MINING METHODS AND COSTS, LINCOLN TUNGSTEN MINE, WAH CHANG MINING CORP., LINCOLN COUNTY, NEV.

BY A. C. JOHNSON AND ROSS M. MCDONALD
MINING METHODS AND COSTS, LINCOLN TUNGSTEN
MINE, WAH CHANG MINING CORP.,
LINCOLN COUNTY, NEV.

BY A. C. JOHNSON AND ROSS M. MCDONALD

* * * * * * * * * Information Circular 7907
This publication has been cataloged as follows:

**Johnson, Albin Carl, 1897—**


19 p. illus., map. 26 cm. (U.S. Bureau of Mines. Information circular 7907)

1. Tungsten mines and mining—Nevada—Lincoln Co. 2. Wah Chang Mining Corporation. I. McDonald, Ross M., joint author. II. Title. (Series)

TN23.U71 no. 7907 622.06173

U.S. Department of the Interior. Library
CONTENTS

Summary ......................................................... 1
Introduction .................................................... 1
Acknowledgments ................................................. 2
History .......................................................... 3
Geologic summary ............................................... 4
Description of deposit .......................................... 5
The ore .......................................................... 5
Methods of exploration ......................................... 6
Development and mining ......................................... 7
  General development ........................................ 7
  Development details .......................................... 7
  Stoping ....................................................... 9
  Underground transportation .................................. 13
  Auxiliary operations ........................................ 16
Production ........................................................ 17
Ventilation ...................................................... 17
Mine drainage ................................................... 17
Fire prevention .................................................. 18
Safety methods and first-aid organization .................. 18
Summary of costs ............................................... 18

ILLUSTRATIONS

Fig.

1. Location map, Lincoln mine ............................... 2
2. Aerial view of Lincoln mine, Wah Chang Mining Corp .... 3
3. Vertical-longitudinal section looking eastward,
   Lincoln mine .................................................. 7
4. Winze plant layout, 600-foot level ........................ 10
5. Winze timber detail ......................................... 11
6. Standard drapoint chute .................................... 12
7. Section through winze plant, 600-foot level ................ 14
8. Measuring pocket, 925-foot level .......................... 15

TABLE

1. Labor, power, and supply costs per ton at the Lincoln
   tungsten mine, Lincoln County, Nev., Jan. 1, 1957 to
   June 30, 1957 ............................................... 19
MINING METHODS AND COSTS, LINCOLN TUNGSTEN MINE,
WAH CHANG MINING CORP., LINCOLN COUNTY, NEV.1/

by

A. C. Johnson2/ and Ross M. McDonald3/

SUMMARY

This paper is one of a series being prepared by the Bureau of Mines on exploration, development, mining methods and costs at various mines in the United States. It describes such methods at the Lincoln tungsten mine of the Wah Chang Mining Corp., Lincoln County, Nev. The purpose of these reports is to promote development and conservation of our mineral resources by disseminating technologic information on mining methods, practices and costs.

The Lincoln mine in Lincoln County, Nev., in the southeastern part of the State, was acquired by the Wah Chang Mining Corp., in April 1951. Mining methods and costs are of special interest at this property because of the low costs and good production record achieved through a well planned program of exploration, development, and exploitation. Operations were discontinued in July 1957 after the Federal Government suspended the tungsten purchase program.

The mine was developed by the Callahan-Carlisle, 100-, 200-, 300-, 500-, 600-, 750-, and 900-foot levels.

Shrinkage stoping with drawpoint loading was the principal mining method. An incentive pay system, good planning, and mechanization were the important factors in maintaining a high production with low costs.

INTRODUCTION

The Lincoln mine comprising 42 claims is located in the Tem Piute mining district on the east slope of the Timpahute mountains near the north end of the range in secs. 27, 25, 26, and 36, T. 3 S., R. 56 E.; secs. 30 and 31, T. 3 S., R. 57 E.; and sec. 1, T. 4 S., R. 56 E., Mount Diablo base meridian. Figure 1 shows the highways leading to the property.

The altitude of the mine workings ranges from 5,925 to 6,925 feet. The climate varies from dry hot summers to reasonably cold winters. Light-to-medium snows fall in winter. Figure 2 depicts the terrain.

