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EXPLORATORY DRILLING FOR URANIUM ORE ON THE COLORADO PLATEAU BY THE ATOMIC ENERGY COMMISSION

Drilling for uranium ore on the Colorado Plateau has been done by various methods and for several purposes.

CLASSIFICATION OF DRILLING ACCORDING TO PURPOSE

Exploratory drilling may be divided into three phases according to the purpose for which it is intended: (1) Investigative or reconnaissance drilling, (2) Exploration drilling, and (3) Development drilling.

Investigative or reconnaissance drilling is done in relatively unexplored areas where insufficient surface information has been found to warrant close-spaced drilling, but where there is enough geologic evidence to justify holes spaced on centers of 500 to 1000 or more feet (164 to 305 meters) to provide geologic information beyond that obtainable from surface exposures. Core drilling provides the most complete information; a study of the core, and of radiometric logs, may enable rejection of certain areas from further search, and suggest concentrated search of other areas.

Individual contracts let by the AEC for this type of drilling have been for 30,000 to 50,000 feet (9,144 to 15,240 meters) of drilling. If favorable results are obtained, the second phase, exploration drilling, is undertaken.

The second phase of drilling, exploration drilling is undertaken when geologically favorable areas have been outlined, and it may be done over broad areas in parts of which mining is well advanced but in which more information is needed to guide the search for additional ore bodies. Holes typically are spaced on 50- to 300- foot centers (15.2 to 91.4 meters), depending on the estimated probable size of any ore bodies, and upon the size of ore bodies required for a profitable mining operation in the locality.

The third phase, development drilling, is initiated if ore was discovered in the second phase. It may be close-spaced or offset drilling, on 25- to 100- foot centers (8.2 to 30.5 meters) adjacent to known ore, designed to find extensions of known ore or additional ore bodies, or it may be designed to determine the size, shape, position, grade, or other characteristics of an ore body. Once mining has been started, it may be more practical to do some of the drilling from established open pits or tunnels rather than from the natural surface. Development drilling was initiated by the AEC to encourage small mining operators to continue work in areas where mines were running out of ore. Most contracts let were for 20,000 to 30,000 feet (6096 to 9,144 meters) of drilling.

CLASSIFICATION OF DRILLING ACCORDING TO TECHNIQUE

Much exploratory drilling has been done using various types of drills which, from the mechanical standpoint, may be classed as (1) diamond, (2) pneumatic-percussion, (3) rotary, and (4) churn.
Diamond Drilling

Diamond core-drilling is used extensively on the Plateau. Although it is the most expensive type of drilling, the data obtainable from the core are important, or necessary, in making preliminary geologic studies. In later drilling, some money can be saved by coring only those zones for which information is especially needed.

Modern truck-mounted diamond core-drills are very mobile and can drill relatively deep holes.

A diamond core-drilling contract should stipulate a guaranteed percentage of core to be obtained.

In exploratory work with the conventional diamond drill a plug-bit (either a rotary bit or a diamond blast-hole bit) is used to drill through barren overburden to the ore sands. Air is a faster medium than water for plug-bitting. Furthermore, most of the shaly formation overlying the ore sands are extremely friable and absorbent, necessitating the setting of casing in the drill holes. Drilling with air therefore saves water, -- an expensive item in many parts of the Plateau. Wear on the bits is also much less using air. For these two reasons, plug-bitting with air for the conventional diamond drill is both faster and cheaper.

The following specifications are a composite of the characteristics of four separate drilling rigs made by Joy Manufacturing Company.

This entire assembly, except for the compressor, is mounted on the frame of a standard dual power-wheeled Chevrolet two-ton truck. The drill head and integral hoist are Joy Manufacturing Company's model 22HD (N-2). This head has a rated capacity of 1000 feet (305 meters) of NX drill steel. There are four possible drill speeds: In first gear the bit RPM is 190; in second gear it is 390; in third gear, 700; and in fourth gear 1,200. The 24-inch spindle (59 cm) is powered by two hydraulic cylinders with an area of 14 square inches (90.3 square cm).

The hoist drum is 12.5 inches (31.7cm) in diameter and 6.75 inches (17.1 cm) long; it holds 211 feet (69.1 meters) of 0.5-inch (1.27 cm) wire rope.

A 30-horsepower Case 4-cylinder gasoline engine powers the drill head. The "Hydro" hydraulic pump develops a pressure of 600 pounds per square inch (42.4 kilos per square centimeter).

