Northern Pennines, and determined the *general* consequent drainage system of the region.

Dr. Marr, Professor Kendall, Professor Fearnsides, and others have dealt with some of the interesting and important Glacial and post-Glacial changes of drainage, of which there are many examples in the Northern Pennines. These Pleistocene changes may be studied especially well in the Howgill Fells, the Bowland Fells, and the Craven Lowland country.

NOTICES OF MEMOIRS.

I.—Address to the Geological Section of the British Association for the Advancement of Science, Newcastle-on-Tyne, 1916.[1] By Professor W. S. Boulton, D.Sc., F.G.S., President of the Section.

WE are assembled here in Newcastle-on-Tyne, the heart of a great industrial community, where coal, the very lifeblood of industry, has been raised for more than three centuries in ever-increasing amount; and of all minerals which our science has helped us to win from the earth for man's comfort and use, coal must assuredly take pride of place. . . .

It has been the custom for the President of this Section to deal with some large, outstanding question of theoretic interest, and on this occasion I wish to refer to the present outlook of Economic Geology, more especially in this country.

If we attempt to compare the growth of applied geology in Britain with that, say, in the United States of America, or even in our great self-governing Dominions, or to appraise the knowledge of, and respect for, the facts and principles of geology as directly applicable to industry in these countries and in our own, or to compare the respective literatures on the subject, I think we shall have to confess that we have lagged far behind the position we ought by right of tradition and opportunities now to occupy. The vast natural resources of the countries I have named have doubtless stimulated a corresponding effort in their profitable development. But making due allowance for the fact that Britain is industrially mature as compared with these youthful communities, we cannot doubt that in this special branch of geology, however splendid our advances in others, we have been outstripped by our kinsmen abroad.

This comparative failure to apply effectively the resources of geology to practical affairs is unquestionably due, in no small measure, to our ignorance and neglect of, and consequent indifference to, science in general, more especially on the part of our governing classes. This War, with all its material waste and mental anguish, may bring at least some compensation if it finally rouses us from complacence and teaches us to utilize more fully the highly trained and specialized intelligence of the nation.

[1] Slightly abridged.

The Geological Survey.

In any discussion of the present outlook of economic geology in Britain we naturally turn first to the work of the Geological Survey. When in 1835 the National Survey was founded with De la Beche as its first Director, it was clearly realized by the promoters that its great function was to develop the mineral resources of the Kingdom, which involved the systematic mapping of the rocks, and the collection, classification, and study of the minerals, rocks, and fossils illustrative of British Geology. For upwards of eighty years this work, launched by the enthusiasm and far-sighted genius of De la Beche, has been nobly sustained. We geologists outside the Survey are ever willing to testify to the excellence, within the Treasury-prescribed limits, of the published maps and memoirs. Indeed, it would be difficult to name a Government service in which the officers as a body are more efficient or more enthusiastic in their work. . . .

But the time is opportune, I think, when we may ask whether the Survey is fulfilling all the functions that should be expected of it; whether it is adequately supported and financed by the Government; whether it should not be encouraged to develop along lines which, hitherto, from sheer poverty of official support, have been found impracticable.

It will be admitted that the re-mapping of the coalfields, which were originally surveyed on the old 1 in. Ordnance Maps more than half a century ago, before much of the mining information now available could be utilized, is a primary duty and a pressing public necessity. But it would be a great mistake to allow other areas which have apparently little or no mineral wealth, and are destitute, so far as we at present know, of any geological problem of outstanding interest, like the problem of the Highland Schists, to remain, as at present, practically unsurveyed. Take, for example, the great spread of Old Red Sandstone in South Wales and the Border counties of England, which on the present Government maps is indicated with a single wash of colour, and here and there an outcrop of cornstone. It is true that the southern fringe of this area has been recently surveyed in more detail in re-mapping the South Wales Coalfield; but there remain upwards of 2,000 square miles of Old Red Sandstone unsurveyed. A map indicating merely the outcrop of the main bands of sandstone, conglomerate, marl, and limestone would be of great assistance to engineers in such works as water-supply and sewage, as well as to agriculture. I am aware that many other areas more clamorously demanding a survey could be cited; but I give this example because it happens that a few months ago the Survey maps of the area were found to be useless for the purposes of an engineering work which had necessarily to be based upon the local geology.

It is sometimes said, and with truth, that the great function of a Survey is to produce a geological map which should be a 'graphic inventory', so far as its scale permits, of the mineral resources, actual and potential, of a country. After all, such a map, even when accompanied with its horizontal section and used by the trained geologist, is a very imperfect instrument by which to summarize and accurately to interpret the results of the surveyor's work. There is so much to express that a single map will not always suffice. It may be desirable to show not only the outcrops of the strata at the present surface, but the thickness of the beds, and even the shape of a buried landscape or sea-planed surface, now unconformably overlaid by newer rocks. That the Geological Survey are alive to the importance of such work is shown by some of their recent publications. The memoir on the *Thicknesses of Strata in the Counties of England and Wales, exclusive of rocks older than the Permian*, published this year, is a most valuable compilation, bringing together officially for the first time a vast amount of useful fact, mainly from open sections and borings. May we not look forward to the time when the Survey can issue maps with 'isodiametric lines' showing the thicknesses in the case of important beds; for example, sheets of productive coal-measures, water-bearing beds, and so forth? In any case, we may confidently expect maps that will show by contours the shape and depth of those buried rock-surfaces, whether unconformities or otherwise, which limit strata of peculiar economic value. The Director of the Survey has already given us a foretaste in his valuable and suggestive maps of the Palæozoic platform of South-East England,[1] and in the contoured maps of the base of the Keuper and of the Permian to the east of the Yorkshire, Nottingham, and Derby Coalfield, and the rock-surface below sea-level in Lincolnshire.[2]

Some of the new edition 1 in. colour-printed maps, excellent though they are, suffer by being overburdened with detail already, and we ought to consider whether it is not possible to issue maps of selected districts in series, as is done in the beautifully printed atlases of the United States Geological Survey, where each map of the series shows one particular set of features. . . .

We have yet to realize that technical knowledge, of the highest value to the country and obtained at great cost and labour, should be distributed as widely as possible, and at the lowest or even at a nominal charge. I would go further, and put much of the technical information in a simple and attractive form. We might even hope, for example, to eradicate the lingering superstition of the water divining-rod, which is still requisitioned by some public bodies. How admirably clear, simple, and direct is the information on water-supply in the little Survey memoir entitled *Notes on Sources of Temporary Water Supply in the South of England and Neighbouring Part of the Continent*, price 2*d.*, evidently produced under the stress of War conditions, and all the better for it.

