

HISTORY AND GEOLOGY REVIEW OF MAGNETIC IRON MINING IN THE WESTERN ADIRONDACKS

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INTRODUCTION

Today when people talk about mining, they generally have an adversarial opinion of this industry. In addition, many fail to recognize the importance mining provides to today's economy. There is an old saying that goes "if it can't be grown, it must be mined". Today, most mining in New York State revolves around the sand, gravel and construction aggregates industry. However, New York has a rich history of mining that goes back into the early 18th century and the dominant material mined was iron. Much of this iron was mined in the Adirondacks and, not only an important commodity to the early colonists for everyday use, it also played a critical role in the fight for independence from Great Britain.

The purpose of this trip is to examine the history of western Adirondack iron mining, along with an overview of the regional and site specific geology. We will visit and discuss the mine history and limiting factors that governed the life of the Clifton Iron Ore, Jayville and Benson Mines.

GENERAL IRON MINING HISTORY

Iron was most likely discovered by Native Americans as a result of their fire pit coals contacting rocks containing iron. The heat from the fire caused the iron to deoxidize into crude steel. They later found that they could pound this material into various useful shapes (Farrell, 1996). One of the earliest known iron mining and forging operations in New York occurred in 1736 when Cornelius Board and Timothy Ward formed the Sterling Forge and Furnace Company in Rockland County (Levine, 2012). Initial reference of Adirondack iron discovery is made by Swedish naturalist Peter Kalm, who in 1749 noted the magnetic "iron sands" in the Crown Point area of Lake Champlain. Little did he know he was virtually standing on ore deposits which would be mined for over one and a half centuries (Farrell, 1996).

In colonial times, early American settlers were forced to purchase many manufactured products from the British. They were prevented from manufacturing goods, thus providing a market for British wares. Though smelting of raw iron for further refinement by the British was allowed, production of final products was outlawed. Yet there was a need for finished goods by the colonialists and, with the scattered colonial populations, these laws were largely ignored (Farrell, 1996).

Early Adirondack mining most likely began along the shores of Lake Champlain where forces and arms were mustered to fight the British. Philip Skene built a forge with hammers at Skenesborough (now Whitehall) in 1761 and used boats to transport ore from an area north of Port Henry. Benedict Arnold's regimental book records in June 1775 that he ordered men to dig ore from what was to become the Cheever mine, located north of Port Henry. This ore was refined to make implements and arms (Farrell, 1996). This iron was also used to build a fleet of ships that Arnold used to battle General Carlton and his well-armed fleet of British ships around Valcour Island in September 1775. Though badly beaten in this day long fight, Arnold was able to slip his fleet past the British under the cover of darkness and sailed toward Crown Point. These actions by Arnold successfully held the British from attacking again for almost a year (Farrell, 1996).

After the war of independence, iron mining and manufacturing continued to develop around Lake Champlain. Forges were used to process the ore and in 1798 the first Catalan forge was built around Plattsburgh (Hyde, 1974). Additional forges were built around the Lake Champlain area, including several at Ticonderoga prior to

1800. Typically, these forges were an open hearth construction with a two and a half to three foot opening (Farrell, 1996). This type of forge or bloomery used charcoal to heat the ore to a semi-molten state called a bloom or loupe, which was then removed and hammered to expel impurities. The iron mass was then reheated and hammered multiple times and then shaped into a billet of wrought iron (Dawson, et al., 1988).

As the demand for iron increased, the size of the furnaces grew to increase capacity. Stack heights were raised and water power was used to increase the blast capacity. This increased blowing capacity allowed for more contact between the ore and fuel, carburizing the metal. The metal melted into a mass, which allowed for separation from the gangue and permitted the iron to be poured into casts of various shapes (Farrell, 1996).

The population continued to grow and the demand for iron products, such as farm implements and utensils, continued to provide a market for the Lake Champlain iron industry. With the completion of the barge canal system, transportation was improved and allowed for additional forges and furnaces to be built in support of new iron mine development (Farrell, 1996). This growth extended westerly from the Lake Champlain area to areas that had plentiful resources of magnetite, forests for wood, marbles and limestone for flux, and water to drive air compressors and trip hammers. Ore deposits were rather easily detected when surveyor's compasses were perturbed by the magnetic fields. The location and size of these deposits could be further defined later by dip-needle surveys (Dawson et al., 1988). In fact, the Benson Ore body, what would later become the largest open pit iron mine in the world, was discovered in 1810 by engineers surveying a road from Albany to Ogdensburg when their compasses were affected by the magnetic ore. Both large and small operations became plentiful in all areas and more than two hundred mines and forges operated during the 1800's (Hyde, 1974).

Expansion of the iron industry did not come without some difficulty. Most of the areas west of Lake Champlain were unsurveyed, mountainous and wilderness. New York Surveyor General Simon DeWitt ordered that the unappropriated lands in Essex County be surveyed. This survey of what was later to become the Iron Ore Tract was completed in March 1812. Survey compasses were affected by ore deposits and several of the lots were later developed. In 1824, while preparing fields for planting, ore was discovered very shallow to the surface on the D.E. Sanford Lot 25 of the Iron Ore Tract. Harry Sherman and Elijah Bishop arranged to pay Sanford to explore and develop the ore on this property. A short time later, a large ore vein was discovered and later referred to as the Sanford or Old Bed Deposit. The magnitude of the size of this vein was not realized at first and would eventually be mined for over a century and a half (Farrell, 1996).

Other lots within the Iron Ore Tract were developed, including Lots 21, 23, 24 and 25. Eventually Lots 24 and 25 were purchased by the firm of Lee, Sherman and Withersbees, later to become Withersbee Sherman and Company, who, along with The Port Henry Iron Ore Company and the Chateauguay Iron Ore Company, became major iron ore players through the nineteenth century in Essex and Clinton counties (Farrell, 1996). By 1842, iron production in Essex and Clinton Counties exceeded any other county in the state and perhaps the world and the quality of the iron produced rivaled the ores from Sweden (Hyde, 1974).

EXPANSION TO THE WESTERN ADIRONDACKS

The iron mining history of the western Adirondacks includes several small pyrite (FeS_2) mines. One notable pyrite mine was in Stellaville. The Stella Mines were located along County Route 17, a few miles north of the Hamlet of Hermon, NY. However, due to the sulfur, pyrite is not mined for iron production rather than for the making of sulfuric acid (Carl, 2007). In addition, there were numerous small magnetic iron developments near Colton, Russell and Fullerville (Leonard & Buddington, 1964). This report and field trip will focus on three major iron mines that were within the St. Lawrence County Magnetite District, Clifton Iron Company, Jayville and Benson Mines.

Around 1810, engineers in the process of surveying the route for a military road from Albany to Ogdensburg surveyors had their compasses affected by a magnetic ore body located just easterly of Star Lake. Some thirty years later, State Geologist Ebenezer Emmons referenced this "Chaumont" deposit in his annual report on mineral resources of the state. The remoteness of this ore body did not make it a viable resource until 1889, when logging activity brought the railroad into the neighborhood of the deposit (Crump and Beutner, 1968).

Clifton Iron Company. Located roughly 3.5 miles southeast of DeGrasse, the Clifton deposit was likely discovered prior to 1840 (Leonard and Buddington, 1964). John Worden while surveying lands in the area is credited with discovering the ore body (Palmer and Thomas, 1969). The mine was first opened in 1858 (Linney, 1943), however operations here did not move forward until 1863 when the Clifton Iron Company was founded by Zebulon T. Benton, John B. Morgan, Samuel B. Smith and Charles G. Myers (Palmer and Thomas, 1969). Significant mining operations then began around 1865 with several small pits and shafts (Leonard and Buddington, 1964). The firm of Myers Steel and Iron Wire built forges, furnaces and miscellaneous machinery for use in the production of steel (Palmer and Thomas, 1969) and, in 1866, built a charcoal furnace at Twin Falls on the Grasse River in Clarksboro (figure 1) (Leonard and Buddington, 1964). Evidence at the site suggests that the ore was refined into pig iron by the “Bessemer Process” with waterpower from the adjacent sluiceway powering the bellows (Palmer and Thomas, 1969). In 1868, a new furnace was built at the mine (Leonard and Buddington, 1964) with its famous 160 foot high brick chimney bearing the date “1868” on all four sides (Palmer and Thomas, 1969).

The Clifton ore deposit is located approximately 2 miles southwest of Clarksboro and several roads were built around the area. Huffle Road was built from the mine to the Clarksboro furnace. Horse and oxen drawn wagons were initially used to haul ore and were eventually replaced by railroad. The main workings at the mine were the Dodge, St. Lawrence, Dannemora and Sheriden veins and analysis of the ore showed that it was very pure (Palmer and Thomas, 1969).

In April 1864, the New York State legislature passed a bill allowing Clifton Iron Company to construct a 23 ½ mile railroad from the mine to the Rome, Watertown and Ogdensburg Railroad at East DeKalb. The scarcity of iron after the Civil War made it impossible to use iron rails and maple timbers were used instead (Palmer and Thomas, 1969).



Figure 1. Remains of Clarksboro furnace at Twin Falls (photo by J. E. Zaykoski, 2013). Inset shows charcoal fragments found on-site.

Construction of this railroad presented engineers with many challenges and unique solutions. Rather than build the railroad from the mainline in East DeKalb, construction began at the mine. The terrain along the route is very rugged and special four wheeled engines and cars were built in order to navigate the tight turns. The track was standard gauge and constructed using spruce ties with notches cut near the ends. Maple rails were attached using wedges driven into the spruce notches and no rail spikes were used in initial construction (Thompson n.d.). The rail is said to have been completed by January 1, 1868 (Palmer and Thomas, 1969). Once in operation, problems with the rail began soon after. Polished rail surfaces were used and were then sanded to allow for climbing uphill grades. Continued use created large splinters that were torn from the rails, some of which broke through the floors of the engines. To solve this problem, many iron straps were spiked to the rails around curves and road crossings. This created another problem as train traffic drew out the metal spikes and the plates would wrap around a wheel and break through the floor of ore cars causing derailments. The combination of the track problems and the crooked terrain made for slow train travel and, at peak use only 3 to 4 trains made the trip from Clarksboro to East DeKalb daily (Thompson n.d.). See Figures 2 and 3.

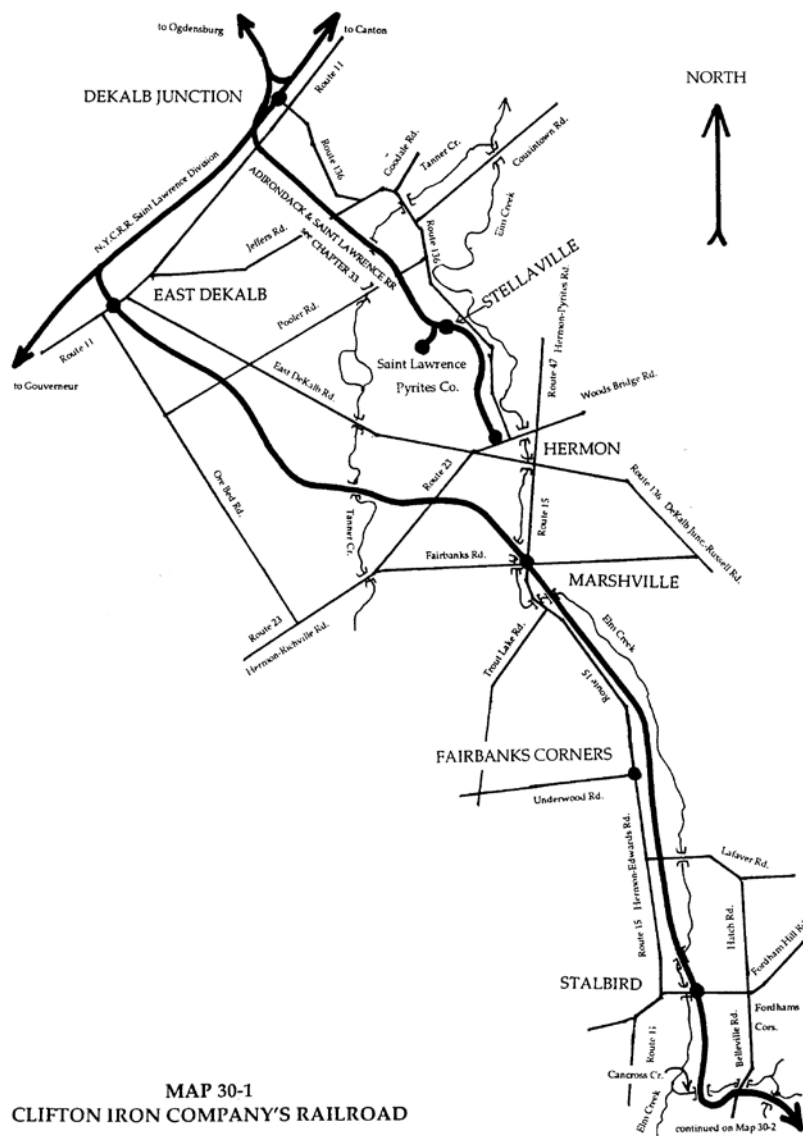


Figure 2. Clifton Iron Company's Railroad (Kurdish, 1996).

