Malpighi's autobiography, and collections of many important contributions to the anatomy of plants and discoveries in physiology, were published in London in 1696, under the auspices of the Royal Society. In 1897, Malpighi's native town, Crevalcore, marked the bicentenary of his death (1894) by a festival of homage, when a bronze statue of the philosopher, erected in the market place, was unveiled. A memorial volume was issued afterwards, containing appreciations by Virchow, Weiss, Haeckel, Kölliker, and others.

This brief notice, written for remembrance' sake, may fitly close, as it began, with words written long ago in this journal by Sir Michael Foster—" To look across two centuries at a great man, struggling with the beginnings of problems which have since come down to us, some in part solved, but others with their solutions put still further off by the very increase of knowledge, is a useful lesson to every one of us. In any case the great men who in the past opened up for us paths of inquiry . . . ought not to remain mere names known to us chiefly through being attached to some structure or to some piece of apparatus. We ought all of us to be able to form some idea of what they were and what they thought." T. E. JAMES.

Geophysical Prospecting.

By Prof. A. S. EVE, F.R.S., McGill University, Montreal.

" Here we are on Tom Tiddler's ground
Picking up gold and silver."
—*Song of an Old Game.*

AN eminent geologist has said that " the best way to find out what is under the ground is to bore a hole in it." Truly the diamond drill is the miner's best friend in exploration, presenting samples of successive layers for him to worry over with the geologist; but drilling is an expensive game and the world is wide, so that some guidance is necessary as to where to bore the next hole.

Until quite recently the chief aids to exploration were (1) the divining rod, known in the U.S.A. as the ' doodle bug,' not now used by any mining engineer of repute; (2) magnetic surveys, whereby can be found magnetic ores, such as magnetite or pyrrhotite, but ineffective for non-magnetic ores such as pyrites; and (3) the intelligent applications of geological principles.

To-day, however, there is much more assistance available, new in type, and varied in character. Just as invisible and submerged submarine boats may be detected from the surface of the sea by some physical dissimilarity between the boat and its surrounding medium of sea water, so also ore bodies of fair magnitude can be detected by the wise appreciation of some inherent property different in the ore from the surrounding medium of rocks. Oil has not yet been detected by direct methods; the search has been rather for folds below the ground or for salt domes, where the oil tends to collect in paying quantities.

Now the chief methods of ore hunting, which is a good sport, are these: (1) Electrochemical detection; (2) electrical, tracing the equipotential lines between earthed conductors using direct or alternating current; (3) magnetic methods, as heretofore; (4) electromagnetic detection with direction-finding coils, not unlike direction-finding by ships at sea, only here the ore body must be stimulated by alternating currents flowing in horizontal or vertical loops, using audio or radio frequency. This is the hunt for an electrical echo.

In the search for oil the procedure is usually quite different, and this fact is evidence of the great flexibility of geophysical operations in the field. The chief methods for oil hunting are: (1) Seismic, using an artificial explosion and a seismograph a few miles away to detect the first swift message of the uproar, travelling by a route far down below the earth's surface; (2) gravitational, using that most exquisite and sensitive apparatus, an Eötvös torsion balance; (3) magnetic, where disseminated magnetite makes such search possible; (4) electrical, just as for ore bodies, but on a larger scale. So far, no certain information as to the success of this last method over oil fields is available.

Many of these methods have been already well tested over ' proving grounds ' above known ore bodies, so that to some extent their rival merits are known to the initiated, while on the other hand many mine managers and engineers are puzzled to distinguish between those schemes which rest on a sound scientific basis, and other plans which may be termed psychological, fraudulent or subconscious methods, based on the mystical or unknown, sometimes worthy of study, but with a balanced scepticism.

