UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF RAW MATERIALS
SALT LAKE EXPLORATION BRANCH

REVIEW OF DIAMOND DRILLING
PRACTICES AT MARYSVALE, UTAH

Part I
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June 1952
Salt Lake City, Utah
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Title of Report: REVIEW OF DIAMOND DRILLING PRACTICES AT MARYSVILLE, UTAH

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REVIEW OF DIAMOND DRILLING PRACTICES AT MARYSVALE, UTAH

PART I

ABSTRACT

On August 22, 1950, the first diamond drilling for the Atomic Energy Commission in the Marysvale District, Utah, was started. This first drilling was done by two drill rigs of the Bureau of Mines under the supervision of Mr. A. A. McKinney. On August 15, 1951, the Bureau of Mines' rigs were moved out of the Marysvale area after drilling 19 surface holes for a total of 10,278 feet. This drilling was done in a total of 1,243 shifts, giving an average of 8.3 feet per shift. Core recovery averaged 95.9 percent. The cost of drilling per foot of hole was approximately $10.00. No underground drilling was performed by the Bureau of Mines.

In December, 1952, a contract specifying both surface and underground diamond drilling was let to Boyles Brothers Drilling Company of Salt Lake City, Utah, under Contract No. AT(30-1)-1066. The first Boyles Brothers drilling was started on January 15, 1951, with drill hole No. 8. On August 18, 1951, Boyles Brothers completed 21 holes for a total of 11,861 feet of surface drilling and 19 holes for a total of 3,341 feet of underground drilling, the maximum amount called for under this first contract.

Contract No. AT(30-1)-1197, for continued diamond drilling in the district, was awarded to Boyles Brothers and was started simultaneously with the completion of their first contract on August 18, 1951. Through February 25, 1952, Boyles Brothers completed on their second contract, 20 holes for a total of 10,517 feet of surface drilling and 4 holes for a total of 1,348 feet of underground drilling.

The drilling conditions encountered in the Marysvale area are unusually difficult. Drilling costs are high and special techniques are required to attain a satisfactory core recovery. The type of rock that has been drilled varies from an extremely hard silicified rhyolite to a very soft, highly altered, quartz monzonite. The many years of experience with diamond drilling by Mr. Paul Park, foreman for Boyles Brothers, has been an extreme asset to the project. With respect to the drilling conditions in the Marysvale area, Mr. M. H. Kline, Chief, Special Minerals Branch of the Bureau of Mines, stated that, "The drilling conditions encountered on the Marysvale job were the most difficult in more than ten years of experience with this type of work. The fractured and altered character of the rock necessitated using special techniques and equipment to make good core recovery and obtain satisfactory footage."

The following Table No. 1 shows the drilling statistics for underground and surface drilling by both the U. S. Bureau of Mines and the Boyles Brothers Drilling Company.
ORE RESERVES DEVELOPED BY AEC EXPLORATION DIAMOND DRILLING

106,410 tons of measured and indicated ore at a grade of 0.26 percent U₃O₈ was developed in the Marysvale district by exploration mining methods performed by private companies. In conjunction with this underground exploration and development work, 37,345 feet of underground and surface diamond drilling was completed by AEC. The result of this drilling increased the total ore reserves to 287,160 tons at a grade of 0.26 percent U₃O₈. Thus the diamond drilling performed developed 180,750 tons of indicated and inferred ore at a grade of 0.25 percent U₃O₈. This shows that 4.71 tons of ore were developed per foot of diamond drilling, which represents 23.5 pounds of U₃O₈ per foot drilled. The overall contract cost for all drilling was $345,877 or $9.26 per foot. The drilling cost per ton of ore developed is $1.97 or $.39 per pound of U₃O₈ developed. This does not include the cost of per diem, salaries, supplies, instruments, services, etc. for AEC personnel. It is estimated that approximately $80,000 has been expended on the Marysvale project by this office, in addition to the contract costs of drilling. The total cost to the Commission for the exploration work in Marysvale over a period of approximately 18 months is estimated to be $425,877 which represents a cost of $2.36 per ton of ore developed or $.47 per pound of U₃O₈ developed.

