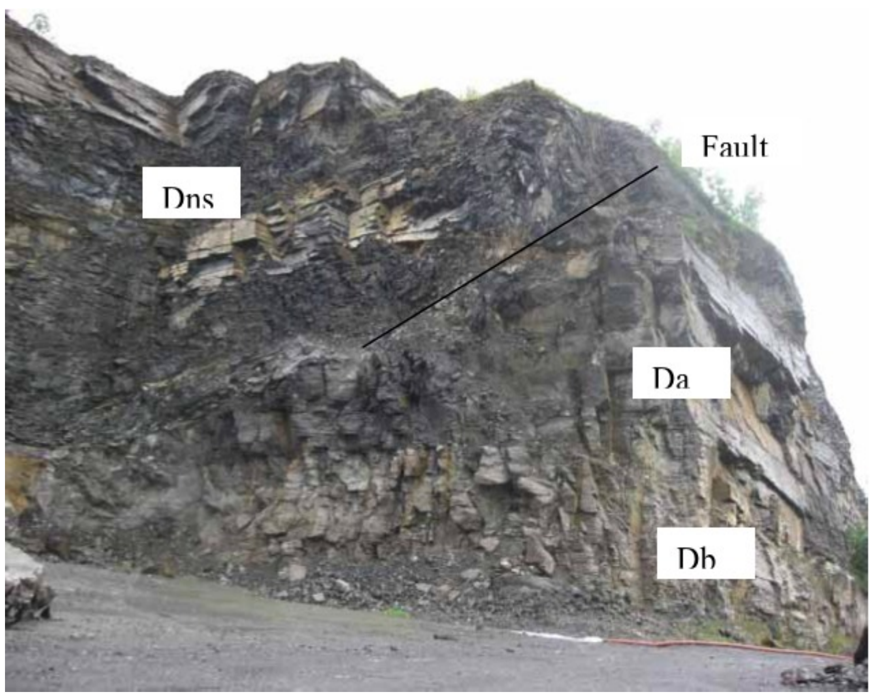

Figure 12. Photo looking south-southeast showing the general expression of Sucke's Fault in the east wall of the Apple Orchard.

covered Devonian shales and a large drainage basin feeds to a sinkhole just west of this quarry. During dry weather, the sinkhole may be dry or is surrounded by a small pond a few feet across. This pond grows dramatically during wet weather (see Figure 14).

STOP 7. Ace in the Hole Quarry. Most of the aggregate stone used by Peckham Materials is blasted, excavated and hauled to their surge pile by Holcim US. Peckham started the Ace in the Hole Quarry in the early 1990's to cover times when the cement company could not haul enough stone or the needed quality of stone to meet the aggregate demand.

This quarry consists of a highly faulted, westward dipping west limb of an anticline primarily containing repeated sections of New Scotland and Kalkberg argillaceous and siliceous limestone. Holcim US has removed Coeymans and Manlius Limestone from the east wall. The west side of this quarry is bounded by Sucke's Fault (see Figure 15).

The north-south trending Sucke's Fault typically dips to the west at about 60 to 80 degrees. However, the fault plane tends to wander at times and varies from slightly overturned to as low as 20 degrees. The two sides of the fault tend to widen in areas where the fault begins to rotate and larger fault slivers are common. The fault acts as a barrier to east-west flow of water and locally promotes north-south flow. Large doubly-terminated, internally flawed quartz crystals (nicknamed "Catskill" diamonds) are periodically found near this fault (see Figure 16).

We will stop for lunch at this location before returning to the parking lot and proceeding to the Greenport Quarry.

