

From Mine to Me

How copper ore becomes copper wire



Sierrita Mine

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How copper ore becomes copper wire



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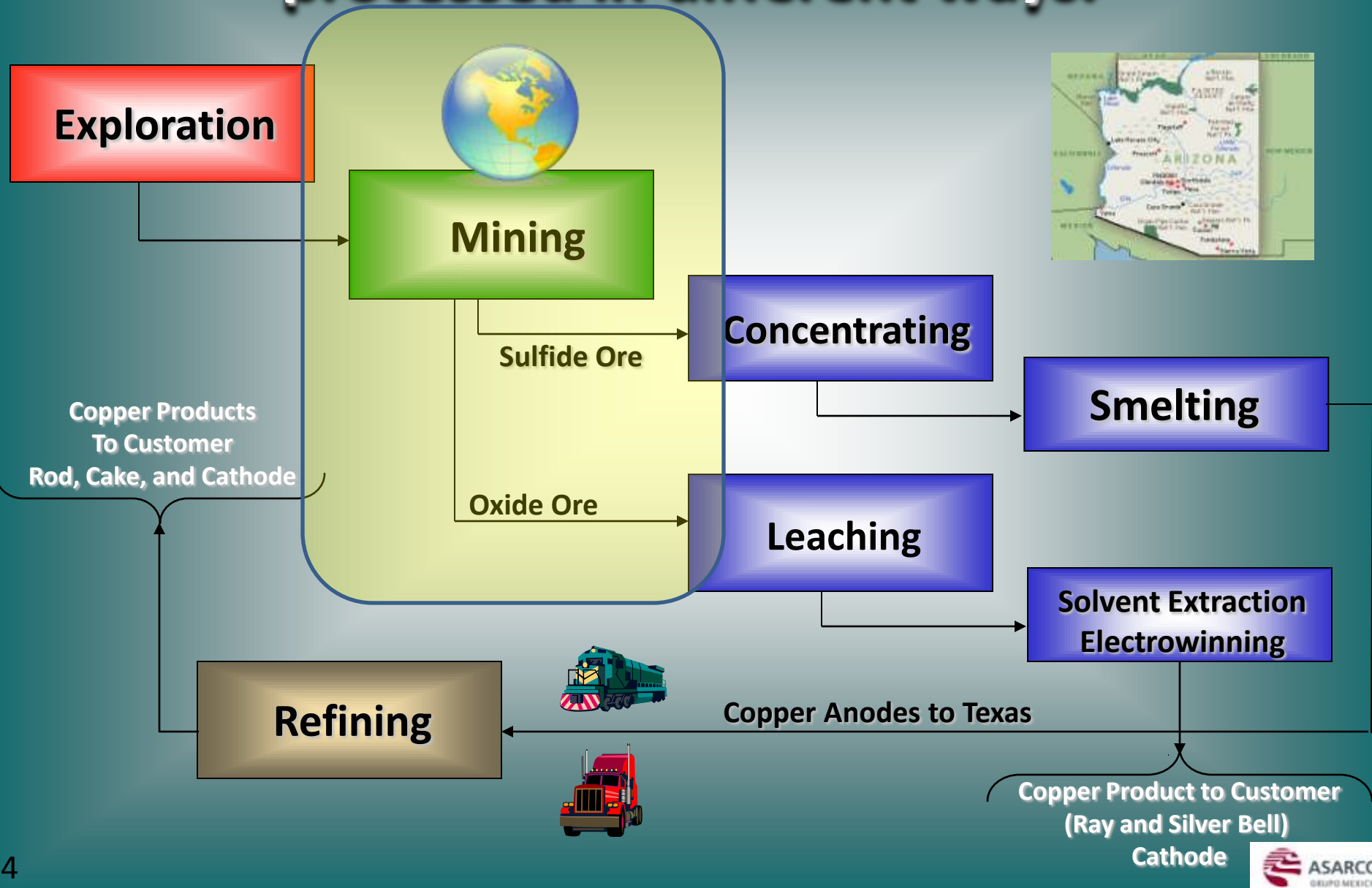
Arizona Major Mines



Arizona Copper Mines

- Bagdad
- Bisbee
- Carlota
- Hayden Smelter
- Johnson Camp
- Miami
- Mineral Park
- Mission
- Morenci
- Pinto Valley
- Ray
- Resolution
- Rosemont
- Safford
- San Manuel
- Sierrita
- Silver Bell
- Tohono

Copper sulfide ore and copper oxide ore are processed in different ways.



Sulfide ore: Chalcopyrite & Bornite

Chalcopyrite



Chalcopyrite can be called copper fool's gold. It is made of copper, iron, and sulfur. It is a brassy yellow, metallic mineral and it is very heavy.

Chalcopyrite is not as hard as pyrite, which is called fool's gold. Chalcopyrite will not scratch glass, but will scratch a copper penny. Pyrite will scratch glass.

Chalcopyrite is also a brighter yellow than pyrite. It often tarnishes to a blue-green, iridescent color on weathered surfaces. Chalcopyrite is the main copper sulfide ore.

Bornite is also known as Peacock Copper because of the blue-green tarnish. On freshly broken surfaces, it is bronze colored.

Bornite is a copper iron sulfide and is as hard as a penny.



Bornite



Chalcocite

Chalcocite is a sooty black, heavy, copper sulfide. It is a very rich ore of copper, as it doesn't contain very much sulfur. It is softer than a penny and can easily be cut with a knife.

Other minerals are found in copper deposits.



pyrite

Pyrite is also known as fool's gold.

It is composed of iron and sulfur and contains no copper or gold.

However, pyrite is very common in gold and copper ore deposits. In copper deposits, it is known as "gangue" or waste.



Molybdenite is an ore mineral of molybdenum. It is often found with chalcopyrite in copper deposits.

Copper is pure copper and is known as "Native Copper". It is rare in porphyry copper ore deposits. But some beautiful specimens have come from Ajo, Ray, and Bisbee.

Copper is the same color as pennies, as they are coated with copper. Fresh copper is reddish brown colored, but after weathering and handling, the copper becomes coated with tarnish. This tarnish can be black or green.

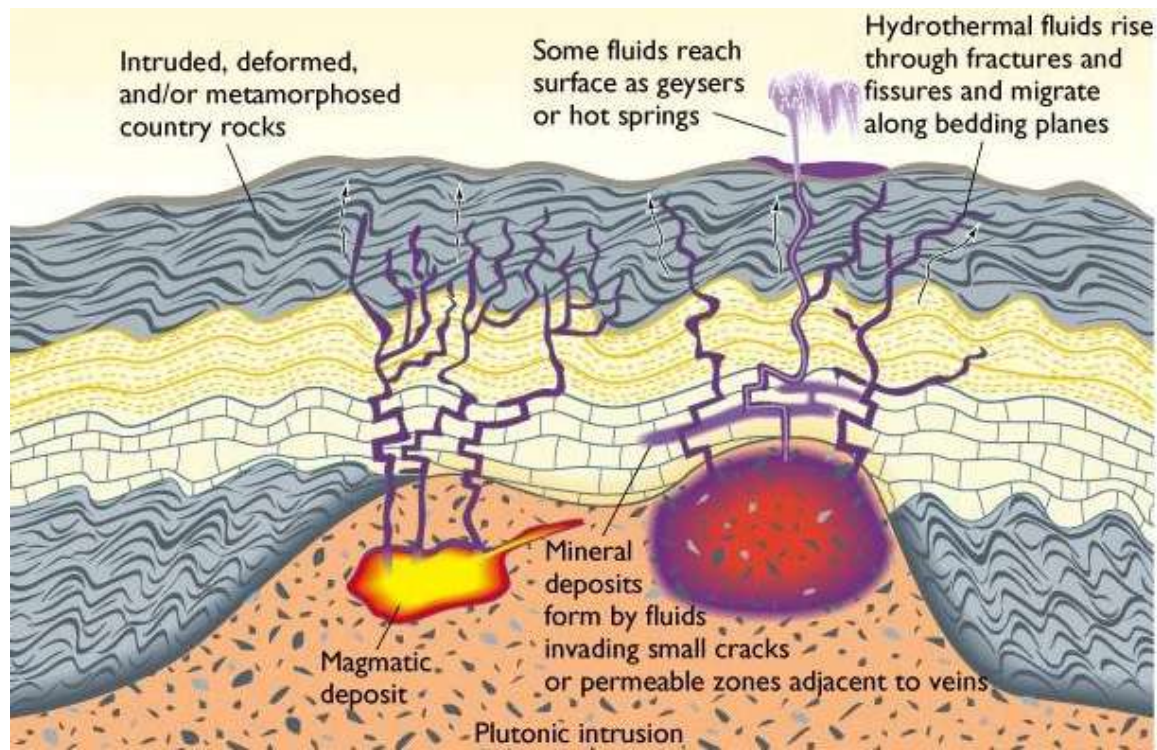
Copper is malleable, which means it bends easily. It also can easily be drawn into a wire.



copper

How did copper sulfide ore form?

- Intrusions of granite containing copper and other metals pushed into the crust and solidified about 3 to 5 km under the surface about 65 million years ago.
- Hydrothermal (hot water) fluids containing metals are pushed into cracks in the rock forming veins.
- The copper sulfide minerals are disseminated (spread out) through the surrounding rock at low concentrations (<1%).



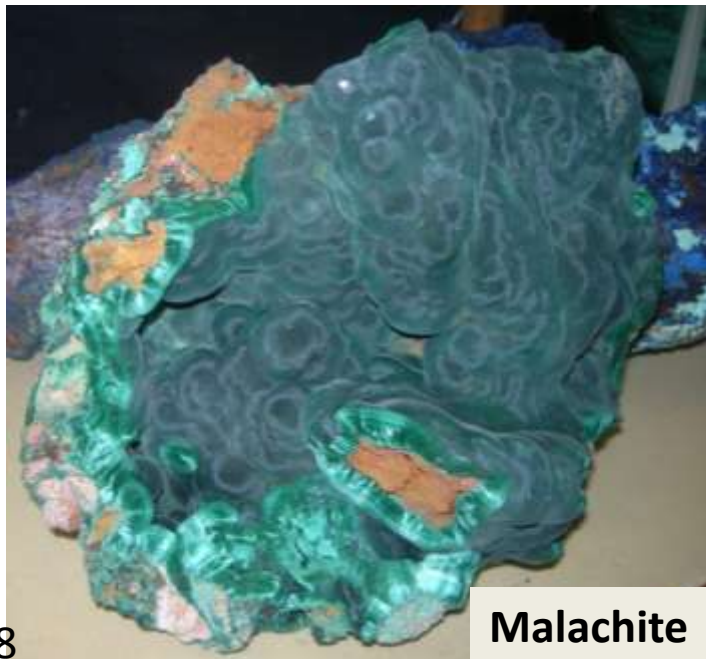
Copper “oxides”: azurite, malachite



Azurite is a light to dark blue-colored mineral that forms small crystals.

Azurite and malachite are composed of copper carbonates. They contain copper, carbon, and oxygen. They are softer than glass and may or may not scratch a penny.

Because they are carbonates, acid will break down the carbonate and release carbon dioxide bubbles. Make a powder by scratching or grinding the minerals. Then drop some acid (such as vinegar) on the mineral and it will make some bubbles of carbon dioxide. You may need to look at it with a magnifying glass to see the bubbles.



Malachite is a dark green to grass green-colored mineral. It usually forms in rounded, globular shapes.

Copper “oxides”: chrysocolla

Chrysocolla is a beautiful blue-green mineral that looks like turquoise. However, it is softer than glass. Turquoise will scratch glass, while chrysocolla will not.

Chrysocolla is composed of copper silicate. It contains copper plus silicon and oxygen and also contains variable amounts of water. Because of the affinity for water, it can absorb water. If you lick your finger and touch it to the chrysocolla, your finger will slightly stick to the mineral.



- Chrysocolla (blue-green copper silicate)

How did copper “oxide” ore form?



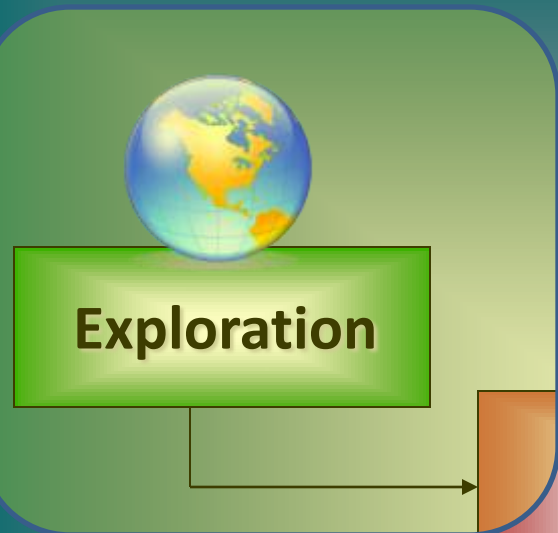
Secondary Enrichment

- Downward seeping rain water in the ground reacts with pyrite (fools gold) and chalcopyrite (copper iron sulfide) to make sulfuric acid.
- The acid leaches the copper out of the rock and makes copper-rich solutions.
- The left over iron oxide (rust) in the upper parts of the leached copper deposit make the ground reddish colored (iron hats).
- Malachite (green copper carbonate), Azurite (blue copper carbonate), Chrysocolla (blue-green copper silicate), and Chalcocite (copper sulfide) are deposited at the top of the water table.



How do you find copper?

Mining begins with geological exploration.



Copper Products
To Customer
Rod, Cake, and Cathode

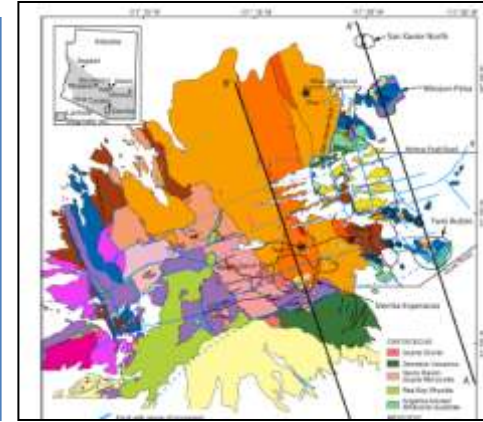
Copper Anodes to Texas

Copper Product to Customer
(Ray and Silver Bell)
Cathode



How is copper ore found?

- **Mapping:** Geologists observe the rocks and structures and make geologic maps and cross-sections.
- **Sampling:** Geologists take samples for observation and analysis.
- **Geochemical Analysis:** Geochemists analyze the rocks and minerals for their chemistry.
- **Geophysics:** Geophysicists make measurements of magnetism, gravity, electrical features, and other properties.
- **Drilling:** Core drill rigs are used to bring up core from deep in the Earth.
- **Assaying Core:** The core that is brought up is analyzed for its chemistry and mineralogy.
- **Economic Feasibility Studies:** Is there enough copper to make a profit?
- **Writing Reports:** Reports are written to convince the management and investors to proceed with starting a mine.





**Geologists examine mineralized outcrops
and make geologic maps.**

A helicopter tows a magnetometer to explore for a copper deposit.



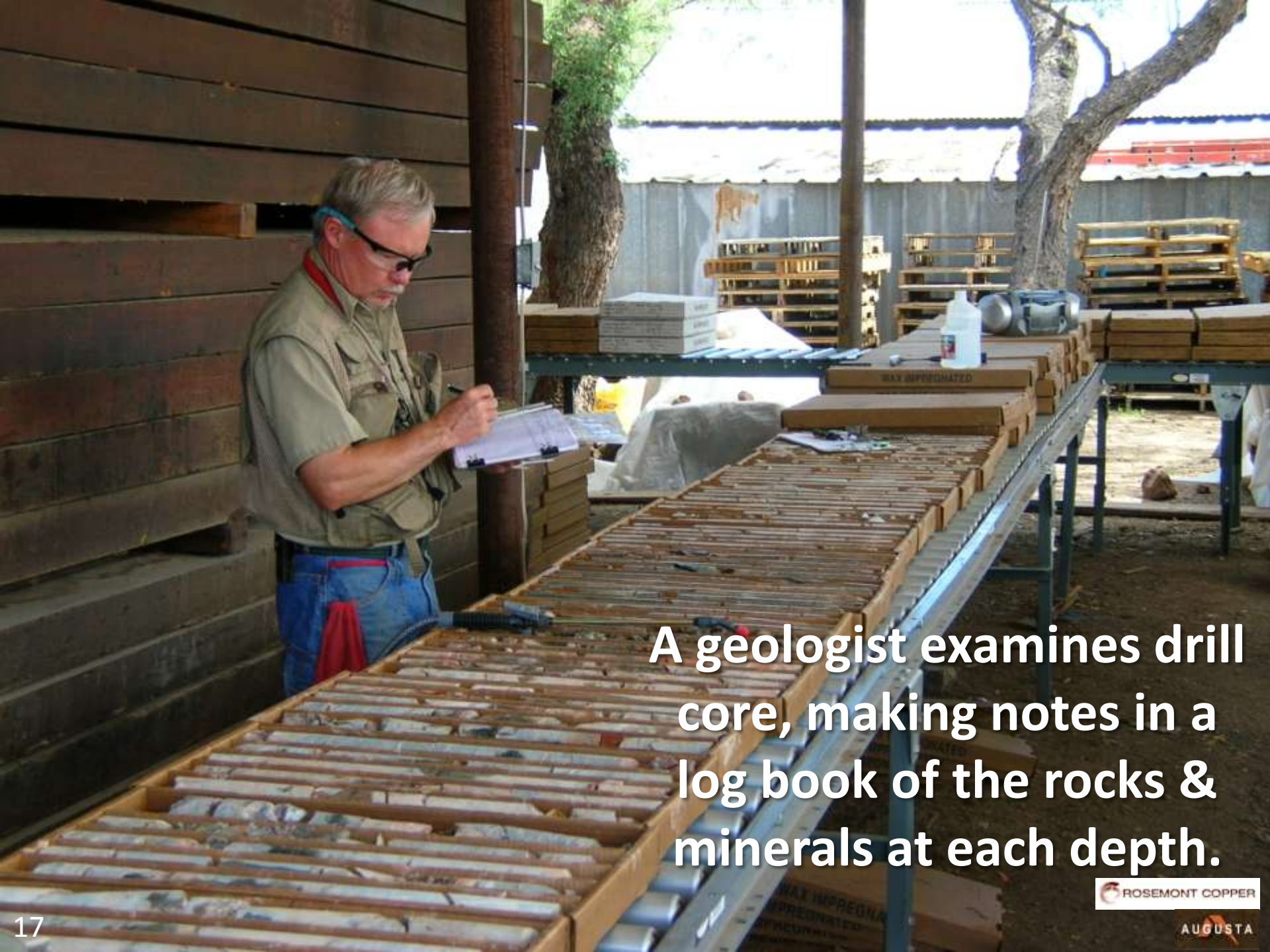
It detects magnetic minerals, such as magnetite, which is an iron oxide that commonly occurs around copper deposits.

A core drilling rig drills an angled hole to search for copper minerals.



**An
Exploration
Geologist
examines
drill core
with a
magnifying
hand lens,
recording
minerals
and
structures.**





A geologist examines drill core, making notes in a log book of the rocks & minerals at each depth.

Drill core shows green malachite, blue-green chrysocolla, and brassy chalcopyrite.



Drill core is stored in labeled boxes in a Core Storage Building.



A geologist records sample numbers and labels samples to send to a laboratory for chemical analysis.



A geologic map is made showing the rock types, faults, mineralized areas, scale of the map, and north arrow.

