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THE RUBY HILL PROJECT

Eureka, Nevada

Gold-silver-lead ores were discovered near Eureka, Nevada, in September of 1864. However, the ores could not be successfuly treated to recover the valuable metals, and it was not until 1869 that a successful furnace was installed. The success of this first blast furnace inspired the installation of nineteen small smelters in the Eureka district and resultant fumes and smoke appropriately earned Eureka the title of "Pittsburgh of the West".

Most of the production from Ruby Hill was between 1871 and 1888, and during this period it is said that the Eureka district controlled the lead markets of the world. In 1905 the last smelter was shut down, and the Richmond-Eureka Mining Company was formed, a consolidation of a number of smaller properties with the two largest operators in the camp, the Richmond Mining Company and the Eureka Consolidated Mining Company.

There was sporadic production by leasers from the old Ruby Hill workings on the footwall of the Ruby Hill fault through the 1920's, although the camp was largely "worked out" prior to 1900. Total production from the Ruby Hill to date has been approximately 2,722,000 tons of ore, with an estimated value of $122,000,000. This production has provided the required incentive over the years to encourage the search for new ore bodies.

Because a number of the ore bodies being mined were terminated by the Ruby Hill fault, it was early recognized that extensions of the bonanza ore bodies might exist in the hangingwall of the fault. Accordingly the Ruby Hill fault was penetrated in a score or more places in the search for a possible hangingwall extension, and during the early 1880's Eureka Consolidated sank the 1,200-ft. Locan shaft to search for the Eldorado dolomite and down-faulted ore bodies. However, the work in the Locan was greatly handicapped because of inability to handle appreciable quantities of water which were encountered on the 1200 level. In addition, the fact thatmany students of the district considered the fault to be premineral was discouraging.

The Locan was sunk to the 1200 level without encountering much water to that depth, probably because the shaft was in Secret Canyon shale at about the normal ground water level. When the crosscut was driven from the shaft to the ore-bearing wedge of Eldorado dolomite, however, and the main branch of the Ruby Hill fault was penetrated, the water within that block was tapped and"the crosscut and the lower part of the shaft filled with water so suddenly that the men had barely time to escape" (Curtis - 1884, page 109). The water then rose in the Locan shaft to the normal ground water level at elevation approximately 5,930. Further work was abandoned since no practical method was available to handle the large water flow.

In 1919 the Ruby Hill Development Company, which was organized and promoted by a Canadian named Thayer Lindsley, tried to unwater the Locan shaft to the 1200 level to explore the possibility that ore existed on the hangingwall side of the Ruby Hill fault in the down-thrown block of the favorable host rock, Eldorado dolomite. It was found necessary to retimber the Locan shaft below the 600 level, and many difficulties were encountered in the pumping operation. By the time the top of the 1200 station was reached, the money was exhausted and the project was abandoned.

This early attempt at unwatering the Locan was not successful, but in 1923 Richmond-Eureka Mining Company successfully unwatered the 1200 level of the Locan, crosscut to the Ruby Hill fault, and drifted along the fault for a few hundred feet where a large inflow of water was encountered in Geddes formation, and work had to be suspended. Richmond-Eureka then retreated to the 900 level, above the water table, and started a vertical drill hole in the hangingwall of the Ruby Hill fault to look for the Eldorado formation, with attendant chances of finding ore at deeper levels. This drill hole was completed to a depth of 760 feet, at which point the hole caved, gave considerable trouble, and was finally abandoned.

In 1937 Thayer Lindsley organized the Eureka Corporation, and obtained a lease on the Ruby Hill property from Richmond-Eureka Mining Company. A diamond drill hole from the surface, which was started in August, 1937, and which took fourteen months to complete, encountered no ore, but did pick up lead-zinc mineralization. A second hole was then drilled from the Locan 900 level, and forty feet of good grade gold-silver-lead-zinc ore were intercepted. The old Richmond-Eureka hole from the Locan 900 level was then deepened, and it intersected thirty feet of ore. On the basis of this favorable work, Eureka Corporation started sinking the Fad shaft in 1941. In 1942 shaft sinking operations were curtailed at a depth of 540 feet because pumping equipment could not be obtained. Following application of the Eureka Corporation to the War Production Board for equipment priorities, the U. S. Bureau of Mines drilled three additional holes from the Locan 900 level, and all of these hit ore. This drilling was completed in February, 1945.

In the fall of 1944 the hoist and compressor house, with all equipment, were destroyed by fire. In February, 1945, the construction of a new surface plant was started and new hoisting equipment and compressor and power plant installed.

In late 1945 sinking of the Fad shaft was resumed, and in 1947 the shaft was completed to below the 2250 level. A station was cut at the 2250, and crosscutting toward the ore body was started. In March of 1948 the crosscut crossed the Martin fault from Secret Canyon shale into the Eldorado dolomite, which is the host rock for the ore deposits. See Figure 1 and Figure 2.

At the time the 2250 level crosscut penetrated the Eldorado dolomite, installed pumping capacity in the Fad shaft was approximately 2,500 gpm., and 1,500 gpm. were being pumped. On March 25, 1948, high-pressure water was encountered in the face of the crosscut, and within a short time flow increased to over 2,000 gpm. A water door, which had been installed earlier, failed, and the mine was flooded. Eureka Corporation then installed Diesel power generation and pumping capacity adequate to remove 5,000 gpm. from the mine. This proved to be inadequate - more power generation and more pumping capacity were added, and as high as 9,000 gpm. were being pumped by November of 1948. The water in the shaft was lowered to within 54 feet of the 2250 station, when a sudden inrush of muddy water occurred, and the shaft was again flooded. Although a number of experts were called in and an elaborate drawdown test was made, no practical solution was found, and the shaft remained full of water to the water table at the 1,030-ft. level.

During the next several years, several additional holes were drilled from the surface and substantial additions were made to estimated ore reserves. However, no new attempt was made to unwater the Fad shaft. Eureka Corporation opened a new operation about one mile away and successfully mined several thousand tons of oxidized ores through the TL shaft. Marketing of the ore proved too difficult, however, and this operation was also shut down, in 1958.

Recent History at Ruby Hill

In 1960, four companies, including Richmond-Eureka Mining Company, Eureka Corporation, Newmont Mining Corporation, and Cyprus Mines Corporation, agreed to finance a program embracing additional drilling from the surface and a feasibility study. This work was under the direction of R. J. Hendricks of Cyprus Mines. Hecla Mining Company acquired a small interest in the venture by advancing a part of the funds put up by Eureka Corporation.

The new drilling program was completed during 1960. After its completion, an ore reserve estimate of about 2,500,000 tons assaying 0.216 ounces of gold per ton, 8.85 ounces of silver per ton, 6.45% lead, and 11.45% zinc was computed (see Eureka Corporation 1962 report). Additionally, a study of the water problem was made by Leeds, Hill & Jewett, San Francisco, ground water engineers, and some metallurgical testing, limited by availability of suitable samples, was performed by Newmont and by Lakefield Research of Canada, Ltd.

At this time many problems remained to be satisfactorily answered, including the question of the practicability of recovering the Fad shaft, application of techniques of driving underground headings within a cementation cover to control inflow of water into the openings, the quantity of water which must be pumped in order to drain the ore bodies before extraction, source and cost of power, and most importantly, net recoverable values of the metals contained within the mineralized zone.

In order to bring the mine into the production stage, a very substantial capital outlay was indicated, and a decision was made to attack the venture in two stages. The first stage would be to attempt to seal off the large quantity of water intersected by the 2250 level drift, then if the seal were successful, to unwater the mine, drive approximately 1,000 feet of heading under a cementation cover on the 2250 level and drill the mineralized zones to secure samples for complete metallurgical testing. If the seal were unsuccessful, two or more holes would be drilled from surface with large coring equipment to obtain the samples for metallurgical work.

The decision to attempt the seal of the water on 2250 and to drive subsequent openings under cementation cover was based on (1) a realization that permanent unwatering would require pumping 10,000-15,000 gpm. on a sustained basis, (2) the requirement for availability of 15,000 KW of power, roughly estimated at a cost of $3,000,000 to $4,000,000, and (3) the existing power plant on the property, comprised of three 1,000 KW Kiesel engine-generator sets.

Simultaneously with underground work during the first stage, engineering studies embracing power source and plant, mine plant, mill, and underground development would be undertaken in detail, so that as soon as metallurgical results were available a decision could be made as to the economics of proceeding with the second stage, that is, placing the property into production.

On April 1, 1963, Ruby Hill Mining Company (owned 75% by Richmond-Eureka and 25% by Eureka Corporation) leased its property to Newmont Mining

Corporation, Cyprus Mines Corporation, Hecla Mining Company, Richmond-Eureka Mining Company, and Eureka Corporation, with the first three companies to provide funds for completion of the first stage of work (on December 20, 1963, Eureka Corporation was reorganized as a Nevada corporation and renamed Silver Eureka Corporation). Hecla was named as operator.

The 2250 "Seal"

Hecla started work at Ruby Hill April 16, 1963, and first efforts were directed to sealing of the 2250 level crosscut so that the Fad shaft could be unwatered.