In addition to the calculated reserves, 309,500 tons of speculative ore, at a grade of 0.22 percent U₃O₈ were developed principally as the result of AEC diamond drilling in Marysvale.
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<thead>
<tr>
<th>Operator</th>
<th>Period of Operation</th>
<th>Total No. of Holes Drilled</th>
<th>Total Feet Drilled</th>
<th>Total No. of Shifts</th>
<th>Average Feet Per Shift</th>
<th>Average Core Recovery %</th>
<th>Overall Cost Per Foot</th>
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REVIEW OF
DIAMOND DRILLING PRACTICES
AT MARYSVALE, UTAH

PART II

GENERAL FEATURES OF DRILLING CONTRACTS

The Boyles Brothers contract required AX, BX, and NX cores from holes up to one thousand feet in depth. It also allowed for near-surface non-core drilling. A price schedule was set up by the contract for reaming in all sizes, and for cementing on a footage basis. Allowances were not made for handling casing, or drilling mud, as it is not customary to do so in hard rock drilling contracts.

The contractor was required to maintain three complete surface drill rigs, and also retained one underground drill to be used at the option of the Commission. The inclination of the surface holes ranged between 45 degrees and 90 degrees and underground holes from 0 degrees to 90 degrees. All of the following statistics have been compiled from 41 holes drilled by Boyles Brothers, unless otherwise stated.

TYPE OF DRILLING

Through February 25, 1952, Boyles Brothers and the Bureau of Mines have drilled a total of 60 surface holes, of which 65 percent or (39 holes) have been drilled on a 45 degree inclination, 25 percent or (15 holes) drilled on a 60 degree inclination, and 10 percent or (6 holes) drilled on an inclination varying between 60 degrees and 90 degrees. The depths of the 60 holes were distributed as follows:

- 5 holes between 200 and 300 feet . . . . . 8% of total footage
- 9 holes between 300 and 400 feet . . . . . 15% of total footage
- 12 holes between 400 and 500 feet . . . . . 20% of total footage
- 13 holes between 500 and 600 feet . . . . . 20% of total footage
- 12 holes between 600 and 700 feet . . . . . 20% of total footage
- 6 holes between 700 and 800 feet . . . . . 10% of total footage
- 1 hole between 800 and 900 feet . . . . . 2% of total footage
- 1 hole between 900 and 1000 feet . . . . . 2% of total footage
- 1 hole over 1000 feet . . . . . . . . . . . . 3% of total footage
45 Degree Holes

Twenty-four holes by Boyles Brothers were drilled at an inclination of 45 degrees. A total of 12,600 feet were drilled using 2,578 feet of cement and 1,852 feet of reaming. This drilling required 877 shifts. The statistics for the 45 degree holes are as follows:

Cost per foot $9.08
Feet per shift 14.4
Feet of cement per hole 107.0
Feet of cement per hundred feet of hole 20.0
Feet of reaming per hole 72.0
Feet of reaming per hundred feet of hole 16.0
Average depth of hole (feet) 525.0
Average core recovery 78%

60 Degree Holes

Based on ten holes drilled by Boyles Brothers the statistics for the 60 degree holes are as follows:

Cost per foot $10.36
Feet per shift 11.5
Feet of cement per hole 169.0
Feet of cement per hundred feet of hole 37.0
Feet of reaming per hole 67.0
Feet of reaming per hundred feet of hole 15.0
Average depth of hole (feet) 450.0
Average core recovery 72%

60 to 90 Degree Holes

Based on six holes of Boyles Brothers the statistics for the holes with inclination varying between 60 degrees and 90 degrees are as follows:

Cost per foot $9.13
Feet per shift 11.9
Feet of cement per hole 131.0
Feet of cement per hundred feet of hole 19.0
Feet of reaming per hole 72.0
Feet of reaming per hundred feet of hole 11.0
Average depth of hole (feet) 689.0
Average core recovery 78%

Size of Hole Drilled

The compiled statistics for each of the drilling sizes for 41 holes drilled by Boyles Brothers, are as follows:

NX Drilling

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<tr>
<td>Average footage of NX drilling per hole</td>
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<tr>
<td>Total reaming of NX hole</td>
<td>2,285</td>
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The primary purpose of reaming is to case bad parts of the hole without having to reduce size of the hole. The main trouble encountered in reaming was the binding of reaming tools because of altered rock, fault gouge zones, etc. The use of mud, where there was excessive water loss, was an advantage as it raised the cuttings and caked the walls allowing the drill string to go in and out of the hole with greater ease and with less opportunity of sticking the drill rods. This practice would often stall-off or avoid the necessity of reaming.