1/ Work on manuscript completed January 1959.
3/ Chief engineer, Wah Chang Mining Corp., Lincoln Division, Bishop, Calif.
The townsite, during peak operations, consisted of 40 two-bedroom homes, 10 three-bedroom homes, 22 Wingfoot trailers, 9 modern Edwards trailers, and 2 trailer courts that accommodated 50 trailers. The trailer courts had water and sewerage facilities, and were equipped with wash house, toilet, and showers. There was a 5-room school with modern equipment. Classes were conducted from the first through the eighth grades. The town also had a boarding house, commissary, and a theater where movies were shown twice a week.

The property of the North Tem Piute Mining and Development Co. adjoins the south end of the Lincoln mine on a continuation of the ore zone. Production from the North Tem Piute property has been intermittent and small. Other production from the district has consisted of small amounts of silver ore mined from the west side of the Timpahute Range.

FIGURE 1.- Location Map, Lincoln Tungsten Mine, Lincoln County, Nev.

84 miles from Caliente, Nev. and 120 miles from Tonopah, Nev. A landing strip suitable for light aircraft is located 5.5 miles west of Tempiute.

Communications with the main office in Bishop, Calif., were by radio-telephone since the nearest telephone service was at Alamo, a small farming community 52 miles southeast of Tempiute. A local post office provided mail service.

ACKNOWLEDGMENTS

The authors are grateful to J. J. Strutz, Jr., general manager, Wah Chang Mining Corp., Bishop, Calif., for supplying and permitting the use of production, performance, and cost figures covering the period from January to June 1957, inclusive.

Appreciation is expressed for suggestions and comments made by E. G. Woods, general superintendent, and John J. Russell, assistant general superintendent, Lincoln Division, Wah Chang Mining Corp.
FIGURE 2. - Aerial View of Lincoln Mine, Lincoln County, Nev.
(Courtesy, Robert Symons, Symons Flying Service, Bishop, Calif.)

HISTORY

The Millick brothers discovered scheelite in the district in 1916; however, the area was inactive until 1936 when Wesley Koyen located 2 claims which he worked intermittently until 1937, when he, G. W. Thiriot, D. F. Thiriot, and Winifred Green located an additional 16 claims. About 250 tons of ore mined from short adits driven along the Grubstake and Moody ore zones were concentrated at a small mill built at Black Rock, 15 miles west of the mine.

Early in 1938, the property was leased to C. L. Baker and A. K. McFarlane. They assigned it to J. G. Barry of El Paso, Tex., who, in turn transferred it to D. B. Fegles of the Fegles Construction Co., Minneapolis, Minn. This company operated the property under the name of Lincoln Mines, Inc., from 1939 to June 1945, and produced about 58,000 tons of ore. The ore mined ranged in grade from 0.79 to 1.30 percent tungsten trioxide (WO₃). A 40-ton-a-day mill was constructed in 1939. Its capacity was enlarged to 75 tons per day in 1941. The Atolia Mining Co., San Francisco, Calif., leased the property from June 1945 to October 1948. This company produced and milled from the property about 24,000 tons of ore that had an average grade of 0.67 percent tungsten trioxide. The mill then was dismantled.
The Bureau of Mines investigated the deposit in 1942 and 1944. The work comprised trenching, sampling, constructing some roads and trails, and core drilling. The Federal Geological Survey mapped the outcrops and some of the regional geology in 1942 and 1943.

After the Atolia operation ended, the property owners built a 20-ton-a-day mill at the Moody tunnel and carried on intermittent high-grading operations until 1951 when the Wah Chang Corp. (then the Black Rock Mining Corp.) acquired the property.

GEOLOGIC SUMMARY

The following paragraphs are exact quotations from the literature cited in footnote 4.

The north end of the Tem Piute Range consists of folded and faulted Paleozoic limestone, hornfels, and quartzite invaded by two small granite stocks and by several narrow, short, basalt dikes.

