1973

Field guide to the Friedensville Mine of the New Jersey Zinc Company : in conjunction with the Northeast Section Meeting of the Geological Society of America at Allentown, Pennsylvania, March, 1973

R. W. Metsger

Geological Society of America. Northeastern Section.

A. H. Willman

C. G. Van Ness

FIELD GUIDE

TO

THE FRIEDENSVILLE MINE

GW The New Jersey Zinc Company
A GULF + WESTERN COMPANY
NJZ

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By

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FIELD TRIP

SCHEDULE

March 21, 1973 8:00 p. m. -- Orientation Meeting

Identical Schedules for March 22 and 23, 1973

8:00 a.m.	Leave George Washington Motor Inn
8:25 a.m.	Arrive at Friedensville On the Bus, the group will be divided into two sections for both geology and rock mechanics.
8:40 a.m.	Section A underground, B surface
10:00 a.m.	Return to Change Area
10:15 a.m.	Section B underground, A surface
11:30 a.m.	Return to bus
12:00 noon	Return to George Washington Motor Inn

It is suggested that field clothes be worn on the trip. Hard hats, safety glasses, and high (16") waterproof boots are required underground.

ROAD LOG

Miles	
0.0	George Washington Motel
0.1	Turn east onto Route 22.
1.1	Bridge over Lehigh River.
	The quarrying operation to the right is reclaiming a large blast furnace slag dump. The crushed and sized product is being used for road metal.
2.4	Approach lights for Allentown-Bethlehem-Easton Airport. A small "Valley Iron" pit was mined near the end of Runway 24. This pit exposes Allentown dolomite.
3.9	Turn south onto Pennsylvania Route 378.
5.9	Cambrian Allentown dolomite outcrop, showing interbedded dark gray shale and medium gray dolomite.
	The tall black and white building north of the road is Martin Tower, the recently opened corporate headquarters of the Bethlehem Steel Corporation.
	To the east on the hill is Moravian College, North Campus.
6.4	Outcrop of Allentown dolomite.
6.8	Downtown Bethlehem to east, including historic area and Central Moravian Church.
6.9	Hill to Hill Bridge, which passes over Lehigh River.
	To the east along the river is the main plant of the Bethlehem Steel.
	The campus of Lehigh University can be seen along the flank of South Mountain, to the southeast. The group of modern buildings on the crest of South Mountain are the Homer Research Center of Bethlehem Steel.
7.7	Traffic light--follow Pennsylvania Route 191.
7.9	Multiple Intersection--follow Route 191 on Wyandotte St. Begin to climb flank of South Mountain, the core of which is composed of Pre-Cambrian mixed gneisses believed to be Grenville aged.

Miles	
8.9	Outcrop of mixed gneiss, largely quartz-oligoclase-muscovite gneiss previously called Byram gneiss.
9.0	Intersection with Mountain Drive west, leading to Homer Research. This is at the crest of South Mountain.
9.9	Intersection with Black River Road.
10.7	Large sinkhole developed along Route 191 in the Beekmantown dolomite.
11.4	Right turn onto Saucon Valley Road.
11.6	Stop sign, continue on Saucon Valley Road, pass Friedens Church, constructed in 1839. A few hundred feet northwest of the church are the open cuts mined in the late nineteenth century, which will be visited during the trip.
12.1	Turn south onto Camp Meeting Road.
12.4	Left turn into parking lot of Friedensville Mine.

ACKNOWLEDGMENTS

The writers would like to thank The New Jersey Zinc Company for allowing both the surface and mine inspection and publication of this guide.

Special thanks are due the following New Jersey Zinc Company personnel:

Mr. R. L. Wood, Vice President of Mining
Mr. H. B. Wiles, Manager of Friedensville

for being the hosts and

Miss Eileen Balogh, Secretary to the Mining and Exploration Departments

who typed the manuscripts.

