meter had become crusted with ice spicules, and it had to be thawed out before it could be used. Many other difficulties had to be encountered, and it is surprising that any successful observations were made; but Mr. Mossman, assisted by Mr. W. Martin, secured, besides other observations, hourly observations on twenty days.

The magnetic observations are discussed by Dr. Chree, F.R.S., who remarks that the results show how very carefully the observations were made. The observations extended over the period May, 1903, to February, 1904.

The following values are given:—declination, 5° 31′·2 east; inclination, 54° 30′·6 south; horizontal force, 0·25704; mean daily range of declination obtained from the hourly readings, 8′·65.

While the *Scotia* was anchored and frozen in Scotia Bay observations of the tide were made by means of a very simple gauge. A long wire, fastened to the sea floor by a heavy weight, passed over a pulley, and was kept taut by a lighter weight at the other end. As the ship rose and fell with the tide this weight moved up and down a vertical scale, which was observed half-hourly.

The tides seem to be normal for a place in the Southern Ocean. The semi-diurnal tides are considerable, but the solar tide is unusually large compared with the lunar tide, the ratio being three-fifths, or 0·6, as compared with 0·465 of the equilibrium theory. The semi-diurnal tides are almost exactly "inverted," so that low water occurs very nearly when the moon is on the meridian.

THE METEORS OF HALLEY'S COMET.

IN view of the approaching return of Halley's comet, the Aquarid meteor shower of May ought to be awaited with special interest. We know comparatively little of this system, as it has been seldom observed. It is certain, however, that it is the richest of our May showers, and that its radiant point conforms very nearly both in date and place with the radiant and epoch of particles following the path of Halley's comet. This circumstance alone is significant, and the supposed connection of the comet and meteoric display will be sure to receive ample investigation during the next few years.

The Aquarids should be looked for after 1 a.m. in the mornings between the end of April and May 7, and they are directed from a region at about 337°−2°, just below the equator. Lieut.-Colonel Tupman determined the radiant as about 10° west of the point assigned, and further observations are required to ascertain the exact place, and also the precise date of the maximum of the shower.

If really associated with Halley's comet, the meteors ought, in immediate ensuing years, greatly to increase in numbers, though we possess no historical records of rich showers having been observed in 1759 or 1835, when the comet previously returned to perihelion. But many meteoric phenomena have eluded recognition, and it is very possible that some returns of these Spring Aquarids may have escaped notice, as they are only visible just before sunrise, and were never specially looked for until after their discovery nearly forty years ago by Lieut.-Colonel Tupman. This stream, like the Perseids and Leonids and many other showers, is evidently one visible nearly every year, and forming a complete ellipse. It now remains for observations in immediately ensuing years to determine whether, like the Leonids and Andromedids of November, it develops unusual intensity near the time of return of the parent comet.

W. F. Denning.

SOME UNSOLVED PROBLEMS IN METAL-MINING.[1]

IN one sense every mine is an unsolved problem from the day the first pick is put into the ground until the mine is finally abandoned as exhausted, and even then it is not always certain that it really is worked out, and that sinking or driving another 10 feet might not give it a renewed lease of life. Unlike most engineering problems, which have generally to be solved before work is commenced, a mining problem is never fully solved until all work upon it is finally concluded.

