SECRETS *of the* EARTH

CHELSEA CURTIS FRASER

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LOOKING INTO A FIERY CRATER

SECRETS OF THE EARTH

BY

CHELSEA CURTIS FRASER

Author of "The Young Citizen's Own Book,"
"Boys' Book of Sea Fights," etc.

"Look," said God,
And with fingers slow,
Drew away the mantle rock.
Man followed, groping,
To touch the flesh of his true mother;
And standing in great valleys,
He saw the ages passing.

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TO

Billie

A STURDY LITTLE ROCK
BEARING FINE ORE

PREFACE

WE all have that human characteristic of loving to delve into secrets, especially such rare, soul-stirring secrets as are hidden in the great treasure-chest of the world beneath our feet. At first those treasures were shrouded in ignorance or superstition, but as the years have gone by and merged into centuries, pick and shovel, dynamite and ingenuity, have tapped into these valuable and wonderful stores, and the world has prospered as a result. But in all these ages, geologists and miners have merely dug out small pockets of the vast mineral wealth which apparently exists for future generations to garner, study, and utilize. Geology as a science is still comparatively young, still in knickerbockers, but rapidly becoming a lusty youngster whose power the coming races will enthrone.

In preparing this volume, it has been the author's purpose to present, not a technical treatise on geology, but rather certain phases of the subject and its related industries, which are of most interest to young readers. Every care has been taken to give only reliable information; and in order to add spice some actual incidents and anecdotes have been judiciously used.

PREFACE

It is hoped that this small contribution to popular geology will awaken for its readers a new and abiding respect for the wonders beneath us; and that it will result in a further reading on the subject, indeed if not some personal investigations and the thrilling touch of hand against rock itself. While addressed to young readers, there is also the hope that older people, even those who are already deep in the study of this captivating science, may find the contents helpful as supplementary reading.

C. C. F.

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Secrets of the Earth

I

THE STORY OF COAL

COAL has come to be one of our commonest and most useful products. Yet, a comparatively few years ago it lay neglected in the earth. What, then, is it and how is it obtained?

Geology tells us that during the Carboniferous Period plants of all kinds grew rank and luxuriant, covering practically the whole world, because of the same sort of moist, warm air on which to thrive. Ferns grew, not knee-high as now, but into great soft-bodied trees which would fill a good-sized room. The graceful, feathery staghorn moss then straggled all over the swampy world, with stems as thick as your body, and sent up big branches as high as fifty feet. Then there were the horsetails, which grew into great forests, and which were festooned so thickly with creeping plants that you could not have forced your way through, even with an axe, in years.

In fact, all vegetable life was big and fat and juicy and lazy and stupid in those days. The plants were of a very low form of life, lacking "backbone" to make them lasting. Hardly any of them had flowers. Some were so ugly and shapeless that you could not have told leaf from stem, or stem from branch. Parts just ran together, like a mass of spilled jelly. No matter where you stood, whether in what is now Iceland, or what is now Africa, you would have thought yourself in a vast hothouse. The air was almost suffocating, and filled always with the odor of great beds of decaying vegetable matter. You could not see more than a few hundred rods because of the mist of steam always hanging over everything.

From time to time the folding of the earth's crust created hollow places in its surface—hollow places filled with layers of these decaying giant plants. And water rushed in and filled these depressions, carrying much sand and clay upon the dead and dying vegetable matter. This dampness and immense weight hastened greatly the natural decay of the woody plants.

When wood decays, a substance in it called carbon mixes with the oxygen of the air, a process very similar to burning dry wood by touch-ing a match to it. In either case, the carbon is freed from the plant, and what remains of the former woody fiber—ashes composed of salts of potash and silica and lime—unite with other earthen chemicals to form new bodies.

In the case of coal formation, the water and earth covering over the decaying plants kept in much of the carbon, just as covering over a piece of dry wood when we burn it does the same, leaving the remains black and large (like charcoal) and not reducing it far enough to bring it to white, loose ashes.

This is the way coal was made. Some of the layers, or strata, are fifty or sixty feet thick, while others are no thicker than cardboard. On top of each layer is a stratum of sandstone or dark-gray shale, which was made by the sand and mud washed in by the water when the plants were on top of the earth. These shaly rocks split easily, and in them man has found many interesting fossil impressions of the ferns which later turned into coal. How strange that a little thing this way, in changing into something else, should leave behind its everlasting former portrait—the picture to tell what it looked like, where it came from, and what it eventually changed into! May we be careful of our own growth and every-day actions so that the impression *we* leave behind us on our fellow beings will speak as loudly as the fern of having lived to make the world better and more comfortable!

After the coal seams were formed in the earth, what should occur from time to time but heavy wrinklings of the earth's crust. These contortions brought some of the coal seams to the top of the ground. The savages were the first to discover that the strange, black lumps of rock would burn and give forth a delightful heat; but the white man was the first really to make much use of coal. When a vein of coal cropped out on a white man's farm, he broke some of it up with a maul, shoveled it into his wheelbarrow, and trundled it home. After a while hundreds of people wanted coal, then thousands, and now millions depend upon it almost entirely for their fuel and comfort in cold weather.

The truth of the matter is, coal to-day is easily the "big chief" of all the underground tribe of minerals. Coal's importance to the whole world far eclipses any other product of this great rocky crust on which we live. In peace, in industry, in war, the nation which has the greatest abundance of coal is the strongest and best off. We had a strong lesson of this during the late World War, when Germany's forcible possession of the great coal-fields in northern France came very near to bringing triumph to the kaiser's invaders. We know it right here in America at the present time when, because of miners' strikes and a shortage of cars, many homes are cold and cheerless, and great industries are shut down, causing much want and suffering.

Yes, 75 per cent of the total weight of minerals taken out of the earth is coal. Geologists tell us that at the present rate of consumption, the supply of the world's coal, which is easily obtainable, will be gone in 200 years. This might make us shudder, but for the cheering thought that none of us will be alive then, and that the fertile brains of those to succeed us will undoubtedly scheme out some new form of fuel equally as good or better.

This mineral, used as a fuel, was first mentioned by Theophrastus about 300 B. C., so we may guess that coal was dug up previous even to that early date. Excavations in England brought forth flint axes and mauls embedded in layers of coal, which would indicate that workmen of the Stone Age might have known of its heating properties and used them. And the fact that coal clinkers or cinders have been found in old Roman walls, together with Roman tools for breaking up rock, goes to prove that coal was used for warmth prior to the Saxon invasion.

The first charter granting permission to dig and gather coal was issued to the freemen of

Newcastle, England, in 1239, who were to take out coal in those fields. The real history of coal as an important mineral product may be said to have begun at this time. In America, the first discovery of coal was made at Ottawa, Illinois, but the first mine was not opened until 1751, at Richmond, Virginia. In 1792, coal was found by Nicho Allen, near Wilkes-Barre, Pennsylvania.

In regard to the latter discovery, it is said that Allen encamped one night, and built his fire upon some small black stones that lay scattered about in profusion. Having cooked his supper, he went to sleep. He was awakened in the middle of the night by intense heat, and found himself lying in a circle of flames. His fire had ignited the "stones" under the brands, and these had fired those immediately around until he had been encompassed. It was with difficulty that he escaped. He told his story far and wide, and afterwards a company was organized to mine and ship the "black stones" to Philadelphia.

Colonel Shoemaker, a worthy colonial gentleman, was at the head of the enterprise. Upon his recommendation most of the first consignment of 100 tons was sold to the city for use in the pumping works. The Philadelphia engineers did not understand how to burn it, and after several unsatisfactory attempts, broke it up and threw it about the yards for gravel. A feeling of indignation against Colonel Shoemaker arose, and he was denounced as a rascal for having sold the city rocks instead of fuel!

In 1814, two ark loads of large lumps of coal (twenty-one lumps to a ton) were sold at the falls of Schuylkill. A whole morning was wasted in futile attempts to burn this, and at noon, the employer and his workmen, discouraged at their ill luck, shut up the furnace and went to dinner. On their return they were astonished to find a roaring fire, the furnace doors red-hot and the furnace itself in danger of melting down. From that day dates the successful use of anthracite (hard) coal in America.

Now there are many hard and soft coal (bituminous) mines in operation over the face of the globe. In some places the coal layers are horizontal, and crop out wherever they pass through a hill. In other places they cannot be seen, but are very close to the surface, and very little digging is necessary to uncover them. As a rule, however, the coal seams run diagonally through the earth's crust, outcropping at the surface and slanting downward, and this requires deep shafts and radiating tunnels for the working of them.

Suppose you are invited to visit one of these deep-shaft mines? You will go up to the mine bravely enough, but when you look down into the great black well of the shaft, which may be as deep as a big city skyscraper, your heart begins to jump in a way to make you feel weak. But the cage, or elevator, soon comes up, and you get in with a bunch of miners and go down, down, down, down, into that Styx-like maw, past one "level" or tunnel, then another, and another, all marked by a ghostly looking oil or electric light, until you come to a stop.

"Lower level; all out!" calls the grimy lift-boy; and together with the few who are left in the cage, you step forth into a dimly lighted passage. The air is so damp and cold that you gather your coat a little closer about you. You notice a group of miners standing near, some of whom are already crowding into the lift for its return journey. Their day's work, their shift, is over. The fresh-faced, clean-jacketed men who came down with you are to take their places. The new miners start off down the level, gayly laughing and joking; the old miners are more quiet, and look very tired. How dirty they are! It is hard for you to tell whether they are whites or Negroes. Their hands, faces, overalls, are all black with coal dust. On the cap of each is mounted a small lamp, surrounded by a screen, which throws a faint gleam of light around him, showing him where the black walls are, and causing the hard ebony diamonds in the latter to glisten and sparkle brightly. The screen about the lamp protects the flame from direct contact with the inflammable gases, which are frequently found in mines, and goes far to avert the danger of an explosion. Such explosions have often thrown down enough rock to block up a passage and imprison the men behind.

The dust-covered glasses of the few electric lights about you shut out most of the light, but you notice that the roof is low, and that all along the sides the tunnel is supported by heavy posts across the tops of which are strong timbers to keep the roof from caving in. At your feet, the earth is muddy and damp. In this ooze two shining lines of silver, on top of ties, show where tracks are laid. These run off in the distance till they look no larger than fine threads and are swallowed up in the noisome gloom.

From out of this pit of blackness there comes a distant hollow rumbling sound, as if Pluto and all his black imps are back in there in some underground chamber, having a merry bowling match with the roundest rocks they can find. Closer and closer these sounds roll. Finally you see a blaze of red light shatter the distant blackness, the rolling noises grow into a roaring medley made by a rattling of chains, a clattering of couplings, and the rough shouts of men, and— a queer-looking little locomotive pants up to the shaft with a line of dirty, box-like open cars, which are loaded with shining lumps of coal.

In a few minutes the cars have been emptied, and you are invited to jump on one of them and go back into the diggings. By this time your timidity has vanished; you rather enjoy the situation. So you respond with alacrity, and spring on the last car just as it rumbles past you. You would like to talk with the miner hanging on close to you, but the clatter and rattle is too great for words.

The little locomotive pulling this train is not operated by steam like those in the outside world. Steam would mean a fire-box, and a fire-box would mean the possible escape of a tiny spark which in one instant might ignite the mine gases with terrible results. So a safer power is utilized —in this case, a pneumatic engine does the pulling. The air supply which revolves the sturdy little driving wheels is gained from large tanks carried just above them, where a pressure of 600 pounds per square inch is confined in each. When the air becomes exhausted from these tanks, all the engineer has to do is to stop at any one of the numerous refilling stations along his course, and recharge them. This is done by using a nozzle connected to a high-pressure tube coming from a main supply pipe.

Formerly the only safe way of getting the coal out of the interior of mines to the shaft was by single little cars pulled by a mule. Boys operated these cars, which traveled very slowly, as might be expected. In Europe, mules are still used to a great extent. Many of these animals have never seen daylight, and consequently are practically blind. They are born in the mines where they work, are stabled there, and never know what sunlight looks like.

All along the tunnel down which your little train is whizzing, you pass openings of various shapes and extents. Into some of them—sort of cross-streets leading back into distant diggings—tracks lead off from your line. But most of the openings are merely big chambers like the interior of a low barn, and have been formed by the miners scooping out the coal they once contained. Above these pockets is a vast amount of earth and rock, sometimes hundreds of feet in thickness. There is always danger that the roofs will cave in, so where the rooms are large, the men leave supporting pillars of coal.

Presently the little train you are on comes to a stop before one of these chambers. With the clatter of wheels gone, you are now able to ask questions of the engineer, and you are greatly surprised to find that you are more than a quarter of a mile under the "sod," and have traveled fully three miles since you left the shaft. Involuntarily you glance hastily upward, as if to assure yourself that hills and houses and trees are not really tumbling down upon you, and then your look goes downward and you begin to wonder if there is surely enough earth under your feet to keep from cracking and letting you through into the boiling liquids of the world's middle.

But your attention is soon back to realities. The engineer is talking to you. He is telling you how miners used to get out coal in this mine, and how they do it now. Shorn of his quaint phrases and ungrammatical speech, the facts of his statements are about as follows:

Not many years ago the miner used to do all the digging with his muscles; now machines do most of it for him. In those days he often had to work in places so small that he would have to lie on his side, often in water, and peck away with his pickaxe all day long, week in and week out. So hard was the floor on which he lay that big callouses formed on his hips, elbows and other exposed parts, callouses as hard as the toughest rawhide. But for them he never could have stood the brutal cuts and chafings of his rough bed.

As soon as he could hew out a proper opening for the purpose, this miner of the past would drill a hole into the seam by hand, push in a cartridge of powder, thrust in a slender fuse, light it, and run for dear life. Sometimes he was caught by the fall of coal and slate; if not, he would return and have his helper shovel the ton or two of coal that he had dislodged into the empty mule-car near by.

Nowadays in this and most other large mines, where cutting must be done, it is all accomplished by means of a small machine. The miner puts this mechanical cutter on the floor against the wall of coal, and turns on the air or electricity, according to which power operates it. A buzzing is the answer, as the sharp steel chisel cuts rapidly into the coal, fairly eating it up. Soon there is a deep gully cut all along the side of the chamber.

The machine cutter now goes to another room that needs his attention, while new men come in and bore deep holes into the coal rock along the gully made by their predecessor. The drills are pneumatic, very powerful, and work ten times as fast as the old hand tools. Late in the day, other miners come in, insert sticks of dynamite in these holes, and then connect the detonator of each stick with electric wires which lead to a switch out in the tunnel, out of direct line with the mouth of the chamber. A simple closing of the switch then discharges each load, as fast as desired.

The jar which accompanies these explosions is something terrific. It comes not only from the shock of heavy charges of the terrible explosive itself, but from the concussion of great blocks of coal thrown in all directions through the air. Woe to the human being who might chance to be in that chamber, or in front of its open portal! Down below the whole ground trembles perceptibly in the neighborhood; and up above, under the blue vault of the heavens, passers-by would feel the shake.

Before you leave your mine you learn that mining coal is mighty dangerous work; that hardly a day passes in which some poor chap is not carried out with a broken leg or broken back as a result of a sudden fall of slate upon him. Any blow of a pickaxe, or twist of a drill, may break into an underground vein of water which will burst out and flood the mine. The wooden props which support the roof may break at any moment and let tons of rock down upon any one unfortunate enough to be underneath.

Then there are the dreaded poisonous gases. The coal, as has been said before, was made while under water. Therefore the gas which was formed in the decaying leaves and wood could not escape. It is always leaking out from coal, and no miner knows what instant his tools may break into a natural pocket that is highly charged with the vile stuff.

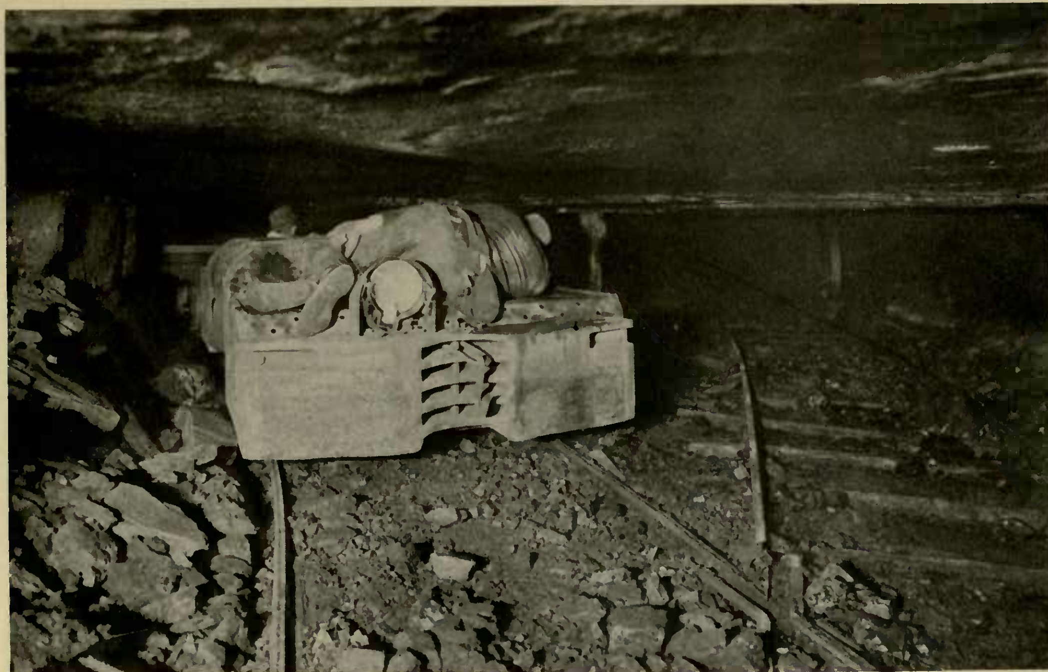
One kind of gas is called "choke-damp," because it chokes or suffocates any one who breathes it. There is also "white-damp," the gas which you see burning with a pretty blue flame over a hot coal fire. But worst of all is "fire-damp." If you stir up the water in a swamp, you will see bubbles of this gas arise to the surface. While harmless in a swamp, it is quite the opposite in a mine. For when it unites with a certain amount of mine air it becomes explosive as soon as the slightest fire meets it. Even coal dust sometimes explodes when the air is full of it and a heavy blast of powder sets it into violent commotion.

The only way to make a mine at all safe from dangerous gases is to keep it full of fresh, pure air. There is no wind to blow through the chambers and passages, so air has to be forced in. One way is to keep a large fire at the bottom of the air shaft. This causes hot air to rise from the fire, creating a vacuum or sucking force in the lower part of the shaft. The vacuum is so strong that fresh air from outside is pulled in, and this is gradually distributed through the workings of the mine. But the best system yet found is that used in most large public buildings—a great fan at the shaft entrances, which draws in fresh air constantly and also forces it along the various tunnels.

When the coal reaches the surface, either by tunnel or by shaft, you will find it passing rapidly through a series of operations which render it fit for the market. These processes are carried on in a great structure called a "breaker." The breaker is usually erected close to the main shaft of the mine, and railway tracks run right into it, so that the cars can be loaded as fast as possible.

This building is a place of dust and noise, of rambling sheds, inclined tramways and chutes; a monstrous, grimy structure not at all pleasing to look at, but very interesting to study within.

The loaded mine cars reach the breaker at a point high in the air. As fast as they arrive they are tilted so that they dump their cargo into the chutes provided for it. As the coal goes rattling down the incline it is carried beneath massive steel rollers which smash up the large lumps into much smaller ones. Then it goes on to a succession of screens with meshes of various sizes. By this process it is sifted and sorted with mechanical precision, until it finally reaches the bottom, where each grade falls into the bin intended for it. As fast as the big steam railway cars run under these bins, the bottoms of the latter are swung open, and the coal pours into them and is carried far and wide over the country to keep us warm, to cook our food, to keep our factories and great industries humming.



A MODERN COAL MINER AT WORK

But it is not enough merely to sort the coal into sizes. It must also be cleaned as well, for few mines are free from slate and other impurities, which, if left untouched, would reduce the quality and value of the coal. The best cleaning is done by mixing the coal with running water. As the slate is heavier than the coal, it sinks; thus the coal is easily separated from it.

As the coal passes through the breaker and over the screens it is watched by keen-eyed, deft-fingered boys, who pick out and throw aside whatever large pieces of stone or slate they discover. These lads are called "breaker boys." They are taking the first steps in the life of a miner, and in every mining town there are numbers of such little fellows busily engaged, and helping to earn the living for the household.

The fathers of these boys are usually foreigners, and miners themselves. As they are poor, and begin work at an early age, they have little opportunity to obtain a good education. But our Government does all it can to improve their working and living conditions. To this end the Bureau of Mines is constantly sending out helpful reading matter to the miners, and sometimes lecturers, telling them how to prevent accidents in the mines, how to take better care of their health, and how night-schools will give them better educations if they will only attend them.

Their wives, too, receive from the Bureau bulletins which acquaint them with the importance of keeping their homes clean and sanitary, their children healthy, and their cooking wholesome.

II

SOME BY-PRODUCTS OF COAL

THE value of coal can by no means be measured by its heating capacity. Important as it is to the world as a fuel, it is undoubtedly just as useful to us for the many by-products which chemists have pried from its black interior.

Three of the most valuable of these by-products are coke, gas, and coal-tar. From the latter alone a countless host of useful compounds have been worked out, and hardly a week goes by that does not witness new additions to the fold. Some are important therapeutic agents; others are delicate flavors for foods, or fragrant perfumes; a small number are helpful to the photographer, who takes your picture; a few belong to the class of powerful explosives in which dynamite is included; many are good substitutes for widely used natural products, such as rubber, camphor, and the like; finally, there is a vast array of coloring compounds which meet all possible needs in the dyeing or staining of textiles, leather, wood, straw, feathers, hair, etc.

As we think of this we do not have to day-dream very much in order to bring vividly before our mind the days far, far back, when this old world was much younger, and strange objects grew upon it and ran over its changing face. We see before us the great-great-grandfather of this wonderful thing, Coal: the luxuriant tropical vegetation of the Carboniferous Period; the slow transformation of that rank growth, buried beneath water, sand, and mud; the elapse of centuries, and the presence of peat, the change into lignite, and finally the new garb of coal. The scene switches swiftly. We seen now the dark bowels of the earth, hear the thud of the miner's pick, the dull report of a blasting charge, the return to sunlight, the entrance into the glowing coke oven; the quick tragedy of disintegration, as gas and tar and ammonia pour forth and leave behind an incandescent mass of coke; the separation of oxygen, hydrogen, and nitrogen; the start of the humble, homely coal-tar on its career of kaleidoscopic brilliancy!

Most people think of coal-tar as a material for roofing, for lining Bessemer converters in making steel, for producing electric arc-lamp carbons, for preserving timber, for keeping boat joints from leaking, and, in recent years, for laying the dust on modern highways. But, as we have shown, it is far more useful than in just those ways. To be more explicit, we may say that this material has furnished by separation no less than 190 substances of a definite composition.

The ingredients are secured from the coal-tar by what is known as "fractional distillation." The tar-distiller starts with as much as forty tons of tar at a time, which he puts into a huge cylindrical steel retort. As the heat below gets in its work, the vapors pass through a long coil of iron tubing, or condenser, which ends in a suitable receptacle for imprisoning them. The distillation is interrupted at certain points, and the condensed fractions are removed. There are five primary ones, as follows:

Tar water (containing ammonia). Light oil. Carbolic oil. Creosote oil. Anthracene oil. Residual pitch.

These compounds form the bottom of the coal-tar chemical industry of to-day.

The average amounts of the products derived from the distillation of 1,000 pounds of bituminous coal are as follows:

	Pounds
Coke	700
Tar	50
Gas-water, 9 to 11 gallons.	
Gas, 300 cubic meters	170.4
Benzene in the gas	9.38
Benzene in the tar	.5
Total benzene	9.88
Toluene in the gas	3.12

Toluene in the tar..................	.4
Total toluene	3.52
Total benzene and toluene..........	13.4
Napthalene	3.0
Anthracene	.2
Phenol	.7

Coke plants are usually so equipped that when the gas which issues from the ovens in such abundance is passed through the "scrubbers" most of the hydrocarbons, benzene and toluene, present as vapor, are recovered in the liquid form. But in the manufacture of illuminating gas, they are allowed to remain in the form of vapor, in order to increase the luminous power.

A given quantity of coal will generally produce a little less than 72 per cent of coke, about 22 per cent of gas, 6 per cent of coal-tar, and 0.36 per cent of tar useful for dyes.

A very large part of the Pennsylvania coal product is converted into coke for use in the steel mills and manufactories where it is needed. The coke furnaces thus become a feature of the coal industry, and they have grown to immense proportions because of the demand of the steel trade, although of late years there has been an increasing demand from households for it. It is generally used by citizens for starting coal fires, but some make a compound fuel of it by mixing it with anthracite in home furnaces.

So complete are the appliances used in the manufacture of coke that virtually all the work can be carried on by machinery. First the coal is put into great furnaces, direct from the car in which it is received from the mine. Here it is subjected to just enough heat to char it deeply. During this roasting process gas escapes from it, and is caught in a hood and conveyed subsequently to huge gas tanks from which it is distributed through underground pipes to consumers, who may use it for either lighting or cooking.

As soon as the coke is properly charred it is drawn from the furnaces by a long mechanical arm, operated by an engine on a car, which rakes the light, porous pieces into a trough. The latter has running through it an endless belt which carries moving buckets or scoops. The buckets convey the coke into waiting railroad cars, ready for shipment.

Acetylene gas is another product owing itself partly to coal. This gas is generated when calcium carbide is put into water. Calcium carbide is a hard, porous, grayish material, produced by fusing pulverized coke and air-slaked lime in an electric furnace. One ton of carbide makes 11,000 cubic feet of acetylene gas. This is as powerful in illumination as twenty-five times that amount in ordinary coal gas.

Acetylene gas is a comparatively modern illuminant and heating agent, having come into use only within the last decade. It gives a white, brilliant light, fully as strong as electricity, and is much more economical to maintain. But it has the drawback of requiring more attention, and it is also more dangerous to have around, for the gas sometimes explodes with great force if the lamp is not properly adjusted. On account of these defects, it is not as popular as formerly with vehicle owners and householders, who generally prefer electricity. Where electricity cannot be had, however, acetylene gas is still widely used for illuminating purposes.

Another of the important uses of this gas is in the way of heating. Its remarkable properties in this respect are in every-day use in the industries all over the manufacturing world. Great bars of steel that formerly resisted being severed by the hacksaw, are now literally melted in two with acetylene gas almost as neatly as you could halve a potato with a butcher knife, and in a very short time. Railways cut their rails with it when making repairs and installations. Structural iron workers use it in cutting great steel girders when building modern skyscrapers and bridges. Broken metal castings are mended, cracks being melted together so nicely that you cannot find them afterwards.

Did you ever stop to think where the pretty dyes came from—the brilliant reds, greens, yellows, blues, browns, etc.—with which your neckties, shirts, caps, and hats are colored? Or where the Easter-egg dyes come from, with which you decorate Mrs. Hen's belongings early each spring? Or where those colors originated in Sister Sue's gay little parasol? Or from what source came that rich mahogany shade on mother's birchwood sewing stand that you gave her last Christmas? From coal-tar taken from coal. To be more explicit, from the compounds of phenol, anthracene, and toluene, which have been extracted from coal-tar.

It was not so many years ago that cochineal and madder furnished the reds, logwood the black, and indigo the blues, for almost all fabrics, which had these colors or their combinations in them. But that was before chemists had begun to dream that the coal they burned in their grates possessed better color values. First, an experimenter discovered how to make coal-gas, and as soon as the process began to be generally used it was noticed that a brownish, pungent-odored syrup flowed away as a troublesome by-product. After a time this was named coal-tar by the scientists, who began to pick it to pieces. Marvelous substances were extracted, one after another, in quick succession, until, as we have already said, the number reached into the hundreds, many of which can be converted into beautiful dyes.

Before the World War, Germany made most of the dyes of the world, the other countries having given little study to the business and therefore knowing little about it, as all their colors were obtained from Germany. But when hostilities opened up a breach, there was nothing for the others to do but try their hand at the job if they were to continue having good coloring agents at reasonable cost.

At first their attempts were clumsy and marked with poor success. Black stockings bought in the stores were gray stockings after the first washing. Shirts with pretty pink and green stripes faded into a nondescript tint in the washtub. In other words, the colors were not well "set"; they lacked permanency.

But the new American dye manufacturers, with their customary versatility and ingeniousness, soon solved the problem, and dyes just as good or better than the former European product soon began to appear. At the present time America, within the space of four years, has become the leading dye-producing country outside of Germany, and that nation has undoubtedly forever lost its exclusive prestige in this line of endeavor.

III

OIL, THE NEW INDUSTRIAL GIANT

THREE famous statesmen have recently paid their tribute to the importance of oil. Said Admiral Fisher, chief of the British Navy: "The oil-engine will revolutionize commerce, and alter the whole art of war at sea."

Earl Curzon, British Foreign Secretary, stated: "In the recent World War the Allies floated to victory on a sea of oil."

