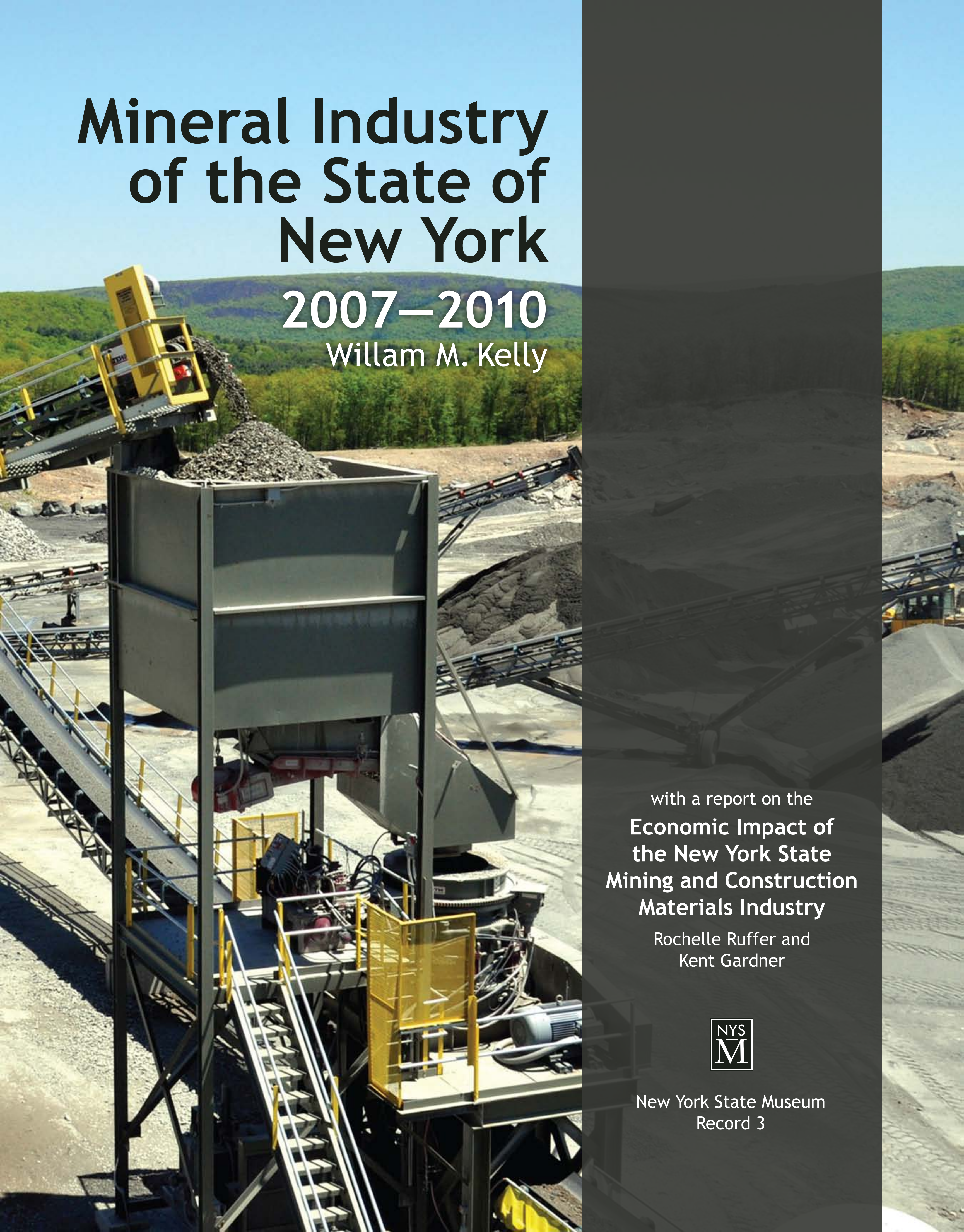

Mineral Industry of the State of New York

2007—2010

Willam M. Kelly

with a report on the

Economic Impact of the New York State Mining and Construction Materials Industry

Rochelle Ruffer and
Kent Gardner

New York State Museum
Record 3

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Front cover: Crushing, sorting and stacking equipment at a crushed stone quarry.
Photo courtesy of George Haas, Baschmann Services, Inc.

Back cover: Wheeled loading equipment and crushed stone stock piles.
Photo courtesy of David Hamling, New York Construction Materials Association.

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PREFACE

The ultimate source of wealth and the basis of modern society is the earth. It is said, "If it can't be grown, it has to be mined," which implies that all of the goods, and the services based on those goods, that support New York's standard of living are derived either from agriculture or mining. The Mineral Information Institute currently states that each citizen of New York will be responsible for the consumption of 3.3 million pounds of minerals, metals, and fuels in their lifetimes. In addition to recycled materials, nearly 38,000 pounds of *new* minerals must be provided *every year* for the things that each person in the state uses. These minerals are in addition to the approximately 1,000 gallons of petroleum, 7,000 pounds of coal, and 76,000 cubic feet of natural gas consumed per capita annually. However, fuels are not the subject of this report and will not be discussed further. Some of the mineral products needed are exotic and are not part of New York's natural resources, but many are. Volumetrically, the bulk of the minerals needed to sustain modern life are those used to build things. Crushed stone, sand and gravel, and cement producers comprise over 90 percent of the mines in New York. These products are vital for roads, bridges, buildings, airports, schools, and homes.

Historically, the New York State Geological Survey produced publications dealing with the state's mineral industry. In the early twentieth century, there were annual publications on the topic. By mid-century these were published less frequently, for instance, every five or more years. For most of the latter half of the century, the Survey cooperated with the U. S. Bureau of Mines to produce an annual review of the mineral industry of New York, published in the *Minerals Yearbook, Volume II, Domestic* series. With the demise of the Bureau of Mines during the Clinton administration, the Survey continued to work with the U. S. Geological Survey to produce the reports, which are currently published by the federal government.

However, the information provided in the *Minerals Yearbook* is very limited in scope. This bulletin provides a deeper overview of the mineral industry in New York and a review of the current state of the largest portion of that industry, specifically the construction materials—crushed stone, sand and gravel, and cement. The status of other currently mined commodities is reviewed herein but no attempt has been made to discuss all commodities ever mined in New York. The primary users of the construction materials are the concrete and hot mix asphalt industries. The status of these in New York is surveyed as well. In addition, included here is an investigation of the economic impact of the industry performed by economists at the Center for Governmental Research located in Rochester.

The New York State Legislature recognized the importance of the mining industry in promulgating the Mined Land Reclamation Law (MLRL) in 1975:

> *The legislature hereby declares that it is the policy of this state to foster and encourage the development of an economically sound and stable mining industry, and the orderly development of domestic mineral resources and reserves necessary to assure satisfaction of economic needs compatible with sound environmental management practices.*

A study of the economic impact of New York's mining and construction materials industry performed by the Center of Governmental Research, an independent nonprofit organization, is included in this report as Appendix 1 and demonstrates the importance of the mining industry to the state and local economies. The mining, concrete, and hot mix asphalt industries contribute over $5 billion annually to New York's economy. These vital industries are responsible for 30,000 jobs paying above-average wages of $48,000. Total annual wages generated by the mining industry equates to approximately $1.3 billion. In addition, the mining industry contributes at least $101 million in taxes to the state coffers every year.[1] In 2009, permit fees paid by mine operators to the state equaled $4,026,545. The Department of Environmental Conservation holds $190 million in financial security to ensure successful reclamation of the approximately 2,100 permitted mines in the state (NYS Department of Conservation 2009a).

The importance of this industry to the state and local economy is significant and should not be hastily discounted. The direct economic impacts to localities include above-average-wage jobs, a reasonably priced supply of aggregate for municipal highway departments, and property tax revenues. The legislative policy to "foster and encourage the development of an economically sound and stable mining industry" is more important today than ever before.

The mining industry in New York is currently beset by a growing number of issues that are jeopardizing its economic stability and vitality. If left unresolved, these issues, described below, have the potential to produce a profound impact on New York's future economy and derail the legislative policy set forth in the MLRL.

- Mining uses are being "zoned out" from local communities that adopt land-use laws prohibiting these uses based upon community pressure and a "Not in My Backyard" mind-set. New York's mineral resources are finite and mines can only be developed where suitable resources exist. Relatively few geological materials are suitable for construction materials, the main products mined in New York. There are portions of New York where suitable geological resources do not naturally occur. In addition, there are areas where the suitable resources have been depleted or cannot be mined because the reserves have been built on by other uses, the local zoning does not allow mining, or environmental constraints prevent mining.
- There is an unspoken misperception that mining resources are unlimited or can be imported from more distant locations with no significant economic or environmental impact. Local governments should be encouraged to give sufficient consideration to the importance of mineral resources, the economics of the industry and the need for mines to be located within in a reasonable distance to markets (including municipal highway departments), in the comprehensive planning process.[2] Lack of proper planning for mineral resources has and will result in permanent loss of mineral resources available to future generations, serious shortages, and increased costs of construction aggregate, which will need to be brought in from more distant sources and eventually from outside the state and country.
- The number of permitted mines has decreased from approximately 2,500 in 1995 to about 2,100 in 2009. This dramatic decrease is largely attributable to prohibitory zoning measures and increased difficulty and costs of obtaining permits, leading to the depletion of existing mines faster than new mines can be permitted.
- Mining is one of the most heavily regulated industries in New York. New environmental regulations have increased the difficulty and cost of obtaining permits.
- Public misconceptions of mining, often expressed in the form of a "Not in my Backyard" attitude, are widespread and have led to longer and more costly environmental reviews.
- Mining companies frequently expend millions of dollars to obtain a mining permit in addition to the millions in capital expenditures in land and heavy equipment needed to begin a mine.
- Smaller mining companies cannot afford the cost of obtaining and keeping a mining permit and are being bought out by larger companies. This reduces the level of competition, which puts upward pressure on construction material prices.
- Construction materials must be transported to areas where suitable resources do not exist or are in short supply. There are local shortages of materials; this has gotten worse in the last few years and will become more widespread if appropriate actions are not taken.
- As an example of the economic consequences of a local shortage, concrete sand that sells for approximately \$8/ton in much of upstate New York sells for up to \$25/ton in the New York City area. Concrete sand is one of the most common construction materials and is transported to the metropolitan market from Canada, New Jersey, the Capital District, the Adirondacks, and central New York. The increased cost is a result of the increased transportation distance.
- New York's infrastructure is aging and requires significant reconstruction. Increased aggregate costs will reduce the amount of infrastructure work that can be done or will require taxes to be raised.
- Transporting construction materials for long distances causes unnecessary wear and tear on the infrastructure, which increases the need to raise taxes.

A careful balance needs to be reached between protection of the environment, landowners' rights, and the need for mining. Like agriculture, mining is a necessity of modern life. Careful and comprehensive planning, including identification, classification, and protection of valuable geological resources, is required to ensure that supplies of mining resources are available to future generations.

William M. Kelly
June 2010

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[1] "The Economic Impact of the New York State Mining and Construction Industry," June 2009, prepared by the Center for Governmental Research for the New York State Geological Survey.

[2] The Economic Impact Study (Appendix 1) found that a decrease of a quarter of the mines in proximity to the NYS Thruway would result in a 42% increase in the cost of construction aggregate, a cost directly attributable to having to transport the resource greater distances. A decrease of one-half the mines would result in a 59% increase in costs

Chapter 1

MINERAL RESOURCES OF NEW YORK

HISTORICAL OVERVIEW

Since the arrival of European colonists in New York, the extraction of mineral wealth has been an important societal goal. Mining, then and now, provides the raw materials for consumer goods. Iron was used for cooking utensils and stoves, among other things. It was the basis for many construction projects. The availability of "hydraulic" cement was as important in the success of the Erie Canal as it is to the maintenance of the New York State Thruway. Mines provided materials to improve the standard of living of the populace. Late-nineteenth-century clay mines in the Hudson River Valley provided clay to make literally billions of bricks used to replace the highly flammable wooden building materials of New York City. The State of New York has, since the 1980s, ranked about fifteenth in the nation in terms of mineral value extracted annually. The Mineral Information Institute reports that each person in New York consumes, on average, 9,871 pounds of stone, 7,811 pounds of sand and gravel, and 714 pounds of cement *every year* (Mineral Information Institute 2009).

Mining in New York began as soon as people entered the region after the retreat of the last glacial period. Native Americans extracted chert for projectile points; clay for pottery; and red, yellow, and black iron and manganese minerals for pigments. Various types of stone were used by these early peoples for jewelry, decoration, and tool making. The modern history of mining in New York began in the southeastern part of the state. As European settlers spread inland, into the Hudson Valley and Adirondacks and westward through the Mohawk Valley to western New York, mining activities accompanied them. Not all portions of the state are equally endowed with mineral wealth. Consequently, many more mines were established in regions such as the Hudson Highlands and Adirondacks than in the Catskills or Southern Tier. Furthermore, since "you can only mine the ore where the ore is," certain commodities were mined only in specific parts of the state. For example, no salt mines ever existed in the Adirondacks and no garnet was ever mined in the Southern Tier.

The Colonial Period

As soon as Europeans arrived in New Netherland, they began to search for mineral wealth, particularly precious metals. Initially, they traded for metal with the Native Americans and later, as homesteads and communities were established, the Europeans began to explore on their own. Gold and silver were never found in economic quantities, but other metals were equally or more important for daily life. Iron was first extracted from "bog" deposits. These were small pockets of limonite that were literally deposited in swamps. At the same time, limonite occurred in weathered pockets of rock in the Hudson Highlands and was used for ore. These deposits soon proved to be too small and lean, and further exploration revealed many deposits of magnetite. This mineral became the iron ore of choice. The ore was reduced to metal in local refineries and used for cookware, tools, weapons, and construction materials. The earliest iron mines of this period were located in Columbia and Orange counties. Lead and copper were also metals that the people of the colonial period sought. Galena and chalcopyrite were mined in several counties in the Hudson Valley and in the Mid-Hudson region. The lead ore mineral galena also contains traces of silver, and unsuccessful attempts were made to establish mines for the latter metal. In addition to metals, stone of several types was quarried for building purposes. Depending on the local geological resources, marble, limestone, and sandstone were quarried for building stone. Clay deposits, which are common in the Hudson Valley and across the state, were mined for brick and rough pottery.

The Nineteenth Century to World War I

New York's mining industry achieved its height during this period. The center of iron mining migrated from the lower Hudson Valley to the Adirondacks, although the Mid-Hudson limonite mines and siderite mines still produced iron ore. At the time of the Civil War, iron from the Adirondacks constituted 25 percent of the

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nation's production and was critical to the war effort. From stoves to cannons to horseshoes, many essential items were made in North Country blast furnaces. Between 1880 and 1918, 23 million tons of iron ore worth $70 million were mined statewide, mostly in the Adirondacks. Also in this region, mines for galena for lead; pyrite for sulfur; graphite for pencils, crucibles, and electrical components; garnet for abrasive; and talc, used in paint and soap, were established during this period. A single mine in the southern Adirondacks yielded diatomaceous earth, known as "infusorial earth," which was used for polishing. Emery, a mixture of magnetite, corundum, and other minerals, was mined at Peekskill and used as an abrasive. Quartz, derived from rocks in Ulster County and sand in Oneida County, was used for glass manufacturing. Molding sand, primarily recovered a few inches below the surface of Albany County, was used by the iron foundries.

Granite, sandstone, slate, marble, and limestone continued to be mined for construction purposes and mill stones. The type of stone mined, and hence the final product, depended upon the geological formations of each region of the state. Clay was mined statewide for brick, terra cotta, roofing tile, and pottery. Small iron mines appeared in hematite deposits in central New York south of the Mohawk Valley, but these were rather quickly converted to pigment mines, to provide the raw material for "barn red" paint. Red and green paint pigment was made from finely ground slate from Washington County.

In central and western New York, halite and gypsum were mined. Halite was produced in underground mines and also was extracted from brines from specially prepared wells for use as a food preservative and in chemical processes. For most of this period, the New York State government controlled a large portion of the state's salt brine industry. Gypsum, used for fertilizer and plaster, was mined in open cuts. Limestone of a special composition was mined for the raw material for portland cement across the state where it was available.

The Modern Period

During the period from the end of World War I to the beginning of World War II, mining in New York generally declined. In some cases, commodities whose availability had been restricted during the war, and hence were mined in New York, appeared again on the world market, rendering the New York mines uneconomic. Some New York mines simply ran out of ore. Graphite mining ceased. Quarries for building stone greatly diminished. Only a few of the largest iron mines survived and only two garnet mines remained in operation during the early part of this period. Two small emery mines in Westchester County continued to operate but eventually failed. However, World War II brought resurgence in some quarters of the mining industry. Because of the necessity of a domestic source for certain raw materials, large iron mines in the Adirondack counties of Essex, Clinton, and St. Lawrence were rejuvenated. From 1938 to 1945, more than 8 million tons of ore were produced from the mines at Mineville, Essex County, alone. A nineteenth-century iron mine at Tahawus in Essex County was activated as an ilmenite mine to provide titanium dioxide, an essential component of paint pigment and chemical smoke screens. The titanium oxide operation remained in operation for forty years but closed in 1982 and all of the iron mines had closed. Neither iron nor titanium was being mined in New York by the beginning of the twenty-first century. Lower-cost ore available offshore made the iron mines uneconomic, and the loss of processing facilities in New Jersey forced the closure of the ilmenite mine. Mining for sphalerite (zinc ore) and industrial talc began in the post–World War I period and continued until the beginning of the twenty-first century. The last of the gypsum mines closed in 1999. Mined gypsum in New York was supplanted by synthetic gypsum derived from exhaust scrubbing equipment at coal-fired electrical power plants.

Some mines did fare well in the modern period. Industrial talc mines in St. Lawrence County expanded, although the last of these operations closed permanently in early 2009. The talc was used for filler in paper, ceramics, and rubber. It was not used for cosmetics. Mines for sphalerite, a primary zinc ore, were established in 1920 and continue to operate sporadically in St. Lawrence County, and there was interest in sphalerite produced as a by-product of limestone quarrying south of Patterson in the Mohawk Valley. As of this writing, the last of these mines is on furlough. Halite, extracted both as rock salt and brine, is still an important commodity. Clay is mined primarily for landfill liner and cover material. Small mines produce "peat" for agricultural purposes, primarily potting soil. Garnet is still produced for abrasives and water filtration. During this modern period, a new commodity came to maturity. The mineral wollastonite entered the market as a filler material and found particular utility in the manufacture of molded resin automobile body panels. Two New York mines in the Adirondacks produce a third of the world's supply of this mineral. Granite, slate, and bluestone (sandstone) quarries show continued strength. By far the most important mines in the State of New York in the modern period are those that produce construction aggregates (crushed stone, sand, and gravel) and portland cement.

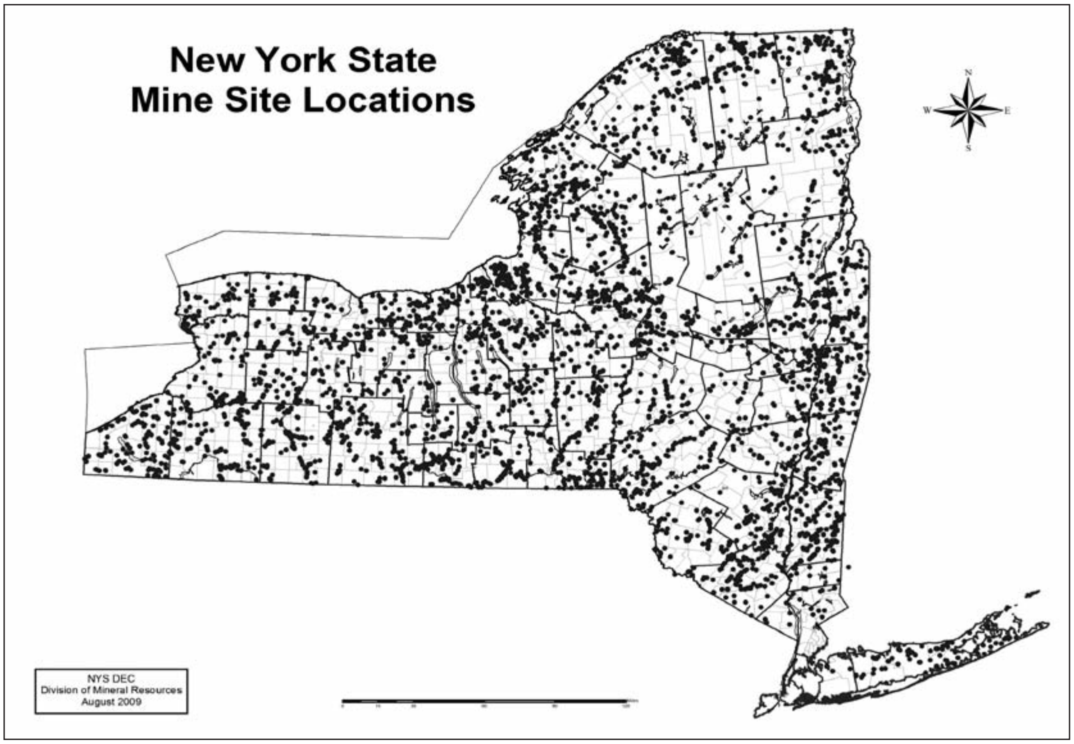

Figure 1. Location of mines of all types in New York.
Source: NYS Department of Environmental Conservation, Division of Mineral Resources.

CURRENT PRODUCTION

In 2009, there were approximately 2,200 permitted mines in New York (NYS Department of Environmental Conservation 2007) (Figure 1). Of these, about 460 were operated by governmental agencies. Mines operated in fifty-six counties in the state. During the last five to ten years, there has been a steady decrease in the number of mines and mining applications in New York. Mines are distributed relatively evenly across the state. This is because most mines produce materials used for construction aggregates, that is, crushed stone and sand and gravel. These are products that are high in volume but low in value. They must be produced close to market lest the value of transporting the material to the site of use exceeds the valued of the product itself. Depending on variables such as the cost of fuel and traffic congestion, the cost of hauling distances of thirty miles or less can be greater than the value of the material being delivered. A total of 64,000 acres in New York were affected by mining in 2007. Mining disturbs more than 0.30 percent of the land surface in only eight of New York's counties. The maximum disturbance is 0.41 percent. For comparison, 4.6 percent of New York is paved for roads and parking lots. Since 1975, 22,688 acres of mined land have been reclaimed (Figure 2).

Dimension stone (e.g., pavers, landscape stone, and architectural elements) is produced dominantly from sandstone (bluestone) deposits (Figure 3) but also from metamorphic rocks of generally granitic composition (Figure 4). A prominent exception is the anorthositic gneiss quarried in the Adirondack region under the guise of "granite." Colored slate, particularly red, is

Figure 2. Reclaimed talc mine with grasses and trees restored, Talcville, New York.

Figure 3. A wire saw is used to quarry blocks of sandstone, commercially known as "bluestone," for use as dimension stone, Walton, New York. The blocks will be re-sawn to desired size and thickness.

Figure 4. Blue "granite" (anorthosite gneiss) is quarried in Ausable Forks, New York.

Figure 5. Crushed stone quarry, near Saranac Lake, New York. Rocks being extracted are marble (white) and granitic gneiss (dark).

quarried in Washington County. Several slate mining and distribution companies operate there but much of the slate is actually quarried in Vermont. Crushed stone used for construction aggregate is also primarily sedimentary rock in the form of dolostone, limestone, and sandstone. But in regions where these rocks do not occur or are of poor quality, metamorphic rock (Figure 5) and diabase (trap) are used. It should be noted that most of the "granite" mines operating in New York are actually producing crushed (granitic gneiss) stone. By far the largest numbers of mines in the State produce sand and gravel, a material widely deposited at the end of the last Ice Age. Clay was also widely deposited at the end of the last glacial period. The most extensive deposits, and the thickest, are in the Hudson River Valley. Once used for brick and tile manufacture, clay is now primarily used for landfill liner and cover. A special type of sand deposit, called industrial sand, yields fine-grained, uniform sand for molds used in casting metal.

Shale, till, marl, and topsoil are mined for fill or cover material. Peat, in the form of swamp deposits or

Figure 6. Peat mine, Columbia County, New York. Organic-rich muck (peat) is mixed with manure and sand to make potting soil. White material is marl.

"muck," is a component of potting soil or is used for agricultural improvement (Figure 6). The muck is piled to dry, then mixed with manure and sand and then reground to produce a marketable product. Garnet is mined for abrasive uses, both coated abrasives and loose powders, for fine grinding or garnet-assisted water jet cutting (Figure 7). By-product garnet is separated from wollastonite tails and used for sand blast grit. Rock salt, used mostly for melting ice and snow, is produced from underground mines (Figure 8). Salt is also produced as brine by solution mining in New York for medical use and chemical feed stock. Wollastonite is mined and either marketed raw or, after chemical modification, for use as filler (Figure 9). This product has found a substantial market in automobile body panels in the past three decades. Commodities mined in New York, number of mines, and location are given in Table 1.

Mineral resources can only be mined where they occur. The bedrock and surficial geology and geologic history of New York control where materials can be mined. Not all resources are located advantageously close to markets. Some resources simply do not occur in large areas of the state. An example is the lack of high-quality carbonate rock sources in the Southern Tier. In this case, materials must be transported into the area, with attendant increased product cost. Furthermore, because a particular resource, such as limestone or sand and gravel, is present in a region, it does not necessarily follow that the resource is available for mining. Many issues can restrict or preclude mineral extraction. For example, road access may not be sufficient for heavy trucks, or environmental constraints may exist that preclude mining in an area. The establishment of a mine may not be compatible with wetlands or scenic rivers. Soil type, such as prime agricultural land, archeological

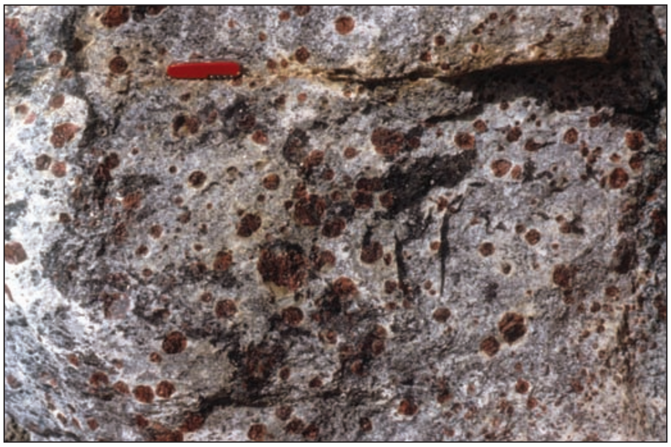

Figure 7. Garnet ore at Barton Corporation's Ruby Mountain Mine. Knife is 4 inches long. Tenor is approximately 15% garnet of the pyrope-almandine variety.

Figure 8. Pillar of halite (rock salt) in an underground mine in central New York. The ore is greater than 95% halite.

Figure 9. Wollastonite mine face, Lewis, New York. Tenor of the ore is up to 60% wollastonite. Dark streaks are pyroxene (diopside) and grossular-rich garnet.

resources, and the presence of existing mines, must be considered. A mineral resource may already have something built on it. If a commercial shopping mall or private residence is constructed on a deposit of gravel or limestone, that resource will not be available for mining no matter what the quality of that resource. Finally, local zoning or land-use laws may not permit establishment of a new mine or expansion of an existing one.

MONETARY VALUE

New York consistently ranks fourteenth to sixteenth in mineral value produced in the fifty United States. The USGS (2008) annually surveys mineral producers in New York and estimates that the total value of mineral products mined in the state in 2007 was $1.6 billion (see also: Appendix 1 on economic impact, this volume). Crushed stone is generally the leading mineral product. Following this in value are cement, salt, and construction sand and gravel. New York is the only source of domestic wollastonite in the United States. New York is first in the production of industrial garnet, third in salt production and, until early 2009, fourth in talc. Total production and value are given in Table 2.

Table 1. Commodities Mined in New York.

Commodity	No. of mines	Produced in: (county)
Bluestone	84	Albany, Broome, Chenango, Delaware, Tompkins, Ulster
Clay	35	Albany, Cayuga, Chautauqua, Delaware, Erie, Niagara, Onondaga, Rensselaer, Saratoga, St. Lawrence, Ulster, Washington, Yates
Dolostone	25	Clinton, Dutchess, Hamilton, Herkimer, Monroe, Montgomery, Niagara, Orange, Orleans, Rockland, Saratoga, St. Lawrence, Ulster, Washington, Wayne
Garnet	1	Warren
Glacial till	2	Cayuga, Onondaga
Granite	23	Dutchess, Essex, Franklin, Fulton, Jefferson, Oneida, Saratoga, St. Lawrence, Warren, Washington
Industrial sand	1	Oneida
Limestone	82	Albany, Cayuga, Clinton, Columbia, Erie, Genesee, Greene, Herkimer, Jefferson, Lewis, Madison, Monroe, Montgomery, Niagara, Oneida, Onondaga, Ontario, Orleans, Oswego, Putnam, Saratoga, Schenectady, Schoharie, Seneca, St. Lawrence, Tompkins, Ulster, Warren, Washington, Wayne
Marble (crushed)	2	St. Lawrence, Rensselaer
Marl	1	Genesee
Peat	5	Cattaraugus, Columbia, Rensselaer, Schenectady
Salt (rock)	2	Livingston, Tompkins
Salt (wells)	124	Schuyler, Wyoming
Sand & gravel	1,744	All counties except: Bronx, New York, Queens, Richmond, Rockland, Westchester
Sandstone	27	Chenango, Clinton, Delaware, Franklin, Greene, Orange, Orleans, Rensselaer, St. Lawrence, Steuben, Sullivan, Ulster, Washington
Shale	46	Albany, Allegany, Broome, Chenango, Erie, Greene, Jefferson, Lewis, Orange, Rensselaer, Saratoga, Schenectady, Schoharie, Sullivan, Ulster, Washington, Westchester
Slate	11	Washington
Topsoil	22	Chemung, Erie, Herkimer, Jefferson, Niagara, Oneida, Oswego, Otsego, Saratoga, St. Lawrence, Steuben, Tioga, Washington
Wollastonite	2	Essex, Lewis
Zinc	1	St. Lawrence

Source: New York State Department of Environmental Conservation 2009.