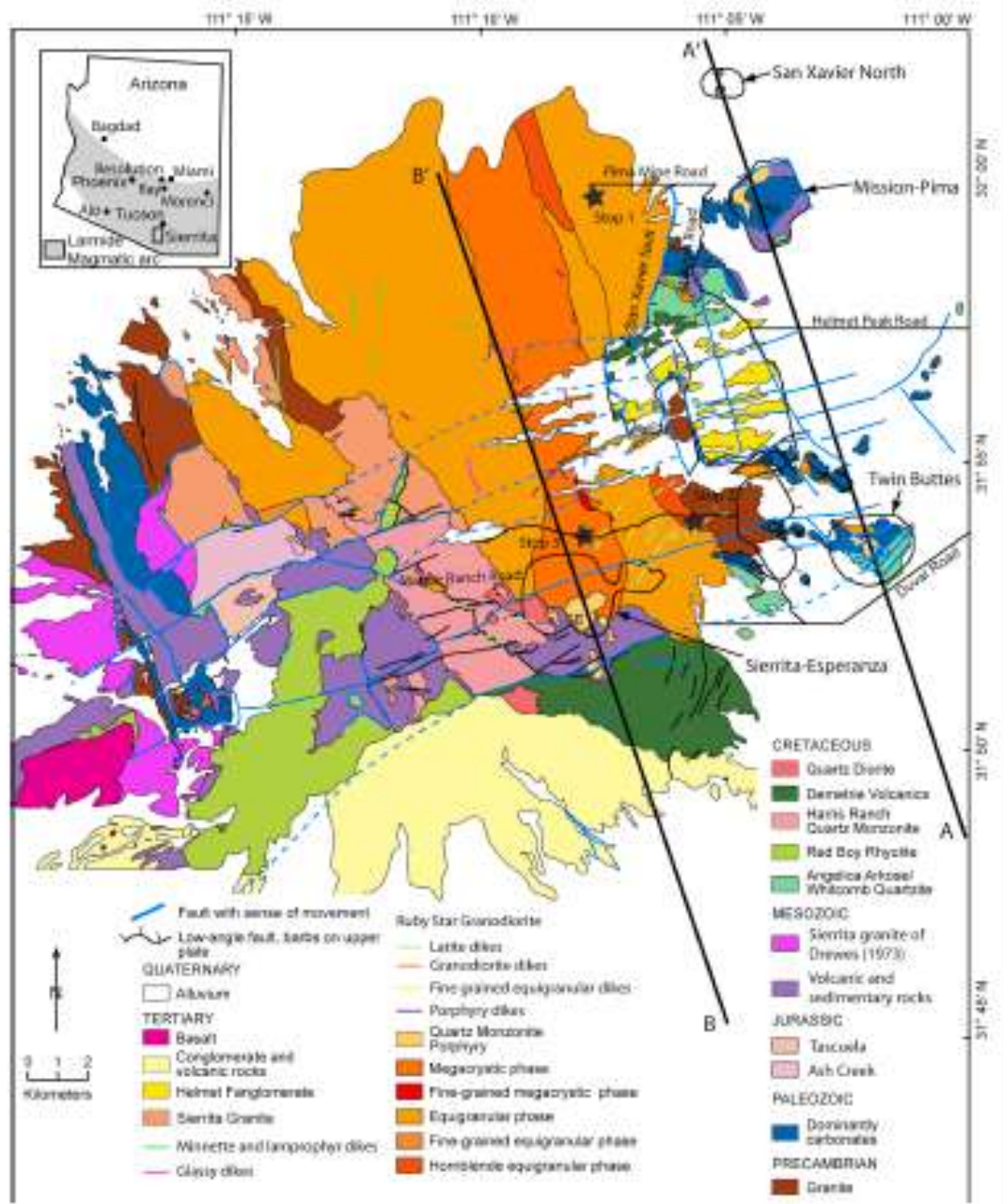
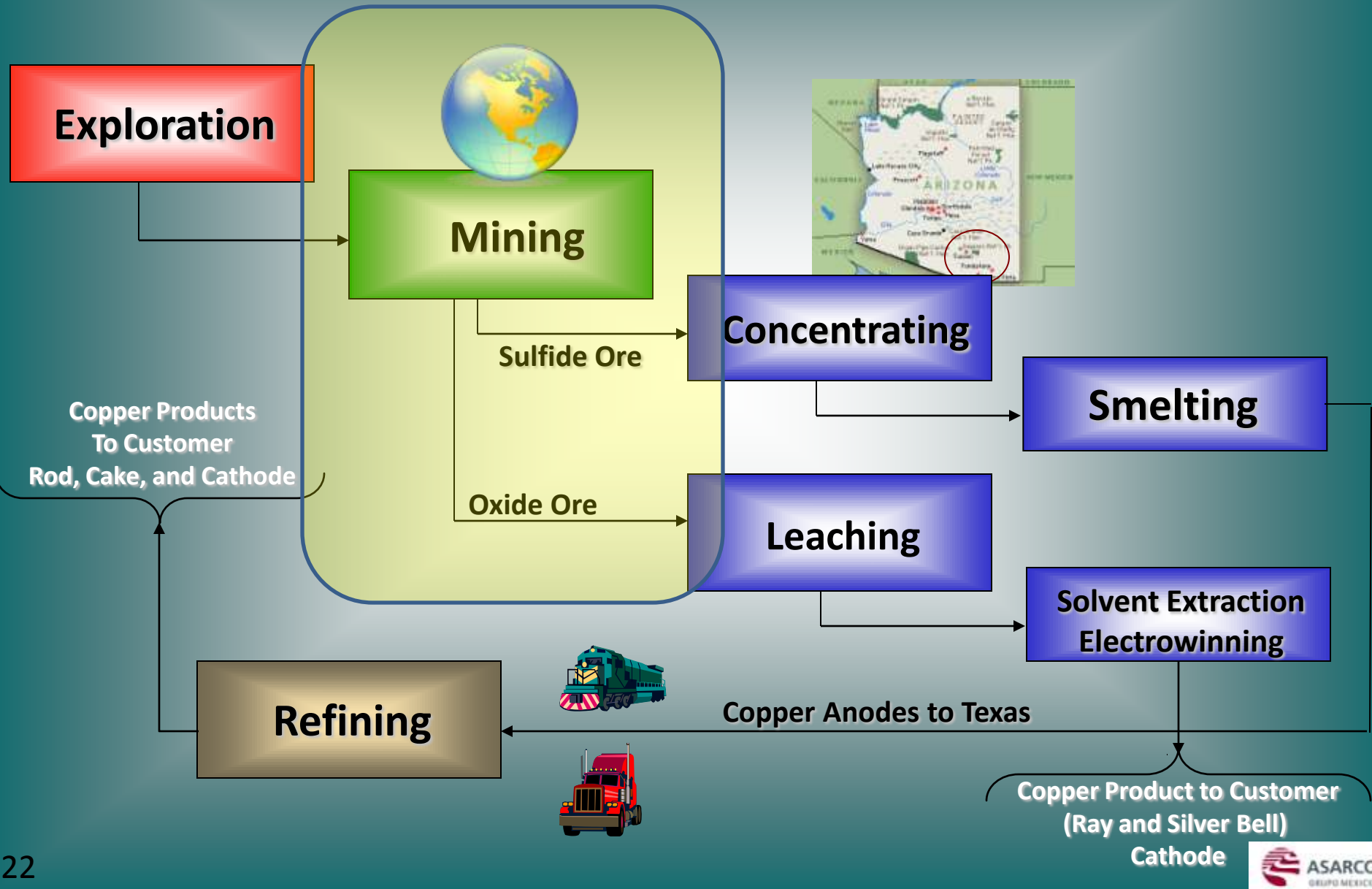


Figure 3. Geologic map of the Sierrita Mountains showing field trip stops, locations of mines, and locations of cross sections. Compiled and simplified from Cooper (1960), Drewes (1973), Spencer et al. (2003), Johnson et al. (2003), Richard et al. (2003), and Spencer et al. (2003).

Sierrita Mine

How is copper ore removed from the ground?



Low grade (<1%) copper ore can be mined in Open Pit mines as the ore is near the surface.



23

The open pit looks like a series of benches or terraces in a circular or oblong shape.

Drill rigs bore holes into the terraces. The holes are filled with explosives and blasted.



Blasting breaks the rock away from the walls, allowing it to be scooped up by shovels.



Electric Shovels pick up 100 tons of broken ore in each scoop and load it into Haul Trucks.





Shovels are used to load the Haul Trucks.

Haul Trucks have GPS (Global Positioning System) tracking for efficiency.



The largest loader on Earth is the LeTourneau L2350 with a 53 cubic yard bucket.



The largest-capacity Dump Truck in the world can carry 400 tons.

Liebherr's T282B Haul Truck is used at the Ray Mine.

Ray Mine



Truck sprays water to reduce the dust.



Haul Trucks dump ore in the Primary Crusher.



Pinto Valley Mine



Ore is dumped into the in-pit crusher.



The gyratory crusher rotates to crush the ore into 8-inch pieces, like a mortar and pestle.



**The
Conveyor
System
carries ore to
a Heap Leach
Pad,
Stockpile, or
Concentrator
(Mill).**



Sometimes there are two conveyor belts taking ore from the in-pit crusher to the Mill.



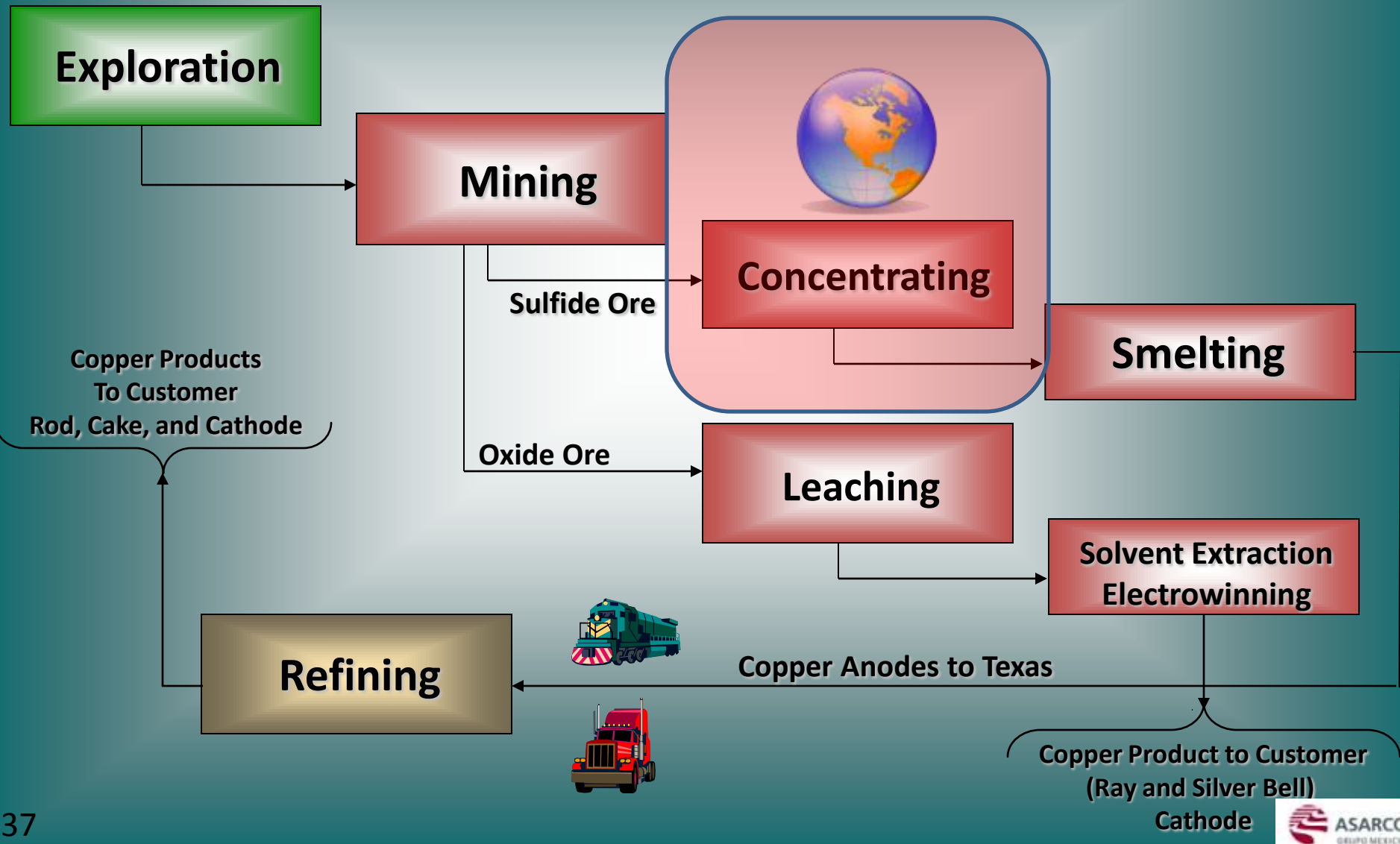
Sierrita Mine

In the Maintenance Shop, a Haul Truck is much larger than a person.



How do they get copper out of sulfide ore?

Concentration includes Grinding & Flotation.



The Control Center uses computerized tracking for trucks, shovels, machinery, & processes.



Sulfide ore is ground up in the Semi-Autogenous Grinding (SAG) and ball mills. The ore-rock slurry is concentrated in the flotation tanks.



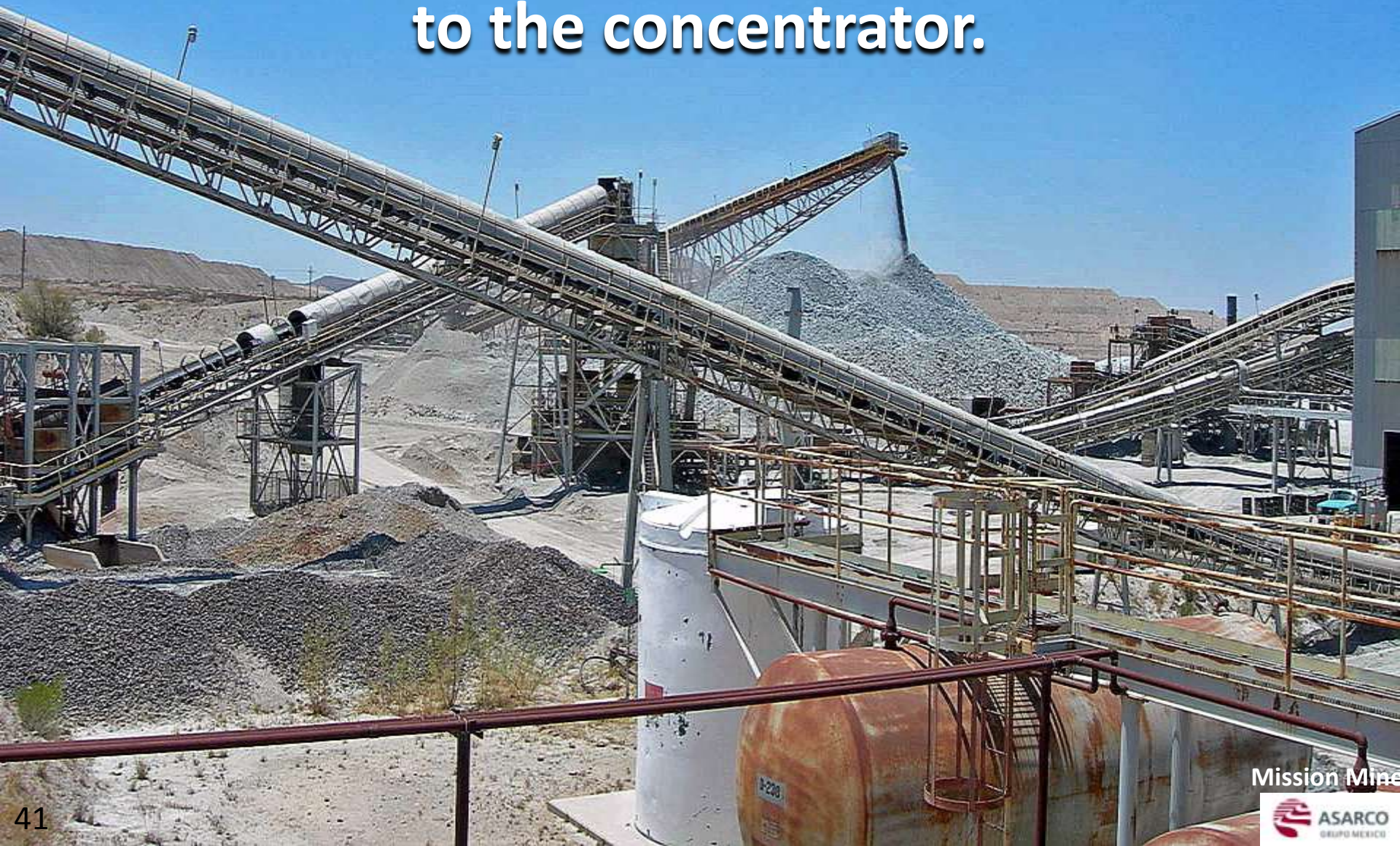
Ray Mine Concentrator

The conveyor drops ore into the Concentrator ,
where the ore is ground into fine grains.

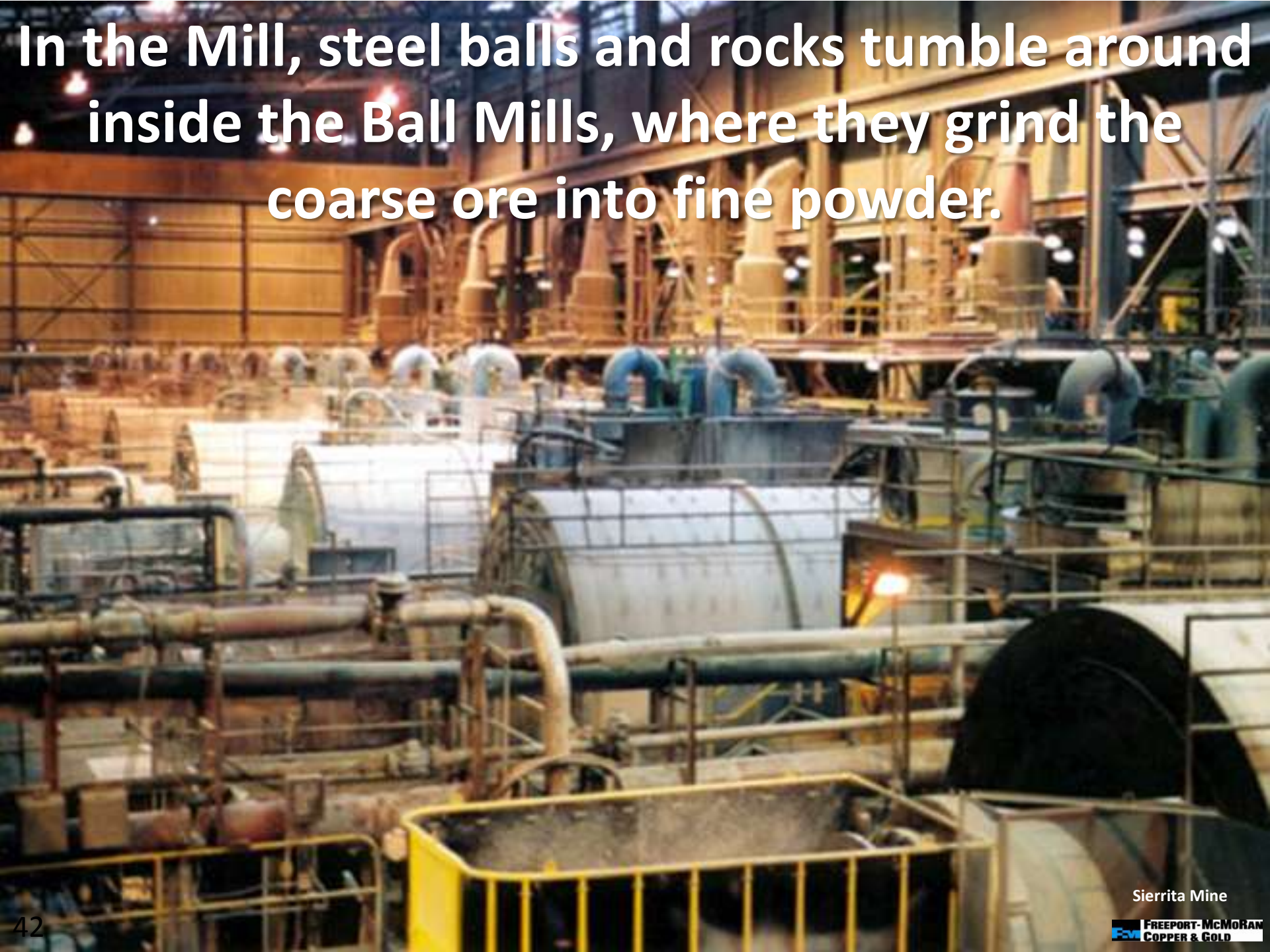


Sierrita Mine

Sometimes the coarse ore is moved on a conveyer belt to a stockpile, before it is taken to the concentrator.