Franklin K. Lane, formerly Secretary of the Interior, said in a report to President Wilson: "It draws railroad trains and drives street cars. It pumps water, lifts heavy loads, has taken the place of millions of horses, and within twenty years has become a farming, industrial, business, and social necessity. The naval and merchant ships of this country and all Europe are being fitted out to use it. The airplane could never have amounted to anything without it. There has been no such magician as this drop of mineral oil since the day of Aladdin."

Indeed oil has become, from a mere lubricating and lamp-burning commodity twenty years ago, the biggest and most important industrial giant of the age. It has risen like a meteor in the sky, with a sudden, swift, dazzling jump—until today it has the record for producing the bulk of our mechanical energy, and of having made more poor men rich in a short time than all the gold and diamond mines that ever existed. All of the big nations of the earth are doing their level best to get control of as many oil lands as possible, realizing that the nation possessing the greatest amount of crude oil will be the future giant in both industrial and fighting strength. In other words, oil is to modern nations what water is to the sailor, what muscle is to the wrestler. It is just about as near to being indispensable as anything you can find.

The World War, which called for new strength in such an emphatic manner, showed us the necessity of oil as nothing else could. Oil drove our submarines, our submarine-chasers, many of our great battleships. Oil also carried our brave dispatch-bearers on their motorcycles, made the long lines of trucks transport our field supplies and troops at break-neck speed across the country to the front-line trenches, whirred the propellers of the fighting airplanes, to say nothing of its use in greasing countless great and small field-guns, and keeping the bearings of railway cars and automobiles in good working order. And those left behind to back up the fighters used oil just as lavishly and helpfully. For them it helped to operate a myriad of machines in hundreds and hundreds of factories, furnished power for transporting the manufactured products from factory to pier, and from pier across the seas. The Red Cross depended upon it for many of their important surgical supplies, likewise hospitals sought its healing influences in various by-products.

This great jump of oil in popularity is due principally to the wide use of gasoline, at this time its chief by-product.

Figures are tiresome things at best, but it will be interesting to know that since the year of 1878 the consumption of petroleum (crude oil) has increased nearly thirty-fold. During the month of June, 1920, the daily average production was 1,240,633 barrels, the highest ever attained, and even then there were more calls for oil than could be filled. So great was the demand during the late war that automobiles used for pleasure had to be put under gasoline restrictions in order to provide gasoline for business and war purposes.

In recent years oil has not only made riches for the capitalist, but also for many with little or no money. There are many cases where needy adventurers, even men with criminal records, became suddenly rich by rushing into the newly opened Texas fields. Land owners all the way from cattle kings down to worthless, shiftless proprietors of a small patch of unfertile dirt, and ignorant half-breed Indians, made millions in almost a night. One man at Ranger, in less than a year, changed from the poorest of the poor to the owner of seven million dollars. Business men and professional oil operators also arose in a few years to dizzy riches. This sounds like the fairy stories of old in its improbabilities, but it only goes to accent the old saying that "truth is stranger than fiction."

At the present time there are 225,000 oil wells in the world. Many of these produce less than one-quarter of a barrel per day, while the big "gushers" average close to fifty barrels daily. The great bulk of oil wells cost $50,000 to establish, while some run into twice that figure, owing to the hardness of the soil and the depth to which they must be bored in order to make a strike. Then, too, the life of the average well is not long. As a rule, their supply grows less and less as the months roll by. A Texas well which began at 1,200 barrels a day less than two years ago, has now fallen off to an insignificant (by comparison) fifteen barrels a day.

Two great petroleum corporations control most of the world's oil supply. Of these, the Standard Oil Company, of the United States, possesses about two-thirds of the refined supply, while a good share of the remainder is produced by the Rothschilds in Europe. Of course there are many smaller concerns getting out petroleum on an independent basis, but their output is small when balanced against the enormous volume of production of the two interests named.

Probably the greatest developed oil field in the world is that at Baku, a Russian port on the west shore of the Caspian Sea, just south of the Caucasus Mountains. The contrast between the stupendous grandeur of the mountain scenery and the industrial activities of Baku, lying in the valley far below, is a most striking one. Hundreds of spidery towers rise up into the air about the town, forming a maze of lattice work very difficult to penetrate with the eyes at a distance. These wells are constantly pouring a wealth of crude oil into immense nearby reservoirs, while tank trains are coming and going all the while. The earth of the town is saturated with the oil, so much so that nothing can be grown; and white shoes are never worn by the citizens. Even the air itself is heavy with the odor of the dark-brown petroleum, and almost everybody you meet has a greasy, leathery look about him. But they do not seem to mind that, for they are largely oil workers themselves, and are doing their share to produce Baku's annual output of 50,000,000 barrels.

In the United States are many oil fields, quite widely scattered. These wells producing the highest grade petroleum are situated in Pennsylvania, which is the oldest oil field in the world. Pennsylvania crude oil has a high percentage of paraffin in it, which makes it an almost ideal fluid. From it the best oils for lamps are made, also the finest qualities of lubricants for greasing cars, wagons, machinery, automobiles, etc., and the highest grades of gasoline. It is often mixed in refineries with lower grade oils from other fields, so as to bring up the quality of the latter's products.

Oil is contained in rocks of considerable porosity, mainly sandstone and shale, which, when containing oil or gas, are usually referred to as "sand."

In this district the main producing "sand" averages about thirty feet in thickness, and is found from 1,100 to 1,800 feet below the surface. The early colonists learned that there was petroleum here, and also in the western part of what is now the State of New York. While they knew of its illuminating qualities, they preferred to go on burning candles or sperm-whale oil, rather than make the long trips back and forth to the oil districts.

The Indians had discovered the strange fluid long before this. At first they were very much afraid of it, but later found that by rubbing it over their bodies they shone beautifully, and so determined that it must be some form of "good medicine." They then went to the springs where they had found the oil floating, threw their blankets into the water, and carried the heavy, soggy things back to camp. Here they were wrung out, and their oily contents traded to others.

It is said that one day, after this practice had been going on for some time, an Indian war party built a fire near one of these oil springs. Here a council was held, during which the majority of the band declared for returning to their village, fearing that the enemy tribe against which they had been advancing was too strong for them. But the old chief was very angry, called his followers cowards, and finally became so violent at the protests of his son-in-law, Sag-nee-wah, that he picked up one of the blazing fire brands and cast it toward him. Sag-nee-wah saved himself a searing by dodging. The brand flew into the pool near by, ignited the heavy scum of oil, and at once there was a flash, and tongues of fire leaped up all over the surface of the spring.

None of the savages understood this phenomenon. So they immediately ran from the scene in the greatest fright, going back to their people with the story of the terrible wrath of the Great

Spirit, as manifested in the "pool of good medicine" where they had been only a few minutes before anointing their bodies for warfare.

It was not until about ten years after the rush for gold into the California diggings that the first company was organized for securing crude oil in Pennsylvania. These men did some prospecting, selected a piece of land that looked promising, paid the owner for it, and then went to work with pick and shovel. Poor dolts, they thought to dig this first oil well as they would have dug for drinking water—by making a large hole down into the ground! You can imagine the result: they came to an underground stream long before they could have reached the oil-bearing strata, and their "well" was truly a well from that moment on, but one of *water* instead of oil.

Realizing their folly, the men then drove down several sections of iron pipe till the sand belt was struck in which the oil was contained. Just back of this was a pocket of natural gas, such as is often found below the oil, and when the drill tapped into this, the gas was strong enough to force the oil up into the pipe and out at the top, where it spurted several feet high—a mild little "gusher."

The news of this "strike" traveled fast, and soon people in the East were scraping together all their spare money and rushing into the Pennsylvania fields looking for oil lands to buy. A song of the day had this for its refrain—

"Stocks par, stocks up,
Then on the wane;
Everybody's troubled with
Oil on the brain."

A few years later the first real gusher was tapped. The workmen had drilled down close to a thousand feet, and were working away patiently when a furious stream of oil burst forth out of the casing at the top of the ground. They and their tools were drenched with oil in a moment, and the men had to make a hurried jump in order to save their lives. The oil spurted in a thick, dark stream, many feet over the nearby treetops, and came down like a shower of molasses. Hundreds of barrels were lost before means were found for capturing the valuable fluid. That strike made these men all rich.

An oil field is not necessarily a small district; very often it will extend over a large portion of a whole State, sometimes several adjoining States. When a prospector thinks there is oil in a certain spot, he secures permission of the owner to sink a test well there. If this turns out to suit him he may buy the property, but usually he secures the oil privileges by guaranteeing the owner a royalty, that is, a certain amount of money for each barrel of oil he takes out. We will say he offers a royalty of fifty cents, and sells his product to the refineries for $4.00 a barrel. You will readily see that if there is only one well, the owner will soon be well off with his royalty, for a hundred barrels a day would bring him nearly twenty thousand dollars a year; and the operator himself of course should make much more.

When he decides to go ahead, the operator builds his derrick. This is made of four heavy uprights of wood which lean together toward the top, in the form of a pyramid, and are braced by cross-timbers. The tower is from forty to eighty feet high, according to the depth of the well, and stands directly over it. Close by an engine-house is set up. From the engine flywheel a heavy belt runs up to a pulley in the top of the derrick. This pulley turns a shaft to which is connected the drilling mechanism.

The work goes on day and night till success or failure manifests itself. Imagine yourself an oil-well owner during this time. Just think how your pulse quickens as the sharp-toothed drill bites deeper and deeper into the earth, and the steel casing outside of it is driven down, rat-a-tat-tat, rat-a-tat-tat, into the clay and sand. Will the next stroke bring you that coveted dark fluid? Oh, will it? Or will you have to go on drilling (how gloomy the thought!) for a long time yet, only to find nothing but water and rock? Rat-a-tat-tat, rat-a-tat-tat! One moment you are wallowing in the richest of dreams, seeing yourself a second John D. Rockefeller; the next, you are as blue as a heron, in the dumps, fearful of failure. Rat-a-tat-tat, rat-a-tat-tat!

As the drill keeps nipping away at the soil, the pump sucks out the water and loose bits of rock. This well may be a great gusher, pouring out several thousands of barrels a day. Again, it may evolve itself into a sluggish "pumper" only—a well lacking sufficient gas force to throw up the oil, and calling for constant pumping from above in order to make it a paying proposition. There are many of the latter type of wells in various oil fields. Sometimes these can be made to flow moderately by exploding a heavy charge of dynamite at the bottom. This breaks up the rock, making a larger opening, and often gives an obstructed gas pocket a vent for heaving the oil upward.

Since the Pennsylvania field is the oldest it is but natural that many of the wells which at first produced largely should have flowed out. For a long time these dry wells were considered worthless. They were plugged up, according to State law, and left alone. But what surprised the oil men was that very often when a certain well went dry, an adjoining one began to give forth more oil than ever before. Greatly puzzled, but bent on finding the reason, geologists made the most careful investigations. By putting two and two together they came to the conclusion that the renewed influx of oil into these wells was caused by water entering the oil sand at the old hole, which had not been properly plugged, and driving the oil by back-pressure through the porous rock to the producing well.

This opened their eyes. Now nearly every well that goes dry is heavily flooded, and new wells are drilled in advance of the flood, one acre apart. These new holes, in about three years, begin to be influenced by the subterranean flood water, and produce much more oil as a consequence. But as the oil becomes exhausted, water takes its place, and after a while there is more water than oil, and the well is abandoned for good.

Whence come the great volumes of oil issuing from the many gushers of the California oil fields? How long will they continue to flow, making fortunes for those who have an interest in them? Will the gushers cease spouting tomorrow, or will they continue to furnish man with nature's bountiful supply of petroleum for months, maybe years?

Geologists, engineers, and oil operators all are more or less befogged when it comes to furnishing answers to these questions. Some operators, who have had wells gushing without perceptible loss for several years, may claim that their wells are practically inexhaustible, but they are really not so sure as they pretend and have an uneasy, guilty feeling when they say it, too. Although they know that all the gushers of the great California fields seem to be fed by the same steady, gigantic subterranean force, like many small water pipes leading from one large feeder in which a terrific pressure is always present, their experts tell them that the life of any oil field is comparatively short.

The oil situation in the world really is somewhat critical. Our modern inventions and mode of living are using up this wonderful fluid at a tremendous rate. We are told that the world's production of oil will soon be on the decline and in twenty years the supply will be much less than the present demand unless some great new fields are discovered.

But meanwhile so much oil is flowing out of these California wells that it is the biggest job they ever undertook to find places to store it, and cars in which to ship it. For the huge output has not only taxed their resources to the limit, but has called for an expenditure of more than a million dollars to handle it. Great reservoirs of concrete have been built to contain the oil, and a vigilant watch is maintained over these day and night to prevent seepage and contact with fire.

Fire indeed is one of the greatest perils in the oil fields all over the world. Nobody is permitted near the vats or gushers with a flame of any kind; smoking is positively prohibited. One tiny match has often set a great gusher into a spouting volcano of fire and the blackest sort of smoke clouds, to burn for days and weeks while the men helplessly tried to extinguish it. Reservoirs, too, have had all their valuable contents destroyed in the same manner, it being practically impossible to put out the flames when once they are started till the last drop of oil is consumed. Everyone who has been in railroad yards has observed the cards on tank cars, warning of keeping away with all fire.

In the Maricopa oil fields of California is a well called the "Lakeside." This is probably the deepest and heaviest producing gusher ever bored. Its great volume of oil flows up through the ground a distance of 2,225 feet—close to half a mile. Usually the velocity of the flow of a well of this type will force sand and rock into the pipe and clog it up, but this has never happened with the Lakeside's 6-inch casing. For many weeks following its tapping this great well projected high into the air thousands of barrels of beautiful crude oil every day. This spouted

SHOOTING AN OIL WELL

higher than the tallest trees, and came down in a vast cascade, flooding the entire country thereabout for several miles. It was absolutely beyond control. For weeks the engineers, braving the blinding deluge, tried their best to get a cap over the pipe and stop the loss, but it would only be torn each time out of their hands by the fierce pressure, as the wind will whisk away a feather. In time, however, man's ingenuity and perseverance succeeded. The great gusher was capped, and thereafter has been feeding its tremendous supply of oil into a big conducting pipe which connects with a great reservoir over half a mile long.

Although natural gas is usually found wherever oil wells are sunk, and probably does do much in some instances to force up the tapped oil, at the same time there are many reputable geologists and oil engineers who hold to the theory that underground water exerts most of the pressure, and facts seem to give them good grounds for this belief, called the "diatomic theory." These experts point out that the greatest gusher of all—the Lakeview, which we have mentioned—varies in intensity with the rise and fall of the ocean tides, although the ocean is at a considerable distance, with a mountain range between. And they also point out that which we have previously noticed: the extra impetus given to producing wells by flooding a nearby exhausted one. All of which would seem to show that water does have a strong influence over the flow of oil, at least.

Before crude petroleum can be utilized to any great extent it must be refined, which is a process of removing from it its grossest impurities. In the beginning of its history it was carried for this purpose in wagons and boats, from the oil fields to Pittsburgh, where the only refinery was situated. Then came the railroads, which replaced both the wagons and boats as a medium of transportation. The railroads provided special flat cars to which were fastened great cylindrical steel tanks that would hold thousands of gallons each.

There was only one difficulty about sending oil by rail, and that was that it still had to be hauled by team from the oil wells to the railroad station, often a distance of several miles, and this was no easy task. At length some one said to himself, "Why can't we run a pipe direct from the well to the railroad?" It proved a wonderfully good idea; so simple, too! So pumping engines were put in a few miles apart, and almost all the big fields began sending their oil straight to the cars through a feed pipe.

Before this it had been necessary to build refineries as near the oil regions as possible in order to save expense in transportation; but now they could be built wherever wanted. There are cases where the feed lines travel as much as a hundred miles to reach the nearest refinery. They go over hills and through swamps. They cross rivers, sometimes by means of bridges, sometimes by being anchored to the bed of the stream. They cross deep ravines and gorges not too wide by simply stretching across from ledge to ledge. In salt marshes they are laid in concrete to keep rust from destroying the iron. If these great oil arteries were to be ruined by any means, so that oil had to be carried in the old way, kerosene and gasoline would become much more expensive necessities than they are today.

At the present time crude oil can be brought at small expense from the fields far west of the Mississippi River to the Atlantic seaboard, refined, and distributed throughout that part of the country, or loaded into "tankers" (oil ships) and taken across the ocean. In the early days of this pipe system great trouble was encountered by the pipes getting choked with impurities, shutting off the flow or diminishing it. But some ingenious chap invented what he called a "go-devil" to do away with this nuisance. The go-devil is about three feet long, and shaped like a cartridge, but its body is composed of flexible plates which allow it to turn around any bend in the pipe line. From time to time the go-devils are inserted in the pipe at the wells, and the rush of oil forces them along to the receiving end, by which time they have done their duty of scraping out the pipe line, and can be shipped back and used over and over again.

If you hold a piece of cold earthenware in the steam of a teakettle water will collect on it. This is distilled water, and is much purer than that in the kettle. Petroleum was at first distilled in a rough way; but now it is done with the utmost care and exactness. The crude oil is pumped into boilers holding six hundred barrels or more. The fires are started beneath, and the oil soon begins to turn into vapor. This vapor passes through coils of pipe, and sometimes long lines of parallel pipes, on which cold water is pumped. This causes the vaporized oil to turn once more into liquid, and this liquid is a crude form of the kerosene we buy for lamps.

Kerosene oil is only one of the many useful substances found in petroleum. Some of these are light, like gasoline and benzine; some are heavier, like kerosene and thin lubricants; while paraffin and tar are heaviest of all. In the separation of these by-products, there are also gases, which pass off first and are used to provide fuel for the furnaces. Nothing is lost. Every atom of the crude oil goes into something valuable for making our lives easier and more comfortable. One by one come the other substances, according to weight or specific gravity. The still man keeps close watch. When the color of the distillate changes he turns the cock of that tank shut and opens another. This process is called "fractional distillation," and the various products are known as "fractions." No two kinds of petroleum and no two oil wells are just alike in their chemical properties, so it needs a highly skilled still man to manage the cocks.

After its distillation kerosene oil is still unfit for good illuminating purposes. It has both a disagreeable smell and a way of smoking the lamp chimney. So it is treated with sulphuric acid and caustic soda, which carry away the remaining impurities.

Then it is given three tests. These are to make sure that the oil is light enough to absorb freely through the wick; that it is of the right consistency to produce a vapor that will flash into fire when a certain amount of heat has been applied; and that it will not burn too easily on the surface when heat is applied to it, as this would make it unsafe.

We do not burn oil in our lamps, as we are in the habit of saying. What we really do is to heat the oil until it gives off gas, and then we burn the gas. The chimney is merely a helper in regulating combustion. The hot air rises in the chimney, the cold air rushes in underneath to take its place, and this brings the necessary oxygen to the flame for making it burn brightly and steadily. The more air we let in from below, the brighter the light, up to a certain point. Burners and chimneys are all carefully thought out by the manufacturers, and made so that they will give the best results possible. In a close, stuffy room no lamp will give a clear light, because there is not oxygen enough for its flame.

In a wax candle we light the wick, its heat melts the wax, the wax runs up the wick in the form of oil, the oil is reduced to gas, and the flame feeds upon the gas—just as with kerosene oil. Wax alone will melt, but it will not take fire. Ignition of practically all substances requires the formation of gas first.

The by-products of petroleum are many and important. Omitting such well-known substances as kerosene and gasoline, we have many grades of lubricants for oiling machinery; tar, as used in dyes; naphtha for dissolving the resins used in varnishes; benzine for cleansing clothes, printers' types, and almost everything else; paraffin for candles and fruit sealing, for covering match heads, and for making waxed paper with which to do up our lunches when a picnic is in prospect. Even printers' ink and waterproof roofing-paper both owe their existence to petroleum. In medicine, vaseline is one of the greatest standbys. It can be mixed with drugs without changing their character, and it never becomes rancid. For this reason it is used largely as the principal part of salves and ointments. It also has a certain medicinal or healing value on its own account.

IV

IRON ORE, THE WORLD'S RICHEST MINERAL

FROM iron ore is made *steel,* man's richest metal, industry's greatest asset except coal. From steel the modern world makes its wonderful tools, constructs its great bridges, tunnels, and buildings; builds its famous railways, shapes its powerful steamships and war implements. From plowshare to pen, from super-dreadnaught to watch spring, steel reaches over countless products of the manufacturing realm with deep mothering interest. "They are mine," she says proudly; "all mine! Are they not beautiful children—wonderfully smart children?"

Would you like to know the size of the American steel industry alone? Then reflect that even before the great World War broke out, in the slack and uncertain days of 1914, it employed more people than live in all the four States of Nevada, Arizona, New Mexico and Wyoming. More money is invested in the industry than the national wealth of Switzerland.

Think of an ore train so long that it would take a fortnight to pass a certain point, going all the time at freight-train speed! Think of ore ships moving one behind another and stretching from Detroit, Michigan, to Erie, Pennsylvania! Think of a row of blast furnaces (for making ore into steel) reaching from New York City twenty miles past Philadelphia! Picture a column of rolling mills and puddling furnaces stretching from New York to Indianapolis! Imagine a stream of ten tons of liquid iron flowing out of great crucibles and becoming pig metal every second of the year!

This will give you a faint idea of the vastness of the steel industry. But for American steel we might be little better than savages to-day. Without American steel probably German submarines would be ruling the seas at this time, and German hordes tramping ironshod over British, French, Italian and American lands. Steel is king! The nation possessing great wealth of iron ore not only has in her mines a university of great civilizing and progressive influences, but she also has the most formidable weapon she can possess with which to protect herself from enemy invasion.

There is a wide distance between the primitive miner of iron ore, his own crude furnace and molding appliances, and the present gigantic and systematic methods employed by specialists in the production of iron and steel. The United States Steel Corporation, a group of many rich men combining a working capital of more than two billions of dollars, controls most of the steel industry of this country. These men not only own the greatest share of the iron mines, but also the multitude of blast furnaces, rolling mills, and other enterprises connected with the smelting and production of iron and steel in various forms and qualities. Finished products are made where there is a large demand for them. These include such things as railway rails, structural steel, armor-plate, automobile-plate, and tubing. Less used products they leave to the smaller industries to manufacture.

Leaving aside European interests, it was not so very long ago that Pennsylvania was the source of all our steel. Now great steel mills are operated in all sections of the country—north, south, east and west. With the great ore deposits of the Lake Superior region at their very doors, the mills of the United States Steel Corporation at South Chicago and Gary, Indiana, are working day and night. At Birmingham, Alabama, other mills are transforming the ore of the surrounding mountains into rails and structural steel, while out at Irondale, Washington, a new era in the industries of the Pacific coast was opened a year or so ago when the plant of the Western

Steel Corporation began to turn out pig iron and steel ingots.

The story of modern iron-ore mines naturally begins at Hibbing, Minnesota, the iron-ore capital of the world, and the richest village on the planet. Most of the streets in Hibbing start at one man-made precipice and end at another; for not content to be the proud possessor of the biggest iron mine in existence, this enterprising little metropolis has gathered several other good-sized mines around her, as a hen gathers in her brood. In 1910 the population of the iron town was less than 9,000, and yet it had a street-lighting system as ornamental and efficient as that of such large cities as Cleveland, Minneapolis, and Detroit, and far more beautiful than that of the nation's capital, Washington.

The streets are well paved, and everybody seems to have an automobile, even the miners; so that street-cars would be about as necessary as a fifth wheel on a wagon. Going up to Hibbing from Duluth you get the idea that the ore capital risks money lavishly, as in the parlor cars and day coaches alike appear signs which warn against playing cards for money in railroad trains.

Hibbing's great mine is the Hull Rust, which is a hole in the ground rivalling the immense Galliard Cut at Panama. This mine is a vast terraced amphitheater cut out of rolling ground, and covers an expanse of two miles in length by a half mile in width. Could you dump the huge Gatun Dam of Panama fame into it, there would still be a yawning chasm unfilled. A ten-story office building set down into its deepest trench would leave the flag-pole of the building barely reaching to the line of the original surface.

Ordinarily we think of mining as an occupation for human moles that burrow in the ground and bring out hard ores from cavernous depths. But when nature laid down the Lake Superior ore ranges she spread her precious layer close to the surface, so that for the most part burrowing and blasting was quite unnecessary. This is particularly the situation in the Mesaba Range, the richest stretch of iron-bearing ore ever discovered. The work is done by stripping off the surface deposits and useless vegetable mold, until the iron ore is uncovered, whereupon it is removed by steam-shovels to waiting cars. This becomes quarrying rather than mining, in the strict sense of the word, but though it may lack some of the picturesque features of mining operations deep in the earth, it is much more convenient commercially, and makes the cost of the product far less than if it were garnered through shafts and tunnels where the light of day never penetrates.

The ore bodies are first thoroughly explored by churn- and diamond-drilling, surface and ore contours are sketched on maps by the engineers, and complete plans made for stripping and mining before excavation really begins. Then things begin to hum. It is somewhat uncanny to see a whole battery of huge steam-shovels biting into the soft, red-brown stuff that looks more like some sort of sand than iron-ore. These shovels are operated from heavy cars which travel slowly along tracks built on "shelves" or "benches" which are left, terrace-like, around the sides of the great bowl where operations are carried on.

When one of these large scoops buries itself in the earthen matter it usually shovels out a hole twenty-five feet deep and fifty feet wide. Just think of that! In such a trench a whole company of soldiers could conceal themselves. This is "making the dirt fly" in deadly earnest!

In stripping operations, that is, working off undesired soil to expose the iron-ore, the steam-shovels dump enough of the scrapings ahead of them to form a roadbed for their own tracks, as they advance. When there is a surplus of such foreign earth it is generally dropped to one side, out of the way; but sometimes, owing to a rise on that side and an accumulation of too much dumpings, the piles slide down in true avalanche fashion and partially bury the cars or knock them from the tracks.

As a rule very little dynamite is used in this form of mining, the big shovels doing practically all of the loosening work as well as the loading. Strange little trains, pulled by diminutive steam locomotives, are a part of each shovel outfit. In each train there are all the way from five to a dozen flat-cars, each of which holds from five to thirty yards of dirt. The first car is usually the steam-shovel itself, which empties its load of iron ore on the nearest flat-car. Often a locomotive is required at each end of the train when the cargo becomes heavy, or the grade is steep.

Day and night the work goes on—two tons to the shovelful, five shovelfuls to the minute, and five minutes to the carload. A whole ore train is loaded in less time than a child with a toy shovel could fill his little red express wagon. Not long ago a big 300-ton steam-shovel loaded 7,689 tons of ore in a single day.

The railroads reaching from the mines down to Duluth, Superior and Two Harbors, where most of the ore goes for lake shipment, are of the best construction, like the main lines of our biggest eastern roads. The long ore trains crawl through the hills and vales that Proctor Knott declared, in his celebrated speech in Congress, would not, except for the pine bushes, "produce vegetation enough in ten years to fatten a grasshopper," but where to-day farmers are growing splendid crops of potatoes and wheat. Where gold and silver were located on the map Knott made famous, we now find the richest iron mines in the world—mines that beggar the bonanzas of California.

The haul from Hibbing to Duluth is eighty odd miles. Just before the trains reach Duluth they come to Proctor, the biggest ore yard in the universe. Here they are weighed on a scale unique in its convenience and accuracy. A section of the tracks are on this scale, the trains pass over it without stopping, and as it leaves the weight of every loaded car is automatically registered.

From Proctor the trains run down to the huge unloading piers at Duluth. These piers are vast platforms built out over the lake, nearly half a mile long, and wide enough to accommodate two tracks which are elevated to the approximate height of a two-story building. Beneath the tracks is a series of large pockets, holding some two or three hundred tons of ore each. The ore is dropped mechanically into these pockets, and the train returns to Hibbing for a new cargo.

Even while the trains are dropping their burden special ore-ships are alongside. From the ore pockets on the piers long funnels reach down to the hatches of these vessels, and the ore goes flowing down till the pockets are emptied or the ships supplied.

These ore-ships are a picture in themselves. They remind us of the exclamations of an old Cape Cod salt who beheld one of them for the first time: "Now clap your eyes on that! D'ye call that a *ship?* Bless your mizzen-scuppers, why a loggy lighter with a city store on one end and a match-factory on t'other would look more like a ship than *that!* It's so long, how'd the skipper and chief engineer ever get acquainted? And you say the skipper bunks in the skys'l fo'c'stle for'd, while the cook and ship's boy has the quarterdeck? Well, I wouldn't ship on such a bloody drogher for all the gold in the world!"

In a general way the big freighters do fit the old sailor's sketchy description. Some of them are more than 600 feet long, and only 60 feet beam. A big sort of house at one end, occupied by officers and crew, and a great stretch of flat decking in between, surely make them look like uncanny monsters of the deep, in their dull, dark dresses of paint. More than thirteen thousand tons of ore have been carried on one of the largest of these ships. The cost of operating them on trips is often as much as three hundred dollars a day.

