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phelps dodge MORENCI INC.

Phelps Dodge Morenci, Inc. General Offices

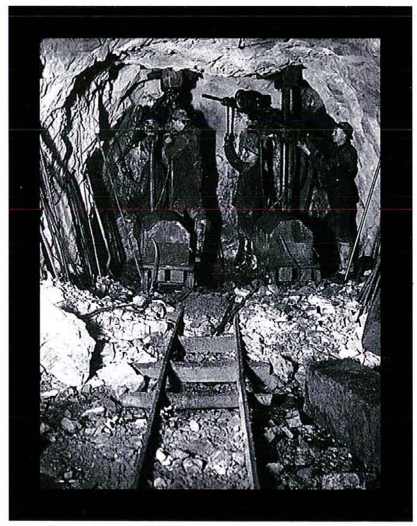
On the cover: About two miles long and nearly as wide, the Phelps Dodge mine at Morenci, Arizona, produces more copper than any other mine in North America.

Note: For the reader who may find flotation, raffinate, leaching and other mining-related terms confusing, a glossary has been provided at the last page of this brochure.

THE START OF IT ALL

Prospectors who arrived in the Clifton-Morenci area way back in the 1860s probably would have been surprised to know they were triggering a chain of events that would figure prominently in the history of the American West.

The prospectors were looking for gold. What they found were outcroppings of green and blue copper oxides on a brush-covered hill near Chase Creek. Was this enough to warrant further exploration? To the average person, it probably was not. For one thing, it was dangerous territory. The Apaches were shielding their homeland against intruders and had been particularly savage in defense of their Gila Valley hunting grounds. Also, there was no real promise of how rich the copper ore might be.



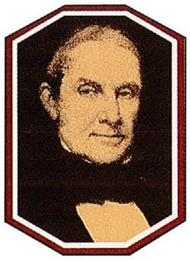
All early-day Morenci mining was conducted underground.

But if one characteristic branded the men and women who were then forging westward it was their perseverance. Defying a frontier fraught with danger and forever hoping for a bonanza all their own, farmers, merchants, adventurers, prospectors and miners were moving west. If there were riches to be found, America was prepared to find them! In the case of copper, it didn't take long.

Mining claims were staked with names such as "Longfellow," "Yankee," "Copper Mountain," "Arizona Central," "Montezuma," "Shannon," and "Metcalf." Men as colorful as the ore they sought joined in the parade. Henry and Charles Lesinsky, Robert and James Metcalf, Dr. James Douglas, and William Church, the miner who had come down from Colorado and whose camp was named "Morenci" after a town about 75 miles from Detroit, Michigan that probably had some connection to Church or to the backers of Church's Detroit Copper Mining Co. Rich copper ore was discovered. Crude smelters were erected. And in New York City, the merchant firm of Phelps, Dodge & Co. agreed to pay fifty-thousand dollars for one-half interest in the Detroit Copper Mining company, thus creating a partnership that would launch copper mining in the Southwest. And, as the saying goes, the rest is history.

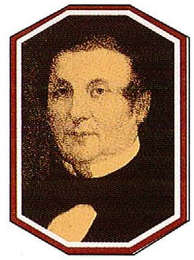
IMAGINE A TIME 50 MILLION YEARS AGO!

More than 50 million years ago, massive mineral activities were occurring deep within the earth, creating a rarity of nature. Metals were forming in concentrations thousands of times greater than on the earth's surface. Over the many millennia that followed, these areas eroded and ultimately were exposed to the surface. In the 1860s, prospectors from the New Mexico Territory ventured into the area and discovered beautiful blue and green rocks. The "rocks" were copper oxide. This was where the Morenci mining operation is located today.



Anson Greene Phelps

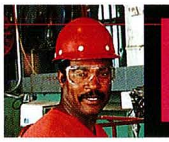
William Earl Dodge



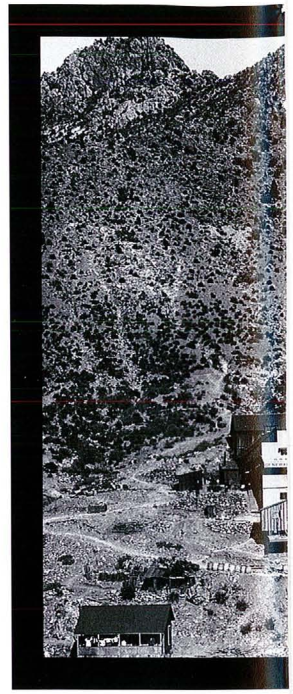
Daniel James

Orphaned in 1789 when he was eight years old, a penniless Anson Greene Phelps worked hard for success. He began the business venture that would evolve into the Phelps Dodge Corporation. In the 1830s, Phelps brought his sons-in-law, William Earl Dodge and Daniel James, into the firm. Dodge focused on the operations of Phelps Dodge & Co. with headquarters in New York City while James became the resident partner of Phelps James & Co. in Liverpool, England.

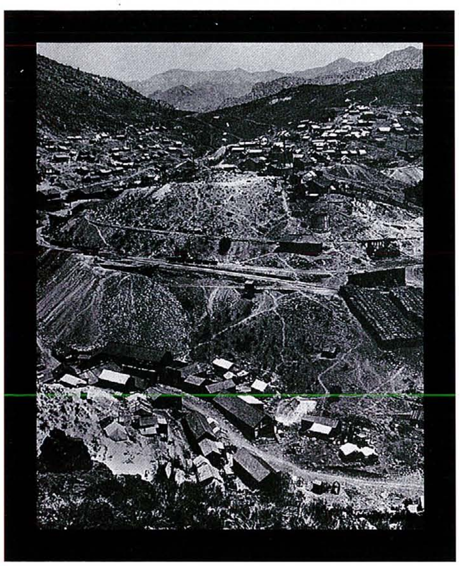
1872 TO 1937 — 65 HISTORIC YEARS



Part of mining's history in the West involved the Longfellow Copper Company which began operations at a site that is now a part of the Morenci open pit mine. It was 1872 and miners were only starting to tap the rich copper ore bodies that waited underground. In fact, oxide ore from the Longfellow Mine was averaging 20 percent copper, 30 times richer than Morenci's present-day ore.



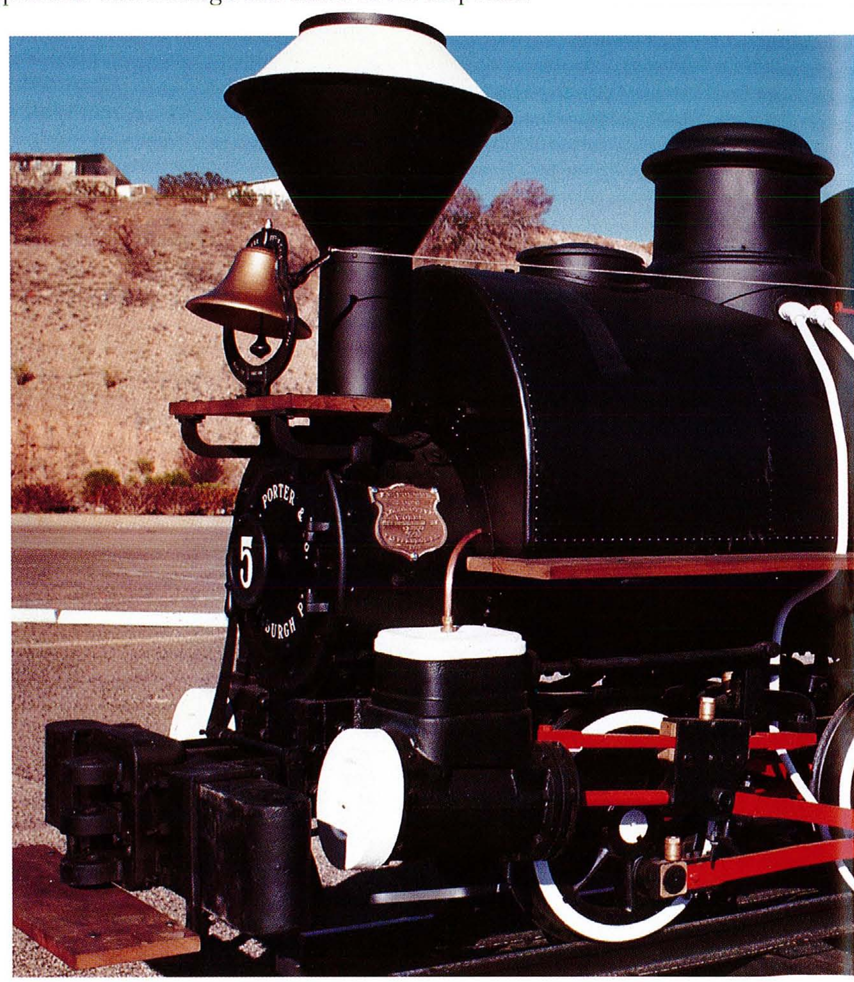
Facing up to the growth at hand, the Longfellow Copper Company brought the first mine railroad to Arizona in 1879 — one that used "baby gauge" track with a spacing of only 20 inches between rails (present-day rails are 56-1/2 inches apart.) The rails were there, but no locomotive, so mules were put to work. The cars were loaded with ore in Morenci. Mules and a brakeman climbed aboard one of the cars, and ore, mules and men coasted down the mountain side to the smelter in Clifton. Then the mules pulled the cars back up the mountain to Morenci where the process started all over again.



This was Morenci, Arizona Territory, as it looked in the late 1800s. Morenci was the town site of the Detroit Copper Mining Company.

After a year of this, the mules were given a well-deserved rest when the Longfellow Copper Company purchased a baby gauge locomotive. Today, an 1888 model of one of these tiny engines is on display in the Morenci Plaza.

Mining in 1872 and for the next 60 years was all underground. During the Great Depression, copper prices fell so low that in 1932 all mining was suspended. The underground mines never reopened. Although underground mining was no longer economic, a very large low-grade copper sulfide ore body had been discovered surrounding the old underground workings. Since 1907, there had been a number of successes at mining "large-tonnage, low-grade" ores at places such as Bingham Canyon, Utah; Ajo, Arizona; and Sacramento Hill in Bisbee, Arizona. And so, in 1937, with the nation's economy still showing no reliable sign of improvement, still held in the death-grip of the Great Depression, Phelps Dodge made the courageous decision to begin mining by the open pit method in Morenci. Two years later, World War II broke out. Copper suddenly became a greatly needed commodity and Morenci's early return to copper production would become critical to the nation's defense.



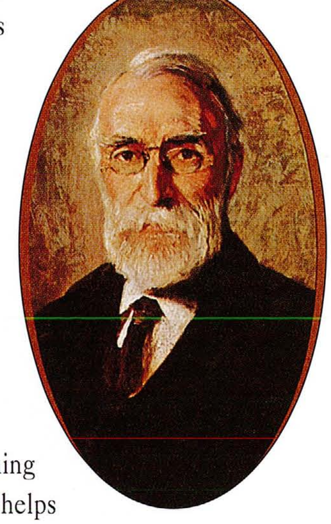
$50,000 FROM NEW YORK FOR A MINE IN ARIZONA

An isolated outpost of goods and services near Morenci before the turn of the century.

In 1881, that young man from Colorado named William Church whose mining camp was known as "Morenci" and whose mining venture was named the Detroit Copper Mining Company made the difficult trip from Arizona to New York City. Without a mining engineer's report or even an ore sample, Church walked into the offices of a mercantile firm and coolly requested the $50,000 he needed to build a copper smelter.

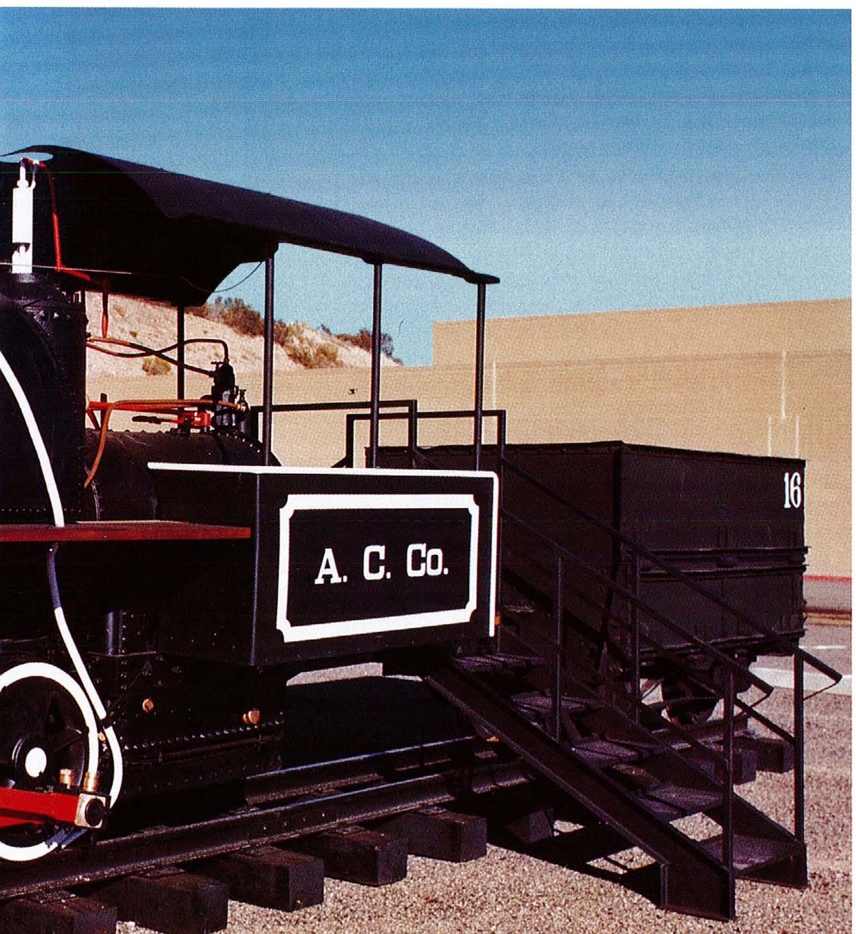
Until then the firm, Phelps, Dodge & Co., had been engaged in the import and export business with factories in Connecticut and New York. Their business was in kettles, copper wire and buttons for uniforms. Yet, Church's sincerity and confidence, not to mention his boldness, so impressed the Phelps, Dodge partners that they commissioned Dr. James Douglas to examine Church's holdings in Morenci as well as another property in Bisbee, Arizona. A distinguished metallurgist and mining geologist, Douglas returned with favorable recommendations which persuaded Phelps Dodge to purchase a substantial interest in Church's company and to acquire the Atlanta claim at Bisbee.

In 1882, soon after Phelps, Dodge & Co. entered the picture, the Arizona Copper Company, a Scottish firm headquartered in Edinburgh, purchased the Longfellow Copper Company holdings. Fifteen years later, in 1897, Phelps Dodge acquired the remainder of the Detroit Copper Mining Company. Phelps Dodge and their Scottish counterparts were the dominant companies in the Morenci Mining District until 1921 when Phelps Dodge acquired the Arizona Copper Company.



Dr. J. Douglas:

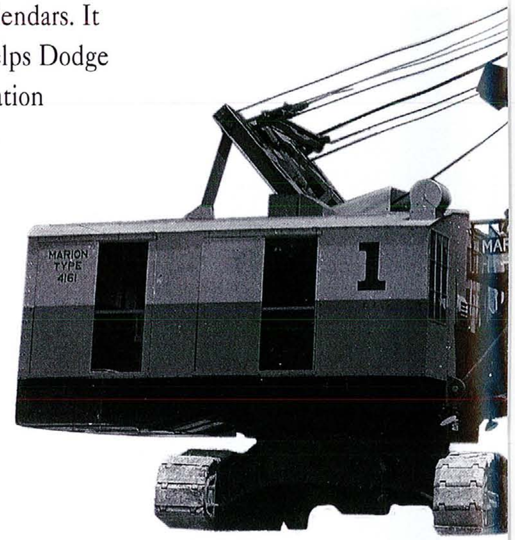
He provided the assessment of the Morenci and Bisbee ore bodies that brought Phelps Dodge to Arizona. The town of Douglas, Arizona, was named in honor of this distinguished metallurgist and mining geologist.



Baby gauge locomotive No. 5. Purchased in 1888 by the Arizona Copper Company, it is now on display in the Morenci Plaza.

A SPECIAL DAY IN THE HISTORY OF MINING!

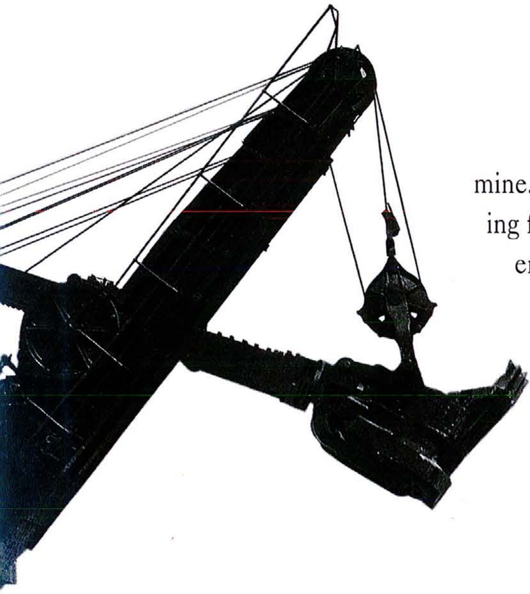
August 24, 1937 was a date miners at Morenci noted on their calendars. It marked an event some still fondly remember. On that day Phelps Dodge Shovel No. 1 dug deep into Arizona soil at the 5,350-foot elevation and brought up the first dipper of rock from the new Morenci open pit mine.



The event might not have been so memorable had what followed not been so impressive. Today, the Morenci picture is vastly different from the days of the Metcalfs, Lesinskys, Douglas and Church.

Crude machinery has been replaced by state of the art, computerized mining technology. Baby gauge locomotives have long been retired, succeeded by 2,000 horsepower locomotive engines that operate on the Phelps Dodge Morenci, Inc. Industrial Railroad. More than three billion tons of material have been removed since 1937 to create the vast amphitheater of the Morenci open pit

A shovel with 56-cubic-yard capacity loads a Morenci haul truck having a payload of 240 tons.



mine. Originally worked by a mere handful of pioneer miners, today the Morenci mining facility provides direct employment for more than 2,000 workers. The mine's influence has become international, providing employment locally and creating business opportunities globally.

On August 24, 1937, shovel No. 1 removes the first dipper of rock from the new Morenci open pit mine. Mining begins at the 5,350-foot elevation.

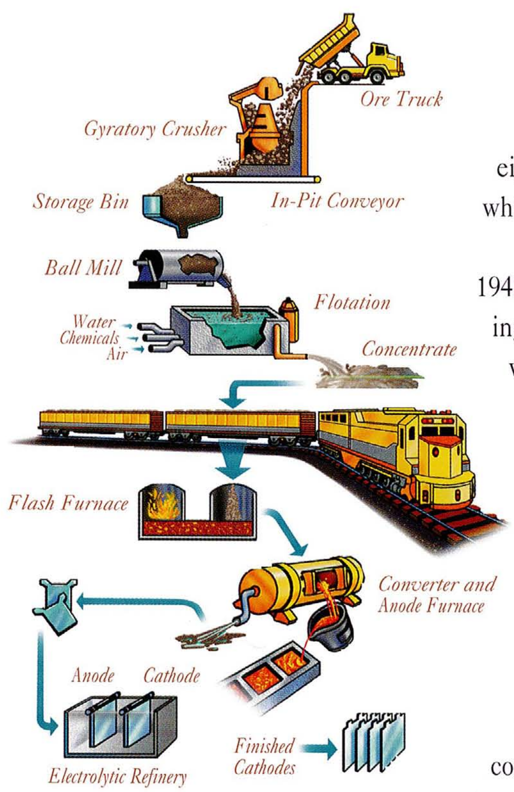
A modern locomotive on the Morenci Industrial Railroad.

FROM ARIZONA ORE TO COPPER FOR THE WORLD

Turning Arizona ore into copper for the world is not a magical process. It requires the hard work and technical skills of dedicated men and women and procedures that have continually improved over the years.

Geologists begin the process by exploring, drilling, discovering and mapping the ore body. With that information, mine planners in the engineering department undertake the layout of areas to be mined, giving consideration to truck haulage distances, ore grades and the ore's milling characteristics — all of which have an impact on mining costs.

In the mine, drilling supervisors lay out the pattern for blast holes. Drilled to a depth of 65 feet, the holes are loaded with the blasting agents, ammonium nitrate and fuel oil, a volatile combination known as ANFO. Blasting produces well fragmented rock which is loaded into trucks by electric-powered shovels. The trucks unload the higher-grade ore into crushers located in the mine.



Emerging from the in-pit crushers are rocks no larger than six to eight inches. These move up and out of the mine on a conveyor system which is linked to the Morenci and Metcalf concentrators.

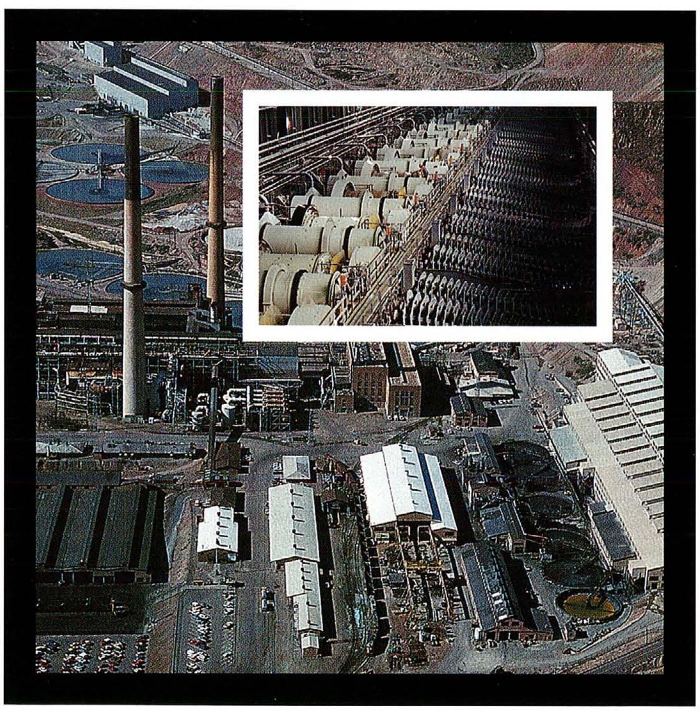
The Morenci concentrator, the larger of the two, was constructed in 1942 and immediately expanded to meet the nation's copper demands during World War II. The somewhat smaller but newer Metcalf concentrator was built in 1974.

Except for a difference in the method used to separate the smaller and larger particles, the two concentrators use similar crushing, grinding and flotation processes.