Table 2. Mineral Production and Value* in New York as Measured by Shipments, Sales, or Marketable Production.

Commodity	2005 quantity	2005 value	2006 quantity	2006 value	2007^p quantity	2007^p value
Clay	785	11,657	813	30,430	699	28,488
Gemstones	NA	78	NA	90	NA	96
Gypsum	2,226	11,409	413	2,118	299	1,535
Salt	6,835	326,518	4,885	257,312	7,985	400,491
Sand & Gravel	31,293	203,537	34,962	235,857	33,301	277,740
Stone, crushed	52,583	446,601	52,636	437,847	46,780	426,943
Stone, dimension	42	7,471	39	3,856	49	6,450
Combined: cadmium (zinc by-product, cement, garnet (industrial) talc, wollastonite, zinc)	XX	286,252	XX	368,282	XX	393,174
Total	**XX**	**1,293,523**	**XX**	**1,335,792**	**XX**	**1,534,917**

*Thousands of metric tons and thousands of dollars, ^{p}Preliminary, XX not applicable, NA not available. Data are rounded to no more than three significant digits; may not add to totals shown.

USGS 2008.

Chapter 2

AGGREGATES IN NEW YORK

Construction aggregates are the most widely used commodity mined in New York. These are hard, inert materials capable of forming a stable mass either by compaction or with the addition of portland or bituminous cement. When mixed with a cementitious binder, the aggregates comprise from 80 to 95 percent of the finished product. When used in their natural form, for example, for road base, they are 100 percent of the final mass (Herrick 1994). The main sources of aggregates in New York are crushed stone, sand and gravel, and recycled aggregates (concrete and asphalt). Secondary aggregates, in the form of blast furnace slag or recycled tires, are or have been used but are of minor volumetric importance. Recycled and secondary sources of aggregate are insufficient in quality and quantity to satisfy all of New York's aggregate demand. Consequently, it is essential to maintain primary sources of construction aggregates.

For the past decade, construction aggregates have amounted to roughly half of the total value of mineral production in New York (Table 3). Demand is driven by the construction industry, which itself reflects the state of the economy. In 1999, crushed stone and sand and gravel comprised 42 percent of total value of state mineral production. This rose to 55 percent before dropping to 48 percent during the economic downturn caused by the recession of 2003. The value of construction aggregates rose to 50 percent of total by the mid-2000s and was 53 percent according to the most recent figures (2007) available (U. S. Geological Survey 2001, 2004, 2006, 2007). The southern Hudson River Valley region and Long Island are the largest consumers of both sand and gravel and crushed stone.

Table 3. Value of Construction Aggregates and Percentage of Total Value of New York Mineral Products.

Year	Value of construction sand & gravel plus crushed stone (thousands)	Percentage of total mineral value, New York
1999	$418,000	42%
2000	458,000	45%
2001	513,000	49%
2002	549,000	55%
2003	524,000	52%
2004	516,000	47%
2005	649,000	50%
2006	671,000	50%
2007	827,000	50%

Source: U.S. Geological Survey.

The number of mines and permitted reserves in New York is declining. Beginning in the 1990s, the trend in the industry has been a shift, particularly in sand and gravel operations, from small mining operations, often "family-run," to larger, consolidated activities that involve fewer, larger companies. This is driven by economies of scale, cost of capitalization, and by governmental requirements for detailed studies of environmental and other impacts. Many small firms with limited initial investment capital are being eliminated. Figure 10 shows the trend in the number of permitted mines in New York for the past fifteen years.

The costs of mining in New York, which in part drive the downward trend in the number of mines, are varied. Capitalization, land acquisition, and permitting costs have increased greatly in the recent past. Permitting costs can equal half of the overall costs. Included in this category are legal fees; engineering and geological analysis; and interpretation, drilling, and specialized studies of acoustics, viewscape, vehicular traffic, wetlands, wildlife, cultural resources, air quality, and seismic (blasting) impacts. In the mid-1980s, a permit for a medium-sized (≈60 acres) mine could be obtained for as little as $5,000 to $10,000 and higher. Currently, permitting costs for a similar mine are $50,000 and $100,000. In the 1980s, a mining permit could be obtained in a year or less. At present, the time between submission of an application for a mining permit and the issuance of the permit can be lengthy, and can extend into years in extreme cases.

The New York Court of Appeals has recognized the high cost of establishing a mine. Commenting in a legal

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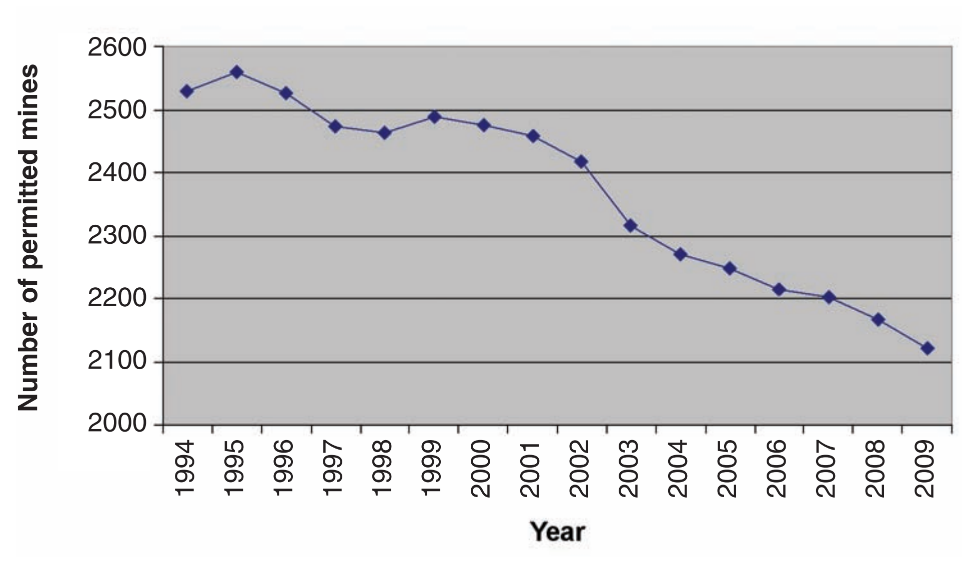

Figure 10. Trend in the number of permitted mining operations in New York since 1994.
Source: NYS Department of Environmental Conservation Division of Mineral Resources Annual Reports: http://www.dec.ny.gov/pub/36033.html.

decision on a western New York mining operation, the court held: *"Indeed, in light of the stringent requirements imposed by the Mined Land Reclamation Act, such costs frequently, if not invariably, run into the hundreds of thousands of dollars or more, and represent a significant portion of the investment necessary for a landowner to devote real property to quarrying"* (Glacial Aggregates LLC v. Town of Yorkshire 2010). After the investment of potentially large amounts of money in the application process for the mining permit, mining companies have no guarantee that they will be successful. Either the State of New York or the courts may find reasons to deny the permit. For example, in 1997, a Massachusetts company expended $600,000 on permitting activities for a crushed stone mine in Rensselaer County. The administrative law judge who oversaw the project recommended issuance of the permit based on the facts but the permit was denied (NYSDEC 1998).

Costs associated with permitting a large mine are considerably greater than those cited above. On average, the permitting process for a large mine in New York will cost approximately $2 million. For example, a company based in Erie County spent over $2 million during the permitting process for a sand and gravel mine that would ultimately affect 400 acres over a 100-year life-of-mine. A Vermont firm spent $2 million in acquiring permits for a mine in Rensselaer County in 1995. A Warren County company expended between $3 and $4 million for a permit to operate a 190-acre crushed stone quarry in Washington County. In addition to these costs, mining companies must finance land acquisition, development, and equipment costs. At current prices, a single-wheeled loader of large capacity can cost $1 million and a truck for haulage $500,000. The processing plant, used to clean and sort sand and gravel or crushed stone aggregate, averages $2 to $3 million and can cost up to $7 million for state-of-the art equipment.

Chapter 3

CRUSHED STONE

The use of crushed stone for construction projects has a long history in New York. The State Geologist, Frederick Merrill, reported in 1895 that crushed stone was the material of choice for making durable roads of good quality. At that time, trap rock, granite *sensu lato*, and metamorphic rock, limestone, sandstone, and shale were used for road metal. Merrill noted that limestone was the best material as the fine-grained detritus produced in the crushing process acted like mortar when placed on a road surface. Igneous and metamorphic rocks did not produce cohesive fines and were less favored. He also noted that if these rocks were micaceous, they disintegrated rapidly. Shale was to be avoided except for local, light-duty roads. Sand and gravel were relegated to base layers (Merrill 1895). The production and use of crushed stone grew as New York's economy expanded. While the total amount of stone quarried in New York remained relatively constant, the advent of concrete use for building and construction projects caused the amount of dimension stone produced in New York to decrease while crushed stone tonnage increased. By the 1920s, crushed stone accounted for 50 percent of the total value of stone produced in the state (Newland 1921).

In the late nineteenth century, small crushed stone operations were widespread in New York. Often, the stone to be crushed was stripping waste that was produced as a quarry was developed for another resource. However, even at that time there were some larger quarries established specifically for the production of crushed stone (Merrill 1895). Trap rock (diabase) from the Palisades in Rockland County was quarried in large quantities. Dolostone from quarries farther north on the Hudson River provided what was then recognized as a superior product for road surfaces. Quarries in the Hudson Highlands (e.g., Iona Island) were established to feed the construction and concrete industries; the fine residue from the crushing process was sold as polishing compound. One of the largest quarries in the state at the time was located in South Bethlehem, Albany County. Dedicated crushed stone quarries existed west of Albany in Schoharie County.

GENERAL GEOLOGY

As noted above, several types of stone were used for crushed stone in the past. That is also true currently. In the past, materials used for making roads varied locally. If a road was intended for light to moderate traffic, local stone, whatever it consisted of, could safely be used. Shale was an exception to this rule. However, if traffic was anticipated to be heavy, use of high-quality aggregate was economically warranted. Unfortunately, rocks that produce good-quality crushed stone are not evenly distributed geographically in New York and this results in the necessity to import suitable stone.

At present, several types of rock can be used for crushed stone in New York. These included igneous rocks such as diabase (trap) and granite; metamorphic rocks such as gneiss and marble; and sedimentary rocks, most prominently represented by limestone, dolostone, and sandstone. Figure 11 shows the distribution of rocks that can be quarried for crushed stone that will meet modern quality specifications. In practice, igneous rock is rarely used for crushed stone as little of this rock type exists in New York. Trap rock is only quarried from the diabase sill in Rockland County and there is little unmetamorphosed granite in New York.

However, rocks of high metamorphic grade are abundant in the Adirondacks and in the Hudson Highlands and Manhattan Prong of southeastern New York. Commonly, what is called crushed "granite" is in fact metamorphic rock such as granitic gneiss. The mineralogical composition of these rocks is variable in terms of modal percent quartz, plagioclase, and K-feldspar. So strictly speaking geologically, the rocks are meta-granite, meta-syenite, meta-quartz diorite, and so on. Some marble units and calc-silicate rock produce acceptable-quality aggregate. Perhaps surprisingly, a micaceous pelitic gneiss is the source of crushed stone at a quarry in Dutchess County.

Among the sedimentary rocks, sandstone and carbonate units produce suitable stone. Within the realm of carbonate rocks, all other properties being equal, the amount of noncarbonate minerals present, expressed as

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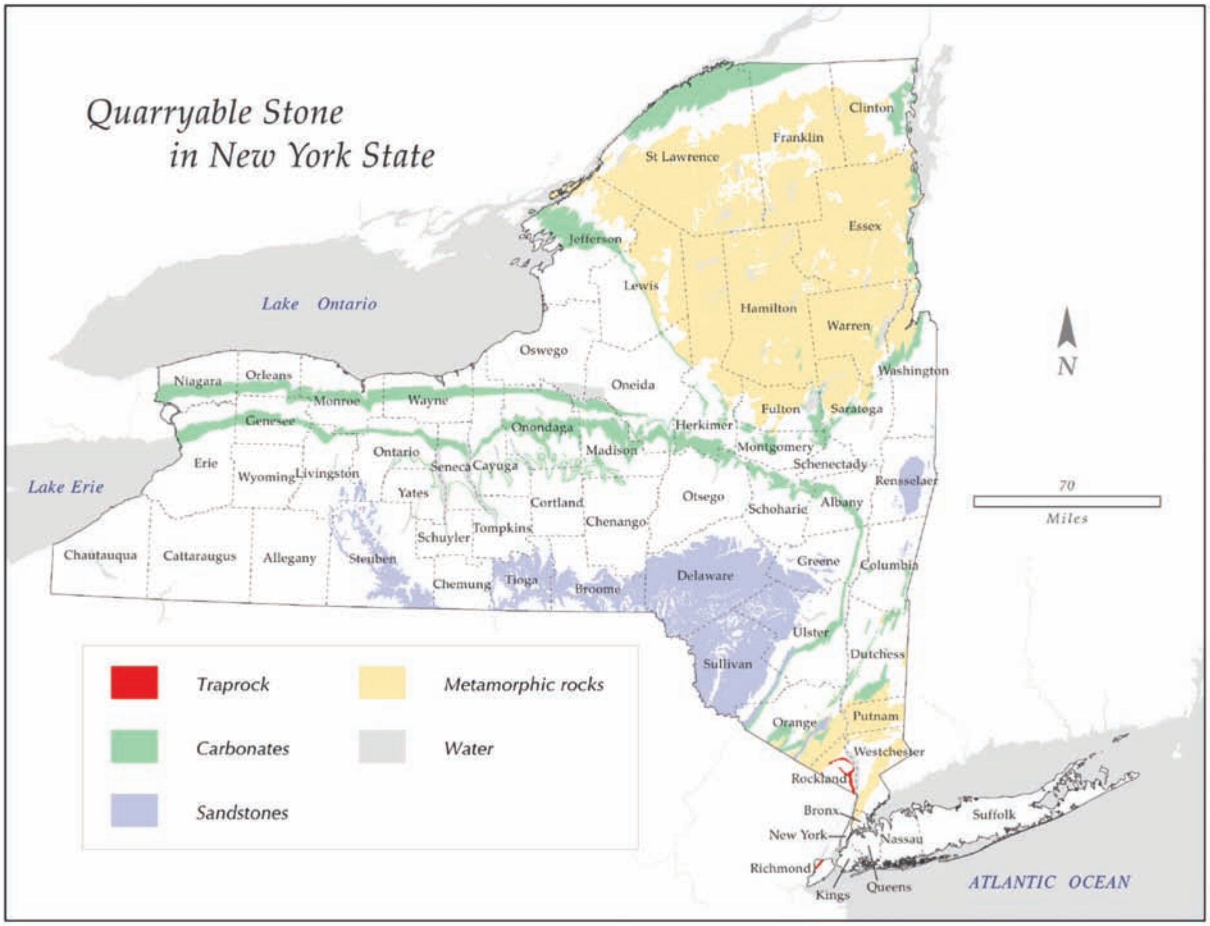

Figure 11. Map of rocks suitable for crushed stone.
Source: NYS Department of Transportation 2010.

acid insoluble residue (AIR), can affect the final use of the product. Rock units with low values of AIR may not be suitable for use in the top layer, the friction surface, of certain roads. If this is the case, high-friction aggregate can be blended in or the rock can be used for other purposes (e.g., base layers), where polishing of the aggregate is not an issue.

A mineral resource can only be mined where it exists, and it is clear from Figure 11 that there are large areas of New York that are not underlain by rock which qualifies for use as crushed stone. Furthermore, Figure 11 is a generalization that overestimates the amount of quarryable stone. Not all of the rock in the regions highlighted is suitable for aggregate production. For instance, large parts of Broome, Delaware, Sullivan, and Ulster counties are shown as potential sources of sandstone. However, while good-quality sandstone does exist in that area, a large portion, perhaps half, of the bedrock in the region is shale interbedded with the sandstone; shale has no utility for construction aggregate. Similarly, the Adirondack region and the Hudson Highlands, shown as metamorphic rock in Figure 11, do contain rocks that produce acceptable crushed stone. But again much of the rock in those regions is comprised of micaceous schist, charnokite, and gneiss that will not make tough, durable aggregate. Furthermore, just as is the case with sand and gravel deposits, environmental concerns, existing residential or commercial buildings, infrastructure, park lands, and so on, all restrict the access to the resources that is actually available for development.

METHODS

Development of a modern quarry and production facility for construction aggregates is a complex process. New plant construction can take up to six years for planning, design, site preparation, and construction. If a "greenfield" site is chosen for the facility, diamond drilling is done to extract core of the bedrock. The core is used to determine the quality and the quantity of the stone available. This information is used to guide the overall mining plan. If the site is forested, the trees must be logged and removed. The overburden, soil and unusable rock, is then stripped off the proposed quarry site. Soil is typically retained for reclamation purposes, depending on the final disposition of the site. A large amount of material must often be removed from the site in order to establish a new facility. In 2009, 600,000 cubic yards of "mud" and 3 million tons of rock were removed to build a new plant in Rockland County (Maio 2009).

Location of mining faces and face height, if the rock is homogeneous, is based on permitted limits and the most economical setbacks and slope angles to maximize the use of the reserves. Typical face height varies from 6 to 9 meters (20 to 30 feet) to 18 to 21 meters (60 to 70 feet). Face height and location may depend upon selective quarrying needed to meet NYS Department of Transportation requirements for the quality of the aggregate.

To separate the rock from the quarry face, the rock is drilled and blasted. Blast hole drilling is accomplished by track-mounted or truck-mounted percussion rotary air blast drills. In general, at larger operations and where the terrain is level, a truck-mounted drill is used. In smaller operations, or where the ground is uneven or sloped, track-mounted equipment is used. Hammer-type drills are used for this procedure. Technologically newer down-the-hole drills have a percussion mechanism, with the "hammer" located just behind the drill bit. Impact from the hammer strikes the bit directly so no energy is lost at the joints of the drill stem and the percussion casing provides stability to the drill bit. This produces a straighter hole, that is drilled more quietly. Older drills have the percussion mechanism mounted at the top of the drill mast so that the impact energy has to travel through the entire drill string to reach the bit.

Blasting can be done using either contracted or in-house personnel. In New York, the most commonly used explosive agents are a mixture of ammonium nitrate and fuel oil (ANFO) or emulsions (an immiscible water-in-oil mixture of ANFO and additives, the latter serving to boost the energy of the explosion and provide water resistance). Emulsions are often used where water may be encountered in the blast hole or in the rock. Both types of blasting agents are generally pumped into the blast holes from a bulk truck as a flowable material. Cartridge-type explosives are used in specialized situations. Typically, a booster explosive will be placed at the bottom of the hole, which will be ignited by a detonator. Nonelectric detonators are currently more commonly used than electronic detonators. Electronic detonators are used in specialized situations such as unusual rock face configurations, proximity to neighbors, or problems with rock breakage.

Blast vibration monitoring can also be either contracted or accomplished in-house. Often, ground vibrations at the property perimeter and/or more remote locations are recorded when new mining operations are established. In some cases, permanent monitoring stations are established on neighboring properties. NYSDEC mining permits require that all blasts be monitored with at least one properly calibrated seismometer. Additional seismometers are used if site-specific conditions warrant. The ground vibration caused by blasting is measured in terms of peak particle velocity (ppv). At present, New York standards are based upon guidelines researched and designed by the U.S. Bureau of Mines to prevent even cosmetic damage to the weakest building materials (Siskind et al. 1980). The U.S. Bureau of Mines research indicated that the maximum allowable ground vibration that would prevent any damage varied, dependent on the frequency. At frequencies above 40 hertz, the allowable peak particle velocity is capped at 2.0 inches per second (ips). The allowable ppv is capped at 0.75 ips for mid-range frequencies at typically newer homes containing dry wall interior, and at 0.50 ips for mid-range frequencies for older homes containing plaster interior. The allowable ppv is variable for very low frequencies (see Figure 12).

The U.S. Bureau of Mines guidelines (Siskind 1980a) for air overpressure (or air blast), the blast-induced vibrations that travel through the air, have also been adopted in New York. These standards prevent damage

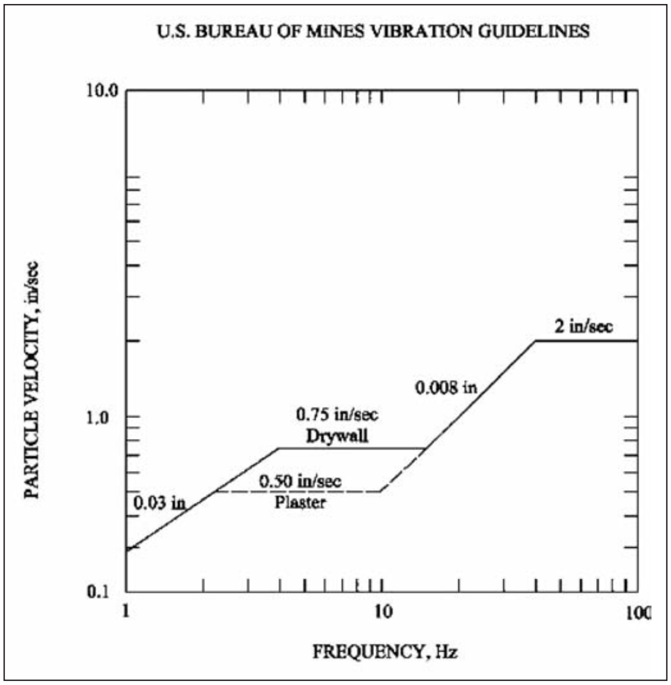

Figure 12. USBM Ground Vibration Guidelines.
Siskind et al. 1980.

to the building material most susceptible to air overpressure: glass in a poorly installed window. These limits vary depending on the type of measuring system:

Measuring System	Maximum Air Overpressure
0.1 Hz High Pass	134 dB Align
2.0 Hz High Pass	133 dB
5 or 6 Hz High Pass	129 dB
C Slow (Not Exceeding 2 seconds)	105 dB

Most commercially available seismographs use a 2.0 Hz high pass system.

Commonly, there are misconceptions about blasting and the damage caused by the resulting ground vibration. When questioned, most people believe that the louder the noise caused by the air overpressure, the greater the potential damage caused by the ground vibration. There is not necessarily a relationship between the two. The human body is very sensitive to blasting. Research has shown that an observer experiencing a mine blast accompanied by loud noise is likely to judge the ground vibration to be very strong, and therefore to suspect structural damage, at a ppv level of one tenth to one hundredth of that needed to damage a structure (Hemphill 1981).

Figure 13. Typical crushed stone quarry. Dolostone units mined here are typically the Tribes Hill Formation.
Courtesy Callanan Industries, Inc.

Figure 14. Quarry face in a carbonate rock quarry. The geological formations are nearly horizontal.
Courtesy Callanan Industries, Inc.

Figure 15. Wheeled loading and hauling equipment is used to move blasted rock to the crushing plant.
Courtesy Callanan Industries, Inc.

Quarry blasts typically liberate between 10,000 and 15,000 and between 70,000 and 100,000 tons of material. The size of the blast and layout of the shot pattern must take the geology, structure, and weaknesses in the rock (mud seams), and neighboring properties, into account. A typical crushed stone quarry is shown in Figures 13 and 14 on page 14. The blasted material is loaded into haul trucks (Figure 15) to be transported to a fixed or movable crusher (Figures 16a, 16b), but it is not uncommon for "load and carry" procedures to be used. Trucks vary in capacity, dependent on the needs of each operation, but typically range from 30 to 35 tons to 75 tons with about 50 tons capacity being the average. The crushed product is screened and stockpiled (Figure 17).

Figure 16a. Truckload of blasted rock at primary crusher.
Courtesy Callanan Industries, Inc.

Figure 16b. Rock dumped into primary crusher.
Courtesy Callanan Industries, Inc.

Figure 17. Typical crushing and screening operation. Primary crusher (right) feeds material to secondary crushers and sizing screens. Material is stockpiled by size (background).
Courtesy Callanan Industries, Inc.

PRODUCTS AND USES

The term "crushed stone" is applied to rock that has been broken into small, irregular fragments of specific particle size (Table 4). In 2006, 52,100,000 metric tons of crushed stone were used in New York (USGS 2006). Due to the economic downturn of the past two years, the 2008 total production of crushed stone was about 43,852,000 metric tons (Table 5). The material is used in metallurgical and agricultural operations, but by far, the majority of crushed stone used in New York is consumed by the construction industry. It can be used without a cement or bitumen binder or it can be mixed with a binding substance such as asphalt or portland cement. Unbound materials are used for a variety of purposes including road base, road surfacing, railroad ballast, or filter stone. Bound crushed stone is used in concrete and black top for road construction and repair, airports, dams, sewers, and residential and commercial foundations (Tepordei 1985).

Information about companies that produce crushed stone in New York is published by the New York State Department of Environmental Conservation, Division of Mineral Resources. Data organized by commodity is available in electronic format at http://www.dec.ny.gov/cfmx/extapps/MinedLand/standard/commodities. More specific information is available in a searchable mines database available at http://www.dec.ny.gov/cfmx/extapps/MinedLand/search/mines.

AVAILABILITY

Many geological formations in New York that can be used as a source for crushed stone have been mapped and adequately described in the past century. As a result, exploration for and development of new mines will most likely occur in one of the known formations. However, as has been shown, geological materials suitable for good-quality crushed stone are not uniformly distributed in the state. It will be necessary to continue to transport certain products (e.g., concrete sand or high-friction aggregate) from one part of New York to another, or import the material from out-of-state. Furthermore, the environmental and land-use issues that affect sand and gravel mines also impact the crushed stone industry.

It is very important that there be planning, at the state and local levels, for future mineral resources of all kinds, but specifically for construction aggregates. These geological materials directly support the physical infrastructure and economic development of New York's communities. Zoning and land-use planning can effectively direct most industrial operations into areas reserved for such activities. Preserving these resources for sustainable growth will require that the rocks be identified, characterized for suitability and, in the best case, protected from uses that would prohibit mining.

QUALITY

Details regarding the chemical and physical properties of crushed stone products to be used in New York are specified by the New York State Department of Transportation, Standard Specifications (New York State Department of Transportation 2008). The following generalized description of quality requirements for construction aggregates is derived from Herrick (1994). Stone to be used for aggregates should have a tendency to break into equant, roughly cubic particles with a minimum of flat and elongated shapes. Important physical

Table 4. Definitions and Specifications of Selected Aggregate Products.

Product	Specification
	Large coarse aggregate
Macadam	3.5 to 1 inch (90 to 25mm)
Riprap, jetty stone	Heavy, irregular rock for river, harbor, dam, and shore embankment protection
Filter stone	Crushed stone in sublayer under riprap or jetty stone
	Graded coarse aggregate
Concrete aggregate	3.5 inch to No. 4 sieve (90 to 4.75mm)
Bituminous aggregate	3.5 to No. 4 sieve (90 to 4.75mm)
Bituminous surface aggregate	1.5 inch maximum
Railroad ballast	75 to 1.5 inch (1905 to 37.5 mm)
	Fine aggregate, stone sand
Stone sand – concrete	Crushed fine aggregate produced from quarried stone, No. 4 sieve to No. 200 sieve (4.75 to 0.074mm)
Stone sand – bituminous mix and seal	Crushed fine aggregate produced from quarried stone, No. 4 sieve to No. 200 sieve (4.75 to 0.074mm)
	Combined coarse and fine aggregate
Graded road base or sub-base	2 inch to No. 200 sieve (50 to 0.074mm)
Unpaved road surfacing	1 inch to No. 200 sieve (25 to 0.074mm)

Source: New York state Department of Transportation 2008.

Table 5. Crushed Stone Production in New York.

Type of stone	Number of quarries	Quantity (Metric tons)	Value
Limestone	59	24,412,000	$220,500,000
Dolostone	18	10,063,000	84,093,000
Sandstone	14	2,348,000	27,759,000
Granite	8	1,194,000	13,517,000
Slate and marble	5	228,524	2,211,000
Other	24	5,606,500	44,388,000
Total	**128**	**43,852,024**	**392,430,000**

Source: USGS 2008.

properties for crushed stone are strength, porosity, and the ability to resist volumetric change in freeze/thaw conditions. Fine-grained rocks tend to be stronger and more abrasion resistant. Tightly interlocking grains produce the best aggregates.