When the big ore carriers arrive at the lower lake ports—Lorain, Cleveland, Ashtabula, Conneaut, Erie, and Buffalo—they are quickly unloaded at huge piers. Gravity may load a ship, but it has never yet unloaded one, and so machinery does the work entirely. The Hulett unloader, one of the chief mechanical agents used, reminds you of the glorified walking-beam of an old side-wheel steamer, with one of the two beams left off. At the lower end it has a wonderful set of claws, and above them an "ankle" of startling agility. These great claws open and shut by electricity, and take up seventeen tons of ore with as much ease as you might close your hand on a nice, juicy, red apple. The operator is stationed inside the leg just above the claws, so as it swings back and forth, up and down, he goes with it from hour to hour, getting all the sensations of riding a roller-coaster, and good pay for his experience. Once it took a week, with a regiment of men to unload a small ore-ship. Now, in half a day, a corporal's guard can empty the biggest ore-carrier that ever cut the waves.

This ore is stored in huge bins, from which it is transported by train to the blast furnaces.

The modern blast furnace is a tremendous and spectacular institution,—tremendous in size and output; spectacular in its appearance when in operation, especially at night when the vividness and weirdness of its saffron-green cupola flames, shooting erratically into the dark heavens, cause exclamations of awe and wonderment from those who see them for the first time.

At the top the blast furnace takes in iron-ore, coke, and limestone. Without the two last-named products, good pig iron would not result. The furnace is a large circular, silo-shaped affair, about ninety feet high, which is kept going day and night, Sundays and Christmas alike, year in and year out. The coke, limestone, and ore, are soon melted, as a veritable inferno of heat exists down near the bottom of the furnace, caused by a tremendous blast of air driven into the fire by huge engines. The blast causes all the oxygen in the air to unite with the carbon, and to leave through the gaspipes leading from the furnace.

The pure ore and the limestone melt together under the fire, while the foreign matter in the ore unites at once with the molten coke. Being lighter than liquid iron these newly wedded substances rise to the top of the bubbling caldron like oil rises to the top of water or cream to the top of milk.

There are two holes in the lower part of the furnace. Out of the upper one of these, when tapped, comes the waste matter, now liquid slag, which soon hardens and is shipped away to be made into prosaic cement.

When the iron, now as liquid as milk, is drawn off through the lower hole, it is plain molten iron. At some furnaces it is run into large cavities in sand, called "sows," and then conducted to

IRON MINERS AT WORK

smaller ones, called "pigs," where it is allowed to cool and harden. The iron is then in the form of grayish-brown slabs about the size of two bricks placed end to end, and is termed "pig iron." At other furnaces the molten iron is drawn off into metallic molds instead of sand ones; and at still other furnaces it is "machine cast," drawn off into ladles, transferred to molds mounted on an endless belt, and cooled by water through which the belt runs.

In some cases the furnace and steel mill are in the same plant, and the pig iron is delivered in its molten condition directly to the steel-maker, and he reduces it to steel before it has a chance to harden. But though it may never become "pig" it is known as "pig" just the same.

Up to this point all things made of steel have a common history. Pig iron is the common denominator of every fraction of the steel industry. The 200-ton casting for a powerful electric dynamo, the tiny second-hand for the highest grade watch, the powerful 16-inch gun that weighs as much as a locomotive, and the microscopic screw with threads that elude the human vision,—all come the same road. The ore that was bought of the land-owner in the Lake Superior iron region for the paltry sum of 25 cents a ton, now, in the form of fine watchsprings, is worth $7,000,000.

But once out of the blast furnace, pig iron comes to the parting of the ways. Some of it will go to the puddling furnace and become wrought iron (such as blacksmiths use); some will take the cupola route and become cast iron (iron poured in molds according to foundry method); much more will go into the Bessemer converter and become soft, malleable steel; but still more will take the path that leads to the open-hearth furnace. A little, comparatively speaking, remains behind. It finds its way into a crucible furnace or an electric furnace, and becomes the tool steel of the industrial world, the refined, tough, hard steel that goes into the making of knives, saws, bits, drills, cutters, reamers, taps, dies, and the like.

In making wrought iron—used generally in the manufacture of chains, pipe, bolts, wagon rods, nuts, and the like—close to 600 pounds of pig iron is heated until it reaches the consistency of dough. Slag soon begins to form, and being lighter and more fusible than the pure iron, floats to the top, and the greater portion is poured off. At this stage the iron begins to form into small pasty globules, about the size of a pea, each globule surrounded by a thin covering of fluid slag.

Stripped to the waist, with arms and muscles like those of a prizefighter, the puddler stirs or "puddles" the iron for nearly an hour and a half. He takes a bar of iron, known as a rabbling-iron, which in itself would make a staggering load for most men, puts one end through the furnace door, and turns the pigs over and over until they are melted, stirring the mass so as to expose all parts of it to the action of the intense overhead flame until the impurities are largely eliminated. The iron is then formed into two or three pasty balls, as a woman might knead dough and divide it for loaves. These balls are not touched by the hands, however. The work is done with more discretion than that, the rabbling-iron being utilized. They are taken out of the furnace glowing with heat and dripping with slag, and conveyed by tongs to the "squeezer," where most of the remaining slag is pressed out.

It is a strange thing about iron that, before it is converted into steel, it cannot be "tempered" or made harder. Compared to steel, iron is always soft and quite pliable. But once put through the converting process, and becoming steel, treating it later with heat will give it almost any degree of softness or hardness. For instance, if you have a piece of soft steel and wish to make it harder, you would heat it to a cherry red and plunge it quickly into water. This renders the steel as hard as such metal can be made. If too hard for the purpose in view, the temper is "drawn," that is, the hardness is reduced. To do this it is only necessary to subject the steel again to heat for a very limited length of time, or until the proper color shows on it, signifying the degree of hardness desired. It is then withdrawn, and cooled naturally.

Cast iron is different from steel in hardness and color. It can stand almost as much squeezing together as the best steel, but it is comparatively weak in resisting a pulling or straining force. A sharp blow will easily crack or shatter it.

In making cast iron the cupola furnace is usually used, but not always. A bed of coke is laid down, then a layer of iron, then another layer of coke, and so on. It is then fired, the iron melts and runs out, and is poured into molds. Air-brake parts for railways, radiators, car brackets, and pipe fittings, are examples of its use.

The story of Bessemer steel is one of the fascinating chronicles of the industrial world. It has to do with two men working in different countries, each without knowledge of what the other was doing, reaching the same conclusion about the same time. Both were granted American patents; but upon application for renewal, the Patent Office held Kelly to be the inventor. The world, in spite of this, gives the credit to his contemporary, Bessemer, and the method is known as the Bessemer process accordingly.

Kelly was a maker of old-fashioned cooking-pots and kettles. It is related that one day he was sitting in front of his furnace and observed a point of incandescence where there was no charcoal, only the metal and the air. This led him to believe that air alone would burn out the impurities from molten iron. So he experimented along this line, and produced a tilting converter. When his engineer tried this out he blew such a tremendous blast through the first charge that iron and all went up as sparks, to Kelly's chagrin and the onlookers' amusement. He finally succeeded in getting the amount of air regulated, and soon afterward poured out the finest tempered steel. People were so surprised that they said the next thing Kelly would be doing would be to burn ice! Since his crude old converter was first used, billions of dollars' worth of Bessemer steel has flowed out of the world's converters.

To go into a great building where there is a battery of Bessemer converters is to see more heat than Dante ever pictured in his "Inferno." A converter is like a huge egg of steel swung on trunnions at its middle. The shell is lined with fire-brick, which is the greatest resistant of heat that can be found. Were it not for this unmeltable lining, the steel shell would collapse into liquid as the white-hot metal enters.

Into the open top of this gigantic egg some twenty tons of molten pig iron are poured. And then, through more than two hundred little holes in the bottom, powerful engines pump in as many streams of cold air. As the oxygen-laden air sweeps up through the molten iron, it comes in contact with molten carbon and silicon—which constitute the impurities—and carries them away through the open top of the converter, up through a gaping hole in the roof of the building, up into the outside atmosphere.

Millions of red and white sparks fill the air, as if some demon within the fiery fluid were spitting out his spite in a last cataclysm of terrible rage. A thousand boilers, with safety-valves hissing under tremendous pressure, have the voice of a soothing nightwind in comparison. First the flame that pours out is violet; then it merges bewitchingly into orange, becomes a ghostly and then a dazzling white, and burns finally into a faint blue, which is a sign that all the impurities are gone.

Then the blast ceases, the carbon that is necessary to replace the needed portions burnt out is added, the great brick and steel egg swings back to position, the carbon is mixed with the fervent fluid, and then the egg tips over on its side, and out of its top flows the liquid steel, Bessemer steel now, into a great ladle.

When the converter is swung back again into an upright position, a man with colored glasses, to protect his eyes, walks out over the converter and peers down into its white-hot depths to see if the heat from the last charge has melted away any of the fire-brick lining. If it has, he hurls balls of fire-clay in putty form down into the burned-out holes to stop them up, or sets a crew of workmen to re-lining the damaged places after the converter has cooled.

The whole operation of conversion takes about twenty minutes—a ton of steel a minute. Bessemer steel is used for structural beams and girders, for railroad rails, wire, and pipe.

In 1900 there was twice as much steel produced in the United States by the Bessemer process as by the open-hearth method. But with the rapid exhaustion of ores having the proper amounts of phosphorus for converter practice, the open-hearth process largely replaced the other. The open-hearth system successfully handles ores having any amount of phosphorus in them.

An open-hearth furnace looks a good deal like an ordinary bake-oven; but when you look in through the water-cooled door a vast difference appears. Instead of pans of fat loaves of bread, there is an imposing pool of fiery liquid as bright as the filament of a strong tungsten lamp, so dazzling that it can be looked at with safety only.

through colored glasses. Tinted here and there with streaks of soft blue and dainty pink, it looks for all the world like melted stick-candy.

In preparing a battery of open-hearth furnaces for a charge, finely-ground dolomite is shoveled in first. This melts like glass, and fills up all cracks and crannies caused by the intense heat of the preceding charge. Then a little train rolls up before the battery, and an electric crane dumps box after box of scrap metal from the cars into the furnaces.

Off some distance is a great steel tank lined with fire-brick and full of liquid pig metal. This tank is called a mixer. In it hundreds of tons of the flowing, glowing iron are mixed. It is then drawn off in a giant ladle, like water from a spigot, is carried across to the furnace by an electric crane, and poured into it. Every now and then, as the process goes on, a laborer puts a shovelful of limestone into the mixture.

When the scrap has melted, and the contents of the caldron are cooked enough; when the impurities have been driven off by the limestone and tolled away, the fiery broth is "seasoned," as it were, with the proper amount of carbon, spiegel, ferro-manganese, tungsten, ferro-silicon, vanadium, or whatever is necessary to give the desired quality to the resulting steel.

Then comes the tapping of the furnace. An electric crane lifts a great ladle into position, a workman jams a crowbar through a clay-plugged hole at the base, and out flows the frenzied stream into the ladle. The slag rises to the top and overflows, congealing on the outside of the big dipper. Then the crane picks up the ladle, swings it over to the pouring platform, and a clay plug in the ladle's bottom is also punched out, permitting the purified liquid to run swiftly out into molds. It then becomes steel ingots.

Great care has to be taken in handling these ladles. Should there be a few drops of moisture clinging to the inside of them when the hot metal is poured in, a great explosion may occur and cause horrible burns, if not death, to the workmen. And the "tappers" and others who manipulate the dippers, filling and emptying them of their glowing burdens, must use the utmost skill and caution at all times to prevent an accidental spill. Their job is always one of playing tag with the Grim Reaper of life. Hardly a week goes by that some poor fellow is not caught, touched, and eternally retired.

There are two other important types of steel furnaces—the crucible furnace and the electric furnace.

In a crucible furnace the metal is placed in graphite-clay pots, covers are put on, and the pots subjected to great heat. Silica is gradually absorbed out of the clay in the pots, and is transformed into silicon by coming into contact with the carbon in the steel. The silicon in its turn absorbs the oxygen, which quiets the frothing and foaming contents of the kettle, and they are then ready to be poured into the waiting molds.

The electric furnace operates in much the same way. But its heat is so pure that there is no necessity of putting the steel in covered pots to keep out the gases and other impurities. An electric arc, established between huge electrodes and the surface of the slag, produces the heat in such a furnace. By varying the materials used in the formation of the slag, any impurity can be coaxed off, leaving the glowing steel as pure as crystal. The alloys are mixed in, and the steel is thus made fit for any kind of use intended.

When properly mixed, the molten liquid is poured into ingot molds, where it hardens. It is then ready to be sold to the steel manufacturers of the world, to be worked up into all those numerous and valuable things of commerce and industry that constitute the last word in fine steel.

V

WHERE COPPER IS KING

COPPER is a metal which has been known from the earliest times, and is frequently spoken of in the Bible. We find it stated there that Tubal Cain was the first worker of brass, of which copper is the principal part. Palestine indeed abounded in copper. King David used immense quantities of it in building his famous temple. All sorts of vessels and weapons of copper were made in the temple and tabernacle.

As the ores of copper are usually in beautiful colors, it is not to be wondered at that they attracted early attention. In ancient times, however, it seems that copper was not employed so much by itself as it was as an alloy with other metals, such as silver, zinc and tin. When alloyed with tin it formed what is known as bronze. This compound was very popular for coins, medals and statues, and is still used for tablets and statues to a considerable extent. The famous Statue of Liberty, in New York Harbor, is made of bronze.

In America, the Mound Builders and Indians used native copper in a pure state long before the white man made his appearance, and for a long time they jealously guarded the secret of the location of the lodes from which they obtained their supplies of ore. Wonderful examples of savage copper work, in the shape of spear points, arrowheads and knives, have been unearthed in some localities. These show that the Indians possessed the secret of tempering the reddish metal, a feat that modern metallurgists have in vain tried to equal.

Although copper is found to-day in many parts of the earth, being one of the most generally distributed metals, the United States produces well over half of the world's supply. The region around Butte, Montana, is exceedingly rich in the mineral and the southern half of Arizona is now literally sprinkled with phosphorous copper mines. The Calumet and Hecla mines, formerly the most bountiful in the country, have now been surpassed and Michigan has dropped to third place among the copper-producing states.

The free metal is not often found in large quantities, though a specimen weighing 2,020 pounds was found in Brazil. The Academy of Sciences at Petrograd has on exhibition an enormous nugget of copper which was found in Kamtschatka, and there is another specimen in Canada which measures fifteen feet around.

It may seem strange to you to learn that so hard a substance as copper is soluble in water. But it is so. The water flowing from copper mines always contains copper in a dissolved state. This was first noticed when the celebrated copper spring at Wicklow County, Ireland, was discovered, about the middle of the eighteenth century. The discovery was due to a miner who, having left an iron shovel in the water of the mine, found it later heavily coated with copper. This principle has since furnished miners with a simple test when prospecting. A drop of nitric acid is placed upon the specimen to be tested and allowed to remain a few minutes, whereupon the blade of a knife is drawn across the spot where the acid was applied. If the specimen contains copper, a plainly visible amount will be found clinging to the blade when the knife is raised.

Copper is largely employed in the arts as a sheeting for the bottoms and trimmings of ships, for all kinds of utensils subjected to dampness (copper will not rust); for telephone, telegraph and electric wires; for tubing and many other articles too numerous to mention. Alloyed with zinc it forms brass; alloyed with tin it produces gun-metal, bronze, bell-metal and speculum-metal. It is used in gold quartz mills in the form of a plate amalgamated with mercury, to hold the particles of gold as they pass over it.

Oxide of copper is employed in glass factories to give those pretty red and green colors to the ware which you have admired. As a sulphate, copper yields the well-known blue vitriol, which is used largely by the dyer and calico printer and in the making of galvanic batteries. Lastly, copper perhaps is more familiar to us all in its use in the mints of all civilized countries for coining the smaller forms of legal tender—with us, the cent; with Great Britain, the penny; and for similar small coins in other countries.

But we can get a better idea of the value and importance of copper if we take a trip of inspection to one of the world's most famous copper mines, the Calumet and Hecla mine in the Upper Peninsula of Michigan.

In every direction you will see, towering above the surrounding buildings, tall, elevator-like structures, from one side of each of which may be seen a great incline running down into the mine near it. On the other side of these buildings, or tipples, are high frames supporting a series of wheels, through which run long cables. These extend across the street into an engine-house. Here power is furnished for pulling up and paying back the little cars, called "skips," in which rock is brought to the surface. Another form of car, termed a "cage," is used for transporting the miners up and down the shaft.

INSPECTING A VEIN OF COPPER ORE

If you visit the interior of one of the mines, you would find Shaft No. 5 a most interesting one to enter. This is on the conglomerate lode, is one of the richest mine entrances, and has the great depth of 8,100 feet—almost two miles! That is going down into the earth a considerable distance, especially if it is your first time down. In fact, there is only one mine deeper, and that is the Tamarack, which is not far distant. The Tamarack has a depth of 9,000 feet.

Shaft No. 5 runs down at an angle of about 37 degrees, following the incline of the copper vein clear along. The cage which carries the men is a box-like car with seats rising one above the other, similar to stair steps, or much like seats in a theater. If the seats did not set at a strong pitch in this fashion, the men would slide off in going up and down. On each side of the car is a strong railing, and a powerful headlight at the end. Beneath are wheels running upon the track of the incline. A strong wire cable is attached to the car, and as the engine above drives this cable around a drum, like an endless belt, the cage must go with it. When he wishes to stop, the operator in the cage lets go of the cable with his clutch, and applies the brakes.

As you glide swiftly down into the dark maw of the earth, a damp, cool breeze strikes your face. The headlight casts flickering, will-o'-the-wisp shadows along the walls. Big timbers rush suddenly out at you from in front, and instinctively you dodge; but by that time they have whisked by you and new ones are appearing. These are the sturdy props, set in the shaft by man, to keep the walls of the tunnel from caving in.

As you go deeper the air grows cooler, and the size of the timbers increases. Most of them are now more than two feet in diameter, and if you were not going so fast you would see, probably with a quaking heart, that some of them are bent from the enormous pressure of rock above. Indeed, your headlight does illuminate one old-timer long enough for you to note that it is badly splintered. Your companions look at it casually, and calmly remark that before another twenty-four hours the "proppers" will probably have it replaced. Devoutly you pray that it doesn't give away until you repass on your outward trip, at least!

It is not long before the pressure of air on your ears becomes uncomfortable. Soon it is so terrific that your ears begin to ache.

The miner next to you notes your trouble, with a sympathetic grin. "Ears kickin' up a fuss, eh?" he roars out so that you can hear him above the din and racket of pounding cage wheels on the clattering track. "Jest open yer mouth, sonny, an' give a good swaller. That'll cure it, sure!"

You take this advice, and to your surprise and delight the pain disappears.

As the cage bowls along you observe every little way a sort of landing, where the shaft is wider, and where a beacon light dimly burns in a fight with the blackness all about. These are called "levels." They are the stations from which miners have been landed and taken on when they worked in the vicinity, also from which the copper ore they have loosened has been loaded for its trip up to the world of sunlight.

At the Forty-ninth Level is a pump, used for keeping the mine free of water. You have a good chance to look about you here, because the cage stops for a few moments to let off some of your companions. Before you go on you note that you are feeling much warmer. A look at the thermometer surprises you. It shows 94 degrees—good, strong summer heat! You are told that this is due to the efficient working of the ventilating machinery of the mine, and not to the fact that you are getting closer all the time to the boiling fires of the earth's center, and you heave a sigh of relief at the explanation.

Really the truth of the assertion is soon afterward made manifest; for as the cage drops on down and reaches the Seventy-fourth Level, you find the temperature 75 degrees. This is just a little too cool to be thoroughly comfortable, but you are advised the ventilators cannot entirely overcome the cold air here owing to the near presence of considerable water. Everything is wet and slimy.

At the Eightieth Level your car stops and your guide steps off with you. The walls and footing are comparatively dry, and you are given an excellent opportunity for observing the method of mining. Here in the "drifts," or transverse tunnels, lie tracks connecting with the shaft tracks, and on them the tram-cars run forward with their loads of ore as fast as they are loaded. The propping is of the very stoutest character. Not only are the timbers large and tough, but they are planted closer together than in the levels higher up, so that greater resistance can be maintained against the greater weight of earthen matter, whose pressure is something tremendous. Three months is the limit of life for these huge props. Then they must be renewed.

From the drift the "stopeing" is done. This consists in taking out the rock in 80-foot sections between levels. For instance, the miners in the Eightieth Level work upward toward the Seventy-ninth Level, allowing the ore to fall back to the Eightieth to be loaded into the tram cars, hauled by a small pneumatic locomotive to the shaft, dumped there into the first empty skip, and sent to the surface. When the work is done there will be but one big hole from the Eightieth to the Seventy-ninth Level, and so on down until, when the entire vein has been worked out, there will be just one great cellar under the shell of the earth, supported here and there by pillars of rock and wood.

The work of loosening the copper ore is done in much the same manner as in coal mining. That is, automatic drills, looking a lot like gatling guns, are used in making holes in the rock around the ore-bearing sections. At the end of his shift the miner inserts sticks of dynamite in these holes, and when the men have all gone out of harm's way, the charges are exploded by electricity. There is a terrific din, which will cause your ears to ring for hours afterward, as the shots go off, one following closely upon the heels of another, and the rock goes tumbling down in a great sloughing pile.

In the next shift, the trammers clean up this loose rock and send it to the shaft. As the skip load of ore goes up to the surface, it runs straight into the tipple at the mine mouth. With the exception of the large pieces of rock, it is dumped automatically into a bin, below which stand the ore cars. The large chunks are carried into the crusher, where heavy steel rollers squeeze them into many small fragments, as you might crush a lump of baked mud in your mother's clotheswringer. The pieces then fall through the bin, which has a swinging bottom, as fast as cars appear below to receive them.

The ore is then brought to a stamp mill, where the crushing process is carried much further. Gradually powerful little trip-hammers break up the pieces. Each time they are projected onto a screen of diminishing sized mesh, until all the rock is as fine as ordinary sand.

Then comes the separation work. Remember that it is not the ordinary rock itself which is wanted, but the smallest part of it—the pure copper ore. Up to this point it has been necessary to dig, handle and convey a dozen pounds of common, worthless rock, in order to secure the pound of pure copper that it contained. Now the wheat is to be separated from its chaff, as it were.

At first it might strike you as a very simple, even crude, method for so big an undertaking. But it is efficient, nevertheless; and simplicity is always desirable where good results are not lost by its adoption. Specific gravity is the agency used in this case. Since, as with gold, the free copper is considerably heavier than the rock in which it is found, the valuable metallic sand will fall to the bottom, when cast in flowing water, and the rock sand go drifting onward. This process of settling is further assisted by shooting a powerful jet of water up into the air. The mixed sands fall down into this jet; the rock waste is carried away by the supporting spray; while the copper sands, for the most part, descend straight. A light rubber ball dancing at the apex of a fountain jet—a spectacle most people have seen—is a good illustration of the rock sand part of this action.

But this does not take out all of the copper particles. So the separation process is continued. At last the sand reaches a sort of large table having a distinct slope to it. Thin strips of wood run up and down this, to keep in the water and sand which flow over the table while it shakes back and forth very gently and regularly. Whatever copper grains are in the mixture settle in the troughs, while the rock sands are carried over with the rush of water.

Smelting is the last step in preparing the ore for the market. It is put into a furnace and melted, whereupon the foreign substances rise to the surface in a kind of scum, and are scooped off. Oxygen is then blown into the molten mass to drive out the remaining impurities, but the oxygen itself must be gotten rid of. This is done by inserting a stick of wood down into the molten copper. The oxygen promptly burns itself up, and the copper is then drawn off in a pure state and poured into molds for ingots.

It was in the early days of this famous copper region that the great conglomerate vein now owned by the Calumet and Hecla interests was uncovered. In those days the finding by hunters and woodsmen of old copper pits dug by the ancient miners was of frequent occurrence. But nobody knew that these had been opened up for the purpose of obtaining copper. Nobody knew that there was such a thing anywhere around as copper. The secret had died with the ancient miners.

The story goes that one day a man out hunting wild hogs, which were very plentiful then, routed out a big bristly fellow which made fast time through the timber, somehow managing to evade the two shots the hunter sent after him. But a hog is too short-legged and heavy-bodied to run very fast, and the hunter kept this one in sight till he vanished into one of the strange pits which marked the neighborhood.

This was surely a huge mistake on the part of Mr. Piggy, so far as his welfare was considered. But for the welfare of the world at large it was one of the most fortunate things that ever happened. When the hunter came to the brink of the hollow, the animal was frantically trying to scramble up the farther side, making the dirt fly with his sharp-pointed little hoofs. He presented a capital mark during his slow headway. Having rammed home another charge in his gun, the man took careful aim and this time brought the hog to earth.

As he came up to get his trophy, the hunter noticed something bright shining on the ground where the animal's hoofs had scraped off the thin, overlying earthy deposits. Looking closer, he found several other salmon-colored pieces of rock like the first. He did not know copper when he saw it, but was sufficiently interested in the luster of the pretty bits of rock to chip off some pieces with his hunting-axe, and later on showed them to a friend who was better posted in geology than himself. This friend, greatly excited, told him that the bits of rock contained superb specimens of copper, and wished to be led to the old pit. There more investigation showed the rocky ground to be fairly studded with ore containing the rich, pure copper. The vein thus uncovered by an accident was the so-called conglomerate vein which has been such a bonanza to the Calumet and Hecla company ever since.

When, in bygone ages, the rock of this section had become molten, so intense was the heat from below that such materials as gravel, sand and rock, had been mixed with the pure molten copper until all became a batter-like mass which cooled in the form of a gigantic wedge or layer known to geologists and miners as a "conglomerate" vein.

From the surface this vein runs at a strong angle down into the crust of the earth, as a far-leaning post might do. Just how deep it goes nobody knows, and probably never will know. Shafts have followed it, however, very nearly two miles down, and still the rich ore is there in large quantities.

The Calumet and Hecla Mining Company was organized fifty years ago, and began work on two separate mines along the conglomerate vein. One of these was called the Calumet; the other, the Hecla. Each mine consisted of numerous shafts, so extensive was the layer. Later, as the result of further exploration in the surrounding country, other mines were opened up by the organization. These were the Ahmeek, the Allouez, the Tamarack, the Centennial, the Isle Royale, the Superior, the Laurium, and the La Salle. A few years ago the Osceola mine, which had belonged to another copper company, was also taken over.

During all these years many another mine, too, has been opened up by the C. and H. people, only to be abandoned because copper was not found in paying quantities after diamond drill had uncovered deceiving amounts of the ore. So there have been some "downs" sprinkled in with the "ups," which Dame Fortune has handed out to this big mining corporation, but the "downs" have been of such small dimensions as compared with the tape-busting "ups," that the business has been a huge success from the very first. To the two big conglomerate mines, the Calumet and the Hecla, is due the chief credit for this success.

But it is not the mere taking out of the copper-bearing rock in which the Calumet and Hecla company is interested. It practically owns the two large counties, Houghton and Keweenaw, where its mines are situated. And the township of Calumet is really its own property, every inch, except for one or two small lots. Houses, stores, churches, schools and other buildings, are erected in this township only because the C. and H. company says they may be.

The taxes on this real estate are paid by the mining concern. It furnishes water, electric light, fire protection, police protection, and all other public conveniences, to all the various villages of the township. The company has built churches, schools, libraries, theaters, hospitals, and other public edifices.

Nor have amusements been forgotten. Excellent baseball grounds and grandstands may be found. Here play teams representing various departments of the big copper industry, all of which belong to a league. In the winter months a hockey league is maintained in the same way, and skiing courses are laid out and kept in the pink of condition. A brass band, famous wherever it is heard, is another gift of the H. and C. people to their employes.

There is still another secret of this company's success, one which touches the employe even more directly. When you think of a mining camp your mind instinctively pictures a bunk-house and the narrow streets and dirty, shambling buildings of the mining settlements of the coal fields. In the copper country you never see such unsightly shacks. Instead you behold row upon row of neat frame houses, each with its own lot of 60-feet frontage, everything neat and orderly. These houses are rented to employes at a low rate, the rental including sewage system, free water and free garbage collection. Coal is sold to the tenant at cost price. Each back yard is large enough for a pretty little vegetable garden, and seldom will you find a home, as you pass along, which does not raise enough vegetables to supply the family table throughout the season with fresh, wholesome foods.

This company has produced close to $400,000,000 worth of copper since its organization, and paid dividends of more than $125,000,000 on its early $25 shares. And this is only one of several sections in America where copper is king.

VI

THE WONDERS OF GOLD

GOLD has long been esteemed as the most precious of metals. From the earliest period of the world's history it has been used by man as his chief medium of exchange—for buying and selling; also for personal adornment in the way of jewelry. Although the quantity of gold found, compared with other metals, is very small, yet gold leads them all for being well scattered over the universe. It is found in nearly all hilly and mountainous countries.

In its pure state gold has a deep yellow color and a high metallic lustre. It is nearly as soft as lead, and can be easily beaten out cold into sheets so thin that you can see light through them. And it can be drawn out so fine that a mere grain will make 500 feet of wire, wire as dainty as the finest spider's gauze. If you were to put it in a fire you would be astonished to find that, although so soft a metal, it will take 2,016 degrees Fahrenheit to melt it. While most of the common acids will eat into such hard metals as iron and steel, they have no effect whatever on gold. But chlorine and nitro-muriatic acid will corrode and dissolve it, forming what is called chloride of gold, which is very soft and putty-like and can be dissolved in ordinary water.

