UNDERGROUND MINING METHODS AND COSTS AT THREE SALT WASH URANIUM MINES OF CLIMAX URANIUM CO.

BY W. L. DARE

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UNDERGROUND MINING METHODS AND COSTS AT THREE SALT WASH URANIUM MINES OF CLIMAX URANIUM CO.[1]

by

W. L. Dare[2]

SUMMARY AND INTRODUCTION

This information circular is one of a series published by the Federal Bureau of Mines in which the methods and costs of producing uranium ore on the Colorado Plateau are discussed. This report describes the three largest company-operated uranium mines of Climax Uranium Co. - the G-1, the Mineral Joe, and the Frank No. 1.

Climax Uranium Co., a subsidiary of American Metal Climax, Inc., was incorporated May 11, 1950, just 2 years after establishment of the domestic uranium program by the Atomic Energy Commission. Twenty-five years earlier Arthur H. Bunker, now chairman of the board, American Metal Climax, Inc., organized and operated the U. S. Vanadium Co. at Rifle, Colo.[3] Soon after Climax Uranium Co. was organized, it entered into a contract with the Federal Government to build a uranium-vanadium processing mill in Grand Junction, Colo. Under the contract Climax leased from the Federal Government certain uranium-bearing lands that had been withdrawn from public entry in 1948. From Minerals Engineering Co., on June 12, 1950, Climax acquired other uranium-vanadium properties on Calamity, Outlaw, and Monogram Mesas in Colorado and on Polar Mesa and in the Yellow Cat area of Utah. To house the milling equipment, Climax leased the old Grand Junction sugarmill building of the Holly Sugar Co. Milling facilities, based on a then new process developed for treating both uranium and vanadium, were completed, and the plant went into production in 1951.

The uranium-ore deposits in the three mines described in this report lie within the Salt Wash member of the Jurassic Morrison formation. Two of the mines are in the Uravan mineral belt in Colorado;[4] the third is on the Navajo Indian Reservation in Arizona (fig. 1). The three Salt Wash deposits were larger than average, but now the ore reserves of two of them are thought to be nearly exhausted. The three operations typify the three general methods of mine development and illustrate the wide degree of mechanization used on the plateau.

1/ Work on manuscript completed February 1959.
2/ Mining engineer, Bureau of Mines, Region III, Denver, Colo.
3/ Mining Engineering, Climax Uranium Co.: August 1955, p. 41.
4/ Fischer, R. P., Hilpert, L. S., Geology of the Uravan Mineral Belt: Geol. Survey Bull. 988-A, 1952, 13 pp.

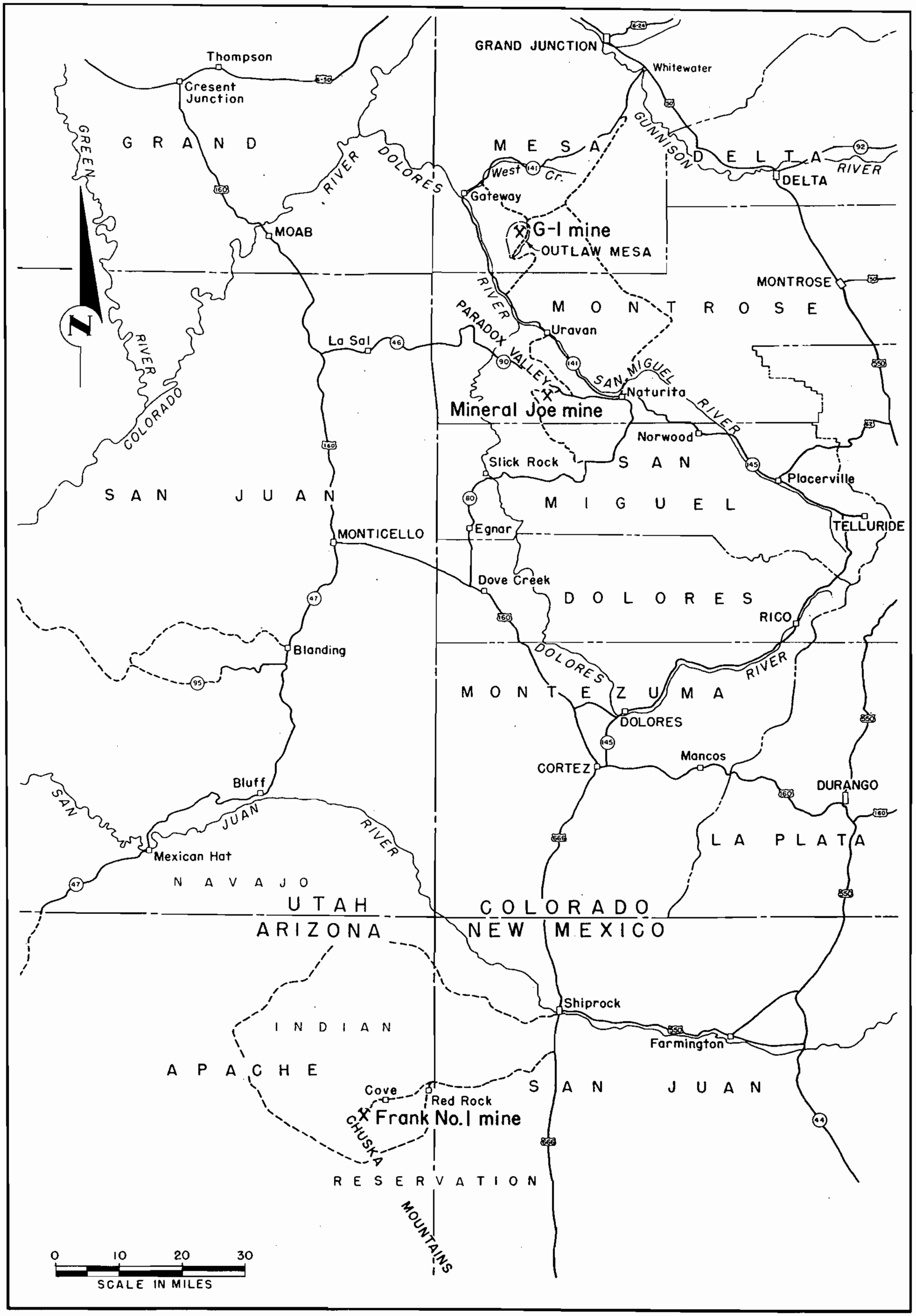

FIGURE 1. - Location of G-1, Mineral Joe, and Frank No. 1 Mines.

The deepest of the three mines is entered through a 255-foot, two-compartment vertical shaft; the shallowest is entered through 15° and 20° inclines; the third is entered through adits driven into the ore from surface outcrops.

Loading and hauling in the shaft-developed mine are done with slushers and track-mounted equipment. The ore is stoped through short raises driven from a haulage level beneath the ore.

The deposit developed by the inclines has been the thickest of the three. In mining it the operator was one of the first on the plateau to use crawler and rubber-tired equipment underground for loading and haulage.

The ore in the adit-developed mine has been less regular and thinner than that in the other two mines; and, except for drilling, this operation is not mechanized. The ore is moved in wheelbarrows and hauled to the surface by burros.

The lightweight, leg-mounted rock drill is the only common piece of production equipment used by all three operations. Electric power is available only at the shaft-developed mine. Comparative costs in units of manpower are tabulated at the end of this report.

ACKNOWLEDGMENTS

The assistance of the officers and staff of Climax Uranium Co. is gratefully acknowledged. A. M. Mastrovich (vice president and general-manager), L. J. Brewer (manager of mines), E. D. Bieber (field representative), and Bob Nakoka (geologist) were very helpful. Fred Brooks (engineering supervisor) is especially thanked for reviewing this report.

G-1 MINE

For completeness, the following description of the G-1 operation is expanded to include a brief description of the nearby G-3 mine, which is managed from the same Outlaw Mesa field camp.

The G-1 mine on Outlaw Mesa has been a large ore producer by Salt Wash standards. For 6-1/2 years, beginning in November 1950, the G-1 mine has consistently produced more than 1,000 tons a month, at times more than 2,000 tons a month. It is one of the few Salt Wash mines that has produced over 100,000 wet tons of uranium-vanadium ore. When the major ore bodies were depleted by mid-1957, work was begun to develop a number of smaller ore bodies at the southwest fringe of the deposit.

The mine workings are in sec. 7, T. 50 N., R. 17 W., and secs. 12 and 13, T. 50 N., R. 18 W., Gateway mining district, Mesa County, Colo. The mine and the mine camp are on a small, sage-covered flat (fig. 2) at the north end of Outlaw Mesa, an oval land area about 14 square miles in extent. The mesa, typical of the semi-arid plateau country, is bounded on the east and southeast by Blue Creek Canyon, on the west by Calamity Creek, and on the north by

Indian Creek, a fork of Calamity Creek. Altitudes on the mesa range from about 7,000 feet at its northeast end, where it merges with the southwest flank of the Uncompahgre Plateau, to about 5,300 feet at its southern tip. Relief is moderate, but steep washes and rims cross the terrain. The area is covered with pinon, juniper, sagebrush, and scrubby bushes. Water is scarce, except during the spring runoffs or infrequent summer downpours.

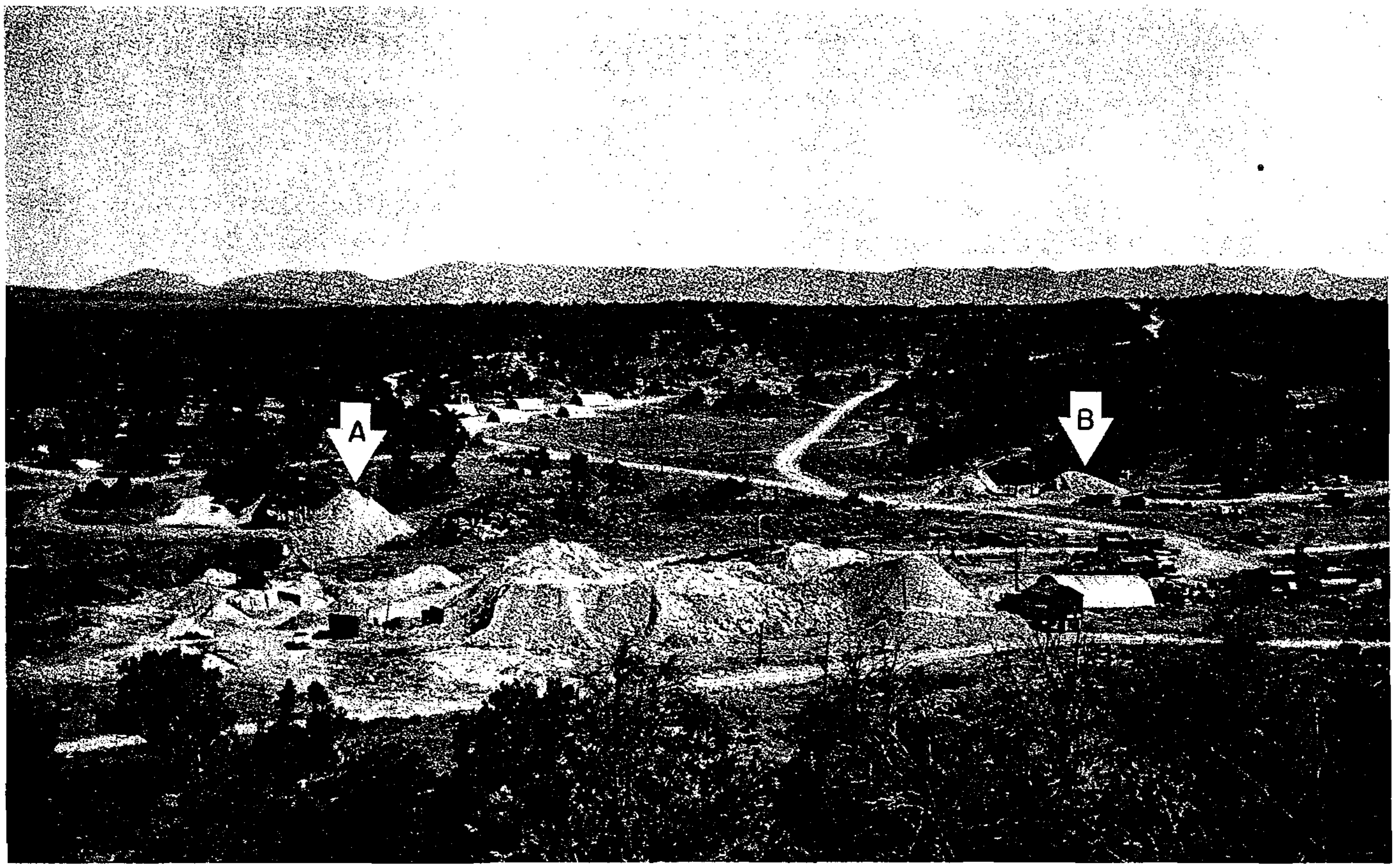

FIGURE 2. - Looking Northeast at G-1 Mine and Camp on Outlaw Mesa. The two incline mines between G-1 dumps and camp are indicated by A and B and are not part of Climax operation. Uncompahgre Plateau is visible in the distance.

The mesa can be reached over three dirt roads that branch from Colorado Highway 141. The Pine Mountain road is about 25 miles long and impassable during most of the winter and spring. It leaves Highway 141 at West Creek, about 4 miles northeast of Gateway, Colo., and winds up Casto Draw and along Ute Creek at grades as steep as 20 percent. Another road leaves Highway 141 in Dolores River Canyon about 11 miles northwest of Uravan, Colo., runs 20 miles up the north fork of Mesa Creek, crosses Blue Mesa, and reaches Outlaw Mesa at its southern tip. The roadbed across Outlaw Mesa is in poor condition much of the time and is often washed out. The third and best road was completed in 1950. It is the main route of travel between Grand Junction, Colo., and the mines on Outlaw, Calamity, and Tenderfoot Mesas. From Colorado Highway 141 in Unaweep Canyon this 30-mile route crosses the Uncompahgre Plateau, from where it turns down Indian Creek to Outlaw Mesa. This road, too, is sometimes difficult to travel, especially when it becomes a quagmire during spring thaws. It is not uncommon to see trucks and autos buried to their beds in mud.

Carnotite was discovered on Outlaw Mesa about 1911. The first mining was begun in 1914. Foster's Camp and Outlaw Camp were the headquarters for two of the earliest mining operations. Operating from these camps, the early-day radium miners extracted carnotite ores from a number of small mines on the northwest end of the mesa overlooking Calamity Gulch. In those days the high-grade ore was packed on burros north across Calamity and Tenderfoot Mesas and down to West Creek over the steep, twisting Picketts Trail. From there the ore was freighted on wagons to the railpoint at Whitewater, Colo., over what is now Colorado Highway 141. Only high-grade ore was produced from Outlaw Mesa before 1938, when the demand for vanadium caused renewed activity and the mining of low-grade ore.[5]

The G-1 mine is within a block of ground that was withdrawn from entry by Public Land Order 494, effective July 9, 1948. Between January 1949, and November 1951 the Federal Geological Survey explored Outlaw Mesa for uranium by a drilling program on behalf of the Atomic Energy Commission. Climax Uranium Co. entered into a contract with the Federal Government in the spring of 1950, whereby Climax agreed to supply funds to build a uranium-vanadium ore-processing mill in Grand Junction. To provide in part the then existing need for a supply of ore to the mill, and in consideration for its construction, the Atomic Energy Commission leased to Climax certain lands on Outlaw Mesa that contained the G-1, G-2, and G-3 ore deposits. The G-1 ore deposit, the largest of the three, is an extension of the deposit underlying the Mesa No. 5 claim to the north. This deposit was located on April 24, 1948, a few months before the 1948 public land withdrawal. Ralph Foster & Sons diamond-drilled the Mesa No. 5 claim in 1951 and sank its incline in the fall of 1953. As mining progressed Climax did supplemental surface drilling on the leased ground.