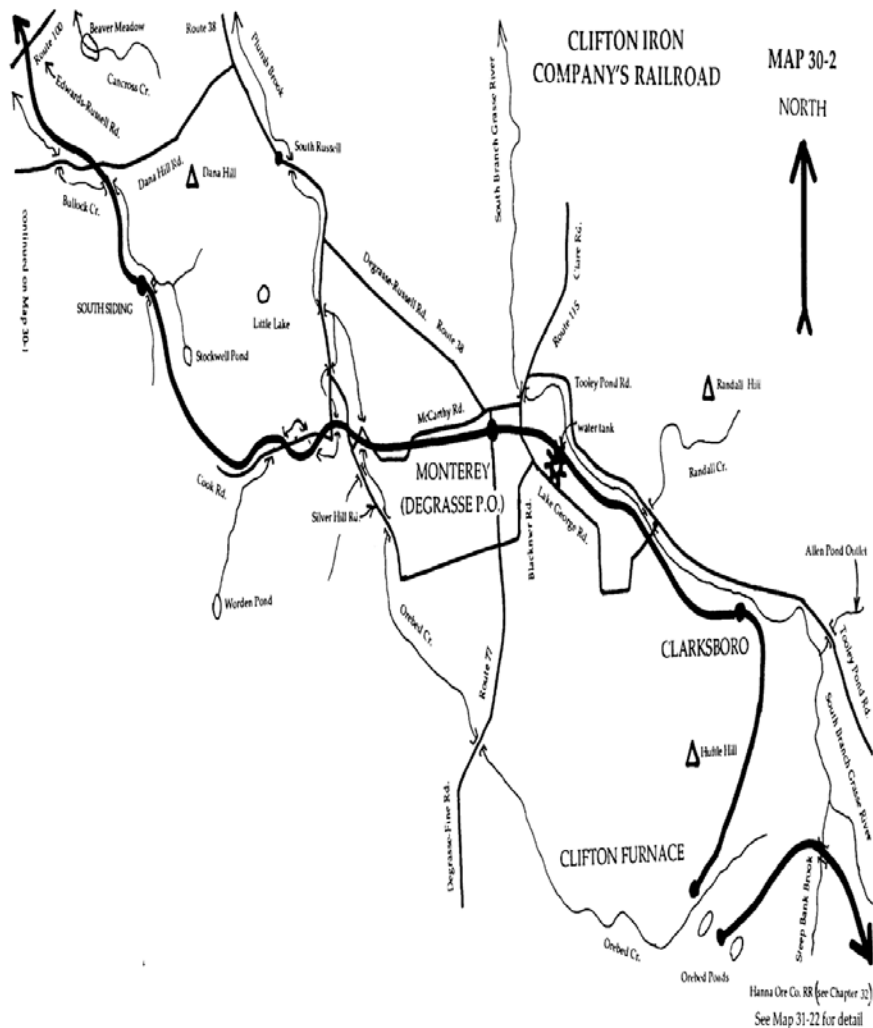


Figure 3. Clifton Iron Company's Railroad (Kurdish, 1996).

Mining operations by The Clifton Iron Company brought the first white settlers to the area and Clarksboro became a boom town with a population reaching close to 700 people. On April 21, 1868, the Town of Clifton was organized. The new town contained 61,930 acres taken from the town of Pierrepont and was described as largely forest covered and a popular area for sportsman. Early 1869 was said to be a very busy period for Clifton and Clarksboro. However, on September 4, 1869, fire destroyed the steel mill at the mine and caused \$140,000.00 in damages that were only partially insured. This tragedy and the illness of mine developer George Clark left the mine idled. Clark intended to resume operations at the mine, but was informed the company was in troubled financial condition owing \$ 55,000.00. With the mine operations suspended, the population of Clarksboro dwindled down to less than 50 people. The loss of the Clifton operations did not slow down Clark as the nearby Benson Mines operations were an extension of his interests (Palmer and Thomas, 1969).



Figure 4. Aerial View of Clifton Iron Mine taken by Dwight Church St. Lawrence Historical Society

The Clifton Mine lay idle for decades until 1940, when the M.A. Hanna Company of Cleveland performed a dip needle and diamond drill surveys of the ore body. The results showed an ore body of sufficient size to allow for further development (Leonard and Buddington, 1964). The Hanna Ore Co., Clifton Mine Division (a subsidiary of The M.A. Hanna Co.) was formed and purchased the mine properties in 1941 (Linney, 1943) and mining production began in June, 1942 (Hunner, 1943; Leonard and Buddington, 1964).

With the purchase of the properties, the Hanna Ore Co. began to develop the property (Figure 4). Due to the remoteness of the mine a new road had to be constructed, which followed the original trail and became known as the Lake George Road. The railroad was extended from Newton Falls to the mine and telephone power lines run from Edwards. Stripping operations took place during the winter of 1941-1942. The first shipment of lump ore took place on June 3, 1942. Lump ore shipments continued while the new facility was constructed. A beneficiation plant was built and housed crushers, magnetic separators, a wet grinding mill, separators and sintering plant. While surface mining operations continued, underground mining plans were put into action and the sinking operations of the vertical shaft began in July, 1942 (Hunner, 1943) in order to intersect the ore 500 feet underground (Linney, 1943).

Mining operations were conducted by a work force of roughly 175 men, who mostly came from the surrounding farms and, with no experience in mining, they required several months of training to develop them into skilled miners (Hunner, 1943). Due to the remote location of the mine, Hanna Ore Co. was responsible for maintaining the roads, including snow plowing responsibilities in the winter. The mine produced around 900 tons of ore daily until operations ceased in 1952 (Barnes, 1962). Reports cited the ore was exhausted and deeper operations were too costly to continue. In all from 1942 through 1952, a total of 2 to 2 1/2 million long tons of ore averaging 38% iron were mined (Leonard and Buddington, 1964). All structures were demolished and little remains of the mine today, other than some remnant foundations (Barnes, 1962).

Jayville Mine. Jayville is located in the Town of Pitcairn, roughly 1.25 miles east of the former hamlet of Kalurah (Leonard and Buddington, 1964) and 29 miles east of Carthage by rail (Newland, 1908). The mine, located on the eastern and western flanks of a north trending hill, was originally opened in 1854 by Zebulon H. Benton. However, little mining activity occurred at that time. The mine contained ores made up of Magnetite and Vonsenite (Ferris Ferric Borate – $\text{Fe}_2\text{Fe}(\text{BO}_3)_2\text{O}_2$) (Leonard and Buddington, 1964). The ore was mined and drawn by wagons some 15 miles to the blast furnaces at Fullerville (Ingalls, 1914). In 1886, with financing by Byron Benson, the Carthage and Adirondack railroad was completed to Jayville (Carl, 2009). Mining operations resumed under the name of the Magnetic Iron Ore Company and continued to 1888, when the property was abandoned (Leonard and Buddington, 1964).

Iron mining in the western Adirondacks cannot be examined without a discussion about railroads. The rugged and remoteness of the terrain made ore transportation difficult at best and this was the case in the remote community of Jayville. With the completion of the Black River Canal and the tracks of the Utica and Black River Railroad reaching Carthage in 1872, prominent business men knew of the magnetic ore resources to the east and began efforts to build a railroad to the western Adirondacks. In 1868, the NY legislature passed a bill authorizing the issuance of bonds for capital stock in the Black River and St. Lawrence Railway Company. The proposed railroad would be constructed with the cheaper wooden rails that were acceptable for short local runs. The railroad was completed from Carthage only to Natural Bridge in 1869 and operated for less than a year before its failure. Local communities lost money and the blame was placed on the use of wooden rather than iron rails (Carl, 2009).

Byron Benson was born in Fabius, New York in 1823 and left home as a young man to operate a stave mill. After the Civil War, Benson and friend Robert Hopkins moved to Pennsylvania to make their fortune in the oil industry. Forming the Colorado Oil Company they later partnered with D. McKelvey to drill several oil wells in Butler and Wardwell Counties. Later Benson and several partners organized the Tide Water Pipe Line Company Ltd. and built a 100 mile long pipeline from Corryville to Williamsport (Carl, 2009).

There is speculation as to why Benson moved his interests to northern New York, though there is an account suggesting he had been investigating the prospects of the Jayville deposit. In 1873, Benson's younger brother, Caldwell Belden Benson, and others were scouting an iron deposit in Jayville (Lupulescu et al, 2014). On March 23, 1883, the Carthage and Adirondack Railroad was chartered and construction began later that year. The rail followed the right-of-way of the former Black River and St. Lawrence Railroad and steel rails were used. Construction of the railroad to Jayville was completed and it was formally opened on January 1, 1887 (Carl, 2009).

With the railroad complete, mining efforts at Jayville intensified. Byron Benson leased the property from Benton and mined the ore under the name of the Magnetic Iron Ore Company. Ore was removed from several pits and underground workings accessed by shaft or drift. Estimates are the mine yielded 25,000 to 200,000 tons of ore, ranging in grade from 40 to 60 percent iron (Leonard and Buddington, 1964).

Mining operations at Jayville ended in 1888 and, for a period of time, the railroad supported some logging. In 1917 the Watertown Herald reported that J. W. Hughes of Rochester had reopened up the Jayville mine. Money was spent pumping out water in an effort to mine under Twin Ponds where the mother lode of ore was suspected. However, the water filled the mine as fast as it could be pumped and, after 3 years, the operation was shut down (Miller and Carvell, 2010). Little remains of Jayville today. In 1929, dairy farmer Frank Hall purchased what buildings that were left in Jayville and had them torn down. The old Jayville boarding house was relocated and used as a hunting camp, which later burned down (Carl, 2009).

Benson Mine. Benson Mine was at one time the largest open pit iron mine in the world (Hyde, 1974), yet its discovery was quite by accident. Around 1810, engineers, while in the process of surveying the route for a military road from Albany to Ogdensburg, had their compasses affected by a magnetic ore body located just easterly of Star Lake in an area known as Little River. Some thirty years later, State Geologist Ebenezer Emmons referenced this "Chaumont" deposit in his annual report on mineral resources of the state (Crump and Beutner, 1970). In 1888, the Carthage and Adirondack Railroad was extended eastward from Jayville to Little River and its potentially large iron deposit. With the prospects of this new mine, The Magnetic Iron Ore

Company abandoned its Jayville operations and moved their equipment to this new location (Carl, 2009). See figure 5.

The Benson Mine main deposit is 2.5 miles long (Figure 5), averaging 400 feet in width and 90 feet deep, containing a low grade magnetic and nonmagnetic ore that is roughly 23% iron. However, what made this deposit attractive for development is the ore is at the surface and no underground mining methods were needed (Lupulescu et al, 2014). The mine operated at a low level for several years until 1893, when the United States suffered an economic depression. This, combined with low cost of the Mesabi Range ores, led to the mine being abandoned (Crump and Beutner, 1970). The mine briefly reopened in 1900, shipping 67,000 tons of concentrate (Tillinghast, 1948) and, in 1907, the Benson Mines Company was formed and open pit operations began. The mine operated sporadically through World War I and was again abandoned in 1919 (Crump and Beutner, 1968).



