Miners and Their Work Underground

F. M. Holmes

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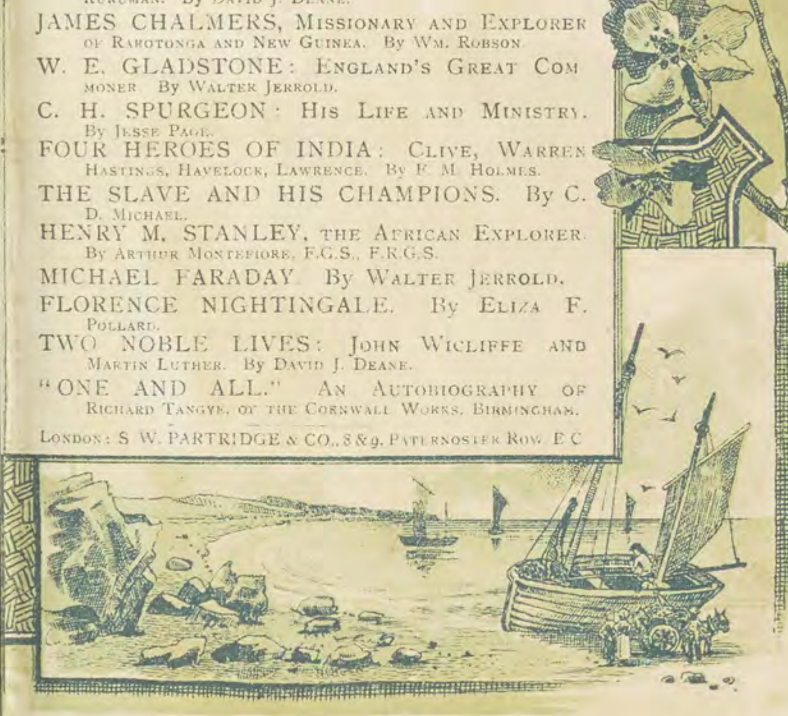

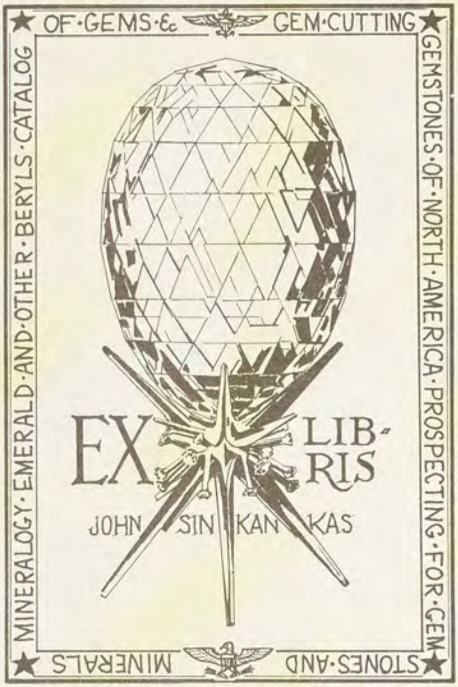
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ALLUVIAL WASHING AT THE SOUTH AFRICAN GOLD FIELDS.
(*From a photo by Coney.*)

MINERS AND THEIR WORKS UNDERGROUND:

STORIES OF THE MINING OF COAL, OF VARIOUS METALS, AND OF DIAMONDS.

BY

F. M. HOLMES,

AUTHOR OF "ENGINEERS AND THEIR TRIUMPHS," "CHEMISTS AND THEIR WONDERS," ETC.

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PREFACE.

THE object of the present volume is to present, in a purely popular and non-technical manner, some of the extraordinary developments in the mining of coal, and of various metals, and of diamonds, during comparatively recent years. No attempt is made to deal exhaustively with this large subject; but the idea is simply to gather up some of the more salient features, and to indicate a few of the leading principles,—including also a glance at the past history of mining,—and to weave these into a more or less connected narrative.

Mining is one of the earliest arts known to man. No one can tell at what remote date some individual, perhaps more intelligent or more inquisitive than his fellows, picked up a piece of mineral from the sand of a stream, or from the outcrop of a vein on the mountain side—it might be a glittering grain of gold or a piece of oxide of tin—and having become possessed of it, proceeded to make use of it and to search for more.

Many a mine, even in later days, has been discovered by accident, and in the following pages numerous stories have been collected to illustrate the fact. The old superstition of the divining rod has also played its part. But Science also has had its word to say, both from a geological and from an engineering point of view; and the invention of the diamond drill, and the facility it gives of boring test-holes deep in the ground, has placed in the hands of man a more perfect means for the discovery of minerals than the world has previously known.

The profession of civil-engineering has been of signal service to mining; so much so that a subdivision of the profession has arisen, known as mining-engineering; while the assistance rendered by the chemist, not only in the invention of the safety-lamp, but also in such departments as the blasting of the mineral and in the efficient and economical separation of metals from their ores, has been very great. Thus, chemistry, geology, and engineering have all helped to make mining what it is to-day.

Throughout the centuries, one advance after another has slowly been made, and one great difficulty after another has slowly been overcome, until now men can conduct their underground labours hundreds of feet below the pit bank, and extend their workings for miles around their main shafts.

To trace out the story of such developments, free from technicalities, but recognising the great amount of human effort and of ingenuity displayed, is the endeavour in the following pages.

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DIGGING FOR DIAMONDS.

TOWNS UNDERGROUND;

OR, THE STORY OF THE COAL MINE.

CHAPTER I.

A FRUITFUL ADVENTURE.

"HA' your husband come hame yet?"

"Na. Ha' yourn?"

"Na. But I ha' heard o' na explosion and na accident."

The two women looked anxiously at one another, and then glanced round at the chill January morning. They were standing at their cottage doors and wondering why their husbands, who had been engaged on night duty in the coal mine near, had not returned to their homes.

Others soon joined the two; and it presently became evident that none of the men employed on night duty at the pit had been seen at their dwellings. What could be the reason?

Then suddenly some one came with news. The beam of the pumping engine had broken, and the shaft was blocked!

"Oh! na gas—that's a blessing!" one poor wife would sigh.

"And na water!" added another; "there's na fear o' drowndin'."

"They're in the three-foot seam," cried a third, "and they ha' plenty o' food."

"Aye, aye, the day-shift 'll soon git 'em oot. They'll soon be back agin."

And so the good women strove to comfort themselves as they hurried to the mine's mouth. But as the cold winter day wore on and not one worker returned, the hearts of the relatives began to sink lower and lower. Still they endeavoured to hope, and still they refused to believe that the blocked-up shaft could not be reopened in time.

Yet, in the result, scarcely any of the entombed miners were rescued alive! Why was this? Why did such a dire disaster follow the blocking of the shaft?

The accident occurred early in the morning. The night men were being shifted, and about sixteen of them had already come up, when—crash! the beam of the large pumping engine broke in two, and down the shaft fell one piece, smashing and tearing to pieces everything in its way.

The third load of men was just coming to the surface. The cage in which they were being hauled up was broken at once, and four of the men were hurled to the bottom of the pit and died almost directly; the other four clung to the cage, and though one lost his life through a falling timber, three were ultimately saved.

THE RESCUE PARTY DESCENDING THE MINE.

But the others—one hundred and ninety-nine of them, entombed in the mine below—they could not be reached. The rescue party soon found that there were thirty feet of blockage at the foot of the pit. The mass of iron that had fallen weighed about twenty tons, and it tore away the woodwork lining of the shaft and filled up the pit with a mass of rubbish. Furthermore, directly the engine broke and ceased working, water poured into the mine at the amazing rate of one thousand five hundred gallons a minute, and a torrent of water deluged the rescuers as they were at work. The shaft was very narrow, so that but few could work at the same time, and as the rescuers had no secure foothold, they had to be suspended in the shaft by ropes from the pit's mouth.

"They be workin' theirselves," said one. "I can hear their jowling."

By "jowling" he meant the dull, deadened sounds of men at work underground, and these sounds spurred on the rescuers to renewed exertions. But toiling under the difficult conditions upon which they were obliged to work, they could not make speedy progress, and soon grew exhausted.

Man after man was drawn to the surface, dead tired, soaked with water, and even senseless, but others were always ready to step silently into their places and descend the pit of death; for volunteers came up from all quarters to assist in the work of rescue.

Gradually the sounds of the entombed miners grew fainter, and after about two days and nights following the catastrophe, they ceased altogether. Still the rescuers worked on with a dogged persistency which we trust will always remain a trait of the British character.

At length, eighty-four hours after the accident occurred, an entrance was made through the rubbish, large enough for a man to creep through. One named William Adams was the first to penetrate. But when he reached the yard seam, the sight he beheld by his flickering lamplight almost struck him backward with horror. His former comrades were lying before him as if asleep. Some reclined with their arms behind their heads; some reposed on another's breast; some, whom he recognised as fathers and sons, were lying embraced.

He raised the hand of the nearest; it was cold as ice; he drew back, and the hand of his sometime comrade fell on the black ground with a deadened thud, that made the profound silence around seem still more awfully silent. He had come to an underground chamber of death.

The imagination of a sensational novelist could scarce depict a more weird and ghastly scene. The dense darkness of the mine was but feebly lit by the flickering light of his lamp, while around him were stretched the bodies of scores of friends who but a few days before he had seen hearty and happy. He felt completely overpowered, his breath came thick and short, and his limbs trembled.

But bravely he pressed on. Face after face wore the same dread seal of death, and all appeared calm and restful; at length, scarce able to totter, he dragged himself back to the narrow entrance. He had been overcome by foul gas as well as by the terrible sight he had witnessed, and it was some time before he recovered sufficiently to tell his sad tale.

Then the "underviewer" of the mine, Mr. Humble, went down; and with him went Mr. Hall, an official from a neighbouring mine. But they did not remain

WAITING FOR NEWS OF THE ENTOMBED COAL MINERS.

long; they soon saw that the deaths had occurred from carbonic acid gas, which is mercifully speedy in its deadly work.

"All killed! eh, my canny fellows, all killed!" moaned the underviewer, as he came to the surface; and the strong Northumbrian was so affected by the sight of horror he had beheld that he was moved to tears. Mr. Humble was the friend of his men, and for the time being the shock of distress was too much for him.

The grief of the relatives was appalling. There was scarce a house in the mining village over which the angel of death had not spread his dark wings; one inmate or more was missing from well-nigh every humble dwelling; and one poor woman had lost her husband and three sons at this one fell blow. Altogether, two hundred and four were slain, including those who had lost their lives in the shaft through the falling beam. The heart of England was profoundly touched, as it always is on such terrible occasions, and the sum of £81,000 was raised for the benefit of the widows and orphans.

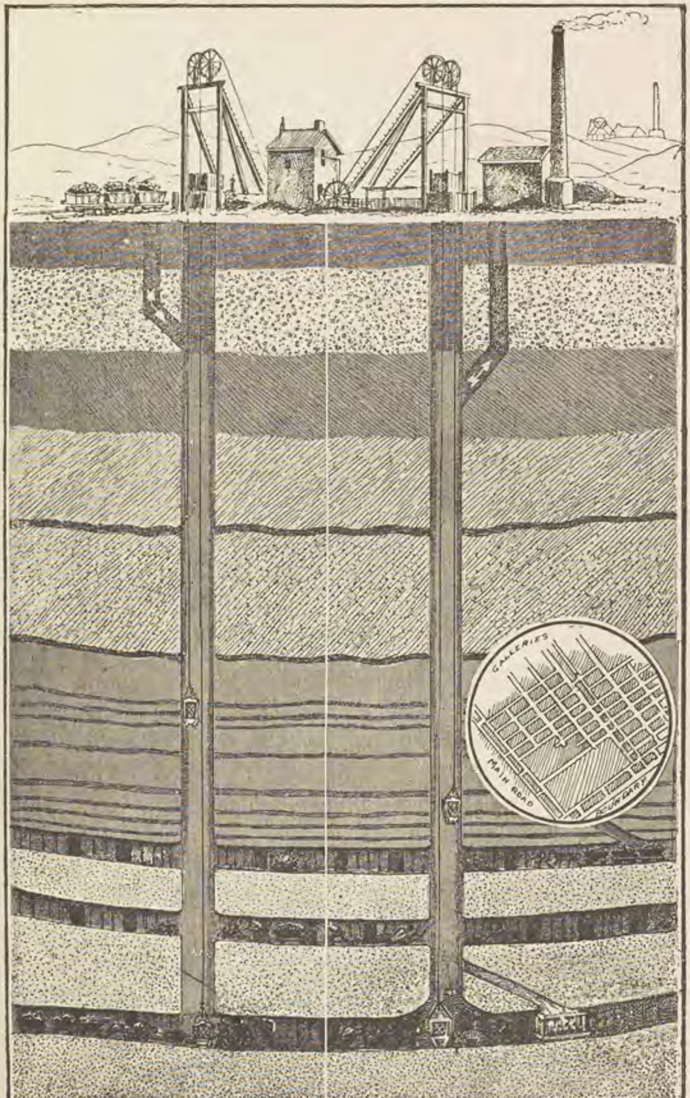
But this shocking calamity, which is known as the Hartley Mine disaster, and took place in January 1862, led to the passing of the Duplicate Shafts Act in the same year. Since that date, mining engineers have been obliged to sink two shafts to a coal mine, and these two are further used for the very necessary purposes of ample ventilation. One shaft admits the fresh air, and is called the downcast shaft; while the other affords egress for the foul air, and is called the upcast shaft. It must not be supposed, however, that no coal mines were furnished with two shafts before this date, for Roger North, referring to the latter part of the seventeenth century, speaks of the sinking of another pit as an infallible remedy for foul air.

Sometimes the mine, or rather its numerous roads, extends for twenty miles underground. The absolute necessity, therefore, of fully adequate means of ventilation becomes very apparent, especially when the mine is what is known as "fiery," that is, when it gives forth the dreaded "fire-damp." In chemical language fire-damp is light carburetted hydrogen gas, and must be distinguished from the carbonic acid gas or "choke-damp," which is also given out in coal mines, and which proved so disastrous to the entombed miners in the Hartley Pit.

The depth also at which mines are now worked is likewise very great. The average depth in Great Britain is 1,200 feet, while Ashton Moss, near Manchester, is considerably more than double that depth —*viz.*, 2,850 feet. The immense size and profound depths of modern coal mines therefore render the ventilation of these widely ramifying workings of surpassing importance.

Before the great use of the steam engine, however, coal mines were seldom, if ever, more than three hundred feet deep. Indeed, in former days, pits were comparatively shallow, and the workings were quite near the pit, so that the terrible fire-damp was scarcely known. But in some of the deep and extensive mines which engineering has constructed in the close of the nineteenth century, the gas hisses and crackles on the coal walls like fire, and, spite of all ventilation, the air is close and warm with noxious fumes.

Yet, so great are the resources of science, that hundreds of men live and move and do their useful work in the mines; and, what is perhaps more sur-



SECTIONAL PLAN OF COAL MINE.

(The circular diagram shows the method of working out the seam of coal horizontally.)

prising, numbers of horses are stabled in the underground workings, and never come up to the light of day, as do the men. The horses live for years in the black coal seams, in good health and without losing their eyesight; though probably the only light which they ever see is the feeble glimmer of a Davy lamp.

Their duty is to haul corves—that is, small trucks of coal—for very long distances, so far do these subterranean roads and cross-roads extend, and to such great developments has coal-mining reached. A deep, widely-radiating coal mine, perhaps a score of miles in size, with all its marvellous appurtenances, is now quite a commonplace of mining existence.

The progress has been slow. We take the Hartley disaster as a convenient standpoint, whence a great improvement may be dated; but mining in some form has existed in Britain for centuries. Moreover, mining has been known in the world from very remote days, for the art appears to be one of the oldest. Thus, there is an ancient Egyptian papyrus dating from B.C. 1400, in the Turin Museum, depicting a gold mine; and the Chinese are said to have bored holes of very great depth ages agone—presumably to search for minerals.

What, then, is a mine? In these days, at all events, it is not simply a hole in the ground, but comprises the deep pit or shaft leading down from the ground, together with the roads, cross-roads, and galleries running therefrom and from one another. And in the term mining is included all the methods employed in obtaining useful minerals from below the earth's surface, and also the various operations necessary to prepare some of them for the metal worker.

Of these minerals, coal was by no means the first. The ancients do not seem to have employed coal, though it is said that the ancient Britons knew something of it, and that the Anglo-Saxons to a certain extent made use of it in domestic life. But apparently the licence granted by Henry III., about the year 1234, to freemen at Newcastle-on-Tyne, permitting them to dig coal, is the first mention of coal-mining in English history.

Wood, with perhaps peat, was doubtless the almost universal fuel then in Britain, and indeed it remained very largely in use for a considerable time. In fact, in the reign of Elizabeth, Parliament interfered to prevent manufacturers—*i.e.*, probably smelters of iron ore—from burning wood, the destruction of trees for this purpose being so great.

But what were those early coal mines like? and furthermore, how came men to know that such a useful mineral lurked below in the earth?

Where does the wonderful story of the coal mine begin?

CHAPTER II.

SMALL BEGINNINGS.

"Take care; that is an old pit there!"

"What, in the side of the hill?"

"Aye, the seam of coal cropped out there."

"Do you mean that coal appeared on the surface of the hillside, and was visible on the surface?"

"Yes, or came very near the surface. Coal you know is really a rock, and just as other rocks appear at the surface, so coal also sometimes shows itself on the ground, if all such seams have not been worked. Some seams, or beds of coal, lie horizontally in the earth, but other veins vary considerably in their slope, and if prolonged far enough must appear on the earth's surface."

"And you think this hole was opened to work a slanting vein of coal, which had cropped out on the surface of the ground?"

"I feel sure of it."

"Oh, then I can see how mankind discovered coal. I

ENTRANCE TO A COAL MINE FROM A HILLSIDE.

have often wondered how it happened. I can imagine now that in Britain, at all events, the old inhabitants, perhaps searching for peat for a fire, found the black, brittle rock, and found also that it would burn.

"Aye, but not having very efficient instruments for digging they would not descend far."

In this way might a mining engineer answer a friend, as they strolled over a bleak hillside in a colliery district. And the conversation suggests an answer to the question, Where does the story of the coal mine begin?

The early history of coal is obscure, but we imagine that coal really discovered itself. That is, certain seams cropped out at the earth's surface at different places, and the inhabitants found that the black stuff would burn. So, gradually it came into use.

Early coal pits therefore, we gather, were really holes in which coal had been dug from the earth's surface, and the seam had been followed down. As to its use, it is said that King John used coal in Windsor Castle in 1213, and also that about this date the monks of Newbattle were granted a coal pit at Preston, Haddington, but no doubt wood was then the chief article of fuel.

Indeed, the use of sea-coal—that is, coal brought by sea—was prohibited in and near London about 1270, and in 1306 a petition was sent by Parliament to the king against it. Nevertheless wood was dear, and King Coal gradually prevailed. The black, brittle fuel appears to have come into general use in London about the year 1400, and Dick Whittington the Celebrated, who was thrice Lord Mayor of London, is said to have traded in coal, which was carried in three-masted vessels called "Cattes"—a point which may throw some dry light of fact on the pleasant story of Dick Whittington and his cat.

But whatever may be the truth, it seems to be the fact that, according to Rymer's "Fœdera," coal first became an article of trade from Newcastle to London in 1381. Though it came into general use in London about a score of years later, it was not until another two hundred years had passed, when the Plantagenets and the Tudors had all gone, and Charles I. was on the throne, that coal became commonly used in England. Probably the difficulties of carriage had something to do with this state of things.

Thus, then, it was not until shortly before the Civil War in the Stuart period that King Coal fully came to his throne in England ; in other words, came into something like common use in the country.

Why? For one reason, it was believed to be prejudicial to health, and when about the years 1270—1300 its use may be said to have commenced in London, it was at first employed in the arts and manufactures ; though we imagine that in coal districts it was used for other purposes also.

But, judging from the fact that wood was then dearer than coal in London—which appears to have been the case—we imagine that the coal of those days was, we say, dug from the "outcrops"—that is, from the seams which appeared at the surface—and that the pits were very shallow. They would form a striking contrast to the wonderful network of extensive roads and galleries of a coal mine to-day.

Were there then no other means of discovering coal besides the outcrops? Were outcrops so plentiful, or did they lead to such large beds, that no other means were necessary to discover coal beneath the surface? That opens up a very curious point in the history of coal-mining. Miners were wont to resort to the divining rod to discover the secrets of the earth ; and though the superstition was slain by Chevreul and others, yet the delusion seems still to be believed in by some miners—not necessarily coal miners—in remote places.

Briefly, the divining rod was a forked stick

—generally of hazel wood, though sometimes of copper, or of iron, or even of brass—by the use of which the presence of water and of minerals was said to be discovered underneath the surface of the earth.

The rod was suspended over the ground in such a position that it could easily move ; as, for instance, the prongs were placed between the fleshy parts of the hands below the thumbs, the stick hanging downward. It was then supposed to incline distinctly to the spot where the mine, or the water, was to be found.

Now, it is believed that when the action of the rod was not due to conscious fraud, it was most likely the result of the mind acting more or less unconsciously through the hands. Probably the person using the rod had observed that coal cropped out at the surface near certain strata, or that such minerals as he desired to find had been found under certain circumstances, and he used the rod in places where such conditions were fulfilled, while in low-lying land, as at the foot of hills or slopes, water may generally be found if a sufficiently deep pit be dug.

We may suppose, therefore, that the divining rod played its little part in the finding of coal as of other minerals, and, possibly, sometimes with success. The experiments being made in a coal country—as might be indicated by outcrops at the surface, or on strata such as had been found near to such outcrops—led to coal being discovered on digging beneath the surface.

