PEQUEA SILVER MINE

(Pequea Township Park)

GEOLOGY GUIDE

Don Wise, Franklin and Marshall College
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History. Ore in the Pequea area was known in colonial times but the bulk of the workings visible today probably date from around the time of the Civil War. An 1863 stock prospectus for the "Lancaster Lead Company" attempted to raise $250,000 to begin major mine operations. The prospectus describes extensive and ongoing exploration in 1863 with the sinking of a number of surface shafts but makes no mention of the main underground workings nor of the present open cut excavations. It speaks only of the northerly dip or inclination of the veins indicating that the folding had not been recognized as of the date. Apparently, the stock was sold and most of the present underground workings as well as the surface strip mining around the folds were completed soon thereafter, presumably as part of the lead supply for Civil War musket balls.

Minerals. Around the mine, the most abundant mineral is milky white vein quartz, the host material for the ore. The chief ore malena was galena, a lead sulfide. Characteristics for its identification include a silvery metallic luster and a fracture or cleavage into tiny cubes. Galena from this mine included a large number of silver atoms that substituted for lead atoms in the crystal structure. These silver atoms wrapped the crystal structure and caused pronounced curvature of the galena's cleavage surfaces. When the Pequea ore was smelted, a significant amount of silver was also recovered. Analyses are reported to have included 10 to 16 ounces of silver to the ton, or about $50 per ton at present prices. Unfortunately for modern mineral collectors, the mine was so thoroughly worked in its day and the old dumps were so thoroughly picked over by later mineral collectors that finding even a tiny fragment of galena is now quite rare. Small amounts of sphalerite (zinc sulfide) also occur in the ore.

Rocks. The two most abundant host or country rocks are: 1) massive, light gray dolomite of the Vintage Formation (Dolomite is a magnesium-rich limestone.) 2) black, limey phyllites and limestone's of the Conestoga Formation (Phyllite is a recrystallized shale.) Both formations were deposited in the sea between about 500 and 450 million years ago. From about 450 to 200 million years ago these delomite and shale formations were folded and fractured at great depth. During this time hot waters moved through them to emplace the quartz and galena. During deformation, the dolomite was brittle and fractured to provide openings for the hot waters whereas the shale flowed and acted as a seal. For this reason the galena bearing quartz veins are now concentrated in the dolomite where the hot waters were trapped just beneath the impermeable shale cover. Since that time erosion has removed the former mountains to expose these deeper roots of the once mighty Appalachians.

Mine Workings. This walking tour follows the surface outcrop of the ore veins along exposures that date from Civil War times. The block diagram of **Figure 1** shows the east-west trend of these fold hinges and how they crop out as curving lines in the valley wall. This method of digging along a line of outcrop was a simple and cheap way of mining the ore but was obviously limited in extent.
For efficient underground workings, most efficient excavations are generally along a horizontal tunnel or adit. To get under the maximum amount of ore, this adit would be driven as low as possible on the valley but just high enough to be above the water table to ease mine drainage. Such considerations would have determined where to start the underground workings **Figure 2 & 3.** Apparently, the localization of ore in the fold hinges was recognized by the time underground workings began because the mine adit does not start at the logical location of the vein outcrop but in the black phyllite and heads directly toward the hinge zone. All these details of the underground workings show signs of sophisticated knowledge both of site geology and mining methods, presumably by the "Mr. F.P. Herington, an experienced and highly skillful mining engineer" described in the 1863 prospectus. There are several other mine shafts in the local area supporting the interpretation that these ores occurred in very irregular small and discontinuous pods and pockets. The abandonment of the main mine workings probably resulted from the removal of all the ore in the visible pockets in the mine and the decreasing demand for lead immediately following the Civil War.

Geology. Several major chapters in the geologic history of this area are responsible for these deposits.