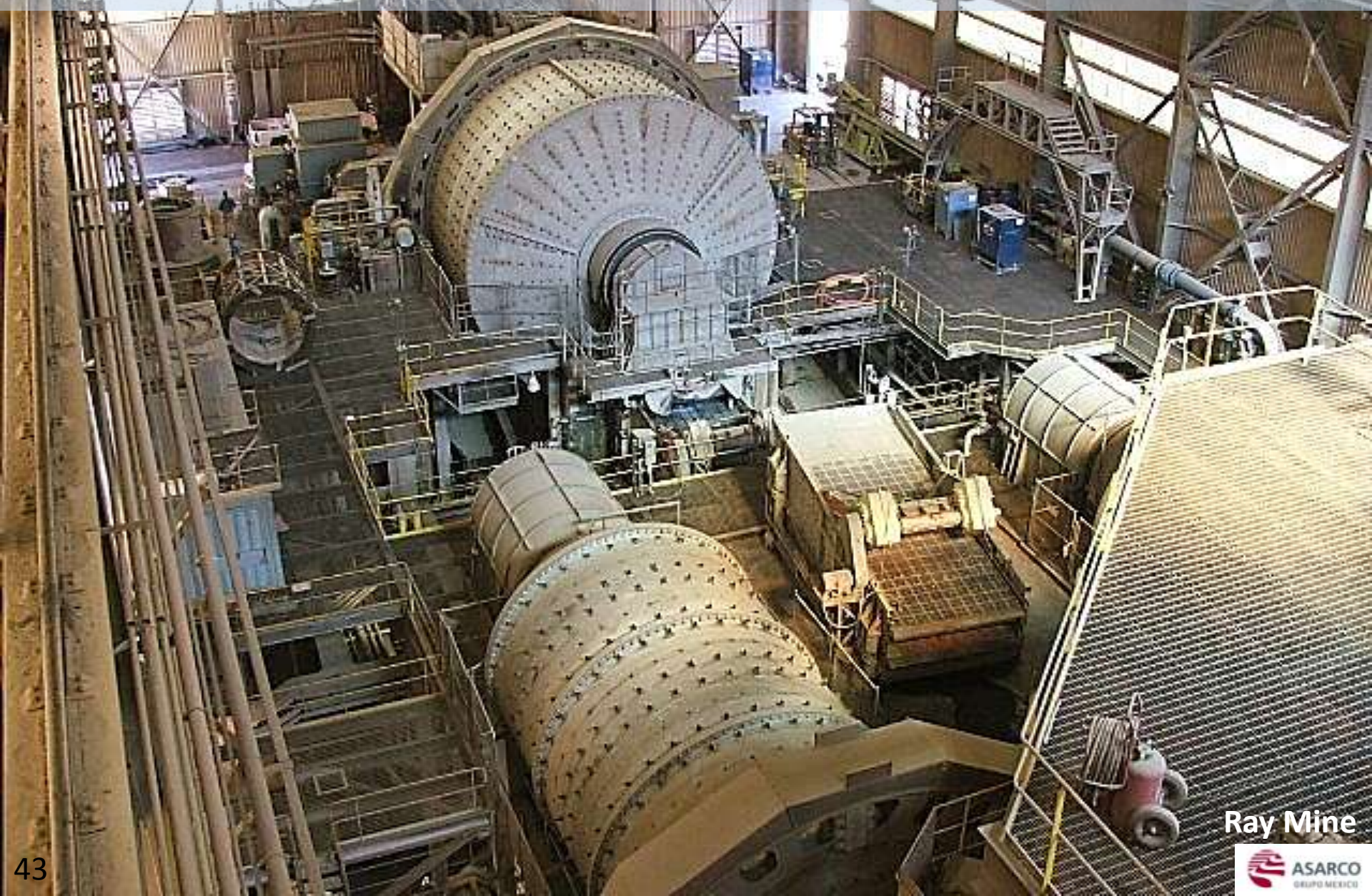
In the Mill, steel balls and rocks tumble around inside the Ball Mills, where they grind the coarse ore into fine powder.



Steel balls used in the Ball Mills to grind the ore are bigger than a hand.



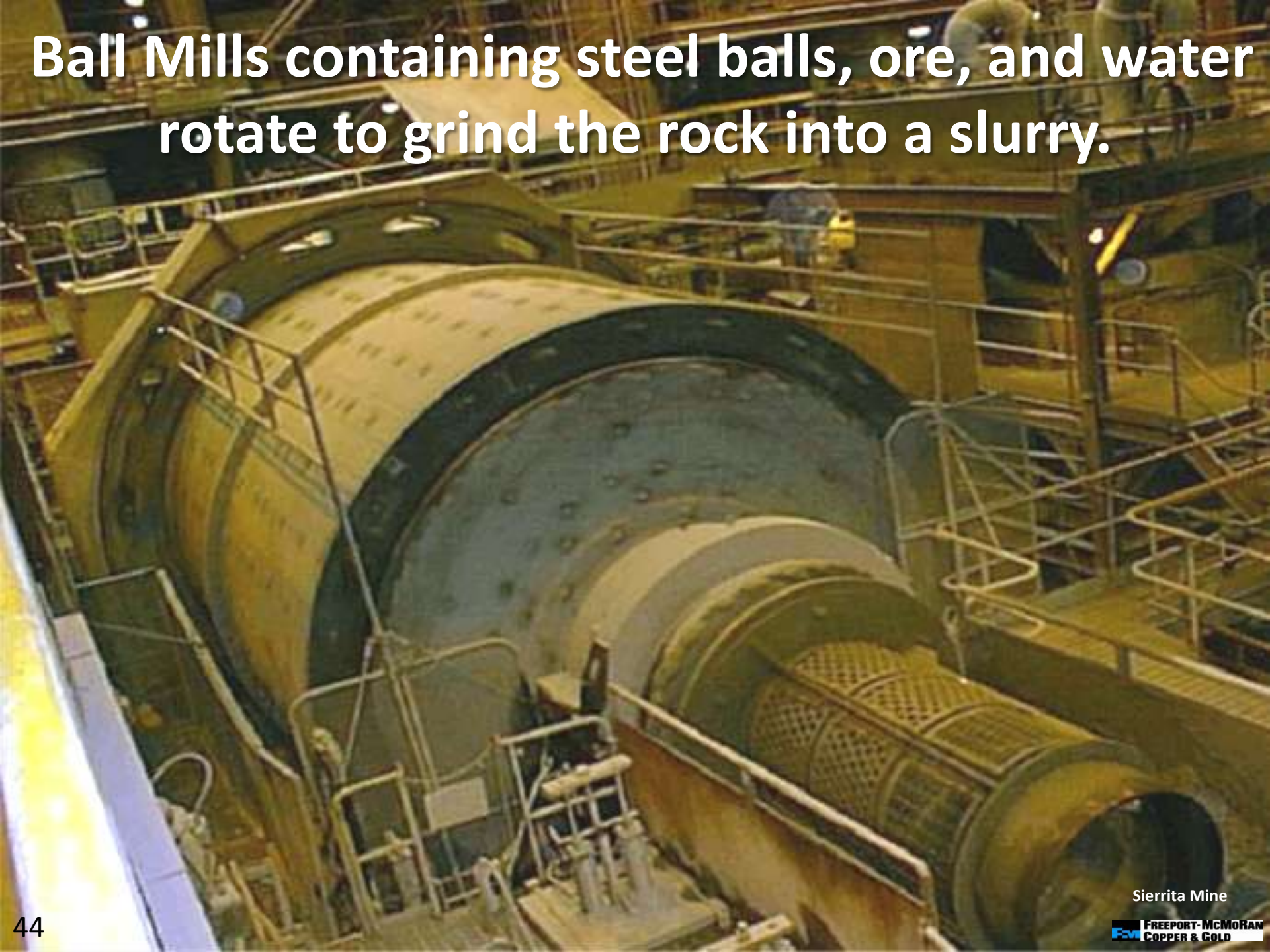
The SAG (Semi-Autogenous Grinding) Mill (34-foot diameter) and Ball Mills (18-foot diameter) rotate to grind the ore.



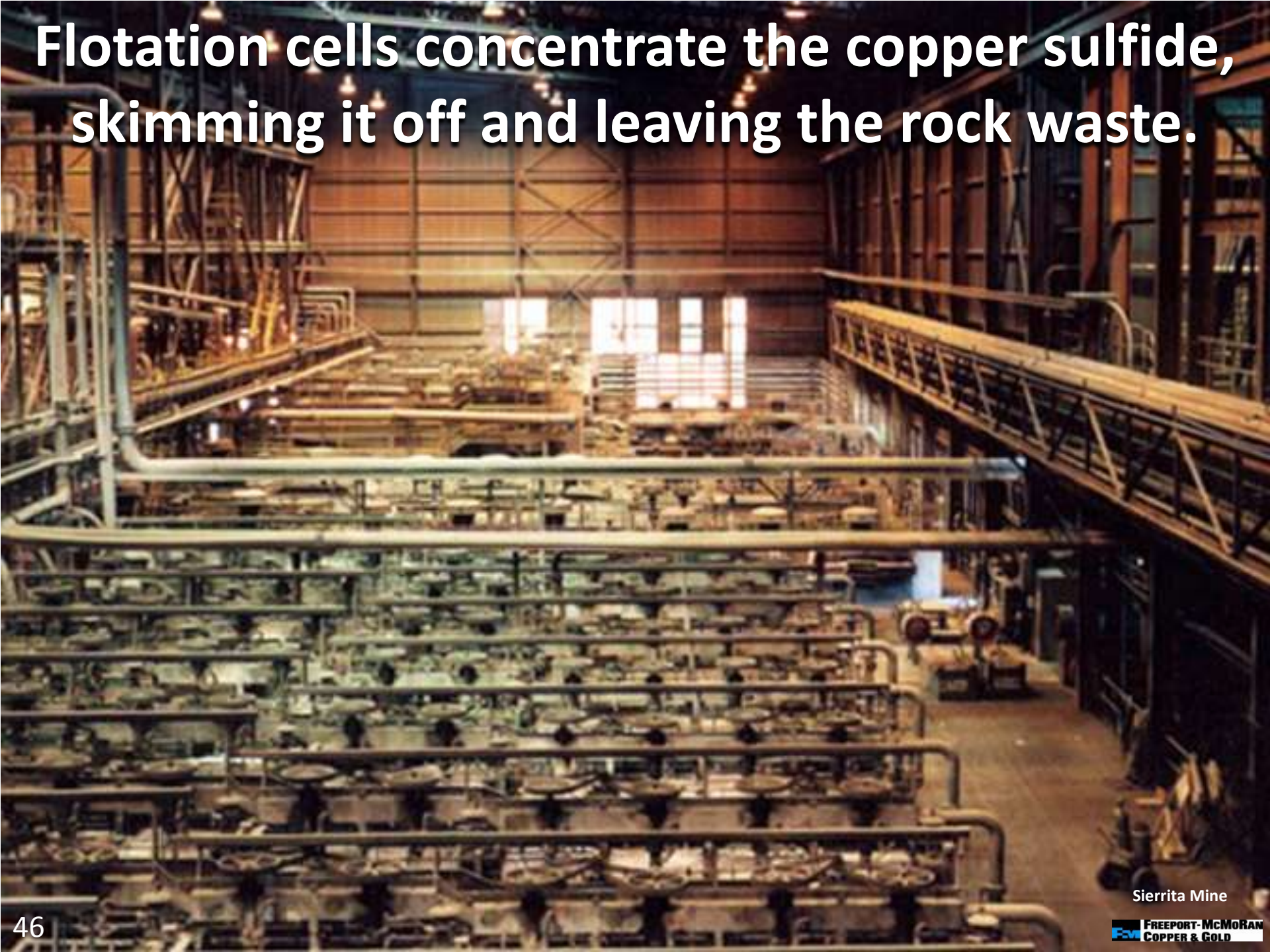
Ray Mine



Ball Mills containing steel balls, ore, and water rotate to grind the rock into a slurry.



Flotation cells concentrate the copper sulfide, skimming it off and leaving the rock waste.



Sierrita Mine

Air is injected to make bubbles. Organic reagents, such as pine oil, coat the sulfide grains, making them float.



The copper sulfide attaches to the bubbles and is skimmed off by paddles.



The copper sulfide-rich slurry is filtered, forming a black powder called copper concentrate.



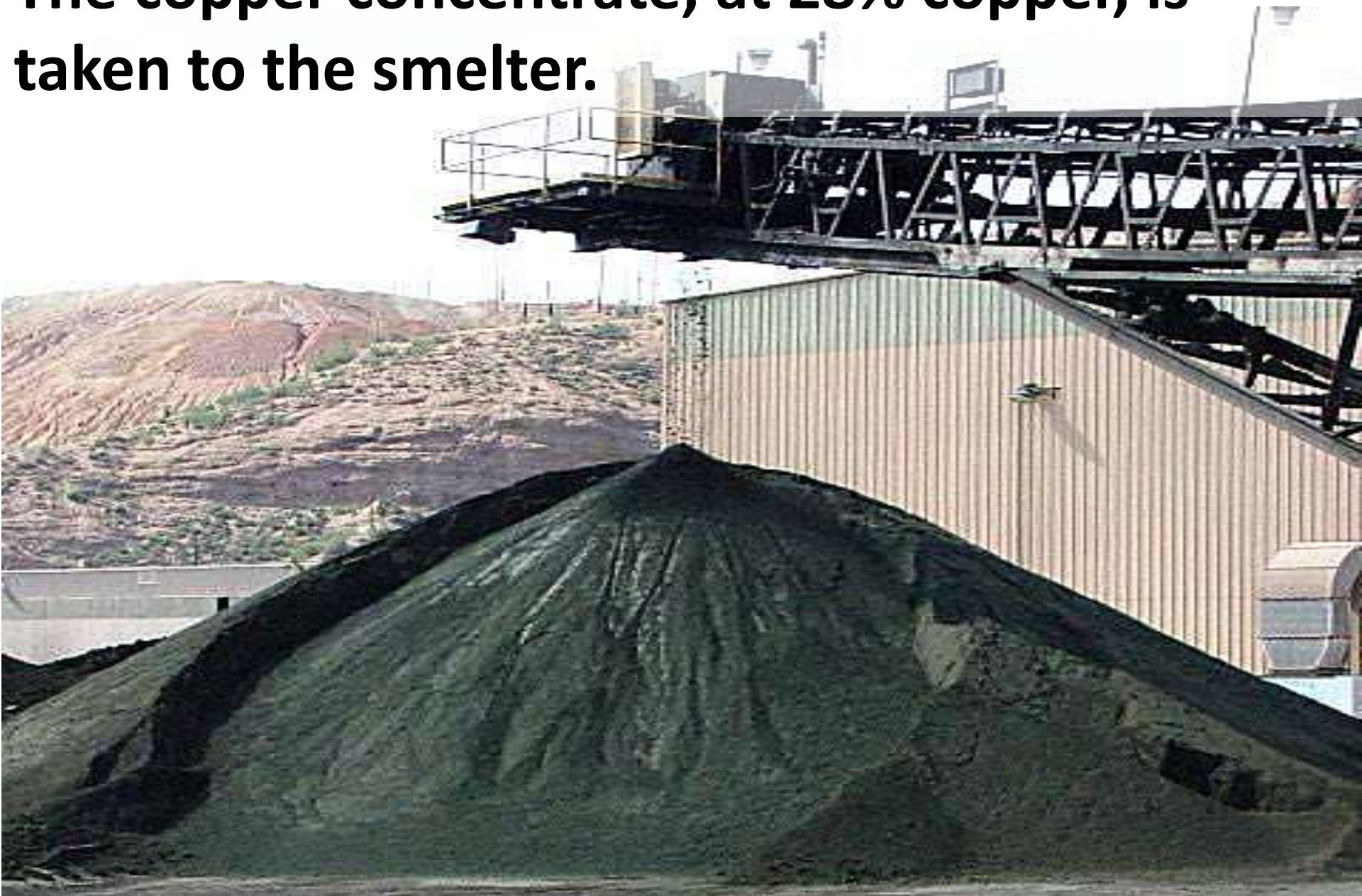
The sulfide slurry is dried in a filter press that squeezes out water or on drying wheels.