For it must be remembered that all minerals—coal included—are found in beds or seams in the earth as well as in veins or lodes ; sometimes, as in the case of gold, these veins are termed reefs. The idea is that coal was once luxuriant vegetation, which flourished in former ages of the earth's history on land slightly above sea-level; that this thick layer of vegetation subsided slowly and became gradually covered with sand and mud. The process continuing, the masses of plants would become heavily covered and pressed hard seam by seam; and the excessive pressure, together with the operation of chemical changes, would mineralise or fossilise the decayed vegetation into brittle, black rock.

The close examination of coal by the microscope shows that it chiefly consists of the cortical parts of plants; that is, the bark, mingled with the remains of other vegetable life, the spores and spore-cases of some lycopodiaceous trees, appearing at times in great quantity. Indeed, the chemical constituents of coal are similar to those of wood, there being, however, much more carbon in coal than in wood, and much less oxygen.

The proportions of the two have been given thus:—Wood,—49·1 (or 50·0) of carbon, 6·3 (or 6·2) hydrogen, and 44·6 (or 43·8) oxygen. Coal,—82·6 carbon, 5·6 hydrogen, and 11·8 oxygen (anthracite coal sometimes contains 94 per cent. of carbon). There are also reckoned to be five kinds of rocky fuel, one being lignite, the chemical constitution of which appears somewhat midway between coal and wood, thus:—carbon 65·7, hydrogen 5·3, and oxygen 29·0. The other "fossil fuels" are coal, anthracite, bituminous shale, and bitumen. For practical purposes in Britain, two chief divisions are spoken of as anthracite coal and bituminous coal.*

* The former is also called Welsh coal or culm, and does not flame; the latter does flame when ignited, and one of its numerous varieties is called Cannel or candle coal.

The dreaded fire-damp is also known as marsh gas, and is developed by vegetable matter decaying, and in touch with water. In process of passing into coal the wood or peat gives off some of its oxygen and hydrogen in the shape of this marsh gas and of carbonic acid, which may afterwards become so deadly to miners.

Further, Sir William Logan showed long since that coal always rests upon beds of hardened clay or shale, in which roots of plants are found; while over the layer of coal is usually discovered a bed of sand or shale called the "roof," and in this roofing, branches and stems of ancient plants are to be seen. Coal is also found associated with limestone. Various kinds of ferns, firs, club mosses, and gigantic reeds are believed to have been the forms of ancient vegetation, the fossilised remains of which are now our beds of coal.

These beds or seams vary from one inch up to even ten or twelve yards in thickness—as witness the celebrated "Ten Yard Coal" in South Staffordshire—and they suggest wonderful pictures of the strange, luxuriant vegetation and marshy jungles which once flourished here, ages and ages ago.

We can now see that masses of coal lie together, and that an outcrop is likely to lead to greater quantities within, or to indicate that a wide seam is nigh ; we can also see that certain strata point to the presence of coal, and the occurrence of these strata probably caused men to search for the fossil fuel.

The sinking of bore-holes yields of course the best evidence to-day. They may be driven for a few feet to test the character of the subsoils, or even to thousands of feet to obtain definite information as to the existence, and value, of coal seams. The boring is accomplished by different methods, the object being, however, the same—to obtain specimens of the soil at different depths. Among the deepest borings may be mentioned the works by the Prussian Government near Merseburg, where the holes were sunk near upon 6,000 feet in the ground, in the search for coal.

Thus, then, we gather that coal first drew the attention of mankind to itself by its "outcrops," or appearance on the surface of the soil ; these outcrops were dug, and probably led to other efforts to discover the existence of the precious mineral, as, for instance, by the observation of the surrounding strata ; while finally—if anything in engineering affairs can be called final—boring is resorted to as affording the best and most reliable evidence as to the presence of coal.

Should the district be hilly and an outcrop found on the slope, a gallery or level may be driven down it ; but in these days, coal mines are frequently met with in flat stretches of country, and thence shafts or pits must be sunk down to the coal seam. And the excavation and preparation of these pits are a very expensive process.

But long before the deep and elaborate mines of to-day were in vogue, an event occurred which may be regarded as a very important point in the history of coal-mining, and as indicating how greatly the industry was developing. Men were leaving the shallow pits of the past, and digging deeper into the mysterious recesses of the earth. And as they did so, they were met by a stupendous difficulty, which threatened to seriously hinder their work, if not to stop it altogether.

A new era in coal-mining was to be born. What was it ?

CHAPTER III.

GREAT IMPROVEMENTS.

"THAT'S main sträange, Bill! What was it, think ye?"

"Aye, they do say 'twas a demon, neighbour; but I know not what to think!"

"There's one mon dead, Bill. But faith, I don't hold with believin' in demons and sich-like in the airth."

"Eh, but there was fire too, neighbour! Jackson said as how there was a flash and a bang like gunpowder, and the men were thrown on their faces with a mighty wind like some great spirit passing—and then they found one mon was dead!"

"Aye, aye, I know; I was there. But I don't hold wi' believin' in demons and ghostes."

"What were it then?"

"That I can't tell jist now. But maybe there's summat in a mine what goes off with a bang, like as there's summat what chokes ye wi' choke-damp. I reckon our mester will find it out."

Whether the "mester" did discover this new demon we cannot tell; but the disaster of which our friends were talking was the first explosion of fire-damp in a coal mine recorded in British history. It occurred in 1676 at Mostyn on the Dee, and must have alarmed and surprised the miners and all connected with mining very considerably.

Hitherto, such a calamity had been unknown. With what wonder then, and what consternation, must the sudden explosion have been received! No doubt, some of the more ignorant and superstitious put it down to the action of evil powers. Others set to work to discover the cause. It must have created some stir, for it was recorded in the "Philosophical Transactions" of the Royal Society.

AFTER THE EXPLOSION.

As a matter of fact, miners were more troubled in those times by the suffocating choke-damp or carbonic acid gas; but we gather that in the days of shallow pits, or holes in the hillside, the danger from either gas was not very great. The remedy for choke-damp was certainly of a very quackish nature, and reminds one of the quackery prevailing about the time of the Great Plague, in 1665. The method was to "dig a hole in the earth and lay the poisoned miners on their bellies with their mouths in it ; if that fail, they tun them full of good ale ; but if that fail, they conclude their case as desperate."

And desperate we fear it was. But now a new terror had arisen, and miners were threatened with the fiery death of explosion. The crash at Mostyn was doubtless the forerunner of others in different places ; and as mines became deeper and the ramifications wider or longer, collections of fire-damp would appear and make their terrible presence felt.

How, then, did the miners of those days meet their new enemy? They pursued one wise course, one foolish course, and often gave up the contest in despair. They introduced a strong current of air, to dissipate the fiery gas, which was of course a sound policy. Another plan may have been efficacious for the time being, but it was undoubtedly dangerous. It was simply to burn the fire-damp by igniting it with lighted candles.

The plan was something like this :—A man wrapped in wet sacking and holding a long pole, to which was fastened one or more lighted candles, crawled along the floor of the mine, and while he lifted the lights to the roof, held his face to the earth to escape the flashing flames that followed.

It is probable also that miners heard the gas hissing from cracks and crevices in the coal, and the workmen may have ignited these, when the gas would burn as in a gas-jet in a room at home. For it is when mixed with air in certain proportions—*viz.*, from one-quarter to a sixteenth of its volume—that fire-damp is explosive.

This plan of the old miners in firing the gas proved impracticable, as may well be imagined, when pits became more extensive; and the consequence was that many mines were abandoned. The miners gave up the conflict as hopeless. Discretion they thought rightly was, in this case, the better part of valour. Thus, the presence of the terrible fire-damp seemed likely to scorch out the growing development of the mining industry. And it was not until the invention of the Safety Lamp by Sir Humphrey Davy, in 1816, that the dangerous difficulty was decreased or removed.

Before this great improvement was effected, however, there was yet another terrible obstacle to be overcome, and one which had shown itself even before fire-damp—*viz.*, water. So, the miner suffered from fire, from water, and from danger of suffocation by choke-damp.

Water no doubt soon began to trouble him when pits were dug of any depth at all; and how did he cope with this difficulty? In two ways. He drove a drain through the slope of the ground from the side or bottom of the shaft, if the ground descended from the level of the pit mouth; or he raised the water by pumps.

In Roger North's delightful "Lives of the Norths," originally issued about 1740, we get instances of both these methods. Speaking in the "Life of Lord Keeper North," of certain coal mines, as they existed about the years 1670-80, he says, "When they are by the side of a hill, they drain by a level carried a mile under ground, and cut through rock to the value of £5,000 or £6,000. . . ." And again, speaking of Sir Ralph Delaval's collieries, he quotes Sir Ralph's opinion, "that chain pumps were the best engines, for they draw constant and even."

We also get a picture of a colliery owner's troubles even in those days. Sir Ralph was at dinner one day when a servant brought a letter, which told of a flood bursting into his greatest colliery.

"'My lord,' said Sir Ralph, 'here I have advice sent me of a loss in a colliery, which I cannot estimate at less than £7,000; and now you shall see if I alter my countenance or behaviour from what you have seen of me already.' . . . He said his only apprehension was that the water might come from the sea; and 'then,' said he, 'the whole colliery is utterly lost; else, with charge, it will be recovered.' Whereupon he sent for a bottle of the water, and finding it not saline as from the sea was well satisfied."

The water it appears was afterwards "drained" by "engines" upon which some £2,300 were spent, and in about six weeks Sir Ralph raised coal again.

The chain pumps of which Sir Ralph spoke, appear to have been constructed by fixing a number of circular and flat pistons working in a barrel, or it might be buckets without a barrel, to a chain which worked round a cog-wheel at the top, and sometimes also at the bottom. The wheel being revolved caused the chain to revolve also, and carry the empty buckets or pistons to the water below, and being filled, brought them to the top, where they could be discharged. The apparatus in fact must have been something like dredgers still in use for cleaning the beds of rivers. The pumps of those days were probably largely, or entirely, of wood; and it was not until the improved manufacture of iron, some years later, that iron pumps were used.

We can now form some fairly clear idea of what coal-mining was like toward the end of the seventeenth century. Pits were becoming deeper, and troubles from gases and from water were hindering the progress of the miner. Still he strove manfully to overcome these difficulties with cumbersome wooden pumps, and drains cut through the earth; with wet sacking to protect himself from fiery gas, and with such watchfulness as he could muster to protect himself from choke-damp.

The men would send a dog along the gallery to see if he could breathe; or they would light a candle to see if it would burn. But they had already gained the idea of two shafts; for Roger North writes, "Sinking another pit, that the air may not stagnate, is an infallible remedy." Many years, however, were to elapse before the sinking of two shafts to every mine was rendered compulsory.

Yet another great modern improvement had also been introduced—*viz.*, blasting by gunpowder. For the cutting of the big drains, and the sinking of a pit—which at that time might occupy a year—and also for the removal of the coal itself, gunpowder would be found of immense service, especially if the cutting had to be made through hard rock. Indeed, blasting powder is still largely used, for modern explosives are sometimes too rapid in their action; and safety-fuses are believed to consist of gunpowder surrounded by cotton.

It was in 1620 that gunpowder was introduced for blasting purposes; but it does not appear to have been largely used until a century later. It was not gunpowder which gave a great impetus to the mining industry, and sent it forward with immense vigour and success. Mining was waiting, so to speak, for such a touch—waiting for something which would enable it to cope successfully with its thronging difficulties and dangers, to reopen its abandoned pits and exorcise its demons of fire-gas and choke-damp.

Whence came these wondrous touches?

CHAPTER IV.

FIGHTING ENEMIES.

"WHAT's the new-fangled thing for?"

"Gettin' rid o' the water."

"And how do it act?"

"By summat they calls steam."

"I never heerd of it afore."

"Nor I; I don't think much on it. But the mester, he'm main gone on it."

"Well, and if it will git rid o' the water, I shall be mighty glad. The water is a powerful trouble in our pit."

"It is so; it git wuss and wuss."

"And who made this new-fangled thing?"

"Chap they calls Savery, and it's a-gwine to pump out the water like winkin'!"

It was indeed one of Captain Savery's steam engines of which these two miners were supposed to be speaking, and on its introduction it must have struck the pitmen of Devon and Cornwall with wonder. Captain Savery was the first man to take out a patent for applying the power of steam to different machines. The date was 1698, and in the next year he exhibited a working model before the Royal Society. His engines were used for some time in draining mines in Devonshire and Cornwall ; and in 1705 Newcomen, Cawley, and Savery introduced a steam engine called the "atmospheric" engine, in which the "beam" was first used, and which held the field for about seventy years. The engine was largely used for mines, and the beam has been employed ever since in pumping engines.

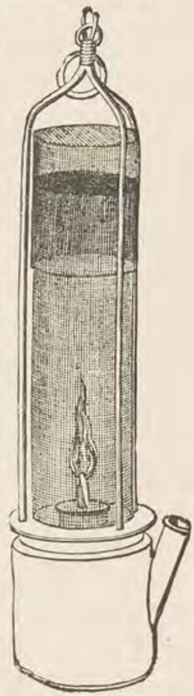
The beam, it may briefly be said, works on a pivot in the centre ; and one end being attached to the upright piston of a steam engine, and a pump rod fixed to the other end of the beam, it is consequently raised and depressed as the piston rod falls or rises.

Clumsy as Newcomen's engine was, it appears, we say, to have been largely used for mines ; especially so, we may suppose, after Smeaton greatly improved it. But when the magic touches of James Watt had changed it from a wasteful and awkward machine into an efficient and economical instrument, mining proprietors were not slow to perceive its advantages. There is something almost pathetic in the eager manner in which they caught at Savery's and Newcomen's engines ; and it indicates how greatly they felt the difficulty of efficiently draining away the water in their mines, and how anxiously they sought any apparatus that would help them in this respect.

Watt's machine soon superseded Newcomen's as a pumping engine, and it is worthy of note that the early days of the steam engine were intimately connected with mines, if indeed not actually promoted or improved to supply the needs of miners. Indeed, it may be said, in a word, that the steam engine has from the first been the great assistant of the miners, and has contributed more than anything else to the immense development of mining, and to the present perfection of mining methods.

And it is to be borne in mind that many improvements in the engine—at all events for mining purposes—originated in Cornwall where coal was dear. In his "Records of Mining," Mr. John Taylor traces and summarises some of the immensely improved efficiency—and consequent value—of steam engines for mining. The efficiency for mining objects was estimated by the standard which was termed *duty*. Thus, in 1769, Mr. Taylor estimated that the old atmospheric engine—which we have said held the field for about seventy years—raised five and a half million pounds one foot high by consuming a bushel of coal; but in 1839 the improvements enabled the engines, by consuming the one bushel, to raise fifty-four million pounds one foot high, and some of the best Cornish engines had risen to between sixty and eighty millions. In other words, the efficiency of the engines had increased about fifteen times; and when we add that several of these engines were employed at some mines, and that the simple expense of drainage alone had risen to £12,000 or £13,000 annually, the immense value to mining, of efficient and economical engines, will be apparent.

At the present time, they are of the greatest service in three distinct ways—*viz.*, they drive enormous fans, sometimes forty-five feet in diameter, for the purposes of ventilation, sending the air along the roads and crossings of the mine at the rate of from 2,000 to 4,000 feet per minute; they work stupendous pumps lifting perhaps 11,000 gallons per minute; and they haul the cages up and down the deepest shafts, carrying the miners to and from their work, and raising the coal that has been dug. These engines are quite distinct from the locomotives engaged in the transport of coal, or even the winding engines which may haul coal-corves by means of ropes, perhaps two miles or more, along the roadways of the mine underground.



THE DAVY SAFETY-LAMP.

It was, therefore, we hold, the steam engine in varied forms which gave to coal-mining—and mining generally—that great impetus which at one period it seemed to lack. It was the steam engine which enabled miners to overcome many of the stupendous difficulties and dangers which beset them, and assisted them to develop and enlarge their operations to an amazing extent.

One improvement, however, the steam engine did not effect : it did not abolish the danger of the fire-damp except by increasing the power of ventilation, and the peril of the dreaded gas remained. In fact, it was not until the safety-lamp was introduced by Sir Humphrey Davy in 1816 that miners could really cope with the difficulty of fiery mines.

The safety-lamp is a contribution of chemistry to coal-mining, and Davy—who was one of the greatest of English chemists—was led to invent the lamp after his investigations into the nature of flame and of fire-damp. George Stevenson also invented a safety-lamp, and received a testimonial of £1,000 for his production. His lamp is called by miners the "Geordie," while Davy's is of course the well-known Davy lamp. We need not enter here into the controversy which arose concerning the two lamps.

To understand the principles of the Davy lamp, which has been of such immense value to miners, we must look more closely at the fire-damp itself. It is, as we have said, light carburetted hydrogen or marsh gas, and is highly explosive when mingled in certain proportions with atmospheric air.

Further, when exploding it turns ten times the quantity of air into choke-damp, which is frequently as perilous to miners as the explosion itself. Should the pitmen escape deadly injury from the firing of gas, or the masses of rock and coal hurled about the mine, yet the clouds of choking vapour rolling afterwards along the passage ways may smother many a one in their fatal folds.

Now, the problem Davy had to solve was how to keep a lamp alight, and therefore supplied with air, without permitting the fire-damp to reach it. He found by experiments that, if two vessels be filled with explosive gas and connected with a narrow tube and one be fired, the flame would not pass over to the other, if the narrowness and also length of the tube, together with the heat-conducting quality of the material of which it was made, bore certain relations to one another. The reason of this was that the flame on cooling becomes extinguished. The question therefore arose what "tube" could be adapted to a lamp in a mine?

Davy found the answer in wire gauze. The tiny holes in the gauze may be regarded as a number of short "tubes," narrowness and conducting power of heat compensating for shortness of length. Davy himself directed that the apertures "should not be more than one twenty-second of an inch square." A light therefore enclosed in a cylinder of such wire gauze is protected from the fire-damp ; but that some of the deadly gas reaches the flame is evident, for the flame of the lamp enlarges when fire-damp surrounds it.

This pale, enlarged flame acts as a danger-signal to the watchful miner, for he knows that fire-damp is present ; and though it will not explode while the gauze of his lamp remains sound, yet as the flame may increase and fill the cylinder, the gauze may be broken or burnt in the high temperature ; and a rent in the protecting gauze would mean communication between the flame and the fire-damp, and consequent explosion.

Mines are frequently inspected by the aid of the safety-lamp, to observe if the fatal fire-damp is collecting. The overseer, or person charged with the duty, goes round the workings in the morning, and again during the day, and holds up his lamp to the roof and near the walls. Should the lamp burn with the pale, enlarged flame, he knows that precautions against fire-damp should be taken at once.

Explosions occur at times in mines that are considered safe. Such a one was that near Alfreton, in November 1895, when seven men unhappily lost their lives. In some parts of the pit naked lights were even permitted. But one Monday morning when the "datallers"—or men whose business it is to prepare the pit for full work—went down, an explosion occurred. The large ventilation fan was working slowly, and it was surmised that the explosion was caused by some small blasting operations which were being conducted, and which liberated suddenly a quantity of gas. The immense importance, therefore, of every precaution being taken against this insidious enemy of the miner cannot be emphasized too strongly.

The "Clanny" and the "Geordie" safety-lamps have glass cylinders as well as the wire gauze, but Davy appears to have been the first to introduce the gauze, which permits the air to enter to feed the flame, but prevents the flame from communicating with the fire-damp.

In those days, however, when the Davy lamp first appeared, the currents of air in mines scarcely ever rushed along at a speed of five feet per second; and it is highly significant of the vast improvements in ventilation that have since been made, that now the air rushes along at rates of twenty to twenty-five feet per second, or two thousand feet and more per minute.

Under these circumstances, the old "Davy" is no longer secure, but the "Tin Can Davy" has arisen, which is simply the old Davy shut up in a lantern. Miserable is the light, however, and it is falling into desuetude. We are not surprised that miners open their lamps and burn dip-candles, for the light that filters through the wire gauze in the black, non-reflecting veins of a coal mine is poor indeed.

Other inventors have come forward with lamps to suit the new conditions of the increased speed of air. And in the "Report on Accidents in Mines" issued in 1886 the commissioners say,—

"There are four lamps in which the quality of safety, in a pre-eminent degree, is combined with simplicity of construction and with illuminating power at least fully equal to that of any of the lamps hitherto in general use. These are Gray's lamp, Marsaut's lamp, the lamp of the latest pattern proposed by Evan Thomas (No. 7), and the bonneted Mueseler lamp."

These lamps, we may explain, present some points of resemblance as well as of difference ; thus, a cylinder of glass surrounds the light for a little distance, after which two or three wire gauze cylinders are mounted on the glass cover. If three wire gauzes be used, the lamp will stand a rush of air and fire-damp even of fifty feet per second, or three thousand feet per minute, without causing an explosion—unless the glass crack.

Surrounding the gauze to still further protect it, is a metal cover or bonnet which does not fit tightly, and affords ingress and egress to the air. In the Marsaut lamp the air enters above the glass cylinder, and the outgoing air passes under the small bonnet at the top. In short, there are now various adaptations and improvements of the Davy lamp, but the principle of the wire gauze in some form or other, which Davy introduced, still appears to be the centre and core of them all.

Devices have also been introduced for locking the lamps so that miners cannot open them secretly, and some lamps have been made in which the flame is extinguished when opened. The temptation to work by a naked light is very great, for the light of most of these lamps is at best very feeble. I have been in a coal mine in which every light except my own was exposed.

"And why," I asked, "are the men so careless ?"

"Oh," replied the overseer, "it is not a fiery mine, and the ventilation is so good."

Certainly the fresh air rushing through the narrow, low lanes and crossways was something like a gale of wind at the top of "bleak Hampstead's swarthy moor" ; and the difference between the closed Davy and the flaring dip-candles stuck on the wooden supports of the roof was very remarkable. Lying there on the coal in a four-foot seam, chatting to the miners, watching them at work at the face—*i.e.*, where they are actually cutting out the coal—and wielding a pick myself for a few minutes, I soon learned to understand why the pitmen risked working with a naked light.

