CIRCULAR 114

Survey of Surface Mining in New Mexico

by JOHN H. SCHILLING
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STATE BUREAU OF MINES AND MINERAL RESOURCES NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY
CAMPUS STATION **SOCORRO, NEW MEXICO**

FRONTISPIECE

UPPER, NORTHERN PART OF QUESTA MOLYBDENUM OPEN-PIT MINE, LOOKING NORTHWARD. BARE, ERODED SLOPES IN UPPER MIDDLE ARE NATURAL OUTCROPS OF THE YELLOW ALTERED-ROCK BADLANDS TYPICAL OF PARTS OF RED RIVER CANYON. *Photo Courtesy Molybdenum Corporation of America.*

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For sale by the New Mexico Bureau of Mines and Mineral Resources
Campus Station, Socorro, N. Mex. 87801 —Price $1.00

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FOREWORD

Disturbance of the natural scenic beauty of New Mexico's landscapes by mining has been of increasing concern to the State's citizens, along with concern over the destruction of surface features by highways, slash timbering, overgrazing, housing and recreational facilities, and almost every other activity of man.

In some regions of New Mexico, picturesque ghost towns, small mine dumps, and weather-beaten head frames of long-abandoned mines are prime tourist attractions. Modern-day deep mining utilizes trim, well-kept headframes and mills, occupying only a few acres of the surface. Surface mining does disturb many acres of land, but as it is the economical way in which to mine low-grade, large-size mineral deposits, more surface mining will be done in New Mexico. Sand and gravel, coal, much of the copper and molybdenum, and some uranium deposits are, and will be, obtained by open-pit and strip mining.

This Circular consists of a series of short articles describing surface mining in New Mexico, telling of the problems involving different types of near-surface mineral deposits, and the efforts minerals-producing companies are making to contain surface disturbance and to rehabilitate mines and dumps when it is economically feasible.

We can insist that all open pits be filled and that the original contour of the land be restored, but your $3,000 automobile might then cost $10,000, and your $15-per-month electricity bill may be $50 a month.

Don H. Baker, Jr.
New Mexico State Bureau
of Mines and Mineral Resources

Open-Pit Mining

by John H. Schilling
Nevada Bureau of Mines

Surface mining methods must be varied greatly to mine differently shaped ore bodies. Most large molybdenum, copper, and other metal deposits are thick in relation to their horizontal dimensions. When such deposits are mined out, the result usually is a huge pit several thousand feet deep, yet less than a mile wide. In contrast, coal and gravel deposits are relatively thin, tens of feet thick at the most, but extend horizontally for great distances with many acres of land affected by surface mining. The total surface area affected by open-pit metal mining is small compared to the area affected by strip mining of coal, or the total area disturbed by sand and gravel pits.

The U.S. Department of the Interior in 1967 published *Surface Mining and Our Environment,* which presents information about the amount of land turned up by surface mining. According to this report, 6,453 acres of land in New Mexico have been disturbed by all types of surface mining, or less than 1 acre out of every 10,000. Metal mining accounted for 4,700 acres. In contrast, in West Virginia, which is about one-fifth the size of New Mexico, 192,000 acres of land have been disturbed by surface mining, or more than 600 of every 10,000 acres in the state.

To strip-mine coal, a long, narrow strip of coal is exposed by removing the overburden, the coal is mined, then the adjacent strip of coal is exposed by removing the overburden which is placed in the hole left by the first trench, the cycle being repeated again and again. Thus, the pit is refilled as part of the mining process, and landscaping requires mainly that the surface be smoothed into pleasing contours and vegetation be reestablished. This is being done successfully in many areas, in most cases at a cost that is not prohibitive to the mine operator.

Open-pit metal mining begins in somewhat the same fashion. Ore is exposed by removing the barren overburden, and a layer of the ore is then removed. However, as the thick ore is mined downward layer by layer, the pit walls become so steep that they are unsafe. To rectify this, the top of the pit must be widened as mining progresses downward. By the time the bottom of the ore is reached, the widened top of the pit often is in the barren rock surrounding the orebody. During this process all the barren rock encountered must be dumped outside the pit limits. The ore is hauled to the mill, where the metal values, commonly less than 0.9 percent of the ore, are removed, and the waste material (tailings) placed in a tailings pile. The waste materials from thick mineral deposits cannot be put back in the pit while mining continues, as they can be during strip-mining of thin deposits such as coal.

In most cases it would not be economically feasible to refill such huge holes after open-pit metal mining ceased. It is scientifically impossible to return the land to its original ecological or physical condition by filling the pit.

Sand and gravel mines often can be located where they will best fit into the surrounding environment because sand and gravel are so widespread and abundant in New Mexico. The location and size of strippable coal deposits are also known with considerable accuracy. Thus, for these mineral commodities, enough useful data can be compiled so that both the mining and the rehabilitation of the land can be planned in some detail. In contrast, the location and number of future open-pit metal mines can be estimated only in the most general way, and because minable metal deposits are rare, they must be mined soon after being discovered in order to meet the rapidly increasing demand for metals. These two factors make long-range environment planning extremely difficult at best.

Over the next hundred years, possibly three more large open-pit molybdenum mines may be opened in New Mexico, and probably will be located in, or adjacent to, the more mountainous areas of the State. The same considerations hold true for all possible types of large open-pit metal mines. Over the next hundred years it seems unlikely that more than twelve large open-pit metal mines will be developed in New Mexico. This is a four-fold increase over the present three mines of this type. Some small open pits undoubtedly also will be opened, but because small operations are becoming increasingly uneconomical, their number can be expected to decrease, thus they are a relatively minor factor in future environmental planning.