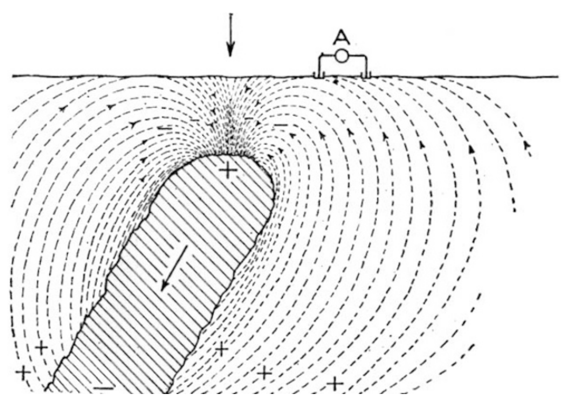

FIG. 1.—Diagram illustrating a sulphide ore body acting as a battery while being oxidised above by rain and surface water. Current lines are dotted and the galvanometer and two detecting electrodes are shown at *A*.

Sulphide ore bodies are slowly oxidised by surface and rain water, so that the mass acts as a large battery with the negative electrode the higher, so that currents flow towards this upper region from below (Fig. 1). The current can be readily detected by non-polarisable electrodes placed on the ground and connected by insulated wires to a sensitive galvanometer or portable microammeter. This method was first due to Barus, and it has been extended by Schlumberger, using porous pots containing a saturated solution of copper sulphate and a copper rod as electrode. All sulphide bodies which oxidise, and also

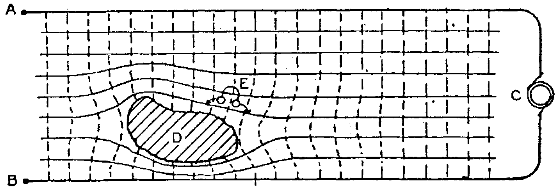

FIG. 2.—Diagram of an alternating current sent from generator *C* to two long bare copper conductors well connected to the earth. The lines of current flow are normally perpendicular to the conductors, but tend to crowd toward the good-conducting ore body *D*. *E* is the telephone (with amplifier) for getting silence points on the equipotentials which spread away from the ore body.

magnetite, may be detected by this simple and direct process. The depth of detection must naturally depend upon the size of the ore, the rate of oxidation, and the conductivity of the ground around and above it.

As to direct electric methods, it is safe to commend the long parallel bare copper wires pegged to the ground to which the current from a dynamo or a few 'B' batteries is led. Detection may be made, with due allowance for the natural or electrochemical currents, by the same electrodes and microammeter as those just described. Lundberg, to whom this parallel conductor scheme is due, uses about 500-cycle alternating current in the parallel conductors, and obtains his equipotentials with the help of iron electrodes thrust into the ground, whence insulated wires lead to a telephone headpiece, with such amplification as may be desirable. Since lines of current-flow converge into good conducting ore bodies, it follows that equipotentials tend to curve away from and around the ore body, both underground and on the earth's surface (Fig. 2). It is naturally impossible to detect by such methods those ores like zinc blende, the conductivity of which is almost identical with that of the surrounding rock. Nor is it possible to declare whether the indication is due to a worthless or to a paying vein.

Instead of two parallel wires, a large loop of well-insulated wire may be laid upon the surface of the earth and an alternating current from a 500-cycle generator passed around the loop. This current will cause an electromotive force and resulting current around the ore body. A coil near the surface of the earth will be stimulated by induction, and again detection can be made by head telephones and amplifier (Fig. 3). Direction, magnitude, and phase of this induced current can all be investigated, and the scientific problem is one of some complexity and great interest. Lundberg and Bieler, for example, use detection methods which are quite different in actuality though apparently the same to a superficial observer. One compares magnitude, the other, balancing phase difference, compares horizontal components with the vertical.

The Radiore Company uses a vertical loop of many turns to which is led alternating current of high or radio frequency (10,000 metres wave-length). The ore body is stimulated by induction rather than by radiation, and the effect is again detected by a loop, tuned to resonance, with amplifier and head telephones. The penetration to some depth into the earth and the emergence from that depth of the excited radiation presents some interesting and important physical problems awaiting further investigation. Dr. Appleton suggested to the writer the possibility of producing repeated maxima and minima in the coil by gradual change of wave-length in the loop, so that a vein or sheet of conducting ore body might have its depth determined by a method quite analogous to that by which he has found the height of the Heaviside layer far over our heads, which renders radio telegraphy or telephony effective by reflection and refraction. The difficulty arises, however, that in ore-prospecting short radio waves must then be used, and such waves do not travel far into the earth.