Stage 1. The story begins about 500 million years ago in Cambrian times when this area was the edge of an ancient ocean **(Figure 4A)** and lasted for about 50 million years. The city of Lancaster lay at the edge of a great limestone bank, somewhat like the barrier reefs of Australia today. North of Lancaster the thick bedded, shallow water limestone's, we see today, were deposited in the quiet marine backwaters. To the south of Lancaster, are the thin-bedded sandy and muddy limestone's and black shale's of the Conestoga Formation. These are the continental slope deposits of material washed or collapsed into deeper water from off the limestone bank. At location #9 along Silver Mine Road is an outcrop of one of the submarine slide materials. This contains boulders of the shallow water limestone's which slid off the bank and down the submarine slope into this area. The Vintage Dolomite constitutes the shallow water deposits which were later overwhelmed and covered by the black shale's and limestone's of the Conestoga Formation. The deeper ocean waters were rather stagnant so that organic carbon was preserved to cause the deep blue color of the Conestoga limestone's and the black color of its shale's. The stagnant waters also preserved some of the sulphur, iron, lead, zinc, and silver collected by primitive animals living in those seas. This is probably the original source for the pyrite cubes (iron sulfide) that occur throughout the area, as well as the ore minerals.

Stage 2. About 450 million years ago in Ordovician time, the sea began to close. Bits and pieces of oceanic islands mashed into the continent for almost 200 million years **(Figure 4B)**. The later part of this cycle involved the impact of Africa itself. (It separated again with the opening of the modern Atlantic Ocean about 200 million years ago.) As these pieces docked and mashed into North America, the Appalachian Mountains were produced. These were high, rugged alpine ranges like the Himalayas; quite different in appearance from their eroded roots comprising the Appalachians of today. The collision telescoped the edge of the continent, piling sheet after sheet of rock onto the continent. Deep water sediments were thrust northward onto the slope deposits along the Martic Line, now recognizable as the front of the Martic Hills about two miles to our south. Slabs of slope deposits peeled off to be stacked one on top of another. This included a thin slab of the top of the Vintage Dolomite and bottom of the Conestoga Formation **(Figure 5)**. The thrust stacking is the reason for the doubling of the ore horizon in the mine area. As deformation continued, the stack was folded into the geometry we see today. All these processes took place at high temperatures and pressures at depths of several miles beneath the mountains. Temperatures around 300C (572 F) re-crystallized many of the rocks, including some of the shale's into shiny black phyllites or even schist's in which fine flakes of micas are visible. Hot waters were forced through the rocks, dissolving mineral material at some places and re-depositing it as quartz, calcite, and galena. Wherever there were traps for these hot waters or open spaces for them to fill, vein deposits were likely to occur. Here in the mine area, the dolomite was quite brittle and opened up with great gash-like fractures whereas the Conestoga black shale's merely stretched and flowed to provide an overlying seal for the hot waters. The result was deposition of veins concentrated in the dolomite just below the twice-repeated caps of black shale and/or phyllite. Such ore deposits localized in the hinge zones of folds are sometimes called "saddle reefs".

STAGE 3. Erosion of the former mountains down to their roots, exposing the mine in the topography of today. This erosion proceeded in several steps with most of its taking place in the last 5-10 million years. All the rocks were eroded to a nearly flat surface. This probably took place near sea level but subsequent uplift raised it to the 400-foot elevation to produce the Lancaster surface now visible as the similar elevations of hilltops throughout the region. The flat hilltops and uplands on either side of Silver Mine Run are somewhat eroded remnants of that surface. With the uplift, streams began to cut down through the old surface to produce the deep valley's of today.

Self-Guided Tour. Numbered steel markers are keyed to the descriptions below. They lead due north along Silver Mine Run and then loop around the west or left hand valley wall. The final marker (#9) is a roadside outcrop, east of the stream and half way up Silver Mine Road. For the tour, the block diagram of Figure #1 would be helpful. Also note that geographic north is directly up the valley with east to the right and west to the left.

Stop #1: Old Lime Kiln. This is a two-kiln structure typical of those that dotted the region in the 1800's and early 1900's. Collapse of the north kiln allows inspection of the inner crucible-like shape. In operation, the kiln was filled with alternating layers of wood and limestone or dolomite **(Figure 6).** This was lighted and allowed to burn freely for a brief time before being covered at the top by dirt and ash and the flow of air restricted by dirt piled around the bottom inlet. For about a week, this burn was watched constantly to allow just enough gas from the limestone and the combustion to escape while the intense heat was maintained inside the kiln. (As a lad I saw one of the last of these burns in the 1930's with half dozen old timers sitting around the hot pile mostly loafing and telling tales while they roasted apples and potatoes.) After about a week, all the wood was burned and all the carbon dioxide was driven out of the limestone to leave the rocks as quicklime, a white powdery form of calcium oxide. This was dug out the opening at the bottom to be mixed with water, sand, and rock to produce mortar and cement for walls. It also could be made into whitewash paint for barns and houses or used as a powder to disinfect the ubiquitous privies of that time. Most of the dolomite for the kiln probably came from the large quarries visible through the trees just across Silver Mine Run to the east.

