THE MABBS VEIN AND THE A. E. SEAMAN MINERAL MUSEUM OF MICHIGAN TECH

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Introduction

The A. E. Seaman Mineral Museum of Michigan Tech relocated to a permanent newly constructed building at 1404 E. Sharon Avenue in 2011. During construction, two open and uncapped mine shafts were discovered that lie directly under the west wall of the building inexorably connecting a past producing native copper mine with the museum holding the finest collection of minerals from the local mines. The first shaft uncovered during construction of the museum's main building was called the F shaft (Figure 1); it began to be sunk during the week of September 12-16, 1864 (1). Brothers John and Austin Mabbs were instrumental in opening this mine and the Portage Lake Mining Gazette, September 17, 1864, reported this occurrence was christened the "Mabbs Lode" (1). This "lode" is actually a tabular deposit of minerals that filled a fissure/crack which cross-cuts the host lava flows and is better referred to as a fissure or vein deposit. The term lode, on the other hand, is applied in the Keweenaw Peninsula to tabular native copper deposits that are geometrically constrained within the tops of a lava flows or in interflow conglomeratic beds. By July 22, 1865 this tabular body of native copper ore was referred to as the "Mabbs Vein" (2). Towards the north-eastern end of the Keweenaw Peninsula, fissure/vein mines were the first significant native copper mines of the district with the first profitable mine being the Cliff Mine (Figure 2). The Cliff Mine opened in 1845, only 19 years before the Mabbs Vein. It is likely that the Mabbs brothers expected it would be similarly productive and profitable but it proved to be ill fated.

The objectives of this document are to provide a historical background of this native copper mine, which is now a part of the history of the A. E. Seaman Mineral Museum. The background will begin with the lives of the Mabbs brothers who started mining the vein, the sequence of events in mining the vein, the geologic setting of the vein, and finally the capping of the shafts and construction of the A. E. Seaman Mineral Museum on top of the vein.

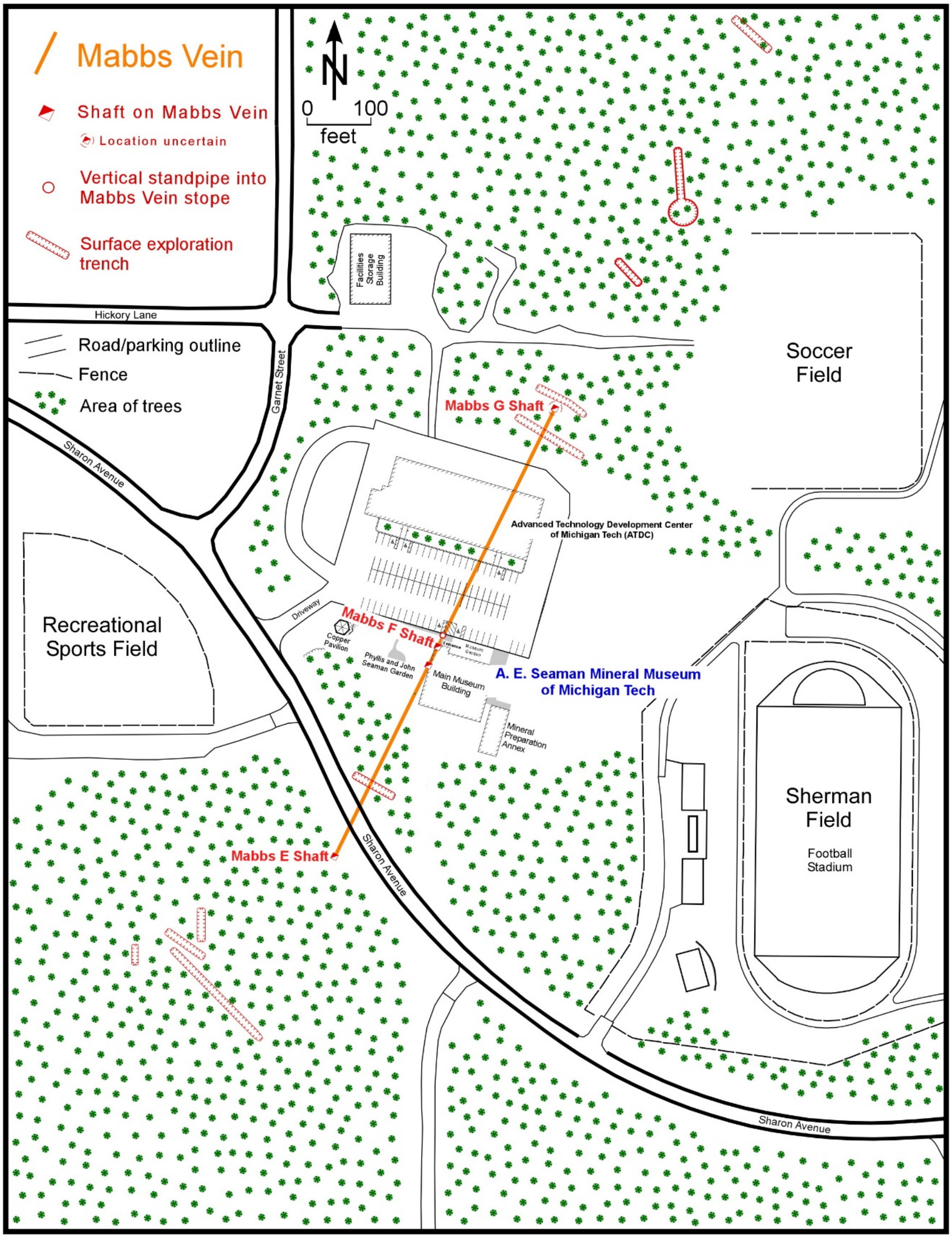


Figure 1: Local geographic setting of the Mabbs Vein on Michigan Tech's south campus. This map is based on a site map prepared for construction of the museum, field observations and mapping by Bornhorst, map by Butler and Burbank (6), maps from Michigan Tech Archives & Copper Country Historical Collections, and satellite images from Google.com and site map by OHM Advisors.