The method proposed to effect the seal was (1) drill a hole from surface which would intersect the crosscut near the face, (2) reverse the flow of water into the presumed open fissure at the face of the crosscut, then (3) inject a cement slurry through the drill hole from surface into the reversed flow of water. Sealing would be achieved as cement gradually built up on the walls of the fissure until finally it was completely closed. As an added precaution the drift itself would be filled with cement.

Please refer to Figure 1, and note that Hamburg dolomite and Eldorado dolomite are separated by the Secret Canyon shale. The shale is impervious and acts as a watertight membrane between the two water-bearing dolomites. Velocity tests conducted at several points in water standing in the Fad shaft and drill holes all showed that water was flowing downward from the Hamburg into the Eldorado formation. That fact, coupled with additional evidence, led to the conclusion that Hamburg water and Eldorado water were unrelated, and that the Eldorado dolomite was fed from Diamond Valley, lying north of the mine.

Diamond Valley is about thirty miles long and five to ten miles wide. It was formed by a large N-S fault on either side; the down-thrown block resulted in a deep trough now filled with alluvium. The alluvium is very deep; a wildcat hole drilled by a major oil company did not enter bedrock for a depth of over 7,000 feet. Thus Diamond Valley forms an alluvium-filled reservoir of impressive size.

Under static conditions, the water table in the Fad shaft is at elevation 5890 and the base level of ground waters in Diamond Valley is at about elevation 5850. The difference of forty feet in these two water elevations is regarded as the hydraulic gradient required for the water now moving down the Fad shaft and northward into the Diamond Valley "reservoir". Reversal of the hydraulic gradient by unwatering of the Fad shaft would result in a flow from Diamond Valley into the Eldorado formation, and accounts for the very large quantities of water encountered by Eureka Corporation's development crosscut on 2250 level.

Wells Completion, Inc., was selected as the drilling contractor, and Eastman Oil Well Survey Company was retained to supervise the directional control of the hole. Drilling operations started on June 6, 1963.

The collar of the hole was selected at a point approximately 150 feet northwest of the target to take advantage of expected deflection based on an average of results from previous drill holes.

The hole was drilled with a 9-5/8-inch bit to a depth of 1,815 feet, where it was cased with 7-5/8-inch casing to 1,125 feet. The remainder of the hole was drilled with a 6-3/4-inch bit.

Surveys were made at frequent intervals to determine the position of the hole. After the hole had reached a depth of 1,900 feet, a multiple shot survey at 30-ft. intervals was run as a check. In all, eighteen whipstocks were set to control the direction of the hole, the first at 586 feet and the last at 1,900 feet.

The hole was completed on July 28, 1963, at a depth of 2,260 feet; it intersected the crosscut at the center and about sixteen feet back from the face. Please refer to Figure 2 and Figure 3. Two vertical sections through the drill hole are shown on Figure 4.

During the period of drilling the directional hole, the mine crew was installing a 10-ft. concrete bulkhead in the Fad shaft just above the water table at 1030 level, and the walls of the shaft were concrete-lined for twenty-four feet above the bulkhead.

A 10-inch and a 12-inch pipe column were extended through the shaft concrete bulkhead to the collar of the shaft. Approximately 1,100 gpm. were pumped into one of the columns during the sealing operation. The other column was used for instrumentation to continuously record the shaft water level as the sealing operation progressed (because of the relatively small diameter of the pipe column as compared to the large cross-section of the shaft, increased resistance as the seal progressed could be quickly overcome by increased head).

Continuously recording instrumentation was also installed in two of the earlier diamond drill holes from the Locan 900 level (Fad 800 level). "D" hole, which was sealed off in the Secret Canyon shale, was used to measure the water table elevation in the Hamburg dolomite. "E" hole, which was cased through the Hamburg and Secret Canyon formations, was used to measure the piezometric water level in the Eldorado dolomite.

Also, pumps were installed at the TL shaft approximately 6,000 feet distant, and pipe laid to connect the pump discharge to the top of the pipe column at the collar of the Fad shaft. This system was capable of 1,200 to 1,000 gpm. over an extended period.

After "holing through", the directional drill hole was cased with

5-1/2-inch pipe and a formation packer was set above the point where circulation was lost. Slots were cut in the casing from 8 to 10 feet above the bottom of the crosscut to allow introduction of cement grout.

A 2-1/2-inch ID range line was installed from the collar to a point at the top of the slots described above. An attempt was made to install a packer at the bottom of the range line, but it worked loose and was lost. Cementation was then started without the packer, using a downflow in the annulus to prevent grout from being pumped up between the two casings. However, this failed and the hole became plugged at the bottom. The hole was then drilled out inside the 5-1/2-inch casing and was blasted to reopen the casing. The range line, with a new packer, was reset, and cementation started. No further difficulty was encountered.

During the sealing operation, 900 to 1,200 gpm. of water were pumped continuously into the Fad shaft, and cement slurry was pumped into the drill hole through the range line.

Cement was delivered in bulk by trucks hauling from a plant in Salt Lake Valley and delivered to a 1,200-bag storage silo. Cement was fed from the silo to alternate batch tanks, where it was mixed with water to form a slurry of the desired density. From the batch tanks the slurry was pumped through a reciprocating high-pressure grout pump into the range line. The cementation phase of the work was directed by Grouting Consultants and Contractors, Ltd., of Toronto, Canada.

Cement injection into the drill hole was started on July 28; however, the hole plugged on July 29, as described above, and pumping of cement did not resume until July 31. From that time cement was injected continuously until August 16, at which time pump pressure reached refusal. The range line was then immediately withdrawn. During the period of injection a total of 24,350 sacks of cement were pumped into the hole.

The "E" hole water level rose a maximum of 12.4 feet on the fourth day of grouting, then fell consistently (with the exception of August 17-19), and on August 30 was at a level exactly equal to its level before beginning cementation. (As mentioned earlier "E" hole measures only Eldorado piezometric water level.) This data, combined with the rapid rise in the Fad shaft and "D" hole water levels, indicated that the desired seal was being formed. By August 6, or after injection of approximately 8,500 bags of cement, it was reasonably certain that an effective seal had been formed. However, for safety reasons, and as added insurance, injection continued with the objective of filling the entire space between the face and the water door with cement.

Following the grouting, water was pumped into the shaft at a rate of 1,200 gpm. Total rise in the Fad shaft level was 263 feet above the beginning point, compared to a rise of 49 feet when 1,160 gpm. were pumped during a test prior to grouting. It was apparent that water was still flowing downward in the Fad shaft but that very little water was flowing into the 2250 service drift, where the cementation was directed. There was undoubtedly flow into the 2250 haulage drift (which made 250-350 gpm. after the heading crossed the Martin fault into Eldorado dolomite - see Figure 3) and into the 2000 level crosscut just off 2000 station (which we believed made 300 (?) gpm. after this heading crossed the Martin fault into Geddes limestone), as well as a considerable flow of water into the Hamburg formation.

From the information available, it was concluded that sealing was achieved. The effectiveness of the seal following unwatering of 2250 level, when the seal would be under pressure, was still problematical.

At this point a decision was made to cement the bottom of drill hole No. 513 to 1,900 feet and to whipstock the hole to a point about 20 feet ahead of the face, the lower part of this hole to be cored. Pressure grouting (and possibly reverse-circulation cementation) were planned. A cement plug in the bottom of the hole was placed, following removal of the grout range pipe and 5-1/2-inch casing pipe. This plug was drilled to a depth of 1,900 feet and a whipstock started. While orienting the whipstock (on Sunday, August 18) the drill string became stuck in the hole. After a week of frustrating and unsuccessful attempts to recover, the hole was abandoned. A whipstock, eight drill collars, a set of jars, numerous subs, about 520 feet of drill pipe and a keyseat wiper were lost in the hole at an estimated cost of $14,000. In addition, the cost of fishing was approximately $15,000. Loss of the hole was extremely disappointing. Fortunately, the precaution of this additional pressure grouting later proved to be unnecessary to successful unwatering of the shaft.

Unwatering Fad Shaft

Following completion of the directional hole and injection of cement into the 2250 crosscut, with apparently good results in sealing the large water flow there, the Ruby Hill participants decided to attempt unwatering of the Fad shaft.

It was first necessary to overhaul two of the three 1,000 KW Worthington Diesel engine-generator sets, to put them in condition for continuous operation. Pumping was started prior to completion of this work, but at a reduced rate.

Pumping began September 8, with a 100-hp. B-J sinker pump, to lower the water in the Fad shaft to a point below the concrete bulkhead, and the water level was held at approximately 5,900 feet elevation during the time the bulkhead was being removed.

Pumping with a 450-hp. B-J submersible was started on September 26 at an approximate rate of 1,000 gpm.; during the first half of October, with only No. 1 Worthington Diesel-generator in operation, only 1,000 kilowatts of power were available for pumping, hoisting and other use. One 4GT pump was operated on 800 level, plus the 12-stage B-J 450-hp. submersible pump which was previously set in the shaft at 1800 level. The pumping rate was therefore limited to a maximum of approximately 1,200 gallons per minute.