Assuming that the ore deposits found in the future are of about the same size as those now being worked, over the next hundred years a maximum of less than twenty square miles of New Mexico will be affected by open-pit metal mining. This is less than 0.1 percent of the total area of the State.

The same fluids that formed the metal deposits commonly alter the surrounding country rock, forming areas that will support little vegetation, and which are unstable and easily eroded. Thus, many metal mines are in areas that are not prime scenic land or more useful for other purposes, even though located in the midst of areas of great natural beauty. Metal mining uses only a very small amount of the total land, and only a small part of the mineralized land thus used has any other value, aesthetic or otherwise.

Numerous areas in the State are dependent almost entirely on mining, and even people in these areas often are not fully aware of its economic impact. Modern mines are huge enterprises, and require many skilled, highly paid workers and expensive supplies and services in order to operate. In 1969, $222 million worth of metals were mined and $744 million of nonmetals and petroleum were produced in the State. Thus the value of the mineral commodities produced in New Mexico was almost three times that of all the ranch and farm production.

Few people realize what a large share of the state and local taxes are paid by minerals companies. For example, the Kennecott Copper Corporation's copper-mining complex is the largest single taxpayer in the State, and the Molybdenum Corporation of America is the largest taxpayer in Taos County.

Our modern civilization could not exist without minerals. A decrease in the supply of minerals would return us to the 18th century; a complete lack of minerals would make cave-men of us all. Minerals are abundant in the earth's crust, yet deposits which are sufficiently rich to be mined economically are exceedingly rare. However, the mining industry must recognize that mining makes only temporary use of the land, and should try to confine its presence to the practical minimum, and leave as little evidence of its presence as is reasonably possible.

TABLE 1.
ESTIMATE OF LANDS OCCUPIED BY SOLID WASTE RESULTING FROM METAL MINING IN NEW MEXICO

Commodity	Type of Solid Waste	Total Accumulation through 1968**		1969	
		Tons (Thousands)	Acres	Tons (estimated) (Thousands)	Acres
Manganese	Mine Waste Mill Tails Smelter Slag	2,250*	600*	+	
Molybdenum	Mine	57,500	810	25,000	400
	Tails	10,500	39	3,500	10
	Slag				
	Total	68,000	849	28,500	410
Gold	Mine	5,000	100	+	
	Tails	1,000	400		
	Slag	250	20		
	Total	6,250	520		
Lead-Zinc	Mine		100		+
	Tails		300		
	Slag		12		
	Total		412		
Copper#	Mine	555,000	2,150	12,200	30
	Tails	307,500	1,870	4,048	6
	Slag	4,500	15	200	2
	Total	867,000	4,035	16,448	38

* Total all types
\+ Insignificant
\# Copper Industry labor strike, 7/15/67–3/30/68
** Based on data by U.S. Bureau of Mines

TABLE 1. (cont.)

Uranium	1948-1969**	36,421,000 tons crude ore	
		157,885,000 lbs. U_3O_8	
		38,307,511 lbs. V_2O_5	
	1969	Surface mined crude ore	1,536,000 tons
		Surface mined waste	35,838,000 tons
		Underground mined ore	3,194,000 tons
		Underground mined waste	1,130,000 tons
	1969	Area occupied by ore and waste	1102 acres††
		Open pit area	200 acres

** Based on data by U.S. Bureau of Mines

†† Includes Anaconda, Kerr-McGee, United Nuclear, United Nuclear-Homestake, Foote Minerals, and Ambrosia mine dumps

Copper Surface Mining in New Mexico

by W. W. Baltosser
Kennecott Copper Corporation

Surface mining, as applied to copper, is the process of removing the topsoil, rock, or other strata above the mineral deposit, then removing the rock that makes up the ore body.

In New Mexico, copper mined by surface-mining methods is in masses of low-grade ore with the copper occurring in varying and widely dispersed amounts. The ore bodies are covered with waste material; also within the ore body are large masses of waste rock containing little or no copper. Thus, open-pit copper mining is a dual operation involving both the disposal of waste rock and the recovery of ore.

The large open-pit copper mines of New Mexico are in the southwestern corner of the State. Kennecott's Chino mine at Santa Rita, worked since 1910, is the largest. The recently activated Tyrone operation, owned by Phelps Dodge Corporation, is projected to be an open pit of similar size. A smaller pit, owned by the United States Smelting, Refining, and Mining Company, is in operation near Fierro.

Open-pit copper mines are dug in the form of amphitheaters. The various levels or steps, cut in the pit sides, are called benches. These benches are the working places for big power shovels that load ore and waste rock into trucks or trains after it has been loosened and fragmented by blasting. The benches also serve as the road or haulageway for transportation of the material.

Smaller copper mines, covering only a few acres, have operated from time to time in other parts of the State, but most of these are no longer active.

When compared to underground methods, surface mining offers a number of distinct advantages. Usually the metal values are so low that underground mining would not be economically feasible. In cost-per-unit of production, surface mining is generally cheaper than underground methods; this allows for mining low-grade deposits. It also provides safer working conditions and is generally considered a more desirable environment in which to work.

Ordinarily the amount of surface area disturbed is proportionately small compared to the quantity of ore recovered. The major disturbance of the surface is normally at the start of operations, and the ore removal continues for many years. The Chino mine at Santa Rita, for example, has been in almost continuous operation for about 60 years.

