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Hydrogeological Problems and Their Resolutions at the Friedensville Mine

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The Friedensville orebody is situated in Upper Saucon Township, Lehigh County, Pennsylvania, approximately five miles southeast of the city of Allentown, and four miles south of the city of Bethlehem.

The Friedensville area, physiographically, is located in a small reentrant, known as the Saucon Valley, of the Great Valley Province into the Reading Prong of the New England Upland. The Saucon Valley, itself, is a lowland somewhat oval shaped approximately eight miles long and four miles wide, surrounded by ridges except where it is connected with the Great Valley through a break in the rim, known as Saucon Gap.

The floor of the Valley is underlain by lower paleozoic dolomites and limestones. The area is one of low relief possessing numerous sinkholes with an average elevation in the Valley of approximately 375 feet above sea level. Exploration drilling revealed and mine excavation has confirmed fractured and weathered ground in excess of 1,000 feet below the Valley floor. These characteristics have resulted in considerable porosity and permeability which developed over the eons establishing a very complex underground drainage system.

Zinc ore at the Friedensville Mine occurs in the lower part of the Beekmantown formation of Ordovician age. The ore is associated with a westerly plunging, asymmetrical anticline, overturned to the north, with present mining and development along the south limb.

The mineralogy is simple, consisting of sphalerite and pyrite with dolomite and quartz as gangue minerals.

Mining of zinc ore in the Saucon Valley dates from 1855, following original discovery in 1845 at the site of what later became the Ueberroth Mine.

The ore outcropped on surface which enabled four open cut pits: the Ueberroth, Old Hartman, Triangle and Correll to begin mining operations during the succeeding years.

As the depth of the quarry increased, recourse was made at the Ueberroth to mine underground which finally reached an approximate depth of 300 feet.

Excessive volumes of water were encountered due to extensive seepage through the highly fractured and weathered country rock, and in an endeavor to overcome this difficulty, the largest Cornish pump then in existence was installed at the mine.

The following is an excerpt from an article entitled, "History of Lehigh County, Pennsylvania" published in 1884:

> "Various pumping engines were introduced from time-to-time, but none that was equal to the work assigned to it until 1872, when "The President", a mammoth engine, was erected and put in operation, and which realized in a full measure the expectations of the Company, as it easily and speedily rid the mines of water. As this is the largest engine in the world, a description of it may not be uninteresting.
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> It is a vertical condensing engine, ten feet stroke, with a cylinder of cast iron one hundred and ten inches in diameter, and weighing forty tons. It has two flywheels thirty-five feet in diameter, weighing ninety-two tons apiece, four walking-beams weighing

> twenty-four tons apiece, twenty-six other pieces weighing over seven tons apiece, while the nut, made of steel, which secures the piston rod to the cross-head, weighs eleven hundred pounds. The total weight of the engine is six hundred and sixty-seven tons. Sixteen boilers supply the steam for it, it has three thousand three hundred horse-power, and is capable of raising seventeen thousand gallons of water per minute from a depth of two hundred and twenty feet."

By 1893, all mining ceased in the area, due to high cost of production, adverse water conditions, expiration of patents for zinc oxide manufacture and competition with the high grade ores from the New Jersey area.

During the succeeding years, The New Jersey Zinc Company acquired title to the properties and an extensive program of prospect drilling and hydrologic investigation was continued intermittently to delimit ore occurrence and study the problems resulting from underground water.