During the last few months a series of much more important publications by the Geological Survey has appeared. I refer to the Special Reports on the Mineral Resources of Great Britain, of which some six volumes are completed. The Survey is to be congratulated upon starting a line of investigation and report which is a return to some of its oldest and best traditions. The Preface, by the Director, to the first volume of the series, that on the *Tungsten and Manganese Ores*, is illuminating and symptomatic, for it reveals a consciousness

[1] A. Strahan, Pres. Address to Geol. Soc., 1913.
[2] Mem. Geol. Surv., *Thicknesses of Strata*, pp. 88 and 110.

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of our shortcomings in the past and points the way to reform in the future.

He says: "The effects of the War, in increasing the demand for certain minerals of economic value, have led to many inquiries as to the resources in Britain of some materials for the supply of which dependence has been placed upon imports, and have raised the question whether further exploitation and improvements in method of preparation of those minerals would now be justified."

Valuable mineral deposits in old workings, the delimitation of still unworked ground, old waste-products now of great value under changed conditions of demand, are vital matters dealt with in these volumes. In a pregnant passage the Director says: "It has become apparent also that some of our home products would be at least equal to material we have been importing, provided that they could receive equally careful preparation for the market, and that with improved treatment and greater facilities for transport, they would be fit to compete with some of the foreign materials."

In the volume on *Barytes and Witherite*, it is stated that "apart from the very highest qualities, there is no scarcity of barytes in Great Britain, but that notwithstanding that fact more than half the amount used in this country has been imported, and that 34 per cent of the amount used came from Germany". Owing to fineness of grinding and low freights, the imports of this mineral from Germany have increased at a bigger rate than our own output, a state of things that surely will never recur. . . .

The Geological Survey and the Imperial Institute.

I desire here to refer to the Research Department of the Imperial Institute at South Kensington. From the Scientific and Technical Research Department reports and papers appear from time to time on the mineral resources of Britain and the Colonies. Thus, "The Occurrence and Utilization of Tungsten Ores" appeared in 1909, and similar reports on the ores of chromium, titanium, zinc, etc., and on the coal and iron resources of the British Crown Colonies and Protectorates have been published. These reports are all unsigned, although presumably written by competent persons. Such investigations, although primarily dealing with the Colonies, necessarily overlap to some extent similar work undertaken by the Geological Survey in this country. The point, however, I wish to make is that the work, both for Britain and the Crown Colonies and Protectorates in so far as it relates to prospecting, mapping, and reporting on mineral resources, could be done more effectively by the staff of the Geological Survey. There is no need to duplicate such a staff in the Government service. Men of the standing of our Government surveyors, specially trained on the economic side, who are at present investigating our home mineral resources, are admirably fitted to do similar work in the Crown Colonies. As for the self-governing Dominions and India, they have their own Geological Surveys and may be relied upon to develop their own mineral wealth. . . .

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So far as I am aware, there is not any official connexion between the Imperial Institute and the Geological Survey; and it is to be regretted that in the recent Act of Parliament whereby the management of the Institute is definitely transferred to the Colonial Office, and which provides for the appointment of an Executive Council of twenty-two members to supersede the present Advisory Committee, no provision is made for the co-operation of the Geological Survey in the geological and mineralogical side of the Institute's work. And may I say, in passing, that I think it is also a grievous mistake to develop a Research Department at the Institute without making some attempt to collaborate with the neighbouring Imperial College of Science and Technology, which, with its fine equipment and expert staff of researchers and teachers, should constitute a real Imperial College of Science and Research, in fact as in name?

But, these matters apart, it will be recognized on all hands that an ample field remains open for the energy and enterprise of the Imperial Institute as a Clearing House of scientific and technological knowledge for the whole Empire, and especially for bringing the results of scientific investigation into touch with the main streams of industry and commerce. . . .

The Development of Concealed Coalfields.

I pass on to consider what is, or should be, another phase of the work of our National Survey, namely, the discovery and development of concealed coalfields.

The Royal Coal Commissions of 1866 and 1901, and frequent addresses and reports by leading geologists in recent years upon the extension of our coalfields under newer rocks, bear witness to the sovereign importance of this branch of economic geology. One after the other the coalfields are being re-mapped by the Geological Survey, and we confidently expect the work to continue. But as the known coalfields become opened up and gradually exhausted, the question of the survey and development of concealed coalfields becomes ever more pressing and vital to our position as a great industrial nation.

In the Yorkshire, Nottingham, and Derby Coalfield the rapid extension of workings eastward under the Permian and Triassic cover during recent years has been remarkable; and although the estimates of its buried Coal-measures adopted by the Commission of 1901, at that time thought conservative, have since come to be regarded as too liberal, we may still rely upon a buried field of workable coals larger in area than the exposed Coal-measure ground of this great coalfield, so that the whole combined field will prove the richest in our islands.

The Kent Coalfield has made a peculiar appeal to popular imagination, partly because of its proximity to London, and its distance, amid England's fairest garden, from the great and grimy industrial areas of the North. A recent address by Dr. Strahan vividly describes the rapid exploitation of this field.[1]

[1] "The Search for New Coalfields in England": Royal Institution of Great Britain, March 17, 1916.

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A problem of perhaps wider geological interest than that of the Kent Coalfield, and certainly of greater complexity, and containing the possibility of an even richer economic harvest, is the occurrence of buried Coal-measures under the great sheet of red rocks between the Midland coalfields, and under newer beds in the area to the south and east of them, towards London.

For the ultimate solution of this problem an appeal will have to be made to many geological principles of which the high theoretical interest is universally acknowledged, although their practical importance is not so immediately apparent. Thus the minute zonal work in the Chalk, the laborious studies among Jurassic Ammonites, as well as the detailed investigations of minor transgressions and non-sequences in the Mesozoic rocks generally, will all have their value when estimating the nature and thickness of cover over the buried Coal-measures. . . .

One obvious line of attack is the more intensive study of the structure of the exposed coalfields, which is made possible by our ever-widening knowledge obtained largely from coal workings, present and past. . . .

Geological Features of the Visible Coalfields which bear upon the Distribution and Structure of Concealed Coalfields in the South Midlands of England.

In touching upon this question of possible buried coalfields in the South Midlands of England, I wish briefly to refer to a few points connected with our detailed knowledge of already explored coalfields which must be taken into account. They may be grouped under two heads—

(1) The stratigraphical breaks which are said to exist within the Coal-measures themselves; and

(2) The post-Carboniferous and pre-Permian folding, and its relation to pre-Coal-measure movements.

Geologists who have made a close study of the detailed sequence of any British coalfield are fairly agreed that, while sedimentation was accompanied by a general subsidence, the downward movement was discontinuous, possibly oscillatory, as evidenced, on the one hand, by the occurrence of marine bands in a general estuarine series, and, on the other hand, by those coal-seams, particularly, which consist of terrestrial accumulations of plant-material. But on a critical analysis of prevalent views we meet with considerable difference of opinion as to the inferences to be drawn from the known facts.

