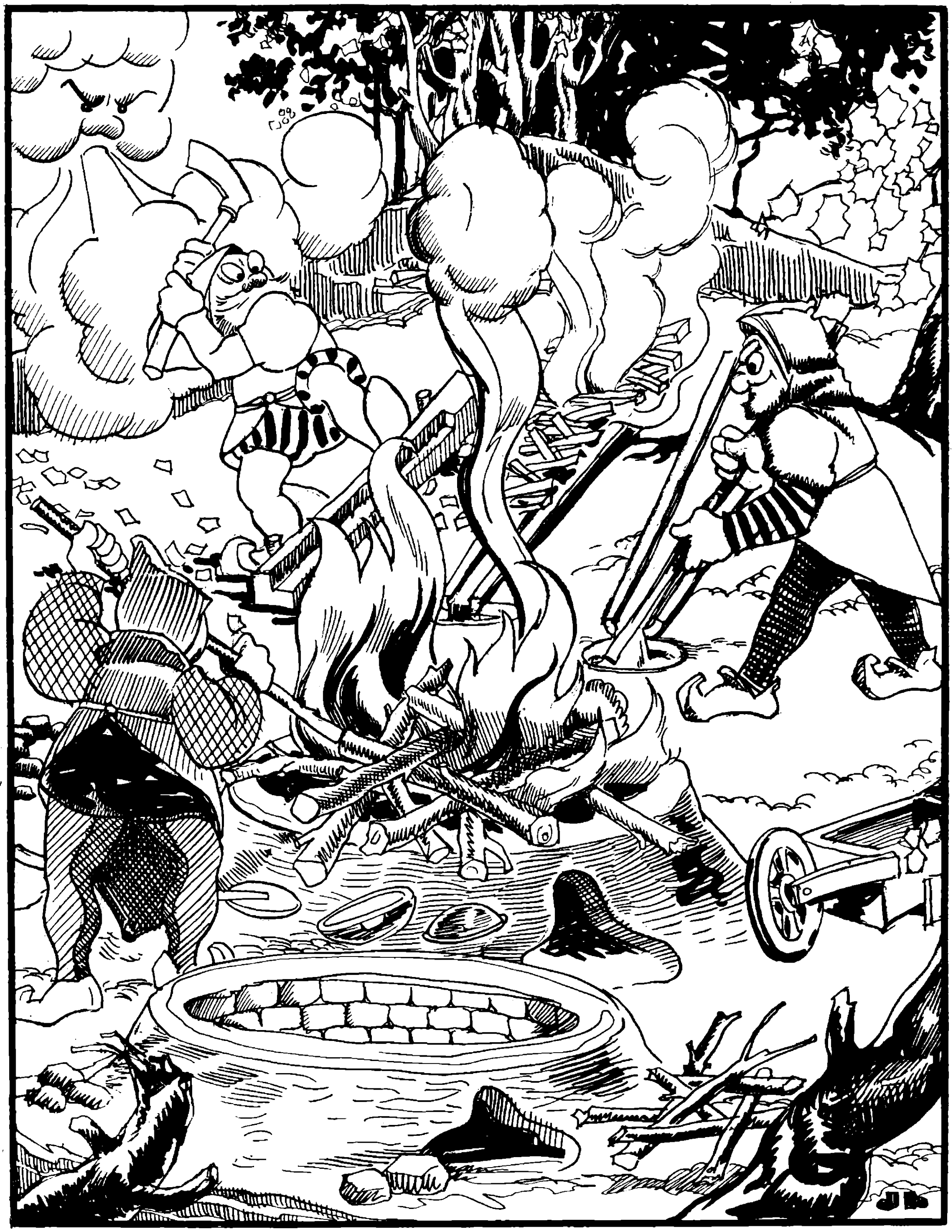
MYSTERIES OF MINING

This is the twelfth in a series of features describing various interesting phases of mining and the mining industry.



Primitive smelting was carried on in this fashion; the early metallurgists took advantage of prevailing winds to fan their flames into high temperatures. Drawing adapted, with variations from "De Re Metallica", by Agricola.

SMELTING

Probably the most important discovery ever made by man was that of the use of fire to fashion metals. Until this most vital discovery was made, the Age of Metals did not start; up to that time primitive man treated his pieces of native gold, native silver, or native copper as soft stone, to be shaped by belaboring it with his stone hammer, and not by melting it into the desired forms.

The discovery, when it did come, was the result of an accident, as were most of the advances achieved by primitive man. History does not tell us exactly how smelting originated (the reducing of metals from their ores through the use of furnace heat), but various authorities have made good guesses.

One theory is that the first smelting of copper was caused by the ignition of an oil seepage that came in contact with an outcrop of copper ore in the Caucasian region. Another authority is of the opinion that an Egyptian lady inadvertently dropped a piece of malachite (copper carbonate) paste, a cosmetic, into the charcoal fire of a brazier. A third version is that a primitive man, dropping his flint knife into a camp-fire, observed drops of molten copper shining in the ashes.