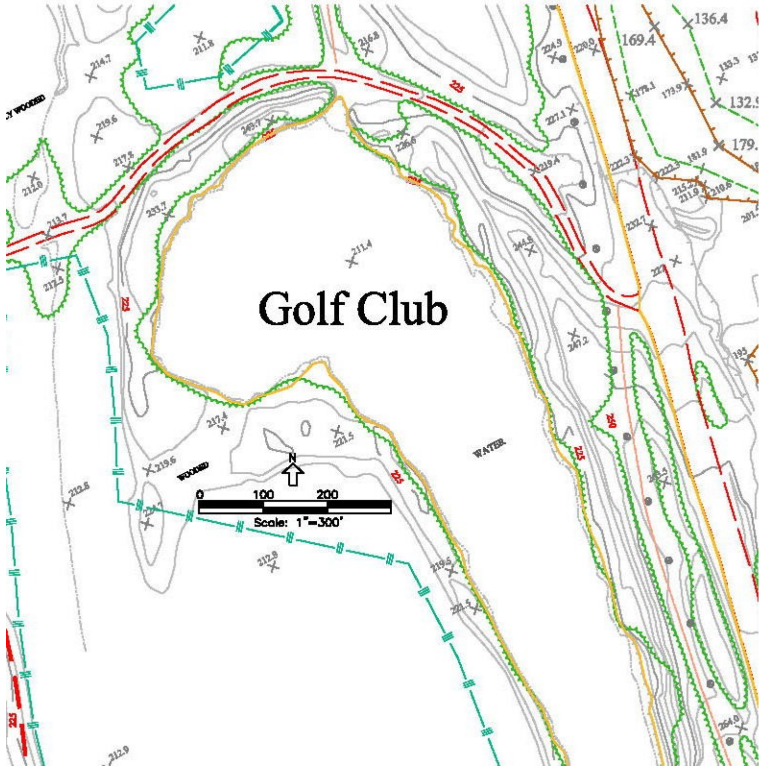

Figure 13. Map showing the northern end of the Golf Club Quarry.

Figure 14. Photo looking northwesterly of the pond backed up behind the Streekie Lake sinkhole which is located in the lower right portion of the photo.

Mileage		Route Description
0.0	0.0	From the Catskill Quarry entrance, turn left onto U.S. Route 9W.
3.4	3.4	Turn right onto U.S. Route 9W and N.Y.S. Route 23A.
4.0	0.6	Turn right onto N.Y.S. Route 385 heading towards the Village of Catskill.
4.9	0.9	Route 385 becomes Bridge Street, crosses the Catskill Creek and climbs up the hill out of the village. Turn left, staying on N.Y.S. Route 385 (Spring Street), following signs for the Rip Van Winkle Bridge.
5.5	0.6	Turn right onto N.Y.S. Route 23 east to the Rip Van Winkle Bridge.
5.9	0.4	Stop and pay toll.
10.1	4.2	Cross the Rip Van Winkle Bridge. Note that any of the islands in the Hudson River contain sand dredged for channel maintenance. The home of Frederic Church of the Hudson River School of artists), Olana, is visible on the hill directly to the east at the end of the bridge. This route passes over a mix of Ordovician age shales. Go past Columbia Greene Community College on the right and the intersection with U.S. Route 9. Turn left onto Fingar Road about 0.3 miles beyond the intersection with Route 9.
10.8	0.7	Drive along the south side of Becraft Mountain on Fingar Road. Turn left onto Newman Road.
12.9	2.1	Turn right into the parking lot and office of A. Colarusso and Son.

Figure 15. Photo looking northerly of chevron folding in Sucke's Fault in the Ace in the Hole Quarry.

Figure 16. Photo showing doubly-terminated quartz crystal ("Catskill" diamond) found in Sucke's Fault. The crystal is approximately 11 inches long.

The haul roads, location of quarry faces and various hazards frequently shift in an operating quarry. Therefore, we will drive by convoy to each stop.

STOP 8. Overview of Aggregate Processing and Blacktop Plants. Like the Catskill Quarry, mining activities at Becraft Mountain have included both cement stone mining and mining for the production of construction aggregates. The differing end products actually result in beneficial production logistics, as the rock formations suitable for construction aggregates are generally not suitable for cement manufacturing and vice versa.

Crushed stone aggregate [any of several hard, inert materials, such as sand, gravel, slag, or crushed stone, used for mixing with a cementing or bituminous material to form concrete, mortar, or plaster; or used alone, as in railroad ballast or graded fill] is a finite, non-renewable natural resource which is essential in the construction and maintenance of roads, industrial development, building structures, airports, railways and dams and should be recognized as an important component of any comprehensive land-use or resource management program.

The New York State Department of Environmental Conservation Division of Mineral Resources website states that each person in New York consumes about 50 pounds of mineral products per day [NYSDEC Division of Mineral Resources http://www.dec.state.ny.us/website/dmn/rocktalk.htm]. This amounts to approximately 175,000,000 tons of mineral products consumed per year in New York State. Most of this consumption comes in the form of construction materials such as those being produced at the A. Colarusso & Son, Inc. (Colarusso) quarry on Becraft Mountain.