The water pump is a Gardner-Denver mud pump, model FF-FFX-E. The 3-inch (7.62 cm) pistons in use have a rated maximum pressure of 440 pounds (150 kilos). This pump is powered by the truck motor through a V-belt from the truck drive-shaft.

Drill-head power is transmitted from the Case engine through a 1941 Ford truck clutch. A chain coupling is used to couple the drill-head shaft to the engine shaft, and the hydraulic pump is chain-driven from the shaft of the drill power unit.

The Case engine, drill head, and hydraulic pump are mounted on a single frame that runs on skids recessed in the truck bed, and this entire unit can be moved parallel to the long axis of the truck by hydraulic pressure.
The drill-rig tower is 30 feet (9.14 meters) high, has two head sheaves, and is raised and lowered hydraulically.

A Joy Manufacturing Company style "N" core barrel is used; it is 20 feet (6.1 meters) long and has an outside diameter of 2 3/4 inches (6.99 cm). Two-inch (5.08 cm) diameter core is recovered, using Joy "Truco" diamond bits without waterways.

Drill rods used are Joy Company "N" and have an outside diameter of 2 3/8 inches (8.59 cm). They are flush-coupled and handled in 20- or 30- foot lengths (6.1 or 9.1 meters).

The casing is flush-coupled and is of NX size, having an outside diameter of 3.5 inches (8.89 cm) and an inside diameter of 3.07 inches (7.8 cm).

The Winter-Weiss Portadrill is an air-blast type machine having the essential features and parts of the standard water-circulation type except for an Allis Chalmers "Ro Flo" rotary blower instead of a water pump. This blower requires a pressure of 25 pounds (11.4 kilos) when a hole is spudded-in, but, thereafter, the pressure need not be maintained as it is the volume of air rather than the pressure that removes cuttings from the hole. The drill is a rotary type and uses 5 5/8 - or 6 1/4- inch (14.27 or 15.87 cm) starting bits; 4 3/4 - inch (12.07 cm) run bits are used in sandstone, and 4 3/4-inch finger bits are used in siltstone and mudstone. Ten-foot (3.05 meter) rods are used commonly. The over-all length of the turning stem, or kelly is 16 feet (4.88 meters). Three forward speeds control the rotation; these are co-joined to five speeds in the cab.

About 50 feet (15.2 meters) can be drilled in an hour. The original setting up of the drill takes only one minute. About 10 feet (3.05 meters) of shale, mudstone, or creek sand were drilled in 6 1/2 minutes; 10 feet of dense gray sandstone in 11 1/2 minutes; and 10 feet of white sandstone in 10 1/2 minutes. The addition of each 10-foot drilling rod required an average of 1 2/3 minutes.

Ordinarily, moist clays collect on this type of bit and cause it to stick; to overcome this, water is poured down the hole to soften the balled clay, and a volume of air is used that is great enough to force the resultant sludge upward. The rods are flush-coupled so that there are no collars to alter the air stream and allow clay to collect on the rims of the collars. When the moist rock is penetrated, dry drilling is resumed.

The Portadrill drilled many holes to 170 feet (51.9 meters) and, under favorable conditions at one locality, it drilled to 600 feet (183 meters).

Although the Portadrill is an expensive machine, it is preferable to the percussion-type wagon drills in that it operates at a lower cost per foot, drills deeper, has equal or greater speed and portability, recovers longer samples, and is more adaptable to drilling in wet ground.

A number of wagon-drilling projects were completed successfully, but some were discontinued where damp formations were penetrated.
Core Drilling with Air

Two experimental attempts to core the Salt Wash sandstone member of the Morrison formation were made with the air medium at the Blanding, Utah Cottonwood Camp under contract to Joy Manufacturing Company. Regular diamond bits and five-foot swivel-type core barrels with specially perforated inner tubes were used in the first attempts. To a depth of 35.5 feet (10.82 meters) the rate of penetration was more rapid than with water circulation, and core recovery exceeded 90 percent. At 35.5 feet operations had to be discontinued using the normal circulation method owing to excessive vibration caused by the abrasive action of the returning cuttings that made lubrication of the drill rods impossible. From 35.5 to 57.9 feet (10.82 to 17.66 meters) the reverse circulation method was used. This method worked, but the drilling progress was slow, and the core was coated with rock dust from the cuttings. The factor most adverse to progress seemed to be the loss of air into the Salt Wash sands. The compressor put out 90 psi (16.1 kilos per square centimeter) at the surface, but the porous nature of the walls reduced the pressure to such an extent that the cuttings could not be removed from the face of the bit. The experiment was stopped at 57.9 feet (17.66 meters).