It would seem, then, that the art of metallurgy (the science and art of preparing metals for use from their ores) was born at the edge of the campfire; primitive man used fire in that way most frequently, and it is more than possible that in a copper-bearing region enough copper would be reduced to its metallic state to suggest to the relatively undeveloped mind of the observer that he "had something".

It is impossible to exaggerate the tremendous importance of the recognition of this basic fact in metallurgy. The discovery that metal could be separated from the rock by melting in whatever way it happened, was a momentous step in man's conflict with nature. The prehistoric savage that first saw the little lump of molten copper in the ashes of his camp-fire could not foresee what this portentous nor could he have imagined the tre-

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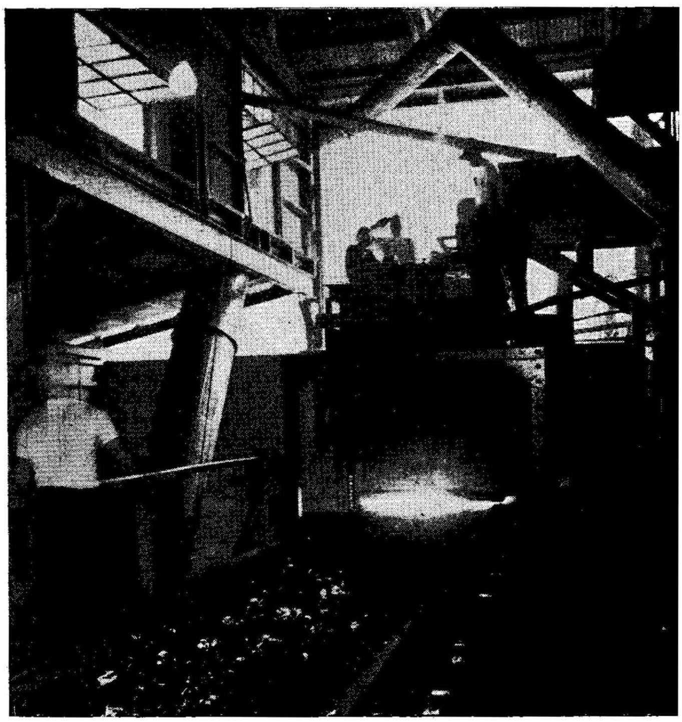

Sintering hearth at the Philippine Smelting Company plant at Mambulao, where modern smelting is used on refractory ores and concentrate.

mendous train of industrial progress it would start; but we, who look back along the dim vista of the ages, may well be amazed at the consequences. At first the smelting of metals for the making of better tools enabled man to clear the forest more rapidly, to grow bigger crops, to build better dwellings, and to construct safer boats. That, however, was only a beginning: the use of copper led to the use of other metals, and thereby gave the means for making instruments of precision for the scientific investigation of the secrets of nature. With the smoke of that lonely camp-fire in the remote past there rises the vision of achievements unbelievable, of devices to assist human muscle, of bridges thrown over gulfs of space, of steel roads that thunder with the traffic of continents, of whispering wires that flash the news of the day round the earth, of other metallic threads that bring the energy of the mountain torrent into the innermost chamber, of many-storied towers that top the tallest trees, of boats that mock the vagrant wind and dive beneath the restless wave, of machines that fly above the mountain crests and thread the clouds of heaven, of all that brought man from the darkness of the jungle into the glory of the sunlight, from savagery into civilization.

The camp-fire may be regarded as the first metallurgic hearth; the next step was to make a hole for the collection of the molten metal; this hole, sooner or later, was lined with clay, the fire-resisting quality of which had been proven previously by the baking of pottery; the clay would keep the metal clean; later still the hole in the floor of the hearth was enclosed by stones, which were ranged in the form of a wall; and so a furnace was evolved. Rudimentary furnaces invariably are holes in the ground filled with ore and wood, or charcoal. In Japan, fifty years ago, the furnace for smelting copper, tin, and lead ores was "a mere hole in the ground", and recently similar rudimentary furnaces have been found in use by the natives of central Africa and the Malay peninsula. It was a fortunate coincidence that the fuel used by primitive man to generate his heat was also an effective chemical agent for reducing his oxidized ores to the metallic state. Our pioneer metallurgist eventually ascertained that carbonized wood, that is, charcoal, was ignited more readily and gave a fiercer fire than ordinary wood; so he burned his twigs and branches under a cover of earth, to carbonize them without exposing them to complete combustion, the result being a brittle fuel that he could break easily into pieces suitable for his furnace.