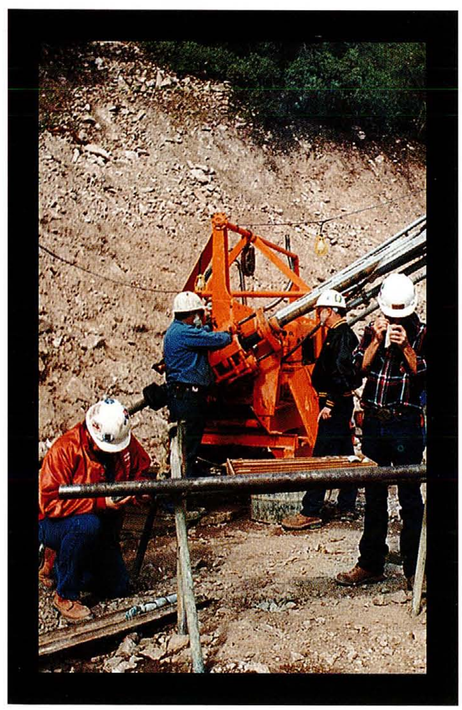
With secondary and tertiary crushers, the concentrators further reduce the size of the rocks and then grind the crushed material in ball mills. After grinding to the consistency of beach sand, the material is introduced to flotation machines where copper-rich particles are separated from the barren particles. The barren material is piped in slurry form to tailing retention dams where cyclones segregate the coarse material from the fine. The coarse material is used to build berms that contain the tailing. Water conservation is a high-priority item at Morenci, so the water that carries the barren material to the tailing retention dams is continuously recycled to the concentrators.

Ore which contains less than one percent copper when mined can be upgraded to about 30 percent copper with this physical process. After being dried to optimum moisture levels with porous ceramic filters, the copper concentrate, a powdery material, is shipped by rail to New Mexico and other locations for smelting. Smelters will melt the copper containing minerals, primarily chalcocite, a copper sulfide, and separate the copper metal from other elements. After smelting, the metallic copper, called "anode," must go through one more "purifying" process before it is ready for the market place. This is accomplished by sending the anodes to a refinery where they are refined into 99.99% pure copper.

A crawler such as is used to move a space shuttle to its launching pad is shown moving one of the two in-pit crushers to its new operating site within the mine.



The Morenci Concentrator is at lower right, the Metcalf Concentrator at the upper left.
Inset: Ball mill and classifier section of Morenci Concentrator.

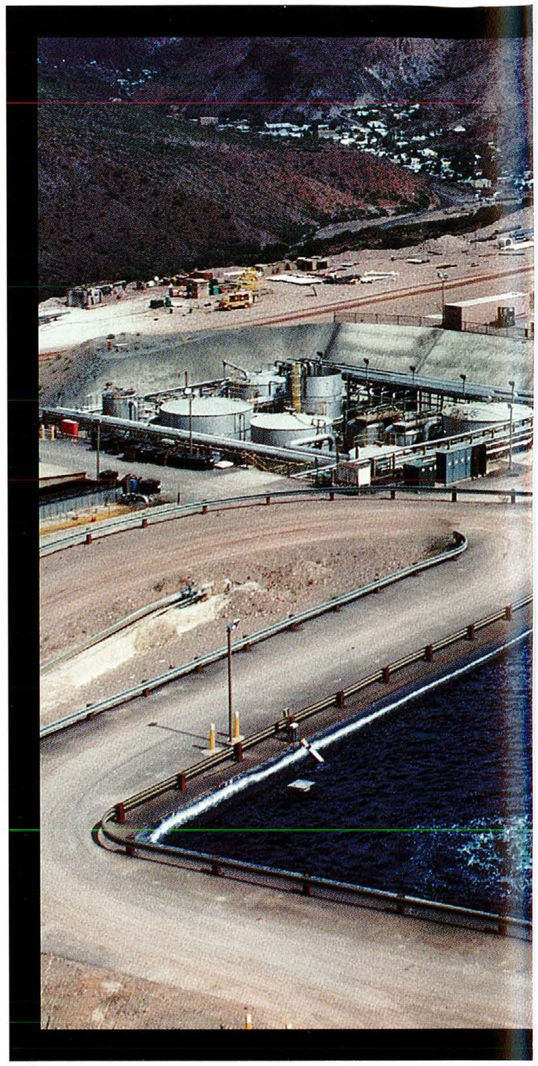


As a first step in finding the ore body, geologists undertake geologic mapping, walking over the outcroppings, noting rock types, ore minerals and the thickness and orientation of veins and faults. Exploration drilling then confirms the location of the ore body.

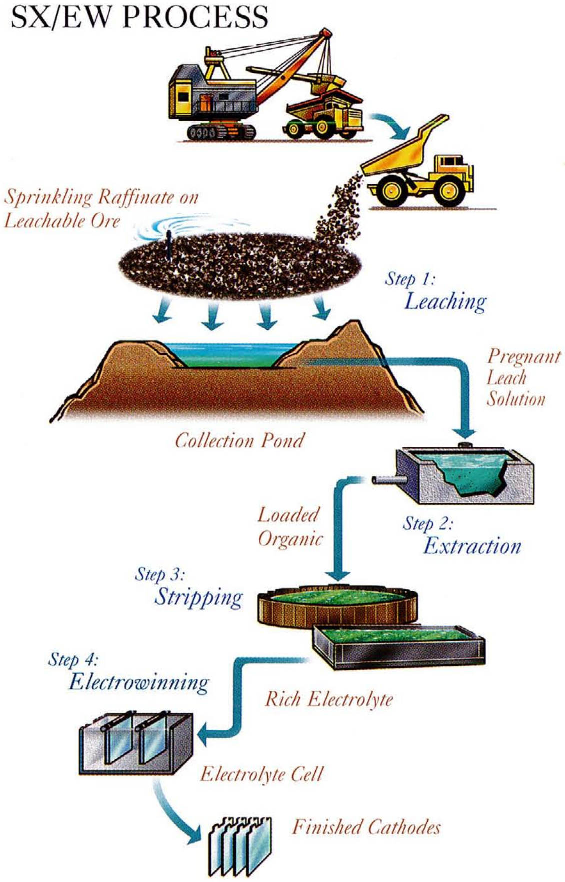
1987 and 99.99% PURE COPPER!

From the time mining began in the Morenci district, copper had been produced from local smelters in the form of ingots and anodes. Large and loaf-like, copper ingots weighed about 200 pounds. Anodes, on the other hand, are in "slab" form and weigh about 750 pounds. For the past several decades, anodes have been the most favored shape. In December 1984, Morenci closed its last operating smelter and began sending its copper concentrates primarily to Phelps Dodge's New Mexico smelters. In 1987 a new process was introduced at Morenci which complements the conventional concentrating process still used at Morenci and which produces copper in still another form. It is 99.99% pure!

The new process is called hydrometallurgical solution extraction/electrowinning (SX/EW) and results in copper cathodes weighing approximately 200 pounds. As shown in the diagram on the next page, the SX/EW process consists of four steps in which three interdependent solution streams transfer the copper from one step to the next.



SX/EW PROCESS

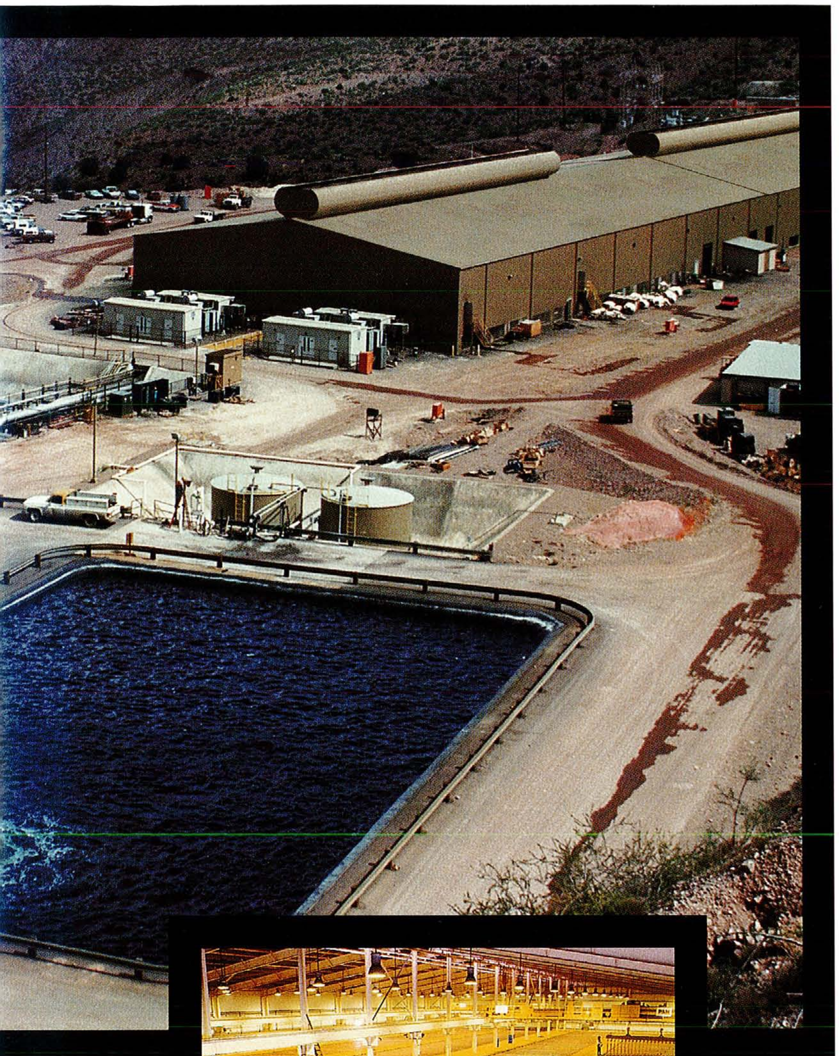


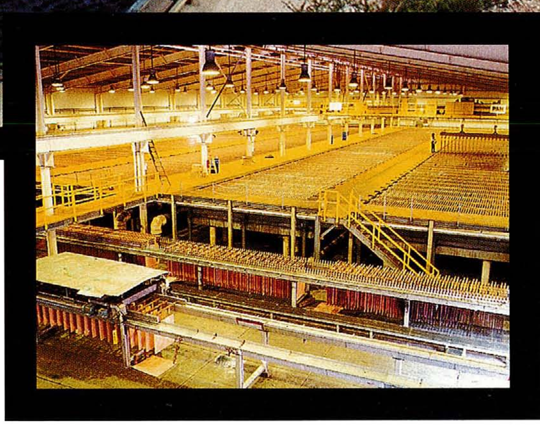
1. LEACHING. In the first step, a slightly acidic water, called "raffinate," is sprinkled on one of the low-grade ore stockpiles. The water percolates through the stockpile, dissolving copper minerals contained in the rock. This copper-laden water, called "pregnant leach solution," exits from the bottom of the stockpile, flows to a collection pond, and is pumped to the tanks at one of the solution extraction plants.

2. EXTRACTION. Now the pregnant leach solution is mixed with a diluent that contains an organic compound specifically designed to extract the copper. After the solutions have been combined for about two minutes, the mixture is allowed to settle.

The pregnant leach solution, which has given up its copper to the organic compound, is the heavier of the two solutions and settles to the bottom becoming raffinate again, where it is pumped back to the top of the stockpile to begin another cycle. The diluent containing the copper-laden organic, now known as "loaded organic," floats to the top of the tank and is pumped to the next section of the solution-extraction plant.

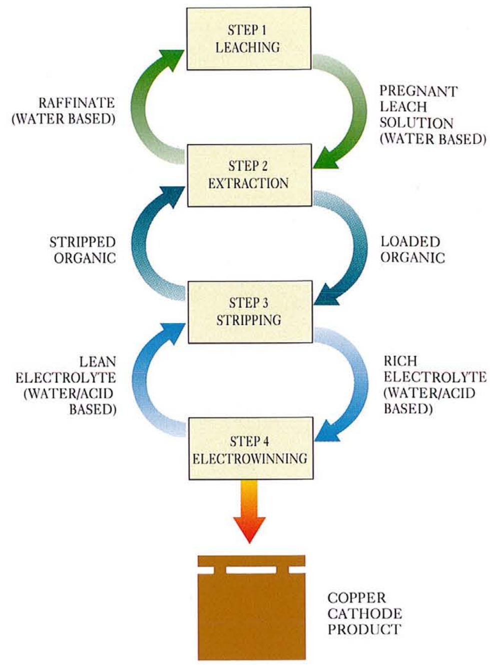
SX/EW Central Site showing tankhouse at upper right and plant feed pond in foreground. Inset: A view inside the tankhouse.





3. STRIPPING. Here the loaded organic is mixed with a sulfuric acid solution called "electrolyte" and the copper migrates from the organic to the electrolyte. The mixed solutions then are allowed to settle. The organic solution that has been "stripped" of its copper ("barren organic") floats to the top and is returned to the extraction step to pick up another load of copper. The electrolyte containing the copper ("rich electrolyte") settles to the bottom and is pumped to the electrowinning tankhouse.

SX/EW PROCESS FLOW DIAGRAM



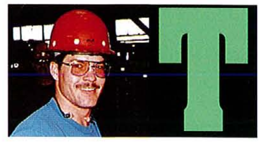
In this process, over 500 million pounds per year of cathode copper will be produced. The cathode copper is transported to one of Phelps Dodge's rod mills or to outside customers to be cast into rod, the next step in its transformation into directly usable consumer products.

4. ELECTROWINNING. In this final step, the rich electrolyte is pumped through a series of tanks or "cells" in the electrowinning tankhouse. Hanging in the tanks are insoluble lead plates, alternating with sheets of copper or stainless steel. Each lead plate serves as the anode pole of an electric circuit. Each cathode pole begins as a thin "starter sheet" of pure copper weighing about 15 pounds, or as a stainless steel "blank." A direct current passes from the anode through the electrolyte, causing the copper ions in the electrolyte solution to plate (attach) onto the cathode.

After seven days in the cell, approximately 200 pounds of 99.99% pure copper plates onto the cathode sheet. At this point, the cathodes are ready for sale or for further processing into other copper products at Phelps Dodge manufacturing plants around the U.S.A. The electrolyte that has passed through the tankhouse is partially depleted of its copper. Now called "lean electrolyte," it is returned to the stripping step of the process to have its copper content upgraded once again.

WE ALL WANT A CLEANER AND BETTER PLANET FOR OUR CHILDREN AND GRANDCHILDREN

A winter wonderland scene on upper Chase Creek.



The term "pay dirt" has a special meaning to miners. It refers to ore that is rich enough and of sufficient quantity to justify mining. But it also means that the miner looks to the land for his livelihood. Literally, his pay comes from the land, and because it does, he has a reverence and affection for the earth.

The miner therefore has a deep felt commitment for the protection of the environment. As an example, a significant engineering feat at Morenci now causes Chase Creek waters to enter the San Francisco River purer than at any time in the millions of years since powerful geologic forces created the great Morenci ore body.

Long before the prospectors of the 1860s noted copper outcroppings in the area and long before an ounce of copper was mined, the waters of Chase Creek contained significant amounts of copper and other minerals. Yet, one of the water quality features of the Morenci operations is a clean-water bypass system that collects Chase Creek waters upstream of the Morenci mineralized area, pipes the water around the mining and leaching operations and discharges it downstream, back into Chase Creek. With the construction of the bypass, for the first time in the 56 million years since the copper deposit was formed at Morenci, the water that flowed down Chase Creek no longer touched the natural copper outcroppings.

The Morenci operations provide still another example of the care taken to protect the environment. The SX/EW component solutions are constantly recycled rather than being discarded.

Surface water quality and ground water quality are protected by a $9 million flood control system that includes a $2 million dam. This structure cuts off both surface and alluvial subsurface flows in Chase Creek which bisects the Morenci mineralized zone. Through a series of deep monitor wells, groundwater quality downstream of the dam is frequently checked on a scheduled basis by a staff of environmental professionals.

During the winter of 1992–93, the flood control systems underwent a test that is unlikely to be exceeded. Rainfall in December 1992 was the second highest in the 40 years of record. This was followed by the wettest January and the fourth wettest February in 41 years. Approximately 233 million gallons of fresh, high-mountain flood waters were bypassed around the Morenci mineralized zone to flow through the town of Clifton in a creek that would then flow toward the Gulf of California. None of the Chase Creek waters that contacted the mineralized zone were allowed to escape the mining area!

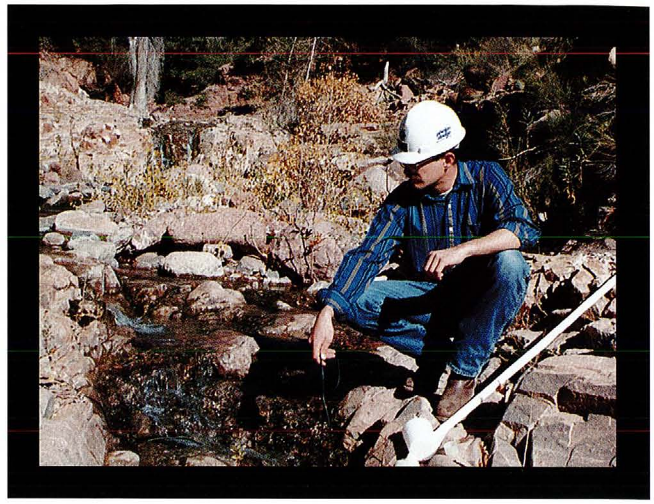
After a field inspection of the Chase Creek flood control system in 1987, the United States Environmental Protection Agency (EPA) wrote, "EPA commends the work and the superb efforts of Phelps

Dodge's staff. EPA officials who visited the Morenci facility were very impressed with the work."

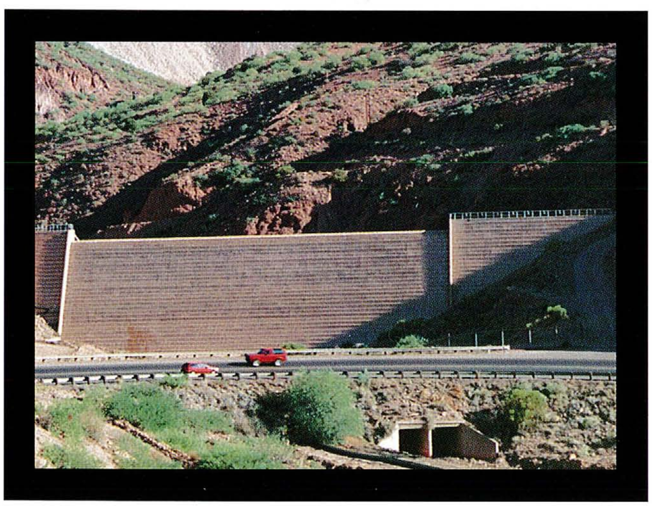
Part of the Phelps dodge Mission Statement reads: "To create and enhance the long-term value for our shareholders and our employees in an environmentally responsible manner as good citizens of the communities in which we live and work." These are examples of how Phelps Dodge Morenci, Inc. strives to meet that mission.

At an annual meeting of the Company's shareholders, Douglas C. Yearley, Chairman of the Board, President and Chief Executive Officer, said, "We are guided by two basic truths at Phelps Dodge. One is that we all want a cleaner and better planet for our children and our grandchildren. The second point is that it just makes good business sense to be environmentally responsible."

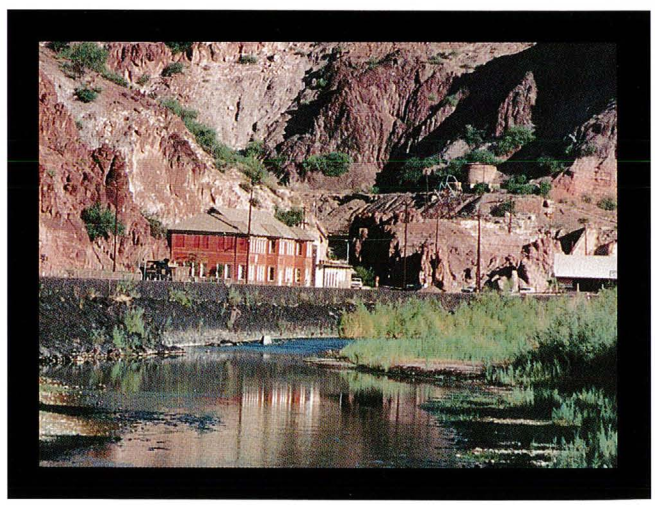
Morenci employees are proud of the fact that they work in one of the most beautiful areas of the nation. They are committed to keeping it that way.



Monitoring water quality in Chase Creek above the Morenci mining complex.



Lower Chase Creek water quality and flood control dam.



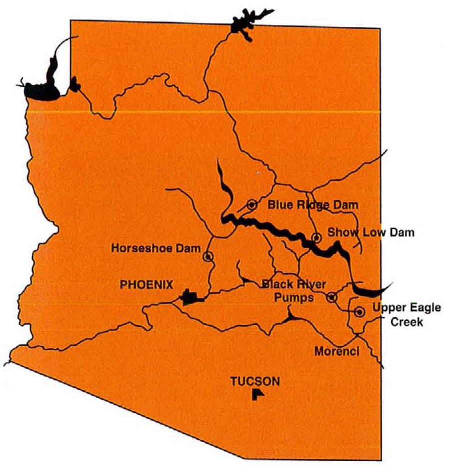
The beautiful San Francisco River in Clifton.

MORENCI'S NEED FOR WATER CREATED NEW ARIZONA LAKES

Copper mining has created a partnership between man and his environment that many of us may miss unless we look beyond merely the metal and the mines. The Morenci water story is a good case in point.

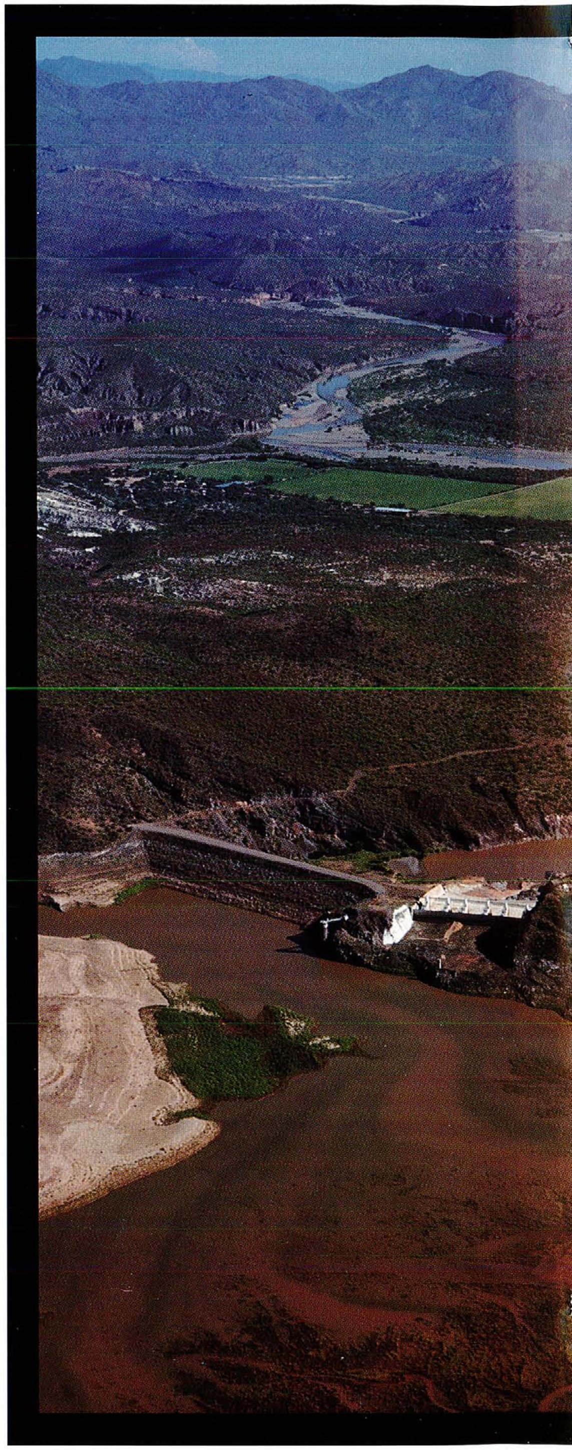
Miners have been careful users of water since the days when water for mining towns was delivered in canvas bags on the backs of burros, when the prospector's life could depend on how much of the precious commodity was left in his canteen. In our arid Southwest, people, farms and industries all need water to exist, and mining is no exception. But while the mines need water to process copper ore, they recycle it rather than consume it as in the case of families and farms.