In the second experiment a specially designed bit with carboloy slugs in place of diamonds was improvised for use. This bit had large airways to permit easy circulation away from the bit face. Ten- and twenty-foot (3.05 and 6.1 meters) single tube core barrels were used successfully. The added rigidity of the longer barrels eliminated some of the vibration as the hole deepened. Core recovery was only 72 percent. It is believed that resulted from using the outer barrel of a swivel-type core barrel assembly as a single barrel; the core was too loose in the barrel to stay in place, and it probably ground itself up and blocked the barrel. The hole was drilled to a depth of 83 feet (25.3 meters) with air. At that depth excessive moisture was penetrated in mudstone, and the hole was completed with water circulation.

Pneumatic Percussion Drilling

Pneumatic percussion drilling is done either by light hand-held drills or by drills mounted as a wagon drill or on a truck, halftrack, or tractor. This drilling method is the cheapest when exploring for relatively shallow deposits. Typical costs (1955) range from $0.50 to $1.50 per foot ($1.64 to $4.92 per meter). In dry formations percussion drilling is satisfactory to depths of 250 feet (75 meters) and, in exceptional cases, to 400 feet (122 meters). Percussion drilling is limited to shallow holes because wet drilling has not proved successful. Owing to lower cost for bits, heavy percussion drills with extra heavy steel will far out-perform diamond drills and rotary drills in unusually hard formations. Percussion drills and sectional steel are also used in underground exploration. Holes may be drilled for 100 feet (30 meters) from mine openings although many operators limit them to 50 feet (15 meters). A number of holes may be fanned out both horizontally and vertically from one set-up.

Rotary Drilling

Rotary drilling, originally developed for seismic work in oil exploration, is now common on the Plateau. It is competitive in cost with percussion drilling and is faster and can be used to drill to greater depths.
The drill rigs are truck-mounted. Drilling is usually done dry although wet drilling is also practiced. Rotary drilling is best used to depths of 200 feet (61 meters) and where no core is required. For best results the ground should be fairly consolidated and the overburden thin. Where the ground is dry and not to hard, this is the fastest type of drilling. For comparatively shallow holes, average contract-drilling costs are $0.60 to $1.50 per foot ($1.97 to $5.22 per meter). Core can be obtained if desired.

Auger Drilling

The Pennsylvania Drilling Company, which manufactures this drill, claim that it is the sturdiest on the market, but they believe it impractical for use on the Colorado Plateau because it is restricted to use in soft ground, and it cannot be used to sample accurately. Its tips would not penetrate hard sediments, and seams of limy rock stopped it completely on Tenderfoot Mesa, Colorado.

In favorable ground it drilled over 300 feet (91.5 meters) in one eight-hour shift. It drilled 40 feet (12.2 meters) per hour in medium sandstones, and 120 to 150 feet (36 to 45 meters) per hour in shale. This drilling was done with five- to six-inch (12.7 to 15.2 cm) finger bits tipped with tungsten carbide. These tips were detachable and cost $0.80 each (in 1952). The drill was driven by a 126 horsepower Ford engine, and equipped with a hydraulically operated 13,000 - pound (5850 kilo) lift. In 1951 this drill cost $6500, not including the two-ton truck on which it was mounted.

Although the auger drill has not been satisfactory for use on the Colorado Plateau, its possible use elsewhere should be considered. It does drill a hole that has a relatively constant diameter and straight walls; this makes the hole easy to case but less in need of casing because mud is smeared over, and helps to cement, friable rocks; this smearing can, however, be so extensive that a radiation log of the hole is meaningless due to inter-horizon mixing and contamination.

Wagon Drilling

The first drilling on the Colorado Plateau (at least as early as 1919) was done by drills using light jackhammers with long, hard-sharpened steel to depths rarely exceeding 30 feet (9.15 meters). Most of these holes were placed to extend the limits of known ore-bodies that cropped out on rims.