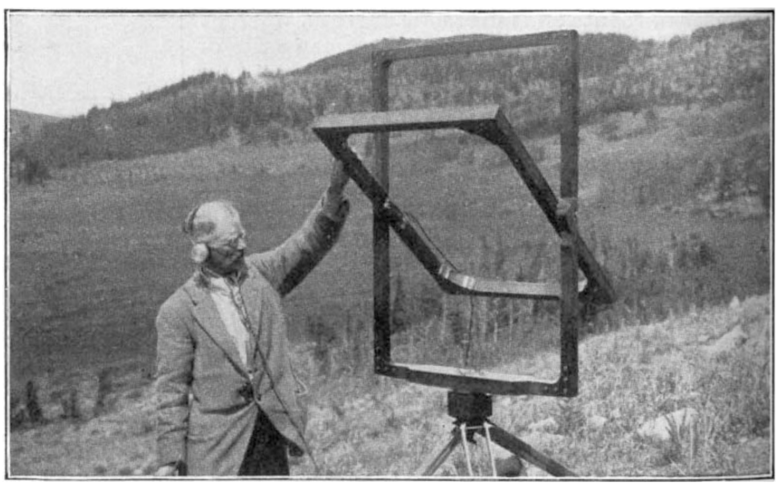

FIG. 3.—Transit tripod with coil, turning in azimuth or dip, and the telephones. Large horizontal loop with 500-cycle alternating current. Near Caribou Mine, Colorado.

Investigations of these and allied problems over a known ore body or 'proving ground' may well fall within the scope of government-assisted research. Thus, last summer the United States Bureau of Mines had a party working near the Caribou Mine, 10,000 feet up in the Central Rockies in Colorado. This party consisted of Dr. C. A. Heiland, of the School of Mines, Boulder, Colorado; Dr. D. A. Keys, of McGill University; and the present writer. Satisfactory and concordant results were obtained with magnetic and diverse electrical methods, and a new scheme was also evolved which was quite effective in the dry region of the Rockies, but disappointing amid swampy districts when tested in Northern Quebec. Indeed methods must be varied to suit local conditions, and all eggs in one basket is a poor policy. The reports of this expedition will be published this year by the Bureau of Mines, Washington, following a

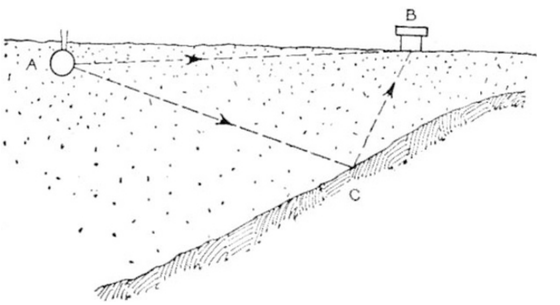

FIG. 4.—Diagram showing small charge at *A* sending out waves which are reflected upward from a fault or discontinuity at *C* and pass to *B*, so that the route by way of the fault (*ACB*) may be quicker than direct route *AB*, because speed increases with elasticity and therefore with depth. All the lines should be drawn slightly curved, concave upward.

brief summary, already published, of the elementary principles involved (Technical Paper 420).

Extensive experiments both in the laboratory and in the field have been made during the last four years by Dr. Max Mason, president of the University of Chicago. His interesting address to the Mining and Metallurgical Engineers of America has been printed, and can be obtained from the Physical Exploration Corporation, 111 Broadway, New York City. This is a valuable report which indicates the scope and possibilities of geophysical methods.

Let us revert to oil hunting. The sound work done in south-west Persia with the Eötvös torsion balance has been set forth clearly in Appendix 12 of the "Summary of Progress of the Geological Survey of Great Britain for 1926" (London: H.M. Stationery Office). In Texas and Mexico, although abundant work has been carried out by the great oil companies of America, yet all this information, whether obtained by gravitational or seismic methods, at great cost to these companies, is retained as confidential, and they do not publish the methods employed or the results obtained.