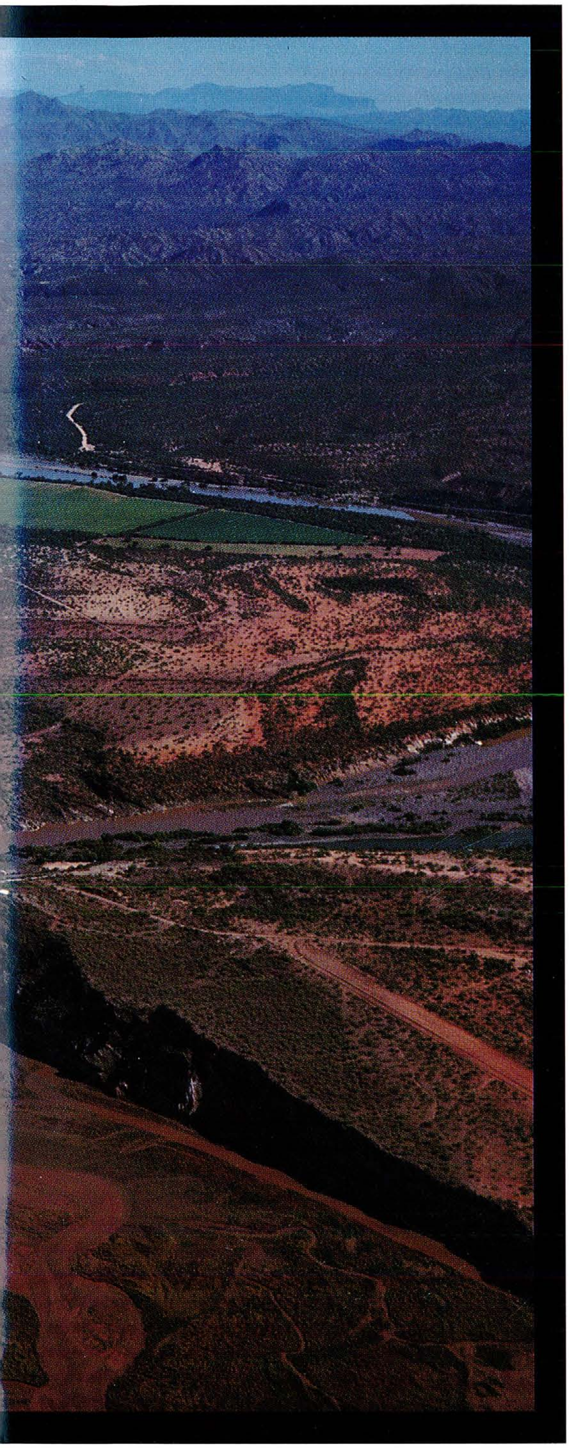
At Morenci, water is reused on average more than three times. While approximately 500 gallons of water is required to treat a ton of copper ore in the concentrators, only 85 gallons is "new" water. The remainder is reclaimed at the concentrate thickeners, tailing thickeners and at the tailing dams.



Originally, when Morenci mining was underground, an adequate supply of water for processing the copper ore was available from Eagle Creek, Chase Creek and the San Francisco River. Getting water to the mines was difficult, but the effort was made and a sufficient supply was assured. Things changed when Morenci began using open pit mining methods in the late 1930s and when World War II copper demand drove the concentrator capacity to 45,000 tons of ore per day. Now a new supply of water was needed, and Phelps Dodge began to look to sources outside the mining district.

What eventually developed was a very complicated system of facilities for collecting, storing, distributing and recycling water required for both domestic and industrial uses at Morenci. These included dams, reservoirs, pumping plants, well fields, pipelines and support facilities located in six different Arizona counties and as far away as 180 miles from the point of the water's ultimate use at Morenci.





Built by Phelps Dodge in the 1940s, Horseshoe Dam on the Verde River provides flood protection and additional stored water for the farms and cities of the Salt River Valley.

Phelps Dodge solved part of the water dilemma with the assistance of the Salt River Project. SRP owned water rights to Black River which flows within 50 miles of Morenci. Remembering how the Verde River had topped Bartlett Dam in 1941 and flooded parts of Phoenix, Phelps Dodge made a proposal to build Horseshoe Dam farther upstream to eliminate the flood danger and to provide additional stored water for the farms and cities of the Salt River Valley. Excess flood waters behind Horseshoe Dam could now be stored and, in return, Phelps Dodge received "credits" to water it could pump from Black River.

As the Morenci mine developed further and a more secure water supply was required, Phelps Dodge built another dam which created Show Low Lake and still another, Blue Ridge Dam on East Clear Creek south of Winslow. Phelps Dodge also explored for and discovered a deep groundwater basin in Upper Eagle Creek 30 miles north of Morenci. A well field was developed there to add another stable supply of water for Morenci.

With foresight and imaginative planning, Phelps Dodge managed to secure a sufficient water supply to support the Morenci operations far into the future. The Morenci program is a monument to the cooperation of the Salt River Project, Show Low Irrigation District, Arizona Fish and Game Commission, U.S. Forest Service and Phelps Dodge.

Morenci's water requirements were met. And what of the partnership between man and his environment? While the miner takes water and ore from the earth, he has returned dams for vital flood control and lakes for everyone to enjoy. As an example, it is conservatively estimated that more than 150,000 people each year are able to enjoy the camping, fishing, boating and other recreational opportunities provided by the lakes which were created by the dams built in Arizona and New Mexico by Phelps Dodge.

And, of course, not to be forgotten in the process is the end result of the miner's labors: Copper, the metal that moves our nation.

MORENCI — SAFEST OPEN PIT MINE IN THE NATION

The Phelps Dodge mine in Morenci was named the safest open pit mine in the nation for the year 1992 when Morenci employees worked more than two million hours without a single lost-time injury.

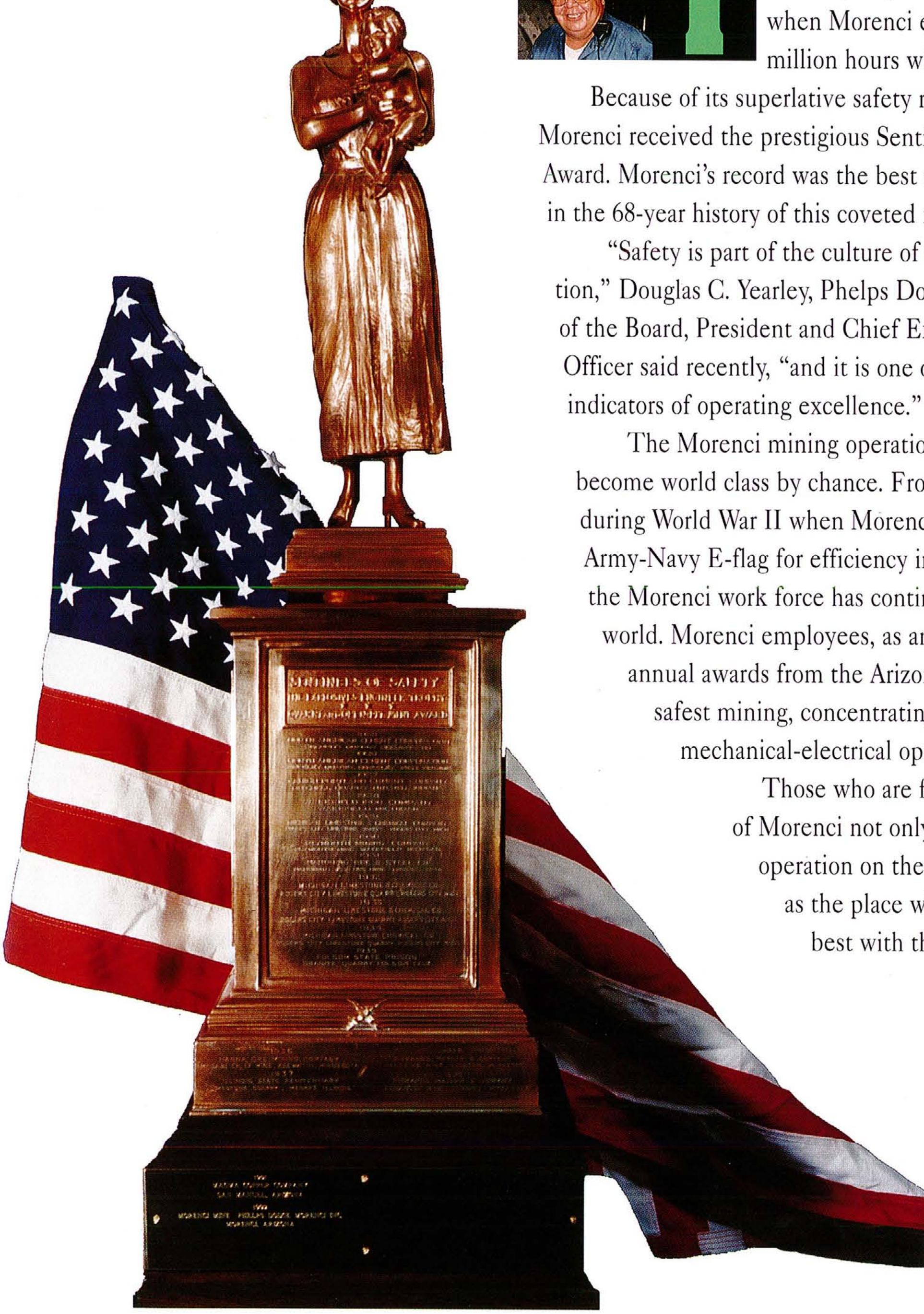
Because of its superlative safety record, Morenci received the prestigious Sentinels of Safety Award. Morenci's record was the best ever achieved in the 68-year history of this coveted national award.

Morenci was awarded the Army-Navy E-flag for excellence for its support of the war effort during World War II.

"Safety is part of the culture of this corporation," Douglas C. Yearley, Phelps Dodge Chairman of the Board, President and Chief Executive Officer said recently, "and it is one of the leading indicators of operating excellence."

The Morenci mining operation did not become world class by chance. From the time during World War II when Morenci employees were awarded the Army-Navy E-flag for efficiency in producing copper to the present, the Morenci work force has continued to set standards for the mining world. Morenci employees, as an example, have repeatedly won annual awards from the Arizona State Mine Inspector for the safest mining, concentrating, hydrometallurgical and mechanical-electrical operations in the state.

Those who are familiar with mining operations think of Morenci not only as the largest copper-producing operation on the North American Continent, but also as the place where you find copper mining at its best with the best!



This trophy, the Sentinels of Safety Award, was presented to Phelps Dodge Morenci, Inc., employees by the Mine Safety and Health Administration and the American Mining Congress in recognition of the Morenci Team's safety achievements. It was designed by the renowned Italian sculptor Begni Del Piatta. The national Sentinels of Safety competition was conceived by President Herbert Hoover, a Mining Engineer, when he was Secretary of Commerce with the Bureau of Mines under his jurisdiction.

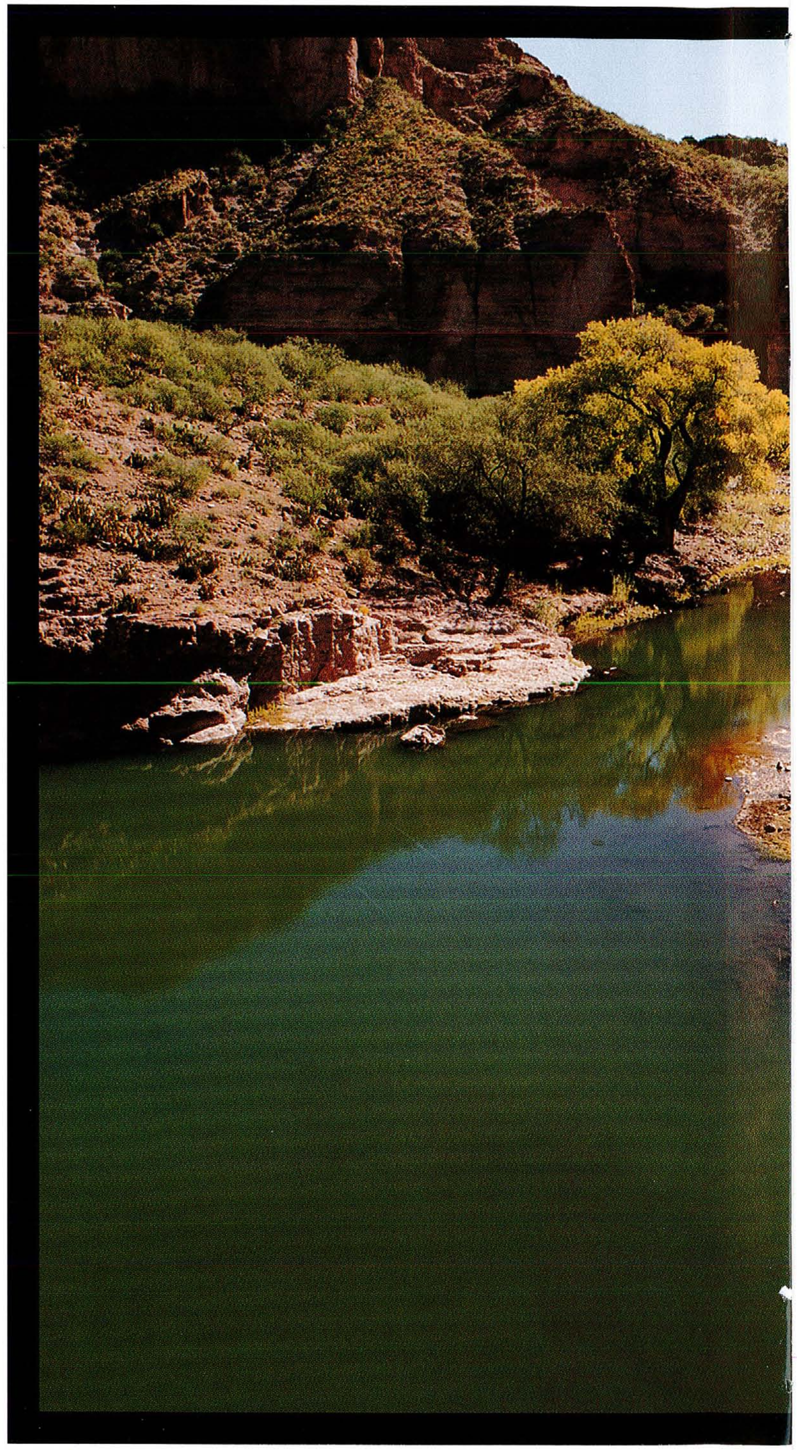
LIFE IN MORENCI HAS BEEN A MOVING EXPERIENCE

The old town of Morenci stood in the way of mining the upper levels of the Morenci open pit. So, in 1965, as the pit expanded southward, a planned relocation of the town site began.

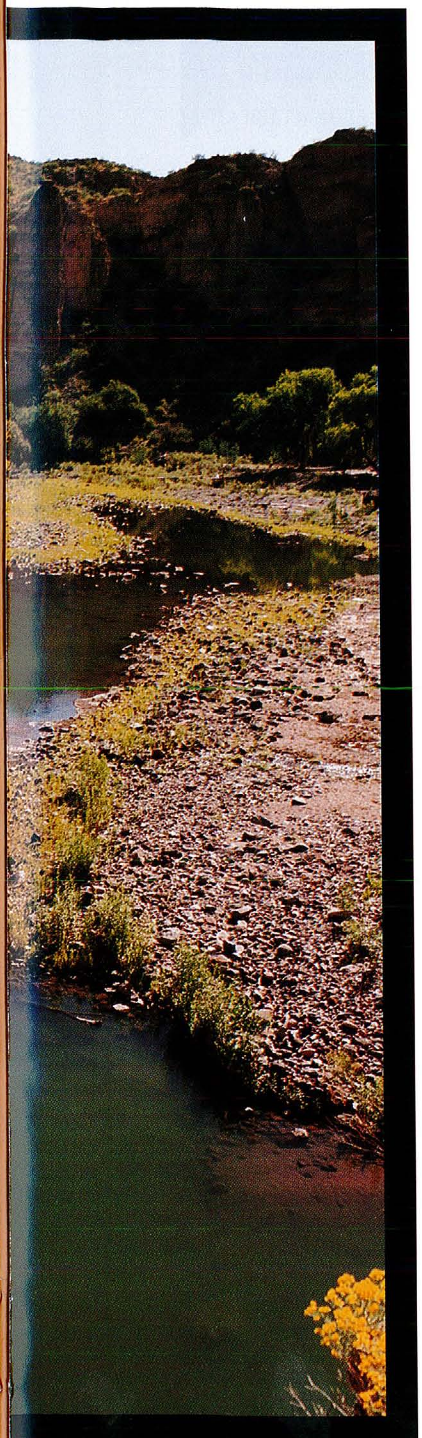
Over the years, old Morenci was systematically dismantled while a new Morenci was created, and by 1982 the move was complete. The new Morenci town site, the commercial plaza and the residential areas are all owned and were constructed by Phelps Dodge. The community of Morenci consists of approximately 1,200 residences, but 550 of the homes actually are located within the incorporated area of the Town of Clifton.

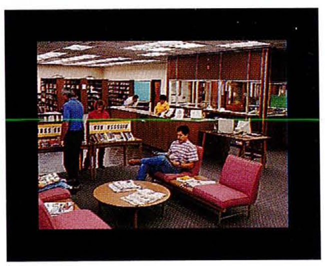
In recent years, much of the old housing has been extensively renovated, and a shopping center was completed. Adjacent to this shopping area is a library, the Morenci Club, a fast food restaurant, swimming pool and recreational area. Nearby, a clinic provides medical services to employees and their families. There is a motel, two apartment complexes and a number of churches. Farther to the south, within the residential area, there is a high school, and middle and elementary school.

Clifton, the county seat for Greenlee County, was incorporated in 1909. The San Francisco River meanders through Clifton while the Gila River runs a course south of Clifton, through the fertile, grass-covered meadows of the Duncan and Safford valleys. These water resources, together with Eagle Creek and the Blue and Black rivers, form local recreation sites. The spec-



Lower Eagle Creek Canyon.





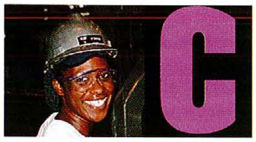
The Morenci town site was constructed in the mid-1960s for the employees of Phelps Dodge Morenci, Inc. It includes a shopping center, motel, restaurants, bowling alley, theater and other retail amenities.

tacular Coronado Trail cuts a path northward through Morenci and the mountains and valleys of the Apache-Sitgreaves National Forest and rises from a height of about 3,500 ft. at Clifton to more than 9,000 ft. at the Mogollon Rim.

Clifton/Morenci residents enjoy a semi-arid climate with an average annual precipitation of 13.04 inches. Average daily maximum temperatures range from a low of 54.2 degrees in December to a high of 94.6 in June, while average daily minimum temperatures range from 35.6 degrees in December to 69.7 degrees in July.

The Clifton/Morenci area provides convenient access to shopping, medical facilities, schools, churches and recreation. Safford, located 45 miles southwest of Clifton, offers an expanded range of service for local residents.

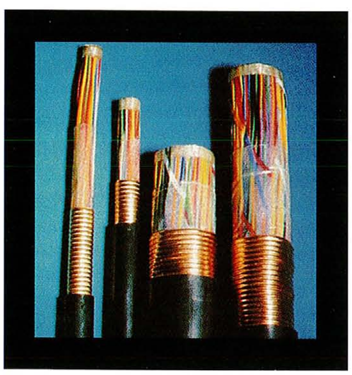
COPPER — THE METAL THAT LIGHTS UP THE WORLD



Copper probably was first widely used in the valleys of the Tigris and Euphrates rivers — around 8700 B.C. With its use came the beginning of western civilization. The Sumerians who invented bronze by alloying copper with tin ... the Egyptians who relied on bronze saws and tools to build the great pyramids ... the Phoenicians who created a mercantile empire by mining copper in Spain and England. For these and other early civilizations, copper was an essential element of their development.

Copper has played a vital role in the growth of our nation. As the United States industrialized, it relied heavily on copper and copper alloys. Copper's most important role — in which it never has been matched — came with the harnessing of electrical energy. Copper has been a virtually indispensable metal for all electrical and electronic products because it is the best practical conductor of heat and electricity, surpassed in conductivity only by silver, which is too costly for most applications.

Copper's unique combination of physical, mechanical and electrical properties make it one of the most versatile of all metals. It can be alloyed with zinc, tin, lead, nickel, aluminum, iron, beryllium, cobalt, phosphorus, silver and gold to produce an endless variety of brasses, bronzes and other alloys with unique properties of their own. Copper and its alloy products can be made soft and ductile so that they are easy to bend, yet hard to break. They also can be made hard and rigid or "springy."



Copper products are found throughout our society.

Copper and copper alloys were used in the plumbing systems of the palace of Cheops in Egypt, dating back at least 5,000 years. The Romans used copper and bronze for valves and fixtures. And today, copper continues to serve us in both familiar and innovative ways. It is essential in generating and distributing electrical power, in modern communications and in transportation. It delivers electricity to our appliances and provides running water and sanitation in our homes.

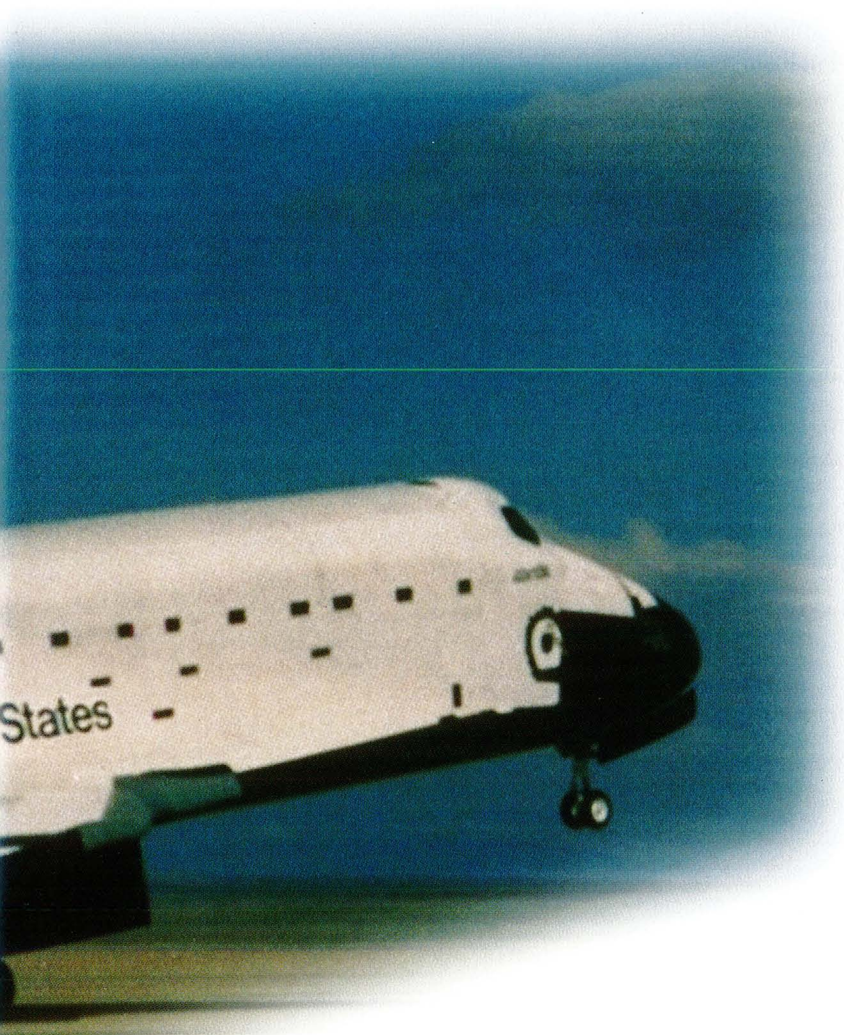
Today, more than ever, there is no substitute for copper. Surprising to many, every man, woman and child in the United States uses 1,750 pounds of copper in their lifetime. Look around. In construction, business, industry and homes you will find copper and copper alloys on the job — lighting up the world!