The lives of John (1823-1904) and Austin (1828-1909) Mabbs

John and Austin Mabbs were born in Jefferson, England in 1823 and 1828, respectively. Their Puritan father William Hawys Mabbs was born in 1791 in Mountnessing, Essex, England and in 1820 married their mother Hannah Hill Stace (3). They had 8 children. In 1835, they immigrated with their children (at that time) to Onondaga County, New York. Soon after, in 1835, William and Hannah and family, except John, were living in Hillsdale County, Michigan (4, 5). It appears that John remained in New York until 1852 when he moved to Chicago. In Chicago, John worked for the Moses Company and was involved in erection of the first pumping engine of the Chicago water works. About 1856, John and his brother Austin moved to Houghton County, Michigan as the brothers are listed as leasing the Old Isle Royale Mine on tribute from the Isle Royale Mining Company in 1857 (6). Tribute miners were paid a percentage of the value of whatever ore they mined instead of wages from the company. Analysis of historical records reviewed here show that John and Austin lived in Houghton from about 1856 through 1876.

John was active in the community and is listed as a founding member (1861) of the First Congregational Church of Hancock. The church building was completed in 1863 on the corner of Hancock and Tezcuco Streets in Hancock, but subsequently burned to the ground. John married Martha W. (born in 1820 in Vermont) in 1862. Martha became a member of the church in 1864, John's brother Austin became a member in 1865 and his sister Sophia joined in 1866. In 1876, a year before leaving the area, John was a Deacon and Trustee of the church while his brother Austin was the clerk (7).

While living in Houghton, John was an inventor. In 1866, he was granted a U.S. Patent "Improvement in Quartz-Crushers" which was an improvement in the class of pulverizers known as Chili Mills (8). He was granted another U.S. Patent in 1876, "Improvement in track-cleaners" which was an improvement in railroad track snow removers (8).

Austin Mabbs was active in preserving the mining history of the area, as on March 29, 1866, Austin was a founding member of "The Houghton County Historical Society And Mining Institute" (10). It is fitting that the vein named after him and his brother John now partially lies below the A. E. Seaman Mineral Museum that preserves the mineral heritage of the native copper mines.

John Mabbs, was a machinist upon arrival to Houghton but quickly adapted to the mining environment. In 1864, prior to opening the Mabbs Vein, he was appointed Agent of the Isle Royale Mining Company. He has been credited with several cost-saving innovations (11, 12, 13). He introduced a larger drum with a diameter of 16 ft for hoisting ore from greater depths than previous drums used in operation at that time. He added an easy-to-fix flat band hoist with a 16-ft sheave to increase the speed of raising a skip car (11). He bought an incomplete and unworkable pneumatic diamond drilling machine in Chicago and brought it back to Houghton where he made it workable. With some old engines, John made an air compressor and used cast iron pipes for getting air underground to power a diamond drilling machine. John convinced Rand to make a light and portable diamond drill machine for use in a mine. Thus, John Mabbs introduced the mining world to the power diamond drill (12).

Mining operations in the 1860s used black powder for blasting of rock. In 1869-1870, John Mabbs introduced high explosives to the Keweenaw Peninsula (12, 13). He purchased 4,000 pounds of nitroglycerine oil from New York to be delivered to the Keweenaw Peninsula. Accidents related to nitroglycerine in Pennsylvania led to fear of this explosive. The shipment was blocked by an angry mob and forced to take an alternate route to Cleveland where it was transferred to a ship bound for the Keweenaw. Upon arrival in Hancock, city authorities ordered it removed. John hid it and was able to do a few test blasts before a mob threatened to ride him out of town. The stash of nitroglycerine oil had to be moved multiple times to keep search parties from finding it. Eventually, John had it moved to the Marquette-Ishpeming area where it was used in the iron mines. Later nitroglycerine-based dynamite would become the standard explosive used in the native copper mines.

The end of tribute mining at the Old Isle Royale Mine led John Mabbs to leave the Houghton area in 1877 and relocate to Deadwood, South Dakota (an area with active gold mines) (14) . He was joined by his brother Austin shortly afterwards. Together, they started the Mabbs Brothers firm selling quartz mills, mining machinery, and explosives (14). The Mabbs Brothers continued in business together until 1880 when John left for Colorado to erect a large mill at Cripple Creek, Colorado (14). The Cripple Creek & Victor Gold Mine has produced about 23 million oz of gold since 1890 to today (15). From Cripple Creek, John returned to Chicago where he was an inspector for the public works department and was the chief engineer for the Chicago Board of Trade (14). In 1886, John was living in Chicago as he applied for a U.S. Patent from a Chicago address in that year (26). His U.S. Patent "Pneumatic Elevator" is an improvement to passenger elevators designed to prevent the possibility of the car falling and resulting in a loss of life. John died in 1904 at the age of 81 and his funeral was held at the Pilgrim Congregational Church demonstrating he remained active in the Congregational Church throughout his life (14).

Austin Mabbs remained in Deadwood, South Dakota until his death in 1909 (17). During his time in Deadwood, Austin was known for being a house mover, but his interest in mining continued as he obtained mining patents in 1898 (18) and 1899 (19).

Development of the Mabbs Vein

The first profitable native copper mine began production in 1845 on a vein northeast of Houghton in Keweenaw County, the Cliff Mine, a fissure/vein type of deposit (Figure 2). By the summer of 1848, Pope reports that "twenty miles each way from Portage Lake was pretty well explored, so far as it could be done by individual effort …, but as no copper had been found" (11). The lack of instant success led many of the Keweenaw Peninsula's migrants to leave before the winter of 1848-49 for the next major mining rush in North America, the gold fields of California. In the Portage Lake area, the Quincy Mining Company found indications of copper from 1848 to 1853, but without success of finding a valuable deposit. The Old Isle Royale Mine (Figure 3, one of the shafts of the Isle Royale amygdaloid deposit) began production in May of 1852, just south of Portage Lake near Houghton (6); it was the first significant native copper mine in the Portage Lake area and the first significant lode type of deposit in the Keweenaw Peninsula. In 1853, the fame of the Isle Royale amygdaloid deposit spread to Europe, and in that same year, many miners from Cornwall, England, Ireland, and Germany immigrated to the U. S. (11).