At the very outset, even before we are in a position to attack the different subdivisions of the subject, we are brought face to face with what may almost be described as one of the fundamental problems underlying the whole of metal-mining, and one the solution of which can never attain finality. The work of the metal-miner being limited to the extraction from the earth's crust of the ores of the various metals, whilst it is the business of the metallurgist to smelt these, so as to reduce therefrom the metals that they contain, and to fit the latter for their use in the arts, the question what constitutes an ore is one that the miner cannot answer for himself, and for the reply to which he is dependent entirely upon the development of metallurgical science for the time being. Not all metalliferous minerals are ores from the smelter's point of view. Take, for example, an ordinary brick clay, which is a complex hydrous silicate containing, say, 15 per cent. of aluminium and 5 per cent. of iron; it is true that we can extract both these metals from it by a series of complicated laboratory processes, but no means for doing this economically on a practical working scale have yet been discovered. Hence no one would dream of calling clay an ore of aluminium, and far less of iron. Nevertheless, it is not beyond the bounds of possibility that our modern metallurgists, or their younger and more progressive brethren, the electro-metallurgists, may within a few years devise some practicable process for extracting aluminium from clay, when clay would straightway become an ore of aluminium, though it is not one now; and if perchance it happened that comparatively pure oxide of iron were obtained as a by-product in the same process, the clay might even be reckoned as an ore of iron also. Until some such process shall be devised, clay is looked upon by the metal-miner as a non-metallic mineral, as so much worthless gangue or waste. The history of metal-mining has shown again and again that the waste rock of one generation is the valuable ore of another, as, for example, the zinc blende of the Alston district, which is now being recovered from the waste which the old miners had left behind as worthless in their excavations, or had thrown aside on their waste heaps, the value of the mineral having been recognised when a Belgian metallurgist discovered how to extract zinc from it.

The point may be further illustrated by a consideration of the world's supply of iron ore; iron, the most useful of all metals, is at the same time, next to aluminium, the most abundant, geologists calculating that 4·7 per cent. of the earth's crust consists of iron; if this estimate be correct, the very small portion of the earth's crust underlying the London Metropolitan area (fifteen miles' radius) down to the depth of only one mile would contain no less than 360,000 millions of tons of iron, none of which is in the form of a true iron ore. At the present day no one would call a mineral containing less than 25 per cent. of iron an iron ore, and unless it contains double that percentage it will not find a very ready or a very appreciative market amongst iron smelters.

As the result of various improvements in the last few decades, the whole trend of modern mining is towards the utilisation of large deposits of low-grade material, the increased scale of operations enabling economies to be effected that were impossible whilst small quantities alone were dealt with. One of the cardinal problems that will confront our successors will be how to work with profit minerals of lower grade than any that we have yet attacked, so as to enable the miner to include within his sphere of operations deposits too poor for us to deal with to-day.

The possibility of determining by some means the whereabouts of the hidden treasures of the earth has long been an object of the miner's desire, the methods for accomplishing which range from the mediæval adept with his divining rod, belief in which is not wholly extinct to-day, down to a series of modern attempts to use electric currents for the same purpose. Up to the present these attempts have been unsuccessful, in spite of the ambitious claims of some of their advocates.

In view of the fact that minerals differ so widely in their electric and magnetic properties, it is quite possible

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[1] From the "James Forrest" Lecture, delivered at the Institution of Civil Engineers on April 27 by Prof. Henry Louis.

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to conceive that some method of detecting concealed mineral deposits by these means may be devised. Indeed, for one particular class of minerals such a method has long been in existence; in Scandinavia there are many deposits of magnetite, and many others of which magnetite forms a constituent, so that all such deposits distinctly affect a magnetic needle. The Swedish prospector has long used the so-called mining compass, which consists essentially of a small magnetic needle so suspended as to be able to move both horizontally and vertically. When this compass is brought over ground in which such deposits of magnetic mineral exist, the needle indicates their presence by its change of dip, so much so that it has been customary for years past in Sweden to buy and sell mineral properties by their "compass-drag," or their effect on the miners' compass.

When, by any means, some indication is obtained of the approximate position of a mineral deposit, it has to be more precisely located by boring. Boring is of but little value for tracing mineral veins, owing to their going down so nearly vertically and to their great irregularity, but it is often used to locate irregular masses of ore; for example, bore-holes have recently been employed successfully in Cumberland for proving deposits of red hæmatite in the Carboniferous limestone, even where this is overlain by Triassic rocks. Obviously bore-holes are most valuable when stratified deposits have to be tested, and everyone will remember the conspicuous success that attended their use in proving the permanence in depth of the auriferous banket beds of the Witwatersrand.