Well-cemented sedimentary rocks, often found in older geologic formations, yield acceptable aggregate. High clay-content rocks, such as shale, produce crushed stone dominated by flat, elongated fragments. Furthermore, these rocks will often disintegrate when subjected to repeated freezing/thawing or wet/dry cycles and hence are unacceptable. Clay content may also make dolomitic rocks unsound. The presence of easily weathered minerals such as feldspars, ferromagnesian silicates, and sulfides can be deleterious.

Rocks to be used for construction aggregates should be chemically inert. Rocks containing silica in the form of chert or chalcedony may react with highly alkaline cement and cause concrete to deteriorate. Certain carbonate rocks in New York, for example, the Onondaga Formation, contain abundant chert. Dolomitic limestone with moderate to high clay content also is not acceptable due to potential microfracturing caused by chemical reaction between the aggregate and the cement. Iron sulfide minerals in aggregate will react to form hydroxides and sulfates and can be deleterious if present in excessive amounts. The minerals pyrite and marcasite are very common in some of New York's limestone and dolostone. Breakdown of these minerals, when present in concrete, can lead to discoloration and also to expansion and weakening of the mix. Aggregate rich in quartz can have high negative surface charge on the particles that causes bituminous cements to separate from the aggregate. Water can penetrate between the aggregate particle and the binder, causing separation (stripping) and failure of blacktop mixes. Quartzite, along with some granite and high-grade metamorphic rocks, can have this effect. However, chemical additives can mitigate the problem.

In some cases, unusual chemical properties of New York rocks can increase their utility and market value. Chemically pure forms of carbonate rocks can be used for chemical stone, flue gas scrubber, and cement. Stone for filters and flue gas scrubbers call for $CaCO_3$ content of 90 percent or greater. That used for cement requires limestone with low (<4%) MgO and low total Na_2O and K_2O. For example, in central New York, the Jamesville Member of the Manlius Formation and the Edgecliff Member of the Onondaga Limestone are chemically suited for use in the Solvay process for the production of soda ash. Limestone, which can be used for flue gas desulphurization, can be quarried from the Chamont Limestone of the Black River Group in northwestern New York. The Beacraft, Manlius, and Coeymans Formations of the Helderberg Group have long been a raw material source for the manufacture of cement.

DISTRIBUTION

Carbonate rocks are the most commonly used for construction aggregates in New York. These rocks are generally found statewide with some notable exceptions. The generalized distribution of carbonate rocks in New York is shown on Figure 18. Statewide, the youngest carbonate units have the simplest distribution patterns. These strata, and the noncarbonates with which they are interlayered, are nearly flat-lying but generally dip slightly to the south and west. In central and western New York, the carbonate rocks are exposed in east–west trending outcrop belts. Along the Hudson River in eastern New York, carbonate rocks crop out in belts that trend north to south. No carbonates are exposed in the Southern Tier of counties along the Pennsylvania border. Sandstone and shale conceal the limestone and dolostone in this area.

The youngest carbonate unit in New York is limestone of the Middle to Late Devonian Tully Formation. It is exposed to the north of the Pennsylvania border in central New York. Its outcrop belt trends east–west. Eastward, where rocks of equivalent age are exposed, the Tully Limestone is completely replaced by shale and sandstone units. North of the Tully outcrop belt (and stratigraphically older rocks) are the Middle Devonian Hamilton Group, Middle Devonian Onondaga Formation, Early Devonian Onondaga Formation, the Early Devonian Helderberg Group, and the uppermost Silurian carbonates. These units are exposed in parallel east–west outcrop belts. These carbonate units extend to Albany County where the units change orientation to become north–south trending outcrop belts immediately to the west of the Hudson River. The rocks extend from there southward into New Jersey. The outcrop pattern of the oldest and northernmost carbonate unit exposed in central and western New York, the Lockport Group, trends east–west only and disappears near Utica.

Older Late Cambrian and Early Ordovician carbonate rocks underlie the carbonate units exposed in central and western New York and also form north–south trending outcrop belts in eastern New York. Uplifts of the Adirondack Dome and the Frontenac Arch have been sufficient to expose the older carbonates on the flanks of these areas. Outcrop patterns of carbonate units outcropping around the dome and arch reflect the structural complexity of the areas and the limited lateral extent of some of the units.

In the Hudson Highlands of southeast New York, Lower Cambrian quartzite and Middle Cambrian–Upper Ordovician carbonate strata are exposed. Tectonism imparted a northeast–southwest trend to the outcrop patterns of these carbonate rocks. The irregularity of the carbonate outcrop pattern reflects the extensive folding and faulting of the strata. All of the carbonate rocks described below are being, or have been recently, used for aggregate resources in New York.

CARBONATE ROCK RESOURCES

Tully Formation

The Tully limestone crops out in the Finger Lake region of central and western New York from Canandaigua Lake in Ontario County eastward to the Chenango River Valley in Chenango County. Heckel (1973) subdivided the Tully into two members, Upper and Lower. The Lower Member extends only as far eastward as the east branch of the Tioghnioga Valley between DeRuyter and Sheds in Madison County, where it is truncated by the Upper Member. Farther east in the Chenango River Valley, the Upper Member is replaced by shale and sandstone. Heckel (1973) described the Tully as a well-bedded, hard, dense, medium-gray to light-gray fine-grained limestone. The uppermost part of the Tully from Cayuga Lake eastward is interbedded with black shale and is transitional with the overlying shale. To the east of the Skaneateles Lake area, the Tully becomes progressively more sandy and shaley to the exclusion of the carbonate rock. The Tully averages 7 meters (22 feet) in thickness. Locally it exceeds 10.7 meters (35 feet). The Tully thins laterally, disappearing westward and thinning to 7 feet in its last exposure to the east.

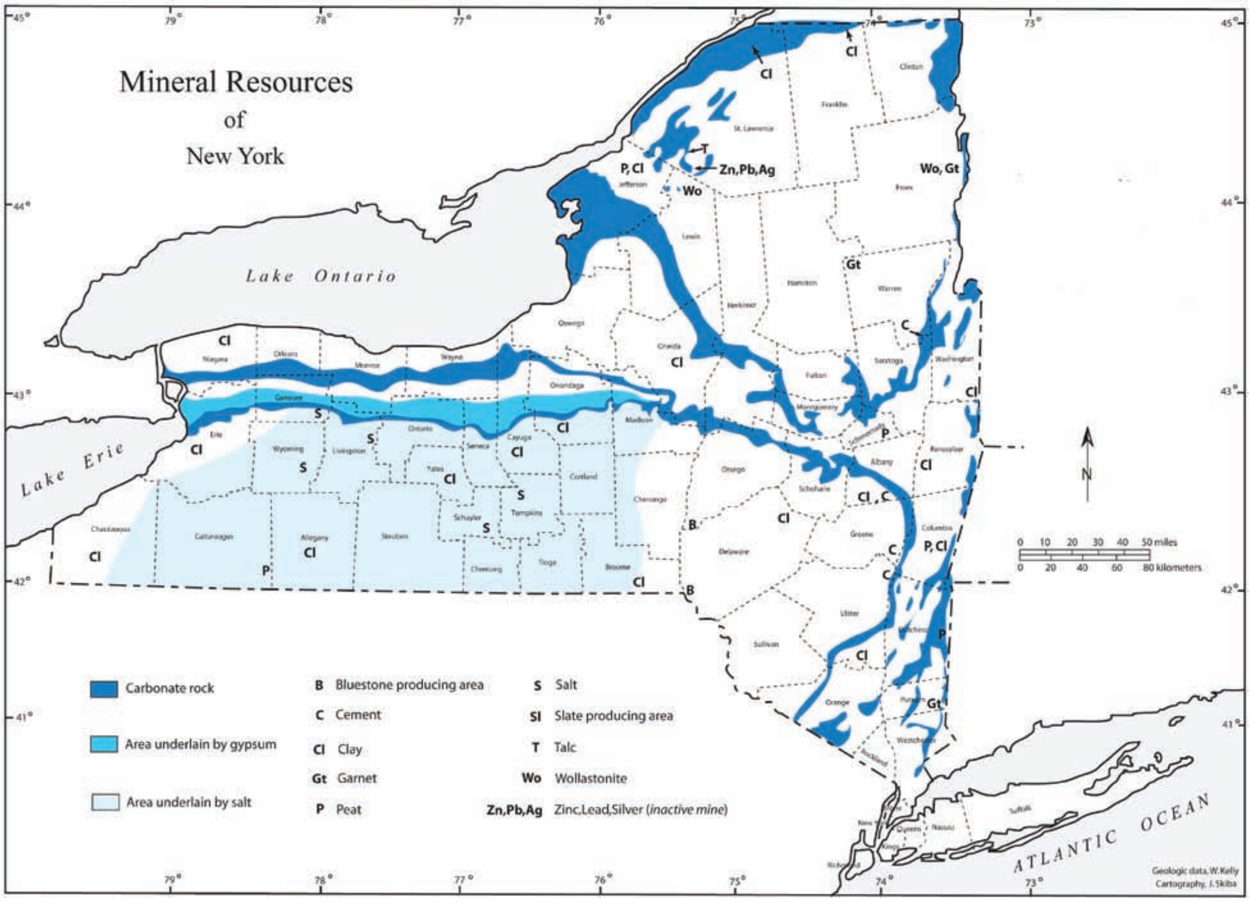

Figure 18. Distribution of carbonate rock in New York.

Onondaga Formation

The lower Middle Devonian Onondaga is a very widespread unit in New York. The limestone extends from Illinois eastward through New York and southward into Tennessee. In New York, it crops out from the Buffalo to the Helderberg region in Albany County where its outcrop belt sharply changes orientation and extends southward to Kingston and then southwestward to enter New Jersey near Port Jervis. Oliver (1954, 1956) was able to distinguish four members of the Onondaga based upon fossil content and lithology. The members are from oldest to youngest: Edgecliff, Nedrow, Morehouse, and Seneca. Chert is very abundant in some of the strata above the Edgecliff and below the Nedrow in the western part of the state. Ozol (1963) designated the strata in this interval as the so-called Clarence Member of the Onondaga. The fossil content, lithology, and the gamma-ray pattern recorded in wells (Rickard 1975) indicate that the Clarence is a chert-rich facies referable to the Edgecliff. Lindholm (1967) subdivided the Onondaga in the Buffalo to Albany County area based on lithology and fossil abundance. There is little correspondence between the subdivisions of Oliver and those of Lindholm. The relationship between Lindholm's lithofacies and the members of Oliver and Ozol is shown in Lindholm (1967). There has been no attempt here to reassign the named members to the lithofacies of Lindholm (1967).

The Onondaga limestone is to various degrees chert-bearing throughout, although the stratigraphic position of the chert-rich horizons and the overall abundance of chert varies. The unit is mostly fine-grained limestone except for the lower part, which is coarse-grained and composed predominantly of fossils. From the area south of Utica and west to Geneva, the middle of the unit contains more clay and dolostone than elsewhere. Near Syracuse in Onondaga County the Onondaga limestone is about 21 meters (70 feet) thick. Its thickness increases both to the west and to the east—reaching nearly 46 meters (150 feet) in thickness in the Buffalo area, about 33 meters (110 feet) in Albany County, greater than 49 meters (160 feet) near Kingston, and an estimated 61 meters (200 feet) near Port Jervis.

Edgecliff Member, Onondaga Formation

The Edgecliff Member is present throughout the outcrop belt of the Onondaga Formation in New York. Oliver (1954) describes the Edgecliff in the central part of the state as a massive, light-gray to pink, very coarsely crystalline limestone, characterized by a profusion of tabulates, large rugose corals, and crinoid columnals. This unit is locally a coral biostrome, largely made up of coral skeletons in a matrix of crinoid debris. Bioherms up to several hundred feet across occur in this unit. Chert is generally sparse throughout the Edgecliff and is mostly confined to the upper part of the unit, though it may occur throughout (Oliver 1954, 1956).

The Edgecliff becomes finer-grained and darker-colored both to the west and to the east of the Syracuse area. South of Albany County, the lithology of the Edgecliff changes markedly. The coral fauna is sparser and the limestone is darker-colored and more fine-grained. It is distinguishable from the overlying Nedrow and Morehouse only by the presence of large crinoid columnals, which are characteristic of the Edgecliff everywhere (Oliver 1956). The Edgecliff is about 3 meters (8 feet) thick in the Syracuse area. Westward, near Buffalo, it is 1 to 5 meters (3 to 15 feet) thick with locally thicker reef areas. To the east of Syracuse, the Edgecliff thickens to 8 to 9 meters (25 to 30 feet) at Clockville, Oriskany Falls, and Cobleskill and up to 21 meters (70 feet) locally in reef areas. To the south of Albany County the unit thins to 5 meters (15 feet) at Warwarsing and may be as thin as 2 meters (6 feet) near Port Jervis at the New Jersey border.

Nedrow Member, Onondaga Formation

The Nedrow Member crops out from the Buffalo area east to Albany County and south to Kingston. It is not present between the Edgecliff and Morehouse Members at Warwarsing, 22 miles southwest of Kingston. In the Syracuse area, the Nedrow Member is characterized by its slightly argillaceous nature and the species of gastropod fossils it contains. It consists of a lower thin-bedded, argillaceous interval and more sparsely fossiliferous upper part in this area. Chert is relatively uncommon throughout. To the west, at Oaks Corners, and to some degree at Honeoye Falls, the Nedrow is overall lithologically similar to the argillaceous lower part in the Syracuse region (Ozol 1963). The Nedrow is not so argillaceous in the Syracuse area as to prevent its use as aggregate. At Oaks Corners and other locations, the Nedrow is too argillaceous to be used in some aggregate applications. West of these localities neither the distinctive lithology nor fossils occur and it is difficult to distinguish the Nedrow from the overlying Morehouse and the underlying "Clarence Member." To the east of Syracuse, the Nedrow is less argillaceous and coarser-grained. Its lithology is so similar to the underlying Edgecliff in the Helderberg region of Albany County that only its fossils distinguish it (Oliver 1956). At Leeds and at Kingston, the Nedrow is a light-colored, coarse-grained, cherty limestone distinguishable only by its gastropod fauna (Oliver 1956). The Nedrow is 3 to 5 meters (10 to 15 feet) thick in the Syracuse area and about 13 meters (40 feet) thick in the Buffalo area. It is 5 meters (15 feet) thick in the Helderberg region and thickens considerably to 13 meters (43 feet) at Leeds. Southward it thins further to an estimated 10 meters (34 feet) at Saugerties and pinches out to the south-southwest between Kingston and Warwarsing.

Morehouse Member, Onondaga Formation

The Morehouse Member is present along the entire outcrop belt of the Onondaga Formation in New York from Buffalo east to Albany County and south to the New Jersey border. On the edge of Morehouse Flats near Syracuse, the Morehouse Member is a medium-gray, fine-grained limestone with dark-gray chert that is particularly abundant in the upper part (Oliver 1954). Fossils are very abundant in the upper part, and the Morehouse Member is generally characterized by their variety. Both to the west and to the east the Morehouse thickens considerably and is coarser-grained. To the west, chert is more evenly distributed throughout the member. Chert diminishes in the upper and lower portions of this member until the member can be divided into a non-cherty lower part, a cherty middle part, and a non-cherty upper part. The Morehouse is darker- colored and finer-grained to the south of the Albany County. The tripartite lithologic subdivisions are valid as far as the Kingston area although the uppermost unit is not exposed there (Oliver 1956). The Morehouse is poorly exposed between Kingston and the New Jersey border. Where it is exposed, there is very little chert present.

The Morehouse is 6 to 7 meters (20 to 24 feet) thick in the Syracuse area. Westerly, its thickness increases to 18 meters (60 feet) at Phelps, and it maintains this thickness into the Buffalo area. To the east of Syracuse, the Morehouse is about 21 meters (70 feet) in thickness at Cobleskill and in the Albany area. It increases to over 30 meters (100 feet) at Saugerties, and is estimated at 60 meters (190 feet) at Port Jervis on the New Jersey border.

Seneca Member, Onondaga Formation

The Seneca Member extends from the Buffalo area east to Cherry Valley, southeast of Utica. Lithologically, the Seneca is nearly identical to the Morehouse (i.e., medium-gray, fine-grained limestones with dark-gray chert and abundant fossils). The fossils, however, are distinctive. The Seneca contains abundant brachiopods (*Chonetes lineatus*). Beds up to several feet in thickness are composed almost entirely of these shells. Stratigraphically upward, the Seneca is progressively darker-colored and thinner-bedded. At the top it is argillaceous and is interbedded in a gradational contact with the Union Springs Shale (Oliver 1954).

The lithology and fossil content of the Seneca remains constant as far west as Canandaigua Lake. In the Buffalo area, the Seneca is even less distinctive. The presence of the Tioga bentonite at the base is used to distinguish it from the Morehouse (Oliver 1954). Little of the Seneca member is exposed in the quarries in the Buffalo area and the lithology is poorly known. To the east of Seneca County, the Seneca Member retains its lithological characteristics, although progressively more beds are missing from the top. East of Cherry Valley, no Seneca remains in the section (Oliver 1954). The Seneca Member is 6 to 7 meters (20 to 25 feet) thick from the Buffalo area to central New York. Eastward, it thins and at its last appearance near the village of Cherry Valley, the Seneca has a thickness of 2 meters (6 feet).

Helderberg Group

The outcrop belt of the Lower Devonian Helderberg Group strata parallels that of the overlying Onondaga Limestone from the New Jersey state line to the Finger Lake region. The Helderberg carbonate units thin and disappear at an upper unconformity near Geneva, west of Cayuga Lake between Fayette and Oaks Corners. Only the lowermost Helderberg carbonate formations (Rondout and Manlius) span the entire outcrop belt. The strata above (Coeymans, Kalkberg, etc.) are restricted to the eastern and southeastern part of the state. The subdivisions of the Helderberg carbonates are, from oldest to youngest: the Rondout, Manlius, Coeymans, Kalkberg, New Scotland, Becraft, Alsen, and the Port Ewen Formations. The Helderberg Group is primarily limestone. The Rondout Formation is the only dolostone. The Manlius and Coeymans, and especially the Becraft Formation, are relatively pure limestone. The Kalkberg and Alsen are locally cherty and the New Scotland and the Port Ewen Formations are argillaceous to very argillaceous. In the Helderberg region of Albany County, the Helderberg Group is 68 to 76 meters (225 to 250 feet) thick. It thins to the west as follows: 61 meters (200 feet) thick south of Utica, 41 meters (135 feet) near Syracuse, 20 meters (65 feet) at Union Springs, and disappears west of Cayuga Lake. To the south of the Helderbergs, the Group thickens to 91 to 107 meters (300 to 350 feet) in the Catskill quadrangle. It continues to thicken farther to the south and southwest.

Alsen and Port Ewen Formations, Helderberg Group

The Alsen occurs in southeastern New York and in the Hudson Valley and is present sporadically as far west as Howe Caverns. The Port Ewen is restricted to southeastern New York and the Hudson Valley. The Alsen is composed of fine-grained, dark-gray limestone with interbedded calcareous and argillaceous shale and is characterized by the presence of bedded and nodular chert. The Port Ewen is a fine-grained siliceous limestone with much interbedded shale and some chert (Rickard 1962). The Alsen in its westernmost, albeit discontinuous, exposures is 2 to 3 meters (6 to 11 feet) thick. South of the Helderbergs the unit is 6 to 9 meters (20–30 feet) thick. Rickard (1962) measured 10.7 meters (35 feet) of Alsen to the south at Austen Glen and concluded from a published description of the rocks that there are 6 meters (20 feet) of Alsen at Kingston. The Port Ewen is 10.7 meters (35 feet) thick at Catskill and on Beacraft Mountain near Hudson. A similar thickness is probably maintained into New Jersey. The Port Ewen at its northernmost exposures is 3 to 5 meters (10 to 15 feet) thick. To the south, it thickens rapidly and reaches an estimated 35 meters (100 feet) at Port Ewen. Near Port Jervis, the thickness of the Port Ewen is approximately 55 meters (180 feet) (Rickard 1962).

Becraft Limestone, Helderberg Group

The Becraft limestone crops out from the New Jersey border north to the Helderbergs in Albany County and west to Schoharie County. In the Helderbergs, the Becraft is described (Rickard 1962) as coarse-grained, crinoidal, dark-gray or pink limestone, with such an abundance of fossils that in places it may be classified as a shellrock or conquinite. It is usually massive, although in some places it has thin-bedded shaley limestone at the base. To the south, the Becraft thickens and can be divided into a lower portion that has many interbeds of green shale and an upper portion of pure limestone with chert nodules. The Becraft is variable in thickness. Between the Canajoharie area and Albany it is 3 to 8 meters (10 to 27 feet) thick. Between Albany and Kingston, the unit is from 14 to 20 meters (45 to 65 feet) in thickness. South of Kingston, the Becraft thins to about 20 feet (Rickard 1962).

New Scotland Formation, Helderberg Group

The New Scotland Formation extends from New Jersey north to the Helderberg Mountains and west to the Schoharie region. In the Helderberg Mountains, the New Scotland is composed of massively bedded calcareous and argillaceous strata which weather gray or brown. Fine-grained, thin-bedded, somewhat siliceous limestone beds are also to be found, especially near the top (Rickard 1962). Westward, the New Scotland is less argillaceous and has more strata of pure limestone, some of which contain chert nodules or beds. South of Canajoharie, the New Scotland is completely replaced by the Kalkberg. South of the Helderbergs, scattered chert nodules are common in this unit at Catskill. The New Scotland becomes more siliceous in the Hudson River Valley and in southeastern New York. Rickard (1962) estimates that the New Scotland is 18 to 21 meters (60 to 70 feet) thick in the Schoharie and Cobleskill valleys. The unit thickens south of Albany. Twenty meters (65 feet) of this unit were measured in the Helderbergs and 22 meters (75 feet) at Catskill. From published descriptions, Rickard (1962) estimated that there are 30 meters (100 feet) of New Scotland at Kingston and 49 meters (160 feet) near Port Jervis.

Kalkberg Formation, Helderberg Group

The Kalkberg cherty limestone extends from Oriskany Falls to the Hudson River Valley, thence south and southwestward into New Jersey. Rickard (1962) describes the Kalkberg as fine-grained, dark-blue, siliceous limestone which is thin to medium bedded with moderately irregular bedding planes. He noted that the most characteristic features are the abundant beds or nodules of black or bluish-black chert and the presence of calcareous and argillaceous shale interbedded with the limestone. In the Hudson Valley the Kalkberg is mostly a medium bedded limestone with some shaley beds in the upper part and with abundant chert in the lower 5 to 7 meters (15 to 25 feet). Locally, as at the Indian Ladder escarpment of the Helderberg Mountains, chert is not at all common and much of the upper Kalkberg weathers shaley (Rickard 1962). Chert is abundant from Canajoharie westward. At the type locality, the Kalkberg is 16 meters (54 feet) thick. Northward, through the Albany region, it is 12 to 15 meters (40 to 50 feet) thick. Its thickness reaches a maximum of 24 meters (80 feet) in the vicinity of Sharon Springs. The unit thins to 2 meters (6 feet) thick at Oriskany Falls, its westernmost exposure.

Coeymans Limestone, Helderberg Group

The Coeymans Limestone is exposed near Syracuse in central New York eastward through Albany, and thence southward to New Jersey. The Coeymans has been divided into three units, the Deansboro, Ravena, and Dayville Members. These three members are not everywhere present. It is present as a single sequence of beds (Ravena Member) only from Cherry Valley eastward. Only the upper portion of the Coeymans (Deansboro Member) extends as far west as the Syracuse region. The lower portion (Dayville Member) extends westward only to the region south of Utica.

From the Helderberg Mountains, north of the village of Ravena, to its westernmost extent at Cherry Valley, the Ravena Member is a pure and very hard, coarse-grained limestone whose resistance to erosion makes it the cap rock of an escarpment. The Ravena has massive individual layers from 25 centimeters (10 inches) to a few meters thick with irregular, wavy bedding planes that give rise to a characteristically rough-weathering surface. Commonly present are coarse-grained lenses or beds almost entirely composed of fossils, both shells and crinoid columns. The fossil brachiopod *Gypidula coeymanensis* is locally present in abundance.

South of Ravena, the lithology of the Ravena Member is similar except that it is lighter colored (especially when weathered), generally finer grained, and has thinner and less irregular bedding. The Deansboro Member is coarse-grained, hard, and massively but somewhat irregularly bedded. Coarse-grained beds of crinoid columnals are common. *Gypidula coeymanensis* is present throughout but not in the great abundance typical of the Ravena Member. The remnants of coral reefs (bioherms) are in several very restricted geographical areas. The reef-area rock is composed of extremely coarse-grained fossil accumulations (crinoids, corals, etc.) with bedding obscure or absent. The Dayville Member is a gray, coarse-grained, crinoidal limestone interbedded with dark-blue, fine-grained limestone. The proportion of the latter type of limestone increases from the central part of the outcrop belt westward. The two types are sub-equal in the area south of Utica.

At Cherry Valley the Coeymans Limestone is 30 meters (100 feet) thick. It thins to the east, being 11 meters (36 feet) thick in the Helderbergs south of Albany. The unit becomes thinner to the south of Albany. South of the village of Ravena, the Coeymans strata are generally 3 to 5 meters (10 to 15 feet) thick. It is 3 meters (9 feet) thick on Becraft Mountain and 5 meters (15 feet) thick in Catskill. Southwest of Kingston, the unit thickens slightly to 5 to 6 meters (15 to 20 feet). It may reach nearly 9 meters (30 feet) farther to the southwest (Rickard 1962). The Dayville Member is approximately 12 meters (40 feet) thick throughout, increasing to 15 meters (50 feet) only near Cherry Valley where it becomes the lower part of the Ravena Member. The Deansboro Member is 9 to 10 meters (30 to 35 feet) thick near Cherry Valley where it is transitional into the upper part of the Ravena Member. Its thickness remains relatively constant but does increase to 15 meters (49 feet) near the village of Deansboro. To the west, it thickens to 15 to 18 meters (50 to 60 feet) and has been variably thinned by erosion to 9 to 12 meters (30 to 40 feet) at Oneida Creek, West Stockbridge Hill, and Clockville and to 6 meters (20 feet) at its westernmost exposures at Perryville and Chittenango Falls.

Manlius Formation, Helderberg Group

The Manlius limestone is present across the entire outcrop belt of the Helderberg carbonates. Minor lithological differences within the Manlius have been used to subdivide it into five members. The units are, from oldest to youngest, the Thacher, Olney, Elmwood, Clark Reservation, and Jamesville Members. The Manlius is the finest-grained limestone of the Helderberg Group and is also one of the purest (insoluble residue commonly less than 5–10%). It is dark-colored on a freshly broken surface and weathers a very light gray. Although predominantly fine-grained and thin-bedded, the fine-grained strata of the Manlius are replaced locally, near the top of the formation, by somewhat coarser-grained, poorly bedded fossil accumulations (biostromes) formed of stromatoporoids. These stromatoporoid biostromes are also relatively free of noncarbonate impurities. Where biostromes occur in the Manlius, there are often interlayers of thin-bedded argillaceous "waterlime," which locally are several feet in thickness (Rickard 1962).

Thacher Member, Manlius Formation, Helderberg Group

In New York the Thacher Member constitutes the entire Manlius Formation from the Port Jervis region on the New Jersey border northward to Thacher Park near Albany and westward to Cherry Valley. Only to the west of Cherry Valley do higher members of the Manlius appear, where they are laterally transitional first to the middle and then to the lower strata of the overlying, coarser-grained Coeymans Limestone. At its westernmost extent near Jamesville, the Thacher Member pinches out. The Thatcher, particularly the lower part, contains very fine-grained "ribbon" limestone. Stromatoporoid biostromes often overlie or laterally replace these beds. Where stromatoporoids are not present (such as in the westernmost exposures from Oriskany Falls to Clockville), Rickard (1962) subdivides the Thatcher into a thick-bedded variety, which are 12 to >24 centimeters (5 to >10 inches) thick, and a thinner-bedded variety 2 to 12 centimeters (1 to 5 inches) thick. The thin-bedded variety has argillaceous or calcareous shale partings. Johnson (1958) found that the thin-bedded Thacher in Albany County had nearly 10 percent insoluble residue, whereas the other lithologies had less than 5 percent. The thin- and thick-bedded strata are fine-grained, dark-blue limestone, generally with smooth to slightly irregular bedding planes. At Oriskany Falls, the Thacher is about 11 to 13 meters (35 to 40 feet) thick. It maintains a similar thickness for about 50 kilometers (30 miles) farther west to the area where it pinches out. The thickness of the Thacher varies to the east and south but is generally between 10 and 11 meters (30 to 40 feet) thick between Oriskany Falls and East Kingston. It is 13.7 to 15.2 meters (45 to 50 feet) thick at Howe's Cave, Schoharie, and Becraft Mountain.