The south granite stock is about a mile in diameter, the north stock about 4,000 feet. Although the two are separated at the surface by a belt of limestone and hornfels 600 feet wide, they probably join at shallow depth. The stocks are partly concordant with the invaded sedimentary rocks, especially on the west side; they form the core of a faulted dome in the sedimentary rocks. The beds dip away from the intrusives at angles of 45° to 85°, except at the north end, where they appear in places to dip into the intrusive at small angles. Hornfels is in contact with both stocks for more than half their perimeters. On the west side of the south stock, the basal hornfels has been cut away by granite, which is there in direct contact with limestone. However, both stocks may be entirely surrounded by the basal hornfels at some point in depth.

On the west side of the south stock, the limestone adjoining the granite and that adjoining the second or platy hornfels have been partly altered by contact metamorphism to thick bodies of tactite in bands parallel to the bedding. The remaining limestone up to the upper hornfels has been bleached irregularly and locally recrystallized. Around the north stock, only a few narrow lenses of tactite have been found, principally on the northeast side, although the limestone is directly in contact with granite along other parts of the stock.

Near the intrusives, within the major block containing the tactite bodies, there are numerous minor faults that strike in different directions and have offsets not greater than a few feet. These minor faults


5/ Work cited in footnote 4. This publication credits the geology to an unpublished Geol. Survey report, Tungsten Deposits of the Tem Piute Range, Lincoln County, Nev., by D. G. Wyant.
cut across the sedimentary rocks and some tactite and are in places mineralized with seams of scheelite, fluorite, and sphalerite. The faults appear to have been important controls for mineralization.

DESCRIPTION OF DEPOSIT  

The principal ore deposits occur in the bands and isolated pods of tactite adjacent to the granite on the west side of the south stock. The tactite bodies exposed around the north stock are narrow and discontinuous, although one series of lenses on the northeast side has a total length of 400 feet and averages 1 to 2 feet in width. However, these tactite zones contain too little scheelite to be economically significant.

The minerals observed in the tactite are listed in the approximate order of their abundance: garnet (andradite to grossularite, almandine), quartz, limonite, actinolite, calcite, fluorite, pyrite, pyrrhotite, diopside, sphalerite, scheelite, chlorite, hematite, clinosoisite, epidote, molybdenite, powellite, jarosite (?), and bismuthinite (?). The scheelite is buff to white; it fluoresces pale yellow to white in ultraviolet light, indicating that it contains a small amount of molybdenum.

Small lenses of both glassy and crystalline quartz occur in the tactite and in the limestone. Brecciated quartz is present at many places along the contact between the tactite and the granite, and quartz veins are common in the granite. Most of these veins contain limonite casts after pyrite. One quartz lens in the limestone contains a small amount of molybdenite and powellite.

The tactite bodies of the south stock are grouped into the following zones on the basis of their relative proximity to the granite: No. 1 or Moody zone, No. 2, No. 3, and No. 4 or Grubstake zone. The Moody zone, 6,200 feet long, with an average width of 40 feet, and the Grubstake zone, nearly 2,000 feet long, with an average width of 30 feet were the first zones that were explored or developed.

THE ORE

Three classes of scheelite-bearing tactite (iron sulfide, garnet, and calcite-fluorite-chlorite) are found in the ore zones. The iron-sulfide type is a hard, dense ore containing a predominant amount of pyrite and pyrrhotite with lesser amounts of garnet and quartz. This type of tactite contains as much as 70 percent iron sulfide and is found adjacent to the granite footwall. Although usually low grade, some higher grade bands up to 5 feet in thickness may contain from 0.5 to 1.5 percent tungsten trioxide. The scheelite crystals are finely disseminated and are pinpoint in size.

The garnet type is a dense, hard, crystalline tactite consisting chiefly of garnet with smaller amounts of quartz, calcite, fluorite, and pyrite.

---

Marmatite occurs in the garnet tactite in local enrichments that contain 0.1 to 6 percent zinc. Scheelite, unevenly distributed throughout the ore shoots, occurs in crystals from pinpoint size to one-fourth inch in diameter. Iron-sulfide-type tactite underlies and the hornfels hanging wall overlies the garnet tactite ore shoots in the Moody zone.