The Cretaceous Burro Canyon formation and the Brushy Basin, which is the upper member of the Jurassic Morrison formation, cover most of Outlaw Mesa. The Burro Canyon formation caps the higher ground. The beds strike northwesterly and dip about 4° SW., away from the Uncompahgre Plateau.

The ore in the G-1 mine occurs in the upper sandstone lenses of the basal Salt Wash member of the Morrison formation. The lenses have a maximum thickness of 90 feet and an average thickness of about 40 feet. They are generally crossbedded and massive and are mainly white, gray, or light to dark brown.[6] In the vicinity of the ore the sandstone has been principally light brown and speckled with small limonite stains. As in other Salt Wash ore deposits, the ore layers sometimes overlapped each other with barren material between or split and then converged. In general, the ore has occurred as tabular and irregular lens-shaped masses, the thicker parts sometimes podlike or crescent-shaped and called "rolls." The general dip of the ore has been the same as that of the enclosing beds, about 4° SW., but locally it has flattened or has dipped as much as 25°. Carnotite was the principal ore mineral and often was found closely associated with carbonaceous material. The ore has lain about 80 to 190 feet beneath the surface and has averaged about 8 feet in thickness,

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5/ Brasher, G. K., Carnotite Resources of Outlaw Mesa, Mesa County, Colo.: Geol. Survey TEIR 163, 1952, p. 9.

6/ Work cited in footnote 5 (p. 5), pp. 13-15.

thicker than that found in most Salt Wash deposits. The thickest ore occurred where three overlapping lenses had an aggregate height of 25 feet. The thick ore layers terminated rather abruptly, but a thin ore seam often connected one to another. The smaller ore bodies being developed at the southwest fringe of the deposit are estimated to average about 3 feet in thickness.

The G-1 mine is entered through two tracked inclines (fig. 3). The main entry, through which the entire mine production before 1958 was hoisted, is 286 feet long and 8 by 8 feet in cross section. It was driven almost due east on a minus 15° grade to bottom just outside the main ore body. The first 90 feet of the incline was broken by drilling and blasting one long V-cut round from the surface. The holes in the round were wagon-drilled progressively deeper along the projected course of the incline to establish its grade. After firing, the broken rock from the opencut round was mucked out in 2 days with a crawler-mounted, front-end loader. To muck out the rock broken in the lower 200 feet of the incline the tractor backed out with each load until turning room was established within the ore zone. After track was laid to the bottom of the incline, the ore was loaded into a 4-ton, Granby-type mine car and hoisted to the surface. The first 100 feet of the incline was timbered with sets of 8-inch round timbers lagged at the back. The remainder of the incline was driven mostly through sandstone that has stood well without support. After the incline intersected the ore horizon, about 110 feet vertically beneath the surface, an 8- by 8-foot tracked haulageway was continued on a minus-3-percent grade due east for 160 feet. The haulageway cuts gradually beneath the southwesterly dipping ore, and at its end the track is 4 feet lower than the bottom of the ore. Work on the incline was started in August 1950, and it was bottomed in October 1950. Production commenced in November 1950, and the ore was stockpiled until the mill was completed in June 1951.

From the tracked haulageway, headings about 8 feet wide and 8 feet high were turned into the ore zone in directions to follow the best ore exposures. Where the ore widened, the headings were widened into rooms. The sandstone backs have stood well across 40-foot spans. A few spans 60 feet wide have stood with only minor sloughing for nearly 3 years. As the headings and rooms became interconnected, the plan of the mine workings acquired the pattern of an open stope with various size pillars in random arrangement (fig. 4). Most of the pillars are waste. Inclines, as steep as 25 percent, were driven to follow the vertical deviations of the ore lenses. No timber or roof bolts were used for roof support in the initial advance, but timber support was used later where some of the ore pillars were recovered.

Access to a group of smaller ore bodies that are on the downdip fringe of the older stopes will be through 5- by 7-foot headings being driven on track grade from the bottom of the second incline. This entry, started in 1957, is 410 feet long and 5 by 7 feet in section and was driven on a minus-20° grade to bottom 190 feet below the surface. When drifting linked the two inclines in February 1958, the natural flow of air currents materially improved mine ventilation.

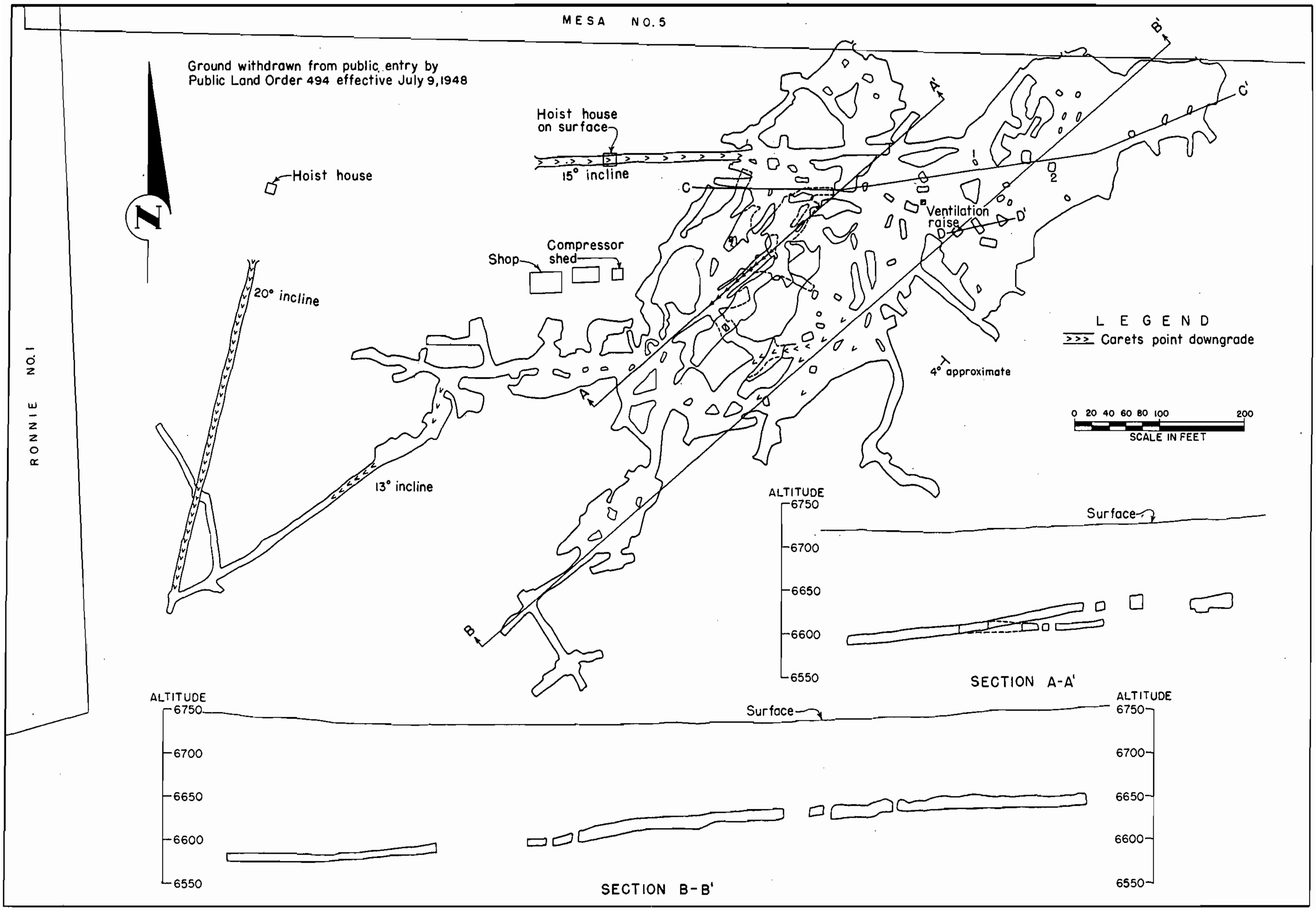
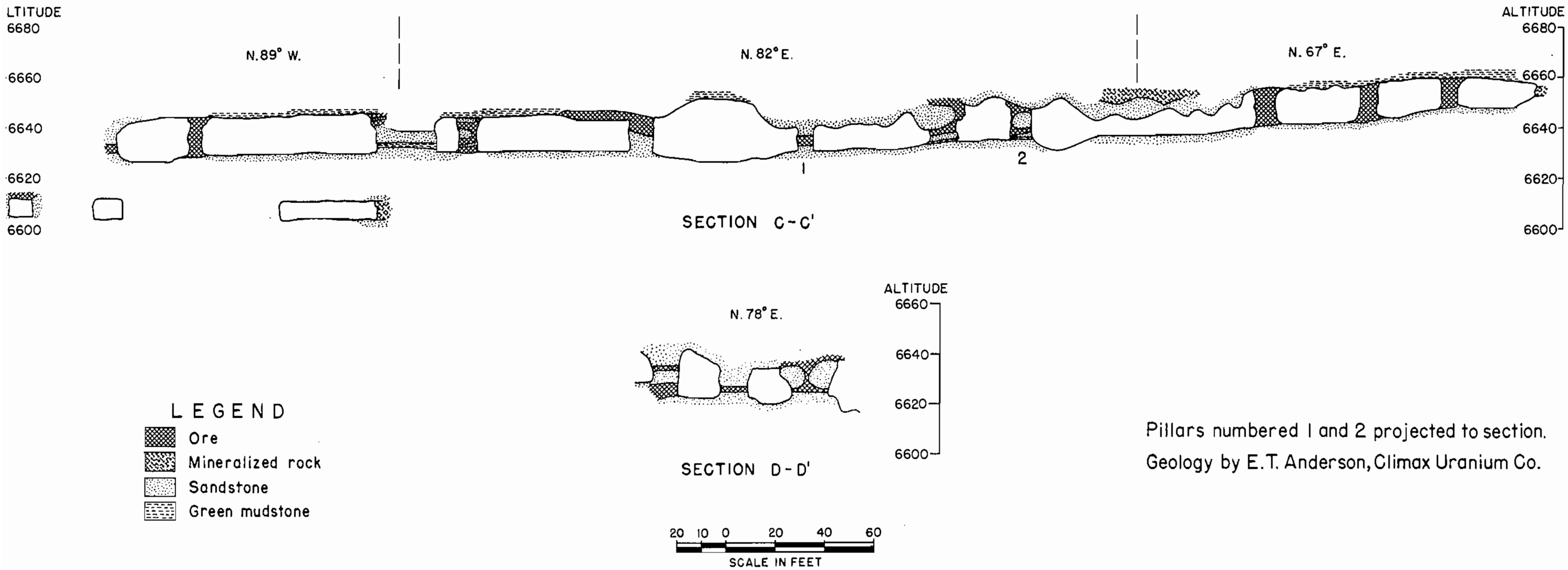


FIGURE 3. - Plan and Generalized Sections of G-1 Workings.



Sections refer to figure 3.

FIGURE 4. - Sections C-C' and D-D', G-1 Workings.

In common with other Salt Wash operations, drilling is done with airleg-mounted drills and 5- and 6-foot lengths of 7/8-inch hexagonal steel. The one-use-type, tapered-socket, 1-19/32-inch drill bits are hard-surfaced with tube borium welding rod. Everett Roberts, foreman, reported that in the G-1 ore approximately 300 feet of hole can be drilled with a hard-surfaced bit. However, the tungsten carbide insert chisel bit integral with the steel has given good results in drifting through the usually better cemented waste rock. In the softer ore gage wear on a chisel bit far exceeds the wear on its crown. Heading rounds in sandstone are broken with 26 holes patterned about a three-hole triangular burn cut and charged with 1-1/8- by 8-inch cartridges of 45-percent semigelatin dynamite. A slower 35-percent explosive usually is used in driving through mudstone, as a faster explosive sometimes causes the mudstone to freeze and the holes to "bootleg". Stope rounds are drilled to break 50 to 60 tons of ore.

The G-1 mine was one of the first Salt Wash operations to use trackless diesel-powered equipment underground. It is one of the few Salt Wash mines where the ore has been thick enough to permit trackless haulage without requiring excessive overbreaking for headroom. To accommodate the machines, development headings in the G-1 mine were driven at least 7 feet high and 8 feet wide. The stopes have been large enough so that the equipment could be maneuvered with relative ease, and the grade of the ore has been high enough so that dilution caused by the use of the larger equipment has not been a serious penalty. The use of trackless equipment has had advantages in the undulating ore zone, but where the elevation of the ore changed abruptly, development headings sometimes had to be relocated or regraded. A disadvantage of the large equipment is the higher cost to drive the larger waste headings.

The rubber-tired ore haulers are loaded with Allis-Chalmers HD-5G front-end tractor loaders (fig. 5). The loaders carried their 1-yard loads directly to the hoisting car when working within 100 feet of the track. The diesel-powered ore hauler, a Scoot-Crete CD, has a Marmon-Harrington four-wheel drive and four-wheel steering and can carry its 3-1/2-ton load at 2 to 4 miles an hour through the stopes. The dump box is built over its forward wheels, on which are mounted 8.25- by 20-inch 12-ply tires. This machine is 16 feet long and 6 feet, 4 inches wide. Seven feet of headroom is needed to accommodate it; about 8 feet is needed where it is filled with the loader. A three-wheel Scoot-Crete KD-2 ore hauler is also used. This smaller diesel-powered machine is 12 feet long and 5 feet wide and requires about 6 feet of headroom. Its 2-ton-capacity dumpbox is built over its two front-drive wheels, which are mounted with 7.50- by 16-inch tires. The driver sits over the single rear-steering wheel, which has a 7.50- by 10-inch tire. This unit is powered by a two-cylinder, four-cycle, air-cooled, German-made Deutz F2L 612 diesel-engine. Fuel-oil consumption averaged about 3 gallons per 8-hour shift. Both haulers can operate on 25-percent grades. The smaller unit is slower and is backed up the steeper grades for better traction. Their loads are dumped directly into the 4-ton Granby car, as figure 6 illustrates.

Failure of the front idler spokes on the front-end loaders used underground has caused breakdowns in the service of these machines. That type of breakdown is fairly common in small mines using this type of equipment but is less frequent when similar loaders are used on the surface. It is caused when the crawler-tracks near the idlers repeatedly "hang up" on protrusions on the floor or strike the walls as the loader is pivoted sharply. The added weight of approximately 1 yard of ore in the bucket increases the stress on the idlers. It is interesting to note that, at the G-1 mine, less engine repair has been necessary on tractors used continually underground than on those used on the surface. On the CD ore carrier the parts that require replacement most frequently are the chassis springs.