Did you ever suspect that your ring was not solid gold? That your stickpin, your watchcase, that five-dollar goldpiece in your purse, were not the simon-pure, sure-enough yellow metal? That nobody, prince or pauper, wears jewelry made of gold and nothing else?

There is a very good reason why it should not be pure. Generally speaking, all manufactured articles of so-called gold, whether money or jewelry, are alloyed; that is, other metals are mixed in with the gold. This is no humbug on the buyers and users; it is a good thing and perfectly lawful, provided the quantity of pure gold in each piece of jewelry is plainly marked upon it so that you know what you are getting.

You see, gold in itself is altogether too soft a metal to stand the constant handling given coins, and the wear coming upon jewelry. Very soon the outlines and engravings would be obliterated, and all form, beauty, and character, lost. In the case of money it would even give rogues a good chance to scrape gold off of coins, or "sweat" it off with acids, and still be able to dispose of them at face value.

So the mints and goldsmiths put harder metals with gold in order to make money and jewelry wear longer. Copper and silver are the alloys commonly used. These blend nicely with the lustre of the gold, and if used sparingly do not change it materially while giving it much longer life. The goldpieces of the United States contain about eleven parts gold to one of copper. Jewelry is marked by "carats" (K), a carat being an old-time weight equal to 1-24th of a troy ounce. Pure gold is spoken of as being "twenty-four carats fine"; therefore, if you have a ring marked "14 K" you know that fourteen parts of it are gold, and ten parts alloy. Jewelry of a light yellow color denotes silver alloy, which is the most durable. If the yellow is quite deep you may confidently believe that copper has been used.

Not only is gold extensively employed in coinage and ornaments of dress, as well as plate, but we find it widely used in the arts for gilding and plating, as it imparts to materials often the most worthless the semblance of its own unrivaled richness and splendor.

Just when or where gold was first discovered and made use of will probably never be known, but we do know that it was familiar in the time of King Solomon, who used it lavishly in his temple; and even before this, when the Lord requested Moses to employ it generously in constructing the famous ark of the covenant. "And thou shalt overlay it with pure gold, within and without shalt thou overlay it, and shalt make upon it a crown of gold round about. And thou shalt cast four rings of gold for it, and put them in the four corners thereof; and two rings shall be in the one side of it, and two rings in the other side of it."

There is an old account of a province visited by De Soto in his expedition of 1538-40, which was located in the section now known as North Carolina. At the time of the Spanish invasion the country was ruled by a beautiful Indian queen called Xualla. Here De Soto found trinkets and ornaments of gold, and tomahawks formed from an alloy of gold and copper, and his adventurers were wild with the thought that a great gold lode itself must be near. But they searched in vain, and finally went away disappointed. The Indians kept their secret. The white men did not know that less than fifteen miles from them, on the Carolina side of the Savannah River, lay one of the richest gold deposits in the world. In 1820, however, Americans found this and began to mine it. Within ten years the annual output was close to half a million dollars. At Charlotte a United States mint was established, to coin the gold conveniently.

IN AN AFRICAN GOLD MINE—HALF A MILE DEEP

Closely following this, gold mining was opened up in Virginia, then in Georgia, Alabama and Tennessee. Georgia has been the greatest producer of any of the Southern States. These mines supplied most of the gold in the United States up to the time of the great discovery of the yellow metal in California, in 1849. The credit for this discovery goes to James W. Marshall, who "struck it" rich enough to excite himself into widely publishing the news, causing a grand stampede of adventurers into the State from all quarters of the country.

But there were really others who first found gold in California. Its existence was known to both Indians and Mexicans long before Marshall could lisp his own name. According to Spanish records and maps, gold had been taken out of Arizona and California by Spanish-Mexican miners as early as 1748, a good hundred years before the "discovery" in California. But it is safe to believe that the native red men had used the metal before this. Shortly after the organization of the Catholic missions in Lower California, the Indians who were sent into the upper country to persuade other natives to submit to the guardianship of the priests spoke of the "shining sands" in the streams which they crossed in their journey. Some even returned wearing crudely beaten bracelets made of the rich yellow material. However, the whites they met suffered the "shining sands" to remain where nature had placed them, because the priests declared the search for gold to be evil in the sight of God.

As we have said, a man by the name of James Marshall was the first to awaken wide interest in the gold in California. Marshall was engaged by one Captain Sutter to build a sawmill at Coloma, on the American River. Marshall hired Peter L. Wimmer and his wife, Elizabeth Jane, to go with him, to assist in the work. They arrived at their wild destination in the year 1847, and at once proceeded to erect a little shack in which to live. As soon as this was done the men, with ten Indians who had accompanied them, began to put up the sawmill.

The work progressed slowly, as the Indians were poor carpenters. But during the month of December, the dam and headgate had been completed. Water was turned on at night, so as to wash out the sand and gravel which had been dug up by the men during the day. Every morning Marshall inspected the millrace, to see how well the washing had cleaned it out. On these occasions he often noticed tiny shining specks in the bottom, but being unfamiliar with the appearance of gold, paid no heed to them.

On the morning of the 19th of January, 1848, both Marshall and Wimmer were walking leisurely along the tailrace of the mill, when all at once the former stooped over and picked up a bit of glinting substance that lay on a flat rock in the now dry bed of the race. Over and over he turned the object in his hands. The more he inspected it the more he was struck with its close resemblance in outline to the "bear" which had adorned the State flag he had lately helped to raise as an emblem of California's independence. While he admired the deep lustre of the specimen, he would never have picked it up except for this remarkable resemblance it bore to that "bear."

Handing it to Wimmer, he said, "What do you think of that, Pete?"

Peter took it, juggled it a moment, squinted closely at it, then exclaimed, "Jim, I'll bet a cooky that's a chunk of solid gold. I'd gladly let you pay me off in that metal!"

Jennie Wimmer, the housekeeper, had prepared to make a kettle of soft soap that day. The two men had fixed her kettle of lye over the fire before they left the cabin.

Now Marshall spoke up. "Pete," said he, "we will send this lump to Jennie, and let her boil it in her soap-kettle all day. If it doesn't tarnish it must surely be gold."

Wimmer then called his young son, and the boy started home with the message and the shining thing clutched in his fist. On the way he saw a saucy squirrel. Before he thought he had made a missile of his possession, but though he missed his mark he very luckily struck the trunk of the tree to which the squirrel had been clinging, and was able to find it again. Afraid to risk another shot, he went on to his mother with the yellow "stone."

No inquiry was made about the specimen until the next morning at breakfast. Then the men began to joke Mrs. Wimmer about it. What kind of soap had the "bear" made? Would it do away with the necessity of grease in soap-making? If so, there was plenty more of the stuff out there in the sand and gravel!

Even Jennie had forgotten the lump in her kettle for the moment. She now went to it, poured the soft-soap into a hewed trough made to receive it, and at the bottom found the lump—a beautiful, lustrous thing, polished bright by the action of the lye. Quickly she returned to the cabin with it, throwing it on the table before the two men. "There is your nugget!" she cried. "I knew it was pure gold the moment I saw it. Now you can see it for yourself!"

Other small nuggets were collected by Marshall and Wimmer. Four or five days later, the former took them to Fort Sutter, where he was called to report progress to Captain Sutter himself. Here convincing tests of the nuggets were made with nitric acid, and Captain Sutter accompanied him back to the mill on his return. Everybody was greatly excited. Marshall gave his first nugget to Mrs. Wimmer, saying that she could have it to make a ring. Instead of completing the sawmill, every one went to gathering in the precious gold. Yellow grains of rock were to be preferred many times over to yellow grains of wood. Let sawdust take care of itself! But a little later the mill was finished and sawed the lumber to make cabins and "rockers."

Today none of that little group who were first in the field are alive. James W. Marshall died in 1885, alone, in his cabin at Kelsey's Diggings, Eldorado County, with not enough money to pay his funeral expenses. Like the others of his little company he had found much gold, but he could not keep it.

News of the finding of large quantities of gold in the Coloma district spread abroad like wildfire. In nearly every city and town of the North and South, and even the East, men left their work and hied excitedly westward in groups or singly. By the spring of 1849 more than thirty thousand brave, adventurous fellows had gathered at Independence, Missouri; Leavenworth, Kansas; St. Joseph, Missouri; and Council Bluffs, Iowa, ready to face the dangers and trials of the long trip across the plains and mountains, where lurked the fiercest of wild animals and the most treacherous of Indians. In long caravans of canvas-canopied wagons they moved, many with their wives and children. Finally they arrived—but numbers were missing, pathetic mounds of earth all along the weary trail marking the last resting-places of women, children and men.

The quartz rock which contains the gold is found in narrow veins which fill up what were once open cracks in the older rocks. This quartz vein is so much harder than the other rocks that the wind and the rain and the frost cannot eat or break it away. As the soft rocks on each side of it are worn away the gold quartz is robbed of support; it falls down, and is left in lumps on the hillside. When the winter and spring floods come the pieces of quartz are carried down by the rushing waters into the bed of the nearest mountain stream. There the current knocks them against coarser rocks and boulders until they are smashed to atoms. The small, heavy particles of gold drop to the bottom, and the rest of the rock bits, being lighter, are carried away to some large river.

A great many grains of gold, however, take another course. These cling to the ground and are not carried into streams by the rains and floods, for the very good reason that they lodge in crevices of rocky slopes which protect them until loose gravel, sand and earth, are plastered over them by the settling waters. As the years go by the accumulation of dirt on top of them increases, and they become well buried.

You will see by this that the streams offer a chance to get gold with the least exertion, as it is already exposed, or at least very nearly so. It is for this reason that the miners who first rushed into the California gold fields sought out likely streams and looked for what they wanted in the gravel and sand of their beds. This type of mining, which had no real digging to it, they called "placer mining." Each miner had a pan of tin or iron which he filled about half-full of the gravel, or "pay dirt," as he called it. Then holding it under water, he shook off the stones and mud over the side of the pan, leaving grains of gold mixed with black sand at the bottom. This black sand was iron pyrite. By skilfully dipping the pan under the water, and giving it a whirling motion, and a tilt now and then, practically all of the black sand was coaxed over the edge of the pan, leaving small particles of free gold in the bottom.

You might find it interesting to try out this method of placer mining in a make-believe way, then you will have a very vivid idea of just how the miner does it. In a dish-pan put some coarse sand, some gravel, a little clay or mud, and a handful of shot varying from the finest bird shot to BB. Hold the pan in both hands under a running faucet and manipulate it constantly with a whirling and tipping motion in the manner previously described. The aim is to get all the soil matter out of the pan without losing any of the shot. The quicker you can do this the better "gold miner" you are.

Any earth which yields ten cents worth of gold to the pan is known as "pay dirt." Fifteen cents to the pan is good. Twenty cents to the pan is rich. About forty panfuls can be washed out by one man in a day.

Another contrivance which soon came into use in the California gold fields was the "cradle." This was a long box, sometimes only a hollowed-out log. At the top was a sieve which sifted out the stones. Nailed to the bottom were small cleats of wood, or "riffles," which kept the water from running so fast as to sweep the gold out of the cradle with it.

This device was placed on rockers, and was also tilted slightly. The miner shoveled the gravel into the top of the cradle, and his partner rocked it. The sieve held back the stones, the water broke up the lumps of earth and gravel, washed them down the cradle, the grains of gold were stopped by the riffles, and sank to the bottom.

Placer mining is the simplest of all processes for getting gold out of the ground, but it can only be operated on a paying basis where a supply of water can be had for the sluicing purposes. Even then the profits as a rule are not very large. The early miners were not long in recognizing this fact. At first they thought only of getting the free gold, or that which lay in the sand and gravel, but after awhile they got to thinking that that gold dust must have come from some place where there was probably much more of it, and they began to trace it. Thus they followed up the streams into the mountains. As they went they made many important discoveries. They found that this gold had come from beds where in ancient times rivers had flowed. There was gold still remaining in these beds, but it was covered quite deeply with layers of gravel, sand, and soil, leaves and moss, making a good deal of digging necessary.

The men used to placer mining soon began to frown. The digging was very hard. Worse still they often spent days and weeks making a pit, only to find less than ten cents' worth of gold in it. Some of the greenhorns found what they thought were wonderful nuggets, but older miners laughed heartily when they brought the specimens to them, and said they had discovered pyrite, or "fool's gold."

Finally some miner, tiring of digging, thought that if a powerful stream of water could be directed against the great banks of earth, the layers of soil could soon be washed away on a wholesale plan, the muddy flood diverted into sluices, and the gold easily separated and saved. This was done. Great reservoirs were built high up in the mountains, and water was brought down by means of ditches, pipes or flumes, to the scene of mining operations. The ditches and flumes poured the waters directly out upon the banks, like a stream; but the pipes had a large hose fastened to them, such as a fireman uses, with a nozzle at the other end, from which a swirling, gushing stream could be thrown anywhere within reach by the miner handling the hose. This is called "hydraulic mining," and usually brings far better returns than placer mining.

After a few years large companies had been organized for mining gold in California on a systematic basis. These men employed skilled geologists and mining engineers to help them, and bought the best equipment they could get for working. They determined to sink deep holes or shafts down into the hillsides, wherever tests showed a good gold vein existed, and from each shaft run off horizontal tunnels or levels, so that the gold in the white quartz rock could be reached with pick and shovel. The placer miners laughed at them, and called their shafts "coyote holes"; but in time the placers failed, and then that class of men changed their tune, especially when they saw the great quantities of gold that were being taken out of the regular mines. Today practically all gold comes from the white quartz veins of this sort of mine, and is garnered a good deal the same way as coal and copper.

A vein of gold is the most uncertain thing in the world. You may find it quite thick where you first strike it, then as you begin to go down into it, it may run thinner and thinner until it is a mere thread, and finally plays out entirely. On the other hand it may be very thin where first uncovered, and then surprise you by growing wider and richer as you follow it down. Often in a comparatively narrow streak, great bulges or swellings—called "lodes"—will occur here and there, like balls on a spindling chair leg. Such lodes are pockets of the finest treasure, and every miner dreams of the moment he may run into one as he laboriously picks away.

As a rule all gold mines produce paying amounts of silver also. The silver is found in the quartz occasionally, and of course is always saved.

When the broken rock of the gold mine is raised to the mouth of the shaft, it is sent in cars to a stamping mill. Here the ore is fed into a great steel box called a "mortar." Immense hammers, often weighing a thousand pounds each, drop down upon the ore, one after another, until it is fine enough to go through a wire screen in the front of the mortar. You may well imagine that when several hundred of these hammers—as happens in large mills—are pounding away with all their might, a stamping mill is a pretty noisy place.

The ore, crushed to a fine powder, now runs over sloping tables covered with copper. Sticking to the top of the table is a film of quicksilver. This holds fast all the gold grains, and unites them in a mass, which is scraped off from time to time. Later the golden plaster is subjected to enough heat to drive the quicksilver from it.

Another method of separating the rock from the pure gold is by the cyanide process. Cyanide is mixed with water to form a strong solution, and into this the crushed gold ore is thrown. The cyanide element in the water causes the gold to dissolve and the false rock to sink to the bottom. The water with the liquid gold is then run into boxes filled with zinc shavings. The gold particles cling to the shavings like a burr to a dog's tail, giving them a sort of gold plate. The shavings are finally placed in a furnace, which causes the zinc to melt first and run off, leaving the gold free.

When news of the discovery of gold in California reached Australia, it was not believed at first, but when a vessel arrived at Sydney from those gold fields, with 1,200 ounces of gold on board, the whole island went wild. In July, 1849, a British barque sailed from Australia with 168 passengers, of whom was one E. H. Hargraves, a keen observer of rocks and soils. As soon as this ship arrived at San Francisco, all hands except the crew made for the gold fields. Mr. Hargraves had not been working long before he noticed that the geological structure was very much like that of New South Wales, where he had passed more than eighteen years. He told his companions he believed there might be gold in Australia, too. He was laughed at, but he did not give up his idea.

In January, 1851, he landed back in Sydney, bent upon testing out his faith. A month later he set out on horseback for the point where he intended to make his first explorations. Finally he stopped at a wayside hotel which was operated by a Mrs. Lister. She was a refined, bright woman, driven into the occupation by misfortune. Mr. Hargraves asked her if she knew where he could get a guide, and told her of his enterprise. She was quite enthusiastic with the plan, and promised to send her young son with him as guide, saying the latter knew the country thereabouts like a book.

Fifteen miles from Guyong, Mr. Hargraves washed his first pan of dirt. Sure enough, he found gold—more than he had in California! He was greatly excited. He tried a second pan. More gold yet! His excitement grew. A third pan—what would *that* bring? The third pan was washed. In the bottom were many glittering particles of yellow. The gentleman turned to his young companion, and cried: "Lad, this is a remarkable day in the history of New South Wales. I shall be a baronet, you shall be knighted, and my old horse there shall be stuffed, put in a glass case and sent to the British Museum!"

It turned out in part that way. While the horse was never stuffed, nor the boy guide knighted, Mr. Hargraves himself was knighted, and given a pension for life.

With his discovery the California gold fever waned and transferred its great heat into Australia, where in a short time every miner with sufficient money to pay his passage was headed. There were not nearly enough ships to carry them. And they came from all countries. One year later, 105,000 miners were encamped at three gold centers: Ballarat, Bendigo, and Castlemaine. In five short years Melbourne rose from a town to be the foremost city in the Southern Hemisphere. Reports of panning $100 to $200 per day, and of finding nuggets worth thousands of dollars, upset even the most sober-minded. Farms, shops, ships, were deserted. It was shearing time, but there were no shearers; it looked as if when harvest time came there would be no one to gather in the crops.

In Queensland, in 1886, the famous Mount Morgan mine was opened. This wonderful mine proved to be literally a mountain sandwiched with gold. At once it began paying dividends of $2,000,000 a year, and to-day it is still producing that much in gold, but added to this immense profit is another one now derived from great deposits of copper which have been unearthed by the company in the same mine.

But in all the history of gold excitements, the Klondike craze, awakened in the year 1896 in Alaska, is probably without a peer. For years the great movement kept up, and Alaska was opened to the outside world. Like most great booms, however, it was short-lived. Now the gold mined in the Klondike region is a negligible quantity.

In Alaska the greatest difficulty in mining is the cold. Not only do the miners have to be bundled in heavy furs, but the ground is frozen so hard the year around that they cannot scoop up gravel, or make a hole down into it, until it is first thawed out by building fires upon it or by using pipes filled with scalding steam. The steam is projected through a sharp nozzle which is driven gradually down into the softening ground.

The hills and mountains of Alaska contain untold and undreamed of wealth. But for the extreme weather conditions, it is quite probable that we should have long ago opened up these vast treasure chests of valuable ores and exposed them to the wonder of other nations. One of these days either science or the mere physical bravado of Americans will do the trick. It is bound to be performed.

When several grains of gold gather together in a mass they form what miners call a "nugget." Nuggets are the great prizes for which the average miner works and looks forward to finding. The largest one known was found in Australia, at Ballarat, in 1858. It weighed 2,159 ounces, and was sold for $42,000. A boy could not carry such a lump of gold without a cart or wheelbarrow. When found this nugget was 190 feet deep, in the white quartz of the earth, was irregular in shape, and much honeycombed by the action of water.

Although America has produced no record-breaking nuggets, she has, nevertheless, given up some that were very close rivals of those found in Australia. A prospector named Martin found one in Arizona weighing 151 pounds. The discovery came about in a queer way. Martin and a comrade were encamped in a canyon, when a cloudburst caused the stream to rise so rapidly that they were caught. The comrade was drowned, but Martin escaped, though severely injured. After the torrent had subsided he returned to bury his friend, whose body he found lodged under the roots of a tree. In dislodging the body he saw beside it the huge nugget. It surely seemed that Providence had rewarded him for his faithfulness to this friend.

Twenty-eight States and dependencies of this country produce an output of gold. In 1918 this totaled 3,320,748 fine ounces, with a value of $68,646,700.

The Rand mines of South Africa, owned and controlled by the British government, have proved the greatest gold "find" of history. In 1918 they produced over half of the gold mined in the world. The mines are being worked conservatively, with no attempt to get as much as possible in the shortest time and thus flood the world's gold market.

VII

THE STORY OF SILVER

IN Nevada there is a famous silver mine called the "Comstock." Strange as it may seem, Mr. Comstock, for whom the mine was named, was not the discoverer. Nor was this world-renowned silver mine a silver mine at all in the beginning of its fame, but a gold mine of great promise and large output.

Ten years after the discovery of gold in California, the placers in that country began to become exhausted, and miners began to look elsewhere for the precious yellow metal. Among these roamers were two Irishmen, Peter O'Riley and Pat McLaughlin. The restless pair finally drifted into what is now the State of Nevada. Here one day a hunter told them that he had seen some gold taken out at the foot of Mount Davidson, and they made haste to that locality. But while they found gold, there was a discouraging scarcity of it for some time. Finally they decided to sink a hole for water. When four feet down their picks struck a strange, black-looking dirt, a sort of decomposed ore.

At first the peculiar earth was given no more than a curious inspection by both miners, but after a while McLaughlin determined to test it in a crude fashion. Therefore he put some of the dirt in his rocker and washed it out. The result was astounding. The bottom of the rocker was literally covered with pure gold. In a few minutes the two Irishmen were working feverishly in the black dirt, as if they had gone daft, and were taking out gold at the rate of $500 a day.

About this time a miner named Comstock came upon the scene, and claimed the ground as his by right of previous discovery. There was really some foundation for his claim, as he had actually visited the locality before the Irishmen, and had staked out a claim. When O'Riley and McLaughlin became convinced of the truth of Comstock's story, they offered to take him in as a partner, but would concede no more. To this Comstock agreed, when he learned that the others were willing that the property should be named after him.

As the gold lode was sunk deeper and deeper it began to thin out, so that it no longer yielded one-third yellow metal, and its fame began to tarnish. But it was only a momentary setback. With the thinning of the gold-bearing strata, a rich silver vein was struck, which soon developed into many other equally rich veins of almost pure horn silver. In a short time the Comstock mine was more famous than ever, but now as a silver mine instead of a gold mine.

Only one mine on earth ever surpassed the Comstock in its output of silver. This was the lode known as the "Veta Grand," near the city of Zacatecas, in Mexico. The Veta Grand mine is also one of the oldest in North America, having been in operation before the days of Cortez. This mine has turned out about a billion dollars' worth of metal, while the Comstock has equalled half that amount, with $100,000,000 in gold added.

The processes by which nature forms deposits of silver ought to be almost as interesting to the ordinary reader as to the prospector himself. The earth's crust, of course, is lavishly veined with watercourses. This water runs, trickles, and seeps, everywhere through the rocks beneath our feet. As it goes it rubs off or wears away billions of tiny particles of earth and rock along its path, thus forming certain chemical solutions which have in them a portion of the precious metal itself, grains of which have been gathered here and there after the terrific heat and gases below have projected them upward through fissures and have crystallized them at the surface.

These countless underground streams, flowing hither and thither, through this crevice and pocket, and into that fissure and seam, always are leaving behind them some of their sediment.

Slowly the pockets fill up with the silver particles, which become a solid mass mixed with other mineral matter, or as miners call it, a "lode." To accomplish this it has taken centuries. Thus crannies in the rock in every direction, if at all reachable by water, may in time become filled with the precious metal, as if a myriad of invisible hands were fetching the treasure from all sides and hiding away a bonanza to enrich some future lucky prospector.

In the Comstock mine great and unusual dangers were met in getting out the ore. The vein of quartz which bore it was fifty or sixty feet wide. Some of this was very soft, some very hard. Pillars held up the tunnel roof all right in the hard sections, but the soft rock persisted in continually falling in until the walls were literally covered with heavy posts standing side by side on end, across which was a close lathing of similar timbers to support the fickle roof, all bolted securely together. In other places great hollow pillars were formed by laying squared timbers in a square formation, one upon the other, rail-fence fashion.

Water also bothered the miners tremendously for a time. The surrounding earth seemed full of small streams. Seldom was a new pocket cut into, or a tunnel lengthened, than water gushed out with more or less force. Some of these out-lets could be plugged up again, but others could not, and the latter made the diggings very muddy and wet in spite of the pumps which were constantly sucking out the inflowing water through long pipes. Then there were the "water pockets" which a pick sometimes encountered. These large reservoirs of water in the walls would rush out with a roar, and for the time being would flood that portion of the mine and drown the unlucky miner who was slow in running away. These water pockets often contained strong minerals, such as sulphur, which hurt the miners' eyes and lungs when the waters were first freed, and many a poor chap had to be carried out of the mine by his comrades for medical attention.

In addition, much of this inflowing water was very hot, so hot as to scald the skin when it struck, especially in the deeper workings of the mine. Miners here worked stripped to the skin, and though ice was sent down to them, they could stand it for only short periods, and other shifts took their places.

Finally a mining engineer named Sutro planned to remedy the water nuisance by driving a big four-mile-long tunnel through the heart of the mountain, letting out the hot water and the foul air. The mine owners quickly raised the money for this huge undertaking, and the tunnel was put through as designed. It was a fine success. Out went the hot water as fast as it came in; and in came bushels and bushels of clean, fresh air. From the very beginning the Comstock mine was so ready to originate and follow improved mining methods that it was called the mining school of the world. To-day, however, it is a poor producer, and seems practically played out.

Silver is one of the oldest known metals. Along with gold it was familiar to the ancients, and much esteemed by them not only as a medium of exchange but as a decorative substance. The Hebrews called it *Keseph,* meaning "to be pale." The Greeks knew it as *argyros,* signifying "shining."

The ceiling of the pavilion of the Peacock Hall in Delhi was originally covered with silver filigree work, but in 1799 the Mahrattas, after the capture of the city, took the silver down and melted it. The value of this mass was then estimated at one million dollars. The silver of course came from the early mines of India.

From time immemorial the mines of Peru have been fabulously rich in silver products. Silver was really the cause of the barbarous acts of the Spaniards in their conquest of that country, the reason for their murdering the people and plundering the tombs of the Inca kings, the royal repositories and ancient temples, all gorgeously ornamented and stored with silver. From the Temple of Cusco the despoilers are said to have secured more than eleven million dollars' worth of the precious metal.

But in spite of the comparatively large silver production of Peru, our own United States exceeded it by more than six times during the last few years, leading all other countries. Mexico was a close second, with Canada, Turkey, and Peru in order. In 1918 the United States produced 67,810,100 fine ounces, and Mexico followed closely with an output of 62,517,000 ounces. While decreasing the output of gold, the World War demands greatly increased the production of silver over previous years, as silver sold at a higher price and consequently became more profitable to mine, and there was an enormous need of it for paying off soldiers and meeting other national expenses. Nearly all countries find more or less silver within their domain, and about half the States of our nation have mines in operation. Utah and Montana are the leading producers.

Silver in this country is almost entirely mined as a by-product of copper, lead, or gold itself. Were it not for the other minerals found with silver it would not pay to mine it, but since there is always more or less silver in copper and lead ores it is easily obtainable. Though it is rarely found in pure chunks, nuggets have been discovered which weighed several hundred pounds. Silver is also found in sea water, and small quantities in the form of chloride have been detected in volcanic dust.

As a product of the sea, we might say that for several years mining under the most unfavorable conditions was carried on at Silver Islet, a storm-beaten ledge situated about one mile from the mainland of Lake Superior, not far from Thunder Cape on the Canadian side. The ore when first discovered appeared as shining streaks of white, from three to ten feet under water, and proved to be worth an average of $1,500 a ton. It was of the kind known as "packing ore," and was sufficiently rich to be packed in barrels and smelted (purified) without further treatment. The workings, which extended 1,000 feet under water, were protected at great expense and risk of life by a system of breakwaters, cribs, and coffer-dams, ballasted with rock and clay. On many occasions the furious storms of Lake Superior have utterly wrecked the works, but they have been patiently rebuilt each time.

Silver in its native state is a white, lustrous metal which melts at a temperature of 961 degrees Fahrenheit. Of all metals it is the best conductor of electricity. It is ductile, and capable of taking a high polish. It is also extremely malleable, being so tough that it can be drawn out into the very finest of wire without breaking.

If you should take a thin film of silver and hold it up to the light you would find that the light would come through it, but would be blue instead of white. If you should melt a lump of silver it would immediately absorb twenty-two times its volume in oxygen from the air, then discharge this again as fast as it grew cold and solid again. If you should drop this melted mass into water, cooling it suddenly, the oxygen would become imprisoned before it could escape freely. The oxygen gas would then struggle until it burst through the hardening crust, forcing up a part of the fused silver into tiny little bubbles all over the surface—a phenomenon known as "spitting."

Silver forms ideal alloys with many metals. That consisting of nine parts of silver to one part of copper is the standard alloy used by the United States for making its silver coins, its dollars, half-dollars, quarter-dollars, and dimes. A similar alloy is also used by our government for stamping out silver medals of honor, such as given to its heroes in time of peace and war. When Uncle Sam wants silver for any reason, he sends out circulars describing the quantity and quality to various silver mine owners or brokers, asking for bids. The one whose price is lowest gets the order. When the silver is received it is carefully tested, or assayed, by the government experts, to see that it is up to the requirements. It is then refined, mixed with the right amount of copper to harden it, melted, and poured in molds, coming out as bars of shining white metal.