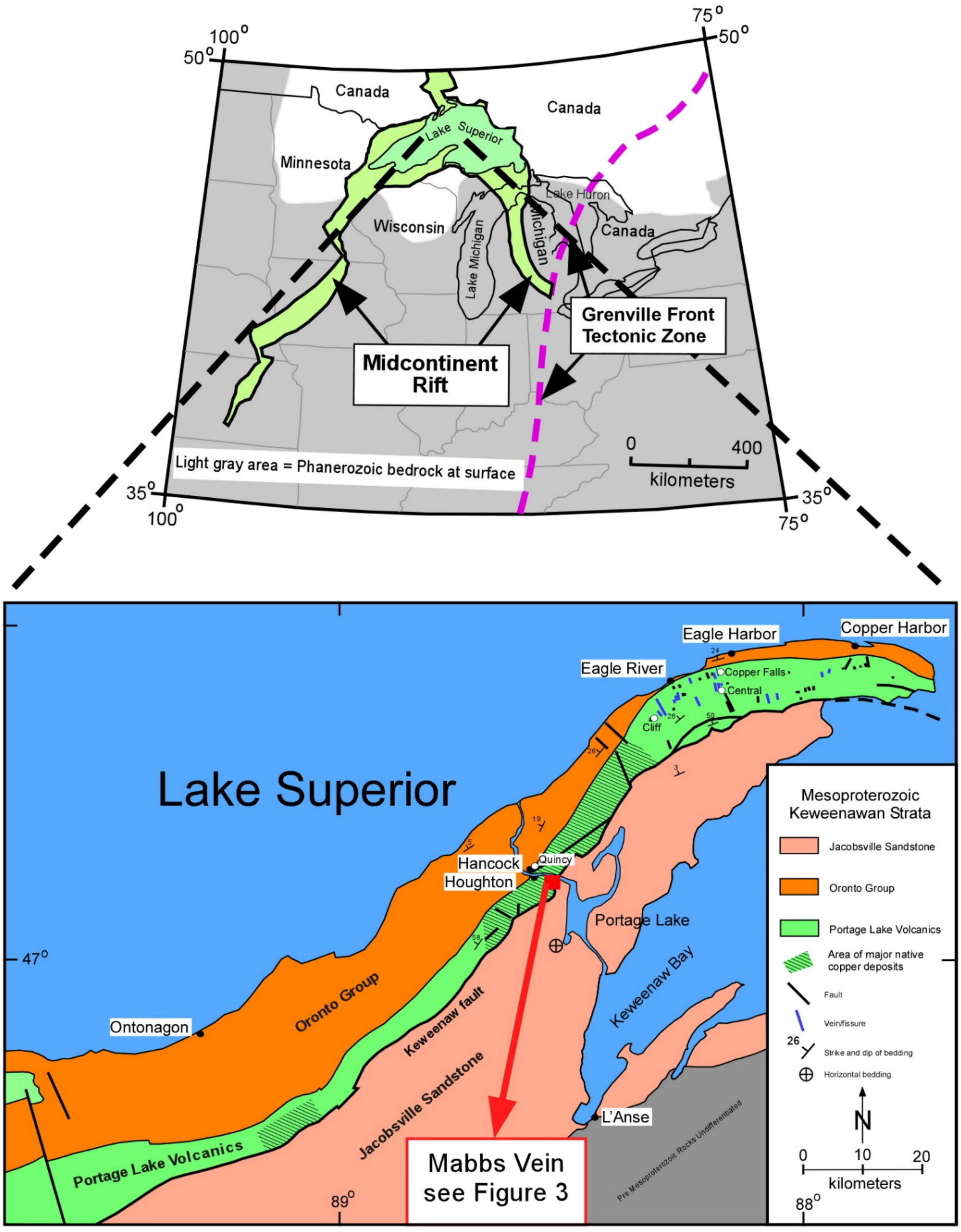


Figure 2: Regional geologic setting of the Mabbs Vein located in Michigan's Keweenaw Peninsula.

By 1854, the Isle Royale Mining Company built a railroad to ship ore to a processing plant (stamp mill) on Portage Lake (Figure 3, the long ago abandoned railroad connect to the processing plant/; located where the Krist Food Mart and Holiday Apartments are located today). The tailings were deposited in nearby Portage Lake (Figure 3, Portage Cove housing development today). Soon after the railroad and processing plant were completed, the Isle Royale Copper Company made its first shipment of copper to Pittsburg for smelting (11). While native copper mining in the Portage Lake area became firmly established with the discovery of the Pewabic amygdaloid lode by Quincy Mining Company in 1856 and the Franklin Mine in 1857 (6), the Old Isle Royale Mine was not a profitable operation.

The Old Isle Royale Mine produced only 18,700 lbs of copper in 1853 and quickly increased to about 350,000 lbs in 1856 and 1857 (6). However, the mine struggled to produce enough copper to cover expenses, and thus; the company was forced to make assessments of shareholders in order to pay for floating debt. The company ceased mining at the Old Isle Royale Mine in 1857 and in that same year leased the mine on tribute to John and Austin Mabbs (6). The Mabbs brothers maintained production of about 350,000 lbs of copper in 1858 to 1860 (6). They increased production in 1861 and 1862 to about 850,000 lbs of copper (6). Even though they were tributors, the brothers seemingly convinced the company to purchase the prospective Webster Mining Company property in 1862 (the Mabbs vein is located on the Webster property) (6), perhaps because of its proximity to the company's railroad. The success of the Mabbs brothers led to the Isle Royale Mining Company to end its tributor arrangement with the Mabbs brothers and resume company control of mining activities in 1863. Unfortunately for the company, production for 1863 decreased to about 600,000 lbs of copper (6). Given the past mining success of the Mabbs brothers, John was appointed the agent of the Isle Royale Mining Company in 1864 even though he was a machinist by trade. During 1864, his first year as agent, production at the Old Isle Royale Mine remained at about 600,000 lbs of copper (6), however, it seems logical to conclude that John sought a means to increase production back to the level he and his brother achieved during tribute mining.

The Webster property represented a good location to open a new mine. The railroad that transported ore from the Old Isle Royale Mine to the processing plant on Portage Lake was located just to the south of the Webster property (Figure 3, today the abandoned railroad grade is part of the Michigan Tech Recreational Trails and is covered by Houghton High School). Thus, it was relatively inexpensive to add a rail spur should a mine be opened on the Webster property. John and his brother Austin's exploration success quickly led to initiation of mining a native copper-bearing vein on the Webster property during the week prior to September 17, 1864, termed the Mabbs Vein (1). At the beginning of mining in September of 1864, there was confusion as to the nature of the Mabbs vein as it was reported that the miners were "inclined to consider the Mabb's lode a contact deposit or some occurrence of geological phenomena of which we have no data" (20).