Some mines, however, are so fiery that the utmost precautions are taken to prevent the striking of a match, or the unlocking of a lamp for even a second. The strictest discipline prevails, and the concealment of matches or keys and the use of a naked light are derelictions of duty punishable by imprisonment. For the striking of a match might cause a fearful explosion, slaying hundreds of brave men in the fiery mines of the north.

But let us descend one of these ; let us swing a Davy in our hand ; let us wander for miles in the black lanes underground ; let us talk to men and overseers ; and hear of the sinking of shafts two thousand feet deep, of the dangers of that innocent-looking coal dust, of the different kinds of coal, and of all the wonders in successfully working a twenty-mile fiery mine in the bowels of the earth. It will be a most interesting experience, and perhaps not unattended with danger.

CHAPTER V.

IN A COAL MINE.

"Are you going down the mine ?"

"Yes—and you ?"

"I am going with you. Don't you recognise me ?"

"Oh, excuse me ; at the moment I did not."

In fact, both visitor and engineer were so transmogrified by the rough apparel and huge boots they had donned, suitable for underground explorations, that for the moment they did not recognise one another, especially as they were not familiar friends.

But now, being assured of each other's identity, they strolled together towards the pit's mouth.

"This shaft we are going down cost many thousands of pounds to sink," said the engineer. "We had to encounter much water. Of course, in the ordinary way the miners stand in the pit, and send the excavated material up in buckets lifted by an engine; rock of course is blasted out by dynamite, or gunpowder, or some suitable explosive. Then the sides of the shaft are supported by timbers and built up. But here the water troubled us a good deal."

"Would not pumping keep it under?"

"It did keep it under, but not sufficiently; for we wanted to line the sides strongly and render them impervious to water. An old plan was by what is called 'tubbing.' In this method, cast-iron beams were used, also thousands of wooden wedges, which were driven in the earth; and then large cast-iron rings or segments were built into the shaft, and the water could be pumped out. But tubbing was very difficult and costly, though it has been often used at various collieries.

"At South Shields, however, some years ago, when efforts were made to dig coal from under the sea, tubbing was completely unsuccessful. Directly pumping ceased, the water rose in the shaft six feet a minute, and yet the shaft was fourteen feet in diameter."

"Why, it was like pouring water in a jug."

"Aye, indeed. Well, they solved the problem at length by using combined methods of Kind, a German engineer, and Chaudron, a Belgian. A big boring tool, some three or four feet in diameter, was set to work, and having cut a hole a certain distance, was withdrawn, and a larger boring cutter employed, the fragments cut out rolling below into a big bucket let down into the smaller hole. A point being reached, where there seemed probability of a watertight bed, and where a sound joint free from water could be effected, rings of cast-iron were let down, the first ring to go down having a case filled with moss, which, when pressed by the heavy iron cylinders above, packed very tightly and formed a watertight joint."

"And did you employ that method here?"

"On the first occasion; but when we sunk the shaft deeper, we used compressed air."

"Ah, that is the great resource of the engineer nowadays in working against water. I suppose you had a sort of caisson full of the compressed air below, and hollowed out the shaft under the caisson; then the earth and fragments of rock were drawn out through an air-lock which is worked on much the same principle as a lock on the river."

"That is it. I perceive you have seen something of working with compressed air. The plan was first applied to mining by a French engineer, Monsieur Triger, and the pressure of air is made so great as to keep back the water. Ah! well, now here we are at the shaft."

"Yes, these are the characteristic features," replied his companion. "There are the uprights over the pit supporting the wheel, upon which runs the rope which hauls the cage up and down, and the other end of the rope travels to the engine-shed, I suppose?"

EXTERIOR OF A COAL MINE.

"That is so; and a fine winding engine we have. We will just look at it. You see the large drum, or cylinder, on which the rope is wound? There it runs —to that wheel which you noticed over the shaft.

"The engine," he continued, "is so well made that it can stop the cage at a second's notice, either in travelling up or down; and it is quite powerful enough to haul up the cage full of coal or of men. Indeed, we have another engine connected, in case an accident should happen to this one. Furthermore, you will see that the 'keps'—that is, the hinged gratings covering the mouth of the shaft—open when the engine is hauling up the cage and shut when the cage is out of the pit. Nothing can fall down the shaft. In short, you will see, from the very commencement, here at the pit's mouth, right throughout, that everything engineering skill and scientific knowledge can suggest has been done to protect the lives of our men, and fight the perils of this dangerous mine.

"In this shed," he continued, as the two walked away from the engine-house, "the lamps are tested and given out to the miners, and the names or number of the men are also entered.

"A couple of lamps for us," he cried, as he entered the shed; and two lamps having been lighted and tested, and handed over to the engineer and his companion, the two men left the shed and mounted a few steps up the incline around the pit's mouth.

The cage soon came up. It was full of tubs or corves of coal, and had two or three stories, so that one shelf could contain men, and another, if necessary, empty or filled waggons of coal. The top was well covered, so that if anything fell the men would be sufficiently protected. The cage could hold eight men, and eight entered, including the engineer and his visitor. At a signal, the engine swung the cage clear of the "keps" upon which it had been standing; they opened, and then—down, down plunged the cage into impenetrable blackness.

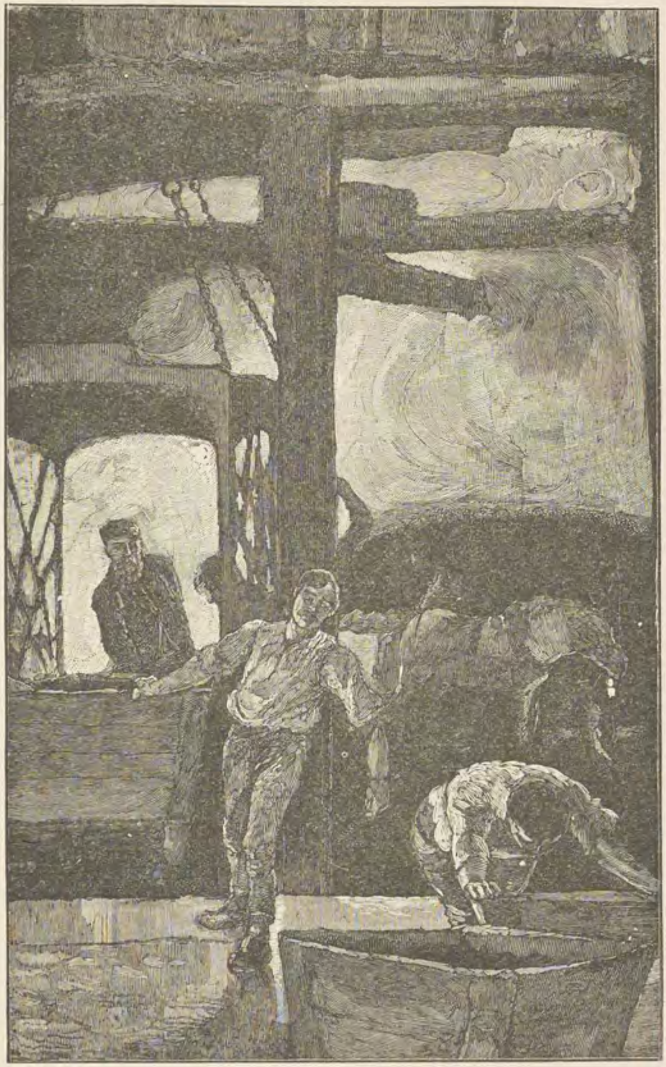
The first feeling is one of a horrid sinking, the very pit of your stomach seems falling away, and dizziness and nausea creep over you. In fact, you are falling downward at the rate of near upon a thousand feet a minute. Curiously enough, the next second you may seem to be rushing upwards—a peculiar sensation probably due to the current of air rushing in the shaft and travelling much faster than even the cage itself.

Then you can perceive lights in the gloom; they are the lights of the Davy lamps, one of which is carried by each miner. Next you hear the engineer explaining that the cage is sliding down between fixed uprights, and consequently there is no oscillation or swinging from side to side as in former days; also that the ropes are of strong steel wire and will hold you firmly.

"And that big pipe there," he adds, "by the side of the shaft, is for pumping the water out. But, heigho, here we are!"

A sudden jerk, and the cage has stopped. Hoarse cries sound around; there is a rumble of waggons both far and near, dim lights flash here and there; horses are stamping and clattering, chains clanking, and wheels whirring; while men are hurrying hither and thither.

It is the bottom of the shaft; and here meet the lines of tram waggons from different parts of the underground workings, and here, too, meet the men in their journeys to and fro. For noise and bustle the



AT THE FOOT OF THE SHAFT.

spot is like a big railway junction above ground. But, with all the blackness and dim lamps, what a sudden change from the daylight and the quietness overhead!

You are suddenly plunged into quite a new world, and a very strange one.

"This is called the 'pit's eye,'" said the engineer. "It is the bottom of the downcast shaft, and well lined with bricks."

Scarcely have you recovered from the dizziness of the rapid rush below, when you seem to be aware that you are standing in mud; between other noises you catch the sound as of running water somewhere near, and notice by the dim, confusing lights that the men's safety-lamps are being again examined. The pitmen are even turning out their pockets to show that they have no matches or lamp-keys.

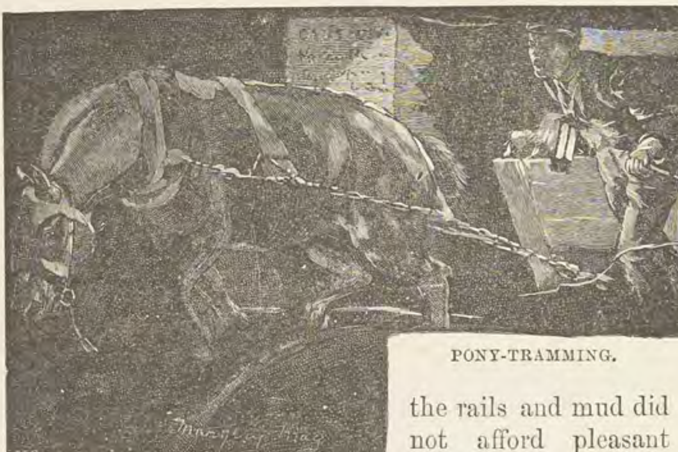
"Come this way," said the engineer, and he led his guest some distance along a passage, which the dim Davy showed to have been whitewashed, to a door which barred their further progress. In the passage several miners could be seen with their lamps, waiting for their opportunity to ascend to the pit bank, their spell of work being over.

The engineer pushed the door with all his force and, the visitor assisting him, it slowly opened, but as though some one were pushing against it on the other side. Once the two men got through the entrance, the door swung back fast.

And then a new wonder met their view. A huge fire was burning and roaring with mighty heat, a man feeding it stripped to the waist.

"For ventilation," explains the engineer; "this furnace creates an enormous draught; you found how difficult it was to open the door against it, and perhaps you noticed the chimney belching forth smoke overhead. That chimney belongs to this furnace, and we are here at the bottom of the upcast shaft. Now we will get on up to the 'face' where the 'holers' are at work. But I warn you it is a long distance."

It was a long distance. The black passage after a while became much lower, and the visitor groped his way with bent back, and stick padding along the ground. This was to test the footpath for his feet, for the two were walking along a waggon way, and



PONY-TRAMMING.

the rails and mud did not afford pleasant walking ground, especially when the men could not see clearly.

Occasionally a distant rumble fell upon the ear; then the sound grew louder; the engineer caught his visitor, pushed him against the wall of the passage, and a train of small but heavy waggons flashed by, their presence marked by dim lights and noise.

By the dim light the visitor thought he saw fleeting glimpses of horses, and of half-naked men with blackish faces, from which their eyes gleamed curiously. Then onward again the engineer and his guest resumed their march.

At intervals, passages opened up from the main roadway; sometimes a dim light danced here and there; sometimes a distant rumble sounded; but now, for the most part, the adventurers walked on in profound silence and dense darkness, save for the feeble glimmer of their own lamps. And the blackness around seemed to absorb that feeble glimmer as quickly as possible.

The air became close and heavy; the visitor's back ached with the constant bending; yet if unconsciously he raised his head, his hat knocked against the roof, as if to remind him sharply of the want of space. There was nothing for it but to continue walking with bowed body.

After a time, however, the engineer paused. "We might rest here a minute," said he; "I daresay you won't mind; and then we can have a chat about the methods of opening out coal mines. You were speaking of it before we changed our toggery. Well, now you can see we have been pursuing a main roadway; we call it a level-heading, and from this on either hand branch out other roads or galleries, which are again cut by other cross-roads."

"A stranger would soon lose himself in all these byways and alleys of the mine."

"Yes, and you must remember they are not level. This seam of coal is not horizontal in the ground, but sloping, therefore the galleries on one side of this level-heading run upward—following the coal seam—and the galleries on the other side run downward, as they also follow the slope of the seam."

"Then you do not cut out the galleries higher than the coal itself?"

"No, we just follow the seam. The level-heading must of course be bigger to permit the corves to be drawn along; we have driven a level roadway right along the seam and, so far as we can tell, right through the middle of it.

"Different collieries are opened out in different ways, according to the lie of the coal. You know in a general way, no doubt, how the beds of coal are found in the earth. In the coal fields of the Midlands, where the coal lies not so very far from the surface, comparatively shallow pits may be sunk at no great distances from one another. But in the north, where shafts have to be deeper, we sink a pit about the centre of the seam, and radiate from the pit-bottom in every direction and to great distances. Moreover, seams often lie one below the other, with layers of thick clay or shale between, so pits have to be deepened as this one was, to reach the lower seams. Now, if you are rested, we will get on to the galleries, where we shall see the men working at the face."

"I suppose, then, you are opening up this mine on the 'long-wall' system?"

"Something like that," replied the engineer. "There is also the 'post-and-stall' method, or as it is called in Scotland the 'stoop-and-room' method; we think the long-wall the better for ventilating purposes, and also that more coal can be obtained from the same area. As you see, we are gradually taking the coal away from each road and supporting the roofs by timbering or masonry. Of course, in the post-and-stall method we leave pillars of the coal to support the roof. In some mines, moreover, where the seam is very sloping and very thick, the coal is dug out in portions and the excavations filled up with waste stuff, such as slag from the blast furnaces. Short, thick pieces of oak wood are also used to support the roof in alleys and by-ways. Two pieces are placed upright—one on either side of the hole or pathway—and then a cross piece wedged in between the roof and tops of these uprights."

SUPPORTS FOR THE ROOF.

"Do you use explosives much in this mine?" asked his guest.

"Very seldom here, the mine is too fiery; but we use dynamite sometimes, especially if we have to get through a slice of rock or shale. Compressed powder is used with good effect in some mines; also gun-cotton and other explosives. Bore-holes are driven into the stuff; the explosive is placed in them, and fired by a time-fuse or by electricity—the men withdrawing to a safe distance. But blasting powder is still, I fancy, the favourite with mining engineers ; and millions of tons of stuff are rattled down by its use."

"Yet here you cannot employ it?"

"No, it would not do. Explosions are far too risky in fiery mines. Here the 'holers' undercut the coal and then drive in wedges at the top, when the part that has been undercut falls, perhaps a ton at a time. Ah, here we are! Now we can see the holers at the face!"

He paused before a black, cavernous hole in the side of the roadway.

"There," said he, "if you look up there, you can see the man at work."

His guest raised his head and knocked his hat against the low roof of the roadway at once ; but he caught a glimpse of two or three twinkling lights in the far distance of the dark cavern.

"Ah, take care! We shall have to go on all fours in here, I expect."

And suiting the action to the word, the engineer climbed up the low wall and commenced to creep into the dark hole.

"We call this a 'stall,'" said he, "and the coal which is being dug out at the top is brought down to the level-heading we have left, by comparatively small boxes—as they may be called—fastened to this chain on the floor. The seam of coal slopes upward here, and the gallery or stall you see follows the slope. The full box of coal coming down drags up the empty one."

Crawling upward over the rough coal in the close air, hitting their heads now and then against the oaken posts supporting the low roof, and hearing the fiery gas hiss out of the cracks in the coal, the engineer and his friend slowly made their way up the narrow and low opening to the top, where a miner and his mate, stripped to the waist in the warm air, were at work undercutting or "holing" the coal.

"There, this is the 'face,'" exclaimed the engineer; "we can go no farther here."

The miner turned his head at the unexpected sound

UNDERCUTTING THIN COAL.

of strange voices, and then resumed his work. Lying on his side, he struck a sharp double-pointed pick-axe against the face of coal which rose above him. His object was, as the visitor soon saw, to make a deep groove in the lower part of the wall of coal, which would undermine the upper part.

Pick! Pick! Pick! The man continued to chip out the coal, and dust and small pieces flew out of the groove which he was digging.

"We have to be careful of that dust as well as of the fire-damp," said the engineer. "A naked flame might fire it, and it is bad to breathe."

"Aye, it is so," ejaculated the miner. "That'll about do, I reckon," he added, as he looked at the groove, which was sunk some distance in the coal. "Now I will wedge this down."

A few blows with a hammer on a stout iron wedge forced in the wedge at the top of the coal wall; then the process was several times repeated.

"Get back, get back," he cried presently, as he drew back himself. Then he and his mate reaching forward struck the mass a few blows with picks; finally down fell the coal with a crash, some of the pieces rolling near the feet of the men, as, huddled up in the low gallery, they awaited the fall of the face.

"That is how coal is won in this mine," exclaimed the engineer. "Some mines are not so fiery, and such extreme precautions as you have seen here are not so necessary; the coal can be blasted out instead of being forced down by wedging. But it is generally holed, or 'kirved' some people call it, as you see. This undercutting is undoubtedly the most arduous part of a miner's labour. Some machines have been invented to do the work, the motive power being compressed air or electricity; but though they appear to have been used in America, they have not at present come much into vogue in Britain. Now I will take you back a different way."

So saying, he turned off at right angles from the gallery or stall, in which they had watched the miner, and entered another narrow gully.

"What are these cloths for?" asked the guest as they pushed against a piece of sacking hanging from roof to floor; "I have seen some before."

"For ventilation. They guide the current of air in the way it should go. You can judge now for yourself how absolutely important is ventilation in a mine, and you have seen the fire we burn at the foot of the upcast shaft. The pure fresh current of air is led from the downcast shaft and guided through every gallery and stall of the mine, no matter how small, to the upcast shaft; and these cloths, called brattice cloths, and the doors also, guide the current. I suppose we have 200,000 cubic feet of air poured into this mine every minute—and even more. Yet you see how warm the temperature is."

A DEEP UNDERCUT.

"The object, of course, is to weaken the fire-damp below firing point."

"Quite so, and also to cool and purify the atmosphere and free it as far as possible from contaminations. You see, we have numbers of men and horses breathing, and lights burning in this confined space, and fresh air is a necessity quite apart from danger of fire-damp; then, if the atmosphere were allowed to remain long unchanged, it would probably become overcharged with coal dust."

"Now," added he, pausing, and knocking his stick against the black wall, "I am going to mention something else of the utmost importance, and yet I doubt if the outside public ever think of it. What do you imagine is behind here?"

And again he rapped the wall of coal.

"I have no idea; coal perhaps, or clay."

"No, the workings of an old mine, probably full of water. If we were to let our men dig much farther this way, we might be deluged and drowned out in a few minutes!"

"Horrible!" exclaimed the other, shrugging his shoulders and looking around. In a moment he pictured the narrow black gully, rapidly filling with a filthy stream of black water; he saw the final submersion, even while hurrying down the narrow channels, and all formed a horrible scene of a terrible and lonely death.

"Therefore all mining plans are kept," added the engineer; "and they should be designed as absolutely accurate as possible. Yet I expect few of the outside public suspect the great necessity of making such plans. Now, shall we explore a few more galleries?"

"Are they all like this?"

"Yes; scores of them! ah, take care!"

A rumble of tram waggons sounded along another roadway which they had now entered, and the engineer pushed his friend against the wall just in time, as a train of laden corves thundered by.

"I see no horses," cried the visitor.

"This road is worked by a stationary engine which draws the waggons by a steel rope; here it is."

And the engineer held his Davy lamp down to the floor and showed the rope between the rails.

"The engine winding that rope and drawing the trucks along is quite a mile distant," said he. "In some headings we haul the loaded trucks by horses, but in this one by steam power. In smaller mines, and indeed in galleries near the bottom of the pit, men or boys called trammers, or hurriers, or putters, push the waggons along. They are filled, of course, out of the stalls or galleries, and being taken to the pit-bottom, are hauled up in the cage. Arrived there, they are sifted or screened, the largest falling into a railway waggon, and the smaller pieces being kept together and sold as 'nuts' and cobbles, and smaller yet as 'slack.'

"But before you follow the coal and ascend to the surface, you might see the stables and the ambulance box; we keep just a few surgical appliances and simple remedies down here, so that in case of accident we shall be able to render some assistance."

An hour or so later the engineer and his visitor stood again at the pit mouth, blinking their eyes in the sunshine after the long spell of darkness below, and watching the wire rope rushing down the shaft again.

"No one would think that the ground beneath our feet is honeycombed with hundreds of passages. It is really quite a marvel."

"Aye, and the number of persons working underground is marvellous also. There are considerably more than half a million in the United Kingdom, while the coal raised is now much more than one hundred and sixty million tons in the year. Coal-mining has become one of our greatest industries, and all that science and engineering skill can do, is being done to render it more healthy and more safe."

THE STORY OF THE IRON MINE.

CHAPTER I.

THE WISEACRES.

"WHAT stuff is this, think ye?"

"Eh, mon, but it's differ from the slaty clay aboot it."

"Is it goold, maybe?"

"Goold? Fiddlesticks!"

The two speakers were examining with great care a reddish grey nodule that had fallen from the roof of a coal bed above them.

"It looks some'ing like clay, but it ain't clay," asserted one positively.

"It be clay, but it's got a lot else mixed wi' it," declared the other.

"Let's break it," said a third.

"I wonder if there's any more," said a fourth.