The Eötvös balance consists of two small heavy gold balls at the ends of a light aluminium bar suspended by a platino-iridium wire. If the balls were at the same level and if the earth were a uniform sphere at rest, the arrangement would be astatic. Actually, however, such a torsion balance, truly of the Henry Cavendish type, tends to set itself along the direction of maximum or minimum curvature of the irregular level or equipotential surface at the place under investigation, and we can find $g(1/R_1 - 1/R_2)$, the horizontal direction tendency (H.D.T.) in magnitude and direction. R_1 and R_2 are the minimum and maximum radii of curvature of the 'level' surface. The torque tends to set the beam along the ridge of an anticline and across the valley of a syncline. Eötvös, however, hung one ball about sixty centimetres below the other and thus determined also the direction and magnitude of the gradient of gravitation, which is the change of numerical value of g per horizontal unit distance. The vertical gradient of gravity does not here concern us at all. The theory of the torsion balance is often obscured by double partial differentials which alarm the unaccustomed reader, whereas the problem is one of ordinary statics with a slight admixture of dynamics and three-dimensional analytical geometry. The truly alarming feature of the work is the correction for altitude and latitude and for terrain and topographical features. In many cases, however, comparative values of the H.D.T. and of the horizontal gradient of gravity are all that are required for the determination of some local problems in geology or mining.

In seismic work, small charges of high explosives are used to obtain reflection of the shock from faults or discontinuous strata. In these cases the time to the seismograph by the direct route is comparable to the time by the reflected route, and the record is therefore hard to interpret (Fig. 4). It will be noted that this plan resembles quite closely the methods now available of determining the depth of the ocean by echo methods. Much larger scale work is used in the Gulf region. There large charges of 150 lb. of T.N.T. are exploded and timed by radio signal. The velocity of the shock is governed by the elasticity and by the density of the medium. Density varies but little with depth, but the elasticity increases with

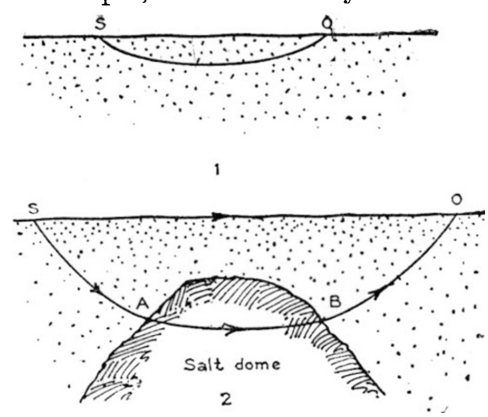

FIG. 5.—Diagram showing (1) that the quickest path from an explosion at *S* to an observer at *O* is a curved one, *SO* (diagram 1), through the earth, because elasticity increases with depth; and (2) that *S* and *O* are farthest apart and the quickest route *SABO* (diagram 2) is by way of the salt dome beneath, which can be thus detected because of the high velocity of the waves in the salt dome.

the pressure, and the pressure with the depth, perhaps in a linear relation. Hence the first shock signal which travels a few miles and reaches the recording seismograph is that compressional wave which has passed deep down a few thousand feet into the earth and emerged after its curved and concave path (Fig. 5). If a salt dome intervenes, there is yet higher speed, and by numerous shocks and measurements the size and shape of the salt dome may be determined, the site purchased, and the hunt for oil, now aided by torsion balance work, pursued. If success follows, there is avoided that scramble for the oil field which has so often in the past involved loss due to hasty and wasteful boring and pumping, and violent fluctuations in supply and cost.

To sum up: geophysical methods wisely used can be helpful and profitable. If the possibilities are over-stated or improper claims made, there will be a lack of confidence retarding that advancement which careful development should achieve.

News and Views.

