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GROUTING AND SHAFT SINKING THROUGH WATER-BEARING GROUND

Authors

A.V. Ayugat, Jr., Shaft Superintendent
UNITED PARAGON MINING CORP.
J.H. Aquino, U/G Geology Head
UNITED PARAGON MINING CORP.
P. White, P.Eng., Grouting Specialist
MULTIURETHANES LTD.

Abstract

The Longos Gold mine is a 500 TPD underground, narrow-vein, gold mine located at Paracale, Camarines Norte, Philippines. Current mining operations are located on various levels to a depth of 240 m below surface. Sinking of the 4.27 m diameter Mainshaft commenced in 1981 to develop additional mining levels to a depth of 500 m below surface. In March 1983, shaft sinking operations encountered a waterflow of 850 GPM at a depth of 257 m which flooded the Mainshaft and disrupted shaft sinking operations. Recovery efforts by former mine owners were unsuccessful and shaftsinking operations were abandoned. In 1994, UNITED PARAGON MINING CORPORATION dewatered the Mainshaft to a depth of 240 m through underground development openings from adjacent mine workings. Preparations to stop the 850 GPM water flow into the bottom of the Mainshaft commenced in June 1995. Shaft bottom grouting operations commenced in January 1996. By September 1996, the shaft had been successfully grouted and sunk through water-bearing faulted and altered rock to a depth of over 300 m.

Introduction

The Paracale area of Camarines Norte, Philippines, has been an active gold mining region since 1925. The Longos Vein has been commercially mined by several mine owners since 1937. UNITED PARAGON MINING CORPORATION purchased the existing mining operations in 1990 and embarked on an aggressive exploration and modernization program which has significantly increased gold production in recent years.

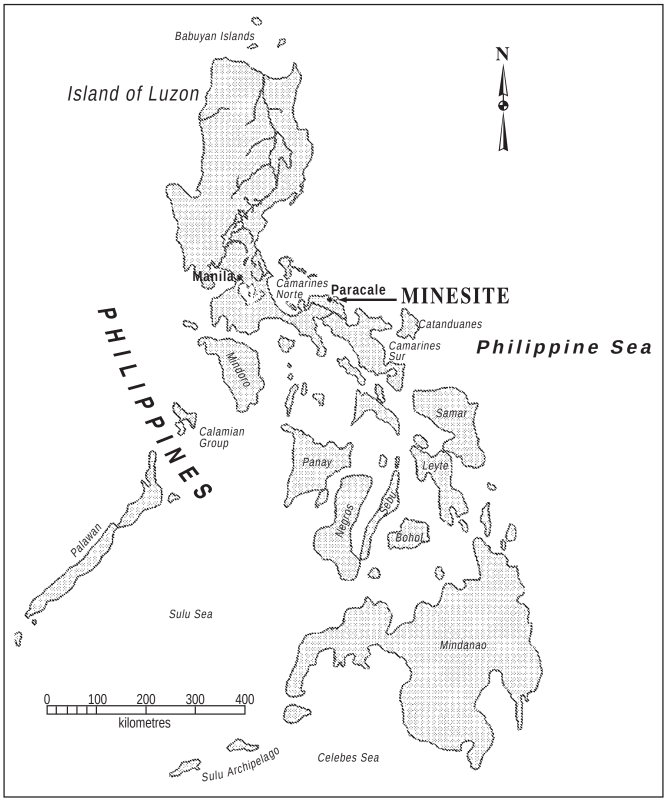

FIGURE 1 - LOCATION MAP

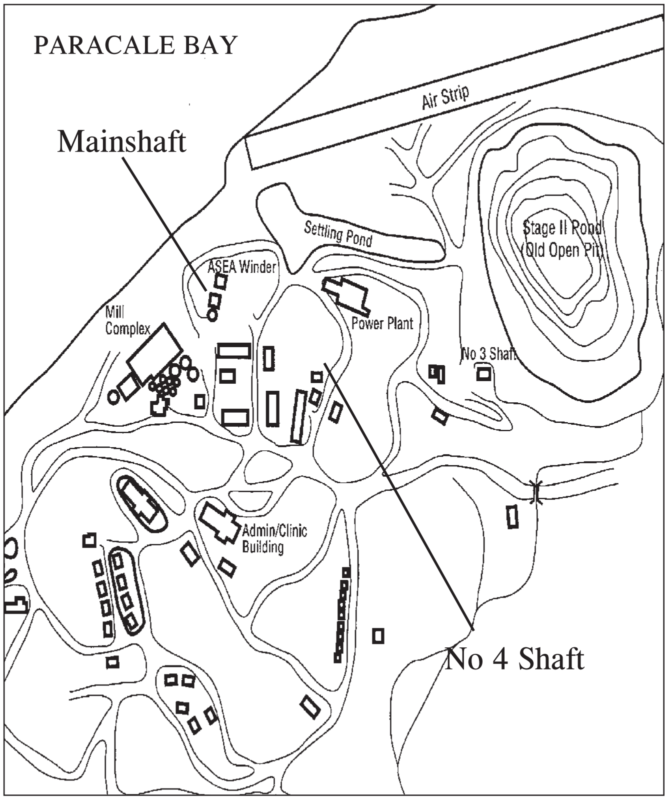

FIGURE 2 - SURFACE PLANT

The Longos Vein occurs as a fault zone which outcrops into the floor of the Pacific Ocean and accounts for the majority of the 3000 GPM of seawater which is continuously pumped from the mine workings. The Longos Vein was previously mined by a number of shallow shafts and by an open pit. Current mining operations are undertaken through the No 4 Shaft, the last remaining accessible shaft on the property, which stops at a depth of 240 m below surface.

FIGURE 3 - NO. 4 SHAFT

The Mainshaft project commenced under former mine owners in 1980 to develop lower workings of the Longos Vein to a depth of 500 m below surface. A shaft sinking plant was installed and shaft sinking commenced in June 1980. In March 1983, while installing a grout curtain at a depth of 257 m, a seawater inflow of 850 GPM was encountered and the Mainshaft was flooded to within 14 m of surface. Recovery efforts were unsuccessful and the Mainshaft sinking project was abandoned.

The Mainshaft flooding was a direct result of grouting methods and procedures which were inappropriate to site conditions. Grout holes were not flushed clean of drilling debris and mud infillings, nor was water pressure testing undertaken. The holes were grouted to full depth in one pass, rather than using a stage down drilling and grouting technique. Grout injection pressures were too high (1000 - 2000 psi) for the weak, highly-fractured ground conditions.

The use of excessive grouting pressures further weakened the rock formation adjacent to the shaft and caused the shaft bottom to blow out. Seawater entered the shaft and rose at the rate of 12 m per hour until the shaft had filled to sea level. Recovery efforts were attempted for the following three months and consisted of drilling and grouting along the shoreline adjacent to the Mainshaft, as well as dewatering two adjacent shallow shafts. These operations were virtually shots-in-the-dark and did not have any effect on the water inflow at the shaft bottom.

FIGURE 4 - MAINSHAFT

Geological Setting

The Paracale Gold District is essentially underlain by an ultramafic complex which has been metamorphosed into serpentinite and talc schist by the intrusion of quartz diorite stock (Paracale Granodiorite). The granodiorite stock was emplaced laterally along a strong structural weakness within the ultramafics. Flow patterns and mineralogical differences within the stock indicate that emplacement occurred in pulses, with the later pulses pushing against the earlier, partly solidified portions. The quartz diorite intrusive is host to several economically significant mineralized zones.