The result was that the men sought for more of such nodules in the slaty clay that had fallen from the coal-mine roof, and they eventually found several of the rounded lumps, but of varying sizes.

"I am goin' to break one," reiterated the third speaker, rubbing some of the clay from the nodule he carried. "There's summat in this stuff, but I dunno what."

"I never heerd tell o' their finding these stones up to the Noocastle mines, 'ave you?" exclaimed another.

"Na, and I don't think they be worth much, now we have found 'em," hazarded the fourth.

"*Cr-rack! Crash!*"

"Hullo! he's broke one. Well, what's there?"

The men crowded around and examined the broken nodule.

"Tut, there ain't naught. I told 'ee so."

"Eh, mon! but I think there be!"

"I sin a whole bed o' the stuff 'tother day near the Mockford Pit," exclaimed another miner, "and they do say as how iron could be got out of it by burnin' it."

"Iron?"

"Aye."

"Mighty differ from the bloodstone and red stuff they git the iron from in the north, or the 'redding' down Bristol way."

"Or from the loomps o' stuff I've sin dry up in the marshes in Sussex," chimed in another. "What'll the maaster say aboot it?"

The "maaster," or his friends, soon found that iron was indeed in it. The roundish masses discovered by the men were, in fact, variously sized nodules of impure carbonate of iron—clay ironstone the mineral is now popularly called. And the bloodstone and red stuff to which the men referred in their conversation are now known as hematite or red oxide of iron.

We suppose the conversation to have taken place among a group of miners in South Staffordshire towards the close of the sixteenth century. And it is curious that, while the coal basins of Staffordshire are rich in clay ironstone, the coal fields of Newcastle yield but little.

Red hematite on the other hand—that is, red oxide of iron—is found in great masses at Whitehaven and also at Ulverstone, varying from fifteen to sixty feet in thickness. Yet it occurs sometimes in thin strata, and while some forms are hard, as in bloodstone, others are so soft that when rubbed they will smear the fingers. The softer kind is sometimes termed red iron ochre; while in the neighbourhood of Bristol the red oxide is often known as redding. This is probably the ore which was smelted in the early days.

Because, although the ironstone of Staffordshire was probably not known until about the commencement of the seventeenth century, yet iron had been known for ages. And not only in Britain, but in many other countries had it been used.

Who, then, discovered iron?

No one knows; nor does any one know how it was discovered. Native pure iron is a rarity on the earth. Though probably more widely diffused than any other metal, yet iron exists almost always combined with something else. There are its oxides, its sulphides, and its carbonates. It is found in sand and in water. But very rarely is it discovered alone, and then it is believed to have come, except in a few instances, from another planet, in the form of meteoric stones. Possibly rough cutting instruments were produced in early days from meteoric iron.

But if iron exists almost only in compounds, how was it first discovered? Who found that from the blood-red hematite, or the lustrous black oxide, was to be gained the most useful of all the metals—invaluable iron?

The answer lies buried in the far back past. All we know is, that iron instruments made in prehistoric days have been found in comparatively large numbers, so that obviously iron had been discovered, and methods of extracting it from one or more of its compounds—that is, from the ore—had been discovered ages ago.

If we may trust tradition as graven on the Arundelian Marbles, iron was found fifteen hundred years before Christ, on Mount Ida; the metal was discovered after a wood had been burned by lightning, the great heat of the burning wood reducing the ore lying on the ground or close to its surface.

Or perhaps iron was found, as tradition says glass was first made, by an ordinary fire. Prehistoric man required a fire, and happened to kindle it upon iron ore, whereupon the heat smelted out some of the iron from the ore, and the metal was found when the fire was cold; even so the Phœnicians, according to legend, found glass after kindling a fire on sand with natron, or soda, near. The black oxide was, it is said, reduced in India in very ancient days.

Fires for forges—for heating the iron red-hot and shaping it—were probably built in hollows on the hillside, where some wind, but not too much, could be gained, to make the iron molten. Man probably soon noticed that his fires burned better when a draught blew upon them, and this may have caused him to blow upon embers with his breath ; but being an arduous process, if long maintained, and also insufficient for iron-smelting, looked round for some device whereby he might save himself the laborious expenditure of breath. A fan of some kind was doubtless soon in use, and probably a fan at the end of a tube was not long in following—the tube directing the air in a stream on to the required spot. The first hammers for striking the iron when it was hot were most likely lumps of stone, and perhaps after a time pieces of cold iron that had been smelted and beaten to something like a hammer-head.

In any case, mankind did begin to smelt and forge iron, and had made some advance in the working of steel when Homer wrote. "As some smith or brazier," says he, "plunges into cold water a loudly hissing great hatchet or adze, tempering it ; for hence is the strength of iron."

Now, whence did prehistoric and ancient man obtain his iron ore ? It must have been found on or near the surface of the ground. Thus Ure, writing of a very beautiful iron ore called variously "Iron Glance," "Red Iron Ore," and "Specular Iron Ore," says :—

"It exists in very great masses, constituting even entire mountains ; in the cavities and fissures of these masses, the beautiful crystals so much prized by collectors of minerals occur. The ore of Antenna is a very hard, compact *fer oligiste* (Iron Glance) of a beautiful metallic aspect. The workable bed has a height of sixty-six feet, and consists of metalliferous blocks mixed confusedly with sterile masses of rock, the whole covered with a rocky detritus under a brownish mould."

THE DANNEMORA IRON MINES, SWEDEN.

There are also "iron mountains" at Taberg and Gellivara in Sweden, and in Missouri in the United States. Moreover, as we have seen with coal, minerals sometimes crop out of the surface of the earth, while again mineral ores are found in gravel, sand, and alluvial deposits, as in bog iron ores in different places, and in the streams of Cornwall, now exhausted.

We judge, therefore, that mankind found iron ore of some kind originally on or near the surface of the ground. The richest iron ore is probably the black oxide, which has been known in India from a very early date. It is the famous loadstone of antiquity, and having been found at Magnesia in Asia Minor, the Greeks are supposed to have called it magnes, from which we get the name magnet.

The most famous iron mines perhaps in all the world are those at Dannemora in Sweden, and the ore in those mines is this black oxide of iron ; or, as some persons call it, magnetite or magnetic iron ore. At Dannemora and also at Arendahl, it is found in immense beds, and furnishes excellent iron, being free from phosphorus and sulphur.

We in Britain are not much favoured with this eminently satisfactory and fine ore ; but it is found in China and Siberia, Canada, and some of the American States, as well as in Sweden and Norway. In appearance it is something like black crystal, and when pure it contains oxygen and iron in the proportion of about 73 per cent. of iron to 27 per cent. of oxygen.

Brown hematite is another oxide, and is found in Devonshire, South Wales, and the Forest of Dean. Ireland is also blessed with some in the county of Antrim. The well-known paints, brown umber and yellow ochre, consist of this ore mixed with clay or earth. Brown hematite is the ore chiefly used in Germany and in France.

Probably the principal source of iron in Britain is impure carbonate, or the clay ironstone and the Blackband ironstone—the latter having a large proportion of bituminous or coaly material. Comparatively pure carbonate of iron is found in a crystallised condition, and is spoken of as spathic iron or sparry iron ; it produces a natural steel, which, as most people are aware, is a combination of iron and carbon. Quantities of this spathic iron have been found in Styria ; also in the Savoy Alps, in Saxony, Spain, and other places ; some is found in Britain, but its existence in Somersetshire was not discovered until after the year 1851.

It is the impure carbonates which largely occur in Britain, and dull-looking earthy ores they are. Considerable quantities are found in the coal measures of Staffordshire ; also in South Wales, Gloucester, and Somerset. It was the clayey carbonate that the Staffordshire miners found in their coal measures, where it occurs so abundantly. Nevertheless, iron ore—probably an oxide—had previously been found and worked in England.

But shortly after the clay ironstone had been found in Staffordshire, a difficulty occurred which threatened to render it valueless.

Like its twin brother coal, the infant giant of the British iron trade was almost throttled in its youth. Indeed, the danger to its life was greater, and it languished near to death. What enemy was this ?

CHAPTER II.

DUD DUDLEY'S DREAM.

"THAT smoky stuff will never melt the ore."

"Why not? It do give out a lot o' heat."

"Not the right kind o' heat, I reckon. And why not use wood?"

"'Cos they're stopping the use of wood. Mad Dudley says if some new fuel ain't found to smelt the ore, the iron works will go out o' feshion here in England."

"Oh, well, the wood will last out our time. You'll never smelt iron ore with coal."

Yet, alas! for the wiseacre's prediction, coal, or rather a preparation of coal—*viz.*, coke—is very widely used to-day, nearly three hundred years later, for smelting iron ore, and the dream of the "madman" has been realised.

He was one Dud, or Dad Dudley, a roundabout relative to the Lords Dudley who owned much land in the "Black Country" of South Staffordshire. The use of wood for smelting iron had destroyed so much timber that iron works had been limited in number by Act of Parliament; and as the use of coal was then (about 1620) becoming general in England, it is not surprising that some minds were turning to the question of employing it as a substitute for wood charcoal.

There was plenty of coal on Lord Dudley's estates, and plenty of iron ore also; and Dud Dudley was persuaded that the one would reduce the other and extract iron from it. His patent, taken out in Lord Dudley's name, was dated 1620. But though he experimented for many years, and in 1665 issued his book on "Iron made with Pit Coale," he was not successful;

or, if successful, the iron masters did not look favourably upon his plan, and his secret died with him.

People thought him mad.

The truth seems to be that he used coal in furnaces suitable only for wood charcoal ; and furthermore, as charcoal contains so much carbon, no doubt very fine qualities of iron and steel were obtained by using it for smelting iron ores. So that, even if he were able to melt or reduce the ore with coal, it is probable that the iron produced was not so fine as when smelted by charcoal.

The secret therefore slept. Another worker in the same field was Simon Sturtevant, who preceded Dud Dudley by a few years ; for about 1611 he obtained a patent for the employment of coal in iron manufacture. But it was not until Abraham Darby, the Quaker, introduced the plan again about 1713 at Coalbrookdale, or rather when coke was used about 1750, that the modern British iron trade was really started on its wonderful career.

Yet if Dud Dudley's "mad" ideas had not been successfully realised, the infant giant of the British iron industry might have perished for want of fuel ; or, on the other hand, it might have destroyed all the timber on this fair isle. It was the want of wood, and the consequent restrictions placed on iron works by Parliament, that almost killed the growing trade.

Why, then, is an abundance of fuel so necessary for the production of iron ? We know the metal must be heated red-hot to forge it and shape it ; but why is heat so necessary to produce it ?

Because, as we have seen, iron is very rarely found pure in nature, and heat is necessary to procure it from its compounds. It is clear that with all the varieties of iron ore in existence—and there are a great number—the methods of obtaining them and of extracting the iron from them are likely to vary considerably. And this is indeed the case.

Thus, the ironstone ore found in the North Riding of Yorkshire is one of the poorest, being indeed but a sort of hard mud, containing perhaps only 20 to 40 per cent. of iron. But as it is chiefly gained in places like stone quarries, and near to quantities of coal, it is very largely and inexpensively used.

On the other hand, an abundance of iron ore is obtained from coal measures, while quantities are gained under the Metalliferous Mines Act, and are not connected directly with the brittle, black fuel.

Thus, we have iron ore from quarries, from coal measures, and from what may be called iron mines—that is, mines of iron ore. Yet another source is in sand, as witness the iron sand of India, Taranaki in New Zealand, and elsewhere. The iron sand of India is a black oxide, a magnetic iron ore in fact; and it requires no great stretch of the imagination to suppose that from this sand the natives obtained iron in early days. This iron sand contains also another metal—titanium.

But though there are these numerous varieties of iron ore, the principal kinds may be described as four in number, and may be thus divided:—First, the black oxide, or magnetic iron ore; second and third, the red and brown hematites—specular kidney ore and red iron ore being included under the title of red hematite; and fourthly, the carbonates—including the Blackband, and clay ironstones, and the spathic ore.

The variety of red hematite called specular iron, because of its metallic lustre, has been worked on the island of Elba for over two thousand years. It is found there in large crystalline masses of a steely grey colour, but yielding a red tint when scraped or when broken into thin pieces. It is very rich in iron, producing sometimes nearly 70 per cent. of the useful metal. Specular iron is also found in several other parts of the world. Speaking generally, red hematite is probably the most abundant variety of iron ore in the world. Vast quantities are found near Bilbao in the north of Spain, and millions of tons are now exported to England.

With the old methods of reducing iron ore, ancient workers were not able to use any but the richest, such as the hematites and the magnetic oxides. Indeed, the rough and clumsy processes used even by the Romans in the Forest of Dean, left quantities of iron in the cinders. So much so, indeed, that the cinder heaps in Dean Forest, and known as Dane cinders, supplied in later days the principal supply of ore for a score of furnaces for considerably more than two hundred years. But now iron masters use lime as a flux in charging their furnaces, and the lime uniting with the impurities of the ore floats on the top of the melted iron.

Charcoal alone was used in iron-smelting until 1618, the year in which Dud Dudley introduced coal; but coal was not successful at first; and in 1740 the production of iron in England had declined so much, that it was, so to speak, but a ghost of its former self.

The lack of wood and of proper methods of reducing the ore almost starved the infant Hercules; but he recovered and speedily attained to enormous vigour.

Moreover, a new discovery of iron ore was soon made—a discovery which revealed one of the largest sources of ironstone in the kingdom.

CHAPTER III.

THE LARGEST PIG-IRON REGION.

"There's boun' to be a mighty chaänge here, neighbour."

"Na, d'ye think so?"

"Aye." And the speaker nodded his head knowingly.

"Why? 'cause they've diskivered that stuff in the hills yon."

"Aye. That stuff's iron, lad, or 'ave got iron in it, and it's boun' to chaänge the feäce o' things."

The companions were looking out over a wild, picturesque, mountainous region, dotted with fertile valleys, in the North Riding of Yorkshire.

"They've foun' iron I say in them hills, or ruther, it's ironstone; and noo they've foun' it, they'll waänt to work it; an' if they work it, they'll 'ave to dig holes for it and put up furnaces to melt it. Aye, I tell 'ee, lad, this 'ere diskivery as they call it, is boun' to chaänge the feäce o' things."

The shrewd old Yorkshireman was right, though probably he did not foresee the enormous "chaänge" that has since taken place. Ironstone—chiefly a clayey carbonate—was discovered in the year 1850 by Mr. J. Vaughan in the Cleveland hills, and since then lonely villages have sprung into populous towns. The important city of Middlesboro', which in 1829 was a marsh and a farmhouse, has become a great centre of the iron-manufacturing and shipbuilding industries, and Cleveland has become probably the largest pig-iron making region in the world.

Now, Cleveland ironstone in Yorkshire occurs as a thick bed or seam, varying from six to sixteen feet thick and lying almost level in the geological formation known as the Middle Lias. The plan of working it, therefore, is something like the "post-and-stall" or "bord-and-pillar" system of the coal mines.

The pit or shaft having been sunk, a main road or level-heading is driven some twelve feet wide, and then at right angles *bords*, or wider roads, are driven five yards in width and twenty yards apart. At thirty yards distance cross-cuts are made, parallel with the main road, and thus the whole bed is first divided into blocks or "pillars" ninety feet by sixty feet.

These blocks are then cut up in a somewhat similar manner. First, a passage, called a drift, is cut six feet wide right across the block or "pillar," and about one-third of the distance along the bord—that is, thirty feet from the corner of the pillar. Then the square at the corner is worked out; the neighbouring square follows, and then the third square, which brings the miner to the next bord. Another "drift" has meantime been probably driven across the remainder of the pillar at the same distance from the other corner, and the same plan is pursued. Thus the entire block or pillar is at length removed.

The method it will thus be perceived much resembles the "bord-and-pillar" system of working coal; and the fact that this system prevailed in Durham perhaps suggested it to the miners of Cleveland. In many respects, therefore, the mining of iron ore resembles the mining of coal.

Indeed, when any mineral is found in the form of beds or seams, the plan pursued is much of the same character, though where gas does not prevail blasting may be more frequently employed. But the seams are opened out more or less on a line with the horizon, and between the adjacent strata.

But, as already pointed out, there is another very broad division of mineral deposits in the earth. These are known as veins, or reefs, or lodes. Geologically speaking they are regarded as fissures in the surface of the earth, which have been filled partially or wholly by material different from the substance of the surrounding rocks. One old English miner believed the "veins" of water met with in mining to be the veins of the Earth, and "when," said he, "the water bursts into our workings, it is the earth revenging hisself for having cut his veins." Curiously, the man believed the earth was alive.

Now, the method of working these veins of ore differs in some important particulars from that of seam-working. Thus, the slope of the vein or lode has to be attentively considered, for it may run vertically into the earth or at any steep or sloping angle.

The problem therefore that presents itself to the mining engineer is this—how most efficiently, economically, and safely to extract the ore from a lode running into the earth, he knows not how deeply, and he knows not at what angle. Its slope may be so gentle that a man could walk easily down it when opened, but it may be so steep as to be worse than vertical. For in a vertical lode the cage can be hauled easily up and down, but in a very steep slope other means must be adopted to ensure safety and facility of exit and entrance.

In mining such a slope a vertical shaft is sunk—often at great expense—and cross-cuts or passages are opened out at different levels from this shaft to the lode, as it runs sloping through the earth. In an inclined shaft, the ore extracted pays for at least part of cost. For an extensive underground working, the best arrangement appears to be a main vertical pit and several secondary inclined shafts. Because, it must be remembered, the extent of some of these metallic lodes is enormous. Thus, the Comstock lode in Nevada has a shaft over 3,000 feet deep; but the miners have been driven from the lower levels by the great heat—which was no less than 170 degrees, Fahrenheit—and also by the steam, which was caused by the action of air on sulphurous rock, through which the varying levels penetrated.

In such extensive workings, small shafts are frequently sunk from the upper level to the end of the level immediately below it. The two levels have thus each a communication with the main shaft and also with one another, and the ventilation is vastly improved. The facilities also for raising the ore are much greater. These small shafts are called winzes.

The broad difference between the two classes of mines will now be evident. In mining a coal or an ironstone seam, the mineral to be extracted spreads in a bed more or less horizontally around you, from the bottom of the shaft; though the shaft may be deepened to tap another seam lying below. In mining a mineral vein, on the other hand, levels or galleries are driven out from the shaft upon the vein at every few fathoms depth, one below the other; these galleries being connected by winzes.

It must not be supposed that the lode runs in a straight line through the earth; on the contrary, its course is marked by great fluctuations and irregularities. All these have to be provided for and mined out, sometimes by digging winzes upward instead of downward. Furthermore, the men frequently work by breaking the "back" of the level; that is, they stand on platforms and dig upwards from the upper part or "back" of a level towards the floor of the one above. Thus, the ore easily falls to the level below, whence tram waggons convey it to the main shaft. Sometimes, on the contrary, the ore is worked downward and the broken parts hauled away through the gallery below. These methods are known as overhand and underhand stoping.

The general plan, therefore, of working a metalliferous vein or lode is to divide it by means of levels and winzes into big squarish blocks of perhaps sixty feet in thickness, and mining parties can then be set to work at various points at once. Should the ore prove suitable, the pick is used to bring it down; otherwise blasting is resorted to, and quantities dislodged by this means.

The general object of the engineer is to open up fresh ground—that is, deepen the shaft and drive new galleries, at the same time that the excavation of the ore is proceeding from the upper levels. By this means, portions of unmined ore are kept in readiness for miners, and a steadiness of work and "output" can be fairly maintained. Otherwise, while unproductive strata is being cut through, no ore would be gained from the mine.

As the work proceeds, new shafts will probably have to be sunk, their position being determined by the direction which the ore has been found to take, and so planned as to cut the vein at a much deeper point than the first shaft. The new pit, also, will be placed, if possible, to correspond with the deepest galleries already cut, or with still deeper galleries which are proposed to be cut.

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The difficulty of water is as great in lode mines as in the seams of coal, and immense adits for drainage have been cut in certain instances. An adit is, of course, a tunnel driven from the shaft of the mine to a hillside of a greater or lesser distance away.

Thus, among the greatest adits in the world are the Ernst-August Gallery, draining a mine in the Hartz mountains—an adit which, with its branches, is fifteen miles long ; the Rothschönberger in Saxony, twenty-five miles long; and the Gwennap in Cornwall, which eclipses both, for it is forty miles long, and drains no less an area than thirty square miles.

The Ernst-August adit is a triumph of engineering skill. It was commenced at different places at the same time and so accurately planned that the various sections joined each other exactly when completed. This great precision was partly obtained by the use of an immense magnet, two hundred pounds in weight, which swayed a compass through sixty-five feet of solid rock. The magnet was kept in one of the sections and the compass placed in the other.

In mines where adits cannot be cut, pumping engines are used to lift or to force the water, some of the engines being of immense size and having cylinders a hundred inches in diameter. These pumping engines have enormous work to perform, sometimes forcing water one thousand feet high to lift it out of the shaft.

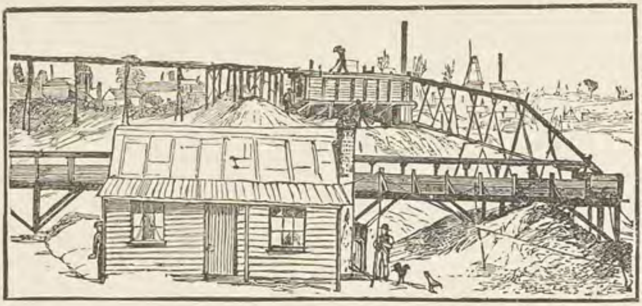
The mining of iron ore occupies a position somewhat midway between the mining of seams of coal and the mining of metalliferous lodes. For while ironstone is largely found in seams like coal and in coal measures, and also in open workings which may be called quarries, or in sand, yet some of the richer oxides seem to belong to a formation known as pipe-veins—irregular cavities descending into the rock ; and again the native carbonate or spathic iron, as distinct from the ironstone, is found in what geologists call "primary" rocks, and exists in large lodes in various countries. It is also associated with lead ores in different mining districts of Great Britain.