The bars are run through steel rollers which flatten them till they are converted into long ribbons of silver just the right thickness for the coin to be made. This wide ribbon is sawed into strips of the width of the coin, following which the strips go under a punch which cuts them into many plain discs. A stamping machine, with engraved steel die below and above, imprints the design on both sides of the coins at one operation, as they fall under it automatically. Still another machine cuts a little bevel off the sharp edges, and another one cuts in the little creases (called "milling") around the outside. A big revolving "drum," containing sawdust, receives the coins, and tumbles them over and over and upon each other for a long time. Finally they come out smooth and beautifully white and lustrous, and are carefully counted by girls, registered, put into packages, and stored in strong vaults till the banks of the country call for them.

Great quantities of silver are used in the arts and industries of the world. For making jewelry and silverware it is perhaps the most widely employed. Its greatest fault in either of these uses is its disposition to tarnish. No matter how pure it may be, silver likes to unite with sulphur, and it will always do so if there is a bit of it around. The sulphur—some of which is contained in the yolk of so simple a thing as a hen's egg—has a tendency to turn the silver a bluish, smutty black, and it is so prevalent in town and city life, in the form of sulphureted hydrogen in the air, that practically every silver owner meets more or less of it, and has to scrub away with some kind of fine grit on a cloth in order to keep the precious metal nice and bright.

On the back of many silver articles, especially tableware, you will see the words, "Triple plate," or "Quadruple plate." This means that the article is not solid silver, but contains a core of some other metal upon which three or four films (or "plates") of pure silver have been placed. This is the best substitute for solid silver; it looks just as well, in fact just the same, and if the plating is heavy it may never wear through during a person's lifetime. The plating is done by an electrical process. Two metal rods are laid across the open top of a jar containing a solution of silver cyanide, potassium cyanide, and water. From one end of a rod dangles the article to be plated, hanging in the bath. From the other end hangs a piece of silver plate. The rods are connected with opposite poles of a battery. The electrical current passes through them, releases the silver from the silver cyanide, and this is deposited on the spoon, or whatever the subject may be. The cyanide that has lost its silver then begins to draw from the silver plate, to replace it. This giving and taking process is continued until the operator considers the plate on the spoon heavy enough. He arrives at this decision not by guesswork entirely, because he took the weight of the core spoon before he placed it in the jar or bath, and having determined the weight of silver he wished deposited upon it, he simply adds the two weights, and the sum is what the finished spoon must weigh. So from time to time he tosses it on a scale till the desired balance has been attained.

Silver is used extensively in photography for making dry-plates, films, and sensitized paper. Compounded it is used to give a yellow color to stained glass, to form silver nitrate and be cast into sticks to be used as a caustic in medicine, to act as the basis of many indelible inks, to give foundation to some black hair dyes. Silver sulphide, formed by tarnish, is the groundwork of the so-called "oxidized" finish so popular upon many articles of art. This tarnish may be removed by a weak solution of potassium cyanide, which, however, is a deadly poison and must be handled with extreme caution.

VIII

DIAMOND, THE KING OF GEMS

FROM the remotest ages there has been a romance and fascination surrounding the diamond which is far greater than that belonging to any other form of personal adornment or belonging. At times other precious stones have been valued more highly, but they have never been regarded with the same strong feeling which has attached to the "king of gems." Because of their rarity, diamonds were the exclusive property of the proudest and most puissant of princes, and the ornament of the most sacred shrines. Their possession inspired respect of the multitudes, and did much to enhance the power of their owners.

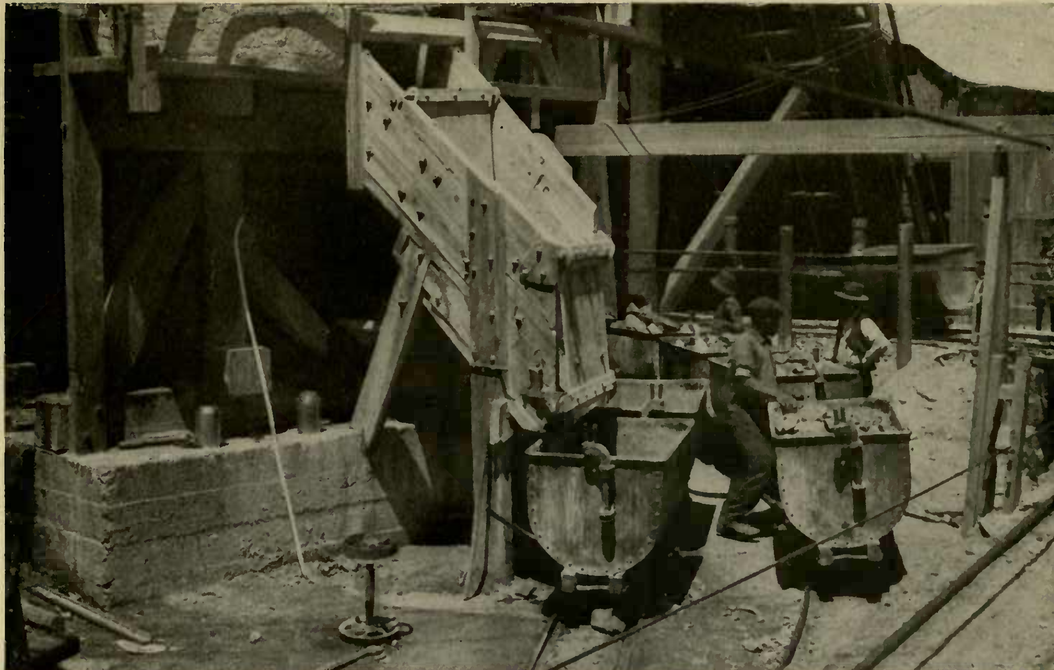
The skin-clad barbarian, idly searching through gravel banks along streams for sharp stones from which to make his arrow and spear points, was irresistibly attracted by the glittering pebbles which cast back the sun's rays in scintillating flashes, as his brown toes turned them rollingly over. Such a prize he would keep, unless some stronger warrior took it from him by force, or at least until the tribal chief seized it as his right. Other pebbles might have brighter color, might possess more interesting configurations; but none had that bewitching, mysterious play of shimmering, beautiful light effects given off by the various sides and sharp edges of the wonderful diamond pebbles.

As men became more civilized their admiration for the diamond grew rather than diminished. Its brilliant radiance held them spellbound, and created in every beholder, humble or rich, a keen desire for possession. There seemed always a strange sort of personality about it, as of a living thing rather than an inanimate object. Its moods seemed ever to change, like those of a human being's eyes; it sent out to its beholder as many different messages, inspired as many different fanciful thoughts in him, as he viewed it from this angle and that, as a living soul. This very weird quality wove around it a strange, remarkable shroud of mystery, awoke superstitions in man's breast that he never dreamed had lain there, and gave rise to stories and traditions of the most entrancing and fanciful kind. The most remarkable story of all —that diamonds had been found in meteorites, or "falling stars"—was a true one. Present-day scientists say that a meteor is a ball of liquid carbon and iron, which striking the cool earth would possibly crystallize into diamonds.

Rulers became so mad to possess the diamonds that they made rigid laws that finders of them should not keep them, but must turn them over to the throne. To keep peace with pagan gods, these ugly creatures were often adorned with the finest of the gems thus brought in, and the altars of the rulers themselves were lavishly set with others. The smaller stones might be the subject of barter, but the large and brilliant gems were for the monarch and his heirs—to use, if he saw fit, as embellishments to religious shrines.

Out of the Orient, where diamonds were first commonly known, came wondrous stories of the beauty and splendor of the great gems owned by potentates of those Eastern lands, and the Western nations listened and were amazed. Thus grew up a sentiment which has endured even into this century, when discoveries of diamonds in many lands have made the King of Gems a possible possession for everyone with sufficient money to purchase one. The diamond is still looked upon as the most imposing of the many articles by which wealth can be represented, and the owner of a fine brilliant is accorded something of the honor, even in democratic countries, that has long been the heritage of monarchs and queens.

The diamond is a thing of paradoxes. Although known from the most ancient times, it



LOADING CARS WITH DIAMOND-BEARING EARTH, KIMBERLEY, SOUTH AFRICA

is the newest of gems in its present form, for its full beauty was never brought out until modern cutting and polishing methods were applied, the greatest advance in these finishing arts having been made right here in our own country, the result of special machinery. As another instance of its paradoxical qualities, although the diamond is always the symbol of wealth and opulence, the diamond finders themselves have never ceased to be, as a rule, the very poorest of the poor. Again, should a stone have the slightest tinge of color—something that makes other gems worth so much—its value is at once lowered; the whiter it is the more precious. Lastly, though the old world has known the diamond all its history, it remained for the new world to create a market for the glittering baubles. To-day most of the diamonds produced by the world are sold in the two Americas, and the great majority of these go to the United States, where the gems are more commonly worn than anywhere else on the earth.

You have no doubt heard the phrase, "Diamond cut diamond," when reference is made to two antagonistic forces of about equal strength. This saying grew out of the fact that a diamond is the hardest substance known, and that it can only be cut with its own kind or its own kind of grit. Of all precious minerals it is the only one composed of a single chemical element. This element in the diamond is crystallized carbon. It is found in all colors of the rainbow, and more. Often it takes on a sooty blackness, like coal, but these colored specimens have little value. It is closely related to both coal and graphite, but of course has undergone an entirely different chemical fusion in the furnace of the earth at some time in the dim, dim past.

In formation, a diamond closely resembles wood, in that it has a grain and splits easily along the plane of such grain. Just as a woodworker carefully determines the direction of the grain in his lumber before beginning to cut it, so do lapidarists (gem cutters) note the diamond grain before attempting to work it up. A small groove is sunk in the stone parallel with the grain, a thin steel blade is inserted, struck a quick, sharp blow, and the diamond pops apart. In this way expert lapidarists used to separate stones, remove defective parts with the least loss of material, and get them in proper size for cutting and polishing.

But within the last few years a better method has been found. Now most lapidarists saw the stones apart, and this scheme is particularly advantageous when the gems have to be cut across the grain. The sawing is done by a thin revolving disc, much like a common circular saw, but having no teeth. The disc is made of an amalgam of copper and bronze, and has a very thin edge which readily cuts through the diamond when diamond dust and olive oil are fed beneath it during the process.

Diamond cutting requires great skill, judgment, and patience. The sides, or "facets," must all be of perfectly equal size, uniformly situated about the stone, and they must be perfectly flat and of the same angle. In this process the stone is securely fastened in a mechanic's "dop" or holder, which is pressed against a steel wheel covered with diamond-dust paste. The wheel revolves at a speed of 2,500 revolutions per minute. The first facet to be ground is the large horizontal one at the top center of the stone, called the "table." Next the eight large facets around the girdle of the stone are ground, each facet requiring the removal of the gem from the dop and its replacement with cement in a new position. Then the eight small facets around the table are formed. Finally eight intermediate ones are ground, which cut the large girdle facets into sixteen small ones. This completes the top of the stone, and gives it thirty-two facets and one table. The underside is cut in much the same manner, producing twenty-four facets and one culet.

As each surface is cut it is polished until absolutely flawless, without the semblance of a scratch under even the strongest magnifying glass, the finest diamond dust and olive oil being used in this procedure. As the cutting and polishing is all done by eye, the artisan must have great keenness and accuracy of vision, as well as skill of hand and knowledge of his work. The perfection and wonderful delicacy of diamond cutting can perhaps be better understood when it is stated that a skilled lapidarist can cut diamonds so tiny that 250 of them will weigh but one carat, each stone being a complete, full-cut brilliant!

In almost every country of the world diamonds have been found. Yet only three localities produce enough to be called really productive—South Africa, Brazil and India—and these supply the bulk of the diamonds which are sold in the open markets, the Kimberley fields of South Africa standing ahead of all others in quality and quantity of output.

India is the first country in which diamonds are known to have been mined. There is no doubt that long before that many diamonds lying loose were picked up along the water-courses of that motherland of civilization. But the men of those prehistoric times did not search deeply into natural affairs; they regarded the diamonds as the tokens of the Thunder-god, left where his bolts had struck deep into the earth. It remained for the lure of gold to entice men to the drifts where a rich harvest was awaiting them.

It has been observed that in almost every land where diamonds are found in dirt washed up by rivers, gold is also found, which goes to show that both have been washed down into the valleys from the mountain-sides. As soon as the ancient Aryans, searching for gold, began to wash the gravelly sands, they found the sharp, white crystals that had hitherto only been discovered by chance. And the princes, jealous of their prestige, soon sent watchers to the mines to claim all the larger stones, and to levy tribute upon the yield of smaller gems. An occasional gem of large size was smuggled away by the finder, to be secretly sold to other princes in whose territory no diamond mines were to be found, and these nobles began to blossom out also in the finest of gems. In the constant wars that waged among the leaders of the country, the victor cherished as his richest spoil the treasured diamonds of the vanquished; and in this way the gems were even more widely distributed.

Egypt knew the diamond as a graving tool, and possibly also as a gem, while the roving Phœnecians traded extensively in the stone, likewise in the white sapphire and zircon, which are like it in whiteness but neither so hard nor so brilliant.

When the Greeks spread out in a conquering flood over the western part of Asia, they took as their most treasured spoil the diamonds of conquered kings, and the writers of that period, whose books have come down to us, told marvellous stories of the jewels of the East. Rome followed Greece as a world power, and developed commerce so that all sorts of precious stones were known and worn by the sybaritic patricians of the great empire. Rubies, emeralds, and other precious stones glittered in the scarlet and purple robes of the rulers—but outshining, outdazzling them all were the diamonds themselves.

So coveted were the diamonds, even at this early period, that unscrupulous persons began to try to counterfeit them, to try to create substances which would look like diamonds and find a sale as such. These imitations were made chiefly of a sort of paste by the Mediterranean traders, but were never very successful, as a diamond is one of the most difficult gems to counterfeit, owing to its whiteness and great hardness. Of late years Americans and Europeans have been far more fortunate in creating artificial diamonds; indeed, have done so with such consummate skill that no one can detect the natural from the man-made stone. These fine imitations, however, are not sold on the market, as they are too small to be of value. They are made by dissolving carbon in melted iron and cooling it suddenly, which crystallizes the carbon into tiny diamonds. They sell at a very low price compared to genuine diamonds, which at this time are quoted at from $90 to $200 per carat, depending on quality.

As the thin and scattered diamond-grounds of India began to give forth smaller supplies of diamonds, a new impetus was given the trade by the discovery of these gems in Brazil. Gold miners there had unearthed stray gems as early as 1670, but it was not until 1725 that their real nature was known, when a trader purchased some of them from two Portuguese miners. Immediately there was a rush of prospectors and miners to the district, and a town, since known as Diamantina, sprang up. Gold was forgotten; every man hastened to wash the river beds in quest of the glinting white gems. Closely following the adventurers came the law. The Portuguese crown declared its sovereignty over all diamond-bearing beds, and no one was allowed to mine without paying heavy taxes; even then the largest and best stones were confiscated by the crown. This brought the quest in disrepute, and soon the fields were scarcely worked except by the throne's own slaves and hirelings.

Native Indians and escaped slaves, along with lawless white men, scattered into new districts and prospected. In many instances they were lucky, and before they were detected and again overridden by the law, succeeded in selling many good stones. Whenever one of these lawless miners was caught, he was made a slaveworker in the mines of the Portuguese government. To get these slaves to work harder, the one who found an unusually large diamond was promised his freedom. In this way the government obtained better service than could be gotten through use of the overseer's lash, and secured many fine specimens of stones. Good to relate, the agreement with the men was kept, and every fortunate finder was sent away rejoicing in his freedom.

Finally Brazil became an independent nation, and then the government mining was largely abandoned, and everyone was given a chance to find and record a mine of his own, and to work it in his own interests, as in the United States mining system. But men found that so much rock and earth had to be handled in order to find even a few diamonds that the game was more often a losing one than a winning one.

As the lust for gems has had much to do with the wars and conquests of the past, so the discovery of the greatest diamond fields of all time —those of South Africa—has wrought a new empire there. But for the finding of diamonds there, we have strong grounds for belief that the semi-desert would still be devoted to a pastoral grazing ground of the Boers. As it is now, cities have sprung up, immense fortunes have been made, and the way has been carved through war and commerce for a new union of states.

No one knows just when the first diamonds were discovered in South Africa. The first accident that led to the world's attention being attracted was one in which a Boer woman living near Hopetown, on the Orange River, picked up a glittering diamond among the pebbles where her little son was playing along the shore. She did not know its value, but was attracted by its brilliance, and showed it to a neighbor. This man—Van Niekirk by name—recognized the stone as a diamond, and bought it for a small sum. He in turn sold it to an Irishman, who showed it to Dr. Guibon Atherstone, a noted mineralogist at Grahamtown. The scientist at once pronounced it a very fine specimen of diamond, of more than 20-carat weight. He induced the owner to put it in the Paris exhibition, where it attracted widespread comment. Later, Sir Philip Wodehouse, governor of Cape Colony, bought the gem for $2,500, and continued its public display to attract people into the new country.

In 1867 the rush of miners began, and soon they were busily searching along every water-course for the precious stones. The Boers themselves did not join in the quest, and went on about their staid grazing duties as before, calmly smoking their pipes and blinking contentedly at the energetic actions of the newcomers. As a sharper instance of this calm indifference of the Dutchmen to the excitement going on all about them, it is related that a Boer who was building a chimney plastered it with pebbly mud from a swale near by. Later when his attention was called to the fact that a number of glittering diamonds were among these embedded pebbles, he merely nodded gravely, and said, without the least sign of flurry, "Yaw; they won't hurt; I will leave them!"

At first the miners had poor success, but when, in 1869, a native picked up a stone weighing eighty carats, which has since been named "The Star of South Africa," news of the find was spread broadcast, and renewed interest taken. Where previously there had been one hundred miners in the Vaal River field in May, August found more than two thousand. By the following April there were five thousand prospectors, and more coming in every day.

It was a hard journey from the coast, either by wagon or on foot, and the adventurers found the cost of living a burden from the outset, with supplies difficult to secure. But they kept arriving. Voluntary associations were formed to preserve the law and to impose mining licenses, and rules were laid down for the marking and working of claims. Each claim was thirty feet square, and anyone was free to take possession of a claim which had not been worked for three days. The Boers sought to levy taxes, but this effort was resisted, and the territory annexed to Cape Colony to circumvent it. Washing methods were rough, and many small stones were lost.

Finally, disappointed in the Vaal River diggings, the prospectors spread out over the country in quest of more productive fields. One of these chanced upon the gem-plastered chimney of Farmer Van Wyk, previously mentioned. Struck with the possibilities of the locality, he went to work and was soon taking out diamonds in a fashion to attract many others to claims in the same locality. More and more miners swarmed in. Soon the famous De Beers mines were opened up, also the noted Kimberley mines. A peculiar snuff-colored earth was found here, and all through this, well scattered, were the precious stones, ranging in size from pin heads to crystals the size of a pea. The greatest treasure-house of the world had been found at last, although few, if any, of the miners then suspected it.

A typical mining town, rough and full of bad men, grew up among the mines. Shafts went deeper and deeper, and the individual miners found that the work was getting so costly that it no longer paid well. Negro laborers became adept thieves and robbed their employers, only to lose their ill-gotten treasure to the rogues of the town. Crime was common. The strictest laws could not entirely keep it down. No man's mind was at ease; if he did not find diamonds he was worried; if he found them he was troubled with the greater and more gnawing fear of having them stolen from him, perhaps losing his own life in the operation from a cowardly knife thrust from behind.

When the yellow ground was exhausted, and a stratum of blue-clay rock was met, most of the miners concluded that the bonanza times were over, and sold out. The era of consolidation had begun. Men with money combined their capital, combined their claims, combined their intellects, and continued the mining operations on the huge and efficient scale that such power makes possible. Machines were brought in for the digging, expert engineers were engaged to work out the mining problems that arose, miners were hired. Thus the De Beers and the Kimberley mines became the greatest producing diamond mines in the world, and are such today. The syndicate which controls them and other paying mines absolutely fixes the price of diamonds for the universe from its London office. When we buy a diamond ring or stickpin, or anything else containing a diamond, we pay the price set down by this monopolistic ring of men for that class of diamond.

The great diamond mines of South Africa are more or less circular in shape, the formation being like a huge cup of rock filled with the blue ground in which the diamonds are found. As the walls of rock are almost vertical, the taking out of the blue earth has left cavernous pits, with walls straight up and down for hundreds of feet.

It is necessary to elevate the diamond dirt to the ground level, then deposit it in the open field, where it is allowed to "weather" from six months to a year before being broken up and washed. The gravel from the washings is passed over greased boards which catch and hold every diamond, no matter how small. They are then extracted and sent away to the lapidary works to be cut and polished.

Greatest of all diamonds ever found was the "Cullinan." This dazzling wonder was taken from the Premier Mine, South Africa, on January 25, 1905. It measured 4 by 2½ by 2 inches in the rough, and weighed over 1 1/3 pounds avoirdupois—3,024¾ carats. Its primal value defied estimation, so different was it from all other stones.

The "Cullinan" was found by the superintendent of the mine, Mr. F. Wells. He describes the discovery thus: "I had a gang of natives working. We had gone down about five feet from the surface. . . . . We were just about to knock off for the day when I saw something white and sparkling lying on a slope of the blue dirt. The rays of the setting sun caught it, and it flashed like a small bonfire that might be blazing fiercely. Almost overcome, I rushed to the spot. The earth was already loose about the stone; my knife blade finished the work, and in a few moments it was in my trembling hands. I was dazed. I dashed headlong to the office and showed it to Mr. McHardy and Mr. Cullinan. They, too, were amazed. . . . . The next day word was sent out that the biggest diamond ever known had been found."

Mr. Wells was awarded $10,000 for this find.

No person, no government, could afford to purchase this wonderful gem. What, then, was to be done with it?

General Botha, premier of the colony, hit upon a happy solution. He suggested that the Transvaal buy the company's interest in the gem, and present it to their king, Edward VII. Sealed in an ordinary tin box, the great diamond was sent by registered mail, and received no more care in the handling than might some simple token from a shepherd lad to his lassie. It was presented to the king on the sixty-sixth anniversary of his birth, as a testimonial of gratitude for the grant of autonomy bestowed upon the Transvaal colony by the English government. King Edward assured the donors that the precious gem would ever be "preserved among the historic jewels which form the heirlooms of the crown." As is often the case with large diamonds there were in this certain imperfections and the jewel was cut into several brilliants. The largest of these, known as "The Star of South Africa," is itself the greatest and most lustrous diamond in the world. It is 530 1/5 carats in size and several of the smaller pieces of the "Cullinan" are over 150 carats.

Another famous diamond is the "Koh-i-nur." This is the most ancient noted gem in the history of the world—older than the rising of the Star of Bethlehem, or the Tables of the Law—as old as Egypt's pyramids. Its history is a record of war and bloodshed, from the first trace that can be found of it in India, an heirloom of the Rajahs of Malwa, until its acquisition by the British crown, in 1849. During this time it passed to the Moguls of Delhi, to the Persian conqueror, Nadir Shah, to Afghan princes, to the "Lion of the Punjab." All through its devious course it gleams through a crimson mist of terrible sacrifice. One prince after another was imprisoned, tortured in cases to blindness; but not for this would they surrender the coveted jewel, and only stern death itself wrenched it from them.

Once in its history the "Koh-i-nur" was captured by stratagem; twice was it a gift of ransom. The story of its tragic travels from owner to owner is too long to tell here, but we will cite its experience with the fierce Persian, Nadir Shah. Nadir descended upon Delhi for conquest, and carried back with him booty that reached into the hundreds of millions. Chief amongst all this treasure was the great diamond, called by Nadir "Koh-i-nur," meaning "Mound of Light." Nadir had come within a hair of missing this prize.

When he appeared triumphant before the court at Delhi, where Mohammed sat on the Peacock Throne, surrounded by such splendor and luxury as to outrank the rivalry of such things for ages back, the defeated ruler gave him unheard of quantities of jewels as his trophy; but the particular gem—the "Koh-i-nur"—which Nadir coveted, was not among them. Mohammed stoutly denied knowing where it was when approached by the angry victor; but just then a traitor from the harem told Nadir that it was hidden in the folds of Mohammed's turban.

Before his departure for Persia, Nadir restored Mohammed to the Mogul throne. Upon this occasion he craftily invited his royal captive to exchange turbans with him in token of their everlasting friendship. Helpless and speechless, Mohammed could do nothing else than obey this courtesy. So away went the clever Persian, carrying with him both the ruler's turban and the rare diamond it contained.

The "Koh-i-nur" is a brilliant diamond of grayish tinge, weighing 102¾ carats. It has been recut from its distinctive Oriental shape, having thereby lost over 80 carats and much of its intrinsic historic value. In 1911 it was taken from England to India, its original source, and blazed paramount at the crowning of an emperor of India at the Delhi Durbar.

Still another famous diamond is the "Great Mogul," the chief treasure of the Moguls of India for generations. This was found about 1650, and became the property of the diamond merchant, Mir Jumla, who presented it to Shah Jehan in an effort to curry favor with the new court. It was partially cut, and weighed 787½ carats. The Venetian cutter, to whom Shah Jehan entrusted it, was very unskillful, and in cutting it wasted so much that when he was done it weighed only 280 carats. The diamond was then in the form of a dome-shaped rosette, like an egg cut in half. It was of fine texture, of beautiful color and brilliancy, flashing soft, rosy lights rather than fiery red ones.

What wonder that the natives fell on their faces and worshipped it, believing it to be the spirit of their deity! One of Shah Jehan's four sons also worshipped the gem, to such an extent that he kept his father in prison seven years in order to get possession of it and the kingdom. Shah Jehan was so incensed that he threatened to grind the great diamond to bits, but his daughter prevented this, and it finally went to the cruel son at his father's death.

The diamond was last seen in the court of Aurang-zeb, about 1665. No further record of it can be found. In some unaccountable manner it vanished, as a lump of ice melts away in the hot sun, leaving no trace.

The "Regent" diamond, in the Louvre, in Paris, weighs 136 carats, and is valued at $2,500,000. It is a splendid brilliant, discovered in India, in 1701, by a slave in the mines. In order to escape with his prize, the slave made a deep wound in his leg, and inserted the diamond, bandaging the injury in an innocent manner. Subsequently he sold the stone to a merchant of Jamchund for 1,000 pounds. This man later disposed of it to a Mr. Pitt for $96,000. The latter had it cut and polished, the operation requiring two years and costing $23,500. So imbued with fear did Mr. Pitt become, that he would some day be murdered and robbed of his treasure, that he sold it for $675,000 to the Regent of France, for the boy-king-to-be, Louis XV. Sixty years later it was conspicuous in the new crown of especial splendor made for the coronation of Louis XVI. During the French Revolution the Tuileries was plundered, the crown jewels stolen; but the "Regent" diamond, too well known to be disposed of without detection, was found cast aside by the cunning thieves.

This famous gem was prominent next in the sword hilt of Napoleon, at his marriage to Josephine; and again at his marriage to Marie Louise, where it reposed in his gorgeous head-gear.

Among the most valuable diamonds of recent times are the "Victoria" and the "De Beers." The former weighs 180 carats, and was purchased by the Nizam of Hyderabad. The "De Beers" weighs 225 carats, and is still in possession of the mine owners.

IX

LEAD, FATHER OF BULLETS

WHEN you attach a lead fish-sinker to your line, do you ever stop to think how that lead came to be?—how it was found?—how it was put into the hands of man, ready for his skill to work upon? When you drop a BB shot into your airgun, or a "twenty-two" cartridge into your little "real" rifle, do you ever stop to think what the world would do if there were no lead from which to make such projectiles? What would those famous old woodsmen and Indian-fighters, Kit Carson and Daniel Boone, have done without the lead from which to mould their round balls which proved so deadly to animal and redskin? What would modern hunters do? What would soldiers and sailors at war do?

Without lead many of our every-day comforts and conveniences would be either a thing of the past or would be sadly altered. For instance, lead is much used for water-pipes, especially where bends are to be made on the premises. It is used for making chambers to contain sulphuric acid and other acids which would eat through almost any other material. It is used for making many kinds of toys, especially miniature train wheels, tiny soldiers, roly-polys, come-backs, swinging pollies, boat anchors and keels. It is also used extensively for making paper-weights, and for cores of gear-wheels in modern clocks. The soles of divers' boots are composed of it.

This is not all. You will find that when molten lead is heated at a moderate temperature, with constant stirring, a substance called *litharge* may be obtained from it. Litharge is a valuable fluid much used in manufacturing arts; it is used in the manufacture of flint glass, in glazing earthenware, as a paint, and for drying oils. *Minium,* another by-product of lead, has been known ever since the time of Pliny, and is a scarlet crystalline granular powder; it finds extensive use in the arts as a pigment, in the manufacture of flint-glass, as a cement for making steam-tight or gas-tight joints, and in the manufacture of secondary batteries. *White-lead,* still another form, is a white, heavy powder, and is extensively used as a pigment or as a body for building on other colors; and boat-builders also use it for making water-tight joints. *Lead acetate,* another by-product, finds wide use in medicine, in the industrial arts, in refining sugar, and in chemical analysis. *Lead sulphate,* yet another form, is often used as a substitute for white-lead.