Construction aggregates are mechanically processed by a combination of crushers (primary, secondary and, often, tertiary), screens and conveyor systems. These mechanisms serve to reduce, separate and stockpile rock materials that have previously been removed from the quarry by blasting.

A high percentage of blacktop and Portland cement concrete is composed of aggregate: approximately 94 percent of asphalt pavement is aggregate and 80 percent of concrete is aggregate. Due to the high percentage of aggregates in asphalt and concrete every mile of interstate highway contains 38,000 tons of aggregates and about 400 tons of aggregates are used in construction of the average

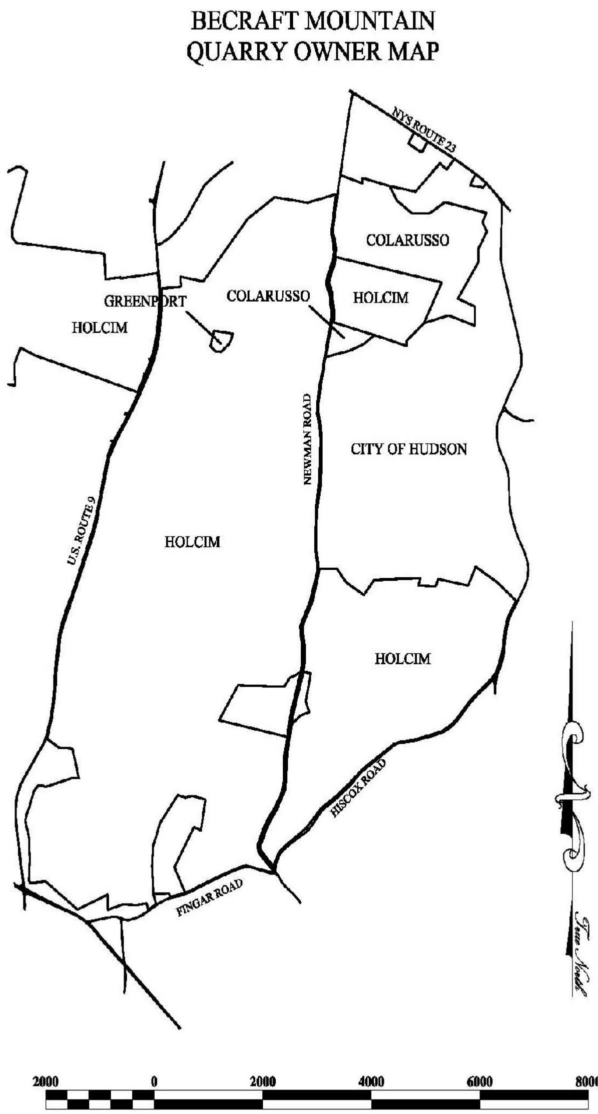

Figure 17. Becraft Mountain Quarry Owner Map.

home [National Stone, Sand and Gravel Association website: http://www.nssga.org/].

Note that approximately 25 percent of cement used on the east coast is imported.

The properties that make a particular rock unit attractive for use as a construction aggregate can make it undesirable for use in cement production. Cement stone manufacturing generally targets pure or relatively pure limestones - limestones with high calcium oxide (CaO) contents. Extensive mapping, core drilling, sampling and chemical analysis is performed to confirm a rock unit's suitability for use in cement manufacturing.

