

together with the direct smelting ore and precipitate go on to the smelter into a great gas-fired furnace to melt the copper and remove the sulphur. When the copper is melted it runs out of the smelter, sizzling hot, into a great iron pot which is picked up by an overhead crane to be poured into another kind of furnace to further purify the copper. Finally it is emptied from that furnace into another pot which the crane picks up and swings over a series of molds into which it pours the molten copper. These molds are tipped up automatically and the cakes of pure copper are dumped out on steel sheets from which they are wheeled away in hand trucks to the freight cars which take them to the places where they are made into something useful. Some of the cakes go to Uncle Sam's Mint where your penny is made.

From the ground to your pocket this is the road the copper has to travel. The geologist finds where the copper is buried in the ground. The engineers drill deep holes to find out how much there is and then make plans to get it out of the ground. Other engineers plan the buildings for the machinery and build them while the top layer of worthless material is being carried away. Finally all is ready to blast out the ore, load it into cars or trucks bound for the mill where the copper minerals are separated from the worthless rock. From the time the shovels scoop up the ore in the big pit to load it into cars or trucks it will be four days before the little specks of minerals are separated from the rock and melted into cakes of pure copper.

Arthur L. Flagg
Department of Mineral Resources
State of Arizona
Phoenix, Arizona

Your Copper Penny

Perhaps the penny in your pocket came out of the ground in Arizona, for more copper is dug out of the Arizona mountains than is mined in any other state. This has been so for more than fifty years. If all the Arizona copper mined in one year could be made into a single block we would have a cube of metal 120 feet on each side which would weigh one-half million tons.

For hundreds of years copper has been used in a great many ways. Today it is an indispensable metal. Centuries ago the Phoenicians, living along the Mediterranean sea, who were the world's greatest sailors, brought back quantities of tin from the mines in what is now known as Cornwall, England and sold it to the Egyptians. The Egyptians mixed the tin with copper from the island of Cyprus in the Mediterranean sea, making a metal called bronze, harder and more durable than either copper or tin. In our own Southwest the Indians found bits of pure copper on the ground where huge copper mines have been opened in recent years. These bits they hammered into ornaments, principally little ceremonial bells.

Copper comes from very deep within the earth. As it journeyed to the surface in molten rock it mixed with sulphur (and sometimes other elements) to form a solid we call a mineral. If there is enough copper in the rock, and perhaps a little gold and silver, to pay the costs of taking the rock out of the ground and taking the metals out of the rock then the rock is called ore. Sometimes the ore is found filling a crack in the ground making a vein. It may have a lot of copper with a little rock and be enclosed in small space. At other times the copper occurs as little grains of pin-head size in huge masses of rock, just a little copper scattered through a lot of rock. The ore in the vein because it has more copper and less rock may be worth many dollars per ton, while the huge masses of rock with only pin-head grains of copper minerals may not be worth more than a few dollars a ton. Most of the copper being mined in Arizona today comes from these huge masses with only tiny specks of copper mineral, so small you can hardly see them, along with some molybdenum and a little gold and silver. Every day in Arizona approximately 70 trainloads of copper ore are mined and treated. In each train there are 38 or more cars carrying a total of 172,000 tons of ore. All of this ore put together would make a pile 500 feet long, 300 feet wide by 22 feet high, yet it is only the amount of ore mined in a single day.

Before we try to find out how the copper is taken out of the rock to make your penny let's see how large a chunk of ore we need to get enough copper to make just one penny. About twelve pounds

of copper can be taken out of a ton of rock such as is mined in the big Arizona open-pit mines. That much copper would make 2,000 pennies or to be more exact 1,920 pennies. Since there are 2,000 pounds of rock in a ton of ore you would need almost one pound of rock to get enough copper to make your penny. To get that copper out of the ground and into the penny costs less than a penny.