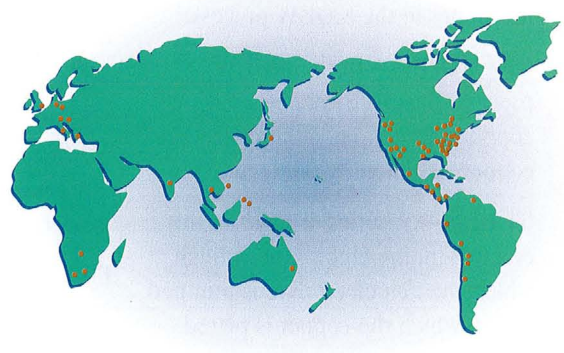
PHELPS DODGE — 56 OPERATIONS IN 25 COUNTRIES WITH OVER 15,000 EMPLOYEES

In its copper mining and industrial manufacturing businesses, Phelps Dodge Corporation employs over 15,000 people who work at 56 operations in 25 countries around the world. Phelps Dodge Mining Company employs more than 6,900 people with operations in five countries. It ranks among the world's largest producers of copper. Approximately 60 percent of the copper produced by Phelps Dodge Mining Company is produced at Morenci. Truly, the Morenci mine is Phelps Dodge Corporation's flagship.

The corporation is also one of the world's largest producers of carbon black, the leading North American fabricator of wheels and rims for medium and heavy trucks, a major manufacturer of magnet wire and specialty conductors, and has operations and investments abroad in mines and wire and cable manufacturing facilities.

Phelps Dodge has been part of the Arizona community since 1881.





Phelps Dodge has operations throughout the world.

GLOSSARY

(Note: The descriptions below are not intended to be full and complete but rather brief explanations of terms as they are used in this brochure.)

ALLUVIUM — Sand, clay, etc. deposited by flowing water, usually along a river bed.

ANFO — Term applied to combination of ammonium nitrate and fuel oil. Explosive used in blasting of ore.

ANODE — At a smelter, a slab-like piece of copper weighing about 750 lbs which has been poured into a mold. In the SX/EW process, the electrical pole to which direct current is applied.

AQUEOUS LEACH SOLUTION — Water-based solution in the hydrometallurgical solution extraction/electrowinning (SX/EW) process.

BABY GAUGE — Railroad tracks only 20 inches apart as compared with the more conventional tracks which are spaced at 56-1/2 inches.

BALL MILL — Rotating cylinder partially filled with steel grinding balls. The balls cascade as the mill rotates, pulverizing the ore.

BARREN ORGANIC — Organic solution which has been stripped of its copper in the SX/EW process.

CATHODE — In the SX/EW process, the electrical pole to which copper ions plate or adhere; also the copper slab thereby produced.

CELLS — A series of tanks in the electrowinning tankhouse through which the rich electrolyte is pumped and in which the copper is plated.

CONCENTRATOR — A plant where barren material is rejected (tails) thus concentrating the copper in the ore.

CRAWLER — One of a pair of an endless chain of plates driven by sprockets and used instead of wheels by certain power shovels, tractors, bulldozers, drilling machines, etc.; also used to move the in-pit crushers.

CYCLONE — A device that separates coarse material from fine material. Used in dust collectors and to segregate feed material at the concentrator and in building tailing dams.

DIPPER — A digging bucket rigidly attached to an arm on an excavating machine; also the machine itself.

ELECTROLYTE — Sulfuric acid solution in the SX/EW process to which the copper flows in the stripping procedure.

ELECTROWINNING — Final step in the SX/EW process in which pure copper is extracted from solution and deposited on cathodes in an electrolytic procedure.

FAULT — In geology, a break in rock strata or veins that causes a section to become dislocated along the lines of the fracture.

FLOTATION — The method of mineral separation in which a froth created in water by a variety of reagents floats some finely crushed mineral, whereas other minerals sink.

HYDROMETALLURGY — The treatment of ores, concentrates and other metal-bearing materials by wet process.

IN-PIT CRUSHER — Machine for crushing rock or other materials, located in an open pit mine.

LEACHING — The removal in solution of the more soluble minerals by percolating waters.

LEAN ELECTROLYTE — Electrolyte that has passed through the tankhouse and is returned to the stripping step.

LOADED ORGANIC — Fluid containing the copper-laden organic compound in the SX/EW process.

OUTCROPPING — The emergence of a mineral from the earth so as to be exposed on the surface of the ground.

PREGNANT LEACH SOLUTION — Copper-laden water in the SX/EW process.

RAFFINATE — A slightly acidic water used in the SX/EW process.

RICH ELECTROLYTE — The electrolyte solution which contains the copper in the SX/EW process.

SHOVEL — Any bucket-equipped machine used for digging and loading rock materials.

STARTER SHEET — Thin sheet of copper or stainless steel which serves as the cathode starting base for the deposit of copper in the electrowinning step of the SX/EW process.

SULFIDE ORE — Ore in which the sulfide minerals predominate.

SX/EW — Abbreviation for the hydrometallurgical solution extraction/electrowinning process — a four-step procedure for the production of 99.99% pure copper.

phelps dodge mining company

Our Mission: To Be The World's Best Mining Company

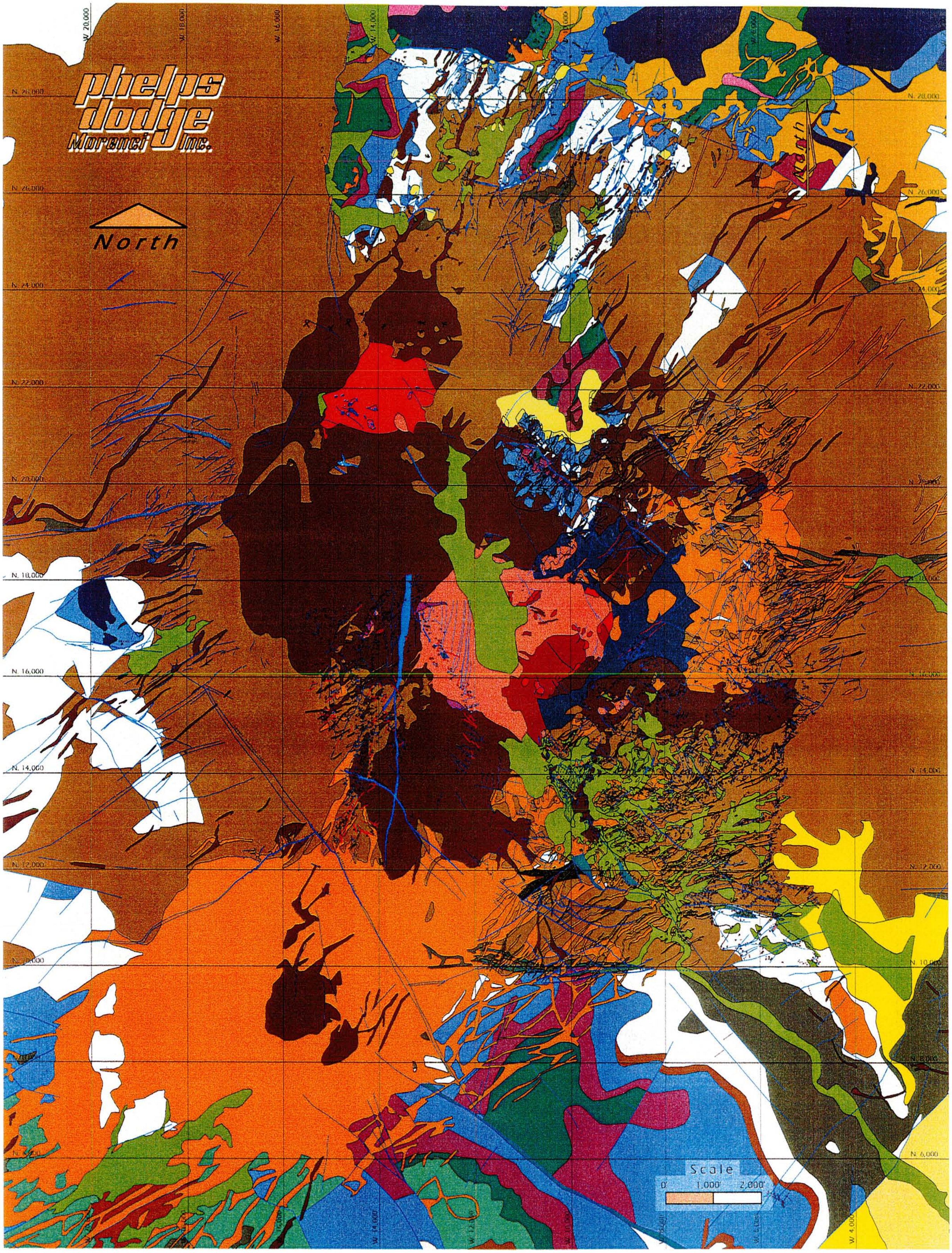
Phelps Dodge Morenci, Inc.
4521 Highway 191
Morenci, AZ 85540

For Tour Information
Call (520) 865-4521

Morenci District
Geology Map
May 2001

Explanation

Stockpiles / Mine Dumps
Quaternary alluvium/talus
Oligocene rhyolite & rhyodacite flows, ash flows/intrusives
Oligocene Andesite and basaltic andesite flows and intrusives
Quartz Matrix breccia
Eocene Rhyolite breccia
Candelaria breccia
Fragmental Older Granite porphyry
Eocene younger granite porphyry
Eocene older granite porphyry 2
Eocene older granite porphyry 1
Eocene Quartz Monzonite porphyry
Eocene diabase
Eocene monzonite porphyry
Eocene dacite porphyry
Paleocene diorite porphyry
Cretaceous Pinkard Formation
Mississippian Modoc Limestone
Devonian Morenci Formation
Ordovician Longfellow Limestone
Cambrian Coronado Quartzite
Precambrian granite
Precambrian granodiorite
Precambrian Pinal Schist

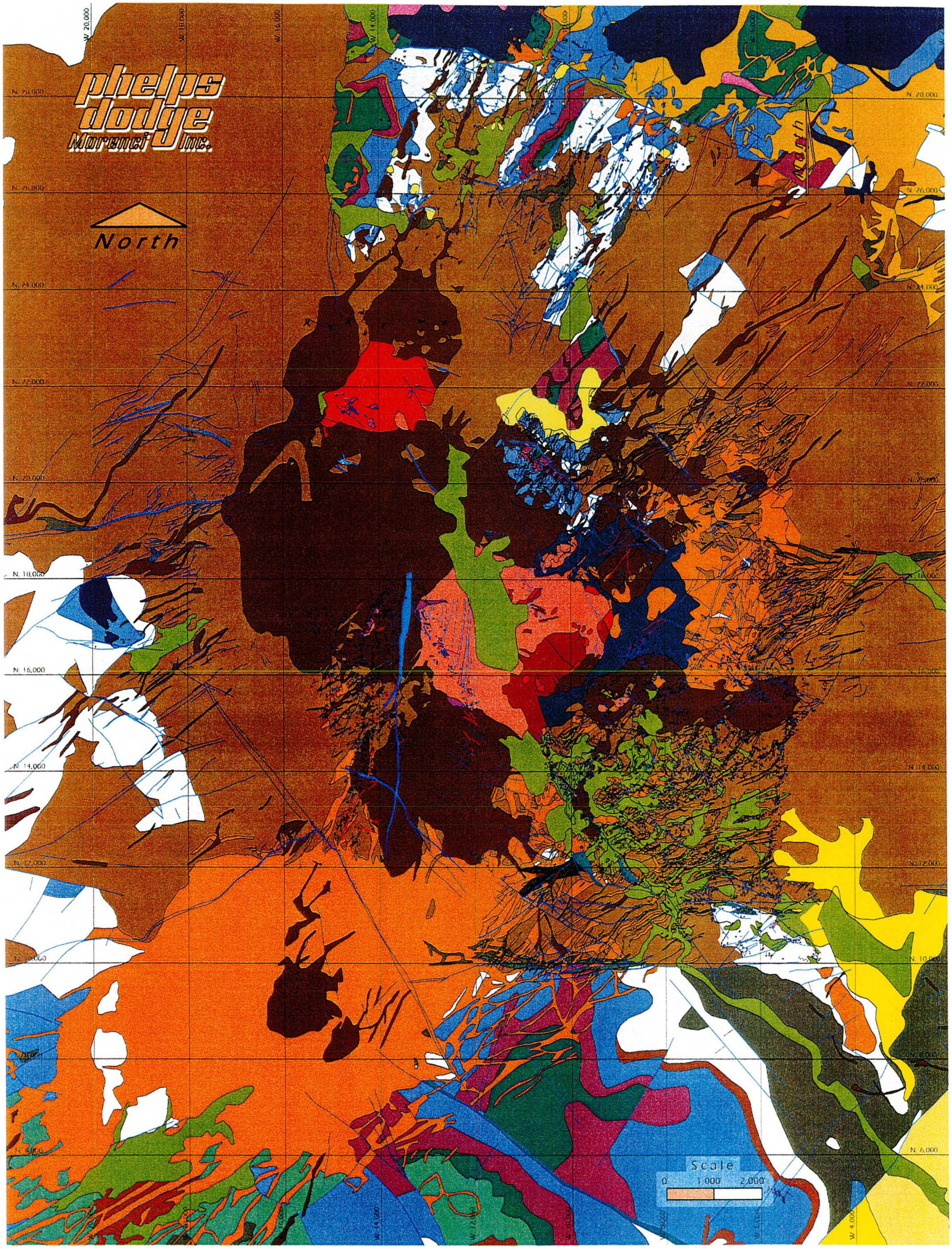


Morenci District
Geology Map

May 2001

Explanation

- Stockpiles / Mine Dumps
- Quaternary alluvium/talus
- Oligocene rhyolite & rhyodacite flows, ash flows/intrusives
- Oligocene Andesite and basaltic andesite flows and intrusives
- Quartz Matrix breccia
- Eocene Rhyolite breccia
- Candelaria breccia
- Fragmental Older Granite porphyry
- Eocene younger granite porphyry
- Eocene older granite porphyry 2
- Eocene older granite porphyry 1
- Eocene Quartz Monzonite porphyry
- Eocene diabase
- Eocene monzonite porphyry
- Eocene dacite porphyry
- Paleocene diorite porphyry
- Cretaceous Pinkard Formation
- Mississippian Modoc Limestone
- Devonian Morenci Formation
- Ordovician Longfellow Limestone
- Cambrian Coronado Quartzite
- Precambrian granite
- Precambrian granodiorite
- Precambrian Pinal Schist



Morenci District
Geology Map

May 2001

Explanation

- Qal — Stockpiles / Mine Dumps
- Qal — Quaternary alluvium/talus
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- Tbc — Candelaria breccia
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- Eocene Quartz Monzonite porphyry
- Db — Eocene diabase
- Mo — Eocene monzonite porphyry
- Dpg — Eocene dacite porphyry
- Paleocene diorite porphyry
- Cretaceous Pinkard Formation
- Mississippian Modoc Limestone
- Devonian Morenci Formation
- Ol — Ordovician Longfellow Limestone
- Cambrian Coronado Quartzite
- Precambrian granite
- Precambrian granodiorite
- Precambrian Pinal Schist

Arizona Conference of SME
Geology Division – 2001 Spring Meeting
Hosted by Phelps Dodge Morenci, Inc.
Morenci, Arizona 85540

Agenda

<u>Saturday – May 19</u>

8:00 am – 9:00 am	Registration	
9:00 am – 10:30 am	Welcome and Opening Remarks	Steve Enders – VP MineSite Exploration
	Overview of Morenci Operations	David Travis-Manager Resource Management
	Geology Overview of the Morenci Mining District	Ralph Stegen-Chief Geologist Geological Services
10:30 am – 3:30 pm	Tour of Mine/Facilities	
	Tour stops include:	
10:45 am – 11:05 am	Morenci Open Pit-Overview of district geography-mining and stockpile areas.	
11:20 am–12:20 pm (5150) Bathroom Break 12:30 pm–1:00 pm (drop cut)	Metcalf Open Pit-Leached capping traverse, enrichment blanket traverse, discussion and overview of applied geology techniques for daily mining operations.	
1:00 pm – 1:45 pm	Lunch-Sack lunches will be provided in the field. *We will eat on the bus in route to Coronado*	
1:45 pm – 2:15 pm	Coronado Open Pit-History, exploration techniques, development techniques, copper oxide traverse.	
2:30 pm – 3:00 pm	Southside Open Pit-Hypogene traverse, cal-silicate skarn traverse.	
3:10 pm – 3:30 (ish) pm	Stacking Conveyors-Overview of conversion to mine for leach.	
4:30 pm – 6:30 pm	"Tailgate Geology" and Social Hour – Morenci Motel Sports Bar	

Safety glasses, hard hats, closed toed shoes, long pants and a shirt which covers the shoulders are required for the tour.

GEOLOGY OF THE MORENCI MINING DISTRICT: THE REGIONAL CONTEXT

Mary A. Walker & Michael R. Pawlowski
Phelps Dodge Morenci, Inc.
Morenci, AZ 85540

The Morenci mining district, containing the Morenci, Metcalf, and Northwest Extension deposits, is currently the largest copper-producing district in the United States. This porphyry copper district is located in the transitional zone between the Colorado Plateau and the Basin and Range physiographic provinces. Geologic events have affected the area since Precambrian time, as is typical of most regions in the Southwest. The region is now an intricately faulted plateau with sedimentary, intrusive, and extrusive rocks exposed throughout the district, ranging in age from Precambrian to Recent.

Precambrian outcrops consisting of schist, granite and granodiorite are overlain by a series of Paleozoic sedimentary rocks that reflect the transgression and regression of Paleozoic seas onto the continent. These seas were formed in response to changing tectonic regimes that affected western North American throughout the Paleozoic. The uppermost Paleozoic sedimentary sequence is early Mississippian and is disconformably overlain by lower Cretaceous sandstones and shales, reflecting a continental transgression by seas during the late Mesozoic. The stratified formations in the Morenci district can be correlated with Paleozoic and Mesozoic formations in Arizona and New Mexico. These regional correlations provide a framework through which the local district evolution can be evaluated.

The first significant post-Precambrian hypabyssal igneous rocks in the Morenci district are late Paleocene to early Eocene. These rocks were emplaced during the tectonic event generally defined as the Laramide Orogeny. The Laramide stocks, laccoliths, and associated dikes and sills are primarily porphyritic and have age dates ranging from 65 to 52 m.y.a. The intrusive rocks are a comagmatic calc-alkaline series with diorite porphyry, monzonite porphyry, and older granite porphyry being the principal intrusives associated with hydrothermal alteration and mineralization. A post-mineralization granite porphyry occurs in the central portion of the district and is characterized by the absence of stockwork veining. Diabase dikes are also present in the district that crosscut the monzonite porphyry and are intruded by or as xenoliths in older granite porphyry. Large uplifts and subsequent erosion occurred throughout this region from the early Eocene through the early Oligocene. Evidence from stratigraphic relations in the Baca Basin to the north, as well as characteristics of the supergene enrichment blanket at Morenci suggest that the region was a positive area during this time.

Weathering and erosion of this region ceased in the early Oligocene with the eruption of the Mogollon and Bursum Calderas, two large volcanic centers located to the northeast. Today, the areas west, north and east of the district are covered by Oligocene (32-26 m.y.a.) and early Miocene (18 m.y.a.) volcanic rocks. The volcanic series includes rhyolites, basalts, andesites, rhyolite tuffs, and perlites with thicknesses of over 460 meters. A mid- to late-Miocene regional tilt of 10 to 18 degrees to the northwest is reflected in the surrounding volcanic units. The district is also bounded on the south by a Pliocene tuffaceous conglomerate and related clastics generally referred to as the Gila conglomerate. This conglomerate records a new episode of weathering and erosion that occurred throughout this region. Stream incision and rapid erosion along the San Francisco and Gila rivers began in the Pleistocene.

Structural characteristics within the Morenci district reflect various stress regimes that have affected the southwestern North American continent. The Transition zone physiographic province, in which the Morenci district lies, is distinguished by plateau-like uplifts, monoclines, and basement uplifts associated with the Laramide Orogeny and major late Cenozoic, 20 to 10 m.y.a., normal faults similar to those found in the Basin and Range province. Generally, structural trends in this district reflect the influence of these two tectonic events.

Structural evidence suggests that relative stability prevailed in the Morenci area throughout much of the Paleozoic and Mesozoic. The first marked disruption of the stratified formations occurred at the time of the intrusive porphyries. A distinctive strike maxima for intrusive contacts, veins, and faults occurs at N20E to N40E throughout the district. This is a common late-Laramide trend throughout southwestern North America. A predominantly west- to northwest-striking fault pattern cuts and offsets the earlier northeast-trending Laramide structures and is associated with the late Cenozoic Basin and Range faulting. New studies propose the influence of a major regional fault zone, trending N30E, called the Morenci-Reserve fault zone. The fault zone includes the San Francisco-Malpais horst, Pinal-Malpais graben, and the Pinal-Eagle Creek horst that appears to be associated with the development of the second episode of enrichment and Pleistocene erosion.

LARAMIDE INTRUSIVE COMPLEX OF THE MORENCI DISTRICT, GREENLEE COUNTY, ARIZONA

J. B. Griffin, J. A. Ring, R. E. Lowery
Phelps Dodge Morenci, Inc.
Morenci, AZ, 85540

The Morenci district was intruded by a series of Early Tertiary calc-alkaline hypabyssal intrusive rocks, ranging in composition from diorite to monzonite and granite. These rocks host, to varying degrees, control hydrothermal alteration, mineralization, and breccias.

The first Laramide intrusion was a cluster of hornblende diorite porphyry stocks and radiating dikes intruding Cretaceous sediments southwest of the mine. Potassium-argon age dates on hornblende yield 64.7 ± 2.0 and 63.0 ± 1.9 mya for the intrusion. The mineralogy of the gray-mottled diorite porphyry includes large plagioclase and hornblende phenocrysts with subordinate quartz and biotite. The oscillatory-zoned plagioclase phenocrysts range in the labradorite cores from An 52 to An 58 and with rims from labradorite (An 57) to andesine (An 34). Potassium feldspar has only been identified in the matrix. The microcrystalline groundmass also contains plagioclase and altered fine-grained mafic minerals. Alteration and mineralization are not well developed and the diorite porphyry is interpreted as pre main-stage hydrothermal mineralization. The modal and normative compositions are diorite.