John's gamble opening the Mabbs Vein paid off as production for Isle Royale Mining Company increased in 1865 to about 800,000 lbs of copper, with an estimated 700,000 lbs produced from the Mabbs vein, and the remaining production from the Old Isle Royale Mine (6). Agent John Mabbs forwarded to the Directors of Isle Royale Mining Company in February, 1866 a positive

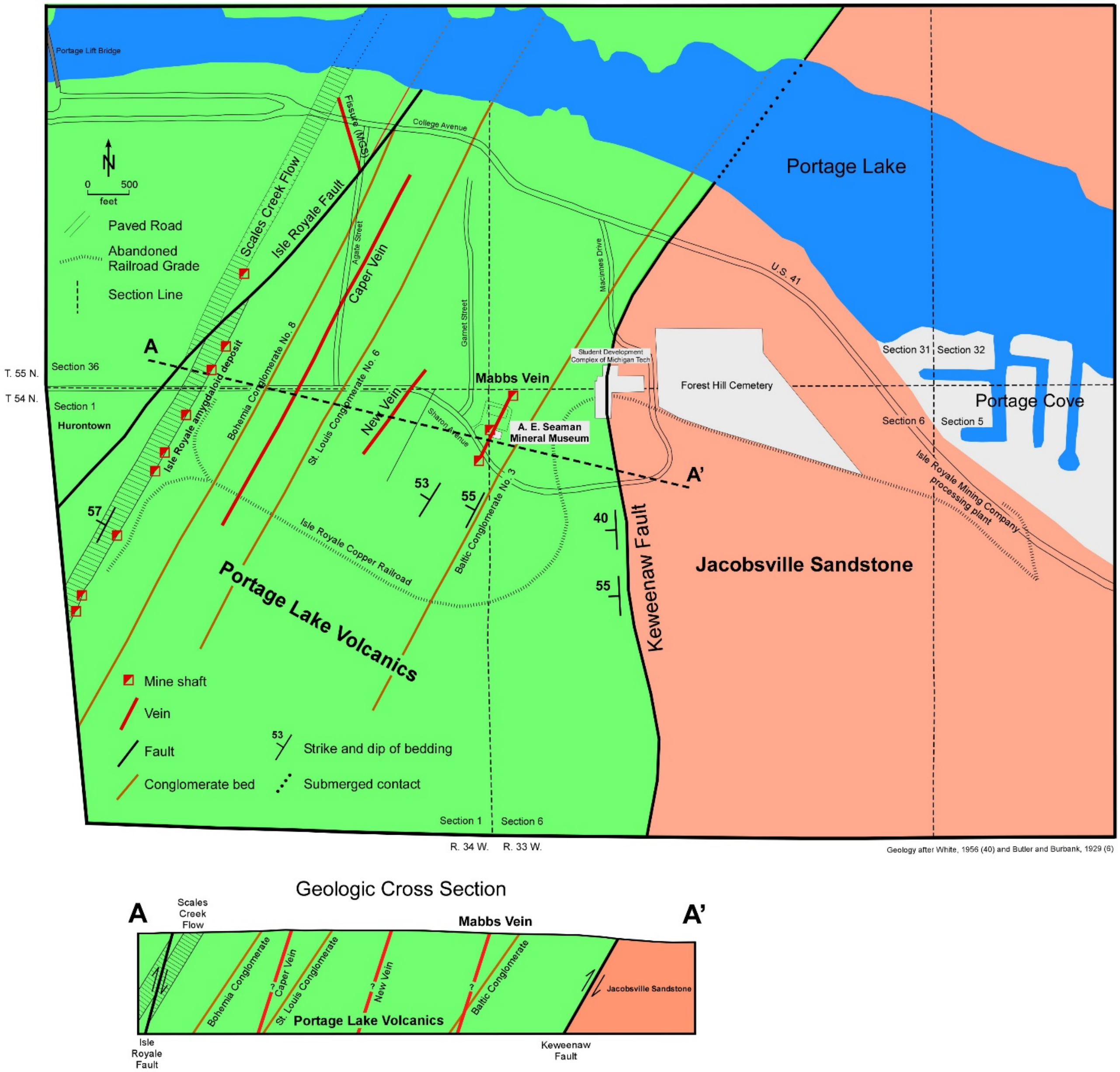


Figure 3: Geologic setting of the Mabbs Vein located on Michigan Tech's south campus on the east side of Houghton, Michigan. Figure 2 provides regional geologic setting and Figure 1 provides detailed geographic setting of the Mabbs Vein.

report from Mining Captain Daniel Northy on the 1865 mining progress at the Old Isle Royale Mine and Mabbs Vein, as well as a positive projection for 1866 (21, 22). However, the 1866 overall company production fell to about 500,000 lbs copper as compared to 800,000 lbs the previous year with an estimated 400,000 lbs from the Mabbs Vein in 1866. This decrease likely led to a formal investigation of mining activities by the company directors in the first half of 1867 (23, 24). Overall production spiked back up in 1867 to about 800,000 lbs of copper (6), with an estimated 500,000 lbs from the Mabbs Vein, perhaps with extra effort due to the investigation. By 1867 the Mabbs was recognized as a vein-type deposit.

The investigation by the directors likely led to a halt in mining at the Mabbs Vein by mid-1867 (24) and following cessation, with the mine quickly flooding with water. Production for Isle Royale Mining Company, now only from the Old Isle Royale Mine, fell to about 300,000 lbs of copper in 1868 as compared to 800,000 lbs the year before (6). The continued fall in production from the Old Isle Royale Mine in 1869 to 150,000 lbs copper led to suspension of mining by the company in 1870 (6). John retained his position as Agent until suspension of mining in 1870 as he attempted to introduce high explosives to local underground mining in 1869-1870.

After mining ceased in 1870, John, no longer the Agent, and his brother Austin once again leased the Old Isle Royale Mine and the Mabbs Vein on tribute. For the years of 1871 to 1874, the Mabbs' tributor production was likely only from the Old Isle Royale Mine at a level of about 200,000 lbs of copper. Production dropped to about 100,000 lbs in 1875 (6). The continued fall in production to only about 30,000 lbs copper in 1876 (6), likely corresponded with the end of tribute mining by the Mabbs brothers. The Mabbs brothers left the Houghton area soon thereafter in 1876-1877.