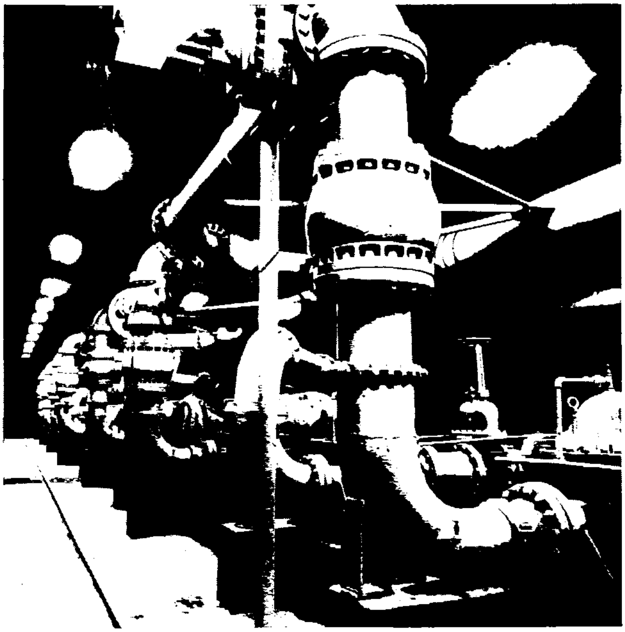
It was not until 1945, the decision was made to locate the new Friedensville shaft and in 1947 preliminary operations were initiated.

Early in 1948, ground was broken for the new shaft. The finished cross section of the steel lined and concrete reinforced shaft is 20 feet - 6 inches by 13 feet. It was decided that sinking would be accomplished by pressure grouting the ground surrounding the shaft and excavation would descend through an impervious zone.

During excavation of the shaft, however, outbreaks occurred at 75 feet, 146 feet and 247 feet below the collar and flooding was allowed to fill the shaft to ground water level for stabilization preparatory to casting underwater plugs by the Prepakt method.

Shaft stations and pump stations were excavated as the shaft was sunk to a depth of 1260 feet.

In 1971, after more was learned about the orebody, the shaft was deepened to a final depth of 2070 feet. Bulkhead doors were provided to protect the shaft and new pumping facilities were installed to increase the capacity from 22,000 gallons per minute to 40,000 gallons per minute with room for a maximum of 50,000 gallons per miute.



418 Level Pump Station

It was not until January of 1958, that development work and drawdown of the water table permitted mining to commence. The method of mining is best described as modified open stope. Basically, mining is performed in the following manner:

> A -20% decline is driven along the hangingwall following the approximate plunge of the orebody. At 30 foot vertical intervals, horizontal entries are driven from the decline along the hangingwall contact outlining the orebody.
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> Stopes 37½ feet wide are advanced from the hangingwall across the orebody to the footwall leaving pillars 35 feet wide by 60 feet long for support. This procedure is repeated advancing downward on the orebody.

Mining is accomplished through the use of mobile diesel powered equipment. All mine development work and stoping follows established test hole patterns with followup grouting procedures when required. In areas of suspected water potential, long hole test drilling of 100 or more feet is undertaken using a diamond drill or a mobile mounted 5 inch rotary percussion drill.

20 Ton Truck Being Loaded
By a 8 Yard LHD

On Tuesday, February 17, 1976, a diamond drill crew was test drilling at the 1170 hangingwall drift in an area where production had been suspended for approximately a month and a half due to ground water conditions. An attempt was being made through this drilling to learn more about the areas water source and its potential.

At approximately 9:00 P.M., the diamond drill crew heard a loud report from the adjacent stope. The two man crew made a quick investigation of the noise and discovered a large flow of water emanating from the upper left corner of the rib-back juncture near the stope's face. Immediately, the crew notified supervision and at once predetermined emergency plans were put into effect. During the night, the entire staff was called in for emergency assignments. The following morning corporate officials, federal and state regulatory agencies were notified of the water outbreak.