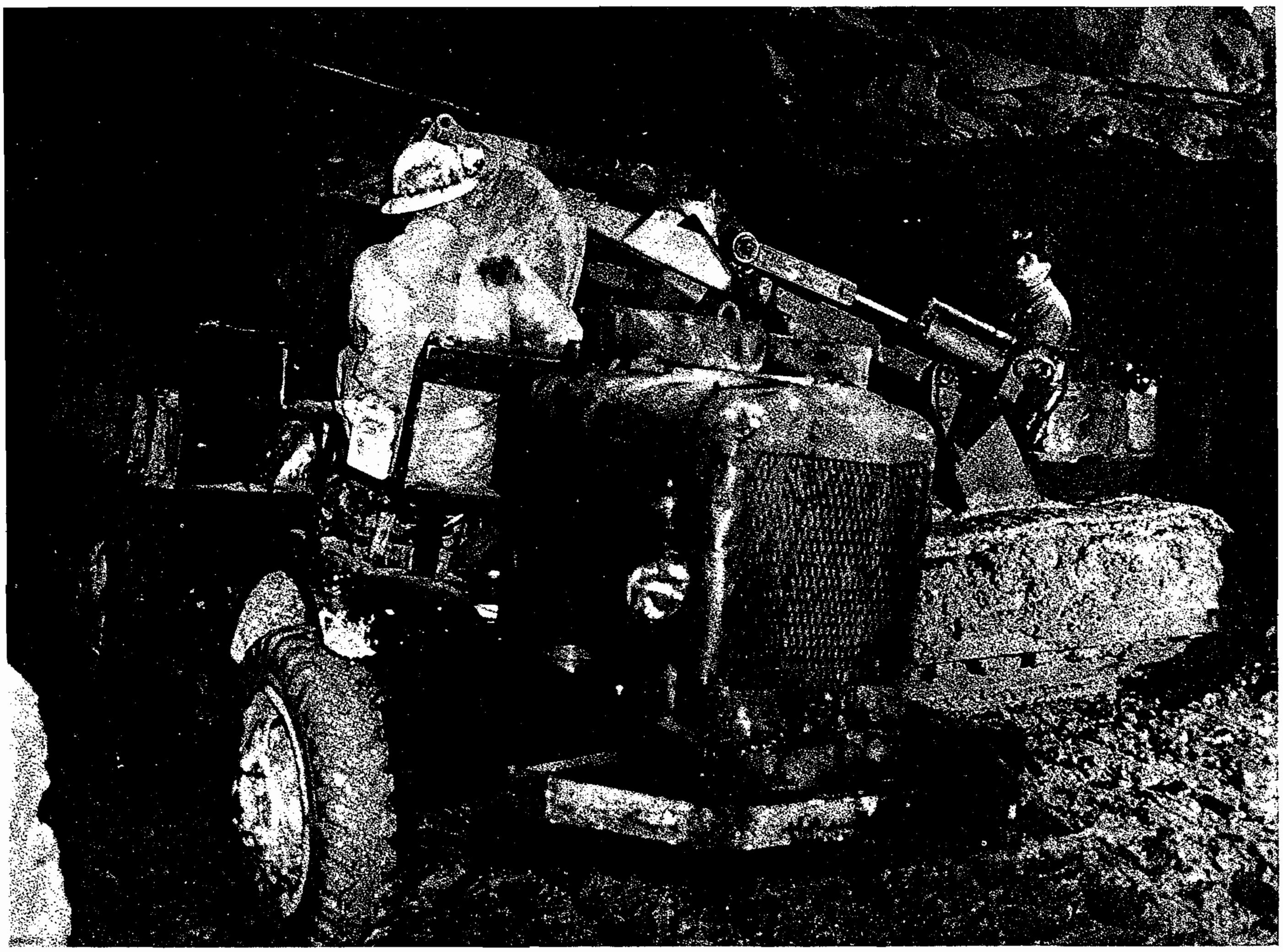


FIGURE 5. - Loading Ore Hauler in G-1 Mine.

As stoping progressed in the G-1 mine, the ground immediately above and ahead of the existing workings was tested with 6-foot holes fanned out with the leg-mounted machines. Ten-foot downholes discovered a 4-foot-thick split of an ore layer beneath one stope.

FIGURE 6. - Dumping Load Into Hoisting Car at Main G-1 Incline.

Through both inclines the single hoisting cars are pulled to the surface by small, single-drum gasoline-driven hoists wrapped with 6 by 19, 5/8-inch wire rope. The inclines are tracked with 20-pound rail, which was laid to 24-inch gage in the main incline and 18-inch gage in the newer incline. At the main incline the track on the waste-filled surface ramp is on a 4-percent grade, which returns the 80-cubic-foot-capacity Granby-type car underground after it is dumped. The car is tipped to empty onto the ground by either of two camelback dump blocks, one opposite the ore pile and the other opposite the waste pile. The first block is hinged and can be swung back out of the way by an air-operated cylinder controlled by the hoistman. Only limited storage is provided at the dumping points, as the track is only about 10 feet above the ground. A crawler-mounted loader is used to move the waste to the dump area and to load the ore trucks for their 50-mile haul to the company Grand Junction mill. At the newer incline the end-dump 1-ton mine cars are hand-dumped.

The hoist at the main incline is not at the end of the waste ramp for a direct pull, as is the hoist at the newer incline and at most other inclines on the plateau, but rather it is directly opposite the ramp on the higher ground over the entry. The rope from the hoist drum runs forward to the upper of two 30-inch sheaves affixed to a 10-foot-high, vertical, 15- by 5-1/2-inch I-beam, set and guyed at the end of the ramp. From the upper sheave the rope runs down and behind the I-beam and is reeved through the lower sheave and then back to the coupling on the mine car. The sheaves turn in slots cut in the web of the beam.

Ventilation is provided by a low-pressure, 4-foot-diameter, 20,000-c.f.m. disk fan exhausting through a 110-foot, 5- by 6-foot, timbered raise about 450 feet east of the older incline. Aiding the disk fan are three small, 2,600-c.f.m. centrifugal blowers mounted over the collars of 12-inch churn-drill holes that intersect the workings. Compressed air is furnished by a skid-mounted, two-stage, air-cooled, 600-c.f.m., Joy WK-80 compressor. Water for camp use is hauled about 1-1/2 miles from a spring on Indian Creek, northeast of the mine. The shop at the G-1 mine is equipped to make most repairs on equipment used at the G-1 and other Climax operations in the Gateway, Uravan, and Bull Canyon districts. No powerlines enter the area, and electric power for the fans, shop equipment, and camp is furnished by a 19-kw. continuous-output, diesel-electric set.

An underground diamond-drilling program was begun in March 1958 to further test the ground above and below the stopes before final cleanup begins. Under its lease agreement, Climax is required to keep the workings open until approval is given by AEC to pull the ore pillars. Fifty-foot, vertical, EX coreholes were drilled with a Chicago Pneumatic CP No. 55 drill. As of May 1958, additional ore had been found beneath the old stope level, but its extent was unknown at that time.

Equipment used at the G-1 mine includes the following items:

Number	Item
2	Hoist, single-drum, Skagit; 85-hp. gasoline engine.
3	Tractor, crawler, front-end loader, Allis-Chalmers HD-5G.
1	Ore carrier, Scoot-Crete CD.
1	Ore carrier, Scoot-Crete KD-2.
3	Mine car, 20-cu.-ft., end-dump.
1	Mine car, 80-cu.-ft., Granby-type.
1	Compressor, 2-stage, 600-c.f.m., skid-mounted, Joy WK-80.
1	Diesel-electric generator, 19-kw. continuous rating, Caterpillar D311.
1	Fan, 4-ft. disk, 20,000-c.f.m. approx.
3	Blower, centrifugal, 2,600-c.f.m. approx.
4	Drill, airleg-mounted, Gardner-Denver S48F.
1	Diamond-drill, Chicago Pneumatic CP No. 55.

During the productive period of the mine, the crew, other than the shop crew, consisted of two drillers, two loaders, one hoistman, one topman, and one leadman, all of whom worked one shift a day, 12 days on and 2 days off. Labor productivity in 1956 averaged 5.74 tons of ore per man-shift and 8.50 tons of both ore and waste per man-shift, which is considerably higher than the general average in Salt Wash mines. The hourly wage rates paid the miners in May 1958 were as follows:

Job classification:	Hourly wage	Job classification-continued:	Hourly wage
Leadman..................	$2.20	Equipment operator, underground	$2.10
Mechanic..................	2.16	Driller........................	2.02
Dozer operator...........	2.16	Equipment operator, surface....	1.95
Shaftman..................	2.16	Mucker, miscellaneous labor...	1.81

The nearby G-3 mine is part of the company operation on Outlaw Mesa. This newly developed mine is managed from the G-1 camp and is about one-fourth mile southwest of the G-1 mine in sec. 13, T. 50 N., R. 18 W., and sec. 18, T. 50 N., R. 17 W. The deposit, smaller and thinner than that mined at the G-1 mine, lies within the same withdrawn block of ground and was developed by Climax under the provisions of the same amended contract with the Federal Government. Early in 1958 the G-3 was being geared to produce about 1,500 tons a month to compensate for the decrease in the G-1 output.

The ore is deeper than the G-1 deposit, and access was gained by sinking a two-compartment vertical shaft first bottomed at 252 feet in July 1956. The shaft was timbered with 7-foot conventional sets of 8- by 8-inch native pine into a 5- by 5-foot hoistway and a 5- by 4-foot manway. The sets are tight-lagged with 2-inch pine. The shaft, which for most of its depth was sunk through shales of the Brushy Basin member of the Morrison formation, is about at the center of the major area of uranium deposition. A small shaft station was first cut at 252 feet in the upper ore-zone. From the results of exploratory drilling, it was believed that the shaft would penetrate the mineralized zone at least 50 feet from the nearest ore. As the miners drove out from the shaft, three individual lenses of ore about 20 feet in total thickness were found, one above another. The bottom lens curved down and then back under the bottom of the shaft. The shaft was deepened to 280 feet, and a lower station was cut.

Small development headings in the G-3 mine are being driven for the most part within the ore zone for track haulage. The ore updip to the north and east of the shaft is being opened up through short raw raises driven from headings beneath the ore. The ore downdip is being developed through inclines.

The 18.5-cubic-foot-capacity end-dump mine cars are hand-trammed to the station over 20-pound rail laid to 18-inch gage. In the stopes above track level the ore is conveyed to open steel-slide chutes at the ore passes by 7-1/2-horsepower, double-drum hoists equipped with 30-inch scrapers. Mucking in the haulage drifts and in inclines whose grade does not exceed 10° is done with an overhead loader.

Cage-and-car unbalanced hoisting is used at the G-3 mine. The cage is hoisted by a 36-inch-diameter, split-drum, 1,750-pound-rope-pull hoist, powered by a 50-horsepower induction motor. A 6 by 19, 3/4-inch hoisting rope is wrapped only on the overwind half of the drum.

The four-post-type headframe is 36 feet high to the 36-inch-diameter sheave wheel. It is of the same design as that used at the company Mineral Joe shaft on Monogram Mesa. Like the Mineral Joe headframe, it was built in 18-foot sections, which permit easy erection and dismantling. At the surface the mine cars are uncaged by a topman at a housed-in landing deck, 14 feet above the shaft collar (fig. 7). The bins consist simply of timber-partitioned bunkers beneath the trestle, open at one side for access by the front-end loader.

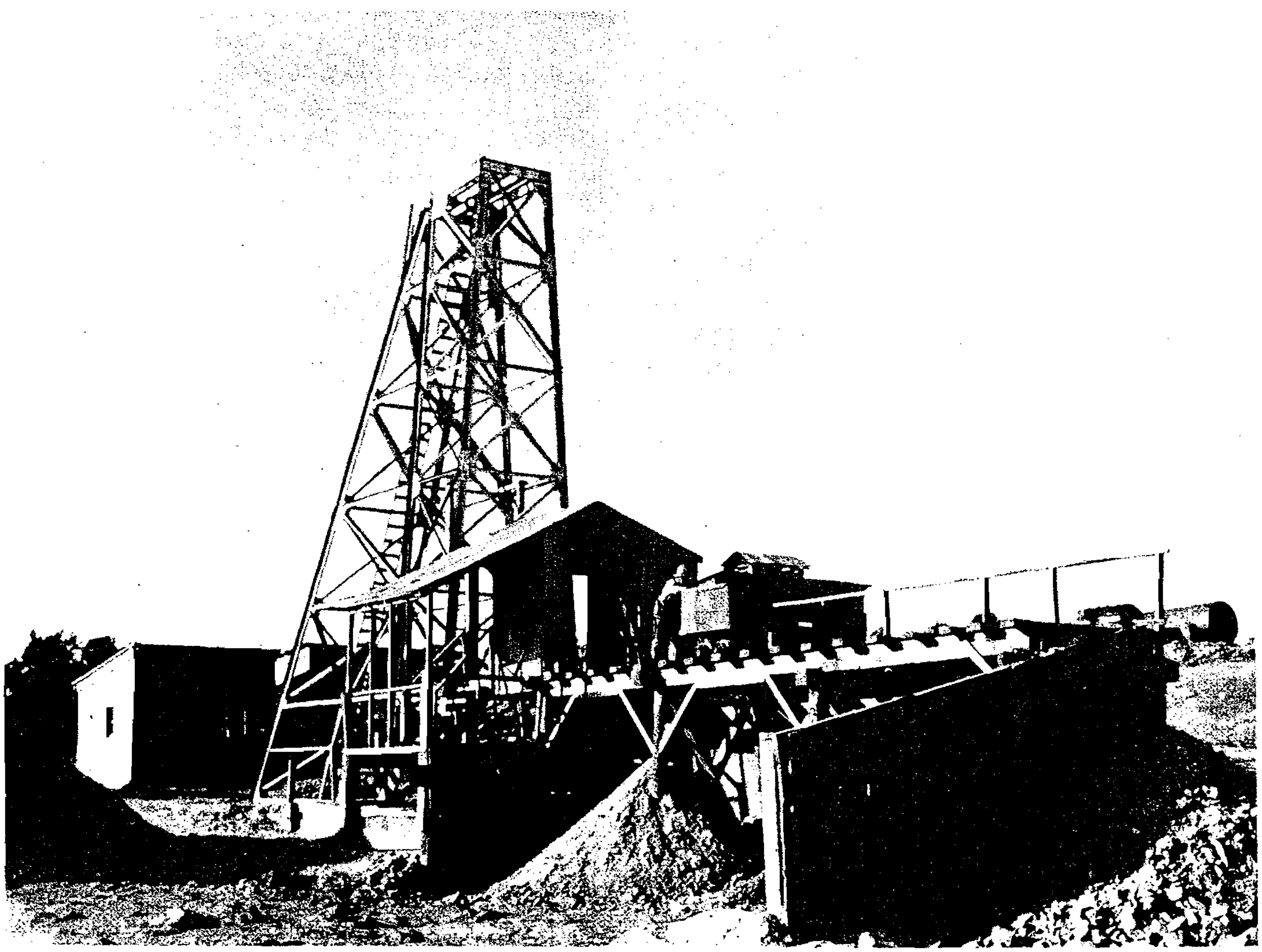


FIGURE 7. - Tramming Mine Car to G-3 Ore Bins.