An elongate monzonite porphyry stock and dike-swarm complex intrudes the diorite porphyry and older rocks two to three miles north-northeast of the center of the diorite porphyry. The 4-mile long, northeast-trending monzonite porphyry stock is centered across the southwest quadrant of the Morenci ore deposit. Dike swarms extend out from the stock to the southwest and northeast along strike about 4 miles in each direction. The orientation of the monzonite porphyry dikes are conformable with the most common regional Laramide orientation reported by Heidrick and Titley(1982). A K-Ar date from biotite gives 56.5 ± 1.7 mya. The gray to tan porphyry is composed of crowded phenocrysts of feldspar and subordinate variable amounts of biotite in a microcrystalline groundmass of feldspar and quartz. Hydrothermal and supergene alteration associated with main-stage mineralization obscures the original texture and chemistry of most of the rock. Unaltered feldspar phenocrysts are unzoned andesine to oligoclase. Quartz is usually found in the matrix but some locations grade into a quartz monzonite porphyry which contains small quartz phenocrysts. Orthoclase also tends to be confined to the fine-grained matrix. Normative calculations of weakly-altered porphyry indicate a composition ranging from granodiorite through quartz monzonite. Modal analysis indicate compositions of tonalite and granodiorite.

Diabase and sub-ophitic gabbro dikes are intruded along east-west faults that have strike lengths of up to three miles, but comprise less than three percent of the volume of the rock in the district. Sills of diabase also occur in one location at the northern periphery of the district. Continuous zones ten to one hundred feet wide comprise subparallel bifurcating dikes combining with faults. The faults intruded by the diabase are major fissures with apparent displacements of several hundred feet. A significant portion of the diabase is comminuted by movement on the faults and results in a green or red-brown, crumbly outcrop in contrast to massive black fresh outcrops. The diabase has not been dated but field relationships show it cuts monzonite porphyry and is cut by later porphyritic rocks. The diabase and the rock it intrudes are locally very strongly mineralized. The weakly mineralized diabase dikes extending away from the district center are composed of augite, labradorite, and hornblende, which are most commonly altered to chlorite, epidote, and magnetite.

The diabase intrusion indicates the importance of the orientation of the local pre-existing fractures. The east-west orientation is a subordinate trend in the Morenci dike and vein orientation pattern as it is at many other Laramide intrusions. The fact that these are major fractures with much greater length and displacement than others may be reflecting a local basement fabric. Local stresses displacing basement structures that reach less differentiated magma may have caused the diabase injection.

The Morenci breccia is hosted by Precambrian granite and a high-biotite zone of the monzonite porphyry and is located north of the diabase dikes in the Morenci pit. This breccia body is a 250-foot by 1600-foot long lens that is 75 to 200 feet thick and plunges about 25 degrees to the north away from the diabase dikes toward the older granite porphyry stock. The breccia is composed of fragments of biotitic monzonite porphyry, diabase, Precambrian granite, and aplite. The matrix is composed of quartz, potassium feldspar, biotite, and rock flour. Rock fragments in this breccia are veined and mineralized, and some later veins also cut the matrix.

A quartz-bearing intrusive complex centered overlapping the northeast edge of the monzonite porphyry stock consists of two granite porphyries that are older than the main-stage mineralization. The complex also includes two porphyries and three breccias that are younger than main-stage mineralization. The intrusive complex is elongate in a north 20 degree east orientation. Dike swarms and apophyses of small stocks and plugs strike from north 20 east to east-west, with the majority of the dikes striking north 40 to 50 east. Intrusion of the complex is less dominated by the regional stress field orientations as the intrusions become younger in age. Evidence for this is the increase in local plugs, stocks, and breccias and the varied orientation of the dikes and apophyses.

The pre main-stage intrusions are referred to as older granite porphyry 1 (ogp1) and 2 (ogp2). The older granite porphyry 1 has been dated at 57.6 ± 2.2 mya. This intrusion is dominated by small plugs and dike swarms. The gray to tan porphyry is characterized by small (less than 4 mm) subhedral quartz phenocrysts and crowded rectangular feldspar phenocrysts less than 4 to 6 mm in diameter. Petrographic examination of the feldspar indicates andesine composition. The aphanitic groundmass consists of albitic plagioclase, quartz, and orthoclase. The normative composition of the granite porphyry is alkali granite. Modal composition of altered rock is granodiorite to quartz monzonite. The ogp2 is intruded as a stock complex with brecciation on its eastern margin. This intrusion is characterized by large (5 to 10 mm) and abundant (7 to 10 percent) bipyramidal quartz phenocrysts and matrix support of the feldspar phenocrysts. The contacts between ogp2 and ogp1 are both intrusive and transitional. This is the last intrusion affected by main-stage alteration and mineralization.

Following the older granite porphyries an unmineralized explosive breccia, the Candelaria breccia, developed in the northern-most Morenci area. Prior to dumping, the breccia was exposed over an area of 2700 feet in an east-west direction and 1900 feet in a north south direction. Contact orientations and drill data indicate a funnel shape for the breccia. A K-Ar date on sericite gives 52.8 ± 2.0 mya. Fragments within the breccia are predominately Precambrian granite and older granite porphyry with less quartz, aplite, and Pinal schist. The matrix consists of sericite, quartz, open spaces, and specularite. Following a quiescence, the Candelaria breccia was intruded by rhyolite dikes and plugs.

The younger granite porphyry and younger rhyolite porphyry complex are the last major intrusions in the district. No unaltered material has been recovered for age dating, however, field relationships indicate an age younger than mineralization. Both intrusions form a laccolithic-shaped plug near the middle of the older granite porphyry stock. The plug is approximately 4700 feet in diameter with its root steeply dipping to the north-northwest.

The greenish-gray younger granite porphyry is composed of unzoned, euhedral plagioclase phenocrysts and large (5-10mm) bipyramidal quartz phenocrysts with subordinate k-feldspar, and biotite altering to chlorite. The porcelean-like matrix consists of quartz, feldspar, and sericite. In contrast the younger rhyolite porphyry is light-gray to gray and displays nearly equigranular, shardy and broken phenocrysts of quartz and plagioclase in a very fine-grained matrix of quartz, plagioclase, and sericite.

The Metcalf breccia formed contemporaneously with the younger rhyolite intrusion. The breccia developed as the younger intrusives migrated into the older granite porphyry stock and forms a rind along the margins of the laccolith. Fragments contained in the breccia are predominantly older granite porphyry with subordinate younger granite porphyry, Precambrian granite, quartz, and monzonite porphyry. The matrix is similar to the younger rhyolite porphyry and commonly displays flow-banding around fragments.

A second intrusive breccia also associated with the younger porphyries is the King breccia. Located near the southeastern edge of the younger granite porphyry plug the breccia forms a near cylindrical pipe between the older porphyries and the younger intrusives. The breccia is exposed over an area of approximately 300 feet by 500 feet at its greatest lengths. The clast-supported fragments are predominantly older granite porphyry with subordinate Precambrian granite, monzonite porphyry, quartz vein fragments, and younger granite porphyry. The matrix is predominately rhyolite and rock flour with minor open spaces.

Several notable trends are recognized in the study of the Laramide intrusive rocks of Morenci. These include the calc-alkaline differentiation trend of the intrusions that is suggestive of a common magma source for all intrusions. The progression from a regionally dominated stress field to a stress field dominated by local magma bodies. And finally the migration of the intrusive center 5 miles northeast along an arcuate north 40 to 20 degree east trend over approximately 13 million years.

HYDROTHERMAL ALTERATION AND MINERALIZATION OF THE MORENCI PORPHYRY COPPER DEPOSIT, GREENLEE COUNTY, ARIZONA

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Hydrothermal alteration and mineralization is associated in time and space with an intrusive complex composed of several distinct biotite granodiorite to granite porphyry stocks and dikes, as discussed earlier (Ring, et. al., 1993). Adjacent to the intrusives, Cu-Fe-Zn skarns occur in Paleozoic sediments, while Precambrian granite and granodiorite host Cu-Mo stockwork mineralization. Although the geometry of known ore-grade mineralization in the Morenci district is demonstrably due to low-temperature copper redistribution during the Eocene to Miocene, the style and intensity of hydrothermal silicate and sulfide alteration assemblages had a major impact on the efficiency of supergene processes. Because of the textural destruction attending pervasive hydrothermal phyllic and supergene argillic alteration, study of hydrothermal alteration is difficult, requiring detailed and time-consuming examination of outcrops and core. Most of the data developed in this talk was gathered during routine mapping and core-logging within the pit areas.

Crosscutting relationships indicate that temporal variations of intrusive-hosted vein assemblages are essentially identical district-wide. Earliest veins are generally composed of quartz ± Kfeldspar, although these are locally preceded by biotite + magnetite veins in the more mafic Precambrian and Laramide intrusives. Where present, quartz + molybdenite veins cut the potassic assemblage veins. The preceding vein sets are collectively termed early veins, and are generally restricted to the vicinity of the causative porphyries, exhibit variable vein orientations, and limited wallrock alteration. Sphene, rutile, and apatite are common accessory minerals. Carbonates may also be present in quartz + Kfeldspar veins that were intercepted in deep drill holes.

The main stage of mineralization consists of multiple generations of quartz + sericite + pyrite ± chalcopyrite stockwork veins. These are associated with intensive wallrock alteration, more uniform NE and ENE strike orientations, and occur throughout the district, often being the only vein assemblage. Two distinctive types of quartz + sericite + sulfide veining have been recognized, and generally occur in mutually exclusive spatial domains: pyrite-rich, and chalcopyrite-rich.

Hypogene protore throughout most of the district averages 0.10-0.15% Cu and 4-7 wt. % pyrite, and is accompanied by intense sericitization (i.e., classic phyllic alteration). Veins are generally less than 5 mm thick, and consist predominately of pyrite and generally subordinate quartz. Vein-controlled alteration halos, typically 5 to 20 mm thick, are composed of felted mats of quartz + sericite + pyrite that obliterate primary textures. Chalcopyrite occurs as blebs in pyrite and as discrete grains in veins and halos. Pyrite + chalcopyrite microfractures without silicate alteration halos commonly occur, cutting the larger sericite veins.

Chalcopyrite-rich quartz + sericite veins occur in zones of +0.3% Cu as chalcopyrite ± bornite that average approximately 0.6% Cu. Total sulfide contents are approximately 2 - 3 wt. %, with chalcopyrite to pyrite ratios generally greater than 1. The largest of these higher-grade zones is localized along the southeastern to northeastern contact zone of the monzonite porphyry stock. Smaller, erratic zones of higher-grade chalcopyrite mineralization also occur along the margins of the older granite porphyry. Typically 5 to 10 mm thick, the veins are composed of quartz + sulfides, and they cross-cut earlier potassic and molybdenite veins. Although Kfeldspar and green biotite are observed as paragenetically early phase in these veins, sericite was deposited with sulfides and occurs in alteration halos.

Large, through-going quartz + sulfide fissure-veins appear to be the latest hydrothermal event and exhibit district-wide NE strikes. Vein widths are 10 cm to over 1 m, with individual strike lengths on the order of hundreds of meters. Geochemical analyses and polished section microscopy have indicated that fissure-veins often contain relatively high-grade Cu-Zn-Au-Ag mineralization, in addition to the ubiquitous quartz + pyrite.

Peripheral alteration has not been well characterized, consisting of chlorite + epidote and scattered quartz + sericite veinlets. Base and precious metal mineralization is locallized by large (1 - 5m) through-going quartz veins, many of which were exploited by early underground miners.

Cu-Zn sulfide ± magnetite mineralization occurs in skarns formed from Paleozoic limestones and shales adjacent to the monzonite and granite porphyry stocks. Mineralization in the skarns is predominately vein-controlled, with only minor amounts of massive replacement bodies. Large volumes of ore-grade copper mineralization did not occur in the skarns, although early underground production was from high-grade supergene ore hosted by skarns. Mineralogical relations in the contact aureoles define two principal stages of skarn development. An early anhydrous stage is accompanied by trace amounts of sulfides and magnetite, and is characterized by diopside in shales and interbedded silty limestones, and by garnet in limestone. A later hydrous stage dramatically affected the anhydrous minerals, forming veinlet-controlled and massive assemblages consisting principally of actinolite, tremolite, chlorite, epidote, and calcite. Actinolite + tremolite alteration of diopside commonly forms as thin halos of sulfide + magnetite veinlets, but also completely replaces the pyroxene. Epidote occurs as discrete rims on garnet cores, as zones of monomineralic replacement bodies, and less commonly as veinlets in actinolite + tremolite. Pyrite, chalcopyrite, and magnetite, with accessory sphalerite and bornite occur in veinlets generally associated with hydrous assemblages minerals. Massive sulfides occur along dike contacts and as replacement bodies localized along distinct lithologic contacts. Magnetite also forms large replacement bodies in limestone in the vicinity of dike contacts, and are locally extensive. Peripheral alteration of limestones include both weakly developed calc-silicate skarn alteration associated with base metal mineralization, and as jasperoid alteration that accompanies Ag-Mn mineralization.

Structural orientations of individual vein sets present evidence of a systematic change in stress fields during evolution of the hydrothermal system. Porphyry dikes exhibit district-wide northeasterly high angle contacts that are similar to orientations observed in other porphyry copper deposits throughout the southwest United States. Early barren potassic and molybdenite-bearing veins show low-angle dips and preferred orientations that vary from place to place within the district. Main-stage sulfide stockwork veinlets are generally high angle, and exhibit weakly preferred ENE to NE strikes that are observed throughout the district. Late fissure veins show strongly preferred NE-striking high-angle orientations that are nearly identical to the dike contact orientations. These relationships are interpreted to indicate that initial porphyry emplacement was guided by cracks propagated in a regional stress field. Early stockwork veinlets, however, occurred at a time when the stress field was dominated by localized stresses thought to be due to the cooling of the intrusives. With time, stresses accompanying magmatic processes were less important, and the stress field under which sulfide deposition occurred was dominated by regional stresses.

A reconnaissance fluid inclusion study has been conducted to determine fluid characteristics of the major vein types. Quartz + Kfeldspar, quartz + molybdenite, and quartz + sericite + pyrite vein samples from both the monzonite porphyry and the older granite porphyry have been studied. Additional studies have been made on a chalcopyrite-rich quarz + sericite vein in Precambrian granite and an epithermal quartz + Ag + Mn vein hosted by Ordovician limestone. No differences were seen in the fluid populations of the first group of samples when discriminated by rock type. However, a systematic progression of fluid characteristics was observed through time.

Early quartz + Kfeldspar veins contain halite-bearing fluid inclusions that homogenized by vapor disappearance, some of which had ferric chloride daughter products (Th = 250-310°C; salinity = 30-35 wt.% NaCl equiv.). Late quartz ± Kfeldspar veins contained halite-bearing inclusions approximated by the $NaCl-H_2O$ system that homogenized by dissolution of halite (Th = 320-360°C; salinity = 39-43 wt.% NaCl equiv.). In addition, coexisting liquid- and vapor-rich, two-phase inclusions provide evidence of low salinity fluids that boiled at 375 and at 400-450°C, indicating pressures of 210 and 260-360 bars, respectively.

Inclusions in quartz + molybdenite veins are predominately low-salinity (2 - 10 wt.% NaCl equiv.), liquid-rich inclusions that homogenized at 310-400°C. One halite-bearing primary inclusion was observed that homogenized by halite dissolution at 340°C (41 wt.% NaCl equiv.). Both the low salinity and high salinity inclusions are similar to those observed in late quartz ± Kfeldspar veins.

Quartz + sericite + pyrite veins were characterized by two-phase inclusions that homogenized at slightly lower temperatures (290-360°C) and with higher salinities (5-15 wt.% NaCl equiv.) than those seen in quartz + molybdenite veins. Limited evidence of boiling consisted of a single pair of liquid-rich and vapor-rich inclusions that homogenized at 354°C, indicating 160 bars pressure. Similar temperatures and salinities were also observed in most primary inclusions studied in the quartz + sericite + chalcopyrite vein (Th = 330-370°C, salinity = 5-8 wt.% NaCl equiv.). However, a few inclusions that contained chalcopyrite daughter products also had sylvite, suggesting that high-grade copper deposition may have been associated with a fluid distinct from fluids associated with other vein types.

Samples collected at various distances from the vein wall were studied from a 3 meter-wide quartz + calcite vein hosted by silicified Ordovician limestone located 2 km south of the Morenci pit. The vein locallizes silver plus minor gold mineralization associated with variable amounts of Mn-oxides and Cu-Zn-Pb sulfides. Combined fluid inclusion and petrographic studies show that fluids responsible for quartz deposition cooled from 330°C to 250°C and became more dilute (from 6 to 3 wt.% NaCl equiv.) with time. Earliest inclusions (330°C, 6 wt.%) in the quartz + Ag + Mn vein overlap in temperature and salinity with fluid inclusions observed in stockwork quartz + sericite veins. Boiling was documented both early at 300-310°C, and late at 260-280°C, corresponding to pressures of 100 and 40 bars, respectively.

Depths of burial can be estimated from the pressures determined from coexisting liquid-rich and vapor-rich inclusions in stockwork veins. Maximum depths are derived by assuming pure hydrostatic loads, while the assumption of pure lithostatic load would provide minimum depth estimates:

Pressure	Maximum Depth	Minimum Depth	Depth to Top of Kp
260-360 b	3.2-4.4 km	1.1-1.5 km	0.7 km
210 b	2.6 km	0.9 km	0.7 km
160 b	1.9 km	0.7 km	0.7 km

The estimated depths of burial suggest that the reconstructed Paleozoic plus Mesozoic stratigraphic column is not sufficient to account for the pressures required by the fluid inclusion evidence of boiling. The additional rock mass required is most likely to be from a coeval andesitic volcanic pile attending Laramide intrusive activity. The higher pressures seen in early hydrothermal events are most likely due to a mixed hydrostatic/lithostatic head that was predominately lithostatic. Conversely, lower pressures attending stockwork quartz + sericite veining are likely due to a dominately hydrostatic head.

The available geological evidence indicates that early sulfide-deficient veining was a result of water/rock reactions dominated by the wallrocks, with high salinity fluids that were locally derived. Molybdenite mineralization occurred during a transition from high salinity to low salinity fluids with otherwise similar attributes to the early potassic vein formation. Sulfide deposition was concomitant with the introduction of low-salinity solutions that were far from equilibrium with the host rock in sufficient quantities to control water/rock reactions. Multiple fracturing events occurred in a relatively low-pressure environment in reponse to dominantly external stresses.

THE EVOLUTION OF SUPERGENE ENRICHMENT IN THE MORENCI

PORPHYRY COPPER DEPOSIT, GREENLEE COUNTY, ARIZONA

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Director: Spencer R. Titley

Abstract
(modified)

Supergene enrichment in the Morenci porphyry copper deposit was formed as a result of the coupled processes of erosion and chemical weathering that accompanied five stages of landscape evolution in the Cenozoic Era as shown on the accompanying figure.

Stage 1 (64 to 53 Ma): Low-grade primary chalcopyrite and pyrite mineralization was deposited as a result of Laramide magmatic and hydrothermal processes at about 55 Ma.

Stage 2 (53 to 30 Ma): Initial unroofing and erosion removed approximately 1.8 km of rocks overlying the deposit and shed detritus to the north in the Eocene and to the south in the early Oligocene.

Stage 3 (30 to 18 Ma): The deposit was preserved under 640 to 950 meters of volcanic rocks as a result of mid-Tertiary extension and volcanism.

Stage 4 (18 to 2 Ma): Most of the supergene copper enrichment at Morenci appears to have been formed as a result of Basin and Range deformation between ~13 and ~4 Ma. Sixteen new $^{40}Ar/^{39}Ar$ ages from alunite, jarosite, and potassium-bearing manganese oxides in the district recorded three cycles of enrichment and leaching that peaked at about 7.3 Ma. Microbiological and geological studies revealed that acidophilic iron oxidizing bacteria and dissimilatory sulfate reducing bacteria contributed to leaching and enrichment of copper in the supergene environment, at least since the late Miocene.

Stage 5 (2 Ma to present): Destruction of the current enriched blanket accompanied base-level drop and stream incision as a result of progressive drainage integration in southern Arizona in the late Pliocene and Pleistocene.

LEACHED CAPPING FORMATION AND SUPERGENE ENRICHMENT AT METCALF

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11/05/00

Introduction

The Metcalf deposit is an ideal location to study supergene processes. The 5200 Bench traverses a classic, but tilted, enrichment profile consisting of a 200-m (650-ft) thick zone of leached capping that overlies a partially leached, 180-m (590-ft) thick enriched blanket. Actively weathering zones along this bench provided a natural laboratory to study supergene processes and were the sites of multi-year geological and microbiological studies. This overview has been excerpted from Enders (2000) and Enders et al. (1998 and in prep), and is only a small portion of the wealth of insight that can be gained from the study of ore deposits in operating mines.

Four figures are attached for your reference. The first figure is a geologic cross section of the Metcalf area along the trace of the 5200 Bench and shows the location of the study sites. The second figure is a leached capping appraisal worksheet that shows the same sites along the traverse of the 5200 Bench in the south Metcalf pit. The third figure contains schematic cross sections through the Metcalf and Western Copper areas showing age dates and relationships. And, the fourth figure is a summary diagram of biochemical and geochemical cycles in the supergene environment.

Geologic Setting

Leached capping occurs in variable thicknesses across the district, but is probably best displayed in the Metcalf area. In general, mineralization in Metcalf occurs almost entirely within the monzonite and the older and younger granite porphyry intrusive complex. In this area, the War Eagle fault exerts a strong control on the supergene profile, both offsetting enrichment and controlling deep leaching and enrichment in the hanging wall of the fault zone. Pervasive hypogene quartz-sericite-pyrite alteration overwhelms the original texture of the monzonite and older granite porphyry host rocks. The rocks have been intensely fractured and veined, with fracture densities ranging from about 0.25 to over 0.40/cm in places.

Metcalf contains a classic, but tilted, enrichment profile that consists of a 200-m thick zone of leached capping (0.06% Cu) that overlies a 180-m (590-ft) thick enriched blanket (0.42% Cu). In the southern part of the Metcalf pit, leached capping is over 450 m (1,475 ft) thick. Copper grades in the leached capping display a gradual increase with depth from 0.02 to about 0.11% Cu. The leached capping has an abrupt contact with the composite enriched blanket below. In places, however, the upper 90 meters (295 ft) of the enriched blanket have been partially leached. Partial leaching is also well displayed as relatively narrow, oxidized fractures that penetrate approximately 180 to 270 meters (590 to 885 ft) into the enriched blanket exposed on the east-side of the Metcalf Pit wall.