THE discovery in the United States in 1922 by T. Midgley that lead tetra ethyl has a remarkable action in delaying detonation or 'knocking' in the internal combustion engine when added to petrol in minute amounts, has brought this organo-metallic derivative from the obscurity in which it had remained since it was first prepared and described in Great Britain by Buckton nearly seventy years ago (*Phil. Trans.*, **149,** 431) to be an important article of commerce. It is an oily colourless liquid, density 1·66; of boiling point above 200° C., with decomposition. It possesses toxic properties which are specific in character and differ from ordinary lead poisoning in that the first symptoms are insomnia and fall in blood pressure. The oil is slightly volatile and can be absorbed through the skin. Attention has been directed recently by eminent chemists to these poison dangers which might occur with the indiscriminate use of petrol containing small amounts of lead tetra ethyl, and on Feb. 29 in the House of Lords it was announced that an Interdepartmental Committee is to be appointed forthwith consisting of representatives of the Ministry of Health, the Home Office, and the Medical Research Council, to investigate the poison hazard associated with the sale of ethyl petrol in Great Britain.

IN 1924, at an experimental plant in New Jersey, where the manufacture of pure lead tetra ethyl was being carried out, a number of serious poison cases occurred, and the newspaper publicity which followed led to a voluntary suspension of the sale of ethyl petrol in the United States until the poison hazard had been investigated by the Surgeon-General of the U.S. Public Health Service. It was recognised that the manufacture and handling of lead tetra ethyl is attended with danger if not done with proper precautions, but the debatable points were the hazards to retail distributers, garage employees, and the individual users of ethyl petrol in which the lead compound is diluted by about one part in 1300. After elaborate and careful investigations, it was concluded by the Surgeon-General that no poison hazard could be traced to the use of ethyl petrol, and the manufacture of lead tetra ethyl was resumed on June 1, 1926. Researches in the direction of finding other substances of a non-poisonous character and equally as efficacious as lead tetra ethyl, have up to the present been without success, although iron carbonyl is used to some extent in Germany, so that unless a grave and well-established hazard exists, the abandonment of the use of lead tetra ethyl does not appear to be justified.

IT is, perhaps, little appreciated in Great Britain that the present low price of sugar has placed British Colonies which supply us with this commodity in a distinctly precarious position; and it is not generally recognised how vital a matter Imperial preference is to some of the British West Indies, Mauritius, Demerara, and Fiji. There are two main factors concerned, one economic and one scientific; and the latter is the general low level of research work in our cane plantations. The almost universal aim in progressive cane-sugar countries is to induce the plant to produce more tons of sugar to the acre; for this purpose men versed in scientific methods have been enlisted. It must be confessed, however, that the British Colonies are very much behindhand in this respect. A short article in the current issue of the *International Sugar Journal*, under the heading "Scientific Work in the Plantations," deals with this matter, using as a text the action of the Oahu Plantation Company in the Hawaiian Islands, when faced with the serious situation caused by the trade slump following the boom year of 1920. In January 1921 this company founded a "Department of Agricultural Research and Control," and the results thus far obtained by its scientific officers on one single programme of work, namely, the proper feeding of the cane with artificials, are briefly summarised. Astonishing success has attended the application of scientific research to the fields for this purpose; and it is claimed that if in the factory a piece of machinery were invented giving equal financial results, it could be capitalised at one million dollars. So it would seem that such an investment in research is a paying proposition.

THE quarterly report of the Empire Cotton Growing Corporation, issued on Feb. 9, clearly indicates the extent to which this body is involved in the present serious crisis in the Lancashire cotton industry. The purpose of the Corporation was described and discussed in our issue of Nov. 5, p. 645. Briefly, its income is, in the main, obtained from a levy of 6*d.* per bale of cotton entering England; and its aim is to enable British buyers to control this raw material, by increasing the amount grown within the Empire. The Act legalising the levy expires in July next, and representative bodies have been sounded as to the attitude likely to be taken up by the trade when the question comes before Parliament during the present session. The result of this inquiry appears to be that, while fully appreciating the work that the Corporation has been able to accomplish, it is unlikely that the spinners will agree to the continuance of the levy, at any rate at the present figure.

THE position of the cotton industry has, indeed, become so precarious that drastic retrenchment in every possible direction has become a vital necessity,