On October 18, a second 4GT pump was put into operation on the 800 level, and the submersible was allowed to pump at full capacity, a rate of nearly 2,000 gpm. Capacity of the submersible pump dropped off as the shaft water level receded.

By November 1, 1963, and although the pumping rate had not exceeded 2,000 gallons a minute, the shaft was unwatered to a point 428 feet below the previous average water level. In a drawdown test conducted by the USGS in 1952, during which 3,600 gallons per minute were pumped for a period of thirty days, the water level was only lowered 264 feet. During the same period of the drawdown test, the Eldorado water level (as measured in hole "F") was lowered approximately 100 feet. This compares with the lowering of the Eldorado water during the present unwatering (as measured by hole "E") of 29 feet. This indicated that a substantial portion of the Eldorado water had been sealed off from the Fad shaft.

The 1700 station was unwatered on November 28, 1963. On the morning of February 28, the 2250 level was unwatered, and the shaft water level held at 30 to 40 feet below the floor of the 2250 station.

An inoperable submersible pump which was installed in the chippy compartment (hanging from 2000 level to below the 2250 level) was removed, and the chippy compartment cleared to 2000. Two new 10-inch pump columns were installed from the 1700 sump to the 2000 level. Two submersible pumps were reinstalled in the chippy compartment, hung from beams just below 2000 station. These pumps were used to unwater the shaft to below 2250.

The two submersible pumps left by Eureka Corporation in the north hoisting compartment (which were hung from 1700 level to a point just above the 2250 station) were both removed from the shaft.

The two submersible pumps installed in the chippy compartment were left there permanently, and were valved and piped so that each can pump either to the 1700 sump or to the 800 sump. These two pumps will be available for unwatering if the shaft is later flooded. The electrical starters for these two pumps are both located on 800 level. One of the pumps (450-hp., 12-stage) is presently capable of holding the water at a point just below 2250 level, but the second pump (350-hp.) is not. Both submersible pumps are hung from the same set of beams and include shrouds extended over the motors to reduce the fouling of intake screens by rocks and other debris. These pumps were operated until 2250 level station pumps were installed.

Except for a small amount of water from the 2250 haulage drift (150-200 gpm.) and the 2000 drift (200 gpm.), all of the water pumped from the shaft on March 1, 1964, was water which originated from the Hamburg dolomite, above the Hamburg-Secret Canyon contact at 2,100 feet below the collar; the pumping rate was approximately 2,040 gpm.

2250 Station Cementation

Considerable work in drilling and high-pressure cementation of the rocks in the neighborhood of the original openings on 2250 to make the workings safe from the large volumes of high-pressure water known to be present was planned as soon as the level was reached. This phase of the work turned out to be even more difficult and time-consuming than anticipated.

The haulage drift west of the access crosscut, and the access drift, were completely filled with muck. At the shaft, muck covered with cement was found to a depth of four feet. From the shaft the top of the cement sloped back gradually to a point about twenty feet from the shaft, then steepened rapidly until the cement filled the station tightly to the back at a point about forty-five feet from the shaft. Water was draining continuously out of the access crosscut at a rate of 150 to 200 gpm. It was believed that this water was originating from the west face of the haulage drift, but since the latter was caved full the condition of the drift or origin of the material filling it was unknown. The pumproom contained three feet of mud covered with a shell of cement.

It was apparent that the muck filling the 100 feet of haulage drift might be acting as a friction plug, so that it could not be safely removed. Nor could the cement filling the station be removed, since it might be acting as a bulkhead keeping the seal in the service drift in place.

Please refer to Figure 5, a plan of underground openings on the 2250 level. Early pressure-grout holes are also shown.

The south half of the station was cleaned back seven sets, or 42 feet, to the point where cement fill was almost as high as the station caps. A part of the access crosscut between the station and haulage drift was cleaned out. A hole (No. 1) was then drilled from the station end of the crosscut which intersected the haulage drift about 43 feet from its face. The hole apparently drilled into loose muck, but no high-pressure water was encountered.

Next the access crosscut was cleaned. The haulage drift east of the ore pocket was found in good condition, with steel sets intact. From the pocket west, the steel sets had been pushed eastward several feet and were badly twisted and distorted. The haulage drift west of the crosscut is packed tightly with muck. This debris apparently came from the face with great force, pushing the steel sets out of place and completely filling the drift and crosscut. Between the pocket and crosscut, steel sets, lagging, a mucking machine, and a rocker dump car body jammed together and formed a barrier which prevented muck being washed east past the pocket.

In drilling holes for cementation, a length of 2-1/2-inch collar pipe (not less than 10 feet) was first cemented into place, a full-opening high-pressure valve installed, and the collar pipe tested at grouting pressures. As holes were deepened, they were frequently tested with the grout pump, to avoid hitting high-pressure water in a hole which might "short-circuit", or leak through fractures in the rock.

All drilling was with G-D DH99 drills and 1-1/8-inch sectional long-hole steel with 1-7/8-inch bits. Holes were drilled to water, grouted, redrilled to water, etc., until they were completed to the planned objective. Initial cementation on 2250 level was at rather low pressures (600 to 700 psi. - compared with static pressure of 500 psi.). As grouting proceeded, higher pressures could be used.

The greatest difficulty in the drilling and grouting program was the inability of the Secret Canyon shale, in disturbed or faulted areas, to stand pressures required for cementation.

The cementation, or pressure-grouting, work was done under the supervision of Cementation Company of Canada, Limited, under the direction of a superintendent and three shift foremen. Three high-pressure grout pumps and mixing tank sets, designed and manufactured by Cementation Company, were rented.

As may be seen by the section along the plane of the Martin fault, Figure 6, a circular pattern of drill holes was developed around the haulage and service drift openings.

During the cementation program carried out from the 2250 station, 53 holes were drilled, including a total of 5,147 feet of new drilling and 20,064 feet of redrilling. A total of 10,583 sacks of cement were injected into these holes. See Figure 7.

Static pressure determined in drill holes when water was encountered was uniformly 520 psi. At this pressure flows of up to 600 gpm. were commonly encountered. Often large amounts of rubble accompanied the water, and working conditions until the drill steel could be withdrawn and the valve closed were distinctly uncomfortable.

Cementation termination pressures reached 1,750 psi. to 2,000 psi. in all of the holes. Many of the grout holes drilled through previously injected cement and the possibility of voids or weak, unconsolidated zones in the area surrounding the openings was virtually eliminated.

Cementation of the area around the service drift and haulage drift proceeded very satisfactorily, and by June 1, it was concluded that the area was well "tightened up" and could be assumed safe.

2250 Level Crosscutting

During the progress of the cementation of the Martin fault area surrounding the old haulage and service drifts, it was decided not to reenter this area but to drive a new heading south, avoiding the previously disturbed ground altogether.

Figure 7 illustrates the position of the proposed development crosscut, and a number of holes which were drilled from Drill Site No. 5 to accurately determine the position of the Martin fault.

At the time of starting crosscutting, approximately 1,500 gpm. of water were being pumped from the mine.

The main crosscut was then advanced 93 feet in Secret Canyon shale, all of which was incompetent and required rock bolting for support, to a point 40 feet east of the Martin fault, to allow cementation of the fault area and of the Eldorado formation west of the fault. It was planned to install the water door at the fault intersection, and utilize the concrete lining to provide ground support.

The grout cover holes drilled through the fault essentially formed three rectangles at intersection with the fault; the first being eight feet by ten feet and centered on the door location; the second being a 25-ft. square and the third being a 50-ft. square. (See Figure 8.) Drilling and injection were started in the center and progressed outward to the 50-ft. cover. Injection pressures were approximately 1,500 psi. A total of 4,023 feet was drilled from the face in 39 drill holes (see plan), and 2,073 sacks of cement were injected in these holes. Communication between the holes was disappointing, and the cementation work progressed very slowly. Test holes drilled after completion of the grouting program indicated an effective grout curtain to a point only about 30 feet west of the fault. Poor grouting results were probably due to two factors: (1) fractures and fissures in the Eldorado are tight and contain enough gouge to limit cement acceptance and communication between holes, and (2) all of the holes were collared in very incompetent Secret Canyon shale; this resulted in pumping particles of shale and mud from the Secret Canyon into the water-bearing fractures in the dolomite, resulting in blocking, or partially blocking, the channels required for successful cement injection. Chemical treatment was used in most of the holes and may have helped to partially overcome the difficulties.

After completion of the grouting program, the drift was advanced 41 feet to a point a few feet west of the fault; the face stopped in yellow Eldorado dolomite. The Secret Canyon formation east of the fault was distorted and brecciated, with substantial amounts of clay and gouge material. A few feet of Geddes limestone were encountered just east of the fault.

A 100-ft. grout cover was then drilled and pressure-grouted. This cover consisted of twenty holes plus a center-line pilot hole. The cover required 2,174 feet of new drilling, 10,123 feet of redrilling, and injection of 1,022 sacks of cement. Cementation was carried out at 2,000 psi. with refusal pressures up to 3,000 psi.