Mineralization

Leached capping consists of a stockwork of quartz + hematite +/- goethite +/- jarosite veins and veinlets left behind as a result of nearly complete leaching of the precursor pyrite and chalcocite mineralization. In places, hematite boxworks are common and appear as 0.1 to 1 mm features that form a sponge-like or honeycomb surface on open fractures. These boxworks are soft and leave a maroon-red streak characteristic of hematite that has replaced chalcocite. These boxworks have been interpreted to represent the destruction of a pre-existing chalcocite enriched blanket at Metcalf during Miocene to Pliocene time. In other areas, a mixture of brown, powdery goethite + hematite +/- jarosite are common, and are often associated with silica boxworks after pyrite. Oxidized quartz + pyrite +/- sericite veins contain a fine mixture of 0.5 to 2 mm thick, yellow powdery jarosite and silica in a quartz boxwork. Elsewhere, variable mixtures of transported hematite +/- goethite +/- jarosite occur as paint or thin coatings on fracture surfaces.

Copper in the leached capping occurs as remnant sulfide, oxide, carbonate or sulfate minerals. Where leached capping grades into zones of partial leaching, the rocks may contain pervasive oxidation along veins with hematite in the sericite selvages that are in sharp contact with un-oxidized pyrite and chalcocite in the interior of the rock. In other areas, copper occurs in small amounts as neotocite, tenorite, cuprite, native copper, malachite, brochantite, or chrysocolla. Copper oxides may also be tied up as micron-size particles of copper carbonate and silicate minerals inter-grown with iron hydroxides, mineraloids, and gangue in the leached capping. The possibility of copper occurring in lattice substitution within the hydrous or non-hydrous iron oxides as well as in the complex cupiferous Fe-Mn-(Ca-Si)-bearing oxides/hydroxides cannot be ruled out, as some of the ill-defined Cu-Mn-phases or mineraloids are known to contain this type of copper occurrence in northern Chilean oxide copper deposits and SW Arizona.

Alteration

Leached capping retains the strong supergene argillic alteration commonly found with the underlying enriched blanket. Kaolinite commonly occurs along fractures and veins in the leached capping as a result of intense local acid attack of the wall rock from dissolution of pyrite. Iron oxides also occur pervasively throughout the groundmass of the rocks imparting a reddish color to the kaolinite and staining all of the rocks in this zone. The dominant clays are smectites.

Alunite veins are common in the district, and some show evidence of multiple generations of alunite deposition. Alunite +/- jarosite +/- kaolinite occurs in 0.1 to 1-cm wide veins and as fracture filling in the leached capping. Individual veins typically cross cut the quartz-sericite +/- sulfide or iron oxide stockwork and have very sharp contacts with weakly to strongly sericitized wall rock. Alunite also commonly fills pre-existing quartz + sericite + hematite veins and contains "clasts" of remnant wall rock and oxidized sulfides. In some samples, alunite appears to have filled open-spaces after hematite cemented the fractured wall rock. Alunite is microcrystalline and typically white to yellow and pistachio green in color. It generally occurs intermixed with silica and kaolinite in variable amounts and with small amounts of sericite from the wall rock, although very pure alunite veins occur in places. In some places, alunite appears to be admixed with small amounts of jarosite. Veins of jarosite and jarosite+alunite occur in some of the higher elevations in the Metcalf pit.

Age of Supergene Mineralization at Metcalf

The bulk of supergene enrichment at Metcalf occurred during the second cycle of leaching and enrichment in the late Miocene when Basin and Range tectonism further dissected the district and deepened the Duncan basin. This cycle appears to have been the longest in duration and the most widespread. Eleven alunite, one jarosite, and one manganese-oxide $^{40}Ar/^{39}Ar$ ages, from samples collected across the district record a cycle that began about 11.0 Ma and continued through 7.0 Ma, with a prominent maximum at 7.4 Ma. The older samples from this cycle contain one generation of alunite and represent simple enrichment histories whereas there is a preponderance of multiple generations of alunite in the younger samples.

The oldest dates for this cycle are from alunites at the top of the enrichment profile at Metcalf. A cluster of samples in this area range in age from 9.88 +/- 0.26 Ma to 8.82 +/- 0.08 Ma and show a local decrease in age with depth. One sample of alunite from a remnant sulfide zone in leached capping in the hanging wall block of the War Eagle fault records an age of 11.0 +/- 0.24 Ma and is the second oldest supergene date in the district. Presumably, this structural domain was significantly higher in elevation prior to late Miocene faulting.

The bulk of the thick high-grade enrichment blanket and the Chase Creek Graben appear to have been developed by 7.0 Ma. Alunite with ages from 7.78 Ma to 7.0 Ma was found in the Metcalf, Western Copper, Northwest Extension, and American Mountain areas. A date of 7.01 +/- 0.16 Ma was recorded in alunite, from the center of the enriched blanket in the footwall block of the War Eagle fault. Another sample approximately 258 m below in the same profile recorded an age of 8.82 +/- 0.08 Ma, and further supports the classical notion of decreasing age of enrichment with depth in this simple enrichment profile that is outside of the Chase Creek graben.

The third cycle of leaching and enrichment began at the end of the Miocene and extended into the early Pliocene toward the waning stages of Basin and Range extension in the region. Enrichment in this cycle was formed from leaching of earlier-cycle enriched blankets leaving hematitic and jarositic leached caps above the enriched blanket. A sample from the leached capping in the hanging wall of the War Eagle fault records a jarosite date of 5.64 +/- 0.12 Ma for the formation of the leached capping in this part of the district.

The fourth cycle of leaching began in the Pleistocene as a result of base-level drop caused by down cutting of the Gila River, and is continuing today. Samples from the top of Metcalf, record jarosite dates of 1.69 +/- 0.08 and 0.87 +/- 1.3 Ma for the formation of partial leaching that has destroyed portions of the enriched blanket in this part of the district. Leaching and oxidation of the present blanket is continuing today, and can be observed in action as the deposit is exposed during mining operations and in adjacent drainages in the district.

Supergene Processes

Microbiological and geological studies in the Morenci district revealed that acidophilic iron oxidizing bacteria (*Thiobacillus ferrooxidans*) and dissimilatory sulfate reducing bacteria (SRB) contribute to leaching and enrichment of copper in the supergene environment. Sampling of actively weathering zones along the Metcalf 5200 bench showed populations of *Thiobacillus ferrooxidans* reaching populations $>10^7$ MPN/ml and populations of viable SRB with over10^3 MPN/ml at some sites. Micro-fossilized SRB, similar in morphology to those grown in-vitro, occur as 1-2 µm rod-shaped grains of chalcocite encapsulated in alunite 95 meters below the pre-mine surface and 35 meters (115 ft) above the enriched blanket at Metcalf. Sulfur isotopic studies of that chalcocite revealed an anomalously light (-20.5 and – 15.8 per mil) δ34S biogenic signature compared to supergene sulfides from other porphyry copper deposits in southwestern North America (averaging -1.7 per mil). $^{40}Ar/^{39}Ar$ dating of alunite from the Metcalf area indicate the micro-fossilized SRB are of late Miocene age and were formed during the most important period of supergene enrichment in the Morenci district.

The results of geological and microbiological study in the Morenci district strongly indicate that microorganisms play a fundamental role in the formation of supergene enrichment. It is clear that acidophilic iron oxidizing bacteria like *T. ferrooxidans* catalyze a number of geochemical reactions in the weathering environment that leach copper out of the oxidized zone above the water table. Although the predominance of evidence indicates that the enrichment process proceeds via geochemical reactions, in some environments dissimilatory sulfate reducing bacteria (SRB) appear to contribute to enrichment by directly precipitating chalcocite from solution through bacterial sulfate reduction. Evidence for these processes can be observed today in actively weathering environments and in the geologic record in the leached capping, partially leached zones, and enriched blanket at Metcalf.

Supergene ore forming processes are thus the result of both biochemical and geochemical reactions. These reactions are linked through a series of cycles involving water, oxygen, carbon dioxide, iron, sulfur, and copper near the surface of the earth where the atmosphere, hydrosphere, and biosphere interact with the earth's crust. Supergene processes begin in the vadose zone above the water table when *T. ferrooxidans* in the soil and rock near the earth's surface interact with the mineralized interface of an eroding copper deposit. Chemical weathering below the water table is limited by oxygen content, and the oxidation of pyrite and chalcopyrite in this environment is geologically slow. Above the water table, however, there is abundant oxygen, carbon dioxide, and moisture which is an optimum environment for bacterial leaching of sulfides. Oxidation of pyrite or chalcopyrite yields ferrous ion that then is oxidized to ferric ion by *T. ferrooxidans*, beginning a propagation cycle that promotes mineral dissolution. Formation of the first enrichment blanket is relatively inefficient because of the slow kinetics of chalcopyrite dissolution possibly due to surface passivation phenomena. The formation and preservation of this early cycle profile will, therefore, be dependent on the relative rates of chemical weathering and erosion. However, once chalcopyrite has been converted to chalcocite, subsequent leaching and enrichment cycles are more efficient. Seasonal and climatic cycles promote the growth of bacteria during wet periods. During dry periods, the evaporative concentration of the biogenic sulfuric acid and ferric sulfate promotes mineral dissolution and the formation of soluble salts such as chalcanthite. These salts, then, constitute the mobile fraction of minerals that are ready to be leached and transported during the next hydrologic pulse. Reduced carbon from dead *T. ferrooxidans* is flushed along with the other soluble minerals down to the water table where SRB populations thrive in anaerobic conditions (microenvironments) at pHs >5.5. In that environment, SRB may contribute to enrichment by reducing sulfate to sulfide (H_2S) preferentially precipitating copper as covellite instead of iron as a mono-sulfide, prior to diagenesis to chalcocite.

Supergene processes end or slow down predominantly as a result of hydrologic, climatic, and tectonic effects. Although supergene processes would terminate if the source were depleted in pyrite or copper minerals and equilibrium chemical conditions were reached; these static conditions are unlikely to persist for very long in geologic time. Under certain geologic and climatic conditions, tectonic and climatic forces can work separately or in conjunction to impose drying conditions on the supergene profile or by shifting the location of the redox boundary. For example, sulfide zones can be stranded above the water table as in many areas of the Morenci district, or left to desiccate in dry climatic conditions such as in northern Chile since the mid-Miocene. In these environments *T. ferrooxidans* will die and geochemical reactions will proceed slowly in the absence of significant moisture. Alternatively, dynamic tectonic environments coupled with cyclical climatic conditions would promote deep leaching and the formation of thick supergene blankets such as Morenci.

Summary

The end result of these processes was that copper was efficiently leached and mobilized in the vadose zone. Soluble copper was then available to enrich chalcopyrite and pyrite to form secondary copper sulfides below the water table, thus converting a sub-economic copper occurrence into a world class ore body over the last 10 million years. At Morenci, these naturally occurring bacteria are used to help leach the copper out of the ore in hydrometallurgical operations, making it one of the most productive copper mines in the world.

References

Enders, M.S., 2000, The evolution of supergene enrichment in the Morenci porphyry copper deposit, Greenlee County, Arizona: unpublished Ph.D. dissertation, University of Arizona, 517 p.

Enders, M.S., Knickerbocker, C., Southam, G., and Titley, S.R., (in prep.), The role of microorganisms in the supergene environment of the Morenci porphyry copper deposit, Greenlee County, Arizona: draft manuscript for submittal to Economic Geology.

Enders, M.S., Knickerbocker, C, Southam, G., and Titley, S.R., 1998, The occurrence of acidophilic iron oxidizing bacteria and their role in supergene enrichment of the Morenci

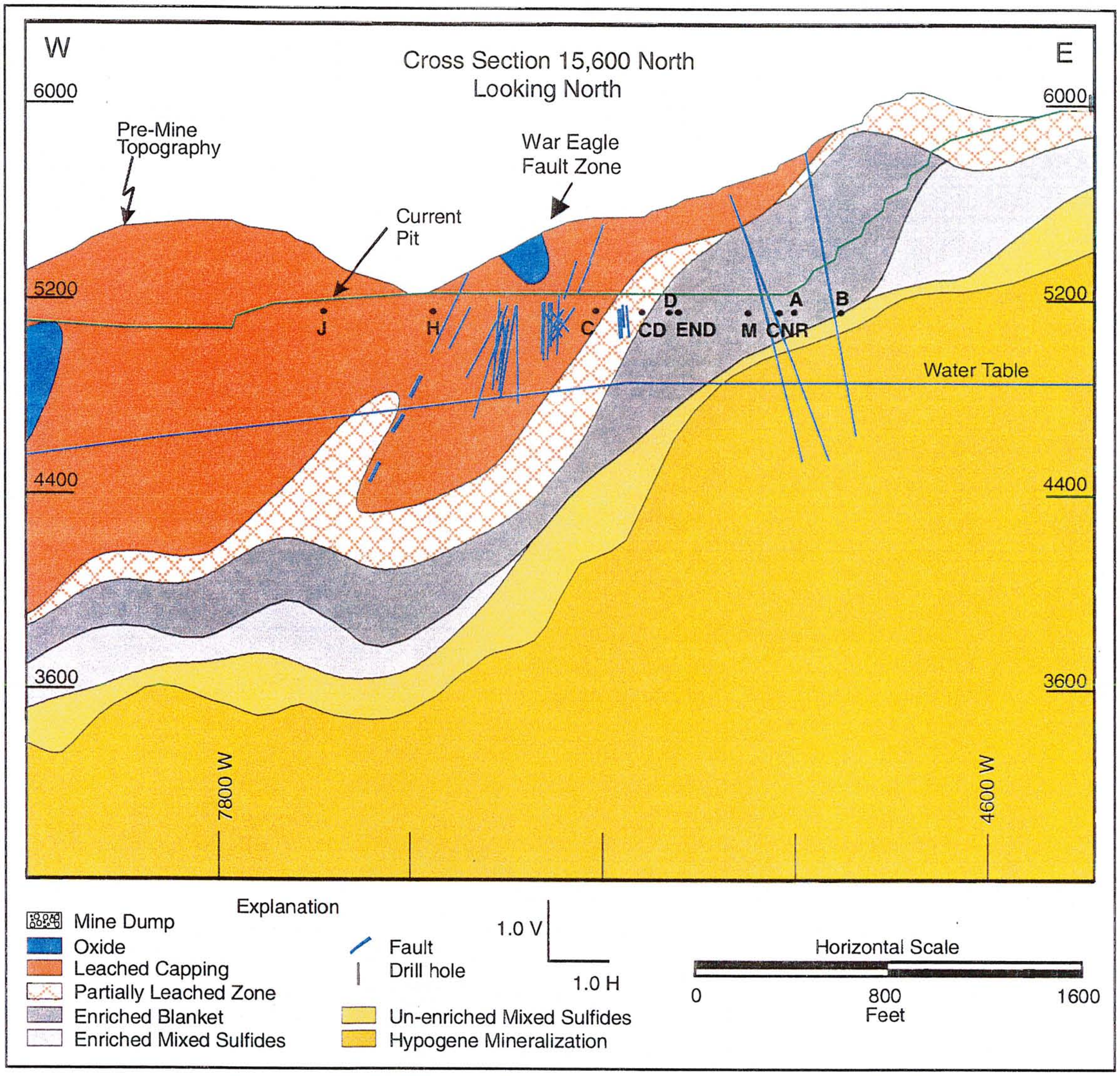


FIGURE 41. Cross section 15,600 N looking north across the Metcalf area. Showing the supergene mineral profile, current pit limit as of August 1998, the water table as of April 1995, and sample locations along the 5200 bench. In this area of the Morenci district the enriched blanket is tilted steeply to the west towards the Chase Creek drainage as a result of deep leaching and enrichment combined with offset along the War Eagle fault. Partial leaching has affected the upper 90 meters of the enriched blanket and has penetrated the blanket along steeply dipping fault zones in the upper elevations. Near the pre-mine surface, small zones of residual copper oxide mineralization remain in an otherwise hematitic leached capping. At depth, supergene sulfide minerals show pronounced downward zoning as described in Figure 40. See line of section location on Figure 51.

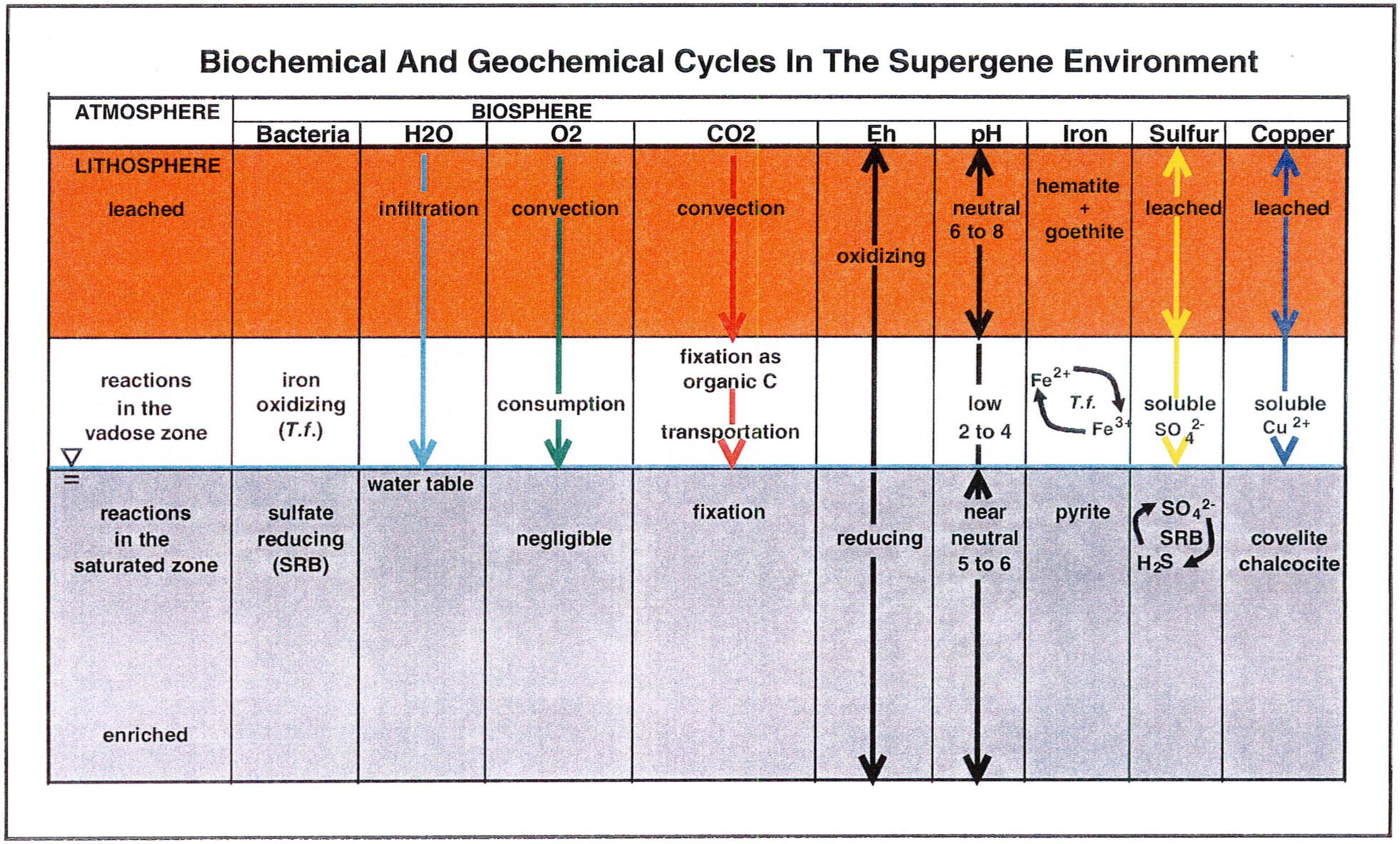
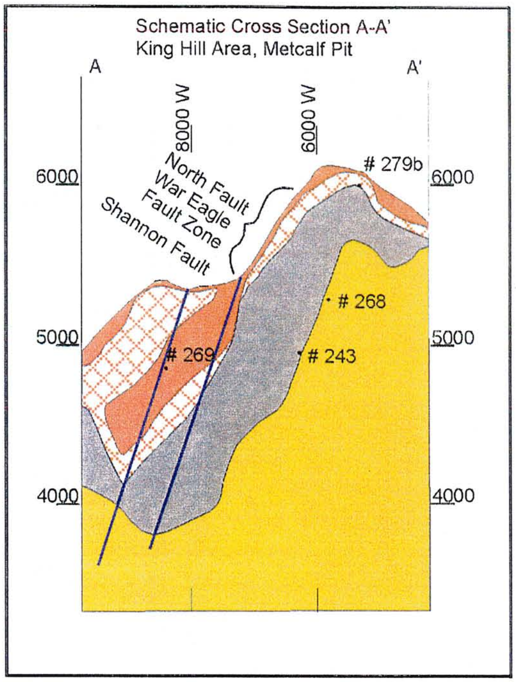
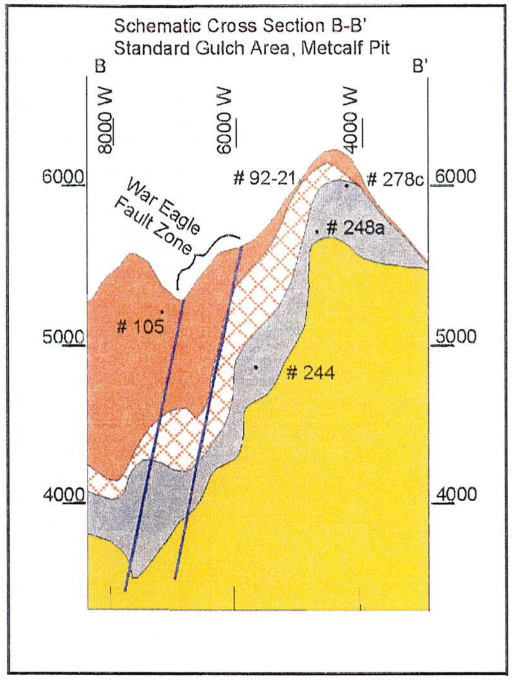
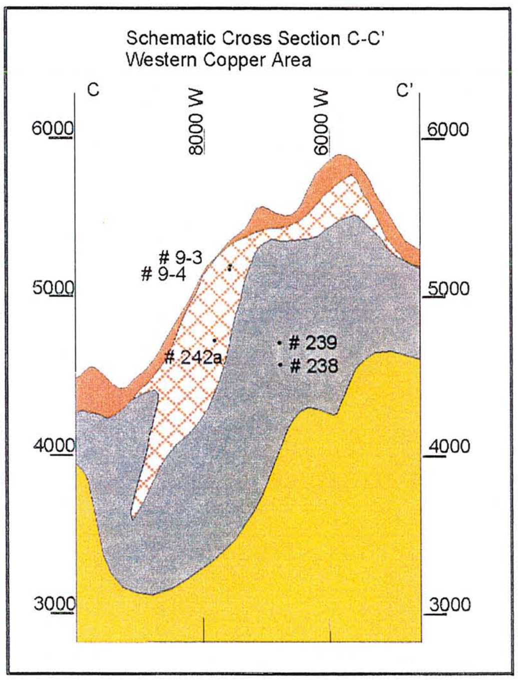


FIGURE 61. Biochemical and geochemical cycles in the supergene environment.