This practice was soon followed by wagon drilling and conventional diamond drilling. Many prefer the larger EX - size (1 5/8" core) although NX-size (2 1/8" core) was also used, and AX-size bits (1 1/8" core) were used until early in 1952, then discontinued.

Wagon drilling has the general advantages of cheaper operation, greater bit-life, faster penetration, and no usage of water. It has the disadvantage of providing no core, of being inefficient in wet ground, inconvenient sample-collecting, and restricted depth. At least one machine has been developed that will drill in wet ground, and more-efficient dust-collectors have been devised to improve sampling.

For shallow exploration in dry moderately indurated sediments, such as is done on the Colorado Plateau, the advantage of the wagon drill probably outweighs those of the diamond drill.
The Pennsylvania Drilling Company's Hossfeld drill, used on Tenderfoot Mesa, Colorado, is a small compact wagon drill mounted on two pneumatic-tired wheels. It can be quickly moved and operated by one man. The drill combines the principles of churn and percussion wagon-drill. It employs water in a closed continuous circuit, and detachable rock bits, 1 1/2 - to 2 5/8 - inch (3.8 to 6.7 cm) in size. Power is furnished by an air-cooled 5-horsepower 4-cycle gasoline motor that drives the 60-pound (27.2 kilos), 16-foot (4.9 meters) drill on a 7 1/2-inch (19.05 cm) stroke, delivering 350 direct drilling blows per minute. It has an automatic continuous-feed transmission. A flat belt and idler start and stop the drill, and the motor is mounted on a sliding base for taking up excess slack in the belt. This rig consumes only about four gallons of gasoline per 100 feet of drilling in hard limestone. It costs $975 (in 1952), F.O.B. factory, at Winona, Minnesota.

Although this drill is quick and handy to operate, it required 13.6 hours to drill 118 feet (25 meters). It is tiny, lacks power and weight, and cannot drill deep enough for most exploration on the Plateau. The main objection, however, is that the sampling is unreliable. In tests it recovered only about 40 percent of the total recoverable sample-cuttings. If it can be correlated with radiation logging, its cheapness, portability, and simplicity may make it desirable in development work for the immediate guidance of shallow mine workings.

The Cannon Drilling Company's rigs at Monument Valley, Arizona and Temple Mountain, Utah were large, air-driven, percussion-type non-core drifter drills mounted on D4 Caterpillar crawler tractors. Ingersoll-Rand drifters Model 71-WD were used; these had 4-inch (10.1 cm) hammers and used 1 1/8-inch (2.84 cm) drill steel. The drills were mounted on a 20-foot (6.1 meter) steel boom which pivoted on a steel framework mounted on a tractor. A 1 1/2 ton, 7-horsepower, vane-type Thor hoist was used for pulling the string of rods. Once the boom had been raised to the vertical position, its movement was controlled by an air motor geared to an endless chain connected to the drifter mounting.

Air supply for the drilling was provided by a 500 cfm (14.15 cubic meter per minute) Chicago-Pneumatic compressor driven by a 128-horsepower Caterpillar diesel engine. Compressor and driving engine were mounted on a separate four-wheel chassis towed by the tractor.

Hexagonal drill steel of 1 1/8-inch (2.84 cm) diameter with No. 2 thread and standard couplings was used in 15-foot (4.58 meters) lengths. Most of the drill bits were of 1 7/8-inch (4.78 cm) diameter and had four rectangular tungsten carbide inserts above the bit shoulders. These protruding inserts allowed the bit to cut as it was drawn from the hole -- a feature that prevented sticking. The bits had two air ports, one at the side and one at the bottom. The bottom hole was usually pre-plugged to prevent its being plugged by clay during the drilling.

This wagon drill proved to be the most successful developed on the Colorado Plateau, being fast, maneuverable, and rugged. Their maximum depth is believed to be about 150 feet (47.5 meters). In rough terrain, however, a larger caterpillar should be used or, better, the drilling unit and compressor should be joined, and mounted on a half-track vehicle or a
The first wagon drill used under contract to the Grand Junction Exploration Branch of the Atomic Energy Commission was operated by the Minerals Engineering Company of Grand Junction on Cove Mesa, Arizona. The rig used now is essentially the same.

The entire assembly, including the compressor, was mounted on an army half-track. A D-73 Gardner-Denver jackhammer was bracketed to an endless chain activated by an air-driven sprocket.

The main mast was raised and lowered by two double-telescoping hydraulic cylinders.