Figure 5. Google Earth View of Benson Mines showing former flooded strip mine and tailings.

In 1941, the Jones and Laughlin Ore Company leased the Benson Mineral lands and, in the fall of 1942 the Defense Plant Corporation undertook construction of a modern plant facility (Tillinghast, 1948; Crump and Beutner, 1970). With the new modernized plant, open pit production began in 1944, shipping ore to Pittsburgh furnaces (Crump and Beutner, 1970). Production briefly halted in 1946, due to a strike. The strike ended in July 1946. However production did not resume until September of that year in order for extensive plant repairs to be completed (Tillinghast, 1948). In December, 1946 the holdings of the Defense Plant Corporation were purchased by Jones and Laughlin (J & L) Steel Corp and operated under the name of Jones and Laughlin Ore Company (Crump and Beutner, 1970). In 1952, Jones and Laughlin Ore Company merged with the parent corporation and became the New York Ore Division of Jones and Laughlin (J&L) Steel Corporation (Crump and Beutner, 1970) and operated continuously through 1978 (Lupulescu et al, 2014). Major expansion of the mine occurred during the 1950's and, by 1960, the company reportedly had 840 workers and had the capacity to produce 1,800,000 long tons of ore concentrate (Lupulescu et al, 2014).

REGIONAL GEOLOGY

The St. Lawrence Magnetite District lies within the Adirondack Highlands portion of the Adirondack Mountains and is the southernmost extension of the Grenville Province (McLelland, Daly and McLelland, 1996; Lupulescu et al., 2014). Tectonic activity formed the Adirondacks, with major activity occurring between 1.3 and 1.0 billion years ago that can be broken down into three periods of orogenic (mountain building) activity: the Elzevirian (1,245-1,225 Ma), Shawinigan (1,190-1,145 Ma) and ending with the Grenvillian' which is separated into the Ottawan (1,090-1,020 Ma) and Rigolet (1,000-900 Ma) pulses (Lupulescu et al., 2014). The rocks of the Adirondacks are further divided into the orthogneissic Highlands and the northwest lying Lowlands characterized by metasediments, particularly marbles. The Highlands and Lowlands are separated by a high strain shear zone known as the Carthage-Colton mylonite zone (CCMZ) (McLelland, Daly and McLelland, 1996).

A quick look at the Adirondack Lowland rocks (Figure 7) show they are dominated by marbles, gneisses and quartzite metamorphosed from limestone, shale and sandstones. Though highly metamorphosed, these rocks show metamorphic grades ranging to upper amphibolite conditions. By contrast, the Highlands are comprised of sedimentary rocks laid down on preexisting basement, intruded by younger igneous rocks that were all metamorphosed to granulite facies (Lupulescu et al., 2014). Tonalites are the oldest metamorphosed igneous rocks found in the Highlands, with emplacement roughly between 1,330-1,300 Ma (McLelland and Chiarenzelli, 1990b, p.181). Rocks of the anorthosite-mangerite-charnockite-granite (AMCG) suite were emplaced around 1155 Ma and later intruded by rocks such as the Hawkeye Granite (1,100-1,090 Ma). The last magmatic episode emplaced the Lyon Mountain Granite (1,070-1,040 Ma) and the mangerites in the northern Highlands around 1,080 Ma. Magmatic rocks of the AMCG suite were intruded into older metasediments that can be correlated to comparable rocks exposed in the Lowlands (Lupulescu et al., 2014). Both regions show evidence associated with strong ductile strain, including multiple events of intense deformation and strong penetrative fabrics (McLelland, Daly and McLelland, 1996).

The rocks of the St. Lawrence County magnetite district are characteristic of Adirondack geology. The bedrock is roughly 80 - 85% igneous rocks with about 15% metasedimentary and roughly 5% metagabbro and amphibolite (Figure 7). Potsdam sandstone also outcrops in the northwestern part of the district. Metasomatic skarn is present in many parts of the district and is closely associated with magnetite bodies. Also notable is the relationship of magnetite to granite, with all magnetite deposits within the district being adjacent to younger granites. Deposits occur within the narrow belts of metasedimentary rocks that are surrounded by granitic or granitic gneiss rocks. In some areas of alaskite or microcline granite, magnetite has replaced skarns (Leonard and Buddington, 1964).

The origin of magnetite deposits is a topic that has been debated amongst geologists for many years. There have been several lines of thought on the origin of the ores that can be grouped into three categories: 1) metamorphism of iron-rich sedimentary rocks; 2) movement and concentration of iron from silicates rich in iron and magnesium during metamorphism; and 3) replacing and depositing ore by hydrothermal solution after metamorphism. Currently there is support for the first process described above (Lupulescu et al., 2014; Chiarenzelli, 2014, Personal Comm.).

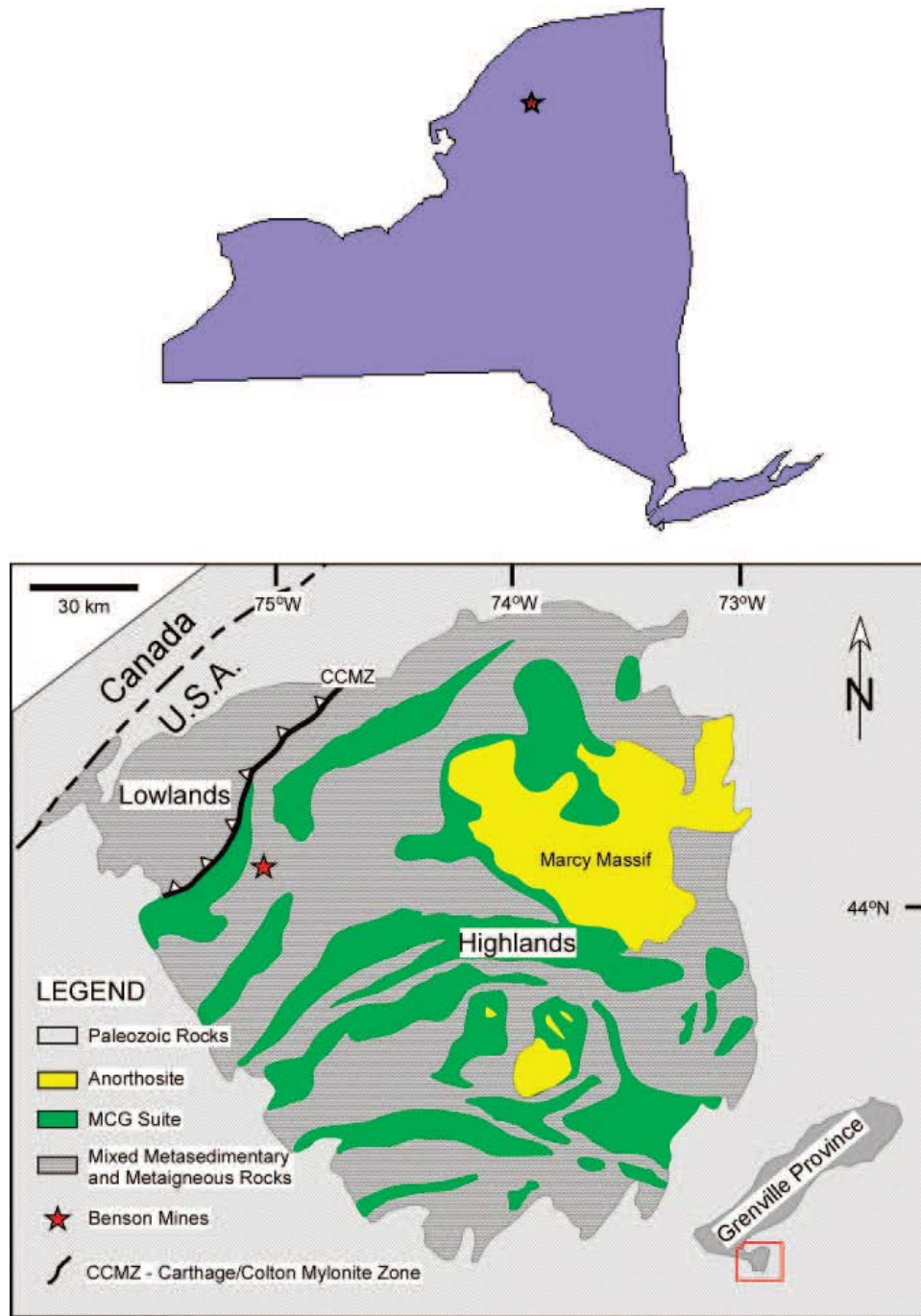


Figure 6: Simplified geological map of the Adirondacks, prepared by Jeffrey Chiarenzelli (Lupulescu et al, 2014).

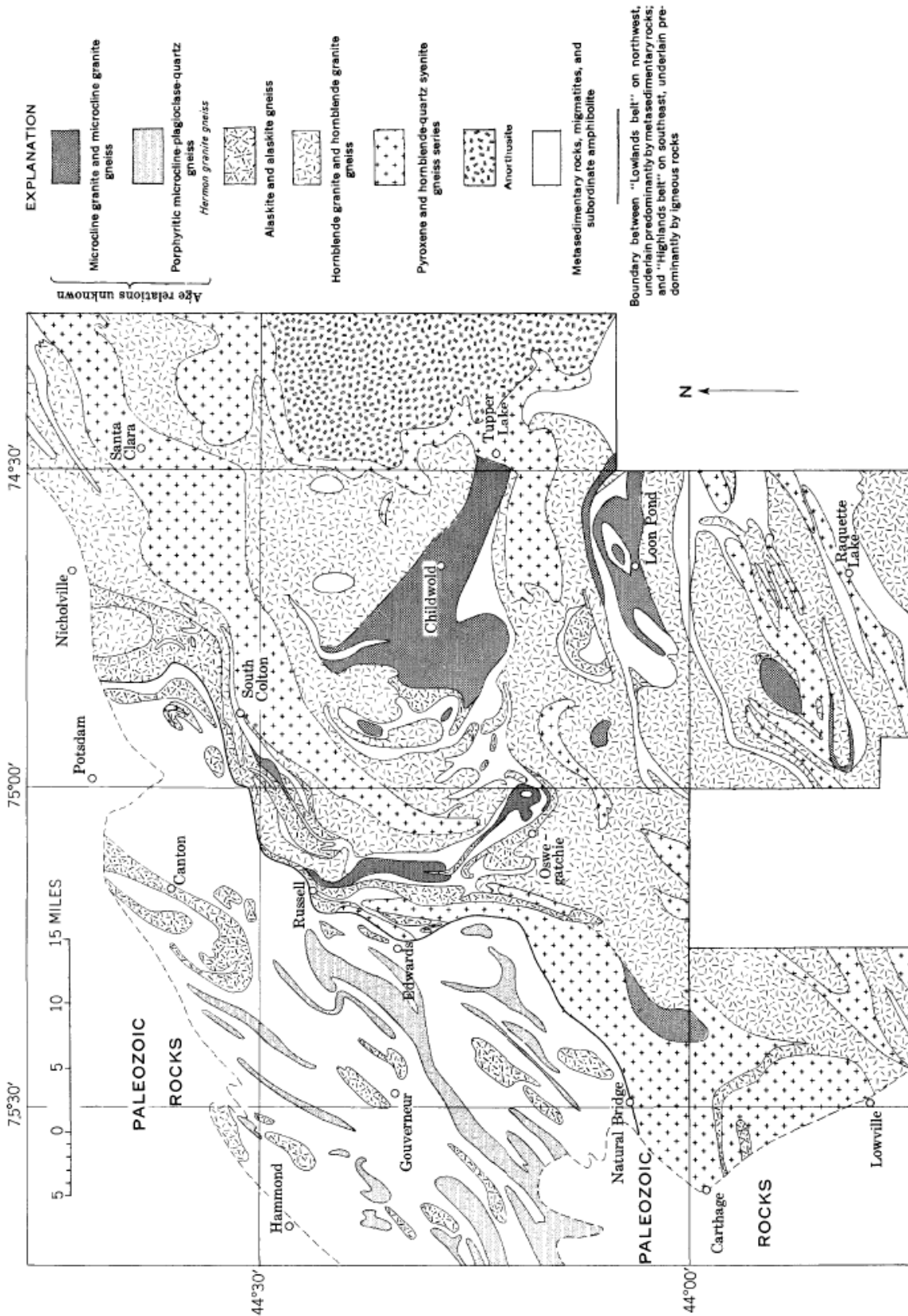


Figure 7. Geologic map of the northwest Adirondacks (Buddington and Leonard, 1962)

Clifton Deposit. Located roughly 3.5 miles southeast of DeGrasse, the Clifton deposit was likely discovered prior to 1840 (Leonard and Buddington, 1964) and John Worden, while surveying lands in the area, is credited with discovering the ore body (Palmer and Thomas, 1969). The mine was first opened in 1858 (Linney, 1943). However operations here did not move forward until 1863 when the Clifton Iron Company was founded by Zebulon T. Benton, John B. Morgan, Samuel B. Smith and Charles G. Myers. Mining took place until late 1869, when fire destroyed the mill (Palmer and Thomas, 1969).