The greatest possible recovery of minerals from mining operations is desirable. Fullest possible recovery, in some instances, requires the leaching of low-grade waste dumps along with use of the most efficient mining methods. Kennecott operates, and Phelps Dodge will operate, a leach-precipitate plant to recover copper from waste material, thus taking positive steps to make the most complete recovery from each ore body. A valuable metallic resource is being conserved by these leach-precipitate operations. To make the fullest possible recovery from leaching operations, the waste material must be dumped over naturally impervious surfaces or over prepared surfaces to prevent the loss of the leach solutions. This also directly prevents pollution of adjoining areas and of ground water.

The blasting, loading, and hauling of ore and waste from open-pit copper mines are only about half of the processes involved in producing salable copper. Chino operates a reduction plant at Hurley, about 10 miles from the open-pit mine, where the ore is concentrated, smelted, and refined. Phelps Dodge has a concentrator at Tyrone.

Concentrating consists of crushing, grinding, flotation, and drying. When received at the mill (the common name for the concentrator), the ore is in pieces ranging from boulders weighing a ton or more, to sand- or gravel-sized particles. A series of crushers and grinding mills reduce the ore to tiny particles small enough to pass through a screen with 10,000 openings to the square inch. The pulverized ore, mixed with water to make a slurry, then goes to the flotation section where chemical reagents are added. One chemical, a frother, with the addition of air, creates bubbles by the action of the flotation machine; another chemical coats the copper mineral particles and causes them to adhere to the bubbles. The bubbles, carrying particles of copper minerals with some waste interlocked, rise to the top of the flotation cells. The overflow is wet-copper concentrate containing from 15 to 35 percent copper. The water is removed to make a dry concentrate for smelter feed. This process is repeated as many times as is necessary or practical, to recover as much copper as possible.

The waste material, called "tailings," is disposed of by pumping it through large pipelines to the tailings disposal area. Here, more than 50 percent of the water is recovered and piped back to the mill for reuse.

It is possible at some future time that the tailings, which now cover an area of about three square miles (1,850 acres) and are 60 to 100 feet thick, will be reworked for the copper still contained. At present, it is not economically feasible to rework the tailings, but improved technology or some unforeseen breakthrough in metallurgy may make reworking the mill tailings possible.

At the smelter, a mixture of copper concentrates and precipitates is used as feed for the reverberatory furnace which melts the material. Chemical reactions cause the molten mass to separate into two parts. A fluid waste material called "slag," rises to the top and is drawn off from time to time and discarded. The heavier iron and copper parts of the mixture settle to the bottom; this is called "copper matte." The molten matte is taken by overhead cranes to a converter where silica is added and air is blown through the hot liquid mass. The air burns off the remaining sulfur and oxidizes the iron. The iron combines with the silica flux to form a fluid slag that floats on the surface and is removed periodically. After several hours of blowing, only molten copper, about 98 percent pure, remains in the converter. This is termed "blister" copper. Blister copper contains some impurities and further refining is necessary. Molten blister copper is poured into the refining furnace. The refining process consists of forcing compressed air through the molten blister to oxidize the impurities and then "poling" the bath by blowing natural gas into it to remove the oxygen. Prior to the use of natural gas, this was done by introducing green logs, or poles, into the bath; hence, the term "poling."

Fire-refined copper is poured into 50-pound, or larger, bars for shipment to Chino customers. Most of Chino's production goes to copper, brass, and bronze fabricators, and ends up eventually as copper tubing, sheet, brass, hardware, bronze fittings, and the like.

In addition to ore sent to the mill, millions of tons of waste rock are sent to the dumps. This waste rock contains too little copper to justify conventional milling, and copper is recovered by leaching. Water pumped to the top of the dumps percolates downward and leaches out the soluble minerals. These copper-bearing solutions flow to the precipitation plant where copper is stripped from the solutions.

The precipitation process consists, in essence, of forcing the copper-rich water through large cones or other structures filled with scrap iron, usually in the form of tin cans from the mountains of garbage collected in cities and sold to copper producers. The copper replaces the iron in scrap metal, and the iron in the resulting solution is pumped back over the waste dumps. Precipitate copper contains 80 percent or more copper and is used to enrich the smelter feed.

A study was made by the Federal Government in 1955-1956 to determine the amount of surface disturbed by mining in the United States. The resulting report stated that all the acres used for surface mining total fourteen one-hundredths of one percent (0.14%) of the total land area of the United States. This report was given at the Fifteen Annual Conservation Conference of the National Wildlife Federation in Washington, D.C., on December 12, 1968 by Joseph S. Abnor, assistant to the president of Pickands, Mather and Company. He noted that each surface-mining operation and locality has unique characteristics. A sand-and-gravel pit and a copper pit differ in many ways. A phosphate mine in Florida has little in common with a phosphate operation in Idaho. Flora and fauna that flourish in the Appalachians will not survive in an arid western state. It follows that no single set of procedures will be universally applicable.

The report showed that of more than 50 minerals produced by surface mining in the United States, about 95 percent of the acreage disturbed by surface mining is attributable to only seven commodities. These are coal, about 41 percent of the total; sand and gravel, about 26 percent; stone, gold, clay, phosphate, and iron together, about 28 percent, and all others combined, about 5 percent. It is immediately apparent that the area disturbed by copper mining is very small compared to the total acreage. The annual increase is small because once the perimeter of an open pit has been defined, the mining is downward, not outward.