**DIAMOND DRILL BITS**

Bortz, congo and carbon stones were used in both flat and rounded face bits. From a cost standpoint bortz stones in a round face bit usually gave the best performance. In the round faced bit the stones are more securely held on the edges of the bit and since the bit contains more stone it cuts faster in hard ground. Bits with a hard matrix were used almost entirely as they were found to be tougher, more resistant to abrasion and gave better results in hard broken ground.

Impregnated bits were not used for several reasons. First, it is seldom possible to use more than even 50% of the impregnated matrix and there is no factory salvage allowance made for the used bit as customary in the case of cast or sintered bits. Secondly, loss of gauge usually imposes a reaming job on the following new bit.
CORE BARRELS

Five types of core barrels have been used in drilling at Marysvale. A regular swivel tube barrel using a standard bevel wall bit was used in broken rock, but only when BX core was being drilled.

The Series C swivel barrel was used with a face discharge bit as well as a regular bit. This barrel was designed for the purpose of facilitating the use of mud in drilling by having a greater clearance between the core barrel and the wall rock and also a greater clearance between the inner and the outer tubes. This design made it necessary to use a wicker face bit. The Series C barrel was used in weathered, decomposed, or altered monzonite and granite and in gouge zones. As a rule this barrel would give good results unless there were small particles of hard rock in the gouge. In such a case the water had a tendency to wash out the mud and leave the hard particles in the barrel.

The Series D swivel barrel can be used either with a face discharge bit or a regular discharge, the face discharge bit giving the best core recovery in gouge and decomposed rock. The disadvantage of this barrel is its thin construction of the shell and bit thus increasing the chance of snapping-off the bit or both the bit and shell while drilling. This happened several times.

The ridged tube barrel was used mostly in solid or highly jointed rock. It was also successfully used to advance through rock which had caved into the hole. A swivel tube barrel, as a rule, would pick up sand or cave in attempting to reach the bottom of the hole and would not allow the advancing of the hole with core until completely shutting off the area of cave.

The single tube core barrel was used in drilling rhyolite. Because of its rugged construction, it lasted better through both the decomposed and the hard parts of the rhyolite without blocking. The core return was poor with the single tube, but core was relatively unimportant in the rhyolite. After a hole was cut through the rhyolite, the rock was usually cemented or reamed.

SCREW FEED VS HYDRAULIC

Both the screw feed and the hydraulic feed boring head were used by Boyles Brothers. There does not appear to be any distinct difference in the performance of the two types of drills, although statistics indicate a slightly greater feet per shift average for the screw feed drills. For an unknown reason the screw feed operates better in highly jointed rock than does the hydraulic. The hydraulic has an advantage in being able to retain an even pressure on the bit by manually adjusting the feed to the need whereas the screw feed has four positions of feed and no variations without changing gears.

In general it can be said that capability of the driller has more to do with performance of a drill than does the type of feed that the drill is equipped with.
CEMENT

Three types of cement have been used, Cal Seal, Lumnite, and Portland, plus combinations of these. Cal Seal has been the predominate type used because in most instances, it was used to cement soft materials such as fault gouge, highly altered rock, etc., and it bonds much better with them in forming a wall. Also, the setting time of Cal Seal is much less than the other types and thus allows less dilution. Lumnite cement is used when the rock to be cemented is hard cave, as the Lumnite type of cement sets very hard. However, there is one difficulty in using Lumnite in this type of rock in that it sets too hard and has a tendency to drive the bit off the hole where the cement is drilled. There were no advantages to using Portland cement. It does not set hard enough in 72 hours to do any good. The use of a combination of Portland cement and Lumnite cement to get water return has been quite successful, especially as to time involved. It is also successful in holding circulation after it has been recovered. A combination of mud, bran and manure has been used for plugging and sealing to keep a fair water return when the loss has been only seepage through small fractures. Cement cartridges have been used with success when crevices cause "quick set cement" to run off too fast.

Cementing and drilling cement are probably the most hazardous parts of the whole drilling operation. The reaction of cement to the rock and water is never definitely known. "Cal Seal" proved to be the safest cement to use after the setting control had been learned for the area. However, drilling "Cal Seal" is slower than drilling other types.

Special applications and unusual difficulties in handling cement in the Marysvale area are discussed later under the various rock-types drilled.