Sample Number	Age (Ma)	Mineralogy	Type	Phases
279b	0.87 +/- 1.3	Jarosite	III	2
268	1.69 +/- 0.08	Jarosite	III	1
243	6.2	Alunite	I	1 ?
269	11.00 +/-0.24	Alunite	I	1
278c	9.29 +/- 0.06	Alunite	I	1
248a	8.82 +/-0.08	Alunite	I	1
105	5.64 +/- 0.12	Jarosite	III	1
244	7.01 +/- 0.16	Alunite	I	1 ?
92-21	9.88 +/- 0.26	Alunite	?	?
9-3	7.78 +/- 0.32	Alunite	II	2
9-4	7.29 +/- 0.34	Alunite	I	1
242a	7.45 +/- 0.02	Alunite	II	1
239	7.78 +/- 0.28	Alunite	I	2 (mixed)
238	6.3	Alunite	II	1

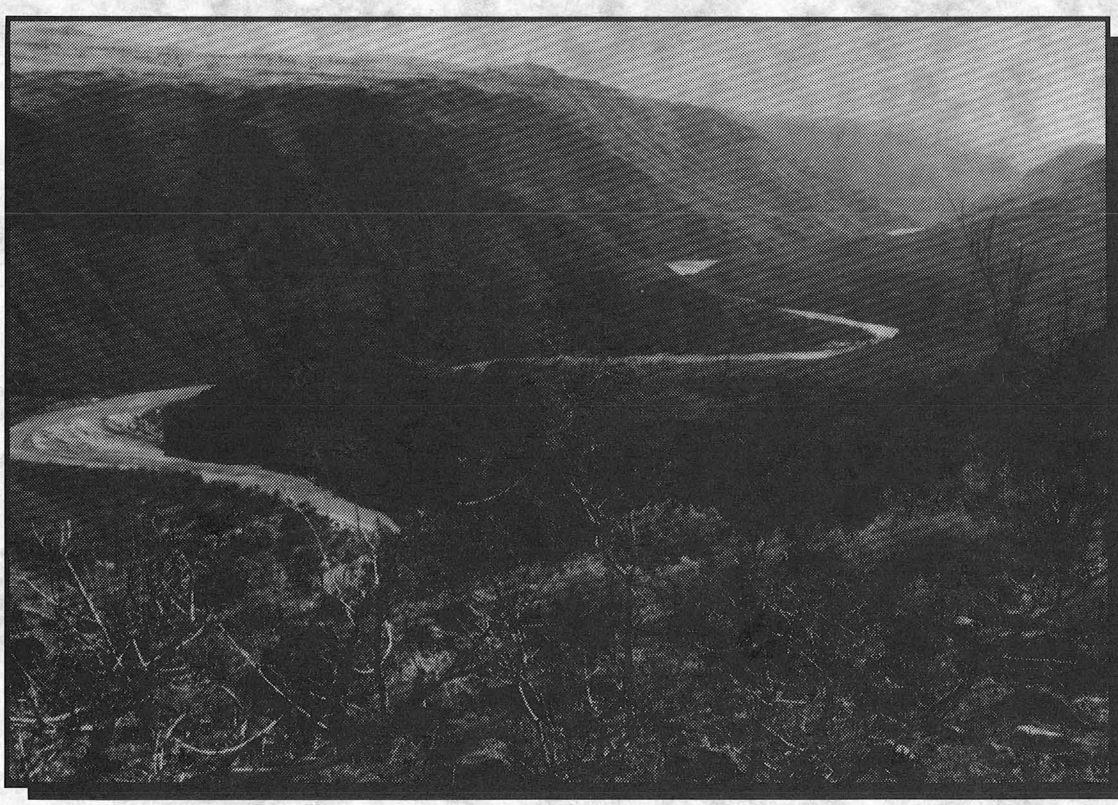
FIGURE 67. Schematic cross sections through Metcalf and Western Copper areas. Showing the projected location of supergene age dating samples. See Figure 62 for cross section locations and text for description.

U.S. Department of the Interior
Bureau of Land Management
Arizona State Office

Safford Field Office

March 1997

Record of Decision
Environmental Impact Statement
Morenci Land Exchange



The Bureau of Land Management is responsible for the balanced management of the public lands and resources and their various values so that they are considered in a combination that will best serve the needs of the American people. Management is based upon the principles of multiple use and sustained yield; a combination of uses that take into account the long term needs of future generations for renewable and nonrenewable resources. These resources include recreation, range, timber, minerals, watershed, fish and wildlife, wilderness and natural, scenic, scientific, and cultural values.

BLM/AZ/PL-97/005

Front Cover: Overlooking southern portion of the Eagle Creek offered lands property (middleground) at the confluence of Eagle Creek and the Gila River.

United States Department of the Interior
BUREAU OF LAND MANAGEMENT
Safford District Office
711 14th Avenue
Safford, AZ 85546
(520) 428-4040

In reply refer to:
2200 AZA 28789 (044)

February 19, 1997

Dear Reader:

Enclosed you will find our Record of Decision for the proposed Morenci Land Exchange. Our decision has been based upon public input, a thorough analysis of the proposal, and the laws that authorize the BLM to conduct an exchange.

It has been our pleasure to work with the public in our evaluation of this proposal. Each time the public participates in our decision-making process, we become more aware of public needs and better able to serve those needs. We would like to thank all of you who have participated to date, and encourage your continued interest and participation in future projects.

On March 7, 1997, a Notice of Availability for this Record of Decision will be published in the Federal Register. Within 30 days of this date, you have the right of appeal pursuant to 43 Code of Federal Regulations, Part 4. Please submit any appeal to Denise P. Meridith, Arizona State Director, Arizona State Office, P. O. Box 555, Phoenix, Arizona 85001-0555.

Sincerely,

Margaret L. Jensen

Margaret L. Jensen
Gila Area Manager

RECORD OF DECISION

ENVIRONMENTAL IMPACT STATEMENT

MORENCI LAND EXCHANGE

Case Number: AZA 28789

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
SAFFORD FIELD OFFICE
SAFFORD, ARIZONA

Denise P. Meridith
Arizona State Director

February 7, 1997

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RECORD OF DECISION

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MORENCI LAND EXCHANGE

INTRODUCTION

This Record of Decision (ROD) approves a land exchange between the U.S. Department of Interior Bureau of Land Management, Safford Field Office and Phelps Dodge Corporation. The approved exchange is a modification of the Equal Appraised Value Alternative presented in the Morenci Land Exchange Final Environmental Impact Statement. It involves trading 3,605.24 acres of Bureau of Land Management-administered public land located in Greenlee County, Arizona for 1,040.00 acres of private lands owned by Phelps Dodge Corporation located in Graham, Greenlee, Cochise, and Pima counties. The public and private lands involved in this trade have been appraised, by methods approved by the Federal Government, and are substantially equal in dollar value. The appraised value of the offered lands and the selected lands are within 3 percent of each other. Approval of the land exchange will bring lands with important resource and public land management values into public ownership and transfer BLM-managed public lands to private ownership. The public lands transferred to Phelps Dodge Corporation ownership are expected to be used for mining purposes that will enable Phelps Dodge to expand and continue operation of some features of the Morenci copper mine.

This Record of Decision describes the selected alternative, other alternatives considered, the rationale for adopting the selected alternative, required mitigation, and a description of public participation in the identification, development, and evaluation of significant issues generated by this proposal. Environmental analysis of this project, as presented in the final environmental impact statement, has been thoroughly reviewed by federal agencies, state agencies, and private organizations and individuals. Comments and issues raised in this process have been addressed through the creation of the Equal Appraised Value Alternative, additions and clarification of sections in the final environmental impact statement, and in the response to comments in the final environmental impact statement and in this record of decision.

DECISION

It is the decision of the Arizona State Director of the Bureau of Land Management to authorize the exchange of BLM managed public lands for private lands as described in the Equal Appraised Value Alternative of the Morenci Land Exchange Final Environmental Impact Statement, page 2-8, with the following modification. Third-party mining claims on 160 acres of selected land, occurring in parcel K (230 acres), are unresolved. Therefore, these 160 acres of parcel K will be excluded from the exchange. In order to more closely equalize the value of the selected public and offered private lands packages, 80 acres of the offered (240 acre) Clyne property will be included in the land exchange. Legal descriptions of the Federal and private lands to be exchanged in this action are presented in Appendix 1 of this ROD. The Equal Appraised Value Alternative, as modified, includes the following actions.

1) Phelps Dodge Corporation will acquire title to 26 parcels (3,604.79 acres) of public lands located in Greenlee County, adjacent to the existing Morenci Mine. A general description and a map of these lands are provided on pages 2-2 and 2-3 of the final environmental impact statement. Legal descriptions of these lands are provided in Appendix 1 of this ROD. Fourteen of these parcels are less than 1 acre each in size and are surrounded by private land. The remaining 11 parcels range in size from five acres to about 2,560 acres. The value of these lands has been appraised, using a federally-approved methodology, at $450,598.75.

2) The Bureau of Land Management will acquire title to four properties of private land (1,040.00 acres) located in Greenlee, Graham, Cochise, and Pima counties. A general description and maps of these lands are provided on pages 2-4 through 2-9 of the final environmental impact statement. Legal descriptions of these lands are provided in Appendix 1 of this ROD. These properties consist of: the 280 acre Eagle Creek property located in Greenlee/Graham counties; the 360 acre Stewart Trust property located in Cochise County; the 320 acre Peterson property located in Cochise County; and 80 acres of the 240 acre Clyne property located in Pima County. The value of these lands has been appraised, using a federally-approved methodology, at $464,000.00.

3) A total of 160 acres of selected public lands, encumbered by third-party mining claims occurring on parcel K, will be excluded from the exchange. Additionally, a 50-acre portion of parcel F, found within the 1/4 mile wide proposed Wild and Scenic Rivers corridor, on the northern bank of the lower San Francisco River will be excluded from this exchange (see figure 3-8 on page 3-34 of the FEIS).

4) Since the appraised value of the selected (public) lands is $13,401.25 less than the appraised value of the offered (private) lands, the Safford Field Office of the Bureau of Land Management must either pay Phelps Dodge Corporation the difference or Phelps Dodge Corporation may waive the payment of this difference prior to completion of the land exchange. The BLM does not possess sufficient authorized and appropriated funding to reimburse the $13,345.00 in cash. Phelps Dodge and BLM have agreed that a waiver of this amount would expedite the exchange and serve the public interest by reducing BLM expenses. Therefore, Phelps Dodge Corporation has waived the balancing payment of $13,401.25 pursuant to 43 CFR 2201.6.

MITIGATION

Threatened and Endangered Species

The and Phelps Dodge will comply with the three conservation recommendations listed in the biological opinion (BO)(AESO/SE 2-21-95-F-081) for the effects of the proposed exchange on the Arizona hedgehog cactus (*Echinocereus triglochidiatus arizonicus*). The U.S. Fish and Wildlife Service issued this BO on November 21, 1995 and concluded that the exchange would not jeopardize the continued existence of the cactus.

Wild and Scenic Rivers

All portions of parcel F (50 acres) within the one-quarter mile wide Wild and Scenic River corridor on the north side of the San Francisco River have been excluded from the exchange (see figure 3-8 on page 3-34 of the FEIS).

Third Party Mining Claims

All selected public lands with mining claims held by entities other than Phelps Dodge Corporation have been excluded from the exchange. All mining claims held by Phelps Dodge on lands that will remain in the exchange, will be relinquished prior to conveyance.

Mineral Withdrawals

The Eagle Creek property as well as the Clyne property will be withdrawn from all forms of land entry including mineral entry and leasing.

Access To Public Lands

Since publication of the FEIS, route #1 (Forest Trail 12) has been reserved to the U.S. Forest Service as Right-of-Way AZA 30035. Additionally, Phelps Dodge has agreed to keep route #5 open to the public (see Figure 3-6 in the FEIS).

Rights-of-Way

With the addition of AZA 30035, there are a total of four rights-of-way that occur on the selected lands. The following management actions will take place pertaining to these rights-of-way:

- Right-of-way AZA 7456 held by the Arizona Department of Transportation will be reserved to the United States.

- Phelps Dodge will accept patent to the selected lands subject to that portion of right-of-way No. AZA 9015 occurring on the selected lands and authorized to the Arizona Electric Power Cooperative, Inc.

- The portion of right-of-way AZA 22983 authorized to Phelps Dodge occurring on the selected lands will be relinquished at the close of escrow.

- Right-of-way AZA 30035 will be reserved to the U.S. Forest Service.

- The United States will accept title to the offered properties subject to existing easements. All such easements occurring on the offered private lands will be subject to normal renewal procedures after expiration of their current term.

Visual Resources

Phelps Dodge and the Apache Sitgreaves National Forests will work together to protect the visual quality of the Coronado Mountain viewshed from the Highway 191 Scenic Byway found on public lands.

Cultural Resources

Nineteen archaeological sites on the selected lands will be the subject of data recovery efforts as described in the approved *A Cultural Resources Data Recovery Plan For The Phelps Dodge Morenci Land Exchange, Greenlee County, Arizona* (SWCA 1996).

Hazardous Substance

The selected public and offered private lands have been examined in accordance with Section 120(h) of SARA. No evidence was found to indicate that any hazardous substance was stored for one year or more or disposed of or released on the offered or selected lands, except for a site on parcel L of the selected public lands which held a minor amount of petroleum-contaminated soil. The petroleum-contaminated soil found on parcel L was cleaned under the supervision of BLM by Zenitech Corporation. The cleanup consisted of excavation, sampling, backfilling, and documentation. Zenitech's conclusion and recommendation was that no further action would be required at the site. BLM Hazmat specialists concurred.

Grazing

Phelps Dodge will accept patent to the selected lands subject to such rights that grazing permittees hold to continue grazing on allotments No. 40030, 40100, 40010 until October 26, 1997, June 29, 1997, and June 28, 1997, respectively. Permittees will be compensated by Phelps Dodge for their authorized privately-owned range improvements.

MONITORING

No monitoring activities are required or will be conducted as a direct result of the approval of the land exchange.

MANAGEMENT CONSIDERATIONS

The rationale to approve this exchange of lands is primarily based on the analysis of the environmental impacts presented in the final environmental impact statement as modified in this ROD, weighed against the prerequisites for approval of an exchange that are found in Section 206 of the Federal Land Policy Management Act of 1976 (FLPMA) as amended by the Federal Land Exchange Facilitation Act of 1988 (FLEFA). These laws authorize the Bureau of Land Management to complete land exchanges provided that the exchange meets specific regulatory requirements and has been found to serve the public interest.

In considering whether the public interest will be served by the exchange, Section 206 (a) of FLPMA directs the Secretary to do the following: "That when considering public interest the Secretary concerned shall give full consideration to better Federal land management and the needs of State and local people, including needs for lands for the economy, community expansion, recreation areas, food, fiber, minerals, and fish and wildlife and the Secretary concerned finds that the values and objectives which Federal lands or interests to be conveyed may serve if retained in Federal ownership are not more than the values of the non-Federal lands or interests and the public objectives they could serve if acquired."

In the case of the Morenci Land Exchange the values of and objectives for the private lands to be acquired from Phelps Dodge Corporation have been considered and are found to be clearly more than the values of and public objectives for the public lands to be conveyed to Phelps Dodge Corporation

All lands to be acquired by the BLM are within Long-term Management Areas (LTMA) designated in the Safford District Resource Management Plan and would thus serve the purpose of consolidating Federal lands and improving their management by simplifying the land ownership pattern in these areas. Individual parcels contribute to the fulfillment of the public interest clause by contributing to the attainment of public objectives found in the RMP and/or by containing high natural resource values, including critical, occupied and potential habitat for several threatened and endangered species.

The Peterson and Stewart Trust properties provide needed access and trail head facility sites for the Dos Cabezas Wilderness. Acquisition of these properties will benefit recreational users of the wilderness and facilitate administrative access which in turn will improve management of these public lands. Acquisition of these properties also consolidates lands in the Dos Cabezas Long-Term Management Area which simplifies the land ownership pattern and will contribute to improved management of Federal lands in the area.

The Eagle Creek property is one of the private land inholdings in the Gila Box Riparian National Conservation Area (RNCA) and contains critical habitat for the razorback sucker, proposed critical habitat for the cactus ferruginous pygmy owl, occupied habitat for a cactus that is morphologically similar to the endangered Arizona hedgehog cactus and for threatened spikedace, potential habitat for the southern bald eagle, southwestern willow flycatcher, peregrine falcon, and lesser long-nosed bat. It is also within the ½ mile wide corridor of the proposed Gila Box Wild and Scenic River segment. It contains significant cultural resources, and is an important camping area for river runners who camp overnight on the river. Acquisition of this property will provide long-term protection for threatened and endangered species habitat and cultural resources, improve management of public lands by simplifying the land ownership pattern in the RNCA, and provide legal access to a valuable recreation site for public land users.

The Clyne property is one of the private inholdings within the Cienega Creek Long Term Management Area (LTMA). Acquisition of a portion of the property is a step toward consolidating federal lands and simplifying the land ownership pattern in the Cienega Creek LTMA. The property contains mesquite-juniper grasslands and riparian vegetation in Shellenberger Canyon. Potential habitat for the endangered peregrine falcon and lesser long-nosed bat as well as for a variety of other wildlife exist on this property. One-quarter mile of Shellenberger Canyon has a low volume of perennial streamflow.

The 26 parcels of public land to be transferred to private ownership include 14 small parcels, less than 1 acre each in size, that are surrounded by private land in and around the existing Morenci mining operation. These lands are extremely difficult to manage and their transfer to private ownership will simplify the land ownership pattern and enable development of the mineral resources in the immediate area of the existing mine. These parcels do not contain significant natural resource values and are encumbered with mining claims held by Phelps Dodge Corporation which shall be relinquished prior to conveyance.

Twelve larger parcels are adjacent to the existing Morenci mine and about 92 percent of them are encumbered by mining claims held by Phelps Dodge Corporation Similarly, these mining claims will be relinquished prior to conveyance. The foreseeable uses of these lands are considered to be mining-related.

In summary, the State Director finds that approval of the exchange will meet the public interest provisions of Section 206 of FLPMA by:

1) Facilitating better Federal land management by acquiring private lands within LTMAs and disposing of isolated public lands outside of LTMAs. This will result in a simplified land ownership pattern, removal of management conflicts, and provide for more efficient management of these lands.

2) Providing lands which enable Phelps Dodge to continue operation and expand some areas of the Morenci copper mine which has a significant impact on the local economy and assists in meeting society's needs for minerals. The Phelps Dodge Morenci mine produces about 20 percent of the copper mined in the United States.

3) Improving recreation opportunities by providing public recreation sites and/or improving access to public lands in the Gila Box RNCA, Cienega Creek LTMA, and Dos Cabezas Wilderness.

4) Providing for the needs of fish and wildlife through the acquisition of critical habitat for the razorback sucker, potential habitat for the spikedace, and habitat for desert bighorn sheep.

In approving the land exchange, secondary consideration has been given to the situation involving the foreseeable uses of the selected public lands that are considered to be independent of the successful completion of an exchange. The Bureau of Land Management believes that the ultimate uses of the selected public lands will be for mining purposes whether or not the exchange is completed. If the land exchange is not completed, it is almost certain that the public lands will be used for mining purposes under provisions of the 1872 Mining Law, as amended. Therefore, mining-related impacts will occur whether or not the land exchange is completed. In this case, the foreseeable mining-related uses of the selected public lands account for a vast majority of the environmental impacts identified and analyzed in the final environmental impact statement.

This belief is supported by the fact that Phelps Dodge Corporation holds mining claims on approximately 92% of the public lands selected for exchange and their stated intent to utilize these lands for mining purposes under the 1872 mining Law, as amended. A recent court decision (1996) in the United States District Court for the District of Arizona No. CIV 96-1009 PHX PGR (Dan Zobel et al. Plaintiff vs. Charles R. Bazan et al. Defendant and Carlota Copper Company Intervenor Defendant) also supports this conclusion. In rendering his decision, Judge Paul G. Rosenblatt noted that "because mining has been accorded a special place in the national laws related to public lands, the development of mineral resources in the national forests [i.e. public land] may not be prohibited or unreasonably circumscribed." Furthermore, Judge Rosenblatt concluded that "...a true 'no action' alternative under the National Environmental Policy Act (NEPA) is, as a practical matter, not available to the [defendant] as a consequence of the mining laws....".

In addition, evaluation of the regulation of mining activities on private versus federal lands reveals that, as a consequence of the exchange, loss of federal authority over mining activities is limited to replacing Bureau of Land Management surface reclamation standards with State of Arizona reclamation standards, found in Arizona Mined Land Reclamation Act, as well as replacing provisions in the Native American Graves Protection and Repatriation Act (NAGPRA) with provisions found in State Law A.R.S. 41-865 State Graves Protection Act (see Table 2-2 on page 2-11 of the FEIS). The federal authority over certain aspects of the Morenci mining operation, by agencies such as the Environmental Protection Agency, Army Corps of Engineers, and U.S. Fish and Wildlife Service, remains substantially unchanged.

In light of the situation involving foreseeable uses and regulatory authority over mining operations on public versus private land, it appears that the real trade occurring here is the replacement of federal surface reclamation standards with state reclamation standards and the replacement of federal protection for Native American graves with state protection for Native American graves for the public objectives that would be served by acquiring the offered private lands. No Native American graves have been found or are expected to be found on the selected public lands.

In summary, it is clear from the environmental impact statement that the net environmental impacts of the exchange would be very beneficial to the natural resources involved and the public interest would be well served by completing the exchange. The primary and secondary considerations lead the State Director to conclude that: since all regulatory requirements for the land exchange have been satisfied, and the public interest provisions of Section 206 of FLPMA are served, and the environmental impacts from the foreseeable uses will occur with or without the exchange; and the loss of federal regulatory authority over mining is limited to the replacement of federal surface reclamation standards and protection for graves with state standards and protection, it is, therefore, prudent and in the best interest of the public for BLM to relinquish title to the selected public lands and acquire title to the offered private lands as described in Appendix 1 of this document.

ALTERNATIVES

Three alternatives, the proposed action, the equal appraised value alternative which is considered both the environmentally preferred and BLM preferred alternative, and the no action alternative, were considered and analyzed in the environmental impact statement. These alternatives are summarized as follows:

The Proposed Action would exchange 27 parcels (3,758 acres) of public lands for four properties (1,200 acres) of private land owned by Phelps Dodge Morenci Inc. This alternative is presented on pages 2-2 through 2-8 of the final environmental impact statement.

The Equal Appraised Value Alternative would exchange 26 parcels (3,604.79 acres) of public lands for three properties and a portion of a fourth property (1,040 acres) of private land owned by Phelps Dodge Morenci Inc. This alternative is presented on page 2-8 of the final environmental impact statement.

The No Action Alternative would not exchange any lands. This alternative is presented on page 2-8 of the final environmental impact statement.

Several alternatives were considered but not analyzed in detail in the final environmental impact statement. These include alternatives that involved: 1)direct sale of the selected lands to Phelps Dodge combined with purchase of the selected lands utilizing Land and Water Conservation funds; 2)minimizing the selected lands package to include only those lands identified for use in production operations, support, and transitional uses for the mine; and reducing the offered private lands accordingly; and 3) trading a different set of private lands for the selected public lands.

PUBLIC INVOLVEMENT

During the initial scoping and preparation of the draft and final environmental impact statements for the Morenci Land Exchange the Bureau of Land Management consulted with and received input from federal, state, and local agencies, elected representatives, Indian tribes, non-governmental organizations, and private individuals.

A Notice of Intent to prepare an environmental impact statement was published in the Federal Register on November 3, 1994. The notice also announced the date, time, and location of four public meetings to be held in Phoenix, Tucson, Clifton and Safford, during December 1994, to disseminate information on the proposed land exchange and gathering public comments and concerns. One hundred and forty-one people attended these public meetings. Shortly after the publication of the Notice of Intent, a news release was sent to newspapers with local and statewide distribution. Mailers were sent to approximately 1,400 individuals and organizations on the Field Office mailing list. The news releases and mailers contained substantially the same information as the Notice of Intent. As a result of this effort, 121 comment letters were received by the Safford Field Office regarding the Morenci Land Exchange. Substantive issues raised in these letters were addressed in the draft environmental impact statement.