Olney Member, Manlius Formation, Helderberg Group

The Olney extends from west of Cayuga Lake east to the Sangerfield quadrangle and south of Utica. The lithology of the Olney is similar to that of the Thacher Member of central New York and differs only in being slightly coarser-grained, more massively and irregularly bedded, and in containing stromatoporoid biostromes in stratigraphic positions where the Thacher has none. Rickard (1962) feels that the biostromes in the Olney are discontinuous as those in the Thacher, but notes a persistent one that commonly occurs some 1.5 to 3 meters (5 to 10 feet) from the top of the unit. A biostrome is often also found near the base of this unit. At the most westerly occurrence, the Olney is about 2 to 3 meters (6 to 9 feet) thick. At Skaneateles, the thickness is estimated to be about 10 meters (30 feet). The Olney maintains this thickness eastward to Oriskany Falls.

Elmwood, Clark Reservation, and Jamesville Members, Manlius Formation, Helderberg Group

The uppermost three members of the Manlius crop out in an area from 32 kilometers (20 miles) west of Syracuse, eastward to the Richfield Springs quadrangle, and south of Little Falls. At Syracuse, the Elmwood consists of upper and lower waterlime beds with a fine-grained limestone in the middle. Rickard (1962) described the waterlimes as drab yellowish-brown, thin-bedded, and mud-cracked. The middle limestone bed often contains stromatoporoids, and Rickard noted that stromatoporoid biostromes are commonly seen where they are also present in the underlying Olney Member. To the west of Syracuse, the middle limestone bed pinches out. To the east of Knoxville, in the Sangerfield quadrangle, the waterlime progressively changes to fine-grained blue and drab limestone (Rickard 1962).

The Clark Reservation is a fine-grained, dark-blue, white-weathering limestone locally characterized by a diagonal fracture system (Rickard 1962). South of Utica, the Clark Reservation becomes thinner, weathers a dark brown, and becomes more argillaceous. The Jamesville Member is composed of fine-grained, dark-blue limestone in thin beds which are locally intercalated with discontinuous stromatoporoid biostromes. East of Syracuse, the Jamesville becomes coarser-grained, brownish-weathering, and slightly irregularly bedded. In quarries near the Syracuse area, the thickness of the upper three members is 12 to 15 meters (40 to 50 feet). The thickness is variable, and this is attributable to the variation of the Jamesville Member, which is 6 meters

(20 feet) thick near Syracuse thinning to 2 meters (6 feet) near Utica. The Clark Reservation is 1 to 2 meters (3 to 5 feet) and the Elmwood 3 to 5 meters (10 to 15 feet) thick.

Rondout Formation, Helderberg Group

The Rondout Formation is present from Cayuga Lake to Albany County and southward to the New Jersey border. Although the Rondout has been subdivided into the Glasco and Wilbur limestone, Whiteport and Rosendale dolostone, and Fuyk sandstone, in this report the members are not differentiated. Furthermore, the Rondout is not generally acceptable for use as a source of construction aggregate but it is included here because it was quarried near Catskill in the 1990s. It was used for stone crushed to a powder form and mixed with ¾-inch gravel for use as sub-base for pavers (Item 4). From the Helderberg Mountains westward, the Rondout Formation is a fossil-poor, very fine-grained argillaceous dolostone with some argillaceous limestone and a considerable amount of calcareous shale. Although locally massive, it is generally thin-bedded. To the south of the Helderbergs, the Rondout is thicker-bedded and less argillaceous. The Rondout is about 3 meters (10 feet) thick at Seneca Falls. It is 13 to 18 meters (45 to 60) thick between Marcellus Falls near Syracuse eastward to Oriskany Falls. Six to 7 meters (20 to 25 feet) thick in the Helderbergs, the Rondout thins to 3 meters (10 feet) to the south before thickening again to 10 meters (30 feet) near Catskill. It maintains a thickness of about 10 meters (30 feet) south to Kingston, then thickens to the southwest reaching 15 meters (50 feet) at Rosendale and 16 meters (55 feet) at High Falls. The Rondout continues to increase in thickness to the southwest.

Cobleskill Formation

The Cobleskill Formation can be traced from Gallupville in Schoharie County westward along the base of the Helderberg Escarpment to the area of Cayuga Lake. According to Rickard (1962), the Cobleskill Formation contains two major types of rock—fossiliferous limestone and relatively barren dolostone. Limestone predominates between Gallupville and Clockville. Farther west, dolostone dominates the unit except for significant recurrences of limestone near Union Springs and southwest of Seneca Falls. Thickness of the Cobleskill at its type section is variously given as 1½ meters (5 feet) (Darton 1894) to about 2 meters (7 feet) (Prosser 1899), depending upon where the location of the upper contact was taken to be. Rickard (1962) has identified what he believes to be a traceable horizon 9 feet above the basal contact, which marks the boundary between fossiliferous strata in the Cobleskill and a barren, fine-grained dolomitic limestone of the overlying lower Rondout Formation.

Salina Group

The outcrop belt of the Salina group extends eastward from Buffalo to the Helderbergs then southward to Kingston and the Rondout Valley into eastern Pennsylvania (Rickard 1969). The Salina Group consists of five formations which are, from oldest to youngest, the Vernon, Syracuse, Camillus, Bertie, and the Brayman. The lithology of the Salina Group is largely shale but the Bertie and the Brayman are carbonate units and hence are mentioned here. The Salina Group is approximately 122 meters (400 feet) thick in western New York and thickens considerably to the east to reach a maximum of 305 meters (1,000 feet) near Syracuse and then rapidly thins to less than 30 meters (100 feet) in Schoharie County. In southeastern New York, the Salina increases in thickness from Kingston to eastern Pennsylvania where it exceeds 610 meters (2,000 feet) (Rickard 1969).

Lockport Group

The Lockport Group in New York extends 320 kilometers (200 miles) from Niagara Falls to Ilion, where the unit pinches out. At Niagara Falls there are four formations of the Lockport which are, from bottom to top, the Gasport, Goat Island, Eramosa, and Oak Orchard Formations. To the east, in the Bergen quadrangle, the Gasport Formation is replaced by a unit which Zenger (1965) calls the "limestone lentil." In the Rochester area the Lockport is made up of the Penfield Formation, which is roughly equivalent to the Gasport, Goat Island, and Eramosa. Here, the Penfield is overlain by the Oak Orchard Formation. Between Clyde and Oneida the entire Lockport is composed of the Sconondoa Formation. The Ilion Member makes up the entire Lockport in the Rome, Utica, and Winfield quadrangles (Zenger 1965). The Lockport is generally characterized by brownish-gray color; medium granularity; medium to thick bedding; stylolites; carbonaceous partings; vugs filled with sulphate, sulfide, and halide minerals; and poorly preserved fossils. It is 60 meters (200 feet) thick at Niagara Falls, approximately 55 meters (180 feet) thick in the Rochester area, about 45 meters (150 feet) thick at Clyde, and 23 meters (75 feet) thick at Oneida. In the Rome, Utica, and Winfield quadrangles it is 0 to 21 meters (0 to 70 feet) thick (Zenger 1965).

Oak Orchard Formation, Lockport Group

The Oak Orchard extends from Niagara Falls to the region northwest of Auburn (Zenger 1965). Further east the Oak Orchard becomes the Sconondoa Member. At Niagara, the Oak Orchard is brownish-gray to dark-gray, fine- to medium-grained, generally thick-bedded, saccharoidal dolostone. Sylolites, carbonaceous partings, and vugs are common. Brownish-gray, porous, sandy-textured pockets occur locally. Light-gray chert nodules present in the member at Oak Orchard Creek, along the Erie Barge Canal, and at outcrops in Rochester. Zenger (1965) reported that the Oak Orchard is between 30 and 43 meters (100 and 140 feet) thick in the Niagara–Rochester region.

Eramosa Formation, Lockport Group

Zenger (1965) traced this unit only in the Tonawanda–Lockport area of New York. He described the Eramosa as medium-dark-gray to dark-gray, fine-grained, thin- to medium-bedded, argillaceous, bitumin-bearing dolostone. It is 5 to 6 meters (15 to 20 feet) thick in the Niagara Falls–Tonawanda quadrangles.

Goat Island Dolostone, Lockport Group

The Goat Island Dolostone extends from Niagara Falls east to Sweden, southeast of Brockport. The Goat Island at the reference section is light-olive-gray to brownish-gray, medium-grained, thick-bedded, saccharoidal dolostone. In general, the Goat Island is much less fossiliferous than the underlying Gasport and is more likely to contain chert. Chert nodules are abundant at the top in a thin zone that continues upward into the basal part of the overlying Eramosa. Sporadic nodules are present in the lower part. Stylolites and carbonaceous partings are abundant. Vugs, where they occur, contain gypsum, calcite, and sphalerite (Zenger 1965). Near Niagara Falls the measured thickness is approximately 6 to 7 meters (19 to 25 feet).

Gasport Formation, Lockport Group

The Gasport extends from Niagara Falls through the Albion quadrangle. East of Brockport, the unit loses its identity. Although it is composed of a complex of facies, the Gasport is predominantly olive-gray to brownish-gray, coarse-grained, medium- to thick-bedded, crinoidal dolostone (Zenger 1965). The fossil fragments are coarse-grained and the matrix is much finer-grained and argillaceous. Biostromes and bioherms occur locally. The unit is entirely limestone in some places and entirely dolostone in others with no general trend being apparent.

At the Niagara River, the thickness ranges from 5 to 7 meters (15 to 23 feet). The member reaches a maximum thickness of 10 meters (30 feet) in the Lockport and Gasport areas. Thinning eastward, it is 3½ meters (13 feet) thick at the easternmost exposure.

Penfield Formation, Lockport Group

The Penfield Member occurs from Rochester eastward into the Palmyra quadrangle (Zenger 1965). The basal Penfield is dolomitic sandstone. Above this sandstone, the quartz content decreases and the strata are quartzose dolostones. The dolomitic sandstone is medium- to light-gray, medium-grained, and medium-bedded. Carbonaceous partings, cross stratification, and microstylolites are common. The quartzose dolostones over the sandstone are medium dark-gray to brownish in color. The grain size varies from fine to coarse with the coarser-grained layers containing large fragments of crinoids. Conglomeratic, fossil-fragment zones were observed east of Rochester. The bedding ranges from thin to massive. Coarse, porous, sandy-textured patches and lenses are common in the upper half of the unit. Vugs containing dolomite, sphalerite, gypsum, and other minerals are present throughout. Zenger (1965) reported that the Penfield is between 12 and 18 meters (40 to 60 feet) thick.

Clinton Group

Between the Niagara River and the region south of Utica, the rocks of the Lower Silurian Clinton Group crop out in a narrow band approximately 200 miles long and between 5 and 5 miles wide in its broadest extent (Gillette 1947). Near Syracuse, in the central part of its outcrop band, the Clinton Group is subdivided into several formations comprised primarily of shale with subordinate carbonate rock, sandstone, and hematite beds. The Clinton Group is typically not suitable for use as aggregate. However, farther west, the DeCew Formation occurs (Fisher 1960; Brett et al. 1995). The calcareous DeCew formation has been used and is discussed herein. The Clinton Group increases in thickness east from Niagara Falls eastward, reaching its maximum thickness between Rochester and Syracuse. It thins from Syracuse toward its easternmost exposure.

DeCew Formation, Clinton Group

In New York the DeCew extends from Niagara Falls to Rochester. Zenger (1965) described the DeCew at Niagara Falls as medium dark-gray, fine-grained, thin to massively bedded, argillaceous dolostone. Parts of the unit are very convolute, referred to by Grabau (1913) as enterolithic structure. The lower part contains intercalated shale. The DeCew at Rochester is olive-gray to brownish-gray, medium-grained, “enterolithic,” siliceous dolostone. The unit is about 3 meters (8 feet) thick at Niagara Falls and about 5 meters (15 feet) thick at Lockport. It maintains this thickness to Rochester.

Trenton Group

The Late Ordovician Trenton Group crops out from the Thousand Island region southeastward through the Black River Valley in Jefferson and Lewis counties, through Oneida and Herkimer counties, and then sporadically crops out around the Adirondacks and east to the vicinity of Glens Falls, Warren County, and north along the Lake Champlain lowlands (Fisher et al. 1970). Trenton Group is subdivided into the Denley, Sugar River, Kings Falls, Rockland, Larrabee, and Amsterdam Formations (from youngest to oldest, respectively) and the Dolgeville Facies of the Denley Formation (Kay 1968; Fisher 1977). These units are primarily limestone with interbedded calcareous shale and marl. The total thickness of the Trenton Group ranges from approximately 122 to 160 meters (400 to 525 feet) in Jefferson County, thins appreciably to the south, and thickens again to the east (Fisher 1977).

Denley Formation, Trenton Group

The Denley Formation crops out as a belt parallel the Black River Valley from the Thousand Islands region southeast to the vicinity of Trenton Falls (Johnsen 1971). Kay (1968) subdivided the Denley into (from oldest to youngest) the Camp, Glendale, Poland, Russia, and Rust Members. The Camp Member is distinctively marly, the Poland Member is calcarenitic, and the Rust Member is a shaley calcarenite with the other members being primarily calcisiltites. The Denley Formation consists of variably shaley calcarenite and calcisiltite and has a distinctly marly lithology (Camp Member) at the base. This formation ranges from approximately 60 meters (200 feet) near Trenton Falls (Kay 1968) to approximately 91 meters (300 feet) near Watertown (Johnsen 1971).

Dolgeville Formation, Trenton Group

The Dolgeville is limited to a belt extending from just north of Norway, Herkimer County, to the vicinity of St. Johnsville, Montgomery County (Kay 1937). Flagler (1966) described the Dolgeville as a black, calcareous to highly calcareous shale, interbedded with dark-gray to dark- brown or black finely crystalline nonfossiliferous argillaceous limestone. Fisher (1977) stated that the Dolgeville Facies is the lateral equivalent of the Denley Formation. The maximum observed thickness of the Dolgeville is 54 meters (177 feet). It pinches out toward the north and the south.

Sugar River Formation, Trenton Group

The Sugar River Formation is the most persistent unit of the Trenton Group in New York, where it forms a belt on the west side of the Black River Valley from the Thousand Islands region southeastward into the Mohawk Valley. Farther east in the upper Hudson Valley and into the southern Lake Champlain region it merges into the Glens Falls Formation (Johnsen 1971). The Sugar River Limestone is a thin-bedded shaley calcarenite and calcisiltite (Kay 1968). It maintains a thickness of approximately 12 to 15 meters (40 to 50 feet) from Watertown to southern Lewis County and thins toward the southeast to a minimum of 2 meters (7 feet) in the Mohawk Valley (Chenoweth 1952; Johnsen 1971). It is reported to be approximately 30 meters (100 feet) thick in the Glens Falls area (Griggs, pers. comm., 2010).

Kings Falls and Rockland Formations, Trenton Group

The Kings Falls Formation is found in Lewis and Jefferson Counties (Kay 1968). The Rockland Formation is present along the belt of Trenton outcrop from the Boonville area in northern Oneida County, where it is quarried, northwest along the Black River Valley through Lewis and Jefferson counties (Johnsen 1971). The Kings Falls Formation is characterized by thick beds of calcarenite and coquinite and frequently contains large ripples (Kay 1968). The Rockland Formation is composed primarily of dark-gray calcilutites, medium-gray fine calcisiltites, and medium-gray fine- to medium-grained calcarenites (Johnsen 1971). The Kings Falls is approximately 30 meters (100 feet) thick at its type section, and the Rockland has a fairly constant thickness of approximately 18 meters (60 feet) throughout New York although it is only approximately 2 meters (6 feet) thick at Canajoharie.

Larabee and Amsterdam Formations, Trenton Group

The Larrabee and Amsterdam Formations are both found along the lower Mohawk Valley with the Larrabee Formation extending northeastward to the southern Lake Champlain region (Kay 1937). Lithologically, the Larrabee consists primarily of thin-bedded limestone which is locally shaley. The Amsterdam is described as a gray-black, rough-fracturing, heavy-ledged limestone. The Larrabee Formation varies in thickness being 15 to 25 feet in the lower Mohawk Valley and up to 35 feet thick in the southern Lake Champlain area. The Amsterdam Formation varies from approximately 10 to 30 feet in thickness.

Black River Group

The middle Upper Ordovician Black River Group crops out as a narrow 192-kilometer (120-mile) long belt from just north of Ingham Mills, Herkimer County, northwestward along the Black River Valley to Watertown and the Thousand Islands region in Jefferson County. In the Black River Valley, the group is less than two kilometers (one mile) in outcrop width and in the vicinity of Watertown, its outcrop is approximately 22 kilometers (14 miles) wide (Young 1943). The Black River is subdivided into three formations which are the Pamelia, Lowville, and Watertown (from oldest to youngest, respectively). The Black River Group increases in thickness from approximately 15 meters (50 feet) at the southern end of the Black River Valley to 45 meters (150 feet) near Lowville in Lewis County, and reaches its maximum thickness of 70 meters (230 feet) in the vicinity of Watertown in Jefferson County (Young 1943). It is absent at Canajoharie but thickens east to the Lake George Lowland.

Watertown, Lowville, and Pamelia Formations, Black River Group

The Watertown Formation only occurs in the vicinity of Watertown in Jefferson County. The Lowville and Pamelia Formations crop out throughout the range of the Black River Group—from Ingham Mills, Herkimer County, northwest to Lake Ontario past Watertown and westward into Ontario (Walker 1973). In the type area, the Watertown Formation appears as two very thick ledges of dark-gray to black, fine-textured, hackly fracturing, semicrystalline limestone (Young 1943). The Lowville Formation is comprised of a complex interbedded sequence of mud-cracked, laminated dolostone; mud-cracked, thin-bedded, medium-grained, bioclastic limestone; oolite; *Tetradium* (coral) bioclastic limestone; and *Loxoplocus* (snail) bioclastic limestone (Walker 1973). The Pamelia consists of basal dolomitic sandstone overlain by a variable thickness of pale-gray to buff dolostone.

The Watertown is approximately 4 meters (13 feet) in thickness near its type area. The Lowville varies in thickness from approximately 10 meters (35 feet) at House Creek to 26 meters (87 feet) at Roaring Brook, Lewis County (Walker 1973). The Pamelia Formation ranges from 5 meters (18 feet) at Turin Road to 15 meters (51 feet) at Mill Creek, Lewis County.

Chazy Group

The late Lower Ordovician Chazy Group is found in a narrow outcrop belt along the western shore of Lake Champlain in Essex and Clinton counties. It is primarily composed of limestone. The Chazy Group in New York is subdivided into three formations which are (from oldest to youngest) the Day Point, Crown Point, and Valcour (Fisher 1968); of these three, only the Day Point and Crown Point were used for aggregates. Thicknesses of 228 meters (750 feet) to almost 274 meters (900 feet) have been reported for the Chazy. Imperfect exposures and numerous faults make it difficult to obtain accurate measurements of the thickness (Fisher 1968).

Day Point and Crown Point Formations, Chazy Group

The Day Point and Crown Point Formations crop out in a narrow belt along the western shore of Lake Champlain in Clinton and Essex counties. The Day Point Formation consists of a basal quartz-rich unit of cross-bedded sandstone and siltstone (Fisher 1968). The Crown Point is composed of bioclastic wackestone, packstone, and grainstone with variable post-depositional dolomitization (Speyer and Selleck 1986). The Day Point varies in thickness from 80 to 300 feet (Fisher 1968) with rapid areal variations (Oxley and Kay 1959). The entire Chazy group is comprised of the Crown Point Formation at Crown Point, New York, where it is 90 meters (295 feet) thick. The unit thins to 15 meters (50 feet) at Ticonderoga and is thinner at Whitehall, New York (Fisher 1984).

Beekmantown Group

The Upper Cambrian–Middle Ordovician Beekmantown is distributed throughout the St. Lawrence Valley, the Mohawk Valley, the northern Hudson Valley, southern Champlain Valley and Dutchess County (Fisher et al. 1970; Mazzullo 1974; Kröger and Landing 2008, 2010). The Beekmantown is subdivided into six recognizable units in the area in which it crops out. These are, from oldest to youngest, the Galway, Little Falls, Tribes Hill, Rochdale, Fort Cassin, and Providence Island Formations (Kröger and Landing 2010). Lithologically, the Beekmantown Group is composed primarily of marine carbonate and clastic rocks. The lithologies of the economically important calcareous formations of the group are discussed below. In total, the Beekmantown Group is approximately 200 meters (656 feet) thick, although much of the stratigraphy is not economically viable and the units are geographically limited.

In southeastern New York, the name “Wappinger Group” was applied to a discontinuous belt of rocks that extended from Port Jervis in Orange County northeastward to the vicinity of Stissing Mountain in Dutchess County that consists primarily of carbonate rocks (Offield 1967). The name “Wappinger Group” is now recognized as a junior synonym of the Beekmantown Group and Stissing Formation in Dutchess County. In easternmost New York, where metamorphism has masked the characteristics of the subdivisions of the Beekmantown Group, the term Stockbridge limestone or dolostone is used (Fisher 1977). Knopf (1946) reports a total thickness of 1,158 meters (3,800 feet) for these rocks at Stissing Mountain in Dutchess County.

Scotia Member, Fort Cassin Formation, Beekmantown Group

The Scotia Member was once called the "Ogdensburg Formation." The name has been abandoned (Kröger and Landing 2009a; Landing and Westrop 2006; Landing 2007). The Scotia is present in outcrops in the vicinity of Massena and Ogdensburg in St. Lawrence County (Fisher 1977). It consists of fine-grained, fairly uniform, gray dolostone and sandy dolostone with calcite masses and shale partings common, especially in the lower part of the section (Chadwick 1919). Cushing (1916) described 36 meters (120 feet) of the Ogdensburg Formation in exposures between Morristown and Ogdensburg in St. Lawrence County.

Rochdale Formation, Beekmantown Group

The Rochdale is distributed in discontinuous outcrops in a narrow, northeast-southwest trending belt in the northern Hudson and southern Champlain valleys (Mazzullo 1974; Landing and Westrop 2006). Formerly known as the Fort Ann Formation, the name was abandoned in favor of the senior synonym, Rochdale (Landing and Westrop 2006). The type area is in Rochdale village, Dutchess County. Where it occurs in northern New York it consists of fossiliferous, medium-bedded, finely crystalline, medium-gray, finely laminated limestone with a basal 1- to 2-meter (3- to 7-foot) breccia consisting of dolostone and black chert clasts in a crystalline dolomite matrix. The unit is approximately 28 to 40 meters (90 to 125 feet) in thickness.

Tribes Hill Formation, Beekmantown Group

The Tribes Hill Formation crops out along the Mohawk Valley in Herkimer and Montgomery counties. It is subdivided by Kröger and Landing (2009b) into four subunits which are the Sprakers, Van Wie, Wolf Hollow, and Canyon Road Members. The Tribes Hill Formation is composed primarily of marine carbonate and clastic rocks. and has an average thickness of approximately 44 meters (145 feet) in the Mohawk Valley. A portion of the Tribes Hill formerly known as the "Great Meadows" Formation, a name now abandoned (Landing et al. 2003; Landing 2007), was quarried where it cropped out in the southern Champlain Valley region. It is comprised of finely laminated or cross-stratified siltstone interbedded with occasional shale and sandstone units, locally cherty, medium-bedded, quartzose, and calcitic dolostone (Fisher 1977; Mazzullo 1974), and finely crystalline, medium-bedded limestone which weathers to a pure-white color. The unit has an average thickness of approximately 85 meters (280 feet) at Smith's Basin in Washington County.

A unit formerly known as the "Halcyon Lake" Formation in Dutchess County is a synonym of the Tribes Hill Formation (Kröger and Landing 2007). It crops out between Edenville and Warwick, in the vicinity of Florida and is also prominent near Breeze Hill, Orange County. It is a calc-dolomite consisting primarily of lustrous, fine- to medium-grained, mottled-gray dolostone interbedded with very finely crystalline, siliceous, medium-gray dolostone (Offield 1967). According to Offield, the "Halcyon Lake" is so variable lithologically and exposed in such disconnected outcrops that a reliable complete section cannot be pieced together. However, Landing et al. 2010 showed that the same succession of members that make up the Tribes Hill comprise "Halcyon Lake." The unit here is on the order of 150 to 180 meters (500 to 600 feet) in thickness (Offield 1967), although Knopf (1946) reported a thickness of 107 meters (350 feet) in Dutchess County.

Canyon Road Member, Tribes Hill Formation, Beekmantown Group

The Canyon Road Member has a very spotty distribution. It outcrops between East Canada Creek and Greens Corners in Montgomery County. Lithologically, it is extremely fossiliferous and has a varied lithology consisting of silty, sandy, phosphatic calcarenites, dolomitic calcilutites, pebble conglomerates, calcitic dolomite, steel-gray silty dolomite, and oölitic dolmitic limestone (Fisher 1984). The Canyon Road Member reaches a maximum thickness of 7 meters (22 feet) just west of Tribes Hill in Montgomery County. It thins to the east and west.

Wolf Hollow Member, Tribes Hill Formation, Beekmantown Group

The Wolf Hollow is the most widely exposed member of the Tribes Hill Formation with many exposures present from Little Falls in Herkimer County to near Galway in Saratoga County (Fisher 1954), north to Plattsburg (Landing and Westrop 2006), and south in Dutchess County (Landing 2007). The Wolf Hollow is typically a massive, thick-bedded, white-weathering, blue-black dolomitic calcilutite with dolomitic patches, minor quartz and thrombolites. It maintains a relatively uniform thickness of approximately 6 to 8 meters (20 to 28 feet) throughout its areal extent (Fisher 1954). The "Gailor Dolomite" is now considered a junior synonym of the Tribes Hill (Landing et al. 2010). At the so-called type locality, the "Gailor" is the Wolf Hollow Member.

Sprakers Member, Tribes Hill Formation, Beekmantown Group

Formerly called the Palatine Bridge Member, the Sprakers Member crops out from East Canada Creek in Montgomery County to Hoffmans in Schenectady County (Fisher 1954). It is comprised of fine- to medium-grained, thin-bedded, light blue-gray arenaceous dolomite and silty calcilutite with a large amount of intercalated calcareous shale (Fisher 1954). The Sprakers Member is extremely variable in thickness with a maximum of approximately 15 meters (50 feet) at Flat Creek in Montgomery County, and thins both east and west.

Little Falls Formation, Beekmantown Group

The Little Falls Formation extends primarily from Poland in Herkimer County eastward to the vicinity of Randall in Montgomery County, thinning toward Saratoga Springs in Saratoga County (Zenger 1980). The upper Little Falls was once known as the "Whitehall Formation" in the Champlain Valley but the name has been abandoned (Landing et al. 2003). The Little Falls Formation locally consists of a thick series of dolostone beds which are variable in color and texture. These are usually admixed with rounded quartz grains and frequently penetrated by light-gray or white chert nodules and stringers. Glauconite is occasionally present. Locally, pyrite may be common. Interstitial hematite is prevalent in a reddened zone which is riddled with vugs containing quartz crystals, termed "Herkimer Diamonds," and anthraxolite (Fisher 1965). At its type section and throughout much of the Mohawk Valley, the Little Falls Formation is approximately 122 meters (400 feet) in thickness.

The Little Falls crops out sporadically between Goshen in Orange County and Stissing Mountain in Dutchess County, where it was formerly known as the "Briarcliff Formation," now abandoned (Kröger and Landing 2007). It consists of heavy-bedded, light-colored dolostone and calc-dolostone separated by occasional intervening beds of a darker, impure dolostone (Knopf 1956). Chert occurs in scattered nodules and a diagnostic feature of the formation is the occurrence of quartz-calcite druses and black shale partings (Offield 1967). The dolostone is approximately 213 meters (700 feet) in thickness (Knopf 1956).

Galway Formation, Beekmantown Group

Exposures of the late Middle Cambrain Galway Formation occur between Amsterdam in Montgomery County and Saratoga Springs in Saratoga County (Zenger 1980), extend along the Lake Champlain lowlands and appear as upper "Stissing" Formation in Dutchess County (Kröger and Landing 2007). The Galway consists primarily of quartzose dolomite intercalated with dolomitic and calcareous sandstone (Fisher 1956). It is approximately 38 meters (125 feet) thick in the vicinity of Saratoga Springs in Saratoga County.

NONCARBONATE ROCK RESOURCES

Although carbonate rock is the most commonly used type of rock for construction aggregates, suitable carbonates are not universally available in New York State. Parts of the state are too far from carbonate outcrop belts for the rock to be economically transported to market. In this situation, diverse varieties of noncarbonate rock are used. Depending on the geographic location, sandstone, diabase (trap rock), and various metamorphic rocks can be used. The terminology for the rocks used by the industry is not always consistent with the lithologic definitions of geologists. "Sandstone" can include siltstone, quartzite, conglomerate, and greywacke. "Granite" can encompass coarse-grained igneous rocks, but high-grade gneisses, although metamorphic in origin, are commonly included in with granite. "Trap rock" includes all dense, dark-colored, igneous rocks, regardless of chemical composition or grain size (Tepordei 1985). The general distribution of these rocks is shown on Figure 3. Descriptions of the noncarbonate rock currently used for construction aggregates follow from geologically youngest to oldest.