The first product of the primitive smelting of copper ore was a spongy mass of metal, incompletely fused and containing extraneous matter; this was hammered with stone, to liberate the cinders and bits of unreduced ore, thereby obtaining a lump of impure metal, which, as was learned ultimately, could be refined by being returned to the fire and re-melted. The lumps of copper recovered among prehistoric remains are such as would be smelted in a hole in the ground about one foot in diameter, and the operation was conducted somewhat as follows: a fire of charcoal was started in the hearth-furnace; upon this fuel was spread a layer of ore, followed by alternate layers of fuel and ore in quantity sufficient to yield a lump of copper that when hammered made a cake 8 to 10 inches in diameter and about 1 ½ inches thick. When the smelting was completed, the slag, or vitreous refuse, was removed and the metal allowed to collect on the bottom of the hearth, from which it was extricated when it had just become solid, at which stage copper is peculiarly brittle and readily broken under the hammer. The copper was then detached and shattered on a stone into pieces convenient for hammering into the needed tools. This was done before the introduction of casting enabled the early artificer to obtain the requisite shape in a stone mould. The absence of sulphur in the prehistoric copper proves that it was smelted from ores containing either the native metal or from ores thoroughly oxidized, and therefore free from sulphides.

After a time the primitive metallurgist grasped the idea that the copper would run, like fat or wax, when placed in a hot fire; next he noted that, on cooling, the molten metal, like fat or wax, retained the form of the surface on which it was poured. So the idea of casting originated. It came slowly, arduously, incompletely, as to a little child, not with the flash of intuition that is characteristic of a trained mind. When the idea of casting was apprehended it gave purpose to the melting of the copper. At first the casting took the form of thick sheets in open moulds of sand, as the earliest copper adzes suggest, for these according to Petrie, are flat and of almost uniform thickness except at the edge, where they were both shaped and hardened by hammering. A mere impression made in sand or clay gave place in due course to an ingot-cavity sculpture in rock, the shape of an axe or a spearhead being carved in a stone of uniform grain. From the ingot-cavity the primitive metallurgist advanced to the idea of a hollow mould, and when the sides tended to collapse, in concave lines, he developed lugs intentionally. In Crete, during Minoan times, the copper was cast in thick plates with four lugs, one at each corner, to facilitate handling during transport. After the metal had been poured into the mould, it cooled, the consequent contraction releasing it intact. When the primitive metallurgist had learned how to rid the copper of sundry obvious impurities, such as clinker and slag, by subjecting it to another melting operation, he caught the idea of preventing the inclusion of such impurities by performing the refining in a special container of clay similar to the hole in which the first smelting had been done; and, just as he had deepened the cavity in his hearth, to make it more capacious, so he now deepened his shallow clay container until it ceased to be a dish and became a pot or crucible. Thus the use of clay for lining the hole in the ground that served as the first metallurgic hearth led to the making of a fire-proof container of clay in which the refining of the metal could be performed more cleanly and more completely. In the Katanga the natives use the ant-hills, or termite cones, as the material for their copper furnaces, this aluminous earth having the qualities of a fire-clay.

The primitive metallurgist soon noticed that the wind caused his fire to burn more freely, and thus in due course the effect of a draught was appreciated. Fans, made out of tough grass or rushes, may have been used for the purpose at first, as is done today by the natives in western Africa. Later, the hole or hearth was placed on the windward side of a hill, and a trench was dug into the slope, to conduct the air from the fire, this upward trench serving as a chimney. Much of the cinder or slag from the making of iron in Roman Britain lies on the tops of the hills, suggesting, therefore, that natural currents of air on windy slopes were utilized as a blast in the reduction of the ore. It is probable that some of the earliest copper furnaces were like those used for extracting bismuth from its ores in the sixteenth century, as described by Agricola. A trench, in sloping ground, was filled with brushwood, on which logs were laid. The wood was set on fire, and when the trench was full of glowing embers the ore was shoveled upon them. More wood was added at intervals. The molten metal ran into a hole at the lower end of the trench, which was so placed as to be in the path of the prevailing wind, this being the only blast used in the operation. Pryce tells us of the remains of ancient tin hearths in Cornwall, these consisting of mere holes in the ground, in which a charcoal fire was started before the tin ore was added, to be reduced by aid of the blast from a bellows. Primitive man learned early how to obtain pulsation of air by means of alternate influx and compression in a bag made from the hide of the animals he killed for food. Such use of a bellows is depicted on an Egyptian tomb bearing the name of Thothmes III, of the eighteenth dynasty, in the fifteenth century B.C. The bellows, two of them, fitted into frames, were worked by the feet, the operator standing with one foot on each of them; he pressed the inflated one while he pulled up the other, which was deflated, by means of a string that he held in his hand. In the Belgian Congo the natives make their bellows, for the reduction of copper ore, out of two sacks of antelope skin, each of these having an opening of two inches at one end, and at the other a transverse aperture eight inches long, the lips of which are rendered rigid by means of bamboo rods sewn to the hide. This aperture serves as a valve, which is opened and shut by the movement of the operator's hand; he lifts the bottle and at the same time admits the air, which he forthwith compresses; then he closes the valve and expels the air at the other end through a tube made of wet bark into the furnace.

Next Month: MODERN SMELTING.