The deepest bore-hole put down up to the present is one at Paruschowitz, in Upper Silesia, which attained a depth of 6573 feet; it commenced at a diameter of 12·6 inches and finished at 2·7 inches, and it is easy to imagine the difficulties that attend the boring of so small a hole to the depth of $1\frac{1}{4}$ miles. The engineers in charge stated that they could not have reached this depth had not Mannesmann weldless steel tubes been available for the boring rods; I mention this fact as illustrating the dependence of mining upon the allied arts, for at first sight few would imagine that an improvement in special rolling-mill practice could increase our knowledge of the deeper portions of the earth's crust.

Bore-holes such as these are now always made by means of the well-known diamond drill, which brings up a core of the rocks passed through, and thus affords positive information respecting them. Unfortunately, the only kind of diamonds suitable for this purpose, the dark opaque stones, showing no distinct cleavage, known in the trade as "carbons," are very scarce and proportionately dear, so that diamond-drilling is now a very costly operation; I have, however, good grounds for saying that we are within measurable distance of seeing such "carbons," or at any rate "boot," produced artificially. For rocks of moderate hardness, these diamonds have of late years been replaced to some extent by shot made of specially hard chilled iron, but these are of little use in the harder rocks. One of our greatest needs at the present moment is a metal that shall be strong, tough, and very considerably harder than quartz; the production of such a material would conduce more to the technical advancement of several branches of mining than almost any other discovery that could be named.

Mineral deposits may be distinguished as superficial, shallow, or deep-seated in the earth's crust; the first of these require no opening up, properly speaking; the second can mostly be opened up by adit levels, whilst the third class can only be reached by means of shafts. The deepest shafts in the world are in the copper-mining district of Lake Superior, where there are at least two close upon 5000 feet in depth; with the exception of this district, of a few shafts in the Bendigo district of Victoria, a few at Johannesburg, and some in the Przibram mines in Bohemia, it may be said that there are practically no shafts in metal-mines more than 3000 feet deep, so that the ability to reach considerably greater depths than have hitherto been attained in most mineral fields may be taken for granted. Indeed, so far as the actual sinking is concerned, there would probably be no serious difficulty in sinking a shaft 10,000 feet deep, provided that it could be known with certainty that a deposit of ore would be met with of sufficient value to recoup the outlay incurred in such a sinking; in other words, the main problems connected with deep sinking are economic rather than technical.

For centuries the only property made use of to effect the separation of minerals was the difference in their densities; in 1858, however, an entirely new property was brought into play for the purpose, namely, the difference in their magnetic susceptibilities. This idea was due to a famous Italian engineer, Sella, whose name is well known in connection with the Mont Cenis tunnel. He was called upon to treat the iron ores of Traversella, in Piedmont, which consist of magnetite containing a certain proportion of copper pyrites (the mass carrying 2 per cent. to 4 per cent. of copper), which interfered with the use of the ore for iron smelting. Sella devised a machine carrying rotating electromagnets, by which the magnetic iron ore was separated from the non-magnetic copper ore, so that both could be utilised.

Other machines on similar principles were subsequently devised, and, naturally enough, they emanated from countries rich in deposits of magnetite, such as Scandinavia and some of the eastern States of America. Sweden especially took a prominent part in the development of the magnetic system of separation, and the Wenström machine, patented in 1884, which was one of the first practical machines brought out, is still largely used, as it is well adapted to the separation of lump ore. Other machines, more particularly designed for the treatment of finely crushed ore, were brought out in rapid succession, and to-day one of the main difficulties that beset the mining engineer lies in the selection of the most suitable machine for any given purpose out of the vast number with which the market is flooded. All these machines work either by means of a moving magnetic field, produced by travelling pole-pieces, passing through the mass of crushed ore, or by causing a stream of the ore to traverse a stationary field, these results being obtained either by travelling belts or revolving drums, or, as in the case of Edison's machine, by the deflection of a falling stream. It soon became apparent that, where very clean concentrates were required, the best results could only be obtained by applying magnetic separation to a pulp of mineral suspended in water, and wet magnetic separators were soon introduced, and are to-day preferred wherever possible; they avoid the necessity for artificial drying, which is, moreover, in the case of minerals that contain iron pyrites, apt to affect the magnetic susceptibility of this mineral sufficiently to interfere seriously with the success of the operation. Attempts have been made to devise magnetic separators without moving parts, by the use of polyphase rotating fields, but although the idea looks promising, no satisfactory machine on this principle has yet been constructed.