MUD

Mud is definitely advantageous to use as a circulating medium where there is a high but not a complete water loss, as mud stops small leaks and helps to prevent caving. However, the clearances presently used in diamond drill hole equipment, are not made to handle a highly viscous mud. In fact, a 30 to 32 viscosity (31 is best) mud is about as high as can be used. The practice of circulating mud often stalls the necessity of reming the hole. A discussion of where mud can be used to an advantage is discussed under rock-types.

WATER

A total of 1,594,980 gallons of water was used in drilling 22,379 feet of hole. This averages about 72 gallons per foot of hole. The water circulation was 7 to 8 gallons per minute and the water pressure 100 pounds per square inch when the water return was fair.

All water used had to be trucked from the town of Marysvale, an average distance of about six miles, at a cost of approximately $.70 per foot drilled or about one cent per gallon.
RHYOLITE

The Mount Belknap rhyolite - Red Facies was the only rhyolite drilled. Flow breccia, elliptical vesicles and glass streaming give the rock a flow banded appearance. The rock is increasingly a pyroclastic tuff breccia towards base of the series.

Fragments of the rhyolite approach a hardness of 7 (Mohs scale), and they usually break with sharp angular edges. This general character of the rock has caused the most grief for drilling and has been the costliest to Boyles Brothers, as well as the Commission. The drilling cost increased proportionately with the intensity of silicification of the rhyolite.

The rhyolite dikes are glassy, show banding parallel to their walls and show a more uniform texture than the above mentioned rhyolite flow. The dikes are often highly altered and the main drilling difficulty arises from their tendency to cave.

Statistics

It was fortunate for the contractor that the rhyolite was at the top of the hole for this permitted the driller to drill and cement through the rhyolite, then set the casing and reduce to BX for farther drilling. Nine out of the forty-one holes were collared in rhyolite and 8.5 percent of the total rock drilled was rhyolite. Approximately 8 feet per shift was averaged. This rock cost the Commission approximately $14.50 per foot with $6.25 of this amount being for cement. Practically all of this drilling was of the NX size.

The percent of core recovery for rhyolite was low but it was not, in most cases, important that the core be saved.

Drilling Practice

As much as 350 feet of rhyolite had to be drilled through before getting into the monzonite or granite below. The important ore zones do not occur within the rhyolite and therefore the contract was set up to permit the rhyolite to be drilled as non-core drilling. However, non-core drilling does not work well in this type of rock. It is too slow and the loose rock will pivot in the plug bit. As a result it was found to be cheaper and faster to drill the rhyolite with a core bit.

In areas of rhyolite containing only small zones of alteration it is best to drill ahead of the casing, then ream by rotating the casing and using mud as a circulating medium. This method will not work if there are too many loose, blocky fragments of the hard rhyolite, because the fragments will cut off the casing or bit in rotating. When these loose fragments do exist, the hole must be drilled ahead, then the casing driven or chopped ahead.

In areas of unaltered but highly fractured rhyolite, the hole is first drilled, then cemented to hold the fractured rock in place, and then reamed to hold the hole with casing. -16-
Silicified rhyolite presents a still more difficult problem. It must be drilled and cemented, not letting the back end of the core barrel at any time go beyond the cemented hole. This cannot be carried over 100 feet of depth, as cement will not usually hold longer than that. The casing cannot be reamed as there are too many sharp and very hard materials to cut the casing. This casing must be set and the core size reduced when cement cannot hold the hole.

**Highly Silicified Rock**

If the rock is solid and not interspersed with zones of soft material, the main difficulty is in holding the gage of the hole. When the silicified rock is interlayered with softer material, bits do not have any life at all. Likewise, core barrels are short lived. (See appended list of bits vs runs). Most of this rock is very expensive to drill with the possibility most of the time of losing the hole. In areas of such rock, some other means of exploration should be considered.

Drill hole 60 was an example of an attempt to drill the highly silicified rock which had zones of clay interspersed. The cost per foot to the Commission was $19.21 and the cost per foot to the contractor was greater. The following list shows the footage each bit lasted before being a complete loss. This list is not arranged in the order that the bits were used from 147.7 to 261 foot hole depth.