Nevertheless, the ironstone is the most frequent form of iron ore in Britain. It ranks, indeed, next in importance to coal, and is closely associated with that mineral in mining operations. Among its chief districts are Cleveland in Yorkshire, the Black Country in the Midlands, Merthyr Tydvil in South Wales, and parts of Scotland.

But when raised to the surface the ore has to be subjected to much manipulation to free the metal from its compounds, for iron, like the great majority of the metallic ores, with the exception of gold, consists of a complex mixture, in which the metal exists, not only combined chemically with one or more substances, such as iron with oxygen in oxides of iron, but also more or less completely and mechanically mixed with earthy or sparry material, and even with the ores of other metals.

It is the lurid fire freeing the iron from the dross that gives to the great Iron Districts their distinctive character. Here are the furnaces burning continually, and belching forth flame and smoke; here are the great sheds for casting the molten metal, the rolling mills, the steam hammers, the Bessemer crucibles—all the giant apparatus for extracting the invaluable metal and working it into shape for convenient use.

For the work of the miner is over, and the work of the founder has begun.



MINING THE PRECIOUS METALS

CHAPTER I.

"PICKING UP GOLD AND SILVER."

"IT shines like fire.'

"Aye, but it is not fire."

"Fish it out, and let us look at it."

The shining stone was pulled from the flames and soon became duller in appearance when withdrawn from the heat; but the man examined it, and burnished it, and decided that it was indeed no common stone which had attracted his attention.

Finally he took it to the mint at Lima, where it was tested and found to be valuable. It was silver ore!

Such, put into brief English, was the discovery of silver mines in Peru. A shepherd was tending his flocks on the slopes of the mountain, and kindled a fire to cook his food, when his attention was drawn to a stone shining in the heat. It was found to be good silver ore; and as the Spaniards recognised the children's saying—"Findings, keepings"—and made such findings the property of the discoverer, the shepherd became a wealthy man. The Spaniards enacted this law in order to encourage such discoveries.

Many of the most valuable mines in the world have been found by accident. An Indian clung to a bush one day, to prevent himself from falling; the bush gave way and came up by the roots, and behold! glittering bits of native silver caught the Indian's eye as he stumbled downward. Those bright little pieces led the way in 1545 to the celebrated mines of Potosi!

Many similar incidents lie scattered on the broad page of history. A boy picks up a yellow stone in North California; his father thinks nothing of it, but he is a poor settler, and has no latch to his cabin door, so, because this yellow stone is heavy, it is used to fasten the door withal. By-and-by, the stone is shown to a visitor, and he gives his opinion that the yellow stone is a metal. Henceforth, the stone door-fastener rises in the estimation of its master, and is exhibited as a notable specimen of curious rock. Then comes a day, some three years after it was picked up, when the owner is going to a market town, and he takes the yellow stone to a jeweller, and asks fifteen shillings for it. The goldsmith pays. The humble stone proves to be a gold nugget worth nearly £900!

This incident happened about the year 1803; forty-five years later—that is, in 1848—a man named James Marshall chanced upon gold again in the sand and gravel of a stream in California, when widening a mill race. The news spread. Tremendous excitement followed, gold seekers rushed in, and the great gold mines of California blazed forth in all their splendour.

Again, birds were observed to pick up curious pellets in Lower Hungary; and examination revealed veins of gold ore. Another story tells how a vein of silver, probably the richest in Chili, was found by a hunter named Godoy.

One day, when weary with the chase, he sat himself down under a huge rock to rest. Glancing round, he was struck by the brightness and by the colouring of one of the projections. He drew out his knife and chipped off a piece, for the rock here was somewhat soft; and he took a fragment to Copiapo. It proved to be chloride of silver.

Entering into partnership with a capitalist who was to work the mine, they soon found quantities of the precious metal; but the reckless hunter, thinking he had fickle fortune on his side, sold his share for less than £3,000, and searched the Andes for more silver. But his "luck" had left him and he died in poverty.

The fragments of metallic ore, which have been picked up at various times, are believed to be caused by the action of floods upon the outcrops of mineral lodes. Such fragments are termed "shoad stones" in the north of England, and the discovery of mineral veins by such stones is called "shoading"; and in Cornwall similar methods are known as "costeaning." Thus, trenches are dug right through to the solid rock in search of the vein or lode.

Scientific deduction has also sometimes predicted the existence of metals. In 1844, Sir Roderick Murchison, when addressing the Geographical Society, foretold the presence of gold in East Australia; Queensland it may be remembered was not made a separate colony until 1859. Sir Roderick was led to make his deduction by noticing the great similarity existing between some specimens of rock from East Australia, probably New South Wales, and districts where gold was found in the Ural mountains—between Russia and Siberia—which he had visited. It is said that a man named Smith acted on the suggestion,

GOLD-PROSPECTING.

searched for the precious metal, and found a nugget which he took to the Colonial Governor.

"Give me £500," said Smith, "and then I will show you the place where I found it."

But the Governor declined the offer.

The discovery by Mr. Edward Hargraves in 1851, led, however, to much greater results ; and his success may also in a sense be regarded as due to deduction.

He went from New South Wales to California seeking gold, and noticed the similarity existing between the strata of the rocks he saw in gold-bearing California and those he had left at home at Conobolas, about thirty miles west of Bathurst in New South Wales.

When he returned, he examined the earth and commenced digging, and finally on February 12th, 1851, he struck gold. He informed the Government, who treated the matter much more seriously than on the previous occasion ; the request of Hargraves for a reward was granted, and he was appointed Commissioner of Crown Lands.

Popular excitement rose high, and the gold fever raged furiously. It rapidly spread to Victoria and to other parts. The fury was increased by the sensational discovery of a large nugget of gold amid a quantity of quartz, by a native tending sheep for Dr. Kerr of Wallawa. That such luck should fall to ignorant black folks would stimulate the keen-eyed, intelligent whites, and the cry of gold in Australia rang round the world.

Nugget after nugget was found and fed the fever, while no doubt highly exaggerated, or even utterly untrue stories were also circulated. That gold richly existed in the Australian Colonies, however, was an undeniable fact, and numbers of persons flocked to the diggings. It was one of the mad times of the world, —such a strange, wild time as followed the opening up of gold in California.

Some remarkable discoveries were indeed made.

Thus, a splendid mass of virgin gold, called the Victoria Nugget, and weighing 340 ounces, came to England from the Bendigo diggings in Victoria. Rich alluvial gold was found here in 1851, and quartz-mining has followed.

Again at Murroo Creek, fifty miles northward from Bathurst, three blocks of quartz were found which yielded no less than 112 lbs. of pure gold. Then there was the celebrated "Welcome" nugget which weighed no less than 2,019¾ ounces; another report placing it at 2,217 ounces. It was found on June 11th, 1858, at a place called Baker's Hill, Ballarat, and was valued at £8,367 10*s.* 10*d.* By comparison with this splendid mass, the largest nugget found in Britain, weighing less than three ounces, appears very trivial.

Such instances as those at Baker's Hill continued to feed the gold fever; and the output of gold in New South Wales and Victoria during the first ten years after the discovery of the precious metal, in 1851, was simply enormous. Gold has since been found in other Australian Colonies, and is in fact largely worked in various parts of the island continent.

One of the latest discoveries was at a spot some forty miles north of Coolgardie in Western Australia. The outcrop of a reef of gold was found extending for over half a mile. Half a mile of golden rock! and that only an outcrop! It reads like a fairy tale realised! The discovery was made on August 9th, 1894, and a few weeks later, on September 16th, the lease of the Londonderry mine at Coolgardie was bought by Lord Fingall for a little less than £250,000!

The existence of gold had previously been discovered in Western Australia in 1870; but with such rich veins the "Westralian" gold fields leapt to the front, and have been reported as likely to be the richest in Australia. Gold has also been found in the north of the colony and likewise in the district of Murchison.

Gold also occurs in many other parts of the world. Comparatively slight quantities have been discovered in Wales and in Wicklow; also in Cornwall, and other counties of the United Kingdom; while on the European Continent, the principal deposits are believed to exist in Hungary, and diorite rocks, which have gold associated with them, exist in Italy.

Going farther afield, the Russian Empire in Asia can boast of producing the precious metal; while gold mines and gold-washings are found in India. In British Columbia gold was found in 1858; in Nova Scotia and also in New Zealand in 1861; and in South Africa in 1868. In the Witwatersrandt mines, in South Africa, of which Johannesberg is the centre, the output of gold has been enormous. The chief sources of the world's supply exist in Australia, America, and South Africa, though gold-producing deposits are found more or less throughout the world.

Both gold and silver have been known from the earliest times. Both are beautiful; both have been found more or less pure; both are malleable, ductile and comparatively easy to work. Both, moreover, are soft metals, though silver is the harder of the two; and gold, as is well known, requires an alloy to render it sufficiently hard for the purposes of coinage. In Great Britain the alloy consists of two parts of copper to twenty-two parts of pure gold.

Previous to the gold fevers in California and Australia the greatest discovery of gold in the century was probably in the Ural mountains in Siberia; and at a mine called Zarewo-Alexandrowsk a mass of native gold weighing some twenty-three pounds was found in 1826; other pieces weighing two to four pounds were also discovered.

Like gold, silver is widely distributed. Native silver is found in many localities and also in many forms. Thus, native silver mines have been worked at Konigsberg in Norway for nearly three centuries, and some exceedingly heavy pieces have been dug there. The famous Comstock lode in Nevada, one of the Western American States, has been found rich in native silver, and it is common also in other veins in Chili, Peru, and Mexico.

Moreover, there are various silver ores found in different parts of the globe. Argentite, or sulphide of silver, yields a quantity of the precious metal, and silver sulphide is also found in combination with copper, when it is called stromeyerite. Chloride of silver, or horn silver, is also an important and valuable ore. There is further stephanite, or sulph-antimonite of silver, popularly called brittle silver ore; dark and light red silver ores; embolite, or chloro-bromide of silver, and also other ores. Montana and Colorado have lately come to the front as great silver-producing States in America, eclipsing even Nevada.

Now, though we have the numerous forms in which the two precious metals, gold and silver, are found, we may for mining purposes divide them into two or three classes. Thus, the gold deposits may be arranged into two—*viz.*, veins, or lodes, or reefs, and secondly alluvial deposits or "placers"; while silver may generally be spoken of as found in veins or lodes.

How then are these deposits worked?

CHAPTER II.

THE GOLD SEEKERS.

"Where is the gold?"

"Aye, that's what I would like to know."

"In the sand, pardner."

"And is that why they are all washing the sand?"

The third man laughed. "I call it washing out the sand," he cried. "Come, move on, pardner. I'm located hyar."

It was the early days of the Californian gold diggings. The discovery by Marshall had been noised abroad, and numbers of persons were thronging to the auriferous stream. A man named Captain Sutter is said to have been a friend of Marshall, and the discovery took place near Sutter's water-mill.

How did the diggers work? It will be clear that the gold found in the stream must be alluvial gold, as distinct from rock gold in lodes or veins; and consequently the diggers came armed with buckets and baskets, shovels and canvas sheets. The most simple plans were in force. Thus, a tub or tin pail having been filled with mud and sand, and stirred up with water, the heavier matter was allowed to settle for a second or so, and the water was poured away. Then eagerly the digger sought in the sediment for the glittering gold.

An improvement on this plan was the use of sieves of woven willow, and at length some unknown gold seeker invented the famous "cradle." Some called it a rocker; the Indians promptly dubbed it a gold canoe.

In fact, it somewhat resembled a cradle; the upper end, however, was raised higher than the lower, one

CRADLING AND PANNING GOLD.

side of which was perforated, while over one part of the top was fixed a grating or sieve. The auriferous earth was placed on the grating, and the cradle was then rocked, while water was poured into the stuff as it fell through the grating. The water washed the earthy material and carried off the lighter part, while a sediment which it was hoped would be rich in gold was left; a sediment also was left on a few bars nailed at the bottom of the cradle. Sometimes these cradles were so large that four men were required to work them; on the other hand, some were so small that one could manipulate his alone. A compartment for quicksilver could be added, and all the sand and mud was made to pass through it; the quicksilver having such affinity for gold that the two metals amalgamated, and the gold was thus drawn out of the mud. Heat is afterwards required to separate the two metals.

Now, the principle of all this gold-washing is that gold is some six or seven times heavier than quartz, or indeed any stone or material likely to be found with it; therefore water has much less power in moving it than in moving other matter. Furthermore, gold is about nineteen times heavier than water. No wonder therefore that washing the golden sand was found to be efficacious.

This comparatively easy method of gaining gold made some of the miners wildly reckless. For instance, when enterprising dealers would establish stores at the diggings, the miners would give extravagant prices in native gold for common commodities. The men would shake out the gold to the amount asked, and if any fell on the rough counter would never trouble to reclaim it, crying, "Never mind; there's loads more where that came from."

The stores were often of the most primitive description, consisting of an awning for a roof, and planks set on upright barrels for a counter.

The rewards of the miners varied greatly. Some chose rich places—partly by shrewdness and observation, and perhaps partly by accident. Some expended their gains in wild extravagance, and some in riotous living.

But simple as was this method of mining, it was probably not the simplest. This alluvial gold probably explains the story of Jason's golden fleece. It was most likely a sheepskin pegged in the stream, and a number of golden grains became caught in the wool. The same course is pursued to-day in various parts of the world, ox-hides or sheepskins being stretched in the stream.

As operations increased with the alluvial gold, improvements were made in the cradle. A plan which found favour at the Australian diggings was the use of the "puddler." The "wash dirt"—that is, the earth in which the grains of gold are expected to be found—having been dug up, either from high or low deposits, was brought to the "puddling machine." It was a circular vessel of cast-iron with an upright post in the centre, to which was attached heavy harrows of iron. These would churn up the "wash dirt" to a watery paste, in which the gold would easily sink to the bottom. The thick liquid being drawn off, the larger stones were picked out, and the sediment was sluiced; *i.e.*, it was passed through an inclined trough having a few bars of wood called ripples at the bottom. The flowing water carried off the lighter portions, which were called tailings, and the ripples caught the gold.

The gold seekers found their precious metal sometimes in the river bed, and sometimes they had to search holes and gravel in the alluvial soil. In the search, even the course of the stream was at times diverted to another channel. In New Zealand and Western Australia, the sea silts up some sands of gold; but such "ocean placers," as they are called, have not hitherto been found of great importance. Alluvial gold is also found in spots separated from streams, the former rivers having been dried or removed by geological changes.

In placers or diggings where the result would seem to warrant the expense, greater operations than the large cradle or puddler for mere washing have been conducted. Thus, streams of water are conveyed in pipes to the gold-producing material, and gushing through the pipe at great pressure, will wash the deposit and remove the extraneous matter from the gold. The method is spoken of as hydraulic mining or piping. Sluices or wooden flumes are also constructed for similar purposes, the principle being in all methods the same—*viz.*, to remove the earth by flowing water while preventing the gold from escaping.

The discovery of gold "placers" away from streams seems also to have been largely due to accident. A party of miners traced an auriferous patch of gravel, and began to dig into a hillside; when, to their surprise, they found that the gold deposit continued under the high ground.

The search for gold, generally increasing, and becoming more scientific, led to the discovery of many other "dead rivers" or "deep leads." Men then began to realise by what they saw that rivers which had long since ceased to flow—at all events over these grounds—had at one time caused these rich deposits of golden ground to accumulate.

Furthermore, it has been found that some of these old rivers have been filled up with volcanic lava; in certain instances more than once, and at different intervals, so that several layers of golden gravel are found sandwiched between beds of volcanic rock. The pursuit, therefore, of even "alluvial" gold-mining, has led to operations under hills and under rocks, in places where an ordinary observer would never dream of finding traces of a river. In fact, many of the "placers," both in Australasia and in California, are found in such "deep leads." Near Ballarat, for instance, miners have boldly dug down for five hundred feet, to strike the bed of an old river, which swept down golden earth ages and ages agone.

In such cases hydraulic mining becomes both useful and, to an extent, economical—that is, economical of time and labour. It is, however, wasteful of earth, for it often covers fertile fields with arid soil. Reservoirs and water piping are on the other hand constructed, which may prove of benefit when the immediate object for which they were made has passed away. Economical of time and labour though this method of mining may be, it is prohibited in some places, because of the damage it has wrought to the surrounding neighbourhood, and the rivers it has silted up. It is said also that it may wash away too much gold with the dirt. Yet immense quantities of earth, amounting to thousands and thousands of tons, have been thus treated.

Reef-mining for gold does not differ very materially from vein-mining for other metals. Gold is found more or less slightly in several hard rocks, but more

HYDRAULIC MINING.

abundantly in quartz—which is silica—and in limestone. When many of the immense alluvial deposits became worked out, more attention was paid to the production of gold from veins or lodes.

The theory is that alluvial gold has been brought down or disintegrated from the rocks in which the vein ran, just as rocks themselves were disintegrated. It would not, however, be safe to say that any portion of the old vein or reef would be found to be rich in gold, for probably the ancient torrent carried away much of the rock in which the gold was embedded.

The direction of the mining shaft, for a gold reef, is largely determined by the position of the lode. Thus, one vein may be found averaging three feet wide, and appearing perpendicularly between walls of other mineral matter. Another lode may lie horizontally, another sloping, while yet a fourth may pursue a twisting and a tortuous path through the earth.

Further, these veins are very capricious. Some will yield a hundred times more than others ; then again, a lode may dwindle away to nought, like a stream in a sandy desert. Once again, a lode may be found to contain iron pyrites mixed with the gold, and presently the erratic gold will cease, and the iron pyrites appear alone. The saying, "as rich as a gold mine," might appropriately be varied, "as capricious as a gold reef."

The actual work in the mine itself much resembles the working of the tin and copper mines of Cornwall. The blasting-charge, the pick-axe, and the shovel—all are in use. Tons of quartz or of limestone are brought down, and drawn out of the mine by steam or water power. The pit may be perpendicular, with lateral galleries, and hundreds of feet of air-pipes convey air to the miners below. There being no fear of fire-damp, gas has been turned on to some extensive underground workings for alluvial deposits.

When the vein gold is brought to the surface, the uninitiated would probably marvel at its dissimilarity to the precious metal. "Where is the gold?" they would ask.

GOLD IN QUARTZ FROM WEST AFRICA.

A piece of phenomenal richness. All the dark veins are pure gold.

The answer is, it is embedded in the quartz or the limestone, or contained in the metallic ores with which gold is sometimes found. First, therefore, the quartz or the gold rock is turned over to the stamps. This is a complicated piece of apparatus consisting of a number of hammers, which break the gold rock to powder. Sometimes the vein rock is first roasted, which greatly facilitates the powdering process, and causes the gold particles to run together. But should pyrites be present, the gold is spoiled—that is, it becomes filmed over with sulphur or oxide of iron. Improved rolling and crushing mills are now made which may probably supersede the complicated stamping batteries.

After being powdered, the treatment of the pulverised vein gold-stuff is much the same as the alluvial "wash dirt." Contrivances for this purpose are now carried to a high state of efficiency; thus, there are quicksilver troughs, and amalgamation plates, and also blanket "strakes" for catching every conceivable form and dust of gold. The pyrites—*i.e.*, metallic sulphurets—are also caught, for they may be found to contain gold when procured in gold-bearing veins. But in all these various processes the principles already pointed out are found—that is, advantage is taken of the greater heaviness of gold, and of the strong affinity prevailing between gold and quicksilver.

GOLD IN QUARTZ FROM WEST AFRICA.

The gold in this piece is in microscopical portions, producing only a few ounces to the ton.

The treatment of auriferous ores also varies greatly, the system of separation differing with the ore and the locality in which it is found. Where sulphur is present, for instance, it can be eliminated by burning the ore in kilns. When so treated, the sulphur passes off in vapour, and can be used for making sulphuric acid, while the cinders containing the gold and other substances must be again treated, to separate the precious metal. These processes, however, may be described as belonging to the chemistry of the metals, rather than to mining.

The production of gold during the nineteenth century has increased enormously. Chemical science and engineering skill have both been brought to bear upon its extensive working and subsequent treatment, while comparatively deep and far-reaching mines, the powerful and ingenious machinery used in working it, and the immense quantities resulting, would greatly astonish the old diggers of shallow mines, or the washers of golden sand of centuries ago.

CHAPTER III.

SALTING A MINE. THE SILVER DIGGERS.

"We ought to have guarded the mouth of the mine."

"Tut, nonsense; get on. No one will come here now."

Yet some one was there. Noiselessly the new comer had stolen to the platform, and was gazing down the shaft and listening to these strange words.

What did they mean?

The listener was a mining engineer, and he had been retained to report upon this particular mine. He had already examined it, and his trials had been very satisfactory. "But," he had said to the owner, "I would like to sink the shaft ten feet or so deeper, and sample the ore I may find there."

During the night after he had made this remark, he went home past the mouth of the mine, and to his surprise he heard noises therein. So he listened and caught the conversation already recorded. Further, he was able to perceive two men at the bottom of the shaft—which must have been a shallow working, compared with certain mining shafts in England. One of the men was drilling a hole, and one was working a machine something like a churn.

Quietly the mining engineer returned home.

"I will not sink the shaft any deeper," he said next day to the mine owner.

"No! why not?" exclaimed the owner.

"I have concluded not to recommend the mine."

Thereupon the owner burst forth into angry objurgations, until the expert significantly said, "I was at your mine during the night and saw what was going on."

Then the rascal stared at the engineer in astonishment; his mouth fell, and he left the expert without saying another word.

He had been "salting" the mine, and the engineer had discovered it. The rascal was making a solution of gold by a certain chemical process, and was running it into the rock. The solution has great penetrative power, and on the rock being tested, the presence of gold would be found.

This incident, which is paraphrased from the *Globe Democrat* of St. Louis, occurred in New Mexico. The same writer also exposes other nefarious practices of a similar nature.