The copper industry is voluntarily contributing effort and expense to preventing unnecessary disturbance, as well as to correct past effects. The location of most of the open-pit copper mines is in arid parts of the country. The dryness plus the waste material and quite sterile tailings make it difficult to project a program for covering these areas with trees or vegetation although intensive experimentation is underway. Many of these areas grew only sparse vegetation or scrub timber before mining began.

The proposal is sometimes made, often in jest but sometimes seriously, that waste material be dumped back into the pit to "fill up the hole." Unfortunately, except in a few rare instances, this suggestion is not practical, even though mine operators would like to do so to reduce haulage costs and to solve the problem of where to put expanding dumps. "Filling the hole" is undesirable because covering the low-grade mineral values now exposed would preclude the ultimate recovery of its mineral wealth at some future time. Ore presently marginal or even submarginal may become profitable to mine or may be needed sometime in the future when our natural resources decrease and demands increase. Technological advances have pushed the cutoff point in mining to include the use of ores with low mineral content. Ten years ago, they would have been considered useless waste.

In the early days of mining in the West, the value of minerals from the unexplored mountains and deserts was vital to the national economy and to the opening up of the western country. The population was sparse, and the mining methods, particularly hydraulic mining, were crude and destructive. The side effects of mining, now considered harmful, were started in those frontier days. However, harmful effects have become less and less severe as mining methods have been improved. There has been very little increase in harmful side effects during the past decade. Corrective measures have been voluntarily undertaken by the mining companies with considerable success during this time. These measures will continue to have even wider applications in the future as improved technology is applied. Techniques to improve water conservation and land rehabilitation are constantly being devised and put into operation.

The mining industry is concerned with preserving a beautiful America, and is doing much to bring this about.

The economic importance of copper mining to the State of New Mexico is not fully realized by much of the population. Areas directly dependent on the mines for a large part of their employment are aware of the payrolls derived from the operations, and the general prosperity of the mining companies is reflected in the prosperity of these communities.

The general public is not entirely aware of the portion of the tax burden carried by mining companies, and, therefore, may not realize that the large share of local and state taxes is paid by these firms. In New Mexico, Kennecott Copper Corporation, one of the largest single taxpayers, pays 90 percent of the school district tax bill. Promoters of bond issues in Grant County stress the fact that about 90 percent of the cost of these bond issues will be paid by the mining industry, with some assistance from the utilities companies. As copper mining increases in the state, the impact on the economy of taxes paid by copper mining companies will become greater.

Open-Pit Uranium Mining in New Mexico

by George B. Griswold
Getty Oil Company

Uranium mining is one of New Mexico's newest major industries. It started in 1950 when Paddy Martinez discovered carnotite ores outcropping on the slopes of Haystack Mountain west of Grants. At that time domestic reserves of uranium were in such short supply that the Atomic Energy Commission initiated an incentive program for uranium exploration by offering bonuses of first discoveries and by accepting long-term ore purchase contracts. Early exploration was centered in the Colorado Plateau with particular emphasis on the Moab, Utah area where Charles Steen and Vernon Pick had made fabulous discoveries. The Haystack Mountain discovery by Martinez was by itself not a large find, but it served to concentrate new exploration in the Grants area. Within a few short years thereafter, New Mexico ranked first in the nation in the mining of uranium, and it still holds that position.

Much remains to be known concerning the genesis of New Mexico uranium deposits, but the important deposits all possess these characteristics: (1) they are restricted to particular sedimentary units of Jurassic age, with coarse-grained sandstones being most favorable, (2) they are associated with zones or lenses containing significant amounts of organic material, (3) ore controls include original sedimentary features such as stream channels and cross-bedding, and (4) deposits are of the manto type, i.e. flat lying deposits ranging from a few inches to several tens of feet thick but extending up to thousands of feet in the horizontal direction. Individual ore bodies are very complex in detail, hence mining techniques are variable. At present the majority of uranium ore is being mined by underground techniques. These shaft mining operations are concentrated in a west-trending belt forty miles long commencing just west of Mount Taylor and reaching to Church Rock just north of Gallup. These underground mines do not scar the landscape, and are visible only by the headframes which mark each shaft.

Open-pit mining for uranium is now limited to a single deposit, the Paquate-Jackpile Mine on the Laguna Indian Reservative east of Mount Taylor. The mine lies on the Laguna Reservation and is operated by The Anaconda Company. Although this is the only open-pit uranium mine in the State, it is rated as one of the most significant deposits of uranium in the world. At present, some 3000 tons of ore are being removed from the mine every day which makes it one of the largest producers in the United States.

The Paquate-Jackpile mine is a combination of two large open-pit mines. The Jackpile mine was the scene of the initial discovery of uranium ore in the area. A small radioactive anomaly was discovered in 1951 at the base of the Dakota Sandstone that is a prominent mesa former in this area. Drilling delineated a several million ton ore reserve which was mined by conventional open-pit mining. Before this ore body was exhausted, Anaconda exploration personnel had found the Paquate ore body immediately to the west. Mining today is concentrated in the Paquate pit.

Ore is being extracted at a rate of about 3000 tons per day. Overburden is relatively thick requiring an additional ten tons of barren sandstone and shale to be removed for each ton of ore mined. Mining is done in benches approximately twenty-five feet high using large rotary drills for blast-hole drilling and huge, 700 hp. front end loaders to load into 50 ton haulage trucks. All ore leaves the mine by standard gauge railroad to Bluewater (located ten miles west of Grants) where Anaconda operates a large uranium ore concentrator.