Drill rods were of high-carbon steel, had an outside diameter of 1 1/8-inch (2.56 cm), were 18 feet (5.49 meters) long, and were left-hand threaded on both ends. Couplings were 3 feet (.914 meters) long and of 1 1/2-inch (3.81 cm) diameter. Bits were standard two-vent plug type, with four Haystelbite double-bevelled inserts.

Air was supplied to the tools and the chain-drive unit by a Le Roi model 210 cfm Airmaster compressor mounted over the half-tracks. It developed 115 pounds (51.8 kilos) of pressure. Air circulation could be continued after the hammer was stopped.

For the same cost, this rig drilled twice as many feet as did the conventional diamond core drill used on the same mesa later.

At the start of this contract the equipment used was the same as that employed on Cove Mesa, but it proved inadequate. Hence the unit has been replaced by a truck-mounted rig consisting of a Gardner-Denver D99 hammer with a 4-inch (10.16 cm) piston, 1 1/4-inch (3 1/8 cm) big-hole, round steel, and 2 3/8-inch (6.02 cm) bits. The air hoist is a new, more powerful Gardner-Denver model, and the compressor is a portable, heavy-duty Gardner-Denver 315 cfm (8.92 cubic meters per minute) model driven by a Caterpillar diesel engine. However, a new 500 cfm (14.15 cubic meters per minute) truck-mounted compressor will soon replace the older smaller one. This combination promises to make an ideal machine for wagon drilling. It has power, speed, and unusual portability.

Minerals Engineering is currently (1952) building an even larger wagon drill of similar design but having a Gardner-Denver hammer with a 5-inch (12.7 cm) piston delivering 1000-pound (454 kilos) blows and using 2-inch (5.08 cm) round steel.

Although the sampling operation of early wagon drilling done on contract for the Atomic Energy Commission was closely supervised, results were unsatisfactory. A search was made for an industrial dust collector. After many inquiries a Multiclone unit and a Duclone Dust Collector, type SD, size 1, made by the Duclone Company of 147 East Second Street, Mineola, New York, were purchased. In accordance with the adaptations added by the U.S. Bureau
of Mines(1), 4-foot (1.2 meters) tripod legs were added to each unit to raise it about 18 inches (45.7 cm) above the ground, making room for the insertion of a receptacle under the discharge. To the bottom of each unit was attached a conico-cylindrical dust-trap, or hopper, with a 2 1/2-inch (6.35 cm) discharge closed with a plug in the Multiclone and a trap door in the Duclone. After a trial period the hopper was discarded and a flat, circular metal stage was suspended on springs from the bottom of the unit. Fitted on this stage, and held firmly against the bottom of the unit, for catching the sample was a lucite tube 6 inches (14.2 cm) in diameter, about 12 inches (30.5 cm) long, and with 0.25-inch walls (6mm). This permitted visual inspection of the sample as it accumulated without stopping the drill, and it gave a sample layered somewhat according to the lithologic layers penetrated.

Although these industrial collectors were designed for use with a blower, the blower was eliminated and the air returning from the hole used instead.

A few experiments with a standard Longyear AX-size (1 7/8" or 4.8 cm) under-reamer indicate that it can be used successfully to obtain side hole samples from non-core holes. It required modification for use with the air medium.

Churn Drilling

Churn drilling has been used very little for exploration on the Plateau although it is relatively inexpensive and can be used to drill to great depths. Sampling techniques are awkward, samples are bulky, and they may not properly represent thin ore beds because of dilution. Another disadvantage is that relatively large amounts of water are required.

PRESENT DRILLING TRENDS

In 1953 at the end of five years of drilling on the Colorado Plateau by the Atomic Energy Commission, the U.S. Geological Survey, and private drilling companies, the areas in which ore was known to lie close to the surface had been drilled, and it became apparent that subsequent drilling would have to provide the following:

1. Deeper holes, with more of the hole not being cored.
2. Larger-diameter core where core is required.
3. More dry samples from dry-hole, non-core drilling.

Deeper Holes  Because many of the shallow ore bodies have been discovered, it is necessary to extend the search farther from the surface. The depth to be recommended for holes on the Plateau, and the need for coring, have been determinable to a large extent by studies of the nature and thickness of formations exposed on the canyon walls. In areas where there are not such good exposures, geologic information will have to be gained by other means to provide criteria for specifying the depth of holes and the stratigraphic intervals to be cored; each hole should provide information to aid the driller and geologist in determining the locations, coring intervals, and drilling methods for additional holes.