On one occasion an expert was engaged to report upon a mine which had already been favourably noticed by others. Yet as the engineer proceeded along the workings, he felt very dissatisfied. He could see no indications of the precious metals. Nevertheless, he took samples from the various parts, which in due time were thoroughly tested and yielded rich results.

The engineer was greatly surprised and felt almost forced to believe the mine was good. But before reporting, he stipulated that he should be allowed to treat the workings as he pleased for forty-eight hours; otherwise he could give no certificate.

The owners at length consented. So he went with a number of men down the mine and blasted out pieces right and left, and took samples from the newly exposed walls. Not one trace of precious metal did these samples yield.

His first idea had therefore been correct; but how had the mine been "salted"?

He discovered after a time that some of the talc on the sides of the mine had been scraped away, gold dust had been mixed with it, and the compound fired from guns all over the mine. Thus gold was sprinkled almost everywhere, and a sample taken at any part would yield traces of the precious metal when tested.

These swindling practices are sometimes resorted to, in order that purchasers may be induced to buy worthless shafts in the expectancy that they contain rich quantities of silver or of other minerals. The mine has probably been opened a short distance, and the owners propose to net a profit by cheating a customer, who will most likely prove to be at first or at last a public company. So has the false been made to imitate the real.

Though silver was one of the first known metals and has been used by mankind for hundreds of years, yet the nineteenth century has witnessed a far greater production of the precious white mineral than probably ever before in the world's history. This is due to the great silver mines of the Western States of North America, and also of New South Wales, which have only been known in the latter half of the century.

The development of silver production in North America may be dated from 1859, when the workings on the surface of the famous Comstock lode in Nevada were begun; and almost fabulous amounts have also been raised in New South Wales since 1883, when the metal was discovered there.

The silver region of this colony is at the Barrier ranges of mountains near South Australia, and covers an area of about a hundred miles by twelve. Enormous deposits have been found, and one company—the Broken Hill—has raised literally millions of ounces, while the produce of the district is estimated as worth nearly £2,000,000 annually.

Silver is also found in Tasmania, in galena ore—galena being a sulphide of lead. Indeed, silver is frequently found with lead, or rather with lead ores. But native silver and ores of silver occur in numerous forms and in many places. Native silver, for instance, is sometimes found crystallised in an arborescent form, while other specimens are massive, and others again are simply grains or even specks scattered through various kinds of vein stone. Still further, native silver may be found, curiously enough, connected with silver ores and also with native gold; when silver reaches to one-fifth as much as the gold, the metallic compound is known as electrum. The pale gold of Transylvania contains nearly 40 per cent. of silver; that is, about thirty-eight hundredths are silver. Silver ores usually contain some gold and gold ores some silver, so that the precious metals run together, even in the earth.

One of the most wonderful silver mines in the world is that of the great Comstock lode in Nevada. Strictly speaking, it might be more accurate to describe it in the plural, for the length of the various shafts and galleries reaches to some two hundred and fifty miles. A considerable quantity of gold has also been mined here, raising the value of the total product to very many millions of pounds.

The lode is certainly a most extraordinary one. It lies nearly north and south and dips also about forty-three degrees to the east. Its width—that is, the width of the ores or "bonanzas," as rich ores are termed in the miners' language of the West—varies from ten to fifty feet, and runs between very unstable walls. The vein stuff itself consists of decayed rock, quartz, and clay ; and in this earthy matter lie the precious metals. The stupendous size of the mines enabled more than three thousand men to be employed at one time, including those at the amalgamating mills, where the silver and gold are separated from their compounds.

The depth to which some of the shafts have been sunk is very great. Thus, the Yellow Jacket Shaft had attained a depth of 3,065 feet, when the miners found that water reached a temperature of 170 degrees Fahrenheit, and the great heat of the lower levels prevented it from being worked deeper. As an illustration of the difficulties of forming a sound judgment, even in working such rich lodes, it may be added that some thousands of pounds were lost in sinking a shaft, which it was expected would prove of great service, but which was found to be unsatisfactory.

Mention must also be made of the cages used on the Comstock. They are remarkably light and yet efficient ; and lightness, it will be seen, is of great importance in travelling up and down such deep shafts. The cages are moreover provided with

INTERIOR OF COMSTOCK SILVER MINE, NEVADA

"safety-catches," which hold the cage should the rope break; but in construction they are little more than platforms of timber five feet by four, resting on iron bars with rods of iron on either side, and provided with a sheet-iron cover to protect the men inside. Blocks are also attached, moved by hand levers, for keeping the cage in its place while ascending or descending between the guides.

Another noteworthy point about the Comstock is the special method adopted of supporting the outside ground around the vein. This ground was not only unstable, but the vein was very wide, and special plans are often adopted when wide lodes have to be worked.

The method pursued at the Comstock was to build strong frameworks of timber, consisting chiefly of twelve-inch balks, squared and tenoned together, to form what may be described as openwork or skeleton pillars. Thus, four pieces of the timber were fastened together at the ends to form a square; on each corner a post some six feet high was raised, and on the top of the four posts another open square of timber was placed.

As the valuable ore was cut away, these pillars could be piled up one above the other to the required height, to support the overhanging roof, any vacant space being filled with waste—*i.e.*, barren rock. To walk through the excavated or "stoped" levels of the Comstock to the "face" when the ore was still being procured is like walking through gigantic timber cages.

The ore was stoped away—that is, excavated right across its width, and worked overhand, the contents of the vein being approached by advancing upwards from below, the miners starting from a winze or a shaft. Blasting, of course, is very largely in use in all mines save those of fiery coal.

This method of timbering the Comstock may be taken as a specimen of working a wide vein ; another plan being to cut out the ore in narrow divisions, parallel to the dip of the lode, and fill up the space with waste rock or rubbish.

The immense metallic production of the Comstock has lessened of late years ; but the Eureka and Richmond silver mines are celebrated for their production of silver, as also are the mines of Montana ; while the story of Leadville in the heart of the Rockies reads almost like a romance. Ore was discovered here, and within some five years a large town had sprung up with smelting works and railways. Leadville is in Lake County, Colorado, and its output in lead, gold, and silver has been enormous.

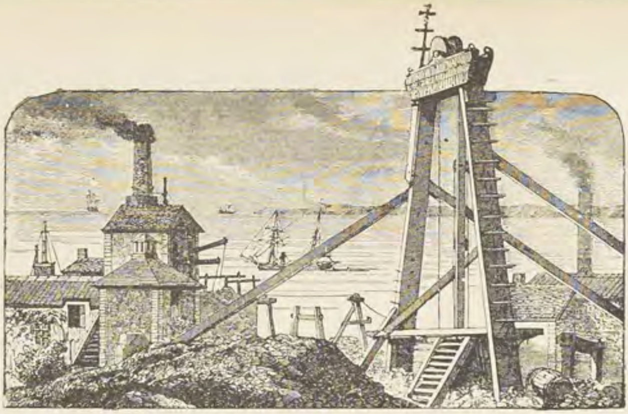
A frequent method of treating silver ore is known as amalgamation ; that is, the ore is amalgamated with mercury, there being an affinity between the two metals. In the Freiburg process the ore is pulverised by mills or stamps, and the resulting mass is amalgamated with quicksilver in barrels or in pans.

The pulverised ore is roasted with salt, forming chloride of silver, and the resulting mass is mixed in barrels with due proportion of quicksilver, scrap iron, and water. The barrels are then rotated, and the mass is squeezed in linen bags to expel a quantity of the mercury, and the pressed amalgam left is distilled in iron retorts, from which the mercury passes off. A further purifying process can be carried on by fusing with lead, and subjecting the mixture to cupellation. That is, the mixture is melted, and air blown upon it ; the oxygen of the air then unites with the lead to form oxide of lead or litharge, and the silver is left on the furnace bed.

The Freiburg or "barrel-amalgamation" process has been superseded at Freiburg in Saxony, where it originated, by the Augustin process, in which the chloride of silver is treated with copper, when the silver is precipitated and chloride of copper formed, from which the copper has in turn to be extracted. In the Comstock district, however, the Freiburg process has been largely used.

But in consequence of the numerous ways in which silver is found, the processes for extracting it from the ores vary perhaps more than those for any other metal. Nevertheless, the three leading principles of the various methods have already been indicated:—First, the amalgamation of silver and mercury, the mercury being afterwards eliminated by distillation. Second, the conversion of the silver into a soluble salt, from the solution of which the precious metal is precipitated by copper or iron: this process is suitable for sulphuretted ores, such, for instance, as are found in the quartz-vein stuff of the Freiburg lodes. And third, the alloying of the silver ore with lead ore, as in the case of smelting the two together and separating the silver by cupellation.

Both silver and gold were among the earliest metals known to man, and they are now among those which are most eagerly sought, and, when possible, most largely worked. No problem connected with mining them seems too great to be overcome; and their discovery, often by chance, has led to some of the most sensational periods of the world's industrial history, and to some of the largest mines mankind has ever known.



IN VARIOUS VEINS:

THE MINING OF COPPER, TIN, LEAD, ZINC, QUICKSILVER, ETC.

CHAPTER I.

IN A COPPER MINE.

"IT'S amazin' how soon rats find out a mine and begin to annoy the men. Look there now—them rats have took nearly all my dinner, and, dash it all! they've eat my candles! Ha! there goes one."

And at that moment a fat rascal scurried along the dim gallery, and the miner in the excitement and vexation of the moment, hurled his pick-axe at it—with no effect.

"Where they come from, I can't think. We wants a heap o' terriers down here, that's what we want. They'd give the varmint beans—drat 'em. Now what be I to do for a light? I can't use them nibbled-up things."

And he pointed as he spoke to the emaciated and gnawed candles.

"Ah, of course you can use dips down here, not being a fiery coal mine."

"Well, ye see sir, I'm old-feshioned, I am. And to my thinkin' there's nothink like a good old dip-candle—leastways for outdoor work. You can stick it in a dab o' clay, or alongside a prop o' timber, and—there you are! You get as much light as you kin have, and get it where you wants it."

"So you like it better than a lamp."

"Don't want no trimmin', a dip don't; and now, drat them rats! my candles is spiled. I've heerd tell of a man what lost his life through rats. He got so mad with their worryin', that he chased one he saw, and it led him to a foul or fiery part, and he was a deader, poor chap. Eh, Tom, have ye a dip or two to spare?"

Tom had several "dips," and thus supplied we proceeded through the galleries of the copper mine.

"Well, you have not fire-damp or choke-damp to contend with, that is one comfort."

"Nay, but we have water and we have old workings. Water collects in abandoned galleries, and so does suffocating 'dead air.' A borin' tool might go too far through a party wall, or a blast explode too far, and then the pent-up water or air rushes through, and mayhap sweeps away the barrier and drowns the mine."

"Aye, I remember reading of a very remarkable occurrence of that kind near Liege," replied the old miner's companion, "and the old workings being under the river Meuse, the rush and roll of water seemed continuous. It appeared almost as though the river itself poured into the mine. But the sturdy engineers, not to be beaten, set up pumping machinery at each of the four shafts with which the mine was worked, and maintained pumping for no less than seven years. The water indeed was not subdued until the expiration of that great lapse of time. Then the indomitable miners commenced work again. This probably is the most notable instance of the kind on record."

"Very like; well now, sir, there's a question as has oftentimes puzzled me, and p'raps you can answer it,—Which was the first metal discovered by man?"

"Well, tradition says it was copper, and also that it was found at Cyprus, from which island its name was derived."

"Now, what argyments is there in support o' that?"

"Well, it is known that the ancient nations used copper—generally perhaps in the form of bronze—though some instruments have been discovered made of copper alone. Bronze is, of course, usually copper mixed with tin, and numbers of bronze articles have been found dating from prehistoric times. It is believed also that the word translated brass in the Bible would be more accurately rendered bronze; while the term Bronze Age is used by archæologists, to indicate a period when people were using bronze for fashioning cutting instruments and weapons.

"There is at Naples, in the National Museum, a superb collection of bronzes, which indicates how largely the metal was employed for ordinary articles of everyday use. Razors and saws seem to have been made of bronze, as well as swords and spears.

"Iron comes after bronze; the poems of Homer indicate the people leaving the use of bronze for that of iron; and as a stage of development the use of bronze—*i.e.*, we may say copper and tin with possibly also sometimes zinc and lead added—follows the stone age, or the use of stone, and precedes that of iron."

"Yes, well," said the old miner approvingly, "that all sounds very likely and probable. But now, how did the ancients, as you call 'em, discover copper?"

"Possibly by searching for stone. They may have come across pieces of copper ore, or even pieces of native copper, when looking for suitable stones wherewith to fashion such instruments as they desired. For as you know there are numerous ores of copper, and native copper crystallised in various forms is often met with where copper ores are found, while a comparatively low heat is sufficient to extract it from its ores."

"Then there's tin again; what about that metal? How did they find tin?"

"Tin also was very early known, and as blocks of it have been found in the ancient Lake Dwellings of Europe, it is believed to have been smelted over two thousand years ago. The ore of tin is often found near the surface of the ground, and also in streams, as alluvial gold is found. Probably the tin for which the Phœnicians used to trade to Cornwall was gained from these stream-works. Furthermore, the ore can be reduced to metal by a low heat and by charcoal, so that it was comparatively easy to work.

"The peroxide of tin is its principal ore, occurring in two forms—in veins where it is mingled with other metals, and is known as tinstone; and the stream-tin which occurs as grains, or larger masses in alluvial soil. What may be called pebbles of tin are sometimes discovered in the stream-works, weighing ten or twelve pounds. The tin pyrites, which is really a double sulphuret of tin and copper, is rare, but is found in Cornwall."

"So the ancient mines was summat like diggings, I reckon."

"Most of the ancient mines, for any metal, were probably more or less like the Cornish stream-works; and the fact that the ancients used gold and silver, copper and tin, does not necessarily imply much mining work or mining knowledge; for deposits of metals or metallic ores were frequently found in a pure state, and also near the surface of the ground. Moreover, it must be remembered that those easily mined and superficial deposits were much more abundant then, than now."

"Aye, they were soon snapped up, I'll be bound," assented the old miner.

"So, as the world grew older, men had to drive deeper for the earth's mineral wealth. Nevertheless, Herodotus—an old historian, and sometimes called the Father of History—mentions that the Phœnicians quite burrowed into a mountain in Thasos when searching for metals, and the Egyptians apparently knew how to dig shafts and drive passages."

"Aye, aye, they were beginning at it then," interrupted the other; "and men got on from one thing to another, I dessay."

"So I hold the story to be something like this," his companion continued; "mankind was led to dig in the earth for metals by reason probably of finding substances, such as tin and gold, in alluvial deposits; possibly also they came across shoad stones lying near the outcrops of veins, and perchance they hit upon the outcrops of veins themselves. Copper, lead, tin, and zinc, you know, are found in veins, though tin as well as gold is also found in alluvial deposits. And I suspect that at all events, as far as Britain is concerned, the stream-works in Cornwall were the earliest forms of mining known."

"And how came the bits o' tin ore in the sand o' the stream ?" asked the old miner.

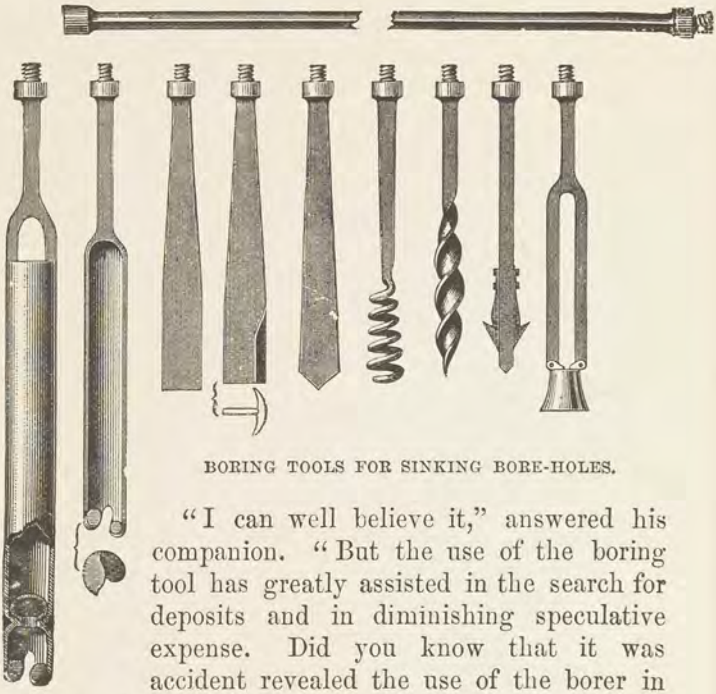
"Probably the continual rush of the water through some vein or mineral deposit broke up the ore by degrees, and scattered pieces along the bed of the river. And even now streams help the prospector greatly in his search for minerals. He scrutinises rock sections such as may be found in cliffs, or the valleys of rivers, and often washes the stuff at the beds of rivers for traces of the heavy metals. Moreover, he may discover vein stones in a valley, and track the watercourse upwards in the hope of discovering the vein from which they were washed.

"Thus I see the *Engineering and Mining Journal* states that the outcrop of the vein of the Great Western quicksilver mine in California appeared really like an immense ditch, more than a hundred feet wide, and having steep sides, which in some parts were seventy-five feet high."

"Crikey ! I should like to have found that mine," exclaimed the old pitman. "Funny ain't it, to think o' quicksilver runnin' about in a mine."

"Oh, but like most other metals quicksilver is found in ores. Cinnabar, or red sulphide, is the chief—so you must not think of quicksilver running loose in the mines. But to return to our ancient miners,—when they found a vein by the outcrop, or what not, they appear to have simply dug it down for a little distance, and then opened another excavation. In fact, the modern method of opening up the ground by a well-planned series of shafts, and winzes, and levels, as you have here, was not practised till toward the close of the eighteenth century."

"It is much better," returned the old man. "It divides up the ore into convenient blocks for blasting, and it is much cheaper to boot; for the expenses of mines is big enough in all conscience. Why! what d'ye think the new shaft cost at Tresevean!—that's a well-known copper mine in Cornwall—£20,000 it cost, and that is after an inclined shaft had been in use for years—£20,000, sir, and it was 1,800 feet deep."



BORING TOOLS FOR SINKING BORE-HOLES.

"I can well believe it," answered his companion. "But the use of the boring tool has greatly assisted in the search for deposits and in diminishing speculative expense. Did you know that it was accident revealed the use of the borer in mining, just as accident has led to the discovery of some of the richest mines?

"It happened in this way, so the story goes. A party were exploring for artesian wells at Oignies in France, when lo, the boring tool brought up coal!

And subsequent efforts showed that the coal field thus chanced upon extended for a hundred thousand acres. I need scarcely say that the ground was soon pierced in all directions."

"I reckon it were," replied the old miner. "But ain't you heard tell of the lode lights as showing where a mineral vein or lode lies. You can see them glimmerin' in the dark they say, and pointing out where the vein of mineral ore runs beneath."

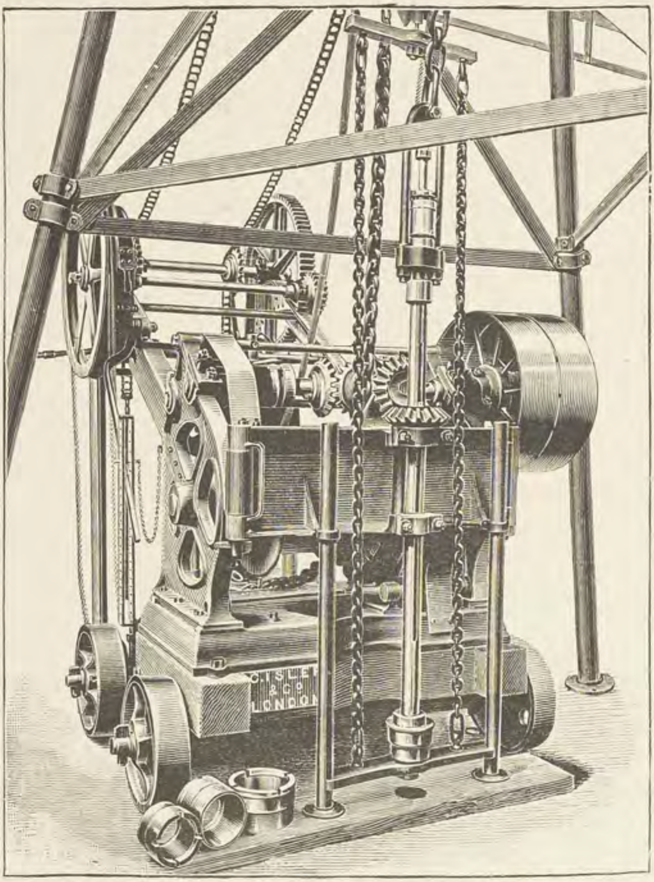
"That is easily explained. The upper part of mineral lodes often contains phosphates, and when these are acted upon by water and organic matter, phosphuretted hydrogen gas is generated—hence your lode light. I do not attach much importance to them; still I doubt not but that they may have been seen, once upon a time, before the drainage was so great. But the sinking of bore-holes yields now the best evidence of minerals beneath the earth."

"Aye, and some wonderful apparatus they've got for boring."

"Well, there are, roughly speaking, three kinds—*viz.*, boring with a rod, with a rope, and with the diamond drill.

"Boring with a rod is very much like boring with an auger, which is, however, fitted with a valve for scooping out the stuff that is bored out, and as the work progresses other rods are added, one after the other, to increase the length as the auger descends; at first a chisel is used instead of the auger. By the rope method, the chisel and instrument for scooping the stuff cut by the borer, is continually raised and then permitted to fall; and thus it pierces its way through the earth; for boring in soft rocks this method has been successfully used.