Without lead for their storage batteries, submarines could not operate when they were submerged; so it is extremely doubtful if we should have such a thing as an under-sea boat in that event, for what good would a submarine be if it could not propel itself under water? Similar use of lead will be found in the storage batteries of present-day automobiles—those which run by electricity, and those which start by the same medium. Commercial solders are composed largely of lead.

Lead is one of the oldest known of metals, and is, next to gold, the heaviest. It will be found mentioned in the Book of Numbers as a part of the spoils taken from the Midianites. It is also referred to in the Book of Job.

Lead constitutes a greater percentage of the rock in which it is found than any other known metal. Hence it is comparatively cheap to mine, particularly because galena, in which it is found, usually contains a little silver, zinc, arsenic, and antimony, and sometimes copper and even gold. Most lead mines produce enough zinc, especially, to make the latter metal a considerable source of revenue to the owners.

Lead ore, or galena, is found in enormous quantities in many parts of the world. Along the Atlantic border of the United States there are numerous localities in which it is found in veins which cut through the Archean and Paleozoic rocks. These deposits have not been worked, however, for many years.

The ore bodies of the Mississippi Valley, where most of the mineral is mined, are among the finest in the world. One of the most productive fields is in southeastern Missouri. The ore is mixed in limestone through a thickness of about 200 feet. The mines of La Motte, Doe Run, and Bonne Terre are among the best of the district.

The argentiferous lead ores of the Rocky Mountain States are found in carboniferous limestone, and yield both hard and soft ores which contain cerussite and silver chloride. In the deeper workings the oxidized ores give way to unchanged sulphides, which are now of immense importance.

Lead-silver mines are operated at several localities in Colorado, Idaho, and Utah. And large quantities of lead in crude form are imported into the United States from Mexico and British Columbia. Western smelters do the refining.

Usually there is not the slightest indication, on the surface, of the valuable lead ore which may lie under it. Therefore, most of the mines have been found by sinking down holes into the rock and taking tests of the mineral pierced by the drill as it comes up in fine powdered form. The ordinary well-type of drill is used, such as already described in an earlier chapter. When it is found that there is a sufficient quantity of lead ore, or its attendant ores, to make the mine pay, shafts are sunk to the levels of the ore bodies. Tunnels called "drifts" are driven off from the shaft, so that the veins can be reached fully and conveniently.

The lead vein has been formed in a great crack in the rocks. These cracks go down from the surface of the earth, right through all the rocks, till, if you could follow far enough you would probably come to a place where the internal fires are so hot that everything—lead ore and surrounding rocks—are in a state of boiling liquid, just like lead when you melt it yourself.

The vein has been formed by water running up and down this crack. Whenever the water found a hole or crevice in the rock it began to fill it up. The water which trickled down through the rocks dissolved a small part of the rock that it had run over. When the water got into a pocket and stayed there, it slowly evaporated, and the rocky sediment of limestone or other rock gradually filled it up, forming in some mysterious manner a compound of lead. This lead-laden water doubtless was forced up, through fissures in the earth, by the fierce gases of the furnace below, where the lead really was first mixed with the water. The zinc, silver, antimony, and other metals found with lead, owe their origin to a similar ejectment, and then slow evaporation of nature.

You must have noticed that when syrup is left uncovered, the water in it "dries up," and after a while you can see the grains of sugar left in the saucer, or on the top of a jar of jam. In the same way, if a solution containing lead or any other metal becomes cooler, the water cannot hold as much of the metal dissolved in it as it did when it was warm, so the metal crystallizes along the rocky sides of the seam, bit by bit, closing up the passage till it is all filled.

Some veins have been traced through the hills for miles and miles, continuing to furnish the richest kind of lead ore. Then, as suddenly as you come to the end of a groundmole's hole, the vein will come to an end. Perhaps near by a new vein will appear. Or perhaps the one vein will divide itself into three or four smaller ones. Much the same order of things will meet your eye if you will go to a dried-up mud puddle and look at the cracks in its sun-baked bed.

The rocky walls on either side of the lead vein are called the "hanger" and "ledger" walls, the former being the one under which the slanting mine shaft is dug, and the latter being the one on the opposite side. Between these walls the whole space of the one-time crack is filled solid with the galena or lead-bearing ore. All of this valuable core is taken out by the miners, leaving only sufficient rock for propping up the roof.

In sinking the shaft, first a series of slanting holes, which converge like the spokes of a wheel, are bored into the earth. These holes are then charged with dynamite, and exploded at the same instant. This blows out the core of rock they are surrounding, forming a large hole. The hole is then made more square by boring holes around it in four corners and dynamiting these sections. The process is repeated time after time, as fast as the loose earth and rock can be removed, till the mine is a real mine, tracks are laid, and cars begin to run back and forth carrying out the valuable ore.

In most lead mines, when your eyes become accustomed to the darkness, you can see the lead ore shining along the walls quite brightly. In some of them little caves of beautiful white calcite crystals—contrasting strangely with the dusky ore—can be found. A common occurrence is to see curious things hanging from the roof and sides of the passages which look like milk-white icicles. These are called "stalactites." They grow, particle by particle, just like icicles, and usually have a drop of water at the end of each stem; but they are hollow in the middle, and are formed from limestone which has separated itself from the mine water trickling through the walls here and there. In places the limestone water drips to the floor in sufficient quantities to form similar white spearlike points. The latter are called "stalagmites." All caves of limestone rock are made picturesque with these two types of excretion.

Occasionally pockets are found near the surface which contain pure galena. These are more or less in the shape of semi-spheres, sometimes hundreds of feet across. Here mining is easy and a real bonanza. Unfortunately few places are found where lead is obtained so readily.

Lead ore, after being brought to the surface, is crushed to the fineness of sand, and sent to the "jigs," where it is mixed with water in the huge frames of that name, and subjected to a steady shaking motion by means of machinery. This jigging movement carries away the lighter and worthless rock, called "gangue." It also separates the zinc and lead ores from one another, and each is collected in troughs or chutes, and carried to bins until needed.

Some of the very fine material cannot be separated by the jigs, and passes to concentrating tables. Here, mixed with water, it passes over boards which shake the material in such a way as to separate not only the valuable ore from the gangue, but the zinc from the lead ore as well. These products are then sent to the bins with those from the jigs.

In smelting, there are three processes used. These are the *roasting* and *reaction,* the *roasting and carbon-reduction,* and the *iron precipitation* process. All produce a crude lead which requires refining later in order to yield a product fit to sell and use. We will not attempt to describe these processes here, as they are too technical to be of general interest. But we will say a few words in regard to the refining.

After smelting, the lead is still too impure to use successfully, owing to the presence in it of copper, arsenic, antimony, zinc, iron, bismuth, tin, sulphur, and possibly gold and silver. If there is not enough of the last two precious metals to make special treatment necessary, it is refined by blowing steam through the molten metal, which is contained in a kettle, or by slowly melting it in an open furnace which shakes back and forth during the operation. The impurities collect on the surface in a scum. The scum is skimmed off, leaving the metal well refined. It is then cast into "pigs" for market, each pig weighing from 80 to 110 pounds.

Out of a total world production of lead in 1913, of 1,270,458 short tons, the United States contributed 411,878 tons, considerably more than any one other country. About one-third of the world's lead is made into pipe, one-fifth goes into shot, and the rest into sheet lead, alloys, and other products.

X

GRAPHITE, BACKBONE OF PENCILS

IT may surprise you to know that what you have always thought to be lead in your so-called "lead pencil" is not lead at all, but is made of graphite, or plumbago. This substance is considerably lighter than lead, as you can readily find out for yourself by splitting apart the wood of a pencil, freeing the "lead," and weighing the latter, then comparing it with a bit of real lead of about the same quantity. As a matter of fact, just balancing first one and then the other in the hand will quickly show you that lead is much heavier, size for size, than graphite. Graphite has a specific gravity of 2.2; lead reaches as much as 11.4, being more than five times heavier.

Why, then, if lead pencils are not made of lead at all, are they known by that name? There is only one explanation for this. When graphite was first discovered and used, it was not given the name of graphite, but was called black-lead, or plumbago.

Two of the features about lead which did more to fool the early geologists than anything else were the close resemblance in color, and the marking powers, of this mineral as compared with the same points in the newly discovered black-lead. While it was noticed that there was some difference in structure, and that the lead would not mark as blackly as the plumbago, it was still thought they were both of one family. And while geologists, as well as many other people, know differently now, the old name had gotten such a grip on the fancy of pencil users that to this day they still cling stoutly to the old name of "lead pencil"; and pencil manufacturers have thought to humor them enough to make no attempt to tag their product under its right title, although it is true that manufacturers using graphite in other forms for the public have long sold their compounds under their true names, and citizens thus accept them and speak of them. How strange that a customer will go in a store and ask the clerk to show him some "lead pencils," then stop his automobile in front of the first garage, and ask the attendant to sell him a can of "graphite lubricant"—when in each case he refers to the same identical substance in connection with the pencil and lubricant! But people all over the world get into some queer habits sometimes from very simple causes, as we see.

While the uses of graphite do not have as wide a range as some other minerals which Mother

Nature has secreted in the earth, these uses are very important. Chiefest among them is that of the pencil, of course. Just pause for a moment and think what you would do, what your father would do, what your teacher would do, what newspaper men would do, what clerks and bookkeepers would do, what lawyers would do, what railway conductors would do, what postoffice forces would do, what armies and navies would do, what the mayor and governor and President would do—if there was no such thing as graphite for pencil cores! There is a strong probability at best that the world would not do half the business it does to-day, for never has a satisfactory substitute been found for graphite as a pencil center.

Yet few pencils, if any, contain a core of pure graphite. This mineral, in a pure state, is far too soft to wear well in a pencil, or to make fine enough marks to be suitable for general notes or drawings. Pure graphite in a pencil would crumble away in sharpening, almost melt away in marking, and would create broad lines which would smut with the least touch of the hand or any other object. For this reason, and to make pencils of varying degrees of hardness and fineness, which will render them suitable to the wide range of uses to which the world now applies them, pencil manufacturers mix the fine graphite powder with different amounts of carbon (coal) grit. The latter stiffens the graphite core, makes its wearing qualities far greater, reduces the smutting fault to a comparative nothing, and gives the writer or artist just the kind of a record, in tone and fineness of line, that he wants.

You probably have noticed, when writing or drawing with a pencil, that sometimes it will, if a "hard" pencil, scratch the paper a little rather than leave a gray mark. This is a defect in the mixture in making the compound of the core, and is caused by too much carbon at that particular point, a large grain of carbon which in some manner has escaped the powdering process. As a rule only inferior brands of pencils, selling at a low price, will be found with unbalanced mixtures of this kind.

The proportion of graphite in a pencil—in other words, its "hardness" or "softness"—is designated by manufacturers by symbols printed on the pencils. "B" stands for soft, "H" for hard. "BB" is very soft, or very little carbon. "HH," or "2H," is double-hard. "HHH," or "3H," is triple-hard; and so on up to "HHHHH," or "5H," which is about as hard as pencils are made, the kind used for the finest of mechanical drawings and similar work.

Graphite also finds extensive use as a lubricant. Mixed with various oils and greases, it gives these a heavier and far more slippery body than they naturally possess themselves. In this form we find it employed in lessening friction between the gears of automobiles, printing-presses, and similar large machines, as well as in smaller ones, such as bicycles, carts, phonographs and mechanical window displays. Compounded with turpentine it makes stove blacking; with oils, it forms a splendid waterproof paint. Used dry with foundry sand it makes an ideal casting medium. Mixed with clay by a fusing action, it makes the best of refractory crucibles, crucibles which will not melt under the greatest heat man can create from the materials nature has given him and taught him to use.

Graphite varies a little in color, running from a dark steel-gray to a smutty black, according to the locality of its supply. It crystallizes in the hexagonal form, and may occur in foliated shape also. Its greasy feeling, softness and the black streak generally running through it, make it easily distinguished. It is nearly pure carbon, with only one or two per cent of impurities.

When you have looked at your pencil, you know that it was made in some factory; but did you ever stop to think that the graphite ("lead") is a vegetable product like the wood? The graphite was first a gas which chemists call carbon dioxide. It is formed by combining two parts of oxygen with one part of carbon.

We are all busy manufacturing this gas in our bodies, and breathing it out as fast as it collects. The fire in the grate is turning the coal into the same kind of gas, and sending it up the chimney. This gas was present very early in the history of the world. It probably came out of the sun, along with the rest of the material from which the earth was made.

We are all so accustomed to seeing plants and trees growing in the ground that we think all the food for them comes from the dirt. Really only one fiftieth part of the substance of a plant consists of mineral matter absorbed from the ground; the other forty-nine fiftieths consist of carbon, nitrogen and water taken from the air.

At the time when the coal of the world was formed, the globe was a very different place from what it is to-day. There was a great deal more carbonic acid gas in the air than there is now. Carbonic acid gas, although it feeds plants, poisons all the other living things, humans, animals, fishes, reptiles, birds and insects. If you were to shut up the doors and windows of your room, seal up all the crevices, and block up the chimney, so no pure air from outside could get in, you would soon begin to feel very stupid and sleepy. Later you would be assailed with a dull headache, your eyes would grow heavier and heavier, your senses would whirl round and round, and before long you would probably fall into a stupor from which you might never awake, because you would be poisoned by the deadly gas which we are all breathing forth out of our bodies.

Scientists say that in the Carboniferous Period the earth was one great steaming greenhouse. We now find the remains of tropical vegetation all over the world. Even at those coldest of cold points—the North and South Poles—the fossils of soft plants, which now grow only in hot countries like Africa and South America, are found in great quantities. This goes to prove that in those prehistoric days, millions of years before man or woman came, everything everywhere was the same hot, misty place, all the year round, without any perceptible difference. It was the age of perpetual oven-like heat. The whole land was, moreover, soaking with water; for we find that it rained every day, and poured down fifty times harder than rains we are used to. From almost any place you might choose to stand, you would find some body of water within range of your vision—a stream, a pond, a lake, or a swamp.

Steam was constantly rising up into the air from the wet earth, and being condensed into clouds which girdled the universe in a great white chain of billowy links, twenty miles high. These clouds kept the heat of the earth from escaping into space, and at the same time stored up most of the dry heat which came from the sun. This did much to keep the earth the hot, moist place it was in the beginning, and to create a suffocating amount of carbonic acid gas, which caused the great plants to thrive in magnificent abundance, but prohibited other forms of life from existing. In other words, the whole world was one vast greenhouse. If you would know how such an atmosphere affects human health, visit a few greenhouses and note the pale faces of the attendants and their listless step.

During this time in the world's history, when huge masses of vegetable matter covered the whole country, the surface of the earth was constantly sinking. A land on which was growing some great forest thousands of miles across, would gradually sink down lower and lower, until the rivers all around it would spill into it, instead of running into the sea as before, and a great lake would result. At other times the ocean itself would flood into a tract of land that had sunken below its bed, and a larger ocean would result.

If the covered land consisted of trees and plants, the force of waters would soon knock them down, lap over them, and form them into a tangled mass of mud and vegetable fibre at the bottom of the new lake or new ocean-way, as the case might be. The violent and frequent rains of that time would not be long in gnawing away the sides of mountains and hills, as well as the banks of streams. So the rivers after a rain would be thick with mud, and at times would flow like treacle, bringing down enough sand and gravel to fill up the vast lake in which the old forest of huge plants had been drowned. Floating masses of vegetation often became waterlogged and sank to the bottom.

Long before the lake had been filled up with this mud and decaying plant life, other plants took foothold in the muck and began to take their place. There were giant horse-tails, mosses with brilliant green fringe as long as your arm, jungle plants with leaves as large as a big kite; and all kinds of rank water weeds would struggle up through the morass and intertwine on the surface like a net. Then as the lake became shallower and shallower, scale trees and monkey-puzzle trees and tropical ferns would spring up out of the marsh, and their dead stalks and leaves would later help to fill up the remainder of the lake—until at last a new forest had grown up right on top of the old one.

This great heap of mud and sand and growing trees, piled up and growing on the sinking crust of the world, would make it very much heavier at this place, and aid in causing the land to sink down into the earth again. This would of course create a new hollow, which would quickly fill up with water from nearby higher bodies. The inrushing new waters would kill the new forest. Its trees would fall as a tangled mass to the bottom; and so, on and on, the story would be repeated. These plants turned into coal.

Coal, the source of graphite, may truthfully be said to be bottled sunshine. The sunbeams gave the growing plants their strength and energy to break up the little particles of carbonic acid gas, digest the carbon, and build it into their own bodies, and set the oxygen free. As you sit before the grate warming yourself on a cold winter's day, you are really enjoying the sunshine of millions of years ago, preserved for you by little green plant cells which lived and died in that far-away past, that you in time of need might have comfort in the form of fuel, and graphite for pencils and other things.

If a tree falls on the ground and dies, nearly all its substance is broken up into gases, and escapes into the air; but if the tree falls into water, the water preserves it, and it may last for hundreds of years. The first thing to protect our coal was the water into which the tree trunks fell. The second thing was a layer of clay or mud-rock which formed itself over them. This layer is not always on top of the coal; there may be one or two layers of sandstone between. The layer of clay stuff, which is called "shale," acts in the same way as the air-tight lid of a fruit jar in which a housekeeper is putting up some fruit. It keeps out the air, and prevents the carbonic acid gas, which has formed by the decomposition of vegetable matter, from escaping. The objects thus bottled up are kept from further going to pieces, and remain in the same state in which they were when the "lid" was sealed down over them, until finally, by the action of the weight of rocks piled on top of them, and the heat coming up from the center of the earth, the plant trunks are squeezed and baked and boiled into cakes of coal, or graphite.

Very frequently we find the roots of the coal plants and trees growing in a layer of clay or sandstone; then we have a seam of coal formed from the remains of the vegetation resting directly on the stumps of the old trees. Above these we find a bed of sandstone, then another of shale, then a higher bed of clay. In the latter are the roots of trees of another generation of forests, with a layer of coal on top of them; and so on until in some places as many as fifty seams of coal have been formed, one above the other, and sandwiched in between layers of sandstone and clay.

While graphite, like coal, is composed chiefly of carbon, a product of this buried plant life, it is a very much rarer mineral. It is found only in those spots where molten rock has squeezed through cracks above or below the seams of coal, which has caused the coal to go through a sort of baking process that has changed it into the softer, greasy-feeling substance we call graphite, plumbago, and black-lead. Thus, strange though it may seem at first thought, we now see that the wood casing of a pencil and the pencil's "lead" come in reality from the same identical thing—a tree.

Although it is found in many different parts of the world, graphite seldom occurs alone in large deposits, but is usually mixed with other minerals. It requires special treatment after mining in order to separate it from the rock and other earthen matter in which it lies embedded. The substances with which it is found are limestone, gneiss, or schist, and especially minerals of the pre-Cambrian age. It has also been found in small quantities in meteorites, or heavenly bodies which have been thrown to the ground from out of the skies.

There are two forms of graphite which we recognize. One of these is the crystalline or true graphite; the other is the amorphous or pulverulent form.

The vein-like deposits of crystalline graphite have undoubtedly been formed in fractures, probably at considerable depth. Various theories have been advanced by geologists to explain this composition; in the case of the veins in Ceylon, Weinschenk believes that the graphite came originally from volcanic eruptions and was due to a reaction between carbon dioxide and cyanogen compounds. Crystalline graphite is used largely in the manufacture of crucibles and lubricants.

Many amorphous graphite deposits were once coal beds which have been converted into graphite by the creeping in of igneous rock, as in Sonora, Mexico, and at Turret, Colorado, both of which places possess valuable mines of this kind of plumbago. It is used chiefly in pencils, paints and boiler compounds.

In 1898 a way was found at Niagara Falls for making artificial graphite from coke. That very year 200,000 pounds of carbon rods, were graphitized in the electric furnaces, and scientists were enthusiastic at the success of the experiment. By 1912 the production had risen to 12,896,347 pounds. It is said that the artificial kind of graphite is just as good as the natural mineral as an electricity conductor, for use as a lubricant, and for making "leads" for pencils.

Even though the production of graphite in the United States has been increasing almost every year, we do not turn out half enough to meet the domestic demand, and so our manufacturers have to import considerable quantities from other countries in order to get enough for all of their purposes. Our country produced, in 1913, 4,445 short tons of natural graphite, and manufactured 6,817 short tons. Close to 30,000 short tons were imported.

XI

LIMESTONE, EVERY MAN'S FRIEND

ONE of the most common stones, and one of the most useful, is limestone. It is used in nearly every nook and cranny of the civilized world in one form or another. And it is found in nearly all parts of the country, also. When the Lord made this valuable stone, so necessary to the well-being of every person, he took all pains to see that it should be planted in everybody's backyard, so to speak, where it would be easy to reach.

In its very simplest form, limestone is a rock formed by the combination of calcium or magnesium with oxygen or carbon. Magnesium and calcium are both metals that closely resemble tin or zinc in appearance.

We all know that oxygen is the part of the air that keeps up our life when we breathe it into our lungs. We likewise know that while this oxygen is in our bodies it undergoes a chemical change, so that when we expel it out of our lungs into the air again it is no longer pure oxygen, but has become a deadly gas called carbon dioxide. The coming together of pure oxygen, and this carbon dioxide from decaying vegetable life, forms a combination which, meeting either calcium or magnesium, makes the many different kinds of limestone known to us. Each of the metals produces its own peculiar kind of stone, and each kind of stone has its numerous uses.

In certain forms of crystallization, the combinations mentioned make a clear stone which is so transparent that it resembles glass. This peculiar substance, however, is found only in a few places. Elsewhere there are other substances or impurities which produce a great variety of colors, and add special characteristics to the looks and texture of the limestone, just as people's faces and forms and dispositions vary according to their heritage and environment.

Like all things else, limestone had once to be made. One kind was built under water by myriads of tiny animals which extracted the rock-forming materials from the salty seawater in which they lived, and deposited them in fantastic forests of coral. Another kind was formed by accumulations of shells of different kinds. Still other kinds were shaped by nature out of the materials left by the seas when they evaporated, or changed their beds owing to a new wrinkling of the earth's crust somewhere not far distant.

By these different methods have been developed many kinds of rock, and all limestones, varying all the way from the most delicately colored onyx, and the whitest marble, through many classes of the ordinary limestone, down to the slimy or muddy matter closely resembling ordinary earth. From the different classes and qualities of stone are prepared not only many necessary articles, but the finest gems of art, as well.

Thus the beautiful marbles which, when hewn and shaped by man's hand, produce the greatest examples of statuary in the world, are in reality nothing but limestone. The famous Colosseum of ancient Rome—the largest theater the universe has ever known—and the more modern Cathedral of St. Peter in the same city, were built of travertine, a form of limestone, and are the most magnificent specimens of limestone architecture ever raised to the heavens from which all things animate and inanimate have come. In our own time, and own country, striking examples of the beautiful and impressive structures built from limestone are the National Capitol and Washington's Monument, at Washington, and St. Patrick's and St. John's Cathedrals, in New York City.

In addition to its architectural uses, limestone plays a most important part in the commercial and industrial life of the world of to-day, more so than in the past. One of its most valuable applications in this connection is in the refining of metals, where it is used as a "flux," or means of making iron and similar substances melt easier, and in collecting or separating certain impurities from the molten mass. It would be impossible to make iron or steel without limestone, especially of the quality and on the large scale with which they are now produced. Millions of tons of limestone are used annually in the steel industry alone.

Limestone is burned in kilns to produce lime. The intense heat drives out the carbon dioxide from the hard rock, leaving only the metallic substance and the oxygen. In this form it is known as "quicklime," which is used in the making of mortars and plasters, and for the treatment of soils as an enriching agent.

You cannot have failed to hear a good deal about a substance called "concrete"; in fact, every city boy sees concrete every day of his life, walks upon it to and from school, perhaps sits on a concrete bench at recess, perhaps crosses a concrete bridge with a letter which he mails for his mother in a concrete postoffice, after the day's studies are over and he has left the concrete schoolhouse. Great skyscraper office buildings and warehouses are made of concrete. Even huge ships, with concrete hulls, decks and cabins, are now ploughing their way back and forth across the oceans.

The truth is, concrete is a substance known to everyone, and is one of the most essential constructive materials known to modern civilization. But while thousands mix and mould it, and countless millions admire it in a finished state, only a comparatively few know that without limestone there would be no cement worthy of the name to bind together the water, sand, and gravel, which give strength and body to the compounded concrete. For this last purpose the use of limestone has reached gigantic proportions.

At this time the subject of transportation is one of the greatest importance. The late war left the railroads in a sad state of repair, with little good rolling stock; therefore, manufacturers and shippers all over the land have been trying to keep their goods moving out to dealers and consumers by the use of automobile trucks. Of course this state of affairs immediately called almost every shipper's attention to the condition of the roads, and everything that could be done to improve them was done, so that the trucks could make better time. Every decent road in the country was well sprinkled with farmers coming into town with farm produce, with city buyers chugging out to call on the stay-at-home farmers, and with town and city automobiles making inter-city trips to dispose of homemade articles. "We want good roads!" "Give us good roads!" became the cry of the drivers, the producers, the consumers. People even moved their household goods from city to city, as much as a hundred miles, by truck, and these persons and the moving-van owners also cried for good roads.

How did they get them? By the counties and State raising funds to buy—limestone. Limestone became at once the most important single substance for making bad roads good and good roads better. Now you will see it on roads almost everywhere. On some roads it is laid raw, being crushed into small pieces and evenly distributed over an earthen bed, usually clay. On other roads it is sometimes more finely crushed, and mixed with tar or some similar binder to give it a solid body. Even the railroads often call for it as something fine for ballasting up their tracks.

On the farms—especially those of the central and eastern States—millions of pounds of lime, either as finely ground limestone or as burned lime, are needed to "sweeten" the soil and make possible the better production of important foods for man and beast. In other words, crops grow much more thriftily and with more appealing taste because of this homely limestone.

But its usefulness does not stop here. We could go on and on for some time, naming its valuable uses, and not speak of one twice, were we so minded. It is enough to finish, however, with a reference to its importance in chemical manufacture. In this industry it is used to produce such well-known and highly desirable chemicals as caustic-soda soda-ash, salicylic acid, baking soda, and a variety of kindred compounds. Would you believe it?—even the refreshing glass of soda-water, the tart bottle of pop or ginger ale, and many other sparkling drinks which you may have tried, owe their very popular existence to the gas derived from limestone! Strange though it may seem, the sugar with which they are sweetened required a certain proportion of lime in its preparation.

The story of the progress of limestone, from the quarry where it is won from massive beds or ledges, to its ultimate use, is very interesting. The methods of getting it out differ, according to the use that is to be made of the stone. For the gigantic building blocks and slabs the most painstaking care is required to prevent the shattering or cracking of the desired pieces, one check in any one of which would mean the ruination of that particular segment, and the loss of hours of laborious toil. In this case the top or useless earth and stone, called "the stripping," is removed until the solid, usable rock is reached. This is cut off in blocks or slabs by different means. Sometimes the sections are marked out by holes drilled close together. Steel wedges driven in these will often break loose the whole block; but if this fails or does not look feasible, light charges of blasting powder are inserted in the holes and exploded.

In some quarries heavy machines are now used for freeing the blocks from the quarry walls. These are so powerful and well handled that they actually chisel, with a greater ease than you could cut out a square of wood from a soft pine board, the great blocks of limestone from the parent ledge. Derricks operated by steam or electricity swing the huge blocks upon flat cars standing on nearby tracks which run down into the pit and along just below the serried walls. The cars transport them to the stone-cutting establishments all over the land. Here, by means of special machinery, with water as a lubricant, the great pieces are sawed, chiseled, and planed into the desired shapes and sizes. If they are to appear in an ornamental way, artisans wielding sturdy little pneumatic chisels sculpture them into the most elaborate and beautiful figures.

But for the greater use of limestone this care in quarrying is not required, for the reason that the stone must ultimately be broken up into small fragments. Consequently, the quarrymen invariably adopt the faster method of coaxing the blocks from their holdings, which is to force them loose with charges of dynamite. The holes are not bored so close together, nor so deep, for small blocks; and lighter charges are used, sometimes only a few pounds. But when great piles of stone are to be secured, long rows of holes are drilled back of the "face" or wall of the quarry, and loaded with *tons* of explosive. All of the holes are fired together, and a successful shot brings down a veritable avalanche of broken rock.

Another method, popular in some parts of the country, is to dig tunnels under great masses of limestone, and pack the ends of the tunnels with hundreds of kegs of powder and some dynamite. Such a blast actually lifts the mountain or hill if it is of ordinary size, and shatters the rock in a chaotic storm.

So we see that explosives are required for tearing the broken limestone from the heart of the hillside or mountain-side; and somewhere far back in the history of the steel rail, the carving knife, the toothsome bonbon, the sparkling soda, there was a terrific thud of confined explosive as these familiar friends of ours began their life of usefulness to mankind.

XII

LITTLE GRAINS OF SAND

YES, just little grains of sand. Very common, very ordinary, very old friends, played with since we were the tiniest of tots, there on the summer seashore where Mother and Daddy took us, and there in the kindergarten where we received our first day's schooling.