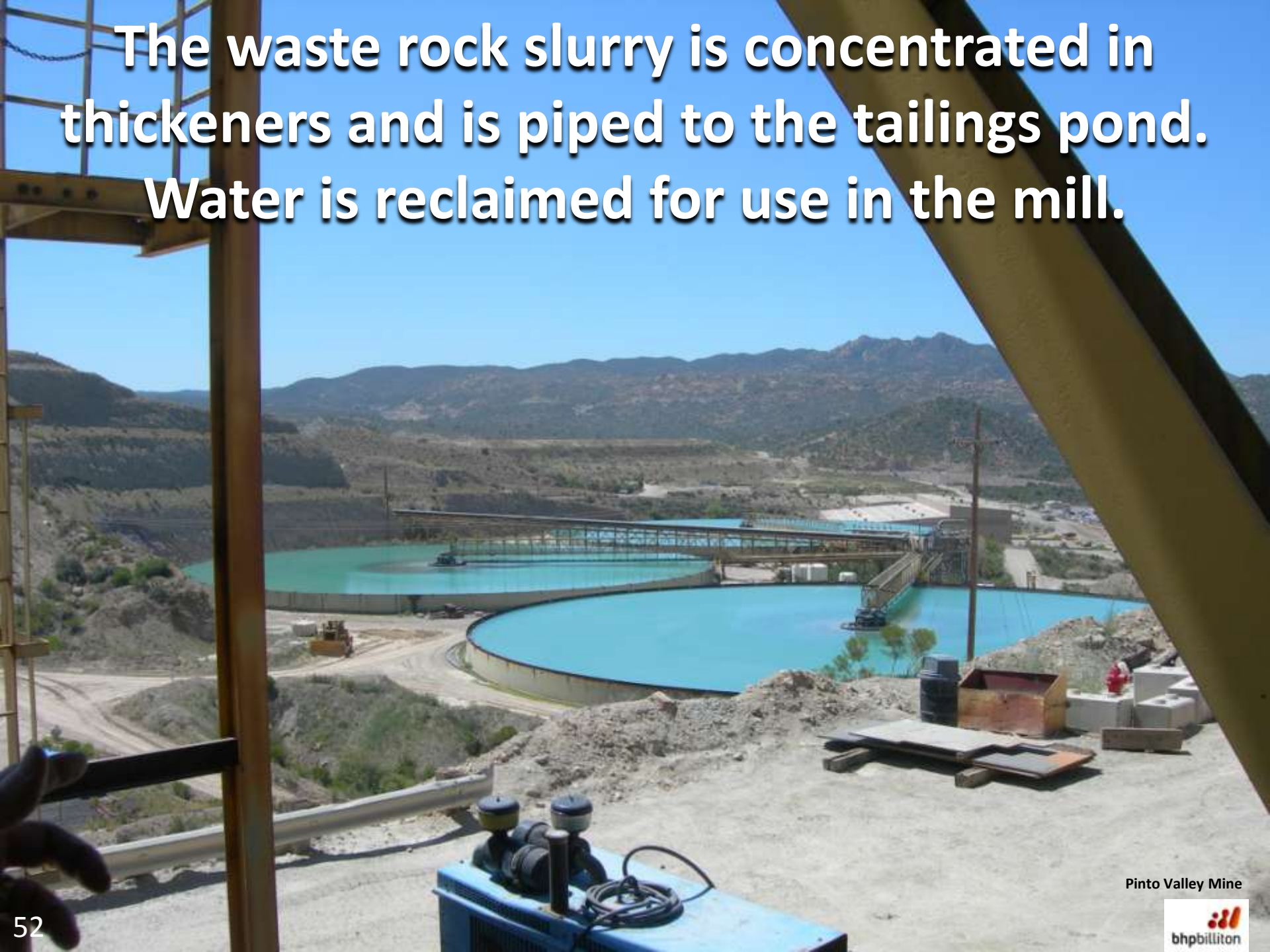
Pinto Valley Mine



The copper concentrate, at 28% copper, is taken to the smelter.



The waste rock slurry is concentrated in thickeners and is piped to the tailings pond. Water is reclaimed for use in the mill.

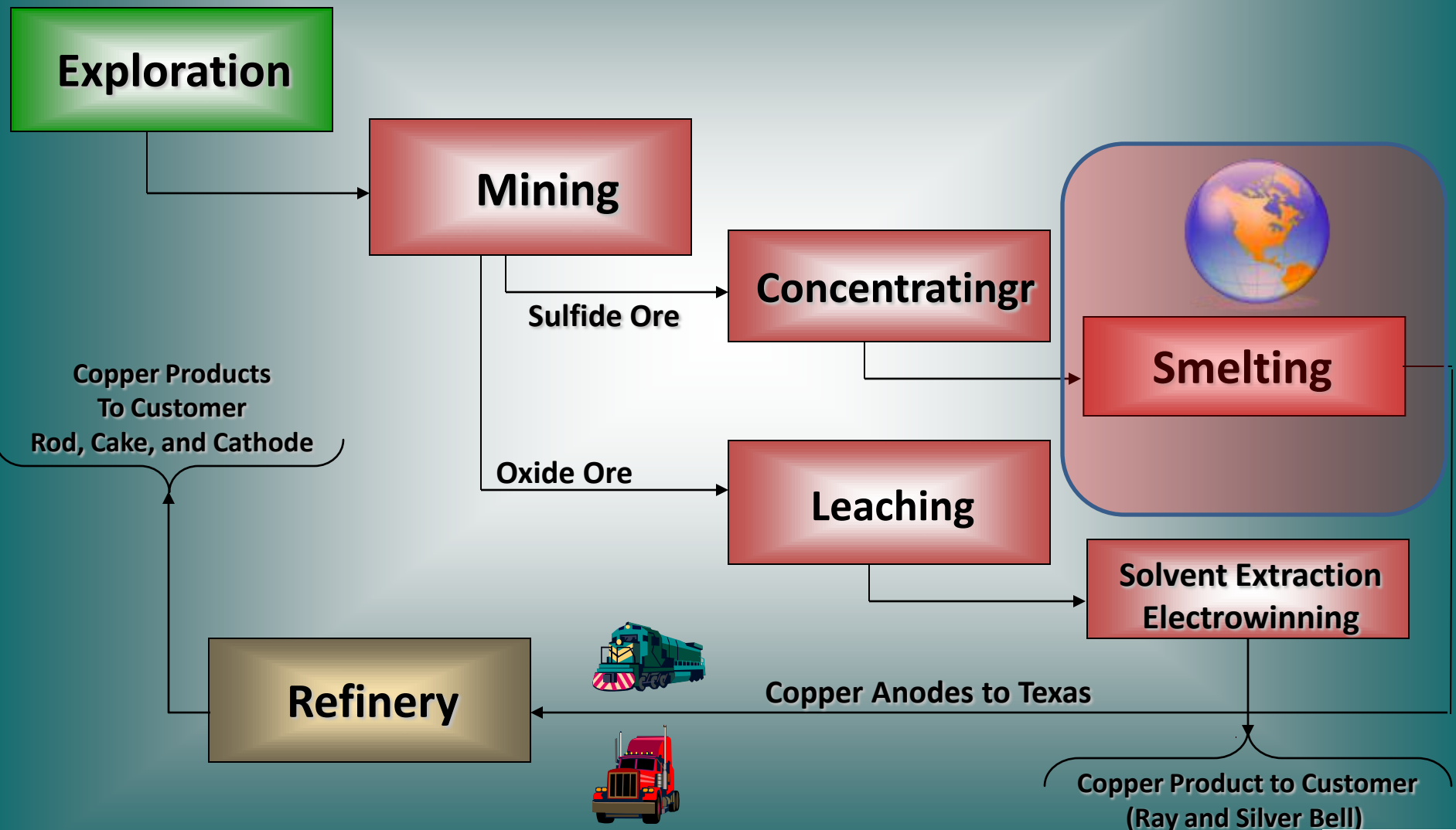


The waste rock slurry is pumped to a tailings pond and the water is reclaimed.



How is sulfide ore processed for use as copper?

Smelting purifies copper sulfide ores.

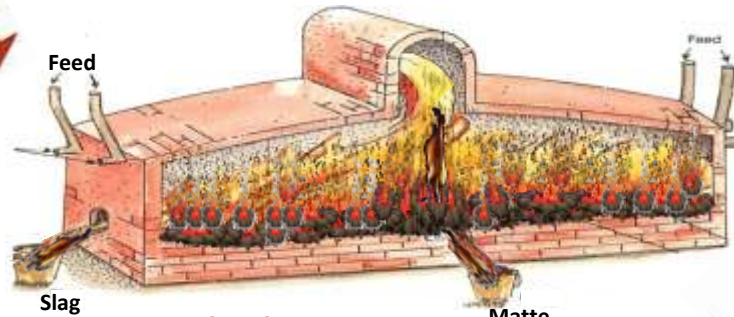


Smelter Process

Concentrate from the Mill

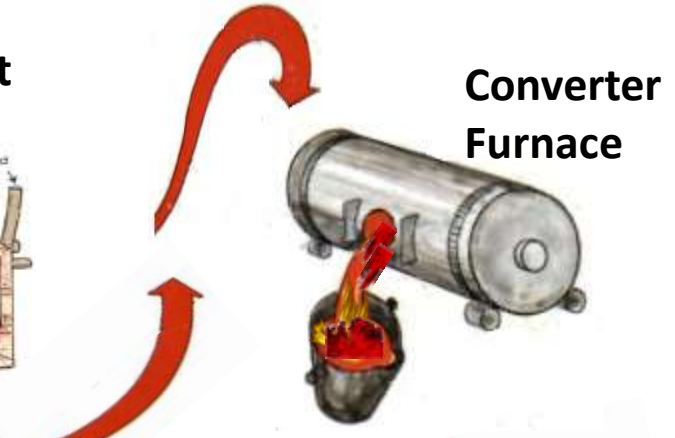


Concentrate
Dryer



Flash Furnace

Gases to Sulfuric Acid Plant



Converter
Furnace

Blister Copper
98% pure



Anode Furnace



Anodes
Finished Smelter
Product



Anodes
Casting

Refinery

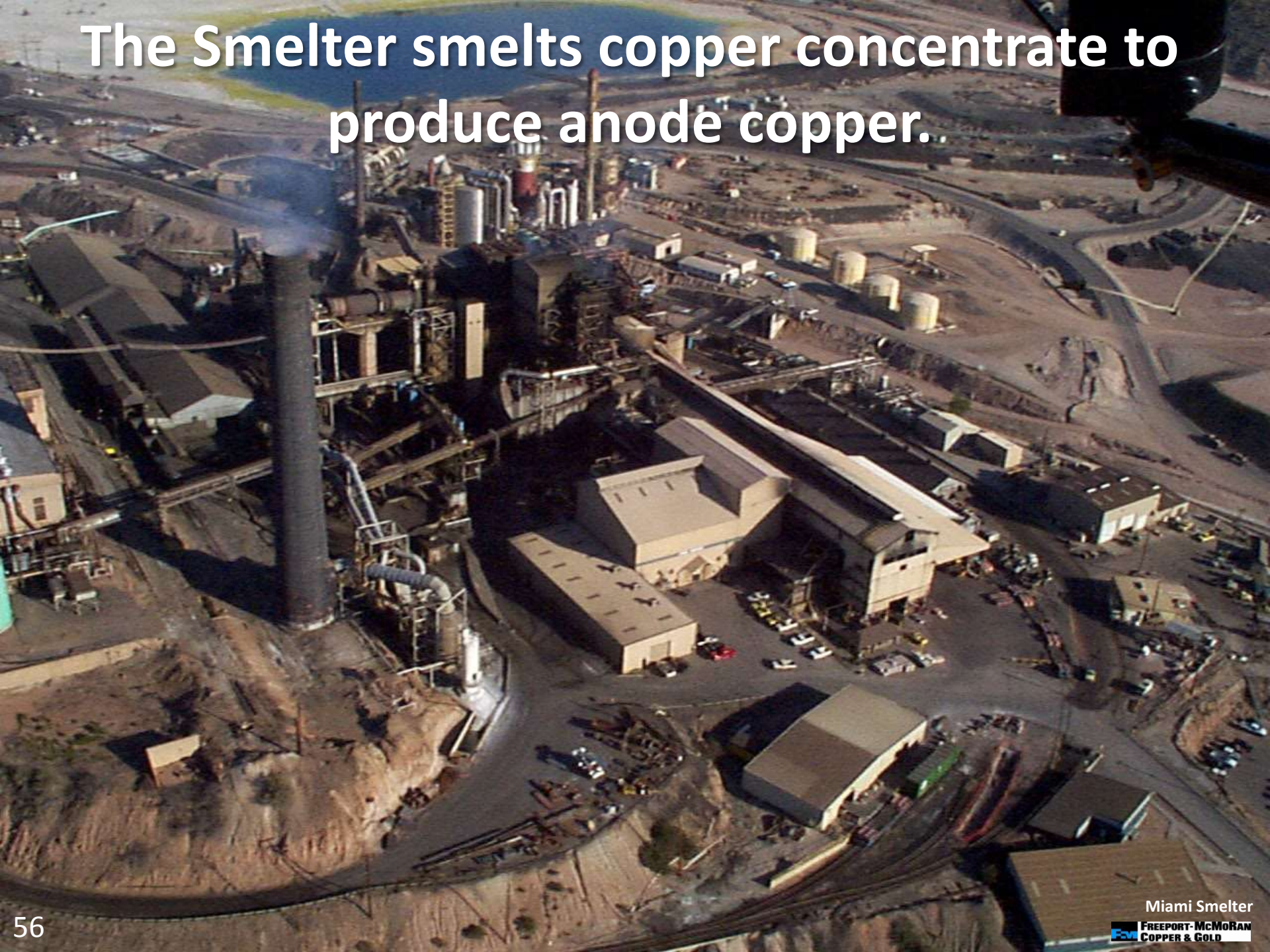
Shipped to
Amarillo



Amarillo produces
the Cathodes

Hayden

The Smelter smelts copper concentrate to produce anode copper.



Ore from the Ray Mine is shipped by Copper Basin Railroad to Hayden to be processed into concentrates.



The Smelter control room keeps track of all processes by computers and sensors.



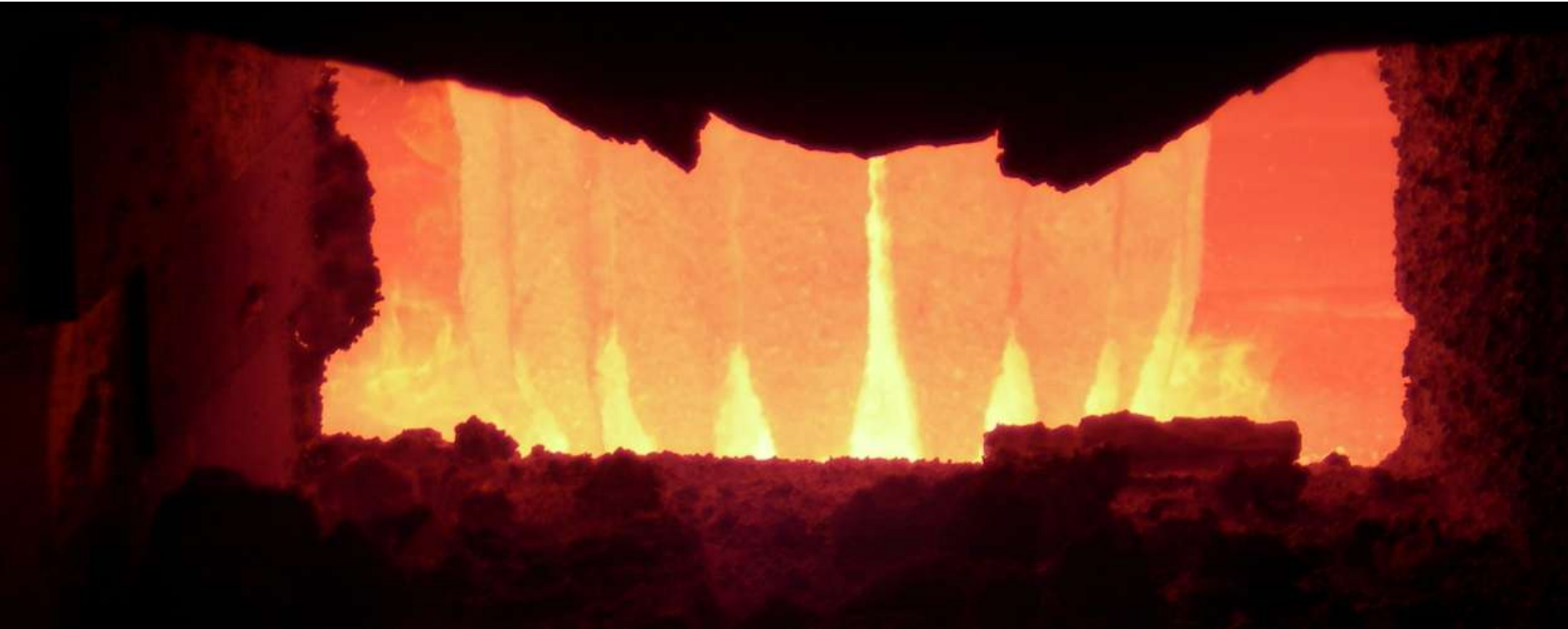
The dried copper concentrate is sent to the Flash Furnace at the Smelter.



The Oxygen Plant makes oxygen for use in the Flash Furnace.

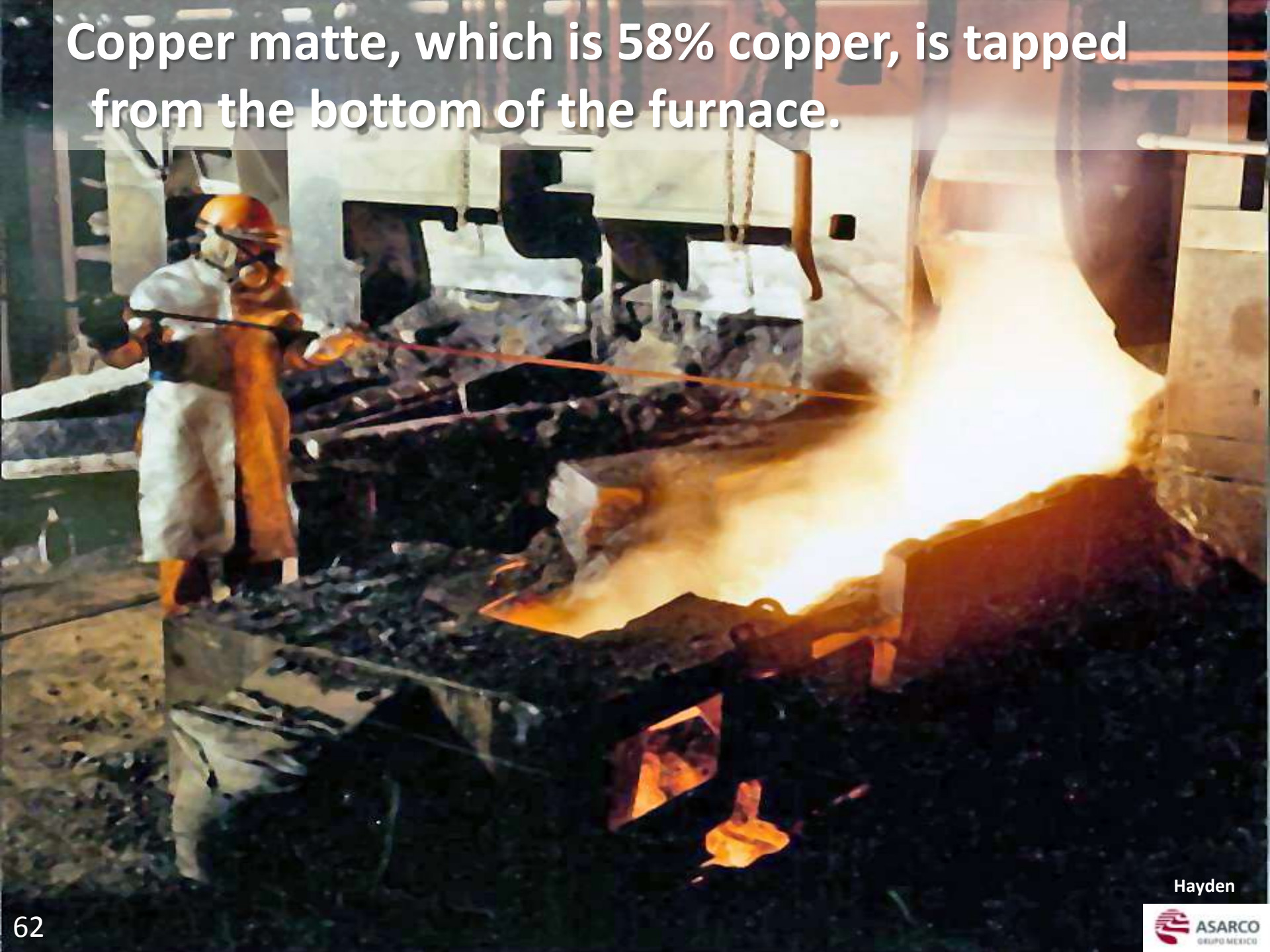


Copper concentrate ignites when it is blown into the Flash Furnace with oxygen and silica flux.