Palisades Diabase

The Palisades sill is a sub-horizontal, latest Triassic or early Jurassic, diabasic intrusion, locally known as "trap rock." It is composed of plagioclase, clinopyroxenes, and olivine with accessory biotite, sphene, zircon, and iron-titanium oxides. It is a dense, medium- to fine-grained dark-gray rock with aphanitic contact zones. It is generally mafic in character although small felsic segregations occur. The sill is a composite of multiple stages of intrusion (Puffer et al. 2009). Parts of it are strongly differentiated, the most famous example of which is a 10 meter (~30 feet) thick layer of olivine lying just above the lower contact. Average thickness of the sill is 300 meters (~1,000 feet). The exposed Palisades is about 80 kilometers (48 miles) in length. It occurs along the west wall of the Hudson River Valley from Staten Island north to Haverstraw and thence westward to Pomona (Best 2003). Environmental restrictions have been placed on the extraction of the rock such that no quarrying can occur in the east-facing cliffs, thereby protecting the viewscape from the Hudson River and east side of the river valley. Figure 19 shows a quarry in the Palisades sill.

Wiscoy Formation, Java Group

The Upper Devonian Wiscoy Formation comprises the upper part of the Late Devonian Java Formation in the eastern portion of the outcrop belt of the Java. The Wiscoy interfingers with and replaces the Hanover Member (shale) of the Java Formation in the eastern part of its outcrop belt. The Wiscoy Member varies in thickness between 33 and 58 meters (108 to 190 feet) (Over 1997). It is characterized by medium dark- to dark-gray argillaceous siltstones, silty mudstones, and fine sandstones (deWitt 1960; Haley and Aldrich 2006). At its type locality in Wiscoy Creek, it is a very silty mudrock and siltstone. However, east of there it is near-shore fine-grained sandstone. The outcrop belt of the Java Formation extends from Silver Creek in Chautauqua County eastward to near Addison in Steuben County. However, it is only in the eastern portion of the upper part of the Java Formation that the rock would be useful for construction aggregate.

Walton Formation, West Falls and Sonyea Groups

The Walton Formation is a Late Devonian, nonmarine sublitharenite of relatively uniform composition comprised of sub-angular grains of medium size. Interbedded in this unit are green, gray, and red siltstone and shale. It is often called a graywacke or subgraywacke depending on the classification system. Both the upper Walton, which is part of the West Falls Group, and the lower Walton, part of the Sonyea Group, are quarried for construction aggregates. It is the sandstone units within these formations that are selectively mined and the siltstone and shale are left in place. This unit is locally worked for aggregates where it contains minimal shaly sones or interbeds. The rock is dominantly quartz (47%) and rock fragments (9%) with interstitial "sericite" (27%), chlorite (6%), muscovite (6%), and plagioclase, K-feldspar, biotite, and opaque phases (<2% each) (Kelly and Albanese 2005). There is evidence of pressure solution and recrystallization at a burial depth estimated at more than 4 kilometers (2½ miles). In the eastern Catskills, the Walton is 365 meters (1,200 feet) thick (Gale 1985). Maximum thickness is estimated at 580 meters (1,900 feet). The upper Walton crops out in eastern Broome, central Delaware, northeast Sullivan, and western Ulster counties. The lower Walton is found in eastern Sullivan and central Ulster counties.

Oneonta Formation, Genesee Group

The Oneonta Formation is composed of red, green, and gray mudstones with subordinate red to gray, very fine- to fine-gained sandstones, either graywacke or subgraywacke, in beds of up to 6 meters (20 feet) in thickness. Its age is late Middle and early Late Devonian (Bridge and Willis 1994). The mudstones range from fissile and relatively nonbioturbated to blocky and intensely bioturbated with desiccation cracks throughout and represent flood-basin deposits. The sandstone sets are sharp-based, sheets and lenses, cross-bedded or planar-bedded flood deposits. The major sandstone bodies are interpreted as fluvial channel deposits. It is approximately 275 meters (900 feet) thick (Gale 1985). This formation crops out in central Chenango, northern Delaware, central Greene, and southwestern Schoharie counties. It is worked locally for aggregates where it contains minimal shaly zones.

Mount Marion Formation, Marcellus Subgroup, Hamilton Group

The Mount Marion is a Middle Devonian marine unit composed of fine-grained sandstone, siltstone, and shale in eastern New York. The upper portion of the formation, the top of the Otsego Member, is reworked near shore sandstone which can be quarried for construction aggregates. Lithologically, this rock is shaley sandstone, sandstone, and quartz and minor chert pebble conglomerate. Total thickness of the Mount Marion is about 213 meters (700 feet). Thickness of the sandstone-dominated rock is about 100 meters (328 feet). The Mount Marion forms a belt of rock that crops out from Cherry Valley, Otsego County eastward through the Helderbergs, and south to Kingston in Ulster County. This unit is used for aggregates at Coxackie in Greene County.

Bellvale Formation, Hamilton Group

The Bellvale Formation is dominantly dull-gray fine-to coarse-grained flaggy sandstone (60%) with interbedded siltstone and shale (40%), the latter being more prevalent at the bottom of the unit. The rock is texturally immature to sub-mature but is a well-indurated sandstone. It is composed of angular quartz, chert, and phyllitic rock fragments in a microgranular quartz matrix with variable sericite and chlorite. The rock is classified as a sub-graywacke or lithic greywacke and ranges to lithic arenite (Jaffe and Jaffe 1973; Kriby 1981). The quartz grains are sutured and indicate partial recrystallization (Offield 1967). Quartz veins and fracture fillings are common. Conglomeratic beds occur throughout, and become more common at the top of the unit. The unit is Middle Devonian in age, and referred to the Hamilton Group. The Bellvale Formation crops out in two belts in a narrow northeast-trending overturned syncline in Orange County. The unit is estimated to be 396 to 610 meters (1,300 to 2,000 feet) in thickness. The outcrop belt extends from the New York–New Jersey border and pinches out about 10 to 11 kilometers (6 or 7 miles) southwest of Castleton-on-Hudson. This unit is worked for aggregates in Woodbury, Orange County.

Grimsby Formation, Medina Group

The Medina Group (Lower Silurian) is a deltaic to nearshore, shallow marine unit. It is from 24 meters (80 feet) to 35 meters (115 feet) thick and consists of white, green, and red sandstone, siltstone, and shale (Martini 1971). The formation as a whole is grossly lens-shaped. It crops out along the south shore of Lake Ontario. It includes the Whirlpool Sandstone, Power Glen Shale, Devils Hole Sandstone, Grimsby Formation, Thorold Sandstone, Cambria Shale, and Kodak Sandstone in an upward succession. The Grimsby sandstone is quarried for aggregates in two layers totaling about 14 meters (45 feet) in thickness. The Grimsby is a hematitic quartzose sandstone, red in color with gray mottling and is fine- to medium-grained. It contains red-gray mottled greywacke, siltstone, and shale interlayers (Lumsden and Pelletier 1969). It tends to become more silty or shaley in the lower portion of the unit and this is intensely burrowed and fossiliferous. Shale pebble conglomerates represent reworked material from older rocks that have been incorporated into the Grimsby. The Medina can be traced from Hamilton, Ontario to Fulton, New York.

Potsdam Formation

The Potsdam Formation is middle-upper Middle Cambrian sandstone that is divided into two members (Landing et al. 2009). The Keeseville Member, which is currently quarried for aggregates, is a white to buff, tan-weathering homogeneous quartz arenite. Feldspar is 10 percent or less of the rock, which is silica-calcite-cemented. Fisher (1968) ascribes the rock to a low-energy, intertidal or shallow sub-tidal environment of bays and lagoons protected by barrier islands. The Ausable Member lies under the Keeseville and is tan to pink arkosic sandstone with quartzose shale interbeds and quartz pebble conglomerate lenses (Fisher 1968, Landing et al. 2009). The feldspar component of the rock is locally up to 50 percent. Zircon, magnetite, hematite, biotite, pyroxene, and hornblende are accessory minerals. The Potsdam discontinuously rims the Adirondack Mountains except in the Black River Valley. It is thickest in the area from Fort Ann, 40 meters (130 feet), to Ausable Chasm, 139 meters (455 feet), and thickens to 750 meters (2,460 feet) north of Plattsburgh. The total thickness is difficult to determine due to lack of continuous exposure. A reasonable assumption for the northern Champlain Valley is about 750 meters (2,460 feet). The Ausable was probably deposited in high-energy fluvial and tidal channel bank environments.

Rensselaer Formation

The Rensselaer is largely limited to one thrust slice in the Taconic overthrust. It is of Early Cambrian age. The unit is a primarily turbidite, a feldspathic greywacke consisting of pebble conglomerate to medium sand. The Rensselaer is made of quartz with muscovite and rock fragments (argillite) interbedded with (Mettawee) red and green slate and argillite. It is hard, quartz-rich greywacke with a matrix of silt or fine sand (quartz dominant), feldspar (plagioclase and microcline), chlorite, and other micas. It is dark-green or gray on fresh surface and weathers brownish-gray. It displays massive bedding 0.6 to 3 meters (2 to 10 feet) and is coarser-grained on the west half of the Rensselaer Plateau. On the west face of the plateau, two sections are separately recorded at 274 meters (900 feet). Potter (1973) reports that it may be much thicker in the central part of the plateau. Total thickness is probably 365 to 396 meters (1,200 to 1,300 feet). The Rensselaer is a rather restricted geologic unit in New York. It primarily occurs within central and eastern Rensselaer County, where it is an important source of aggregates, with minor outliers. Major quarries are located in Cropseyville, Rensselaer County. It occurs from Boydonton to East Nassau in a north–south direction and east–west from Postenkill to Berlin. Its outcrop area is roughly 35 x 15 square kilometers (22 x 9 square miles).

Everett Formation

The Everett Formation is a gray or greenish fine- to medium-grained schist or phyllite. It is composed of quartz, plagioclase (albite or oligoclase) muscovite, garnet, with minor staurolite, chloritoid, and chlorite. It is probably of Early Cambrian age. Where it is quarried for aggregates, it is of slightly higher metamorphic grade and has a gneissic texture with bands of biotite and hornblende. The Everett schist is at least 465 meters (1,500 feet) thick. The unit crops out in the eastern Taconic Mountains in several thrust fault-bounded slices that trend northeasterly though eastern Dutchess County and on the New York–Massachusetts border in Columbia County. Metamorphic grade in the Taconic Mountains increases eastward and southward so it is likely that only in southeastern New York will the Everett be of suitable quality for use as an aggregate. In the central and northern Taconics, the Everett Formation is a fine-grained, well-foliated phyllite, unsuited for construction aggregate.

Precambrian Gneisses

Throughout the Adirondacks and to a lesser extent in the Hudson Highlands, high-grade metamorphic rocks are extracted for construction aggregates. The rocks are meta-igneous and meta-sedimentary in origin (Figure 19), generally having been subjected to upper amphibolite or granulite grade metamorphism during the Grenville orogenic cycle. In some cases these are named units, but more commonly they are not, as the regional stratigraphy of these regions is not established with certainty. These rocks have been subjected to strong deformation, and were thickened by intense folding and thinned or repeated by large scale shearing. Overall thicknesses of the units are estimations. Commonly, the thickness of a given unit will be on the order of hundreds to thousands of feet. Hence, the site geology of a quarry is more important than the overall thickness of the rocks to be mined. The rock units are large and regionally homogeneous but modal variations of the mineral phases occur commonly.

Most commonly quarried are rocks that are broadly classified as "granitic gneiss," although the mineralogical and bulk chemical composition varies from granite *sensu stricto* to quartz syenite, syenite, granodiorite, and diorite. Interlayered with these rocks is amphibolite composed of plagioclase and amphibole minerals. Also interlayered are pure or feldspathic quartzite, calc-silicate gneiss, and marble. All of these rocks are successfully quarried in areas underlain by Precambrian rocks in New York. Specific examples of rock mined for aggregates are described below.

In Warren County, folded granite gneiss and amphibolite are quarried at a mine where approximately 100 meters (330 feet) of quarry rock are exposed. The granite gneiss is composed of plagioclase, quartz, potassium feldspar, hornblende, and garnet. This unit is interlayered with amphibolite, which is primarily plagioclase and hornblende. In Essex County, several types of rock are used for construction aggregates. Some are meta-sedimentary in origin and include quartz-plagioclase (± K feldspar) gneiss, coarse-grained diopsidic marble, and amphibolite. These units, taken together, make up over 128 meters (420 feet) of mined rock. Also in Essex County, meta-igneous rocks in the form of meta-anorthosite and interlayered diorite gneiss are used for aggregates. The meta-anorthosite is dominantly plagioclase feldspar, with 10 to 20 percent iron-magnesium bearing silicates such as amphiboles, biotite, and garnet with minor iron oxide minerals. The diorite gneiss is composed of sodic plagioclase feldspar and mafic minerals.

The Green Lake Formation is quarried in the southern and central Adirondacks. McLelland (1972) describes this unit as being between 60 meters (200 feet) and 600 meters (2,000 feet) thick. This unit is dominantly a light-colored garnet, quartz, plagioclase, K feldspar, sillimanite gneiss interlayered with minor amphibolitic, calc-silicate, and biotite-rich gneisses. Locally, there are layers of quartzite of variable purity. In Washington

Figure 19. Diabase (trap rock) quarry in Palisades sill. Lifts are approximately 50 feet.

County the Hague Gneiss, oldest unit of the Springhill Pond Formation in the Lake George Group (Fisher 1985), is quarried. This is a banded quartz, plagioclase, sillimanite, biotite, hornblende, garnet, potassium feldspar, gneiss, which contains bodies of amphibolite. In northern Oneida County, quartz granofels, quartz syenite gneiss, and biotite gneiss are used for aggregates. The quartz granofels is a phaneritic, nonporphyroblastic, nonfoliated unit composed of plagioclase, quartz, and biotite. The quartz syenite is a feldspar, quartz, minor biotite, and chorite gneiss, and the biotite gneiss is plagioclase, quartz, and biotite (McLelland 1972). In Fulton County, the Peck Lake Formation is quarried. This is described by McLelland (1972) as a garnet, biotite, quartz, plagioclase (oligoclase) gneiss with amphibolite and quartzite layers. Overall, this unit is estimated to be 1,525 meters (5,000 feet) thick. While leucocratic variants of the Peck Lake exist, it is not possible to further sub-divide this formation. A 150-meter-(500 feet) thick unit of granodiorite and diorite gneiss is also quarried. In Franklin County, the so-called St. Regis Granite Formation is used for construction aggregates. This is comprised of granitic gneiss mixed with amphibolite several hundred feet thick. The gneiss is made of K-feldspar, quartz, and hornblende.

In the metamorphic rock of the Hudson Highlands of Dutchess County, undifferentiated granite gneiss and hornblende granite gneiss of the Grenville orogen are quarried. The rocks are composed of quartz, K-feldspar, and hornblende with minor pyroxene, garnet, epidote, and chlorite. Minor dolomitic marble is interlayered with these rocks.

Chapter 4

SAND AND GRAVEL

Sand and gravel must surely have been among the first mineral resources extracted in New York. However, little was written about these materials in the nineteenth and early twentieth centuries except to disparage them for not making quality road surfaces. But sand and gravel were recognized as vitally important for subgrade materials. Merrill (1897) cites 2,000 years of knowledge that the perfect road must have a hard, smooth, waterproof surface and a thoroughly dry foundation. He states, "The surface of a good road must have sufficient strength to resist the wear and tear of traffic, and smooth enough to prevent undue strain and wear on vehicles. In conjunction with this, the *soil beneath must be made dry and kept dry*" (emphasis in original). Sand and gravel made this latter condition possible. By the 1920s, the value and volume of sand and gravel deposits were recognized to be large. The large-scale production of these commodities was thought to be "merely a problem in extraction" (Nevin 1929).

GENERAL GEOLOGY

Sand and gravel, like crushed stone, are fundamental to the construction industry. Unlike crushed stone, sand and gravel deposits are unconsolidated and hence do not require blasting to liberate the material from the earth. There are more mines for sand and gravel in New York than for any other commodity. They occur in all counties but New York, Bronx, Queens, Kings, Richmond, and Nassau. Sand and gravel deposits found in New York are the result of deposition of sediments by rivers and streams related to the melting of the late Pleistocene Wisconsinan ice sheet. Virtually all of the state was covered by 1 to 2 kilometers (0.6–1.2 miles) of ice. Material carried in the ice was generally deposited as till but where it was transported and winnowed by melt water, relatively clean sand and gravel were deposited. The glacial sand and gravel deposits generally take the form of kames, deltas, beaches, eskers, and outwash channel fill. The material in these deposits varies in size from sand to large cobbles with occasional large boulders. Post-glacial alluvial processes, particularly running water but also wind and freshwater and marine waves and currents, have also generated sand and gravel deposits.

The exception is a small area in southwestern New York in the vicinity of Allegheny State Park. Two Pleistocene ice lobes flowed around the higher land of the park area and created a triangular notch about 60 kilometers (37 miles) long and 27 kilometers (17 miles) deep in the roughly east–west margin of the Pleistocene glacial maximum. Known as the Salamanca reentrant, this unglaciated area is roughly 725 square kilometers (280 square miles) in size, and is small compared to the glaciated area of the state. But in this area, ice contact deposits are absent and only the outwash deposits are present.

PRODUCTS AND USES

Sand, as defined for construction use, consists of particles smaller than 4.76 mm (3/16 inch). Sand in this size range is dominantly quartz with variable amounts of feldspar, mica, silt, and clay. Gravel is material larger in grain size than sand and has more variable composition, often including rock fragments and reflecting the geological formations in the local area (Harben and Bates 1984). A commercially useful sand and gravel deposit should have a wide range of particle sizes so that several different final products can be extracted from it. Table 6 lists the typical sizes and uses for sand and gravel products quarried in New York. In 2006, 34,962,000 metric tons of sand and gravel were quarried in the state (USGS 2006).

While glacially derived sand and gravel are relatively widespread in New York, not all sand and gravel deposits can be developed for use as sources of construction aggregates. Some are not of sufficient quality to produce useful aggregates. Sand and gravel deposits should contain little fine silt or clay, organic matter, fissile shale, friable sandstone, or other easily disaggregated rock types. If fine particles are present, they must be removed by processing. The deposit should not contain excessive amounts of reactive chert or siliceous lime-

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Table 6. Typical Size and Uses for Sand and Gravel Products Mined in New York.

Size (inches)	Use
0.003–0.19	Portland concrete, mortar, pool sand, patio base, play sand, pipe bedding, road and driveway traction, filtration
1/4	Playground surfaces
3/8	Driveways, portland concrete, landscaping, roofing, filter systems
3/4	Portland concrete, septic systems, driveways, landscaping, backfill, drainage
1	Drainage, driveways, backfill
1–3	Drainage around houses, decorative uses
2–8	Drainage, fill, very muddy locations

Source: Harben and Bates 1984.

stone to avoid alkali-aggregate reactivity which, if used in concrete mix, may cause the subsequent product to crack or blister (Harben and Bates 1984). Finally, the shape of the particles bears on the quality of the deposit. Flat or elongate particles, often derived from shale, siltstone, or low-grade micaceous metamorphic rocks are not desirable. Chert, siliceous limestone, shale, phyllite, and slate are rather widespread in certain parts of New York and contribute potentially deleterious materials to the sand and gravel. Quality issues constrain sand and gravel deposits that can be economically exploited.

One other use, primarily for sand and generally derived from offshore, deserves mention. Coastal sediment is continually lost due to erosion, land subsidence, and sea-level rise. Loss or retreat of New York's beaches, dunes, and barrier islands are serious problems. These geomorphic features provide important protection of the coast, infrastructure, commercial, and residential properties in coastal communities as population and development on the coast increases. The loss of sand and landforms endangers life, property, recreational opportunities, and sensitive environmental areas. Upland sand resources are, however, insufficient to provide the material necessary for restoration of lost sand. Beach nourishment from marine sources to mitigate the removal or submergence of coastal sand is a necessary and common practice on the south shore of Long Island. This method uses dredged sand from offshore, which is pumped on shore to widen and elevate the beach and dunes. This practice is often cost effective and environmentally acceptable and provides short-term (perhaps ten years) protection. The process can reduce the risk of storm damage and flooding, and improve degraded coastal ecosystems (Williams et al. 2009).

AVAILABILITY

Other impediments exist to the development of the deposits. As crushed stone, sand and gravel are heavy materials of low unit value and cannot be transported economically far distances. They are used in large amounts in construction projects and therefore the source of the materials must be close to the point of use. Since most construction projects are in populated areas, the presence of a sand and gravel mine can be a source of contention. The issues include dust, noise, visibility, and truck traffic (Harben and Bates 1984). Perhaps the most difficult problem arises as the result of the location of sand and gravel deposits. Ice contact deposits such as kames are found on valley walls. Beaches and deltas are located at the transition between valley walls and valley bottoms. Outwash deposits form valley floors. These locations are sites of competition for other development. Well-drained, low-relief surfaces are desirable for dwellings, business establishments, roads, and municipal construction. Once a deposit has been overbuilt, it is generally no longer available for mining.

There are ways in which this conflict can be mitigated. In parts of California, the Surface Mining and Reclamation Act of 1975 (SMARA) and subsequent amendments resulted in the designation of "natural resource districts" wherein lands are reserved for mineral development. SMARA helps identify and protect mineral resources in areas in the state subject to urbanization or other irreversible land uses that preclude mineral extraction. Construction aggregates were selected as the first commodity targeted for protection due to its importance to society and its threat of loss by urban development (California SMARA 1975). In order that the lands not be permanently lost to the community, sequential land use is assumed (Harben and Bates 1984). For example, lands where aggregate resources are present are used first for sand and gravel extraction and then for residential development, recreation, or municipal facilities.

In Canada, Ontario's Mineral Development Strategy provides methods to identify areas of high mineral potential based on economic and geologic factors. These results are then analyzed in conjunction with other land-use information that gives consideration to areas with mineral resources before final land-use decisions are made that might prohibit exploration or mining (Ontario Mines and Minerals Division 2009). Under the Provincial Policy Plan, as much of the available aggregate resources as possible is made available close to the market. In cognizance of future needs, regulations state that demonstration of immediate need for the resources is not required. Aggregate operations are protected from development or other activities that would preclude or hinder their expansion or continued use. In areas adjacent to or in known aggregate resources, development or activities that would preclude or hinder the establishment of new operations or access to the resources shall only be permitted under certain regulated conditions (Ontario Province 2005). This type of regional land-use planning would benefit New York.

In parts of New York, inland sources of sand and gravel are scarce, either due to the original paucity of deposits or land-use conflicts. This is particularly true in the lower Hudson Valley, the New York City Metropolitan Region, and on Long Island. Aggregate resources located offshore on the continental shelf offer a limited possible alternative. Most of the land controlled by New York under Lakes Erie and Ontario is authorized for sand and gravel extraction. Taking of material offshore Chautauqua County is prohibited (Public Lands Law Section 22.2.a), with minor exceptions near Walnut and Cattaraugus Creeks. To date, the New York State Office of General Services has not been approached about offshore mining in the Great Lakes. Apparently, upland sources are currently sufficient and more cost effective than these alternatives. Taking of sand and gravel from New York State land offshore Long Island is also prohibited except when, in the opinion of the U.S. Army Corps of Engineers, the removal of the material is necessary for navigational improvements (Public Lands Law Section 22.2.b). While offshore sand and gravel cannot be mined in New York waters (three miles from shore), for the past two decades the Federal Minerals Management Service has been aware of the interest in sand and gravel from the federal outer continental shelf as a source for aggregates for sale and coastal restoration. At present, these outer continental shelf deposits are not cost effective. Federal regulations are in place for competitive lease sales for offshore mineral resources. Since the late 1980s, the Minerals Management Service (MMS) has leased over 30 million cubic yards of outer continental shelf sand for twenty-three coastal restoration projects in five states. None of these projects were in New York, however (MMS 2009).

Beach nourishment is viewed for many developed coasts as a cost-effective and environmentally acceptable short-term (perhaps a decade of protection) method for mitigating coastal erosion, reducing storm and flooding risk, and restoring degraded coastal ecosystems. For beach nourishment to be successful, however, large volumes of high-quality sand are necessary. Federally sponsored beach nourishment projects in the past eighty years have consumed about 920 million cubic meters (≈1,200 million cubic yards) of sand (Bliss et al. 2009). For project benefits to exceed costs, the sand deposits must be located reasonably close to the beaches being considered for nourishment. Up to 8.1 billion cubic meters of sand may be available in New York waters off the south shore of Long Island for coastal restoration projects. This includes cape- and ridge-associated marine sand deposits as well as paleo-stream channels, blanket and outwash deposits, ebb-tidal shoals, and low sea-level stand deltas (Bliss et al. 2009). In the cape- and ridge-associated marine sand deposits on the inner continental shelf outboard of New York waters, there are probably 2,200 million cubic meters (≈2,900 million cubic yards) of sand. However, not all of this material will be available for extraction because of geographic, economic, environmental, geologic, and political factors, and preemptive use (Bliss et al. 2009).

There are currently 1,744 sand and gravel mines in New York. Of these, 1,499 operate above the water table as upland sources. Those operating below the water table number 245. The processes used to acquire the product are similar across New York. Information about companies that produce sand and gravel in New York is published by the New York State Department of Environmental Conservation, Division of Mineral Resources. Data organized by commodity is available in electronic format at http://www.dec.ny.gov/cfmx/extapps/MinedLand/standard/commodities. More specific information is available in a searchable mines database available at http://www.dec.ny.gov/cfmx/extapps/MinedLand/search/mines.

METHODS

Upland Sources

Upland, or dry-pit, sources of sand and gravel are those that operate generally above the water table. The process of mining sand and gravel from these sources is as follows. At a typical sand and gravel operation, wheeled equipment, such as front-end loaders with multiple yard bucket capacity, are used to extract the material from the mining face. Hydraulic shovels are infrequently used to load haul trucks to transport the material in the mine. Trucks or conveyors are used to transport the mined material to a permanent or portable processing plant. If haul distances are short or in small operations, a loader can be used to take the raw material directly to the processing plant.

The sand and gravel is passed over a grizzly, if necessary, to remove oversized material or the material may be fed to scalping screens. This removes deleterious materials such as roots, clay balls, and large rocks. The sand and gravel is then run over a multideck inclined set of screens, either reciprocating or vibratory, made of steel, rubber, or polyurethane for size separation. A typical set of screens would include opening sizes of 38 millimeters (1½ inch), 19 millimeters (¾ inch), 12 millimeters (½ inch), and 5 or 6 millimeters (¼ or 3/16 inch). An average screening plant has a capacity of between 100 and 300 tons per hour. If needed, water is sprayed at various rates onto the screens while in operation to suppress dust and wash the product.

Oversized material is reduced in jaw, gyratory (cone), or impact crushers to the desired size. This also produces a more angular product from the originally rounded, water-worn coarse gravel and cobbles. Impact crushers are more costly to operate but are being used to achieve desired particle shapes and remove less sound material. Sand products, after being separated on a screen deck, may travel to a classifier where they are washed and sized. The sands are then dewatered with screw-type equipment and placed in stockpiles. Transportation to stockpile areas is via fixed conveyor system, a radial stacker, or an extendable belt conveyor system. A radial stacker is a conveyor system that rotates from a fixed pivot point, and stores the conveyed material in an arc-shaped stockpile. The extendable belt conveyor system has the capability of lengthening or shortening itself by moving the head section. The head section is mounted on wheels, and moves on rails, which allows the conveyor to supply several stockpiles, hoppers, or silos.

Below Water Table Sources

Sand and gravel deposits that are in areas of low relief can be mined below the water table with dredging equipment. Mining is often started with an excavator that creates a pond of sufficient size for a dredge. Dredging equipment is usually of a suction type with a rotary cutter head. The cutter head is especially necessary in deposits which contain higher concentrations of gravel. Occasionally, clam-shell equipment or a dragline is used. Dredges are usually in the range of 500 to 1,000 horsepower. Mined material is transported as a pumped slurry at 6,000 to 7,000 gallons per minute via pipeline to the processing plant. The material can be pumped directly to the plant or to a sump in order to separate sand and gravel from the water. From this point, processing of the material is the same as for sand and gravel from upland sources.

Offshore Sources

Currently, one operator, based in New Jersey, recovers sand and gravel from the Ambrose Channel under permit for navigational improvements and sells into the aggregate New York market. Westward-directed longshore drift along the south shore of Long Island brings sand and gravel into the shipping channel used for the approach to New York Harbor. This material is roughly 92 percent coarse to fine sand and 8 percent gravel. The materials are recovered by the dredge *Sandy Hook*, a trailing-arm suction hopper vessel, propelled by the tug *Sand Miner*, which is dedicated to sand mining (Figure 20). The dredge unloads its cargo in South Amboy, New Jersey, where the sand and gravel are drained,

Figure 20. Trailing-arm suction hopper dredge *Sandy Hook* operates in lower New York Harbor to extract construction sand and gravel.

processed, and washed. The finished product is then loaded onto barges, commonly of 611 cubic meters (800 cubic yards) capacity, and delivered to a market area that stretches from Atlantic City, New Jersey, to New Haven, Connecticut.