The Longos Mine consists of the Longos/Tomex Vein, the Longos East Extension, the ACR/LC Vein and the Contact Vein, and currently has proven and probable ore reserves of 1,900,000 tonnes and an anticipated mine life of over 10 years. Active mining operations are underway on several levels to a depth of 240 m. The development of the Mainshaft to a depth of 500 m is required to fully access these ore reserves and to satisfy future production requirements.

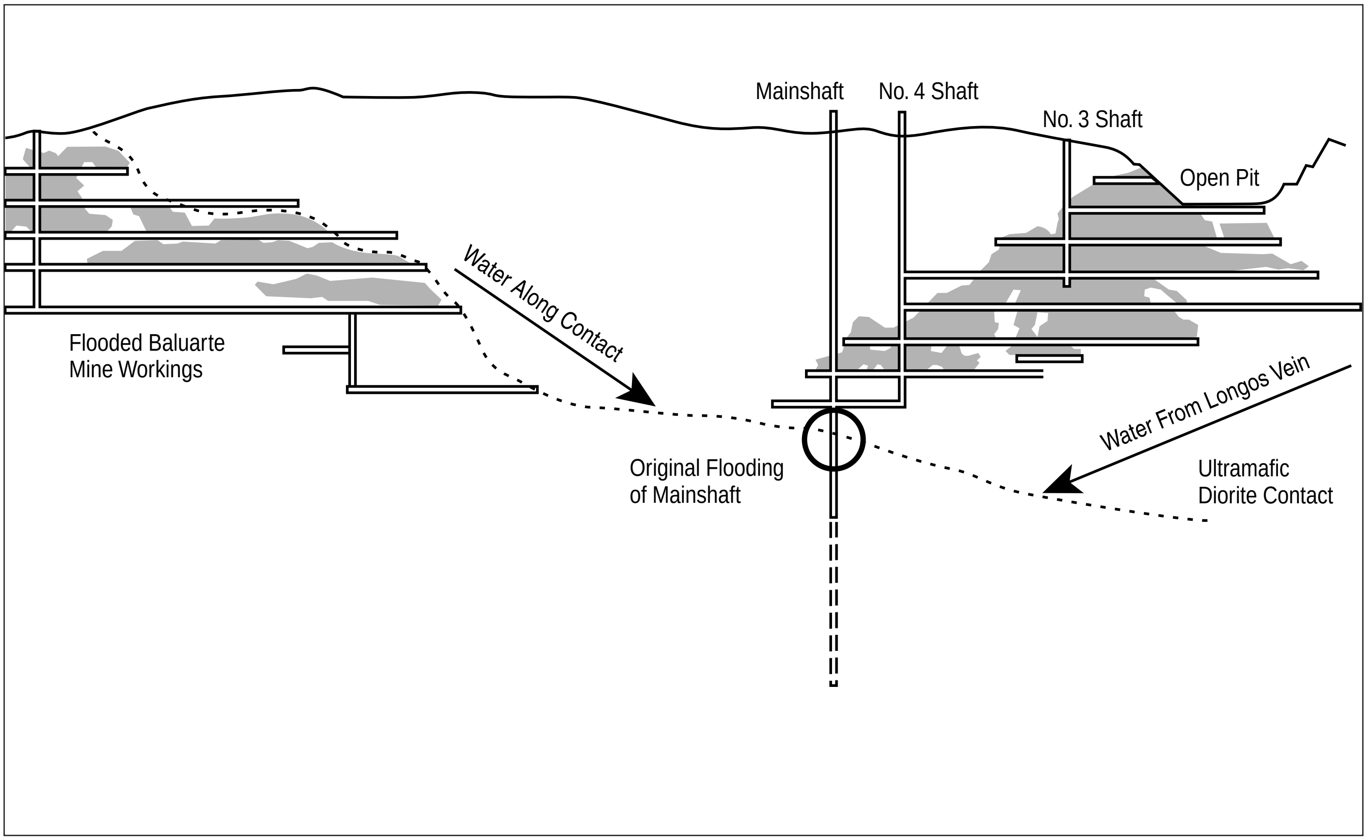

FIGURE 5 - WATER FLOW PATHS

When the flooding occurred, the hanging wall alteration zone associated with the Longos Vein had been exposed in the northeast portion of the shaft floor, which was approximately 5 m above the ultramafic/granodiorite contact. Subsequent diamond drilling and observations during shaft sinking showed that the contact consisted of a 1 m thick hybrid zone, predominately ultramafics, overlain by a 1.5 m thick layer of sandy material which was the primary source of water inflow to the shaft bottom.

Although the fracture density and RQD were similar for both the ultramafics and granodiorite, water pressure testing and geological observations showed that the fractures in the ultramafics were sealed with quartz-calcite fillings, whereas in the granodiorite the fractures were open and pores were noted. The footwall alteration zone was highly-fractured with open, interconnecting, water-bearing fissures.

Due to differences in temperature (32-34^{0}C) measured between water inflows at various locations, it was established that water was following in at least two separate flowpaths to the shaft bottom, as shown if Figure 5. One of these flows was associated with the faulted Longos/Tomax Vein. The other source of water is now believed to be along the ultramafic/granodiorite contact from the flooded Baluarte mine workings located within 300 m of the underground Longos mine workings.

Mainshaft Project

From 1983 to 1993, the Mainshaft remained isolated and unconnected with the active Longos mine workings. It was noticed, however, that the water level in the Mainshaft gradually dropped as lower mining levels were opened in the adjacent mine workings.

In January 1994, dewatering pumps were reinstalled into the Mainshaft, starting at a depth of 120 m. The shaft water level was gradually lowered and development drifts were connected to existing mine workings at depths of 210 m and 240 m in February 1994 and January 1995 respectively. Ventilation fans, sumps, dewatering pumps and electrical services were installed. The original shaft sinking stage and hoists were refurbished. Old service pipes and power cables were stripped and replaced. Ventilation equipment, dewatering pumps and settling sumps were installed.