"But the diamond drills—ah! they are the boys! They are really superseding all others, particularly for



DIAMOND DRILLING MACHINE WITH BORING CROWNS.

deep bores and for mineral searching. The diamond drills I should think could pass through any rock and at almost any angle, and moreover obtain specimen 'cores' of all the strata through which they pass. The diamond drill consists of a steel cylinder fitted around one edge with teeth of hard, black diamonds. I mean real black diamonds and not coal. These black diamonds are found in Brazil, and are called carbonados. They are imperfectly crystallised, but exceedingly hard, and when the cylinder to which they are attached is turned round they cut their way through earth and rock, the part cut away rising up through the cylinder. Lengths of tubing are attached as the drill descends, and thus the core of earth or rock is contained in the tube and can be lifted out as desired. A stream of water can also be forced down to wash away the detritus arising from the abrasion of the rock. Sometimes these drills are made so large that they are a foot and a half in diameter; sometimes so small that they are only one and a quarter inches in diameter; there are also several sizes between."

BORING CROWN OF DIAMOND. DRILL SET WITH DIAMONDS.

"Eh, there's many bigger than what we use for boring our blast holes," quoth the old miner grimly. "Now, sir, have you a mind to see a blast? 'cos we're just about to do one! Got the dinnermite, Tommy?"

Tommy had the "dinnermite," and the old miner took two or three cartridges from him and handled them tenderly as though he loved them.

CHAPTER II.

BLASTING A MINE. THE SULPHUR OF SICILY.

"WHAT drill are you using here?" asked the visitor.

"Not di'monds, sir; hard steel's good enough for us. There she is! She works by compressed air."

The machine stood on a light trolley running on wheels, and the spectator could see that it worked in much the same manner as a diamond drill, with a crown of steel, however, instead of the teeth of the black diamonds.

"When we bores a number o' small holes and fills 'em with the 'splosive, we call that the small-shot system. There you see, the set of small holes; now we shall put these dinnermite cartridges, one into each hole, and then tamp them—that is, close them with sand or clay—fire the time fuses, and scuttle off."

He helped Tommy fill the holes with the cartridges, tamp them, and fire the fuses, and then the little party withdrew to a safe distance. A roar as of muffled and distant thunder shook the air and rolled through the gallery of the mine, reverberating to its farthest corners. Hurrying forward again, the men found heaps of loose stuff shattered down by the explosion, and ready to be loaded into waggons and hauled away to the pit's mouth.

"There's work for you," exclaimed the old miner. "See what a lot o' pick-axe labour that's saved. When we're a driving in a heading from the face, or sinkin' a shaft through rock, we cut out a hollow for powder and fire it by 'lectricity. Oh, we has a rare bust up some times—two or three hundred pounds o' powder a bangin' off at once. It do bring down the stuff."

THE HYDRAULIC CHISEL AT WORK.

"But, as a rule, it is better to have two or three smaller blasts than one enormous one."

"Aw, aye, our engineer knows what he's about; but what miners would do without blastin', I can't think. It's like their right hand, I should say."

"Yes, blasting was, I suppose, the first great step forward in mining enterprise, after the ancient methods, and curiously, gunpowder was, I believe, first used in England for this purpose at a copper mine in Staffordshire. It is said by John Taylor that certain German miners, who were brought to this country by Prince Rupert, used it first. But some years probably elapsed before Cornwall employed this powerful aid to the miner."

"Ah, the Cornish miners were beginnin' to get deeper then, and found out how valyble it was."

"Yes, and they began to discover, about the commencement of the eighteenth century, that there was rich copper ore in Cornwall, lying lower than the ores of tin, and different from the 'mundic,' or iron pyrites, which is often found in mines. And when the Cornish folk found they had valuable copper ore beneath their ground, the mining of this mineral increased with considerable activity, as you may suppose.

"It is chiefly copper pyrites or yellow copper ore, a sulphide of copper and iron, which is mined because it is so abundant. But the richest ore is ruby copper or red oxide of copper, containing, when pure, almost 90 per cent. of the metal; while another important ore—the green carbonate—is the well-known mineral found so largely in Russia, and called malachite. When pure, it contains some 57 per cent. of the metal. Then we have a blue carbonate, or as it is called chessylite, or azurite; and also purple copper ore—a sulphide; and further, grey copper ore—a sulph-antimonite. There are also several other ores, among which may be mentioned an oxychloride found in Chili, and some other countries.

"The richest copper mine in the world is believed to be the Calumet and Heckla, on a peninsula of Lake Superior in Michigan, United States. It has produced about 50½ million pounds in one year.

"The Indians, it is said, used to obtain copper from this region ages ago. Native copper is found in the neighbourhood of the Lake, and one of the largest masses of native copper ever found, was gained at the Central Mines, Lake Superior, in 1886. It was an enormous mass weighing 800 tons."

"What heaps o' pennies could be made out o' that," exclaimed the old miner.

"When alloyed with tin," replied the other. "Well, it is satisfactory that we can get quantities of copper from abroad, for the yield from our Cornish and Devonshire mines has been declining since the year 1860, when their maximum amount was reached. We get copper pyrites from Huelva in Spain, while South Africa, Venezuela, Australia, and the United States also yield us some supplies; the smelting of the ore is largely carried on at Swansea in South Wales and the district around; also in Lancashire. There are no fewer than six operations in the usual Swansea process—so it is rather a complex business, as you may imagine. Well, well, here we are at the shaft again."

The speaker was quite right as to the decline in the output in Cornish copper, and it is curious that one of the deepest and largest copper mines in the county—*viz.*, Dolcoath—after yielding copper ore to a great depth, changed altogether, and the miners found ore of tin awaiting them. The mine is now about half a mile deep, and the tin workings are almost exclusively in the granite. This immense mine has a number of shafts communicating together below the ground by numerous galleries, which again frequently communicate with one another by means of winzes.

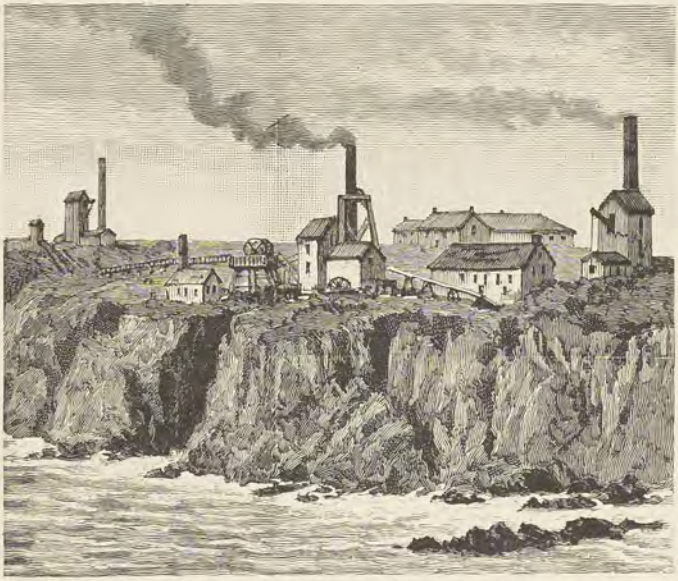
Tinstone is also found in Cornwall in the "killas," which is a kind of slaty clay or clayey slate, and is associated with a number of other minerals such as arsenic, apatite, mica, and tourmaline. Deposits of tinstone (binoxide of tin), which is the principal ore of the metal, have been found in different parts of the world —Queensland and New South Wales among others.

Whether these discoveries will have a markedly depressing effect upon Cornish tin mines remains to be seen. Cornwall was probably the first district to produce tin for the world, and its extensive mines are now becoming exhausted, or have to be wrought at such a great depth that the heavy expense renders it difficult to compete with the large supplies brought from abroad.

In the St. Austell, St. Agnes, St. Just, and St. Ives districts the mineral veins are chiefly of tin ore; in the Gwennap, Redruth, and Camborne districts they are chiefly of copper; in the Breage, Marazion, and Gwinear districts they are mixed. In the St. Austell district immense quantities of china-clay, which is used in pottery work, are prepared from decomposed granite; and ores of antimony, manganese, and some lead are also found in this richly metalliferous and mining county of Cornwall.

Tin and copper, however, still remain the chief products; and the popular Cornish toast, "Fish, tin, and copper," represent three of the great Cornish industries.

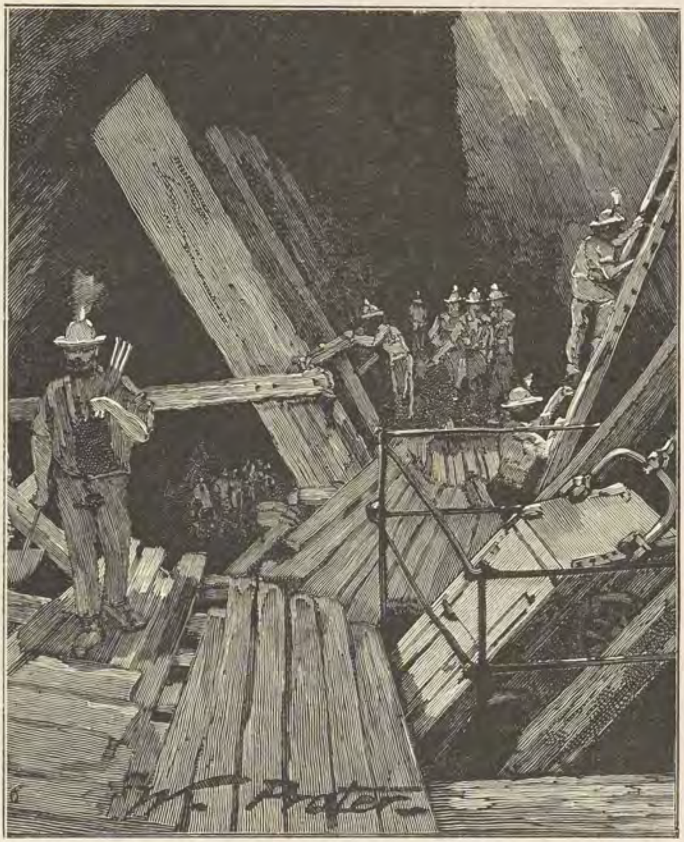
Mineral veins are sometimes of great length in the earth. Thus, the great Van lode in Montgomeryshire is known to exist for a length of nine miles, and is sometimes forty feet wide; but lodes vary very much in productiveness, some parts being rich and others poor. Moreover, the lode does not always lie together,



EXTERIOR OF CORNISH TIN MINE.

but sometimes in "bunches." The mining engineer therefore has to consider these varieties and form his plans accordingly, so that he may extract the greatest amount of ore with due regard to economy; for it would prove a sad waste of money to keep his men at excavating poor ore, or in driving winzes and galleries to unproductive rubbish.

As for conveying the metallic ore along the levels, the systems pursued are more and more approaching to the method followed in coal mines. Coal leads undoubtedly. It is the largest industry, and the most



INTERIOR VIEW OF A CORNISH TIN MINE.

dangerous, and if a system of haulage succeeds well in the miles of underground workings of a large coal mine, why should it not be adopted in a great metal mine?

The waggons used at the great Van mines are made of sheet iron, placed on a frame of oak and run on wheels of cast steel ; the body of the waggon is so made that it can be pushed into the cage and drawn up the shaft. Arrived at the top it is run on a "tippler," which turns it over with great ease and empties the ore where required.

Sometimes men or boys "tram"—that is, push these waggons along the galleries of metal mines; but horse power and mechanical means of hauling them, as in coal mines, are also adopted. Especially are mechanical methods valuable in the cases of inclined galleries. Locomotives are used in the adit of the Rio Tinto mines in Spain where copper pyrites is obtained ; steam engines, however, are objectionable unless the ventilation is exceedingly good ; though, if worked by compressed air, the engine is beneficial, instead of harmful, by improving the ventilation. Compressed air locomotives, however, appear to be more expensive to work than steam engines heated by coal.

Compare those complex and highly improved methods with the oldest and most primitive plan—*viz.*, that of carrying the mineral on the miner's back. Yet, bending and panting, miners may be seen to-day, creeping along the little galleries in some parts of the world, conveying the mineral to the shaft, and even to the mine's mouth, painfully crawling up steps in the rock on their hands and knees. This is probably owing to the fact that the mines are small.

In the sulphur mines of Sicily, however, boys used to convey the ore to the shaft, and even to the surface, though the mines were large. But when the shafts came to be over three hundred and twenty feet deep, water power was used—when available. Of late years, however, the principle of utilising steam power has been adopted and is spreading.

The method of working these immense sulphur mines —which have sometimes yielded nearly 400,000 tons a year—differs in principle but very little from the "bord-and-pillar" system, adopted in Britain for some coal and ironstone seams.

Thus, the deposit of sulphur ore is tunnelled through and through with a network of level galleries; the huge square blocks are then hewn down, a pillar being left to support the roof. Frequently this pillar proves insufficient, and a terrible collapse occurs. The excavation sometimes rises to the height of a hundred feet, and a width of fifty feet.

The method of extracting the sulphur appears very wasteful and also detrimental to the neighbouring crops. The ore is simply burnt in walled pits called calcarones on the hillside. Much of the sulphur rises as sulphurous acid, which is very injurious to vegetation; the other part melts and runs down a gutter at the foot of the calcarone. The fire is regulated by the opening or closing of air-holes, so that the burning of some of the sulphur liquefies the remainder. But still the fumes are so noxious that certain mines stop work in the season to avoid the injury to the crops.

Such a method of reducing the ore would not be tolerated for a moment in England. Chemistry and civil engineering together have devised methods for recovering and utilising every noxious fume, and at Lawes's Chemical Works at Barking, where sulphuric acid is made on a large scale, and copper pyrites is burnt to obtain the sulphurous acid, not a particle of noxious odour can be detected outside the building.

Apparatus avoiding these fumes, and in which the heat is conveyed by high-pressure steam, is used at the Latera sulphur works with success.

The molten sulphur of calcarones is run into a stone tank, whence it is ladled into damp moulds of poplar-wood, and becomes the sulphur or brimstone of commerce. Nearly all commercial sulphur comes from Sicily.

It seems curious to think of sulphur as obtained from mines ; but more curious still is the liquid metal gained from mines—mines which are probably the most deadly on earth.

CHAPTER III.

THE MOST DEADLY OF MINES.

Which is the most dangerous mine?

Surely the fiery coal seam, where deep in the earth the gas hisses and crackles, like serpents along the black walls—surely such a mine is the most perilous.

No, for science is doing her best to vanquish the poisonous and explosive vapours, and her efforts are being crowned with success.

Nor do we mean military mines, stored with gunpowder and exploded for the destruction of the enemy, though such mines are deadly enough. But there are certain metalliferous mines, furnishing a useful mineral, which are yet so deadly that the workers in some of them have only lived two years.

Under their toil-grimed faces lurks a horrid pallor, their limbs shake with palsy, and their teeth fall out ; they are slowly being done to death.

These deadly mines are the cinnabar or quicksilver mines, and quicksilver is, as everybody knows, liquid at ordinary temperatures.

The principal European mines of quicksilver are situated at Almaden in Spain, the name of the place being Arabic and signifying simply, "the mine of quicksilver"; cinnabar, the principal ore of mercury, being the ore which is found.

These mines of Almaden are believed to be very ancient, and are said to have been worked by the Iberians before the Romans. The mines are very unhealthy. The mercurial fumes permeate the system and produce continual salivation. Tremblings seize the body; the limbs shake like aspen leaves; the teeth are loosened; pain in the bones supervenes; and at length, if the disease continues unchecked, the miner dies. For nearly two hundred years, that is, from 1645 to 1843, the Spanish Government sent galley slaves to work in these mines, and the unfortunate men soon died.

The cinnabar is a sulphide of mercury, and is red in colour like cochineal. It is the crude form of the pigment vermilion, and sometimes contains pure mercury in drops. It is found in limestone and slate in several parts of the world. The mercury is obtained from it by burning the ore, the sulphur rising as sulphurous acid, and the mercury being collected in a condenser. Or the cinnabar may be distilled with iron filings or slaked lime, which combines with the sulphur and sets the mercury free.

It is said that the Phœnicians, those sturdy sailors of an early day, obtained cinnabar from Almaden, as also did the Greeks. The ore contains about eighty-six parts of quicksilver to about fourteen of sulphur;

neither of them healthy substances for the unfortunate miner, though doubtless useful in certain conditions and under medical advice. The mineral is found in crystals, and also in masses, and sometimes in scattered forms ; and though it is sometimes opaque, it is also at times nearly transparent.

The mine next in importance to Almaden in Europe is at Idria, about twenty-eight miles from Trieste in Austria. At one time these mines were also worked by prisoners. The men were malefactors who were condemned to this task for life, but the poisonous nature of the employment was so great, that they soon lost their appetite, and usually died in about two years' time.

Prisoners are not now sent to these mines, but free men are induced by high pay to work them. It would appear that, with certain precautions, and by working only a comparatively short time, the men may escape with their lives. A pension is given them when disabled, and should they die, their widows and children are provided for.

Productive quicksilver mines are also worked in Peru and in California. The mercury of Peru became famous after the New World broke upon the startled gaze of mediæval Europe, three centuries and more ago. The chief Peruvian mine is now near Huancavelica, and is called Santa Barbara. A church has been cut out of the cinnabar in this mine, and is dedicated to San Rosario. But the most valuable mines are now in California, where a New Almaden exists to supplement the supplies of the Old Almaden in Spain, which has been worked for so many centuries.

Mercury is not found in Great Britain, which, however, considering its size, is rich in mineral wealth. Coal, of course, heads the list by many millions of tons ; iron ore with iron pyrites coming next. Tin, for which Britain has so long been famous, is obtained from two counties only—*viz.*, Devon and Cornwall ; while copper, which is chiefly found in these two counties, is also met with in Lancashire, Carmarthen, Anglesey, Cumberland, Chester, Cardigan, and the Isle of Man.

There remain three other very important minerals, which are more or less extensively mined in Great Britain—*viz.*, salt, zinc, and lead. These, however, by no means exhaust the list, for small quantities of gold, silver, fluor spar, cobalt, and nickel ore, and large quantities of oil shale, ochre, umber, manganese, etc., are also found.

Like gold and silver, lead was a metal very early known in the world's history. It is chiefly gained from galena, or sulphide of lead, which is found in veins in different formations ; much of the lead, however, from the Colorado and Nevada mines is obtained from the carbonate, or cerussite. The chief sources of the British supply are the Crossfell mines, situated in a district in the north of England, where Cumberland, Durham, and Northumberland meet. Native lead is very rarely met with ; but silver seems always present in galena, and after smelting a process of desilverisation takes place. The proportion of silver to lead is very small, varying from two to ten ounces to the ton, though sometimes larger quantities are found.

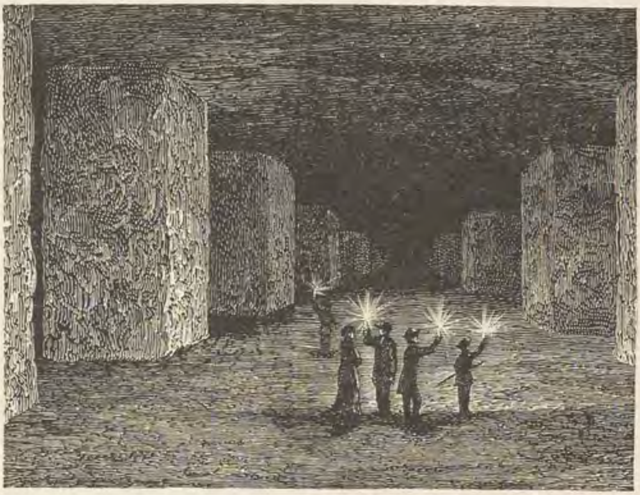
Curiously enough the black lead of which pencils are made contains no lead. Mineralogists term the mineral, graphite or plumbago. It is a composite substance principally containing carbon, but also composed of silica, alumina, and other minerals. It is found in masses and in seams in various parts of the world; but the once large supplies at Borrowdale in Cumberland are worked out.

Blende, or sulphide of zinc, one of the principal ores of that metal, is also found with galena, and sometimes with the ores of tin and of copper. Calamine, or carbonate of zinc, is the other ore from which the metal is chiefly obtained, and it is believed that the ancient brass was made by adding calamine to molten copper, for zinc in those days appears to have been unknown as a separate metal. Brass is an alloy of zinc and copper, even as bronze is chiefly an alloy of copper and tin, though sometimes lead, zinc, and it may be silver, are added. In addition to blende and calamine there are other ores of zinc, as zincite or red oxide, etc., but those previously mentioned are by far the more important.

The mining of all the various metallic ores which occur in veins or lodes is very similar, nor does even the obtaining of rock salt present any very widely different features.

The presence of brine, however, instead of ordinary water, in salt districts, causes the owners to save the liquid in reservoirs, and afterwards evaporate it to obtain the salt. At Northwich, in Cheshire, there are four beds of rock salt, one below the other, the two upper ones being each about ninety feet thick. At Droitwich, in Worcestershire, beds occur one hundred and fifty-four feet thick. In Lancashire, some appear to be five hundred feet thick. Large deposits are believed to exist on the east coast of England between Hartlepool and Middlesboro'; but while the Northwich rock salt is found at some 250 feet below the surface, the depths of the east coast salt is from 800 to 1,600 feet. These deposits would probably not have been discovered, but for the use of the boring tool, the salt having been found when boring for water.

Use of them is also made through the boring tool, for brine is made and evaporated, instead of the rock salt being actually mined. Thus, a bore-hole is sunk and a double pipe inserted; fresh water is let down the outside pipe, and when brine is formed, it is lifted



INTERIOR OF SALT MINE.

by pump through the inner pipe, and salt gained from it by evaporation. So water, through bore-holes, is made to do the work of miners.

The Cheshire salt mines are worked on the pillar system, the roof being supported by pillars left during excavation, and standing about twenty-five yards apart. Sometimes these pillars prove insufficient, and several instances have occurred of the collapse of old salt mines from this reason, or on account of the weakness of the roofing. Blasting is used in the course of excavation for the removal of the rock salt.