Jukes-Browne, referring to Coal-measure time, says "that it was a period of internal quiescence, a period in which terrestrial disturbances were at a minimum ",[1] and this notwithstanding his advocacy of the tremendous plication of the Malvern and Abberley Hills in the middle of the Coal-measure period, that is, in the interval between the Middle and Upper Coal-measures of England. Another high authority says "The Coal-measure Period as a whole was one of crust movement ".[2]

[1] *The Building of the British Isles*, p. 169, 1911.
[2] Q.J.G.S., vol. lvii, p. 94, 1901.

Dr. Gibson, after a detailed survey of the North Staffordshire Coalfield, where the Middle and Upper Coal-measures are fully and typically developed, asserts that "no break has been detected in the Coal-measure sequence"; [1] and a like conclusion is to be drawn from the work of the Government surveyors and from borings in the Yorkshire, Derby, and Nottingham Coalfield and that of East Warwickshire.

Mr. Henry Kay [2] would fix a local unconformity at the base of the Halesowen Sandstone of South Staffordshire, and another at the base of the Keele Beds (or so-called Lower Permian Marls); while in the Coalbrookdale Coalfield the well-known Symon Fault, described by Marcus Scott as a great erosion-channel in the Middle or Productive-measures, subsequently filled up by the unproductive Upper Coal-measures,[3] was interpreted by W. J. Clarke in 1901 [4] as a pronounced unconformity, a view which has been generally accepted ever since, and which was eagerly seized upon by those who hold that the Malvernian disturbance occurred at this time. . . .

The plate which illustrates Marcus Scott's paper on the Symon Fault [5] shows the upper beds plotted out from the lowest workable seam in the older measures, which he assumes to be horizontal (their original position); while Clarke, using Scott's data, plots his sections from the base of the Upper-measures, which he uses as a horizontal datum-line.[6] Incidentally I may remark that in both cases the sections are drawn with a much-exaggerated vertical scale, and, of course, correspondingly exaggerated dips.

In my opinion, both these interpretations are misleading (apart from the question of scale), because in neither case is the adoption of the horizotal datum-line strictly justified by the facts. In the one case the curvature of the basin is made too great, and in the other the dips in the Middle-measures are unduly increased; for, as mining plans show, the base of the Upper-measures is by no means horizontal. The fact is that the undulations in the measures throughout the coalfield are extremely slight, there being scarcely any perceptible dip in the strata, as noted by Scott, except near what is called the "Limestone Fault", where the dips, as will presently appear, can be otherwise accounted for. Furthermore, there is a significant absence of faults other than those which affect Middle and Upper-measures equally.

I believe there is another and a simpler explanation of this classic disturbance, and one which harmonizes, in part, the views of both Scott and Clarke; and at the same time helps to give us a reasonable interpretation of the apparently conflicting statements which have been made by working geologists respecting the relationship of the Coal-measure divisions in the Midlands.

The Keuper Marls of the Midlands occur either in horizontal or

[1] Q.J.G.S., vol. lvii, p. 264, 1901.
[2] Q.J.G.S., vol. lxix, pp. 433–53, 1913.
[3] Q.J.G.S., vol. xvii, pp. 457–67, 1861.
[4] Q.J.G.S., vol. lvii, pp. 86–95, 1901.
[5] Ibid.
[6] Ibid.

very gently undulating sheets, but Dr. Bosworth has shown that around Charnwood Forest they dip in all directions, "sometimes to the extent of 20 or even 30 degrees," and that everywhere the inclination is in the direction of the rock-slope beneath, though always at a smaller angle than the slope. This local dip (or 'tip', as he calls it) "seems most likely to have been largely caused by contraction of the marls under pressure and by loss of moisture".[1]

In a paper dealing with the Coal-measures of the Sheffield district published this year,[2] Professor Fearnsides directs attention to a research by Sorby, embodied in a memorable contribution to the Geological Society of London in 1908[3] upon the contraction of clay sediment due to loss of water. It appears to me that the penetrating genius of Sorby, with that clarity of vision which comes from patient and exact quantitative experiment, may help us to clear up some of the difficulties to which I have referred. If the Coal-measure clays have lost something like five-sixths of the original thickness they possessed as mud or slime, as Sorby's quantitative experiments seem to indicate, is it not possible that the discordance we are discussing between the Middle and Upper Coal-measures is due, in part at all events, to differential contraction and consequent local sagging during the extremely slow squeezing out of the water by the pressure of overlying sediment? We must remember that the Middle Coal-measures consist essentially of clays, and that over a large part of the Midlands they were deposited on a very uneven floor, and that to start with they were therefore of very variable thickness. It is easy to see, also, that an arenaceous fringe of sediment where the measures abut against a rise in the floor would suffer far less vertical contraction from this cause than the clay, because of the very diminished "surface energy" of the constituent sand particles, and that this would have the effect of accentuating the dip due to the sag.

It is to be noted that Scott's observations and the bulk of his section referred to the central parts of the coalfield, while Clarke deals primarily with the district just north of Madeley and along the south-eastern fringe of the "Limestone Fault", which may prove to be, in my opinion, in its early stage at all events, a pre-Coal-measure ridge of limestone.

It is quite possible, indeed probable, that portions of the undulating surface of the Middle Coal-measures suffered local erosion, which, however, need not imply folding of the beds with prolonged subaerial denudation; for it seems likely that such local erosion was subaqueous, producing a non-sequence similar in character (and origin perhaps) to the relatively small stratigraphical breaks which have been recognized recently in the Jurassic strata in the West of England and elsewhere.

Thus, in North Staffordshire, where the Midland Coal Basin is deepest, no break between the Upper and Middle-measures exists; but approaching the southern margin of the basin, to the south of

[1] *The Keuper Marls around Charnwood*, pp. 47–50, 1904–11.
[2] Trans. Inst. Min. Eng., vol. l, pt. iii, 1916.
[3] Q.J.G.S., vol. lxiv, pp. 171 et seq., 1908.

the South Staffordshire Coalfield, where the Middle Coal-measures are rapidly thinning, there are, if Mr. Kay's observations are correct, signs of a non-sequence or local unconformity. The same is true, but on a larger scale, in the Symon Fault of the Coalbrookdale Coalfield,[1] and is to be explained, if the above reasons are valid, by the rapid variation in thickness of the Middle-measures, due to the irregular floor upon which they rest, to the consequent sagging of the beds, and also to local subaqueous erosion. Further, such partial unconformities or non-sequences would generally indicate the proximity of that marginal fringe where the Upper-measures overlap the Middle and rest on pre-Coal-measure strata.