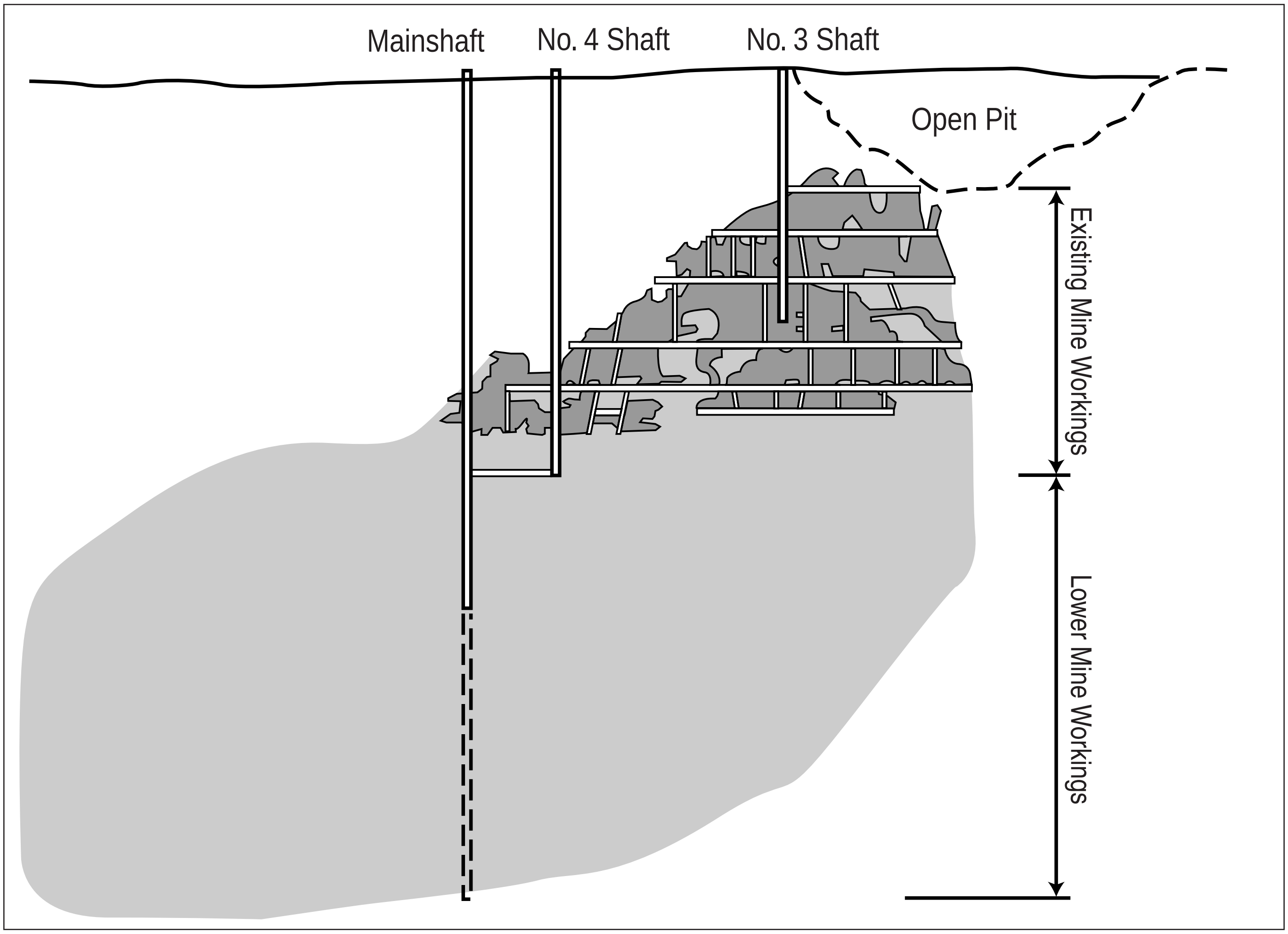

FIGURE 6 - EXISTING MINE WORKINGS

Site Conditions

By August 1995, the Mainshaft had been equipped to the bottom level of adjacent mine workings at a depth of 240 m below surface. The remaining 17 m of shaft below this level remained filled with accumulated debris. Flygt 2201 shaft bottom pumps were handling 500 GPM of seawater rising to the 240 m level from the water inflow location at the original shaft bottom at a depth of 257 m.

Three vertical pilot holes were diamond drilled from the 240 m shaft station, as shown in Figure 8, and several inclined holes were drilled from accessible mine workings to obtain core samples and to undertake water pressure tests. Insitu water pressures were measured and showed an existing dynamic head located above the 240 m level. Holes drilled into the water flowpaths encountered artesian water flow conditions concurrently with water inflows to the shaft bottom of 500 GPM.

Grouting Program

An evaluation of site conditions by a mining engineer specializing in mine grouting operations established that the Mainshaft water inflow could be brought under control and that shaft sinking could be safely undertaken through the Longos Vein water-bearing fault structure. Site conditions, although challenging, were not beyond those successfully overcome on other mining projects.

Due to the specialized nature of the work involved and the anticipated duration of the project, it was decided to train company shaft sinking personnel using state-of-the-art grouting techniques, materials and equipment. Detailed lists of equipment and bills of material were prepared for procurement.

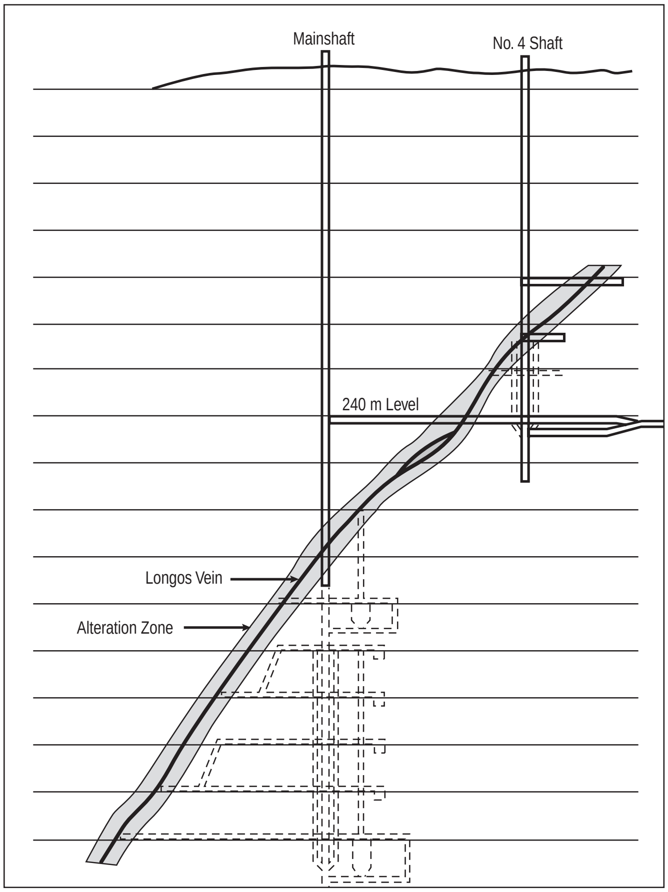

FIGURE 7 - MAINSHAFT DEVELOPMENT

The maximum possible use was made of Philippine-manufactured materials and site-fabricated equipment. Small quantities of specialized grouting materials were imported from Japan and Belgium. A limited number of specialized grouting equipment were imported from Canada, United States and Switzerland.