- Melted copper and iron sink to the bottom of the furnace.
- Flux binds with iron and silica and other impurities to become slag, which floats to the top and is poured into large slag ladles.
- Sulfur combines with oxygen to form sulfur dioxide gas; this releases heat to keep the furnace hot.

Copper matte, which is 58% copper, is tapped from the bottom of the furnace.



The copper matte from the flash-furnace is transferred while molten to the converters.

Air is blown into the molten copper matte to burn away iron and any remaining sulfur.

The converter rotates on its side and pours molten copper into a large ladle to take it to the anode furnace.



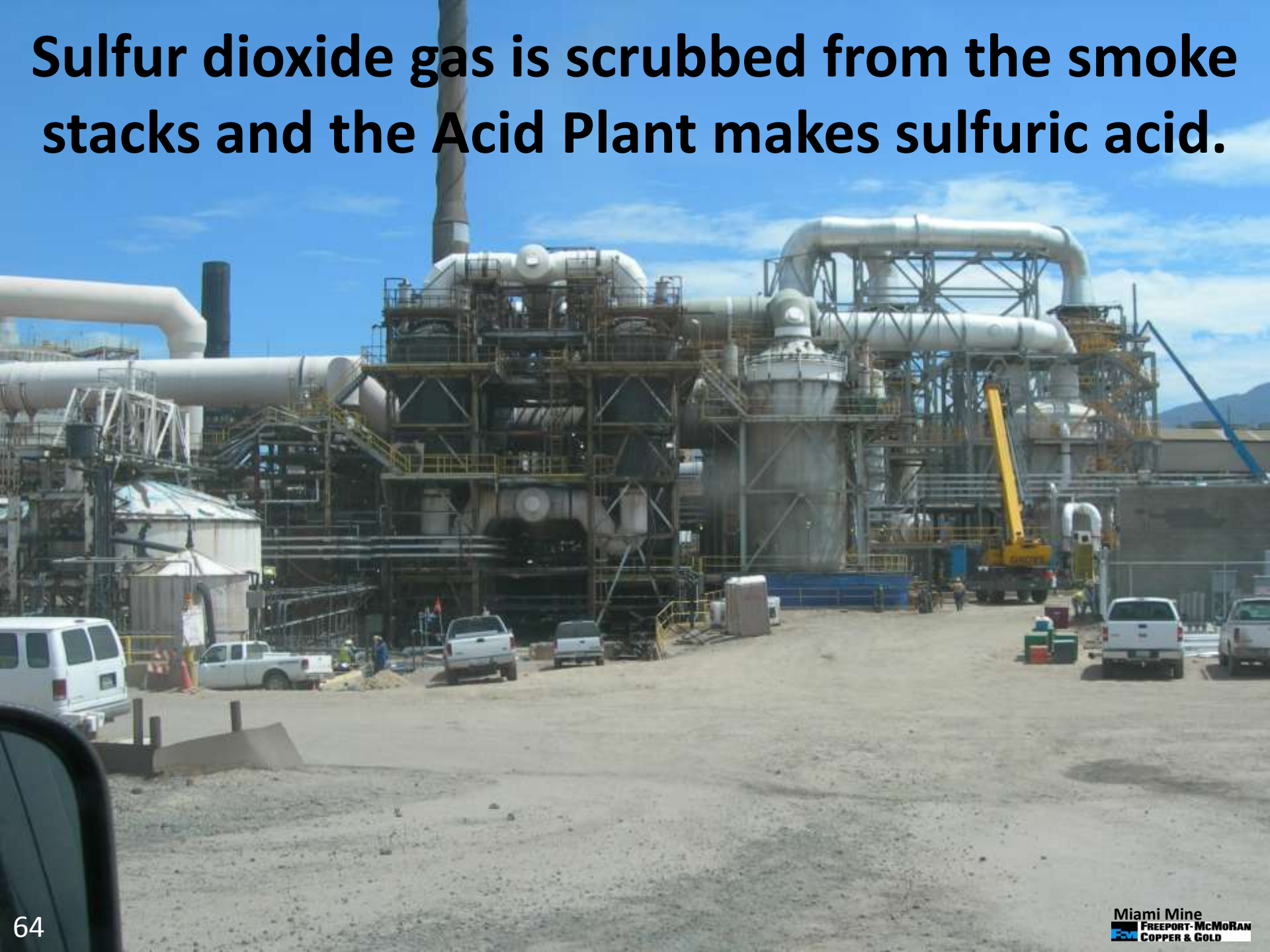
65

The molten copper, called blister copper, is 98% pure.

Hayden



Sulfur dioxide gas is scrubbed from the smoke stacks and the Acid Plant makes sulfuric acid.



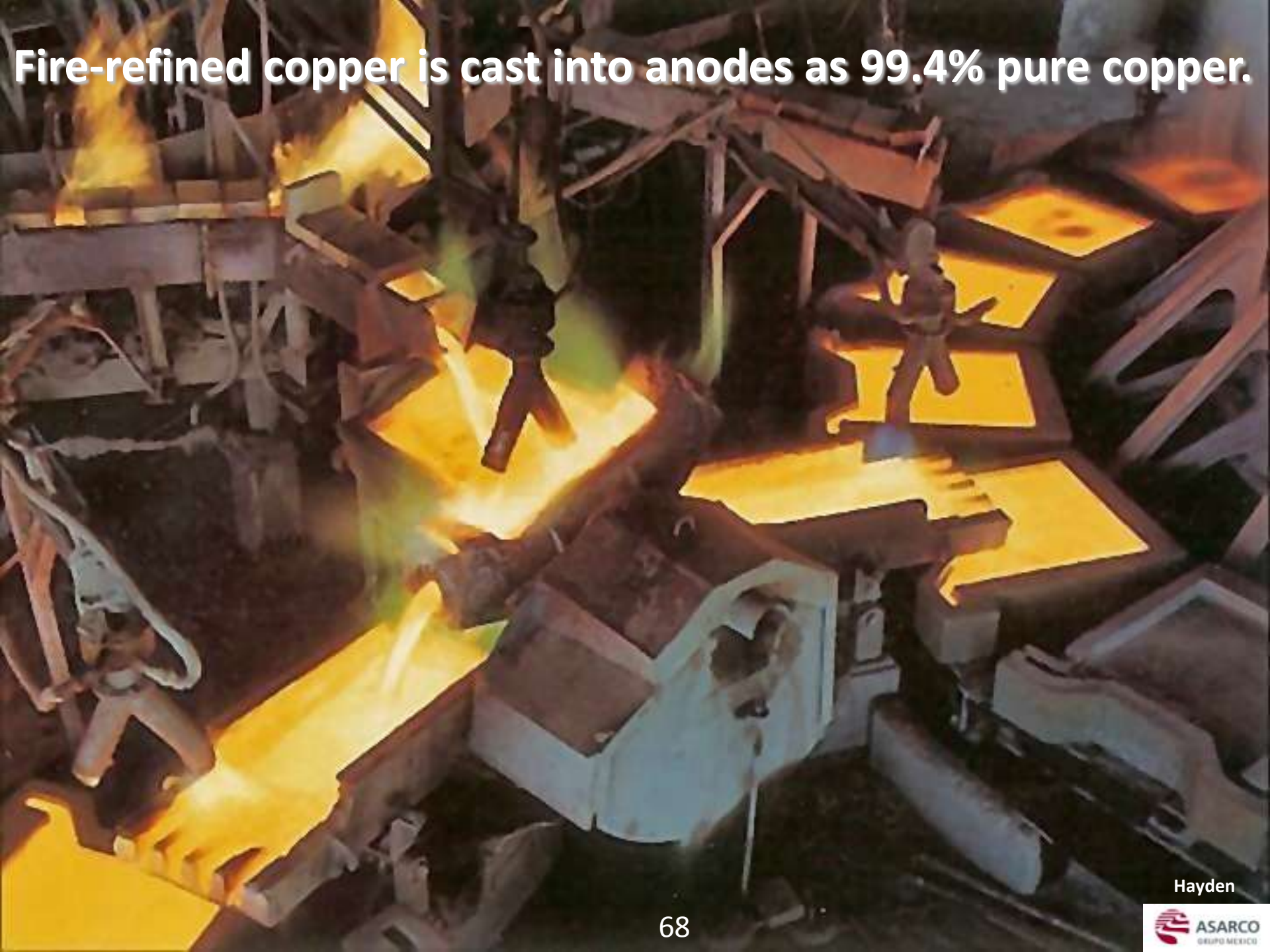
In the anode furnace, molten blister copper is refined by blowing air into it.

- **Oxygen in the air removes sulfur from the blister copper.**
- **Natural gas/steam mixture is used to burn off the oxygen from the blister copper.**
- **Yellow flame turns to a blue-green flame when most of the extra oxygen has burned away.**

From the Anode Furnace, fire-refined copper is poured into molds on an anode casting wheel.



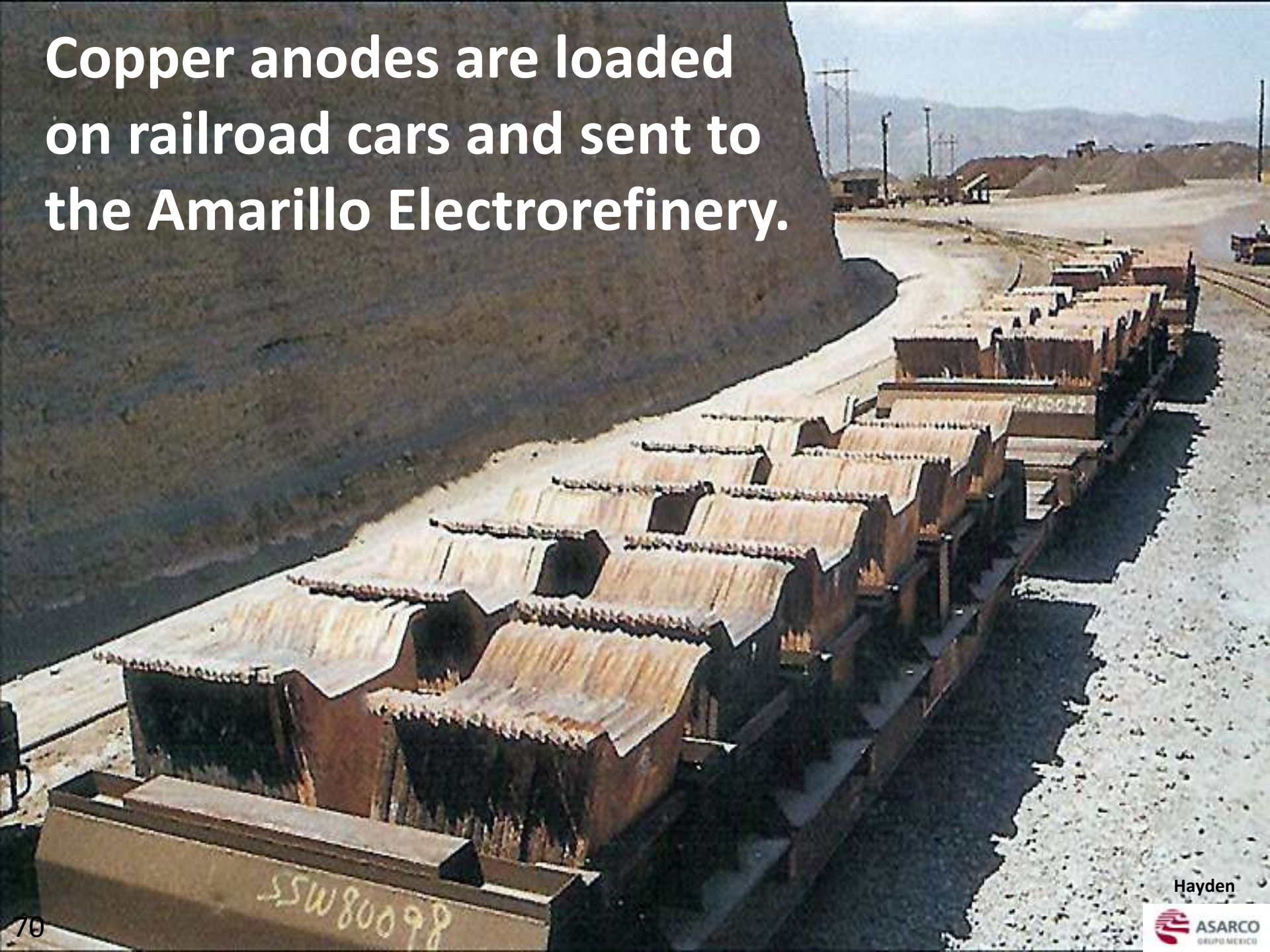
Fire-refined copper is cast into anodes as 99.4% pure copper.



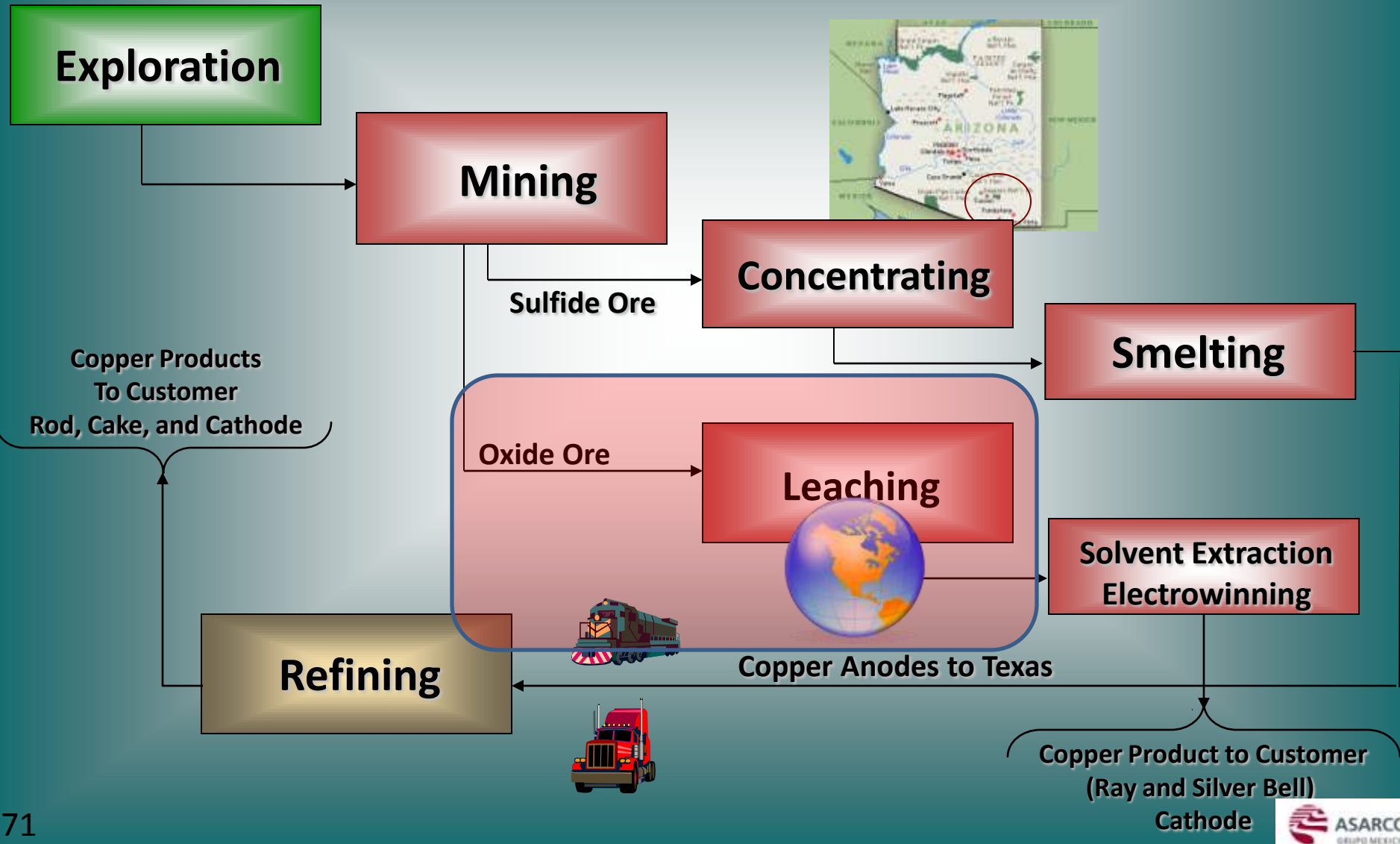


The cooled copper anodes weigh 700 pounds.

Copper anodes are loaded on railroad cars and sent to the Amarillo Electrorefinery.



How do they get copper out of oxide ore? Oxide Ores are leached with sulfuric acid.



An electric shovel loads ore into Haul Trucks.



Three 100-ton scoops fill a haul truck.

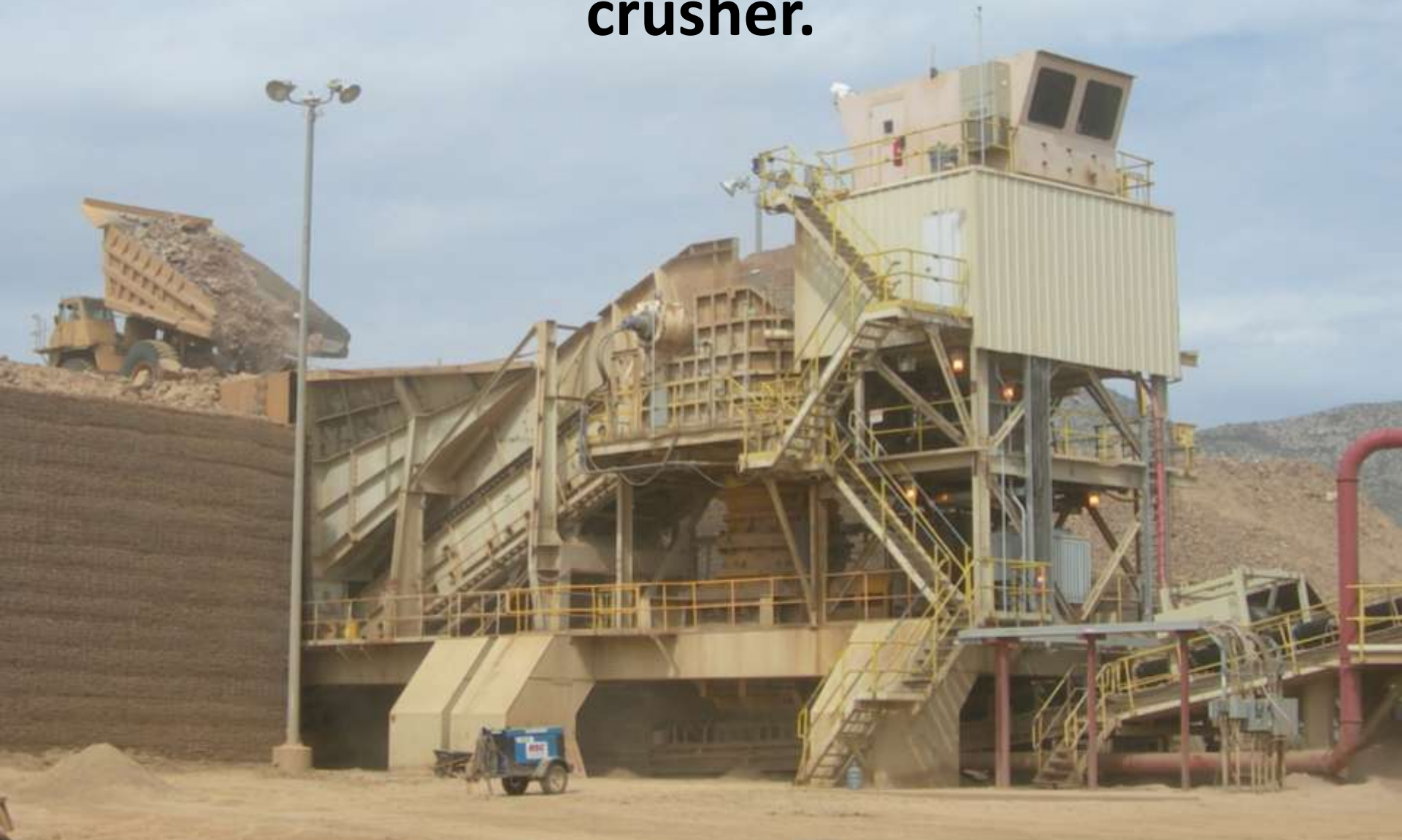
Silver Bell Mine



The GPS-monitored Haul Truck loaded with copper ore drives to the primary crusher.