The Middle and Upper Coal-measures of the Midlands record general but intermittent subsidence, with a considerable pause at the end of Middle Coal-measure time, followed by a much more general depression, as shown by the extended and overlapping sheet of Upper Coal-measures. But there is no evidence which I regard as convincing that regional elevation or great orogenic movements occurred until after the Upper Coal-measures were laid down.

The floor upon which the Middle Coal-measures were deposited along the southern fringe of the Midland Coalfields was a sinking and already folded and denuded floor, and it is to be expected, therefore, that these measures rest in submerged gulfs and estuaries, which would mean that some, at any rate, of the several coal basins were originally isolated wholly or in part, and their separation is not to be interpreted as due to folding and subsequent denudation.

Dr. Newell Arber has argued that the Middle Coal-measures of Coalbrookdale, the Forest of Wyre, and the Clee Hills, were deposited in three separate basins, which as regards the Sweet Coal or Productive-measures were never continuous.[2] On the other hand, just as it is certain that the Productive-measures on either side of the South Pennines were originally continuous, so it is probable that as we go northward from this southern fringe the Productive-measures spread out into more extensive sheets. . . .

As an example of such intensive geological work, I should like to refer to the detailed plotting by Mr. Wickham King of the Thick Coal of South Staffordshire on the 6 in. maps. For more than twenty years he has been engaged in collecting and tabulating an immense number of levels and other data from colliery officials, and from old and sometimes half-forgotten borings; and he has now produced a contoured map and a model to the same scale, showing in great detail the folds and faults in the Thick Coal. In 1894 Professor Lapworth, to whose initiative this work was due, emphasized the value of such "plexographic maps" of coal seams, and predicted that such maps would be drawn in all the coalfields.[3] The data obtained in South Staffordshire also enable us to determine, at

[1] Mr. Wedd has recently described a similar break between the Middle and Upper Coal-measures of the northern part of the Flint Coalfield. (See Summary of Progress of Geol. Surv. for 1912, pp. 14, 15.)

[2] Phil. Trans. Roy. Soc. London, Series B, vol. cciv, pp. 431–7: "On the Fossil Floras of the Wyre Forest, etc."

[3] Fed. Inst. Min. Eng., vol. viii, p. 357, 1894–5.

some places exactly, at others approximately, the shape of the pre-Coal-measure floor and the outcrops of its constituent formations; and to disentangle, in part, the pre- and post-Coal-measure movements. Thus we get additional evidence to show that before Middle Coal-measure time, denuded folds, with a north-west or Charnian trend, and other folds with a north-east or Caledonian trend prevailed. The post-Carboniferous and pre-Permian movements emphasized and enlarged some of these folds. As already remarked, a matter of great practical importance is as to how far these pre-Coal-measure folds interfered with the continuity of deposition of the productive series, with, for example, the original extension of the Thick Coal of South Staffordshire. Since Jukes-Browne's time it has been known that the Thick Coal group as a whole thins, and the coal itself deteriorates, southward towards the Clent and Lickey Hills. It is the discontinuity and local deterioration in an *east* and *west* direction, beyond the Boundary Faults, due to pre-Coal-measure flexures, and irrespective of post-Carboniferous movement, that I have been emphasizing.

The powerful disturbances of post-Carboniferous and pre-Permian age, which have affected all our coalfields, I have no intention of discussing here. Professor Stainier, the Belgian geologist, has just published a lengthy and able discussion on the subject,[1] while the lucid account by Dr. Strahan in his Presidential Address in 1904 and his recently summarized views in a lecture to the Royal Institution will be in the minds of all geologists.

I do not think, however, that it is generally realized what a great part the two dominant pre-Carboniferous systems of folding played in determining the trend of the post-Carboniferous flexures. In the South Pennines, in the Apedale disturbance of North Staffordshire and in the Malverns we have nearly north and south folds due to a great easterly thrust; but elsewhere in the Midlands and the North the movements were taken up, to the west of these north and south lines by the Caledonian folds, and to the east by the Charnian flexures. It is very instructive to watch in the centre of the South Staffordshire Coalfield the old Charnian fold of Silurian rocks that make up Dudley Castle Hill, the Wren's Nest, and Sedgley Hill struggling, as it were, against the newer post-Carboniferous easterly squeeze, which has impressed a north and south strike upon each of the domes, arranging them *en échelon* from north-west to south-east, and incidentally permitting the great laccolitic intrusion of Rowley Regis.

It will be found, however, that the vast majority of the folds and faults in the Midland and Northern Coalfields are not along what may be called strict Hercynian lines—that is, north to south and east to west—but along the locally older Caledonian and Charnian directions. It was as if the great north and south flexures of the Southern Pennines and Malverns, and the east and west Armorican folds of the South of England, to a large extent exhausted the mighty attack of the Hercynian movements coming from the South and East of Europe;

[1] Trans. Inst. Min. Eng., vol. li, pt. i, pp. 99–153, 1916.

while smaller intervening and relatively sheltered areas were allowed to yield along their old north-west and north-east lines.

Need for Systematic Survey by Deep Borings.

After all, when we turn our attention to the possible extension of the Coal-measures under the newer strata of South-Central England, the geological data at our disposal are lamentably and surprisingly few. Notwithstanding our eagerness to unravel the difficulties, and so to open up new fields for mining activity, very little positive progress has been made in the last twenty years. Of late a few deep borings have been sunk; one near High Wycombe, after piercing the Mesozoic cover, ended in Ludlow rocks; another at Batsford, in Gloucestershire, fifteen miles north of the well-known Burford boring, struck what are regarded as Upper Coal-measures, also resting on Silurian rocks.

At the present time it seems specially fitting to call attention once again to our haphazard method of grappling with this great economic question. Are we to go on indefinitely pursuing what is almost 'wild-cat' boring, to use the petroleum miner's expressive slang? Or shall we boldly face the fact that systematic exploration is demanded; and that this pioneer work is a national obligation, the expense of which should be a national charge?

At the meeting of the Organizing Committee of Section C, already referred to, a recommendation was forwarded to the Council in the following terms:—

"The Council of the British Association for the Advancement of Science recommends that the site, depth, and diameter of every borehole in the British Isles, exceeding 500 feet in depth, be compulsorily notified and registered in a Government Office. That all such boreholes be open to Government inspection during their progress. That copies of the journals and other information relating to the strata penetrated by the boring be filed in a Government Office under the same restrictions as those relating to plans of abandoned mines."