The calcite-fluorite-chlorite-type ore (locally called granitite) is found where remnants of marbleized limestone occur along the hanging wall of the Moody zone. The garnet tactite forms the footwall and marbleized limestone forms the hanging wall of the granite zones. The granite ore shoots have been found in widths of 4 to 20 feet and extending vertically 50 to 120 feet. A relatively soft ore, it consists chiefly of calcite, fluorite, chlorite, and minor amounts of quartz, garnet, and pyrite. The scheelite occurs in fairly large crystals. The ore varies in grade from 0.5 to 2.5 percent WO₃, but the average grade is 0.8 percent. Zinc in the form of marmatite varies from 0.2 to 4.2 percent.

All three types of scheelite-bearing tactite are found in the Moody zone, but a hard tactite, principally garnet and quartz, predominates in the Grubstake zone. However, substantial amounts of granite occur in one large shoot in the Grubstake zone. The garnet- and sulfide-type ore shoots predominate in the district and have been the major producers.

Although the mine has been operated primarily for tungsten, the Wah Chang Mining Corp. has produced fluorite and zinc concentrates as byproducts. The average run-of-mine ore contained 1.2 percent zinc and from 2.5 to 4.8 percent fluorite (CaF₂). The cutoff grade for the tungsten ore was 0.35 percent WO₃.

**METHODS OF EXPLORATION**

The more continuous ore shoots were found in the Moody zone, and the best ore normally occurred along the hanging wall. Therefore, it was standard practice to drift along the hanging wall and explore the footwall portion by drilling long holes (spaced on 20-foot centers) to the granite footwall. Sludge samples were logged and assayed at 3-foot intervals.

The Grubstake zone was explored by diamond drilling from stations cut along the Moody drifts. Favorable areas indicated by the drilling program were investigated and developed by crosscutting to the Grubstake zone and drifting on the ore. There were no standard intervals between the diamond-drill holes. The holes were spaced, as required, within a given area. EX bits giving a 7/8-inch-diameter core were used to drill. Where necessary, the holes were reamed, cased, or cemented. All diamond drilling was contracted by the Palmer Drilling Co. of Bishop, Calif.

Long-hole drilling from the Moody to the Grubstake zones was practiced in areas where the zones were not widely separated. Although long holes were drilled to depths of more than 100 feet, the best overall results were obtained in holes that did not exceed 70 feet in depth.
The exploration procedure was reversed in the areas where the Grubstake zone was first explored. The long-hole drilling and diamond-drill holes were drilled from the Grubstake zone to the granite footwall of the Moody zone.

Diamond drilling seldom gave conclusive results in the generally variable ore, and drifting or raising was often necessary to complete exploration of favorable drill-hole intersections. There was no differentiation between exploration and development headings; most of them served both purposes.

A close control of the grade of ore from all working places was maintained by various sampling methods that were used to guide mining. The mine geologist selected chip samples from all development faces, the miners took grab samples from mine cars and skips, and bimonthly the mine engineers collected grab samples of the broken ore in the stopes. Supervisory personnel maintained further control by examining the faces, muck piles, and loaded muck trains with ultraviolet lamps.

Sets of maps were maintained at the mine and included geologic plans, cross sections, and assay plans. Grade of ore and estimated tonnages were determined by combining all available information such as geological and sample data obtained from drifts, raises, crosscuts, nearby stopes, diamond-drill holes, and long-hole drilling.

DEVELOPMENT AND MINING

General Development

The mine was opened on the following levels: Callahan-Carlisle, 100, 200, 300, 500, 600, 750, and 900. These levels, listed in order of their increasing depth within the ore body, had a vertical range of 1,000 feet. The 100, 300, and 600 levels were opened by adit. The shallow Burdick shaft serviced the 200 level, but all ore was transferred to the 300-level through ore passes or completed stopes and was trammed to the surface. The inclined, 2-compartment, Moody shaft intersected the 100, 300, 500, and 600 levels. A 3-compartment, vertical winze from the 600 level opened the 750 and 900 levels. The mining practice maintained a level interval of approximately 150 feet (see fig. 3).

Development drifts were generally driven along the hanging wall of the Moody zone. If long-hole drilling indicated a separate footwall ore shoot, a footwall drift was driven to develop the ore. Where the ore shoots were wide enough, the main development drifts were enlarged to accommodate double tracks, which allowed preparation and drifting to proceed simultaneously.