Bits used are the fish-tail bit, the Hawthorne(1) and Hughes(2) types, the diamond-set plug bit, and the standard diamond core bit and core barrel.

The circulating medium may be air, water or mud. It has been the practice to drill overburden and other non-core intervals with the conventional core-drill rig, changing to core barrel and diamond bit where core is to be recovered. If the non-core intervals are numerous or thick, there is, however, a trend toward using separate drills for the coring and non-coring. Where the non-core interval in each hole is sufficient to utilize the capabilities of the rig to near-maximum efficiency, however, the larger drills appear to accomplish this drilling more rapidly and economically than other types of rigs.

Churn drills or spudders and, more recently, large rotary rigs such as the Mayhew 1000(3) or Failing 1500(4) serve the purpose.

Large Diameter Core  Although the rocks of which core is desired are principally fine- to medium-grained sandstones with some intervening layers of mudstone and siltstone, the cementation varies, and there are some limestones. Thicknesses of units range to 60 or more feet (18.3 meters). Where the rock types are variable in a hole, it is a problem to select drilling equipment and technique that will give a satisfactory rate of drilling as well as good core-recovery. In poorly cemented or fractured rock BX-size tools give better recovery than the smaller AX-size even with the same types of bits and core barrels. Hence the AEC now requires at least BX-size core, and it is probable that the still larger NX-size (3 inch or 7.6 cm hole diameter) would give still better results. The BX-size (2 3/8 inch or 6 cm) hole, or larger, is also necessary to accommodate the probes normally used to log the hole. The most satisfactory probe is 32 inches (81.3 cm) long and has a diameter of 2 inches (5.08 cm).

(1) Manufactured by Herb J. Hawthorne, Inc., Houston, Texas
(2) Distributed by Hughes Tool Co., Denver, Colorado
(3) Distributed by Mayhew Supply Co., Dallas, Texas
(4) Distributed by George E. Failing Co., Grand Junction & Denver, Colorado
More Dry-Hole, Non-Core Drilling This is not diamond drilling, but it is discussed here because there is a tendency to use this type of drilling, both percussion and rotary, instead of diamond drilling although it has the disadvantage of yielding cuttings rather than core.

Percussion drills are generally limited to depths of 200 feet (61 meters), but some drilling of this type has been done to depths of over 400 feet (122 meters). Rotary drills, using air as the circulating medium, can be used to drill to any practical depth, and they produce dry cuttings. Sample-recovery of over 97 percent has been maintained by using a Duclone dust collector on the collar pipe of the hole, and using air jets to force the cuttings into the sampler rather than letting some escape around the drill steel.

The speed and economy of dry-hole non-core drilling, with recovery of adequate samples, make it appealing, especially if a few core-holes are drilled in the vicinity to augment the geologic information.

FIELD ADMINISTRATION OF DRILLING PROJECTS

To administer the drilling, field camps have been established near the drilling sites, unless they were close to town, to house AEC personnel and, where feasible, some of their families. Vehicle-drawn trailers equipped with bottle-gas units for cooking and heating are used for housing and for office space. Members of the drilling crews have been similarly accommodated by the drilling contractor.

The AEC crews have comprised the following:

1. Geologists - to specify locations for holes to be drilled, to collect and study samples, and to evaluate the data for information regarding geology and ore reserves.

2. Engineers and surveyors - to administer the details of contract fulfillment, to plan and direct the preparation of roads to the drill site, and to survey and prepare maps of drill sites, hole locations, and other necessary features.

3. Other personnel such as heavy-equipment operators to build or improve roads and drill sites, and mechanics to maintain and repair motor vehicles and heavy equipment.

In 1953 some half-million feet of holes were drilled and some ten field camps were scattered over the Plateau.

The camps were under the general supervision of the project engineer who was responsible for all phases of camp- and project-operation, including harmonious supervision of personnel, sanitation, and the provision of power, water, work-supplies, and camp facilities in general.

The projects undertaken first were those at the geologically most-favorable sites which were also easily accessible. Areas drilled later were more difficultly accessible, so that of a total of eight projects active at one time, differences in the terrain required that as much heavy equipment serve two of them as was required for the other six. On one six-drill project, six bulldozers were required at one time.