The most famous salt mines in the world are those of Wieliczka in Galicia, which have been worked for five hundred years or more. The mines extend for miles underground, and are hewn into streets and squares with over thirty miles of tramway, while the greatest depth to which they reach is some 12,000 feet.

Salt is also found in many parts of the world, and in some places it is gained, as formerly in England, by evaporating sea water.

Though we give the black flag for deadliness to quicksilver mines, yet everywhere the miner seems to meet with risk. Mining, even under favourable conditions, must be called a hazardous occupation. Where poisonous fumes or deadly gases do not prevail, the miner has still to face falls from the roof and sides of the workings, and these falls are more dangerous than fire-damp.

Explosions of fire-damp attract the greatest public attention no doubt, and people are apt to regard those accidents as the most perilous danger, but statistics show that the miner suffers more from the falls.

Indeed, the average of fatal accidents in metal mines is but very little less than the average in coal mines; and over one-third of the deaths is caused by falls of ground. Other accidents are due to falls from cages, ladders, and man-engines, or to the breaking of ropes and chains, to overwinding, to casualties connected with blasting, to entanglements with machinery, and to explosions of boilers.

But the sad list of fatalities is diminishing, one great cause being the extension of knowledge among miners generally of first aid to the injured, taught through classes of the St. John Ambulance Association. Many a valuable life has been saved by the prompt assistance a "first-aid" man can now render his fellow, before the doctor arrives. Another cause of diminished mortality is due to the use of a compressed-air breathing apparatus, invented by Fleuss, by means of which a man can enter a noxious mine in safety after an explosion, and remove injured and insensible men. Honourable mention must also be made here of the excellent work done by the admirable Miners' Permanent Relief Societies, which give aid to disabled miners, and to those dependent on them, should they lose their lives in some mining accident.

The various Acts of Parliament which have been passed for the regulation of mines—*viz.*, in 1860, in 1872, 1877, and others—have done very much to enforce better conditions of work and reduce the risk of accident. The more important of these Acts are the Coal Mines' Regulation Act of 1872, and the Metalliferous Mines' Regulation Act of 1872 and of 1877. The two Acts are largely similar, but the latter is less strict, there being an absence, or almost complete absence, of fire-damp in the Metalliferous Mines. There are, however, various other important Acts, such as the Explosives Acts, the Acts regulating the employment of women and children, the Employers' Liability Act, etc., which touch mining very closely. Parliament has therefore of late years interfered considerably with the working of mines, and on the whole, we believe most people would agree, with very great benefit to the miners.

The Metalliferous Mines Act regulates working, not only for copper and tin, lead and iron, but also for salt and for underground excavations for stone, slate, and other minerals.

In addition to the work of Parliament, science and civil-engineering have also contributed numerous improvements to the working of metal mines as well as of coal mines. A brief summary of these improvements would include the use of the diamond drill in seeking for minerals, also the use of machine drills for driving levels, sinking shafts, and excavating the ore ; the increased strength of explosives, especially of the nitro-glycerine class, such as blasting gelatine and dynamite ; and the use of compressed air instead of steam for driving winding engines underground, tending greatly to the purification of the atmosphere. For treating alluvial deposits there are now the continuous "jiggers" for sifting the soil, instead of the cradles by hand labour. And among other developments there are improved stone breakers and ore crushers and an extended use of hydraulic mining, while, speaking more generally, there is the increased use of steel for various objects, and a greater employment of electricity, both for blasting and for signalling.

For the future, the greatly increased use of electricity for lighting and for supplying power seem directions in which developments are likely to occur.

All these improvements have done much to render mining less dangerous and more efficient, to enable men to tunnel for miles under the earth, to excavate tons of mineral, with speed and with a minimum of hand labour, and to raise it to the surface with safety and despatch.

DIGGING FOR DIAMONDS.

CHAPTER I.

AN EXTRAORDINARY DISCOVERY.

A SHEER accident led to the discovery of the South African Diamond Fields.

It was in March 1867 that a Dutch farmer, whose name was Schalk van Niekerk, noticed some children playing with a curious stone. He examined it carefully, was struck with its peculiarities, and at length submitted it to Dr. Atherstone of Graham's Town.

This gentleman examined it closely and tested it. He ascertained its specific gravity and its hardness, and subjected it to polarised light, finally deciding that it was a diamond. It was bought by Sir Philip Wodehouse, the governor of the colony, for £500.

The news spread like wildfire. Diamond diggers thronged to the neighbourhood where it had been found, and in June 1868, Professor Tennant—who is our authority for the story of the finding of this South African diamond—was able to direct the attention of the Royal Geographical Society to the presence of other diamonds at the Cape. He referred to two specimens bought by Sir Philip Wodehouse, one shaped as an octahedron, three-quarters of an inch by three-eighths of an inch in size, and weighing slightly over twenty-one carats; while the second was also an octahedron, and weighed nearly nine carats. Diamond-seeking in South Africa had fairly begun.

The region where the jewels were sought may be said to commence at the junctions of the Vaal, the Orange and the Harts rivers, and extend for some distance along the streams; the district has been described as desolate and bare, consisting of rock and sand, and situated some distance from the upland districts of pasture where the Boer families resided.

The most extraordinary stories of variable success are told of those early days. One man in his first day's labour found a stone valued at £2,500. Another toiled for six months without finding a single gem; then he discovered a stone that repaid him for all his trouble.

And labour and trouble this diamond-digging must have been. Under a burning sun, with poor food to support him, and poor lodging to shelter him, the miner bent his back and toiled with pick-axe and spade and groped in the gravels, suffering all kinds of hardships, and frequent disappointments.

At first the diggings were little else than scratchings on the surface; then an enterprising man dug down ten feet and found diamonds at that level. The precious stones were discovered in red gravel containing iron, and after loosening this gravel with a pick-axe, the miner picked out the large pieces, and the remainder had to be washed or sifted.

Should the miner not have any washing apparatus, or not possess the means of taking the diamondiferous earth to the river, he must be content with merely sifting it through a fine sieve, and closely examining it to detect the precious stones. But a ruby or a diamond soiled with the moist ferruginous earth is not easily seen; and washing, though giving much more labour, yields much more satisfactory results.

In washing the soil, the diamondiferous earth was first puddled—that is, it was shovelled into a shallow trough, and while one man poured water into it, another stirred it about with a spade. At the same time the trough was slightly raised at one end, and nearly all the sand floated away; the gravel was then shovelled on to a cradle something like the gold-washing cradle, and having three sieves with perforations of different sizes. While one miner rocked the cradle, another poured buckets of water over it, which floated the smaller stones down to the lower sieves.

Perhaps a shout of triumph was heard as the water flowed from the upper sieve; the keen-eyed, wary searchers have at last discovered a rough little stone something like dull and blurred glass, which they know to be a diamond. And being in the upper sieve, the stone is likely to be a large one.

But as often happened, nothing but the dullest gravel met the eager gaze. Stay, there were the lower sieves to be examined, and even when these had been carefully scrutinised, and made to yield their wealth, there remained a little ledge at the bottom of the rocker, on which a small quantity of fine gravel collected. Even these rinsings were washed, say in a small hand-basin, and minute diamonds, specks of gold, and perhaps rubies, might be found among them. For small rubies were also found at the diamond fields.

So great was the rush to the diamond diggings, that in 1870, only three years after the discovery of the first stone, some ten thousand diggers were scattered about the Vaal river, and its junction with the Hart, seeking for the precious gems. At first the triangular space about this junction afforded a good many diamonds to those early seekers, who prospected, and dug, and puddled gravel with unremitting toil.

In the early days of the diamond diggings, persons seem to have claimed stretches of ground without licence from anybody. At that time the diamond district about the Vaal was not under British authority, but the diggers announced that they would not object to any government, nor to the payment of a licence of £1 per annum, provided that the government could prove its right to the soil.

Meantime, the diggers organised a sort of government themselves, appointing a committee, who granted licences to new comers on payment of half a crown, and allotted the claim which he selected if it were unoccupied. Numbers of the diggers were armed with rifles and revolvers, and seem to have proclaimed the fact pretty loudly, as an announcement that they were prepared to defend themselves against any hostile interference.

The arrangements of the committee seem to have been fairly just and complete. The claims were about twenty feet square, and any person finding a new run of the precious stones, was entitled to four ordinary claims. A man finding a diamond on the claim of another and retaining possession of it, was to be considered a thief; while among other regulations it was declared that no claim-holder was to be absent from his claim for more than three working days continuously, or employ more than five natives on his claim. Natives, it may be stated, were largely employed from the first at the diamond mines.

Partnerships were frequent, for one man could not work advantageously alone. Consequently, combinations of twos and fours came to be usual.

The innocent and simple natives of course soon found that something was greatly attracting the white men, and the children of nature gathered all sorts of pebbles hoping that the whitefaces would purchase them. On one occasion, so the story goes, a native named Swatbooy did find a splendid diamond. He discovered it in 1869 near Sandfontein on the Orange river, and sold it for five hundred sheep, ten cattle, and a horse, to Schalk Niekerk, the fortunate discoverer of the first diamond.

It is significant of Swatbooy's idea of wealth, that he took his payment in sheep and cattle ; and with a horse to ride he would feel like a prosperous South African farmer. As for Dutch Niekerk, who was so much concerned with the early days of the diamond at the Cape, he appears to have sold his purchase for considerably over £11,000. In 1870 the stone was brought to England, and having been cut was valued at £20,000. The cutting reduced it from 83½ carats, which it originally weighed, to 46½ carats. It was appropriately enough termed the "Star of South Africa," and has since been called the "Dudley," as the Countess of Dudley became the owner ; it is a superb brilliant, without any colour and of remarkable purity.

South Africa has become famous for the number of large stones it has produced, but some of the South African diamonds are tinted brown or yellow. One of the finest not so tinted is the famous "Porter Rhodes" blue-white diamond, weighing 150 carats. It was discovered in 1880 and valued at £60,000.

The term carat has two meanings. As regards the weighing of jewels it has a fixed value, being equal to $3\frac{1}{6}$ grains troy, and is again divided and subdivided into carat grains, that is quarters and also eighths, sixteenths, etc. As regards gold, however, a carat has not a fixed weight, but indicates a proportion; thus, pure gold is spoken of as 24 carats, and the gold for British coinage containing twenty-two parts of gold to two of copper is spoken of as 22 carat gold, or 22 "carats fine." Some difference of opinion appears to exist as to the origin of the term carat; certain authorities regarding it as the fruit or seeds of the carob tree, which were equal in size, and were used as weights in Eastern countries.

Much larger diamonds have been found, but owing to the yellow colour of some of them, their value is much reduced. Thus, at the celebrated De Beers mine in 1884, a yellowish stone weighing 302 carats was found, and four years later another yellow stone as large as a hen's egg, weighing $428\frac{1}{2}$ carats, was found. This stone was held to be the largest diamond known, but owing to its colour it was only valued at about £3,000 at the surface. In 1895, however, a much larger diamond was reported to have been discovered in the Transvaal, weighing 634 carats, and valued at £634,000!

But these discoveries took place after the early diamond diggings on the Vaal river; since then, the diamond-mining in South Africa has developed greatly, and cities have sprung up like fairy palaces in the night, while Kimberley, the richest diamond mine in the world, has been opened.

THE OPEN WORKINGS OF THE DE BEERS MINE, KIMBERLEY.

(From a photo by Mr. J. E. Middlebrook, Kimberley.)

CHAPTER II.

DIAMOND STORIES.

The finding of the "Star of South Africa" no doubt stimulated the search for diamonds—if indeed it required stimulating—in the rocks and gravels of the Vaal.

But in the very next year—*viz.*, in 1870—the "dry diggings," as distinguished from the "wet diggings" by the river, were discovered at a place unpoetically called Du Toit's Pan, and situated about midway between the Modder and the Vaal.

A pan, as the name indicates, signifies in South African language a depression in the earth; and from the peculiar formation of the diamond pans it has also been called a pipe or a chimney. Diamond pipes penetrate into other strata, and are filled with a particular igneous rock, called gabbro, which becomes changed near the surface, and is known as yellow earth.

It is believed these pipes or pans are former volcanic openings filled with volcanic matter, which burst its way upward from depths beneath, and that the "blue ground," having within it fragments of rocks, became altered by meteoric action when near the surface. Probably the alluvial soil where the diamonds were first found in South Africa has been washed down in the course of ages from such pans or pipes.

Du Toit's Pan was not to have all the diamond digging to itself, for in the next year, 1871, a diamond mine was discovered—probably the most wonderful in the world. About two miles from Du Toit rose a conical hill called Colesberg Kopje. It was elliptically shaped, and measured some three hundred and thirty yards long, by about two hundred broad at its widest part. One day diamonds were found there, and it was discovered that the whole hill was composed of diamondiferous rock.

The report spread, and diggers rushed to the spot; claims were pegged out, and work commenced in earnest. There was no water in the neighbourhood, and fever appeared. Then some one sank wells and struck water and sold it to the miners by the bucketful and the cask.

There were in a comparatively short time about four hundred claims, which were each in size about thirty-one feet square; but these claims came to be greatly subdivided, some to even a sixteenth of a claim. One proprietor, however, may now hold several claims. A mining board controlled the whole, and as some claims were dug down more quickly than others, the surrounding shale was frequently falling in; it had therefore to be cut to a slope, and the board divided the expense among the various claim-holders. Gradually, individual diggers combined, and the process of amalgamation toward a company began.

But in a comparatively short time the whole of the hill was mined away; and as the rich rock was found to descend through the ground between almost upright walls of shale, it has been worked to the depth of some hundreds of feet, the rock being brought to the surface by numerous inclines of wire rope. Thus, not only has a hill been removed, but an immense mine has been hollowed in its place, while on its borders flourishes the town of Kimberley. The Colesberg Kopje—which no longer exists—is now indeed the famous Kimberley diamond mine.

As the miners dug down, falls of earth on the sides

KIMBERLEY, SOUTH AFRICA, WHEN A CANVAS TOWN.

increased, and greatly extended the area of the mine. In 1885, there were great falls of earth into the mine, seriously interfering with the output of diamonds. At first, only about eleven statute acres were enclosed for the mine; but, owing to the falls, about thirty acres were afterwards enclosed.

The town of Kimberley is now substantially built, but it was not always so. First, canvas roofs fluttered in the breeze; then corrugated iron appeared; and lastly well-built houses rose on the once waterless desert. But the days of thirst are past. Kimberley now enjoys a water supply brought in pipes from the Vaal river some score of miles away, and the once dry and thirsty region has water enough and to spare. In 1885 also the railway reached Kimberley, bringing it vegetables and fruit.

Other mines have also been discovered. A mile distant from Kimberley are the De Beers' mines, while less than three-quarters of a mile from Du Toit's Pan is the Bultfontein mine, and a circle, not four miles in diameter, would enclose them all. Kimberley is to this rich diamond district what Johannesberg is to the Transvaal gold fields some three hundred miles away. Both are centres of their respective mining districts, and both are cities which have, so to speak, grown up in a night.

Diamond-mining has now become a settled industry in South Africa. The old days of individual workers have passed away; combinations of diggers have given place to companies, and various companies have amalgamated. The tendency, of course, is to reduce the working expenses, and also to regulate the supply of diamonds so that days when numbers are found may be made to balance the periods when few are forthcoming.

I.D.B., as it is familiarly known at the mines—that is, illicit diamond-buying—or the purchase of diamonds without a licence, and therefore presumably stolen, has always existed, but has lately been reduced by engaging the native labourers for a short period, say three months, and during that period keeping them in a large enclosure. But so keen was the feeling that large numbers of diamonds were stolen, and so strong was the determination to check these thefts, that trapping by detectives was made legal, and in fact anybody could be arrested on suspicion of possessing a rough diamond without a licence.

A curious story is told illustrating this fact, and also showing that the close resemblance which glass can be made to assume to diamonds renders detection sometimes extremely difficult. A man was tried at Kimberley for purchasing diamonds without a licence; but when the judge was about to sentence him, the question was raised as to whether the stone was genuine, and examination proved that it was in fact only a bit of glass. Yet he had given some hundreds of pounds for it; and his punishment, even if it did not come from the judge, was sufficiently severe.

A rough diamond is a dull and uninteresting object, quite unlike the flashing brilliant of the jewel-case, and this appearance in its rough state renders imitation even more easy. A good test for a rough diamond is to touch it with a file; but the curious idea that a true diamond will resist a blow with a hammer is an entire mistake. Indeed, a fall on the floor may injure a valuable stone.

For centuries, India was the only country where diamonds were found in any quantity. They occurred on the east side of the Deccan from the Pennar river to the Sone, and were mined at Cuddapah and other places in the Madras Presidency, and called the Golconda region. None were found at Golconda itself, however, for that famous place for the precious stones was not a mine, but a stronghold where they were collected. There were other mines in Bundelkhund.

Little seems known, however, about those old Indian diamond mines ; the diamonds themselves seem to have been found in beds of clay or sand, or in ferruginous sandstone. Pits were dug a few feet in diameter, but if after sinking the "shaft" a little distance the Indian miner met with no precious stone, he abandoned his work and went elsewhere.

The mining appears to have been conducted by certain castes or tribes, who followed no regular system in their operations and who gained but a miserable living from their exertions, probably because of the uncertain and precarious returns. A few diamonds are still found and a few mines still exist at Panna, Karnul, and other places ; but so few that it seems strange India should have been the land in which the famous Koh-i-noor, Orloff, Sancy, Pitt, and other historical diamonds were found.

For a long time Borneo has also yielded diamonds, which were found in a red clay together with platinum and gold. The Mattan stone, said to be a very fine and pure gem in the shape of an egg, is believed to have seen found at the Landak mines about the year 1787, and weighs 367 carats uncut. For this diamond the Rajah of Mattan is said to have refused £50,000, and also two gunboats from the Governor of Batavia ; but on the other hand certain Dutch experts, who claim to have examined it, declare that it is but a piece of rock-crystal—that is, a more or less transparent form of quartz. Lenses of rock-crystal are frequently spoken of as pebble lenses.

Diamonds have also been found in the Ural mountains, also in districts of Australia and certain parts of the United States; but the chief source of diamonds during some part of the eighteenth and the beginning of the nineteenth century was Brazil.

The sensational discovery was made here in 1727, that certain crystal-looking stones found in gold washings, which negroes had for long been accustomed to use as counters in playing cards, were in reality diamonds. They were discovered in the province of Minas Geraes, and the chief diamond mines are still situated there, but they are also found in other provinces. They occur in sand and loose gravel mixed with clay, which also contains specks of gold and lumps of quartz.

It was the province of Minas Geraes that yielded the splendid diamond, "Star of the South." It was found in 1853 in the river Bogagem by a negress, and weighed $254\frac{1}{2}$ carats. When cut it weighed 125 carats, and was curiously enough sold to the Indian Prince, the Gaekwar of Baroda, for £80,000. Thus, to India, the famous home of the diamond in days gone by, was brought a stone not unworthy of comparison with some of her richest treasures. It seems to mark the fact that the supremacy of India for diamond production had passed.

Yet, for romantic and historical interest, few gems, if any, can surpass some of those famous Indian diamonds. There is the famous Koh-i-noor, for instance, now belonging to the British Crown. No one knows accurately where it was mined, nor how long it has been in the possession of mankind. Tradition says it was discovered in a Golconda mine near the river

Kishna, and blazed five thousand years ago on a hero named Karna. But the story is lost in the mist of legend and tradition. The first clear fact seems to be that the family of the Rajah of Malwa owned it for generations, and that in 1304 the Sultan Ala-ed-din acquired it, after defeating the Rajah. When, some two hundred and fifty years or so later, the great Aurungzebe owned it, he used it as one of the peacock's eyes ornamenting his celebrated peacock throne.

Again it changed hands when, in 1739, Nadir Shah conquered Mohammed Shah. Nadir not finding it among the treasures at Delhi, learned that Mohammed had hid the splendid diamond in his turban, and therefore, at the conclusion of peace, he offered to exchange turbans as a token of amity. Nadir was the conqueror, so Mohammed handed over his turban and lost his famous gem.

Nadir gave it its present name, for when on unfolding the turban his eyes caught its size and brilliancy, he cried, "Koh-i-noor," which signifies in English "Mountain of Light," and it has retained that proud name ever since.

After a series of romantic occurrences it passed into the possession of the rulers of the Punjaub, and when that State was annexed to the British Crown, the famous diamond was presented to the Queen. Unfortunately, it appears to have been unwisely re-cut shortly after it was brought to London, and the weight was reduced from $186\frac{1}{16}$ to $106\frac{1}{16}$ carats.

Diamonds are not cut as by a knife, though that is the word used to designate the grinding and polishing of the precious stones ; they are rubbed into shape, and the facets ground upon them by means of rapidly revolving metal discs fed with oil and diamond dust, and now driven fleetly round by steam power. But in the early days of diamond-cutting steam power was unknown.

When wisely "cut," the diamond flashes with a brilliancy and a "fire" surpassing any other stone, this being due to its great properties of refracting and also reflecting light; for much of the lustre in a well-cut stone is reflected from its inner surface.

And what, it may be asked, is a diamond? Marvellous to say, it is closely related to some of the blackest of substances—*viz.*, lampblack, coke, and charcoal. One hardly thinks of these as of the same nature as diamonds, yet they are chemically akin, for the diamond is natural crystallised carbon, the researches and experiments of several noted chemists, commencing with the English chemist Smithson Tennant in 1797, showing this to be the fact. Wood and animal charcoal, coke, and lampblack are also more or less impure varieties of carbon, so also is graphite or black lead.

So it happens that carbon is concerned in producing one of the brightest and also some of the blackest of substances known on the earth.

Through what mysterious processes of nature have these carbon crystals passed who shall say, or how far the pipes of diamondiferous soil descend into the bosom of the earth? But the depth to which the mines have already been driven, and the steady persistency with which they are worked, would mightily astonish those fitful Indian diggers of centuries ago.

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