Car-pass stations were cut at 200 feet intervals in the hanging wall of the Moody drifts. After serving their original purpose, these stations were used for diamond-drilling stations or for material storage.

Development Details

By contract the Centennial Development Co. of Eureka, Utah, sank the 600 winze. This vertical winze consisted of 2 hoisting compartments and a third
compartment used for a manway, pipelines, and electrical cables (see fig. 4). Overall plan dimensions outside the timber were 15 feet 10 inches by 6 feet 8 inches. Each compartment was 4 feet 6 inches by 5 feet 4 inches inside the timber. Wallplates, end plates, and corner posts were made from 8- by 8-inch fir timber, and the center posts and dividers were made from 6- by 8-inch fir timber (see fig. 5). Timber sets were on centers of 6 feet 3 inches. Rounds were drilled with handheld Ingersoll-Rand jackhammers and were detonated electrically. A Riddell shaft mucker was used to muck the winze.

Drifts and crosscuts on the sill were driven 7.5 by 9 feet in the rock section. In most places, the drifts stood well without timber, but where ground support was required, 8- by 8-inch fir timber sets were placed on centers of 5 feet 4 inches. Gunite was used for ground that air slacked or sloughed. This ground was not heavy, and gunite was more economical to use than timber.

A Joy jumbo, mounting two 3-1/2-inch Ingersoll Rand DB35 drifters, was operated in the heading with the most priority. Four-winged carbide-insert bits (Copco or Timken) on 1-1/8-inch round lugged steel were used in these machines. Drilling in all other headings was done with Ingersoll Rand machines mounted on jacklegs with Atlas Copco integral steel and a carbide-insert chisel bit. An average round required 32 holes, but this number varied considerably according to ground conditions. A 5-hole burn cut was used by most of the miners. Hercules EP 160 3X powder was the principal type of explosive used. Rounds were either blasted electrically or bunch blasted with fuse primers.

Headings were mucked with Eimco 12B or 21 Rocker shovels, which loaded into 32-cubic-foot C. S. Card rocker dump cars. All track was 18-inch gage.

Two- or 3-compartment raises (6 by 6 feet per compartment) were driven for development. The manway raises at the end of each stope were cribbed. The type of round drilled depended on ground conditions and was left to the judgment of the miners who drove the raise. Drilling was done with Ingersoll Rand R-48 stopers.

Blasting at the end of the shift was the normal practice. However, blasting on shift was permitted if it did not interfere with other work.

**Stoping**

The principal mining method was shrinkage stoping with drawpoint loading. A standard stope block was 100 feet long. A cribbed manway raise was carried in each end of the stope, and drawpoints were spaced on 20-foot centers. The drawpoints were cut by driving a 5- by 6-foot crosscut one round into the wall of the development drift, and then by raising a round from the end of the crosscut. The raises from adjacent drawpoints were connected and belled out. Footwall drawpoints permitted a more even draw of broken muck than drawpoints on the hanging-wall side. Drawpoint control sets of 8- by 8-inch timber were rock-bolted into place. Figure 6 shows a standard drawpoint chute. The draw was controlled by lagging held in place across the control sets by 1- by 4-inch strap iron. Eimco 12B or 21 Rocker shovels were used to muck the drawpoints.
FIGURE 4. - Winze-Plant Layout, 600-Foot Level, Lincoln Tungsten Mine, Lincoln County, Nev.
**FIGURE 5.** - Winze-Timber Detail, 600-Foot Level, Lincoln Tungsten Mine, Lincoln County, Nev.
Drawing a stope through chutes was seldom practical. The tactite tended to break into large slabs and boulders that made large-scale chute loading virtually impossible. Drawpoint loading was normally used at this operation.

A 4-man crew mined a standard shrinkage stope. One man advanced the cribbed manways, 2 men drilled and blasted and another mucked the drawpoints. All stopes were mined on a single-shift basis.