These huge masses of rock carrying the little specks of copper mineral are always buried under a covering of rock, called cap-rock, which contains so little copper that it does not pay to mine it. So, before we can begin to dig out the copper rock that will pay, it is necessary to get rid of this top layer of worthless rock. Mining this top layer of worthless material is not a difficult job. The real job is to find a place to put it. Of course the cost of moving all this worthless rock is a part of the cost of getting out the copper that can be sold so this job must be done for as little expense as possible. There is another big expense before we can begin to take the copper out of the rock. After all the machines necessary for mining the ore and the cars and locomotives to haul the ore are bought a big building must be built in which to put the machinery necessary to get the copper out of the rock. So, before we begin to sell any of the copper from our mine millions of dollars must be spent to do all these other things.

After the top layer of worthless material has been carried away; after all the buildings have been built and the machinery placed in them, we are ready to begin to take ore out of the ground. The first step is to drill vertical holes about a foot in diameter into the ore down about sixty feet. These are loaded with the proper amount of blasting powder and exploded to break down many tons of ore. Huge power shovels pick up the ore and load it into cars or trucks to take it to the mill or concentrator where the copper is removed from the rock. Each car as it comes along to the mill is turned bottom-side up to dump the ore into huge bins.

Some of the chunks are too big for one man to lift; then there are grains so small that the wind whisks them around like dust on a dirt road. Big and little all go tumbling into the opening of a huge crusher to break the big pieces down to the size of a baseball. Then away these pieces go to another crusher, and another, to be broken again and again until the pieces are no bigger than an olive. The next job is to loosen the copper minerals from the rock. This step is called grinding and breaks the rock down to the fineness of flour.

The grinding is done in a huge drum-like machine called a ball mill. The small pieces of ore (ball mill feed) are fed into this mill with water, a few drops of pine oil frothing agent and a chemical substance called a collecting agent much like the detergent used in the washing machine or dish pan. Inside the ball mill are very hard specially made steel balls about the size of a baseball.

As the mill turns over slowly the ore and balls are all tumbled around together which grinds the ore very fine. The finer the ore particles are the higher they ride in the mixture of rock, water, balls, oil and frothing agent until they flow out of one end of the mill, a stream of mud.

This grinding process and the steps which follow are the most important parts of the task of getting the copper out of the rock. Though only a tiny bit of collecting agent is added to the mixture in the mill it does a very important and interesting job. It forms a very, very thin coating on the minerals which contain the copper but will not coat the worthless rock. The frothing agent as it is called also does an equally important job in the next step.

The stream of thin mud coming out of the end of the ball mill flows into a box of wood or metal called a flotation cell. Suspended in this, reaching almost to the bottom, is a shaft with blades like an outboard motor on the bottom end which is revolved rapidly. This beats up the mixture much as you would beat an egg and makes bubbles out of the frothing agent. These bubbles hunt out the bits of chemically-coated copper minerals and stick to them. They act like balloons and take the particles of valuable mineral to the top of the cell, as froth. The worthless rock particles sink to the bottom and are carried away to waste dumps. The frothy mixture of bubbles and the valuable minerals is called a concentrate.

Each ton of rock taken out of the ground has been reduced to about 65 pounds of concentrate consisting of the copper minerals, small amounts of molybdenum with the gold and silver; everything worth saving that was in the rock.

In most copper mines all the ore is not exactly alike. In addition to the kind which must go through the concentrating process just described there are some ores which require only crushing before they can go along with the concentrate for the final treatment. These are called direct smelting ores. Still another kind of ore is found in some mines called leaching ore because the copper can be dissolved or leached out of the rock by acid mixed with water. This ore as it comes from the mine is all crushed to about one-half inch size and put into large shallow tanks with the mixture of water and acid. When all the copper is dissolved out of the rock the beautiful blue solution goes to another tank in which the copper is taken out of the water by a chemical process, in the form of a dark mud called precipitate. This too goes along with the direct smelting ore, and the concentrate to the smelter where the pure copper is melted out.