I would go further and urge that the Government should undertake the sinking of deep borings at selected points. This is no new idea. In his Presidential Address to the Geological Society of London in 1912 Professor Watts pleaded most forcibly the vital importance of a State-aided underground survey of the area to which I have referred. The work is too vast for individual effort, or even for a private company to undertake. It is not suggested that deep borings should be sunk with the express purpose of finding coal. What is wanted is a systematic survey by borings at such spots as are likely to throw light upon the structural framework of the Palæozoic floor and the thickness of its cover. . . .

For many years I lived near our great exporting centres of the finest steam coal in the world; and as I watched the steady and incessant streams of coal-wagons, year in, year out, coming down from the hills, I was constantly reminded that we are rapidly draining the country of its industrial life-blood. Is it an extravagant demand to ask that an infinitesimal fraction of this irreplaceable Nature-made

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wealth should be set aside to provide the means for the discovery and development in our Islands of new mineral fields?

Chemical and Microscopical Investigation of Coal-seams.

The recovery of bye-products in the coking of coal, which up to the beginning of the War was almost exclusively undertaken by the Germans, is likely in the future to become an important British industry. This will ultimately demand a thorough knowledge of the microscopic and chemical structure of all the important coking seams in our coalfields.

Remembering how varied both in microscopical structure and chemical composition the individual laminæ of many of the thick coal-seams are, it will readily appear how important such a detailed investigation may become, having regard to the great variety of these bye-products and their industrial application. Moreover, thin seams, hitherto discarded, may pay to be worked, as may also an enormous amount of small coal, estimated at from 10 to 20 per cent of the total output, which up to the present has been wasted.

Geology of Petroleum.

It has been frequently remarked that in order to account for the vast accumulation of coal in the Carboniferous strata, it is necessary to postulate a special coincidence over great areas of the Northern Hemisphere of favourable conditions of plant growth, climate, sedimentation, and crustal subsidence; conditions which, although they obtained at other geological periods over relatively small areas, were never repeated on so vast a scale. Having regard to the estimates of coal deposits in Cretaceous and Tertiary strata, published in our first International Coal Census, the "Report on the Coal Resources of the World",[1] it would appear that we might reasonably link the Cretaceo-Tertiary Period with the Carboniferous in respect of these peculiar and widely prevalent coal-making conditions. For I find that of the actual and probable reserves of coal in the world, according to our present state of knowledge, about 4½ million million tons of bituminous and anthracite coal exist, the vast bulk of which is of Carboniferous age; while there are about 3 million million tons of lignites and sub-bituminous coals, mostly of Cretaceous and Tertiary age.

When we look to the geological distribution of *petroleum*, we note that it is to be found in rocks of practically every age in more or less quantity, but that it occurs *par excellence*, and on a great commercial scale, in rocks of two geological periods (to a smaller extent in a third); and it is significant that these two periods are the great coal-making periods in geological history—the Carboniferous and the Cretaceo-Tertiary. . . .

The world's production of petroleum has trebled itself within the last fifteen years. In 1914 the United States of America produced 66·36 per cent, and North and South America together nearly three-fourths of the world's total yield; while the British Empire

[1] Report on "The Coal Resources of the World", for the Twelfth Intern. Geol. Congress, 1913.

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(including Egypt) produced only a little more than 2 per cent. In the near future Canada is likely to take its place as a great oil- and gas-producing country, for large areas in the middle-west show promising indications of a greatly increased yield. But Mexico is undoubtedly the country of greatest potential output. Its Cretaceous and Tertiary strata along the Gulf Coastal Plain are so rich that it has been stated recently on high authority that "a dozen wells in Mexico, if opened to their full capacity, could almost double the daily output of the world".[1]

As is well known, natural supplies of petroleum are not found in the British Isles on a commercial scale; but for many years oil and other valuable products have been obtained from the destructive distillation of the oil shales of the Lothians. If Mr. Cunningham Craig is right in his views recently expressed,[2] these shales, or rather, their associated freestones, have been nearer to being true petroliferous rocks than we thought; for he believes that the small yellow bodies, the so-called 'spores' in the kerogen shales, are really small masses of inspissated petroleum absorbed from the porous and once petroliferous sandstones with which the shales are interstratified.

If recent experiments on peat fulfil the promise they undoubtedly show, we shall have to take careful stock of the peat-bogs in these Islands. It is well known that peat fuel has been manufactured in Europe for many years. But my attention has been called to a process for the extraction of fuel-oil from peat, which has been tried experimentally in London, and is now about to be launched on a commercial scale, utilizing our own peat deposits, like those of Lanarkshire and Yorkshire. . . .

It is sometimes asked whether the adoption of mineral oil as a power-producer is likely to supplant coal, and thereby seriously reduce the output of that mineral. The world's yield of petroleum will doubtless go on increasing at a very great rate; but from the experience gained in some of the fields in the United States and Eastern Canada, it seems unlikely that this increase can continue for a very long period. Practically complete exhaustion of the world's supply is to be looked for within 100 years, says one authority.[3] Even if the output rose to ten times the present yield, it would represent only about half the present world output of coal, and it is practically certain that so high a yield of oil could not be maintained for many years. Owing to the almost certain rapid increase in the output of coal, estimates made by the same authority already quoted indicate that the total production of petroleum could never reduce the world's output of coal by more than about 6½ per cent.[4]

For us, and probably for those of the next generation, the geology

[1] Ralph Arnold, "Conservation of the Oil and Gas Resources of the Americas": *Econ. Geol.*, vol. xi, No. 3, p. 222, 1916.
[2] Institution of Petroleum Technologists, April, 1916.
[3] H. S. Jevons, *British Coal Trade*, 1915, p. 710.
[4] Ibid., p. 716.

of petroleum will continue to be of immense practical importance; but coal will doubtless remain our great ultimate source of power.

An obligation rests upon us to see that the oil resources of the British Empire and of territories within our influence are explored, if possible, by British geologists, with all the specialized knowledge that can be brought to bear; and I am glad to think that the University of Birmingham and the Imperial College of Science and Technology, London, with this end in view, are doing pioneer work in giving a systematic and specialized training to our young petroleum technologists. . . .

Underground Water.

Since the year 1856, when the Frenchman, Darcy, attempted by a mathematical formula to express the law governing the transmission of water through a porous medium, nearly all investigation upon this important engineering question has been carried on in the United States; and many of the results have been published in the valuable Water Supply and Irrigation Papers of the United States Geological Survey. Particular reference should be made to the work of Hazen, King, Darton, and Slichter, the last of whom has given us the clearest and most convincing explanation of the behaviour of water percolating through a porous rock. He and his co-workers have experimentally investigated the factors which determine the underground flow, and expressed their relationship by mathematical formulæ; and they have made it clear, by careful measurement extended over long periods, that the rate of flow through average porous water-bearing rocks and under ordinary pressure gradients is extremely small, something like a mile a year, or even less.[1]

Geologists who are in touch with the application of these principles to such engineering matters as water-supply, sewage, and drainage will readily appreciate the great value of such researches. At the same time, one must reluctantly confess that, with few exceptions, the investigations have not been adequately grasped and utilized in present-day engineering practice in this country. As to their geological bearing, we have only to be reminded of the important processes of solution, cementation, and fossilization in rocks in order to comprehend the value of a just estimate of the behaviour of this vast and slow-moving chemical medium in which the superficial rocks of the crust are immersed. . . .