Ore shoots too flat to mine by shrinkage stopes were mined by open stopes with random pillars. Manways were carried along the boundaries of the stope with raise pillars left along the manways. The stope was then prepared by driving a scam drift from the manway raise. Sill pillars of varying thicknesses were left over the haulage drifts. The stope was mined up the dip, and the broken ore was slushed to a chute or drawpoint. If the hanging wall were too weak for stoping up the dip or toward the manways with longitudinal retreat panels, the crew provided ground support by 1-inch by 6-foot-slotted roof bolts and random pillars of waste or low-grade ore. Empty stopes were filled with waste whenever this practice was convenient. Five and 7-1/2 hp. air-operated slushers in the open stopes pulled 32-inch scrapers with replaceable blades.

Ingersoll-Rand jacklegs with Atlas Copco integral, carbide-insert, chisel-bit steel were used for drilling in the stopes. Electric milli-second caps and Hercules EP 160-3X powder were used for blasting. Each round was lamped and marked by a mine boss who used a M12 Mineralight and aluminum spray paint to delineate the ore.

**Underground Transportation**

Haulage was accomplished with Mancha locomotives, 3-ton battery and 1-1/2-ton battery that pulled five to seven 32-cubic-foot S. C. Card rocker dump cars. On the main 600-level haulage, one 4-ton and one 2-ton diesel trammer were in use.

Ore from the 300 and 500 levels was transferred to the 600 level via ore passes. All ore passes were equipped with air-operated overshot arc gates.

The above production plus the 600- and 900-level production was trammed to the mill through the 600 adit (Carl Dice). A 4-ton Mancha diesel trammer, which pulled 12 to 20 cars performed this work. Battery trammers were used to gather haulage on the 600 level. Ore from the Callahan and Carlisle levels were trucked to the mill.

Production from the 900 level was handled through the 3-compartment 600 winze (see fig. 7). Hoisting equipment consisted of a 150 hp. double drum, Jackson foundry electric hoist. Two 43-cubic-foot Joshua Hendry skips with cages provided ample hoisting capacity.

The skip loading pocket at the 925 level was composed of 2 measuring pockets (see fig. 8), which were filled by a 20-hp. electric slusher through a scam drift from the 900 pockets. The pocket gates were air operated. Raises were driven from the 900-level pockets to the 750 level to handle ore and waste.
FIGURE 7. - Section Through Winze Plant, 600-Foot Level, Lincoln Tungsten Mine, Lincoln County, Nev.
FIGURE 8. - Measuring Pocket, 925-Foot Level, Lincoln Tungsten Mine, Lincoln County, Nev.
The Moody shaft was used for men and supplies to service the mine. Hoisting was done with a 50 hp. single drum, Hendrie and Bolhoft electric hoist. A company-built skip ran on a 36-inch gage track laid with 30-pound rail. A 25-foot high steel headframe supported the 36-inch sheave wheel.

**Auxiliary Operations**

The compressor house, hoist room, blacksmith shop, mine office, change room, and saw shed were located at the 100-level portal area.

Compressors consisted of 1 stationary Atlas AR7, 1,750 c.f.m.; 1 stationary Ingersoll-Rand Imperial-type 10,600 c.f.m.; 3 portable Ingersoll-Rand Gyro-Flo AR600 c.f.m.; and 1 portable Worthington 550 c.f.m.

The mine shops serviced and did most repairs on rock drills, mucking machines, slushers, and other mine equipment. A machine shop at the mill site supplemented the mine shops. A 48-inch swing saw and an 18-inch bench saw were included in the saw shed.

A sectionalized mine office building contained offices for the mine superintendent, engineers, mine foreman, and shift bosses.

Mine workings provided enough water for drilling. Water for drinking and the change room was hauled to the mine from the townsite at Tempiute. This water, and the domestic and mill supply, was pumped to Tempiute from two wells in Sand Valley. A 37 hp. Byron Jackson deep-well submersible pump operated the No. 1 well, which was 200 feet deep with 12-inch casing. Water was pumped at 400 gallons per minute into a 20,000-gallon surge tank. Water from the second well was pumped into the same surge tank by a 75 hp. Byron Jackson deep well submersible pump rated at 1,000 gallons per minute. Two 220-hp. Byron Jackson 4-stage pumps, in series, with a rated capacity of 500 gallons per minute, or a 160-hp., 4-stage Byron Jackson centrifugal pump rated at 250 gallons per minute, pumped water from the surge tank to the camp storage tanks through a 6-inch line 26,000 feet long.

