Geological Surveys and Development.¹

By Sir ALBERT E. KITSON, C.M.G., C.B.E.

THE importance and value of a geological survey to a country has long been recognised by all progressive nations that desire to utilise the mineral resources with which Nature has endowed them. But though such value is fully appreciated and freely acknowledged by all thoughtful, observant people, the nation as a whole has no understanding of it, and no definite views on the matter. The rapid advance of science, and the application of the wonders of science to industry, in practically all divisions of the activities of mankind, are incontrovertible facts, and no nation or community under present-day conditions can afford to neglect to utilise all the assistance that science can give towards increase in production and reduction in cost of the fruits of the industries upon which that nation is mainly or largely dependent for its existence and advancement.

Where the question of cost is not an insuperable barrier to its establishment, a geological survey is formed. As regards our Empire, not only Great Britain, but also the British Dominions—India, Canada, Newfoundland, Australia, New Zealand, and South Africa—long since established such surveys and recognised their value. The Colonies and Protectorates that now have geological surveys in full operation and doing valuable work are Nigeria, the Gold Coast, and Sierra Leone in West Africa; in Central and East Africa—Uganda and Nyasaland, with the Anglo-Egyptian Sudan, and the Mandated Territory of Tanganyika; and the Federated Malay States. Among those which have had surveys for certain periods, but which have been varied, suspended, or concluded, are Jamaica, British Honduras, British Guiana, Gambia, Somaliland, Zanzibar, Ceylon, and the Falkland Islands. Geological advice is being given in Ceylon, Palestine, and Somaliland. In those now without surveys much useful work was done, and the discontinuance of operations was due to various causes.

There is a great deal of misconception regarding the functions of a geological survey, using the term geological in its broadest sense. By many it is thought to deal with the rocks of a country, to describe them, and to show on maps and in reports their divisions, disposition, and distribution; perhaps also to include the economic minerals, such as coal, brown coal, lignite, rock-salt, ores of iron, manganese, copper, nickel, zinc and lead; or valuable gem-stones, such as diamonds, rubies, sapphires, and opals. But there is very little, if any, recognition of the great part that geology plays in a most unobtrusive manner in connexion with mining, agriculture, stock-raising, water supply, forestry, public works, sanitation, geography, and education.

The importance of the remote possessions of a great Empire is dependent upon many factors—

¹ From the presidential address, entitled "The Utility of Geological Surveys to Colonies and Protectorates of the British Empire", to Section C (Geology) of the British Association, delivered at Johannesburg on July 30.

such as natural resources and their situation, physical character of the country, lines of communication and transport, nature of climate, soils and water supply, density and distribution of population, character of the peoples, conditions regarding agriculture and pasturage. To develop these fully there should be a government with wide vision and foresight, capable and energetic, with a broad outlook on possibilities of development, and ready to assist financially and sympathetically all proposals that show reasonable prospects of economic success.

The Colonies and Protectorates of the British Empire are almost without exception in the tropics. Many of them are wholly or partly in zones which are blessed with an abundant rainfall, and covered with dense forests or low vegetation. Some comprise areas of low rainfall, and, in consequence, have seasonally arid conditions, and little vegetation. A geological survey of the former is necessarily slow, for the dense vegetation and depth of soil effectually obscure the nature of the underlying rocks and what they contain. In such country much time, labour, and expense are necessary to examine carefully the watercourses, by cutting and clearing lines along them and through the dense bush between them. Nevertheless, it should be remembered that such country may have valuable mineral deposits lying hidden within a few yards of any line of traverse through the forest, and merely awaiting discovery. In areas of low rainfall and scanty vegetation, however, the examination of the country is rendered much easier and can be done much more quickly and thoroughly.

FUNCTIONS OF A SURVEY.

Opinions differ as to how the work is to be commenced. One geologist may consider it advisable to make first a series of rapid reconnaissances through the various districts, along natural boundaries such as the coast-line, large rivers, main paths or roads, railways, if any, or through promising belts of country; then later a series of rapid cross-traverses connecting with the first series, and, later still, numbers of others linking the two series in various directions. This method enables him to get, in the quickest manner, a general knowledge of the geology of the country as a whole. The mapping, in detail, of the geology, in conformance with a mathematical scheme of division of the country, can be done later as opportunity offers. Another geologist may prefer to survey in detail certain areas, such as a known mining field, a belt of country, or the main lines of communication, leaving outlying districts for later work.

Both methods have their advantages and disadvantages, but these cannot be discussed here. The particular features of the country and the wishes of the government will determine the system of work.