The conditions are so complex and the controlling factors vary so much in different river-basins that it is impossible to obtain for the whole country anything like an accurate and reliable expression for the relationship between rainfall, percolation, and run-off. The interminable and costly legal wrangles during the passage of a Water Bill through Parliament bear witness to the truth of this statement. What is needed is a continuous record in the different catchment areas of the country of observations on river discharge, percolation, and so forth, extended over many years. Fortunately, our rainfall observations, thanks to the British Rainfall Organization, are now

[1] Slichter, Water Supply Paper No. 67, U.S. Geol. Surv.: "The Motions of Underground Waters."

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or could be made, ample for this purpose. But except for attempts by local water companies and corporations to obtain the data I have referred to, there exists no public control to deal with the matter.

In 1906 a Committee of the Royal Geographical Society, with Dr. Strahan as Chairman, and with the aid of a grant from the Royal Society, undertook to investigate river discharge, suspended and dissolved matter, rainfall, area, and geological conditions in some specially selected river-basins. The final report, which has now appeared, dealing with the Severn above Worcester, the Exe, and the Medway, constitutes a most valuable record. . . .

It will be obvious to all geologists that important theoretical questions, such as the rate of denudation and deposition, and vital engineering matters, such as the position and permanency of harbour works, would be greatly assisted by exact quantitative estimates of the material carried down by rivers.

In 1878 Joseph Lucas urged the importance of a Hydro-geological Survey of England, and the Royal Commission on Canals and Waterways in their final report in 1909 recommended the appointment of some public authority to do for the whole country what this Committee has so admirably done for these three river-basins.

Organization of Expert Knowledge.

We are reminded by the report of a later Royal Commission—that on Coast Erosion in 1911—that systematic observations and the collation and organization of geological and engineering knowledge are urgently needed in connexion with the protection of our coasts and the reclamation of new lands. For it will be remembered that the Commission found that during the last thirty-five years the gain of land, as shown by Ordnance Survey maps, has been more than seven times the loss by erosion.

Here, again, the British Association may reflect with pride that it paved the way for this national inquiry. For many years its Committee on Coast Erosion gathered and collated evidence on erosion, and induced the Admiralty to instruct the Coastguard to observe and report upon changes that take place from time to time. . . .

Is it not abundantly clear that in economic geology, as in the case of other applied sciences, we must rely in the future less upon chance individual effort and initiative? We must concentrate, centralize, and organize; and at every stage we shall need expert control and advice as regards those larger scientific issues of national importance which have a direct practical bearing.

II—The Mapping of the Earth, Past, Present, and Future. Being an abridged report of Address to the Geographical Section (E), British Association, Newcastle. By Edward A. Reeves, F.R.A.S., F.R.G.S., President.

AFTER a brief allusion to the increasingly important part Science had been called upon to play in the present great crisis and the value of a more thorough and general scientific training, the President pointed out the various ways the present War will affect the map-maker, owing to the surveying and arranging of new boundaries, etc , as after all is over our present maps and atlases will have to be very largely revised and brought up to date.

He divided his Address into the following headings :—

1. A brief general summary of what has been done in the past towards the mapping of the earth's surface.
2. A sketch of how things stand at the present time.
3. A few remarks upon future work, specially as regards instruments and methods.

Commencing with a historical sketch of geographical exploration and representation of the surface features of the earth from as early a date as B.C. 276, the President stated that—

It was not until the latter part of the fifteenth century, the time of the great Portuguese and Spanish discoveries, that any real advance was made, but then Europe seemed to awake from a long sleep, and a grand new start was made.

One of the first acts of King John II of Portugal (1481–95), whose memory deserves to be equally held in respect with that of his great uncle Prince Henry, was the calling together of the Committee, or 'Junta', of learned men to consider the best means of finding the latitude when the Pole Star was too low to be of service, to decide upon the most approved form of instrument for the taking of observations, and to furnish suitable tables of declination, etc., for the computations. Equipped with the new tables, which may, perhaps, be considered the first Nautical Almanac, and the simplified astrolabe, the Portuguese navigators started on the famous voyages, with a much better chance of properly fixing positions than their predecessors. The Vernier had not yet been invented, and so the difficulty of obtaining accurate readings of the circles was still considerable. To overcome this difficulty it was decided to construct astrolabes with very large circles, and the instrument carried by Vasco da Gama in his famous voyage round the Cape in 1497 had a circle which measured just over two feet in diameter. . . .

The difficulty of taking anything like accurate observations at sea was for centuries a very serious one, and long before the invention of the reflecting quadrant or sextant many were the attempts to devise some instrument for accomplishing this. . . .

It was not until the ingenious invention of the reflecting octant, suggested first of all by Sir Isaac Newton, that anything approaching accuracy was possible. Hadley's quadrant was the first of such instruments to be put into actual use, but there is no doubt that the idea should be ascribed to the famous Sir Isaac Newton, although the instrument was probably independently invented by Hadley.

With the invention of the sextant, or its predecessors the octant and quadrant, rapid progress was made in improvements in navigation and surveying instruments.

The introduction of the Nonius by Peter Nuñez in the middle of the sixteenth century, and later of the Vernier by the Frenchman Francis Vernier, which, owing to its simplicity, soon superseded the former, were of great importance, since it was no longer necessary to construct the enormous large arcs and circles which had hitherto been indispensable to give anything like accuracy.

The magnetic compass not only made an enormous difference in navigation and exploration by sea, since it enabled the sailor to launch boldly out into the unknown oceans with confidence, but it soon began to leave its mark on land-surveying and geographical exploration. Much has been written on the invention of the compass, and many have been the disputes upon the subject, but it was certainly in use in Mediterranean countries of Europe as early as the twelfth and thirteenth centuries. The date when it was first used for land-surveying is not known exactly, but in Europe it was probably about the early part of the sixteenth century. . . .