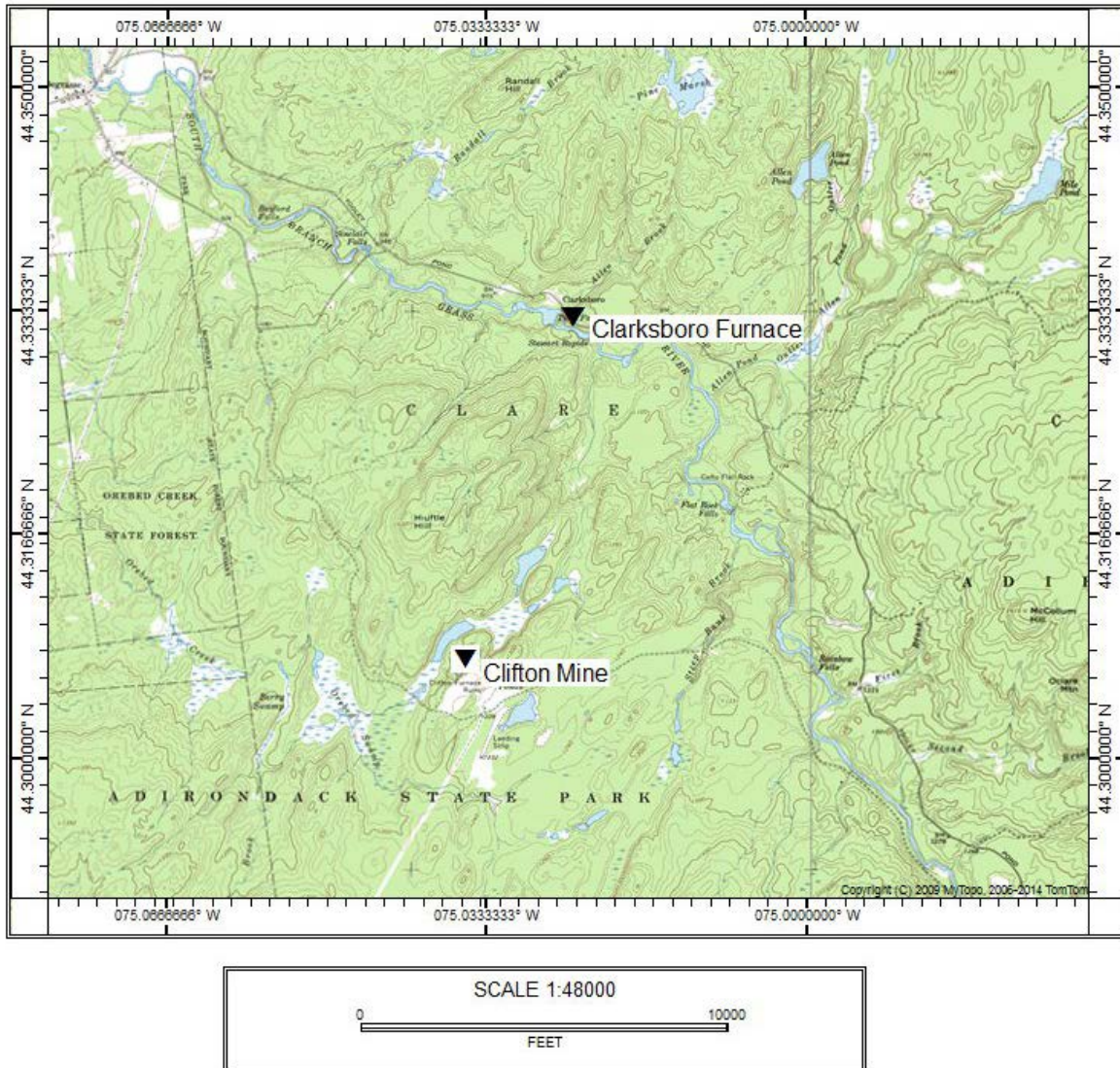


Figure 8. Location of the Clifton Iron Mine and Clarksboro Furnance near Twins Falls on the Grass River.

The Clifton ore deposit is located within a narrow belt of metasedimentary rocks on the east flank of the northeasterly trending Stark anticline. These rocks include a large phacoidal granite gneiss, along with many thin sheets of the same. Hypersthene metadiabase dikes intrude this complex and sheets of alaskite and alaskite gneiss are located within and near the metasedimentary rocks. Specifically, the ore is hosted within skarn, quartz feldspar granulites and gneisses, along with phacoids of hornblende granite gneiss and the associated quartz syenite series, metadiabase and granites and granite gneiss series. Skarn ores contain only magnetite ore

and deposits are usually small to medium in size and compact. Ore grade is extremely variable. (Leonard and Buddington, 1964). Chiarenzelli (2014 Personal Comm.) revealed that ore specimens were recently dated by U-Pb zircon method of Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), giving an age of 1052.8 +/- 3.0 Ma. This age is likely either for the time of igneous intrusion or the time of zircon growth in rocks which originally had none. He further states that, due to the scarcity of zircons, their size, U/Th ratio and morphology, he believes they are likely metamorphic.

Structurally, the Clifton deposit has a complex habit unlike the fishhook patterns of many of the magnetite bodies in the district. At the location of the mine the Stark anticline is upright with its axis gently dipping southward (Figure 9). The major rock in the hanging wall is a quartz feldspar granulite (Leonard and Buddington, 1964).

Jayville Deposit. Operations at the Jayville mine began in 1854 and continued to 1888, shipping ore with a grade ranging from 40 to 60 percent. Located on the flanks of a north, trending hill, magnetite is the prominent mineral mine here. However, it is accompanied by Vonsenite and supergene hematite in places. Similar to the Clifton deposit, the ore is hosted in a pyroxene amphibole skarn and a quartz-bearing amphibole skarn rich in fluorite. Adjacent to the skarn are alaskite gneisses and sodic granite (Leonard and Buddington, 1964). Using U/Pb zircon methods (LA-ICP-MS), an age of 1045.7 +/- 8.9 Ma was recently obtained (Chiarenzelli, 2014 Personal Comm.).

The main ore body has been described by Leonard and Buddington (1964) as a shoot on the northwest limb of an isoclinal syncline which has been overturned. The ore shoot plunges to the northwest in rocks that are steeply dipping at angles up to 60° (Smock, 1889).

The Benson No. 1 working probably provided the most ore for the mine (Leonard and Buddington, 1964), due to the size of the ore body, which is said to be twenty feet wide and 400 feet long (Smock, 1889). Ore was shipped to Fullerville furnaces (Ingalls, 1914), Scranton and Bethlehem (Smock, 1889).

In 1947, an unknown metallic mineral was collected from two drill holes at Jayville. Initially, this mineral was thought to be ilvaite but later identified, as vonsenite (Ferrous ferric borate). Lab analyses gave not only high B₂O₃ content but also showed a high soluble Fe content of the nonmagnetic fraction, making vonsenite a major constituent of the ore zone. When comparing hand samples of magnetite and vonsenite, they cannot be distinguished from one another though Vonsenite has a slightly bluish appearance. Vonsenite is weakly magnetic. However where these minerals constitute ore, this property is not of much use in identifying one from another (Leonard and Vlisidis, 1961).

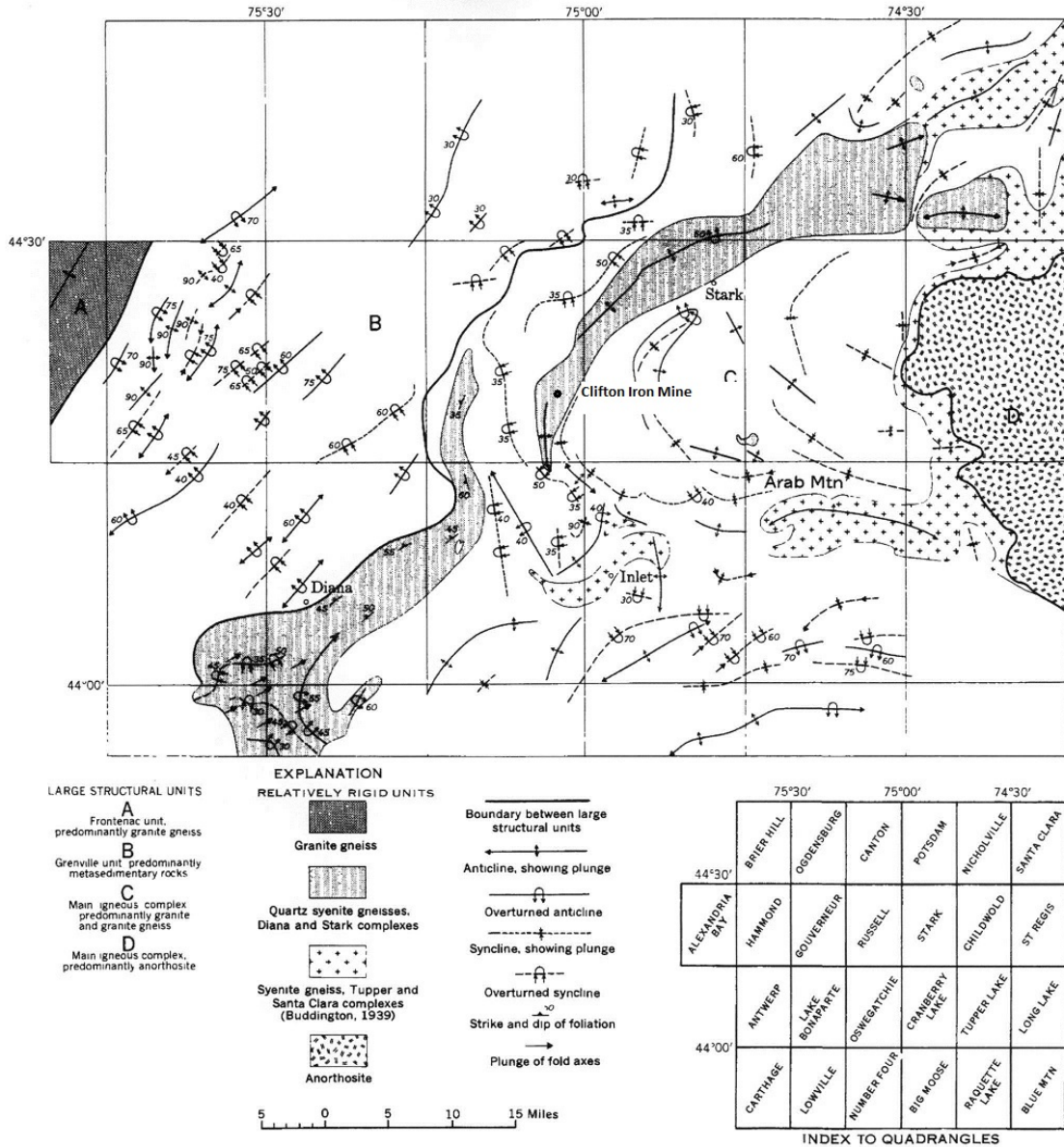


Figure 9. Map of the northwest Adirondack area showing relations of structure axes and isoclinal folds overturned toward more rigid units (Buddington and Leonard, 1962). Clifton Iron Mine Label by J.E. Zaykoski, 2014