Stop #2: Entrance to the mine adit. This entrance is now closed by an iron gate for safety purposes. Note that you are looking west into the mine and that the rocks are inclined to the north or right. The mine begins in the black phyllite of the Conestoga Formation and heads directly toward the main hinge of the old fold, suggesting that the mining engineer knew exactly what he was doing. The block diagram of figure 2 shows how the adit was driven westward for 200 feet to intersect the hinge. The large room at that location suggests removal of a significant amount of ore. An inclined shaft followed the hinge zone and presumably the ore downward to a depth of 30 feet. The main adit then turned northwestward for 50 feet to intersect the same hinge zone in the upper vein. En-route, a "gopher hole" (visible at location #3) leads to the surface, possibly for ventilation purposes or a remnant of an earlier exploration attempt. At the second hinge zone a large room was excavated, presumably in another concentrated pocket of ore. An inclined shaft was driven downward from the main adit following the hinge zone in the upper vein northwestward to a depth 60 feet. At this depth a second level was started, probably the limiting depth to which the available pumps could maintain the water table. This level followed the vein for about 30 feet before being abandoned. At the level of the main adit, the workings turned southward for another 70 feet. These workings passed through the hinge zone of a small fold which seemed to have localized a rich ore pocket judging from the local widening of the tunnel to about ten feet diameter in that area. The final 40 feet of the adit hooks toward the west and passes through one more fault repetition of the Vintage Dolomite-Conestoga Shale contact. Much of the waste rock from this extension was piled in the new opening created by ore removal. Unfortunately, the contact of this third repetition of Vintage with Conestoga was un-mineralized at this location. One can not fail to be impressed by the intelligence with which these workings follow the complex geology. From stop #2 on the walking tour, proceed 100 feet to the north and then cut back along the trail to the next stop nearly directly above the adit. As you proceed, you will be passing over and beside piles of waste rock.

Stop #3: Open cut by the "gopher hole". These next stops of #3 - #8 follow the ore veins through several folds as they crop out on the valley wall. These include two up-folds or anticlines separated by a down-fold or syncline. This stop is probably the best surface location for viewing both the upper and lower ore veins. (The cross section on Figure 3 includes this location as its upper portion.) At this stop, the lowest place on the south wall of the cut exposes the Vintage Dolomite with some Conestoga phyllite and shale on top of it with a final cap of a bit of the upper dolomite slab. The path is in the largely removed mass of the upper dolomite, which can be seen below the north dipping Conestoga black shale and phyllite in the "gopher hole" connects with the rear portion of the mine as shown on Figure 3. Note the localization of the quartz veins near the contacts. Also, note that the dip of beds is toward the north similar to that of the mine adit. We are on the north limb of the first fold, an anticline.

Stop #4: Mine tunnel at crest of the first anticline. The path goes through the tunnel as a steep but short climb. When one thinks of trying to cut even this little tunnel with today's pneumatic drills and dynamite, the task is non-trivial. In Civil Was and older times, it was done by hand held steel drills driven by someone swinging a heavy sledgehammer. Holes were filled with black powder, blasted, removed, and the process was repeated.

Note that the beds are tilted off to the west at this location. Their tilt direction has changed 90 degrees from Stop #3 and they can be seen curving over the top or crest of a fold at this location. The folds here do not have horizontal hinges but are tilted so they plunge westward at about 30 degrees. If they were not plunging, the beds here on the crest would be perfectly flat.

This exposure is in the upper dolomite and its contact with the overlying black phyllite. Looking back from the far side of the tunnel is probably the best place to see how the quartz veins were localized within the brittle dolomite and trapped along the contact of the two rocks.