The surveying equipment of the pioneer explorer of early days, say, of from twenty to sixty years ago, usually consisted of a sextant and artificial horizon, a chronometer or watch, prismatic compass, boiling-point thermometers, and aneroid. With the sextant and artificial horizon the astronomical observations for latitude and longitude were taken, as well as those for finding the error of the compass. The route was plotted from the compass bearings and adjusted to the astronomically determined positions. The latitudes were usually from meridian altitudes of the sun or stars, and longitudes from the local mean time derived from altitudes east or west of the meridian, compared with the times shown by the chronometer, which was supposed to give Greenwich mean time.

The sextant, in the hands of a practical observer, is capable of giving results in latitude to within 10″ or 20″, provided it is in adjustment, but the difficulty is that the observer has no proper means of testing for centering and graduation errors.

The great drawback to the sextant for survey work is that it is impossible to take accurate rounds of horizontal angles with it, since, unless the points are all on the same level, the angles must be too large. It is essentially a navigator's instrument, and nowadays has been almost entirely superseded by the theodolite for land-surveying.

As regards the longitude, the difficulty was always to obtain a steady rate for the chronometer, owing principally to the unavoidable oscillations and concussions met with in transit. Formerly it was customary to observe lunar distances for getting the Greenwich mean time instead of trusting to the chronometers, but these, even with the utmost care, are very unsatisfactory.

In more recent years the occultation of a star method of finding the Greenwich mean time superseded almost entirely the lunar distance, but all of these so-called 'absolute' methods of finding longitude are fast becoming out of date since the more general introduction of triangulation and wireless telegraphy.

Heights of land were usually obtained by the boiling-point thermometer or aneroid.

This, then, was the usual equipment of the pioneer. With such an outfit the greater part of the first mapping of Africa and other regions of the world was carried out, with results that were more or less reliable according to the skill of the explorer and the time and opportunities at his disposal.

In recent years considerable improvement has been made in the instruments and methods of the geographical surveyor: the introduction of the Invar tape for the measuring of the baselines, the more general application of triangulation, the substitution of the theodolite for the sextant, the use of the plane-table for filling in the topographical details of the survey, the application of wireless telegraphy to the determination of longitudes, these and other improvements have all tended to greater accuracy and efficiency in geographical and topographical mapping, so that in many respects the rough approximate methods of the earlier explorers are fast being superseded by instruments and methods more in keeping with modern requirements in map-making.

Still, the principle underlying all surveying is the same, and the whole subject really amounts to the best and most accurate methods of measurement with a view to representing on a plane, on a greatly reduced scale, the leading features of a certain area of the earth's surface in their relatively correct positions; and so it resolves itself into geometrical problems of similar angles and proportional distances. This being the case, it is clear that it becomes in the main a question of correct angular and linear measurements, and all the improvements in survey methods have had for their object the increased accuracy of accomplishing this, together with greater facility for computing the results. . . .

So far what I have said has had chiefly to do with some of the earlier attempts at surveying and map-making, and the instruments and methods by which these have been carried out; and I will now try to give you an outline of what has been done in comparatively recent times, and state briefly the present position of various parts of the world as regards the condition of their mapping and the survey basis upon which their maps depend.

Little by little civilized man, by his daring, his love of adventure, and the necessities of events and circumstances, has penetrated into the unexplored parts of the earth and pushed back the clouds and mists that so long shrouded them from his knowledge, until at the present time the regions that are entirely unmapped are very few indeed, and do not amount to more than about one-seventh of the whole land-surface of the globe, including the unexplored areas of the Polar regions, which may be either land or water. Not content with a mere vague acquaintance, he has striven for greater accuracy, and has turned to various branches of science and called them to his aid, in order that he may obtain more correct knowledge and a better comprehension of the earth's features. To enable him to fix with definiteness the position of places upon its surface, map out the various land-forms, and obtain their accurate measurements, he has consulted the astronomer and mathematician. Commencing, as we have seen, with the rudest instruments and measuring apparatus, these, as greater accuracy was required, have gradually been improved, until the present-day appliances and equipment of a surveyor are a wonder of refinement and delicacy. . . .

I have attempted to form an estimate of the condition of the world's surveys as represented by the differently tinted areas on the maps for 1860 and 1916;[1] and, taking the total area of the land-surface of the earth, together with the unknown parts of the Arctic and Antarctic regions which may be either land or water, to be 60,000,000 square miles, I have obtained the following results:—

	1860 Sq. Stat. Miles.	1860 Proportion to Whole.	1916 Sq. Stat. Miles.	1916 Proportion to Whole.
1. Mapped from accurate topographical surveys based on triangulation or rigorous traverses	1,957,755	= 0·0326 or roughly 1/30	8,897,238	= 0·1482 or roughly 1/7
2. Mapped from less reliable surveys, chiefly non-topographical	2,017,641	= 0·0336 or roughly 1/30	5,178,008	= 0·0866 or just over 1/12
3. Mapped from route traverses and sketches	25,024,360	= 0·4170 or roughly 2/5	37,550,552	= 0·6258 or little less than 2/3
4. Entirely unsurveyed and unmapped	30,997,054	= 0·5166 or just over 1/2	8,350,794	= 0·1391 or little less than 1/7

These proportions can perhaps be more clearly seen from the following small diagram.

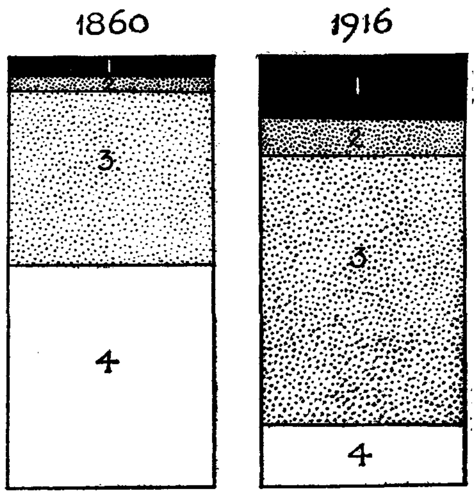

Diagram showing the relative proportions of the earth's surface in 1860 and 1916, which are—1, fully mapped; 2, partially mapped; 3, slightly mapped; and 4, not mapped in the two periods referred to.

It is plain that with the same rate of progress as that of the past sixty years or so it would take just over four hundred years more

[1] The two maps have not been reproduced from Mr. Reeves' Address, but the small diagram is given and shows the areas mapped and unmapped and their relative proportions.

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to complete the accurate trigonometrical surveying and topographical mapping of the earth's land-surface, including the parts of the Polar regions that may possibly be land—that is, the 60,000,000 square miles which we have taken for this total area; but this will certainly not be the case, since the rate at which such surveys have been carried out has been greatly accelerated during recent years, owing to the rapidly increasing demands for accurate topographical maps, improvements in methods, and other causes, so that it will possibly not be half this time before all the parts of the earth's surface that are likely to be of any use to man as settlements, or capable of his development, are properly surveyed and mapped. There are, of course, regions, such as those near the Poles and in the arid deserts, that are never likely to be accurately triangulated and mapped to any extent, and it would be mere waste of time and money to attempt anything of the kind. . . .