Mining of the Mabbs Vein

Mining at the Mabbs Vein began in September 1864 with initial reports of rich coarse stamp and barrel copper (1). By April of 1865, they had sunk the main shaft, F shaft, down to about 70 feet deep and recovered 10,000 lbs of barrel and stamp copper (25) (Figure 1). Only 70 ft below the surface, they recovered a 2,300 lb mass of copper in June, 1865 (26). The vein was described in July, 1865 (27) as striking N25°E which is about 10° from the N15°E strike of the adjacent lava flows. Based on modern data, the angle between the strike of the vein and the lava flows is less than 5° (Figure 3). The vein is steeply dipping, about 75°, with a total width of about 6 to 8 feet wide and carried copper over its entire width (29). It is not a continuous tabular body but rather consists in most places of multiple seams and branches, from ½ to 5 inches wide, interwoven with each other (27) (Figure 4). The veins contained masses of native copper and coarsened where there was an abundance of seams and branches giving the vein a broken appearance. The adjacent basalt was hydrothermally altered and contains chlorite and epidote and fine stamp copper. During sinking of F shaft, 600 lbs of copper per 6 feet of depth was produced (27). The estimated grade of copper calculated from the plan dimensions of the F shaft, roughly 6 by 6 feet, and the typical density of basalt is 1.5 %. The smelting of copper derived from the Mabbs Vein shows that the copper contained a significant amount of arsenic (28).

By the end of 1865 development at the Mabbs vein was well underway (21, 22). The main F shaft had been sunk down to the 2nd level about 160 feet below the surface and drifts were proceeding to the north and south (Figure 2). The 1st level drift to the north was about 250 feet long with about 150 feet until reaching G shaft (on the north end). The 1st level drift to the south was about 200 feet long, towards the E shaft (currently fenced in on the edge of Sharon Avenue and about 370 feet south of F shaft) and yielded good copper along the entire length. Drifts north and south of F shaft on the 2nd level were only about 20 feet long. Winzes north and south of the F shaft yielded abundant copper with a 1000-lb mass being extracted from the southern winze. The winze south of the F shaft reached the bedrock surface and was used for ventilation (Figure 1, unnamed shaft, shown on Isle Royale Company maps as a shaft). A second shaft, G shaft, had been sunk on the northern end of the vein and was down about 70 feet below the surface, encountering light stamp copper. A drift was then started to the south towards F shaft. A third shaft, E shaft, had been sunk on the southern end of the vein and was also down about 70 feet below the surface where a 1st level drift was started to the north. The 1865 production from the Mabbs vein was about 700,000 lbs of copper (22).

Figure 4: View to the southwest of the Mabbs Vein in the south sidewall of the unnamed ventilation shaft located just southwest of the F shaft just prior to capping. The flooded shaft can be seen at bottom right of the photograph, about 5 ft in diameter. The white subvertical vein near the center of the photo is one of the multiple seams and branches of the Mabbs Vein and is between 2 and 4 inches wide. The photograph is oblique to strike so the dip of the vein is an apparent dip as the actual dip of the vein is slightly shallower being 75^{o} to the northwest or towards the right. In the upper left-hand corner of the photo, the greenish color is due to malachite from oxidation of copper in the unconsolidated landfill soil and rocks above the surface of the basalt bedrock (about 3 ft of fill overlies bedrock). Just to the left of the central part of the visible vein the greenish, malachite, color is indicative of the presence of native copper in the rocks.

By February, 1866 the three shafts on the Mabbs Vein were all sunk to the 1st level, about 90 ft below the surface, or deeper and the 1st level drifts almost connected the them underground (21). The F shaft was down to 210 feet below the surface, or 50 feet below the 2nd level, and at about 160 ft below the surface was yielding a good amount of copper. The 2nd level drift extended about 125 ft north and south of the F shaft. It is estimated that about 400,000 lbs of copper was produced from the Mabbs Vein in 1866. Mining activity at the Mabbs Vein greatly increased in late 1866. May of 1867, stoping was reported on the Mabbs Vein north and south of F shaft on all three levels (1st, 2nd and 3rd) (23). (During construction activities as described below, an excavator broke into the top of the stope just northeast of F shaft and today shows on Figure 1 as the vertical standpipe). The F shaft was down to the 3rd level or about 240 ft below the surface, its maximum depth. A reasonable estimate of production from the Mabbs Vein was 500,000 lbs of copper in the first half of 1867. However, by May 13, 1867, mining activity ceased at the Mabbs Vein (24). In his answer to the company directors, John Mabbs drew analogy of the Mabbs Vein with those vein mines to the north in the Keweenaw Peninsula such as the Cliff, Central, and Copper Falls Mines (see Figure 2). Central was the largest vein-type (fissure) deposit which produced 52 million lbs of copper over its lifetime and represented the most optimistic analog for the Mabbs Vein. He reasoned that these mines had not yielded as much copper above the 3rd level as the Mabbs Vein, yet they yielded much more copper from deeper levels (24). Thus, he states that "if I owned this vein I would not let it stop short of the 5th level; and as we have about 6000 feet of this vein on this property, I should wish to see it tested in some other places" (24). Given earlier reports of large infiltration of water into the mine (27), the openings on the Mabbs Vein likely quickly flooded upon suspension of mining. The total distance between the E, F, and G shafts on the Mabbs Vein is about 770 feet (Figure 1).

Activity at the Mabbs vein resumed again in 1875 while the Mabbs Brothers were leasing this property and the Old Isle Royale Mine as tributors (20). They dewatered the mine and briefly resumed mining. They reportedly produced considerable mass, barrel, and stamp copper. One can speculate on the amount of production from Mabbs in 1875. The reported 1875 yearly company production was 95,000 lbs of copper as compared to 30,000 in 1876 (6). At most the Mabbs yielded 60,000 lbs of copper but more likely less.

A reasonable cumulative estimate of production of copper from the Mabbs Vein was about 1.6 to 2 million lbs. which ranks above smaller mines of the Keweenaw Peninsula but is insignificant as compared to the larger mines which produced hundreds of millions to several billion lbs of copper. Among vein-type deposits, the Mabbs was insignificant too.