The following grouting program was developed and implemented:

- drill relief holes into waterflow paths from 240 m level
- clean debris from shaft bottom
- drill relief/grout holes in shaft walls above shaft bottom
- install drain pipes to handle water from water flow paths
- pour concrete floor and walls in existing shaft bottom
- grout holes in sequential order to stop existing inflow
- drill additional grout holes below shaft bottom
- continue grouting until stage has been completed
- sink shaft to bottom of grouted stage
- drill and grout next lower stage
- continue shaft sinking, drilling and grouting in stages

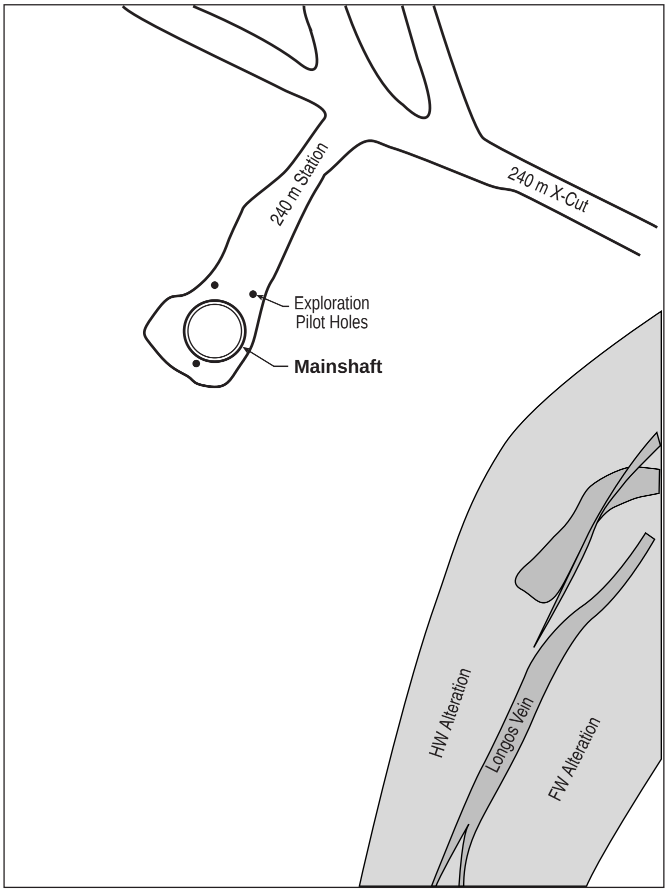

FIGURE 8 - 240m SHAFT STATION

Drilling Relief Holes

Several BQ holes were drilled from the 240 m level using Kempe/Tone compressed-air operated diamond drills to divert water from the intersected water flow paths away from the shaft bottom. These holes were initially successful in supplying up to (100) GPM of water each when the shaft was filled with debris below the 240 m level.

Cleaning Shaft Bottom

The shaft bottom debris included old pipes of various sizes, scrap lengths of wire rope and power cables, as well as an old percussion drill originally used for drilling grout holes into the shaft bottom, all of which were buried in spilled muck.

Shaft sinking crews cut scrap into pieces and hand-mucked debris from the shaft bottom into sinking buckets while continuing to pump water from the shaft bottom with the Flygt 2201 pumps. Cleaning the shaft bottom commenced in August 1995 and reached the shaft bottom at 257 m below surface in September.

The volume of water entering the shaft bottom gradually increased from 500 GPM to 850 GPM as the debris was removed and corresponding water head within the shaft was reduced. The artesian water flows from the drain holes on the 240 m level gradually reduced and finally stopped as the shaft water level was lowered.

Drain Pipes and Concrete Plug

After cleaning the shaft and removing the old shaft concrete formwork, the bottom of the shaft concrete liner was found at 255 m below surface, or 2 m above the shaft bottom. An opening into the shaft bottom measuring 0.6 m x 2 m was found to be the flow path of the 850 GPM water inflow. The existing rock on the shaft bottom was excavated a further depth of one meter using pick-and-shovel methods to improve access to this aperture.

Temporary formwork was installed and the shaft walls were concreted from 255 m to 258 m depth while allowing water to flow into the shaft bottom. This concrete lining was required to prevent further collapse of weak ground in the shaft walls and to provide an impervious shaft lining to contain the grout to be installed in the open fissures.

Approximately sixty 1 inch and 2 inch diameter drainage pipes with valves were wrapped in geotextile fabric and installed - one at a time - in the flowing aperture and secured in position with hydraulic cement. This work was performed within the floor of the shaft while standing in approximately one meter of water and working under flowing water conditions.

Additional drainage pipes were installed in drill holes in the shaft bottom to intersect and divert the remaining water inflows. A concrete plug was poured in stages on the shaft bottom, allowing water to flow through the installed drainage pipes into a sump pit until the concrete had developed sufficient strength. After completing installation of the shaft bottom concrete plug and allowing sufficient time for the concrete to cure, it was possible to close valves on the drainage pipes, reducing shaft bottom water inflow from 850 GPM to 30 GPM. This work was completed in October 1995.

Grouting Materials

The grouting materials selected for this project were:

- ordinary Portland cement
- high-yield bentonite
- superplasticizer
- sodium silicate
- microfine cement
- water-activated polyurethane resin

FIGURE 9 - QUALITY CONTROL STATION

The use of locally-produced ordinary Portland cement was selected as the major consumable grouting material based on availability and cost. High-yield bentonite was initially used to minimize bleed and to produce stable grout mixes. This practice was discontinued due to the excessive quantity of bentonite required to control bleed when it became apparent that bentonite would not hydrate properly in seawater. Low dosages of high-range water-reducing superplasticizer were used to facilitate grout mixing and to reduce the apparent viscosity of grout mixes.

Several grout formulations were developed to accommodate various site conditions, but the majority of grouting was undertaken with the following grout mixes:

Ingredients	Portland	Microfine
Sea Water	160 liters	160 liters
Cement	80 kg	80 kg
Superplasticizer	250 ml	nil
W:C Ratio	2:1	2:1
Yield	185 liters	185 liters
S.G.	1.40	1.40
Marsh Funnel	33 sec	30 sec
Bleed	<25 %	<7 %

A quality control station was established adjacent to the colloidal mixer and each batch of grout was routinely sampled for various performance measurements (S.G., Marsh flow time, bleed) and to monitor the rate of curing, as shown in Figure 9.

FIGURE 10 - COLLOIDAL GROUT MIXER

The concurrent injection of sodium silicate at the shaft bottom was used in conjunction with cement grouting to provide for fast gelling of the cement grout to prevent grout washout and to minimize grout migration away from the location being grouted.

Microfine cement was used for secondary grouting operations to access rock formations and water flow paths which were no longer accessible, due to previous grouting operations, when using grouts formulated from ordinary Portland cement.

Water-activated polyurethane resin was used for special applications where small volumes of fast-curing grouts were needed for special applications.

Grouting Equipment

A high-shear, Concrete-type, colloidal grout mixer was located on surface adjacent to the shaft collar, as shown in Figure 10. This unit had a tank capacity of 6 cubic feet and was driven at 1750 RPM by a direct-connected 15 HP electric motor. A 2 inch water line was used to supply the colloidal mixer with 35 C salt water from the mine dewatering pump line. This unit was able to maintain grout production up to 80 liters per minute.

The colloidal mixer discharged into a site-fabricated, 300 liter agitator tank equipped with a strainer basket, rotating paddles and stationary baffles. This unit was operated by a compressed air motor.