An advance of 76.6 feet was made under this cover (denoted as 200 Series), all in highly fractured, crushed, and partially recemented Eldorado dolomite. See Figure 9.

The intensely-fractured dolomites did not accept cement freely enough to allow complete penetration of the fine fractures, and, as a consequence, these fractures continued to make small volumes of water totaling approximately 88 gpm., 14 gpm. of which was from the face. Although the fractured dolomite was "leaking" water, cementation consolidated the ground so that no erosion occurred, and no increase in flow was experienced.

The next grout cover (300 Series) consisted of seventeen holes and included 2,104 feet of new drilling, 6,938 feet of redrilling, and the injection of 972 sacks of cement. Twenty-six days were required to complete the cover and drive the heading. The initial grouting was completed in seventeen and a half days, but wet conditions caused stoppage of the drive and an additional three days of grouting.

All of the advance was through highly-fractured dolomites requiring support; rock bolting and steel mats provided good support but reduced the cover and resulted in added amounts of water estimated at 40 to 50 gpm. As a result of this experience, it was decided to discontinue use of rock bolting in subsequent drives.

It also became evident at this point that more holes would be required to achieve the penetration of grouting materials necessary for an effective cover. Accordingly, a new cover pattern was developed which included 22 holes, plus a pilot hole in each corner of the heading, plus an additional center-line pilot hole if the corner pilot holes showed excessive water. To this basic pattern it was necessary to add extra holes in the back; this was required because the back "leaked" more than either rib or the bottom of the heading, probably due to relaxation of the rocks caused by gravity.

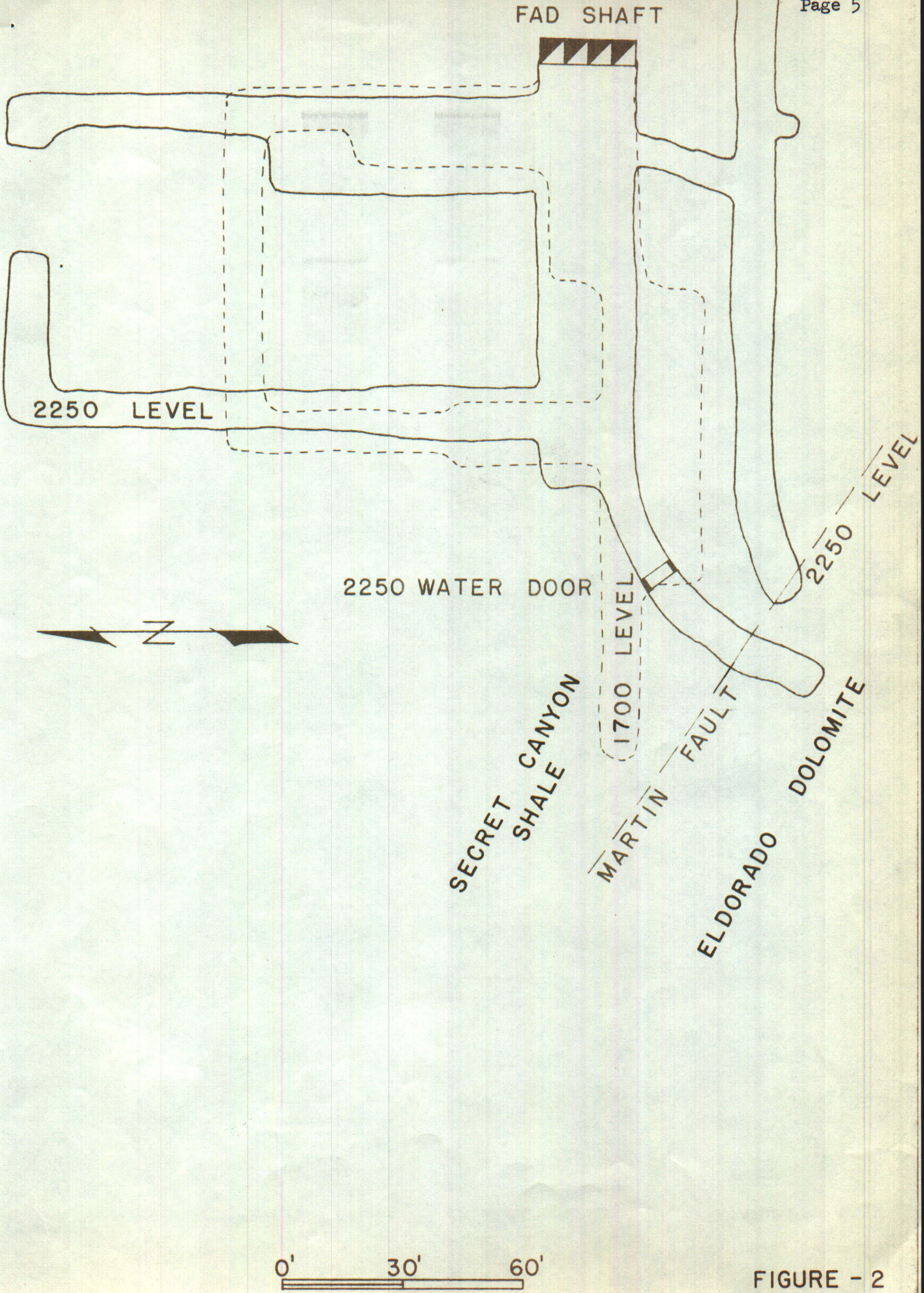
Additional "short" holes were placed in the back as needed.

Figure 10 on the following page illustrates a section through this cover, at right angles to the crosscut axis, and at a distance of 100 feet from the face. Figure 11 shows a typical long section through the cover.

This cover design proved to be very satisfactory and with occasional slight modifications was used throughout the balance of the crosscutting.

Working on a three-shift-per-day seven-day-per-week basis, about 100 feet of crosscut advance were attained per month.

A water door was installed adjacent to the Martin fault. The concrete bulkhead was fourteen feet long and placed in Eldorado dolomite. Armco Steel tunnel liner plate was used to line 53 feet of the crosscut east of the bulkhead, and Martin fault, all Secret Canyon formation which consisted of soft, brecciated shales with little competency. The steel liner and door were designed by the Hecla Engineering Department and fabricated by the Coeur d'Alenes Company.


FAD SHAFT
2250 LEVEL
2250 WATER DOOR
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2250 LEVEL
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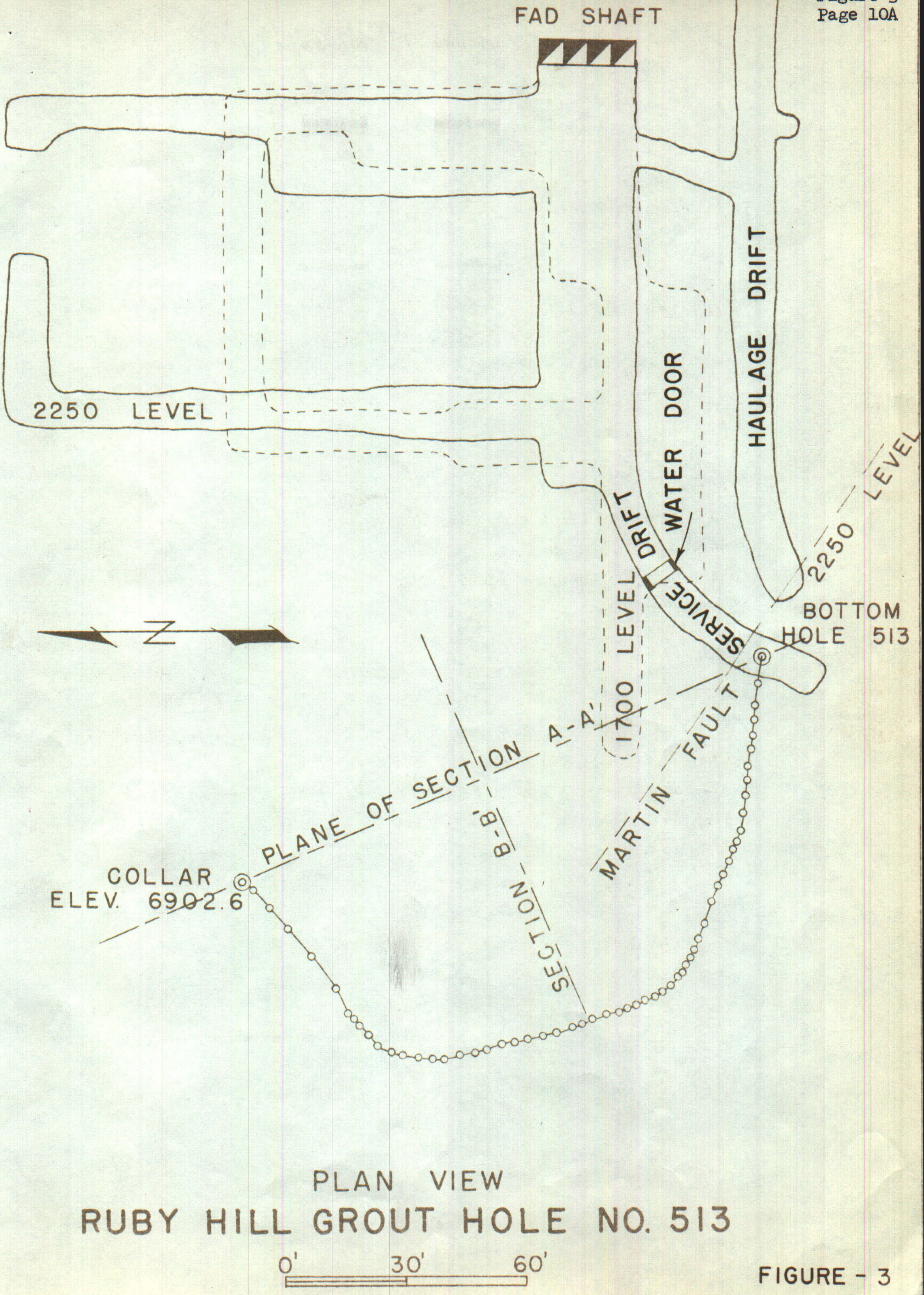
SHALE
MARTIN FAULT
ELDORADO DOLOMITE
N
0'
30'
60'