Geological Context of the Mabbs Vein

The Mabbs Vein is a part of the geologic history of the 1.1 billion year old Midcontinent rift system of North America (Figure 2; 31). The rift was an area where the Earth's continental crust was stretched or pulled apart producing a long linear basin. Synchronous with subsidence, the rift was filled with many basalt lava flows, the Portage Lake Volcanics in the Keweenaw Peninsula (Figure 3). These lava flows erupted from linear fissure volcanoes located in the center of the rift. Occasional layers of gravel and sand (conglomerate and sandstone) were deposited between lava flows by streams flowing from the edge of the rift towards the center. Many of these layers have been given informal names (see Figure 3). Today a thickness of about 25 km of layered rift-filling succession of lava flows with interflow conglomerate and sandstone is present under the western half of Lake Superior. This succession of dominantly magmatic rocks is overlain by about 8 km of clastic rift-filling sedimentary rocks of the Oronto Group (Figure 3; 31) resulting from infilling with gravel, sand, and mud during continued sagging of the rift after magmatic activity essentially ended. Late in the geologic development of the rift, compressional forces faulted and fractured the rift and surrounding basement rocks. The rift-filling rocks were uplifted by reverse fault movement along the high angle Keweenaw fault and a resulting rift-flanking basin was filled with clastic sedimentary rocks of the Jacobsville Sandstone (Figure 2 and 3). The Isle Royale fault is a reverse fault with similar orientation as the Keweenaw fault (Figure 3). The Mabbs Vein and several other veins to the west of Mabbs are oriented similar to one another and are steeply dipping similar to the Isle Royale fault. While there are no significant offsets along these veins (they are simply open fractures), they were likely formed by the compressional event that produced the Keweenaw and Isle Royale faults.

It is likely that the native copper deposits of the Keweenaw Peninsula were emplaced during this compressional event by upward-moving Cu-bearing hot waters. These mineralizing hydrothermal fluids followed porous and permeable pathways upward towards locations nearer to the surface where conditions were favorable for precipitation of native copper and associated minerals within the lava flow dominated succession of the rift-filling rocks. These pathways included the vesicular and brecciated tops of lava flows, interflow conglomerate and sandstone layers, and faults and fractures that cut across the layered rocks. As fluids moved through these pathways, precipitation of minerals from them eventually filled the open spaces producing tabular lode and tabular fissure/vein deposits. Lode deposits are those hosted in the porous and permeable tops of lava flows and interbedded conglomerate and sandstone layers.

Vein or fissure deposits are tabular deposits of minerals that are generally controlled by tabular fractures or faults and cut across surrounding layered rocks. The fractures and faults are often oriented at a high angle, or near vertical, compared to horizontal (see Figure 3, geologic cross section). In the northern part of the Keweenaw Peninsula, vein/fissure deposits cut across the rock layering at near right-angles and have near vertical orientation. In comparison, the Mabbs Vein, and those veins in the same vicinity, have a strike near parallel to the host basalt lava flows and conglomerate beds (figure 3). Mabbs has a steep dip similar to those in the northern part of the Keweenaw Peninsula. The steep dip of the Mabbs Vein results in it cross cutting the host rocks (Figure 3).

The native copper deposits were exposed at the Earth's surface after the last glacial continental retreated from Lake Superior about 10,000 years ago. Some 2000 and 3000 years later (7000 to 8000 years ago) the native copper of the Keweenaw Peninsula was discovered and exploited by native peoples (32). In the early 1600s European explorers to the area were introduced to native copper and the U. S. Congress resolved to investigate native copper of the Lake Superior region in 1800 (33). But it wasn't until Michigan's first state geologist, Douglass Houghton's 1841 report that Europeans began migrating to the Keweenaw in search of riches from mining copper. United States government geologists Foster and Whitney completed the geological survey of the Keweenaw Peninsula started by Douglass Houghton but terminated with his untimely death in

1845, and in 1850, they reported on the geology of the Lake Superior district including the copper range (34). The second geological survey was completed by Winchell in 1861 (35). Among these earliest geological publications about Keweenaw native copper is the first geological account of the Mabbs Vein, which was published by the Geological Society of London in 1866 (36). Bauerman's (36) geological cross section through the Portage Lake region on page 452 shows the Mabbs lode; this cross section is generally accurate as we know the geology today. Bauerman notes that the Mabbs lode was recently discovered (1864) but that it was not clear at that time if it was a new belt of flow top deposits or an "actual fissure-vein" (36). The Mabbs Vein was initially thought to be hosted in the top of a lava flow, a possible lode deposit. Bauerman reported that the tabular body (Mabbs) dipped at 75^o rather than the dip of the lava flows of 52 to 60^o (36), or in other words, the tabular body was a vein that cut across the stratigraphy (see geologic cross section Figure 3). As mining of the Mabbs Vein progressed, it became apparent that the strike of the tabular deposit was clearly about 10^o off of the strike of the lava flows. Since its geographic location is in an area not previously know at that time to host native copper deposits, there was anticipation that perhaps a new native copper belt had been discovered.

In 1878, the American Journal of Science (Proceedings of the American Academy of Arts and Sciences) published an article by Raphael Pumpelly in which five pages of the article focused on the Mabbs vein (37). Pumpelly was a well-know mineralogist, and the common low-grade metamorphic mineral pumpellyite was named after him. A variety of pumpellyite is called chlorastrolite (locally known as "greenstone"). "Greenstone" occurs on Isle Royale and the Keweenaw Peninsula; it was named the "Official State of Michigan Gem" in 1973. Pumpelly studied the minerals in specimens from immediate vicinity of the Mabbs vein (poor rock pile?). He established a sequence of mineral formation summarized here (37). The original minerals in the basalt cross-cut by the vein consist of plagioclase, pyroxene, olivine, and magnetite. The initial event of hydrothermal alteration of the basalt likely involved oxidation and the formation of hematite as well as hydration. Chlorite forms as an alteration replacement of pyroxene and in veinlets. The chlorite is cross cut by veinlets of calcite followed by quartz, and another generation of chlorite. Pumpelly described native copper as emplaced after quartz but the relationship of native copper and calcite was less clear. Pumpelly's description does not include the mineral epidote, although it was reported by others. This is the only and last geological publication with any significant geological description of the Mabbs Vein.

Construction of the A. E. Seaman Mineral Museum on top of the Mabbs Vein

An Isle Royale Mining Company map circa 1910 shows the Mabbs Vein and four shafts, the main F shaft, the E and G shafts and another shaft near F shaft (likely the winze noted above that was deepened and used for ventilation) (Figure 1). A U. S. Geological Survey map published in 1929 (6) shows the three lettered shafts as well as related exploration trenches on the extension of the vein. In the 1960s, alumnus Tom Rosemeyer (personal communication) then a Michigan Tech student, was unsuccessful at finding the Mabbs shafts, indicating the surface expression was covered and out of sight by then. Michigan Tech commissioned a detailed study in 1971 in preparation of construction the Student Development Complex (38) and a map from this study shows two mine shafts on the Mabbs Vein, F shaft and the adjacent unnamed ventilation shaft, as well as the area being an old landfill (rocks and soil, not household garbage). At the Museum's

Copper Pavilion, bedrock is less than 5 ft below the surface and to the east of the museum towards the Michigan Tech football field bedrock is exposed in a creek at the bottom of the slope. The landfill material, in vicinity of the museum, that covered the two shafts begins just east of the museum main building and forms a wedge towards the creek. The Mabbs vein and its 3 shafts were noted on a map in a Michigan Tech 1975 M.S. thesis by Holcomb (39). When constructing Michigan Tech's Advanced Technology Development Center (just north of the museum building and completed in 2005) it was not realized that it was built on top of underground mine openings; there are no shafts or openings to the bedrock surface under the Center or parking lot according to old records. While there have been no issues for the Center related to mine openings, the story is different for the A.E. Seaman Mineral Museum.