The pumps were operated on a 440-volt circuit by remote control from the mill. Power was transmitted to the pump transformers at 7,200 volts. Static head at the pump site was 1,400 feet.

Electrical power purchased from the Lincoln County Power district was transmitted at 69 kv. through a 58.35-mile, company-owned powerline to a 2,500-kv. substation at Tempiute. Power was transmitted from the substation to the mine at 7,200 volts. Mine substations supplied 440-volt 3-phase power for mine operations.

Total plant consumption per month averaged 1 million kilowatt-hours. Approximately 130,000 kilowatt-hours at a cost of 5-3/4 mills per kw.-hr. with no peak load or demand charges were used at the mine.
PRODUCTION

The mine was operated on a 2-shift, 6-day week basis, but operations were constant through 12 consecutive days. The total mine crew consisted of 85 men under the direction of a mine superintendent, a general foreman, a shift foreman, and 2 shift bosses for each shift.

Monthly production averaged 20,000 tons of ore with an average grade of 0.40 percent WO₃. The ore-to-waste ratio was 4 to 1. Waste was gobbed in old stopes when practical.

The percentage of extraction varied with ground conditions and the distance between levels. Pillars were required in some places to provide ground support. Where possible, they consisted of low-grade ore or waste. The mine crew left small pillars between drawpoints and a 15- to 20-foot pillar between the back of a stope and the level above. The sill pillar above the stope was removed when the upper level was no longer in use. In some stopes, under favorable conditions, nearly complete extraction of ore was obtained; however, in some stopes only 60 to 70 percent extraction of the ore was possible.

Dilution became a serious problem in the more flat-lying open stopes and in ore shoots with a hornfels hanging wall. Pillars and rock bolts were used to control this situation.

VENTILATION

Most of the mine workings received an ample supply of fresh air by natural ventilation. Where necessary, 5 hp. Joy Axivane fans with 12- to 15-inch vent lines were used. The air flow was upcast through the adits and up the Moody shaft in winter. The direction of air flow was reversed in summer.

MINE DRAINAGE

Water that flowed from the 300-south level at a rate of 30 gallons per minute was collected in a sump and was then pumped by a 30 hp. Ingersoll-Rand Moto pump (2MRV 30) through a 2-inch line through M321 raise, the 200 level, and the M223 raise to the surface. A 2-inch line carried the water through the Carlisle level and up a diamond-drill hole to the 200 North Callahan level. The water was then pumped to a surface storage tank with an overflow to a second storage tank above the 100 level. Water from the second tank was taken down the Moody shaft for drill water on the 500 and 600 levels. The overflow was wasted. This installation also provided drill water for all workings above the 500-foot level except for the 200 South Callahan level.

Twenty gallons of water per minute were pumped from the 900 level and the 600 winze to a sump on the 600 level. An Ingersoll-Rand 2MRV20 pump was used for this purpose. Some of this water was returned to the 750 and 900 levels for drill water. Excess water from the 600-sump and water from the 600 level flowed out the Carl Dice adit.
FIRE PREVENTION

A 15-man volunteer fire department provided protection from surface fires for the camp, mill, and mine. Fire hydrants and hoses were located near the surface installations. A tank truck equipped with pump and hose was also available for surface fires. Foam-type fire extinguishers were maintained in all mine buildings and at various underground sites.

A stench-warning system manufactured by Reed Engineering Co., Los Angeles, Calif., was installed to warn underground crews of fire or other emergencies. This system utilized a stench bomb connected into the air line at the compressor room. Tests that evacuated the crew from the mine proved the efficiency of the system. Chemox masks were kept in the lamp room and first-aid station for mine rescue or fire-fighting work.

SAFETY METHODS AND FIRST-AID ORGANIZATION

Basic safety rules were explained to employees and enforced by mine supervisory personnel, and all working places were examined daily for unsafe conditions. Violators of safety rules were subject to penalties ranging from a 3-day layoff to dismissal.

A complete safety tour was made of the mine every two weeks. The safety committee consisted of 4 men - 2 company and 2 union representatives. After each safety tour, the committee reported its findings to the mine department. Prompt action was taken to alleviate any unsafe conditions noted in the report.