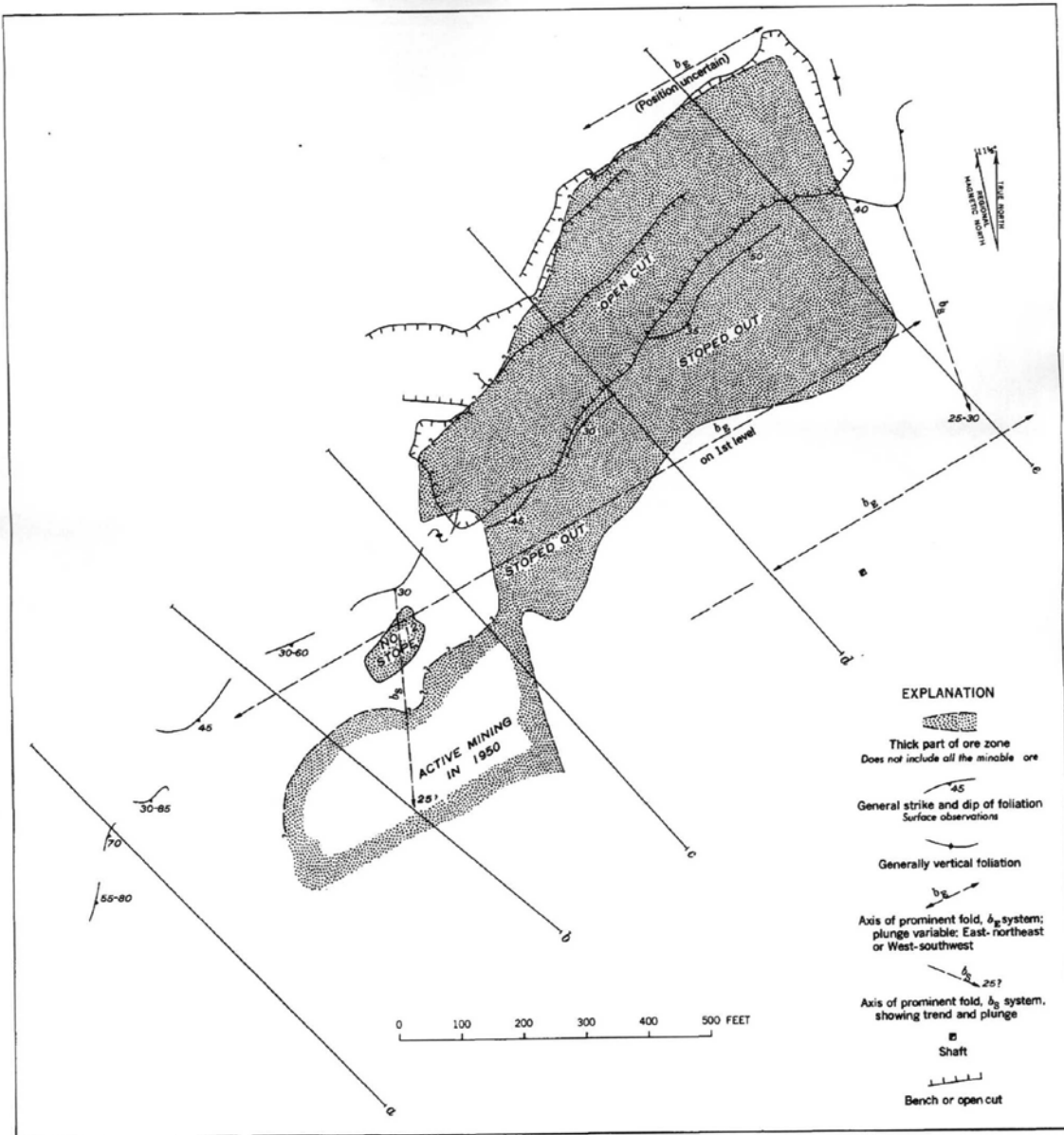


Figure 10. Key structural features and horizontal projection of main ore shoots, Clifton mine (Leonard and Buddington, 1964)

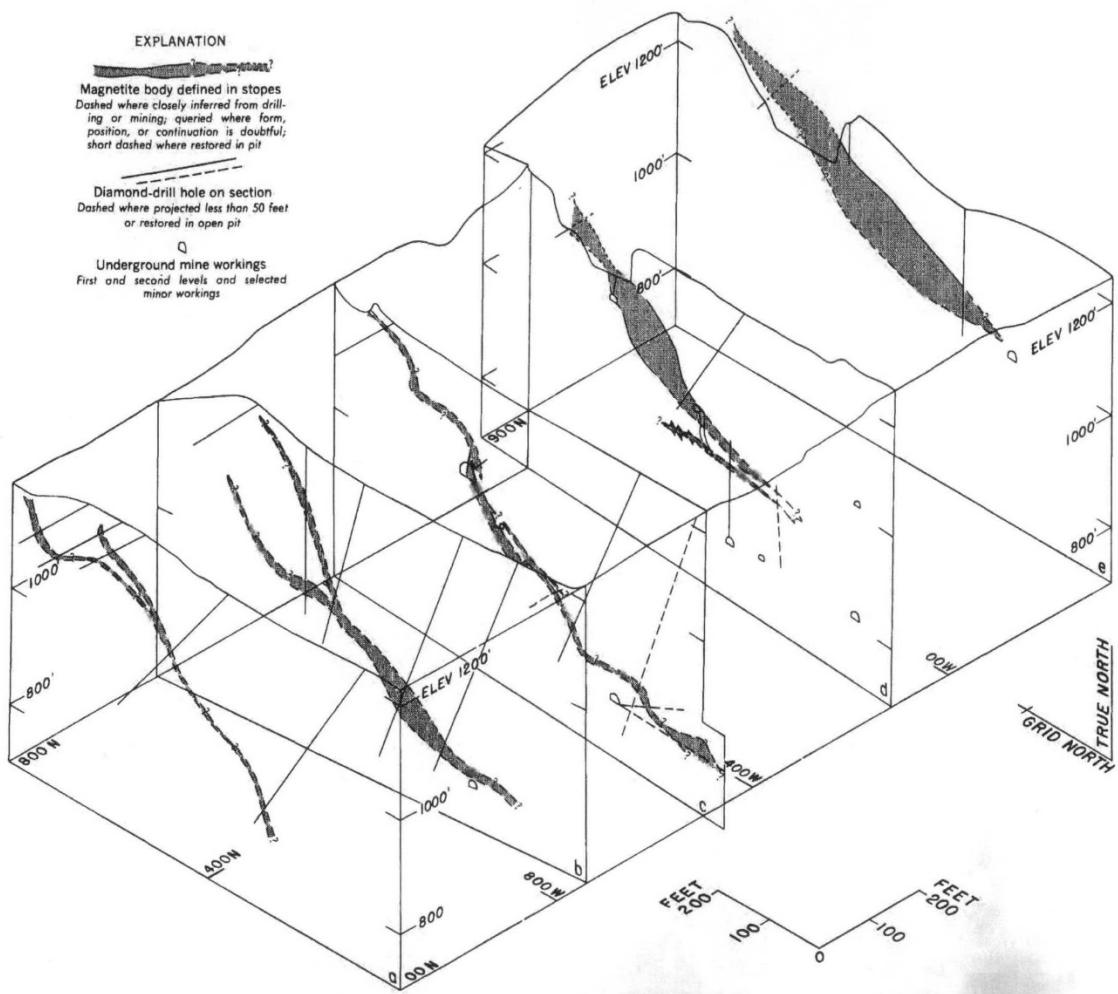


Figure 11. Skeleton block diagram of Clifton ore body (Leonard and Buddington, 1964).

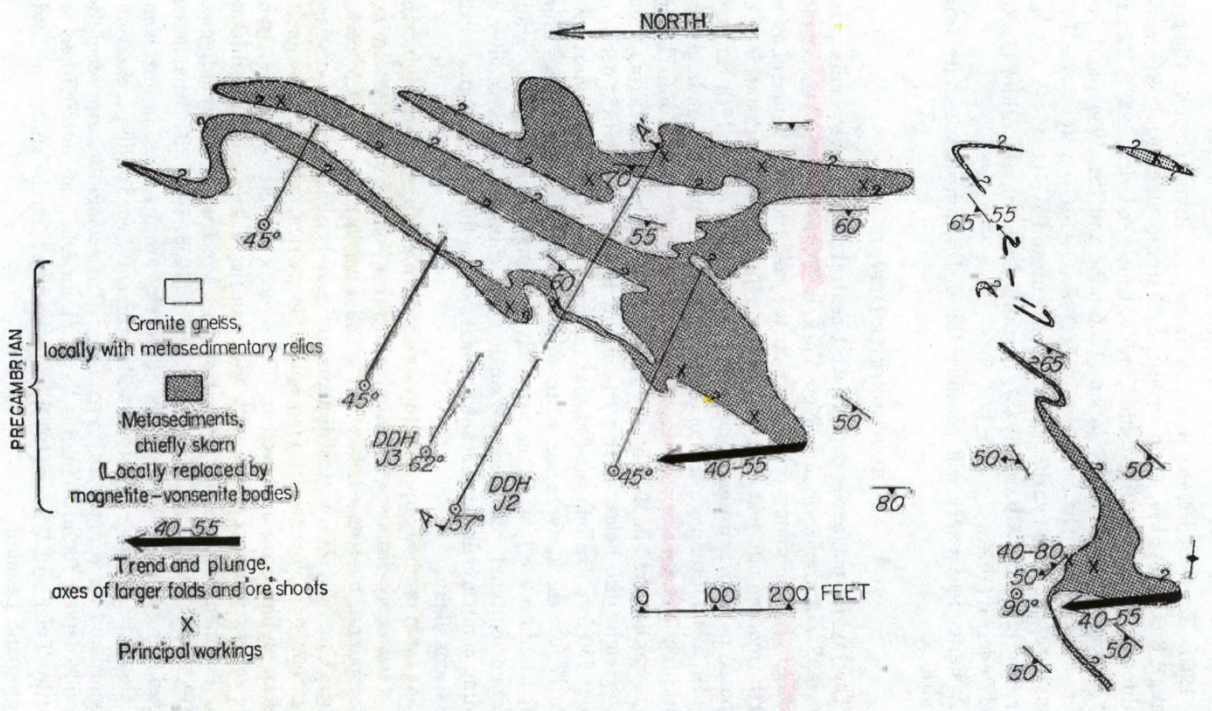


Figure 12. Geologic sketch map of the Jayville magnetite deposit (Leonard and Vlisidis, 1961).