Stop #5: Gentle south limb of anticline. The same contact as stop #4 is visible in the rock face. Note that it now has curved across the anticline to dip off to the southwest. The old miners were clearly removing the vein quartz at this level to leave the rock face. On the other side of the path to the east are mine dumps of waste rock removed from the excavations. Proceed along the path down over the hillside. The trench or excavation on the left or east side of the descent represents removal of the same contact seen at stops #4 and #5. The fact that the trench goes directly down over the slope indicates that steepness of the beds. Small weathered outcrops of the dolomite are visible with a steep dip to the south.

Stop #6: Across the axis of the syncline. If you look carefully at the outcrop, a dip of the layers to the north can be seen, a reversal from the previous two stops. This indicates that we have crossed the bottom of a synclinal fold. The rocks are the same contact of the upper ore level that we have been following since stop #4.

Stop #7: North dipping rock face. This large exposure shows the veins at the contact of the upper ore zone. Dips to the north indicate we are still on the same limb of a fold as at stop #6.

Stop #8 Reversed dip on other side of an anticline. This exposure is in another trench cut down over the hill. It is poorly exposed but the same contact of the upper ore zone was once traceable from stop #7 over the top of an up-fold or anticline and then down along this trench. Poor outcrop shows the reversal of dips to the south.
Proceed back to the road and turn left (east) for about 200 yards to the road-side outcrop of top #9.

Stop #9 Submarine landslide deposit. The large limestone boulders sticking out of this outcrop started from the vicinity of Lancaster. They are part of the thick beds of the limestone bank, the edge of which collapsed and slid down into the deeper water of the submarine slope to become inter-bedded with the Conestoga Foundation.
For the more sophisticated geologists: look around the left side of the outcrop and note the bedding with the cobbles oriented parallel to cleavage rather than sub-parallel to bedding. Further, the cleavage dips to the north suggesting the wrong direction of tectonic transport, namely from the north. Actually, this is part of a cleavage pattern that was once nearly horizontal with proper south to north transport but was upended and tilted to the north by the uplift of Mine Ridge. Details are given in Wise, 1970.

Summary: You should now have proven to yourself that 1) you can recognize quartz, dolomite and black shale or phyllite, 2) that rocks can fold because you have walked out their outcrop, 3) that there are geologic reasons for ore to occur where it does, in this case involving hot waters that deposited the veins, 4) that a geologic history of ancient events can be read from careful observations, and 5) that the old timers who worked this mine had a pretty sophisticated idea of how the ore lay and how to get at it.

References:

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Wise, Donald U., 1960, The Pequea Silver Mine. In some tectonic and Structural problems of the Appalachian Piedmont along the Susquehanna River: Guidebook 25th Annual Field Conference of Pennsylvania Geologists; D.U. Wise and M.E. Kauffman. Eds, p. 53-59.