There may be potential to expand this activity. Several countries, including the United Kingdom, Japan, and Germany, derive significant portions of their construction aggregates, in the form of sand and gravel, from offshore deposits. In 2005, marine sand and gravel accounted for 19 percent of total sand and gravel in England and 46 percent in Wales. Some metropolitan regions are almost entirely dependent on marine resources for construction aggregates. Eighty percent of total aggregate used in the City of London originates offshore (British Geological Survey 2007). It should be noted that most of the sediment on the continental shelf south of Long Island is fine to medium sand, with 10 percent or less gravel (Coch et al. 1997a, 1997b; Harsch et al. 1997; Williams et al. 2003). Most aggregates require medium- to coarse-grained sand, so only a small percentage of channel maintenance sand has value as construction material. Offshore sand mining is cost effective and practicable in the general New York City area for two reasons: (1) shortages of upland sources have led to elevated costs of concrete sand and other sand products in this market area—concrete sand that sold for approximately $8/ton in upstate New York sells for up to $25/ton in the New York City area (Griggs, pers. comm. 2010); and (2) many end users have established infrastructure to receive aggregate by water. In general, offshore sand mining costs significantly more than upland sand mining and would only be feasible where the construction material costs are elevated and suitable and where specialized docking facilities exist.

Chapter 5

CEMENT

HISTORY

Cement manufacture involves the processing of selected raw materials, either natural whole rock or a specific combination of rock materials, to make a synthetic mineral mixture that will bind to an aggregate filler and yield a durable, physically and chemically stable, and strong product. Generally, the term refers to "hydraulic" cement, primarily portland cement, which has the property of hardening under water and which is the chief binding agent for concrete and masonry. Portland cement concrete is one of the principal materials used in infrastructure, commercial, and residential construction. In 1818, engineer Canvass White found bedrock in Madison County, New York, that could be processed into hydraulic cement. Cement from this and other limestone units found in Cayuga and Onondaga counties were used in the construction of the original Erie Canal (1817–1825). In 1871, the first landmark building constructed with reinforced concrete was erected in Port Chester, New York (Auburn Univ. 2007).

Historically, New York produced two types of cement, which differed primarily in the raw material sources. "Natural" cement was made from whole-rock limestone formations, which contain between 54 and 75 percent calcium and magnesium carbonates and 20 to 40 percent silica, alumina, and iron oxides. Portland cement is made from limestone with higher calcium carbonate content, perhaps as high as 95 percent, and lower amounts of accessory minerals. Other rock, mineral, or chemical admixtures are introduced to portland cement to produce the proper chemical composition. Natural cement was first made from "waterlime" rock in 1823, in an accidental discovery during the construction of the Delaware and Hudson Canal in Ulster County. It was noticed that the lime calcined from certain rocks in the Rosendale area would harden under water rather than slake (Ries and Eckle 1901). In 1899, there were 29 cement works in New York that produced 4,689,167 barrels of 136-kilogram (300-pound) capacity, that were valued at $2,813,500 (2009 value: $71,594,555).

The Rosendale region produced what was recognized as the best natural cement in the United States. Here, strata in the Upper Silurian Rondout Formation were utilized. The strata had a workable aggregate thickness of up to 30 feet. Large room and pillar mines that extended 300 meters (1,000 feet) across the face (along strike) and down dip for 249 to 365 meters (800–1,200 feet) yielded the raw material. The Rondout was also quarried for natural cement at Howe's Cave in Schoharie County. Other New York "waterlimes" were also used for natural cement production. In central New York, the natural cement rock was found at the top of the Manlius Formation in Onondaga and Madison counties. In the western part of the state, quarries in Erie County once rivaled the Rosendale mines. The rock used here was the Upper Silurian Bertie Dolostone of the Salina Group (Newland 1921).

Portland cement production in New York began in 1881 at Beacon, Dutchess County. Raw materials were derived from the Kingston area. This enterprise was so successful that another plant was opened closer to Kingston in 1883. Statewide, the industry grew rapidly during the 1890s and by 1902, production exceeded a million barrels per annum (Newland 1921). In 1906, the portland cement industry surpassed natural cement production (2,423,724 bbls. *vs*. 1,691,565 bbls.), although the latter persisted in New York until 1970 when the last of the Rosendale quarries was closed. Originally, the locus of portland cement manufacturing was in the Hudson River Valley south of Albany. These plants drew on units (e.g., Manlius, Coeymans, Becraft, Alsen) of the Lower Devonian Helderberg Group. These rocks were used for portland cement in Schoharie County as well. In Glens Falls, Washington County, rocks of the Ordovician Black River–Trenton Groups were quarried for this use. In central New York, portland cement plants used the Tully Formation in Tompkins County and the Manlius, Coeymans, and lower Onondaga Formations in Onondaga County.

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USES

Portland cement comprises the majority of New York hydraulic cement output with most of the remainder being masonry cement. Most of the portland cement is used in concrete. Approximately 1 ton of portland cement is used to make 4 cubic yards of concrete. In general, ready-mix concrete is the primary use of portland cement in New York. Concrete product manufacture is the next-largest use in concrete blocks; concrete pipe; prestressed, precast concrete; and other concrete products. Highway contractors and building material dealers account for the remainder (Johnson 1985). Quantities of cement shipped to customers in New York, from all sources, are shown in Table 7.

RAW MATERIALS

The primary ingredient needed for cement manufacture is slaked lime (CaO), which is produced from the mineral calcite ($CaCO_3$) in limestone although in theory marble or marl could be used. Secondary raw materials must be added to provide silica (SiO_2) and alumina (Al_2O_3) that are needed for the growth of the synthetic minerals that will form the cement. Iron, as ferrous oxide (FeO), is also needed in the raw materials or must be added. Although the source of these secondary components can be diverse, the final ratio of silica to alumina plus iron oxide must be tightly controlled (Ames et al. 1994). Traditional sources of these additional materials in New York have been clay and shale, which occur widely and often in association with the limestone units. While there is considerable flexibility in the choice of raw materials for cement, the chemical and physical properties of the raw feed to the kiln exert a large effect on costs. There are some rocks in the state, so-called "impure limestone," which have approximately the correct blend of lime, silica, alumina, and iron to be used directly without additives. These were the rocks that were the raw material to New York's natural cement industry. However, a rock that has exactly the correct blend of ingredients for modern cement is very rare.

In addition to the raw materials described above, a source of sulfur as SO_3 is required. This is added to control the setting time of concrete made with the cement. A common source of SO_3 is gypsum ($CaSO_4{\bullet}2H_2O$), which was mined in western New York until very recently. To a degree, synthetic gypsum, derived from sulfur dioxide (SO_2) flue gas scrubbers on power plants, has supplanted natural gypsum (Ames et al. 1994). Source materials for cement manufacture can contain components, within limits, other than those described. However, if present in amounts above prescribed levels, they become deleterious. Magnesium compounds such as the mineral dolomite ($CaMgCO_3$) are the most common of the unwanted materials. Magnesia (MgO) is beneficial in the kiln feed in amounts less than 4 percent in that it acts as a flux and is considered to be tolerable. However, amounts in excess of that are intolerable because the formation of magnesium minerals, such a periclase, in concrete cause expansion and disruption of the concrete, which can lead to failure (Ames et al. 1994).

PRODUCTS

Various physical and chemical environments require that several different types of portland cement be manufactured. Eight types of cement (five primary, three air-entraining) are produced in New York. The types and uses are listed in Table 8.

Types IA, IIA and IIIA are cements used to make air-entrained concrete. They have the same properties as Types I, II, and III, except that they have small quantities of air-entrained materials combined with them. Although, as indicated by historical references, some ancient and early-twentieth-century concretes were accidentally air entrained, the New York State Department of Public Works and the Universal Atlas

Table 7. Cement Shipments to Final Customer, by Destination and Origin in 2007.

Location	Portland cement (tons)	Masonry cement (tons)
Eastern New York *	682,100	17,600
Western New York†	850,700	23,100
Metropolitan New York‡	1,950,500	99,200

* Delaware, Franklin, Hamilton, Herkimer, Otsego, and all counties farther east and south, except Metropolitan

† Broome, Chenango, Lewis, Madison, Oneida, St. Lawrence, and all counties farther west

‡ Bronx, Kings, New York, Queens, and Richmond, Nassau, Rockland, Suffolk, and Westchester

Data from U. S. Geological Survey [van Oss 2009].

Table 8. Types and Characteristics of Portland Cement.

Type	Characteristics
I	Normal portland cement. It is general-use cement suitable for all applications where the special properties of the other types of cement are not required. It is used in buildings, bridges, floors, pavement, and pre-cast concrete products.
II	Used for structures wherein moderate resistance to sulfate in water or soil is desired. This type of cement generates less hydration heat at a slower rate than Type I.
III	Sets quickly and achieves high early strength. It is ground finer than other types and used when high strength is required very soon after placement.
IV	"Low heat" portland cement. It is used in massive concrete structures (e.g., dams) where the rate and amount of heat produced by hydration must be kept to a minimum. It develops strength more slowly than other portland cements.
V	Sulfate-resistant portland cement. Used only in concrete structures where the groundwater or soil has high sulfate content. It is manufactured to resist chemical weathering.

Cement Company were the first to recognize that certain natural organic materials, primarily wood and animal by-products, would greatly increase the resistance of concrete road surfaces to freeze—thaw and deicing chemicals (Whiting and Stark 1983; Rixom and Mailvaganam 1986). The most commonly used materials to encourage air entrainment are salts of wood resins, synthetic detergents, salts of petroleum acids, and salts of fatty or resinous acids (Dolch 1984).

Blended cements are also produced in New York. Blended cement is a mixture of portland cement and blast furnace slag or of portland cement and a pozzolan (most commonly fly ash). The use of blended cements in concrete reduces the amount of water required for the mix and diminishes bleeding, improves workability, enhances sulfate resistance, and inhibits the alkali-aggregate reaction. Blended cements also reduce the heat evolved during hydration, thus reducing the chances for thermal cracking upon curing.

PRODUCERS

Cement producers are located in Albany, Greene, and Warren counties. All of the facilities are foreign-owned. The mine and cement plant in Albany County is operated by the French-owned Lefarge Group. Lefarge in North America is the largest diversified supplier of construction materials in the United States and Canada and is the world's leading cement manufacturer. The mine from which the raw materials are extracted in Albany County is the largest producer of crushed stone in the state (Figure 21). The cement producers in Warren and Greene counties are operated by the Heidelberg

Figure 21. Cement and construction aggregate quarry, Ravena, New York. Note trucks and equipment at center for scale.

Cement Group, a German-owned company. The 550,000 tpy Warren County cement plant uses modern preheater technology and supplies cement by truck, rail, and barge throughout eastern New York and New England. Cement and slag grinding capacity at the company's Greene County plant augments the cement plant's capacity and produces blended products. A second cement plant in Greene County is owned by Holcim, a Swiss-owned company. Holcim also owns reserves on Becraft Mountain and recently spent $58 million in a futile attempt to open a new, state-of-the-art plant to replace its existing operation.

Chapter 6

HOT MIX ASPHALT

MATERIALS

Hot mix asphalt (HMA, asphalt concrete) is a mixture of coarse and fine construction aggregate mixed with asphalt binder, a petroleum derivative. Typically, the mix is 5 percent binder and 95 percent aggregate. It is widely used for pavement, and is placed and compacted at elevated temperature, typically 135°C (275°F) to 163°C (325°F). Hot mix asphalt is usually applied in layers 4 to 8 inches thick. The lower (base) layer(s) are typically composed of angular aggregates chosen to resist failure. The base layer is coarser-grained than the top layer but fine aggregate is added in the mix to fill voids between the larger particles and provide load transfer to the larger particles. The top layer, called the top course or friction layer, is made of finer aggregate that is durable and has good friction properties to prevent vehicles from skidding.

Crushed stone is commonly used for aggregate, but other materials such as reclaimed asphalt pavement, crushed concrete, foundry sand, coal fly ash, and slag can be used (Industrial Resources Council 2010). New York State specifications allow for local high-quality aggregate use from sand and gravel deposits, limestone and dolostone units, metamorphic rocks such as schist and gneiss, and igneous rock such as diabase, for aggregate sources. There are various "friction" levels required in roads and most of these aggregates meet Department of Transportation quality specifications. One exception is for the highest friction surface. In this case, noncarbonate stone is necessary in the surface layer. Crush-count requirements can limit the use of fine-grained gravels for roads with very high traffic loads (B. Barkevich, pers. comm., 2010).

Asphalt plants now operating in New York may be up to fifty or sixty years old. New asphalt plants are typically of the drum-type with capacities of 408 metric tons (450 short tons) per hour or more. Most of these can use reclaimed asphalt pavement (RAP) in the mix. Many batch plants are being refitted to handle RAP as well. The New York State Department of Transportation allows 20 percent RAP in surface and binder courses of pavement and 30 percent in base courses. New York City allows 40 percent in some mixes. New York towns and counties do not specify proportions but generally follow state specifications. Hot mix asphalt for commercial projects, such as driveways and parking lots, can contain whatever amount the producer believes is suitable (B. Barkevich, pers. comm., 2010).

Polymer modifiers are added to modern asphalt to improve the elasticity of the asphalt and increase durability. Modifiers add to the cost of the asphalt (five to ten dollars per ton) but the increased cost is mitigated by the longer life of the pavement. An additive which is being investigated and which is coming into increased use is recycled roofing shingles. The large amount of high-quality asphalt in shingles makes them an attractive addition to the hot mix asphalt mix. Currently, the preferred variety of shingles is manufacturers' waste but shingles removed from buildings by contractors are also being investigated for use. Adding 5 percent recycled shingles to hot mix asphalt can reduce the cost by $1.00 to $2.80 per ton and improve the quality of the mix used in paving (Northeast Recycling Council 2007).

HISTORY

Asphaltic concrete mixtures were first used in the United States in the late 1860s for sidewalks, and to a limited degree, roads. The first true asphalt pavement, a mixture of asphalt and sand, was installed in Newark, New Jersey, in 1870. In the late nineteenth century, all asphalt was derived from an asphalt lake in Trinidad or from one in Venezuela. Since builders quickly realized the advantages of asphalt paving, they created competing proprietary brands of hot mix asphalt, which were aggressively marketed. The first of these patents was filed in 1871, by a resident of Brooklyn, New York. However, as requirements for pavement became more stringent, including warrantees, the proprietary pavements were forced from the market by the 1920s. The early-twentieth-century use of refined petroleum asphalt surpassed the use of natural asphalt as oil

Mineral Industry of the State of New York, by William M. Kelly, New York State Museum Record 3

refineries proliferated (National Asphalt Pavement Association 2010). In New York, coal tar was routinely used as a binder prior to 1950. In 1976, New York State prohibited the use of coal tar in base course, road shoulders, and all roadway paving (Mundt et al. 2009).

Centrally operated hot mix production facilities existed in the late nineteenth century. Early mixing and drying equipment was modified from portland cement concrete mixers. Originally, hot mix asphalt was spread and smoothed by hand and rolled by a horse drawn or steam powered roller, a very labor-intensive process. By the early twentieth century, modified mechanical spreaders, first used for portland cement, were in use. Hot mix asphalt facilities in the 1950s were dirty, dusty industrial operations with little in the way of equipment to reduce emissions of chemicals or particulates. This is no longer the case. Centrifugal dust collectors, wet scrubbers, and large bag houses (fabric filters) now remove these materials from the exhaust gasses generated by the plant.

Fillers and fibers, including asbestos, were routinely added to asphalt products nationally. New York never used asbestos for mainline road paving but began investigating its use in 1959, and some low-volume use of this material was reported (Mundt et al. 2009). Asbestos pavement, containing 1 to 3 percent asbestos, was shown to have greater flexibility and crack resistance and reduced brittleness, and allowed higher binder content. It did, however, increase the cost. The U. S. Environmental Protection Agency proposed a ban on the use of asbestos in road construction in 1971, and by 1979 its use was widely prohibited. Tests of the use of furnace slag began in New York in 1920 and by the 1950s this material was used in 70 percent of pavements, either as a surface treatment or in the foundation material (Mundt et al. 2009). Typical fillers currently used in New York include baghouse dust and stone dust. The cost of crumb rubber is high, and its use as filler is limited in New York.

During the 1970s, the need for conservation of natural resources led to the increased use of recycled asphalt pavement in freshly produced hot mix asphalt. Currently, asphalt pavement is the most recycled material in the United States, with over 95 million metric tons being used annually (National Asphalt Pavement Association 2010). This includes 1.36 million metric tons (1.5 million tons) of RAP used in New York annually. In New York, recycled pavement is, on average, 10 percent of road paving mixes (Mundt et al. 2009). However, old pavements with coal tar are prohibited from recycling in New York.

Superpave (SUperior PERforming Asphalt PAVEments) guidelines for binder selection and mixture performance were developed to design mixes that would meet specific weather (e.g., high and low temperatures) and traffic (load) conditions. New York began implementing these in the middle to late 1990s. Using the Superpave guidelines, all mixes produced in New York use a performance-graded binder that is suitable for the specific climate and traffic volume for the pavement. The blend of aggregate, asphalt, and voids is designed to produce a road surface that will be durable and resist rutting. Typical asphalt for upstate New York use is graded 64–22, meaning that the pavement will meet its performance specifications between the temperatures of 64°C (147°F) and -22°C (-8°F). In Westchester County and southeastern New York, a 70–20 Superpave mix is used due to the warmer ambient temperatures in that region.

USE

The primary use of hot mix asphalt is in paving. Approximately 94 percent of the roads in the United States are paved with this material. Parking lots are commonly so paved as well. It is used for small and large projects that range from residential driveways and golf cart paths to military and commercial airport runways. Asphalt pavement is used to line reservoirs and industrial retention ponds and in sea walls and groins to control shoreline erosion. It can be used in such agricultural and industrial applications as cattle feed lots, poultry and green house flooring, freight yards, and as landfill cap.

PROCESSES

At a hot mix asphalt plant, aggregates are blended, heated, and mixed with a binder to produce a product that meets specific requirements. The plants can be stationary or portable and are generally of two types. Batch plants (Figure 22) dry, sort, if not previously sorted, and heat the aggregate. Asphalt binder is heated separately. These components are then mixed in a pugmill to make a single batch that commonly weighs on the order of 2,000 kilograms to 5,440 kilograms (4,400 to 12,000 pounds). Cold aggregate is fed into the plant by one of three methods: open-top bins fed by a front-end loader, tunnels under stockpiles fed by conveyor or loader, or bunkers or large bins with aggregate fed by trucks or dump-bottom freight cars. Feeders on the bottom of the continuous belt type or vibratory bins deposit aggregate onto a conveyor or bucketline, which carries the aggregate to the dryer. The aggregates then enter a dryer to remove moisture and heat the material (Figure 23). The dryer is a revolving cylinder 1.75 to 3.3 meters (5 to 10 feet) in diameter and 7 to 13 meters (20

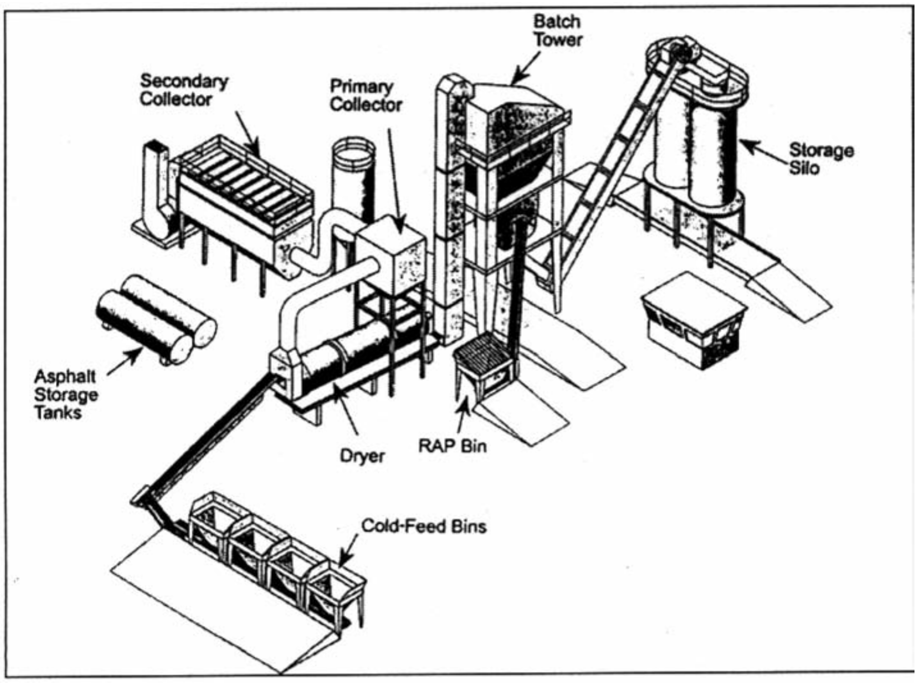

Figure 22. Typical components of a batch-type hot mix asphalt plant.
Indiana Department of Transportation 2010.

Figure 23. The dryer in a batch-type hot mix asphalt plant heats and dries the aggregate. Also shown: conveyor for aggregate feed (left) and baghouse (rear).
Courtesy Northern Bituminous Mix, Inc.

to 40 feet) in length. An oil- or gas-fired burner provides the heat with fans for primary air supply and exhaust. Dryers have "flights" (longitudinal fins or channels) that lift and drop the aggregate through the flame and hot gasses. Once heated, the material is passed over screens for separation by size and then stored hot (Figure 24). Hot aggregates, fillers if any, and asphaltic

Figure 24. Baghouse dust collection system (center). Also aggregate hoppers (foreground) and hot screen and pugmill (left background).
Courtesy Northern Bituminous Mix, Inc.

binder are drawn from storage in measured amounts and thoroughly mixed in a pugmill into a batch. The hot mix asphalt can then be discharged into trucks or placed in a surge bin to await shipment to the paving site (Indiana Department of Transportation 2010).

Hot mix asphalt plant operators have recognized the potential for air pollution and have developed equipment to mitigate the problems. Close attention is paid to the burners so that they do not become dirty or clogged, and air-fuel mixtures are kept properly adjusted to avoid the emission of excessive smoke or other deleterious products of incomplete combustion. Dust control systems are integrated into the design of the plant and its operations. Dust collectors can be one of two types in New York: wet scrubbers or baghouses (fabic filters). Sometimes more than one type is used, particularly if the aggregate is very dusty. The primary type of collector used in New York is the baghouse (Figure 25). While a small number of plants use wet scrubbers, even newly constructed plants install baghouses (B. Barkevich, pers. comm., 2010). A baghouse allows the accumulated dust cake to be reclaimed and used in the hot mix asphalt as filler or it can be discarded. In a wet scrubber, the dust is trapped in water and is not recoverable. Furthermore, the waste water containing the dust from a wet scrubber must be properly handled to prevent pollution. The amount of water that requires treatment can be considerable since a wet scrubber can consume about 1,136 liters (300 gallons) per minute (Indiana Department of Transportation 2010).

Drum-type plants (Figure 26) heat and dry previously sorted aggregate with binder in a drum. Drum plants differ from batch plants in that the aggregate is not only dried and heated in the dryer drum but the binder is mixed there as well. The processes are the same at both types of plants including cold aggregate storage and feeding, dust collection, and storage of the mix. Drum-type plants have no hot gradation screens or pugmills. Aggregates in various size gradations are withdrawn from stockpiles and placed in a multiple-bin feed system. Precision feeders control the amount of aggregates that are delivered and fed cold into the drum. Typically, the burner that heats the material is located in the feed end of the drum, but other arrangements (e.g., counter-flow units) are possible. The interior of the drum is equipped with flights that direct the motion of the aggregate and lift and drop the material through the burner flame. As the aggregate is heated and dried, weighed amount of binder is introduced into the drum where it is thoroughly mixed. A dust collection system captures the dust produced by the drum. The hot mix asphalt product is discharged continuously into a surge bin and subsequently loaded into trucks for delivery.

Figure 25. Hot screen deck and mill of batch-type hot mix asphalt plant. Baghouse also shown (left center).
Courtesy Northern Bituminous Mix, Inc.

No matter which type of plant is used to produce the hot mix asphalt, fillers and modifiers are routinely added to the mix to improve performance. Recently, the use of polymer modified asphalt has increased dramatically with approximately 1.36 million metric tons (1.5 million tons) of material being used annually. It has been shown that polymers aid in the elastic recovery of the asphalt. The materials used for fillers and modifiers, and the purpose of the addition of these, are given in Table 9. Crude oil from which New York's asphalt is produced has multiple sources, including Venezuela, Mexico, Canada, and the U.S. mid-continent region. Most of this material is brought by barge, rail, or trucks to refineries in the Northeast. The asphalt is either shipped directly to an HMA plant or to an intermediate company which will modify the asphalt to meet New York State specifications. Final delivery is typically by tanker truck.

PRODUCTS

Virtually all of the hot mix asphalt produced in New York is dense-graded mix, a relatively impermeable product suitable for all pavement layers and all traffic conditions. They mixes are used for structural, high friction, patching, and leveling needs. These contain well-graded aggregates, asphalt binder with or without modifiers, and reclaimed asphalt pavement (Washington Asphalt Paving Association 2010).

Open-graded mixes use only crushed stone or gravel and a small amount of manufactured sand. Consequently, they are porous and allow water to penetrate. This product, depending on the specific mix, can be used for surface course paving or as a drainage layer

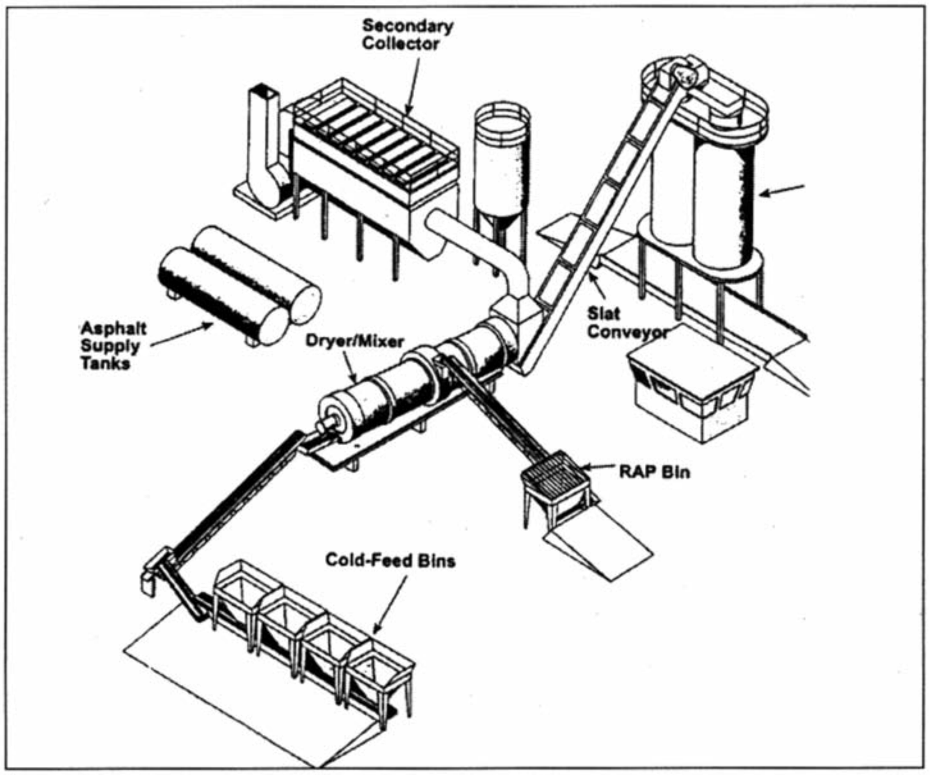

Figure 26. Typical components of a drum-type hot mix asphalt plant.
Indiana Department of Transportation 2010.

below dense-graded asphalt. Open-graded mix is reported to reduce road spray from precipitation and decrease road noise by up to ten decibels (National Asphalt Producers Association 1995). These mixes are becoming popular in New York as their use garners LEED (Leadership in Energy & Environmental Design) points in "green" building certification, but to date their applications are currently limited (B. Barkevich, pers. comm., 2010). Open-graded mixes have voids, typically 15 percent, that are critical to the proper function of this type of asphalt. Anything that leads to clogging of the voids, such as de-icing sand, will degrade performance.

Stone matrix (gap-graded) asphalt was earlier used in New York. This material was developed to allow for stone-to-stone contact in the aggregate. Since the crushed stone does not deform as much as asphalt, this should reduce rutting and increase durability. Stone matrix asphalt is more expensive than dense-graded mixes due to the need for more durable aggregate, higher asphalt content, and the addition of modifiers and fillers (National Asphalt Paving Association 2001). In New York they have fallen from favor due to higher costs (B. Barkevich, pers. comm., 2010).

Warm mix asphalt is rapidly increasing in use in New York. Warm mix is spread at temperatures of 93°C (200°F) to 135°C (275°F), which is on the order of 25 percent lower than typical hot mix asphalt. Reduced temperature results in less fuel usage and decreased fumes and greenhouse gas emissions from the plant. Warm mix is reported to provide better compaction on the road. Its use can increase the haul distance for paving mixes. Reducing the temperature at which the hot mix asphalt is produced will reduce the level of oxidation of the asphalt and lead to better long-term pavement performance. Warm mix permits the use of increased amounts of recycled asphalt pavement.