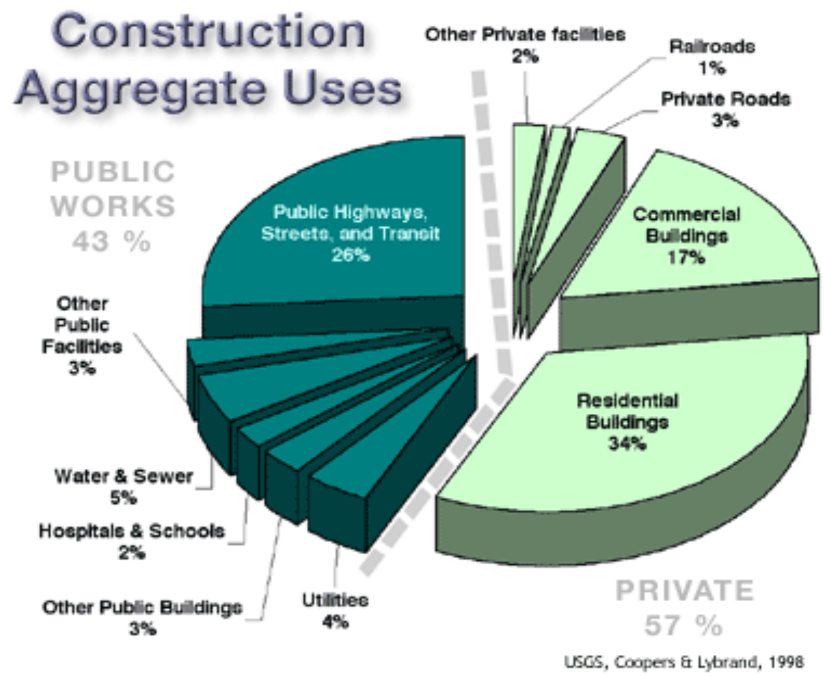

Figure 18. Construction Aggregate Uses.

Although CaO is the most important component of limestone used in Portland cement, other oxides such as iron, silicon and aluminum among other components must be present in the correct proportions. The raw materials (limestone, shale, iron ore, flyash, bauxite, etc.) are crushed and ground to a fine powder and fed to a kiln that heats the powder to about 2700 degrees F, breaking down the chemical bonds. As the material cools, the resulting chemical reaction forms an intermediate product called "clinker". The clinker is finely ground along with gypsum to make the finished cement.

Figure 19. Photo showing feed hopper of primary crusher at aggregate processing plant at the Colarusso quarry on Becraft Mountain.

By contrast, construction aggregate producers in limestone terrains target rock units with high acid insoluble residues (AIR). The geologic formations on Becraft Mountain consist of interbedded high and low residue limestones. Colarusso preferentially removes some of the high residue limestones, leaving the lower residue limestones for Holcim. In general, Colarusso mines the geologic units (New Scotland and Kalkberg Formations) containing high acid insoluble residue (AIR, usually in the form of

SiO_2, Fe_2O_3 and Al_2O_3) for high friction aggregates. Example oxide analyses for sampled rock units are shown in Figure 21..

Figure 20. Photo showing blacktop plant at Colarusso quarry on Becraft Mountain.

STOP 9. Thrust Faulting on East Side of Becraft Mountain. The geologic structure of Becraft Mountain is a doubly plunging, asymmetrical, faulted, north-northeast trending syncline. As a whole, the structure in the eastern portion of the syncline is more complex, owing to the orientation of the stresses impart by continental collisions (i.e. the Acadian Orogeny). The east limb dips at high angles to the west and is highly contorted and thrust faulted. The center of the syncline is contorted and thrust faulted. The west limb of the syncline dips to the east at a few degrees. A strong basal, or sole, fault separates the carbonates from the Ordovician shales they overrode. Numerous thrust faults in the eastern portion of the syncline result in an imbricate arrangement of sheets and repeated sections of rock units.

STOP 10. Overview of Mine Impoundment and Description of Past Mine Plans. Universal Atlas Cement (UAC) and their predecessors mined the Holcim property, primarily on the west side of Newman Road, for cement stone until 1976. This portion of Becraft Mountain contains the gently easterly dipping western flank of the asymmetrical

Ft	*SiO2*	*Al2O3*	*Fe2O3*	*CaO*	*MgO*	*SO3*	*Na2O*	*K2O*	*TiO2*	*P2O5*
0'-11'	35.80	3.58	1.92	30.78	1.60	0.47	0.06	0.73	0.19	0.06
11'-23'	35.73	4.54	1.97	30.12	1.56	0.34	0.06	0.94	0.22	0.08
23'-35'	30.65	6.48	2.34	31.07	1.52	0.39	0.06	1.43	0.29	0.07
35'-47'	30.75	4.44	1.65	32.77	1.52	0.27	0.06	0.92	0.20	0.10
47'-59'	28.29	1.87	1.02	37.55	1.08	0.38	0.06	0.36	0.11	0.05
59'-71'	8.56	1.83	1.12	47.00	1.53	0.59	0.07	0.43	0.11	0.06
71'-83'	8.20	1.59	0.70	46.84	1.97	0.26	0.07	0.37	0.11	0.04
83'-93'	7.44	1.58	0.53	47.94	1.57	0.16	0.07	0.39	0.11	0.05
93'-100'	9.64	2.04	0.76	44.88	1.98	0.17	0.07	0.49	0.12	0.04

Figure 21. Example oxide analysis of chip sample hole.

syncline and includes Helderberg Group units from the Alsen-Becraft down to the Rondout Formation. This area represented some of the thickest exposures of cement stone (Alsen, Becraft and Becraft-Contact) on Becraft Mountain and was the logical area for cement stone quarrying operations to be concentrated. The initial quarrying occurred down to an elevation of approximately 285 to 295 feet above sea level (asl).