Stretchers and first-aid equipment were kept in the lamp room and first-aid stations on each level. An ambulance was maintained in the mine yard at all times. A trained nurse, in charge of a well-equipped first-aid station at the townsite, was available to give further emergency treatment.

SUMMARY OF COSTS

The prevailing wage rate was $2.185 per hour for miners, with time and one half paid for all work in excess of 8 hours per day or 40 hours per week. All mining was contracted. Specific mining operations were paid for on the following basis: Crosscuts, drifts, and riases by linear foot of advance; stopes by cubic foot of excavation; and mucking and tramming by the ton.

In the 6-month period, the Lincoln mine produced 119,229 tons of ore by the shrinkage-stope method of mining. Production per man-shift was 6.98 tons, and 17,071 man-shifts were worked.

Table 1 gives a breakdown by mining and development of labor, power, and supply costs per ton.
TABLE 1. - Labor, power, and supply costs per ton at the Lincoln tungsten mine, Lincoln County, Nev., Jan. 1, 1957 to June 30, 1957

<table>
<thead>
<tr>
<th>MINING</th>
<th>Per ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling and blasting</td>
<td>$1.27</td>
</tr>
<tr>
<td>Explosives</td>
<td>.06</td>
</tr>
<tr>
<td>Drill steel</td>
<td>.02</td>
</tr>
<tr>
<td>Rock drills and hose</td>
<td>.01</td>
</tr>
<tr>
<td>Mucking</td>
<td>.37</td>
</tr>
<tr>
<td>Slushing</td>
<td>.09</td>
</tr>
<tr>
<td>Tramming</td>
<td>.51</td>
</tr>
<tr>
<td>Timbering</td>
<td>.43</td>
</tr>
<tr>
<td>Pipe and track</td>
<td>.37</td>
</tr>
<tr>
<td>Compressors</td>
<td>.20</td>
</tr>
<tr>
<td>Lubrication</td>
<td>.01</td>
</tr>
<tr>
<td>General shop</td>
<td>.15</td>
</tr>
<tr>
<td>Nipping</td>
<td>.06</td>
</tr>
<tr>
<td>Lighting</td>
<td>.05</td>
</tr>
<tr>
<td>Sampling</td>
<td>.06</td>
</tr>
<tr>
<td>Diamond drilling</td>
<td>.05</td>
</tr>
<tr>
<td>Equipment rental</td>
<td>.07</td>
</tr>
<tr>
<td>Hoisting</td>
<td>.10</td>
</tr>
<tr>
<td>Pumping</td>
<td>.02</td>
</tr>
<tr>
<td>Allocated expense, including depreciation and supervision</td>
<td>1.37</td>
</tr>
<tr>
<td>Bishop office expense</td>
<td>.09</td>
</tr>
<tr>
<td>Total</td>
<td>5.36</td>
</tr>
</tbody>
</table>

DEVELOPMENT

<table>
<thead>
<tr>
<th>DEVELOPMENT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling and blasting</td>
<td>.86</td>
</tr>
<tr>
<td>Mucking</td>
<td>.20</td>
</tr>
<tr>
<td>Tramming</td>
<td>.06</td>
</tr>
<tr>
<td>Timbering</td>
<td>.12</td>
</tr>
<tr>
<td>Pipe, track, and lighting</td>
<td>.04</td>
</tr>
<tr>
<td>Allocated expense, including depreciation and supervision</td>
<td>.42</td>
</tr>
<tr>
<td>Bishop office expense</td>
<td>.03</td>
</tr>
<tr>
<td>Total</td>
<td>1.73</td>
</tr>
</tbody>
</table>

COMBINED MINING AND DEVELOPMENT COSTS

<table>
<thead>
<tr>
<th>Overall</th>
<th>Percent distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>$381,533</td>
</tr>
<tr>
<td>Materials</td>
<td>233,690</td>
</tr>
<tr>
<td>Other, including depreciation and supervision</td>
<td>230,113</td>
</tr>
<tr>
<td>Total</td>
<td>845,336</td>
</tr>
</tbody>
</table>