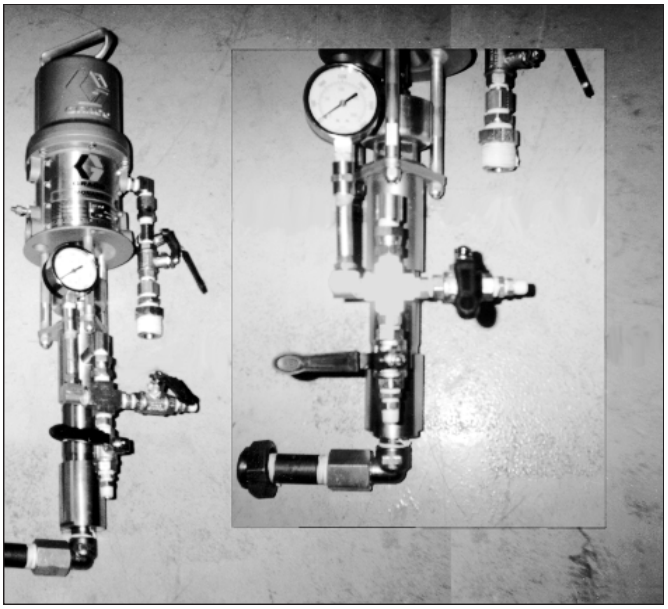

FIGURE 11 - SODIUM SILICATE PUMP

Two 1 inch diameter grout pipes were installed from the shaft collar to the bottom of the shaft and were setup on surface so that either one of the grout lines could be connected directly to the agitator tank. All of the grout used on this project was placed using gravity flow direct from the agitator tank and through one of the 1 inch shaft grout pipes.

A HANY ZMP 50 pneumatic grout pump was positioned on surface and was used infrequently just to clear the shaft grout lines whenever plugging occurred.

Sodium silicate was stored in 200 liter drums on the 240 m level and was fed by gravity flow to the shaft bottom through a 1 inch diameter pipeline. A pneumatically-operated, positive-displacement, chemical transfer pump, as shown in Figure 11, was located at the shaft bottom and was used to pump sodium silicate to grout holes as required. This pump had an output capacity of up to 20 liters/minute and a pressure capability of up to 1000 psi. The sodium silicate pump output was adjusted using an air regulator on the compressed-air supply to the pump, to provide an appropriate sodium silicate flow rate to suit site conditions.

FIGURE 12 -MAGNETIC FLOW METER

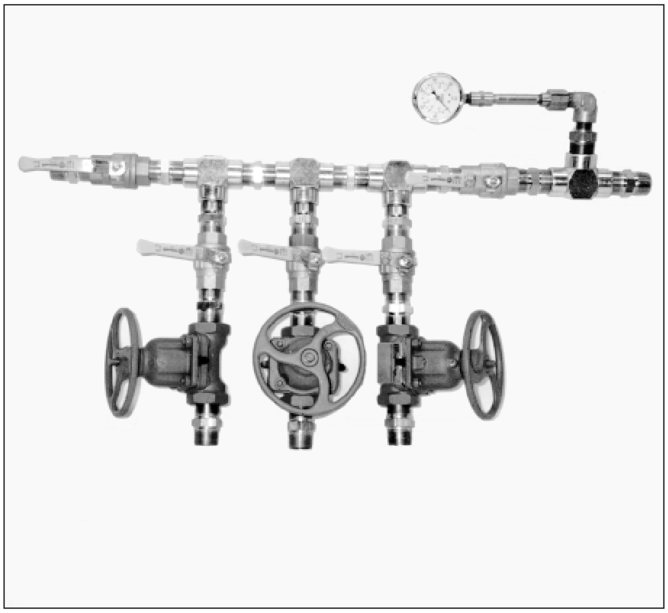

FIGURE 13 - MULTI-VALVE GROUT HEADER

High pressure 1 inch hydraulic hoses were used for all grout hose connections at the shaft bottom. A 1 inch magnetic flowmeter with totalizer, as shown in Figure 12, was connected to the bottom of the grout supply pipe to continuously indicate rate of grout flow and cumulative grout volumes in liters. The flowmeter was used to monitor the volume of cement grout placed at various locations and for regulating grout flow rates and pressures. A multi-valve grout header, as shown in Figure 13, incorporating 1/4-turn, full-port ball valves and diaphragm valves was fabricated for use on the shaft bottom. The ball valves were used for on/off operations and the diaphragm valves were used to regulate grout flow rates so as not to exceed the mixing capability of the colloidal mixer. A bypass line was connected to the header for draining and flushing the grout supply line into an old sump on the 240 m level upon completion of grouting operations.

Three types of grout plugs were used depending on site conditions:
- drain pipes or standpipes
- mechanical grout plugs
- polyurethane grout plugs

At the start of the grouting operations, many drain pipes and standpipes had been previously installed and cemented into place. After all of these had been grouted, additional drilling was undertaken which required new grout plugs to be installed. Mechanical grout plugs utilizing expandable rubber sleeves were difficult to install and could not be reliably sealed into position due to broken ground conditions.

Polyurethane grout plugs were fabricated on site in various pipe diameters and lengths up to 3 m to accommodate site requirements. Geotextile cloth was wrapped around the pipes, strapped into position, soaked in water-activated polyurethane resin and inserted into the hole to be grouted with the valve in the open position to allow water to flow through the grout plug. The polyurethane cured within a few minutes after installation and secured the grout pipe within the hole, following which the valve could be closed to stop the water inflow. This technique was effective in broken ground conditions where mechanical grout plugs could not be used.

Standpipe fittings, as shown in Figure 14, were connected to the various types of grout plugs prior to hooking up grout hoses. The use of multiple valve standpipe fittings allowed for pressure relief and flushing of grout hoses at any time during the grouting operation without disconnecting grout hoses from the header. Several grout plugs could be grouted at the same time by connecting hoses between adjacent grout plugs.

A conventional 1 inch dial-face water meter, as shown in Figure 15, calibrated in liters was used to undertake water pressure tests prior to grouting operations. This water meter was connected to a manifold containing a pressure gauge on the upstream side and was hooked up to the grout hole to be tested. The static and dynamic pressures were measured along with the flow rate by allowing ground water to flow through the meter. LUGEON values were calculated and used in the selection of the appropriate grout formulation to accommodate site conditions.

FIGURE 14 - STANDPIPE FITTINGS

Typical Grouting Operations

Following drilling of grout holes and installation of grout plugs, water pressure tests were conducted and LUGEON values were calculated for each hole. A sequence of grouting operations was established based on site conditions and the number of grout holes available. Hose connections were hooked up in advance with the shaft bottom header bypass valve open and the discharge valves closed. After all preparations had been made on the shaft bottom, a signal was then given to the colloidal mixer crew on surface to start mixing an appropriate grout mix based on the water pressure test results.

The agitator tank was filled with water and was used to prime the 1 inch grout supply line. Water was allowed to flow through the bypass valve on the shaft bottom grout header and be discharged to the sump area on the 240 m level. A discharge valve on the shaft bottom header was periodically opened to check when grout had reached the shaft bottom, after which the bypass valve was closed and the grout flow was directed to the appropriate grout hole.

At the beginning of the project, the static grout pressure at the bottom of the 1 inch grout supply line was 400 psi. Dynamic grout pressures dropped as the grout flow rate increased due to friction losses encountered in the grout supply line. Typical grouting pressures of 300 psi were sustained at flow rates of 60 - 80 liters per minute. As the shaft was deepened, the available grout column pressure increased from less than 400 psi to over 600 psi.