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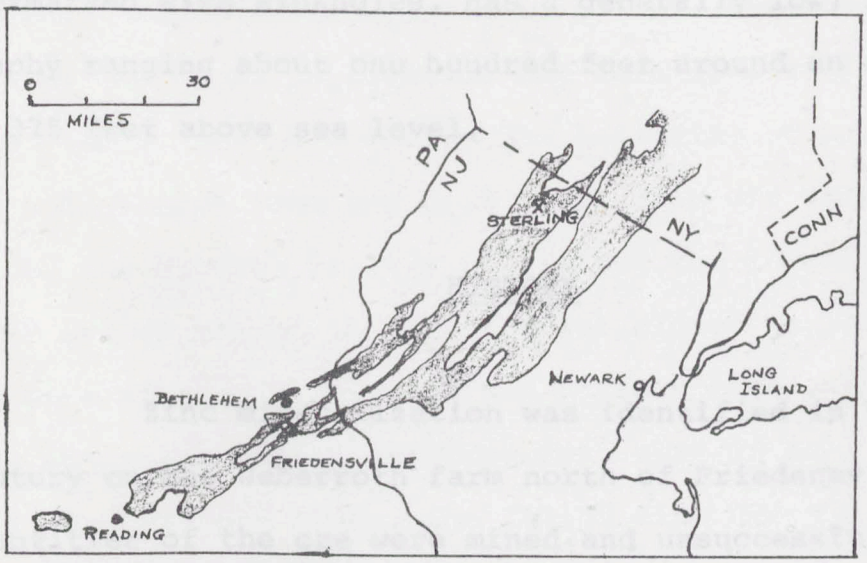

Figure 1. Index map showing location of zinc mines relative to Pre-Cambrian rocks(shaded).

LOCATION AND PHYSIOGRAPHY

The New Jersey Zinc Company's Friedensville mine is located in the valley of the Saucon Run Creek about four miles south of Bethlehem, Pennsylvania. The surrounding ridges of Pre-Cambrian crystalline rocks, breached only on the east, rise about five hundred feet above the valley floor. The latter, pockmarked with sinkholes, has a generally low, rolling topography ranging about one hundred feet around an average elevation of 375 feet above sea level.

HISTORY

Zinc mineralization was identified in the nineteenth century on the Ueberroth farm north of Friedensville. Small quantities of the ore were mined and unsuccessful attempts were made to treat it. Finally a process of producing zinc oxide was developed and in 1853 Samuel Wetherill erected furnaces at Augusta, now south Bethlehem. Production started from the Ueberroth mine in the fall of the year at the rate of 2,000 tons of zinc oxide per year. In 1855 the Pennsylvania and Lehigh Zinc Company was formed to mine and process these ores. The name of the company was changed in 1860 to the Lehigh Zinc Company which subsequently acquired control of all of the mines and operated them continuously until 1876.

For a period during the 1870's a Cornish pump, reputedly the largest built, operated at the Ueberroth mine pumping approximately 12,000 gallons per minute from a depth of approximately 250 feet. The pump was called "The President" and history or romance has it that President Ulysses S. Grant visited the mine and christened the pump when it was put into service. The serious hydrologic problem disclosed by the pumping inhibited exploration and development of this area for many years. Too much water, the depletion of oxidized ore, and competition from the high grade zinc ore from New Jersey forced the closing in 1876 of all but the Correll mine. The first era of mining in the district closed in 1893 with flooding of the Correll and New Hartman mines. The New Jersey Zinc Company acquired the Ueberroth mine in 1899 through merger with the previous owner, the Lehigh Zinc Company. Additional property was purchased intermittently thereafter.

Exploration by The New Jersey Zinc Company commenced in 1899 and was conducted intermittently until the mid-1930's. Extensive diamond drilling during the period 1937 to 1942 proved up tonnage and grade within the previously delineated ore outlines. Hydrologic studies and pumping tests were conducted to reduce the uncertainties involved in resuming exploitation of the deposits. Development was started in 1945 and shaft sinking commenced in 1947. The shaft was bottomed at 1,261 feet in August of 1952. Development work and draw down of the water table were sufficiently advanced

by early 1958 to permit the start of production. Since that time approximately 7½ million tons of ore have been mined.