FIGURE - 2



PLAN VIEW

RUBY HILL GROUT HOLE NO. 513

FIGURE - 3

RUBY HILL GROUT HOLE NO. 513

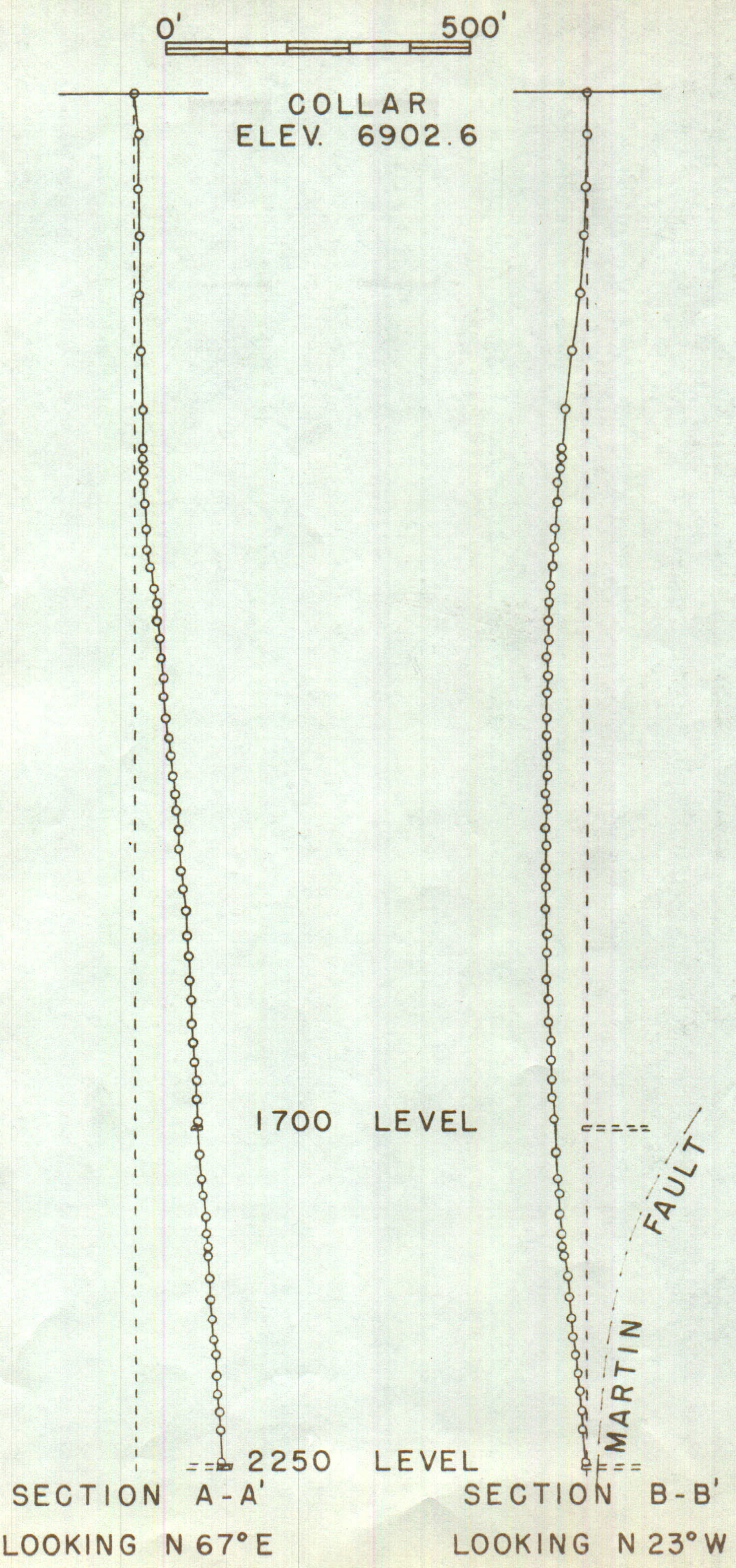
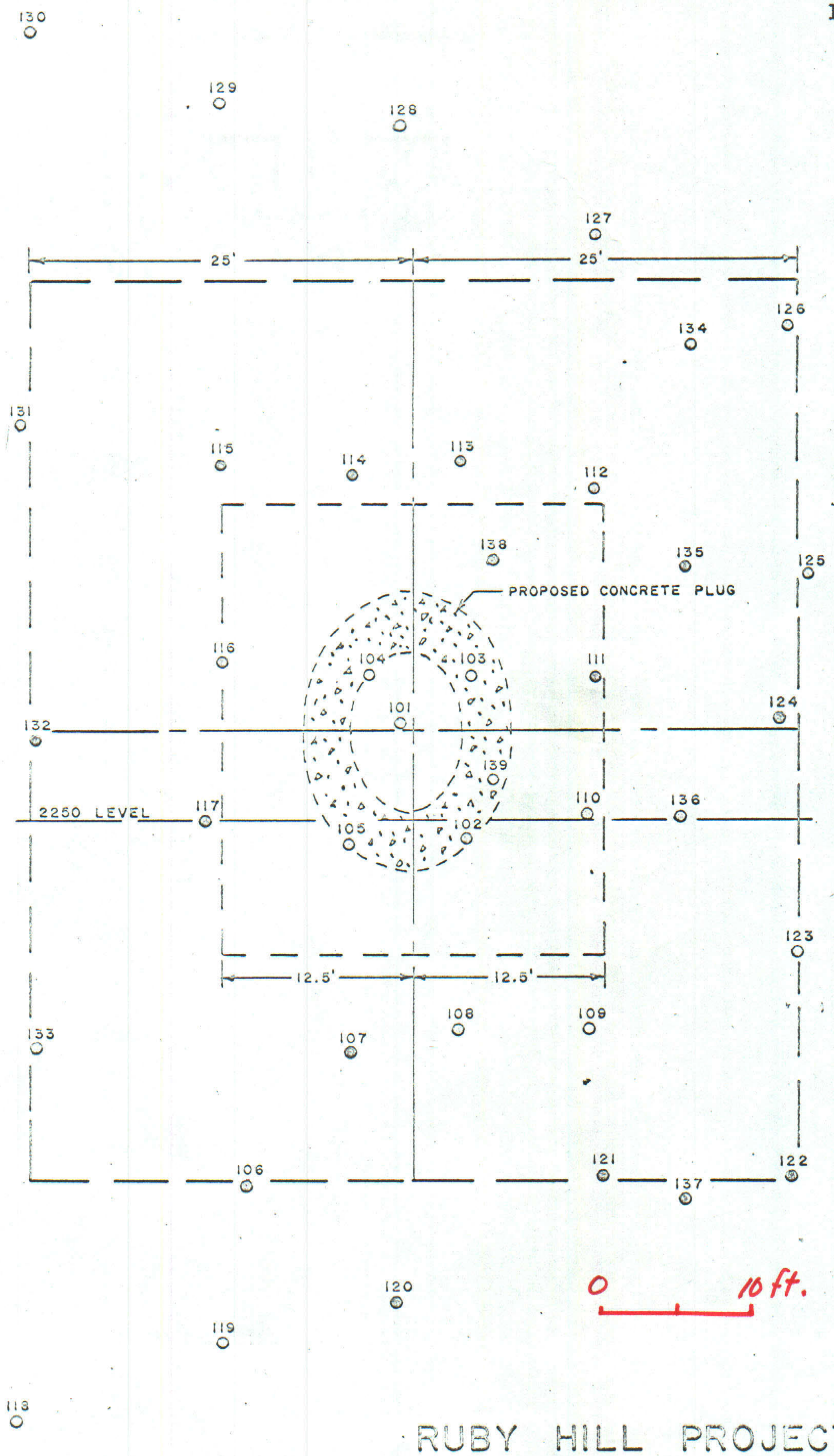