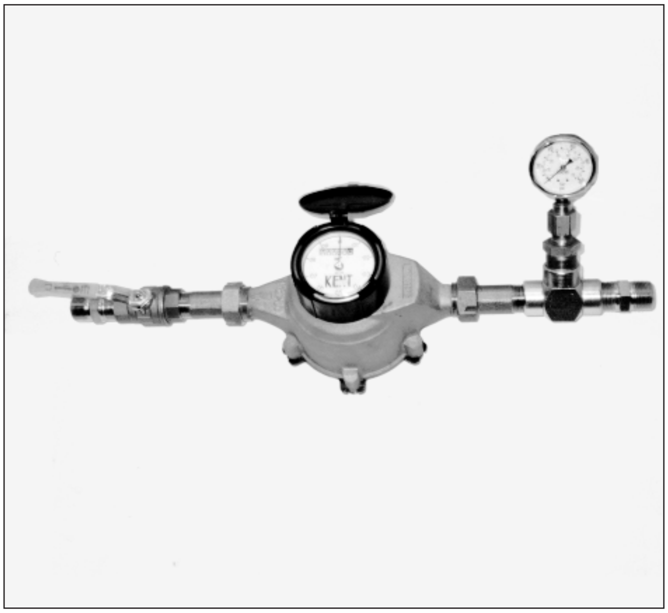

FIGURE 15 - WATER PRESSURE TEST METER

At locations where the water flow paths were wide open and grout flow rates would exceed the grout mixing capacity of the colloidal mixer, the diaphragm valves on the shaft bottom header were partly closed to maintain flow rates in the range of 70 - 80 liters per minute. As holes came to refusal, the diaphragm valves could then be opened and the rock formation being grouted would accept grout directly from the supply line with gradually decreasing flow rates within the performance range of the colloidal mixer and gradually increasing pressures.

Typically, the shaft bottom grout header was connected to two grout holes at the same time, but only one header discharge valve was opened at a time. In the event of any delay or problem occurring with the hole being grouted, the second hole could be brought on line by closing and opening the respective valves on the grout header.

Similarly, as one hole was approaching refusal, a second hole was typically brought on line concurrently and two holes were grouted at the same time to make effective use of grout mixing capacity. Occasionally, at the termination of grouting operations, it was common for three or four grout holes to be hooked up at the same time with each hole taking a small volume of grout under maximum grout column pressure.

Grouting operations were terminated when a combined grout flow rate to all connected holes of less than 10 liters/minute was reached. Due to the high temperature of the seawater used for mixing grout, it was considered undesirable to hold grout in the agitator tank for long periods of time. Similarly, due to the high pressures existing in the shaft grout column, it was considered desirable to maintain grout flow to avoid potential problems with plugging the shaft supply line.

During grouting operations, the flow rate, cumulative grout volume and pressure were continuously monitored by the grout header operator. Whenever grout flow was sustained for long periods of time without any decrease in flow rate or increase in grout pressure, the grout mix was thickened, usually by adding an additional bag of cement to the grout mix. Grouting with the thicker mix continued until a flow rate decrease or pressure rise was indicated, when use of the original grout mix was resumed by deleting one bag of cement from the grout mix.

Depending on site conditions, the use of microfine cement was occasionally used to facilitate penetration of finer cracks than could be penetrated using ordinary Portland cement. The use of microfine cement accounted for approximately 15% of the total cement quantity on this project. The colloidal mixing crew was able to switch back and forth from batching ordinary cement grout to microfine cement grout as required to accommodate conditions as encountered at the shaft bottom.

Whenever changes in the grout formulation were requested from the shaft bottom, there would typically be a lag time of up to 10 - 15 minutes for the previously mixed grout to be consumed before the requested grout formulation was available at the shaft bottom header. Dynamic changes in the shaft bottom flow rate and header, grout pressure usually signalled when the changeover to the requested grout formulation actually reached the shaft bottom.

From time-to-time, when a delay occurred for more than a few minutes, to grouting operations at the shaft bottom, grout was discharged through the bypass valve to the sump on 240 m level to avoid potential problems with plugging of the shaft grout supply line and all grout lines and hoses were flushed with water. Normal grouting operations were resumed when the problem causing the delay had been overcome.

Grout Stage Layouts

The purpose of the initial grouting operation was:
- to stop the 850 GPM water inflow at the shaft bottom
- to secure the shaft wall lining above the old shaft bottom
- to secure the shaft bottom for shaft sinking purposes

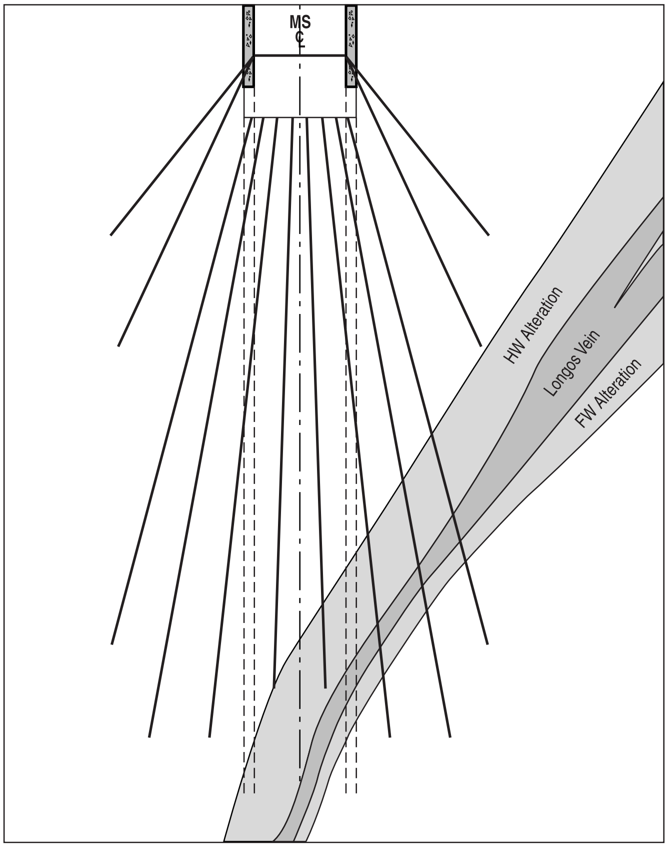

FIGURE 16 - ORIGINAL GROUTING LAYOUT

The initial grouting program provided for rings of grout holes to be installed starting 3 m above the shaft bottom and progressing deeper in two long stages, as shown in Figure 16, with each stage covering approximately 30 m below the shaft bottom. Each ring of holes was to have been drilled at different angles and depths to provide adequate grout coverage between adjacent holes and adjacent rings as follows:

Ring	Holes	Angle	Depth
A	18	49°	11 m
B	18	65°	16 m
C	18	74°	26 m
D	16	79°	30 m
E	10	83°	30 m
F	4	89°	30 m

The top rings (A, B & C) of the first stage were drilled as BQ holes using Kempe/Tone compressed-air operated diamond drills working from platforms setup within the shaft utilizing the sinking stage. Due to the low performance rate using these diamond drills, a decision was taken to reduce the length of the grout stage from 30 m to 12 m, as shown in Figure 17, to enable the use of jackleg drills and extension drill steel.The required number of stages was correspondingly increased from 2 - 30 m stages to 6 - 12 m stages.