MINERAL DEPOSITS

The economically important mineral at Friedensville is sphalerite. Together with cemented pyritic, siliceous and dolomitic detritus it forms the matrix of a breccia. No consistent zoning or segregation of the sulfide minerals is evident.

Two distinct breccia types, not everywhere mineralized, are present. Both are products of solution and collapse in a zone about 100 feet thick and of large areal extent near the base of the Beekmantown formation.

As seen in the mine and in drill cores the bedding in the hanging wall rock has slumped. Well above the ore the beds are undisturbed. As the ore is approached there is a gradually increasing bedding plane separation with a concomitant rupture of the individual beds. The "mortar" in the resulting brickwork pattern is generally honey-colored sphalerite, pyrite, and dolomite in diverse proportions.

Further down from the hanging wall the beds are completely disrupted. Fragments of rock, ranging greatly in size, have been rotated and transported so that no semblance of the original bedded structure remains. The large interstices are filled primarily with sphalerite, pyrite, and carbonate,

again in various proportions. The sphalerite is commonly medium to dark gray in color so that much of the best ore resembles barren rock to the unpracticed eye.

The footwall of the orebody is normally much more sharply defined than the hanging wall with the coarse "rubble" breccia lying directly on barren, undisturbed, often shaly dolomite. In a few areas the brickwork "crackle" breccia, so representative of the hanging wall, is also present in the footwall but these occurrences are atypical.

Given the presence of sphalerite, the grade of the ore is, in large measure, dependent on the interstitial volume. Hence, the crackle breccia is a low grade ore type while the rubble breccia comprises the areas of high grade ore. Because the bedding plane separation in the crackle breccia diminishes toward the hanging wall, that contact is an assay contact. Generally speaking, the footwall contact is sharp.

Diamond drilling in areas outside the known orebodies has revealed that the breccias are much more extensive than the sulfide mineralization. Where barren the matrix is composed of the insoluble minerals of the formation cemented with carbonates and to a lesser degree silica. The stratabound nature of the deposits and the apparent lack of structural control of the mineralization leads to the conclusion that the orebodies were formed prior to the deformation of the area.

White dolomite and quartz filled joints present in the breccia fragments, but not extending into the matrix, have

been interpreted (Callahan, 1968) to indicate that the matrix was incompetent relative to the fragments at the time of regional deformation. However, a case can also be made for that fracturing and cementation to have occurred prior to the solution collapse stage.

If, as seems probable, the mineralization antedates the tectonism of the area, the ore deposition took place some time before the end of the Ordovician period.

The orebody and the country rock have been altered extensively by ground water activity. Oxidized zinc in the form of hemimorphite and to a lesser extent smithsonite, occur with ferruginous clays in the deepest levels of the mine. Limonitic saprolites adjacent to the zinc orebody were mined for iron during the 1800's. Drilling has shown these to have roots as deep as 1,700 feet.

In a geological discussion of the rocks of the Friedensville area it should be noted that much of the data has been collected in the immediate vicinity of the mine. The rocks do not crop out in Saucon Valley to the extent that they do in other areas and therefore a lot of the information is biased, having been obtained in the area immediately adjacent to the mineralization. To what extent some of these features are common in similar geologic environments remote from mineralization is indeterminate.

STRATIGRAPHY

The zinc deposit at Friedensville occurs in the lowermost part of the Beekmantown formation. The carbonate unit of lower Ordovician age as shown in the generalized stratigraphic column taken from the Graton Sales Volume is locally termed Beekmantown. The formational names are not those used in the most recent publications by Drake. The terms Tomstown and Beekmantown have largely been supplanted and are local names. The youngest rocks in Saucon Valley are Triassic in age, the Triassic border fault being approximately two miles south of Friedensville. In the immediate Saucon Valley area the youngest rocks are the Martinsburg shale of middle Ordovician age. Drake (1970) mapped the Martinsburg in a recumbent antiformal fold near Lanark approximately two miles west of Friedensville.