FIGURE - 4



RUBY HILL PROJECT

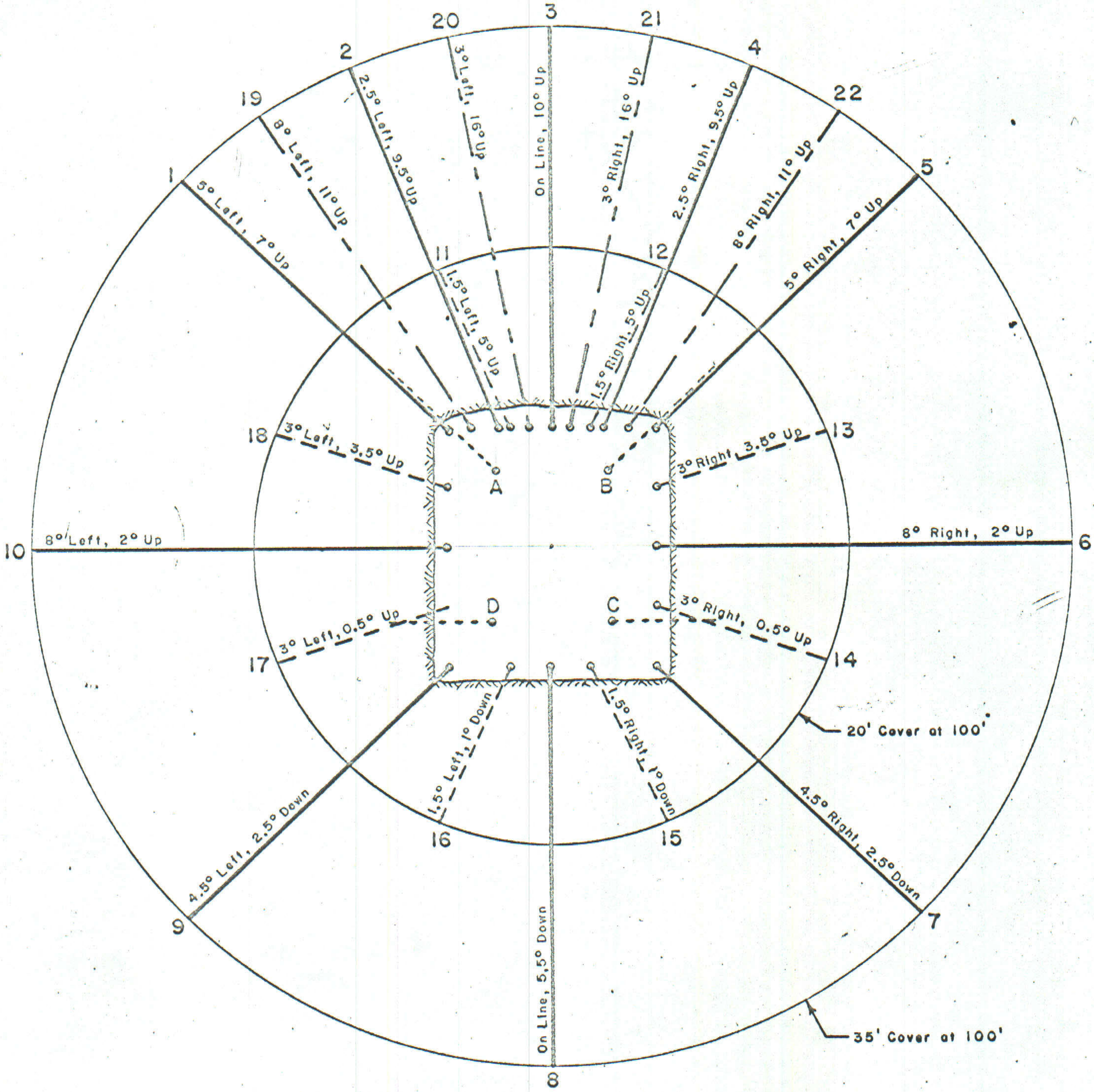
SECTION IN PLANE OF 59° DIP FAULT
LOOKING S 76° W
SHOWING INTERSECTION OF GROUT HOLES

SCALE 1" = 10'

FIGURE - 8

July, 1964

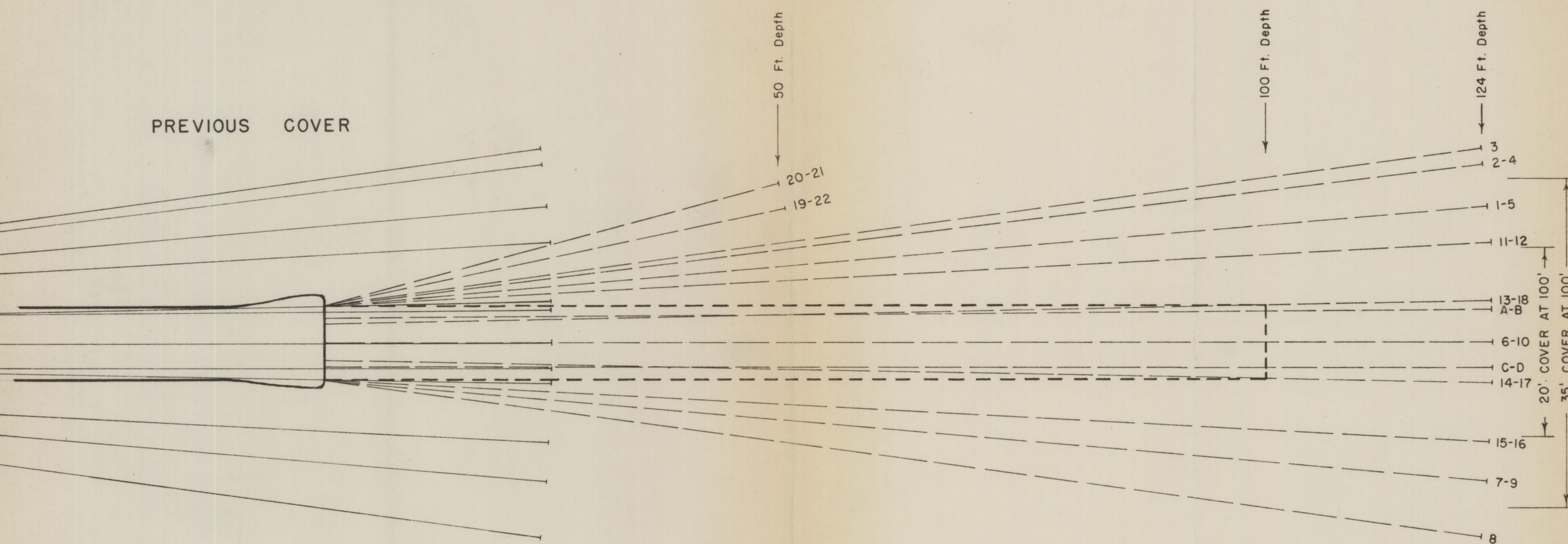
A = 2° Left, 2° Up
B = 2° Right, 2° Up
C = 2° Right, Flat
D = 2° Left, Flat



ALL HOLES TO BE DRILLED TO 120', EXCEPT HOLES 19, 20, 21, & 22, WHICH WILL BE DRILLED TO 50'