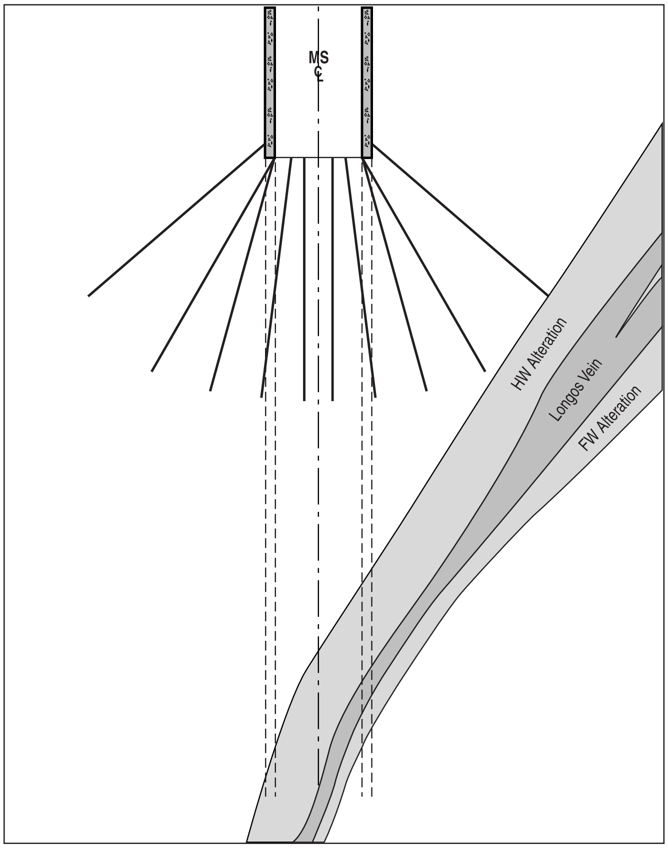

FIGURE 17 - REVISED GROUTING LAYOUT

Initial Grouting Operation

The initial grouting operation consisted of grouting through the drain pipes in the shaft bottom to fill the large water flow channels closest to the shaft. During this operation, all of the grout holes in Rings A, B and C above, and all of the relief holes at the 240 m level, were opened to relieve water flow and pressure from the area being grouted.

At the start of the initial grouting operation, the static water pressure at the shaft bottom was measured at 30 psi. This low pressure reading was attributed to the diversion of water flow through other open drainage pipes and through connecting fissures to the 240 m level.

This operation continued from pipe to pipe until all drain pipes in the shaft bottom had been grouted. The duration of this initial grouting operation was 3 hours and 3,360 kg of cement were consumed. Sodium silicate was injected into the same grout plugs, concurrently with cement grout, at a dosage rate of 2-5% of the cement grout flow rate to provide for a fast-gelling grout. At the end of the 3 hour operation, all drainage pipes at the bottom of the shaft had become plugged due to grouting or to grout migration from adjacent holes.

Grouting subsequently proceeded systematically through Rings A, B and C to seal water flow paths which had been intersected by drill holes from these rings and to fill available water flow paths further away from the shaft bottom. Several holes were found to have been already grouted as a result of the preceding grouting operation at the shaft bottom. The remaining open holes on the 240 m level were also grouted as an extension of this grouting operation.

Upon completion of the initial grouting operation, jackleg drills were used to drill a secondary ring of horizontal holes to a depth of 3 m at a height of about 1.5 meters above the shaft bottom. Grout plugs were installed, water pressure testing was conducted and grouting resumed with cement grout in conjunction with sodium silicate.

On the following days, additional holes were drilled and grouted on the lower rings of the first stage in sequence, including holes into the shaft bottom. Drilling, water pressure testing and grouting operations continued until no major water flow paths remained within several meters around the shaft or within 12 m of the shaft bottom.

At that time, 53 days after the start of grouting operations, the initial stage of grouting was terminated and the shaft was deepened from 257 m to 262 m depth below surface.

Subsequent Grouting Operations

The subsequent grouting operations were conducted following shaft sinking and installation of the shaft concrete lining. The grouting operations employed the same equipment, materials and techniques which had been developed during the initial stage of grouting. The relevant statistics for the various stages of grouting are as follows:

Stage	Stage Collar	Stage Duration	Grouthole Drilling	Grout Volume	Portland Cement	Microfine Cement
1	257 m	53 days	812 m	183 m^3	103.8 t	7.6 t
2	262 m	23 days	800 m	54 m^3	19.6 t	2.6 t
3	271 m	31 days	1,416 m	35 m^3	12.2 t	5.0 t
4	279 m	34 days	1,723 m	102 m^3	38.9 t	12.7 t
5	289 m	26 days	1,440 m	71 m^3	30.6 t	9.0 t
6	297 m	37 days	3,460 m	134 m^3	30.0 t	20.2 t

The highest grout consumption occurred in the first stage of grouting (257 - 269 m) when all of the major flow paths were filled. This stage also included the grouting of pilot holes and drain holes from the 240 m level which extended beyond the limited area around the shaft bottom.

Subsequent examination of ground conditions exposed during shaft sinking indicated a 3 m thick altered and argillized zone which would have collapsed upon exposure and had to be supported with steel sets.

For these reasons, the second stage of grouting (262 m - 274 m) was initiated after sinking only 5 m below the initial shaft bottom. The reduced grout consumption during the second stage was attributed to improved ground conditions below 262 m depth and the effects of the first stage of grouting.

The third stage of grouting (271 m - 283 m) encountered further improved ground conditions, as is evident from further reduced consumption of ordinary Portland cement and an increase in the use of microfine cement. It was observed that the static ground water pressure had increased to 100 psi as a result of previous grouting operations. The ground conditions encountered while shaft sinking through this area were improved from the previous stage and could stand unsupported.

The fourth stage of grouting (279 m - 291 m) consumed three times as much grout as the preceding stage due to the close proximity of the faulted structure of the Longos Vein and the increased number of grout holes which penetrated the Longos Vein. It is significant that microfine cement represented 25% of the total quantity of cement consumed on this stage, indicating a large number of very narrow flow paths remaining after grouting with ordinary Portland cement. The Longos Vein was found to be massive and moderately argillized on the HW and FW. Outside the argillized zone was the granodiorite which was highly-slicified and fractured.

The fifth stage of grouting (289 m - 301 m) into the footwall of the Longos Vein consumed less grout than the previous stage, but microfine cement still represented approximately 25% of the total quantity of cement used. During excavation through this area, the Longos Vein was found to have split and was actively water-bearing.

The sixth stage of grouting (296 m - 308 m) consumed a significant volume of microfine cement, representing 40% of the total cement used. Shaft sinking through this area exposed multiple criss-crossing fine fractures and joints. A 200 mm wide water-bearing fissure was also exposed.

Shaft Sinking Operations

The Mainshaft is being constructed as an open, circular, concrete-lined shaft of 4.27 m inside diameter, using a five deck shaft-sinking stage, SIG PLF 24 hand-held sinking drills and a Cryderman shaft mucker. Shaft sinking utilizes a 310 kw ASEA double drum hoist with a 2.4 m drum diameter and rope speed of 6 m/sec. This ASEA hoist will eventually be the production hoist.