It would be farthest from our thoughts, we are sure, ever to connect this homely substance of Mother Earth with valuable and important things which great factories manufacture, and which we and other people all over the world need very much. Yet it is true that were it not for sand we would miss many comforts and conveniences which we enjoy to-day. It is extremely doubtful if we should have any window glass, glass dishes, cameras, telescopes, opera glasses, magnifying glasses, mirrors, bottles, marbles, lamp chimneys and lamps, and numerous other articles made of glass. Just think what that would mean: Dark houses in the day-time in cold weather and no chance to look out at passing sights; no photographs of our dear ones or anybody else; no magazines and books with pictures; no "movies"; no way even to see an image of ourselves unless we went, like the primitive savage, to the clear brook, where a hazy reflection might meet our gaze; no intimate understanding of insect life and fine structures of all kinds, such as the magnifying glass has given the world.

Common sand consists either of small crystals of quartz, or of the remains of larger crystals, which have been broken up into small particles or grains. If you examine a few grains of sand under the miscroscope you will be surprised to see how transparent and beautiful they are. In the quartz will generally be found a small proportion of mica or isinglass, some feldspar, magnetite, and other resistant minerals. Sand is really produced by the wearing effects of rains, and the abrasion or rubbing together of stone against stone, or rock against rock. Gradually the tiny bits of rock are scoured off from the parent quartz, and go to mingle with countless other particles, and become "sand," as we know it. It is blown about by the winds of every day, and carried hither and thither by the streams. Even you and I, when we strike off for a hike, help to distribute it when we get it in our shoes, and travel a mile or so before we deem it necessary to shake it out. It is an important part of most soils, and is very abundant on the surfaces along the courses of rivers, on the shores of lakes and the sea, and in arid or desert regions.

Have you ever noticed at the seaside, when you have been walking across the damp sand, that the sand around your foot seemed to dry up strangely when you first put down your foot, and then, as soon as you raised it, became very wet again?

If you will remember that the sand consists of little crystals of quartz, and that each of these are six-sided columns, with six-sided pyramids at each end, you will be able, probably, to figure out just how the phenomenon occurs. Understand that the little grains of sand arrange themselves automatically in rows, side against side, so that they fit into one another and make a very compact mass. When your foot pressed down the crystals beneath it, these disturbed grains tried to wedge their pointed ends into the long joints between the sides of the grains just beneath them. The crystals below were forced aside enough to open up tiny spaces between them, and as quick as "scat" the water above ran down into these crevices, leaving the sand above quite dry. Just as soon as the pressure of your foot was removed, the disarranged crystals formed in perfect order again, squeezed out the water from the cracks between, and caused it to seek the upper sand level once more.

By reason of this very compact natural arrangement of all sand grains, sand makes one of the finest bulwarks for stopping cannon balls and other high-powered shot that has ever been used. Almost all government target ranges have hills of sand behind the targets to prevent farther progress of the missiles, which might otherwise go on and injure people far behind them. In all wars bags filled with sand have proven splendid shields in making hasty entrenchments. Each little grain of the countless millions of sand crystals forms its own peculiarly strong resistance to the advance of the bullet, and the consequence is that this resistance is multiplied so fast, as the missile forces its way in, that it soon loses all power to advance another iota, and becomes "dead."

A very interesting sight are the sand dunes along the shores of Lake Michigan. Especially at the southern end of the lake do these mounds of clear sand rise up to great heights, appearing like small mountains rather than hills. In spite of the fact that the tides and the vagrant winds are keeping these dunes in an almost constant state of movement, wiry grasses persist in growing in them, and sometimes shrubs and trees have taken root and help to keep them anchored in place.

Some sands contain the valuable ores, iron, gold, and platinum; and other metals are occasionally obtained from sand in paying quantities.

It is usually one of the principal ingredients in making concrete, is used extensively by railway locomotives for making the wheels stick better to the tracks in going up a steep grade, is often thrown on icy walks to help pedestrians, is employed in making mortar for laying bricks, and is widely used all over the world as a filtrating agent for purifying drinking water. Properly mixed with clay, it forms one of the finest soils for the production of crops.

But of all its numerous uses there is none perhaps quite so important as that applied to the manufacture of glass. Here sand becomes a veritable giant of value to mankind.

Common as is glass it is safe to say that it adds more to our daily comfort and happiness than the costliest gems which the mines can yield. We have already spoken of what a dreary place this world would be with no window panes to give us light, and none through which to view the outside universe as it swirled by in never-ending interest. And it is quite evident that none of us would wish to go back to the times when people drank out of gourds and horns instead of glass goblets. Nor would we care to use bottles made of skins in place of our convenient present-day glass bottles. In the beautiful stained glass windows of the great cathedrals, and in exquisite vases and costly cut glass tableware, we see something of the artistic possibilities of this very useful substance.

Glass is not a natural substance, like gold, silver or coal, but is an artificial compound; that is, it is made by putting together several substances. The principal ingredients used are: (1) sand (or crushed quartz or flint), (2) lime, and (3) sodium carbonate, or potassium carbonate or sodium sulphate. For various kinds of glass, other materials are added, such as manganese, cobalt, copper, zinc, tin, arsenic, saltpeter, etc.; pigments for coloring are also added.

Cheap grades of glass are made from common sea and river sand; but for the manufacture of better qualities the sand is quarried; that is, dug out of pits. Thus, ordinary bottles and window glass would be made from sea and river sand, while such fine quality as plate glass and mirror stock, also high-grade tableware, would be formed from the quarried sand.

Lime is found in nearly all varieties of glass, but lead oxide is substituted in making those kinds which require a brilliant luster and a high degree of transparency, such as *flint* glass used for lamp chimneys, for cut glassware, and for some of the lenses of optical instruments, and the *strass* or paste used in imitation diamonds.

The lime has the effect of softening the glass, so it must be used sparingly.

In preparing the sand for making glass the manufacturer does everything possible to free it from impurities. In many cases it is stirred in great quantities of water, then burned in the flames of a fire, and finally sifted through copper gauze screening. Iron is the most troublesome impurity; if there is the tiniest bit of it in the sand it cannot be used for making colorless glass.

In the seventeenth century ground flint-rock was used in the best glass, because it was purer than any sand they could then find; hence the name *flint glass*. Curiously enough this name is still applied to a variety of glass which is extraordinarily soft and has not a bit of flint in it, hard sands taking its place.

The mixing of the ingredients into what the glassmaker calls the "batch" is a process that often requires the services of an expert chemist, and in the most modern factories it is customary to prepare the batch according to the formulas outlined by this skilled engineer.

Two types of melting furnace are commonly used—the *pot furnace* and the *tank furnace*. In the former the ingredients are melted in huge pots made of fire-clay, arranged in a circle around a central fire, at the base of a large chimney. As these pots are very difficult to make, and of uncertain durability, the tank furnace, heated by gas, has come into general use. This type of furnace is provided with a tank in which the ingredients are melted, and from which the molten mass is drawn. There are usually several of them in operation at one time, and all are worked without interruption, new material being fed into them at one end as the supply of melted glass is drawn out at the opposite end.

Window glass was formerly made entirely by hand labor, but in recent years machines have been introduced. In the old way there was a man especially trained for each part of the operation. The "gatherer" dipped a long iron blowpipe into the white-hot molten glass. Skillfully twisting this about he formed on the end, as you might twist syrup on a toothpick, a mass of the substance weighing from twenty to forty pounds. This ball of melted glass he spun round and round in an iron mould until it assumed the shape of a great pear. Then he passed it on to the "blower."

The blower, by a process of clever blowing through the tube, with now and then just the right kind of a circular swing, shaped the mass into the form of a cylinder, sometimes as long as himself. Allowing it to cool somewhat, he would hold the end of the cylinder in the furnace, blow into the pipe, and then cover the mouthpiece with his thumb. The exhaled air, thus imprisoned, and expanding with the heat, would split an opening in the end of the glass cylinder, which the blower would enlarge by revolving the end swiftly in the furnace. As soon as the hole was as large as the diameter of the cylinder, and the mass had cooled to a cherry-red heat, an assistant would detach the glass from the blowpipe, and the cylinder would be cracked lengthwise with a red-hot iron or a diamond on a long handle.

The opened cylinder, with the split side up, was then placed on a fire-clay table which revolved in an oven. The heat soon flattened the cylinder into an irregular surface. This the next workman, the "flattener," smoothed out with a tool made of an iron rod, to each end of which a block of wood was fastened. The smoothed sheet was next placed in the coolest part of the furnace, and was afterward removed to the cooling stone. When rigid enough to be moved, it was carried to the annealing chamber.

Annealing is a process of "tempering" the glass, or making it tougher, so that it will not break readily when subjected to sudden changes of temperature. The glass is slowly heated until the melting point approaches; then it is very slowly cooled, this process taking place in a chamber having various compartments of different degrees of heat.

Plate glass is the most expensive form of window glass, and is made by a special process. The ingredients are melted in huge, open vessels, some of which have a capacity of almost three tons. These tanks rest upon frames behind fire-clay doors. When the melting has reached the required stage the tank is drawn out by a great fork mounted on a truck, and is rolled to the casting table. There it is hoisted by a crane, and the contents poured in a fiery, livid stream upon the metal table. A heavy roller spreads out the mass evenly to the desired thickness, whereupon it is placed in the annealing chamber and left several days. It comes out in the form of rough plate glass, and must be polished before it can be sold and used. Polishing is done by means of grinding machines which rub the surface with sand, emery powder, and rouge, first on one side and then on the other. In this process almost half of the thickness of the plate is worn away, but when it is done it is surely a beautiful sheet of glass, clear, as smooth as smooth can be, and sparkling in its brightness. Its thickness is then from one-fourth to three-eighths of an inch.

To make glass stronger, for places where it is subjected to jars and strikings, some reinforcing medium is often employed, which adds greatly to its durability, though affecting to some extent its transparency. One of the most used methods is to make the glass up of two sections, with a wire netting cemented between when the glass sheets are soft and "tacky." Such glass may crack in short lengths when exposed to severe shocks, but it cannot fall out in chunks like common glass, and it is much employed as a fire protection around elevator shafts, in windows close to machinery, and in basement windows where exposure to blows is always imminent. A more recent method is that of manufacturing the glass with a sheet of transparent celluloid in its center. Such glass is even stronger than the wire screen variety, since practically every atom of the glass is securely attached to the tough, flexible compound of the celluloid, rendering it essentially break-proof. This kind of glass is now much used in automobile curtain lights.

A large part of the ordinary glassware that you see in the stores and on your neighbor's table is made by pressing into that shape when the glass is in a soft condition. The press consists of an iron mould which contains the design of the object to be made, and a plunger which is worked by a lever. The gatherer sticks his iron rod into the molten glass in the furnace, and brings out a large lump on the end of it. Some of this is cut loose and forced down into the mould by means of the plunger. It rapidly cools, the piece of glassware is removed, and is then put into the annealing furnace. Some articles are made in two parts. In manufacturing a goblet, for instance, the bowl is shaped in one press, the stem in another, and the two parts are then softened where they join, and connected. A good deal of the more expensive tableware is made by blowing. In many factories machines operated by compressed air take the place of the human blower with his sturdy lungs.

Cut glass is the most expensive and ornate tableware in use. Often the object is cast in a mould, but as often it is blown. In either case its plain surface is then marked with the chosen design. Then it is held by the workman against a steel wheel with a sharp edge. This wheel whirls at great speed, being kept wet with a small stream of water, mixed with hard sand, which assist greatly in making the cuts smoothly and deeply, without burning. It takes a skilled cutter to follow some of the intricate designs found on the costliest pieces; but there are some men who are so expert at the wheel that they can form very beautiful patterns as they work, having no guide except their own artistic conception and unerring hand.

After the design is cut the article is held against a wheel of sandstone, which also has a sharp edge around it in its middle. This wheel smooths the rough edges of the cuttings, and also runs in water. Next a wooden wheel, fed with pumice-stone, gives a smoother finish and final polish to the article, whose newly cut crevices are then cleaned out by means of a delicate brush made of spun glass. How strange that sand, the main ingredient of glass, should be used to grind and cut the manufactured substance, and that fine glass itself should be found the best thing for giving the cuts their final cleaning!

In making a glass bottle the operator takes a mass of molten glass from the furnace, swabbing it around a long metal blowpipe. In small shops he usually blows through this tube with his mouth, but in large factories most of such work is done by pneumatic machinery. When the mass of liquid glass is blown into a pear-shaped object, it is placed in a red-hot mould the size and shape of the article to be made. Here the blowing is continued until the pressure of the incoming air forces the soft glass into every little crook and cranny of the mould. It is then slowly cooled, and removed from its close-fitting metal jacket, which parts in the middle. Should there have to be lettering or a design of any kind on the bottle, this is made in the mould and is cast into the glass at the same time the bottle is shaped.

Glass is colored by the oxides of various metals; that is, molten metals which have had a certain amount of oxygen injected into them until a distinct color results. In this manner iron produces a pale yellow or a pale green; manganese gives us a pretty pink and an amethyst-violet. Copper produces a deep green or deep blue of great richness, but by adding a reducing agent a beautiful ruby-red color is imparted to the glass. A still finer ruby glass is formed by using gold in place of copper oxide. A pretty blue is produced by cobalt oxide; a milky white by tin oxide, calcium fluoride, or bone-ash; and many delicate tints are formed by combinations of the various coloring substances.

The exquisite stained glass windows of many great churches are made up of numerous pieces of different-colored glasses. These have been cut very carefully to match various sections of one large design, and when fitted together by master workmen they produce an effect of outline and harmony of color that is bewitchingly mellow and beautiful, especially when the sun or bright skies from without reflect a strong light through them. On cheaper ornamental windows the colors are painted on them, and burned into the glass.

During the World's Columbian Exposition, held at Chicago in 1892, an exhibition of spun glass created wide attention. So fine were these tiny threads of glass that they were woven into cloth from which a dress was made for the Queen Regent of Spain. White silk constituted the warp, and glass the woof. The fabric was woven on a hand loom. Such spun glass is made by melting a glass rod in the flame of a blowpipe, and drawing the melted thread over a wheel which revolves at a high rate of speed.

The iridescent effect seen in the frost work on Christmas cards is produced by fine flakes of glass.

Another interesting use of glass may be seen in the collection of "fadeless flowers" at Harvard University. In this rare collection there are some 800 large sprays and clusters, and over 2,000 magnified parts of flowers. These were originally real flowers, but by some secret process of a German chemist they have been coated with a very thin layer of silvery glass, which not only holds them up into lifelike position but preserves them against all change in color or substance.

VIII

LITTLE LUMPS OF CLAY

CHILDREN know clay best as the substance from which marbles are made in factories, and from which certain handiwork is modeled in the schoolroom. Brawny workmen know it best as the material from which brick and tile are formed. Mothers know it best as the stuff from which their pretty china tableware and other articles of household pottery are ushered into the world. Sculptors know it best as the substance from which they model their first statues and statuettes, before casting the beautiful finished forms in plaster of paris and bronze. Farmers know it best as a valuable soil when properly mixed with other earths.

Little lumps of clay—how plain, how common, how homely; and yet how very valuable to us all!

When clay is dry it is very hard and compact. When moist, its particles stick together, and this makes it possible to mould it into any form desired. If moist clay is subjected to an intense heat it will bake almost as hard as a stone, but will crack easily under a sudden blow.

Clay is composed of silica and alumina, and may contain small quantities of iron, calcium, magnesium, potassium, and sodium. Most clay is formed by the decomposition or rotting away of rock containing feldspar. It varies in color from nearly white to gray, dark blue, and red, according to the nature of the ground in which it is found. If it contains iron it usually turns red when burned. This is why we have red brick, red tiling, and red pottery ware.

Porcelain clay, or kaolin, is usually white or light gray. Potter's clay and pipe clay are similar to kaolin, but not so pure, and are used in making the cheaper grades of pottery. Fire clay will withstand intense heat. It is used for lining furnaces, for smelting iron, and for making fire brick and crucibles. Tripoli and "fuller's earth" are kinds of clay which are easily made into a fine powder; the former is sometimes used for polishing purposes, while the latter is sold on the market, under fanciful names, as an inflammation reducer in the ills of mankind. Clay is also used in the manufacture of soap, in putting the glazed surface on some kinds of paper, in the manufacture of paint, for adulterating food, and for making filters.

Bricks are one of the most important kind of things made from clay. The story of the brick is an interesting one. It carries us back into the days of the remotest past, when Egypt was the center of what little civilization then existed. According to the Bible, brick making was the principal task of the captive Israelites in Egypt. There was a plentiful supply of clay and sand on the banks of the river Nile, also water in the stream itself with which to mix the substances, and usually an intensely hot sun to bake the bricks. These might have been made of just the water and sand and clay, but even in that day the Egyptians had learned the need of some reinforcing medium to make the bricks stronger; so for some time they had been using straw mixed in the compound. When the captives clamored for straw, therefore, it was not for making fires with which to bake bricks, but for laying in the brick mixture and weaving it closer together, in the same way that steel wires and rods are placed in great concrete walls of to-day, and horsehair in plaster.

The Chinese employed bricks for buildings many centuries before the Christian era. The Romans introduced the industry into Britain and other conquered territories. At the present time bricks exist in England which are stamped with the initials of Roman brickmakers who lived many centuries ago. A well-built brick house will outwear a wooden one many times. The first brick building in America was built in 1633, on Manhattan Island, from material imported from Holland. At the present time, wherever there is suitable clay, and building is to be done, there springs up a brick-making plant to take care of all needs.

The first thing necessary in the making of good bricks is a clay free from fossil remains, and one containing little iron or lime. If sand is not already present in the clay in the proportion of one part of sand to two parts of clay, enough sand must be added to secure this relation. The clay and the sand are first mixed into a pliable mass by the addition of water. From this body the bricks may be moulded by hand, or they may be moulded and cut by machinery. Machines which will make over 100,000 bricks a day are now in general use. From the trough in which the sand and clay are mixed the material is forced through tunnel-like openings the size of the brick. This long column of clay emerges from the machine like meat from a mincing machine, and steel wires come down upon it and cut it into proper lengths, as you might clip off sections of a cotton string with scissors, as fast as it could be unwound from a ball.

The clay bricks thus formed drop down on endless belts which carry them to the drying sheds. After the bricks are dried long enough in the open air to "set" them, they are sent to kilns to be hardened. In these kilns they are piled in hollow squares in such a way that the heat of a big fire in their middle will penetrate them and convert the plastic clay into a stonelike substance. The firing takes from six to ten days. During this period bricks for ordinary building purposes are kept at a cherry-red heat. Others for finer purposes are raised to almost a white heat.

A harder form of brick is that used for paving purposes, and usually called "vitrified brick." To make these hard enough to withstand the wear of heavy traffic, lime is added to the clay and sand. During the burning process, the lime fuses and renders the bricks extremely firm and durable. "Facing bricks" are those which occupy exposed and prominent positions. They are more elaborately finished, more uniform in color, and are sometimes glazed by a special process in which salt is thrown on the flames, while the article to be enameled receives a coating of the burned salt.

Tiles and pipes, baked in the same way as bricks, are extensively used for drainage purposes. These are usually formed in moulds, the clay being rammed in by a plunger. When fairly dry they are removed from the mould, and later go to the kilns for final burning.

Another substance which is made of almost the same materials as brick is terra cotta. To make this, fire brick, bits of pottery, partly burned clay, and fine white sand, are ground to powder and mixed very thoroughly. This mixture is moulded, dried, and burned. Until recently all terra cotta was of a yellowish brown color, but now it is made in gray, white, and bronze, as well. Terra cotta is an ornamental form of brick, and goes a long way in beautifying a dwelling or business structure. It is usually used as a veneer, or outside facing, to walls, etc., covering much coarser and cheaper materials.

One of the fine arts handed down through the centuries is that of making vessels of clay. To this art is applied the name *ceramic,* derived from a Greek word meaning *pottery.* Clay containing the right amount of moisture can readily be worked into a plastic state which will admit of its being fashioned into almost any shape desired. When dried the clay becomes hard and firm; when subjected to intense heat it becomes still harder.

The simplest forms of pottery can be made with a few crude tools. Therefore, primitive peoples have always attained a good degree of skill in making earthen dishes. Some of the finest specimens of the ability of these persons are found in the examples of Indian pottery discovered in the pueblos in the southwestern part of the United States. Even the descendants of these peoples produce, by fine skill of the hand, wares of the most exquisite beauty of pattern.

The first step in the making of pottery starts with the preparation of the material. Clay of various grades is used. Before grinding, any hard substances, such as pebbles and bits of rock, are separated from the clay. During the grinding, proportions of fine sand, feldspar, or flint, may be added. The proportions of these ingredients determine the sort of ware to be made.

Vessels are fashioned in moulds, sometimes by hand, and sometimes with the aid of machinery. The potter takes enough clay for the vessel he is to make, and throws it on the center of a horizontal disc called the *potters' wheel.* Sometimes this is turned by hand, sometimes by foot like a bicycle, and sometimes by steam, or electric power. In either case the speed of the wheel is easily regulated. With moist hands the workman punches and scrapes at the soft vessel as it whirls round and round before him on the wheel. If a hollow vessel is desired he fashions the clay into a cone, then presses upon the apex with his thumbs, till gradually the revolving lump of clay is brought out magically, right before our own eyes, into the most beautiful, symmetrical specimen of pottery. The finishing touches are put on with tools of wood and leather; then the vessel is placed in the drying-room to harden.

At the present time revolving moulds, called "jiggers," are used in practically all large manufactories, and they greatly increase the output. Plates and saucers are made by placing the mould for the upper side of the article on the wheel; then pressing the clay down on it, next laying over the clay the mould which forms the bottom, the moulds being so adjusted that a uniform thickness is secured for each plate.

Vases and many other hollow vessels of fine ware are now made in moulds of plaster of paris, applied in sections so they can be easily taken apart. This is the casting method. The mould is filled with a thin mixture of water and clay, and allowed to stand until a layer of clay is deposited on the sides, when the mixture is poured out. The porous plaster of paris absorbs the water, leaving the shell of clay. When this has sufficiently hardened the mould is taken apart. The most delicate wares are made by casting.

If you should mould something in clay, and let it harden in a natural way, you would find that it will again absorb moisture—perhaps at a time when that is the last thing you wish it to do; for moisture causes the vessel to become soft and weak again. So to prevent this reabsorption of moisture the manufacturers heat their products to a high temperature in a great oven called a "segar." A number of these ovens are stacked in a kiln, one above the other. The "firing," as it is called, lasts from thirty-six to forty-two hours, during which the ware is so hot that it looks almost white. Before it is removed from the oven it is allowed to cool slowly by a gradual shutting off of the heat. When it is removed it is called "biscuit."

This process has hardened the clay vessel to a surprising extent, but the surface is still comparatively rough, and has many tiny pores in it which do not look well and which would prove unsanitary lodging places for food particles should the dishes be so used. To fill these pores, and at the same time to apply a smooth, glossy surface to the dish, which will make it easier to wash and keep clean, a coating called "glaze" is put on. For glazing various substances are employed, including lead oxide or litharge, powdered feldspar, flint, white clay, paris-white, and other substances. The glaze compound is ground to a very fine powder, then mixed with water. At this stage it is known as "slip," and is about the thickness of cream.

If you were to watch the workman you would see him dip each article in the big tank of slip, then set it aside, next to many others, to dry. Here, in the course of a short time, the water in the slip evaporates, causing the coating to thicken and harden. To hasten this hardening process, and make the finish as glossy as possible, the ware is next put in a firing kiln for the second time in its brief history. At first the kiln is not very hot, but gradually the operator increases the temperature. At its highest point he lets it stand a while; then as slowly as before, he begins to decrease the heat, the ware cooling by degrees. Sudden changes in temperature would crack and blister the film. The firing changes the glaze to a beautiful transparent gloss which brings out clearly any figures which may have been placed on the ware proper.

Some of the very prettiest pottery owes its appeal to its splendid color effects. These colors are not in the clay itself, but are mixed in the glazes. One part of an urn or vase may be dipped in a glaze of one color, and another part of the ware dipped in a glaze of another color. And sometimes the glaze is poured on in an oven, and the flow stopped by heat, which produces the most bewitching shaded effects.

Designs and decorations are put on with brushes by hand, either before or after glazing. If put on afterward a third firing is necessary, in order to set them and make them lasting. Glazing is usually the finishing operation, and when the ware comes from the glazing kiln it is ready to be packed and sent off to the stores for public use.

Pottery making is one of the oldest of arts. Scientific men of to-day who have dug up buried cities in the Old World, have probably learned more about the degree of civilization of the former inhabitants through specimens of ancient pottery than by any other single clue; for there is practically no decay to good earthenware vessels. The early Egyptians, Assyrians, and Babylonians were very expert in making pottery, as were the Greeks and Romans, who followed in the art. The Chinese and Japanese are famed for the delicacy of their clay products. Ware from Holland, France, and Great Britain is much prized for its pattern and durability.

In the United States no attempt was made to manufacture pottery on a large scale until 1825. Since then the industry has steadily increased until now the yearly output is close to $35,000,000, and our wares compare well with the best.

XIV

"THE SALT OF THE EARTH"

IF you wish to know what an important thing salt is in the world, you can quickly convince yourself by the very simple test of asking your mother to put no salt in any of the food she cooks for you for a couple of weeks, and also place none on the table for you to use. You really can not understand fully just how tasteless and wretchedly flat your food will seem until you have gone through this experiment, and you will straightway thank your lucky stars that there is such a thing as salt, and make up your mind to appreciate it for its full worth in the future.

Of course we do not know exactly, but it is extremely doubtful that we could live long if there were no little grains of salt. Scientists tell us that without salt we would care very little about food, and it would actually have very little man-building energy in it for us besides. We would soon grow thin, our smooth bodies would become harsh of skin and covered with scurvy, and our faces and limbs would turn a repulsive sallow color. Without salt we could not have the preserved meats and fishes which the markets sell us. It would be missed in the manufacture of soda ash, sodium carbonate, and caustic soda. Soap manufacturers would wonder what to use for hardening their toilet soaps; potters would be in a quandary to find a substitute for glazing their coarser wares; glassmakers would have a merry time to find something as good for improving the clearness of some of their glass. Farmers would miss it sorely, because it has proven a first-class fertilizer, attracting and holding moisture, and setting free the inert plant life in the soil. They would also miss it as an essential food-tonic for their cattle. And what a sad fix wild animals would be in without it! for all such yearn for salt as we yearn for drinking water, and travel great distances in order to find a salty spring from which to lap, or a "salt lick" upon which to scrub their tongues.

When cereal and vegetable foods began to be used by people, many centuries ago, salt became a necessity. But in those days it was very difficult to obtain, as everybody thought the salty spots on the surface were the only places to get it, and that these springs were special gifts from the gods. They never dreamed of securing it from the ocean, or digging down into the earth after it, where it lay in some sections in large quantities. So few were the salt springs that the ancient Roman historians tell us the German

BLASTING IN A SALT MINE

tribes fought fiercely for the possession of them.

Salt was used by the early Hebrews and other Semitic peoples, and by the Greeks and Romans, in their offerings. By them it was undoubtedly regarded as a symbol of purity and faith. The "covenant of salt," mentioned in the Old Testament, was one which could not be broken, as salt stood for things everlasting. Christ spoke of his disciples as "the salt of the earth" when he referred to their spiritual influence in the world.

Among the Orientals of the present day, as well as the past, salt used at a meal is representative of friendship and hospitality; hence the Arab phrases, "there is salt between us," signifying friendship; "to eat of a man's salt," or to partake of his hospitality; "to sit above the salt," or in the place of distinction. In Persia a man who is said to be "untrue to salt" is accused of disloyalty.

Salt and incense were of vast importance in developing the ancient highways of commerce. The salt of Palmyra and Tadmore built up the extensive trade between the Syrian ports and the Persian Gulf; the great Salt mines of northern India were the center of a wide trade before the time of Alexander the Great; a caravan route united the salt oases of the Libyan desert; and to the present day the traffic in salt forms a large part of the caravan trade of the Sahara. One of Italy's oldest roads, the *Via Salaria,* is the route by which the salt of Ostia was carried up into the Sabine country.

Cakes of salt were anciently used as money in parts of Abyssinia and Tibet, and salt taxes existed both in ancient and medieval times.

Fortunately for the world there are few things more generally found or cheaper, to-day, than salt. The ocean, which occupies approximately three-fourths of the surface of the globe, holds inconceivable quantities of the valuable saline mineral. This has been carried, in part, into the seas by the rivers which empty into them, and the rivers have absorbed it from the salt deposits that exist here and there in the earth's surface. The remainder of the ocean's salt is absorbed from beds of the substance on the oceans' own floors.