The Haul Truck dumps ore into the primary crusher.



Conveyors move ore from the primary crusher to the screens and a secondary crusher.



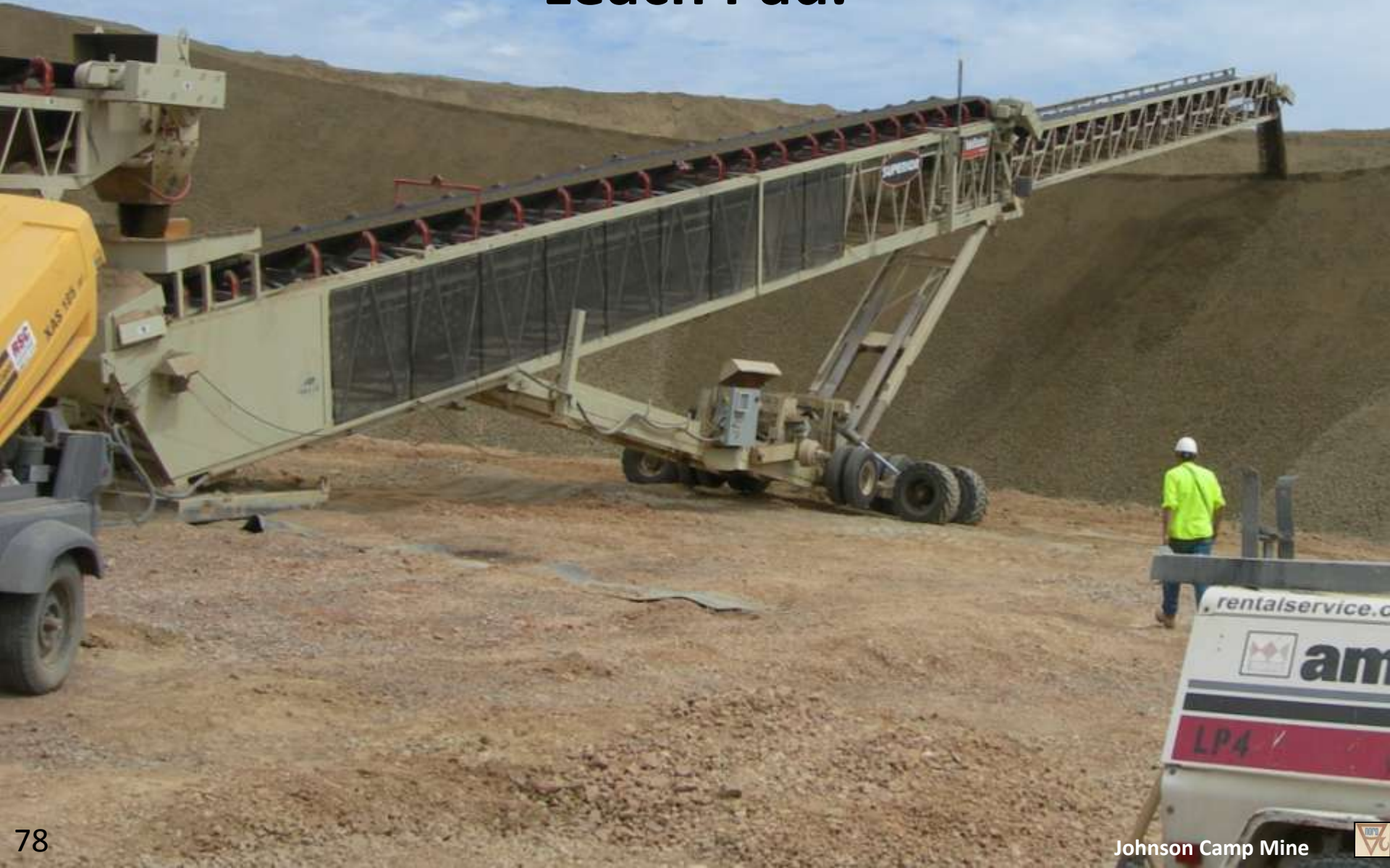
Oxide ore for the Leach Pad is pre-treated by adding small amounts of weak acid at the Agglomerator.



Ore on the Grasshopper Conveyors is transferred to the Leach Pad.



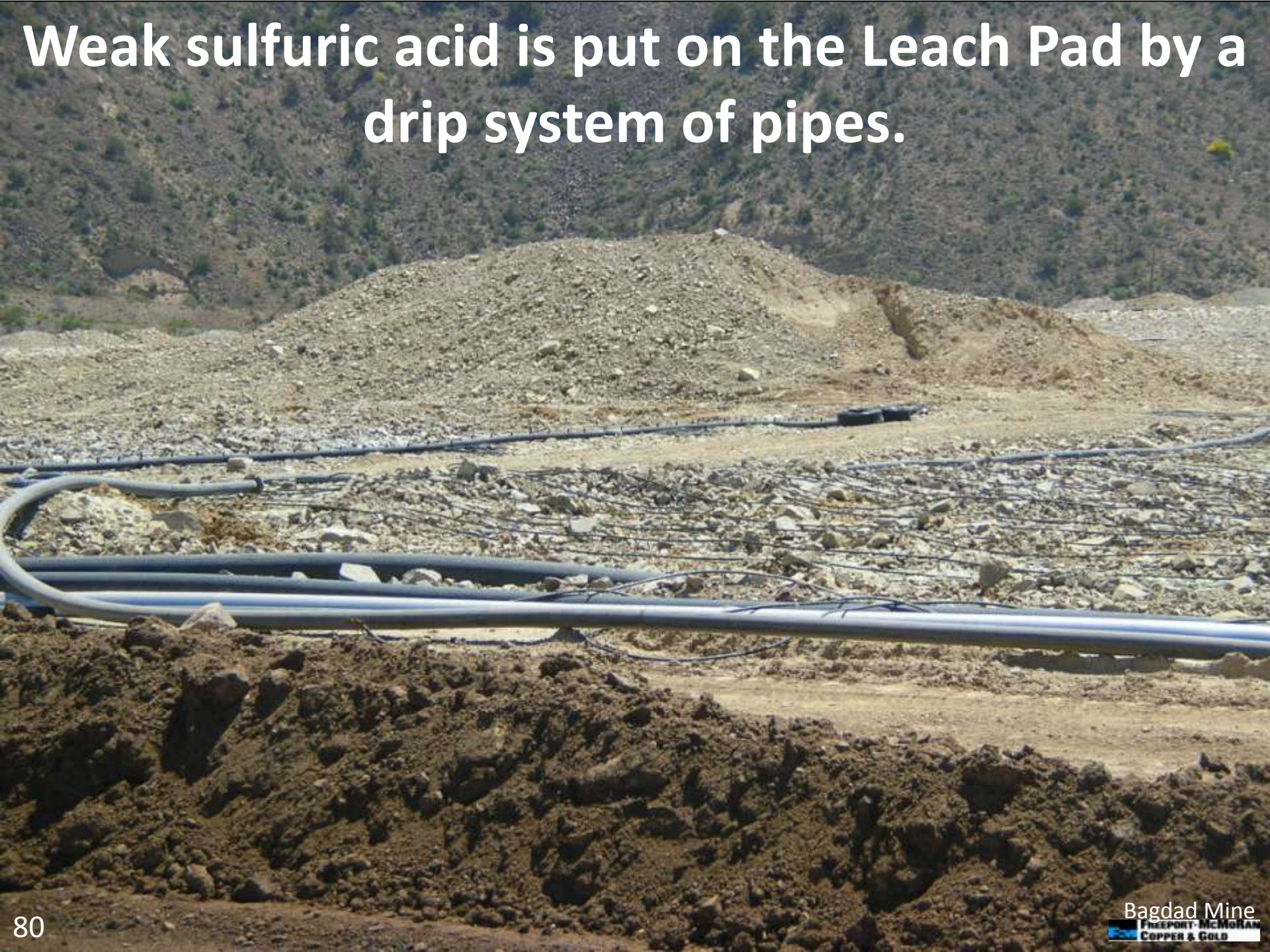
A telescoping stacker distributes ore to the Leach Pad.



A weak acid solution seeps down through the rock in the lined Leach Pad. It dissolves soluble copper, like water dripping through coffee grounds to make coffee.



Weak sulfuric acid is put on the Leach Pad by a drip system of pipes.

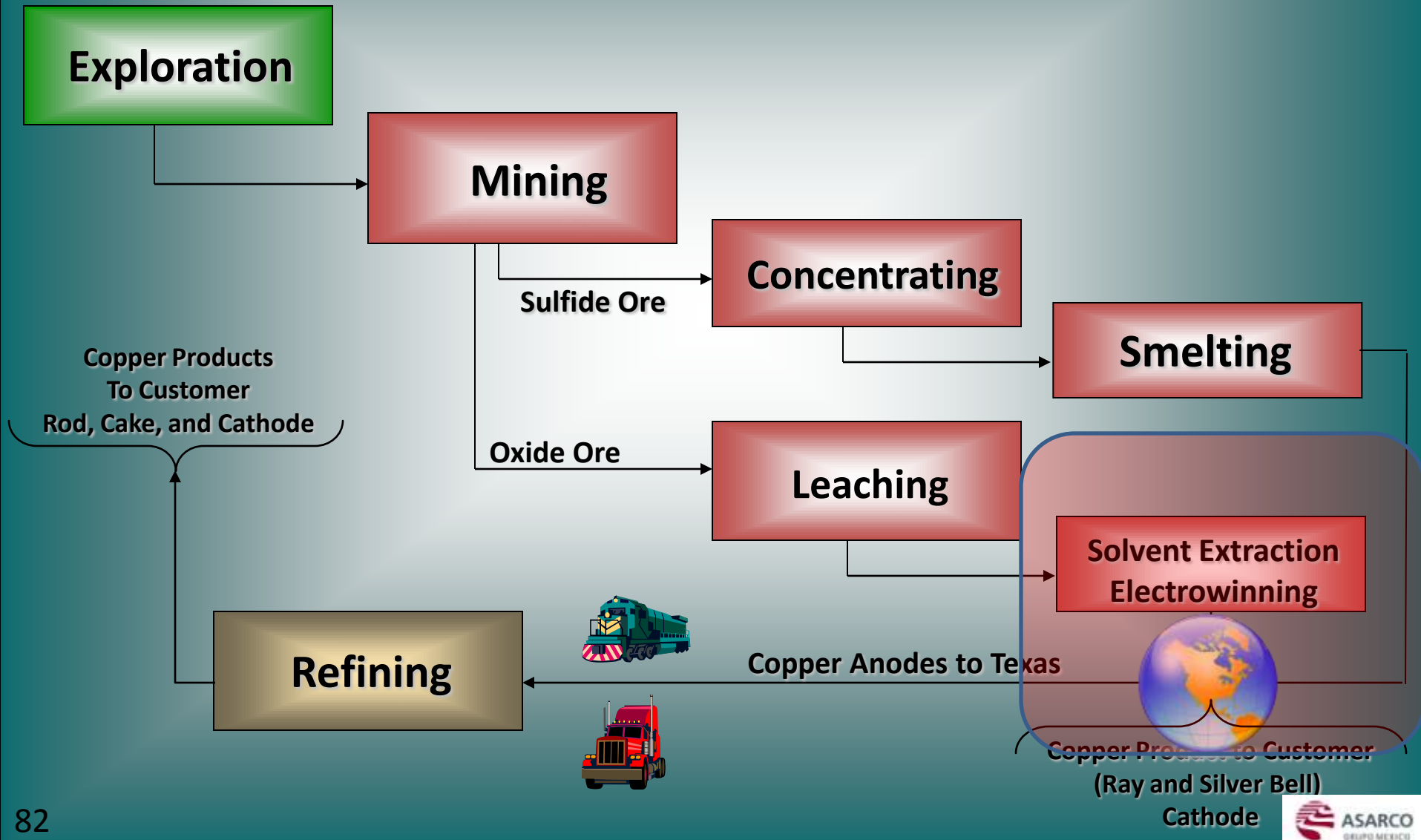


The copper-rich solution is collected from the bottom of the Leach Pad and is piped to a Pregnant Leach Solution (PLS) pond.



How is oxide ore processed for later use?

Solvent Extraction - Electrowinning



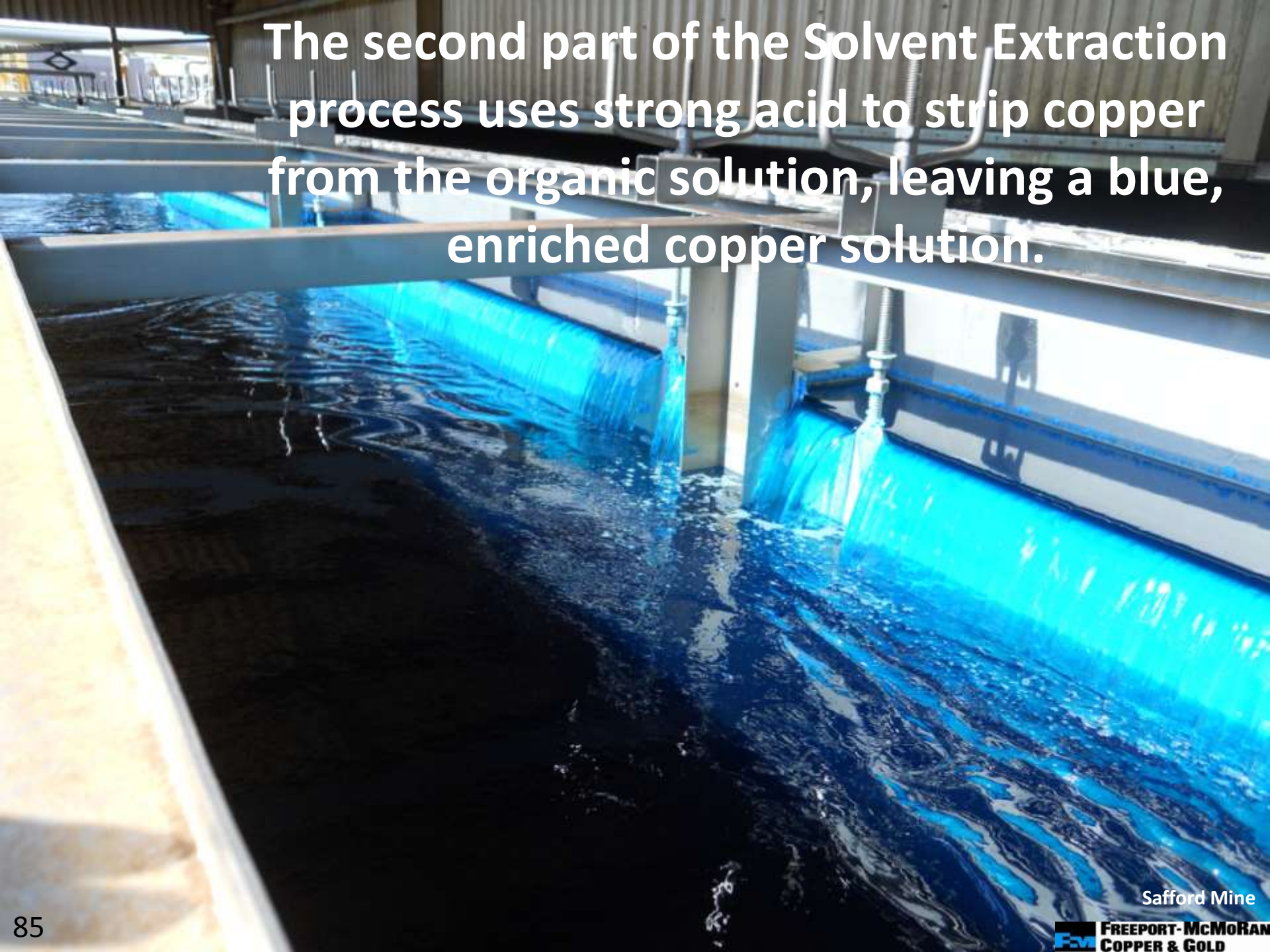
Copper is extracted from the PLS solution in the Solvent Extraction buildings.



The Solvent Extraction process uses an organic solvent to grab copper ions from the PLS and exchange them for hydrogen ions in acid.



The second part of the Solvent Extraction process uses strong acid to strip copper from the organic solution, leaving a blue, enriched copper solution.



Safford Mine

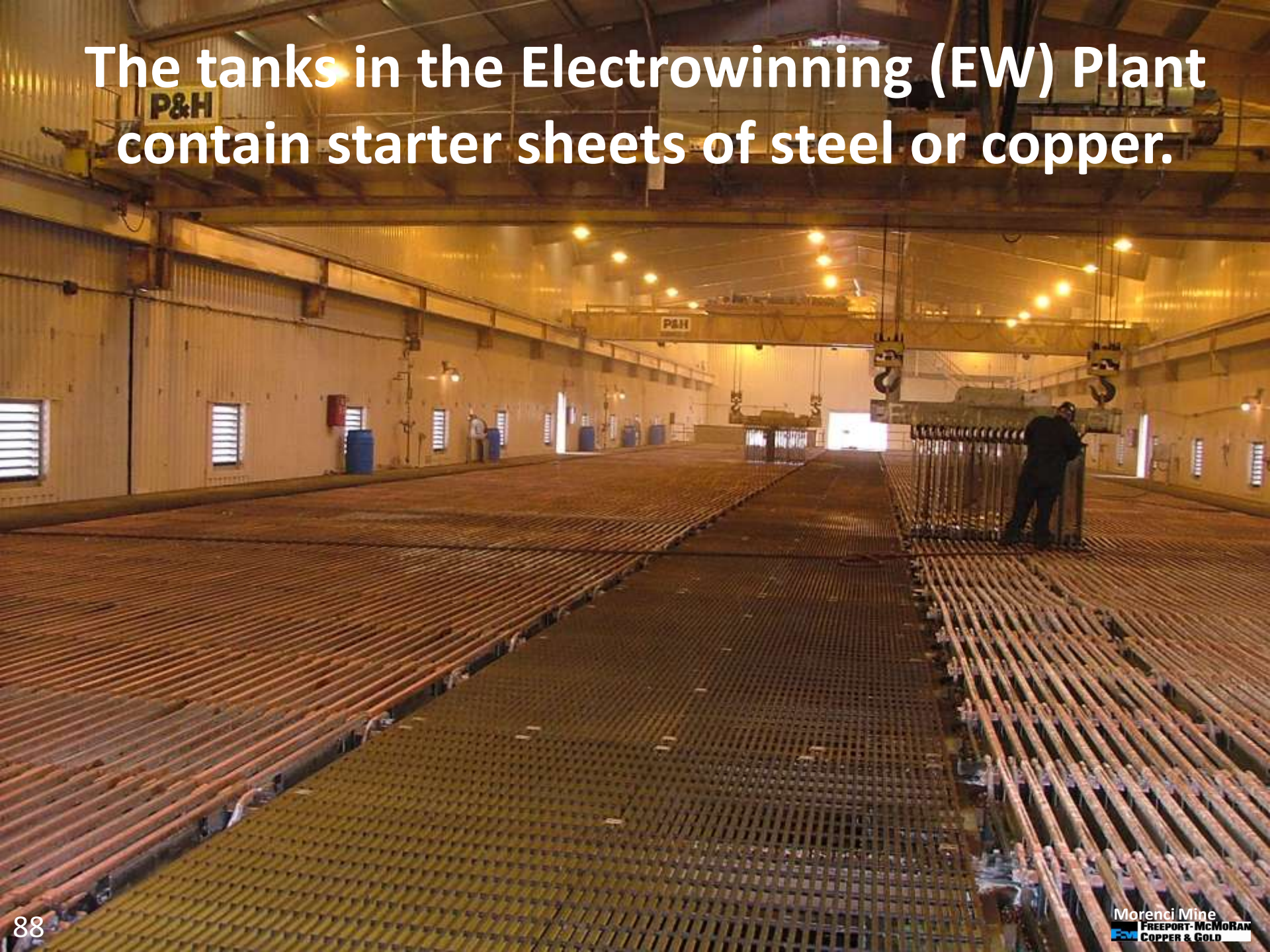
The enriched copper solution is then sent to the electrowinning Plant.