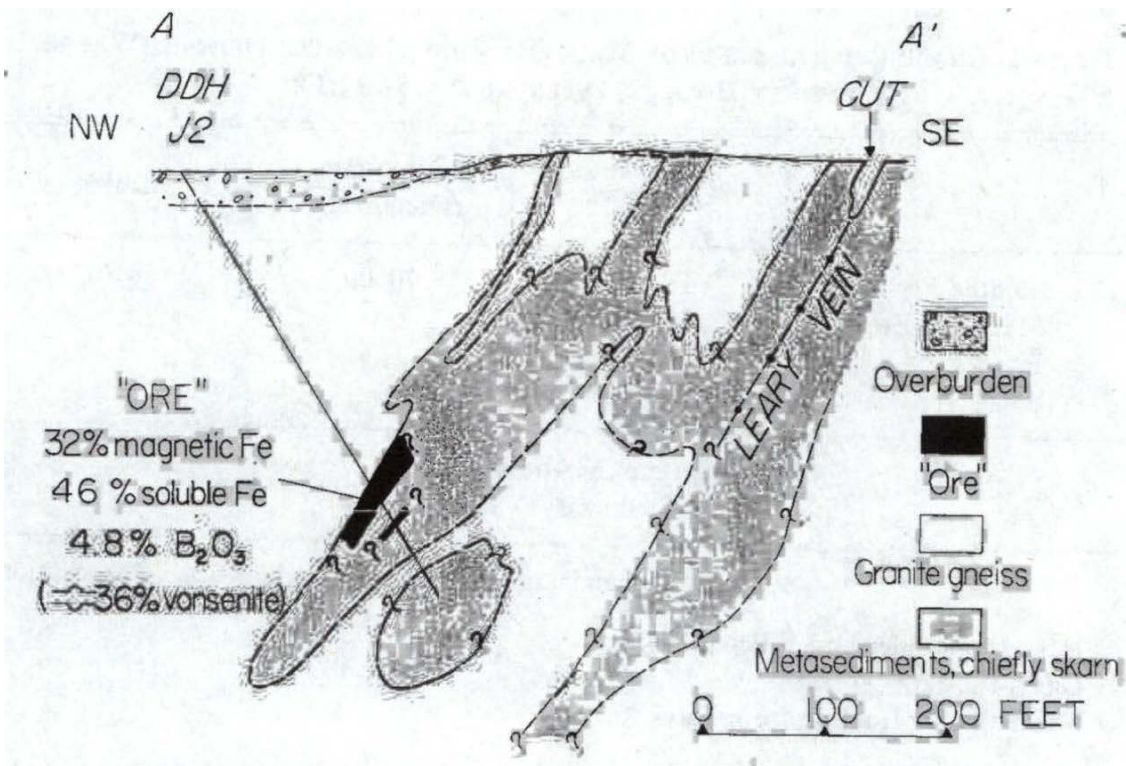


Figure 13. Cross section of Jayville magnetite deposit (Leonard and Vlisidis, 1961).

Benson Mines. Benson Mine was at one time the largest open pit iron mine in the world (Hyde, 1974) yet its discovery was quite by accident. Around 1810, engineers, while in the process of surveying the route for a military road from Albany to Ogdensburg, had their compasses affected by a magnetic ore body located just easterly of Star Lake in an area known as Little River. The main deposit is 2.5 miles long, averaging 400 feet in width and 90 feet deep, containing a low grade magnetic and nonmagnetic ore that is roughly 23% iron (Figure 14). That the ore is located at the surface made this deposit attractive for development (Lupulescu et al, 2014) and allowed the Magnetic Iron Ore Company to abandon the Jayville operation in favor of this location (Carl, 2009).

The Benson mines ore is mined in the main pit and the smaller Amoeba pit, located west of the main workings (Crump and Beutner, 1970). The ore is hosted within a sequence of gneissic metasedimentary rocks with varying amounts of garnet, pyroxene, microcline, albite, sillimanite, calcite, quartz and magnetite (figure 14) (Lupulescu et al, 2014). Structurally, the ore is contained within a syncline that has been overturned to the west and plunges roughly 20° to the north with a secondary roll on the east limb. The Amoeba pit is thought to be at the bottom of a roll forming an anticline and syncline on the east limb of the main syncline. The Benson ore is only found where the stratigraphic footwall has been overturned, becoming the hanging wall (Figure 15). At the southern end of the structural trough, the ore stops where the hanging wall is no longer the hanging wall (Crump and Beutner, 1970).

The ore at Benson mines is a low titanium magnetite, similar to other Adirondack magnetites. Origin preference is metamorphism of an iron rich sedimentary protolith. Lupulescu et al (2014) argues for this origin based on 1) the appearance that ore is conformable for more than 3 kilometers in the same sequence of the metasedimentary rocks; 2) large scale replacement is not very abundant or not seen at all; 3) microscopic ore grain textures suggest that some were present during the silicate development; 4) the abundance of the high aluminum and potassium minerals sillimanite and potassium feldspar imply a clastic sedimentary protolith; 5) experimental work has shown that the silicate and ore minerals were stable at 640° ± 50° C.

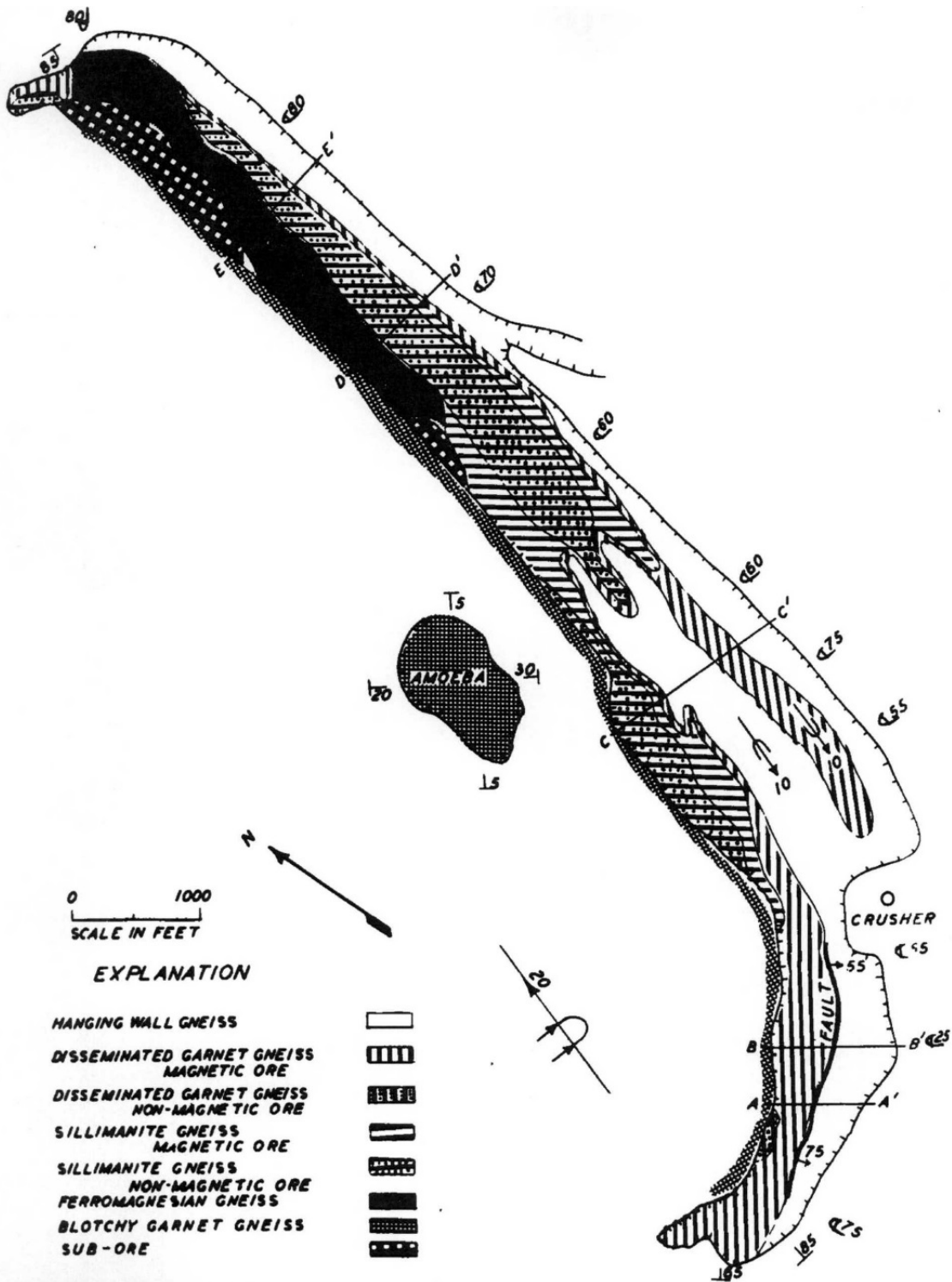
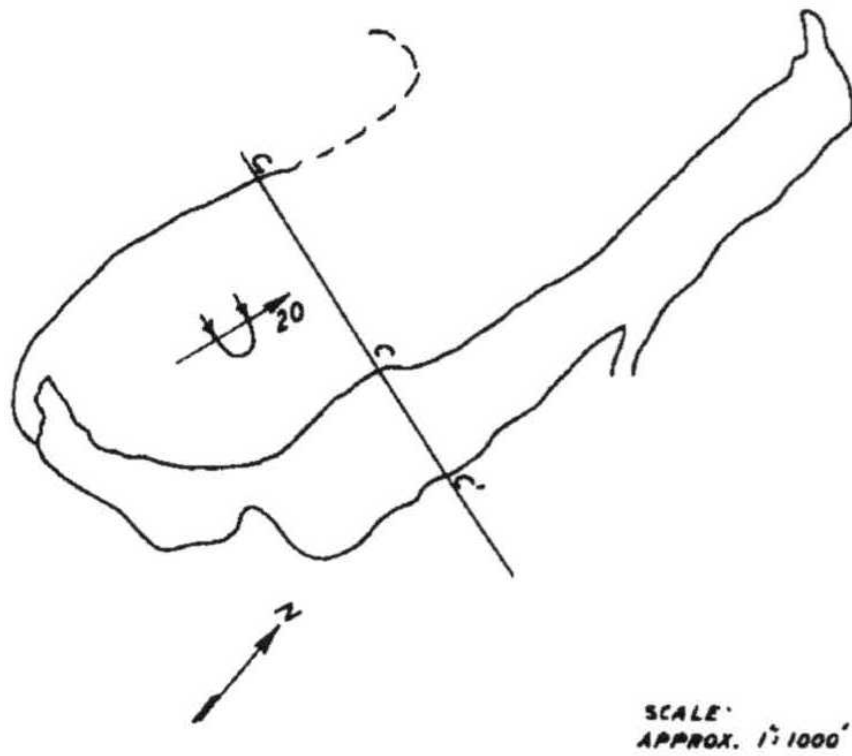


Figure 14. Benson Mines Pit Diagram (Crump and Beutner 1970)

PLAN OF MAJOR STRUCTURE



SECTION OF MAJOR STRUCTURE

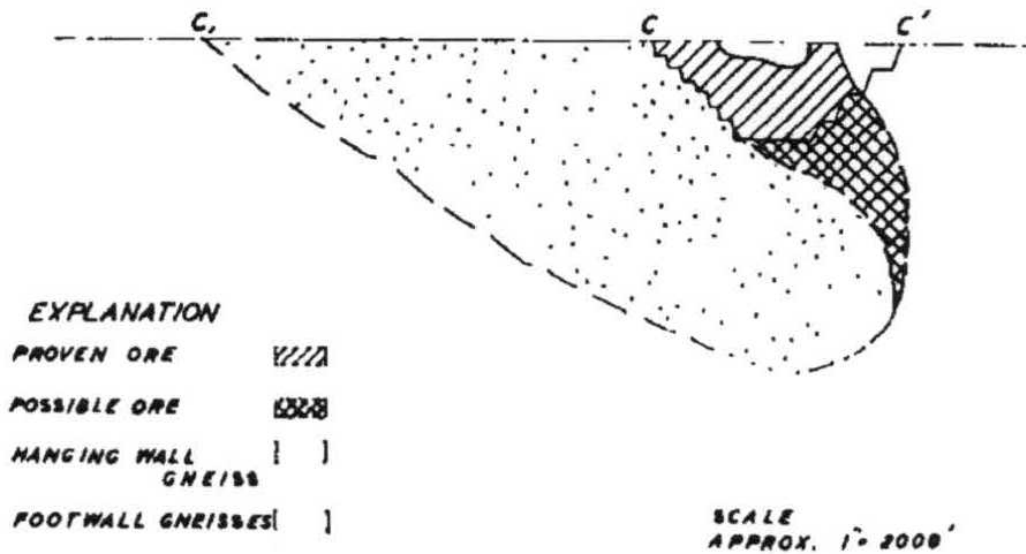


Figure 15. Major Structure of Benson Deposit (Crump and Beutner, 1970)