Compressed air is furnished by a 600-c.f.m. Chicago Pneumatic portable compressor. Power is generated by a 105-kw. continuous-output Caterpillar D337 diesel-electric set.

Equipment used at the G-3 mine consists of the following items:

Number	Item
1	Compressor, 600-c.f.m., portable, Chicago Pneumatic 600 RO-2; diesel.
1	Diesel-generator, 105-kw. continuous, 60-cycle, Caterpillar D337.
1	Hoist, divided-drum, 1,750-pound-rope-pull; 50-hp. induction motor.
2	Loader, overhead, Eimco 12B.
8	Mine car, 18.5-cu.-ft., low, C. S. Card type Z.
2	Slusher hoist, 2-drum, air, 7-1/2-hp., Joy FF-211.
1	Tugger hoist, 1-drum, air, 12-hp., Joy AF-111.
6	Drill, airleg-mounted.
1	Front-end loader, Michigan 75A (on surface).

The 6-man crew employed at the G-3 mine has recently been increased to 25. They are paid at the same rates as at the G-1 mine.

The men from both the G-1 and G-3 operations live at the camp, either in the company-owned Quonset huts or in privately owned trailers. Meals at the cook house cost $0.85 each. The company charges $5.00 per month to supply electricity to a trailer. Mesa County built and staffs a 1-room prefabricated schoolhouse for the children at the camp.

MINERAL JOE MINE

The Mineral Joe shaft is in sec. 22, T. 46 N., R. 17 W., Bull Canyon mining district, Montrose County, Colo. It is on the northeast side of Monogram Mesa, overlooking Paradox Valley (fig. 8). The shaft collar is at an altitude of about 6,280 feet and is about 700 feet above the valley floor and 800 feet below the mesa rim. Paradox Valley, a collapsed salt anticline, trends northwest and is about 2 miles wide at this point.

The nearby Thunderbolt mine was one of the first mines in Paradox Valley to produce carnotite ore. The first shipment of ore from this mine was made in about 1910. The mine was worked from the Hequembourg Camp (named after the mine operator), which was built in 1910 a short distance below the Thunderbolt adits. In that year the mine was reported to have had a labor force of 40 miners.[7] Standard Chemical Co. acquired the Thunderbolt mine and was the world's leading producer of radium ores between 1913 and 1921. The first ore shipped by Standard was in April 1913. It is believed to have been produced by Hequembourg from the Thunderbolt in 1912.

Minerals Engineering Co., Grand Junction, Colo., located the Mineral Joe Nos. 1-12 and 14 claims in March 1948 (figs. 9 and 10). Climax Uranium Co. acquired the claims in June 1950 and began an exploratory drilling program the same month on the Mineral Joe No. 2 claim. The ore underlying the No. 2 claim was the first to be developed in the claim group. A 560-foot, minus 12° incline, started in June 1951, was driven south from the canyon wall into

7/ Curran, T. F. V., Carnotite in Paradox Valley, Colo.: Eng. Min. Jour., vol. 92, December 1911, p. 1287.

the ore zone. The first haulageways were advanced southeast along the deposit into the contiguous Nos. 3 and 4 claims. Later, a haulageway was driven northwest from the incline to develop the ore under the No. 1 claim, which adjoins the older Oversight claim of Union Carbide Nuclear Co. From November 1951 to February 1952 the Mineral Joe Nos. 1-7 claims were tested extensively by Climax with a second drilling program.

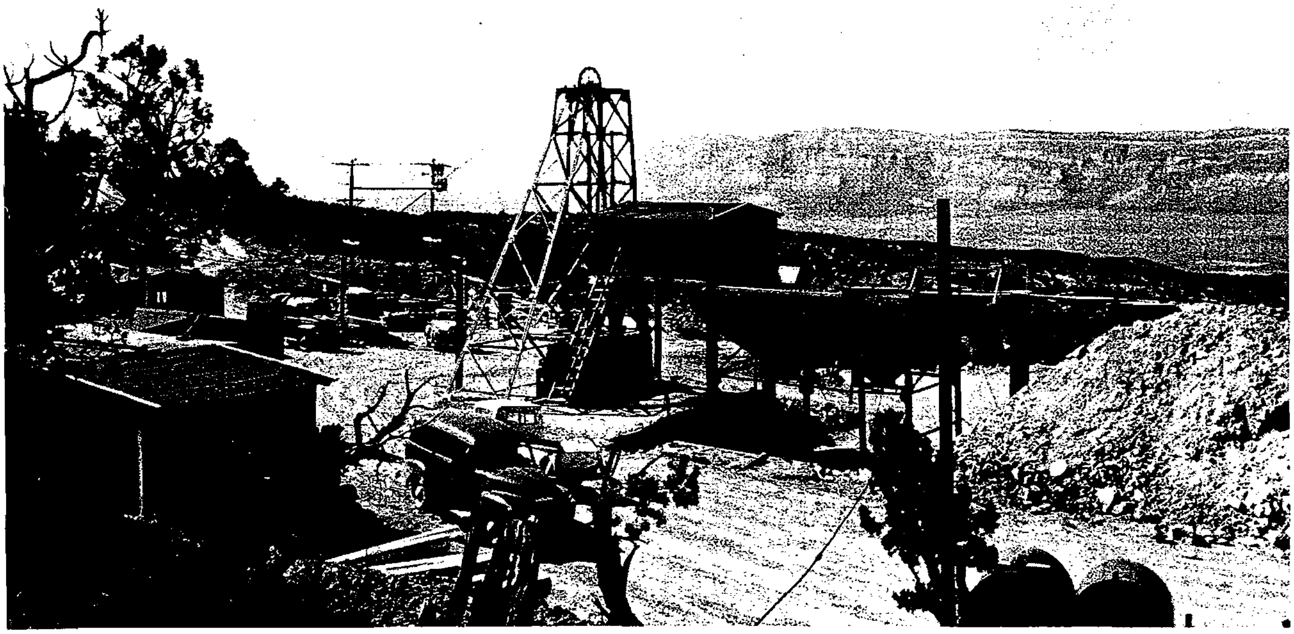


FIGURE 8. - Mine Plant at Mineral Joe Shaft.

The cluster of ore bodies that lies across the northern part of the Mineral Joe Nos. 12 and 14 claims was discovered as a result of a third drilling program, which Climax started in June 1953. This program covered the Nos. 8-14 claims and lasted until 1954. The Mineral Joe shaft was sunk to develop this ore. In 1953 the Federal Geological Survey, working on behalf of the Atomic Energy Commission, found indications of ore across the northern part of the No. 9 claim and extending a short distance into the adjoining Nos. 8 and 12 claims, when seven of nine diamond-drill holes penetrated ore or mineralized ground. Climax verified the results of the Survey findings by offset holes. The ore delineated by that work now is being mined through a 1,500-foot haulageway driven from the shaft. Mineralized ground was cut in other holes drilled between the ore bodies mined near the shaft and those discovered by the Survey. More underground work may prove them to be linked by interjacent ore. The results of wide-spaced drilling are often only indicative of what might be found underground. Often, a promising ore hole was found to have penetrated only a small isolated ore pod. On the other hand, ore bodies have been found that nearby drillholes missed. One problem encountered at the Mineral Joe mine and experienced at many mines where contract drillers crowded their drill bits to increase the rate of penetration was that the holes were not always where they should have been underground. Some of the earlier, supposedly vertical holes were found to have deflected 85 to 100 feet in a depth of about 400 feet.

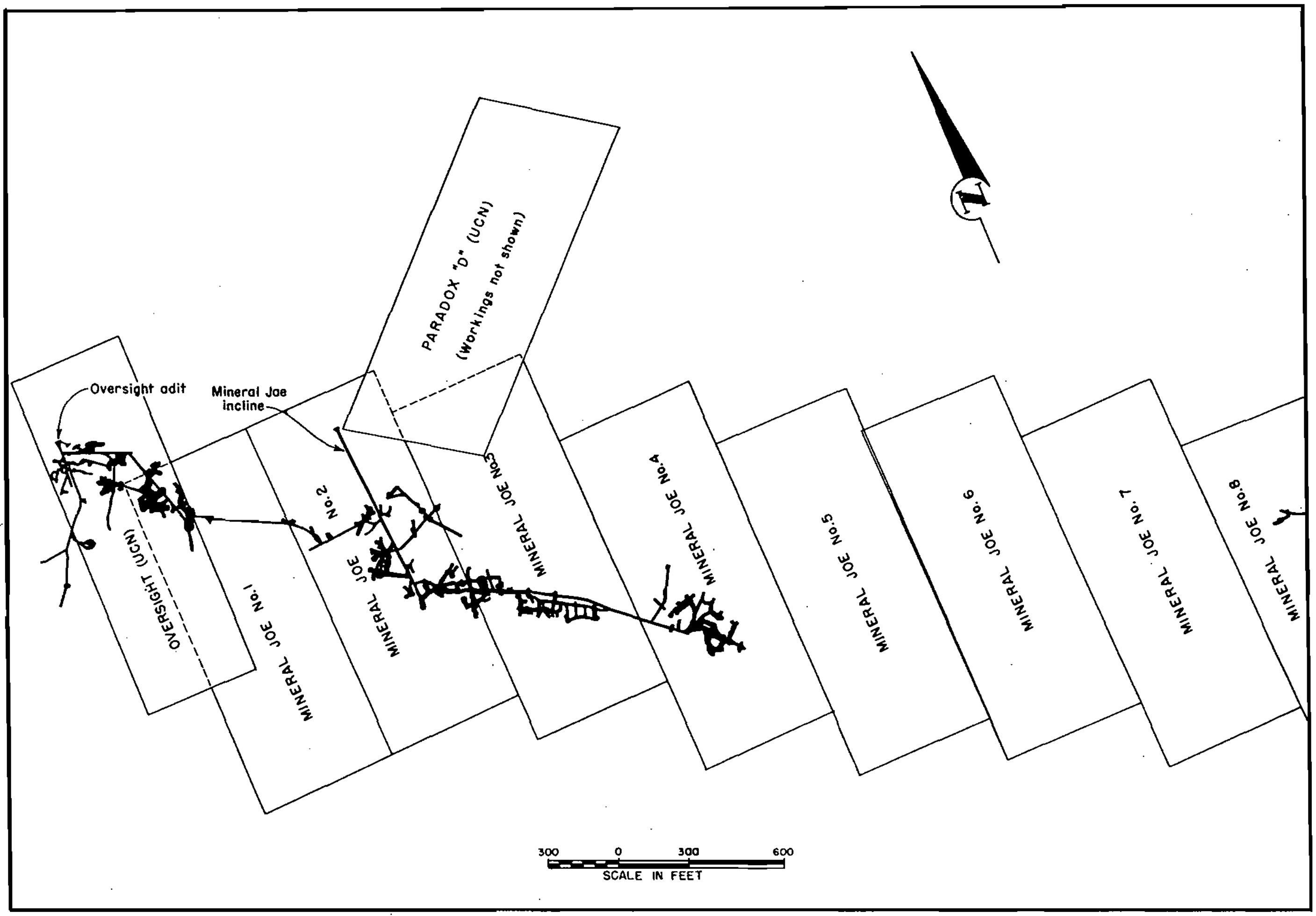


FIGURE 9. - Mine Workings on Mineral Joe and Adjoining Claims (Northwest Half).

The main ore layers developed through the Mineral Joe shaft occurred in the uppermost sandstone stratum of the Salt Wash member of the Morrison formation. In the nearby Thunderbolt mine the upper sandstone, the ore-bearing stratum, splits into three separate units parted by mudstone lenses as thick as 15 feet.[8/] The main ore layers at the Mineral Joe Nos. 12 and 14 claims have occurred in the upper unit. The strata at the shaft strike about N. 50° W. and dip 10°-17° SW. The ore has ranged in thickness from a knife edge to 28 feet; its average thickness has been about 5 feet. The thicker ore has consisted of two or three layers of ore minerals separated by thin bands of barren or low-grade sandstone. The deposit has been rather uniformly mineralized, but the higher grade parts have stopped abruptly. The ore minerals have been carnotite and vanadium clay minerals.

8/ Cater, Jr., F. W., Geology of the Naturita NW Quadrangle, Colo.: Geol. Survey, Quadrangle Map GQ 65, 1955.

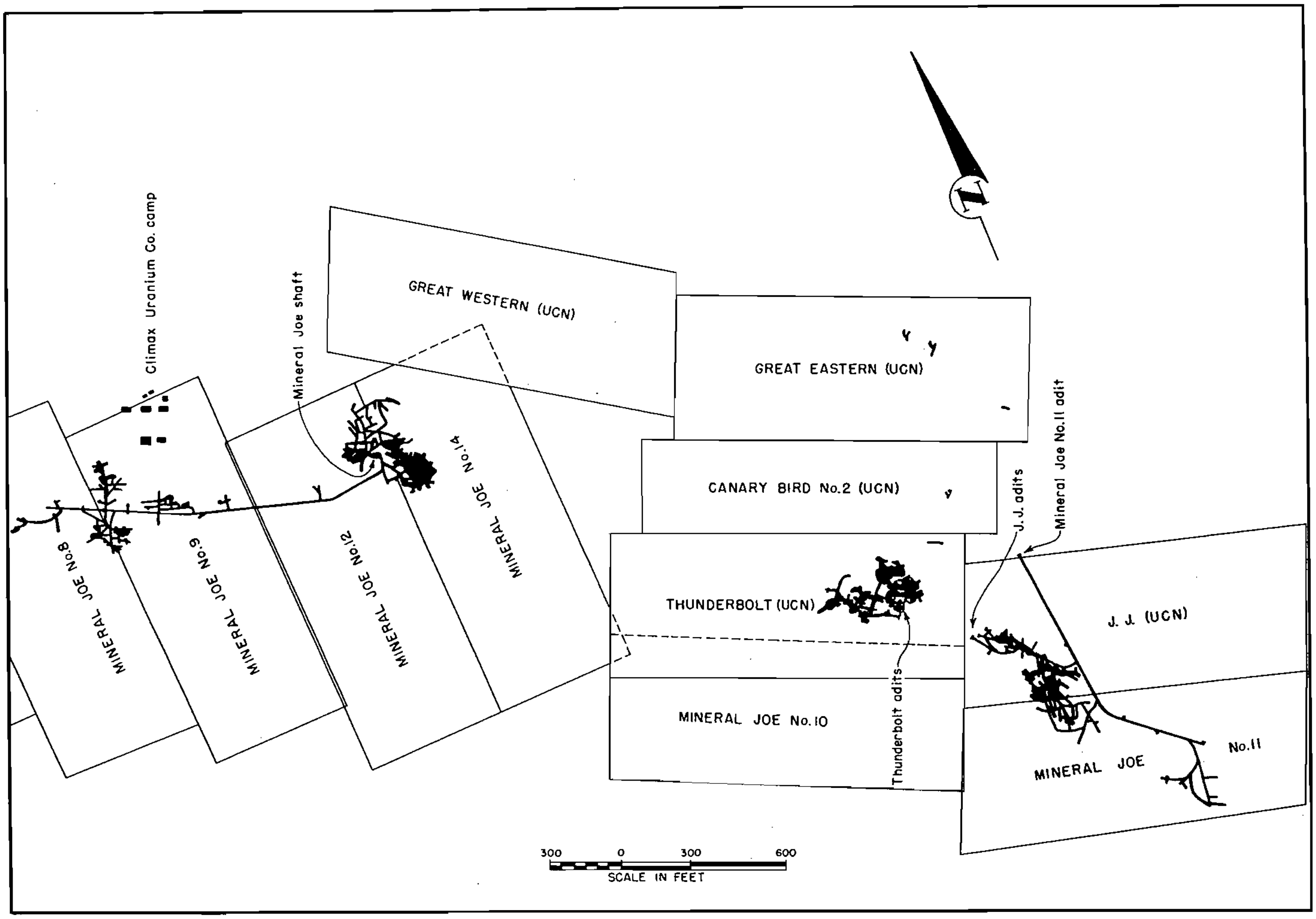


FIGURE 10. - Mine Workings on Mineral Joe and Adjoining Claims (Southeast Half).