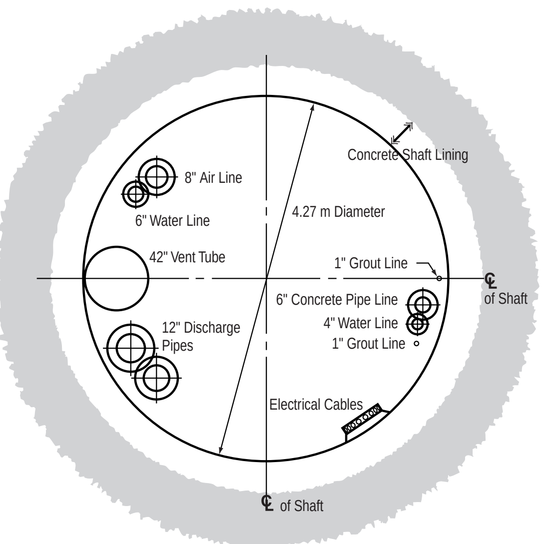

FIGURE 18 - SHAFT SINKING INSTALLATIONS

The sinking stage hoist is a 45 kw Parkal double drum hoist with a drum diameter of 1.2 m and a rope speed of 1.5 m/sec. The Cryderman shaft mucker utilizes a single drum 90 kw Parkal hoist with a drum diameter of 1.5 m and rope speed of 3.5 m/sec.

Shaft sinking utilizes the benching method. Each bench utilizes 32 blastholes, loaded with 25 mm x 300 mm Powergel and initiated with non-electric Exel long-period detonators. Powder factor is 1.3 kg per cubic meter. Each bench blast produces 46 tonnes of muck which is hoisted into a 60 tonne waste bin at the shaft collar.

Typical shaft sinking cycle times are as follows:

Activity	Time
Blast Initiation	0.00 hr
Ventilation	0.30 hr
Lower stage, pump, Cryderman	0.25 hr
Mucking	4.25 hr
Clean bench	1.50 hr
Drilling blastholes	2.00 hr
Remove equipment	0.25 hr
Load and blast	1.25 hr
	———
	10.00 hr

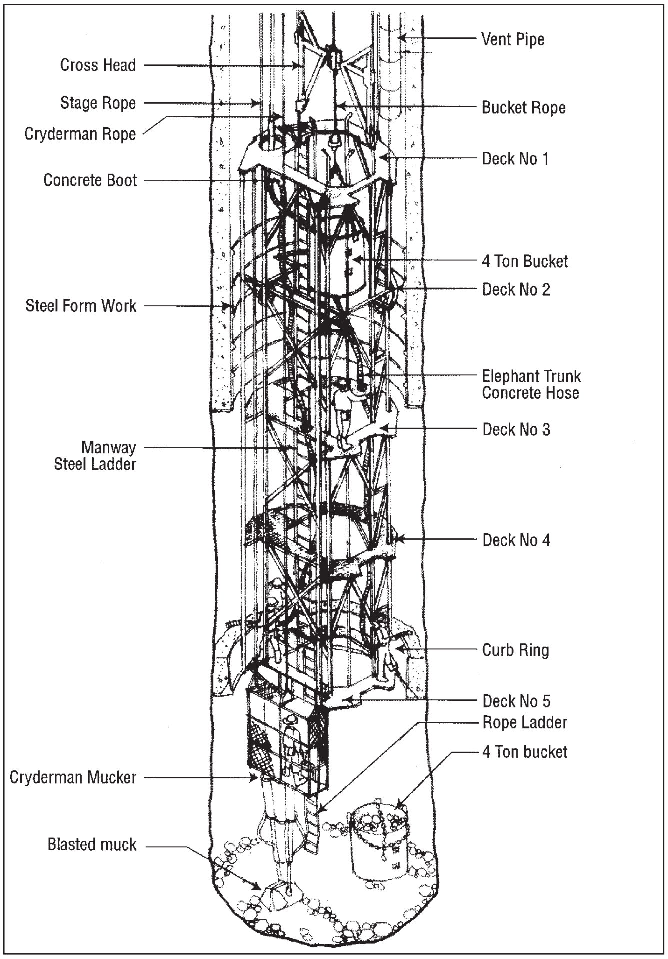

FIGURE 19 - SHAFT SINKING EQUIPMENT

Flygt BS2201 pumps are used to dewater the shaft bottom, and are raised and lowered by pneumatic tugger hoists mounted on the sinking stage. Water rings are installed every 60 m and are equipped with pumps.

After every 6 m of shaft advance, the shaft walls are drilled and grouted using polyurethane resin and cement grout to eliminate any residual water jets or dripping water. A curb ring is lowered on chainblocks and is suspended on 6 hanging rods. Segmented concrete form work with a total height of 6 m is used to line the shaft wall above the curb ring in 3 m or 6 m concrete lifts, depending on ground conditions. Each 6 m lift consumes 40 cubic meters of Class A concrete mix.

Interior shaft steelwork and equipment will be installed in 1998 following completion of shaft sinking operations.

Overall Assessment of Grouting Operations

In 1994, when Mainshaft recovery operations commenced, UNITED PARAGON MINING CORPORATION faced a formidable technical challenge. At that time, the Longos Mine was handling approximately 3,000 GPM of seawater inflow accumulating from all working levels, including 500 GPM from the bottom of Mainshaft. Deepening of the Mainshaft was regarded as critical to the future development of the mine and extraction of potential ore reserves at depth.

However, the bottom of the Mainshaft was filled with debris and was not readily accessible for examination. Ground conditions in the portion of the Longos Vein to be penetrated by the shaft sinking operation were assumed to be extremely difficult. The shallow angle of intersection with the Longos Vein, together with adjacent faulted and altered rock formations, provided for unpredictable and potentially unstable site conditions.

The portion of the Longos Vein to be exposed by shaft sinking was at the bottom of the mine over 100 m lower than active mining operations. There was no possibility for drainage of water inflows through other areas of the mine or any other means of diverting water away from the shaft excavation.

The success of the grouting operation depended upon several factors:

- a practical and comprehensive technical strategy
- state-of-the-art grouting equipment
- availability of suitable grout materials
- understanding and use of appropriate grouting techniques
- determined and innovative supervision and workforce

All of the above factors were recognized by UNITED PARAGON management who provided world-class grouting expertise, materials, equipment and techniques at the disposal of Mainshaft project personnel. The Mainshaft project supervisors and miners were selected from across the Philippines to assemble a high-calibre mining crew capable of undertaking both shaft sinking and grouting operations under difficult circumstances.

The basic training program required less than one week for the initial setup and commencement of grouting operations after all of the equipment and materials were available on site. The transfer of grouting technology involving the application of different grouting materials and techniques under a variety of site conditions required less than one month to complete.

The implementation of the grouting program encountered all of the problems and difficulties that could be expected from adverse, unpredictable and weak ground conditions in water-bearing rock formations at depth. Water never stopped flowing into the Mainshaft during excavation through the Longos Vein. However, the inflow of water was brought under control and kept within tolerable limits for shaft sinking purposes by the proper utilization of the available grouting equipment, materials and skills.

Acknowledgements

We wish to acknowledge the excellent work of many employees of UNITED PARAGON MINING CORPORATION, whose efforts were rewarded by the successful outcome of this challenging project. We also wish to extend our appreciation to Mr. C.P. Bumanglag, Vice President, Operations, for his guidance and direction during the planning and execution of the Mainshaft grouting and shaft sinking activities.

NOTES

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CANADA
6214 Kestrel Road
Mississauga, Ontario L5T 1Y9
Tel: (905) 564-7650
Fax: (905) 564-7998
Toll Free: 1-800-663-6633
email: mme@multiurethanes.com

USA
PO Box 127
Buffalo, NY 14207
Tel: (716) 842-0066
Fax: (716) 842-0055
Toll Free: 1-800-663-6633
email: usa@multiurethanes.com