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QUARTZ MONZONITE

This intrusive rock is relatively light colored with large dark grains. The texture is coarse-grained and entirely crystalline. Plagioclase and orthoclase are in equal amounts with quartz amounting to less than 10 percent. The rock often contains chlorite as an alteration product. Usually the rock hardness is 5 or 6 (Mohs scale). Compared with the other rocks, monzonite has very few joints.

Statistics

Twenty-four out of the forty-one holes were collared in monzonite and 67 percent of the core drilled was monzonite. Approximately 17 feet per shift was averaged. Monzonite cost the Commission an average of $8.15 per foot for drilling with cementing accounting for $1.20 of this amount. Approximately 60 percent of the core was BX size with MX drilling 20 percent and AX drilling 20 percent. The core recovery was good, probably averaging 85 percent recovery.

Drilling Practice

Fresh quartz monzonite is good drilling and no particular problems are involved except it is necessary to use sharp bits. Fractured monzonite does not cave except where it is in contact with fault zones or in areas of strong alteration.

Highly altered monzonite can be drilled and reamed with good results, using mud. Cementing, except in rare instances, is of no advantage except to improve the chances of recovering the casing. Cement alone will not hold long.

GRANITE

Granite is a light colored intrusive rock, fine-grained, but entirely crystalline. Variations in grain size are common and sometimes a porphyritic tendency is noticeable. This rock, especially near its intrusive contact, is highly jointed giving it a block appearance which is a hindrance to drilling. Although granite has a hardness of 6 or 7 (Mohs scale) it does not present a drilling problem because it does not cave unless the rock is soft. Where the rock is highly jointed water loss is a problem.

Statistics

Only 2 holes collared in granite, but 33 percent of the holes were bottomed in granite. Out of the 25,379 feet drilled 18 percent was in granite. The average was 14.5 feet per shift at a cost to the Commission of $7.65 per foot. Of this amount $.65 was for cement. The core recovery was good, probably averaging 85 percent. An equal amount of core was drilled in BX and AX with practically no NX drilling of granite. The statistics show the BX drilling averages better than twice the number of feet per shift that the AX does and the percentage of core recovery is higher. Of course, some consideration must be given to the fact that when bad drilling rock was encountered it was often necessary to reduce from BX to AX drilling.
Drilling Practice

Granite underlies the monzonite, at various depths from the surface, so when it is encountered it is usually in the lower section of the hole.

Most of the granite drilled has been highly fractured and short runs are the rule. BX drilling is the ideal size to drill the granite. However, it is difficult to keep the hole up to this size coming through the overlying monzonite and often overlying rhyolite.

LATITE

Under this heading comes all of the Bullion Canyon Volcanic Series, including latitic to andesitic tuffs, pyroclastic breccias and agglomerates, and porphyritic quartz latite flows. These rocks are usually partially altered and have a hardness of 4 to 5 (Mohs scale). The only drilling problems that arise are in the intensely altered rock where caving is the detrimental factor.

Statistics

A total of 6 holes were collared in latite and 6.5 percent of the total core was latite. Approximately 8 feet per shift averaged. The Commission paid an average of $14 per foot; $6 of which was for cement. Practically all of this drilling was with an NX core barrel. The core recovery was low, averaging about 35 percent recovery.

Drilling Practice

Fresh latite is fair drilling and drills somewhat the same as the quartz monzonite, except that it is considerably more fractured, necessitating shorter runs. The altered latite has to be handled much the same way as altered rhyolite.

DRILLING IN ORE ZONES

The deposition of ore in this area was accompanied by a considerable amount of hydrothermal alteration. Also, the sites of ore deposition were usually in fault and shear zones. This means that the ore itself is enveloped with an often wide zone of fault gouge and highly altered rock. In addition, these zones contain many very hard layers in the form of small veins of quartz. As a result, unfortunately, core recovery has been poor, so poor in fact, that it is necessary to rely on radiometric probing to determine the extent and grade of the ore zones drilled.

DRILLING IN OVERBURDEN

In working through the overburden, which may be as much as 100 feet, three ways have been tried.

1. Standard pipe driving; this was not successful whatsoever, mainly because of the inclination of the hole and the type of overburden which has to be flushed out of the pipe.


2. Using an oversize TC bit and using mud as a circulating medium; some success was obtained by this method where the depth of overburden did not exceed 25 or 30 feet.

3. Drilling ahead of the pipe and then reaming with a TC bit using mud as a circulating medium, or driving without rotating the casing; this method has proven to be the most successful.