New York State has recently developed special specifications for warm mix that allows the New York State Department of Transportation to call for bids on projects that use this material. In 2010, about fifteen projects were slated to be completed with warm mix. In the past five years, approximately 227,000 metric tons (250,000 tons) of warm mix have been spread in New York. Currently, four companies are approved for use of warm mix on NYS DOT projects. This number is expected to double by the 2011 paving season and it is projected that in ten years more than half of the blacktop produced in the United States will be warm mix.

Table 9. Fillers and Modifiers Added to Asphalt Cement (after Roberts et al. 1996). Note that while extenders, oxidants, antioxidants, and hydrocarbons are used in asphalt products for surface treatments, micro-surfacing, and stone penetration, these compounds find only limited use in hot mix asphalt.

Type	Purpose	Examples
Filler	Fills voids, reduces asphalt content Meet gradation standards Increase stability Improve asphalt-aggregate bond	Crusher fines Lime Portland cement Fly ash Carbon black
Extender	Substitute for a portion of asphalt cement	Sulfur, Lignin
Rubber/plastic	Increase HMA stiffness at high service temperatures Increase HMA elasticity to resist cracking Decrease HMA stiffness to reduce cracking at low temperature	Natural/synthetic latex Styrene-butadiene-styrene Reclaimed rubber Polyethylene/polypropylene Ethylene acrylate copolymer Polyvinal chloride Ethylene propylene Polyolefins
Fiber	Improve tensile strength of mix Improve cohesion of mix Allow higher asphalt content without increasing draindown	Rock wool Polypropylene Polyester Fiberglass Cellulose
Oxidant	Increase post-placement stiffness of HMA	Manganese salts
Antioxidant	Increase durability of HMA	Lead compounds Carbon Calcium salts
Hydrocarbon	Restore aged asphalt to current specifications Increase HMA stiffness	Recycled oil Natural asphalts
Antistripping agents	Minimize separation of asphalt cement from aggregates	Amines Lime
Waste materials	Replace aggregate or asphalt volume with less expensive waste product	Reclaimed asphalt pavement Roofing shingles Recycled tires Glass

PRODUCERS

There are approximately 200 hot mix asphalt plants currently operating in New York (Figure 27). In a pattern similar to ready mix concrete plants, HMA producers are distributed across the state with increased numbers concentrated near population centers. As hot mix asphalt has to be spread while it is within a certain temperature range, the distance that it can be transported is limited. Maximum transport distance is roughly 120 kilometers (75 miles). Longer hauling is possible but it is expensive and the quality of the material at delivery may be jeopardized. Average transportation distance is 80 kilometers (50 miles) or less with 48 kilometers (30 miles) being preferred (B. Barkevich, pers. comm., 2010).

The price for hot mix asphalt varies by region within New York. Material used in the New York City Metropolitan Region and in southeastern New York can be significantly higher in cost than the same product in upstate regions. In part, this is due to the cost of shipping for the aggregate component of the HMA. In addition, labor and hauling costs are higher in downstate areas. On average, prices range statewide between $50 and $100 per ton.

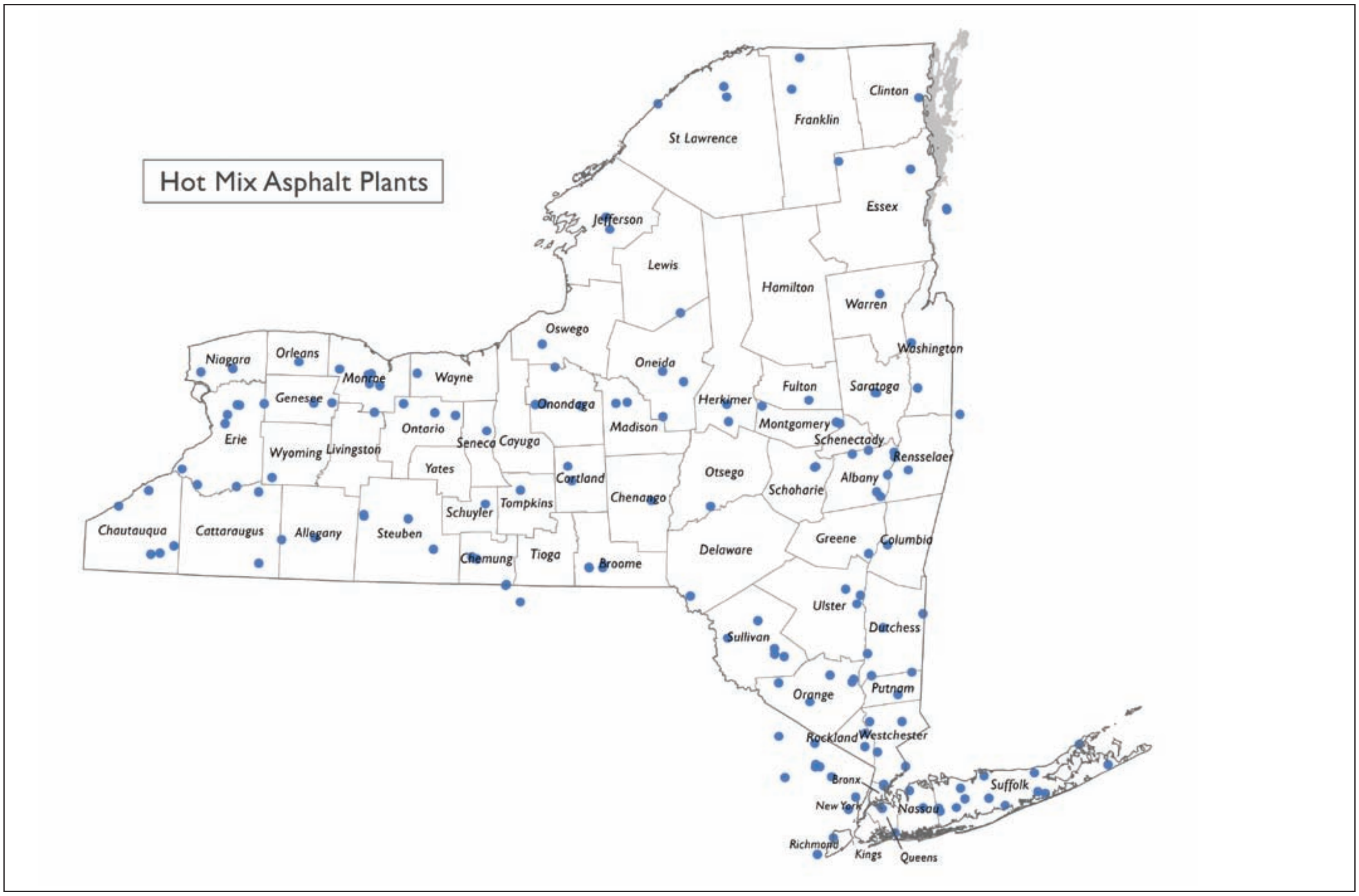

Figure 27. Location of hot mix asphalt plants that serve New York. Note that some are located outside state borders but still serve the New York market.

Data: New York State Department of Transportation.

Chapter 7

READY MIX CONCRETE

HISTORY

The term “ready mix concrete” refers to a type of concrete that is manufactured in a batching plant or factory according to a specific formula and is then delivered to a work site by truck-mounted transit mixers. Although the first load of ready mix concrete was delivered to a building site in Baltimore, Maryland, in 1913, the early ready mix plants appeared in the 1930s when the standard of practice was for contractors to mix concrete at the work site from bagged cement and aggregates delivered separately. The ready mix concrete industry expanded significantly in the 1960s. Modern ready mix concrete is made under computer-controlled conditions. This results in specialty mixtures designed for very specific purposes. The use of ready mix concrete allows a precise recipe to be delivered to the work site. This eliminates the need for an on-site concrete mixing plant and the need for storage space for the materials to make concrete at the site. Ultimately, the use of ready mix concrete reduces noise and labor costs and can improve air quality at the work site.

The concrete is delivered freshly mixed and in a plastic state from a centrally located batching plant that can serve a wide area. This is an advantage as the plant can be located, for instance, in an industrially zoned area and make deliveries to residential districts or into congested city work sites. However, when the materials are combined at a batch plant, the mixing begins at the plant so travel time from the plant to the work site is critical. Batch plants cannot be too far away from the site. The concrete should be placed within ninety minutes of being mixed. The weight of concrete is 1,776 kg/cubic meter (3,915 lbs/cubic yard) for general purpose concrete, and means that the transit mix truck is 33 tons for a normal 7.6-cubic-meter (10-cubic-yard) load. Therefore, concrete manufacturers strive to keep transportation distances to a minimum to avoid hauling heavy loads great distances.

PROCESSES

Ready mix concrete is commonly manufactured in batches of 1.5 to 9 cubic meters (2 to 12 cubic yards). The manufacturing plants are relatively simple. Facilities for handling bulk raw materials are present, including silos for cement storage, wheeled loaders, and perhaps conveyors to move aggregates (sand, gravel, crushed stone) from on-site storage piles to a mixer. A source of clean water is required. The batch plant weighs the various ingredients and feeds them into a weigh hopper. Aggregates comprise about 60 to 75 percent of the mix by volume. Ten to 15 percent is cement and 15 to 20 percent is water. Entrained air bubbles may be up to 5 to 8 percent. The batch plant and weigh hoppers are atop an elevated structure that allows the mixer trucks to drive underneath the plant to be loaded (Syverson 2008).

Additives are solid or liquid substances that improve workability, reduce shrinkage, or modify setting times. Air entraining substances provide resistance to freeze–thaw cycles. Additives can reduce the amount of water required in the mix, to increase slump (flowability) and improve workability. They provide increased strength and they reduce cracking due to shrinkage. Some additives protect reinforced concrete from corrosion caused by exposure to de-icing salt or a marine environment. Plastic or cellulose fibers increase the strength of the concrete and reduce shrinkage and cracking. Coal fly ash and slag are added as a replacement for portland cement. These materials make concrete stronger and less permeable and extend the set time.

Ready mix concrete plants in New York are of two varieties, batch and central mix facilities (Figure 28). At batch plants, the components of the concrete are weighed and loaded directly into the transit mixer truck. Then the requisite water is added, and the final mix is made in the truck. In central mix plants the concrete is made in batches and loaded into the truck as a wet mix (Figure 29). In both cases the stone, gravel,

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Figure 28. Batch (left) and central ready mix concrete plants.
Courtesy Northern Ready Mix, Inc.

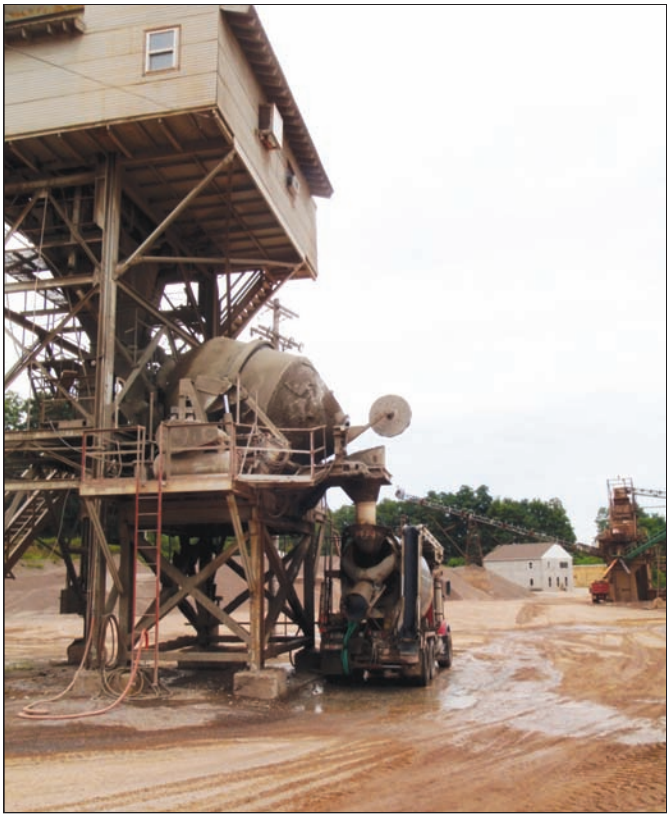

Figure 29. Central ready mix concrete plant in the process of lifting the batch mixer to load the wet mix into a transit mixer truck.
Courtesy Northern Ready Mix, Inc.

sand, cement, water, and additives are delivered to the mixer, either truck-mounted or stationary, from hoppers that weigh the requisite components. These in turn are controlled by computer systems.

PRODUCTS

Probably the most widely used form of ready mix concrete is as a cast-in-place material. Cast-in-place concrete is ready mix that is transported to the work site and placed in forms. The concrete is mixed according to specifications at an off-site location. It is used for most building foundations and slabs as well as walls, columns and beams, and floors and roofs. Cast-in-place concrete is used for large sections of bridges as well as for pavement. This material is used because of its long-term durability and structural strength. A variation of pre-cast concrete that uses ready mix concrete is “tilt-up” construction. In this process, reinforced concrete products are cast in forms at the work site and then “tilted-up” or lifted into final position. Structural elements, such as wall panels and bridge girders, can be made in this way. This technique has the advantage of ease of construction. Furthermore, large structural members or panels do not have to be transported by truck to the work site.

A related product is self-consolidating concrete, also known as self-compacting concrete. This material was new to the market in the 1980s. It is a highly flowable concrete that fills forms and is capable of encapsulating very dense arrangements of reinforcing steel without leaving voids and without the necessity of mechanical vibration. It settles into place entirely due to its own weight. This is accomplished by the addition of “superplasticizers” and viscosity modifiers, resulting in a product that is easily pumped and will flow into complex shapes and into hard-to-reach areas of the forms. The product commonly has more cement volume, less coarse aggregate, and more sand than typical concrete mixtures. Use of this material can reduce costs, labor requirements, and noise levels on the work site (National Ready Mixed Concrete Association 2010d).

Flowable fill, also called “controlled low-strength material,” is self-compacted, cementitious material used primarily as backfill or structural fill. It is an economical alternative to compacted granular fill. Flowable fill is a self-leveling material that does not require vibration or tamping. It hardens with minimal subsidence. Compressive strength of flowable fill is much lower than that of normal concrete. It must be less than 8.3 MPa (1,200 psi), is commonly less than 2.1 Mpa (300 psi), and may be as low as 1.4 MPa (200 psi). This allows for future excavation by hand if necessary. Mixtures with more than 20 percent entrained air by volume are used to reduce the strength of the material. Compressive strength in the range of 0.3 to 0.7 Mpa (50 to 100 psi) have a load-bearing capacity similar to well-compacted soil. Density when placed is between 171 kg/m^3 and 216 kg/m^3 (115 and 145 lb/ft^3). Density can be further reduced by the addition of light-weight aggregate or fillers. Because the material flows into place, neither compaction nor leveling is necessary. Flowable fill can be made with very large amounts of such nonstandard materials as fly ash or aggregates in amounts not suitable for concrete. Flowable fill is used for slab support in unsuitable soil conditions, in closing roadway cuts and utility trenches, and as pavement base. It is used to fill cavities in abandoned mines and tunnel shafts, underground structures and tanks, under pavement, and with rip-rap in river bank and ocean soil erosion control. Flowable fill is not designed to replace concrete. It will not resist freeze-thaw cycles, abrasive environments, or aggressive chemicals. However, if flowable fill degrades in place, it will continue to act as granular fill (National Ready Mixed Concrete Association 2010a).

Pervious concrete allows storm water to pass directly through it because it contains little, if any, fine aggregate and the size range of the coarse aggregate is restricted to allow for little packing. Both rounded and angular aggregate can be used, leaving voids in the final product that constitute 15 to 35 percent by volume. Allowing water to pass through reduces the requirements for drainage infrastructure associated with pavements such as roads, driveways, and parking lots. Pervious concrete reduces storm water runoff and increases groundwater recharge. The exposed coarse aggregate enhances vehicular traction and reduces hydroplaning. This type of concrete can achieve compressive strength up to 20 MPa (3,000 psi), which is strong enough to support such heavy vehicles as fire trucks. In addition to parking lots and low traffic-volume streets, pervious concrete is used for sidewalks, paths, retaining walls, and slope protection (National Ready Mixed Concrete Association 2010b). Due to its ability to reduce or eliminate surface runoff from a building site, pervious concrete is becoming very popular in New York.

Ready mix concrete is used in insulating concrete form construction. This technique involves the use of interlocking rigid foam blocks or panels that are assembled on the work site in place of the traditional wood and steel concrete forms. Reinforcing is added and concrete is poured into the cavities in the forms. The foam forms are left in place. This type of construction offers significant thermal advantages. Walls so made have an insulation value of approximately R-20. In addition, they allow little to no air infiltration because they form an unbroken envelope on the building. They also deaden external noise. Finally, the thermal mass of the concrete moderates external temperature fluctuations (National Ready Mixed Concrete Association 2010c). The insulating value, air-tight construction, and thermal mass combine to an equivalent insulation value of R-40.

A market is developing in New York for roller-compacted concrete. The difference between this material and typical ready mix concrete is the method of placement. Roller-compacted concrete contains the same ingredients as normal concrete (i.e., fine and coarse aggregate, cement and additives) but it is a drier mix. Large capacity and mixing efficiency are critical to economical construction by this method. When spread, typically with an asphalt paver, roller-compacted concrete is sufficiently stiff to bear the weight of and be compacted by vibratory rollers. It is a high-strength concrete that can be constructed without expansion joints and without forms or reinforcing steel. It requires no finishing. If appearance is important, joints can be sawn into the surface after curing. If not, the material is allowed to crack naturally (Portland Cement Association 2010). It is commonly used for heavy-duty pavements, although the use of this technique began in the construction of gravity dams (American Concrete Institute 1999). Roller-compacted concrete is used for ports, military facilities, parking, storage and staging areas, intersections, and low-speed roads. In New York, this material has recently been used in large quantity for runways at the U. S. Army Military Post at Ft. Drum and in the harbor at Oswego (G. Novitzki, pers. comm., 2010).

PRODUCERS

In New York there are approximately 350 ready mix plants of which 274 are New York State Department of Transportation-approved facilities. Ready mix plants are not as likely to seek Department of Transportation certification as, for example, crushed stone quarries, as some of the ready mix facilities will never produce concrete for New York projects. The plants are located across New York with concentrations in the populated areas (Figure 30). Ready mix concrete, as construction aggregate, is a high-volume, low-value commodity. This, combined with the relatively short life span between mixing and placement, means that the plants must be relatively close to their markets.

The greatest concentration of ready mix concrete facilities is in the New York City Metropolitan Region. According to the New York City Concrete Promotional

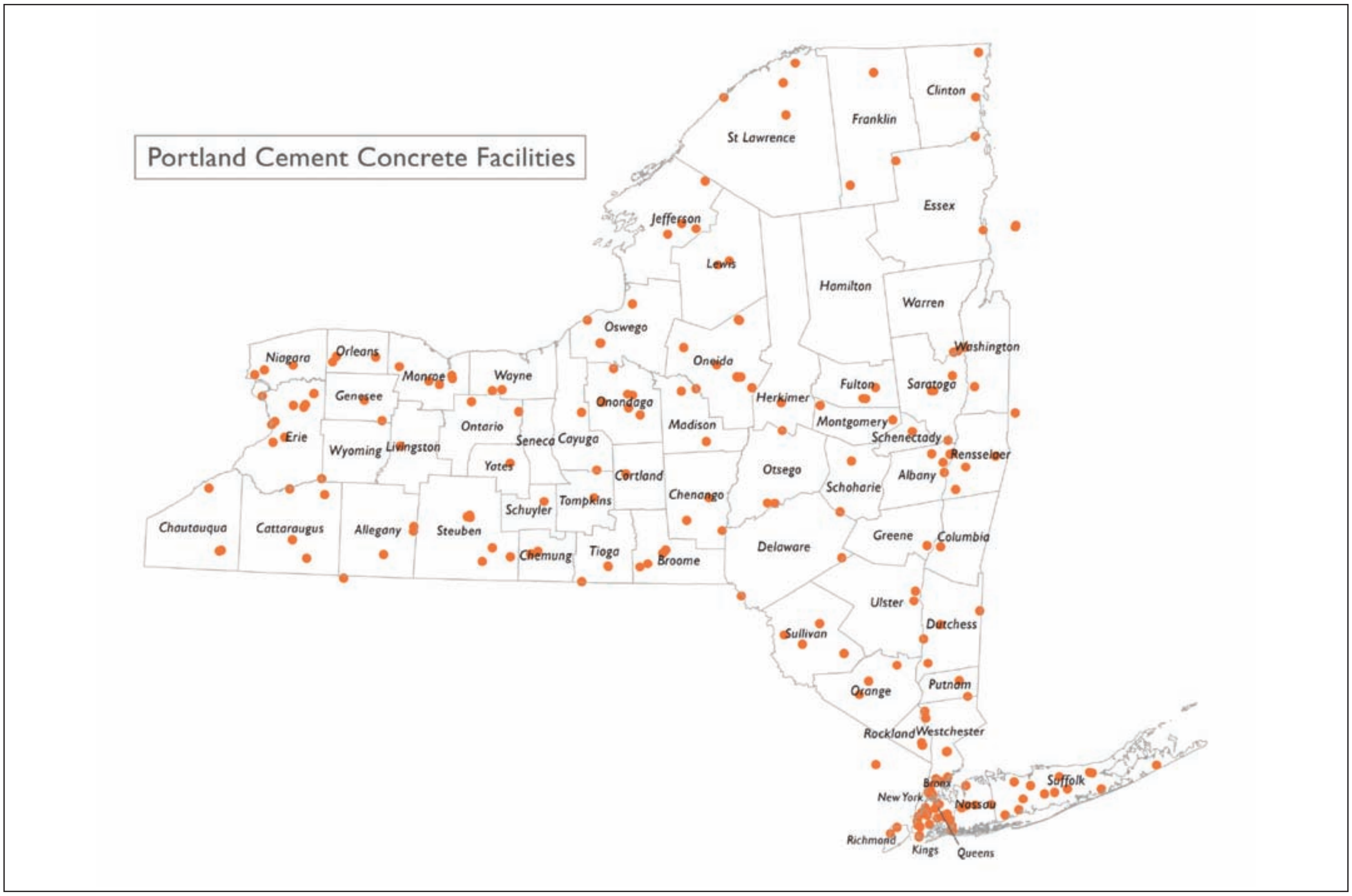

Figure 30. Location of ready mix concrete plants in New York. Note that this map only shows facilities with NYS Department of Transportation approval. Some plants are located outside New York boundaries but feed into the New York market.

Council, forty-four plants located in Queens (19), Brooklyn (15), the Bronx (6), and on Staten Island (4) produce 2.7 million cubic yards of concrete annually. This is a sufficient volume of concrete each year to build Yankee Stadium forty-seven times, the Lincoln Tunnel twenty times, or lay a two-lane road from New York City to Detroit.

Chapter 8

THE ECONOMIC IMPACT OF THE NEW YORK MINING AND CONSTRUCTION MATERIALS INDUSTRY

The NYSGS contributes to the annual U. S. Geological Survey *Minerals Yearbook* publication series, specifically, *Volume II, Domestic*. Consequently, the NYSGS is informed of the conclusions of the USGS regarding the value of the mineral resources extracted from New York each year. This and occasional informal estimates of the value of New York's mineral production are the only source of definitive information about the economic contribution to the state's economy by the mineral-production and -consumptive industries. The State of New York does not now routinely collect data on mineral production, value, or use within its borders, nor has it done so since the early to mid-twentieth century. While economic impact studies of the mineral industry and related activities are common (if not annual publications) in such western states as Alaska, Arizona, California, and Nevada, such investigations are rare in the east. Only one eastern state, Florida, has recently published even a partial study of the economic impact of its mineral industry. No such study has ever been undertaken for a state in the northeast in modern times.

In order to gain a better understanding of the mineral value and volume produced, labor income, employment, and fiscal impact in the mineral and related industries, the NYSGS entered into a contractual relationship with the Center for Governmental Research in Rochester, New York, to design and perform such an investigation. Drs. Rochelle L. Ruffer and Kent Gardner of the Center for Governmental Research (CGR) were the project directors. In addition to simply examining the mining industry, the dominant users of New York's mineral products were included in the investigation. These are the manufactures of portland cement, ready mix concrete, and hot mix asphalt, which comprise the construction material industries. Drs. Ruffer and Gardner worked with NYSGS and other state agency staff and members of the industries of interest to determine the combined economic impact of New York's mining and construction materials industries.

By an online and paper survey, nearly 200 New York companies involved in mining; manufacture of cement, ready mix concrete, and hot mix asphalt provided detailed data to CGR for analysis. These data included number of operations, total annual production, total sales with separate figures for sales to public works projects, production costs, number of employees, and annual payroll for full-time and part-time employees. Using a standard economic impact model the CGR extrapolated the available data to produce a report that encompassed the entire industry. The text of that report by R. L. Ruffer and K. Gardener is reproduced in its entirety in Appendix 1.

The mining industry in New York, as reported for economic impact purposes, is comprised of only those industries extant at this writing. The mined commodities are: cement, clay, crushed stone, dimension stone, garnet, gypsum, industrial sand, peat, salt, sand and gravel, talc, till, topsoil, wollastonite, and zinc/lead (sphalerite/galena). The crushed stone, cement, and sand and gravel industries are by far the dominant producers of mineral value and volume in New York. The primary users of the output of these three industries are the hot mixed asphalt and ready mixed concrete construction industries. It is these aggregated mining and construction industries that were queried to determine the economic impact of New York's mining and construction materials industry. Close-up determination of the impact of these industries on New York's economy required consideration of data such as production, employment, and payroll. Both the direct and indirect (spillover) economic impacts were included. Conclusions were determined for total jobs, wages, sales, personal income, and corporate taxes as a range with a low and high estimate.

The Center for Governmental Research (CGR) reported that sales of the mining and construction materials industry were between \$3.3 and \$3.5 billion in 2007. The industries paid \$1.2 to \$1.3 billion in wages and supported 28,000 to 30,000 jobs in New York. The industries contributed \$87 million to \$101 million in fiscal payments to New York. It must be noted that this is a minimum figure. Data for additional fees and taxes paid by members of the industries were not recoverable. For example, payments for motor fuel tax paid by

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the mining industry are captured but it is not possible to capture the expenditures for motor fuel tax by the many industries that support mining. Consequently, the value reported for this category is low. However, it is demonstrated that the economic impact to the economy of New York is at least $4.6 and $4.9 billion annually.

The commodities produced by the mining and construction materials industries are fundamental to the lifestyle and well-being of all residents of New York. The materials are used in construction of the state's infrastructure, housing and commercial buildings, ice and snow control, and other uses. Availability of the commodities depends on the existence of a mine or processing facility within an economically feasible distance of the market for the commodity. As Figures 1, 27, and 30 show, mines, hot mix asphalt plants, and ready mix concrete plants are currently widely and relatively uniformly distributed in New York. However, there are societal pressures resistant to the establishment of new mines and manufacturing facilities or the renewal of permits for existing operations in large parts of New York. In order to investigate the economic impact of either not establishing new mines as resources at existing mines that are exhausted, or the denial of mining permit renewals at currently operating mines, CGR modeled the economic impact of the loss of mines on one specific sector of New York's infrastructure, that is, the New York State Thruway. Transportation costs are a significant portion of the delivered priced of crushed stone used in highway construction. Sources of crushed stone must be close (approximately 30 miles) to point of use to avoid excessive cost of haulage. CGR compiled the locations of all mines used as sources of material by the New York State Thruway and then randomly removed one-quarter and one-half of the mines. Costs were then recalculated for material transportation, based on current fuel prices. The analysis demonstrated that if 25 percent of mines were not available to supply crushed stone to Thruway construction projects, transportation costs would increase by 42 percent or $1.6 million annually. If 50 percent of mines are unavailable, costs would increase by 52 percent or $2.2 million annually. This analysis is illustrative but does not address the costs on all construction projects statewide. For example, no attempt was made to estimate the increase in the cost of raw materials due to the decreased availability of those materials because of the lack of mining capacity. However, this analysis does indicate the magnitude of increased cost in one important aspect of the availability and use of construction materials. Similar costs would be imposed on any construction projects operating under similar constraints on availability of resources.

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The Economic Impact of the New York State Mining and Construction Materials Industry

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The Economic Impact of the New York State Mining and Construction Materials Industry

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SUMMARY

The mining industry in New York State is large and diverse, encompassing commodities such as bluestone, clay, dolostone, garnet, granite, industrial sand, limestone, peat, salt, shale, sandstone, talc, trap rock, wollastonite, zinc, sand and gravel, gypsum, glacial till, marble, marl and topsoil. Highway construction, new housing construction, ice control, and landscaping are among the wide variety of projects that use these materials.

The majority of mining is New York is for construction materials that are used to build and maintain the State's infrastructure. Thus, in addition to the products listed above, three other critical project resources include hot mixed asphalt (HMA), ready mix concrete (RMC) and cement. Together with crushed stone of all types and sand & gravel, these materials drive the New York State mining and construction materials industry (MCMI).