The ground opened through the Mineral Joe shaft has been highly fractured and cut by a series of small faults, whose strikes generally parallel Paradox Valley. One fault about 100 feet north of the shaft displaced the ore vertically about 25 feet. This fault is believed to be the same as that cut in the Mineral Joe incline to the northwest, where the fault has a displacement of about 100 feet. Another almost parallel fault found south of the shaft has a displacement of about 15 feet. The fault blocks were downthrown toward Paradox Valley. The ore developed through the shaft up to May 1958 has lain 230 to 400 feet beneath the surface.

The vertical Mineral Joe shaft was collared in landslide material and was sunk with a rock size of 7 by 13 feet to a depth of 255 feet. The shaft station was cut at 250 feet at the base of the upper unit in the ore-bearing sandstone. The shaft was collared in April 1954 and bottomed in 38 calendar days on a two-shift basis. The shaftmen, three on a shift, worked under a footage contract. The topman and hoistman worked on company time. The contract-labor rate for drilling, blasting, mucking, and hanging timber for the first 100 feet was \$25.00 a foot. The rate was increased to \$30.00 a foot from 100 to 255 feet.

The shaftmen drilled 24-hole V-cut rounds using 7/8-inch hexagonal steel and Portland Throwaway bits. The cut was a single V with four holes in each row. Occasionally in the tighter shales, two additional cut holes were drilled inside and at opposite ends of the V. The rounds were mucked into a sinking bucket with a clamshell operated by two 7-1/2-horsepower, Joy, air-operated tugger hoists.

The shaft was timbered into two 5- by 5-foot compartments with conventional sets of 8- by 8-inch native pine hung on 7-foot, 8-inch centers (fig. 11). The walls were tight-lagged with 2-inch pine, and the hoisting compartment was lagged off from the manway every other set where ladders were staged. The ground stood well, and shaft timbering was advanced in 50-foot sections; the clamshell was lowered after each section was timbered. For most of its depth the shaft penetrated the soft shales of the Brushy Basin member of the Morrison formation. During 4 years of service shaft blocking has held well. Native pine in 1954 cost $55.00 per thousand board feet. The Throwaway bits cost $0.18 each when purchased in lots of 1,000. The total direct sinking cost was very close to $100 a foot. The first ore, produced from development headings, was shipped in December 1954.

In the vicinity of the shaft the 6- by 7-foot tracked haulage drifts were driven from the station to cut beneath most of the ore (fig. 12). Guided by exploratory drilling, the drifts were advanced so that they would roughly bisect the ore bodies. However, as with other Salt Wash deposits, the irregularities of the ore bodies could not be defined precisely by the limited amount of drilling, and the ore did not always lie as anticipated. Most of the ore developed near the shaft has been 4 to 25 feet above the level of the track. North of the shaft, on the downthrown side of the larger fault, the ore was stoped at track level.

To the northwest, the ore bodies within the Mineral Joe Nos. 8 and 9 claims are being developed and mined through a 1,500-foot heading driven generally N. 70° W. To gain additional depth in this heading - the ore bodies developed are as much as 45 feet beneath the station - 160 feet of its length is a minus 17-1/2° incline. Sandstone backs in the haulageways have stood well, and only occasional drift sets were needed where northwest-striking faults and fractures were crossed. The haulageways are dry and well lighted. The drifts are on a 1/2-percent grade and the 18-inch-gage track of 20-pound rail is straight and well-ballasted.

Before stoping is begun, the ore is blocked out by small slusher headings. A systematic method of blocking out a Salt Wash ore body is seldom possible, for the irregularity of the ore precludes ordered or regular spacing of openings. Consequently, a Salt Wash mine map might suggest a haphazard approach to development. The slusher headings, therefore, are first driven to explore the ground and in doing so serve to block out the ore.

From the haulage drifts raises are driven up through the ore zone. Five- by six-foot crosscuts are then driven from the raises through the ore to the waste. Small slusher drifts test the ground between the crosscuts. Spacing of the raises is determined by the length of the ore bodies or the distances

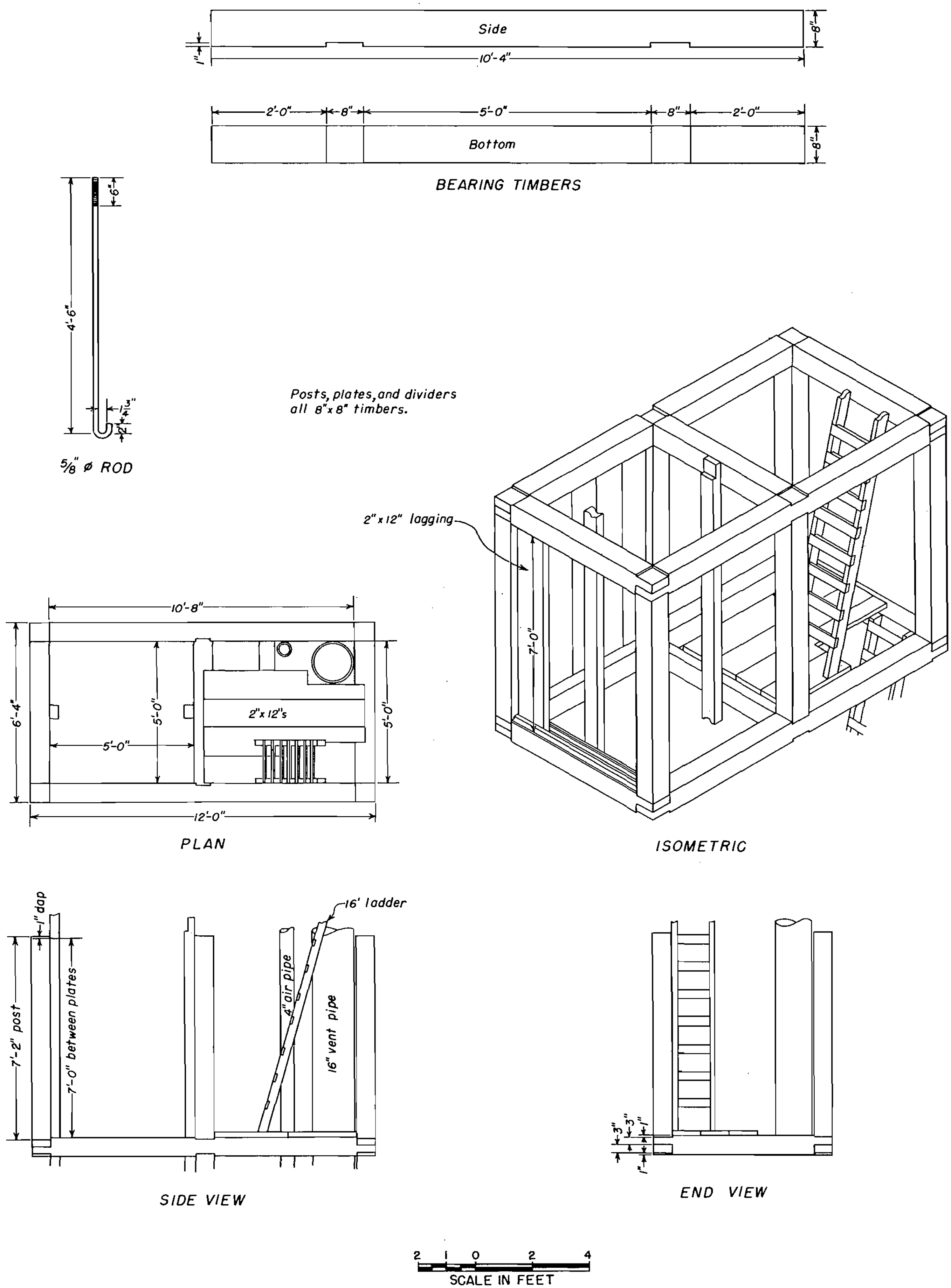


FIGURE 11. - Timber Sets in Mineral Joe Shaft.

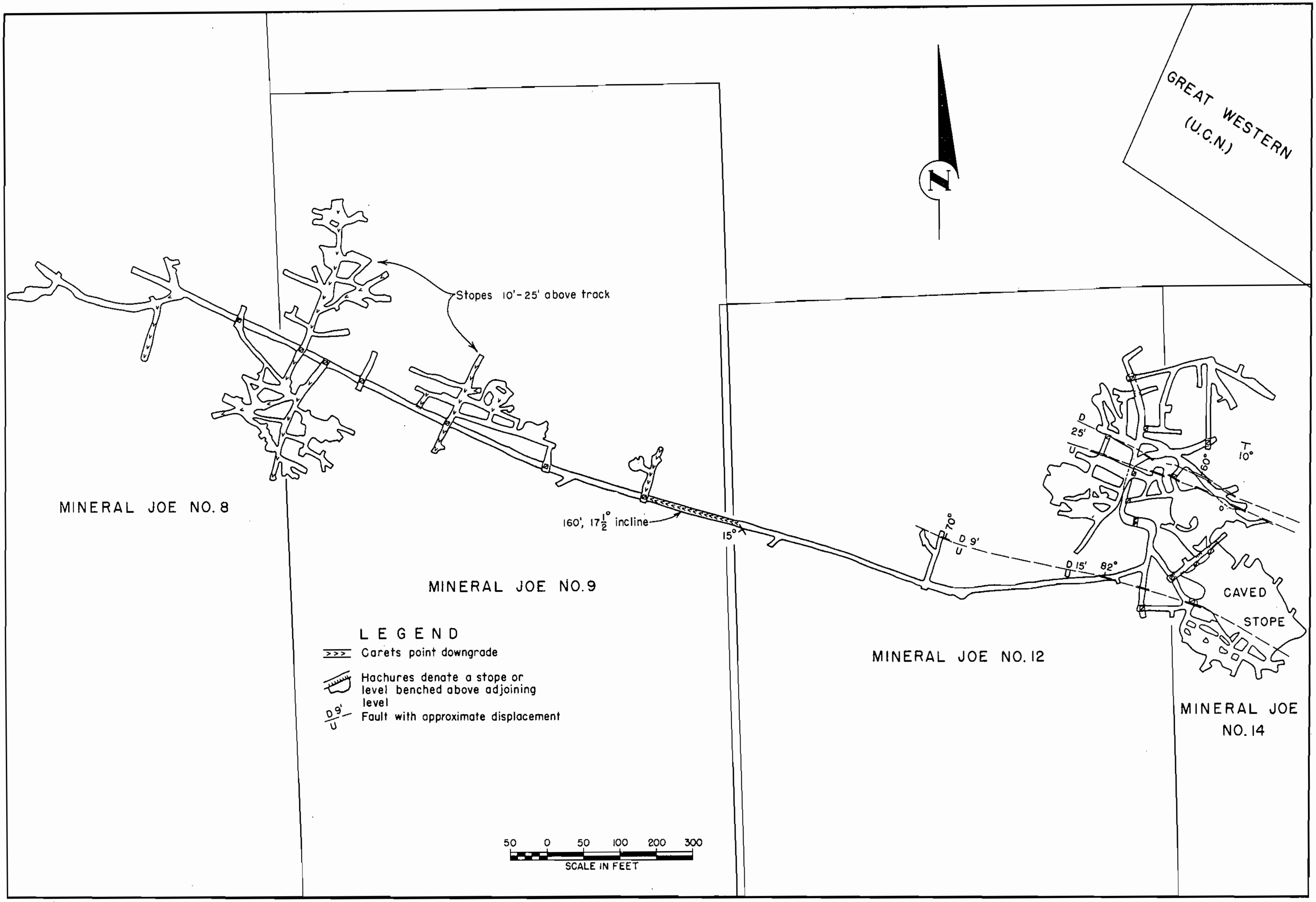


FIGURE 12. - Plan Map of Mineral Joe Shaft Workings.

between them. The drifts and crosscuts often must be turned to conform to local irregularities of the ore, or they may be widened into rooms to mine out isolated pods or lenses.

The rock is drilled with airleg-mounted drills and 6-foot lengths of 7/8-inch hexagonal steel integral with tungsten carbide insert chisel bits (fig. 13). When the gage of the bit is too small for additional use, the steel is used further by cutting off the bit and turning down the bit end to use with tapered-socket, one-use, four-wing bits. Drift rounds consist of 18 holes patterned around a three-hole, triangular, burn cut; the three burn holes are collared about 5 inches apart. Thirty-five percent semigelatin dynamite and standard-delay electric caps are used for all blasting. The color of the ore is an excellent guide to its grade. A Geiger counter is seldom needed underground.

FIGURE 13. - Collaring Drill Hole in Mineral Joe Slusher Drift.

Ore broken on the stoping level is conveyed to slide chutes at the haulage drifts by small portable 5- and 7-1/2-horsepower, electric-driven, double-drum hoists and 30-inch semihoe scrapers (fig. 14). The minus 50° chutes serve only to direct the ore into the mine cars spotted beneath them and provide no storage (fig. 15). The small slusher hoists are used for pulls up to about 100 feet; for longer pulls, two hoists are used in relay. Up to the final stage of recovery a pad of ore is left along the bottom of the slusher headings to keep the scrapers from digging into the soft waste bottoms and diluting the ore.