The air photo illustrates how bench mining in this "rim rock" setting blends in with the original topography. Similarly the waste dumps, now being placed in long, thin (20 feet high) banks, blend very well with the terrain. That the mining at the Paquate-Jackpile Mine fits well its environment, is a deliberate and well thought-out program being carried out by management of The Anaconda Company. The disposal of waste in thin banks is not the *cheapest* way, but it is the *best* way from the standpoint of minimizing the effect of moving the 96.5 million tons of rock since the mine was placed into production. Other steps toward land restoration include "rough topping" the surface of dumps and filling in of old arroyos to retard natural erosion. Dumps recover natural vegetation (prairie grass and tumbleweed) almost immediately after being placed, and it appears certain that other desert plants such as greasewood and cacti will cover most of the surfaces within a period of a few years.

Open-pit mining of uranium is compatible with the overall development of New Mexico's natural resources. The mining companies appear to be most willing to minimize the effect of excavation. Other benefits include the employment of 175 Laguna Pueblo Indians in the mining operations which has allowed these citizens to learn new trades and skills while earning good wages. The direct royalty received by the tribe to date exceeds $15 million. This money has sponsored schools, roads, new industry, electric power distribution, and similar improvements on what was once a very harsh land.

Photo Courtesy The Anaconda Company.

ANACONDA'S PAQUATE-JACKPILE OPEN-PIT URANIUM MINE, AIRVIEW EASTWARD. MESA GIGANTE ON THE SKYLINE; LAGUNA INDIAN VILLAGE OF PAQUATE IN LEFT FOREGROUND.

Photo Courtesy The Anaconda Company.

ANACONDA'S PAQUATE-JACKPILE OPEN-PIT URANIUM MINE, AIRVIEW WESTWARD. BENCH MINING AND LOW-PROFILE WASTE DUMPS BLEND INTO THE SURROUNDING MESA COUNTRY. CEBOLLETA MOUNTAIN ON SKYLINE, LAGUNA INDIAN VILLAGE IN RIGHT CENTER.

Molybdenum Mining at Questa

by John H. Schilling
Nevada Bureau of Mines

Molybdenum is one of the most versatile of the alloying elements, and is used extensively in iron and steel to increase hardness, strength, and resistance to corrosion. Molybdenum metal also is used in electronic, missile, and nuclear-energy applications without being alloyed with other metals. Molybdenum compounds are used as lubricants, in fertilizers, and as catalysts.

Molybdenum is found the world over, but in only a few places is it abundant enough to warrant the extensive mining and milling facilities necessary for its recovery. A mine obviously can be located only where there is ore, in contrast to a factory, road, or town, which can be built on any one of a number of suitable alternate sites.

Only two mines in New Mexico produce molybdenum, the Santa Rita copper mine, from which molybdenum is a byproduct, and the Questa Molybdenum mine. Both are open pit mines, use mass-mining rather than selective methods, and mine low-grade ores. Other molybdenum mines in the world are underground as well as open-pit operations, and also use mass-mining methods, with the end results being much the same—a large, deep pit.

The Questa molybdenum mine is in the Taos Range of the. Sangre de Cristo Mountains, in north-central New Mexico. The mine is in Red River Canyon, which penetrates the range from the west and provides access to Red River, a tourist-oriented town in the heart of the mountains. A good paved road (State Highway 38) follows Red River Canyon. Nature has developed huge, treeless, yellow scars which mar the canyon walls. The soft, decomposed rock in these yellow altered areas is eroded more easily than the surrounding rock, and the eroded debris is carried into the canyon bottom by mudflows after heavy rains.

These "badlands" were not caused by mining and are similar to badlands elsewhere that are scenic attractions. Red River gets its name from its yellow-red color after every rain, when silt from the badlands finds its way into the stream. The trout in the river survive these extremely muddy natural conditions. When "tailings" from mining operations accidentally get into the stream, they usually add less silt than a normal summer rain storm.

The trim blue buildings of the Questa mill are at a wide spot in the canyon, and cover the floor and north slope. The open pit from which the ore is mined is to the northwest in a side canyon, and is not visible from the highway. Like the mill, the open pit is in an area of few trees, and what trees are present are usually small and stunted. Vegetation has great difficulty growing in such areas of altered and mineralized rock.

Veins carrying the mineral molybdenite (the main ore of molybdenu) were discovered in 1916 in the area which is now the open pit. These small, thin, rich veins were mined by relatively costly underground methods from 1916 until 1958, during which time 11,000,000 pounds of molybdenum was produced.

When it was realized that the veins would soon "play out," a search was begun for more ore. A huge low-grade molybdenum deposit, which overlapped the rich veins, was discovered. The deposit consisted of paint-thin layers of molybdenite along numerous criss-crossing fractures.

The Molybdenum Corporation of America, owners of the property since 1921, spent over $40,000,000 before ore could be mined. By the end of 1964, Molycorp had done more than 140,000 feet of drilling and 8,000 feet of tunneling to determine the size and grade of the ore body, and 33,000 tons of ore had been "mined" and tested to determine if the molybdenum in the ore could be recovered. An open pit was planned that would cover a roughly circular area having an average diameter of 1,600 feet, an average depth of 800 feet, and containing over 20,000,000 tons of ore averaging 0.16 percent molybdenum (slightly over 3 lbs. of molybdenum per ton). Over 70,000,000 tons of waste material would have to be removed to get to the ore. As a result of proving the ore, a mill that could process 10,000 tons of ore per day was built.