UAC developed a drop-cut down to an elevation of about 245 feet (75 m) starting in the late 1950's in order to mine out a wedge of cement stone (Becraft and Becraft Contact) left in the floor. The cut began in the northern end of the property and proceeded southward. Ex-

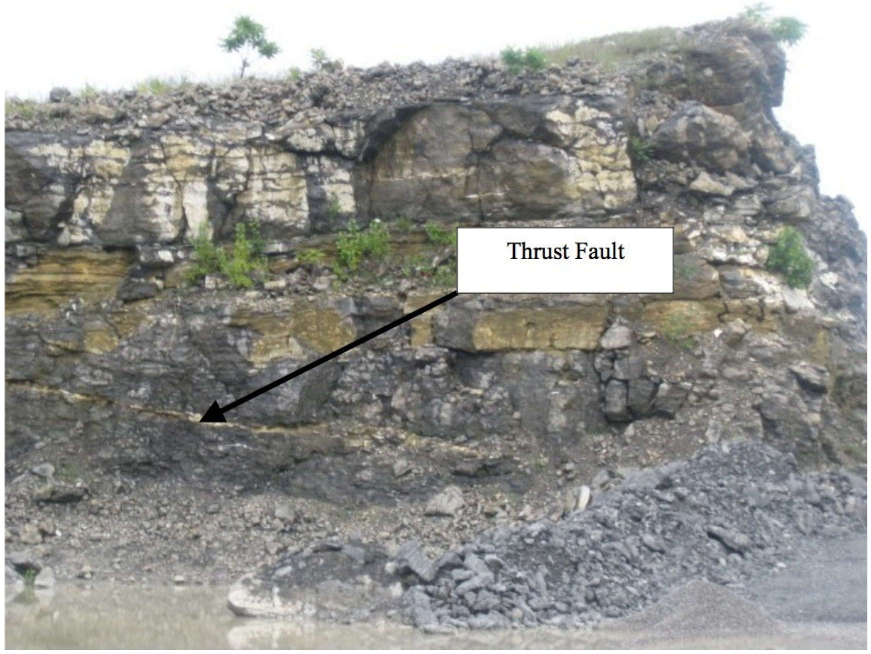

Figure 22. Photo looking east showing end-on view of thrust fault in Kalkberg Formation on east side of Colarusso Quarry.

Figure 23. Photo showing water-filled (mine impoundment) at the Greenport Quarry. The excavated rock from the mined area in this photo was used largely for cement stone manufacturing.

cavation for cement stone (Becraft and Becraft contact) was limited from advancing to the full width of the first cut owing to the easterly dip of the western flank of the syncline. This resulted in a pinching out of the cement stone (Becraft and Becraft Contact) to the west. Mining by Universal Atlas ceased in 1976 and the excavated drop-cut slowly filled with water.

The upper–lift quarry faces westerly of the water-filled drop cut (mine impoundment) include Becraft Contact over the New Scotland Formation. The uppermost quarry lift has been advanced to the west in recent years to prepare the area for deeper excavation.