The construction of new permanent home of the A. E. Seaman Mineral Museum began on October 23, 2010 by the local contractor, Moyle Construction. Within the first day it became clear that the east side of the building was over landfill material. The original building was designed on the basis that the subgrade material was in-situ glacial sediments and thereby not requiring a deep footer/foundation. By November 2, the area under the east ¾ of the building had been excavated for a deep footer/foundation. The footer and foundation was poured on the morning Nov 3 with foundation. During the afternoon of November 3, while preparing the west side foundation for pouring, a mine shaft was discovered (Figure 5A) lying directly below the future west side wall of the museum. Since the east side foundation was already completed, adjusting the location of the building was not an option. Subsequent research showed this shaft to be the main F shaft on the Mabbs Vein.

The F shaft was not plugged but simply covered with some old pipes and rocks. The top of the F shaft was well-timbered, being about 6 feet on a side (Figure 5B). Since details of the shaft, such as its depth of 240 feet and being on the Mabbs Vein, were not known at the time of discovery, Michigan Tech's site engineer, Mike Wilmers, justifiably assumed that it was possible this shaft was a shallow opening that could be filled. Thus, an attempt was made to fill the shaft by dumping a large dump truck full of pebbles into the shaft. While the filling attempt was clearly futile, it was indeed very fortunate it was attempted. The F shaft was filled with water and the dumping of pebbles into it created a strong upward hydrostatic pressure that unplugged another adjacent open shaft just to the south of the F shaft. This second opening, not consistently shown on maps, was an unnamed winze/shaft likely used for ventilation (Figure 1). The museum building has a master beam that is oriented E-W with three master support columns on the west and east sides of the building as well in the middle of the building. This design results in needing only one internal steel column in the interior of the building in order to provide maximum interior layout flexibility. The lucky unplugging revealed that the second unnamed ventilation shaft was located under the west wall master support column (Figure 5C). The ventilation shaft was plugged at the top by various sized rocks, but such means of plugging are not permanent. Thus, without proper capping the loss of this plug in the future would have likely caused significant damage to the museum building and would have required expensive repair.

A.

B.

C.

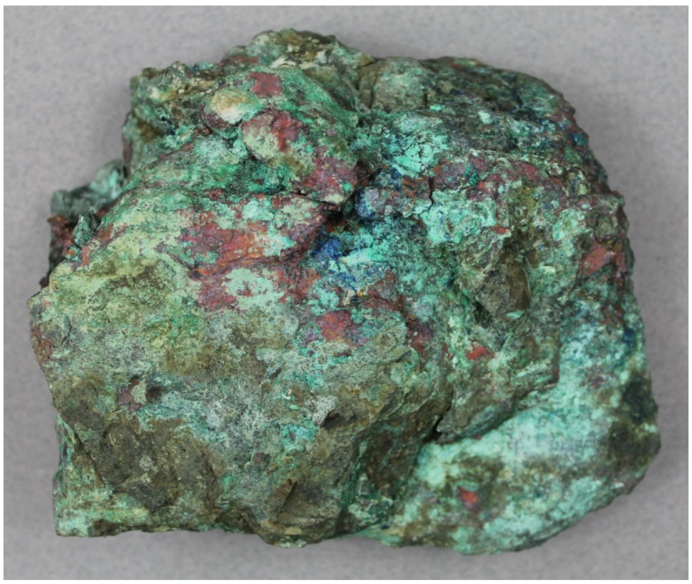
D.

E.

Figure 5: A. View of A. E. Seaman Mineral Museum towards southeast with orange fencing around newly discovered mine shaft; B. View of Mabbs F Shaft after discovery; C. View of water filled ventilation shaft after gravel was dumped into F shaft; D. View towards north (ATDC in background) showing F shaft after excavation of trench, note green color indicative of alteration of native copper; E. View to south showing ventilation shaft beneath main column support footer after excavation of trench.

In preparation for capping, the area between and around the two rectangular shafts was cleared of overlying unconsolidated glacial materials down to the bedrock surface producing a wedge shaped the trench, larger at the top (Figure 5D, 5E). During excavation Mike Jupe of Moyle Construction recovered several masses of surface altered native copper from near the bedrock interface (Fig. 6A). The native copper mass is well coated with cuprite followed by malachite and then azurite (Fig. 6B). The Mabbs underground workings were notable for intersecting numerous fracture that were well connected with each other and others leading to rapid infilling of the workings with groundwater (27) hence the surface alteration of the mass can be interpreted to be the result of chemical reactions involving groundwater (supergene alteration).

A.



B.

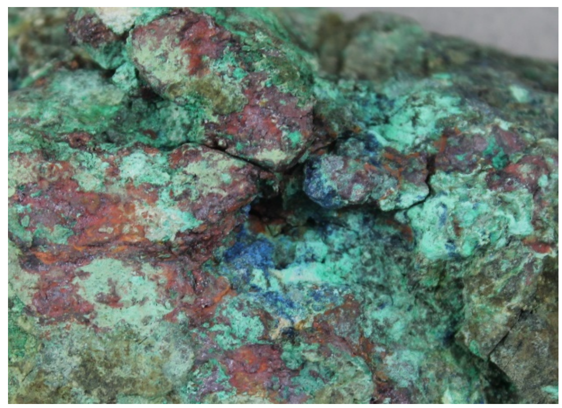


Figure 6: A. Surface altered native copper mass weighing 3.5 lbs recovered from the Mabbs Vein excavation. Mass is about 4.7 inches across, 3.9 inches tall and a maximum thickness of 2 inches. The darker green color on the lower left side of the specimen is epidotized host basalt. B. Close up of native copper coated by reddish cuprite which is in turn coated by malachite. Blue azurite appears to be a copper alteration product after malachite. Field of view 2.4 inches wide. A. E. Seaman Mineral specimen DM31552, Donor Mike Jupe.