Just as the original metal bearing minerals were formed with the aid of heat deep within the earth so it takes heat to separate the copper from the sulphur and whatever else is mixed with it. The frothy bubble balloons with valuable metal sticking to them

together with the direct smelting ore and precipitate go on to the smelter into a great gas-fired furnace to melt the copper and remove the sulphur. When the copper is melted it runs out of the smelter, sizzling hot, into a great iron pot which is picked up by an overhead crane to be poured into another kind of furnace to further purify the copper. Finally it is emptied from that furnace into another pot which the crane picks up and swings over a series of molds into which it pours the molten copper. These molds are tipped up automatically and the cakes of pure copper are dumped out on steel sheets from which they are wheeled away in hand trucks to the freight cars which take them to the places where they are made into something useful. Some of the cakes go to Uncle Sam's Mint where your penny is made.

From the ground to your pocket this is the road the copper has to travel. The geologist finds where the copper is buried in the ground. The engineers drill deep holes to find out how much there is and then make plans to get it out of the ground. Other engineers plan the buildings for the machinery and build them while the top layer of worthless material is being carried away. Finally all is ready to blast out the ore, load it into cars or trucks bound for the mill where the copper minerals are separated from the worthless rock. From the time the shovels scoop up the ore in the big pit to load it into cars or trucks it will be four days before the little specks of minerals are separated from the rock and melted into cakes of pure copper.

Arthur L. Flagg
Department of Mineral Resources
State of Arizona
Phoenix, Arizona

Your Copper Penny

Perhaps the penny in your pocket came out of the ground in Arizona, for more copper is dug out of the Arizona mountains than is mined in any other state. This has been so for more than fifty years. If all the Arizona copper mined in one year could be made into a single block we would have a cube of metal 120 feet on each side which would weigh one-half million tons.

For hundreds of years copper has been used in a great many ways. Today it is an indispensable metal. Centuries ago the Phoenicians, living along the Mediterranean sea, who were the world's greatest sailors, brought back quantities of tin from the mines in what is now known as Cornwall, England and sold it to the Egyptians. The Egyptians mixed the tin with copper from the island of Cyprus in the Mediterranean sea, making a metal called bronze, harder and more durable than either copper or tin. In our own Southwest the Indians found bits of pure copper on the ground where huge copper mines have been opened in recent years. These bits they hammered into ornaments, principally little ceremonial bells.

Copper comes from very deep within the earth. As it journeyed to the surface in molten rock it mixed with sulphur (and sometimes other elements) to form a solid we call a mineral. If there is enough copper in the rock, and perhaps a little gold and silver, to pay the costs of taking the rock out of the ground and taking the metals out of the rock then the rock is called ore. Sometimes the ore is found filling a crack in the ground making a vein. It may have a lot of copper with a little rock and be enclosed in small space. At other times the copper occurs as little grains of pin-head size in huge masses of rock, just a little copper scattered through a lot of rock. The ore in the vein because it has more copper and less rock may be worth many dollars per ton, while the huge masses of rock with only pin-head grains of copper minerals may not be worth more than a few dollars a ton. Most of the copper being mined in Arizona today comes from these huge masses with only tiny specks of copper mineral, so small you can hardly see them, along with some molybdenum and a little gold and silver. Every day in Arizona approximately 70 trainloads of copper ore are mined and treated. In each train there are 38 or more cars carrying a total of 172,000 tons of ore. All of this ore put together would make a pile 500 feet long, 300 feet wide by 22 feet high, yet it is only the amount of ore mined in a single day.

Before we try to find out how the copper is taken out of the rock to make your penny let's see how large a chunk of ore we need to get enough copper to make just one penny. About twelve pounds

of copper can be taken out of a ton of rock such as is mined in the big Arizona open-pit mines. That much copper would make 2,000 pennies or to be more exact 1,920 pennies. Since there are 2,000 pounds of rock in a ton of ore you would need almost one pound of rock to get enough copper to make your penny. To get that copper out of the ground and into the penny costs less than a penny.