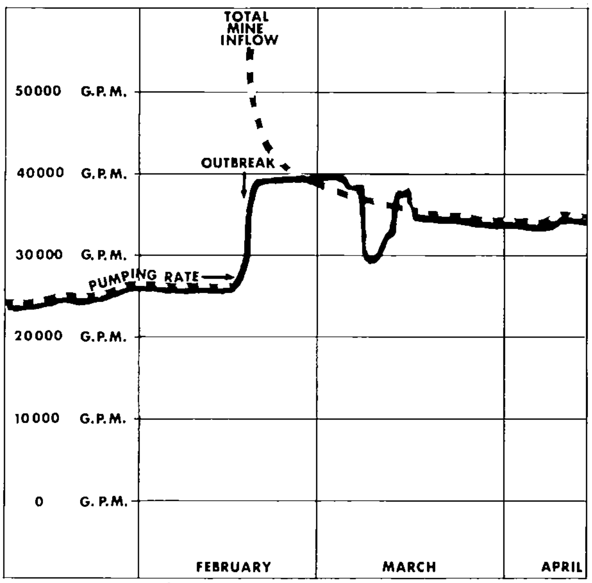
The Outbreak

Measures were taken the following day to establish maximum pumping plant efficiencies, methods to measure water inflow, availability of water storage in the lower mine levels, monitoring of the water table, measuring the underground filling rate, and collecting samples of the mine water inflow for analysis.

The Engineering Department established that the rate of inflow from the outbreak was nearly 35,000 gallons per minute. This flow, combined with the existing mine discharge of 26,500 gallons per minute, totaled approximately 60,000 gallons per minute or 86,400,000 gallons per day.

It is of interest to note that under the existing conditions it was quite difficult to measure an inflow of this size. However, personnel from the Engineering and Geology Departments utilized all measurements available and projected that the high water mark would be reached very early in the morning of February 25. Actual cresting occurred at 4:30 A.M. that morning after the water had risen well into the 1170 level. At 7:00 A.M., the water for the first time was going in a positive direction.

As the inflow dropped off and the mine water receded, the final bulkhead door on the 1850 level was opened on April 14, 1976.

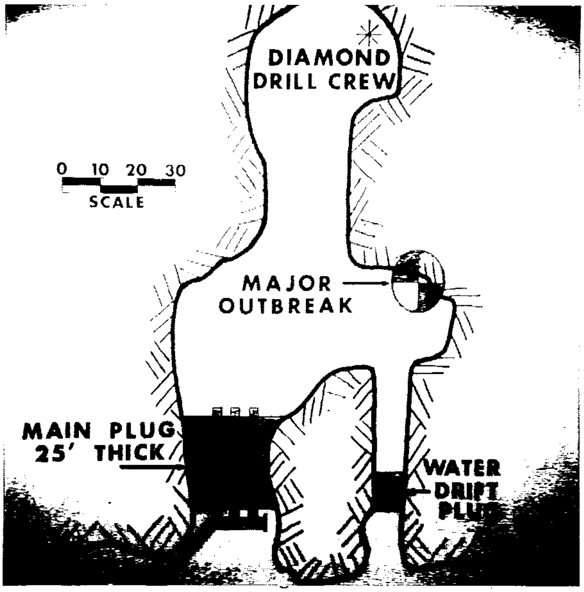


Inflow vs. Pumping Before and After the Outbreak

While the mine was being dewatered, the staff at Friedensville was busy studying ways to control the free flowing water. It was decided that concrete plugs, constructed with piping and valves would be used for water control.

A diversion drift measuring 50 feet long by 8 feet wide by 8 feet high was driven to intercept the water near the base of the outbreak. Upon completion of this drift, the primary water route was then prepared for installation of the first concrete plug. This plug which measures 25 feet long by 21 feet wide by 15 feet high was filled with coarse aggregate and then injected with sand and cement. Through the base of the plug, three - 20 inch pipes with valves were provided to carry the water.

After completion of the first plug, the water was allowed to flow through the 20 inch pipes and diverted away from the diversion drift. The small water drift was then prepared for construction of a 10 foot long solid plug.



Plan View Of The Outbreak Area

Both plugs were pressure tested and grouted where necessary. The final phase of this project included installation of a 30 inch pipe line which carried the water to a system of water raises discharging into the sumps of the 1520 level pump station.

Although this appears to be an appropriate time to conclude this paper, there was one other significant incident that occurred in June of 1976. This event took place near the completion of the shaft deepening project which was mentioned earlier. Details, however, are quite complex and are discussed at this time in the simplest manner.