The following remarks indicate some of the various activities of a survey of a young colony :

Reconnaissances and rapid surveys through the country, noting specially the physiography, nature of rocks with their structural features (anticlines, synclines, strike, dip, foliation, cleavage, jointing, faults, dykes, and reefs), nature, occurrence and testing of minerals in rocks and gravels of streams by crushing and panning. Kinds of soils, nature and volumes of streams regarding irrigation and water-power, underground water supplies, sites for dams and reservoirs, archaeological notes, collection of rocks, minerals and concentrates, with general reports on all, and preliminary special reports on mineral deposits and other interesting features.

Detailed surveys and reports on particular areas, deposits and occurrences, such as mentioned in the preceding paragraph.

Special reports on the country along routes of proposed railways, water-power, sanitation, and other matters.

Assistance and advice to other departments on geological matters.

Surface and underground surveys of mines, with reports, maps, and sections.

Advice to mining companies and prospectors on the examination of their mines, areas, and specimens of rocks and minerals.

Assays, analyses and other determinations of samples of minerals collected by the survey, or received from the public, with reports on them.

Advice to Government regarding operations of prospectors and prevention of fraudulent flotation of companies.

Assistance to educational institutions by information supplied and descriptive museum collections.

Scientific (mainly geological and geographical) reports, with microscopical and chemical descriptions of rocks, maps, and photographs.

Special examination of minerals in concentrates and reports on them.

Publication of reports, maps, sections, assays, analyses, etc.

Formation of a geological museum, mainly of practical geology, with descriptions and uses of the materials therein.

There are numbers of other kinds of geological work that need enlargements of the staffs of the geological surveys before they can be undertaken, such as observations with regard to transport of sediment and chemical character of water in streams; inland denudation, and coastal erosion; underground flow of water through rocks; and decay of rocks under tropical conditions.

It may be advisable to describe very briefly the main features of the method adopted in the Gold Coast in the rapid examination of country possessing no reliable maps.

Traverses are made, by bicycle mainly, with (a) the prismatic or pocket compass, for direction; (b) cyclometer, or measuring wheel, for distance; (c) aneroid barometer, with thermometer attached, for altitude and temperature; and (d) watch, for time.

On leaving a camp all four observations are taken, but instead of the traverse being tabulated in columns as usual—which method gives no graphic idea of the orientation of the traverse—the graphic method is used. This shows at once the direction

being taken, for the bearing of each line is roughly plotted in the field-book, as to direction and length, and a continuous traverse obtained, in which, in its relative position, each natural feature is placed. The observations embrace features, such as sites of camps, and prominent landmarks, edges of stream flats and banks, water-levels, gullies, tops of rises or ridges or plateaux, edges of plateaux or hills, huts, villages, outcrops of rocks, showing dips, strikes, characters, and any special features. All four observations (a-d) are taken at each of such places, except the occasional omission of that for time when stoppages are frequent. But at places where the stoppage is for ten minutes or more, the time observation also is taken on leaving, for the purpose of correction for altitude because of change in air-pressure.

So far as possible, samples of the gravels of all streams, as well as the loam beside outcrops of quartz reefs and dykes, and the material from road-gutters or paths, are panned, and concentrates of heavy minerals obtained. (In certain types of country panning is the most useful aid to prospecting, not only in the discovery of gems and stable metallic minerals, such as native gold, platinoid minerals, oxides of tin, thorium, titanium, iron, chromium, tungsten, and manganese, but also of many rock-forming minerals, which indicate the probable character of the rocks at the spot, or in the basin of the stream tested.) Specimens of rocks and samples of quartz are collected for reference, museum purposes, microscopic examination of thin sections, or testing by assay, analysis, or other methods. Coal, lignite, limestone, and other economic rocks, brick and pottery clays, and pigments are sought; also fossils, which, if found, are used to determine the age of the strata associated with them.

In addition to the general observations indicated, notes are made of the colour, kind, and thickness of soil, the nature of the vegetation, size and kind of stream and gravel, and measurement of volume of water—when there is opportunity, and if of possible economic value, with regard to domestic supplies and possible hydro-electric power and irrigation.

It will thus be seen that the geologist in a new country, by taking the opportunity to make the observations mentioned in the last section, is helping his colleagues in other departments by collecting evidence of probable future value.

It may be specially mentioned here that not only on the economic mineral side of geology is a geological survey of value to a colony. It is also of much assistance to such departments as agriculture, forestry, water supply, and public works, as indicated previously.

Agriculture and Forestry.—The growth of plants, whether grasses, herbs or trees, is dependent on the chemical and physical properties of the soil, on the configuration of the land, and on climatic and other conditions. Since plant foods consist largely of certain rock-forming minerals in a soluble condition, it is necessary to know what is the chemical character of the soil. This can be ascertained by

analyses of samples collected by geologists, for much of the value of the analyses depends upon a careful determination of the types of rock forming the base of the subsoil.