Many and varied have been the influences that have led to the surveying and mapping that have already been accomplished, and it would be interesting if we had time to analyse them. Among the preliminary surveys, I think it would be found that military operations would hold an important place. Many an unexplored region has been mapped for the first time as the result of frontier expeditions, such as those of the frontier regions of India and parts of Central and South Africa, while the need of a more exact acquaintance with the topographical features for military requirements have frequently led to more exact trigonometrical surveys. Our own Ordnance Survey is indeed an example of this, for in the first place it resulted from the military operations in Scotland in the latter part of the eighteenth century.

Among other causes that have resulted in surveying and mapping might be mentioned the delimitation of boundaries, commercial or industrial undertakings, such as gold-mining and land-development, projects for new railways, all of which have at times been fruitful in good cartographical results. Nor must we forget Christian missions. The better-trained missionary has always recognized the importance of some sort of a survey of the remote field of his operations, and the route to it, if for no other reason, with a view to the good of his fellow-workers and those who come after him; and in the earlier days especially perhaps most of all pioneer mapping was done by the self-sacrificing service of the missionary. We have only to think of such men as Moffat, Livingstone, Arnot, Grenfell, and others of the same sort to be reminded of the debt due to the missionary from all interested in geographical mapping. . . .

The future surveyor will be in a much better position than his predecessors, not only on account of the improvements in instruments and apparatus for his work, but because, in many parts, a good beginning has been made with the triangulation to which the new surveys can be adjusted. In Asia a considerable amount of new work of this kind has been done over the frontier of India in recent years by the Survey of India, among the more important of which is the connecting of the Indian triangulation with that of Russia by way of the Pamirs. The many boundary surveys that have been carried out in Africa, the triangulations of Egypt, the Soudan, East and South Africa, and other parts of the continent are well advanced, and will be of the utmost value to the future surveyor. One of the most important lines is the great triangulation which, it is hoped, will some day run across the continent from south to north, from the Cape to Egypt. Owing to the energies of the late Sir David Gill, this important chain of triangles has already got as far as the southern end of Lake Tanganyika; the part to the west of Uganda near Ruwenzori has also been finished, and it now remains to carry the chain through German East Africa and down the Nile Valley. The latter, it is hoped, will by degrees be accomplished by the Soudan and Egyptian Survey Departments, although it may be delayed for some years yet; and the former, which was to have been undertaken by the Germans, it is hoped will after the War be accomplished by British surveyors, through—not German East Africa—but newly acquired British territory. Running right through parts of Africa that are but imperfectly mapped in many districts, the stations of this triangulation will be invaluable for the adjustment of any network of triangulation for future surveys in the interior, and, indeed, has already been utilized for the purpose.

The carefully carried out boundary surveys between various countries of South America will be of the greatest assistance in future exploration and survey in the interior of that continent, wherever they are available, while the Survey Departments of Canada and the United States are doing excellent work and extending their surveys far into the imperfectly mapped regions of North America. So, altogether, the surveyor of the future will soon have a good foundation of reliable points to work from. It is important to remember that running a chain of triangles across a country, though important as a framework, does not constitute a map of the country; and what is wanted, at any rate in the first place, is a series of good topographical maps, based upon triangulation, showing the leading features with sufficient accuracy for the purposes of ordinary mapping, so that on scales of 1 : 250,000 or even 1 : 125,000 there is no appreciable error.

As regards instruments, the Astrolabe à Prisme is being increasingly used for taking equal altitude observations with most excellent results, but at the present time the 5 in. transit micrometer theodolite, already referred to, is perhaps all that is required for general work. It has now been thoroughly tested and found most satisfactory. As regards smaller instruments, there is the 4 in. tangent-micrometer theodolite, and for rapid exploratory survey, where weight is a great consideration, a little 3 in. theodolite has been found useful.

For baseline measurement the Invar tape should be taken on all serious work, and for filling in the topographical features a good plane-table is doubtless the instrument to use. In mountainous regions and in some other special conditions photographic surveying doubtless has a future before it, and in military operations when the photographs are taken from aircraft it has proved itself invaluable; but in ordinary surveying it is, I think, not likely to take the place of well-established methods. The introduction of wireless telegraphy for the determination of longitude is likely to increase in usefulness. Good examples of the work done with it have lately been given in the *Geographical Journal* and elsewhere.

REVIEWS.

I.—THE SKULL OF *ICHTHYOSAURUS*, STUDIED IN SERIAL SECTIONS. By Professor W. J. SOLLAS, F.R.S. Phil. Trans., ser. B, vol. ccviii, pp. 63–126, with 22 text-figures and 1 plate, 1916.

IN this paper Professor Sollas gives a detailed account of the results of his method of serial sections applied to the skull of an Ichthyosaur, probably a variety of *I. communis*. No less than 520 sections were prepared, photographed, and modelled in wax, and the resulting reconstruction gives a clearer idea of the details of the structure of the skull than has hitherto been attainable. The relations of the roofing bones of the skull, that unite by extensively overlapping sutures, are now for the first time made clear, and the presence of a septo-maxillary element is demonstrated; in the lower jaw the presence of the *goniale* (prearticular) is shown.

Professor Sollas has met with the usual difficulty in determining the relative position of the bones forming the auditory capsule, the existence during life of extensive areas of cartilage between them resulting in their displacement when putrefaction took place. He puts the pro-otic low down, below the opisthotic and in contact with the basi-occipital, a position which seems inconsistent with the share which this element must have taken in helping to enclose the auditory labyrinth.

Another point of special interest is the presence of a series of structures which are regarded as the remnants of a hyobranchial apparatus. Not only is this interpretation an improbable one, but the facts seem capable of a simpler explanation. The elements (marked *a* and *b* in fig. 17) which are regarded as branchials closely resemble in form the upper bifurcated ends of cervical ribs, while those marked *s.d.* may be halves of a neural arch. Professor Sollas admits that these bones lie dorsal to the hyoids, and furthermore notes the presence in the specimen of the displaced centra of the atlas, axis, and third cervical, so that it therefore seems at least possible that the presumed branchial bones are displaced appendages of these vertebræ.

The paper is illustrated with twenty-two text-figures, mostly of sections of the skull, and a plate giving figures of the basi-occipital and basisphenoid, both of the reconstructed skull and of other specimens. Some diagrammatic figures of the various bones might have been added with advantage.

The paper as a whole is a valuable contribution to our knowledge, and the author is to be congratulated on the successful application of his elaborate and laborious method of investigation to a fresh subject.

C. W. A.