Mining began late in 1965. At the same time, drilling had continued and more ore was found, resulting in a large expansion of the present pit. By the end of 1968, ore reserves totaling in excess of 120,000,000 tons, with an average grade of 0.11 percent molybdenum, had been delimited.

In 1968 Molycorp announced that it would expand the mill to handle 15,000 tons of ore per day—a potential rate of 14,000,000 lbs. of molybdenum per year—and would add $12,000,000 in equipment and facilities. If operations are conducted at the planned rate, reserves will be exhausted in less than 25 years—if no additional ore is found.

Ore is mined from a series of benches in the open pit; waste is removed at the same time to allow continued expansion of the pit. Holes are drilled into the ore, the holes are loaded with explosives, and the ore is broken by blasting. The broken ore is loaded into large diesel-electric trucks by electric shovels that scoop up 10 and 17 cubic yards at one bite. The trucks each carry 90 tons of ore to the mill. As waste rock is encountered, it also is loaded into trucks and dumped in huge piles outside the final limits of the pit. These dumps are located where they will do as little damage as possible to plant life and scenery.

At the mill, the ore passes through a series of crushers

Photo Courtesy Molybdenum Corporation of America.

AIRVIEW TO NORTHWEST OF QUESTA MOLYBDENUM MINE. RED RIVER CANYON, N. MEX. HIGHWAY 38, AND QUESTA MILL OF MOLYBDENUM CORPORATION OF AMERICA IN LEFT FOREGROUND; OPEN-PIT MINE IN RIGHT BACKGROUND.

which reduce the large chunks to thumb-size pieces. The ore is then ground to powder in ball mills. Water and ore are fed continuously into one end, and the powdered ore-water mixture pours out the other end. The powdered ore-water mixture is conditioned with chemicals and oils and fed into flotation machines, which are eggbeater-like devices that churn the mixture into a froth of air bubbles. The tiny particles of molybdenite stick to the air bubbles which rise to the top and are skimmed off the top or allowed to overflow. Particles of other minerals in the ore will not stick to the bubbles, and sink to the bottom.

The molybdenite-water mixture is then passed through settling tanks, filters, and dryers which remove all the water. This molybdenite concentrate is shipped to Pennsylvania, where it is converted into the products used by industry.

The waste material (tailings), comprising more than 99 percent of the volume hauled to the mill, is carried out of the mountains in three pipes that parallel the highway, and ends up in the tailings pond west of Questa, 8.5 miles west of the mill. In the pond, the waste settles out of the water and the clear, silt-free water is returned to Red River by way of additional decant ponds.

700 men are employed at the mine and mill. Such year-round, high-paying jobs are vital to Taos County, which historically has been an economically depressed area.

When a mine and mill are superimposed on an environment, care must be taken to avoid air and water pollution. At the Questa mine, air pollution is no problem, as no smelter is operated and the mill does not emit dangerous or noxious fumes.

Water pollution could be a problem, so great care is taken to avoid contaminating Red River. The water from the altered areas along Red River has always been highly acidic, due to the natural weathering of the pyrite (iron-sulfur mineral) in the rock, but because precipitation is light, the amount of water draining into Red River from side canyons is small, and the increase in acidity is too slight to cause problems. During mining, much pyrite is removed before nature can convert it to acid; if anything, mining cuts down on the amount of acid produced. Thus acid mine water is no problem, as it often is elsewhere.

After every rain the side canyons dump large amounts of clay and silt into Red River. The ecology of the area has adjusted to these mudflows that bury trees and silt up the streams. Trout, for example, thrive in spite of the periodic silting. Some people blame the muddy water and buried trees on mining, and consider the silt to be much more harmful than it is. Actually the benches of the open pit greatly lessen erosion, and the powdered waste rock from the mill is caught in a settling pond and clarified before being returned to the river many miles below the mill. When first installed, the pipeline that carried the waste occasionally broke and discharged silt into the river; the pipeline has since been improved so as to decrease the frequencies of breaks.

Molycorp has planted trout in a decant pool and the trout have done very well. Water comes from the tailings pond through a 2-mile ditch to the decant pond before it is discharged to the Red River. Fish were planted in the tailings pond, but due to lack of oxygen, they did not do well.

Obviously the landscape will be affected by mining activity, and some scenic beauty has been destroyed. The Questa pit, dumps, and mill eventually will cover 1.2 square miles. Where possible the dumps have been placed so that they will also be out of sight and will destroy as few trees as possible. The mill buildings are painted an attractive blue to fit into the scenery. The tailings pipes along the road have been routed to avoid cutting down trees, they have been buried if possible, or grass has been planted to camouflage them.

When the mine is abandoned it may be desirable to stabilize the dump and pit walls by planting trees, shrubs, and grass, and rounding off the steep slopes with a bulldozer. Research is needed to determine what reclamation measures are practicable and desirable both at the Questa mine and elsewhere.

Surface Mining of Construction Materials in New Mexico

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Prior to 1930, many New Mexico buildings were constructed of sun-dried adobe brick, and roads throughout the State were unpaved. The first large-scale use of Portland cement concrete was to build a 22-foot-wide pavement from Belen to Bernalillo. This required about 180,000 tons of sand and gravel, which was dug out of the valley floor and from the low terraces east of the route.