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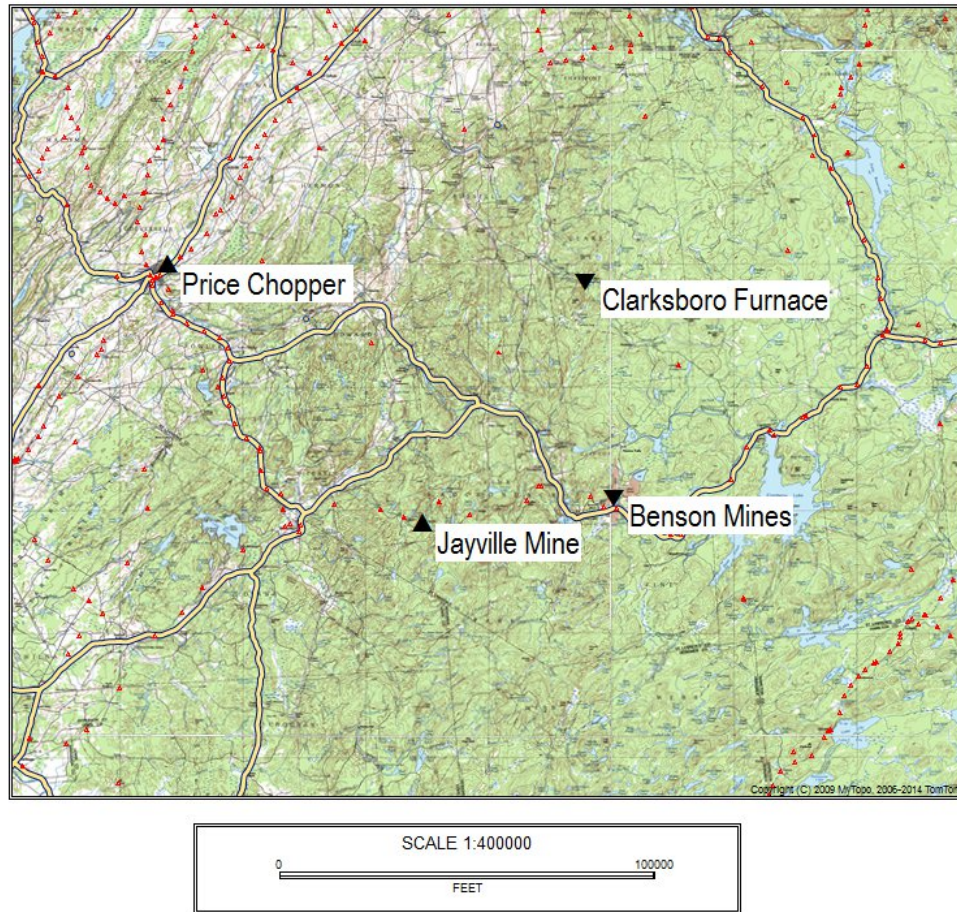
Road Log for the Trip

Figure 16. Road map of the field trip. The trip begins in the Price Chopper parking lot in Gouverneur.

The field trip begins at the Price Chopper parking lot, located on the west side of E. Main Street (US Route 11) in the northeast portion of the village (Figure 16). The address is 389 E. Main Street, Gouverneur, NY 13642. (N 44.15983°, W75.19078°). Please note the coordinates are in DECIMAL DEGREES.

| Cumulative Mileage | Miles from last point | Route Description |
|--------------------|-----------------------|--|
| 0 | 0 | Leave parking lot and turn right at the light onto E. Main Street. |
| 0.8 | 0.8 | Turn left onto NYS Route 58/812. |
| 6.9 | 6.1 | turn right onto NYS Route 812 |
| 16.8 | 9.9 | turn left onto NYS Route 3 |
| 19.2 | 2.3 | turn right onto Jayville Road |
| 23.4 | 4.3 | Kalurah. Bear left at the intersection. |
| 24.6 | 1.2 | Arrive at Jayville Mine. Park at gravel pit. |

We will park at the gravel pit and walk around to the various stops at this old mine. We will visit several different shafts and drifts. Please use caution as these areas are not well marked and all are flooded.

Stop 1. Jayville Mine (N 44.16062°, W 75.18896°)

Leonard and Buddington (1964) describe eleven principal workings at the mine with the Benson No. 1 shaft (N 44.16032°, W 75.18929°) located on the northwest side of the hill believed to have supplied most of the ore shipped from Jayville (Figures 17 and 18). This shaft is inclined about 65° NW and has a slope length of 350 feet. There was no processing of the ore at the mine, other than hand sorting with low grade ore being cast aside. Ore was loaded onto rail cars and shipped to furnaces in Scranton and Bethlehem.

Leonard and Buddington (1964) describe the other workings as follows. The author has provided the Latitude and Longitude information for each;

Fuller No. 1 (Open Cut) (N 44.15938°, W 075.18979°): Located roughly 180 feet south southwest of Benson No. 1, the cut is roughly 100 feet deep with ore analyses showing 47 and 52 percent Fe.

Benson No. 2 (N 44.15960°, W 075.18960°): Located less than 100 feet southwest of Fuller No. 1, the shaft is inclined at 55° W, 60 feet deep through 12 feet of ore ranging in grade from 37 to 49 percent.

Adit (N 44.16000°, W 075.18958°): Located about 150 feet south of Benson No. 1 shaft, this adit opens up a lens of ore 60 – 70 long and 20 feet wide.

Fuller No. 2 Shafts (N 44.15813°, W 075.19044°): Located roughly 400 feet southwest of Benson No. 2 and is said to be 50 feet deep, with ore averaging 54 percent Fe.

Fuller No. 3 (N 44.15803°, W 075.19029°): Located roughly 100 feet southeast of Fuller No. 2 shafts, a 30 to 40 foot opening accessed by a drift.

New York No. 1 (N 44.15951°, W 075.18842°): This shaft is located roughly 170 feet due south of the Leary shaft, inclined to the northwest and 300 feet deep with short drifts at the bottom. Ore averaged 47 percent Fe.

Hart No. 2 (N 44.15787°, W 075.18842°): Located slightly north and west of the former train station, this shaft is 60 feet deep.

Hart No. 1 (N 44.15685°, W 075.18890°): This shaft is located just to the west of the former railroad station and is roughly 300 feet deep, with ore shoots 10 feet thick. Ore analyses averaged 55 percent Fe.

New Find (Hustler mine): This small pit is located off the map, but contained ore analyzed at 52 and 58 percent.

Leary (New York No. 2) (N 44.16016°, W 075.18910°): Located roughly 120 feet southerly of the building foundation in the gravel pit, this shaft is roughly 50 feet deep with ore analyses ranging 22 to 38 percent Fe.

The Jayville mine lacked any ore processing facilities other than simple hand separation of low grade ore. There are many old shafts and drifts around the site and caution is advised as all are flooded.

We will walk around and visit several shafts and drifts that accessed the mine, as well as look at some of the few foundation features found at the mine.



Figure 17. Bedrock Geologic and Magnetic Map for Jayville Mine (Leonard and Buddington, 1964).

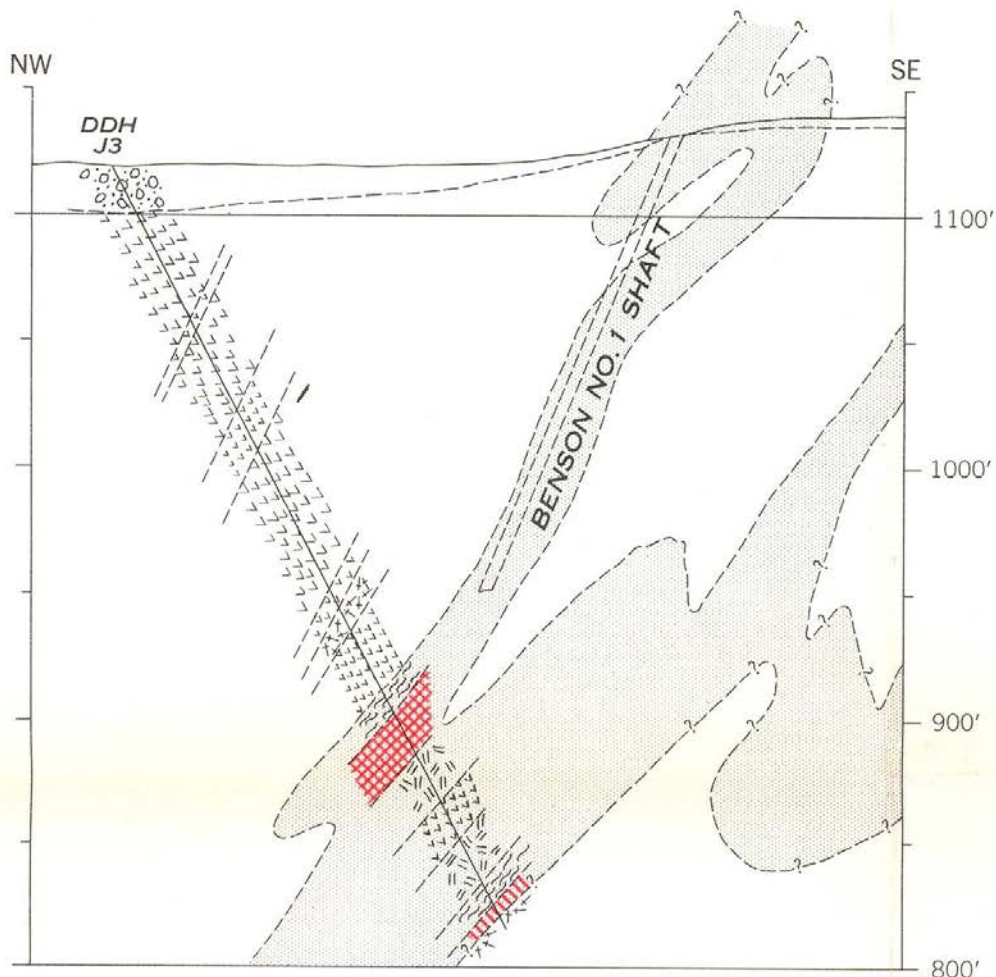


Figure 18. Cross Sectional View for Benson No. 1 Shaft (Leonard and Buddington, 1962).

Jayville stop 1. Benson No. 1 shaft: This working provided most of the ore that was transported from this mine. Presently flooded and not sealed.

Jayville stop 2. Adit (drift): This drift opens to a 60-70 foot seam of ore. Do not walk in as it becomes a decline and is flooded.

Jayville Stop 3. Fuller No. 3 working: This is another drift leading to ore that is flooded. Do not enter.

Jayville Stop 4. Gravel pit area. Here, the foundations of a couple buildings remain. Perhaps a loading dock for ore onto rail cars and a building housing machinery.

Jayville Stop 5. Train station location and water tower foundation.

Jayville Stop 6. Hart No. 1 shaft.

Return to cars to travel to the Clifton Furnace ruins at Clarksboro.

| Cumulative Mileage | Miles from last point | Route Description |
|--------------------|-----------------------|---|
| 30.1 | 5.5 | Return to Route 3. Turn right going east. |
| 38.8 | 8.7 | Turn left onto Route 58. |
| 39.1 | 0.3 | Turn right onto County Route 27A. |
| 40.9 | 1.8 | Turn left onto CR 27 towards DeGrasse. |
| 48.7 | 7.8 | Turn right staying on CR 27. |
| 49.1 | 0.4 | Turn right onto Tooley Pond Road. |
| 52.1 | 3.0 | Twin Falls. Pull off the road and park. |

Stop 2. Clifton Furnace at Clarksboro (N 44.33314°, W 75.02531°)

Clifton Iron Company was founded by Zebulon Benton and sporadic mining operations began in 1863 (Leonard and Buddington, 1964). In April, 1864, the New York State legislature passed a bill allowing Clifton Iron Company to construct a 23 ½ mile railroad from the mine to the Rome, Watertown and Ogdensburg Railroad at East DeKalb. The scarcity of iron after the Civil War made it impossible to use iron rails and maple timbers were used instead. Major mining operations then began in 1865 and a charcoal furnace was constructed at Twin Falls on the Grasse River. Later in 1868, a new furnace was constructed at the mine, located roughly 2.0 miles southwest of Twin Falls. The mill at the mine succumbed to fire in September, 1869, forcing the mine to be shuttered (Palmer and Thomas, 1969).

In 1940 the M. A. Hanna Company purchased the mine and operated it until 1952 when it closed for good. All structures were torn down at the mine.

At this stop we will carefully cross the sluiceway and visit the old furnace, ore and charcoal piles. The access to the island is a hemlock log that must be shimmed across. You may or may not wish to access the island.