The Center for Governmental Research (CGR) performed an economic and fiscal impact study of the industry at the request of the NYS Geological Survey. To do so, CGR surveyed firms within the MCMI industry to obtain production, sales, employment and wage information. As discussed in greater detail below, survey respondents represented at least half of the permitted acreage. With such a firm foundation of actual responses, CGR is able to estimate the characteristics of the entire industry with confidence.

CGR reports economic impact in terms of jobs and wages generated by the industry, and takes into account both direct and spillover impacts. Fiscal impact is reported in terms of sales tax, personal income tax and corporate taxes paid to the state.

Economic and Fiscal Impact Findings

The results of the survey served as the foundation of our estimate of the industry's economic impact. CGR extrapolates sales, employment and payroll for mines, as well as for HMA, RMC and cement operations. While these assumptions, based on averages, are reasonable, CGR emphasizes that this is a diverse industry. The value of products and the skill levels of workers vary significantly from product to product. Our survey data were not detailed enough to account for all of these various differences. The conclusions of the analysis should be treated as reasonable estimates, not as precise measurements.

CGR uses the IMPLAN input-output modeling system to provide labor income and employment impacts, both direct and spillover for the MCMI industry.[*] CGR calculates that in 2007:

- Total NYS sales of the MCMI totaled between $3.3 to $3.5 billion dollars.

Economic Impact of the MCMI

	Direct	Spillover	Total
Labor Income (millions of dollars)			
High Estimate	$833.6	$482.4	**$1,316.0**
Low Estimate	$765.1	$442.8	**$1,207.9**
Jobs (thousands of jobs)			
High Estimate	17.5	12.9	**30.4**
Low Estimate	16.1	11.9	**28.0**

- The MCMI was responsible for generating $1.2 to $1.3 billion in wages and 28,000 to 30,000 jobs in New York State, both direct and spillover.

- The MCMI industry contributes to the fiscal health of the state and localities through sales tax, personal income tax, motor fuel tax, corporate franchise tax and Mined Land Reclamation Law fees. The total fiscal contribution of the industry is estimated at $87-101 million annually. There are additional taxes and fees paid by industry participants that we did not attempt to estimate.

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[*] See methodology section for a description of IMPLAN. The direct economic impact consists of the actual expenditures of NYS MCMI—i.e., the industry is directly involved with the transaction. Spillover expenditures result from the subsequent spending of those who receive the direct expenditures.

By way of comparison, the wood product manufacturing sector is responsible for about $335 million in payroll and employs about 9,300. Primary metal manufacturing pays about $700 million to 12,000 workers, while the warehousing & storage sector pays its 20,000 employees about $800 million. The average direct payroll per worker used in the study was about $48,000. This is slightly higher than the median salary for NYS industry.

Fiscal Impact of the MCMI (millions of dollars)

	Direct	Spillover	Total
NYS and Local Sales Tax			
High Estimate	$22.6	$13.1	**$35.7**
Low Estimate	$20.8	$12.0	**$32.8**
NYS Personal Income Tax			
High Estimate	$28.6	$13.3	**$41.9**
Low Estimate	$26.3	$6.5	**$32.8**
Corporate Tax*	$5.8	n/a	**$5.8**
*As reported by the NYS Department of Taxation & Finance - 2004- mining only			
Mined Land Reclamation Law (MLRL)	$2.9	n/a	**$2.9**
Motor Fuel Tax			
High Estimate	$14.8	n/a	**$14.8**
Low Estimate	$13.1	n/a	**$13.1**
Total Fiscal Impact			
High Estimate	$74.7	$26.4	**$101.1**
Low Estimate	$68.9	$18.5	**$87.4**

Illustration: Impact of Closing Mines on Construction Costs

Despite the fact that the mining and construction materials industry brings significant economic benefits to the state and localities, mining operations are not always welcomed by individual communities. Local governments often enact restrictive zoning that have the effect of excluding or severely limiting mining. As a consequence, new or expanded mines are difficult to permit yet existing mine reserves are being depleted at a faster rate than new reserves are being brought into production.

Much of the material mined is of relatively low value, yet is expensive to transport. Transportation costs, therefore, comprise a relatively large share of the cost of the delivered material. Closure of mines has the effect of increasing the final delivered cost as the material will necessarily be transported a greater distance.

To reflect this, CGR estimates the effect of reducing the number of mines in the state. This report illustrates the potential impact on transportation costs from the loss of mines with close proximity to construction sites. While the illustration does not begin to address the cost impact on all construction projects in NYS, it provides a starting point for consideration and discussion.

Our hypothetical scenario estimates that if the number of mines were reduced by one-half, transportation costs associated with NYS Thruway construction sites could rise as much as 59%, or $2.2 million, in one year.

These conclusions are applicable to the entire industry. Continued shrinkage of the industry will drive up the cost of new construction and highway reconstruction. Our data did not permit a more detailed analysis by region, but clearly the impact would be more pronounced downstate.

Annual Cost Implications of Increasing Transportation Distance

	Cost of Fuel per Gallon	All mines included	One-quarter mines taken away	One-half mines taken away
Average Distance from Exit to Nearest Mine (miles)	----	13.5	19.1	21.4
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$2	$3.4	$4.8	$5.3
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$3	$3.6	$5.1	$5.7
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$4	$3.9	$5.5	$6.1
Percentage Change in Cost (from all mines included)			42%	59%

Acknowledgements

CGR would like to thank all the companies who took the time to respond to the survey or contacted us to let us know the survey was not applicable to them. William Kelly, NY State Geologist, Director, New York State Geological Survey/ New York State Museum and David Hamling, Executive Director and professional geologist, New York Construction Materials Association have been incredibly helpful. They gave generously of their time, providing background information about the industry, offering input on the survey design, helping to encourage firms to fill out the survey, providing names of sources for data and other questions, and commenting on the final report.

CGR received input and help from many people in the process of conducting this analysis, but would like to specifically thank Andrew Clemente, Bonded Concrete; Jim Cleason, Abram Cleason Company; Paul Griggs, Griggs-Lang Consulting Geologists; Dan Meehan, Hanson America; Bill Poole, Lafarge North America; and Rich Riccelli, Riccelli Trucking, for answering our questions about the industry. We also thank Bradley J. Field, Director, Division of Mineral Resources and Christopher McKelvey, Division of Mineral Resources, Bureau of Resource Management and Development, Resource Development Section, both from New York State Department of Environmental Conservation, for providing data on the mines and for answering other questions related to permitted mines. Finally, Christopher Waite from the New York State Thruway Authority provided data on the NYS Thruway's use of aggregate.

CGR is wholly responsible for the final assumptions used to develop these estimates, however.

Staff Team

Hung Dang, Kate McCloskey, Kirstin Pryor, and Katherine Corley all contributed to the project in various ways.

Our dedicated research assistants, Matt Rubenstein and Melanie Zilora, were enormously helpful. They contributed to data collection and data analysis in many ways and we are grateful for the many hours they devoted to the various tasks assigned.

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INTRODUCTION

The mining and construction materials industry (MCMI) in New York State makes an economic impact on the state's economy as great as 30,000 jobs, $1.3 billion in total payroll and about $100 million in public sector revenues. Total sales for the industry are between $3.3 billion and $3.5 billion. The Center for Governmental Research developed these estimates using a number of resources, including a survey of industry participants. Details of the approach used and assumptions applied follow.

The mining industry in New York State is large and diverse, encompassing commodities such as bluestone, clay, dolostone, garnet, granite, industrial sand, limestone, peat, salt, shale, sandstone, talc, trap rock, wollastonite, zinc, sand and gravel, gypsum, glacial till, marble, marl and topsoil. Highway construction, new housing construction, ice control, and landscaping are among the wide variety of projects that use these materials.

The majority of mining in New York provides construction materials that are used to build and maintain the State's infrastructure. Thus, in addition to the products listed above, three other critical project resources include hot mixed asphalt (HMA), ready mix concrete (RMC) and cement. Together with crushed stone of all types and sand & gravel, these materials drive the New York State mining and construction materials industry (MCMI).

Other economically-significant uses of the output of this industry are bridge construction, commercial and public construction projects, drainage control, parking and driveway paving.

CGR surveyed firms within the MCMI industry to obtain production, sales, employment and wage information. CGR then estimated MCMI's impact on the NYS economy as a whole, but does not provide estimates of the local impact on communities in which the mines are located. Both economic and fiscal impacts are estimated; CGR reports economic impact in terms of jobs and wages generated, and fiscal impact in terms of sales tax and income tax generated.

This report helps to shed further light on the very important role that the mining and construction materials industry plays in the state. In addition to the traditional economic impact study, CGR estimated the effect of reducing the number of mines in the state. If all communities were to adopt a "not in my backyard" mentality, the cost of construction would increase. This report illustrates the potential impact of the removal of mines from close proximity to construction sites. While the method used does not begin to address the cost impact on all construction projects in NYS, it provides a starting point for consideration and discussion.

OUTLINE OF REPORT

CGR's findings are presented in five parts:

(1) *Survey Results:* CGR summarizes the results of a survey sent to 204 companies.

(2) *Extrapolation of Survey Data:* CGR uses the results of the survey to extrapolate information about the remaining operations in NYS in order to estimate the potential sales revenue in NYS for 2007.

(3) *Economic and Fiscal Impact Estimates:* CGR estimates the economic impact of the mining and construction materials industry using the IMPLAN input-output modeling system. In addition, CGR provides sales and personal income tax estimates for the labor income generated in the industry, fuel taxes, corporate taxes paid to NYS from the mining industry, and fees paid under the Mined Land Reclamation Law.

(4) *Impact of Reduced Number of Mines:* CGR considers the impact on costs of NYS Thruway capital and maintenance projects if some mines were to "disappear."

(5) *Methodology:* CGR describes the methodology used throughout the report to extrapolate data and provide estimates.

FINDINGS

Survey Results

The New York State Department of Labor provides data on wages and employment for the mining industry. However, the category "mining" does not include the construction materials included in MCMI. Thus, CGR determined that it was necessary to collect primary data on the industry through a survey of mine operators. A copy of the survey can be found in the appendix.

Of the 204 companies who received surveys, 91 of them completed the survey.* These 91 companies will be referred to as the survey

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*The 204 companies were chosen to fairly represent the different types of minerals as well as both the small and large players in the industry. In addition, all companies attending the NY Construction Materials Association meeting in May 2008 were given an opportunity to participate.

respondents, and it is their responses which are discussed in this section. The survey responses pertaining to employment, sales and production provide an illustration of the industry-wide numbers, but not industry totals. The results of the survey indicate that the MCMI is a powerful force in the NYS economy, as illustrated in the following tables.

- The survey respondents alone account for 6,500 full time jobs in New York State and about $310 million in payroll.
- The survey respondents alone totaled $1.7 billion in product sales in 2007.

Characteristics of Survey Respondents	
Number of Firms	91
Full Time Employees	6,419
Part Time & Seasonal Employees	460
2007 Payroll ($million)	$310.4

Summary of Survey Respondents:
Sales & Production

	Mining	HMA	RMC	Cement	Total
Number of Permitted Mines/ Number of Plants	331	129	95	3	558
2007 Production (millions of tons, except RMC - millions of yards)	69	12.6	2.9	2.4	N/A
2007 Sales (millions of dollars)	$779.8	$450.5	$235.1	$254.1	$1,719.5

Extrapolation of Survey Data

The tables above do not represent the entire industry. As the following figures attest, this $1.7 billion represents only a small portion of the total sales and production of the industry. CGR used the following data to extrapolate the survey results for each segment of the industry, ultimately allowing sales estimates for the entire industry.

Mining Operations

The 91 firms from the survey represent 191 operational mines with sales of about $780 million. As CGR estimates total mining sales as between $1.4 billion and $1.6 billion, the survey captured about half of the industry.

Hot Mixed Asphalt

According to the Asphalt Institute, NYS produced a total of 19.5 million tons of HMA in 2006.[*] Thus, the survey respondents represent 64% of the estimated NYS HMA industry.

Ready Mixed Concrete

According to the National Ready Mixed Concrete Association, NYS produced 11.615 million cubic yards of RMC in 2007. The survey respondents account for approximately 25% of the total 2007 RMC production in NYS.

Cement

Similarly, the Northeast Cement Shipper's Association calculates that there were 3,748,916 tons of cement shipped within New York between 10/1/05 and 9/30/06.[†] The survey responses represent 63% of the cement shipped within NYS during that time period. Some of the cement shipped is imported from outside NYS, so 3.7 million tons is larger than the total produced in NYS. The analysis includes all three NYS cement producers.

Sales Estimates

As stated, the 2007 sales and production figures reported by survey respondents are only a portion of the more substantial sales and production totals for the industry as a whole. CGR has extrapolated the survey data to

Total Sales of Mining & Construction Materials Industry (millions of dollars)

Mining	
High Estimate	$1,630
Low Estimate	$1,441
Hot Mixed Asphalt	$704
Ready Mix Concrete	$940
Cement	$254
TOTAL	
High Estimate	$3,528
Low Estimate	$3,339

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[*] The statistic is calculated from the data on liquid asphalt by using a conversion factor that HMA is produced using 5% liquid asphalt.
[†] Latest data available

estimate the potential sales revenue generated by the MCMI industry. CGR estimates that in 2007 the MCMI generated between $3.3 billion and $3.5 billion in sales.*

Economic and Fiscal Impact Estimates

An economic impact study estimates the wages and jobs that an industry is responsible for generating as a result of its economic activity. Essentially, it answers the question, “How is the economy larger because of this industry’s activity in the community?”

Economic impacts are measured in terms of two types of expenditures: direct and spillover. The **direct** economic impact consists of the actual expenditures of NYS MCMI, i.e., the industry is directly involved with the transaction. **Spillover** expenditures result from the subsequent spending of those who receive the direct expenditures. Thus, an employee of a sand and gravel mine is part of the direct employment impact. The employees of supplier firms or of retailers who receive the patronage of mine employees are considered part of the spillover employment impact.

Labor Income and Employment Impacts

CGR reports the economic impact in terms of labor income and employment, as the following table shows.

Economic Impact of the MCMI

	Direct	Spillover	Total
Labor Income (millions of dollars)			
High Estimate	$833.6	$482.4	**$1,316.0**
Low Estimate	$765.1	$442.8	**$1,207.9**
Jobs (thousands of jobs)			
High Estimate	17.5	12.9	**30.4**
Low Estimate	16.1	11.9	**28.0**

CGR estimates that the MCMI generated between $1.2 billion and $1.3 billion in wages and was responsible for 28,000 to 30,000 jobs throughout New York State in 2007.

By way of comparison, the wood product manufacturing sector is responsible for about $335 million in payroll and employs about 9,300.

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* See methodology section for more details about the extrapolation procedure. The sales estimate assumes the survey respondents produce the same revenue per unit of product as those not responding to the survey.

Primary metal manufacturing pays about $700 million to 12,000 workers, while the warehousing and storage sector pays its 20,000 employees about $800 million. The average direct payroll per worker used in the study was about $48,000, slightly higher than the median salary for NYS industry .

Fiscal Impact

CGR provides a conservative estimate of the fiscal impact of the MCMI. Not all taxes and fees were included in these estimates. We include:

- Local and state sales tax, and personal income taxes paid by individuals employed by the industry (both direct and spillover);[*]
- Fuel taxes paid by industry participants;
- Fees paid according to the Mined Land Reclamation Law; and
- Corporate franchise taxes (we used the latest data available--2004—from the New York State Department of Taxation and Finance for C Corporation taxpayers in the mining industry).[†]

Fiscal Impact of the MCMI (millions of dollars)

	Direct	Spillover	Total
NYS and Local Sales Tax			
High Estimate	$22.6	$13.1	**$35.7**
Low Estimate	$20.8	$12.0	**$32.8**
NYS Personal Income Tax			
High Estimate	$28.6	$13.3	**$41.9**
Low Estimate	$26.3	$6.5	**$32.8**
Corporate Tax*	$5.8	n/a	**$5.8**
*As reported by the NYS Department of Taxation & Finance - 2004- mining only			
Mined Land Reclamation Law (MLRL)	$2.9	n/a	**$2.9**
Motor Fuel Tax			
High Estimate	$14.8	n/a	**$14.8**
Low Estimate	$13.1	n/a	**$13.1**
Total Fiscal Impact			
High Estimate	$74.7	$26.4	**$101.1**
Low Estimate	$68.9	$18.5	**$87.4**

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[*] Depending on the residency of the direct and spillover employees, there may be additional local income taxes generated (e.g. NYC personal income tax).

[†] When considering the entire MCMI industry (not just mining), the corporate tax generated is obviously much larger than that reported in the fiscal impact table.

Based on CGR estimates, in 2007 the public sector in NYS gained between $87 million and $100 million as a result of the MCMI.

Impact of Closing Mines on Transportation Costs & Cost of Construction

Mining operations within the mining industry are often forced to defend their existence. Many voters would prefer not to have a mine in their community. To illustrate the cost implications of not having operational mines in the vicinity of construction projects, thereby increasing the distance from mines to construction sites, CGR analyzed the impact that removing a percentage of mines would have on the transportation costs of aggregate.

CGR considered the 496 miles of the NYS Thruway mainline in constructing this hypothetical scenario. Given the sporadic nature of construction, CGR used the average metric tons of aggregate utilized by the NYS Thruway over the last three years to calculate the cost of transporting aggregate from the mine to the highway construction site.[*] CGR calculated the mileage from each mainline Thruway exit to the nearest of the76 limestone, dolostone, and traprock mines (commodities most heavily used in construction) across New York State. Given the rising cost of fuel over the last year, CGR computed the cost of transporting the metric tons of aggregate for various fuel costs and found that:[†]

- Randomly removing one-quarter of the mines increased transportation costs by 42%, regardless of the price per gallon of fuel, by increasing the distance from an exit on the NYS Thruway to the nearest mine. If the price of fuel were to rise again to $4 per gallon, the cost of transporting the average amount of aggregate used by the NYS Thruway each year would increase by $1.6 million if one-quarter of the mines were randomly taken away, and by $2.2 million if the number of mines were reduced by one-half. This means that if any random one-half of the mines were no longer in operation, transportation costs for construction projects would increase by 59%—ultimately affecting NYS taxpayers.

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[*] The average annual tonnage of aggregate used by the NYS Thruway is 768,800 metric tons.

[†] See the methodology section for details on the assumptions made for this illustration.

Annual Cost Implications of Increasing Transportation Distance				
	Cost of Fuel per Gallon	All mines included	One-quarter mines taken away	One-half mines taken away
Average Distance from Exit to Nearest Mine (miles)	----	13.5	19.1	21.4
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$2	$3.4	$4.8	$5.3
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$3	$3.6	$5.1	$5.7
Cost of Transporting Aggregate for Thruway Projects (millions of dollars)	$4	$3.9	$5.5	$6.1
Percentage Change in Cost (from all mines included)			42%	59%

METHODOLOGY

There is no one data source that gives an accurate picture of the mining and construction materials industry. The New York State Department of Labor provides data on wages and employment for mining, but this does not include the construction materials side of the MCMI. Furthermore, the DEC provides data on the number of active mines, and the number of affected acreage for these mines. However, not all permitted acreage is actively being mined. For these reasons, CGR determined it was necessary to first estimate the acreage being actively mined and then to collect primary data from mine operators via the survey. Details on the methodology used for both aspects, as well as for calculating the economic and fiscal impact, are included in this section.

Creating the Data Set

The DEC provides data on the number of permitted mines, with about 64,000 acres affected statewide. Not all the affected acreage is actively being mined. To estimate the number of acres currently being mined, CGR consulted with DEC's Division of Mineral Resources, including Director Bradley Field and Christopher McKelvey of the Bureau of Resource Management and Development, Resource Development Section and reviewed the data provided by their offices. CGR also consulted with industry experts, including NY Construction Materials Association Executive Director Dave Hamling, NY State geologist William Kelly and consulting geologist Paul Griggs. In addition, CGR used the data collected from survey respondents. To be conservative in our estimate of the economic impact of the mining industry, CGR determined that it would use a range of affected acres of 55,000 to 62,000. As 83% of affected acres among survey respondents were used for mining, CGR applied the same proportion to all mines included in the study. Thus, the operational acreage for the study analysis ranged from 46,000 to 52,000 acres.

Survey of Mine Operators

With support from the New York State Geological Survey / New York State Museum and the New York Construction Materials Association, CGR distributed 204 surveys to companies in the MCMI. Potential respondents were given the option of returning the survey via mail, fax, or e-mail, or completing an online version. The 204 companies were chosen to fairly represent the different types of minerals as well as both the small and large players in the industry. In addition, all companies attending the NY Construction Materials Association meeting in May 2008 were offered an opportunity to participate.

As seen below, survey respondents represented at least half of the industry. With such a firm foundation of actual responses, we make our extrapolations to the entire industry with confidence.

CGR received 103 responses, 12 of which were designated not applicable based on the respondent's self-reported status such as "out of business" or "sold out." Thus, the data CGR reported from the survey encompasses the 91 companies who completed the survey.

The survey specifically asked how many mines permitted by the DEC each respondent had. The 91 firms from the survey represent 191 operational mines with sales of about $780 million. As CGR estimates total mining sales as between $1.4 billion and $1.6 billion, the survey captured about half of the industry.

The commodities produced by the 191 operational mines accounted for in the survey are presented below.

Commodities Produced by Survey Respondents (Operational Mines only)

Commodity	Number of Mines	Percent of All Operational Mines	Total Acreage	Percent of All Operational Acres
Bluestone	5	12%	44	13%
Dolostone	16	84%	1,903	85%
Garnet	1	100%	107	100%
Granite	7	47%	542	71%
Limestone	38	66%	6,877	77%
Salt	2	67%	9,932	99%
Sand and Gravel	104	15%	6,742	32%
Sandstone	7	15%	783	81%
Topsoil	2	22%	37	12%
Shale	4	29%	260	45%
Trap Rock	1	100%	153	100%
Wollastonite	3	100%	261	100%
Zinc	1	100%	432	100%
Total	191		28,073	

In all cases but topsoil, the percentage of operational acres represented by survey respondents is equal to or larger than the percentage of operational mines. This suggests that the mines in the survey represent, on average, the larger acreage mines of the commodities represented. Four commodities (clay, glacial till, marble and peat) are produced by operational mines but were not represented by the survey respondents.

Payroll Estimates

In order to estimate the payroll of the MCMI, CGR used employment and payroll information from the survey data to estimate wages and employment for the remaining mines for which we had no direct data beyond that included in the DEC's database of permitted mines.

Characteristics of Survey Respondents

Number of Firms	91
Full Time Employees	6,419
Part Time & Seasonal Employees	460
2007 Payroll ($million)	$310.4

Since we did not ask survey respondents to attempt to estimate payroll and employment for each product—and many mines produce more than one—we did not have sufficient detail to estimate employment and payroll information by product. We did, however, separately estimate payroll and employment for mining operations on the one hand, and HMA/RMC/Portland Cement on the other.

Potential Total Sales Estimates

In order to estimate the potential total sales of the mining component of the MCMI, CGR used sales and production information from the survey to estimate sales per operational acre.

To estimate the potential total sales of the HMA component of the MCMI, CGR used sales and production information from the survey to estimate sales per ton of HMA produced. CGR then combined survey responses, the sales per ton estimate, and information from the Asphalt Institute on the total amount of HMA produced in New York State in 2006[*] to estimate the potential total sales of the HMA component of the MCMI.

Similarly, CGR estimated the potential total sales of the RMC component of the MCMI by using sales and production information from the survey to estimate sales per cubic yard of RMC produced. CGR then combined survey responses, the sales per cubic yard estimate, and information from the National Ready Mixed Concrete Association on the total amount of RMC produced in 2007 to estimate the potential total sales of the RMC component of the MCMI.

Using information provided by survey respondents producing HMA and RMC on payroll and employment, CGR estimated direct payroll and employment for nonrespondent firms.

Total Sales of Mining & Construction Materials Industry (millions of dollars)	
Mining	
High Estimate	$1,630
Low Estimate	$1,441
Hot Mixed Asphalt	$704
Ready Mix Concrete	$940
Cement	$254
TOTAL	
High Estimate	$3,528
Low Estimate	$3,339

Estimating the Economic Impact

CGR used IMPLAN, a regional input-output modeling system, for estimating the economic impact. IMPLAN is widely acknowledged as one of the best models of economic activity available. The IMPLAN database, created by MIG, Inc., consists of two major parts: 1) a national-level

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[*] Latest data available.

technology matrix, and 2) estimates of sectorial activity for final demand, final payments, industry output and employment for each county in the U.S., along with state and national totals. Data are updated annually. IMPLAN estimates the direct and spillover (indirect and induced) impacts of economic change through the use of multipliers, and estimates the impact of an increase in demand in a particular sector on 511 different industries/sectors of the local economy.

Estimating the Impact of Reducing the Number of Mines

In order to calculate the additional cost of removing mines from proximity to the construction sites, CGR first mapped the 76 operational limestone, dolostone, and trap rock mines throughout NYS.[*] Using DEC data on the mines' latitude and longitude along with cartographic tools, we calculated the average distance from each of the 75 exits on the NYS Thruway to the nearest operational mine that produced one of these three commodities.

To calculate the absolute cost, CGR used the following assumptions:

Assumptions for Transportation Cost Analysis	
Labor cost per hour	$20
Overhead per hour (depreciation/maintenance of truck, etc)	$40
Cost per gallon of fuel	$2-$4
Number of miles driven in a day	240
Miles per gallon	4.5
Number of tons hauled in one load	20
Number of metric tons hauled in one load	18

The assumptions above equate to assuming $76 per hour per truck when gas costs $3 per gallon, $81 per hour per truck when gas costs $4 per gallon, and $87 per hour per truck when gas costs $5 per gallon. This includes all costs, including labor, depreciation, insurance, overhead and fuel.

CGR obtained information on the metric tons of aggregate used on the NYS Thruway for 2005, 2006 and 2007 from the New York State Thruway Authority to calculate the absolute costs of transporting aggregate. While the absolute costs are dependent on the previously explained assumptions, the percentage change in costs is in direct relationship to the percentage change in the average miles from the mine to the construction site. To that extent, this illustration can be extended to any type of construction project using aggregate. If the closest mine to a given construction site does not receive a permit and the distance to the

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[*] These commodities are commonly used in construction projects.

nearest relevant mine increases by 50%, one can expect the costs of transporting the aggregate to increase by 50%.

These conclusions are applicable to the entire industry. Transportation costs are a significant share of the total cost of aggregates. Continued shrinkage of the industry will drive up the cost of new construction and highway reconstruction. Our data did not permit a more detailed analysis by region, but clearly the impact would be more pronounced downstate.

CONCLUSION

This analysis makes a powerful statement about the significant contributions that the Mining & Construction Materials Industry makes to the New York State economy. **This important industry pays $1.2 to $1.3 billion in wages to 28,000 to 30,000 workers. Total sales for the industry are $3.3 to $3.6 billion. In addition the industry provides possibly $100 million in payments to the public sector.**

Moreover, the cost of the products of the MCMI industry affects expenses for the entire construction sector, particularly the construction and maintenance of the state’s critical road network. State and local government alike should recognize this industry’s importance and take steps to preserve its viability.

APPENDIX: SURVEY OF MINES

Thank you for taking the time to fill out the survey. If you filled out the survey online, you do not need to do anything else. You are finished and may disregard the paper form of the survey below. If you have elected to fill out the survey in paper form rather than online, please fill out the following survey **ASAP** and return it to Rochelle Ruffer via fax: (585) 325-2612, e-mail: rruffer@cgr.org or mail to: CGR One S. Washington Street, Suite 400 Rochester, NY 14614. If you have any questions, feel free to contact me via e-mail or phone (585-327-7056).

All answers are confidential. If you are unwilling or unable to provide answers to all questions, please fill out the survey to the best of your ability and send back the survey with those questions for which you have provided answers. In order to cover all aspects of the mining industry, we've included cement plants in the survey. Please only respond to those questions relevant for you. In addition, the survey is specific to your New York State (NYS) operations.

Economic Survey of the Mining and Construction Materials Industries in New York State

1. List the number of operations you own or control in New York State for the following:

Mining operations covered by NYSDEC Permits	
Hot Mix Asphalt Plants	
Ready Mixed Concrete Plants	
Cement Plants	

2. Provide your 2007 production from all NYS operations for the following:

Mining / Aggregate production	tons
Hot Mix Asphalt	tons
Ready Mixed Concrete	yards
Cement	tons

3. Provide the total sales of your NYS production in 2007 for the following:

Mining / Aggregate production	$
Hot Mix Asphalt	$
Ready Mixed Concrete	$
Cement	$

4. What percentage of NYS sales goes to public works projects for the following:

Mining / Aggregate production	%
Hot Mix Asphalt	%
Ready Mixed Concrete	%
Cement	%

5. What product(s) do you produce at your locations? ______________________________

6. What is your ton-mile cost for delivering products? $_____________ per ton-mile

7. What is the mileage of your typical / average delivery? _______________miles

8. Under which 4-digit NAICS Code do you report company data? ***(Check all that Apply)***

☐ **2122** (Metal Ore Mining) ☐ **2123** (Nonmetallic Mineral Mining and Quarrying) ☐ **Other**_____________________

9. How many employees did you employ in 2007? Full Time________ Part Time_________

10. Provide your 2007 payroll. $ _________________________