An erosional unconformity separates the Martinsburg from the underlying Jacksonburg. The Jacksonburg of middle Ordovician age is the cement rock unit. Beneath the Jacksonburg and separated by an erosional unconformity, with relief of tens of feet, is the ore-bearing Beekmantown horizon. Conformably below the Beekmantown in descending sequence are the Cambrian formations locally designated Allentown and Tomstown. The Tomstown is shown as being equivalent to the Leithsville on the 1961 Pennsylvania geologic map. Both the

Allentown and Tomstown are dolomitic. Below the dolomite units is the lowermost Paleozoic unit, the basal Cambrian Hardyston quartzite. The Hardyston is unconformable with the underlying Pre-Cambrian rocks which are believed to be Grenville age.

The Jacksonburg, Allentown, Tomstown, and Hardyston formations are non-ore-bearing and are consequently not as well known as the Beekmantown. The Beekmantown is limey dolomite with local zones of limestone ranging through the various shades of gray to black. Drake subdivides the Beekmantown into the lower Rickenbach unit and the upper portion called the Epler unit. This break between the Rickenbach and the Epler is thought to occur as shown in the stratigraphic column by CM, the Callahan Marker.

The top and bottom boundaries of the Beekmantown are placed at easily recognized lithologic changes. The bottom is placed at the base of the Evans Marker (EM), a medium to dark gray thinly bedded dolomite that is locally a limestone characterized by thin anastomosing shale partings (Callahan). The Allentown immediately beneath is a light medium and dark gray dense saccharoidal dolomite. The upper Beekmantown is characterized by light colored interbeds of limestone and dolomitic limestone all of which contrast sharply in appearance with the overlying dark gray to black shaly limestone of the Jacksonburg separated by a strong erosional unconformity.

Thickness	System	FORMATION	MEMBER NAME	MEMBER FEET	LITHOLOGY
	ORDOVICIAN	MARTINSBURG			Shales and slates
700'		JACKSONBURG Oj	Cement Rock	300'	Thin-bedded, highly argillaceous limestone.
			Cement Limestone	400'	Thin-bedded, argillaceous limestone.
1225'		BEEKMANTOWN Ob		180'	Limestone and Limy Dolomite.
			U.Sg	200'	Limestone and Dolomite, local sandgrains.
				300'	Limestone and Dolomite.
			C.M.	125'	Dolomite, local sandgrains.
				100'	Light Gray Dolomite
			Thc.	200'	Dolomite, local breccia, Ore horizon.
			E.M.	120'	Shaley Dolomite or limestone.
1600'	CAMBRIAN	ALLENTOWN Co		130'	Dolomite, local shale partings.
				10'	Dolomite, local sandgrains.
				360'	Dolomite, Some intervals resemble the local layers Sandstone, Oölites and Cryptozoa.
				1100'	Interbedded cryptozoan reefs, oölite beds, shaley beds, and sandstone layers. Result of "cyclic" deposition.
900'		TOMSTOWN Ct			Massive dolomites interbedded with calcareous shales. Occasional sandstone beds. Oölites near top.
200'		HARDYSTON			White to purple grits becoming locally arkosic to jaspery.
	PRE-C	PRE-CAMBRIAN P€			Gneiss, schist, and marble.

FIG. 2. *Generalized Stratigraphic Column Lehigh and Saucon Valleys Pennsylvania.*

From Graton Sales Volume

There is an overall paucity of distinctive features in the section which could serve as key beds. Repeated studies have failed to reveal key beds such as those which are so numerous and useful in the Tennessee and Mississippi Valley districts.