The Electrowinning Plant contains many tanks containing enriched copper solution.



The tanks in the Electrowinning (EW) Plant contain starter sheets of steel or copper.

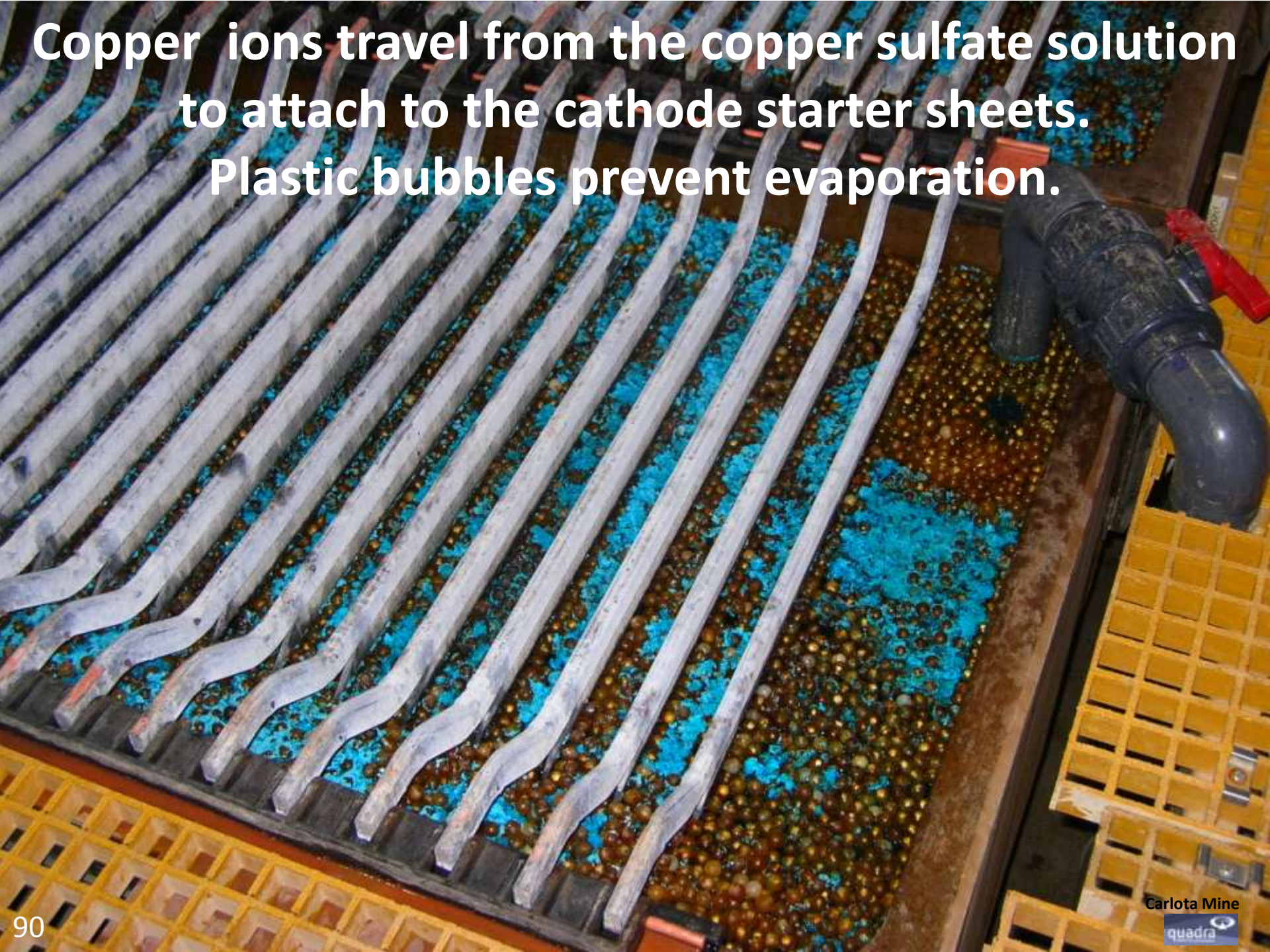




Electricity is passed through the anodes in the EW Tanks. Copper is plated onto the cathodes.



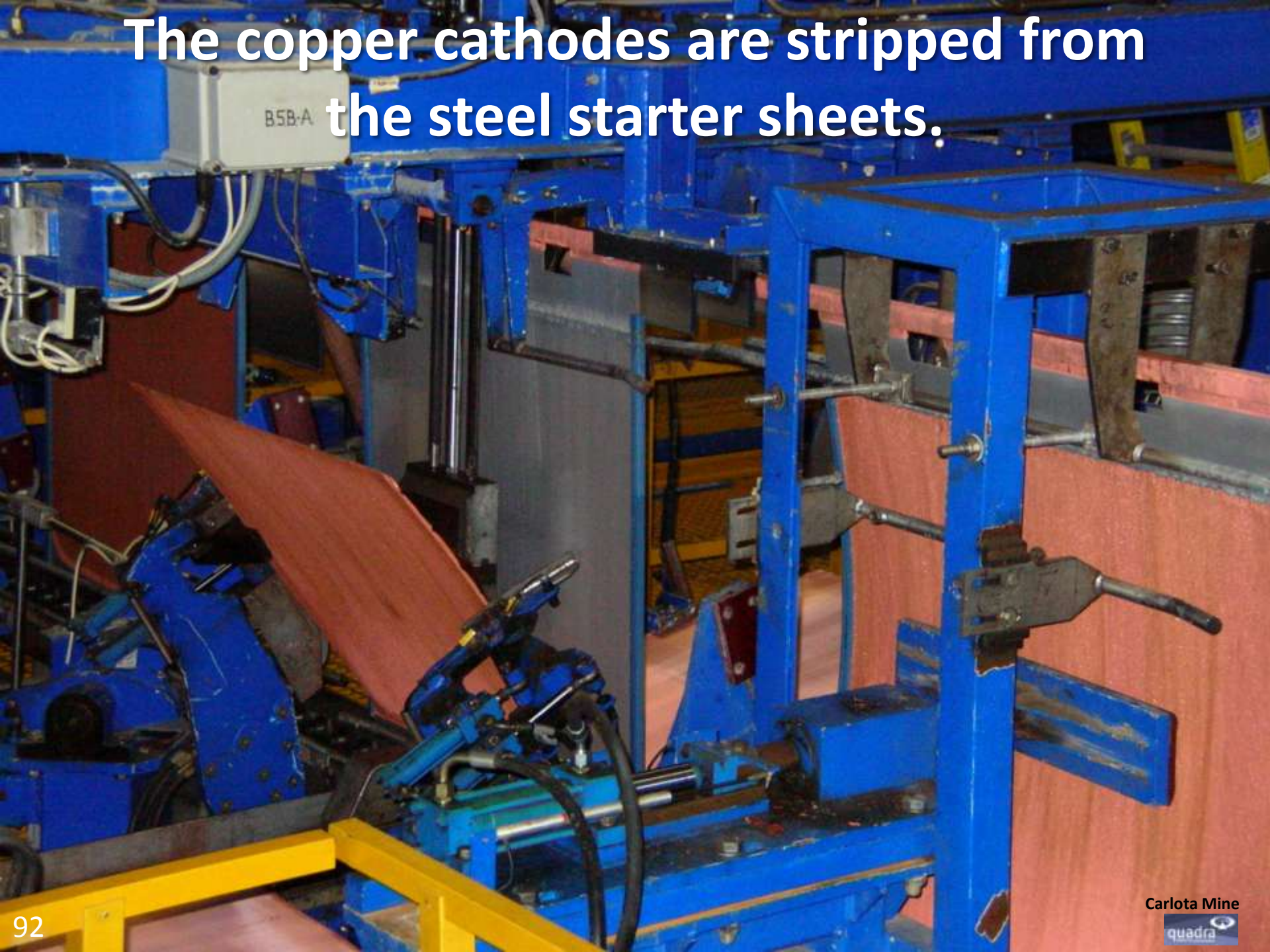
Copper ions travel from the copper sulfate solution to attach to the cathode starter sheets. Plastic bubbles prevent evaporation.



When the copper is 3/8-inch thick on the starter plates, they are raised and rinsed.



The copper cathodes are stripped from the steel starter sheets.



The 200-pound copper cathodes are wrapped in bundles for shipment to the Rod Plant.



Copper cathodes are are 99.98% to 99.99% pure copper.

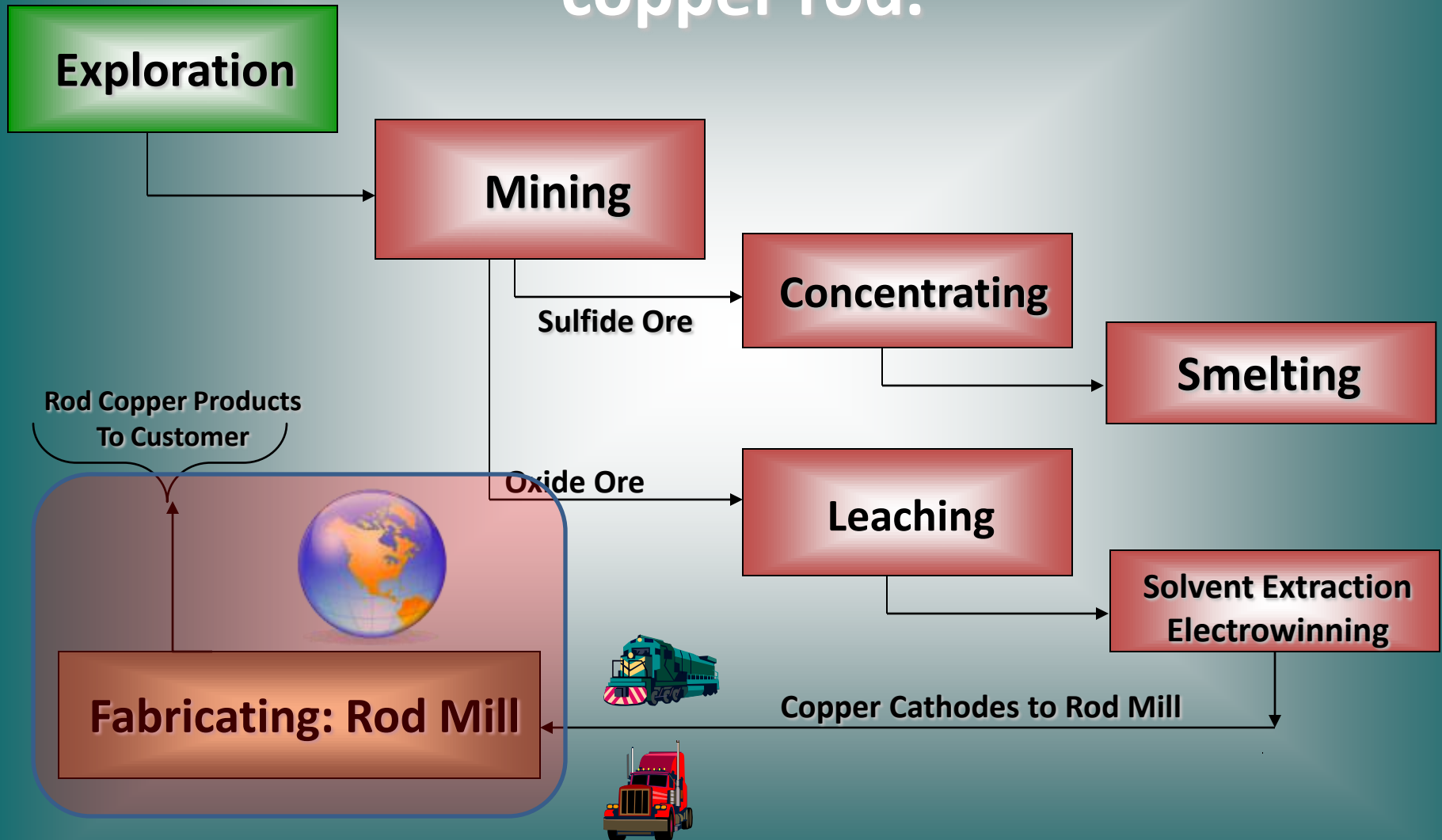


Copper cathodes are loaded on flatbed trucks for transport to manufacturers.

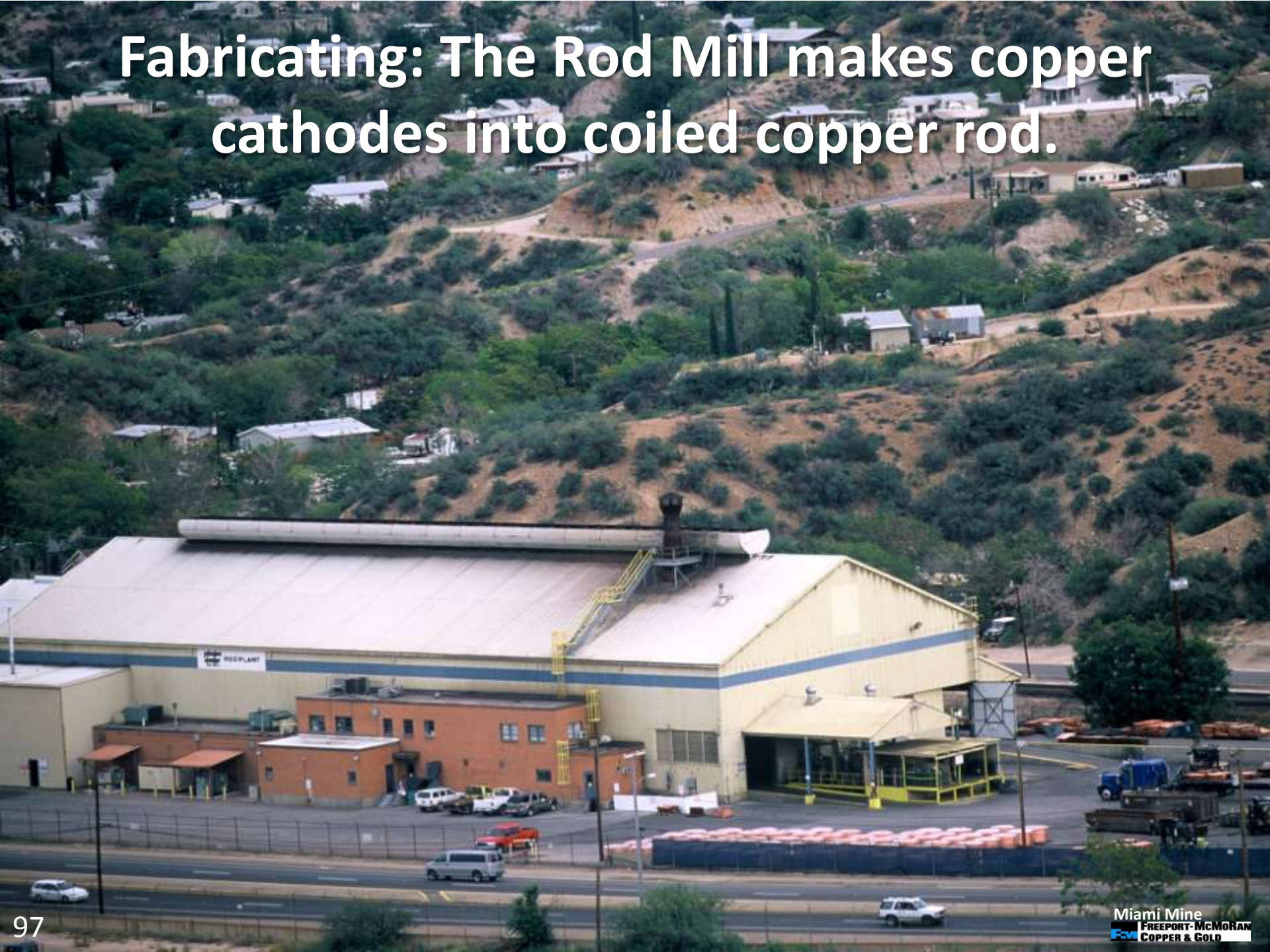


How is copper processed for further use?

Rod Mill makes Copper Cathodes into coils of copper rod.



Fabricating: The Rod Mill makes copper cathodes into coiled copper rod.



The Rod Mill melts the copper cathodes and shapes the copper into continuous copper rod.