Today, the mine itself, located 2.0 miles south southwest of Twin Falls is owned by the Clifton Hunting Club. The club has a strict no entry policy and therefore we will not be able to visit the mine.

After visiting the remains of the 1863 furnace, carefully turn around and return to NYS Route 3.

| Cumulative Mileage | Miles from last point | Route Description |
|--------------------|-----------------------|--|
| 55.1 | 3.0 | Return to County Route 27. |
| 58.5 | 0.4 | Turn left and remain on County Route 27. |
| 66.3 | 7.8 | Turn left and remain on County Route 27. |
| 67.1 | 0.8 | Turn left onto NYS Route 3. |
| 75.1 | 8.0 | Turn left and enter Benson Mines gate. |

Stop 3. Benson Mines at Star Lake (N 44.17045°, W 74.99963° - crusher site)

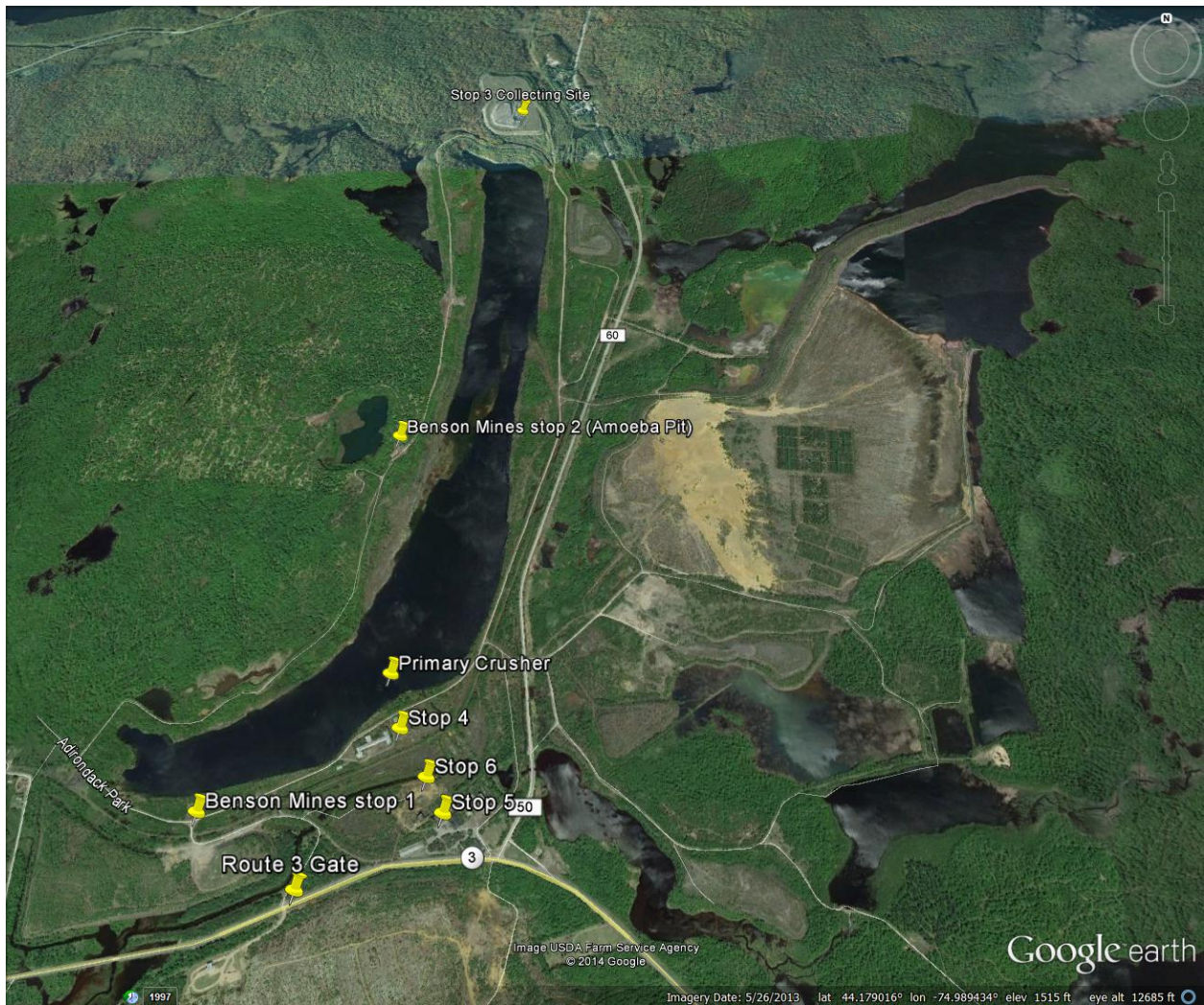


Figure 19. Benson Mines stops.

MINING AND CONCENTRATING METHODS

The open pit mine is now flooded (Figure 19). When in operation it utilized standard quarry methods to remove ore. A standard bench used nine inch holes drilled to a depth of 55 feet. The ore required roughly one half pound of explosives per long ton. Once broken, the muck pile is excavated with large 5 cubic yard electric shovels, loading an average of 25 tons into large dump trucks. The ore is then hauled to the 54 inch primary gyratory crusher located in the pit (Figure 20). The ore is then carried via conveyor belt to two 18 inch secondary gyratory crushers and then discharged into 500 ton silos that act as surge bins to feed the fine crushers (Tillinghast, 1948).

Originally, only magnetic ore was concentrated. However methods were later developed to process the nonmagnetic ore known as martite (Figure 21). Magnetic ore travelled from storage silos to one of three rod mills, where it was ground to pass a 20-mesh screen. From here, the ore was fed to three magnetic separators, with the waste then cycled back through for additional grinding and magnetic separation. From here, the concentrate is dewatered and transferred to the sintering plant. Tailings are pumped to a waste pond (Tillinghast, 1948).

The martite was concentrated in two sections, a rod mill section and an aerofall section, with the difference being the method of reducing the ore to a liberation size. In the rod mill, ore is ground to 18 mesh and the oversize is returned to the rod mill. The 18 mesh ore is sent to a set of rougher spirals that utilize the different specific gravities. The concentrate from the rougher moves to a cleaner spiral and the middlings return to the rougher spiral feeder tank. The tailings are classified and the minus 100 mesh portion sent to a floatation section (Jones & Laughlin, n.d.).

The concentrate is then sent to storage silos at the sintering plant. Here the roughly 64 percent concentrate is mixed with five percent coal, one percent lime and 30 percent fine sinter that is obtained from screened finished sinter. The mix is ignited and passed through an oil fired chamber where suction is applied. The entire sintering process is completed in eleven minutes when the sinter is sent to be screened and cooled. Once cooled to around 350° F., sinter is loaded onto railroad cars and shipped to steel plants at Pittsburgh and Aliquippa, Pa., and Cleveland, Ohio (Jones & Laughlin, n.d.).

BENSON MINES EPILOGUE

The mine continued operations until 1978 (Lupulescu et al, 2014). However problems, from the past industrial activity began to show in 1987 (Jesmore, 2014 NYSDEC, Personal Comm.). After almost ten years of inactivity, the quarry water rose to a level that began to float spilled petroleum to the surface and an oil sheen was discovered on the Little River. New York State Department of Environmental Conservation undertook an investigation and found that the network of underground pipes that carried fuel oil to various parts of the plant had corroded to the point where large volumes of petroleum were leaking directly to the ground. In all, it is estimated that roughly 1,000,000 gallons of fuel oil was lost. A groundwater dam was erected between the spill area and the Little River. Recovery wells were sunk and pumping activity has recovered about 350,000 gallons to date. In addition, the investigation revealed a number of PCB issues as well as a solvent spill and mercury problem (Figure 19), (Jesmore, 2014, NYSDEC, Personal Comm.).

Stop 1. View of the flooded mine looking northward. Here we will discuss the overall geology of the mine.

Stop 2. Amoeba Pit. This is a brief look at the small pit located westerly of the main workings.

Stop 3. Northern waste rock piles. The waste rock in this area was removed from the northern end of the mine where pegmatites intruded. Magnetite and martite can be found around the mine. This waste rock dump is a good location to collect minerals. Some minerals such as sillimanite, calcite, garnet, bornite, hornblende, tourmaline and molybdenite can be found. Dark green fluorite cubes have been found, though these are rare.

Stop 4. Here we will stop and discuss the processing of the ore and look at the remains of the plant.

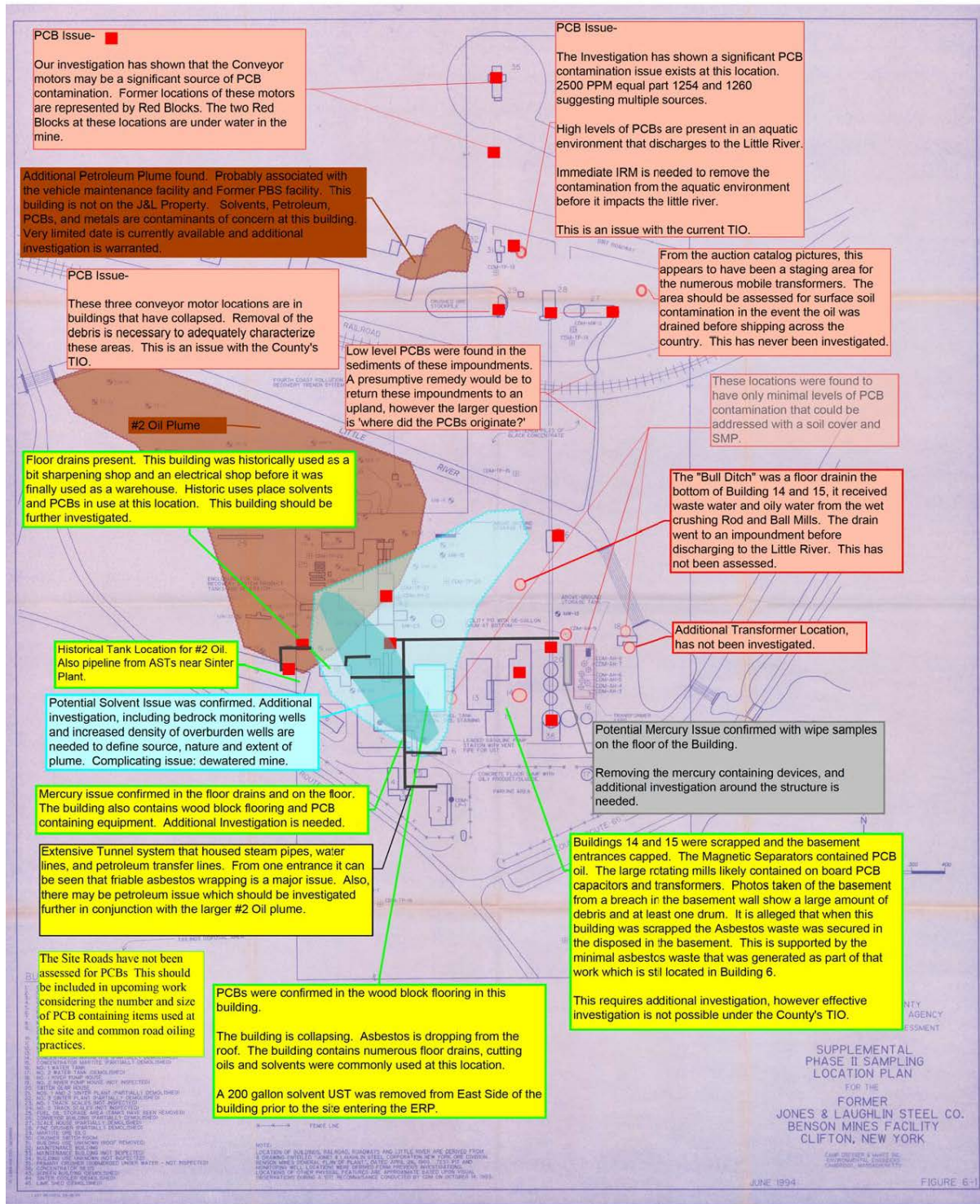


Figure 22. Environmental Investigation Map (NYSDEC).