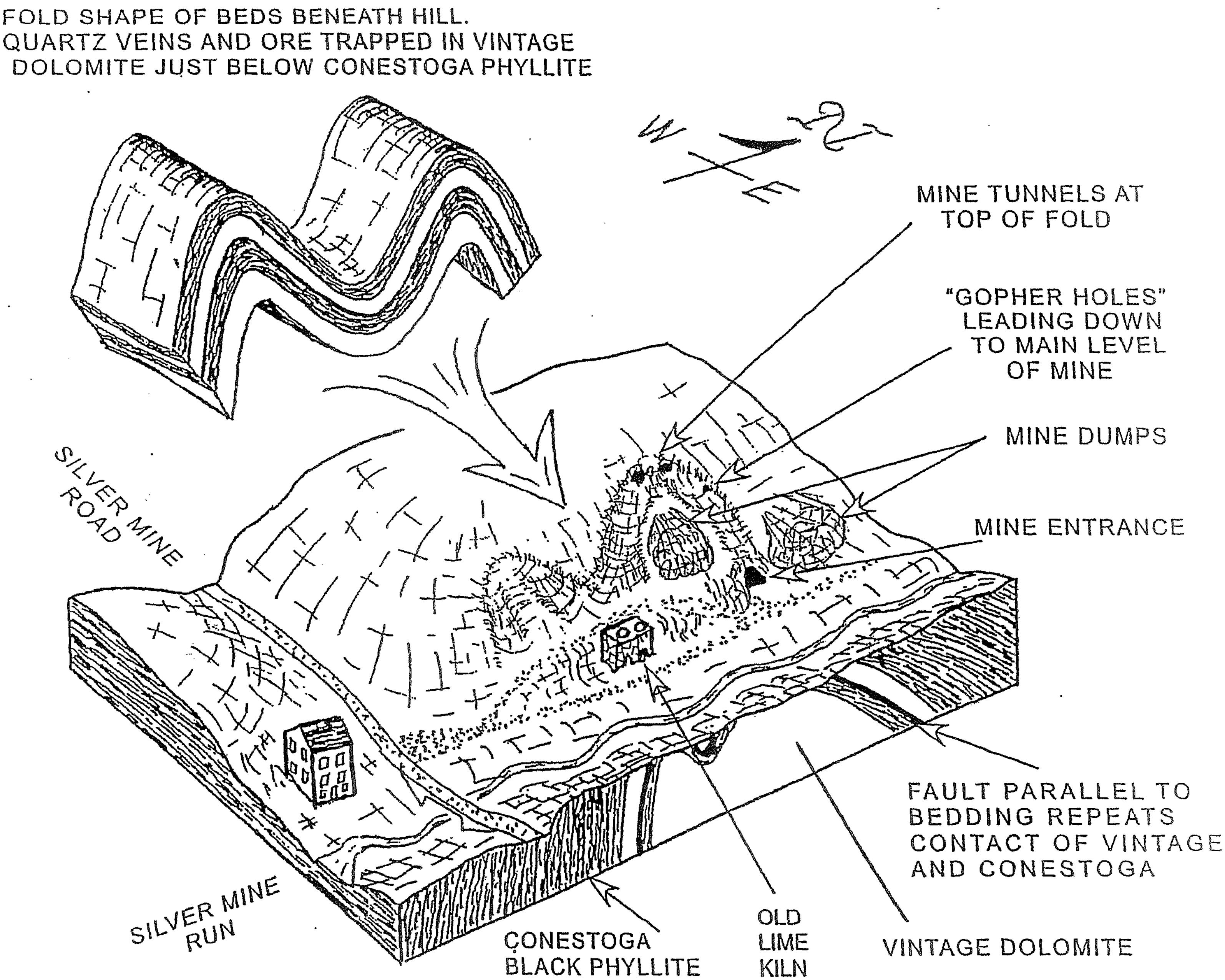


Figure 1: Overview of Silvermine area. The surface workings follow the outcrop line in the valley wall of two anticlines (upfolds)