A fossil locality found in drill core about six feet stratigraphically below the base of the Evans Marker was identified by Josiah Bridge (private communication) as Ophileta levata and another as probably referable to Gasconadia. Bridge commented that "Both forms are characteristic of the Stonehenge and equivalent of the Tribes Hill limestone of New York. We consider these forms to mark the horizon at or very close to the base of the Ordovician." Callahan collected several small fossils from drill core penetrated in the supposed Beekmantown age rocks which were identified by Bridge as cephalopods and gastropods a form of which occur in Stonehenge and lower Nittany divisions of the Beekmantown.

Several distinctive sedimentary features separate the Friedensville ore deposit from those Ordovician deposits described in eastern and middle Tennessee and in the upper Mississippi Valley district of Wisconsin and Illinois. As noted Friedensville lacks the numerous distinctive key beds and varying sedimentary features that are present in both of the other early Ordovician mineral deposits. The composition of the breccia fragments at Friedensville differs significantly from the composition of those breccias in eastern Tennessee. At Friedensville no dolomite fragments have been found that

could be identified from another superjacent horizon such as the Jacksonburg. This is not true in eastern Tennessee where fragments recognizable from horizons above the ore breccias have been found.

STRUCTURE

Knowledge of the structure of the Saucon Valley is quite generalized because of the paucity of rock outcrops. The structure in the vicinity of the mine was determined from exposures in the open pits, and underground workings together with drill hole information. The structure in the vicinity of the mine is southwesterly plunging asymmetrical anticline with a vertical north limb at the Ueberroth pit and a moderately inclined south limb exposed in the mine area. The old Hartman mine is on the crest of the anticline. The syncline to the north of the Ueberroth pit is bounded on its north side by the Colesville fault and Pre-Cambrian crystallines of South Mountain. Callahan notes the following, "Fracturing is prominent in the open pits and in the mines. The most prominent attitude is north 40° to north 60° east with dips ranging from 75° northwest to vertical. Some of the fractures are along ore boundaries. Within the range of mining most fractures are weathered and consequently quite obvious. Some small scale faulting is also present in the orebody but whether it is tectonic or an expression of solution collapse is debatable."

"Fracture cleavage in the beds and flow cleavage in the mineralized interstices of the breccia fragments while present locally is less prominent in fresh faces underground than in weathered exposures on the surface. It is the writer's opinion that structure per se did not control the localization of ore inasmuch as ore deposits are present on all elements of the fold and are not related to faulting. At most, tectonics merely deform horizontally disposed orebodies and determine their subsequent pattern and attitude of occurrence. Because the Taconic revolution is the earliest post-Beekmantown tectonic event in the area and the sulfide minerals themselves show evidence of deformation as well as indifference to structural setting, it is suggested that mineralization is pre-Taconic, that is Ordovician in age."

Drake (1970a) describes the structure of Saucon Valley as complex. "In the Saucon Valley, site of the Friedensville zinc mine rocks of the Musconetcong Nappe are restricted to the east edge of the valley, and are separated from all other rocks to the west by the Black River fault, an apparent cross structure that is not understood completely at present." Drake suggests that at least two tectonic units are present in the valley, with thrust sheets of both the Musconetcong Nappe and the Lyons Station--Paulin's Kill Nappe in fault contact.

Drilling by The New Jersey Zinc Company along the northern border of Saucon Valley has revealed the Colesville