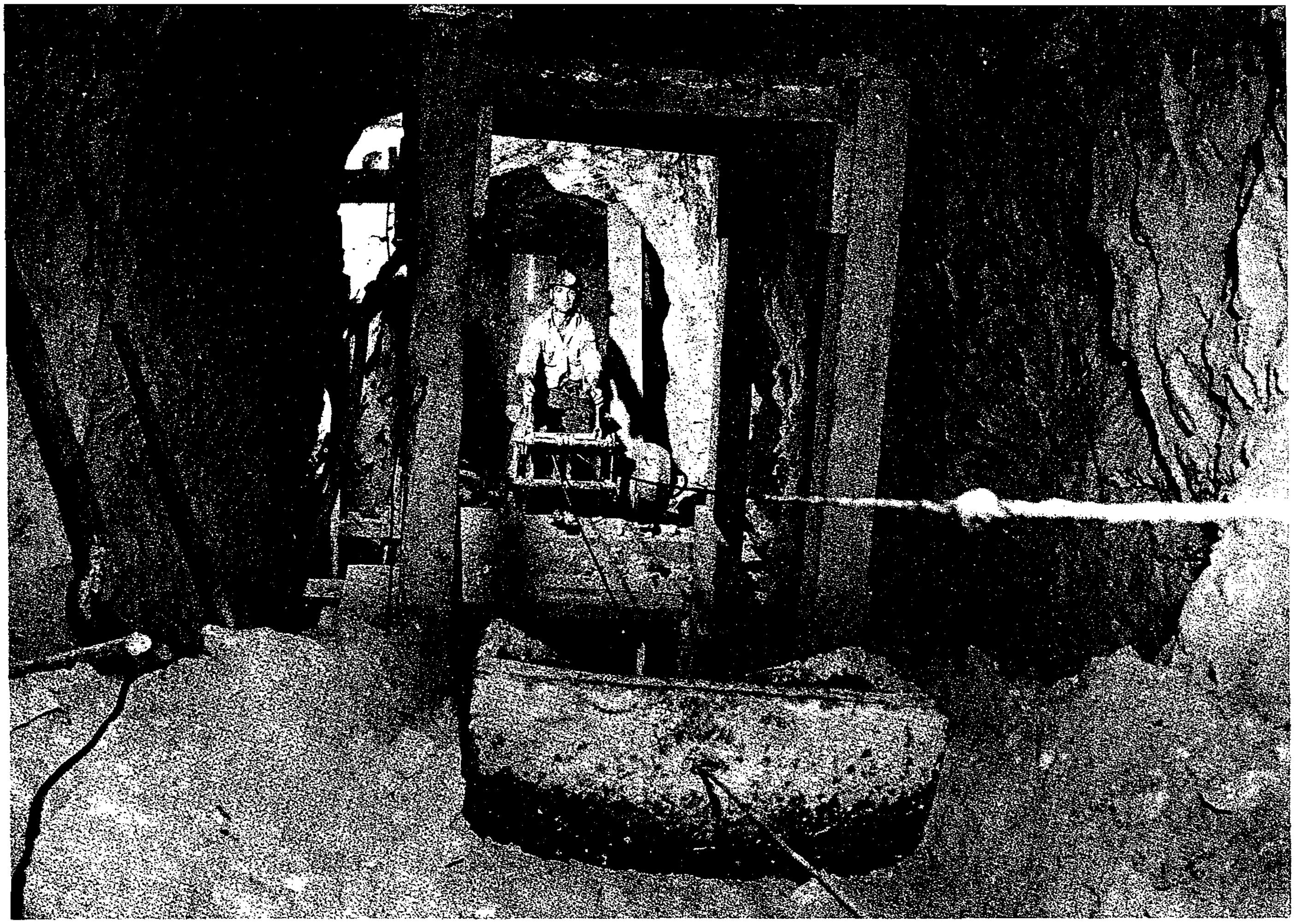


FIGURE 14. - Scraping Ore in Mineral Joe Slusher Drift.

The pillars or blocks of ore are recovered on retreat toward the haulage level. Barrier pillars that border and protect the haulage drifts are left in place and will be pulled during the final phase of mining. A predesigned system of recovery may be difficult to follow as it will be difficult to maintain a uniform caveline where the rooms and pillars are randomly spaced. Caving will be affected by the larger fractures and undulations of the backs.

Before October 1957 pillars had been recovered with safety from one stope southeast of the shaft. The pillars were broken in a series of slab rounds, beginning with the pillars farthest from the haulage drift. Near the crosscuts the pillars were blasted to heave the ore into the paths of the scrapers. As cribs were constructed for back support, the pattern of the slab rounds was changed to lessen the throw of the ore. The pillars were reduced by taking 6-foot slices across their short sides. The 6-foot-wide rounds consisted of four vertical rows of holes drilled 6 feet deep. The bottom four holes were shot first, timed to break in succession, beginning with the hole nearest the free face. The ore above was then slabbed down to the cut and heaped at the bottom. This lessened the amount of fly ore blasted into the cribbed area, and only the ore broken by the bottom holes had any real chance to damage the cribs. Waste that could be sorted from the pillar ore was used to fill some of the cribs.

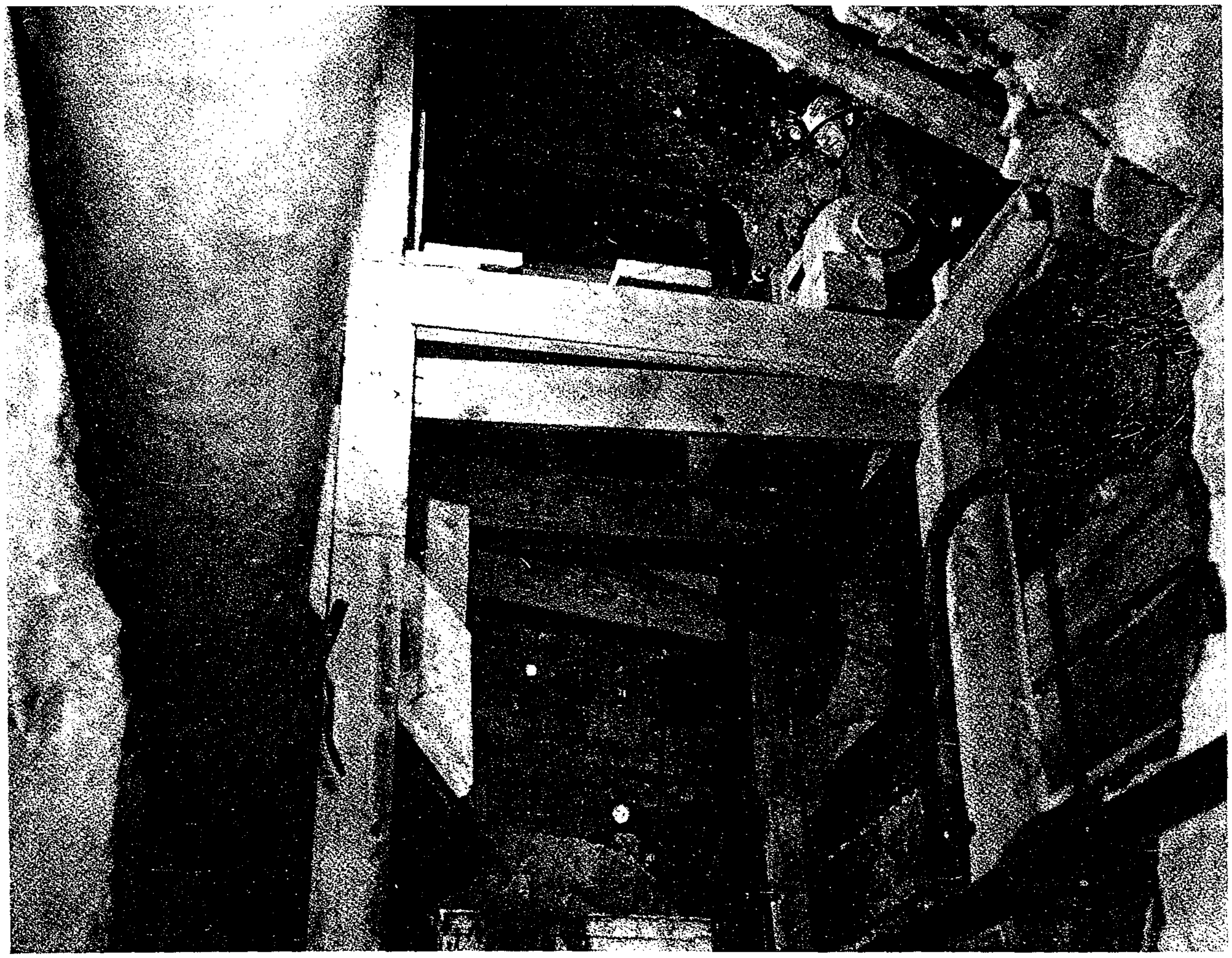


FIGURE 15. - Filling Mine Car at Scraper Chute in Mineral Joe Mine.

The timber cribs were set 6 to 10 feet apart as the pillars were recovered. The cribs were 5 feet square and built of round timber slabbed on two sides to a 6-inch thickness (fig. 16). Wedges driven into splits cut in the ends of the timbers tightened the cribs. To augment the cribs, 10- to 14-inch-diameter props were later placed at random locations between them. Afterwards, weight on the props provided the initial warning of the impending roof fall.

An area of approximately 80 by 100 feet was opened up before the first significant signs of crushing showed. During the preceding 30 days or so, props had to be replaced occasionally, the greater number breaking near the end of the period. Two-inch lagging was used for headboards on the props. Its limited compressive deformation did not prolong the length of time for a load to reach the full supporting power of the props. The props, by buckling, registered signs of heavy back pressure almost immediately. Heavy pressure occurred first at the end of the stope where pillar recovery had been started first and where cracks in the back rock had had a longer time to develop. General subsidence was indicated when a number of props buckled and the cribs began to take noticeable weight. Work in the stope was discontinued to await further developments. During the next 4 days the cribs took heavy weight; and some time between the fourth and seventh day, when the mine crew was off duty, the cribs were crushed, and a large section of the back caved. Superintendent O'Korn thought that the general cave may have been caused in part by uneven pressure on several 21-foot-high cribs which buckled rather than compressed evenly.

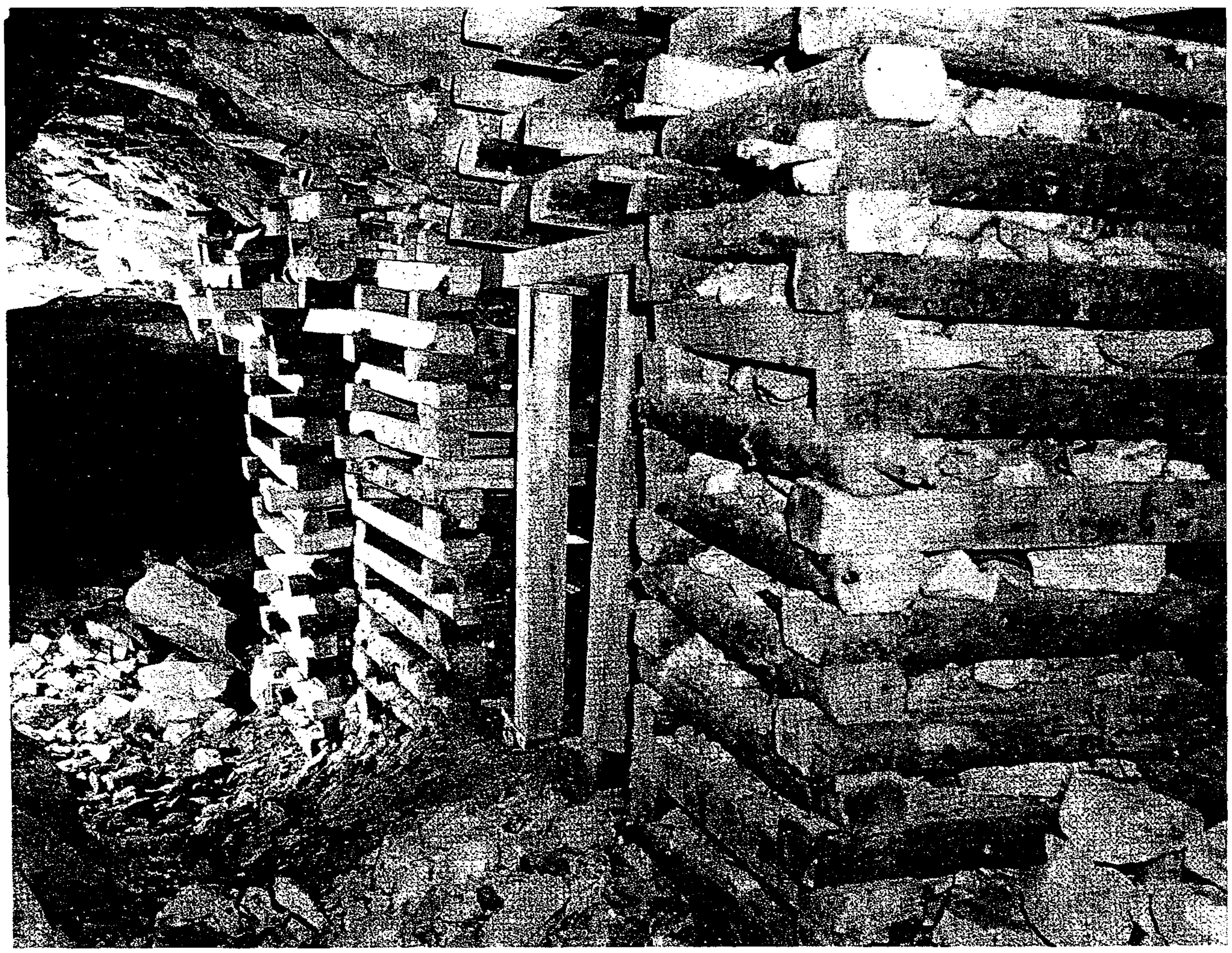


FIGURE 16. - Row of Cribs Near Caved Stope in Mineral Joe Mine.

The cave occurred in September 1956, and 1 year later the domed back was only about 40 feet above the original floor of the stope. The top of the broken material near the center of the cave was about 5 feet beneath the dome. The rock above the back of the original stope consisted of 4 to 5 feet of barren sandstone overlain with green mudstone. The sandstone broke in large blocks along vertical cracks that must have developed during the early stages of roof movement, although some fractures may have been there initially. At the boundaries of the cave the first few feet of mudstone also broke along vertical fractures, whereas that above broke along conchoidal fractures, falling in progressively smaller pieces. The back may have to be induced to cave with artificial support maintained only along the line of extraction. The thickness of the sandstone cap, and whether or not it is broken by fractures, will limit the expanse that can be held open. After any initial movement, however slight, the longer the span is kept open, the less warning the cave will give before it occurs and the more difficult it will be to control.

The ore is hand-trammed to the Mineral Joe shaft. The longest single tram (in October 1957) was about 750 feet from the face of the northwest haulage drift to the bottom of the incline that ascends to the station level. Three men working together, but each loading his own 18-1/2-cubic-foot-capacity end-dump mine car with an overhead loader and tramming it to the incline, mucked out drift rounds in about 1-1/2 hours. A 10-hp., single-drum, electric-driven, Joy RH room hoist was used to hoist the cars up the 160-foot incline, from where they were pushed by other trammers 660 feet to the shaft.

The Mineral Joe and G-3 are two of the three shaft operations on the Colorado Plateau where cage hoisting is used. The mine cars are hoisted in a lightweight cage by a small, single-drum hoist. The 28-inch-diameter hoist drum, wrapped with 3/4-inch-diameter, 6 by 19, hoist rope, is driven by a 50-horsepower induction motor and with the comparatively short lift has an average hoisting speed of about 300 feet per minute. The four-post-type headframe is 36 feet high and was built by the fabricator in 18-foot sections that are bolted together at splice plates on each of the six legs (fig. 17). Except for dismantling joints, all members have welded connections. The topman cages the mine cars at a housed-in landing deck 13-1/2 feet above the shaft collar and trams them to either of two 30-ton-capacity ore bins or to the waste dump. The hopper-bottom steel-and-timber ore bins can be dismantled for moving to other jobs.