A permanent cap, roughly 16 foot wide by 54 foot long, was designed by consultant Michael T. Drewyor PE PS LLC. The overlap on top of bedrock on all sides of the shafts provides solid support for the cap. During excavation in preparation for capping, a third circular opening about 2 foot in diameter was uncovered just north of the F shaft and this opening visually connected to a larger opening extending north under the parking lot. Based on description of the mining of the Mabbs Vein reported above, this opening is likely the top of a stope extending upward from the 1st level.

As a prelude to permanent capping, unconsolidated glacial materials were purposefully plugged into the top of both shafts to provide a level surface upon which to initially construct a safe work surface. Unused scrap floor decking from Moyle Construction was placed over top of each of the two plugged shafts but the circular opening into the stope was left open. About one ft of concrete was poured over the bottom of the trench and decking to provide a horizontal safe working surface. A 12 inch diameter PVC pipe was placed into the circular opening leading to the stope with the initial concrete poured around it. The pipe extended vertically above the final top of the cap to provide future access to water in the stope. A 12 inch rectangular mesh of 1 inch diameter steel reinforcing rod was erected about 8 inch above the concrete platform (Figure 6B). Roughly 450 tons of concrete, about 3.5 foot thick, was continuously poured November 11, 2010 on top of the platform (Figure 6C). Pouring of the cap was completed by early evening (Figure 6C) and by the next day several feet of sand was compacted on top of the cap, providing a more natural subgrade than the cap, on which the footer was poured (figure 5D). The footer for the outside walls of the museum was framed and poured the next day (Figure 6E).

During capping of the mine shafts, construction activities other on the accessible parts of the building continued. In spite of the need to cap two mine shafts, the scheduling was adjusted to minimize overall project delay to only about 2 days.

The 4.5-foot-thick reinforced concrete cap permanently secured the two mine shafts. The pipe extending through the cap into the top of the stope is covered by a manhole along the sidewalk in front of the museum with an opportunity to provide access for a local source of water (Figure 1 and 5E). The main F shaft is located at about the west corner of the museum entrance (Copper Pavilion side). The location of the unnamed ventilation shaft is best visualized from within the museum as it lies beneath the southwest corner of the museum gift shop.

A.

B.

C.

D.

E.

F.

Figure 7: A. View to south showing F shaft in foreground and ventilation shaft in background; B. Plugged shafts, protective concrete pad, and reinforcing rod mess near base of cap, note standpipe in foreground which provides access to stope; C. Beginning of pouring the reinforced concrete cap; D. Completed concrete cap; E. Placing compacted sand covering over cap; E. Poured wall footers on top of cap, with the not yet capped standpipe visible in foreground, which is now covered by the manhole cover next to the sidewalk at the front of the museum.

In 2012, the Michigan Tech summer field geophysics class led by Dr. Jeremy Shannon completed a resistivity profile about 20 feet from the southwest corner of the main museum building to confirm historical accounts that there was a subsurface open mine stope. The resistivity data support the existence of a water-filled mine stope in the subsurface adjacent to the main building of the museum and under the Phyllis and John Seaman Garden (Figure 8). This is consistent with historical records and in turn supports that a stope exists beneath the parking lot between the main building of the museum and the Advanced Technology & Development Center.

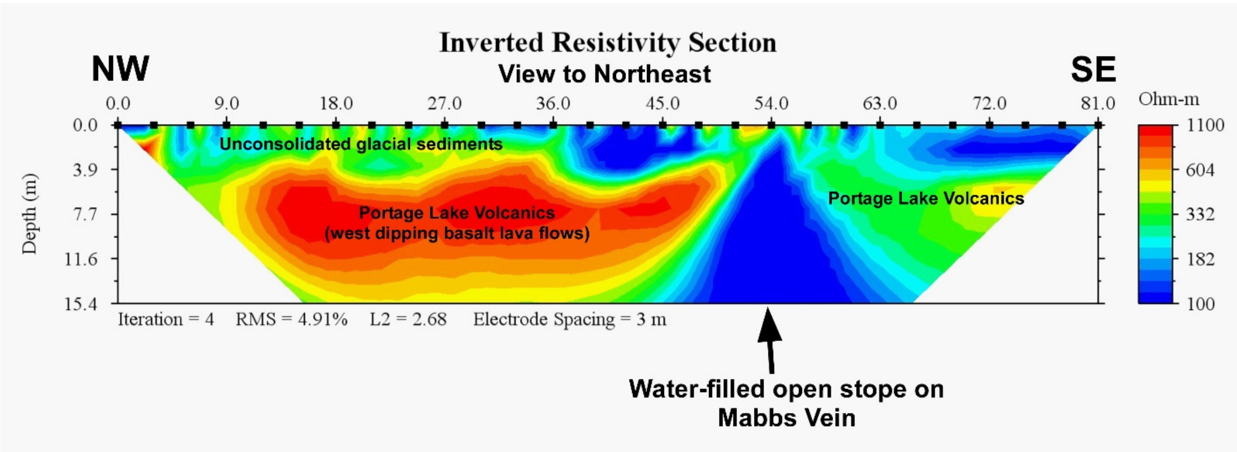


Figure 8: Resistivity section across the Mabbs Vein approximately perpendicular to the strike of the vein and host basalt lava flows about 20 ft from the southwest corner of the main museum building (see Figure 1). The geophysical measurements and contouring were completed by Michigan Tech students as part of an intensive summer course in field geophysics taught by Dr. Jeremy Shannon.

Acknowledgements

The staff of the Michigan Tech Archives facilitated the historical research on the Mabbs Vein. The biographical history of the Mabbs brothers was acquired through many online searches. To accurately portray the history, I've tried to minimize the number of assumptions to those that are very logical to be real. Inevitability there are factual errors and if you discover them I'd like to correct this manuscript. The description of the construction was mine as I was the museum representative during construction of the main building for A. E. Seaman Mineral Museum. I appreciate all of the discussions with the many people involved in the process of construction. Jeremy Shannon followed up on my suggestion to do geophysics on the Mabbs Vein with the summer field geophysics students and provided the results presented here. Thanks to Mike Jupe of Moyle Construction as he had the foresight to gather mass copper and vein rocks from the Mabbs Vein excavations and then donate them to the museum. Special thanks to Bob Barron, John Jaszczak, Larry Molloy, Tom Rosemeyer, and Darlene Comfort who provided me reviews that helped improve this manuscript. The photographs in Figures 4, 5, 6, and 7 were all taken by me.

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