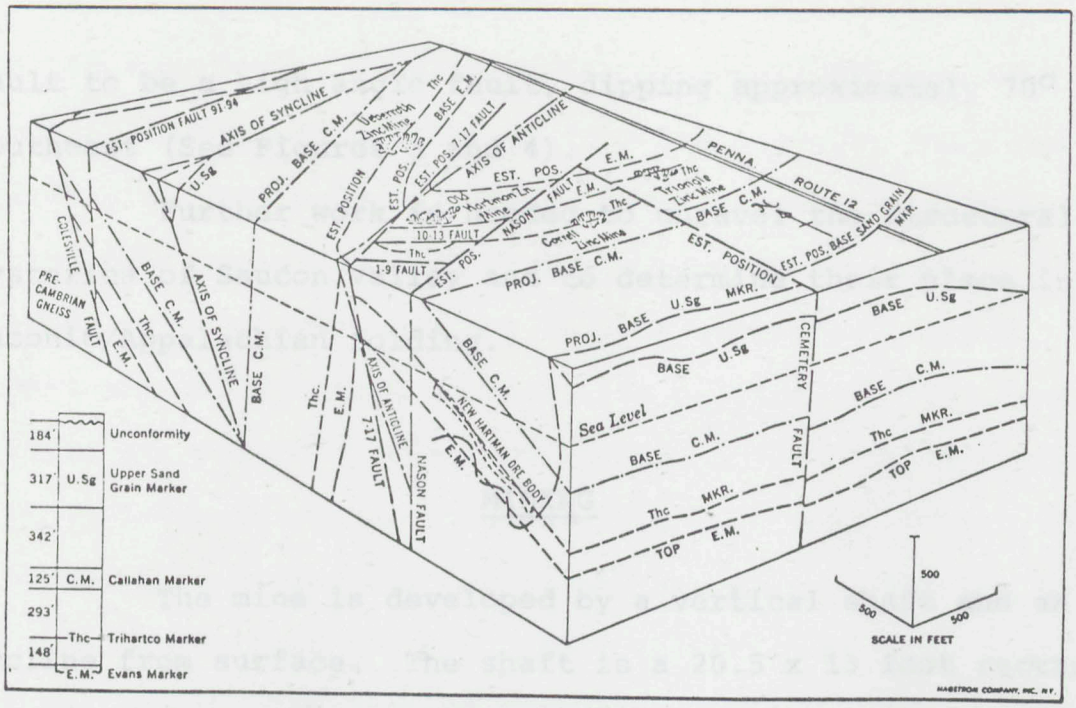

FIG. 3. *Block Diagram, Friedensville Mine Area Friedensville, Pennsylvania.*

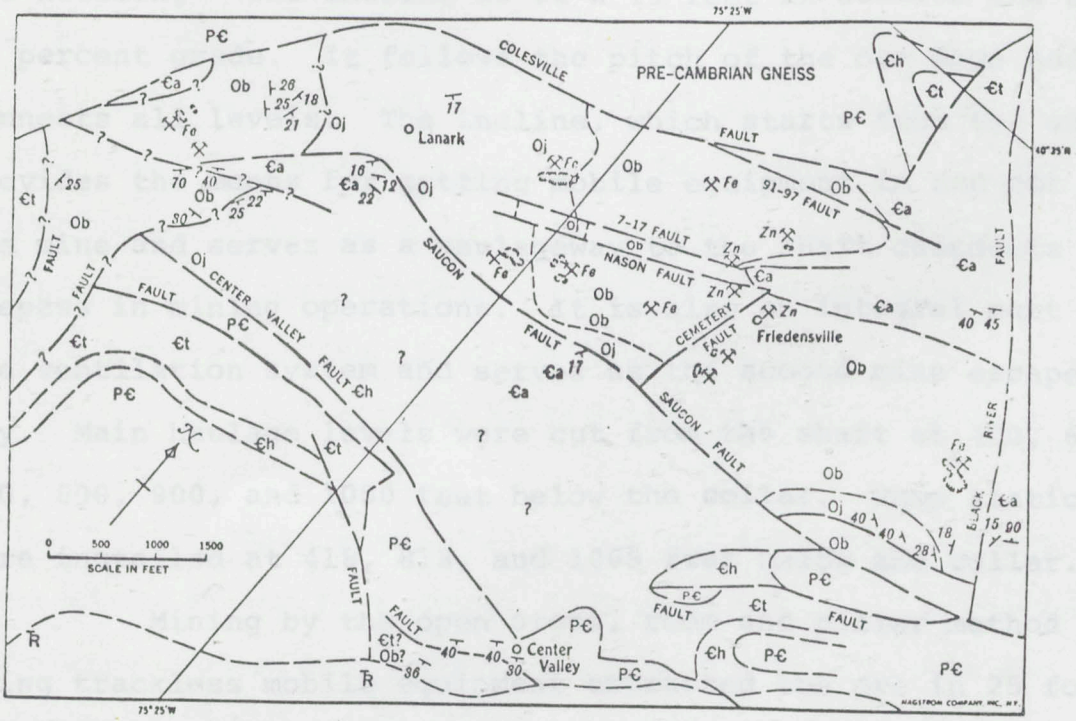

FIG. 4. *Geologic Map—West End of Saucon Valley Lehigh County, Pennsylvania.*

fault to be a high angle fault, dipping approximately 70° southeast (See Figures 3 and 4).

Further work is needed to unravel the structural mysteries of Saucon Valley and to determine their place in the Taconic/Appalachian folding.

MINING

The mine is developed by a vertical shaft and an incline from surface. The shaft is a 20.5 x 13 foot rectangular concrete-lined opening with steel sets sunk to a depth of 1,261 feet. It has seven compartments as follows: two services, one escapeway, one counterweight, one service cage, and two ore hoisting. The incline is 15 x 15 feet in section and on 20 percent grade. It follows the pitch of the ore down and connects all levels. The incline, which starts from the surface, provides the means for getting mobile equipment in and out of the mine and serves as a haulageway to the shaft crosscuts and orepass in mining operations. It is also an integral part of the ventilation system and serves as the second mine escapeway. Main haulage levels were cut from the shaft at 400, 600, 700, 800, 900, and 1050 feet below the collar. Pump stations were installed at 418, 818, and 1068 feet below the collar.

Mining by the open stope, room and pillar method using trackless mobile equipment extracted the ore in 25 foot vertical slices or benches down to the 900 foot level. Below