At first magnetic separation was only applied to the naturally magnetic ores, magnetite and magnetic pyrites; it was soon, however, extended to certain other minerals that can be rendered magnetic by heating, such as spathic iron ore, brown hæmatite, iron pyrites, &c. As early as 1875 a magnetic separator was used at Przibram for separating roasted spathic ore from zinc blende, this forming an excellent example of the value of magnetic separation. The presence of spathic iron ore causes great difficulties in smelting zinc ores, as it forms a readily fusible silicate of iron which destroys the zinc retorts; at the same time, the densities of the two minerals are so nearly the same that separation by ordinary dressing is impossible. The application of magnetic separation has solved the difficulty, and has rendered available for the smelter numerous ferriferous zinc ores that were previously useless. The process is receiving an extended application in America for treating argentiferous galena and zinc blende, finely divided, and intimately mixed with a large proportion of iron pyrites, in which the proportion of zinc is too high to admit of the ore being smelted direct, whilst the large amount of iron pyrites present interferes with ordinary wet dressing. This ore is crushed and then gently heated, which renders the pyrites magnetic, so that it can be removed by a magnetic separator; the dressing of the residual mixture of zinc and lead ores by the ordinary methods then offers no particular difficulties.

Whilst the ordinary methods of magnetic separation were thus extending the sphere of their applicability, another

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form of magnetic separation was coming to the front. For a long time the method was confined to minerals that were naturally or artificially magnetic in the everyday acceptance of that word, that is to say, were capable of being attracted by an ordinary horse-shoe magnet. Faraday had discovered so far back as 1845 that numerous bodies, not magnetic in this ordinary sense, were nevertheless affected by powerful magnetic fields, but it was not until 1896 that this principle was applied to the separation of minerals by J. P. Wetherill; he succeeded in separating a series of minerals, all very feebly magnetic, from the somewhat more feebly magnetic zinc oxide and other zinc ores of New Jersey by the use of very powerful magnetic fields, produced by means of electromagnets with wedge-shaped pole-pieces, and since his original invention this principle (the magnetic separation of non-magnetic material, as it is sometimes called) has found an extended application, one of the most recent being the magnetic concentration of specular hæmatite by the Edison deflection method, using pole-pieces of the Wetherill type. Such separations as that of wolfram from tinstone, of raw spathic ore from zinc blende, of garnets from silver ore, which are necessary before any rational metallurgical treatment of the ores is possible, but which offer insuperable difficulties to the ordinary methods of dressing, have been rendered possible by the adoption of the Wetherill principle, and I see no reason to doubt but that it will find still more extended application in the future. I may point out that no successful wet separator for feebly magnetic minerals has yet been devised; this is a problem presenting numerous difficulties, but probably quite capable of solution, and at the same time very well worth solving.

Magnetic separation, though so comparatively novel, has already been extensively applied, the largest installations being naturally those for the treatment of iron ores. At the present moment the output of high-grade magnetite concentrate, produced by this process, in Sweden cannot fall far short of half a million tons per annum, and in Norway active preparations are in progress for work on a much larger scale at Dunderland, Salangen, Ofoten, and Sydvaranger, from which a yearly output of fully two millions of tons of high-class iron concentrates is expected.

Attempts to utilise other properties of minerals for their separation may be said to belong wholly to the present century. Thus Messrs. Blake and Morscher in 1901, and Mr. Negreanu in 1902, have attempted to use electrostatic methods, depending upon the variations in the electrification of minerals due to their varying electric conductivities; the former of these two methods has been used with success for the dressing of blende in the United States.