Compressed air is furnished by two Gardner-Denver WBG, water-cooled, 310-c.f.m., two-stage compressors, driven by 75-horsepower, 440-volt induction motors. Compressed air is delivered underground through a 4-inch air line reduced to a 3-inch line at the shaft station. Drilling water is stored in a 1,000-gallon tank in a small station cut 15 feet below the shaft collar. For both mine and camp use, 750 gallons of water are hauled 4 miles each day from a spring in Paradox Valley. When the spring does dry in the summer, water must be hauled about 16 miles from a spring northwest of the town of Paradox.

Fresh air is delivered underground through 16-inch-diameter metal ventilation pipe hung in the manway compartment of the shaft, and through 22-inch churn-drill holes that intersect the haulage drifts. Small electric-driven, 2,600- and 4,600-c.f.m., centrifugal and axial-flow blowers force the fresh air underground and boost it where it is needed.

Electric power is furnished by San Miguel Power Association, Inc., and delivered to the mine transformers at 13,700 volts. The average cost of power from June 1955 - January 1957 was $0.87 a ton.

Principal mine equipment used at the Mineral Joe operation includes the following items:

Number	Item
1	Hoist, single-drum, 28- by 24-inch, Hendrie & Bolthoff Ajax No. 3; 50-hp. induction motor.
2	Compressor, 310-c.f.m., 2-stage, Gardner-Denver WBG; 75-hp. induction motor.
1	Hoist, single-drum, 10-hp., electric, Joy RH.
1	Scraper hoist, 2-drum, 10-hp., air, Ingersoll-Rand H5NN-1H.
4	Scraper hoist, 2-drum, 7-1/2-hp., electric, Joy FF-211.
3	Scraper hoist, 2-drum, 5-hp., electric, Joy S-211 and Ingersoll-Rand 5NN-OH.
1	Loader, Eimco 12B.
9	Drill, airleg-mounted, Gardner-Denver S48F.
8	Mine car, 18-1/2-cu.-ft., C.S. Card, low type Z.
2	Blower, axial-flow, 4,500-c.f.m.
2	Blower, centrifugal, 2,600-c.f.m. (approx.).

Fifteen men were employed at this 1,000-ton-a-month operation in May 1958. The mine operated one shift a day, with 4 men working on the surface and 11 underground. The job classifications and hourly wage scales were as follows:

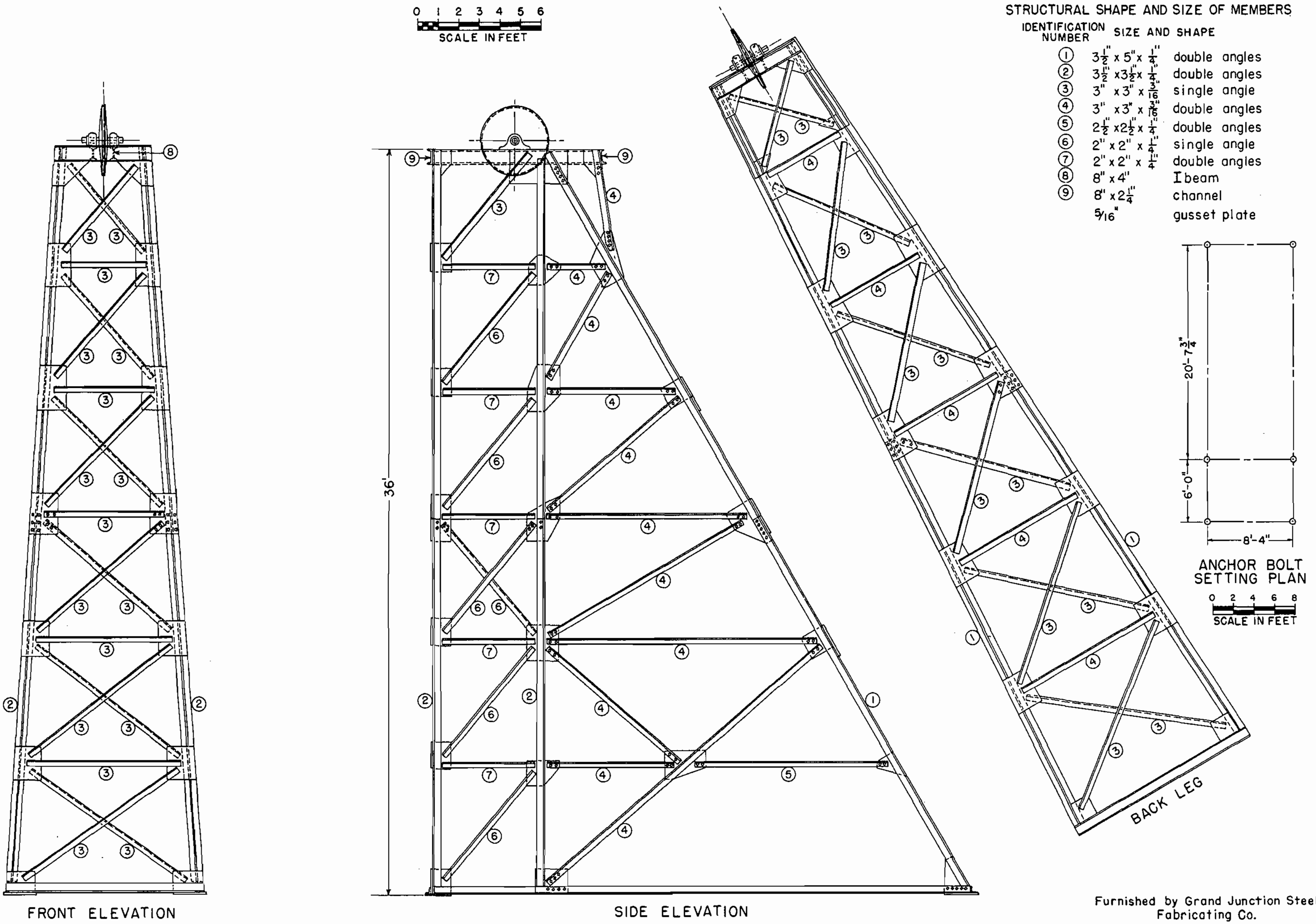
Classification:	No. of men	Hourly base wage
Mechanic..........................	1	$2.16
Hoistman..........................	1	2.16
Topman............................	1	2.02
Driller...........................	3	2.02
Slusher operator..................	3	2.02
Trammer...........................	4	2.02
Hoistman (at incline).............	1	2.02
Truck driver......................	1	1.81

Production, including both ore and waste, averaged 5.03 tons per man-shift during 1956. Production of ore alone averaged 3.10 tons. These averages are based on the total working force, including miners and supervisors.

Most of the men live in one of the four prefabricated wooden bunkhouses at the company camp. A few live in their own trailers. Meals are served at the boardinghouse for $0.85 each.

FRANK NO. 1 MINE

The Frank No. 1 mine, on the Navajo Indian Reservation, Apache County, Ariz., is believed to be the only consistently producing uranium mine on the plateau where the entire mine crew is Navajo. Except for drilling, this operation is not mechanized. In May 1958 the Frank ore deposit, after yielding 70,000 tons, was believed to be almost worked out, except for fringe ore and that remaining in pillars. An underground diamond-drilling program was started in the latter part of 1957, to test the ground between the stopes before the recovery of ore pillars begins.



STRUCTURAL SHAPE AND SIZE OF MEMBERS

IDENTIFICATION NUMBER	SIZE AND SHAPE	
1	$3\frac{1}{2}$" x 5" x $\frac{1}{4}$"	double angles
2	$3\frac{1}{2}$" x $3\frac{1}{2}$" x $\frac{1}{4}$"	double angles
3	3" x 3" x $\frac{3}{16}$"	single angle
4	3" x 3" x $\frac{3}{16}$"	double angles
5	$2\frac{1}{2}$" x $2\frac{1}{2}$" x $\frac{1}{4}$"	double angles
6	2" x 2" x $\frac{1}{4}$"	single angle
7	2" x 2" x $\frac{1}{4}$"	double angles
8	8" x 4"	I beam
9	8" x $2\frac{1}{4}$"	channel
	5/16"	gusset plate

Furnished by Grand Junction Steel Fabricating Co.

FIGURE 17. - Erection Drawing of Mineral Joe Headframe.

The mine is in the rugged Lukachukai Mountains about 10 miles west of the Arizona-New Mexico border and about 32 miles south of the Arizona-Utah border. The Lukachukai Mountains are a northwestern spur of the larger Chuska Range. The relatively flat topped Chuska Mountains are about 60 miles long, trend northwesterly across the New Mexico-Arizona border, and reach a maximum altitude of 9,808 feet. Altitudes in the vicinity of the Frank No. 1 mine range from about 9,400 feet in the higher ground southeast of the mine to about 5,600 feet at the beginning of the desertlike expanse 6 miles west. The altitude at the mine is about 7,425 feet. The mine is reached from Shiprock, N. Mex., by traveling south 6-1/2 miles on U.S. Highway No. 666, thence 33 miles westerly on a partly improved road to Cove, Ariz. The mine is about 3 miles southwest from Cove.

The Lukachukai Mountains end near Cove in a series of fingerlike, cliff-rimmed ridges, separated by twisting box canyons. The ridges were termed mesas and given numbers by the AEC when the area was drilled in 1950-51. The Frank No. 1 mine is on a short spur called Mesa 4-1/2, between Mesas 4 and 5. Ponderosa pine and aspen grow on the higher ridges. Pinon, juniper, and sagebrush cover the lower ground.

Carnotite was discovered about 1918 in the Carrizo Mountains area, a few miles north of the Lukachukai Mountains, and many claims were located in the next few years. Little mining was done, however, until 1942, when the wartime need for vanadium increased.[9/] The first Lukachukai ore was reportedly found by a Navajo.[10/] The first organized prospecting was begun in 1949 by F. A. Sitton of Dove Creek, Colo. Frank Nacheenbetah, mine foreman, located the ore discovery on Mesa 4-1/2 in 1950 and assigned the ground under royalty provisions to Climax. Mining at the Frank No. 1 mine was begun in April 1951.

The Frank No. 1 ore deposit has consisted of widely separated clusters of lenticular masses of ore occurring in paleo stream channels in the Salt Wash about 40 feet above the Jurassic Bluff sandstone.[11/] On Mesa 4 the beds dip 1°-2° NE. Most of the ore pods have terminated abruptly, although bands of minerals often connected one with another. Some of the ore has occurred as a number of thin lenses, one above another, and the best ore was found where they coalesced. Ore bodies mined through the north adit were tabular, flat, and as much as 15 feet thick. Some of the randomly spaced pillars in the north stopes are crossed by a number of thin mineralized bands, but these bands do not enrich the pillars to ore grade. Lenses of ore exposed on opposite sides of some of the pillars are staggered vertically as much as 5 feet. Frank Nacheenbetah reported that the main ore bodies at the north-end of the mine comprised three separate seams; the bottom seam usually contained the

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9/ Stokes, W. L., Carnotite Deposits in the Carrizo Mountains Area, Navajo Indian Reservation, Apache County, Arizona, and San Juan County, New Mexico: Geol. Survey Circ. 111, 1951, pp. 2-3.

10/ Stokes, W. L., Some Stratigraphic, Sedimentary, and Structural Relations of Uranium Deposits in the Salt Wash Sandstone: AEC RME-3102, 1954, p. 40.

11/ King, J. W., Geology and Ore Deposits of Mesa V, Lukachukai District, Arizona: AEC RMO-754, 1951, p. 12.

highest grade ore. The ore mined through the south adit also has been nearly flat lying, but was generally thinner, reaching a maximum thickness of only about 7 feet. The average ore thickness throughout the Frank No. 1 mine is estimated to have been between 2.5 and 3 feet.

The Frank No. 1 mine is entered through adits. The two main haulage entries were driven north and south from opposite sides of the ridge to connect near its center (fig. 18). These entries are about 5 by 7 feet in cross section and were tracked with 16-pound rail laid to 18-inch gage. No timber was used, except for portal sets.

The portal of the north adit (fig. 19) is 32 feet lower than the portal of the south adit and was driven beneath the north ore bodies. The stopes, which are as high as 15 feet above track level, are reached through short open raises. Farther south the ore was intersected at track level. The south adit was driven northerly into the hill from an outcrop of ore. To keep the adit in the gently northeasterly dipping ore zone, parts of it were driven on grades of minus 2 percent. Thus, the ore could be stoped at track level.

In the stopes at the north end of the mine, the thicker ore was usually overlain by competent sandstone backs, and no timber was stood between the relatively closely spaced pillars. Mudstone, which overlies some of the thinner ore, sloughed. Occasional stulls were used in the south stopes where larger areas of mudstone were exposed across the backs. Because of the large number of waste islands occurring within the ore bodies, most of the pillars are waste.

The ore was drilled with airleg-mounted drills and 7/8-inch hexagonal steel integral with tungsten carbide insert chisel bits. Rounds were broken with 40-percent semigelatin dynamite in 8- by 1-1/8-inch cartridges. When driving in ore, the miners first advanced a standard-size drift into the best ore exposed. Then they broke slab rounds from the sides of the drift at places where the thickest ore showed. New headings were turned off to follow the best ore in whatever directions it took.

Nacheenbetah reported that a gray, fairly soft sandstone interlensed with thin bands of blue mudstone has been a promising ore host, and that he has followed any black mineralized seam through such rock in the search for thicker ore. If the sandstone became tighter, the chances of finding thicker ore became less. If a thin, mineralized seam turned upward, he reported that it usually stopped; but if it turned downward, the chances were more favorable that the ore lens thickened ahead. As is true in other Salt Wash deposits, red mudstone and sandstone indicated the end of favorable ground, and development headings usually were stopped when red rocks were encountered. Nacheenbetah, however, drifted through red sandstone if he had reason to believe that it was but a finger extending into the channel or a podlike mass within the channel. The possibility of finding ore lenses adjacent to the red sandstone was sometimes favorable.[12]

12/ Masters, J. A. Geology of the Uranium Deposits of the Lukachukai Mountains Area Northeastern Arizona: AEC RME-27, 1953, p. 11.