After the installation of the new ore handling facilities in the new shaft section, work began on removing the old ore handling facilities (crusher, skip loading pocket). This work was scheduled to be completed in approximately one week. During this one week period, production hoisting was stopped but mining continued and the new ore pass was being filled. While these changes were being made, all bulkhead doors on the lower levels were closed and secured.

Our problem began on a weekend with a call from the mine that the 1520 level pump station had automatically shut down due to a lack of water. After a quick inspection of the mine, this was ruled out. Returning to the shaft to inspect the 1520 level pump station, we learned from the pumpman that the pumps were back on line and the situation appeared normal.

Unfortunately, the situation was anything but normal. As the evening progressed into early morning, the 1520 level pumps began to lose their prime, due to an unknown blockage at the sump suction screens. Suddenly, we were flooding the 1500 level. Extra help was called in and a backflush line was installed from one of the main pump discharge columns directly to the sump suction pipes.

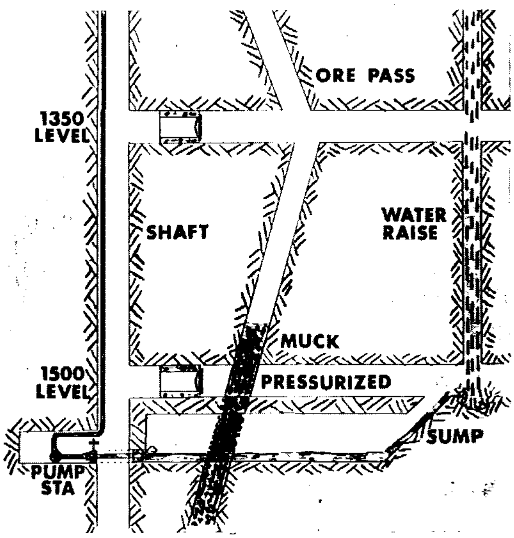
The station was completely shut down as we opened the valves on the backflush line allowing the water to pass through the suction screens, in order to clear whatever blockage was present. Our plan worked and the pumps began to draw down the excess water.

Key personnel waited anxiously, realizing that the 1500 level bulkhead door had to be opened as soon as the level was dewatered for inspection of the sumps and suction screens.

At the proper time, the ditch valve on the bulkhead door was opened, which produced a blast of water and air; valves located near the top of the bulkhead produced a blast of compressed air. The latches on the bulkhead door were released but the door wouldn't budge.

For the first time, we realized what had taken place behind the door to cause the emergency. Thirty thousand plus gallons per minute of water was falling down a vertical raise from the 1350 level to the 1500 level sumps. The water raise was acting as an air pump, and the filling of the ore pass with crude ore above the level blocked the only exit for the increased volume of air.

Our system for measuring water depth in the sumps and activating the pumps is accomplished automatically through the use of a probe tank located in the pump station. This tank is connected with the sumps and normally the water elevation in the probe tank is the same as the sump, regulating the demand for pumps as needed. However, during the time of this incident, the air pressure behind the bulkhead door was much greater than atmospheric pressure. The water elevation in the probe tank was much higher than the actual sump level, causing the pumps to pull the sumps lower than desired. In fact, it was later felt that the suction screens were exposed. When this occurred, our suction screens became partially blocked by mud and plastic materials which made their way into the sumps.



Idealized Section Of The Pressurized Area

The problem causing the condition was known, but opening the door was still another matter since we couldn't budge the door. After a harrowing several hours of jacking the door open with one - 50 ton and two - 35 ton jacks, along with fighting wind and a muddy water spray, the door was finally opened wide enough for atmospheric equilibrium. With this, another crisis ended.

It is needless to say that the challenges at times seemed to be overwhelming for the small staff at the Friedensville mine. Their devotion, personal drive, and professional abilities will always be recognized as an outstanding accomplishment.