Finally, the difference in surface tension has been employed in Elmore's oil separation process, in the various flotation processes, devised since the discovery of the principle by C. V. Potter in 1901, and applied to the very intractable zinc-lead ores of the Broken Hill district of New South Wales, and finally in the Elmore vacuum process. All these processes seem to depend upon the differential adhesive force, with which water, oil, or gas cling to the surface of different minerals. These methods are still in their infancy, and the underlying principles cannot yet be said to be properly understood, but already they promise to be of great value in recovering valuable material from slimes that are not amenable to any other mode of treatment, particularly for treating those intimate mixtures of zinc blende and galena that have for so long defied the ingenuity of both miners and metallurgists. There are grounds for hoping that many of the problems that have hitherto baffled the ore-dresser may be solved by some application of these modern methods.

SCIENCE AND INDUSTRY.

A SERIES of articles has appeared in the *Revue scientifique* (May 18 and July 13, 1907; February 22, 1908) comparing the teaching of technical chemistry in France with the instruction given in the same subject in other countries. The last article is of special interest as presenting a French view of the relation subsisting between science and industry in our own country. After describing in detail the excellent organisation of scientific education in Germany, Belgium, and Switzerland, and emphasising the closeness of the union existing in these countries between the manufacturer and the man of science, it is stated that the system of technical education adopted in England presents no feature worthy of commendation.

The English manufacturer fails to realise how much he may profit from the assistance of pure science:—"l'industriel anglais paraît ou veut ignorer le chimiste de carrière qui vient à lui avec un bagage scientifique; son but étant de produire 'beaucoup et à bon marché' il lui suffit quand il remarque un ouvrier plus intelligent et plus perfectible que ses camarades de l'envoyer aux écoles du soir, prendre un semblant d'instruction théorique et cela sur la seule partie de la chimie qui peut intéresser son métier." The many technical colleges under the control of municipal authorities in this country do not aim at producing highly trained "chemists" in the scientific sense of the word, but waste their resources in providing evening classes for workmen and artisans, and in imparting the rudiments of science to boys from the primary schools.

The university colleges, on the other hand, with the exception of the Central Technical College, provide only a training in pure chemistry. Until science and industry become more intimately united in this country it is predicted that the technical schools will go on producing merely good workmen and the universities men who are unable to investigate practical problems or apply discoveries made in the laboratory on an industrial scale.

It would appear that the chemist is as little appreciated in France as in our own country, and it is pertinently asked whether this is not due to his lack of "*general* culture" which prevents him from acquiring the broad ideas necessary for the initiation or development of important enterprises. The same question no doubt may be asked of the chemists in this country, but whatever be the answer there is no doubt that, for the proper development of our industry in the near future, a closer union between the industrialist and the chemist is vitally necessary.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

Cambridge.—The board of managers of the Arnold Gerstenberg studentship gives notice that a studentship will be offered for competition in the Michaelmas term of 1909. The competition will be open to men and women who have obtained honours in part i. or part ii. of the natural sciences tripos, and whose first term of residence was not earlier than the Michaelmas term of 1903. The studentship, which will be of the annual value of nearly 90*l.*, will be tenable for two years.

The Linacre lecture will be delivered by Dr. W. Osler, F.R.S., on Wednesday, May 6, in the lecture-room of anatomy and physiology, New Museums. The subject of the lecture will be "Thomas Linacre, his Life and Works."

It is proposed to grant the use of the Senate House on May 15 for a meeting of the members of the University to be addressed by Mr. Haldane, Secretary of State for War, in the explanation of his scheme in connection with the training of officers for war.

Part i. of the natural sciences tripos will commence on Monday, May 25, and part ii. on Wednesday, May 27. The number of entries for the two parts is about two hundred and twenty.

Glasgow.—Among the recipients of the honorary degree of Doctor of Laws on Commemoration Day, April 22, were several distinguished by their scientific attainments. In the afternoon a portrait of Prof. M'Kendrick was presented to the University, with the sum of 450*l.* for the equipment of a laboratory of experimental psychology in the new physiological buildings, in honour of Prof. M'Kendrick's thirty years' service to the University as professor of physiology. In presenting the representatives of science for the degrees, Prof. Gloag, dean of the faculty of law, made the following references to their work:—

Mr. G. T. Beilby, F.R.S., chairman of the governors of the Glasgow and West of Scotland Technical College.—The present head of the Glasgow and West of Scotland Technical College, who is a Fellow of the Royal Society,

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