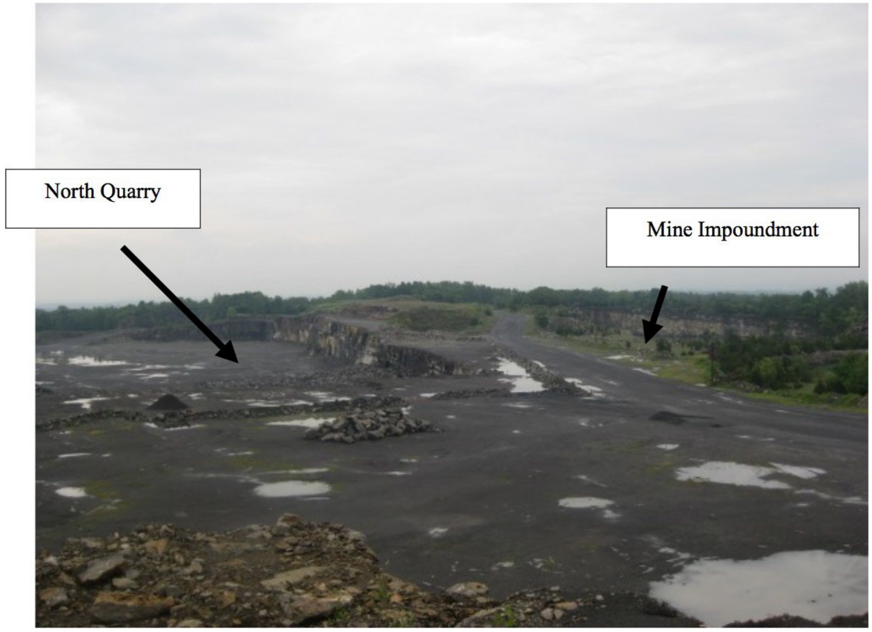

Figure 24. Photo showing differing elevations of mine impoundment surface (260 feet asl) on right and dry North Quarry floor (235 to 245 feet asl) on left.

STOP 11. Overview of Mine Impoundment and North Quarry. Presently, Colarusso is advancing a cut south from the North Quarry towards the area to the west of the mine impoundment. Colarusso is quarrying the New Scotland Formation and upper part of the Kalkberg Formation for use as construction aggregate. Ultimately, the underlying Kalkberg Formation will be removed as another lift, exposing the Coeymans and Manlius Formations for future cement-stone quarrying.

The North Quarry is being advanced toward the south with a floor elevation of approximately 235 to 245 feet asl. This is some 15 to 25 feet below the elevation of the water surface in the mine impoundment (260 feet asl). The aggregate-grade stone (the New Scotland and the Kalkberg formations) extends down to an elevation of approximately 150 or 160 feet asl in the area immediately west of the impoundment. The underlying cement stone (the Coeymans and Manlius Formations) extend down further to an elevation of approximately 90 or 100 feet asl. The ability to mine to these depths is predicated upon the hydraulic connection (or lack thereof) between the impoundment and the excavated cuts, unless the impoundment is first drained. The North Quarry is not pumped, and the elevation difference between the North Quarry floor and the water level in the adjacent mine impoundment indicates that the intervening rock is comparatively tight (see Figure 24).

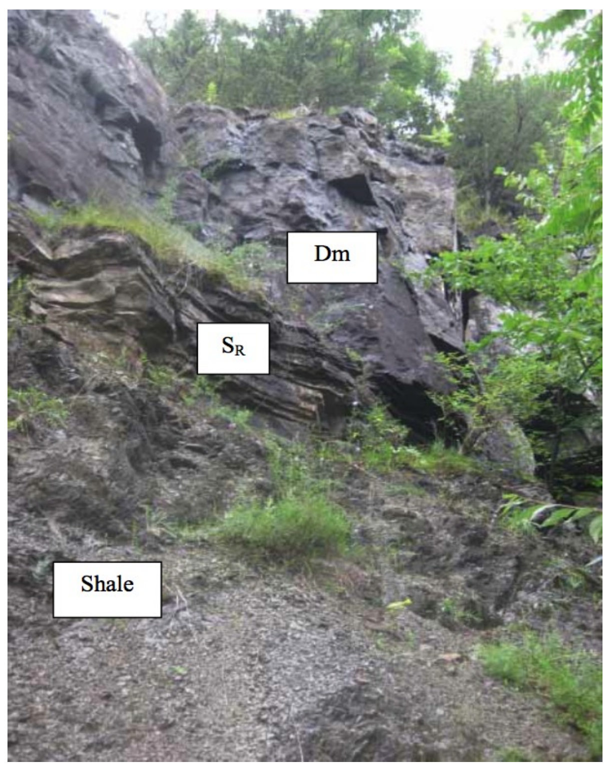

Figure 25. Photo of showing angular unconformity between the Ordovician shale and the overlying Silurian Rondout Formation.

STOP 12. Angular Unconformity and Old West Quarry. The angular unconformity (Taconic Orogeny) between the Ordovician shales and the overlying Silurian Rondout Formation is evident on the west side of Becraft Mountain in an outcrop south of the old West Quarry. The West Quarry was mined for cement stone (Manlius Formation) during the early and middle parts of the past century.