the 900 foot level, extraction has been by 30 foot slices or benches. Crosscuts are driven from the incline, and laterals driven along the hanging wall to develop each benching level. Mining progresses downward from the uppermost portion of the orebody in successive benches forming stopes en echelon. Stopes are on 72.5 foot centers with pillars 35 feet thick. Pillars are square or rectangular depending upon requirements.

Operations at Friedensville have been severely influenced by hydrological and ground stability problems, both of which have their roots in the combination of structural and weathering phenomena of the Saucon Valley.

To provide information as a background for mine planning, a rock mechanics program was set up in 1964. Records of rock strain within the mine and subsidence of the surface have been kept since that time. Measurements are made at monthly intervals or more frequently as dictated by ground conditions. In addition to geodetic measurements, an acoustic seismograph was set up in 1970 to monitor rock fracturing in the mine. This has provided a continuous record of micro seismic activity since its installation.

From time to time in situ stresses are determined by overcoring.

Mine development below the 990 foot level is presently being directed toward a change of mining method from the room and pillar system to a totally supported system of cut and fill. Shaft deepening to a depth of 2,060 feet is also in progress

under contract by The Cementation Company of America. A 20 foot pentice separates the two sections of shaft to maintain protection and to allow production to continue as the shaft is deepened. Upon removal of the pentice at the completion of sinking, the shaft will be continuous vertically to a depth of 2,060 feet.