Many of these sand and gravel pits were later developed to supply materials for commercial use in the fast growing Albuquerque area, and for highway construction. In 1963, E. B. Bail, reporting to the Bernalillo County Planning Commission, said there were only 1,500 acres of prime sand and gravel reserves remaining in Bernalillo County, containing 53 million tons of sand and gravel. He estimated these deposits would be depleted by 1985.

In many parts of New Mexico construction materials such as sand and gravel, occur in large quantities, especially in the valleys of major streams and their tributaries. Including caliche, which is the major source of road aggregate in eastern and southeastern New Mexico, all counties produce sand and gravel. Locally, as near Grants and Hobbs, suitable commercial gravel is sparse and may need to be trucked for relatively long distances.

Open-pit surface mining of construction materials often is not considered when surveys of surface mining disturbance are made. The types of pits for construction materials usually are relatively small, often covering only a few acres. These include quarries for production of limestone, sandstone, marble, basalt, granite, and gypsum, and pits to obtain sand and gravel, clay, perlite, scoria, and pumice. Some of the quarries have been in operation for many years, whereas in contrast, some of the sand and gravel pits are used for only a few weeks to provide materials for a highway.

Construction materials produced in New Mexico in 1969 include: 64,000 tons of clays worth $83,000; about 350,000 tons of limestone to make cement and lime; 322,000 tons of perlite worth $3.8 million; 238,000 tons of pumice worth $504,000; 150,000 tons of gypsum worth $575,000; 2,166,000 tons of stone (mainly as crushed rock for aggregate and road metal) worth $3.5 million; and 12.8 million tons of sand and gravel worth $12.4 million. The total value of these construction materials was about $28 million.

Questionnaires distributed by the New Mexico Sand and Gravel Association and by the New Mexico Mining Association indicated that considerable planning has been done to reclaim the areas disturbed by surface mining of construction materials. These involve use of the land as sites for commercial, industrial, and residential development; recreation facilities; programs of erosion control and conservation; and for a large amount of the rural areas, a direct reversion to pasture and grazing lands. In some of the urban areas, lands that had served to produce construction materials have now become too valuable in the expansion of the cities, and have been or are being covered by buildings, parks, streets, and freeway systems.

Many of the sand and gravel producers obtain their materials from arroyo beds, in which case there is never a permanent scar. When the intermittent streams flow, they wash away the pits and replenish the sand and gravel at the same time.

Mining of construction materials for the State Highway Department disturbs more than twice as much acreage as any other type of surface mining in New Mexico; however, this poses no serious rehabilitation problem because it comes under the stringent regulations of the Policy and Procedure Memorandums of the U.S. Bureau of Public Roads. The New Mexico State Highway Department has a Landscaping Division which determines in advance exactly what type and how much rehabilitation will be done. This may mean seeding with plants or grass, construction of a stock pond for cattle, or even, as for New Mexico State University in Las Cruces and the University of New Mexico in Albuquerque, utilizing large excavations as sites to build stadiums.

Borrow and materials pits used or being used by the State Highway Department total an estimated 15,000 acres, in addition to the reported 6,500 acres disturbed by other types of surface mining. Under Federal regulations, the pits must be located so they are not easily visible from the highways and must be constructed so that they will not contaminate drainages. Some of the older pits did not fall under this regulation, and are visible from the highways. The present rate of usage, including access roads as well as the areas of borrow pits and materials pits, is about 1,500 acres per year. Almost 80 percent of these pits are reclaimed as soon as their materials are no longer needed;

about 300 acres per year remains in a disturbed condition. Many of the pits that are not reclaimed are on a permanent stand-by basis whereby some materials are used at irregular intervals when needed for local resurfacing. The yearly figure also includes pits used during previous years.

New Mexico has an area of 77,724,800 acres of land. Through 1970, about 15,000 acres have been disturbed by construction activities of the highway building program. Less than one tenth of this amount has been disturbed by other surface mining operations to obtain other construction materials. This amounts to about 2/100ths of one percent of the land surface, or one acre out of every 5,000.

Strip Mining of Coal in New Mexico

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In 1958 New Mexico's coal mines produced 116,656 tons, valued at less than a million dollars. With the opening of strip mines in the San Juan Basin area of northwestern New Mexico, and the development of Kaiser Steel Corporation's underground York Canyon mine west of Raton, where coking coal is mined for shipment to California steel mills, production of coal has risen to an all-time high. The 4,570,000 tons mined in 1969 were worth $19,600,000. About 80 percent of this coal was obtained from strip mines, and essentially all of the strip coal was from the Navajo mine near Fruitland, the McKinley mine northwest of Gallup, and the smaller Sundance mine southeast of Gallup.

Most of the strip-mined coal is used in the Four Corners power plant near Fruitland and the Cholla power plant at Joseph City, Arizona. Maximum power production at the Four Corners plant would require more than 8 million tons of coal per year. Public Service Company of New Mexico and Tucson Gas & Electric Company will build their San Juan power plant near Waterflow and strip mine coal north of the San Juan River. Eventually, they will mine 3.6 million tons a year; by that time the State's total coal production should triple that of 1969.

Strip mining of coal in New Mexico is carried out on terrain that ranges from relatively flat surfaces to rolling hills, and in many places amid "badlands" formed by steep-walled gullies separated by ragged rock ridges.

Natural vegetation varies from sparse grass and desert shrubs to small junipers and piñons in some of the higher areas on the borders of the San Juan Basin. All the strip mines are in arid to semiarid areas that receive about ten inches of precipitation a year. Thus for the most part, only the native semiarid vegetation types grow on the original soil or on reclaimed spoil banks.