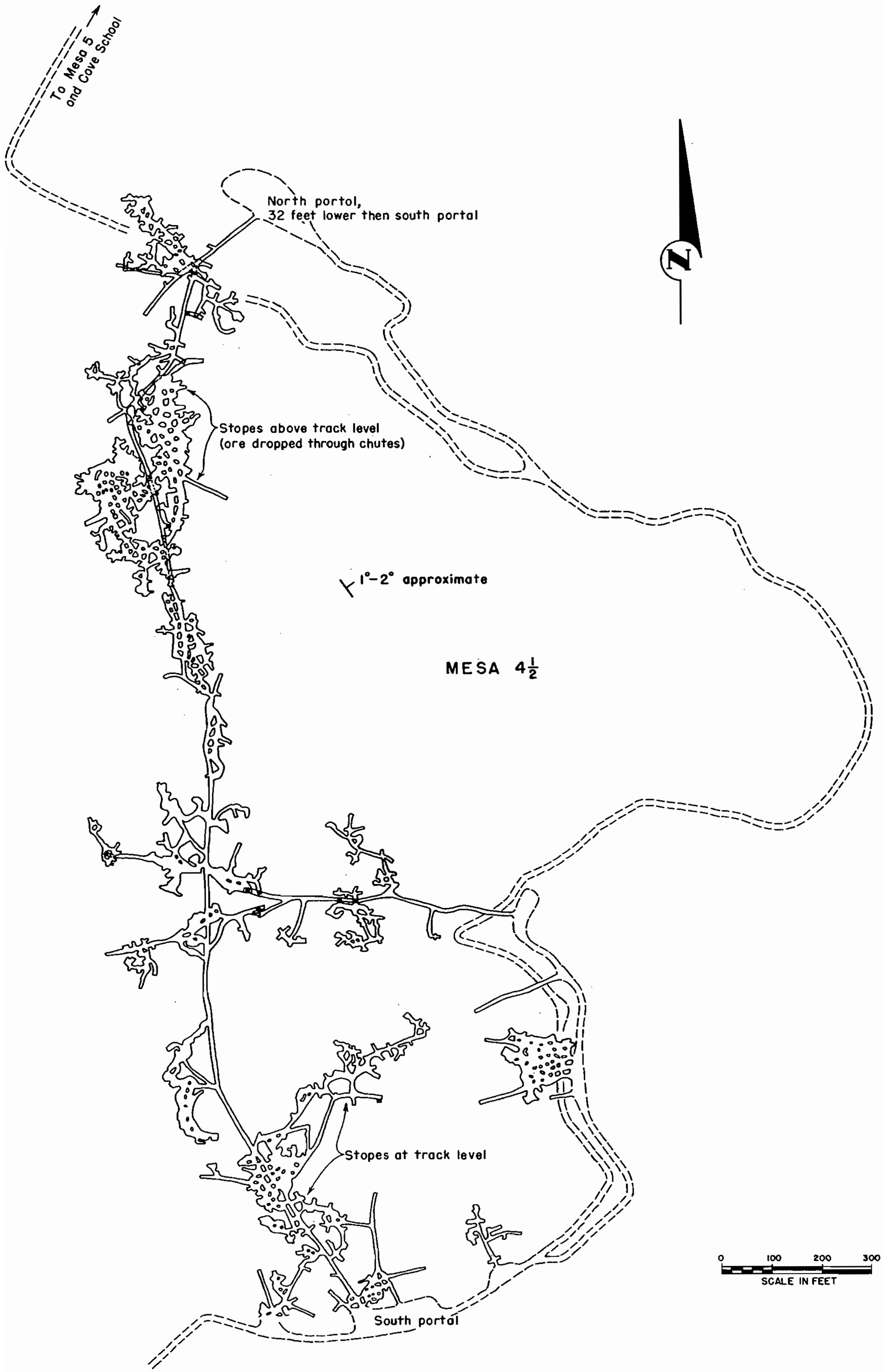

FIGURE 18. - Plan Map of Frank No. 1 Workings.

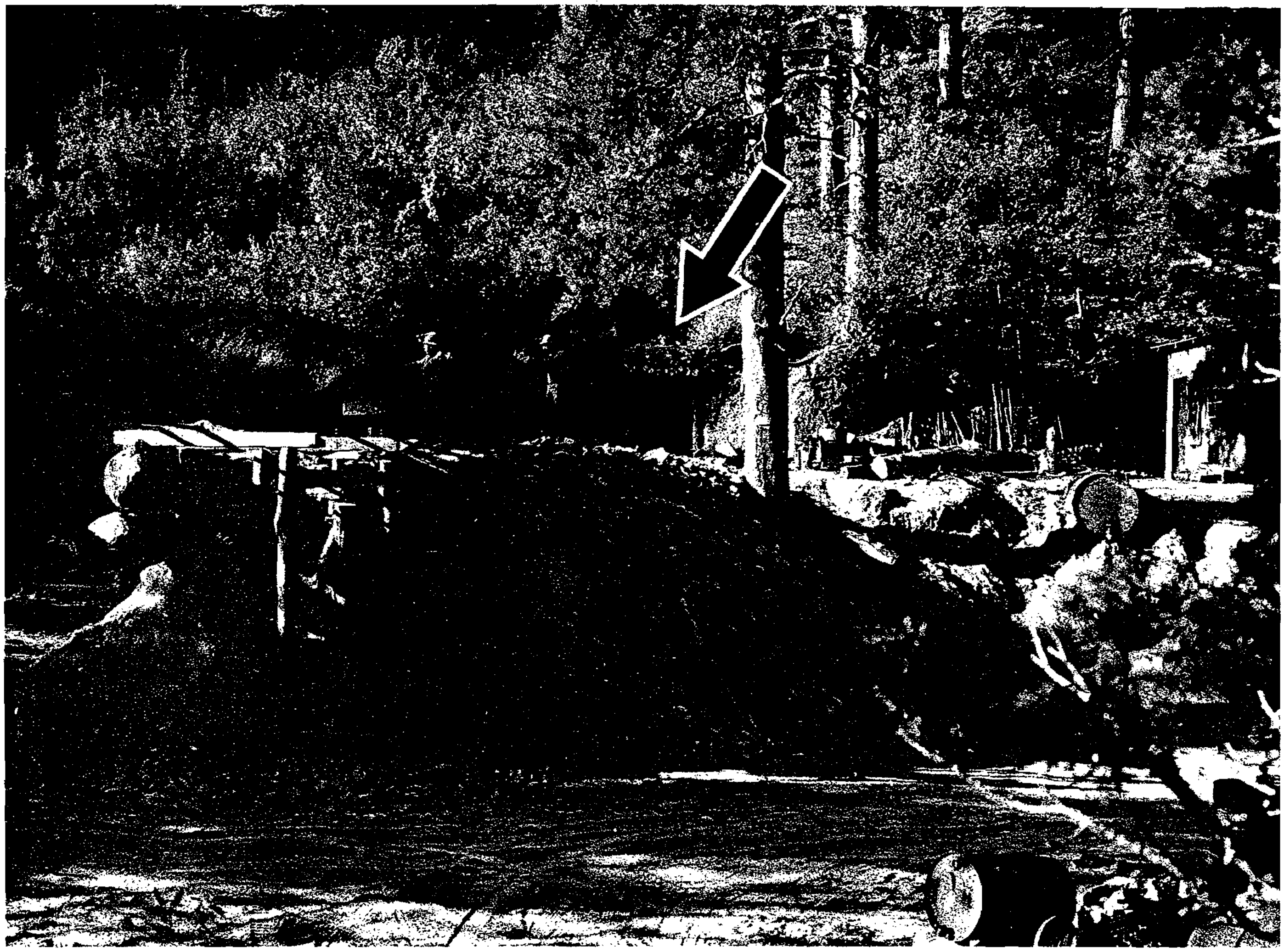

FIGURE 19. - Portal of Frank No. 1 North Adit.

Gray mudstone pods occasionally contained yellow uranium oxide minerals within their laminations, even when the sandstone above and below was barren.

In stopes above track level, wheelbarrows are used to transport the ore to the haulage-level chutes (fig. 20). Nacheenbetah reported that this method of transportation is well adapted to the small irregular undulating stopes. Hand loading has enabled the miners to keep the ore clean. Burro haulage and hand tramming are used to transport the end-dump 16-cubic-foot mine cars through the adits (fig. 21). On the surface the cars are dumped from short cribbed trestles onto the ground (fig. 19). A front-end tractor loader is used to load the ore trucks for the 48-mile haul to the Kerr-McGee mill at Shiprock. Some of the Frank ore has been shipped to the Climax mill in Grand Junction, 337 miles away. The ore has contained an average of 0.25 to 0.30 percent U_3O_8 and the average of 1.14 to 1.20 percent V_2O_5.

The Navajo Tribal Council stresses that Navajo workers be employed in mines on the reservation. As a whole, the Navajos make good uranium miners and have a keen knack of knowing waste from ore. Their patience is undoubtedly a help where the irregulars ore lenses must be broken and handled selectively. An underground diamond-drilling setup is shown in figure 22.

FIGURE 20. - Dumping Ore Into Chute in Frank No. 1 Stope.

Seventeen men, working one shift a day, are employed at this 950-ton-a-month operation. The size of the crew has remained unchanged since production started in 1951. Beside the mine foreman, 13 men work underground and 4 on the surface. An average of nine muckers and trammers is needed to handle the rock broken by four drillers. In May 1958 miners were paid $1.91 an hour and muckers and trammers $1.55 an hour. As would be expected, the productivity of labor is lower at the Frank mine than at the other two operations. In 1956 the average tons producer per manshift for all labor and supervision at the mine was 2.47, and the average of both ore and waste was 4.33 tons produced per man-shift.

The Navajo Tribal Council royalty scale is as follows:

Mine value per ton of ore	Royalty, percentage of gross value of ore
$ 0.01 to $ 10.01	10
10.01 to 20.01	11
20.01 to 30.01	12
30.01 to 40.01	13
40.01 to 50.01	14
50.01 to 60.01	15
60.01 to 70.01	16
70.01 to 80.01	17
80.01 to 90.01	18
90.01 to 100.01	19
100.01 or more	20

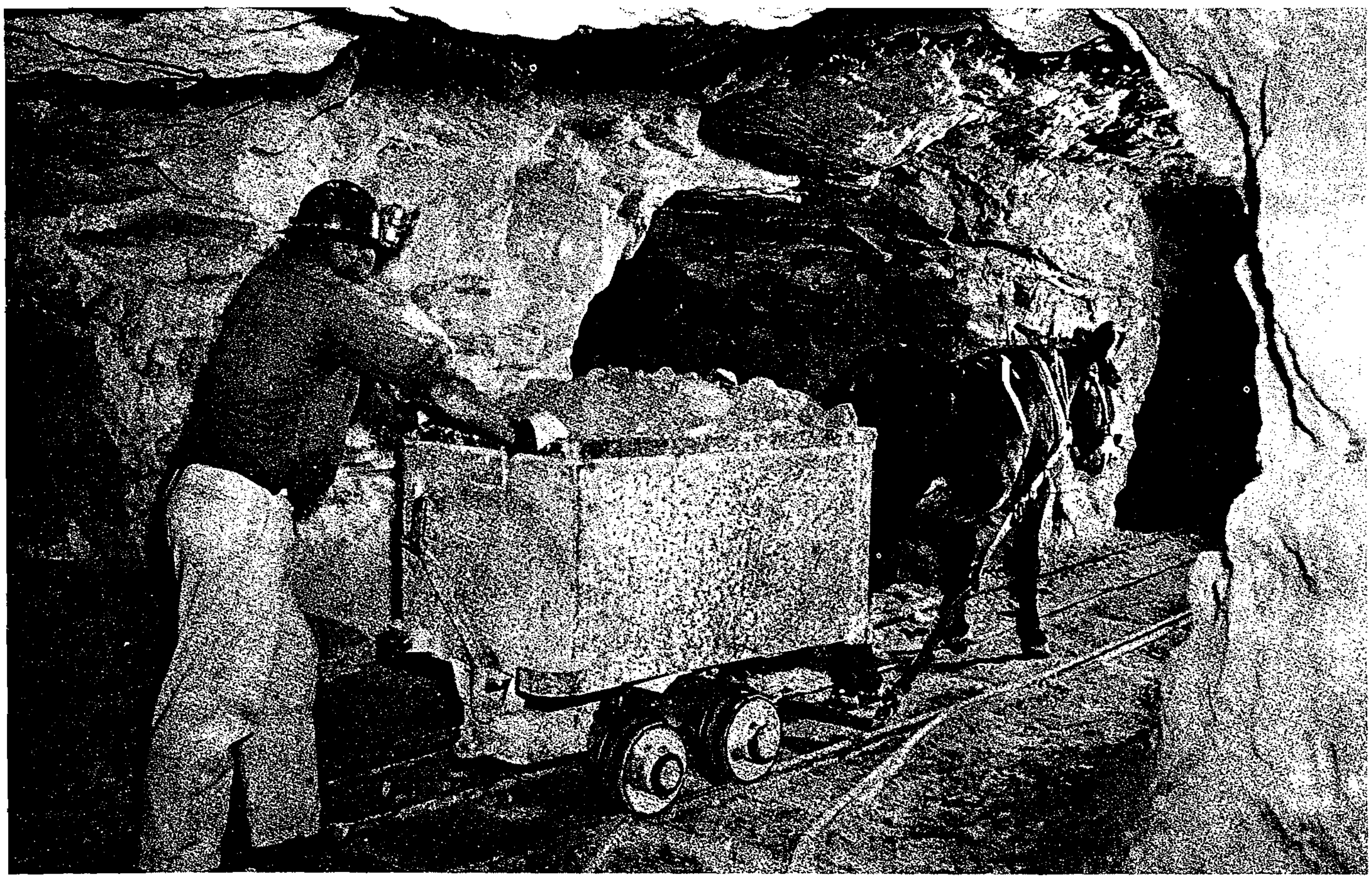

FIGURE 21. - Burro Haulage in Frank No. 1 North Adit.

The royalty paid to the Navajo assignor is as follows:

Mine value per ton	Royalty, percentage
$30.00 or less	2
30.00 to $60.00	3
60.00 to 80.00	4
80.00 or more	5

In addition to the above royalties, Climax paid the Navajo Tribe an additional 10 percent of the initial production bonus and the assignor an additional 5 percent of the bonus.

FIGURE 22. - Testing Ahead With Underground Diamond Drill.

No electric power service is available in the Lukachukai Mountains. Equipment used at the Frank No. 1 mine includes the following items:

Number	Item
1	Compressor, 365-c.f.m., portable, rotary Gardner-Denver RP365D.
1	Compressor, 315-c.f.m., skid-mounted, Ingersoll-Rand IKA-315.
4	Drill, airleg-mounted, Gardner-Denver S48 and FL2B.
7	Mine car, 20-cu.-ft., end-dump.
1	Tractor, front-end loader, Allis-Chalmers HD-5G.
2	Burro

COMPARATIVE OPERATIONAL DATA

As would be expected, the unit production costs and the productivity of labor varied at the three operations. Dollar costs were not available. Operational data listed in table 1 were calculated for 1956, the last year when all were close to full production.

TABLE 1. - 1956 operational data for G-1, Mineral Joe, and Frank No. 1 mines

	G-1	Mineral Joe	Frank No. 1
Estimated ore thickness.......................feet	8	5	2.5 - 3
Production, ratio of ore to waste................	2.08:1	1.61:1	1.33:1
Ore producer per man-shift[1/] ....tons	5.74	3.10	2.47
Ore and waste produced per man-shift[1/] .... do.	8.50	5.03	4.33
Percent of labor and supervisory cost to total direct cost....................................	55	62	72
Powder used per ton of ore.................... lb.	2.4	3.1	3.4

1/ All labor at mines, underground and surface.

As the table shows, the G-1 ore deposit was the thickest of the three, and in 1956 it had the best continuity as shown by the largest ratio of ore to waste hoisted. The Mineral Joe ore was similarly better than that mined at the Frank No. 1. The physical characteristics of the three deposits, and certainly the method of mine development and the type of loading and haulage equipment used, affected the tons of ore produced per man-shift accordingly. The tons of ore plus waste produced per man-shift were similarly staggered. The percentage of the direct labor cost to the total direct costs at the three mines was lowest at the G-1 and highest at the Frank No. 1. This again alined with the amount of mine mechanization and the unit productivity of labor. The more primitive the operation, the higher the cost of labor relative to the total direct mining cost. An unseen factor, which undoubtedly must be reflected in the data, is the decrease in dilution going from diesel-powered trackless equipment to wheelbarrows.

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