On land, underground and surface deposits of salt alike are found the world over, and some great inland bodies of water are saturated with this simple substance, which they are ready to yield at the demand of the salt-gatherer. There are not many such inland salt lakes, but the three or four which do exist are quite remarkable as compared with ordinary fresh-water bodies. Here in the United States we have one of these in Great Salt Lake, in Utah, which every year is a source of keen interest and wonder to thousands of tourists. This remarkable body of water stands at the head of its kind in this country for its great salt density, having more than twelve per cent of pure salinity. So heavy with salt is it that it is almost impossible for a person to swim far; but how easy it is to float! Just stretch yourself out and lie on your back, serene and confident, and you will float like a chip. If you could attach a sail to yourself you could be your own sailboat, and go skidding about without the least effort on the part of hand or foot. When you come out and let the sun dry you off, the evaporating water on your body will leave little grains of salt as a memento of your strange experience. No one could sink in Great Salt Lake if he wished to ever and ever so hard. Everybody is safe from drowning.

The Dead Sea, in Asia, is recognized as the most fully impregnated with salts of all the bodies of water on the face of the globe. More than one-fourth of its bulk is salt. But chloride of sodium—the chemist's name for common salt —is not the dominant salt, chloride of magnesium forming more than sixteen per cent of the salty content. The Caspian Sea, the largest landlocked body of water known, and Lake Balkash, and the Sea of Aral, are other salt lakes of Asia, all notable for their strong saline quality.

At one time almost all the common salt of commerce was produced by gathering and evaporating the salty waters of the inland lakes we have named and those of the great oceans. The fact is, considerable quantities of salt are still obtained in this way from San Francisco Bay, Great Salt Lake, and the waters along the seaboard countries of Southern Europe. Since there are about three-eighths of a pound of salt in each gallon of sea water, it has been estimated that, if the Pacific Ocean were to dry up, or be gathered and boiled up in great kettles, it would yield close to 4,419,000 cubic miles of solid salt. If this were spread out one mile deep it would more than cover the entire continent of Europe.

Salt is obtained in ways that differ as widely as do the localities where it is found. Perhaps the most picturesque and interesting of all the salt-gathering industries is found in our own country.

Away down in Southern California, in the middle of the Colorado desert, about one hundred miles from the ocean and eighty miles from the Mexican boundary line, is the little station of Salton, on the Southern Pacific Railroad. It lies between the San Bernardino and the San Jacinto ranges of mountains. Here the valley sinks to a level more than four hundred feet below the level of the sea, making it the most depressed spot in the United States. Should these mountains and the surrounding country settle a little by a movement of the earth's crust, which may happen any day, the Pacific Ocean will flow over and fill in this strange valley, making it once more its own, as it undoubtedly at one time was a part of this great body, for it has been comparatively recently cut off from the ocean by the delta of the Colorado River.

In this remarkable depression, and only a short distance to the south of Salton, is a field of crystallized salt more than a thousand acres in extent. When the sun shines on this great crust of white, it scintillates like a world of diamonds, fairly blinding the eyes of those not used to the sight. The field is growing constantly, for all around it numerous salt springs are flowing down from the surrounding hills, draining into the basin, where they rapidly evaporate, leaving fresh deposits of almost pure salt. This film of white covers the entire area like the frosted crust of a gigantic cake, and it is all the way from ten to twenty inches thick.

The Salton field is worked by a company of men who own the tract and employ a number of laborers to gather the salt for the market in a very unique manner indeed. First the crust is plowed by a heavy steel share which makes a broad and shallow furrow, one following another, leaving high ridges of the plowed-up material between, as a farmer plows his ground. The plow is not pulled by horses, however, but by a sturdy little locomotive, which runs on two tracks at right angles to the furrows, and which pulls the plow along by means of two steel cables running through pulleys just behind the engine.

As the plowshare cuts into the salt, brine from the springs oozes up into the furrows. Laborers with hoes follow after the plow, work out the earthen particles in the salt by chucking it in the water, and stack up the clean white crystals in conical heaps. These men are Coahuila Indians, the only ones who can be hired to do the trying work, as the temperature is 140 degrees on the average, and furthermore, dark glasses must be worn to protect the eyes against the almost intolerable glare of the white field. The air, laden with impalpable tiny particles of salt, creates an intense, burning thirst which the workmen find it impossible to satisfy with the lukewarm, alkaline water of the artesian well, 900 feet deep, their only supply of drinking water.

When the mounds of salt in the field are well dried out by the hot California sun, broad-tired wagons carry the salt to flat-cars which, in turn, transport it to the mill in Salton. Here it passes through grinders which crush it up into a uniform powder. It is then sifted and sewed up into sacks by Japanese workmen.

Out of this field of 1,000 acres of virgin salt, not more than ten acres are worked at this time. Yet from such a small portion about 700 tons can be plowed and shipped every day. As fast as the crust is removed a new one forms. Thus the supply seems practically inexhaustible.

Under certain atmospheric conditions this salt field displays remarkably perfect examples of the phenomenon known as the mirage. Beautiful flowering fields, crystal-like lakes with wooded shores, and even towering cities and pretty cathedrals and castles, appear in most deceptive form.

The greater part of the world's salt, however, is produced from what is known as "rock salt," that is, salt which has been obtained by going down into the earth after it, either by means of wells or mines. The well method is the easier one of the two. Here holes are drilled far down until the salt is struck, much the same as in making an artesian well. The hole is cased by piping, and water is often pumped in to dissolve the salt just below the pipe end. Once dissolved and in the form of a brine, steam pumps suck it up through the pipe. It is then put in great kettles and evaporated by fires underneath, or it is placed in large vats out in the open air, where the winds and sun dry up the water, in a somewhat slower but less expensive manner, and leave the clear salt remaining. Most of the rock-salt in the United States—even in Michigan, which is the greatest home producer—is secured in this manner.

England is the chief salt-producing country. Her counties of Cheshire, Staffordshire, and Worcestershire, are noted for their fine saline deposits, especially. Droitwich, in Cheshire, has been celebrated for its "wyches," or salt springs, ever since the Roman occupation, and the word salary (latin, *salarium*) is due to the fact that salt was once made a part of the Roman soldier's pay.

Salt has been made in England from natural brine springs for centuries, but the mining of the rock-salt deposits, through which water must flow in order to become salty, is a comparatively modern industry there. The splendid Cheshire beds were discovered in 1670 by men boring for coal, and have been mined ever since. The salt is so hard sometimes that it has to be blasted with gunpowder. It is curious, but coal, oil, and natural gas, are often found close to salt. In China there is a remarkable salt spring from which sufficient natural gas escapes to provide a fuel for evaporating the brine.

Vast as are the English deposits, those found at Wieliczka, in Galicia, Austria, are a close second in productiveness, and really superior in the way of extent. The remarkable formation and capaciousness of these workings make them the most famous in the world.

Just imagine, if you can, a region under your feet where there is a solid mass of salt measuring 500 miles in length, 20 miles in breadth, and 1,200 feet in thickness! For nearly eight hundred years men have been hacking away at this immense bed of salt, and although their labors have left a veritable underground city, they have made only a comparatively wee, wee hole in the enormous bulk of white which constitutes the "ground" in that vicinity.

In a coal, iron, silver, lead, copper, or mercury mine, you may see many strange and curious sights; but none can compare with the wonderful sensations you will experience when you visit the underground salt city at Wieliczka. It is one of the "show-places" of Europe, owned by the Austrian government, and is often visited by official heads. From the very beginning these salt workers seemed of the opinion that it would be just as easy to form a pretty chamber in their mine as an ugly one, while they went about their task of gleaning the milk-white crystals. Anyhow, instead of merely digging for the sake of digging, like miners elsewhere, they formed their chambers and aisles and slopes into the most entrancing architectural effects. And with such an eye-intoxicating, soul-stirring substance as this beautiful snow-like salt to work in, no wonder that, as their labors grew, they became proud and enthusiastic, and that the public at large opened their mouths and stared in delighted wonder.

Thus day by day, week by week, month by month, year by year, decade by decade, century by century, from a single pretty chamber this strange mine of Wieliczka has developed into a regular city of beautiful booths and vaults, arcades, amphitheaters, parks, boulevards and winding avenues, arches and bridges and balconies and stairways, all embellished with crystal-white statuary, shrubbery, and other forms of decorative art. Young miners have grown old, with frosted hair and beards, in this ambitious work of creation. Aye, they have died in the harness, as white as the crystals about them, while sons and grandsons took up the tasks they had laid down. And all so that you and I may witness what man can do while engaged in a homely commercial enterprise.

As we go down into this rare underground city, where electric lights and candles cause prismatic hues of sparkling light to radiate from countless tiny facets of salt crystals all about us, we are struck speechless with awe and admiration. We go through and pass silent chapels that speak eloquently of angels and heaven and other pure things, then across an altar, into a dazzling ball-room, around graceful pillars, and by richly garnished throne—all hewn from the solid salt-rock. Salt staircases lead us from one floor to another, from balcony to street level, from marvel to amazement. Chandeliers of the same sparkling white substance hang from ceilings here and there. What statesman is this, standing in statuesque ermine, just at our right elbow? God's cleanest snows could not be more white than that splendid horse, with alert ears and majestically held head, over by the wall yonder. Let us sit down in this fine salt chair for a little rest, and look around a bit. Everywhere is salt, everywhere is sparkle. But the salt does not seem to be salt. It is too beautiful, too throbbing of life, too unusual of shape, to be salt. Surely, we think, it must be the "earth" of which all fairyland is made; and this about us is that fairyland!

Altogether the mines have a length close to three miles along the bed, and there are eight levels. In the topmost three are the sights which tourists delight in viewing; the levels below are for "business only." Many of the horses used in transporting the salt to the shaft are born underground, and have never seen daylight. These animals are practically blind, but have, by instinct or development, a wonderful sense of location.

About a thousand miners work at Wieliczka. They exercise such care in making their excavations that accidents are very rare, although in the history of the mines some terrible disasters are recorded which have resulted from fire or the flooding of the mine by a subterranean lake. On account of the whiteness of everything around, the galleries are much better illuminated than the average coal mine. The air, too, is kept very pure by its contact with the salt, so that both men and animals enjoy good health. At the end of the day the miners ascend to the surface in "lifts," or elevators, and when all are up the shafts are closed and locked.

You would hardly think that salt is a commodity worth stealing, or that the owners would object if a miner did take away from such a vast storehouse a few meager pinches of it. But in that country salt is a taxable commodity, and it appears that at one time so much of it was smuggled out in miners' boots and pockets that every man was thereafter searched when leaving work, just as though he were an employe of a gold or diamond mine. The practice is still continued, although in a perfunctory way, as the miners are now too well paid to be tempted to augment their income by theft.

Near the entrance of this famous mine stands a block of buildings—the offices of the manager.

Here visitors are first received, provided with a guide, and asked to pull on a pair of overalls to protect their good clothes while exploring the subterranean passages. The outfits worn by Royalty, as may be expected, are of a superior character, and each time they are worn are carefully labeled with the name of the wearer and the date of the visit.

You can descend in two ways—by a hydraulic cage, or by a staircase hewn out of solid salt. When you begin to get into the real levels of the mine there bursts upon your view a little world of such fantastic ermine beauty that you are quite sure, for a few moments, you are either dreaming or gazing upon the work of genii and fairies. You behold a spacious plain containing a strange little whitewashed city, with houses and roads, all scooped out of one vast mass of salt rock. It is, everywhere, as bright and glittering as crystal, while the blaze of lights continually burning is reflected from the dazzling columns which support the lofty arched vaults of the mine, in a manner most bewitching. These arched ceilings are tinged with all the colors of the rainbow, and sparkle with all the luster and richness of precious stones. Your guide, from time to time, as you go along, manipulates the numerous lights to give you the best effects. For the highest figures, all the electric lamps and candles in the vicinity are lighted. To show the remote corners, fireworks in the form of colored flares and rockets are utilized.

The first level is 216 feet below the surface. It contains the famous Letow Ballroom, which was excavated over a hundred and fifty years ago. Here many festive gatherings, presided over by the Emperor, have been held. At one end of the room is a colossal Austrian eagle, with transparencies painted on slabs of salt. In an alcove at the other end of the apartment stands a throne of green, the crystals of which flash out rays of weird green and ruby-red. It is on this throne that the Emperor has always sat when he visited the mines.

Close by is St. Anthony's Chapel. Even older than the Ballroom, this ornate chamber dates back to 1698. It may be considered the religious center of the queer underground city. Legends say that it is the work of a single miner. Be that as it may, one thing is sure: it was an artist as well as an indefatigable worker who conceived and wrought that beautiful interior. The walls and altar are embellished with many fine carvings, all executed in salt. The character of these blends in spirituously with the snow-like tone of the whole apartment, giving you a peculiar, sweet sense of rest under the subdued artificial lighting system. Would you believe it? they hold "real" regular services in this Chapel; and on the 3d of every July there is a special mass, attended by scores of people, some of whom come long distances. Then there are other shrines and temples. Perhaps the finest of these is Queen's Chapel, which, in addition to its splendid altar of salt, exhibits on one wall a realistic view of Bethlehem, carved in salt, while overhead hangs an elaborate salt chandelier.

In the second level you will come upon the Michelowitz Chamber. This is an immense room approximately ninety feet square, with a ceiling 118 feet up. The chamber has remarkable acoustic properties. You can utter the lowest whisper, and a friend at the farthest opposite corner will hear your words as though his ear were at your very lips.

The third level contains a salt railway station. Here the twenty-five miles of mine tracks have their upper terminal. It is as busy a little station as you will find at a good-sized junction town above ground almost anywhere in the country. There are always miners and visitors waiting on the salt platform or in the salt seats in the station, for a train to come or go. At the same time others will be found in the restaurant-room, partaking of refreshments and chatting gaily. When you hear the rumble of an approaching train in the tunnel near by, hear its wailing, echoing shriek, and note its twinkling lights coming toward you and growing bigger and bigger like expanding eyeballs of fire, you shrink just a little closer to your guide, then laugh at your foolishness as nearness makes the coming monster take on a familiar, friendly aspect.

In strong contrast to the "dry" features of the mine, there are sixteen subterranean lakes which lap salty shores within its confines. Of course these bodies are all intensely salty, and while people bathe in them the water is not fit to drink or use for cooking. The larger one of the lakes is navigated by a ferryboat, which is hauled from shore to shore by means of a rope.

XV

SOME RARE MINERALS

THE world's minerals are constantly changing, constantly becoming something else. Therefore from a comparatively few "raw" materials to begin with, the world is able to find these substances in various stages of development, each stage having its own peculiar value to the peoples who unearth them and make use of them. But that is not all. There are many of these ores which would be absolutely without value when used alone, and their wonderful possibilities never would have been known had not man experimented with them in his laboratory, and made scientific investigations, as a result of which he found that by mixing or alloying them with other mediums he could produce something of great usefulness to his fellow-beings.

For instance, the miners who worked the Comstock silver mine (which we have spoken of elsewhere), in its early days, threw on the "waste dump" the mineral *cerusite,* a lead carbonate which is now valued at more than a thousand dollars a ton. In this and other Colorado metal mines, the early miners, not knowing what they were doing, threw away the valuable tungsten portion of their ores. After the same manner, it was not until quite recently that pitchblende was known to contain those important constituents, uranium and radium, the latter especially valued to-day for its wonderful usefulness in the treatment of the malignant diseases which afflict people.

Altogether there are two values placed upon a mineral—scientific and economic. The scientific value depends largely upon the scarceness or rarity of a mineral. The economic value, on the other hand, depends wholly upon the usefulness to mankind of any part of a mineral. All rare minerals have both a scientific and an economical value. Some of the more important of these will be considered in this chapter.

Aluminum

Some years ago there was a college boy who read about an interesting metal called "aluminum," which had been discovered in France. A French chemist, by taking common clay which exists in vast quantities almost everywhere, had succeeded in producing by some secret means a wonderful metal with the strength of iron, the toughness of copper, and almost the lightness of pine wood. This aluminum was said to be by far the lightest of all known metals. It was of a whitish color, with a faint tinge of blue, and looked much like tin. Moisture could not make it rust, however, like tin and iron. The boy read that the new metal had been used in France for making jewelry, and that a rattle made of it had been presented to the baby son of the Emperor of France as a great rarity.

This college boy, whose name was Hall, thought by day and dreamed by night of this strange aluminum, made from so simple a substance as clay—or alumina, as the scientists love to call clay. The papers said the cost of producing aluminum was $90 a pound. The boy knew this was too costly a process ever to make the metal really useful, for common people could never afford to buy it. So he wondered if some new way could not be found in which to take clay and produce the same result by a cheaper method.

When this young man graduated, even the pleasure of receiving his diploma could not keep his mind away from aluminum. In fact, an idea came to him, and he obtained the use of the college laboratory, and set to work. For almost a whole year he tried mixing clay with various substances in an effort to produce the desired result. But it was no use—there was no aluminum. At length he tried a stone from distant Greenland called "cryolite," which had already been used for making a kind of porcelain. This stone melts very easily. To his unbounded delight he found that the clay and the cryolite fused together in just the manner he wanted, when he passed an electric current through them, the molten clay melting the cryolite, the clay being decomposed by the current. At the negative electrode, the compounded molten aluminum ran down to the bottom of the crucible, and here young Hall was able to draw it off through a tap-hole. The positive electrode was composed of heavy carbon plates or cylinders, and here oxygen was set free.

Triumph had come at last. This young man, just out of college, had not had his dreams in vain. Dreams and hard work together had performed the miracle, just as they will ever perform miracles in the future for those who apply them properly. A process had been discovered, in this particular instance, for reducing the cost of aluminum production from $90 to 20 cents a pound. What a benefaction to man!

Only a few months later a Frenchman, who had also been quietly working away at the same problem, made the same discovery. This man—Heroult, by name—obtained patents in his own country, while young Hall covered the rights in the United States and Canada.

The clay from which aluminum is made is now called "bauxite," and in this country is found chiefly in Georgia, Alabama, and Arkansas. Mining it is much more agreeable than coal or iron mining, for all the work is done above ground, as sand or gravel is taken out of the quarries you have seen.

When bauxite is purified the result is a fine white powder which is pure alumina, consisting of the unformed metal, aluminum, and the gas, oxygen. Aluminum element is found not only in clay, and indeed in most rocks, except sandstone and limestone, but also in several of the precious stones. In fact the oxide of aluminum is known to the chemist as "alumina," to the mineralogist as "corundum," to the jeweler as ruby and sapphire, and to the lapidarist as emery. We may stake a good deal that you never imagined before that the tiny jewel bearing in your watch which makes it run so accurately, the grit in the wheel on which you sharpened your chisel in the manual-training room of your school, the material of which your mother's choicest kitchen metal-ware is made, all came from the simple clay which children in the kindergarten pummel about into various images.

The uses of aluminum are constantly increasing. It is a good conductor of electricity, and sometimes takes the place of copper wire in the construction of electric lines. The top of the famous Washington Monument is covered with a thin sheet of aluminum, which is connected with a lightning rod, to protect the monument from destruction during thunder storms. A single ounce of the metal, put into a ton of steel when the latter is being poured out, will drive away the gases which often make little holes in castings. Mixed with copper it makes a beautiful bronze which has the yellow gleam of gold. When a piece of jewelry which looks like gold is offered to you at too low a price to be real gold, the chances are that it is aluminum bronze, very pretty at first, but very likely to tarnish and lose its luster before long. Aluminum also alloys splendidly with silver. Mixed with a very little bit of the precious metal, the whole mass looks like silver and will deceive most people.

With so many good qualities and so few bad ones, it is small wonder that aluminum is employed for more purposes than can be counted. Thirty years ago it was an interesting curiosity, but now it is one of the most-worked metals. Automobiles and air-planes owe much of their success and efficiency to it. Engine cases for them, frames, gear cases, fenders, hoods, bodies, all owe their light features to its employment. Travelers, soldiers, and campers, prefer aluminum dishes to those made of heavier materials. Strange as it may seem this accommodating material is even used for "wallpaper," threads of it being combined with silk to give a specially brilliant effect in stage settings. Equally as strange, it can be made into a paint which will protect iron from rust, and woodwork from burning so quickly.

Tungsten

You probably know tungsten best for its use in the filaments of modern incandescent electric lamps. When made of this valuable metal, the filaments are twice as durable as the old carbon filaments, give a much superior quality of white light, and consume less than half as much electricity. Thousands of filaments can be made from a single pound of tungsten, so that while we know the metal best in this way, its use therein is really quite limited compared to its other applications.

For example, tungsten salts are utilized in the arts. Tungstate of sodium is used in photography. Tungsten is employed for fireproofing theater curtains, cloth, etc. It is also used in dyeing, being a powerful mordant which forms an insoluble compound with any coloring matter, and holds it within the tissues of the fabric.

But the chief economic use of tungsten is as an alloy with other metals, such as iron, aluminum, steel, etc. An alloy of aluminum and tungsten, known as "partinium," is used in the construction of airships and automobiles. It was much employed by the Germans in the late war in the construction of the great frameworks of their Zeppelins.

An alloy of tungsten and its sister metal, molybdenum, is a good substitute for platinum, and for some purposes is said to be better.

The most important as well as the most general use of tungsten is as an alloy of steel. This metal is to the steel industry what copper is to the electrical world, and possibly even more. Steel containing 5 to 6 per cent tungsten is very hard and tough, though still workable. By putting 10 per cent in it the steel is rendered so hard that it cannot be worked in a lathe and must therefore be forged or ground to shape. Tungsten steel is highly magnetic, not easily rusted, and requires no tempering or annealing. A machine equipped with tungsten-steel tools will do more work than five similar machines using carbon-steel tools. Tungsten-steel drills, by holding their temper when red-hot, can be run at many times greater speed than ordinary drills. For bridge building and the erection of modern sky-scraper city buildings, tungsten-steel has been found to be the most dependable for girders.

The World War gave a great impetus to the use of tungsten. Steel made of it was used in the manufacture of high-powered siege and field guns; it was employed in hardening armor-piecing shells, and in producing armor-plate for tanks and war vessels.

Tungsten is not found as a pure metal. The truth is, if you were to know the metal by sight and feeling ever so well, you would not recognize, in the fine gray powder from which it is made, any connection or relationship. To form the solid metal the powder is reduced with aluminum filings, and also by fusing with charcoal in special furnaces. The metal thus produced is of a steel-gray color, malleable, but hard enough to scratch glass. It is not easily acted upon by mineral acids, and is stronger than either iron or nickel. It is so ductile that it can be drawn into the finest wire.

Tungsten is classed as an "acid mineral." The principal basic elements associated with it are calcium, iron, manganese and lead. In the beginning, when tungsten minerals were discovered in 1781, they were thought to exist in only a few favored countries, and within a small area; but during recent years they have been found in almost every mining country on the globe. However, no vast deposits have been unearthed anywhere. As a rule the deposits are very spare, occurring in small stringers of the pure minerals, or in lodes carrying other metals or minerals.

It takes about 3,080 degrees C. to melt tungsten, which is one of the highest melting points required by any metal.

Platinum

This metal was first taken to Europe in the year 1735 from Colombia, South America. Being a white metal, resembling silver in appearance, it was called *platina* in Spanish, *plata* being the Spanish name for silver. It is, however, much heavier than silver, and is with the exception of two extremely rare minerals, iridium and osmium, the heaviest of all substances known. It is fusible with other metals only with great difficulty, and is very resistant to acids.

These latter properties make the metal invaluable for the construction of certain kinds of chemical apparatus, such as crucibles, basins, wire and foil. Platinum is of rare occurrence, and owing to the very limited supply, the price is constantly rising. At one time during the late war it went as high as $100 an ounce, but is now somewhat lower, owing to increased supply and a falling off in demand. Formerly the metal was made into coins in Russia, but this soon ceased as the value of it mounted far above that of gold.

Native platinum is found as grains and small nuggets in the beds of streams. Practically the whole of the metal used commercially comes from the Ural Mountains. So ductile is this extremely heavy substance that it has been drawn into wire so fine that a mile's length weighs only a single grain! It is largely used in the manufacture of fine jewelry, in making electrical, photographic, dental and surgical supplies, as well as munitions of war.

Radium

While radium is a metal it is never found or prepared in metallic form. It can be reduced to this condition, but there would be sure to be some loss of the constituents, as the substance oxidizes rapidly, and is soon lost in the air, vanishing like a ghost. As the mineral has such a fabulous value, and is so hard to get even in the smallest quantities, chemists must do everything in their power, you see, to prevent any loss of material.

For this reason radium is usually prepared either in the form of chloride or as a bromide, which conserves the element so that it will last indefinitely and without any apparent loss. It is very difficult and dangerous to handle because of its wonderful and mysterious penetrating powers, the cause of which no man has yet been able to explain, trained in science though he be. In its pure state, looking much like salt and equally as harmless, it is one of the biggest deceivers that ever was. It will quickly destroy the life in seeds. Should you take a tube containing it in your bare hand, though it never touched you its intense violet rays would cause ugly and painful sores to appear on the hand.

Radium gives off a slight light, but its real activity is learned only through the effects it produces. It gives off enough heat to melt its own weight of ice every hour, or to raise its own weight of water from the freezing to the boiling point. When a tube of radium is placed on a surface coated with sulphide of zinc, or some other similar substance, the surface becomes luminous. It discharges electrified bodies, and makes any gas on which it acts a conductor of electricity. If a photographic plate is wrapped in black paper, and an opaque object, such as a penny, is coated with radium and laid upon the paper with the coated side up, a picture of the penny will be made upon the plate.

Altogether, radium is easily the most wonderful and costly metal which old Mother Nature has let us get our fingers on in the pocket of her rugged apron. It is valued at $9,000,000 a pound. A glass tube of this substance, which is no larger around than a straw, and no longer than a pin, is worth $4,000. Very recently the State of New York purchased two and one-quarter grams of radium, in behalf of the State

Institute for Malignant Disease, at a cost of $225,000. The metal is to be used by the Institute in research work and the cure of some of its patients. It took twenty-one cars to carry the 625 tons of carnotite ore, from which this small amount of radium was gleaned, from the mines in the Colorado desert. An equal bulk of coal and chemicals was employed in the process of extraction.

Carnotite occurs with pitchblende in Paradox Valley, Colorado, in amorphous masses. It is a new mineral, named after the French scientist, Carnot, and is mainly confined to the limits of the United States. Its color is a rich yellow or orange. It usually occurs in white or gray sandstone, and is often found with copper or silver ores. Quite the opposite in looks is pitchblende. This is an ugly black mineral bearing some resemblance to pitch. It is remarkable in having strong radio-active properties; that is, it is constantly emitting invisible rays of light, which make the air a conductor of electricity. For instance, if a piece of pitchblende is placed near a charged gold-leaf electroscope, the charge of electricity rapidly escapes, and the gold-leaves fall together.

It was these peculiar properties of pitchblende which led Professor and Madame Curie, the discoverers of radium, to separate from the ore the particular elements—radium and polonium—to which these special effects of pitchblende are due. This was in 1898, in Paris. The most productive mines of pitchblende are those at Joachimsthal, in Bohemia, although it is also found in some of the Cornish mines. The feldspar quarries of southern Norway produce it in small cubic crystals, embedded in the feldspar.

But carnotite has become in the last few years the chief ore supply of radium, and the whole world looks to our own Colorado and Utah for most of this valuable mineral.

The manufacture of radium is a long, tedious chemical process, complicated by many difficulties, and requiring special care and skill. Previous to 1912 there were no laboratories for its production in the United States, and the carnotite was sent to Europe. In that year the United States Government established a laboratory at Denver, and since that time this institution has successfully extracted such radium as we have used, employing new and better processes than those which had existed heretofore.

The action of radium upon the tissues of the human body makes it a valuable agent in the treatment of cancer in its first stages, for the removal of scars, warts and corns, and in the treatment of that form of goiter which causes the eyes to protrude from their sockets. The radium may be applied directly to the part to be treated, or it may be given internally in diluted solution. But it is safe only in the hands of experts who understand its whims through long experience.

Mercury

"Quicksilver" is the common name for the element mercury. It is a silver-white metal, 13.5 times heavier than water; it flows freely, and when spilled is about the most difficult thing to recover you ever saw, evading the touch of everything except that on which it lies. It is the only metal which is a liquid at ordinary temperatures. At 37.9 degrees F. below zero it freezes and becomes solid; at 675 degrees F. it changes to vapor. When heated or cooled it expands or contracts quickly and at a very regular rate. For this reason it is especially valuable for making thermometers, and mirrors, in which guises it is probably most familiar to us.

Mercury is most extensively used for extracting gold and silver from ores. But it is also used extensively in the arts. Its compound with chlorine is widely used as a medicine under the name of "calomel." Another compound with chlorine is the well-known and exceedingly poisonous "corrosive sublimate," often used as an antiseptic. "Vermilion," another compound, with sulphur, is used in some red paints. Mercury is largely employed also in the manufacture of explosive caps, both for blasting purposes and in the production of cartridges used in small firearms as well as large fieldpieces. Dentists use it, electricians value it, barometer manufacturers could not get along without it. And what would the mirror makers ever do without it?

Mercury occurs native, but only in small quantities. Most of it is taken from the ore cinnabar, which in a pure state contains 86.2 per cent of mercury and 13.8 per cent of sulphur. The crystals of cinnabar are often transparent with a deep-red color and brilliant luster. The mercury occurs in the ore in the form of little globules of liquid embedded here and there in its surface.

Mercury is obtained by roasting the ore in a current of air. This heating process drives off the sulphur, which combines with the oxygen of the air to form a gas, thus leaving the mercury free. Spain, Mexico, and the United States produce most of the world's supply. The chief mines of this country are near San Francisco.

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