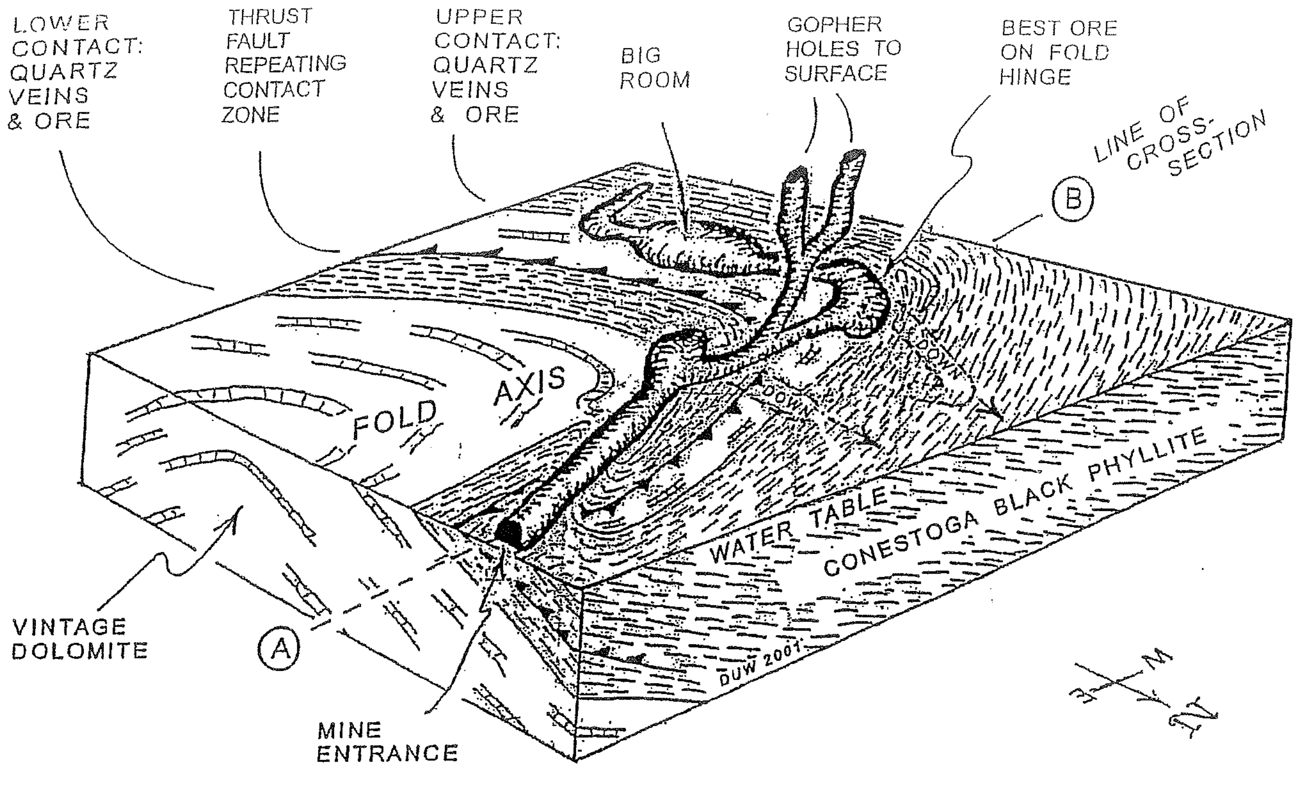


Figure 2: Underground workings (note that this view is from the northeast whereas figure 1 is from the southeast.) The workings follow the double or repeated contact of the Vintage Dolomite with the Conestoga Phyllite. Ore-bearing quartz veins were localized on these contacts near the crests of folds.

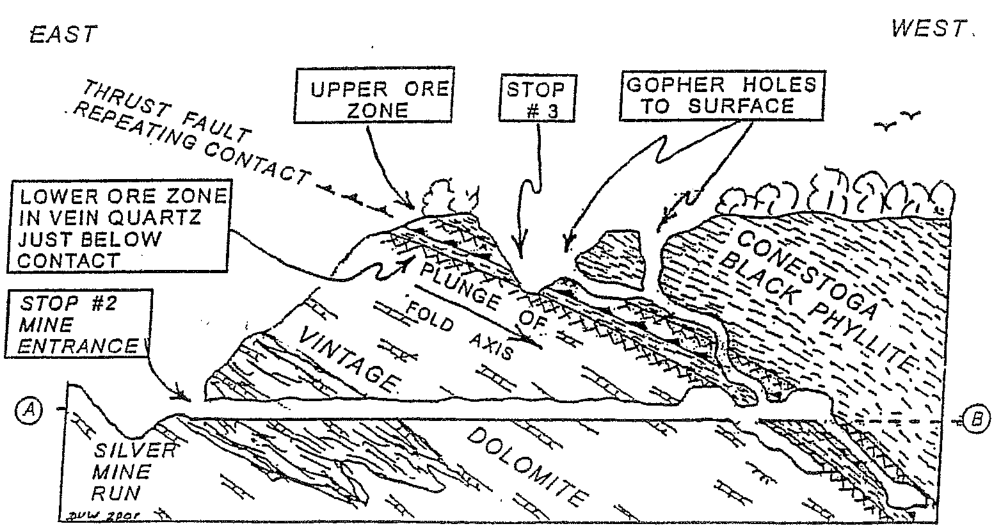
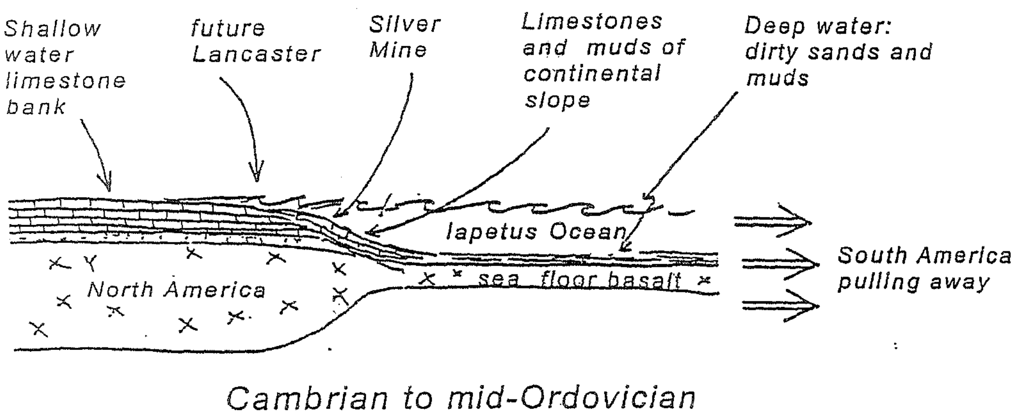


Figure 3: Idealized cross section of the mine workings from east to west.