Release of the draft environmental impact statement coincided with publication of a Notice of Availability in the Federal Register on December 20, 1995. News releases were sent to newspapers with local and statewide distribution and mailers were sent to approximately 1,400 individuals and organizations on the Safford Field Office mailing list. Three public meetings were held in Phoenix, Tucson, and Safford during January 1996, to gather comments on the environmental impact statement and proposed land exchange. One hundred eighty three people attended these public meetings. Sixty five comment letters were received regarding the draft environmental impact statement.

Release of the final environmental impact statement coincided with publication of a Notice of Availability in the Federal Register on October 10, 1996. News releases were sent to newspapers with local and statewide distribution and mailers were sent to approximately 1,400 individuals and organizations on the Safford Field Office mailing list. Twelve comment letters were received regarding the final environmental impact statement.

COORDINATION AND CONSULTATION WITH INDIAN TRIBES

During initial scoping, the Bureau of Land Management coordinated with the ten Indian tribes listed in Table 3-12 on page 3-39 of the final environmental impact statement. Coordination consisted of letters and phone calls to each tribe to solicit their concerns and presentations by the project team to representatives of the San Carlos Apache Tribe and Gila River Indian Community. Twenty-two tribal representatives attended the presentation to the San Carlos Apache Tribe while six tribal representatives attended the presentation to the Gila River Indian Community. All ten tribes were sent copies of the archaeological survey report (SWCA 1995) and the draft data recovery plan (SWCA 1996) for their review and comment. Bureau of Land Management personnel accompanied representatives of the San Carlos Apache and White Mountain Apache tribes on a visit of several archaeological sites on portions of the selected lands. Meetings were held with the resource advisory committees of six tribes. These efforts at consultation with the tribes are documented on pages 5-2 and 5-3 of the final environmental impact statement and in *The Morenci Land Exchange: Native American Consultation and Places of Traditional Importance to Native American Tribes within Approximately 4,090 Acres North of Clifton, Greenlee County, Arizona* (SWCA 1996).

The Bureau of Land Management has documented expending over 2,000 hours in consultation efforts with Native American tribes on this proposal.

RESPONSE TO ISSUES IN THE FINAL ENVIRONMENTAL IMPACT STATEMENT

BLM received 12 comment letters on the final environmental impact statement. Through analysis of the comments within these letters BLM has determined that the following four issues need clarification or additional discussion.

Issue 1. The EIS is inadequate or an "end run" around NEPA because it does not analyze the direct, indirect, and cumulative impacts of existing mining operations at the Morenci Mine and the cumulative impacts resulting from other mining operations in the Gila River watershed.

This issue was derived from comments made by Sparks, Tehan & Ryley, P.C. representing the San Carlos Apache Tribe, Ronnie Lupe Chairman of the White Mountain Apache Tribe, Bureau of Indian Affairs Phoenix Area Office, and Landi Fernley of The Southwest Center For Biological Diversity.

Response 1. The scope of analysis presented in the FEIS was determined through consideration of the factors addressed in General Response 6 on page 7-10 through 7-13 of Chapter 7 Comments and Responses in the FEIS. BLM determined that impacts associated with existing mining operations (e.g., groundwater pumping, water diversions from the Black River, discharges to the San Francisco River, water quality impacts on threatened and endangered species, etc.) are beyond the scope of analysis of this EIS.

This determination hinges on several specific findings: 1) A close causal relationship does not exist between the decision to be made, approval or denial of the land exchange, and impacts of existing mining operations, including the Morenci mining operation; 2) the BLM decision concerning the proposed land exchange does not authorize continued mining operations on private lands and at most merely enables Phelps Dodge to continue or expand some aspects of the Morenci mining operation; 3) the land exchange and existing mining operation are not connected actions; 4) the land exchange and existing mining operation are not similar actions; and 5) the land exchange and existing Morenci mining operation do not have cumulative significant impacts that warrant discussion in the same EIS.

The authority for the BLM to conduct land exchanges is found in section 206 of the Federal Land Policy and Management Act of 1976 as amended by the Federal Land Exchange Facilitation Act of 1988. Regulations implementing the exchange provisions of these laws are found in 43 CFR Part 2200. These laws and regulations provide the authority necessary for BLM to consider and complete land exchanges and are completely independent from BLM's authority to approve mining operations on Federal lands found in 43 CFR 3809. The fact that BLM has chosen to exercise its authority to consider and conduct a land exchange in no way constitutes an end run on NEPA or any other Federal law that grants the BLM authority to approve or deny other activities.

Issue 2. BLM has not complied with its federal trust responsibilities because 1)the EIS is inadequate with regard to analysis of impacts to Indian water rights to the Gila River and its tributaries, or 2) the BLM's efforts to consult with the tribes are insufficient.

This issue was derived from comments made by Sparks, Tehan & Ryley, P.C. representing the San Carlos Apache Tribe, Bureau of Indian Affairs Phoenix Area Office, and Landi Fernley of The Southwest Center For Biological Diversity.

Response 2. BLM has complied with its federal trust responsibility to Indian tribes in its preparation of the Morenci Land Exchange EIS and ROD. Compliance was accomplished through the completion of consultations with all interested Indian tribes and through the analysis of impacts to trust resources.

BLM contacted all potentially interested tribes, provided them with information on the proposed exchange, and inquired as to their interest in the exchange. BLM consulted with all tribes that expressed an interest in the exchange. Consultations were extensive and were conducted with all parties identified by tribal officials and with other tribal members and tribal staff. Consultations were carried out through letters, phone calls, field trips, meetings with tribal staff, meetings with tribal cultural committees, and meetings with tribal councils. Consultation included providing the draft EIS, draft reports, and draft mitigation plans to the tribes for their review and comment. Consultations were carried through to completion and all input received from the tribes was seriously considered in the preparation of the EIS and ROD. These consultations are summarized in the EIS and discussed in detail in a report entitled *The Morenci Land Exchange: Native American Consultation and Places of Traditional Importance to Native American Tribes Within Approximately 4,090 Acres North of Clifton, Greenlee County, Arizona* (SWCA 1996).

All known resources, values, and use opportunities that could be impacted by the land exchange were analyzed in the EIS, including all resources and values defined as Indian trust resources, i.e., legal interests in property held in trust by the United States for Indian tribes or individuals. All discussions of resources, values and uses, including trust resources and discussions of expected impacts are contained in the various resource sections of the EIS. While trust resources were not discussed in a separate section of the EIS, the resources analyzed consisted of all natural, cultural, and social resources, that may be affected by the land exchange.

It is BLM's belief that the agency has met its obligation to complete reasonable and good faith consultations with Native Americans and that BLM has met its trust responsibility to Indian tribes by analyzing the expected impacts to trust resources, considering alternatives that would avoid or lessen impacts, and providing for the mitigation of any impacts identified. We believe that such consultations and impact analyses are adequately discussed in the project reports, EIS, and ROD.

Issue 3. BLM's reliance on federal and state permit requirements for protecting some environmental resources (e.g., the state's Aquifer Protection Permit for protection of groundwater quality) does not constitute an adequate analysis of the project's impacts to those resources, therefore the BLM has not fulfilled its NEPA responsibilities.

This issue was derived from comments made by Sparks, Tehan & Ryley, P.C. representing the San Carlos Apache Tribe, Bureau of Indian Affairs Phoenix Area Office, Josephina Bianes Melendrez, and Landi Fernley of The Southwest Center For Biological Diversity.

Response 3. There are three major environmental programs that regulate potential contamination from mining. These include: the Clean Water Act, the Clean Air Act, and the Aquifer Protection Program. The agencies that administer these programs are: U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, and the Arizona Department of Environmental Quality. Phelps Dodge must acquire or maintain a series of permits from these agencies which ensure protection for natural resources from industrial contamination. These agencies verify monthly and quarterly, the compliance of the Morenci mine with these environmental programs. Phelps Dodge is currently in full compliance with these regulations.

With industry, an accidental mechanical or operator release of contaminants may occur. In the case of such a release, the responsible party must immediately report the incident to the Arizona Department of Environmental Quality and the Coast Guard/Environmental Protection Agency National Response Center. A written report must be submitted to the Department of Environmental Quality within 30 days, documenting the clean up of the release. The Department may follow up to ensure remediation to their satisfaction. For all accidental releases to date, Phelps Dodge has satisfied the requirements of the Arizona Department of Environmental Quality and Environmental Protection Agency relating to the release.

These referenced agencies and their environmental protection programs have been previously discussed in both the Draft and Final EIS. They are authorized to regulate and enforce the environmental safeguards of mining. They have fully participated in the Morenci Land Exchange EIS process. Based on their input and our best available information, Phelps Dodge is operating their existing mine and will operate on the selected lands under the jurisdiction of these agencies and in full compliance with their programs established for the protection of the environment.

More specifically, the purpose of issuing National Pollutant Discharge Elimination System (NPDES) and Aquifer Protection Permit (APP) is to improve and protect water quality by eliminating the discharge of pollutants into storm water or groundwater. The requirements to obtain a NPDES or APP permit are to use the best available technology and management practices in the design and operation of the system. This greatly reduces the possibility of a discharge or leak. In the unlikely event that a very large storm causes a discharge, the NPDES permit requires the operator to have an emergency spill response plan and detection system to ensure that any releases do not migrate any great distance from the operation.

In the case of the APP, the operator is required to have a leak detection system which includes monitoring wells to further ensure that all leaks are contained within the operation. Therefore, it is not anticipated that any contamination would reach or affect the San Carlos Apache Reservation or any other lands outside of the Phelps Dodge-owned lands.

Issue 4. The foreseeable mining related uses of selected lands parcel A will impact streamflow in Chase Creek, a tributary of the Gila River. These impacts will adversely affect streamflow in the San Francisco and Gila Rivers. Existing resources and Tribal water rights will be adversely impacted.

This issue was derived from comments made by Sparks, Tehan & Ryley, P.C. representing the San Carlos Apache Tribe, Bureau of Indian Affairs Phoenix Area Office, and Landi Fernley of The Southwest Center For Biological Diversity.

Response 4. Impacts to Chase Creek associated with the projected expansion of the Phelps Dodge Morenci mining operation have been analyzed by BLM and are presented in an internal report titled *Analysis of Impacts to Streamflow in upper Chase Creek as a Result of Projected Expansion of the Morenci Mining Operation.* Consideration of the appropriate scope of analysis presented in the Morenci Land Exchange Final EIS limits the response, presented here, to the impacts on Chase Creek associated with use of selected lands parcel A for mining purposes. No portion of Chase Creek would be destroyed as a result of the land exchange or foreseeable uses of the selected lands. The following discussion references Figure 2-6 and Figure 3-3 in the FEIS.

At the present time, flow in upper Chase Creek is diverted at the Upper Chase Creek Dam located below Garfield Gulch into a bypass system. The bypass system routes flow around the existing mining operation and returns it to lower Chase Creek, where it eventually reaches the San Francisco River, a tributary of the Gila River. The by-pass system, which was constructed to prevent impacts to water quality, is discussed on page 3-14 of the FEIS. Figure 3-3 in the FEIS is in error since it incorrectly depicts the existing diversion upstream of Garfield Gulch. Projected development of the new open pit on Phelps Dodge lands south of selected lands parcel A will require upstream relocation of the current diversion point on Chase Creek. As a result, the following changes and impacts are likely to occur on portions of selected lands parcel A and are discussed in the following paragraphs.

The northern portion of selected lands parcel A is included in an intermittent foreseeable use category and is in the Chesser Gulch watershed. Chesser Gulch is a tributary of upper Chase Creek. The lands included in this category are not expected to be substantially impacted by the projected mining operation. Runoff derived from these lands will not be affected by projected expansion of the mining operation or movement of the Chase Creek diversion point for the bypass system. They will continue to flow to the San Francisco River.

A small eastern portion of selected lands parcel A is also included in the intermittent foreseeable use category and will not be affected by the projected mining operation. Runoff derived from these lands will continue to flow into Sycamore Gulch and then on to the San Francisco River.

Under the existing situation all runoff derived from the southern portion of selected lands parcel A identified for use as leach stockpiles and substantially affected by the projected mining operation, are either already impounded by the existing mining operation or are diverted into the bypass system that routes upper Chase Creek streamflow around the existing mining operation.

The eastern portion of these southern lands contribute runoff to King and Placer gulches. Flow from these gulches is currently impounded by the mining operation and does not contribute to flow in the San Francisco River. The change in the point of diversion on Chase Creek will not affect this situation.

The western portion of these southern lands consist of 320 acres and currently contribute runoff to Garfield Gulch and Upper Chase Creek. Change in the point of diversion on Chase Creek, driven by the development of the new open pit located on private land, will cause runoff derived from these lands to be impounded by the mining operation and no longer contribute to flow in the San Francisco River.

Analysis conducted to quantify the impacts of the projected expansion of the Morenci mining operation on streamflow in the Gila River at the head of the Safford Valley that are currently derived from the selected lands in the watersheds of Chase Creek and Garfield Gulch utilized the following methodology: 1) Watershed areas of the southwestern portion of selected lands parcel A that are expected to be substantially impacted by mining operations were determined from a USGS topographic map land area and slope indicator; 2) Expected runoff contributing to streamflow from this watershed were quantified by utilizing the NRCS TR-55 Graphical Peak Discharge method; 3) Two levels of analysis were conducted. The first assumed average climatic and watershed conditions prevail and the other assumed that additional moisture equivalent to the 100-year storm in addition to the average condition prevail.

Under average climatic conditions the direct impact of impounding runoff from these 320 acres is calculated to result in an average annual reduction in flow of 27 acre-feet in Chase Creek. Information from USGS gaging stations indicate the average annual streamflow in the San Francisco River near Clifton is 163,000 acre-feet while streamflow in the Gila River at the head of Safford Valley averages 370,000 acre-feet per year. Thus the calculated reduction in streamflow from Chase Creek to these rivers is 0.0002 of the total average annual flow of the San Francisco River and 0.00008 of the total average annual flow of the Gila River at the head of the Safford Valley.

A worst-case scenario using average annual runoff plus a 100- year storm event is calculated to result in an annual reduction in flow in Chase Creek of 70 acre-feet. This is 0.004 of the total average annual flow of the San Francisco River and 0.0002 of the total average annual flow of the Gila River at the head of the Safford Valley.

These small calculated changes in streamflow in Chase Creek are not expected to have any impacts on resources, including threatened and endangered species or their habitat, in the San Francisco or Gila rivers. All runoff impounded by the mining operation will require an associated water right. Any impacts to streamflow in the Gila River resulting from the exchange or foreseeable uses of the selected lands will be required to conform with state and federal water rights currently under adjudication.

The BLM recognizes that water rights matters in the Upper Gila basin are presently subject to litigation, and jurisdictional boundaries are unclear. Water rights on the Gila River are currently under litigation in state and federal courts. During the litigation process, surface water rights will be adjudicated and the legal relationship of groundwater and surface water in the Gila River basin, including the Morenci mine, will be defined. The United States will then use the court-adjudicated water rights and the defined relationship between groundwater and surface water to uphold federal trust responsibilities as they relate to federal water rights. Under federal as well as state law, Phelps Dodge Morenci, Inc., will be required to conform to water rights on the Gila River as defined through this litigation.

Responses 51-14, 52-4, 52-1, 52-6, and 53-3 on pages 7-111, 7-113, 7-114, 7-114, and 7-116, respectively, of the FEIS clearly state, among other things, that the exchange of selected lands; 1) does not provide Phelps Dodge with additional water rights to the surface water runoff generated by selected lands; and 2) will not affect the outcome of the on-going Gila River Adjudication.

The controversy and litigation surrounding water rights on the Gila River is complex and unresolved. These legal issues are clearly beyond the scope of the EIS.

If and when Phelps Dodge Morenci, Inc. develops this area for mining, they will be required to obtain an APP permit, 404 permit, and 401 state water quality certification. These permits regulate allowable impacts to both surface and groundwater quality. The 404 permitting process will require NEPA analysis and will allow for public comment at that time. Additional discussion of these permits is found in Response 3 on pages 15 and 16 of this document.

APPENDIX 1

LEGAL DESCRIPTIONS OF SELECTED AND OFFERED LANDS APPROVED FOR EXCHANGE

APPENDIX 1

Legal Descriptions of Lands Approved For Exchange

OFFERED (PRIVATE) LANDS

Gila and Salt River Meridian, Arizona

EAGLE CREEK TRACT
T. 5 S., R. 29 E., Greenlee County, Arizona
sec. 30, SW¼, NW¼SE¼, SW¼SE¼;
sec. 31, NW¼NE¼.

The area described contains 280.00 acres.

CLYNE I PROPERTY
T. 19 S., R. 18 E., Pima County, Arizona
sec. 9, SE¼NE¼;
sec. 10, SW¼NW¼.

The area described contains 80.00 acres.

PETERSON PROPERTY
T. 14 S., R. 28 E., Cochise County,
sec. 3, E½SW¼, SW¼SW¼, SE¼;
sec. 10, NW¼NW¼.

The area described contains 320.00 acres.

STEWART PROPERTY
T. 14 S., R. 28 E., Cochise County, Arizona
sec. 7, E½E½, NW¼NE¼, W½SE¼;
sec. 8, S½SW¼.

The area described contains 360.00 acres.

The areas described aggregate 1,040 acres.

SELECTED (FEDERAL) LANDS

Gila and Salt River Meridian, Greenlee County, Arizona

PARCEL A
Township 3 South, Range, 29 East,
section 15, all;
section 21, SE¼SW¼, SE¼;
section 22, N½NE¼, SE¼NE¼, S½;
section 23, S½SW¼, SW¼SE¼;
section 26, lots 1, 2, 3 and 5, W½NE¼, SE¼NE¼, NW¼, NE¼SE¼;
section 27, lots 1 to 5, inclusive, N½NE¼, SE¼NE¼, NW¼NW¼;
section 28, lots 1 to 6, inclusive, lot 10, N½NE¼, SW¼NE¼, NE¼NW¼;
section 35, lots 9,10 and 11.

PARCEL B
Township 3 South, Range, 29 East,
section 35, lot 12.

PARCEL C
Township 3 South, Range, 29 East,
section 35, lot 18.

PARCEL D
Township 4 South, Range 29 East,
section 1, lot 7.

<u>PARCEL</u> **<u>E</u>** Township 4 South, Range 29 East,
section 11, lot 9;
section 12, lots 16, 17, 18 and 19.

<u>PARCEL</u> **<u>F</u>** Township 5 South, Range 29 East,
section 12, lots 19, 21, 22, 23 and 24.

<u>PARCEL</u> **<u>G</u>** Township 3 South, Range 29 East,
section 31, lots 1, 4, 5, and 8, W½E½.
Township 4 South, Range, 29
section 5, lot 11;
section 6, lots 2, 11 and 21.

<u>PARCEL</u> **<u>H</u>** Township 3 South, Range 29 East,
section 32, lots 22, 23, 24 and 25.

<u>PARCEL</u> **<u>I</u>** Township 4 South, Range 29 East,
section 6, lot 25.

<u>PARCEL</u> **<u>J</u>** Township 4 South 28 East,
section 12, lot 15;
Township 4 South, Range 29 East,
section 7, lot 23.

<u>PARCEL</u> **<u>K</u>** Township 4 South, Range 29 East,
section 7, lots 20, 25, and 26;
section 8, lots 13, 14, 16 and 17;
section 18, lots 25 and 26.

The selected lands in sections 7, 8 and 18 of the above parcel were resurveyed to exclude conflicting mining claims.

<u>PARCEL</u> **<u>L</u>** Township 4 South, Range 29 East,
section 20, lots 3, 9,15, 18 and 19, SW¼SW¼.

<u>PARCEL</u> **<u>P1</u>** Township 4 South, Range 29 East,
section 6, lot 24.

<u>PARCEL</u> **<u>P2</u>** Township 4 South, Range 29 East,
section 7, lot 22.

<u>PARCEL</u> **<u>P3</u>** When the survey was done, this parcel was included in lot 23, section 7,
Township 4 South, Range 29 East (PARCEL J)

<u>PARCEL</u> **<u>P4</u>** Township 4 South, Range 29 East,
section 7, lot 19.

<u>PARCEL</u> **<u>P5</u>** Township 4 South, Range 29 East,
section 18, lot 22.

<u>PARCEL</u> **<u>P6</u>** Township 4 South, Range 29 East,
section 11, lot 8.

<u>PARCEL</u> **<u>P7</u>** Township 3 South, Range 29 East,
section 35, lot 17.

<u>PARCEL</u> **<u>P8</u>** Township 4 South, Range 29 East,
section 1, lot 8.

PARCEL **P9** Township 3 South, Range 29
section 28, lot 11.

PARCEL **P10** Township 3 South, Range 29 East,
section 32, lot 26.

PARCEL **P11** Township 4 South, Range 29 East,
section 5, lot 14.

PARCEL **P12** Township 4 South Range 29 East,
section 17, lot 14. **This lot is part of PARCEL K.**

PARCEL **P13** Township 4 South, Range 29 East,
section 17, lot 15.

PARCEL **P14** Township 4 South, Range 29 East,
section 20, lot 17.

PARCEL **P15** This parcel does not exist; it was patented as part of the Apache mining claim.

PARCEL **P16** Township 4 South, Range 29 East,
section 20, lot 16.

PARCEL **P17** Township 4 South, Range 29 East,
section 20, lot 14.

The areas described aggregate 3,604.79 acres.

EXCEPTING AND RESERVING TO THE UNITED STATES:

1. A right-of-way thereon for ditches or canals constructed by the authority of the United States. Act of August 30, 1890 (43 U.S.C. 945).

2. A right-of-way of the Arizona Highway Department for a Highway, effective March 7, 1973, under the Act of August 27, 1958 (72 Stat. 885) Title 23, U.S. 317, as to lot 10, sec. 28, T. 3 S., R. 29 E., Gila and Salt River Meridian, Arizona (AZA 7456).

3. A right-of-way for Route #1 (Forest Trail #12) as reserved under right-of-way no. AZA 30035, pursuant to Title V of the Act of October 21, 1976 (43 U. S. C. 1767) as to NW¼NW¼, sec. 15, T. 3 S., R. 29 E.,and the right to enforce all or any of the terms and conditions of the right-of-way, including the right to renew or extend it upon its termination.

SUBJECT TO:

1. Those rights for a power transmission line granted to Arizona Electric Power Cooperative, Inc., its successors or assigns, by right-of-way no. AZA 9015 pursuant to the Act of October 1976 (90 Stat. 2776; 43 U.S.C. 1761), as to lot 21, sec. 12, T. 5 S., R. 29 E., Gila and Salt River Meridian, Arizona.

2. Such rights as grazing permittee, Lines Brothers (c/o Ruskin Lines) may have to continue his grazing use until October 26, 1997 (Allotment No.40030).

3. Such rights as grazing permittee, Jeff Menges, may have to continue his grazing use until June 29, 1997 (Allotment No. 40100).

4. Such rights as grazing permittee, Lines Brothers (c/o Ruskin Lines), may have to continue his grazing use until June 28, 1997 (Allotment No. 40010).