There is, however, another aspect to be considered. Many soils are not sedentary ones—derived directly from the underlying rocks—but are soils of transport. The character of the soil, or even the subsoil, often bears no genetic relation to the underlying rocks, and where such soil is of no great thickness, a geological knowledge of the rocks underlying it is necessary. In connexion with irrigation, the character of the soil of the supply channels needs the attention of the geologist. He should note if there is any crust of minerals on the soil, on the evaporation of water. If so, these minerals should be analysed to see if they are those injurious to plants, when in large proportion, such as certain sodium and magnesium salts. This is important in areas with soil derived directly from rocks of marine origin, particularly young clays, mudstones and sands deposited in brackish lagoons and estuaries. If these minerals be present, he may be able to devise means by which the proportion of these harmful salts when in solution can be steadily reduced by flowing away with the water, and not being alternately and continuously precipitated and dissolved.

Water Supply.—This question of water supply is one that concerns some colonies much more than others, but all are affected to some degree. In cases involving the conservation of the water of annual streams, the problem is dependent largely upon geological considerations. But where underground water is sought, whether of the character of an artesian supply, or due to seasonal rains, the problem is a much wider one, and may be difficult to settle satisfactorily. For artesian water, not only the configuration of the country, but also the disposition and nature of the rocks must be known before any conclusion can be formed as to the chances of success in obtaining such supplies. This is essentially a work for the geologist, and even for him it is quite likely that the evidence available in the district may be insufficient—owing to the absence of natural sections—and that he may be compelled to wait for the result of boring done at spots indicated by him. Therefore, it is advisable that a geological report should precede the efforts to obtain permanent water supplies, and not, as so frequently happens, be asked for after one or more costly attempts have failed.

Public Works.—To this department, perhaps, more so than to any other, the geological survey can be of assistance, specially with regard to—

(1) The discovery of rocks, suitable for constructional purposes (such as for houses, bridges, drains, macadam), and of limestone, for lime, mortar, concrete, cement, and house-washes.

(2) The character of the foundations for bridges, large buildings, dams, and breakwaters.

(3) The nature of the rocks in areas where new roads are to be made. This is mainly for possible variations of route with reduction of expense in construction and maintenance.

Hydro-Electric Power.—This question may be regarded as quite outside the duties of a geologist. A little consideration, however, will show that the geologist has a good deal to do with it, especially where the question of dam-building and reservoir formation is concerned. For the construction of a dam, and the formation of a reservoir for hydro-electric purposes, it is of great importance to know the geology of the area and the nature of the rocks, whether soluble (as limestones) or insoluble; porous and brittle, or impervious and firm, and all the variations between; their normal or faulted condition; their disposition, strike and dip, the latter against or with the direction of the current.

The geologist has to help the engineer not only with regard to the suitability of the rocks at the site of the dam, but also in the whole of the area to be occupied by the proposed reservoir.

Sanitation.—Under the usual conditions for the disposal of nightsoil by burial in depots in the neighbourhood, where there is no proper sewerage or sterilisation system, the geological survey is able to help very considerably in the question of sanitation. The risk being run by using contaminated water is illustrated by a case brought under notice some years ago on the Continent. In this the cause of an outbreak of typhoid fever could not be determined until a geologist said it was probably due to a nightsoil depot on the side of a ridge, several hundred yards distant from a spring on the opposite side of that ridge. He was laughed to scorn. But, by pouring water, stained with a permanent dye, on the depot, he proved that the spring was taking the drainage from it. The geologist showed by scientific observation of the strata that the beds were dipping through the ridge from the depot towards the spring.

SOME PRACTICAL RESULTS FROM SURVEY DISCOVERIES.

In order that a clear impression may be gained of the practical results following the activities of these surveys in Colonies, a few remarks may be made regarding the development of certain mineral deposits discovered solely and directly by the geological and mineral surveys of three colonies.

Nigeria.—The mineral survey of Southern Nigeria discovered the large, black coal field in 1909, surveyed it in detail over the greater portion of a length of some 24 miles and width of 10 miles, and prepared a geological-topographical map of the country, showing altitudes, outcrops of coal, and other information. Further work was done later and the coal-bearing area extended considerably. Mining operations by Government were commenced on the largest seam in 1916, and since then development has continued steadily. The total quantity of coal, in round numbers, produced from 1916 to Mar. 31, 1928, is 2,210,000 tons, valued at the mine at £1,282,000. The total net profit to Government to Mar. 31, 1928, is £452,559. The total cost of the geological survey of Nigeria since its inception in 1919 to Mar. 31, 1928, is approximately £68,700, and of the mineral survey of Southern

Nigeria for the period 1903-1913, about £20,000, or a total of approximately £88,700. Thus the total profit to the Government from this one discovery by a Government geologist is more than five times the total cost of the geological and mineral surveys.