Mining is accomplished through the use of mobile, diesel driven equipment. Two and three drill jumbos with remote controls are used for drilling. Drill holes are charged with 40 percent gelatin type explosive and detonated electrically. Ammonium nitrate--fuel oil mixture is also used, water permitting. Broken ore is loaded into 20-ton Wagner telescopic shuttle trucks. Loading is done by three and one-half and five cubic yard front end loaders. Two aerial platform giraffes of 40 and 65 foot height are used for ground cleaning and roof bolting. Haulage is to the nearest main haulage level via the incline. Ore is dumped into the ore pass from the main haulage levels. Ore is drawn from the ore pass at the 1050 foot level and transferred by conveyor through a bulkhead door to the 1121 crusher station. Primary ore crushing to approximately four-inch size is done underground at this station, and the ore hoisted to the surface in two, six-ton skips operating in balance. Skip loading and hoisting to a bin in the headframe are automatic. Ore from the skip bin is crushed to one and one-quarter inch size in the headframe and conveyed to a 2,500 ton mill storage silo.

MILLING

The mill has a capacity of 2,500 tons per day, and concentrates the ore by the flotation process. A noteworthy feature of the milling operation is a continuous analytical system using an on-stream X-ray analyzer to monitor feed, tailings, and concentrate pulp streams for their zinc content. The system is a great aid for mill metallurgical control. Concentrates are hauled by truck to the company smelter at Palmerton, a distance of 28 miles. The gangue is discarded as tailings, used as mine backfill, or diverted to the limestone processing plant where the tailings are thickened, filtered, dried, air classified, and stored for sale as bagged or bulk dolomitic limestone.

Mine and mill are equipped to handle 2,500 tons per day of crude ore. Lack of sufficient underground work force has curtailed production below capacity. At normal production of about 2,000 to 2,200 tons per day, grade of ore milled is 6.4 percent and the concentration ratio is ten to one.

PUMPING & HYDROLOGY

Friedensville is probably the wettest mine in North America. Pump capacity is 31,000 gpm. All mining is below the water table and careful test holing of ground in advance of mining is mandatory.

Water encountered by mining is diverted by ditch to underground sumps with 400,000 gallons capacity each. Approximately 8,000 gpm are pumped directly to surface and the remaining 19,000 gpm are pumped in relays by pumps of lesser head from the 1068 pump station through 818 and 418 pump stations to the surface. Untreated mine water passes through three surface settling lagoons into Saucon Creek, a tributary of the Lehigh River.

All mine openings connected with the shaft are fitted with water-tight bulkhead doors. In times of power failure, or other pumping emergency, these doors are closed to protect the pump stations, shaft, and shaft stations from flooding. The doors have withstood several instances of flooding behind them to depths of 200 feet.

The Saucon Valley is a karst area. Surface diamond drilling has shown extensive weathering to depths of 1,700 feet in several holes. Mining, presently at a depth of 1,050 feet, has also outlined pockets or zones that are unmineable due to intense oxidation. Even in competent ground, the prominence of fracturing allows for free movement of water and establishes an elaborate underground plumbing system without discernible pattern.

Width of fractures varies from a fraction of an inch up to six inches or more. Most are filled with clay, sand, and fragments of rock and are water bearing. Flushing action washes out the fracture allowing water flow to increase.

In four such instances, the volume of flow increased, flooding the shaft during sinking operations above the 400 level. This has occurred several times in mining operations also with flows encountered in drifting reaching 15,000 gpm and occasional pump burdens at or higher than capacity.

Due to the company's pumping operation, the water table is depressed in Saucon Valley. In anticipation of this condition, at its own expense, the company arranged for the City of Bethlehem to extend water mains into Saucon Valley. From the basic system installed for the company by the city, Upper Saucon and Lower Saucon Townships' Water Authorities extended the system considerably. Financing the installation of the authorities' systems was accomplished by issuing long-term, low interest rate bonds arranged for by the company.

In remote areas of the valley, where no city water was available to residents, the company, at no cost to the user, provided two 1,000 gallon storage tanks together with the necessary pump hooked to existing house plumbing. Water from the City of Bethlehem system is delivered as required to these installations by tank truck at moderate cost. The arrangement, though not as satisfactory as direct pipeline service, is adequate for domestic use.

In areas of the valley served by the city and authority systems, fire protection is now available to the residents, an unusual feature in a rural, residential area.

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