Figure 26. Photo of ripple marks in Manlius Formation on floor of West Quarry. Arrow shows inferred flow direction.

During the Late Silurian and Early Devonian, warm, shallow seas bordered by lands of relatively low relief largely covered New York State. In the Greenport area, the first sediments were deposited in very shallow, quiet (lagoonal), highly saline waters. These sediments formed the relatively fossil poor, thinly bedded, impure dolomites and calcareous shales typical of the *Rondout Formation*. In the Greenport area, sandy portions of the Rondout likely represent near shore sand bar deposits in the generally lagoonal environment.

The Early Devonian seas advanced and covered previous landmasses due to a rise in water level or a downwarping of the land. Water circulation within the deeper oceans gradually increased and living conditions generally improved. Examples of the numerous invertebrates (including brachiopods, trilobites, crinoids, gastropods and bryozoans) that lived in the Early Devonian seas are preserved in the numerous fossils and fossil fragments in the quarry stone.

The *Manlius Formation* was deposited in slightly deeper water than the Rondout. The Manlius sediments were deposited in very shallow, generally quiet, somewhat saline (lagoonal) water and lithified into typically fine-grained, uniformly bedded limestones. Small reefs called biostromes occur scattered throughout the Manlius. The reefy parts of the Manlius were deposited in shallow, clear, agitated waters and typically consist of medium-grained, irregularly bedded limestones. Ripple marks in the Manlius Formation are evident on the sloping floor of the West quarry (see Figure 26).

Cement stone was crushed on site and transported by train and trestle over U.S. Route 9 to the Universal Atlas Cement Plant (see Figure 6). The railroad grade and crusher foundation is still evident in the area west of the notch (see Figure 27).

Figure 27. Photo of concrete foundation (c. 1937) of crusher used to reduce cement stone for use at Universal Atlas' cement plant in Greenport, New York.

STOP 13. South End of Mine Impoundment. Large reserves of aggregate and cement stone remain on Becraft Mountain. Excavation will largely be done below the surface elevation of the water in the impoundment. Future quarrying will eventually necessitate dewatering of the quarry as excavation proceeds to depth. Proper planning necessitates that operators gain a handle on what quantities of water will necessarily be pumped from the quarry to maintain dry operating conditions.

The Greenport Quarry is located within a comparatively small drainage basin. Precipitation, where not falling within the internally draining quarries, tends to run off the site in a focused, but radially outward manner. Water budgets have been performed to assess what fractions of incident precipitation will be lost to evapotranspiration, surface runoff and infiltration. The constantly changing quarry configuration(s) result in altered hydrologic boundaries. The infiltration (always) and runoff (sometimes) components of the incident precipitation must be managed by the operator, in the most environmentally sound and economically viable manner possible, in concert with the geology (and chemistry) of the desired excavation sequence.

Walls and floors of quarries excavated below the water table will only yield groundwater as fast as the host rock permits. Accurate mapping of joints (see Figure 28) and other discontinuities, in relation to the position of recharge areas (and the mine impoundment), is of critical importance, as are the hydraulic conductivities of the excavated units. Hydraulic conductivities can be estimated via pump tests, slug tests, packer tests and flow net construction, combined with proper geologic interpretation.

STOP 14. Blasting Overview. We will stop at a drilled shot if time allows to describe drilling and blasting procedures, current best management practices, view videos of recent blast and discuss and review vibration standards and results.

Figure 28. Photo of water-producing discontinuity in quarry wall. Flow is estimated at approximately 200 gpm.

ACKNOWLEDGEMENTS

The authors would like to thank the quarry owners and operators, Holcim US, Peckham Materials, A. Colarusso and Son and O & G for allowing us to use their property for this trip. Access to these sites is stringently regulated by the Mine Health and Safety Administration and is restricted without the express permission of the quarry owners and operators. Due to their graciousness, the authors are bale to lead a large number of educational tours to these quarries and we would like to remain in their good graces. Please do not attempt to visit these quarries without proper authorization.

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Much of the information presented herein is based on geologic and hydrogeologic investigations performed by the authors as consulting geologists to the mining industry over the last 25 years. In addition, the following publications were relied upon to provide general information used in this presentation.

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