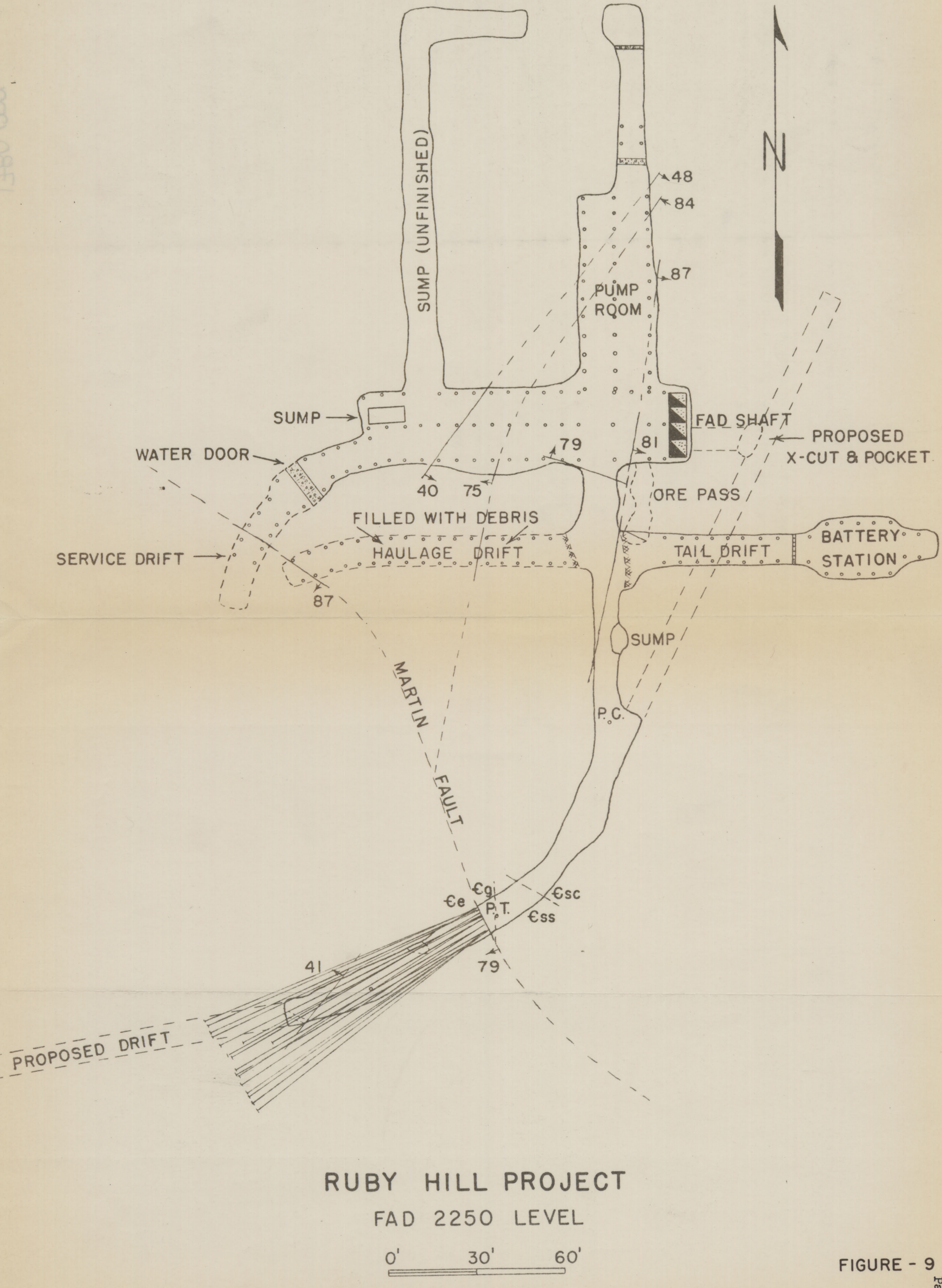
FIGURE-10

GROUT HOLE PATTERN



LONGITUDINAL SECTION
GROUT HOLE PATTERN

FIGURE - 11



RUBY HILL PROJECT

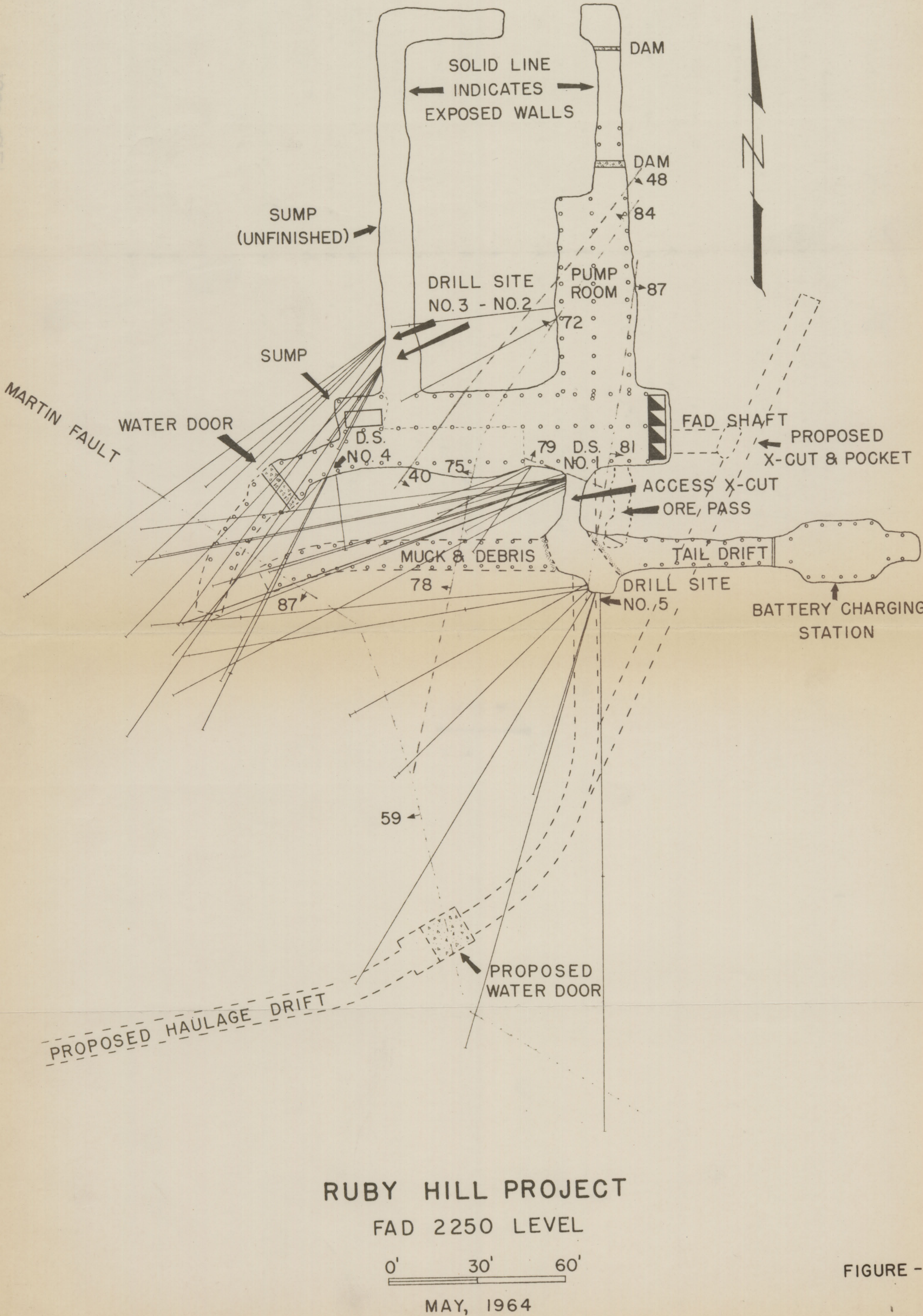
FAD 2250 LEVEL

0' 30' 60'