Strip mining begins with the opening of a long trench, or "box cut," through the overburden of soil and rock above the coal bed. The first cut is usually made near the outcrop of the coal (intersection of the coal bed with the surface) where the outer, shallower wall of the cut is in overburden 20 to 30 feet deep. The very shallow coal is often weathered and useless. After the overburden is stripped off of the coal and deposited in a spoil bank on the outside and parallel to the initial cut, the coal is mined. Successive deeper adjacent parallel cuts about 100 feet wide are dug, and the spoil is deposited in the cut previously excavated. The final cut, its depth dictated by the economic limits to which the coal can be strip-mined (at the present time where coals are 100 to 200 feet deep), results in an open trench bounded on one side by the last spoil bank and on the other by the undisturbed "highwall."

The resulting terrain, unless graded or partly leveled, looks like the knobby ridges and valleys of a gigantic washboard, with the last cut a deep, open trench facing the highwall, a nearly vertical cliff.

In most areas of New Mexico, the overburden includes hard sandstones that must be blasted using an ammonium nitrate-fuel oil mixture or similar explosives. In some instances the coal, too, is "shot" by explosives to break it into smaller fragments. Giant walking draglines that swing 40- to 50-cubic-yard buckets on 250- to 285-foot booms strip off the overburden after it has been broken by blasting. Shovels and front-end loaders handling 10 to 16 tons of coal per scoop load the coal into large trucks (many with a 125-ton capacity) that carry the coal to crushing and blending plants.

In strip mines where the ridge-and-valley spoil piles are not modified after mining, the ridges may have peaks 50 or more feet high, with steep slopes. Erosion during rains tends to wash the ridge material into the valleys, thus partially filling them. The rain waters concentrate in the valleys and in the deep trench of the last cut. The localization of water helps promote the growth of vegetation in the valleys. Small open cuts serve as stock tanks, and larger ones that receive sufficient rainfall may be developed into ponds.

As most of the New Mexico coals are low in sulfur and iron, there is no problem with acid waters as compared with spoil piles from metal mines that are worked in ores containing much iron sulfide.

Revegetation of some spoil piles by reseeding has not been too successful in northwestern New Mexico. In most areas, natural revegetation appears to take place about as fast as it does with artificial treatment, according to the U. S. Bureau of Land Management. At best, artificial reseeding provides a temporary cover until the natural vegetation re-establishes itself.

Much of the New Mexico coal presently being strip-mined has a high ash content, ranging from 12 to 22 percent. At mine-mouth power plants, such as the Navajo mine which is a few miles from the Four Corners power plant, the bottom ash and precipitated fly ash are trucked back to the strip mine. About half the ash is placed in the valleys between the spoil-bank ridges, compacted, and covered to a depth of about 3 feet with spoil material pushed from the peaks. The result is an undulating topography that has a greater resistance to water and wind erosion than a flat plain. The other half of the fly ash is used to refill the last trench.

The cost of this ash disposal, ash backhaul and partial leveling of the spoil banks is an additional 10 percent, approximately, of the mining costs.

The companies now operating the two large strip mines in the State partly level off the spoil piles, attempt to stabilize the surfaces to cut down on dust being blown into surrounding areas, and are experimenting with optimum slopes and revegetation. At the Navajo mine, Utah Construction & Mining Company, in cooperation with the Bureau of Indian Affairs, has set up test areas to experiment with the reseeding of several grass types on various slopes and in various spoil materials. Pittsburg & Midway Coal Mining Company at the McKinley mine are conducting similar vegetation experiments. They have had considerable success with Russian olive, Chinese elm, and western wheat grass on spoil bank mounds, but spruce failed to grow.

According to the U.S. Department of the Interior, in its report *Surface Mining and Our Environment*, 1,200 acres had been disturbed in New Mexico by coal strip mining through 1964. When the Navajo mine comes into full operation of 8.5 million tons a year, mining an average 12-foot-thick coal seam, they may strip about 400 acres per year. Tons of coal strip-mined through 1964 were 7,555,800; 11,870,400 tons were strip-mined in New Mexico from 1965 through 1969; estimated production from strip mines in 1970 is about 6.5 million tons. As the amount of coal strip mined in the 5-year period from 1965 through 1969 averaged about 2.5 million tons, it can be calculated that about 150 acres per year have been strip-mined, giving a total through 1969 of about 2,000 acres directly disturbed by strip mining of coal. This is 0.003 percent of New Mexico's surface area. As for the future, if Utah Construction & Mining Company were to completely mine their 31,000-acre lease, an area containing enough strippable coal to operate the Four Corners power plant for about 130 years, it would eventually lead to the disturbing of 0.04 percent of the State's surface.

After 20 years of natural revegetation, most of the rolling ridges and valleys of abandoned and reclaimed strip-mine areas will support as many cattle and sheep as they did before being strip-mined. However, it will be apparent to anyone that the terrain is "man-made," just as the terraced irrigation fields in the Rio Grande valley are works of man. Also remaining after the steam plumes from the power plants no longer float thinly and lazily in the clear desert air, will be the cool sparkling waters of lakes used to provide water to the plants—such as Morgan Lake at the Navajo mine and Four Corners power plant southwest of Fruitland. This oasis amid the Navajo Reservation badlands may resemble a mirage, but it provides bass, catfish, and boating for northwestern New Mexico's people.