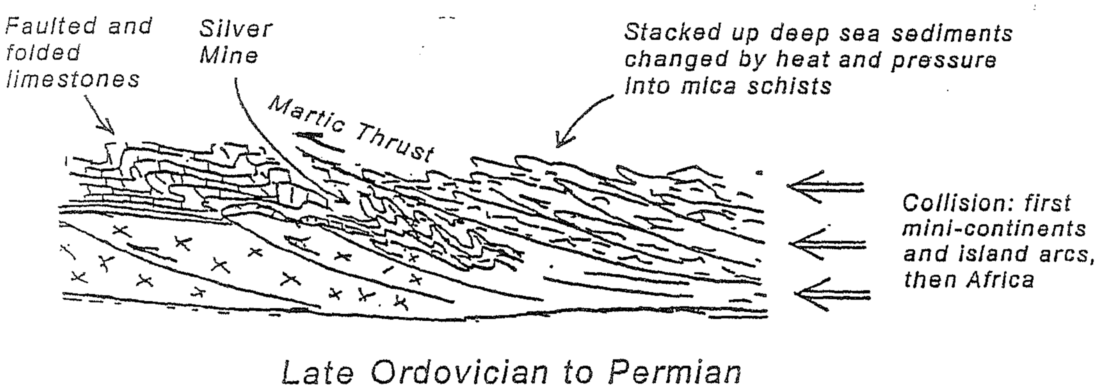


Figure 4:
Geology of the area about 500 -250 million years ago. The edge of North America lay in the Lancaster area as a shallow-water limestone bank with the present mine area on the submarine slopes leading off into deep waters to the south. Subsequently, the collision of Africa telescoped and folded these rocks several times.

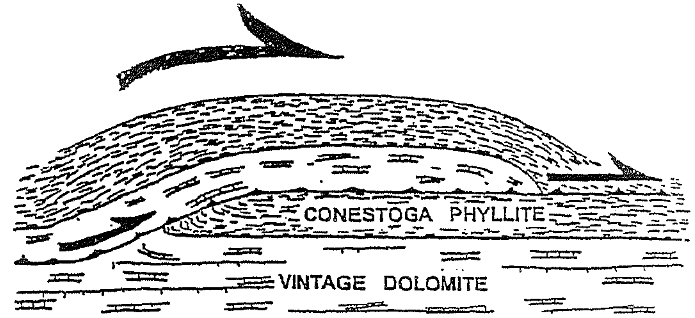


Figure 5: Method of repeating the contact of Conestoga Phyllite over Vintage Dolomite.

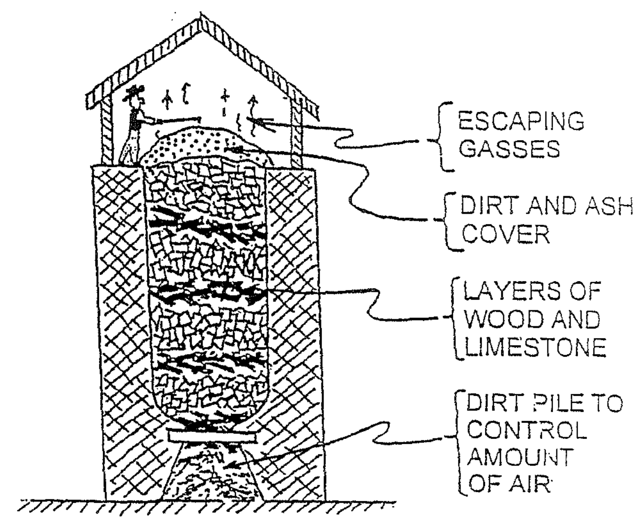


Figure 6: Operation of a typical lime kiln.