AUGUST, 1964

FIGURE - 9

Figure 9
Page 25

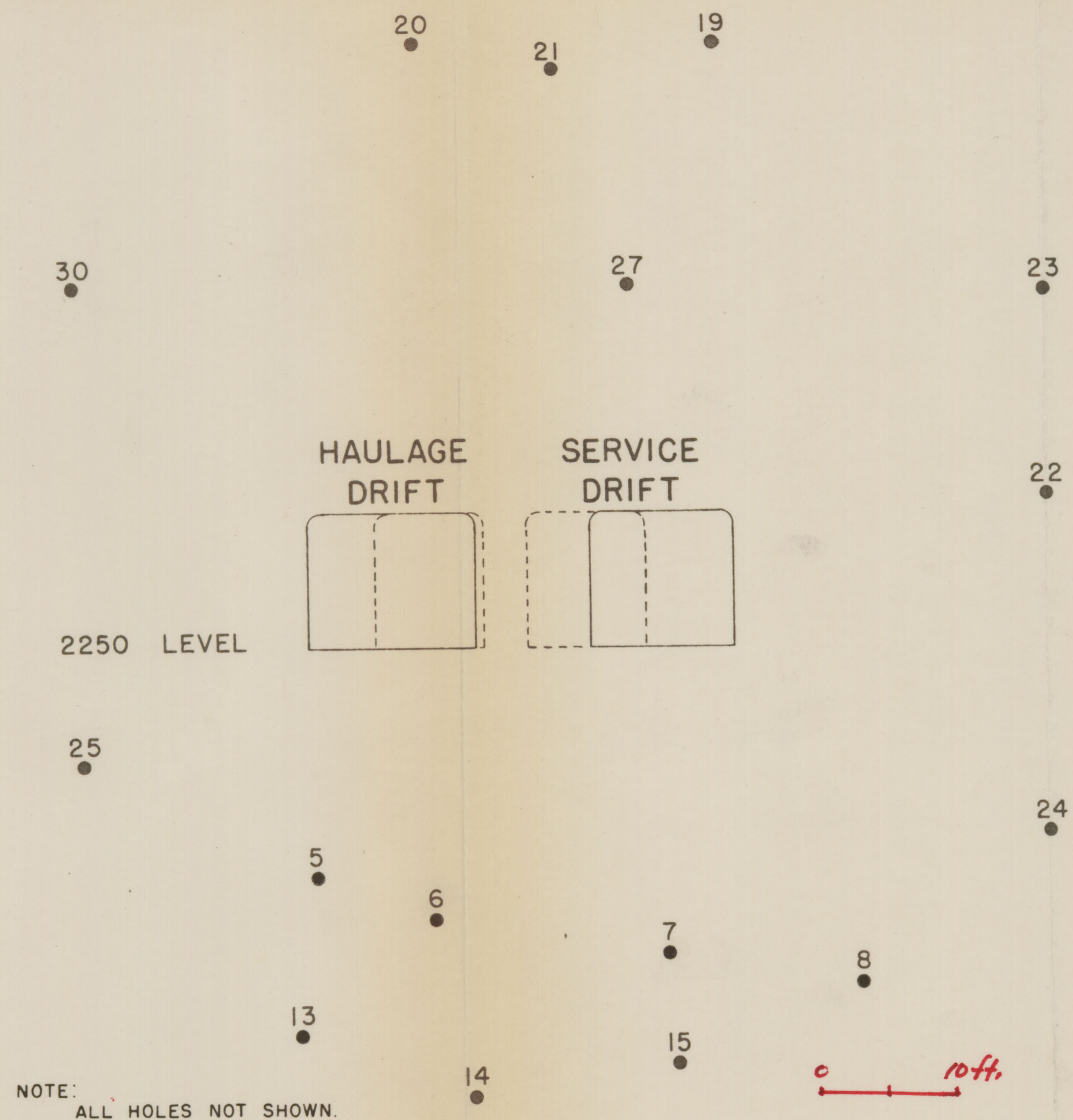


RUBY HILL PROJECT

FAD 2250 LEVEL

MAY, 1964

FIGURE - 7

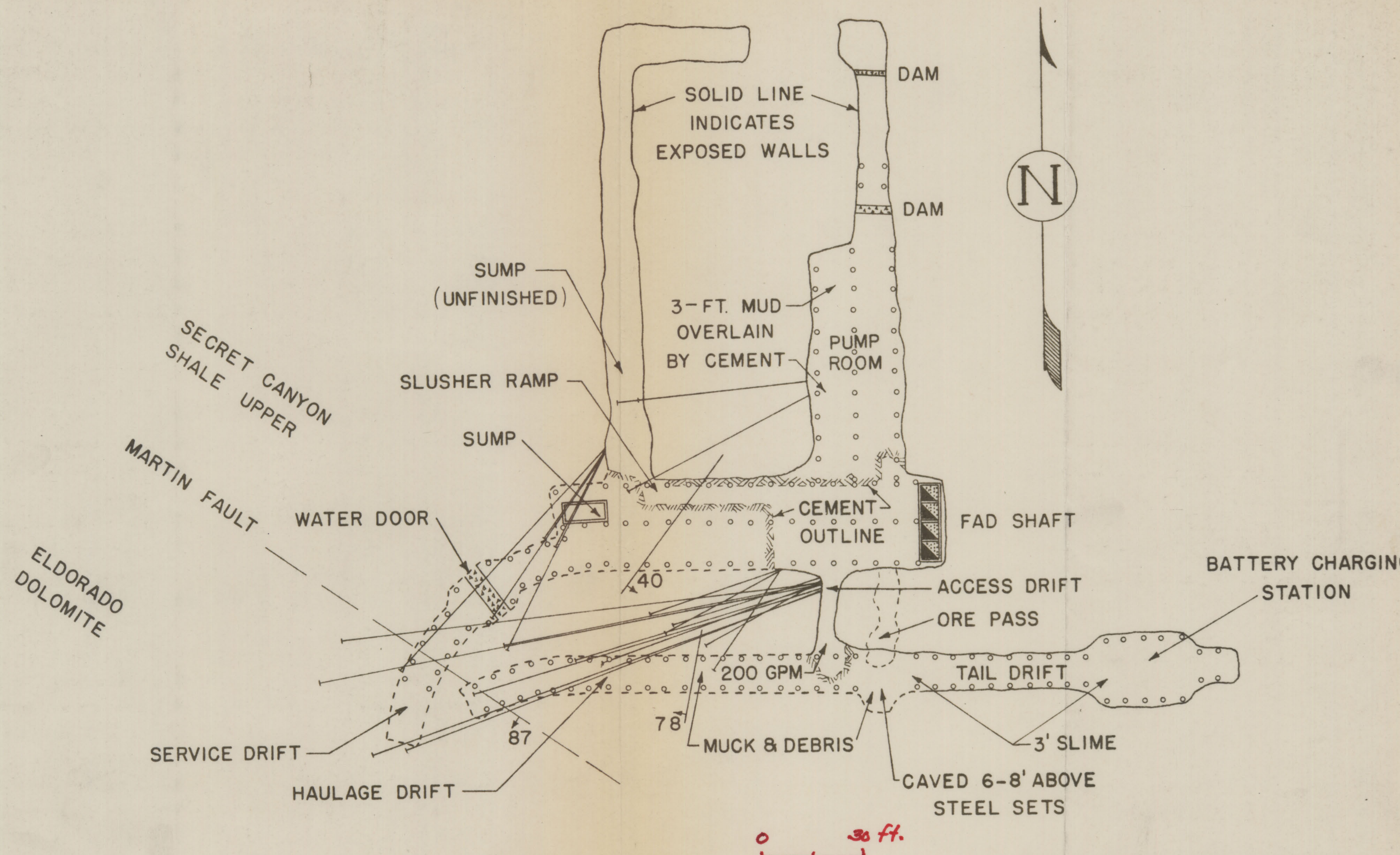


RUBY HILL PROJECT

SECTION IN PLANE OF MARTIN FAULT
SHOWING INTERSECTION OF GROUT HOLES

SCALE 1" = 10'

FIGURE - 6



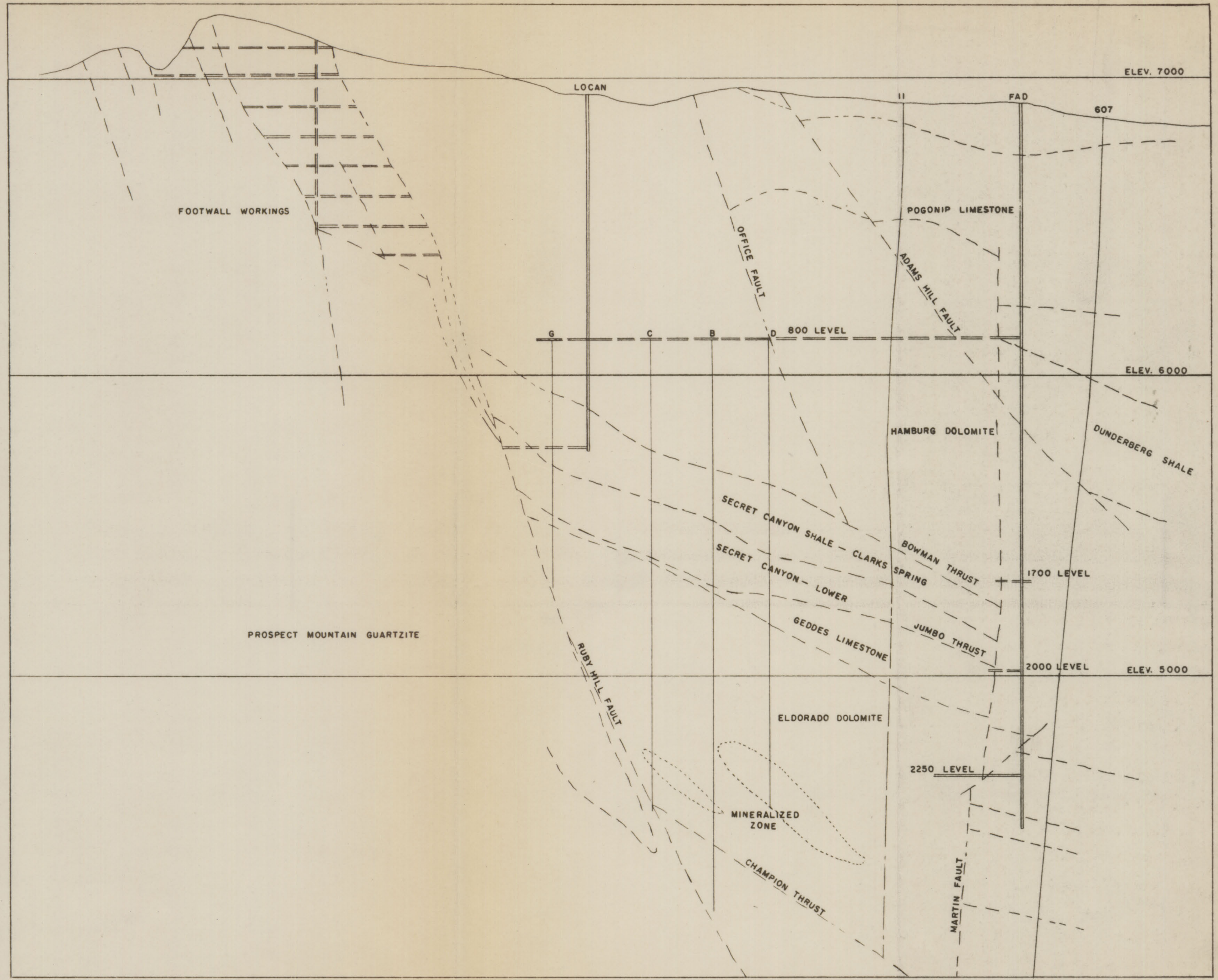
RUBY HILL PROJECT

FAD 2250 LEVEL

SCALE 1" = 30'

MARCH 1964

FIGURE - 5



RUBY HILL PROJECT

VERTICAL SECTION LOOKING
NW THROUGH FAD AND LOCAN SHAFTS

SCALE 1"= 100'

FIGURE - I

1780 0006