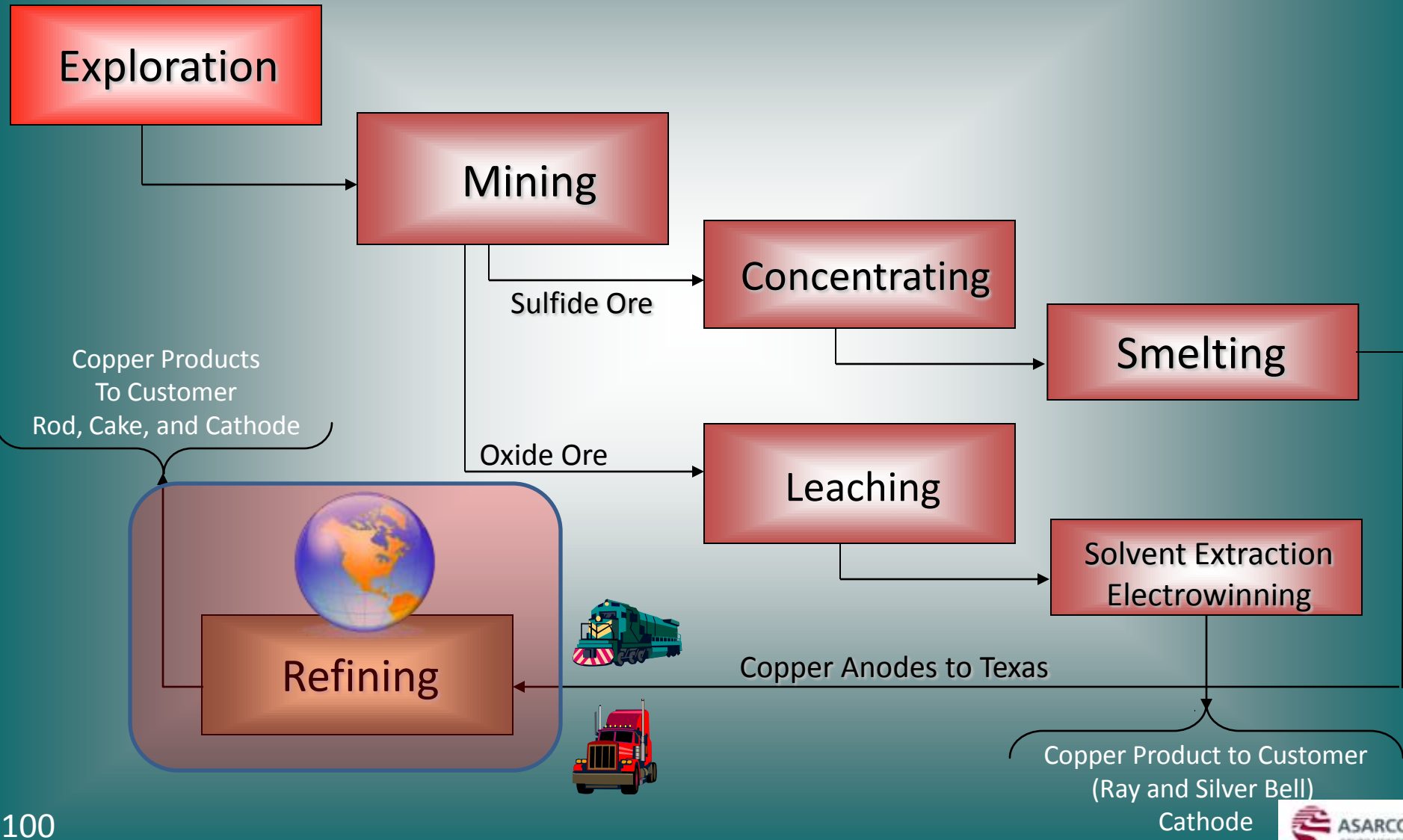


The copper rod from the Rod Mill is coiled and tied for shipping to customers.



How is copper processed for further use?

Refining makes the copper anodes more pure.



The Copper Refinery in Amarillo, Texas, makes the copper more pure.



The Electro-refining Tank House at the Amarillo Refinery is nearly ½ mile long.



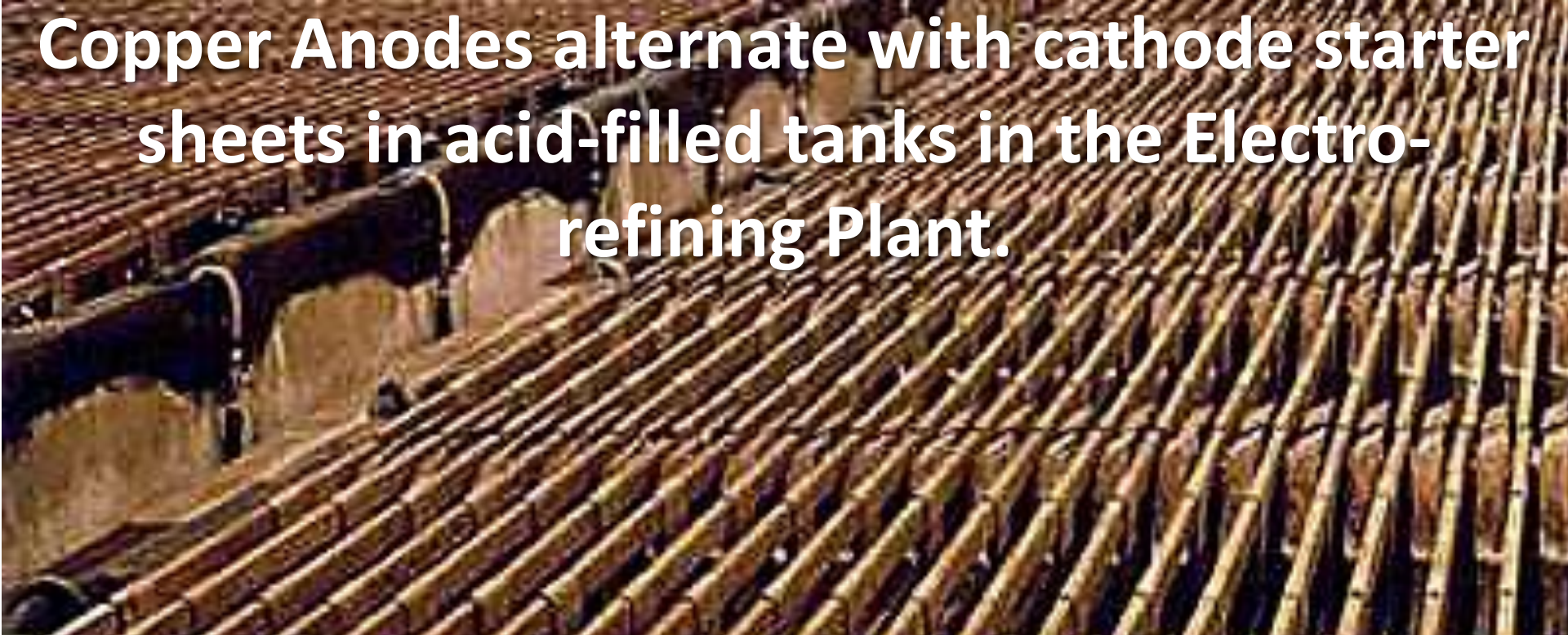


Copper Anodes are 99.4% pure copper when they start into the copper refinery.

Amarillo Refinery

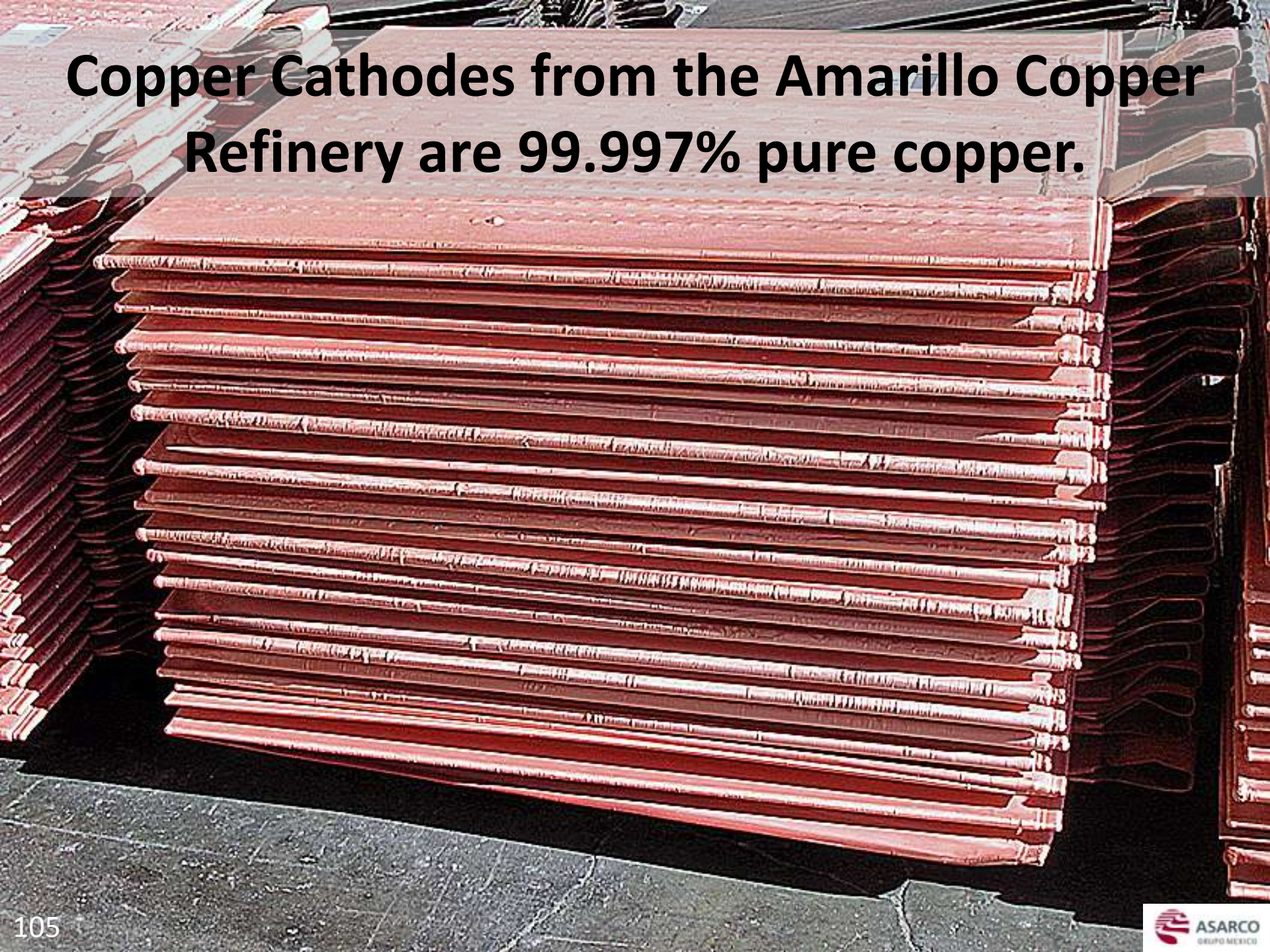


Copper Anodes alternate with cathode starter sheets in acid-filled tanks in the Electro-refining Plant.

A large industrial tank filled with rows of copper anodes and cathode starter sheets. The sheets are arranged in a grid pattern, and the tank is filled with an acid solution. The background shows the structure of the tank and the rows of sheets extending into the distance.

- Copper moves from the anodes at the positive pole of an electric circuit to a starter plate called a cathode at the negative pole.
- An electric current is sent between the plates, until the 99.997% pure copper is 3/8-inch thick.

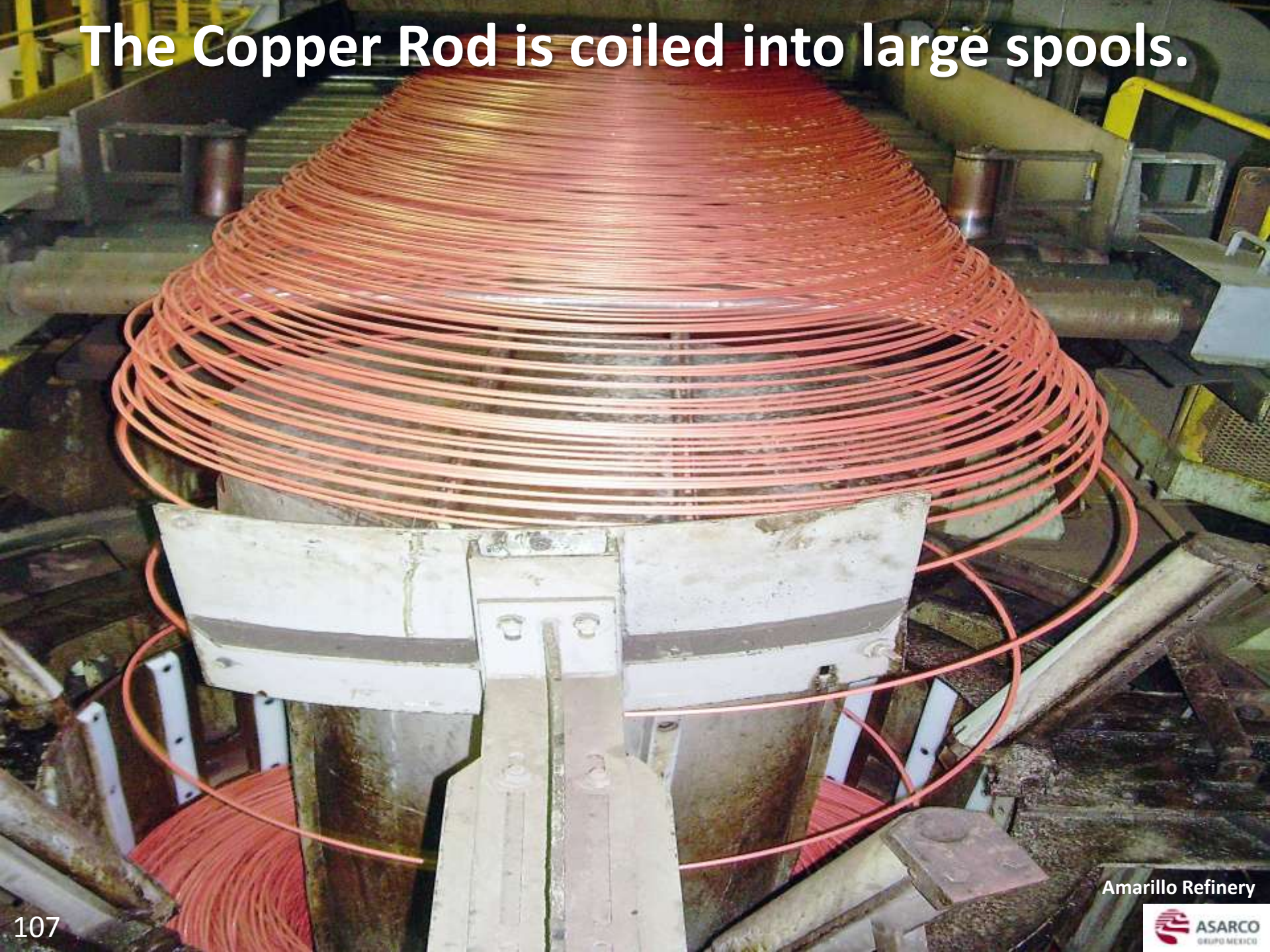
Copper Cathodes from the Amarillo Copper Refinery are 99.997% pure copper.



Rod Casting melts the copper cathodes and shapes the copper into a continuous rod.



The Copper Rod is coiled into large spools.



The Cake Casting machinery melts the copper cathodes and casts them into copper cakes.



Amarillo Refinery





The Cake Casting machinery melts the copper cathodes and casts them into copper cakes.

Copper Cake is used to make Busbars, Connectors, Sheeting, and Coins.



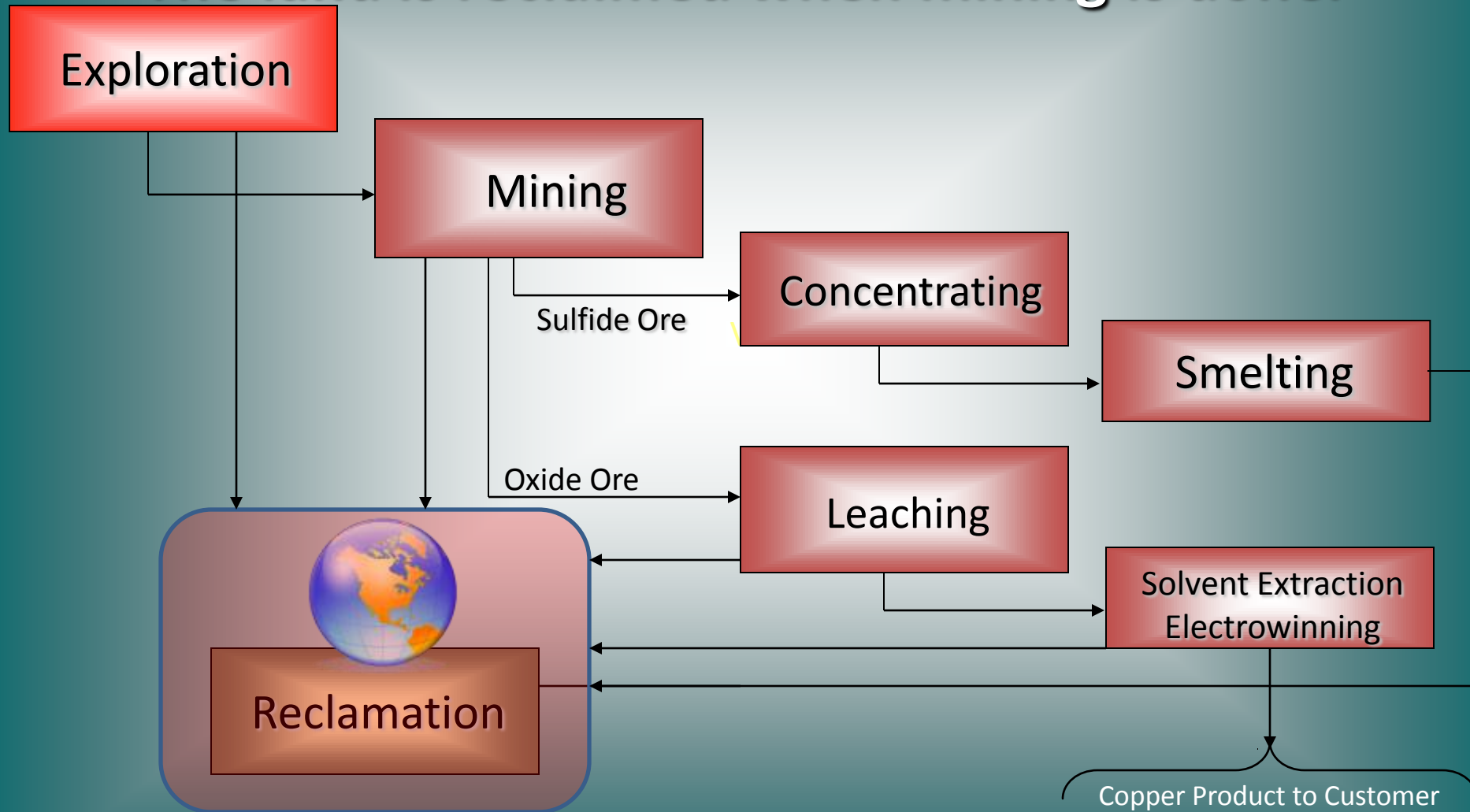
Silver & Gold are also produced at the refinery.



Silver / Gold Ingots

How does the mining industry contribute to a sustainable future?

The land is reclaimed when mining is done.



Greenhouse studies are done to find native plants that are best for later reclamation.



Disturbed ground is sprayed with seed and mulch.



08/07/2005

Cows help revegetate the slopes of the tailings dams by fertilizing the ground as they eat the distributed hay and planted grasses.



Some reclamation of non-active areas is done at the same time as mining.



Slopes are revegetated with native grasses.



How is copper used?

The percentage of copper used in the United States by industry is:

- Building Wire (16%),
- Plumbing & Heating (14%),
- Automotive (11%),
- Electric Utilities (9%),
- Air Conditioning & Commercial Refrigeration (8%),
- Telecommunications (7%),
- Factory Equipment (6%),
- Electronics (6%),
- Appliances & Extension Cords (3%), and
- Other (20%).

How is copper used?

Without copper, there would be no electrical or electronic devices.



Coins

Pennies, dimes, quarters



wire



Pipes



Pots and pans



Copper items

How is copper used?

The Statue of Liberty in New York is made of copper that has tarnished to green.



Original Copper



Green tarnish now



The dome on the Arizona State Capitol building in Phoenix has a copper roof.

Alloys are mixtures of elements



Statues are made of bronze.

Bronze medals are made of copper and tin with some zinc.



Brass is copper and zinc.