These huge masses of rock carrying the little specks of copper mineral are always buried under a covering of rock, called cap-rock, which contains so little copper that it does not pay to mine it. So, before we can begin to dig out the copper rock that will pay, it is necessary to get rid of this top layer of worthless rock. Mining this top layer of worthless material is not a difficult job. The real job is to find a place to put it. Of course the cost of moving all this worthless rock is a part of the cost of getting out the copper that can be sold so this job must be done for as little expense as possible. There is another big expense before we can begin to take the copper out of the rock. After all the machines necessary for mining the ore and the cars and locomotives to haul the ore are bought a big building must be built in which to put the machinery necessary to get the copper out of the rock. So, before we begin to sell any of the copper from our mine millions of dollars must be spent to do all these other things.

After the top layer of worthless material has been carried away; after all the buildings have been built and the machinery placed in them, we are ready to begin to take ore out of the ground. The first step is to drill vertical holes about a foot in diameter into the ore down about sixty feet. These are loaded with the proper amount of blasting powder and exploded to break down many tons of ore. Huge power shovels pick up the ore and load it into cars or trucks to take it to the mill or concentrator where the copper is removed from the rock. Each car as it comes along to the mill is turned bottom-side up to dump the ore into huge bins.

Some of the chunks are too big for one man to lift; then there are grains so small that the wind whisks them around like dust on a dirt road. Big and little all go tumbling into the opening of a huge crusher to break the big pieces down to the size of a baseball. Then away these pieces go to another crusher, and another, to be broken again and again until the pieces are no bigger than an olive. The next job is to loosen the copper minerals from the rock. This step is called grinding and breaks the rock down to the fineness of flour.

The grinding is done in a huge drum-like machine called a ball mill. The small pieces of ore (ball mill feed) are fed into this mill with water, a few drops of pine oil frothing agent and a chemical substance called a collecting agent much like the detergent used in the washing machine or dish pan. Inside the ball mill are very hard specially made steel balls about the size of a baseball.

As the mill turns over slowly the ore and balls are all tumbled around together which grinds the ore very fine. The finer the ore particles are the higher they ride in the mixture of rock, water, balls, oil and frothing agent until they flow out of one end of the mill, a stream of mud.

This grinding process and the steps which follow are the most important parts of the task of getting the copper out of the rock. Though only a tiny bit of collecting agent is added to the mixture in the mill it does a very important and interesting job. It forms a very, very thin coating on the minerals which contain the copper but will not coat the worthless rock. The frothing agent as it is called also does an equally important job in the next step.

The stream of thin mud coming out of the end of the ball mill flows into a box of wood or metal called a flotation cell. Suspended in this, reaching almost to the bottom, is a shaft with blades like an outboard motor on the bottom end which is revolved rapidly. This beats up the mixture much as you would beat an egg and makes bubbles out of the frothing agent. These bubbles hunt out the bits of chemically-coated copper minerals and stick to them. They act like balloons and take the particles of valuable mineral to the top of the cell, as froth. The worthless rock particles sink to the bottom and are carried away to waste dumps. The frothy mixture of bubbles and the valuable minerals is called a concentrate.

Each ton of rock taken out of the ground has been reduced to about 65 pounds of concentrate consisting of the copper minerals, small amounts of molybdenum with the gold and silver; everything worth saving that was in the rock.

In most copper mines all the ore is not exactly alike. In addition to the kind which must go through the concentrating process just described there are some ores which require only crushing before they can go along with the concentrate for the final treatment. These are called direct smelting ores. Still another kind of ore is found in some mines called leaching ore because the copper can be dissolved or leached out of the rock by acid mixed with water. This ore as it comes from the mine is all crushed to about one-half inch size and put into large shallow tanks with the mixture of water and acid. When all the copper is dissolved out of the rock the beautiful blue solution goes to another tank in which the copper is taken out of the water by a chemical process, in the form of a dark mud called precipitate. This too goes along with the direct smelting ore, and the concentrate to the smelter where the pure copper is melted out.

Just as the original metal bearing minerals were formed with the aid of heat deep within the earth so it takes heat to separate the copper from the sulphur and whatever else is mixed with it. The frothy bubble balloons with valuable metal sticking to them