Gold Coast.—The specially important discoveries made by the geological survey of the Gold Coast are huge deposits of manganese ore and bauxite (aluminium ore), and widespread alluvial deposits of diamonds. The manganese deposits were found in 1914 before the War, but not exploited until 1916, when the vital need for high-grade manganese ore caused the development of these deposits. Production of ore commenced in 1916, and the total production to Mar. 31, 1928, is 1,785,643 tons of high-grade ore, valued at £3,350,706, free on board ship at Sekondi.

Diamonds were first discovered in February 1919. These diamonds, though small, are of very good quality, and have a ready sale for industrial purposes and jewellery. Since mining operations were commenced in 1921 there has been a large progressive increase each year until, for the year ended Mar. 31, 1929, the figures are: production, 648,343 carats; value, £538,860; export duty paid, nearly £27,000. The total weight of diamonds produced is 1,824,630 carats, valued at £1,758,348, on which the Government has received roundly £87,900 from the export duty of 5 per cent on the total value.

The Gold Coast has a great potential asset in its huge deposits of high grade bauxite—the total conservatively estimated quantity being upwards of 250 million tons. These deposits are not yet developed, owing mainly to the high cost of transport of bauxite to a port of shipment. Bauxite is an ore of low value and so cannot bear heavy charges for freight, but, with extension of railway communication and reduction of freight charges, the Colony should see a great development of this particular source of wealth, and a further mineral example be added to revenue from Geological Survey discoveries.

Sierra Leone.—The Geological Survey of this Colony is much younger than those of Nigeria and the Gold Coast. The Director has discovered large

deposits of iron ore (haematite) of good quality, and considerable deposits of alluvial platinum and gold—all now being developed—besides occurrences of chromite, corundum, ilmenite, rutile, manganese, and graphite, all of them also minerals of economic value. If found on further examination to occur in promising quantities, these deposits should prove to be of commercial value.

The West African geological surveys have no offices and laboratories in the Colonies. During the dry and tornado seasons of the year, the geologists are engaged on geological surveys and examinations of various kinds in the Colonies, but during the rainy season field work is suspended and the staffs return to England. In these respects their organisation differs from that of the other Colonies. The specimens of rocks and concentrates collected are then examined and distributed for various modes of treatment, and reports not made or completed on the Coast, as well as microscopic examination of thin sections of rocks, are done in London. The greater portion of the chemical work, such as assays and analyses, devolves upon the Imperial College of Science and Technology and the Imperial Institute under special arrangements.

A country difficult to examine because of its natural features cannot be certainly expected to yield its mineral secrets, or confess its paucity of mineral deposits, in the course of a few months, or even years of effort. Let it be borne steadfastly in mind that spectacular discoveries of valuable mineral deposits are not the only benefits that a geological survey can bestow upon a country, however important they may be, and however valuable may be their contributions to the revenue and prosperity of the country.

In this address an attempt has been made to show the value of geological surveys to young countries, and the application of scientific knowledge and methods, both theoretical and practical, to the discovery of the valuable inorganic and organic resources of Nature, as opposed to the search for them in a more or less haphazard manner. To-day science plays the predominant rôle in these revelations, and is steadily forcing a recognition of this fact upon the peoples of the earth, for their common benefit.

The Public Regulation of Wages in Great Britain.¹

By Prof. HENRY CLAY.

A GREAT change has taken place during the last twenty years in the methods of negotiating wage-changes. In 1910, when the Labour Department of the Board of Trade published the result of an inquiry into collective agreements, it was estimated that 2,400,000 workpeople worked under conditions specifically regulated by such agreements. It is not possible to compute a figure for a recent year to correspond with the 2,400,000 of 1910, because the status of collective bargaining

in certain important industries is obscure; but if we add together the numbers covered by trade boards, agricultural wages boards, joint industrial councils, and unions in certain industries, which, like coal and cotton, have adopted none of these forms of organisation, we get a total of eight millions out of a wage-earning population, which, excluding domestic service, numbers something less than fourteen millions. When we remember that the influence of an agreement or a determination, reached by a representative body, tends to go beyond the limits of the membership of the organisations, and even trades, directly represented,

¹ From the presidential address to Section F (Economic Science and Statistics) of the British Association, delivered at Johannesburg on Aug. 2.